Trusted TMR 24 Vdc Valve Monitor Module - 40 Channel

Product Overview

The Trusted® TMR 24 Vdc Valve Monitor Module interfaces to 20 field devices. Each field device is controlled through an output channel, and monitored through a separate input channel. Triplicated diagnostic tests are performed throughout the Module including measurements for current, and voltage on each portion of the voted output channel. Tests are also performed for stuck on and stuck off failures. Fault tolerance is achieved through a Triple Modular Redundant (TMR) architecture within the Module for each of the 20 input and 20 output channels.

Automatic, line-monitoring of the field device is provided. This feature enables the Module to detect both open and short circuit failures in field wiring and load devices.

In addition to the normal control of the field device, this Module includes features that allow for partial stroke testing of valve devices while maintaining the field device availability in case of a demand. The valve is monitored through limit switches, and the valve position, travel times, and test status are reported.

This Module is not approved for direct connection to hazardous areas and should be used in conjunction with Intrinsic Safety Barrier devices.

Features:

- 20 Triple Modular Redundant (TMR) control output points per Module.
- 20 Triple Modular Redundant (TMR) feedback input points per Module.
- Advanced valve diagnostics and active valve testing.
- Comprehensive, automatic diagnostics and self-test.
- Automatic line monitoring per point to detect open circuit, short circuit, field wiring, and load faults.
- 2500 V impulse withstand opto/galvanic isolation barrier.
- Automatic over-current protection (per channel), no external fuses required.

- On-board Sequence of Events (SOE) reporting with 1 millisecond resolution.
- Module can be hot-replaced on-line using dedicated Standby (adjacent) Slot or SmartSlot (one spare slot for many Modules) configurations.
- Front Panel output status LEDs for each point indicate output status, feedback status and field wiring faults.
- Front Panel Module status LEDs indicate Module health and operational mode (Active, Standby, Educated).
- TüV Certified Risk Class 6.

PREFACE

DISCLAIMER

It is not intended that the information in this publication covers every possible detail about the construction, operation, or maintenance of a control system installation. You should also refer to your own local (or supplied) system safety manual, installation and operator/maintenance manuals.

REVISION AND UPDATING POLICY

This document is based on information available at the time of its publication. The document contents are subject to change from time to time. The latest versions of the manuals are available at the Rockwell Automation Literature Library under "Product Information" information "Critical Process Control & Safety Systems".

TRUSTED RELEASE

This technical manual was updated for **Trusted Release 4.0**.

LATEST PRODUCT INFORMATION

For the latest information about this product review the Product Notifications and Technical Notes issued by technical support. Product Notifications and product support are available at the Rockwell Automation Support Centre at
http://rockwellautomation.custhelp.com

At the Search Knowledgebase tab select the option "By Product" then scroll down and select the Trusted product.

Some of the Answer ID's in the Knowledge Base require a TechConnect℠ Support Contract. For more information about TechConnect Support Contract Access Level and Features please click on the following link:

https://rockwellautomation.custhelp.com/app/answers/detail/a_id/50871

This will get you to the login page where you must enter your login details.

IMPORTANT	A login is required to access the link. If you do not have an account then you can create one using the "Sign Up" link at the top right of the web page.

DOCUMENTATION FEEDBACK

Your comments help us to write better user documentation. If you discover an error, or have a suggestion on how to make this publication better, send your comment to our technical support group at http://rockwellautomation.custhelp.com

SCOPE

This manual specifies the maintenance requirements and describes the procedures to assist troubleshooting and maintenance of a Trusted system.

WHO SHOULD USE THIS MANUAL

This manual is for plant maintenance personnel who are experienced in the operation and maintenance of electronic equipment and are trained to work with safety systems.

SYMBOLS

In this manual we will use these notices to tell you about safety considerations.

	SHOCK HAZARD: Identifies an electrical shock hazard. If a warning label is fitted, it can be on or inside the equipment.
	WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which can cause injury or death, property damage or economic loss.
	ATTENTION: Identifies information about practices or circumstances that can cause injury or death.
	CAUTION: Identifies information about practices or circumstances that can cause property damage or economic loss.
	BURN HAZARD: Identifies where a surface can reach dangerous temperatures. If a warning label is fitted, it can be on or inside the equipment.
	This symbol identifies items which must be thought about and put in place when designing and assembling a Trusted controller for use in a Safety Instrumented Function (SIF). It appears extensively in the Trusted Safety Manual.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.
NOTE	Provides key information about the product or service.
TIP	Tips give helpful information about using or setting up the equipment.

WARNINGS AND CAUTIONS

WARNING: EXPLOSION RISK

Do not connect or disconnect equipment while the circuit is live or unless the area is known to be free of ignitable concentrations or equivalent

AVERTISSEMENT - RISQUE D'EXPLOSION

Ne pas connecter ou déconnecter l'équipement alors qu'il est sous tension, sauf si l'environnement est exempt de concentrations inflammables ou équivalente

MAINTENANCE

Maintenance must be carried out only by qualified personnel. Failure to follow these instructions may result in personal injury.

CAUTION: RADIO FREQUENCY INTERFERENCE

Most electronic equipment is influenced by Radio Frequency Interference. Caution should be exercised with regard to the use of portable communications equipment around such equipment. Signs should be posted in the vicinity of the equipment cautioning against the use of portable communications equipment.

CAUTION:

The module PCBs contain static sensitive components. Static handling precautions must be observed. DO NOT touch exposed connector pins or attempt to dismantle a module.

ISSUE RECORD

Issue	Date	Comments
6	July 05	Reformat. Threshold settings added Vibration spec change Text Changes and additions
7	Aug 06	Channel states
8	Dec 06	Weights & Dims
9	Mar 07	Extra mux channels
10	Sep 07	Specifications
11	Nov 07	STATE descriptions
12	Aug 08	Accuracy
13	Apr 10	Rack 7 minor change
14	Jun 16	Rebranded and reformatted with correction of Relative Humidity Range and Operating Temperature statements in the Specification Section, also correction of any typographical errors
15	Apr 19	Updated Specifications section and main text to a more consistent format. Updated Front Panel section to updated product design. Updated content for the following sections: 1.3 Host Interface Unit (HIU), 1.4 Front Panel Unit (FPU), 1.7 Fault Detection and Testing, 1.9.1 Switch Diagnostics, 2.2 Field Cable Selection, 3.4 System.INI File Configuration, and 5.4 Companion Slot Updated Output Turn-on/off Delay specification. Updated header and footer to display Rockwell Automation publication number. Added trademarks statement.

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1. Description

The TMR 24 Vdc Valve Monitor Module is a member of the Trusted High Integrity I/O Product Range. All High Integrity I/O Modules share common functionality and form. At the most general level, all I/O Modules interface to the Inter-Module Bus (IMB) which provides power and allows communication with the TMR Processor. In addition, all Modules have a field interface that is used to connect to Module specific signals in the field. All Modules are Triple Modular Redundant (TMR).

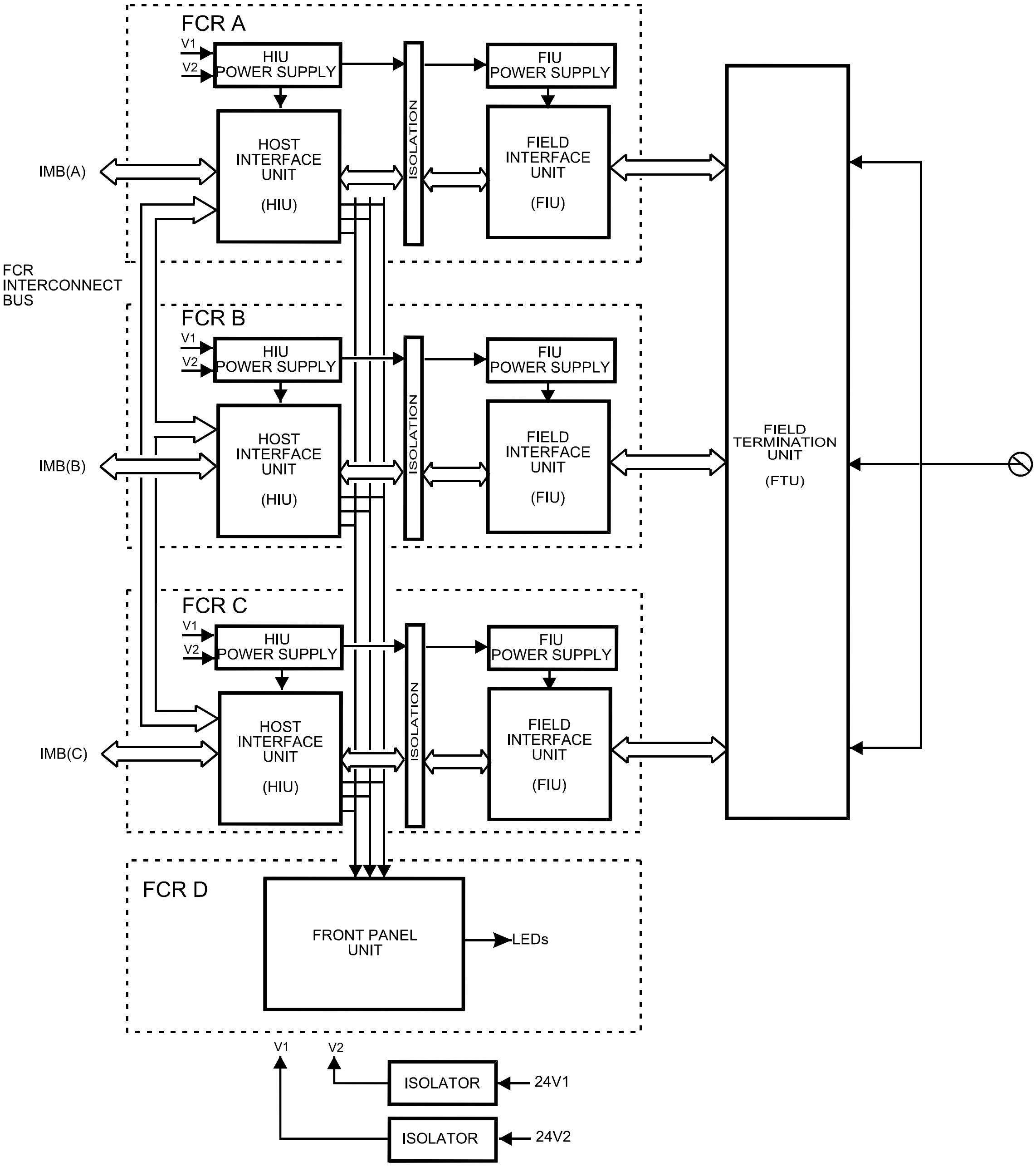

Figure 1 Module Architecture

All High Integrity I/O Modules are made up of 4 sections: Host Interface Unit (HIU), the Field Interface Unit (FIU), the Field Termination Unit (FTU), and the Front Panel Unit (or FPU).

