Monitored Digital Input Modules

Monitored digital input modules provide input sensing for 16 field input devices. With a line monitor device installed at the field switch, monitored digital input modules detect input switch status and field wiring open and short circuits. Input and line status are reported back to the controller for use in application program logic.

Features

- Sixteen input points.

- Fault tolerant operation when connected in parallel with another module of the same type.

- Hot-replaceable.

- Complete, automatic testing of all input circuits.

- Automatic line monitoring detects open and short field wiring faults.

- Individual front panel indicators on each module show the module's active/fault and power status, as well as input status and line fault status for each point.

- 2500 volt minimum electrical isolation between field and logic circuits.

- TÜV certified, Risk Class 5.

The input module circuits are completely and automatically tested, providing a fail-safe interface for safety-critical inputs. Two or three monitored digital input modules can be connected in parallel to obtain fault tolerant input sensing. In these fault tolerant configurations, a failed module can be removed and replaced without interrupting the input signals.
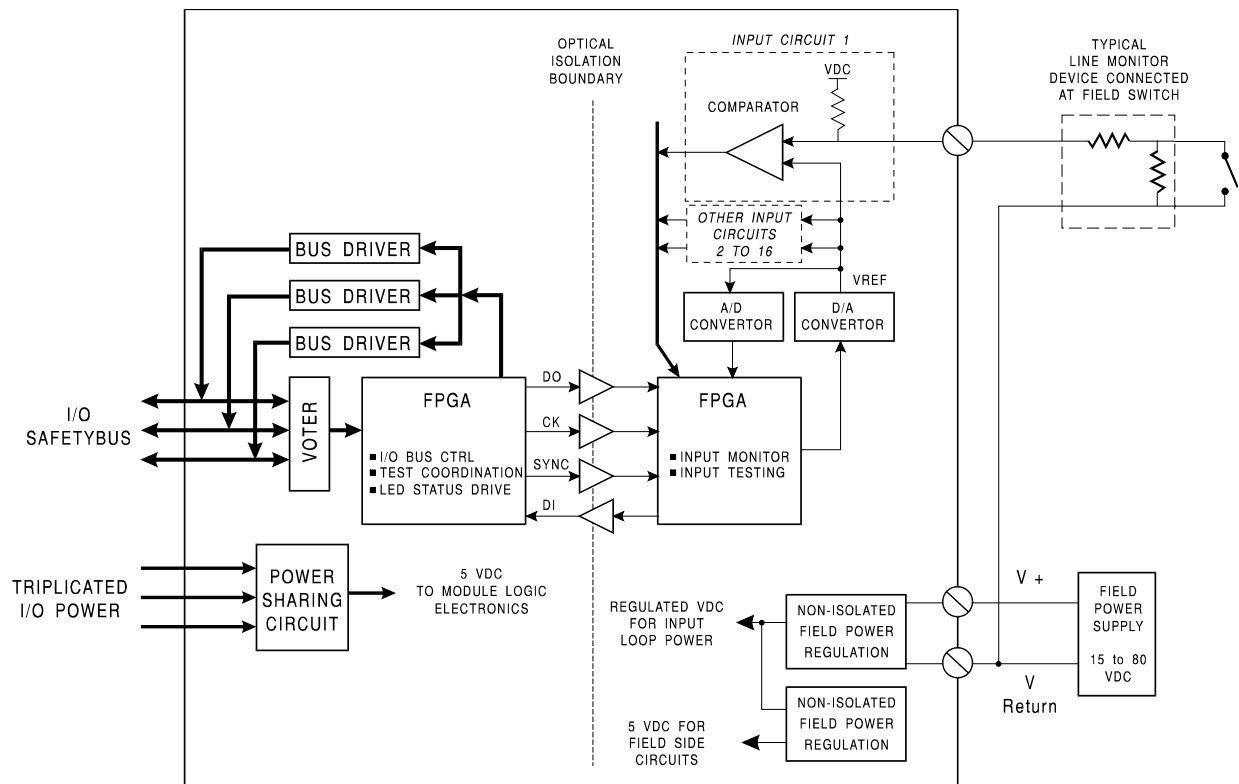
The module requires connection to a field power supply voltage, ranging from 15 to 80 VDC. This field power is internally regulated by the module to 24 VDC to power the field inputs — providing safe, low-voltage inputs signals common in safety system applications.

Module Operation

A block diagram of a typical monitored digital input module is shown in Figure 1.

Figure 1. Block Diagram of the Monitored Digital Input Module.

A field power supply is connected to the monitored input module. The field power is internally regulated to 24 Vdc to power the input module's field interface circuits. For each input circuit, the regulated power passes through an internal dropping resistor to the input screw terminal which is wired to the field input switch. The other side of the field switch is

wired back to the field power supply return. Optionally a line monitor device can be connected across the input switch in the field (as shown in Figure 1).

The input module monitors the voltage of the input circuit after the internal dropping resistor, comparing it to a reference voltage generated by the D/A converter inside the module. The comparator generates an on or off state depending on which voltage signal is greater than the other.

The field-side FPGA controls and monitors the reference voltage signal and reads the status of all 16 input comparators. This information is stored and sent through optical isolation to the logic-side FPGA. The logic-side FPGA interfaces the input data to the I/O Safetybus and drives the module's front panel status LEDs.

