MIT Research Reactor

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Phase 0 Review of MITR Approach to a Digital I&C Upgrade

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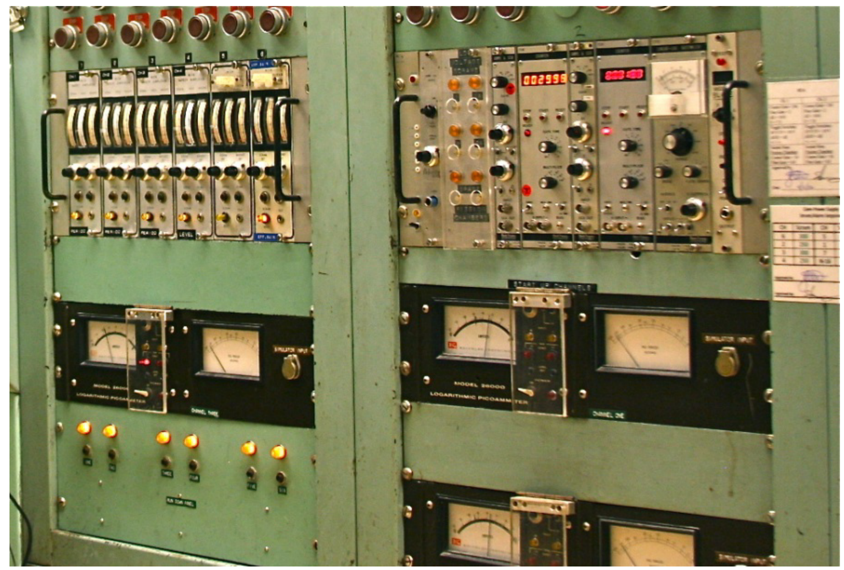
Discussion Topics

- Existing MITR Nuclear Instrumentation & Control
- Upgrade to Digital Nuclear Safety System
- Fission Chambers & Pre-Amplifiers
- Description of DWK 250 Channel
- Description of Scram Logic Circuit
- Security & Cyber Vulnerability Evaluation
- License Amendment Request – Documents & Schedule
- Questions & Comments

Existing MITR Nuclear I&C

- Ten channels – Channels #1 through #9 plus Channel #N-16
- Channels #1 through #6 are the six fully analog nuclear safety channels to be upgraded to digital
- Ch. #1 through #3 for short reactor period scram
- Ch. #4 through #6 for high neutron flux level scram
- Ch. #1 & #2 operate on fission chambers for source range and are switched to ion chambers for power range



- Ch. #3 operates on ion chamber that comes on scale starting ~0.5 kW

Operational Specifications for Nuclear Safety System Ch. #1 - 6

- Two out of three period and flux level channels must be operable whenever the reactor is critical
- Short period trip at 10 seconds
- High neutron flux level trip at 6.5 MW
(80 kW without primary flow)
- Time from initiation of scram signal to 80% control rod insertion is < 1 second.
- Channel tests quarterly, before each startup, and after repair or de-energizing

- Quarterly channel calibration on startup checklists (annual per Tech Spec)

Instrument Transition from Source Range to High Power Range

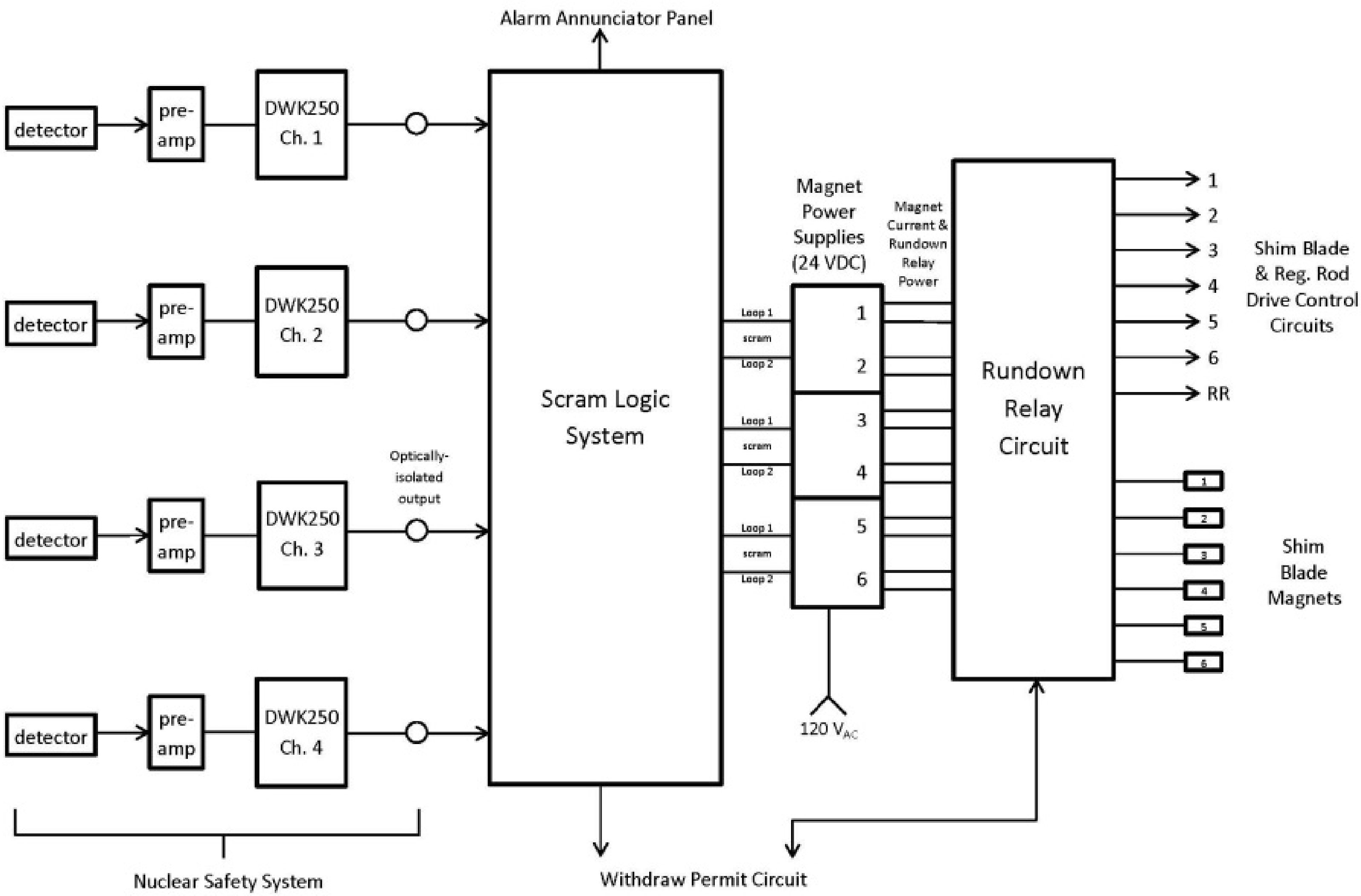
- Prior to startup, Ch. #1 & 2 are on scale with their fission chambers; Ch. #3 is not on scale
- ~0.5 kW Ch. #3 comes on scale; switch Ch. #1 to ion chamber
- When Ch. #1 on ion chamber comes back on scale, switch Ch. #2 to ion chamber
- By 2 kW, Ch. #2 on ion chamber comes back on scale, so all three are now on scale on ion chambers

