T8461C

Rockwell Automation Trusted TMR 24/48 VDC Digital Output Module - 40 Channel

Verified product scope

- 40 TMR digital output channels arranged in five groups of eight.
- 18 to 58 VDC field supply and 20 to 32 VDC backplane supply.
- Automatic diagnostics, line monitoring, electronic overcurrent protection and 1 ms SOE resolution.
- Official module dimensions are 266 x 31 x 303 mm and official weight is 1.3 kg.

Source and identification note

Rockwell Automation ICSTT-RM451D-EN-P, PD-T8461 Issue 16

Rockwell Automation's current product page lists T8461C as Active. Country of origin must follow the supplied unit and current manufacturer documentation; the current product page lists Mexico while noting that manufacturing location can vary.

Request a quotation	Product reference	
info@apterpower.com +86 18106909650 www.apter.com/inquiry.php	T8461C	

The following pages are selected from the manufacturer publication identified above. External interactive links and unrelated contact pages have been removed for web delivery.

Trusted TMR 24V DC/48V DC Output Module - 40 Channel

PD-T8461 Issue 16

Rockwell Automation Publication ICSTT-RM451D-EN-P - March 2021
Supersedes Publication ICSTT-RM451C-EN-P - January 2019

Rockwell Automation

Product Description Original Instructions

Product overview

The Trusted® Triple Modular Redundant (TMR) 24V DC / 48V DC Digital 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 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 onboard 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 onboard 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 TMR output channels per Module.
- Comprehensive, automatic diagnostics and self-test.
- Automatic line monitoring per channel to detect open circuit and short circuit field wiring and load faults.
- 2500V impulse withstand opto/galvanic isolation barrier.
- Automatic overcurrent protection (per channel), no external fuses required.
- Onboard Sequence of Events (SOE) reporting with 1 ms resolution.
- Module can be hot-replaced online using dedicated Companion (adjacent) Slot or SmartSlot (one spare slot for many Modules) configurations.
- Front Panel output status light-emitting diodes (LEDs) for each channel indicate output status and field wiring faults.
- Front Panel Module status LEDs indicate Module health and operational mode (Active, Standby, Educated).
- TÜV Certified IEC 61508 SIL 3.
- Outputs are powered in isolated groups of eight. Each such group is a Power Group (PG).

Description

The TMR 24V DC/48V DC Digital 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).

