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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn.: Document Control Desk

Subject: Response to Request for Additional Information for the License Amendment Request to Upgrade the Nuclear Safety System at the MIT Reactor, License R-37, Docket No. 50-20 (CAC No. MF5003)

The Massachusetts Institute of Technology (MIT) hereby submits a response to the Request for Additional Information (RAI) on the License Amendment Request (LAR) to upgrade the Nuclear Safety System at the MIT Reactor (MITR). The RAI was created on 12 October 2017 subsequent to a regulatory audit that was performed by Nuclear Regulatory Commission (NRC) staff at the MIT Reactor on 24-26 July 2017. This audit identified additional information that would be required to be docketed in order to support a licensing decision by NRC.

Accordingly, MIT provides responses in the following format: the NRC RAI question in italics, followed by the MIT answer in normal font. Wherever necessary, MIT's responses will reference updated supporting documents and drawings in various Enclosures.

1.0 MITR Quality Assurance program

RAI #1: *Provide a summary description of the MIT QA program as applied to the NSS design modification and how the MIT staff has implemented its QA program for this project.*

a) Describe the QA programmatic elements related to the design control and testing of the MIT-developed components of the NSS (e.g., independent QA approval of the design and testing procedures, and traceability of design changes and approvals during final development and testing).

b) Provide examples (e.g., records) that illustrate how the QA program was implemented.

Response to RAI #1a:

The MIT Reactor Quality Assurance (QA) Program was applied to all equipment/modules that were designed, fabricated, and assembled to form the new Nuclear Safety System (NSS), as an upgrade to the MIT Reactor Protection System.

The QA Program was applied in the procurement of the four nuclear safety channels, each of which is composed of a neutron detector, a pre-amplifier, and a Mirion DWK 250 wide-range neutron flux monitor. All of this equipment was received with a completed Factory Acceptance Test procedure and a Site Acceptance Test procedure. Written procedures were created and approved for their installation in the reactor and in the control room. Pre-operational tests included detector plateau tests and discriminator set point calibration. Manufacturer drawings, schematics, and certifications are all on file.

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Similarly, the MITR QA Program was applied to all in-house custom built equipment/modules. The initiating file for the new NSS was QA#-E-2012-1, created in 2012 to track the design and development of the project. In addition, each individual type of module in the new NSS has its own QA file number for ease of tracking and review for the individual modules and assemblies. Each has been written up with a design description and safety evaluation, as per NUREG-1537. Likewise, an overarching description and safety evaluation for the integrated new NSS was written for the QA#-E-2012-1 file. All of these write-ups are provided with the response to RAI #2 below.

Adhering to the MITR QA Program, for each module, drawings and/or schematics were reviewed and approved by reactor staff members as validation for their agreement with the associated design description, workability, safety of operation, compliance with SAR and Technical Specifications, compatibility with other modules of the NSS, and compatibility with existing systems. Safety-related components (those listed in the response to RAI #8 below) were assembled with standard industrial parts; where necessary, automotive standards were applied to ensure the robustness of logic devices. The procurement of parts and components was documented in bills of materials. When a manufacturer was contracted to do assembly such as for circuit boards, the manufacturer's QA certification was requested and kept on file. After manufacturing, the assembled products were inspected by reactor Instrumentation personnel and QA Program staff for verification of fabrication compliance per design specifications. For modules developed in-house, written procedures were developed, reviewed and approved to test and accept the equipment as meeting design goals.

Pre-installation documents in the form of procedures provide verification that the module has been constructed as designed, and provide a record of the results and the dated signatures of the individuals performing the work. Prior to NRC approval of the LAR, the new NSS will be set up in a test rack in the control room. The integrated system will be operated in parallel with the existing nuclear safety system for observation, and for testing using the "New Nuclear Safety System Global Test Special Procedure" (Enclosure Q, for response to RAI #4 below). Once NRC approval is received, removal of the existing NSS and installation of the new NSS will be carried out in accordance with the "New Nuclear Safety System Installation Plan" (Enclosure R, for response to RAI #5 below). Further post-installation testing will be carried out in accordance with the "New Nuclear Safety System Global Test Special Procedure". This special procedure serves as the acceptance test for the system in its integrated form.

The QA Program also requires performance of an Industrial Safety Needs Assessment Checklist. This will be performed before the New NSS Installation Plan is implemented, for personnel safety, safe equipment mounting, proper electrical wiring, etc.

The QA Program requires operating procedures such as startup and shutdown checklists and periodic checks for proper operation, maintenance, configuration, and calibration. The Reactor Systems Manual will be updated after installation of the new NSS to reflect the as-built system.

NRC-approved Technical Specification updates, along with the associated SAR updates, will be distributed to the official sets of reactor documents and circulated as part of training on the new NSS. According to the QA Program, all licensed personnel shall receive an adequate level of training, which in this case also includes lectures and a system walk-through with supervised hands-on performance of the new operating procedures.

Response to RAI #1b:

The following provide examples that illustrate how the QA Program was implemented in the design, development, fabrication, and testing of the Scram Logic Cards, the Signal Distribution

Module, and the Magnet Power Supply Modules. These illustrate how the MIT Reactor QA Program was implemented for equipment/modules built in-house.

Enclosure-A shows contents from QA File #2017-35 for the Scram Logic Card Modules. The file begins with Procedure Manual (PM) 1.13 page 12, the Quality Assurance Requirement Checklist. This form is a standard requirement for all MITR QA files. It has the name(s) of the reactor personnel who initiated the file and determined the class of change, type of change, and extent of change. After that, the form requires seven types of documents that are created throughout the various stages of development of the equipment. These include a Safety Review (including cover page and 50.59 evaluation, in this case indicating that a license amendment is required) which describes the equipment, and documents the corresponding Safety Evaluation (in this case, the write-up developed based on NUREG-1537, and included with the response to RAI #2 as Enclosure E); a Specifications document that indicates the goals of the equipment; a Procurement document that lists source(s) and contains component data sheets; Drawings and Schematics (cover page only; drawings themselves are in Enclosure E); a Fabrication document that includes invoices, QA certifications, a compliance statement, and the as-built Bill of Materials; a Bench Testing document that shows the testing steps and certifies the results; and a document of Handling & Installation Instructions. As each of these documents is completed, reactor personnel sign and date its line on the PM 1.13 form.

Enclosure-B shows contents from QA File #2017-34 for the Signal Distribution Module. It begins with Procedure Manual (PM) 1.13 page 12, the Quality Assurance Requirement Checklist. For this module, the form requires six types of documents. These include a Safety Review which describes the equipment, and documents the corresponding Safety Evaluation (in this case, the write-up developed based on NUREG-1537, and included with the response to RAI #2 as Enclosure D); a Specifications document that indicates the goals of the equipment; a Procurement document that lists source(s) and contains component data sheets; Drawings and Schematics (cover page only; drawings themselves are in Enclosure D); a Fabrication document that includes invoices, QA certifications, a compliance statement, and the as-built Bill of Materials; and a Bench Testing document that shows the testing steps and certifies the results.

Enclosure-B1 shows contents from QA File #2017-38 for the Magnet Power Supply Modules. It begins with Procedure Manual (PM) 1.13 page 12, the Quality Assurance Requirement Checklist. For these modules, the form requires six types of documents. These include a Safety Review which describes the equipment, and documents the corresponding Safety Evaluation (in this case, the write-up developed based on NUREG-1537, and included with the response to RAI #2 as Enclosure H); a Specifications document that indicates the goals of the equipment; a Procurement document that lists source(s) and contains component data sheets; Drawings and Schematics (cover page only; drawings themselves are in Enclosure H); a Fabrication document that includes a compliance statement; and a Bench Testing document that includes two completed testing procedures and certifies the results.

2.0 NSS Description and Operation

RAI #2: *Provide complete system descriptions and logic schematics that describe the function and operation of all components developed by MIT, as appropriate.*

Response to RAI #2 overall:

Documents that together provide complete system descriptions and safety evaluations of the parts of the NSS developed by MIT, along with their corresponding drawings and schematics, are as follows:

Enclosure C. Q/A File #E-2012-1 document "Overview of New Nuclear Safety System with Integrated Supporting Modules" – provides overarching complete system description and safety evaluation for the integrated NSS.

Enclosure D. Q/A File #2017-34 document "Signal Distribution Module", along with Drawing R3W-268-2 "NSS Global Connection Diagram", and Drawing R3W-274-3 "Signal Distribution Module Board Wiring Diagram".

Enclosure E. Q/A File #2017-35 document "Scram Logic Card Modules", along with Drawing R3W-263-2 "RPS Scram Logic Card" (11 sheets, showing the main schematic and ten sub-circuit diagrams).

Enclosure F. Q/A File #2017-36 document "LED Scram Display", along with Drawing R3W-270-2 "LED Scram Display Detailed Schematic", and R3W-271-1 "LED Scram Display Module Block Diagram".

Enclosure G. Q/A File #2017-37 document "<100 kW Key-Switch Module", along with Drawing R3W-259-4 "<100 kW Key-Switch Module".

Enclosure H. Q/A Files #2017-38 and #2017-39 document "Magnet Power Supply Modules and Rundown Relay Panel", along with Drawing R3W-258-4 "Magnet Power Supplies and Rundown Relay Panel".

Enclosure I. Q/A File #2017-41 document "Withdraw Permit Circuit Modification", along with Drawing R3W-203-4C (Sheet 3 of 4) showing the existing Withdraw Permit Circuit, and Drawing R3W-203-4D (Sheet 3 of 4) showing the proposed modification.

Enclosure J. Q/A File #2017-28 document "DWK 250 'Test' Condition Scram Bypass Assembly", along with Drawing R3W-264-3 "DWK 250 'Test' Condition Scram Bypass Assembly".

Enclosure K. Q/A File #2017-30 document "Blade Drop Timer Interface Module", along with Drawing R3W-267-3 "Drop Timer Interface".

Enclosure L. Q/A File #2017-40 document "Safety System Monitoring & Status Display PLC".

In addition, during the audit, NRC staff identified the following information, which is missing, and needs to be provided as part of the complete description of MIT-developed components of the NSS:

a) *The LAR and supplemental information does not describe the "DWK 250 test condition scram bypass," key switch. Provide a description of how this switch is used to perform surveillance or pre-startup testing. A summary description of any other MIT-developed features for maintenance, surveillance, or calibration purposes must also be included.*

A description and safety evaluation of the DWK 250 "Test" Condition Scram Bypass (TCB) Assembly is provided in Enclosure J, which also includes a circuit schematic. The description and safety evaluation document provides an explanation of how this Assembly is used to perform pre-startup testing and surveillance.

b) *The LAR and its supplements, MIT described the use of a cable plug when a DWK 250 module is removed for maintenance or trouble shooting. However, the information provided does not describe how the cable plug will be used and test procedures have not been provided to the NRC. Provide a description of how the cable plug will be used during maintenance or trouble shooting and identify the test procedures that will make use of the cable plug.*

MIT has decided that use of such a cable plug is no longer needed when a DWK 250 chassis is removed for maintenance or troubleshooting. This cable plug was described in the write-up for the Signal Distribution Module which was docketed on 12 May 2016 and later in a revised version on 6 July 2017. An update removing this description is provided in Enclosure D, which also includes an update of the R3W-268-2 Nuclear Safety System Global Connection Diagram.

The original concept of the cable plug was to help prevent the "Safety System Trouble" alarm on the Console Annunciator Panel from being locked in whenever a DWK 250 chassis was physically removed from the system. Installing the cable plug in place of the missing chassis would clear the Safety System Trouble alarm. However, in the current design, this annunciator alarm originates from the Safety System Monitoring & Status Display PLC, and could be cleared via the PLC. Therefore, the cable plug is no longer necessary.

c) *Drawing R3W-256-2, DWK Safety System Global Connection Diagram, does not show all connections to the NSS components. For example Revision 1.6 does not include the following connections: (1) between Signal Distribution Module (SDM) and the PLC and (2) KSM to PLC.*

   1) *Provide the updated description for the final design of the PLC.*

   2) *The Mirion DWK 250s have an interlock signal to tell the PLC if the channels are connected in the correct location. However, this information was not provided in the LAR and supplemental information. Explain how this interlock signal works and its configuration in the PLC.*

Drawing R3W-256-2 "DWK Safety System Global Connection Diagram" has been superseded by Drawing R3W-268-2 "Nuclear Safety System Global Connection Diagram".

An updated Drawing R3W-268-2 "Nuclear Safety System Global Connection Diagram" has been provided in Enclosure D. This update incorporates the connection between the SDM and the PLC and the connection between the KSM and the PLC.

An updated description and safety evaluation for the final design of the PLC is provided in Enclosure L. MIT has decided that use of an interlock signal to tell the PLC if the DWK 250 channels are connected in the correct locations is no longer needed. No such interlock has been installed.

The original concept of an interlock required construction of an internal continuity circuit, which added complexity to the design. In the current design, the nuclear safety channel cables will rarely be unplugged, and if they became inadvertently swapped, the mismatch would be readily apparent on the LED Scram Display during startup checklist testing. Finally, while undesirable, swapped nuclear safety channel cables would not hinder the scram function of the nuclear safety system.

d) *The amendment and supplemental information does not describe the drop timer interface. Describe how this interface operates, how it will be used, and the test procedures that will be used with the drop timer interface.*

A description and safety evaluation of the Blade Drop Timer Interface (DTI) module is provided in Enclosure K, which includes an explanation of the function of this module in testing of drop times of the reactor's neutron-absorbing control blades (shim blades), along with a circuit schematic. This drop time measurement is performed only with the reactor shut down, with frequency as specified in Technical Specification 4.2.3.

Three procedures are included as Enclosure M: "Special Procedure for Fabrication and Testing of the Blade Drop Timer Interface" for assembling and testing the DTI module, "Special Procedure for Installing and Testing the Blade Drop Timer Interface Module" for final installation in the control room, and "Procedure for Shim Blade Drop Time Testing" for performing an actual shim blade drop time measurement, using the DTI module together with the Blade Drop Timer. The former procedure mentions use of a signal junction box for connection between the SDM and the DTI. A circuit diagram (Drawing R3W-272-1) for this junction box is included as Enclosure M1.

e) *During the audit, MIT did not provide documentation supporting the nominal trip setting for the "<100 kW" operating mode being set at 80 kilowatts (kW). Describe how the uncertainty and drift were used to established the 80 kW setpoint for the system while operating in the "<100 kW" operating mode.*

A memo supporting the 80 kW set point is provided as Enclosure N. The MITR SAR section 4.6.7.2 establishes the Limiting Safety System Settings (LSSS) for operation in the natural convection mode to be <100 kW. MITR procedures establish the trip set point at 80 kW based on characteristics of the current nuclear safety system. The fluctuations in reactor power indication by the DWK 250s are measured at full power to be no more than 0.32% (with >95% confidence as measured at 5.7 MW steady-state for a span of more than 24 hours).

Measurement of the uncertainty and drift in the DWK 250 power indication was done at equilibrium full power because at full power a calorimetric power calculation is available, and provides an accurate determination of reactor power for comparison. Furthermore, at full power, the effects of uncertainty and drift are amplified, and thus more readily measurable. The 0.32% magnitude of the uncertainty and drift at full power is equivalent to 18 kW. Very conservatively applying this with no scaling to the 100 kW range of operation still supports 80 kW as a nominal trip set point beyond the 95% margin of uncertainty. Therefore, the decision to continue to use the 80 kW trip set point assures a sufficient margin prior to reaching 100 kW.

Enclosure N1 (four pages) contains graphs showing measurement of uncertainty and drift on all four DWK 250 chassis, measured at 5.7 MW for a time span of 24 hours. Enclosure N2 provides plots for linearity measurements for DWK 250 Channels #1, 2, and 3, and Enclosure N3 provides a separate one for Channel #4.

f) *The description of the light emitting diode (LED) Scram Display was modified to include the use of the lamp test and the "DWK 250 test condition scram bypass" key switch. Provide an updated description for the final design of the LED Scram Display.*

The description of the LED Scram Display module has been revised to include the "Lamp Test" pushbutton. When held in, this button activates all the LED indicator lights for convenient visual check by the operator. The indicator lights will be tested prior to reactor startup per written procedures. The revised description of the LED Scram Display Module is provided as Enclosure F. Also included are a detailed schematic (Drawing R3W-270-2) and an overall block diagram (Drawing R3W-271-1).

A description and safety evaluation of the DWK 250 "Test" Condition Scram Bypass (TCB) Assembly was provided in Enclosure J, which includes an explanation of how this Assembly is used to perform pre-startup testing and surveillance, as mentioned above under RAI Question #2a, along with circuit schematic R3W-264-3.

g) *The SDM provide access to each of the four DWK 250 channels through the breakout box to set adjustable parameters by a dedicated computer. Clarify if the breakout box will be used in the final NSS design, and if so, how it will be used and its access controlled.*

The RS-232 Breakout Box and its connecting cable (K-19) have been removed from the Nuclear Safety System. They will not be used for the final Nuclear Safety System design. In the original concept, the Breakout Box was designed to facilitate accelerated testing and parameter verification for each of the DWK 250 chassis using a computer. In the current design, no computers will be connected to the DWK 250. Therefore, this feature was never used, and will not be used in the final design. All DWK 250 parameters will be verified by using the front panel keypad only, prior to any reactor startup. Likewise, the RS-232 serial port on the front of each DWK 250 chassis is now covered by a capture device held in place by security screws. This issue is similarly addressed in our response to RAI #7.

A memo discussing the RS-232 Breakout Box, the RS-232 serial port on the front of each DWK 250 chassis, and other aspects of cybersecurity access control, is provided as Enclosure O.

3.0 System Response

RAI #3: *Provide the system response time calculation to confirm the actual value for the final NSS design.*

A memo explaining the system response time calculations is provided as Enclosure P. The actual system response time was measured to be 446 milliseconds (mean value and median of five measurements). This is consistent with the "no more than 500 ms" statement in the supplemental

information submitted on 6 July 2017 (ADAMS Accession No. ML17193A188). It is also consistent with the conservative system response time calculation of 610 milliseconds.

Enclosure P also includes a 2-page technical report and an email message referenced by the memo.

4.0 NSS Testing

RAI #4: *Describe the test approach and test procedures used to test and validate the final design of the NSS system. Additionally, provide the Test Plan and test summary report(s) that describe the results observed during testing in accordance with the test procedures for the MIT-developed components and the integrated system tests for the final NSS design.*

The New Nuclear Safety System Global Test Special Procedure ("Global Test Procedure") is provided as Enclosure Q, completed and signed by reactor staff. Pre-installation, this procedure is performed to verify and validate, to the extent possible, the final NSS design and construction, with the modules connected together in the test rack, prior to final installation. After NRC approval, the new NSS will be installed in the control room instrumentation cabinets. Once that final installation is completed in accordance with the New Nuclear Safety System Installation Plan (provided as Enclosure R), the Global Test Procedure will be performed again. At that stage (post-installation), the purpose of the Global Test Procedure is to demonstrate that signals will properly propagate in the new NSS, from the detectors to the relevant equipment and provide all necessary reactor protective features, such as warnings and automatic scrams. The procedure encompasses parameter verification, analog meter calibration, range change-over in the neutron flux monitors, low count rate alarm and scram tests, short period alarm and scram tests, high power alarm and scram tests, coincidence tests (functional tests of the Scram Logic Card modules), DWK 250 watchdog timer tests, and DWK 250 key switch tests. These pre-installation tests and the post-installation test provide confirmation and documentation that the integrated NSS meets the final NSS design criteria.

A test summary report is provided as Enclosure Q1, recording the satisfactory completion of bench testing of all MIT-developed components, and the satisfactory completion of a pre-installation integrated system test.

Other written procedures for verification and validation are as follows:

PM 6.1.3.1A	DWK 250 Detector Pulse Height Discriminator Calibration
PM 6.1.3.1B	DWK 250 Detector Plateau Calibration
PM 6.1.3.1C	DWK 250 Pulse to Campbelling Overlap Calibration
PM 6.1.3.1D	DWK 250 Full Power Flux Calibration
PM 6.1.3.1E	DWK 250 Range Change-Over Verification
PM 6.1.3.2	DWK 250 Period Verification
PM 6.1.3.16	Detector Linearity Checks

These procedures, provided as Enclosure Q2, are to be performed with the modules connected together in the test rack, prior to final installation. After the final installation, they will be performed annually. Since the detectors, their pre-amplifiers, their connecting cables, and the DWK 250 chassis are already installed in their final locations, there is no need to repeat these six procedures prior to first use.

RAI #5: *Describe the test approach and provide the installation test procedure(s) that will be used to integrate the final NSS design into the MITR-II for the NSS upgrades.*

The new Nuclear Safety System Installation Plan, in the form of a written procedure, is provided as Enclosure R.

The test approach is that once NRC approves the NSS upgrades, final system installation will be implemented using this written procedure, which dictates that the installation is to be performed with the reactor shut down. The four fission chamber detectors and their pre-amps will not be affected, as they have already been installed in their final positions. As a preliminary step, the main electrical supply lines to the control room (L21 and L22) will be de-energized and locked out. Next, all relevant systems that will be removed will be tested as de-energized. Existing "Wire Removal" forms that track the installation of wires and cables will be used throughout the replacement process.

Removal of existing safety system equipment will come first, followed by alignment of UPS units, and then installation of new nuclear safety system equipment. The written procedure spells out the final location of each piece of new equipment. This is then followed by installing the connecting cables between the new equipment modules. The procedure describes these steps in detail, and has a second person immediately verify that each cable is connected correctly. Where necessary, the written procedure refers to use of a drawing for verification. Finally, electrical power will be applied and the equipment will be switched on. At this point, the Global Test Procedure will be performed, along with other procedures regarding the Withdraw Permit Circuit, nuclear instrument scram times, and blade drop times for all six shim blades, all as described by the Nuclear Safety System Installation Plan.

5.0 Technical Specification

RAI #6: *Provide the following:*

a) Revised TS 3.2.3 and TS 4.2.1 with justification and bases for the changes proposed.

b) Clarify if the installation of the proposed NSS system will require changes to the surveillance frequency identified in the TS. If so, describe how the periodicity of the surveillance frequency was determined.

c) Provide the surveillance requirements to be performed associated with these TSs.

Revised TS 3.2.3 "Reactor Protection System" and revised TS 4.2 "Reactor Control and Safety Systems", with justification and bases for the changes proposed, are provided in Enclosure S and Enclosure T, respectively. Each of the enclosures contains two versions – one showing only the final version of the text, and the other showing the tracked changes updating the Technical Specification revisions previously submitted as part of the LAR on 30 September 2014.

Installation of the proposed NSS will not require any changes to the surveillance frequency identified in the TS.

The surveillance requirements to be performed associated with these Technical Specifications remain unchanged, in that the calibration and trip set point verification for reactor period and neutron flux level are to be performed when the equipment is initially installed, any time a significant change in indication is noted, and at least annually. The seven procedures listed in the response to RAI #4 represent how these calibration and trip set point verifications are performed.

6.0 Mirion DWK 250 RS-232 Port Communication

RAI #7: *Explain if the RS-232 port is going to be used. If used, explain how it is going to be used and controlled and the corresponding test procedures.*

As described in the response to RAI #2g above, the RS-232 port is not going to be used. – See Enclosure O. which is the memo discussing the RS-232 Breakout Box, the RS-232 serial port on the front of each DWK 250 chassis, and other aspects of cybersecurity access control.

The RS-232 serial port on the front of each DWK 250 chassis is covered by a capture device held in place by security screws. The special tool needed for the security screws is to be kept in the KeyWatcher cabinet in the Operations Office. This capture device also forces a selector switch to remain in the position that enables the front port and disables the terminal strip on the rear of the DWK 250 chassis. No computers will be connected to the DWK 250, and all DWK 250 parameters will be verified by using the front panel keypad only, prior to any reactor startup.

7.0 System Classification

RAI #8: *Provide a clear description of the classification for each component of the NSS.*

A block diagram of the new nuclear safety system with integrated support modules is provided in Enclosure U.

The path of scram signal propagation is marked on the block diagram with boldface arrows and lines. The NSS components that are safety related are:

1. The four Nuclear Safety Channels, each consisting of neutron detector, pre-amplifier, and DWK 250 neutron flux monitor chassis.
2. Signal Distribution Module (SDM).
3. The two Scram Logic Card (SLC) modules.
4. LED Scram Display module.
5. <100 kW Key-Switch Module (KSM).
6. The three Magnet Power Supply Modules (each powering two shim blade magnets).
7. Rundown Relay Panel.
8. Withdraw Permit Circuit (WPC).
9. DWK 250 "Test" Condition Bypass Assembly (TCB)
10. The six Shim Blade Magnets (existing equipment).
11. The six Shim Blade Drive Circuits (existing equipment).

The NSS components that are considered non-safety related are:

a. Blade Drop Timer Interface (DTI) Module.
b. Blade Drop Timer [existing equipment].
c. Safety System Monitoring & Status Display PLC.
d. Console Meters/Recorders [existing equipment].
e. Console Annunciator Panel [existing equipment]

RAI #9: *Explain why the LED scram display is considered a non-safety related component.*

The LED Scram Display module is considered a safety related component. – See also the response to RAI #8 above. A revised description and safety evaluation for the LED Scram Display is provided in Enclosure F, as previously referenced in the response to RAI #2f.

8.0 Console Layout

RAI #10: *Provide the console layout indicating where the NSS components will be located in the final design.*

The existing and proposed console layouts are provided in Enclosure V, indicating where the new NSS components will be located in the control room console. The Enclosure includes a memo providing human factors considerations for the proposed layout based on engineering principles.

9.0 Cyber Security

RAI #11: *Provide an explanation of the method that will be used to configure the DWK-250 settings and how these settings will be protected from unauthorized modification.*

As described in the responses to RAI #2g and RAI #7 above, the RS-232 serial port on the front of each DWK 250 chassis is not going to be used. – See Enclosure O. Likewise, the RS-232 Breakout Box is not going to be used. The Breakout Box and its connecting cable (K-19) have been removed from the Nuclear Safety System. No computers will be connected to the DWK 250. All DWK 250 parameters will be set manually and verified manually by using the front panel keypad only, prior to any reactor startup.

DWK 250 adjustable parameters can be changed only with use of the "red" key in the S2 key switch on the front of DWK 250 chassis. Adjustable parameters include calibration settings, trip set points, alarm set points, voltage monitoring ranges, and discriminator threshold. The "red" key is kept in a monitored, high security KeyWatcher key storage cabinet. It is accessible only by selected reactor staff such as senior members of Reactor Operations and the Instrumentation Supervisor.

In summary, these RAI responses and enclosures represent additional information identified as outstanding during the NRC Site Regulatory Audit in July 2017, completing documentation of the final design, and including integrated testing results. The RAI responses and enclosures submitted herewith do not contain any proprietary information.

In addition to the ten Enclosures listed in the Response to RAI #2, this RAI response submittal also contains the following 12 Enclosures:

Enclosure A. Contents from Q/A File #2017-35 for the Scram Logic Card Modules.

Enclosure B. Contents from QA File #2017-34 for the Signal Distribution Module, along with Enclosure B1 containing excerpts from QA File #2017-38 for the Magnet Power Supply Modules.

Enclosure M. "Special Procedure for Installing and Testing the Blade Drop Timer Interface Module" & Enclosure M1 Signal Junction Box schematic drawing R3W-272-1".

Enclosure N. Memo "Justification for Use of 80 kW as a Trip Set Point on the DWK 250 Flux Monitors for <100 kW Operation with the New Nuclear Safety System", along with Enclosure N1 (four graphs) and Enclosures N2 & N3 (two linearity plots).

Enclosure O. Memo "Response to RAI #7 and Cyber-Security Question for the Mirion DWK 250".

Enclosure P. Memo "System Response Time Estimation and Verifications for the New Nuclear Safety System", along with internal technical report on Time Response Estimations, and internal correspondence on Blade Drop Tests with new nuclear safety system.

Enclosure Q. Procedure "New Nuclear Safety System Global Test Special Procedure", along with Enclosure Q1, the Test Summary Report, and Enclosure Q2, a set of seven verification and validation procedures to be performed for the integrated system.

Enclosure R. Procedure "New Nuclear Safety System Installation Plan".

Enclosure S. Technical Specification 3.2.3 Reactor Protection System, final version and version showing tracked changes.

Enclosure T. Technical Specification 4.2 Reactor Control and Safety Systems, final version and version showing tracked changes.

Enclosure U. Revised "Block Diagram of Nuclear Safety System with Integrated Support Modules".

Enclosure V. Memo "Human Factors Considerations for Design and Implementation of the New Nuclear Safety System" (includes eight figures).

Sincerely,

Edward S. Lau, NE
Assistant Director of Reactor Operations
MIT Research Reactor

Alberto Queirolo
Director of Reactor Operations
MIT Research Reactor

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 12/14/2017 (Date) ______________ (Signature)

Enclosures: As stated.

cc: USNRC – Senior Project Manager
Research and Test Reactors Licensing Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

USNRC – Senior Reactor Inspector
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

QUALITY ASSURANCE REQUIREMENTS CHECKLIST: QA # 2017-35

Plan, procedure or equipment affected: Nuclear Safety System - Scram Logic Card Modules

Initiator: Shawn Hanvy / TL (Tim Laurini) Date: 9/25/2017 / 9/6/17

Class of change: ☒Class A ☐Class B ☐Class C
Type of change: ☐Procedure ☐Mechanical ☒Electrical ☐ ______
Extent of change: ☒Installation ☐Modification ☐Maintenance ☐ ______

Approval of QA requirements as listed in Sections I - ~~III~~ below:

Superintendent: Sarah [signature] Date: 10/27/17 Director of Reactor Operations: [signature] Date: 10/18/17

I	Document List		Completed By:	Date:
✓	Proposal (Class C changes)		N/A	N/A
✓	Safety Review (Class A/B changes)		E. Lau [initials]	6 JUL 2017 11/04/2017 [initials]
✓	Specifications		S. Hanvy	2/27/2013
✓	Procurement		S. Hanvy	7/29/2016
✓	Drawings and Schematics		S. Hanvy	5/31/2017
✓	Fabrication		S. Hanvy	1/31/2017
✓	Bench Testing		S. Hanvy	7/2/2017
✓	Handling and Installation Instructions		S. Hanvy	9/11/2017
NA ✓	Industrial Safety Checklist		N/A	N/A

Above requirements are complete. Equipment is ready to be installed or procedure is ready to be implemented.

Superintendent or DRO: Sarah [signature] Date: 12/14/17

II	Document List		Completed By:	Date:
✓	Installation and Inspection			
✓	Testing and Calibration			
✓	Operating Procedures and Checklists			

Above requirements are complete. Equipment is ready to be placed in operation.

Superintendent or DRO: ______ Date: ______

III	Document List		Completed By:	Date:
✓	Reactor Systems Manual			
✓	Safety Analysis Report			
✓	Safety Review Distribution			
✓	Training			

All requirements of QA package complete:

______ QA Supervisor ______ Date

______ Superintendent ______ Date ______ Director of Reactor Operations ______ Date

Additional approvals needed by: ☐ MITRSC (approval attached) ☐ USNRC (approval attached)

Safety Review Form No. 2017-35

Item: Scram Logic Cards

Submitted by E. Lau/S. Tucker Date 11/8/2017

Q/A number (required for all equipment changes) ______

	Yes*	No
Does the item change or contradict the Technical Specifications?		X
Does the item contradict the SAR?	X	

*Attach explanation

Description of Change (Attach extra pages if necessary):

See attached.

Safety Evaluation (Attach extra pages if necessary):

See attached.

Summary of Review:

a) Does the proposal:

	Yes	No
i) require a license amendment (10CFR50.59(c)(2))	X	
ii) decrease scope of requalification program (10CFR50.54(i-1))		X
iii) decrease effectiveness of security plan (10CFR50.54(p))		X
iv) decrease effectiveness of emergency plan (10CFR50.54(q))		X

b) Reviewer's Comments:

Reviewer [signature] Date 11/9/17

Reviewer [signature] Date 11/9/17

Reviewer [signature] MAHOWALD Date 11/14/17
(Reactor Radiation Protection Officer)

Approved [signature] Date 11/15/2017
(Director of Reactor Operations)

Date of MITRSC approval if required 11/16/2017 Date of NRC approval if required ______

List of Communications containing MITRSC additional conditions:

10 CFR 50.59 & 50.54 (p and q) changes included in Annual Report to NRC, Fiscal Year ______

Evaluation of SR#-2017-35 under 50.59 Requirements

This change requires a change to the SAR and a license amendment per 10 CFR 50.59. See QA File #E-2012-1.

ALARA Determination for SR#-2017-35

The changes will have no impact on ALARA because the changes do not change the time spent in high radiation areas.

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Specifications

NSS Scram Logic Card Modules

1. There are four independent nuclear safety channels, each of which is composed of a fission chamber, a pre-amplifier, and a DWK 250 chassis. Each DWK 250 chassis outputs six trip conditions: High Power, 100 kW (when enabled), Short Period, Low Count Rate, Fault, and Test. Any time two or more DWK 250 chassis output a trip condition, the NSS Scram Logic Cards (SLCs) output a reactor scram signal, which opens the Withdraw Permit Circuit (WPC) and removes power from the control blade electromagnets. The trip signals **DO NOT** have to come in to an SLC simultaneously to cause a scram. Once a trip condition clears at a DWK 250 chassis, the signal must be manually reset at the SLC. If the trip signal for a particular channel is not reset at the SLCs, even if the condition has cleared at that particular DWK 250, and another channel senses a trip condition, the SLCs' two-out-of-four logic will be satisfied, thereby subsequently causing a scram.

    a. A tripped condition or state occurs when any device in the signal path is de-energized.

    b. A tripped condition must exist for 2-5 milliseconds to cause reactor scram in order to prevent false-scrams.

    c. The time from initiation of a scram signal and movement of each operable blade from its current position to its 80% inserted position is less than one second for each blade.

2. In addition to their scram function, the SLCs will latch any high power/100 kW, short period, or test/fault condition trip signal from any of the four DWK 250 chassis.

    a. A total of four Reset circuits, one to clear each channel.

    b. Latched-in trip conditions that have caused a scram must be reset before the SLCs will re-energize output to the WPC and magnet power supply.

3. The signal paths between the DWK 250s and the SLCs will be equipped with optical isolation devices to protect the DWK 250s from any interference by downstream circuitry or equipment. These devices ensure that signals flow in only one direction. The opto-isolators may be stand-alone components or built into the logic circuits.

4. The SLCs will contain a circuit that takes input from a "100 kW / Full Power Operation" key switch. This switch will be in the "Full Power Operation" position during routine

full-power operation, thereby disregarding the 100 kW high power trips from the DWK 250s. When the key switch is in the "<100 kW Operation" position it will allow the primary system pressure scrams for MP-6 and MP-6A to be bypassed as well as the low flow primary scram.

5. Quality Control Requirements for SLC components:

   a. The SLC circuits that are responsible for reactor scrams will use components that conform to quality control and industry standards, and are manufactured by reputable companies. The majority of these components are qualified to the specification laid out by the Automotive Electronics Council (AEC) Component Technical Committee.

      i. AEC qualification helps establishes standards for reliable, high quality electronic components. Components meeting AEC specs are suitable for use in harsh automotive environments without additional component-level qualification testing.

   b. A component used in the SLC's 2-out-of-4 coincidence logic circuit will include the Texas Instruments (TI) SN74LVC1G0832 logic gate which is not available in AEC qualification.

      i. QA data from TI has shown a mean time between failure (MTBF) of 9.661E8 and Failures-in-Time (FIT) of 0.9; which is the number of failures per 1E9 device-hours. This device is therefore deemed acceptable for use in the new Nuclear Safety System.

6. SLC Circuit Board Layout

   a. PCB material will be FR4
   b. 1 oz. copper pour
   c. Minimum clearance for traces will be 0.006 inches; provides insulation up to 100V DC or AC
   d. PCB will be conformal coated after testing
   e. Logic IC will be powered by 5Vdc
   f. Zener diodes will be used to transition the 24Vdc signal to 5Vdc.

7. SLC Component Temperature Operation Requirements

   a. The components shall meet or exceed the commercial grade temperature requirements of 0°C to 85°C

8. External Testing

   a. A test fixture composed of toggle switches and push buttons powered by an external 24Vdc supply shall be used to verify the Scram Logic Card's functionality by simulating all possible DWK 250 relay output combinations.

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Q/A File #2017-35 "Scram Logic Card Modules"

Description of the Scram Logic Card Modules

An identical pair of Scram Logic Cards housed in separate modules within the same NIM bin (NIM Bin 1 in Figure 1) process the two-out-of-four scram logic decision independently in parallel. A scram decision and hence a scram signal output from either scram logic printed-circuit card will trigger the reactor's scram function, namely interrupting magnet current, dropping the shim blades by gravity into the reactor core, and thereby shutting down the reactor. The Scram Logic Cards are located downstream from the Signal Distribution Module which passes along DWK 250 trip signals and inputs them into both circuit cards simultaneously.

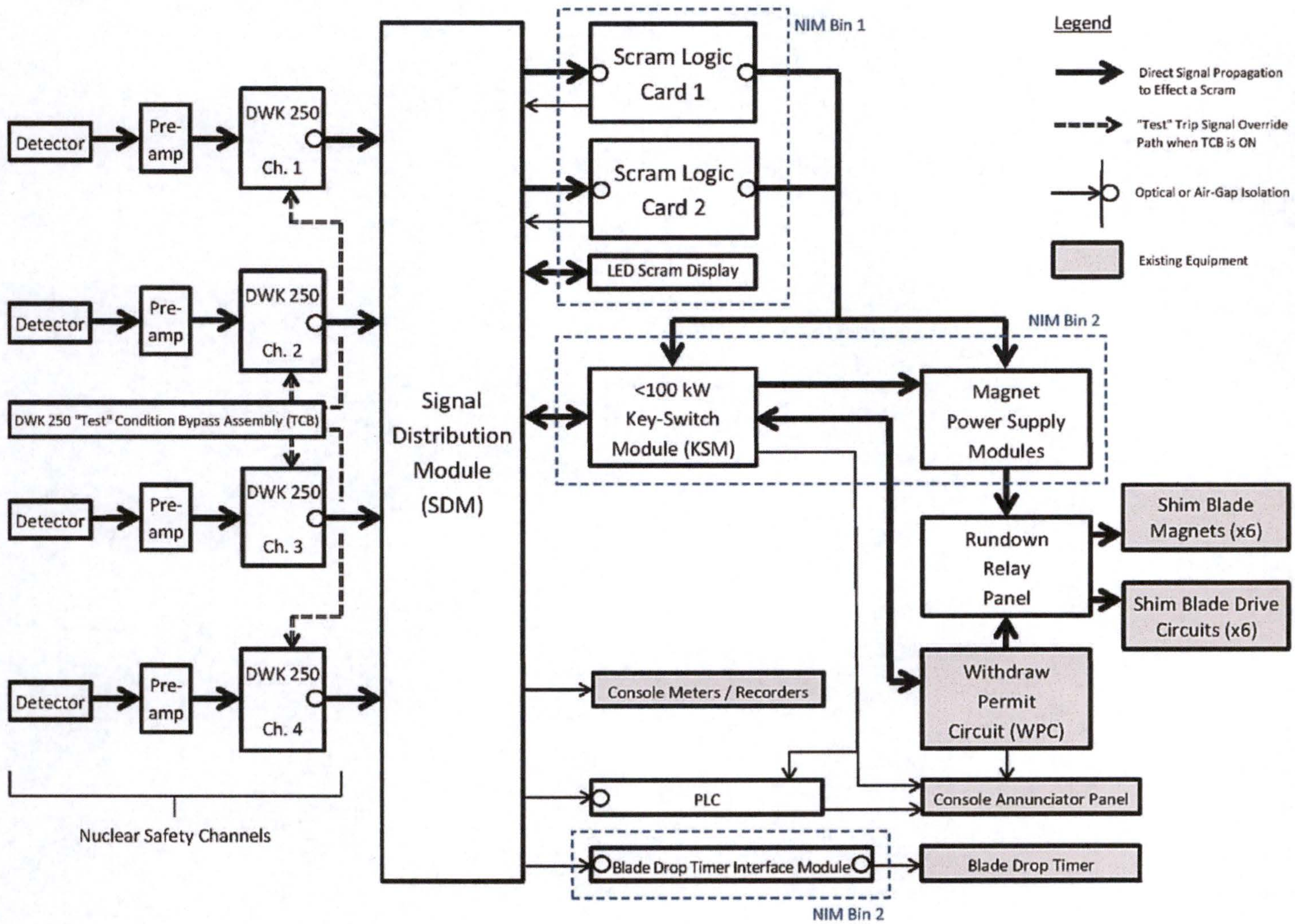

Figure 1: Block Diagram of Nuclear Safety System with Integrated Support Modules

Each Scram Logic Card (SLC) is housed in a dedicated protective chassis that is constructed of standard industrial aluminum stock. Figure 2 and Figure 3 show a spare SLC module that is identical to Scram Logic Cards #1 and #2. The printed-circuit card is constructed using standard industrial FR-4 board (composite material composed of woven fiberglass cloth with an epoxy resin binder), with the logic devices being high quality industrial discreet solid-state components, conforming to industrial quality standards for automotive electronics. The SLC modules do not contain a fan or any other moving parts. Their operation is entirely analog using discrete solid-state components. The choice of all components on the circuit boards was determined in house; an ISO 9001-2008 certified electronic hardware manufacturer (Advanced Circuits) performed the printed-circuit board fabrication and card assembly. The cards were manufactured to certification IPC Class 2-A600, for dedicated-service electronic products requiring continued performance and extended life.

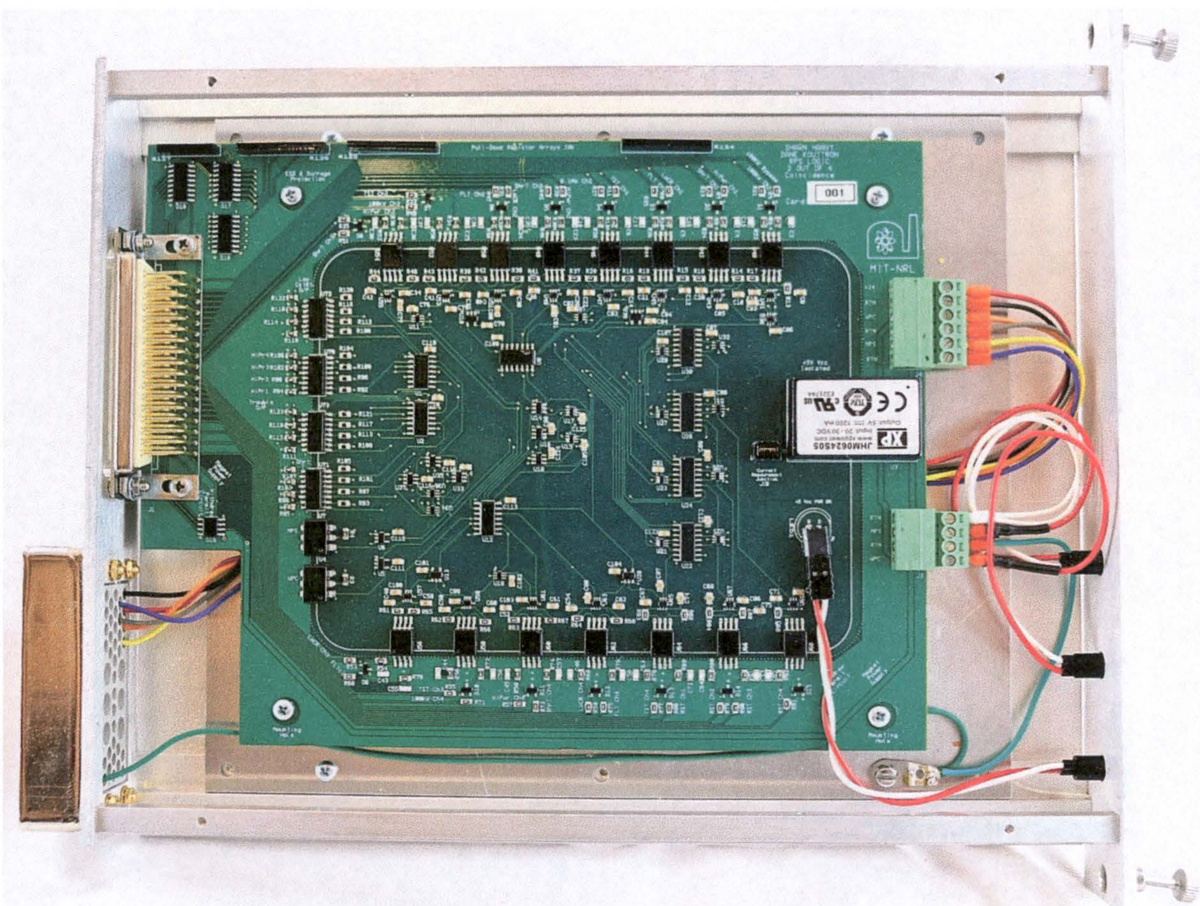

Figure 2: Scram Logic Circuit Card in a Scram Logic Card Module

The printed circuit board, as shown in Figure 2, has four layers which are electrically insulated from each other except at vertical interconnect access (VIA) points. Most components are mounted on the top plane of the board, but a few small ones such as capacitors are on the bottom plane. The second plane from the top supplies power to the components, and the third, a ground plane, contains the return paths.

Power for the two SLC modules comes from a pair of $24V_{DC}$ power supplies via the X14 connector of the Signal Distribution Module. The two $24V_{DC}$ power supplies are set up in parallel, connected via an auctioneering diode array, so that if one fails, the other will take over without interruption.

The top plane of the board has two isolated regions which are distinguishable by their different shades of green. Components in the lighter green near the perimeter of the board are supplied directly by $24V_{DC}$ power. The darker green inner area operates at $5V_{DC}$. All the logic executions take place in the darker area, with signals entering the region from the top and the bottom as seen on Figure 2, and logic output leaving the region on the left and the right.

The two voltage regions are isolated from each other electrically, connecting only via optical isolators ($5V_{DC}$ High Speed CMOS Optocouplers and High Collector-to-Emitter Voltage Optocouplers) and an isolated board-mount 24-volt to 5-volt, medically-qualified DC-DC converter. Throughout the circuit card, Zener diodes were used to convert $24V_{DC}$ to $5V_{DC}$ just upstream of the various optical isolators. Where necessary, pull-down resistors and current-limiting resistors are used to ensure binary signal clarity; surge-suppression diodes are used to protect the circuit card from electrostatic discharge (ESD).

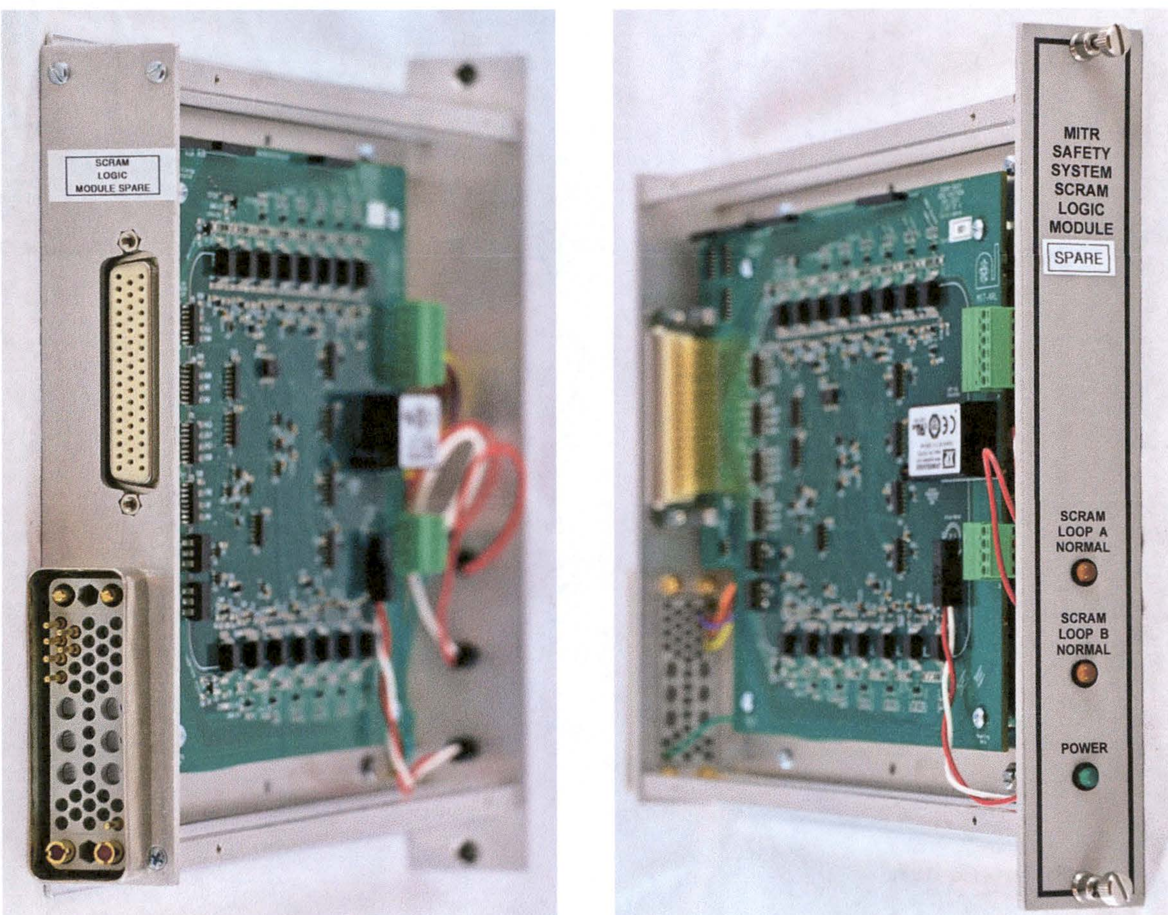

Figure 3: Back and Front Views of Scram Logic Card Module

The scram logic was designed in house, as asynchronous sequential binary logic. Therefore, the circuits do not contain or use a clock. If only one of the four DWK 250 chassis outputs a trip signal, while the other three do not, the scram logic will not initiate a scram signal. This will prevent a reactor scram due to a false indication from only one channel, and therefore will improve system stability. It also allows for testing and calibration of a single channel at power without the need for a bypass device. If now another DWK 250 chassis also outputs a trip signal to the scram logic circuit, the coincidence logic will complete a decision and output a scram signal by de-energizing the circuit, thereby removing power from normally-energized relays in the magnet power supplies and the Withdraw Permit Circuit to produce a reactor scram. Therefore, two or more DWK 250 chassis outputting safety trips will result in a scram signal output by the scram logic circuit. Furthermore, if one DWK 250 is under test, powered off, or removed from service, any trip signal from one of the other DWK 250s will result in a scram.

The design process for the scram logic went as follows: A logic diagram for the scram voting logic was first developed on paper. It was then algebraically simplified as a Boolean expression, and converted back to a reduced logic diagram. This diagram was then verified and tested with logic simulator software. The logic diagram was further verified by programming the logic design into a field-programmable gate array (FPGA) development board, the DE0-Nano from Terasic. The FPGA was then tested with an input board built in-house that simulated all possible combinations of inputs from the four DWK 250s plus the 100 kW operation key-switch.

Once the logic diagram was completed, it was entered into circuit design software with integrated circuits (IC) components selected by the reactor's Instrumentation Supervisor, and checked by the Senior Project Specialist, to produce a simulated logic circuit. This simulated circuit was then tested to verify correct operation. After the circuit design was completed, printable circuit board (PCB) design software was used to lay out the components and wire traces in a set two-dimensional areas to be stacked in four layers. The resulting circuit (Figure 4), in a Gerber-format (ASCII vector image) file, was sent to an intermediate manufacturer for fabrication of a prototype board. In-house testing of this prototype allowed adjustment of components, verification of voltage stability, and finalization of circuit design.

Once the final design and components were chosen, the layout was sent to the final manufacturer, Advanced Circuits, for fabrication of another prototype circuit card. This prototype card was tested in house, using the same voltage as the relay contacts from the DWK 250s. Several iterations of the prototyping processes occurred until the prototype satisfied all performance requirements, at which point five assembled copies of the final design were ordered from the manufacturer. One of the five cards received an independent visual inspection to ensure the logic components matched the parts list. When in-house testing and verification were completed satisfactorily on all five circuit cards, the cards were coated with conformal acrylic polymer for surface protection. One card was mounted in each of the two Scram Logic Card chassis, one in a spare SLC chassis, and two remain unmounted as spares.

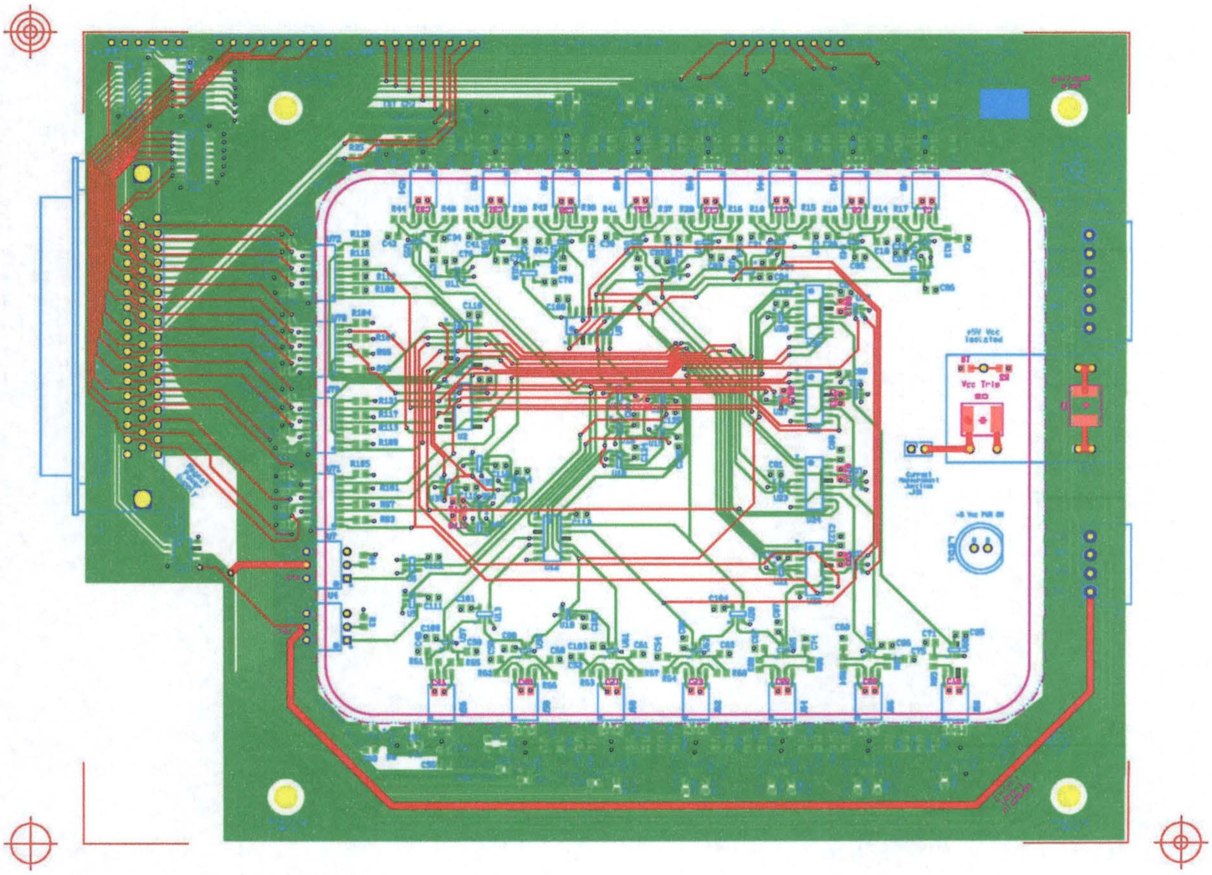

Figure 4: Part of N.I. Ultiboard layout for compilation to a Gerber file – PCB-with-Components Prototype

Reactor Drawing R3W-263-2 "NSS Scram Logic Card" main schematic and sub-circuits (total of 11 sheets) contains the schematics of the Scram Logic Card. These schematics divide functions of the cards into ten sub-circuits (SCs):

1. SC1 – "Optocoupled Schmitt Trigger Filter Input (SC1)"

   This input SC reduces the voltage from the $24V_{DC}$ signals to $5V_{DC}$ for the logic circuits, and de-bounces (damps any bouncing of) input signals during voltage/current transients.

2. SC2 – "ESD and Surge Protection (SC2)"

   Provides ESD and surge protection to the circuit components on the PCB.

3. SC3 – "Channel Logic (SC3)"

   Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 1, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

4. SC4 – "Channel Logic (SC4)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 2, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

5. SC5 – "Channel Logic (SC5)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 3, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

6. SC6 – "Channel Logic (SC6)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 4, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

7. SC7 – "Alarm Latch (SC7)"

Latches the Schmitt-triggered trips from the DWK 250 channels, stores them until the corresponding channel reset pushbutton is depressed, and forwards the latched signals to SC9. Also initiates alarm signals for the LED Scram Display module.

8. SC8 – "Alarm Indicator (SC8)"

This output SC converts signal voltage from the $5V_{DC}$ logic circuits to $24V_{DC}$ for alarm indications, using optocouplers. It forwards the alarm signals for the LED Scram Display module.

9. SC9 – "2 out of 4 (SC9)"

Executes 2-out-of-4 coincidence logic based on all latched-in alarms, whether active or not yet reset. The outputs of SC9 and SC10 feed into two independent AND gates outputting to two independent solid state relays that drive the 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit.

10. SC10 – "2 out of 4 (SC10)"

Executes 2-out-of-4 coincidence logic based on the outputs of the four channel logic SCs. Automatically resets once the DWK 250s are restored to normal operating conditions. The outputs of SC9 and SC10 feed into two independent AND gates outputting to two independent solid state relays that drive the independent 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit.

For logic operation related to scram decision-making, specifically in SC3, SC4, SC5, SC6, SC9, and SC10, five different types of Texas Instrument integrated circuit logic gate chips are used, ranging from 2-input to 4-input AND gates, plus OR-AND gates and AND-OR gates. All are qualified for automotive applications except the AND-OR gate. All have wide operating temperature tolerance (-40 C to 85 C or better). They all meet industrial standards for ESD protection.

There are a total of 29 inputs to each SLC. Each DWK 250 chassis produces eight binary outputs: High Power, Short Period, 100 kW High Power, Low Count Rate, Internal Fault, Test, High Power Warning, and Short Period Warning. The first six of these outputs go to the SLC as channel trip inputs. In total there are 24 trip inputs coming from the four DWK 250 chassis. Another four inputs to the SLC are resets, one for each channel, for the latched alarms coming from each DWK 250. The last input is from the key-operated switch on the <100 kW Key-Switch Module (KSM). A latched-in alarm will not clear until the corresponding channel's reset pushbutton is depressed on the LED Scram Display Module. Holding down one or more of the reset pushbuttons does not prevent a scram; likewise the LED indicator lights will still illuminate to show the corresponding trip signals.

When the KSM's key switch is turned to <100 kW Operation, a signal indicating the key switch position is sent to the two SLCs. If reactor power reaches 100 kW, the DWK 250s will output 100 kW High Power trips, and the SLCs will interpret these as high power channel trips. So if two or more DWK 250 simultaneously output the trip, the SLC will generate a scram signal. When the KSM's key switch is turned to Full Power Operation, the 100 kW High Power trips will still be generated from the DWK 250s and will all reach the SLCs, but the key switch position will signal the SLCs not to interpret them as high power channel trips. If the KSM's key switch is turned to <100 kW Operation when reactor power is already above the 100 kW scram set point, the system will scram on high power on all four channels simultaneously.

There are a total of 21 outputs from each SLC. Two of the outputs feed the independent relays that de-energize the Withdraw Permit Circuit and the Magnet Power Supply Modules in the event of a scram. Sixteen of the outputs feed trip indications to the LED Scram Display. The remaining three outputs feed indicator lights on the front of the SLC module.

The SLC's scram signal outputs are in $24V_{DC}$ binary form to drive relays in the Withdraw Permit Circuit, in the Magnet Power Supply Modules and Rundown Relay panel, and in the <100 kW Key-Switch Module. It is important to point out that the scram signal output is not a signal pulse that travels downstream along a transmission path. Instead, the system is always energized at 24 volts DC in the normal (no scram) operating condition. When a scram "signal" is output, the system is actually de-energized to 0 volts, ensuring de-activation of all downstream modules and shutting down the reactor. In this way, any system failure that causes loss of signal will have the same result of a reactor scram.

Safety Evaluation

The Scram Logic Card (SLC) is designed with solid-state logic devices that operate at low voltage ($5V_{DC}$) and with supporting components that operate at $24V_{DC}$. It is always in a powered state during normal operation. If a scram decision is made, it de-energizes, dropping power to 0 volts. If the SLC fails, it drops power to 0 volts, which is equivalent to a scram decision.

Failure Analysis

While failure of a qualified printed circuit board is rare, failure of individual components, particularly logic gates, would hamper logic decision-making. Logic gates can fail because of fast voltage transients, excessive heat buildup, oxide buildup, electrical over-stress, or electrostatic discharge. All of these conditions will cause the logic gate to fail open, either directly or in the form of a short circuit which will eventually burn through into an open circuit. This failure mode will resemble a scram decision.

However, it is known that logic components could fail in an energized condition. In this case, multiple logic pathways are used within each SLC to make redundant logic decisions. For instance, there is channel logic handling for trips from each DWK 250 channel. These channel trips are also latched on separate components. The channel logic output and the latched trips are fed to two independent 2-out-of-4 coincidence circuits. The outputs of the two coincidence circuits feed into two independent AND gates outputting to two independent solid state relays that drive the 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit. Deactivation of any one of these coincidence circuits, AND gates, or solid state relays will suffice in producing a reactor scram. Finally, there are two identical Scram Logic Cards that process the trips from the DWK 250 channels. Deactivation of either SLC will produce a reactor scram.

Redundancy and Independence

The two SLCs are each housed in their own aluminum chassis. Although they are mounted within the same NIM bin, their operations are completely independent, and do not interfere with each other. This multi-level redundancy and independence ensures a high degree of reliability in the operation of the Scram Logic Cards.

Component Isolation and Qualification

All logic operation takes place in a low-voltage environment ($5V_{DC}$). The logic components are physically mounted in a low-voltage region on the PCB. This region is electrically isolated from the rest of the PCB. Signals input and output across this isolation boundary are handled by the use of optoisolators and optocouplers, and an isolated board-mount 24-volt to 5-volt DC-DC power converter. The optoisolators and optocouplers both make use of high-speed light emitting diodes (LEDs) and photoreceptor receivers, and accordingly act as one-way devices by nature of their construction. Both types have an operating temperature range of at least -40 C to 100 C. The use of these optical and isolation devices satisfies the protection requirement for the low-voltage components.

Each SLC uses two solid-state output relays – one to the Withdraw Permit Circuit and the other to the magnet power supplies. These relays use infrared LEDs to optically isolate their inputs, thereby ensuring the signal path is one-way only, to protecting the SLCs. They have a fast switching speed from closed to open (maximum 0.5 milliseconds), and an operating temperature range of -40 C to 85 C.

All key components for logic operation are qualified for automotive applications, meeting industrial standards for electrical over-stress (EOS) and electrostatic discharge (ESD) protections, and allowing a wide range for operating temperature. Where necessary, diodes are used throughout the circuitry for surge suppression, and resistors to limit maximum current.

The SLCs receive their 24-volt power through the Signal Distribution Module (SDM) from two $24V_{DC}$ power supplies which meet medical qualifications. These two power supplies are fed from a common $120V_{AC}$ source, and have an internal fuse which will protect against surges that exceed $250V_{AC}$ on that line. They also have an output overload that will trip at no more than $35V_{DC}$. In the unlikely event of an excessive line voltage surge, both power supplies will likely trip, interrupting power to the two SLCs, scramming the reactor. Similarly, loss of off-site electrical power will shut down the SLCs, which are in a powered state during normal operation and have no internal battery backup. The SLC outputs a scram "signal" by de-energizing itself to 0 volts, thereby de-activating all downstream modules and shutting down the reactor.

Response Time Budget

The operation of the Scram Logic Cards is entirely bistable-based and asynchronous. The voltage transition from $24V_{DC}$ to the $5V_{DC}$ logic is accomplished with analog components, and the scram voting utilizes asynchronous sequential logic. There is no microprocessor in the signal path and thus no scan time or cycle time. As a result, the longest signal transition time through the logic card is 0.19 milliseconds, as evaluated from component-level data sheets. The actual time as measured is only ~0.038 milliseconds. Most of the time budget is for the isolation optocouplers passing input and output signals across the $24V_{DC}$ / $5V_{DC}$ boundary. This time budget is minuscule when compared to the opening times for the mechanical relays that interrupt shim blade magnet current, which are on the order of 15 milliseconds. The integrated system response time, which includes transit time across the SLCs and all other modules, is measured at no more than 500 milliseconds. This was measured based on time from initiation of the trip signal at the Mirion DWK 250 to movement of each operable blade from its full-out position to its 80% inserted position, which per MITR Technical Specification 3.2.1.1(b) must be less than one second.

Cybersecurity

Since there are no programmable or re-configurable logic elements in the SLCs, and no connections external to the Nuclear Safety System, the SLCs are not subject to cybersecurity threats.

Human Factors

Human interface with the SLC modules is minimized, with no switches or adjustable controls, and only three LED indicator lights on the front of each. (See Figure 3.) A green LED indicates that power is on, and two amber LEDs indicate normal (non-scrammed) conditions in Scram Loop A and Scram Loop B in the Withdraw Permit Circuit. During normal operation, all three indicators are lit. All external cable connections to the SLC modules will be labeled and color-coded. There are two external connections for each SLC module – an I/O cable with a DB50 connector, and an output NIM bin connector. It is not physically possible to interchange the input cable and output connector. Swapping of like I/O cables between the two SLC modules could cause incorrect LED displays but would have no impact on the scram functions. The color-coded labels improve human interface for purposes of installation and maintenance. Once the SLC modules are installed, there will be no regular human interface with them. They will be handled only by or under the supervision of license reactor staff. Since the maximum voltage in the modules is only $24V_{DC}$, electrical hazard to instrumentation personnel is minimal. Therefore, human factors engineering remains adequate.

The SLC modules will be mounted within the protective metal instrumentation cabinets of the control room. The instrumentation cabinets will provide the modules with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting of approximately 68 F (20 C). There is a temperature alarm with a setpoint no higher than 78 F (26 C) that is monitored whenever the reactor is operating, or is shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components in the SLC modules.

If the air conditioning is off for an extended period of time while the reactor is operating, the instrumentation cabinet temperature rise may cause component malfunction. Since all the Nuclear Safety System support module circuits are normally closed and energized, and they open when there is a scram condition, therefore a component malfunction will open a circuit and induce a scram. The control room containing the instrumentation cabinets is continuously attended by a licensed operator whenever the reactor is operating. There is a portable air conditioner available in the vicinity of the control room as a backup if the main system fails. Written protocols exist for operator response to a room temperature alarm condition, including shutdown should the adverse condition persist.

Pre-Operational Testing and Routine Surveillance

For pre-operational verification, the SLC modules were tested by simulating a trip condition for each combination of High Power, Low Count Rate, Short Period, Fault, and Test, to verify the cards initiated a scram condition for every combination of two parameters from any of the four DWK 250 channels. This test was completed in full power and <100 kW modes on both of the SLCs as well as the spare.

The SLC modules will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation.

Routine functional verification of the SLC modules will be performed in the reactor startup checklists so that certain tests will be completed prior to every reactor startup. The startup checklists will test the SLCs by verifying the 2-out-of-4 logic for each parameter, but will not test each combination as described above. Example of startup checklist testing for the High Power trips is as follows:

High Power Trip Channels 1 and 2
High Power Trip Channels 1 and 3
High Power Trip Channels 1 and 4
High Power Trip Channels 2 and 3
High Power Trip Channels 2 and 4
High Power Trip Channels 3 and 4.

On the startup checklists, the same testing sequence will also be performed for Low Count Rate, Short Period, Fault, and Test, for a total of 30 such tests. The tests will each be satisfied by observing a scram signal is successfully output from the two SLCs in parallel.

These pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the scram logic circuits.

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Procurement

NSS Scram Logic Card Modules

The components for the Scram logic card were purchased from Digi-Key Electronics and the data sheet for each component is included. Each component and the assembled printed-circuit board (PCB) meet the receipt requirements of PM 1.19.

1.19 Receiving, Storing, and Issuing of Materials

All materials received shall be:

- Checked against the requisition on which it was ordered so as to ensure receipt of the material requested.
- Visually inspected for obvious defects.
- Subject to a detailed inspection of all parts.
- Any material identified as not meeting NRL specification should be either:

  (a) returned to the supplier, or

  (b) evaluated for acceptability on some other documented basis. For materials within the scope of the QA program, see Section 1.13.6, "Non-Conformance to QA Standards."
- Once material or equipment has been accepted, it is either issued or placed in storage. Storage areas are assigned by category (i.e., raw materials, finished machine parts, electrical components, etc.)

1.19.1 Nuclear Materials

The receiving, storing and issuing of nuclear materials must be in accordance with applicable regulations, licenses, plans and procedures:

a) NRC Regulations:

10 CFR 20 Standards for Protection Against Radiation

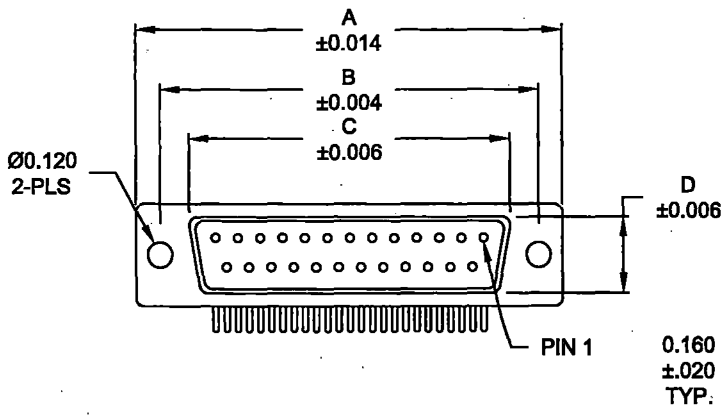
10 CFR 40 Domestic Licensing of Source Material

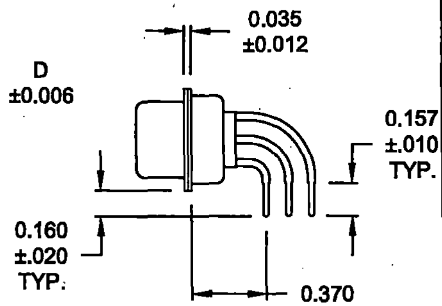
10 CFR 21 Reporting of Defects and Noncompliance

10 CFR 70 Domestic Licensing of Special Nuclear Material

10 CFR 73 Physical Protection of Plants and Materials

DESCRIPTION: FEMALE - 0.370 RIGHT ANGLE / MACHINED - ECONOMY

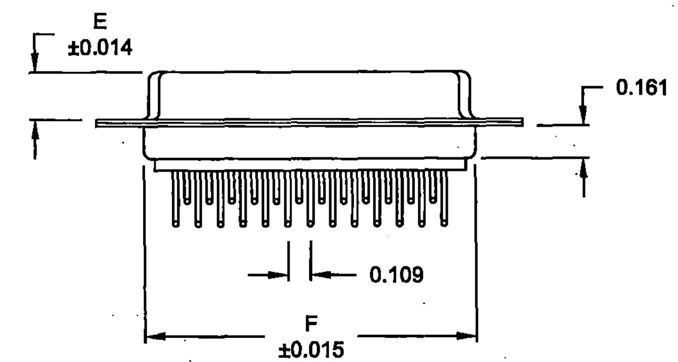


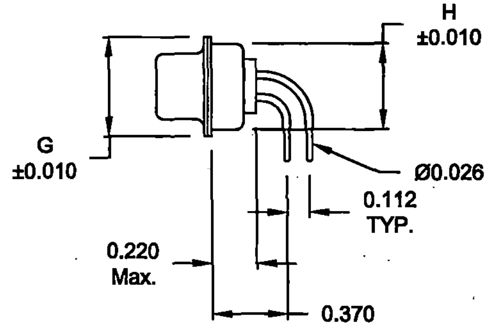


No. OF PINS	DIMENSIONS A	B	C	D	E	F	G	H
9	1.213	0.984	0.642	0.311	0.236	0.756	0.496	0.427
	30.80	24.99	16.30	7.90	5.99	19.20	12.60	10.85
15	1.541	1.312	0.970	0.311	0.236	1.091	0.496	0.427
	39.15	33.32	24.65	7.90	5.99	27.70	12.60	10.85
25	2.087	1.852	1.512	0.311	0.236	1.618	0.496	0.427
	53.00	47.04	38.40	7.90	5.99	41.10	12.60	10.85
37	2.728	2.500	2.157	0.311	0.236	2.256	0.496	0.427
	69.30	63.50	54.80	7.90	5.99	57.30	12.60	10.85
50	2.638	2.406	2.055	0.429	0.240	2.169	0.602	0.527
	67.00	61.11	52.20	10.90	6.10	55.10	15.30	13.39

174-EYY-21YRYY1

- SERIES
- POSITIONS
  - E09
  - E15
  - E25
  - E37
  - E50
- GENDER
  - 2 = FEMALE
- TERMINATION
  - 1 = PC MOUNTING
- SHELL PLATING
  - 3 = NICKEL
- RoHS COMPLIANT
- HARDWARE OPTIONS
  - 00 = NO HARDWARE
  - 14 = SHORT BRACKET WITH 4-40 SCREW LOCK
  - 24 = SHORT BRACKET WITH 4-40 SCREW
  - 46 = BRACKET WITH 4-40 INSERT AND BOARDLOCK
- PLATING OPTIONS
  - 1 = GOLD FLASH
  - 2 = 30MICRO-INCH GOLD
  - 3 = 50MICRO-INCH GOLD





MATERIAL:

SHELL: STEEL, NICKEL PLATED
INSULATOR: UL 94V-O RATED, WHITE PA6T
PROCESS TEMP.: 260° PROCESS TEMPERATURE
CONTACT: BRASS

ELECTRICAL:

CURRENT RATING: 5 AMPS
CONTACT RESISTANCE: 15 mOhms Max.
INSULATION RESISTANCE: 1,000 MOhms min.
VOLTAGE: 500VAC FOR 1 MINUTE
TEMPERATURE: -50° C TO 100° C

RoHS COMPLIANT

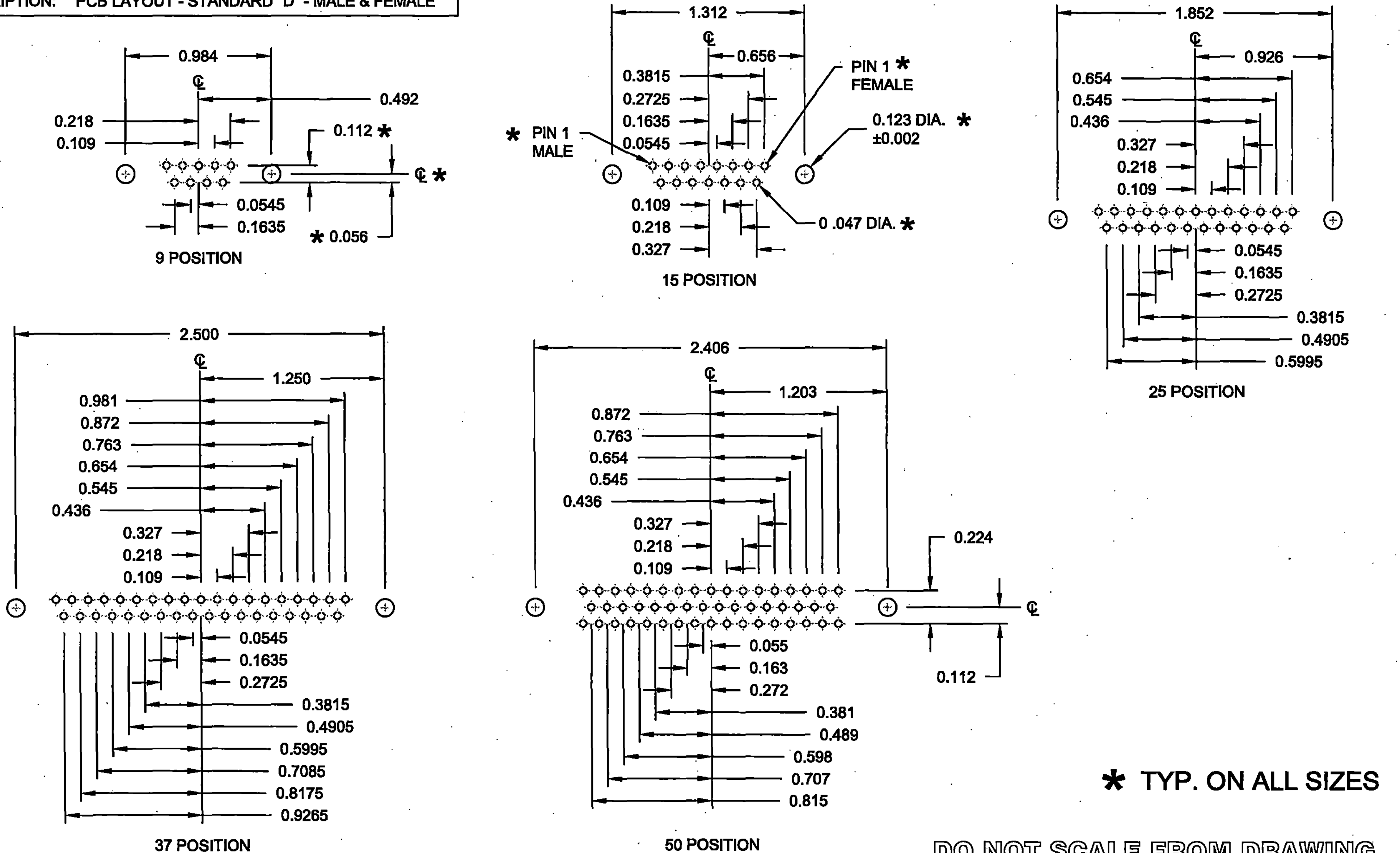
DO NOT SCALE FROM DRAWING

THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF NorComp AND SHALL NOT BE REPRODUCED, COPIED OR USED AS THE BASIS FOR THE MANUFACTURE OF SALE OF APPARATUS WITHOUT WRITTEN PERMISSION.

NorComp

DRAWN: WAYNE ROBBINS		DATE: 11-28-05	
CHECKED:		DATE:	
SCALE: 1 : 1	SHEET 1 OF 3		REV 9
DWG NO. 174-EYY-21YRYY1			

DESCRIPTION: PCB LAYOUT - STANDARD "D" - MALE & FEMALE



DO NOT SCALE FROM DRAWING

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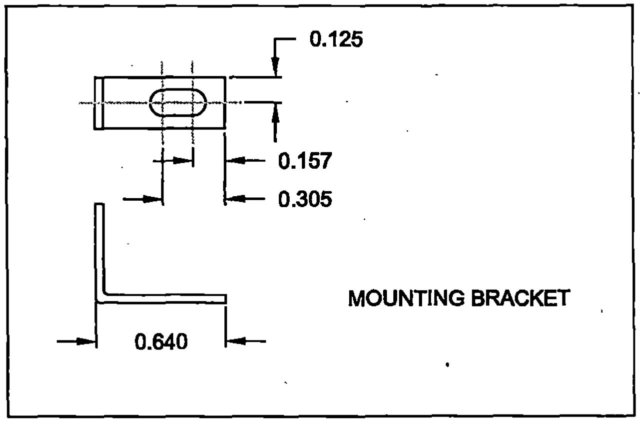
NorComp

DRAWN: C. SMITH		DATE: 03-08-06	
CHECKED:		DATE:	
SCALE: FULL	SHEET 2 OF 3		REV 9
DWG NO. 174-EYY-21YRYY1			

DESCRIPTION: CLINCH NUT HARDWARE

173/174 SERIES



HARDWARE OPTIONS

REPLACE -YY IN LAST 3 DIGITS WITH OPTION CHOSEN

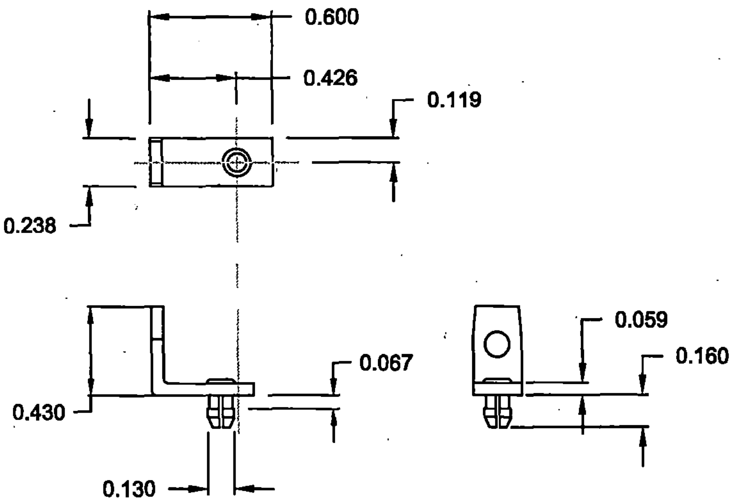
MATERIAL: COLD ROLLED STEEL

PLATING: CLEAR ZINC

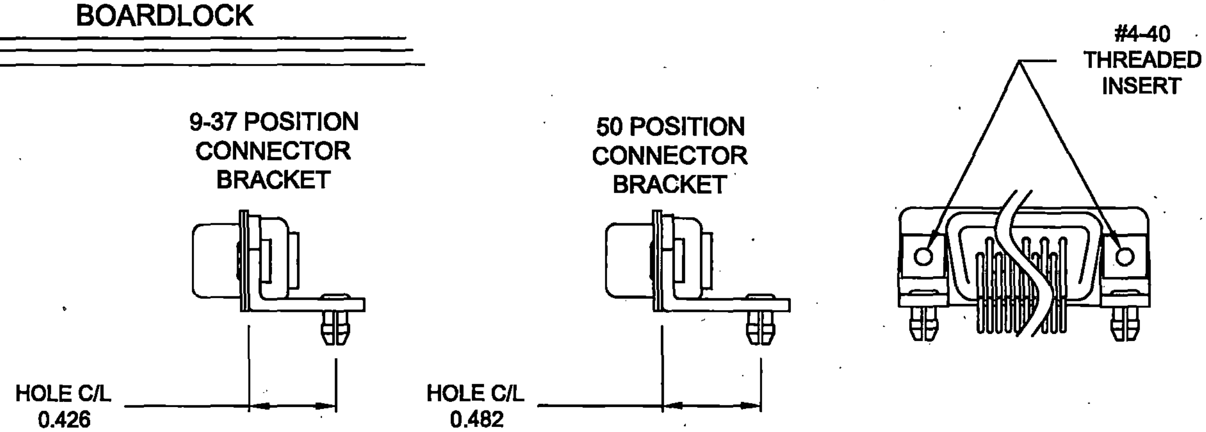
173 / 174 SERIES

14Y = SHORT BRACKET & 4-40 FEMALE HEX SOCKET
24Y = SHORT BRACKET & 4-40 SCREW

46Y = BRACKET WITH 4-40 INSERT AND BOARDLOCK



MOUNTING BRACKET
WITH BOARD LOCK

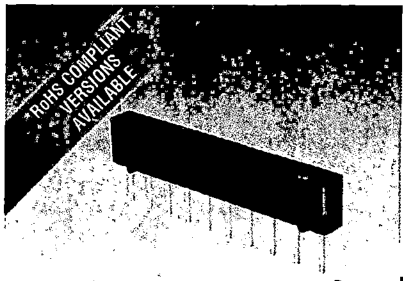


BRACKETS MOUNTED ON CONNECTOR

DO NOT SCALE FROM DRAWING

RoHS COMPLIANT

NorComp	THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF NorComp AND SHALL NOT BE REPRODUCED, COPIED OR USED AS THE BASIS FOR THE MANUFACTURE OF SALE OF APPARATUS WITHOUT WRITTEN PERMISSION.	DRAWN: PAM JENKINS	DATE: 11-28-05	
		CHECKED:	DATE:	
		SCALE: 1 : 1	SHEET 3 OF 3	REV 9
		DWG NO. 174-EYY-21YRYY1		



BOURNS®

Features

- RoHS compliant* versions available (see How to Order "Termination" option)
- Low profile provides compatibility with DIPs
- Compatible with automatic insertion equipment
- Superior package integrity
- **Now available with improved tolerance to ±0.5 %**

4300R Series - Thick Film Molded SIPs

Product Characteristics

Resistance Range
.... 10 ohms to 10 megohms
Maximum Operating Voltage ....100 V
Temperature Coefficient of Resistance
50 Ω to 2.2 megohms.....±100 ppm/°C
below 50 Ω.....................±250 ppm/°C
above 2.2 megohms.......±250 ppm/°C
TCR Tracking.........................50 ppm/°C
maximum; equal values
Resistor Tolerance............... See circuits
Operating Temperature
.................................-55 °C to +125 °C
Power Rating................... Derate to zero
power from + 70 °C to + 125 °C
Insulation Resistance
.... 10,000 megohms minimum
Dielectric Withstanding Voltage
....200 VRMS
Lead Solderability..... Meet requirements
of MIL-STD-202 Method 208

Environmental Characteristics

TESTS PER MIL-STD-202...... ΔR MAX.
Short Time Overload..................±0.25 %
Load Life....................................±1.00 %
Moisture Resistance..................±0.50 %
Resistance to Soldering Heat
....±0.25 %
Terminal Strength ....±0.25 %
Thermal Shock ....±0.25 %

Physical Characteristics

Flammability .... Conforms to UL94V-0
Lead Frame Material
.........................Copper, solder coated
Body Material.................. Novolac epoxy

How To Order

43 06 R - 101 - 222 __ __

Model
(43 = Molded SIP)
Number of Pins
Physical Configuration
(R = Thick Film Low Profile)
Electrical Configuration
- 101 = Bussed
- 102 = Isolated
- 104 = Dual Terminator

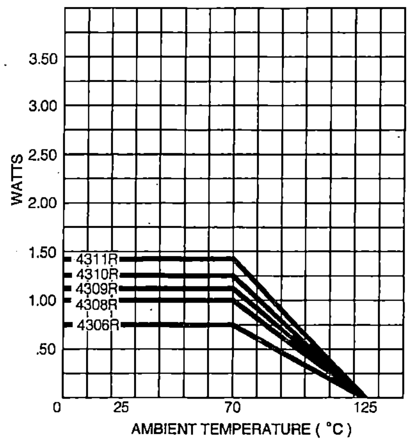
Resistance Code
- First 2 digits are significant
- Third digit represents the number of zeros to follow.

Resistance Tolerance
- Blank = ±2 % (see "Resistance Tolerance" on next page for resistance range)
- F = ±1 % (100 ohms - 1 megohm)
- D = ±0.5 % (100 ohms - 1 megohm)

Terminations
- All electrical configurations EXCEPT 104: LF = Tin-plated (RoHS compliant version)
- ONLY electrical configuration 104: L = Tin-plated (RoHS compliant version)
- Blank = Tin/Lead-plated

Consult factory for other available options.

Package Power Temp. Derating Curve

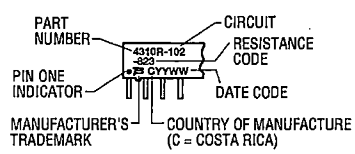


Package Power Rating at 70 °C

4306R.....................................0.75 watts
4308R.....................................1.00 watts
4309R.....................................1.13 watts
4310R.....................................1.25 watts
4311R.....................................1.38 watts

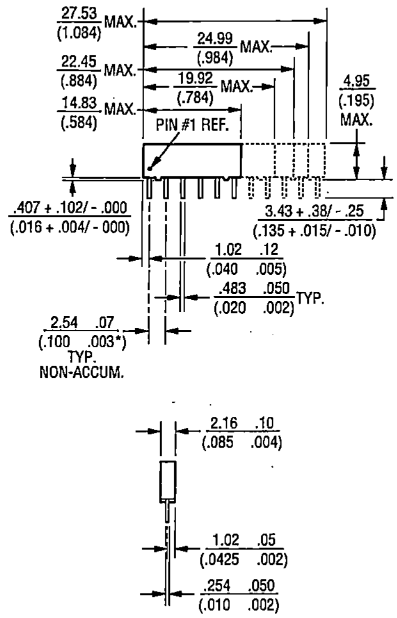
Typical Part Marking

Represents total content. Layout may vary. Marking may be truncated on shorter versions due to size constraints.



For Standard Values Used in Capacitors, Inductors, and Resistors, click here.

Product Dimensions



Governing dimensions are in metric. Dimensions in parentheses are inches and are approximate.

*Terminal centerline to centerline measurements made at point of emergence of the lead from the body.

*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.
Specifications are subject to change without notice.
Customers should verify actual device performance in their specific applications.

For information on specific applications, download Bourns' application notes:

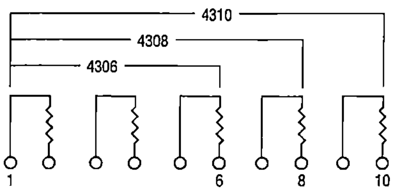
- DRAM Applications
- Dual Terminator Resistor Networks
- R/2R Ladder Networks
- SCSI Applications

4300R Series - Thick Film Molded SIPs

BOURNS®

Isolated Resistors (102 Circuit)

Model 4306R-102-RC (6 Pin)
Model 4308R-102-RC (8 Pin)
Model 4310R-102-RC (10 Pin)



These models incorporate 3, 4 or 5 isolated thick-film resistors of equal value, each connected between two pins.

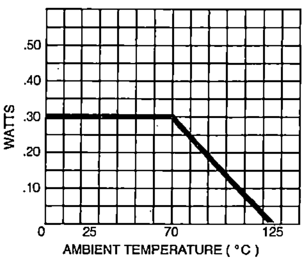
Resistance Tolerance

10 ohms to 49 ohms .... ±1 ohm
50 ohms to 5 megohms .... ±2 %*
Above 5 megohms .... ±5 %

Power Rating per Resistor

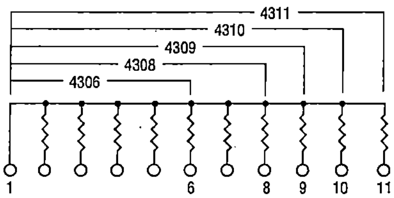
At 70 °C .... 0.30 watt

Power Temperature Derating Curve



Bussed Resistors (101 Circuit)

Model 4306R-101-RC (6 Pin)
Model 4308R-101-RC (8 Pin)
Model 4309R-101-RC (9 Pin)
Model 4310R-101-RC (10 Pin)
Model 4311R-101-RC (11 Pin)



These models incorporate 5, 7, 8, 9 or 10 thick-film resistors of equal value, each connected between a separate pin.

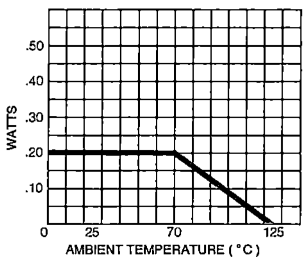
Resistance Tolerance

10 ohms to 49 ohms .... ±1 ohm
50 ohms to 5 megohms .... ±2 %*
Above 5 megohms .... ±5 %

Power Rating per Resistor

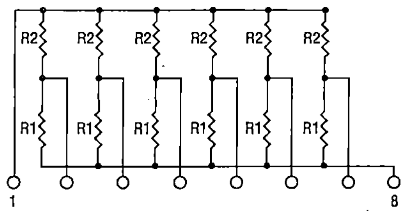
At 70 °C .... 0.20 watt

Power Temperature Derating Curve



Dual Terminator (104 Circuit)

Model 4306R-104-R1/R2
Model 4308R-104-R1/R2 (shown)
Model 4309R-104-R1/R2
Model 4310R-104-R1/R2
Model 4311R-104-R1/R2



4308R-104 (shown above) is an 8-pin configuration and terminates 6 lines. Pins 1 and 8 are common for ground and power, respectively. Twelve thick-film resistors are paired in series between the common lines (pins 1 and 8).

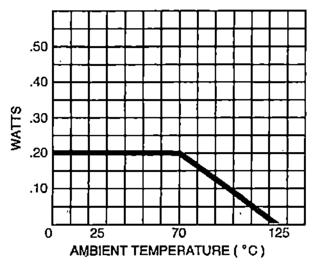
Resistance Tolerance

Below 100 ohms .... ±2 ohms
100 ohms to 5 megohms .... ±2 %*
Above 5 megohms .... ±5 %

Power Rating per Resistor

At 70 °C .... 0.20 watt

Power Temperature Derating Curve



Popular Resistance Values (101, 102 Circuits)**

Ohms	Code	Ohms	Code	Ohms	Code	Ohms	Code	Ohms	Code
10	100	180	181	1,800	182	15,000	153	120,000	124
22	220	220	221	2,000	202	18,000	183	150,000	154
27	270	270	271	2,200	222	20,000	203	180,000	184
33	330	330	331	2,700	272	22,000	223	220,000	224
39	390	390	391	3,300	332	27,000	273	270,000	274
47	470	470	471	3,900	392	33,000	333	330,000	334
56	560	560	561	4,700	472	39,000	393	390,000	394
68	680	680	681	5,600	562	47,000	473	470,000	474
82	820	820	821	6,800	682	56,000	563	560,000	564
100	101	1,000	102	8,200	822	68,000	683	680,000	684
120	121	1,200	122	10,000	103	82,000	823	820,000	824
150	151	1,500	152	12,000	123	100,000	104	1,000,000	105

Popular Resistance Values (104 Circuit)**

Resistance			
Ohms		Code	
R_1	R_2	R_1	R_2
160	240	161	241
180	390	181	391
220	270	221	271
220	330	221	331
330	390	331	391
330	470	331	471
3,000	6,200	302	622

* Add "F" after resistance code for ±1 % tolerance available from 100 Ω through 1M Ω, or add "D" after resistance code for ±0.5 % tolerance available from 100 Ω through 1M Ω.
Part number suffix examples: -103 = 10K Ω, ±2 %; -103F = 10K Ω, ±1 %; -103D = 10K Ω, ±0.5 %
** Non-standard values available, within resistance range.

REV. 05/12

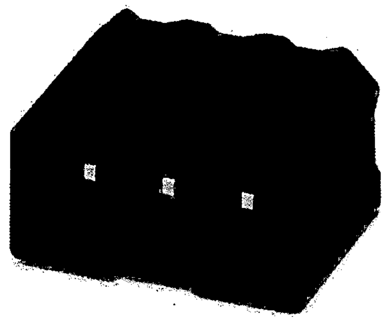
Specifications are subject to change without notice.
Customers should verify actual device performance in their specific applications.

PHOENIX CONTACT

Extract from the online catalog

PTSM 0,5/ 2-HH-2,5-THR R16

Order No.: 1778625



http://eshop.phoenixcontact.de/phoenix/treeViewClick.do?UID=1778625

Header, Nominal current: 6 A, Rated voltage (III/2): 160 V, Number of positions: 2, Pitch: 2.5 mm, Color: black, Metal surface: Sn, Assembly: SMD/THT/THR

Product notes

WEEE/RoHS-compliant since: 09/17/2009

Commercial data

GTIN (EAN)	4 046356 529808
sales group	E430
Pack	500 pcs.
Customs tariff	85369010
Catalog page information	Page 185 (NTK-2010)

http:// www.download.phoenixcontact.com Please note that the data given here has been taken from the online catalog. For comprehensive information and data, please refer to the user documentation. The General Terms and Conditions of Use apply to Internet downloads.

Technical data

Dimensions / positions

Length	7.5 mm
Pitch	2.5 mm
Dimension a	2.5 mm
Number of positions	2

Pin dimensions	0,6 x 0,6 mm
Pin spacing	2.50 mm
Hole diameter	1.1 mm

Technical data

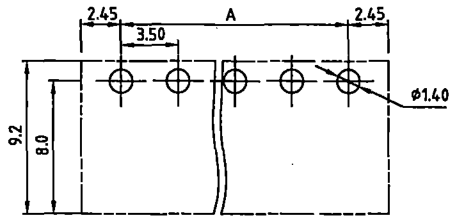
Range of articles	PTSM 0,5/..-HH-THR
Insulating material group	IIIa
Rated surge voltage (III/3)	2.5 kV
Rated surge voltage (III/2)	2.5 kV
Rated surge voltage (II/2)	2.5 kV
Rated voltage (III/2)	160 V
Rated voltage (II/2)	160 V
Connection in acc. with standard	EN-VDE
Nominal current I_N	6 A
Nominal voltage U_N	50 V
Maximum load current	6 A
Insulating material	LCP
Inflammability class acc. to UL 94	V0
Nominal voltage, UL/CUL Use Group B	150 V
Nominal current, UL/CUL Use Group B	6 A

Certificates / Approvals

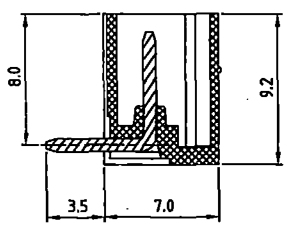
c UL us

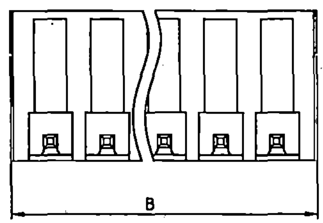
Certification CUL, UL

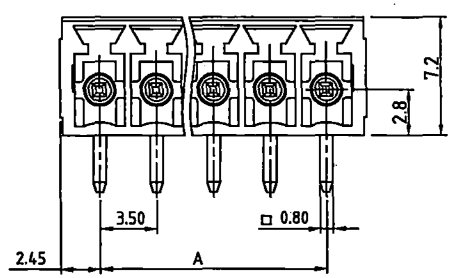
Certifications applied for: UL / CUL



RECOMMENDED PCB LAYOUT







TECHNICAL CHARACTERISTICS

MATERIAL
INSULATOR: PA 66
FLAMMABILITY RATING: UL94-V0
COLOR: GREEN
CONTACT: BRASS
SOLDER TAIL PLATING: TIN

ENVIRONMENTAL
OPERATING TEMPERATURE: -40 UP TO 105°C
COMPLIANCE: LEAD FREE AND ROHS

ELECTRICAL	cULus	VDE
CURRENT RATING:	10 A	10.5 A
WORKING VOLTAGE:	300 VAC	300 VAC
WITHSTANDING VOLTAGE:	1.6 KV	2.5 KV
CONTACT RESISTANCE:	20 mOhm max	

STANDARD
UL CERTIFIED E315414
VDE CERTIFIED 40023402

MECHANICAL
PITCH: 3.5MM

SOLDERING
JEDEC LEAD FREE WAVE SOLDERING PROCESS

PACKAGING
BOX

DIMENSION
A = (NB. PINS -1) x PITCH
B = ((NB. PINS -1) x PITCH) + 4,9

RoHS Compliant

REV	DATE	FILE	BY
G			
F			
E			
D	04-APR-16	UPDATE	AK
C	12-SEP-14	MATERIAL	AS
B	29-APR-14	MATERIAL	QL
A	31-OCT-08	PDF	JP

PROJECTION:

APPROVAL: FBr

GENERAL TOLERANCE
.X = +/- 0.2
.XX = +/- 0.15

UNIT: MM
SCALE:
SHEET: 1/2
DRAW: MARVIN

WÜRTH ELEKTRONIK

DESCRIPTION: SERIE 3221 - 3.50MM HORIZONTAL PCB HEADER WR-TBL

WERI PART NO: 691 322 110 0xx

SIZE **A4**

Anti-Surge Thick Film Chip Resistors

Type: ERJ PA2, P03, PA3, P06, P08, P14

Features

- ESD surge characteristics superior to standard metal film resistors
- High reliability
  Metal glaze thick film resistive element and three layers of electrodes
- Suitable for both reflow and flow soldering
- High power ···0.20 W : 0402 inch / 1005 mm size (ERJPA2), 0603 inch / 1608 mm size (ERJP03)
  0.25 W : 0603 inch / 1608 mm size (ERJPA3)
  0.50 W : 0805 inch / 2012 mm size (ERJP06), 1210 inch / 3225 mm size (ERJP14)
  0.66 W : 1206 inch / 3216 mm size (ERJP08)
- Reference Standards··· IEC 60115-8, JIS C 5201-8, EIAJ RC-2134B
- AEC-Q200 qualified
- RoHS compliant

■ **As for Packaging Methods, Land Pattern, Soldering Conditions and Safety Precautions,**
Please see Data Files

Explanation of Part Numbers

1	2	3	4	5	6	7	8	9	10	11	12
E	R	J	P	0	6	D	1	0	0	2	V

Product Code
Thick Film Chip Resistors

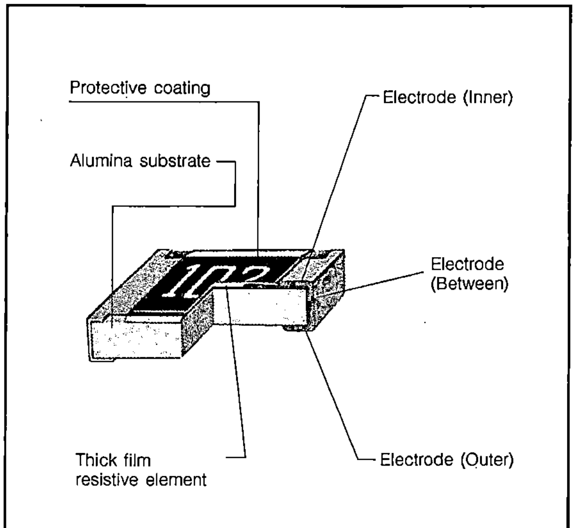
Size, Power Rating		
Code	Inch	Power R.
PA2	0402	0.20 W
P03	0603	0.20 W
PA3	0603	0.25 W
P06	0805	0.50 W
P08	1206	0.66 W
P14	1210	0.50 W

Resistance Tolerance	
Code	Tolerance
D	± 0.5 %
F	± 1 %
J	± 5 %

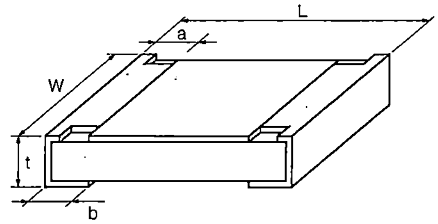
Resistance Value
The first two or three digits are significant figures of resistance and the third or 4th one denotes number of zeros following. Three digit type (±5 %), four digit type (±1 %, ±0.5 %) Example: 222→2.2k Ω, 1002→10k Ω

Packaging Methods		
Code	Packaging	Part No.
X	Punched Carrier Taping 2 mm pitch, 10,000 pcs.	ERJPA2
V	Punched Carrier Taping 4 mm pitch, 5,000 pcs.	ERJP03 ERJPA3 ERJP06 ERJP08
U	Embossed Carrier Taping 4 mm pitch, 5,000 pcs.	ERJP14

Construction



Dimensions in mm (not to scale)



Part No. (inch size)	Dimensions (mm)					Mass (Weight) [g/1000pcs.]
	L	W	a	b	t	
ERJPA2 (0402)	$1.00^{\pm0.05}$	$0.50^{\pm0.05}$	$0.20^{\pm0.15}$	$0.25^{\pm0.05}$	$0.35^{\pm0.05}$	0.8
ERJP03 (0603)	$1.60^{\pm0.15}$	$0.80^{+0.15}_{-0.05}$	$0.15^{+0.15}_{-0.10}$	$0.30^{\pm0.15}$	$0.45^{\pm0.10}$	2
ERJPA3 (0603)	$1.60^{\pm0.15}$	$0.80^{+0.15}_{-0.05}$	$0.15^{+0.15}_{-0.10}$	$0.25^{\pm0.10}$	$0.45^{\pm0.10}$	2
ERJP06 (0805)	$2.00^{\pm0.20}$	$1.25^{\pm0.10}$	$0.25^{\pm0.20}$	$0.40^{\pm0.20}$	$0.60^{\pm0.10}$	4
ERJP08 (1206)	$3.20^{+0.05}_{-0.20}$	$1.60^{+0.05}_{-0.15}$	$0.40^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	10
ERJP14 (1210)	$3.20^{\pm0.20}$	$2.50^{\pm0.20}$	$0.35^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	16

Ratings

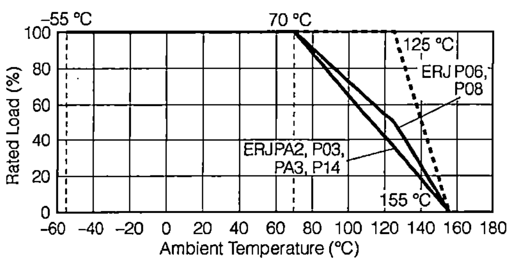
Part No. (inch size)	Power Rating[3] at 70 °C (W)	Limiting Element Voltage[1] (V)	Maximum Overload Voltage[2] (V)	Resistance Tolerance (%)	Resistance Range (Ω)	T.C.R. ($\times 10^{-6}$/°C)	Category Temperature Range (°C)
ERJPA2 (0402)	0.20	50	100	±0.5, ±1	10 to 1M (E24, E96)	±100	–55 to +155
				±5	10 to 1M (E24)	±200	
ERJP03 (0603)	0.20	150	200	±0.5	10 to 1M (E24, E96)	±150	–55 to +155
				±1	10 to 1M (E24, E96)	±200	
				±5	1 to 1M (E24)	R < 10 Ω : –150 to +400 10 Ω ≦ R : ±200	
ERJPA3 (0603)	0.25	150	200	±0.5, ±1	10 to 1M (E24, E96)	±100	–55 to +155
				±5	1 to 1.5M (E24)	±200	
ERJP06 (0805)	0.50	400	600	±0.5, ±1	10 to 1M (E24, E96)	R < 33 Ω : ±300 33 Ω ≦ R : ±100	–55 to +155
				±5	1 to 3.3M (E24)	R < 10 Ω : –100 to +600 10 Ω ≦ R < 33 Ω : ±300 33 Ω ≦ R : ±200	
ERJP08 (1206)	0.66	500	1000	±0.5, ±1	10 to 1M (E24, E96)	±100	–55 to +155
				±5	1 to 10M (E24)	R < 10 Ω : –100 to +600 10 Ω ≦ R : ±200	
ERJP14 (1210)	0.50	200	400	±0.5, ±1	10 to 1M (E24, E96)	±100	–55 to +155
				±5	1 to 1M (E24)	R < 10 Ω : –100 to +600 10 Ω ≦ R : ±200	

(1) Rated Continuous Working Voltage (RCWV) shall be determined from RCWV=√Power Rating × Resistance Values, or Limiting Element Voltage listed above, whichever less.
(2) Overload (Short-time Overload) Test Voltage (SOTV) shall be determined from SOTV=2.5 × RCWV or max. Overload Voltage listed above whichever less.
(3) Use it on the condition that the case temperature is below 155 °C.

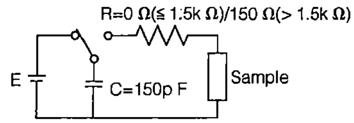
Power Derating Curve

For resistors operated in ambient temperatures above 70 °C, power rating shall be derated in accordance with the figure on the right.

✻ When the temperature of ERJP14 is 155 °C or less, the derating start temperature can be changed to 125 °C. (See the dotted line)

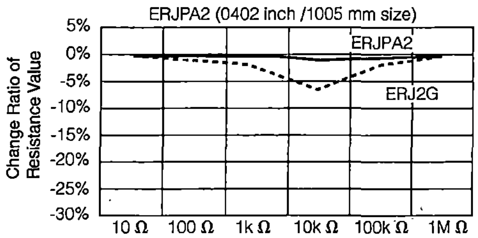


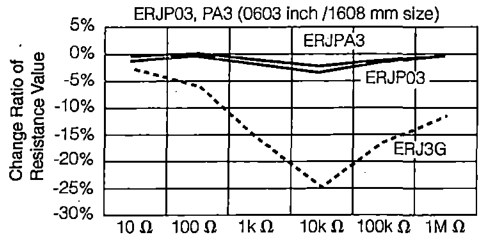
ESD Characteristic

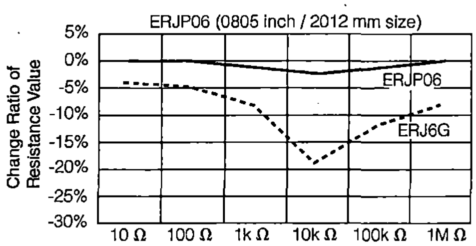


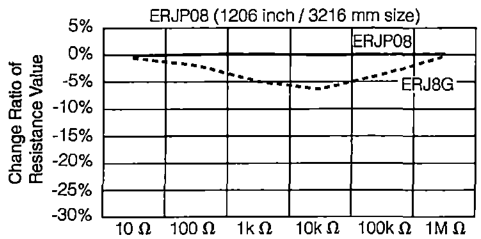
0402 inch size : E=±1k V
0603, 0805, 1206, 1210 inch size : E=±3k V

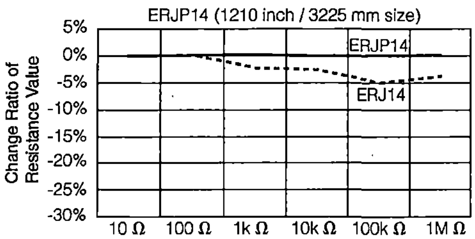
——— Anti-Surge Thick Film Chip Resistors(ERJP Type)
-------- Thick Film Chip Resistors(ERJ Type)











Anti-Pulse Thick Film Chip Resistors

Type: ERJ T06, T08, T14 ERJ T14L

Features

- Anti-Pulse characteristics
  High pulse characteristics achieved by the optimized trimming specifications (ERJT06, T08, T14)
- Further high pulse characteristics achieved by trimming-less specifications (ERJT14L)
- High reliability
  Metal glaze thick film resistive element and three layers of electrodes
- Suitable for both reflow and flow soldering
- High power ··· 0.25W : 0805 inch / 2012 mm size (ERJT06)
  0.33W : 1206 inch / 3216 mm size (ERJT08)
  0.50W : 1210 inch / 3225 mm size (ERJT14, ERJT14L)
- Reference Standards···IEC 60115-8, JIS C 5201-8, EIAJ RC-2134B
- AEC-Q200 qualified
- RoHS compliant

■ **As for Packaging Methods, Land Pattern, Soldering Conditions and Safety Precautions,**
Please see Data Files

Explanation of Part Numbers

- ERJT06, T08, T14 Type

1	2	3	4	5	6	7	8	9	10	11
E	R	J	T	0	6	J	1	0	0	V

Product Code
Thick Film Chip Resistors

Size, Power Rating		
Code	Inch	Power R.
T06	0805	0.25 W
T08	1206	0.33 W
T14	1210	0.5 W

Resistance Tolerance	
Code	Tolerance
J	± 5 %

Resistance Value
The first two digits are significant figures of resistance and the third one denotes number of zeros following. Example: 222→2.2 kΩ

Packaging Methods		
Code	Packaging	Part No.
V	Punched Carrier Taping 4 mm pitch, 5,000 pcs.	ERJT06 ERJT08
U	Embossed Carrier Taping 4 mm pitch, 5,000 pcs.	ERJT14

- ERJT14L Type

1	2	3	4	5	6	7	7	8	9	10	11
E	R	J	T	1	4	L	M	1	0	0	U

Product Code
Thick Film Chip Resistors

Size, Power Rating		
Code	Inch	Power R.
T14	1210	0.5 W

Product specifications	
Code	Specifications
L	Trimming-less

Resistance Tolerance	
Code	Tolerance
K	±10 %
M	±20 %

Resistance Value
The first two digits are significant figures of resistance and the third one denotes number of zeros following. Example: 222→2.2 kΩ

Packaging Methods		
Code	Packaging	Part No.
U	Embossed Carrier Taping 4 mm pitch, 5,000 pcs.	ERJT14L

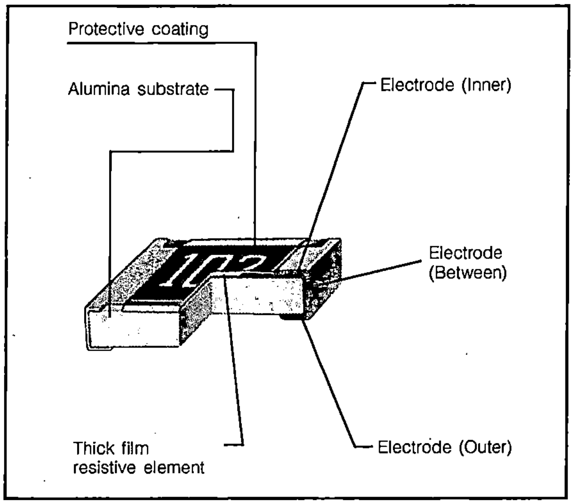
❇ Please contact us for 2012 (mm) and 3216 (mm) size trimming-less types.

Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use.
Should a safety concern arise regarding this product, please be sure to contact us immediately.

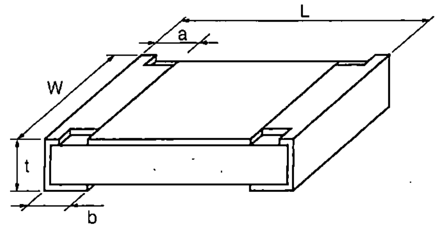
Panasonic

Anti-Pulse Thick Film Chip Resistors

Construction



Dimensions in mm (not to scale)



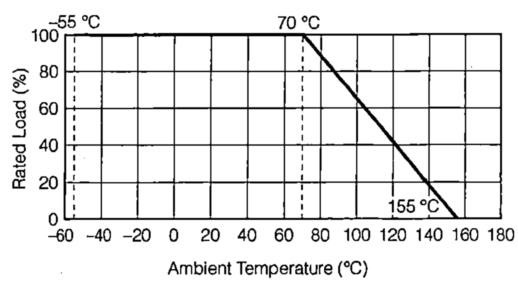
Part No. (inch size)	Dimensions (mm)					Mass (Weight) [g/1000pcs.]
	L	W	a	b	t	
ERJT06 (0805)	$2.00^{\pm0.20}$	$1.25^{\pm0.10}$	$0.25^{\pm0.20}$	$0.40^{\pm0.20}$	$0.60^{\pm0.10}$	4
ERJT08 (1206)	$3.20^{+0.05}_{-0.20}$	$1.60^{+0.05}_{-0.15}$	$0.40^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	10
ERJT14 ERJT14L (1210)	$3.20^{\pm0.20}$	$2.50^{\pm0.20}$	$0.35^{\pm0.20}$	$0.50^{\pm0.20}$	$0.60^{\pm0.10}$	16

Ratings

Part No. (inch size)	Power Rating at 70 °C (W)	Limiting Element Voltage(1) (V)	Maximum Overload Voltage(2) (V)	Resistance Tolerance (%)	Resistance Range (Ω)	T.C.R. ($\times10^{-6}$/°C)	Category Temperature Range (°C)
ERJT06 (0805)	0.25	150	200	±5	1 to 1 M (E24)	Less than 10 Ω : −100 to +600 Less than 33 Ω : ±300 More than 33 Ω : ±200	−55 to +155
ERJT08 (1206)	0.33	200	400	±5	1 to 1 M (E24)	Less than 10 Ω : −100 to +600 More than 10 Ω : ±200	−55 to +155
ERJT14 (1210)	0.50	200	400	±5	1 to 1 M (E24)	Less than 10 Ω : −100 to +600 More than 10 Ω : ±200	−55 to +155
ERJT14L (1210)	0.50	200	400	±10 ±20	1 to 1 M (E12)	Less than 10 Ω : −100 to +600 More than 10 Ω : ±200	−55 to +155

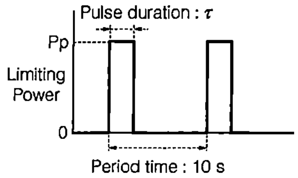
(1) Rated Continuous Working Voltage (RCWV) shall be determined from RCWV=$\sqrt{\text{Power Rating} \times \text{Resistance Values}}$, or Limiting Element Voltage listed above, whichever less.
(2) Overload (Short-time Overload) Test Voltage (SOTV) shall be determined from SOTV=2.5 × RCWV or max. Overload Voltage listed above whichever less.

Power Derating Curve
For resistors operated in ambient temperatures above 70 °C, power rating shall be derated in accordance with the figure on the right.



Limiting Power Curve

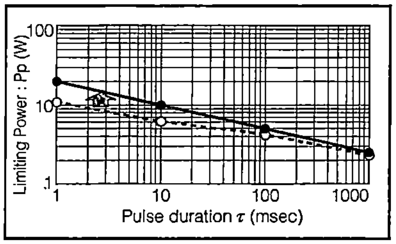
- In rush pulse Characteristic



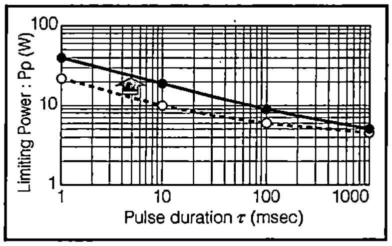
Test cycle : 1000 cycles
Spec : Resistance value = within ±5%

▲ : Anti-Pulse Thick Film Chip Resistors (ERJT14L Type)
● : Anti-Pulse Thick Film Chip Resistors (ERJT Type)
○ : Thick Film Chip Resistors (ERJ Type)

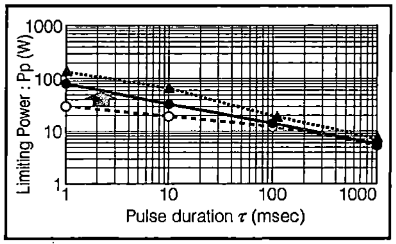
- **ERJT06** (0805 inch/2012 mm size)



- **ERJT08** (1206 inch/3216 mm size)



- **ERJT14,ERJT14L** (1210 inch/3225 mm size)



* Please contact us for 2012 (mm) and 3216 (mm) size trimming-less types.

Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use.
Should a safety concern arise regarding this product, please be sure to contact us immediately.

Anti-Surge Thick Film Chip Resistors (Double-sided resistive elements structure) 0805

Type: **ERJ P6W**

Features

- ESD surge characteristics superior to standard metal fi lm resistors
- High reliability
  Metal glaze thick fi lm resistive element and three layers of electrodes
- Suitable for both refl ow and fl ow soldering
- High power···0.50W:2012(0805)size(ERJP6W)
- High pulse characteristics···1.5 times higher than 0805 inch size Anti-Surge Thick Film Chip Resistors (ERJP06)
- Reference Standards···IEC 60115-8, JIS C 5201-8, EIAJ RC-2134B
- RoHS compliant

Packaging Methods, Land Pattern, Soldering Conditions and Safety Precautions

Please see Data Files

Explanation of Part Numbers

1	2	3	4	5	6	7	8	9	10	11	12
E	R	J	P	6	W	F	1	0	0	2	V

Product Code
Thick Film Chip Resistors

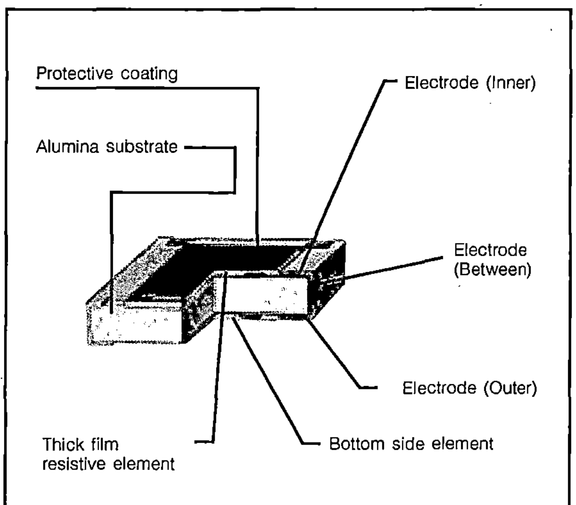
Size, Power Rating	
Type: inch	Power R.
P6W : 0805	0.50 W

Resistance Tolerance	
Code	Tolerance
F	± 1 %
J	± 5 %

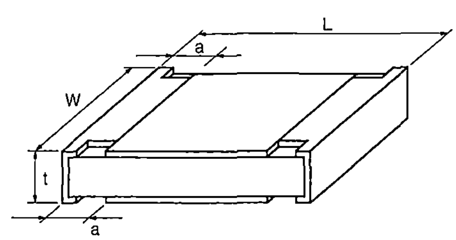
Resistance Value
The first two or three digits are significant figures of resistance and the third or 4th one denotes number of zeros following. Three digit type (±5%), four digit type (±1%) Example: 222→2.2 kΩ, 1002→10 kΩ

Packaging Methods	
Code	Packaging
V	Punched Carrier Taping 4 mm pitch, 5,000 pcs.

Construction



Dimensions in mm (not to scale)



Type (inch size)	Dimensions (mm)				Mass (Weight) [g/1000pcs.]
	L	W	a	t	
ERJP6W (0805)	$2.00^{\pm0.20}$	$1.25^{\pm0.20}$	$0.35^{\pm0.20}$	$0.65^{\pm0.10}$	6

Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use. Should a safety concern arise regarding this product, please be sure to contact us immediately.

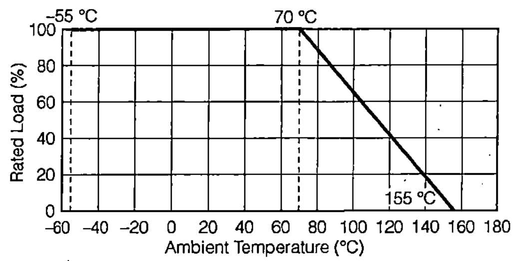
■ Ratings

Type (inch size)	Power Rating[3] at 70 °C (W)	Limiting Element Voltage[1] (V)	Maximum Overload Voltage[2] (V)	Resistance Tolerance (%)	Resistance Range (Ω)	T.C.R. ($\times10^{-6}$/°C)	Category Temperature Range (°C)
ERJP6W (0805)	0.50	150	200	±1	10 to 1 M (E24, E96)	±200	–55 to +155
				±5	1 to 1 M (E24)	R < 10 Ω : –100 to +600 10 Ω ≦ R : ±200	

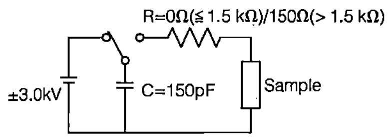
(1) Rated Continuous Working Voltage (RCWV) shall be determined from $RCWV=\sqrt{\text{Power Rating} \times \text{Resistance Values}}$, or Limiting Element Voltage listed above, whichever less.
(2) Overload (Short-time Overload) Test Voltage (SOTV) shall be determined from SOTV=2.5 × Power Rating or max. Overload Voltage listed above whichever less.
(3) Use it on the condition that the case temperature is below 155 °C.

Power Derating Curve

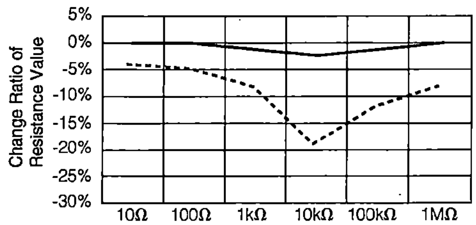
For resistors operated in ambient temperatures above 70 °C, power rating shall be derated in accordance with the figure on the right.



■ ESD Characteristic

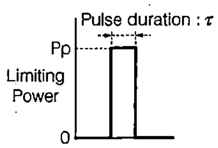


——— Anti-Surge Thick Film Chip Resistors(ERJP6W Type)
-------- Thick Film Chip Resistors(ERJ6G Type)



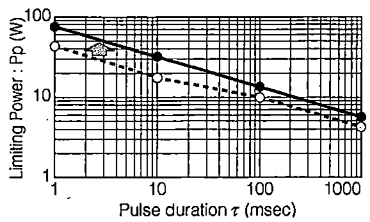
■ Limiting Power Curve

● In rush pulse Characteristic



Test cycle : 1 cycles
Spec : Resistance value = within ±1%

——— Anti-Surge Thick Film Chip Resistors(ERJP6W Type)
-------- Anti-Surge Thick Film Chip Resistors(ERJP06 Type)



Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use.
Should a safety concern arise regarding this product, please be sure to contact us immediately.

ASSR-1611

High Current, 1 Form A, Solid State Relay (MOSFET) (60V/2.5A/0.1Ω)

AVAGO TECHNOLOGIES

Data Sheet

Lead (Pb) Free
RoHS 6 fully compliant

Description

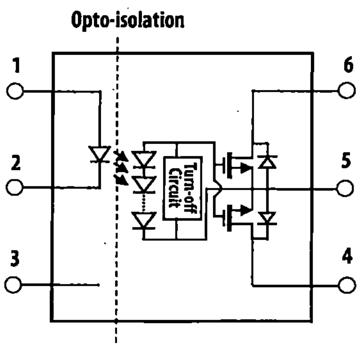
The ASSR-1611 is specifically designed for high current applications, commonly found in the industrial equipments. The relay is a solid-state replacement for single-pole, normally-open, (1 Form A) electromechanical relays.

The ASSR-1611 consists of an AlGaAs infrared light-emitting diode (LED) input stage optically coupled to a high-voltage output detector circuit. The detector consists of a high-speed photovoltaic diode array and driver circuitry to switch on/off two discrete high voltage MOSFETs. The relay turns on (contact closes) with a minimum input current of 5mA through the input LED. The relay turns off (contact opens) with an input voltage of 0.8V or less.

The ASSR-1611 connection A, as shown in the schematic, allows the relay to switch either ac or dc loads. The connection B, with its advantages of reduced on-resistance and higher output current, allows the relays to switch dc loads only.

The electrical and switching characteristics are specified over the temperature range of -40°C to +85°C.

Functional Diagram



Truth Table

LED	Output
Off	Open
On	Close

Features

- Compact Solid-State Bi-directional Signal Switch
- Single Channel Normally-off Single-Pole-Single-Throw (SPST) Relay
- 60V Output Withstand Voltage
- 2.5A or 5A Current Rating
- Low Input Current: CMOS Compatibility
- Low On-Resistance: 20mΩ Typical for DC-only, 65mΩ Typical for AC/DC
- High Speed Switching: 3.2ms (T_{on}), 0.1ms (T_{off}) Typical
- High Transient Immunity: >1kV/µs
- High Input-to-Output Insulation Voltage
  - (Safety and Regulatory Approvals)
    UL recognized - 3750 V_{RMS} and 5000 V_{RMS}* for 1 min per UL1577
  - CSA Component Acceptance

*5000 V_{RMS}/1 Minute rating is for Option X21 only.
(Please consult your regional Avago representatives)

Applications

- Industrial Controls
- Factory Automation
- Data Acquisition
- Measuring Instrument
- Medical System
- Security System
- EMR / Reed Relay Replacement

CAUTION: *It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation which may be induced by ESD.*

Ordering Information

ASSR-1611 is UL Recognized with 3750 V_{RMS} and 5000 V_{RMS} (option X21*) for 1 minute per UL1577 and is approved under CSA Components Acceptance Notice #5.

Part Number	Option RoHS Compliant	Package	Surface Mount	Gullwing	Tape & Reel	Quantity
ASSR-1611	-001E	300mil DIP-6				50 units per tube
	-301E		X	X		
	-501E		X	X	X	1000 units per reel

To order, choose a part number from the part number column and combine with the desired option from the option column to form an order entry.

