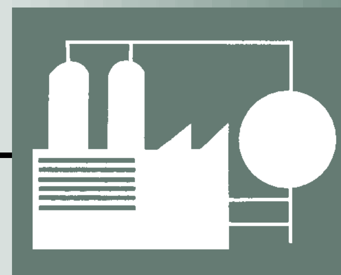
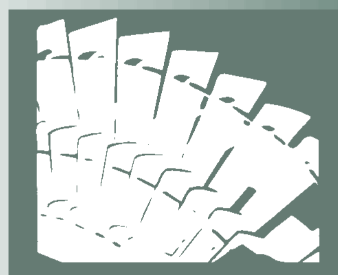
Trident

Technical Product Guide

Version 1.0 Systems



Emergency Shutdown Systems



Turbine Control Systems

Burner Management Systems

Fire and Gas Protection Systems

An Invensys company

Technical Product Guide

Printed in the United States of America.

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Table of Contents

Triconex Part No. 9791029-001, April 2000

Preface

The Trident fault-tolerant control system is the newest product offered by Triconex, the industry leader for critical-process applications requiring maximum safety and uninterrupted operation. Leading producers of chemical, oil and gas, pulp and paper, and electric power have successfully implemented Triconex fault-tolerant control to improve safety, increase productivity, and reduce downtime.

This *Trident Technical Product Guide* will familiarize you with theory and terminology for fault-tolerant control, reliability and availability. The guide covers configuration and specifications of the Trident system, and describes the capabilities of the TriStation 1131 Developer's Workbench and the communication ports which enable the Trident to interface with external devices using Modbus protocol.

The information in the *Trident Technical Product Guide* applies to Version 1.0 Trident systems.

The Triconex sales and application staff is readily available to provide additional information or assistance as needed. Trident also offers technical courses on configuration, programming and Trident maintenance. Open enrollment courses are held at our headquarters in Irvine, California and at our regional business centers. If desired, on-site training can be arranged at your facility for your operation and maintenance personnel.

Product, support and service information are available for users 24 hours a day through Internet connections. Administered by the Customer Satisfaction Group at Triconex Headquarters, customer reference documents can be downloaded or diagnostic files uploaded for analysis by Customer Satisfaction Engineers.

For Trident product information and support, please visit our website at http://www.triconex.com or call our Technical Support Group at (949) 699-2100, toll free (800) 325-2128, or fax (949) 768-6601.

The Trident is a state-of-the art controller that provides fault tolerance by means of Triple-Modular Redundant (TMR) architecture.

Introduction

What is Fault-Tolerant Control?

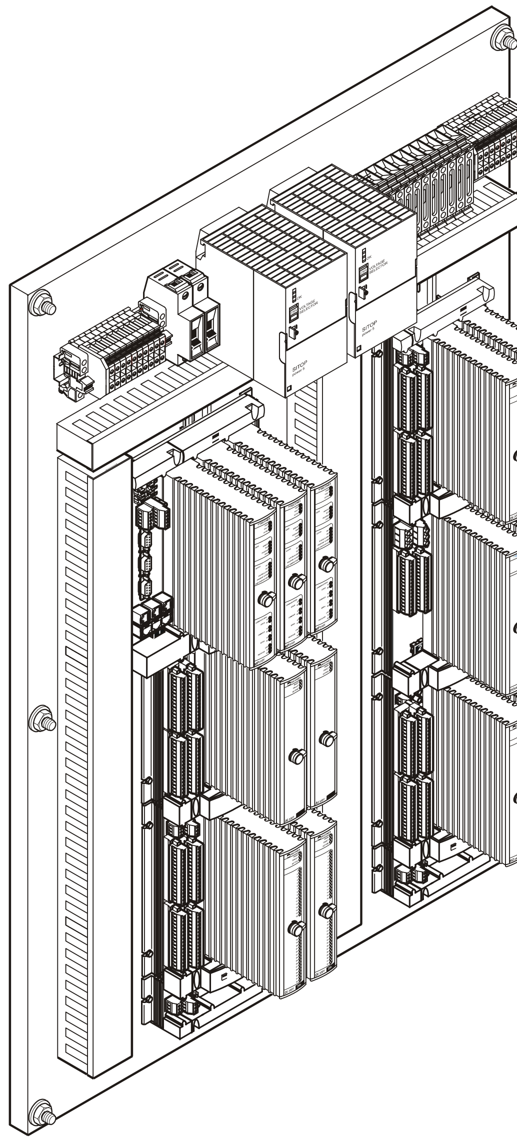
Fault-tolerance in a control system identifies and compensates for failed system elements and allows repair while continuing to control an industrial process without interruption. A high-integrity control system such as the Trident can be used in critical process applications that require a significant degree of safety and availability.

What is the Trident?

The Trident is a state-of-the art controller that provides fault tolerance by means of Triple-Modular Redundant (TMR) architecture. TMR integrates three isolated, parallel control systems and extensive diagnostics in one control system. The system uses two-out-of-three voting to provide high-integrity, error-free, uninterrupted process operation with no single point of failure.

The Trident controller uses three identical channels. Each channel independently executes the application program in parallel with the other two channels. Specialized hardware/software voting mechanisms qualify and verify all digital inputs and outputs from the field, while analog inputs are subject to a mid-value selection process.

Because each channel is isolated from the others, no single-point failure in any channel can pass to another. If a hardware failure does occur on one channel, the other channels override it. Meanwhile the faulting module can easily be removed and replaced while the controller is online without interrupting the process.



Trident System Mounted on a Panel

Setting up applications is simplified with the triplicated Trident system, because it operates as a single control system from the user's point of view.

The user terminates sensors and actuators at a single wiring terminal and programs the Trident with one set of application logic. The Trident manages the rest!

Extensive diagnostics on each channel, module, and functional circuit immediately detect and report operational faults by means of indicators or alarms. All diagnostic fault information is accessible by the application program and the operator. The program or the operator can use diagnostic data to modify control actions or direct maintenance procedures.

Other key features of the Trident controller that ensure the highest possible system integrity are:

- Ability to withstand harsh industrial environments
- Optimization for applications with small to medium point counts
- Support for remote and distributed I/O
- Wall- or skid-mounting outside of control room and enclosures
- Support for up to six analog and digital I/O modules
- Hot spare I/O modules for critical applications where prompt attention from the operator is not possible
- Integral support for redundant field power and logic power sources
- Integration of I/O modules with field termination assemblies
- Field installation and repair at the module level while the controller remains online and without disturbing field wiring
- Execution of application programs developed and debugged using the TriStation 1131 Developer's Workbench
- TriStation and Modbus communication directly from the Main Processors

What are Typical User Applications?

Each day Trident systems supply increased safety, reliability and availability to a worldwide installed base. The following are a few typical applications. For details on the Trident's value to your applications, ask your sales representative for additional documentation and customer references.

Emergency Safety Shutdown (ESD)

Trident controllers provide continuous protection for safety-critical units in refineries, petrochemical and chemical plants and other industrial processes. For example, in reactor and compressor units, plant trip signals—for pressure, product feed rates, expander pressure equalization and temperature—are monitored and shutdown actions taken if an upset condition occurs. Traditional shutdown systems implemented with mechanical or electronic relays may provide shutdown protection, but can also cause dangerous nuisance trips.

The Trident also increases system integrity by providing these features:

- Automatic detection and verification of field sensor accuracy
- Integrated shutdown and control functionality
- Direct connection to the supervisory data highway for continuous monitoring of safety-critical functions

Boiler Flame Safety

Process steam boilers function as a critical component in most refinery applications. Protection of the boiler from upset conditions, safety interlock for normal startup and shutdown, and flame-safety applications are combined by one integrated Trident system. In traditional applications, these functions had to be provided by separate, non-integrated components. But with the fault-tolerant, fail-safe Trident controller, the boiler operations staff can use a critical resource more productively while maintaining safety at or above the level of electromechanical protection systems.

What is TriStation?

The TriStation 1131 Developer's Workbench is an integrated tool for developing, testing and documenting applications for the Trident controller. The programming methodology, user interface and self-documentation capabilities make TriStation superior to traditional and competing engineering tools. TriStation complies with the IEC 1131 International Standard for Programmable Controllers and follows the Microsoft Windows guidelines for graphical user interfaces.

What about Communication Capabilities?

Multiple ports on the Main Processors enable the Trident to communicate with the following external devices by means of Modbus protocol:

- Modbus masters
- Distributed Control Systems (DCS)
- Operator workstations

With future releases, the Trident system will provide a greater variety of communication methods, protocols and physical media types. These will enable the Trident to communicate with:

- TCP/IP open networks
- Network printers
- Other Trident systems and/or Tricon V9 systems

For more information, see page 27.

The Trident is designed with a fully triplicated architecture throughout, from the input modules through the Main Processors (MPs) 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, and compares output data from each MP. The MPs vote the input data, execute the application program, and send outputs generated by the application program 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.

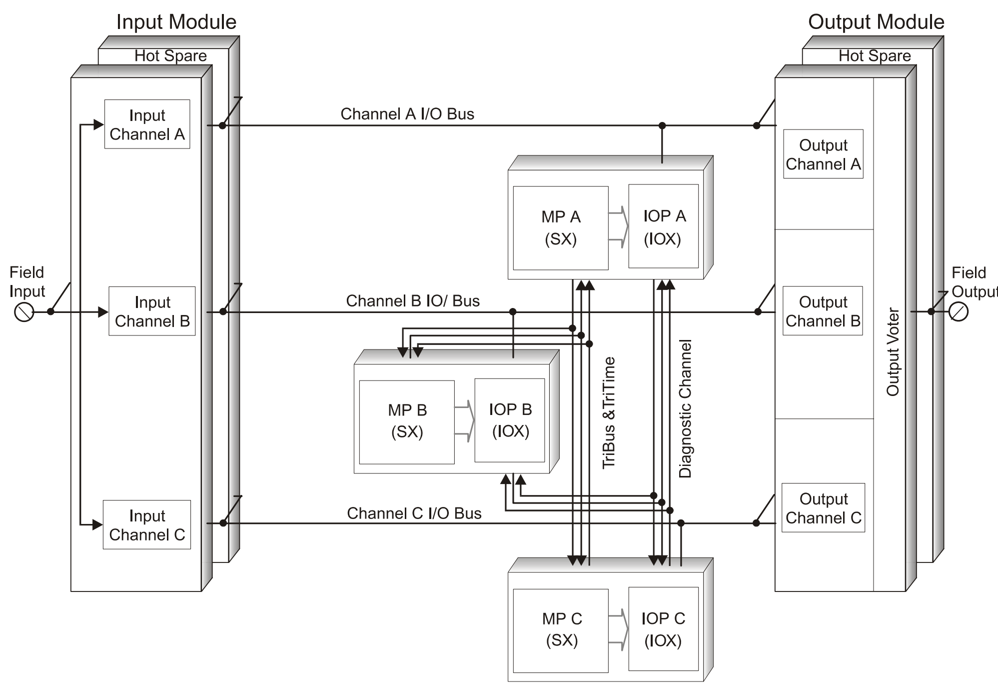
For each I/O module, the controller can support an optional hot-spare module. When present, the hot-spare takes control if a fault is detected on the primary module during operation. The hot-spare position is also used for online hot repair of a faulty I/O module. For details, see "On-Line Module Repair" on page 7.

Main Processor Module

Every Trident system contains three MPs. 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.

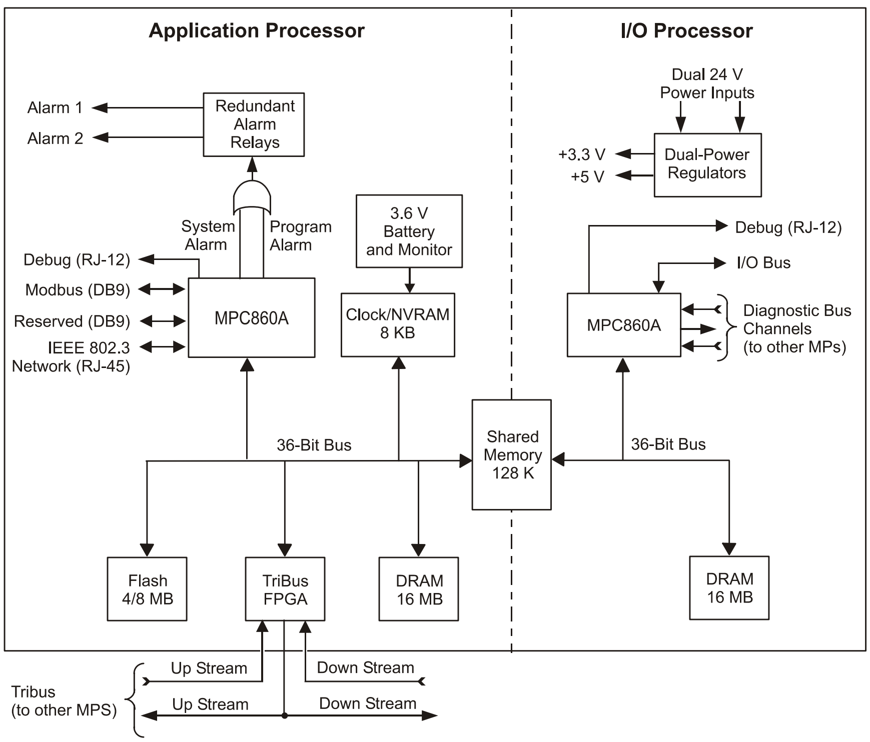
The I/O control processor polls the input modules and transmits the new input data to the MPs. The MPs then assemble the input data into tables which are stored in memory for use in the voting process. The input table in each MP is transferred to its neighboring MP by the TriBus. After this transfer, voting takes place. The TriBus uses a programmable device with direct memory access to synchronize, transmit and compare data among the three MPs.



Simplified Trident Architecture

System Overview

If a disagreement occurs, the signal value found in two out of three tables prevails, 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.



Main Processor Architecture

The MPs send the corrected data to the application program. The 32-bit MP executes the application program 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, MP 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 a 16-megabyte DRAM for the user-written application program, sequence-of-events (SOE) and I/O data, diagnostics, and communication buffers. The application program is stored in flash EPROM and loaded in DRAM for execution. The MPs receive power from redundant 24 VDC power sources. In the event of an external power failure, all critical retentive data is stored in NVRAM.

A failure of one power source does not affect controller performance. If the controller loses power, the application program 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 protocol. Each MP provides:

- One IEEE 802.3 (Ethernet) Tristation port for downloading the application program to the Trident controller and uploading diagnostic information.
- One Modbus RS-232/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 though an MP.

