Trusted™ TMR 24Vdc Analogue Input Module – 40 Channel

Introduction

The Trusted™ TMR 24V dc Analogue Input module interfaces to 40 sourcing field input devices, acting as a current sink for all these devices. Comprehensive diagnostic tests are performed on each input channel. Fault tolerance is achieved through a Triple Modular Redundant (TMR) architecture within the module for each of the 40 input channels.

Using the built-in line-monitoring feature, the module can detect open and shorted field cables. Line monitoring functions are independently configured for each input channel.

The module provides on-board Sequence of Events (SOE) reporting with a resolution of 1ms. A change of state triggers an SOE entry. States are determined by voltage thresholds that can be configured on a per channel basis. When the field voltage and field return are connected to the auxiliary input channels of the module, thresholds can be specified as a ratio of the field supply voltage.

Features

- 40 Triple Modular Redundant (TMR) input channels per module.
- Comprehensive, automatic diagnostics and self-test.
- Selectable line monitoring per channel to detect open circuit and short circuit field wiring faults.
- 2500Vdc opto/galvanic isolation barrier.
- On-board Sequence of Events (SOE) reporting with 1ms resolution.
- Module can be hot-replaced on-line using dedicated Companion (adjacent) Slot or SmartSlot (one spare slot for many modules) configurations.
- Front panel input status LEDs for each channel indicate input 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

1. Description

The TMR 24V dc Analogue Input 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 Trusted™ 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).

