Trusted TMR Pulse Generator and Monitoring Module

Product Overview

The Trusted® Triple Modular Redundant (TMR) Pulse Generator and Monitoring Module interfaces through special Thyristor Drivers, to two Stepper Motors, which form an integral part of a damper rod control system. The Module is based upon the Trusted T8461 Digital Output Module. Feedback of Thyristor activation and rod position is provided by the Module as a % movement figure and a series of fault signals. Triplicated diagnostic tests are performed throughout the Module in order to locate and annunciate hardware failures. Inputs are treated as analogues and are fully tested by the nature of their operation. Fault tolerance is achieved through a TMR architecture within the Module.

The Module has been configured to provide the control and interlock requirements for a high power stepper motor control system which is used to position Damper Rods in a Nuclear reactor. The functionality of this Module is highly specialised and is detailed later in this Product Description (PD).

Features:

- Two Stepper Motor controls.
- Special control algorithms and fault diagnostics resident within the Module.
- Bi-directional fast and slow movement.
- Emergency stop and hold facility.
- Rod position indication.
- Thyristor driver fault indications.
- ESD Rod release.
- 2500 V impulse withstand opto/galvanic isolation barrier.
- Automatic over-current protection (per channel), no fuses required (outputs).

- Front Panel status Light Emitting Diodes (LEDs) for each point indicate status and field wiring faults.
- Front Panel Module status LEDs indicate Module health and operational mode (Active, Standby, Educated).

PREFACE

In no event will Rockwell Automation be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment. The examples given in this manual are included solely for illustrative purposes. Because of the many variables and requirements related to any particular installation, Rockwell Automation does not assume responsibility or reliability for actual use based on the examples and diagrams.

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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 applies to **Trusted Release: 3.6.1**.

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

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

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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 contains 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
5	July 05	Formatting
6	Dec 06	Weights and Dims
7	Sep 07	Tbl16 Chns rotated
8	Nov 09	Table 5 change
9	Apr 10	Rack 7 change
10	Aug 15	Rebranded and reformatted with correction to Relative Humidity Range and Operating Temperature statements in the Specification Section, also any typographical errors

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Table of Contents

1. Description

The TMR Pulse Generator and Monitoring (PG/M) 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).

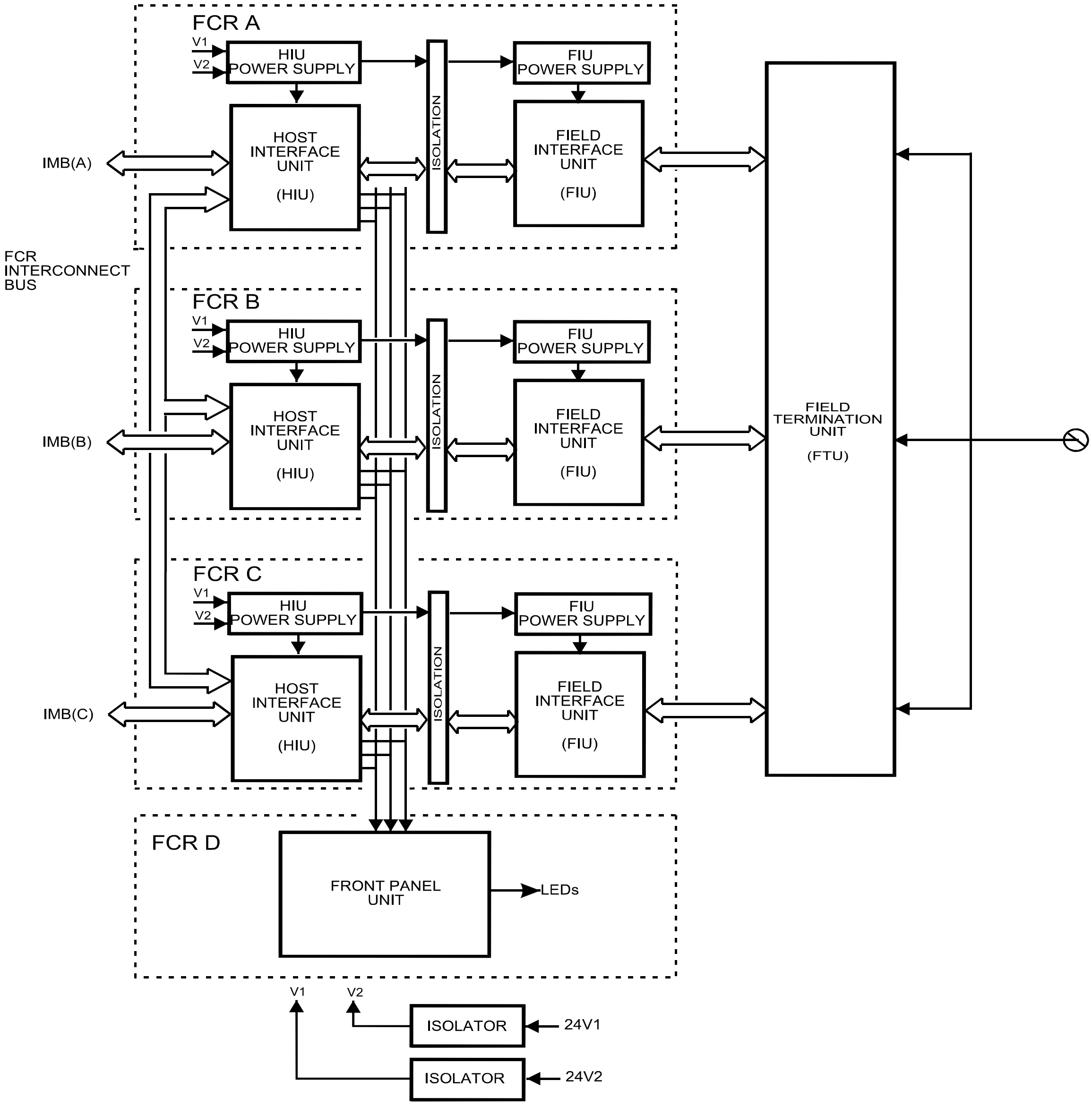

Figure 1 Module Architecture

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 PG/M Module.

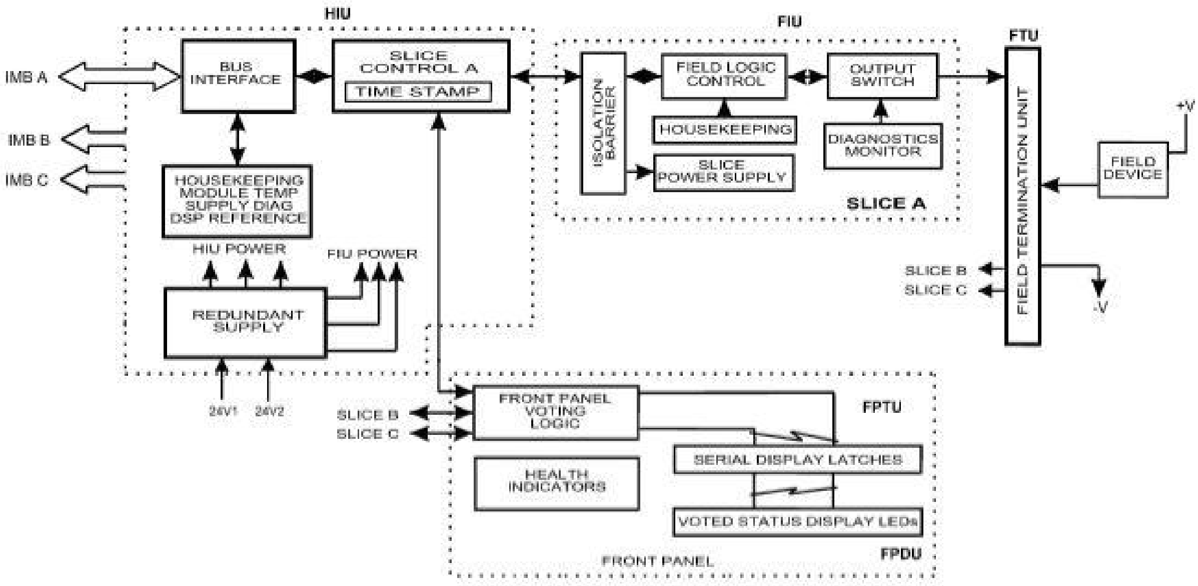

Figure 2 Functional Block Diagram

1.1. Field Termination Unit (FTU)

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

The SmartSlot link is passed from the HIU to the field connections via the FTU. These signals go directly to the field connector and maintain isolation from the I/O signals on the FTU. The SmartSlot link is the intelligent connection between Active and Standby Modules for 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 Pulse Generator and Monitoring Module, the FIU contains one stage of the output switch structure, and analogue to digital (A/D) monitoring circuits for each of the channels. Two additional A/D circuits provide optional monitoring of the external field I/O supply voltage.

