REACTOR PROTECTION AND CONTROL
PROCESS INSTRUMENTATION REPLACEMENT PROJECT AT
DONALD C. COOK NUCLEAR PLANT UNITS 1 AND 2

SPEC 200/SPEC 200 MICRO
HARDWARE AND FIRMWARE SYSTEM DESCRIPTION

REPORT NO. 2985-WGS-03, REV 0

Prepared by: ____________________ Date 12/7/92

Approved by: ____________________ Date 12/7/92

Introduction

A hardware and firmware description of the upgraded Reactor Protection Process Instrument Replacement equipment is provided in the following attached documents:

- General System Description (Document No. 0310-4120)
- SPEC 200/SPEC 200 MICRO Simplified Block Diagram
- SPEC 200 MICRO Control System Overview (Document No. TI 280-100)
- SPEC 200 MICRO Control Blocks (Document No. TI 280-110)

GENERAL SYSTEM DESCRIPTION

The existing Foxboro H-Line analog process protection system consists of four protection sets; within each protection set are multiple racks. Each rack contains various analog modules that process system inputs temperature, pressure, level, and flow. These racks provide contact outputs to the reactor trip logic and Engineered Safeguards Actuation (ESF) system functions. D. C. Cook is replacing the H-Line equipment with Foxboro SPEC 200 and SPEC 200 MICRO, microprocessor based modules, on Units 1 and 2.

A. General Description of the SPEC 200/SPEC 200 MICRO System

The SPEC 200/SPEC 200 MICRO process protection system is a micro-processor based replacement for the obsolete analog process protection system. The SPEC 200/SPEC 200 MICRO system is designed to be installed in the existing process protection system racks once the analog hardware and internal rack wiring are removed. The SPEC 200/SPEC 200 MICRO uses existing field terminal blocks, minimizing the disruption of field cables and preserving the existing field interfaces. The SPEC 200/SPEC 200 MICRO system processes the same inputs as the analog system, performs the same calculation and bistable functions, and supplies contact outputs to the reactor protection logic for initiating a reactor trip and ESF functions, and isolated analog outputs to indicators, recorders, plant computer and various control systems. Similar to the H-Line system, the SPEC 200/SPEC 200 MICRO system uses individual SPEC 200 MICRO modules to perform trip functions, though non-diverse trip functions are sometimes combined on the same SPEC 200 MICRO module. The following modules make up the SPEC 200/SPEC 200 MICRO system:

Input Modules:

- N-2AI-H2V
- N-2AI-P2V
- N-2AI-T2V
- N-2AI-C2L

Processor Modules:

- N-2CCA-S
- N-2CCA-D

Output Modules:

- N-2AO-V2H
- N-2AO-L2C-R

The various input, processor, and output modules are assembled and wired in nests and configured to perform the desired function. The nests provide low voltage power for the modules from multinest power supplies. The nests and power supplies are mounted in the existing racks and configured to perform the control functions desired.

1. Input Modules

Analog input signals such as 4-20 mA, 10-50 mA, millivolt, thermocouple, RTD's, are accepted by the SPEC 200 family of input signal converter modules, and are converted to a 0-10 V dc system signal level. Each input converter module is an isolated input module with two channels of independent inputs. The live zero- based, 10 volt span signal provides exceptional sensitivity, simplifies scaling, and provides a safe system to work on. All instruments are wired in parallel which simplifies loop interconnections and permits the addition and removalofloop components without interrupting the integrity of loop operation.

2. Processor Modules

The SPEC 200 MICRO control card is a microprocessor-based unit which performs signal conditioning, regulatory control, and logic control functions. Control strategies are built by configuring interconnections between the control cardinput/output terminal and up to six blocks per control card. Each control block may be any one of the twenty block types listed:

PID - PID Control	SEQ - Sequencer
NONL - Nonlinear extender	DTIM - Dead time
INT - Integral-Only	LLAG - Lead/Lag
AMB - Auto/Manual Bias	SWCH - Switch
RTIO - Ratio	SEL - Select
MIB - Multiple Input	ALRM - Alarm
GATE - Logic Gate	RAMP - Ramp
CHAR - Characterizer	TIMR - Timer
DIN - Contact In	ACUM - Accumulator
DOUT - Contact Out	CALC - Calculator

The SPEC 200 MICRO control card uses a single nest slot. It has four analog inputs, two analog outputs, two contact inputs and two contact outputs. With the extended control card, two nest slots are utilized. This extension and control card provides for four analog inputs, two outputs, ten contact inputs and ten contact outputs. Each configured block is processed five times a second, which includes analog to digital conversion as well as error checks.

One level of security is provided as a result of SPEC 200 MICRO's low modularity. The SPEC 200 MICRO control card allows functional distribution to a very low level due to the inherent physical and input/output modularity of the card itself. This small number of shared functions allows the design of a control system with a strategy that emphasizes hardware fault containment.

Built into the control card hardware and software are the following security features:

- Comprehensive on-line diagnostics continuously monitor the status of the system, and trigger system alarms to the operator upon failure.
- Local indicators provide quick and easy identification of the failed card.
- Detection of BAD input signals.
- Verification that the correct outputs are being received by the digital to analog output converters.

Control strategies and the data base are also protected. Upon detection of failures and dependent on the type of failure, strategies can be configured to fall back to manual control or to hold the last output signal. Upon loss of power the output will go to zero. When power is restored, the output, as configured by the user, can remain at zero or return to its last value. During power interruptions, protectionof the control strategy data base is provided on each control card by battery backup for as much as 15,000 hours on a new battery, and a minimum of approximately 1000 hours on a battery at the low voltage threshold. Communication with the control blocks configured in a SPEC 200 MICRO control card is via an on-line operator interface, the SPEC 200 MICRO Display Station. The station presents to the operator all relevant process information within the control block. The control station's information is updated five times per second.

The display is vacuum fluorescence which is very bright, easy to see, highly dependable and requires low maintenance because it is totally electronic using microprocessor-based circuitry. The SPEC 200 MICRO display station provides for more functions, and for greater flexibility than conventional analog panel displays.

3. Output Modules

To transmit control and status information to the field and other devices, a family of SPEC 200 output converters is provided which include 10-50 mA and relay switching modules. These output modules are qualified Class 1E to non-Class 1E isolators.

4. Power Supplies and Distribution

A multi-nest power supply is provided to supply power to each system rack. addition Power is distributed to each nest through a power distribution module. This module protects control modules and the power supply from over-voltage, reverse voltage, and over-current conditions. The multi-nest power supply furnishes both +15 and -15 V dc thruogh nest power distribution modules for operation of display and nest-mounted instrument electronics, and 24 V ac for operation of recorder chart drives. Power supply redundancy is provided by utilizing the (N+1) approach for each group of racks..

A 75 Vdc power supply is provided to power the 10 to 50 mAmp transmitters. The 75 Vdc is distributed to the field input moduleds via the same nest power distribution modules as the electronics power to the isolated field bus. N+1 redundancy of the 75 Vdc power supply is implemented.

5. Test Panel

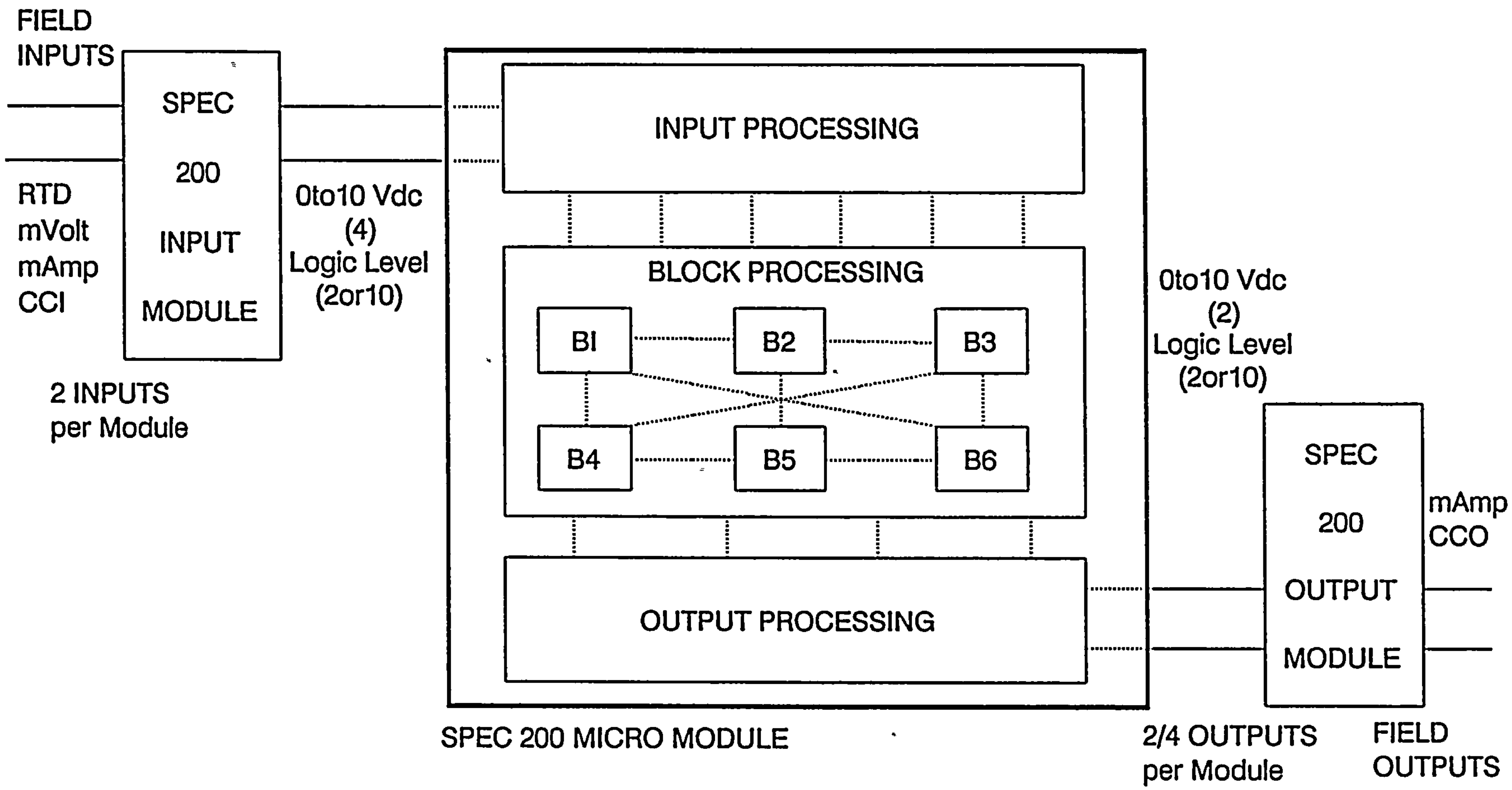
The protection system is designed to permit periodic testing of the analog channel portion of the reactor trip system during reactor power operation without initiating a protective action unless a trip condition actually exists. This is because of the coincidence logic required for reactor trip. These tests may be performed at any plant power from cold shutdown to full power. Analog channel testing is performed at each instrumentation rack by individually introducing dummy input signals into the instrumentation channels and observing the tripping of the appropriate output bistables. Process analog output to the logic circuitry is interrupted during individual channel test by a test switch which, when thrown, deenergizes the associated logic input and inserts a proving lamp in the bistable output. Interruption of the bistable output to the logic circuitry for any cause (test, maintenance purposes, or removal from service) will cause that portion of the logic to be actuated (partial trip), accompanied by a partial trip alarm and channel status light actuation in the control room. Each channel contains those switches, test points, etc., necessary to test the channel.

6. Maintenance Interface

The maintenance interface for adjusting set points and tuning parameters is the SPEC 200 MICRO panel display. The SPEC 200 MICRO normally operates without a display attached. To adjust setpoints a multiconductor cable is plugged into the SPEC 200 MICRO module. The other end of the cable is connected to the SPEC 200 MICRO panel display. The display reads the configuration from the SPEC 200 MICRO module. A key-lock on the display allows the technician to switch the display from "operate" to "tune" in order to adjust set points or tuning parameters. The setpoint is read on the front of the display. A seperate port on the display connects to a Personal Computer for configuration of the SPEC 200 MICRO module. During normal operation the display and configurator are not connected; each SPEC 200 MICRO module operates independently.

B. General Description of Modification

At the D. C. Cook Plant, AEP will remove the H-Line analog equipment and wiring in each of the process protective racks and replace this equipment with SPEC 200/SPEC 200 MICRO. In each protection set, the instrument loops in each rack will, to the extent possible, remain in that rack. The functions previously performed in H-Line modules will be distributed among analog input, SPEC 200 MICRO and analog/contact output modules. Sharing of non-diverse functions on modules is documented in the functional diagrams. The new system performs the same functions previously performed by the H-Line equipment.



Power Distribution via SPEC 200 Nest
Power Distribution Module and
Multi-Nest Power Supply

SPEC 200/SPEC 200 MICRO SIMPLIFIED BLOCK DIAGRAM

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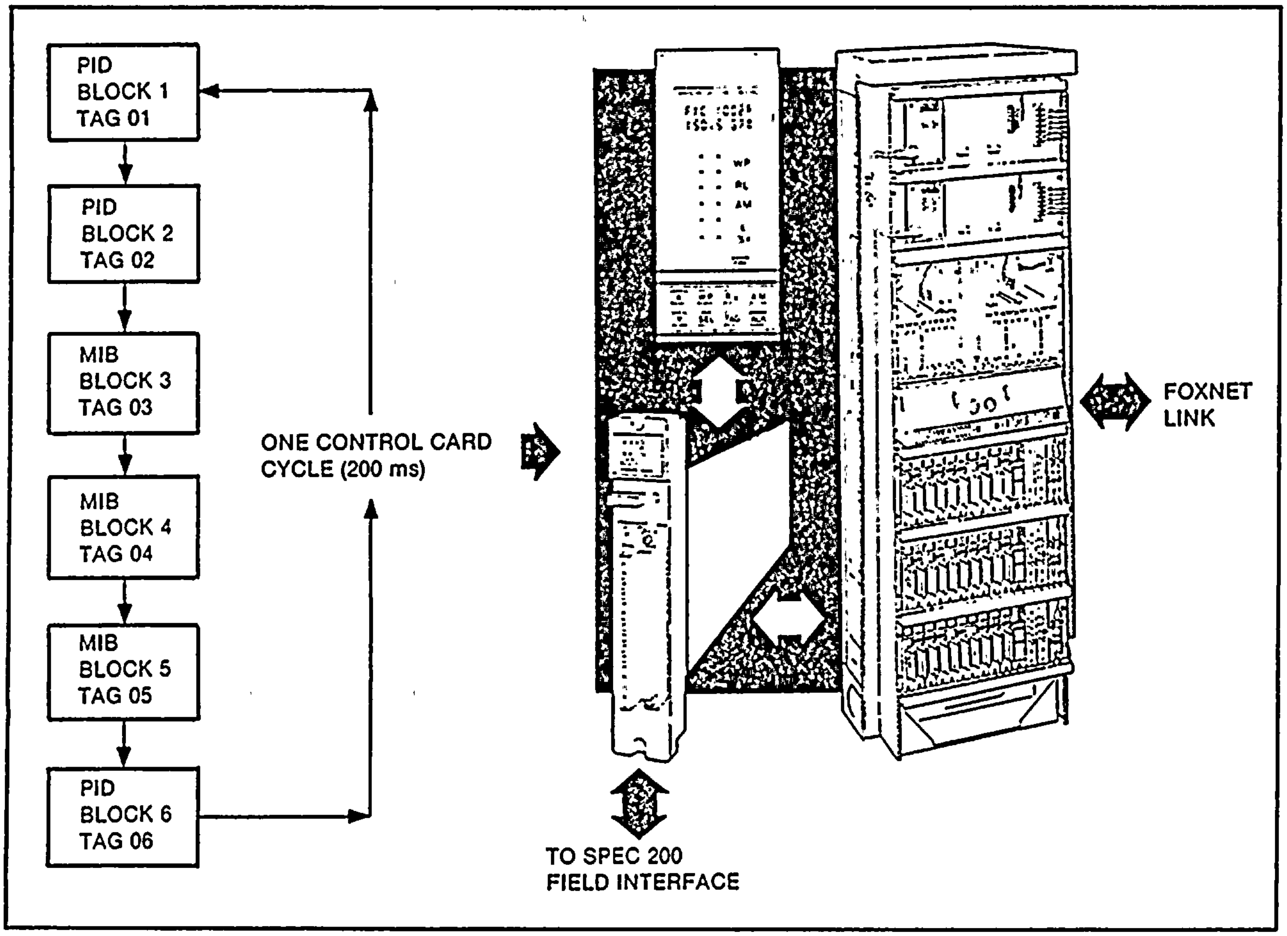

SPEC 200 MICRO CONTROL SYSTEM OVERVIEW

Provides process data acquisition and control in a stand-alone system, or in a distributed system using the FOXNET Process Communications Link to communicate with FOXNET hosts.