Testing and Diagnostics

Standard I/O Module Testing

The processor modules send triplicated read data requests to the input module over the I/O Safetybus. The processors' addressing data and data read requests are voted by the module (preventing I/O Safetybus failures upstream from the module from affecting its ability to be read). The voted result is then passed to the I/O bus interface logic.

After receiving the voted data read request, the I/O bus interface logic sends its input data to the module's three bus drivers. Each of the three bus drivers is independently controlled — preventing failures in a single driver from being propagated into the rest of the system.

The bus drivers then move the data onto the I/O Safetybus which, in turn, passes it to the processors.

Each module's voter circuits are periodically tested by the processor modules. Discrepant data are sent through one of three legs of the I/O Safetybus to determine whether the module's voter is able to outvote the incorrect data. A failure to return the correct majority-voted result to the processors produces an I/O module error indication at the processor modules and a module fault indication at the I/O module.

Each type of module has a unique identification code that is read by the controller. This code lets the controller know which type of module is installed in each I/O chassis slot and address that module and its points specifically. The processor modules periodically check each module's identification code to determine whether the type of module installed matches type of module indicated in the I/O configuration that was loaded when the system was started. If a module is removed, or is replaced with a module of a different type, the processor modules will indicate I/O module errors.

Loopback logic tests periodically write data to the module and then read it back to determine whether the module's I/O bus interface logic is functioning correctly.

Input Circuit Testing

The field interface circuits of the monitored input module are completely tested to detect stuck-on or stuck-off input circuit faults and optionally identify input wiring open and short circuits. The automatic execution and evaluation of the input testing is controlled by the triplicated Regent processor modules.

During normal operations, the internal reference voltage is set to three levels and the comparator output is read. These three reference voltage levels represent thresholds that determine whether the input signal is on or off and if the field wiring is open circuit or short circuit. The logic-side FPGA determines input status and line fault status based on the comparator data for the three voltage levels. The FPGA data is provided to the I/O processors for application processing.

On a background basis, the I/O processors test the input circuit comparators and logic circuits for stuck-on and stuck-off failure modes. During testing the D/A converter generates two reference voltages outside the normal operating range of the field input voltages to test that the comparator output can turn-off and turn-on. The I/O processors read the resulting input status, line fault status, and reference voltage readings for the test cycle to determine if there are faults in the input circuits or the common data paths.

If the I/O processors detect a faulted input circuit, an I/O
module fault is indicated at the processor modules and the
Fault LED on the face of the input module is turned on.

Input Circuit Test Interval

The Regent processor modules schedule testing of the input
circuits on a background basis. The test interval for these
circuits may range from a few seconds to several minutes,
depending on the application program scan time and the size
of the I/O configuration. The equation below can be used to
estimate the test interval for monitored digital inputs.

$$TI = 172 * IOU_{QTY} * TSCAN + 2$$

where:

TI =   Test interval, seconds

IOU_{QTY} =   Quantity of I/O Units in the system (1 to 16)

$TSCAN$ =   The application program scan time, seconds

For example, for a system with 8 I/O units and an application
scan time of 60 milliseconds, the test interval would be:

$$TI = 172 * IOU_{QTY} * TSCAN + 2 \quad = \quad 172 * 8 * 0.060 + 2$$

$$TI = 84.6 \text{ seconds}$$

In this system, all of the monitored input modules would be
tested for stuck-on and stuck-off faults approximately every 85
seconds. This test interval can be used in reliability and
availability calculations to select the fault tolerant input
configuration that meet the application's safety requirements.

Note: Due to I/O processor fault filtering algorithms, it may take up
to four test intervals to report a failed input module as a
permanent fault

Front Panel Indicators

Figure 2 shows the physical features of the monitored digital
input module. The front panel of each module contains
fault/active and power indicators for the module as well as
input status indicators for each channel.

Active/Fault Status Indicator

This green and red LED pair indicates the overall health of
the module and its field circuits. During normal operation the

green ACTIVE indicator flashes at the controller's scan rate. If a module fault occurs the red FAULT indicator turns on and the green indicator turns off.

Power Status Indicator

The POWER GOOD LED indicates the presence of field voltage at the module's field power input terminals and the overall health of the module's field power regulator circuits.

Input Status Indicators

Input status indicators show contact and line status for each point.

A yellow contact status indicator is turned on when the contact is closed or the line has shorted.

A red line status indicator is turned on when the field wiring is open circuit or short circuit. If line monitoring is not desired, this LED can be disabled (see Disable Fault LED, page 20 for more details).
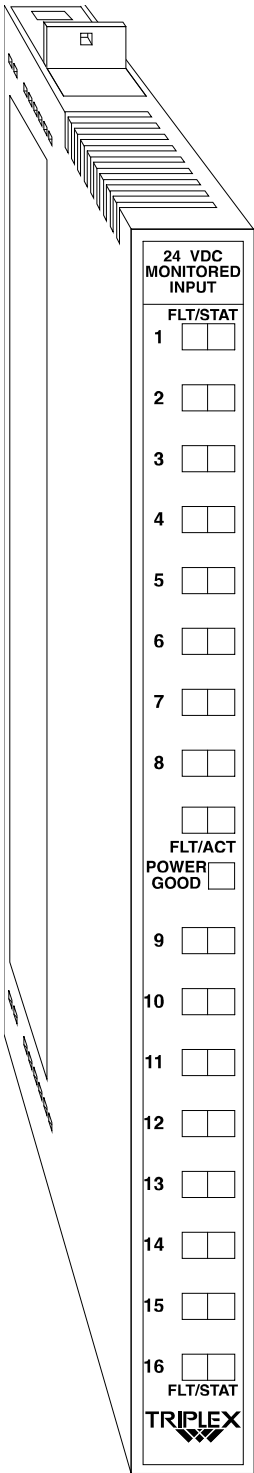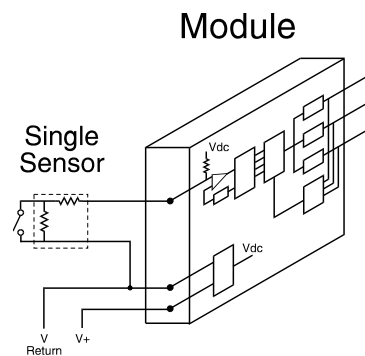
Figure 2. Monitored Digital Input Module.

