The Tricon is designed with a fully triplicated architecture throughout, from the input modules through the Main Processors (MPs) to the output modules.

Theory of Operation

Fault tolerance in the Tricon is achieved by means of a Triple-Modular Redundant (TMR) architecture. The Tricon provides error-free, uninterrupted control in the presence of either hard failures of components, or transient faults from internal or external sources.

The Tricon is designed with a fully triplicated architecture throughout, from the input modules through the Main Processors to the output modules. Every I/O module houses the circuitry for three independent legs. Each leg on the input modules reads the process data and passes that information to its respective Main Processor. The three Main Processors communicate with each other using a proprietary high-speed bus system called the TriBus.

Once per scan, the three Main Processors synchronize and communicate with their two neighbors over the TriBus. The Tricon votes digital input data, compares output data, and sends copies of analog input data to each Main Processor.

The Main Processors execute the application and send outputs generated by the application to the output modules. The output data is voted on the output modules as close to the field as possible, which enables the Tricon to detect and compensate for any errors that might occur between the voting and the final output driven to the field.

For each I/O Module, the system can support an optional hot-spare module which takes control if a fault is detected on the primary module during operation. The hot-spare position can also be used for online system repairs.

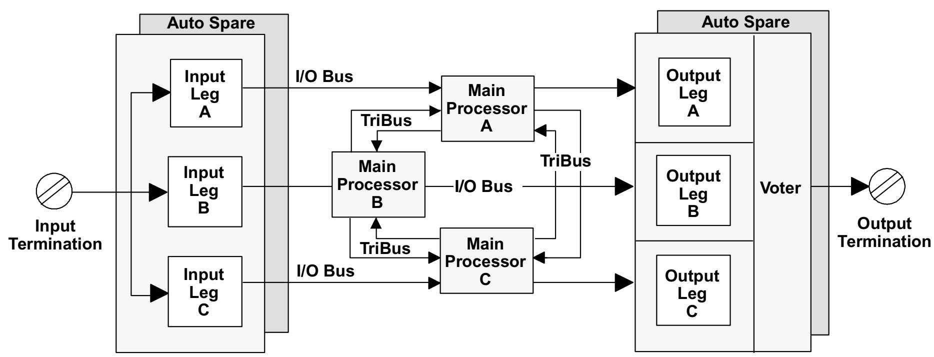
Main Processor Modules

A Tricon system contains three Main Processor (MP) Modules to control three separate legs of the system. Each Main Processor operates in parallel with the other two Main Processors, as a member of a triad.

The individual input table in each Main Processor is transferred to its neighboring Main Processors over the proprietary TriBus. During this transfer, hardware voting takes place. The TriBus uses a Direct Memory Access programmable device to synchronize, transmit, vote and compare data among the three Main Processors.

If a disagreement is discovered, the signal value found in two out of three tables prevails, and the third table is corrected accordingly. One-time differences which result from sample timing variations can be distinguished from a pattern of differing data. The three independent Main Processors each maintain data about necessary corrections in local memory. Any disparity is flagged and used at the end of the scan by the built-in Fault Analyzer routines to determine whether a fault exists on a particular module.

After the TriBus transfer and input data voting have corrected the input values, these corrected values are used by the



Simplified Trident Architecture

A dedicated Processor (IOPCOMM) on each Main Processor manages the data exchanged between the Main Processors and the I/O modules. A triplicated I/O Bus is located on the chassis backplane and is extended from chassis to chassis by means of I/O Bus Cables.

As each input module is polled, the new input data is transmitted to the Main Processor over the appropriate leg of the I/O Bus. The input data from each Input Module is assembled into a table in the Main Processor and stored in memory for use in the hardware voting process.

Main Processors as input to the user-written application. (The application is developed in the TriStation and downloaded to the Main Processors.) The 32-bit main microprocessor executes the user-written application in parallel with the neighboring Main Processor Modules.

The user-written application generates a table of output values based on the table of input values, according to the rules built into the application by the customer. The IOP on each Main Processor manages the transmission of output data to the output modules by means of the I/O Bus.