The SPEC 200 MICRO control system provides the user with regulatory, logic, sequential, and calculating control capability. Its major functional capabilities are control, signal conditioning and alarming, logic operations, dynamic compensation, calculation, signal selection, and timing functions.

SUITABLE FOR SMALL OR LARGE SYSTEMS

The smallest SPEC 200 MICRO system can be designed to control a single loop. Such a system could consist of one nest with a power supply, one single loop I/O component, one SPEC 200 MICRO control card, and one SPEC 200 MICRO continuous display station.

The largest SPEC 200 MICRO system can have thousands of loops in a distributed system architecture. Multiple FOXNET hosts can provide faceplates, graphics, and process management functions. The SPEC 200 MICRO Network Communications Module can co-exist with other FOXNET slave station types. The FOXNET link can have up to 100 stations, limited only by FOXNET configuration and required throughput.

POWERFUL MICROPROCESSOR-BASED CONTROL ALGORITHMS

The SPEC 200 MICRO control blocks provide the power to build advanced control strategies, which can offer

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greater security, more precise control and increased flexibility of operator interaction with the control strategy. In contrast to an analog control system, these benefits derive from using additional software blocks, rather than extra hardware modules. More control power for the same capital outlay results when control strategies employ these powerful block features. New features include inversion of logic inputs and outputs, direct connection of analog outputs to any continuous value type parameter in the control scheme, and separation of control card output limiting from alarming functions.

SECURITY THROUGH LOW MODULARITY

The physical and I/O modularity of the SPEC 200 MICRO control card allows functional distribution to a very low level. SPEC 200 MICRO offers a microprocessor-based system with the modularity of an analog system. Therefore, you can partition control schemes with either one or two control loops per control card. This can be very useful in a fault containment strategy to achieve control security.

STAND-ALONE OR DISTRIBUTED SYSTEM ARCHITECTURE

The SPEC 200 MICRO system offers you the choice of either architecture. The data base configuration procedure and system hardware have been designed so that you can easily upgrade a stand-alone system to a distributed system.

COMPATIBLE WITH EXISTING SPECTRUM INSTALLATIONS

The Network Communications Module can be added to any FOXNET installation. It emulates a MICROSPEC Unit Control Module station type, for compatibility with SPECTRUM hosts.

RETROFIT EXISTING SPEC 200 INSTALLATIONS

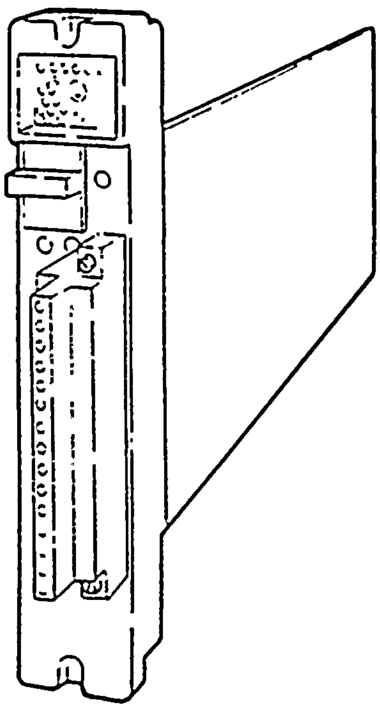
You can upgrade existing SPEC 200 installations to state of the art microprocessor-based control, with either a stand-alone or distributed system architecture. SPEC 200 I/O components, power supplies, and racks can be retained. Field wiring to the I/O components does not have to be disturbed. Because SPEC 200 MICRO display stations use existing SPEC 200 2AK cables, there is no need to install new display cables. Shelf-mounted display stations can slip directly into existing shelves. DIN sized display stations can be replaced in the existing cutout. The control block types can replace all the 2AC control functions and the 2AP signal processing and alarm functions of the existing system.

SPEC 200 MICRO HARDWARE

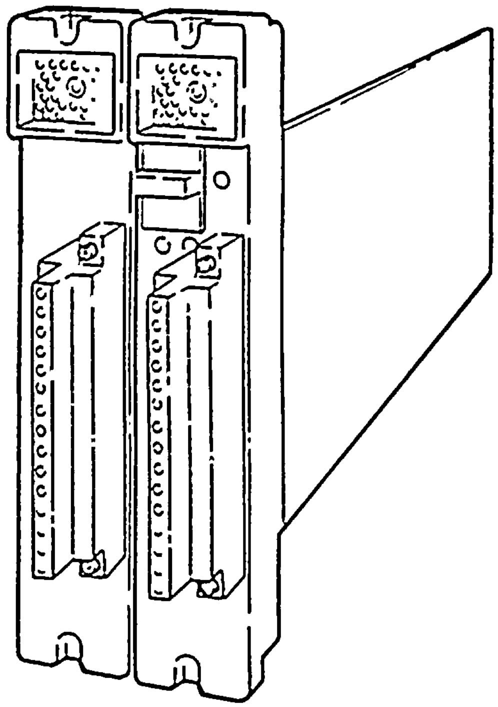
The SPEC 200 MICRO hardware is as follows:

Control Card

The Control Card (Figure 1) is a nest-mounted microprocessor-based unit which performs signal conditioning, regulatory control, and logic control functions.



CONTROL CARD



EXTENDED CONTROL CARD

Figure 1. SPEC 200 MICRO Control Card

Control functions are provided by user configuration of up to 6 control blocks, from a menu of 21 different block types. Most block types have multi-functions; e.g., the Proportional (P), Integral (I), and Derivative (D) block includes alarming, output clamping, P only, P + I, P + I + D, and other functions normally related to feedback and feedforward controllers. The extended control card version adds additional contact I/O capability.

The control card uses a single nest slot. It has four analog inputs, two analog outputs, two contact inputs, and two contact outputs.

The extended control card uses two nest slots. It has four analog inputs, two analog outputs, two contact inputs, and two contact outputs on the right hand half; and eight contact inputs and eight contact outputs on the left hand half.

Display Stations

The display stations (Figure 2) are microprocessor-based panel-mounted units available in two types. The Continuous Display Station provides an operator interface to regulatory control blocks. The Discontinuous Display Station provides an operator interface to logic control blocks. Both displays use vacuum fluorescent display technology. These displays provide sequential paging to display more than one control block; two nine-digit alphanumeric readouts provide configurable loop tag identification, highly accurate digital readout of block parameters in percent or engineering units, and the ability to modify control block tuning parameters.

The display station sizes are DIN and 3 × 6 inches. Both station types support an optional configuration port. Optional station labeling, user specified, has the following capabilities: display/loop descriptor = 3 lines, 23 characters per line maximum; continuous display high and low scale values = 4 characters maximum; discontinuous display contact descriptors = 5 characters maximum per contact state (8 contacts maximum with 2 contact states per contact).

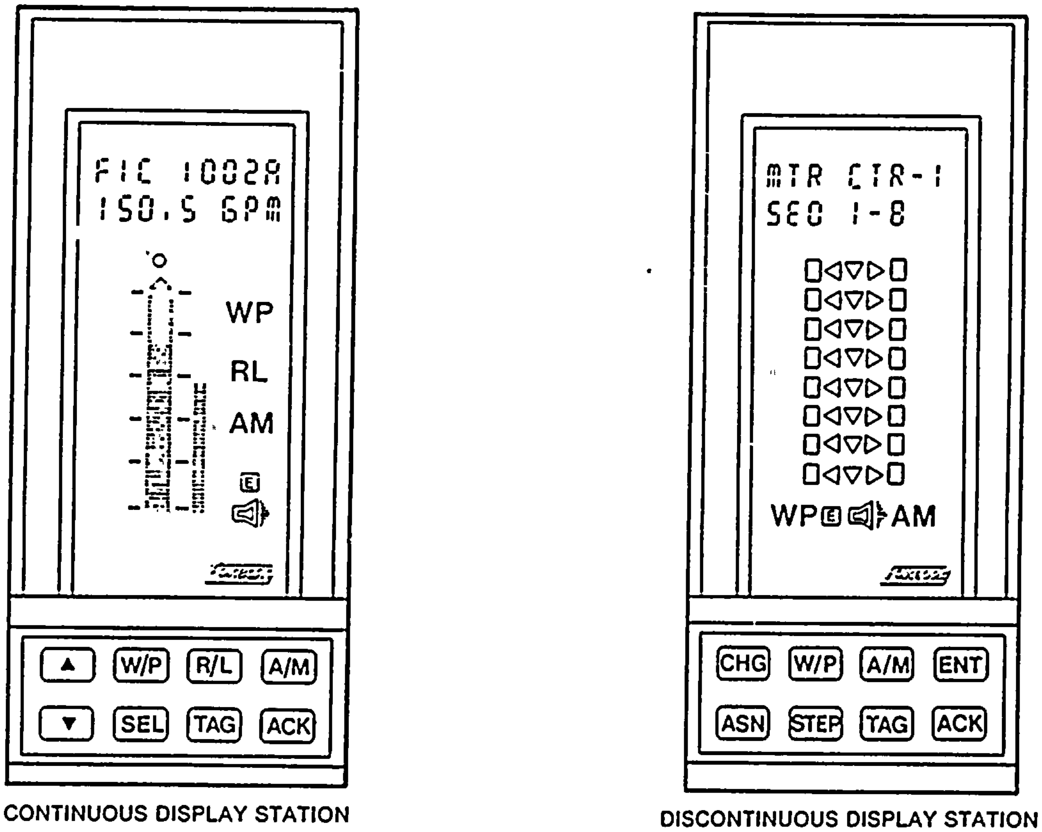


Figure 2. SPEC 200 MICRO Display Stations

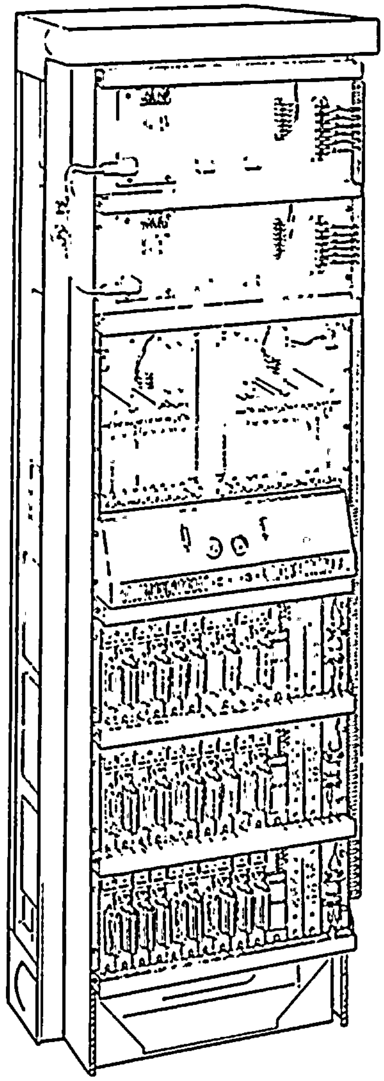


Figure 3.
SPEC 200 MICRO Network Communications Module

Network Communications Module

The Network Communications Module (NCM) (Figure 3) provides a FOXNET interface for up to 30 control cards. The FOXNET host provides a CRT-based operator interface to the control cards. SPEC 200 display stations can be used as a backup operator interface. The control cards can be mounted in the NCM, or in SPEC 200 nests mounted in external SPEC 200 racks. In addition to FOXNET communications, the NCM provides control card-to-control card communications. However, these control cards must be connected to the same NCM.

The NCM has one main processor and can have an optional backup processor. An NCM having two processors requires two power supplies (Figure 4). A single-processor NCM can have a redundant power supply to supply backup power to the I/O nests but not to the processor. The NCM can support up to 3 nests; each nest can have up to two 3AX+MPXA multiplexer cards (one multiplexer supports up to five control cards) and 10 control cards. SPEC 200 I/O components can be placed in the NCM nest, in lieu of control cards, or in external SPEC 200 nests. The processor nest can have one 3AX+ACT alarm contact assembly (for contact output of processor status), up to four 3AX+LP2-D FOXNET interfaces (2 maximum per processor), and up to two 3AX+AS2 configurator terminal interfaces (one maximum per processor). Normally, there will be one configurator terminal interface. An F7003B modem can be used to extend the distance from the NCM to the configuration terminal.