Figure 2 shows a simplified functional block diagram of the Trusted 24 Vdc Valve Monitor Module.

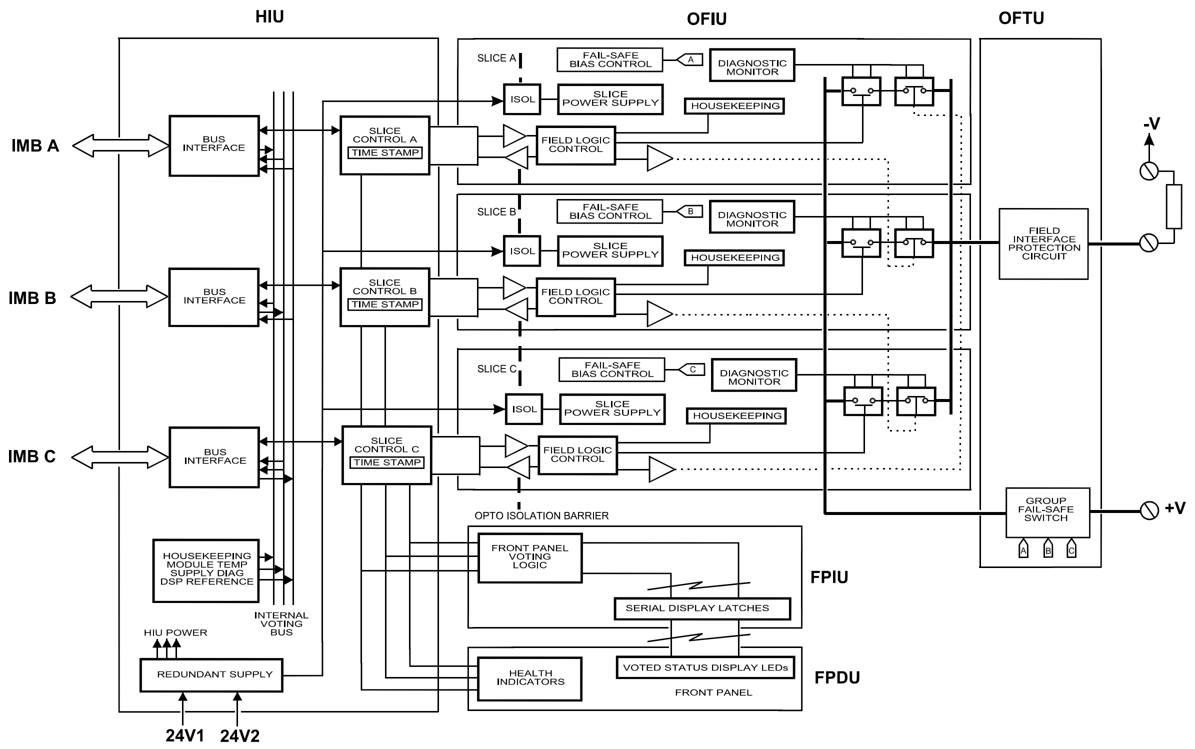

Figure 2 Functional Block Diagram

1.1. Field Termination Unit (FTU)

The Field Termination Unit (FTU) is the section of the I/O Module that connects all three FIUs to a single field interface. The FTU provides the Group Fail Safe switches and passive components necessary for signal conditioning, over-voltage protection, and EMI/RFI filtering. When installed in a Trusted Controller or Expander Chassis, the FTU field connector interconnects to the Field I/O Cable Assembly attached at the rear of the Chassis.

The SmartSlot link is passed from the HIU to the field connections via the FTU. These signals go directly to the field connector and maintain isolation from the I/O signals on the FTU. The SmartSlot link is the intelligent connection between Active and Standby Modules for coordination during Module replacement.

1.2. Field Interface Unit (FIU)

The Field Interface Unit (FIU) is the section of the Module that contains the specific circuits necessary to interface to the particular types of field I/O signals. Each Module has three FIUs, one per slice. For the TMR 24 Vdc Valve Monitor Module, the FIU contains one stage of the output switch structure for each of the 40 output channels. Both voltage and current flow are monitored for each output channel. 20 of the output channels are used to control field devices. The remaining 20 are used to monitor the positional feedback voltages for those field devices. Output channels used for feedback monitoring are never energised.

The FIU receives isolated power from the HIU for logic. The FIU provides additional power conditioning for the operational voltages required by the FIU circuitry. An isolated 6.25 Mbit/sec serial link connects each FIU to one of the HIU slices.

The FIU also measures a range of on-board “housekeeping” signals that assist in monitoring the performance and operating conditions of the Module. These signals include power supply voltages, current consumption, on-board reference voltages, and board temperature.

1.3. Host Interface Unit (HIU)

The HIU is the point of access to the Inter-Module Bus (IMB) for the Module. It also provides power distribution and local programmable processing power. The HIU is the only section of the I/O Module to directly connect to the IMB Backplane. The HIU is common to most high integrity I/O types and has type dependent and product range common functions. Each HIU contains three independent slices, commonly referred to as A, B, and C.

All interconnections between the three slices incorporate isolation to prevent any fault interaction between the slices. Each slice is considered a Fault Containment Region (FCR) as a fault on one slice has no effect on the operation of the other slices.

The HIU provides the following services common to the Modules in the family:

- High Speed Fault Tolerant Communications with the TMR Processor via the IMB interface.
- FCR Interconnect Bus between slices to vote incoming IMB data and distribute outgoing I/O Module data to IMB.
- Galvanically isolated serial data interface to the FIU slices.
- Redundant power sharing of dual 24 Vdc Chassis supply voltage and power regulation for logic power to HIU circuitry.
- Magnetically isolated power to the FIU slices.
- Serial data interface to the FPU for Module status LEDs.
- SmartSlot link between Active and Standby Modules for coordination during Module replacement.

- Digital Signal Processing to perform local data reduction and self-diagnostics.
- Local memory resources for storing Module operation, configuration, and field I/O data.
- On-board housekeeping, which monitors reference voltages, current consumption and board temperature.

1.4. Front Panel Unit (FPU)

The Front Panel Unit (FPU) contains the necessary connectors, switches, logic, and LED indicators for the Front Panel. For every type of Trusted I/O Module the FPU contains the Slice Healthy, Active/Standby and Educated indicators (LEDs), also the Module removal switches. Additional bi-colour LEDs provide status indication for the individual I/O signals. Serial data interfaces connect the FPU to each of the HIU slices to control the LED status indicators and monitor the Module removal switches.

1.5. Line Monitoring and Output States

The Module automatically monitors the control output channel current and voltage to determine the state of the output channel. The numerical output state and line fault status reported back to the application is represented below.

Description	Numerical Output State	Line Fault Status
Field Fault	6	1
Field Short Circuit	5	1
Output Energised (On)	4	0
No Load, Field Open Circuit	3	1
Output De-energised (Off)	2	0
No Field Supply Voltage	1	1

Table 1 Line Monitoring Fault Status

The Field Fault condition is used to report cases where the output is commanded De-energised (Off), but voltage is being supplied to the output circuit through some external source.

Default threshold values used for non line monitored inputs are as follows (in raw units):

Default = 1000, -1000, 3000, 3000, 5000, 5000, 7000, 7000

1.6. Housekeeping

The Module automatically performs local measurements of several on-board signals that can be used for detailed troubleshooting and verification of Module operating characteristics. Measurements are made within each slice's HIU and FIU.

1.7. Fault Detection and Testing

Extensive diagnostics provide the automatic detection of Module faults. The TMR architecture of the Module and the diagnostics performed verify the validity of all critical circuits. Using the TMR architecture provides a Fault Tolerant method to withstand the first fault occurrence on the Module and continue normal output controls without interruption in the system or process. Faults are reported to the user through the Healthy status indicators on the Front Panel of the Module and through the information reported to the TMR Processor. Under normal operations all three Healthy indicators are green. When a fault occurs, one of the Healthy indicators will be flashing red. This indicates that the Module should be replaced.

Module replacement activities depend on the type of spare Module configuration chosen when the system was configured and installed. The Module may be configured with a Dedicated Standby Slot or with a SmartSlot for a spare replacement Module.

From the IMB to the field connector, the I/O Module contains extensive fault detection and integrity testing. As an output device, most testing is performed in a non-interfering mode. Data input from the IMB is stored in redundant error-correcting RAM on each slice portion of the HIU. Received data is voted on by each slice. All data transmissions include a confirmation response from the receiver.

Periodically, the TMR Processor commands the on-board Digital Signal Processors (DSPs) to perform a Safety Layer Test (SLT). The SLT results in the DSP verifying with the TMR Processor its ability to process data with integrity. In addition, the DSP uses Cyclical Redundancy Checks (CRC) to verify the variables and configuration stored in Flash memory.

Between the HIU and FIU are a series of galvanically isolated links for data and power. The data link is synchronised and monitored for variance. Both FIU and HIU have on-board temperature sensors to characterise temperature-related problems.

The power supplies for both the HIU and FIU boards are redundant, fully instrumented and testable. Together these assemblies form a Power Integrity Sub-system.

1.8. Sequence of Events Characteristics

The Module automatically measures the field voltage and current to determine the state of each output channel, and the field voltage only for the feedback channels. An event occurs when the output transitions from one state to another, or when the feedback channel voltage crosses a pre-defined threshold. When a channel (either control or feedback) changes state, the on-board timer value is recorded. When the TMR Processor next reads data from the Module, the channel state and real-time clock value are retrieved. The TMR Processor uses this data to log the state change into the system Sequence of Events (SOE) log.

