Trusted TMR Analogue Output Module – 40 Channel

Product Overview

The Trusted® TMR Analogue Output Module interfaces to 40 field devices. 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 40 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.

The Module provides on-board Sequence of Events (SOE) reporting with a resolution of 1 ms. An output change of state triggers an SOE entry. Output states are automatically determined by voltage and current measurements on-board the Module.

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

Features:

- 40 Triple Modular Redundant (TMR) output channels per Module.
- Comprehensive, automatic diagnostics and self-test.
- Automatic line monitoring per point to detect open circuit and 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 ms resolution.
- Module can be hot-replaced on-line using dedicated Companion (adjacent) Slot or SmartSlot (one spare slot for many Modules) configurations.
- Front Panel output status Light Emitting Diodes (LEDs) for each point indicate output status and field wiring faults.

- Front Panel Module status LEDs indicate Module health and operational mode (Active, Standby, Educated).
- TüV Certified for non-interfering applications, refer to the safety manual T8094.
- Outputs are powered in isolated groups of eight. Each such group is a Power Group (PG).

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, 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
7	Aug 05	Format /Text editing
8	Dec 06	Weights & Dims
9	Jul 07	Certification
10	Sep 07	Specification
11	Nov 07	STATE descriptions
12	Feb 08	Channel LED colours
13	Apr 10	Rack 7 table minor change
14	Jun 16	Rebranded and reformatted with correction to Relative Humidity Range and Operating Temperature statements in the Specification Section, also correction of any typographical errors
15	Jan 19	Updated Specifications section and main text to a more consistent format. Updated Front Panel section to updated product design. Updated to display Rockwell Automation publication numbers. Added trademarks statement.

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Table of Contents

1. Description

The TMR 4-20 mA Analogue Output Module is a member of the Trusted range of Input/Output (I/O) Modules. All Trusted 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).