Bus and Power Distribution

The triplicated I/O bus and redundant logic power (shown in "I/O Bus and Logic Power Distribution" on page 5) are carried from baseplate to baseplate by user-installed Interconnect Assemblies, 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 Mbaud. The MPs synchronize at the beginning of every scan. Then each MP sends its data to its upstream and downstream neighbors and the TriBus takes the following actions:

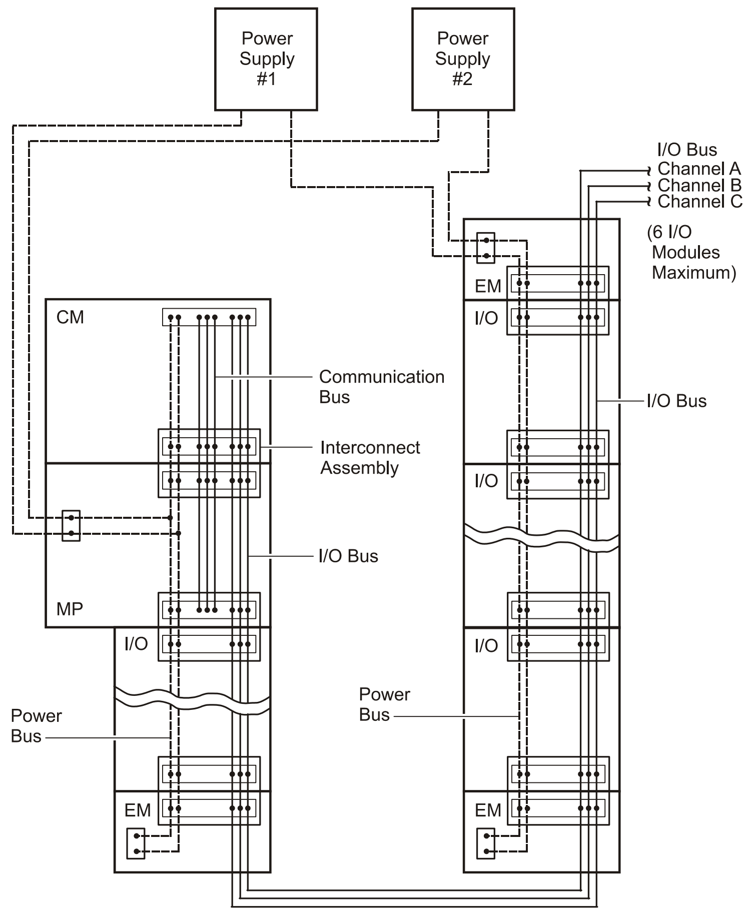
- Transfers input, diagnostic and communication data
- Compares data and flags disagreements for the previous scan's output data and application program memory

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. The left position holds the active I/O module and the right position holds the hot-spare I/O module. Each field connection on the baseplate extends 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.

A 2 Mbaud triplicated I/O bus transfers data between the I/O modules and the MPs. 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 about eight baseplates due to vertical space restrictions.

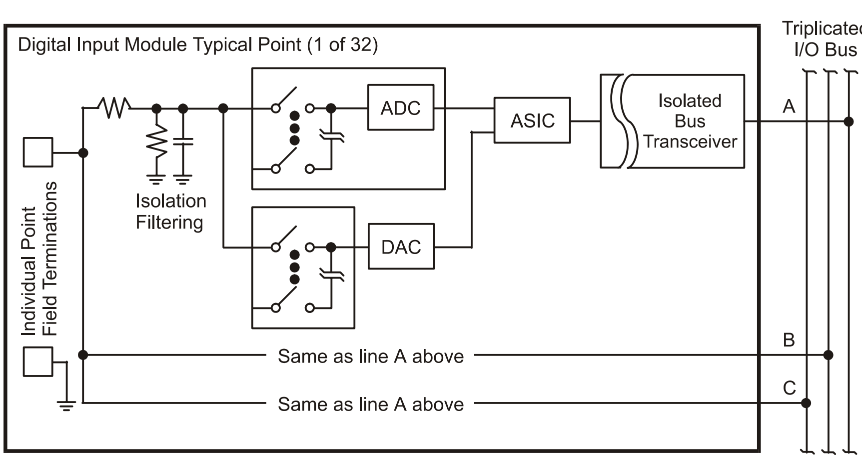


I/O Bus and Logic Power Distribution

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.

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 and provides optical isolation between the field and the Trident controller. A fault on one channel cannot pass to another. Each channel includes a proprietary ASIC which handles communication with its corre-



Schematic for Digital Input Module

sponding 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.

Special self-test circuitry is provided to detect and alarm all stuck-at and accuracy fault conditions in less than 500 milliseconds. This important 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

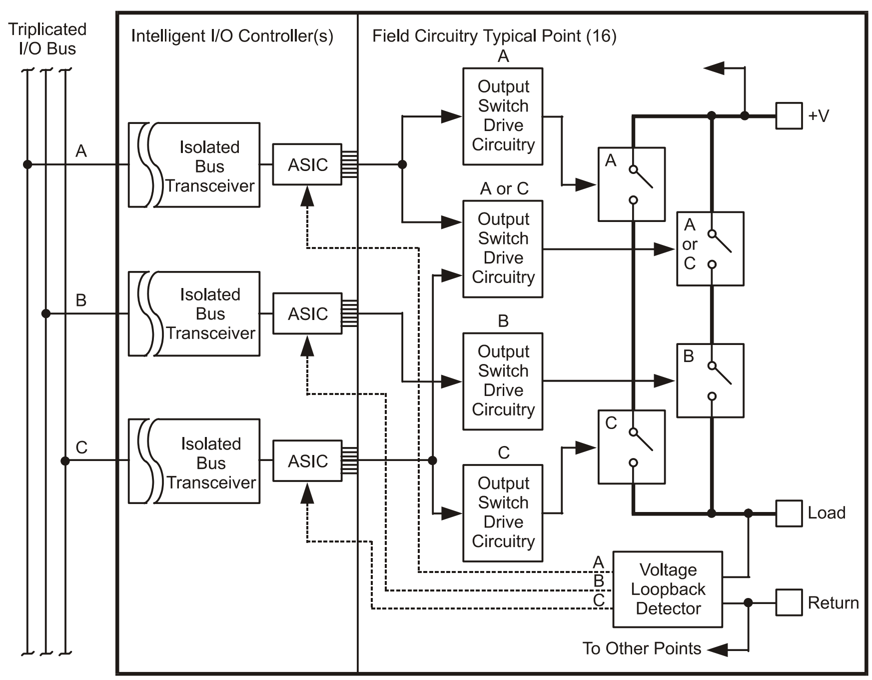
A Digital Output (DO) Module contains the circuitry for three identical, isolated channels. Each channel includes a proprietary ASIC which receives its output table from the I/O communication processor on the corresponding MP. All DO Modules use the Trident's patented Quad Output Voter circuitry to vote 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 switches (channels A and B, or channels B and C, or channels A and C) command them to close. The Quad Output Voter circuitry has multiple redundancy on all critical signal paths, guaranteeing safety and maximum availability.

A DO Module periodically executes the Output Voter Diagnostic (OVD) routine for each point. To allow unrestricted safe operation under a variety of multiple-fault scenarios, OVD detects and alarms these types of faults:

- Points—all stuck-on and stuck-off points are detected in less than 500 milliseconds
- Switches—all stuck-on or stuck-off switches or their associated drive circuitry are detected

During OVD execution, the commanded state of each point is momentarily reversed on one of the output drivers, one after another. Loop-back 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 2.0 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.

OVD is specifically designed to check outputs which typically remain in one state for long periods of time. The OVD strategy for a DO Module ensures full fault coverage of the output circuitry, even if the commanded states of the points never change.

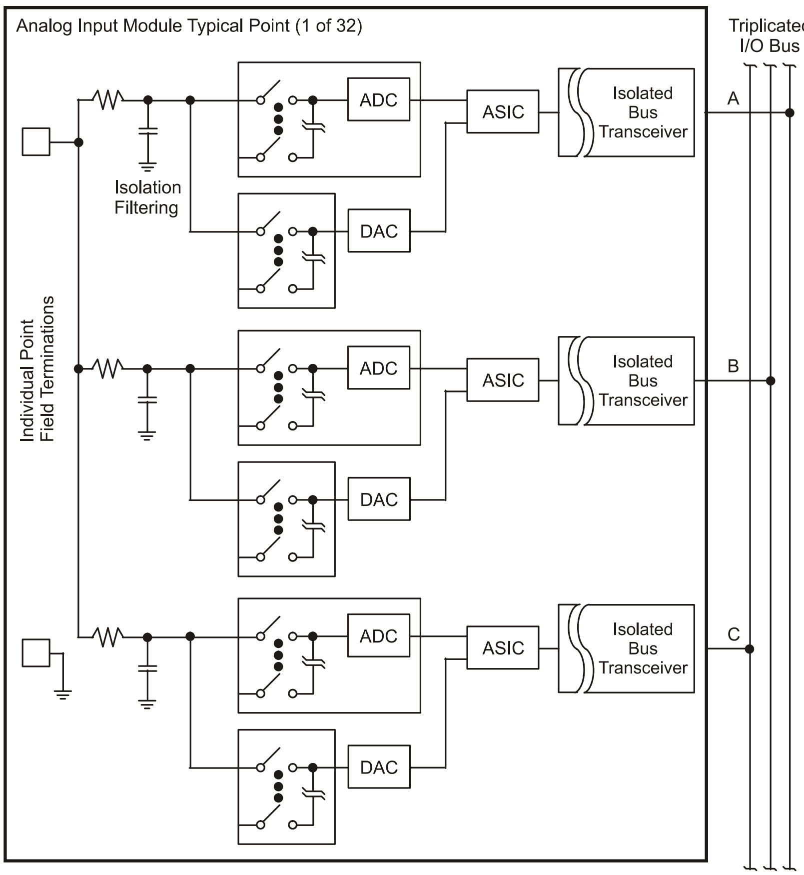


Schematic for Digital Output Module

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. The middle value is selected by each MP, and the input table in each MP is corrected accordingly. In TMR mode, the mid-value data is used by the application program; in duplex mode, the average is used.

Each AI Module is guaranteed to remain in calibration for the life of the



Schematic for Analog Input Module

Trident controller. Periodic manual calibration is not required.

Special self-test circuitry is provided to detect and alarm all stuck-at and accuracy fault conditions in less than 500 milliseconds. This important safety feature allows unrestricted operation under a variety of multiple fault scenarios.

Logic Power

Each module is designed to operate directly from redundant 24 VDC power sources as shown in the drawing called "I/O Bus and Logic Power Distribution" on page 5. Logic power is carried from baseplate to baseplate, allowing a single logic power connection per I/O column. The power conditioning circuitry is protected against over-voltage, over-temperature, and over-load conditions. Integral diagnostic circuitry checks for out-of-range voltages and over-temperature conditions. A short on a channel disables the power regulator rather than affecting the power sources.

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, the user is able to 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 provides light-emitting-diode (LED) indicators that display the status of the module or the external systems to which it may be connected. PASS, FAULT and ACTIVE indicators are common to all I/O modules. Other indicators are module-specific.

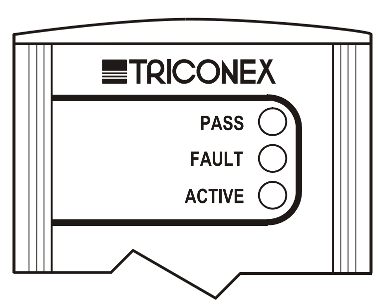
Normal maintenance of a Trident system consists of replacing plug-in modules. A lighted FAULT indicator shows that the module has detected a fault and must be replaced.

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 *Developer's Guide for Trident Systems.*

On-Line Module Repair

The logical slot set-up of Trident modules allows two methods of online repair: the *hot spare* method and *on-line module replacement.*

With the hot spare method, a logical slot contains two identical I/O modules. The primary module is active, and the



Front Panel Indicators

other module—the hot spare—is powered but inactive. The Trident cycles control between the two healthy I/O modules approximately every two hours, so that each undergoes complete diagnostics on a regular basis. If a fault is detected on the primary module, the Trident automatically switches control to the hot spare, allowing the system to continuously maintain three healthy legs. The faulty module can then be removed and replaced.

A module can still be replaced on-line even when only one I/O module is normally installed in a logical slot. If a fault occurs, the Fault indicator turns on, but the module remains active on two legs. A replacement module is then inserted into the unused space in the slot. The Trident grants control to this second I/O module after it passes a diagnostic test. Once the replacement module becomes active, the faulty module can be removed. This repair 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 being used in the system. For example, if a Trident system normally operates with four DI modules, then 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 on-line replacement of any DI module in the system.

A typical Trident system is configured into one or more vertical I/O columns guided by DIN rails and mounted on a sheet-metal panel.

Setting up a Trident System

A Trident system consists of:

- Field-replaceable Main Processors (MPs) and I/O modules
- The baseplates on which the modules are mounted
- Field wiring connections
- A programming workstation called TriStation

A typical Trident system is configured into one or more vertical I/O columns guided by DIN rails and mounted on a sheet-metal panel, as shown at right. Multiple I/O columns are connected by means of extender modules and I/O bus cables. The completed panel is often installed in a floor- or wall-mounted enclosure such as a Rittal cabinet or a Hoffman box.

"Product Specifications" on page 13 provides details about the available baseplates, modules and accessories.

Planning the System Configuration

Before a Trident system can be physically installed, its configuration must be planned, based on the requirements described in this section.

Selecting Modules and Baseplates

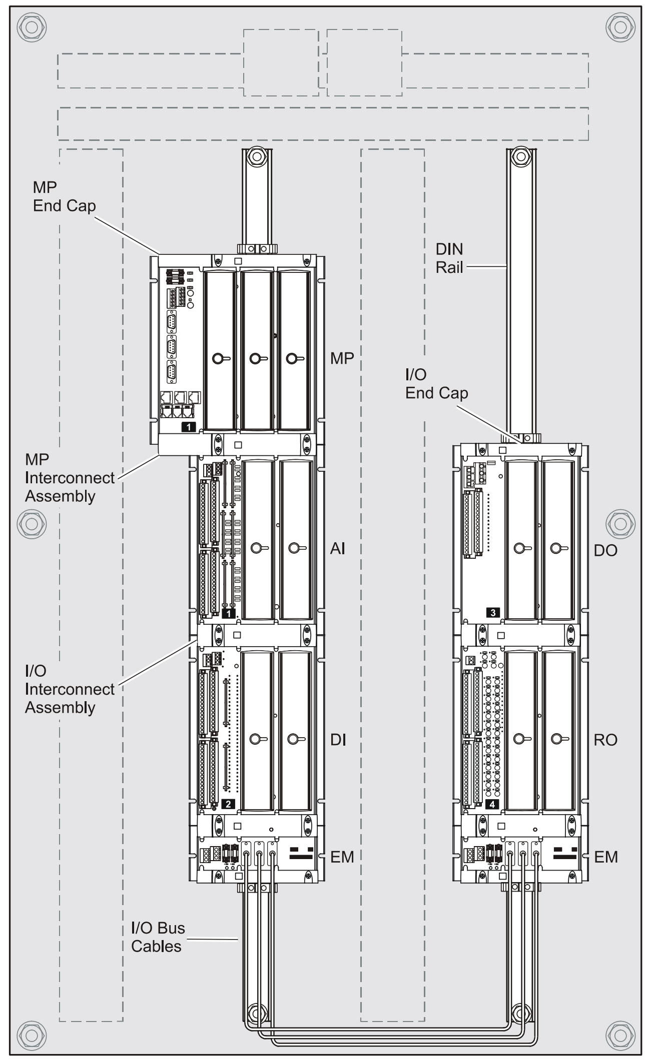
A Trident system must include three MPs and their baseplate and may include any combination of other module types and baseplates:

- Digital Input (DI)
- Digital Output (DO)
- Analog Input (AI)
- Relay Output (RO)

A system may include a maximum of 1024 I/O points on 32 baseplates. The total number of points for each module type may not exceed:

- 1024 digital inputs
- 512 digital outputs
- 428 analog inputs
- 1024 relay outputs

Performance and other considerations may limit the maximum number of I/O points in some applications. Please contact Triconex Customer Satisfaction for help with configuring large systems.