The user may configure each channel to be included in the system SOE log. Full details of SOE are contained in Trusted Sequence of Events and Process Historian Package, publication ICSTT-RM243 (PD-T8013).

1.9. Output Switch Structure

The outputs of the Valve Monitor Module provides a TMR switch topology where the load is driven by a total of three fully monitored, fail-safe (6 element) switch channels, one physically resident on each OFIU in the Module. Any single switch or entire slice failure is designed to leave two of the three fail safe switch channels operational to power the load.

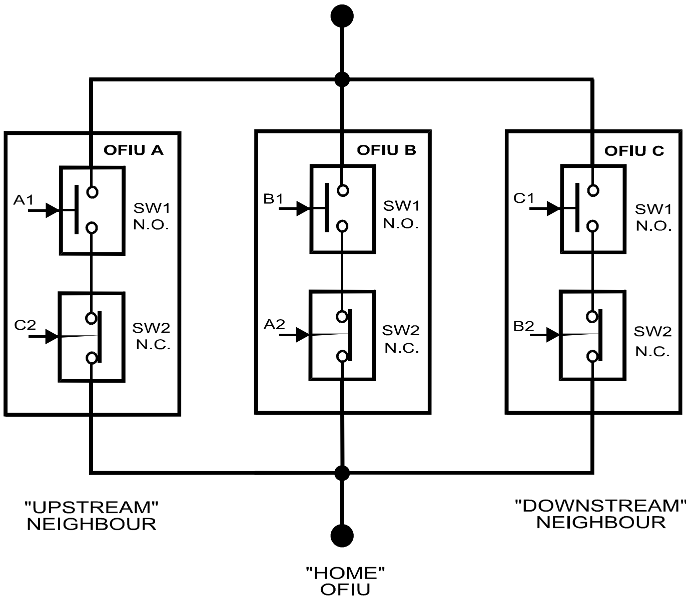

Figure 3 Output Switch Structure

The upper switches in shown in Figure 3 are denoted as N.O. (Normally Open), and are controlled by the FIU on which they are physically resident.[1] The lower switches are depicted as N.C. (Normally Closed), and are controlled by the "upstream" neighbouring FIU.[2]

Note: In this context, N.O. is defined as being in the off state in the absence of control signal power, and similarly, N.C. is the on state in the absence of control signal power. These switches are constructed from enhancement mode MOSFETs and are both guaranteed to be off in the absence of Module power to create gate voltage signals to bias them on[3] (unlike electromechanical relays for example).

[1] Their "home" FIU.

[2] The home FIU, supplies an independent control signal for the "downstream" OFIU FSS.

[3] For an unfaulted transistor.

The reason that the lower switches are specified to be on in the absence of control signal power is to allow two channels to power the load should an entire slice fail. Even if an entire slice fails, the surviving output circuits will carry the necessary control. The structure of each FIU output is shown below:

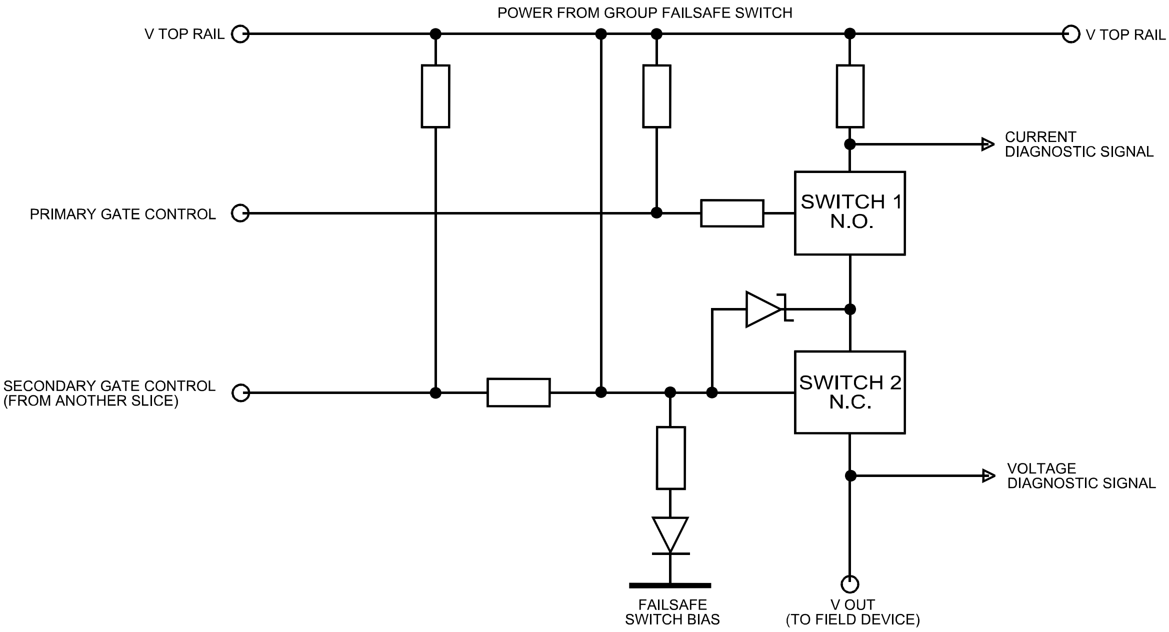

Figure 4 Simplified Switch Circuit Diagram

A 0.1 Ω resistor provides a means of continuously monitoring the switch current. A signal transistor is used to drive the gate of Switch 2. It provides Switch 2 with a negative gate voltage, to minimise it’s on resistance, and serves to hold Switch 2 on in the event that the secondary gate control loses power.

The Zener diode between the gate of Switch 2 and source is only required to protect the gate from large voltage spikes on the drain that might capacitively couple through when Switch 1 and Switch 2 are in the off state.

The resistors in series with the gate of Switch 1 and the signal transistor serve to protect the drive logic in the event of a malicious switch failure. The pull-up resistors define the gate voltages in the absence of power.

1.9.1. Switch Diagnostics

During normal operation, Switch 1 and Switch 2 are maintained on. In this state, Switch 1 and Switch 2 exhibit a low resistance.

To determine the ability of the system to control the load via Switch 1 and Switch 2, their gate voltages are modulated, one at a time. As the gate voltages are modulated, the monitoring signals synchronously change in a predictable fashion. The local DSP analyses the relative amplitude and phase of these small AC signals, to determine the on resistance and threshold voltages of each switch.

The current to the load does not need to be completely interrupted in order to obtain a level of confidence in the ability of the transistors to turn off. For the TMR switch configuration in the on state, only one fail safe switch at a time needs to be modulated, while the other two bear the load current.

1.9.2. Short Circuit Protection

Output channels are classified as protected under IEC 61131-2, specifically 'Protected Outputs Requirements'.

In a fuse-free design such as in the Trusted, the Module is required to respond rapidly in the event of an over-current or over-power situation. In fact, this protection scheme offers advantages to fuses in both automatic recovery and speed of action.

The topology of the channel provides a natural limit to the instantaneous current flow, giving the Module time to respond. Furthermore, the over-current protection circuitry is inherently self-testable, since the threshold can be a programmable value.

The P-channel architecture of Switch 1 and Switch 2 utilises an open-drain output structure. Under short-circuit conditions the maximum instantaneous current with a 24 V field voltage is naturally limited to less than 5 A per channel. This is because high output currents cause the gate-source voltages of the two transistors to be reduced, tending to turn them off.

The output current is monitored by the DSP and sustained over current conditions result in a latched over-current condition and de-energise the associated output. After removing the fault condition the latched over-current condition can be cleared by operating the system Fault Reset button or by transitioning the commanded channel state.

The output also includes a non-replaceable fusible link for absolute protection.

1.9.3. Group Fail Safe Switches

To support safe operation, the Module is equipped with a series of switches which provide source power to a group of 8 channels. The Module Group Fail Safe Switch (GFSS) is intended as a final control switch which can de-energise any outputs that cannot be de-energised in the normal way. For safety, the presence of two or more faults within the Module will cause the Group Fail Safe Switches to de-energise, resulting in all of the outputs in its group de-energising.

There are three switches in parallel which comprise the GFSS, one associated with each 'slice' of the power group. The GFSS' are controlled via a signal from one of the other two neighbouring slices. This means that if one slice determines from the output states that an output is not in a de-energised state when it should be, then it can command its own GFSS and those of the other slices GFSS to de-energise. This results in two of the three elements of the GFSS structure to de-energise, leaving only one GFSS element energised. If two slices do the same thing then the last GFSS output will de-energise. For example, this would occur if two or more output switch elements fail in a 'stuck-on' state such that the output cannot de-energise.

The GFSS control signal is generated by a charge pump driven from the comms clock to the slice power group. If the clock fails then the GFSS bias collapses. This means that even if the ability of the slice to communicate with a power group is lost, the GFSS can still be de-energised by stopping the comms clock. If a slice fails, the watchdog on the HIU will time out and reset the slice, this will shutdown the FIU power supply and the associated GFSS control signal will also de-energise.

1.10. Control / Feedback Circuits

Like the TMR 24 Vdc Digital Output Module, the TMR 24 Vdc Valve Monitor Module has 5 groups with 8 output circuits each, for a total of 40 output channels. Only 20 of the channels (4 per power group) are used to control field devices. The remaining 20 channels always remain de-energised and are used to monitor feedback, taking advantage of the channels built-in voltage measurement capability.

Throughout this document, the 20 channels used to control field devices will be referred to as “control outputs”. The remaining 20 channels used to monitor feedback will be referred to as “feedback inputs”. Each control output is paired with a feedback input. This I/O pair represents the entire interface for a single field device.

The Module Configuration section contains more details on the physical layout of the control outputs and feedback inputs.

1.11. Valve Testing

In order to test a valve, a signal is sent by the application program to the Module. The Module will then change the state of the valve control output until either the positional feedback indicates that the valve has moved, or a timer expires. The results of the test are supplied to the application program as a set of time values, each of which corresponds to a limit switch change. The application program can use the time values to determine the operational health and characteristics of the valve.