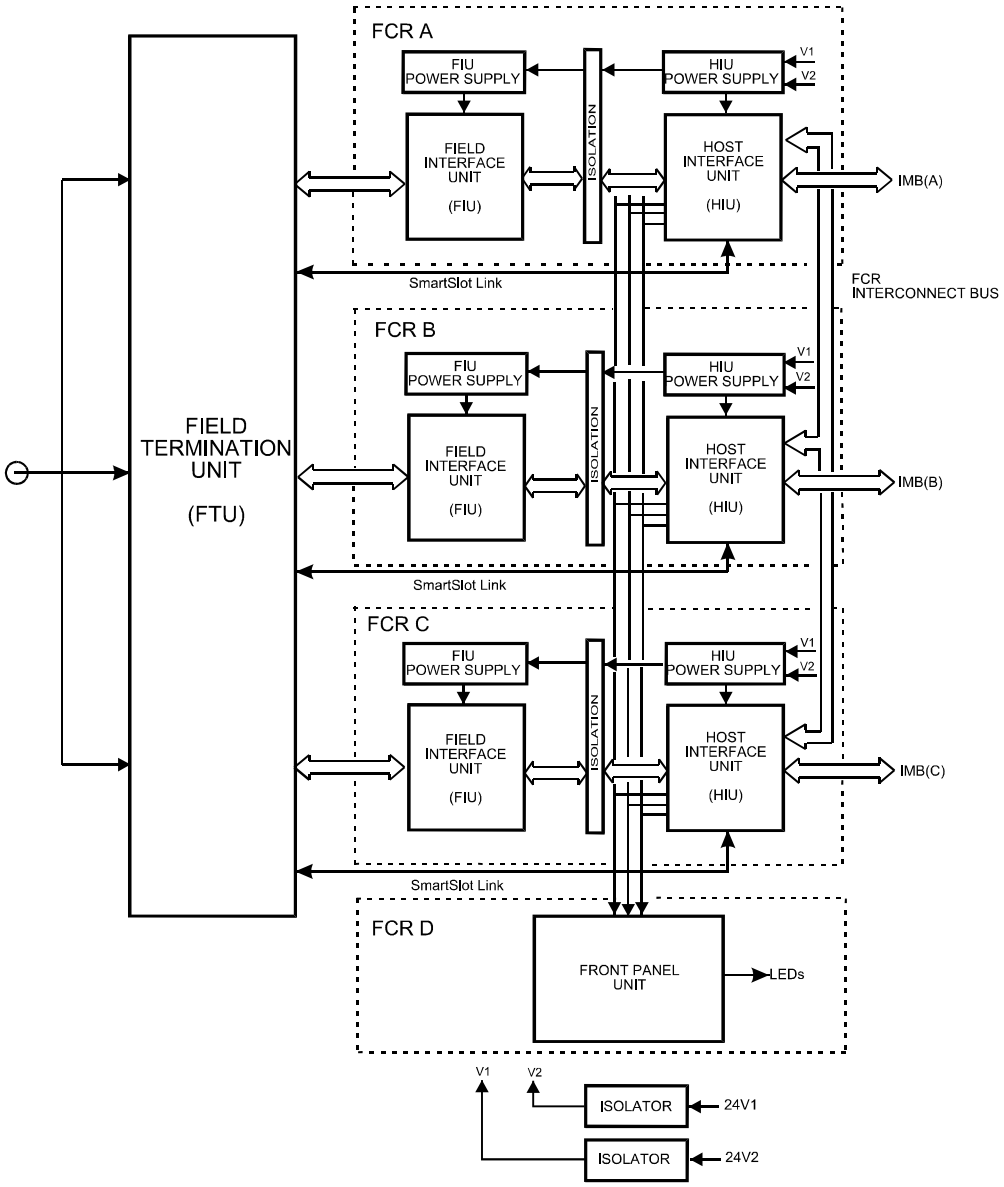

Figure 1 Module Architecture

All High Integrity I/O modules comprise 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 functional block diagram of the Trusted™ 24V dc Analogue Input module.

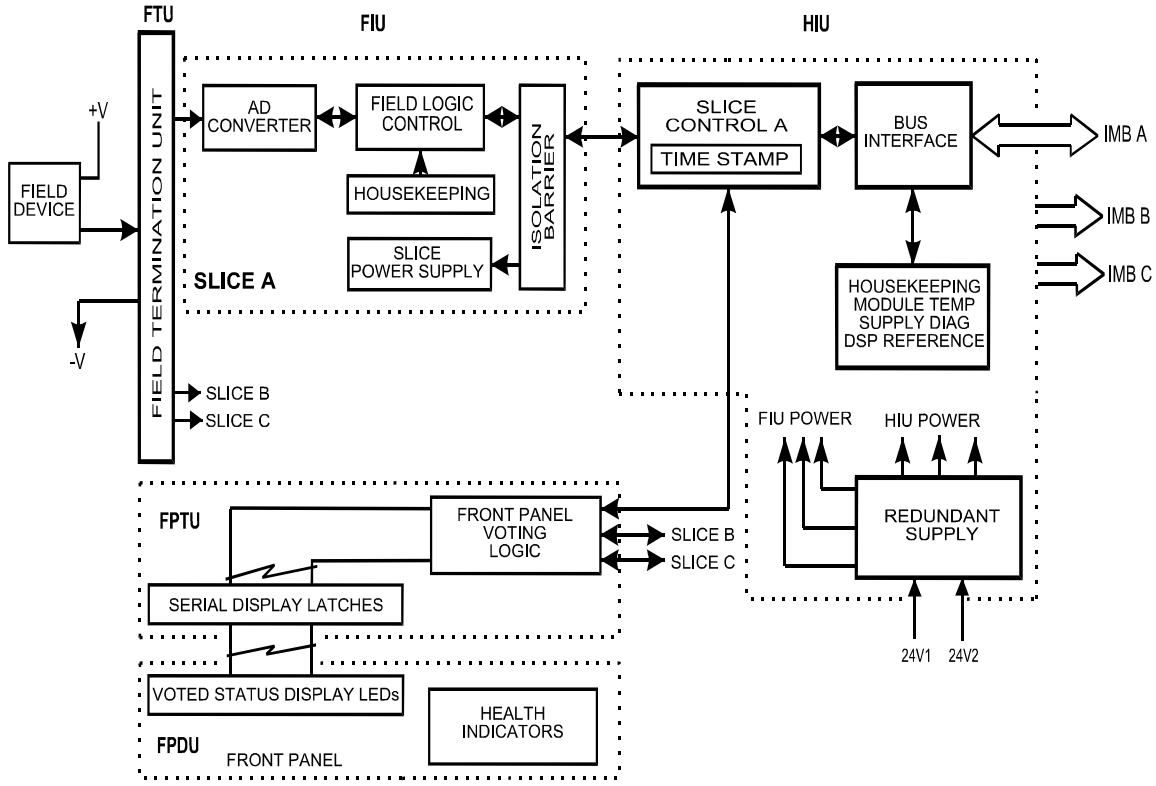

Figure 2 Functional Block Diagram

1.1. Field Termination Unit (FTU)

The Field Termination Unit (FTU) is the I/O module assembly that connects all three FIUs to a field connector. The FTU primarily contains passive components necessary for front-end signal conditioning. When installed in a Trusted™ Controller or Expander Chassis, the FTU field connector mates 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 I/O cable assembly and maintain isolation from the I/O signals on the FTU. The SmartSlot link is the intelligent connection between active and standby modules for co-ordination during module replacement.

1.2. Field Interface Unit (FIU)

The Field Interface Unit (FIU) is the section of the module that contains the specific circuits necessary to interface to the particular types of field I/O signals. Each module has three FIUs, one per slice. For the TMR 24V dc Analogue Input module, the FIU contains an analogue to digital (A/D) converter for each of the 40 field inputs.

