The Trident controller is designed with a fully triplicated architecture throughout, from the input modules through the Main Processors to the output modules.

System Overview

Fault tolerance in the Trident controller is achieved through the Triple Modular Redundant (TMR) architecture. The Trident provides error-free, uninterrupted control in the event of hard failures of components or transient faults from internal or external sources.

The Trident is designed with a fully triplicated architecture throughout, from the input modules through the Main Processors (MPs) to the output modules. Each module houses the circuitry for three independent channels. Each channel on an input module reads the process data and passes it to the corresponding MP. The three MPs communicate with each other using a proprietary, high-speed bus called the TriBus.

Once per scan, the MPs synchronize and communicate with their neighbors over the TriBus. The TriBus sends copies of all analog and digital input data to each MP, then compares output data from each MP. The MPs vote the input data, execute the application, and send outputs generated by the application to the output modules.

In addition, the Trident controller votes the output data on the output modules as close to the field as possible. This allows the Trident to detect and compensate for any errors that could occur between the TriBus voting and the final output driven to the field.

Each I/O Baseplate supports two modules in one logical slot which means both the active and hot-spare module receive the same information from the field termination wiring.

The Main Processors switch control between the two healthy I/O modules approximately every hour, so that each module undergoes complete diagnostics on a regular basis.

If a fault is detected on the active module, Trident automatically switches control to the hot-spare module, allowing the system to continuously work in triplicated control. The faulty module can then be removed and replaced. For details, see “Online Module Repair” on page 11.

Main Processor Module

Every Trident system contains three Main Processors. Each MP controls a separate channel and operates in parallel with the other two MPs.

A dedicated I/O control processor on each MP manages the data exchanged between the MP and the I/O modules. A triplicated I/O bus, located on the baseplates, extends from one column of I/O modules to the next column using I/O bus cables.

The I/O control processor polls the input modules and transmits the new input data to the MPs. The MPs then assemble the input data into tables which are stored in memory for use in

Simplified Trident Architecture
System Overview

If a disagreement occurs, the signal value found in two out of three tables prevailed, and the MPs correct the third table accordingly. One-time differences which result from sample timing variations are distinguished from a pattern of differing data. The MPs maintain data about necessary corrections in local memory. Built-in fault analyzer routines flag any disparity and use it at the end of each scan to determine whether a fault exists on a particular module.

The Main Processors send the corrected data to the application. The 32-bit MP executes the application in parallel with the neighboring MP and generates a table of output values that is based on the table of input values according to user-defined rules. The I/O control processor on each MP manages the transmission of output data to the output modules by means of the I/O bus.

Using the table of output values, the I/O control processor generates a smaller table for each output module and transmits these tables to the appropriate channels of the output modules over the I/O bus. For example, Main Processor A transmits a table to Channel 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.

Each MP provides 16 megabytes of DRAM for the user-written application, sequence-of-events (SOE) and I/O data, diagnostics, and communication buffers. The application is stored in flash EPROM and loaded in DRAM for execution. The Main Processors receive power from redundant 24-volt DC power sources. In the event of an external power failure, all critical retentive data is stored in NVRAM (Non-Volatile Random Access Memory).

A failure of one power source does not affect controller performance. If the controller loses power, the application and all critical data are retained indefinitely.

Ports on the Main Processors enable the Trident to communicate with TriStation and with external devices by means of Modbus and Ethernet protocol.

Each MP provides:
- One Ethernet (IEEE 802.3) TriStation port for downloading the application to the Trident controller and uploading diagnostic information. This port can also be used to download Trident firmware to the Flash ROM.
- One Modbus RS-232 or RS-485 serial port which acts as a slave while an external device is the master. Typically, a distributed control system (DCS) monitors—and optionally updates—the Trident controller data directly through an MP.
**Bus and Power Distribution**

The triplicated I/O bus and redundant logic power (shown in the figure to the right) are carried from baseplate to baseplate by user-installed Interconnect Assemblies, I/O Extender Modules and I/O Bus Cables.

The TriBus, which is local to the MP Baseplate, consists of three independent, serial links operating at 25 megabits per second. The MPs synchronize at the beginning of every scan, then each MP sends its data to its upstream and downstream neighbors. Next, the TriBus takes these actions:

- Transfers input, diagnostic and communication data
- Compares data and identifies disagreements with the output data and application memory of the previous scan

An important feature of the Trident architecture is the use of a single transmitter to send data to both the upstream and downstream MPs. This ensures that the same data is received by the upstream processor and the downstream processor.

Each column of modules must have a separate logic power connection.

Field signal distribution is local to each I/O baseplate. Each I/O module transfers signals to or from the field through its associated baseplate assembly. The two I/O module slots on the baseplate tie together as one logical slot. Either position can hold the active I/O module while the other position holds the hot-spare I/O module.

Each field connection on the baseplate extends to both active and hot-spare I/O modules. Consequently, both the active module and the hot-spare module receive the same information from the field termination wiring.