1.11.1. Positional Feedback

Monitoring the position of the valve is accomplished by measuring the voltage of the feedback channel that is connected to one or more limit switches. Where multiple limit switches are available, a mechanism external to the Module is used to combine the various limit switch positions into a single voltage measurable by the Module. The feedback path utilizes the voltage-monitoring portion of an output channel circuit. As such, the output circuit itself is never energised.

Thresholds will be applied to the voltage level to produce a discrete state (in much the same way as in a TMR 24 Vdc Digital Input Module). Each discrete state will fully describe the positions of all connected limit switches. If the number of limit switches allows, additional states may be used to provide end-of-line monitoring.

1.11.2. Normal Operation

Normal operation of the control output is the same as that of a 24 Vdc Digital Output channel. In all cases, the normal operation of a control output takes precedence over any active testing.

Just like a regular 24 Vdc Digital Output Module, all control outputs are considered safety critical. Their safe state is De-energised (Off).

When the control output is commanded to change states (i.e. from Energised/On to De-energised/Off), the Module will record the time difference from the commanded change to one or more changes in the positional feedback levels. The recorded times will be available to the user application.

1.11.3. Test Operation

Valve testing is initiated by sending the TEST signal from the user application to the Module. Each signal will initiate a valve test on a per-channel basis (i.e. the application could send the TEST signal to all channels, several channels, or a single channel at any given time).

A valve test consists of changing the state of the valve (i.e. from Energised/On to De-energised/Off or vice-versa) and monitoring the positional feedback. When a specific valve position is achieved, the valve is returned to its original state. If the position is not achieved by a specific maximum time, the valve is also returned to its original state.

In order to initiate a test, the following conditions must be met:

- The Module is currently in the Active operational mode.
- The control output circuit must be healthy.
- The feedback circuit must be healthy (not state 0 or 6).
- The reported state of the control output must be either Energised/On or De-energised/Off, and must match the commanded state. The test will not be initiated if the control output does not have a load, is in OVC, etc. It is also possible that the test will not be initiated just after the commanded state of the control output is changed, as the reported state may not yet match the commanded state.

- The control output must not be forced. This applies only to control outputs with entries in the FORCE section of the Module's configuration. "Forcing" a control output through the IEC 61131 Toolset will not inhibit valve testing.
- A valid, non-zero maximum test time must be specified.
- A valid, non-zero end state must be specified.
- The Module is not currently inside of an Active/Standby changeover operation.

A Test Error will occur if any of the pre-conditions are not met when a valve test is initiated.

During the valve test, the Module will record the time difference from the start of the valve test to one or more changes in the positional feedback levels. The recorded times will be available to the user application.

Once a valve test has been initiated, it will continue until one of the following conditions is met:

- The positional feedback indicates that the desired position has been achieved.
- The maximum time allowed for the test has expired.
- The commanded state of the control output is changed.
- A line fault condition is detected. (i.e. OVC, no-load).
- The control output circuit or feedback input circuit is declared as faulty.
- The TEST signal is negated (i.e. turned Off/De-energised).
- The Module changes operational modes (i.e. Active to Standby or Active to Shutdown).
- An Active/Standby changeover is initiated.

Condition 1 is the only manner in which a valve test will complete successfully. Condition 2 will result in a valve test failure. All other conditions will result in an aborted valve test.

At the completion of a valve test, the control output will be commanded to its pre-test state if possible. This will occur regardless of the reason that the test is considered complete. In some cases it may not be possible to achieve the pre-test state due to line-fault conditions, fault degradation rules, or a change in Module state. (i.e. a control output was Energised/On before initiating a valve test, and during the valve test the Module was placed in Standby. The valve test would abort, but the control output would be forced to the Off/De-energised state because the Module is in Standby.)

Here are the usual application logic steps associated with performing a valve test:

1. Write the maximum allowable valve travel time to the ETIME signal.
2. Write the desired end state to the ESTATE signal.

3. Turn the TEST signal off (logic '0'). This will clear the results of the previous test (if any). The Valve Test State will be reported as 0 (Idle). All other valve test variables (such as the Test Times, Sampled ETIME, and Sampled ESTATE) will be cleared to 0.
4. Write 0 (Valve Test State) to the MXOUT signal.
5. Wait for the MXIN value to be 0 (Valve Test State). MXDAT should now contain the Valve Test State which should be 0 (Idle).
6. Turn the TEST signal on (logic '1'). This will initiate the valve test.
7. Wait for the Valve Test State in MXDAT to read a value greater than 1 - either 2 (Test Complete), 3 (Test Error), 4 (Test Aborted), or 5 (Test Failure).
8. If the Valve Test State in MXDAT is 2 (Test Complete), collect the valve travel times.
9. Write 1 (Test Time 1) to MXOUT. Wait for MXIN to equal MXOUT.
10. Copy the value in MXDAT to a local variable. This is the time (in milliseconds) from the start of the test until the positional feedback voltage level reached state 1.

Repeat 9 and 10 as necessary. You may want to collect one, some, or all of the Test Times depending on the initial valve state, the configuration of the limit switches, and the voltage thresholds used.

Repeat from step 1 for each new valve test. Skip steps 1 and 2 only when ETIME and ESTATE remain the same for each test.

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2. Installation

CAUTION:

The Module always resides in the allocated I/O Module slot (position) within the Trusted Controller or Expander Chassis. These Module positions are keyed for T8449 Modules to prevent installation of the incorrect Module type. Other Module positions are keyed to match their intended Module type. The Module must not be installed in other Module locations, as this may cause damage to the Module.

2.1. Module Insertion and Removal

CAUTION:

The Module contains static sensitive parts. Static handling precautions must be observed. Specifically verify that exposed connector pins are not touched. Under no circumstances should the Module housing be removed.

Before installation, visually inspect the Module for damage. Verify that the Module housing appears undamaged and inspect the I/O connector at the back of the Module for bent pins. If the Module appears damaged or any pins are bent, do not install the Module. Do not try to straighten bent pins. Return the Module for replacement.

Verify that the Module is of the correct type.

Record the Module type, revision and serial number of the Module before installation.

To install the Module:

1. Verify that the field cable assembly is installed and correctly located.
2. If I/O Module keys are used, verify that all keys are installed in the correct positions and properly seated in their slots.
3. Release the ejector tabs on the Module using the release key. Verify that the ejector tabs are fully open.
4. Holding the ejectors, carefully insert the Module into the intended slot.
5. Push the Module fully home by pressing on the top and bottom of the Module fascia.
6. Close the Module ejectors, ensuring that they click into their locked position.

The Module should mount into the chassis with a minimum of resistance. If the Module does not mount easily, do not force it. Remove the Module and check it for bent or damaged pins. If the pins have not been damaged, try reinstalling the Module.

2.2. Field Cable Selection

I/O cables suitable for use with the Trusted TMR 24 Vdc Valve Monitor are detailed in the following Product Descriptions:

- Trusted I/O Companion Slot Cables, publication ICSTT-RM311 (PD-TC200)
- Trusted I/O SmartSlot Cables, publication ICSTT-RM313 (PD-TC500)

The Product Descriptions detailed above also detail the types of Field Termination Assembly (FTA) or Versatile Field Termination Assembly (VFTA) which may be used with each type of Module.

2.3. Termination

Unused outputs should be commanded off in the application and wired through a 4K7 0.5 W resistor to zero volts.

2.4. Module Pin-out Connections

	C	B	A
1	SmartSlot Link C	SmartSlot Link B	SmartSlot Link A
2	-	-	-
3	Chan 5 OP (+)	Pwr Group 1 (+)	Chan 1 OP (+)
4	Chan 6 IP (+)	Pwr Group 1 (+)	Chan IP 2 (+)
5	Pwr Group 1 Rtn	Pwr Group 1 (+)	Pwr Group 1 Rtn
6	Chan OP 7 (+)	Pwr Group 1 (+)	Chan OP 3 (+)
7	Chan 8 IP (+)	Pwr Group 1 (+)	Chan IP 4 (+)
8	-	-	-
9	Chan 13 OP (+)	Pwr Group 2 (+)	ChanOP 9 (+)
10	Chan 14 IP (+)	Pwr Group 2 (+)	Chan 10 IP (+)

	C	B	A
11	Pwr Group 2 Rtn	Pwr Group 2 (+)	Pwr Group 2 Rtn
12	Chan 15 OP (+)	Pwr Group 2 (+)	Chan 11 OP (+)
13	Chan 16 IP (+)	Pwr Group 2 (+)	Chan 12 IP (+)
14	-	-	-
15	Chan 21 OP (+)	Pwr Group 3 (+)	Chan 17 OP (+)
16	Chan 22 IP (+)	Pwr Group 3 (+)	Chan 18 IP (+)
17	Pwr Group 3 Rtn	Pwr Group 3 (+)	Pwr Group 3 Rtn
18	Chan 23 OP (+)	Pwr Group 3 (+)	Chan 19 OP (+)
19	Chan 24 IP (+)	Pwr Group 3 (+)	Chan 20 IP (+)
20	-	-	-
21	Chan 29 OP (+)	Pwr Group 4 (+)	Chan 25 OP (+)
22	Chan 30 IP (+)	Pwr Group 4 (+)	Chan 26 IP (+)
23	Pwr Group 4 Rtn	Pwr Group 4 (+)	Pwr Group 4 Rtn
24	Chan 31 OP (+)	Pwr Group 4 (+)	Chan 27 OP (+)
25	Chan 32 IP (+)	Pwr Group 4 (+)	Chan 28 IP (+)
26	-	-	-
27	Chan 37 OP (+)	Pwr Group 5 (+)	Chan 33 OP (+)
28	Chan 38 IP (+)	Pwr Group 5 (+)	Chan 34 IP (+)
29	Pwr Group 5 Rtn	Pwr Group 5 (+)	Pwr Group 5 Rtn
30	Chan 39 OP (+)	Pwr Group 5 (+)	Chan 35 OP (+)
31	Chan 40 IP (+)	Pwr Group 5 (+)	Chan 36 IP (+)
32	-	-	-

Table 2 Field Connector Pin-out

2.5. Trusted Module Polarisation/Keying

All Trusted Modules have been Keyed to prevent insertion into the wrong position within a Chassis. The polarisation comprises two parts; the Module, and the associated field cable.