Configuration

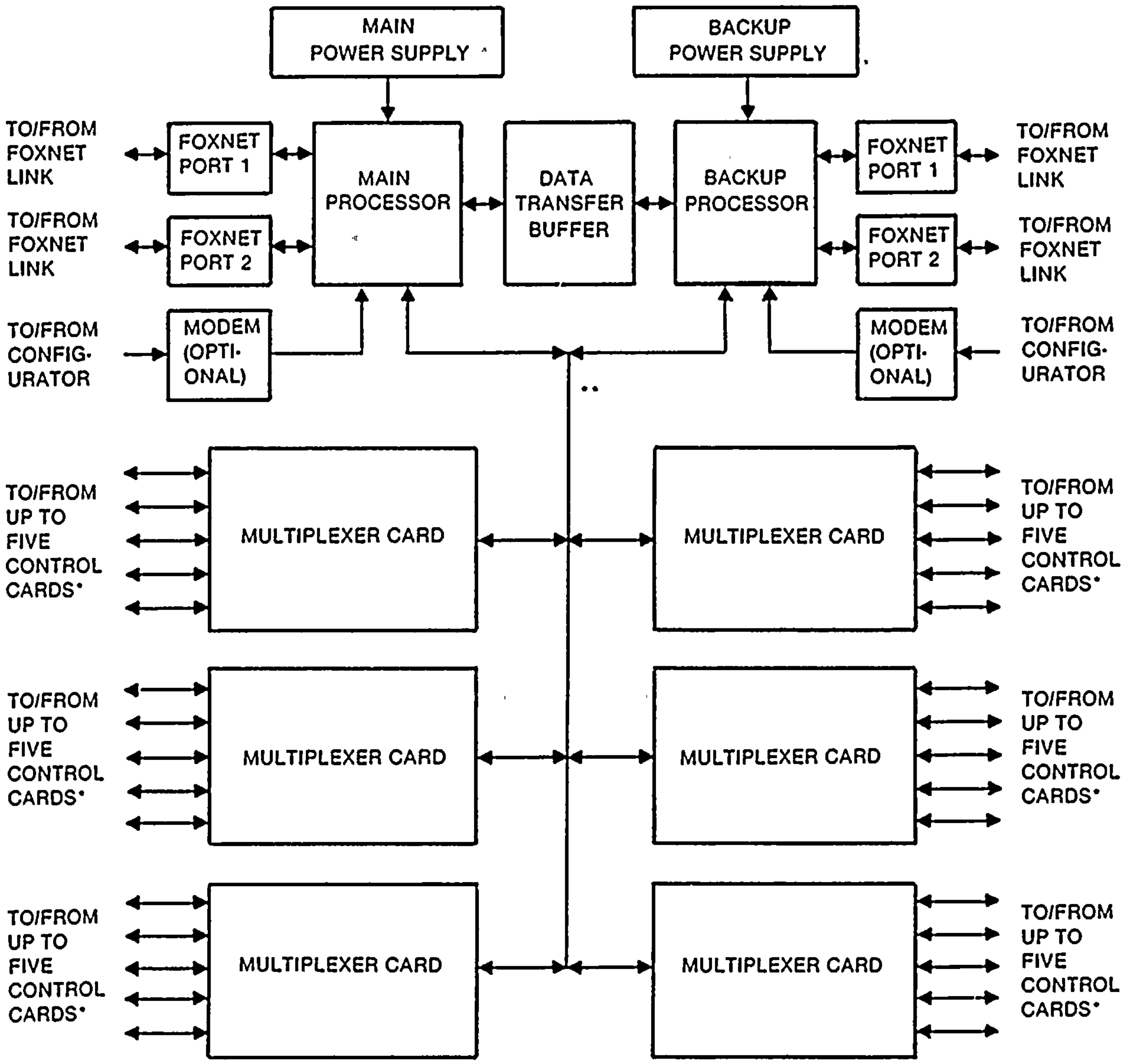
The SPEC 200 MICRO system is configured by using a personal computer (PC). You can use the configuration diskette in an IBM PC. Also, you can use the configuration diskette with many PC's that are IBM compatible. In addition to the configuration diskette, a data base diskette is required for data base storage. The configuration software provides menu-driven "fill in the form" displays. These displays allow you to build your control scheme by configuring or modifying the control blocks contained within the control card.

Configuration is the process of selecting control block types and interconnecting these blocks to produce your desired loop control scheme. Modifications to the control scheme can be made while the system is running on line. The configuration software also provides interactive displays to allow control card operations such as viewing control card status, control card startup operations, and control card data base checkpointing (storing the data base in a file on a data base diskette for backup).

SYSTEM ARCHITECTURE

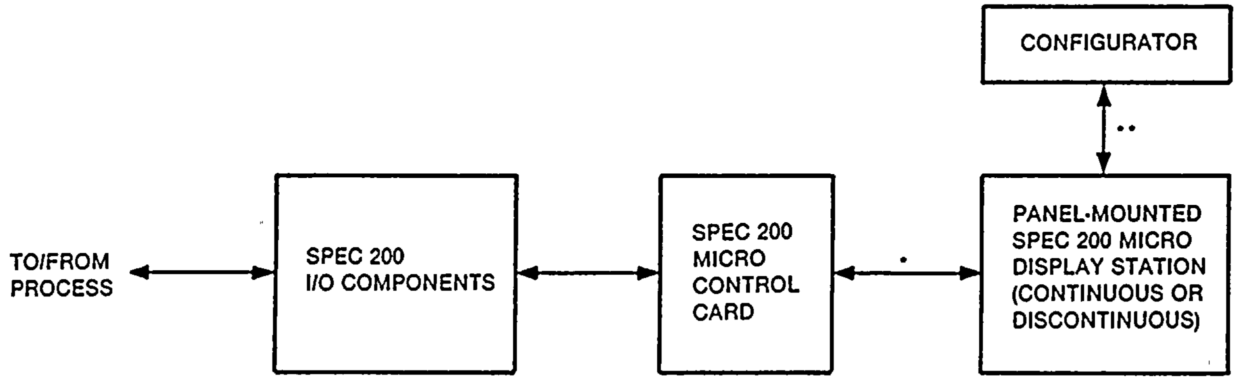
A SPEC 200 MICRO system can be built in one of two basic configurations, a stand-alone or a distributed system. The stand-alone system has a panel-mounted display station operator interface. The distributed system has FOXNET communication facilities, and a FOXNET host for operator interface.

Systems are constructed using the new products previously described in conjunction with existing SPEC 200 and SPECTRUM products.



* = With their specific display stations (optional).
** = Multiplexer card bus.

Figure 4. NCM Block Diagram (Fully Redundant)



• = SERIAL COMMUNICATIONS LINK AND DISPLAY STATION POWER (60 m (200 ft) MAXIMUM).
•• = SERIAL COMMUNICATIONS LINK (RS-232) (15 m (50 ft) MAXIMUM AT 9600 BAUD).

Figure 5. Stand-Alone System Architecture

Stand-Alone System Architecture

A stand-alone system (Figure 5) provides a panel operator interface through the SPEC 200 MICRO display stations. Control functions are performed in the SPEC 200 MICRO control card. Existing SPEC 200 I/O components are used for inputs to and outputs from the control card. The configurator terminal communicates to the control card through a configuration port located on the left side of the display station.

Existing SPEC 200 products used in a stand-alone system include: 2EZ racks, 2ANU nests, 2ANU-L2 nests, 2ARPS power supplies, 2AX+DP10 power distribution component, SPEC 200 I/O components, and 2AK display station cables.

Operator Interface

You can use the display station to access the control blocks within the control card. By pressing the TAG key you can page through the control blocks. Figure 6 illustrates this concept.

When the desired control block is displayed, you can view the block's inputs, outputs, and functional parameters. For example, if you select a PID block, you can view its set-point, measurement, and output values. Also, you can tune the PID block and set its alarm points by turning the keylock on the side of the display to the TUNE position and adjusting the appropriate parameters.

Control Card Operation

STANDBY Mode—In the STANDBY mode, input processing, block processing, and output processing are not performed. The Control Card (CCC) can be in the STANDBY mode with or without a data base.

Following the initial day-one power-up, the CCC enters the STANDBY mode, waiting for a data base to be downloaded, so that it can be ready to CONTROL the process. While in STANDBY, the operator issues a startup or restart command from the configurator terminal, to load a data base into the CCC and place it in the CONTROL mode. Once the CCC enters the CONTROL mode, the operator can issue a standby command from the configurator terminal to switch the CCC back to the STANDBY mode.

In the STANDBY mode, all CCC outputs hold at their last value, as long as power remains applied to the CCC. Upon initial application of power, the outputs remain at the value of the unpowered condition. After a power failure, the outputs are restored to their previous values if the "startup" or "restart" option is chosen. If the "recover in standby" option is chosen, the outputs remain in the unpowered state.

There are three different startup commands by which an operator can startup a control card. They are startup, restart, and restart from memory.

A startup command issued from the configurator terminal causes a previously built data base to be loaded into the control card from the data base diskette and forces all controller type blocks into the Manual mode. Thus, when the control card enters the CONTROL mode, all controller type blocks will be operating in Manual.

A restart command issued from the configurator terminal causes a previously built data base to be loaded into the control card from the data base diskette. When the control card enters the CONTROL mode following a restart command, all controller type blocks will operate in either Manual or AUTO mode depending on what state they were in at the time the data base was checkpointed.

A restart from memory command issued from the configurator terminal or FOXNET host causes the control card to switch from STANDBY to the CONTROL mode without loading a data base. The CONTROL mode is entered only if a valid data base exists in the control card's battery backed memory. All controller type blocks will operate in either Manual or AUTO mode depending on what state they were in when the control card entered the STANDBY mode.

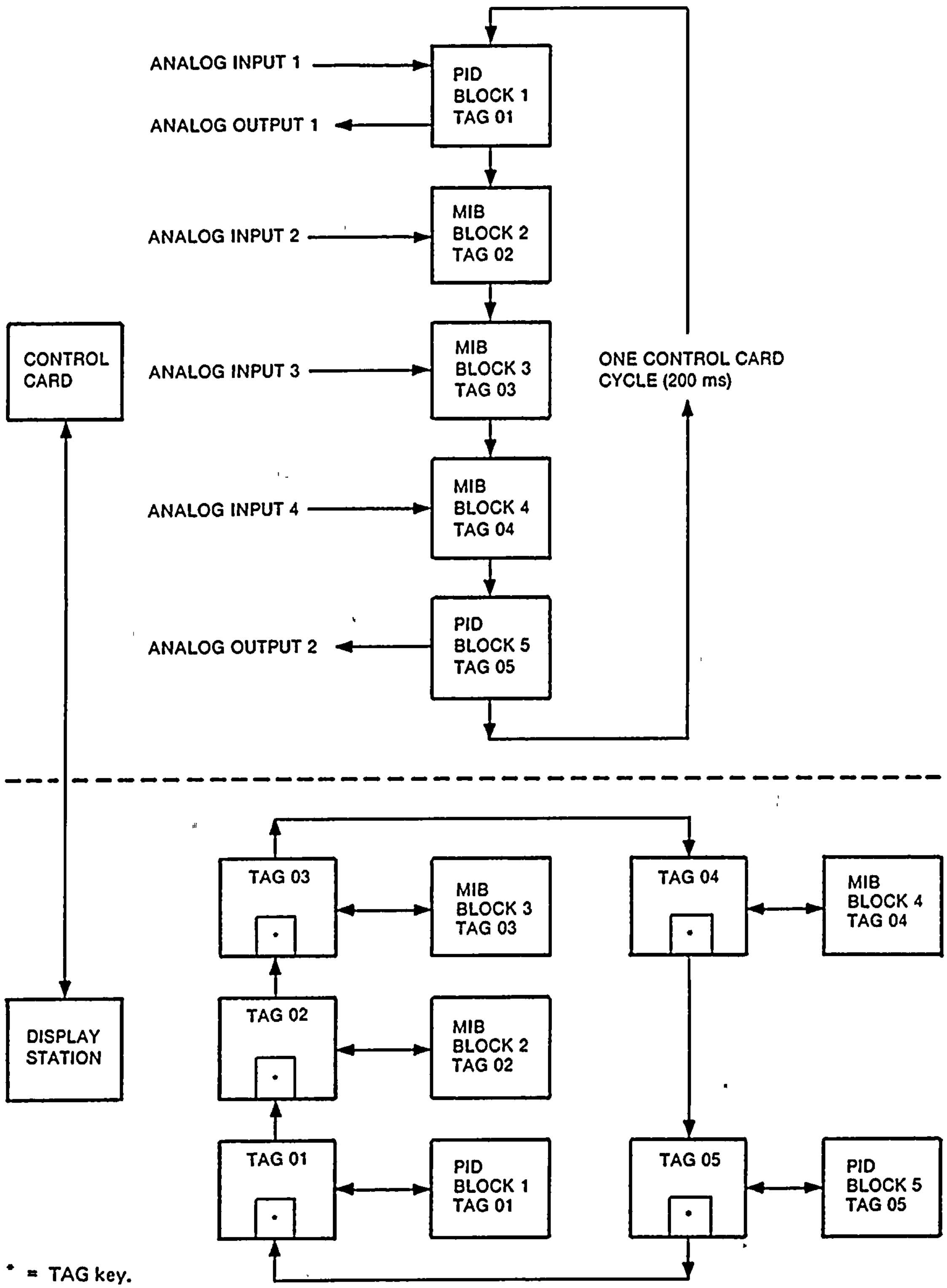


Figure 6. Control Block Paging Concept

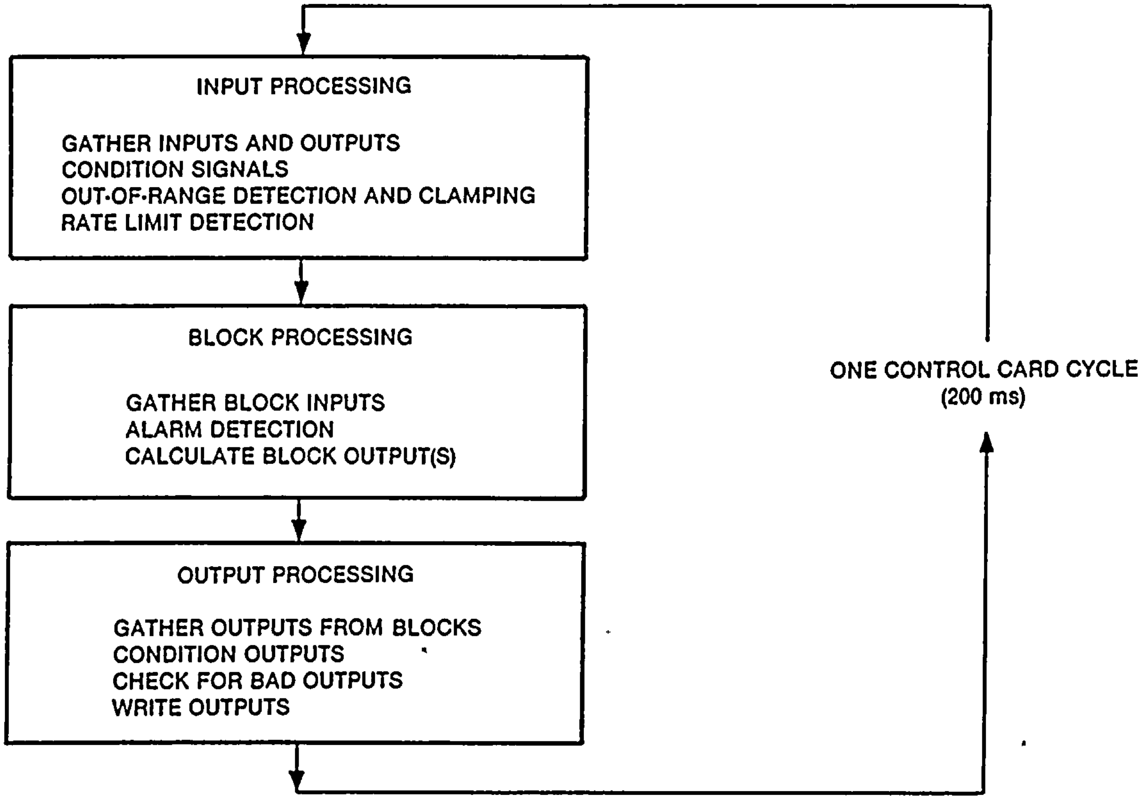


Figure 7. Control Card Cycle

CONTROL Mode—In this mode, the CCC performs input processing, block processing, and output processing (Figure 7). The control mode is the mode in which the CCC controls the process. Control type blocks can be in either Automatic or Manual. The CONTROL mode operates on a periodic basis every 200 milliseconds and is performed in three phases: input processing, block processing, and output processing.

Input Processing—Inputs are checked to determine if they are out-of-range. The values obtained from the CCC input points are the only types that can be out-of-range. An out-of-range value is clamped between -2% and 102% of normalized span.

Input Signal Conditioning—Input signal conditioning is selected to match the type of signal used. The analog signal and contact input conditioning is as follows.

Analog Input Signal Conditioning Indexes

SCIX	Type	Input Span**	Out-of-Range Limits	Usage
1	Linear	0.00 to 10.00 V dc	-0.20 and 10.20 V dc	General Analog Inputs
2	Linear With Suppressed Zero	2.00 to 10.00 V dc	+1.84 and 10.16 V dc	Inter CCC Signals
3	Square Root	0.00 to 10.00 V dc	-0.20 and 10.20 V dc	Differential Head Meter, etc.
4	Square Root*	0.00 to 10.00 V dc	-0.20 and 10.20 V dc	Differential Head Meter, etc.