A triplicated I/O bus between the I/O modules and the MPs transfers data at 2 megabits per second. The I/O bus is contained within an I/O column and can be extended to another I/O column using a set of three I/O bus cables (one for each TMR channel).

Each column is typically limited to eight baseplates due to vertical space restrictions.

Logic power for the modules in each I/O column is distributed using two independent power rails. Each I/O column draws power from both power rails through redundant DC-DC power converters. Each channel is powered independently by these redundant power sources.

Isolation is provided between field and logic power on all I/O modules.
System Overview

Analog Input Module

On an Analog Input (AI) Module each channel measures the input signals asynchronously and places the results into a table of values. Each input table is passed to its associated MP over the corresponding I/O bus. The input table in each MP is transferred to its neighbors over the TriBus.

In TMR mode, the mid-value data is used by the application; in dual mode, the average is used.

AI Modules continuously execute Forced Value Diagnostics (FVD) which is a self-test diagnostic that detects and signals an alarm for all stuck-at and accuracy fault conditions typically in less than 500 milliseconds. This safety feature allows unrestricted operation under a variety of multiple-fault scenarios.

Each AI Module is guaranteed to remain in calibration for the life of the controller. Periodic manual calibration is not required.

Analog Input/Digital Input Module

The Analog Input/Digital Input Module has 16 digital input points (points 1–16) and 16 analog input points (points 17–32).

The AI/DI Module has three isolated sets of electronics, called channels, which independently process field data input to the module. Sensing of each input point is performed in a manner that prevents a single failure on one channel from affecting another channel.

For analog input points, each channel receives variable voltage signals from each point, converts them to digital values, and transmits the values to the three MPs on demand.

For digital input points, an ASIC on each channel scans each input point, compiles data, and transmits it to the MPs on demand.
For all points, the MPs vote the data before passing it to the control program. In TMR mode, the data passed is mid-value. In dual mode, the data passed is the average.

AI/DI Modules sustain complete, ongoing diagnostics for each channel. If the diagnostics detect a failure on any channel, the Fault indicator turns on and activates the system alarm. The Fault indicator identifies a channel fault, not a complete module failure. AI/DI Modules are guaranteed to operate properly in the presence of a single fault and may continue to operate properly with multiple faults.

AI/DI Modules include the hot-spare feature which allows online replacement of a faulty module. The AI/DI Module is mechanically keyed to prevent improper installation in a configured baseplate.

**Analog Output Module**

On an Analog Output (AO) Module, each channel includes a proprietary ASIC that receives its output table from the I/O communication processor on its corresponding main processor. AO Modules use special shunt circuitry to vote on the individual output signals before they are applied to the load. Voter circuitry ensures only one output channel (A, B, or C) is driving the field load. The shunt output circuitry provides multiple redundancy for all critical signal paths, guaranteeing safety and maximum availability.

AO Modules continuously execute Forced Switch Diagnostics (FSD) on each point. By carefully forcing error conditions and observing proper behavior of the voting circuitry, high reliability and safe operation is ensured. This safety feature allows unrestricted operation under a variety of multiple-fault scenarios.

Each AO Module is guaranteed to remain in calibration for the life of the controller. Periodic manual calibration is not required.

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**Analog Output Modules Schematic**
System Overview

**Digital Input Module**

A Digital Input (DI) Module contains the circuitry for three identical channels (A, B and C). Although the channels reside on the same module, they are completely isolated from each other and operate independently. Each channel conditions signals independently. A fault on one channel cannot pass to another. Each channel includes a proprietary ASIC which handles communication with its corresponding MP, and supports run-time diagnostics.

Each input channel on the DI Module measures the input signals from each point on the baseplate asynchronously, determines the respective states of the input signals, and places the values into input tables A, B and C respectively. Each input table is interrogated at regular intervals over the I/O bus by the I/O communication processor located on the corresponding MP. For example, MP A interrogates Input Table A over I/O Bus A.

DI Modules continuously execute Forced Value Diagnostics (FVD) which is a self-test diagnostic that detects and signals an alarm for all stuck-at fault conditions typically in less than 500 milliseconds. This safety feature allows unrestricted operation under a variety of multiple-fault scenarios.

DI Module diagnostics are specifically designed to monitor devices which hold points in one state for long periods of time. The diagnostics ensure complete fault coverage of each input circuit even if the actual state of the input points never changes.

**Digital Output Module**

On the Digital Output (DO) Module, each channel includes a proprietary ASIC which receives its output table from the I/O communication processor on the corresponding MP. Digital Output Modules use the patented Quad Voter circuitry to vote 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 two out of three channels (A and B, or B and C, or A and C) command them to close. The Quad Voter circuitry has multiple redundancy on all critical signal paths, guaranteeing safety and maximum availability.