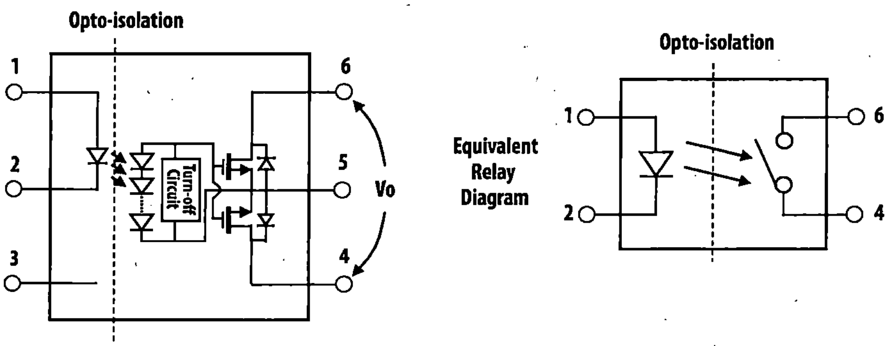
Example 1:

ASSR-1611-501E to order product of 300mil DIP-6 Gull Wing Surface Mount package in Tape and Reel packaging and RoHS Compliant.

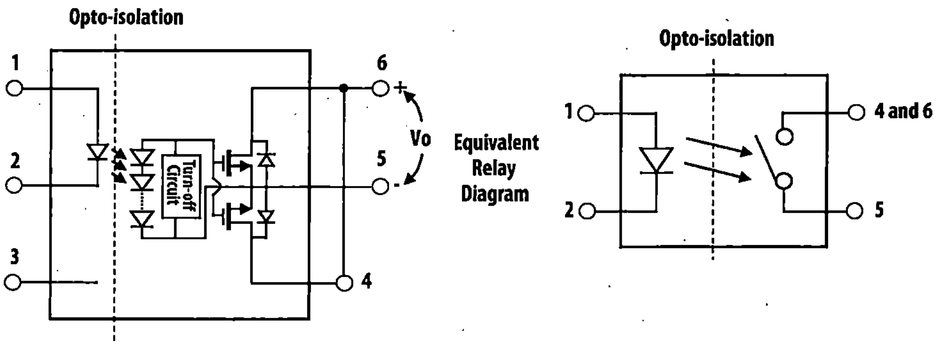
x021* - 'Please consult your regional Avago representatives'

Schematic

ASSR-1611



Connection A – AC/DC



Connection B – DC Only

ACPL-W70L-000E and ACPL-K73L-000E

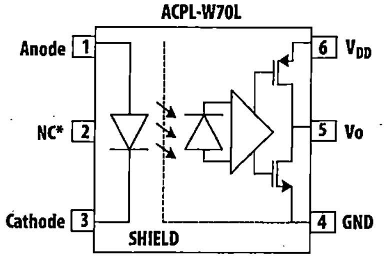
Single-Channel and Dual-Channel High-Speed 15-MBd CMOS Optocoupler with Glitch-Free Power-Up Feature

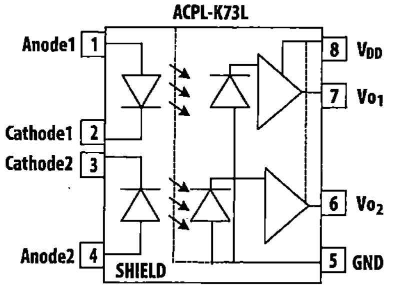
Data Sheet

Description

The ACPL-W70L (single-channel) and ACPL-K73L (dual-channel) are 15-MBd CMOS optocouplers in SSOIC-6 and SSOIC-8 packages, respectively. The optocouplers use the latest CMOS IC technology to achieve outstanding performance with very low power consumption. Basic building blocks of ACPL-W70L and ACPL-K73L are high-speed LEDs and CMOS detector ICs. Each detector incorporates an integrated photodiode, a high-speed transimpedance amplifier, and a voltage comparator with an output driver.

Component Image





Truth Table

LED	V_O Output
ON	H
OFF	L

A 0.1-µF bypass capacitor must be connected between pins V_{DD} and GND.

Features

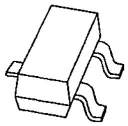
Features

- +3.3V and 5V CMOS compatibility
- 25 ns maximum pulse width distortion
- 55 ns maximum propagation delay
- 40 ns maximum propagation delay skew
- High speed: 15 MBd minimum
- 10 kV/µs minimum common-mode rejection
- –40°C to +105°C temperature range
- Glitch-free power-up feature
- Safety and regulatory approvals:
  - UL recognized: 5000 V_{rms} for 1 min. per UL 1577
  - CSA component acceptance Notice #5
  - IEC/EN/DIN EN 60747-5-5 approval for Reinforced Insulation

Applications

- Digital field bus isolation:
  - CANBus, RS485, USB
- Multiplexed data transmission
- Computer peripheral interface
- Microprocessor system interface
- DC/DC converter

CAUTION It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation that may be induced by ESD. The components featured in this data sheet are not to be used in military or aerospace applications or environments.



BZB84 series

Dual Zener diodes

Rev. 03 — 9 June 2009 **Product data sheet**

1. Product profile

1.1 General description

General-purpose Zener diodes in a SOT23 (TO-236AB) small Surface-Mounted Device (SMD) plastic package.

1.2 Features

- Non-repetitive peak reverse power dissipation: ≤ 40 W
- Total power dissipation: ≤ 300 mW
- Two tolerance series: B = ±2 % and C = ±5 %
- Wide working voltage range: nominal 2.4 V to 75 V (E24 range)
- Small plastic package suitable for surface-mounted design
- Dual common anode configuration
- AEC-Q101 qualified

1.3 Applications

- General regulation functions

1.4 Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Per diode							
V_F	forward voltage	I_F = 10 mA	[1]	-	-	0.9	V
P_{ZSM}	non-repetitive peak reverse power dissipation		[2]	-	-	40	W

[1] Pulse test: $t_p \leq 300$ µs; $\delta \leq 0.02$.

[2] t_p = 100 µs; square wave; T_j = 25 °C prior to surge

founded by Philips

TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS197E

August 1997 - Revised October 2003

CD54HC4002, CD74HC4002

High-Speed CMOS Logic Dual 4-Input NOR Gate

Features

- Typical Propagation Delay = 8ns at V_{CC} = 5V, C_L = 15pF, T_A = 25°C
- Fanout (Over Temperature Range)
  - Standard Outputs . . . . 10 LSTTL Loads
  - Bus Driver Outputs . . . . 15 LSTTL Loads
- Wide Operating Temperature Range . . . -55°C to 125°C
- Balanced Propagation Delay and Transition Times
- Significant Power Reduction Compared to LSTTL Logic ICs
- HC Types
  - 2V to 6V Operation
  - High Noise Immunity: N_{IL} = 30%, N_{IH} = 30%of V_{CC} at V_{CC} = 5V

Description

The 'HC4002 logic gate utilizes silicon gate CMOS technology to achieve operating speeds similar to LSTTL gates with the low power consumption of standard CMOS integrated circuits. All devices have the ability to drive 10 LSTTL loads. The 'HC4002 logic family is functional as well as pin compatible with the standard LS logic family.

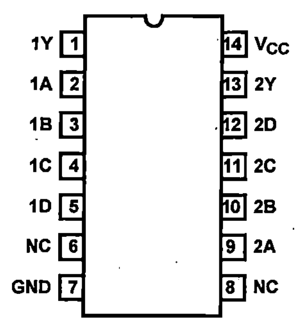
Ordering Information

PART NUMBER	TEMP. RANGE (°C)	PACKAGE
CD54HC4002F3A	-55 to 125	14 Ld CERDIP
CD74HC4002E	-55 to 125	14 Ld PDIP
CD74HC4002M	-55 to 125	14 Ld SOIC
CD74HC4002MT	-55 to 125	14 Ld SOIC
CD74HC4002M96	-55 to 125	14 Ld SOIC
CD74HC4002NSR	-55 to 125	14 Ld SOP
CD74HC4002PW	-55 to 125	14 Ld TSSOP
CD74HC4002PWR	-55 to 125	14 Ld TSSOP
CD74HC4002PWT	-55 to 125	14 Ld TSSOP

NOTE: When ordering, use the entire part number. The suffixes 96 and R denote tape and reel. The suffix T denotes a small-quantity reel of 250.

Pinout

CD54HC4002
(CERDIP)
CD74HC4002
(PDIP, SOIC, SOP, TSSOP)
TOP VIEW



CAUTION: These devices are sensitive to electrostatic discharge. Users should follow proper IC Handling Procedures.

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TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS015C – Revised August 2003

CD4001B, CD4002B, CD4025B Types

CMOS NOR Gates

High-Voltage Types (20-Volt Rating)

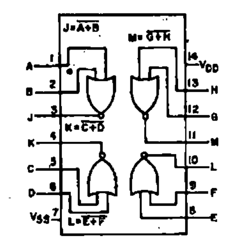
Quad 2 Input – CD4001B
Dual 4 Input – CD4002B
Triple 3 Input – CD4025B

■ CD4001B, CD4002B, and CD4025B NOR gates provide the system designer with direct implementation of the NOR function and supplement the existing family of CMOS gates. All inputs and outputs are buffered.

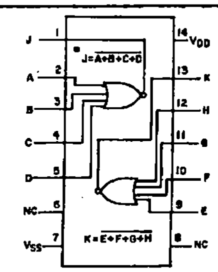
The CD4001B, CD4002B, and CD4025B types are supplied in 14-lead hermetic dual-in-line ceramic packages (F3A suffix), 14-lead dual-in-line plastic packages (E suffix), 14-lead small-outline packages (M, MT, M96, and NSR suffixes), and 14-lead thin shrink small-outline packages (PW and PWR suffixes).

Features:

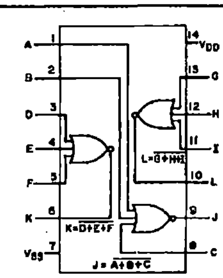
- **Propagation delay time = 60 ns (typ.) at C_L = 50 pF, V_{DD} = 10 V**
- **Buffered inputs and outputs**
- **Standardized symmetrical output characteristics**
- **100% tested for maximum quiescent current at 20 V**
- **5-V, 10-V, and 15-V parametric ratings**
- **Maximum input current of 1 μA at 18 V over full package-temperature range; 100 nA at 18 V and 25°C**
- **Noise margin (over full package temperature range):**
  1 V at V_{DD} = 5 V
  2 V at V_{DD} = 10 V
  2.5 V at V_{DD} = 15 V
- **Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of "B" Series CMOS Devices"**



CD4001B FUNCTIONAL DIAGRAM



CD4002B FUNCTIONAL DIAGRAM



CD4025B FUNCTIONAL DIAGRAM

STATIC ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							UNITS
								+25			
	V_O (V)	V_{IN} (V)	V_{DD} (V)	–55	–40	+85	+125	Min.	Typ.	Max.	
Quiescent Device Current, I_{DD} Max.	–	0,5	5	0.25	0.25	7.5	7.5	–	0.01	0.25	μA
	–	0,10	10	0.5	0.5	15	15	–	0.01	0.5	
	–	0,15	15	1	1	30	30	–	0.01	1	
	–	0,20	20	5	5	150	150	–	0.02	5	
Output Low (Sink) Current I_{OL} Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	–	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	–	
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	–	
Output High (Source) Current, I_{OH} Min.	4.6	0,5	5	–0.64	–0.61	–0.42	–0.36	–0.51	–1	–	
	2.5	0,5	5	–2	–1.8	–1.3	–1.15	–1.6	–3.2	–	
	9.5	0,10	10	–1.6	–1.5	–1.1	–0.9	–1.3	–2.6	–	
	13.5	0,15	15	–4.2	–4	–2.8	–2.4	–3.4	–6.8	–	
Output Voltage: Low-Level, V_{OL} Max.	–	0,5	5	0.05				–	0	0.05	V
	–	0,10	10	0.05				–	0	0.05	
	–	0,15	15	0.05				–	0	0.05	
Output Voltage: High-Level, V_{OH} Min.	–	0,5	5	4.95				4.95	5	–	
	–	0,10	10	9.95				9.95	10	–	
	–	0,15	15	14.95				14.95	15	–	
Input Low Voltage, V_{IL} Max.	0.5,4.5	–	5	1.5				—	—	1.5	V
	1,9	–	10	3				—	—	3	
	1.5,13.5	–	15	4				—	—	4	
Input High Voltage, V_{IH} Min.	0.5	–	5	3.5				3.5	—	—	
	1	–	10	7				7	—	—	
	1.5	–	15	11				11	—	—	
Input Current I_{IN} Max.		0,18	18	±0.1	±0.1	±1	±1	–	$\pm10^{-5}$	±0.1	μA

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RECOMMENDED OPERATING CONDITIONS

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	LIMITS		UNITS
	MIN.	MAX.	
Supply-Voltage Range (For T_A = Full Package Temperature Range)	3	18	V

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

DC SUPPLY-VOLTAGE RANGE, (V_{DD})

Voltages referenced to V_{SS} Terminal) .... -0.5V to +20V

INPUT VOLTAGE RANGE, ALL INPUTS .... -0.5V to V_{DD} +0.5V

DC INPUT CURRENT, ANY ONE INPUT .... ±10mA

POWER DISSIPATION PER PACKAGE (P_D):

For T_A = -55°C to +100°C 500mW

For T_A = +100°C to +125°C .... Derate Linearity at 12mW/°C to 200mW

DEVICE DISSIPATION PER OUTPUT TRANSISTOR

FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW

OPERATING-TEMPERATURE RANGE (T_A) .... -55°C to +125°C

STORAGE TEMPERATURE RANGE (T_{stg}) .... -65°C to +150°C

LEAD TEMPERATURE (DURING SOLDERING):

At distance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max .... +265°C

DYNAMIC ELECTRICAL CHARACTERISTICS

At T_A = 25°C; Input t_r, t_f = 20 ns, C_L = 50 pF, R_L = 200kΩ

CHARACTERISTIC	TEST CONDITIONS		ALL TYPES LIMITS		UNITS
		V_{DD} VOLTS	TYP.	MAX.	
Propagation Delay Time, t_{PHL}, t_{PLH}		5 10 15	125 60 45	250 120 90	ns
Transition Time, t_{THL}, t_{TLH}		5 10 15	100 50 40	200 100 80	ns
Input Capacitance, C_{IN}	Any Input		5	7.5	pF

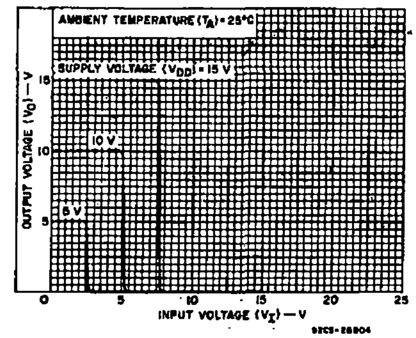


Fig. 1 – Typical voltage transfer characteristics.

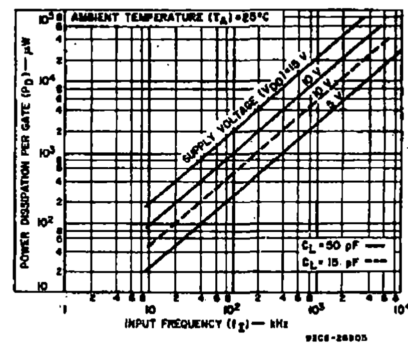


Fig. 2 – Typical power dissipation vs. frequency.

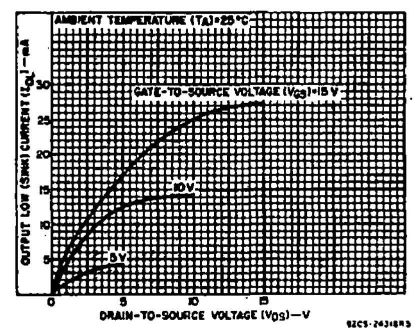


Fig. 3 – Typical output low (sink) current characteristics.

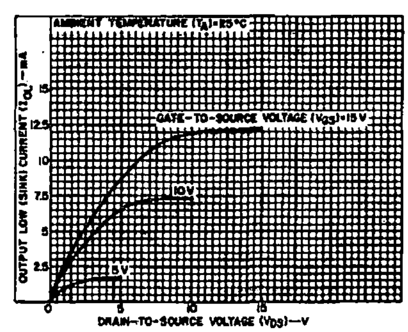


Fig. 4 - Minimum output low (sink) current characteristics.

TEXAS INSTRUMENTS

CD4043B, CD4044B Types

Data sheet acquired from Harris Semiconductor
SCHS041D – Revised October 2003

CMOS Quad 3-State R/S Latches

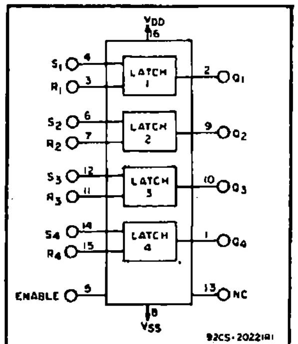
High-Voltage Types (20-Volt Rating)
Quad NOR R/S Latch – CD4043B
Quad NAND R/S Latch – CD4044B

■CD4043B types are quad cross-coupled 3-state CMOS NOR latches and the CD4044B types are quad cross-coupled 3-state CMOS NAND latches. Each latch has a separate Q output and individual SET and RESET inputs. The Q outputs are controlled by a common ENABLE input. A logic "1" or high on the ENABLE input connects the latch states to the Q outputs. A logic "0" or low on the ENABLE input disconnects the latch states from the Q outputs, resulting in an open circuit condition on the Q outputs. The open circuit feature allows common busing of the outputs.

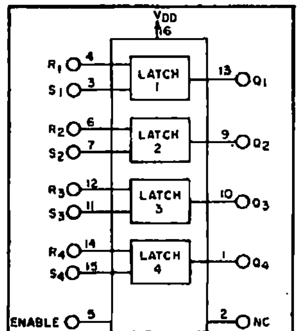
The CD4043B and CD4044B types are supplied in 16-lead hermetic dual-in-line ceramic packages (F3A suffix), 16-lead dual-in-line plastic packages (E suffix), 16-lead small-outline packages (D, DR, DT, DW, DWR, and NSR suffixes), and 16-lead thin shrink small-outline packages (PW and PWR suffixes).

Features:
- 3-state outputs with common output ENABLE
- Separate SET and RESET inputs for each latch
- NOR and NAND configurations
- 5-V, 10-V, and 15-V parametric ratings
- Standardized symmetrical output characteristics
- 100% tested for quiescent current at 20 V
- Maximum input current of 1 μA at 18 V over full package temperature range; 100 nA at 18 V and 25°C
- Noise margin (over full package temperature range): 1 V at V_{DD} = 5 V
  2 V at V_{DD} = 10 V
  2.5 V at V_{DD} = 15 V
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications:
- Holding register in multi-register system
- Four bits of independent storage with output ENABLE
- Strobed register
- General digital logic
- CD4043B for positive logic systems
- CD4044B for negative logic systems



CD4043B
FUNCTIONAL DIAGRAM



CD4044B
FUNCTIONAL DIAGRAM

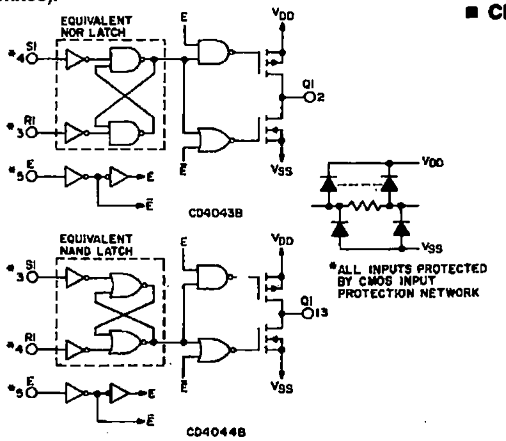
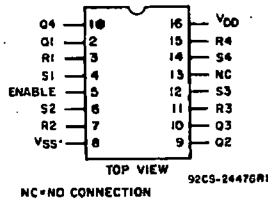
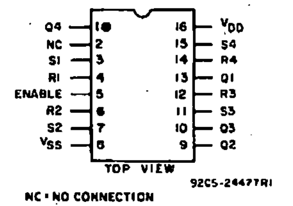


Fig. 1 – Logic diagrams.



CD4043B



CD4044B

TERMINAL ASSIGNMENTS

CD4043B

S	R	E	Q
X	X	0	OC*
0	0	1	NC+
1	0	1	1
0	1	1	0
1	1	1	Δ

*OPEN CIRCUIT
+NO CHANGE
Δ DOMINATED BY S=1 INPUT

CD4044B

S	R	E	Q
X	X	0	OC*
1	1	1	NC+
0	1	1	1
1	0	1	0
0	0	1	ΔΔ

*OPEN CIRCUIT
+NO CHANGE
ΔΔ DOMINATED BY R=0 INPUT

TRUTH TABLES

MAXIMUM RATINGS, *Absolute-Maximum Values:*

DC SUPPLY-VOLTAGE RANGE, (V_{DD})
Voltages referenced to V_{SS} Terminal) .... -0.5V to +20V
INPUT VOLTAGE RANGE, ALL INPUTS .... -0.5V to V_{DD} +0.5V
DC INPUT CURRENT, ANY ONE INPUT .... ±10mA
POWER DISSIPATION PER PACKAGE (P_D):
For T_A = -55°C to +100°C 500mW
For T_A = +100°C to +125°C .... Derate Linearity at 12mW/°C to 200mW
DEVICE DISSIPATION PER OUTPUT TRANSISTOR
FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW
OPERATING-TEMPERATURE RANGE (T_A) .... -55°C to +125°C
STORAGE TEMPERATURE RANGE (T_{stg}) .... -65°C to +150°C
LEAD TEMPERATURE (DURING SOLDERING):
At distance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max .... +265°C

Recommended Operating Conditions T_A=25°C
For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges.

Characteristic	V_{DD} (V)	Min.	Max.	Units
Supply-Voltage Range (T_A = Full Package Temperature Range)	–	3	18	V
SET or RESET Pulse Width, t_W	5	160	–	ns
	10	80	–	
	15	40	–	

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STATIC ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							UNITS
	V_O (V)	V_{IN} (V)	V_{DD} (V)	−55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	
Quiescent Device Current, I_{DD} Max.	–	0,5	5	1	1	30	30	–	0.02	1	μA
	–	0,10	10	2	2	60	60	–	0.02	2	
	–	0,15	15	4	4	120	120	–	0.02	4	
	–	0,20	20	20	20	600	600	–	0.04	20	
Output Low (Sink) Current I_{OL} Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	–	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	–	
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	–	
Output High (Source) Current, I_{OH} Min.	4.6	0,5	5	−0.64	−0.61	−0.42	−0.36	−0.51	−1	–	
	2.5	0,5	5	−2	−1.8	−1.3	−1.15	−1.6	−3.2	–	
	9.5	0,10	10	−1.6	−1.5	−1.1	−0.9	−1.3	−2.6	–	
	13.5	0,15	15	−4.2	−4	−2.8	−2.4	−3.4	−6.8	–	
Output Voltage: Low-Level, V_{OL} Max.	–	0,5	5	0.05				–	0	0.05	V
	–	0,10	10	0.05				–	0	0.05	
	–	0,15	15	0.05				–	0	0.05	
Output Voltage: High-Level, V_{OH} Min.	–	0,5	5	4.95				4.95	5	–	
	–	0,10	10	9.95				9.95	10	–	
	–	0,15	15	14.95				14.95	15	–	
Input Low Voltage, V_{IL} Max.	0.5, 4.5	–	5	1.5				–	–	1.5	V
	1, 9	–	10	3				–	–	3	
	1.5,13.5	–	15	4				–	–	4	
Input High Voltage, V_{IH} Min.	0.5, 4.5	–	5	3.5				3.5	–	–	
	1, 9	–	10	7				7	–	–	
	1.5, 3.5	–	15	11				11	–	–	
Input Current I_{IN} Max.	–	0,18	18	±0.1	±0.1	±1	±1	–	$\pm10^{-5}$	±0.1	μA
3-State Output Leakage Current I_{OUT} Max.	0,18	0,18	18	±0.4	±0.4	±12	±12	–	$\pm10^{-4}$	±0.4	μA

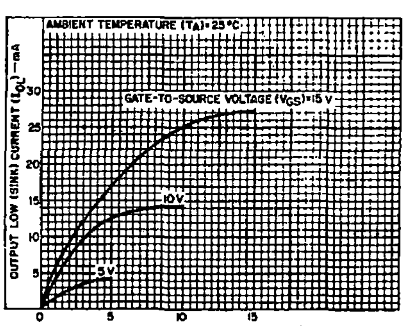


Fig. 2 – Typical output low (sink) current characteristics.

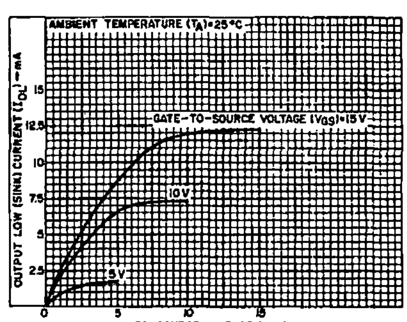


Fig. 3 – Minimum output low (sink) current characteristics.

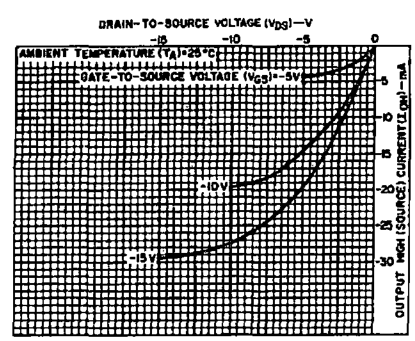


Fig. 4 – Typical output high (source) current characteristics.

DYNAMIC ELECTRICAL CHARACTERISTICS *at $T_A = 25°C$; Input t_r, $t_f = 20$ ns, $C_L = 50$ pF, $R_L = 200$ KΩ*

CHARACTERISTIC	V_{DD} (V)	LIMITS ALL TYPES TYP.	LIMITS ALL TYPES MAX.	UNITS
Propagation Delay Time: t_{PHL}, t_{PLH} SET or RESET to Q	5 10 15	150 70 50	300 140 100	ns
3-State Propagation Delay Time: ENABLE to Q t_{PHZ}, t_{PZH}	5 10 15	115 55 40	230 110 80	ns
t_{PLZ}, t_{PZL}	5 10 15	90 50 35	180 100 70	ns
Transition Time: t_{THL}, t_{TLH}	5 10 15	100 50 40	200 100 80	ns
Minimum SET or RESET Pulse Width, t_W	5 10 15	80 40 20	160 80 40	ns
Input Capacitance, (Any Input) C_{IN}	–	5	7.5	pF

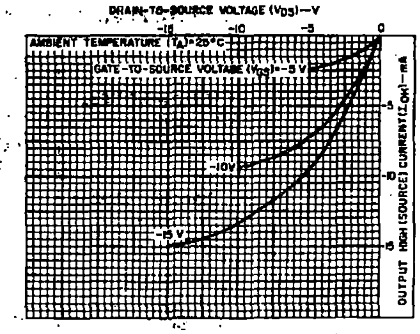


Fig. 5 – Minimum output high (source) current characteristics.

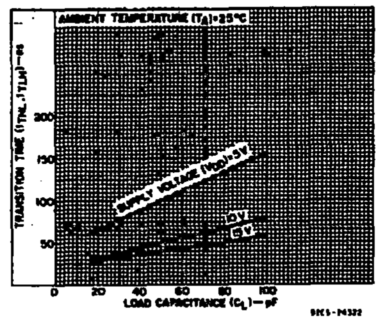


Fig. 6 – Typical transition time vs. load capacitance.

TEST CIRCUITS

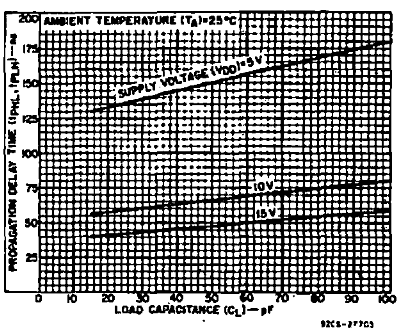


Fig. 7 – Typical propagation delay time vs. load capacitance—SET, RESET to Q, Q̄.

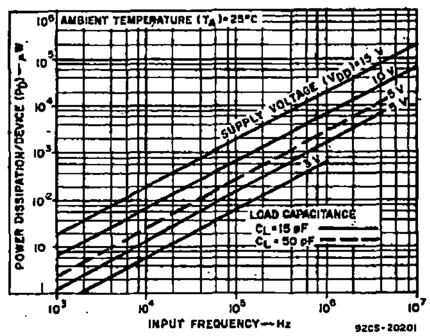


Fig. 8 – Typical power dissipation vs. frequency.

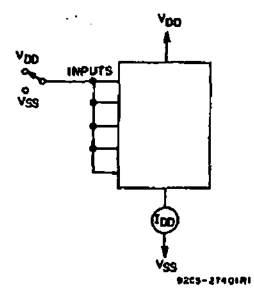


Fig. 9 – Quiescent device current.

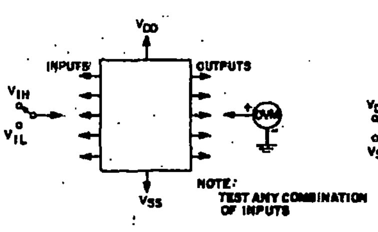


Fig. 10 – Input voltage.

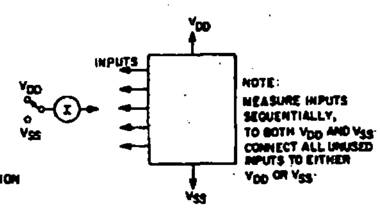


Fig. 11 – Input current.

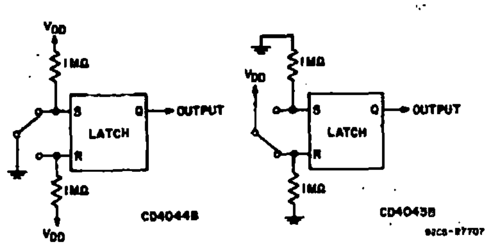


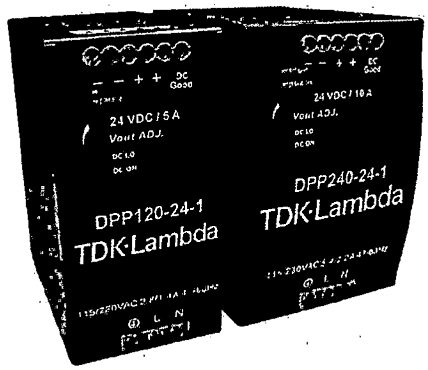
Fig. 12 – Switch bounce eliminator.

TDK·Lambda DPP120-240 Series

120W & 240W DIN Rail Mount Power Supplies

Features

- ◆ Low Cost
- ◆ 12V, 24V or 48V Outputs
- ◆ Auto-ranging input (no manual switching)
- ◆ Parallel Function Switch
- ◆ -40(2) to +71°C Operation



Key Market Segments & Applications

Industrial

RoHS

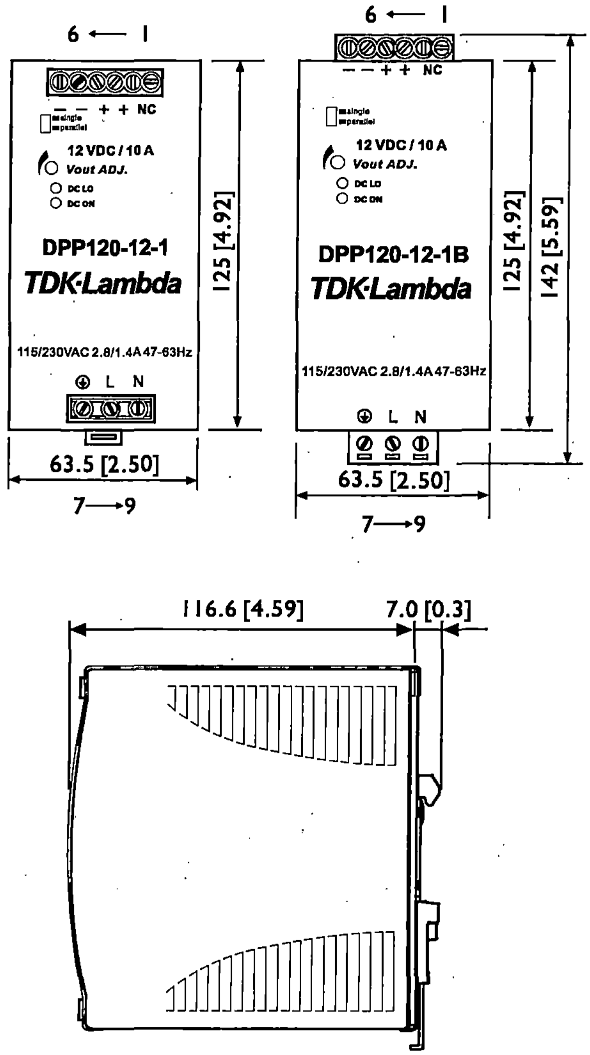
Specifications

Model		DPP120-xx-1	DPP240-xx-1
AC Input Voltage range	VAC	93 - 132 / 186 - 264VAC, single phase. Auto select	
Input Frequency	Hz	47 - 63Hz	
DC Input Voltage range	VDC	210 - 370VDC*	
Inrush Current (115 / 230VAC)	A	24 / 48A	30 / 60A
Power Factor	-	Meets EN61000-3-2	
Input Current (115 / 230VAC)	A	2.8 / 1.4A	5.4 / 2.2A
Output Voltage Accuracy	%	-0, +1% of Nominal	
Line Regulation	%	±0.5%	
Load Regulation	%	±1% (±5% when set in parallel mode)	
Ripple and Noise (20MHz BW)	mV	50mV	100mV
Overcurrent Protection (Typ)	-	110 - 145%	
Overvoltage Protection	V	See model selector	
Overtemperature Protection	-	-	
Hold Up Time (230VAC input)	ms	> 30ms	
Parallel operation	-	Set in parallel (droop) mode - maximum of 3 units	
LED Indicators	-	Green LED = On, Red LED = DC Output Low	
DC Good Relay (24V model only)	-	0.3A rated normally open relay contacts, closes when output is above 17.6 - 19.4V	
Operating Temperature	°C	-40(2) to +71°C (Derate linearly 2.5%/°C from 61 to 71°C)	
Storage Temperature	°C	-40 to +85°C	
Operating Humidity	-	20 - 95% RH (non condensing)	
Cooling (1)	-	Convection	
Withstand Voltage	-	Input to Output 3kVAC for 1 min.	
Isolation Resistance	-	>100M at 25C & 70%RH, Output to Ground 500VDC.	
Vibration (Operating)	-	IEC 60068-2-6 (Mounting by rail: Random wave, 10-500 Hz, 2G, ea. along X, Y, Z axes 10 min/cycle, 60 min)	
Shock (Operating)	-	IEC 60068-2-27 (Half sine wave, 4G, 22ms, 3 axes, 6 Faces, 3 times for each face)	
Safety Agency Approvals	-	UL508 Listed, UL60950-1, EN60950-1, CE	
Conducted & Radiated EMI	-	EN55022 class B	EN55022 class A
Immunity	-	IEC 61000-4-2, -3, 4, -5, -6, -8, -11	
Weight (Typ)	g	920	1000
Size (WxHxD) (1)	in	2.5 x 4.92 x 4.59"	3.27 x 4.92 x 4.57"
Case material	-	Metal	
Warranty	yrs	Three years	

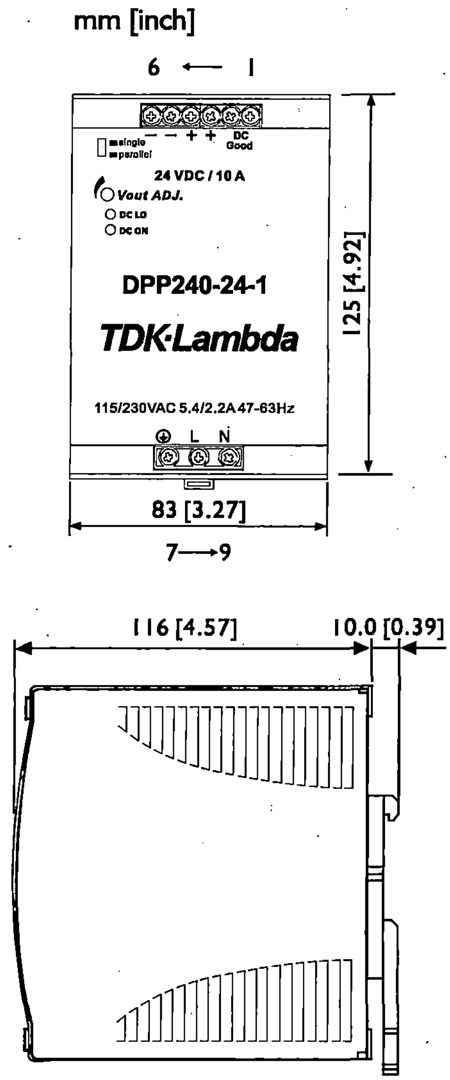
(1) Recommend 1" clearance on all sides
(2) DPP120 -35°C

*Safety certified for AC input only

Outline Drawing (DPP120)



Outline Drawing (DPP240)



Model Selector

Model	Voltage	Adjust. Range	Output Curr.	Over-voltage	Eff.
DPP120-12-1	12V	11.4 - 14.5V	10A	15 - 17.4V	84%
DPP120-24-1	24V	22.5 - 28.5V	5A	30 - 34.8V	86%
DPP120-48-1	48V	45 - 55V	2.5A	60 - 69.6V	87%
DPP240-24-1	24V	22.5 - 28.5V	10A	30 - 34.8V	89%
DPP240-48-1	48V	47 - 56V	5A	60 - 69.6V	90%

Other DIN Rail Products

DPP	15W to 100W
DPP480	480W single and three phase
DSP	10W to 100W low profile
DLP	75W to 240W single phase

For Additional Information, please visit
us.tdk-lambda.com/lp/products/dpp-series.htm

Terminal Assignments

#	Function
1	DC Good relay
2	DC Good relay
3	+V
4	+V
5	-V
6	-V
7	Chassis ground
8	L
9	N

Snap-on Mounting: snap onto DIN Rail TS35/7.5 or TS35/15. (no tools required)

Options

Suffix	Description
Blank	Non detachable connectors
B	Detachable input and output connectors

Input Parameters:

Standard	60950-1
Nominal input voltage	115/230 VAC(Auto select)
Input voltage range (115VAC)	90 – 132VAC
Input voltage range (230VAC)	180 – 264VAC
Input frequency range	47 – 63Hz
Maximum input current	2.2A (115VAC), 0.83A (230VAC)

Output Parameters:

Output Watts	Vout (V)	Adjustment range (V)	Output current (A)
120W	12	11.4 -14.5	10
	24	22.5 – 28.5	5
	48	45 - 55	2.5

Adjusting output voltage beyond the stated range may cause overvoltage protection (OVP) to operate, whereby the output will latch off.To reset for normal operation simply adjust the potentiometer to reduce the output voltage to within its range and cycle the input off then on.

All outputs are SELV **except** under the following circumstance: Outputs connected in series are non-SELV if the total output voltage exceeds 60Vdc
If the total voltage of outputs connected in series exceed the 60Vdc SELV limit then all outputs must be considered non-SELV.

Non-SELV outputs are hazardous and must not be made user accessible. Consideration must be given to service engineers making inadvertent contact with the output terminals in the end equipment.

All outputs have functional spacing to earth, and due consideration must be given to this in the end product design.

Parallel operation - Up to 3 units may be connected in parallel, output loading 10-90% in parallel mode.
For parallel connection, ensure the parallel/single switch is in the upper (parallel) position. Connect up to a maximum of 3 units ensuring he connecting wires used are the same type, gauge and length. This will aid current sharing.

Cooling for unit

The unit must be mounted on a DIN rail and must not be inverted, the output connection uppermost.

Fig. 1

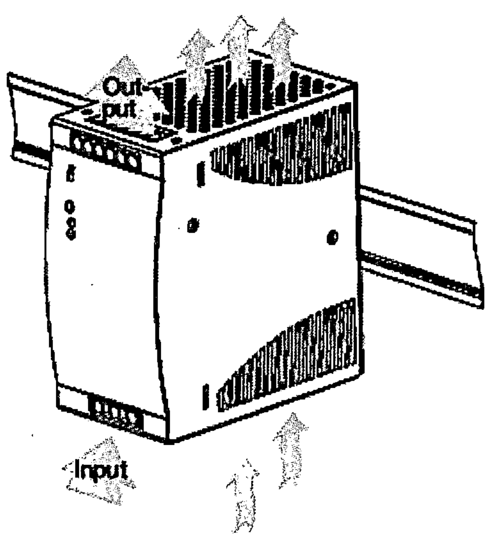
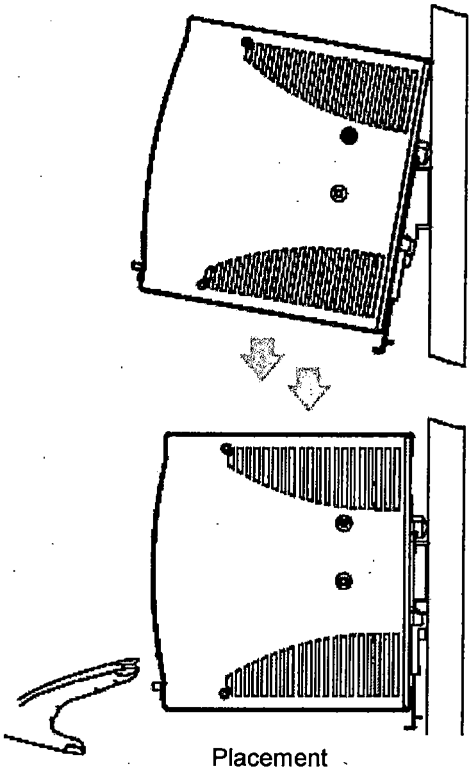
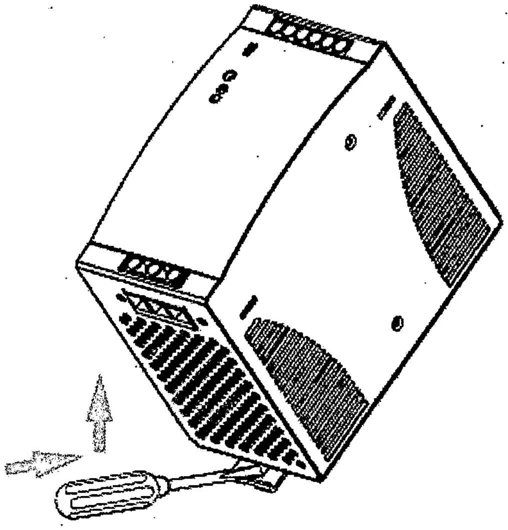


Fig. 2

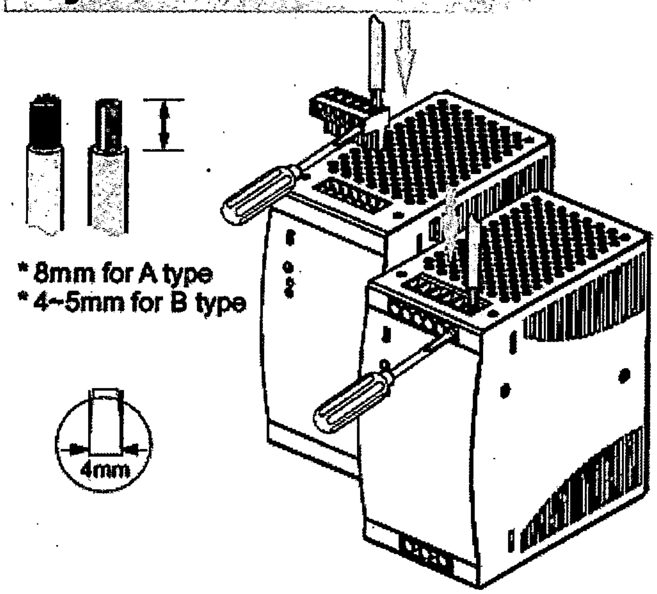


Placement



Removal

Fig. 3



Standard screw type connection:
AWG24 to AWG10 can be used, maximum torque rating for the **input connector** is 1.0Nm (9 pound-inches), for the **output connector** 0.65Nm (5.5 Pound-inches).
For plug type 'B' connection:
AWG24 to AWG14 can be used, maximum torque rating for the input and output connector is 0.8Nm (7 pound-inches),

Mechanical Outline Drawings:

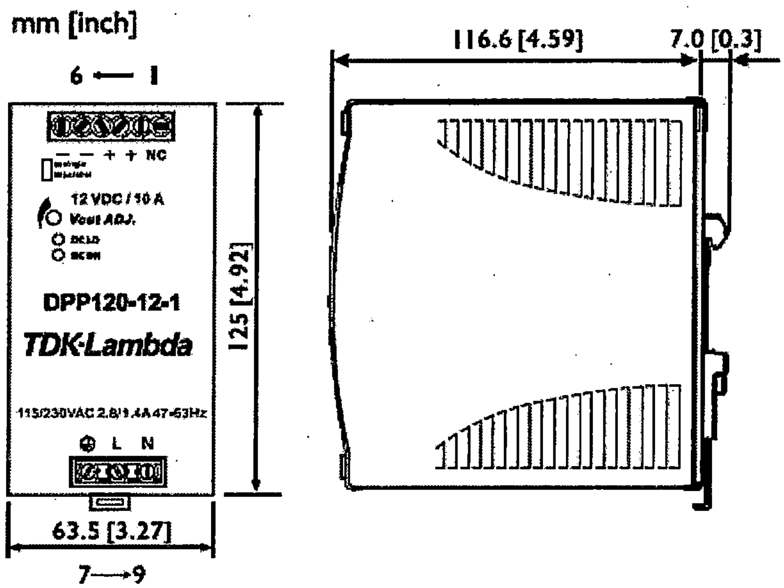
Front panel indicators:
DC ON - The Green LED is on when the output voltage is >75%.
DC LOW - The red LED is on when the output voltage is between 70 – 90%.

The output can be increased by turning the front panel potentiometer clockwise, turning the potentiometer counter clockwise will decrease the output.

Adjusting output voltage beyond the stated range may cause overvoltage protection (OVP) to clamp the output. To reset for normal operation simply adjust the potentiometer to reduce the output voltage to within its range (see table above)

Power ready signal (Rdy) 24V model only.

Contact closed at start up – threshold voltage 17.6 – 19.4Vdc
Contact electrical isolation 500Vdc
Contact rating 60Vdc/0.3A



Weight: DPP240-xx-1 weighs 920g

TDK·Lambda
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Kingsley Avenue, Ilfracombe
Devon, EX34 8ES
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Head Office and Works +44 (0)1271 856600
Facsimile +44 (0)1271 864894
WEBSITE: www.uk.tdk-lambda.com

DIODES INCORPORATED

Lead-free Green

BZX84C2V4TS - BZX84C39TS

TRIPLE SURFACE MOUNT ZENER DIODE ARRAY

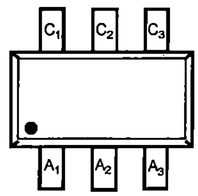
Features

- Zener Voltages from 2.4 - 39V
- Three Isolated Diode Elements in a Single Ultra-Small Surface Mount Package
- **Lead Free/RoHS Compliant (Note 2)**
- **"Green" Device (Note 3 and 4)**

Mechanical Data

- Case: SOT-363
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Solderable per MIL-STD-202, Method 208
- Lead Free Plating (Matte Tin Finish annealed over Alloy 42 leadframe).
- Orientation: See Diagram
- Marking Information: See Page 3
- Ordering Information: See Page 3
- Weight: 0.006 grams (approximate)

Top View



Package Pin Out Configuration

Maximum Ratings @T_A = 25°C unless otherwise specified

Characteristic	Symbol	Value	Unit
Forward Voltage @ I_F = 10mA	V_F	0.9	V

Thermal Characteristics

Characteristic	Symbol	Value	Unit
Power Dissipation (Note 1)	P_D	200	mW
Thermal Resistance, Junction to Ambient Air (Note 1)	$R_{\theta JA}$	625	°C/W
Operating and Storage Temperature Range	T_J, T_{STG}	-65 to +150	°C

Notes:
1. Mounted on FR4 PC Board with recommended pad layout which can be found on our website at http://www.diodes.com/datasheets/ap02001.pdf.
2. No purposefully added lead.
3. Diodes Inc.'s "Green" policy can be found on our website at http://www.diodes.com/products/lead_free/index.php.
4. Product manufactured with Date Code UO (week 40, 2007) and newer are built with Green Molding Compound. Product manufactured prior to Date Code UO are built with Non-Green Molding Compound and may contain Halogens or Sb2O3 Fire Retardants.

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Electrical Characteristics @T_A = 25°C unless otherwise specified

Type Number	Marking Code	Zener Voltage Range (Note 5)				Maximum Zener Impedance (Note 6)			Maximum Reverse Current (Note 5)		Temperature Coefficient of Zener Voltage @ I_{ZT} = 5mA mV/°C	
		V_Z @ I_{ZT}			I_{ZT}	Z_{ZT} @ I_{ZT}	Z_{ZK} @ I_{ZK}	I_{ZK}	I_R	V_R		
		Nom (V)	Min (V)	Max (V)	mA	Ω		mA	uA	@ V	Min	Max
BZX84C2V4TS	KRB	2.4	2.2	2.6	5	100	600	0.5	50	1.0	-3.5	0
BZX84C2V7TS	KRC	2.7	2.5	2.9	5	100	600	1.0	20	1.0	-3.5	0
BZX84C3V0TS	KRD	3.0	2.8	3.2	5	95	600	1.0	10	1.0	-3.5	0
BZX84C3V3TS	KRE	3.3	3.1	3.5	5	95	600	1.0	5.0	1.0	-3.5	0
BZX84C3V6TS	KRF	3.6	3.4	3.8	5	90	600	1.0	5.0	1.0	-3.5	0
BZX84C3V9TS	KRG	3.9	3.7	4.1	5	90	600	1.0	3.0	1.0	-3.5	0
BZX84C4V3TS	KRH	4.3	4.0	4.6	5	90	600	1.0	3.0	1.0	-3.5	0
BZX84C4V7TS	KR1	4.7	4.4	5.0	5	80	500	1.0	3.0	2.0	-3.5	0.2
BZX84C5V1TS	KR2	5.1	4.8	5.4	5	60	480	1.0	2.0	2.0	-2.7	1.2
BZX84C5V6TS	KR3	5.6	5.2	6.0	5	40	400	1.0	1.0	2.0	-2.0	2.5
BZX84C6V2TS	KR4	6.2	5.8	6.6	5	10	150	1.0	3.0	4.0	0.4	3.7
BZX84C6V8TS	KR5	6.8	6.4	7.2	5	15	80	1.0	2.0	4.0	1.2	4.5
BZX84C7V5TS	KR6	7.5	7.0	7.9	5	15	80	1.0	1.0	5.0	2.5	5.3
BZX84C8V2TS	KR7	8.2	7.7	8.7	5	15	80	1.0	0.7	5.0	3.2	6.2
BZX84C9V1TS	KR8	9.1	8.5	9.6	5	15	100	1.0	0.5	6.0	3.8	7.0
BZX84C10TS	KR9	10.0	9.4	10.6	5	20	150	1.0	0.2	7.0	4.5	8.0
BZX84C11TS	KP1	11.0	10.4	11.6	5	20	150	1.0	0.1	8.0	5.4	9.0
BZX84C12TS	KP2	12.0	11.4	12.7	5	25	150	1.0	0.1	8.0	6.0	10.0
BZX84C13TS	KP3	13.0	12.4	14.1	5	30	170	1.0	0.1	8.0	7.0	11.0
BZX84C15TS	KP4	15.0	13.8	15.6	5	30	200	1.0	0.1	10.5	9.2	13.0
BZX84C16TS	KP5	16.0	15.3	17.1	5	40	200	1.0	0.1	11.2	10.4	14.0
BZX84C18TS	KP6	18.0	16.8	19.1	5	45	225	1.0	0.1	12.6	12.4	16.0
BZX84C20TS	KP7	20.0	18.8	21.2	5	55	225	1.0	0.1	14.0	14.4	18.0
BZX84C22TS	KP8	22.0	20.8	23.3	5	55	250	1.0	0.1	15.4	16.4	20.0
BZX84C24TS	KP9	24.0	22.8	25.6	5	70	250	1.0	0.1	16.8	18.4	22.0
BZX84C27TS	KPA	27.0	25.1	28.9	2	80	300	0.5	0.1	18.9	21.4	25.3
BZX84C30TS	KPB	30.0	28.0	32.0	2	80	300	0.5	0.1	21.0	24.4	29.4
BZX84C33TS	KPC	33.0	31.0	35.0	2	80	325	0.5	0.1	23.1	27.4	33.4
BZX84C36TS	KPD	36.0	34.0	38.0	2	90	350	0.5	0.1	25.2	30.4	37.4
BZX84C39TS	KPE	39.0	37.0	41.0	2	130	350	0.5	0.1	27.3	33.4	41.2

Notes: 5. Short duration pulse test used to minimize self-heating effect.
6. f = 1KHz.

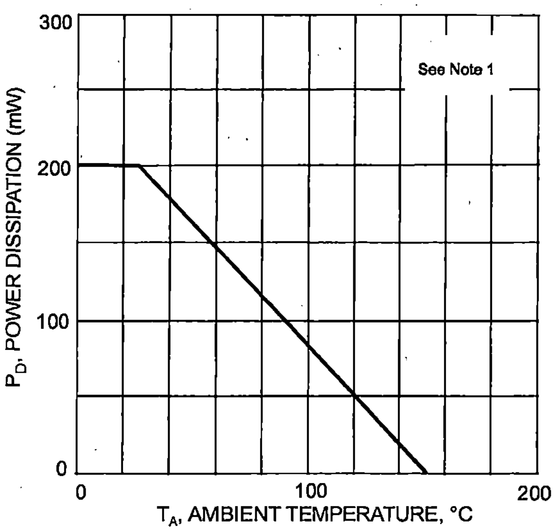

Fig. 1. Power Derating Curve

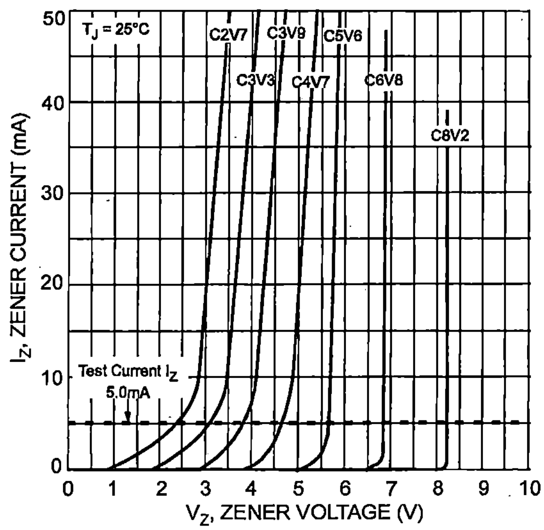

Fig. 2. Typical Zener Breakdown Characteristics

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Type RP73 Series

Key Features

High precision - Tolerance down to 0.05% and TCR down to 5PPM

Power rating to 1.0W Up to 200V DC operating voltage

Terminal finish – electroplated 100% matte Sn

Applications

Communications

Industrial Controls

Instrumentation

Medical

The RP73 resistor series is a stable thin film chip resistor range offering increased power dissipation, higher temperature capabilities and increased working voltages compared to the standard RN73 series. The resistor is produced by sputtering a metal film onto high grade alumina and protecting with three complete printed layers. Values are normally offered in E96 and E24 series. The RP73 resistor has accurate and uniform physical dimensions to reduce placement problems.

Electrical Characteristics RP73 series

		0402														
Rated Power @ 70°C		0.063W														
Resistance range Ω	Min	49R9	49R9				49R9	49R9	49R9	10R		49R9	49R9	49R9	4R7	
	Max	4K99	12K				4K99	60K	69K8	255K		4K99	60K	69K8	511K	
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		25V														
Max overload voltage		50V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

TE connectivity

SMD High Power Precision Resistors

		0603														
Rated Power @ 70°C		0.1W														
Resistance range Ω	Min	24R9	4R7				24R9	4R7		4R7		24R9	4R7		4R7	
	Max	15K	332K				15K	332K		1M0		15K	332K		1M0	
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		75V														
Max overload voltage		150V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

		0805														
Rated Power @ 70°C		0.125W														
Resistance range Ω	Min	24R9	4R7				24R9	4R7	4R7	4R7		24R9	4R7	4R7	1R0	
	Max	30K	511K				30K	511K	1M0	1M0		30K	511K	1M0	1M0	
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		150V														
Max overload voltage		300V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

		1206														
Rated Power @ 70°C		0.25W														
Resistance range Ω	Min	24R9	4R7				24R9	4R7				24R9	4R7			
	Max	49K9	1M0				49K9	1M0				49K9	1M0			
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		200V														
Max overload voltage		400V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

		1210														
Rated Power @ 70°C		0.33W														
Resistance range Ω	Min	24R9	4R7				24R9	4R7				24R9	4R7			
	Max	49K9	1M0				49K9	1M0				49K9	1M0			
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		200V														
Max overload voltage		400V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

		2010														
Rated Power @ 70°C		0.33W														
Resistance range Ω	Min	24R9	4R7				24R9	4R7				24R9	4R7			
	Max	49K9	1M0				49K9	1M0				49K9	1M0			
Tolerance (%)		0.05					0.1					0.5 / 1				
Code Letter		A					B					D / F				
TCR (PPM / °C)		5	10	15	25	50	5	10	15	25	50	5	10	15	25	50
Code Letter		A	C	D	F	G	A	C	D	F	G	A	C	D	F	G
Selection series		E24 & E96														
Max. operating voltage		200V														
Max overload voltage		400V														
Operating temperature range		-55 ~ +155°C														
Insulation resistance		>1000MΩ														
Stability		0.5%														

		2512					
Rated Power @ 70°C		1.0W					
Resistance range Ω	Min	4R7		1R0		1R0	
	Max	100R		100R		100R	
Tolerance (%)		0.1		0.5		1.0	
Code Letter		B		D		F	
TCR (PPM / °C)		25	50	25	50	25	50
Code Letter		F	G	F	G	F	G
Selection series		E24 & E96					
Max. operating voltage		200V					
Max overload voltage		400V					
Operating temperature range		-55 ~ +155°C					
Insulation resistance		>1000MΩ					
Stability		0.5%					

Operating Voltage=√(P*R) or Max. operating voltage listed above, whichever is lower.
Overload Voltage=2.5*√(P*R) or Max. overload voltage listed above, whichever is lower.

Electrical Characteristics RP73P series – High Power

		0402					
Rated Power @ 70°C		0.1W					
Resistance range Ω	Min	10R		4R7		4R7	
	Max	255K		255K		255K	
Tolerance (%)		0.1		0.5		1.0	
Code Letter		B		D		F	
TCR (PPM / °C)		25	50	25	50	25	50
Code Letter		F	G	F	G	F	G
Selection series		E24 & E96					
Max. operating voltage		50V					
Max overload voltage		100V					
Operating temperature range		-55 ~ +155°C					
Insulation resistance		>1000MΩ					
Stability		0.5%					

		0603					
Rated Power @ 70°C		0.166W					
Resistance range Ω	Min	10R		10R		10R	
	Max	332K		332K		332K	
Tolerance (%)		0.1		0.5		1.0	
Code Letter		B		D		F	
TCR (PPM / °C)		25	50	25	50	25	50
Code Letter		F	G	F	G	F	G
Selection series		E24 & E96					
Max. operating voltage		100V					
Max overload voltage		150V					
Operating temperature range		-55 ~ +155°C					
Insulation resistance		>1000MΩ					
Stability		0.5%					

		0805					
Rated Power @ 70°C		0.25W					
Resistance range Ω	Min	10R		10R		10R	
	Max	499K		499K		499K	
Tolerance (%)		0.1		0.5		1.0	
Code Letter		B		D		F	
TCR (PPM / °C)		25	50	25	50	25	50
Code Letter		F	G	F	G	F	G
Selection series		E24 & E96					
Max. operating voltage		150V					
Max overload voltage		300V					
Operating temperature range		-55 ~ +155°C					
Insulation resistance		>1000MΩ					
Stability		0.5%					

		1206					
Rated Power @ 70°C		0.33W					
Resistance range Ω	Min	10R		10R		10R	
	Max	1M0		1M0		1M0	
Tolerance (%)		0.1		0.5		1.0	
Code Letter		B		D		F	
TCR (PPM / °C)		25	50	25	50	25	50
Code Letter		F	G	F	G	F	G
Selection series		E24 & E96					
Max. operating voltage		200V					
Max overload voltage		400V					
Operating temperature range		-55 ~ +155°C					
Insulation resistance		>1000MΩ					
Stability		0.5%					

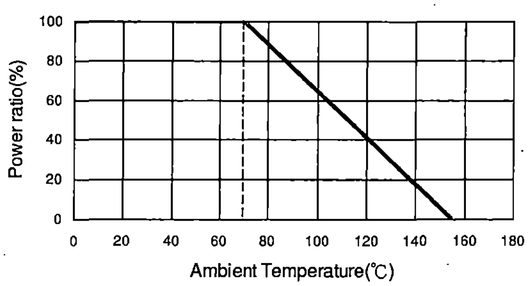
Operating Voltage=√(P*R) or Max. operating voltage listed above, whichever is lower.
Overload Voltage=2.5*√(P*R) or Max. overload voltage listed above, whichever is lower.

Environmental Characteristics

Item	Requirement		Test Method
	Tol. ≤0.05%	TOL. >0.05%	
Temperature Coefficient of Resistance (TCR)	As per TCRs specified in Electrical Characteristics tables		MIL-STD-202 Method 304 +25/-55/+25/+125/+25°C
Short Time Overload	ΔR±0.2%	ΔR±0.2%	JIS-C-5201-1 5.5 RCWV*2.5 or Max. overload voltage whichever is lower for 5 seconds
Insulation Resistance	>1000 MΩ		MIL-STD-202 Method 302 Apply 100VDC for 1 minute
Endurance	ΔR±0.5%		MIL-STD-202 Method 108A 70±2°C, RCWV for 1000 hrs with 1.5 hrs "ON" and 0.5 hrs "OFF"
Damp Heat with Load	ΔR±0.5%	ΔR±0.5%	MIL-STD-202 Method 103B 40±2°C, 90~95% R.H. RCWV for 1000 hrs with 1.5 hrs "ON" and 0.5 hrs "OFF"
Bending Strength	ΔR±0.05%	ΔR±0.2%	JIS-C-5201-1 6.1.4 Bending amplitude 3 mm for 10 seconds
Solderability	95% min. coverage		MIL-STD-202 Method 208H 245±5°C for 3 seconds
Resistance to Soldering Heat	ΔR±0.05%	ΔR±0.2%	MIL-STD-202 Method 210E 260±5°C for 10 seconds
Dielectric Withstand Voltage	By Type		MIL-STD-202 Method 301 Max. overload voltage for 1 minute
Thermal Shock	ΔR±0.05%	ΔR±0.25%	MIL-STD-202 Method 107G -55°C ~150°C, 100 cycles
Low Temperature Operation	ΔR±0.5%	ΔR±0.5%	JIS-C-5201-1 7.1 1 hour, -65°C, followed by 45 minutes of RCWV

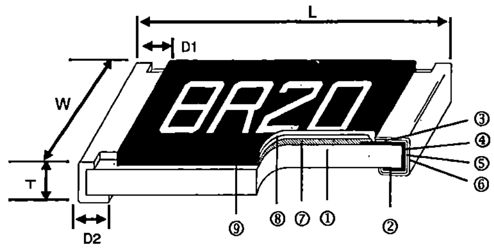
Storage Temperature: 25±3°C; Humidity < 80%RH

Derating Curve



For resistors operated in ambient temperatures above 70°C, power rating must be derated in accordance with this curve

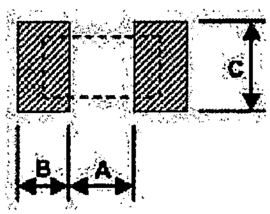
Construction and dimensions



①	Alumina Substrate	④	Edge Electrode (NiCr)	⑦	Resistor Layer (NiCr)
②	Bottom Electrode (Ag)	⑤	Barrier Layer (Ni)	⑧	Overcoat (Epoxy)
③	Top Electrode (Ag)	⑥	External Electrode (Sn)	⑨	Marking

Size	L (mm)	W (mm)	T (mm)	D1 (mm)	D2 (mm)	Weight (g) (1000 Pcs.)
0402	1.00±0.05	0.50±0.05	0.30±0.05	0.20±0.10	0.20±0.10	0.54
0603	1.55±0.10	0.80±0.10	0.45±0.10	0.30±0.20	0.30±0.20	1.83
0805	2.00±0.15	1.25±0.15	0.55±0.10	0.30±0.20	0.40±0.20	4.71
1206	3.05±0.15	1.55±0.15	0.55±0.10	0.42±0.20	0.35±0.25	9.02
1210	3.10±0.15	2.40±0.15	0.55±0.10	0.40±0.20	0.55±0.25	10
2010	4.90±0.15	2.40±0.15	0.55±0.10	0.60±0.30	0.50±0.25	23.61
2512	6.30±0.15	3.10±0.15	0.55±0.10	0.60±0.30	0.50±0.25	38.06

Suggested PCB Layout Plan



Recommended Land Pattern			
Size	A	B	C
0402	0.50	0.50	0.60±0.2
0603	0.80	1.00	0.90±0.2
0805	1.00	1.00	1.35±0.2
1206	2.00	1.15	1.70±0.2
1210	2.00	1.15	2.50±0.2
2010	3.60	1.40	2.50±0.2
2512	4.90	1.60	3.10±0.2

Marking

Case sizes 0805 to 2512 IEC 4 Digit Marking:

Resistance	100R (100Ω)	2K2 (2.2kΩ)	10K (10kΩ)	499K (499kΩ)	100K (100kΩ)
Code	1000	2201	1002	4992	1003

Case Size 0603 E24 3 digit marking – Example 101 = 100R 102=1K0

E24	10	11	12	13	15	16	18	20	22	24	27	30
	33	36	39	43	47	51	56	62	68	75	82	91

Case size 0603 E96 3 digit marking – Examples 14C = 13K7 68B = 4K99 68X = 49R9

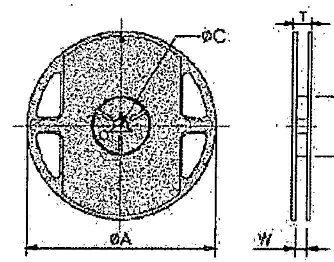
Code	E96	Code	E96	Code	E96	Code	E96
01	100	25	178	49	316	73	562
02	102	26	182	50	324	74	576
03	105	27	187	51	332	75	590
04	107	28	191	52	340	76	604
05	110	29	196	53	348	77	619
06	113	30	200	54	357	78	634
07	115	31	205	55	365	79	649
08	118	32	210	56	374	80	665
09	121	33	215	57	383	81	681
10	124	34	221	58	392	82	698
11	127	35	226	59	402	83	715
12	130	36	232	60	412	84	732
13	133	37	237	61	422	85	750
14	137	38	243	62	432	86	768
15	140	39	249	63	442	87	787
16	143	40	255	64	453	88	806
17	147	41	261	65	464	89	825
18	150	42	267	66	475	90	845
19	154	43	274	67	487	91	866
20	158	44	280	68	499	92	887
21	162	45	287	69	511	93	909
22	165	46	294	70	523	94	931
23	169	47	301	71	536	95	953
24	174	48	309	72	549	96	976

Code	A	B	C	D	E	F	G	H	X	Y	Z
Multiplier	10^0	10^1	10^2	10^3	10^4	10^5	10^6	10^7	10^{-1}	10^{-2}	10^{-3}

NB for 0603 size values other than E24 and E96 will be supplied unmarked
Case sizes smaller than 0603 will be supplied unmarked

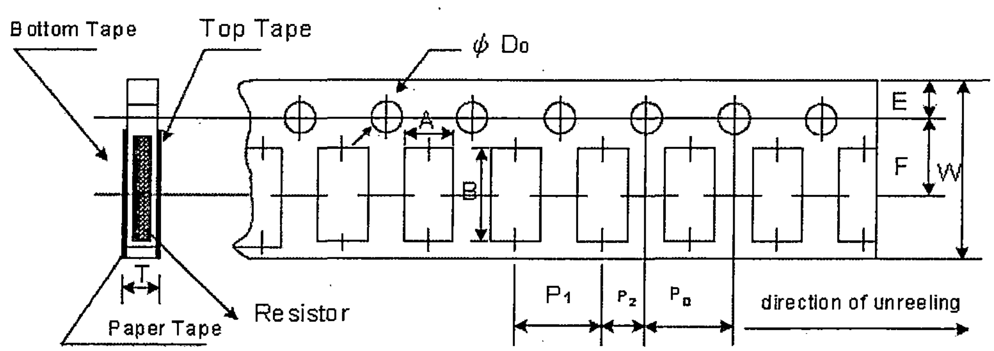
Packaging

Packing Quantity and Reel Specification



<table>
<tr><th>Size</th><th>ØA ±1.0</th><th>ØB ±1.0</th><th>ØC ±0.7</th><th>W ±1.0</th><th>T ±1.0</th><th>Paper Tape</th><th>Embossed Plastic Tape</th></tr>
<tr><td>0402</td><td rowspan="7">178.0</td><td rowspan="7">60.0</td><td rowspan="7">13.5</td><td rowspan="5">9.5</td><td rowspan="5">11.5</td><td rowspan="5">1000 / 5000</td><td rowspan="5">N/A</td></tr>
<tr><td>0603</td></tr>
<tr><td>0805</td></tr>
<tr><td>1206</td></tr>
<tr><td>1210</td></tr>
<tr><td>2010</td><td rowspan="2">13.5</td><td rowspan="2">15.5</td><td rowspan="2">N/A</td><td rowspan="2">4000</td></tr>
<tr><td>2512</td></tr>
</table>

Paper tape Specification



<table>
<tr><th>Size</th><th>A ±0.05</th><th>B ±0.05</th><th>W ±0.10</th><th>E ±0.05</th><th>F ±0.05</th><th>P_0</th><th>P_1</th><th>P_2 ±0.05</th><th>ØD_0</th><th>T</th></tr>
<tr><td>0402</td><td>0.70</td><td>1.16</td><td rowspan="5">8.00</td><td rowspan="5">1.75</td><td rowspan="5">3.5</td><td rowspan="4">4.00 ±0.10</td><td>2.00 ±0.05</td><td rowspan="5">2.00</td><td rowspan="4">1.55 ±0.05</td><td>0.40 ±0.03</td></tr>
<tr><td>0603</td><td>1.10</td><td>1.90</td><td rowspan="4">4.00 ±0.10</td><td>0.60 ±0.03</td></tr>
<tr><td>0805</td><td>1.60</td><td>2.37</td><td rowspan="3">0.75 ±0.05</td></tr>
<tr><td>1206</td><td>2.00</td><td>3.55</td></tr>
<tr><td>1210</td><td>2.75</td><td>3.40</td><td>4.00 ±0.05</td><td>1.60 ±0.10</td></tr>
</table>

Dimensions in millimetres unless otherwise specified

Dimensions Shown for reference purposes only. Specifications subject to change

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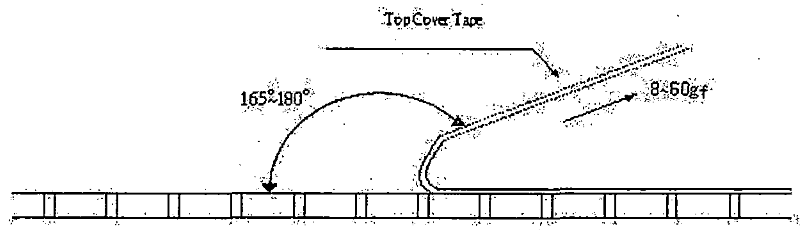
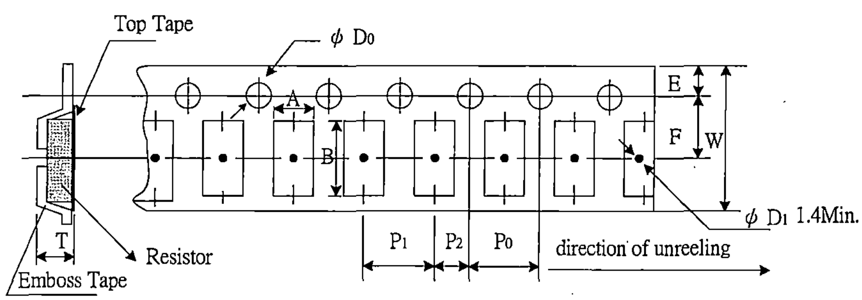
Peel force of top cover tape

The peel speed shall be about 300mm/min±5%
The peel force of top cover tape shall be between 8gf to 60gf



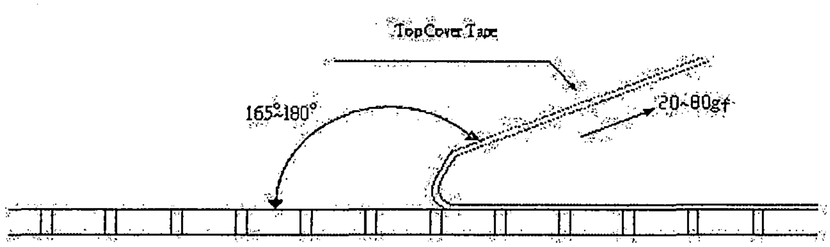
Embossed Plastic Tape Specifications



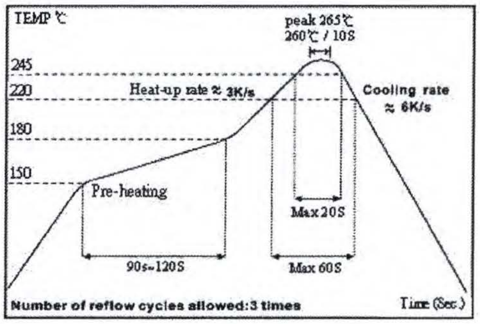
Type	A	B	W	E	F	P_0	P_1	P_2	$ØD_0$	T
2010	2.85±0.10	5.45±0.10	12.0±0.10	1.75±0.10	5.5±0.05	4.00±0.05	4.00±0.10	2.00±0.05	1.50+0.10	1.00±0.20
2512	3.40±0.10	6.65±0.10	12.0±0.10	1.75±0.10	5.5±0.05	4.00±0.05	4.00±0.10	2.00±0.05	1.50+0.10	1.00±0.20

Peel force of top cover tape

The peel speed shall be about 300mm/min±5%
The peel force of top cover tape shall be between 20gf to 80g

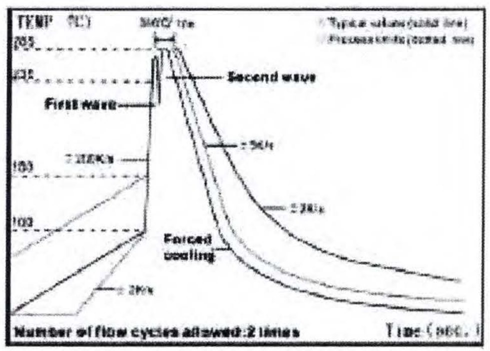


Reflow Solder Profile



Time of Reflow soldering at maximum temperature point 260°C = 10s

Wave Solder Profile



Time of Wave soldering at maximum temperature point 260°C = 10s
Time of Soldering Iron at maximum temperature point 410°C = 5s

How To Order

RP73	C	2A	100R	B	TD
Common Part	TCR	Package Size	Value	Tolerance	Packaging
RP73 – Standard RP73P – High Power	A -±5ppm/°C C - ±10ppm/°C D - ±15PPM F - ±25PPM G - ±50PPM	1E - 0402 1J – 0603 2A – 0805 2B – 1206 2E – 1210 2H – 2010 3A - 2512	100R (100Ω) 1K0 (1000Ω) 100K (100,000 Ω)	A - ±0.05% B - ±0.1% D - ±0.5% F - ±1.0%	TG – 250 cut tape length (1E, 1J, 2A, 2B) TDF – 1000 reel (1E, 1J, 2A, 2B) TD – 5000 reel (1E, 1J, 2A, 2B, 2E) TE – 4000 reel (2H, 3A only

Dimensions in millimetres unless otherwise specified

Dimensions Shown for reference purposes only. Specifications subject to change

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KPS Series, X7R Dielectric, 10 – 250 VDC (Automotive Grade)

Electronic Components KEMET CHARGED.

Overview

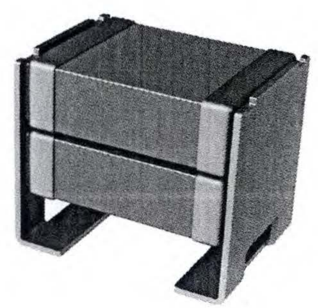
KEMET Power Solutions (KPS) Automotive Series stacked capacitors utilize a proprietary lead-frame technology to vertically stack one or two multilayer ceramic chip capacitors into a single compact surface mount package. The attached lead-frame mechanically isolates the capacitor/s from the printed circuit board, therefore offering advanced mechanical and thermal stress performance. Isolation also addresses concerns for audible, microphonic noise that may occur when a bias voltage is applied. A two chip stack offers up to double the capacitance in the same or smaller design footprint when compared to traditional surface mount MLCC devices. Providing up to 10 mm of board flex capability, KPS Series capacitors are environmentally friendly and in compliance with RoHS legislation. Available in X7R dielectric, these devices are capable of Pb-Free reflow profiles and provide lower ESR, ESL and higher ripple current capability when compared to other dielectric solutions.

Combined with the stability of an X7R dielectric, KEMET's KPS Series devices exhibit a predictable change in capacitance with respect to time and voltage and boast a minimal change in capacitance with reference to ambient temperature. Capacitance change is limited to ±15% from -55°C to +125°C.

KPS Series automotive grade capacitors meet the demanding Automotive Electronics Council's AEC–Q200 qualification requirements.

Benefits

- AEC–Q200 automotive qualified
- -55°C to +125°C operating temperature range
- Reliable and robust termination system
- EIA 1210, 1812, and 2220 Case sizes
- DC voltage ratings of 10 V, 16 V, 25 V, 50 V, 100 V, and 250 V



Ordering Information

C	2220	C	106	M	5	R	2	C	AUTO
Ceramic	Case Size (L" x W")	Specification/ Series	Capacitance Code (pF)	Capacitance Tolerance[1]	Rated Voltage (VDC)	Dielectric	Failure Rate/Design	Leadframe Finish[2]	Packaging/Grade (C-Spec)
	1210 1812 2220	C = Standard	Two significant digits + number of zeros	K = ±10% M = ±20%	8 = 10 4 = 16 3 = 25 5 = 50 1 = 100 A = 250	R = X7R	1 = KPS Single Chip Stack 2 = KPS Double Chip Stack	C = 100% Matte Sn	See "Packaging C-Spec Ordering Options Table" below

[1] *Double chip stacks ("2" in the 13th character position of the ordering code) are only available in M (±20%) capacitance tolerance. Single chip stacks ("1" in the 13th character position of the ordering code) are available in K (±10%) or M (±20%) tolerances.*

[2] *Additional leadframe finish options may be available. Contact KEMET for details.*

One world. One KEMET

C0G Dielectric, 10 – 250 VDC (Automotive Grade)

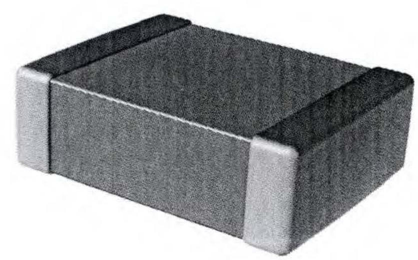
Overview

KEMET's Automotive Grade Series surface mount capacitors in C0G dielectric are suited for a variety of applications requiring proven, reliable performance in harsh environments. Whether under-hood or in-cabin, these devices emphasize the vital and robust nature of capacitors required for mission and safety critical automotive circuits. Stricter testing protocol and inspection criteria have been established for automotive grade products in recognition of potentially harsh environmental conditions. KEMET automotive grade series capacitors meet the demanding Automotive Electronics Council's AEC–Q200 qualification requirements.

C0G dielectric features a 125°C maximum operating temperature and is considered "stable." The Electronics Industries Alliance (EIA) characterizes C0G dielectric as a Class I material. Components of this classification are temperature compensating and are suited for resonant circuit applications or those where Q and stability of capacitance characteristics are required. C0G exhibits no change in capacitance with respect to time and voltage and boasts a negligible change in capacitance with reference to ambient temperature. Capacitance change is limited to ±30 ppm/ºC from −55°C to +125°C.

Benefits

- AEC–Q200 automotive qualified
- -55°C to +125°C operating temperature range
- Lead (Pb)-Free, RoHS and REACH compliant
- EIA 0402, 0603, 0805, 1206, 1210, 1812, and 2220 case sizes
- DC voltage ratings of 10 V, 16 V, 25 V, 50 V, 100 V, 200 V, and 250 V
- Capacitance offerings ranging from 0.5 pF up to 0.47 µF
- Available capacitance tolerances of ±0.10 pF, ±0.25 pF, ±0.5 pF, ±1%, ±2%, ±5%, ±10%, and ±20%



Ordering Information

C	1206	C	104	J	3	G	A	C	AUTO
Ceramic	Case Size (L" x W")	Specification/ Series	Capacitance Code (pF)	Capacitance Tolerance[1]	Rated Voltage (VDC)	Dielectric	Failure Rate/ Design	Termination Finish[2]	Packaging/Grade (C-Spec)
	0402 0603 0805 1206 1210 1812 2220	C = Standard	Two significant digits + number of zeros Use 9 for 1.0 – 9.9 pF Use 8 for 0.5 – .99 pF ex. 2.2 pF = 229 ex. 0.5 pF = 508	B = ±0.10 pF C = ±0.25 pF D = ±0.5 pF F = ±1% G = ±2% J = ±5% K = ±10% M = ±20%	8 = 10 4 = 16 3 = 25 5 = 50 1 = 100 2 = 200 A = 250	G = C0G	A = N/A	C = 100% Matte Sn	See "Packaging C-Spec Ordering Options Table" below

[1] *Additional capacitance tolerance offerings may be available. Contact KEMET for details.*
[2] *Additional termination finish options may be available. Contact KEMET for details.*

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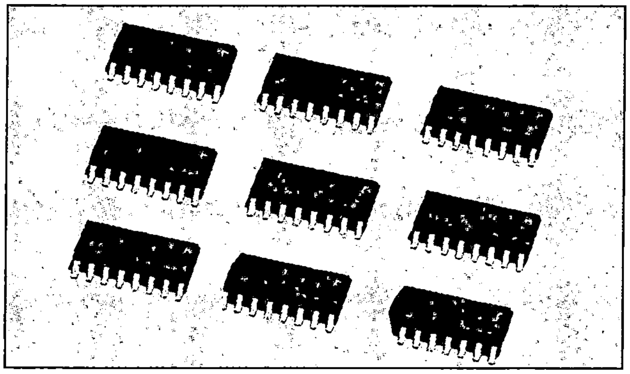
Littelfuse®
Expertise Applied | Answers Delivered

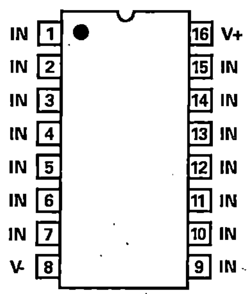
SP720 Series 3pF 4kV Diode Array

RoHS Pb GREEN

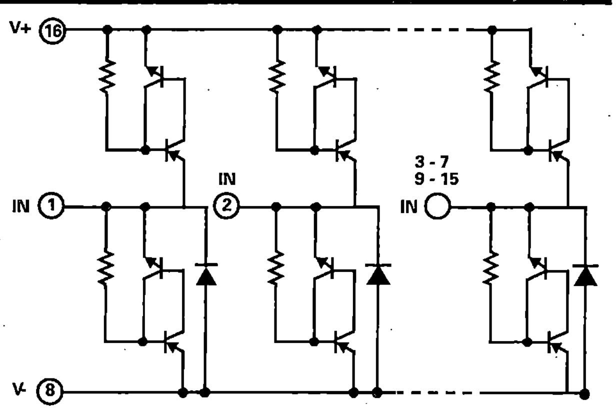


Pinout

SP720 (PDIP, SOIC)
TOP VIEW



Functional Block Diagram



Additional Information

Datasheet | Resources | Samples

Description

The SP720 is an array of SCR/Diode bipolar structures for ESD and over-voltage protection to sensitive input circuits. The SP720 has 2 protection SCR/Diode device structures per input. A total of 14 available inputs can be used to protect up to 14 external signal or bus lines. Over-voltage protection is from the IN (pins 1-7 and 9-15) to V+ or V-.

The SCR structures are designed for fast triggering at a threshold of one $+V_{BE}$ diode threshold above V+ (Pin 16) or a $-V_{BE}$ diode threshold below V- (Pin 8). From an IN input, a clamp to V+ is activated if a transient pulse causes the input to be increased to a voltage level greater than one V_{BE} above V+. A similar clamp to V- is activated if a negative pulse, one V_{BE} less than V-, is applied to an IN input. Standard ESD Human Body Model (HBM) Capability is:

Features

- ESD Interface Capability for HBM Standards
  - MIL STD 3015.7 .... 15kV
  - IEC 61000-4-2, Direct Discharge,
  - Single Input .... 4kV (Level 2)
  - Two Inputs in Parallel .... 8kV (Level 4)
  - IEC 61000-4-2, Air Discharge ....15kV (Level 4)
- High Peak Current Capability
  - IEC 61000-4-5 (8/20μs) .... ±3A
  - Single Pulse, 100μs Pulse Width .... ±2A
  - Single Pulse, 4μs Pulse Width .... ±5A
- Designed to Provide Over-Voltage Protection
  - Single-Ended Voltage Range to .... +30V
  - Differential Voltage Range to .... ±15V
- Fast Switching ....2ns Risetime
- Low Input Leakages ....1nA at 25° (Typ)
- Low Input Capacitance...................................... 3pF (Typ)
- An Array of 14 SCR/Diode Pairs
- Operating Temperature Range....................-40°C to 105°C

Applications

- Microprocessor/Logic Input Protection
- Data Bus Protection
- Analog Device Input Protection
- Voltage Clamp

Life Support Note:
Not Intended for Use in Life Support or Life Saving Applications
The products shown herein are not designed for use in life sustaining or life saving applications unless otherwise expressly indicated.

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Absolute Maximum Ratings

Parameter	Rating	Units
Continuous Supply Voltage, (V+) - (V-)	+35	V
Forward Peak Current, I_{IN} to V_{CC}, I_{IN} to GND (Refer to Figure 5)	±2, 100μs	A

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

Note:

ESD Ratings and Capability - See Figure 1, Table 1

Load Dump and Reverse Battery (Note 2)

Thermal Information

Parameter	Rating	Units
Thermal Resistance (Typical, Note 1)	θ_{JA}	°C/W
PDIP Package	90	°C/W
SOIC Package	130	°C/W
Maximum Storage Temperature Range	-65 to 150	°C
Maximum Junction Temperature (Plastic Package)	150	°C
Maximum Lead Temperature (Soldering 20-40s) (SOIC Lead Tips Only)	260	°C

1. θ_{JA} is measured with the component mounted on an evaluation PC board in free air.

Electrical Characteristics T_A = -40°C to 105°C, $V_{IN} = 0.5V_{CC}$, Unless Otherwise Specified

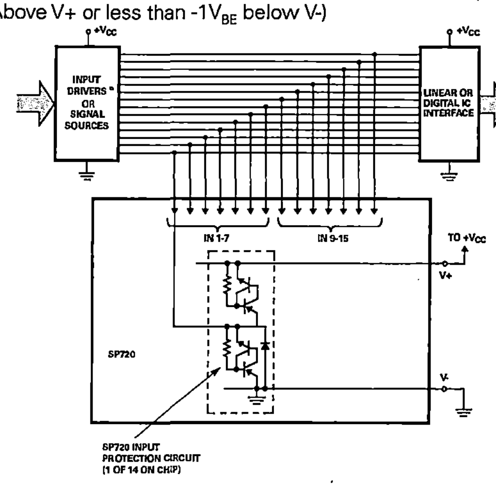
Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Operating Voltage Range, V_{SUPPLY} = [(V+) - (V-)]	V_{SUPPLY}		-	2 to 30	-	V
Forward Voltage Drop:		I_{IN} = 1A (Peak Pulse)				
IN to V-	V_{FWDL}		-	2	-	V
IN to V+	V_{FWDH}		-	2	-	V
Input Leakage Current	I_{IN}		-20	5	20	nA
Quiescent Supply Current	$I_{QUIESCENT}$		-	50	200	nA
Equivalent SCR ON Threshold		Note 3	-	1.1	-	V
Equivalent SCR ON Resistance		V_{FWD}/I_{FWD}; Note 3	-	1	-	Ω
Input Capacitance	C_{IN}		-	3	-	pF
Input Switching Speed	t_{ON}		-	2	-	ns

Notes:

2. In automotive and battery operated systems, the power supply lines should be externally protected for load dump and everse battery V+ and V- pins are connected to the same supply voltage source as the device or control line under protection, a current limiting resistor should be connected in series between the external supply and the SP720 supply pins to limit reverse battery current to within the rated maximum limits. Bypass capacitors of typically 0.01μF or larger from the V+ and V- pins to ground are recommended.
3. Refer to the Figure 3 graph for definitions of equivalent "SCR ON Threshold" and "SCR ON Resistance." These characteristics are given here for thumb-rule nformation to determine peak current and dissipation under EOS conditions.

Typical Application of the SP720

(Application as an Input Clamp for Over-voltage, greater than $1V_{BE}$ Above V+ or less than $-1V_{BE}$ below V-)



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ESD Capability

ESD capability is dependent on the application and defined test standard. The evaluation results for various test standards and methods based on Figure 1 are shown in Table 1.

For the "Modified" MIL-STD-3015.7 condition that is defined as an "in-circuit" method of ESD testing, the V+ and V- pins have a return path to ground and the SP720 ESD capability is typically greater than 15kV from 100pF through 1.5kΩ. By strict definition of MIL-STD-3015.7 using "pin-to-pin" device testing, the ESD voltage capability is greater than 6kV. The MIL-STD-3015.7 results were determined from AT&T ESD Test Lab measurements.

The HBM capability to the IEC 61000-4-2 standard is greater than 15kV for air discharge (Level 4) and greater than 4kV for direct discharge (Level 2). Dual pin capability (2 adjacent pins in parallel) is well in excess of 8kV (Level 4).

For ESD testing of the SP720 to EIAJ IC121 Machine Model (MM) standard, the results are typically better than 1kV from 200pF with no series resistance.

Figure 1: Electrostatic Discharge Test

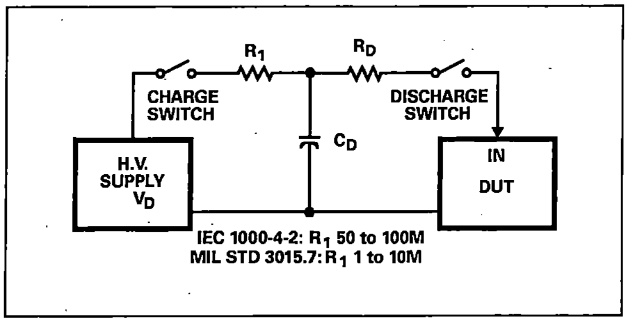


Table 1: ESD Test Conditions

Standard	Type/Mode	R_D	C_D	$\pm V_D$
MIL STD 3015.7	Modified HBM	1.5kΩ	100pF	15kV
	Standard HBM	1.5kΩ	100pF	6kV
IEC 61000-4-2	HBM, Air Discharge	330Ω	150pF	15kV
	HBM, Direct Discharge	330Ω	150pF	4kV
	HBM, Direct Discharge, Two Parallel Input Pins	330Ω	150pF	8kV
EIAJ IC121	Machine Model	0kΩ	200pF	1kV

Figure 2: Low Current SCR Forward Voltage Drop Curve

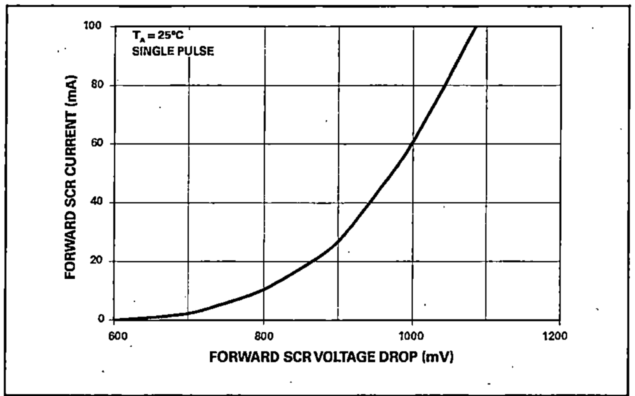
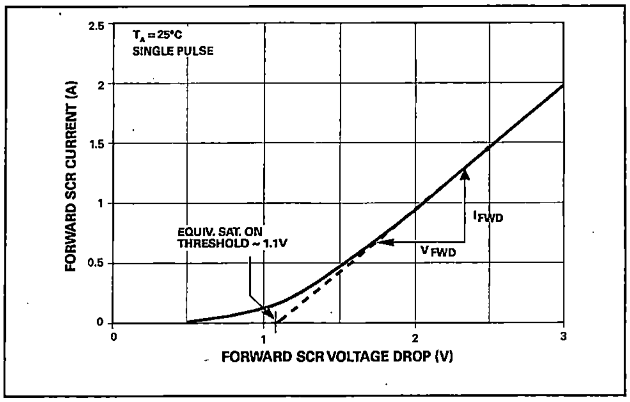


Figure 3: High Current SCR Forward Voltage Drop Curve



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Peak Transient Current Capability for Long Duration Surges

The peak transient current capability rises sharply as the width of the current pulse narrows. Destructive testing was done to fully evaluate the SP720's ability to withstand a wide range of transient current pulses. The circuit used to generate current pulses is shown in Figure 4.

The test circuit of Figure 4 is shown with a positive pulse input. For a negative pulse input, the (-) current pulse input goes to an SP720 'IN' input pin and the (+) current pulse input goes to the SP720 V- pin. The V+ to V- supply of the SP720 must be allowed to float. (i.e., It is not tied to the ground reference of the current pulse generator.) Figure 5 shows the point of overstress as defined by increased leakage in excess of the data sheet published limits.

The maximum peak input current capability is dependent on the V+ to V- voltage supply level, improving as the supply voltage is reduced. Values of 0, 5, 15 and 30 voltages are shown. The safe operating range of the transient peak current should be limited to no more than 75% of the measured overstress level for any given pulse width as shown in Figure 5.

When adjacent input pins are paralleled, the sustained peak current capability is increased to nearly twice that of a single pin. For comparison, tests were run using dual pin combinations 1+2, 3+4, 5+6, 7+9, 10+11, 12+13 and 14+15.

The overstress curve is shown in Figure 5 for a 15V supply condition. The dual pins are capable of 10A peak current for a 10µs pulse and 4A peak current for a 1ms pulse. The complete for single pulse peak current vs. pulse width time ranging up to 1 second are shown in Figure 5.

Figure 4: Typical SP720 Peak Current Test Circuit with a Variable Pulse Width Input

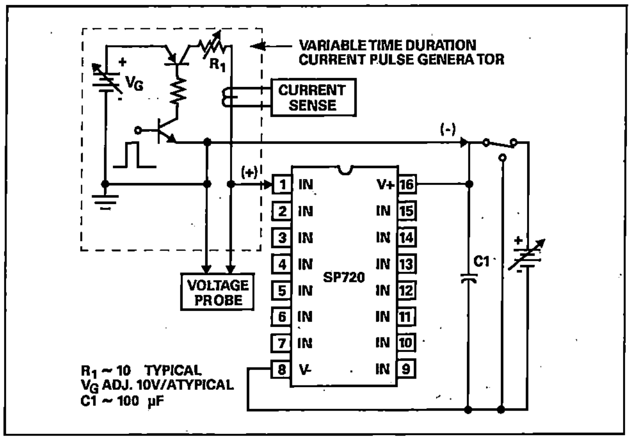
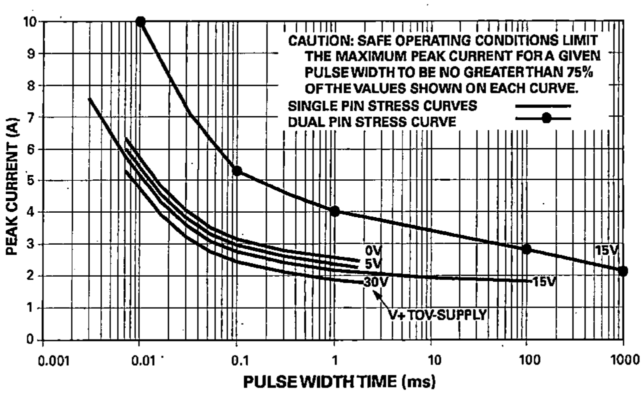


Figure 5: SP720 Typical Nonrepetitive Peak Current Pulse Capability

Showing the Measured Point of Overstress in Amperes vs pulse width time in milliseconds (T_A = 25ºC)



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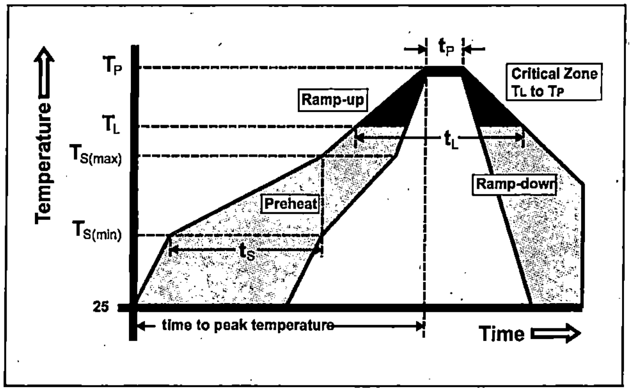
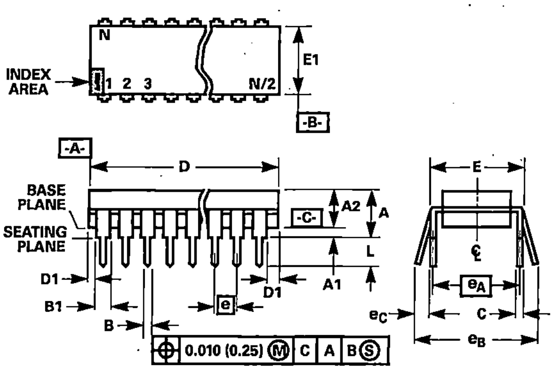
Soldering Parameters

Reflow Condition		Pb – Free assembly
Pre Heat	- Temperature Min ($T_{s(min)}$)	150°C
	- Temperature Max ($T_{s(max)}$)	200°C
	- Time (min to max) (t_s)	60 – 180 secs
Average ramp up rate (Liquidus) Temp (T_L) to peak		5°C/second max
$T_{S(max)}$ to T_L - Ramp-up Rate		5°C/second max
Reflow	- Temperature (T_L) (Liquidus)	217°C
	- Temperature (t_L)	60 – 150 seconds
Peak Temperature (T_P)		$260^{+0/-5}$ °C
Time within 5°C of actual peak Temperature (t_p)		20 – 40 seconds
Ramp-down Rate		5°C/second max
Time 25°C to peak Temperature (T_P)		8 minutes Max.
Do not exceed		260°C



Package Dimensions Dual-In-Line Plastic Packages (PDIP)



Package	PDIP				
Pins	16 Lead Dual-in-Line				
JEDEC	MS-001				
	Millimeters		Inches		Notes
	Min	Max	Min	Max	
A	-	5.33	-	0.210	4
A1	0.39	-	0.015	-	4
A2	2.93	4.95	0.115	0.195	-
B	0.356	0.558	0.014	0.022	-
B1	1.15	1.77	0.045	0.070	8, 10
C	0.204	0.355	0.008	0.014	-
D	18.66	19.68	0.735	0.775	5
D1	0.13	-	0.005	-	5
E	7.62	8.25	0.300	0.325	6
E1	6.10	7.11	0.240	0.280	5
e	2.54 BSC		0.100 BSC		-
e_A	7.62 BSC		0.300 BSC		6
e_B	-	10.92	-	0.430	7
L	2.93	3.81	0.115	0.150	4
N	16		16		9

Notes:

1. Controlling Dimensions: INCH. in case of conflict between English and Metric dimensions, the inch dimensions control.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication No. 95.
4. Dimensions A, A1 and L are measured with the package seated in JE-DEC seating plane gauge GS-3.
5. D, D1, and E1 dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 inch (0.25mm).
6. E and e_A are measured with the leads constrained to be perpendicular to datum -C-.
7. e_B and e_C are measured at the lead tips with the leads unconstrained. e_C must be zero or greater.
8. B1 maximum dimensions do not include dambar protrusions. Dambar protrusions shall not exceed 0.010 inch (0.25mm).
9. N is the maximum number of terminal positions.
10. Corner leads (1, N, N/2 and N/2 + 1) for E8.3, E16.3, E18.3, E28.3, E42.6 will have a B1 dimension of 0.030 - 0.045 inch (0.76 - 1.14mm).

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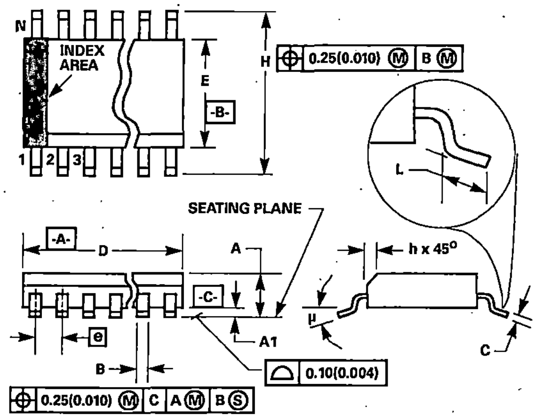
Package Dimensions — Small Outline Plastic Packages (SOIC)



Package	SOIC				
Pins	16				
JEDEC	MS-012				
	Millimeters		Inches		Notes
	Min	Max	Min	Max	
A	1.35	1.75	0.0532	0.0688	-
A1	0.10	0.25	0.0040	0.0098	-
B	0.33	0.51	0.013	0.020	9
C	0.19	0.25	0.0075	0.0098	-
D	9.80	10.00	0.3859	0.3937	3
E	3.80	4.00	0.1497	0.1574	4
e	1.27 BSC		0.050 BSC		-
H	5.80	6.20	0.2284	0.2440	-
h	0.25	0.50	0.0099	0.0196	5
L	0.40	1.27	0.016	0.050	6
N	16		16		7
μ	0°	8°	0°	8°	-

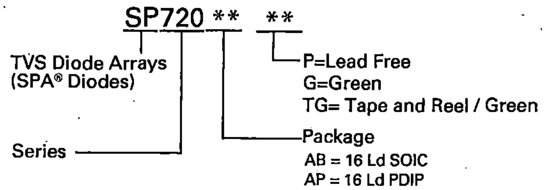
Notes:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E" does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width "B", as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
10. Controlling dimension:MILLIMETER. Converted inch dimensions are not necessarily exact.

Product Characteristics

Lead Plating	Matte Tin
Lead Material	Copper Alloy
Lead Coplanarity	0.004 inches (0.102mm)
Substitute Material	Silicon
Body Material	Molded Epoxy
Flammability	UL 94 V-0

Part Numbering System



See Ordering Information section for specific options available

Ordering Information

Part Number	Temp. Range (°C)	Package	Environmental Informaton	Marking	Min. Order
SP720APP	-40 to 105	16 Ld PDIP	Lead-free	SP720AP(P) [1]	1500
SP720ABG	-40 to 105	16 Ld SOIC	Green	SP720A(B)G [2]	1920
SP720ABTG	-40 to 105	16 Ld SOIC Tape and Reel	Green	SP720A(B)G [2]	2500

Notes:

1. SP720AP(P) means device marking either SP720AP or SP720APP.
2. SP720A(B)G means device marking either SP720AG or SP720ABG which are good for types SP720ABG and SP720ABTG.

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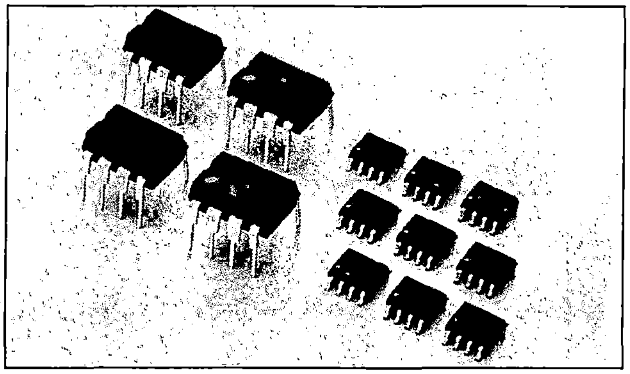
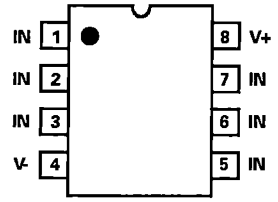
SP721 Series 3pF 4kV Diode Array

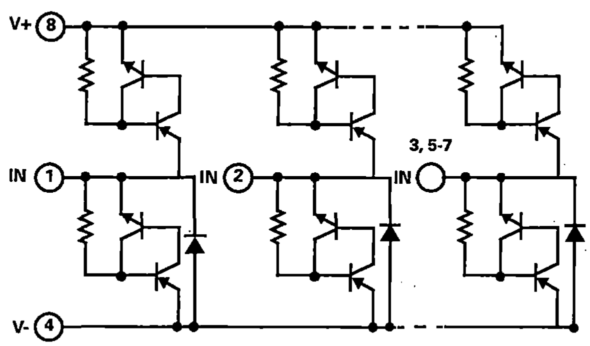
RoHS Pb GREEN



Pinout



Functional Block Diagram



Description

The SP721 is an array of SCR/Diode bipolar structures for ESD and over-voltage protection to sensitive input circuits. The SP721 has 2 protection SCR/Diode device structures per input. There are a total of 6 available inputs that can be used to protect up to 6 external signal or bus lines. Over-voltage protection is from the IN (Pins 1 - 3 and Pins 5 - 7) to V+ or V-.

The SCR structures are designed for fast triggering at a threshold of one $+V_{BE}$ diode threshold above V+ (Pin 8) or a $-V_{BE}$ diode threshold below V- (Pin 4). From an IN input, a clamp to V+ is activated if a transient pulse causes the input to be increased to a voltage level greater than one V_{BE} above V+. A similar clamp to V- is activated if a negative pulse, one V_{BE} less than V-, is applied to an IN input. Standard ESD Human Body Model (HBM) Capability is:

Features

- ESD Interface Capability for HBM Standards
  - MIL STD 3015.7 .... 15kV
  - IEC 61000-4-2, Direct Discharge,
  - Single Input .... 4kV (Level 2)
  - Two Inputs in Parallel .... 8kV (Level 4)
  - IEC 61000-4-2, Air Discharge .... 15kV (Level 4)
- High Peak Current Capability
  - IEC 61000-4-5 (8/20μs) .... ±3A
  - Single Pulse, 100μs Pulse Width .... ±2A
  - Single Pulse, 4μs Pulse Width .... ±5A
- Designed to Provide Over-Voltage Protection
  - Single-Ended Voltage Range to .... +30V
  - Differential Voltage Range to .... ±15V
- Fast Switching .... 2ns Rise Time
- Low Input Leakages .... 1nA at 25°C Typical
- Low Input Capacitance .... 3pF Typical
- An Array of 6 SCR/Diode Pairs
- Operating Temperature Range .... -40°C to 105°C

Additional Information

Datasheet | Resources | Samples

Applications

- Microprocessor/Logic Input Protection
- Data Bus Protection
- Analog Device Input Protection
- Voltage Clamp

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Absolute Maximum Ratings

Parameter	Rating	Units
Continuous Supply Voltage, (V+) - (V-)	+35	V
Forward Peak Current, I_{IN} to V_{CC}, I_{IN} to GND (Refer to Figure 5)	±2, 100µs	A

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

Note:

ESD Ratings and Capability (Figure 1, Table 1)

Load Dump and Reverse Battery (Note 2)

Thermal Information

Parameter	Rating	Units
Thermal Resistance (Typical, Note 1)	θ_{JA}	°C/W
PDIP Package	160	°C/W
SOIC Package	170	°C/W
Maximum Storage Temperature Range	-65 to 150	°C
Maximum Junction Temperature (Plastic Package)	150	°C
Maximum Lead Temperature (Soldering 20-40s)(SOIC Lead Tips Only)	260	°C

1. θ_{JA} is measured with the component mounted on an evaluation PC board in free air.

Electrical Characteristics T_A = -40°C to 105°C, V_{IN} = 0.5V_{CC}, Unless Otherwise Specified

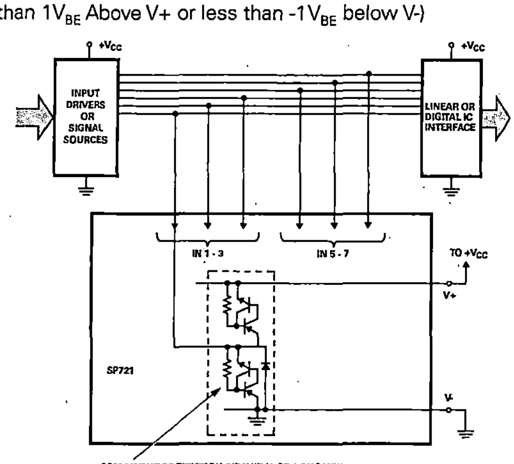
Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Operating Voltage Range,	V_{SUPPLY}		-	2 to 30	-	V
V_{SUPPLY} = [(V+) - (V-)]						
Forward Voltage Drop						
IN to V-	V_{FWDL}	I_{IN} = 1A (Peak Pulse)	-	2	-	V
IN to V+	V_{FWDH}		-	2	-	V
Input Leakage Current	I_{IN}		-20	5	+20	nA
Quiescent Supply Current	$I_{QUIESCENT}$		-	50	200	nA
Equivalent SCR ON Threshold		Note 3	-	1.1	-	V
Equivalent SCR ON Resistance		V_{FWD}/I_{FWD}; Note 3	-	1	-	Ω
Input Capacitance	C_{IN}		-	3	-	pF
Input Switching Speed	t_{ON}		-	2	-	ns

Notes:

2. In automotive and battery operated systems, the power supply lines should be externally protected for load dump and reverse battery. When the V+ and V- Pins are connected to het same supply voltage source as the device or control line under protection, a current limiti ng resistor should be connected in series between the external supply and the SP721 supply pins to limit reverse battery current to within the rated maximum limits. Bypass capacitors of typically 0.01µF or larger romf the V+ and V- Pins to ground are recommended.
3. Refer to the Figure 3 graph for definitions of equivalent "SCR ON Threshold" and "SCR ON Resistance". These characteristics are given here for thumb-rule nformation to determine peak current and dissipation under EOS conditions.

Typical Application of the SP721

(Application as an Input Clamp for Over-voltage, Greater than 1V_{BE} Above V+ or less than -1V_{BE} below V-)



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ESD Capability

ESD capability is dependent on the application and defined test standard.The evaluation results for various test standards and methods based on Figure 1 are shown in Table 1.

For the "Modified" MIL-STD-3015.7 condition that is defined as an "in-circuit" method of ESD testing, the V+ and V- pins have a return path to ground and the SP721 ESD capability is typically greater than 15kV from 100pF through 1.5kΩ.By strict definition of MIL-STD-3015.7 using "pin-to-pin" device testing, the ESD voltage capability is greater than 6kV.The MIL-STD-3015.7 results were determined from AT&T ESD Test Lab measurements.

The HBM capability to the IEC 61000-4-2 standard is greater than 15kV for air discharge (Level 4) and greater than 4kV for direct discharge (Level 2).Dual pin capability (2 adjacent pins in parallel) is well in excess of 8kV (Level 4).

For ESD testing of the SP721 to EIAJ IC121 Machine Model (MM) standard, the results are typically better than 1kV from 200pF with no series resistance.

Figure 1: Electrostatic Discharge Test

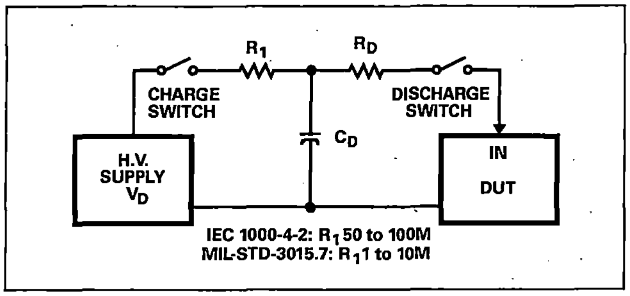


Table 1: ESD Test Conditions

Standard	Type/Mode	R_D	C_D	$\pm V_D$
MIL STD 3015.7	Modified HBM	1.5kΩ	100pF	15kV
	Standard HBM	1.5kΩ	100pF	6kV
IEC 61000-4-2	HBM, Air Discharge	330Ω	150pF	15kV
	HBM, Direct Discharge	330Ω	150pF	4kV
	HBM, Direct Discharge, Two Parallel Input Pins	330Ω	150pF	8kV
EIAJ IC121	Machine Model	0kΩ	200pF	1kV

Figure 2: Low Current SCR Forward Voltage Drop Curve

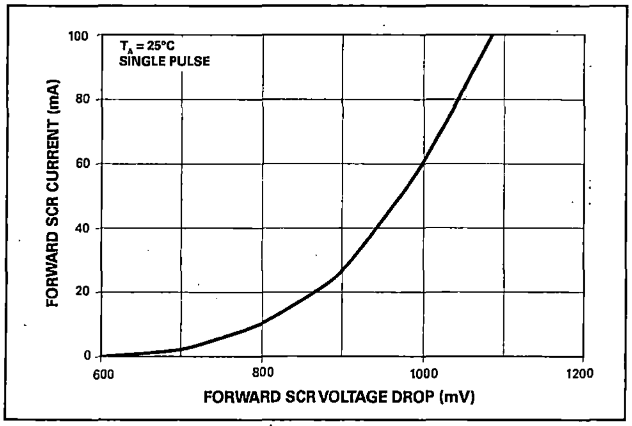
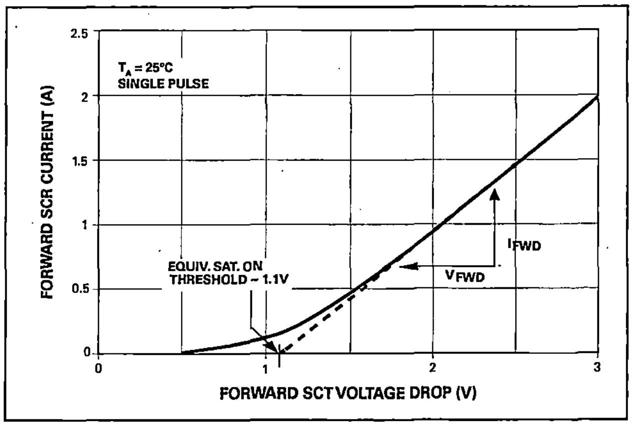


Figure 3: High Current SCR Forward Voltage Drop Curve



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Peak Transient Current Capability of the SP721

The peak transient current capability rises sharply as the width of the current pulse narrows. Destructive testing was done to fully evaluate the SP721's ability to withstand a wide range of peak current pulses vs time. The circuit used to generate current pulses is shown in Figure 4.

The test circuit of Figure 4 is shown with a positive pulse input. For a negative pulse input, the (-) current pulse input goes to an SP721 'IN' input pin and the (+) current pulse input goes to the SP721 V- pin. The V+ to V- supply of the SP721 must be allowed to float. (i.e., It is not tied to the ground reference of the current pulse generator.) Figure 5 shows the point of overstress as defined by increased leakage in excess of the data sheet published limits.

The maximum peak input current capability is dependent on the ambient temperature, improving as the temperature is reduced. Peak current curves are shown for ambient temperatures of 25°C and 105°C and a 15V power supply condition. The safe operating range of the transient peak current should be limited to no more than 75% of the measured overstress level for any given pulse width as shown in the curves of Figure 5.

Note that adjacent input pins of the SP721 may be paralleled to improve current (and ESD) capability. The sustained peak current capability is increased to nearly twice that of a single pin.

Figure 4: Typical SP721 Peak Current Test Circuit with a Variable Pulse Width Input

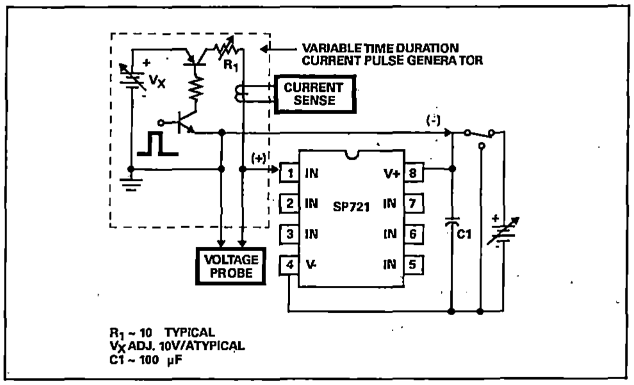
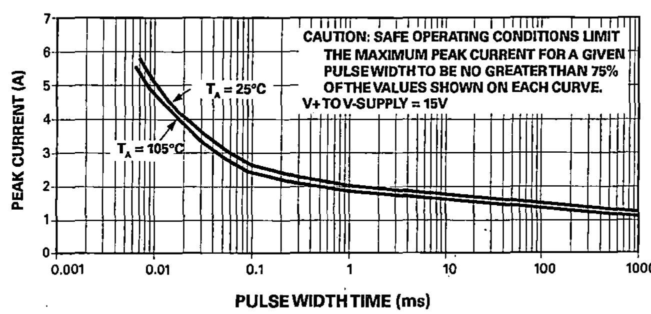


Figure 5: SP721 Typical Single Peak Current Pulse Capability

Showing the Measured Point of Overstress in Amperes vs pulse width time in milliseconds



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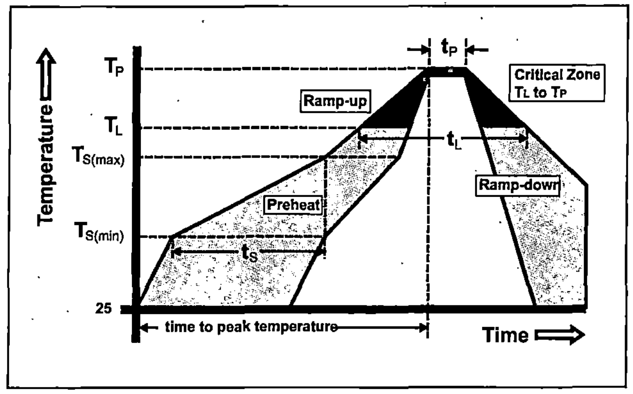
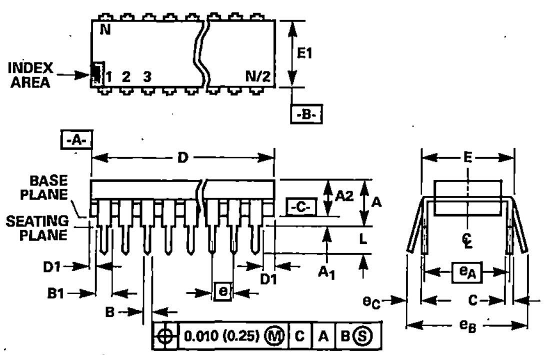
Soldering Parameters

Reflow Condition		Pb – Free assembly
Pre Heat	- Temperature Min ($T_{s(min)}$)	150°C
	- Temperature Max ($T_{s(max)}$)	200°C
	- Time (min to max) (t_s)	60 – 180 secs
Average ramp up rate (Liquidus) Temp (T_L) to peak		5°C/second max
$T_{S(max)}$ to T_L - Ramp-up Rate		5°C/second max
Reflow	- Temperature (T_L) (Liquidus)	217°C
	- Temperature (t_L)	60 – 150 seconds
Peak Temperature (T_P)		260+0/-5 °C
Time within 5°C of actual peak Temperature (t_p)		20 – 40 seconds
Ramp-down Rate		5°C/second max
Time 25°C to peak Temperature (T_P)		8 minutes Max.
Do not exceed		260°C



Package Dimensions — Dual-In-Line Plastic Packages (PDIP)



Package	PDIP				
Pins	8 Lead Dual-in-Line				
JEDEC	MS-001				
	Millimeters		Inches		Notes
	Min	Max	Min	Max	
A	-	5.33	-	0.210	4
A1	0.39	-	0.015	-	4
A2	2.93	4.95	0.115	0.195	-
B	0.356	0.558	0.014	0.022	-
B1	1.15	1.77	0.045	0.070	8, 10
C	0.204	0.355	0.008	0.014	-
D	9.01	10.16	0.355	0.400	5
D1	0.13	-	0.005	-	5
E	7.62	8.25	0.300	0.325	6
E1	6.10	7.11	0.240	0.280	5
e	2.54 BSC		0.100 BSC		-
e_A	7.62 BSC		0.300 BSC		6
e_B	-	10.92	-	0.430	7
L	2.93	3.81	0.115	0.150	4
N	8		8		9

Notes:

1. Controlling Dimensions: INCH. In case of conflict between English and Metric dimensions, the inch dimensions control.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication No. 95.
4. Dimensions A, A1 and L are measured with the package seated in JEDEC seating plane gauge GS-3.
5. D, D1, and E1 dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 inch (0.25mm).
6. E and e_A are measured with the leads constrained to be perpendicular to datum -C-.
7. e_B and e_C are measured at the lead tips with the leads unconstrained. e_C must be zero or greater.
8. B1 maximum dimensions do not include dambar protrusions. Dambar protrusions shall not exceed 0.010 inch (0.25mm).
9. N is the maximum number of terminal positions.
10. Corner leads (1, N, N/2 and N/2 + 1) for E8.3, E16.3, E18.3, E28.3, E42.6 will have a B1 dimension of 0.030 - 0.045 inch (0.76 - 1.14mm).

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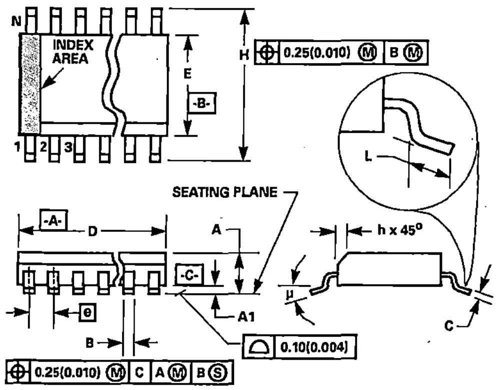
Package Dimensions — Small Outline Plastic Packages (SOIC)



Package	SOIC				
Pins	8				
JEDEC	MS-012				
	Millimeters		Inches		Notes
	Min	Max	Min	Max	
A	1.35	1.75	0.0532	0.0688	-
A1	0.10	0.25	0.0040	0.0098	-
B	0.33	0.51	0.013	0.020	9
C	0.19	0.25	0.0075	0.0098	-
D	4.80	5.00	0.1890	0.1968	3
E	3.80	4.00	0.1497	0.1574	4
e	1.27 BSC		0.050 BSC		-
H	5.80	6.20	0.2284	0.2440	-
h	0.25	0.50	0.0099	0.0196	5
L	0.40	1.27	0.016	0.050	6
N	8		8		7
μ	0°	8°	0°	8°	-

Notes:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E" does not include interlead flash or protrusions. Inter-lead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width "B", as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

Product Characteristics

Lead Plating	Matte Tin
Lead Material	Copper Alloy
Lead Coplanarity	0.004 inches (0.102mm)
Substitute Material	Silicon
Body Material	Molded Epoxy
Flammability	UL 94 V-0

Part Numbering System

SP 721 ** **

- TVS Diode Arrays (SPA® Diodes)
- Series
- Package
  - AB = 8 Ld SOIC
  - AP = 8 Ld PDIP
- G = Green
- P = Lead Free
- TG= Tape and Reel

Ordering Information

Part Number	Temp. Range (°C)	Package	Environmental Informaton	Marking	Min. Order
SP721APP	-40 to 105	8 Ld PDIP	Lead-free	SP721AP(P)[1]	2000
SP721ABG	-40 to 105	8 Ld SOIC	Green	SP721A(B)G[2]	1960
SP721ABTG	-40 to 105	8 Ld SOIC Tape and Reel	Green	SP721A(B)G[2]	2500

Notes:

1. SP721AP(P) means device marking either SP721AP or SP721APP.
2. SP721A(B)G means device marking either SP721AG or SP721ABG which are good for types SP721ABG and SP721ABTG.

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Revised: 02/23/17

Innovative Service Around the Globe **YAGEO**

DATA SHEET

THICK FILM CHIP RESISTORS

Introduction

Product Specification – Mar 25, 2008 V.7

YAGEO
Phycomp

INTRODUCTION

Data in data sheets is presented - whenever possible -according to a 'format', in which the following chapters are stated:

- TITLE
- SCOPE
- APPLICATION
- FEATURES
- ORDERING INFORMATION
- MARKING
- CONSTRUCTION
- DIMENSIONS
- ELECTRICAL CHARACTERISTICS
- PACKING STYLE AND PACKAGING QUANTITY
- FUNCTIONAL DESCRIPTION
- TESTS AND REQUIREMENTS

The chapters listed above are explained in this section *"Introduction Thick Film Chip Resistors"*, with detailed information in the relevant data sheet. Chapters *"Mounting"*, *"Packing"*, and *"Marking"* are detailed in separate sections.

DESCRIPTION

All thick film types of chip resistors have a rectangular ceramic body. The resistive element is a metal glaze film. The chips have been trimmed to the required ohmic resistance by cutting one or more grooves in the resistive layer. This process is completely computer controlled and yields a high reliability. The terminations are attached using either a silver dipping method or by applying nickel terminations, which are covered with a protective epoxy coat, finally the two external terminations (matte tin on Ni-barrier) are added.

The resistive layer is coated with a colored protective layer. This protective layer provides electrical, mechanical and/or environmental protection - also against soldering flux and cleaning solvents, in accordance with *"MIL-STD-202G"*, method 215 and *"IEC 60115-4.29"*. Yageo thick film chip resistor is flameproof and can meet *"UL94V-0"*.

ORDERING INFORMATION - 12NC & GLOBAL CLEAR TEXT CODE

Resistors are ordered in two ways. Both ways give logistic and packing information.

- CTC: This unique number is an easily-readable code. Global part number is preferred.
  - 15 digits code (PHYCOMP CTC): Phycomp branded products
  - 14~18 digits code (Global part number): Yageo/Phycomp branded products
- 12NC: In general,the tolerance,packing and resistance code are integral parts of this number.
  - Phycomp branded product

Further informations will be mentioned in the relevant data sheet.

FUNCTIONAL DESCRIPTION

The functional description includes: nominal resistance range and tolerance, limiting voltage, temperature coefficient, absolute maximum dissipation, climatic category and stability.

The limiting voltage (DC or RMS) is the maximum voltage that may be continuously applied to the resistor element, see *"IEC publications 60115-8"*.

The laws of heat conduction, convection and radiation determine the temperature rise in a resistor owing to power dissipation. The maximum body temperature usually occurs in the middle of the resistor and is called the hot-spot temperature.

In the normal operating temperature range of chip resistors the temperature rise at the hot-spot, .T, is proportional to the power dissipated: $\Delta T = A \times P$.

The proportionally constant 'A' gives the temperature rise per Watt of dissipated power and can be interpreted as a thermal resistance in K/W. This thermal resistance is dependent on the heat conductivity of the materials used (including the PCB), the way of mounting and the dimensions of the resistor. The sum of the temperature rise and the ambient temperature is:

$$T_m = T_{amb} + \Delta T$$

where:

T_m = hot-spot temperature

T_{amb} = ambient temperature

ΔT = temperature rise at hot-spot.

The stability of a chip resistor during endurance tests is mainly determined by the hot-spot temperature and the resistive materials used.

SUMMARIZING

Description	Relationship
Dimensions, conductance of materials and mounting determine	heat resistance
Heat resistance × dissipation gives	temperature rise
Temperature rise + ambient temperature give	hot-spot temperature

PERFORMANCE

When specifying the performance of a resistor, the dissipation is given as a function of the hot-spot temperature, with the ambient temperature as a parameter.