Typical System Configuration

Interconnection of Baseplates

Baseplates are connected by Interconnect Assemblies that carry I/O messages, logic power and system power across baseplates. The MP Interconnect is connected to an I/O baseplate, and the I/O Interconnects are connected to other I/O baseplates.

Extending the I/O Bus

Extender Modules (EM) and I/O Bus Cables must be used to carry I/O messages from one I/O column to another and to supply logic power connections for each I/O column. An

Interconnect Assembly at the bottom of each I/O column to be joined must be snapped into an Extender Module. Two Extender Modules are linked by I/O Bus Cables, as shown above.

Required Accessories

End caps, terminal covers and slot covers are used to minimize the exposure of Trident components to dust, liquids and corrosive atmospheres.

End caps protect the top and bottom of each end-of-column baseplate. They are available for both MP baseplates and I/O baseplates.

Slot covers protect unused baseplate slots. Terminal covers protect any terminals on a baseplate that are not connected to field wiring.

Power and Cooling Considerations

Before operating a Trident system, the logic power consumption and cooling requirements should be determined. The heat load dissipated by the system is calculated by adding the logic power and field power for all of the modules, using the table below.

For maximum reliability, the average ambient temperature of a Trident system should be held below 50° C (120° F). Adequate convection or forced-air cooling should be provided. In vented applications, air should flow into vents at the bottom of the enclosure and exit at the top.

I/O Bus Length

If the total length of the I/O bus is less than three meters (10 feet), the I/O bus can be operated without termination.

If the I/O bus length is greater than three meters (10 feet), the bus should be terminated. The maximum I/O bus length is 60 meters (200 feet) and includes:

- Length of all baseplates
- Extender modules
- I/O bus extension cables

Addressing of System Components

Every baseplate in a Trident system is uniquely identified with an address plug. The address plug on the MP baseplate denotes the network node number for communication purposes. In TriStation, the application must be configured to match the address plugs.

Module	Model No.	Maximum Logic Power (Watts)[1]	Maximum Field Power[2]	
			Primary	Spare
Main Processor	3101	8	Not applicable	Not applicable
Digital Input	3301	3	7	Negligible
Digital Output	3401	3	4	Negligible
Analog Input	3351	3	4	Negligible
Relay Output	3451	3	4	Negligible

1.To convert Watts to British thermal units: BTU = Watts x 3.414.

2.Field power is the percentage of field circuit power that is dissipated within the baseplate.

Mechanical Installation

A Trident system is physically set up by installing the following components on a user-supplied sheet-metal panel:

- One Main Processor (MP) baseplate with three MP modules
- Up to 32 baseplates with one or two I/O modules each
- Interconnect Assemblies for connecting baseplates
- I/O bus extenders and cables for connecting I/O columns
- End caps for the top and bottom of each I/O column

Panel Mounting of Baseplates and Modules

The sheet-metal panels on which baseplates are mounted and the DIN rails used for guidance are user-supplied. The panels should be made of 12-gauge or heavier steel and the DIN rails should be compatible with the DIN 50-022 standard.

Before Trident components can be installed, the DIN rails must be attached to the panel by following instructions from the respective manufacturers. The basic steps for installing Trident components are:

- Fastening the baseplates onto the panels
- Joining the baseplates together with interconnect assemblies
- Connecting multiple columns of baseplates with extender modules and I/O bus cables
- Installing the MP and I/O modules onto the baseplates

Typical Enclosures

When all baseplates, modules and connective devices are securely mounted on a panel, the whole system is normally placed in one of these types of user-supplied enclosures:

- A floor-mounted enclosure such as a Rittal cabinet for one I/O column
- A wall-mounted enclosure such as a Hoffman box for two or more I/O columns

Connecting Logic Power and Field Power

The Trident controller offers a very flexible power-handling system. The main options for the required logic power and field power connections entail the use of:

- One set of redundant power supplies for both field and logic power
- One set of redundant power supplies for logic power and another set for field power
- Power supplies in any desired combination—for example, a separate power supply for each I/O column or I/O module

Connecting Field Devices

Terminations for connecting field devices are integral to each baseplate. Normally the wiring for field devices is connected to Trident field terminations after the panel containing the baseplates and modules is placed in an enclosure.

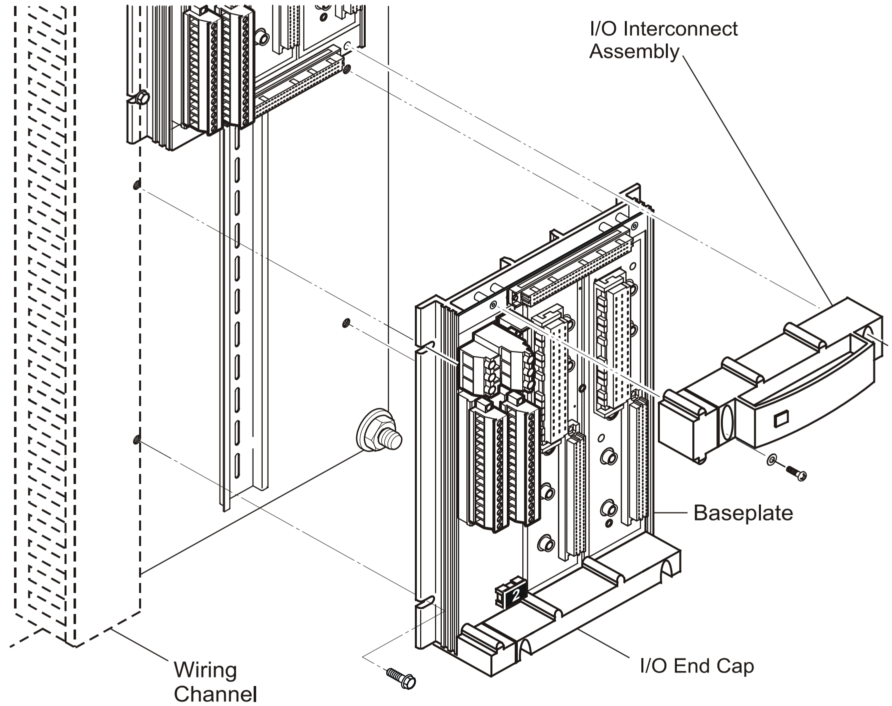
Connecting to a TriStation PC

The Trident controller communicates with the TriStation PC using IEEE 802.3 protocol. The TriStation PC requires the installation of:

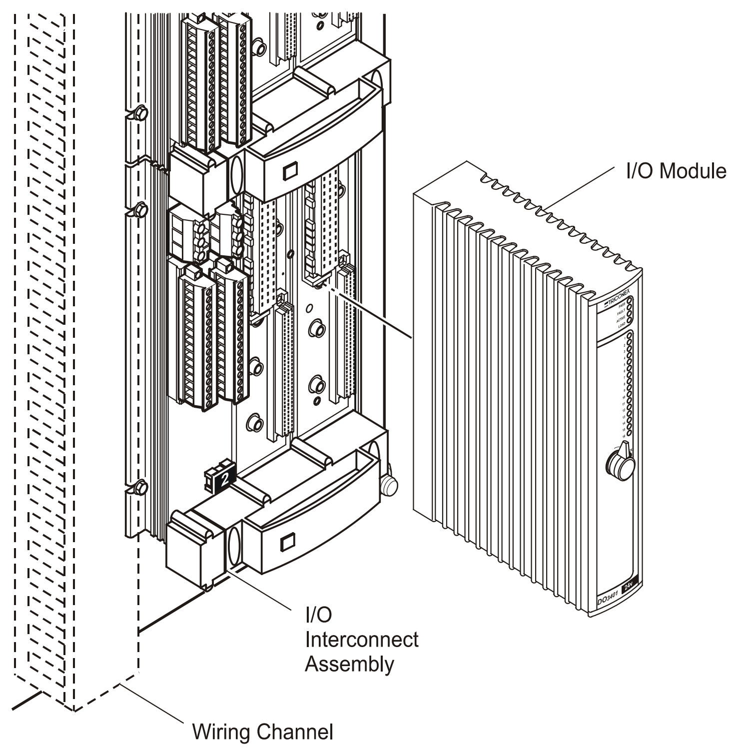
- An IEEE 802.3 (Ethernet) card
- Data Link Control (DLC) protocol

A port on the MP must be connected to the TriStation PC using one of these options:

- A 10BaseT modular cross-over cable
- An IEEE 802.3 (Ethernet) network hub and 10BaseT modular straight cables



Mounting Components on a Sheet-Metal Panel



Placing an I/O Module on a Baseplate

The Trident supports a complete range of modules for applications with low point counts and distributed I/O.

Product Specifications

The Trident supports a complete range of modules for applications with low point counts and distributed I/O. This section provides a summary and specifications for each standard product in the Trident family, and information on:

- International approvals (page 16)
- Environmental specifications (page 17)
- Dimensions and clearances (page 17)

Main Processor Modules and Baseplates

Every Trident system is controlled by three Main Processor (MP) Modules that reside on a single baseplate. Each MP Module acts as one channel of the triplicated Trident system. For features and specifications, see page 18.

Digital Input Modules and Baseplates

The Digital Input (DI) Module has three independent channels which process all data sent to the module. An ASIC on each channel scans each input point, compiles data, and transmits it to the MPs upon demand. The MPs vote on the data before processing it to ensure the highest integrity. For specifications, see page 22.

Digital Output Modules and Baseplates

A Digital Output (DO) Module contains the circuitry for three identical, isolated channels. Each channel includes a proprietary ASIC which receives its output table from the corresponding MP. All DO Modules use the patented Quad Output Voter circuitry to vote on individual output signals just before they are applied to the load. For specifications, see page 23.

Analog Input Modules and Baseplates

The Analog Input (AI) Module has three independent input channels. Each channel receives variable voltage signals from each point, converts them to digital values, and transmits the values to the three MPs on demand. One value is then selected using a mid-value selection algorithm to ensure correct data for every scan. For details, see page 24.

Solid-State Relay Output Modules and Baseplates

The Relay Output (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. For specifications, see page 24.

Extender Modules

Extender Module Kits are used to:

- Carry I/O messages from one I/O column to another
- Provide logic power terminals for each I/O column

For details, see page 25.

Interconnect Assemblies

Trident baseplates within a single I/O column are connected by Interconnect Assemblies that carry I/O messages and logic power across the baseplates. For details, see page 26.

Required Accessories

The following accessories are required to protect Trident components from dust, liquids and corrosive atmospheres:

- End caps
- Terminal covers

Slot covers. For details, see page 26.

Components for the Trident system are offered in convenient TriPaks and kits, but are also available as individual parts. For details, see “Standard Products of the Trident Family” on page 14.

Product Specifications

Standard Products of the Trident Family

Model	Product Name	Qty	Description	Consists of
5101	Main Processor TriPak	3	Main Processor Module	3101
		1	Main Processor I Baseplate Kit	2101
5301	Digital Input TriPak	1	Digital Input Module	3301
		1	Digital Input Baseplate Kit	2301
5351	Analog Input TriPak	1	Analog Input Module	3351
		1	Analog Input Baseplate Kit	2351
5401	Digital Output TriPak	1	Digital Output Module	3401
		1	Digital Output Baseplate Kit	2401
5451	Relay Output TriPak	1	Relay Output Module	3451
		1	Relay Output Baseplate Kit	2451
2281	I/O Bus Extender Module Kit	2	Extender Module	3000678-100
		3	2-ft. I/O Bus Cables (Set of 3)	4000056-002
		1	I/O Interconnect Assembly	2921
		1	Top End Cap – I/O	2910
		1	Bottom End Cap – I/O	2911
2291	I/O Bus Termination Kit, I/O Baseplate	1	Extender Module	3000678-100
		1	I/O Interconnect Assembly	2921
		1	I/O Bus Terminator Kit	3900064-003
2292	I/O Bus Termination Kit, MP Baseplate	1	Extender Module	3000678-100
		1	MP Interconnect Assembly	2920
		1	I/O Bus Terminator Kit	3900064-003
2101	Main Processor I Baseplate Kit	1	MP Baseplate	3000671-100
		1	MP Interconnect Assembly	2920
		1	10BaseT Crossover Communication Cable	1600044-020
		1	Trident User Docs (hardcopy)	8901
		1	Triconex Documentation Set (CD)	8823
		1	Accessories Kit	8401
		1	Top End Cap – I/O	2910
		1	Top End Cap – MP	2912
		1	Bottom End Cap – I/O	2911
		1	Bottom End Cap – MP	2913
2301	Digital Input Baseplate Kit	1	I/O Baseplate	3000673-020
		1	I/O Interconnect Assembly	2921
		1	Slot Cover	2900
		1	Terminal Cover	2901
2351	Analog Input Baseplate Kit	1	I/O Baseplate	3000675-010
		1	I/O Interconnect Assembly	2921
		1	Slot Cover	2900
		1	Terminal Cover	2901

Model	Product Name	Qty	Description	Consists of
2401	Digital Output Baseplate Kit	1	I/O Baseplate	3000674-030
		1	I/O Interconnect Assembly	2921
		1	Slot Cover	2900
		1	Terminal Cover	2901
2451	Relay Output Baseplate Kit	1	I/O Baseplate	3000676-310
		1	I/O Interconnect Assembly	2921
		1	Slot Cover	2900
		1	Terminal Cover	2901
7243	TriStation 1131 Developer's Workbench V3.0	1	CD-ROM containing:	
			• Developer's Workbench	
			• TriStation 1131 User Docs (online)	
		1	TriStation 1131 V3 User Docs Set (hardcopy)	
7223	CEMPLE V3.0	1	CD-ROM containing:	
			• Developer's Workbench with CEMPLE	
			• *CEMPLE User's Guide* (online)	
		1	*CEMPLE User's Guide* (hardcopy)	
			Note: TriStation 1131 is required to run CEMPLE	
8401	Trident Accessory Kit	1	Set of Spare Fuses	
		1	Set of Address Plugs (1 through 10)	3000698-010
8901	Trident User Documentation (hardcopy)	1	*Trident Planning & Installation Guide*	
8744	TriStation 1131 V3 User Documentation (hardcopy)	1	*Getting Started for Trident Users*	
		1	*Developer's Guide for Trident Systems*	
		1	*Triconex Libraries*	
		1	*Safety Considerations Guide*	
8745	CEMPLE V3 User Documentation (hardcopy)	1	*CEMPLE User's Guide*	
8823	Triconex Documentation Set	1	CD-ROM containing:	
			• TriStation 1131 V3.0 User Documentation	
			• TriStation 1131 V2.0 User Documentation	
			• CEMPLE V3.0 and V2.0 User Documentation	
			• *Trident Technical Product Guide*	
			• *Trident Planning & Installation Guide*	
			• *Safety Considerations Guide*	
			• Tricon V9.4 User Documentation	
n/a	I/O Bus Terminator Kit	1	Set of 3 Terminators	3900064-003
n/a	Modbus Communication Cable	1	Provides an IBM 9-pin connector and 25-pin connector.	4000016-015
n/a	Modbus Communication Cable—Custom Length	1	Provides an IBM 9-pin connector and 25-pin connector.	4000016-0xx
			Custom length in 5-ft. increments, up to a maximum of 50 ft. Last 2 digits (0xx) of model number are replaced with the required length.	
n/a	I/O Bus Cable, Custom Length	1	Set of 3 cables is required to extend an I/O bus.	4000056-xxx
			Custom length in 5-ft. increments, up to a maximum of 200 ft. Last 3 digits (xxx) of model number are replaced with the required length (followed by zeros if less than 100 ft.).	