Application

Simplex Configuration

Monitored digital input modules provide a suitable interface to safety-critical input signals. The circuits in the monitored digital input modules are automatically tested and annunciated, providing a fail-safe interface to digital inputs. This simplex input configuration is illustrated in Figure 3.
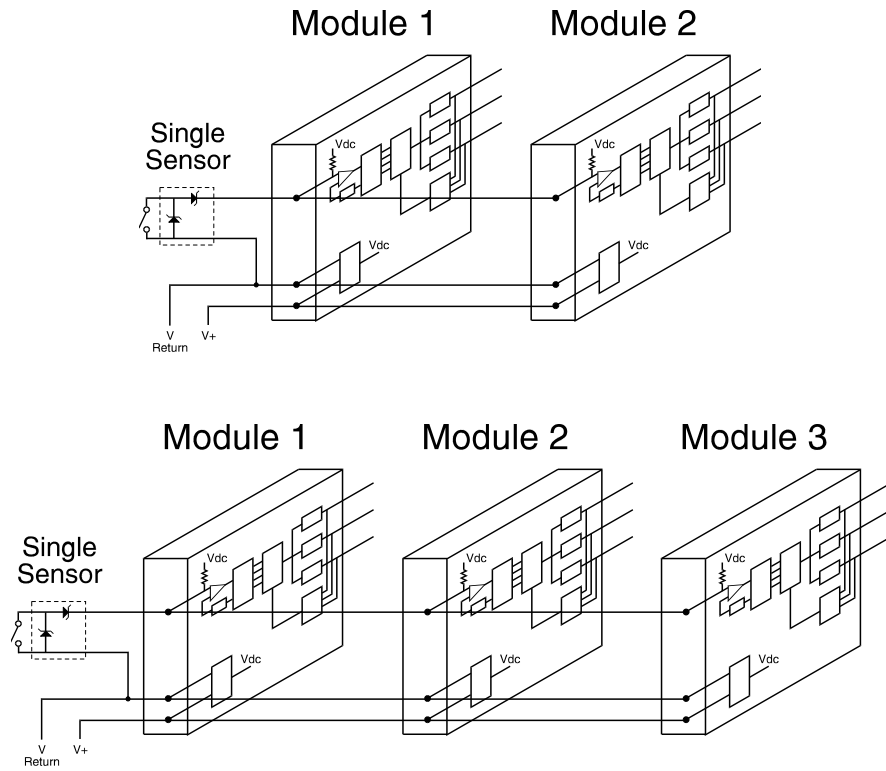

Figure 3. Single Monitored Digital Input Configuration.

Fault Tolerant Configurations

For fault tolerant applications, redundant monitored input modules are used in a fault tolerant configuration. In one configuration the redundant input modules are connected in parallel to a single field input device as illustrated in Figure 4. If redundant field sensors are installed in the field, the modules are connected so that each sensor connects to one of the modules as illustrated in Figure 5. In these fault tolerant configurations, each monitored digital input module is hot replaceable. If a fault occurs on one module, it can be removed and replaced while the system continues to correctly sense the inputs from the remaining module(s).
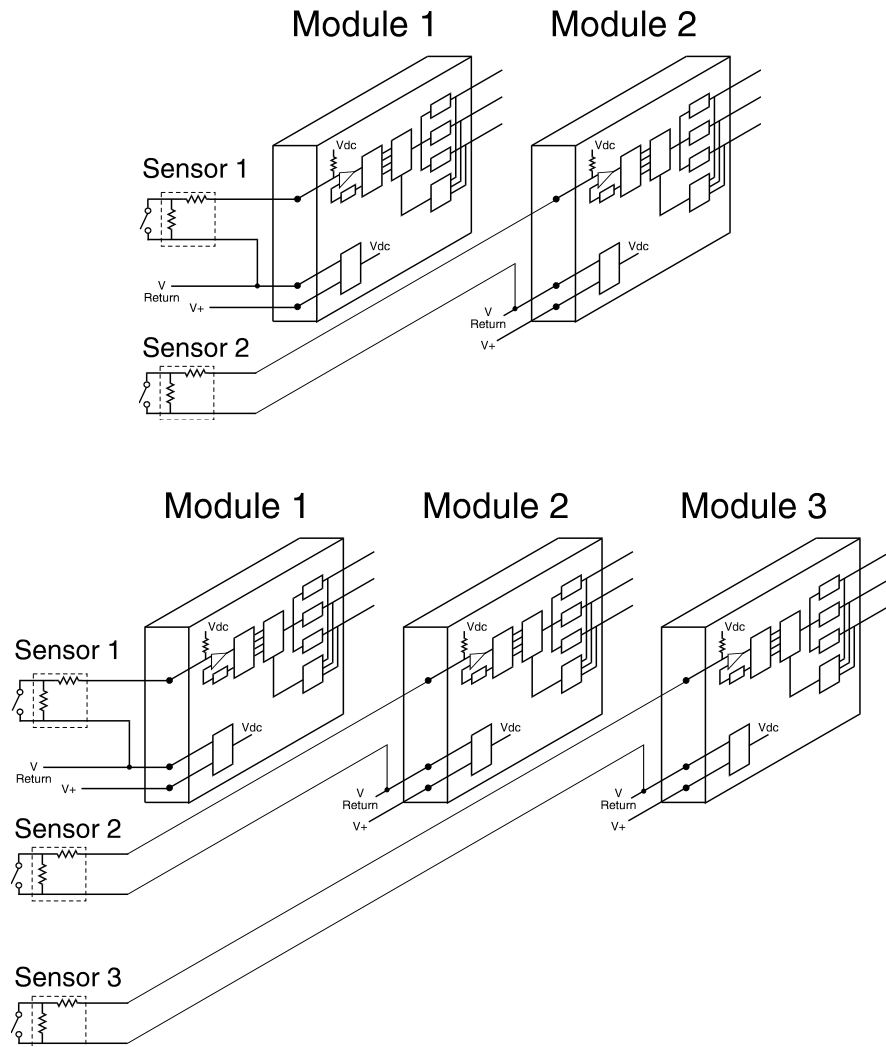
**Figure 4. Fault Tolerant Monitored Digital Input Modules
Connected to a Single Sensor.**