From $\Delta T = A \times P$ and $T_m = T_{amb} + \Delta T$ it follows that:

$$P = \frac{T_m - T_{amb}}{A}$$

If P is plotted against Tm for a constant value of A, parallel straight lines are obtained for different values of the ambient temperature. The slope of these lines,

$$\frac{dP}{dT_m} = \frac{1}{A}$$

is the reciprocal of the heat resistance and is the characteristic for the resistor and its environment.

THE TEMPERATURE COEFFICIENT

The temperature coefficient of resistance is a ratio which indicates the rate of increase (decrease) of resistance per degree (°C) increase (decrease) of temperature within a specified range, and is expressed in parts per million per °C (ppm/°C).

EXAMPLE

If the temperature coefficient of a resistor of R_{nom} = 1 kΩ between –55 °C and +155 °C is ±200 ppm/°C, its resistance will be:

at 25 °C:
1,000 Ω (nominal = rated value)

at +155 °C:
1,000 Ω ±(130 × 200 ppm/°C) × 1,000 Ω
= 1,026 Ω or 974 Ω

at –55 °C:
1,000 Ω ±(80 × 200 ppm/°C) × 1,000 Ω
= 1,016 Ω or 984 Ω

If the temperature coefficient is specified as ≤200 ppm/°C the resistance will be within the shaded area as shown in Fig. 1.

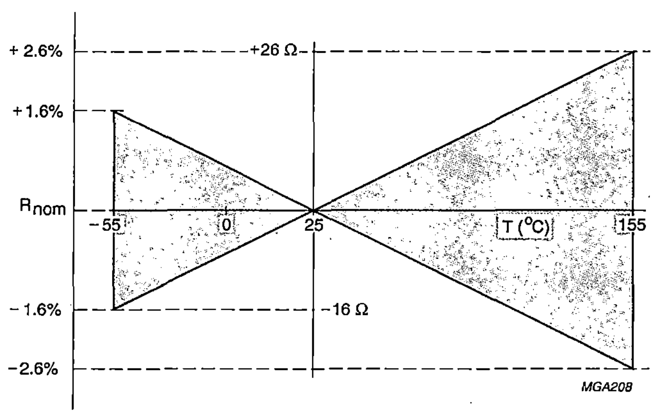


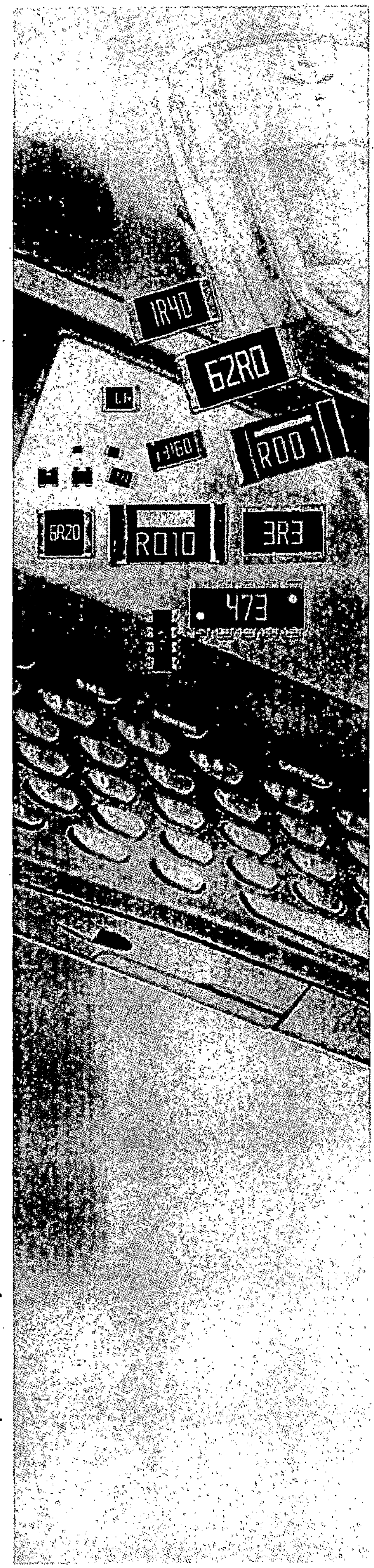
Fig. 1 Temperature coefficient.

Innovative Service Around the Globe **YAGEO**

DATA SHEET

CHIP RESISTORS

Marking



Product Specification – June 01, 2011 V.2

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MARKING

RESISTANCE CODE

Wherever it is possible, chip resistors are provided with a resistance code.

The resistance code includes the first two or three significant digits of the resistance value (Ω) followed by the number of zeros; see Table 1.

Whether two or three significant values are represented depends on the tolerance:

- ±5% requires two digits (E24 series)
  - For example: 244 = 24 × 10^4 = 240,000 = 240 kΩ
- ±1% and lower requires three digits (E24/E96 series)
  - For example: 3160 = 316 × 10^0 = 316 Ω

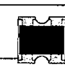
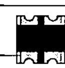
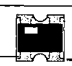
Table 1 Resistance value indication

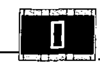
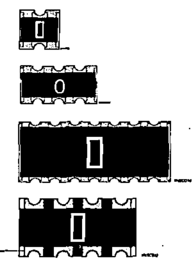
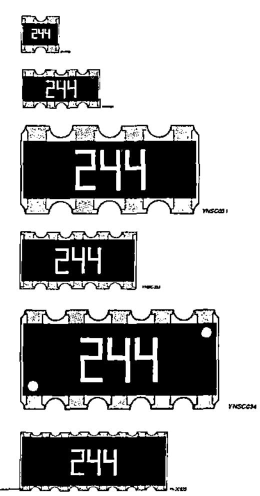
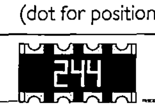
Indicator	Tol. ≥ 5%	Tol. ≤ 1%
R [1]	0.001 to 9.1 Ω	0.001 to 97.6 Ω
0	10 to 91 Ω	100 to 976 Ω
1	100 to 910 Ω	1 to 9.76 kΩ
2	1 to 9.1 kΩ	10 to 97.6 kΩ
3	10 to 91 kΩ	100 to 976 kΩ
4	100 to 910 kΩ	1 to 9.76 MΩ
5	1 to 9.1 MΩ	10 to 97.6 MΩ
6	10 to 91 MΩ	–

NOTE

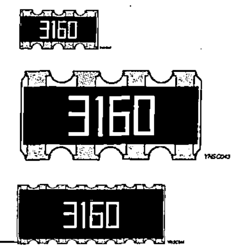
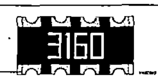
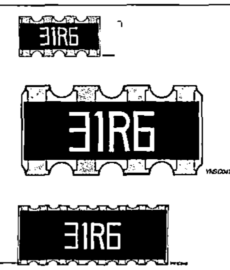
1. R denotes the decimal point.

GENERAL PRINCIPLES AND ILLUSTRATORS OF MARKING CODES

KINDS	FORMS	PRODUCT TYPES	RESISTANCE RANGE	ILLUSTRATORS & EXAMPLES
No marking	–	Sizes 0100/0201/0402 of all series	All	
		All sizes of TR series	All	 Fig. 1 No marking
		Size 0603 of RL series	R < 100 mΩ except 10/20/30/40/50/60 mΩ	
		YC102/122	All	 Fig. 2 No marking
		TC122	All	 Fig. 3 No marking
		TC124	All	 Fig. 4 No marking
		ATV321	All	 Fig. 5 No marking (rectangle for position)
		Speciality	Out of standard resistance value	Based on type

KINDS	FORMS	PRODUCT TYPES	RESISTANCE RANGE	ILLUSTRATORS & EXAMPLES
1-Digit marking	0	All sizes of RC/AF/AC series except wide termination	Jumper = 0 Ω	 **Fig. 6** Value = 0 Ω
		Size 1218 of RC/AC series	Jumper = 0 Ω	 **Fig. 7** Value = 0 Ω
		YC162 YC124/164 YC248 TC164	Jumper = 0 Ω	 **Fig. 8** Value = 0 Ω
3-Digit marking	XXX	Size 0603 to 2512 of RC/RV/AC series Size 0603 to 1206 of AR/AF/RE series Size 0805 to 2512 of SR series except wide termination	5% E24: R ≥ 10 Ω	 **Fig. 9** $240 = 24 \times 10^0 = 24\ \Omega$
		Size 1218 of RC/AC/SR series	5% E24: R ≥ 10 Ω	 **Fig. 10** $240 = 24 \times 10^0 = 24\ \Omega$
		YC162 YC124/164 YC324 YC158 YC358 YC248	5% E24: R ≥ 10 Ω	 **Fig. 11** $244 = 24 \times 10^4 = 240\ K\Omega$ (dot for position)
		TC164	5% E24: R ≥ 10 Ω	 **Fig. 12** $244 = 24 \times 10^4 = 240\ K\Omega$

KINDS	FORMS	PRODUCT TYPES	RESISTANCE RANGE	ILLUSTRATORS & EXAMPLES
3-Digit marking	**X<u>X</u>X** with short bar below	Size 0603 of RC/RE series	1%, 0.5% E24	 Fig. 13 240 = 24 × 10^0 = 24 Ω
		Size 0603 of AR/AF/AC series	1% E24	
		Size 0603 of RT/RJ	1%, 0.5%, 0.25%, 0.1%, 0.05% E24 exception values 10/11/13/15/20/75 of E24 series	
	XXX formed with 2 numerals + 1 letter	Size 0603 of RC/RE series	1%, 0.5% E96	 Fig. 14 88A = 806 × 10^0 = 806 Ω
		Size 0603 of AR/AF/AC series	1% E96	
		Size 0603 of RT/RJ	1%, 0.5%, 0.25%, 0.1%, 0.05% E96 including values 10/11/13/15/20/75 of E24 series	
	XRX	Size 0603 to 2512 of RC/AC series Size 0603 to 1206 of AR/AF series Size 0805 to 2512 of SR series except wide termination	5% E24: R < 10 Ω	 Fig. 15 2R2 = 2.2 Ω
		Size 1218 of RC/AC/SR series	5% E24: R < 10 Ω	 Fig. 16 2R2 = 2.2 Ω
	RXX	Size 0603 of RL series	5%, 1%: R = 10/20/30/40/50/60 mΩ 5%, 1% E24: R ≥ 100 mΩ, reference to Table 3	 Fig. 17 R22 = 220 mΩ
		Size 0603 of RT series	5%, 1% E24: R ≥ 100mΩ, reference to Table 3	
	$\overline{\text{XmX}}$ with top bar	PR series	1.5 mΩ	 Fig. 18 1m5 = 0.0015 Ω = 1.5 mΩ

KINDS	FORMS	PRODUCT TYPES	RESISTANCE RANGE	ILLUSTRATORS & EXAMPLES
4-Digit marking	**XXXX**	Size 0805 to 2512 of RC/RV/AC series Size 0805 to 1206 of AR/AF/RE series except wide termination	1% E24/E96: R ≥ 100 Ω	 Fig. 19 1002 = 100 × 10^2 = 10 KΩ
		Size 0805 to 2512 of RT/RJ series	1%, 0.5%, 0.25%, 0.1% E24/E96: R ≥ 100 Ω	
		Size 1218 of RC/AC series	1% E24/E96: R ≥ 100 Ω	 Fig. 20 1002 = 100 × 10^2 = 10 KΩ
		YC124/164 YC248 YC324	1% E24/E96: R ≥ 100 Ω	 Fig. 21 3160 = 316 × 10^0 = 316 Ω
		TC164	1% E24/E96: R ≥ 100 Ω	 Fig. 22 3160 = 316 × 10^0 = 316 Ω
	XRXX, XXRX	Size 0805 to 2512 of RC/AC series Size 0805 to 1206 of AR/AF/RE series except wide termination	1% E24/E96: R < 100 Ω	 Fig. 23 31R6 = 31.6 Ω
		Size 0805 to 2512 of RT/RJ series	1%, 0.5%, 0.25%, 0.1% E24/E96: R < 100 Ω	
		Size 1218 of RC/AC series	1% E24/E96: R < 100 Ω	 Fig. 24 31R6 = 31.6 Ω
		YC124/164 YC248 YC324	1% E24/E96: R < 100 Ω	 Fig. 25 31R6 = 31.6 Ω
		TC164	1% E24/E96: R < 100 Ω	 Fig. 26 31R6 = 31.6 Ω

KINDS	FORMS	PRODUCT TYPES	RESISTANCE RANGE	ILLUSTRATORS & EXAMPLES
4-Digit marking	RXXX	Size 0805 to 2512 of RL series except wide termination	5%, 1% E24, reference to Table 4	 Fig. 27 R020 = 0.02 Ω = 20 mΩ
		All sizes of PF series	20 mΩ/25 mΩ/50 mΩ	
		Size 0805 to 2512 of PT series except wide termination	5%, 1% E24: R ≥ 100mΩ, reference to Table 4	 Fig. 28 R220 = 220 mΩ
		Size 1218 of RL series Size 0815 of PT series	5%, 1% E24, reference to Table 4	 Fig. 29 R025 = 25 mΩ
	RXXX with top bar	All sizes of PR series All sizes of PF series	1/2/3/4/5 mΩ 6/7/10 mΩ	 Fig. 30 R001 = 0.001 Ω = 1 mΩ

NOTE

1. Please contact with local sales force for unavailable resistance

Table 2 EIA-96 marking rule

CODE	VALUE	CODE	VALUE	CODE	VALUE	CODE	VALUE	CODE	VALUE	CODE	VALUE	CODE	VALUE	CODE	VALUE
01	100	13	133	25	178	37	237	49	316	61	422	73	562	85	750
02	102	14	137	26	182	38	243	50	324	62	432	74	576	86	768
03	105	15	140	27	187	39	249	51	332	63	442	75	590	87	787
04	107	16	143	28	191	40	255	52	340	64	453	76	604	88	806
05	110	17	147	29	196	41	261	53	348	65	464	77	619	89	825
06	113	18	150	30	200	42	267	54	357	66	475	78	634	90	845
07	115	19	154	31	205	43	274	55	365	67	487	79	649	91	866
08	118	20	158	32	210	44	280	56	374	68	499	80	665	92	887
09	121	21	162	33	215	45	287	57	383	69	511	81	681	93	909
10	124	22	165	34	221	46	294	58	392	70	523	82	698	94	931
11	127	23	169	35	226	47	301	59	402	71	536	83	715	95	953
12	130	24	174	36	232	48	309	60	412	72	549	84	732	96	976

Table 2. shows the first two digits of the three-digit EIA-96 part-marking scheme.
The third character is a letter multiplier:

$X = 10^{-1}$, $Y = 10^{-2}$, $A = 10^{0}$, $B = 10^{1}$, $C = 10^{2}$, $D = 10^{3}$, $E = 10^{4}$, $F = 10^{5}$

Table 3 EIA-24 marking rule for size 0603 of RL/PT

CODE	VALUE (mΩ)
R01	10
R02	20
No marking	25 (2)
R03	30
R04	40 (2)
R05	50 (2)
R06	60 (2)
R10	100
R11	110
R12	120
R13	130
R15	150
R16	160
R18	180
R20	200
R22	220
R24	240
R25	250 (2)
R27	270
R30	300
R33	330
R36	360
R39	390
R40	400 (2)
R43	430
R47	470
R50	500 (2)
R51	510
R56	560
R62	620
R68	680
R75	750
R82	820
R91	910

NOTE

1. All above values for E24 series are marked with a 3-digit code (RXX).
2. The partial values of 25/40/50/60/250/400/500 mΩ are belonged to non-E series.
3. Except customer special requirement, values for E96 series are no marking
4. 5% and 1% follow the same marking rules.

Table 4 EIA-24 marking rule for size 0805 to 2512 of RL/PT

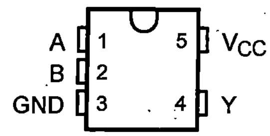
CODE	VALUE (mΩ)	CODE	VALUE (mΩ)
R010	10	R110	110
R011	11	R120	120
R012	12	R125	125 (2)
R013	13	R130	130
R015	15	R150	150
R016	16	R160	160
R018	18	R180	180
R020	20	R200	200
R022	22	R220	220
R024	24	R240	240
R025	25 (2)	R249	249 (3)
R027	27	R250	250 (2)
R030	30	R255	255 (3)
R033	33	R270	270
R036	36	R300	300
R039	39	R330	330
R040	40 (2)	R360	360
R043	43	R390	390
R047	47	R400	400 (2)
R050	50 (2)	R430	430
R051	51	R470	470
R056	56	R500	500 (2)
R060	60 (2)	R510	510
R062	62	R560	560
R068	68	R620	620
R075	75	R680	680
R082	82	R750	750
R091	91	R820	820
R100	100	R910	910

NOTE

1. All above values for E24 series are marked with a 4-digit code (RXXX).
2. The partial values of 25/40/50/60/125/250/400/500 mΩ are belonged to non-E series.
3. Except customer special requirement, values for E96 series are no marking.
4. 5% and 1% follow the same marking rules.

- **Qualified for Automotive Applications**
- **Operating Range of 2 V to 5.5 V**
- **Max t_{pd} of 9 ns at 5 V**
- **Low Power Consumption, 20-μA Max I_{CC}**
- **±8-mA Output Drive at 5 V**
- **Schmitt Trigger Action at All Inputs Makes the Circuit Tolerant for Slower Input Rise and Fall Time**
- **ESD Protection Level Per AEC-Q100 Classification**
  - **2000-V (H2) Human-Body Model**
  - **200-V (M3) Machine Model**
  - **1000-V (C5) Charged-Device Model**

DBV OR DCK PACKAGE
(TOP VIEW)



description/ordering information

The SN74AHC1G08 is a single 2-input positive-AND gate. The device performs the Boolean function $Y = A \bullet B$ or $Y = \overline{\overline{A} + \overline{B}}$ in positive logic.

ORDERING INFORMATION†

T_A	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING§
−40°C to 85°C	SOT (SOT-23) – DBV	Reel of 3000	SN74AHC1G08IDBVRQ1	A08_
	SOT (SC-70) – DCK	Reel of 3000	SN74AHC1G08IDCKRQ1	AE_
−40°C to 125°C	SOT (SOT-23) – DBV	Reel of 3000	SN74AHC1G08QDBVRQ1	A08_
	SOT (SC-70) – DCK	Reel of 3000	SN74AHC1G08QDCKRQ1	AE_

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at http://www.ti.com.
‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.
§ The actual top-side marking has one additional character that designates the wafer fab/assembly site.

FUNCTION TABLE

INPUTS		OUTPUT
A	B	Y
H	H	H
L	X	L
X	L	L

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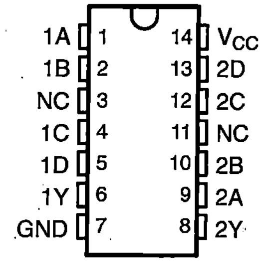
- **Qualified for Automotive Applications**
- **Wide Operating Voltage Range of 2 V to 6 V**
- **Outputs Can Drive up to Ten LSTTL Loads**
- **Low Power Consumption, 20-μA Max I_{CC}**
- **Typical t_{pd} = 11 ns**
- **±4-mA Output Drive at 5 V**
- **Low Input Current of 1 μA Max**

D OR PW PACKAGE
(TOP VIEW)



description/ordering information

This device contains two independent 4-input AND gates. It performs the Boolean function $Y = A \bullet B \bullet C \bullet D$ or $Y = \overline{A} + \overline{B} + \overline{C} + \overline{D}$ in positive logic.

ORDERING INFORMATION†

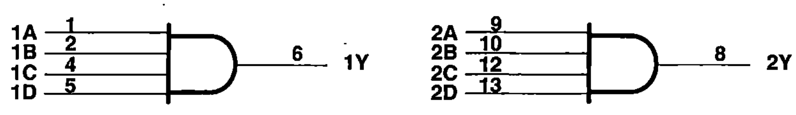
T_A	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	SOIC – D	Reel of 2500	SN74HC21QDRQ1	HC21Q
	TSSOP – PW	Reel of 2000	SN74HC21QPWRQ1	HC21Q

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at http://www.ti.com.
‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.

FUNCTION TABLE
(each gate)

INPUTS				OUTPUT
A	B	C	D	Y
H	H	H	H	H
L	X	X	X	L
X	L	X	X	L
X	X	L	X	L
X	X	X	L	L

logic diagram (positive logic)



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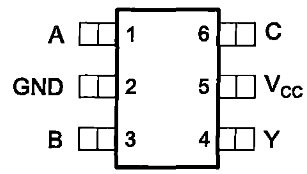
SINGLE 3-INPUT POSITIVE-AND GATE

Check for Samples: SN74LVC1G11-Q1

FEATURES

- **Qualified for Automotive Applications**
- **Supports 5-V V_{CC} Operation**
- **Inputs Accept Voltages to 5.5 V**
- **Max t_{pd} of 4.1 ns at 3.3 V**
- **Low Power Consumption, 10-μA Max I_{CC}**
- **±24-mA Output Drive at 3.3 V**
- **I_{off} Supports Partial-Power-Down Mode Operation**

DCK PACKAGE
(TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

The SN74LVC1G11-Q1 performs the Boolean function $Y = A \bullet B \bullet C$ or $Y = \overline{\overline{A} + \overline{B} + \overline{C}}$ in positive logic.

This device is fully specified for partial-power-down applications using I_{off}. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

ORDERING INFORMATION

T_A	PACKAGE(1)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	SOT (SC-70) – DCK	Reel of 3000	SN74LVC1G11IDCKRQ1	7LR

(1) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

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Single 3-Input Positive AND-OR Gate

Check for Samples: SN74LVC1G0832

FEATURES

- Available in the Texas Instruments NanoFree™ Package
- Supports 5-V V_{CC} Operation
- Inputs Accept Voltages to 5.5 V
- Provides Down Translation to V_{CC}
- Max t_{pd} of 5 ns at 3.3 V
- Low Power Consumption, 10-μA Max I_{CC}
- ±24-mA Output Drive at 3.3 V
- Input Hysteresis Allows Slow Input Transition and Better Switching Noise Immunity at the Input (V_{hys} = 250 mV Typ @ 3.3 V)
- Can Be Used in Three Combinations:
  - AND-OR Gate
  - AND Gate
  - OR Gate
- I_{off} Supports Live Insertion, Partial-Power-Down Mode, and Back-Drive Protection
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 200-V Machine Model (A115-A)
  - 1000-V Charged-Device Model (C101)

DESCRIPTION

This device is designed for 1.65-V to 5.5-V V_{CC} operation.

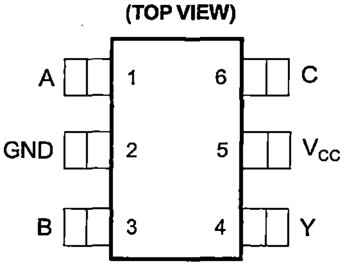
The SN74LVC1G0832 device is a single 3-input positive AND-OR gate. It performs the Boolean function Y = (A • B) + C in positive logic.

By tying one input to GND or V_{CC}, the SN74LVC1G0832 device offers two more functions. When C is tied to GND, this device performs as a 2–input AND gate (Y = A • B). When A is tied to V_{CC}, the device works as a 2–input OR gate (Y = B + C). This device also works as a 2–input OR gate when B is tied to V_{CC} (Y = A + C).

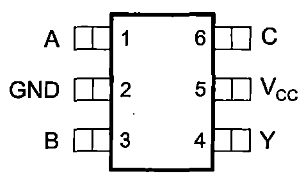
NanoFree™ package technology is a major breakthrough in IC packaging concepts, using the die as the package.

This device is fully specified for partial-power-down applications using I_{off}. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

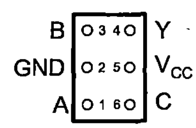
DBV PACKAGE
(TOP VIEW)



DCK PACKAGE
(TOP VIEW)



YZP PACKAGE
(BOTTOM VIEW)



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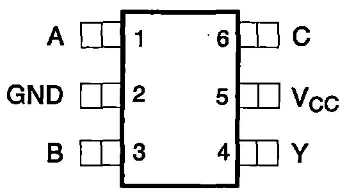
SINGLE 3-INPUT POSITIVE OR-AND GATE

Check for Samples: SN74LVC1G3208-Q1

FEATURES

- **Qualified for Automotive Applications**
- **Supports 5-V V_{CC} Operation**
- **Inputs Accept Voltages to 5.5 V**
- **Max t_{pd} of 5 ns at 3.3 V**
- **Low Power Consumption, 10-μA Max I_{CC}**
- **±24-mA Output Drive at 3.3 V**
- **Input Hysteresis Allows Slow Input Transition and Better Switching Noise Immunity at the Input (V_{hys} = 250 mV Typ at 3.3 V)**
- **Can Be Used in Three Combinations:**
  - **OR-AND Gate**
  - **OR Gate**
  - **AND Gate**
- **I_{off} Supports Partial-Power-Down Mode Operation**

DCK PACKAGE (TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

This device is designed for 1.65-V to 5.5-V V_{CC} operation.

The SN74LVC1G3208-Q1 is a single 3-input positive OR-AND gate. It performs the Boolean function $Y = (A + B) \cdot C$ in positive logic.

By tying one input to GND or V_{CC}, the SN74LVC1G3208-Q1 offers two more functions. When C is tied to V_{CC}, this device performs as a 2-input OR gate ($Y = A + B$). When A is tied to GND, the device works as a 2-input AND gate ($Y = B \cdot C$). This device also works as a 2-input AND gate when B is tied to GND ($Y = A \cdot C$).

This device is fully specified for partial-power-down applications using I_{off}. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

ORDERING INFORMATION

T_A	PACKAGE(1)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	SOT (SC-70) – DCK	Reel of 3000	CLVC1G3208IDCKRQ1	DGR

(1) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE(1)

INPUTS			OUTPUT
A	B	C	Y
H	X	H	H
X	H	H	H
X	X	L	L
L	L	H	L

(1) X = Valid H or L

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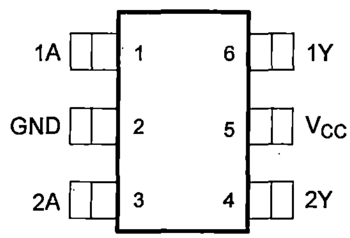
DUAL SCHMITT-TRIGGER INVERTER

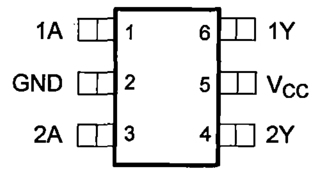
FEATURES

- **Qualified for Automotive Applications**
- **Supports 5-V V_{CC} Operation**
- **Inputs Accept Voltages to 5.5 V**
- **Max t_{pd} of 5.4 ns at 3.3 V**
- **Low Power Consumption, 10-μA Max I_{CC}**
- **±24-mA Output Drive at 3.3 V**
- **Typical V_{OLP} (Output Ground Bounce) <0.8 V at V_{CC} = 3.3 V, T_A = 25°C**
- **Typical V_{OHV} (Output V_{OH} Undershoot) >2 V at V_{CC} = 3.3 V, T_A = 25°C**
- **I_{off} Feature Supports Partial-Power-Down Mode Operation**
- **Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II**
- **ESD Protection Exceeds JESD 22**
  - **2000-V Human-Body Model (A114-A)**
  - **1000-V Charged-Device Model (C101)**

DBV PACKAGE
(TOP VIEW)



DCK PACKAGE
(TOP VIEW)



See mechanical drawings for dimensions.

DESCRIPTION/ORDERING INFORMATION

This dual Schmitt-trigger inverter is designed for 1.65-V to 5.5-V V_{CC} operation.

The SN74LVC2G14 contains two inverters and performs the Boolean function $Y = \overline{A}$. The device functions as two independent inverters, but because of Schmitt action, it may have different input threshold levels for positive-going (V_{T+}) and negative-going (V_{T-}) signals.

This device is fully specified for partial-power-down applications using I_{off}. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

ORDERING INFORMATION(1)

T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING(3)
–40°C to 85°C	SOT (SOT-23) – DBV	Tape and reel	SN74LVC2G14IDBVRQ1	C14_
	SOT (SC-70) – DCK	Tape and reel	SN74LVC2G14IDCKRQ1	CF_

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.
(3) DBV/DCK: The actual top-side marking has one additional character that designates the wafer fab/assembly site.

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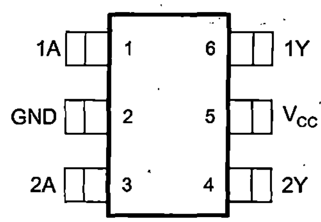
DUAL SCHMITT-TRIGGER BUFFER

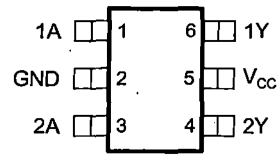
FEATURES

- **Qualified for Automotive Applications**
- **Supports 5-V V_{CC} Operation**
- **Inputs Accept Voltages to 5.5 V**
- **Max t_{pd} of 5.4 ns at 3.3 V**
- **Low Power Consumption, 10-μA Max I_{CC}**
- **±24-mA Output Drive at 3.3 V**
- **Typical V_{OLP} (Output Ground Bounce) <0.8 V at V_{CC} = 3.3 V, T_A = 25°C**
- **Typical V_{OHV} (Output V_{OH} Undershoot) >2 V at V_{CC} = 3.3 V, T_A = 25°C**
- **I_{off} Supports Partial-Power-Down Mode Operation**
- **Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II**
- **ESD Protection Exceeds JESD 22**
  - **2000-V Human-Body Model (A114-A)**
  - **1000-V Charged-Device Model (C101)**

DBV PACKAGE (TOP VIEW)



DCK PACKAGE (TOP VIEW)



See mechanical drawings for dimensions.

DESCRIPTION/ORDERING INFORMATION

This dual Schmitt-trigger buffer is designed for 1.65-V to 5.5-V V_{CC} operation.

The SN74LVC2G17 contains two buffers and performs the Boolean function Y = A. The device functions as two independent buffers, but because of Schmitt action, it may have different input threshold levels for positive-going (V_{T+}) and negative-going (V_{T-}) signals.

This device is fully specified for partial-power-down applications using I_{off}. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

ORDERING INFORMATION(1)

T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING(3)
–40°C to 125°C	SOT (SOT-23) – DBV	Reel of 3000	SN74LVC2G17QDBVRQ1	C17_
	SOT (SC-70) – DCK	Reel of 3000	SN74LVC2G17QDCKRQ1	C7_

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.
(3) DBV/DCK: The actual top-side marking has one additional character that designates the wafer fab/assembly site. Pin 1 identifier indicates solder-bump composition (1 = SnPb, • = Pb-free).

FUNCTION TABLE (EACH INVERTER)

INPUT A	OUTPUT Y
H	H
L	L

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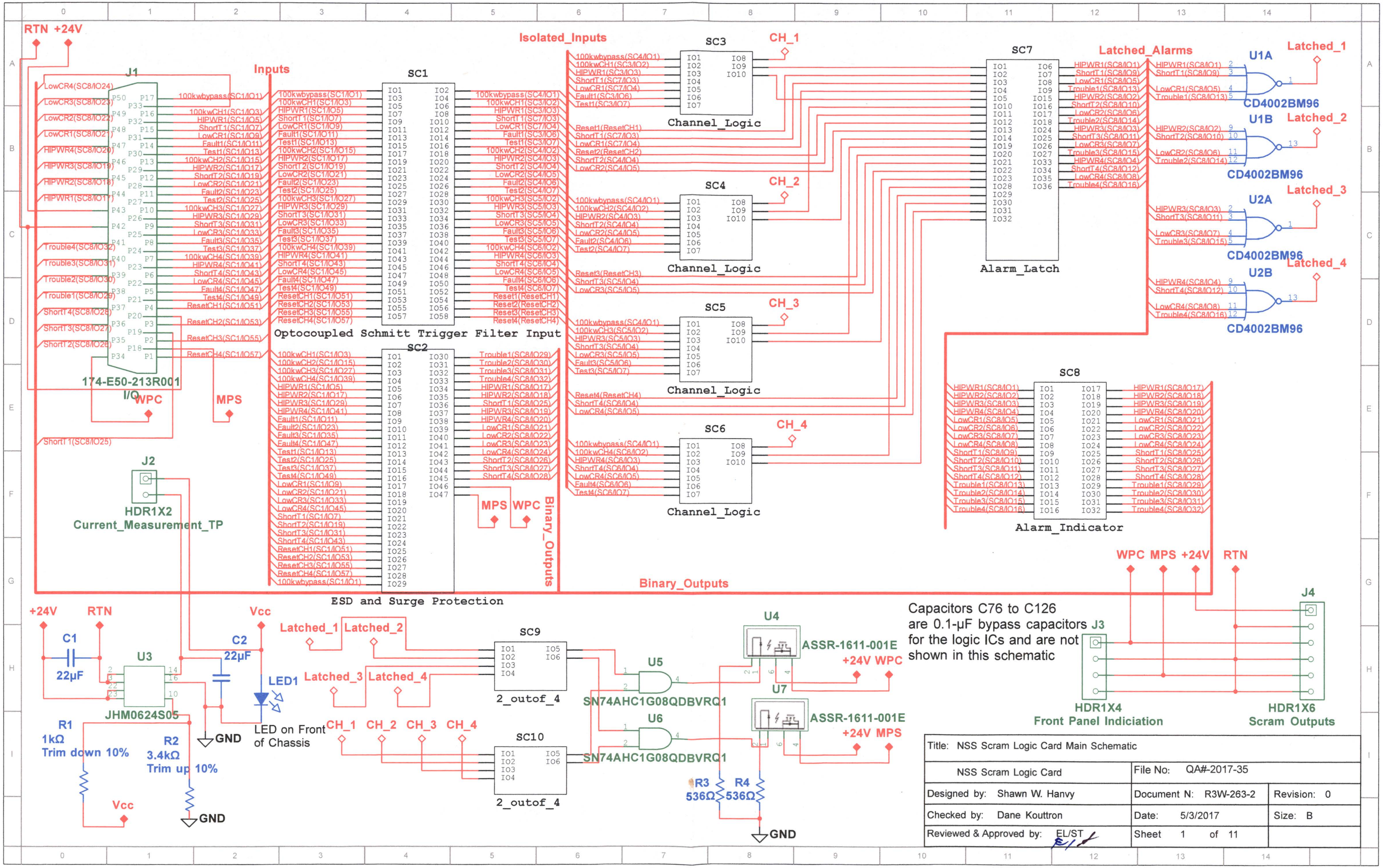
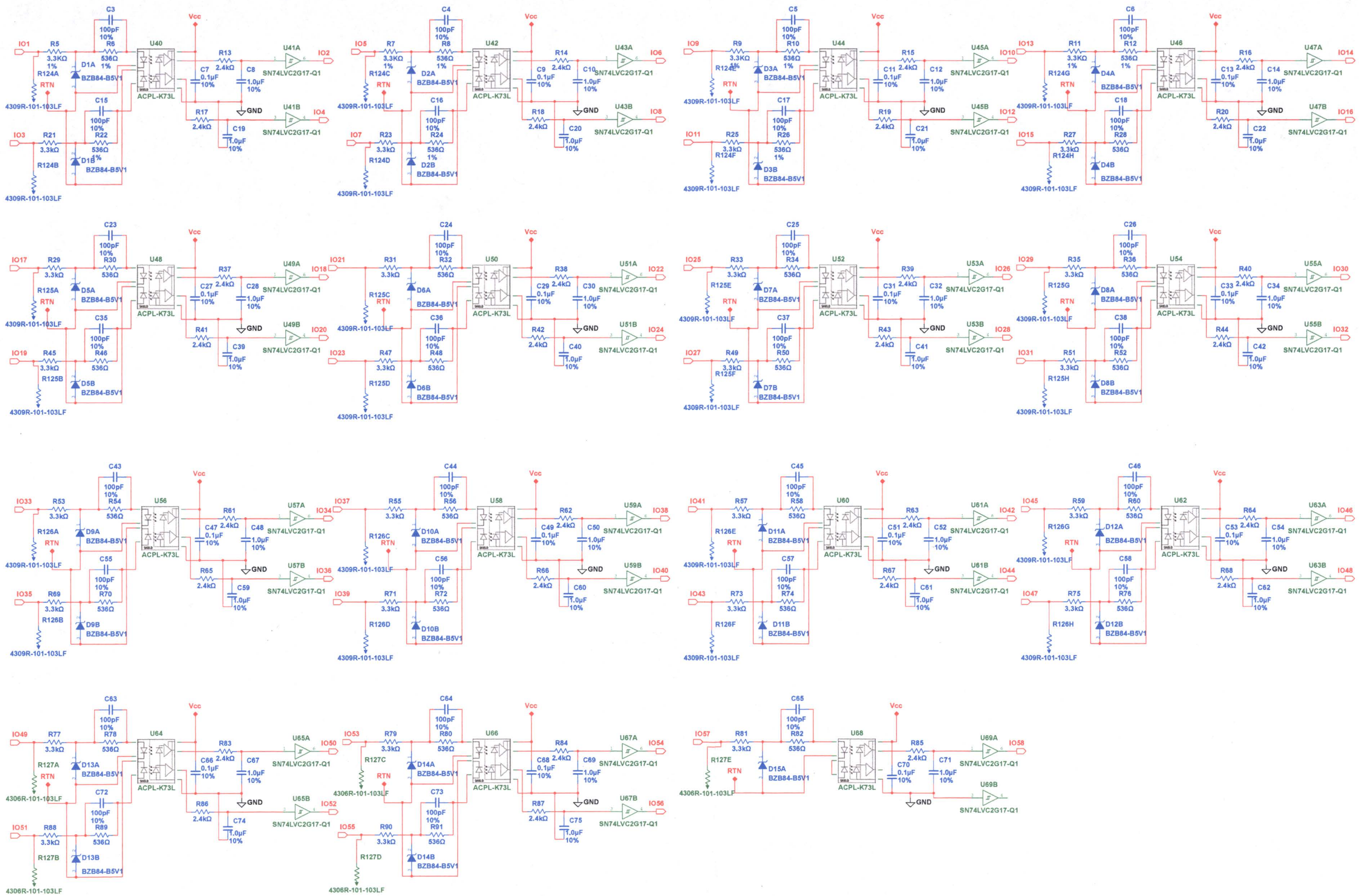
Drawings and Schematics

NSS Scram Logic Card Modules

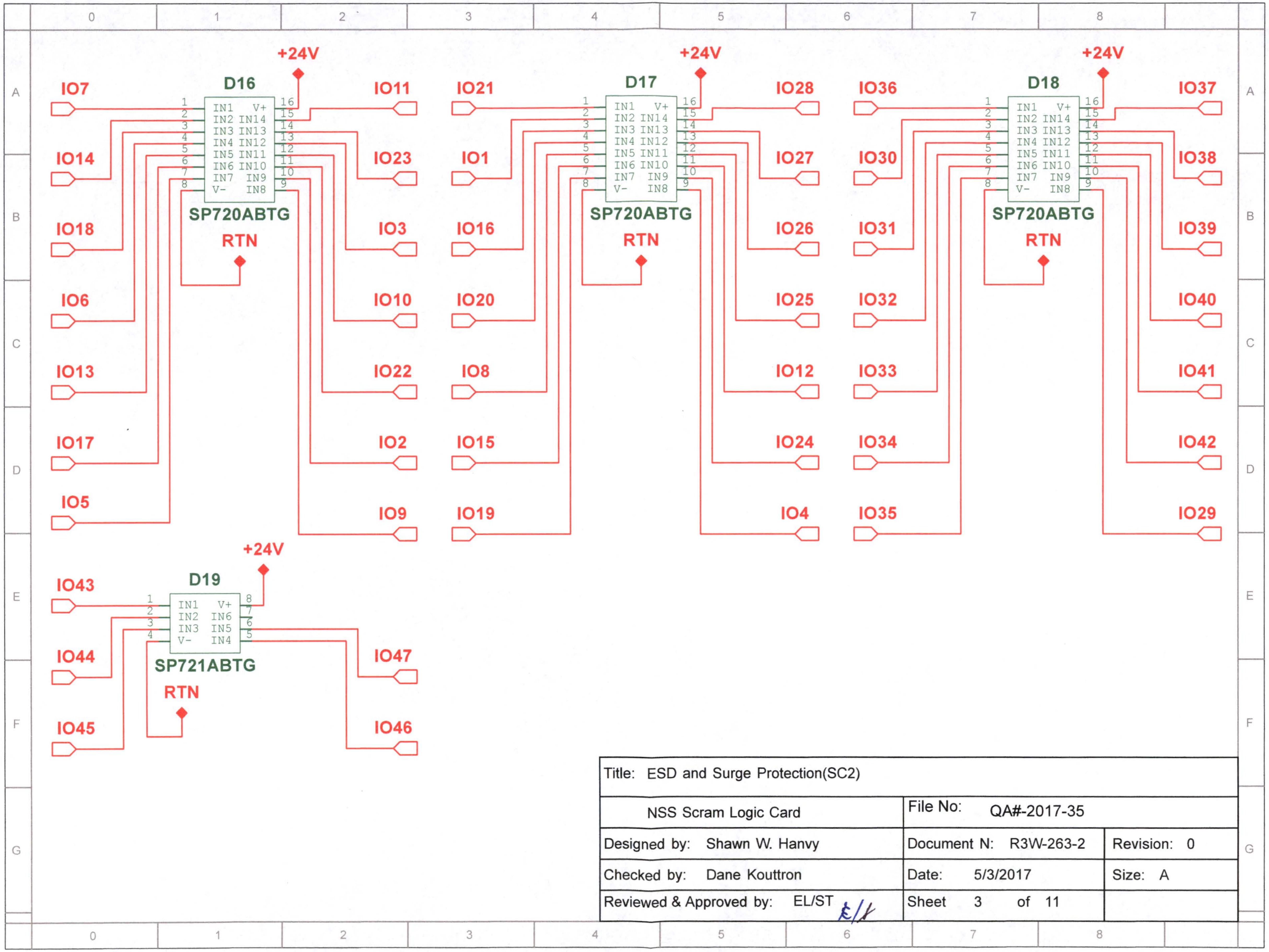
Drawing number R3W-263-2 is the schematic for the Scram Logic Card and is comprised of eleven sheets. The first sheet is the main circuit diagram, which contains ten sub-circuits (SC1-SC10). Each sub-circuit schematic is laid out on the remaining pages. Images of the completed Nuclear Safety System (NSS) Scram Logic Cards mounted in single-width (1U) NIM modules are shown on Figure 2 and Figure 3 in the system description portion of the safety review document. The Gerber file for the printed circuit board design is depicted in Figure 4. The final physical location of the two Scram Logic Card Modules in the reactor control room is detailed in the New Nuclear Safety System Installation Plan.



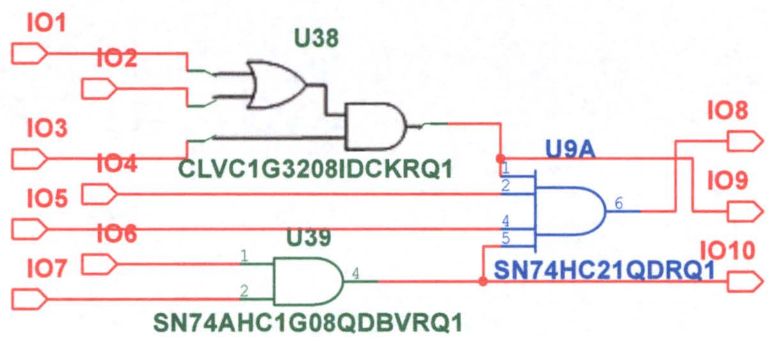
RTN +24V
Inputs
Isolated_Inputs
Latched_Alarms
J1
174-E50-213R001
I/O
WPC
MPS
SC1
Optocoupled Schmitt Trigger Filter Input
SC2
ESD and Surge Protection
Binary_Outputs
SC3
Channel_Logic
CH_1
SC4
Channel_Logic
CH_2
SC5
Channel_Logic
CH_3
SC6
Channel_Logic
CH_4
SC7
Alarm_Latch
SC8
Alarm_Indicator
U1A
U1B
U2A
U2B
CD4002BM96
Latched_1
Latched_2
Latched_3
Latched_4
J2
HDR1X2
Current_Measurement_TP
+24V
RTN
C1
22µF
U3
JHM0624S05
C2
22µF
Vcc
LED1
LED on Front of Chassis
GND
R1
1kΩ
Trim down 10%
R2
3.4kΩ
Trim up 10%
SC9
2_outof_4
SC10
2_outof_4
U5
U6
SN74AHC1G08QDBVRQ1
U4
U7
ASSR-1611-001E
+24V WPC
+24V MPS
R3
536Ω
R4
536Ω
Capacitors C76 to C126 are 0.1-µF bypass capacitors for the logic ICs and are not shown in this schematic
J3
HDR1X4
Front Panel Indiciation
J4
HDR1X6
Scram Outputs
WPC MPS +24V RTN
Title: NSS Scram Logic Card Main Schematic
NSS Scram Logic Card
File No: QA#-2017-35
Designed by: Shawn W. Hanvy
Document N: R3W-263-2
Revision: 0
Checked by: Dane Kouttron
Date: 5/3/2017
Size: B
Reviewed & Approved by: EL/ST
Sheet 1 of 11



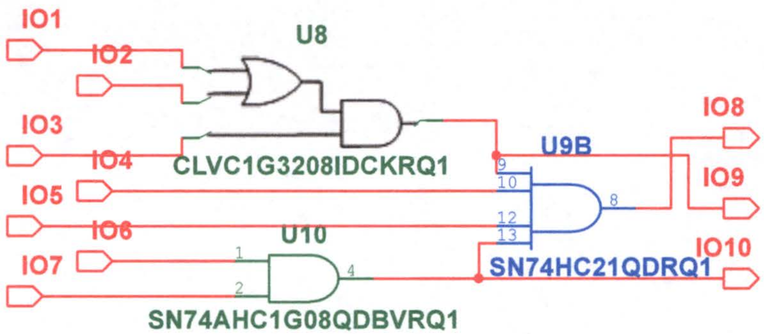
Title: Optocoupled Schmitt Trigger Filter Input (SC1)			
NSS Scram Logic Card	File No: QA#-2017-35		
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0	
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A1	
Reviewed & Approved by: EL/ST	Sheet 2 of 11		



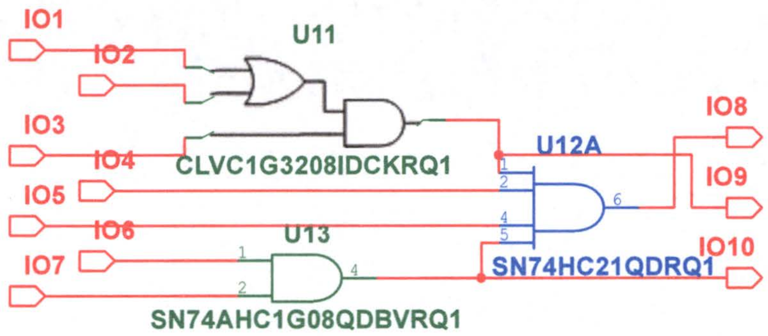
Title: ESD and Surge Protection(SC2)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST E/	Sheet 3 of 11	



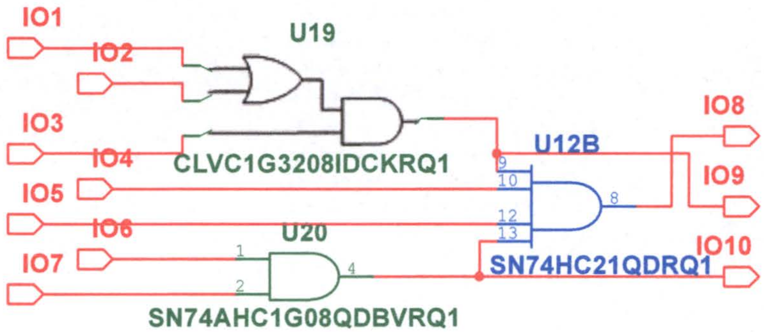
Title: Channel Logic (SC3)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST EH	Sheet 4 of 11	



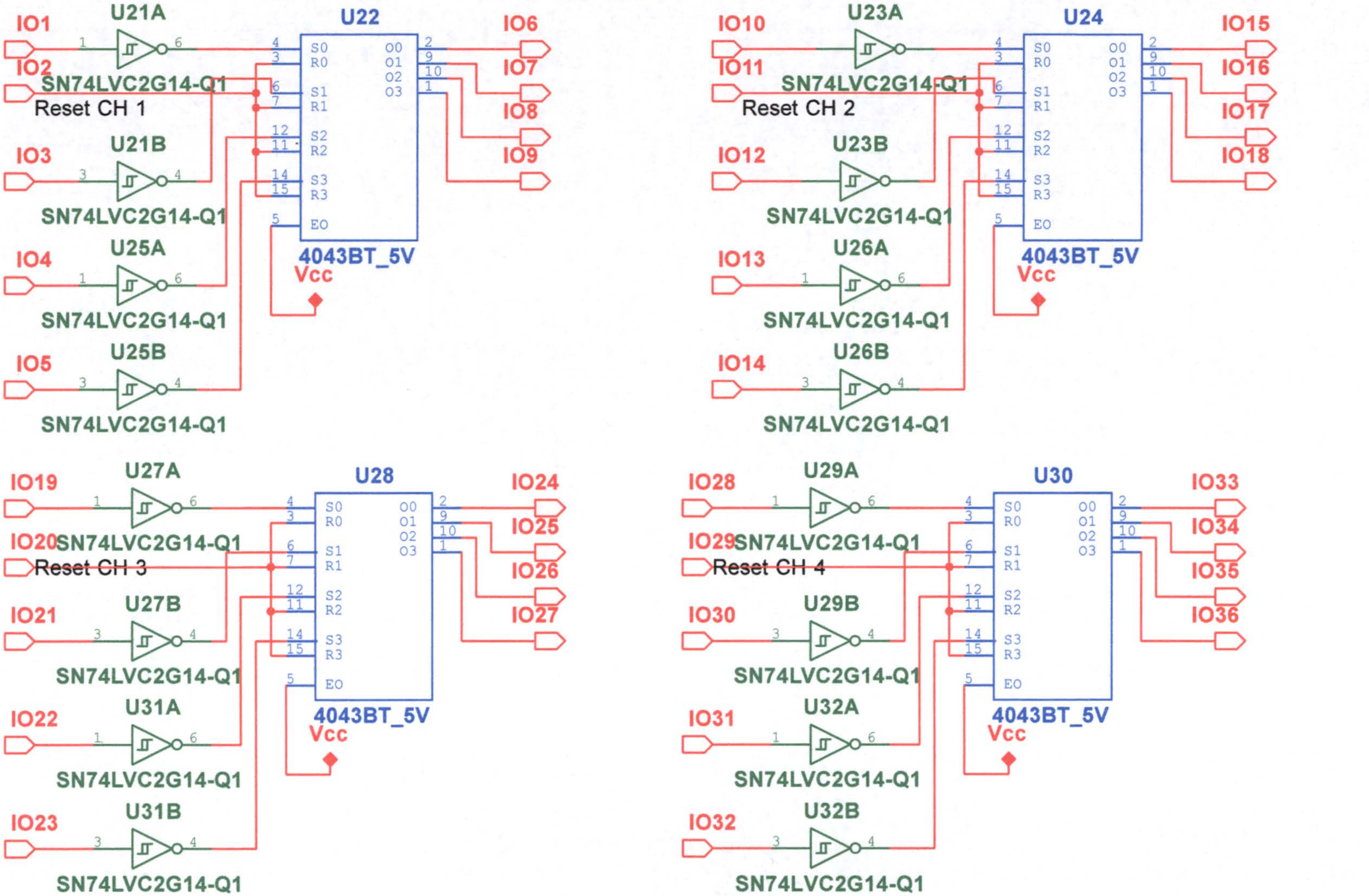
Title: Channel Logic (SC4)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 5 of 11	



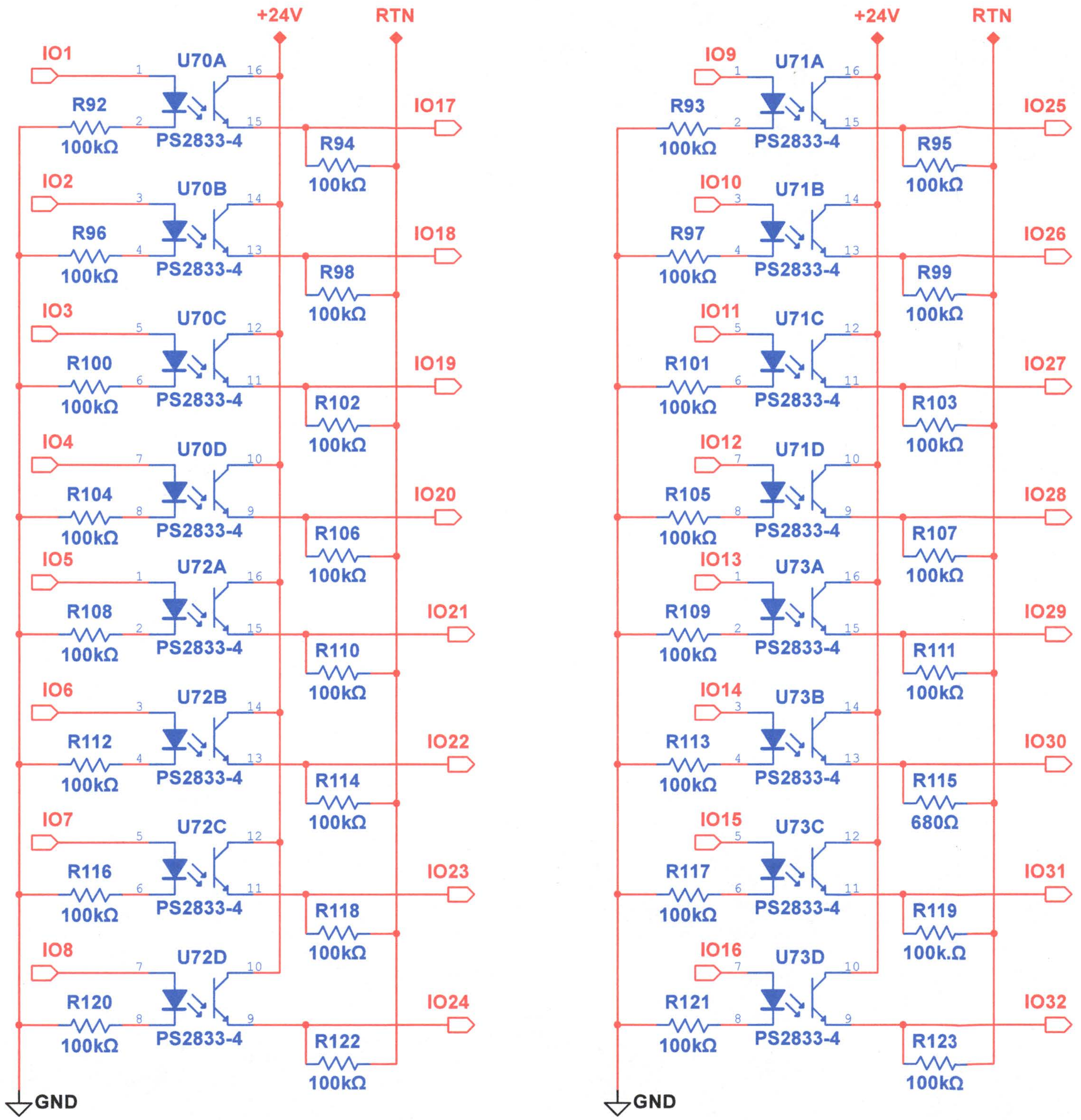
Title: Channel Logic (SC5)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 6 of 11	



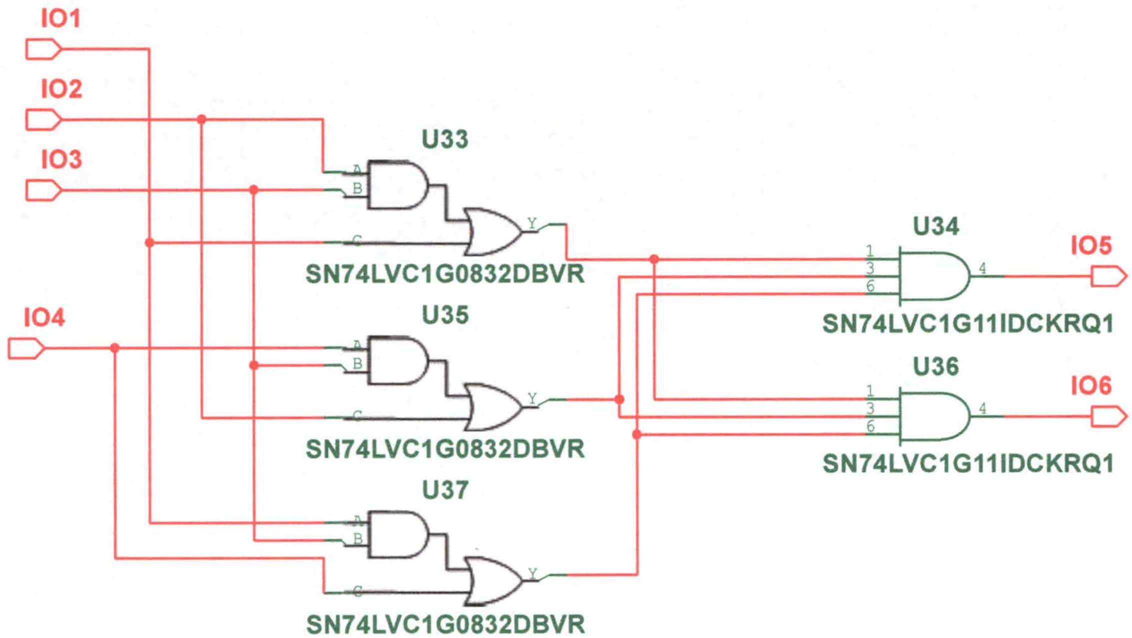
Title: Channel Logic (SC6)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 7 of 11	



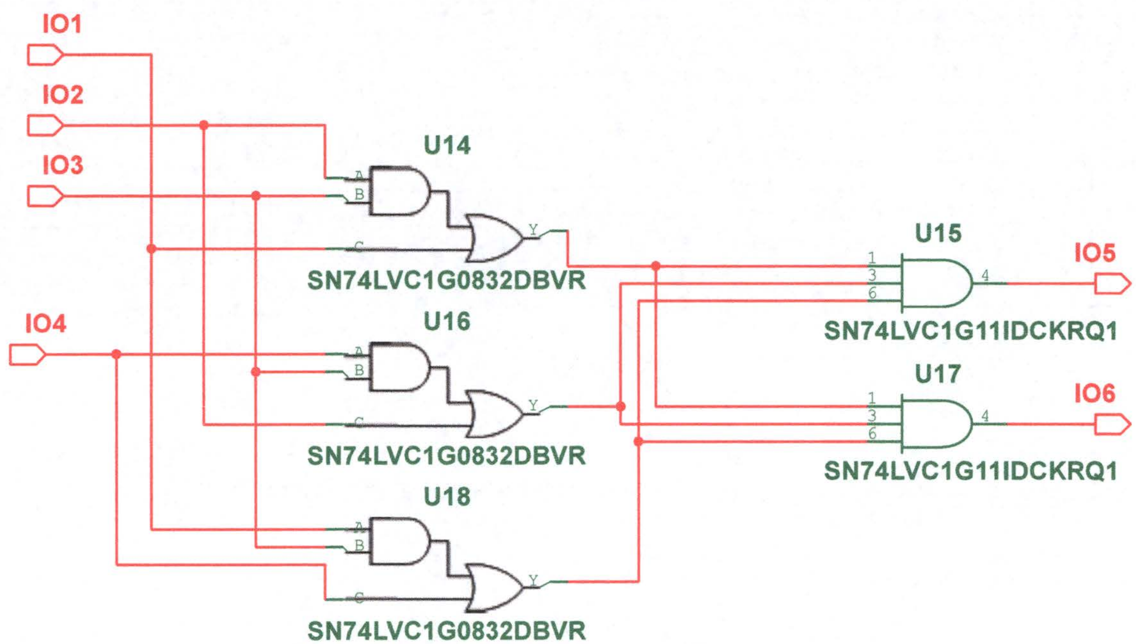
Title: Alarm Latch (SC7)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 8 of 11	



Title: Alarm Indicator (SC8)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: B
Reviewed & Approved by: EL/ST	Sheet 9 of 11	



Title: 2 outof 4 (SC9)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 10 of 11	



Title: 2 out of 4 (SC10)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 11 of 11	

Shawn Hanvy
Instrumentation Supervisor
hanvysw@mit.edu

Mail Stop: NW12-106
138 Albany Street
Cambridge, MA 02139

Phone: 617-253-0342
Fax: 617-253-7300
Web: http://nrl.mit.edu

Fabrication

NSS Scram Logic Card Modules

The Scram Logic Cards' printed-circuit board (PCB) fabrication and component placement was performed by Advanced Circuits. The invoice for the fabrication and a memo declaring their QA standards and certifications are attached. The Bill of Materials (BOM) that Advanced Circuits used to manufacture the cards, the final as-built BOM and re-work materials are also provided.

MIT NUCLEAR REACTOR LABORATORY

AN MIT INTERDEPARTMENTAL CENTER

Shawn Hanvy
Instrumentation Supervisor
hanvysw@mit.edu

Mail Stop: Your Room Number
138 Albany Street
Cambridge, MA 02139

Phone: 617-253-0342
Fax: 617-253-7300
Web: http://nrl.mit.edu

Fabrication Compliance

Three Scram Logic Cards have been fully tested and installed in a 1U NIM chassis with LED indicating lights. The rear cover for the NIM chassis have been modified to accept the D-Sub 50 connector needed to connect the unit to the Signal Distribution Module. Two units are installed in the system, running in parallel and the third unit functions as a spare unit for a direct replacement.

3/14/2017

Shawn Hanvy

AC-Order-Confirmation-[73292]

leanne@4pcb.com
Sent: Friday, July 29, 2016 1:57 PM
To: Shawn Wesley Hanvy

Thank you for your order!
Please review your order details carefully and
call us immediately if you need to make any corrections.

Your sales representative is: Ashley Trahan (800) 979-4722 x1339
Mail To: ashley@4pcb.com

MailTo: hold@4pcb.com for corrections after 5:00 PM MT

Advanced Circuits
21101 East 32nd Parkway
Aurora CO 80011
(800) 979-4722
www.4pcb.com

PAGE: 0
AC WORK ORDER-NO: 73292
CUSTOMER-NO: 49471
SHIP-TO: 0001
ORDER-DATE: 07/29/2016

SHIP-DATE: 08/05/2016

SOLD-TO:
NRL
138 Albany St
Cambridge MA
02139 United States

SHIP-TO:
NRL
138 Albany St

Cambridge MA
02139 United States

Contact: Shawn Hanvy
Phone: 6172530342
Fax:
E-mail: hanvysw@mit.edu
FileName: RPS logicprototype V3pt5.zip

TERMS: CREDIT CARD
PartNumber: RPS Logic v3pt4
Rev:

CUST-PO: CC

SHIP-VIA: Assembly
ShippingAccount: 160736461
Type: New Order

REFERENCE-#: 0
Your Web Order Number: 1083255
Your Quote Number: 4496937

LN	ITEM-NUMBER	DESCRIPTION	QUANTITY	NET-PRICE	EXT-AMOUNT
1	104	Prototype - 4 Layer	5EA	148.18	740.90
2	55	Electrical Test	1EA	145.00	145.00
3	94	Handling	1EA	10.00	10.00
4	712	Elec.Test Disc.	1EA	-145.00	-145.00

Grand Total: 750.90

ITAR: no
Certs: IPC Class 2-A600
Electrical Test: YES
Material Type: FR4
Material Thickness: 0.062"
Unit Dimensions: 07.710 x 06.000
Array Dimensions: 08.710 x 07.000
Array Qty: 5
Tab Rout: YES
Copper Weight: 1 oz
Solder Mask Sides: Both Sides

AS9100: no
5% OVERAGE: no
Board Finish: LFSOLDER
Array Number Up: 1
Scoring: NO
Inner Copper Weight: 1.0
Solder Mask Color: GREEN

Legend Silk Scrn: Both Sides	Legd/Silk Scrn Color: WHITE
Castellated Holes: no	
Blind/Buried Vias: None	SM Plugged Via: no
Via-In-Pad: None	Microvias: None
Plated Slots: no	Plated Edges: no
CounterSinks: no	CounterBores: no
CtrSinksPlated: 0	CtrBoresPlated: 0
CtrSinksNon-Pltd: 0	CtrBoresNon-Pltd: 0
Ctrld Dielectric: no	Ctrld Impedance: no
Etchback: no	# Pem Nuts: 0

NOTE: This order is subject to Advanced Circuits Terms and Conditions.
Please visit our website www.4pcb.com/pcb-term-conditions.html for details.

RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516 (ASM WO 73551)

carl@4pcb.com
Sent: Tuesday, August 02, 2016 12:11 PM
To: Shawn Wesley Hanvy
Cc: leanne@4pcb.com; mkrigbaum@4pcb.com; assemblytechsupport@4pcb.com

Alrighty Shawn, thanks again for your order; 73551. Boards will be done 8/5 so have your parts here 8/4. No use spending money on overnight . Two-day is just fine. Anything else; you just ask. Thanks for your order. Talk to you later, Carl

Customer Supplied Material:
Please ship material to the address below; place the Quote Number or Assembly Work Order on all packing slips and on the outside of the box; please email the tracking number to your assembly sales representative.

Attn: Marcus Krigbaum
Advanced Circuits
21101 E 32nd PKWY
Aurora, CO 80011-8149

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Carl Wehrle
North Eastern Regional Sales
1-800-979-4722 (ext.1684) | Carl@4pcb.com
21101 E. 32nd Pkwy. Aurora, CO 80011 | www.4pcb.com
If I am not available, please contact Leanne Darras at ext 1307 – leanne@4pcb.com

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From: Shawn Wesley Hanvy [mailto:hanvysw@mit.edu]
Sent: Tuesday, August 02, 2016 8:18 AM
To: Carl Wehrle
Cc: Leanne Darras
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516

From: carl@4pcb.com [carl@4pcb.com]
Sent: Monday, August 01, 2016 4:14 PM
To: Shawn Wesley Hanvy
Cc: leanne@4pcb.com
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516

Here you go Shawn. Two-sided SMT as requested (corrected). Thanks again for the opportunity; appreciate it. Please look them over and let us know what you think. If you've questions or need anything else; just ask. Hope to hear from you again soon. Carl

A-43516-1 Quote Comments:

- **ALL parts are quoted as customer supplied**
- DNI parts are EXCLUDED from the labor pricing
- CPL is required for production.
- CPL (component placement list) is a list of X Y coordinates for all the reference designators on your board. See attached for an example. It's generated using the same software that generated the bare-board fab-files. It should be a matter of checking a previously unchecked box to output that file.
- Quoted Lead Free per PCB specs please verify
- No Assembly Prints available

DNI Locations

Reference Designators	MPN	Notes
R1	**NP**	**Per BOM**
R2	**NP**	**Per BOM**

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Carl Wehrle
North Eastern Regional Sales
1-800-979-4722 (ext.1684) | Carl@4pcb.com
21101 E. 32nd Pkwy. Aurora, CO 80011 |
www.4pcb.com
If I am not available, please contact Leanne Darras at ext 1307 – leanne@4pcb.com

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From: Shawn Wesley Hanvy [mailto:hanvysw@mit.edu]
Sent: Monday, August 01, 2016 12:33 PM
To: Carl Wehrle
Cc: Leanne Darras
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516

We are going to want to have all 5 PCB assembled at the 10 day labor rate.

From: carl@4pcb.com [carl@4pcb.com]
Sent: Monday, August 01, 2016 12:28 PM
To: Shawn Wesley Hanvy

Cc: leanne@4pcb.com
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516
Welcome!

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Carl Wehrle
North Eastern Regional Sales
1-800-979-4722 (ext.1684) | Carl@4pcb.com
21101 E. 32nd Pkwy. Aurora, CO 80011 |
www.4pcb.com
If I am not available, please contact Leanne Darras at ext 1307 – leanne@4pcb.com

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From: Shawn Wesley Hanvy [mailto:hanvysw@mit.edu]
Sent: Monday, August 01, 2016 10:23 AM
To: Leanne Darras; Carl Wehrle
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516

Thank you for your help Carl!

Shawn

From: Shawn Wesley Hanvy
Sent: Monday, August 01, 2016 8:55 AM
To: leanne@4pcb.com
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516
NP stands for No Populate, which means I do not want a part placed on the foot print. What are the assembly prints and how do I go about getting them? Also, what is a "SMT Sides"? It is listed on the quote page for 1.

Shawn

From: leanne@4pcb.com [leanne@4pcb.com]
Sent: Friday, July 29, 2016 6:12 PM
To: Shawn Wesley Hanvy
Subject: RE: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292 Assembly quote# A-43516

Hello,

Please see the attached assembly quote.

A-43516 Quote Comments:

- **ALL parts are quoted as customer supplied**
- DNI parts are EXCLUDED from the labor pricing
- CPL is required for production 1 sided per PCB Quote please verify
- Quoted Lead Free per PCB specs please verify
- No Assembly Prints available

DNI Locations

Reference Designators	MPN	Notes
R1	**NP**	**Per BOM**
R2	**NP**	**Per BOM**

Leanne Darras
Regional Sales Associate
ADVANCED CIRCUITS 1-800-979-4722 (ext.1307) |
leanne@4pcb.com
21101 E. 32nd Pkwy. Aurora, CO |
www.4pcb.com

If I am not available, please contact Ashley Trahan at ext. 1339- Ashley@4pcb.com or Carl Wehrle at ext.1684 - carl@4pcb.com

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From: Shawn Wesley Hanvy [mailto:hanvysw@mit.edu]
Sent: Friday, July 29, 2016 8:44 AM
To: Ashley Trahan
Subject: Design files and BOM Quote# 4495996 ISO CERT board WO# 73292

Here are the files, I would like to have 5 made and depending on assembly time we will have all 5 done. I have the card to make the purchase. Talk to you soon.

Shawn

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dane Kouttron
Special Projects Engineer
kouttron@mit.edu

138 Albany Street, Cambridge, MA 02139-4296
Telefax No. (617) 253-7300
Tel. No. (617) 253-4211

Activation Analysis
Coolant Chemistry
Nuclear Medicine
Reactor Engineering

MIT NRL Safety System Vendor Quality Assurance

The MIT NRL safety system hardware fabrication will require hardware to be assembled and tested by external vendors. For the fabrication of our safety system printed circuit board assemblies we have chosen vendors who have ISO 9001-2008 certification. ISO 9001-2008 was chosen as it identifies inspection, testing and review of product along with a quality assurance program to target output conformity. The quality assurance requirements are split amongst the two activities; fabrication of the printed circuit board, and fabrication of the printed circuit board assembly.

Printed Circuit Board Fabrication:
The assembly of the four layer printed circuit board will be completed to the specifications defined by the CAM assembly files provided to the vendor from the MIT NRL. Automated Optical Inspection (AOI) will be required of board layers. The 'printed circuit board' will be defined herein as the PCB.

Printed Circuit Board Assembly:
The assembly of the printed circuit board will be completed to the specifications defined by the assembly files, bill of materials and associated instructions. This includes the correct placement of the defined components, soldering techniques per IC manufacturer recommendations and verification that the correct components are installed. The 'printed circuit board assembly' will be defined herein as the PCBA.

Attached below are the ISO certifications for the vendors selected, Advanced Circuits and Advanced Assembly, respectively.

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dane Kouttron
Special Projects Engineer
kouttron@mit.edu

138 Albany Street, Cambridge, MA 02139-4296
Telefax No. (617) 253-7300
Tel. No. (617) 253-4211

Activation Analysis
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Advanced Circuits ISO 9001:2008 Certificate

Certificate of Registration

This certifies that the Quality Management System of

Advanced Circuits, Inc. - Fabrication Group

21101 E. 32nd Parkway
Aurora, Colorado, 80011, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 9001:2008

Scope of Registration:
Fabrication of Bare Printed Circuit Boards

Certificate Number:	C0121245-IS2
Certificate Issue Date:	12-MAY-2015
Registration Date:	06-JUN-2015
Expiration Date *:	05-JUN-2018

Carl Blazik,
Director, Technical
Operations & Business Units,
NSF-ISR, Ltd.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

Authorized Registration and/or Accreditation Marks. This certificate is property of NSF-ISR and must be returned upon request.
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NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dane Kouttron
Special Projects Engineer
kouttron@mit.edu

138 Albany Street, Cambridge, MA 02139-4296
Telefax No. (617) 253-7300
Tel. No. (617) 253-4211

Activation Analysis
Coolant Chemistry
Nuclear Medicine
Reactor Engineering

Advanced Assembly ISO 9001:2008 Certificate

CERTIFICATE

This is to certify that

Advanced Assembly, LLC

20100 E. 32nd Parkway
Suite 225
Aurora, CO 80011
United States of America

has implemented and maintains a **Quality Management System.**

Scope:
The contract manufacturing services for original equipment manufactures (OEM's) in the electronic industry, including but not limited to components of computer peripherals, medical devices, communication equipment, industrial instruments and test equipment.

Through an audit, documented in a report, it was verified that the management system fulfills the requirements of the following standard:

ISO 9001 : 2008

Certificate registration no.	10000294 QM08
Date of original certification	2008-08-19
Date of certification	2014-07-14
Valid until	2017-07-13

UL DQS Inc.

Ganesh Rao
Managing Director

Accredited Body: UL DQS Inc., 1130 West Lake Cook Road, Suite 340, Buffalo Grove, IL 60089 USA

Bill Of Materials
RPS Voting Logic Card

Quantity	Reference	[illegible]	Package	[illegible]	[illegible]	[illegible]
2	C1,C2	22uF	2220	2220C226M5R2CAUTO718	399-5797-1-ND	AEC–Q200
29	C3,C4,C5,C6,C15,C16,C17,C18,C23,C24,C25,C26,C35,C36,C37,C38,C43,C44,C45,C46,C55,C56,C57,C58,C63,C64,C65,C72,C73	100pF	0805	C0805C101K2GACAUTO	399-6917-1-ND	AEC–Q200
66	C7,C9,C11,C13,C27,C29,C31,C33,C47,C49,C51,C53,C66,C68,C70,C76,C77,C78,C79,C80,C81,C82,C83,C84,C85,C86,C87,C88,C89,C90,C91,C92,C93,C94,C95,C96,C97,C98,C99,C100,C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,C111,C112,C113,C114,C115,C116,C117,C118,C119,C120,C121,C122,C123,C124,C125,C126	0.1uF	0805	C0805C104K1RACAUTO	399-6926-1-ND	AEC–Q200

Two parts updated from Advanced CKT FAB

Bill Of Materials
RPS Voting Logic Card

29	C8,C10,C12,C14,C19,C20,C21,C22,C28,C30,C32,C34,C39,C40,C41,C42,C48,C50,C52,C54,C59,C60,C61,C62,C67,C69,C71,C74,C75	1.0uF	0805	C0805C105K3RACAUTO	399-6929-1-ND	AEC–Q200
15	D1,D2,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D13,D14,D15	5.1V Zener Array	SOT-23-3	BZB84-B5V1,215	568-12240-1-ND	AEC-Q101
3	D16,D17,D18	TVS ARRAY	16-SOIC	SP720ABTG	F3162CT-ND	IEC 61000-4-2, Temp -40 to 105 C
1	D19	TVS ARRAY	8-SOIC	SP721ABTG	F3163CT-ND	IEC 61000-4-2, Temp -40 to 105 C
1	J1	50 pin D-Sub	Through Hole, Right Angle	174-E50-213R141	174-150FEA-ND	Temp -50°C ~ 100°C
1	J2	Current Measurement Junction	Through Hole	1778557	277-2301-1-ND	CUL, UL
1	J3	HDR1X4	Through Hole	691322110004	732-2771-ND	Temp -40°C ~ 105°C
1	J4	HDR1X6	Through Hole	691322110006	732-2773-ND	Temp -40°C ~ 105°C
1	LED1	HDR1X2	Through Hole	1778557	277-2301-1-ND	CUL, UL
1	R1	1kOhm	NP	NP	NP	
3	R124,R125,R126	10kOhm	9-SIP	4309R-101-103LF	4309R-101-103LF-ND	Temp -55°C ~ 125°C
1	R127	10kOhm	6-SIP	4306R-101-103LF	4306R-1-103LF-ND	Temp -55°C ~ 125°C
29	R13,R14,R15,R16,R17,R18,R19,R20,R37,R38,R39,R40,R41,R42,R43,R44,R61,R62,R63,R64,R65,R66,R67,R68,R83,R84,R85,R86,R87	2.4K Ohm	0805	ERJ-P06F2401V	P16067CT-ND	AEC-Q200
1	R2	3.4kOhm	NP	NP	NP	
2	R3,R4	536 Ohm	0805	9-2176091-2	A110517CT-ND	Temp -55°C ~ 155°C

Bill Of Materials
RPS Voting Logic Card

29	R5,R7,R9,R11,R21,R23,R25,R27,R29,R31,R33,R35,R45,R47,R49,R51,R53,R55,R57,R59,R69,R71,R73,R75,R77,R79,R81,R88,R90	3.3kOhm	0805	ERJ-P06F3301V	P16070DKR-ND	AEC-Q200
29	R6,R8,R10,R12,R22,R24,R26,R28,R30,R32,R34,R36,R46,R48,R50,R52,R54,R56,R58,R60,R70,R72,R74,R76,R78,R80,R82,R89,R91	536 Ohm	0805	9-2176091-2	A110517CT-ND	Temp -55°C ~ 155°C
16	R92,R93,R96,R97,R100,R101,R104,R105,R108,R109,R112,R113,R116,R117,R120,R121	100K OHM	0805	ERC0805FR-07100KL	311-100KCRCT-ND	Temp -55°C ~ 155°C
16	R94,R95,R98,R99,R102,R103,R106,R107,R110,R111,R114,R115,R118,R119,R122,R123	680 Ohm	0805	ERJ-P6WF6800V	P16883CT-ND	AEC-Q200
2	U1,U2	NOR GATE	14-SOIC	CD4002BM96	296-38049-1-ND	Temp -55°C ~ 125°C
6	U14,U16,U18,U33,U35,U37	SN74LVC1G0832	SOT-23-5	SN74LVC1G0832DBVR	296-18753-1-ND	Temp -40°C ~ 85°C
4	U15,U17,U34,U36	3IN AND GATE	SC70-6	SN74LVC1G11IDCKRQ1	296-36722-1-ND	AEC-Q100
8	U21,U23,U25,U26,U27,U29,U31,U32	Dual Schmitt INV	SC70-6	SN74LVC2G14IDCKRQ1	296-26620-1-ND	AEC-Q100

Bill Of Materials
RPS Voting Logic Card

4	U22,U24,U28, U30	NOR R/S Latch	16-SOIC	CD4043BDR	296-31496-1-ND	Temp -55°C ~ 125°C
1	U3	DC/DC CONVERTER 5V 6W	24-DIP Module (7 Leads)	JHM0624S05	1470-2047-5-ND	Medical
2	U4,U7	SSR SPST-NO	6-DIP	ASSR-1611-001E	516-2192-5-ND	CSA Component Acceptance, UL
15	U40,U42,U44, U46,U48,U50, U52,U54,U56, U58,U60,U62, U64,U66,U68	Optoisolator	8-SSO	ACPL-K73L-060E	516-2338-5-ND	CSA Component Acceptance, UL, IEC/EN/DIN EN 60747-5-2
15	U41,U43,U45, U47,U49,U51, U53,U55,U57, U59,U61,U63, U65,U67,U69	DUAL SCHMITT	SC70-6	SN74LVC2G17QDCKRQ1	296-18297-1-ND	AEC-Q100
6	U5,U6,U10,U1 3,U20,U39	AND Gate IC 1Ch	SOT-23-5	SN74AHC1G08QDBVRQ1	296-23875-1-ND	AEC-Q100
4	U70,U71,U72, U73	Optoisolator	16-SSOP	PS2833-4-ND	PS2833-4-ND	-55 to +100°C, UL approved: File No. E72422 (S)
4	U8,U11,U19,U 38	3IN OR-AND GATE	SC70-6	CLVC1G3208IDCKRQ1	296-28150-1-ND	AEC-Q100
2	U9,U12	AND Gate IC 2Ch	14-SOIC	SN74HC21QDRQ1	296-24750-1-ND	AEC-Q100

RPS Logic Bill of Materials
for Advance Circuits PCB Fabrication

Quantity	Reference	Part	Package	[illegible]	[illegible]	[illegible]
2	C1,C2	22uF	2220	C2220C226M5R2CAUTO7186	399-5797-1-ND	Digikey
29	C3,C4,C5,C6,C15,C16,C17,C18,C23,C24,C25,C26,C35,C36,C37,C38,C43,C44,C45,C46,C55,C56,C57,C58,C63,C64,C65,C72,C73	100pF 10%	0805	C0805C101K2GACAUTO	399-6917-1-ND	Digikey
66	C7,C9,C11,C13,C27,C29,C31,C33,C47,C49,C51,C53,C66,C68,C70,C76,C77,C78,C79,C80,C81,C82,C83,C84,C85,C86,C87,C88,C89,C90,C91,C92,C93,C94,C95,C96,C97,C98,C99,C100,C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,C111,C112,C113,C114,C115,C116,C117,C118,C119,C120,C121,C122,C123,C124,C125,C126	0.1uF 10%	0805	C0805C104K1RACAUTO	399-6926-1-ND	Digikey
29	C8,C10,C12,C14,C19,C20,C21,C22,C28,C30,C32,C34,C39,C40,C41,C42,C48,C50,C52,C54,C59,C60,C61,C62,C67,C69,C71,C74,C75	1.0uF 10%	0805	C0805C105K3RACAUTO	399-6929-1-ND	Digikey
15	D1,D2,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D13,D14,D15	5.1V Zener Array	SOT-23-3	BZB84-B5V1,215	568-12240-1-ND	Digikey
3	D16,D17,D18	TVS ARRAY	16-SOIC	SP720ABTG	F3162CT-ND	Digikey
1	D19	TVS ARRAY	8-SOIC	SP721ABTG	F3163CT-ND	Digikey
1	J1	50 pin D-Sub	ough Hole, Right Ar	174-E50-213R141	174-150FEA-ND	Digikey
1	J2	Current Measurement Junction	Through Hole	1778557	277-2301-1-ND	Digikey
1	J3	HDR1X4	Through Hole	691322110004	732-2771-ND	Digikey
1	J4	HDR1X6	Through Hole	691322110006	732-2773-ND	Digikey
1	LED1	HDR1X2	Through Hole	1778557	277-2301-1-ND	Digikey
1	R1	1kOhm 1%	NP	NP	NP	N/A
3	R124,R125,R126	10kOhm	9-SIP	4309R-101-103LF	4309R-101-103LF-ND	Digikey
1	R127	10kOhm	6-SIP	4306R-101-103LF	4306R-1-103LF-ND	Digikey
29	R13,R14,R15,R16,R17,R18,R19,R20,R37,R38,R39,R40,R41,R42,R43,R44,R61,R62,R63,R64,R65,R66,R67,R68,R83,R84,R85,R86,R87	2.4K Ohm 1%	0805	ERJ-P06F2401V	P16067CT-ND	Digikey
1	R2	3.4kOhm 1%	NP	NP	NP	N/A
2	R3,R4	536 Ohm	0805	9-2176091-2	A110517CT-ND	Digikey
29	R5,R7,R9,R11,R21,R23,R25,R27,R29,R31,R33,R35,R45,R47,R49,R51,R53,R55,R57,R59,R69,R71,R73,R75,R77,R79,R81,R88,R90	3.3kOhm 1%	0805	ERJ-P06F3301V	P16070DKR-ND	Digikey
29	R6,R8,R10,R12,R22,R24,R26,R28,R30,R32,R34,R36,R46,R48,R50,R52,R54,R56,R58,R60,R70,R72,R74,R76,R78,R80,R82,R89,R91	536 Ohm	0805	9-2176091-2	A110517CT-ND	Digikey
16	R92,R93,R96,R97,R100,R101,R104,R105,R108,R109,R112,R113,R116,R117,R120,R121	330 Ohm 1%	0805	ERJ-P6WF3300V	P16879CT-ND	Digikey
16	R94,R95,R98,R99,R102,R103,R106,R107,R110,R111,	680 Ohm	0805	ERJ-P6WF6800V	P16883CT-ND	Digikey
2	U1,U2	NOR GATE	14-SOIC	CD4002BM96	296-38049-1-ND	Digikey
6	U14,U16,U18,U33,U35,U37	SN74LVC1G0832	SOT-23-5	SN74LVC1G0832DBVR	296-18753-1-ND	Digikey
4	U15,U17,U34,U36	3IN AND GATE	SC70-6	SN74LVC1G11IDCKRQ1	296-36722-1-ND	Digikey
2	U9,U12	AND Gate IC 2Ch	14-SOIC	SN74HC21QDRQ1	296-24750-1-ND	Digikey

RPS Logic Bill of Materials
for Advance Circuits PCB Fabrication

Quantity	Reference	Part	Package	Mfg #	Dist #	Distributor
8	U21,U23,U25,U26,U27,U29,U31,U32	Dual Schmitt INV	SC70-6	SN74LVC2G14IDCKRQ1	296-26620-1-ND	Digikey
4	U22,U24,U28,U30	NOR R/S Latch	16-SOIC	CD4043BDR	296-31496-1-ND	Digikey
1	U3	DC/DC CONVERTER 5V 6W	24-DIP Module (7 Leads)	JHM0624S05	1470-2047-5-ND	Digikey
2	U4,U7	SSR SPST-NO	6-DIP	ASSR-1611-001E	516-2192-5-ND	Digikey
15	U40,U42,U44,U46,U48,U50,U52,U54,U56,U58,U60, U62,U64,U66,U68	Optoisolator	8-SSO	ACPL-K73L-060E	516-2338-5-ND	Digikey
15	U41,U43,U45,U47,U49,U51,U53,U55,U57,U59,U61, U63,U65,U67,U69	DUAL SCHMITT	SC70-6	SN74LVC2G17QDCKRQ1	296-18297-1-ND	Digikey
6	U5,U6,U10,U13,U20,U39	AND Gate IC 1Ch	SOT-23-5	SN74AHC1G08QDBVRQ1	296-23875-1-ND	Digikey
4	U70,U71,U72,U73	Optoisolator	16-SSOP	PS2801-4-F3-A	PS2801-4ACT-ND	Digikey
4	U8,U11,U19,U38	3IN OR-AND GATE	SC70-6	CLVC1G3208IDCKRQ1	296-28150-1-ND	Digikey

Card#	OptoCoupler Installed	Output Resistor Installed	Previous installation condition	Current installation Condition	Current Consumption
5	PS2833-4-ND (UPDATED	100K output resistors	previously installed in chassis 2	repotted with acrylic potting, tested using bench	350mA on test fixture all conditions clear 940mA on test fixture with all
2	PS2833-4-ND (UPDATED	100K output resistors	not installed, not previously potted	repotted with acrylic potting, tested using bench	350mA on test fixture all conditions clear 940mA on test fixture with all
4	PS2833-4-ND (UPDATED	100K output resistors	not installed, previously potted	Repotted with acrylic potting, tested using bench	350mA on test fixture all conditions clear 940mA on test fixture with all
3	Origional Opto	Origional Resistor	Previously installed in chassis 1, failure on board	Waiting Repair	
1	PS2833-4-ND (UPDATED	100K output resistors	Installed in Spare chassis,	Repotted with acrylic potting, tested using bench	350mA on test fixture all conditions clear 940mA on test fixture with all

MIT NUCLEAR REACTOR LABORATORY

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Bench Testing

NSS Scram Logic Card Modules

NSS Scram Logic Card Verification Test:

1. Connect NSS Scram Logic Card (SLC) to the Logic Testing Board (described and shown in Figure 4-4 of the SAR Chapter 7 Appendix for the New NSS).
2. Connect the Logic Testing Board to a 24Vdc power supply.
3. Reset locked-in alarms on the Logic Testing Board.
4. Cycle trip conditions and record the response on the data table. (The data table has been independently verified by a Senior Reactor Operator and the QA Supervisor as containing all possible trip condition combinations from the four DWK 250 chassis. Verified by SRO: Eddie Lau QA Supervisor: Susan Tucker .)
5. Reset locked-in alarms and continue testing until all trip condition combinations are verified to have the correct response.

Acceptances Criteria and completed results:

The above Verification Test was completed satisfactorily on five Scram Logic Cards. Results confirm that for every given input trip combination, the correct SLC output response is observed, and that 2-out-of-4 coincidence is achieved. The test results are filed in the NSS test results binder (QA#-2017-35 for the Scram Logic Card Modules).

[signature] 2/14/2017

Approved by Reactor Instrumentation Supervisor Shawn Hanvy Date

MIT NUCLEAR REACTOR LABORATORY

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Handling and Installation Instructions

NSS Scram Logic Card Modules

Before the Scram Logic Cards have the conformal coating applied, the cards must be handled with strict electro-static discharge (ESD) precautions. These precautions are: the worker must be grounded prior to touching any component, and work on the card must be performed on an ESD mat.

The final installation of the Scram Logic Card Modules into the reactor control room instrumentation cabinets is covered in the New Nuclear Safety System Installation Plan.

QUALITY ASSURANCE REQUIREMENTS CHECKLIST: QA # 2017-34

Plan, procedure or equipment affected: NSS Signal Distribution Module

Initiator: T. Lovrini / E. Lau Date: 9/6/17

Class of change: ☒ Class A ☐ Class B ☐ Class C
Type of change: ☐ Procedure ☐ Mechanical ☒ Electrical ☐ ______
Extent of change: ☒ Installation ☐ Modification ☐ Maintenance ☐ ______

Approval of QA requirements as listed in Sections I - III below:

Superintendent [signature] Date 10/27/17 Director of Reactor Operations [signature] Date 12/5/2017

I	Document List		Completed By:	Date:
	Proposal (Class C changes)			
✓	Safety Review (Class A/B changes)		E. Lau	11/1/2017
✓	Specifications		S. Henry	10/28/2017
✓	Procurement		S. Henry	10/28/2017
✓	Drawings and Schematics		S. Henry	10/28/2017
✓	Fabrication		S. Henry	10/28/2017
✓	Bench Testing		S. Henry	10/28/2017
~~✓~~	~~Handling and Installation Instructions~~ QS 12/5/17			
~~✓~~	~~Industrial Safety Checklist~~ QS 12/5/17			

Above requirements are complete. Equipment is ready to be installed or procedure is ready to be implemented.

Superintendent or DRO: [signature] Date: 12/5/2017

II	Document List		Completed By:	Date:
✓	Installation and Inspection			
✓	Testing and Calibration			
	Operating Procedures and Checklists			

Above requirements are complete. Equipment is ready to be placed in operation.

Superintendent or DRO: ______ Date: ______

III	Document List		Completed By:	Date:
✓	Reactor Systems Manual			
	Safety Analysis Report			
✓	Safety Review Distribution			
	Training			

All requirements of QA package complete: ______ QA Supervisor ______ Date

______ Superintendent ______ Date ______ Director of Reactor Operations ______ Date

Additional approvals needed by: ☐ MITRSC (approval attached) ☐ USNRC (approval attached)

QUALITY ASSURANCE REQUIREMENTS CHECKLIST: QA # 2017-34

Plan, procedure or equipment affected: NSS Signal Distribution Module

Initiator: T. Leoni / E. Lau Date: 9/6/17

Class of change: ☒ Class A ☐ Class B ☐ Class C
Type of change: ☐ Procedure ☐ Mechanical ☒ Electrical ☐ ____
Extent of change: ☒ Installation ☐ Modification ☐ ~~Maintenance~~ ☐ ____

Approval of QA requirements as listed in Sections I - III below:

[signature] 10/27/17 [signature] 12/5/2017
Superintendent Date Director of Reactor Operations Date

I	Document List		Completed By:	Date:
✓	Proposal (Class C changes)			
✓	Safety Review (Class A/B changes)		E. Lau	11/1/2017
✓	Specifications		S. Harry	10/28/2017
✓	Procurement		S. Harry	10/28/2017
✓	Drawings and Schematics		S. Harry	10/28/2017
✓	Fabrication		S. Harry	10/28/2017
✓	Bench Testing		S. Harry	10/28/2017
~~✓~~	~~Handling and Installation Instructions~~ 12/5/17			
NA ~~✓~~	~~Industrial Safety Checklist~~ 12/5/17			

Above requirements are complete. Equipment is ready to be installed or procedure is ready to be implemented.

Superintendent or DRO: [signature] Date: 12/5/2017

II	Document List		Completed By:	Date:
✓	Installation and Inspection			
✓	Testing and Calibration			
	Operating Procedures and Checklists			

Above requirements are complete. Equipment is ready to be placed in operation.

Superintendent or DRO: ____ Date: ____

III	Document List		Completed By:	Date:
✓	Reactor Systems Manual			
	Safety Analysis Report			
✓	Safety Review Distribution			
	Training			

All requirements of QA package complete:

____ ____
QA Supervisor Date

____ ____ ____ ____
Superintendent Date Director of Reactor Operations Date

Additional approvals needed by: ☐ MITRSC (approval attached) ☐ USNRC (approval attached)

Safety Review Form No. 2017-34

Item: NSS Signal Distribution Module

Submitted by E. Lau/S. Tucker Date 11/8/2017

Q/A number (required for all equipment changes) ____________

	Yes*	No
Does the item change or contradict the Technical Specifications?	☐	☒
Does the item contradict the SAR?	☒	☐

*Attach explanation

Description of Change (Attach extra pages if necessary):

See attached.

Safety Evaluation (Attach extra pages if necessary):

See attached.

Summary of Review:

a) Does the proposal:

	Yes	No
i) require a license amendment (10CFR50.59(c)(2))	☒	☐
ii) decrease scope of requalification program (10CFR50.54(i-1))	☐	☒
iii) decrease effectiveness of security plan (10CFR50.54(p))	☐	☒
iv) decrease effectiveness of emergency plan (10CFR50.54(q))	☐	☒

b) Reviewer's Comments:

Reviewer Sarah [signature] Date 12/11/17

Reviewer Walmsley Date 12/11/17

Reviewer [signature] Date 12/12/17
(Reactor Radiation Protection Officer)

Approved [signature] Date 12/12/2017
(Director of Reactor Operations)

Date of MITRSC approval if required 11/16/2017 Date of NRC approval if required ____________

List of Communications containing MITRSC additional conditions:

10 CFR 50.59 & 50.54 (p and q) changes included in Annual Report to NRC, Fiscal Year ____________

Evaluation of SR#-2017-34 under 50.59 Requirements

This change requires a change to the SAR and a license amendment per 10 CFR 50.59. See QA File #E-2012-1.

ALARA Determination for SR#-2017-34

The changes will have no impact on ALARA because the changes do not change the time spent in high radiation areas.

Q/A File #2017-34 "Signal Distribution Module"

Description of the Signal Distribution Module

The Signal Distribution Module (SDM) is an interface circuit between the DWK 250 digital neutron flux monitors and all components downstream. Because any trip signal generated from a nuclear safety channel must pass through the SDM on its way to the modules that effect a reactor shutdown, the SDM is considered a safety-related component of the Nuclear Safety System.

Additionally, the SDM contains the auctioneering diodes for the two 24-volt DC power supplies. There are two analog meters mounted on the SDM's protective casing, one showing the electric current from the power supplies, and the other showing voltage. (See Figure 1.) By selection via a rotary switch (also mounted on the case), the voltage meter shows the instantaneous voltage on the SDM, from the first power supply, or from the second power supply.

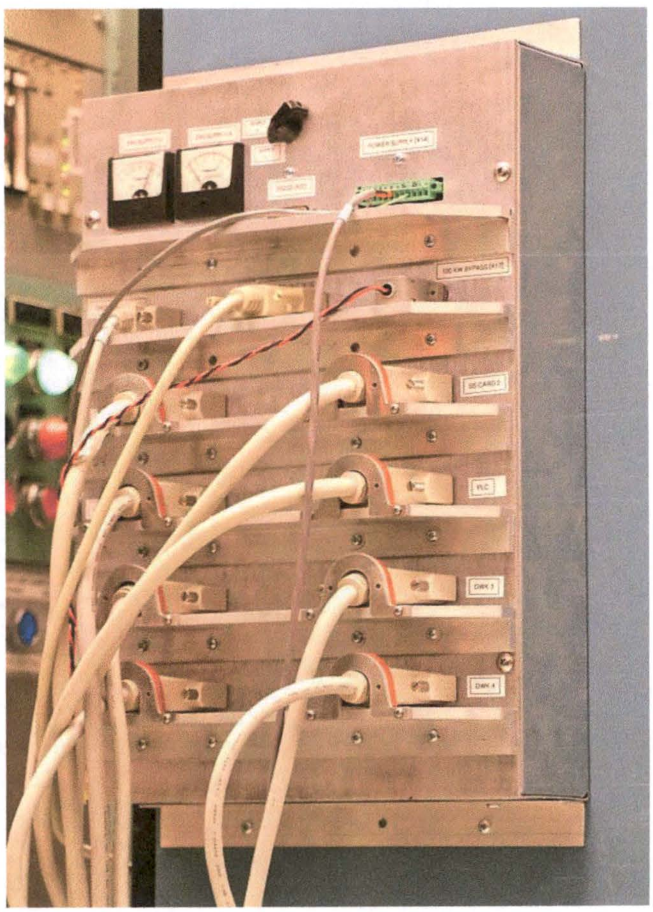

Figure 1 – Exterior of Signal Distribution Module, showing its two Analog Meters at top

As can be seen in schematic diagram R3W-268-2 "Nuclear Safety System Global Connection Diagram" and circuit board diagram R3W-274-3 "Signal Distribution Module Board Wiring Diagram" the SDM has a total of thirteen connections. In terms of signal flow, four of those connections are strictly input (signal coming from each of the four DWK 250 units), six are input/output bidirectional, two are strictly output, and one is not in use. The following lists the roles of the connectors as they are labeled:

1. X10: Receives signal from DWK 250 channel #1.

2. X11: Receives signal from DWK 250 channel #2.

3. X12: Receives signal from DWK 250 channel #3.

4. X13: Receives signal from DWK 250 channel #4.

5. X14: Receives power from two 24-volt DC power supplies that are set up in parallel, but connected via auctioneering diodes on the SDM, so that if one fails, the other will take over without interruption. The X14 connector then passes the 24-volt DC power as output to the "NIM bin 1" instrument rack which contains three downstream components: Scram Logic Card 1, Scram Logic Card 2, and the <100 kW Key-Switch Module. The X14 connector also passes the 24-volt DC power via connectors X10 through X13 to energize the output (scram/alarm) relays of the four DWK 250 channels. (The DWK 250 output relays are electrically isolated from the internal circuitry of the DWK 250, and rely on an external power source for their operation.)

6. X15: Passes signals from the four DWK 250 channels to Scram Logic Card 1. The X15 connector receives signals back from Scram Logic Card 1 and routes them to the LED Scram Display and several non-safety-related monitoring and display devices.

7. X16: Passes signals from the four DWK 250 channels to Scram Logic Card 2. The X16 connector receives signals back from Scram Logic Card 2 and routes them to the LED Scram Display and several non-safety-related monitoring and display devices.

8. X17: Passes signals to and from the <100 kW Key-Switch Module.

9. X18: Passes signals to and from an LED Scram Display module, which captures scram signals from any of the four DWK 250 channels via the Scram Logic Cards, and keeps them latched in until the LED Scram Display module is used to reset the two Scram Logic Cards. (Once the scram condition no longer exists, the DWK 250 will not show what the trip condition was.)

10. X19: Passes analog signals from the four DWK 250 channels to existing console chart recorders and meters.

11. X20: Not in use.

12. X21: Passes signals from all inputs of the SDM to a non-safety-related programmable logic controller (PLC) for monitoring and status display.

13. X41: Passes the "Test" trip signal from each of the four DWK 250 channels through a Signal Junction Box to a Blade Drop Timer Interface Module, which in turn passes a signal to activate the existing Blade Drop Timer. This setup will measure the scram time from initiation of a scram signal to 80% insertion of a shim blade. The Blade Drop Timer Interface Module conditions a binary signal for compatibility with the existing Blade Drop Timer, and includes optical isolation of the SDM from the Blade Drop Timer. The Blade Drop Timer Interface Module and the Blade Drop Timer are mounted in separate NIM bins. The Blade Drop Timer in its own NIM bin receives 12 volts DC from its existing, independent power source. Connector X41 also passes low-voltage and fault signals from each of the two 24-volt DC power supplies to the PLC, by way of the SDM and the Signal Junction Box, via connector P10 on the Box and cable K-45.

Safety Evaluation

The Signal Distribution Module (SDM) is a four-layer FR4 printed-circuit board that facilitates passing of signals between various modules of the new Nuclear Safety System. An ISO 9001-2008 certified electronic hardware manufacturer (Advanced Circuits) fabricated the board.

Failure Analysis

If the board fails, such as by physical damage or other disruption to a scram signal path between a DWK 250 and the Scram Logic Cards, there will be a loss of the signal, thereby causing the Scram Logic Cards to produce a scram. The physical damage could include puncture, impact, fire, or high voltage surge, while other types of disruption could include radio frequency interference, overheating, or corrosion. All would result in a scram.

The connection (X14) to the two 24-volt DC power supplies only passes power to the two Scram Logic Cards and the <100 kW Key-Switch Module. The SDM board does not use the power for its own functions. The two power supplies are fed from an existing, common 120-volt AC source, and have an internal fuse that will protect against overcurrent conditions. They also have an output overload that will trip at no more than 35 volts DC. In the unlikely event of an excessive line voltage surge, both power supplies are designed to trip to protect themselves, interrupting power to the two Scram Logic Cards, scramming the reactor. If the surge affects the SDM board directly, it may create physical damage as described above, again resulting in a reactor scram.

If there is a loss of line voltage or an internal fault on either of the two 24-volt DC power supplies, a relay contact opens on the affected power supply to transmit a signal by way of the SDM and the Signal Junction Box to the PLC, showing on the PLC which power supply is in trouble.

Signals input to the SDM board from the two Scram Logic Cards are passed along to other display and status monitoring devices. If the board should be damaged in these areas, there is no effect on nuclear safety. The console operator may observe a partial loss of indications of reactor power and reactor period, but will not receive false information. There are redundant displays of reactor power and period, such as on the face of each DWK 250 chassis, that will remain operable. There are also four existing independent non-safety-related neutron flux channels or N-16 gamma channels displaying reactor power. Likewise, loss of signal output from the SDM to existing console chart recorders and meters has no effect on nuclear safety. There is redundant recording of reactor power history from the non-safety-related neutron flux channels.

Cybersecurity and Isolation

The SDM is assembled on one circuit board. The module is constructed with standard industrially-rated components. It contains no digital components, and is therefore not subject to cybersecurity threats.

Transient Voltage Suppressor (TVS) diodes are used on the SDM board to ensure voltages never exceed 35 volts. Because the SDM is mostly a passive circuit board, it does not include any optical isolators. However, there are optical isolators built into Scram Logic Card 1, Scram Logic Card 2, the Blade Drop Timer Interface Module, and the PLC panel.

Access Control and Physical Protection

The SDM will be mounted within the protective metal instrumentation cabinets of the control room. The instrumentation cabinets will provide the module with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the NRC-approved Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components on the SDM board.

Human Factors

All cables to the SDM and cable connection points on the SDM will be labeled, as will the circuit board. These markings improve the human interface for purposes of installation and maintenance. Once it is installed, there will be no regular human interface with the SDM board. It will be handled only by or under the supervision of license reactor staff. Therefore, human factors engineering remains adequate.

Verification and Periodic Checks

The new SDM board will be tested for wiring verification using a written procedure prior to first use, will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation, and will receive functional checks periodically as part of the operational checks of the integrated Nuclear Safety System. Therefore, these pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the circuitry.

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Specifications

NSS Signal Distribution Module

1. The Signal Distribution Module (SDM) is an interface circuit between the DWK 250 neutron flux monitors and all new Nuclear Safety System (NSS) components downstream. It provides all necessary connections for the NSS, thereby minimizing the amount of point-to-point wiring.

2. The SDM is to be fabricated in-house on a single printed-circuit board (PCB) composed of FR-4, four layers, with 1-oz. copper pour.

3. The SDM contains the Schottky auctioneering diodes for two external 24-volt DC power supplies. It routes the 24-volt DC power to the relay contacts of each DWK 250, and powers the two Scram Logic Card Modules.

4. Voltage protection shall be provided through use of Transient Voltage Suppressor (TVS) diodes to ensure voltages never exceed 35 volts.

5. Total system current is displayed on a front-mount ammeter.

6. System voltage, and voltage of each of the two 24-volt power supplies, are displayed on a front-mount voltmeter, using a selector switch to choose between them.

7. The SDM's circuit card is to be mounted in a metal enclosure, allowing access to the connectors.

8. Further specifications are listed on Drawing R3W-274-3 "Signal Distribution Module Board Wiring Diagram" and R3W-268-2 "Nuclear Safety System Global Connection Diagram".

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Procurement

NSS Signal Distribution Module

1. The components for the Signal Distribution Module were purchased from Digi-Key Electronics. Components necessary for its construction are as follows:
    a. Maximum Efficiency General Application (MEGA) Schottky barrier rectifier (Nexperia, PMEG45A10EPD)
    b. TransZorb Voltage Suppressor, Surface Mount (Vishay, SMCJ18CA & SMCJ36CA)
    c. Miscellaneous electronic components, such as resistors, connectors, and meters, of generic nature.
2. A data sheet for each specialized component is included.
3. Each component meets the receipt requirements of PM 1.19, as do the assembled printed-circuit boards (PCBs). The invoice, including specifications and a certificate of registration, for the PCB fabricated by Advanced Circuits is attached.

1.19 Receiving, Storing, and Issuing of Materials

All materials received shall be:

– Checked against the requisition on which it was ordered so as to ensure receipt of the material requested.

– Visually inspected for obvious defects.

– Subject to a detailed inspection of all parts.

– Any material identified as not meeting NRL specification should be either:

  (a) returned to the supplier, or

  (b) evaluated for acceptability on some other documented basis. For materials within the scope of the QA program, see Section 1.13.6, "Non-Conformance to QA Standards."

– Once material or equipment has been accepted, it is either issued or placed in storage. Storage areas are assigned by category (i.e., raw materials, finished machine parts, electrical components, etc.)

1.19.1 Nuclear Materials

The receiving, storing and issuing of nuclear materials must be in accordance with applicable regulations, licenses, plans and procedures:

a) NRC Regulations:

10 CFR 20 Standards for Protection Against Radiation

10 CFR 40 Domestic Licensing of Source Material

10 CFR 21 Reporting of Defects and Noncompliance

10 CFR 70 Domestic Licensing of Special Nuclear Material

10 CFR 73 Physical Protection of Plants and Materials

PMEG45A10EPD

45 V, 10 A low VF MEGA Schottky barrier rectifier

16 December 2014 **Product data sheet**

1. General description

Planar Maximum Efficiency General Application (MEGA) Schottky barrier rectifier with an integrated guard ring for stress protection, encapsulated in a SOT1289 (CFP15) power and flat lead Surface-Mounted Device (SMD) plastic package.

2. Features and benefits

- Average forward current: $I_{F(AV)} \leq 10$ A
- Reverse voltage: $V_R \leq 45$ V
- Low forward voltage
- High power capability due to clip-bonding technology and heat sink
- Small and thin SMD power plastic package, typical height 0.78 mm

3. Applications

- Low voltage rectification
- High efficiency DC-to-DC conversion
- Switch mode power supply
- Freewheeling application
- Reverse polarity protection
- Low power consumption application

4. Quick reference data

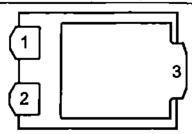
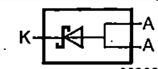
Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$I_{F(AV)}$	average forward current	$\delta = 0.5$; f = 20 kHz; $T_{sp} \leq 130$ °C; square wave		-	-	10	A
V_R	reverse voltage	$T_j = 25$ °C		-	-	45	V
V_F	forward voltage	$I_F = 10$ A; $t_p \leq 300$ µs; $\delta \leq 0.02$; $T_j = 25$ °C; pulsed		-	473	540	mV
I_R	reverse current	$V_R = 10$ V; $t_p \leq 3$ ms; $\delta = 0.3$; $T_j = 25$ °C; pulsed		-	13	30	µA
		$V_R = 45$ V; $t_p \leq 3$ ms; $\delta = 0.3$; $T_j = 25$ °C; pulsed		-	150	500	µA

nexperia

5. Pinning information

Table 2. Pinning information

Pin	Symbol	Description	Simplified outline	Graphic symbol
1	A	anode	 CFP15 (SOT1289)	 aaa-009063
2	A	anode		
3	K	cathode		

6. Ordering information

Table 3. Ordering information

Type number	Package		
	Name	Description	Version
PMEG45A10EPD	CFP15	plastic, thermal enhanced ultra thin SMD package; 3 leads; body: 5.8 x 4.3 x 0.78 mm	SOT1289

7. Marking

Table 4. Marking codes

Type number	Marking code
PMEG45A10EPD	4510 AAAA

8. Limiting values

Table 5. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
V_R	reverse voltage	T_j = 25 °C		-	45	V
I_F	forward current	T_{sp} = 125 °C; δ = 1		-	14	A
$I_{F(AV)}$	average forward current	δ = 0.5; f = 20 kHz; T_{sp} ≤ 130 °C; square wave		-	10	A
I_{FSM}	non-repetitive peak forward current	t_p = 8 ms; $T_{j(init)}$ = 25 °C; square wave		-	170	A
P_{tot}	total power dissipation	T_{amb} ≤ 25 °C	[1]	-	0.9	W
			[2]	-	1.2	W
			[3]	-	3	W
T_j	junction temperature			-	150	°C
T_{amb}	ambient temperature			-55	150	°C

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Symbol	Parameter	Conditions		Min	Max	Unit
T_{stg}	storage temperature			-65	150	°C

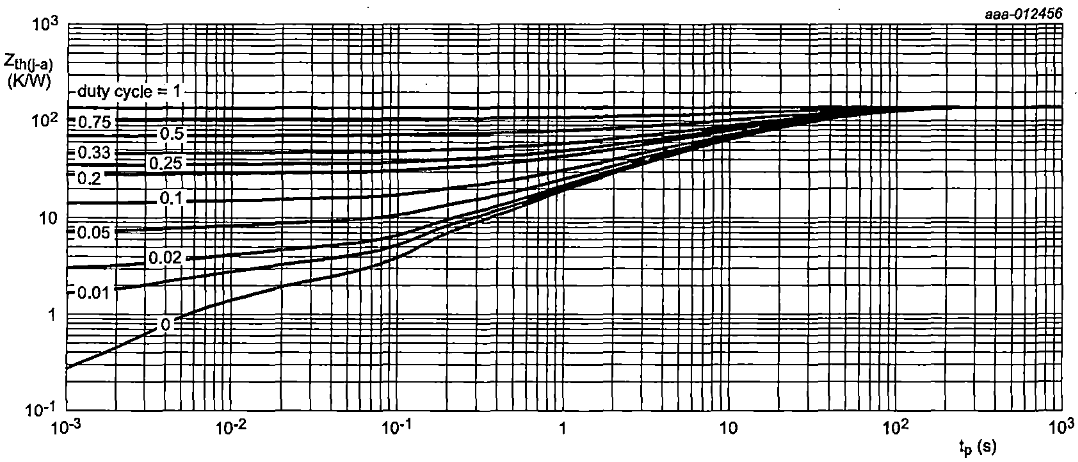
[1] Device mounted on an FR4 PCB, single-sided copper, tin-plated and standard footprint.
[2] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for cathode 1 cm^2.
[3] Device mounted on a ceramic Printed-Circuit Board (PCB), Al_2O_3, standard footprint.

9. Thermal characteristics

Table 6. Thermal characteristics

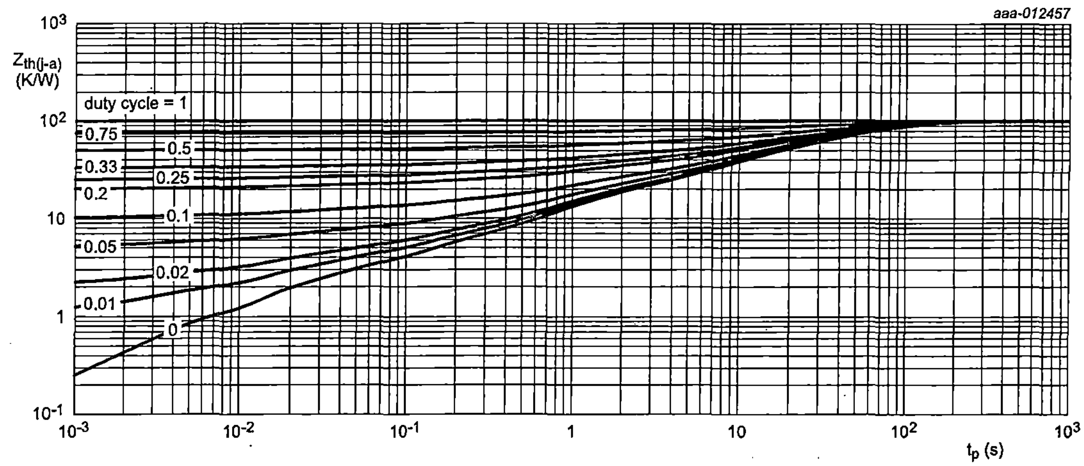
Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	[1][2]	-	-	165	K/W
			[1][3]	-	-	120	K/W
			[1][4]	-	-	50	K/W
$R_{th(j-sp)}$	thermal resistance from junction to solder point		[5]	-	-	4	K/W

[1] For Schottky barrier diodes thermal runaway has to be considered, as in some applications the reverse power losses P_R are a significant part of the total power losses.
[2] Device mounted on an FR4 PCB, single-sided copper, tin-plated and standard footprint.
[3] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for cathode 1 cm^2.
[4] Device mounted on a ceramic PCB, Al_2O_3, standard footprint.
[5] Soldering point of cathode tab.



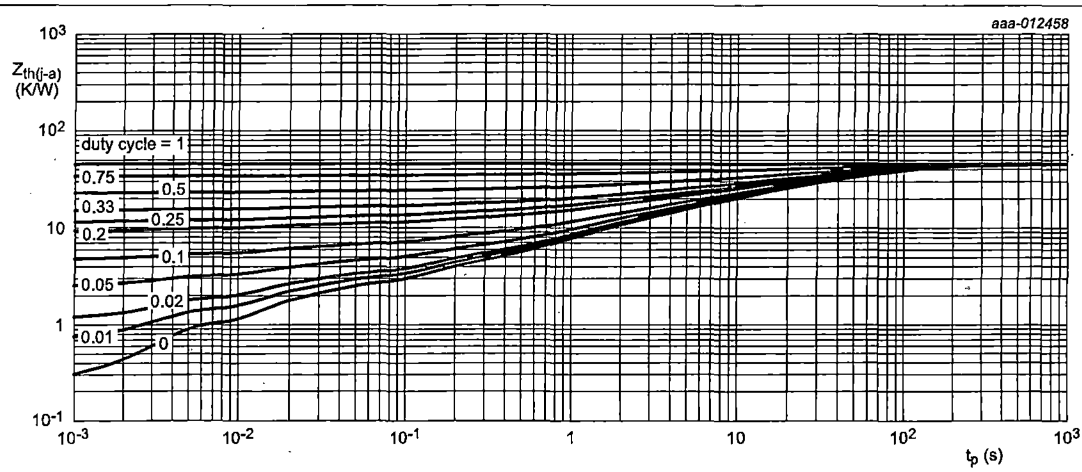
FR4 PCB, standard footprint

Fig. 1. Transient thermal impedance from junction to ambient as a function of pulse duration; typical values



FR4 PCB, mounting pad for cathode 1 cm^2

Fig. 2. **Transient thermal impedance from junction to ambient as a function of pulse duration; typical values**



Ceramic PCB, Al_2O_3, standard footprint

Fig. 3. **Transient thermal impedance from junction to ambient as a function of pulse duration; typical values**

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10. Characteristics

Table 7. Characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_F	forward voltage	I_F = 1 A; t_p ≤ 300 μs; δ ≤ 0.02; T_j = 25 °C; pulsed		-	330	380	mV
		I_F = 2 A; t_p ≤ 300 μs; δ ≤ 0.02; T_j = 25 °C; pulsed		-	357	-	mV
		I_F = 3 A; t_p ≤ 300 μs; δ ≤ 0.02; T_j = 25 °C; pulsed		-	377	-	mV
		I_F = 5 A; t_p ≤ 300 μs; δ ≤ 0.02; T_j = 25 °C; pulsed		-	409	470	mV
		I_F = 10 A; t_p ≤ 300 μs; δ ≤ 0.02; T_j = 25 °C; pulsed		-	473	540	mV
I_R	reverse current	V_R = 5 V; t_p ≤ 3 ms; δ = 0.3; T_j = 25 °C; pulsed		-	10	-	μA
		V_R = 10 V; t_p ≤ 3 ms; δ = 0.3; T_j = 25 °C; pulsed		-	13	30	μA
		V_R = 30 V; t_p ≤ 3 ms; δ = 0.3; T_j = 25 °C; pulsed		-	36	-	μA
		V_R = 45 V; t_p ≤ 3 ms; δ = 0.3; T_j = 25 °C; pulsed		-	150	500	μA
		V_R = 10 V; t_p ≤ 3 ms; δ = 0.3; T_j = 125 °C; pulsed		-	11	-	mA
C_d	diode capacitance	V_R = 1 V; f = 1 MHz; T_j = 25 °C		-	715	-	pF
		V_R = 10 V; f = 1 MHz; T_j = 25 °C		-	240	-	pF
t_{rr}	reverse recovery time ; step recovery	I_F = 0.5 A; I_R = 0.5 A; $I_{R(meas)}$ = 0.1 A; T_j = 25 °C		-	21	-	ns
t_{rr}	reverse recovery time ; ramp recovery	dI_F/dt = 200 A/μs; T_j = 25 °C; I_F = 6 A; V_R = 26 V		-	13	-	ns
$V_{(BR)R}$	reverse breakdown voltage	I_R = 5 mA; T_j = 25 °C; t_p ≤ 1.2 ms; δ = 0.12; pulsed		45	-	-	V
V_{FRM}	peak forward recovery voltage	I_F = 0.5 A; dI_F/dt = 20 A/μs; T_j = 25 °C		-	317	-	mV

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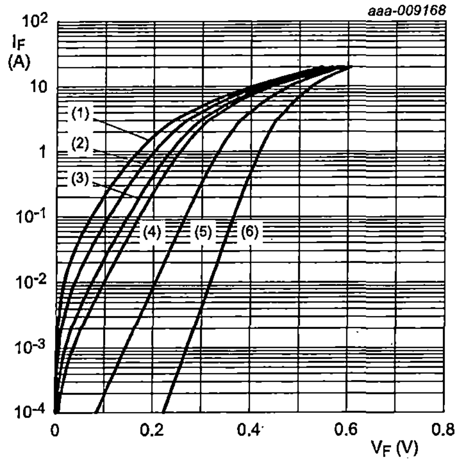
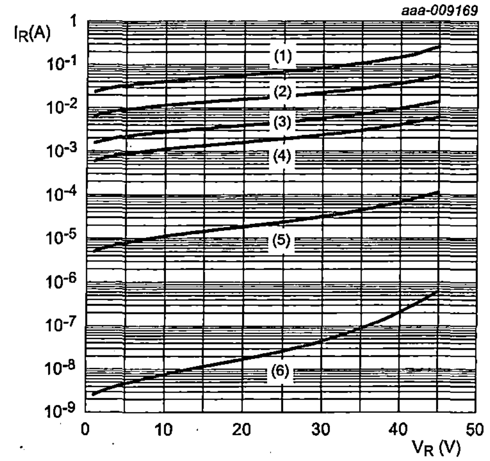


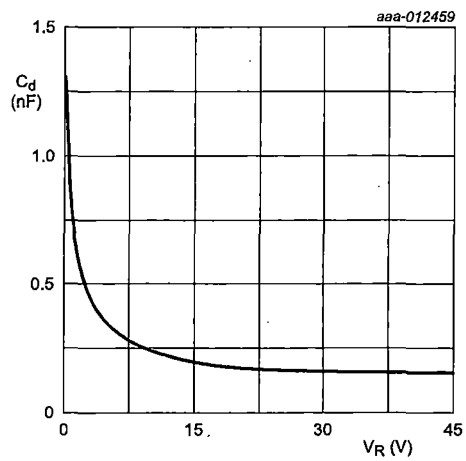
(1) T_j = 150 °C
(2) T_j = 125 °C
(3) T_j = 100 °C
(4) T_j = 85 °C
(5) T_j = 25 °C
(6) T_j = -40 °C

Fig. 4. Forward current as a function of forward voltage; typical values (pulsed condition)



(1) T_j = 150 °C
(2) T_j = 125 °C
(3) T_j = 100 °C
(4) T_j = 85 °C
(5) T_j = 25 °C
(6) T_j = -40 °C

Fig. 5. Reverse current as a function of reverse voltage; typical values (pulsed condition)



f = 1 MHz; T_{amb} = 25 °C

Fig. 6. Diode capacitance as a function of reverse voltage; typical values

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11. Test information

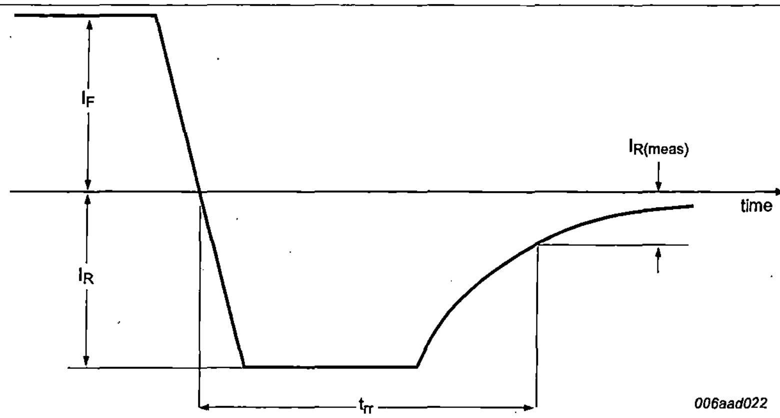

Fig. 7. Reverse recovery definition; step recovery

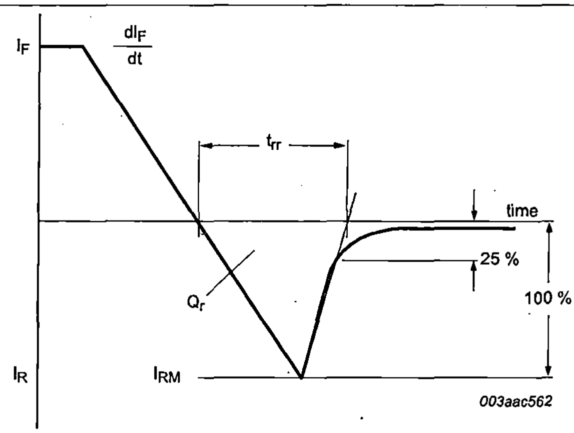

Fig. 8. Reverse recovery definition; ramp recovery

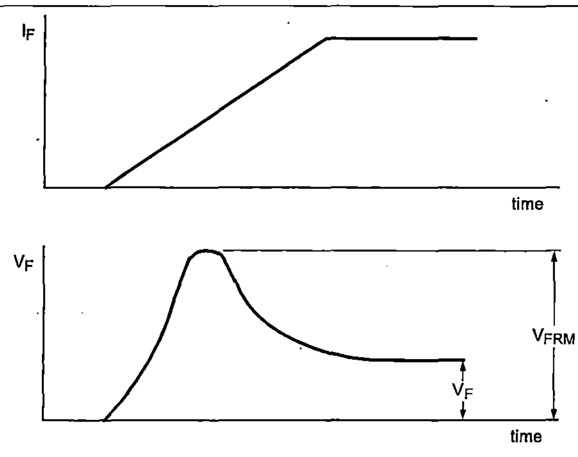

Fig. 9. Forward recovery definition

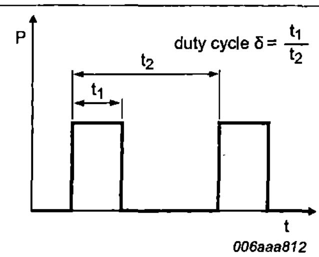

Fig. 10. Duty cycle definition

The current ratings for the typical waveforms are calculated according to the equations: $I_{F(AV)} = I_M \times \delta$ with I_M defined as peak current, $I_{RMS} = I_{F(AV)}$ at DC, and $I_{RMS} = I_M \times \sqrt{\delta}$ with I_{RMS} defined as RMS current.

12. Package outline

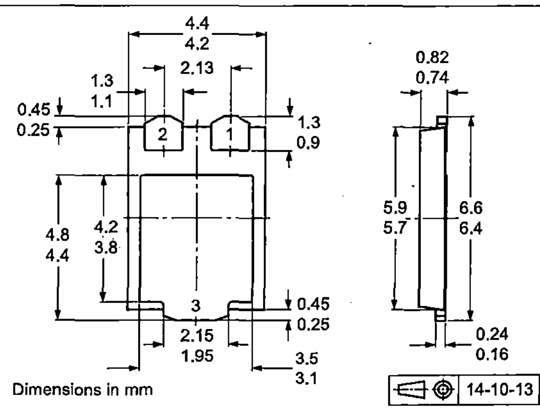

Fig. 11. Package outline CFP15 (SOT1289)

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13. Soldering

Footprint information for reflow soldering of CFP15 package **SOT1289**

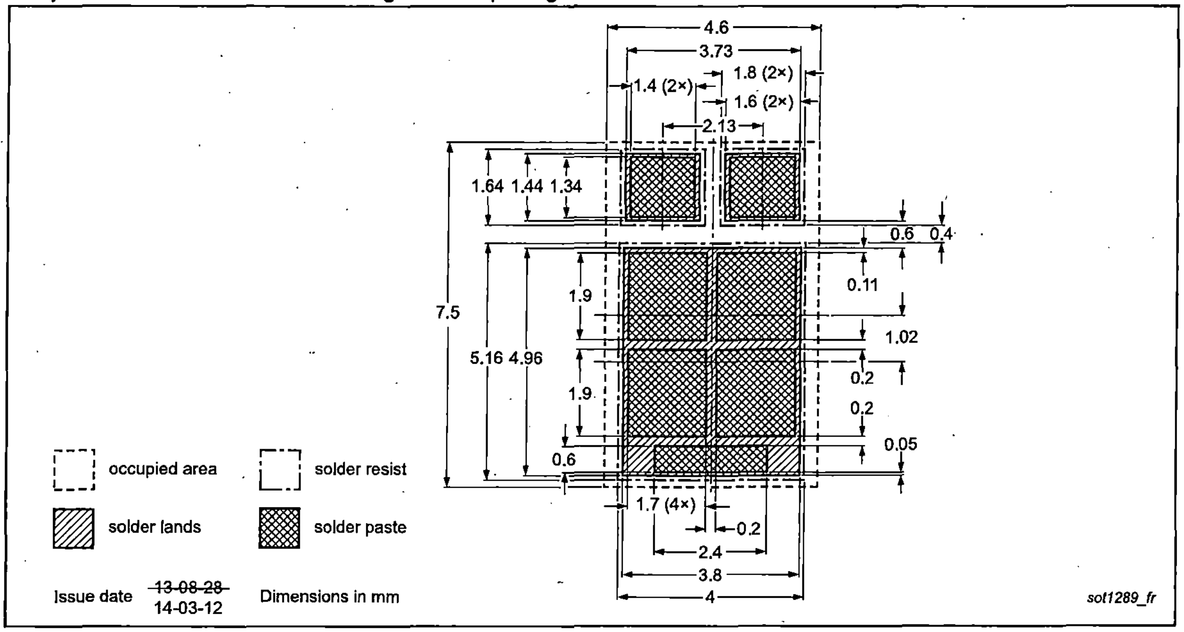

Fig. 12. Reflow soldering footprint for CFP15 (SOT1289)

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14. Revision history

Table 8. Revision history

Data sheet ID	Release date	Data sheet status	Change notice	Supersedes
PMEG45A10EPD v.3	20141216	Product data sheet	-	PMEG45A10EPD v.2
Modifications:	• Package outline drawing updated			
PMEG45A10EPD v.2	20140416	Product data sheet	-	PMEG45A10EPD v.1
PMEG45A10EPD v.1	20140217	Objective data sheet	-	-

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15. Legal information

15.1 Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nexperia.com.