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

The FIU also measures a range of on-board “house-keeping” 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, board temperature, and condensation.

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 Trusted™ I/O module types and has type dependent and product range common functions. Each HIU contains three independent slices, commonly referred to as A, B, and C**.**

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

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

- High Speed Fault Tolerant Communications with the TMR Processor via the IMB interface.
- FCR Interconnect Bus between slices to vote coming IMB data and distribute outgoing I/O module data to the IMB.
- Optically 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 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) comprises a Front Panel Termination Unit (FPTU) and a Front Panel Display Unit (FPDU). The overall 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), and the module removal switches. Additional bicolour 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 Thresholds

The module determines the contact state and line fault status by comparing the input voltage level to four user programmed thresholds and two fixed (minimum and maximum) thresholds. Hysteresis is provided on the thresholds by up-scale and downscale values, corresponding to the thresholds for increasing and decreasing values respectively.

Typical voltage threshold values			**Input Channel State**	**Line Fault Status**
		Over-range	6	1
Tmax	6.0			0
		High-High	5	
T8	2.28		4 or 5[1]	
T7	2.24	High	4	0
T6	1.82		3 or 4	0
T5	1.79	Normal	3	0
T4	1.52		2 or 3	
T3	1.47	Low	2	0
T2	1.12		1 or 2	
T1	1.11	Low-Low	1	1
Tmin	-0.5V			1
		Under-range	0	

Table 1 Example Threshold data (24Vdc)

[1] The channel state value returned is dependent on the previous state value. If the input level is increasing then the lower state value will be returned. If the input level is decreasing the higher state value will be returned.

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

Default = 448, 576, 1344, 1472, 2240, 2368, 3520, 3648, 5120

1.6. Housekeeping

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

1.7. Fault Detection and Testing

From the IMB to the field connector, the input module contains extensive fault detection and integrity testing. As an input device, all 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.

Between the HIU and FIU, there are a series of optically isolated links for data and power. The data link is synchronised and monitored for variance. Both the FIU and HIU have onboard temperature sensors to characterise temperature-related problems. Each FIU is also fitted with a condensation sensor.

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

The module field input is connected to a single bit ADC known as the ΣΔ input circuit. These circuits, one per channel on each slice, produce a digital output which naturally transitions between on and off. Any failure in the circuit causes the output to saturate to stuck-on or stuck-off which is automatically detected. As the conversion process is dynamic and not gated like traditional ADCs, failures are rapidly diagnosed and located.

By using the ΣΔ circuit, the analogue path in the module is short and does not involve many components. This results in analogue failures being contained to a single channel on a single slice instead of causing a group of eight or more inputs to fail.

1.8. Sequence of Events Characteristics

The input module automatically measures the field-input voltage, compares the value to the configurable thresholds, and determines the state of the field input. An event occurs when the input transitions from one state to another. When an input changes state, the on-board real-time clock value is recorded. When the TMR Processor next reads data from the input module, the input state and real-time clock values are retrieved. The TMR Processor uses this data to log the input state change into the system Sequence of Events (SOE) log. The user may configure each input to be included in the system SOE log. Full details of SOE are contained in PD-8013 – Trusted™ SOE And Process Historian.

2. Installation

2.1. Module Insertion/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. Field Cable Selection

I/O cables suitable for use with the Trusted™ TMR 24V dc Analogue Input Module are detailed in the following Product Descriptions.

1. PD-TC200 – Trusted™ I/O Companion Slot Cables
2. PD-TC500 – Trusted™ I/O SmartSlot Cables

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.