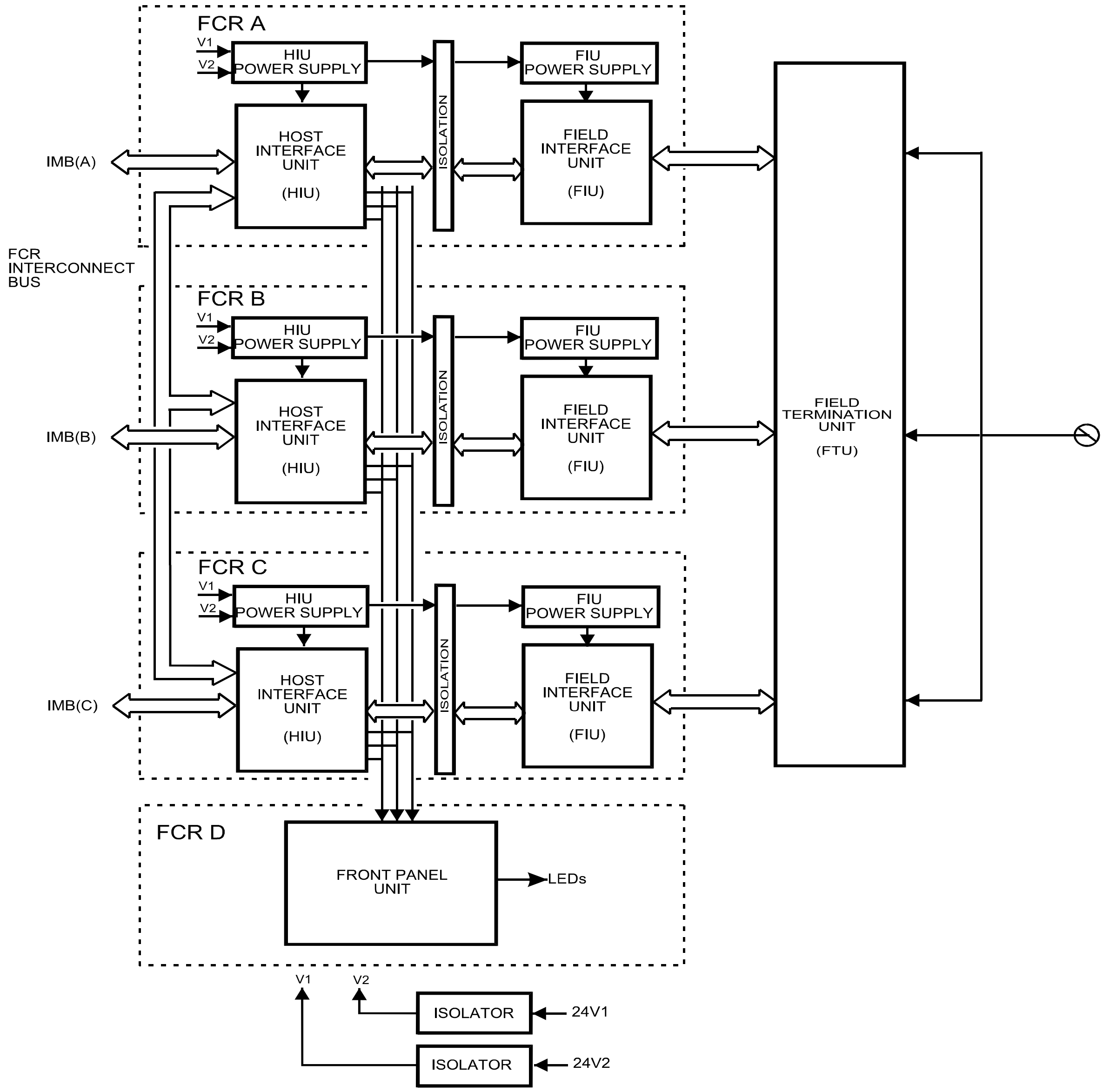

Figure 1 Module Architecture

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 block diagram of the Trusted 24 Vdc Analogue Output Module.