Each Module type has been keyed during manufacture. The organisation responsible for the integration of the Trusted System must key the cable by removing the keying pieces from the cable so that they correspond with the bungs fitted to the associated Module prior to fitting.

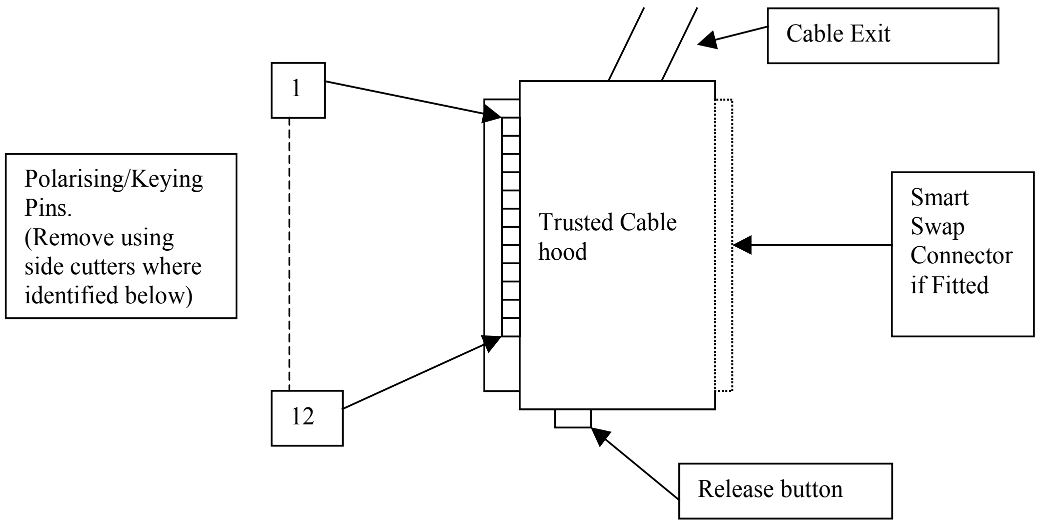

Figure 5 Module Polarisation

For Cables with Companion Slot installations both keying strips must be polarised.

For This Module (T8449) remove keying pins 1, 7 and 10.

3. Application

3.1. Module Configuration

There is no configuration required to the physical Module. All configurable characteristics of the Module are performed using tools on the Engineering Workstation (EWS) and become part of the application or System.INI file that is loaded into the TMR Processor. The TMR Processor automatically configures the Module after applications are downloaded and during Active/Standby changeover.

The IEC 61131 TOOLSET provides the main interface to configure the Module. Details of the configuration tools and configuration sequence are provided in Trusted Toolset Suite, publication ICSTT-RM249 (PD-T8082). There are three procedures necessary to configure the Module. These are:

1. Define the necessary I/O variables for the field output data and Module status data using the Dictionary Editor of the IEC 61131 TOOLSET.
2. Create an I/O Module definition in the I/O Connection Editor for each I/O Module. The I/O Module definition defines physical information, e.g. Chassis and Slot location, and allows variables to be connected to the I/O channels of the Module.
3. Using the Trusted System Configuration Manager, define custom LED indicator modes, per-channel shutdown states, and other Module settings.

3.2. T8449 Complex Equipment Definition

The T8449 I/O Complex Equipment Definition includes 10 I/O boards, referenced numerically by Rack number:

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
1	DO_TEST	OEM Parameters	-	-	-
		Output Command / Test Command	Boolean	Out	40
2	STATE	Field Output State	Integer	In	40
3	AI _MXIN	Output voltage / MUX data selection	Integer	In	40
4	CI _MXDAT	Output current / MUX data	Integer	In	40

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
5	MXOUT	MUX data request	Integer	Out	20
6	ETM_EST	Max Test Time / Test End State	Integer	Out	40
7	LINEFLT	Line Fault Status	Boolean	In	40
8	DISCREP	Channel Discrepancy	Integer	In	3
9	HKEEPING	Housekeeping Registers	Integer	In	57
10	INFO	I/O Module Information	Integer	In	11

BTable 3 Complex Equipment Definition

There are two OEM parameters included in the first rack (DO Board). These OEM parameters define the primary Module position; declaring the Module's chassis and slot location. There is no need to define the secondary Module position within the IEC 61131 TOOLSET. Where systems may be required to start-up with Modules in the secondary position as the Active Module, e.g. primary Module is not installed when application is started, the secondary Module's position should be declared in the Module definition of the System Configuration Manager.

OEM Parameter	Description	Default Value	Notes
TICS_CHASSIS	The number of the Trusted Chassis where the Primary I/O Module is installed	1	The Trusted Controller Chassis is 1, and Trusted Expander Chassis are 2 to 15.
TICS_SLOT	The slot number in the Chassis where the Primary I/O Module is installed	1	The I/O Module slots in the Trusted Controller Chassis are numbered from 1 to 8. The I/O Module slots in the Trusted Expander Chassis are numbered from 1 to 12.

Table 4 OEM Parameters

All of the racks except for 5 (MXOUT), 9 (HKEEPING), and 10 (INFO) have 40 sequentially numbered channels that start with 1. The first channel (1) and all subsequent odd channels pertain to the control functions, while the second channel (2) and all subsequent even channels pertain to the test and feedback functions. Channel 1 (for control) and channel 2 (for test/feedback) together represent the complete interface to the field device 1. Subsequent consecutive pairs represent the interfaces for field devices 2 through 20.

The TMR 24 Vdc Valve Monitor Module provides more information about the feedback input and valve test status than is available on a per-rack basis. To accomplish this, a logical data MUX is used to select one of the possible return values. The MXOUT signal allows the user to request a specific data item, the MXIN signal tells the user which data item is currently available, and the MXDAT value contains the data item. There is a separate MXOUT, MXIN, and MXDAT for each field device.

A complete list of data items (i.e. valid MXOUT and MXIN values) is provided after the rack definitions.

3.2.1. Rack 1: DO_TEST

This board provides the connection to the logical output control signal for each of the field devices as well as the valve test initiation signal.

Channel	Field Device	Description
1	1	Control output command
2		Test initiation command
3	2	Control output command
4		Test initiation command
39	20	Control output command
40		Test initiation command

Table 5 Rack 1: DO_TEST Descriptions

The user application should set the control output control signal to true (logic ‘1’) to turn ON or energise an output, and false (logic ‘0’) to turn OFF or de-energise an output.

A valve test will be initiated on each rising edge of the test initiation signal when it is set to true (logic ‘1’). A falling edge of the test initiation signal when it is set to false (logic ‘0’) will reset the valve test and clear all internal valve test data (such as the Valve Test State, Test Time variables, Samples ETIME, and Samples ESTATE). Valve test data such as Feedback Input Voltage, and the Command Time variables are not cleared.

3.2.2. Rack 2: STATE

This board provides the majority voted numerical output state. This indicates the operational status of the control output and feedback input for each field device.

Channel	Field Device	Description
1	1	Control output state
2		Feedback input state
3	2	Control output state
4		Feedback input state
39	20	Control output state
40		Feedback input state

Table 6 Rack 2: STATE Descriptions

For control outputs, the State indicates the operation state of the output circuit as follows:

Value	Description
7	Channel Fault
6	Field fault (e.g. field leakage to 0 V or 24 V)
5	Short circuit in field wiring or load
4	Output energised (ON)
3	Open circuit in field wiring or load
2	Output de-energised (OFF)
1	No field supply voltage
0	Unused

Table 7 Rack 2: STATE Output Descriptions

For feedback inputs, the State indicates the threshold voltage level of the input circuit as follows:

Value	Description
7	Channel Fault
6	Line fault, at or above maximum detectable voltage
5	User defined voltage range
4	User defined voltage range
3	User defined voltage range
2	User defined voltage range
1	User defined voltage range
0	Line fault, at or below minimum detectable voltage

Table 8 Rack 2: STATE Input Descriptions

3.2.3. Rack 3: AI_MXIN

The AI_MXIN board returns the field loop voltage as well as the specific MUX data item index for the corresponding MXDAT value for each field device.

Channel	Field Device	Description
1	1	Control output voltage
2		MXIN value
3	2	Control output voltage
4		MXIN value
39	20	Control output voltage
40		MXIN value

Table 9 Rack 3: AI_MXIN Descriptions

The voltage is the median value taken from the triplicated Module. The voltage level is reported as an integer, with the units being $^{1}/_{500}$V. This may be used directly, scaled arithmetically or scaled using the IEC 61131 TOOLSET conversion tables.

To scale the value arithmetically simply divide the returned ‘integer’ by 500 to return the voltage as either a REAL or INTEGER as required.

The IEC 61131 TOOLSET conversion tables may be used to convert the value to engineering units, in this case voltage. The full-scale range for this number format is decimal ±64, corresponding to physical range –32000 to +32000.

The MXIN value is an integer index that defines the meaning of the MXDAT value. A complete list of data items (i.e. valid MXIN values) is provided after the rack definitions. The MXIN value is the median value taken from the triplicated Module.

3.2.4. Rack 4: CI_MXDAT

The CI_MXDAT board returns the field loop current and MXDAT values for each field device.

Channel	Field Device	Description
1	1	Control output current
2		MXDAT value
3	2	Control output current
4		MXDAT value
39	20	Control output current
40		MXDAT value

Table 10 Rack 4: CI_MXDAT Descriptions

The current is the sum value taken from the triplicated Module. The current level is reported as an integer, with the units being $^{1}/_{1000}$A. This may be used directly, scaled arithmetically or scaled using the IEC 61131 TOOLSET conversion tables.

To scale the value arithmetically simply divide the returned ‘integer’ by 1000 to return the current as either a REAL or INTEGER as required.

The IEC 61131 TOOLSET conversion tables may be used to convert the value to engineering units, in this case current. The full-scale range for this number format is decimal ±32, corresponding to physical range –32000 to +32000.

The MXDAT value is dependent on the value of MXIN for the corresponding field device. A complete list of data items (i.e. valid MXIN values) is provided after the rack definitions. The MXDAT value is the median value taken from the triplicated Module.