Using the table of output values, the IOP generates smaller tables, each corresponding to an individual output module in the system. Each small table is transmitted to the appropriate leg of the corresponding Output Module over the I/O Bus. For example, Main Processor A transmits the appropriate table to Leg A of each Output Module over I/O Bus A. The transmittal of output data has priority over the routine scanning of all I/O modules.

The IOPCOMM manages the data exchanged between the Main Processors and the communication modules using the communication bus, which supports a broadcast mechanism.

The Model 3008 Main Processors provide 16 Megabytes DRAM each for V9 Tricon Systems. The DRAM is used for the user-written application, sequence-of-events data, I/O data, diagnostics and communication buffers. In the event of an external power failure, the integrity of the user-written program and the retentive variables is protected for a minimum of six months.

The Main Processor Modules receive power from dual Power Modules and power rails in the Main Chassis. A failure on one Power Module or power rail will not affect the performance of the system.

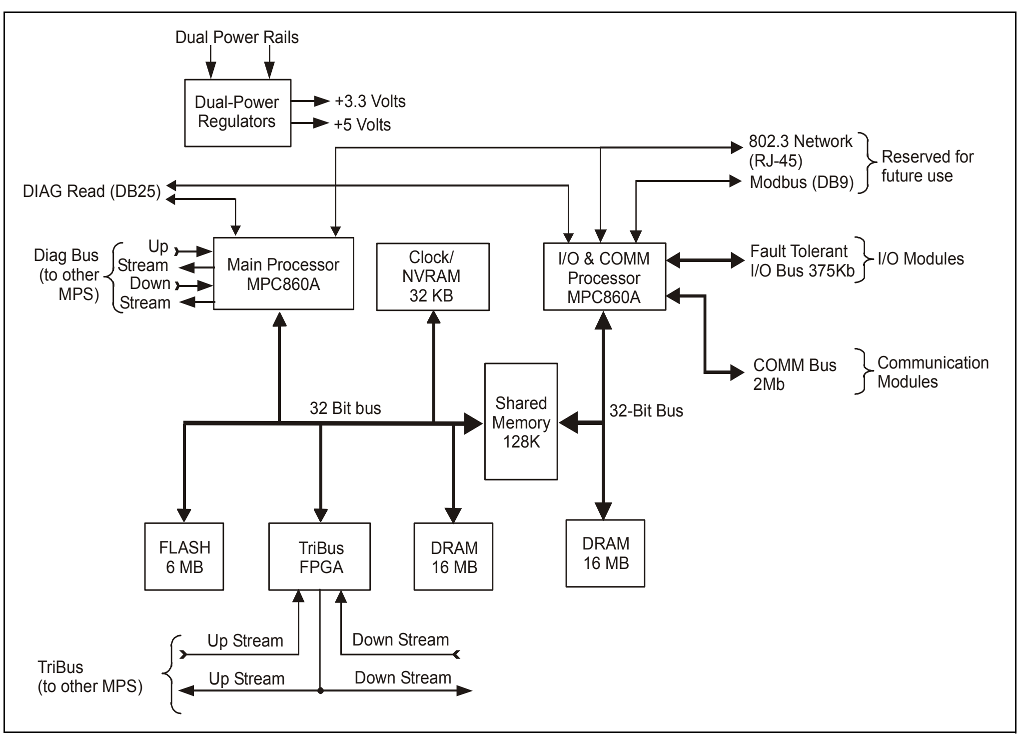
Bus Systems and Power Distribution

Three triplicated bus systems are etched on the chassis backplane: the TriBus, the I/O Bus and the Communication Bus.

The TriBus consists of three independent serial links operating at 25MBaud. The TriBus synchronizes the Main Processors at the beginning of a scan. Then each Main Processor sends its data to its upstream and downstream neighbors. The TriBus performs one of two functions with the data:

- Transfer of data only—for I/O, diagnostic and communication data.
- Comparing data and flagging disagreements—for previous scan's output data and memory of user-written application.

An important feature of the Tricon's fault-tolerant architecture is the use of a single transmitter to send data to both the upstream and downstream Main Processors. This ensures receipt of the same data by the upstream processor and downstream processor.



Main Processor (Model 3008) Architecture

I/O Bus

The 375 KBaud I/O Bus transfers data between the I/O Modules and the Main Processors. The triplicated I/O Bus is carried along the bottom of the backplane. Each leg of the I/O Bus runs between one of the three Main Processors and the corresponding legs on the I/O module.