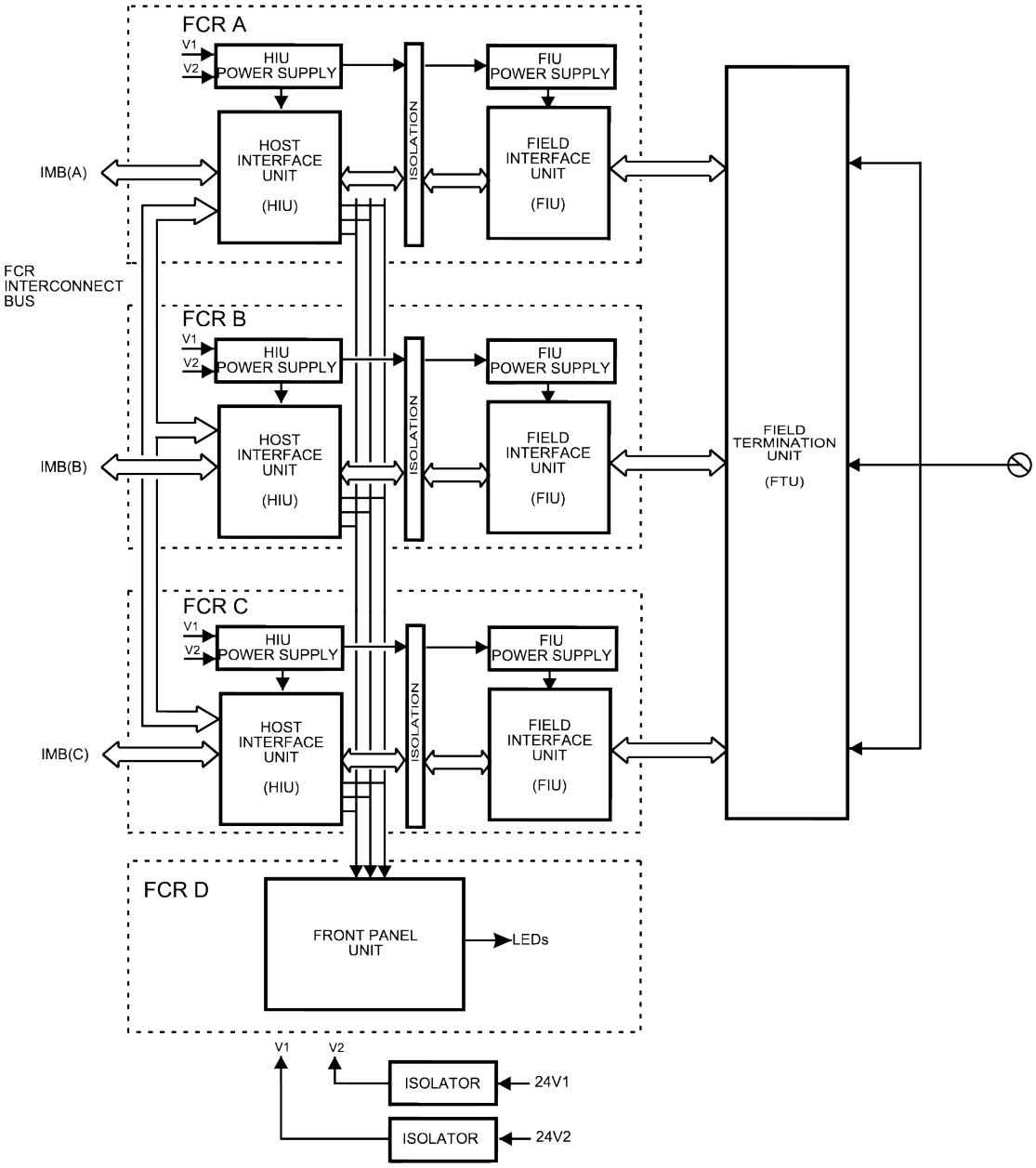

Figure 1: Module Architecture

All High Integrity I/O Modules are made up of four 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 24/48V DC Digital Output Module.