- Throughout the startup, Ch. #4 through Ch. #6 are on scale with their ion chambers; perceptible readings appear ~500 kW

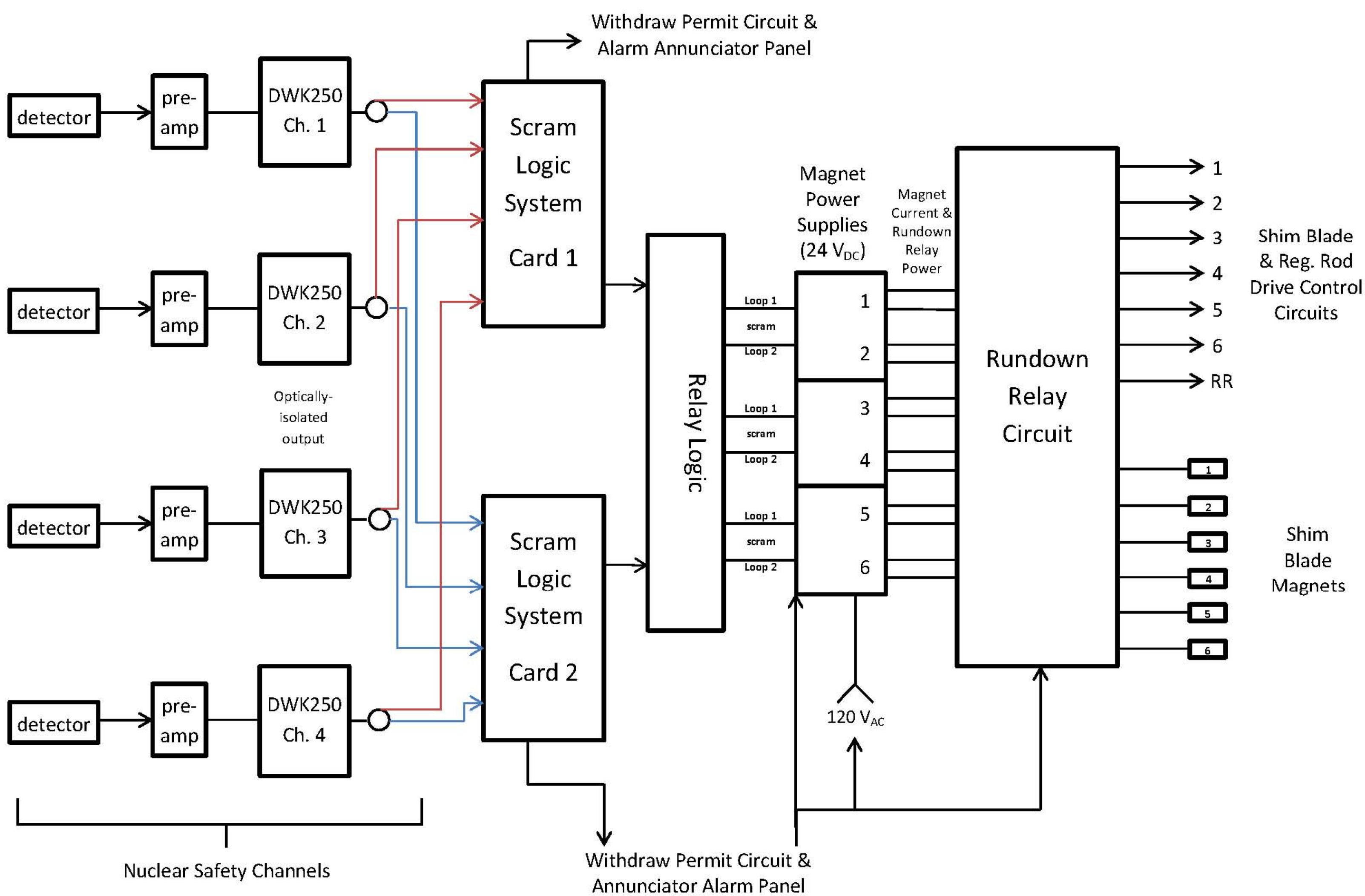
Proposed Upgrades for the Nuclear Safety System