The I/O Bus can be extended between chassis using a set of three I/O Bus Cables.

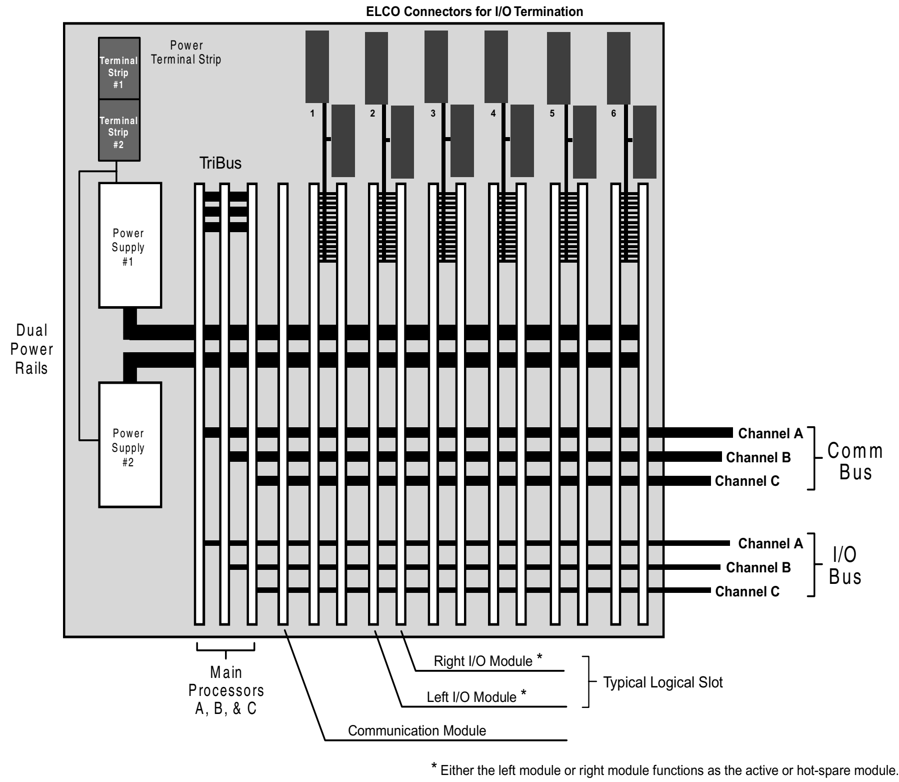
Communication Bus

The 2 MBaud Communication (COMM) Bus runs between the Main Processors and the Communication Modules.

Power for the chassis is distributed across two independent power rails down the center of the backplane. Every module in the chassis draws power from both power rails through dual power regulators. There are four sets of power regulators on each input and output module: one set for each of the legs A, B and C and one set for the status-indicating LEDs.

Field Signals

Each I/O module transfers signals to or from the field through its associated field termination assembly. Two positions in the chassis tie together as one logical slot. The first position holds the active I/O module and the second position holds the hot-spare I/O module. Termination cables are connected to the top of the backplane. Each connection extends from the termination module to both active and hot-spare I/O modules. Therefore, both the active module and the hot-spare module receive the same information from the field termination wiring.



Backplane of the Main Chassis

Digital Input Modules

The Tricon supports two basic types of digital input modules: TMR and single. The following paragraphs describe digital input modules in general, followed by specifics for TMR and single modules.