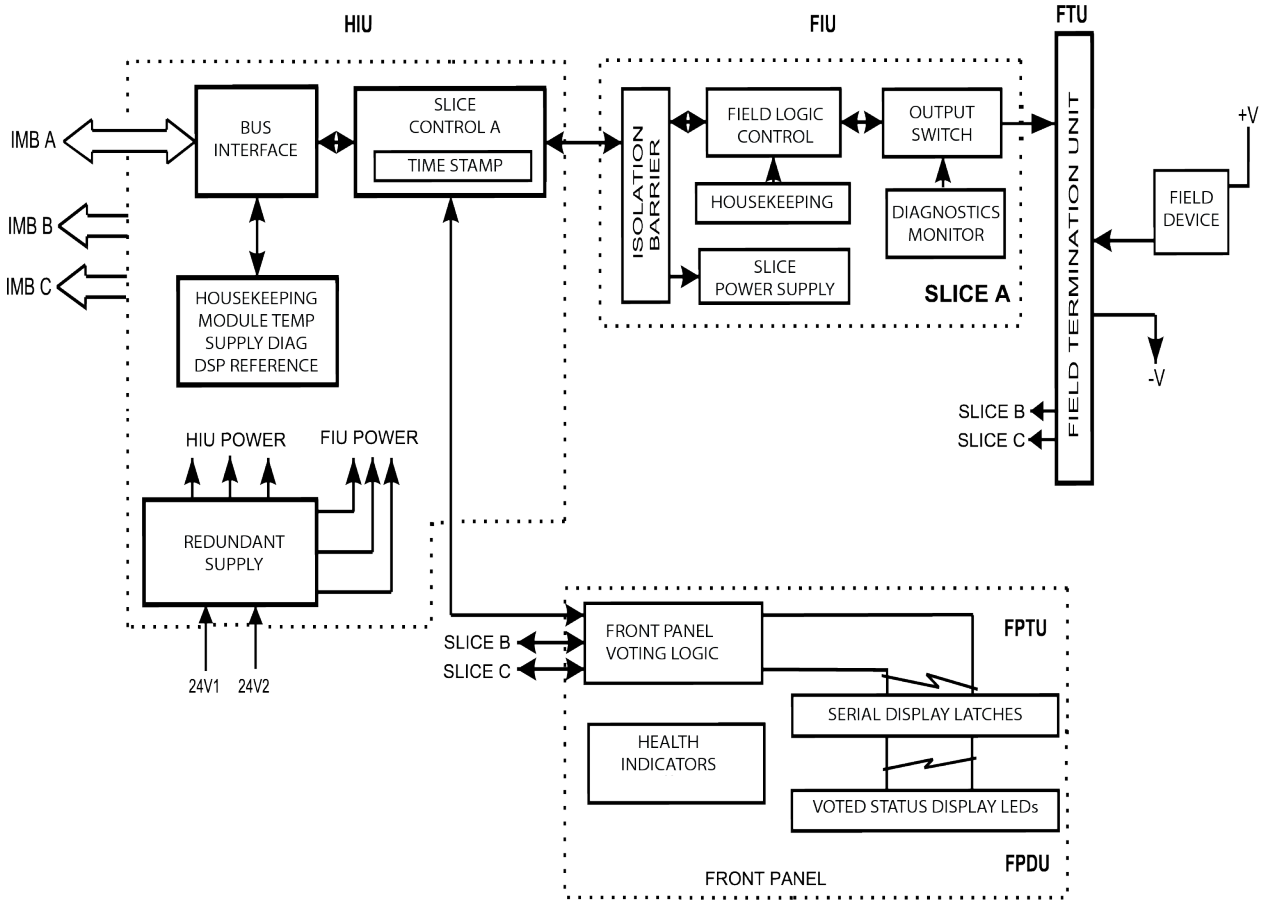

Figure 2: Functional Block Diagram

Field Termination Unit (FTU)

The Field Termination Unit (FTU) is the section of the I/O Module that connects all three FIUs to a field interface. The FTU provides the Group Fail-Safe switches and passive components necessary for signal conditioning, overvoltage 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.

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 24V DC/48V DC Digital Output Module, the FIU contains one stage of the output switch structure, and sigma-delta (ΣΔ) output circuit for each of the 40 field outputs. Two additional ΣΔ circuits provide optional monitoring of the external field I/O supply voltage.

The FIU receives isolated power from the HIU for logic. The FIU provides additional power conditioning for the operational voltages that are 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 onboard "housekeeping" signals that help in monitoring the performance and operating conditions of the Module. These signals include power supply voltages, current consumption, onboard reference voltages, and board temperature.

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 24V DC 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.
- Onboard housekeeping, which monitors reference voltages, current consumption and board temperature.

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, the Educated LED indicators, and the Module removal switches. Additional bicolor 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.

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.

Table 1 Line Monitoring Fault Status

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

It is recommended to fit a dummy load resistor to unused outputs so that a current is drawn that exceeds the NO-LOAD threshold. This helps prevent the Module from signaling a NO-LOAD fault.

Housekeeping

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

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 that is reported to the TMR Processor. Under normal operations, all three Healthy indicators are green. When a fault occurs, one of the Healthy indicators flashes 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 that is 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-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 onboard 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 synchronized and monitored for variance. Both FIU and HIU have onboard temperature sensors to characterize 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 Subsystem.