* = Square root with low cutoff at 0.075 V dc (0.75% of span).
** = Input span corresponds to the normalized range 0% to 100% (0 to 4000 counts) within the block.
Out-of-Range Limits = A signal out of the range defined by these limits is considered "out-of-range" and is clamped to these limits. All output algebraic calculations performed in the blocks are limited to the valid range -2 to +102% of span.

Contact Input Conditioning Options:

- Inversion (per contact)
- BCD to Linear (8 inputs on extended control card only). For use with 0 to 99 BCD thumbwheels.

Block Processing—Each block is processed in order, from one through six. The processing of each block progresses from input to output as follows.

Gather the Inputs—The block inputs are gathered from either SPEC 200 input components or from the outputs of other blocks. If a parameter does not come from either of these sources, a constant value stored in the block is used.

After the inputs are obtained, the block is further processed by implementing the appropriate algorithm according to the configured options. The output value is generated at the end of the algorithm and is available as an input for the succeeding blocks to be processed during the current control cycle.

Alarm Detection—Controller type blocks (e.g., PID) provide absolute, deviation, and output alarm detection. Other blocks include special alarms such as rate-of-change (ALRM blocks) or digital pattern comparison (DIN block).

An alarm condition activates the process alarm indicator at the control card's display station. If the alarm is not in the control block presently displayed, the operator presses the TAG key to display the next block with an alarm. When the block in alarm is displayed, the operator acknowledges the alarm using the ACK key.

Output alarms, indicated at the display station, can be configured within the range -2 to +102% of span.

Block Modes—The following text explains the Initialization, Tracking, Manual, and Automatic block operating modes.

Initialization and Tracking—Controller type blocks that use time-related information in their algorithms (e.g., PID) initialize to a philosophy that "control begins from where the process is now." Appropriate blocks have a feedback input (FBK) and initialize such that their outputs begin at the present value of FBK. Connecting FBK to the appropriate process variable during configuration allows this initialization philosophy to be maintained.

For example, in single-loop PID control schemes, the PID FBK input is usually connected to the control card output. This allows the PID block to initialize its output to the actual final operator position. Thus, the PID will initialize and "start control from where the final operator is now."

The FBK input also supports an output track feature by driving the block's output to the FBK value. This feature is useful when cascade loops are in an open-loop condition.

During startup of the control card from STANDBY to CONTROL, all controller type blocks are initialized for four consecutive control cycles. This allows multi-loop control schemes such as cascade loops to initialize properly up through the cascade so that the primary loop controller starts controlling from where the process is positioned by the secondary controller.

After initialization is completed on the fourth control cycle, the control card enters the CONTROL mode where control begins operation.

Manual/Automatic—Controller type blocks (e.g., PID) can be switched between Manual and AUTO by the operator, through the display station. Logic inputs to the block allow a logic event to externally switch the block between Manual and AUTO. The Manual pointer logic input (MANP) switches the block to Manual. The AUTO pointer logic input (AUTP) switches the block to Automatic. Note that MANP has priority over AUTP.

Output Limits—Output limiting is performed on the output value generated by the block algorithm. Output limits are always active in AUTO. If you specify "Yes" for the block option, MANLIM, the output limits will be active in Manual. Output limiting does not create an alarm condition at the host or panel displays. However, output limit active bits are available for user connection.

Output Processing—The following text explains the block output functions.

Gather the Outputs—The control card outputs are gathered from the blocks according to the block output pointers configured during I/O configuration.

Output Signal Conditioning—Output signal conditioning is selected to match the usage. The analog signal and contact output conditioning is as follows.

Analog Output Signal Conditioning Indexes

SCIX	Type	Normalized Output Range*	Full Output Range	Usage
1	Linear	0.00 to 10.00 V dc	-0.2 to +10.20 V dc	SPEC 200 Interface
2	Linear with Suppressed Zero	2.00 to 10.00 V dc	1.84 to 10.16 V dc	Inter CCC Signals and SPEC 200 Interface

* = Corresponds to the normalized span within the block; i.e., 0.0% to 100.0% represented by 0 to 4000 counts.

Contact Output Conditioning Options (per contact):

- Pulse options: duration 1 to 31 control cycles corresponding to 0.2 to 6.2 seconds. Performed prior to inversion. One shot operation, retriggering disabled while pulse is active.
- Inversion.

Control Card Audible Alarm Line Connections

Each control card has an indicator for audible alarms. This is set upon occurrence of any critical process alarm within the configured control scheme. The indicator is reset when you select the block in alarm on one of the panel display stations and depress the display station ACK key. The display station is the only source that can reset the audible alarm. If there are multiple unacknowledged critical alarms, the indicator resets momentarily as you acknowledge each alarm.

You can connect the audible alarm indicator to any output contact in the control card by configuring an output contact pointer as HB. You can configure the output contact for normally closed or normally open action using the contact inversion option.

You can use the audible alarm to drive external annunciators by following the connection rules for any contact output. If the contact output is configured as normally open, the audible alarm lines of multiple control cards may be wired in parallel (OR'ed) to a single annunciator.

Control Card Fail Mode

The FAIL mode is entered when a "fatal" hardware failure causes the microprocessor to be non-operational. Outputs hold their last value, or clear to the unpowered state, depending on the position of jumpers in the CCC.

Control Card Configuration

You can configure the control card for the stand-alone system by using a Configurator Terminal connected to the display station (Figure 8).

The configurator terminal is a personal computer, with a Foxboro-supplied configurator program providing menu-driven "fill in the form" displays. These displays allow you to use the configurator terminal to configure the control card blocks, tuning parameters, etc. on or off line.

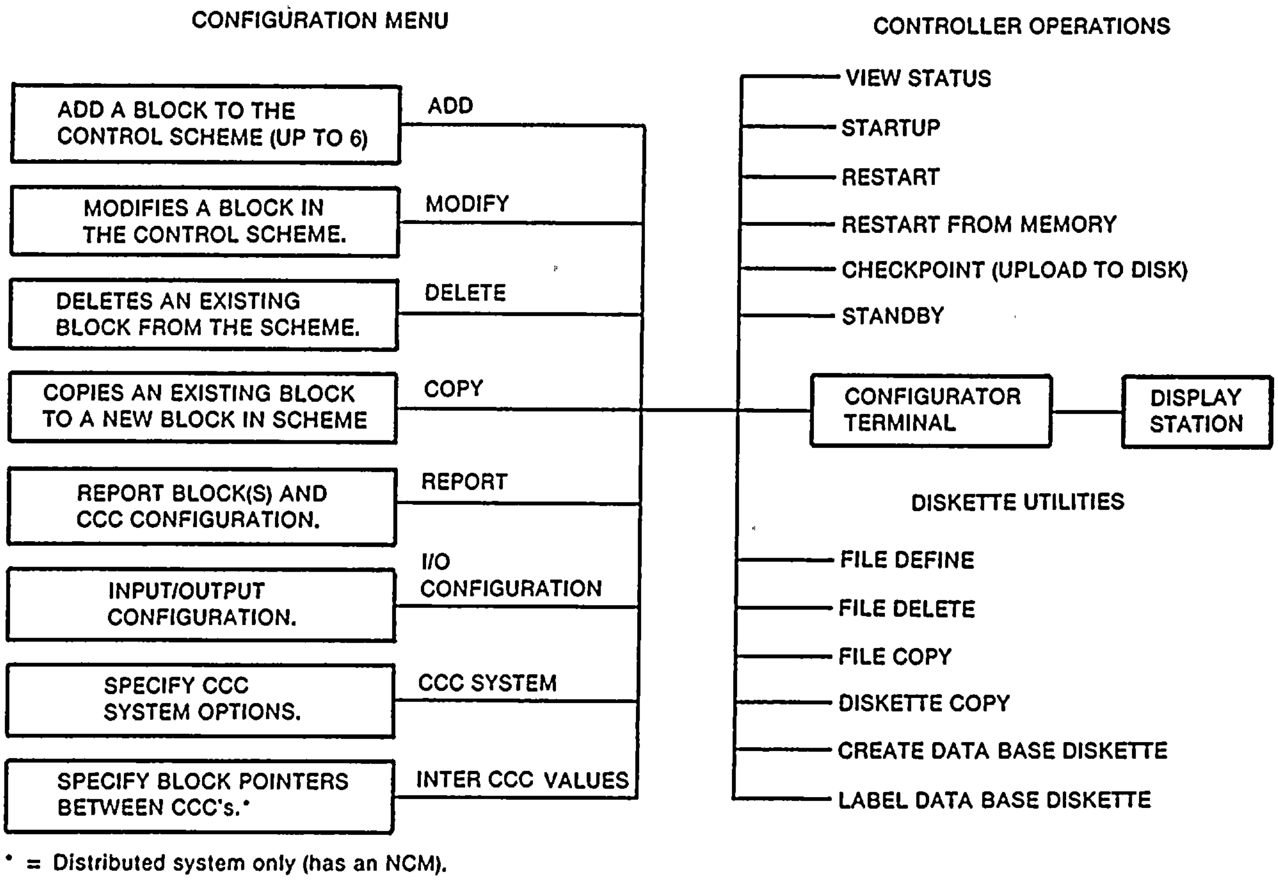


Figure 8. Display Station with Configurator Terminal and Functions

A control file can contain the data base for up to 30 control cards. Each data base diskette can have up to eight files. For a stand-alone system, the file types must be defined as PANEL.

The Foxboro-supplied configurator program has the capability to do the following.

- Configure the control card blocks, tuning parameters, etc. in a file on a data base diskette. Download the control card data base to the control card using the start or restart commands.
- Modify the control card memory-resident data base directly, without using the data base diskette.
- Add a control block.
- Modify a control block.
- Delete a control block.
- Report (make a printer hard copy) a control block, I/O configuration (signal conditioning), and/or control card configuration.
- Specify/change control card modes by performing startup, restart, standby operations, etc.
- Define/redefine a file label or file type.
- Delete an existing file.
- Copy one file into another file.
- Create a data base diskette.
- Label a data base diskette.
- Copy a data base diskette.

Configuration is a simple interactive procedure. The configurator operates interactively in one of four basic modes: configure to controller, configure to diskette, controller operations, or diskette utilities.

In the "configure to diskette" mode, you can do the same operations as in the configure to controller mode, except all the information is stored on a data base diskette. You can then load this information into the control card during a startup or restart operation.

In the "configure to controller" mode, you add, modify, delete, or report blocks in the control card. Also, you can configure the control card inputs, outputs, and signal conditioning options.

In the "controller operations" mode, you can specify that the control card startup or restart from a specific file, or checkpoint the control card data base to a specific file from the control card. Also, you can specify that the control card restart from the data base retained in its memory, or you can switch the control card to STANDBY.

In the "diskette utilities" mode, you can define, delete, or copy files, and create, label, or copy a data base diskette.

The use of invalid keys on the terminal is ignored by the configurator.

Control Block Displays

The following table shows the blocks supported by Continuous Display Stations (CDS) and Discontinuous Display Stations (DDS).

Display	Control Blocks
CDS	PID, PID WITH TUNE EXTENDER, INT, AMB, RTIO, MIB, CHAR, DIN, GATE, LLAG, DTIM, SWCH, ALRM, RAMP, ACUM, AND CALC.
DDS	DIN, DOUT, GATE, AND SEQ.

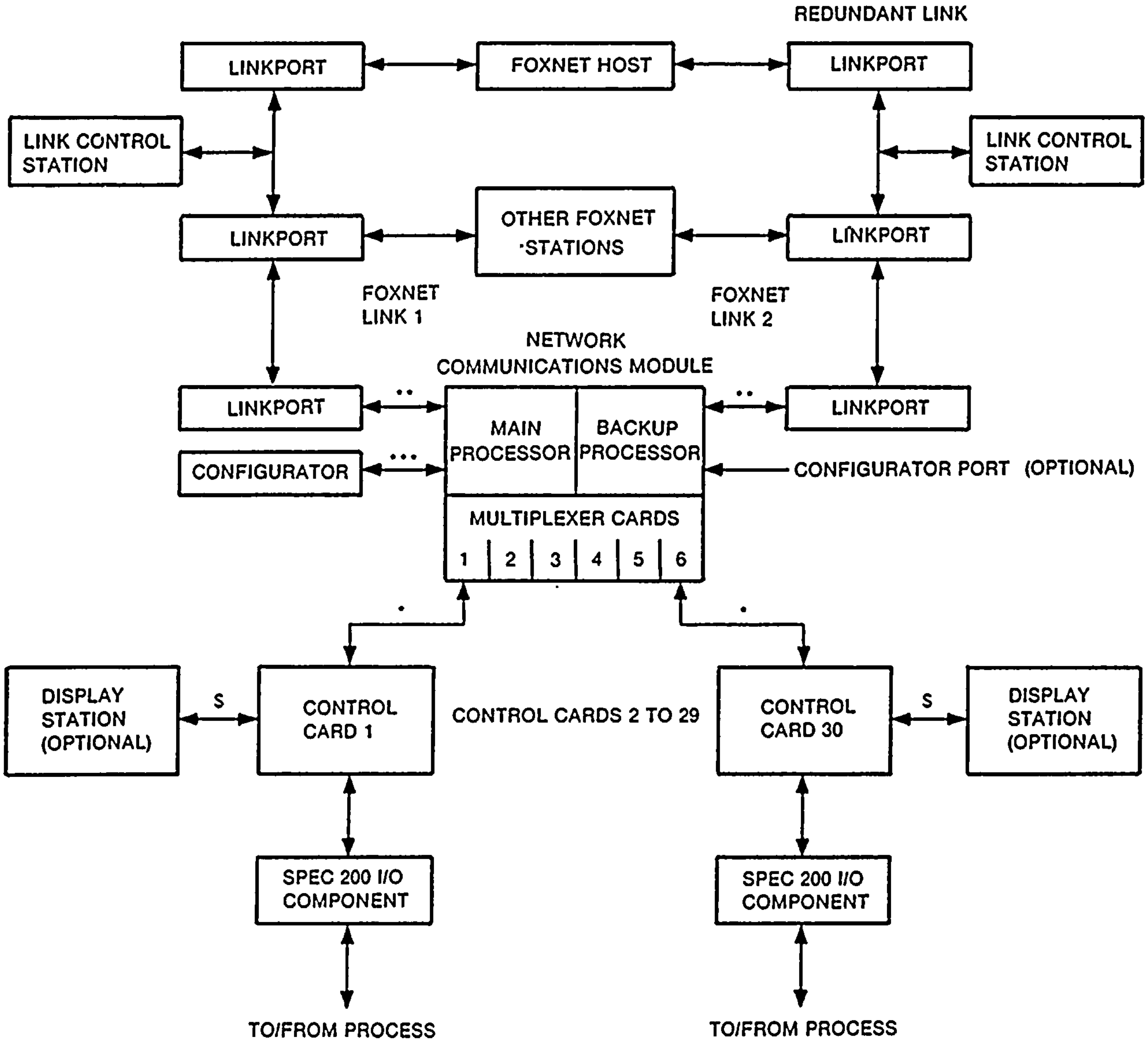
The NONL, SSEL, and TIMR blocks are generally used without direct operator interface, and therefore do not provide a display station faceplate.

Display Station Combinations

The control card can support up to 3 display stations (CDS or DDS) in any combination.

Distributed System Architecture

A distributed system (Figure 9) requires a SPEC 200 Network Communications Module (NCM) to provide FOXNET communications. The Multiplexer cards provide the communications between the NCM processors and the control cards, and between control cards. The operator interface is via a console at the FOXNET host. The display stations can be used as an operator backup for the FOXNET host console. The configurator terminal is connected to the NCM through a configuration port located in the NCM processor nest.