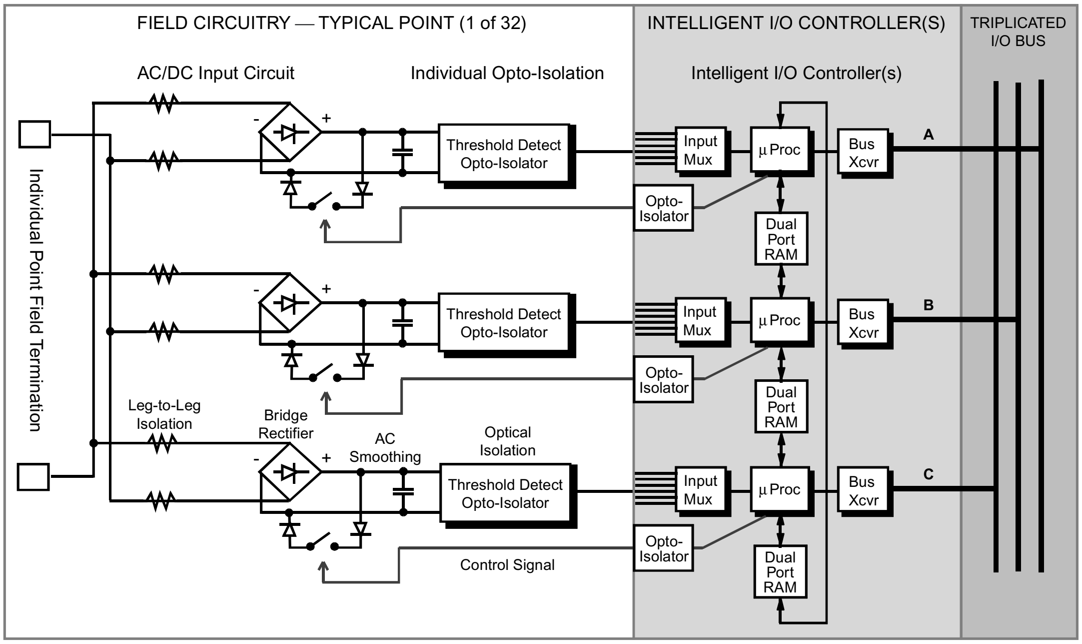
Every digital input module houses the circuitry for three identical legs (A, B and C). Although the legs reside on the same module, they are completely isolated from each other and operate independently. A fault on one leg cannot pass to another. In addition, each leg contains an 8-bit microprocessor called the I/O communication processor which handles communication with its corresponding Main Processor.

Each of the three input legs asynchronously measures the input signals from each point on the input termination module, determines the respective states of the input signals, and places the values into input tables A, B and C respectively. Each input table is regularly interrogated over the I/O bus by the I/O communication processor located on the corresponding Main Processor module. For example, Main Processor A interrogates Input Table A over I/O Bus A.

On *TMR* Digital Input Modules, all critical signal paths are 100 percent triplicated for guaranteed safety and maximum availability. Each leg conditions signals independently and provides isolation between the field and the Tricon. (The 64-point High-Density Digital Input Module is an exception—it has no channel-to-channel isolation.)

DC models of the TMR digital input modules can self-test to detect “stuck ON” conditions where the circuitry cannot tell whether a point has gone to the OFF state. Since most safety systems are set up with a “de-energize-to-trip” capability, the ability to detect stuck ON points is an important feature. To test for “stuck ON” inputs, a switch within the input circuitry is closed to allow a zero input (OFF) to be read by the isolation circuitry. The last data reading is frozen in the I/O communication processor while the test is running.

On *Single* Digital Input Modules, only those portions of the signal path which are required to ensure safe operation are



Architecture of TMR Digital Input Module with Self-Test (DC Model)