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 onboard 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 Product Description, publication ICSTT-RM243.

Output Switch Structure

The Digital Output 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 FIU 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.

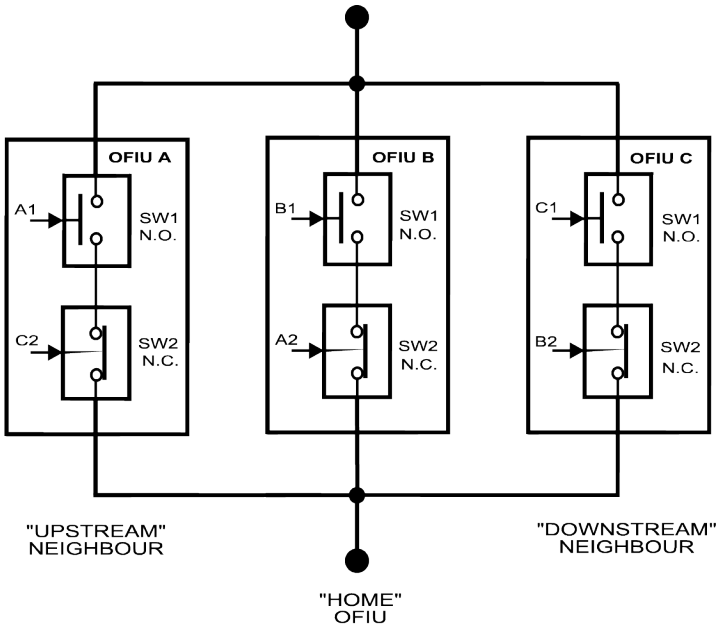

Figure 3: Output Switch Structure

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" neighboring FIU[2].

Tip: 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 carries the necessary control.

The structure of each FIU output is shown in this diagram:

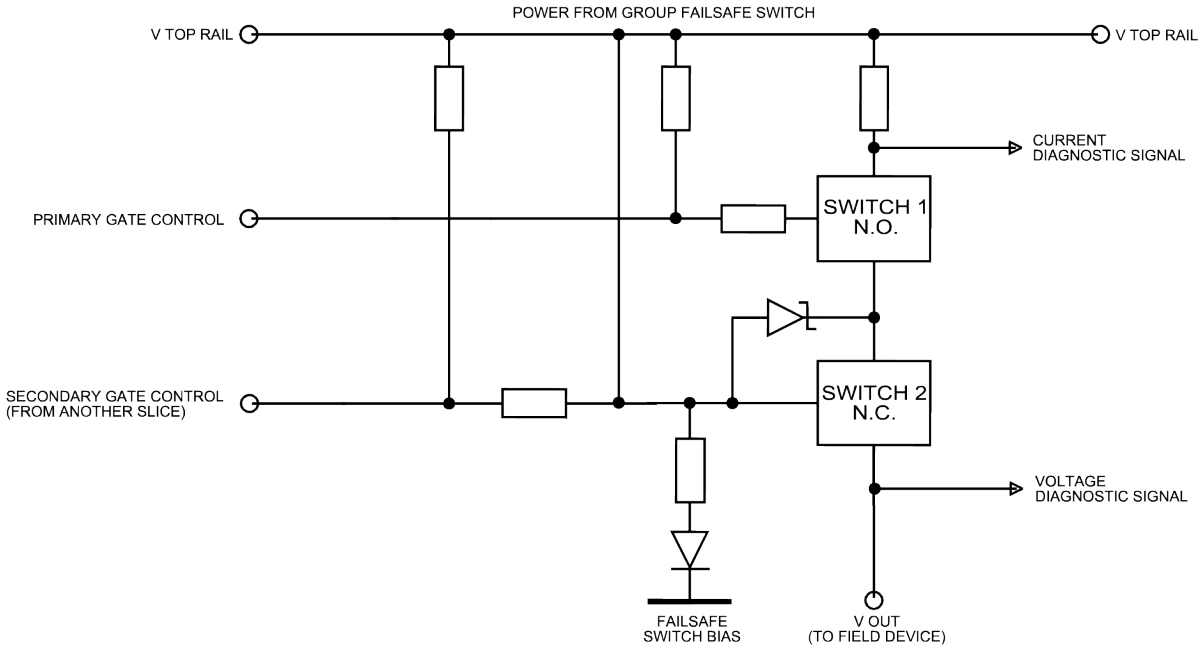

Figure 4: Simplified Switch Circuit Diagram

A 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 minimize its on resistance, and serves to hold Switch 2 on in case 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.

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[1] Their "home" FIU.

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

[3] For an unfaulted transistor.

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

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 analyzes 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 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.

Short Circuit Protection

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

While energizes, the channel output current is monitored to protect the channel switches from damage by a sustained overcurrent condition. Having detected a sustained overcurrent condition a short-circuit fault state is latched and the output is de-energized.

While de-energized, the output may be optionally be configured to detect short-circuit field faults (resistance less than 40 Ω) through System .INI file configuration. The detection of short-circuits while de-energized relies upon a partial energizing of the field circuit to determine the channel load resistance. The partial energizing of a field circuit is designed to constrain any change in field voltage or current to less than 2V or 100 mA, respectively.

A latched short-circuit fault state 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

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 eight output channels, a Power Group. The output Module Group Fail-Safe Switch (GFSS) is intended

as a final control switch, which can de-energize any outputs that cannot be de-energized in the normal way. For safety, the presence of two or more faults within the Output Module causes the Group Fail-Safe Switches to de-energize, resulting in all outputs in its group to de-energize.

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 neighboring slices. This means that if one slice determines from the output states that an output is not in a de-energized state when it should be, then it can command its own GFSS and those of the other slices GFSS to de-energize. This results in two of the three elements of the GFSS structure to de-energize, leaving only one GFSS element energized. If two slices do the same thing, then the last GFSS output de-energizes. For example, this would occur if two or more output switch elements fail in a 'stuck-on' state such that the output cannot de-energize.

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-energized by stopping the comms clock. If a slice fails, the watchdog on the HIU times out and resets the slice, this shuts down the FIU power supply and the associated GFSS control signal also de-energizes.

Installation

Module Insertion and Removal

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.

WARNING: 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.

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.

Cable Selection

I/O cables suitable for use with the Trusted TMR 24/48V DC Digital Output Module are detailed in the following Product Descriptions.

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

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

Custom length multi-core FTA cables are 0.5 mm^2 with a resistance of 40 Ω/km. For example, a 50-m cable has 4-Ω loop impedance at 0.5 A, this equates to a 2V DC volt drop.

Termination

Unused outputs should be commanded off in the application and wired through a 10K 0.5-W resistor to zero volts.

Module Pin-out Connections

This table describes the module pin-out connections:

Table 2 Field Connector Pin-out

	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			
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 (+)
32	Chan 40 (+)	Pwr Group 5 (+)	Chan 36 (+)
32			

Trusted Module Polarisation/Keying

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

Each Module type has been keyed during manufacture. The organization 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 that are fitted to the associated Module before fitting.