Product Specifications

International Approvals

The certifying agencies listed on this page evaluate the Trident controller at regular intervals to ensure that it meets their standards and requirements.

Canadian Standards Association

CSA/NRTL/C certification verifies the Trident's safety when it is:

- Attached to a power distribution system (primary line)
- Operating within specific temperature ranges

CSA certifies that the Trident does not constitute a fire hazard, and operator and maintenance personnel are protected from electric shock when touching or replacing modules.

European Union CE Mark

The CE Mark ensures the electromagnetic compatibility (EMC) of the system with other electrical/electronic equipment. When properly installed, the system is certified to fulfill the requirements of the *European Union EMC Directive No. 89/336/EEC* as defined by the document listed in the table below.

To ensure maximum reliability and trouble-free operation, all field wiring should be installed in accordance with *IEEE Standard 518-1982, IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources,* with particular attention given to all low-level analog signals, such as thermocouple or RTD inputs.

TÜV Rheinland

TÜV certification ensures the suitability of Trident controllers for use in safety-critical applications requiring maximum safety and uninterrupted operation, according to applicable DIN and IEC standards. TÜV certifies that the Trident controller meets the requirements for SIL 3 and AK Class 6 applications. See the international standards listed below.

Factory Mutual

Factory Mutual has approved the Trident for use in Class I, Division 2 Temperature T4, Groups A, B, C, and D hazardous indoor locations in compliance with the standards listed below.

Certifying Agency	Standard Number	Title
Canadian Standards Association	C22.2 No. 0-M982	General Requirements—Canadian Electrical Code, Part II
	C22.2 No. 142-M1987	Process Control Equipment
European Union CE Mark	IEC 61131-2	Programmable Controllers Part 2: Equipment Requirements and Test. Overvoltage Category II is assumed.
Factory Mutual	3611	Electrical Equipment for use in Class I—Division 2; Class II—Division 2; and Class III—Divisions 1 and 2, Hazardous Locations
	3810	Electrical & Electronic Test, Measuring & Process Control Equipment
	3600	Electrical Equipment for Use in Hazardous (Classified) Locations—General Requirements
TÜV Rheinland	DIN VDE 0116	Electrical Equipment of Furnaces
	DIN V VDE 0801	Principles for Computers in Safety-Related Systems
	DIN V 19250	Control Technology: Fundamental Safety Aspects to Be Considered for Measurement and Control Protective Equipment
	EN 54	Components of Automatic Fire Detection Systems: Control and Indicating Equipment
	IEC 61508, Parts 1-7	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
	IEC 61131-2	Functional operation, electrical safety, and EMC compatibility are certified according to: IEC 61131-2:1995, Programmable Controllers Part 2: Equipment Requirements and Test. Overvoltage Category II is assumed.

Environmental Specifications

Designed for critical applications, the Trident performs predictably in a hostile industrial environment. The specifications that follow confirm this built-in reliability. However, due to the number of diverse items that make up a Trident system, not all of the listed specifications apply to every item. Please contact Triconex to obtain the specifications for particular items.

Feature	Specification
Operating temperature for MPs[1]	0° to 60°C (32° to 139°F), ambient, per IEC 60068-2-14, tests Na and Nb
Operating temperature for I/O modules[1]	–20° to 70°C (–4° to 159°F), per IEC 60068-2-14, tests Na and Nb
Storage temperature	–40°C to 85°C (–40°F to 185°F) per IEC 60068-2-2, test Bb, IEC 60068-2-1, test Ab, and IEC 60068-2-30, test Db
Relative humidity	10% to 95%, non-condensing
Sinusoidal vibrations per axis	1 G @ 10 to 150 Hz, per IEC 60068-2-6, test Fc
Shock	15 G for 11 milliseconds, half sine, in each axis, per IEC 60068-2-27, test Ea
Electrostatic discharge	IEC 61000-4-2, Level 3, 8 KV
Conducted susceptibility	IEC 61000-4-4, Class 3, Fast Transient/burst IEC 61000-4-5, Level 3, Surge Withstand IEC 61000-4-6, Level B, RFI IEC 61000-4-12, Level B, Damped Oscillation Wave
Radiated susceptibility	IEC 61000-4-3, Level 3, RFI, AM & PM IEC 61000-4-8, Level B, Magnetic Field
Radiated emissions[2]	CISPR 11, Class A

1. Ambient temperature is measured at the bottom of each baseplate.
2. The Trident system must be mounted in a metal enclosure for European CE Mark compliance.

Dimensions and Clearances

The dimensions given in this section are predicated on the vertical mounting of Trident baseplates on a panel:

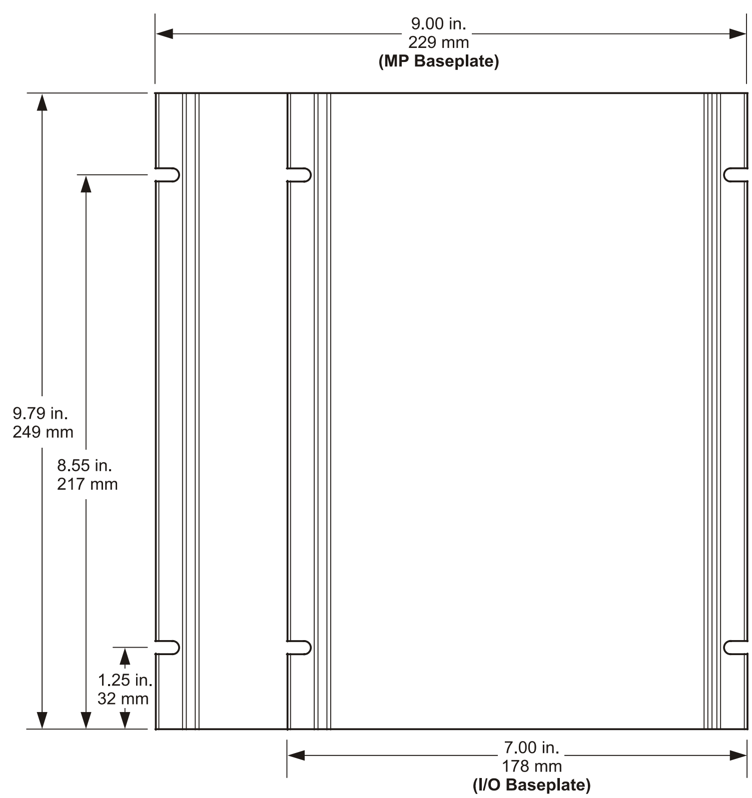
- The MP baseplate is 9 inches wide by 9.79 inches long
- I/O baseplates for all type of I/O modules are 7.0 inches wide by 9.79 inches long

All modules for Trident baseplates have the same dimensions:

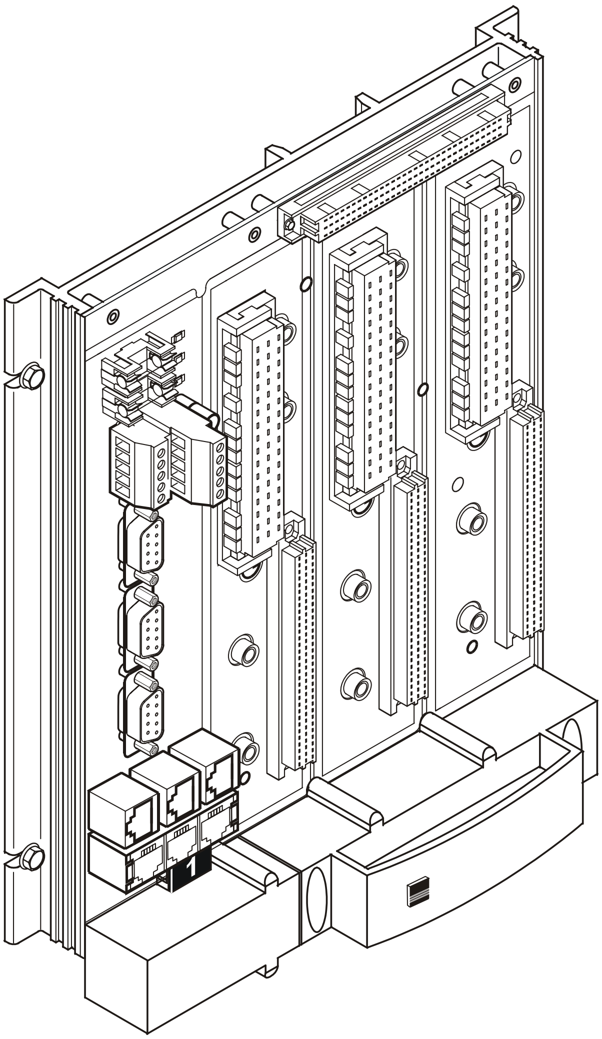
- Height = 8.65 inches (220 mm)
- Width = 1.75 inches (44 mm)
- Depth = 6.65 inches (169 mm)

Clearance should always allow adequate air flow around Trident modules. For typical applications, there should be at least 5 inches (15 cm) of clearance between active modules and the walls of the enclosure.

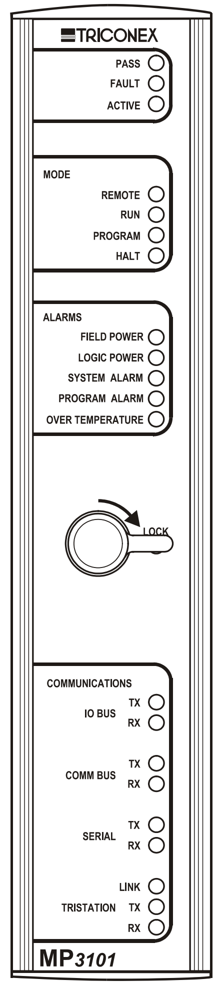
The DIN rails and baseplate assemblies should be arranged on the panel to allow for the installation of wiring channels (such as Panduit) along the left side of vertical columns and along the bottom of horizontal rails.



Product Specifications



MP Baseplate



MP Front Panel

Main Processor Module

Every Trident system is controlled by three Main Processor (MP) Modules that reside on a single baseplate. Each MP Module acts as one channel of the triplicated Trident system and provides the following main features:

- An RS-232/485 Modbus port for direct TMR connection to a DCS (or other external host) without the need for any other modules
- A 10BaseT Ethernet (IEEE 802.3) port for connection to the TriStation 1131 programming workstation
- Five types of alarms and four types of status indicators (described on page 18 and page 19)
- The security of programmatic mode control, including control of write access to Trident variables by the DCS (or other external host)
- A lock lever that gives feedback about the proper seating of the module on the baseplate

Alarm Features

The Trident's fault-monitoring circuitry is able to detect and alarm all single faults and most multiple faults. The following types of alarms are reported by separate indicators on the front panel of each MP:

- The field power alarm reports loss of field power or field shorts and opens
- The logic power alarm reports a missing or faulty system power supply

- Redundant system alarm contacts report problems with the application program or system integrity
- A user-programmable alarm reports any problem that is defined by the user-written application
- An over-temperature alarm reports the actual temperature in degrees C to the TriStation user

Status Indicators

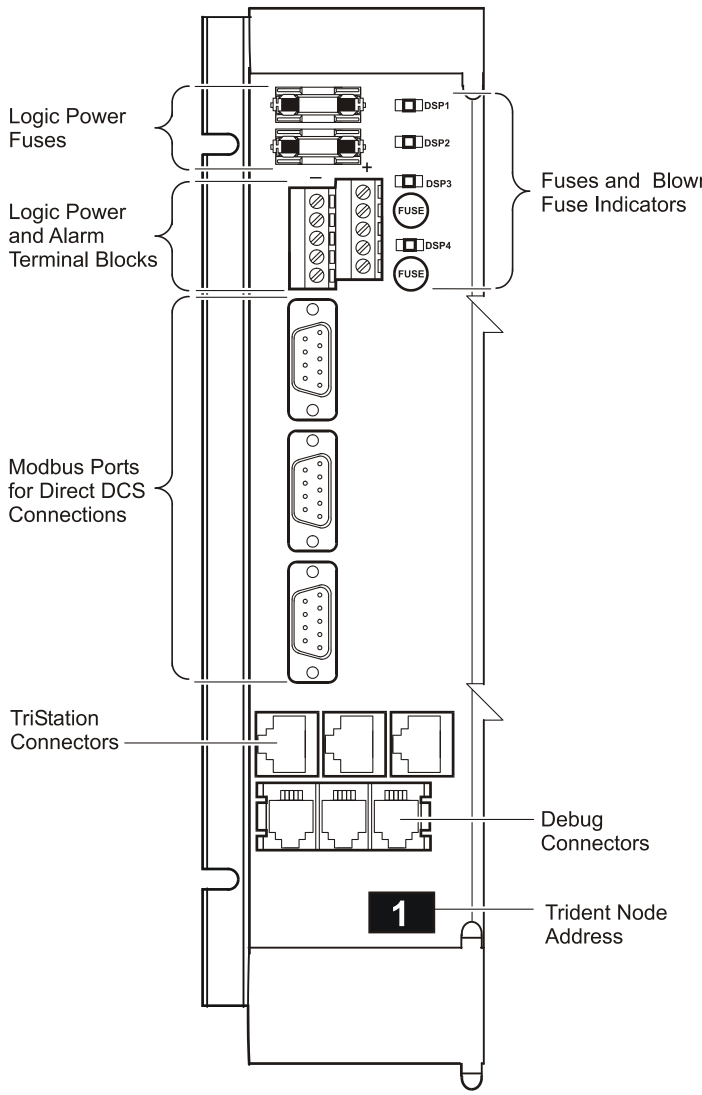
To signal normal or fault conditions for the Trident system, the front panel of each MP provides a complete set of indicators:

- Pass, Fault and Active indicate the health status of the MP module
- Remote, Run, Program and Halt report the operational mode of the system, adding a layer of safety to the programmatic mode control exercised by the TriStation user
- Five types of alarm indicators report various kinds of system faults and conditions (described in "Alarm Features" on page 18)
- RX and TX communication indicators report the transmit and receive status of the I/O bus, Comm bus, serial (Modbus) port and TriStation port

Physical Description

Each MP provides 16-megabytes of DRAM for the user-written application program, sequence-of-events (SOE) and I/O data, diagnostics, and communication buffers.