* = SERIAL COMMUNICATIONS LINK (60 m (200 ft) MAXIMUM).
** = UP TO 150 m (500 ft).
*** = SERIAL COMMUNICATIONS LINK (RS-232) (15 m (50 ft) MAXIMUM AT 9600 BAUD). WITH A F7003 MODEM, 11.3 km (7 miles) MAXIMUM AT 9600 BAUD.
S = SERIAL COMMUNICATIONS LINK AND DISPLAY STATION POWER (60 m (200 ft) MAXIMUM).

Note: The control cards (30 maximum) can be mounted in nests in the NCM or in nests external to the NCM.

Figure 9. Distributed System Architecture

The NCM maintains an image of the control block data base in all connected control cards. The maximum size of the control block data base is 180 blocks, allocated in any combination among up to 30 CCC's. Each CCC cannot have more than 6 blocks.

NCM Functional Overview

During normal operation, the main processor is in the control mode (scanning and writing the CCC's) and performs all of the following functions. The backup processor is in the tracking mode (maintaining an image of the main processor's data base) and only supports a FOXNET read of its data base.

NCM Data Write—The controlling processor writes block parameter changes to the destination control card. These changes can be the result of a FOXNET host write or another control card block parameter write.

NCM Data Read—The controlling processor reads block parameters from all of the control cards. Each control card block type has a fixed set of parameters to be scanned. The block set includes all values necessary for display or manipulation from a FOXNET host. All reads are refreshed at least once every 500 milliseconds.

Inter-Control-Card Communications—The NCM controlling processor performs control card-to-control card block parameter communications. The signal source may be any block parameter normally read during the NCM read cycle. For each receiving control card, an Inter-CCC Values Table is configured which specifies the control card number, block number, and parameter number of the source parameter. The NCM will write the source parameters to the Inter-CCC Values table of the receiving control card. Block pointers, for blocks one to six, can then be configured to point to the Inter-CCC Values table. Twelve entries are available in each Inter-CCC Values table.

Tracking Processor Update—At the end of each processing cycle, the controlling processor transfers a copy of its entire data base image to the tracking processor.

FOXNET Response—The controlling processor responds to FOXNET host requests to read and write data concurrent with other block processing. FOXNET host reads and writes are processed when received. and an immediate response is returned to the FOXNET host.

Figure 10 shows the functions performed during each NCM cycle.

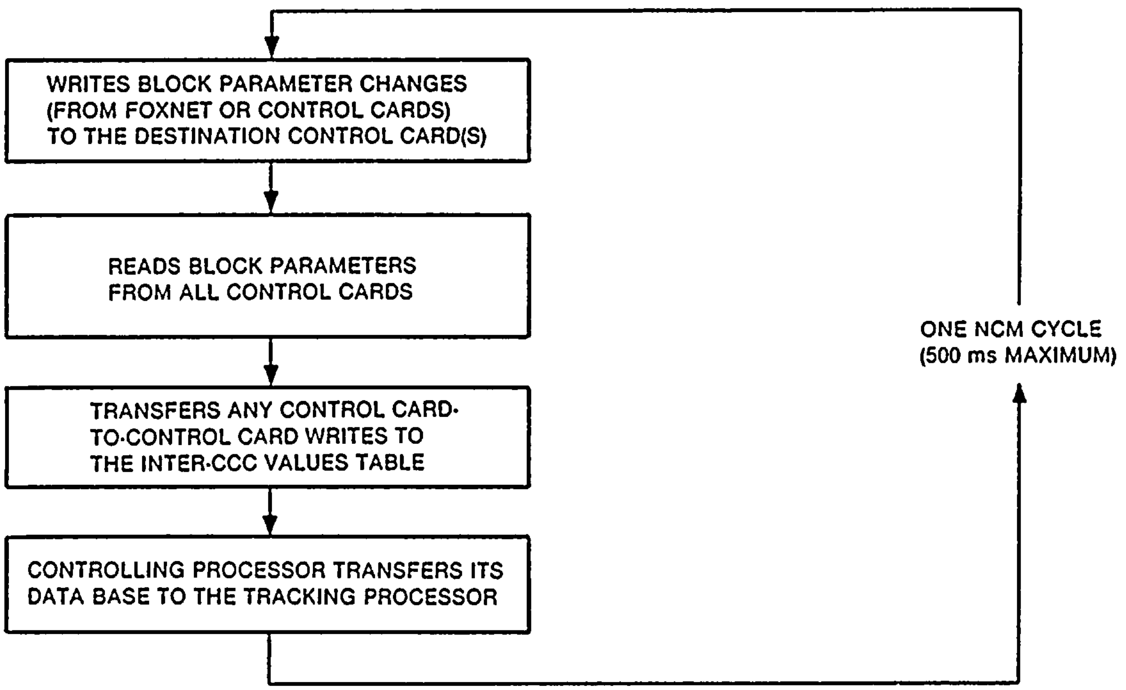


Figure 10. NCM Cycle

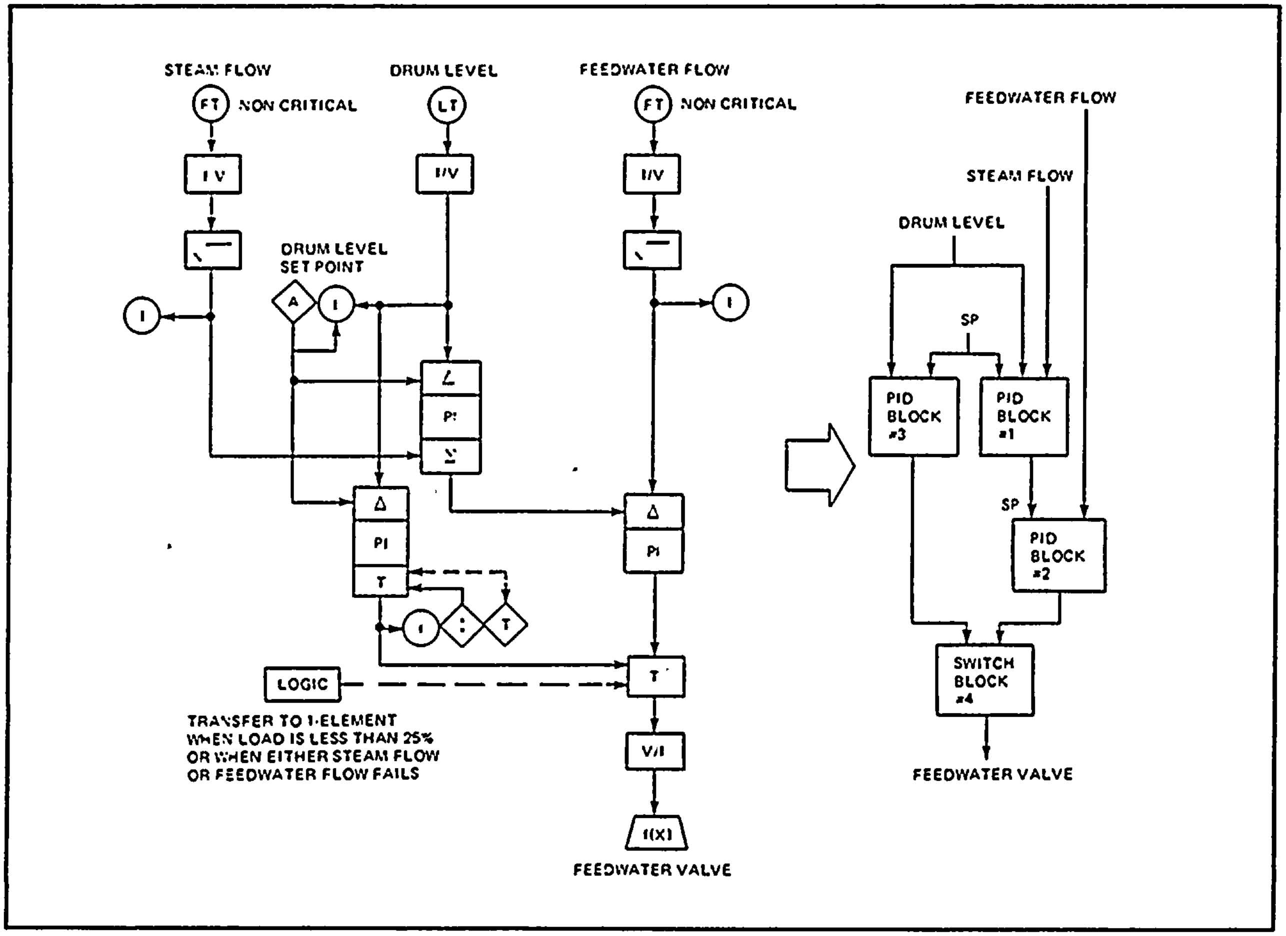
Control Card Configuration

The control card configuration for the distributed system is similar to the configuration for the stand-alone system. However, some additional information is required and is emphasized below.

The file type should be configured as NCM, instead of PANEL. This instructs the configurator software to present the additional configuration displays required. For convenience, you can add a FOXNET station address reference beside the file description, but it is not a requirement. The NCM emulates a MICROSPEC Unit Control Module (UCM) on the FOXNET link. Therefore, the FOXNET host will access no more than 60 of the 180 blocks (maximum) in the NCM.

When you configure the file as NCM, an additional menu is inserted at the NCM level. This menu allows you to proceed to (C) Configure Blocks, (L) List All Blocks, (M) Configure the MAP, or (R) Print a Report. If (C) is pressed, you proceed to configure blocks at the CCC level. If (L) is pressed, a three page display identifies all configured blocks in the NCM by CCC number, block number, block type, and block tag. If (M) is pressed, you can view or configure the MAP function, which specifies the mapping of up to 60 blocks scanned by the FOXNET host in relation to the 180 blocks resident in the NCM. If (R) is pressed, a printed report of the entire NCM data base, duplicating the completed configuration displays, is produced on a printer connected to the configuration terminal.

When configuring each control card in a distributed system, configuration of the Inter-CCC Values table is added to the menu at the CCC level. Also, the Workstation/Panel option can be configured to arbitrate access between the operators at FOXNET workstations and the operators at panel display stations.



SPEC 200 MICRO CONTROL BLOCKS

Provide configurable control capability through a building-block approach to implementing a process loop.

The SPEC 200 MICRO control blocks allow you to quickly and easily translate a process loop design into a working set of control blocks. This is done through an easy-to-use yet powerful and flexible series of control algorithms. These algorithms are implemented as a set of reconfigurable functional control blocks. The SPEC 200 MICRO control block set has all the features needed for almost limitless control flexibility.

SPEC 200 MICRO control blocks offer the following user-oriented features:

- Combination of continuous and logic control functions
- Interconnectable block parameters
- Control loop configuration via an interactive program operating on a personal computer
- Easy conversion of control strategies into fully configured control loops
- Powerful PID algorithm with self tuning, nonlinear, external integral, and output summing features
- Set-point tracking
- Output tracking
- Low cutoff square root signal conditioning
- Comprehensive block status
- Universal parameter access
- Process "bump" protection during system interruptions
- Automatic switchover to MANUAL on out-of-range (bad) inputs

FOXBORO®

- Skip capability for sampled-data loops (use with chromatographs and other sampling type instruments)
- Automatic cascade connections; switchover of primary to TRACKING during open-loop or local set-point operation; back-calculation of primary feedback value

SPEC 200 MICRO algorithms include:

- Standard process functions:
  - Monitoring process variables
  - Alarming (absolute, deviation, and output)
  - Signal characterization
  - Quantizing, rate integration, and accumulation
  - Summing
  - Ratio control
  - Ramping
  - PID control
- Advanced features:
  - Self-tuning
  - Nonlinear compensation
  - Logic and sequential functions
  - Set-point tracking
  - On-line algebraic computations
  - Remote/local and auto/manual switching

SPEC 200 MICRO CONTROL BLOCK CONCEPTS

In the process control loop shown in Figure 1, a measurement signal from the process is passed through a signal conditioner to obtain a conditioned measurement value. The control block reads the conditioned signal, checks for alarm conditions, and calculates its outputs. Output processing then retrieves the control block output, conditions the signal, and converts it to an analog signal at the control card output.

The implementation of a process control loop with traditional analog hardware involves the selection and arrangement in a rack of individual hardware modules for input, signal conditioning, calculation, control, alarm, and output. Planning such a system involves identifying all the hardware modules that are required and correctly ordering each module from the vendor. To maintain the system, a large variety of spare modules is required.

In contrast, one SPEC 200 MICRO control card has the same functionality as that wide variety of analog modules. Instead of wiring together hardware components, control strategies are built by configuring and interconnecting up to six control blocks in each SPEC 200 MICRO control card. The control card has 21 different types of control blocks available. Each control block type performs functions equivalent to those of their hardware component counterparts. Frequently they have greatly expanded features and flexibility. For example, Figure 2 shows a typical temperature/flow cascade control strategy. If you wish to enhance or modify the loop, simply add or modify blocks rather than purchase additional hardware modules.

SIMPLIFIED BLOCK ENTRY AND CONFIGURATION

The process engineer uses a configurator terminal to call up individual block types on the terminal display and configure them into a control strategy.

Construction of the blocks is based on a simple, fill-in-the-blanks method of block parameter specification. Each block type has a one-page form (see Figure 3). Continuous parameters are entered as numeric values, block connections, or control card I/O connections. Logical parameters are entered as logic values, block connections, or control card I/O connections. You can select ADD, MODIFY, or DELETE to add a new block, or co[illegible]/ delete an existing block. Also, you must configure [illegible]al conditioning indexes, connections to the co[illegible]ard input/output terminals, and various control c[illegible]ons.