- Replace Channels #1 – 6
- Wide-range operation so there will be no detector switching
- Field-proven with reliable application in nuclear reactors
- Four channels; each can provide scrams on short reactor period and high neutron flux level (same set points and scram time as previous)
- Two out of four channels are required to be operable whenever the reactor is critical
- Channel test/calibration possible with the reactor operating
- Original Tech Spec will be mostly unchanged

Proposed Upgrades for the Nuclear Safety System

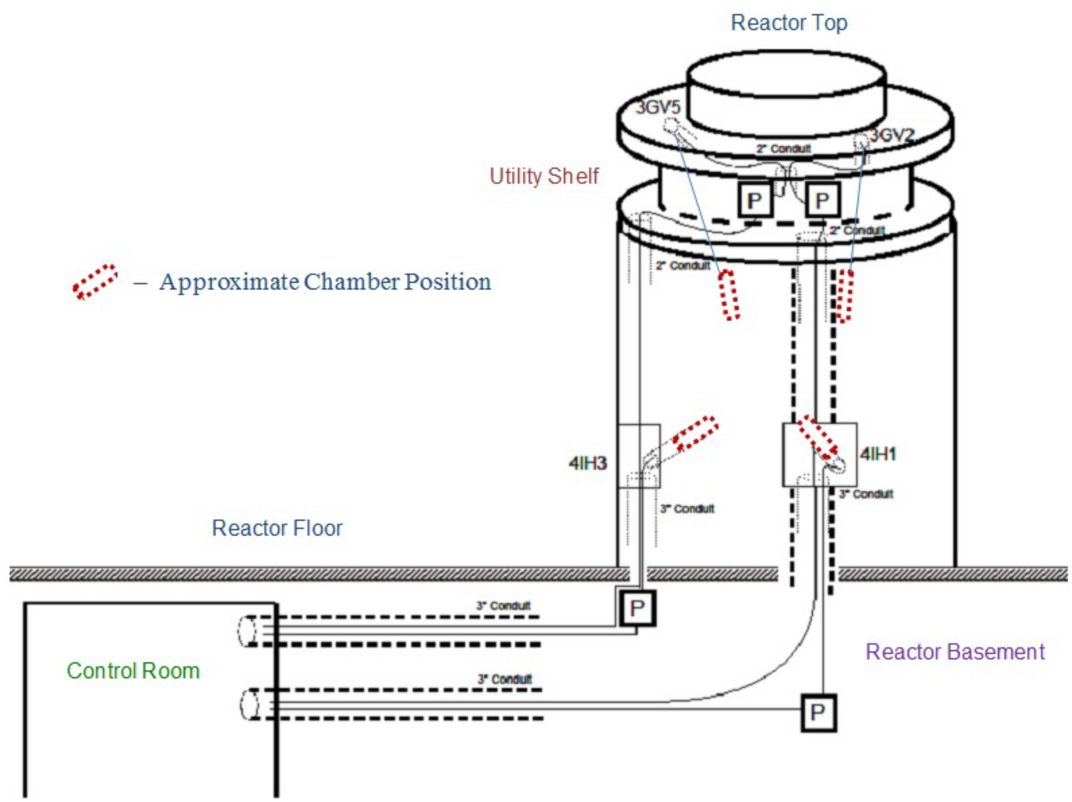


Proposed Upgrade to the Nuclear Safety System – Logic Detail

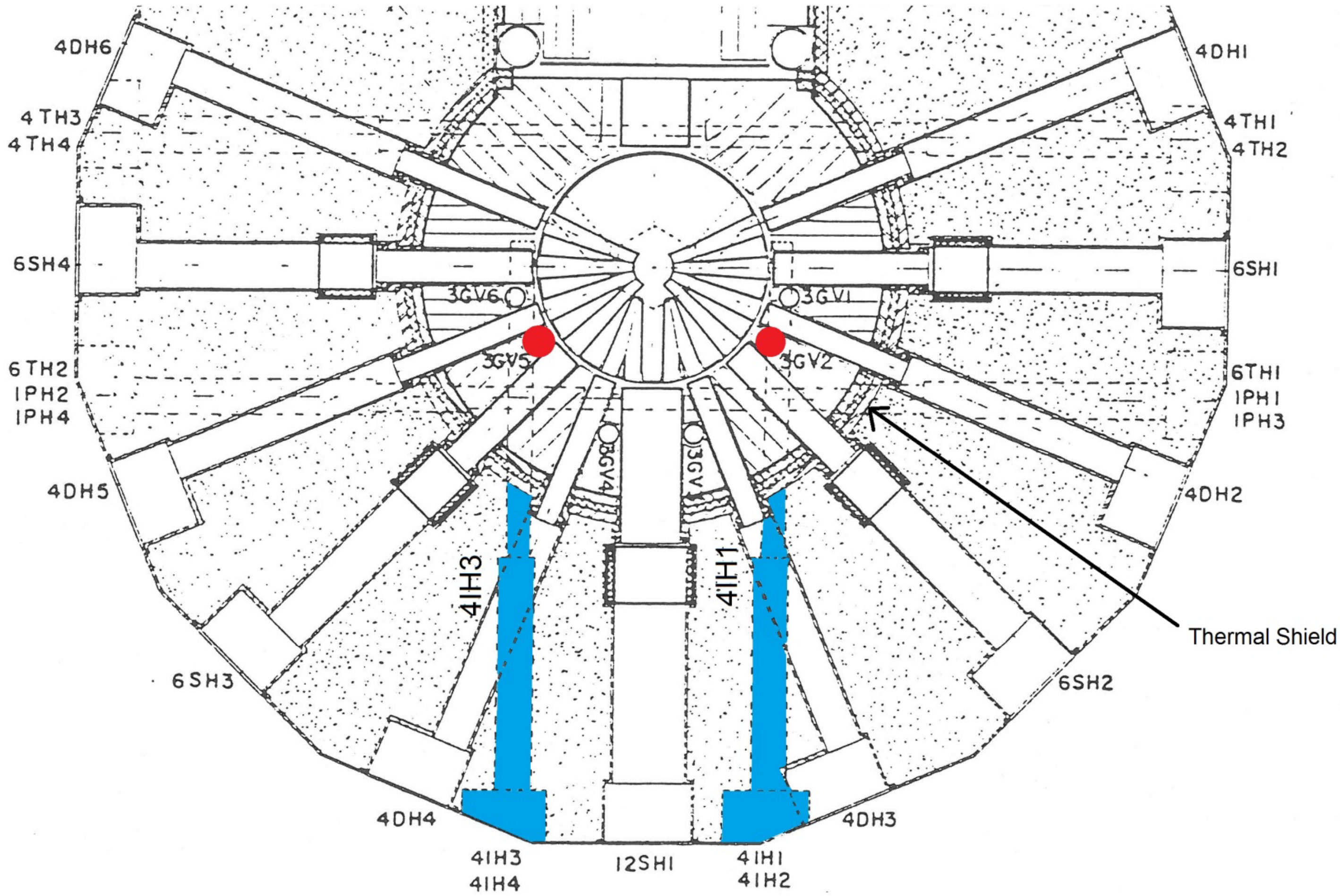


Fission Chambers and Pre-Amplifiers

- All four fission chambers are of identical design and build, from Mirion US