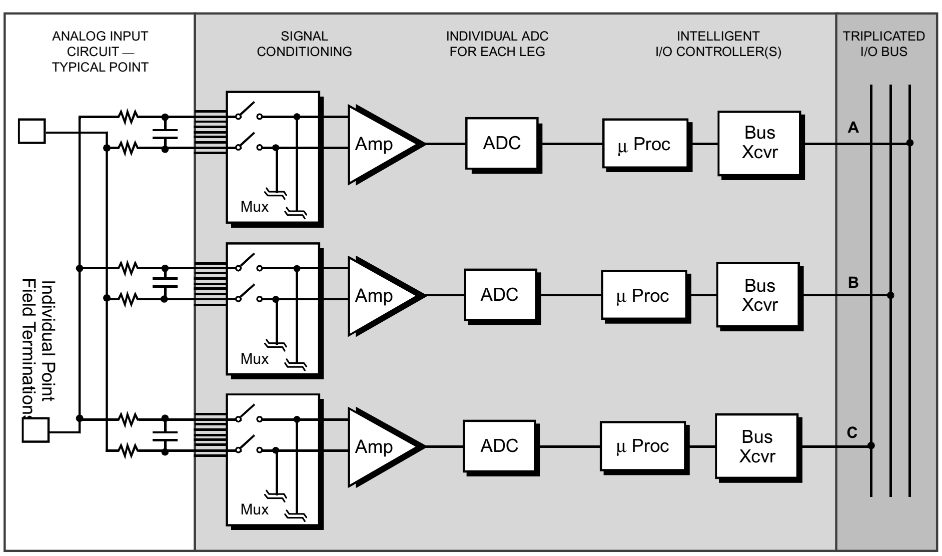
triplicated. Single modules are optimized for those safety-critical applications where low cost is more important than maximum availability. Special self-test circuitry detects all stuck-ON and stuck-OFF fault conditions within the non-triplicated signal conditioners in less than half a second. This is a mandatory feature of a fail-safe system, which must detect all faults in a timely manner and upon detection of an input fault, force the measured input value to the safe state. Because the Tricon is optimized for de-energize-to-trip applications, detection of a fault in the input circuitry forces to OFF (the de-energized state) the value reported to the Main Processors by each leg.

Digital Output Modules

There are four basic types of Digital Output Modules: dual, supervised, DC voltage and AC voltage. The following paragraphs describe digital output modules in general, followed by specifics for the four types.

Every digital output module houses the circuitry for three identical, isolated legs. Each leg includes an I/O microprocessor which receives its output table from the I/O communication processor on its corresponding Main Processor. All of the digital output modules, except the dual DC modules, use special quadruplicated output circuitry which votes on the individual output signals just before they are applied to the load. This voter circuitry is based on parallel-series paths which pass power if the drivers for Legs A and B, or Legs B and C, or Legs A and C command them to close—in other words, 2-out-of-3 drivers voted ON. The quadruplicated voter circuitry provides multiple redundancy for all critical signal paths, guaranteeing safety and maximum availability.

Each type of Digital Output Module executes a particular Output Voter Diagnostic (OVD)



Architecture of TMR Analog Input Module

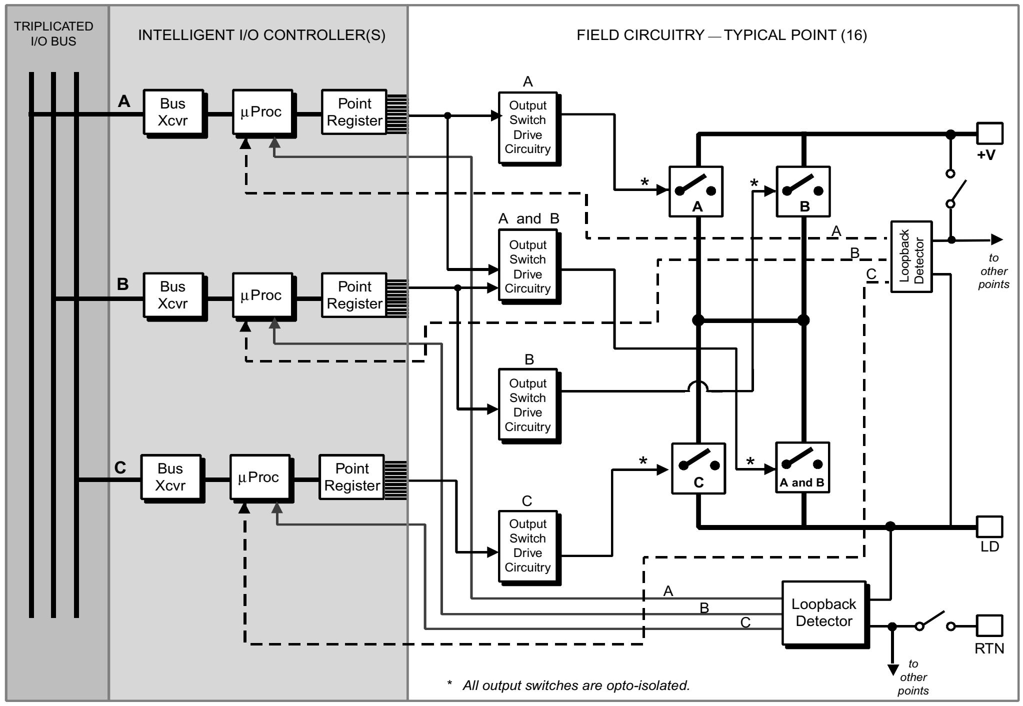
for every point. Loop-back on the module allows each microprocessor to read the output value for the point to determine whether a latent fault exists within the output circuit.

