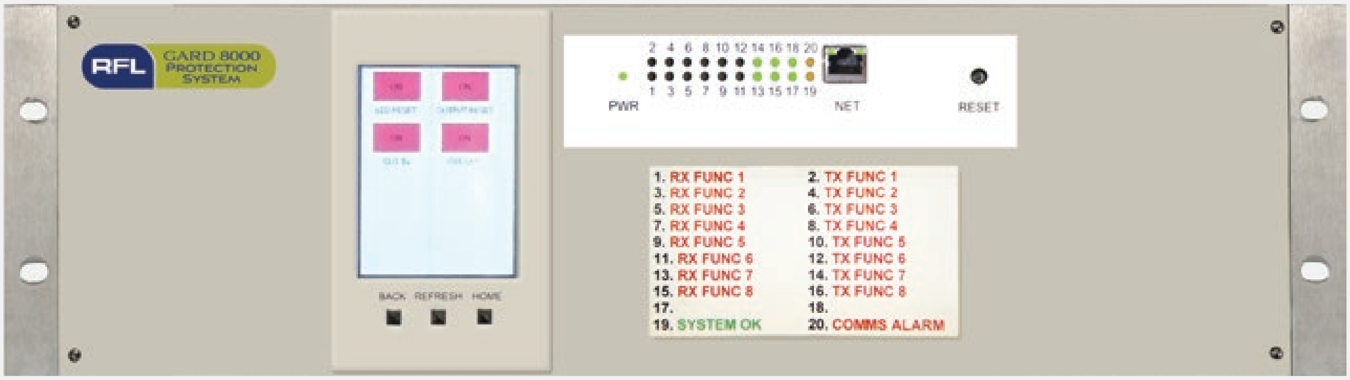
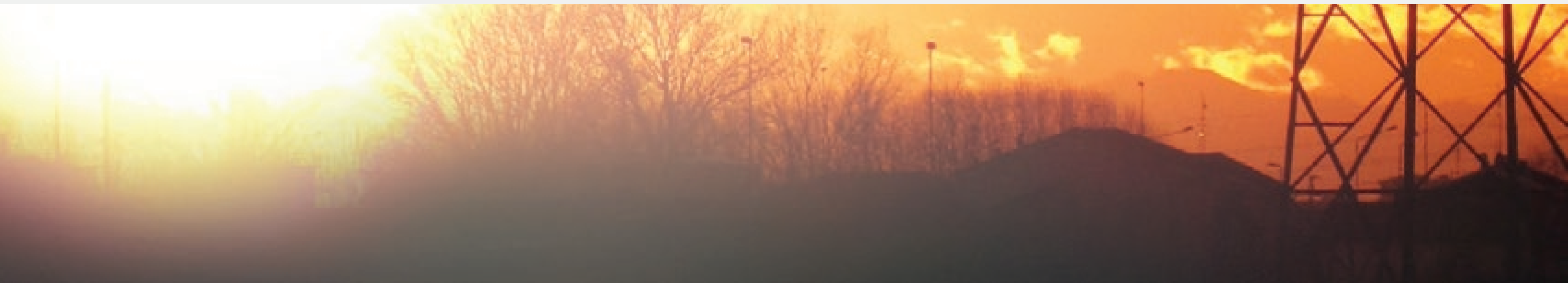
SOLUTIONS FOR AN EVOLVING WORLD

RFL GARD 87L

Current Differential Relay





Your world is changing and so are we.

At RFL, we know your needs change much faster than your infrastructure. Our comprehensive line of solutions meets you wherever you are to help you bridge the gap from yesterday to tomorrow.

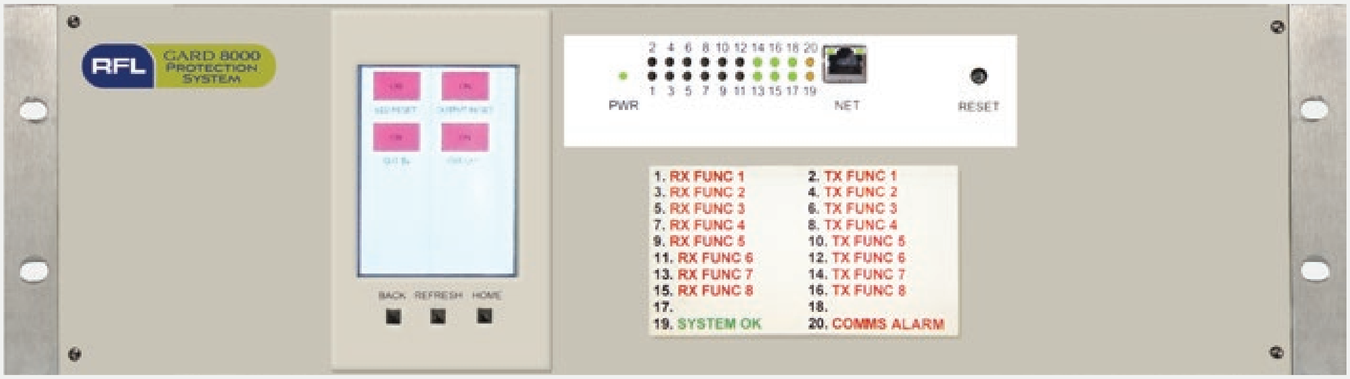
We aren't just engineering products. We are continuously innovating to give legacy equipment the advantage of today's technologies. Our highly adaptable solutions offer more features for more flexibility and a custom fit for your specific needs.

When we deliver, we also deliver our reputation. So when you open that box, you're opening a custom-engineered solution, factory-tested and ready for deployment.

And as long as you own that equipment, you own the attention of RFL. We see you as our partner and we want to ensure that our solution is working for you – now and over the long haul. RFL – delivering solutions that work. Period.