- Each detector is 10.7” long and 2.6” diameter, with a triaxial integral quartz cable 7 feet long
- Each chamber feeds a pre-amplifier (Mirion TKV 23), which passes the amplified fission chamber signal to the DWK 250 for processing
- Pre-amp has a built-in pulse signal and AC signal test generator



Fission Chamber Detector Placement



DWK 250 Analog & Digital Signal Paths

(Image removed for proprietary protection.)

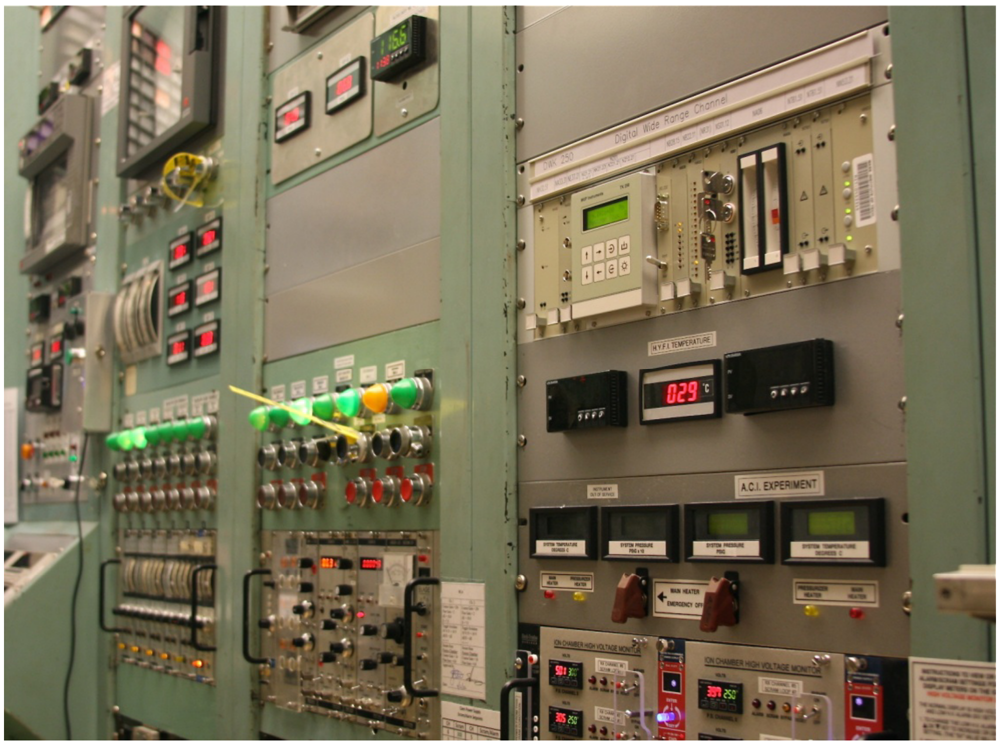
One of Four New Mirion DWK 250 Channels for MITR

- Each channel provides short reactor period scram & high reactor power scram
- Each channel utilizes one fission chamber for wide-range power operation
- Reactor power and period calibration and scram checks can be done with the reactor operating
- Test signal travels along the detector signal path starting from the fission chamber pre-amplifier