The FIU receives isolated power from the Host Interface Unit (HIU) for logic. The FIU provides additional power conditioning for the operational voltages required by the FIU circuitry. An isolated serial link connects each FIU to one of the HIU slices.

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

1.3. Host Interface Unit (HIU)

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

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

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

- High Speed Fault Tolerant Communications with the TMR Processor via the IMB interface.
- FCR Interconnect Bus between slices to vote incoming IMB data and distribute outgoing I/O Module data to IMB.
- Optically isolated serial data interface to the FIU slices.
- Redundant power sharing of dual 24 Vdc chassis supply voltage and power regulation for logic power to HIU circuitry.
- Magnetically Isolated power to the FIU slices.
- Serial data interface to the FPU for Module status LEDs.
- SmartSlot link between Active and Standby Modules for 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 Module, the FPU contains the Slice Healthy, Active/Standby, the Educated indicators (LEDs), and 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

The module automatically monitors the channel line fault status. These are reported back to the application and are represented below.

Description	Line Fault Status
Field Short Circuit	1
Output Energised (On)	0
No Load, Field Open Circuit	1
Output De-energised (Off)	0
No Field Supply Voltage	1

Table 1 Line Monitoring Fault Status

1.6. Housekeeping

The Module automatically performs local measurements of several on-board signals that can be used for detailed troubleshooting and verification of Module operating characteristics. Measurements are made within each slice’s HIU and FIU to determine the condition of the power supplies and common services such as the temperature of the HIU.

1.7. Fault Detection/Testing

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

Periodically, the TMR Processor commands the on-board Digital Signal Processors (DSPs) to perform a Safety Layer Test (SLT). The SLT results in the DSP verifying with the TMR

Processor its ability to process data with integrity. In addition, the DSP uses Cyclical Redundancy Checks (CRC) to verify the variables and configuration stored in flash memory.

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

1.8. Sequence of Events Characteristics

Each Boolean Variable can be configured for automatic Sequence of Events (SOE) logging. This applies to the Input/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 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 Engineering Workstation (EWS). This software package is described in PD-T8013.

1.9. Output Switch Structure

The outputs of the Pulse Generator and Monitoring Module provide 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.

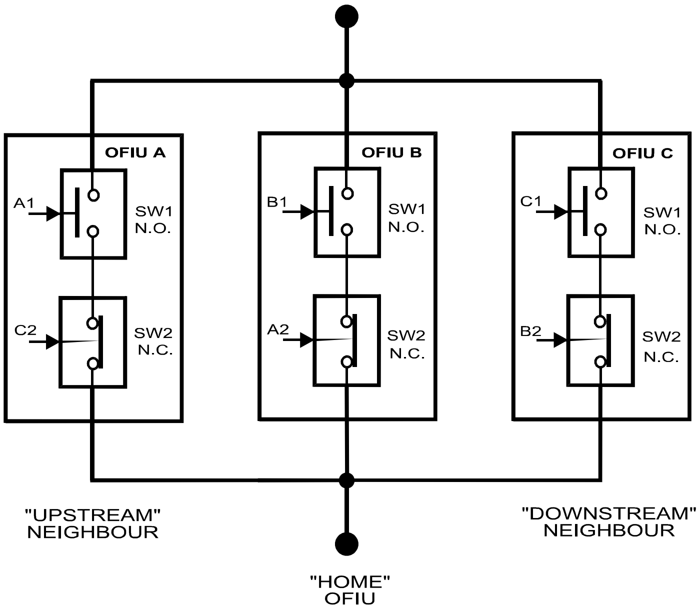

Figure 3 Output Switch Structure

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

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

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

1 Their "home" FIU.

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

3 For an un-faulted transistor.

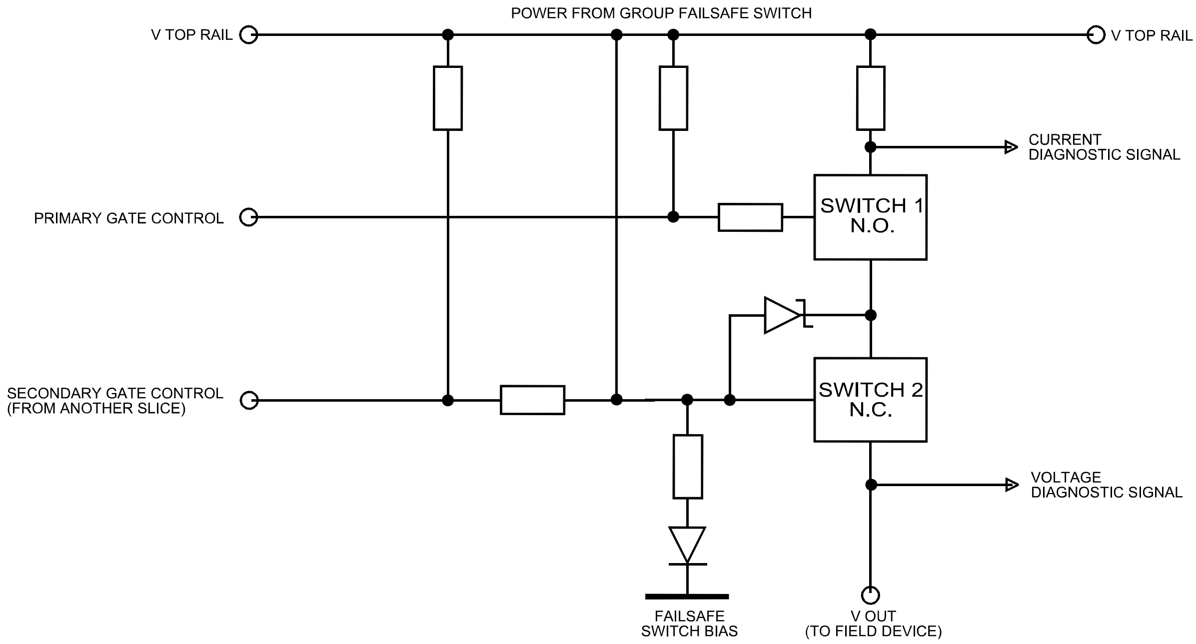

Figure 4 Simplified Switch Circuit Diagram

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 minimise it's on resistance, and serves to hold Switch 2 on in the event that the secondary gate control loses power.

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

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

1.9.1. Switch Diagnostics

During normal operation, Switch 1 and Switch 2 are maintained on. In this state, Switch 1 and Switch 2 exhibit less than 0.5 Ω of resistance each.

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

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

1.9.2. Short Circuit Protection Issues

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

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

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

The output current is monitored by the DSP and sustained over-current conditions result in a latched over-current condition and de-energise the associated output. After removing the fault condition, the latched over-current condition can be reset by either pressing the system fault reset button or turning off the logical output signal to the Module. The output also includes a non-replaceable fusible link for absolute protection.