GARD 8000

Current Differential Relay



System Features

A complete Current Differential Protection in the GARD 8000 Protective Relay and Communications System

Stand-alone or together with a GARD 8000 Distance Protection Module as communications independent back-up

Duplicates the highly successful RFL 9300 measuring principle with added features

Unaffected by up to +/- 4 ms channel asymmetry, giving a tolerance of 8 ms difference in transmit and receive path delays

Dual Breaker option for breaker and a half or ring bus applications

Single Pole trip

Ideal for series compensated line applications

3U or 6U chassis depending on number of functional modules included

Supports NERC/FERC security standards

Phase-segregated measurement; three phase elements, one ground element

High speed operation; 10 ms minimum

Single or redundant communications interface

Extensive Sequence of Event Reporting

Digital fault records in COMTRADE; 32 samples per cycle

Supports DNP 3.0

10 Year Warranty

A wide range of communication interfaces to choose from:

T1/E1, electrical or fiber
RS 449, 56-768 kbps
X.21, 64-768 kbps
V.35, 64-768 kbps
G.703, co-directional, 64 kbps
C37.94 fiber
Fiber, multi-mode or single-mode; up to 80 km

Two- or three-terminal line applications

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

System Description

The Current Differential Protection Module in the GARD 8000 System is a proven current-only, high speed line protection system. The advantages with current-only schemes are well known:

- potentials not required
- unaffected by CCVT transients
- never overreach, never underreach
- is not affected by mutual coupling on parallel lines
- unaffected by power swings

Current Differential Protection was traditionally reserved for short line applications due to the limitation of the required pilot wire. However, with the advantage of new communications technology, digital communications become increasingly available for longer lines as well.

Current Differential Relaying is unquestionably the simplest form of line protection, requiring very few settings to be entered for the actual line. The GARD 8000 Current Differential Protection System provides high-speed fault clearing and high sensitivity without compromising security.

The GARD 8000 Current Differential Protection System can be used for two- or three-terminal lines as well as tapped load applications.

The GARD 8000 Current Differential Protection System is suitable for series compensated lines and is inherently phase selective, making it an excellent choice for single pole trip applications.

The GARD 8000 Current Differential Protection Module can be complemented with an independent full Line Distance Protection Module within the same GARD 8000 chassis for full redundant Pilot Protection or as channel failure back-up for the Current Differential Protection. The Distance Protection Module provides additional protection elements such as voltage elements, recloser and synch check.

The two protection modules can be applied in pilot schemes over the same communications channel, or use independent communications interfaces. Or each can be provided with an independent communications interface and use a third as a common redundant channel.

It has been shown that using independent protection modules within the same chassis with redundant power supplies and redundant communications interfaces provides a higher degree of redundancy than physically separate protection devices. A direct comparison based on component failure rates between conventional, redundant Main 1 and Main 2 pilot protection, with redundant pilot protection within one GARD 8000 chassis shows an increased MTBF (Mean Time Between Failure) of a factor of 10 in favor of the GARD 8000 hardware configuration.

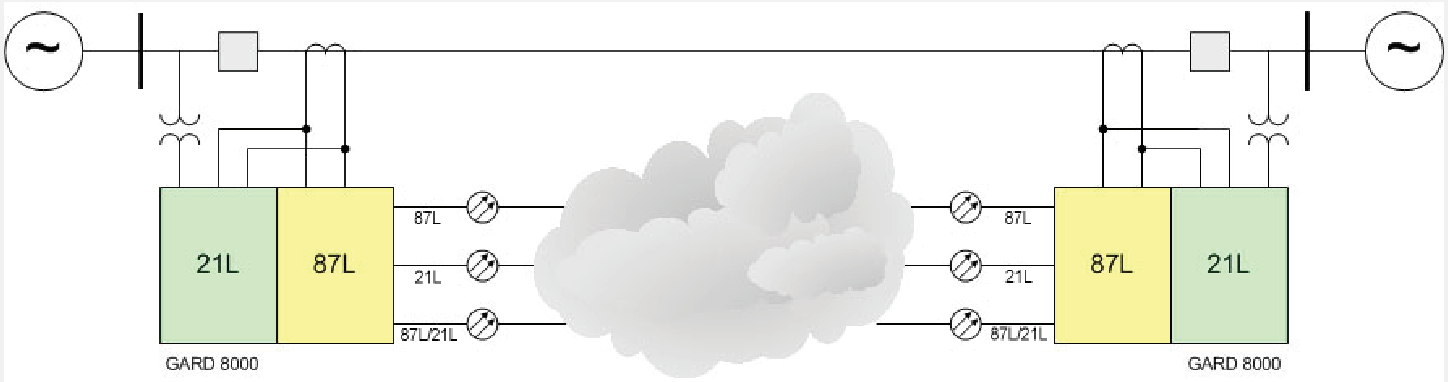


Figure 1. Typical Current Differential Relay (87L) and Distance Relay (21L) Application

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

Protection

Current Differential relaying is a method of extending the benefits of differential protection as applied to transformers, buses or generators to the protection of transmission lines. Comparing current flowing into a line to the current flowing out of the same line allows for a simple protection scheme with high sensitivity and high speed simultaneous tripping of both line terminals. At the same time, the differential scheme is unaffected by external effects such as faults, load and power swings.

The differential current can be measured with different methods:

- Magnitude comparison
- Phase comparison
- Phasor comparison (magnitude and angle)
- Charge comparison
- Combinations of the above

Regardless of the method used, all line differential relays operate on a difference in current into the line compared to the current out of the line.

For an internal fault, the current will flow into the line from both line terminals with the polarity of the current transformers as shown in Figure 2. The local current IL will be practically in phase with the remote current IR. A small phase difference between the two currents is caused by different source angles at the local and remote end.

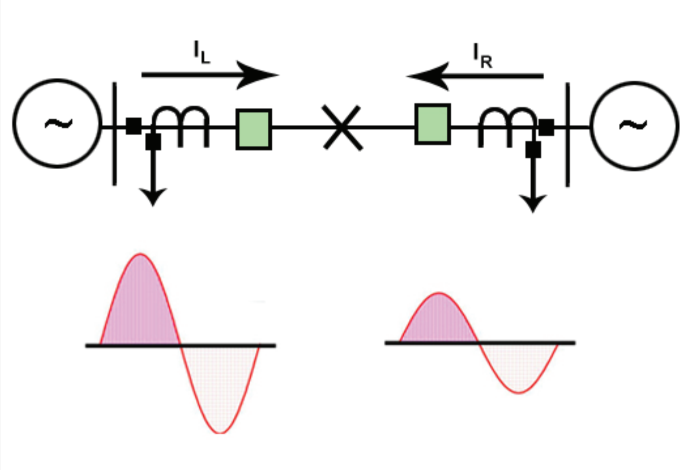


Figure 2. Currents for an Internal Fault

For an external fault, the current will flow into the line in one terminal and out of the other as shown in Figure 3.