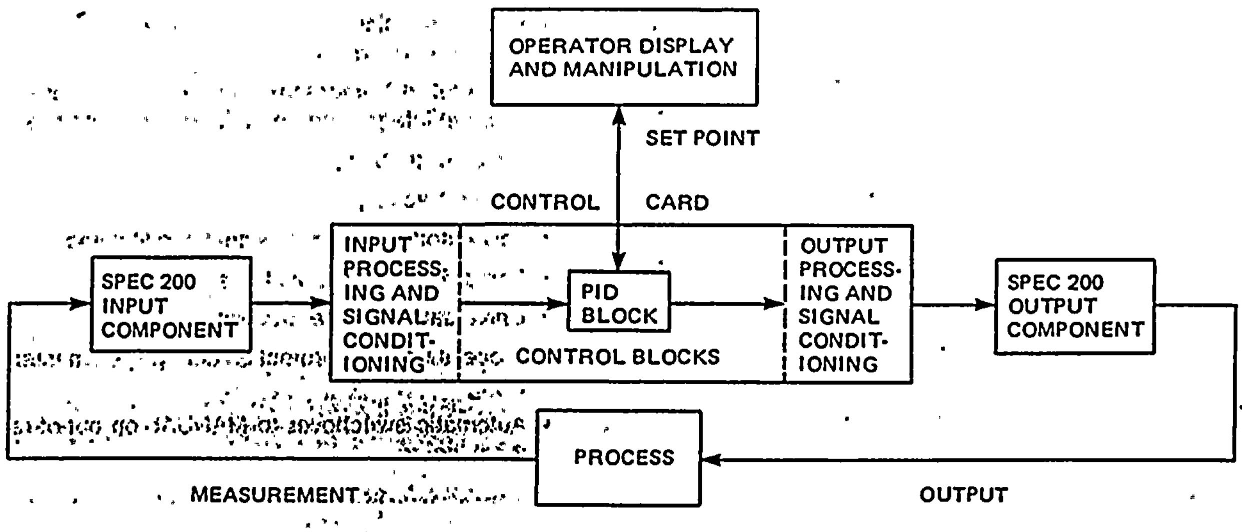
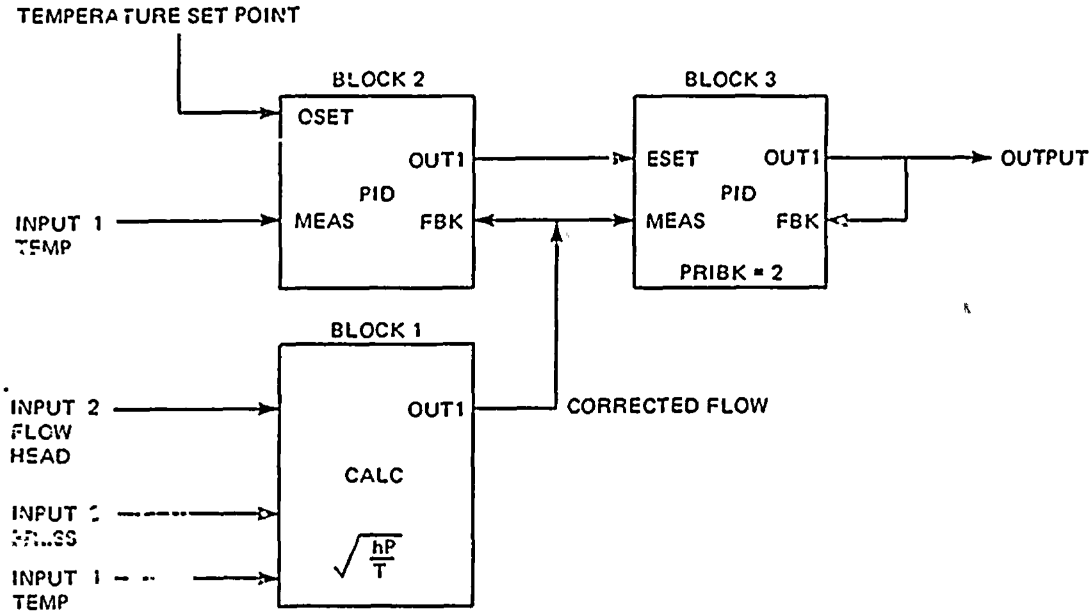


Figure 1. Process Control Loop



Figi Typical Temperature/Flow Cascade Control Strategy

```
ADD BLCCKS      to Disk: DRUM LEVEL                                 08-JUL-85
FILE 1|  DRUM LEVEL #1
CCC 01|  202BTMLVL                                    Options
 BLOCK|  3                                            |HIRNG|N
 TYPE |  PID                                          INCINC|N     Display Deletions
 TAG  | |LRC-01022|                    Critical        ERSQ |N    | ESET|N
                    Alarm  Options      Alarm          NOINT|N
Connections        |  HA  |102.0         N             NODER|N
 MEAS|0.0          |  LA  |-2.0          N                         Display Scaling
 OSET|0.0          |  DB  |0.0                                     |  HS |100.0
 FBK |0.0          |  HD  |102.0         N            |MANLIM|N    |  LS |.0
                   |  LD  |102.0         N                         |  EU | PCT
Optional Conn.     |  DDB |0.0                        |FLUNKA|N
PRIBK|             |  HOA |102.0         N            |FLUNKE|N    Display Options
 ESET|0.0          |  LOA |-2.0          N            |  M BAD|Y   |AIR-C|N
 SKIP|0            |  ODB |0.0                        |SP TRK|N    | W/P |N
TRACK|0
MOVRD|              Tuning                            Extension Blocks
 LOCP|0            |PBAND|1000                        |NONLBK|
 REMP|0            | INT |0.00                        |TUNEBK|
 MANP|0            |DERIV|0.00                        Output Limits
 AUTP|0            | GAIN|0.000                       | HOLIM|102.0
                   | BIAS|0.0                         | LOLIM|-2.0

F1 - Prev Level||F2 - Enter      |          |F4 - Default     ||F5 - Top Level
```

Figure 3. PID Block (Configurator Display Shown Unconfigured)

No user programming is required. Configurations are stored on a data base diskette used with the configurator terminal.

BLOCK PROCESSING

Once the control card configuration is completed on the data base diskette, you can transfer the information to the control card with a startup command. The SPEC 200 MICRO control card processes all of the blocks configured for its control loop once every 200 milliseconds. They are processed in the configured order, except for the self-tuning and nonlinear extenders (of PID blocks), which are always processed with the PID block.

When a control card is started up, the control blocks go through four cycles of initialization. This assures that blocks within complex interconnection strategies are properly initialized with respect to each other and to process variables. Initialization resets time history information stored within blocks and initializes block outputs at appropriate starting values so that control begins without bumping the process. Initialization is a function of the block type. Most blocks, such as PID, initialize by setting the output equal to the feedback value.

OPERATOR INTERFACE—SPEC 200 MICRO DISPLAY STATIONS

During SPEC 200 MICRO control card configuration, you select the blocks which appear at each display station connected to that control card. You can configure the same block to appear at more than one display. Each block type, except TIMR, SSEL, and the PID extender blocks, is capable of creating a faceplate on the display station. If multiple faceplates are configured for the same display station, the operator chooses the desired block faceplate with the "TAG" key. The "SEL" key allows the operator to select the displayable parameters for that block sequentially, thus providing accurate digital readout and manipulation. Other keys allow the operator to change the mode of the control block: for example—auto or manual.

When a control block is displayed, all of the operator-controllable parameters can be displayed for the operator's use on that block except the loop tuning parameters. These tuning parameters are made accessible via a key-lock on the side of the display station.

OPERATOR INTERFACE—FOXNET HOSTS

In a distributed control system architecture using the FOXNET Process Communications Link, SPEC 200 MICRO control blocks are typically viewed and manipulated from a SPECTRUM operator workstation. The console screen provides faceplate or graphic displays which are configured independently from, but connected to, the SPEC 200 MICRO control blocks.

Also, SPEC 200 MICRO panel display stations can be used as a local or backup operator interface. Control blocks have a W/P option that provides arbitration between an operator at the workstation and an operator at the panel display station. This operator can secure the block for use in the panel mode (P), or release the block to a FOXNET host in the workstation mode (W). The panel mode is indicated by an "X" (local) status indication at the workstation and by a "P" indication at the display station.

SPEC 200 MICRO CONTROL BLOCKS

Table 1 lists the functions of each block in the SPEC 200 MICRO control block set, together with a brief description of each typical usage.[1]

CONTROL BLOCK FEATURES

Just as SPEC 200 analog uses 0 to 10 V dc as a normalized signal range, SPEC 200 MICRO control blocks use 0 to 4000 counts to represent a normalized 0 to 100% signal range. The blocks operate on a 12-bit data value within a 16-bit word. Scaling procedures are similar to those used in dedicated component process control equipment. Most block parameters are freely interconnectable (outputs to inputs), or can be entered as constant values, during configuration.

Each block in a control loop is assigned a unique block number when it is added to the data base. With the exception of the NONL and TUNE (extender) blocks, all blocks are processed in numerical order. (The NONL and TUNE blocks are processed at the same time as the PID block to which they are connected.) Thus, you can control the sequence of execution of blocks by assigning each block an appropriate number within the control loop. (For example, the primary controller within a cascade loop can be made to be processed before the secondary controller by assigning it a lower block number.)

[1]These tables are for illustration only and may contain minor terminology differences from actual product features.

Listed below are the 21 control block names and their meanings.

- Control:
  - PID = Proportional/integral/derivative controller
  - TUNE = Self-tuning extender
  - NONL = Nonlinear extender
  - INT = Integral-only controller
  - AMB = Automatic/manual station with bias
  - RTIO = Ratio
- Input and Conversion:
  - MIB = Multiple input block
  - CHAR = Characterizer
- Digital/Logic:
  - DIN = Digital input
  - DOUT = Digital output
  - GATE = Multiple gate
  - SEQ = Sequencer
- Dynamic Compensation:
  - LLAG = Lead/lag dynamic compensator
  - DTIM = Dead time
- Miscellaneous:
  - SWCH = Switch
  - SSEL = Signal selector
  - ALRM = Alarm and limiter
  - RAMP = Universal ramp generator
  - TIMR = Timer
  - ACUM = Accumulator
  - CALC = Calculator

Table 1. SPEC 200 MICRO Control Block Functions

CONTROLLERS

BLOCK NAME: PID (Proportional - Integral - Derivative)

DESCRIPTION:

Enhanced version of proportional (P), integral (I), and derivative (D) controller with manual or automatic operation. Enhanced features include: process alarming; self-tuning and nonlinear operation (using extender blocks); and many logic inputs to modify controller operation.

FUNCTION:

Performs primary function of PID controller, including absolute, deviation, and output alarms. Allows external control of block operation (auto/manual) and set-point operation (remote/local) from a display station/host console or another block. Also includes an output summing (bias) capability.

OPTIONS:

- Reverse and error-squared control action
- Suppressing integral or derivative action
- Set-point tracking
- Automatic switchover to manual on a bad input signal
- Self-generated cascade connections
- Skip (for sampled-data operation)
- Output tracking of feedback signal during override conditions
- Manual override
- High and low output limits
- Output limits active in manual
- Self-tuning control (using TUNE block) extension function
- Nonlinear gain (using NONL block) extension function
- Host-actuated flunk to auto or external set point
- Logic input actuated transfer to auto, manual, local set point, or remote set point

USE:

Feedback-type control of flow, temperature, pressure, level, and other process loops.

DISPLAY:

Continuous Display Station (CDS): Displays active set point, measurement, and output values in bargraph format.

DISPLAY OPTIONS:

- Deletion of remote set-point display
- Air to close/open final operator (output display)
- Panel/workstation arbitration

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: TUNE (Self-Tuning)

DESCRIPTION:
Automatic "Expert System" adjustment of PID control tuning parameters. This is based on continuous monitoring of the process measurement.

FUNCTION:
Self-tuning of the PID block in response to process changes. Extends the capability of the PID block to include self-tuning operation.

USE:
Tuning a process with a large dead time or a process having dynamics which are time-variant.

DISPLAY
Extends tuning parameters of the PID block to include self-tuning feature

BLOCK NAME: NONL (Nonlinear)

DESCRIPTION:
PID block error term processing extender.

FUNCTION:
Alters the proportional gain in a zone about zero deviation to compensate for nonlinear process gain.

USE:
pH and other types of nonlinear control loops.

DISPLAY.
None

BLOCK NAME: INT (Integral Only)

DESCRIPTION:
Produces time integration of the error with integral feedback action.

FUNCTION:
Allows pure integral control action on the error between the set point and the process measurement. Integrates the error signal according to a specifiable time constant. Also included are absolute, deviation, and output alarms. Allows external control of block operation (auto/manual) and set-point operation (remote/local) from a display station/host console or another block.

OPTIONS:
- Reverse control action
- Set-point tracking
- Automatic switchover to manual on a bad input signal
- Self-generated cascade connections
- Skip (for sampled-data operation)
- Output tracking of feedback signal during override conditions
- Manual override
- High or low output limits
- Output limits active in manual
- Host-actuated flunk to auto or external set point
- Logic input actuated transfer to auto, manual, local set point, or remote set point

USE:
Used in a multiple-output control system or as a ramp generator.

DISPLAY:
CDS display: Displays active set point, measurement, and OUT1 (optional) values in bargraph format.

DISPLAY OPTIONS:
- Remote set-point display deletion
- Panel/workstation arbitration
- Air to close/open final operator (OUT1 display)

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: AMB (Auto - Manual and Bias)

DESCRIPTION:
Controllable auto/manual with bias station.

FUNCTION:
The auto control mode allows the input signal to pass through the block with the bias added to it. The manual control mode allows manual manipulation of the block output signal. This block provides a connection for an external feedback signal. Also included are absolute and output alarms. Allows external control of block operation (auto/manual) from a display station/host console or another block.

OPTIONS:
- Automatic switchover to manual on a bad input signal
- Self-generated cascade connections
- Output tracking of feedback signal during override conditions
- Manual override
- High and low output limits
- Output limits active in manual
- Host-actuated flunk to auto
- Balance time for bumpless manual to auto transfer

USE:
Manual loading station (e.g., could protect a downstream calculation from the zero output of a failed transmitter). Typical uses include input scaling or manually biasing an input signal. Also provides a means of auto/manual control over any signal leaving the control card.

DISPLAY:
CDS display: Displays measurement, bias, and output values in bargraph format.

DISPLAY OPTIONS:
- Deletion of bias and/or measurement displays
- Panel/workstation arbitration
- Air to close/open final operator (OUT1 display)

BLOCK NAME: RTIO (Ratio)

DESCRIPTION:
Adjustable ratio multiplier with input/output scaling, and alarm.

FUNCTION:
Multiplies the input measurement (wild flow) by the ratio signal. Ratio signal scaling produces the desired ratio range corresponding to 0 to 100% of the ratio signal. Input and output bias provided. A track feature causes the block's output to automatically track the feedback input signal. Also included are absolute and output alarms.

OPTIONS:
High and low output limits.

USE:
Control of air/fuel mixture to a burner or similar applications requiring ratio control.

DISPLAY:
CDS display: Displays measurement and output values in bargraph format.

DISPLAY OPTION: Panel/workstation arbitration.

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

INPUT AND CONVERSION

BLOCK NAME: MIB (Multiple Input Block)

DESCRIPTION:
Four-channel signal conditioning block.

FUNCTION:
The MIB provides additional signal conditioning for up to four analog inputs. A bias and gain adjustment is provided for each channel. In addition, each input may be passed through a first order filter. Each conditioned input is passed to a unique output.

OPTIONS (each channel):
- Scaling
- Filtering
- Absolute alarming (channel 1 only)

USE:
Scaling, filtering, and alarm implementation on a field measurement.

DISPLAY:
CDS display: Displays channel outputs 1, 2, and 3 values in bargraph format.

DISPLAY OPTIONS: Deletion of either output 1, 2, or 3 from display.

BLOCK NAME: CHAR (Characterizer)

DESCRIPTION:
Linear segment X-Y function calculator. Eleven X-Y specifiable coordinates allow, ten-segment curve approximation for specialized signal characterization. Permits you to build "custom fit" functions for nonlinear signals.

FUNCTION:
Allows characterization of a process variable through construction of a segmented, characteristic curve.

Produces the Y-component output of a user-specified X-Y coordinate graph plot, given the X-component (measurement) as an input.

USE:
Linearization of a nonlinear measurement (e.g., fluid level in a spherical tank, valve output signal, etc.).

DISPLAY:
CDS display: Displays measurement and output values in bargraph format.

DISPLAY OPTIONS: Deletion of either measurement or output display.

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

DIGITAL/LOGIC

BLOCK NAME: DIN (Digital Input)

DESCRIPTION:

Digital signal contact or logic input and comparator block, with pattern recognition for up to 16 user-specifiable patterns.

FUNCTION:

Conditions an eight-bit digital input signal according to the configured INVERT mask, and routes the conditioned signal to OUT1, comparing it against each of up to 16 user-specified, eight-bit patterns. If a match occurs between the input word and any or all of the user-specified patterns, it sets a corresponding bit (or bits) in OUT2, showing which of the 16 patterns matched the input word. (Also sets the special alarm bit in the status word, signalling that a match occurred.) Any number of bits (user selectable) within any of the pattern words can be masked out (and thus ignored) during the pattern comparisons. This allows alarms and/or other control actions on a wide variety of process contact or logical bit combinations.