Figure 5. Fault Tolerant Monitored Digital Input Modules Connected to Redundant Sensors.

Field Wiring

Field wiring terminal blocks on the I/O chassis are used to connect the field power supply and field input wiring to the monitored input module. The terminal blocks are located directly above and below the slot where the module is installed. Each terminal block consists of ten #6 wire clamp screw terminals capable of holding two 12 AWG wires.

The field power supply voltage is regulated to 24 Vdc inside the module. This power is used to source the power to the field input switches. The return side of the field switches is wired back to the field power supply return.

Figure 6 shows the wiring connections for a single monitored input module.

When redundant field sensors are installed, each input module is wired as shown in Figure 6. In a fault tolerant configuration the input signals are connected in parallel across both input modules as shown in Figure 7.
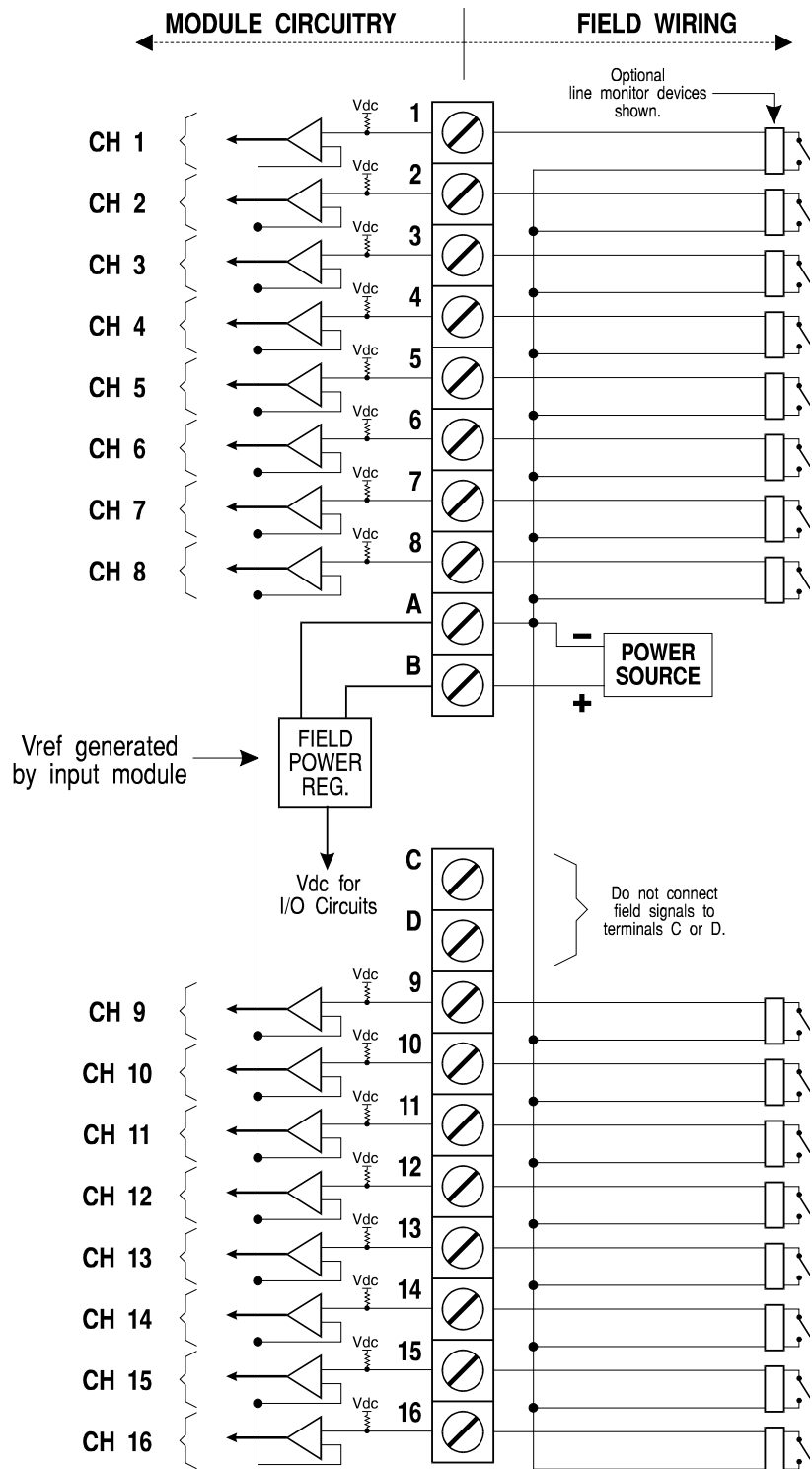
Figure 6. Module Wiring, Single Sensors to a Single Monitored Digital Input Module.
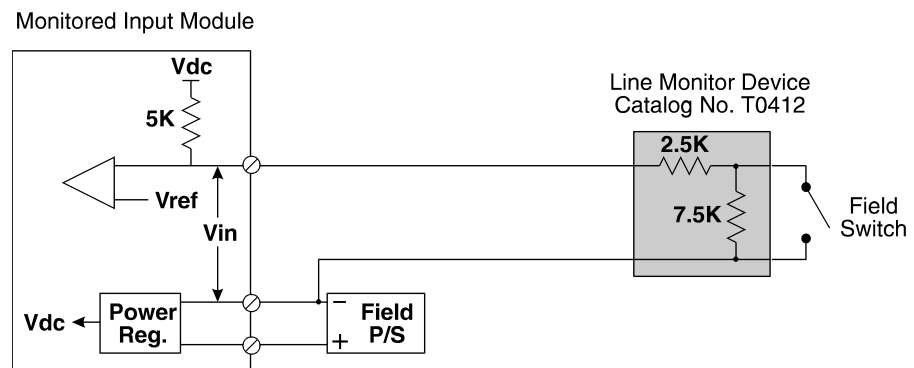
Figure 7. Module Wiring, Single Sensors to Redundant Monitored Digital Input Modules.