The local current, IL will be 180 degrees out of phase with the remote current, IR and they will be of equal magnitude.

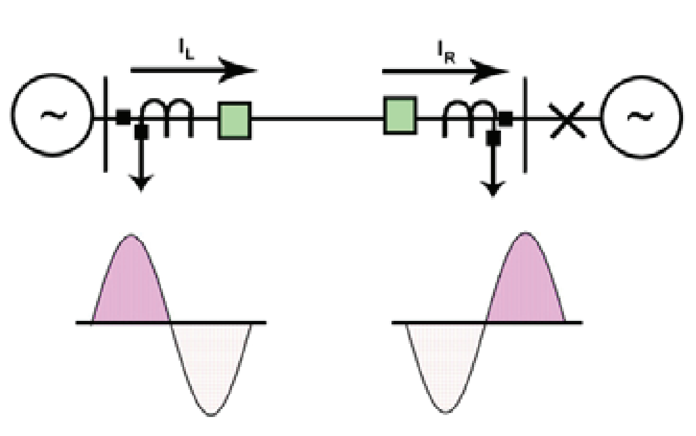


Figure 3. Currents for an External Fault

Most digital current differential relays emulate the electromechanical pilot wire relays operating principle, but more complexity is added due to the communication medium. While the pilot wire relay does its comparison in real-time, a digital current differential relay needs to compensate for the delay introduced by the communications channel for transmitting the digitized current information from one line terminal to the other.

The characteristics of the communications channel need to be taken into account both by the relay's communications interface design and the measuring principle used. The communications interface has to block a corrupted data message from being delivered to the relay and ensure that the two relays remain synchronized to each other. Accurate channel time delay measurement has to be performed so that proper alignment of the measuring quantities can be made. The relay's measuring principle needs to properly handle errors introduced by any asymmetric channel delay (different transmit and receive paths) on switched communications networks in addition to dealing with power system issues causing false differential currents, mainly from ct errors.

The GARD 8000 Current Differential Relay, like its predecessor RFL 9300, has been designed for use with digital communication media. The communications interface and the relay operating algorithm work in synergy to provide the optimum performance of any current differential relay available on the market. The unique design allows for high sensitivity and high speed operation for internal faults while maintaining high security for external faults.

Measurement

The Current Differential Measuring Principle used in GARD 8000 is based on RFL's patented Charge Comparison Measurement Principle.

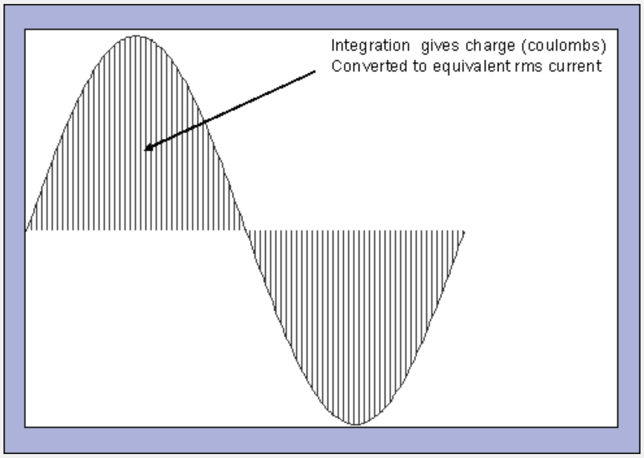


Figure 4. Integration of Current Samples

To perform charge comparison, the current wave of each phase and residual is sampled every Ð ms. The half-cycle area under each wave is measured by integrating current samples between zero-crossings. For each phase and ground, the resulting ampere-seconds area (coulombs of charge) is stored in local memory, along with polarity and start/finish time tags. This storage operation occurs only if the magnitude exceeds 0.5 A rms equivalent and the half-cycle pulse width is larger than 6 ms, but does not exceed 10 ms.

Every positive (negative for 3I0) magnitude is transmitted to the remote terminal, along with phase identification and some timing information related to the pulse width. When the message is received at the remote terminal, it is assigned a received time tag. A time interval representing the channel delay compensation is then subtracted from the received time tag. The adjusted received time tag is then compared with the locally stored time tags looking for a coincidence, or a 'nest'.

A nest is achieved when the adjusted received time tag falls between the local start and finish time tags for a given half-cycle stored in memory, as illustrated in Figure 5.

When the nesting operation is successful, the local and remote current magnitudes (actually charges converted to equivalent currents) are added to create the scalar sum (sum of absolute magnitudes) and arithmetic sum (absolute magnitude of the sum of the signed magnitudes). The scalar sum becomes the effective restraint quantity and the arithmetic sum becomes the effective operate quantity, per the bias characteristic shown in Figure 6.

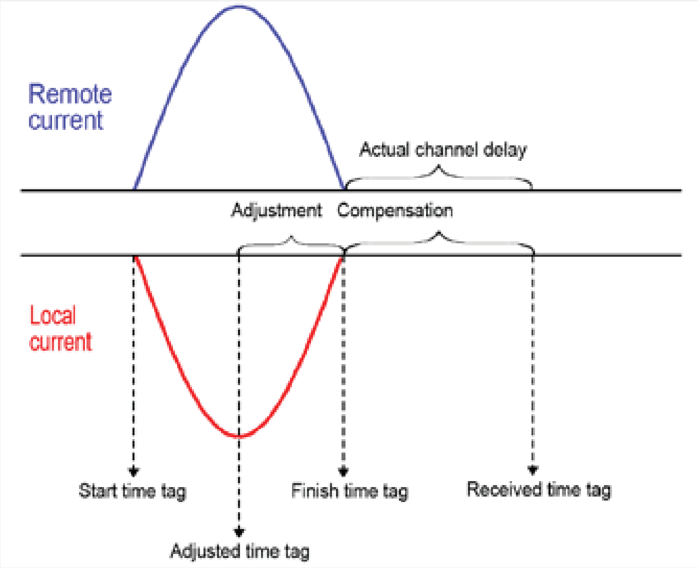


Figure 5. Channel Delay Compensation (external fault)