2.3. Module Pinout Connections

	C	B	A
1	Smart Slot Link C	Smart Slot Link B	Smart Slot Link A
2			
3	Chan 28 (+)	Chan 14 (+)	Chan 0 (+)
4	Chan 28 (+)	Chan 14 (+)	Chan 0 (+)
5	Chan 29 (+)	Chan 15 (+)	Chan 1 (+)
6	Chan 29 (+)	Chan 15 (+)	Chan 1 (+)
7	Chan 30 (+)	Chan 16 (+)	Chan 2 (+)
8	Chan 30(+)	Chan 16 (+)	Chan 2 (+)
9	Return	Return	Return
10	Chan 31 (+)	Chan 17 (+)	Chan 3 (+)
11	Chan 31 (+)	Chan 17 (+)	Chan 3 (+)
12	Chan 32 (+)	Chan 18 (+)	Chan 4 (+)
13	Chan 32 (+)	Chan 18 (+)	Chan 4 (+)
14	Chan 33 (+)	Chan 19 (+)	Chan 5 (+)
15	Chan 33 (+)	Chan 19 (+)	Chan 5 (+)
16	Chan 34 (+)	Chan 20 (+)	Chan 6 (+)
17	Chan 34 (+)	Chan 20 (+)	Chan 6 (+)
18	Chan 35 (+)	Chan 21 (+)	Chan 7 (+)
19	Chan35 (+)	Chan 21 (+)	Chan 7 (+)
20	Return	Return	Return
21	Chan 36 (+)	Chan 22 (+)	Chan 8 (+)
22	Chan 36 (+)	Chan 22 (+)	Chan 8 (+)
23	Chan 37 (+)	Chan 23 (+)	Chan 9 (+)
24	Chan 37 (+)	Chan 23 (+)	Chan 9 (+)
25	Chan 38 (+)	Chan 24 (+)	Chan 10 (+)
26	Chan 38 (+)	Chan 24 (+)	Chan 10 (+)
27	Chan 39 (+)	Chan 25 (+)	Chan 11 (+)
28	Chan 39 (+)	Chan 25 (+)	Chan 11 (+)
29	Chan 40 (+)	Chan 26 (+)	Chan 12 (+)
30	Chan 40 (+)	Chan 26 (+)	Chan 12 (+)
31	Chan 41 (+)	Chan 27 (+)	Chan 13 (+)
32	Chan 41 (+)	Chan 27 (+)	Chan 13 (+)

Table 2 Field Connector Pinout

2.4. Trusted™ Module Polarisation/Keying.

All Trusted™ Modules have been Keyed to prevent insertion into the wrong position within a chassis. The polarisation comprises two parts. The module and the associated field cable.

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

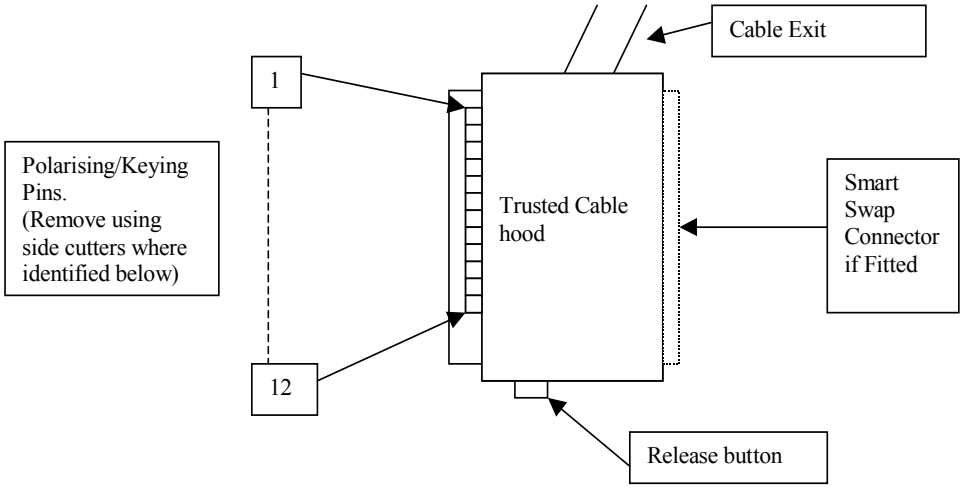

Figure 3 Module polarisation

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

For This Module (T8431) remove keying pins 1,4,5.

3. Application

3.1. Module Configuration

There is no configuration required to the physical input module. All configurable characteristics of the module are performed using tools on the EWS and become part of the application or system.ini file that is loaded into the TMR Processor. The TMR Processor automatically configures the input module after applications are downloaded and during Active/Standby changeover.

The **IEC1131 TOOLSET** provides the main interface to configure the input module. Details of the configuration tools and configuration sequence are provided in PD-8082B Trusted™ Toolset Suite. There are three procedures necessary to configure the input module. These are:

1. Define the necessary I/O variables for the field input data and module status data using the Dictionary Editor of the **IEC1131 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 threshold levels and noise filtering, and other module settings.