Line Monitoring

The Monitored digital input module can perform line
monitoring of the field wiring when a suitable line monitor
device is installed across the field input switch. Two types of
line monitor devices are available to match the type of module
configuration used in the application.

Figure 8 shows a single switch connected to a single monitored
input module. This type of configuration uses the T0412 line
monitor device which contains two resistors, one in series with
the field switch and one in parallel with the field switch.
Figure 8 also applies to fault tolerant input configurations
that include redundant sensors connected to redundant input
modules.

**Figure 8. Line Monitoring, Single Switch Connected to
Single Module.**

For fault tolerant configurations using single sensors
connected to redundant input modules, the T0413 line
monitor device is used as shown in Figure 9. This line
monitor device includes two zener diodes, one in series with
the field switch and one in parallel with the field switch.
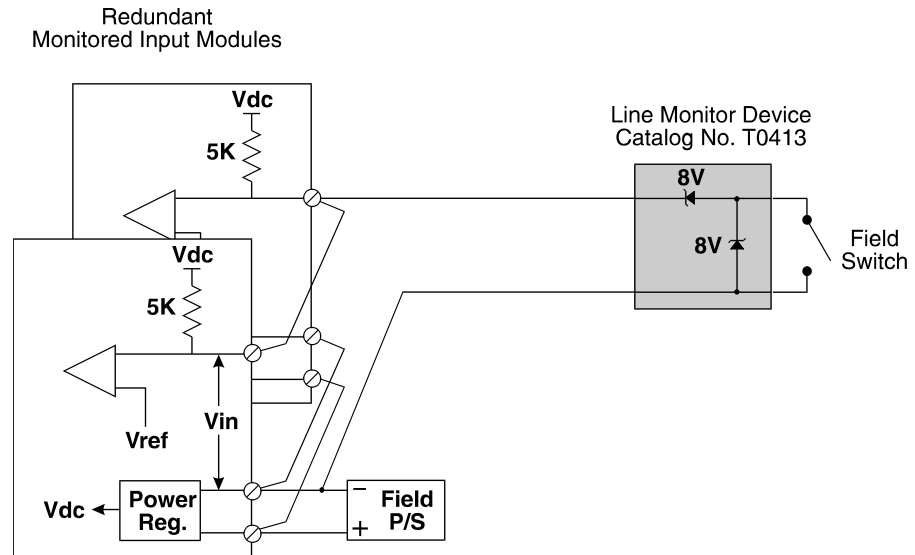
Figure 9. Line Monitoring, Single Switch Connected to Redundant Modules.

With the line monitor device installed, the input voltage, V_{in}, has four possible states as represented in Table 1. When the input module reads the input, the reference voltage, V_{ref}, is set to the values shown in Table 1 to detect the state of the field input and wiring.