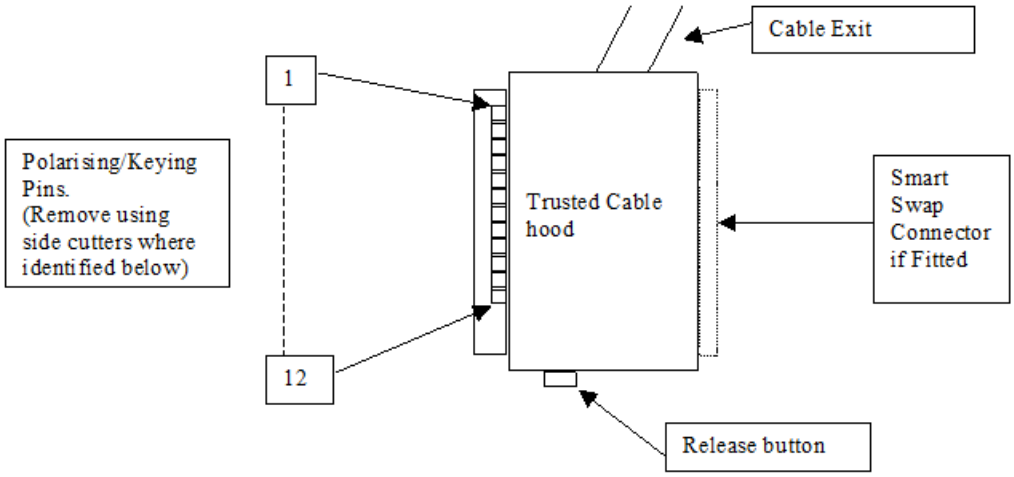

Figure 5: Module Polarization

For Cables with Companion slot installations, both keying strips must be polarized.

For this Module (T8461) remove keying pins 1, 5 and 7.

Application

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 Trusted Toolset Suite Product Description, publication ICSTT-RM249 (PD-T8082). There are three procedures necessary to configure the Output Module:

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, for example, 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.

T8461 Complex Equipment Definition

The T8461 I/O Complex Equipment Definition includes eight I/O boards, referenced numerically by Rack number:

Table 3 Complex Equipment Definition

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
1	DI	OEM Parameters	-	-	-
		Field Output Status	Boolean	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
6	DISCREP	Channel Discrepancy	Integer	In	3
7	HKEEPING	Housekeeping Registers	Integer	In	57
8	INFO	I/O Module Information	Integer	In	11

There are two OEM parameters that are 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, for example, 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.

Table 4 OEM Parameters

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.

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

Table 5 Rack 1: DO descriptions

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

The user application should set the output control signal to true (logic '1') to turn ON or energize an output, and false (logic 'o') to turn OFF or de-energize an output.

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

Table 6 Rack 2: STATE bit Descriptions

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 Output Descriptions

Channel	Description
7	Channel fault

Table 7 Rack 2: State Output Descriptions

Channel	Description
6	Field fault (for example, field leakage to 0V or 24V)
5	Short circuit in field wiring or load
4	Output energized (ON)
3	Open circuit in field wiring or load
2	Output de-energized (OFF)
1	No field supply voltage
0	Unused

Rack 3: AI

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

Table 8 Rack 3: AI Descriptions

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

The voltage is the median value that is taken from the triplicated Module. The voltage level is reported as an integer, with the units being 1/500V. 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.

Rack 4: CI

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

Table 9 Rack 4: CI Descriptions

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

The current is the sum value that is taken from the triplicated Module. The current level is reported as an integer, with the units being 1/1000A. 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.

Rack 5: LINE_FLT

This table describes Rack 5: LINE_FLT:

Table 10 Rack 5: LINE_FLT Descriptions

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

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.

Rack 6: DISCREP

This table describes Rack 6: DISCREP:

Table 11 Rack 6: DISCREP bit Descriptions

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)

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).

Rack 7: HKEEPING

This table describes Rack 7: HKEEPING.

Table 12 Rack 7: Housekeeping Descriptions

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)	-32768	32767	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	-32768	32767	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	1/500V
26	B				
27	C				
28	A	FIU Board Temperature, Output Group 1 (Note: Temperature, °C = input value / 256)	-32768	32767	-
29	B				
30	C				
31	A	FIU Output Group 2 Field Supply Voltage	-32768	32767	1/500V
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	1/500V
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	1/500V
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	1/500V

Channel	Description				
	FCR		Units (Full Scale Range)		
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				

Each input within the housekeeping rack is reported as an integer. In general, the application engineer does 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.