USE:

Alarms and/or other control actions on a wide variety of process contact or logical bit combinations. Also, can alarm illegal input combinations.

DISPLAY:

Discontinuous Display Station (DDS): Displays any subset of the eight output bits in OUT1 on the contact state indicators. An indication of the pattern number of any pattern match can optionally be displayed in the selected variable field.

CDS display: OUT1 is displayed in the selected variable field, and an indication by pattern number of any pattern match which has occurred.

DDS DISPLAY OPTIONS:

- Display of OUT1 in the selected variable field
- Deletion of the pattern number indication
- Alarming on any selected contact state
- Designation of any contact alarm or pattern alarm as critical

CDS DISPLAY OPTIONS:

- Display of OUT1 in the selected variable field
- Deletion of the pattern number indication
- Alarming on any selected contact state
- Designation of any contact alarm or pattern alarm as critical

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: DOUT (Digital Output)

DESCRIPTION:
Digital auto/manual station. Logic signal collector/output block.

FUNCTION:
In the manual mode, allows manipulation of up to eight individual, digital contact outputs. In the AUTO mode, gathers up to eight discrete logic inputs, conditions them according to the configured INVERT mask, and routes the conditioned signal to OUT1. External control of block operation (auto/manual) is allowed from a display station/host console or another block.

OPTIONS:
- Automatic switchover to manual on a bad input signal
- Output tracking of the feedback signal during override conditions
- Manual override
- Host-actuated flunk to manual
- Input inversion (per input)

USE:
Digital auto/manual station.

DISPLAY:
DDS display: Displays any subset of the eight output bits in OUT1 on the contact state indicators. Provides auto/manual switching and manual manipulation of each OUT1 contact.

DISPLAY OPTIONS:
- Selection of displayed output bits
- Panel/workstation arbitration

BLOCK NAME: GATE (Multiple Gate Block)

DESCRIPTION:
Eight-element logic block.

FUNCTION:
Contains eight two-input logic gates. Allows configuration of logical operations using various (AND, OR, XOR, NAND, NOR, NXOR) gating functions and pulse output. This allows you to create multiple logic functions by interconnection of various gating elements. When used as a pulse output device, a gate functions as a "triggered-OR" one-shot (i.e., for a 0-to-1 transition at either input, a 200 millisecond, one-cycle, positive pulse is produced).

USE:
Create combinational logic functions based on contacts, alarm, or status conditions, sequence steps, etc.

DISPLAY:
DDS display: Displays the state of any selected gate output in OUT1 on the contact state indicators.

CDS display: Displays gate outputs in OUT1 in the selected variable field.

DDS DISPLAY OPTIONS:
- Display of OUT1 in the selected variable field
- Alarming of any gate output state
- Designation of any gate output alarm as critical
- Input inversion (per input)

CDS DISPLAY OPTIONS:
- Display of OUT1 in the selected variable field
- Alarming of any gate output state
- Designation of any gate output alarm as critical

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: SEQ (Sequencer)

DESCRIPTION:
Eight-step pattern generator.

FUNCTION:
Functions as an eight-step pattern generator, with additional patterns for INIT and HOLD. In the auto mode, the step being executed is controlled by eight logical inputs. The next step is selected only if its input is active, and the current step equals the previous step number. In the auto mode, if the logical inputs for the HOLD or INIT steps are active, they will override the other steps. INIT has the highest priority. The manual mode allows operator selection of a desired step, or direct manipulation of up to eight of the available outputs in OUT1. The output patterns and number of output steps is user-configurable.

OPTIONS:

- Inversion of the sense of any of the step inputs
- Specification and activation of the INIT and HOLD steps by logic inputs
- Switchover to manual on a bad input signal
- Output tracking of feedback signal
- Manual override

USE:
Controlling phased operations in batch processes, synchronization of process functions, etc.

DISPLAY:
DDS display: In the auto mode, displays the name of the active step in the selected variable field, and the state of the output bits in OUT1 on the contact state indicators. Provides auto/manual switching. In the manual mode, allows operator selection of a desired step, or direct manipulation of the available outputs in OUT1.

DISPLAY OPTIONS:

- Selection of the available output bits to be displayed
- Panel/workstation arbitration
- User-configured step names are up to four characters long

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

DYNAMIC COMPENSATION

BLOCK NAME: LLAG (Lead-Lag)

DESCRIPTION:
Computational dynamic compensator (contains one lead-lag element).

FUNCTION:
Permits rapid (inductive lead) or gradual (capacitive lag) control action to be introduced into a process loop in response to a changing input signal. The amount of lag is determined by a user-configurable GTIM (lag time) parameter. The amount of lead action may be configured through use of the GAIN parameter. An optional bias is available on the output.

OPTIONS:
- Positive impulse action
- Negative impulse action
- Bi-polar impulse action

Positive impulse (IMPP) or negative impulse (IMPN) modes imply a positive or negative shift in the measurement value will be detected, and the corresponding output pulse will be correspondingly positive or negative. When the FOLLOW input is set = 1, the output follows the input. Note, FOLLOW can have a four-character name.

USE:
Process dynamics compensation in feedforward, feedback, and non-interacting control strategies.

DISPLAY:
CDS display: In bargraph format, displays measurement and output. FOLLOW can be initiated or reset from the display station by scrolling the parameter into the selected variable field and pressing the Up (↑) or Down (↓) keys that act as toggle switches.

DISPLAY OPTIONS:
- Deletion of the measurement and/or output indications
- Deletion of the FOLLOW display capability
- Panel/workstation arbitration

BLOCK NAME: DTIM (Dead Time)

DESCRIPTION:
Adjustable length, tapped delay line with selectable tap-off points.

FUNCTION:
Introduces a user-specifiable delay of a process measurement or control action. Delays the input a specified length of time before making it available at the output. Twenty-five delay slots are utilized to store and advance the sampled input. The dead time resolution is therefore 1/25 (4%) of full scale. The maximum full scale length of the delay is established by the MAXDT (maximum dead time) parameter. MAXDT is specified in either of two ranges: 0 to 25 minutes or 0 to 200 minutes (HIRNG). The actual delay produced is a function of the DTIM (dead time) parameter, which represents a percentage (0 to 100%) of MAXDT. The dead time introduced into a signal is thus accurate to within approximately 1/25th of the maximum dead time, in minutes specified by MAXDT.

When the FOLLOW input is set = 1, the output follows the input. Note, FOLLOW can have a four-character name.

USE:
Dynamic compensation in an advanced control system.

DISPLAY:
CDS display: In bargraph format, displays measurement and output. FOLLOW can be initiated or reset from the display station by scrolling the parameter into the selected variable field and pressing the Up or Down keys.

DISPLAY OPTIONS:
- Deletion of the measurement and/or output indications
- Deletion of the FOLLOW display capability
- Panel/workstation arbitration

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

MISCELLANEOUS

BLOCK NAME: SWCH (Dual Switch)

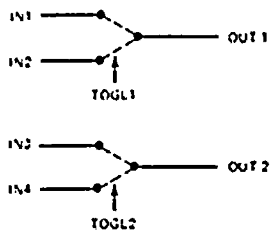
DESCRIPTION:
Dual, single-pole, double-throw switches.

FUNCTION:
Provides two, independent, single-pole, double-throw A/B switching elements that are switched by TOGL1 and TOGL2 as follows.

Operation:

With TOGL1 = 0, then OUT1 = IN1
With TOGL1 = 1, then OUT1 = IN2

With TOGL2 = 0, then OUT2 = IN3
With TOGL2 = 1, then OUT2 = IN4



USE:
Permits independent switching of one output signal from source A to source B and another output signal from source C to source D (for example, switching from one control strategy to another based on a process condition).

DISPLAY:
CDS display: Page 1 displays IN1, IN2, and OUT1 in bargraph format, plus TOGL1 in the selected variable field. Page 2 displays IN3, IN4, and OUT2 in bargraph format, plus TOGL2 in the selected variable field.

DISPLAY OPTIONS:

- Deletion of any of the displayable parameters from the display
- Panel/workstation arbitration
- Toggle names are user configurable, nine characters for each toggle state.

BLOCK NAME: SSEL (Signal Selector)

DESCRIPTION:
Multi-signal discriminator/selector.

FUNCTION:
Selects as its output (OUT1), from up to eight separate signals, either the highest, lowest, or median. OUT2 indicates which input has been selected. Also, the SSEL computes the true average of all active input signals. The NUM option specifies the number of input signals used for selection.

OPTIONS:
- High selection
- Low selection
- Median selection
- Average

USE:
Used in auto-select systems where the number of controlled variables exceeds the number of manipulated variables.

DISPLAY:
None

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: ALRM (Alarm and Limiter)

DESCRIPTION:
Signal out-of-range detector/indicator/rate limiter.

FUNCTIONS (optional):
- Absolute alarm sensing/indication
- Deviation alarm sensing/indication
- Output alarm sensing/indication
- Rate alarm sensing/indication
- Output rate limiting
- Output limiting

When the Follow input is set = 1, the output follows the measurement signal.

USE:
Supplementary or redundant process condition alarm or rate-of-change indication and control.

DISPLAY:
CDS display: Displays measurement, set-point, and output values in bargraph format.

DISPLAY OPTIONS: Deletion of measurement, set-point, and output displays.

BLOCK NAME: RAMP (Universal Ramp Generator)

DESCRIPTION:
Dual, linear ramp generator with single output.

FUNCTION:
Each ramp has an adjustable slope, and can be configured to ramp the output either up or down. The block also has the capability to INITialize to the low output limit, FOLLOW the input (measurement) (with configurable reset balance time), or HOLD at the present output. (The reset balance time allows the output to reset to the input value at a specifiable rate when the block is switched to FOLLOW). Priority of functions is: INIT, FOLLOW, HOLD, RAMP1, and RAMP2. High and low output limits are available. The HI and LO bits in OUT2 indicate when the output has reached its target value and is clamped to the high or low output limits, respectively. Each ramp has a configurable delay, which is the time interval between ramp command and the start of output ramping.

OPTIONS:
- Invert each ramp (negative slope)
- Delay each ramp (0 to 25 minutes)
- HI range (0 to 200 minutes)

USE:
Set point or signal variation of a controlled rate.

DISPLAY:
CDS display: Displays the measurement and output values in bargraph format. The logic states RUN1, RUN2, INIT, and FOLLOW are displayable, and can be toggled from the display if a pointer is not configured.

DISPLAY OPTIONS:
- Deletion of the measurement display
- Deletion of any of the logic states RUN1, RUN2, INIT, and FOLLOW from the display
- Panel/workstation arbitration
- A four-character name can be user-configured for each of the logic states

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: TIMR (Timer)

DESCRIPTION:
Two-stage, variable-length, timed pulse generator with repeat capability.

FUNCTION:
User-configured timing functions for ON delay, OFF delay, timing SEQuencer steps, etc. When the RUN input is set, timer 1 starts and then times out. When timer 1 times out, timer 2 starts and then times out. OUT1 contains two logic bits; T1ON is set while timer 1 is timing, and T2ON is set while timer 2 is timing.

OPTIONS:

- Repeat allows a cycle to continually repeat, thus producing two independently controllable, complementary, variable-length, pulsed waveforms with a repeat period of T1 plus T2.
- Hold stops the timing when activated.

Timers reset when the RUN input resets.

USE:
Allows timing control of process reactions through the use of two independent, sequentially operated timers.

DISPLAY:
None

BLOCK NAME: ACUM (Accumulator)

DESCRIPTION:
Integrator/totalizer.

FUNCTION:
The block scales its input and accumulates it in a two-word (32-bit) accumulator output (AC) of up to 99 999 999 counts. A two-word "target" value for the accumulated value is available for alarming or control. The input can originate from another block or from a SPEC 200 analog input component.

Absolute alarming is performed on the measurement input.

A Hold logical input, while it is active, stops accumulation. A Clear logical input causes the accumulator to be reset. A Set logical input causes the accumulator to be set to either a preset value or to the accumulator value from another ACUM block.

Activation of the Clear or Set function causes the accumulator value to be stored in the TOTAL parameter and protected for the duration of a timer, thus allowing computers on FOXNET time to read the value.

A user-assigned Target value causes a bit to be set in OUT2 when the target value is reached in the accumulator. OUT1 provides a normalized value representing the accumulated value as a percent (0 to 102) of the target.

USE:
Monitoring a d/p Cell transmitter and shutting off flow at a specified total volume, blending, etc.

DISPLAY:
CDS display: Displays the measurement and OUT1 values in bargraph format, and displays the accumulated value in the selected variable field. The engineering units for the measurement and the accumulated value are user-configurable.

DISPLAY OPTIONS:

- Delete OUT1 from the display
- Panel/workstation arbitration

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: CALC (Calculator)

DESCRIPTION:

Multiple input, 35 step, floating-point, programmable calculator. Separate store and access operations interfacing to three independent memories. Seven arithmetic and logical functions. Uses normalized inputs from either stored constants, I/O points, or block outputs. Provides three outputs.

FUNCTION*:

Provides multi-purpose calculation functions. Up to three independent calculation functions can be combined in a single block, due to the three output capability. Operators and operands are specified in algebraic format. Up to 35 sequential operators and operands can be specified per CALC block. Operands can be numerical constants, other block outputs, or direct process I/O values. Also, operands can be written by a FOXNET host. Calculations are performed internally in floating point to preserve accuracy and to minimize the possibility of overflow. When overflow or underflow occurs, calculations are continued using + or − machine infinity, respectively. Inputs from other blocks are normalized to produce floating-point numbers in the range 0.0 to 1.0. This is done to avoid the need to consider internal "counts" in scaling equations.

Each CALC block contains three internal "memories" (or temporary registers) and an accumulator. You can use three store operators (S1, S2, and S3) to transfer intermediate calculation results from the accumulator into any of the three memories to be employed repeatedly throughout the calculations. This avoids having to recalculate parts of the equation using the M1, M2, or M3 operators. At the end of the cycle, memory contents are available for transfer to other control blocks in OUT1, OUT2, and OUT3. Also, the memory contents are preserved from the end of one block execution to the next. Only the accumulator is cleared at the end of the execution cycle. Also, you can use logical input pointers (from another block or from the control card discrete I/O) to conditionally execute part of an equation. Logical values of 1 and 0 are handled as numeric multipliers of values 1.00 and 0.00, respectively.

A number of independent calculations can be made—and their results stored in any of the memories—during each CALC block execution cycle. When the "=" operator is encountered by the block processor, the result of the last calculation in the accumulator is transferred to M1. The three memories are then transferred to their respective outputs and block processing terminates for that execution cycle. The results of the block's final calculations are preserved in the three memories for the next processing cycle.

USE:

Allows real-time computation of process variables (temperature, flow, pressure, etc.). Also, you can use the block to model specialized algorithms, perform signal characterizations, alter control waveforms, etc. Greater-than and less-than operators allow for signal selection and logic functions.

Table 1. SPEC 200 MICRO Control Block Functions (Cont.)

BLOCK NAME: CALC (Calculator) (Cont.)

DISPLAY:

CDS display: Displays OUT1, OUT2, and OUT3 values in bargraph format.

DISPLAY OPTIONS:

- Deletion of OUT1, OUT2, or OUT3 displays.
- Engineering units with high and low scale are independently configurable for each output.