MXDAT values are only valid when MXOUT is equal to MXIN.

3.2.5. Rack 5: MXOUT

This board provides the connection to the MXOUT signal for each field device.

Channel	Field Device	Description
1	1	MXOUT value
2	2	MXOUT value
20	20	MXOUT value

Table 11 Rack 5: MXOUT Descriptions

Values written to MXOUT are sent to the Module to request that specific data items be returned via the CI_MXDAT board. It will take one or more application scans after changing an MXOUT value before the corresponding values MXIN and MXDAT will reflect the change. A complete list of data items (i.e. valid MXOUT values) is provided after the rack definitions.

Writing invalid values to MXOUT (i.e. a value not specifically on the predefined list) will be result in MXOUT being set to 0.

MXDAT values requested by MXOUT are only valid when MXOUT and MXIN are equal.

3.2.6. Rack 6: ETM_EST

This board provides connections to the ETIME and ESTATE signals for each field device.

Channel	Field Device	Description
1	1	End Time for valve test
2		End State for valve test
3	2	End Time for valve test
4		End State for valve test

Channel	Field Device	Description
39	20	End Time for valve test
40		End State for valve test

Table 12 rack 6: ETM_EST Descriptions

The ETIME signal is used to specify the maximum amount of time that a valve test is allowed to continue before returning the valve to its commanded state. ETIME is specified in milliseconds, and may be any value between 0 and 32767. Values outside the valid range will be set to 0. Because a non-zero value (i.e. 1 < value < 32767) must be specified before a value test can be initiated, setting ETIME to 0 inhibits valve testing.

The ESTATE signal is used to specify the desired end state for the feedback input for a valve test. The possible end states correspond to the values reported for feedback input state on the State board (Rack 2) and must be between 0 and 6. Values outside the valid range will be set to 0. Because a non-zero value (i.e. 1 < value < 6) must be specified before a valve test can be initiated, setting ESTATE to 0 inhibits valve testing.

Both ESTATE and ETIME are sampled by the Module when it detects a rising edge on the TEST signal (Rack 1). Changes to ETIME or ESTATE during a valve test are valid, but will not go into effect until the start of the next valve test (i.e. on the next rising edge of the TEST signal).

3.2.7. Rack 7: LINEFLT

The Line Fault board reports line fault conditions for control output and feedback input circuits.

Channel	Field Device	Description
1	1	Control output line fault
2		Feedback input line fault
3	2	Control output line fault
4		Feedback input line fault

39	20	Control output line fault
40		Feedback input line fault

Table 13 Rack 7: LINEFLT Descriptions

The line fault input state is reported as true (logic ‘1’) for a line fault condition (open circuit, short circuit, and no field supply voltage). The logic state is the majority voted value.

3.2.8. Rack 8: DISCREP

Channel	Description
1	Discrepancy status channels 1 to 16 (output 1 is LSB)
2	Discrepancy status channels 17 to 32 (output 17 is LSB)
3	Discrepancy status channels 33 to 40 (output 33 is LSB)

Table 14 Rack 8: DISCREP bit Descriptions

Each of the words reports the discrepancy status of 16 output channels. The corresponding bit within the word is set to ‘1’ when a discrepancy condition is detected on either the control output state or feedback input state for a particular field device (rack 2).

3.2.9. Rack 9: HKEEPING

Channel	Description				
	FCR		Units (Full Scale Range)		
1	A	24V2 Output Voltage	-32768	32767	mV
2	B				
3	C				
4	A	Internal supply voltage (post regulator)	-32768	32767	mV
5	B				
6	C				
7	A	Internal supply current (post regulator)	0	65535	mA
8	B				
9	C				
10	A	Output voltage (post isolation)	-32768	32767	mV
11	B				

Channel	Description				
	FCR		Units (Full Scale Range)		
12	C				
13	A	24V1 Output Voltage	-32768	32767	mV
14	B				
15	C				
16	A	HIU Board Temperature (Note: Temperature, ºC = input value / 256)	-32768	32767	-
17	B				
18	C				
19	A	Front Panel Load Current	0	65535	mA
20	B				
21	C				
22	A	SmartSlot Link Voltage	-32768	32767	mV
23	B				
24	C				
25	A	FIU Output Group 1 Field Supply Voltage	-32768	32767	mV
26	B				
27	C				
28	A	FIU Board Temperature, Output Group 1 (Note: Temperature, ºC = input value / 256)	-32768	32767	-
29	B				
30	C				
31	A	FIU Output Group 2 Field Supply Voltage	-32768	32767	mV
32	B				
33	C				
34	A	FIU Board Temperature, Output Group 2 (Note: Temperature, ºC = input value / 256)	-32768	32767	-
35	B				
36	C				
37	A	FIU Output Group 3 Field Supply Voltage	-32768	32767	mV
38	B				
39	C				
40	A	FIU Board Temperature, Output Group 3 (Note: Temperature, ºC = input value / 256)	-32768	32767	-
41	B				
42	C				
43	A	FIU Output Group 4 Field Supply Voltage	-32768	32767	mV

Channel	Description				
	FCR		Units (Full Scale Range)		
44	B				
45	C				
46	A	FIU Board Temperature, Output Group 4 (Note: Temperature, ºC = input value / 256)	-32768	32767	-
47	B				
48	C				
49	A	FIU Output Group 5 Field Supply Voltage	-32768	32767	mV
50	B				
51	C				
52	A	FIU Board Temperature, Output Group 5 (Note: Temperature, ºC = input value / 256)	-32768	32767	-
53	B				
54	C				
55	A	Diagnostic error code			
56	B				
57	C				

Table 15 Rack 9: Housekeeping Descriptions

Each input within the housekeeping rack is reported as an integer. In general, the application engineer will not normally require these inputs. They are provided to aid fault finding and diagnosis and may be used for reporting and display purposes.

3.2.10. Rack 10: INFO

The Information board supplies the user with information about the general health and status of the Module.

Channel	Description
1	Active Module chassis number
2	Active Module slot number
3	Active Module healthy
4	Active Module mode
5	Standby Module chassis number
6	Standby Module slot number

7	Standby Module healthy
8	Standby Module mode
9	FCR Status
10	Primary Module is active
11	Active Module is simulated

Table 16 Rack 10: INFO Descriptions

The Active Module chassis and slot numbers indicate the position of the currently Active Module. These values will change to match the primary or secondary Module position, depending on their Active status, i.e. Active/Standby changeover will “swap” the values for the Active Module chassis and slot number channels with those in the Standby Module chassis and slot number channels. The chassis and slot numbers are set to zero if the Module is not present.

The Active and Standby Module healthy channel is returned as an integer, however only the least significant bit is used. A value of 0 indicates that a fault has been detected, a non-zero value indicates that the Module is healthy.

The Active and Standby Module Mode is an integer indicating the current operating mode of the associated Module. The value indicates the current internal operating mode of the Module.

Value	Module Mode
5	Shutdown
4	Maintain
3	Active
2	Standby
1	Configuration
0	Unknown, no Module present

Table 17 rack 10: Module Mode Descriptions

The FCR Status channel reports the fault status of the Active and Standby Modules. The value is bit-packed as shown below, the least significant byte is used with the most significant 8-bits set to zero:

Bit Number							
7	6	5	4	3	2	1	0
Standby Module				Active Module			
Ejectors open	FCR C Healthy	FCR B Healthy	FCR A Healthy	Ejectors open	FCR C Healthy	FCR B Healthy	FCR A Healthy

Table 18 Rack 10 FCR bit Descriptions

The ‘Primary Module is active’ channel is set to non-zero if the primary Module is the current Active Module, i.e. the Active Module is in the chassis and slot numbers defined within the OEM parameters.

The ‘Active Module is simulated’ channel is set to non-zero if the Active Module is being simulated, this will only be set if the Module is not present or the simulation enable has been set within the Module’s configuration in the System.INI file.

3.2.11. Available MUX Channels

Valve test information is available through the use of a logical data multiplexer (or MUX). The user requests a specific data item by writing an index value to the MXOUT signal (Rack 5). The Module will respond by setting the MXIN value (Rack 4) to the same value as the MXOUT signal, and by providing the requested data item in MXDAT (Rack 4).

Changes to MXOUT do not have an immediate effect. One or more application scans is required before MXIN and MXDAT will reflect the changes made to MXOUT.

The following are valid index values for MXOUT. Indexes 10 to 15 are only available after a valve test that either completes (reaches its goal state within the allotted time) or fails (does not reach the goal state within the allotted time). After completion or end time, the timers will continue to run until the test initiation command is removed. Later state transitions will be recorded up to 32.766 seconds.

MUX Index	Description
0	Valve Test State
1	Time 1 (Test start or Command received to State 1)
2	Time 2 (Test start or Command received to State 2)

3	Time 3 (Test start or Command received to State 3)
4	Time 4 (Test start or Command received to State 4)
5	Time 5 (Test start or Command received to State 5)
6	Sampled ETIME
7	Sampled ESTATE
8	Feedback Input voltage
9	Raw feedback input voltage
10	Elapsed time since test start or command received
11	Time 1 (if State 1 was not reached by the end time)
12	Time 2 (if State 2 was not reached by the end time)
13	Time 3 (if State 3 was not reached by the end time)
14	Time 4 (if State 4 was not reached by the end time)
15	Time 5 (if State 5 was not reached by the end time)

Table 19 Rack 10: MUX Channels

Valve Test State is used to report the state of the valve test that is in progress. Valve Test State is an integer, with the following valid values:

Value	State	Description
0	Idle	There is no valve test in progress.
1	Test In Progress	A valve test is in progress.
2	Test Complete	The valve test has completed (successfully).
3	Test Error	There was an error and the valve test could not start.
4	Test Aborted	The valve test has been aborted.
5	Test Failure	The valve test has failed.

Table 20 Rack 10: Valve Test State Descriptions

The Valve Test State is reset to 0 on the falling edge of a TEST signal.

Time 1 … Time 5 are used to report the elapsed time (in milliseconds) from the start of the test until the feedback input state changes to the corresponding state when the Valve Test State is not 0 (Idle) or 4 (Test Aborted), (i.e. when the feedback input state changes from state 2 to state 3, the variable Time 3 will be updated with the time elapsed since the start of the test.).