One of Four New Mirion DWK 250 Channels for MITR

- Each DWK 250 monitor incorporates three different microprocessor modules for signal processing
- Each microprocessor executes its function as set by the firmware permanently programmed into its non-volatile memory EPROMs
- Execution of firmware is confirmed by continual checksum comparison
- Microprocessors and firmware have field-proven reliable for >25 years in European nuclear industry

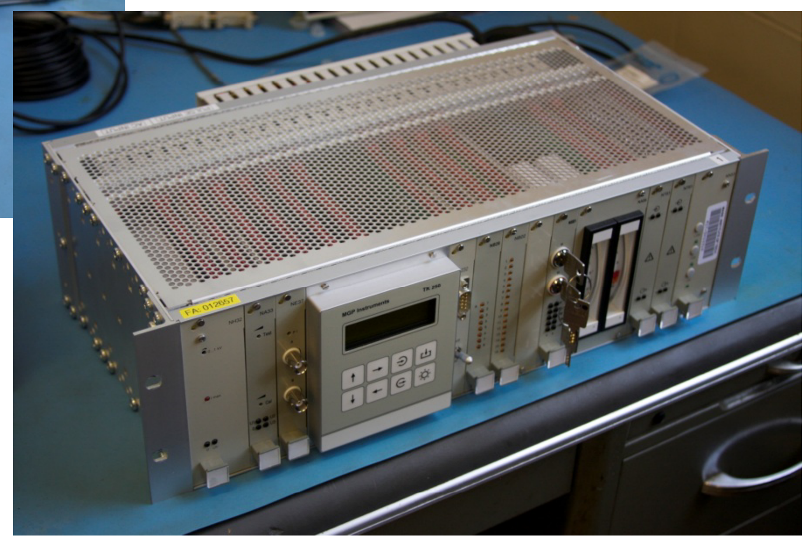
One of Four New Mirion DWK 250 Channels for MITR



- The microprocessors handle pulse signals and also perform "Campbelling", allowing wide-range indication
- Trip set-points do not drift
- Detector voltage and internal operating voltages monitored for compliance with adjustable tolerances
- Continuous Op-code handshaking between the DWK's microprocessors as an active check of functionality

One of Four New Mirion DWK 250 Channels for MITR

- Eight binary (relay) outputs – DWK uses two for internal fault indication; MITR uses two for scram circuit



- Two analog outputs
- One serial communication output (RS232 port)
- MITR will use these for display and recording

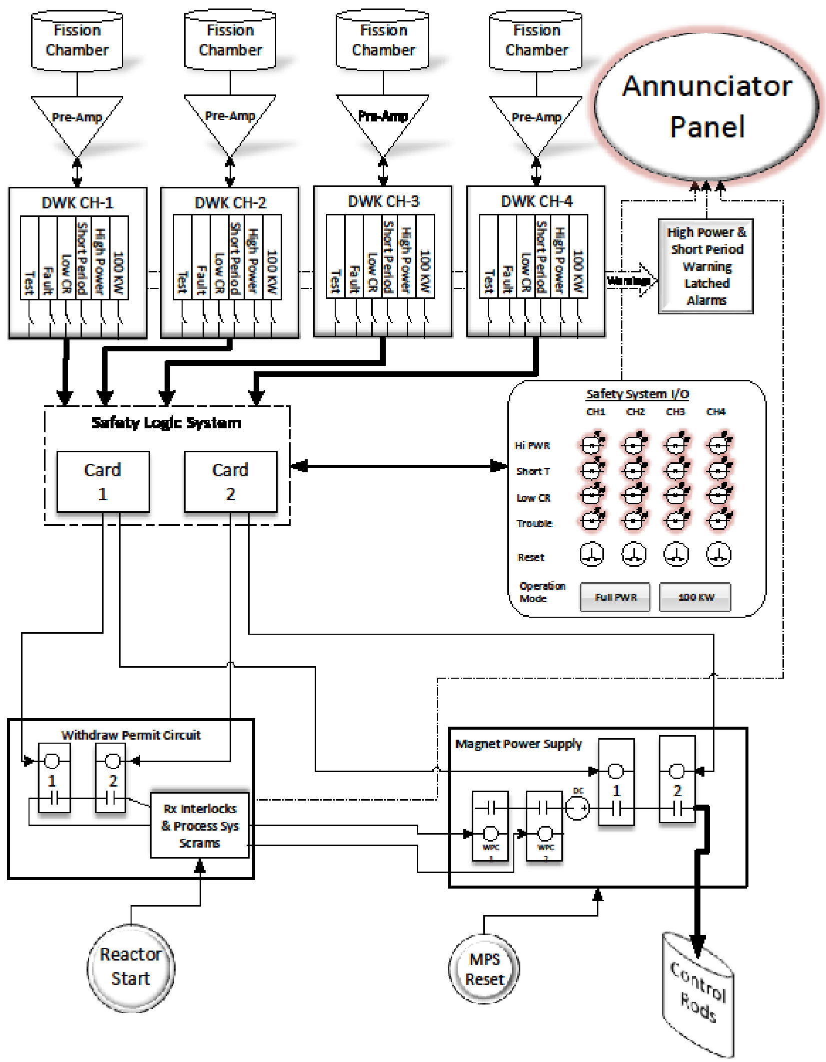
DWK 250 Functional Diagram

(Image removed for proprietary protection.)