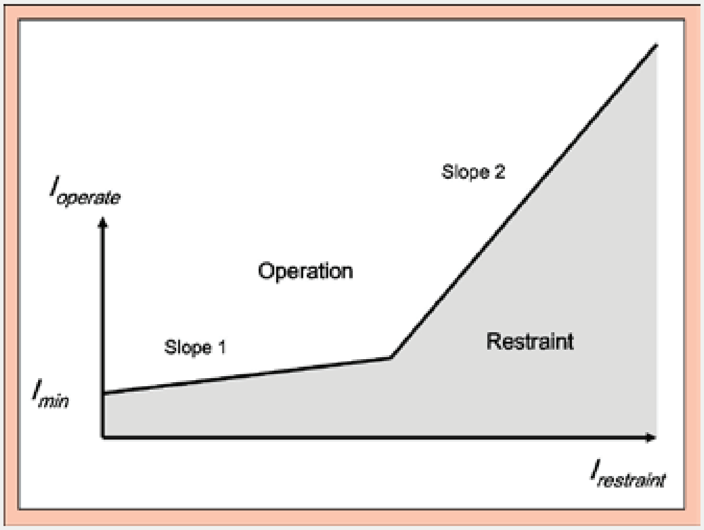


Figure 6. Bias Characteristic

The bias level is an operate threshold which provides security in the presence of spurious operate current due to line charging current, current transformer mismatch and other errors. As shown in Figure 6, the bias level rises sharply after the scalar sum reaches a high value. This provides security for unequal ct saturation during high current external faults. At lower currents, the bias level is much lower allowing for a high sensitivity without sacrificing security.

Measurement (continued)

The operating principle of the charge comparison relay is very similar to that of a percentage differential current differential relay, but instead of comparing phasor quantities, the differential measurement is based on half-cycle charges. The local relay receives a current value equivalent to the positive half-cycle charge from the remote end (negative for the ground subsystem). This value is compared to the corresponding half-cycle charge in the local end. For an internal fault, they are both positive and the scalar and arithmetic sums are formed and compared to the operating criteria.

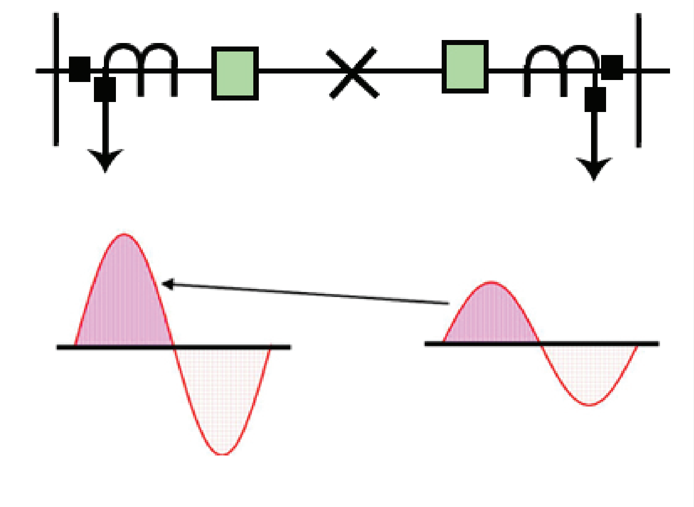


Figure 7. Operation for an Internal Fault

For an external fault, the received positive charge from the remote end coincides with the local negative charge and the relay restrains properly.

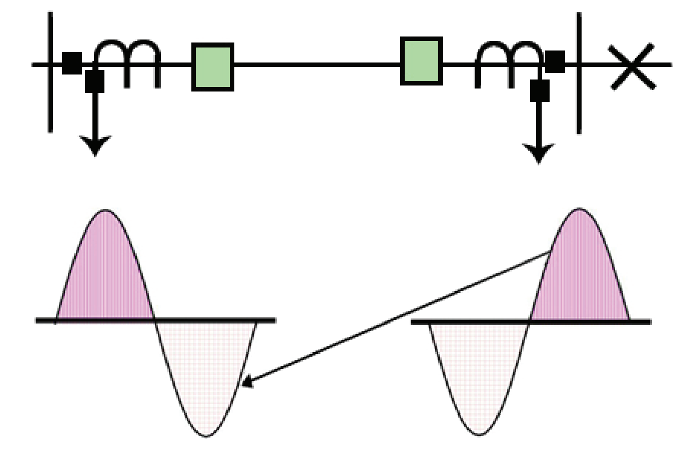


Figure 8. Restraint for an External Fault

Three Terminal Operation

The GARD 8000 is suitable for two or three terminal operation. The three terminal version uses a similar measuring principle, with the major difference being that a third component is added to the scalar and restraint quantity. The scalar sum (restraint quantity) is the time-adjusted sum of the currents in the three line ends; |IL| + |IR1| + |IR2|. The arithmetic sum (operating quantity) is the time-adjusted sum of the signed magnitudes of the currents in the three line ends; $\overline{I_L} + \overline{I_{R1}} + \overline{I_{R2}}$.

Each of the three GARD 8000 is transmitting to and receiving from the two remote relays over two 64 kbps channel slots. The communication can be over separate communication interfaces, or by using two time slots in one interface via a multiplexed network.

The three terminal system will remain operational in case of a break in the communication link between two of the three relays. For instance, if the link between R1 and R2 is non-functional, the relay at L will still have complete current information from all three line ends to make a trip decision for an internal fault, and subsequently trip the two remote relays.