1.9.3. Group Fail Safe Switches

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

There are three switches in parallel, which comprise the GFSS, one associated with each 'slice' of the power group. The GFSSs 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 to de-energise. This results in two of the three elements of the GFSS structure to 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 FIU power supply and the associated GFSS control signal will also de-energise.

1.10. Input Interfaces

Each input channel is provided with three analogue to digital converters (ADCs) which monitor the voltage at the input connection. Each input is a high impedance channel which measures from 0 V to 30 V. If current is to be measured the input must be conditioned by an external resistor. The Module uses its TMR architecture to provide fault tolerance in the event of a hardware failure. No particular dynamic testing is provided on the inputs because of the continuous dynamic nature of the signal being interfaced and the duality of the thyristor drives which are providing the input signals.

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 Pulse Generator and Monitoring Module are detailed in the following Product Descriptions.

- PD-TC200 – Trusted I/O Companion Slot Cables
- 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 this type of Module.

2.3. Module Pin-out Connections

	C	B	A
1	SmartSlot Link C	SmartSlot Link B	SmartSlot Link A
2			
3	Rod 1 Phase C	Pwr Group 1 (+)	Rod 1 Phase A
4	Rod 1 Phase CC	Pwr Group 1 (+)	Rod 1 Phase AA
5	Pwr Group 1 Rtn	Pwr Group 1 (+)	Pwr Group 1 Rtn
6	Rod 1 Gate A	Pwr Group 1 (+)	Rod 1 Phase B
7	Rod 1 Gate B	Pwr Group 1 (+)	Rod 1 Phase BB
8			
9	Mon Rod 1 Phase C power supply A	Pwr Group 2 (+)	Mon Rod 1 Phase A power supply A
10	Mon Rod 1 Phase AA power supply A	Pwr Group 2 (+)	Mon Rod 1 Phase CC power supply A
11	Pwr Group 2 Rtn	Pwr Group 2 (+)	Pwr Group 2 Rtn
12	Mon Rod 1 Phase A power supply B	Pwr group 2 (+)	Mon Rod 1 Phase B power supply A
13	Mon Rod 1 Phase CC power supply B	Pwr Group 2 (+)	Mon Rod 1 Phase BB power supply A
14			
15	Mon Rod 2 Phase A power supply A	Pwr Group 3 (+)	Mon Rod 1 Phase B power supply B
16	Mon Rod 2 Phase CC power supply A	Pwr Group 3 (+)	Mon Rod 1 Phase BB power supply B
17	Pwr Group 3 Rtn	Pwr Group 3 (+)	Pwr Group 3 Rtn

	C	B	A
18	Mon Rod 2 Phase B power supply A	Pwr Group 3 (+)	Mon Rod 1 Phase C power supply B
19	Mon Rod 2 Phase BB power supply A	Pwr Group 3 (+)	Mon Rod 1 Phase AA power supply B
20			
21	Mon Rod 2 Phase B power supply B	Pwr Group 4 (+)	Mon Rod 2 Phase C power supply A
22	Mon Rod 2 Phase BB power supply B	Pwr Group 4 (+)	Mon Rod 2 Phase AA power supply A
23	Pwr Group 4 Rtn	Pwr Group 4 (+)	Pwr Group 4 Rtn
24	Mon Rod 2 Phase C power supply B	Pwr Group 4 (+)	Mon Rod 2 Phase A power supply B
25	Mon Rod 2 Phase AA power supply B	Pwr Group 4 (+)	Mon Rod 2 Phase CC power supply B
26			
27	Rod 2 Phase C	Pwr Group 5 (+)	Rod 2 Phase A
28	Rod 2 Phase CC	Pwr Group 5 (+)	Rod 2 PhaseAA
29	Pwr Group 1 Rtn	Pwr Group 5 (+)	Pwr Group 1 Rtn
30	Rod 2 Gate A	Pwr Group 5 (+)	Rod 2 Phase B
31	Rod 2 Gate B	Pwr Group 5 (+)	Rod 2 Phase BB
32			

Table 2 Field Connector Pin-out

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.

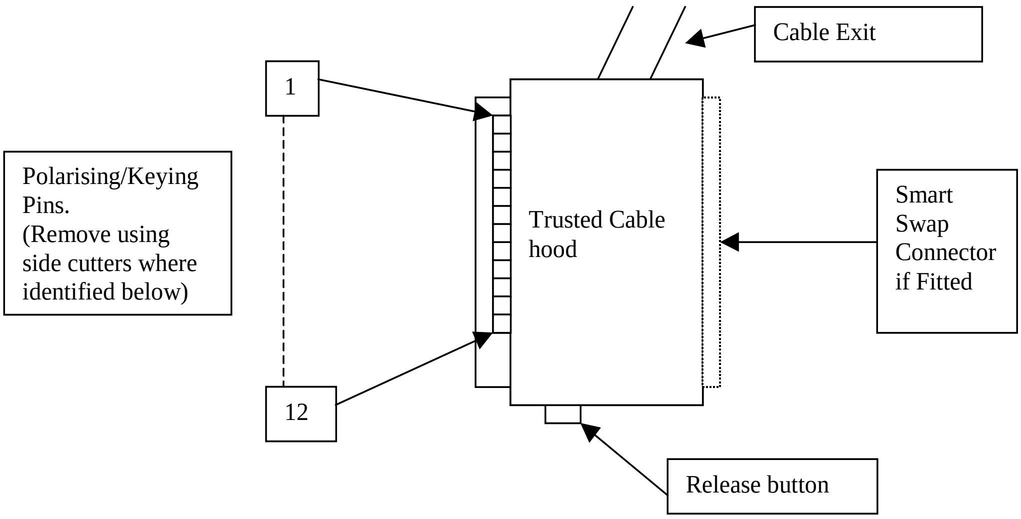

Figure 5 Module Polarisation

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

For this Module (T8444) remove keying pins 1, 7 and 8.

3. Application

3.1. Module Configuration

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

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

1. Define the necessary I/O variables for the field 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. T8444 Complex Equipment Definition

The T8444 I/O Complex Equipment Definition includes 8 I/O boards, referenced numerically by Rack number. There are two OEM parameters included in the first rack (DO Board). These OEM parameters define the primary module position; declaring the Module’s chassis and slot location. There is no need to define the secondary module position within the IEC 61131 TOOLSET. Where systems may be required to start-up with Modules in the secondary position as the Active Module, e.g. primary module is not installed when application is started, the secondary module’s position should be declared in the Module definition of the System Configuration Manager.

Rack	I/O Board	Description	Data Type	Direction	No. of Channels
1	PG_CTRL	OEM Parameters	-	-	-
		Pulse Generator controls	Boolean	Out	16
2	FIELD	Field State	Integer	In	26
3	PI_CTRL	Position Indicator controls	Integer	Out	12
4	PG_FAULT	Pulse Generator faults	Boolean	In	16
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

Table 3 Complex Equipment Definition

3.2.1. Rack 1: PG_CTRL

Channel	Description
1	JOG control signal for Rod 1
2	RUN control signal for Rod 1
3	IN control signal for Rod 1
4	OUT control signal for Rod 1
5	ROD_TRIP control signal for Rod 1
6	PG_INHIBIT_RESET control signal for Rod 1
7	GD_A_INHIBIT_RESET control signal for Rod 1
8	GD_A_INHIBIT_RESET control signal for Rod 1
9	JOG control signal for Rod 2
10	RUN control signal for Rod 2
11	IN control signal for Rod 2
12	OUT control signal for Rod 2

Channel	Description
13	ROD_TRIP control signal for Rod 2
14	PG_INHIBIT_RESET control signal for Rod 2
15	GD_A_INHIBIT_RESET control signal for Rod 2
16	GD_A_INHIBIT_RESET control signal for Rod 2
17	GD_A_INHIBIT_RESET control signal for Rod 2
18	GD_B_INHIBIT_RESET control signal for Rod 2
19	GD_A_INHIBIT control signal for Rod 2
20	GD_B_INHIBIT control signal for Rod 2