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16. Contents

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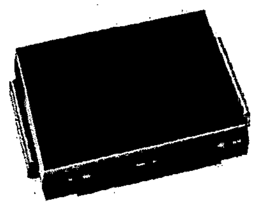
For sales office addresses, please send an email to: salesaddresses@nexperia.com
Date of release: 16 December 2014

Surface Mount TRANSZORB® Transient Voltage Suppressors



DO-214AB (SMC)

PRIMARY CHARACTERISTICS	
V_{BR} uni-directional	6.40 V to 231 V
V_{BR} bi-directional	6.40 V to 231 V
V_{WM}	5.0 V to 188 V
P_{PPM}	1500 W
P_D	6.5 W
I_{FSM} (uni-directional only)	200 A
T_J max.	150 °C
Polarity	Uni-directional, bi-directional
Package	DO-214AB (SMCJ)

DEVICES FOR BI-DIRECTION APPLICATIONS

For bi-directional devices use CA suffix (e.g. SMCJ188CA).

Electrical characteristics apply in both directions.

FEATURES

- Low profile package
- Ideal for automated placement
- Glass passivated chip junction
- Available in uni-directional and bi-directional
- Excellent clamping capability
- Very fast response time
- Low incremental surge resistance
- Meets MSL level 1, per J-STD-020, LF maximum peak of 260 °C
- AEC-Q101 qualified
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

TYPICAL APPLICATIONS

Use in sensitive electronics protection against voltage transients induced by inductive load switching and lighting on ICs, MOSFET, signal lines of sensor units for consumer, computer, industrial, automotive, and telecommunication.

MECHANICAL DATA

Case: DO-214AB (SMCJ)
Molding compound meets UL 94 V-0 flammability rating
Base P/N-E3 - RoHS compliant, commercial grade
Base P/NHE3 - RoHS compliant, AEC-Q101 qualified

Terminals: Matte tin plated leads, solderable per J-STD-002 and JESD 22-B102
E3 suffix meets JESD 201 class 2 whisker test, HE3 suffix meets JESD 201 class 2 whisker test

Polarity: For uni-directional types the band denotes cathode end, no marking on bi-directional types

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)

PARAMETER	SYMBOL	VALUE	UNIT
Peak pulse power dissipation with a 10/1000 µs waveform (1)(2)	P_{PPM}	1500	W
Peak pulse current with a 10/1000 µs waveform (1)	I_{PPM}	See next table	A
Peak forward surge current 8.3 ms single half sine-wave uni-directional only (2)	I_{FSM}	200	A
Power dissipation on infinite heatsink, T_A = 50 °C	P_D	6.5	W
Operating junction and storage temperature range	T_J, T_{STG}	- 55 to + 150	°C

Notes

(1) Non-repetitive current pulse, per fig. 3 and derated above T_A = 25 °C per fig. 2.
(2) Mounted on 0.31" x 0.31" (8.0 mm x 8.0 mm) copper pads to each terminal

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ELECTRICAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)									
DEVICE TYPE MODIFIED "J" BEND LEAD	DEVICE MARKING CODE		BREAKDOWN VOLTAGE V_{BR} AT I_T [(1)] (V)		TEST CURRENT I_T (mA)	STAND-OFF VOLTAGE V_{WM} (V)	MAXIMUM REVERSE LEAKAGE AT V_{WM} I_D (μA) [(3)]	MAXIMUM PEAK PULSE SURGE CURRENT I_{PPM} (A) [(2)]	MAXIMUM CLAMPING VOLTAGE AT I_{PPM} V_C (V)
	UNI	BI	MIN.	MAX.					
(+)SMCJ5.0A [(5)]	GDE	GDE	6.40	7.07	10	5.0	1000	163.0	9.2
(+)SMCJ6.0A	GDG	GDG	6.67	7.37	10	6.0	1000	145.6	10.3
(+)SMCJ6.5A	GDK	BDK	7.22	7.98	10	6.5	500	133.9	11.2
(+)SMCJ7.0A	GDM	GDM	7.78	8.60	10	7.0	200	125.0	12.0
(+)SMCJ7.5A	GDP	BDP	8.33	9.21	1.0	7.5	100	116.3	12.9
(+)SMCJ8.0A	GDR	BDR	8.89	9.83	1.0	8.0	50	110.3	13.6
(+)SMCJ8.5A	GDT	BDT	9.44	10.4	1.0	8.5	20	104.2	14.4
(+)SMCJ9.0A	GDV	BDV	10.0	11.1	1.0	9.0	10	97.4	15.4
(+)SMCJ10A	GDX	BDX	11.1	12.3	1.0	10	5.0	88.2	17.0
(+)SMCJ11A	GDZ	GDZ	12.2	13.5	1.0	11	5.0	82.4	18.2
(+)SMCJ12A	GEE	BEE	13.3	14.7	1.0	12	5.0	75.4	19.9
(+)SMCJ13A	GEG	GEG	14.4	15.9	1.0	13	1.0	69.8	21.5
(+)SMCJ14A	GEK	BEK	15.6	17.2	1.0	14	1.0	64.7	23.2
(+)SMCJ15A	GEM	BEM	16.7	18.5	1.0	15	1.0	61.5	24.4
(+)SMCJ16A	GEP	GEP	17.8	19.7	1.0	16	1.0	57.7	26.0
(+)SMCJ17A	GER	GER	18.9	20.9	1.0	17	1.0	54.3	27.6
(+)SMCJ18A	GET	BET	20.0	22.1	1.0	18	1.0	51.4	29.2
(+)SMCJ20A	GEV	BEV	22.2	24.5	1.0	20	1.0	46.3	32.4
(+)SMCJ22A	GEX	BEX	24.4	26.9	1.0	22	1.0	42.3	35.5
(+)SMCJ24A	GEZ	BEZ	26.7	29.5	1.0	24	1.0	38.6	38.9
(+)SMCJ26A	GFE	BFE	28.9	31.9	1.0	26	1.0	35.6	42.1
(+)SMCJ28A	GFG	BFG	31.1	34.4	1.0	28	1.0	33.0	45.4
(+)SMCJ30A	GFK	BFK	33.3	36.8	1.0	30	1.0	31.0	48.4
(+)SMCJ33A	GFM	BFM	36.7	40.6	1.0	33	1.0	28.1	53.3
(+)SMCJ36A	GFP	BFP	40.0	44.2	1.0	36	1.0	25.8	58.1
(+)SMCJ40A	GFR	BFR	44.4	49.1	1.0	40	1.0	23.3	64.5
(+)SMCJ43A	GFT	BFT	47.8	52.8	1.0	43	1.0	21.6	69.4
(+)SMCJ45A	GFV	GFV	50.0	55.3	1.0	45	1.0	20.6	72.7
(+)SMCJ48A	GFX	GFX	53.3	58.9	1.0	48	1.0	19.4	77.4
(+)SMCJ51A	GFZ	GFZ	56.7	62.7	1.0	51	1.0	18.2	82.4
(+)SMCJ54A	GGE	GGE	60.0	66.3	1.0	54	1.0	17.2	87.1
(+)SMCJ58A	GGG	GGG	64.4	71.2	1.0	58	1.0	16.0	93.6
(+)SMCJ60A	GGK	GGK	66.7	73.7	1.0	60	1.0	15.5	96.8
(+)SMCJ64A	GGM	GGM	71.1	78.6	1.0	64	1.0	14.6	103
(+)SMCJ70A	GGP	GGP	77.8	86.0	1.0	70	1.0	13.3	113
(+)SMCJ75A	GGR	GGR	83.3	92.1	1.0	75	1.0	12.4	121
(+)SMCJ78A	GGT	GGT	86.7	95.8	1.0	78	1.0	11.9	126
(+)SMCJ85A	GGV	GGV	94.4	104	1.0	85	1.0	10.9	137
(+)SMCJ90A	GGX	GGX	100	111	1.0	90	1.0	10.3	146
(+)SMCJ100A	GGZ	GGZ	111	123	1.0	100	1.0	9.3	162
(+)SMCJ110A	GHE	GHE	122	135	1.0	110	1.0	8.5	177
(+)SMCJ120A	GHG	GHG	133	147	1.0	120	1.0	7.8	193
(+)SMCJ130A	GHK	GHK	144	159	1.0	130	1.0	7.2	209
(+)SMCJ150A	GHM	GHM	167	185	1.0	150	1.0	6.2	243
(+)SMCJ160A	GHP	GHP	178	197	1.0	160	1.0	5.8	259
(+)SMCJ170A	GHR	GHR	189	209	1.0	170	1.0	5.5	275
SMCJ188A	GHS	GHS	209	231	1.0	188	1.0	4.6	328

Notes

(1) Pulse test: $t_p \leq 50$ ms
(2) Surge current waveform per fig. 3 and derate per fig. 2
(3) For bi-directional types having V_{WM} of 10 V and less, the I_D limit is doubled
(4) All terms and symbols are consistent with ANSI/IEEE C62.35
(5) For the bi-directional SMCJ5.0CA, the maximum V_{BR} is 7.25 V
(6) V_F = 3.5 V at I_F = 100 A (uni-directional only)
(+) Underwriters laboratory recognition for the classification of protectors (QVGQ2) under the UL standard for safety 497B and file number E136766 for both uni-directional and bi-directional devices

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THERMAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)			
PARAMETER	SYMBOL	VALUE	UNIT
Typical thermal resistance, junction to ambient air (1)	$R_{\theta JA}$	75	°C/W
Typical thermal resistance, junction to lead	$R_{\theta JL}$	15	

Note

(1) Mounted on minimum recommended pad layout

ORDERING INFORMATION (Example)				
PREFERRED P/N	UNIT WEIGHT (g)	PREFERRED PACKAGE CODE	BASE QUANTITY	DELIVERY MODE
SMCJ5.0A-E3/57T	0.211	57T	850	7" diameter plastic tape and reel
SMCJ5.0A-E3/9AT	0.211	9AT	3500	13" diameter plastic tape and reel
SMCJ5.0AHE3/57T (1)	0.211	57T	850	7" diameter plastic tape and reel
SMCJ5.0AHE3/9AT (1)	0.211	9AT	3500	13" diameter plastic tape and reel

Note

(1) AEC-Q101 qualified

RATINGS AND CHARACTERISTICS CURVES (T_A = 25 °C unless otherwise noted)

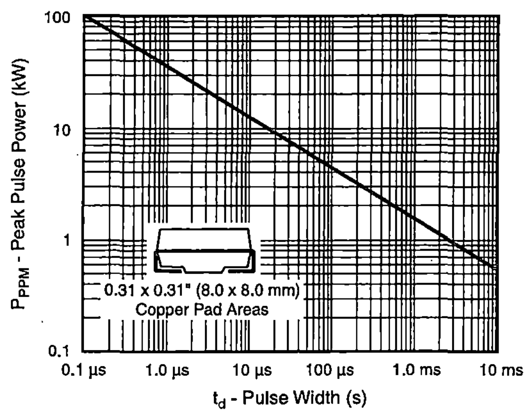

Fig. 1 - Peak Pulse Power Rating Curve

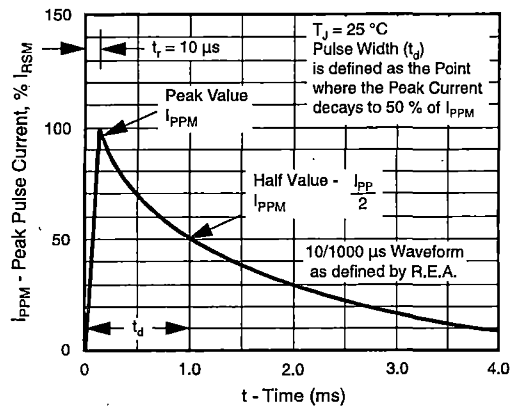

Fig. 3 - Pulse Waveform

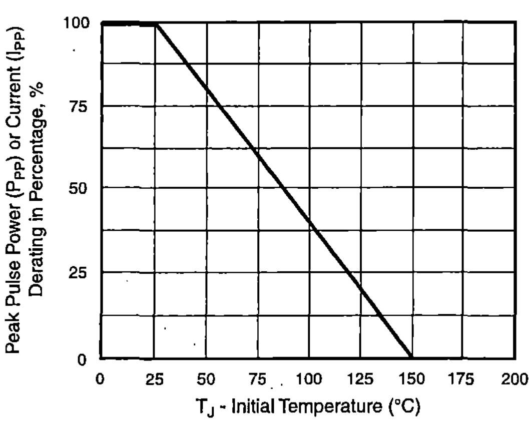

Fig. 2 - Pulse Power or Current vs. Initial Junction Temperature

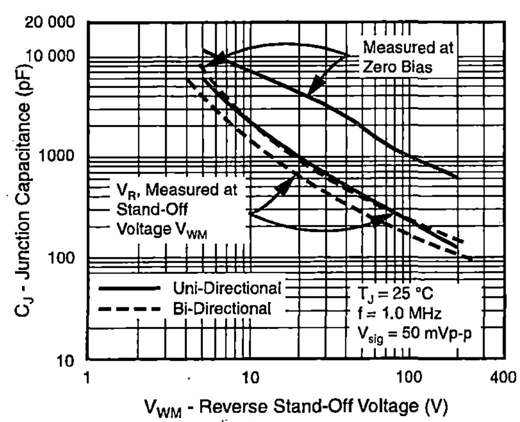

Fig. 4 - Typical Junction Capacitance Uni-Directional

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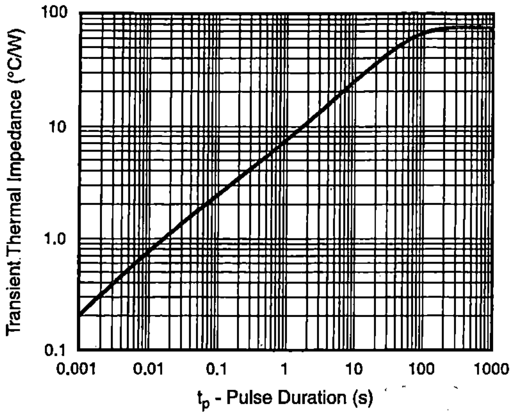


Fig. 5 - Typical Transient Thermal Impedance

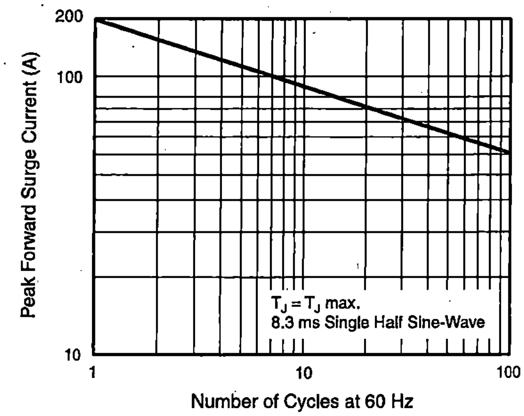
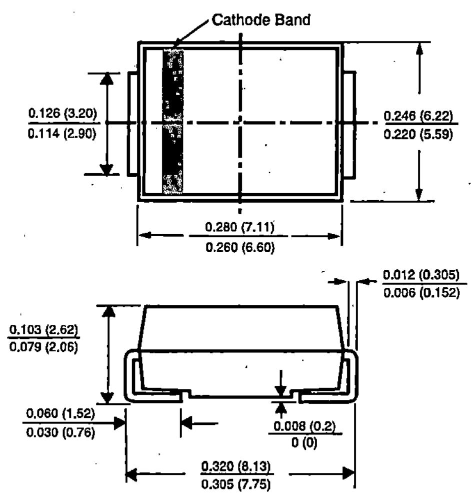


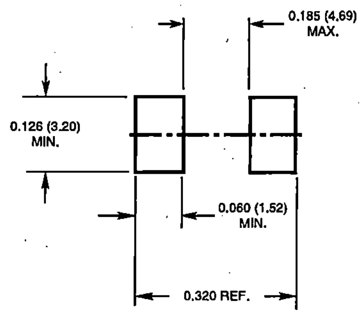
Fig. 6 - Maximum Non-Repetitive Peak Forward Surge Current Uni-Directional Use Only

PACKAGE OUTLINE DIMENSIONS in inches (millimeters)

DO-214AB (SMC J-Bend)



Mounting Pad Layout



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Fwd: AC-Order-Confirmation-[51410]

Shawn Wesley Hanvy
Sent: Tuesday, January 17, 2017 12:50 PM
To: John P Foster; Al Queirolo; Dane Electron Kouttron; Edward Lau; Paul T Menadier

Ship date of 1/24/2017

Shawn Hanvy

Begin forwarded message:

From: <anthony.aragon@4pcb.com>
Date: January 17, 2017 at 12:49:17 PM EST
To: <hanvysw@mit.edu>
Subject: AC-Order-Confirmation-[51410]

Thank you for your order!
Please review your order details carefully and
call us immediately if you need to make any corrections.

Your sales representative is: Dalal Jad (800) 979-4722 x1311
Mail To: dalal.jad@4pcb.com

MailTo: hold@4pcb.com for corrections after 5:00 PM MT

Advanced Circuits
21101 East 32nd Parkway
Aurora CO 80011
(800) 979-4722
www.4pcb.com

PAGE: 0
AC WORK ORDER-NO: 51410
CUSTOMER-NO: 49471
SHIP-TO: 0001
ORDER-DATE: 01/17/2017

|SHIP-DATE:01/24/2017 |

SOLD-TO:
NRL
138 Albany St
Cambridge MA
02139 United States

SHIP-TO:
NRL
138 Albany St
Cambridge MA
02139 United States

Contact: Shawn Hanvy
Phone: 6172530342
Fax:
E-mail: hanvysw@mit.edu
FileName: Sig Dist Mod_v4_1.zip

TERMS: CREDIT CARD
PartNumber: SDM
Rev: 1

CUST-PO: CC
SHIP-VIA: FedX 2nd DAY
ShippingAccount: 160736461
Type: New Order

REFERENCE-#: 0
Your Web Order Number: 10003075
Your Quote Number: 4635250

LN	ITEM-NUMBER	DESCRIPTION	QUANTITY	NET-PRICE	EXT-AMOUNT
1	104	Prototype - 4 Layer	1EA	648.24	648.24
2	94	Handling	1EA	10.00	10.00
3	717	FreeDFM Disc $100	1EA	-100.00	-100.00

Grand Total: 558.24

ITAR: no
Certs: IPC Class 2-A600 AS9100: no
Electrical Test: NO 5% OVERAGE: no
Material Type: FR4
Material Thickness: 0.062" Board Finish: LFSOLDER
Unit Dimensions: 10.000 x 12.000
Array Dimensions: 00.000 x 00.000 Array Number Up: 0
Array Qty: 0
Tab Rout: NO Scoring: NO
Copper Weight: 1 oz Inner Copper Weight: 1.0
Solder Mask Sides: Both Sides Solder Mask Color: GREEN
Legend Silk Scrn: Both Sides Legd/Silk Scrn Color: WHITE
Castellated Holes: no
Blind/Buried Vias: None SM Plugged Via: no
Via-In-Pad: None Microvias: None
Plated Slots: no Plated Edges: no
CounterSinks: no CounterBores: no
CtrSinksPlated: 0 CtrBoresPlated: 0
CtrSinksNon-Pltd: 0 CtrBoresNon-Pltd: 0
Ctrld Dielectric: no Ctrld Impedance: no
Etchback: no # Pem Nuts: 0

NOTE: This order is subject to Advanced Circuits Terms and Conditions.
Please visit our website www.4pcb.com/pcb-term-conditions.html for details.

Certificate of Registration

This certifies that the Quality Management System of

Advanced Circuits, Inc. - Fabrication Group

21101 E. 32nd Parkway
Aurora, Colorado, 80011, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 9001:2008

Scope of Registration:
Fabrication of Bare Printed Circuit Boards.

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

Certificate Number:	C0121245-IS2
Certificate Issue Date:	12-MAY-2015
Registration Date:	06-JUN-2015
Expiration Date *:	05-JUN-2018

Carl Blazik,
Director, Technical
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Drawings and Schematics

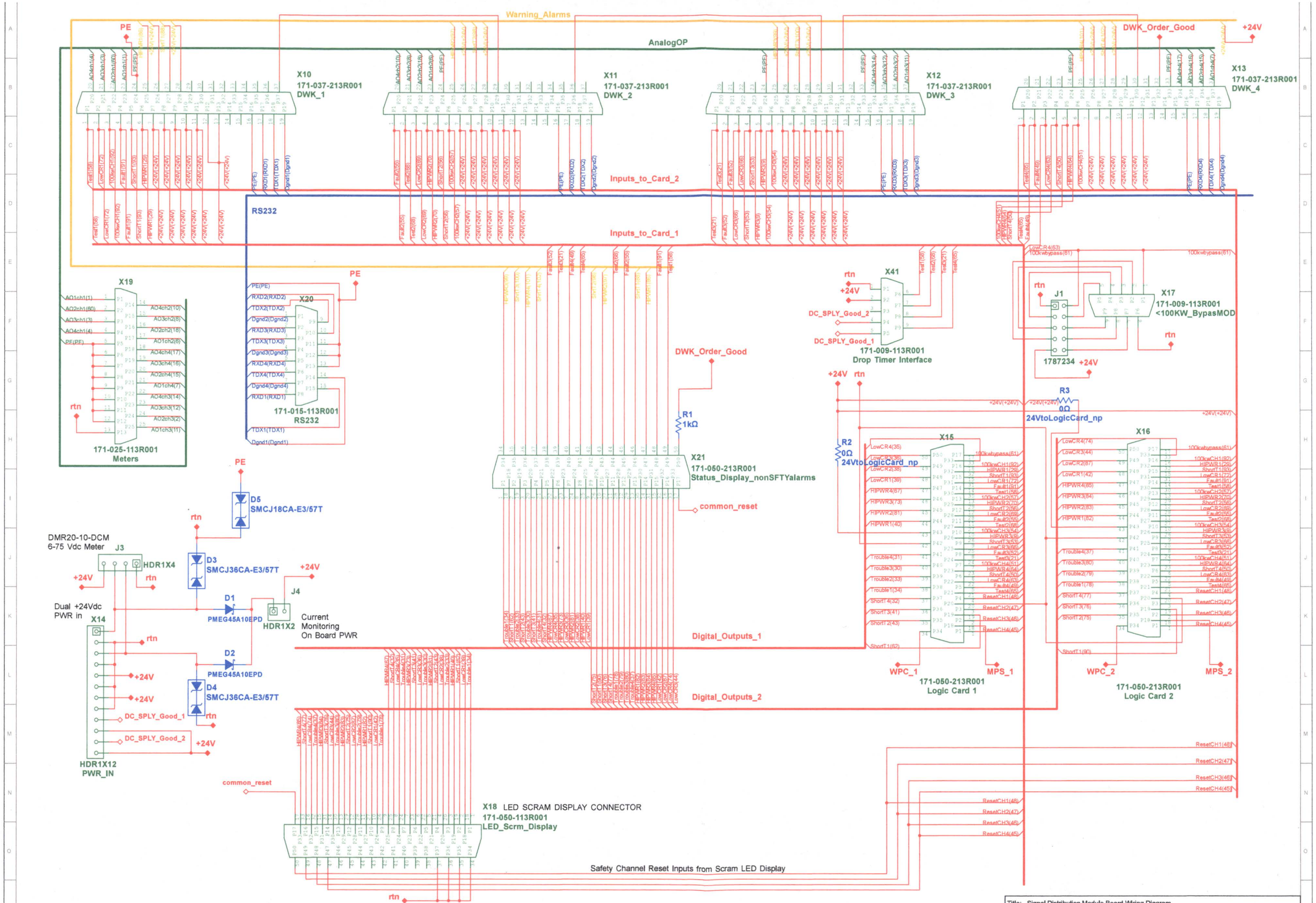
NSS Signal Distribution Module

1. Drawing R3W-274-3 "Signal Distribution Module Board Wiring Diagram" is the schematic showing circuit diagram details for the Signal Distribution Module.

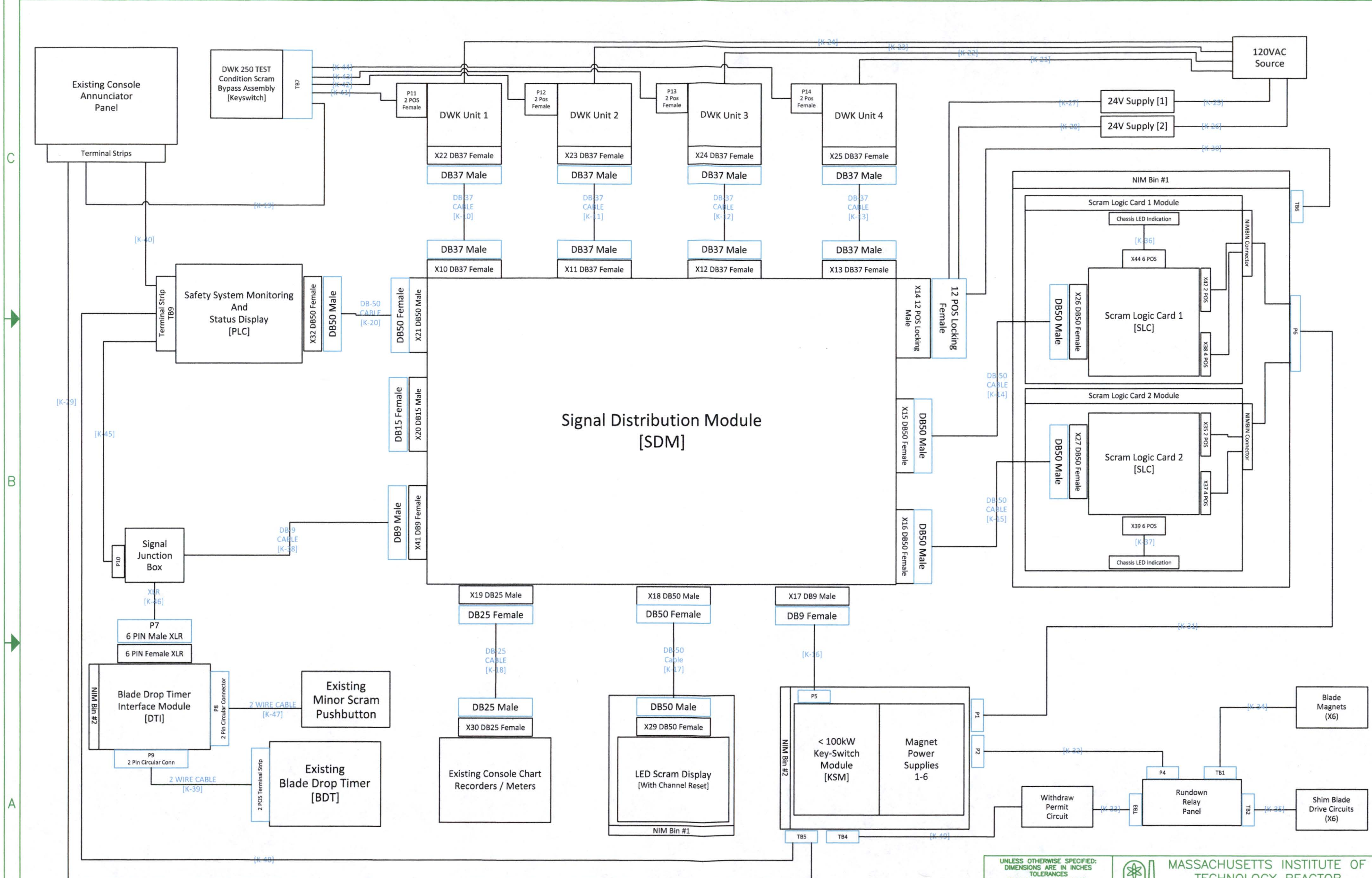
2. Drawing R3W-268-2 "Nuclear Safety System Global Connection Diagram" is a block diagram that shows an overview of all the input and output connections for the Signal Distribution Module.

3. An image of the completed Signal Distribution Module is shown in Figure 1 of the Safety Review for the Signal Distribution Module, QA file #2017-34.

4. The final physical location of the Signal Distribution Module in the reactor control room is detailed in the New Nuclear Safety System Installation Plan.



Title: Signal Distribution Module Board Wiring Diagram		
File No. QA#-2017-34		
Drawn by: S. Hanvy	Document N: R3W-274-3	Revision:
Reviewed & Approved by: PM/EL	Date: 4/5/2017	Size: Custom
Designed by: D. Kouttron	Sheet 1 of 1	



ZONE	REV	DESCRIPTION	DATE	APPROVED

REVISIONS

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± XX .XXX ± XX ANGULAR ± XX
DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

NUCLEAR SAFETY SYSTEM GLOBAL CONNECTION DIAGRAM

DRAWN	KOUTTRON	DATE 11/17/17
REVIEWED & APPROVED	SH/PM	12/1/17
DESIGN	KOUTTRON	4/10/17

SIZE B | FILE NO. QA# 2017-34 | DWG NO. R3W-268 -2 | REV
SCALE NONE | SHEET 1 OF 1

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Instrumentation Supervisor
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138 Albany Street
Cambridge, MA 02139

Phone: 617-253-0342
Fax: 617-253-7300
Web: http://nrl.mit.edu

Fabrication

NSS Signal Distribution Module

1. The Signal Distribution Module was fabricated in-house. Fabrication of the printed-circuit board (PCB) itself was by Advanced Circuits. (Its invoice and certificate of registration are under the Procurement section of this QA file.) The reactor's Instrumentation Supervisor placed the components for the PCB.

2. Parts and materials necessary for the construction of the Signal Distribution Module are listed in the Procurement section of this QA file. A Bill of Materials is attached here.

3. Fabrication compliance:

   After the PCB was manufactured by Advanced Circuits, the Instrumentation Supervisor inspected it and verified it was constructed according to the design specification. The Instrumentation Supervisor then soldered in place all the connectors and the auctioneering diodes. Then the PCB was mounted in its metal chassis with mounting screws.

   The Signal Distribution Module was verified to have been constructed as designed.

Constructed by: Shawn Hanvy, Instrumentation Supervisor — 9/21/2017 Date

Verified by: Edward Lau, Assistant Director of Reactor Operations — 09/21/2017 Date

Quantity	Description	RefDes	Package	Manufacturer
4	DSUB, 171-037-213R001	X10, X11, X12, X13	Norcomp\171-037-213R001	NorComp
3	DSUB, 171-050-213R001	X15, X16, X21	Norcomp\171-050-213R001	NorComp
2	DSUB, 171-009-113R001	X17, X41	Norcomp\171-009-113R001	NorComp
1	HEADERS_TEST, HDR1X12	X14	Generic\HDR1X12	
2	SCHOTTKY_DIODE, PMEG45A10EPD	D1, D2	NXP Semiconductors\SOT-1289-3(SOT1289)	NXP Semiconductors
1	HEADERS_TEST, HDR1X4	J3	Generic\HDR1X4	
2	PROTECTION_DIODE, SMCJ36CA-E3/57T	D3, D4	Vishay\DO-214AB(DO-214AB)	Vishay
1	DSUB, 171-050-113R001	X18	Norcomp\171-050-113R001	NorComp
1	HEADERS_TEST, HDR1X2	J4	Generic\HDR1X2	
1	DSUB, 171-025-113R001	X19	Norcomp\171-025-113R001	NorComp
1	DSUB, 171-015-113R001	X20	Norcomp\171-015-113R001	NorComp
1	PROTECTION_DIODE, SMCJ18CA-E3/57T	D5	Vishay\DO-214AB(DO-214AB)	Vishay
1	HEADERS_TEST, 1787234	J1	Phoenix Contact\1787234	Phoenix Contact
1	RESISTOR, 1kΩ	R1	IPC-7351\Chip-R0805	
2	RESISTOR, 0Ω	R2, R3	IPC-7351\Chip-R0805	

MIT NUCLEAR REACTOR LABORATORY

AN MIT INTERDEPARTMENTAL CENTER

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Bench Testing

NSS Signal Distribution Module

Nuclear Safety System (NSS) Signal Distribution Module Verification Test:

1. Connect two NSS Scram Logic Card (SLC) Modules to the Signal Distribution Module.
2. Connect the Signal Distribution Module to the Logic Testing Board (described and shown in Figure 4-4 of the SAR Chapter 7 Appendix for the New NSS), which simulates trip signals from the four DWK 250 chassis.
3. Connect the Signal Distribution Module to both of the associated 24-volt DC power supplies.
4. Connect the LED Scram Display Module to the Signal Distribution Module, and reset any latched-in trip conditions.
5. On the Logic Testing Board, cycle through representations of the six trip signals from each of the four DWK 250s, in both the Full Power Operation mode and the <100 kW Operation mode. While each trip is still active, check if it is possible to reset it. Record all responses on the data table.
   (The data table has been independently verified by a Senior Reactor Operator and the QA Supervisor as containing all possible trip states from the four DWK 250 chassis. Verified by SRO: [signature] QA Supervisor: Susan Tucker .)
6. Reset latched-in alarms and continue testing until all trip states are verified to have the correct response.

Acceptances Criteria and completed results:

The above Verification Test was completed satisfactorily on the Signal Distribution Module with two Scram Logic Cards (cards #002 and #004). Results confirm that for every given input trip signal, the correct SLC output response is observed. The test results are attached.

[signature] 2/14/2017

Test performed by: Dane Kouttron, Special Projects Engineer — Date

[signature] 2/14/2017

Reviewed and approved by: Shawn Hanvy, Instrumentation Supervisor — Date

board # 002

cause trip, remove trip verify latched state, reset channel after test

CHANNEL 1 TEST

SWITCH STATE

CH1 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH1 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH1 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH1 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH1 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH1 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH1 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 2 TEST

SWITCH STATE

CH2 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH2 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH2 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH2 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH2 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH2 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH2 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 3 TEST

SWITCH STATE

CH3 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH3 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH3 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH3 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH3 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH3 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH3 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 4 TEST

SWITCH STATE

CH4 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH4 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH4 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH4 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH4 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH4 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH4 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

board # 004

cause trip, remove trip verify latched state, reset channel after test

CHANNEL 1 TEST

SWITCH STATE

CH1 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH1 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH1 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH1 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH1 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH1 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH1 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH1 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 2 TEST

SWITCH STATE

CH2 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH2 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH2 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH2 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH2 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH2 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH2 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH2 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 3 TEST

SWITCH STATE

CH3 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH3 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH3 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH3 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH3 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH3 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH3 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH3 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANNEL 4 TEST

SWITCH STATE

CH4 HIPWR	0	1	0	0	0	0	0	0	1	0	0	0	0	0
CH4 SHORT PERIOD	0	0	1	0	0	0	0	0	0	1	0	0	0	0
CH4 100KW	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CH4 LOWCR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
CH4 FAULT	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH4 TEST	0	0	0	0	0	0	1	0	0	0	0	0	0	1
100KW MODE SWITCH	0	0	0	0	0	0	0	1	1	1	1	1	1	1

LIGHT STATE

TROUBLE	0	0	0	0	0	1	1	0	0	0	0	0	1	1
SHORT T	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LOW CR	0	0	0	0	1	0	0	0	0	0	0	1	0	0
HIPWR	0	1	0	0	0	0	0	0	1	0	1	0	0	0

WHILE THE STATE IS SATISFIED CAN YOU RESET IT?

CH4 HIPWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 SHORT PERIOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 100KW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 LOWCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 FAULT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH4 TEST	0	0	0	0	0	0	0	0	0	0	0	0	0	0

QUALITY ASSURANCE REQUIREMENTS CHECKLIST: QA # 2017-38

Plan, procedure or equipment affected: NSS Magnet Power Supply Modules

Initiator: T. Leurini / E. Lau Date: 9/6/2017

Class of change: ☑ Class A ☐ Class B ☐ Class C
Type of change: ☐ Procedure ☐ Mechanical ☑ Electrical ☐ ________
Extent of change: ☑ Installation ☐ Modification ☐ Maintenance ☐ ________

Approval of QA requirements as listed in Sections I - III below:

Superintendent: [signature] Date: 12/14/17 Director of Reactor Operations: [signature] Date: 10/31/2017

I	Document List		Completed By:	Date:
	Proposal (Class C changes)			
✓	Safety Review (Class A/B changes)		E. Lau E	11/09/2017
✓	Specifications		E. Lau/P. Menadier PM	09/06/2017
✓	Procurement		E. Lau/P. Menadier PM	12/12/2017
✓	Drawings and Schematics		E. Lau/P. Menadier PM	12/06/2017
✓	Fabrication		E. Lau/P. Menadier PM	11/20/2017
✓	Bench Testing		E. Lau/P. Menadier PM	11/29/2017
	Handling and Installation Instructions			
	Industrial Safety Checklist			

Above requirements are complete. Equipment is ready to be installed or procedure is ready to be implemented.

Superintendent or DRO: [signature] Date: 12/14/17

II	Document List		Completed By:	Date:
✓	Installation and Inspection			
✓	Testing and Calibration			
	Operating Procedures and Checklists			

Above requirements are complete. Equipment is ready to be placed in operation.

Superintendent or DRO: ____________ Date: ________

III	Document List		Completed By:	Date:
	Reactor Systems Manual			
	Safety Analysis Report			
✓	Safety Review Distribution			
	Training			

All requirements of QA package complete: ____________ QA Supervisor ________ Date

____________ Superintendent ________ Date ____________ Director of Reactor Operations ________ Date

Additional approvals needed by: ☐ MITRSC (approval attached) ☐ USNRC (approval attached)

Safety Review Form No. 2017-38

Item: NSS Magnet Power Supply

Submitted by E. Lau/S. Tucker Date 11/8/2017

Q/A number (required for all equipment changes) ____________

	Yes*	No
Does the item change or contradict the Technical Specifications?	☐	☒
Does the item contradict the SAR?	☒	☐

*Attach explanation

Description of Change (Attach extra pages if necessary):

See attached.

Safety Evaluation (Attach extra pages if necessary):

See attached.

Summary of Review:

a) Does the proposal:	Yes	No
i) require a license amendment (10CFR50.59(c)(2))	☒	☐
ii) decrease scope of requalification program (10CFR50.54(i-1))	☐	☒
iii) decrease effectiveness of security plan (10CFR50.54(p))	☐	☒
iv) decrease effectiveness of emergency plan (10CFR50.54(q))	☐	☒

b) Reviewer's Comments:

Reviewer [signature] Date 11/8/17

Reviewer [signature] Date 11/9/17

Reviewer [signature] Date 11/9/17
(Reactor Radiation Protection Officer)

Approved [signature] Date 11/9/17
(Director of Reactor Operations)

Date of MITRSC approval if required 11/16/2017 Date of NRC approval if required ____________

List of Communications containing MITRSC additional conditions:

10 CFR 50.59 & 50.54 (p and q) changes included in Annual Report to NRC, Fiscal Year ____________

Evaluation of SR#-2017-38 under 50.59 Requirements

This change requires a change to the SAR and a license amendment per 10 CFR 50.59. See QA File #E-2012-1.

ALARA Determination for SR#-2017-38

The changes will have no impact on ALARA because the changes do not change the time spent in high radiation areas.

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Q/A Files #2017-38 & #2017-39
"Magnet Power Supply Modules and Rundown Relay Panel"

Description of Magnet Power Supply Modules (a.k.a. Magnet Power Supplies)

The function of the Magnet Power Supplies is to provide current (~80 milliamps DC) to the electromagnets for all six shim blades (i.e., absorber sections of the control devices) in the reactor core. Each magnet holds the weight of its shim blade, attaching it to its drive mechanism via the magnet. When current to the magnet is interrupted, the shim blade will decouple from its magnet and drive, and travel vertically by gravity into the reactor core, scramming (i.e., automatically shutting down) the reactor in less than one second.

In the existing nuclear safety system, power for the magnets originates in the electronic circuitry of the six nuclear safety amplifiers. These amplifiers provide the necessary trip signals, three on high power and three on short period, and use those signals to interrupt current to the magnets. The interruption is first applied to the magnets for a pre-selected pair of shim blades (blades 1 & 4, or blades 2 & 5, or blades 3 & 6), and then to the remaining four magnets.

The new Nuclear Safety System will not consist of safety amplifiers. Instead, high power and short period trips all originate from four independent Mirion DWK 250 neutron flux monitors. The new Magnet Power Supplies will consist of three modules (photo in Figure 1), with each module providing magnet current to two shim blades (blades 1 & 2, blades 3 & 4, and blades 5 & 6). Each module interfaces with its corresponding rundown relay circuit, with magnet current passing through the Rundown Relay Panel on its way to the magnet. The function of the Rundown Relay Panel will be described in the next section.

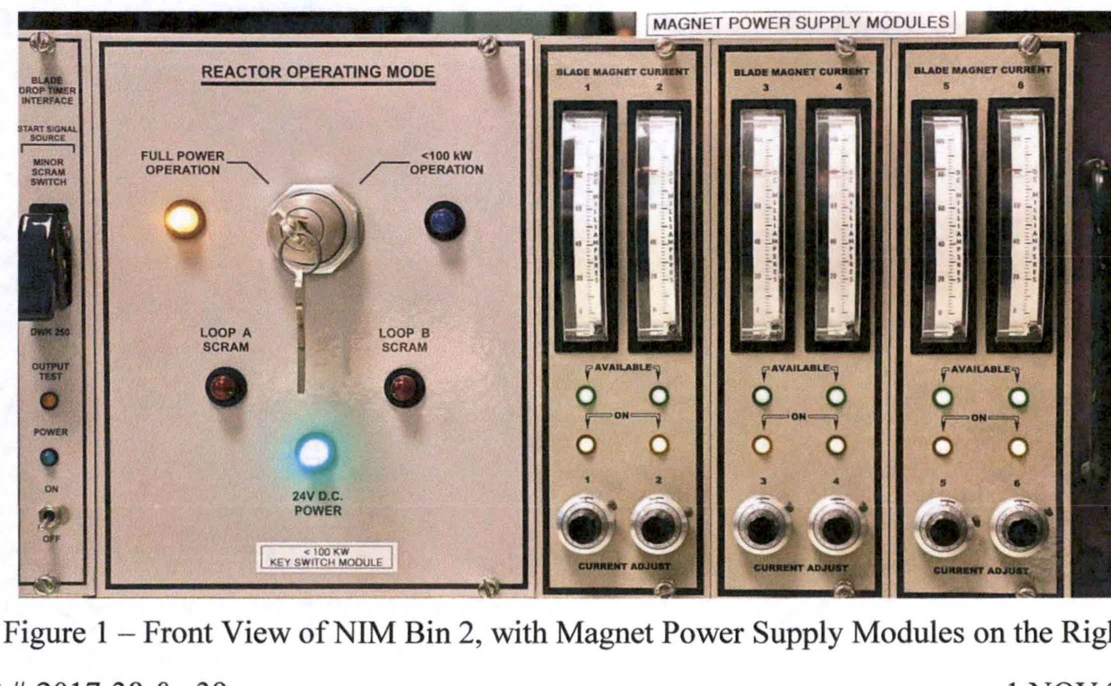

Figure 1 – Front View of NIM Bin 2, with Magnet Power Supply Modules on the Right

Each Magnet Power Supply Module is a stand-alone electronic device, made of discrete components, with its own 24-volt DC power supply. (See photo in Figure 2.) Each module has two "current adjust" potentiometers, one for each associated shim blade magnet. The potentiometer drives a reference for an adjustable regulator for current to the associated shim blade magnet. The adjusted magnet current is displayed on a meter above the potentiometer, again one for each shim blade.

Magnet current is interrupted in each Magnet Power Supply Module via two relays that are controlled by Scram Loops A and B from the output of the Scram Logic Cards. For instance, relay contacts GM1A-1 and GM1B-1 on Drawing R3W-258-4 "Magnet Power Supplies and Rundown Relay Panel" for shim blade 1 belong to relays GM1A and GM1B in Scram Loops A and B respectively. If Scram Loop A, or Scram Loop B, or both A and B are open, i.e. in scram condition, these relay contacts will open to interrupt magnet current to shim blade 1. Likewise, contacts GM1A-2 and GM1B-2 for shim blade 2 will open to interrupt magnet current to shim blade 2.

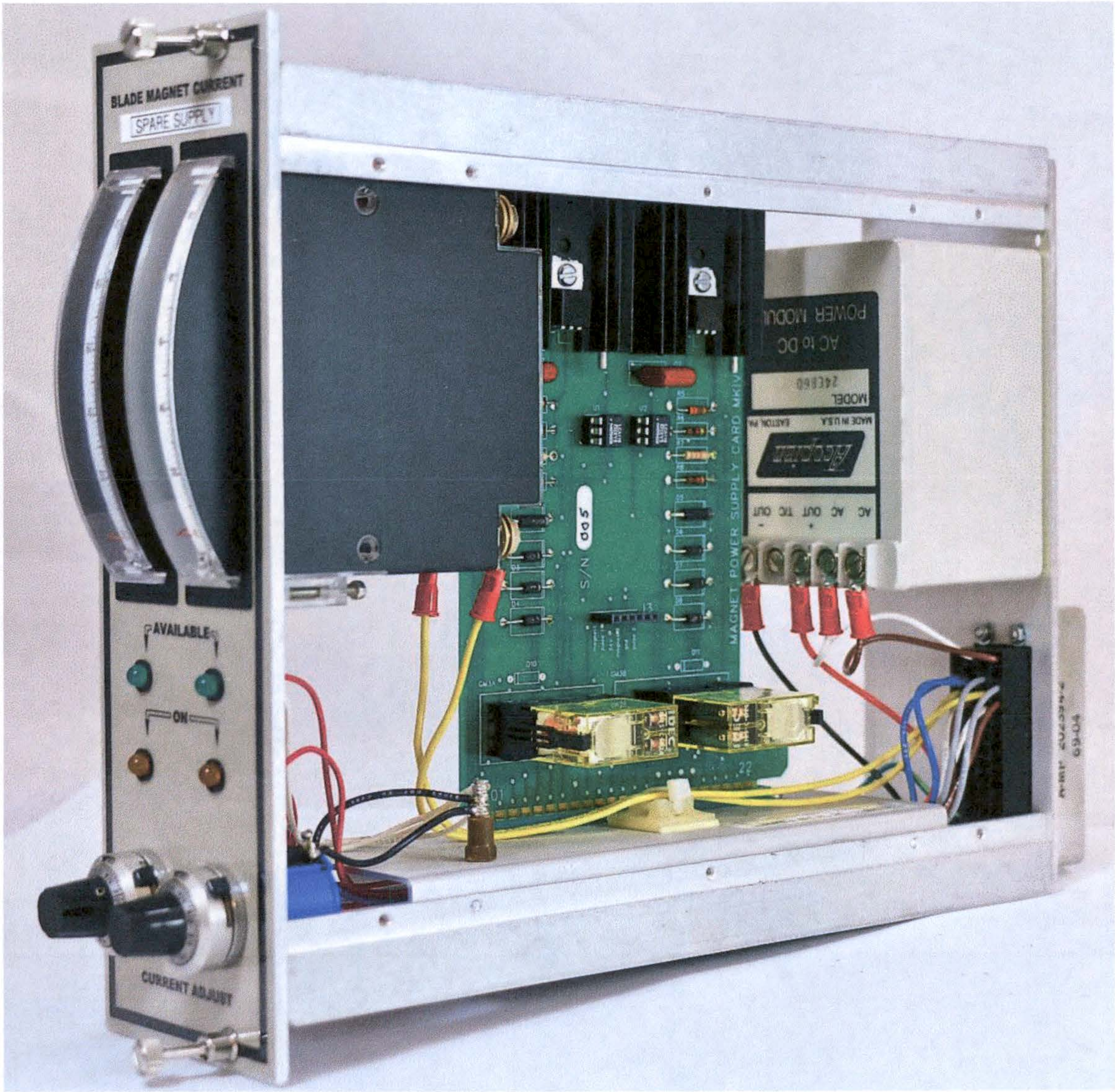

Figure 2 – Magnet Power Supply Module, Showing Interior with 24-Volt DC Power Supply

The Withdraw Permit Circuit (WPC) interrupts magnet current via relays in the Rundown Relay Panel, as described in the next section. For redundancy, when the WPC is open, the 120-volt AC line power from reactor electrical circuit L21 itself will be interrupted, thereby simultaneously de-energizing all three 24-volt DC power supplies for the three Magnet Power Supply Modules. This can be seen on Drawing R3W-258-4, where relay RY4 from the WPC will open relay contact RY4-1 when the WPC is open, thereby interrupting the 120-volt AC line power to all three 24-volt DC Magnet Power Supplies. The independent interruption of the Magnet Power Supplies via the nuclear safety Scram Logic Cards and the WPC provides redundancy and prevents common-mode failure.

Description of Rundown Relay Panel (a.k.a. Rundown Relays)

The function of the Rundown Relays is to move each shim blade's drive mechanism to its "full in" position at its normal speed whenever magnet current to the shim blade's electromagnet is removed. When the blade's magnet current is interrupted, the blade is intended to drop by gravity into the core. Moving the blade drive in behind it automatically is to ensure that the blade reaches its bottom position and stays there following a scram, completing the protective action once it is initiated.

The Magnet Power Supplies are composed of three independently-powered modules, each supplying current to a pair of shim blade magnets. The Rundown Relays, however, are all part of one panel (photo in Figure 3), and use their own pair of 24-volt DC power supplies to energize the controlling circuits for all six shim blades. These 24-volt DC power supplies are set up in parallel, but connected via auctioneering diodes, so that if one fails, the other will take over seamlessly.

Figure 3 – Front View of the Rundown Relay Panel

When the Magnet Power Supplies are energized, current goes through the Rundown Relay Panel via three relay contacts connected in series. For instance, for shim blade 1, these

relay contacts are B1A-1, B2A-1, & RR1-1 on Drawing R3W-258-4; or for shim blade 2, these relay contacts are B1A-2, B2A-2, & RR2-1. Relays B1A and B2A are controlled by the Withdraw Permit Circuit (WPC). If the WPC is open, i.e. in scram condition, these relays interrupt magnet current to the associated shim blade. Relays RR1 and RR2 also interrupt magnet current, if the magnitude of that current drops below a pre-determined value (~5 mA) which is set by an opto-relay (U1 for shim blade 1, U2 for shim blade 2).

The RR1, RR2, etc., relays perform two additional functions: controlling an indicator light that shows the status of the rundown relay circuit for its corresponding shim blade, and overriding normal control of the shim blade's drive motor. The indicator light stays out whenever the magnet current is at normal operating level. It comes on when the magnet current is low or near zero; the corresponding shim blade drive will be moving in, until it reaches its full-in position. Whenever the WPC is open, the indicator lights will stay on, denoting the control overrides which prevent any shim blade drive from being moved outward. Even after the WPC is reset and re-energized, this override condition will remain in effect until the Rundown Relays themselves are reset by the console operator. Additionally, the Rundown Relays cannot be reset if the magnet current is below a pre-determined value. When each Rundown Relay is reset, its indicator light goes out.

The Rundown Relay for each shim blade can be individually reset once the blade drive has reached the full-in position and the WPC has been reset and re-energized. A master reset (pushbutton PB7, acting via relays MR1 and MR2 on Drawing R3W-258-4) is also available to reset all six Rundown Relay circuits simultaneously. Figure 3 includes the master reset pushbutton and shows all Rundown Relays reset and their indicator lights off.

Safety Evaluation

Both the Magnet Power Supplies and the Rundown Relay Panel will continue to perform their safety functions as defined by the SAR.

Redundancy, Independence and Diversity

There are six independent ways to interrupt current to any given shim blade magnet: two relays from the Scram Logic Cards (via scram loops A and B), two relays from the WPC in the blade's rundown relay circuit, one relay in the blade's rundown relay circuit that opens upon low current, and one relay (RY4) from the WPC in the 120-volt AC line power supply. If there is a Nuclear Safety System scram, all six of these ways will have their relays open, to ensure a reactor scram. If there is a process system scram (e.g. low flow on the primary coolant system, low pressure city water, etc.), then only four of the above ways will apply: two relays from the WPC in the blade's rundown relay circuit, one relay in the blade's rundown relay circuit that opens upon low current, and one relay from the WPC in the 120-volt AC line power supply. Most importantly, any one of these ways will cause a magnet current interruption to shut down the reactor, and will activate the Rundown Relay Panel to drive all the shim blades in. (The regulating rod will also be driven in when the WPC is open, but via the existing rod control circuit.)

Except for relay RY4, all five other relays mentioned above in the Magnet Power Supply Module and the Rundown Relay for each shim blade are wired in series. If any one of those is open, magnet power to that shim blade is interrupted.

Each of the three Magnet Power Supply Modules has its own independent 24-volt DC power supply. All three 24-volt power supplies are downstream from the common relay (RY4) that will open when the WPC is open.

The Rundown Relay Panel has its own dual 24-volt DC power supply. A green indicator light at the front of the Rundown Relay Panel illuminates when there is power from the dual 24-volt DC supply. This indicator light is shown lit in Figure 3.

In summary, redundancy of scram relays and independence of scram activation(s) minimizes the risk of common-mode failure of the Magnet Power Supply Modules and the Rundown Relay Panel.

Cybersecurity and Isolation

The Magnet Power Supply Modules and the Rundown Relay Panel are built with standard industrially-rated components. They contain no digital components, being constructed with non-programmable solid-state and discrete devices. Therefore, they are not subject to cybersecurity threats.

The Magnet Power Supply Modules and the Rundown Relay Panel are constructed within metallic enclosures. Along with use of mechanical relays that typically fail open along the scram path, impact from electromagnetic interference is minimized.

Opto-coupled relays, one for each shim blade, are used within the Magnet Power Supply Modules. For instance, they are shown as contacts U1-1 and U2-1 in Drawing R3W-258-4 for shim blade 1 and shim blade 2 respectively. The opto-relays were chosen for their sensitivity to low current, i.e., less than 5 milliamps. Upon sensing current dropping to a low value, the optical portion of the relay will then deactivate the solid-state portion to de-energize the coil of relay RR1 for shim blade 1, or RR2 for shim blade 2, etc.

All the 24-volt DC power supplies for the three Magnet Power Supply Modules and the Rundown Relay Panel are protected by their own fuses against overcurrent conditions. In line with each shim blade magnet, downstream of the Magnet Power Supply Module and Rundown Relay, is a fuse that prevents any power surge from damaging the magnet. Each fuse is rated for no more than 0.25 amperes. Therefore, the Magnet Power Supply Modules and the Rundown Relay Panel are adequately protected from power surges in their operating environment.

Access Control and Physical Protection

The Magnet Power Supplies and the Rundown Relay Panel will be rack-mounted within the protective metal cabinets of the control room console. The console cabinets will continue to provide the equipment with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. The air-conditioning control easily satisfies the operating requirements of all the components, which are of standard industrial qualifications. When the reactor is shut down and the building is secured, the Magnet Power Supply Modules and the Rundown Relay Panel are de-energized.

Human Factors

Human interface with the Magnet Power Supply Modules is via current-adjust knobs, and meters on the modules showing the instantaneous magnet current for the corresponding shim blades. These are quite similar to the interface for the existing magnet power supply equipment. The human interface with the Rundown Relay Panel is via indicator lights and reset pushbuttons, as described previously. These interfaces are in plain sight, and conveniently near the main part of the console for the operator. Therefore, this part of the human factors engineering is adequate and equivalent to the current system.

The new rundown relay panel is also equipped with a master reset pushbutton to allow the operator to reset all six Rundown Relay circuits simultaneously. This enhances the human interface.

All cable connections to the Magnet Power Supply Modules and the Rundown Relay Panel are labeled, as are key electronic components on circuit boards. These markings improve the human interface for purposes of installation and maintenance.

Verification and Periodic Checks

The functions of the Magnet Power Supply Modules and the Rundown Relay Panel were bench-tested, and will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation. Once installed, they will be tested periodically as per the Technical Specifications for the Nuclear Safety System. Therefore, the pre-operational and regular surveillances will ensure the integrity and functionality of this equipment.

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Specifications

NSS Magnet Power Supply Modules

1. For the new Nuclear Safety System, there are three identical Magnet Power Supply Modules.

2. Each Magnet Power Supply Module provides power to two reactor shim blade magnets, each with a variable DC current ranging from zero to 100 milliamps. The nominal operating current is 80 milliamps.

3. The lower part of the current range (below 80 mA) is for testing of shim blade magnets by measuring and recording the magnet drop-out current values prior to reactor startups. The upper part of the current range (above 80 mA, up to 100 mA) allows slightly extra magnetic force to be produced by the magnet to counteract magnet aging factors such as corrosion.

4. The Magnet Power Supply Modules will be capable of interrupting the DC power to their corresponding shim blade magnets via opening of the respective mechanical relays, which is initiated by scram loops A and B in the scram logic circuit.

5. Each Magnet Power Supply Module interfaces with its corresponding rundown relay circuits, with magnet current passing through the Rundown Relay Panel on its way to the magnet.

6. Each Magnet Power Supply Module consists of one printed-circuit board (PCB), a 24-volt DC power supply, four LED indicator lights, two edgewise meters and current-adjust potentiometers (one set for each associated shim blade magnet).

7. When the reactor's Withdraw Permit Circuit (WPC) is open, the 120-volt AC line power from reactor electrical circuit L21 will be interrupted. This will then de-energize all three Magnet Power Supply Modules.

8. Each Magnet Power Supply Module is constructed of standard industrial electronic components.

9. Further specifications are listed on Drawing R3W-258-4 "Magnet Power Supplies and Rundown Relay Panel" and Drawing R3W-266-4 "Magnet Power Supplies".

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Procurement

NSS Magnet Power Supply Modules

1. The components for the Magnet Power Supply Modules were purchased from standard industrial electronic supply houses. Components necessary for its construction are as follows:

   a. 5-watt Surmetic 40 Zener Voltage Regulators (ON Semiconductor, 1N5333B)

   b. Axial Lead Standard Recovery Rectifiers (ON Semiconductor, 1N4004)

   c. Single-Pole, Normally Open OptoMOS Relay (IXYS Integrated Circuits, LCA110)

   d. RJ Series Mechanical Relays (IDEC, RJ25-C-D24)

   e. Precision Potentiometer (Bourns, 3540/3541)

   f. 3-Terminal Positive Adjustable Regulator (Fairchild, LM317T, with heat sink)

   g. Series 280 Thin Edgewise Panel Meters (Yokogawa, 0 to 100 mA self-contained)

   h. Linear Regulated AC-DC Mini Encapsulated Power Supply (Acopian, 24EB60)

   i. Miscellaneous electronic components, such as resistors and capacitors, of generic nature.

2. A data sheet for each specialized component is included.

3. Each component meets the receipt requirements of PM 1.19, as do the assembled printed-circuit boards (PCBs). The invoice, including specifications, for the PCBs is attached.

1.19 Receiving, Storing, and Issuing of Materials

All materials received shall be:

- Checked against the requisition on which it was ordered so as to ensure receipt of the material requested.

- Visually inspected for obvious defects.

- Subject to a detailed inspection of all parts.

- Any material identified as not meeting NRL specification should be either:

  (a) returned to the supplier, or

  (b) evaluated for acceptability on some other documented basis. For materials within the scope of the QA program, see Section 1.13.6, "Non-Conformance to QA Standards."

- Once material or equipment has been accepted, it is either issued or placed in storage. Storage areas are assigned by category (i.e., raw materials, finished machine parts, electrical components, etc.)

1.19.1 Nuclear Materials

The receiving, storing and issuing of nuclear materials must be in accordance with applicable regulations, licenses, plans and procedures:

a) NRC Regulations:

10 CFR 20 Standards for Protection Against Radiation

10 CFR 40 Domestic Licensing of Source Material

10 CFR 21 Reporting of Defects and Noncompliance

10 CFR 70 Domestic Licensing of Special Nuclear Material

10 CFR 73 Physical Protection of Plants and Materials

1N53 Series

5 Watt Surmetic™
40 Zener Voltage Regulators

This is a complete series of 5 Watt Zener diodes with tight limits and better operating characteristics that reflect the superior capabilities of silicon–oxide passivated junctions. All this in an axial lead, transfer–molded plastic package that offers protection in all common environmental conditions.

Features

- Zener Voltage Range – 3.3 V to 200 V
- ESD Rating of Class 3 (>16 kV) per Human Body Model
- Surge Rating of up to 180 W @ 8.3 ms
- Maximum Limits Guaranteed on up to Six Electrical Parameters
- Pb–Free Packages are Available*

Mechanical Characteristics

CASE: Void free, transfer–molded, thermosetting plastic
FINISH: All external surfaces are corrosion resistant and leads are readily solderable
MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 260°C, 1/16 in. from the case for 10 seconds
POLARITY: Cathode indicated by polarity band
MOUNTING POSITION: Any

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Max. Steady State Power Dissipation @ T_L = 25°C, Lead Length = 3/8 in	P_D	5	W
Derate above 25°C		40	mW/°C
Junction–to–Lead Thermal Resistance	θ_{JL}	25	°C/W
Operating and Storage Temperature Range	T_J, T_{stg}	–65 to +200 (Note 1)	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Max operating temperature for DC conditions is 150°C, but not to exceed 200°C for pulsed conditions with low duty cycle or non–repetitive.

*For additional information on our Pb–Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

ON Semiconductor®

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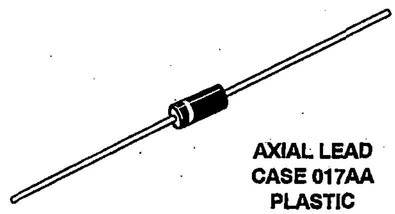
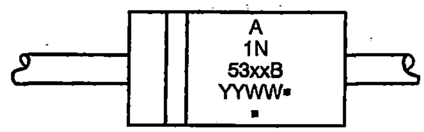


AXIAL LEAD
CASE 017AA
PLASTIC

MARKING DIAGRAM



A	=	Assembly Location
1N53xxB	=	Device Number (Refer to Tables on Pages 3 & 4)
YY	=	Year
WW	=	Work Week
•	=	Pb–Free Package

(Note: Microdot may be in either location)

ORDERING INFORMATION

Device	Package	Shipping†
1N53xxB, G	Axial Lead (Pb–Free)	1000 Units/Box
1N53xxBRL, G	Axial Lead (Pb–Free)	4000/Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

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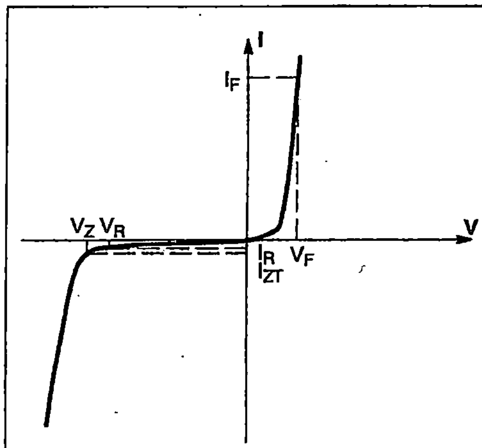
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted, V_F = 1.2 V Max @ I_F = 1.0 A for all types)

Symbol	Parameter
V_Z	Reverse Zener Voltage @ I_{ZT}
I_{ZT}	Reverse Current
Z_{ZT}	Maximum Zener Impedance @ I_{ZT}
I_{ZK}	Reverse Current
Z_{ZK}	Maximum Zener Impedance @ I_{ZK}
I_R	Reverse Leakage Current @ V_R
V_R	Breakdown Voltage
I_F	Forward Current
V_F	Forward Voltage @ I_F
I_R	Maximum Surge Current @ T_A = 25°C
ΔV_Z	Reverse Zener Voltage Change
I_{ZM}	Maximum DC Zener Current



Zener Voltage Regulator

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted, V_F = 1.2 V Max @ I_F = 1.0 A for all types)

Device† (Note 2)	Device Marking	Zener Voltage (Note 3) V_Z (Volts) Min	Nom	Max	@ I_{ZT} mA	Zener Impedance (Note 3) Z_{ZT} @ I_{ZT} Ω	Z_{ZK} @ I_{ZK} Ω	I_{ZK} mA	Leakage Current I_R @ V_R µA Max	Volts	I_R (Note 4) A	ΔV_Z (Note 5) Volts	I_{ZM} (Note 6) mA
1N5333B	***1N5333B***	***3.14***	***3.3***	***3.47***	***380***	***3***	***400***	***1***	***300***	***1***	***20***	***0.85***	***1440***
1N5334B	1N5334B	3.42	3.6	3.78	350	2.5	500	1	150	1	18.7	0.8	1320
1N5335B	1N5335B	3.71	3.9	4.10	320	2	500	1	50	1	17.6	0.54	1220
1N5336B	1N5336B	4.09	4.3	4.52	290	2	500	1	10	1	16.4	0.49	1100
1N5337B	***1N5337B***	***4.47***	***4.7***	***4.94***	***260***	***2***	***450***	***1***	***5***	***1***	***15.3***	***0.44***	***1010***
1N5338B	***1N5338B***	***4.85***	***5.1***	***5.36***	***240***	***1.5***	***400***	***1***	***1***	***1***	***14.4***	***0.39***	***930***
1N5339B	***1N5339B***	***5.32***	***5.6***	***5.88***	***220***	***1***	***400***	***1***	***1***	***2***	***13.4***	***0.25***	***865***
1N5340B	1N5340B	5.70	6.0	6.30	200	1	300	1	1	3	12.7	0.19	790
1N5341B	***1N5341B***	***5.89***	***6.2***	***6.51***	***200***	***1***	***200***	***1***	***1***	***3***	***12.4***	***0.1***	***765***
1N5342B	***1N5342B***	***6.46***	***6.8***	***7.14***	***175***	***1***	***200***	***1***	***10***	***5.2***	***11.5***	***0.15***	***700***
1N5343B	1N5343B	7.13	7.5	7.88	175	1.5	200	1	10	5.7	10.7	0.15	630
1N5344B	1N5344B	7.79	8.2	8.61	150	1.5	200	1	10	6.2	10	0.2	580
1N5345B	1N5345B	8.27	8.7	9.14	150	2	200	1	10	6.6	9.5	0.2	545
1N5346B	1N5346B	8.65	9.1	9.56	150	2	150	1	7.5	6.9	9.2	0.22	520
1N5347B	***1N5347B***	***9.50***	***10***	***10.5***	***125***	***2***	***125***	***1***	***5***	***7.6***	***8.6***	***0.22***	***475***

Devices listed in ***bold, italic*** are ON Semiconductor **Preferred** devices. **Preferred** devices are recommended choices for future use and best overall value.

2. **TOLERANCE AND TYPE NUMBER DESIGNATION:** The JEDEC type numbers shown indicate a tolerance of ±5%.
3. **ZENER VOLTAGE (V_Z) and IMPEDANCE (I_{ZT} and I_{ZK}):** Test conditions for zener voltage and impedance are as follows: I_Z is applied 40 ±10 ms prior to reading. Mounting contacts are located 3/8″ to 1/2″ from the inside edge of mounting clips to the body of the diode (T_A = 25°C +8°C, −2°C).
4. **SURGE CURRENT (I_R):** Surge current is specified as the maximum allowable peak, non−recurrent square−wave current with a pulse width, PW, of 8.3 ms. The data given in Figure 5 may be used to find the maximum surge current for a square wave of any pulse width between 1 ms and 1000 ms by plotting the applicable points on logarithmic paper. Examples of this, using the 3.3 V and 200 V zener are shown in Figure 6. Mounting contact located as specified in Note 2 (T_A = 25°C +8°C, −2°C).
5. **VOLTAGE REGULATION (ΔV_Z):** The conditions for voltage regulation are as follows: V_Z measurements are made at 10% and then at 50% of the I_Z max value listed in the electrical characteristics table. The test current time duration for each V_Z measurement is 40 ±10 ms. Mounting contact located as specified in Note 2 (T_A = 25°C +8°C, −2°C).
6. **MAXIMUM REGULATOR CURRENT (I_{ZM}):** The maximum current shown is based on the maximum voltage of a 5% type unit, therefore, it applies only to the B−suffix device. The actual I_{ZM} for any device may not exceed the value of 5 watts divided by the actual V_Z of the device. T_L = 25°C at 3/8″ maximum from the device body.

†The "G" suffix indicates Pb−Free package or Pb−Free packages are available.

1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

Axial Lead Standard Recovery Rectifiers

This data sheet provides information on subminiature size, axial lead mounted rectifiers for general–purpose low–power applications.

Features

- Shipped in Plastic Bags, 1000 per bag
- Available Tape and Reeled, 5000 per reel, by adding a "RL" suffix to the part number
- Available in Fan–Fold Packaging, 3000 per box, by adding a "FF" suffix to the part number
- Pb–Free Packages are Available

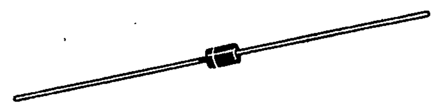
Mechanical Characteristics

- Case: Epoxy, Molded
- Weight: 0.4 gram (approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable
- Lead and Mounting Surface Temperature for Soldering Purposes: 260°C Max. for 10 Seconds, 1/16 in. from case
- Polarity: Cathode Indicated by Polarity Band

ON Semiconductor®

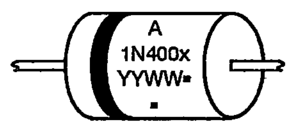
http://onsemi.com

LEAD MOUNTED RECTIFIERS
50–1000 VOLTS
DIFFUSED JUNCTION



CASE 59–10
AXIAL LEAD
PLASTIC

MARKING DIAGRAM



A = Assembly Location
1N400x = Device Number
x = 1, 2, 3, 4, 5, 6 or 7
YY = Year
WW = Work Week
▪ = Pb–Free Package
(Note: Microdot may be in either location)

ORDERING INFORMATION

See detailed ordering and shipping information on page 5 of this data sheet.

*For additional information on our Pb–Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
†Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
†Non–Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz)	V_{RSM}	60	120	240	480	720	1000	1200	V
†RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
†Average Rectified Forward Current (single phase, resistive load, 60 Hz, $T_A = 75°C$)	I_O	1.0							A
†Non–Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							A
Operating and Storage Junction Temperature Range	T_J T_{stg}	–65 to +175							°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.
†Indicates JEDEC Registered Data

THERMAL CHARACTERISTICS

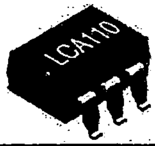
Rating	Symbol	Max	Unit
Maximum Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	Note 1	°C/W

ELECTRICAL CHARACTERISTICS†

Rating	Symbol	Typ	Max	Unit
Maximum Instantaneous Forward Voltage Drop, (i_F = 1.0 Amp, T_J = 25°C)	v_F	0.93	1.1	V
Maximum Full–Cycle Average Forward Voltage Drop, (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$V_{F(AV)}$	–	0.8	V
Maximum Reverse Current (rated DC voltage) (T_J = 25°C) (T_J = 100°C)	I_R	 0.05 1.0	 10 50	µA
Maximum Full–Cycle Average Reverse Current, (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$I_{R(AV)}$	–	30	µA

†Indicates JEDEC Registered Data

IXYS
Integrated Circuits Division



LCA110
Single-Pole, Normally Open OptoMOS® Relay

Parameter	Ratings	Units
Blocking Voltage	350	V_P
Load Current	120	mA_{rms} & mA_{DC}
On-Resistance (max)	35	Ω

Features
- $3750V_{rms}$ Input/Output Isolation
- Low Drive Power Requirements (TTL/CMOS Compatible)
- High Reliability
- Arc-Free With No Snubbing Circuits
- No EMI/RFI Generation
- Small 6-Pin Package
- Machine Insertable, Wave Solderable
- Surface Mount Tape & Reel Version Available
- V-0 Flammability Classification Rating

Applications
- Instrumentation
  - Multiplexers
  - Data Acquisition
  - Electronic Switching
  - I/O Subsystems
- Meters (Watt-Hour, Water, Gas)
- Medical Equipment—Patient/Equipment Isolation
- Security
- Aerospace
- Industrial Controls

Description
The LCA110 is a normally open (1-Form-A) Solid State Relay which uses optically coupled MOSFET technology to provide $3750V_{rms}$ of input to output isolation.

Its optically coupled outputs, which use the patented OptoMOS architecture, are controlled by a highly efficient GaAlAs infrared LED.

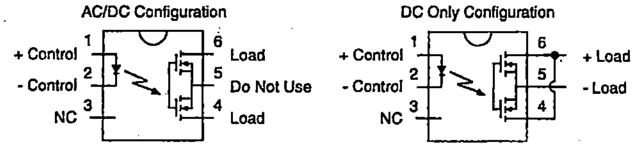
The LCA110 can be used to replace mechanical relays, and offers the superior reliability associated with semiconductor devices.

Approvals
- UL Recognized Component: File E76270
- CSA Certified Component: Certificate 1175739
- EN/IEC 60950-1 Certified Component: TUV Certificate B 09 07 49410 004

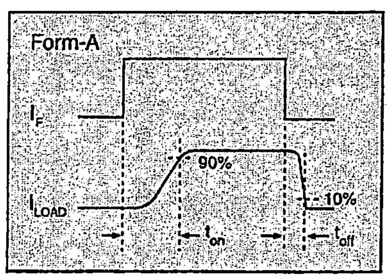
Ordering Information

Part #	Description
LCA110	6-Pin DIP (50/Tube)
LCA110S	6-Pin Surface Mount (50/Tube)
LCA110STR	6-Pin Surface Mount (1,000/Reel)

Pin Configuration



Switching Characteristics of Normally Open Devices



Pb RoHS e3

Absolute Maximum Ratings @ 25°C

Parameter	Ratings	Units
Blocking Voltage	350	V_P
Reverse Input Voltage	5	V
Input Control Current	50	mA
Peak (10ms)	1	A
Input Power Dissipation [1]	150	mW
Total Power Dissipation [2]	800	mW
Isolation Voltage, Input to Output	3750	V_{rms}
Operational Temperature	-40 to +85	°C
Storage Temperature	-40 to +125	°C

[1] Derate linearly 1.33 mW / °C

[2] Derate linearly 6.67 mW / °C

Absolute Maximum Ratings are stress ratings. Stresses in excess of these ratings can cause permanent damage to the device. Functional operation of the device at conditions beyond those indicated in the operational sections of this data sheet is not implied.

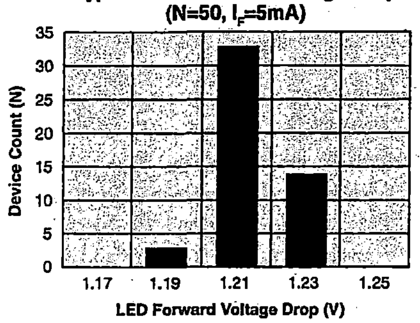
Electrical Characteristics @ 25°C

Parameter	Conditions	Symbol	Min	Typ	Max	Units
Output Characteristics						
Load Current						
AC/DC Configuration, Continuous [1]	-	I_L	-	-	120	mA_{rms} & mA_{DC}
DC Configuration, Continuous [1]	-	I_L	-	-	200	mA_{DC}
Peak	t=10ms	I_{LPK}	-	-	350	mA
On-Resistance [2]						
AC/DC Configuration	I_L=120mA	R_{ON}	-	23	35	Ω
DC Configuration	I_L=200mA	R_{ON}	-	7	10	Ω
Off-State Leakage Current	V_L=350V_P	I_{LEAK}	-	-	1	µA
Switching Speeds						
Turn-On	I_F = 5mA, V_L = 10V	t_{on}	-	-	3	ms
Turn-Off	I_F = 5mA, V_L = 10V	t_{off}	-	-	3	ms
Output Capacitance	V_L=50V, f=1MHz	C_{OUT}	-	25	-	pF
Input Characteristics						
Input Control Current to Activate	I_L = 120mA	I_F	-	-	2	mA
Input Control Current to Deactivate	-	I_F	0.4	-	-	mA
Input Voltage Drop	I_F = 5mA	V_F	0.9	1.2	1.4	V
Reverse Input Current	V_R = 5V	I_R	-	-	10	µA
Common Characteristics						
Capacitance, Input to Output	-	$C_{I/O}$	-	3	-	pF

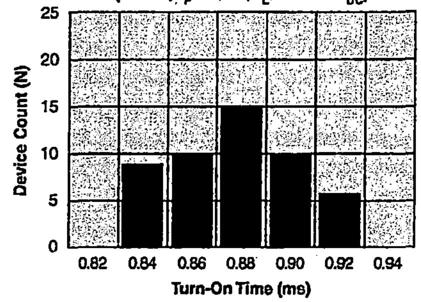
[1] If both poles operate, then the load current must be derated so that the package power dissipation value is not exceeded.
[2] Measurement taken within 1 second of on-time.

PERFORMANCE DATA @25°C (Unless Otherwise Noted)*

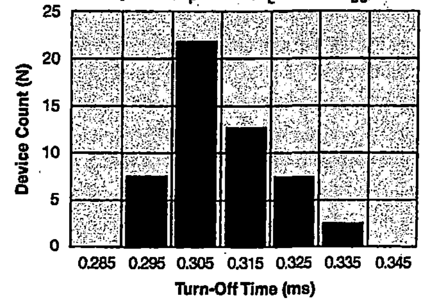
Typical LED Forward Voltage Drop
(N=50, I_F=5mA)



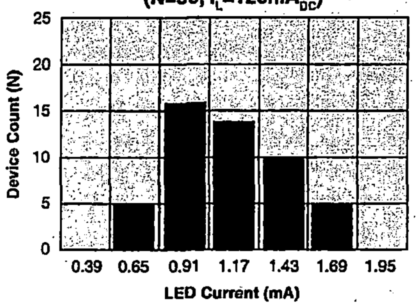
Typical Turn-On Time
(N=50, I_F=2mA, I_L=120mA$_{DC}$)



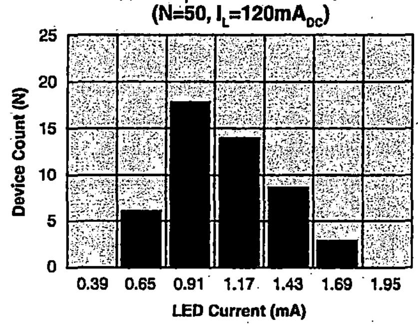
Typical Turn-Off Time
(N=50, I_F=2mA, I_L=120mA$_{DC}$)



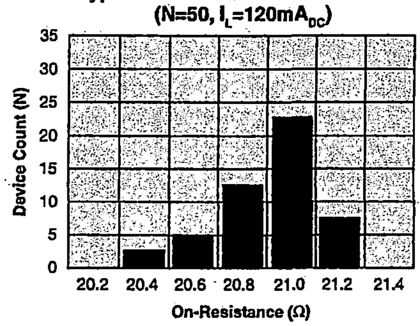
Typical I_F for Switch Operation
(N=50, I_L=120mA$_{DC}$)



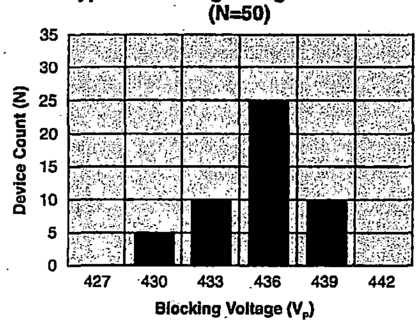
Typical I_F for Switch Dropout
(N=50, I_L=120mA$_{DC}$)



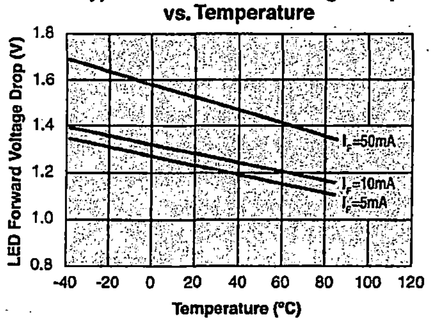
Typical On-Resistance Distribution
(N=50, I_L=120mA$_{DC}$)



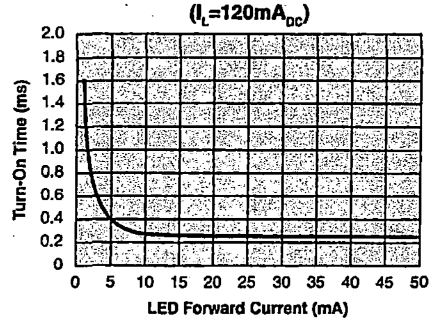
Typical Blocking Voltage Distribution
(N=50)



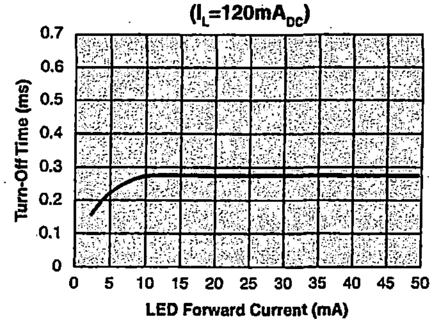
Typical LED Forward Voltage Drop
vs. Temperature



Typical Turn-On Time
vs. LED Forward Current
(I_L=120mA$_{DC}$)



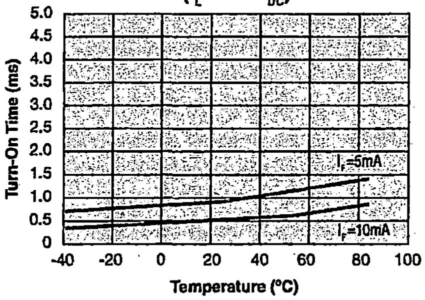
Typical Turn-Off Time
vs. LED Forward Current
(I_L=120mA$_{DC}$)



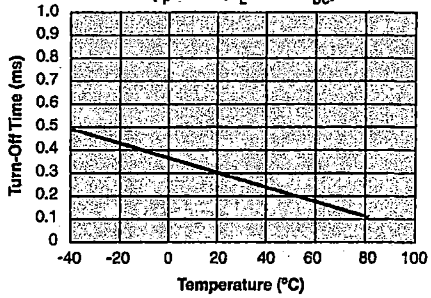
*The Performance data shown in the graphs above is typical of device performance. For guaranteed parameters not indicated in the written specifications, please contact our application department.

PERFORMANCE DATA @25°C (Unless Otherwise Noted)*

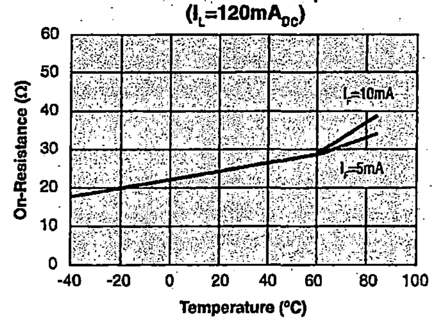
Typical Turn-On Time vs. Temperature (I_L=70mA$_{DC}$)



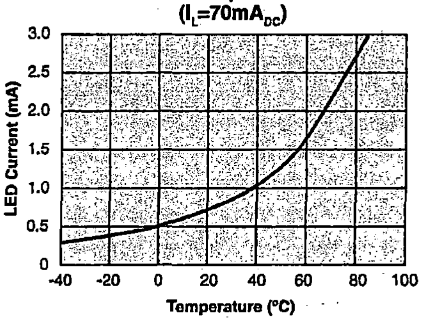
Typical Turn-Off Time vs. Temperature (I_F=5mA, I_L=70mA$_{DC}$)



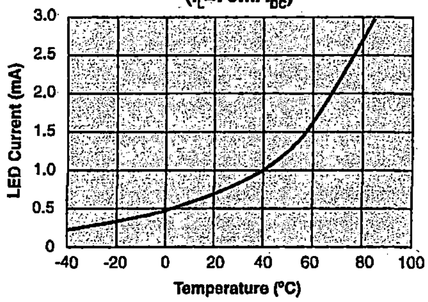
Typical Steady State On-Resistance vs. Temperature (I_L=120mA$_{DC}$)



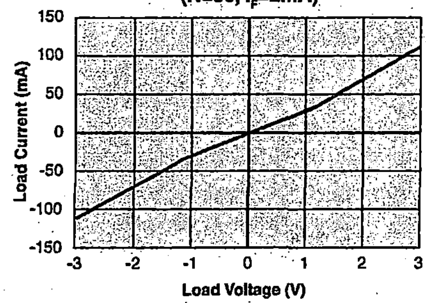
Typical I_F for Switch Operation vs. Temperature (I_L=70mA$_{DC}$)



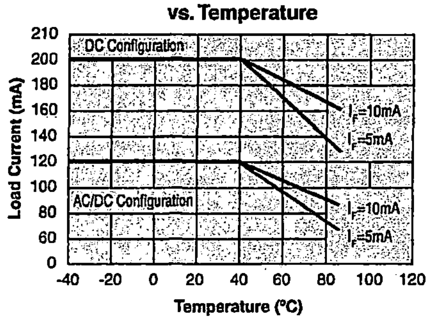
Typical I_F for Switch Dropout vs. Temperature (I_L=70mA$_{DC}$)



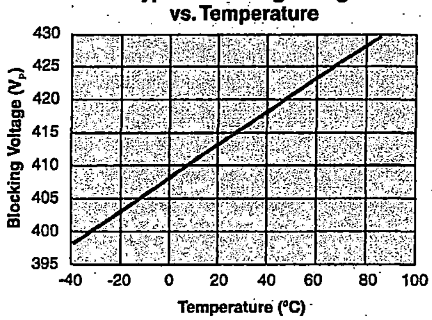
Typical Load Current vs. Load Voltage (N=50, I_F=2mA)



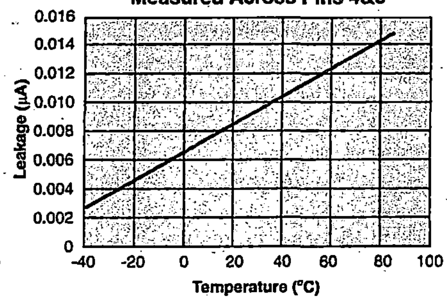
Maximum Load Current vs. Temperature



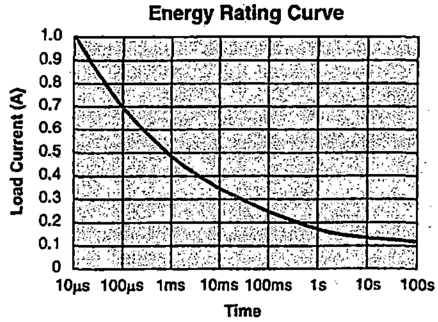
Typical Blocking Voltage vs. Temperature



Typical Leakage vs. Temperature Measured Across Pins 4&6



Energy Rating Curve



*The Performance data shown in the graphs above is typical of device performance. For guaranteed parameters not indicated in the written specifications, please contact our application department.

Manufacturing Information

Moisture Sensitivity

All plastic encapsulated semiconductor packages are susceptible to moisture ingression. IXYS Integrated Circuits Division classified all of its plastic encapsulated devices for moisture sensitivity according to the latest version of the joint industry standard, **IPC/JEDEC J-STD-020**, in force at the time of product evaluation. We test all of our products to the maximum conditions set forth in the standard, and guarantee proper operation of our devices when handled according to the limitations and information in that standard as well as to any limitations set forth in the information or standards referenced below.

Failure to adhere to the warnings or limitations as established by the listed specifications could result in reduced product performance, reduction of operable life, and/or reduction of overall reliability.

This product carries a **Moisture Sensitivity Level (MSL) rating** as shown below, and should be handled according to the requirements of the latest version of the joint industry standard **IPC/JEDEC J-STD-033**.

Device	Moisture Sensitivity Level (MSL) Rating
LCA110 / LCA110S	MSL 1

ESD Sensitivity

This product is **ESD Sensitive**, and should be handled according to the industry standard **JESD-625**.

Reflow Profile

This product has a maximum body temperature and time rating as shown below. All other guidelines of **J-STD-020** must be observed.

Device	Maximum Temperature x Time
LCA110 / LCA110S	250°C for 30 seconds

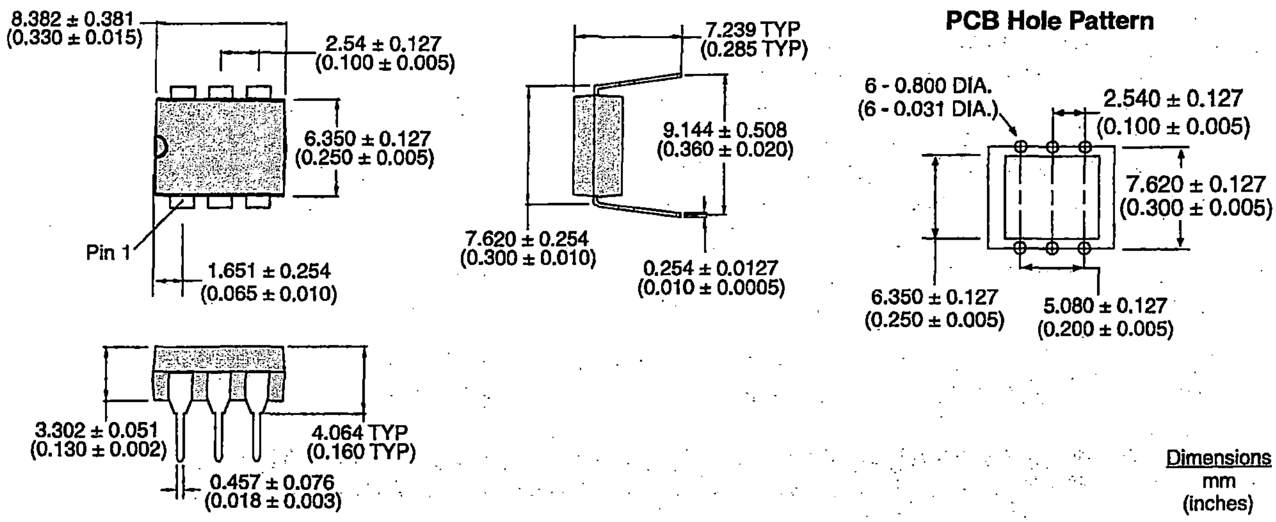
Board Wash

IXYS Integrated Circuits Division recommends the use of no-clean flux formulations. However, board washing to remove flux residue is acceptable. Since IXYS Integrated Circuits Division employs the use of silicone coating as an optical waveguide in many of its optically isolated products, the use of a short drying bake could be necessary if a wash is used after solder reflow processes. Chlorine- or Fluorine-based solvents or fluxes should not be used. Cleaning methods that employ ultrasonic energy should not be used.

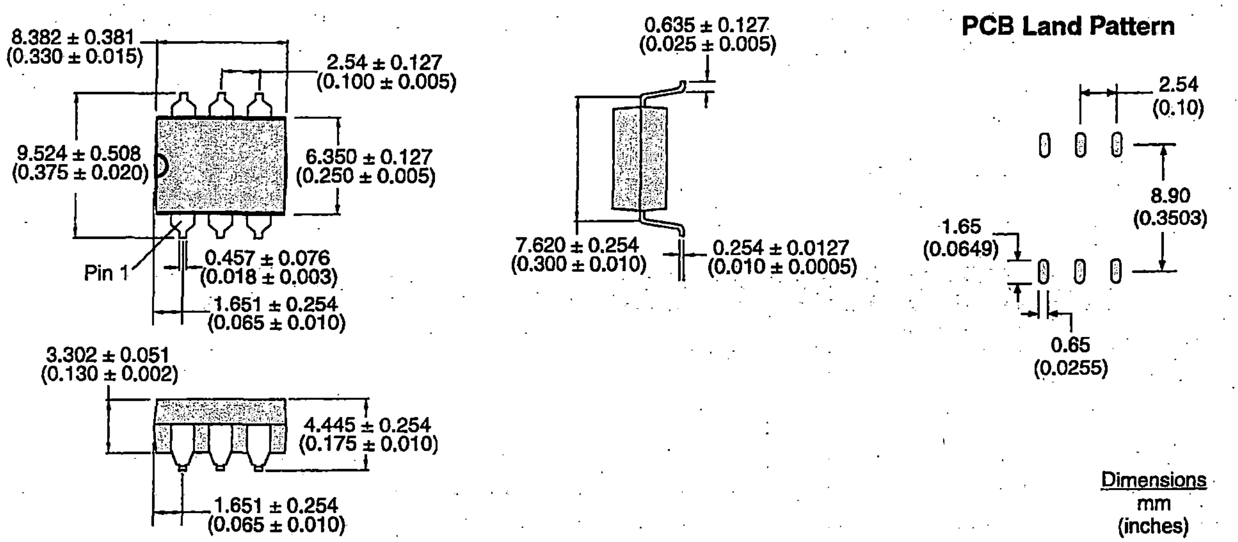
Pb RoHS e3

MECHANICAL DIMENSIONS

LCA110

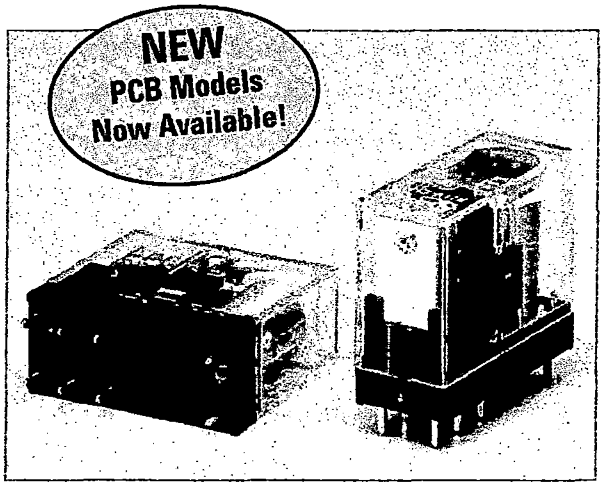


LCA110S



IDEC

RJ Series Relays



Features

- Compact size:
  Blade: 12.7 x 27 x 28.8 mm
  PCB: 12.7 x 25.5 x 28.8 mm
- Contact rating:
  Blade: 8A (DPDT), 12A (SPDT)
  PCB: 8A (DPDT & DPST-NO), 12A (SPDT & SPST-NO),
  16A (SPDT & SPST-NO)
- Operational life:
  200K cycles at full resistive AC load;
  50 million cycles, no load
- Blade model has optional green, non-polarized LED
- RoHS compliant

Specifications

			Blade Models		PCB Models		
			RJ1S	RJ2S	RJ1V	RJ1V (High Capacity)	RJ2V
General Information	No. of poles		1	2	1	1	2
	Contact Configuration		SPDT	DPDT	SPDT, SPST-NO		DPDT, DPST-NO
	Contact Rating		12A	8A	12A	16A	8A
	Contact Material		AgNi		AgNi	AgSnIn	AgNi
	Enclosure Ratings		–		Flux protection		
	Contact Resistance		50 milliohms max		50 milliohms max[Note 1]		
	Operating Time		15ms max		15ms max[Note 2]		
	Release Time		10ms max		10ms max[Note 2]		
	Dielectric Strength	Between contact & coil	5,000V AC, 1 minute		5,000V AC, 1 minute		
		Between contacts of same poles	1,000V AC, 1 minute		1,000V AC, 1 minute		
		Between contacts of different poles	–	3,000V AC, 1 min.	–		3,000V AC, 1 min.
	Vibration Resistance	Damage limits	10-55Hz, amplitude 0.75mm		10-55Hz, amplitude 0.75mm		
		Operating extremes	10-55Hz, amplitude 0.75mm		10-55Hz, amplitude 0.75mm		
	Shock Resistance	Damage limits	100m/s² min (10G)		NO contact: 200m/s² (20G) NC contact: 100m/s² (10G)		
		Operating extremes	1,000m/s² min (100G)		1,000m/s² min (100G)		
	Mechanical Life	AC	30,000,000 operations		30,000,000 operations		
		DC	50,000,000 operations		50,000,000 operations		
	Electrical Life @ Full Rated Load	AC	200,000 operations		200,000 operations		
		DC	100,000 operations		100,000 operations		
	Operating Temperature		-40 to 70° C		-40 to 70° C[Note 3]		
	Operating Humidity		5 to 85% RH		5 to 85% RH		
	Dimensions (H x W x D mm)		12.7 x 27 x 28.8		12.7 x 25.5 x 28.8		
	Weight (Approx.)		19g		SPDT: 17g, SPST-NO: 16g		DPDT: 17g, DPST-NO: 16g

Notes:
1. Measured using 5V DC, 1A voltage drop method.
2. Measured at the rated voltage (at 20°C), excluding contact bounce time.
3. 100% rated voltage.

Ordering Information

Blade Models

RJ☐S-C☐-☐

Contact Configuration
1 - SPDT
2 - DPDT

Options
Blank - Standard
L - LED

Coil Voltage
D12 - 12V DC
D24 - 24V DC
D48 - 48V DC
D100 - 100-110V DC
A24 - 24V AC
A120 - 120V AC
A240 - 240V AC

PCB Models

RJ☐V-☐☐-☐

Number of Poles
1 - SP (Single Pole)
2 - DP (Double Pole)

Contact Configuration
C - FORM C (DT Double Throw)
A - FORM A (ST Single Throw)

Contact Configuration
Blank - Standard
H - High Capacity Type (RJ1 only)

Coil Voltage
D5 - 5V DC
D6 - 6V DC
D12 - 12V DC
D24 - 24V DC
D48 - 48V DC
D100 - 100-110V DC
A24 - 24V AC
A120 - 120V AC
A240 - 240V AC

Specifications con't on following page

Contact Ratings

Contact Ratings	Type		Contact	Allowable Contact Power: Resistive Load	Allowable Contact Power: Inductive Load	Rated Load: Voltage	Rated Load: Resistive Load	Rated Load: Inductive Load cos_=0.3 L/R=7ms	Allowable Switching Current	Allowable Switching Voltage	Minimum Applicable Load
Blade Models	1 pole		NO	AC3000V	AC1875VA	250V AC	12A	7.5A	6A	AC250V DC30V	DC5V 100mA
			NC	AC3000V	AC1875VA	250V AC	12A	7.5A	6A/3A		
	2 poles		NO	AC2000V	AC1000VA	250V AC	8A	4A	4A	AC250V DC30V	DC5V 100mA
			NC	AC2000V	AC1000VA	250V AC	8A	4A	4A/2A		
PCB Models	1 pole	Standard Type	NO	AC3000V	AC1875VA	AC250V	12A	7.5A	12A	AC250V DC125V	DC5V 100mA
				DC360W	DC180W	DC30V	12A	6A			
			NC	AC3000V	AC1875VA	AC250V	12A	7.5A			
				DC180W	DC90W	DC30V	6A	3A			
		High Capacity Type	NO	AC4000V	AC2000VA	AC250V	16A	8A	16A	AC250V DC125V	DC5V 100mA
				DC480W	DC240W	DC30V	16A	8A			
			NC	AC4000V	AC2000VA	AC250V	16A	8A			
				DC240W	DC120W	DC30V	8A	4A			
	2 poles		NO	AC2000V	AC1000VA	AC250V	8A	4A	8A	AC250V DC125V	DC5V 10mA
				DC240W	DC120W	DC30V	8A	4A			
			NC	AC2000V	AC1000VA	AC250V	8A	4A			
				DC120W	DC60W	DC30V	4A	2A			

Coil Ratings

AC	Rated Voltage	Coil Voltage Code	Rated Current (mA) ±15% (at 20°C): Without LED[1] 50Hz	Without LED[1] 60Hz	With LED[1] 50Hz	With LED[1] 60Hz	Coil Resistance (ohms)±10% (at 20°C)	Operating Characteristics[2]: Minimum Pickup Voltage	Dropout Voltage	Maximum Allowable Voltage[3]	Power Consumption
Blade & PCB Models	24V	A24	43.9	37.5	47.5	41.1	243	80% max	30% min	140%	0.9VA (60Hz)
	120V	A120	8.8	7.5	8.7	7.4	6,400				
	240V	A240	4.3	3.7	4.3	3.7	25,570				

DC	Rated Voltage	Coil Voltage Code	Rated Current (mA) ±15% (at 20°C): Without LED[1]	With LED[1]	Coil Resistance (ohms)±10% (at 20°C)	Operating Characteristics[2]: Minimum Pickup Voltage	Dropout Voltage	Maximum Allowable Voltage[3]	Power Consumption
Blade Models	12V	D12	44.2	48.0	271	70% max	10% min	170%	0.53W
	24V	D24	22.1	25.7	1,080				
	48V	D48	11.0	10.7	4,340				
	100-110V	D100	5.3 - 5.8	5.2 - 5.7	18,870			160%	
PCB Models	5V	D5	106	–	47.2	70% max	10% min	170%	0.53-0.64W
	6V	D6	88.3	–	67.9				
	12V	D12	44.2	–	271				
	24V	D24	22.1	–	1,080				
	48V	D48	11.0	–	4,340				
	100-110V	D100	5.3 - 5.8	–	18,870			160%	

Notes:
1. LED Indicator is only available on Blade relays.
2. Operating characteristics are against rated values at 20°C.
3. The maximum allowable voltage is the maximum value which can be applied to the relay coils.

Accessories

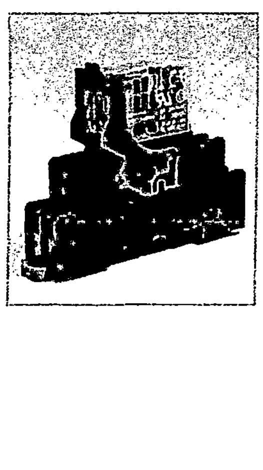
Socket Part Numbers

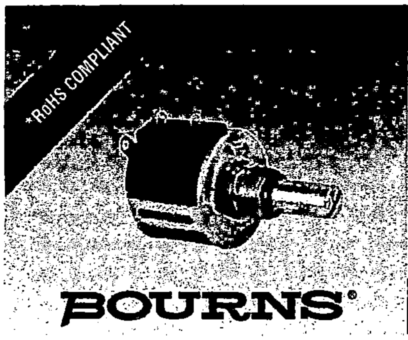
	Relay Type	Socket Type	Socket Part Number
Blade Models	RJ1S (Std)	DIN Rail Standard	SJ1S-05B
		DIN Rail Fingersafe	SJ1S-07L
		PCB Mount	SJ1S-61
	RJ1S-□H (HC), RJ2S	DIN Rail Standard	SJ2S-05B
		DIN Rail Fingersafe	SJ2S-07L
		PCB Mount	SJ2S-61
PCB Models	RJ1V (Std)	DIN Rail Fingersafe	SQ1V-07B*
		PCB Mount	SQ1V-63
	RJ1V-□H (HC), RJ2V	DIN Rail Fingersafe	SQ2V-07B*
		PCB Mount	SQ2V-63

*Hold-down clip or spring must be removed to use with RJ relays.

Socket Specifications

Specifications		SJ1S	SJ2S
	Rated Insulation Voltage	250V AC/DC	
	Applicable Wire	Max up to 2 - #14 AWG	
	Applicable Crimping Terminal	$2mm^2$ x 2	
	Screw Size	M3 Slotted-Phillips screw	
	Weight	30g	34g





Features

- Bushing mount
- Optional center tap and rear shaft extension
- Optional AR lug feature
- Gangable with common or concentric shafts
- High torque available
- Non-standard features and specifications available
- RoHS compliant*

3540/3541 - Precision Potentiometer

Electrical Characteristics[1]

Electrical Characteristics[1]	3540 Wirewound Element	3541 Hybritron® Element
Standard Resistance Range	100 to 100 K ohms	1 K to 100 K ohms
Total Resistance Tolerance	±5 %	±10 %
Independent Linearity	±0.25 %	±0.25 %
Effective Electrical Angle	3600 ° +10 °, -0 °	3600 ° +10 °, -0 °
Absolute Minimum Resistance/ Minimum Voltage	1 ohm or 0.1 % maximum (whichever is greater)	0.2 % maximum
Noise/Output Smoothness	100 ohms ENR maximum	0.1 % maximum
Dielectric Withstanding Voltage (MIL-STD-202, Method 301)		
Sea Level	1,000 VAC minimum	1,000 VAC minimum
Power Rating (Voltage Limited By Power Dissipation or 447 VAC, Whichever Is Less)		
+70 °C	2 watts	2 watts
+125 °C	0 watt	0 watt
Insulation Resistance (500 VDC)	1,000 megohms minimum	1,000 megohms minimum
Resolution	See recommended part nos.	Essentially infinite

Environmental Characteristics[1]

Environmental Characteristics[1]	3540	3541
Operating Temperature Range	-40 °C to +125 °C	-40 °C to +125 °C
Storage Temperature Range	-55 °C to +125 °C	-55 °C to +125 °C
Temperature Coefficient Over Storage Temperature Range[2]	±50 ppm/°C maximum/unit	±100 ppm/°C maximum/unit
Vibration	15 G	15 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Shock	50 G	50 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Load Life	1,000 hours, 2 watts	1,000 hours, 2 watts
Total Resistance Shift	±2 %	±5 %
Rotational Life (No Load)	1,000,000 shaft revolutions[2]	5,000,000 shaft revolutions[2]
Total Resistance Shift	±5 % maximum	±5 % maximum
Moisture Resistance (MIL-STD-202, Method 103, Condition B)		
Total Resistance Shift	±2 % maximum	±5 % maximum
IP Rating	IP 40	IP 40

Mechanical Characteristics[1]

Mechanical Characteristics[1]	
Stop Strength	53 N-cm (75 oz-in.) minimum
Mechanical Angle	3600 ° +10 °, -0 °
Torque	
Starting & Running @ +25 °C	0.49 N-cm (0.7 oz.-in.) max.
Starting & Running @ -40 °C	1.76 N-cm (2.5 oz.-in.) max.
Mounting	170-200 N-cm (15-18 lb.-in.) max.
Shaft Runout	0.08 mm (0.003 in.) T.I.R.
Lateral Runout	0.13 mm (0.005 in.) T.I.R.
Shaft End Play	0.30 mm (0.012 in.) T.I.R.
Shaft Radial Play	0.08 mm (0.003 in.) T.I.R.
Pilot Diameter Runout	0.08 mm (0.003 in.) T.I.R.
Backlash	1.0 ° maximum
Weight	Approximately 21 gm
Terminals	Gold-plated solder lugs
Soldering Condition	
Manual Soldering	96.5Sn/3.0Ag/0.5Cu solid wire or no-clean rosin cored wire; 370 °C (700 °F) max. for 3 seconds
Wave Soldering	96.5Sn/3.0Ag/0.5Cu solder with no-clean flux; 260 °C (500 °F) max. for 5 seconds
Wash processes	Not recommended
Marking	Manufacturer's name and part number, resistance value and tolerance, linearity tolerance, wiring diagram, and date code
Ganging (Multiple Section Pots.)	2 cups maximum
Hardware	One lockwasher (H-37-2) and one mounting nut (H-38-2) is shipped with each potentiometer.

[1]At room ambient: +25 °C nominal and 50 % relative humidity nominal, except as noted.
[2]Consult manufacturer for complete specification details.

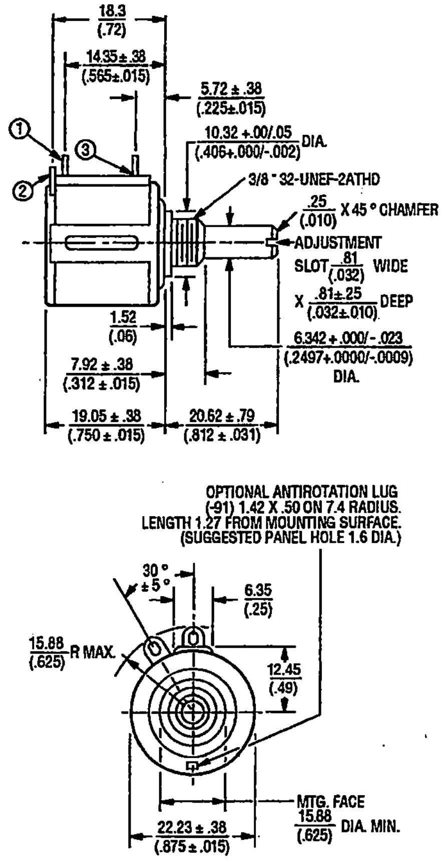
Recommended Part Numbers

Part Number	Resistance (Ω)	Resolution
3540S-1-201L	200	.042
3540S-1-501L	500	.031
3540S-1-102L	1,000	.027
3540S-1-202L	2,000	.021
3540S-1-502L	5,000	.021
3540S-1-103L	10,000	.019
3540S-1-203L	20,000	.014
3540S-1-503L	50,000	.011
3540S-1-104L	100,000	.008

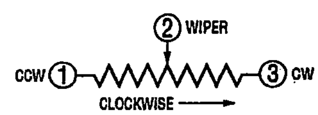
Part Number	Resistance (Ω)
3541H-1-102L	1,000
3541H-1-202L	2,000
3541H-1-502L	5,000
3541H-1-103L	10,000
3541H-1-203L	20,000
3541H-1-503L	50,000
3541H-1-104L	100,000

Product Dimensions

3540S-1/3541H-1



TOLERANCES: EXCEPT WHERE NOTED
DECIMALS: .XX ± .25 (.010), .XXX ± .13 (.005)
FRACTIONS: ±1/64
DIMENSIONS: MM (IN.)



BOLDFACE LISTINGS ARE IN STOCK AND READILY AVAILABLE THROUGH DISTRIBUTION.

FOR OTHER OPTIONS CONSULT FACTORY.

ROHS IDENTIFIER:
L = COMPLIANT

Specifications are subject to change without notice.
Customers should verify actual device performance in their specific applications.
*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.

FAIRCHILD

September 2014

KA317 / LM317
3-Terminal Positive Adjustable Regulator

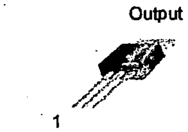
Features

- Output-Current In Excess of 1.5 A
- Output-Adjustable Between 1.2 V and 37 V
- Internal Thermal Overload Protection
- Internal Short-Circuit Current Limiting
- Output-Transistor Safe Operating Area Compensation
- TO-220 Package

Description

This monolithic integrated circuit is an adjustable 3-terminal positive-voltage regulator designed to supply more than 1.5 A of load current with an output voltage adjustable over a 1.2 V to 37 V range. It employs internal current limiting, thermal shutdown, and safe area compensation..

TO-220



1. Adj 2. Output 3. Input

Ordering Information

Product Number	Package	Packing Method	Operating Temperature
LM317T	TO-220 (Single Gauge)	Rail	0°C to +125°C
KA317TU	TO-220 (Dual Gauge)	Rail	0°C to +125°C

Block Diagram

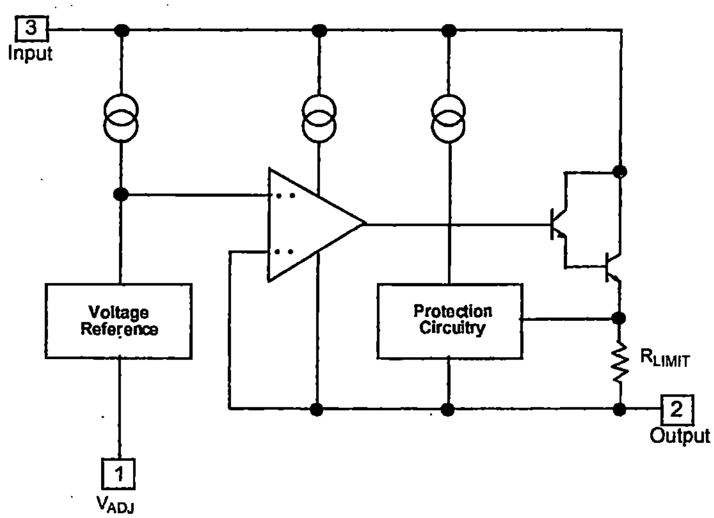


Figure 1. Block Diagram

© 2002 Fairchild Semiconductor Corporation

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter	Value	Unit
$V_I - V_O$	Input-Output Voltage Differential	40	V
T_{LEAD}	Lead Temperature	230	°C
T_J	Operating Junction Temperature Range	0 to +125	°C
T_{STG}	Storage Temperature Range	-65 to +125	°C
$\Delta V_O/\Delta T$	Temperature Coefficient of Output Voltage	±0.02	%/°C

Thermal Characteristics

Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter	Value	Units
P_D	Power Dissipation	Internally Limited	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	°C/W
$R_{\theta JC}$	Thermal Resistance, Junction to Case	5	°C/W

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Electrical Characteristics

$V_I - V_O = 5$ V, $I_O = 0.5$ A, 0°C ≤ T_J ≤ +125°C, $I_{MAX} = 1.5$ A, $P_{DMAX} = 20$ W, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
R_{LINE}	Line Regulation[1]	T_A = +25°C, 3 V ≤ $V_I - V_O$ ≤ 40 V			0.01	0.04	%/ V
		3 V ≤ $V_I - V_O$ ≤ 40 V			0.02	0.07	
R_{LOAD}	Load Regulation[1]	T_A = +25°C, 10mA ≤ I_O ≤ I_{MAX}	V_O < 5 V		18	25	mV
			V_O ≥ 5 V		0.4	0.5	%/V_O
		10 mA ≤ I_O ≤ I_{MAX}	V_O < 5 V		40	70	mV
			V_O ≥ 5 V		0.8	1.5	%/V_O
I_{ADJ}	Adjustable Pin Current				46	100	μA
ΔI_{ADJ}	Adjustable Pin Current Change	3 V ≤ $V_I - V_O$ ≤ 40 V, 10 mA ≤ I_O ≤ I_{MAX}, P_D ≤ P_{MAX}			2.0	5.0	μA
V_{REF}	Reference Voltage	3 V ≤ $V_{IN} - V_O$ ≤ 40 V, 10 mA ≤ I_O ≤ I_{MAX}, P_D ≤ P_{MAX}		1.20	1.25	1.30	V
ST_T	Temperature Stability				0.7		%/V_O
$I_{L(MIN)}$	Minimum Load Current to Maintain Regulation	$V_I - V_O$ = 40 V			3.5	12.0	mA
$I_{O(MAX)}$	Maximum Output Current	T_A = 25°C	$V_I - V_O$ ≤ 15 V, P_D ≤ P_{MAX}	1.5	2.2		A
			$V_I - V_O$ ≤ 40 V, P_D ≤ P_{MAX}		0.3		
e_N	RMS Noise,% of V_{OUT}	T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz			0.003	0.010	%/V_O
RR	Ripple Rejection[2]	V_O = 10 V, f = 120 Hz	without C_{ADJ}		60		dB
			C_{ADJ} = 10 μF	66	75		
ST	Long-Term Stability, $T_J = T_{HIGH}$	T_A = +25°C for End Point Measurements, 1000 HR			0.3	1.0	%

Notes:

1. Load and line regulation are specified at constant junction temperature. Change in V_D due to heating effects must be taken into account separately. Pulse testing with low duty is used (P_{MAX} = 20 W).
2. C_{ADJ}, when used, is connected between the adjustment pin and ground.

Typical Performance Characteristics

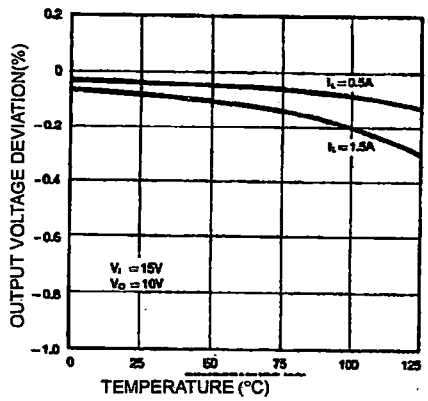


Figure 2. Load Regulation

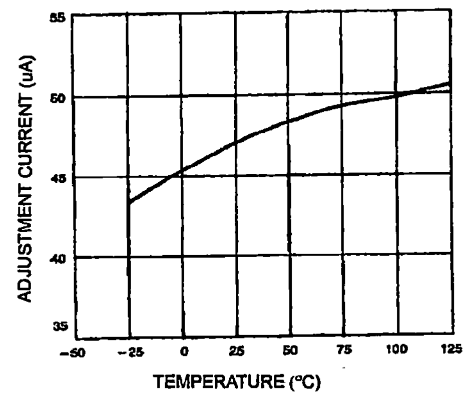


Figure 3. Adjustment Current

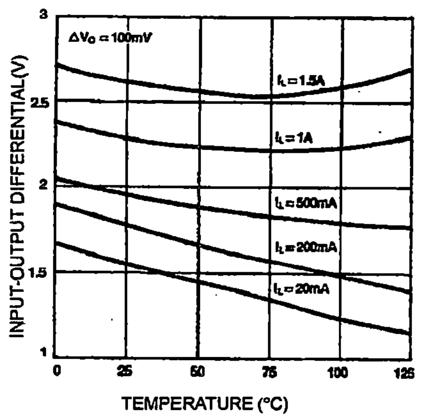


Figure 4. Dropout Voltage

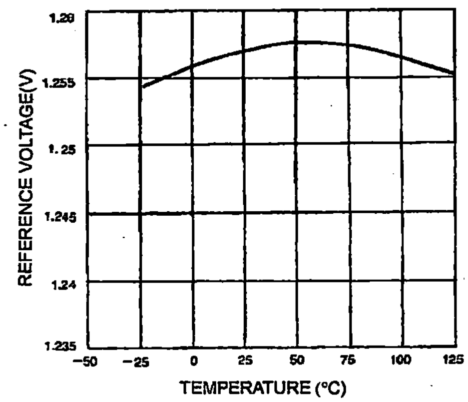


Figure 5. Reference Voltage

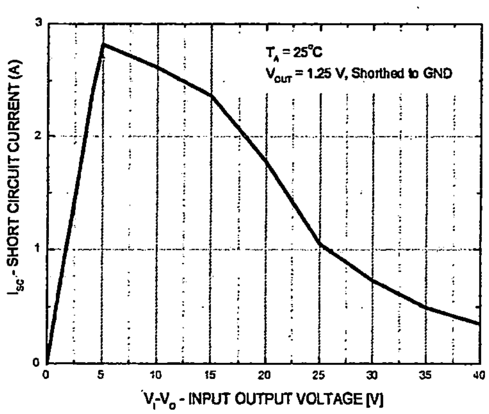
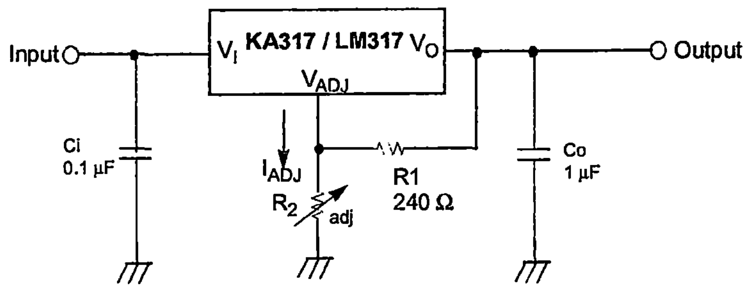


Figure 6. Short Circuit vs-Input-Output Voltage

Typical Application[3]



$$V_O = 1.25\,V\,(1 + R_2 / R_1) + I_{ADJ}R_2$$

Figure 7. Typical Application

Note:

3. C_I is required when the regulator is located an appreciable distance from power supply filter. C_O is not needed for stability; however, it does improve transient response. Since I_{ADJ} is controlled to less than 100 µA, the error associated with this term is negligible in most applications.

Physical Dimensions

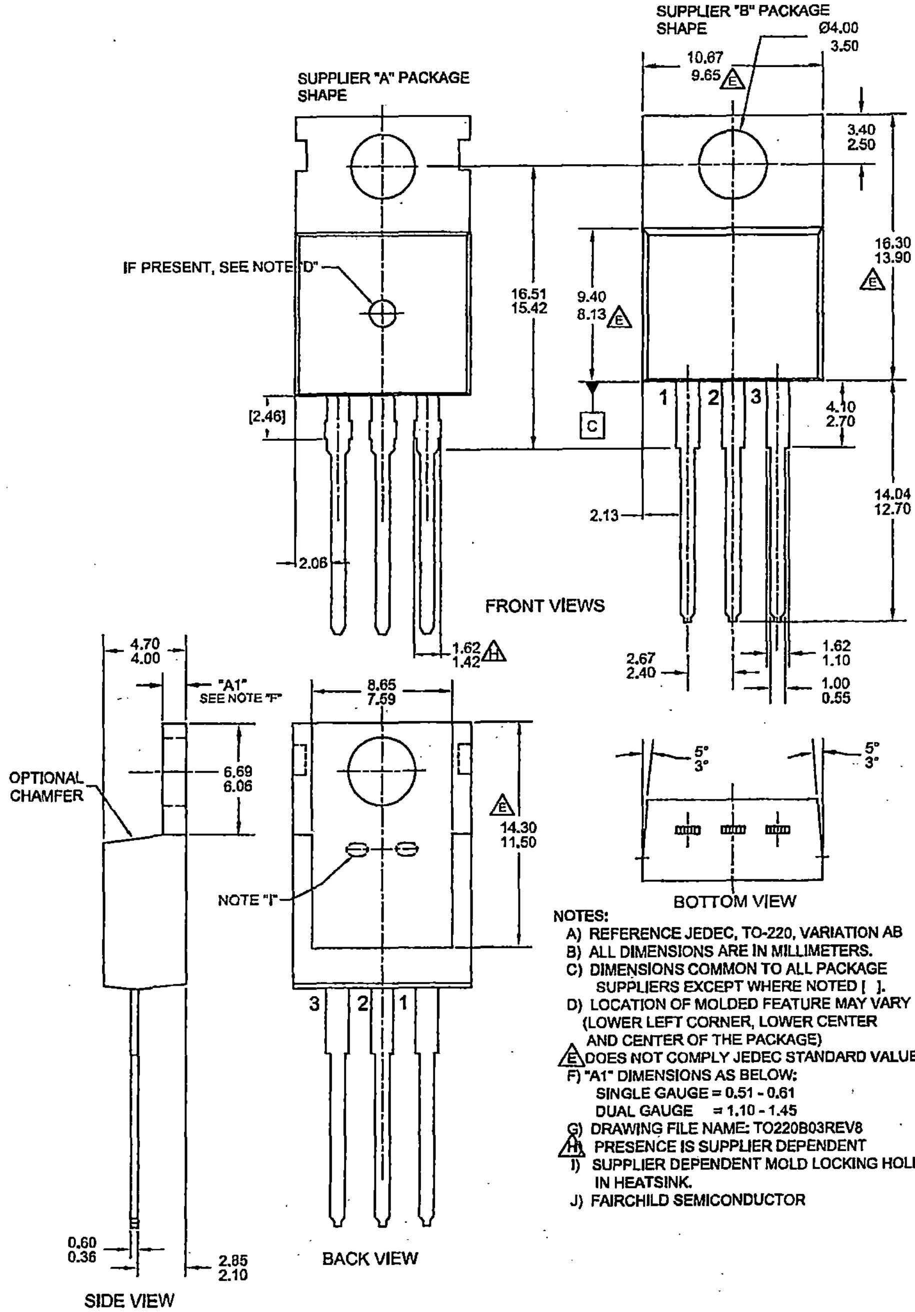
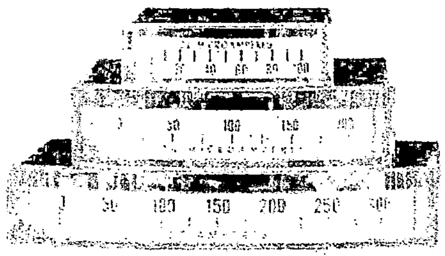


Figure 8. TO-220, MOLDED, 3LEAD, JEDEC VARIATION AB

Series 280 Thin Edgewise Panel Meters



Specifications

These meters are designed to meet all applicable sections of ANSI C39.1.

Accuracy: ±2% of full scale, DC meters; ±3% with 60 Hz sine wave at 25°C for AC rectifier type meters.

Overload: DC Voltmeters — 20% momentary and sustained; DC ammeters (momentary) — 10 times the rated current for 10 consecutive intervals of .5 second with 1 minute intervals between successive applications; DC ammeters (sustained) — 20% for 6 hours.

Dielectric (Hi-pot): 1500 VRMS for 1½" and 2½" sizes: 2600 VRMS for 3½" size.

Response Time: 3 seconds max for μA meters, 2 seconds (max.) for mA, A, mV, & V meters.

Pointer Color: red standard.

Bezel and Mounting Hardware: Included with meter. See below for additional information.

Overshoot: 25% (max.) for 1½" size, 40% (max.) for 2½" and 3½" sizes.

Scale Data: All three sizes designed for 53 degrees deflection. Scale lengths are 1½" size = 1.25", 2½" size = 1.93", 3½" size = 2.70". Note: All scales have linear distributions. 10V, 15V, 30V Rectifier scales will be non-linear.

Dimensions: See page 38.