Rack 8: INFO

This table describes Rack 8: INFO:

Table 13 Rack 8: INFO Descriptions

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

The Active Module chassis and slot numbers indicate the position of the currently Active Module. These values change to match the primary or secondary Module position, depending on their Active status, that is, Active/Standby changeover “swaps” 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 nonzero 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.

Table 14 Rack 8: INFO bit Descriptions

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

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:

Table 15 Rack 8: FCR bit Descriptions

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

The 'Primary Module is active' channel is set to nonzero if the primary Module is the current Active Module, that is, the Active Module is in the chassis and slot numbers defined within the OEM parameters.

The 'Active Module is simulated' channel is set to nonzero if the Active Module is being simulated, this is only set if the Module is not present or the simulation enable has been set within the Module's configuration in the System.INI file.

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 the 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 Product Description, publication ICSTT-RM243 (PD-T8013).

Operation

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 bicolor LED. 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.

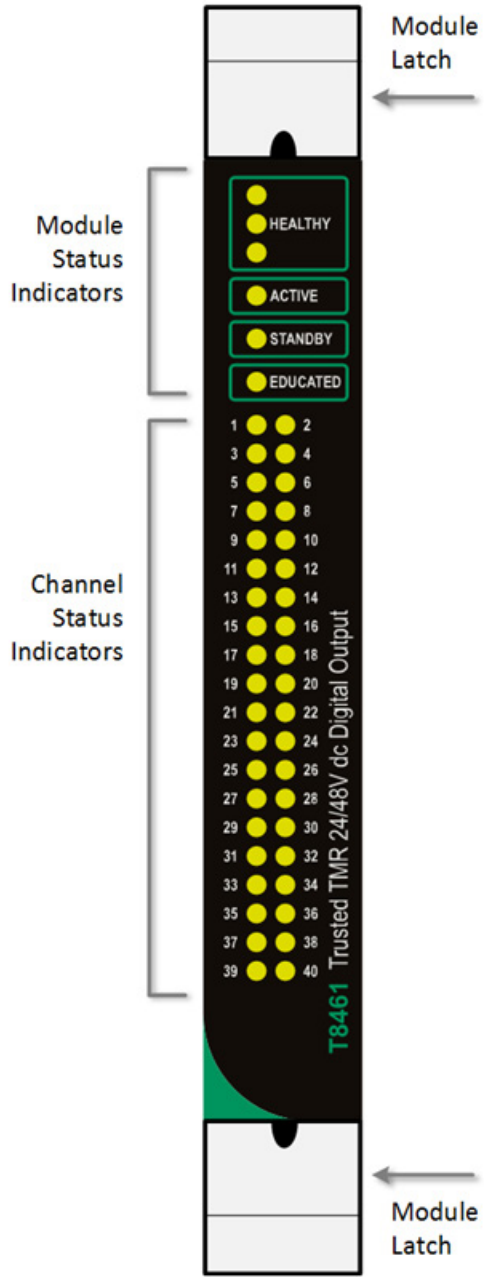

Figure 6: Module Front Panel

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 2003 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:

Table 16 Module Status LEDs

Indicator	State	Description
Healthy	Off	No power applied to the Module.
	Amber	Slice is in the startup 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 is also flashing red.
Educated	Off	Module is not educated.
	Green	Module is educated.
	Green – flashing	Module is recognized by the Processor but education is not complete.
	Amber - Flashing	Active/Standby changeover in progress.

I/O Status Indicators

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 2003 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 customize the output status indications to suit individual application requirements. Without customization, the default indicator modes are suitable for line-monitored digital output devices as described here:

Table 17 I/O Status LEDs

Channel	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.

Tip: 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 Product Description, publication ICSTT-RM249 (PD-T8082).

Fault Finding and Maintenance

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.