Table 4 Rack 1: PG_CTRL Descriptions

3.2.2. Rack 2: FIELD

Channel	Description
1	Phase A voltage feedback on Motor A of Rod 1
2	Phase B voltage feedback on Motor A of Rod 1
3	Phase C voltage feedback on Motor A of Rod 1
4	Phase AA voltage feedback on Motor A of Rod 1
5	Phase BB voltage feedback on Motor A of Rod 1
6	Phase CC voltage feedback on Motor A of Rod 1
7	Phase A voltage feedback on Motor B of Rod 1
8	Phase B voltage feedback on Motor B of Rod 1
9	Phase C voltage feedback on Motor B of Rod 1
10	Phase AA voltage feedback on Motor B of Rod 1
11	Phase BB voltage feedback on Motor B of Rod 1
12	Phase CC voltage feedback on Motor B of Rod 1
13	Position Indicator value for Rod 1

Channel	Description
14	Phase A voltage feedback on Motor A of Rod 2
15	Phase B voltage feedback on Motor A of Rod 2
16	Phase C voltage feedback on Motor A of Rod 2
17	Phase AA voltage feedback on Motor A of Rod 2
18	Phase BB voltage feedback on Motor A of Rod 2
19	Phase CC voltage feedback on Motor A of Rod 2
20	Phase A voltage feedback on Motor B of Rod 2
21	Phase B voltage feedback on Motor B of Rod 2
22	Phase C voltage feedback on Motor B of Rod 2
23	Phase AA voltage feedback on Motor B of Rod 2
24	Phase BB voltage feedback on Motor B of Rod 2
25	Phase CC voltage feedback on Motor B of Rod 2
26	Position Indicator value for Rod 2

Table 5 Rack 2: Field Descriptions

3.2.3. Rack 3: PI_CTRL

Channel	Description
1	RESET control signal for PI for Rod 1
2	PULSER control signal for PI for Rod 1
3	COUNT_UP control signal for PI for Rod 1
4	COUNT_DOWN control signal for PI for Rod 1
5	LOAD control signal for PI for Rod 1
6	NewPosition integer value for PI for Rod 1
7	RESET control signal for PI for Rod 2
8	PULSER control signal for PI for Rod 2

Channel	Description
9	COUNT_UP control signal for PI for Rod 2
10	COUNT_DOWN control signal for PI for Rod 2
11	LOAD control signal for PI for Rod 2
12	NewPosition integer value for PI for Rod 2

Table 6 Rack 3: PI_CTRL Descriptions

3.2.4. Rack 4: PG_FAULT

Channel	Description
1	Missing pulse fault on Motor A of Rod 1
2	Extra pulse fault on Motor A of Rod 1
3	Missing pulse fault on Motor B of Rod 1
4	Extra pulse fault on Motor B of Rod 1
5	<2 or >3 phases on fault on Rod 1
6	Pulse Generator inhibit on Rod 1
7	Gate Drive A inhibit on Rod 1
8	Gate Drive B inhibit on Rod 1
9	Missing pulse fault on Motor A of Rod 2
10	Extra pulse fault on Motor A of Rod 2
11	Missing pulse fault on Motor B of Rod 2
12	Extra pulse fault on Motor B of Rod 2
13	<2 or >3 phases on fault on Rod 2
14	Pulse Generator inhibit on Rod 2
15	Gate Drive A inhibit on Rod 2
16	Gate Drive B inhibit on Rod 2

Table 7 Rack 4: PG_Fault Descriptions

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 8 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 9 Rack 6: Discrepancy 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: Housekeeping

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				

Channel	Description				
	FCR		Units (Full Scale Range)		
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				
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	-32768	32767	-

Channel	Description				
	FCR		Units (Full Scale Range)		
41	B	(Note: Temperature, °C = input value / 256)			
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 10 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.

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

Channel	Description
7	Standby Module Healthy
8	Standby Module mode
9	FCR Status
10	Primary module is Active
11	Active Module is simulated

Table 11 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.

3.3. System.INI File Configuration

There are many operating characteristics of the Module that can be customised for a particular application. The System Configuration Manager is a tool that allows the user to configure the specific operating characteristics for each Module. Descriptions of the items that may be configured for the Trusted Pulse Generator and Monitoring Module T8444 are contained in 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, customisation of the Module definition in the System Configuration Manager is not required.

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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 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.

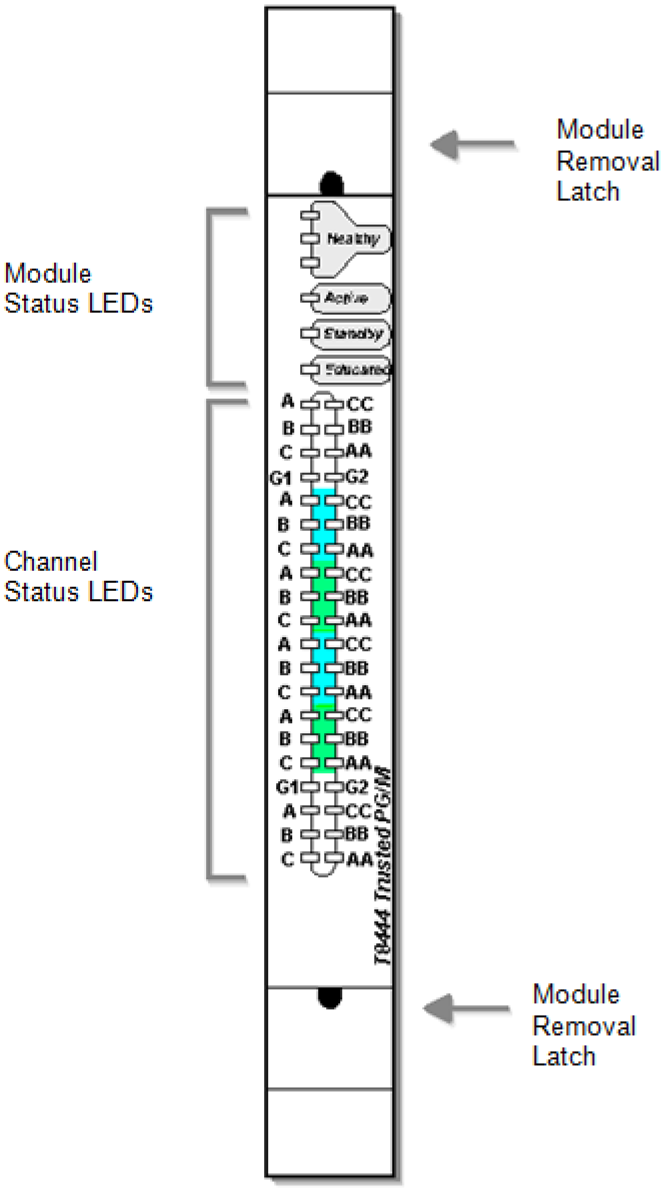

Figure 6 Module Front Panel

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. The FPU 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 12 Module Status Indicators

4.3. I/O Status LEDs

There are 40 channel status indicators on the Module Front Panel, one for each field input/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 input/output status indicator mode is dependent upon the numerical state of the channel. Each 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 status indications to suit individual application requirements. Without customisation, the default indicator modes are suitable for damper control installations as described below. Each channel is provided with a bi-colour LED. The channel LEDs illuminate as follows.