In cases where a state is entered more than once (i.e. state 1 -> state 2 -> state 3 -> state 2), the corresponding Time variable will only be updated for the initial entry. If a feedback state is skipped, the corresponding Time variable will assume the same value as the next valid state (i.e. state 4 -> state 2, so Time 3 assumes the value of Time 2). If a Time variable has a value of 0, that state was not entered during the test.

Example:

The field device is a normally closed, normally energised valve with three limit switches: open, closed, and partial. An end of line device is used to combine the output of the limit switches into a single voltage level, and thresholds are established so that the feedback input states are as follows:

Feedback Input State	Limit Switch State		
	Valve is Closed	**Valve is Partially Open**	**Valve is Open**
5	TRUE	FALSE	FLSE
4	FALSE	FALSE	FLSE
3	FALSE	TRUE	FALSE
2	FALSE	TRUE	TRUE
1	Open Circuit Line Fault		

Table 21 Rack 10: Example - Valve Position Feedback

When the valve is closed, the feedback input state should be reported as 5. A minimal partial stroke is desired for the valve test, so we want the valve to move just enough to change the state of the Closed limit switch. We set ETIME to be 200 ms, and ESTATE to be 4. When the test is initiated, the normally energised valve is de-energised. After 120 ms the Feedback input state changes from 5 to 4. Since ESTATE is also 4 and we have not exceeded the 200 ms time limit set in ETIME, the test has completed successfully. All of the Time variables will be 0 except for Time 4 which will have the value of 120.

While the Valve Test State reports 1 (Test In Progress), the Time variables will be updated, but may not be complete until the test is completed.

The Time variables are also used to report the elapsed time (in milliseconds) from the change of a control output state until the feedback input state changes to the corresponding state. When the Valve Test State is reported as 0 (Idle) or 4 (Test Abort). The Time variables will be updated for a maximum of 32767 ms after control output is changed. The same rules for entering a state more than once or skipping a state from above are also enforced when recording the time for control output changes.

The Time variables are reported as integers with a maximum value is 32767. The Time variables are cleared to 0 on the falling edge of a TEST signal, when the control output is changed, or when a test is aborted for any other reason.

Feedback Input Voltage is used to report the voltage level as measured on the feedback input circuit. The voltage is the median value taken from the triplicated Module. The voltage level is reported as an integer, with the units being $^{1}/_{500}$V. This may be used directly, scaled arithmetically or scaled using the IEC 61131 TOOLSET conversion tables.

Sampled ETIME is used to report the value of ETIME used for the current valve test. It is cleared to 0 on the falling edge of a TEST signal.

Sampled ESTATE is used to report the value of ESTATE used for the current valve test. It is cleared to 0 on the falling edge of a TEST signal.

3.3. Sequence of Events Configuration

The Boolean variables from the DO / TEST board (Rack 1) and the Line Fault board (Rack 7) can be configured for automatic Sequence of Events (SOE) logging. A Boolean variable is configured for SOE during the variable definition in the Data Dictionary Editor. To select SOE, press the Extended Button in the Boolean Variable Definition Dialog Box to open the Extended Definition Dialog. Then check the box for Sequence of Events to enable the variable for automatic SOE logging.

In addition, the integer variables from the STATE board (Rack 2) can be configured for automatic Sequence of Events (SOE) logging in a similar manner.

During operation, the Module automatically reports time-stamped change of state information for the output data. The TMR Processor automatically logs change of state for configured SOE variables into the system SOE Log. The SOE Log can be monitored and retrieved using the SOE Collection Utility program running on the EWS.

3.4. System.INI File Configuration

There are many operating characteristics of the Module that can be customised for a particular application. The System Configuration Manager is a tool that allows the user to configure the specific operating characteristics for each Module. Descriptions of the items that may be configured for the T8449 are provided in Trusted Toolset Suite, publication ICSTT-RM249 (PD-T8082).

Certain characteristics apply to the entire Module and are considered Module Configurable Items. Other characteristics apply to individual output channels and are considered Channel Configurable Items. There are specific default settings for each of the configurable items. If the default settings are appropriate for a given application, customization of the Module definition in the System Configuration Manager is not required.

In order for short circuit detection to function while outputs are de-energised, a short circuit detection template is required.

4. Operation

4.1. Front Panel

Status indicators on the Front Panel of the Module provide visual indications of the Module's operational status and field output status. Each indicator is a bi-colour LED. Located at the top and bottom of each Module is an ejector lever that is used to remove the Module from the Chassis. Limit switches detect the open/closed position of the ejector levers. The ejector levers are normally latched closed when the Module is firmly seated into the Controller or Expander Chassis.

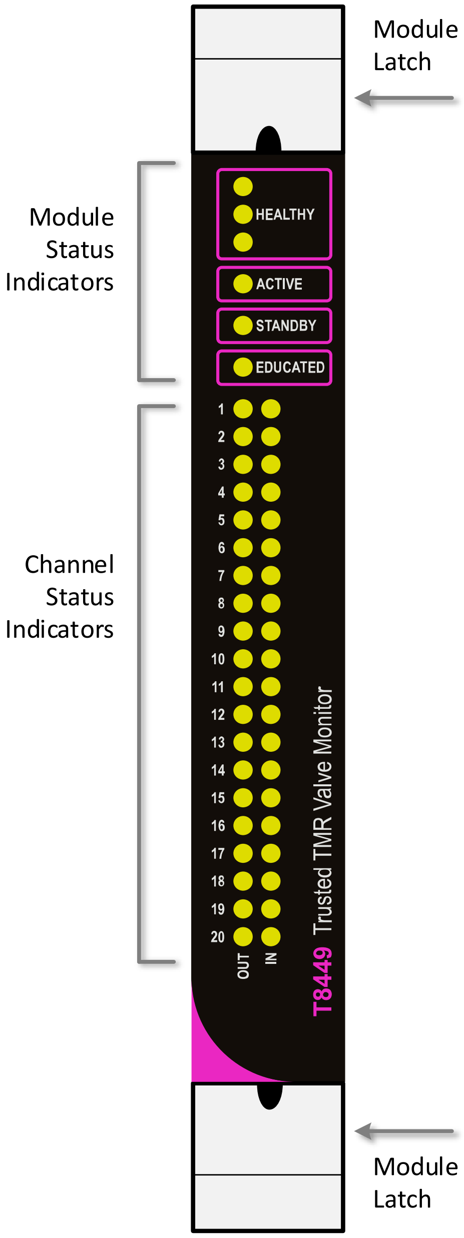

Figure 6 Module Front Panel

4.2. Module Status LEDs

There are six Module status indicators on the Module Front Panel: three Healthy, one Active, one Standby, and one Educated. The Healthy indicators are controlled directly by each Module slice. The Active, Standby, and Educated indicators are controlled by the FPU. The FPU receives data from each of the Module slices. It performs a 2oo3 vote on each data bit from the slices and sets the indicators accordingly.

The Module status indicator modes and their meanings are described as follows:

INDICATOR	STATE	DESCRIPTION
Healthy	Off	No power applied to the Module.
	Green	Slice is healthy.
	Red – flashing	Fault present on the associated slice.
	Red	Power applied to the associated slice.
Active	Off	Module is not in the Active state.
	Green	Module is in the Active (or Maintain) state.
	Red – flashing	Module is in the shutdown state.
Standby	Off	Module is not in the Standby state.
	Green	Module is in the Standby state.
	Red – flashing	Module is in the 'passive' shutdown state.
Educated	Off	Module is not educated.
	Green	Module is educated.
	Green – flashing	Education in progress.
	Amber - Flashing	Active/Standby changeover in progress.

Table 22 Module Status LEDs

4.3. I/O Status Indicators

There are 40 channel status indicators on the Module Front Panel, one for each control output and one for each feedback channel. These indicators are controlled by the FPU. The FPU receives data from each of the Module slices. The FPU performs a 2oo3 vote on each data bit from the slices and sets the indicators accordingly.

The control output status indicator mode is dependent upon the numerical state of the output channel. Each control output state can be defined to have a particular indicator mode: off, green, red, flashing green, or flashing red.

The feedback channel status indicator mode is dependent upon the numerical state of the feedback channel which is derived by comparing the feedback channel voltage level to a set of thresholds. Each feedback channel state can be defined to have a particular indicator mode: off, green, red, flashing green, or flashing red.

The configurable indicator modes allow users to customise the output status indications to suit individual application requirements. Without customisation, the default control output indicator modes are suitable for line-monitored digital output devices as described below:

INDICATOR STATE	DESCRIPTION
Off	Output is Off.
Green	Output is On.
Green – flashing	No Load, output open circuit.
Red	Field short circuit, output over current protection triggered and output channel is latched off.
Red – flashing	Channel fault, or no field supply voltage.

Table 23 I/O Status LEDs

The default status indicator mode for feedback channels is always off.

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5. Fault Finding and Maintenance

5.1. Fault Reporting

Module faults are reported to the user through visual indicators on the Front Panel of the Module and through status variables which may be automatically monitored in the application programs and external system communications interfaces. There are generally two types of faults that must be remedied by the user: external device and/or wiring and Module faults. External device and/or wiring faults require corrective action in the field to repair the fault condition. Module faults require replacement of the Module.

The TMR 24 Vdc Valve Monitor also reports valve test failures, which are considered device/wiring faults.

5.2. Field Device and Wiring Faults

By measuring the output channel voltage and current, the Module automatically detects field wiring and load faults. When a field signal fails open circuit, short circuit or there is not field supply voltage connected, the output status indicator will display the configured LED mode, the corresponding output state will be reported and the line fault status for that channel will be set to ‘1’. All other output channels will be unaffected, except in the case of common cause wiring and supply voltage faults in the field.

The field output voltage and current variables can be monitored to determine the actual operating conditions of each output channel. This additional information assists the user in determining the specific type of wiring fault.

Valve test failures are detected when a valve test is in progress. If a field wiring or load fault is detected during the test the test is aborted, the device is placed in its last commanded state, and the Module reports a field fault. The Module will also report a field fault if a valve test is aborted because the desired feedback state was not reached within the specified time limit.