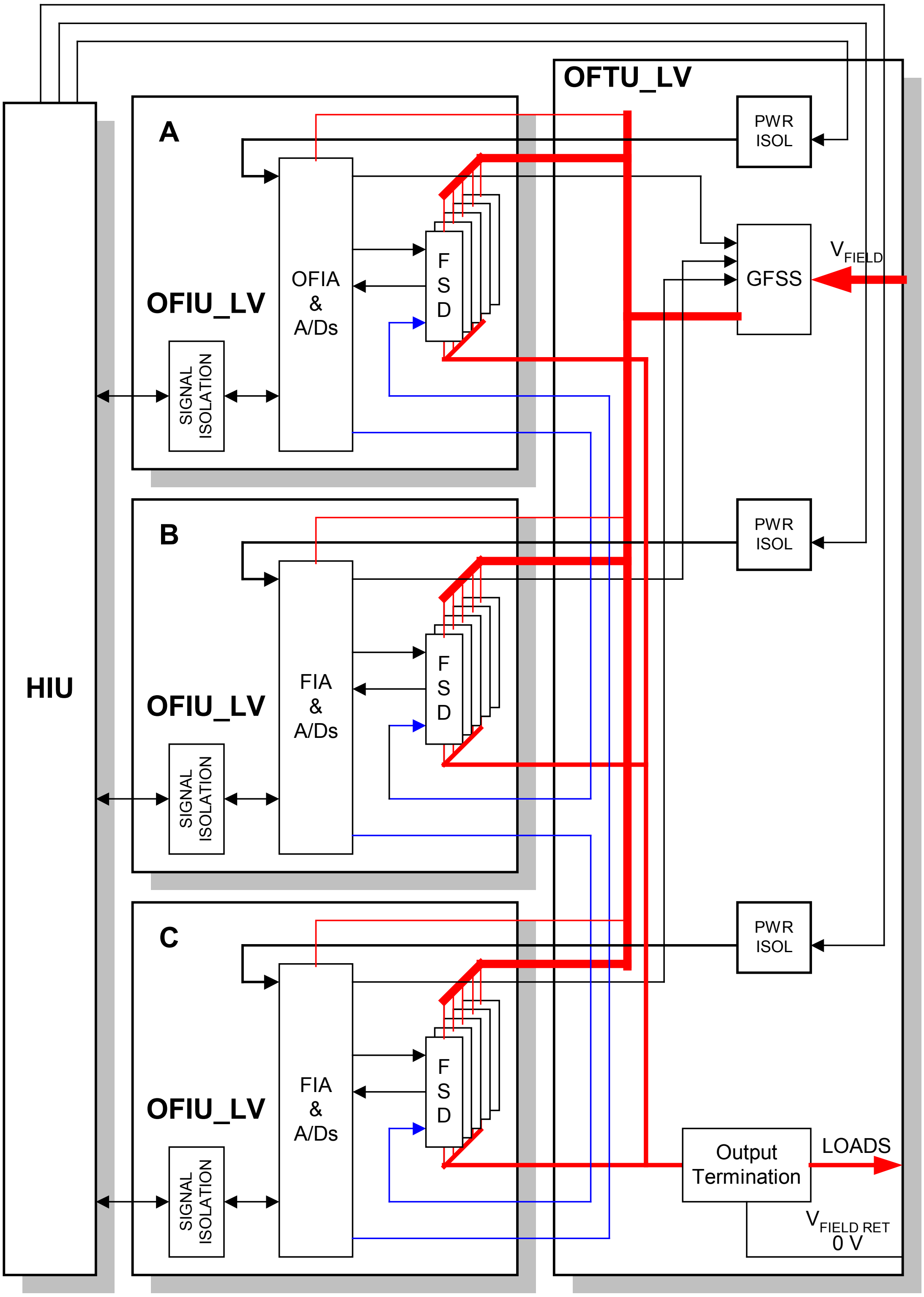

Figure 2 Functional Block Diagram

1.1. Output Field Termination Unit (OFTU)

The Output Field Termination Unit (OFTU) is the section of the I/O Module that connects all three AOFIUs to a single field interface. The OFTU 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 OFTU field connector interconnects to the Field I/O Cable Assembly attached at the rear of the Chassis.

The OFTU receives regulated power and drive signals from the HIU and provides magnetically isolated power to each of the three AOFIU's.

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

1.2. Analogue Output Field Interface Unit (AOFIU)

The Analogue Output Field Interface Unit (AOFIU) is the section of the Module that contains the specific circuits necessary to interface to the field I/O signals. Each Module has three AOFIUs, one per slice. For the TMR 24 Vdc Analogue Output Module, the AOFIU contains one slice of the output driver circuit, for each of the 40 field outputs.

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

The AOFIU 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 help 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 HIU slices.
- Serial data interface to the FPU for Module status LEDs.
- SmartSlot link between Active and Standby Modules for co-ordination 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 output channel current and voltage to determine the state of the output channel. The numerical output state and line fault status are reported back to the application and are represented below.

Description	Numerical Output State	Line Fault Status
Field Short Circuit (Not presently supported)	N/A	N/A
Output Energised (On)	4	0
No Load, Field Open Circuit (Vload > 16.5 V)	3	1
Output De-energised (command < -1024)	2	0
No Field Supply Voltage (Vfield < 18 V)	1	1

Table 1 Line Monitoring Fault Status

1.6. Housekeeping

The Output 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/Testing

Extensive diagnostics provide the automatic detection of Module faults. The TMR architecture of the Output 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. It is recommended that this condition is investigated and if the cause is within the Module, it 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 Companion 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-detecting Random Access Memory (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 (CRCs) to verify the variables and configuration stored in Flash memory.

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

The power supplies for both the HIU and AOFIU 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. An event occurs when the output transitions from one state to another. When a channel changes state, the on-board timer value is recorded. When the TMR Processor next reads data from the Output 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 output 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 Driver Structure

The Analogue Output Module provides a TMR driver topology where the load is driven by a total of three fully monitored, fail safe (6 element) driver channels, one physically resident on each AOFIU in the Module. Any single driver or entire slice failure is designed to leave two of the three fail safe driver channels operational to supply regulated current to the load.