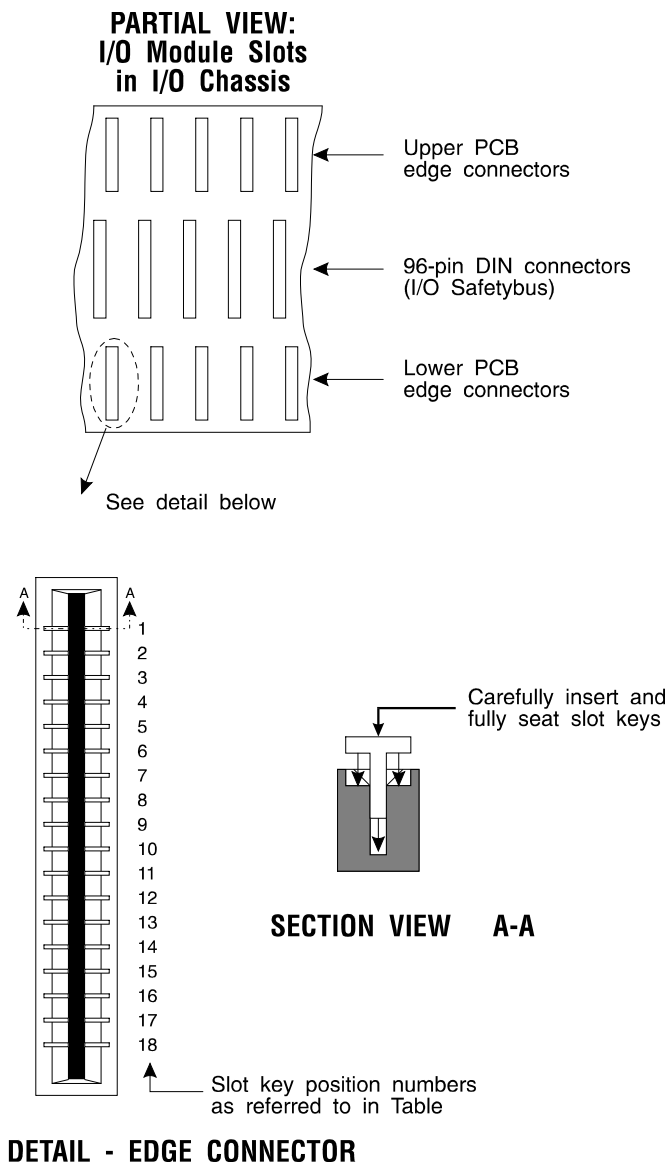**Table 1. Input States and Reference Voltage Thresholds.**

V_{ref} Threshold	Voltage	V_{in} with Line Monitor	V_{in} without Line Monitor
Stuck-on Test	32 Vdc		
	24 Vdc	Wire Open	Switch Open
Open Circuit	20 Vdc		
	16 Vdc	Switch Open	NA
On/Off	12 Vdc		
	8 Vdc	Switch Closed	NA
Short Circuit	4 Vdc		
	0 Vdc	Wire Short	Switch Closed
Stuck-Off Test	-5 Vdc		

Keying

The I/O chassis can be physically keyed to prevent accidental damage caused by inserting a module into a slot wired for a different module type. Figure 10 illustrates how the slot keys are installed on the I/O chassis slot field wiring connectors. The slot key positions for the monitored digital input module are listed in Table 2.

PARTIAL VIEW:
I/O Module Slots
in I/O Chassis

Upper PCB
edge connectors

96-pin DIN connectors
(I/O Safetybus)

Lower PCB
edge connectors

See detail below

Carefully insert and
fully seat slot keys

SECTION VIEW   A-A

Slot key position numbers
as referred to in Table

DETAIL - EDGE CONNECTOR

Figure 10. Installing Slot Keys.

Table 2. Slot Key Positions.

| Module	Upper Connector	Lower Connector
T3411	4	7

Configuration

Each monitored input module is configured using the
WINTERPRET I/O Configuration Editor. In the editor, you will
perform the steps described below to configure the input
module.

1) Set the Module Type:

   Position the cursor on the module slot you wish to define.
   Choose Set Module Type from the Edit Menu and select
   the T3411, 24 Vdc Monitored Digital Input Module from
   the list.

2) Edit the Module Definition:

   Choose Edit Module Definition from the Edit Menu. A
   dialog box will open where you can define the input module
   and point definitions.
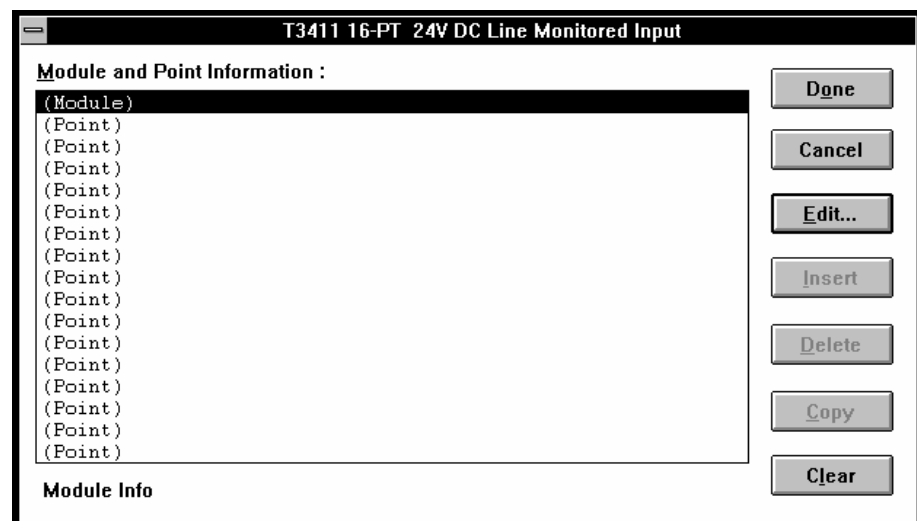
Figure 11. Monitored Digital Input Module Definition.