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 no field supply voltage connected, the output status indicator displays the configured LED mode, the corresponding output state is reported and the line fault status for that channel is set to '1'. All other output channels are 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 display the normal on/off status of the field device.

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 is flashing red. It is recommended that this condition is investigated and if the fault is within the Module, it should be replaced.

Module replacement activities depend on the type of spare Module configuration that is 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.

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 is normally 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 is 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.

SmartSlot

For a SmartSlot configuration, the secondary slot is not unique to each primary slot. Instead, a 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 Smart Slot jumper cable TC-308-02

Smart Slot 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.

Cold Start

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

If an I/O Module is inserted into a functional system slot that previously had no Active Module (for example, removing and reinserting as above), then the Processor educates the Module once it has booted. Once educated, the Educated LED becomes steady green and the Active LED becomes red flashing.

Input Modules are now reading and reporting their inputs. Output Modules have not yet energized 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 push button.

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 automatically determines the secondary Module position if the primary Module is installed and is operable.
- On initial startup, if the primary Module is installed, it becomes 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 becomes 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 becomes Active.
- In order for a Module to become the Active Module, the TMR Processor verifies 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 is informed. Once it becomes aware of the fault, the TMR Processor attempts 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 continues to use the Active Module and continues to check for an available Standby I/O Module. Once a Standby Module is found, the TMR Processor verifies 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 configures 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 reverts it to the Standby state, and the Module in the Maintain state reverts to the Active state.

- When both Module Removal switches are opened on an Active Module, regardless of the Module fault status, the TMR Processor treats it as a request to perform an Active/Standby changeover.

Under normal conditions, an Active/Standby changeover only occurs 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 push button on the TMR Processor. This forces the changeover to proceed even if the new Active Module is not fault free.

Specifications

This table lists the module specifications:

Item	Description
Backplane (IMB) Supply	
Voltage	20V DC to 32V DC
Power	26 W
Field Supply	
Voltage	18V DC to 58V DC
Maximum Current	30 A
Power Dissipation	
Field Supply at maximum power group current.	36 W
System Supply	26 W
Module Location	T8100, T8300 I/O Module Slot
Isolation	
Power Group to Power Group	50V Reinforced (continuous)[4] [Type tested at 1411V DC for 60 s].
Field Common	50V Reinforced (continuous)[5] 250V Basic (fault)[6] [Type tested at 2436V DC for 60 s].
Channel to Channel	None
Fusing	Not user serviceable
Number of Outputs	40
Number of Power Groups	5 Each Power Group comprises 8 channels
Output	
Output On State resistance	1.6 Ω
Maximum Current Rating (Continuous)	0.75 A per channel
Minimum On State Load Current	25 mA
Current Measurement Range	0 A to 1.35 A ±5% / ±5 mA[7]
Voltage Measurement Range	0V DC to +58V DC ±2V DC
Maximum Withstanding	-1V DC to +60V DC
Channel to Channel Crosstalk	< 1%
Maximum Load Capacitance	500 µF
Output Short Circuit Protection	Electronic latching
Sequence of Events	
Event Resolution (LSB)	1 ms
Time stamp Accuracy	±10 ms

[4] 50 Vrms Secondary circuit derived from Mains, OVC II up to 300V.

[5] 50 Vrms Secondary circuit derived from Mains, OVC II up to 300V.

[6] 250 Vrms Mains circuit, OVC II up to 300V. Exposure to voltages at these levels shall be temporally constrained consistent with the system MTTR.

[7] Tolerance is ±5 mA up to 0.9 A, thereafter is ±5%.

Item	Description
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%, noncondensing
Environmental Specifications	See Trusted 8000 Series International Safety and Environmental Approvals, publication ICSTT-TD003
Dimensions	
Height	266 mm (10.5 in)
Width	31 mm (1.2 in)
Depth	303 mm (12.0 in)
Weight	1.3 kg (2.7 lb)