Once the specific field wiring fault has been identified and corrected, the output status variables and output status indicator will display the normal on/off status of the field device.

5.3. Module Faults

Extensive diagnostics provide the automatic detection of Module faults. The TMR architecture of the Module and the diagnostics performed verify the validity of all critical circuits. Using the TMR architecture provides a Fault Tolerant method to withstand the first fault occurrence on the Module and continue normal output controls without interruption in the system or process. Faults are reported to the user through the Healthy status indicators on the Front Panel of the Module and through the INFO and HKEEPING variables. Under normal operations all three Healthy Indicators are green. When a fault occurs, one of the Healthy Indicators will be flashing red. This indicates that the Module should be replaced.

Module replacement activities depend on the type of spare Module configuration chosen when the system was configured and installed. It is recommended that this condition is investigated, and if the fault is within the Module, it should be replaced.

5.4. Companion Slot

For a Dedicated Standby Slot configuration, two adjacent slots in a Trusted Chassis are configured for the same Module function. One slot is the primary slot and the other slot is a unique secondary (or spare) slot. The two slots are joined at the rear of the Trusted Chassis with a doublewide I/O Interface Cable that connects both slots to common field wiring terminations. During normal operations, the primary slot contains the Active Module as indicated by the Active indicator on the Front Panel of the Module. The secondary slot is available for a spare Module that will normally be the Standby Module as indicated by the Standby indicator on the Front Panel of the Module.

Depending on the installation, a hot-spare Module may already be installed, or a Module blank will be installed in the Standby slot. If a hot-spare Module is already installed, transfer to the Standby Module occurs automatically when a Module fault is detected in the Active Module. If a hot-spare is not installed, the system continues operating from the Active Module until a spare Module is installed.

It is recommended that a check is carried out at 2 yearly intervals on the input channel calibration. This check will detect long term drift and any inaccuracy as a result. For more information, refer to the Recommended Proof Test Methods section of the Trusted TMR System Safety Manual, publication ICSTT-RM459.

5.5. SmartSlot

For a SmartSlot configuration, the secondary slot is not unique to each primary slot. Instead, a single secondary slot is shared among many primary slots. This technique provides the highest density of Modules to be fitted in a given physical space. At the rear of the Trusted Chassis, a single-wide I/O Interface Cable connects a primary slot to a unique Trusted Termination Assembly. The Trusted Termination Assembly has a SmartSlot Link Connector that is used for temporary connection to the shared SmartSlot in the Trusted Chassis.

When a primary Module has a failure and requires replacement, a second I/O Interface Cable is temporarily installed between the SmartSlot Link Connector on the associated Trusted Termination Assembly and the SmartSlot in the Trusted Chassis. With a spare Module installed in the SmartSlot and connected to the Trusted Termination Assembly, the SmartSlot can be used to replace the failed primary Module.

Output Module SmartSlot jumper cable TC-308-02.

SmartSlot between Chassis can be performed if the Chassis are version 2 (or higher). These have the connector fitted to enable connection of a TC-006 that verifies the 0 Volt of each Chassis is at the same potential.

5.6. Cold Start

If an I/O Module has shut down (due, for example, to two existing faults), the three Healthy LEDs will be red, the Active and Standby LEDs will be flashing red and the Educated LED will be flashing amber. The I/O functions provided by this Module will have been lost if a hot swap partner has not taken over control. The Module can only be restarted by removing it from its slot and re-inserting it.

If an I/O Module is inserted into a functional system slot which previously had no Active Module (e.g. removing and reinserting as above), then the Processor will educate the Module once it has booted. Once educated, the Educated LED will be steady green and the Active LED will be red flashing.

Input Modules will now be reading and reporting their inputs. Output Modules have not yet energised their outputs. To activate outputs and to set the Module’s Active LED and the Processor’s System Healthy LED steady green, press the Processor Reset pushbutton.

5.7. Transfer between Active and Standby Modules

The TMR Processor is responsible for managing a pair of I/O Modules through an Active/Standby changeover. The following rules apply to Active/Standby changeovers, though the TMR Processor and not the I/O Module enforces them:

- The user must define the primary, and optionally the secondary, I/O Module location for each I/O Module pair. Each primary Module location must be unique and is defined as part of the complex equipment definition within the IEC 61131 TOOLSET. Secondary Module locations can be unique or shared between multiple secondary Modules and are defined within the Module’s section within the System.INI file. The system will automatically determine the secondary Module position if the primary Module is installed and is operable.
- On initial start-up, if the primary Module is installed, it will become the Active Module by default. If the secondary Module has been defined within the System.INI file and no primary Module is present, and if the secondary Module location is unique, the secondary Module will become the Active Module by default. If the secondary Module is installed with no primary Module present, and the secondary Module location is not unique (as in a SmartSlot configuration), then NO Module for that Module pair will become Active.

- In order for a Module to become the Active Module, the TMR Processor will verify that the Module is the correct I/O Module type and that both Module Removal switches are closed. At this point the I/O Module is configured and eventually placed in the Active State.
- A Module in the Active State should never be removed.
- When a fault occurs on the Active Module, the TMR Processor will be informed. Once it becomes aware of the fault, the TMR Processor will attempt an Active/Standby changeover.
- An Active/Standby changeover starts with the TMR Processor checking to see if a Standby I/O Module is installed. If no Standby I/O Module is available, the TMR Processor will continue to utilise the Active Module and will continue to check for an available Standby I/O Module. Once a Standby Module is found, the TMR Processor will verify that the I/O Module is of the correct type, that both Module Removal switches are closed, and that the I/O Module is a part of the correct Module pair by using the SmartSlot link. At this point, the TMR Processor will configure the Standby I/O Module with the same configuration information as the currently Active I/O Module and place the Standby I/O Module into the Standby state. The Active Module is then placed in the maintain state (which suspends field loop testing), and any Module specific changeover data is transferred. The educated light flashes amber before the Active/Standby changeover takes place, to indicate transfer of dynamic change over data (COD). The previous Standby Module then becomes the Active Module and the original Module becomes Standby. If the currently Active Module does not successfully complete the self-tests, the TMR Processor will revert it to the Standby state, and the Module in the Maintain state will revert back to the Active State.
- When both Module Removal switches are opened on an Active Module, regardless of the Module fault status, the TMR Processor will treat it as a request to perform an Active/Standby changeover.

Under normal conditions, an Active/Standby changeover will only occur if the newly Active Module is fault free. Under some circumstances, it is desirable to be able to force a changeover to a known faulted Module. This can be accomplished by opening the Module Removal switches on the currently Active Module and pressing the reset pushbutton on the TMR Processor. This will force the changeover to proceed even if the newly Active Module is not fault free.

6. Safety Considerations

The Trusted TMR 24 Vdc Valve Monitor Module is currently TUV certified for Risk Class 6 safety critical outputs. A single Trusted TMR Valve Monitor Module may be used in both de-energise to trip, and energise to trip safety critical applications.

6.1. Line Monitoring Configurations

If energise to trip outputs are used in safety critical applications, line fault status shall be monitored by the system application and alarmed to plant operations personnel.

6.2. Module Configuration

In the System Configuration Manager there are configurable Module settings that shall be required or shall not be utilised on safety critical outputs. Where applicable, specific notes are used to bring attention to these requirements in the configuration description.

6.3. Locking and Forcing Control Outputs

When the control output channel command is locked from the IEC 61131 Toolset, the corresponding test initiation signal should be locked as well (i.e. always lock outputs in their control output / feedback input pairs). The Safety section of the Trusted Safety Manual contains additional information about locking and forcing of outputs.

6.4. Additional Safety Considerations

For additional safety considerations regarding the overall Trusted System, please refer to the Safety section of the Trusted Safety Manual.

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7. Specifications

Backplane (IMB) Supply Voltage Power	 20 Vdc to 32 Vdc 27 W
Field Supply Voltage Current	 18 Vdc to 32 Vdc 2 A per channel maximum (3).
Module Location	T8100, T8300 I/O Module Slot
Isolation Power Group to Power Group Field Common Channel to Channel (within Power Group)	 50 V Reinforced (continuous) (1) [Type tested at 1411 Vdc for 60 s]. 50 V Reinforced (continuous) (1) 250 V Basic (fault) (2) [Type tested at 2436 Vdc for 60 s]. None
Fusing	Not user serviceable
Number of Channels	40

Output	
Output Off State Resistance	33 kΩ
Output On State resistance	1.6 Ω
Current Rating (Continuous)	2 A per channel maximum (3).
Minimum On State Load Current	50 mA
Field Voltage Range	18 Vdc to 32 Vdc
Measurement Range	0 Vdc to +32 Vdc
Maximum Withstanding	-1 Vdc to +40 Vdc
Maximum Capacitance	at least 2800 µF at 2 A
Turn-on/off Delay	5 ms
Output Short Circuit Protection	Automatic
Input	
Impedance	33 kΩ
Analogue Resolution	12 Bit
Calibration Accuracy	0 V to VFIELD-4 V = 0.12 V VFIELD – 4 V to VFIELD = 0.48 V
Safety Accuracy	0.25 V
Output Short Circuit Protection	Electronic latching
Intrinsic Safety	None – External barrier required
Sequence of Events	
Event Resolution (LSB)	1 ms
Time-stamp Accuracy	±10 ms
Operating Temperature	0 °C to +60 °C (+32 °F to +140 °F)
Storage Temperature	-25 °C to +70 °C (-13 °F to +158 °F)
Relative Humidity - Operating and Storage	10 % – 95 %, non-condensing
Environmental Specifications	Refer to Document. ICSTT-TD003

Dimensions	
Height	266 mm 10.5 in)
Width	30 mm (1.2 in)
Depth	303 mm (12 in)
Weight	1.30 kg (2.7 lb)

Note 1) 50 Vrms Secondary circuit derived from Mains, OVC II up to 300V.

Note 2) 250 Vrms Mains circuit, OVC II up to 300V. Exposure to voltages at these levels shall be temporally constrained consistent with the system MTTR.

Note 3) Total current per Power Group is 8A for ambient temperature T, for 0 °C < T < 50 °C, and is 6A for 0 °C < T < 60 °C.