3) Define the Input Module Fields and Thresholds:

With the cursor at the top of the list in the Module Definition dialog shown in Figure 11, open the Line Monitored Input Module dialog by pressing Enter or double clicking on the "(Module)" selection. The dialog box shown in Figure 12 will open.

Figure 12. Defining the Input Module Fields and Thresholds.

In the module definition dialog you can define a tag names representing all sixteen input points as a 16-bit word. The Name field represents the On/Off status of all sixteen inputs and the Fault Name represents the Line Fault status of all sixteen inputs.

The module tag names represents the 16 inputs as a signed, 16-bit integer. In this format, input point one is the least significant bit (LSB) and input point 16 is the most significant bit (MSB). Enter tag names up to 12 characters long and descriptions up to 40 characters long.

In the module definition dialog you can also set the threshold values used to determine the Open Circuit, On/Off, and Short Circuit input status. Normally these should be left at the default values of 20, 12 and 4 Vdc shown in Figure 12. These values are applicable to field inputs with no line monitor device installed and also for

inputs with the standard (T0412 and T0413) line monitor devices installed. If non-standard line monitor devices are installed, then the threshold values may need to be adjusted.

3) Edit each point:

Choose Edit from the Module Definition dialog box to define a name and description for each input point. In the Line Monitored Input Point dialog, enter names and values for the configuration fields as described below.

Figure 13. Defining a Monitored Digital Input Point.

Name

Also called the tag name, this is the name used in the application program to reference the field input switch's On/Off state. The name can be up to 12 characters long.

Description

This 40-character field provides a place to describe the input point definition. The description is used to help document your system (it does not affect application program operation).

Fault Name

This is the name used in the application program to reference the input point line fault status. The name can be up to 12 characters long.

During operations the input circuit is monitored for open circuit and short circuit wiring faults. This bit is normally on and turns off if either an open circuit or short circuit is detected.

Note: Line fault status is only reported through the Fault Name variables. Line faults are not reported as a permanent I/O module fault and do not turn on the associated system control relay fault bit for the module. Line faults are not latched. If a line fault condition returns to normal, the Fault Name variable status also returns to normal.

Fault Name Description

This 40-character field provides a place to describe the input point fault name definition. The description is used to help document your system (it does not affect application program operation).

Disable Fault LED

Marking the Disable Fault LED check box disables the fault LED for this input point on the face of the input module. Marking this box does not stop the module from line monitoring the input circuit and updating the state of the Fault Name variable, it only stops the module from displaying line faults on the face of the input module. Line faults are still reported to the Regent and are available to the application program through the fault name variable.

This box can be checked for those input points that do not have LMDs installed, or that are spare and have no field switches connected. In this configuration the line fault LED will always be off. If you do not check this box for input points without LMDs installed or unconnected spare input points, the line fault LED will always be on.

Programming

Inputs are referenced in the application program through the tag names defined in the I/O Configuration Editor. When current flows through the input (field switch closed) the input is said to be on, or have a value of one. In ladder logic, the on state would produce power flow in a normally open (N.O.) contact.

Field wiring open circuit or short circuit conditions are referenced in the application program using the Fault Name tag names defined in the I/O configuration Editor. When a line monitor device is installed across the field switch and the wiring is healthy, the Fault Name status is on. If there is a short or open circuit (or there is no line monitor device installed) the Fault Name status is off.

The status of the Name and Fault Name input variables are summarized in Table 3 for the various field input conditions.

**Table 3. Input Status for Field Input Conditions.**

Field Input Condition	With Line Monitor Device Installed		Without Line Monitor Device Installed	
	Name	Fault Name	Name	Fault Name
Switch Open	OFF	ON	OFF	OFF
Switch Closed	ON	ON	ON	OFF
Open Circuit	OFF	OFF	Same as Switch Open	
Short Circuit	ON	OFF	Same as Switch Closed	

Programming Dual Fault Tolerant Monitored Inputs

To program fault tolerant configurations using dual monitored input modules, ladder logic is used to check the status of the inputs and the system control relays (that report a faulted I/O module) and provide a voted input value. Two examples are shown below.

Normally Energized Inputs

Figure 14 shows a ladder logic rung that would be suited for normally energized inputs that de-energize to trip.
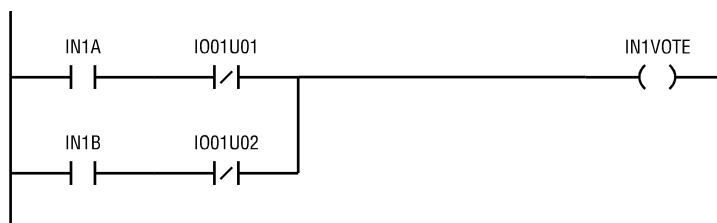
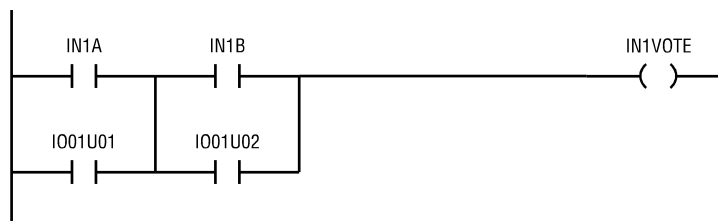**Figure 14. Dual Voting for Normally Energized Inputs.**

In this example, IN1A and IN1B represent the input variables from two redundant monitored input modules. IO01U01 and IO01U02 are the system control relays that report a fault for the monitored input modules (one installed in slot 1 of chassis 1 and the other in slot 1 of chassis 2). The variable IN1VOTE is a shared control relay that will represent the voted value of the two inputs. This variable would be used elsewhere in the application program to represent the status of the field input in the associated safety interlock logic.