4.3.1. Outputs and Gate Outputs

Function	Off	Green Steady	Green Flash	Red Steady	Red Flash	Amber Steady	Amber Flash	Note
Output off no faults	Yes	Not allowed	Not allowed					Slice LEDs Green
Output off with Module fault	Yes	Not allowed	Not allowed					Slice LEDs Red
Output off with Field fault		Not allowed	Not allowed				Yes	Slice LEDs Green
Output off with Module and Field fault		Not allowed	Not allowed				Yes	Slice LEDs Red
Output on no faults		Not allowed	Not allowed	Yes				Slice LEDs Green
Output on with Module fault		Not allowed	Not allowed	Yes				Slice LEDs Red
Output on with Field fault		Not allowed	Not allowed			Yes		Slice LEDs Green
Output on with Module and Field fault		Not allowed	Not allowed			Yes		Slice LEDs Red

Table 13 Default I/O Status Indicators

4.3.2. Feedback Inputs

Function	Off	Green Steady	Green Flash	Red Steady	Red Flash	Amber Steady	Amber Flash	Notes
Input off no faults	Yes			Not allowed	Not allowed			Slice LEDs Green
Input off with Module fault	Yes			Not allowed	Not allowed			Slice LEDs Red
Input off with Field fault				Not allowed	Not allowed		Yes	Slice LEDs Green
Input off with Module and Field Fault				Not allowed	Not allowed		Yes	Slice LEDs Red
Input on no Fault		Yes		Not allowed	Not allowed			Slice LEDs Green
Input on with Module fault		Yes		Not allowed	Not allowed			Slice LEDs Red
Input on with Field fault				Not allowed	Not allowed	Yes		Slice LEDs Green
Input on with both Module and Field fault				Not allowed	Not allowed	Yes		Slice LEDs Red

Table 14 Feedback Inputs

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 PD-T8082.

4.4. Output and Input Separation/Channel Allocation

The Module has 6 pulse outputs, 12 pulse inputs and 2 control signals per motor drive. The Output Module has 5 power groups protected by Group Fail Safe Switches. In order to minimise the effect of a single group failure the I/O is segregated as shown below.

Power Group	Channel	Function	Power Group	Channel	Function
1	1	Rod 1 Phase A	3	21	Mon Rod 2 Phase A power supply A
1	2	Rod 1 Phase CC	3	22	Mon Rod 2 Phase CC power supply A
1	3	Rod 1 Phase B	3	23	Mon Rod 2 Phase B power supply A
1	4	Rod 1 Phase BB	3	24	Mon Rod 2 Phase BB Power supply A
1	5	Rod 1 Phase C	4	25	Mon Rod 2 Phase C power supply A
1	6	Rod 1 Phase AA	4	26	Mon Rod 2 Phase AA power supply A
1	7	Rod 1 Gate A	4	27	Mon Rod 2 Phase A power supply B
1	8	Rod 1 Gate B	4	28	Mon Rod 2 Phase CC Power supply B
2	9	Mon Rod 1 Phase A power supply A	4	29	Mon Rod 2 Phase B power supply B
2	10	Mon Rod 1 Phase CC power supply A	4	30	Mon Rod 2 Phase BB power supply B
2	11	Mon Rod 1 Phase B power supply A	4	31	Mon Rod 2 Phase C power supply B
2	12	Mon Rod 1 Phase BB Power supply A	4	32	Mon Rod 2 Phase AA Power supply B
2	13	Mon Rod 1 Phase C power supply A	5	33	Rod 2 Gate A
2	14	Mon Rod 1 Phase AA power supply A	5	34	Rod 2 Gate B
2	15	Mon Rod 1 Phase A power supply B	5	35	Rod 2 Phase A
2	16	Mon Rod 1 Phase CC Power supply B	5	36	Rod 2 Phase CC
3	17	Mon Rod 1 Phase B power supply B	5	37	Rod 2 Phase B
3	18	Mon Rod 1 Phase BB power supply B	5	38	Rod 2 Phase BB
3	19	Mon Rod 1 Phase C power supply B	5	39	Rod 2 Phase C
3	20	Mon Rod 1 Phase AA Power supply B	5	40	Rod 2 Phase AA

Table 15 I/O Separation/Channel Allocation

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5. Fault Finding and Maintenance

5.1. Fault Reporting

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

5.2. Field Wiring Faults

By measuring the 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 status indicator will display the configured LED mode and the line fault status for that channel will be set to ‘1’. All other channels will be unaffected, except in the case of common cause wiring and supply voltage faults in the field.

The field voltage and current variables can be monitored to determine the actual operating conditions of each 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 status variables and status indicator will display the normal on/off status of the field device.

5.3. Module Faults

Extensive diagnostics provide the automatic detection of Module faults. The TMR architecture of the Module and the diagnostics performed ensure 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 control 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 fault is within the Module, it should be replaced .

5.4. Companion Slot

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

Under normal conditions, an Active/Standby changeover will only occur if the 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. Technical Specifications

6.1. Introduction

The Pulse Generator and Monitoring Module is required to be high integrity but it is not in itself intended to be a safety system.

The design concept maintains the advantages of TMR Systems while retaining a simple implementation of a Damper Rod Control System by the use of redundant paths.

The PG/M generates a series of waveforms which rotate a stepper motor in either a clockwise or anti-clockwise direction. The phasing of the outputs determines the direction of rotation while the frequency determines the speed.

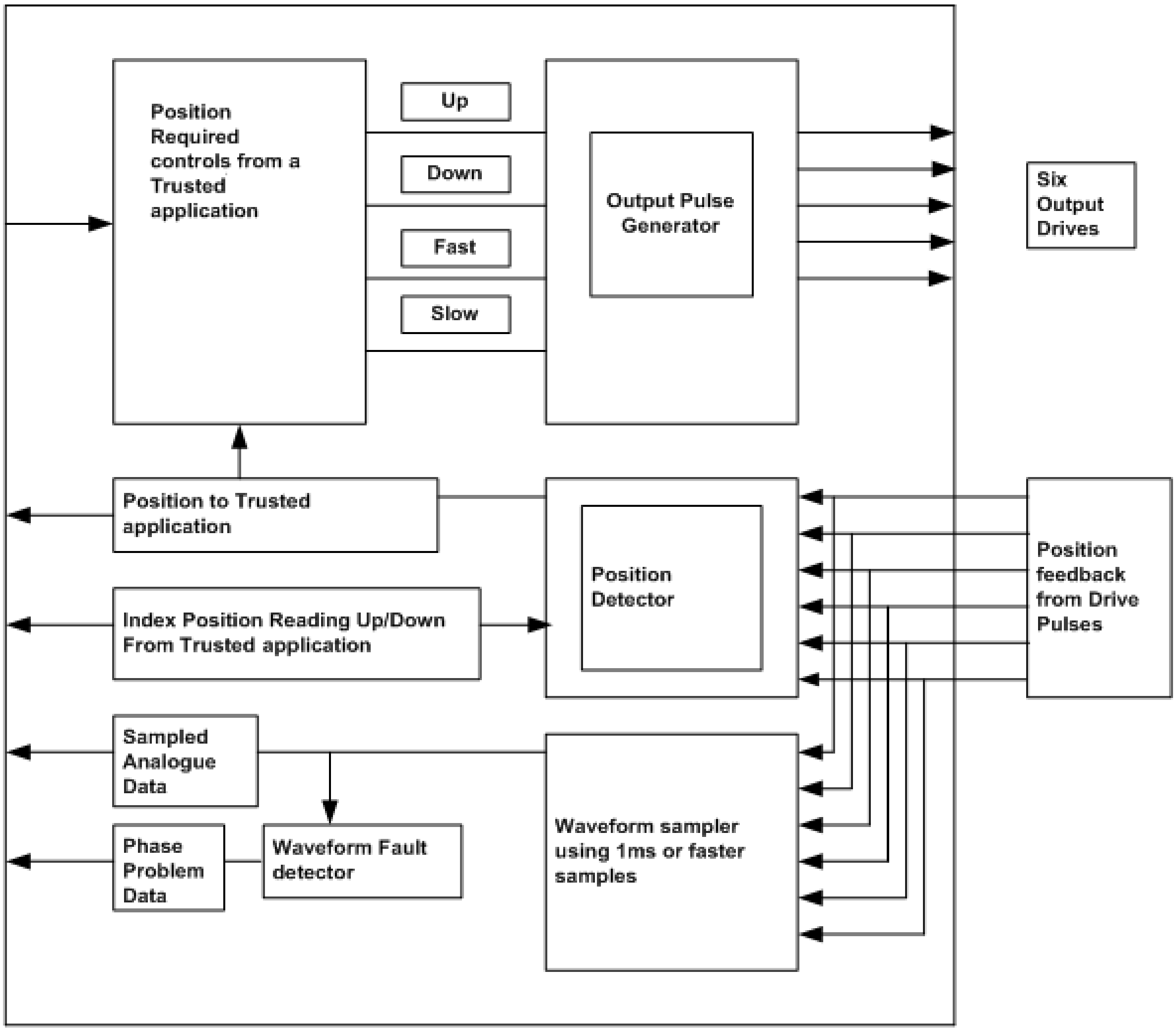
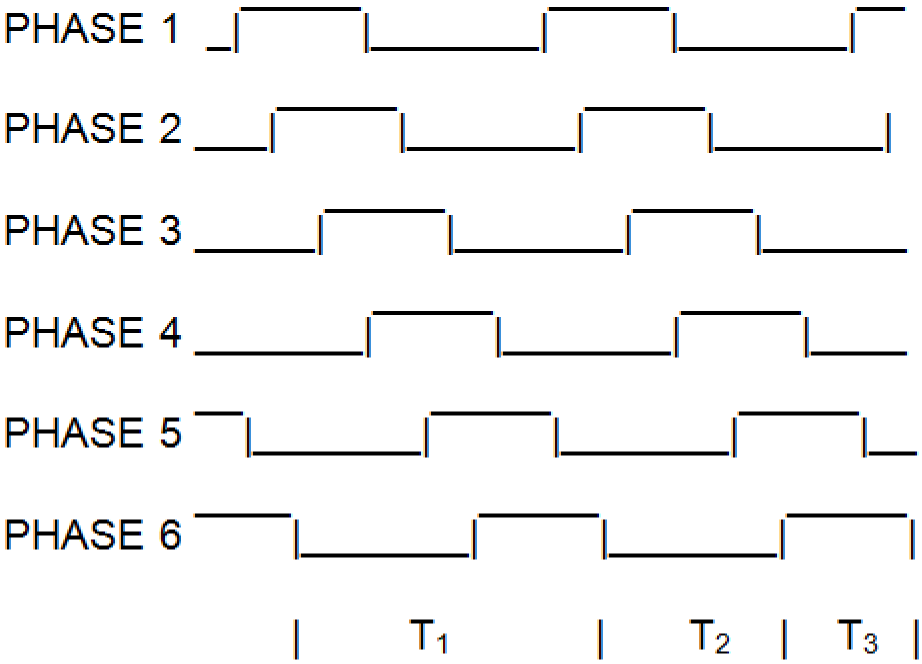