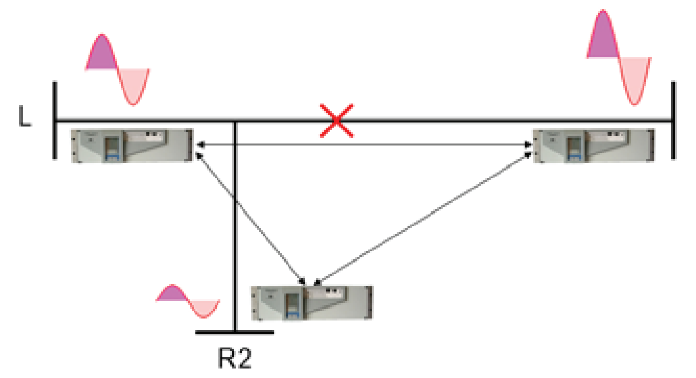


Figure 9. Three Terminal Operation

Input Transformers

CT saturation is always a concern for current differential relays. In addition to the secure dual slope characteristic, the GARD 8000 Current Differential Relay has a patented input transformer design. The transformers faithfully reproduce the current input wave forms, with any dc offset and ct saturation by the use of a flux cancellation technique that creates a near perfect current transformer. The input transformer consists of a small toroidal core with a single turn looped through its center. This single turn is an extension of the secondary winding of the ct supplying the phase current waveform. An active circuit cancels out the flux in the toroidal core. This allows the toroid to handle large dc offsets without saturating. The circuit maintains its accuracy over a 250-ampere (rms) dynamic range. This patented procedure prevents any dc offsets that may be present in the current waveform from saturating the core.

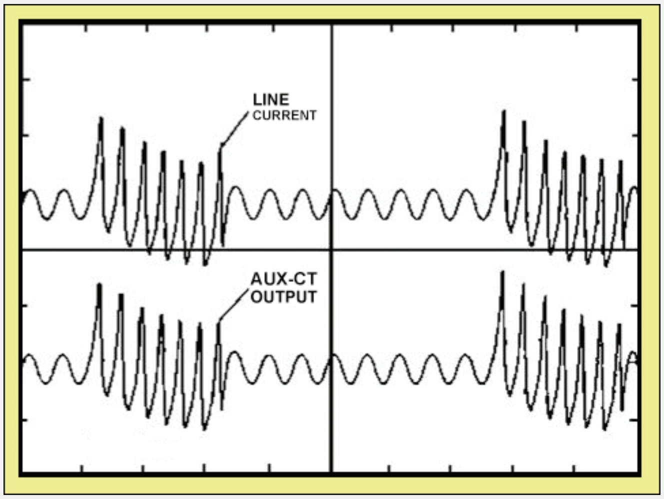


Figure 10. Response of Input Transformers

Input and Output Modules

The GARD 8000 Current Differential Relay provides very high speed tripping combined with high sensitivity and security. In addition, the operating time is very constant (small difference between minimum and maximum operate times) which enables shorter time settings for breaker failure relaying and other back-up elements, resulting in an overall faster protection scheme.

The operating speed is largely independent of current magnitude versus pick-up settings when the operating threshold is exceeded by as little as 0.25 A.

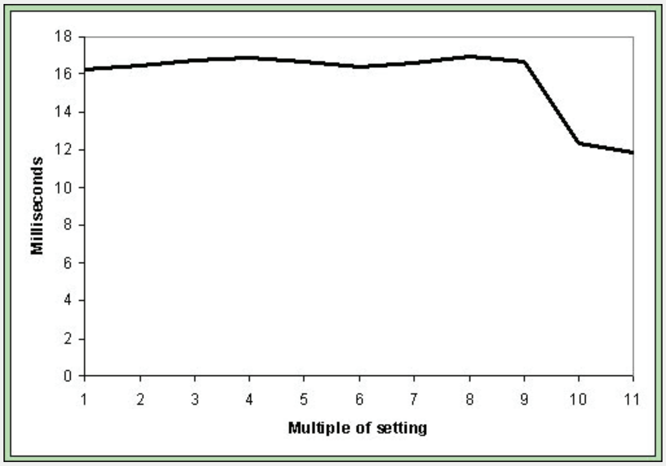


Figure 11. Operating Times for Single Phase to Ground Faults

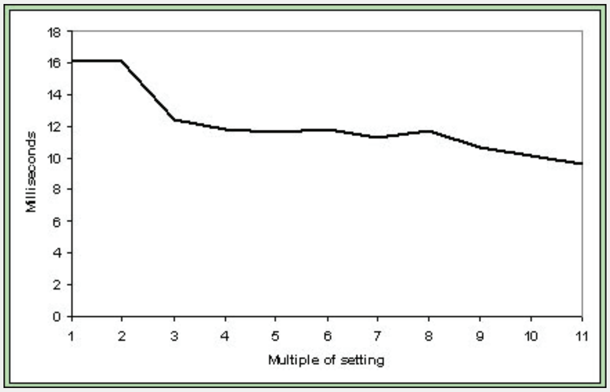


Figure 12. Operating Times for Three Phase Faults

Direct Transfer Trip

The GARD 8000 Current Differential Relay includes one High Speed Direct Transfer Trip function, as well as 8 additional logic signals transmitted to the remote end. The 1 + 8 transfer trip functions can be triggered by any input and/or logic signal in the GARD 8000 System. The receiving relay routes the signals to output contacts, and/or delivers them to the internal logic for use by other protection elements, such as the distance relay.

High Set Trip

The Current Differential measuring element is complemented by a High Set current comparison element that will provide even faster operation for high current faults. The typical operating time from this element is 12 ms, including relay output time.

Overcurrent Back-Up Functions

In case of channel failure, the Current Differential Function is disabled. For these situations, back-up phase and ground overcurrent elements with inverse time characteristics can be enabled. Optionally, the GARD 8000 System can be supplied with an independent Distance Line Protection Terminal.

Protection Specifications

Fault Recording

In addition to the GARD 8000 System SOE, the Current Differential Protection Module provides a detailed log of its operational elements.

IRIG-B or the optional GPS receiver provides a maximum 1ms time stamp resolution.

The Current Differential Protection detailed event log stores up to 15 events, in addition to the 600 events available in the GARD 8000 Main System.

The Current Differential Protection Module has an internal Digital Fault Recorder (DFR).

All analog channels used by the Current Differential Protection function are recorded with 32 samples per cycle (40 samples for 50 Hz). Protection and measuring element status are available as digital channels, facilitating comprehensive fault analysis.