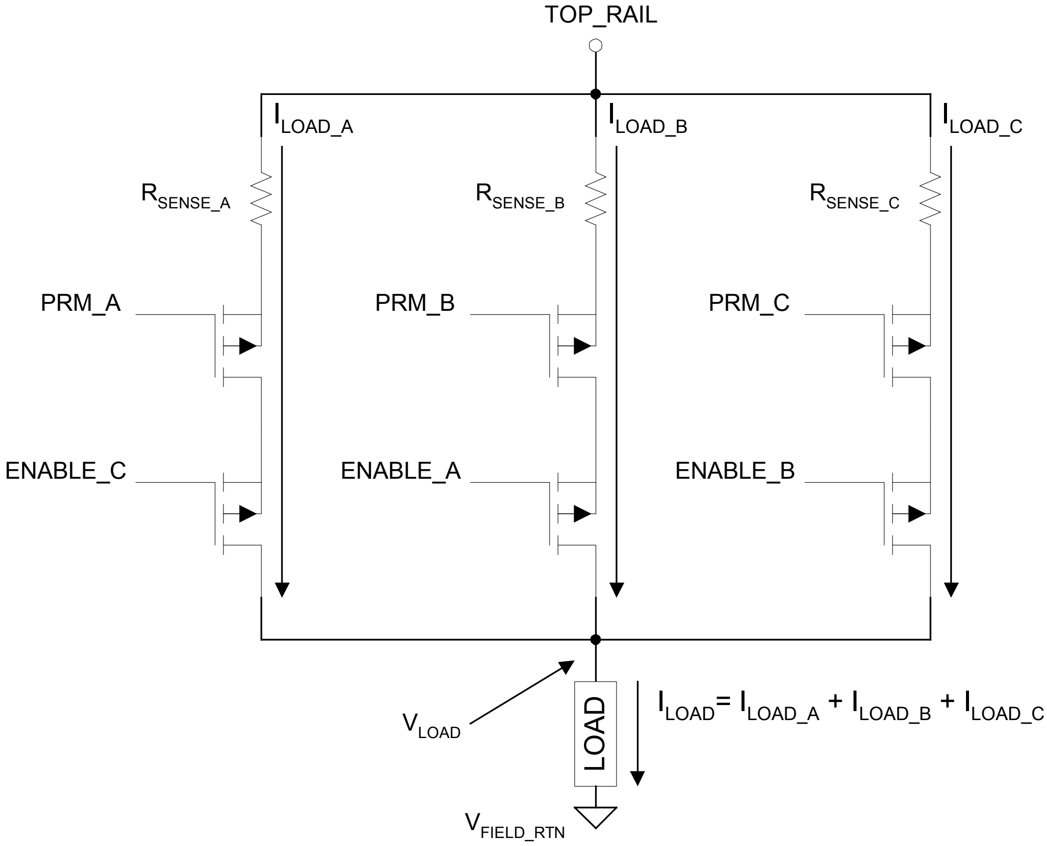

Figure 3 Output Driver Structure

The upper transistors shown in Figure 3 operate in the linear mode, and are controlled by the AOFIU on which they are physically resident.[1] The lower switches are N.C. (Normally Closed), and are controlled by the "upstream" neighbouring AOFIU.[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).

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.

[1] Their "home" AOFIU.

[2] The home AOFIU, supplies an independent control signal for the "downstream" AOFIU GFSS.

[3] For an un-faulted transistor.

The structure of each OFIU output driver is shown below:

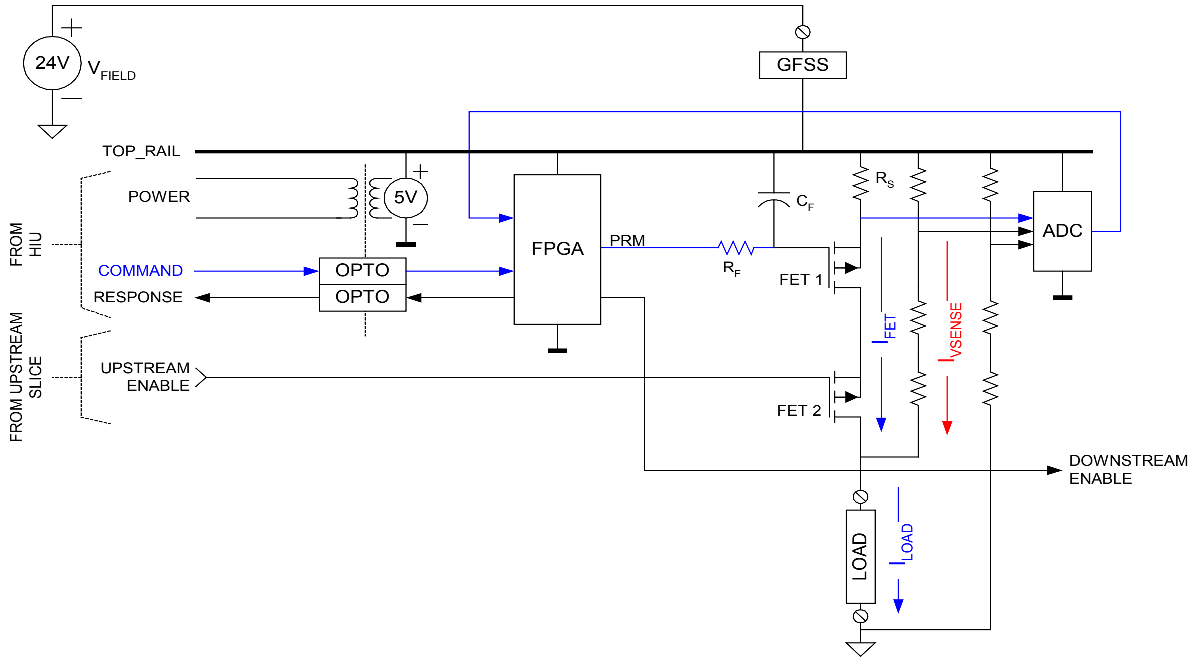

Figure 4 Simplified Driver Circuit Diagram

A sense resistor provides a means of continuously monitoring the output current, as measured with an analogue to digital converter (ADC) channel. Closed loop control logic in the Field Programmable Gate Array (FPGA) provides a Pulse-Ratio-Modulated drive signal to the gate of FET 1 to maintain a constant current equal to the commanded output, based on the ADC feedback.

A level translator transistor is used to drive the gate of FET 2. It provides FET 2 with a negative gate voltage, to minimize its on resistance, and serves to hold FET 2 on in the event that the secondary gate control loses power.

1.9.1. Output Channel Diagnostics

The measured output channel current is continuously monitored relative to the commanded output current, and compared to the current reported from each independent slice. In the event that there is a discrepancy that falls outside the authority of the control loop to overcome, then remedial action is engaged which disables FET 2 for the affected slice and causes the surviving slices to compensate in order to maintain the commanded current to the load.

The voltage across the load is also measured by each slice, and continuously compared for equality. If there is a discrepancy between the slices, then the discrepant slice is removed from service, and the survivors compensate to maintain the commanded current to the load.

Each channel is continuously monitored to determine the presence of field faults, such as an open circuit, or lack of field loop power.

Note that short circuits are not considered to be a fault condition for an analogue current output channel such as provided by this Module. The Module is designed to drive 20 mA indefinitely into 0 ohms. The channel voltages are provided to the application, where such a fault determination may be made if it is required.

1.9.2. Group Fail Safe Switches

To support safe operation, the Output Module is equipped with a series of switches that provide source power to a group of 8 output channels, a Power Group. The Output 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 Output 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 de-energising, 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 OFIU power supply and the associated GFSS control signal will also de-energise.

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2. Installation

2.1. Module Insertion and Removal

CAUTION:

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

Before installation, visually inspect the Module for damage. Ensure 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.

Ensure 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. Ensure 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. Ensure 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. Cable Selection

I/O cables suitable for use with the Trusted TMR Analogue Output Module are detailed in the following Product Descriptions:

- Trusted I/O Companion Slot Cables, publication ICSTT-RM311 (PD-TC200)
- Trusted TMR I/O SmartSlot Slot 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 type of Module.

Custom length multi-core FTA cables are 0.5 mm^2 with a resistance of 40 Ω/km. eg a 50 m cable will have 4 Ω loop impedance at 0.5 A, this equates to a 2 Vdc volt drop.

2.3. Termination

Unused outputs should be commanded off in the application and wired through a 10K 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 (+)	Pwr Group 1 (+)	Chan 1 (+)
4	Chan 6 (+)	Pwr Group 1 (+)	Chan 2 (+)
5	Pwr Group 1 Rtn	Pwr Group 1 (+)	Pwr Group 1 Rtn
6	Chan 7 (+)	Pwr Group 1 (+)	Chan 3 (+)
7	Chan 8 (+)	Pwr Group 1 (+)	Chan 4 (+)
8	-	-	-
9	Chan 13 (+)	Pwr Group 2 (+)	Chan 9 (+)
10	Chan 14 (+)	Pwr Group 2 (+)	Chan 10 (+)
11	Pwr Group 2 Rtn	Pwr Group 2 (+)	Pwr Group 2 Rtn
12	Chan 15 (+)	Pwr group 2 (+)	Chan 11 (+)
13	Chan 16 (+)	Pwr Group 2 (+)	Chan 12 (+)
14	-	-	-

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

Table 2 Field Connector Pin-out

2.5. Trusted Module Polarisation/Keying.

All Trusted Modules have been Keyed to help 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.