Mounting Hardware

Item	Cat. No.
Bezel and Hardware Kit 1½"	4149K16G0001
Bezel and Hardware Kit 2½"	4149K15G0003
Bezel and Hardware Kit 3½"	4149K19G0004
Bezel for 21/2" Meters Stacked	4149K18G0002

Series 280 DC Ammeters (Taut Band)

Size		1½		2½		3½	
Rating and Scale	Terminal Resistance Ohms ±15%	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale

DC AMMETERS — SELF-CONTAINED

Rating and Scale	Terminal Resistance Ohms ±15%	1½ Horizontal Scale	1½ Vertical Scale	2½ Horizontal Scale	2½ Vertical Scale	3½ Horizontal Scale	3½ Vertical Scale
0-50 µA	1,980 Ohms	286 111 CYCY	286 113 CYCY	287 111 CYCY	287 113 CYCY	288 111 CYCY	288 113 CYCY
0-100 µA	990 Ohms	286 111 DRDR	286 113 DRDR	287 111 DRDR	287 113 DRDR	288 111 DRDR	288 113 DRDR
0-200 µA	1,340 Ohms	286 111 EAEA	286 113 EAEA	287 111 EAEA	287 113 EAEA	288 111 EAEA	288 113 EAEA
0-500 µA	235 Ohms	286 111 EMEM	286 113 EMEM	287 111 EMEM	287 113 EMEM	288 111 EMEM	288 113 EMEM
0-1 mA	43.2 Ohms	286 111 FAFA	286 113 FAFA	287 111 FAFA	287 113 FAFA	288 111 FAFA	288 113 FAFA
0-5 mA	3.3 Ohms	286 111 FXFX	286 113 FXFX	287 111 FXFX	287 113 FXFX	288 111 FXFX	288 113 FXFX
0-10 mA	5 Ohms	286 111 GZGZ	286 113 GZGZ	287 111 GZGZ	287 113 GZGZ	288 111 GZGZ	288 113 GZGZ
0-25 mA	2.0 Ohms	286 111 HJHJ	286 113 HJHJ	287 111 HJHJ	287 113 HJHJ	288 111 HJHJ	288 113 HJHJ
0-50 mA	1.0 Ohms	286 111 HYHY	286 113 HYHY	287 111 HYHY	287 113 HYHY	288 111 HYHY	288 113 HYHY
0-100 mA	0.5 Ohms	286 111 JRJR	286 113 JRJR	287 111 JRJR	287 113 JRJR	288 111 JRJR	288 113 JRJR
0-250 mA	0.2 Ohms	286 111 KDKD	286 113 KDKD	287 111 KDKD	287 113 KDKD	288 111 KDKD	288 113 KDKD
0-500 mA	0.1 Ohms	286 111 KMKM	286 113 KMKM	287 111 KMKM	287 113 KMKM	288 111 KMKM	288 113 KMKM
0-1 Amp	0.05 Ohms	286 111 LALA	286 113 LALA	287 111 LALA	287 113 LALA	288 111 LALA	288 113 LALA
0-1.5 Amp	0.033 Ohms	286 111 LCLC	286 113 LCLC	287 111 LCLC	287 113 LCLC	288 111 LCLC	288 113 LCLC
0-2 Amp	0.025 Ohms	286 111 LELE	286 113 LELE	287 111 LELE	287 113 LELE	288 111 LELE	288 113 LELE
0-3 Amp	0.0167 Ohms	286 111 LJLJ	286 113 LJLJ	287 111 LJLJ	287 113 LJLJ	288 111 LJLJ	288 113 LJLJ
0-5 Amp	0.01 Ohms	286 111 LSLS	286 113 LSLS	287 111 LSLS	287 113 LSLS	288 111 LSLS	288 113 LSLS
50-0-50 µA	990 Ohms	286 112 CYCY	286 114 CYCY	287 112 CYCY	287 114 CYCY	288 112 CYCY	288 114 CYCY
100-0-100 µA	1,340 Ohms	286 112 DRDR	286 114 DRDR	287 112 DRDR	287 114 DRDR	288 112 DRDR	288 114 DRDR
500-0-500 µA	43.2 Ohms	286 112 EMEM	286 114 EMEM	287 112 EMEM	287 114 EMEM	288 112 EMEM	288 114 EMEM
01-0-1 mA	22.2 Ohms	286 112 FAFA	286 114 FAFA	287 112 FAFA	287 114 FAFA	288 112 FAFA	288 114 FAFA
5-0-5 mA	5 Ohms	286 112 FXFX	286 114 FXFX	287 112 FXFX	287 114 FXFX	288 112 FXFX	288 114 FXFX
50-0-50 mA	0.5 Ohms	....	....	287 112 HYHY	287 114 HYHY	288 112 HYHY	288 114 HYHY
5-0-5 Amp	0.005 Ohms	286 112 LSLS	286 114 LSLS	287 112 LSLS	287 114 LSLS	288 112 LSLS	288 114 LSLS

DC AMMETERS — SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*

SCALE ONLY

Rating and Scale	Terminal Resistance Ohms ±15%	1½ Horizontal Scale	1½ Vertical Scale	2½ Horizontal Scale	2½ Vertical Scale	3½ Horizontal Scale	3½ Vertical Scale
1 Amp	(0-50 mV) 10 Ohms	286 121 ECLA	286 123 ECLA	287 121 ECLA	287 123 ECLA	288 121 ECLA	288 123 ECLA
5 Amp	(0-50 mV) 10 Ohms	286 121 ECLS	286 123 ECLS	287 121 ECLS	287 123 ECLS	288 121 ECLS	288 123 ECLS
10 Amp	(0-50 mV) 10 Ohms	286 121 ECMT	286 123 ECMT	287 121 ECMT	287 123 ECMT	288 121 ECMT	288 123 ECMT
20 Amp	(0-50 mV) 10 Ohms	286 121 ECNG	286 123 ECNG	287 121 ECNG	287 123 ECNG	288 121 ECNG	288 123 ECNG
50 Amp	(0-50 mV) 10 Ohms	286 121 ECNT	286 123 ECNT	287 121 ECNT	287 123 ECNT	288 121 ECNT	288 123 ECNT
300 Amp	(0-50 mV) 10 Ohms	286 121 ECRX	286 123 ECRX	287 121 ECRX	287 123 ECRX	288 121 ECRX	288 123 ECRX
500 Amp	(0-50 mV) 10 Ohms	286 121 ECSF	286 123 ECSF	287 121 ECSF	287 123 ECSF	288 121 ECSF	288 123 ECSF
1 Amp	(0-100 mV) 20 Ohms	286 121 GBLA	286 123 GBLA	287 121 GBLA	287 123 GBLA	288 121 GBLA	288 123 GBLA
5 Amp	(0-100 mV) 20 Ohms	286 121 GBLS	286 123 GBLS	287 121 GBLS	287 123 GBLS	288 121 GBLS	288 123 GBLS
10 Amp	(0-100 mV) 20 Ohms	286 121 GBMT	286 123 GBMT	287 121 GBMT	287 123 GBMT	288 121 GBMT	288 123 GBMT
20 Amp	(0-100 mV) 20 Ohms	286 121 GMNG	286 123 GMNG	287 121 GMNG	287 123 GMNG	288 121 GMNG	288 123 GMNG
50 Amp	(0-100 mV) 20 Ohms	286 121 GBNT	286 123 GBNT	287 121 GBNT	287 123 GBNT	288 121 GBNT	288 123 GBNT
300 Amp	(0-100 mV) 20 Ohms	286 121 GBRX	286 123 GBRX	287 121 GBRX	287 123 GBRX	288 121 GBRX	288 123 GBRX
500 Amp	(0-100 mV) 20 Ohms	286 121 GBSF	286 123 GBSF	287 121 GBSF	287 123 GBSF	288 121 GBSF	288 123 GBSF

*Shunts not included. See Page 29 for 50mV shunts.

Series 280 AC Voltmeters

AC VOLTMETERS — RECTIFIER TYPE

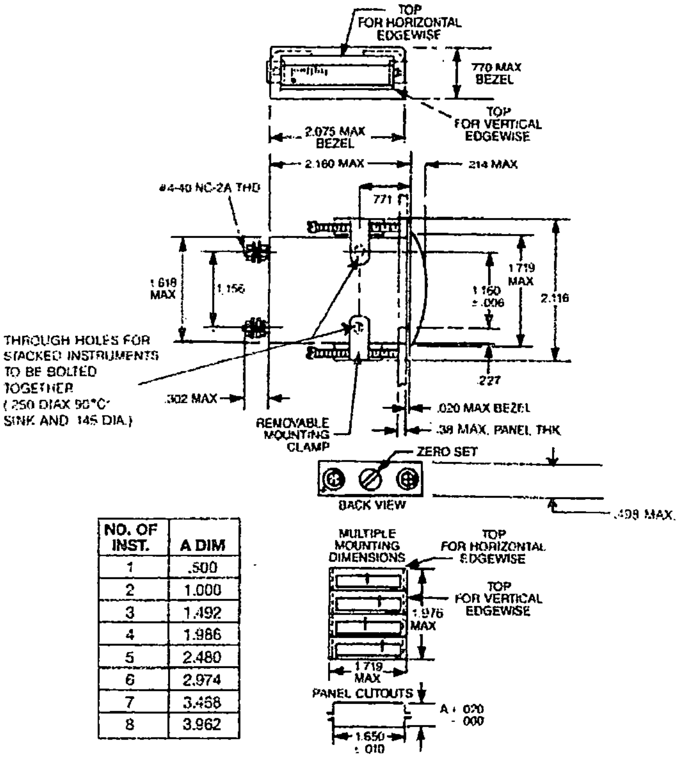
Rating and Scale	Terminal Resistance Ohms ±15%	1½ Horizontal Scale	1½ Vertical Scale	2½ Horizontal Scale	2½ Vertical Scale	3½ Horizontal Scale	3½ Vertical Scale
0-10 Volts	1000 Ohms/volt	286 051 MTMT	286 053 MTMT	287 051 MTMT	287 053 MTMT	288 051 MTMT	288 053 MTMT
0-15 Volts	1000 Ohms/volt	286 051 NDND	286 053 NDND	287 051 NDND	287 053 NDND	288 051 NDND	288 053 NDND
0-30 Volts	1000 Ohms/volt	286 051 NLNL	286 053 NLNL	287 051 NLNL	287 053 NLNL	288 051 NLNL	288 053 NLNL
0-50 Volts	1000 Ohms/volt	286 051 NTNT	286 053 NTNT	287 051 NTNT	287 053 NTNT	288 051 NTNT	288 053 NTNT
0-100 Volts	1000 Ohms/volt	286 051 PKPK	286 053 PKPK	287 051 PKPK	287 053 PKPK	288 051 PKPK	288 053 PKPK
0-150 Volts	1000 Ohms/volt	286 051 PZPZ	286 053 PZPZ	287 051 PZPZ	287 053 PZPZ	288 051 PZPZ	288 053 PZPZ

Series 280 AC Ammeters

AC AMMETERS — RECTIFIER TYPE∆

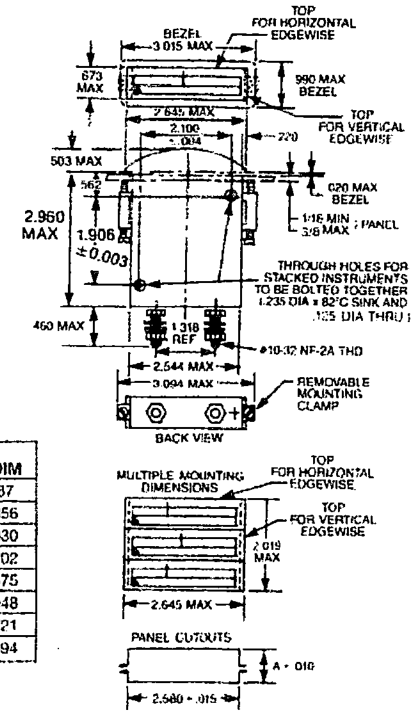
Rating and Scale	Terminal Resistance Ohms ±15%	1½ Horizontal Scale	1½ Vertical Scale	2½ Horizontal Scale	2½ Vertical Scale	3½ Horizontal Scale	3½ Vertical Scale
0-500 µA	1267 Ohms	286 151 EMEM	286 153 EMEM	287 151 EMEM	287153 EMEM	288 151 EMEM	288 153 EMEM
0-1 mA	758 Ohms	286 151 FAFA	286 153 FAFA	287 151 FAFA	287153 FAFA	288 151 FAFA	288 153 FAFA
0-5 mA	196 Ohms	286 151 FXFX	286 153 FXFX	287 151 FXFX	287153 FXFX	288 151 FXFX	288 153 FXFX
0-10 mA	97 Ohms	286 151 GZGZ	286 153 GZGZ	287 151 GZGZ	287153 GZGZ	288 151 GZGZ	288 153 GZGZ
0-20 mA	55 Ohms	286 151 HFHF	286 153 HFHF	287 151 HFHF	287153 HFHF	288 151 HFHF	288 153 HFHF

∆ A 5 AMP AC self-contained 3½" (Type 288) is available as a special, but is not per ANSI C39.1. Contact factory for more information.



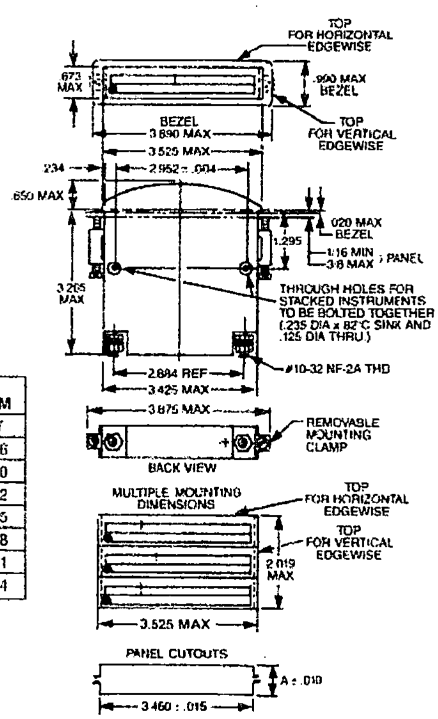
NO. OF INST.	A DIM
1	.500
2	1.000
3	1.492
4	1.986
5	2.480
6	2.974
7	3.468
8	3.962

Fig. 17. Outline Dimensions for 1½-inch Type 286 meters



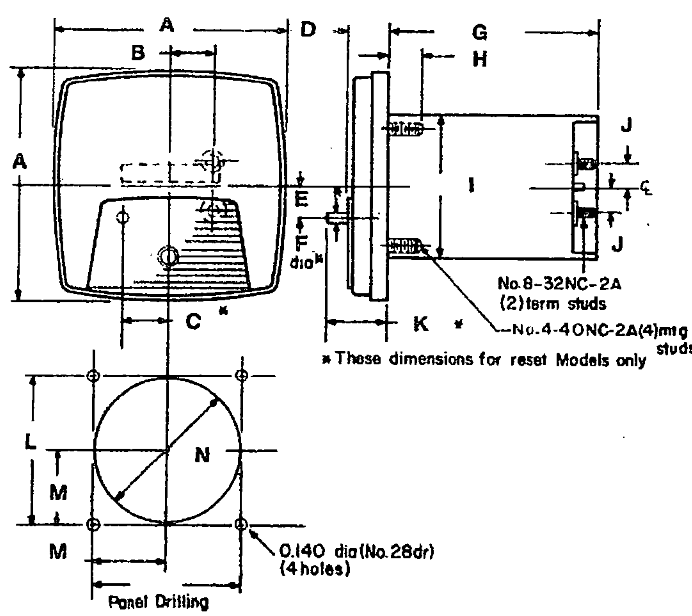
NO. OF INST.	A DIM
1	.687
2	1.356
3	2.030
4	2.702
5	3.375
6	4.048
7	4.721
8	5.394

Fig. 18. Outline Dimensions for 2½-inch Type 287 meters



NO. OF INST.	A DIM
1	.687
2	1.356
3	2.030
4	2.702
5	3.375
6	4.048
7	4.721
8	5.394

Fig. 19. Outline Dimensions for 3½-inch Type 288 meters



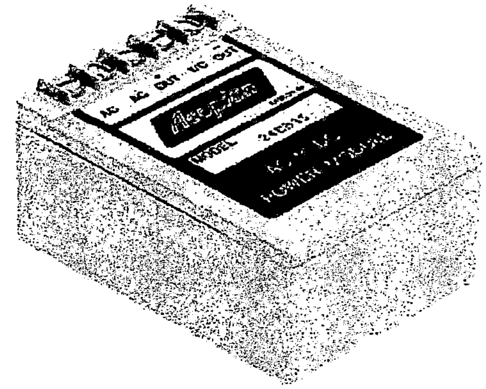
SIZE \ DIM	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2½ BL	2.7	.68	.72	.5	.48	.14	3.253	.5	2.215	.38	.80	1.88	.94	2.22
3½ BL	3.5	.68	.72	.5	.48	.14	3.253	.5	2.215	.38	.80	2.25	1.125	2.22

Fig. 20. New Big Look 2½ & 3½-inch Type 240

single & dual tracking outputs

Mini Encapsulated - with screw terminals

LINEAR REGULATED
AC-DC



- Shipped Within 3 Days
- All Models U.L. Recognized
- One Year Warranty

Although small in size, these mini-modules offer high performance at modest prices. All models, with series regulated outputs ranging from 1 to 75 volts and as high as 2.5 amps, may be mounted in an area only 3.5" x 2.5". Dual output models are available with the ratings commonly required for driving op amps and other balanced loads. Terminal strip input/output connections eliminate all need for sockets or soldering. Short circuit protection, encapsulated construction, and conservative design assure long term reliability.

STANDARD FEATURES

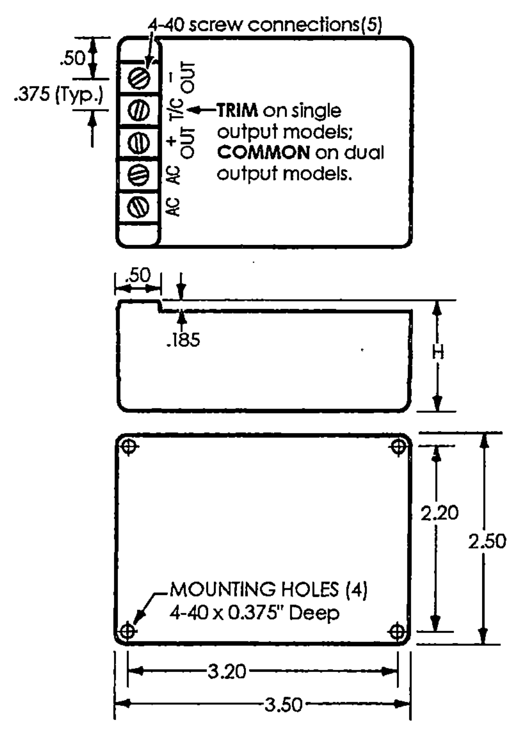
- May be used in series
- No derating or heat sinking required
- Short circuit protected
- Small, lightweight

SPECIFICATIONS

Input Voltage: 105-125 VAC, 47 to 420 Hz, single phase.
Output Voltage Setting: Outputs are factory preset to within ±2% (1 to 9 volt models) or ±1% (10 to 75 volt models) of the nominal output voltage.
T/C terminal: For single output models, the T/C terminal can be used to trim the output more precisely to the nominal voltage rating by connecting an external resistor from the T/C terminal to either the + or – terminal. For dual output models, the T/C terminal is the output common.
Polarity: Either positive or negative terminal of a single output module may be grounded. Dual output modules have a positive/common/negative output terminal configuration.
Ambient Operating Temperature: –20 to +71°C. No derating required.
Storage Temperature: –55 to +85°C.
Temperature Coefficient: From 9 to 75 volts, typically 0.015%/°C; 1 to 8 volts, 0.03%/°C.
Impedance: 0.07 ohms at 1 kHz and 0.2 ohms at 10 kHz (approx.).
Mounting: Threaded mounting holes permit mounting to a chassis, cabinet wall or bracket, or they may be used on a test bench or tabletop. When wall-mounting or DIN rail mounting is desired, use accessory Mounting Kits on page H4.

OPTIONS

230 Volt Input: All models can be alternately furnished for operation on an input of 210 to 250 VAC, 47-420 Hz. To order, add suffix "–230" to model number and $10.00 to price. The "–230" option requires two additional days.



Case Size	H	Approx. Weight
EB-10	1.375	15 oz.
EB-13	1.625	1 lb. 4 oz.
EB-20	2.375	2 lb. 1 oz.

All dimensions in inches.

Acopian
Online Ordering and Instant Quotes for ALL Acopian power supplies at www.acopian.com
P.O. Box 638, Easton, PA 18044 • Phone: (610) 258-5441 • FAX: (610) 258-2842

SINGLE OUTPUT, WITH SCREW TERMINALS

(For Mini Encapsulated power supplies with higher wattage outputs than those shown below, see pages C1-C2.)

Nominal Output Voltage	Output Current Amps.	Regulation Load ±%	Regulation Line ±%	Ripple mV RMS	($) Price	Model	Case Size
1	.500	.4	.05	1	110	1EB50	EB-10
1.5	.500	.3	.05	1	110	1.5EB50	EB-10
1.5	1.0	.5	.05	1	145	1.5EB100	EB-13
1.5	2.5	.6	.05	1	190	1.5EB250	EB-20
2	.400	.25	.05	1	110	2EB40	EB-10
3	.500	.25	.05	1	110	3EB50	EB-10
3.3	.500	.15	.05	1	110	3.3EB50	EB-10
3.3	1.0	.4	.05	1	145	3.3EB100	EB-13
3.3	2.0	.4	.05	1	170	3.3EB200	EB-20
4	.400	.15	.05	1	110	4EB40	EB-10
5	.500	.15	.05	1	110	5EB50	EB-10
5	1.0	.25	.05	1	130	5EB100	EB-13
5	1.5	.25	.05	1	150	5EB150	EB-13
5	2.0	.25	.05	1	170	5EB200	EB-20
5	2.5	.25	.05	1	190	5EB250	EB-20
6	.400	.1	.05	1	110	6EB40	EB-10
6	.550	.25	.05	1	130	6EB55	EB-10
6	1.0	.25	.05	1	150	6EB100	EB-13
6	1.75	.2	.05	1	175	6EB175	EB-20
7	.340	.1	.05	1	110	7EB34	EB-10
7	.450	.2	.05	1	130	7EB45	EB-10
7	.900	.25	.05	1	150	7EB90	EB-13
7	1.15	.2	.05	1	175	7EB115	EB-20
8	.300	.1	.05	1	110	8EB30	EB-10
8	.700	.2	.05	1	150	8EB70	EB-13
8	1.1	.2	.05	1	175	8EB110	EB-20
9	.260	.1	.05	1	110	9EB26	EB-10
9	.450	.15	.05	1	130	9EB45	EB-10
9	.850	.2	.05	1	150	9EB85	EB-13
9	1.5	.2	.05	1	185	9EB150	EB-20
10	.240	.05	.05	1	110	10EB24	EB-10
10	.400	.15	.05	1	130	10EB40	EB-10
10	.750	.2	.05	1	150	10EB75	EB-13
10	1.2	.15	.05	1	185	10EB120	EB-20
11	.220	.05	.05	1	110	11EB22	EB-10
11	.350	.15	.05	1	130	11EB35	EB-10
11	.600	.15	.05	1	150	11EB60	EB-13
11	1.0	.15	.05	1	185	11EB100	EB-20
12	.200	.05	.05	1	110	12EB20	EB-10
12	.400	.1	.05	1	130	12EB40	EB-10
12	.700	.15	.05	1	160	12EB70	EB-13
12	1.2	.2	.05	1	185	12EB120	EB-20
13	.200	.05	.05	1	110	13EB20	EB-10
13	.350	.1	.05	1	130	13EB35	EB-10
13	.600	.1	.05	1	160	13EB60	EB-13
13	1.0	.15	.05	1	185	13EB100	EB-20
14	.200	.05	.05	1	110	14EB20	EB-10
14	.300	.1	.05	1	130	14EB30	EB-10
14	.500	.1	.05	1	150	14EB50	EB-13
14	1.0	.15	.05	1	185	14EB100	EB-20
15	.200	.05	.05	1	110	15EB20	EB-10
15	.400	.1	.05	1	130	15EB40	EB-10
15	.600	.1	.05	1	150	15EB60	EB-13
15	1.0	.15	.05	1	185	15EB100	EB-20
16	.160	.05	.05	1	110	16EB16	EB-10
16	.350	.1	.05	1	140	16EB35	EB-10
16	.500	.1	.05	1	160	16EB50	EB-13
16	.900	.15	.05	1	185	16EB90	EB-20
17	.140	.05	.05	1	110	17EB14	EB-10
17	.325	.1	.05	1	140	17EB33	EB-10
17	.450	.1	.05	1	160	17EB45	EB-13
17	.750	.15	.05	1	185	17EB75	EB-20
18	.120	.05	.05	1	110	18EB12	EB-10
18	.270	.1	.05	1	130	18EB27	EB-10
18	.400	.1	.05	1	150	18EB40	EB-13
18	.550	.1	.05	1	175	18EB55	EB-20

Nominal Output Voltage	Output Current Amps.	Regulation Load ±%	Regulation Line ±%	Ripple mV RMS	($) Price	Model	Case Size
19	.120	.05	.05	1	110	19EB12	EB-10
19	.250	.1	.05	1	130	19EB25	EB-10
19	.400	.1	.05	1	150	19EB40	EB-13
19	.700	.1	.05	1	185	19EB70	EB-20
20	.120	.05	.05	1	110	20EB12	EB-10
20	.200	.1	.05	1	130	20EB20	EB-10
20	.400	.1	.05	1	150	20EB40	EB-13
20	.700	.1	.05	1	185	20EB70	EB-20
21	.120	.05	.05	1	110	21EB12	EB-10
21	.175	.1	.05	1	130	21EB18	EB-10
21	.375	.1	.05	1	150	21EB38	EB-13
21	.600	.1	.05	1	175	21EB60	EB-20
22	.100	.05	.05	1	110	22EB10	EB-10
22	.150	.1	.05	1	130	22EB15	EB-10
22	.300	.1	.05	1	150	22EB30	EB-13
22	.500	.1	.05	1	175	22EB50	EB-20
23	.100	.05	.05	1	110	23EB10	EB-10
23	.200	.1	.05	1	130	23EB20	EB-10
23	.300	.1	.05	1	150	23EB30	EB-13
23	.600	.1	.05	1	185	23EB60	EB-20
24	.100	.05	.05	1	110	24EB10	EB-10
24	.200	.1	.05	1	130	24EB20	EB-10
24	.350	.1	.05	1	160	24EB35	EB-13
24	.600	.1	.05	1	185	24EB60	EB-20
25	.100	.05	.05	1	110	25EB10	EB-10
25	.190	.1	.05	1	130	25EB19	EB-10
25	.325	.1	.05	1	160	25EB33	EB-13
25	.550	.1	.05	1	185	25EB55	EB-20
26	.080	.05	.05	1	110	26EB08	EB-10
26	.170	.1	.05	1	130	26EB17	EB-10
26	.300	.1	.05	1	150	26EB30	EB-13
26	.450	.1	.05	1	175	26EB45	EB-20
27	.080	.05	.05	1	110	27EB08	EB-10
27	.160	.1	.05	1	130	27EB16	EB-10
27	.300	.1	.05	1	150	27EB30	EB-13
27	.500	.1	.05	1	185	27EB50	EB-20
28	.080	.05	.05	1	110	28EB08	EB-10
28	.150	.1	.05	1	130	28EB15	EB-10
28	.300	.1	.05	1	160	28EB30	EB-13
28	.500	.1	.05	1	185	28EB50	EB-20
30	.080	.02	.02	1	120	30EB08	EB-13
32	.070	.02	.02	1	120	32EB07	EB-13
34	.060	.02	.02	1	120	34EB06	EB-13
35	.050	.02	.02	1	120	35EB05	EB-13
36	.050	.02	.02	1	120	36EB05	EB-13
38	.040	.02	.02	1	120	38EB04	EB-13
40	.030	.02	.02	1	120	40EB03	EB-13
40	.060	.02	.02	1	145	40EB06	EB-13
42	.030	.02	.02	1	120	42EB03	EB-13
44	.030	.02	.02	1	120	44EB03	EB-13
45	.030	.02	.02	1	120	45EB03	EB-13
48	.030	.02	.02	1	120	48EB03	EB-13
48	.050	.02	.02	1	145	48EB05	EB-13
50	.030	.02	.02	1	120	50EB03	EB-13
50	.050	.02	.02	1	145	50EB05	EB-13
55	.040	.02	.02	1	145	55EB04	EB-13
60	.050	.02	.02	1	145	60EB05	EB-13
65	.050	.02	.02	1	145	65EB05	EB-13
70	.040	.02	.02	1	145	70EB04	EB-13
75	.030	.02	.02	1	145	75EB03	EB-13
185	.025	Unregulated		2V	80	NX-25B	EB-10
185	.050	Unregulated		3.5V	105	NX-50B	EB-13

LINEAR REGULATED AC-DC

DUAL TRACKING OUTPUTS

Nominal Output Voltages	Amps. per Output	Regulation Load ±%	Regulation Line ±%	Ripple mV RMS	($) Price	Model	Case Size
±5	.150	.1	.05	1.5	120	DB5-15	EB-10
±5	.250	.1	.05	1.5	145	DB5-25	EB-10
±5	.500	.1	.05	1.5	195	DB5-50	EB-20
±10	.200	.05	.05	1	130	DB10-20	EB-10
±10	.300	.05	.05	1	170	DB10-30	EB-13
±10	.400	.1	.05	1	195	DB10-40	EB-20
±12	.100	.05	.05	1	105	DB12-10	EB-10
±12	.150	.05	.05	1	120	DB12-15	EB-10
±12	.200	.05	.05	1	130	DB12-20	EB-10

Nominal Output Voltages	Amps. per Output	Regulation Load ±%	Regulation Line ±%	Ripple mV RMS	($) Price	Model	Case Size
±12	.300	.05	.05	1	160	DB12-30	EB-13
±12	.350	.05	.05	1	170	DB12-35	EB-13
±12	.500	.1	.05	1	195	DB12-50	EB-20
±15	.100	.05	.05	1	105	DB15-10	EB-10
±15	.150	.05	.05	1	120	DB15-15	EB-10
±15	.200	.05	.05	1	130	DB15-20	EB-10
±15	.300	.05	.05	1	160	DB15-30	EB-13
±15	.350	.05	.05	1	170	DB15-35	EB-13
±15	.500	.1	.05	1	195	DB15-50	EB-20

Myro Electronic Control Devices Inc.
11-300 Earl Grey Drive, Suite 186
Phone:+1(888)PCB-MYRO(722-6976)
Fax:+1(613)777-0186
sales@myropcb.com

SN #:1507232454

Order Date : Jul 23,2015
Customer ID: 33663
: Jul 29,2015
PO:
items: 1

Sold To:
3phase@mit.edu(33663)
Massachussetts Instutute of Tech
138 albany street
Cambridge massachussetts 02139
United States
6319781650

Shipping To:
Massachussetts Instutute of Tech
Dane Kouttron
138 albany street
Cambridge,massachussetts,02139
United States
6319781650

Item/No	Project Name	Description	Quantity	Original Price(USD)	Present Price(USD)
1	magnet_card_4	2 Layers.Size (KB):4.300*6.730inch, FR-4, Thickness 1.600mm, base Copper Weight 2.000oz	6	106.22	106.22
Sub Total(USD)				106.22	
Shipping Charge(USD)				35.00	
Total Due(USD)				141.22	

Customer Message:

Customer Signed: ______________________

Date: ______________________

---------------------------Detail---------------------------

1507232454-1 Bare PCB fabrication

Specification

Project Name	magnet_card_4	Layer	2	Finished Thickness	1.6mm/0.063"
Dimension *	4.300 X 6.730 inch / Piece			Quantity *	6 Piece
Material	FR-4	Solder Mask	Double side	LPI color	Green
Pads Finished	Lead free HASL	Silkscreen	Top side	Finished Copper Weight	2.000 oz (top/bottom)
Min. holes Size	0.035 inch	Number Holes	192	Minimum Annular Ring	50 mil
Min. trace/space	0.008inch				
Gold Fingers Number	44	Bevel Angle Beside Gold Fingers	45 Degree	Gold Fingers	**:Yes**
Thickness of the gold	0.00 um	Size of the gold finger	9.7 X 2.7 mm		
Advance Information					
Solder Mask Color Type: Glossy					
Silkscreen Color	White	Via Plugging	Customer Gerber		
Semicircle conducting hole	N	Plated Through Slits	N	Sideplating	N
Packaging Method	Vacuum	Check Accept	National Standard		
Hole Wall Copper-Plating Thickness	18 um				
Other					
Test Method					
		Molding Mode	Numerical Control		
Comments:					

Expected Date*:Jul-30-15
Make individually

Source:Online

Uploaded Files	CAM4.zip

Detail Price			
Project Name :magnet_card_4	**Price (USD)**	**Quantity**	**QTY (USD)**
Unit Price(USD)	6.3700	6	38.2200(USD)
Setup Fee(USD)	68.00	1	68.00(USD)
Shipping Fee(USD)			35.00
total fee(USD)			141.22

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EDWARD S. LAU
Assistant Director of
Reactor Operations

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Tel. No. (617) 253-4211

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Drawings and Schematics

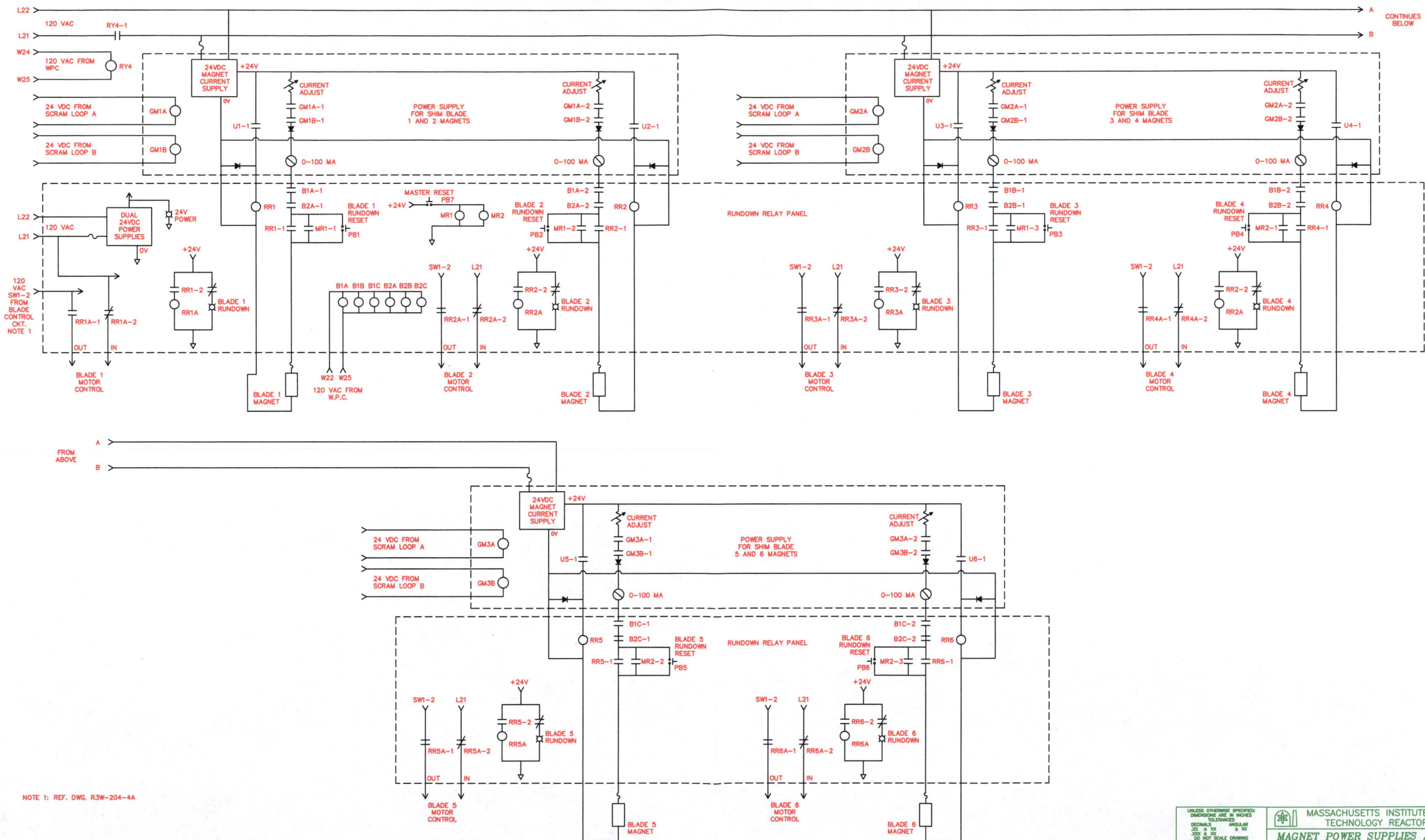
NSS Magnet Power Supply Modules

1. Drawing R3W-258-4 "Magnet Power Supplies and Rundown Relay Panel" is the schematic for the magnet power supplies.

2. Drawing R3W-266-4 "Magnet Power Supplies" shows circuit diagram details for a single power supply module.

3. Images of the completed Nuclear Safety System (NSS) Magnet Power Supply Modules mounted in NIM Bin 2 are in Figure 1 of the Safety Review for the Magnet Power Supply Modules, QA files #2017-38 and #2017-39.

4. The final physical location of the three Magnet Power Supply Modules in the reactor control room is detailed in the New Nuclear Safety System Installation Plan.



NOTE 1: REF. DWG. R3W-204-4A

ZONE	REV	DESCRIPTION	DATE	APPROVED

REVISIONS

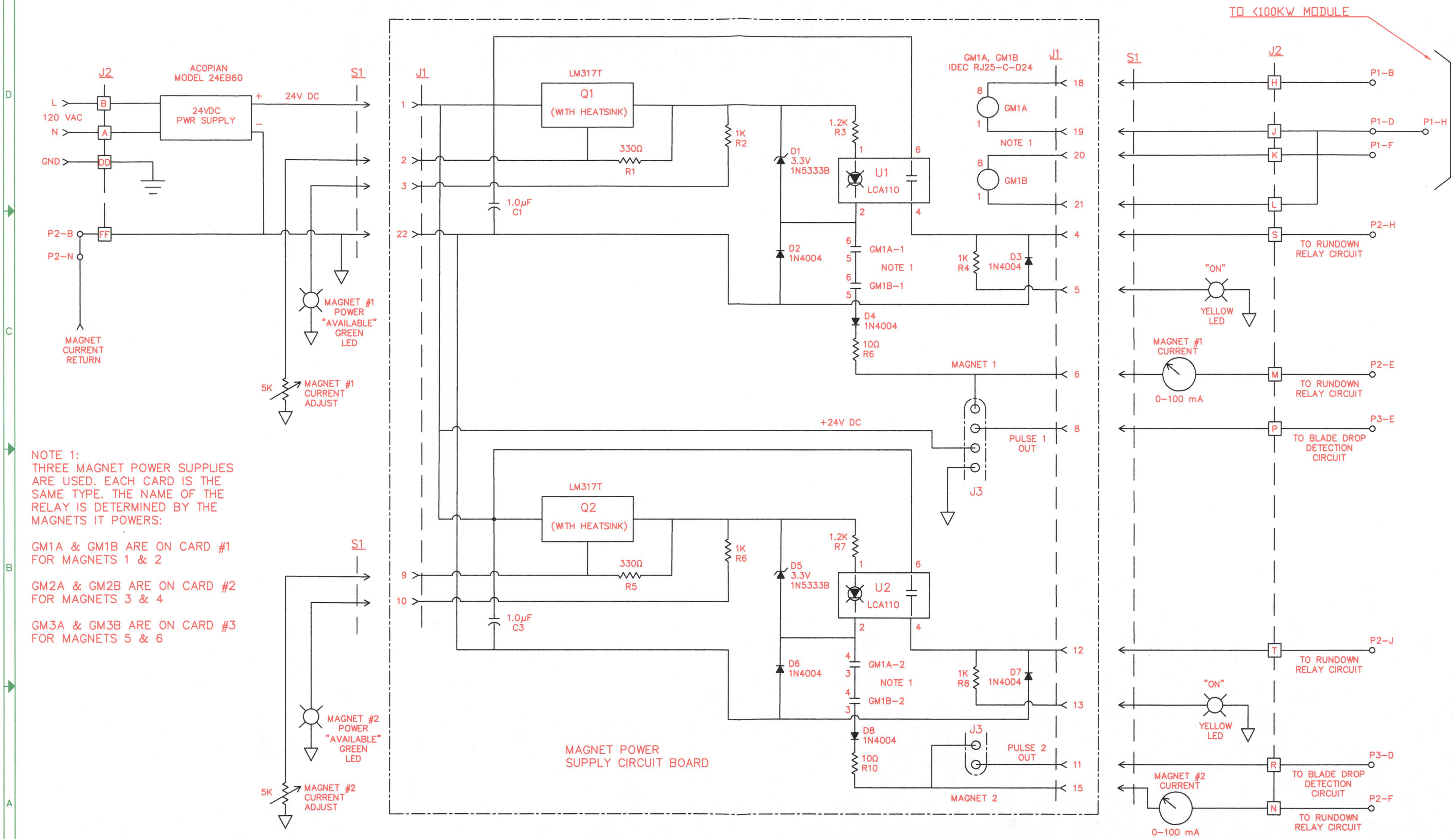
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± XX .XXX ± XX ANGULAR ± XX
DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

MAGNET POWER SUPPLIES AND RUNDOWN RELAY PANEL

DRAWN NAWAZELSKI	DATE 10/31/17	
REVIEWED & APPROVED EL/ST E/F	12/1/17	SIZE D · FILE NO. QA#2017-38,39 · DWG NO. R3W-258 -4 · REV
DESIGN MENADIER	10/31/17	SCALE NONE · SHEET 1 OF 1



NOTE 1:
THREE MAGNET POWER SUPPLIES ARE USED. EACH CARD IS THE SAME TYPE. THE NAME OF THE RELAY IS DETERMINED BY THE MAGNETS IT POWERS:

GM1A & GM1B ARE ON CARD #1 FOR MAGNETS 1 & 2

GM2A & GM2B ARE ON CARD #2 FOR MAGNETS 3 & 4

GM3A & GM3B ARE ON CARD #3 FOR MAGNETS 5 & 6

P1, P2, P3: CONNECTORS ON REAR OF NIM BIN #2

J1: CIRCUIT BOARD EDGE CONNECTOR
S1: CHASSIS SOCKET
J2: NIM MODULE REAR PANEL CONNECTOR
J3: HEADER ON CIRCUIT BOARD CONNECTION TO INTERFACE CIRCUIT FOR BLADE DROP DETECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR
MAGNET
POWER SUPPLIES
DRAWN NAWAZELSKI 10/27/17
REVIEWED & APPROVED EL/ST 12/1/17
DESIGN MENADIER 9/12/17
SIZE D | FILE NO. QA# 2017-38 | DWG NO. R3W-266 -4
SCALE NONE | SHEET 1 OF 1

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EDWARD S. LAU
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Fabrication

NSS Magnet Power Supply Modules

1. The NSS Magnet Power Supply Modules were fabricated in-house.

2. Parts and materials necessary for the construction of the Magnet Power Supply Modules are listed in the Procurement section of this QA file.

3. Fabrication compliance:

   The Magnet Power Supply Modules were verified to have been constructed as designed, using the above components.

Paul Menadier — 11-1-17

Constructed by: Paul Menadier, Senior Project Specialist — Date

Edward Lau — 11/20/2017

Verified by: Edward Lau, Assistant Director of Reactor Operations — Date

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Bench Testing

NSS Magnet Power Supply Modules

1. The verification test for the Magnet Power Supply circuit boards is "Special Procedure for Fabrication and Bench Testing the Magnet Power Supply Circuit Boards". The completed procedure is attached, and describes the equipment used for the test.

   Acceptance Criteria:

   a. The circuit board is able to provide current, using the Magnet Power Supply Circuit Board Test Box, to two simulated magnets over the range from 50 mA to 100 mA.

   b. Each rundown relay (#1 and #2) on each Magnet Power Supply circuit boad de-energizes when the magnet current decreases to a point below 10 mA.

   Result:

   The fabrication, visual inspection, and verification bench tests were all completed satisfactorily as per the above special procedure, for all six Magnet Power Supply circuit boards.

2. The verification test for the Magnet Power Supply Modules is "Special Procedure for Fabrication and Bench Testing of the Magnet Power Supply Modules". The completed procedure is attached, and describes the equipment used for the test.

   Acceptance Criteria:

   a. Magnet currents agrees with the Test Box at 40 mA and 80 mA to within ±2 mA.

   b. Each rundown relay (#1 and #2) on each Magnet Power Supply Module de-energizes when the magnet current decreases to a point below 5 mA.

   Result:

   The fabrication, visual inspection, and verification bench tests were all completed satisfactorily as per the above special procedure, for all three Magnet Power Supply Modules and one spare module.

Paul Menadier / Edward Lau 12/07/2017

Completed and Approved by: Paul Menadier, Senior Project Specialist Date
Verified by: Edward Lau, Assistant Director of Reactor Operations

Special Procedure for Fabrication and Bench Testing of the Magnet Power Supply Modules

Note: While this test procedure is written for the #1 and #2 magnet supply, it may be used for the #3 and #4 supply, the #5 and #6 supply, as well as the "spare" supply. The left hand controls/indicators refer to the odd number magnets, the right hand controls/indicators refer to the even number magnets.

Test Equipment Required

a. Calibrated digital multimeter capable of measuring 100mA DC. (Enter meter information on data sheet on page 4)

b. 100Ω 10W resistor.

c. Magnet power supply Test Box.

d. Magnet power supply module to be tested.

1. Assemble and wire a magnet power supply module according to drawing R3W-266-4.
2. Upon completion, perform a visual check for loose connections, missing or cold solder joints, or any mechanical problems.
3. Insert a completed circuit board into the socket on the module chassis.
4. Connect the power supply module rear contact block to the cable from the "Magnet Power Supply Test Box." This Test Box supplies AC power to the power supply module as well as providing external connections for the magnets, internal dummy load resistors, and support circuitry to test rundown relay operation. A and B loop scram functions are also included. (See Figures 1 and 2).
5. On the Test Box:
   a. Set the Channel A and B Scram switches to "Normal."
   b. Set the "Magnet #2" switch to "Dummy Load."
   c. Set the "Magnet #1" switch to the "Magnet #1" position.
   d. Connect a calibrated digital multimeter set to measure current, in series with a 100Ω10W resistor, to the "Magnet #1" binding posts.

QA#	2017-38	Date
Approved	TMC	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	E	12/4/2017

6. Turn on the Test Box AC power. The power "Available" indicators on the magnet power supply should light. If not, increase the "Current Adjust" controls on the power supply until they light.
7. Reset the #1 rundown relay. The "Energized" and "On" indicators should light, and the left hand magnet current meter should show ≥ 10mA.
8. Using the "Current Adjust" control, increase the current to 40mA, then 80mA while checking the reading on the digital meter. The readings should agree within ± 2mA. Record the readings on the data sheet on page 4.
9. Using the "Current Adjust" control, decrease the value until the rundown relay de-energizes. The "On" and "Energized" indicators go out. Check that the current goes to zero. The value at which this occurs should be ≤ 5mA. Record the value on the data sheet on page 4.
10. Turn off the Test Box AC power.
11. On the Test Box:
    a. Set the Channel A and B Scram switches to "Normal."
    b. Remove the multimeter and resistor from the "Magnet #1" binding posts.
    c. Set the "Magnet #1" switch to "Dummy Load."
    d. Set the "Magnet #2" switch to the "Magnet #2" position.
    e. Connect a calibrated digital multimeter set to measure current, in series with a 100Ω10W resistor, to the "Magnet #2" binding posts.
12. Turn on the Test Box AC power. The power "Available" indicators on the magnet power supply should light. If not, increase the "Current Adjust" controls on the power supply until they light.
13. Reset the #2 rundown relay. The "Energized" and "On" indicators should light, and the right hand magnet current meter should show ≥ 10mA.
14. Using the "Current Adjust" control, increase the current to 40mA, then 80mA while checking the reading on the digital meter. The readings should agree within ± 2mA. Record the readings on the data sheet on page 4.

QA#	2017-38	Date
Approved	[signature]	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	12/4/2017

15. Using the "Current Adjust" control, decrease the value until the rundown relay de-energizes. The "On" and "Energized" indicators go out. Check that the current goes to zero. The value at which this occurs should be ≤ 5mA. Record the value on the data sheet on page 4.
16. Turn off the Test Box AC power.
17. Remove the multimeter and resistor from the "Magnet #2" binding posts.
18. Set the "Magnet #2" switch to "Dummy Load."
19. Turn on the Test Box AC power.
20. On the power supply module, set both "Current Adjust" controls to ~midrange.
21. Reset both rundown relays.
22. Set ~80mA on both meters.
23. Operate the Channel A Scram switch, both rundown relays should de-energize, both "Energized" and "On" lights will go out, and both magnet currents will go to zero.
24. Reset the Channel A Scram switch to "Normal."
25. Reset both rundown relays.
26. Repeat step 23 using the Channel B Scram switch.
27. Repeat step 24 using Channel B Scram and step 25.
28. Turn off the Test Box AC power and remove the connection at the rear of the power supply module.
29. Sign and date the completed procedure if all tests are satisfactory.

QA#	2017-38	Date
Approved	[signature]	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	12/4/2017

Data Sheet

Magnet Power Supply Module (magnet #)	Digital Meter Reading (mA)	Analog Meter Reading (mA)	Analog Meter Error (mA)	Rundown Relay Dropout (mA)	Test Completed Satisfactorily
#1 40mA	40.3	40.0	-0.3	Magnet #1 3.1	✓
#1 80mA	81.4	80.0	-1.4		✓
#2 40mA	40.9	40.0	-0.9	Magnet #2 2.6	✓
#2 80mA	80.9	80.0	-0.9		✓
#3 40mA	40.1	40.0	-0.1	Magnet #3 2.9	✓
#3 80mA	79.5	80.0	+0.5		✓
#4 40mA	41.2	40.0	-1.2	Magnet #4 2.7	✓
#4 80mA	81.0	80.0	-1.0		✓
#5 40mA	40.1	40.0	-0.1	Magnet #5 2.9	✓
#5 80mA	81.5	80.0	-1.5		✓
#6 40mA	40.2	40.0	-0.2	Magnet #6 2.3	✓
#6 80mA	82.0	80.0	-2.0		✓
Spare Left Meter 40mA	40.3	40.0	-0.3	Spare Left 4.0	✓
Spare Left Meter 80mA	80.2	80.0	-0.2		✓
Spare Right Meter 40mA	41.0	40.0	-1.0	Spare Right 3.5	✓
Spare Right Meter 80mA	80.5	80.0	-0.5		✓

Tests Completed By: Paul Menendez Date: 12-7-17

Multimeter Type: FLUKE # 83

I.D. No.: MIT 132

Calibration Date: 3-7-17

QA#	2017-38	Date
Approved	[signature]	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	12/4/2017

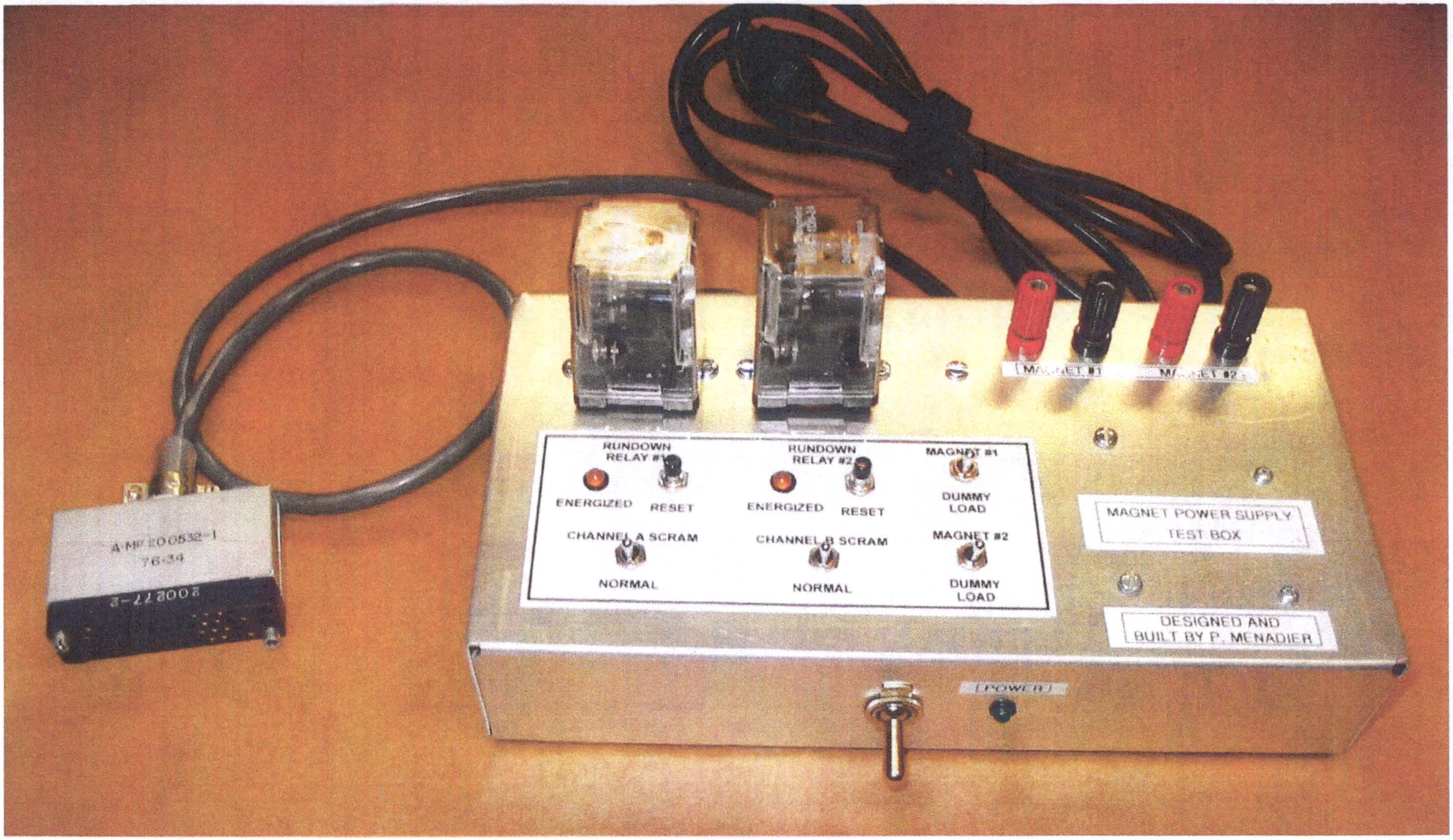


Figure 1

QA#	2017-38	Date
Approved	PM	11-15-17
RRPO Review	[signature]	11/28/17
Q/A App'l	[signature]	12/4/2017

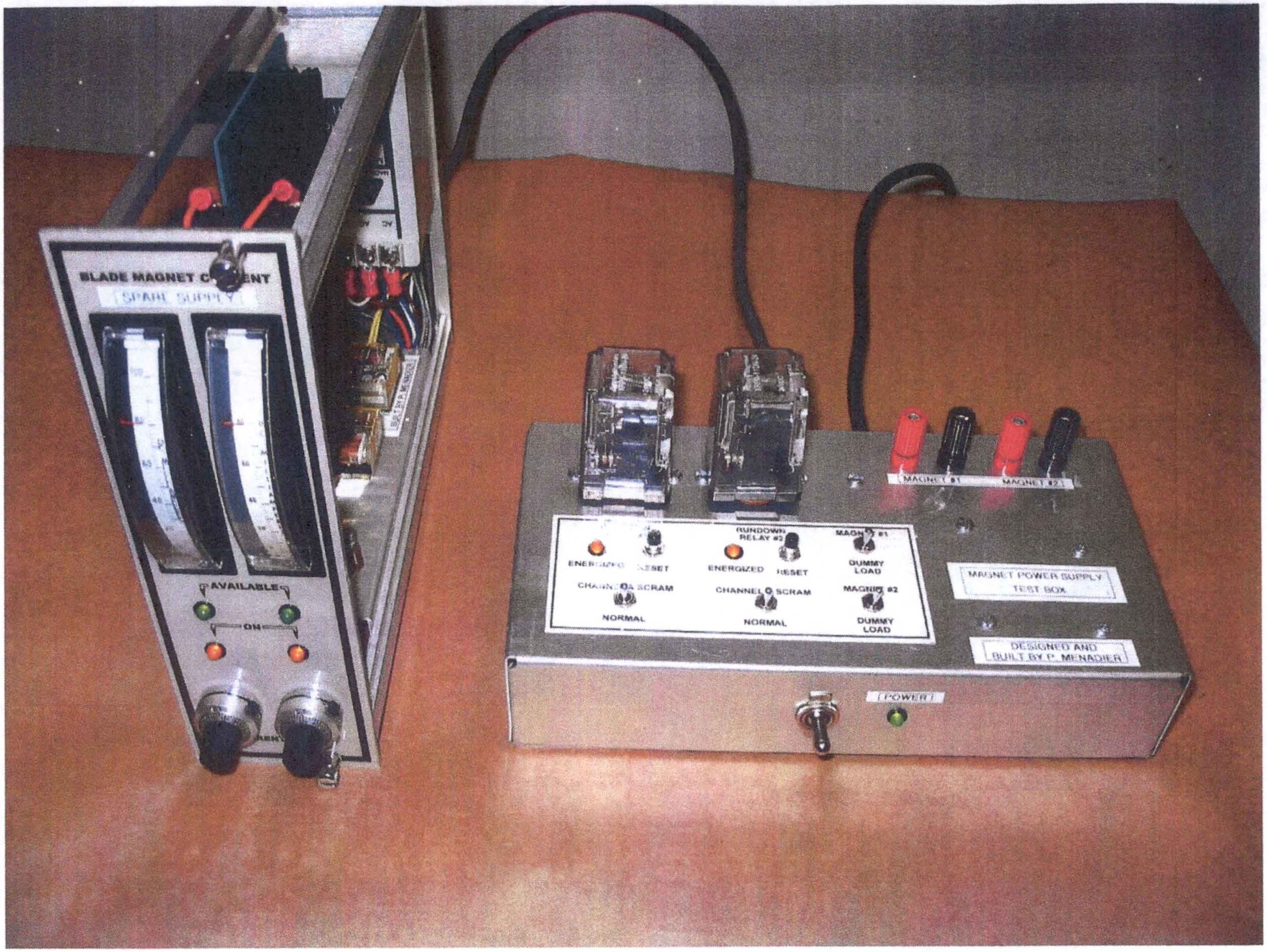


Figure 2

QA#	2017-38	Date
Approved	PM	11-15-17
RRPO Review	WBM	11/29/17
Q/A App'l	E	12/4/2017

Special Procedure for Fabrication and Bench Testing the Magnet Power Supply Circuit Boards

1. Insert and solder all discrete components into the magnet power supply printed circuit board. (Refer to drawing R3W-266-4.) See Figure 1.
2. Perform a visual inspection to check for missing and cold solder connections, also improper solder bridges.
3. Plug the completed circuit board into the "Magnet Power Supply Circuit Board Test Box." This test box will simulate the operation and functionality of a blade magnet current supply module as well as providing some support circuitry to test rundown relay operation. In addition, dummy load resistors are incorporated to take the place of actual blade magnets, also Loop A and Loop B scram switches are provided to test those functions. See Figure 2.
4. Once the circuit board is plugged in, set both "Current Adjust" controls to ~midrange and set both "Magnet" switches to "Dummy Load."
5. Set Channel A and B scram switches to "Normal."
6. Turn on the AC power, the magnet #1 and #2 "Power Available" indicators should light.
7. Reset the #1 rundown relay, its "Energized" indicator should light as well as the magnet #1 "Current On" indicator. Also >50mA current should indicate on magnet #1 meter.
8. Repeat step 7 for the #2 rundown relay. The associated indicators should light and the magnet #2 meter should show >50mA.
9. Increase the magnet #1 current adjust until the meter reads >100mA, then decrease the current until the rundown relay #1 de-energizes. The "Energized" light will be out. The current will go to zero. The value at which the relay de-energizes should be <10mA.
10. Repeat step 9 for magnet #2.
11. Increase both "Current Adjust" controls until their "Power Available" indicators begin to glow dimly. Then reset both rundown relays.
12. Increase both magnet currents to ~80mA.
13. Operate the Channel A scram switch, both rundown relays should de-energize, both relay "Energized" lights will go out, and both magnet currents should go to zero.
14. Reset the "Channel A Scram" switch to "Normal."
15. Reset both rundown relays.

QA#	2017-38	Date
Approved	PM	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	11/29/2017

16. Repeat step 13, using the "Channel B Scram" switch.
17. Turn off the AC power and remove the printed circuit board.
18. If all the above tests are completed satisfactorily, write a serial number on the board, and repeat this procedure for any remaining boards.

Serial Numbers of Completed Circuit Boards:

1. 001
2. 002
3. 003
4. 004
5. 005
6. 006

Test Completed By: Paul Menadier   Date: 11-29-17

QA#	2017-38	Date
Approved	TM	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	11/29/2017

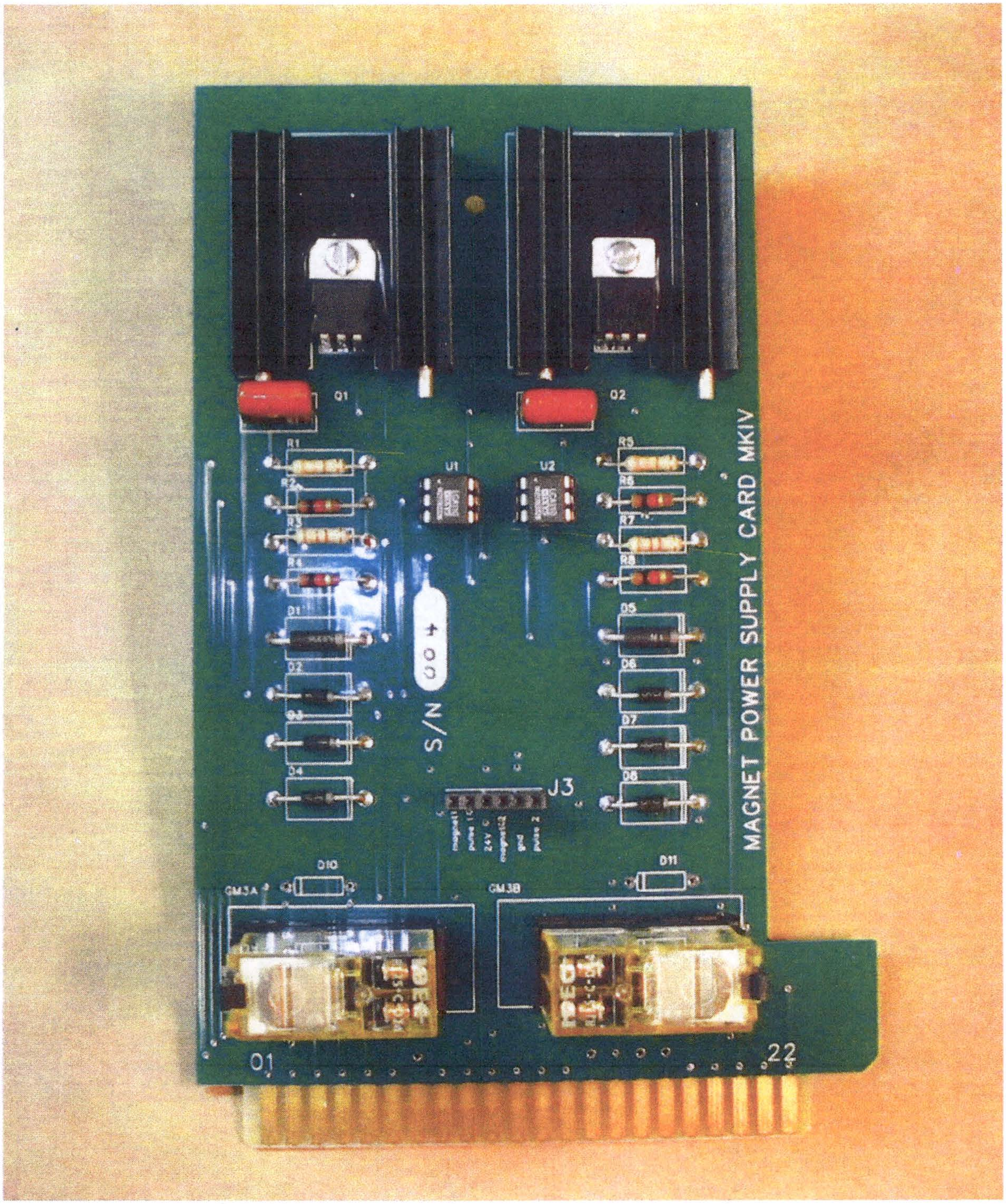


Figure 1

Magnet Power Supply Printed Circuit Board

QA#	2017-38	Date
Approved	P M	11-15-17
RRPO Review	wbm	11/29/17
Q/A App'l	E	11/29/2017

Figure 2

Magnet Power Supply Circuit Board Test Box

QA#	2017-38	Date
Approved	PMR	11-15-17
RRPO Review	[signature]	11/29/17
Q/A App'l	[signature]	11/29/2017

Enclosure C

Q/A File #E-2012-1 "Overview of New Nuclear Safety System with Integrated Supporting Modules"

Description of Integrated Supporting Modules for New Nuclear Safety System

The proposed nuclear safety system (NSS) begins with four independent nuclear safety channels, each of which is composed of a fission chamber, a TKV 23 pre-amplifier, and a digital DWK 250 wide-range neutron flux monitor. The nuclear safety channels detect reactor neutronic power and reactor period, and compare those parameters against their pre-set values. If the pre-set values are reached, the flux monitors will output trip signals. The following describes how these trip signals progress through the NSS modules downstream from the nuclear safety channels and bring about a reactor scram (i.e., automatic shutdown), while the signals are also processed via other modules in the NSS for display and recording. Figure 1 illustrates the flow of signals when all of the modules are connected together.

In addition to the nuclear safety channels, all the modules along the path of the trip signals that lead to a reactor shutdown are categorized as "safety related". These modules are individually described and safety-evaluated in separate documents titled:

Q/A File #2017-34 "Signal Distribution Module"
Q/A File #2017-35 "Scram Logic Card Modules"
Q/A File #2017-36 "LED Scram Display"
Q/A File #2017-37 "<100 kW Key-Switch Module"
Q/A Files #2017-38 & #2017-39 "Magnet Power Supply Modules and Rundown Relay Panel"
Q/A File #2017-41 "Withdraw Permit Circuit Modification"
Q/A File #2017-28 "DWK 250 'Test' Condition Scram Bypass Assembly"

The modules not along the path of the trip signals are categorized as "non-safety related". They perform other functions such as display and recording. These modules are individually described and safety-evaluated in separate documents titled:

Q/A File #2017-30 "Blade Drop Timer Interface Module"
Q/A File #2017-40 "Safety System Monitoring & Status Display PLC"

In Figure 1, all the unshaded modules, including the nuclear safety channels, are new equipment for the proposed nuclear safety system. The Withdraw Permit Circuit (which is modified in a few places) is shown as existing equipment. The Blade Drop Timer, the control room's Console Annunciator Panel, and other existing equipment are depicted as shaded blocks in Figure 1.

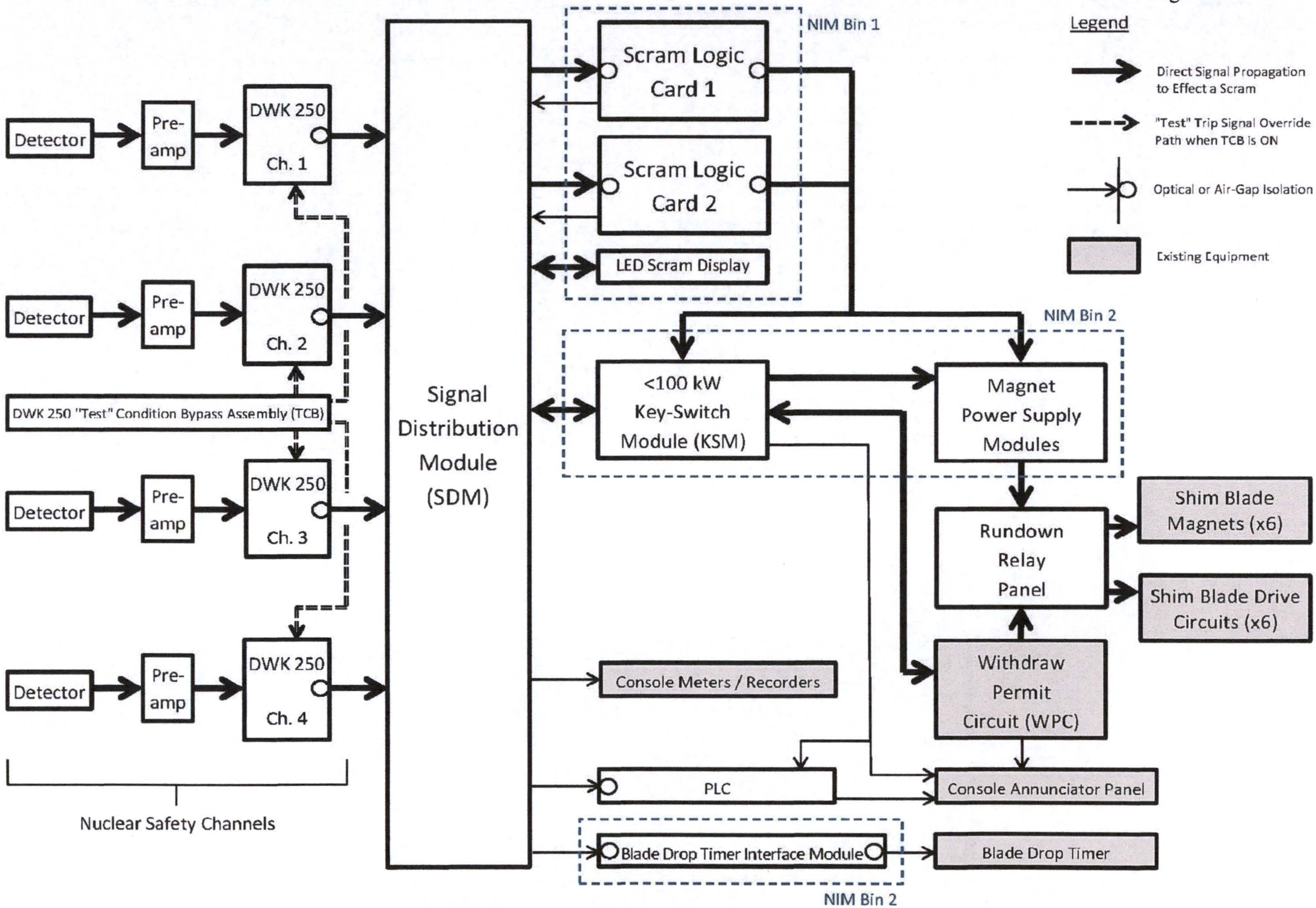


Figure 1: Block Diagram of Nuclear Safety System with Integrated Support Modules

Trip Signal Progression Through the NSS Safety Related Modules

The trip signals that are generated by the DWK 250 neutron flux monitors propagate throughout the various downstream modules until the signals attain their goal of scramming the reactor. It is important to note that in all cases, the propagation manifests by de-energizing signal paths, not by energizing them.

When the reactor is operating at power within its prescribed envelope, no determinative trip signals are generated*. – The relays that generate trip signals on the DWK 250 monitors are closed, and the signal paths downstream are all energized (to 24 volts DC). These signal paths go through the Signal Distribution Module (SDM), the two Scram Logic Cards, the <100 kW Key-Switch Module (KSM), the Withdraw Permit Circuit (WPC), the Magnet Power Supply Modules, and the Rundown Relay Panel. The signal paths through these various modules remain energized, and there is no scram.

If the reactor is operating beyond its prescribed envelope, a trip signal is generated. Relevant relays on the DWK 250 monitors are opened, de-energizing (to zero volts DC) a series of signal paths downstream. With these signal paths de-energizing, the ultimate effect is that electrical power stops going to the electro-magnets that support the neutron-absorbing shim blades, dropping the blades into the core by gravity and achieving shutdown of the reactor.

Each DWK 250 neutron flux monitor outputs trip signals in binary form, via eight binary output relays. Two of them are used for high power warning and short period warning. The other six are for trip functions: high power, short period, high power 100 kW operation, low count rate, test status, and fault / equipment malfunction. These eight output relays have a 24-volt DC source applied across them, from an independent external source, rather than from the DWK 250 chassis. The relay outputs are electrically isolated from the internal circuitry of the DWK 250. The external power source is a pair of 24-volt DC power supplies, fed from an existing, common 120-volt AC source. These 24-volt DC power supplies are set up in parallel, connected via auctioneering diodes on the SDM, so that if one fails, the other will take over without interruption. The 24-volt DC power supply 'wets' the DWK 250 output relay contacts via the SDM. (See the NSS Global Connection Diagram R3W-268-2)

* When the reactor is operating above 100 kW in Full Power Operation mode, each DWK 250 will generate the "High Power 100 kW Operation Trip" signal. This signal is received by the Scram Logic Cards, where it performs a logic comparison that results, in this case, in no output of a scram signal. This is described in further detail later on.

The DWK 250 outputs a trip signal by opening one or more of its output relays. This de-energizes the signal path on the SDM that connects to Scram Logic Card 1 and Card 2. Each DWK 250 has six trip signal paths through the SDM to the Scram Logic Cards, one for each of the six trip conditions listed in the previous paragraph. Together there are 24 such signal paths going through the SDM from the four DWK 250 chassis, passing the trip signals on to Scram Logic Cards 1 and 2.

Scram Logic Cards 1 and 2 perform identical logic comparison functions, and are connected to the SDM in parallel for redundancy, with optical isolation at their inputs as well as their outputs. Each Card is composed of discrete logic components, and is therefore non-programmable. Each Card features general coincidence logic (two-out-of-four logic) in hardware to prevent false trips from a single DWK 250 failure. For instance, if one DWK 250 outputs one or more trip signals, then the Scram Logic Card will receive the signal(s) for logic comparison, and will make a decision not to output a scram signal. If two or more DWK 250s output trip signals, the two-out-of-four voting logic is now satisfied, and the Scram Logic Card will make the decision to output a scram signal. This will de-energize relays in the Withdraw Permit Circuit (WPC) and the Magnet Power Supply Modules.

The scram signal travels downstream from the Scram Logic Cards and reaches the <100 kW Key-Switch Module (KSM). The KSM chassis is mounted within the same Nuclear Instrument Module (NIM) bin as the Magnet Power Supply Modules (NIM Bin 2 in Figure 1). When a scram signal reaches this NIM bin, it is distributed to both the KSM and the Magnet Power Supply Modules. This scram signal opens six relays in the Magnet Power Supply Modules and five in the KSM. Opening of any of the six relays in the Magnet Power Supply Modules will interrupt electrical power to the shim blade magnets directly, as will one (RY4) of the five relays in the KSM. Opening any of the other four relays in the KSM will open existing circuits Scram Loop A and Scram Loop B in the WPC, which in turn also results in interruption of shim blade electromagnet current, shutting down the reactor. These four relays also activate the "Safety System Scram" alarm on the Console Annunciator Panel. Opening of the WPC activates the "Withdraw Permit Circuit" annunciator alarm indication there as well.

The new NSS maintains an important feature of the existing system, in that whenever electric current to a shim blade electromagnet is interrupted, the Rundown Relay Panel moves the corresponding shim blade drive to its "full in" position at its normal speed. This takes place automatically to ensure that the uncoupled blade reaches its bottom position in the reactor core and stays there following a scram, completing the protective action once it is initiated.

When the KSM's key switch is turned to "<100 kW Operation", signals indicating the key-switch position are removed from the Scram Logic Cards, sent to the Safety System Monitoring & Status Display Programmable Logic Controller (PLC), and sent to the Console Annunciator Panel. This key switch position also automatically bypasses all three of the low flow primary coolant scrams. If reactor power reaches the trip set point for <100 kW Operation, the DWK 250 will output the High Power 100 kW Operation trip signal, which will be logically interpreted by Scram Logic Cards 1 and 2. When the KSM's key switch is turned to "Full Power Operation", the PLC's "<100 kW Operation" message clears, and the

low flow primary coolant scrams are no longer bypassed. As reactor power increases to the nominal full power (5.9 MW), it passes the trip set point for <100 kW Operation. At that point, the DWK 250 will output the High Power 100 kW Operation trip signal as before, but now when the Scram Logic Cards receive the signal, they will not interpret it as grounds for outputting a scram signal.

The two Scram Logic Card Modules and the LED Scram Display are mounted within the same NIM bin (NIM Bin 1 in Figure 1). Whenever a trip signal reaches the Scram Logic Cards from the DWK 250 chassis via the SDM, the Cards capture it and send it along to the LED Scram Display (again via the SDM), regardless of the logic decision. The LED Scram Display indicates the trip signal even if it came from a transitory condition, such that it cleared immediately at the DWK 250. This 'latching' can be reset only by manually pushing a Channel Reset button on the LED Scram Display, one button for each of the four DWK 250s. The Channel Reset button also resets the Scram Logic Cards (as they do not have their own reset buttons), and thus the lights on the LED Scram Display. This reset function is a prerequisite to achieving a reactor start.

Finally, in order to facilitate scram logic testing without removing equipment, a DWK 250 "Test" Condition Scram Bypass Assembly (a.k.a. Test-Condition Bypass, or TCB) was added to the NSS. Scram logic tests are performed to demonstrate that simultaneous trip conditions from two or more DWK 250s will initiate a scram of the reactor. In order to activate such trip signals on a DWK 250, one must first put the DWK 250 in "Test" mode. However, the mere act of putting two DWK 250 units in "Test" mode simultaneously will cause the Scram Logic Cards to initiate a scram condition, making proper testing of other trip signals impossible. When the TCB keyswitch is turned to "On", it overrides any Test trip indication to the Scram Logic Cards, thus allowing performance of scram tests of other trip conditions (High Power, Short Period, Low Count Rate, or Fault). The TCB is used only when the reactor is shut down, and it is needed for the conduct of routine surveillance scram testing. The TCB is turned off prior to any reactor startup, and will remain off for as long as the reactor is critical. – The act of turning it on while the reactor is at power will immediately result in a reactor scram. This is because the intermediate state of TCB's key switch temporarily interrupts the "Test" signal path line voltage on all four channels, satisfying the Scram Logic Cards' voting logic to output a scram signal. Therefore, any time the key switch is turned from "Off" to "On" or vice versa, it results in a reactor scram.

Trip Signal Progression Through the NSS Non-Safety Related Modules

All of the above trip signal handling and scram signal handling functions take place via bi-stable, discrete components. There is no system clock or other timing function. In order to register the date and time of a trip event, a digital Safety System Monitoring & Status Display PLC is employed for real-time event logging. Each DWK 250 chassis outputs trip signals to the SDM, where the trip signals are routed separately to the PLC, as well as to the Scram Logic Cards. The two warning signals (short period and high power) from the DWK 250 do not go to the Scram Logic Cards, just directly to the PLC, via the SDM. The PLC will then display and record the names of all of these alarm indications that come in, and will pass two types (warnings and fault alarms) to the Console Annunciator Panel. The

PLC has a built-in optical isolator on each of its signal input connections from the SDM, ensuring the signal flow is unidirectional into the PLC.

Additionally, the PLC will provide an indication if there is trouble with the Nuclear Safety System's pair of 24-volt DC power supplies. A relay contact on each of the two power supplies will open if there is a loss of voltage or opening of the internal fuse on the power supply, sending an alarm signal to the PLC via the SDM.

The "Test" trip signal from each DWK 250 is passed via the SDM not only to the Scram Logic Cards, but also to the Blade Drop Timer Interface Module, which is built with optical isolators at the signal inputs and outputs, and in turn passes the signals to activate the Blade Drop Timer. The Blade Drop Timer measures the time from initiation of a trip signal to 80% insertion of a shim blade, per Technical Specification requirements. The Blade Drop Timer Interface Module is a new piece of equipment that conditions the trip signals so that they are electrically compatible with the existing Blade Drop Timer.

Safety Evaluation

The integrated Nuclear Safety System is highly redundant and will ensure that trip signals are propagated throughout the system to achieve their goal of scramming the reactor, meeting their intended safety functions as defined by Chapter 7 of the Safety Analysis Report. If any of the components along the scram signal path should fail, the result will be an interruption of signal path, thereby resulting in safe shutdown of the reactor. Components that are not along the scram signal path will not interrupt the trip signal paths if they fail; furthermore, their failure will not affect the operation of the Scram Logic Cards and will not interfere with trip propagation or scram signal processing. Components not along the scram signal path include the Safety System Monitoring & Status Display Programmable Logic Controller (PLC) and the Blade Drop Timer Interface Module.

Redundancy of scram relays and independence of activation(s) applies throughout the Nuclear Safety System, hence minimizing the risk of common-mode failure. All mechanical relays fail open. All relays are within metallic enclosures, thereby minimizing the impact from electromagnetic interference (EMI) on their function.

Except the PLC, all the modules downstream of the DWK 250 chassis use mostly low voltages and are built with discrete components that do not use microprocessors. The components are constructed only with non-programmable solid-state and discrete passive devices. As a result, signal propagation is not subject to software scan time processing delays. Additionally, there is no cybersecurity risk to this part of the system.

All the discrete components are standard industrially-rated devices. The mostly low voltage nature of the system will maximize their operational life span, minimize EMI production, and reduce electrical hazards to personnel.

The Signal Distribution Module (SDM) reduces the use of excessive wiring and cable connections for signal transmission. Where applicable, optical isolators are used at interfaces between modules to ensure signal flow is unidirectional.

The Scram Logic Cards each use 2-out-of-4 voting logic in order to avoid unnecessary scrams from neutron flux monitoring channel faults. This increases stability and reliability of the Nuclear Safety System. Scram Logic Cards 1 and 2 work in parallel for redundancy. If either of the two Cards fails, such that it interrupts continuity from the 24-volt DC power supply, a scram signal is the result. Having two Scram Logic Cards operating in parallel reduces the likelihood that a single failure could prevent a scram.

The Scram Logic Cards were designed to provide an active output (24 volts) at each stage of the signal processing when a Scram condition does not exist. A scram signal from either Scram Logic Card is sufficient to result in a reactor scram. Whenever a scram signal is produced, it will indicate and be logged on the PLC, including in which Card(s) it originated.

All the modules in the Nuclear Safety System, including the DWK 250 chassis, will be rack-mounted within the protective metal cabinets of the control room console. The console cabinets will continue to provide the equipment with physical protection comparable to that for the current systems. Routine maintenance and inspection will be performed only

by licensed reactor staff or under the supervision of licensed reactor staff. Where necessary, certain interactions can be performed only by or under the direction of the MIT Reactor Instrumentation Supervisor.

The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

All the modules in the Nuclear Safety System, including the DWK 250 chassis, provide many indications of their operational status, trip signals, and scram signals. The console operator has a ready view of all of these, for instance, on both the LED Scram Display and the PLC. Therefore, human interface is improved. Additionally, the system is designed and constructed to require as little disconnection of cables, modules, and components for routine operation as possible. This is a major improvement over the existing Nuclear Safety System.

Prior to operation with the reactor, the integrated Nuclear Safety System will receive pre-installation and post-installation testing under a Global Test Procedure. The integrated system will be set up to operate in parallel with the existing nuclear safety system for observation. Once the new Nuclear Safety System is operational, its functions will be tested periodically as per the Technical Specifications. Therefore, regular surveillances will ensure its continued integrity. In conclusion, the new Nuclear Safety System is carefully designed and fabricated to ensure that it will fulfill its safety functions.

It should be noted that the Nuclear Safety System provides only part of the functionality of the Reactor Protection System. There are other independent and redundant reactor protective functions that will provide an automatic scram of the reactor based on high temperature, low primary coolant flow rate, low core tank level, etc., as described in the existing MITR Safety Analysis Report. Therefore, the Reactor Protection System will continue to be highly reliable and diverse.

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure D

Q/A File #2017-34 "Signal Distribution Module"

Description of the Signal Distribution Module

The Signal Distribution Module (SDM) is an interface circuit between the DWK 250 digital neutron flux monitors and all components downstream. Because any trip signal generated from a nuclear safety channel must pass through the SDM on its way to the modules that effect a reactor shutdown, the SDM is considered a safety-related component of the Nuclear Safety System.

Additionally, the SDM contains the auctioneering diodes for the two 24-volt DC power supplies. There are two analog meters mounted on the SDM's protective casing, one showing the electric current from the power supplies, and the other showing voltage. (See Figure 1.) By selection via a rotary switch (also mounted on the case), the voltage meter shows the instantaneous voltage on the SDM, from the first power supply, or from the second power supply.

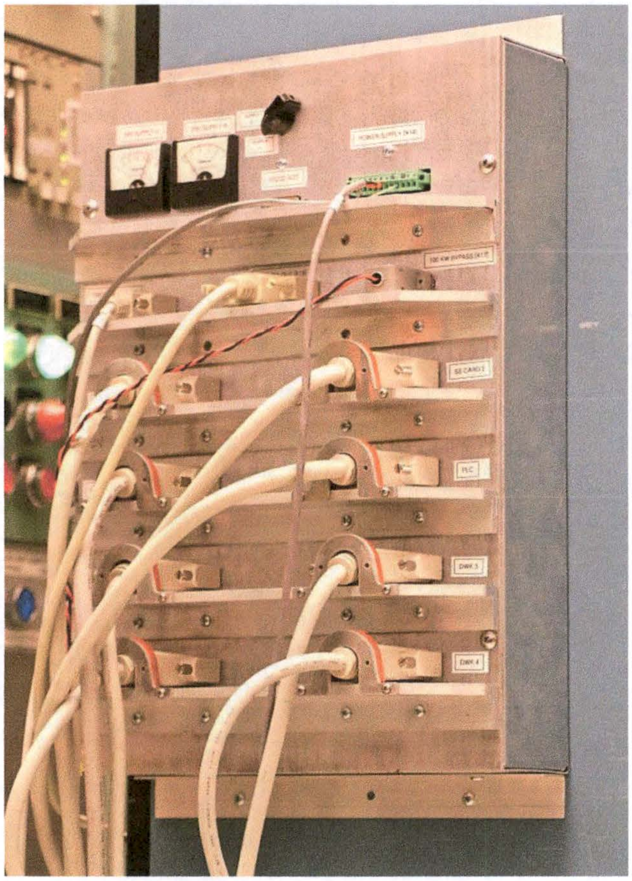


Figure 1 – Exterior of Signal Distribution Module, showing its two Analog Meters at top

As can be seen in schematic diagram R3W-268-2 "Nuclear Safety System Global Connection Diagram" and circuit board diagram R3W-274-3 "Signal Distribution Module Board Wiring Diagram" the SDM has a total of thirteen connections. In terms of signal flow, four of those connections are strictly input (signal coming from each of the four DWK 250 units), six are input/output bidirectional, two are strictly output, and one is not in use. The following lists the roles of the connectors as they are labeled:

1. X10: Receives signal from DWK 250 channel #1.

2. X11: Receives signal from DWK 250 channel #2.

3. X12: Receives signal from DWK 250 channel #3.

4. X13: Receives signal from DWK 250 channel #4.

5. X14: Receives power from two 24-volt DC power supplies that are set up in parallel, but connected via auctioneering diodes on the SDM, so that if one fails, the other will take over without interruption. The X14 connector then passes the 24-volt DC power as output to the "NIM bin 1" instrument rack which contains three downstream components: Scram Logic Card 1, Scram Logic Card 2, and the <100 kW Key-Switch Module. The X14 connector also passes the 24-volt DC power via connectors X10 through X13 to energize the output (scram/alarm) relays of the four DWK 250 channels. (The DWK 250 output relays are electrically isolated from the internal circuitry of the DWK 250, and rely on an external power source for their operation.)

6. X15: Passes signals from the four DWK 250 channels to Scram Logic Card 1. The X15 connector receives signals back from Scram Logic Card 1 and routes them to the LED Scram Display and several non-safety-related monitoring and display devices.

7. X16: Passes signals from the four DWK 250 channels to Scram Logic Card 2. The X16 connector receives signals back from Scram Logic Card 2 and routes them to the LED Scram Display and several non-safety-related monitoring and display devices.

8. X17: Passes signals to and from the <100 kW Key-Switch Module.

9. X18: Passes signals to and from an LED Scram Display module, which captures scram signals from any of the four DWK 250 channels via the Scram Logic Cards, and keeps them latched in until the LED Scram Display module is used to reset the two Scram Logic Cards. (Once the scram condition no longer exists, the DWK 250 will not show what the trip condition was.)

10. X19: Passes analog signals from the four DWK 250 channels to existing console chart recorders and meters.

11. X20: Not in use.

12. X21: Passes signals from all inputs of the SDM to a non-safety-related programmable logic controller (PLC) for monitoring and status display.

13. X41: Passes the "Test" trip signal from each of the four DWK 250 channels through a Signal Junction Box to a Blade Drop Timer Interface Module, which in turn passes a signal to activate the existing Blade Drop Timer. This setup will measure the scram time from initiation of a scram signal to 80% insertion of a shim blade. The Blade Drop Timer Interface Module conditions a binary signal for compatibility with the existing Blade Drop Timer, and includes optical isolation of the SDM from the Blade Drop Timer. The Blade Drop Timer Interface Module and the Blade Drop Timer are mounted in separate NIM bins. The Blade Drop Timer in its own NIM bin receives 12 volts DC from its existing, independent power source. Connector X41 also passes low-voltage and fault signals from each of the two 24-volt DC power supplies to the PLC, by way of the SDM and the Signal Junction Box, via connector P10 on the Box and cable K-45.

Safety Evaluation

The Signal Distribution Module (SDM) is a four-layer FR4 printed-circuit board that facilitates passing of signals between various modules of the new Nuclear Safety System. An ISO 9001-2008 certified electronic hardware manufacturer (Advanced Circuits) fabricated the board.

Failure Analysis

If the board fails, such as by physical damage or other disruption to a scram signal path between a DWK 250 and the Scram Logic Cards, there will be a loss of the signal, thereby causing the Scram Logic Cards to produce a scram. The physical damage could include puncture, impact, fire, or high voltage surge, while other types of disruption could include radio frequency interference, overheating, or corrosion. All would result in a scram.

The connection (X14) to the two 24-volt DC power supplies only passes power to the two Scram Logic Cards and the <100 kW Key-Switch Module. The SDM board does not use the power for its own functions. The two power supplies are fed from an existing, common 120-volt AC source, and have an internal fuse that will protect against overcurrent conditions. They also have an output overload that will trip at no more than 35 volts DC. In the unlikely event of an excessive line voltage surge, both power supplies are designed to trip to protect themselves, interrupting power to the two Scram Logic Cards, scramming the reactor. If the surge affects the SDM board directly, it may create physical damage as described above, again resulting in a reactor scram.

If there is a loss of line voltage or an internal fault on either of the two 24-volt DC power supplies, a relay contact opens on the affected power supply to transmit a signal by way of the SDM and the Signal Junction Box to the PLC, showing on the PLC which power supply is in trouble.

Signals input to the SDM board from the two Scram Logic Cards are passed along to other display and status monitoring devices. If the board should be damaged in these areas, there is no effect on nuclear safety. The console operator may observe a partial loss of indications of reactor power and reactor period, but will not receive false information. There are redundant displays of reactor power and period, such as on the face of each DWK 250 chassis, that will remain operable. There are also four existing independent non-safety-related neutron flux channels or N-16 gamma channels displaying reactor power. Likewise, loss of signal output from the SDM to existing console chart recorders and meters has no effect on nuclear safety. There is redundant recording of reactor power history from the non-safety-related neutron flux channels.

Cybersecurity and Isolation

The SDM is assembled on one circuit board. The module is constructed with standard industrially-rated components. It contains no digital components, and is therefore not subject to cybersecurity threats.

Transient Voltage Suppressor (TVS) diodes are used on the SDM board to ensure voltages never exceed 35 volts. Because the SDM is mostly a passive circuit board, it does not include any optical isolators. However, there are optical isolators built into Scram Logic Card 1, Scram Logic Card 2, the Blade Drop Timer Interface Module, and the PLC panel.

Access Control and Physical Protection

The SDM will be mounted within the protective metal instrumentation cabinets of the control room. The instrumentation cabinets will provide the module with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the NRC-approved Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

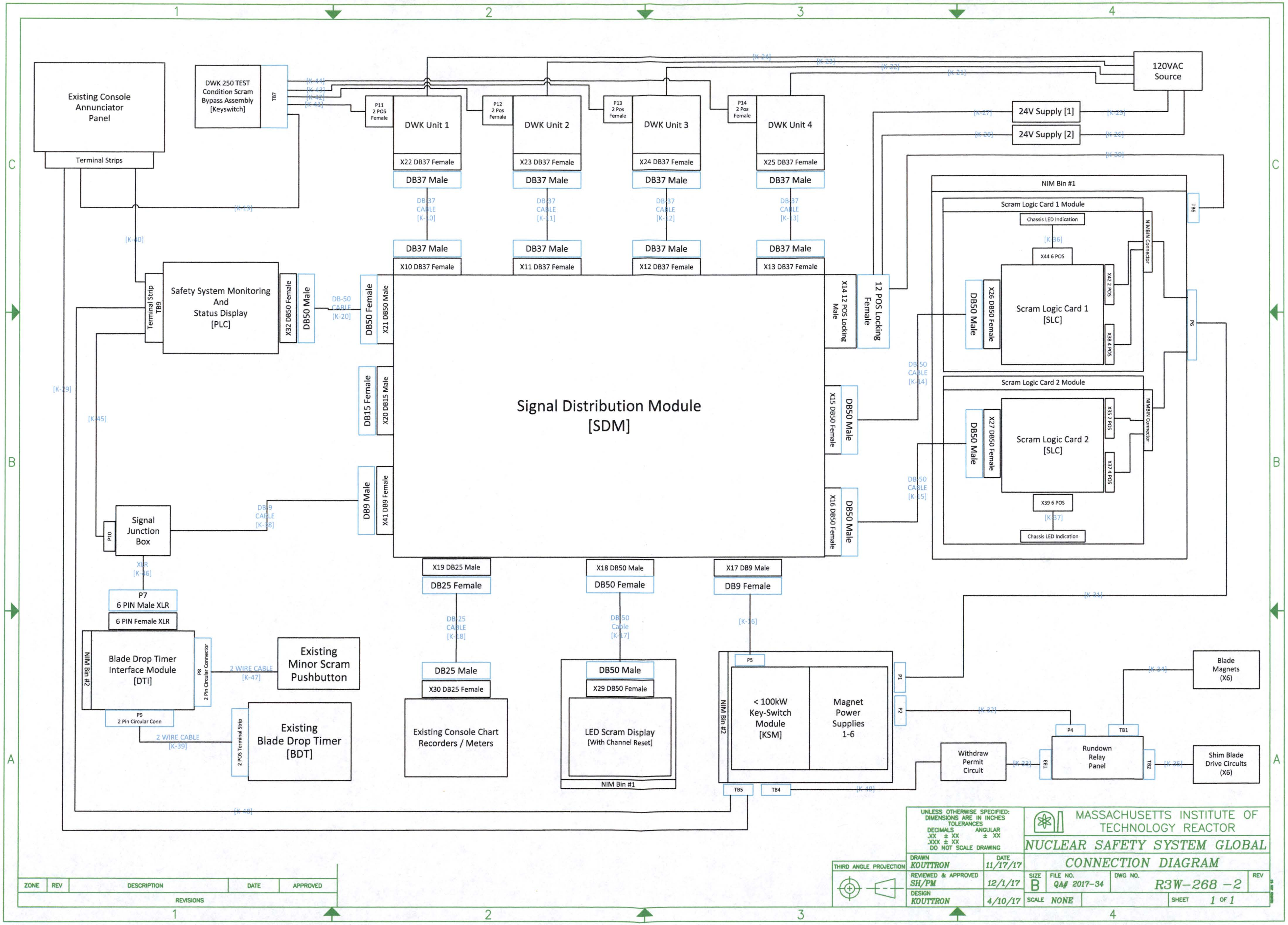
The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components on the SDM board.

Human Factors

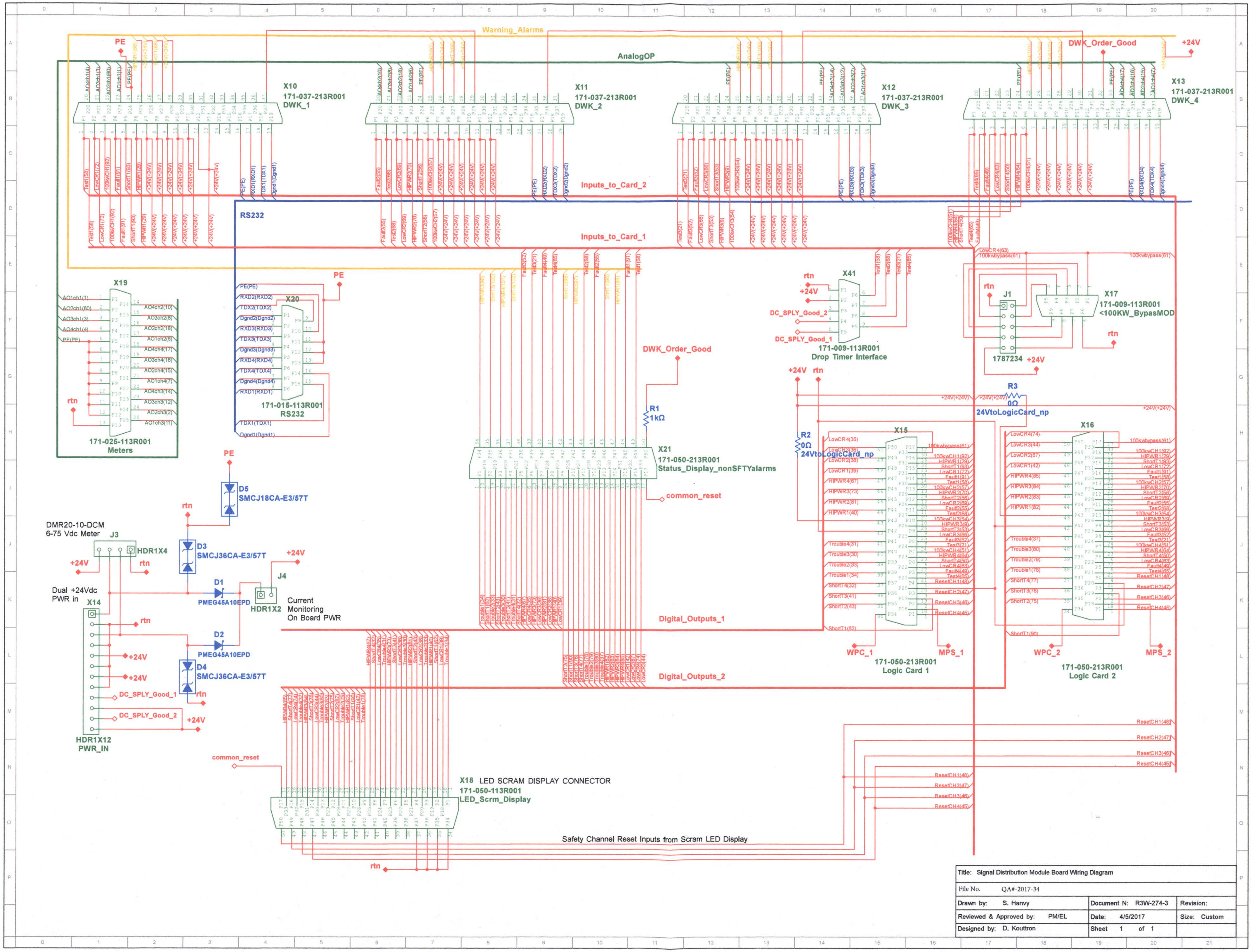
All cables to the SDM and cable connection points on the SDM will be labeled, as will the circuit board. These markings improve the human interface for purposes of installation and maintenance. Once it is installed, there will be no regular human interface with the SDM board. It will be handled only by or under the supervision of license reactor staff. Therefore, human factors engineering remains adequate.

Verification and Periodic Checks

The new SDM board will be tested for wiring verification using a written procedure prior to first use, will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation, and will receive functional checks periodically as part of the operational checks of the integrated Nuclear Safety System. Therefore, these pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the circuitry.



Existing Console Annunciator Panel
Terminal Strips
DWK 250 TEST Condition Scram Bypass Assembly [Keyswitch]
TB7
P11 2 POS Female
P12 2 Pos Female
P13 2 Pos Female
P14 2 Pos Female
DWK Unit 1
DWK Unit 2
DWK Unit 3
DWK Unit 4
X22 DB37 Female
X23 DB37 Female
X24 DB37 Female
X25 DB37 Female
DB37 Male
DB37 CABLE [K-10]
DB37 CABLE [K-11]
DB37 CABLE [K-12]
DB37 CABLE [K-13]
X10 DB37 Female
X11 DB37 Female
X12 DB37 Female
X13 DB37 Female
120VAC Source
24V Supply [1]
24V Supply [2]
NIM Bin #1
Scram Logic Card 1 Module
Chassis LED Indication
X44 6 POS
Scram Logic Card 1 [SLC]
X42 2 POS
X38 4 POS
X26 DB50 Female
DB50 Male
NIMBIN Connector
TB6
P6
Scram Logic Card 2 Module
Scram Logic Card 2 [SLC]
X35 2 POS
X37 4 POS
X27 DB50 Female
X39 6 POS
Safety System Monitoring And Status Display [PLC]
Terminal Strip TB9
X32 DB50 Female
DB50 Male
DB-50 CABLE [K-20]
DB50 Female
X21 DB50 Male
DB15 Female
X20 DB15 Male
DB9 Male
X41 DB9 Female
Signal Distribution Module [SDM]
X14 12 POS Locking Male
12 POS Locking Female
X15 DB50 Female
X16 DB50 Female
DB50 CABLE [K-14]
DB50 CABLE [K-15]
Signal Junction Box
P10
DB9 CABLE [K-38]
XLR [K-36]
P7 6 PIN Male XLR
6 PIN Female XLR
Blade Drop Timer Interface Module [DTI]
NIM Bin #2
P8 2 Pin Circular Connector
P9 2 Pin Circular Conn
2 WIRE CABLE [K-47]
Existing Minor Scram Pushbutton
2 WIRE CABLE [K-39]
2 POS Terminal Strip
Existing Blade Drop Timer [BDT]
X19 DB25 Male
DB25 Female
DB25 CABLE [K-18]
DB25 Male
X30 DB25 Female
Existing Console Chart Recorders / Meters
X18 DB50 Male
DB50 Female
DB50 Cable [K-17]
X29 DB50 Female
LED Scram Display [With Channel Reset]
X17 DB9 Male
DB9 Female
[K-16]
P5
< 100kW Key-Switch Module [KSM]
Magnet Power Supplies 1-6
P1
P2
TB5
TB4
Withdraw Permit Circuit
TB3
P4
TB1
Rundown Relay Panel
TB2
Blade Magnets (X6)
Shim Blade Drive Circuits (X6)
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES
DECIMALS .XX ± XX .XXX ± XX
ANGULAR ± XX
DO NOT SCALE DRAWING
THIRD ANGLE PROJECTION
MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR
NUCLEAR SAFETY SYSTEM GLOBAL CONNECTION DIAGRAM
DRAWN KOUTTRON DATE 11/17/17
REVIEWED & APPROVED SH/PM 12/1/17
DESIGN KOUTTRON 4/10/17
SIZE B
FILE NO. QA# 2017-34
DWG NO. R3W-268 -2
REV
SCALE NONE
SHEET 1 OF 1
ZONE
REV
DESCRIPTION
DATE
APPROVED
REVISIONS


Warning_Alarms
AnalogOP
DWK_Order_Good
+24V
PE
X10
171-037-213R001
DWK_1
X11
171-037-213R001
DWK_2
X12
171-037-213R001
DWK_3
X13
171-037-213R001
DWK_4
Inputs_to_Card_2
Inputs_to_Card_1
RS232
X19
171-025-113R001
Meters
X20
171-015-113R001
RS232
X41
171-009-113R001
Drop Timer Interface
DC_SPLY_Good_2
DC_SPLY_Good_1
J1
1787234
X17
171-009-113R001
<100KW_BypassMOD
DWK_Order_Good
R1
1kΩ
R2
0Ω
24VtoLogicCard_np
R3
0Ω
24VtoLogicCard_np
X21
171-050-213R001
Status_Display_nonSFTYalarms
common_reset
X15
171-050-213R001
Logic Card 1
X16
171-050-213R001
Logic Card 2
WPC_1
MPS_1
WPC_2
MPS_2
D5
SMCJ18CA-E3/57T
DMR20-10-DCM
6-75 Vdc Meter
J3
HDR1X4
D3
SMCJ36CA-E3/57T
D1
PMEG45A10EPD
J4
HDR1X2
Current
Monitoring
On Board PWR
Dual +24Vdc
PWR in
X14
D2
PMEG45A10EPD
D4
SMCJ36CA-E3/57T
HDR1X12
PWR_IN
Digital_Outputs_1
Digital_Outputs_2
rtn
X18 LED SCRAM DISPLAY CONNECTOR
171-050-113R001
LED_Scrm_Display
Safety Channel Reset Inputs from Scram LED Display
Title: Signal Distribution Module Board Wiring Diagram
File No. QA#-2017-34
Drawn by: S. Hanvy
Document N: R3W-274-3
Revision:
Reviewed & Approved by: PM/EL
Date: 4/5/2017
Size: Custom
Designed by: D. Kouttron
Sheet 1 of 1

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure E

Q/A File #2017-35 "Scram Logic Card Modules"

Description of the Scram Logic Card Modules

An identical pair of Scram Logic Cards housed in separate modules within the same NIM bin (NIM Bin 1 in Figure 1) process the two-out-of-four scram logic decision independently in parallel. A scram decision and hence a scram signal output from either scram logic printed-circuit card will trigger the reactor's scram function, namely interrupting magnet current, dropping the shim blades by gravity into the reactor core, and thereby shutting down the reactor. The Scram Logic Cards are located downstream from the Signal Distribution Module which passes along DWK 250 trip signals and inputs them into both circuit cards simultaneously.

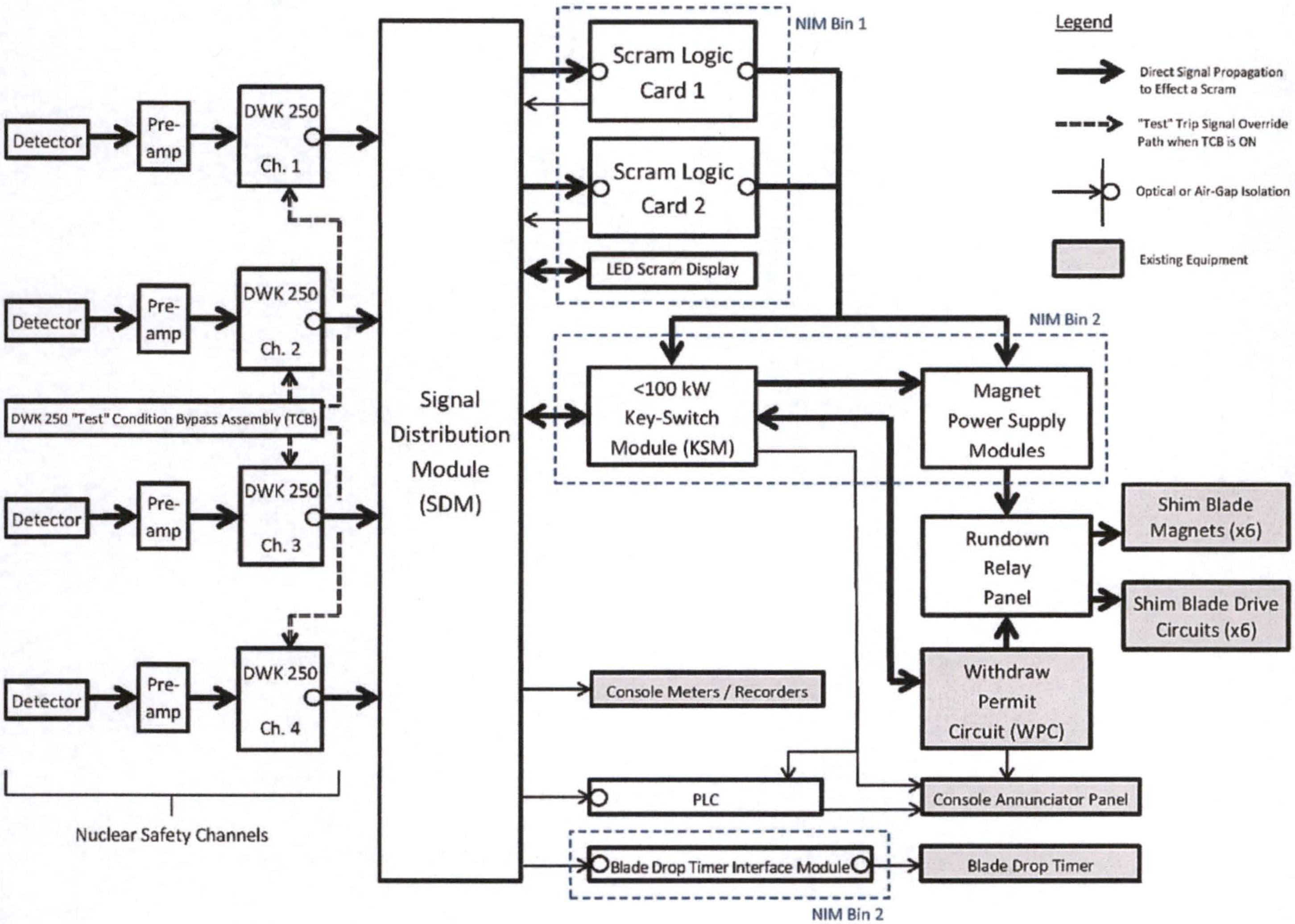


Figure 1: Block Diagram of Nuclear Safety System with Integrated Support Modules

Each Scram Logic Card (SLC) is housed in a dedicated protective chassis that is constructed of standard industrial aluminum stock. Figure 2 and Figure 3 show a spare SLC module that is identical to Scram Logic Cards #1 and #2. The printed-circuit card is constructed using standard industrial FR-4 board (composite material composed of woven fiberglass cloth with an epoxy resin binder), with the logic devices being high quality industrial discreet solid-state components, conforming to industrial quality standards for automotive electronics. The SLC modules do not contain a fan or any other moving parts. Their operation is entirely analog using discrete solid-state components. The choice of all components on the circuit boards was determined in house; an ISO 9001-2008 certified electronic hardware manufacturer (Advanced Circuits) performed the printed-circuit board fabrication and card assembly. The cards were manufactured to certification IPC Class 2-A600, for dedicated-service electronic products requiring continued performance and extended life.

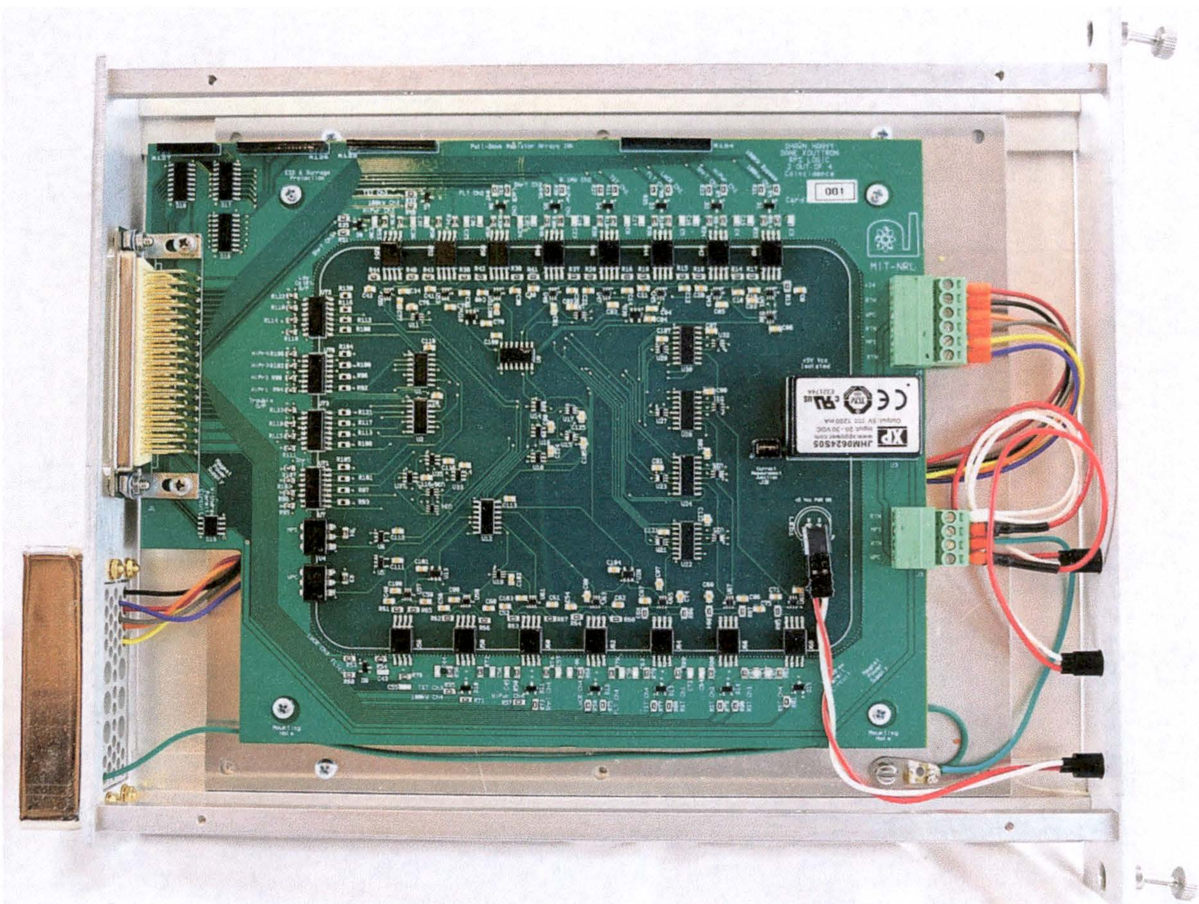


Figure 2: Scram Logic Circuit Card in a Scram Logic Card Module

The printed circuit board, as shown in Figure 2, has four layers which are electrically insulated from each other except at vertical interconnect access (VIA) points. Most components are mounted on the top plane of the board, but a few small ones such as capacitors are on the bottom plane. The second plane from the top supplies power to the components, and the third, a ground plane, contains the return paths.

Power for the two SLC modules comes from a pair of $24V_{DC}$ power supplies via the X14 connector of the Signal Distribution Module. The two $24V_{DC}$ power supplies are set up in parallel, connected via an auctioneering diode array, so that if one fails, the other will take over without interruption.

The top plane of the board has two isolated regions which are distinguishable by their different shades of green. Components in the lighter green near the perimeter of the board are supplied directly by $24V_{DC}$ power. The darker green inner area operates at $5V_{DC}$. All the logic executions take place in the darker area, with signals entering the region from the top and the bottom as seen on Figure 2, and logic output leaving the region on the left and the right.

The two voltage regions are isolated from each other electrically, connecting only via optical isolators ($5V_{DC}$ High Speed CMOS Optocouplers and High Collector-to-Emitter Voltage Optocouplers) and an isolated board-mount 24-volt to 5-volt, medically-qualified DC-DC converter. Throughout the circuit card, Zener diodes were used to convert $24V_{DC}$ to $5V_{DC}$ just upstream of the various optical isolators. Where necessary, pull-down resistors and current-limiting resistors are used to ensure binary signal clarity; surge-suppression diodes are used to protect the circuit card from electrostatic discharge (ESD).

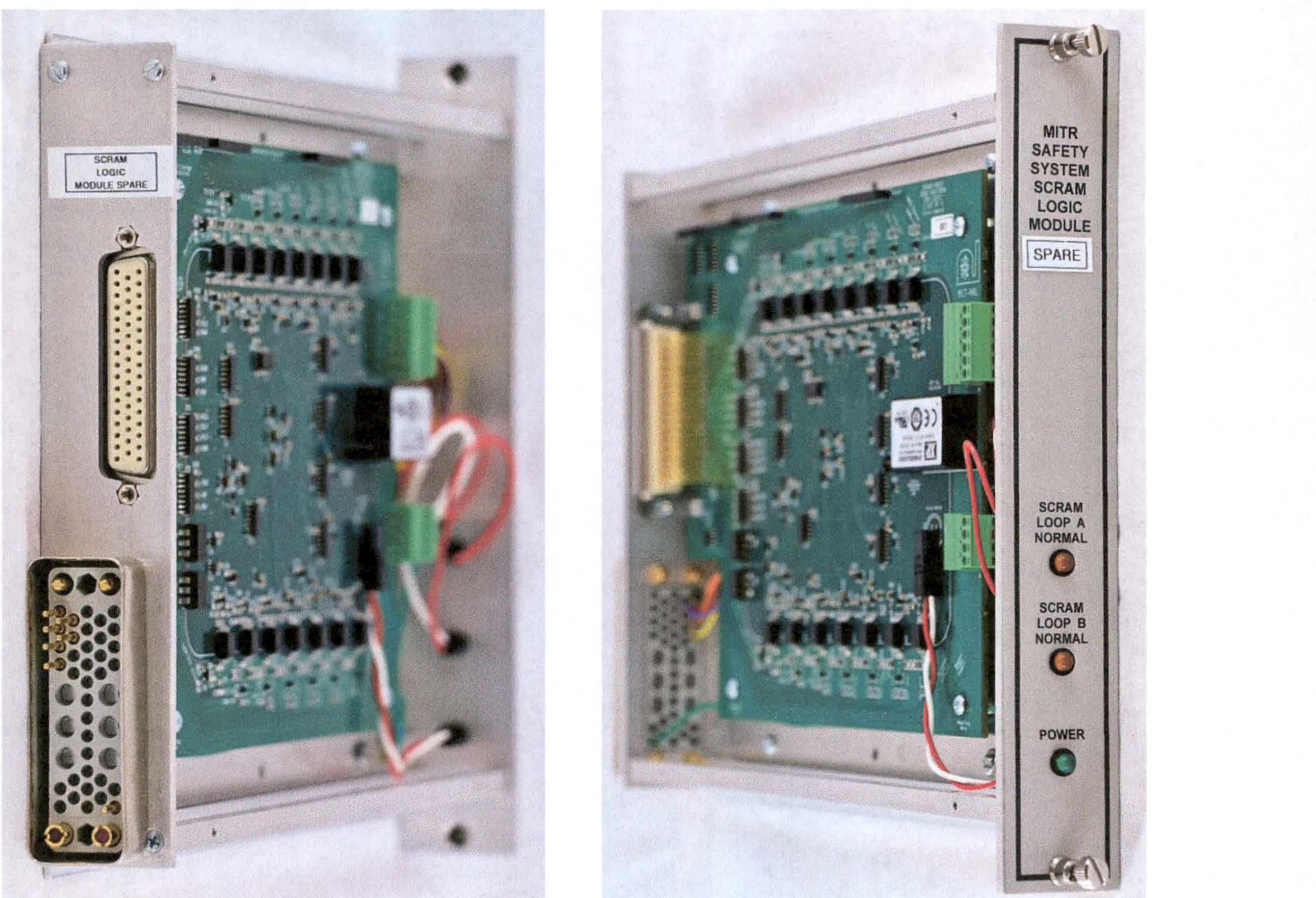


Figure 3: Back and Front Views of Scram Logic Card Module

The scram logic was designed in house, as asynchronous sequential binary logic. Therefore, the circuits do not contain or use a clock. If only one of the four DWK 250 chassis outputs a trip signal, while the other three do not, the scram logic will not initiate a scram signal. This will prevent a reactor scram due to a false indication from only one channel, and therefore will improve system stability. It also allows for testing and calibration of a single channel at power without the need for a bypass device. If now another DWK 250 chassis also outputs a trip signal to the scram logic circuit, the coincidence logic will complete a decision and output a scram signal by de-energizing the circuit, thereby removing power from normally-energized relays in the magnet power supplies and the Withdraw Permit Circuit to produce a reactor scram. Therefore, two or more DWK 250 chassis outputting safety trips will result in a scram signal output by the scram logic circuit. Furthermore, if one DWK 250 is under test, powered off, or removed from service, any trip signal from one of the other DWK 250s will result in a scram.

The design process for the scram logic went as follows: A logic diagram for the scram voting logic was first developed on paper. It was then algebraically simplified as a Boolean expression, and converted back to a reduced logic diagram. This diagram was then verified and tested with logic simulator software. The logic diagram was further verified by programming the logic design into a field-programmable gate array (FPGA) development board, the DE0-Nano from Terasic. The FPGA was then tested with an input board built in-house that simulated all possible combinations of inputs from the four DWK 250s plus the 100 kW operation key-switch.

Once the logic diagram was completed, it was entered into circuit design software with integrated circuits (IC) components selected by the reactor's Instrumentation Supervisor, and checked by the Senior Project Specialist, to produce a simulated logic circuit. This simulated circuit was then tested to verify correct operation. After the circuit design was completed, printable circuit board (PCB) design software was used to lay out the components and wire traces in a set two-dimensional areas to be stacked in four layers. The resulting circuit (Figure 4), in a Gerber-format (ASCII vector image) file, was sent to an intermediate manufacturer for fabrication of a prototype board. In-house testing of this prototype allowed adjustment of components, verification of voltage stability, and finalization of circuit design.

Once the final design and components were chosen, the layout was sent to the final manufacturer, Advanced Circuits, for fabrication of another prototype circuit card. This prototype card was tested in house, using the same voltage as the relay contacts from the DWK 250s. Several iterations of the prototyping processes occurred until the prototype satisfied all performance requirements, at which point five assembled copies of the final design were ordered from the manufacturer. One of the five cards received an independent visual inspection to ensure the logic components matched the parts list. When in-house testing and verification were completed satisfactorily on all five circuit cards, the cards were coated with conformal acrylic polymer for surface protection. One card was mounted in each of the two Scram Logic Card chassis, one in a spare SLC chassis, and two remain unmounted as spares.

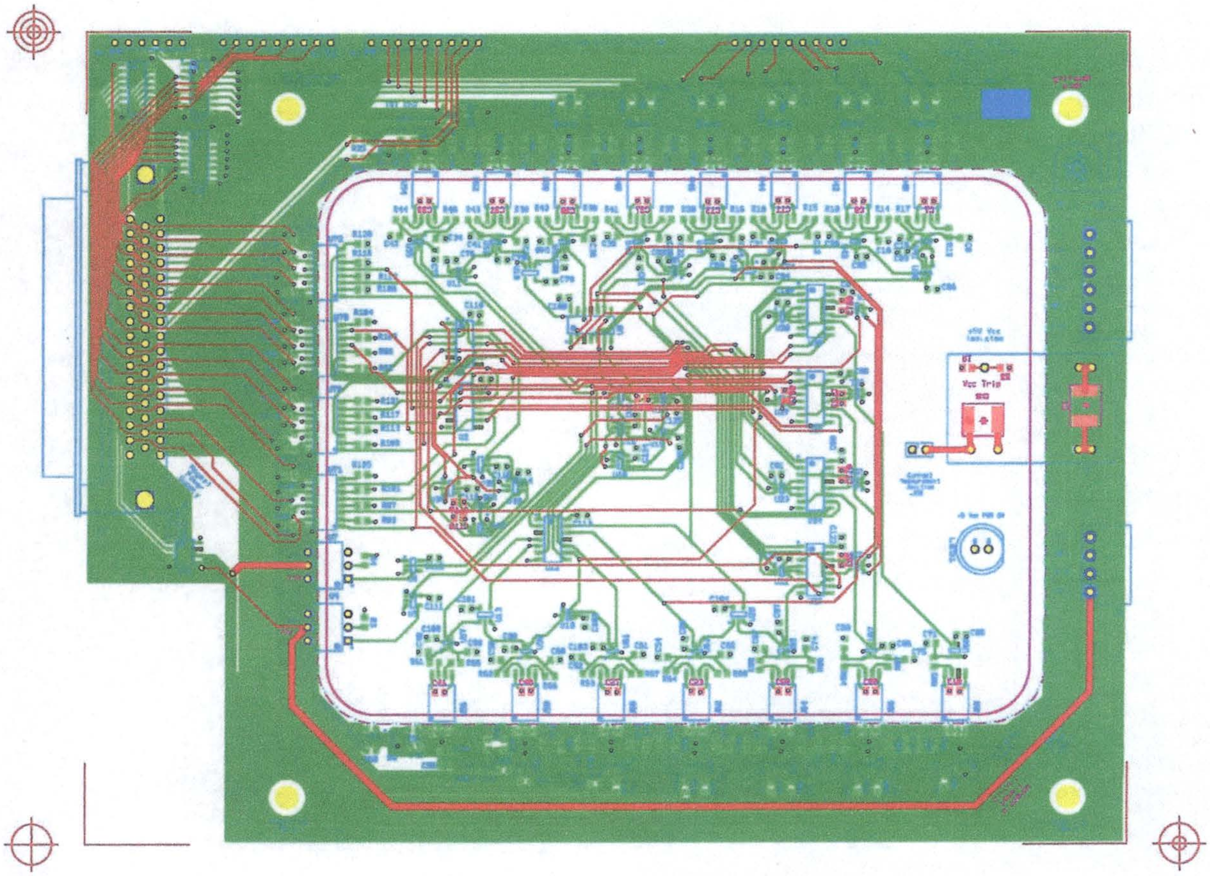


Figure 4: Part of N.I. Ultiboard layout for compilation to a Gerber file – PCB-with-Components Prototype

Reactor Drawing R3W-263-2 "NSS Scram Logic Card" main schematic and sub-circuits (total of 11 sheets) contains the schematics of the Scram Logic Card. These schematics divide functions of the cards into ten sub-circuits (SCs):

1. SC1 – "Optocoupled Schmitt Trigger Filter Input (SC1)"

   This input SC reduces the voltage from the $24V_{DC}$ signals to $5V_{DC}$ for the logic circuits, and de-bounces (damps any bouncing of) input signals during voltage/current transients.

2. SC2 – "ESD and Surge Protection (SC2)"

   Provides ESD and surge protection to the circuit components on the PCB.

3. SC3 – "Channel Logic (SC3)"

   Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 1, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

4. SC4 – "Channel Logic (SC4)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 2, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

5. SC5 – "Channel Logic (SC5)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 3, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

6. SC6 – "Channel Logic (SC6)"

Consolidates the 100 kW key-switch input and trip signals from DWK 250 Channel 4, and forwards the logic result to SC10. Also passes high power trip and channel trouble indications to the SC7 alarm latch.

7. SC7 – "Alarm Latch (SC7)"

Latches the Schmitt-triggered trips from the DWK 250 channels, stores them until the corresponding channel reset pushbutton is depressed, and forwards the latched signals to SC9. Also initiates alarm signals for the LED Scram Display module.

8. SC8 – "Alarm Indicator (SC8)"

This output SC converts signal voltage from the $5V_{DC}$ logic circuits to $24V_{DC}$ for alarm indications, using optocouplers. It forwards the alarm signals for the LED Scram Display module.

9. SC9 – "2 out of 4 (SC9)"

Executes 2-out-of-4 coincidence logic based on all latched-in alarms, whether active or not yet reset. The outputs of SC9 and SC10 feed into two independent AND gates outputting to two independent solid state relays that drive the 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit.

10. SC10 – "2 out of 4 (SC10)"

Executes 2-out-of-4 coincidence logic based on the outputs of the four channel logic SCs. Automatically resets once the DWK 250s are restored to normal operating conditions. The outputs of SC9 and SC10 feed into two independent AND gates outputting to two independent solid state relays that drive the independent 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit.

For logic operation related to scram decision-making, specifically in SC3, SC4, SC5, SC6, SC9, and SC10, five different types of Texas Instrument integrated circuit logic gate chips are used, ranging from 2-input to 4-input AND gates, plus OR-AND gates and AND-OR gates. All are qualified for automotive applications except the AND-OR gate. All have wide operating temperature tolerance (-40 C to 85 C or better). They all meet industrial standards for ESD protection.

There are a total of 29 inputs to each SLC. Each DWK 250 chassis produces eight binary outputs: High Power, Short Period, 100 kW High Power, Low Count Rate, Internal Fault, Test, High Power Warning, and Short Period Warning. The first six of these outputs go to the SLC as channel trip inputs. In total there are 24 trip inputs coming from the four DWK 250 chassis. Another four inputs to the SLC are resets, one for each channel, for the latched alarms coming from each DWK 250. The last input is from the key-operated switch on the <100 kW Key-Switch Module (KSM). A latched-in alarm will not clear until the corresponding channel's reset pushbutton is depressed on the LED Scram Display Module. Holding down one or more of the reset pushbuttons does not prevent a scram; likewise the LED indicator lights will still illuminate to show the corresponding trip signals.

When the KSM's key switch is turned to <100 kW Operation, a signal indicating the key switch position is sent to the two SLCs. If reactor power reaches 100 kW, the DWK 250s will output 100 kW High Power trips, and the SLCs will interpret these as high power channel trips. So if two or more DWK 250 simultaneously output the trip, the SLC will generate a scram signal. When the KSM's key switch is turned to Full Power Operation, the 100 kW High Power trips will still be generated from the DWK 250s and will all reach the SLCs, but the key switch position will signal the SLCs not to interpret them as high power channel trips. If the KSM's key switch is turned to <100 kW Operation when reactor power is already above the 100 kW scram set point, the system will scram on high power on all four channels simultaneously.

There are a total of 21 outputs from each SLC. Two of the outputs feed the independent relays that de-energize the Withdraw Permit Circuit and the Magnet Power Supply Modules in the event of a scram. Sixteen of the outputs feed trip indications to the LED Scram Display. The remaining three outputs feed indicator lights on the front of the SLC module.

The SLC's scram signal outputs are in $24V_{DC}$ binary form to drive relays in the Withdraw Permit Circuit, in the Magnet Power Supply Modules and Rundown Relay panel, and in the <100 kW Key-Switch Module. It is important to point out that the scram signal output is not a signal pulse that travels downstream along a transmission path. Instead, the system is always energized at 24 volts DC in the normal (no scram) operating condition. When a scram "signal" is output, the system is actually de-energized to 0 volts, ensuring de-activation of all downstream modules and shutting down the reactor. In this way, any system failure that causes loss of signal will have the same result of a reactor scram.