The three MPs compare their respective data during every scan using the TriBus, a high-speed, fault-tolerant inter-processor bus. The MPs communicate with the I/O modules over a TMR HDLC I/O bus that operates at 2 Mbaud.



Connectors on the MP Baseplate

In addition to the TriStation and Modbus ports and alarm connectors, the MP baseplate provides redundant, 24V fused logic power connectors. Logic power supplied here can operate the MPs and carry to the I/O baseplates as well, so that no other logic power supplies are needed for the system.

Product Specifications

Common Features for I/O Modules and Baseplates

The Digital Input (DI) Module and Baseplate shown below serve as examples for all types of Trident I/O Modules and Baseplates, whose appearance is very similar. The pages that follow provide detailed specifications for I/O modules that also apply to the baseplates.

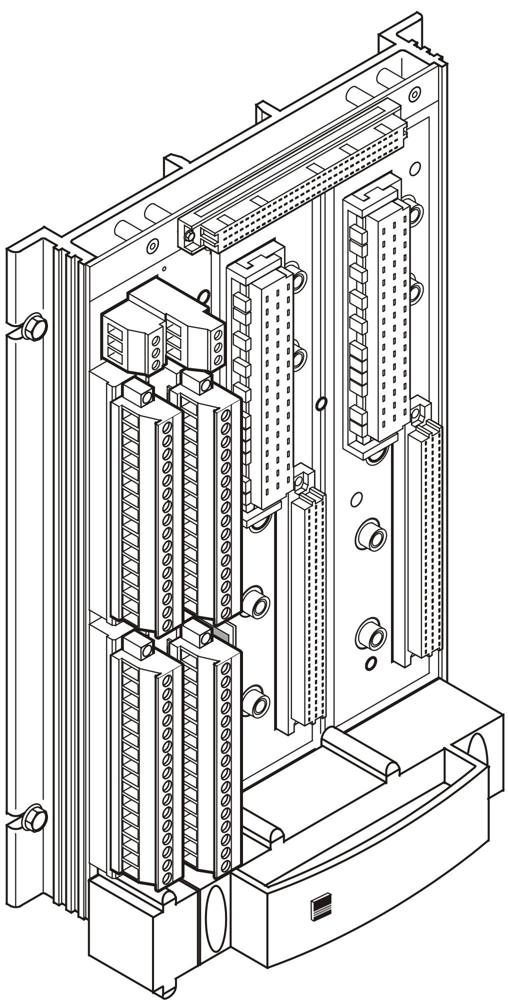
Each I/O module occupies one of two slots on the baseplate that constitute an I/O set. The left module occupies the slot below the “L” label on the baseplate and the right module occupies the slot below the “R” label. At any time, the status of either the left or right module can be active or hot spare (for online replacement or backup).

All types of I/O modules support hot sparing for online replacement of a faulty module or continuous back-up to an active module. Each module is mechanically keyed to prevent improper installation in a configured baseplate.

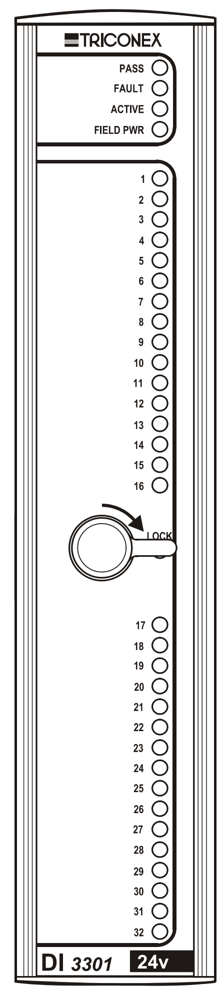
Each I/O Baseplate includes one I/O Interconnect Assembly, one Slot Cover, and one Terminal Cover.

For all types of I/O Baseplates, the wiring for field devices is connected directly to terminals on the baseplate. These are compression terminals that are compatible with 24 to 12 (0.2 mm^2 to 3.3 mm^2) AWG wiring.

The maximum operating temperature for all types of I/O modules is 70° C ambient.



DI Baseplate



DI Front Panel

Common Specifications for All I/O Modules

Logic Power

Feature	Specification
Nominal input voltage	+ 24 VDC
Voltage range	+ 24 VDC – 15% / + 20% + 5% AC ripple (+ 19.2 / +30 VDC)
Logic power	< 3 Watts
Absolute maximum input voltage	+ 36 VDC
Absolute maximum reverse input voltage	– 0.6 VDC
Input power interruption time from nominal	1 millisecond maximum
Power interruption interval	1 second minimum
Reverse current isolation input to input	500 µAmps maximum
Inrush current per input	2.4 Amps maximum
Short circuit current limit per input	2.4 Amps maximum
Functional earth to logic ground isolation	0 Volts, no isolation
Protective earth to functional earth isolation	500 VDC, minimum

Field Power

Feature	Specification
Nominal field voltage	+ 24 VDC
Specified operational voltage range	+ 24 VDC – 15% /+ 20% + 5% AC ripple (+ 19.2 /+ 30 VDC)
Power	See module specifications
Absolute maximum input voltage	+ 36 VDC
Absolute maximum reverse input voltage	– 0.6 VDC
Input power interruption time from nominal	Not applicable
Power interruption interval	Not applicable
Reverse current isolation	500 µAmps maximum
Functional earth to protective earth isolation	500 VDC, minimum
Functional earth to functional earth (logic ground) isolation	800 VDC, minimum

Digital Input Module

The Digital Input (DI) Module has three independent channels which process all data sent to the module. An ASIC on each channel scans each input point, compiles data, and transmits it to the MPs on demand. The MPs vote on the date before processing it to ensure the highest integrity.

DI modules sustain complete, ongoing diagnostics for each channel. If the diagnostics detect a failure on any channel, the module's FAULT indicator is activated, which in turn activates the system alarm. The FAULT indicator points to a channel fault, *not* a complete module failure. The DI Module is guaranteed to operate properly in the presence of a single fault and may continue to operate properly with certain multiple faults.

The DI Module continuously verifies the ability of the system to detect transitions to the opposite state.

Model 3301 — Digital Input Module Specifications

Feature	Specification
Points	32, commoned
Nominal input voltage	+ 24 VDC
Specified operational voltage range	0 – + 30 VDC
Absolute maximum input voltage	+ 36 VDC
Absolute maximum reverse input voltage	– 0.6 VDC
Input delay	< 10 milliseconds, ON to OFF or OFF to ON TC = 6.4 milliseconds, – 3dB @ 25Hz
Input impedance	> 30 K, without baseplate ≈ 3 K, with baseplate
Input power	0.2 Watts/point, @ 24 VDC 0.5 Watts/point, @ 36 VDC
Input threshold	0–5 VDC = OFF region 6–14 VDC = transition region 15–30 VDC = ON region
Diagnostic (loss of view)	Force-to-value diagnostic (FVD), < 2 milliseconds/test
Maximum input toggle rate to maintain diagnostic fault coverage	< 20/second
FVD OFF state glitch	
Duration	< 2 milliseconds
Magnitude	≈ 36% V test voltage
Output Impedance	0–5 VDC, ≈ 100 k Ohms
ADC scan time	< 1 millisecond for all 32 points
Functional earth to protective earth isolation	500 VDC, minimum
Functional earth to functional earth (logic ground) isolation	800 VDC, minimum

Digital Output Module

A Digital Output (DO) Module contains the circuitry for three identical, isolated channels. Each channel includes a proprietary ASIC which receives its output table from the corresponding MP. All DO Modules use the patented Quad Output Voter circuitry to vote on 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 switches (channels A and B, or channels B and C, or channels A and C) command them to close. The Quad Output Voter circuitry has multiple redundancy on all critical signal paths, guaranteeing safety and maximum availability.

For each point, a DO Module periodically executes the Output Voter Diagnostic (OVD) routine. To allow unrestricted safe operation under various multiple-fault scenarios, OVD detects and alarms these types of faults:

- All stuck-on and stuck-off points are detected in less than 500 msec
- Switches—all stuck-on or stuck-off switches or their associated drive circuitry are detected

For more information about OVD, see “Digital Output Module” on page 6.

Model 3401 — Digital Output Module Specifications

Feature	Specification
Points	16, commoned
Nominal output voltage	+ 24 VDC
Specified operational voltage range	+ 15 – + 30 VDC
Absolute maximum output voltage	+ 36 VDC
Absolute maximum reverse input voltage	– 0.6 VDC
Output current	
Switching	< 4.8 Amps, self-limiting 3.0 Amps, typical
Carry	> 0.7 Amps, self-limiting 1.5 Amps, typical
Field alarms	Loss of field power, output point shorted ON or OFF
Loop-back thresholds	0–5 VDC = OFF region 6–14 VDC = transition region 15–30 VDC = ON region
Leakage to load (OFF state)	< 1 milliAmps
Diagnostic glitch duration	< 2 milliseconds, maximum 500 µseconds, typical
Diagnostic fault coverage	
Maximum toggle rate	> 20 milliseconds
Minimum toggle rate	Not applicable
ON state voltage drop	< 1.0 VDC @ 1.5 Amps
Loop-back scan time	< 1.0 millisecond for all 16 points
Functional earth to protective earth isolation	500 VDC, minimum
Functional earth to functional earth (logic) isolation	800 VDC, minimum

Product Specifications

Solid-State Relay Output Module

The Solid-State Relay Output (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. The SRO Module receives output signals from the MPs on each of three channels. The three sets of signals are then 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.

Model 3451 — Solid-State Relay Output Module Specifications

Feature	Specification
Points	32, commoned in pairs
Nominal input voltage	+ 24 VDC
Specified operational voltage range	0 – + 30 VDC
Maximum switching voltage	36 VAC/VDC
Maximum switching power	15 Watts resistive
Maximum off-state leakage	< 1 μAmp
Maximum nominal current	0.5 Amp per channel
Maximum over current	0.7 Amp per channel
Voltage drop @ baseplate	< 0.25 VDC @ 0.5 Amp
Fuses, mounted on baseplate	1 per output, 0.75 Amp, fast-acting
Functional earth to protective earth isolation	500 VDC, minimum
Functional earth to functional earth (logic) isolation	800 VDC, minimum

Analog Input Module

The Analog Input (AI) Module has three independent input channels. Each channel receives variable voltage signals from each point, converts them to digital values, and transmits the values to the three MPs on demand. One value is then selected using a mid-value selection algorithm to ensure correct data for every scan. Sensing of each input point prevents a single failure on one channel from affecting another channel.

The AI Module sustains complete, ongoing diagnostics for each channel. If the diagnostics detect a failure on any channel, the module's Fault indicator turns on and activates the system alarm. The Fault indicator points to a channel fault, *not* a complete module failure. The module is guaranteed to operate properly in the presence of a single fault and may continue to operate properly with multiple faults.

Model 3351 — Analog Input Module Specifications

Feature	Specification
Points	32, commoned
Nominal input current	4–20 milliAmps DC
Specified operational current range	2–22 milliAmps DC
Absolute maximum field voltage	+ 33 VDC
Absolute maximum reverse field voltage	– 0.6 VDC
Absolute maximum input current	50 milliAmps DC
Input bandwidth (3dB)	16 Hz
Source impedance	180 Ohms
Input impedance (with baseplate)	250 Ohms
I to V resistor	100 Ohms, 0.01%
Resolution	12 bits
Absolute error	0.15% of full scale (20 milliAmps)
Diagnostic	Force-to-value diagnostic (FVD)
Scan time	< 1 millisecond for all 32 points
Functional earth to protective earth isolation	500 VDC, minimum
Functional earth to functional earth (logic) isolation	800 VDC, minimum

Extender Module Kits

Extender Module Kits are used to:

- Carry I/O messages from one I/O column to another
- Provide logic power terminals for each I/O column

The Trident user must connect 24V logic power sources to every I/O column, unless the column includes an MP Baseplate connected to its own logic power sources.

Each Extender Module Kit provides:

- Two Extender Modules
- Three two-foot I/O Bus Cables
- One I/O or MP Interconnect Assembly

The main components on an Extender Module are:

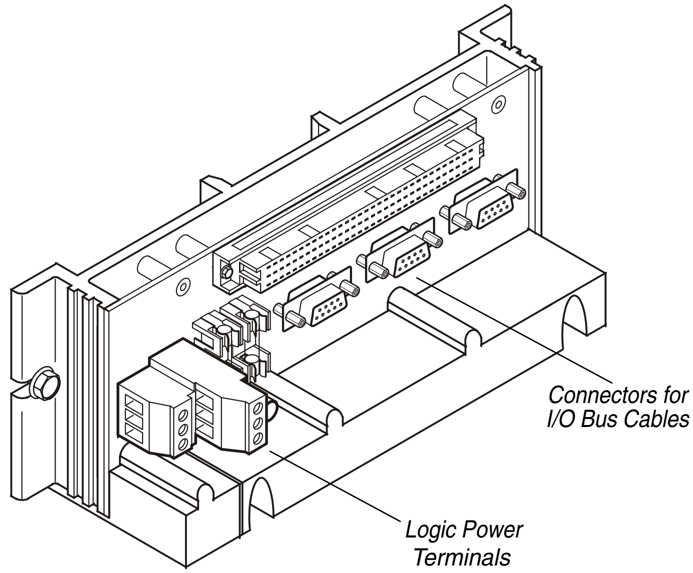
- Two 24V logic power input terminal blocks, each with fuse and blown-fuse indicators
- A protective earth (safety ground) terminal
- Three DB-9-pin I/O bus connectors, one per channel

In a typical Trident system, a maximum of eight baseplates may be connected end-to-end in an I/O column. To extend a system beyond eight baseplates or to distribute the baseplates into multiple I/O columns, Extender Modules and I/O Bus Cables are used, as shown at right.