DWK 250 Quality Standards

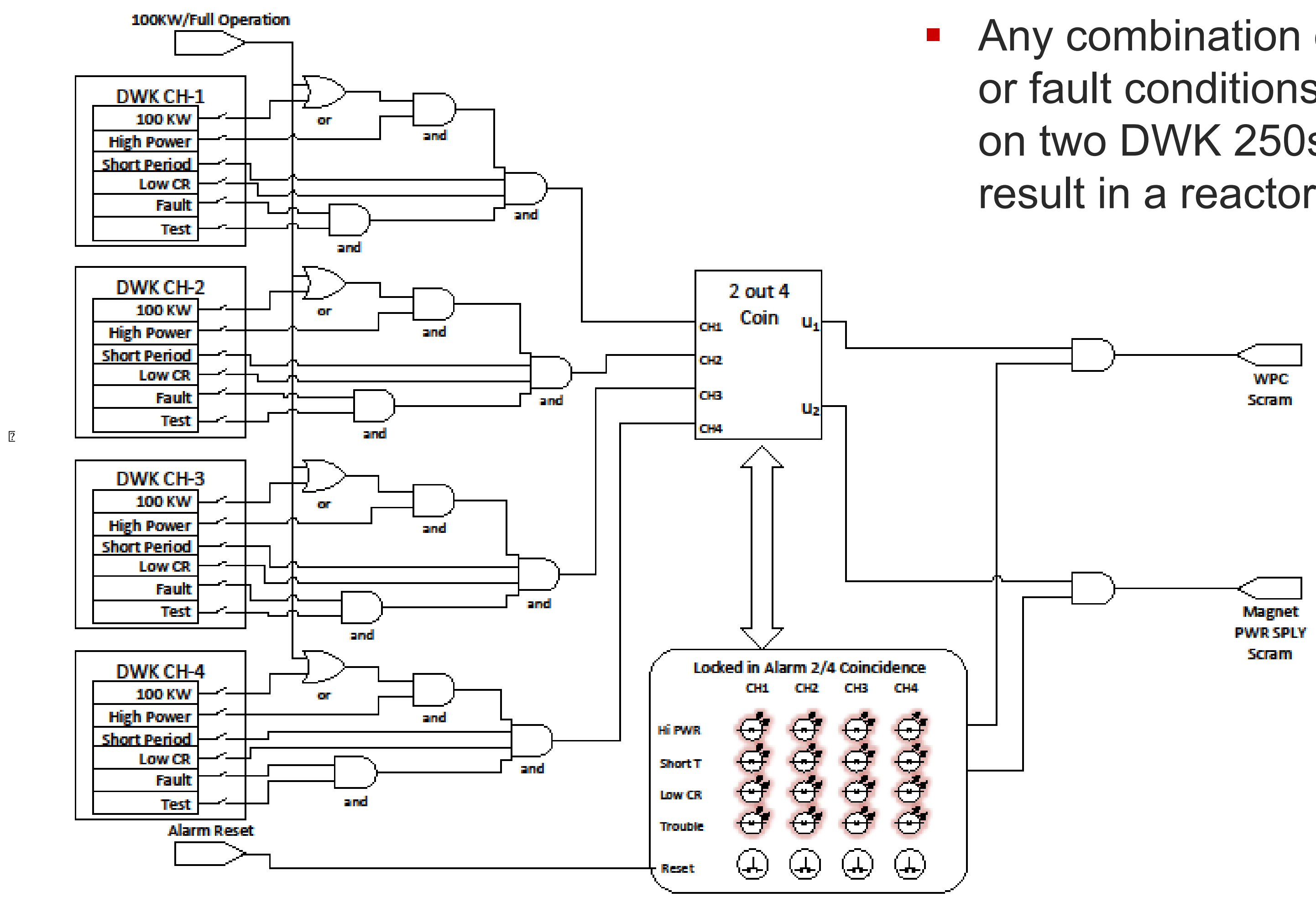
- DWK 250s, their firmware, and their TKV 23 pre-amps were designed and manufactured in Germany
- Qualified by TUV per German nuclear regulatory KTA guidelines 3501, 3505, 3507, and 1401, for type approval tests of safety-related I&C systems in accordance with Category A of IEC 61226
- Category A is equivalent to IEEE 323 Classification 1E equipment for nuclear power stations, and to IEEE 344 Classification 1E equipment with regards to seismic qualification

MITR Protection System Logic Circuit



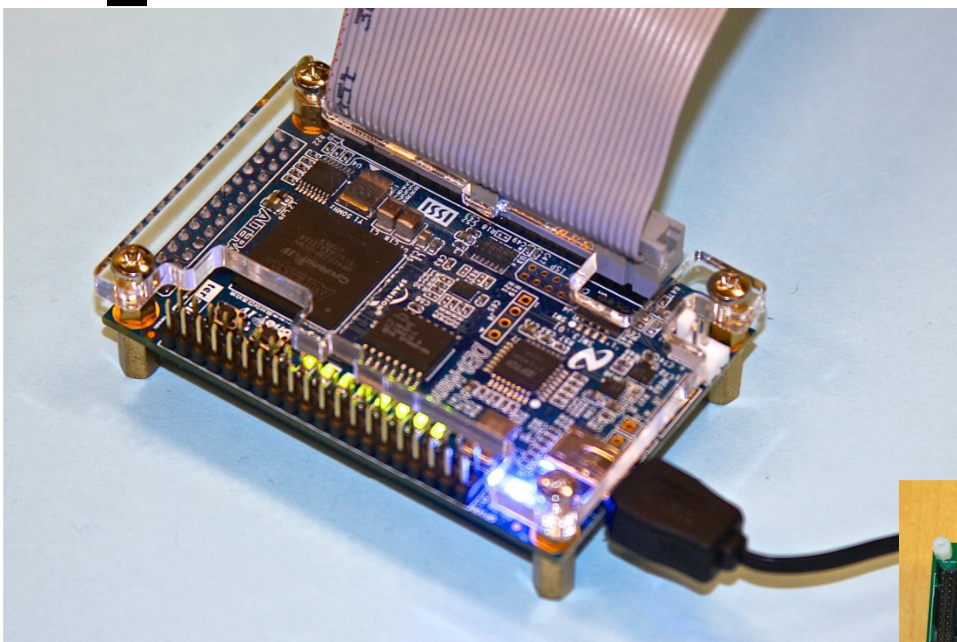
- Two-out-of-four coincidence logic used in this design
- A single scram output from a DWK 250 will not result in an immediate reactor scram unless a second unit has tripped or faulted.
- Total of 29 inputs to the Scram Logic System
- Scram Logic System has two identical logic circuits in Card 1 and Card 2
- Coincidence logic is applied in the cards to produce a reactor scram