3.2. T8431 Complex Equipment Definition

The T8431 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	THRSHIN	OEM Parameters	-	-	-
		Field Input Status	Integer	In	9
2	STATE	Field Input State	Integer	In	40
3	AI	Field Input Engineering Unit	Integer	In	40
4	THRSHOUT	Threshold data	Integer	Out	11
5	LINE_FLT	Line Fault Status	Boolean	In	40
6	DISCREP	Channel Discrepancy	Integer	In	3
7	HKEEPING	Housekeeping Registers	Integer	In	51
8	INFO	I/O Module Information	Integer	In	11

Table 3 Complex Equipment Definition

There are two OEM parameters included in the first rack (THRSHIN 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 **IEC1131 TOOLSET**. Where systems may be required to start-up with a module 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 TrustedTM Chassis where the primary I/O module is installed	The TrustedTM Controller Chassis is 1, and TrustedTM 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 TrustedTM Controller chassis are numbered from 1 to 8. The I/O Module slots in the TrustedTM Expander Chassis are numbered from 1 to 12

Table 4 OEM Parameters

3.2.1. Rack 1: THRSHIN

This board allows the current thresholds for an analogue input channel to be read by the application, under control of the THRSHOUT board (see section 3.2.4).

Channel	Description
1	Channel number being read. Range 0 to 41.
2	States 2 > 1 falling threshold
3	States 1 > 2 rising threshold
4	States 3 > 2 falling threshold
5	States 2 > 3 rising threshold
6	States 4 > 3 falling threshold
7	States 3 > 4 rising threshold
8	States 5 > 4 falling threshold
9	States 4 > 5 rising threshold

Table 5 Rack 1: Threshold input descriptions

THRSHIN reads in the module threshold values controlled by THRSHOUT in Rack 4. See Table 1 for a graphical representation of the states and thresholds.

3.2.2. Rack 2: STATE

This board provides the majority voted numerical input state. This indicates within which threshold band the field input is in and module channel fault status.

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

Table 6 Rack 2: STATE descriptions

The numerical input state is returned as an integer value.

Value	Description
8-15	Internal channel fault on module
7	Unknown
6	Over-range
5	High-High
4	High
3	Normal
2	Low
1	line fault
0	Underrange

Table 7 Rack 2: STATE bit descriptions

The input channel has a value 7 (Unknown) when:

1. The input channel cannot be correctly measured by two or more slices of the TMR input module.
2. The TMR Processor detects a 2-oo-3 channel discrepancy between the three slices of the TMR input module.
3. The module is simulated (not installed or the TMR Processor cannot communicate with 2-oo-3 slices of the module).

3.2.3. Rack 3: AI

The AI board returns the engineering units for the associated field input.

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

Table 8 Rack 3: Channel Field Engineering Units

The voltage is the median value taken from the triplicated module. Field input current is converted to voltage using a 250R resistor on a standard field termination assembly (FTA). This AI value may be used directly or scaled using the **IEC1131 TOOLSET** conversion tables. The voltage is reported as 1024 counts per volt. To allow easy scaling for 4-20mA inputs, zero volts reports as -1024, one volt reports as 0, and 5 volts reports as 4096.

Using a 250R field loop configuration the following table represents normal operating values

Voltage	Current	Engineering Unit
Open Circuit		-2048
0	0mA	-1024
1	4mA	0
2	8mA	1024
3	12mA	2048
4	16mA	3072
5	20mA	4096

Table 9 Rack 3: Normal operating values

3.2.4. Rack 4: THRSHOUT

This board allows the current thresholds for an analogue input channel to be read or written by the application. The application can write new thresholds in the THRSHOUT board for a particular channel, and it can read the current thresholds from the THRSHIN board, under control of a channel in the THRSHOUT board.

Note that channels 0 and 41 are internal reference channels, and are not connected to the field. Channels 1 to 40 are field channels.

Channel	Description
1	Write the threshold data for a particular input channel on channels 3 to 11 to the module. The data is written on a rising edge 0 to 1.
2	Read the threshold data for a particular channel from the module to the THRSHIN board. The data is read on a rising edge 0 to 1.
3	Channel number to write/read threshold data. Range 0 to 41.
4	States 2 > 1 falling threshold
5	States 1 > 2 rising threshold
6	States 3 > 2 falling threshold
7	States 2 > 3 rising threshold
8	States 4 > 3 falling threshold
9	States 3 > 4 rising threshold
10	States 5 > 4 falling threshold
11	States 4 > 5 rising threshold

Table 10 Rack 4: THRSHOUT

3.2.5. Rack 5: LINE_FLT

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

Table 11 Rack 5: LINE_FLT

The line fault input state is reported as true (logic '1') for a line fault condition (open circuit, indeterminate, or short circuit condition). The logic state is the majority voted value.

3.2.6. Rack 6: DISCREP

Channel	Description
1	Discrepancy status inputs 1 to 16
2	Discrepancy status inputs 17 to 32
3	Discrepancy status inputs 33 to 40

Table 12 Rack 6: DISCREP bit descriptions

Each of the words reports the discrepancy status of 16 input channels. The corresponding bit within the word is set to '1' when a discrepancy condition is detected on that input channel's input state (rack 2).