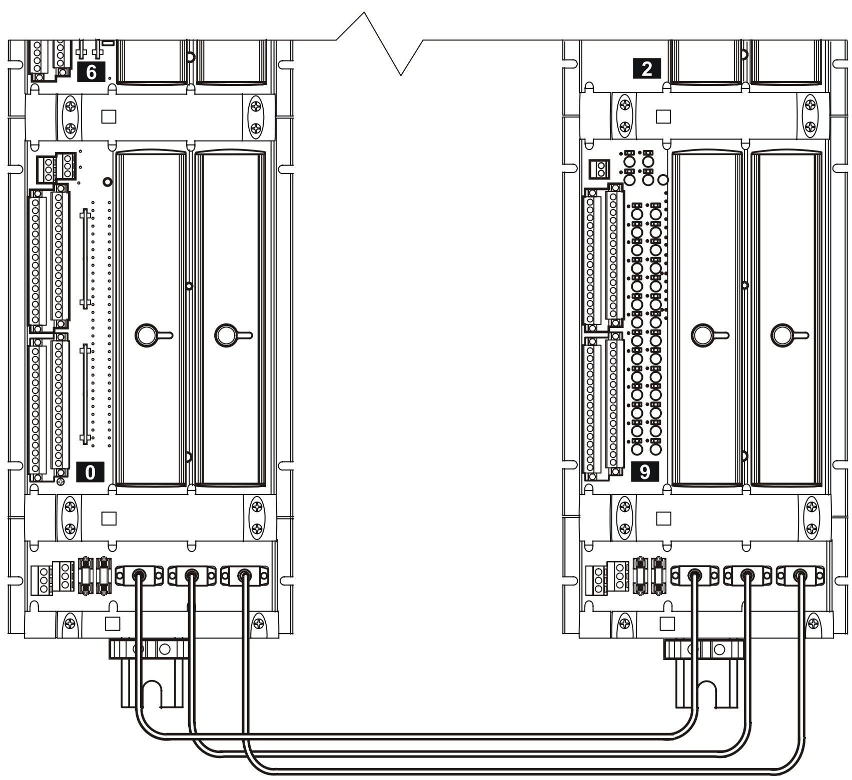
I/O Bus Cables

An I/O bus cable is required for each TMR channel and is terminated at each end by a male 9-pin D connector. Various cable lengths are available.

If the I/O bus is longer than 3 meters (10 feet), the bus should be terminated by adding an I/O Bus Terminator Kit to both open ends of the system. The maximum allowable I/O bus length is 60 meters (200 feet).

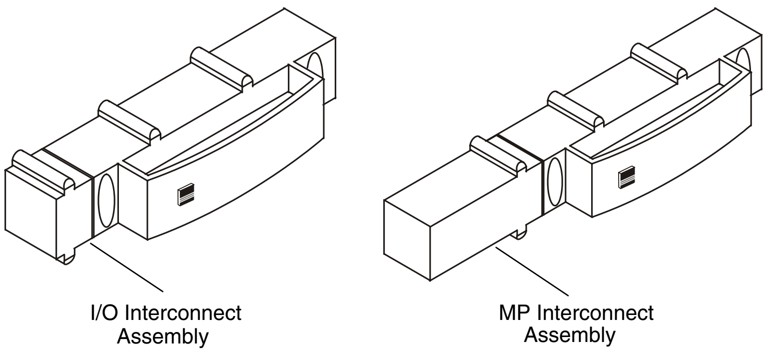


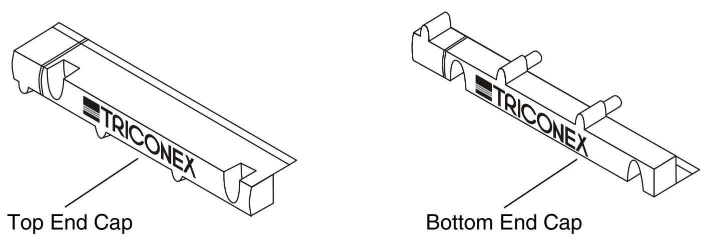
Extender Module



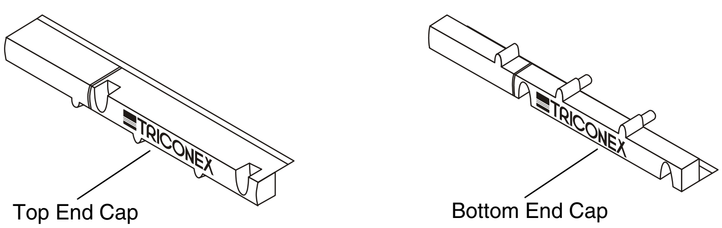
Two Extender Modules Linked by I/O Bus Cables

Product Specifications

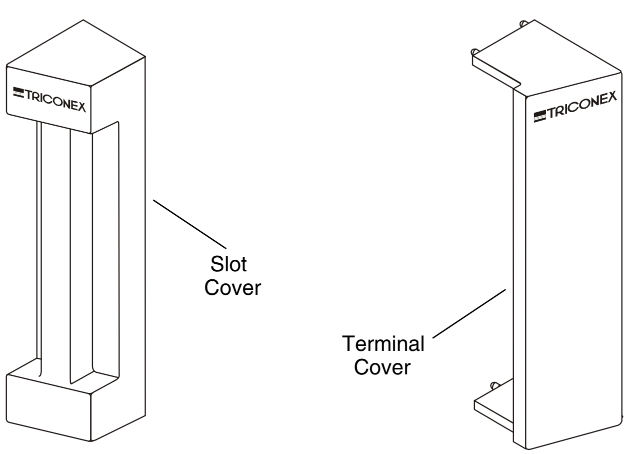




End Caps for I/O Baseplate/Extender Module



End Caps for MP Baseplate



Interconnect Assemblies

Trident baseplates within a single I/O column are connected by Interconnect Assemblies that carry I/O messages and logic power across the baseplates. The MP Interconnect is connected to an I/O baseplate, and the I/O Interconnects are connected to other I/O baseplates.

MP Interconnect Assembly

Physically, an MP Interconnect Assembly consists of a small passive PCB in a molded plastic housing with two DIN-C 96-pin male connectors. The assembly is attached to the top or bottom of an MP baseplate in order to connect adjacent I/O baseplates.

I/O Interconnect Assembly

Physically, an I/O Interconnect Assembly consists of a small passive PCB in a molded plastic housing with two DIN-C 96-pin male connectors. The assembly is attached to the top or bottom of an I/O baseplate in order to connect other I/O baseplates.

Required Accessories

The following accessories are required to protect Trident components from dust, liquids and corrosive atmospheres:

- End caps
- Terminal covers
- Slot covers

End caps protect the top and bottom of each end-of-column baseplate and serve as a card guide. They are available for both MP baseplates and I/O baseplates.

Terminal covers protect any terminals on a baseplate that are not connected to field wiring.

Slot covers protect unused baseplate slots.

TMR ports on the Trident's Main Processor Baseplate support the industry-standard Modbus protocol over a serial link.

Communication Capabilities

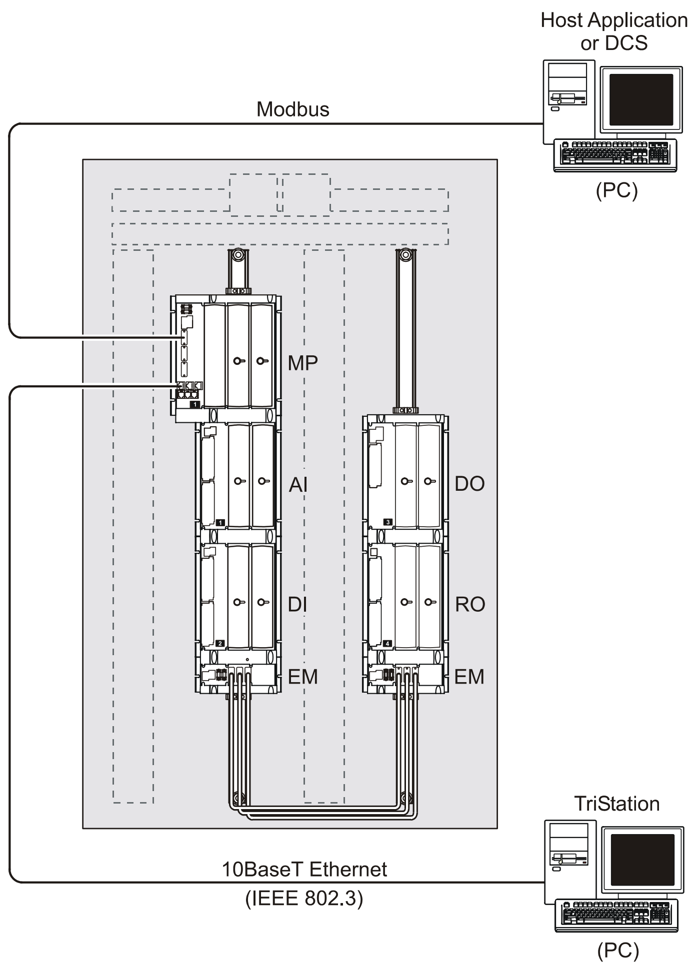
In most process-control applications, two systems monitor and manage the process. One is a Distributed Control System (DCS) and the other is a safety system such as the Trident controller. These two systems are usually isolated, but share a common operator interface. DCS are designed to allow highly effective communication with the process operator, who must be aware of the state of the process at all times. This is desirable for safety systems as well, but was not feasible in the past because of the type of technology used to implement these systems.

Today's state-of-the-art, microprocessor-based Trident controller supports Modbus and Ethernet protocols. Depending on application requirements, the Trident can interface with:

- Any Modbus master, including DCS from Foxboro, Honeywell, ABB, Bailey, Fisher-Rosemount and Yokogawa
- A TriStation programming workstation over 10BaseT Ethernet protocol

Networking with Modbus

In a Modbus network, the Trident acts as a slave while a computer on the network is the master—this can be a DCS, an operator workstation, or any general-purpose computer that supports Modbus protocol. The master can access global variable data in the Trident using the Modbus alias convention, if the Trident user grants access programmatically.



Communication with Modbus Master and TriStation

TMR ports on the Trident's Main Processor Baseplate support the industry-standard Modbus RTU and ASCII interfaces over a serial link. The Trident slave can use RS-232 or RS-422 for a point-to-point interface with the Modbus master. An RS-422 interface uses two twisted-pair wires up to a maximum of 1,200 meters (4,000 feet).

The Trident slave communicates at baud rates up to 115KB.

While the Modbus interface is appropriate for many applications, future releases of the Trident system will offer other communication methods for faster response time or a larger amount of data throughput.

Easy-to-use developer's workbench allow users to develop, test and document process-control applications for the Tricon.

TriStation 1131 Developer's Workbench

The TriStation 1131 Developer's Workbench is an integrated tool for developing, testing and documenting safety and critical-process control applications for the Trident programmable logic controller. The programming methodology, user interface and self-documentation capabilities make the system superior to traditional and competing engineering tools.

TriStation is compliant with Part 3 of the IEC 1131 International Standard for Programmable Controllers with defines programming languages.

The TriStation software runs under Microsoft's Windows NT operating system and follows the Microsoft Windows graphical user interface guidelines. Any PC that is compatible with the NT operating system can be used for TriStation.

The pages that follow describe key TriStation features and the basic elements of TriStation projects.

Functional Overview

TriStation provides three editors to support the following IEC 1131-3 languages:

- Function Block Diagram
- Ladder Diagram
- Structured Text

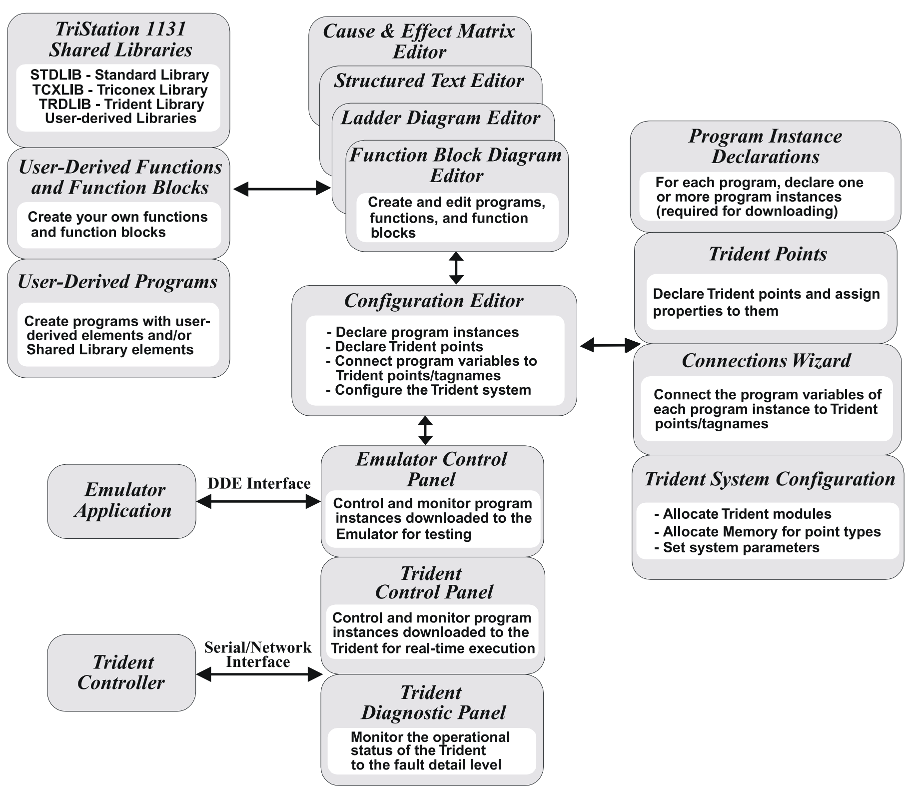
The Workbench also provides the Cause & Effect Matrix Programming Language Editor (CEMPLE) that Triconex developed to support the widely used Cause & Effect Matrix (CEM) methodology. Throughout the process control industry, CEMs are often used to define alarms, emergency shutdown, and mitigation actions.