Safety Evaluation

The Scram Logic Card (SLC) is designed with solid-state logic devices that operate at low voltage ($5V_{DC}$) and with supporting components that operate at $24V_{DC}$. It is always in a powered state during normal operation. If a scram decision is made, it de-energizes, dropping power to 0 volts. If the SLC fails, it drops power to 0 volts, which is equivalent to a scram decision.

Failure Analysis

While failure of a qualified printed circuit board is rare, failure of individual components, particularly logic gates, would hamper logic decision-making. Logic gates can fail because of fast voltage transients, excessive heat buildup, oxide buildup, electrical over-stress, or electrostatic discharge. All of these conditions will cause the logic gate to fail open, either directly or in the form of a short circuit which will eventually burn through into an open circuit. This failure mode will resemble a scram decision.

However, it is known that logic components could fail in an energized condition. In this case, multiple logic pathways are used within each SLC to make redundant logic decisions. For instance, there is channel logic handling for trips from each DWK 250 channel. These channel trips are also latched on separate components. The channel logic output and the latched trips are fed to two independent 2-out-of-4 coincidence circuits. The outputs of the two coincidence circuits feed into two independent AND gates outputting to two independent solid state relays that drive the 24-volt relays in the magnet power supplies and the Withdraw Permit Circuit. Deactivation of any one of these coincidence circuits, AND gates, or solid state relays will suffice in producing a reactor scram. Finally, there are two identical Scram Logic Cards that process the trips from the DWK 250 channels. Deactivation of either SLC will produce a reactor scram.

Redundancy and Independence

The two SLCs are each housed in their own aluminum chassis. Although they are mounted within the same NIM bin, their operations are completely independent, and do not interfere with each other. This multi-level redundancy and independence ensures a high degree of reliability in the operation of the Scram Logic Cards.

Component Isolation and Qualification

All logic operation takes place in a low-voltage environment ($5V_{DC}$). The logic components are physically mounted in a low-voltage region on the PCB. This region is electrically isolated from the rest of the PCB. Signals input and output across this isolation boundary are handled by the use of optoisolators and optocouplers, and an isolated board-mount 24-volt to 5-volt DC-DC power converter. The optoisolators and optocouplers both make use of high-speed light emitting diodes (LEDs) and photoreceptor receivers, and accordingly act as one-way devices by nature of their construction. Both types have an operating temperature range of at least -40 C to 100 C. The use of these optical and isolation devices satisfies the protection requirement for the low-voltage components.

Each SLC uses two solid-state output relays – one to the Withdraw Permit Circuit and the other to the magnet power supplies. These relays use infrared LEDs to optically isolate their inputs, thereby ensuring the signal path is one-way only, to protecting the SLCs. They have a fast switching speed from closed to open (maximum 0.5 milliseconds), and an operating temperature range of -40 C to 85 C.

All key components for logic operation are qualified for automotive applications, meeting industrial standards for electrical over-stress (EOS) and electrostatic discharge (ESD) protections, and allowing a wide range for operating temperature. Where necessary, diodes are used throughout the circuitry for surge suppression, and resistors to limit maximum current.

The SLCs receive their 24-volt power through the Signal Distribution Module (SDM) from two $24V_{DC}$ power supplies which meet medical qualifications. These two power supplies are fed from a common $120V_{AC}$ source, and have an internal fuse which will protect against surges that exceed $250V_{AC}$ on that line. They also have an output overload that will trip at no more than $35V_{DC}$. In the unlikely event of an excessive line voltage surge, both power supplies will likely trip, interrupting power to the two SLCs, scramming the reactor. Similarly, loss of off-site electrical power will shut down the SLCs, which are in a powered state during normal operation and have no internal battery backup. The SLC outputs a scram "signal" by de-energizing itself to 0 volts, thereby de-activating all downstream modules and shutting down the reactor.

Response Time Budget

The operation of the Scram Logic Cards is entirely bistable-based and asynchronous. The voltage transition from $24V_{DC}$ to the $5V_{DC}$ logic is accomplished with analog components, and the scram voting utilizes asynchronous sequential logic. There is no microprocessor in the signal path and thus no scan time or cycle time. As a result, the longest signal transition time through the logic card is 0.19 milliseconds, as evaluated from component-level data sheets. The actual time as measured is only ~0.038 milliseconds. Most of the time budget is for the isolation optocouplers passing input and output signals across the $24V_{DC}$ / $5V_{DC}$ boundary. This time budget is minuscule when compared to the opening times for the mechanical relays that interrupt shim blade magnet current, which are on the order of 15 milliseconds. The integrated system response time, which includes transit time across the SLCs and all other modules, is measured at no more than 500 milliseconds. This was measured based on time from initiation of the trip signal at the Mirion DWK 250 to movement of each operable blade from its full-out position to its 80% inserted position, which per MITR Technical Specification 3.2.1.1(b) must be less than one second.

Cybersecurity

Since there are no programmable or re-configurable logic elements in the SLCs, and no connections external to the Nuclear Safety System, the SLCs are not subject to cybersecurity threats.

Human Factors

Human interface with the SLC modules is minimized, with no switches or adjustable controls, and only three LED indicator lights on the front of each. (See Figure 3.) A green LED indicates that power is on, and two amber LEDs indicate normal (non-scrammed) conditions in Scram Loop A and Scram Loop B in the Withdraw Permit Circuit. During normal operation, all three indicators are lit. All external cable connections to the SLC modules will be labeled and color-coded. There are two external connections for each SLC module – an I/O cable with a DB50 connector, and an output NIM bin connector. It is not physically possible to interchange the input cable and output connector. Swapping of like I/O cables between the two SLC modules could cause incorrect LED displays but would have no impact on the scram functions. The color-coded labels improve human interface for purposes of installation and maintenance. Once the SLC modules are installed, there will be no regular human interface with them. They will be handled only by or under the supervision of license reactor staff. Since the maximum voltage in the modules is only $24V_{DC}$, electrical hazard to instrumentation personnel is minimal. Therefore, human factors engineering remains adequate.

The SLC modules will be mounted within the protective metal instrumentation cabinets of the control room. The instrumentation cabinets will provide the modules with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting of approximately 68 F (20 C). There is a temperature alarm with a setpoint no higher than 78 F (26 C) that is monitored whenever the reactor is operating, or is shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components in the SLC modules.

If the air conditioning is off for an extended period of time while the reactor is operating, the instrumentation cabinet temperature rise may cause component malfunction. Since all the Nuclear Safety System support module circuits are normally closed and energized, and they open when there is a scram condition, therefore a component malfunction will open a circuit and induce a scram. The control room containing the instrumentation cabinets is continuously attended by a licensed operator whenever the reactor is operating. There is a portable air conditioner available in the vicinity of the control room as a backup if the main system fails. Written protocols exist for operator response to a room temperature alarm condition, including shutdown should the adverse condition persist.

Pre-Operational Testing and Routine Surveillance

For pre-operational verification, the SLC modules were tested by simulating a trip condition for each combination of High Power, Low Count Rate, Short Period, Fault, and Test, to verify the cards initiated a scram condition for every combination of two parameters from any of the four DWK 250 channels. This test was completed in full power and <100 kW modes on both of the SLCs as well as the spare.

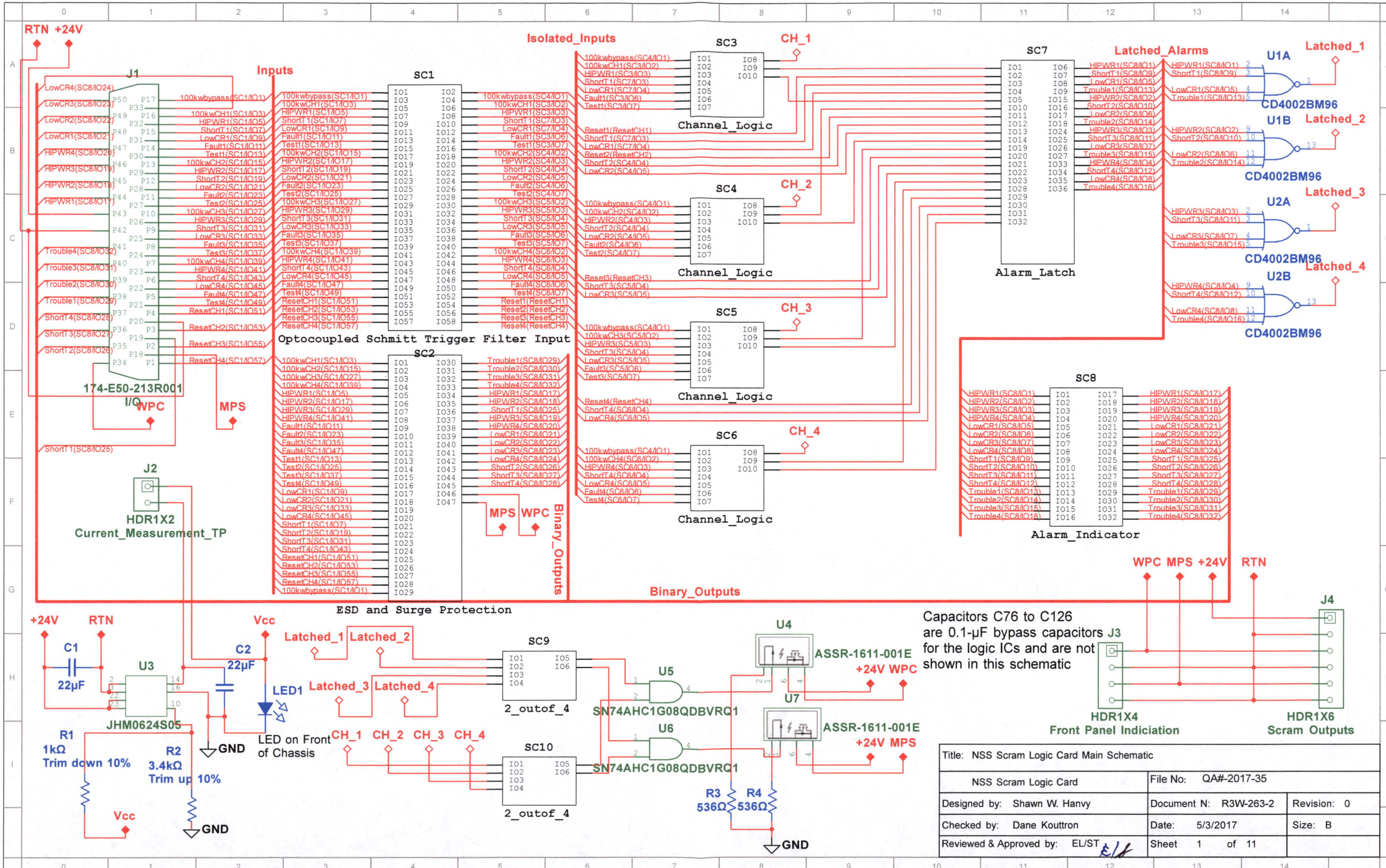
The SLC modules will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation.

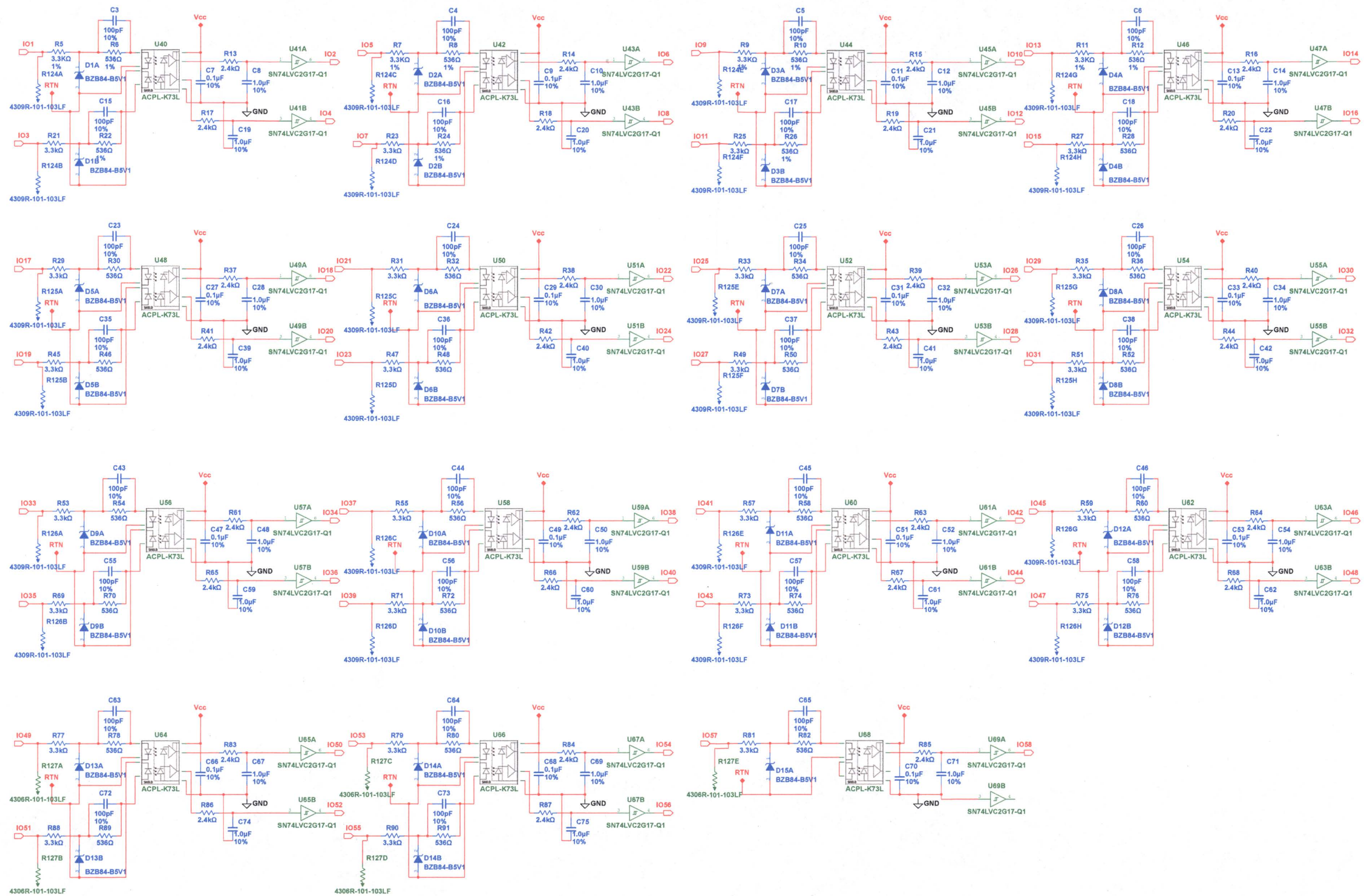
Routine functional verification of the SLC modules will be performed in the reactor startup checklists so that certain tests will be completed prior to every reactor startup. The startup checklists will test the SLCs by verifying the 2-out-of-4 logic for each parameter, but will not test each combination as described above. Example of startup checklist testing for the High Power trips is as follows:

High Power Trip Channels 1 and 2
High Power Trip Channels 1 and 3
High Power Trip Channels 1 and 4
High Power Trip Channels 2 and 3
High Power Trip Channels 2 and 4
High Power Trip Channels 3 and 4.

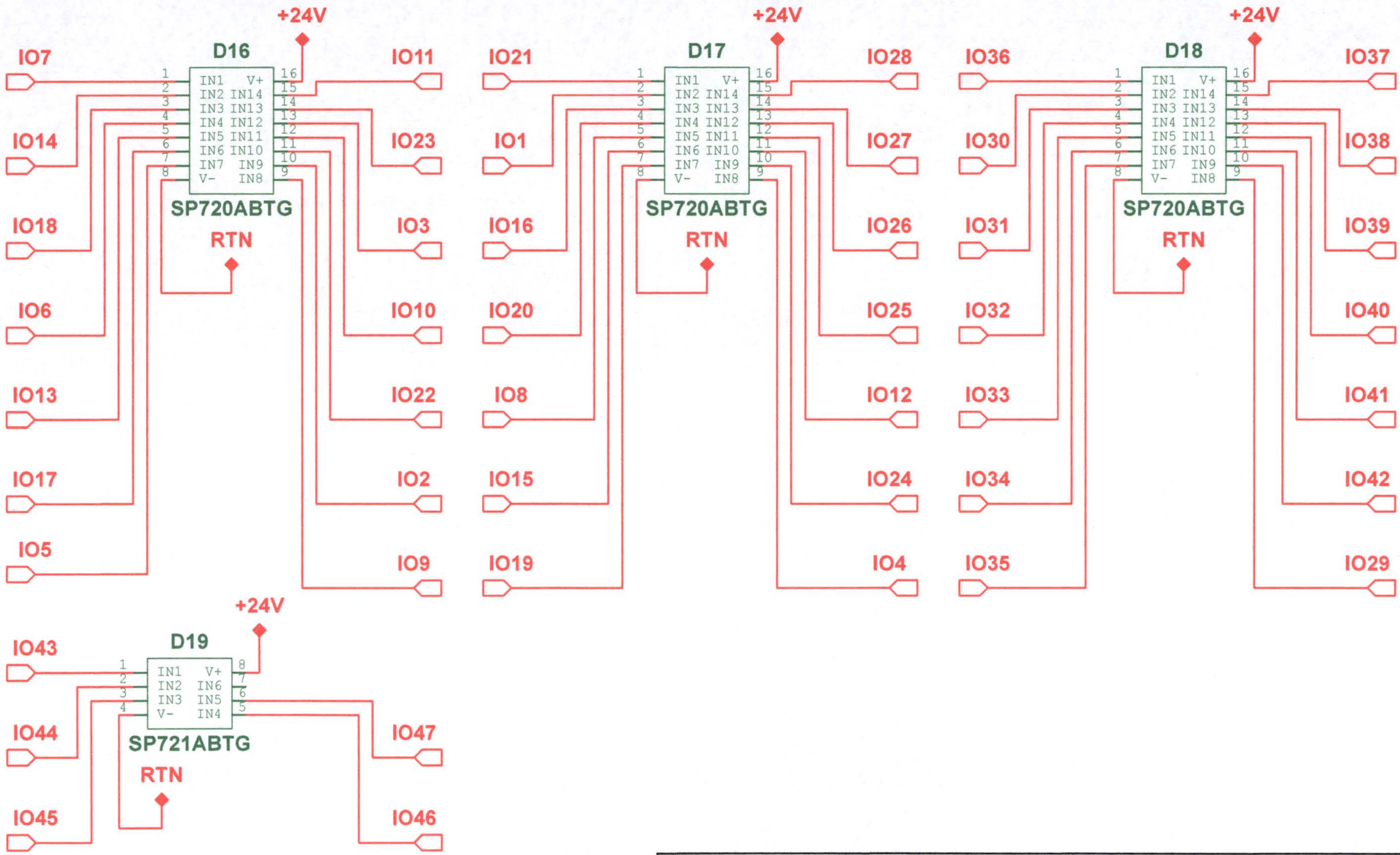
On the startup checklists, the same testing sequence will also be performed for Low Count Rate, Short Period, Fault, and Test, for a total of 30 such tests. The tests will each be satisfied by observing a scram signal is successfully output from the two SLCs in parallel.

These pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the scram logic circuits.

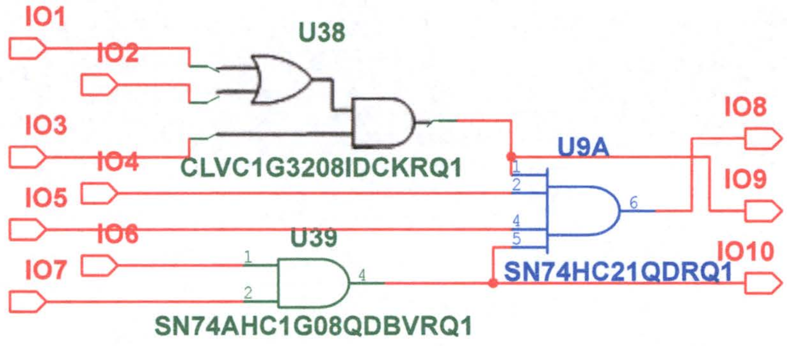

RTN +24V
J1
174-E50-213R001
I/O
WPC
MPS
Inputs
SC1
Optocoupled Schmitt Trigger Filter Input
SC2
ESD and Surge Protection
Isolated_Inputs
SC3
Channel_Logic
SC4
Channel_Logic
SC5
Channel_Logic
SC6
Channel_Logic
CH_1
CH_2
CH_3
CH_4
SC7
Alarm_Latch
Latched_Alarms
U1A
U1B
U2A
U2B
CD4002BM96
Latched_1
Latched_2
Latched_3
Latched_4
SC8
Alarm_Indicator
Binary_Outputs
J2
HDR1X2
Current_Measurement_TP
+24V
RTN
C1
22µF
U3
JHM0624S05
C2
22µF
Vcc
LED1
LED on Front of Chassis
GND
R1
1kΩ
Trim down 10%
R2
3.4kΩ
Trim up 10%
SC9
2_outof_4
SC10
2_outof_4
U5
U6
SN74AHC1G08QDBVRQ1
U4
U7
ASSR-1611-001E
+24V WPC
+24V MPS
R3
536Ω
R4
536Ω
Capacitors C76 to C126 are 0.1-µF bypass capacitors for the logic ICs and are not shown in this schematic
J3
HDR1X4
Front Panel Indiciation
J4
HDR1X6
Scram Outputs
WPC MPS +24V RTN
Title: NSS Scram Logic Card Main Schematic
NSS Scram Logic Card
File No: QA#-2017-35
Designed by: Shawn W. Hanvy
Document N: R3W-263-2
Revision: 0
Checked by: Dane Kouttron
Date: 5/3/2017
Size: B
Reviewed & Approved by: EL/ST
Sheet 1 of 11



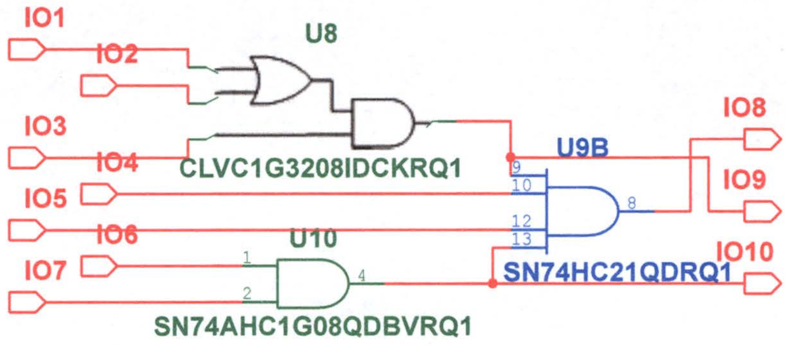
Title: Optocoupled Schmitt Trigger Filter Input (SC1)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A1
Reviewed & Approved by: EL/ST	Sheet 2 of 11	



Title: ESD and Surge Protection(SC2)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST E/ST	Sheet 3 of 11	



Title: Channel Logic (SC3)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST EL	Sheet 4 of 11	



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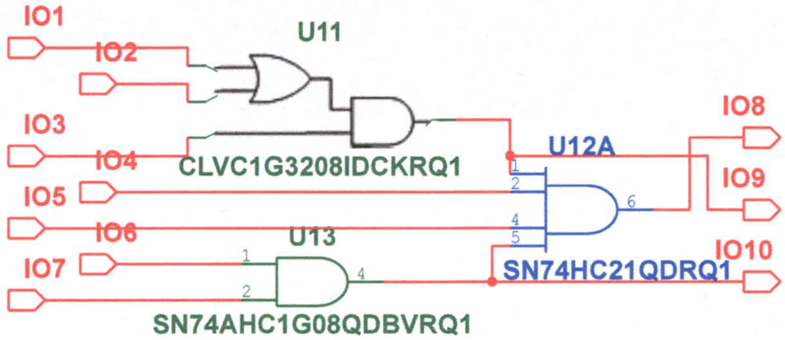
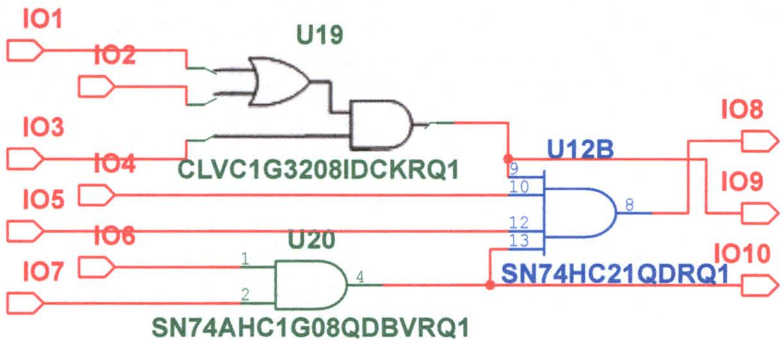
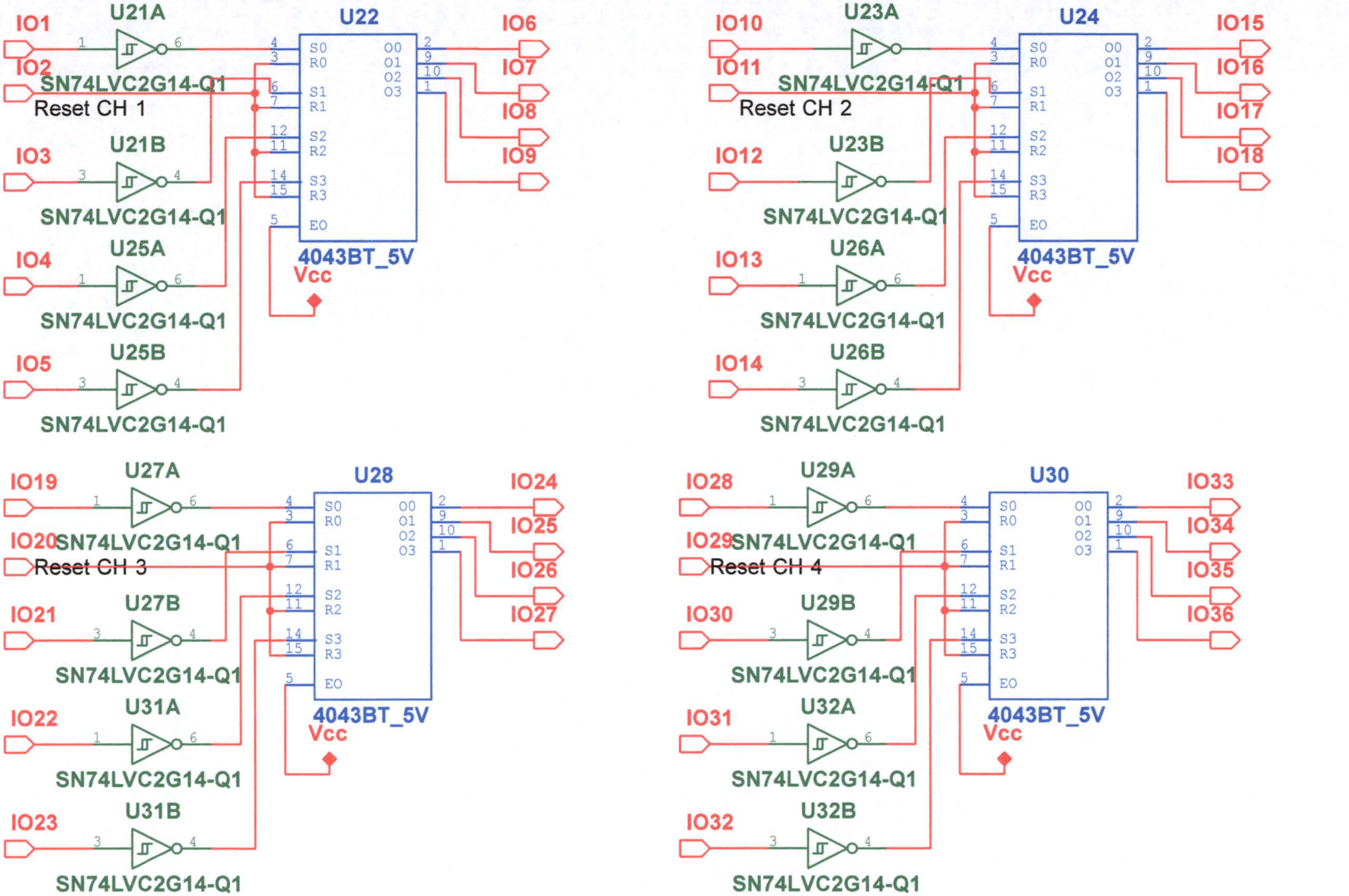
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 5 of 11	



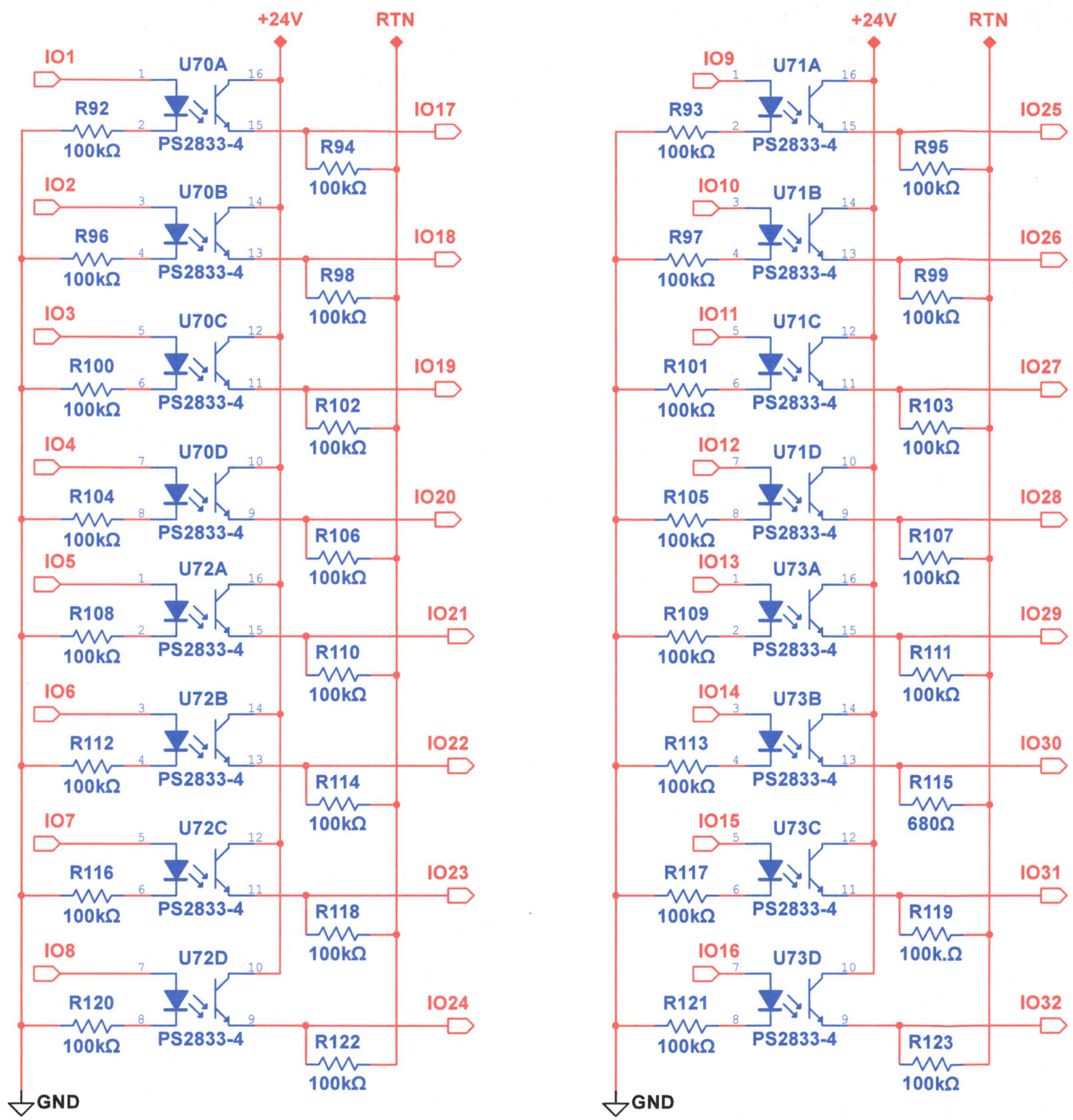
Title: Channel Logic (SC5)			
NSS Scram Logic Card	File No: QA#-2017-35		
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0	
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A	
Reviewed & Approved by: EL/ST E/J	Sheet 6 of 11		



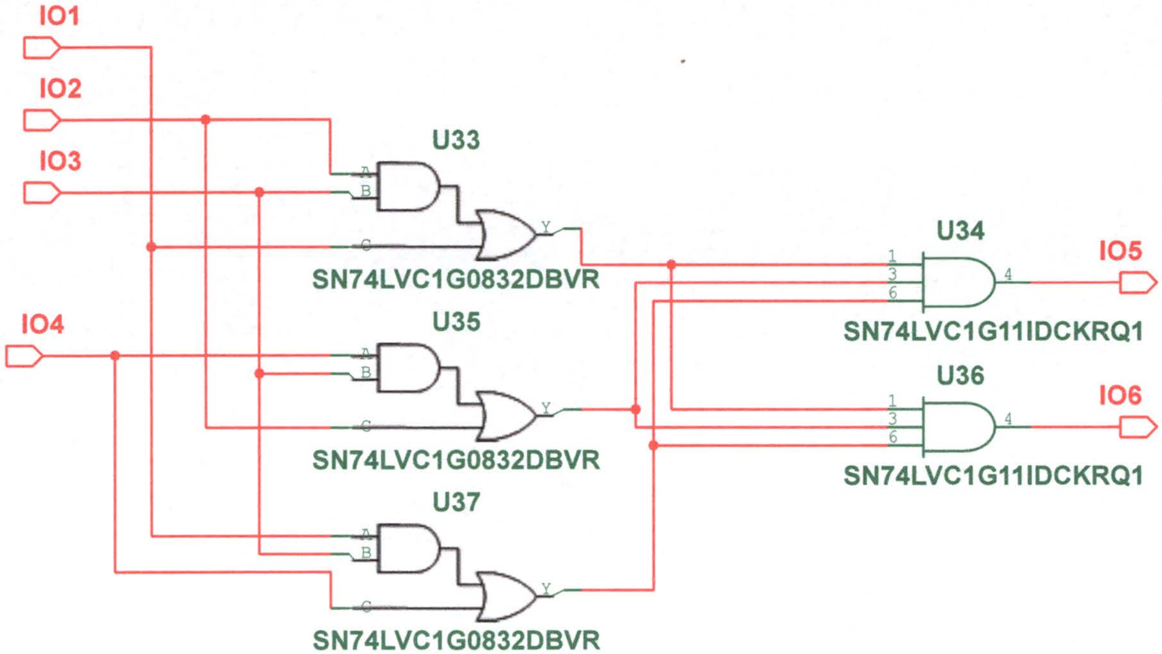
Title: Channel Logic (SC6)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 7 of 11	



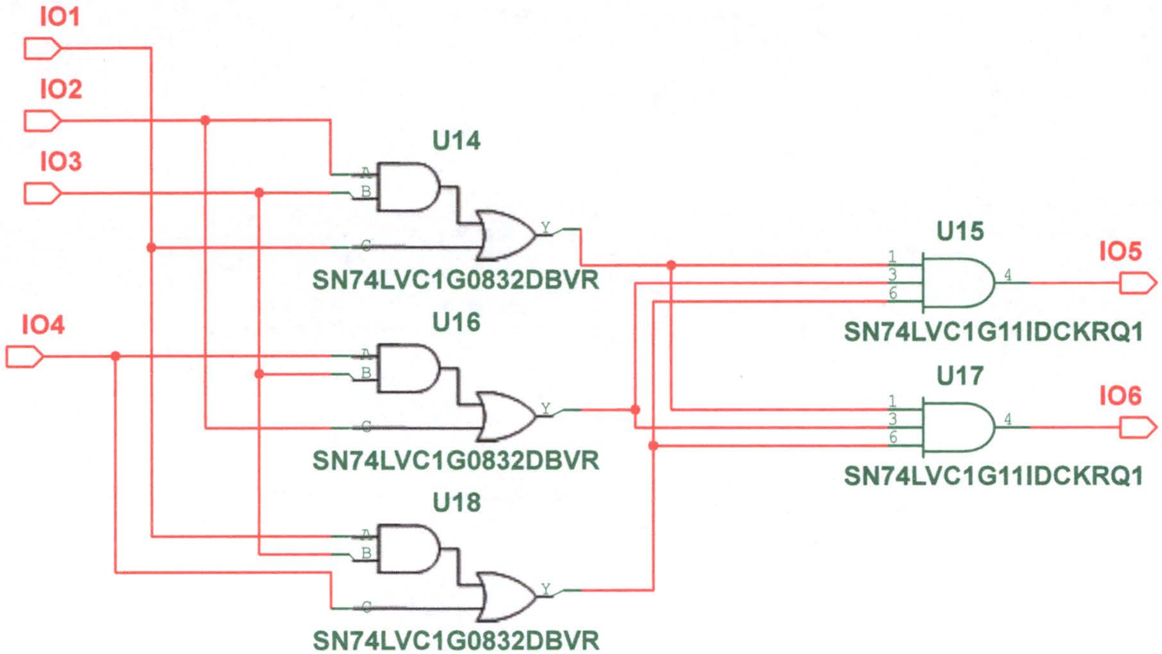
Title: Alarm Latch (SC7)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST EJS	Sheet 8 of 11	



Title: Alarm Indicator (SC8)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: B
Reviewed & Approved by: EL/ST	Sheet 9 of 11	



Title: 2 outof 4 (SC9)		
NSS Scram Logic Card	File No: QA#-2017-35	
Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST	Sheet 10 of 11	



Title: 2 out of 4 (SC10)		
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Designed by: Shawn W. Hanvy	Document N: R3W-263-2	Revision: 0
Checked by: Dane Kouttron	Date: 5/3/2017	Size: A
Reviewed & Approved by: EL/ST E/S	Sheet 11 of 11	

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure F

Q/A File #2017-36 "LED Scram Display"

Description of the LED Scram Display

The LED Scram Display features two 4x4 arrays of light-emitting diode (LED) indicator lights that allow, via the outputs of the two Scram Logic Cards, the console operator to readily identify which DWK 250 chassis has produced a trip signal from its binary outputs, as shown in Figure 1 below. The upper array shows the signals output by Scram Logic Card 1, and the lower array by Scram Logic Card 2.

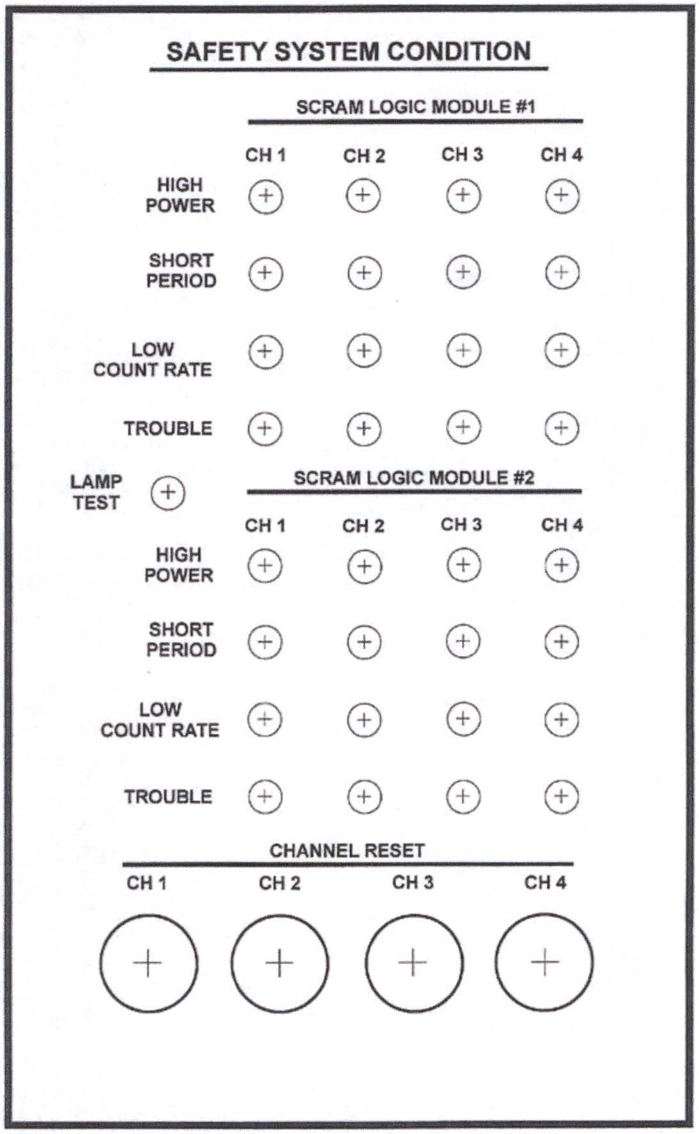


Figure 1 – Front Face Overlay for the LED Scram Display

The LED Scram Display module is labeled "Safety System Condition", as shown in Figure 1 and Figure 2. It receives trip condition signals from Scram Logic Card 1 and Card 2 by way of the Signal Distribution Module (SDM). When a DWK 250 outputs a trip signal, the signal is indicated on the DWK 250 chassis itself. If this trip is transitory, such as a momentary high power, the indicator light on the DWK 250 will go out as soon as the trip condition clears. However, the trip signal will be retained (or "latched") in the Scram Logic Cards, which send it to the LED Scram Display module.

From each of the Scram Logic Cards, the LED Scram Display has four trip indications representing six trip conditions from each of the DWK 250 channels: High Power (full power or 100 kW set point, depending on the position of the key switch on the <100 kW Key-Switch Module), Short Period, Low Count Rate, Test, and Fault / Equipment Malfunction, with the latter two combined as Trouble.

Figure 2 – LED Scram Display Module

The High Power light represents one of two possible high reactor power conditions from the DWK 250 chassis – the [full power] High Power trip or the High Power 100 kW Operation trip – depending on which mode of operation is selected on the <100 kW Key-Switch Module (KSM). For instance, if <100 kW Operation is selected and reactor power reaches the <100 kW operation trip set point, then the DWK 250 chassis will output the High Power 100 kW Operation trip signal. The trip signal first arrives at the Scram Logic Cards, which then output the signal to the LED Scram Display module, illuminating the High Power trip light.

If just one of the four DWK 250 chassis outputs two or more trip signals, the two Scram Logic Cards receive the trip signals for logic comparison, but will not produce a scram signal. This will show up on the LED Scram Display as multiple lights lit up all in a single column, and no scram. However, if two or more of the DWK 250s produce trip signals, then the two-out-of-four voting logic designed into the Scram Logic Cards is satisfied, and the Scram Logic Cards will output a scram signal to shut down the reactor. This will show up on the LED Scram Display as multiple lights lit up in the same row, with a scram.

Therefore, the LED Scram Display provides a visual illustration for the console operator of the status of the Scram Logic Cards. It will be located on the control room console where it is easily visible by the console operator.

The LED Scram Display module contains reset buttons, one corresponding to each DWK 250 channel. The console operator needs to manually push the "Channel Reset" button for the corresponding channel in order to clear the alarm for that channel latched in both of the Scram Logic Cards. The "Channel Reset" buttons reset the Scram Logic Cards, and thus the lights on the LED Scram Display, particularly prior to restart of the reactor. This function puts the LED Scram Display module in the category of "safety-related component" in the new Nuclear Safety System.

The LED Scram Display module also contains a "Lamp Test" pushbutton, as shown in Figure 1 and Figure 2. When held in, this button activates all the LED indicator lights for visual check by the operator. The indicator lights will be tested prior to reactor startup per written procedures.

The LED Scram Display module and the Scram Logic Cards are composed of bi-stable, discrete components only, and therefore are not programmable and do not have a system clock or other timing function. Signal transmission between the LED Scram Display module and the Scram Logic Cards is via the Signal Distribution Module, which is functionally passive as covered in the Signal Distribution Module description.

Schematic and block diagrams of the LED Scram Display are found in Drawing R3W-270-2 "LED Scram Display Detailed Schematic" and R3W-271-1 "LED Scram Display Module Block Diagram".

Safety Evaluation

The LED Scram Display module is composed entirely of discrete components, and is therefore not subject to cybersecurity threats. It is a passive device that is used for visual indication and for resetting the Scram Logic Cards. It does not produce any scram signals. If the module fails, such as by physical damage or other disturbance, the LED indicator lights will not light, and the reset buttons may not function. In this case if the Scram Logic Cards produce a scram, there will be no means to reset the Cards, resulting in a conservative outcome. Furthermore, because the module is a passive device, it will not generate heat or produce interference in the Signal Distribution Module or other neighboring devices.

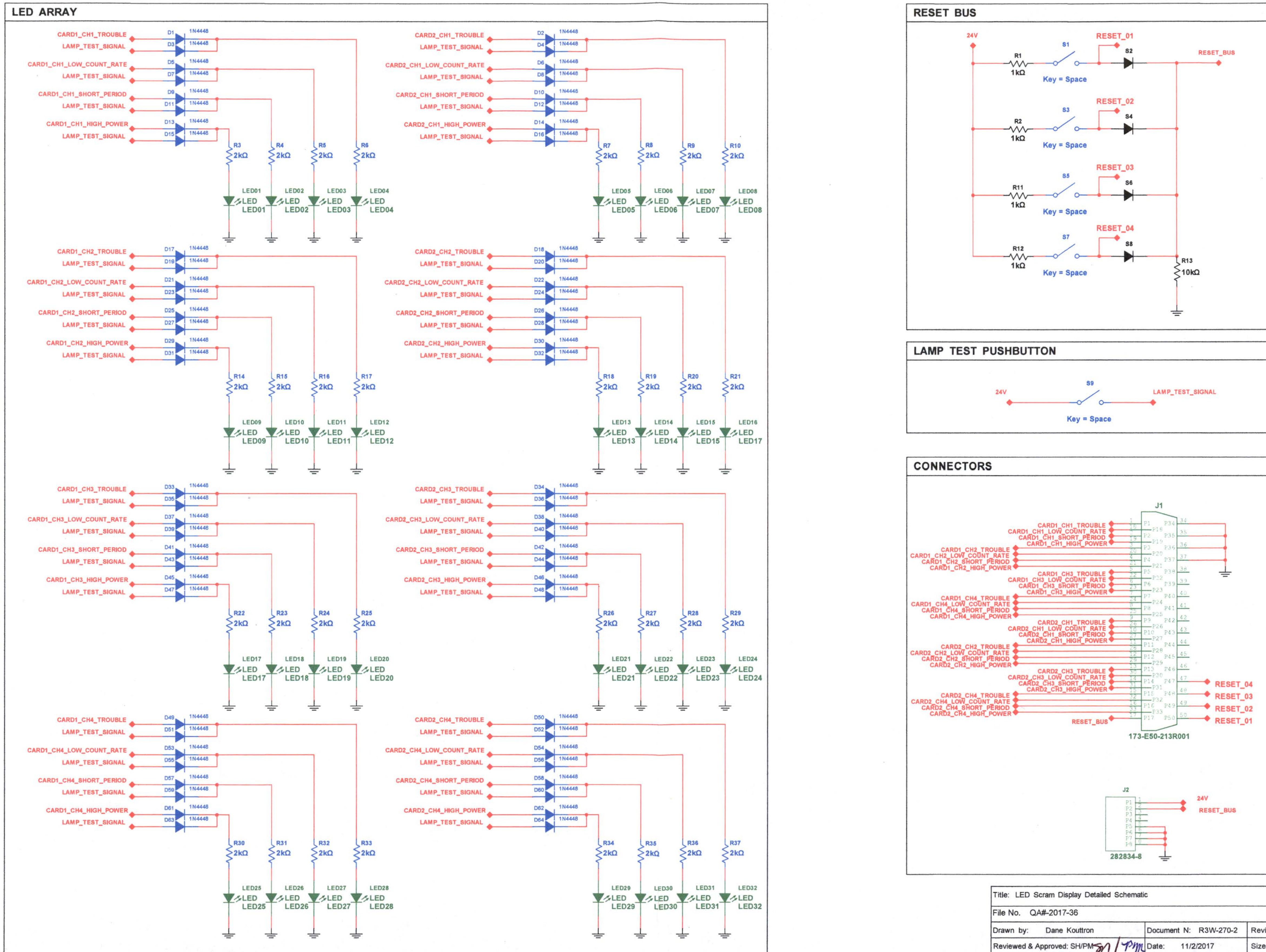
The LED Scram Display module will be bench-assembled using standard industrially-rated components. The module will then be connected to the rest of the new Nuclear Safety System while everything is de-energized. It will be mounted within the protective metal instrumentation cabinets of the control room, which will provide it with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times, when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control is assured.

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components in the modules.

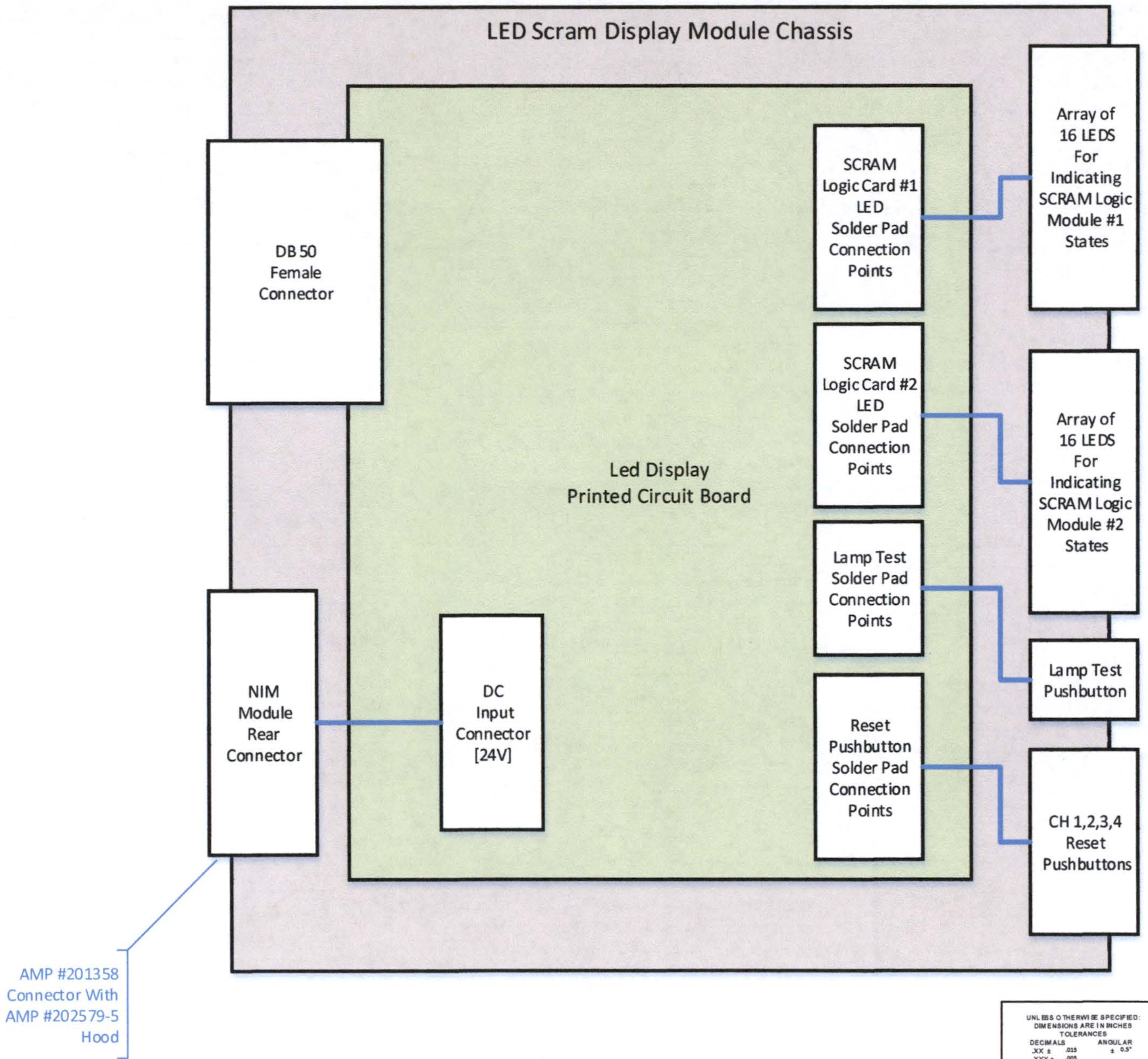
All cables to, and cable connection points on, the LED Scram Display module will be labeled. These markings improve the human interface for purposes of installation and maintenance. The arrangement of the LED Scram Display module's indicator lights and reset buttons are easy to see and use. Therefore, human factors engineering is adequate.

The LED Scram Display module will be tested for wiring verification, including the proper level of illumination of LED lights, using a written procedure prior to first use. It will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation. There will also be periodic operational checks, such as LED indicator light tests using the "Lamp Test" pushbutton prior to reactor startup. Therefore, the pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the module.

LED SCRAM DISPLAY MODULE: Printed Circuit Board Circuit Diagram



Title: LED Scram Display Detailed Schematic		
File No. QA#-2017-36		
Drawn by: Dane Kouttron	Document N: R3W-270-2	Revision:
Reviewed & Approved: SH/PM SH / PM	Date: 11/2/2017	Size: C
Designed by: Dane Kouttron	Sheet 1 of 1	



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .015 .XXX ± .005 ANGULAR ± 0.5°
DO NOT SCALE DRAWING

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

LED Scram Display Module Block Diagram

THIRD ANGLE PROJECTION

DRAWN	D. KOUTTRON	DATE 10.5.2017
REVIEWED & APPROVED	SH/EL	12.1.2017
DESIGN	P. MENADIER	7.10.2017

SIZE	FILE NO.	DWG NO.	REV
A	QA#-2017-36	R3W-271-1	

SCALE 1:1 SHEET 1 OF 1

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure G

Q/A File #2017-37 "<100 kW Key-Switch Module"

Description of the <100 kW Key-Switch Module

The <100 kW Key-Switch Module (KSM) provides positive indication to the console operator if the reactor is set up for the <100 kW mode of operation vs. the Full Power mode of operation. The key switch itself is labeled "Reactor Operating Mode", as shown in Figure 1. The KSM is mounted NIM bin 2, along with the Blade Drop Timer Interface Module and the Magnet Power Supply Modules.

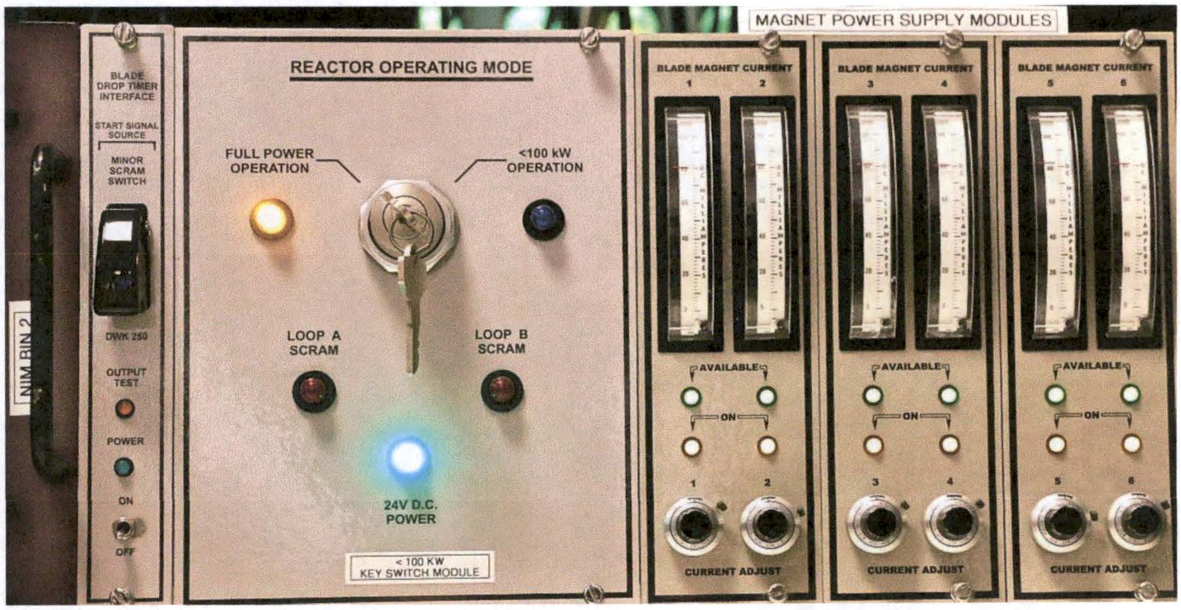


Figure 1 -- <100 kW Key-Switch Module (KSM) mounted in NIM bin 2, with key switch selected to Full Power Operation mode

There are only two positions for the key switch: Full Power Operation mode, and the <100 kW Operation mode. The switch is mechanically spring-loaded for positive detent, so it will move to rest in one of these two positions, making it extremely difficult to leave the key in a neutral position.

When the key switch is turned to <100 kW Operation, a local <100 kW Operation indicator LED light will illuminate. (See key switch pole KS1C on Reactor Drawing R3W-259-4.) Likewise, also from pole KS1C, a signal will be sent to the Safety System Monitoring & Status Display programmable logic controller (PLC), and from pole KS1B, a "<100 kW Operation" alarm will illuminate on the Console Annunciator Panel. Furthermore, when the key switch is selected to <100 kW Operation, the KSM transmits signals via pole KS1D to bypass any scram that comes from Low Flow Primary, Low Pressure MP-6, or Low

Pressure MP-6A, and pole KS1A activates the "Low Flow Primary Scram Bypassed" alarm on the Console Annunciator Panel. If reactor power reaches the trip set point for <100 kW Operation, the resulting High Power 100 kW Operation trip signals from the DWK 250s will be logically interpreted as channel trip signals by Scram Logic Card 1 and Scram Logic Card 2 to scram the reactor.

When the key switch is turned to Full Power Operation, the <100 kW Operation local indicator, the "<100 kW Operation" Console Annunciator Panel alarm light, the "Low Flow Primary Scram Bypassed" Console Annunciator Panel alarm light, and the PLC message will all clear, and the three primary flow scram bypasses are automatically removed. A local Full Power Operation indicator LED light will illuminate via key switch pole KS1C. Furthermore, when the key switch is selected to Full Power Operation, the KSM sends a signal via pole KS1C to Scram Logic Card 1 and Scram Logic Card 2 which causes the DWK 250's High Power 100 kW Operation trip signals to be logically interpreted as not being channel trip signals.

The front of the KSM chassis has two other LED lights that indicate "Loop A Scram" and "Loop B Scram", as seen in Figure 2. These lights come on only when there is a scram condition in the Withdraw Permit Circuit's (WPC's) Scram Loop A or B, respectively.

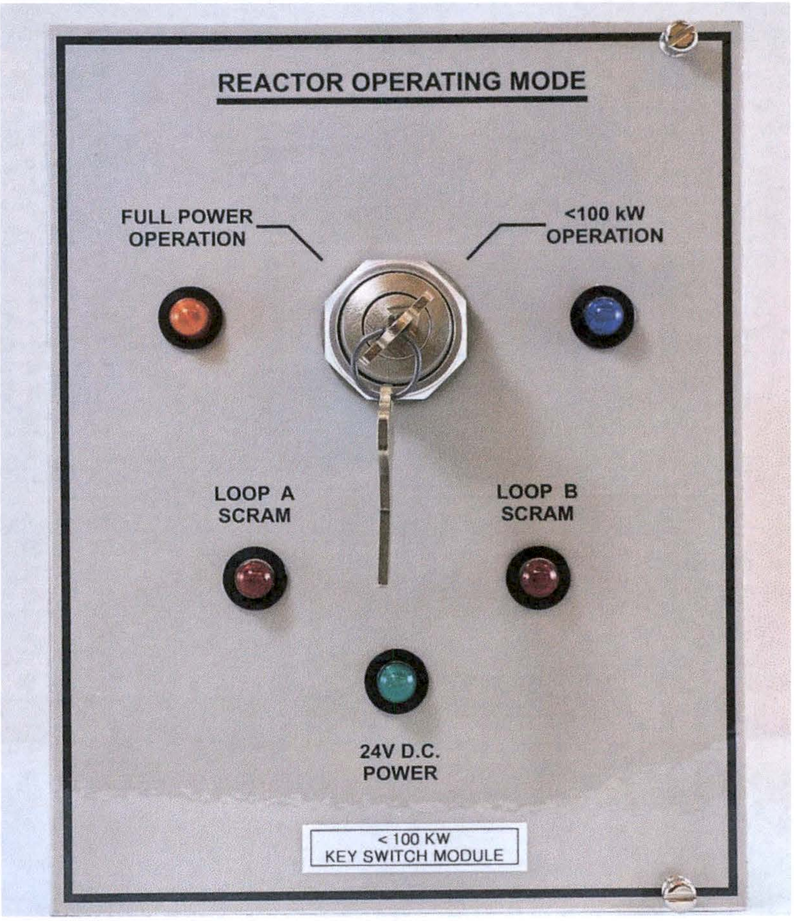


Figure 2 – KSM Front View

The back of the KSM chassis has two connectors, as seen in Figure 3. One is a multi-pin Nuclear Instrument Module (NIM) bin connector and the other is a two-pin round connector (labeled P5). The P5 connector transmit a signal from the KSM to Scram Logic Card 1 and Scram Logic Card 2 via the Signal Distribution Module, specifying when the key switch is in the "Full Power Operation" position. The NIM bin connector transmits signals from the KSM to the Withdraw Permit Circuit, the Magnet Power Supply Modules, the Console Annunciator Panel, and the Safety System Monitoring & Status Display PLC. Additionally, the NIM bin connector receives 24-volt DC power, and receives signals from Scram Logic Card 1 and Scram Logic Card 2.

Figure 3 – KSM Rear Quarter View

Reactor Drawing R3W-259-4 illustrates all the above functions of the KSM. The module receives power from the two 24-volt DC power supplies described in Q/A File #2017-34 "Signal Distribution Module". These are set up in parallel, but connected via auctioneering diodes on the Signal Distribution Module, so that if one fails, the other will

take over without interruption. When the KSM chassis is powered, the "24V D.C. Power" indicator LED light will be lit.

The KSM chassis is mounted within the same NIM bin (NIM bin 2) as the Magnet Power Supply Modules, as shown in Figure 1. When Scram Logic Card 1 or Card 2 outputs a scram signal, the signal reaches this NIM bin, which distributes it to both the KSM and the Magnet Power Supply Modules. This scram signal opens all relays downstream of the Scram Logic Cards as indicated on Drawing R3W-259-4. This set of ten 24-volt relays includes GM1A, GM2A, GM3A, GM1B, GM2B, and GM3B in the Magnet Power Supply modules, and RY5, RY6, RY7, and RY8 in the KSM. (Figure 4 shows the latter four relays inside the KSM.) In fact, any one of the RY5 – RY8 relays opening will open 120-volt relay B3 or B4 in the WPC's Scram Loop A or Scram Loop B (physically located in the WPC), thereby resulting in a scram. Additionally, opening of an RY5 – RY8 relay contact illuminates the "Loop A Scram" or "Loop B Scram" indicator LED light on the KSM chassis, and activates the "Safety System Scram" alarm on the Console Annunciator Panel. Opening of the RY4 relay (also visible inside the KSM in Figure 4), or the GM1 – GM3 relays listed above, will directly interrupt electrical power to shim blade magnets as described in the Q/A Files #2017-38 & #2017-39 document "Magnet Power Supply Modules and Rundown Relay Panel".

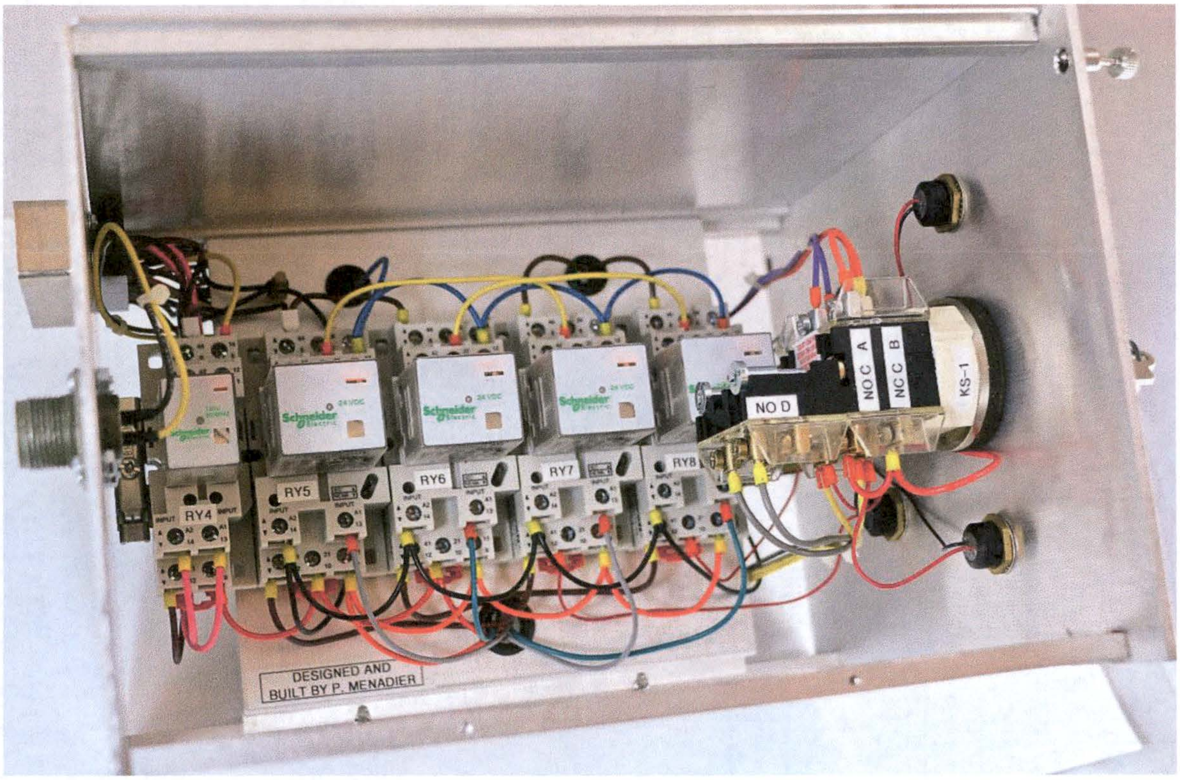


Figure 4 – KSM Interior View with top cover plate removed

Safety Evaluation

The <100 kW Key-Switch Module (KSM) is not responsible for originating any scram signals. Instead, it "informs" the Scram Logic Cards when "Full Power Operation" is the intended mode of reactor operation. When that signal is present, the Scram Logic Cards will disregard High Power 100 kW Operation trip signals from the DWK 250s.

Failure Analysis

The KSM uses 24-volt DC power. If power is lost, the 24-volt LED power indicator light and any other LED indicator light on the front of the chassis will all go out. However, when the key switch is in the <100 kW mode, the main annunciator panel will continue to have its "<100 kW Operation" alarm light on, as that alarm is powered from the annunciator panel itself. If the chassis were damaged, the effect would be the same as a loss of power.

Some of the relays associated with the Scram Logic Card outputs or with the Withdraw Permit Circuit (WPC) are physically located within the KSM. These include relays RY4, RY5, RY6, RY7, and RY8. If this part of the KSM fails, such as by loss of power, physical damage, or other disruption to a circuit path, there will either be a loss of signal in the WPC, thereby causing a scram, or a power cutoff to Scram Loop A or Scram Loop B, equally causing a scram. Likewise, if the 120-volt AC power supply path within the KSM to the magnet power supplies is physically interrupted, the loss of magnet power will cause the shim blades to drop into the core, thereby causing a scram. The physical damage could include puncture, impact, fire, or high voltage surge, while other types of disruption could include radio frequency interference, overheating, or corrosion. All would result in a scram.

The key switch is mechanically spring-loaded for positive detent, so it will move to rest in one of its two positions, making it extremely difficult to leave the key in a neutral position. However, if the key switch should fail and not be in full contact with either of its two designated positions, neither mode indicator LED light will be illuminated, no respective Console Annunciator Panel alarms or PLC alarms will be lit, and none of the bypasses associated with either position will be in effect. Accordingly, if the primary pumps are not on, all the associated low flow scrams will be in effect (WPC open) and will prevent a reactor startup or continued operation. If the primary pumps are on, and reactor power exceeds the trip set point for <100 kW operation, then the High Power 100 kW Operation Trips on the DWK 250s will take effect and scram the reactor.

Another failure mode of the KSM is if it no longer transmits a signal because of physical damage or other disruption as discussed above. This would have the same effects as lack of full contact within the key switch, as described in the previous paragraph. All such abnormal effects either will not affect operation of the Scram Logic Cards, or will produce outcomes more conservative than the normal configurations.

The KSM shares use of the 24-volt DC power supplies with the Scram Logic Cards. If the 24-volt power fails, the Scram Logic Cards will produce a scram.

Cybersecurity

The KSM is constructed entirely of standard industrially-rated discrete components, uses no digital devices, is not programmable, and is therefore not subject to cybersecurity threats.

Physical Protection and Access Control

The KSM will be mounted in the same Nuclear Instrument Module (NIM) bin as the Magnet Power Supply modules. They are all within the protective metal instrumentation cabinets of the control room, which will provide the modules with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the NRC-approved Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

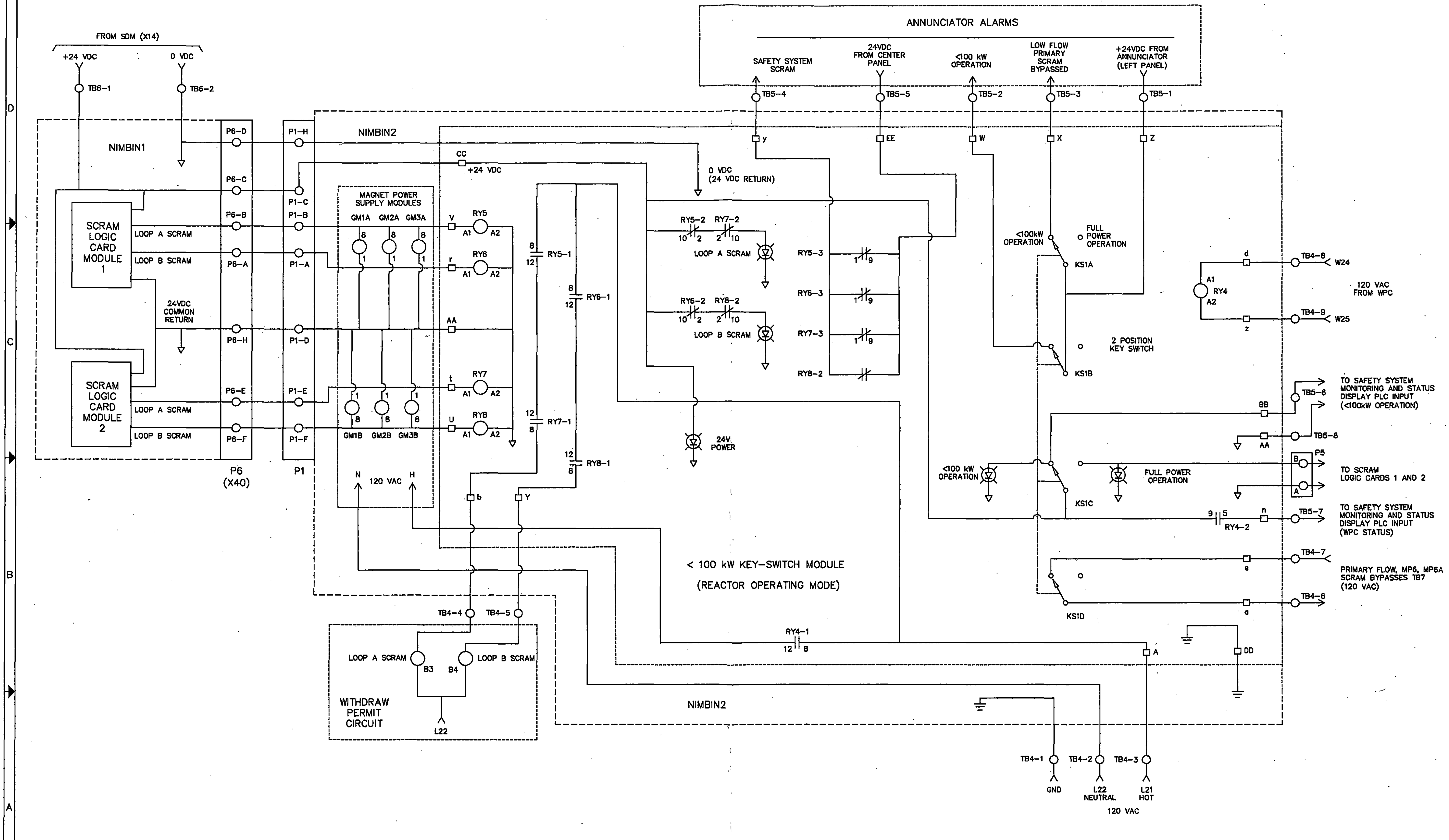
The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components in the KSM.

Human Factors

All cables to, and cable connection points on, the KSM will be labeled, as will the NIM bin. These markings improve the human interface for purposes of installation and maintenance. Once it is installed, there will be no regular human interaction with the KSM chassis other than the key switch itself. The key switch is a standard industrial component. The LED indicator lights adjacent to it confirm when it is latched in either of its two designated positions. The key switch will be handled only by or under the supervision of licensed reactor staff. Therefore, human factors engineering remains adequate.

Verification and Periodic Checks

The KSM assembly will be tested for wiring verification using a written procedure prior to first use, will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation, and will receive functional checks periodically as part of operational checks of the integrated Nuclear Safety System. Therefore, these pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the circuitry.



MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

<100 kW KEY-SWITCH MODULE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES. DO NOT SCALE DRAWING

DRAWN	NAWAZNISKI
DATE	11/14/17
REVIEWED & APPROVED	EL/ST
DATE	12/1/17
DESIGN	MENADIER
DATE	12/14/16
SIZE	D
FILE NO.	QA# 2017-37
DWG NO.	R3W-259 -4
SCALE	NONE
SHEET	1 OF 1

ZONE	REV	DESCRIPTION	DATE	APPROVED

REVISIONS

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure H

Q/A Files #2017-38 & #2017-39
"Magnet Power Supply Modules and Rundown Relay Panel"

Description of Magnet Power Supply Modules (a.k.a. Magnet Power Supplies)

The function of the Magnet Power Supplies is to provide current (~80 milliamps DC) to the electromagnets for all six shim blades (i.e., absorber sections of the control devices) in the reactor core. Each magnet holds the weight of its shim blade, attaching it to its drive mechanism via the magnet. When current to the magnet is interrupted, the shim blade will decouple from its magnet and drive, and travel vertically by gravity into the reactor core, scramming (i.e., automatically shutting down) the reactor in less than one second.

In the existing nuclear safety system, power for the magnets originates in the electronic circuitry of the six nuclear safety amplifiers. These amplifiers provide the necessary trip signals, three on high power and three on short period, and use those signals to interrupt current to the magnets. The interruption is first applied to the magnets for a pre-selected pair of shim blades (blades 1 & 4, or blades 2 & 5, or blades 3 & 6), and then to the remaining four magnets.

The new Nuclear Safety System will not consist of safety amplifiers. Instead, high power and short period trips all originate from four independent Mirion DWK 250 neutron flux monitors. The new Magnet Power Supplies will consist of three modules (photo in Figure 1), with each module providing magnet current to two shim blades (blades 1 & 2, blades 3 & 4, and blades 5 & 6). Each module interfaces with its corresponding rundown relay circuit, with magnet current passing through the Rundown Relay Panel on its way to the magnet. The function of the Rundown Relay Panel will be described in the next section.

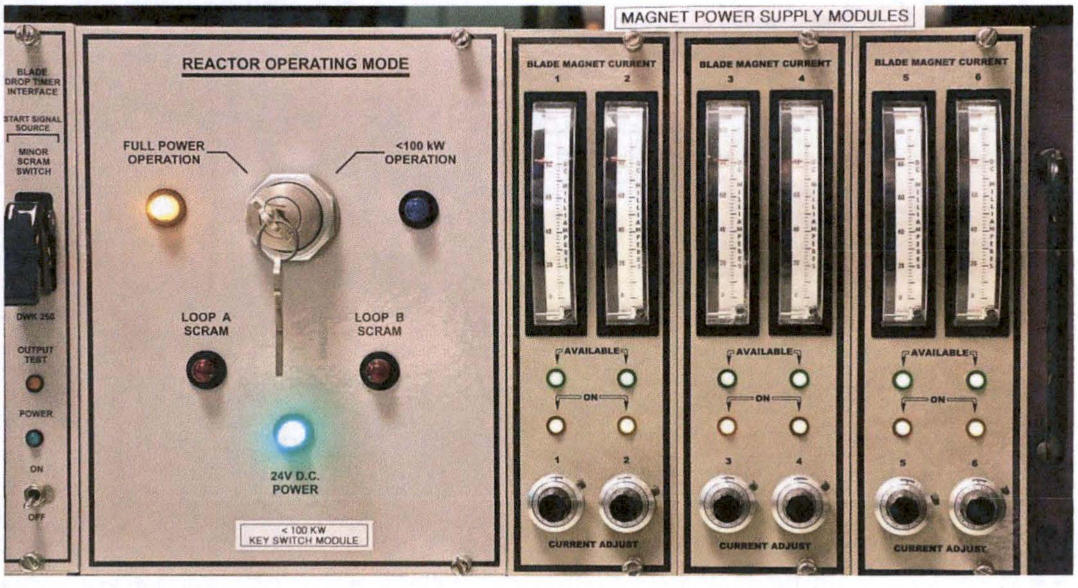


Figure 1 – Front View of NIM Bin 2, with Magnet Power Supply Modules on the Right

Each Magnet Power Supply Module is a stand-alone electronic device, made of discrete components, with its own 24-volt DC power supply. (See photo in Figure 2.) Each module has two "current adjust" potentiometers, one for each associated shim blade magnet. The potentiometer drives a reference for an adjustable regulator for current to the associated shim blade magnet. The adjusted magnet current is displayed on a meter above the potentiometer, again one for each shim blade.

Magnet current is interrupted in each Magnet Power Supply Module via two relays that are controlled by Scram Loops A and B from the output of the Scram Logic Cards. For instance, relay contacts GM1A-1 and GM1B-1 on Drawing R3W-258-4 "Magnet Power Supplies and Rundown Relay Panel" for shim blade 1 belong to relays GM1A and GM1B in Scram Loops A and B respectively. If Scram Loop A, or Scram Loop B, or both A and B are open, i.e. in scram condition, these relay contacts will open to interrupt magnet current to shim blade 1. Likewise, contacts GM1A-2 and GM1B-2 for shim blade 2 will open to interrupt magnet current to shim blade 2.

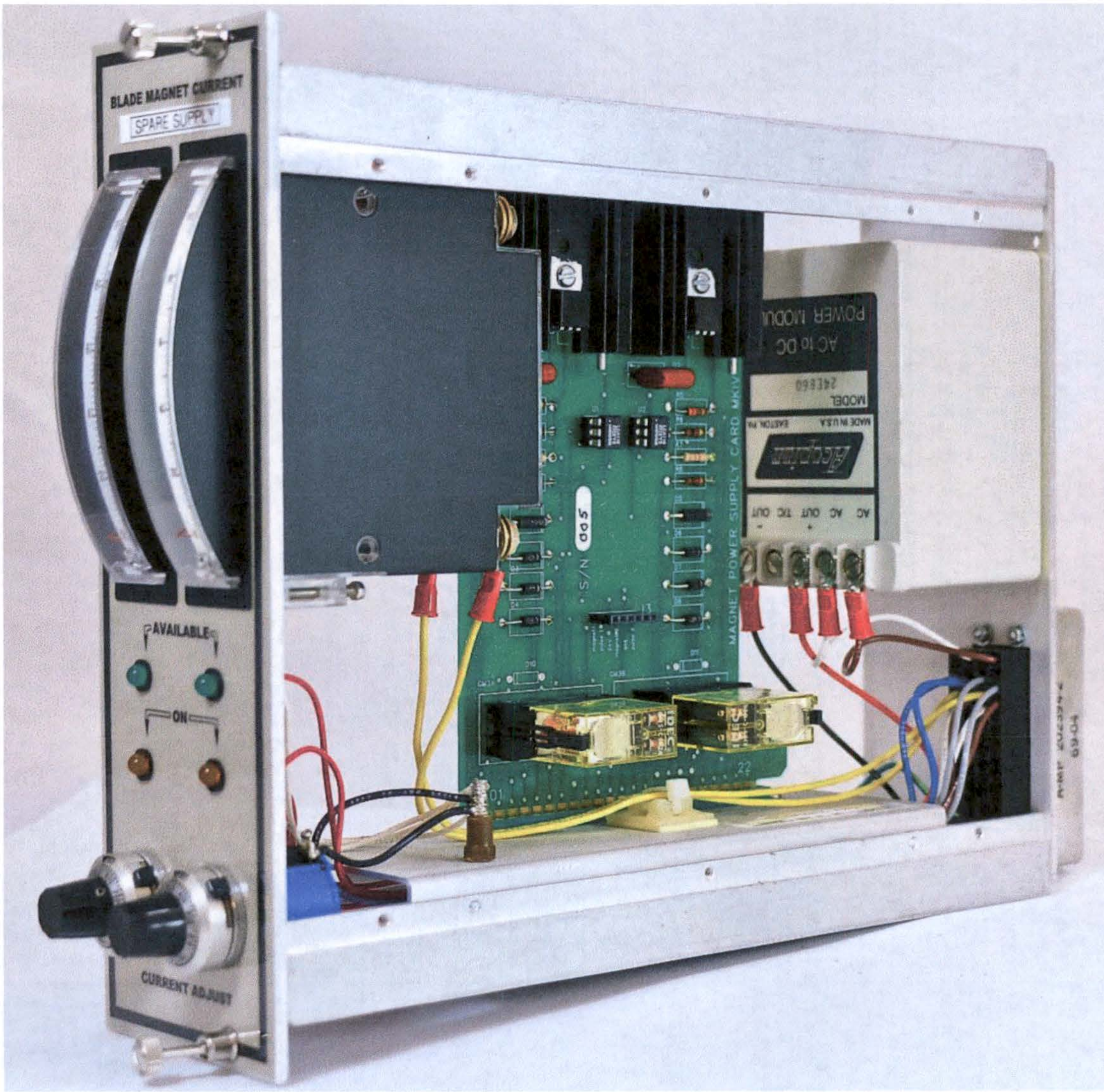


Figure 2 – Magnet Power Supply Module, Showing Interior with 24-Volt DC Power Supply

The Withdraw Permit Circuit (WPC) interrupts magnet current via relays in the Rundown Relay Panel, as described in the next section. For redundancy, when the WPC is open, the 120-volt AC line power from reactor electrical circuit L21 itself will be interrupted, thereby simultaneously de-energizing all three 24-volt DC power supplies for the three Magnet Power Supply Modules. This can be seen on Drawing R3W-258-4, where relay RY4 from the WPC will open relay contact RY4-1 when the WPC is open, thereby interrupting the 120-volt AC line power to all three 24-volt DC Magnet Power Supplies. The independent interruption of the Magnet Power Supplies via the nuclear safety Scram Logic Cards and the WPC provides redundancy and prevents common-mode failure.

Description of Rundown Relay Panel (a.k.a. Rundown Relays)

The function of the Rundown Relays is to move each shim blade's drive mechanism to its "full in" position at its normal speed whenever magnet current to the shim blade's electromagnet is removed. When the blade's magnet current is interrupted, the blade is intended to drop by gravity into the core. Moving the blade drive in behind it automatically is to ensure that the blade reaches its bottom position and stays there following a scram, completing the protective action once it is initiated.

The Magnet Power Supplies are composed of three independently-powered modules, each supplying current to a pair of shim blade magnets. The Rundown Relays, however, are all part of one panel (photo in Figure 3), and use their own pair of 24-volt DC power supplies to energize the controlling circuits for all six shim blades. These 24-volt DC power supplies are set up in parallel, but connected via auctioneering diodes, so that if one fails, the other will take over seamlessly.

Figure 3 – Front View of the Rundown Relay Panel

When the Magnet Power Supplies are energized, current goes through the Rundown Relay Panel via three relay contacts connected in series. For instance, for shim blade 1, these

relay contacts are B1A-1, B2A-1, & RR1-1 on Drawing R3W-258-4; or for shim blade 2, these relay contacts are B1A-2, B2A-2, & RR2-1. Relays B1A and B2A are controlled by the Withdraw Permit Circuit (WPC). If the WPC is open, i.e. in scram condition, these relays interrupt magnet current to the associated shim blade. Relays RR1 and RR2 also interrupt magnet current, if the magnitude of that current drops below a pre-determined value (~5 mA) which is set by an opto-relay (U1 for shim blade 1, U2 for shim blade 2).

The RR1, RR2, etc., relays perform two additional functions: controlling an indicator light that shows the status of the rundown relay circuit for its corresponding shim blade, and overriding normal control of the shim blade's drive motor. The indicator light stays out whenever the magnet current is at normal operating level. It comes on when the magnet current is low or near zero; the corresponding shim blade drive will be moving in, until it reaches its full-in position. Whenever the WPC is open, the indicator lights will stay on, denoting the control overrides which prevent any shim blade drive from being moved outward. Even after the WPC is reset and re-energized, this override condition will remain in effect until the Rundown Relays themselves are reset by the console operator. Additionally, the Rundown Relays cannot be reset if the magnet current is below a pre-determined value. When each Rundown Relay is reset, its indicator light goes out.

The Rundown Relay for each shim blade can be individually reset once the blade drive has reached the full-in position and the WPC has been reset and re-energized. A master reset (pushbutton PB7, acting via relays MR1 and MR2 on Drawing R3W-258-4) is also available to reset all six Rundown Relay circuits simultaneously. Figure 3 includes the master reset pushbutton and shows all Rundown Relays reset and their indicator lights off.

<u>Safety Evaluation</u>

Both the Magnet Power Supplies and the Rundown Relay Panel will continue to perform their safety functions as defined by the SAR.

Redundancy, Independence and Diversity

There are six independent ways to interrupt current to any given shim blade magnet: two relays from the Scram Logic Cards (via scram loops A and B), two relays from the WPC in the blade's rundown relay circuit, one relay in the blade's rundown relay circuit that opens upon low current, and one relay (RY4) from the WPC in the 120-volt AC line power supply. If there is a Nuclear Safety System scram, all six of these ways will have their relays open, to ensure a reactor scram. If there is a process system scram (e.g. low flow on the primary coolant system, low pressure city water, etc.), then only four of the above ways will apply: two relays from the WPC in the blade's rundown relay circuit, one relay in the blade's rundown relay circuit that opens upon low current, and one relay from the WPC in the 120-volt AC line power supply. Most importantly, any one of these ways will cause a magnet current interruption to shut down the reactor, and will activate the Rundown Relay Panel to drive all the shim blades in. (The regulating rod will also be driven in when the WPC is open, but via the existing rod control circuit.)

Except for relay RY4, all five other relays mentioned above in the Magnet Power Supply Module and the Rundown Relay for each shim blade are wired in series. If any one of those is open, magnet power to that shim blade is interrupted.

Each of the three Magnet Power Supply Modules has its own independent 24-volt DC power supply. All three 24-volt power supplies are downstream from the common relay (RY4) that will open when the WPC is open.

The Rundown Relay Panel has its own dual 24-volt DC power supply. A green indicator light at the front of the Rundown Relay Panel illuminates when there is power from the dual 24-volt DC supply. This indicator light is shown lit in Figure 3.

In summary, redundancy of scram relays and independence of scram activation(s) minimizes the risk of common-mode failure of the Magnet Power Supply Modules and the Rundown Relay Panel.

Cybersecurity and Isolation

The Magnet Power Supply Modules and the Rundown Relay Panel are built with standard industrially-rated components. They contain no digital components, being constructed with non-programmable solid-state and discrete devices. Therefore, they are not subject to cybersecurity threats.

The Magnet Power Supply Modules and the Rundown Relay Panel are constructed within metallic enclosures. Along with use of mechanical relays that typically fail open along the scram path, impact from electromagnetic interference is minimized.

Opto-coupled relays, one for each shim blade, are used within the Magnet Power Supply Modules. For instance, they are shown as contacts U1-1 and U2-1 in Drawing R3W-258-4 for shim blade 1 and shim blade 2 respectively. The opto-relays were chosen for their sensitivity to low current, i.e., less than 5 milliamps. Upon sensing current dropping to a low value, the optical portion of the relay will then deactivate the solid-state portion to de-energize the coil of relay RR1 for shim blade 1, or RR2 for shim blade 2, etc.

All the 24-volt DC power supplies for the three Magnet Power Supply Modules and the Rundown Relay Panel are protected by their own fuses against overcurrent conditions. In line with each shim blade magnet, downstream of the Magnet Power Supply Module and Rundown Relay, is a fuse that prevents any power surge from damaging the magnet. Each fuse is rated for no more than 0.25 amperes. Therefore, the Magnet Power Supply Modules and the Rundown Relay Panel are adequately protected from power surges in their operating environment.

Access Control and Physical Protection

The Magnet Power Supplies and the Rundown Relay Panel will be rack-mounted within the protective metal cabinets of the control room console. The console cabinets will continue to provide the equipment with physical protection comparable to that for the current nuclear safety system. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

Environmental Conditions

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. The air-conditioning control easily satisfies the operating requirements of all the components, which are of standard industrial qualifications. When the reactor is shut down and the building is secured, the Magnet Power Supply Modules and the Rundown Relay Panel are de-energized.

Human Factors

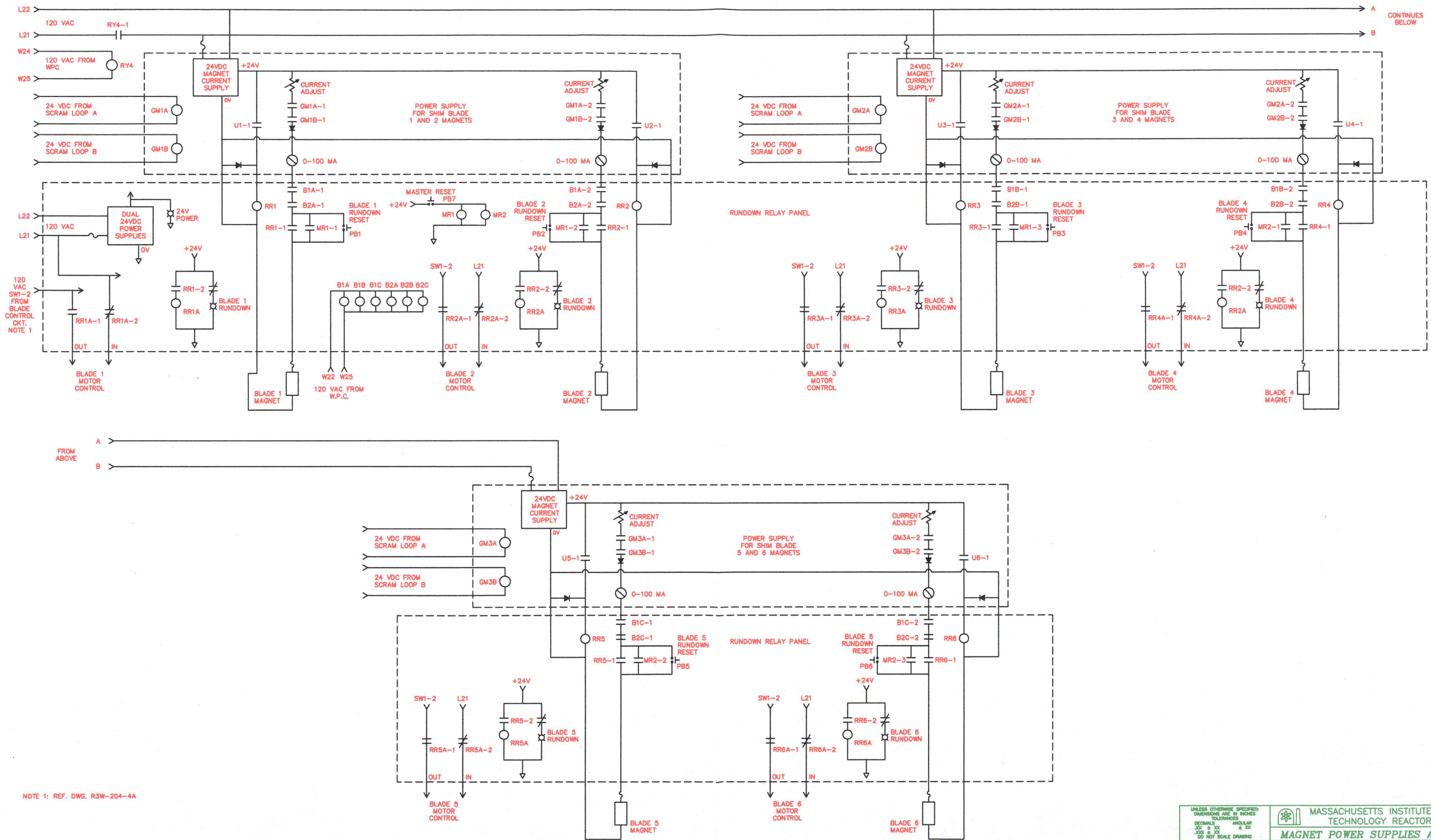
Human interface with the Magnet Power Supply Modules is via current-adjust knobs, and meters on the modules showing the instantaneous magnet current for the corresponding shim blades. These are quite similar to the interface for the existing magnet power supply equipment. The human interface with the Rundown Relay Panel is via indicator lights and reset pushbuttons, as described previously. These interfaces are in plain sight, and conveniently near the main part of the console for the operator. Therefore, this part of the human factors engineering is adequate and equivalent to the current system.

The new rundown relay panel is also equipped with a master reset pushbutton to allow the operator to reset all six Rundown Relay circuits simultaneously. This enhances the human interface.

All cable connections to the Magnet Power Supply Modules and the Rundown Relay Panel are labeled, as are key electronic components on circuit boards. These markings improve the human interface for purposes of installation and maintenance.

Verification and Periodic Checks

The functions of the Magnet Power Supply Modules and the Rundown Relay Panel were bench-tested, and will be set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation. Once installed, they will be tested periodically as per the Technical Specifications for the Nuclear Safety System. Therefore, the pre-operational and regular surveillances will ensure the integrity and functionality of this equipment.



NOTE 1: REF. DWG. R3W-204-4A

ZONE	REV	DESCRIPTION	DATE	APPROVED
		REVISIONS		

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES. TOLERANCES: DECIMALS .XX ± .XX .XXX ± .XX; ANGULAR ± XX. DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

MAGNET POWER SUPPLIES AND RUNDOWN RELAY PANEL

DRAWN: NAWAZELSKI	DATE: 10/31/17	
REVIEWED & APPROVED: EL/ST	12/1/17	SIZE D · FILE NO. QA#2017-38,39 · DWG NO. R3W-258 -4 · REV
DESIGN: MENADIER	10/31/17	SCALE NONE · SHEET 1 OF 1

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure I

Q/A File #2017-41 "Withdraw Permit Circuit Modification"

Description of Withdraw Permit Circuit and Modification

The Withdraw Permit Circuit (WPC) is a startup interlock that consists of a string of relays and contacts in series. Each corresponds to either a startup requirement or to a reactor scram condition. If any of the relays and contacts in this series lineup is open, the circuit interrupts electrical current to the electromagnets that hold the six shim blades, thereby decoupling the shim blades from their drives and effecting a scram. See MIT Reactor Drawing R3W-203-4 (Sheet 3 of 4; Revision C for the existing WPC, and Revision D for the proposed modification).

The WPC will be modified in this upgrade to the digital Nuclear Safety System in the following areas:

1. Removal of the relays and contacts that produce a two-out-of-three logic for the Period Channel Level Signal Off-Scale scram. These are no longer needed for the new Nuclear Safety System. (An earlier approach was to bypass all of these relays and contacts, but leave them physically in the circuit. Later we decided to remove them for simplification and maintainability of the circuit.) Twelve contacts will be removed as a result.

2. Addition of three relays that bypass the primary flow scrams when in the <100 kW operating mode, which uses no forced flow, as allowed by Technical Specifications. These relays are designated RY1 (for the Core Inlet Pressure MP-6A scram), RY2 (for the Low Flow Primary Coolant scram), and RY3 (for the Core Inlet Pressure MP-6 scram). These relays will perform bypass functions that are currently implemented manually using individual upstream key switches. For the upgrade, the relays will be permanently installed into the WPC.

3. Addition of three relays that operate through the rundown relay panel. The first of these relays, designated B2A, interrupts magnet current to shim blades 1 and 2. The second, designated B2B, interrupts magnet current to shim blades 3 and 4. The third, designated B2C, interrupts magnet current to shim blades 5 and 6. Each of these is a redundant addition in series with existing relays B1A, B1B, and B1C respectively.

4. Addition of one contact that opens the WPC redundantly in the case of a scram trip from the Nuclear Safety System. This new contact, designated B4-1 or "Safety System Scram (Loop B)", will serve a redundant function with existing contact B3-1 "Safety System Scram (Loop A)". A scram signal from Scram Logic Card 1 will open relays B3 and B4 in Loop A and Loop B respectively. Likewise, a scram signal from Scram Logic Card 2 will also open relays B3 and B4 in Loop A and Loop B respectively. In the existing system, the Safety System Scram opens only one contact (B3-1).

Safety Evaluation

The removal of old relays and contacts, instead of bypassing them, helps prevent cluttering the Withdraw Permit Circuit (WPC) with unused components. The removal process will be done with the circuit completely de-energized, and will not exert undue physical stress on the other existing components in the circuit.

The addition of new relays and contacts will be done by building them into several separate circuit modules. These new modules will then be connected to the rest of the new Nuclear Safety System while the reactor is shut down and the appropriate circuits are de-energized. All existing and new relays in the WPC are standard industrially-rated mechanical relays, hence minimizing the impact from EMF and radio frequency interference on their function. All are configured to open when de-energized or upon failure. The WPC remains non-programmable and non-digital, consisting only of discrete bi-stable components, and is therefore not subject to cybersecurity threats.

New relays RY1, RY2, and RY3 (mentioned in Item 2 above) bypass three different scrams that all represent the low primary coolant flow condition when operating the reactor in the <100 kW mode. When the <100 kW mode is selected on the <100 kW Key-Switch Module, these three relays will be energized to close and bypass the scrams. A failure of any of these three new relays during a low flow condition will result in a reactor scram. When the Full Power mode is selected on the <100 kW Key-Switch Module, these three relays will remain de-energized and open, and will have no effect on the WPC.

New relays B2A, B2B, and B2C interrupt electrical current to the electromagnets of their respective pairs of shim blades. Their functions are redundant to existing relays. Like those existing relays, if they fail during operation, they will cause their pairs of shim blades to drop into the core, shutting down the reactor.

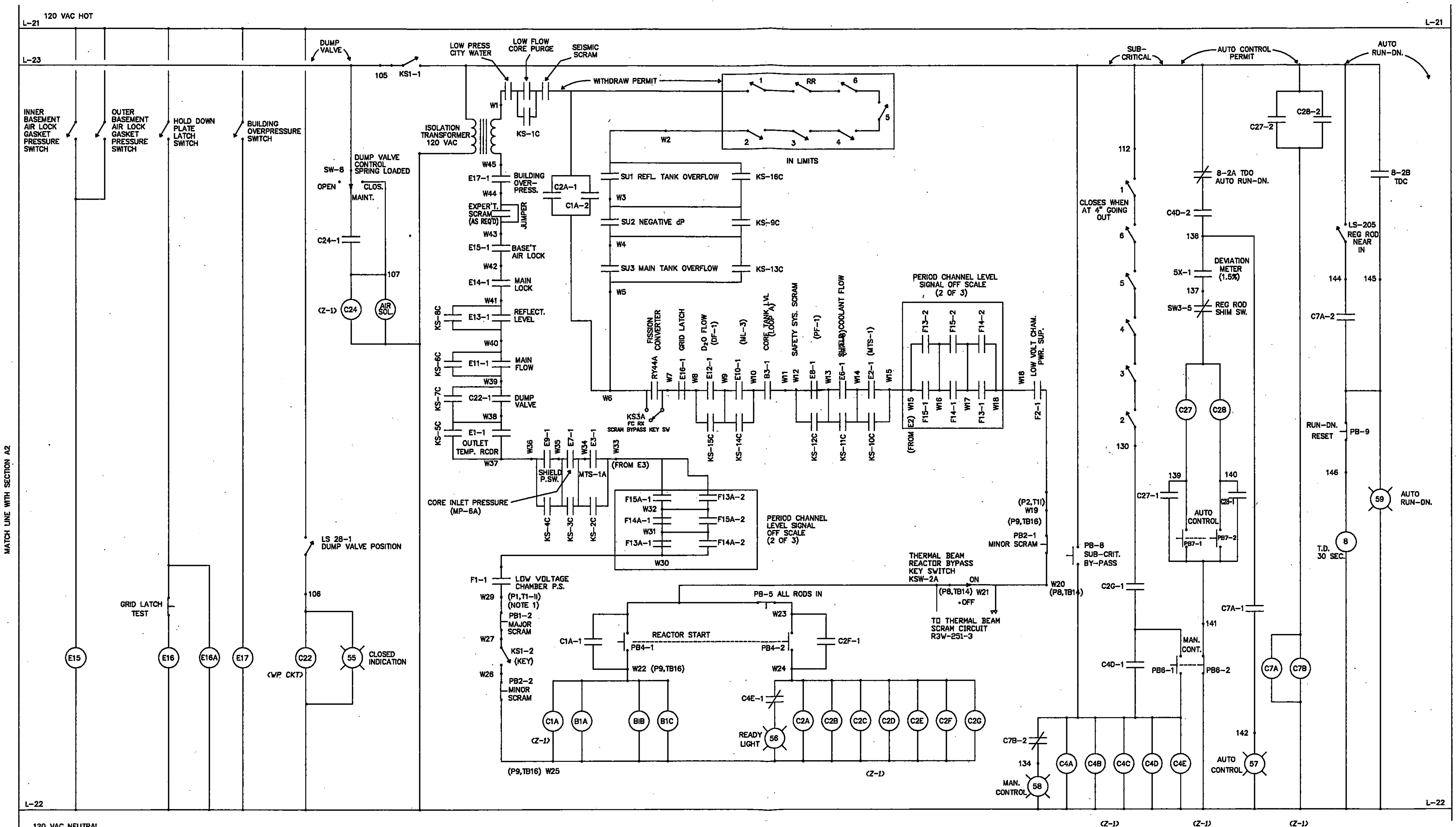
The WPC will remain mounted in its original location within the protective metal instrumentation cabinets of the control room. The instrumentation cabinets will continue to provide the circuit with the same degree of physical protection. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. The control room is attended whenever the reactor is operating. At all other times when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. The air-conditioning control easily satisfies the operating requirements of all the components, which are of standard industrial qualifications. When the reactor is shut down and the building is secured, the WPC is de-energized.

All cable connections to the WPC will be labeled, as will the new circuit modules. These markings improve the human interface for purposes of installation and maintenance.

Human interface with the WPC is via key switches in plain sight on the front of the console. The existing array of key switches for individual scram bypasses will now be supplemented by one that switches between <100 kW and Full Power modes of operation. When this <100 kW key switch is turned to the <100 kW mode of operation, which automatically bypasses the three primary flow scrams, it provides one indicator light on the <100 kW Key-Switch Module, and an alarm on the Console Annunciator Panel denoting "<100 kW Operation". Additionally, the Console Annunciator Panel will have the "Withdraw Permit Bypass On" and "Low Flow Primary Scram Bypassed" alarms illuminated. These indications reinforce the console operator's awareness of operating the reactor in <100 kW mode. Furthermore, there will be indicator lights turning on at each of the three primary flow scram bypass key switches, providing visual confirmation to the console operator of the flow scram bypasses. Therefore, human factors engineering remains adequate and more than equivalent to the current system.

The modified WPC will be tested with a written procedure prior to first use, and periodically as per the Technical Specifications for the Nuclear Safety System and process system scrams. Therefore, regular surveillances will ensure the integrity of the circuit, and the WPC will continue to perform its safety function as defined by the SAR.



NOTES:
1. W29 FOUND AT P8, FAR LEFT TB.
2.

ZONE	REV	DESCRIPTION	DATE	APPROVED
	C	Show Withdraw Permit Bypass Panel contacts	8-19-15	FTH
2D	B	Added Low City Water Press, Core Purge scram ckts.	9-16-11	FTH
2C	A	Added Fission Converter and Thermal Beam scram ckts.	9-15-08	TJE

REVISIONS

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DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .015 .XXX ± .005
ANGULAR ± 0.5°
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THIRD ANGLE PROJECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

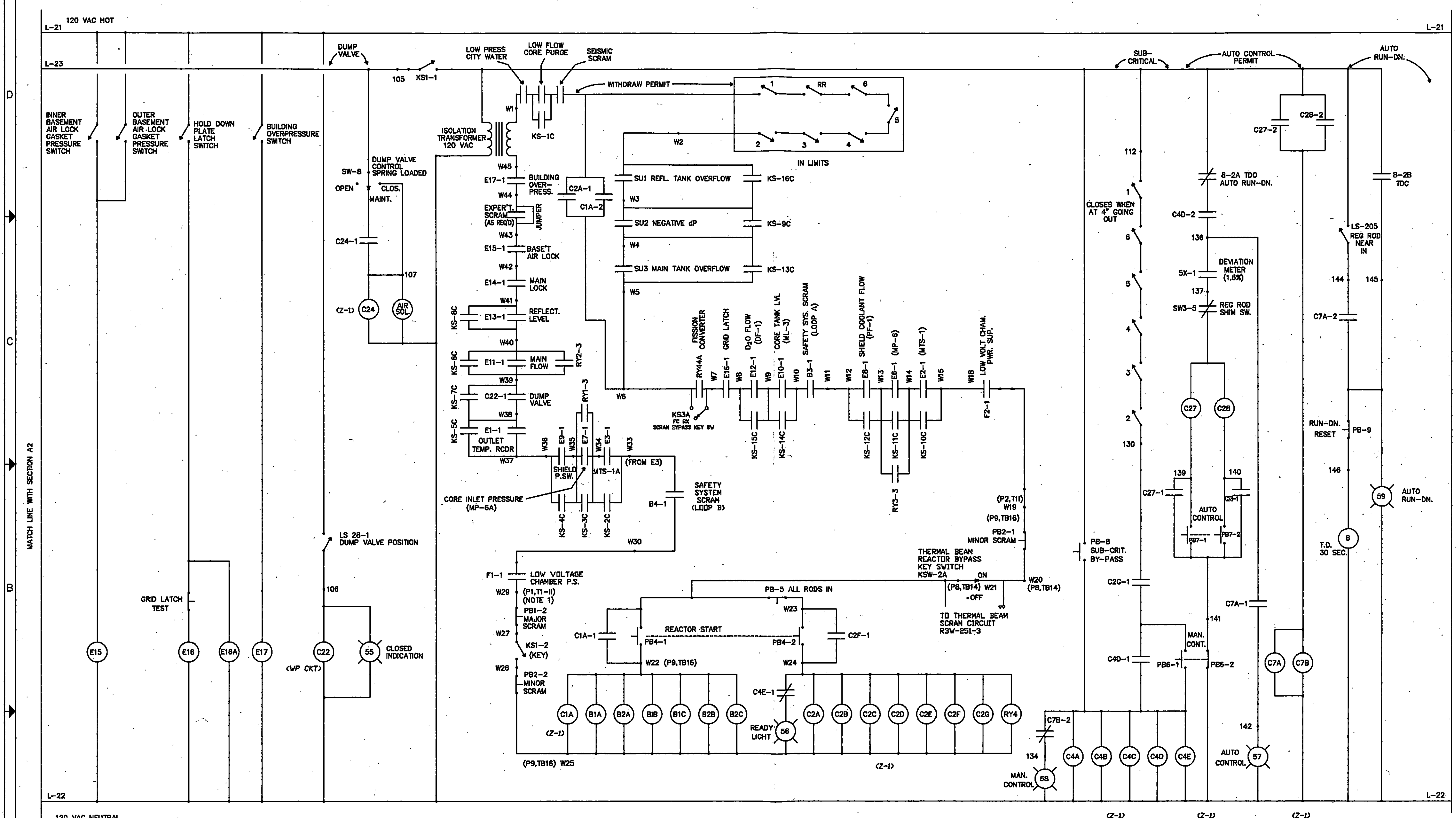
PROTECTIVE SYSTEM

SECTION A3

DRAWN	DATE
P. NAWAZELSKI	8-19-15
CHECKED	
DESIGN SIMPSON	9-19-74

SIZE D | FILE NO. | DWG NO. R3W-203 -4 | REV C

SCALE NONE | SHEET 3 OF 4



NOTES:
1. W29 FOUND AT P8, FAR LEFT TB.

ZONE	REV	DESCRIPTION	DATE	APPROVED
[illegible]	D	Added Safety System Scram Loop B contacts B4-1	8-19-15	PTM
	D	Added RY1, RY2, RY3, RY4 relay coils	8-19-15	PTM
3C	D	Added RY1, RY2, RY3 bypass contacts	8-19-15	PTM
	C	Show Withdraw Permit Bypass Panel contacts	8-19-15	PTM
[illegible]	D	Rev'd Period/Level Channels Circuits (2 of 3) contacts	8-19-15	PTM
[illegible]	B	Added Low City Water Press, Core Purge scram ckts.	7-16-11	PTM
3C	A	Added Fission Converter and Thermal Beam scram ckts.	7-15-08	TJK

REVISIONS

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .015 .XXX ± .005
ANGULAR ± 0.5°
DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

DRAWN P. NAWAZELSKI	DATE 8-19-16
CHECKED	
DESIGN SIMPSON	9-19-74

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

PROTECTIVE SYSTEM

SECTION A3

SIZE D | FILE NO. | DWG NO. R3W-203 -4 | REV D

SCALE NONE | SHEET 3 OF 4

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure J

Q/A File #2017-28 "DWK 250 'Test' Condition Scram Bypass Assembly"

Description of the DWK 250 "Test" Condition Scram Bypass Assembly

The DWK 250 "Test" Condition Scram Bypass Assembly (Test-Condition Bypass, or TCB) was fabricated to facilitate test procedures that demonstrate that a specific trip condition from a DWK 250 nuclear safety channel will result in a scram of the reactor.

As described in the Safety Analysis Report (Chapter 7, with Appendix), there are four independent nuclear safety channels that are composed of their own fission chamber detectors, pre-amplifiers, and DWK 250 neutron flux monitor chassis. Downstream from the nuclear safety channels are two identical Scram Logic Cards (SLCs) that are connected in parallel. Each SLC produces a scram signal when it receives trip signals from any two of the four nuclear safety channels (2-out-of-4 coincidence logic). In order to demonstrate a trip signal from a DWK 250 causing a scram, one must first produce a trip signal from another DWK 250 nuclear safety channel. The following explains why the TCB is needed and describes how it works.

In order to simulate a High Power or Short Period trip condition, one must first activate the Test mode on a DWK 250 chassis. Activating the Test mode will result in a "Test" trip being presented to the SLCs. After that, the generation of another trip signal (High Power, Short Period, Low Count Rate, or Fault condition) will not cause the SLC to produce a scram, because these signals all originate from the same DWK 250 chassis. Next, in order to produce a SLC scram, a trip signal must come from any of the other three DWK 250 chassis, satisfying the 2-out-of-4 coincidence scram logic. However, as soon as a second DWK 250 chassis is put into Test mode, the scram logic is satisfied and the SLCs produce a scram signal. This creates a challenge for routine surveillance testing.

To solve the above dilemma, the TCB was fabricated. It is important to point out that the trip circuits to the SLCs are normally energized. When a trip signal is present, the relevant circuit path becomes de-energized. When the TCB key switch is turned to "On", it maintains the "Test" signal circuit path energized for all four DWK 250 chassis, thus overriding any Test trip indication to the SLC. In other words, when a DWK 250 chassis is put into Test mode, its Test trip is activated with the Test trip signal path going from 24 volts DC to zero. If the TCB key switch is turned to "On", the TCB will restore that voltage to 24 volts DC. At this point, with the Test mode on, one can proceed to generate a trip condition by using a simulated High Power or Short Period. Similarly, when one turns on the Test mode on a second DWK 250 chassis, the Test trip is overridden. When another trip signal (High Power, Short Period, Low Count Rate, or Fault condition) is generated on this chassis, the SLC will initiate a scram signal. This ensures surveillance testing of all the scram-related trips as seen by the SLCs is being performed appropriately.

The TCB is built with simple analog circuitry, an On-Off key switch, and a yellow indicator light that illuminates when the switch is on. (See Figure 1, Figure 2, and Drawing R3W-264-3.)

Figure 1 – Front Face of TCB Panel

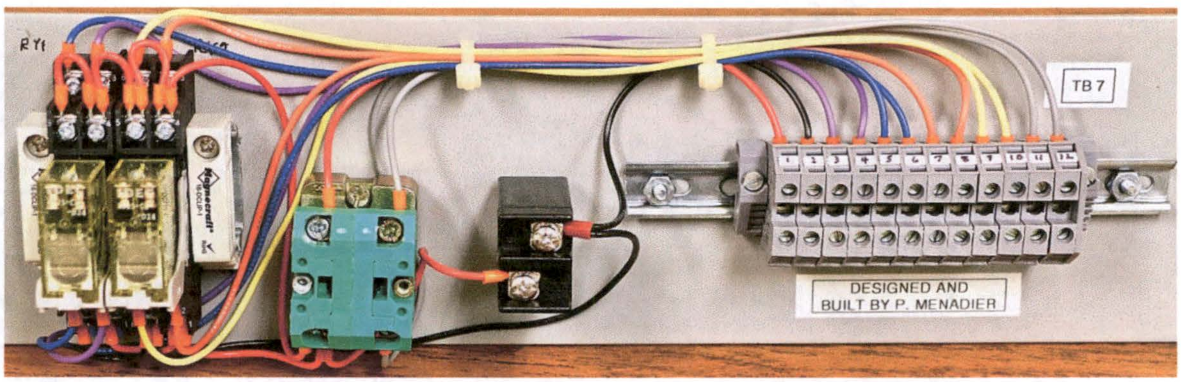


Figure 2 – Internal View from Back of TCB Panel

As described in the document, "Overview of New Nuclear Safety System with Integrated Supporting Modules", the trip relays of each of the four DWK 250 chassis are not powered from the chassis itself, but from an independent, external 24-volt DC power source (two identical units auctioneered in parallel). When the DWK 250 chassis are energized, and there is no trip condition, all of its trip relays are energized with associated contacts closed. When a chassis is placed in Test mode, its "Test" trip relay de-energizes and opens its associated contacts, de-energizing the "Test" trip signal path.

When the TCB key switch is turned to "On", it closes an auxiliary 24-volt DC circuit that energizes relays(*) RY1 and RY2, obtaining power from the same pair of 24-volt DC power supplies mentioned above. The contacts of relays RY1 and RY2, depicted as switches in Drawing R3W-264-3, change states (for instance, from 3-2 to 3-4), restoring the 24-volt DC power to the "Test" trip signal path. Additionally, the yellow "Bypass On" indicator light illuminates, and the "DWK 250 'Test' Scram Bypass" alarm (see Figure 3) on the Console Annunciator Panel activates. The console operator will have to silence the annunciator alarm by pressing the annunciator's acknowledge button. This console alarm remains active as long as the key switch stays in the "On" position.

Figure 3 – Console Annunciator Panel Alarm Plate

The key for the switch is the same reactor bypass key that is used on all the reactor scram bypasses. It is kept in the key cabinet in the control room, monitored by the console operator. Another copy of the key is kept in the secure key cabinet (KeyWatcher) in the Operations Office.

(*) Relays RY1 and RY2 for this circuit are not related to relays RY1 and RY2 in the Withdraw Permit Circuit.

Safety Evaluation

When the TCB key switch is turned to the "On" position, the contacts of relays RY1 and RY2 change state as described in the previous section. During the state transition, the 24-volt DC power along the "Test" trip signal path is interrupted momentarily. As a result, all four DWK 250 chassis' Test trips are presented and latched at the Scram Logic Cards (SLCs), resulting in production of a scram signal from the SLCs. Likewise, when the operator turns the key switch from "On" to "Off", a scram results. Therefore, if the reactor is at power and the key is turned to "On", the result will be a reactor scram. A Caution label is posted near the key switch to remind the operator of the scram potential of this switch. (See Figure 4.)

Figure 4 – Front Face of TCB Panel with Caution Posting

When the reactor is shut down and the key switch is turned, a similar set of Test trips and SLC scrams will be produced, and the console operator will have to reset the Test trips by pressing the Channel Reset buttons for all four channels on the Safety System Condition LED display panel. After that, the console operator can proceed to perform other trip signal checks (High Power, Short Period, Low Count Rate, or Fault condition) to demonstrate that a trip condition from another DWK 250 nuclear safety channel will result in a scram of the reactor.

In the unlikely event that the console operator completes the scram checks and starts up the reactor with the TCB key switch left in the "On" position, the "Test" trip signal path will be left in the overridden condition. While this is undesirable, it does not affect nuclear safety. This is because the TCB affects only the "Test" trip signal path. It does not affect the trip signal paths for High Power, Short Period, Low Count Rate, or Fault. If the key switch should fail such that it remained on when turned to "Off", the same analysis applies. If the

key switch should fail to activate the Console Annunciator Panel alarm, the TCB panel's yellow "Bypass On" indicator light will still illuminate.

Scram tests are performed according to approved, written procedures which dictate use of the TCB key switch and administratively assure that it is turned to "Off" at the end of the scram tests. Additionally, the procedures verify that the Console Annunciator Panel alarm comes on when the key switch is turned on, while the Final Checks of reactor startup checklists dictate a visual check of the Console Annunciator Panel and the bypass indicator lights prior to reactor startup.

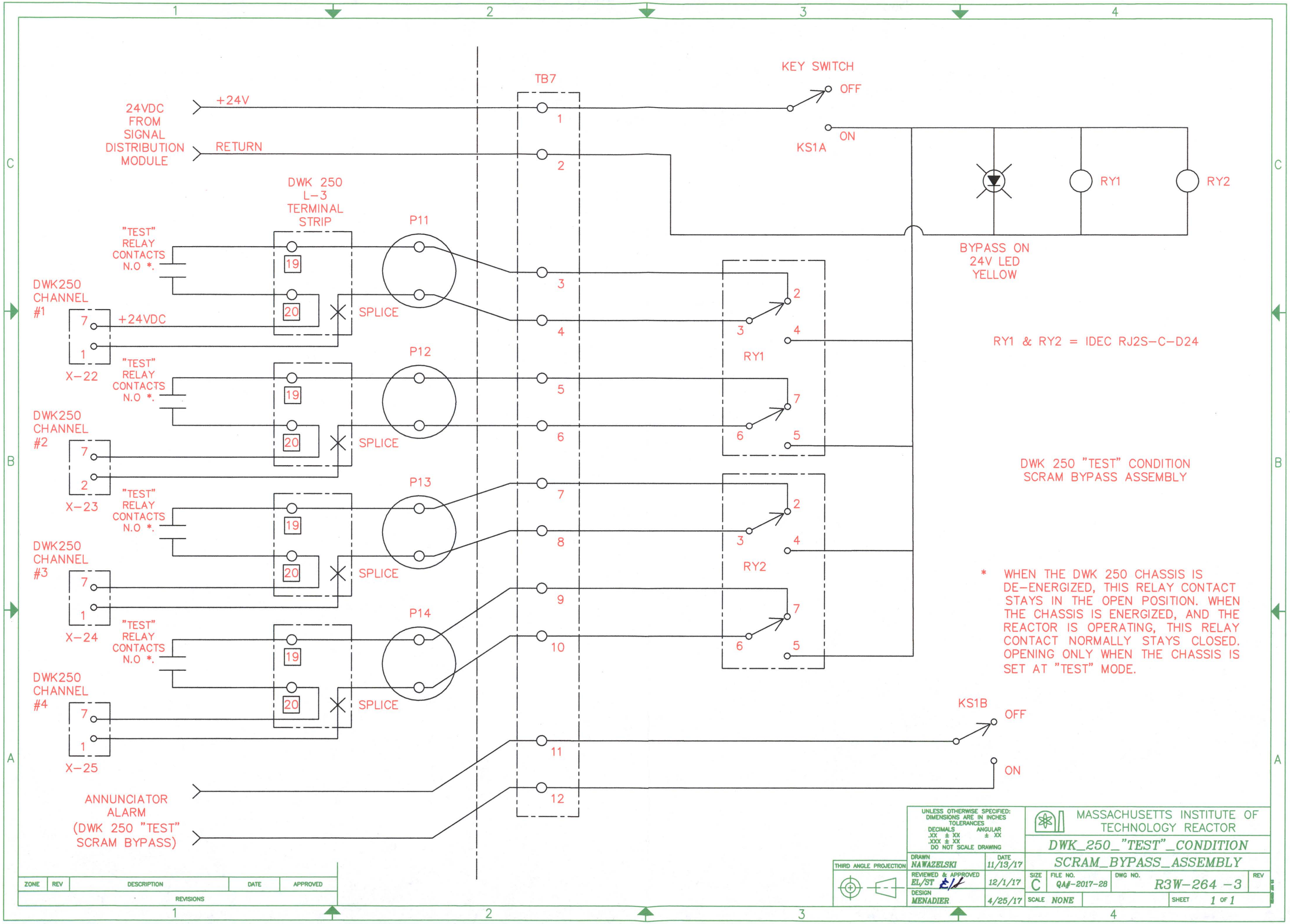
If relay RY1 or RY2 fails such that its contact does not switch states, then the "Test" trip signal path 24-volt DC power will not get restored, and the scram test cannot proceed. If the 24-volt power itself fails, the Scram Logic Cards (which share use of these power supplies) will produce a scram. The TCB does not interfere with the scram function.

The DWK 250 "Test" Condition Scram Bypass Assembly (Test-Condition Bypass, or TCB) is constructed entirely of discrete components, uses no digital devices, is not programmable, and is therefore not subject to cybersecurity threats.

The colorful internal wiring for the TCB assembly is easily traceable. The terminal block and relays are clearly labeled. The key switch and the relays are exercised every time that scram tests are performed. They are easily replaceable. All the components for the TCB assembly are standard, off-the-shelf commercial parts.

The "Test" Condition Scram Bypass Assembly will be mounted in the control room instrumentation rack next to the bypass key-switch panel for the Withdraw Permit Circuit. It will be near all four DWK 250 chassis and the Safety System Condition LED display panel.

The TCB front interface, with only a key switch and a yellow "Bypass On" indicator light, has minimal complexity for the console operator. The assembly operates on 24 volts DC, presents minimal electrical hazard, and produces no significant heat in the control room cabinet. It has been bench-tested and is set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation.



24VDC FROM SIGNAL DISTRIBUTION MODULE
+24V
RETURN
TB7
KEY SWITCH
OFF
ON
KS1A
BYPASS ON 24V LED YELLOW
RY1
RY2
DWK 250 L-3 TERMINAL STRIP
P11
P12
P13
P14
"TEST" RELAY CONTACTS N.O *.
DWK250 CHANNEL #1
DWK250 CHANNEL #2
DWK250 CHANNEL #3
DWK250 CHANNEL #4
+24VDC
X-22
X-23
X-24
X-25
SPLICE
RY1 & RY2 = IDEC RJ2S-C-D24
DWK 250 "TEST" CONDITION SCRAM BYPASS ASSEMBLY
* WHEN THE DWK 250 CHASSIS IS DE-ENERGIZED, THIS RELAY CONTACT STAYS IN THE OPEN POSITION. WHEN THE CHASSIS IS ENERGIZED, AND THE REACTOR IS OPERATING, THIS RELAY CONTACT NORMALLY STAYS CLOSED. OPENING ONLY WHEN THE CHASSIS IS SET AT "TEST" MODE.
KS1B
OFF
ON
ANNUNCIATOR ALARM (DWK 250 "TEST" SCRAM BYPASS)
ZONE
REV
DESCRIPTION
DATE
APPROVED
REVISIONS
THIRD ANGLE PROJECTION
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ± XX .XXX ± XX ANGULAR ± XX DO NOT SCALE DRAWING
DRAWN NAWAZELSKI
DATE 11/13/17
REVIEWED & APPROVED EL/ST
12/1/17
DESIGN MENADIER
4/25/17
MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR
DWK_250_"TEST"_CONDITION
SCRAM_BYPASS_ASSEMBLY
SIZE C
FILE NO. QA#-2017-28
DWG NO. R3W-264 -3
REV
SCALE NONE
SHEET 1 OF 1

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure K

Q/A File #2017-30 "Blade Drop Timer Interface Module"

Description of the Blade Drop Timer Interface Module

The Blade Drop Timer Interface Module is constructed to provide a 12-volt DC signal to initiate the existing Blade Drop Timer that is immediately downstream. Whenever the selected shim blade reaches its 80% insertion position, the Blade Drop Timer will stop. The elapsed time represents how long it takes the selected shim blade to drop. Reactor Technical Specification 3.2.1.1(b) requires the time from initiation of a scram signal to movement of each operable shim blade from its current [full out] position to its 80% inserted position is less than one second for each blade.

The Blade Drop Timer Interface Module ("Interface module") does not itself initiate a scram signal. Such signal is generated by the Scram Logic Cards (SLCs), which apply two-out-of-four coincidence logic, as described in "Scram Logic Card Modules". During testing, the operator will activate "Test" mode on any two of the four DWK 250 chassis. When the second "Test" mode is presented to the SLCs, the SLCs will generate a scram signal to interrupt shim blade magnet current, thereby releasing the shim blade to drop by gravity into the reactor core. Simultaneously, the Signal Distribution Module routes the two "Test" trip signals from the DWK 250 chassis to the Interface module.

It should be noted that other DWK 250 trip signals (High Power, Short Period, Low Count Rate, and Fault) do not feed into the Interface module.

The Interface module contains its own simple two-out-of-four coincidence logic circuit. (See Drawing R3W-267-3.) When "Test" signals from any two of the four DWK 250 chassis are present, the logic is satisfied and the Interface module outputs a 12-volt DC signal to start the Blade Drop Timer, which is immediately downstream from the Interface module. There is no reset button on the Interface module for this output signal; it clears itself when either of the "Test" signals is no longer present.

The Interface module is built with simple binary solid-state circuitry. (See Figure 1.) It uses two integrated circuit logic chips, designated U6 and U7 on its printed circuit board, to perform its coincidence logic (U6A through U6D, U7A & U7B on Drawing R3W-267-3). Logic gates U7C and U7D on the U7 chip are not used, and are connected only to ground. The DWK 250 "Test" trip signals are input to the logic chips via unidirectional optical isolators mounted on the Interface module's circuit board, thereby both protecting the logic chips and preventing any feedback to the DWK 250 chassis. Similarly, when the logic is satisfied, the logic chips output their signal to the Blade Drop Timer downstream via another unidirectional optical isolator.

In addition to using the logic chips for coincidence decision to start the Blade Drop Timer, the Interface module allows the option of taking an input signal from the console Minor Scram pushbutton. This is a convenience feature for the performance of multiple drop time tests. When the guarded "Start Signal Source" selector switch (as shown in Figures 2 and 3) on the Interface module is toggled to "Minor Scram Switch", and the operator presses the console Minor Scram pushbutton, the Interface module initiates a signal to the Blade Drop Timer, thus starting it, without involving the integrated circuit logic chips. Simultaneously, the Minor Scram opens the Withdraw Permit Circuit as it always does, interrupting current supply to the shim blade magnets and releasing the shim blades to drop into the core.