When both input modules are healthy, both inputs must turn off to turn off the voted result and initiate a trip. Because the inputs are normally energized, the voted result is normally on. If a fault occurs on one of the input modules, the voted result will remain on, eliminating a nuisance trip. Automatic testing of the input module will detect the fault and the associated fault bit will be turned on, leaving the voted result under the control of the remaining healthy input module. The faulted module can be removed and replaced. After replacing the input module and performing a voted reset, the fault bit is turned off, restoring the input configuration to the dual mode.

Normally De-Energized Inputs

Figure 15 shows a ladder logic rung that would be suited for normally de-energized inputs that energize to trip.

Figure 15. Dual Voting for Normally De-Energized Inputs.

In this example the variables represent the same status information as described above for normally energized inputs.

When both input modules are healthy, both inputs must turn on to turn on the voted result and initiate a trip. Because the inputs are normally de-energized, the voted result is normally off. If a fault occurs on one of the input modules, the voted

result will remain off, eliminating a nuisance trip. Automatic testing of the input module will detect the fault and the associated fault bit will be turned on, allowing the voted result to be controlled by the remaining healthy input module. The faulted module can be removed and replaced. After replacing the input module and performing a voted reset, the fault bit is turned off, restoring the input configuration to the dual mode.

Programming Triple Fault Tolerant Monitored Inputs

Fault tolerant applications that include triplicated monitored input modules should use the Voter instruction in ladder logic. The voter instruction performs two-out-of-three voting of triplicated inputs, storing the voted result in the defined shared variable. Refer to the Regent User's Guide section 5, Working with Programs and Function Blocks for more details on using the ladder logic Voter instruction.

Maintenance

No periodic maintenance or calibration is required for the monitored digital input modules. There are no user replaceable parts inside these modules.

Safety Considerations

TÜV The monitored digital input modules are TÜV certified for Risk Class 5 safety critical inputs. Safety critical configurations include dual and triple redundant input modules and associated application voting methods.

In safety critical input applications using a single sensor, it is important that the sensor failure modes be predictable and well understood, so there is little probability of a failed sensor not responding to a critical process condition. In such a configuration, it is important that the sensor be tested regularly, either by dynamic process conditions that are verified in the Regent, or by manual intervention testing.

Redundant sensors can be used with redundant input modules to eliminate any single points of failure and extend fault tolerance to include the sensors.

If energize-to-trip inputs are used in safety critical applications, line monitor devices <u>must</u> be installed at the field switches. The Fault Name variables must be configured and line fault status must be alarmed to plant operations personnel.

For de-energize-to-trip inputs, line monitor devices are recommended in order to detect the difference between a normally closed input and a shorted field wire.

For additional safety considerations, please refer to the Safety Considerations section of the Regent User's Guide.

Specifications

Safetybus Power	0.85 load units
Number of Inputs	16, common power return
Field Power	
Voltage:	15 to 80 VDC
Current:	450 mA, maximum
Turn-On Voltage (default)	> 12 Vdc
Turn-Off Voltage (default)	< 12 Vdc
Input Current	5.0 mA, maximum
Turn-On Delay	10 msec, maximum
Turn-Off Delay	10 msec, maximum
Over Voltage Protection	
Field Power Terminals:	100 Vdc continuous
Input Terminals:	27 Vdc continuous
Heat Dissipation	8.5 Watts, 29 BTUs/hour
Fusing	None required, internal resistor limits current to 5 mA if input short circuit.
Isolation	2500 volts minimum (field wiring to control logic)
Input Circuit Test Interval	Function of application program scan time and size of I/O configuration. Typically less than 2 seconds (see page 5 for details).

Intrinsic Safety	External barrier, if required. (requires threshold adjustment, see page 18).
Operating Temperature	0° to 60° C (32° to 140° F)
Storage Temperature	-40° to 85° C (-40° to 185° F)
Operating Humidity	0 to 95% relative humidity, non-condensing

Vibration

10 to 55 Hz:	±0.15mm

Shock

Operating:	15 g, ½ sine wave, 11 msec

Electromagnetic Interference

- IEC 801 Part 2 - Electrostatic Discharges
- IEC 801 Part 3 - Radiated Electromagnetic Fields
- IEC 801 Part 4 - Transients and Bursts
- ANSI/IEEE C37.90 - Surge Withstand Capability

Level 3: Contact discharge of 6 kV
Level 3: 10 V/M, 27 MHz - 500 MHz
Level 4: 2 kV, 2.5 kHz for t = 60 seconds
2.5 kV damped 1 MHz sine wave
4 kV bi-directional impulse, 10 nsec rise time, fast transient

Safety	Certified to DIN V VDE 0801 for Risk Class 5. Also designed to meet UL 508 and CSA 22.2, No. 142-M1981

Dimensions

Height:	12.6" (320 mm)
Width:	1.27" (32 mm)
Depth:	10.12" (257 mm)
Weight	3.3 lbs (1.5 kg)