To support the Trident controller, TriStation supplies the following editors and tools:

- Trident Configuration Editor
- Emulator Control Panel
- Trident Control Panel
- Trident Diagnostic Panel

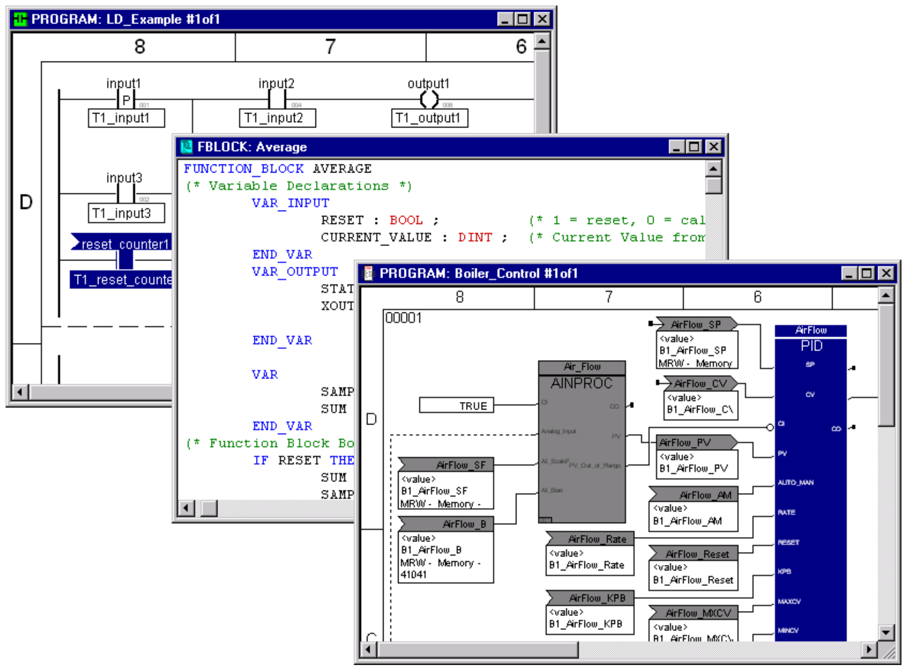
Using these editors and tools, the user can:

- Create programs, function blocks and functions
- Define the I/O module configuration
- Declare tagnames for input/output points
- Declare program instances
- Connect program instance inputs & outputs to tagnames



Overview of TriStation 1131 Components

- Test and monitor program execution with the emulator
- Download and monitor program execution in the Trident
- Monitor the Trident system status and diagnose faults



Sample Logic in FBD, ST and LD Languages

Elements of a TriStation Project

A TriStation project contains all the elements required to implement a safety or control application in a Trident controller. Some of these elements are automatically included in every project by TriStation, while others are created by the user.

Programs

A program is the highest-level executable logic element within a TriStation project. It is an assembly of programming language elements (function blocks, functions, data variables) that work together to allow a programmable control system to achieve control of a machine or process. Each program is uniquely identified by a user-defined type name. One TriStation project supports multiple programs.

Function Blocks

A function block is a logic element which yields one or more results and is uniquely identified by a user-defined type name. To use a function block in a program, an instance of the function block type must first be declared. Each instance is identified by a user-defined instance name. All the data associated with a specific instance of a function block is retained from one evaluation of the function block to the next.

Functions

A function is a logic element which yields exactly one result and is uniquely identified by a user-defined type name. Unlike the function block, the data associated with a function is not retained from one evaluation of the function to the next. Functions do not have to be instanced.

Data Types

A data type defines the size and characteristics of variables declared in a program, function or function block. Examples of data types are BOOL, DINT and REAL.

Shared Libraries

Shared libraries contain predefined function blocks and functions that can be used to develop programs as well as other function blocks and functions. TriStation provides three shared libraries to every project:

- IEC 1131-3 Standard Library – the standard set of function blocks and functions defined by the IEC 1131-3 Standard
- Triconex Library – a set of Triconex function blocks and function that can be used with any Triconex programmable controller
- Trident Library – A set of function blocks and functions that are specifically implemented for use with the Trident controller

Users may also develop their own shared libraries and import them to other TriStation projects.

Configuration

The configuration defines which program elements will be instanced for downloading to the controller as well as which Trident points (tagnames) each instance will access.

Programming Languages

Function Block Diagram (FBD)

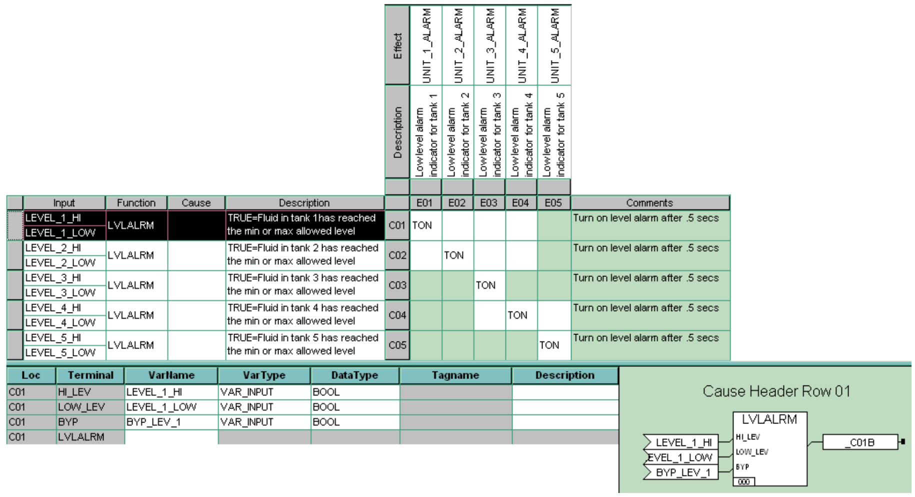
A graphical language that corresponds to circuit diagrams. FBD elements appear as blocks that are wired together, to form circuits. The wires transfer binary and other types of data between elements.

Structured Text (ST)

A high-level, textual programming language, that is similar to PASCAL. ST allows users to create Boolean and arithmetic expressions, as well as programming structures such as conditional (IF…THEN…ELSE) statements. Functions and function blocks may be invoked in ST.

Ladder Diagram (LD)

A graphical language that uses a standard set of symbols for representing relay logic. The basic elements are coils and contacts, which are connected by links. Links are different from the wires in FBD in that they transfer only binary data between the elements.



Sample CEM from a TriStation Project

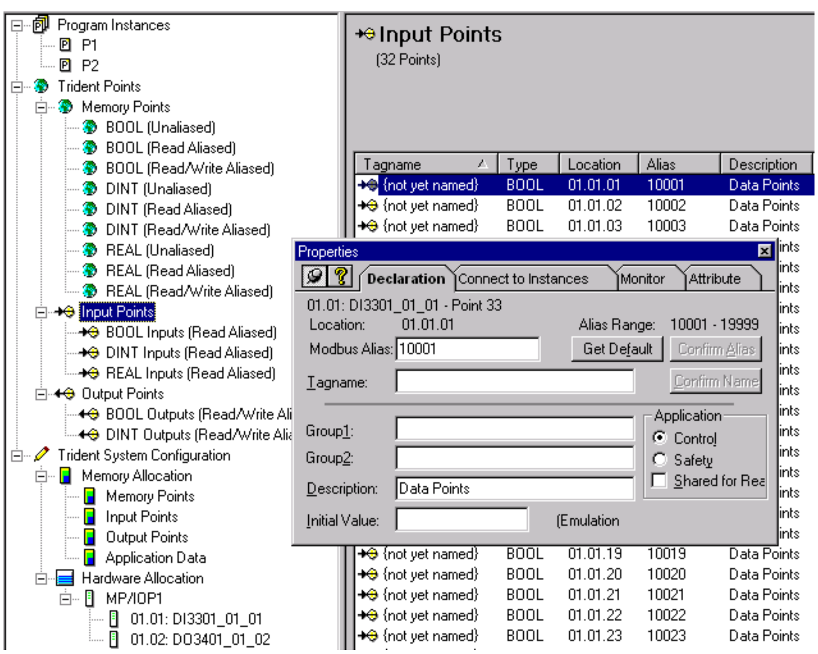
Cause & Effect Matrix Programming Language Editor (CEMPLE)

A high-level graphical language that provides a two-dimensional matrix in which the user can easily associate a problem in a process with one or more corrective actions. The problem is known as the cause and the action as the effect. The matrix associates a cause with an effect in the intersection of the cause row and the effect column.

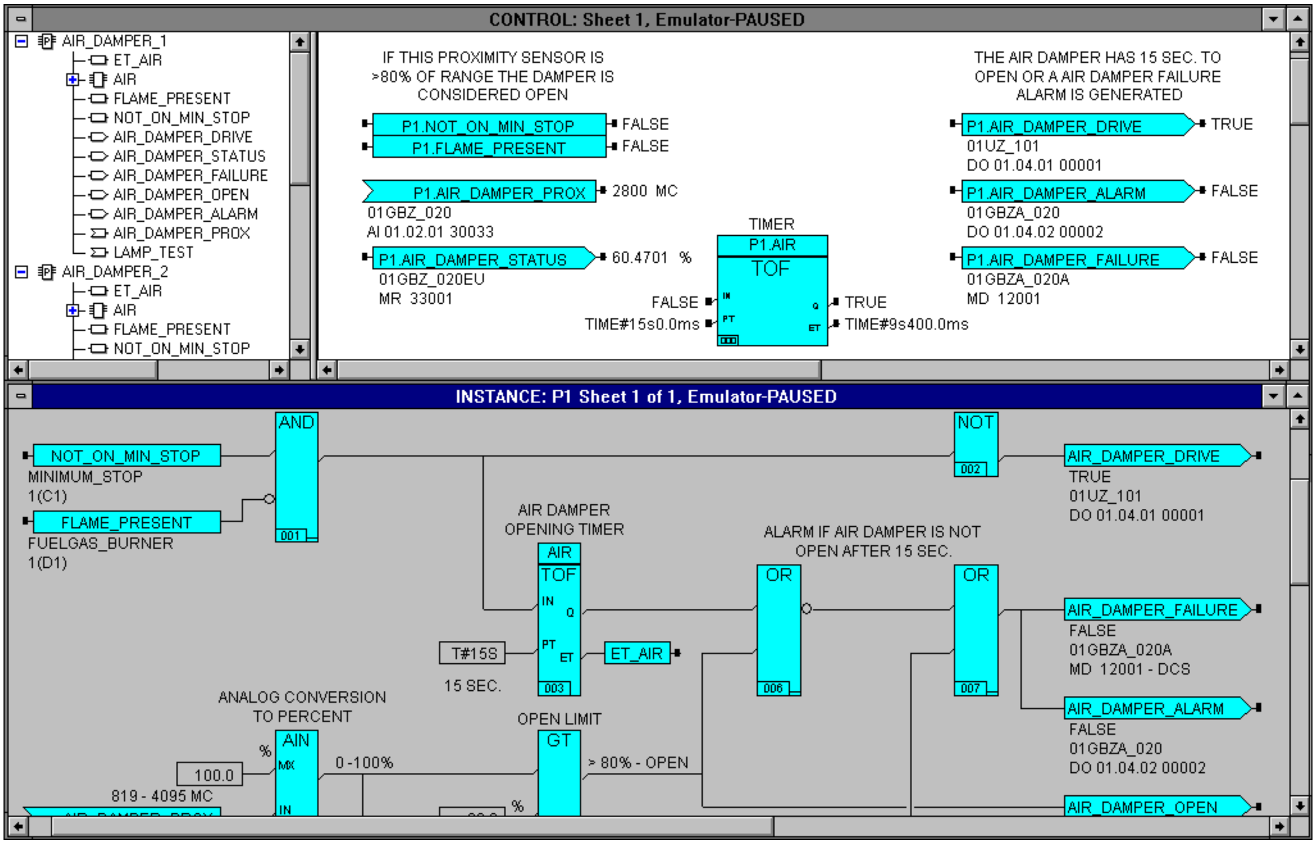
CEMPLE is the world's first automated implementation of CEM, a methodology that is commonly used throughout the process-control industry and readily understood by a broad range of plant personnel. CEM diagrams are automatically translated into IEC 1131-3 compliant Function Block Diagrams, thereby eliminating the risks associated with manual translation from hand-drawn CEMs.

Trident Configuration Editor

The Trident Configuration editor is used to define which programs will be instanced for downloading to the Trident controller as well as which Trident points (tagnames) each instance will access. In addition, the editor allows the user to configure the chassis and I/O modules required by the application. The editor features a split-view window whose left view contains a hierarchical configuration tree. The right view displays information about the item that is currently selected in the



Declaring Tagnames with the Trident Configuration Editor



Emulator Control Panel with Instance View of FBD Logic

tree. Four major editing functions are used to define the configuration of a Trident system:

Hardware Configuration

Through a graphical interface, the user configures the chassis and I/O modules to be used in the application. TriStation automatically allocates any memory required by the module.

Tagname Definition

Allows the user to manually or automatically declare tagnames and other properties for I/O points and aliased or non-aliased memory points.

Program Instance Declaration

Allows the user to instance each program that will be downloaded to the Trident controller and assign a unique identifier to each instance. A program may be instanced more than once.

Program Instance Variable Connections

Allows the user to connect (associate) each input variable and output variable in a program instance with a Trident I/O or memory point.

Tools for the Trident Controller

Emulator Control Panel

The Emulator Control Panel allows a user to connect to the emulator and download the project for testing and debugging. The panel features a data tree that lists the variables for all program instances. Testing and monitoring is achieved by dragging the desired variables from the tree on the left to the monitor sheet on the right and changing the variable values as desired. Commands may be selected to run, single-step, or halt program execution.

Another control panel feature is a split-screen *instance view* (shown above) which displays the values of annotated variables while the project is running.

Trident Control Panel

The Trident Control Panel provides the same features as the Emulator Control Panel except that it allows connection to the Trident controller for real-time execution.

Trident Diagnostic Panel

The Diagnostic Panel allows a user to monitor the status of chassis and modules in the Trident system and diagnose faults. The panel also provides system performance information including the project name & version, memory size, scan time and current execution state.

Other Key Features

Reports & Documentation

TriStation offers multiple methods of sorting data and documenting project elements, both during and after project development. Printouts of user-developed function blocks and programs can be obtained on a variety of user-selected engineering drawing templates. A number of standard reports are available to document the project configuration data. Users can also create customized reports with Crystal Reports™ or any other dBASE-compatible report generator.

Password Security

TriStation provides a security system that defines users and their privileges with regard to editing, library changes, Trident state changes and other operations.

Project History

An audit trail function is provided to document the history of a project and its program version changes. This detailed log keeps track of user actions and comments by automatically time-stamping critical events within a session and manually logging user comments on demand.

Help System

TriStation features an easy-to-use on-line help system which provides detailed information about developing and managing applications in TriStation. Extensive help is provided on using the various editors, libraries and control panels. The help system also includes information about the Trident platform, IEC 1131-3 language reference, a how-to section describing common tasks, a question-and-answer section, and a list of error messages along with cause-and-solution explanations.