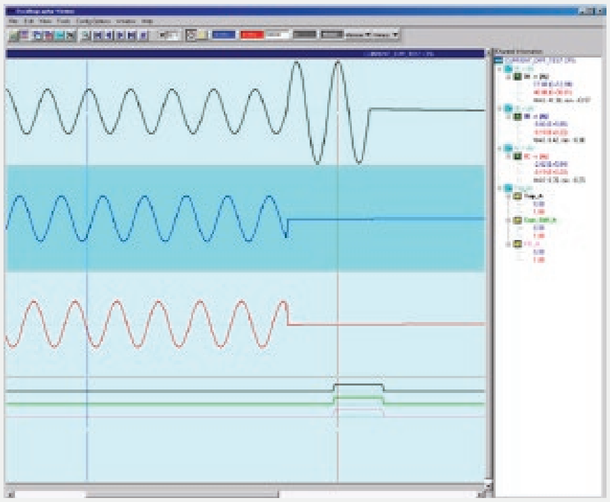


Figure 13. Digital Fault Record

The fault records are stored in standard COMTRADE format and are retrieved via the GARD 8000 System web browser interface. Any compliant COMTRADE viewer can be used to display the records. RFL can provide an optional reader.

Protection Specifications

AC Current Inputs

Nominal	1 or 5 A
Continuous	4 times nominal
One second	100 times nominal
Burden	<0.2 VA for 5 A nominal
	<0.05 VA for 1 A nominal

Frequency

Frequency	50 or 60 Hz

Current Differential Elements

Bias	5A nominal	1.0 - 30.0 A
	1A nominal	0.2 - 6.0 A
Slope 1	0-200%	
Slope 2	0-200%	
Cross-over point	5A nominal	1.0 - 30 A
	1A nominal	0.2 - 6.0 A
High Set Trip	5A nominal	10 - 30.0 A
	1A nominal	2 - 6.0 A
CT ratio	40 - 4000	

Overcurrent Fault Detectors

5A nominal	1.0 - 30.0 A
1A nominal	0.2 - 6.0 A

Instantaneous/Definite Time Overcurrent Elements

5A nominal	1.0 - 50.0 A
1A nominal	0.2 - 10.0 A
Time delay	0.01 - 1.00 seconds

Time Overcurrent Elements

5A nominal	0.20 - 25.00 A
1A nominal	0.04 - 5.00 A
Time Dial	0.05 - 15.00
US	Moderately inverse
	Inverse
	Very inverse
	Extremely inverse
IEC curves	Type A / Type B / Type C

Communication Interfaces

T1/E1; 1.544 Mbps/2.084 Mbps for direct connection to a SONET/SDH multiplexer

RS 449; 56/64 kbps - 768 kbps for connection to a CSU/DSU or a T1 multiplexer

X.21, V.35; 64 - 768 kbps

G.703; co-directional, 64 kbps

C37.94 fiber

Fiber; 64 - 768 kbps,
as specified in the following table:

Wavelength & Emitter Type	Fiber Type	Connector Type	System Gain	Typical Distance
ANSI C37.94	Multimode	ST	25 dB	1 km/0.6 miles
1300nm LED	Singlemode	ST	19 dB	27 km/17 miles
1300nm Laser	Singlemode	ST	6 dB	59 km/37 miles
1550nm Laser	Singlemode	ST	30 dB	90 km/56 miles

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

Protection Specifications (continued)

Terminal Connections

Rear Screw Terminals

Inputs and Outputs

The GARD 8000 System can be configured with up to 20 input and output modules on the rear part of the chassis. Outputs are jumper selectable Form A or Form B. In addition each input and output has an inverter and a timer associated with it that has settings for both pick-up (de-bounce) delay and drop-out (pulse stretch) delay.

Optically Isolated Inputs

Quantity Six per module

Jumper selectable Input Voltage 24/48/125/250 Vdc

Rating	No operation	Operates	Max Input Voltage
24	<14	>19	36
48	<28	>37	68
125	<70	>94	150
250	<140	>189	300

Input current: minimum 1.5 mA

Minimum Pulse Width: 0.03 ms, additional de-bounce time set with logic timer settings

Solid-State Outputs

Quantity	Six per module
Output Current	Maximum 1 A continuous, 2 A for one minute, or 10 A for 100 msec
Open-Circuit Voltage	300 Vdc maximum
Pick-up Time	0 msec

Relay Outputs

Quantity	Six per module
Relay Pick-up Time	4 msec
Output Current Rating	6 A continuous
Surge	30 A for 200 msec

Alarm Relays

Quantity	Two
Contacts	SPDT (Form C)
Rating	100 mA 300 Vdc resistive load

Temperature

Operating	-20° C to + 75° C (-4 F to 165 F)
Storage	-40° C to +85° C (-40° F to +185° F)

Relative Humidity

Up to 95 percent at +40° C (+104° F), non-condensing

System Ports

Front	Electrical TCP/IP (RJ45)RS-232
Rear	Electrical (RJ45) or optical TCP/IP RS-232 RS-485 Optional network port(s) Modbus, DNP 3.0

Time-Code Input

BNC connector for IRIG-B unmodulated (logic-level) or modulated (10 V peak-peak, maximum)

BNC connector for 1- PPS (pulse per second) reference input (logic-level)

Optional GPS receiver (with external antenna). With GPS option installed the system outputs logic-level IRIG-B and 1-PPS signals

RFI Susceptibility

ANSI PC37.90.2 (35 Volts/Meter)

IEC 255-22-3 (RFI Class III)

Interface Dielectric Strength

All optically isolated inputs, power supply inputs, solid state outputs and relay outputs meet the following specifications:

ANSI C37.90-1989 (Dielectric)

ANSI C37.90.1-2002 (SWC and Fast Transient)

IEC 255-5 (1500 Vrms Breakdown Voltage and Impulse Withstand)

IEC 255-22-1 (SWC Class III)

IEC 255-22-2 (ESD Class III)

IEC 255-22-4 (Fast-Transient Class III)

IEC 834-1

Certifications

ISO: The GARD 8000 System with all its functional modules is designed and manufactured using ISO 9001-2000 certified quality program.