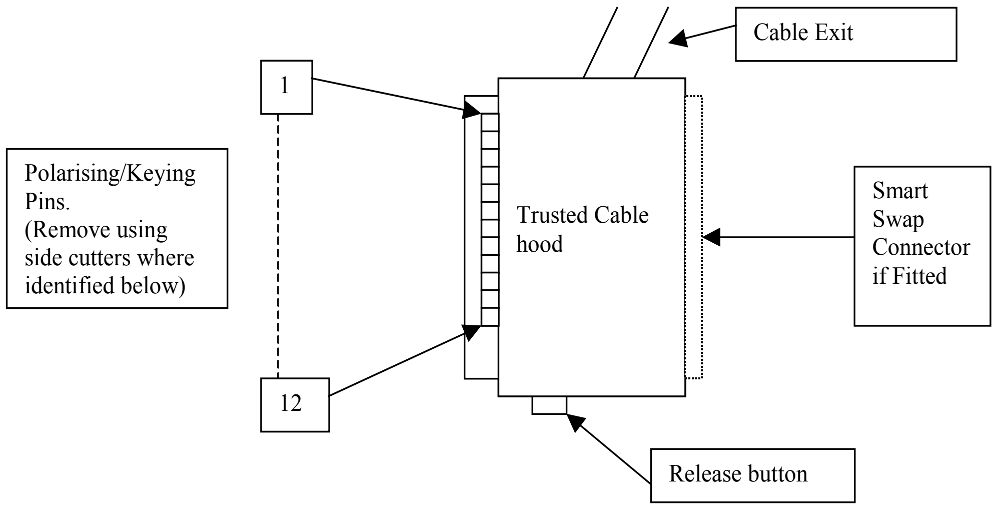

Figure 5 Module Polarisation

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

For this Module (T8480) remove keying pins 1, 6 and 7.

3. Application

3.1. Module Configuration

There is no configuration required to the physical Output 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 Output Module after applications are downloaded and during Active/Standby changeover.

The IEC 61131 TOOLSET provides the main interface to configure the Output 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 Output 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 default or fail safe states, and other Module settings.

3.2. T8480 Complex Equipment Definition

The T8480 I/O Complex Equipment Definition includes 8 I/O boards, referenced numerically by Rack number:

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
1	AO	OEM Parameters	-	-	-
		Field Output Status	Analogue	Out	40
2	STATE	Field Output State	Integer	In	40
3	AI	Output voltage	Integer	In	40
4	CI	Output current	Integer	In	40
5	LINE_FLT	Line Fault Status	Boolean	In	40

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
6	DISCREP	Channel Discrepancy	Integer	In	3
7	HKEEPING	Housekeeping Registers	Integer	In	57
8	INFO	I/O Module Information	Integer	In	11

Table 3 Complex Equipment Definition

There are two OEM parameters included in the first rack (AO 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	Notes
TICS_CHASSIS	The number of the Trusted Chassis where the Primary I/O Module is installed	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	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

3.2.1. Rack 1: AO

This board provides the connection to the logical output control signal for each of the field outputs.

Channel	Description
1	Field output channel 1 command
2	Field output channel 2 command
40	Field output channel 40 command

Table 5 Rack 1: AO Descriptions

The output command scaling is designed to be consistent with the T8431 Analogue Input Module. This relationship is described by the table below:

Command	Output Current
-1024	Off (Minimum leakage current flowing)
0	4 mA
4096	20 mA

Table 6 Rack 1: Output Current Descriptions

3.2.2. Rack 2: State

This board provides the majority voted numerical output state. This indicates the operational status of the output channel and associated field connection.

Channel	Description
1	Field output channel 1 state
2	Field output channel 2 state
40	Field output channel 40 state

Table 7 Rack 2: STATE Descriptions

Value	Description
7	Channel fault
6	Current demand cannot be met
5	Unused
4	Output energised (0+mA)
3	Open circuit in field wiring or load
2	Output de-energised (demand < 0 mA)
1	No field supply voltage

Value	Description
0	Unused

Table 8 Rack 2: STATE value Descriptions

3.2.3. Rack 3: AI

The AI board returns the field loop voltage at the output.