PROGRAM VARIABLE CROSS REFERENCE LISTING

PROJECT NAME: EXBOILER DESCRIPTION: Boiler Burner Management Example VERSION: 107.0 CONFIG VERSION: 1.38 DATE: 06/24/99

PROGRAM INSTANCE	PROGRAM NAME	PROGRAM VARIABLE NAME	TAG NAME	DESCRIPTION	SHEET COORDINATES
B1	Boiler_Control	AirFlow_SP	B1_AirFlow_SP	Boiler 1 Air Flow Controller Setpoint	1(D6)
B1	Boiler_Control	AirFlow_CV	B1_AirFlow_CV	Boiler 1 Air Flow Controller Control Variable	1(D6)
B1	Boiler_Control	PR_VALUE	T1_PR_VALUE		1(D4)
B1	Boiler_Control	FuelFlow_Alarm	B1_FuelFlow_Alarm	Boiler 1 Fuel Flow Alarm	1(B5)
B1	Boiler_Control	GasDet_Num_HA	B1_GasDet_Num_HA	Boiler 1 Number of Gas Detectors in High Alarm	1(D1)
B1	Boiler_Control	WaterFlow_PV	B1_WaterFlow_PV	Boiler 1 Water Flow Process Value	1(B1)
B1	Boiler_Control	DrumLevel_PV	B1_DrumLevel_PV	Boiler 1 Drum Level Process Value	1(A6)
B1	Boiler_Control	FuelFlow_PV	B1_FuelFlow_PV	Boiler 1 Fuel Flow Process Value	1(B7)
B1	Boiler_Control	AirFlow_PV	B1_AirFlow_PV	Boiler 1 Air Flow Controller Process Variable	1(D6)
B1	Boiler_Control	PR_TC	T1_PR_TC	Process Filter Factor	1(D5)
B1	Boiler_Control	FuelFlow_HL	B1_FuelFlow_HL	Boiler 1 Fuel Flow High limit	1(B7)
B1	Boiler_Control	AirFlow_MR	B1_AirFlow_MR	Boiler 1 Air Flow Controller Control Variable	1(C6)
B1	Boiler_Control	GasDet_6HA	B1_GasDet_6HA	Boiler 1 Gas Detector 6 High Alarm	1(C3)
B1	Boiler_Control	GasDet_5HA	B1_GasDet_5HA	Boiler 1 Gas Detector 5 High Alarm	1(C3)
B1	Boiler_Control	GasDet_4HA	B1_GasDet_4HA	Boiler 1 Gas Detector 4 High Alarm	1(D3)
B1	Boiler_Control	GasDet_3HA	B1_GasDet_3HA	Boiler 1 Gas Detector 3 High Alarm	1(D3)
B1	Boiler_Control	GasDet_2HA	B1_GasDet_2HA	Boiler 1 Gas Detector 2 High Alarm	1(D3)
B1	Boiler_Control	AirFlow_SF	B1_AirFlow_SF	Boiler 1 Air Flow Controller Control Variable	1(D8)
B1	Boiler_Control	AirFlow_B	B1_AirFlow_B	Boiler 1 Air Flow Bias	1(C8)
B1	Boiler_Control	AirFlow_MNCV	B1_AirFlow_MNCV	Boiler 1 Air Flow Controller Minimum Control Value	1(C7)
B1	Boiler_Control	AirFlow_MXCV	B1_AirFlow_MXCV	Boiler 1 Air Flow Controller Maximum Control Value	1(C6)
B1	Boiler_Control	AirFlow_KPB	B1_AirFlow_KPB	Boiler 1 Air Flow Controller Proportional Band	1(C7)
B1	Boiler_Control	AirFlow_Reset	B1_AirFlow_Reset	Boiler 1 Air Flow Controller Reset Rate	1(C6)
B1	Boiler_Control	AirFlow_Rate	B1_AirFlow_Rate	Boiler 1 Air Flow Controller Rate Gain	1(C7)
B1	Boiler_Control	AirFlow_AM	B1_AirFlow_AM	Boiler 1 Air Flow Controller - Auto/Manual	1(D6)
B1	Boiler_Control	WaterFlow_MinValue	B1_WaterFlow_MinValue	Boiler 1 Water Flow Min Value	1(B2)
B1	Boiler_Control	WaterFlow_AI	B1_WaterFlow_AI	Boiler 1 Water Flow Analog Input	1(B2)
B1	Boiler_Control	WaterFlow_MaxValue	B1_WaterFlow_MaxValue	Boiler 1 Water Flow Max Value	1(B2)
B1	Boiler_Control	DrumLevel_AI	B1_DrumLevel_AI	Boiler 1 Drum Level Analog Input	1(A8)
B1	Boiler_Control	DrumLevel_MinValue	B1_DrumLevel_MinValue	Boiler 1 Drum Level Min Value	1(A8)
B1	Boiler_Control	DrumLevel_MaxValue	B1_DrumLevel_MaxValue	Boiler 1 Drum Level Max Value	1(A8)
B1	Boiler_Control	FuelFlow_MinValue	B1_FuelFlow_MinValue	Boiler 1 Fuel Flow Min Value	1(B8)
B1	Boiler_Control	FuelFlow_MaxValue	B1_FuelFlow_MaxValue	Boiler 1 Fuel Flow Max Value	1(B8)
B1	Boiler_Control	FuelFlow_AI	B1_FuelFlow_AI	Boiler 1 Fuel Flow Analog Input	1(B8)
Boiler1	Boiler_Logic	PV_OK	Blr1_PV_OK	Boiler 1 Process Variable OK	4(A5)
Boiler1	Boiler_Logic	PV_NOT_LOW	Blr1_PV_NOT_LOW	Boiler 1 Process Variable Not Low	4(A7)
Boiler1	Boiler_Logic	PV_NOT_HI	Blr1_PV_NOT_HI	Boiler 1 Process Variable Not High	4(B7)
Boiler1	Boiler_Logic	MS_Sensor	Blr1_MS_Sensor	Boiler 1 Median Select Sensor	4(B6)
Boiler1	Boiler_Logic	Medsel_Out	Blr1_Medsel_Out	Boiler 1 Median Select Output	4(D6)
Boiler1	Boiler_Logic	Dev_Sensor_1	Blr1_Dev_Sensor_1	Boiler 1 Deviation on Sensor 1	4(D4)
Boiler1	Boiler_Logic	COUT01	Blr1_COUT01	Boiler 1 Median Select Block Control Output	4(C6)
Boiler1	Boiler_Logic	GasPress_OK	Blr1_GasPress_OK	Boiler 1 Gas Pressure OK	3(C3)

Sample TriStation 1131 Report

CEMPLE is the Triconex automated implementation of the traditional CEM methodology that has been used by process control engineers for decades.

CEM Programming Language Editor

This section introduces the Cause & Effect Matrix Programming Language Editor (CEMPLE), an optional editor in the TriStation 1131 Developer's Workbench for developing safety shutdown applications. Background information is provided, and the main features of CEMPLE are described.

Traditional CEM Methodology

Cause and Effect Matrix (CEM) is a methodology that is commonly used throughout the process-control industry to define alarms, shutdowns and mitigation actions. For decades, process control engineers have been planning shutdown strategies with hand-drawn CEMs or non-interactive spreadsheet programs. CEMs are frequently used for fire and gas application systems where the programming logic is simple, but the volume of inputs and outputs that need to be controlled is high. In its simplicity, the CEM is readily understood by a broad range of plant personnel, from process engineers to operators.

The CEM methodology allows the user to easily associate a problem in a process with one or more corrective actions. The problem is known as a *cause* and the action is known as an *effect*. In a typical CEM, a cause is represented by a row in the *matrix* and an effect is represented by a column.

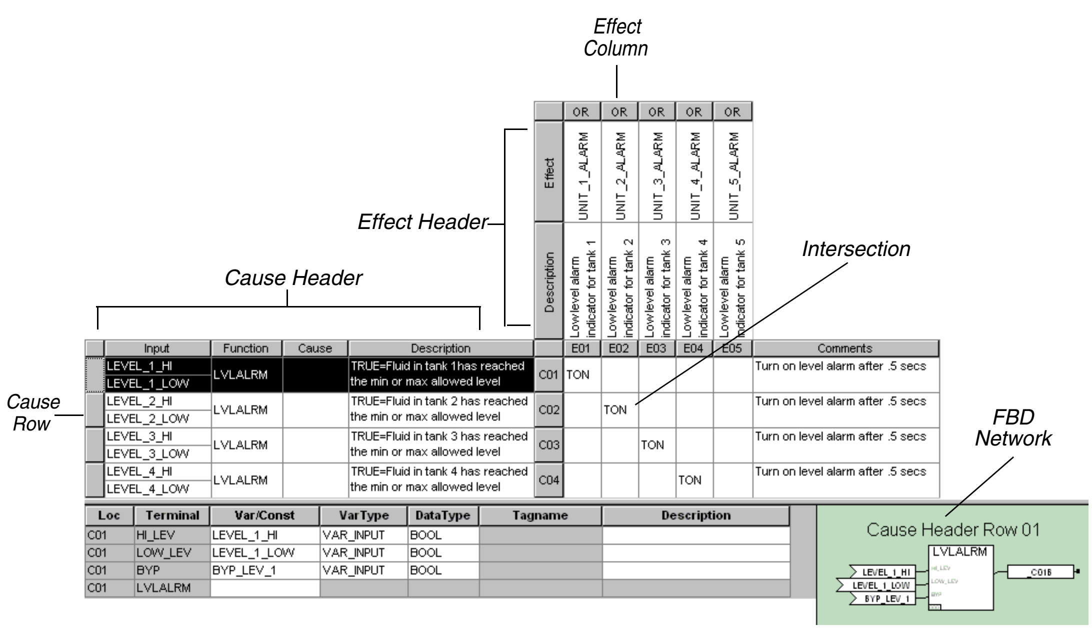
Automated CEM Called CEMPLE

The traditional CEM method is time-consuming and subject to errors caused by misinterpretation of the CEM or inaccurate coding. To greatly reduce these problems and eliminate expensive, redundant engineering, Triconex has introduced CEMPLE, a state-of-the-art automated implementation of CEM methodology.

CEMPLE's Main Features

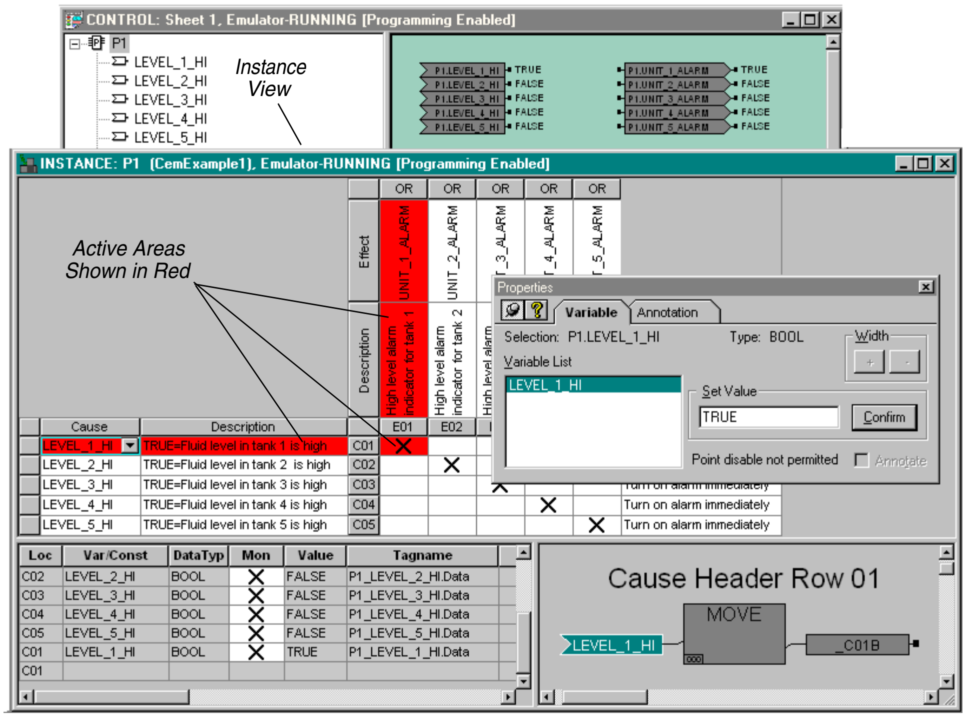
CEMPLE's main features are:

- Invocation of predefined and user-defined functions and function blocks for evaluation by CEM
- Choice of energize-to-trip (OR'd intersections) or de-energize-to-trip (AND'd intersections) matrix evaluation
- Support for up to 99 Cause Rows, 99 Effect Columns, and a maximum of 1,000 active intersections in a CEM
- Automatic generation of Function Block Diagrams (FBD) from the CEM
- Instance view monitoring with active causes, intersections and



Main Components of CEMPLE

CEM Programming Language Editor



Instance View of a CEM

effects displayed in the user's choice of colors

- Ability to name and recall specific CEM views

Main Components

The CEM editor window is divided into three panes: the matrix, the FBD Network and the Variable Detail Table.

Matrix

A CEMPLE matrix has two dimensions which are specifically intended for the development of safety shutdown applications:

- Each *Cause Row* (horizontal dimension) maps a cause to one or more effects.
- Each *Effect Row* (vertical dimension) maps one or more causes to an effect.

In a CEM, causes are represented by Boolean program input variables and effects are represented by Boolean program output variables.

FBD Network

For each Cause, active Intersection, and Effect in a matrix, CEMPLE automatically generates a Function Block Diagram (FBD) which implements the safety shutdown strategy.

Variable Detail Table

This lists the inputs and outputs of the FBD network that is generated by the selected part of the matrix.

Developing and Editing a CEM

A CEM is developed and edited using a variety of graphical interface methods. Commands are selected from a main menu, toolbar and pop-up menu. Variables are added or renamed directly in white cells of the Variable Detail Table. A drop-down list in each cell provides a selection of other variable names. For FBD networks, a dialog box is used to change the variable type and data type of user-declared variables. In addition, CEMPLE provides easy techniques for selecting, editing, sizing and hiding the various parts of a matrix.

User-created functions and function blocks that are invoked by a CEM can be created at any stage of program development, but must be created before they are used in a CEM.

Testing and Monitoring

Like all TriStation programs, CEMs are tested and debugged off-line using the **Emulator Control Panel**. After the project is downloaded, the **Trident Control Panel** can be used to monitor the values of variables during real-time execution.

In an *instance view* of a CEM, active causes, intersections, and effects can be viewed in the user's choice of colors, as shown in the example above. The user can select a cause header or effect header and monitor the associated variables. In the monitor screen shown, selected variables (marked with an x) are being monitored. The highlighted area shows that the UNIT_1_ALARM is on.

As with other types of executable elements, the CEMPLE user can set values and enable/disable variables during emulation and real-time execution. See page 32 for more information about the control panels in TriStation.