Warranty

RFL's standard warranty for all GARD 8000 Systems is 10 years from date of delivery for replacement or repair of any part which fails during normal operation or service.

Specifi cations subject to change without notice

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

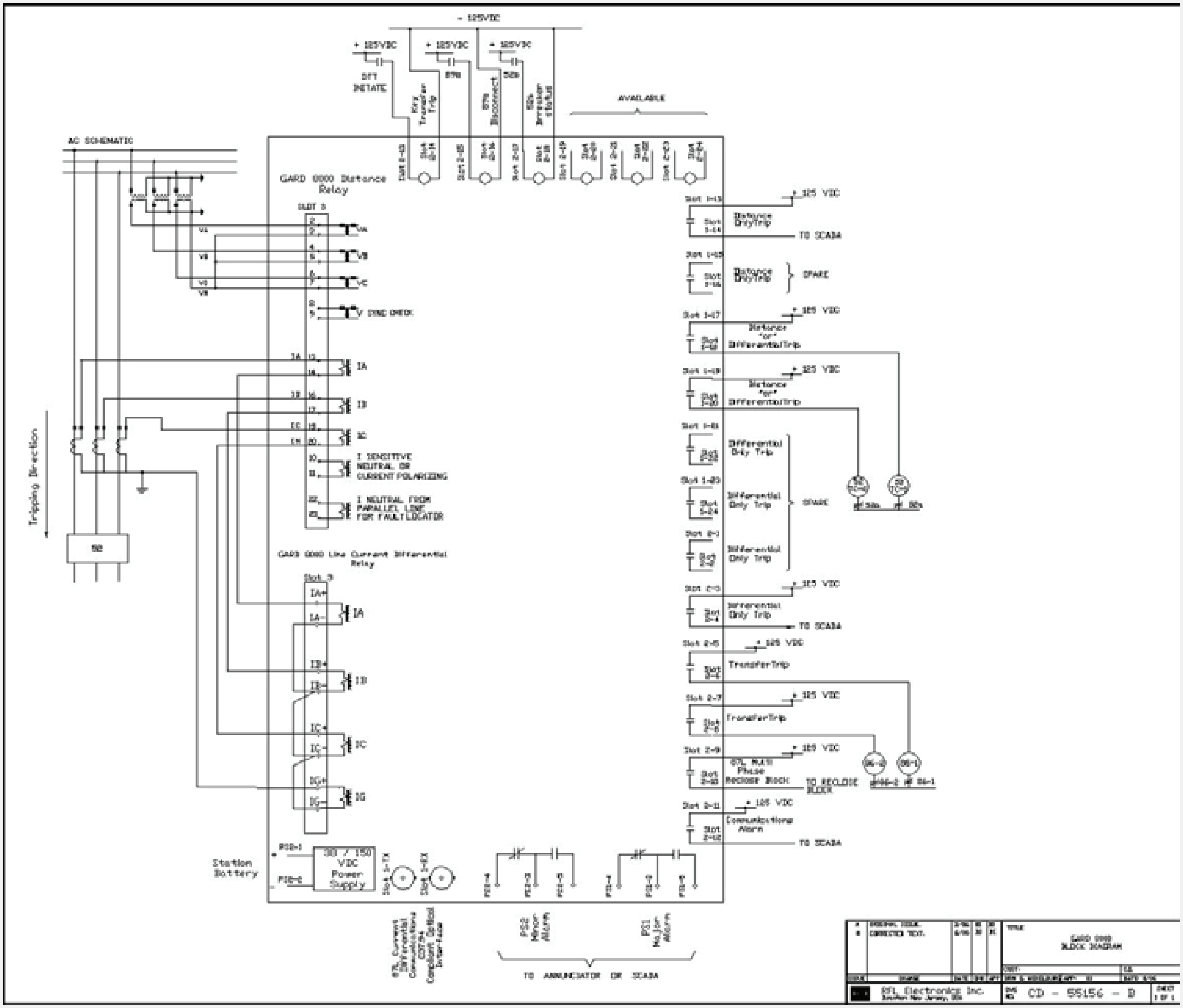


Figure 14. GARD 8000 Current Differential Module AC/DC Schematics

Examples of GARD 8000 System Configurations

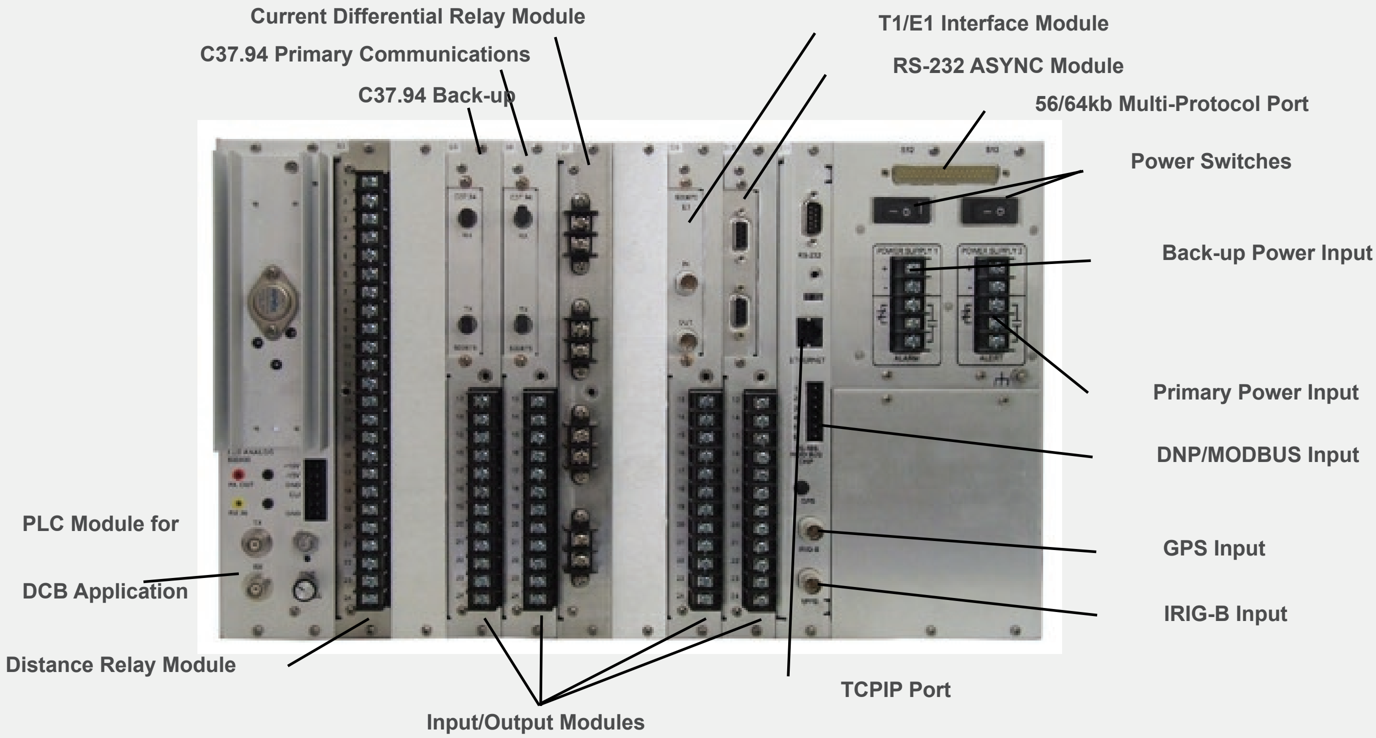


Figure 15. Rear View 6U GARD 8000 with Distance Module, Powerline Carrier Interface, Current Differential Relay and Primary and Back-Up Communications

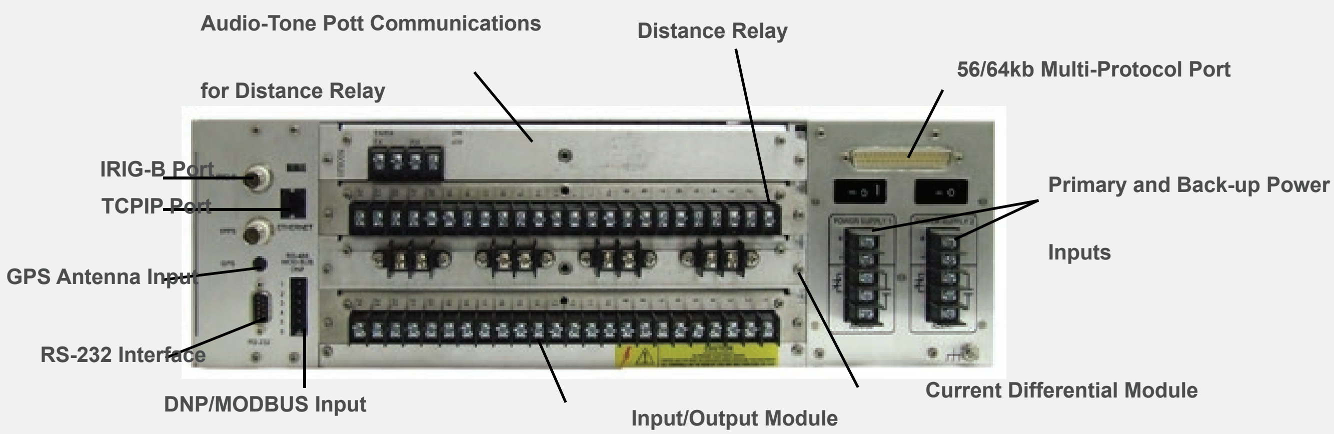


Figure 16. Rear View 3U GARD 8000 with Current Differential Module, Digital Communications, Distance Module and Audio-Tone Communications