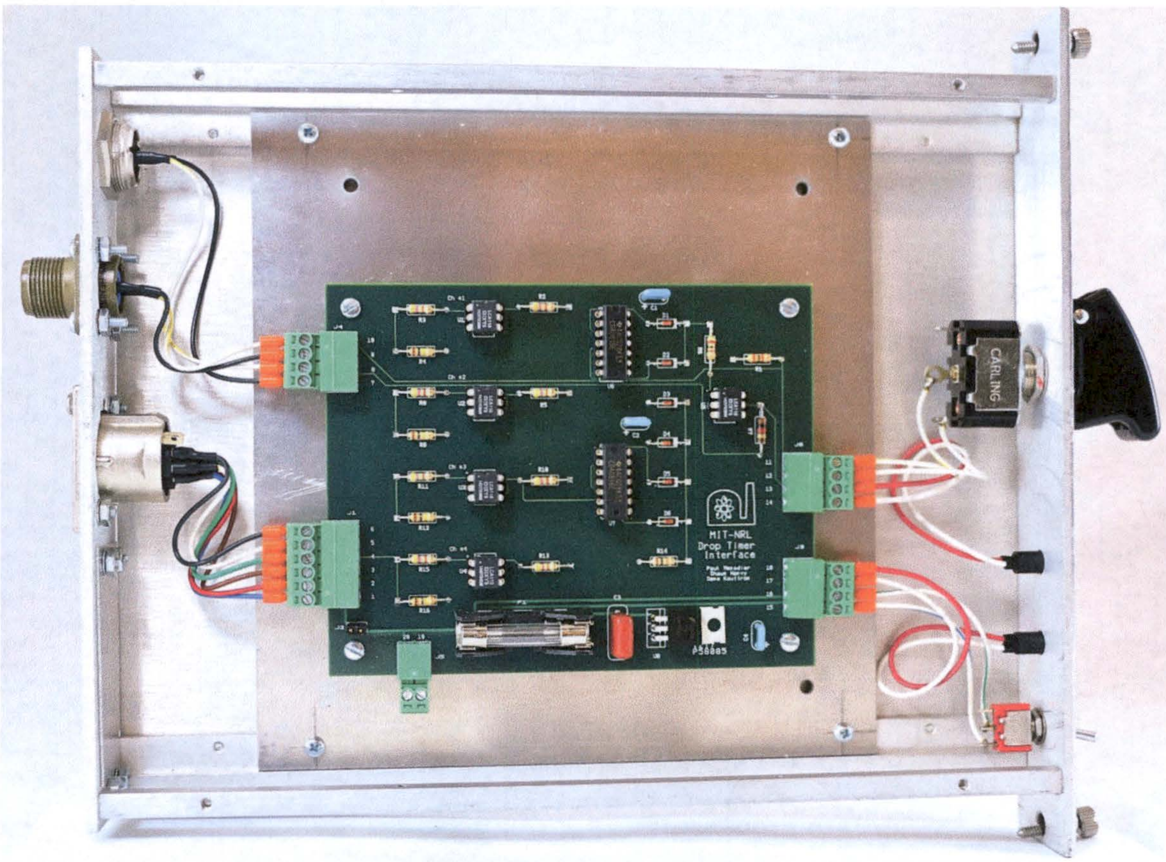


Figure One – Side View of Drop Timer Interface Module

The Interface module will be mounted in control room console NIM Bin 2, which will also house the <100 kW Key-Switch Module and the Magnet Power Supply Modules. The Interface module does not take power from the NIM bin. The Interface module is powered via the Signal Distribution Module from the same pair of auctioneered 24-volt DC power supplies that drive the Scram Logic Cards. The module utilizes a voltage regulator, designated U8, that reduces the 24 volts to 12 volts DC.

The front face of the Interface module has two indicator lights – an amber "Output Test" light and a green "Power" light. A small toggle switch on the front panel turns the module on and off. Normally the Interface module is kept off. It is powered on only when blade drop time tests are being performed while the reactor is shut down, per written procedure. When the module transmits an output signal, the amber "Output Test" lamp lights up.

Figure 2 – Front Quarter View

Figure 3 – Guarded Toggle Switch (S2)

<u>Safety Evaluation</u>

The Drop Timer Interface Module is not a safety-related component of the nuclear safety system. Its only function is to start the Blade Drop Timer downstream whenever two of the four DWK 250s are placed into "Test" mode, or (if selected on the module) when a Minor Scram is initiated.

Component Qualifications and Analysis

The Interface module uses a printed circuit board with simple binary solid-state circuitry. On the circuit board, major components include two Texas Instruments CD4081BE_V15 integrated circuit logic chips, U6 and U7, which are wired to perform two-out-of-four coincidence logic. The logic chips are standard commercial CMOS devices containing AND-gates for general applications. Their operating temperature range is -55 C to 125 C. There are five IXYS Integrated Circuits LCA110 optical isolators (designated U1 through U5) – one on each of the four DWK 250 "Test" signal inputs, and one on the output to the Blade Drop Timer. The optical isolators are standard commercial solid-state relay MOSFET devices that use GaAlAs LEDs for unidirectional optical coupling. Their operating temperature range is -40 C to 85 C, and they are EN/IEC 60950-1 and TUV certified. Additionally, there is an ON Semiconductors / Fairchild LM7812CT fixed-voltage regulator (designated U8) that reduces the DWK 250 chassis input signal from 24 volts DC to 12 volts DC. Beyond this regulator, all operation of the Interface module is 12 volts, to match the operating voltage of the Blade Drop Timer. The voltage regulator is a standard commercial device, and has an operating temperature range of -40 C to 125 C. Therefore, the Blade Drop Timer Interface Module is built with readily-available industrial quality components.

Transit Time

When "Test" mode is activated on two of the four DWK 250 chassis, the Interface module is expected to start the Blade Drop Timer at essentially the same time that the Scram Logic Cards output a scram signal. First, the signal transit time from the output of the DWK 250 chassis via the Signal Distribution Module to the Interface module is estimated to be the same as to the Scram Logic Cards, no more than 10 nanoseconds. Second, the transit time through the Scram Logic Cards has been measured at 38 microseconds, while the transit time through the Interface module has been measured at 300 microseconds. This difference of less than one millisecond is too small to have a measurable effect on the drop time value.

The 300-microsecond transit time through the Interface module assumes the Interface is using DWK 250 "Test" signals as its Start Signal Source, whereas the transit time for signals using the Minor Scram pushbutton as the Start Signal Source can only be smaller, as the only significant component of the Interface used in this signal path is the U5 optical isolator at the output.

Failure Analysis

If the Interface module fails such that its transit time becomes extended, the timing-start at the Blade Drop Timer would be delayed. Since the Blade Drop Timer will stop

whenever the selected shim blade reaches 80% insertion, the measured drop time would be shortened. Therefore, the signal transit time through the Interface module is to be measured at least annually, to monitor its performance so that this failure mode would be identified in a timely manner.

Contrariwise, if the Interface module fails such that its transit time decreases, the drop time value would increase, but this conservative error could not be more than 300 microseconds. Reactor procedures require investigation whenever a shim blade's drop time is in excess of 700 milliseconds. Therefore, this failure mode does not present a tangible concern.

Furthermore, if the Interface module should fail such that it never starts the Blade Drop Timer, the effect of this failure mode is readily apparent.

The Interface module is normally switched off, and is switched on only for blade drop time tests, which are performed only when the reactor is shut down. However, if the module were inadvertently left on with the reactor at power, it would not interfere with the regular scram signal paths. The Interface module is downstream from the nuclear safety channels and the Signal Distribution Module. Signals entering the Interface module flow in only one direction, using input and output optical isolators, towards the Blade Drop Timer further downstream. The Interface's only function is to start the Blade Drop Timer, and it therefore poses no challenge to the nuclear safety system.

Minor Scram Option Analysis

It is important to clarify that the console Minor Scram pushbutton's contacts are normally closed. When the operator depresses the button, the Minor Scram circuit is opened, thereby interrupting the Withdraw Permit Circuit to effect a reactor scram. As shown in Drawing R3W-267-3, when the guarded "Start Signal Source" selector switch is set to "Minor Scram Switch", and the operator presses the console Minor Scram pushbutton, the corresponding signal path within the Interface module becomes open. This allows the 12-volt signal path leading to the input of the U5 optical isolator to energize, transmitting a start signal from the isolator to the Blade Drop Timer. The section of the Minor Scram pushbutton that starts the Interface module is mechanically coupled, but is electrically isolated from the Minor Scram circuit, so there is no interaction between the Interface module and the Minor Scram circuit. Therefore, this design reliably provides the option for the Interface module to use the Minor Scram pushbutton for drop time measurements, without risk of impacting the safety function of the Minor Scram pushbutton.

Cybersecurity and Isolation

The Blade Drop Timer Interface Module has no microprocessor, no software, and no programmable or re-configurable logic elements. The module is optically isolated at its input and output, and it has no connections external to the nuclear safety system. Therefore, the Interface module is not subject to cybersecurity threats.

Human Factors

The Blade Drop Timer Interface Module has minimal complexity for the console operator. Its front panel is labeled appropriately, as shown in Figure 2. The "Start Signal Source" toggle switch by default selects input from the DWK 250 chassis, as the toggle switch has a guard which parks the switch downward to that position when the guard is closed. The "Power" toggle switch is of a different style and has clear labels for "On" and "Off", above and below it. The two indicator lights are of different colors and are easily matched with the labels above them.

The back panel of the Interface module has three connectors, designated P7, P8, and P9, as shown in Figures 4 and 5. Each of these connectors is of a different style, preventing inadvertent insertion of cables at the wrong connector. Maintaining the same convention as the front panel and the control console in general, the connector labels are above the corresponding jack. P7 is for power and signal input, all at 24 volts DC. P8 is for input from the Minor Scram pushbutton, at 12 volts DC. P9 is the 12-volt DC output to start the Blade Drop Timer. Therefore, cable misconnection between these functions is impossible.

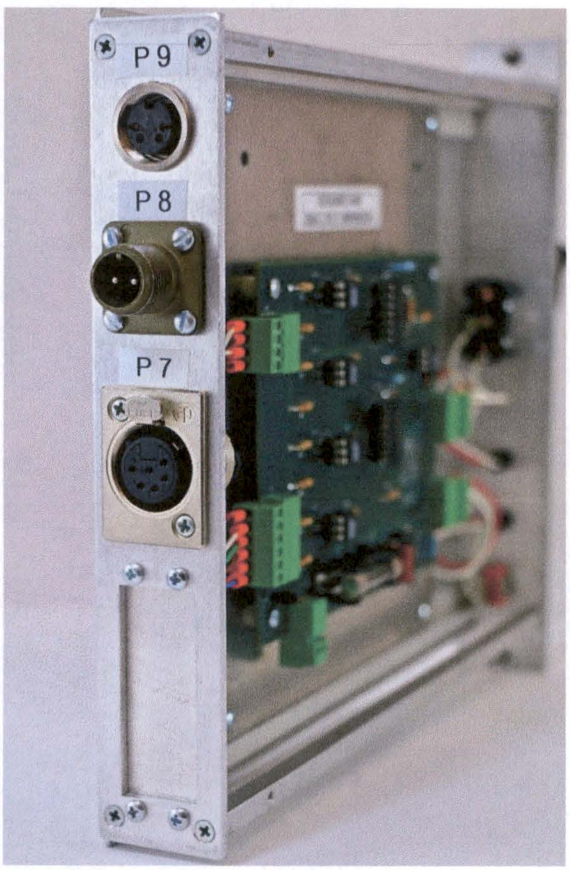


Figure 4 – Rear Quarter View

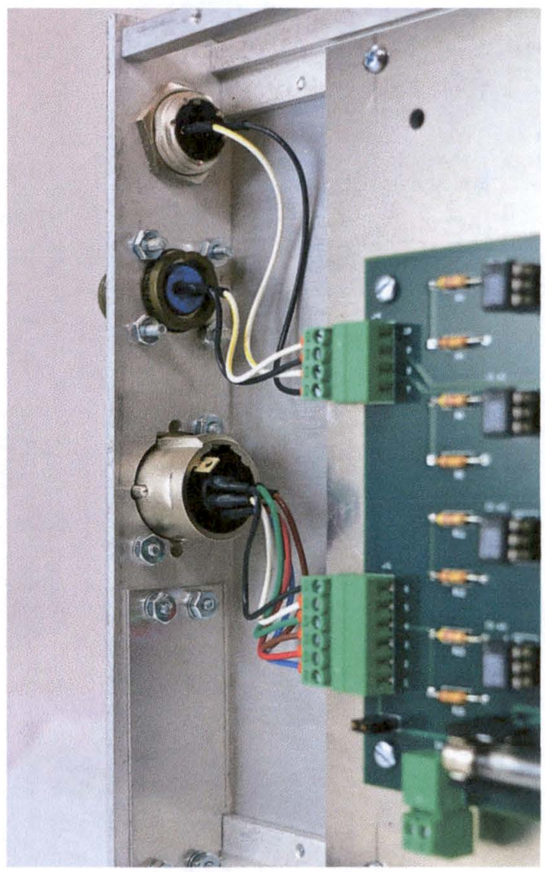


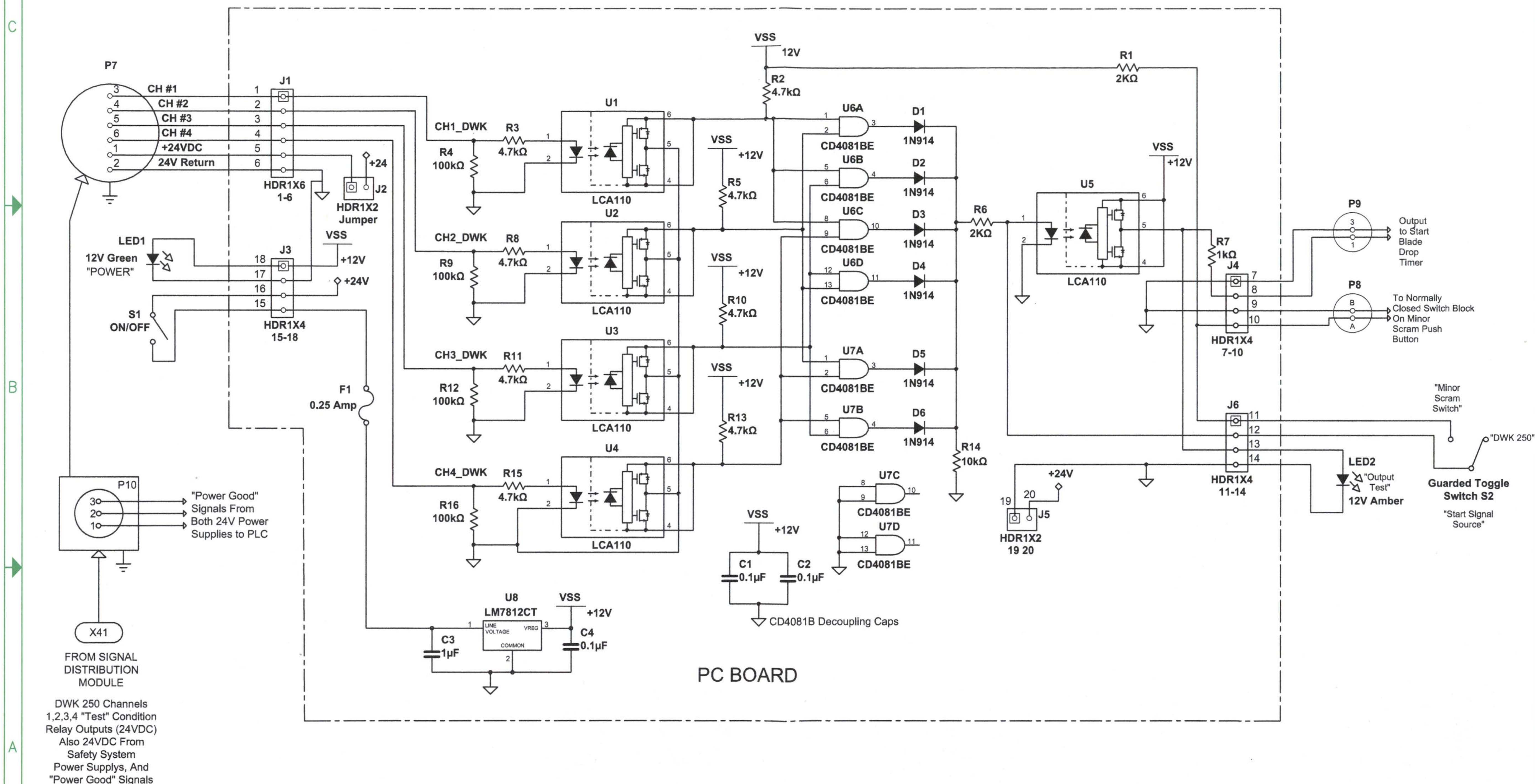
Figure 5 – Inside View of I/O Connectors

Minimal Electrical Hazard

The Interface module operates on 24 volts DC and 12 volts DC, presents minimal electrical hazard, and produces no significant heat in the control room cabinet. It has been bench-tested and tested satisfactorily in its control room instrument cabinet position.

Verification and Periodic Checks

The Blade Drop Timer Interface Module is set up in the control room as part of the integrated new Nuclear Safety System to operate in parallel with the existing nuclear safety system for observation. It will be tested using a written procedure prior to first use, and will receive functional checks periodically as part of the routine shim blade drop time tests. Therefore, these pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the circuitry.



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± XX .XXX ± XX
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DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY REACTOR

BLADE DROP TIMER INTERFACE

DRAWN	HANVY/NAWAZELSKI	DATE 3/29/17
REVIEWED & APPROVED	EL/ST E/L	12/1/17
DESIGN	MENADIER	3/21/17

SIZE C | FILE NO. QA#-2017-30 | DWG NO. R3W-267-3 | REV
SCALE NONE | SHEET 1 OF 1

ZONE	REV	DESCRIPTION	DATE	APPROVED

REVISIONS

Q/A File #E-2012-1 – Digital Upgrade for Nuclear Safety System

Enclosure L

Q/A File #2017-40 "Safety System Monitoring & Status Display PLC"

Description of the Safety System Monitoring & Status Display PLC

The Safety System Monitoring & Status Display PLC ("the PLC") completes three main functions: displaying information to the operator from the nuclear safety system (NSS), logging the time & date of each safety system event for later diagnostics, and routing annunciator warnings to the control room Console Annunciator Panel. A large form factor touch screen is used to present this information in a clear and easy-to-read state for the operator. Care was taken to select a display that maximizes the viewing angle. The display's installation location was selected such that alarm indications and system verifications during the startup checklist were easy to read without a viewing angle restriction. Finally, the display installation location allows access to the instrumentation air conditioning. The thermal dissipation of the display and PLC is 14 watts, and as such, the additional thermal loading on control room HVAC is insignificant.

The PLC receives information from the safety system using optically coupled (input only) digital inputs, routed through well-defined connectors, detailed in the NSS Global Connection Diagram (Drawing R3W-268-2). Connection to the NSS is made available through connector X21 on the Signal Distribution Module (SDM) through cable K-20. This provides a fully-defined interface to the NSS hardware and contains a tamper resistant interconnect. Tamper resistance is provided by the mechanical cable retention hardware present on the SDM. Removal of this cable is logged by the PLC. The inputs sourced from connector X21 contain DWK 250 Channels #1-4 digital outputs, along with NSS Scram Logic Card 1 & 2 latched outputs, and power-good signaling from the NSS 24VDC power supplies. Remaining interconnects to the PLC connect via cable K-20 using connector X21 on the Signal Distribution Module. Inputs and outputs on this connector are also optically coupled to prevent grounding issues and ensure that communications are traveling only in the intended directions. Connector cables K-48 and K-40, respectively, provide the PLC indication from the <100kW Key-Switch Module as well as an output path to connect to the existing control room Console Annunciator Panel.

The Signal Distribution Module provides access to safety system signaling directly. Connectors have mechanical constraints preventing easy removal. These mechanical constraints are held in place with aluminum brackets and maintain positive contact using a hard rubber cushion. Together this helps prevent intermittent connections and provides strain relief for cabling. Shown in Figure 1 is the SDM with the location of the PLC interface, and in Figure 2, the associated brackets that maintain positive contact of the connector.

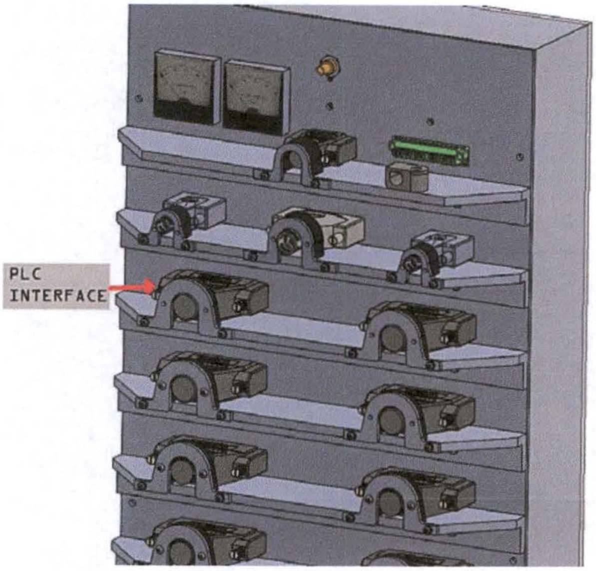

Figure 1: Signal Distribution Module, providing PLC Interface to Nuclear Safety System

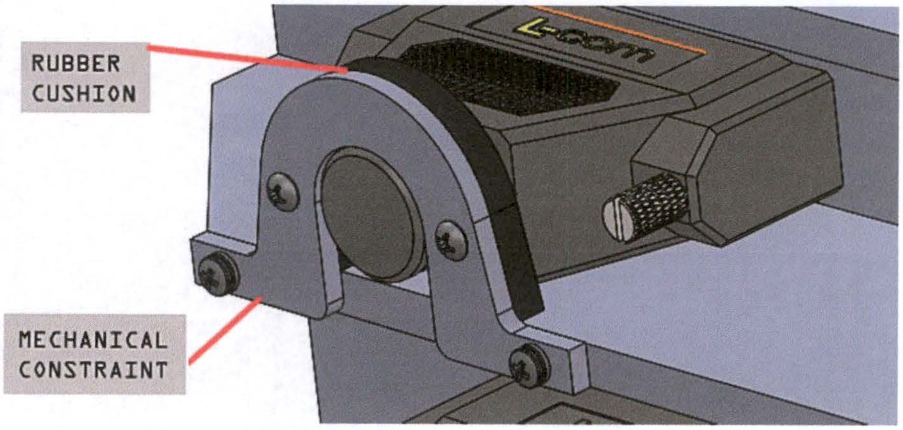

Figure 2: Mechanical Cable Constraint

Internal Logic Diagram:

Each DWK 250 chassis can generate up to eight alarm conditions: High Power Trip, Short Period Trip, High Power <100 kW Operation Trip, Low Count Rate Trip, High Power Warning signal, Short Period Warning signal, Test Trip, and a Fault Trip. Each of these conditions results in the opening of an isolated relay contact internal to the DWK 250 instrument. The High Power Warning signal and the Short Period Warning signal will not cause a reactor scram but are useful for operator display and event logging. The <100 kW Key-Switch Module (KSM) contains a two-position key switch whereby the operating mode for the reactor can be selected. The two available positions are "<100kW Operation" and "Full Power Operation". When the KSM is switched to the <100 kW Operation position, the High Power 100 kW Operation Trip, if generated, will reach the LED Scram Display. When the KSM key switch is on Full Power Operation, the High Power 100 kW Operation Trip will not be acted upon by the Scram Logic Cards. All the other trip alarms will be routed to the LED Scram Display, with the Test Trip and the Fault / Equipment Malfunction Trip combined as the Trouble alarm. However, all eight alarm outputs from any of the four DWK 250 units will be routed to the Safety System Monitoring & Status Display PLC. The PLC will register the date and time each alarm is received, and will maintain a digital record. The operating logic for the PLC is shown in Figure 3, including 2-of-4 logic for the synthetic scram LED indicator.

The PLC panel displays and records all alarm outputs from the four DWK 250 chassis. Additionally, the PLC panel transmits these alarm conditions to the control room Console Annunciator Panel in three annunciator alarms: High Power Warning, Short Period Warning, and Trouble. A Trouble annunciator alarm includes conditions of Test, or Fault / Equipment Malfunction. This is illustrated on the Drawing R3W-268-2 Nuclear Safety System Global Connection Diagram.

Internal logic, as shown in Figure 3, determines if any single DWK 250 unit is disconnected, for example, when a DWK 250 unit is removed for repair, and bypasses the annunciator alarms "High Power Warning" and "Short Period Warning" from that single DWK 250 unit to prevent crowding of the existing Console Annunciator Panel. This allows subsequent, actual high power warnings or short period warnings to appear and be indicated to the operator.

Internal logic base diagram (Drawing R3W-269-2):

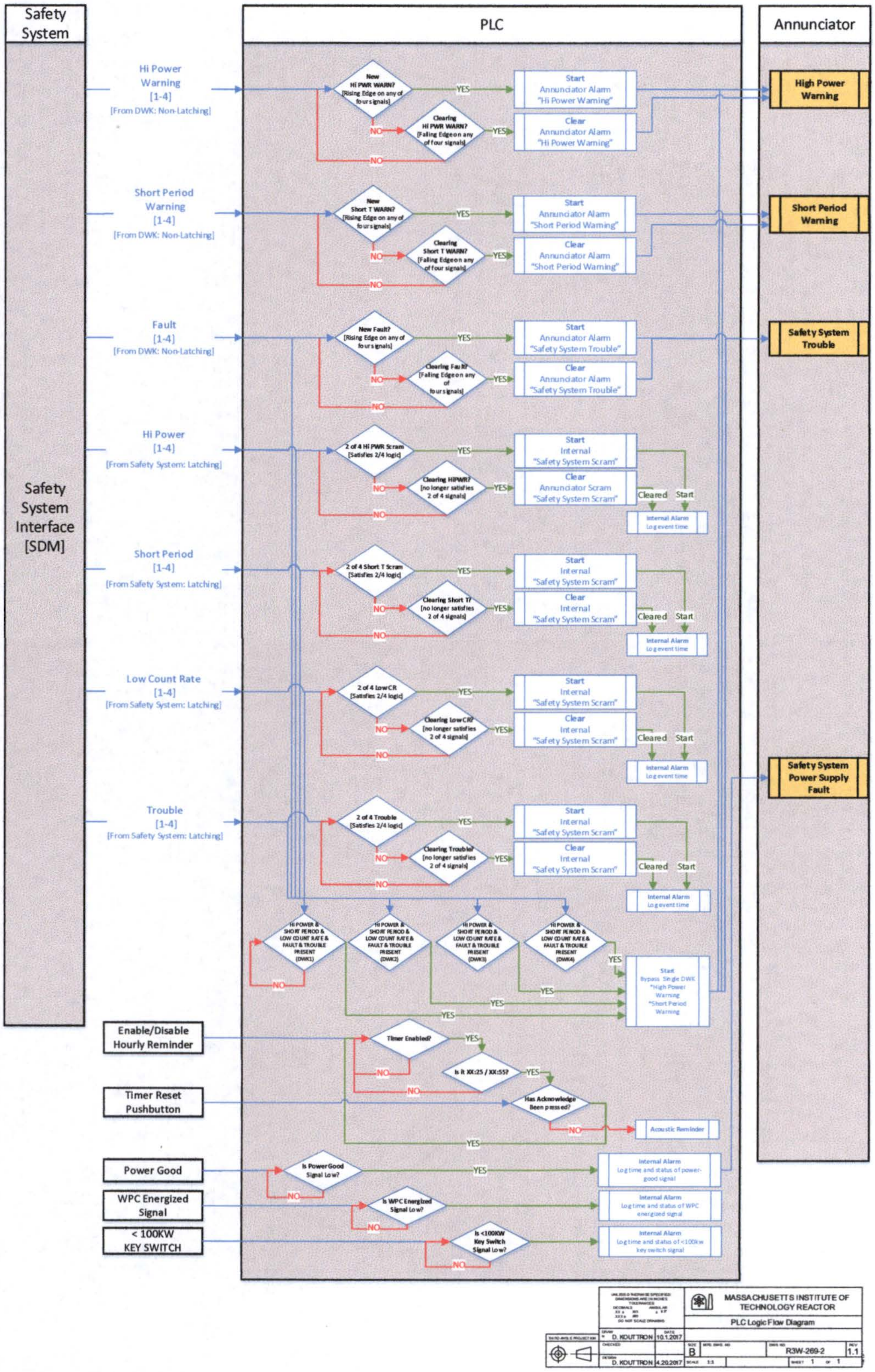

Figure 3: PLC Logic Flow Diagram showing Internal Logic

The PLC subsystem consists of four display screens, each of which is shown or described below:

Main Display:

The Main display, shown in Figure 4, consists of a central clock, a side-menu for accessing each of the four display menus, a listing of the four most-recent alarms, a brightness control, and an acoustic-feedback pushbutton to enable tone synthesis at 30-minute intervals. The most-recent latched-in alarm list [herein shown as Message-1, Message-2, Message-3, Message-4] is visible only when alarms are present. In a non-alarm state the alarm display meshes with the background. Each of the most-recent alarm status lines also indicate the time and date of the alarm with resolution to the second. The position of the menu items and logo are static, such that during menu screen changes, pushbuttons do not change location on the screen. The only functional user-input buttons on this display menu are: Main, Event Log, LED Display, More, the acoustic reminder, and brightness control.

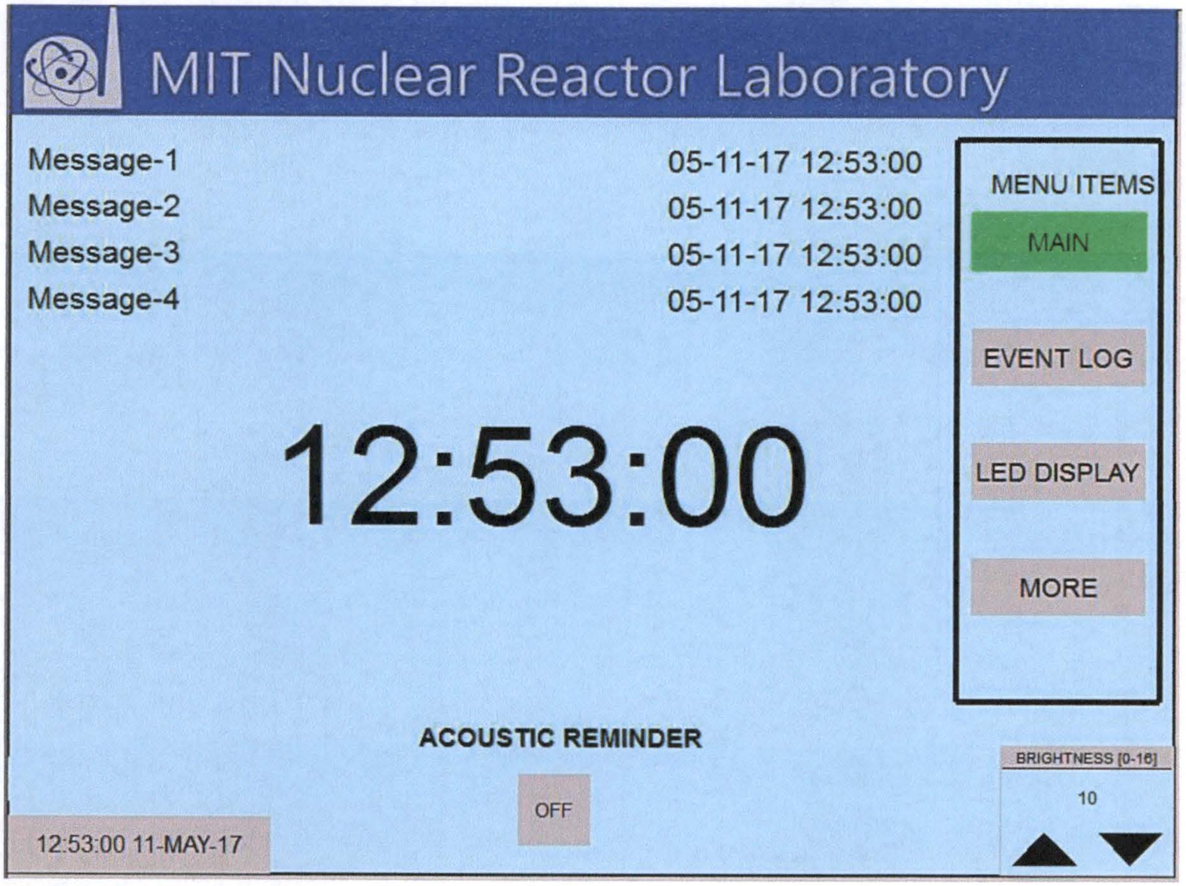

Figure 4: Main Display

Event Log:

The Event Log display, shown in Figure 5, consists of a historical register of alarm activity, including the alarm's name, shown under the "Message" column, and the activation / deactivation time with 1-second resolution. The most recent alarm is displayed at the top of the list, and the historical register shifts events downward in a sequential fashion. When the historical register exceeds 24 events, the most recent stay on the main page; scrolling through using the page-up / page-down pushbuttons is available. The historical register is saved locally in flash memory internal to the PLC. Upon power-cycle the historical register maintains its existing list. A copy of the historical register is also stored externally on a storage device located behind the PLC. Use of this external storage device is discussed below. The only functional user-input buttons on this display menu are: Main, Event Log, LED Display, More, the acoustic reminder, Page Up, Page Down, Line Up, Line Down, Detail, and brightness control.

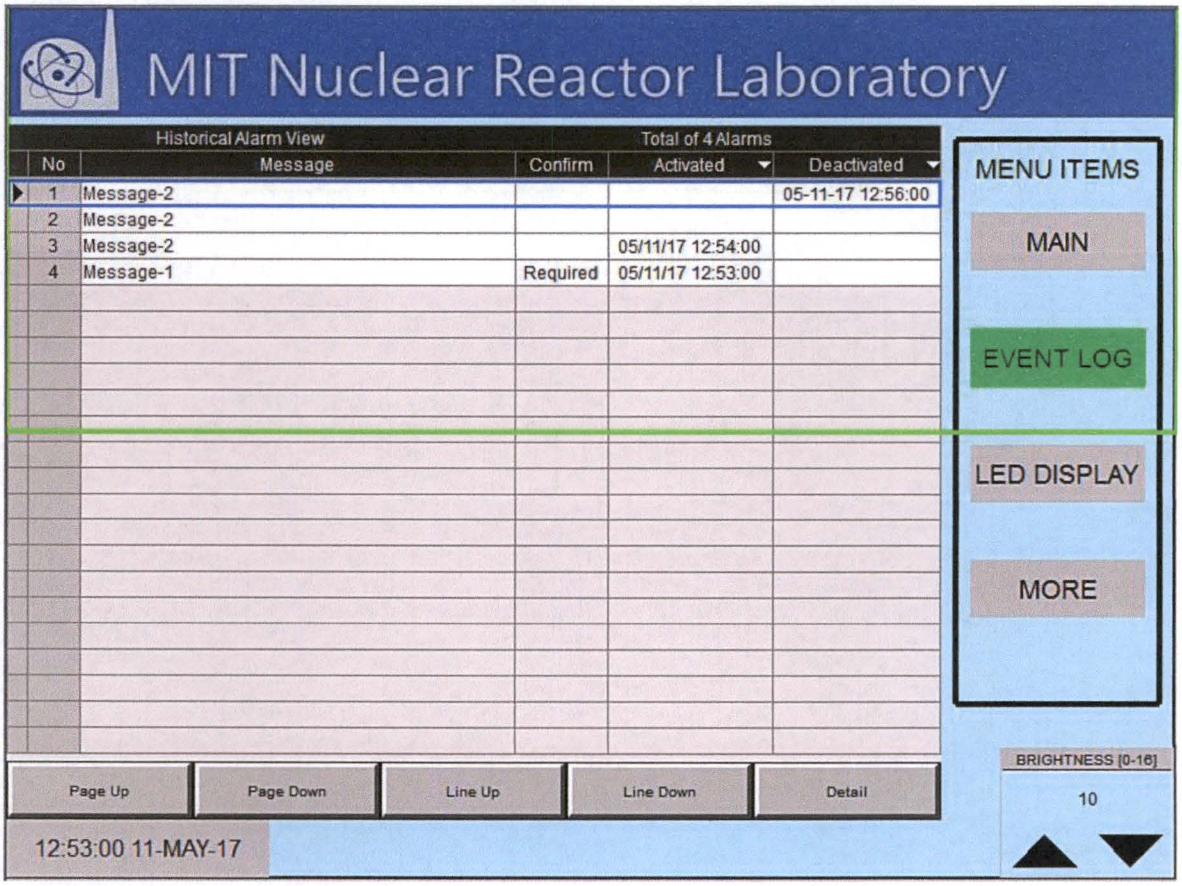

Figure 5: Event Log

The external storage device is connected to the PLC and is accessible only from behind the control room console. This storage drive's purpose is to keep a digital record to help diagnose alarm and scram conditions, in case the PLC record is not readable (e.g., if the screen is damaged). This drive is kept physically secure by a mechanical holster preventing other devices from plugging into this port.

LED Display:

The LED Display, shown in Figure 6, consists of a map of the latched and non-latched alarm inputs that the PLC can log. The top CH# columns refer to the associated DWK 250 channel. Each rectangle is an associated indicator, scanned constantly and displayed for the operator. Going down the column of CH 1, the DWK 250's High Power Warning output is displayed first, shown here as yellow. When the condition is present, it is active yellow flashing, and defaults to gray otherwise. SHORT T WARN refers to the short period warning, which is also active yellow flashing, and defaults to gray otherwise. Both the HI PWR WARN and SHORT T WARN warning outputs are non-latching, but are logged in the event log historic register. Continuing down the column, the DWK 250's FAULT output is displayed. This is a non-latching output active yellow flashing, and defaults to gray otherwise. Continuing, the DWK 250's TEST output is displayed, which is a non-latching output active yellow flashing, and defaults to gray otherwise.

After the sub-divider row, latched outputs from the NSS Scram Logic Cards are displayed. For instance, High Power CH1 indicates that the NSS has observed and has latched the High Power state from the DWK 250 output. This display is active red, and defaults to gray otherwise.

The only functional user-input buttons on this display menu are: Main, Event Log, LED Display, More, and brightness control.

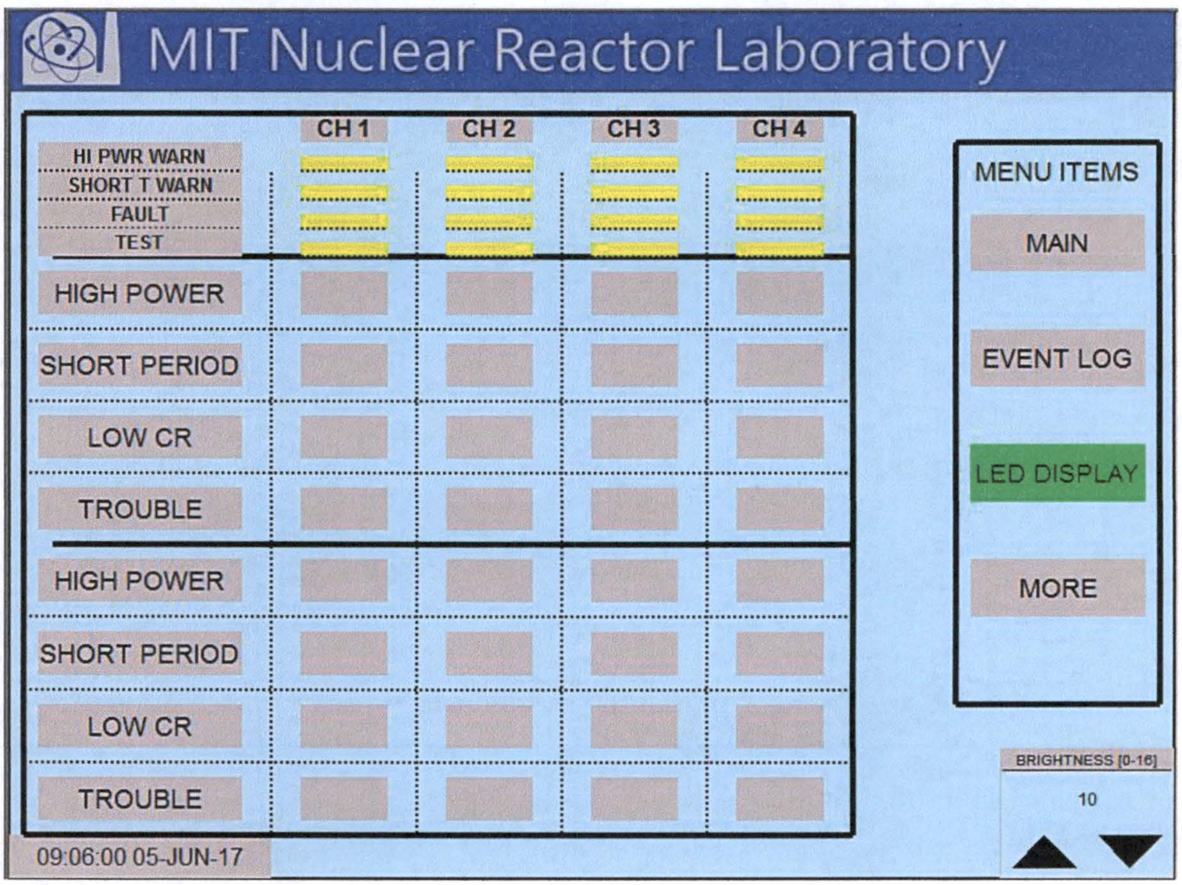

Figure 6: LED Display

More Display:

The More display (not shown) is for administrative activities such as setting the PLC's clock, reporting storage space used and available internal memory.

In-Line Testing of Status Display PLC

During the initial testing phase, the PLC panel will be installed in the control room in a 5' test rack, away from the main operator console. It will be relocated into the main console for final installation. The panel is optically isolated where it connects to the Signal Distribution Module, and is also optically isolated where it connects to the Console Annunciator Panel. The optical isolation devices are on both the signal inbound and outbound ports of the PLC panel.

<u>Safety Evaluation</u>

The PLC is optically isolated at its input from the SDM. It transmits only to the control room's Console Annunciator Panel. Optical isolators built into the PLC's inputs will protect the DWK 250 units from being affected by any potential malware in the PLC's operating software. If this isolation fails, the PLC will be left completely disconnected from the SDM. In that case, none of the trip alarms generated by the DWK 250 units will reach or be registered by the PLC.

Likewise, if the PLC itself fails, none of the trip alarms generated by the DWK 250 units will be registered there. Conditions of High Power Warning, Short Period Warning, or Trouble would not output to the control room's Console Annunciator Panel. In that case, high power warning capability would come from another existing neutron flux monitoring channel that is not part of the nuclear safety system. Furthermore, the DWK 250 chassis have their own indicator lights for these conditions. The existing nuclear safety system does not have any high power warning or short period warning functions. Therefore, the lack of these warning capabilities in the case of PLC failure or failure of its optical isolators will not degrade operational safety. Most importantly, since the PLC is not responsible for generation of any scram signals, its loss will not affect nuclear safety or reactor operation.

If the PLC fails, or one or more of its input optical isolators fail, a DWK 250 Trouble condition (Low Count Rate, Test, or Fault / Equipment Malfunction) will not reach the PLC, but will still light the relevant indicator(s) on the LED Scram Display. Trouble conditions from two or more DWK 250 units will still result in a scram output from the Scram Logic Cards, shutting down the reactor.

If malware corrupts the PLC, the PLC screen may provide or record inaccurate information, including the date and time, and the PLC may fail to output actual alarms, or may output any of its three annunciator alarms when they are not warranted. However, in all cases the console operator has other means in the control room to verify reactor conditions and the status of the nuclear safety channels. This failure mode of the PLC does not interfere with reactor scram functions and therefore has no impact on nuclear safety.

The PLC has network connection capability. However, there is no plan to place it on a public network, where it would have a higher probability of compromise by malware. The PLC writes its recorded data onto a Secure Digital (SD) card that has sufficient memory for the life of the equipment.

The PLC module will be bench-assembled using standard industrially-rated components. The module will then be connected to the rest of the new nuclear safety system while everything is de-energized. It will be mounted on the control room console, which will provide it with physical defense, including against seismic disturbance. Routine maintenance and inspection will be performed only by licensed reactor staff or under the supervision of licensed reactor staff. Password protection will be used to secure the PLC logic. The control room is attended whenever the reactor is operating. At all other times, when the building is unoccupied, it is protected as per the Physical Security Plan. Therefore, access control and configuration control are assured.

The control room and its metal instrumentation cabinets are in an air-conditioned environment. The temperature is continuously maintained within a desirable setting (approximately 68 F). There is a temperature alarm (setpoint no higher than 78 F) that is monitored whenever the reactor is operating, or shut down with the control room attended. This air-conditioning control easily satisfies the operating requirements for all the components in the modules.

All cables to, and cable connection points on, the PLC module will be labeled. These markings improve the human interface for purposes of installation and maintenance. The PLC's display screen conforms to common industrial display format. Therefore, human factors engineering is adequate.

The PLC module will be tested for wiring verification, including the proper level of illumination of the PLC display screen, using a written procedure prior to first use. There will also be periodic operational checks. Therefore, the pre-operational and routine surveillances are sufficient to assure the completeness and integrity of the PLC.

Special Procedure for Fabrication and Testing of the Blade Drop Timer Interface

✓ 1. Assemble the 1 wide NIM module (Mech-Tronics Nuclear # 101)

✓ 2. Insert and solder all discrete components into the custom designed "MIT-NRL Drop Timer Interface" printed circuit board. (Refer to drawing R3W-267-3) See Figure 1.

✓ 3. Visually inspect the completed circuit board for missing or cold solder connections, also improper solder bridges.

✓ 4. Insert the correct IC's into their proper sockets, also the fuse. See Figure 1.

✓ 5. Mount the two toggle switches and two indicator lights on the NIM module front panel. See Figure 2.

✓ 6. Mount the three connectors P7, P8, and P9 on the NIM module rear panel. See Figure 3.

✓ 7. Mount the circuit board into the NIM module. See Figure 4.

✓ 8. Complete wiring the input/output connectors, switches, and indicator lights as per drawing R3W-267-3.

✓ 9. Perform a final visual inspection for loose connections, poor solder joints, or mechanical problems.

✓ 10. Close the NIM module with the appropriate covers.

✓ 11. Insert the "Blade Drop Timer Interface" module into the NSS Test Rack NIM bin 2. See Figure 5.

✓ 12. Connect the P7 connector cable to the X41 connector on the SDM.

✓ 13. Connect a two wire cable from P9 to the remote start input of the blade drop timer installed in the control room console.

✓ 14. Connect a two wire cable from P8 to a normally closed push button switch to simulate the reactor minor scram push button.

✓ 15. Apply 120VAC power to the NSS Test Rack.

✓ 16. Turn on the blade drop timer interface module, the black switch guard should be closed with the switch in the "DWK 250" position, the "Power" indicator should light.

✓ 17. Turn on the blade drop timer. Reset timer.

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Approved	PM	12-5-17
RRPO Review	[illegible]	12/5/17
Q/A App'l	E	12/4/2017

NOTE: Using the Test Data Sheet in this procedure enter results of each test performed.

✓ 18. Reset any scram conditions that may be present on the LED Scram Display Module.

✓ 19. Generate a “Test” condition on DWK 250 Channel #1.

✓ 20. Generate a “Test” condition on DWK 250 Channel #2.

✓ 21. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the “Output Test” indicator on the timer interface will light and the drop timer will start.

✓ 22. Remove the “Test” condition from the DWK 250 channel set in Step 20.

✓ 23. Reset the drop time and the scram conditions on the LED Scram Display Module.

✓ 24. Generate a “Test” condition on DWK 250 Channel #3

✓ 25. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the “Output Test” indicator on the timer interface will light and the drop timer will start.

✓ 26. Remove the “Test” condition from the DWK 250 Channel #3.

✓ 27. Reset the drop time and the scram conditions on the LED Scram Display Module.

✓ 28. Generate a “Test” condition on DWK 250 Channel #4.

✓ 29. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the “Output Test” indicator on the timer interface will light and the drop timer will start.

✓ 30. Remove the “Test” condition from the DWK 250 Channel #4.

✓ 31. Reset the drop time and the scram conditions on the LED Scram Display Module.

✓ 32. Remove the “Test” condition from DWK 250 Channel #1.

✓ 33. Generate a “Test” condition on DWK Channel #2.

✓ 34. Generate a “Test” condition on DWK 250 Channel #3.

✓ 35. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the “Output Test” indicator on the timer interface will light and the drop timer will start.

✓ 36. Remove the “Test” condition from the DWK 250 Channel #3.

✓ 37. Reset the drop time and the scram conditions on the LED Scram Display Module.

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✓ 38. Generate a "Test" condition on DWK 250 Channel #4

✓ 39. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the "Output Test" indicator on the timer interface will light and the drop timer will start.

✓ 40. Remove the "Test" condition from the DWK 250 Channel #4.

✓ 41. Reset the drop time and the scram conditions on the LED Scram Display Module.

✓ 42. Remove the "Test" condition from DWK 250 Channel #2.

✓ 43. Generate a "Test" condition for DWK 250 Channel #3.

✓ 44. Generate a "Test" condition on DWK 250 Channel #4.

✓ 45. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the "Output Test" indicator on the timer interface will light and the drop timer will start.

✓ 46. Remove the "Test" condition from the DWK 250 Channels #3 and #4.

✓ 47. Reset the drop time and the scram conditions on the LED Scram Display Module.

✓ 48. Open the black switch guard on the timer interface module. Raise the switch lever to the "Minor Scram Switch" position.

✓ 49. Operate the push button switch installed in Step 14.

✓ 50. The "Output Test" indicator will light briefly and the drop timer will start.

✓ 51. Close the black switch guard. (The switch will be forced to the DWK 250 position)

✓ 52. Turn off the drop timer interface and the drop timer.

✓ 53. Check that all DWK 250 Channels are returned to normal operating conditions.

✓ 54. Reset all scrams.

Test Data Sheet

DWK 250 Channel Combination	Reactor Scram **Y or N**	Drop Timer Start **Y or N**
1 – 2	Y	Y
1 – 3	Y	Y
1 – 4	Y	Y
2 – 3	Y	Y
2 – 4	Y	Y
3 – 4	Y	Y
Minor Scram Push Button	**N/A**	**Y or N** Y

Procedure Completed Satisfactorily: Paul Menadier Date: 12-5-17

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Approved	PM	12-5-17
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Q/A App'l	[illegible]	12/4/2017

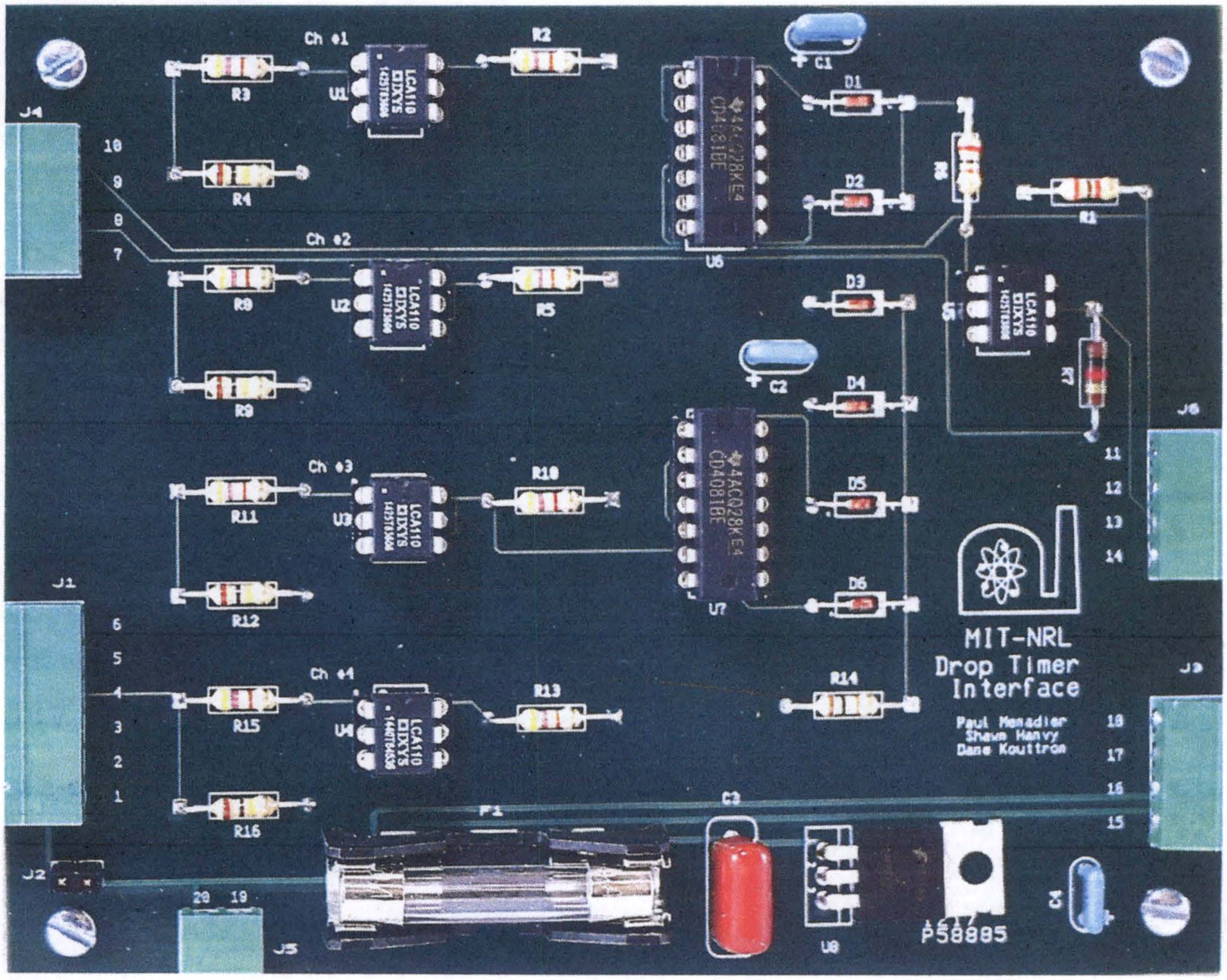

Figure 1
Printed Circuit Board

QA#	2017-30	Date
Approved	PM	12-5-17
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Q/A App'l	[signature]	12/4/2017

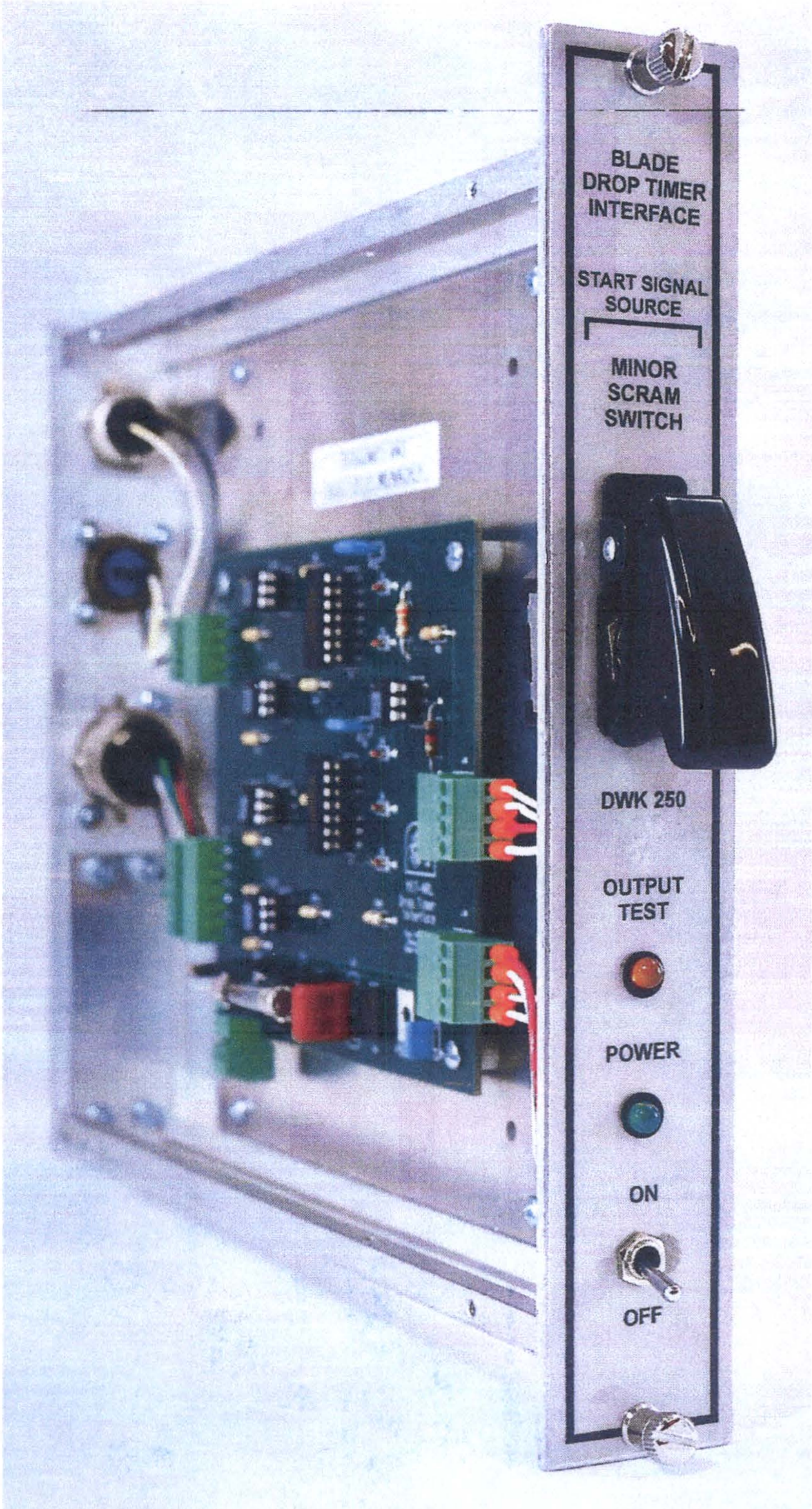

Figure 2
Front Panel

QA#	2017-30	Date
Approved	PMM	12-5-17
RRPO Review	WBV	12/5/17
Q/A App'l	E	12/4/2017

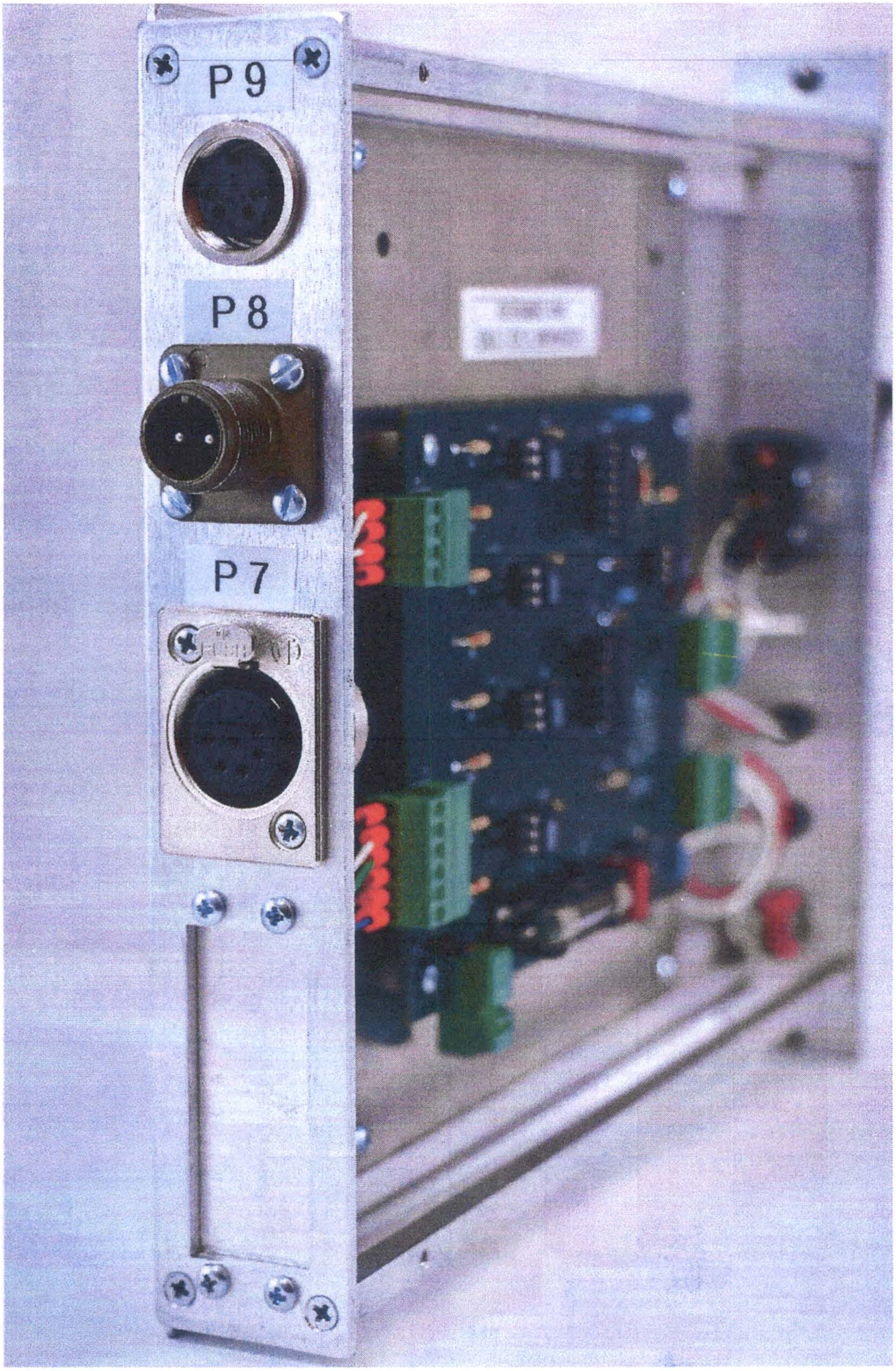

Figure 3
Rear Panel

QA#	2017-30	Date
Approved	PM	12-5-17
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Q/A App'l	E	12/4/2017

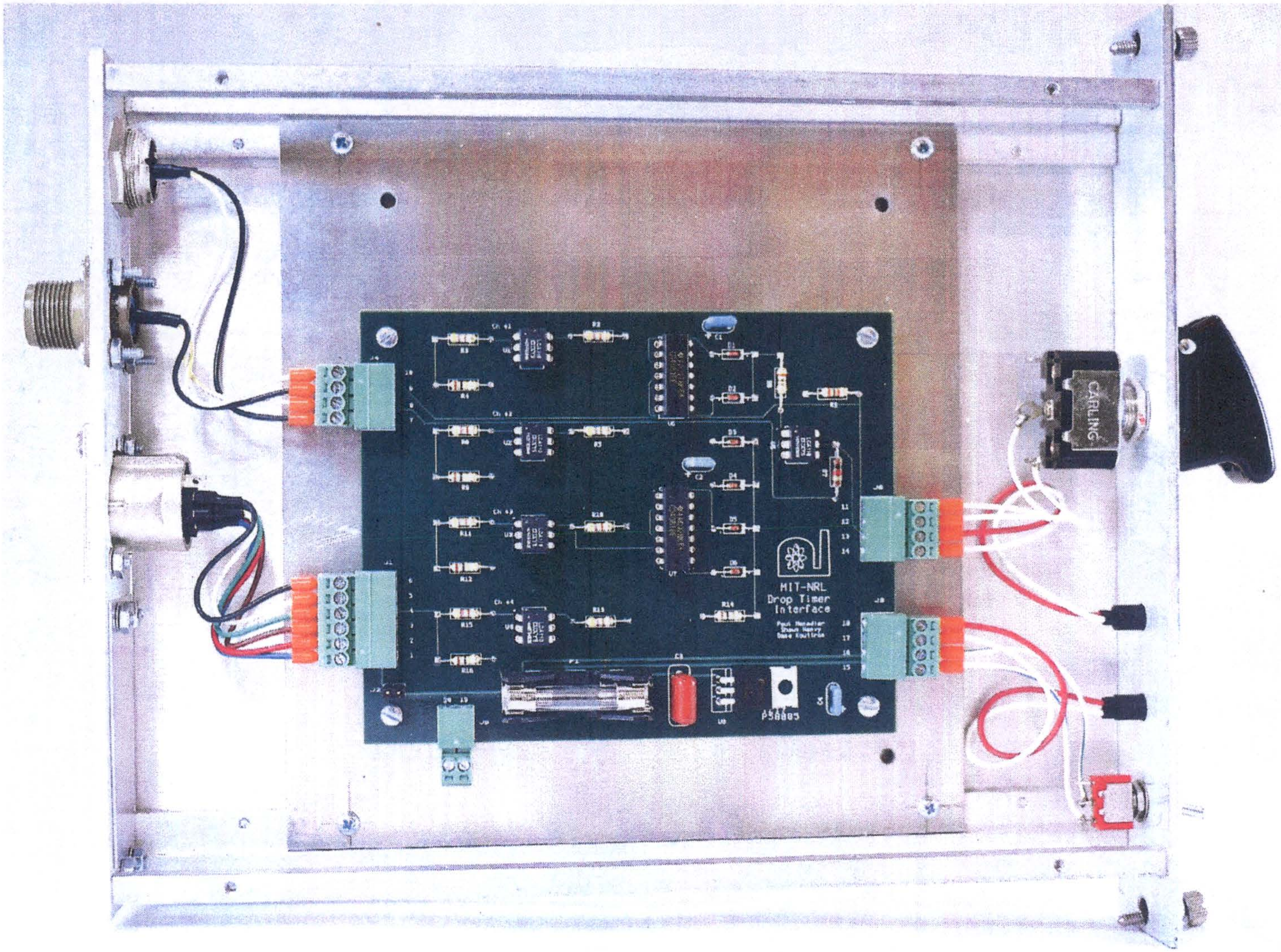

Figure 4
Interior View

QA#	2017-30	Date
Approved	PNM	12-5-17
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Q/A App'l	E	12/4/2017

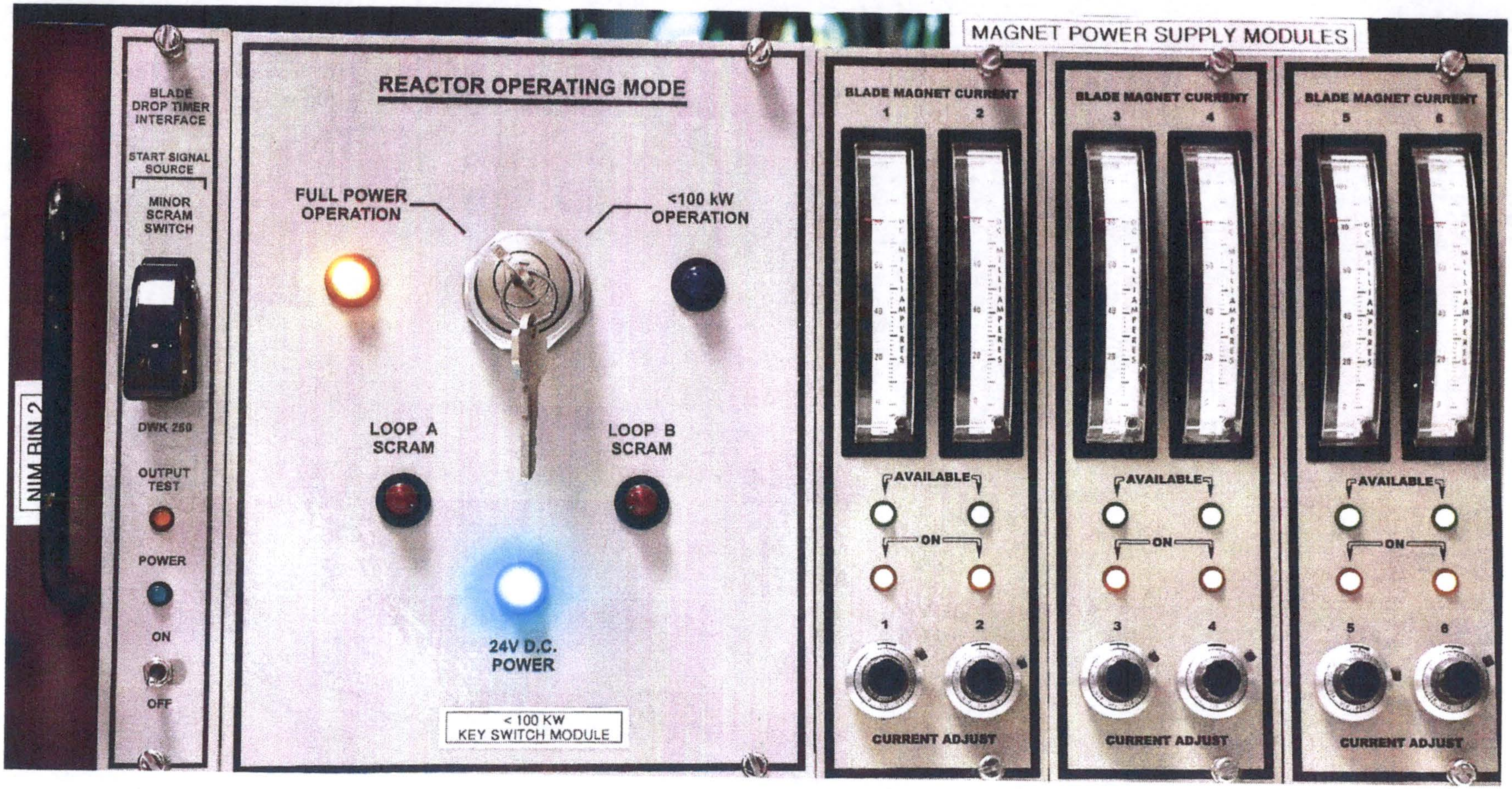

Figure 5
NIM Bin 2 Placement

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Q/A App'l	[signature]	12/4/2017

Special Procedure for Installing and Testing the Blade Drop Timer Interface Module

Initial Condition

1. Reactor is shutdown.
2. Blade Drop Timer remote start selector switch (located in panel 5) set to position #9 (DWK Timer Start).

Procedure

1. Connect cable K38 from X41 on SDM to the Signal Junction box and K46 to P7 on rear of blade Drop Timer Interface (DTI) module.
2. Connect cable K39 from P9 on the DTI to the connector on the Blade Drop Timer (BDT) remote start selector switch.
3. Connect cable K47 from P8 on the DTI to a new normally closed contact block on the minor scram push button assembly.
4. Turn on the BDT and reset the counter.
5. Turn on the DTI.
6. Check the DTI "Start Signal Source" switch is in "DWK 250" position.
7. Obtain a reactor start.
8. Switch DWK 250 #1 and #2 to "Test" mode. A reactor scram should occur, and simultaneously the "Output Test" indicator on the DTI should light and the BDT should start counting.
9. Reset the BDT.
10. Reset the DWK 250 test mode switches.
11. Repeat steps 7 to 9 for all other combinations as specified on the data sheet.
12. Switch the DTI "Start Signal Source" switch to the "Minor Scram Switch" position.
13. Obtain a reactor start.
14. Depress the minor scram push button. A reactor scram should occur, and simultaneously the "Output Test" indicator on the DTI should light and the BDT should start counting.
15. Reset the BDT.
16. Return the DTI "Start Signal Source" switch to the DWK 250 position.
17. Turn off the DTI and the BDT.

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RRPO Review	WM	10/4/17
Q/A App'l	[illegible]	10-4-17

Blade Drop Timer Interface Module Coincidence Verification

Test	DWK 1	DWK 2	DWK 3	DWK 4	Rx Scram	Drop Timer Start
1	1	1	0	0		
2	1	0	1	0		
3	1	0	0	1		
4	0	1	1	0		
5	0	1	0	1		
6	0	0	1	1		

1 = Tripped

0 = Normal

Completed By: ______________________ Date: ______________

QA#	2017-30	Date
Approved	[signature]	10-4-17
RRPO Review	[signature]	10/4/17
Q/A App'l	[signature]	10-4-17

Procedure for Shim Blade Drop Time Testing

Initial Conditions:

1. Reactor shutdown
2. Primary pumps on
3. Drop timer remote start selector switch (located behind panel 5) set to "DWK" position

1. Turn on the blade drop timer interface module, the black switch guard should be closed with the switch in the "DWK 250" position, the "Power" indicator should light.
2. Turn on the blade drop timer. Reset timer.
3. Select the shim blade that is to be tested, and set the timer selector switch to that blade number.
4. Reset any scram conditions that may be present on the LED Scram Display Module.
5. Obtain a reactor start, reset the rundown relay, and start raising the shim blade to be measured.
6. Observe the "Test" light on the timer. It should light briefly as the blade is raised past the ~4 inch height, if the drop-timer proximity switch is working properly.
7. If the "Test" light does not come on in step 6, do not proceed with the test for that blade.
8. If the "Test" light functions, continue raising the blade to the full out position.
9. Generate a "Test" condition on one DWK 250 Channel.
10. Generate a "Test" condition on another DWK 250 Channel.
11. Immediately, a scram should occur. As shown by the Loop A and Loop B scram lights on the <100kW Key-Switch Module. Simultaneously, the "Output Test" indicator on the timer interface will light and the drop timer will start.
12. The blade should drop, causing the "Test" light to flash again, and stopping the counting of the drop timer.
13. The number shown in the display is the drop time, in seconds, for that blade.

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RRPO Review	WBm	12/13/17
Q/A App'l	[illegible]	12/13/2017

NOTE: The timer will count for 10 seconds before the display starts to flash, indicating an overflow condition. However, the time continues to function, so events longer than 10 seconds may be clocked by counting the number of 0.000 display cycles.

14. Record the blade drop time in the Drop Time Book in the control room and initial in the book.
15. Remove the "Test" condition from the DWK 250 channels set in steps 9 and 10.
16. Turn off the blade drop timer and timer interface module.

NOTE: An alternative method for testing blade drop time while testing for multiple drop times is as follows:

1. After Step 5, open the black switch guard on the timer interface module. Raise the switch lever to the "Minor Scram Switch" position.
2. Operate the minor scram push button. A scram will occur.
3. The "Output Test" indicator will light briefly and the drop timer will start.
4. The blade should drop, causing the "Test" light to flash, and stopping the drop timer.
5. After all tests are complete, close the black switch guard. (The switch will be forced to the DWK 250 position).
6. Turn off the drop timer interface and drop timer.

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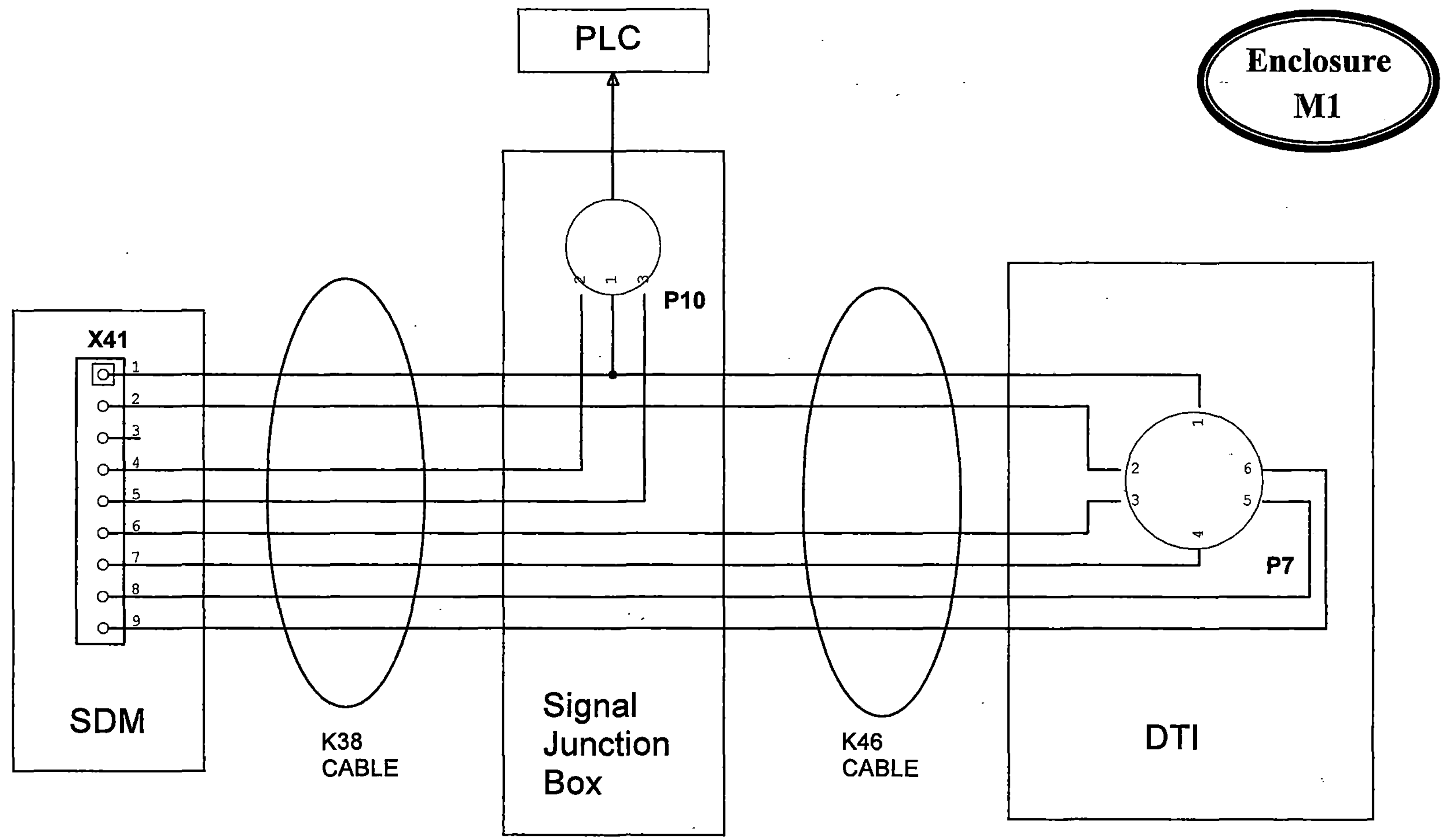

Title: SIGNAL JUNCTION BOX		
File No. QA#-2017-34		
Drawn by: Shawn Hanvy	Document N: R3W-272-1	Revision:
Reviewed & Approved: DEK/EL	Date: 10/6/2017	Size: A
Designed by: Paul Menadier	Sheet 1 of 1	

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MEMORANDUM

Enclosure N

To: New Nuclear Safety System QA File E-2012-1

From: Reactor Staff

Re: Justification for Use of 80 kW as a Trip Set Point on the DWK 250 Flux Monitors for <100 kW Operation with the New Nuclear Safety System

Date: 7 October 2017

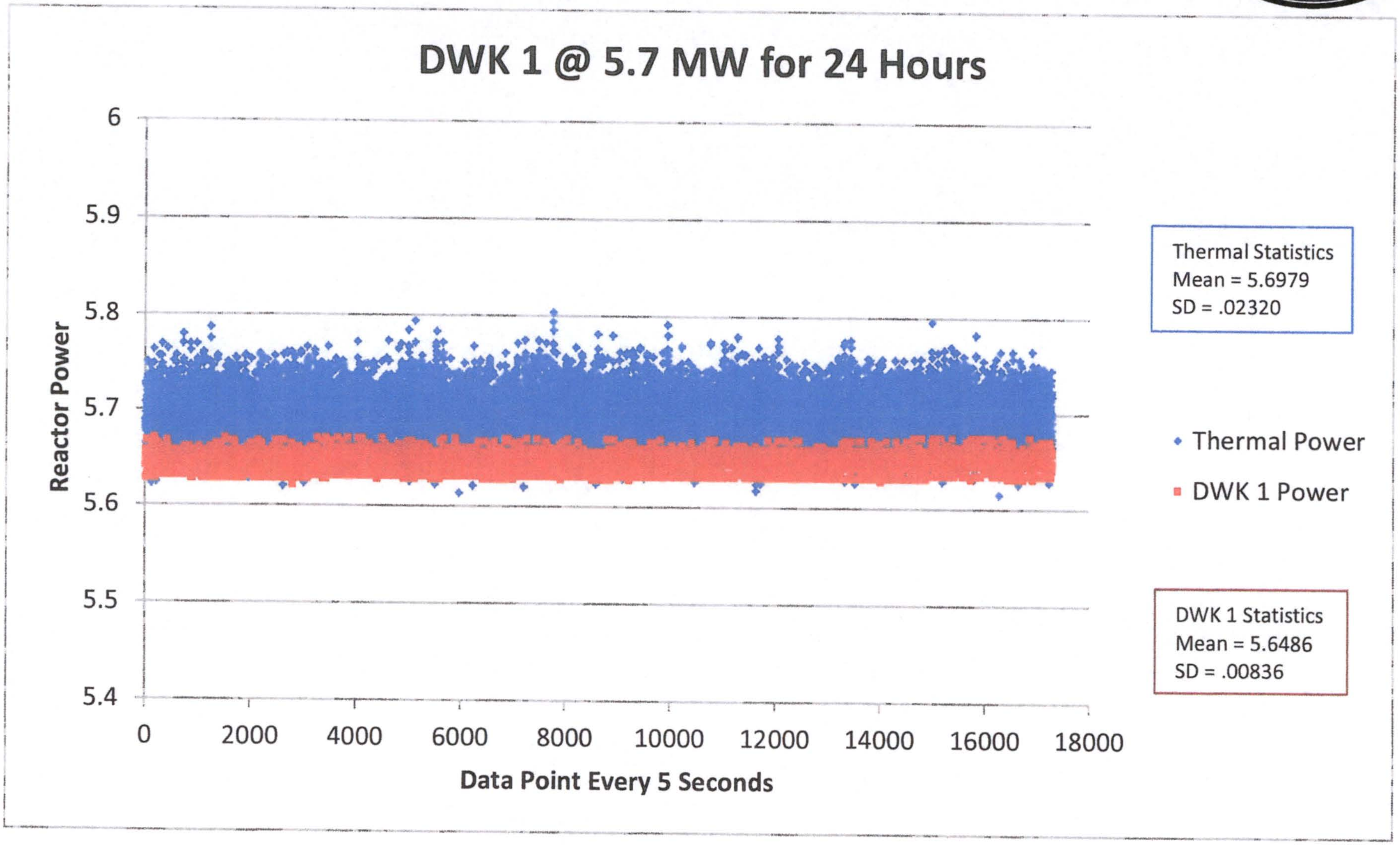
The following summarizes the method of analysis for the new nuclear safety system's channel indications for natural convection operation mode.

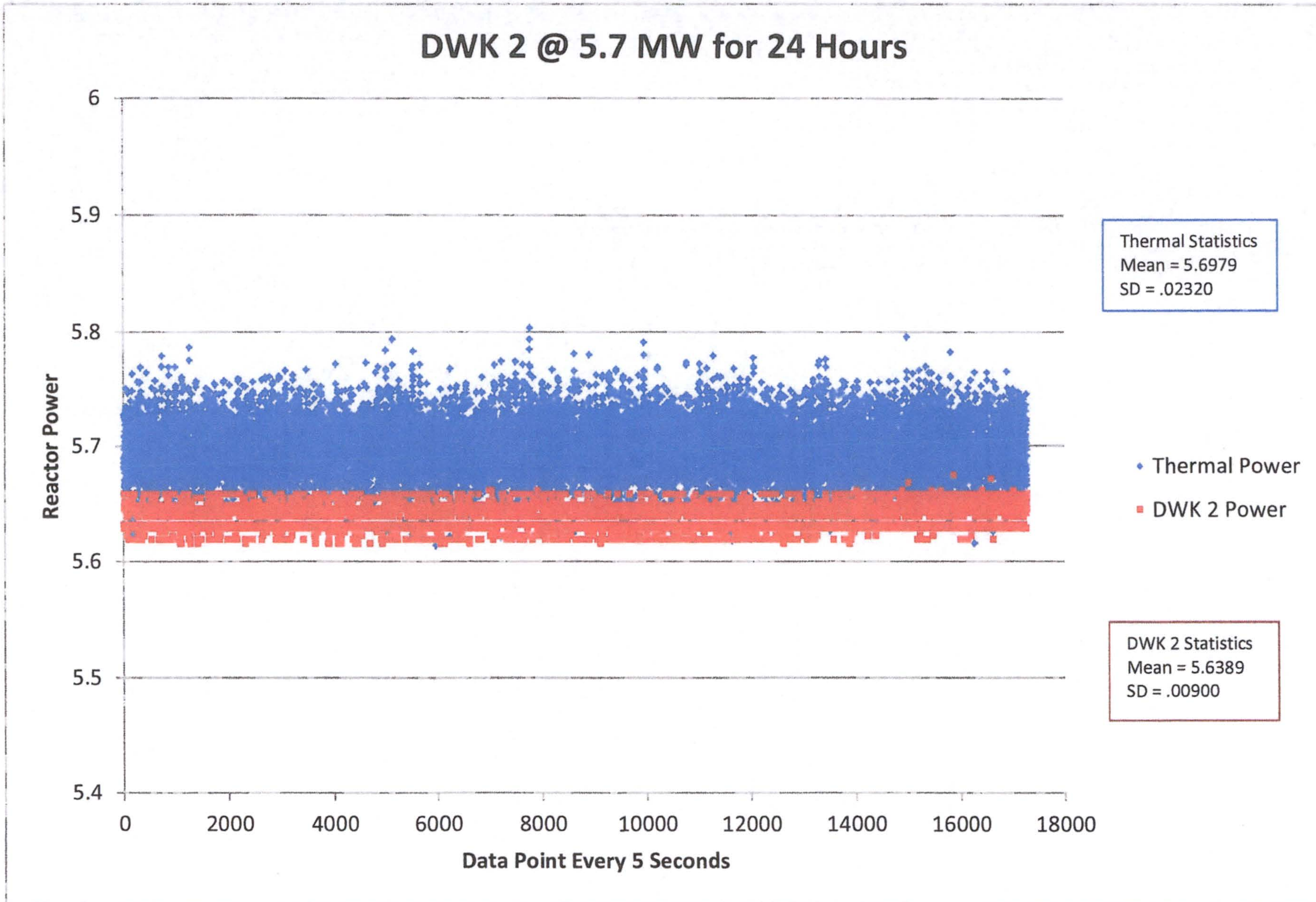
1. Engineering hot channel factors are used in the thermal hydraulic calculations to determine the Safety Limits for the MITR-II reactor core. The reactor power measurement error assumed in the hot channel sub-factors is 5% (SAR section 4.6.4, Table 4-8).
2. The Safety Limit for natural convection mode is calculated at 399 kW (SAR section 4.6.6.3). A conservative Safety Limit for reactor power is established at 350 kW, which establishes a 13% margin of error.
3. The Limiting Safety System Settings (LSSS) for the natural convection mode establish a sufficient margin between normal operating conditions and the Safety Limits. The calculations conservatively assume the reactor was operating at 1 MW just prior to a loss of primary coolant flow and reactor power remains at 100 kW after the loss of flow. Additional conservatism is taken in that the core inlet temperature is assumed to be at the 60°C LSSS (SAR section 4.6.7.2). This calculation establishes the reactor power LSSS at 100 kW.
4. MITR procedures establish the trip set point at 80 kW based on characteristics of the current nuclear safety system.
5. Calorimetric calibrations are completed with the reactor at or above 5.5 MW. These calibrations ensure each DWK 250 neutron flux monitor reads within 2% of reactor thermal power. (See attached figures showing measurement of uncertainty and drift on all four DWK 250 chassis, measured at 5.7 MW for a time span of 24 hours.)
6. Measurement of the uncertainty and drift in the DWK 250 power indication was done at equilibrium full power because at full power a calorimetric power calculation is available, and provides an accurate determination of reactor power for comparison. Furthermore, at full power, the effects of uncertainty and drift are amplified, and thus more readily measurable. According to the attached figures, the fluctuations in reactor power indication by the DWK 250s are measured at full power to be no more than 0.32% (with >95% confidence as measured at 5.7 MW steady-state for a span of more than 24 hours). The 0.32% magnitude of the uncertainty and drift at full power is equivalent to 18 kW. Very

conservatively applying this with no scaling to the 100 kW range of operation still supports 80 kW as a nominal trip set point beyond the 95% margin of uncertainty. Therefore, the decision to continue to use the 80 kW trip set point assures a sufficient margin prior to reaching 100 kW.

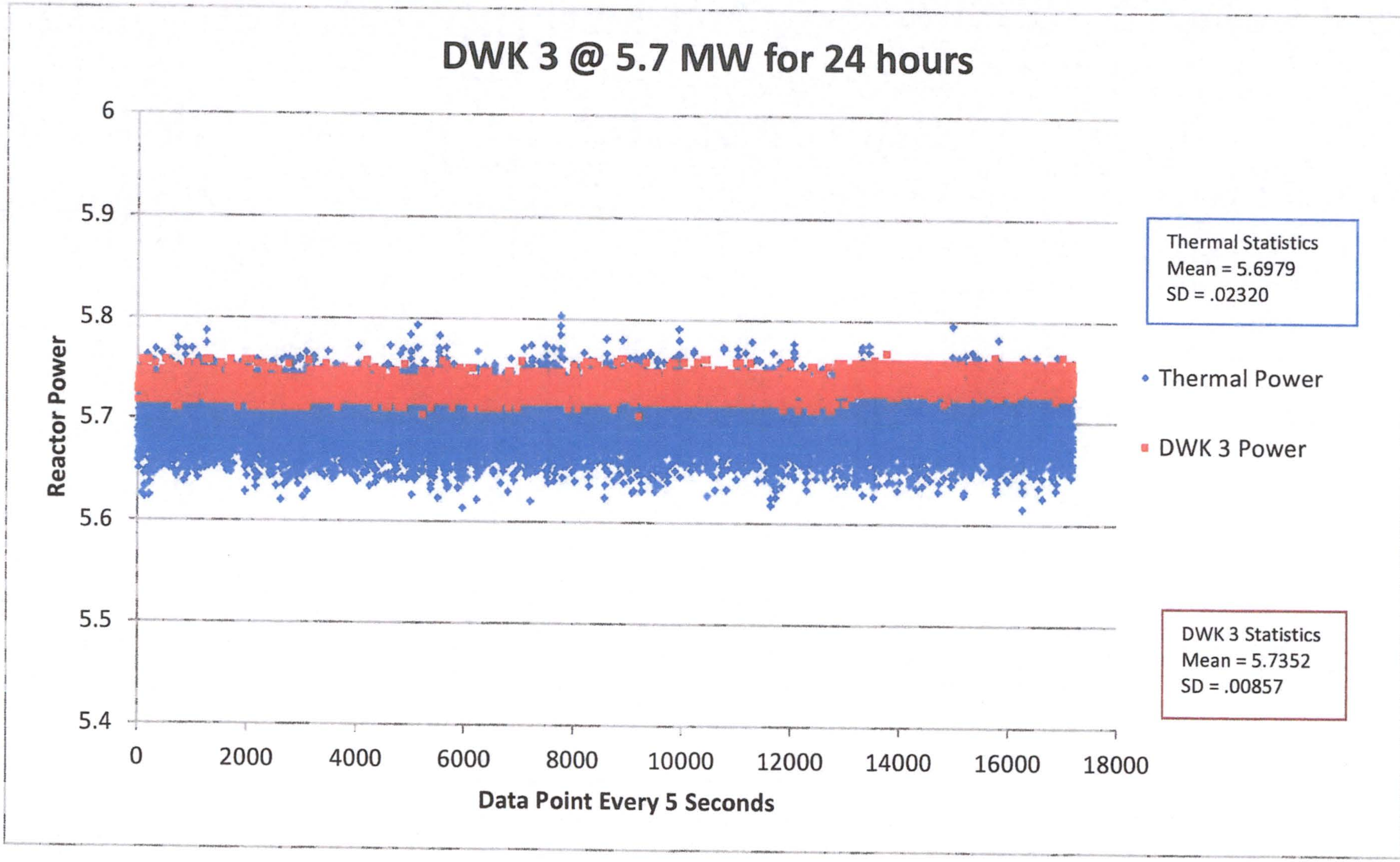
7. Linearity is confirmed from 500 kW to 5.7 MW for DWK 250 nuclear safety channels #1 through #3. For DWK 250 nuclear safety channel #4, power level data was collected from 200 kW to 5.7 MW. (See attached figures showing linearity measurements for DWK 250 nuclear safety channels #1, 2, and 3, with a separate one for nuclear safety channel #4.)

Enclosure N1

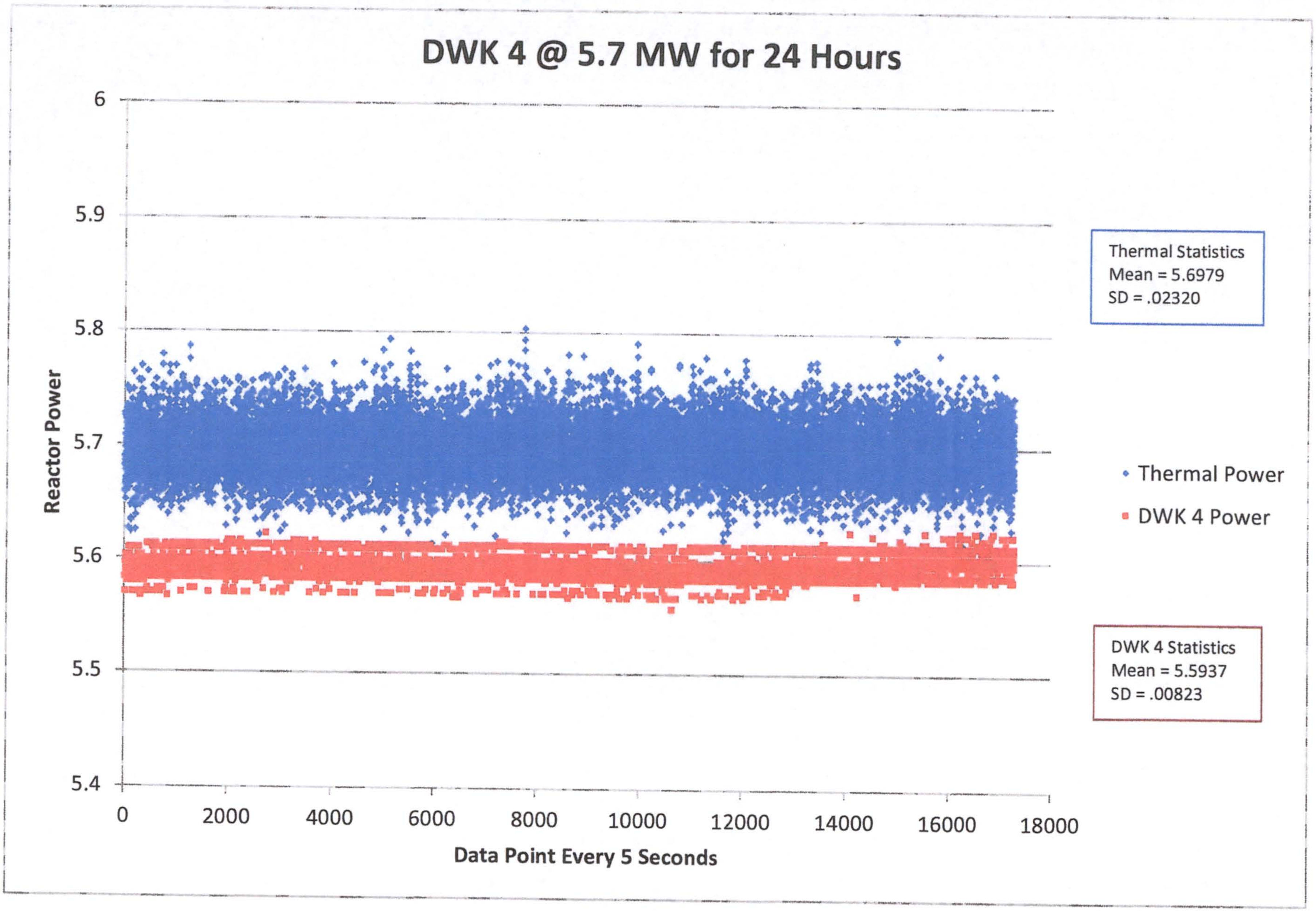




DWK 2 @ 5.7 MW for 24 Hours
6
5.9
5.8
5.7
5.6
5.5
5.4
Reactor Power
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Data Point Every 5 Seconds
Thermal Statistics
Mean = 5.6979
SD = .02320
Thermal Power
DWK 2 Power
DWK 2 Statistics
Mean = 5.6389
SD = .00900



DWK 3 @ 5.7 MW for 24 hours
Reactor Power
6
5.9
5.8
5.7
5.6
5.5
5.4
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Data Point Every 5 Seconds
Thermal Statistics
Mean = 5.6979
SD = .02320
Thermal Power
DWK 3 Power
DWK 3 Statistics
Mean = 5.7352
SD = .00857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Reactor Power
6
5.9
5.8
5.7
5.6
5.5
5.4
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Data Point Every 5 Seconds
Thermal Statistics
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Thermal Power
DWK 4 Power
DWK 4 Statistics
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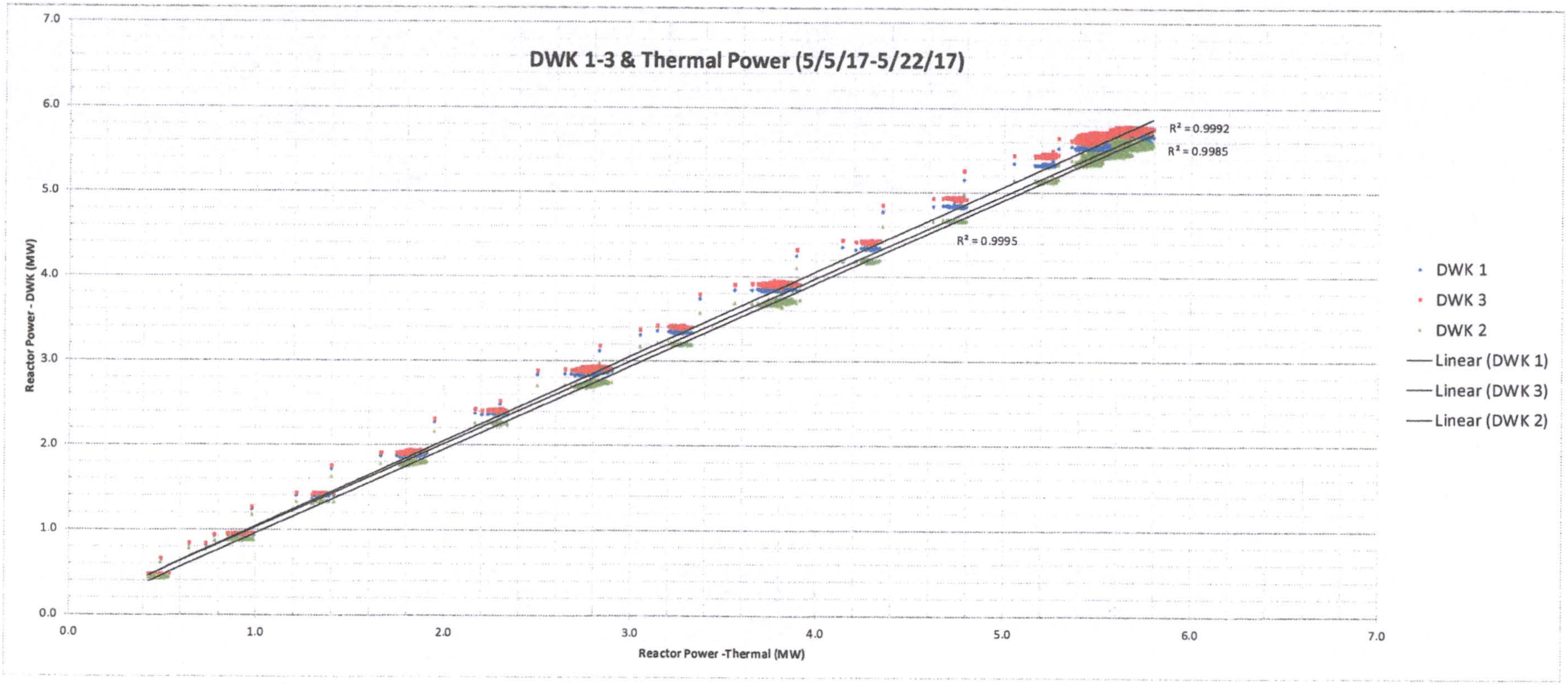
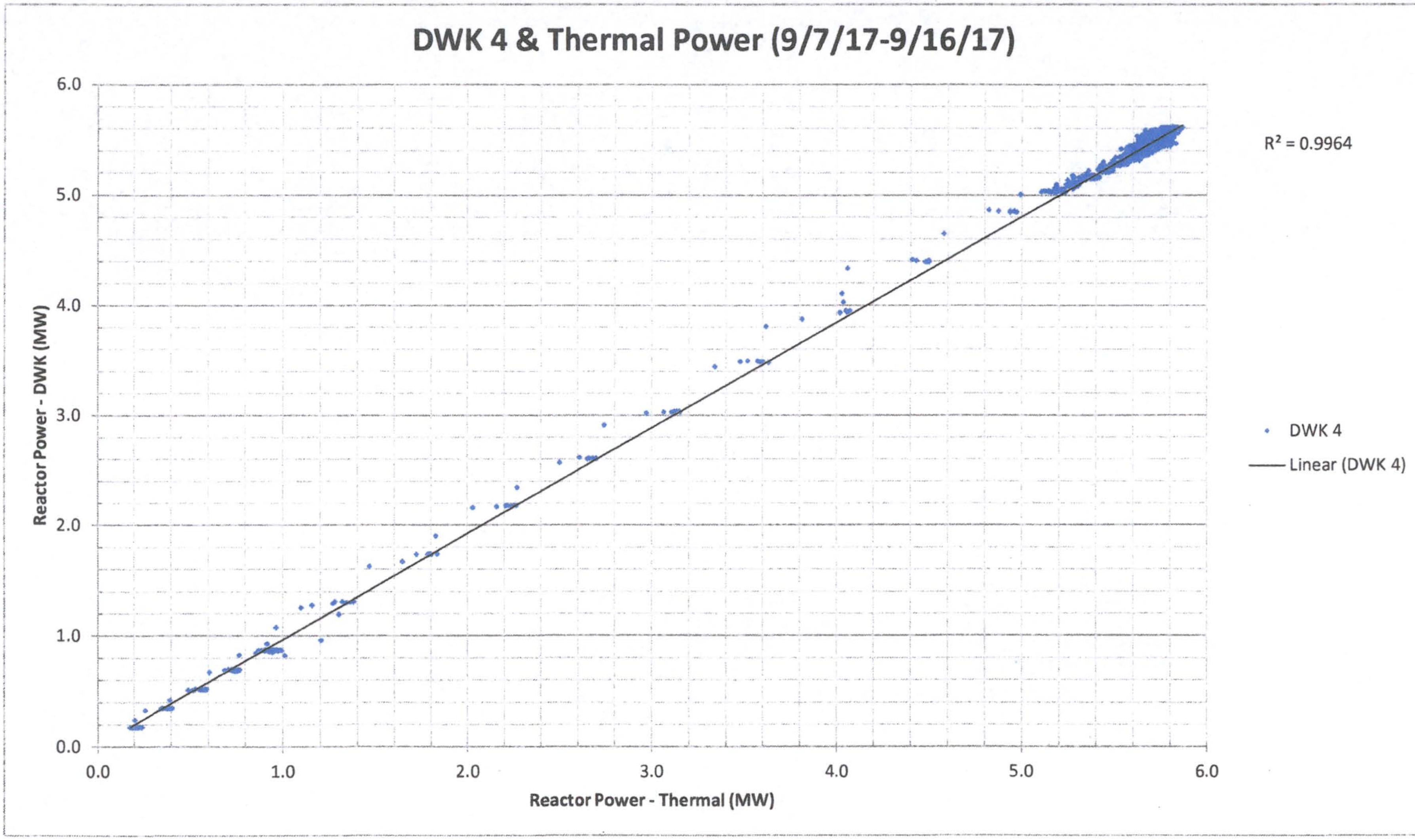
SD = .00823

Enclosure N2



Enclosure N3



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MEMORANDUM

Enclosure O

To: New Nuclear Safety System QA File E-2012-1

From: Shawn Hanvy, Instrumentation Supervisor

Re: Response to RAI #7 and cyber-security question for the Mirion DWK 250

Date: October 5, 2017

The RS-232 Breakout Box and its routing of the RS-232 communication path to the Signal Distribution Module were designed to facilitate accelerated testing and parameter verification of the DWK 250s. Each DWK 250 contains a front mounted standard DB-9 type serial port connector and a wire terminal strip on the rear of the chassis for RS-232 serial interface. Only one of these communication paths can be enabled at a time. This is accomplished via a selector switch on the NK21 module, located below the RS-232 port on the front of each DWK 250 chassis.

Due to time constraints during the Nuclear Safety System build, the additional hardware needed to communicate with the DWK 250 was never constructed. To ensure that a computer is not connected to the DWK 250 and to help prevent any path for cyber-security concerns, the rear communication path is disabled and the front RS-232 ports are physically secured. A capture device physically secures the front RS-232 port and disables the rear communication path of the DWK 250. The device physically holds the selector switch in the position to enable the front port, and covers the entire front RS-232 DB-9 port. The Reactor Operator, who remains in the control room, ensures that the capture device stays secured in place. This capture device, which is held in place with security screws, serves as an additional precaution to prevent unauthorized changes, beyond those provided by the NS01 key switch module. The NS01 module on the DWK 250 provides two key switches that require security keys to be inserted and turned to enable testing and to allow parameter settings to be modified. The key that allows parameter changes is indicated by a red dot and is referred to as the red key. This red key, and the tool to remove the capture cover, are stored in the KeyWatcher cabinet in the Operations Office and have access limited to only a few qualified persons.

All parameter verification and set-point adjustments on the DWK 250 will be carried out via the front panel display. No computers will be connected to the DWK 250 and all parameters must be verified prior to any reactor startup. The Reactor Operator will ensure that the front covers remain on and that no one will attempt to plug any device into the ports.

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MEMORANDUM

Enclosure P

To: New Nuclear Safety System QA File E-2012-1

From: John Foster, Deputy Director of Reactor Operations

Re: System Response Time Estimation and Verifications for the New Nuclear Safety System

Date: 7 October 2017

1. Initial design considerations used historical data to determine the typical blade drop times of a blade from full out to its 80 percent inserted position proximity switch to be 600 ms for the existing system. This time included all electrical and mechanical components from initiating event until the blade is inserted 80% full in.
2. The design of the new magnet power supplies assumed the release time of the mechanical relays being the limiting component at a 10 ms release time. Actual measurements captured on an oscilloscope resulted in a 2.67 ms response time of the entire magnet power supply; however our design considerations continued to assume the conservative 10 ms response time for the new magnet power supplies.
3. The scram logic cards were evaluated based on component level datasheets. The resulting calculation estimated a scram logic card response time of 0.19 ms. Actual measurements captured on an oscilloscope resulted in a 0.038 ms transit time; however our design considerations continued to assume the conservative 0.19 ms transit time for the scram logic cards.
4. The overall predicted scram response time was the sum of the above at 610.19 ms.
5. Once the entire system was fabricated, the actual system response time was measured. Reactor shim blade #1 was selected for the measurement, as its history showed it being the blade with the longest current drop time. The existing system measured a response time of 470 ms. The new system was connected to blade #1 and response time was measured five times. This resulted in measured blade drop times of 445 ms, 446 ms, 447 ms, 446 ms, and 447 ms.
6. The attached two-page internal memo shows the time response estimations used during the design phase. Also attached is an email correspondence which documents the actual as-built blade drop time results using the new system.
7. The supplemental information submitted on 6 July 2017 (ADAMS Accession No. ML17193A188) is correct in that the actual system response time was determined to be no more than 500 ms.

NUCLEAR REACTOR LABORATORY
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Activation Analysis
Coolant Chemistry
Nuclear Medicine
Reactor Engineering

Time Response Estimations:

The total time response estimations for the present safety system hardware consist of a few sequential hardware components, the integration of which provide the safety system hardware response time. Hardware response time shall be defined as the conservative estimations of the full system response time are calculated below. Associated data from each subsystem are available in the appendix.

Timeline:

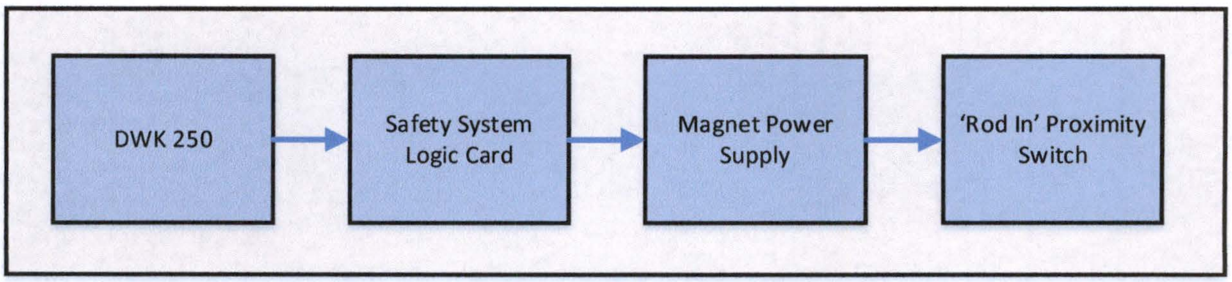

Figure 1: Time Response Event Tree

The time response of the system starts at the contact closure of a scram-causing condition at the DWK 250. From there, the propagation of the scram causing condition passes through voting logic between two safety system control cards. Finally an output from the safety system removes power to the magnet power supplies, effectively removing drive current to the blade-carrying electromagnets. The total projected delay time for this system in time response estimation is calculated below

Safety System Logic Card:
The longest scram condition path through the safety system logic card is approximate **0.19 ms** (milli-seconds), evaluated from component level datasheets. This is mostly derived from the input and output opto-couplers, operating in the negative logic state, as system inputs are in a powered state during normal reactor operation.

Magnet Power Supply:
The magnet power supply topology features a relay contact for removing drive current to the corresponding reactor electromagnet. The response time from the corresponding scram input until magnet power is removed is mostly limited by the relay[1] response time, which, worst-case, has a listed **10 ms** (millisecond) release time. Data captures of the unit operation point to the system response being closer to 2.67 ms, but for worst case estimation 10 ms will be used for this report. An oscilloscope capture of the system response is included below, indicating a 2.67 ms response time between scram condition and removal of magnet power.

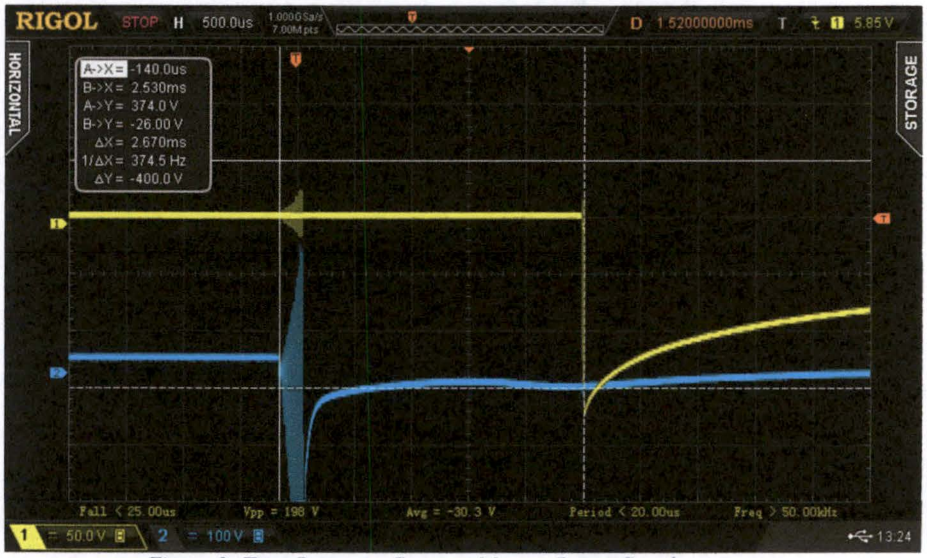

Figure 2: Time Response Capture, Magnet Power Supply

Rod-In Proximity Switch:
The completion of a scram condition, for the purposes of system response timing occurs when a proximity switch is tripped at 80% insertion of a shim-blade. This historically occurs within **600 ms**, as recorded from our blade drop time tests.

Conclusion:
The conservative estimation for system response time is calculated as the integration of the worst case response from the series system elements. The projected conservative estimation for the safety system response time **610.19 milliseconds.**

---

[1] IDEC relay, 24VDC https://www.idec.com/language/english/catalog/Relays/RJSeries.pdf.

John P Foster

'rom: Kouttron <kouttron@mit.edu>
Sent: Tuesday, May 02, 2017 6:22 PM
To: Al Queirolo; Sarah M. Don; John P Foster
Cc: Shawn Hanvy
Subject: Blade drop tests with new safety system

Hi All,

Just wanted to keep you in the loop, earlier today we successfully tested the new safety system triggering a blade drop and the existing blade drop timer hardware, we completed 5 tests on blade 1, with a dropout listed below:

Test 1: 0.445 Sec
Test 2: 0.446 Sec
Test 3: 0.447 Sec
Test 4: 0.446 Sec
Test 5: 0.447 Sec

This compares to a 0.470 Second drop time on the same blade in the same conditions using the existing system. All appropriate wire removal / reinstall forms have been completed, and a logbook entry for the test vas made

Thanks,
-Dane

Enclosure Q

New Nuclear Safety System Global Test Special Procedure

Acceptance Criterion: All steps must be completed as described.

Equipment: Calibrated digital voltmeter (Calibration Due Date 03/07/2018)

Initial Condition Checks

E 1. Ensure all four DWK 250 chassis are on by observing the three green lights on each of the NN53 power supply modules are illuminated.

E 2. Using a calibrated digital voltmeter, check and record the internal voltages at the test jacks 0 and U on each of the NS01 module.

	Ch. #1	Ch. #2	Ch. #3	Ch. #4
i. +15 V (± 0.30 V):	15.03	15.02	15.07	15.05
ii. -15 V (± 0.30 V):	-15.05	-15.05	-15.02	-15.00
iii. +5 V (± 0.10V):	4.996	4.996	4.997	4.970

E 3. Verify and clear any stored faults in the DWK 250

E 4. Clear any locked-in alarms on the LED Scram Display module.

E 5. Ensure the Key Switch Module's Reactor Operating Mode Key Switch is in "Full Power Operation".

E 6. Ensure all keys are removed from each DWK 250's NS01 module.

DWK 250 Parameter Verification

NOTES

- *If the values between TK 250 keypad panel and "Expected Value" agree, initial in the "Actual Value" Column of the Parameters List.*
- *If the values between TK 250 keypad panel and "Expected Value" differ, write the displayed value in the "Actual Value" Column of the Parameters List and inform the Instrumentation Supervisor.*
- *Parameters will appear on the TK 250 keypad panel in the same order as they appear on the parameter list page.*
- *Values can be either a number or character.*

_____ 1. Obtain Parameters List in control room.

_____ 2. At the TK 250 keypad panel:

- _____ A. Press right arrow until "Parameters" appears.
- _____ B. Press down arrow until "General Settings" appears.
- _____ C. Press Enter to cycle through all "General Settings" parameters.
- _____ D. As each "General Settings" parameter appears, verify it matches the corresponding parameter under the "1. General Settings" on the Parameter list. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

  CH 1. _________

  CH 2. _________

  CH 3. _________

  CH 4. _________

_____ 3. At the TK 250 keypad panel:

- _____ A. Press Exit until "General Settings" appears.
- _____ B. Press down arrow until "Time Constants" appears.
- _____ C. Press Enter to cycle through all "Time Constants" parameters.
- _____ D. As each "Time Constant" parameter appears, verify it matches the corresponding parameter under the "2. Time Constants" on the Parameter List. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

  CH 1. _________

  CH 2. _________

  CH 3. _________

  CH 4. _________

_____ 4. At the TK 250 keypad panel:

- _____ A. Press Exit until "Time Constants" appears.
- _____ B. Press down arrow until "Voltage Monitoring" appears.
- _____ C. Press Enter to cycle through all "Voltage Monitoring" parameters.

___ D. As each "Voltage Monitoring" parameter appears, verify it matches the corresponding parameter under the "3. Voltage Monitoring" on the Parameter List. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

CH 1. ______

CH 2. ______

CH 3. ______

CH 4. ______

___ 5. At the TK 250 keypad panel:

___ A. Press Exit until "Voltage Monitoring" appears.

___ B. Press down arrow until "Alarms" appears.

___ C. Press Enter to cycle through all "Alarms" parameters.

___ D. As each "Alarm" parameter appears, verify it matches the corresponding parameter under the "4. Alarms" on the Parameter List. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

CH 1. ______

CH 2. ______

CH 3. ______

CH 4. ______

___ 6. At the TK 250 keypad panel:

___ A. Press Exit until "Alarms" appears.

___ B. Press down arrow until "Analog Outputs" appears.

___ C. Press Enter to cycle through all "Analog Outputs" parameters.

___ D. As each "Analog Outputs" parameter appears, verify it matches the corresponding parameter under the "5. Analog Outputs" on the Parameter List. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

CH 1. ______

CH 2. ______

CH 3. ______

CH 4. ______

✓

__E__ 7. At the TK 250 keypad panel:

- __E__ A. Press Exit until "Analog Outputs" appears.
- __E__ B. Press down arrow until "Select Dimensions" appears.
- __E__ C. Press Enter to cycle through all "Select Dimensions" parameters.
- __E__ D. As each "Dimensions" parameter appears, verify it matches the corresponding parameter under the "6. Select Dimensions" on the Parameter List. Once a channel is complete, initial below. If there are any discrepancies, note at the end of this checklist.

  CH 1. __E__

  CH 2. __E__

  CH 3. __E__

  CH 4. __E__

__E__ 8. At the TK 250 keypad panel, press Exit until "Neutron Flux" appears.

Analog Period Meter Check and Calibration

__E__ 1. Insert black Test Key into the S1 slot on the NS01 module and turn clockwise.

__E__ 2. At the TK 250 keypad panel for all channels:

- __E__ A. Press right arrow until "Testing" appears.
- __E__ B. Press down arrow until "Simulation" appears.
- __E__ C. Press Enter until "Analog output 2 normal" appears.
- __E__ D. Press down arrow until "Analog output 2 simulated" appears.
- __E__ E. Press Enter until "Analog output 2 = X.XXXe+XX" appears. (Value can be anything.)
- __E__ F. Use right, left, down, and up arrows to input Analog output 2 value of "1.920e-02."
- __E__ G. Press Store.

_Ɛ_ 2. At the DWK 250's NA06 edgewise meter and the console analog meter, verify period is equal to 50 sec (+/- 5):

Ch 1. 50 sec Analog Meter 50 sec

Ch 2. 50 sec Analog Meter 50 sec

Ch 3. 50 sec Analog Meter 50 sec

Ch 4. 50 sec Analog Meter 50 sec

_Ɛ_ 3. Verify the console analog period meter equals 50 sec (+/- 5):

Ch 1. 50 sec

Ch 2. 50 sec

Ch 3. 50 sec

Ch 4. 50 sec

_Ɛ_ 4. At the TK 250 keypad panel for all channels:

_Ɛ_ A. Press Enter until "Analog output 2 = 1.920e-02" appears.

_Ɛ_ B. Press right, left, up and down arrows to input an analog output 2 value of "8.940e-02."

_Ɛ_ C. Press Store.

_Ɛ_ 5. At the NA06 panel, verify period is equal to 11 sec (+/- 1):

Ch 1. 11.2 sec

Ch 2. 11.1 sec

Ch 3. 11.3 sec

Ch 4. 11.1 sec

_Ɛ_ 6. Verify the Console analog period meter equals 11 sec (+/- 1):

Ch 1. 11 sec

Ch 2. 11 sec

Ch 3. 11 sec

Ch 4. 11 sec

___ 7. At the TK 250 keypad panel for all channels:

___ A. Press Enter until "Analog output 2 simulated" appears.

___ B. Press down arrow until "Analog output 2 normal" appears.

___ C. Press Exit until "Neutron Flux" appears.

___ 8. Verify the console analog meter and NA06 analog meters return to normal value.

Measuring DWK 250 Range Change-Over

___ 1. At the TK 250 keypad panel for Channel 1:

___ A. Press right arrow until "Testing" appears.

___ B. Press down arrow until "Test Generators" appears.

___ C. Press Enter until "AC Input Test" appears

___ D. Press down arrow until "AC input test= AC" appears.

___ E. Press Store.

___ F. Press Exit until "Neutron Flux" appears

___ 2. Using a voltmeter, monitor voltage at the NA 33 module's U1 and 0 jacks.

___ 3. Turn the "Test" potentiometer at the NA33 module counter-clockwise and monitor that the measuring range change over occurs at 0.6V (+/- .2V) for at least two changes on the NB22 Module (LED lights will change).

___ 4. Turn the "Test" potentiometer clockwise and monitor that the measuring range change over occurs at 2.5V (+/-0.2V) for at least two changes.

___ 5. Turn the "Test" Potentiometer all the way clockwise (feel for slight click).

___ 6. At the TK 250 keypad panel:

___ A. Press right arrow until "Testing" appears.

___ B. Press down arrow until "Test Generators" appears.

___ C. Press Enter until "AC Input Test= AC" appears.

___ D. Press down arrow until "AC input test= off" appears.

___ E. Press Store.

___ F. Press Exit until "Neutron Flux" appears.

___ 7. Remove black Test Key from the Channel #1 NS01 module, and insert it into the next channel to be tested.

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_E_ 8. Repeat steps 1-7 for Channel 2.

_E_ 9. Repeat steps 1-7 for Channel 3.

_E_ 10. Repeat steps 1-7 for Channel 4.

DWK 250 Low Count Rate Scram and Alarm Test

(Note: This section is to be performed when the reactor is shut down.)

_E_ 1. At the TK 250 keypad panel for all channels:

- _E_ A. Press right arrow until "Testing" appears.
- _E_ B. Press down arrow until "Simulation" appears.
- _E_ C. Press Enter until "Pulse count normal" appears.
- _E_ D. Press down arrow until "Pulse count simulated" appears.
- _E_ E. Press Enter until "Pulse count = X.XXX e XX" appears (value can be anything).
- _E_ F. Use right, left, up and down arrows to input a pulse count of "0.000e+00."
- _E_ G. Press Store.
- _E_ H. Press Exit until "Neutron Flux" appears.

_E_ 2. Verify "Low Count Rate" alarm comes in for all 4 channels at the LED Scram Display module and at the Safety System Monitoring & Status Display PLC.

Ch. 1: _E_

Ch. 2: _E_

Ch. 3: _E_

Ch. 4: _E_

_E_ 3. At the TK 250 keypad panel for all channels:

- _E_ A. Press right arrow until "Testing" appears.
- _E_ B. Press down arrow until "Simulation" appears.
- _E_ C. Press Enter until "Pulse count simulated" appears.
- _E_ D. Press down arrow until "Pulse count normal" appears.
- _E_ E. Press Exit until "Neutron Flux" appears.

✓

Ɛ 4. At the LED Scram Display module, clear all locked-in alarms by pressing the red channel reset buttons.

Ɛ 5. Check all PLC alarms clear.

DWK 250 Short Period Trip Signal Test

Ɛ 1. Insert black Test Key into the S1 slot on the NS01 module and turn clockwise.

Ɛ 2. At the TK 250 keypad panel for all channels:

Ɛ A. Press right arrow until "Parameters" appears.

Ɛ B. Press down arrow until "General Settings" appears.

Ɛ C. Press Enter until "Nf. Calibr. factor" appears and record values:

Ch.1: $1.07e^{-7}$

Ch.2: $5.07e^{-8}$

Ch.3: $1.304e^{-7}$

Ch.4: $5.256e^{-8}$

Ɛ D. Press Exit until "Neutron Flux" appears.

Ɛ 3. Calculate 20% AC signal norm. value: (20/Nf. Calibr. factor).

Ch.1: 1.869×10^8

Ch.2: 3.945×10^8

Ch.3: 1.534×10^8

Ch.4: 3.805×10^8

Ɛ 4. Calculate 70% AC signal norm. value: (70/Nf. Calibr. factor).

Ch.1: 6.542×10^8

Ch.2: 13.81×10^8

Ch.3: 5.368×10^8

Ch.4: 13.32×10^8

E 5. Once period has returned to infinite, at the TK 250 keypad panel for all channels:

E A. Press right arrow until "Testing" appears.

E B. Press down arrow until "Simulation" appears.

E C. Press Enter until "AC signal norm. normal" appears.

E D. Press down arrow until "AC signal norm. simulated" appears.

E E. Press Enter until "AC signal norm = X.XXX e –XX" appears. (Value can be anything.)

E F. Use right, left, up and down arrows to input "20% AC signal norm" value (from step 2).

E G. Press Store.

E H. Press Exit until "Neutron Flux" appears.

E 6. Wait for period indication to return to infinite, and then verify console analog meter and neutron flux (on TK 250 keypad panel) read 20% (+/- 1%) for all channels:

Ch.1: Flux:	20 %	Analog Meter:	20 %
Ch.2: Flux:	19.99 %	Analog Meter:	20 %
Ch.3: Flux:	20.00 %	Analog Meter:	21 %
Ch.4: Flux:	20.00 %	Analog Meter:	21 %

E 7. At the LED Scram Display module, clear all alarms by pressing the red "channel reset" buttons. (Note: the "Trouble" alarm will stay in due to the channel still being in test.)

✓ 8. Once period has returned to infinite, at the TK 250 keypad panel for all channels:

E A. Press right arrow until "Testing" appears.

E B. Press down arrow until "Simulation" appears.

E C. Press Enter until "AC signal norm. = (20% AC Signal norm value)" appears.

E D. Use right, left, up and down arrows to input "70% AC signal norm" value (from step 3).

NOTE: *Before performing step "E", locate the analog period meter on the NA06 module and the #4 LED and #6 LED on the NB28 module. Upon pressing Store, monitor period at the analog meter on the NA06 module. The #6 LED will illuminate first. When period reaches 10-11 sec, the #4 LED will illuminate on the NB28 module, signaling that the short period alarm was received. This process will happen VERY quickly.*

E E. Press Store.

✓

_✓_ 9. Monitor period on the analog meter on the NA06 module and the LEDs on the NB28 module. When period is between 10-11 seconds, verify LED #4 illuminates on NB28 module:

Ch. 1: ✓

Ch. 2: ✓

Ch. 3: ✓

Ch. 4: ✓

_N/A_ 10. If change in LED #4 missed, repeat steps 5-9.

_✓_ 11. Verify the "Short Period" alarm lights illuminate on the LED Scram Display module:

Ch. 1: ✓

Ch. 2: ✓

Ch. 3: ✓

Ch. 4: ✓

_✓_ 12. At the TK 250 keypad panel for all channels:

_✓_ A. Press Exit until "neutron flux" appears.

_✓_ 13. Verify console analog meter and neutron flux (at TK 250 keypad panel) read 70% (+/- 10%) for all channels.

Ch.1: Flux:	70.05 %	Analog Meter:	75 %
Ch.2: Flux:	70.02 %	Analog Meter:	75 %
Ch.3: Flux:	70.00 %	Analog Meter:	75 %
Ch.4: Flux:	70.01 %	Analog Meter:	75 %

_E_ 14. At the LED Scram Display module, clear all alarms by pressing the red "channel reset" buttons. (Note: the "Trouble" alarm will stay in due to the channel still being in test.)

✓

DWK 250 High Power Warning and Trip Signal Test

_E_ 1. At the TK 250 keypad panel for all channels:

- _E_ A. Press right arrow until "Parameters" appears.
- _E_ B. Press down arrow until "General Settings" appears.
- _E_ C. Press Enter until "Nf. Calibr. factor" appears and record value: (**Note**: *This value was previously obtained from step 1 of the "DWK 250 Short Period Alarm Test" and can be copied over*).