Figure 7 PG/M Functional Block Diagram

6.2. Phase Rotation



	TIME T1	TIME T2	TIME T3
FREQ. 1 (1.33 Hz)	437.5 ms	312.5 ms	125.0 ms
FREQ. 2 (13.3 Hz)	43.75 ms	31.25 ms	12.5 ms

Note: Timing is shown for clockwise rotation of stepping motor.
For anti-clockwise rotation phase 6 would lead phase 5 which would lead phase 4.

6.3. Fail Safe Actions

This is not a safety system. Other equipment must be supplied for removing the power from the motor drive circuits in an emergency. Fail safe action in this case is to maintain control of the rods whenever possible even if a fault is detected in the Control Module. For example a slice fault will be logged and annunciated to the Trusted Controller but it will not result in the Module entering the “Fatal” state.

This is not a safety critical design and has been classified as Sil 0 however, it can reside in a system which is capable of maintaining AK6 on some of its signals.

6.4. Internal Testing and Monitoring

Maintaining control of the Damper Rods/Stepper Motors is the primary aim of this system. Fail danger faults detected by any diagnostics do not lead to the Module releasing the Damper Rods except in the manner specified in Framatome Spec 08-5011407-00.

Monitoring which detects faults provides alarm indication but unless totally unavoidable does not release control of the Damper Rods.

6.5. Thyristor Driver Interfaces/Stepper Motor Drives

6.5.1. Module Start-up

When a Module is powered up it will maintain all outputs off. Gate signals will be off and Output Drives will be off.

The education process is automatic and follows the Trusted standard procedure.

Once the boot and education sequence is complete the Module will turn on outputs A and B for each Motor. The fault detection will operate and the fault bits will be determined depending upon the field state.

The Gate Drives will remain latched until commanded to reset by the application program.

Should the motor poll pieces not be aligned with A&B it is assumed that a recovery procedure will be initiated by the application to engage the threaded rod.

After a successful start the Position Counters will be set to zero. This value can be amended using the INI file if required.

Should a Module detect a problem with booting and education the start-up will be aborted and the Module will not energise any of its outputs. Restart will be by removal and re-insertion of the Module.

6.5.2. Minimum Output Load

The PG/M Module requires a minimum current to be drawn from each energised output. If the load to which it is connected is not sufficient, it is suggested that a termination resistor of 500 Ω should be fitted

6.5.3. Input Termination Resistance

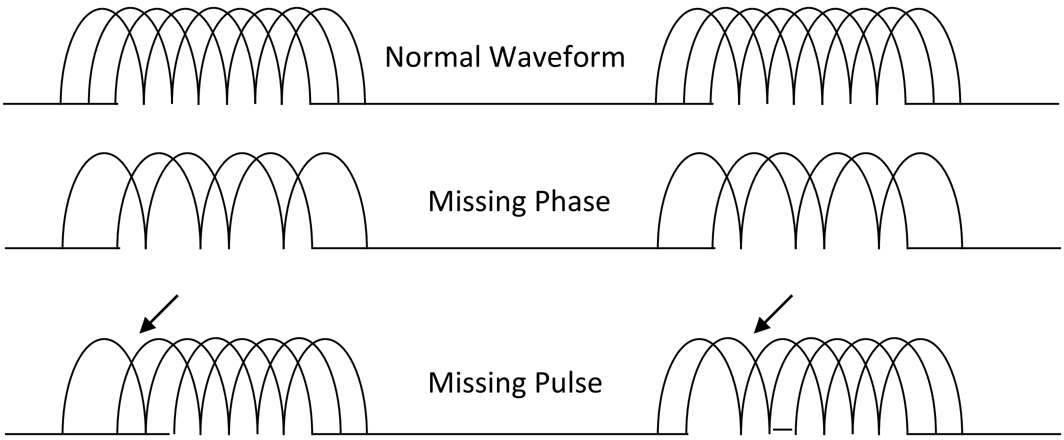
Input circuits accept 0 to 10 V analogue values. Circuits which are interfacing to 4 to 20 mA signals should be conditioned with a 500 Ω resistor.

6.6. Operation with one Thyristor Driver Removed

The PG/M Module interfaces to two Thyristor Drivers from each channel. The design is such that each channel can operate with one Thyristor Driver removed. Loss of feedback from both Thyristor Drivers of one rod does not affect control of any other rods.

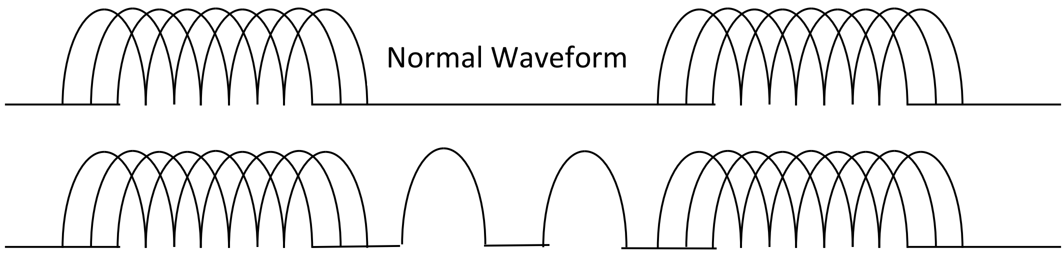
6.7. Detection of a Missing Pulse

Detection of a missing pulse is primarily intended to detect a failed Thyristor in an otherwise working Driver. This is found by detecting a dip in the DC waveform.