Analog Input Modules

On an Analog Input Module, each of the three legs asynchronously measures the input signals and places the results into a table of values. Each of the three input tables is passed to its associated Main Processor Module using the corresponding I/O Bus. The input table in each Main Processor Module is transferred to its neighbors across the Tricon. The middle value is selected by each Main Processor, and the input table in each Main Processor is corrected accordingly. In TMR mode, the mid-value data is used by the application; in duplex mode, the average is used.

Each Analog Input Module is automatically calibrated using multiple reference voltages read through the multiplexer. These voltages determine the gain and bias that are required to adjust readings of the analog-to-digital converter (ADC).

Analog Input Modules and Termination Modules are available to support a wide variety of analog inputs, in both isolated and non-isolated versions: 0-5 VDC, 0-10 VDC, 4-20 ma, thermocouples (types K, J, T, E), and Resistive Thermal Devices (RTDs).



Architecture of 16-point Supervised Digital Output Module

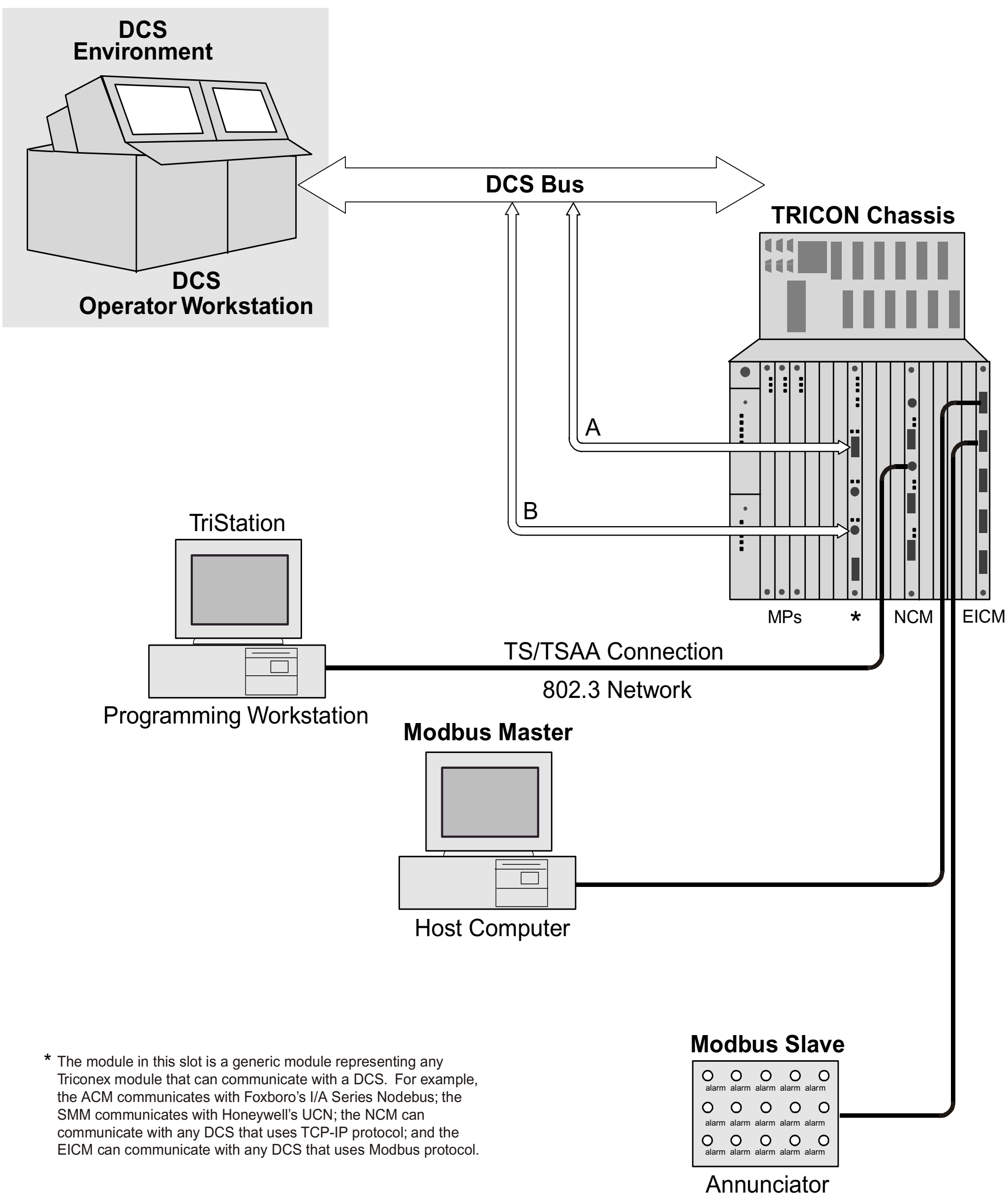
Analog Output Module

The Analog Output Module receives three tables of output values, one for each leg from the corresponding Main Processor. Each leg has its own digital-to-analog converter (DAC). One of the three legs is selected to drive the analog outputs. The output is continuously checked for correctness by “loop-back” inputs on each point which are read by all three microprocessors. If a fault occurs in the driving leg, that leg is declared faulty and a new leg is selected to drive the field device. The designation of “driving leg” is rotated among the legs, so that all three legs are tested.

Termination Modules

Various termination options are available for field wiring of the Tricon High Density chassis, including external panels and direct cabling. A field termination module is an electrically passive circuit board to which field wiring is easily attached. A termination module merely passes input signals from the field to an input module or passes signals generated by an output module directly to field wiring, thereby permitting removal or replacement of the input or output module without disturbing field wiring.