Channel	Description
1	Field output channel 1 voltage
2	Field output channel 2 voltage
40	Field output channel 40 voltage

Table 9 Rack 3: AI Descriptions

The voltage is the median value taken from the triplicated Module. The voltage level is reported as an integer, with the units being $^{1}/_{1000}$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 1000 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 ±32, corresponding to physical range –32000 to +32000.

3.2.4. Rack 4: CI

The CI board returns the field loop current at the output.

Channel	Description
1	Field output channel 1 current
2	Field output channel 2 current
40	Field output channel 40 current

TABLE 10 RACK 4: CI 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.

3.2.5. Rack 5: LINE_FLT

Channel	Description
1	Field output channel 1 line fault
2	Field output channel 2 line fault
40	Field output channel 40 line fault

Table 11 Rack 5: LINE_FLT 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.

3.2.6. Rack 6: DISCREP

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

Table 12 Rack 6: DISCREP 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 that output channel’s output state (rack 2).

3.2.7. Rack 7: 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				
12	C				
13	A	24V1 Output Voltage	-32768	32767	mV
14	B				
15	C				
16	A	HIU Board Temperature (Note: Temperature, °C = 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, °C = input value / 256)	-32768	32767	-
29	B				
30	C				

Channel	Description				
	FCR		Units (Full Scale Range)		
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, °C = 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, °C = input value / 256)	-32768	32767	-
41	B				
42	C				
43	A	FIU Output Group 4 Field Supply Voltage	-32768	32767	mV
44	B				
45	C				
46	A	FIU Board Temperature, Output Group 4 (Note: Temperature, °C = 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, °C = input value / 256)	-32768	32767	-
53	B				
54	C				
55	A	Diagnostic error code			
56	B				
57	C				

Table 13 Rack 7: 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. If a slice is Fatal, then all reported housekeeping inputs are set to zero.

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. If a slice is Fatal, then all reported housekeeping inputs are set to zero.

3.2.8. Rack 8: INFO

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 14 Rack 8: 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 15 Rack 8: INFO bit 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							
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 16 Rack 8: 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.

3.3. Sequence of Events Configuration

Each Boolean Output Variable can be configured for automatic Sequence of Events (SOE) logging. This applies to the Output Status and Line Fault Status variables. 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 to box for Sequence of Events to enable the variable for automatic SOE logging.

During operation, the Output 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 and Process Historian Package running on the EWS. This software package is described in Trusted Sequence of Events and Process Historian Package, publication ICSTT-RM243 (PD-T8013).

3.4. System.INI File Configuration

There are many operating characteristics of the Output 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 Trusted 24 Vdc Analogue Output Module T8480 are contained 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, then customization of the Module definition in the System Configuration Manager is not 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.