6.8. Detection of an Extra Pulse

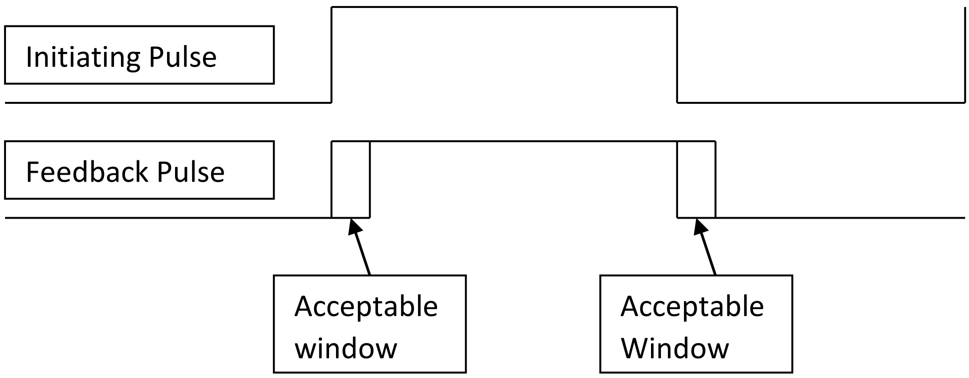
If an extra pulse is generated this will be caused by a faulty firing of a Thyristor.

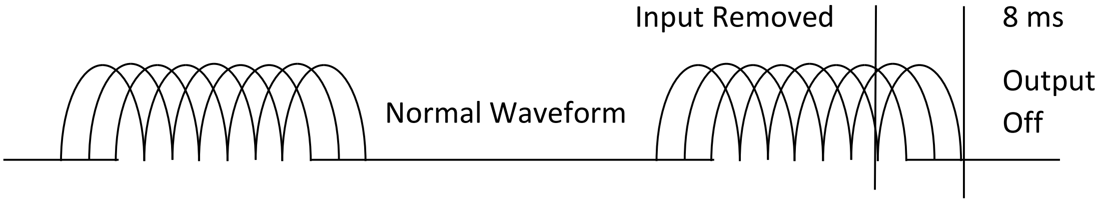


Shorted Gate Pattern

6.9. Detection of a Short / Long Pulse

Deviation of pulse length is detected. This is performed by a window detector. Should a pulse feedback start late or complete early a fault is indicated. The fault detection window is 15 ms.





The window for short and long pulse width is 15 ms. Under normal operation if the input is removed when an AC phase had just started, the SCR would continue to conduct until the AC phase crossed the 0 V line again. Worst case could be close to 8 ms.

6.10. Analogue Feedback Out of Limits

No specific high or low limits are set. Failure of the transmitter is detected by the detection of a missing or extra pulse, so no thresholding other than the detection of the presence of a pulse and missed firings is needed.

6.11. Motor Voltage Monitoring

The Average level of the feedback pulse provides a measure of the voltage being applied to the motor. This level is sampled once per pulse to determine that it is within specification.

6.12. Inference of Position from Motor Pulses

Position is inferred by counting the number of pulses generated by the Module (not the number of Pulses fed back from the motor drivers). All 6 phases are used to operate the counter. The counter counts up when the Rod is withdrawn and down when the Rod is inserted. A count of zero is expected to be with the Rod at rest and fully inserted.

6.13. Number of Pulses for a Full Transition of a Rod from End to End

In one installation each Rod is required to move slightly less than 12 feet. For the purposes of the calculation we will utilise 12 feet. Each rotation of the motor moves the Rod 0.75 inches ergo 192 rotations moves the Rod from end to end. Each rotation requires 2 pulses from each output, therefore each output must pulse 192*2 times = 384. Therefore if all pulses are counted the total will be 384*6 = 2304 pulses.

Because of potential position registration errors the Counter has been configured so that it can count above the expected maximum and below zero. The maximum count values are +32767 to –32768.

The actual values which represent 0 % to 100 % movement are specific to each application and must be calculated from the mechanics of the Rod and motor system.

6.14. Synchronisation/External Timing

No effort is made to synchronise signals between motors.

6.15. Setting of Count Position

Two methods exist for zeroing the rod position counter. The counter can be manually incremented or it can be preset to a particular value from the Trusted application.

6.15.1. Position

Manual increments can be made by jogging the displayed position up or down under control of the Trusted application. Typically the application would receive an input from a switch on the control matrix which would request “Jog up” or “Jog down”. The application then passes this command on to a selected channel in a selected Module and causes the position count to increment or decrement.

Alternatively a position register can be set up in the Trusted Controller which can be loaded to the PG/M in a single action.

6.15.2. Zero/Reset

The counter can be caused to zero/reset by the application of a signal from the Trusted application. As with incrementing the position this control is expected to be from a switch on the control matrix via the Trusted application.

6.16. Analogue Input Discrepancy

Detected on a per channel basis if one or more slices’ analogue values deviate outside a preset window for more than a set number of samples.

6.17. Output 2oo3 Error

Detected by loss of current flow in one slice when commanded on.

6.18. Module Temperature Measurement

Temperature measurements are made on the Module for general monitoring purposes. These are indicative only and are not intended to provide accurate temperature readings.

6.19. Diagnostics

Wherever possible the Trusted standard diagnostics have been maintained. Because of the nature of the design these have been modified so as not to escalate any failures to a position which would result in a rod motor being de-energised. The Module has however been supplied with an application interface which can cause the outputs to shut-down and de-energise if required.

Items such as loss of communication between the Module and the Main Processor will result in a degradation process which maintains the outputs in the last controlled state where ever possible (3-2-Maintain last state).