In addition, External Termination Assemblies are available for specialized applications. See “Special Termination Panels” on page 46 for more information.



Communication Capabilities of Tricon Modules

Communication Modules

By means of the communication modules described in this section, the Tricon can interface with Modbus masters and slaves, other Tricons in peer-to-peer networks, external hosts running applications over 802.3 networks, and Honeywell and Foxboro Distributed Control Systems (DCS). The Main Processors broadcast data to the communication modules across the communication bus. Data is typically refreshed every scan; it is never more than two scan-times old.

Enhanced Intelligent Communication Module (EICM)

Supports RS-232, RS-422 and RS-485 serial communication with external devices at speeds up to 19.2 Kbaud. The EICM provides four serial, opto-isolated ports which can interface with Modbus masters, slaves, or both; or a TriStation. The module also provides a Centronics-compatible parallel port.

Network Communication Module (NCM)

This module supports 802.3 networking over a high-speed 10 Megabit/second data link for the use of Triconex-proprietary protocols and applications (described in the section called "Communication Capabilities" later in this document). NCM also supports OPC Server which can be used by any OPC client. In addition, users can write their own applications using the TSAA protocol—see "Protocols for Open Networks" on page 55 for details.

Hiway Interface Module (HIM)

This module acts as an interface between a Tricon controller and Honeywell's TDC 3000 Distributed Control System (DCS) by means of the Hiway Gateway and Local Control Network (LCN). The HIM enables higher-order devices, such as computers and operator workstations, to communicate with the Tricon.

Safety Manager Module (SMM)

This module acts as an interface between a Tricon controller and Honeywell's Universal Control Network (UCN), one of three principal networks of the TDC 3000 DCS. The SMM appears to the TDC 3000 as a safety node on the Universal Control Network (UCN), allowing the Tricon to manage process-critical points within the overall TDC 3000 environment. The SMM transmits all Tricon aliased data and diagnostic information to TDC 3000 operator workstations in display formats that are familiar to Honeywell operators.