Logic Circuit – concept detail

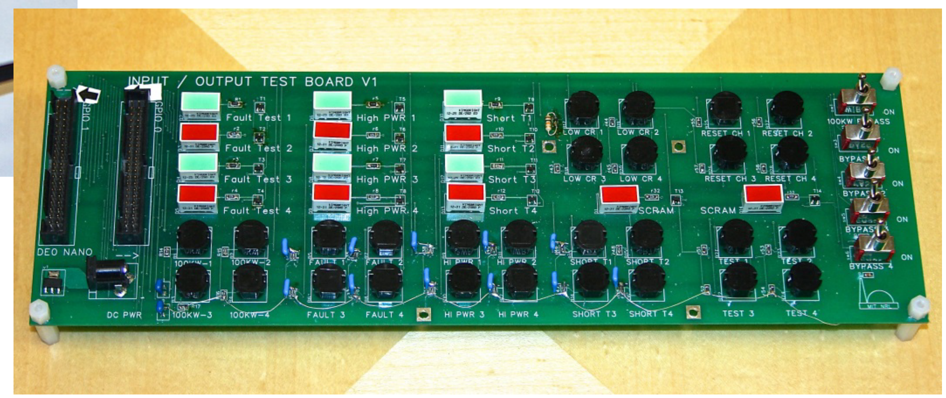


- Any combination of trips or fault conditions on two DWK 250s will result in a reactor scram

Logic Circuit – development

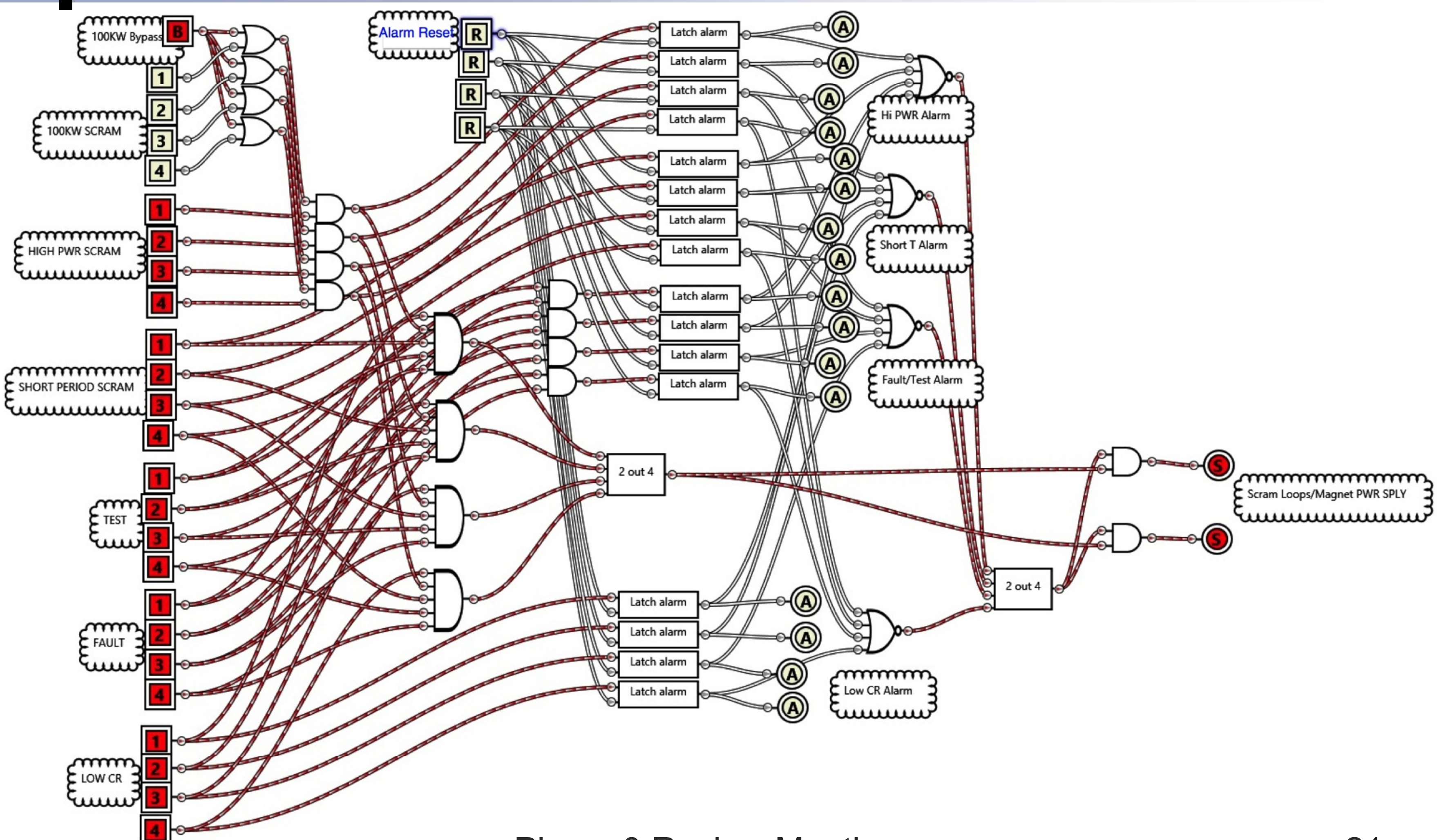


- Boolean logic diagram for two-out-of-four coincidence
- Verified by computer-based logic gate simulator
- FPGA device for logic test