6.20. FTA Output Schematic

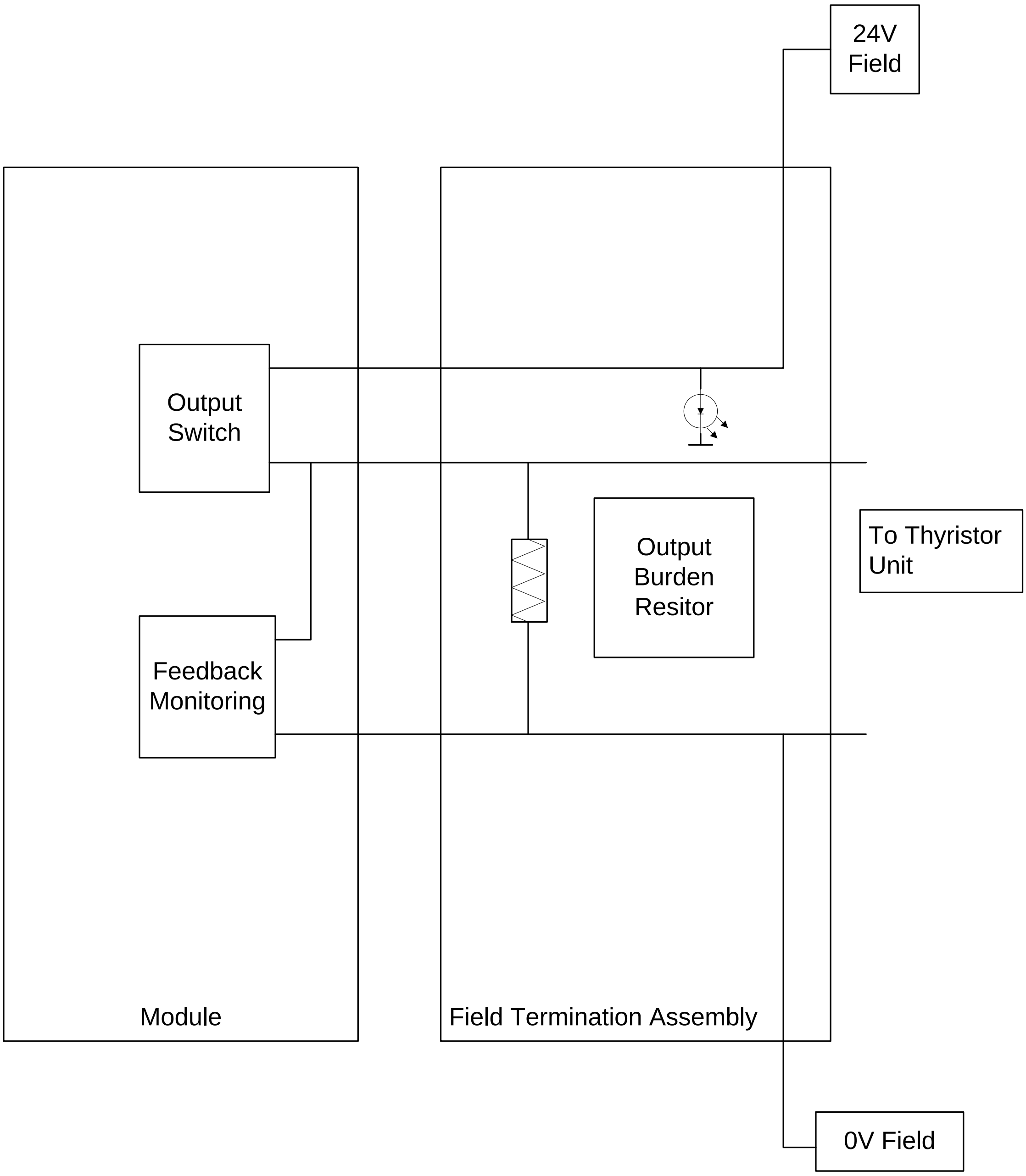


Figure 8 Field Termination Output Schematic

6.21. FTA Input Schematic

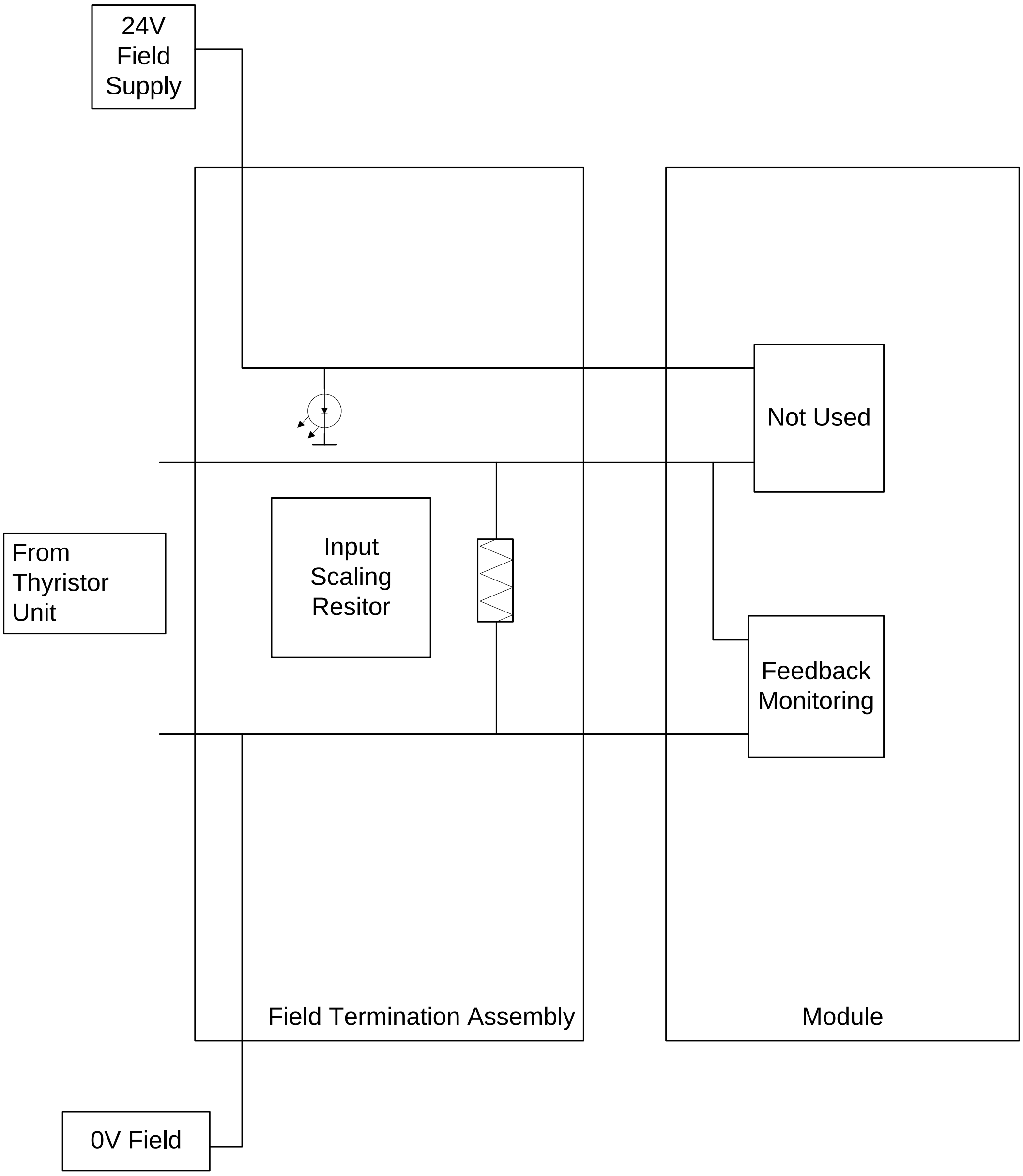


Figure 9 Field Termination Input Schematic

7. Specifications

System Supply Voltage	20 Vdc - 32 Vdc
Circuit Type	Fault tolerant, fully triplicated with optional line monitoring
Number of Channels	40 Channels
Independent Power Groups	5 each of 8 outputs
Operational Output/Field Voltage Range	18 Vdc to 58 Vdc
Output Voltage	
Measurement Range	0 Vdc to +60 Vdc
Maximum Withstanding	-1 Vdc to +60 Vdc
Output Current Rating (Continuous)	0.75 A per channel limited to 6 A per power group
Minimum On State Load Current	25 mA
Output Off State Resistance (effective leakage)	33 kΩ
Maximum capacitance	Pre release 3.5: 30 µF - 55 µF Release 3.5: at least 2800 µF
Output On State resistance	0.6 Ω
Output Short Circuit Protection	Electronic (latching)
Channel to Channel Crosstalk	>-40 dB
Output Short Circuit Protection	Automatic
Input Measurement Range	-20 V to +28 V Limited by ADC range.
Input Impedance	50 kΩ
Power Consumption	
Field Supply (1 A per channel)	24 W Dissipated in field device

System Supply (24 V)	22 W Dissipated in the Module
Field Common Isolation	
Basic Insulation	250 Vdc/Vac$_{rms}$
Maximum Impulse Withstand	2.5 kV
Output Turn-on/off Delay	1.0 ms
Sample Update Time	1.0 ms
Sequence of Events	
Event Resolution	1 ms
Self-Test Interval	2 minutes
Intrinsic Safety	External barrier
Operating Temperature	0 °C to +60 °C (+32 °F to +140 °F)
Non-operating Temperature	-25 °C to +70 °C (-13 °F to +158 °F)
Temperature change	±0.5 °C/min
Relative Humidity range (operating, storage and transport)	10 % – 95 %, non-condensing
Environmental Specifications	Refer to Document 552517
Dimensions	
Height	266 mm (10.5 in)
Width	31 mm (1.2 in)
Depth	303 mm (12 in)
Weight	1.285 kg (2.8 lb)