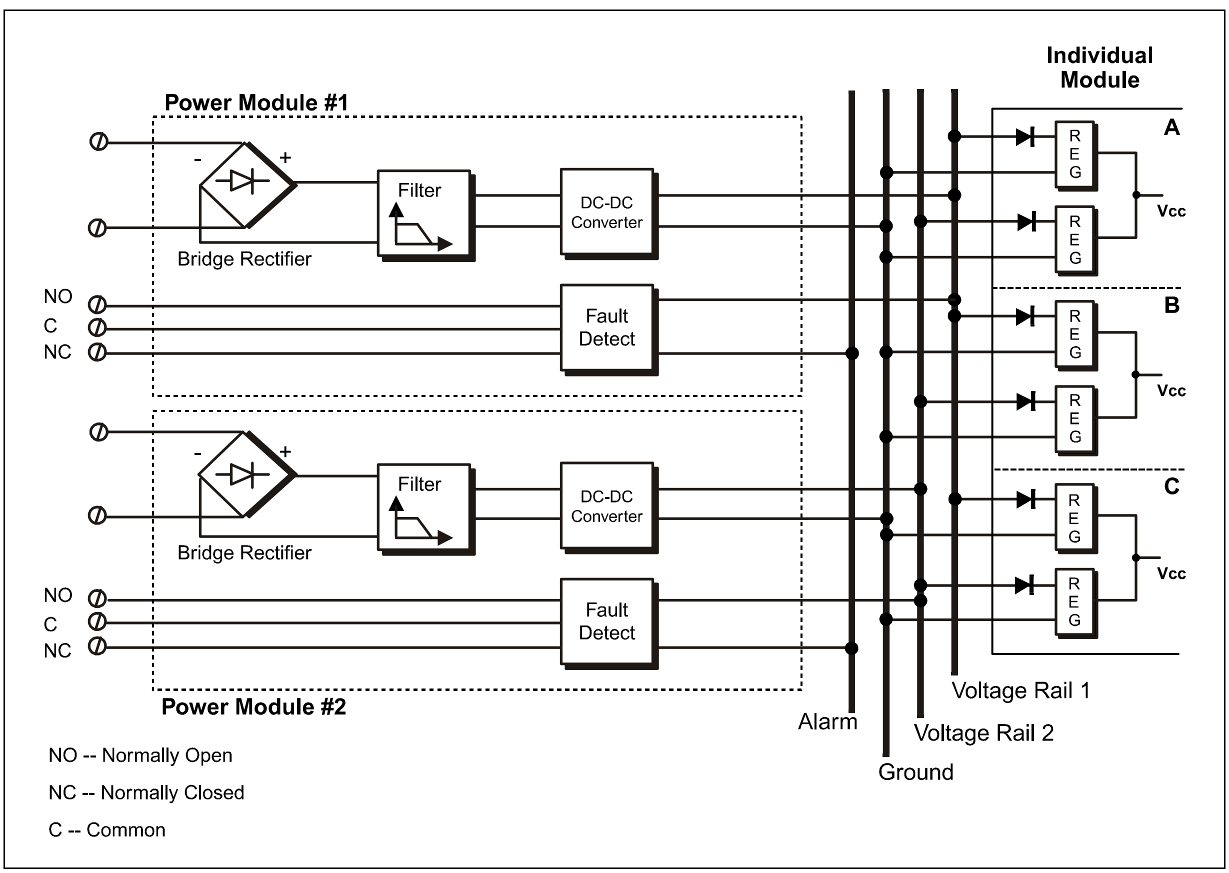
Advanced Communication Module (ACM)

This module acts as an interface between a Tricon controller and Foxboro's Intelligent Automation (I/A) Series DCS. The ACM appears to the Foxboro system as a safety node on the I/A Series Nodebus, allowing the Tricon to manage process-critical points within the overall I/A DCS environment. The ACM transmits all Tricon aliased data and diagnostic information to I/A operator workstations in display formats that are familiar to Foxboro operators.

See the section called "Product Specifications" for specifications of the EICM, NCM, SMM and ACM.

Power Supply Modules

Each Tricon chassis houses two Power Modules arranged in a dual-redundant configuration. Each module derives power from the backplane and has independent power regulators for each leg. Each can support the power requirements for all the modules in the chassis in which it resides, and each feeds a separate power rail on the chassis backplane. The Power Modules have built-in diagnostic circuitry which checks for out-of-range voltages and over-temperature conditions. A short on a leg disables the power regulator rather than affecting the power bus.



Architecture of Power Subsystem