During Output Voter Diagnostic (OVD) execution, the commanded state of each point is momentarily reversed on one of the output drivers, one after another. Loop-back circuitry on the module allows each ASIC to read the output value for the point to determine whether a latent fault exists within the output circuit.

The output signal transition is guaranteed to be less than 2 milliseconds (500 microseconds is typical) and is transparent to most field devices. For devices that cannot tolerate a signal...
transition of any length, OVD can be disabled on a per-point basis from TriStation.

DO Module diagnostics are specifically designed to monitor outputs which remain in one state for long periods of time. The OVD diagnostics ensure complete fault coverage of each output circuit even if the actual state of the output points never changes.

**Pulse Input Module**

On a Pulse Input (PI) Module, six sensitive, high-frequency inputs can be individually configured for non-amplified and amplified magnetic speed sensors common on rotating equipment, such as turbines or compressors.

The PI Module senses voltage transitions from the speed sensors. Every input transition is sampled and time is measured for an optimized number of input gear pulses. The resulting count and time are used to generate a frequency (revolutions per minute), which is transmitted to the Main Processors.

PI Modules have three independent input channels. Each input channel receives pulse input voltages from each point, converts the values to frequency (RPM) data, and transmits the values to the MPs on demand. To ensure correct data for each scan, one value is selected using a mid-value selection algorithm. Sensing of each input point is designed to prevent a single failure on one channel from affecting another channel.
System Overview

Solid-State Relay Module

On a Solid-State Relay (SRO) Module, output signals are received from the MPs on each of three channels. The three sets of signals are voted and the voted data is used to drive the 32 individual relays. Each output has a loop-back circuit which verifies the operation of each relay switch independently of the presence of a load. Ongoing diagnostics test the operational status of the SRO Module.

The SRO Module is a non-triplicated module for use on non-critical points which are not compatible with high-side, solid-state output switches; for example, interfacing with annunciator panels.

HART Communication

Highway Addressable Remote Transducer protocol (HART) is a bi-directional industrial field communication protocol used to communicate between intelligent field instruments and host systems over 4–20 mA instrumentation wiring. Triconex offers these components to enable HART communication between HART devices in the field and Configuration and Asset Management Software running on a PC.

- 2354 Analog Input HART Baseplate
- 2354A Analog Input HART Hazardous Location Baseplate
- 2483 Analog Output HART Baseplate
- 2483A Analog Output HART Hazardous Location Baseplate
- Triconex 4850 HART multiplexer

System Diagnostics and Status Indicators

The Trident controller uses online diagnostics and specialized fault-monitoring circuitry to detect and alarm all single-fault and most multiple-fault conditions. The circuitry includes I/O loop-back, watch-dog timers, loss-of-power sensors, and other proprietary diagnostic mechanisms. Using the alarm information, you can tailor the response of the system to the specific fault sequence and operating priorities of the application.

Any I/O module can activate the system integrity alarm, which consists of redundant normally closed (NC) relay contacts on each MP. Any failure condition, including loss or brown-out of system power, activates the alarm to summon plant maintenance personnel.

The front panel of every I/O module includes light-emitting diode (LED) indicators that display the status of the module or the external systems to which it is connected. Pass, Fault and Active indicators are common to all I/O modules. Other indicators are module-specific.

Normal service of a Trident system consists of replacing plug-in modules. A lighted Fault indicator shows that the module has detected a fault and must be replaced.

All internal diagnostic and alarm data is available for remote logging and report generation. Reporting is done through a local or remote TriStation PC or host computer. For more information on reporting, see the TriStation Developer’s Guide.
Online Module Repair

Because the logical slot for Trident modules can contain two identical I/O modules, a faulted module can be repaired online without interrupting the control process.

In the case where there are two identical I/O modules in the slot, Trident periodically switches control between each module. When one module is active, the other acts as a hot-spare module—powered, but inactive.

Trident switches control between the two healthy I/O modules approximately every hour, so that each module undergoes complete diagnostics on a regular basis.

If a fault is detected on the active module, Trident automatically switches control to the hot-spare module, allowing the system to continuously work in triplicated control. The faulty module can then be removed and replaced.

In the case where there is only one I/O module in the slot and a fault occurs, a second I/O module can be inserted in the slot. After the replacement module passes a diagnostic test, it becomes the active module.

If a fault occurs on a system that does not have a hot-spare module, the Fault indicator turns on, but the module remains active in dual control. When a replacement module is inserted and passes the diagnostic test, Trident switches control to the second I/O module and returns to triplicated control.

After the replacement module becomes active, the faulty module can be removed and sent to Triconex for repair. This method demonstrates the Trident’s ability to automatically transition from triplicated to dual control and back again without process interruption.

Ideally, at least one hot-spare module should be installed for every type of I/O module used in the system. For example, if a Trident system normally operates with four DI Modules, at least one hot-spare DI Module should be installed at all times. With this arrangement, the hot-spare module is tested regularly and can be used for online replacement of any DI Module in the system.