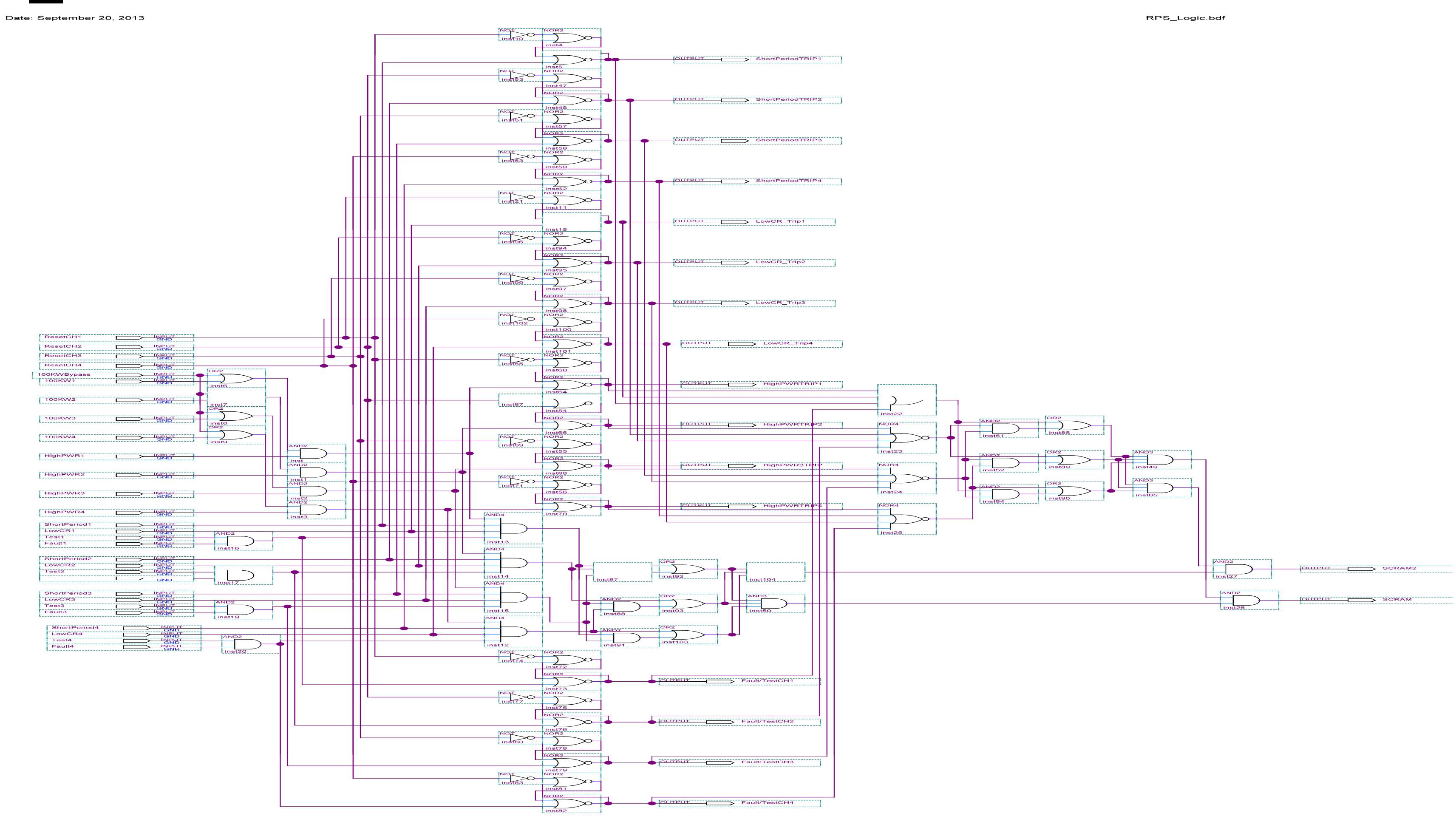


- 29 inputs to logic circuits
- Testing board created
- Generation of CAD layout for prototype printed circuit board

Boolean Diagram – Output of Logic Gate Simulator



Logic Diagram – Output from Quartus II



Security & Cyber Vulnerability Evaluation

- Firmware on the three microprocessors for each DWK 250 cannot be altered
- Firmware and its downloading are safeguarded at Mirion Germany
- Adjustable parameters (alarm set points, discriminator threshold, etc.) can be changed from the front keypad only when a key switch is enabled; otherwise the terminal block at the back must be used, as the front RS232 connector will be physically removed once testing phase is complete
- Final position of DWK 250s will be in the control room, which is continuously monitored or safeguarded
- System will not be connected to any network

License Amendment Request

- Final logic circuit design & testing plan
- SAR Revision
- Amendment to Technical Specifications
- Projected Schedule

Concluding Material

- Questions & Comments

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