  Ch.1: 1.070×10^{-7}

  Ch.2: 5.070×10^{-8}

  Ch.3: 1.304×10^{-7}

  Ch.4: 5.256×10^{-8}

- _E_ D. Press Exit until "Neutron Flux" appears.

_E_ 2. Calculate 112% AC signal norm. value: (112/Nf. Calibr. factor):

  Ch.1: 1.047 E +09

  Ch.2: 2.209E +09

  Ch.3: 8.589 E +08

  Ch.4: 2.131 E +09

_E_ 3. Once period has returned to infinite, at the TK 250 keypad panel for all channels:

- _E_ A. Press right arrow until "Testing" appears.
- _E_ B. Press down arrow until "Simulation" appears.
- _E_ C. Press Enter until "AC signal norm. = (70% AC Signal norm value)" appears.
- _E_ D. Use right, left, up and down arrows to input "112% AC signal norm" value (from step 2).
- _E_ E. Press Store. (Note: power will immediately begin to rise.)
- _E_ F. Press Exit until "neutron flux" appears.

✓

NA 4. When neutron flux reaches greater than 100%, verify high power warning comes in at console annunciator panel:

Ch. 1: ______ } Annunciator Panel simulator not yet available. [initials] 12/12/2017

Ch. 2: ______

Ch. 3: ______

Ch. 4: ______

[initials] 5. When neutron flux reaches 110% power, verify "High Power" trip signal comes in at the LED Scram Display module.

Ch. 1: [initials]

Ch. 2: [initials]

Ch. 3: [initials]

Ch. 4: [initials]

[initials] 6. Verify neutron flux (at TK 250 keypad panel) reads 112% (+/- 5%) for all channels, and console analog meter reads >100% for all channels.

Ch.1: Flux:	1.119×10^2 %	Analog Meter:	>100 %
Ch.2: Flux:	1.120×10^2 %	Analog Meter:	>100 %
Ch.3: Flux:	1.120×10^2 %	Analog Meter:	>100 %
Ch.4: Flux:	1.120×10^2 %	Analog Meter:	>100 %

✓

DWK 250 Negative Period Check

_£_ 1. At the TK 250 keypad panel for all channels:

- _£_ A. Press right arrow until "Parameters" appears.
- _£_ B. Press down arrow until "General Settings" appears.
- _£_ C. Press Enter until "Nf. Calibr. factor" appears and record value: (**Note**: *This value was previously obtained from step 1 of the "DWK 250 Short Period Alarm Test" and can be copied over*).

  Ch.1: 1.070×10^{-7}

  Ch.2: 5.070×10^{-8}

  Ch.3: 1.304×10^{-7}

  Ch.4: 5.256×10^{-8}

- _£_ D. Press Exit until "Neutron Flux" appears.

_£_ 2. Calculate 50% AC signal norm. value: (50/Nf. Calibr. factor):

  Ch.1: 4.673 E+08

  Ch.2: 9.862 E+08

  Ch.3: 3.834 E+08

  Ch.4: 9.513 E+08

_£_ 3. At the TK 250 keypad panel for all channels:

- _£_ A. Press right arrow until "Testing" appears.
- _£_ B. Press down arrow until "Simulation" appears.
- _£_ C. Press Enter until "AC signal norm. = (112% AC signal norm value)" appears.
- _£_ D. Press right, left, up and down arrows until input "AC signal norm. = (50% AC signal norm.)" (from step 2).
- _£_ E. Press Store. (Note: this will cause period to become negative).
- _£_ F. Press Exit until "Neutron Flux" appears.

__[initials]__ 4. Verify negative period for all channels on the console analog meter:

Ch. 1: __[initials]__

Ch. 2: __[initials]__

Ch. 3: __[initials]__

Ch. 4: __[initials]__

__[initials]__ 5. Verify console analog meter and neutron flux (on the TK 250 keypad panel) read approx. 50% (+/- 10%) for all channels:

Ch.1: Flux: 50 %	Analog Meter: 50 %
Ch.2: Flux: 50 %	Analog Meter: 50 %
Ch.3: Flux: 50 %	Analog Meter: 50 %
Ch.4: Flux: 50 %	Analog Meter: 50 %

__[initials]__ 6. At the TK 250 keypad panel for each channel:

__[initials]__ A. Press right arrow until "Testing" appears.
__[initials]__ B. Press down arrow until "Simulation" appears.
__[initials]__ C. Press Enter until "AC signal norm. simulated" appears.
__[initials]__ D. Press down arrow until "AC signal norm. normal" appears.
__[initials]__ E. Press Enter.
__[initials]__ F. Press Exit until "Neutron Flux" appears.

__[initials]__ 7. At the LED Scram Display module, clear all locked-in alarms by pressing the red channel reset buttons.

__[initials]__ 8. If pausing the checklist, turn the black Test Key counter-clockwise and remove it; otherwise continue with the black Test Key switch at the 12 o'clock position.

Coincidence Check

NOTES

- *Certain steps in this procedure call for changing a binary output. To change a binary output, at the TK 250 keypad panel for the selected channel:*
    - *Press right arrow until "Testing" appears.*
    - *Press down arrow until "Binary Outputs" appears.*
    - *Press Enter until "Binary Output X → X" appears.*
    - *The first number is the specific binary output that is being tested (1-6, 8). This number can be cycled by pressing the Enter button.*
    - *Press down arrow to change the Binary output to say "Binary Output X → 1"*
    - *The second number (the number after the right arrow) is the actual binary output. This can either be 1 or 0. A value of 1 puts the specific condition in and a value of 0 removes it. This value can be changed by pressing the up or down arrow key.*
- *To disable a binary output, at the TK 250 keypad panel for selected channel:*
    - *Press Exit to return to "Binary Outputs" screen. Pressing Exit removes the binary output to its real value and completely stops the test.*

___ 1. Place 'DWK 250 "Test" Scram Condition Scram Bypass' key switch to on.

___ 2. Ensure 'DWK 250 "Test" Scram Bypass' alarm comes in on the console annunciator panel.

___ 3. At the LED Scram Display module:

___ A. Clear all locked-in alarms by pressing the red channel reset buttons.

___ 4. Obtain a reactor start and reset rundown relays.

NOTE: The following two steps are applicable only post-installation of the new NSS into the control room instrumentation cabinets.

N/A

___ 5. Shim out all blades to 1.5" and until the rod bottom blue light clears.

___ 6. Shim out the regulating rod to 1.5".

___ 7. Change Channel 1 binary output 2 to 1.

___ 8. Verify "High Power" alarm comes in on LED Scram Display module for Channel 1.

___ 9. Change Channel 2 binary output 2 to 1.

___ 10. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

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___ 11. Verify reactor scram alarm comes in, rundown relays dropout, and all blades and the regulating rod go in to 0" (or blade-in indicator lights on NSS simulator panel).

___ 12. Disable Channel 2 binary outputs.

___ 13. At the LED Scram Display module:

___ A. Clear Channel 2 locked-in alarms by pressing the red channel reset button.

___ 14. Obtain a reactor start.

___ 15. Change Channel 3 binary output 2 to 1.

___ 16. Verify "High Power" alarm comes in on LED Scram Display module for Channel 3.

___ 17. Verify reactor scram alarm comes in.

___ 18. Disable Channel 3 binary outputs.

___ 19. At the LED Scram Display module:

___ A. Clear Channel 3 locked-in alarms by pressing the red channel reset button.

___ 20. Obtain a reactor start.

___ 21. Change Channel 4 binary output 2 to 1.

___ 22. Verify "High Power" alarm comes in on LED Scram Display module for Channel 4.

___ 23. Verify reactor scram alarm comes in.

___ 24. Disable Channel 1 binary outputs.

___ 25. At the LED Scram Display module:

___ A. Clear Channel 1 locked-in alarms by pressing the red channel reset button.

___ 26. Obtain a reactor start.

___ 27. Change Channel 2 binary output 2 to 1.

___ 28. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

___ 29. Verify reactor scram alarm comes in.

___ 30. Disable Channel 2 binary outputs.

___ 31. At the LED Scram Display module:

___ A. Clear Channel 2 locked-in alarms by pressing the red channel reset button.

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✓ 32. Obtain a reactor start.

✓ 33. Change Channel 3 binary output 2 to 1.

✓ 34. Verify "High Power" alarm comes in on LED Scram Display module for Channel 3.

✓ 35. Verify reactor scram alarm comes in.

✓ 36. Disable Channel 4 binary outputs.

✓ 37. At the LED Scram Display module:

✓ A. Clear Channel 4 locked-in alarms by pressing the red channel reset button.

✓ 38. Obtain a reactor start.

✓ 39. Change Channel 2 binary output 2 to 1.

✓ 40. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

✓ 41. Verify reactor scram alarm comes in.

✓ 42. Disable all binary outputs.

✓ 43. At the LED Scram Display module:

✓ A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

✓ 44. Obtain a reactor start and reset the rundown relays.

tw 45. Repeat steps 7-~~43~~ 44 12/13/2017 using binary output 3 instead of 2 and checking for the "Low Count Rate" alarm on the LED Scram Display module.

tw 46. Obtain a reactor start and reset the rundown relays.

tw 47. Repeat steps 7-44 using binary output 4 instead of 2 and checking for the "Short Period" alarm on the LED Scram Display module.

tw 48. Obtain a reactor start and reset the rundown relays.

tw 49. Repeat steps 7-43 using binary output 8 instead of 2 and checking for the "Trouble" alarm on the LED Scram Display module.

tw 50. Place 'DWK 250 "Test" Scram Condition Scram Bypass' key switch to off and verify 'DWK 250 "Test" Scram Bypass' alarm clears.

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tw 51. At the LED Scram Display module:

- tw A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

tw 52. Obtain a reactor start and reset the rundown relays.

tw 53. Repeat steps 7-44 using binary output 1 instead of 2 and checking for the "Trouble" alarm on the safety system condition panel.

tw 54. At the LED Scram Display module:

- tw A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

Display Test

tw 1. At the TK 250 panel for channel 1:

- tw A. Press exit until "Testing" appears.
- tw B. Press down arrow until "Display" appears.
- tw C. Verify all pixels on the TK 250 panel are active.
- tw D. Press exit until "Neutron Flux" appears.

tw 2. Repeat step 1 for channel 2.

tw 3. Repeat step 1 for channel 3.

tw 4. Repeat step 1 for channel 4.

<100 kW Key Switch Module – Reactor Operating Mode Switch

tw 1. Place Reactor Operating Mode key switch in <100 kW Operation mode.

tw 2. Verify blue "<100 kW Operation" LED illuminates.

tw 3. Verify the Low Flow and Low Pressure Reactor Scrams are automatically bypassed. (**NOTE:** Verification of bypass of the Low Pressure Reactor Scrams is applicable only post-installation of the new NSS into the control room instrumentation cabinets.)

DWK 250 High Power Alarm Test (<100 kW Operation Mode)

tw 1. At the TK 250 keypad panel for all channels:

- tw A. Press right arrow until "Parameters" appears.
- tw B. Press down arrow until "General Settings" appears.
- tw C. Press Enter until "Nf. Calibr. factor" appears and record value:

Ch.1: 1.091 E -7

Ch.2: 5.070 E -8

Ch.3: 1.321 E -7

Ch.4: 5.256 E -8

- tw D. Press Exit until "Neutron Flux" appears.

tw 2. Calculate 80 kW Pulse Count value: (1.356/Nf. Calbr. factor):

Ch.1: 1.244 E 7

Ch.2: 2.675 E 7

Ch.3: 1.026 E 7

Ch.4: 2.580 E 7

tw 3. Once period has returned to infinite, at the TK 250 keypad panel for all channels:

- tw A. Press right arrow until "Testing" appears.
- tw B. Press down arrow until "Simulation" appears.
- tw C. Press Enter until "Pulse Count. = (80 kW Pulse Count)" appears.
- tw D. Use right, left, up and down arrows to input "80 kW Pulse Count" value (from step 2).
- tw E. Press Store. (Note: power will immediately begin to rise.)
- tw F. Press Exit until "Neutron Flux" appears.

TW 4. Verify "High Power" Scram comes in on the LED Scram Display module.

Ch. 1: ✓

Ch. 2: ✓

Ch. 3: ✓

Ch. 4: ✓

TW 5. Verify neutron flux (at TK 250 keypad panel) reads 1.356% (+/- 0.5%) for all channels.

Ch.1: Flux: 1.357 %

Ch.2: Flux: 1.356 %

Ch.3: Flux: 1.358 %

Ch.4: Flux: 1.356 %

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Coincidence Check (<100 kW Operation Mode)

NOTES

- *Certain steps in this procedure call for changing a binary output. To change a binary output, at the TK 250 keypad panel for the selected channel:*
    - *Press right arrow until "Testing" appears.*
    - *Press down arrow until "Binary Outputs" appears.*
    - *Press Enter until "Binary Output X → X" appears.*
    - *The first number is the specific binary output that is being tested (1-6, 8). This number can be cycled by pressing the Enter button.*
    - *Press down arrow to change the Binary output to say "Binary Output X → 1"*
    - *The second number (the number after the right arrow) is the actual binary output. This can either be 1 or 0. A value of 1 puts the specific condition in and a value of 0 removes it. This value can be changed by pressing the up or down arrow key.*
- *To disable a binary output, at the TK 250 keypad panel for selected channel:*
    - *Press Exit to return to "Binary Outputs" screen. Pressing Exit removes the binary output to its real value and completely stops the test.*

tw 1. Place 'DWK 250 "Test" Scram Condition Scram Bypass' key switch to on.

tw 2. Ensure 'DWK 250 "Test" Scram Bypass' alarm comes in on the console annunciator panel.

tw 3. At the LED Scram Display module:

tw A. Clear all locked-in alarms by pressing the red channel reset buttons.

tw 4. Obtain a reactor start and reset rundown relays

NOTE: The following two steps are applicable only post-installation of the new NSS into the control room instrumentation cabinets.

tw 5. Shim out all blades to 1.5" and until the rod bottom blue light clears.

tw 6. Shim out the regulating rod to 1.5".

tw 7. Change Channel 1 binary output 1 to 1.

tw 8. Verify "High Power" alarm comes in on LED Scram Display module for Channel 1.

tw 9. Change Channel 2 binary output 1 to 1.

tw 10. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

tw 11. Verify reactor scram alarm comes in, rundown relays dropout, and all blades and the regulating rod go in to 0" (or blade-in indicator lights on NSS simulator panel).

tw 12. Disable Channel 2 binary outputs.

tw 13. At the LED Scram Display module:

tw A. Clear Channel 2 locked-in alarms by pressing the red channel reset button.

tw 14. Obtain a reactor start.

tw 15. Change Channel 3 binary output 1 to 1.

tw 16. Verify "High Power" alarm comes in on LED Scram Display module for Channel 3.

tw 17. Verify reactor scram alarm comes in.

tw 18. Disable Channel 3 binary outputs.

tw 19. At the LED Scram Display module:

tw A. Clear Channel 3 locked-in alarms by pressing the red channel reset button.

tw 20. Obtain a reactor start.

tw 21. Change Channel 4 binary output 1 to 1.

tw 22. Verify "High Power" alarm comes in on LED Scram Display module for Channel 4.

tw 23. Verify reactor scram alarm comes in.

tw 24. Disable Channel 1 binary outputs.

tw 25. At the LED Scram Display module:

tw A. Clear Channel 1 locked-in alarms by pressing the red channel reset button.

tw 26. Obtain a reactor start.

tw 27. Change Channel 2 binary output 1 to 1.

tw 28. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

tw 29. Verify reactor scram alarm comes in.

tw 30. Disable Channel 2 binary outputs.

tw 31. At the LED Scram Display module:

tw A. Clear Channel 2 locked-in alarms by pressing the red channel reset button.

tw 32. Change Channel 3 binary output 1 to 1.

tw 33. Obtain a reactor start.

tw 34. Verify "High Power" alarm comes in on LED Scram Display module for Channel 3.

tw 35. Verify reactor scram alarm comes in.

tw 36. Disable Channel 4 binary outputs.

tw 37. At the LED Scram Display module:

tw A. Clear Channel 4 locked-in alarms by pressing the red channel reset button.

tw 38. Change Channel 2 binary output 1 to 1.

tw 39. Verify "High Power" alarm comes in on LED Scram Display module for Channel 2.

tw 40. Verify reactor scram alarm comes in.

tw 41. Disable all binary outputs.

tw 42. At the LED Scram Display module:

tw A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

NOTE: The remainder of this section is applicable only post-installation of the new NSS into the control room instrumentation cabinets.

N/A 43. Obtain a reactor start and reset the rundown relays.

____ 44. Repeat steps 7-43 using binary output 3 instead of 1 and checking for the "Low Count Rate" alarm on the LED Scram Display module.

____ 45. Obtain a reactor start and reset the rundown relays.

____ 46. Repeat steps 7-43 using binary output 4 instead of 1 and checking for the "Short Period" alarm on the LED Scram Display module.

____ 47. Obtain a reactor start and reset the rundown relays.

____ 48. Repeat steps 7-42 using binary output 8 instead of 1 and checking for the "Trouble" alarm on the LED Scram Display module.

____ 49. Place 'DWK 250 "Test" Scram Condition Scram Bypass' key switch to off and verify 'DWK 250 "Test" Scram Bypass' alarm clears.

N/A 50. At the LED Scram Display module:

N/A A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

N/A 51. Obtain a reactor start and reset the rundown relays.

N/A 52. At the TK 250 keypad panel for Channel 1:

N/A A. Press Exit until "Testing" appears.

B. Press down arrow until "Display" appears.

C. Verify all pixels on the TK 250 keypad panel are active.

D. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 1.

N/A 53. At the TK 250 keypad panel for Channel 2:

N/A A. Press Exit until "Testing" appears.

B. Press down arrow until "Display" appears.

C. Verify all pixels on the TK 250 keypad panel are active.

D. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 2.

N/A 54. Verify reactor scram alarm comes in.

N/A 55. At the TK 250 keypad panel for Channel 2:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 56. At the LED Scram Display module:

N/A A. Clear Channel 2 locked-in alarms by pressing the red channel reset button for Channel 2.

N/A 57. Obtain a reactor start and reset the rundown relays.

N/A 58. At the TK 250 keypad panel for Channel 3:

N/A A. Press Exit until "Testing" appears.

B. Press down arrow until "Display" appears.

C. Verify all pixels on the TK 250 keypad panel are active.

D. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 3.

N/A 59. Verify reactor scram alarm comes in.

N/A 60. At the TK 250 keypad panel for Channel 3:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 61. At the LED Scram Display module:

N/A A. Clear Channel 3 locked-in alarms by pressing the red channel reset button for Channel 3.

N/A 62. Obtain a reactor start and reset the rundown relays.

N/A 63. At the TK 250 keypad panel for Channel 4:

N/A A. Press Exit until "Testing" appears.

___ B. Press down arrow until "Display" appears.

___ C. Verify all pixels on the TK 250 keypad panel are active.

___ D. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 4.

N/A 64. Verify reactor scram alarm comes in.

N/A 65. At the TK 250 keypad panel for Channel 1:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 66. At the LED Scram Display module:

N/A A. Clear Channel 1 locked-in alarms by pressing the red channel reset button for Channel 1.

N/A 67. Obtain a reactor start and reset the rundown relays.

N/A 68. At the TK 250 keypad panel for Channel 2:

N/A A. Press right arrow until "Testing" appears.

___ B. Press down arrow until "Display" appears.

___ C. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 2.

N/A 69. Verify reactor scram alarm comes in.

N/A 70. At the TK 250 keypad panel for Channel 2:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 71. At the LED Scram Display module:

N/A A. Clear Channel 2 locked-in alarms by pressing the red channel reset button for Channel 2.

N/A 72. Obtain a reactor start and reset the rundown relays.

N/A 73. At the TK 250 keypad panel for Channel 3:

N/A A. Press right arrow until "Testing" appears.

↓ B. Press down arrow until "Display" appears.

↓ C. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 3.

N/A 74. Verify reactor scram alarm comes in.

N/A 75. At the TK 250 keypad panel for Channel 4:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 76. At the LED Scram Display module:

N/A A. Clear Channel 4 locked-in alarms by pressing the red channel reset button for Channel 4.

N/A 77. Obtain a reactor start and reset the rundown relays.

N/A 78. At the TK 250 keypad panel for Channel 2:

N/A A. Press right arrow until "Testing" appears.

↓ B. Press down arrow until "Display" appears.

↓ C. Verify "Trouble" alarm comes in on LED Scram Display module for Channel 2.

N/A 79. Verify reactor scram alarm comes in.

N/A 80. At the TK 250 keypad panel for Channel 3:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 81. At the TK 250 keypad panel for Channel 2:

N/A A. Press Exit until "Neutron Flux" appears.

N/A 82. At the LED Scram Display module:

N/A A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

N/A 83. Place 'DWK 250 "Test" Scram Condition Scram Bypass' key switch to off and verify 'DWK 250 "Test" Scram Bypass' alarm clears.

N/A 84. At the LED Scram Display module:

N/A A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

DWK 250 Watchdog Timer Check

tw 1. At the TK 250 keypad panel for Channel 1:

tw A. Press right arrow until "Testing" appears.

tw B. Press down arrow until "Watchdog" appears

tw C. Press Enter until "Test watchdog Circuit?" appears.

tw D. Press Enter.

tw 2. After ten seconds, ensure test is complete by the "Neutron Flux" screen reappearing on the TK 250 keypad panel.

tw 3. Repeat steps 1-2 for Channel 2.

tw 4. Repeat steps 1-2 for Channel 3.

tw 5. Repeat steps 1-2 for Channel 4.

tw 6. At the LED Scram Display module:

tw A. Clear all locked-in alarms by pressing the red channel reset button for each channel.

DWK 250 Key Test

tw 1. For Channel 1, remove the black Test Key from the S1 slot on the NS01 module by turning key counter-clockwise and pulling out.

tw 2. Attempt to run a Binary Output Test. At the TK 250 keypad panel for each channel:

tw A. Press right arrow until "Testing" appears.

tw B. Press down arrow until "Binary Outputs" appears.

tw C. Press Enter until "Binary Output X → X" appears

tw D. Press down arrow to attempt to alter a binary output

tw E. Ensure that a Binary Outputs cannot be changed

tw 3. Press Exit until "Neutron Flux" appears.

tw 4. Repeat steps 1-3 for Channel 2.

tw 5. Repeat steps 1-3 for Channel 3.

tw 6. Repeat steps 1-3 for Channel 4.

Magnet Power Supply Test and Verification

E 1. Place a digital current meter in series with the magnet and Magnet Power Supply.

E 2. Obtain a reactor start and reset the rundown relays.

E 3. Adjust the current output to 80 mA.

E 4. Observer that the current meter and the front panel analog meter are within a 2% agreement.

NOTE: The remainder of this section is applicable only post-installation of the new NSS into the control room instrumentation cabinets.

N/A E

____ 5. Raise the corresponding blade to 1.5 inches to clear the blade in light.

____ 6. Decrease magnet current until the blade drops.

____ 7. Decrease magnet current to zero and verify the run-down relay are actuated.

____ 8. Repeat steps 1-7 for the remaining magnets.

[signature] 12/13/17

Test completed by: Frank Warmsley, Assistant Superintendent Date

[signature] 12/13/2017

Reviewed and approved by: Edward Lau, Assistant Director of Reactor Operations Date

QA#	E-2012-1	Date
Approved		
Q/A App'l	[initials]	12/13/2017

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Activation Analysis
NTD Silicon
Nuclear Medicine
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Enclosure Q1

Memorandum

To: QA File #E-2012-1

From: E. Lau, Assistant Director of Reactor Operations

Subject: Summary of Bench Testing Results for the MIT-Developed Modules of the New Nuclear Safety System (NSS)

Date: 14 December 2017

1. Signal Distribution Module (SDM) – Testing per "Bench Testing – NSS Signal Distribution Module Verification Test" was completed 14 February 2017 using Scram Logic Cards #002 and #004. Results showed that for every given input trip signal, the correct Scram Logic Card output response was observed, confirming that the SDM meets its acceptance criteria.

2. Scram Logic Cards (SLCs) – Testing per "Bench Testing – NSS Scram Logic Card Verification Test" was completed 14 February 2017 on five Scram Logic Cards. Results showed that for every given input trip combination, the correct SLC output response was observed, and that 2-out-of-4 coincidence is achieved, confirming that the SLCs meet their acceptance criteria.

3. LED Scram Display Module – Testing per "Bench Testing – LED Scram Display Module Verification Test" was completed in two stages (2 November 2016 for the printed-circuit board, and 14 February 2017 for the assembled module). Both stages used the Logic Testing Board to simulate input from the four DWK 250 chassis. Results showed satisfactory activation of all the corresponding LED lamps, and reset with the associated Reset button. The "Lamp Test" functionality was also satisfactorily verified.

4. <100 kW Key-Switch Module –Testing per "Special Procedure for Fabrication and Testing of the <100 kW Key-Switch Module" was completed 6 December 2017. Results showed that the key switch satisfactorily switches between the Full Power Operation mode and the <100 kW Operation mode, activating and de-activating the expected scrams, bypasses, and indicator lights for each mode.

5. Magnet Power Supply Modules – Testing per "Special Procedure for Fabrication and Bench Testing the Magnet Power Supply Circuit Boards" and "Special Procedure for Fabrication and Bench Testing of the Magnet Power Supply Modules" was completed 7 December 2017. Results showed that the fabrication, visual inspection, and verification bench tests were all

completed satisfactorily for the printed-circuit boards. The assembled modules satisfactorily provide magnet current at pre-determined levels to within ±2 mA. The rundown relays on each module de-energize correctly when magnet current decreases to a point below 5 mA.

6. Rundown Relay Panel – Testing per "Special Procedure for Fabrication and Bench Testing the Rundown Relay Panel" was completed 6 December 2017. Results showed that the panel and its indicator lights were correctly wired by observing voltages at their designated target points ±0.5 volts.

7. DWK 250 "Test" Condition Scram Bypass Assembly (TCB) – Testing per "Special Procedure for Fabrication and Testing the DWK 250 'Test' Condition Scram Bypass Assembly" was completed 5 December 2017. Results showed that the assembly was constructed correctly, and its key switch satisfactorily bypassed the "Test" trip signal from the four DWK 250 chassis. Cycling the key switch between "Off" and "On" produced the expected scrams during transitions.

9. Blade Drop Timer Interface – Testing per "Special Procedure for Fabrication and Testing of the Blade Drop Timer Interface" was completed 5 December 2017. Results showed that the Interface module was constructed correctly, and its performance met acceptance criteria, providing correct inputs to activate the existing Blade Drop Timer.

10. Integrated System – Pre-installation testing per "New Nuclear Safety System Global Testing Special Procedure" was completed on 13 December 2017. The results showed that the modules of the new Nuclear Safety System, when connected together on the test rack, satisfactorily provided scram signals based on trip signals from the DWK 250 nuclear safety channels. All indicators, analog meters, alarm functions, and reset buttons worked as expected. The Safety System Monitoring & Status Display PLC was observed capable of indicating expected alarms, and showing them clearing upon reset. The integrated system, therefore, meets its pre-installation acceptance criteria.

EL/st

Enclosure Q2

6.1.3.1A DWK 250 Detector Pulse Height Discriminator Calibration

Purpose

To ensure the neutron detector discriminator voltage is set at a level that minimizes the effects of alpha, gamma, and noise currents while maximizing the current from neutrons.

NOTE: This test is a requirement of the Technical Specifications. Only one DWK 250 channel calibration should be performed at a time.

Acceptance Criteria

Set the discriminator voltage to the flattest part of the curve which has a high signal-to-noise ratio.

Prerequisites and Notes

- Record the DWK 250 channel to be tested on the data sheet.
- A minimum count rate of 1×10^3 CPS and the maximum count rate is 5×10^4 CPS
    - o If minimum count rate is not achievable, this count rate can be achieved by preforming a reactor startup and leveling power at or near 5 kW.
- A stable count rate, which is defined by:
    - o No shim blade movement (regulating rod is not included if on auto-control)
    - o Steady D_2O level in the reflector tank
    - o The average count rate of any of the four DWK 250 channels has not decreased during data collection.
- Excel spreadsheets can be used to record in lieu of handwriting *Table 1* and *Table 2*.

Procedure

_____ 1. All operations will take place at the TK 250 keypad panel for the DWK 250 channel under test unless otherwise stated in the procedure.

_____ 2. Insert the red Test key into the S2 key slot on the NS01 module and turn clockwise.

_____ 3. Press the down arrow until "Pulse Count" appears.

_____ 4. Record the pulse count on the data sheet.

_____ 5. Press the right arrow until "Diagn. Values" appears.

_____ 6. Press the down arrow until "Detector Voltage" appears.

_____ 7. Record the initial Detector Voltage on the data sheet.

_____ 8. Using the "0-1 kV" potentiometer located on the NH 32 panel, gently lower the detector voltage till it reads 0 V.

_____ 9. Press Exit until "Neutron Flux" appears.

_____ 10. Press the right arrow until "Parameters" appears.

_____ 11. Press the down arrow until "General Settings" appears.

_____ 12. Press Enter until "discriminator threshold" appears.

_____ 13. Record the current discriminator threshold voltage on the data sheet.

_____ 14. Use the right, left, up and down arrows to set the discriminator threshold voltage to 0.05 V.

_____ 15. Press Exit until "Neutron Flux" appears.

_____ 16. Press the down arrow until "Pulse Count" appears.

_____ 17. Record the channel CPS on *Table 1*.

_____ 18. Repeat steps 10-12 and 14-17 by increasing the discriminator voltage in 0.05 V increments and recording corresponding CPS on *Table 1* until CPS reaches zero.

_____ 19. Plot the data from *Table 1* on a semi-log graph, with counts from 0.1 to end of the decade of the highest recorded CPS on the "Y" axis and discriminator voltage from 0.05 to highest value on the "X" axis.

_____ 20. Press the right arrow until "Diagn. Values" appears.

_____ 21. Press the down arrow until "Detector Voltage" appears.

_____ 22. Using the "0-1 kV" potentiometer located on the NH 32 panel, gently raise the detector voltage until it reads initial detector voltage from step 7.

_____ 23. Press Exit until "Neutron Flux" appears.

_____ 24. Press the right arrow until "Parameters" appears.

_____ 25. Press the down arrow until "General Settings" appears.

_____ 26. Press Enter until "discriminator threshold" appears.

_____ 27. Use the right, left, up and down arrows to set the discriminator threshold voltage to 0.05 V.

____ 28. Press Exit until "Neutron Flux" appears.

____ 29. Press the down arrow until "Pulse Count" appears and record CPS on *Table 2*.

____ 30. Repeat steps 24-29 by increasing the discriminator voltage in 0.05 V increments and recording corresponding CPS on *Table 2* until CPS reaches zero.

____ 31. Plot the data from *Table 2* on a semi-log graph, with counts from 0.1 to end of the decade of the highest recorded CPS on the "Y" axis and discriminator voltage from 0.05 to highest value on the "X" axis.

____ 32. Set the discriminator voltage to the flattest part of the curve which has a high signal to noise ratio.

____ 33. If the new discriminator voltage is different than in step 14, then the discriminator voltage upper and lower thresholds will need to be adjusted accordingly.

_____ 34. Label the "Discriminator Voltage Lower Threshold" and "Discriminator Voltage Upper Threshold" values on the plot.

_____ 35. Update the "Discriminator Threshold," "Discriminator Voltage Lower Threshold," and "Discriminator Voltage Upper Threshold" parameters in the "Parameters List" binder.

____ 36. Verify Fault is present on the TK-250 keypad display panel by observing the letter "F" in the bottom right corner of the display.

_____ 37. Insert the black Test key into S1 slot on the NS01 module and clear the fault by running a "Watchdog Timer Test."

_____ 38. Remove the black and red Test keys from S1 and S2 slots on NS01 module.

_____ 39. Two people initial for completion in "System Test and Calibrations" binder.

_____ 40. Record the successful completion in the Test and Calibration Record Book along with two persons' initials attesting that results meet the acceptance criterion.

_____ 41. If acceptance criterion is not met, notify the Reactor Superintendent and enter malfunction in the Job Work Book.

_____ 42. Create a log book entry for the completion of the procedure.

_____ 43. File the data and plots in the Operations Test and Calibration File.

DWK 250 Detector Pulse Height Discriminator Calibration (Channel No. ____)

Pulse Count from step 4: ___________ CPS.

Initial Detector Voltage from step 7: ___________ VDC.

Current Discriminator Threshold Voltage from step 13: ____________VDC

Table 1 (Detector Voltage at 0 V)			*Table 2* (Detector Voltage at value in step 6)	
Discriminator Voltage	Counts (CPS)		Discriminator Voltage	Counts (CPS)
0.05			0.05	
0.10			0.10	
0.15			0.15	
0.20			0.20	
0.25			0.25	
0.30			0.30	
0.35			0.35	
0.40			0.40	
0.45			0.45	
0.50			0.50	
0.55			0.55	
0.60			0.60	
0.65			0.65	
0.70			0.70	
0.75			0.75	
0.80			0.80	
0.85			0.85	
0.90			0.90	
0.95			0.95	
1.00			1.00	

Completed by Instrumentation: _________________________ Date: _______________

Reviewed by Superintendent: __________________________ Date: ________________

6.1.3.1B DWK 250 Detector Plateau Calibration

Purpose

To verify the detector is operating in the saturation region of the detector curve at full power. If the detector is operating at saturation current at full power it will also be at saturation current at all lower powers. This ensures that the detector output will be linear throughout its operating region and small changes in detector voltage have a minimal effect on detector output current.

NOTE: This test is a requirement of the Technical Specifications. Only one DWK 250 channel calibration should be performed at a time.

Acceptance Criteria

The voltage chosen to operate the detector is based on the manufacturer's recommended range and the plotted data. The upper and lower voltage threshold alarms are set at ± 25 VDC of the detector operating voltage.

Prerequisites and Notes

- Record the DWK 250 channel to be tested on the data sheet.
- Reactor is at full power, or as close as allowed, with no re-shimming in progress.
- Maximum voltage applied to the detector should never exceed 1000 VDC.
- Excel spreadsheets can be used to record in lieu of handwriting *Table 1.*

Procedure

_____ 1. All operations will take place at the TK 250 keypad panel for the channel under test unless otherwise stated in the procedure.

_____ 2. Insert the red Test key into the S2 key slot on the NS01 module and turn clockwise.

_____ 3. Record the initial Neutron Flux on *Table 1.*

_____ 4. Press the right arrow key until "Diagn. Values" appears.

_____ 5. Press the down arrow key until "Detector Voltage" appears.

_____ 6. Record the initial Detector Voltage on *Table 1.*

_____ 7. Slowly adjust the "0-1 kV" potentiometer at the NH32 module until detector voltage equals 0 V (or ≤ 5V).

_____ 8. Press the down arrow until "Ntr. Flux df." appears.

_____ 9. Once reactor period stabilizes at infinity, record "Ntr. Flux df." on *Table 1* (the "Neutron Flux" column) next to the corresponding Detector Voltage.

_____ 10. Press the down arrow key until "Detector Voltage" appears.

_____ 11. Repeat steps 7-10 using the remaining detector voltage values indicated on *Table 1*, adjusting the potentiometer accordingly.

_____ 12. Plot Neutron Flux in % Power (Y Axis) versus Detector Voltage in V_{DC} (X Axis).

_____ 13. Determine a Knee Voltage that is on the flattest section of the curve and closest to the knee of the curve. Label the Knee Voltage on the plot.

_____ 14. Determine the new Detector Voltage by adding 100 V to the Knee Voltage. Label the Detector Voltage on the plot.

_____ 15. Press Enter and use right, left, up and down arrows to adjust detector voltage to the new desired level.

_____ 16. Press the Store key.

_____ 17. If the new Detector Voltage is different than in step 6, then the detector voltage upper and lower thresholds will need to be adjusted according.

_____ 18. Label the "Detector Voltage Lower Threshold" and "Detector Voltage Upper Threshold" values on the plot.

_____ 19. Update the "FC Voltage," "Detector Voltage Lower Threshold," and "Detector Voltage Upper Threshold" parameters in the "Parameters List" binder.

_____ 20. Verify Fault is present on the TK-250 keypad display panel by observing the letter "F" in the bottom right corner of the display.

_____ 21. Insert the black Test key into S1 slot on the NS01 module and clear the fault by running a "Watchdog Timer Test."

_____ 22. Remove the black and red Test keys from S1 and S2 slots on NS01 module.

_____ 23. Record the successful completion in the Test and Calibration Record Book along with two persons' initials attesting that results meet the acceptance criterion.

_____ 24. If acceptance criteria are not met, notify the Reactor Superintendent and enter malfunction in the Job Work Book.

_____ 25. Create a log book entry for the completion of the procedure.

_____ 26. File the data and plots in the Operations Test and Calibration File.

Table 1

DWK 250 Detector Plateau Calibration (Channel No. ____)				
Initial Neutron Flux from step 3: ____________ % Power. Initial Detector Voltage from step 6: ____________ VDC.				
Detector Voltage	Neutron Flux (% Power)		Detector Voltage	Neutron Flux (% Power)
0			300	
10			325	
20			350	
30			375	
40			400	
50			425	
60			450	
70			475	
80			500	
90			525	
100			550	
125			575	
150			600	
175			650	
200			700	
250			750	
275			800	

Completed by Instrumentation: ____________________________ Date: __________________

Reviewed by Superintendent: ____________________________ Date: __________________

6.1.3.1C DWK 250 Pulse to Campbelling Overlap Calibration

Purpose

To verify a smooth transition from pulse mode of operation to the Campbelling mode of operation.

NOTE: This test is a requirement of the Technical Specifications. Only one DWK 250 channel calibration should be performed at a time.

Acceptance Criteria

The "Ni / Np ratio" is equal to 1.00 (± 0.05).

Prerequisites and Notes

- Record the DWK 250 channel to be tested on the data sheet.
- To be completed during startup with reactor power between $5e^4$ CPS and $2e^5$ CPS (nominally at $1e^5$ CPS; approx. between 5-10 kW) and an infinite reactor period.
- Excel spreadsheets can be used to record in lieu of handwriting in the data table.

Procedure

___ 1. All operations will take place at the TK 250 keypad panel for the channel under test unless otherwise stated in the procedure.

___ 2. Insert the red Test key into the S2 key slot on the NS01 module and turn clockwise.

_____ 3. Press the down arrow until "Pulse Count" appears.

___ 4. Record the pulse count on the data sheet.

_____ 5. Press the down arrow until "AC Signal Norm" appears.

_____ 6. Record the AC Signal Norm on the data sheet.

_____ 7. Calculate the "Ni / Np ratio" in the overlap region (step 6 / step 4) and record on the data sheet. Value should be 1.00 (± 0.05).

_____ 8. If step 7 is in specification, skip to step 17. Otherwise complete all steps below.

_____ 9. Press the right arrow key until "Parameters" appears.

_____ 10. Press the down arrow key until "General Setting" appears.

_____ 11. Press Enter until "AC Normalizer" appears.

_____ 12. Record the value as the "AC Normalizer Setpoint" on the data sheet.

_____ 13. Calculate the new AC Normalizer Setpoint (step 12 / step 7) and record as the "New AC Normalizer Setpoint" on the data table.

_____ 14. Using the right, left, up and down arrow keys, insert the "New AC Normalizer Setpoint" from step 13 as the "AC Normalizer Setpoint."

_____ 15. Press Exit until "Neutron Flux" appears.

_____ 16. Repeat steps 3-15 for new Attempt until "Ni / Np ratio" is equal to 1.00 (± 0.05).

Note: If this specification cannot be obtained by the 6th Attempt, contact the shift supervisor and Instrumentation Supervisor for additional guidance.

_____ 17. Remove the red Test key from S2 key slot on the NS01 module.

_____ 18. Update the "AC Normalizer" parameters in the "Parameters List" binder.

_____ 19. Record the successful completion in the Test and Calibration Record Book along with two persons' initials attesting that results meet the acceptance criterion.

_____ 20. If acceptance criteria are not met, notify the Reactor Superintendent and enter malfunction in the Job Work Book.

_____ 21. Create a log book entry for the completion of the procedure.

_____ 22. File the data in the Operations Test and Calibration File.

DWK 250 Pulse to Campbelling Overlap Calibration (Channel No. ______)					
Attempt No.	Pulse Count (Step 4)	AC Signal Norm (Step 6)	Ni / Np Ratio (1.00 ±0.05) (Step 7)	AC Normalizer Setpoint (Step 12)	New AC Normalizer Setpoint (Step 13)
1					
2					
3					
4					
5					
6					

Completed by Instrumentation: ______________________ Date: ______________

Reviewed by Superintendent: ______________________ Date: ______________

6.1.3.1D DWK 250 Full Power Flux Calibration

Purpose

To ensure the DWK 250 is calibrated at full power so that it indicates a neutron flux power equal to the steady-state thermal power.

NOTE: This test is a requirement of the Technical Specifications. Only one DWK 250 channel calibration should be performed at a time.

Acceptance Criteria

The DWK 250 neutron flux display equals the thermal power percentage to +1.0%, or -0.0%.

Prerequisites and Notes

- The reactor is at a steady-state power with no re-shimming in progress.
- The rector power has operated at a steady-state power of ≥5.0 MW for ≥36 hours.

Procedure

_____ 1. All operations will take place at the TK 250 keypad panel for the channel under test unless otherwise stated in the procedure.

_____ 2. Record the thermal power and calculate as a percentage to two decimal places.

_______________ / 5.9 * 100% = ____________________%
(Thermal Power MW) (Thermal Power Percentage)

_____ 3. Insert the red Test key into the S2 key slot on the NS01 module and turn clockwise.

_____ 4. Press the down arrow key until "AC Signal Norm." appears and calculate the new Calibration Factor, Nf, to four significant figures and record in scientific notation.

_______________ / _______________ = _______________
(Thermal Power %) ("AC Signal Norm") ("Nf Calibration Factor)

_____ 5. Press the right arrow key until "Parameters" appears.

_____ 6. Press the down arrow key until "General Settings" appears.

_____ 7. Press Enter until "Nf. Calibr. Factor" appears.

_____ 8. Use the right, left, up and down arrow keys to input step 4 value ("Nf Calibration Factor") as the new Nf Calibration Factor.

___ 9. Press the Store key.

___ 10. Press Exit until "Neutron Flux" appears.

___ 11. Record the neutron flux as displayed on the TK 250 keypad panel:

Neutron Flux: ________________%

___ 12. Verify the value from step 11 matches calculated thermal power percentage from step 3, to +1.0%, or -0.0%.

Note: If value is out of specification, then repeat steps 4-12 as necessary.

___ 13. Remove the red Test key from S2 key slot on the NS01 module.

___ 14. Update the "Nf Calibration Factor" parameter in the "Parameters List" binder.

___ 15. Record the successful completion in the Test and Calibration Record Book along with two persons' initials attesting that results meet the acceptance criterion.

___ 16. If acceptance criteria are not met, notify the Reactor Superintendent and enter malfunction in the Job Work Book.

___ 17. Create a log book entry for the completion of the procedure.

___ 18. File the completed procedure in the Operations Test and Calibration File.

Completed by Instrumentation: ________________________ Date: _______________

Reviewed by Superintendent: ________________________ Date: _______________

6.1.3.1E DWK 250 Range Change-Over Verification

Purpose

To verify the DWK 250 range-changes are at the appropriate values based on manufacturers recommendations.

Acceptance Criteria

The DWK 250 range change-over occurs at 0.6V (± 0.2V) and at 2.5V (± 0.2V) for at least two range changes.

Prerequisites, Special Equipment, and Notes

- The reactor is shutdown.
- No faults present on the DWK 250.
- Precision mini flathead screwdriver
- Digital Multimeter with 2 mm test leads

Procedure

_____ 1. All operations will take place at the TK 250 keypad panel for the DWK 250 channel under test unless otherwise stated in the procedure.

_____ 2. Insert the black Test key into the S1 key slot on the NS01 module and turn clockwise.

_____ 3. Press the right arrow key until "Testing" appears.

_____ 4. Press the down arrow key until "Test Generators" appears.

_____ 5. Press Enter until "AC Input Test =" appears.

_____ 6. Press the down arrow key until "AC Input Test = AC" appears.

_____ 7. Press the Store key.

_____ 8. Press Exit until "Neutron Flux" appears.

_____ 9. Monitor DC voltage at the U1 and 0 jacks of the NA 33 Module using the multimeter.

_____ 10. Using a precision mini flathead screwdriver, carefully turn the "Test" potentiometer on the NA33 module counter clockwise and verify the range change-over occurs at 0.6V (± 0.2V) for at least two range changes on the NB22 Module. (LED lights will increment to signify a range change.)

_____ 11. Using a precision mini flathead screwdriver, carefully turn the "Test" potentiometer on the NA33 module clockwise and verify that the range change-over occurs at 2.5V (± 0.2V) for at least two range changes on the NB22 Module.

_____ 12. Turn the "Test" Potentiometer all the way clockwise (feel for slight click).

_____ 13. Press the right arrow key until "Testing" appears.

_____ 14. Press the down arrow key until "Test Generators" appears.

_____ 15. Press Enter until "AC Input Test = AC" appears.

_____ 16. Press the down arrow key until "AC Input Test = Off" appears.

_____ 17. Press the Store key.

_____ 18. Press Exit until "Neutron Flux" appears.

_____ 19. Remove the black Test key from S1 key slot on the NS01 module.

_____ 20. Record the successful completion in the Test and Calibration Record Book along with two persons' initials attesting that results meet the acceptance criterion.

_____ 21. If acceptance criteria are not met, notify the Reactor Superintendent and enter malfunction in the Job Work Book.

_____ 22. Create a log book entry for the completion of the procedure.

6.1.3.2 Period Channel Calibration Verification

Purpose

To determine reactor period indications accuracy generated by the DWK 250's.

NOTE: This test is a requirement of the Technical Specifications.

Acceptance Criteria

Acceptance criteria are that the DWK 250 period indications agree with calculated period ±5 percent.

Procedure

1. Full power reactor startup checklists completed, PM 3.1.1.1 and PM 3.1.1.2 (or PM 3.1.6 if the startup is a restart after a brief shutdown though it is preferable to perform this calibration without transient xenon).
2. Reactor Operator and Supervisor present for startup and at least one additional staff present to perform the calibration so that the Operator and Supervisor keep their attention on the reactor.
3. Perform a normal reactor startup per the standard operating procedures, keeping the reactor on a steady 50 second period for at least 2 decades while not exceeding 800 kW.
4. As soon as a steady 50 second period is reached, start the calibration verification.
5. Using a stopwatch, measure the amount of time for each channel to increase by 2 decades. Note: Reactor power may need to be cycled in order to complete this procedure for all four DWK 250 channels. Multiple people with multiple stopwatches may also be utilized to minimize the need for power reductions.
6. Record each channel's measured time (in seconds) on the attached data table along with each DWK 250 channel's period indications (local and console).
7. Calculate and record the period for each channel.

$$calculated\ period = \frac{time\ (seconds)\ for\ a\ 2\ decade\ increase}{4.61}$$

8. Check that the observed period indication is within 5% of the calculated period. Note: because period is not linear, ±5% of 50 seconds corresponds to the range 40-67 seconds.
9. If the acceptance criteria are not met, inform the Reactor Superintendent.
10. Make a logbook entry that the calibration was completed.

11. Record successful completion in the Test and Calibration Book along with 2 persons' initials attesting that the results are within the acceptance criteria.

12. File completed data sheet in the Operations Test and Calibration File.

Period Meters Calibration Data

DWK 250 Channel	Nominal Period (sec)	Local Period Meter (sec)	Console Period Meter (sec)	Time for 2 Decade Increase (sec)	Calculated Period (sec)
1					
2					
3					
4					

The above period indications are within the range of 40-67 seconds? ☐ Yes ☐ No

Operator________________________________ Date________________

Supervisor______________________________ Date________________

6.1.3.16 Detector Linearity Check

Purpose

To verify and document linearity in detector response with power level.

Note: This procedure should be performed with a startup to full power, and all the data points should be acquired at even time intervals within the same 24 hr window.

Acceptance Criteria: Detector signal is linear with power level.

Initial Condition: Reactor is shutdown.

Procedure

______ 1. Commence reactor startup per the appropriate startup procedures and stop at the first step (1.0 MW). Record channel readouts following the required soak time at 1.0 MW.

______ 2. Raise reactor power in steps per the operations schedule or the Superintendent's instructions. Record the value displayed on each of the available channels on the attached data sheet at each 1 MW interval and at full power (write in the final power level).

______ 3. Plot the data and fit a line for each detector, and attach the plots to the data sheet. (Note: for channels that read on a log scale, take the log of all the values before plotting or use a semi-log plot.)

______ 4. Sign the test and calibration book in the control room.

______ 5. File the data sheet and plots in the operations office file cabinet.

______ 6. Instrumentation Supervisor review each channel to evaluate for any non-linearity.

______ 7. Notify the Superintendent if any detectors show a non-linear response with power.

Detector Linearity Check Data Sheet

Record the channel readouts below to one decimal place.

MW	CH1 (DWK 250)	CH2 (DWK 250)	CH3 (DWK 250)	CH4 (DWK 250)	CH5 (Linear Flux)	CH6 (Emg. Pwr)	CH7 (Auto Control)	N-16
S/D								
1.0								
2.0								
3.0								
4.0								
5.0								

Plots for each detector attached: ☐ Yes ☐ No

Completed by: ______________________________ Date: _____________

Instrumentation Supervisor Review: ________________ Date: _____________

Superintendent Review: _________________________ Date: _____________

Enclosure R

New Nuclear Safety System Installation Plan

Preliminary

______ All four Mirion fission chambers installed (3GV2, 3GV5, 4IH1, 4IH3).

______ All four Mirion DWK 250 chassis installed in the control room and calibrated per procedures:

- ☐ PM 6.1.3.1A, DWK-250 Pulse Height Discriminator Checks
- ☐ PM 6.1.3.1B, DWK-250 Detector HV Plateau Checks
- ☐ PM 6.1.3.1C, DWK-250 Pulse to Campbelling Overlap Calibration
- ☐ PM 6.1.3.1D, DWK-250 Full Power Flux Calibration
- ☐ PM 6.1.3.2, Period Channel Calibration Procedure
- ☐ PM 6.1.3.16, Detector Linearity Checks

______ The reactor is shutdown.

______ Lock out L21 & L22.

______ Verify all systems deenergized.

- ☐ Rundown Relay Panel
- ☐ Keithley Picoammeter Channels 1 – 3.
- ☐ Nuclear Saftey System Channels 1 – 6.
- ☐ Nuclear Saftey System Detector Power Supply Modules 1 – 6.
- ☐ NIM Bin Rack for Channels 1 – 2 Count Rate and SCA's.

______ Sufficient wire removal forms available.

______ Refer to Figures 1 & 2 for existing and final control panel layouts.

Removal of Old Safety System Equipment

______ Identify and label each channel 1 – 6 neutron detector cable. Use wire removal forms.

______ Remove Nuclear Saftey system channels 1 – 6 including the NIM Bin rack from control room panel 6.

______ Remove channel 3 Keithley 26000 picoammeter from control room panel 6.

______ Remove channel 1 Keithley 26000 picoammeter from control room panel 5.

QA#	E-2012-1	Date
Approved	________	______
RRPO Review	________	______
Q/A App'l	________	______

______ Remove channel 2 Keithley 26000 picoammeter from control room panel 5.

______ Label and disconnect all wires from the Rundown Relay Panel. Use wire removal forms.

______ Remove the Rundown Relay Panel from control room panel 6.

Alignment of UPS Units

______ Remove high capacity UPS from control room panel 3 and install into the bottom of control room panel 6.

______ Remove high capacity UPS from control room panel 4 and install into the bottom of control room panel 5.

______ Install low capacity UPS into the bottom of control room panel 3.

______ Install low capacity UPS into the bottom of control room panel 4.

Installation of New Safety System Equipment

______ Install the Signal Distribution Module (SDM) inside the rack of control room panel 3.

______ Install both 24 volt DC power supplies into the control room panel 3 near the SDM.

______ Install NIM Bin rack with the LED Display and Logic Cards into control room panel 4.

______ Relocate the Audible Count Rate NIM Bin rack to a lower position into control room panel 5.

______ Install NIM Bin rack with the <100 kW Key Switch Module (KSM), Rod Drop Timer Interface Module and the Magnet Power Supplies (x3) into control room panel 5.

______ Install NIM Bin rack with the PLC Display into control room panel 5.

______ Install the new Rundown Relay Panel into control room panel 6.

______ Install the new DWK Test Condition Scram Bypass Assembly into control room panel 3.

______ Connect cable K-41 from TB6 at the DWK Test Condition Scram Bypass Assembly (TCSBA) to P11 at DWK 1.

______ Second person verify cable K-41 is connected correctly.

______ Connect cable K-42 from TB6 at the DWK (TCSBA) to P12 at DWK 2.

______ Second person verify cable K-42 is connected correctly.

______ Connect cable K-43 from TB6 at the DWK (TCSBA) to P13 at DWK 3.

______ Second person verify cable K-43 is connected correctly.

______ Connect cable K-44 from TB6 at the DWK (TCSBA) to P14 at DWK 4.

______ Second person verify cable K-44 is connected correctly.

______ Connect cable K-45 from TB6 at the DWK (TCSBA) to X36 at the existing console annunciators.

______ Second person verify cable K-45 is connected correctly.

______ Install the new remote meters (x8) on console for all channels.

______ Connect a DB37 cable K-10 from DWK 1 at connector X22 to the SDM at connector X10.

______ Second person verify cable K-10 is connected correctly.

______ Connect a DB37 cable K-11 from DWK 2 at connector X23 to the SDM at connector X11.

______ Second person verify cable K-11 is connected correctly.

______ Connect a DB37 cable K-12 from DWK 3 at connector X24 to the SDM at connector X12.

______ Second person verify cable K-12 is connected correctly.

______ Connect a DB37 cable K-13 from DWK 4 at connector X25 to the SDM at connector X13.

______ Second person verify cable K-13 is connected correctly.

______ Connect a DB50 cable K-17 from the LED Scram Display at connector X29 to the SDM at connector X18.

______ Second person verify cable K-17 is connected correctly.

______ Connect a DB50 cable K-14 from Scram Logic Card 1 at connector X26 to the SDM at connector X15.

______ Second person verify cable K-14 is connected correctly.

______ Connect a DB50 cable K-15 from Scram Logic Card 2 at connector X27 to the SDM at connector X16.

______ Second person verify cable K-15 is connected correctly.

______ Connect a DB9 cable K-16 from <100 kW KSM at connector X28 (A.k.a. P5) to the SDM at connector X17.

______ Second person verify cable K-16 is connected correctly.

______ Connect cable K-31 from Scram Logic Card 2 at connector X37 to the <100 kW KSM at connector X40.

______ Second person verify cable K-31 is connected correctly.

______ Connect cable K-32 from Scram Logic Card 1 at connector X38 to the <100 kW KSM at connector X40.

______ Second person verify cable K-32 is connected correctly.

______ Connect cable K-33 from the SDM at connector X14 to the <100 kW KSM at connector X40.

______ Second person verify cable K-33 is connected correctly.

______ Connect cable K-34 from the SDM at connector X14 to the Scram Logic Card 2 at connector X35.

______ Second person verify cable K-34 is connected correctly.

______ Connect cable K-35 from the SDM at connector X14 to the Scram Logic Card 1 at connector X42.

______ Second person verify cable K-35 is connected correctly.

_______ Connect cable K-27 from the 24 volt DC power supply 1 to the SDM at connector X14.

_______ Second person verify cable K-27 is connected correctly.

_______ Connect cable K-28 from the 24 volt DC power supply 2 to the SDM at connector X14.

_______ Second person verify cable K-28 is connected correctly.

_______ Install new Annunciator Panel alarm windows.

_______ Connect cable K-29 from the <100 kW KSM at connector X43 to the Annunciator Panel at connector X36.

_______ Second person verify cable K-29 is connected correctly.

_______ Connect cable K-30 from the NIM Bin rack #2 back (A.k.a. P2) at connector X43 to the Rundown Relay Panel at connector P4.

_______ Second person verify cable K-30 is connected correctly.

_______ Remove all relays for Period Channel Level Signal Off-scale circuitry in the WPC.

_______ Connect new WPC wire to connect point W15 to point W18 on Drawing R3W-203-4.

_______ Install Scram Loop B relay (B4) in the WPC.

_______ Install RY1, RY2, RY3 in the WPC Bypass Panel. See Drawing R3W-260-4.

_______ Wire contact RY1-2 in parallel with contact KS-3A. See Drawing R3W-260-4.

_______ Wire contact RY1-3 in parallel with contact KS-3C. See Drawing R3W-260-4.

_______ Wire contact RY2-2 in parallel with contact KS-6A. See Drawing R3W-260-4.

_______ Wire contact RY2-3 in parallel with contact KS-6C. See Drawing R3W-260-4.

_______ Wire contact RY3-2 in parallel with contact KS-11A. See Drawing R3W-260-4.

_______ Wire contact RY3-3 in parallel with contact KS-11C. See Drawing R3W-260-4.

_______ Wire contact RY1-1 in parallel with contact KS-16B. See Drawing R3W-260-4.

______ Wire contact RY2-1 in parallel with contact KS-16B. See Drawing R3W-260-4.

______ Wire contact RY3-1 in parallel with contact KS-16B. See Drawing R3W-260-4.

______ Second person verify the above nine contact wires are connected correctly.

______ Wire B4-1 contact to wiring points W30 and W33 in the WPC.

______ Wire RY1-3 contact to wiring points W34 and W35 in the WPC.

______ Wire RY2-3 contact to wiring points W39 and W40 in the WPC.

______ Wire RY3-3 contact to wiring points W13 and W14 in the WPC.

______ Second person verify the above four contact wires are connected correctly.

______ Connect a DB25 cable K-18 from the SDM at connector X19 to the Console Chart Recorder and Meters at connector X30.

______ Second person verify cable K-18 is connected correctly.

______ Connect a DB9 cable K-38 (A.k.a. P7/P10 cable) from the Drop Timer Interface Module at the 6-pin XLR connector (A.k.a. P7) to the SDM at connector X41.

______ Second person verify cable K-38 is connected correctly.

______ Connect a 2-wire cable K-39 from the Drop Timer Interface Module at P9 to the Blade Drop Timer at the 2-position terminal strip.

______ Second person verify cable K-39 is connected correctly.

______ Connect wires K-47 from connector P8 at the Drop Timer Interface Module to the normally closed switch block on the minor scram push button.

______ Second person verify cable connections.

______ Connect cable K-45 from the P10 connector to the PLC display at TB9.

______ Second person verify cable connections.

______ Connect a DB50 cable K-20 from the PLC Display at connector X32 to the SDM at connector X21.

______ Second person verify cable K-20 is connected correctly.

______ Connect a DB9 cable K-40 from the PLC Display at connector X33 to the Console Annunciator Panel at connector X34.

______ Second person verify cable K-40 is connected correctly.

______ Connect a DB15 cable K-19 from the RS232 Breakout Box at connector X31 to the SDM at connector X20.

______ Second person verify cable K-19 is connected correctly.

______ Connect a power cable K-21 from DWK 4 to the UPS in control room panel 3.

______ Second person verify cable K-21 is connected correctly.

______ Connect a power cable K-22 from DWK 3 to the UPS in control room panel 3.

______ Second person verify cable K-22 is connected correctly.

______ Connect a power cable K-23 from DWK 2 to the UPS in control room panel 4.

______ Second person verify cable K-23 is connected correctly.

______ Connect a power cable K-24 from DWK 1 to the UPS in control room panel 4.

______ Second person verify cable K-24 is connected correctly.

______ Connect a power cable K-25 from High Capacity UPS in control room panel 5 to the 24 volt DC power supply 1.

______ Second person verify cable K-25 is connected correctly.

______ Connect a power cable K-26 from High Capacity UPS in control room panel 6 to the 24 volt DC power supply 2.

______ Second person verify cable K-26 is connected correctly.

______ Connect cable P1 at NIM Bin rack #2 back to P6 on NIM Bin rack #1 back.

______ Second person verify cable is connected correctly.

______ On the back of NIM Bin rack #2, wire the following connections from TB4:

- ☐ 1 – Ground
- ☐ 2 – L22
- ☐ 3 – L21
- ☐ 4 – Loop A scram relay in WPC
- ☐ 5 – Loop B scram relay in WPC
- ☐ 6 – KS1-D at the <100 kW KSM
- ☐ 7 – KS1-D at the <100 kW KSM
- ☐ 8 – RY4 relay power from the WPC
- ☐ 9 – RY4 relay power from the WPC
- ☐ Second person verify the above wires are connected correctly.

______ On the back of NIM Bin rack #2, wire the following connections from TB5:

- ☐ 1 – Left alarm panel
- ☐ 2 – Left alarm panel
- ☐ 3 – Left alarm panel
- ☐ 4 – Center alarm panel
- ☐ 5 – Center alarm panel
- ☐ 6 – PLC inputs
- ☐ 7 – PLC inputs
- ☐ 8 – PLC inputs
- ☐ Second person verify the above wires are connected correctly.

______ On the back of NIM Bin rack #1, wire the following connections from TB6:

- ☐ 1 – 24 VDC
- ☐ 2 – 24 VDC return
- ☐ Second person verify the above wires are connected correctly.

______ On the back of the Rundown Relay Panel connnect the magnet current supply cables for blade magnets 1 – 6.

______ Second person verify cables are connected correctly.

______ On the back of the Rundown Relay Panel, wire the following connections from TB2:

- ☐ Blade 1 In and Out
- ☐ Blade 2 In and Out
- ☐ Blade 3 In and Out
- ☐ Blade 4 In and Out
- ☐ Blade 5 In and Out
- ☐ Blade 6 In and Out
- ☐ Second person verify the above wires are connected correctly.

______ On the back of the Rundown Relay Panel, wire the following connections from TB3:

- ☐ 1 – Ground
- ☐ 2 – L22
- ☐ 3 – L21
- ☐ 4 – L21
- ☐ 5 – SW1-2
- ☐ 6 – SW1-2
- ☐ 7 – W24
- ☐ 8 – W25
- ☐ Second person verify the above wires are connected correctly.

<u>Energization and Testing</u>

______ Remove the lockout from L21 and L22.

______ Close the circuit breakers for L21 and L22.

______ Verify all equipment is powered.

______ Perform the Global Test Procedure.

______ Perform PM 6.3.12, Isolation of the Withdraw Permit Circuit.

______ Perform PM 6.1.4.1, Nuclear Instrument Scram Times.

______ Perform Blade Drop Times for all 6 control blades.

Administrative Checks

______ Summarize any malfunctioning or out-of-specification equipment or instruments noted during the performance of this checklist.

Item	Job # (If Applicable)

______ Checklist verified to have proper number of pages (12).

Checklist completed by:

____

Approved by Supervisor:

____

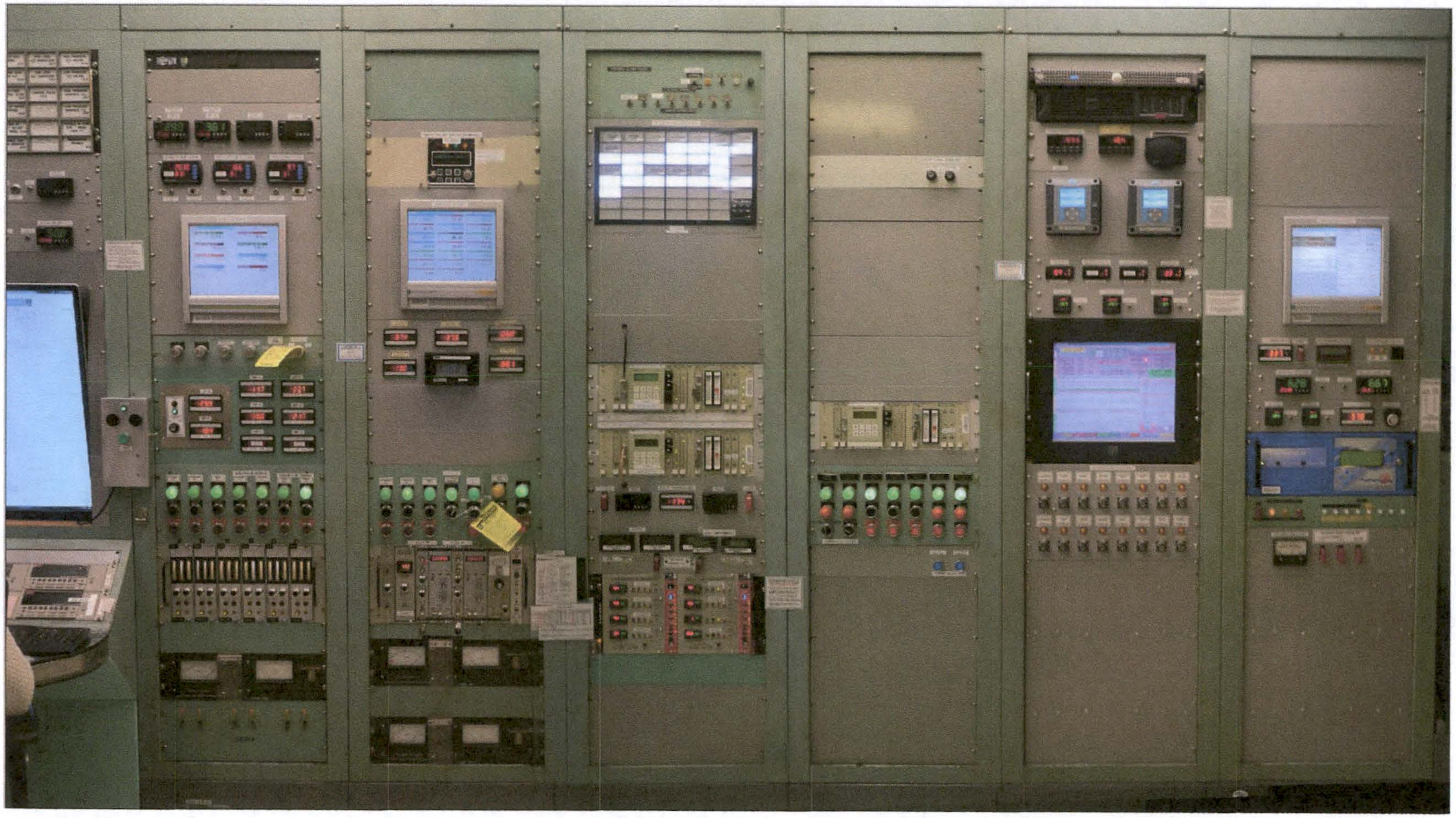
Superintendent Review:

____

Director of Reactor Operations Review:

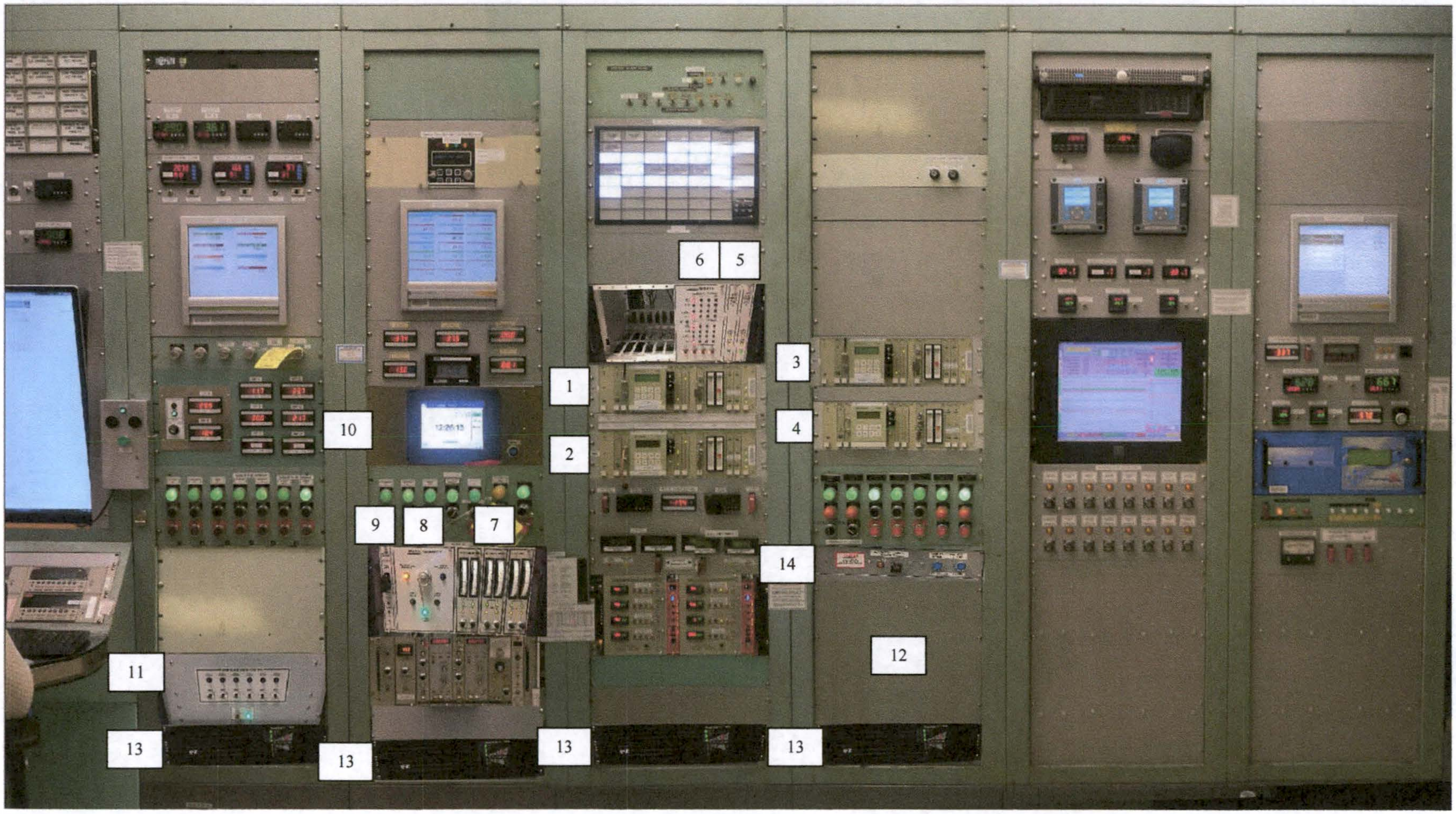
____

Figure 1 Control Room Layout - Existing



QA#	E-2012-1	Date
Approved	________	________
RRPO Review	________	________
Q/A App'l	________	________

Figure 2 Control Room Layout - Final



1. Mirion DWK 250 1
2. Mirion DWK 250 2
3. Mirion DWK 250 3
4. Mirion DWK 250 4
5. Scram Logic Cards 1 & 2
6. LED Scram Display Module
7. Magnet Power Supplies
8. <100 kW Key Switch Module
9. Blade Drop Timer Interface Module
10. Safety System Monitoring & Status Display PLC
11. Rundown Relay Panel
12. Signal Distribution Module (mounted inside)
13. UPS Modules
14. DWK 250 "Test" Condition Scram Bypass Assembly

QA#	E-2012-1	Date
Approved	________	_______
RRPO Review	________	_______
Q/A App'l	________	_______

Enclosure S

3.2.3 Reactor Protection System

Applicability

This specification applies to the reactor protection system.

Objective

To ensure that automatic protection action is provided as required by the reactor protection system.

Specifications

1. The reactor shall not be made critical unless the reactor protection system is operable in accordance with Table 3.2.3-1.

2. Fuel shall not be moved and no work involving reactivity shall be performed in the core unless the period and neutron flux level channels are set to alarm within the zero primary pump limits of Table 3.2.3-1. In addition, the manual major scram is operable for building isolation and the D_2O dump valve selector switch is operable unless the D_2O reflector is already dumped.

3. The reactor shall not be made critical unless scram setpoints are set more conservatively than the corresponding LSSS.

Table 3.2.3-1

Required Safety Channels

			2 Primary Pumps		1 Primary Pump		0 Primary Pump	
	Channel / Parameter	Action	Limiting Setpoint	Min. No. Required	Limiting Setpoint	Min. No. Required	Limiting Setpoint	Min. No. Required
1.	Period	Scram	> 7 sec.	2(1)(5)	> 7 sec	2(1)(5)	> 7 sec	2(1)(5)
2.	Neutron flux level	Scram	< 7.4 MW	2(1)(5)	< 3.2 MW	2(1)(5)	< 100 kW	2(1)(5)
3.	Low count rate	Scram	> 5 cps	2(1)(5)	> 5 cps	2(1)(5)	> 5 cps	2(1)(5)
4.	Primary coolant outlet temperature	Scram	< 60° C	2	< 60° C	2	< 60° C	2
5.	Core tank level	Scram	4" below overflow pipe	1	4" below overflow pipe	1	4" below overflow pipe	1
6.	Reflector tank level	Scram	4" below overflow	1	4" below overflow	1	4" below overflow	1(2)
7.	D_2O dump valve selector switch	Reflector dump & scram	N/A	1	N/A	1	N/A	1
8.	Manual major scram	Reflector dump, containment closure & scram	N/A	2(3)	N/A	2(3)	N/A	2(3)
9.	Manual minor scram	Scram	N/A	1	N/A	1	N/A	1
10.	Primary coolant flow rate	Scram	> 1800 gpm	2(4)	> 900 gpm	2(4)	N/A	0
11.	D_2O reflector flow rate	Scram	> 75 gpm	1	> 75 gpm	1	N/A	0
12.	Shield coolant flow rate	Scram	> 50 gpm	1	> 50 gpm	1	N/A	0

1) Nuclear safety scram logic system ensures that reactor scrams when two trips are present simultaneously from any two of the four nuclear safety channels.
2) For reflector reactivity measurement, the reflector scram can be bypassed at power levels less than 100 kW.
3) One in utility room.
4) At least one safety channel on the primary coolant flow rate scram must be by core inlet pressure sensor.
5) Any nuclear safety system channel removed from service must be left in a tripped state as indicated on the Safety System Condition LED Scram Display.

Table 3.2.3-1 (Continued)

Required Safety Channels

	Channel / Parameter	Action	Setpoint	Minimum No. Required
	Any Number of Pumps (Two, One, or Zero)			
13.	Nuclear safety channel in test or fault	Scram	Channel in test or fault condition	2[(1)(5)]
14.	Building overpressure	Scram	< 3" water above atmospheric	1
15.	Main personnel lock gaskets deflated	Scram	Both gaskets deflated	1
16.	Basement personnel lock gaskets deflated	Scram	Both gaskets deflated	1
17.	Hold-down grid unlatched	Scram	Grid unlatched	1
18.	Experiment scrams	(As Required by Experiment Approval)		

1) Nuclear safety scram logic system ensures that reactor scrams when two trips are present simultaneously from any two of the four nuclear safety channels.
5) Any nuclear safety system channel removed from service must be left in a tripped state as indicated on the Safety System Condition LED Scram Display.

Basis

The nuclear safety system, consisting of four wide-range nuclear safety channels, provides protection against high power level and short reactor period. Each nuclear safety channel produces a trip signal on high power, short period, low detector count rate, channel in test, or channel fault / equipment malfunction. The scram logic system downstream will scram the reactor upon any simultaneous combination of these trips from two of the four nuclear safety channels, thereby ensuring there are two operable channels whenever the reactor is not shut down. These systems are therefore required at all power levels including certain subcritical operations such as refueling, absorber change-out, or other in-core work that affects reactivity. At power levels above 100 kW, protection is also required on primary, D_2O, and shield coolant flows.

The parameters listed in Table 3.2.3-1 are monitored by the reactor protection system. This system automatically initiates action to ensure that appropriate limiting safety system settings and limiting conditions of operation are not violated.

In practice, low power physics tests including rod reactivity worth measurements are usually performed at power levels of less than 10 kW and in the absence of forced convection primary flow. The upper limit of 100 kW for this type of operation was established on the basis of adequate natural convection cooling. The maximum plate temperature at 100 kW with natural convection cooling is estimated to be below incipient boiling, if the coolant outlet temperature is maintained below the normal scram point of 60°C. Therefore, the reactor outlet temperature channel is specified in Table 3.2.3-1 as 60°C for zero pump operation.

The reflector tank low D_2O level scram must be bypassed during low power operation if calibration of the reactivity effect of the D_2O reflector dump safety system is to be performed.

For refuelings, the reactor is in a shutdown condition, primary flow is secured, and the D_2O reflector is normally dumped. Therefore, the nuclear safety channels are set to alarm within the zero primary pump limits for period and level. The capability to isolate the building is required. This is provided by the major scram. Finally, it should be possible to dump the D_2O reflector, if it is not already dumped.

3.2.3 Reactor Protection System

Applicability

This specification applies to the reactor protection system.

Objective

To ensure that automatic protection action is provided as required by the reactor protection system.

Specifications

1. The reactor shall not be made critical unless the reactor protection system is operable in accordance with Table 3.2.3-1.

2. Fuel shall not be moved and no work involving reactivity shall be performed in the core unless the period and neutron flux level channels are set to alarm within the zero primary pump limits of Table 3.2.3-1. In addition, the manual major scram is operable for building isolation and the D_2O dump valve selector switch is operable unless the D_2O reflector is already dumped.

3. The reactor shall not be made critical unless scram setpoints are set more conservatively than the corresponding LSSS.

Table 3.2.3-1

Required Safety Channels

			2 Primary Pumps		1 Primary Pump		0 Primary Pump	
	Channel / Parameter	Action	Limiting Setpoint	Min. No. Required	Limiting Setpoint	Min. No. Required	Limiting Setpoint	Min. No. Required
1.	Period	Scram	> 7 sec.	2[1][5]	> 7 sec	2[1][5]	> 7 sec	2[1][5]
2.	Neutron flux level	Scram	< 7.4 MW	2[1][5]	< 3.2 MW	2[1][5]	< 100 kW	2[1][5]
3.	Low count rate	Scram	> 5 cps	2[1][5]	> 5 cps	2[1][5]	> 5 cps	2[1][5]
4~~3~~.	Primary coolant outlet temperature	Scram	< 60° C	2	< 60° C	2	< 60° C	2
5~~4~~.	Core tank level	Scram	4" below overflow pipe	1	4" below overflow pipe	1	4" below overflow pipe	1
6~~5~~.	Reflector tank level	Scram	4" below overflow	1	4" below overflow	1	4" below overflow	1[2]
7~~6~~.	D_2O dump valve selector switch	Reflector dump & scram	N/A	1	N/A	1	N/A	1
8~~7~~.	Manual major scram	Reflector dump, containment closure & scram	N/A	2[3]	N/A	2[3]	N/A	2[3]
9~~8~~.	Manual minor scram	Scram	N/A	1	N/A	1	N/A	1
~~9.~~	~~Experiment scrams~~	~~(As Required by Experiment Approval)~~						
10.	Primary coolant flow rate	Scram	> 1800 gpm	2[4]	> 900 gpm	2[4]	N/A	0
11.	D_2O reflector flow rate	Scram	> 75 gpm	1	> 75 gpm	1	N/A	0
12.	Shield coolant flow rate	Scram	> 50 gpm	1	> 50 gpm	1	N/A	0

1) Nuclear safety scram logic system ensures that reactor scrams when two trips are present simultaneously from any two of the four nuclear safety channels.
2) For reflector reactivity measurement, the reflector scram can be bypassed at power levels less than 100 kW.
3) One in utility room.
4) At least one safety channel on the primary coolant flow rate scram must be by core inlet pressure sensor.
~~4)~~5) Any nuclear safety system channel removed from service must be left in a tripped state as indicated on the Safety System Condition LED Scram Display.

Table 3.2.3-1 (Continued)

Required Safety Channels

	Any Number of Pumps (Two, One, or Zero)			
	Channel / Parameter	Action	Setpoint	Minimum No. Required
13.	Nuclear safety channel ~~trips for low count rate,~~	Scram	~~Less than two operable, on-scale c~~Channel~~s~~ in	2(1)(5) ~~1~~
14.	Building overpressure	Scram	< 3" water above atmospheric	1
15.	Main personnel lock gaskets deflated	Scram	Both gaskets deflated	1
16.	Basement personnel lock gaskets deflated	Scram	Both gaskets deflated	1
17.	Hold-down grid unlatched	Scram	Grid unlatched	1
18~~9~~.	Experiment scrams	(As Required by Experiment Approval)		

1) Nuclear safety scram logic system ensures that reactor scrams when two trips are present simultaneously from any two of the four nuclear safety channels.
5) Any nuclear safety system channel removed from service must be left in a tripped state as indicated on the Safety System Condition LED Scram Display.

Basis

The nuclear safety system, consisting of four wide-range nuclear safety channels, provides protection against high power level and short reactor period. Each nuclear safety channel produces a trip signal on high power, short period, low detector count rate, channel in test, or channel fault / equipment malfunction. The scram logic system downstream will scram the reactor upon any simultaneous combination of these trips from two of the four nuclear safety channels, thereby ensuring there are two operable channels whenever the reactor is not shut down. These systems are therefore required at all power levels including certain subcritical operations such as refueling, absorber change-out, or other in-core work that affects reactivity. At power levels above 100 kW, protection is also required on primary, D_2O, and shield coolant flows.

The parameters listed in Table 3.2.3-1 are monitored by the reactor protection system. This system automatically initiates action to ensure that appropriate limiting safety system settings and limiting conditions of operation are not violated.

In practice, low power physics tests including rod reactivity worth measurements are usually performed at power levels of less than 10 kW and in the absence of forced convection primary flow. The upper limit of 100 kW for this type of operation was established on the basis of adequate natural convection cooling. The maximum plate temperature at 100 kW with natural convection cooling is estimated to be below incipient boiling, if the coolant outlet temperature is maintained below the normal scram point of 60°C. Therefore, the reactor outlet temperature channel is specified in Table 3.2.3-1 as 60°C for zero pump operation.

The reflector tank low D_2O level scram must be bypassed during low power operation if calibration of the reactivity effect of the D_2O reflector dump safety system is to be performed.

For refuelings, the reactor is in a shutdown condition, primary flow is secured, and the D_2O reflector is normally dumped. Therefore, the nuclear safety channels are set to alarm within the zero primary pump limits for period and level. The capability to isolate the building is required. This is provided by the major scram. Finally, it should be possible to dump the D_2O reflector, if it is not already dumped.

Enclosure T

4.2 Reactor Control and Safety Systems

Applicability

This specification applies to the surveillance of reactor control and safety systems.

Objective

To ensure the reliability of the reactor control and safety systems.

Specification

1. Reactivity Worth of Control Devices: The integral and differential worths of the six shim blades and of the regulating rod shall be measured at least annually. Either calculations of the expected change or measurements shall be made upon changeout of an absorber and upon changes in core configuration that involve a new type of fuel or a change in the total number of non-fueled positions.

2. Rod Withdrawal and Insertion Speed: The withdrawal and insertion speed of each shim blade drive and the regulating rod drive shall be verified annually.

3. Scram Times: The scram time of each shim blade shall be verified annually or whenever any work has been done on either the shim blade, its electromagnet, or its associated drive. For purposes of this check, the scram time shall be measured from the full-out position to the 80% inserted position of the shim blade.

4. Scram and Power Measuring Channels: The instruments or channels listed in Table 4.2-1 shall be tested at least quarterly and each time before startup of

the reactor if the reactor has been in a secured condition or if the instrument or channel has been repaired or de-energized. Calibration of these instruments or channels (except those such as scram pushbuttons that do not require calibration) shall be done at least annually.

5. Channel Tests: Channel tests of the instruments or channels listed in Table 4.2-1 shall be performed if the channel or instrument has been modified or repaired.

6. The following instruments shall be calibrated and trip points verified when initially installed, any time a significant change in indication is noted, and at least annually:

   a) Period
   b) Neutron Flux Level
   c) Primary Coolant Outlet Temperature
   d) Core Tank Level
   e) Reflector Tank Level
   f) Primary Coolant Flow
   g) D_2O Reflector Flow
   h) Shield Coolant Flow

7. Thermal Power: The signals used to compute thermal power shall be calibrated at least annually.

Table 4.2-1

Surveillance of Scram and Power Measuring Channels

Instrument or Channel		Channel Test to Verify
1	Period[(1)]	Scram
2.	Neutron Flux Level[(1)]	Scram
3.	Primary Coolant Outlet Temperature	Scram
4.	Core Tank Level	Scram
5.	Reflector Tank Level	Scram
6.	D_2O Dump Valve Switch	Scram and Reflector Dump
7.	Air-Operator D_2O Dump Valve Switch	Reflector Dump
8.	Manual Major Scram	Magnet Cut-off, Reflector Dump, and Ventilation Trip
9.	Manual Minor Scram	Magnet Cut-Off
10.	Experiment Shutdown	As Specified in Experiment Approval
11.	Primary Coolant Flow[(2)]	Scram
12	D_2O Reflector Flow[(2)]	Scram
13.	Shield Coolant Flow[(2)]	Scram
14.	Fission Converter	As specified in Fission Converter TS 6.6.3
15.	Nuclear Safety Channel Low Count Rate[(1)]	Scram
16.	Nuclear Safety Channel in Test[(1)]	Scram
17.	Nuclear Safety Channel Fault[(1)]	Scram
18.	Hold-Down Grid Unlatched	Scram
19.	Reactor Remote Shutdown(s)	Scram from Medical Facilities and Utility Room

(1) Reactor scrams when two trips in any combination are present simultaneously from any two of the four nuclear safety channels.

(2) Not required for startup in natural convection cooling mode.

9. Heat Balance: The signal from the linear power channel shall be checked against a heat balance calculation at least monthly, for any month that the reactor is operated above 1 MW continuously for at least 48 hours.

10. Control Device Inspection: Control devices shall be inspected annually as follows:

    a) Shim blade absorbers shall be checked visually.

    b) Shim blade electromagnets shall be checked both visually and by measuring the resistance of the coils.

    c) Shim blade and regulating rod drives shall be monitored for proper operation.

11. Control System Interlocks: A channel test of the following interlocks and scram shall be performed at least annually:

    a) Withdraw Permit Interlock,

    b) Subcritical Limit – Shim Blades Interlock,

    c) No Overflow Reflector Startup Interlock, and

    d) Low Level D_2O Reflector Scram.

Basis

The MITR-II has observed the criteria given in Specification 4.2.1 for determination of control device reactivity worths and found it to be adequate. Measurements of the integral and differential worths are required annually. Measurements following changeouts of absorbers and change of core configuration are desirable. However, such measurements are very time consuming. Moreover, sufficient experience exists with such changes that their effect on integral and differential reactivity worths can be predicted with reasonable accuracy. Accordingly, normal MITR-II practice is to do a complete set of measurements following replacement of all

absorber sections rather than to do measurements as each is replaced. (Note: It requires several days to replace one absorber and the entire process is usually done over an interval of several months.) Estimates of the change of worth are used pending the measurement. Estimates, not measurements, are normally used for changes of core configuration.

The insertion and withdrawal speed of the control devices is fixed by the motor and drive design as discussed in Section 4.2.2 of the SAR. These speeds are verified annually.

Scram time is as defined by Specifications 1.3.37 and 3.2.1. It is verified at least annually and whenever maintenance has been performed that could affect it.

The instruments and channels listed in Table 4.2-1 correspond to those in Table 3.2.3-1, "Required Safety Channels" with the exception that surveillance of the building overpressure and gasket deflated scrams is addressed elsewhere (Specification 4.4).

The thermal power indication is calibrated at least annually and the signal from the linear power channel is compared against a heat balance at least monthly for any month that the reactor is operated above 1 MW. These actions are done under conditions of thermal equilibrium which, because of the MITR-II's heat capacity (especially that of the graphite reflector), occurs after 48 hours of steady-state operation.

Control devices are inspected at least annually. The inspection focuses on those components that are important to safety. Those include the absorber sections (Section 16.3.1.5 of the SAR) and electromagnets (Section 16.3.1.4(d) of the SAR). The status of the shim blade and regulating rod drives can be deduced from external observations such as the measurement of blade and regulating rod insertion/withdrawal speeds (Specification 4.2.2). Internal inspections require lowering of the core tank level and removal of the drive. These are usually done whenever an absorber is changed out. As described in Section 16.3.1.5 of the SAR, this is normally done every 125,000 MWH. A prespecified frequency for an internal inspection would involve serious ALARA issues.

4.2 Reactor Control and Safety Systems

Applicability

This specification applies to the surveillance of reactor control and safety systems.

Objective

To ensure the reliability of the reactor control and safety systems.

Specification

1. Reactivity Worth of Control Devices: The integral and differential worths of the six shim blades and of the regulating rod shall be measured at least annually. Either calculations of the expected change or measurements shall be made upon changeout of an absorber and upon changes in core configuration that involve a new type of fuel or a change in the total number of non-fueled positions.

2. Rod Withdrawal and Insertion Speed: The withdrawal and insertion speed of each shim blade drive and the regulating rod drive shall be verified annually.

3. Scram Times: The scram time of each shim blade shall be verified annually or whenever any work has been done on either the shim blade, its electromagnet, or its associated drive. For purposes of this check, the scram time shall be measured from the full-out position to the 80% inserted position of the shim blade.

4. Scram and Power Measuring Channels: The instruments or channels listed in Table 4.2-1 shall be tested at least quarterly and each time before startup of

the reactor if the reactor has been in a secured condition or if the instrument or channel has been repaired or de-energized. Calibration of these instruments or channels (except those such as scram pushbuttons that do not require calibration) shall be done at least annually.

5. Channel Tests: Channel tests of the instruments or channels listed in Table 4.2-1 shall be performed if the channel or instrument has been modified or repaired.

6. The following instruments shall be calibrated and trip points verified when initially installed, any time a significant change in indication is noted, and at least annually:

a) Period

b) Neutron Flux Level

c) Primary Coolant Outlet Temperature

d) Core Tank Level

e) Reflector Tank Level

f) Primary Coolant Flow

g) D_2O Reflector Flow

h) Shield Coolant Flow

~~i) Nuclear Safety Channel Low Count Rate~~

7. Thermal Power: The signals used to compute thermal power shall be calibrated at least annually.

Table 4.2-1

Surveillance of Scram and Power Measuring Channels

Instrument or Channel		Channel Test to Verify
1	Period[(1)]	Scram
2.	Neutron Flux Level[(1)]	Scram
3.	Primary Coolant Outlet Temperature	Scram
4.	Core Tank Level	Scram
5.	Reflector Tank Level	Scram
6.	D_2O Dump Valve Switch	Scram and Reflector Dump
7.	Air-Operator D_2O Dump Valve Switch	Reflector Dump
8.	Manual Major Scram	Magnet Cut-off, Reflector Dump, and Ventilation Trip
9.	Manual Minor Scram	Magnet Cut-Off
10.	Experiment Shutdown	As Specified in Experiment Approval
11.	Primary Coolant Flow[(2)]	Scram
12	D_2O Reflector Flow[(2)]	Scram
13.	Shield Coolant Flow[(2)]	Scram
14.	Fission Converter	As specified in Fission Converter TS 6.6.3
15.	Nuclear Safety Channel Low Count Rate[(1)]	Scram
16.	Nuclear Safety Channel in Test[(1)]	Scram
17.	Nuclear Safety Channel Fault[(1)]	Scram
18.	Hold-Down Grid Unlatched	Scram
19.	Reactor Remote Shutdown(s)	Scram from Medical Facilities and Utility Room

(1) Reactor scrams when two trips in any combination are present simultaneously from any two of the four nuclear safety channels.

(2) Not required for startup in natural convection cooling mode.

9. Heat Balance: The signal from the linear power channel shall be checked against a heat balance calculation at least monthly, for any month that the reactor is operated above 1 MW continuously for at least 48 hours.

10. Control Device Inspection: Control devices shall be inspected annually as follows:

    a) Shim blade absorbers shall be checked visually.

    b) Shim blade electromagnets shall be checked both visually and by measuring the resistance of the coils.

    c) Shim blade and regulating rod drives shall be monitored for proper operation.

11. Control System Interlocks: A channel test of the following interlocks and scram shall be performed at least annually:

    a) Withdraw Permit Interlock,

    b) Subcritical Limit – Shim Blades Interlock,

    c) No Overflow Reflector Startup Interlock, and

    d) Low Level D_2O Reflector Scram.

Basis

The MITR-II has observed the criteria given in Specification 4.2.1 for determination of control device reactivity worths and found it to be adequate. Measurements of the integral and differential worths are required annually. Measurements following changeouts of absorbers and change of core configuration are desirable. However, such measurements are very time consuming. Moreover, sufficient experience exists with such changes that their effect on integral and differential reactivity worths can be predicted with reasonable accuracy. Accordingly, normal MITR-II practice is to do a complete set of measurements following replacement of all

absorber sections rather than to do measurements as each is replaced. (Note: It requires several days to replace one absorber and the entire process is usually done over an interval of several months.) Estimates of the change of worth are used pending the measurement. Estimates, not measurements, are normally used for changes of core configuration.

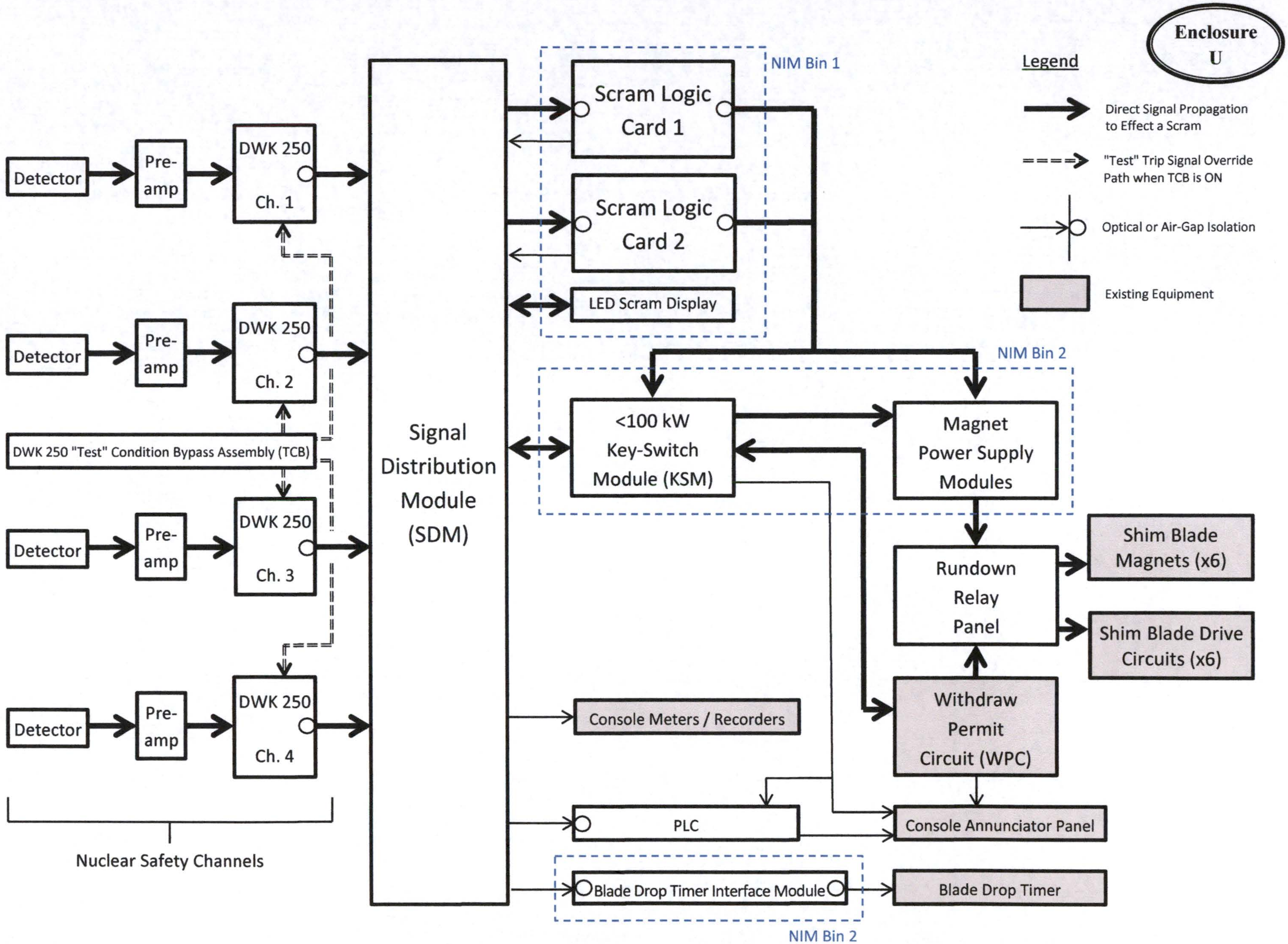
The insertion and withdrawal speed of the control devices is fixed by the motor and drive design as discussed in Section 4.2.2 of the SAR. These speeds are verified annually.

Scram time is as defined by Specifications 1.3.37 and 3.2.1~~.2~~. It is verified at least annually and whenever maintenance has been performed that could affect it.

The instruments and channels listed in Table 4.2-1 correspond to those in Table 3.2.3-1, "Required Safety Channels" with the exception that surveillance of the building overpressure and gasket deflated scrams is addressed elsewhere (Specification 4.4).

The thermal power indication is calibrated at least annually and the signal from the linear power channel is compared against a heat balance at least monthly for any month that the reactor is operated above 1 MW. These actions are done under conditions of thermal equilibrium which, because of the MITR-II's heat capacity (especially that of the graphite reflector), occurs after 48 hours of steady-state operation.

Control devices are inspected at least annually. The inspection focuses on those components that are important to safety. Those include the absorber sections (Section 16.3.1.5 of the SAR) and electromagnets (Section 16.3.1.4(d) of the SAR). The status of the shim blade and regulating rod drives can be deduced from external observations such as the measurement of blade and regulating rod insertion/withdrawal speeds (Specification 4.2.2). Internal inspections require lowering of the core tank level and removal of the drive. These are usually done whenever an absorber is changed out. As described in Section 16.3.1.5 of the SAR, this is normally done every 125,000 MWH. A prespecified frequency for an internal inspection would involve serious ALARA issues.



Block Diagram of Nuclear Safety System with Integrated Support Modules

MIT NUCLEAR REACTOR LABORATORY

AN MIT INTERDEPARTMENTAL CENTER

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MEMORANDUM

Enclosure V

To: New Nuclear Safety System QA File E-2012-1

From: John Foster, Deputy Director of Reactor Operations

Re: Human Factors Considerations for Design and Implementation of the New Nuclear Safety System.

Date: 8 October 2017

The following list outlines the human factors considered for the Mirion DWK 250 channels and all components downstream in the new Nuclear Safety System.

1. Connections to the four DWK 250 channels are connectorized and remove error associated with point to point wiring. Routing of DWK 250 signaling is accomplished by the use of a 4-layer printed circuit board (Signal Distribution Module) to distribute the signals to the proper locations and modules. This minimizes the possibility of items being wired incorrectly and makes for ease of installation. Additionally, the DWK 250 channels have to plug into the Signal Distribution Module at the correct location or an alarm will be generated in the PLC module.

2. Backlighting was activated for an "always on" condition for the DWK 250 channel displays so each display could be easily viewed by the operator at any time.

3. The scram logic card design incorporated the use of 2 out of 4 voting logic to allow for one channel to be in test or out of commission instead of the typical use of a bypass switch or relay. This ensures all equipment remains active and installed regardless of its state thereby mitigating the possibility of improper channel bypassing. If a channel is removed, all trips for that channel become active as seen by the scram logic cards.

4. The method of providing <100 kW high power scram settings on the existing nuclear safety system requires swapping out safety channels 5 & 6 high range amplifiers to low range amplifiers. This creates an opportunity where human errors could occur during the reconnection process. The new system will utilize a key switch that shifts from full power mode to <100 kW mode thereby mitigating the possibility of errors such as cable or card/chassis swapping. The key will be kept in the control room key cabinet, with use

controlled by startup checklists that define the mode of operation (Full Power or <100 kW). An annunciator informational alarm will actuate when in the <100 kW mode. See Figures 1-4 for existing and final annunciator panel layouts.

5. The module layouts in the control room were identified by reactor staff and active reactor operators according to the most efficient use of space and the understanding of how certain modules interfaced with each other and existing equipment. See Figures 5 & 6 for the existing and final control room layout. The rundown relay panel was important to keep in its current location to eliminate the need for additional wiring to interface with the blade drives and magnets. It was important to keep the DWK 250 channels located at an easy-to-view height and in their exact locations utilized during the testing phase including detectors, preamps and cabling. The remaining modules were located in proximity to each other based on how the operator will utilize the equipment during routine surveillances.

6. The remote displays for wide range reactor power and reactor period will remain analog meters, very similar in appearance to the existing system. Additionally, they will be located on console in front of the operator in the same location as those for the existing system. The existing system has dedicated power and period meters for channel 3, while channels 1 and 2 share one set of power and period meters controlled by a selector switch. The new system will have 8 meter displays total (DWK 1-4, each with power and period). Channels 1 & 2 will be on the left hand side of the console and channels 3 & 4 will be on the right hand side of the console. See Figures 7 & 8 for existing and final console meter layouts.

   Channel 1 detector is located in 4IH3; channel 2 detector is located in 3GV2; channel 3 detector is located in 4IH1; and channel 4 detector is located in 3GV5. The 4IH detectors are looking at the lower portion of the reactor core while the 3GV detectors are looking at the higher portion of the reactor core. This arrangement gives the operator two diverse views of the reactor flux regardless of which side of the console they are viewing reactor power/period.

7. Surveillance checklists were developed and tested to ensure all testing evolutions return the systems to their preferred state for reactor operation. Multiple operators performed the draft surveillance checklists in order to ensure sufficient detail and directions were included in the final procedures.

8. Annunciator alarms will be arranged in a method consistent with current NRL practices. The bypass alarm will be added to the left side annunciator panel near all other bypass alarms and will be their characteristic yellow color. The safety system scram alarm will remain in its current location and remain red in color. All other alarms are informational in nature and will be white in color.

Center Annunciator Alarm Panel – Existing

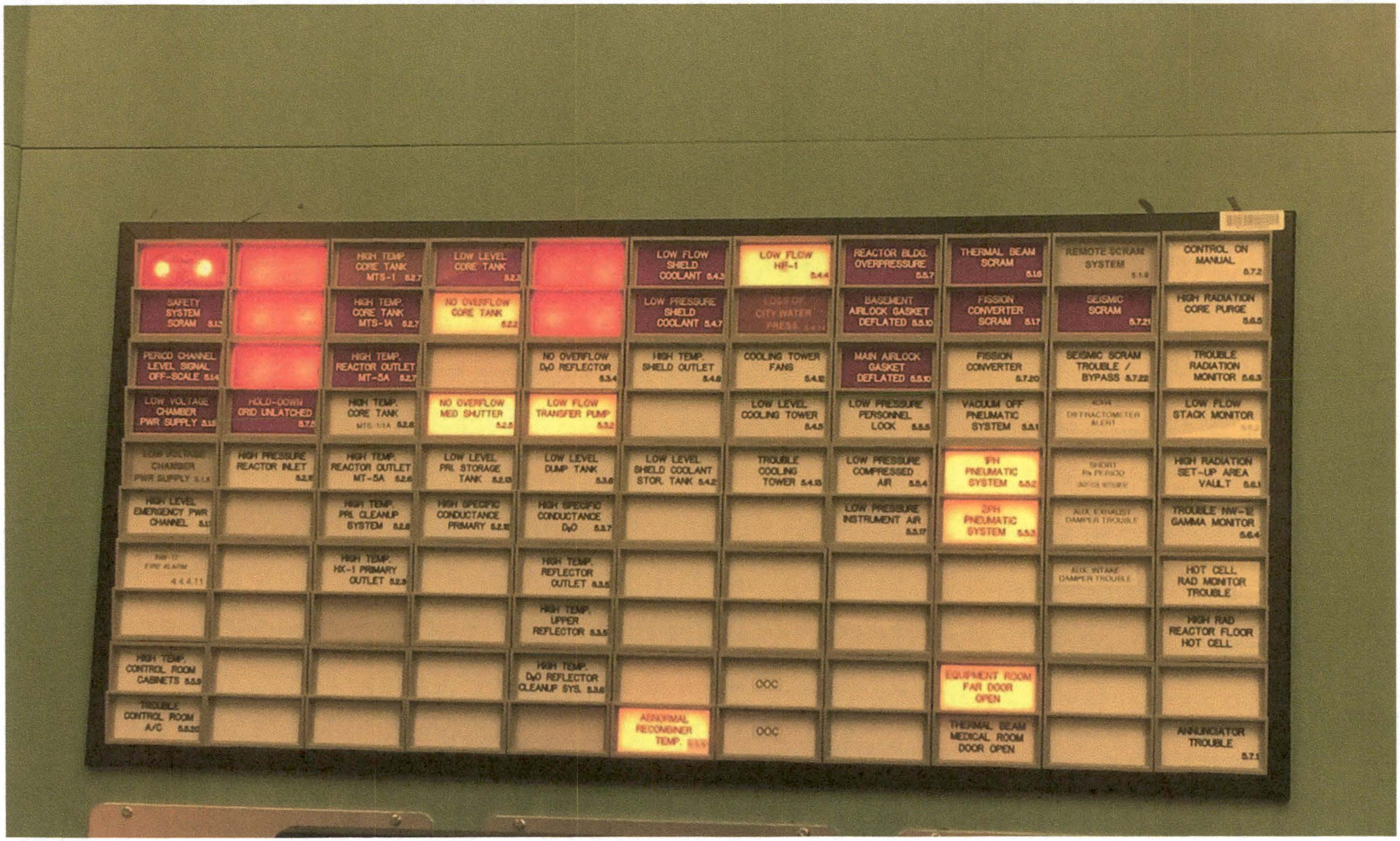
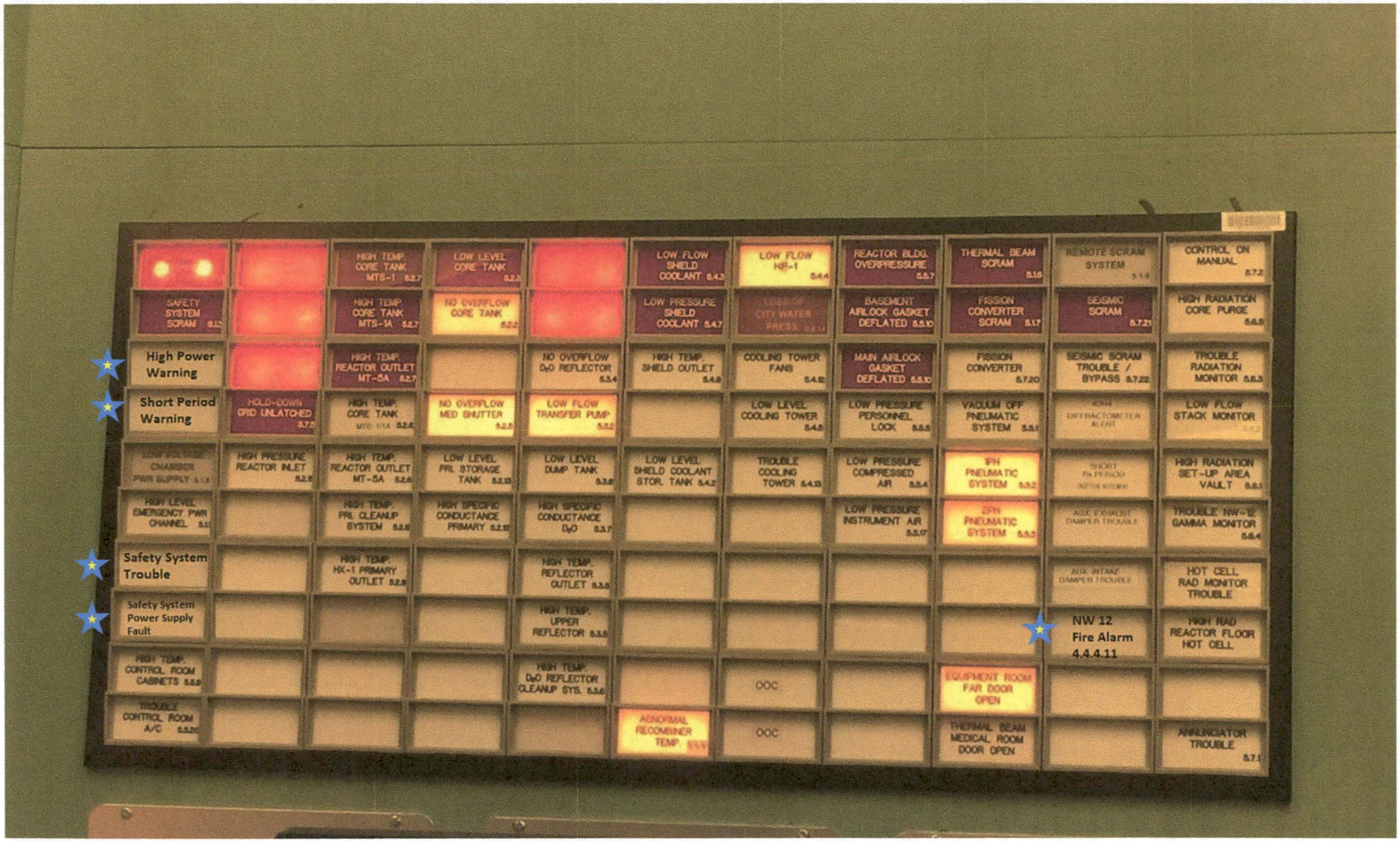


Figure 1

Center Annunciator Alarm Panel – Final



★ Indicates a change from the existing layout.

Figure 2

Left Side Annunciator Alarm Panel – Existing

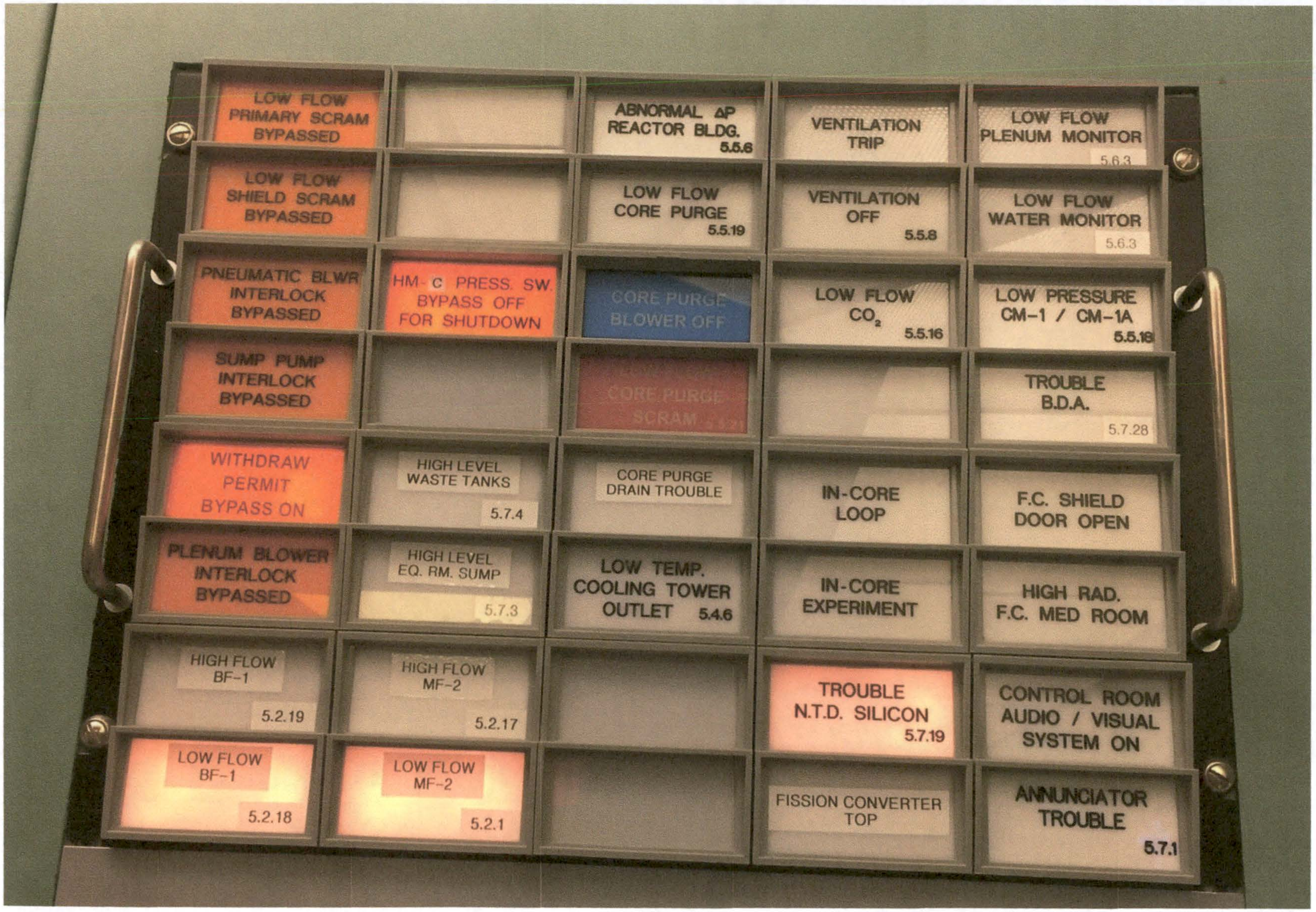
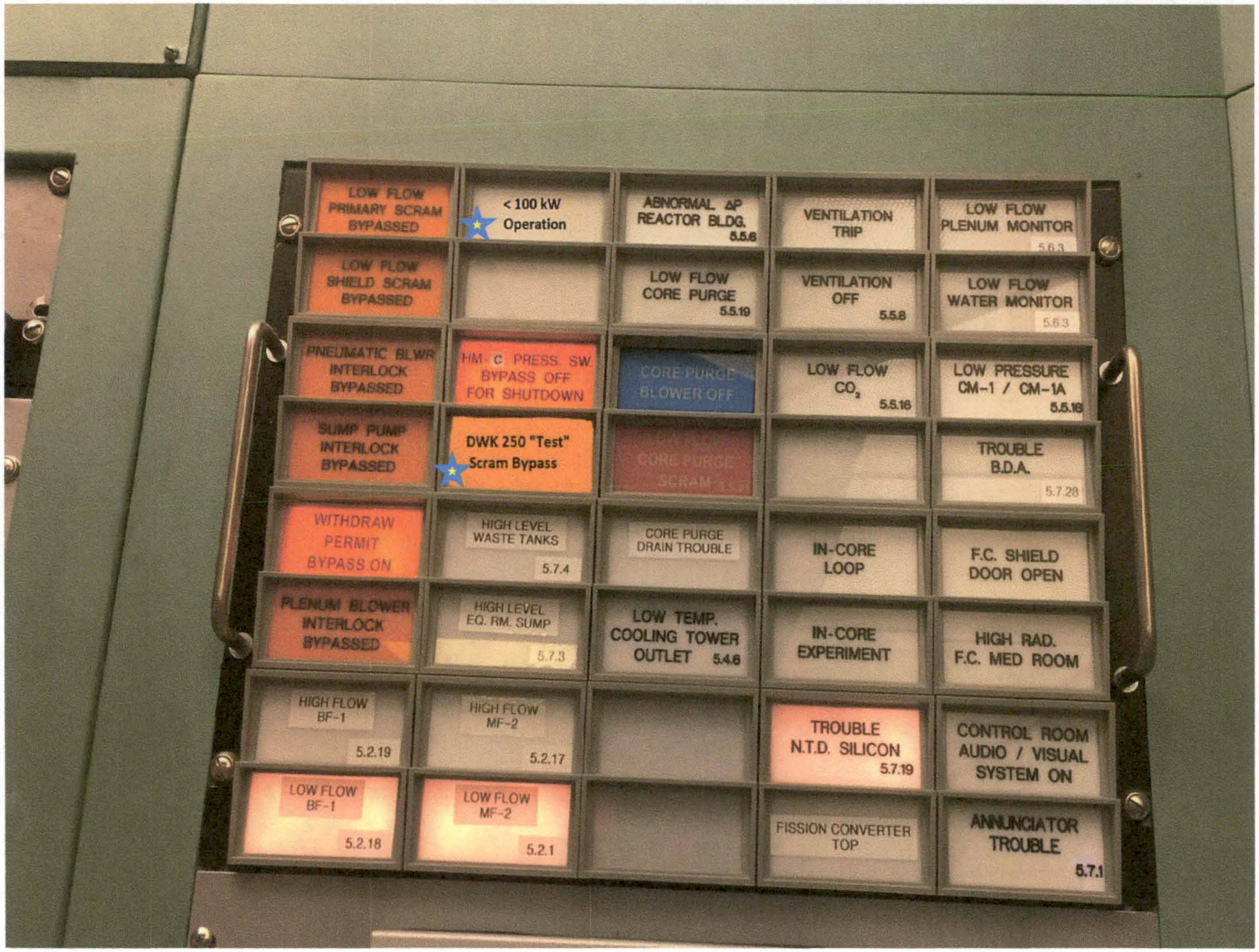


Figure 3

Left Annunciator Alarm Panel - Final



★ Indicates a change from the existing layout.

Figure 4

Control Room Layout - Existing

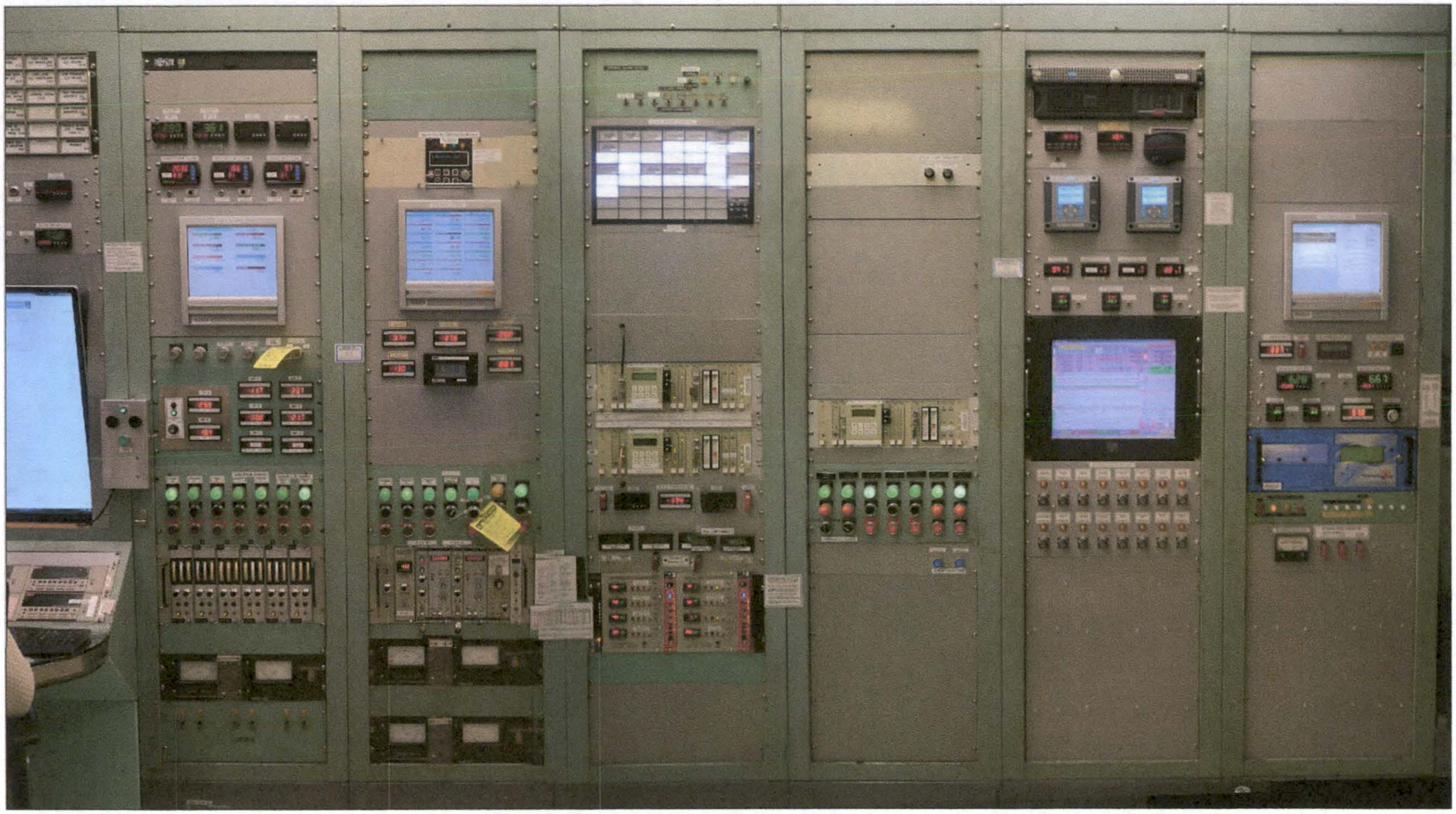
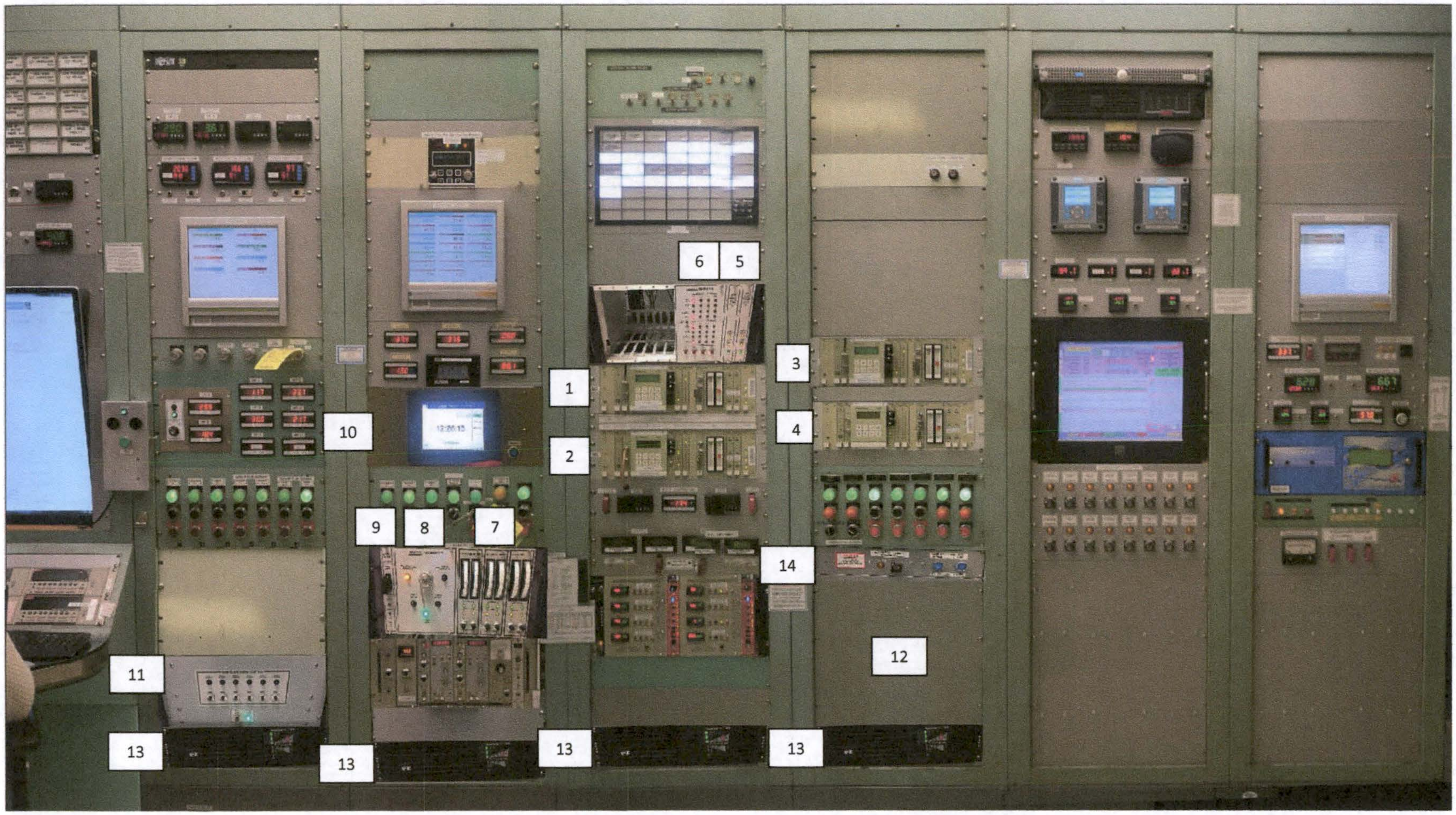


Figure 5

Control Room Layout - Final

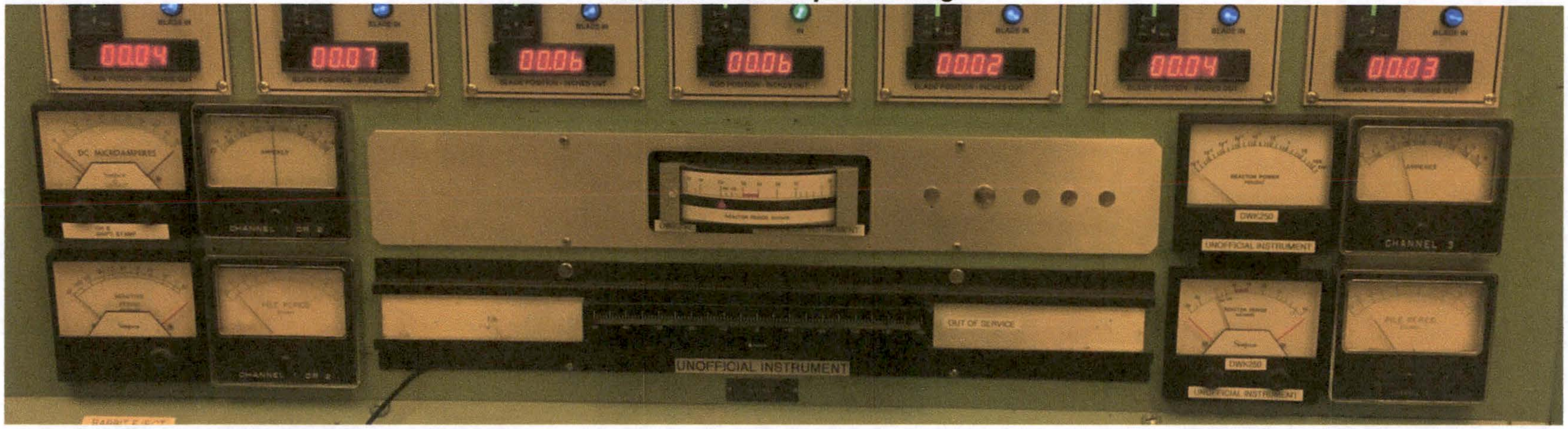


1. Mirion DWK 250 1
2. Mirion DWK 250 2
3. Mirion DWK 250 3
4. Mirion DWK 250 4
5. Scram Logic Cards 1 & 2
6. LED Scram Display Module
7. Magnet Power Supplies
8. <100 kW Key Switch Module
9. Blade Drop Timer Interface Module
10. Safety System Monitoring & Scram Display PLC
11. Rundown Relay Panel
12. Signal Distribution Module (mounted inside)
13. UPS Modules
14. DWK 250 "Test" Condition Scram Bypass Assembly

Figure 6

Console Meters Layout – Existing and Final

Console Meters Layout-Existing



OOC meters | Ch 1 or 2 Pwr/Period | DWK Testing | Ch 3 Pwr & Period

Console Meters Layout-Final

DWK 1 Pwr/Period | DKW 2 Pwr/Period | DKW 3 Pwr/Period | DWK 4 Pwr/Period

★ Indicates a change from the existing layout.

Figures 7 & 8