*Configurable operator/function codes are as follows:

(Enterable) Functional Operator	CALC Function Executed
+	Add next operand to accumulator; store sum in accumulator
-	Subtract next operand from accumulator; store difference in accumulator
*	Multiply accumulator by next operand; store product in accumulator (also logical AND if operand is a logical type)
/	Divide accumulator by next operand; store result in accumulator
$	Take square root of accumulator; store result in accumulator
S1	Store accumulator in M1
S2	Store accumulator in M2
S3	Store accumulator in M3
<	Put next operand in accumulator if less than present value in accumulator
>	Put next operand in accumulator if greater than present value in accumulator
M1	Use M1 as the operand in following operation
M2	Use M2 as the operand in following operation
M3	Use M3 as the operand in following operation
=	Store contents of accumulator in M1; transfer M1 o OUT1; M2 to OUT2; M3 to OUT3; terminate block execution

PROCESS CONTROL EXAMPLE

The following example of a three-element drum level control is given to show how the SPEC 200 MICRO control blocks can be configured to implement a control scheme.

Figure 4 shows a functional control loop diagram of the example.

Figure 5 shows the control blocks and "soft wiring" required for the analog signals in the control scheme example.

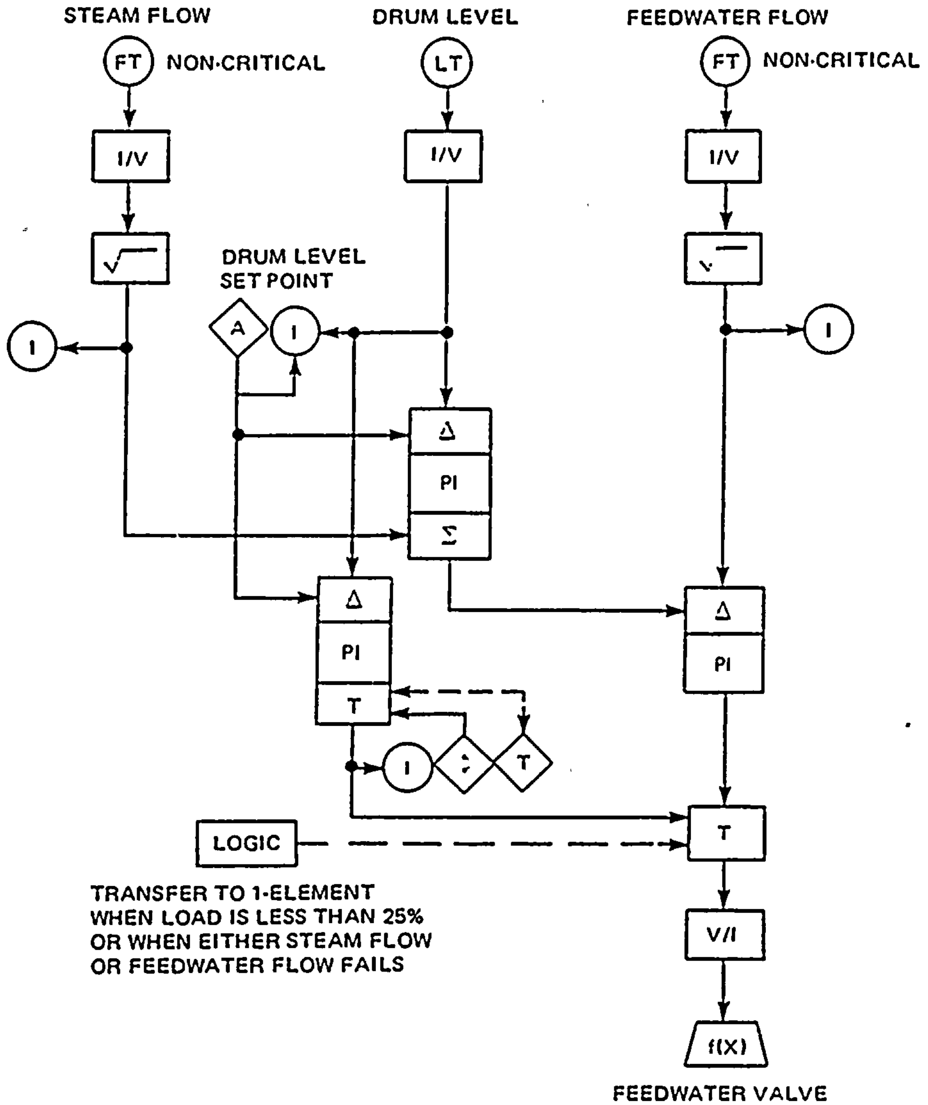
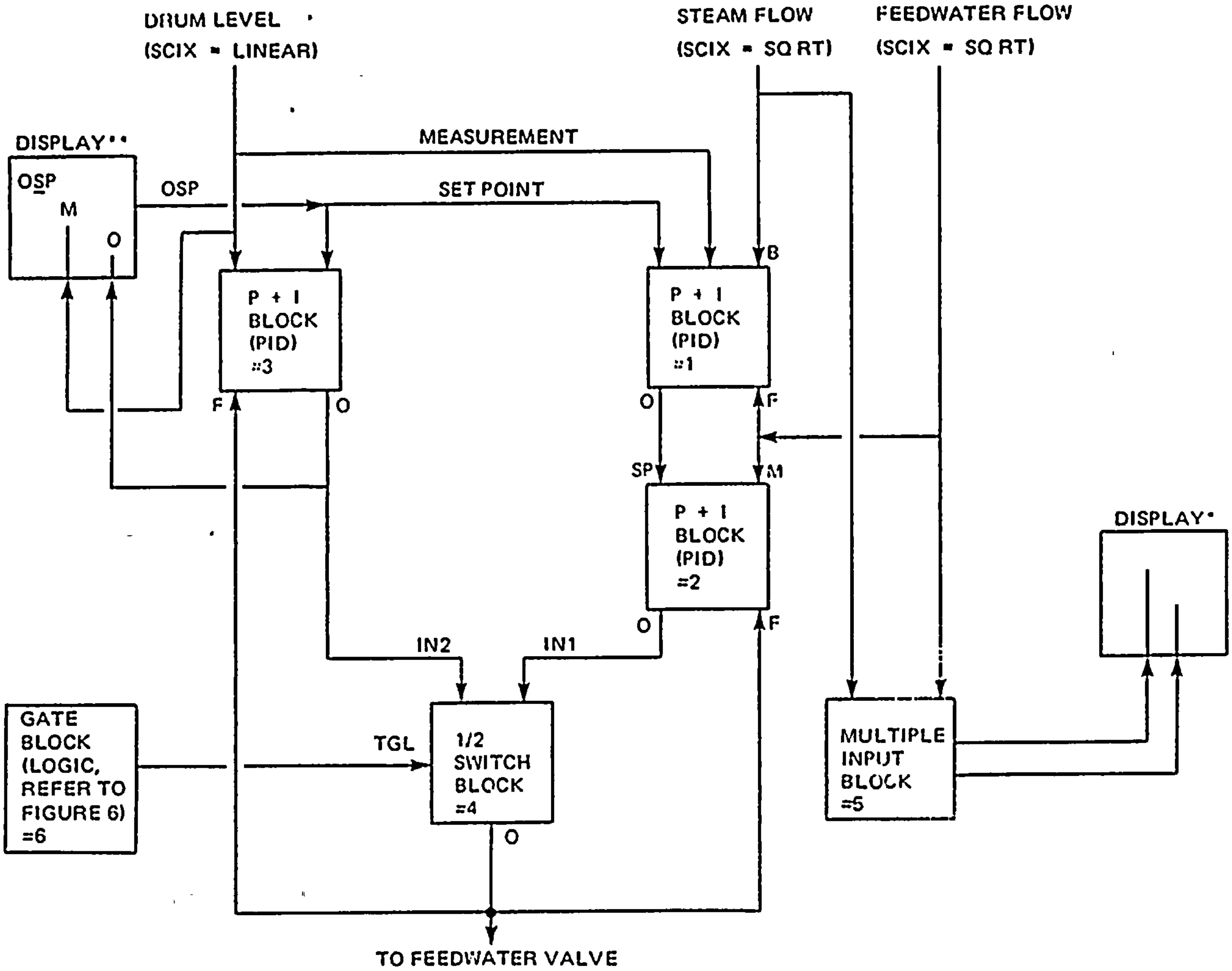


Figure 4. Three-Element Drum Level Control Example



* = FEEDWATER and STEAM FLOW display (indicator).
** = One element DRUM LEVEL control display (operator set loop).

M = Measurement
OSP = Operator set point
O = Output
B = Bias input (performs PID block output + STEAM FLOW summing function).
F = Feedback input.
SCIX = Signal conditioning index

Figure 5. Control Block Analog Connections

Figure 6 shows the control blocks and "soft wiring" required for the logic signals in the control scheme example.

For this control scheme example, configure the control card with three PID blocks, one multiple input (MIB) block, one switch (SWCH) block, and one GATE block. Configure the SCIX for the steam and feedwater flow inputs with square root extraction.

The control scheme developed in Figures 5 and 6 has the following characteristics:

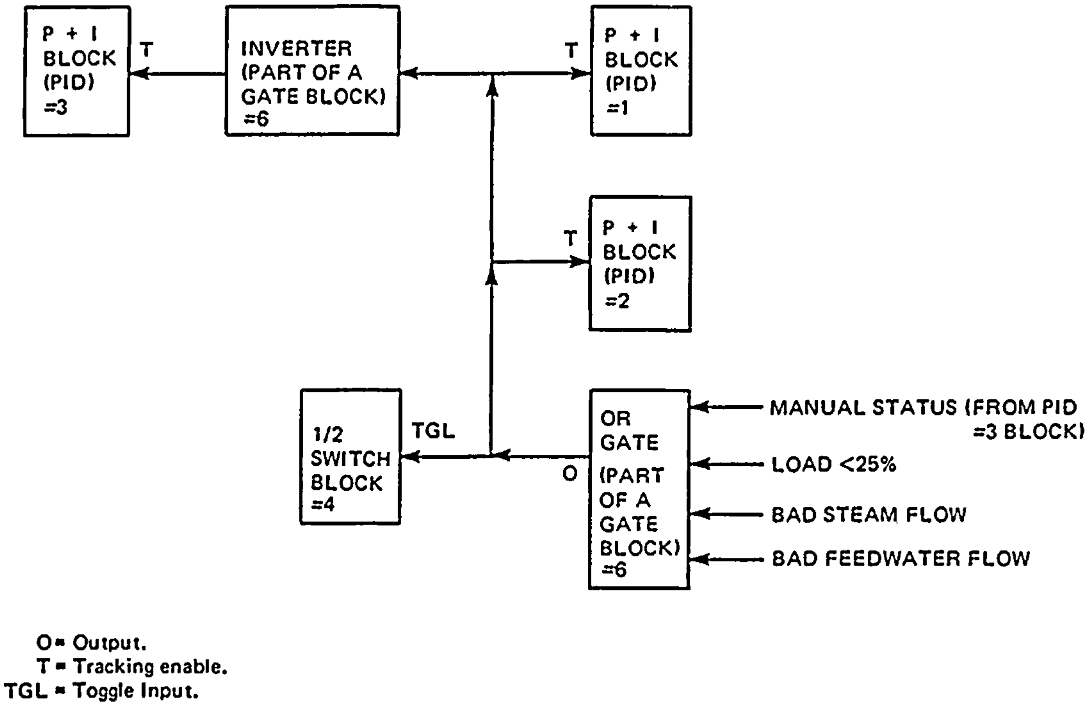


Figure 6. Control Block Logic Connections

- If the loop develops bad steam flow, bad feedwater flow, or load <25%, the control automatically switches from three-element to single-element control.
- The output value displayed for #3 PID is the same as the output value sent to the feedwater valve. This is due to the fact that #3 PID is tracking the switch block output when in three-element control.
- When #3 PID is in MANUAL, it drives the switch block output. This is due to the fact that the manual status signal toggles the switch block to IN2.

Shown below is a block diagram of the minimum hardware required for the control scheme example.

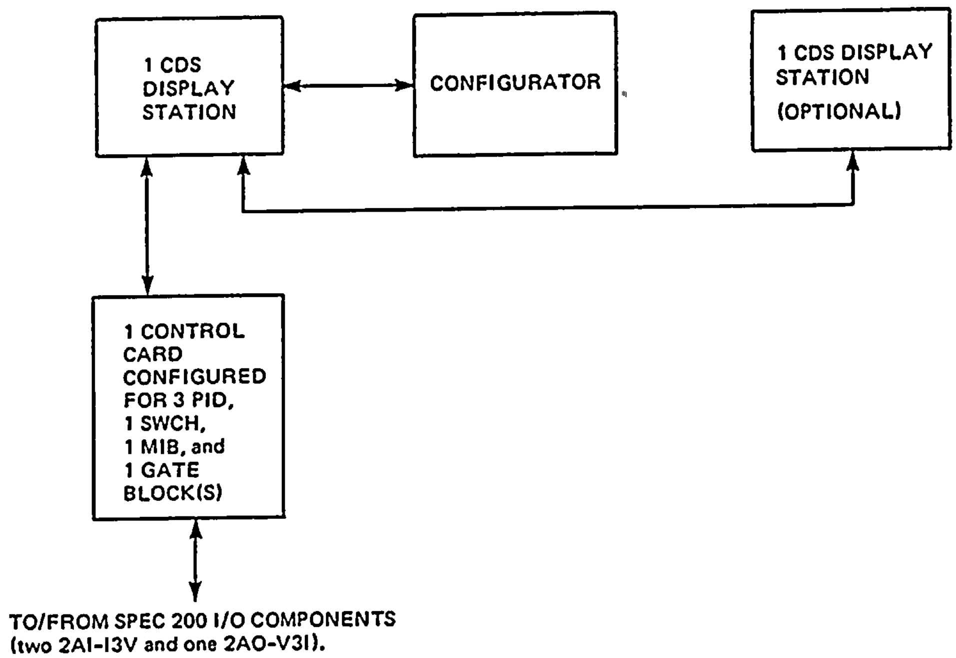


Figure 7. Hardware Block Diagram

If desired, you can add an additional Continuous Display Station (CDS) to continuously monitor feedwater and steam flow from the MIB block.

Figure 8 shows one of the PID block configurator displays after it has been configured for the control scheme example.

```
ADD BLOCKS     to Disk: DRUM LEVEL                          .          08-JUL-85
FILE 1|  DRUM LEVEL #1
CCC 01|  202BTMLVL                                  Options
 BLOCK|  3                                         |HIRNG |N
 TYPE |  PID                                       |INCINC|N     Display Deletions
 TAG  ||LRC-01022|                      Critical   | ERSQ |N     | ESET|N
                    Alarm Options        Alarm     | NOINT|N
Connections        | HA  |75.0            N        | NODER|Y
 MEAS|I2           | LA  |45.0            Y                      Display Scaling
 OSET|65.0         | DB  |2.0                                    | HS |40.0
 FBK |01           | HD  |5.0             N       |MANLIM|Y      | LS |10.0
                   | LD  |5.0             Y                      | EU | INCH
Optional Conn. .   | DDB |2.0                     |FLUNKA|N
PRIBK|             | HOA |100.0           N       |FLUNKE|N      Display Options
 ESET|0.0          | LOA |0.0             N       | M BAD|Y      |AIR-C|N
 SKIP|0            | ODB |2.0                     |SP TRK|N      | W/P |N
TRACK|B6 08 03
MOVRD|              Tuning                        Extension Blocks
 LOCP|0            |PBAND|250                     |NONLBK|
 REMP|0            | INT |1.00                    |TUNEBK|
 MANP|0            |DERIV|0.00                    Output Limits
 AUTP|0            | GAIN|0.000                   | HOLIM|100.0
                   | BIAS|0.0                     | LOLIM|0.0

F1 - Prev Level||F2 - Enter     |                |F4 - Default    ||F5 - Top Level
```

Figure 8. PID Block Configurator Display for Control Scheme Example