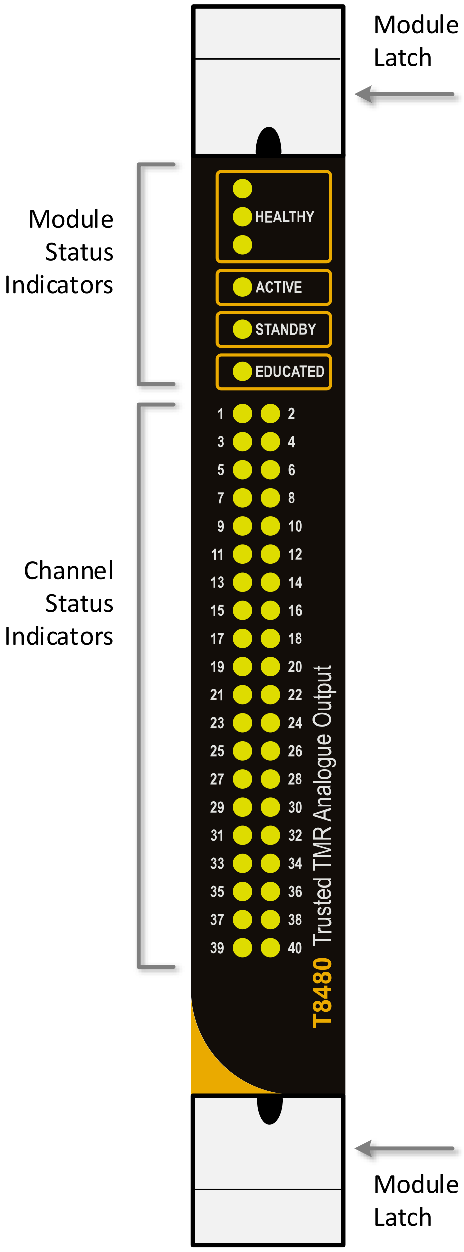

Figure 6 Module Front Panel

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.
	Amber	Slice is in the start-up state (momentary after installation or power-up).
	Green	Slice is healthy.
	Red – flashing	Fault present on the associated slice but the slice is still operational.
	Red (momentary)	On installation – power applied to the associated slice.
	Red	The associated slice is in the fatal state. A critical fault has been detected and the slice disabled.
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 if the Standby LED is off.
	Red – flashing	Module is in the fatal state if the Standby LED is also flashing.
Standby	Off	Module is not in the Standby state.
	Green	Module is in the Standby state.
	Red – flashing	Module is in the fatal state. The Active LED will also be flashing red.

Educated	Off	Module is not educated.
	Green	Module is educated.
	Green – flashing	Module is recognised by the Processor but education is not complete.
	Amber - Flashing	Active/Standby changeover in progress.

Table 17 Module Status LEDs

4.3. I/O Status LEDs

There are 40 output channel status indicators on the Module Front Panel, one for each field output. 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 output status indicator mode is dependent upon the numerical state of the output channel. Each output 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 indicator modes are suitable for line-monitored analogue output devices as described below:

INDICATOR STATE	DESCRIPTION
Off	Output is Off.
Green	Output is On.
Green – flashing	No Load, output open circuit.
Red	Current demand cannot be met.
Red – flashing	Channel fault, or no field supply voltage.

Table 18 I/O Status LEDs

Note: The LEDs indicating channel status may be configured to suit user requirements by implementing the procedure for configuring the System.INI file detailed in Trusted Toolset Suite, publication ICSTT-RM249 (PD-T8082).

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5. Fault Finding and Maintenance

5.1. Fault Reporting

Output 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 wiring and Module faults. External wiring faults require corrective action in the field to repair the fault condition. Module faults require replacement of the Output Module.

5.2. Field 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.

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 Output 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. It is recommended that this condition is investigated and if the cause is within the Module, it 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.

5.4. Companion Slot

For a Companion 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 a unique secondary (or spare) slot. The two slots are joined at the rear of the Trusted Chassis with a double-wide 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.

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 Cable connects the secondary slot directly to the I/O Cable connected to the failed primary Module. With a spare Module installed in the SmartSlot and the SmartSlot I/O Cable connected to the failed primary Module, 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 that 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 will be 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 new 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 new Active Module is not fault free.

6. Specifications

Backplane (IMB) Supply	
Voltage	20 Vdc to 32 Vdc
Power	22 W
Field Supply	
Voltage	18 Vdc to 32 Vdc
Maximum Current	0.9 A
Power Dissipation	
Field Supply at maximum channel current	28 W
System Supply	22 W
Module Location	T8100, T8300 I/O Module Slot
Isolation	
Power Group to Power Group	50 V Reinforced (continuous) (1) [Type tested at 1411 Vdc for 60 s].
Field Common	50 V Reinforced (continuous) (1) 250 V Basic (fault) (2) [Type tested at 2436 Vdc for 60 s].
Channel to Channel (within Power Group)	None
Fusing	Not user serviceable
Number of Outputs	40
Number of Power Groups	5 Each Power Group comprises 8 channels

Output	
Off State Leakage Current @ 24 V	350 µA max.
Current Rating (Continuous)	1 mA to 22 mA
Recommended Output Current	4 mA to 20 mA
Accuracy @ +25 °C	±0.1 % of Full Scale
Accuracy 0 °C to +60 °C	±0.2 % of Full Scale
Field Voltage Range	18 Vdc to 32 Vdc
Maximum Withstanding	-1 Vdc to +36 Vdc
Standby Swap Bump	±350 µA max for 7 sec max.
Fault Condition Bump	±10 mA max for 50 ms max.
Step Response Time	1 mA to 20 mA step change to 1 % of final value <50 ms
Output Short Circuit Protection	22 mA into 0 Ω
Maximum load resistance	See graph below.(3)
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	31 mm (1.2 in)
Depth	303 mm (12 in)
Weight	1.3 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) Maximum Load Resistance