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

Dimensions

GARD 8000
Single Function PLC
3U System Dimensions

Figure 17. Rack or Cabinet Mounting (3U)

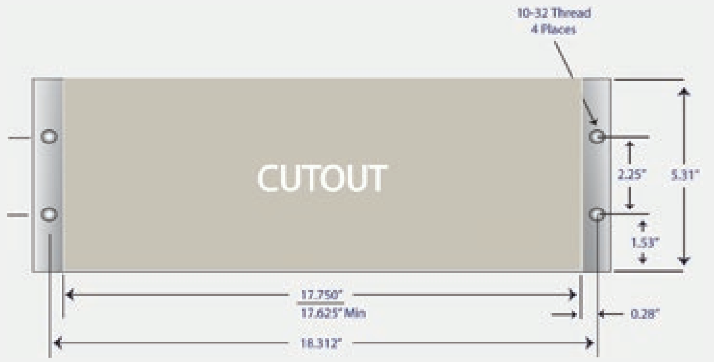


Figure 18. Panel Mounting (3U)

6U System Dimensions

Figure 19. Rack or cabinet Mounting (6U)

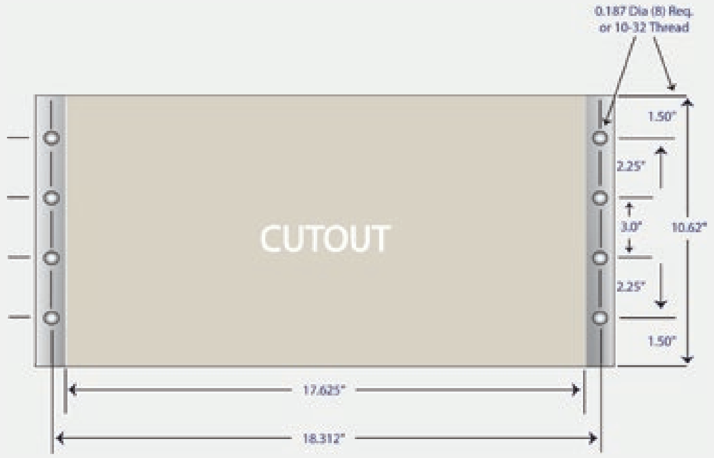


Figure 20. Panel Mounting (6U)

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.

Notes

Notes

RFL Electronics Inc.
353 Powerville Road
Boonton, NJ 07005, USA

Tel: 973.334.3100
Fax:973.334.3863
www.rflelect.com

Because RFL™ and Hubbell® have a policy of continuous product improvement, we reserve the right to change designs and specifications without notice.