TEC MODEL 156 SERIES

ANALOG SIGNAL ISOLATOR

PRODUCT DESCRIPTION

156-PD-01

Technology for Energy Corporation
10737 Lexington Drive
Knoxville, Tennessee 37932

REVISIONS TO 156-PD-01

Revision	Date	Prepared By	Responsible Engineer	Product Manager	Revision Pages
0	11/14/86	[illegible]	[illegible]	V.C. Bailey	ALL
1	4/6/87	[illegible]	[illegible]	V.C. Bailey	1-7; 2-1; 2-2; 2-3; 2-4; 2-6; 2-9
2	3/9/88	[illegible]	[illegible]	V.C. Bailey	1-7
3	6/10/88	[illegible]	[illegible]	V.C. Bailey	4-1
4	7/11/96	Alice Loy	[illegible]	DJ Mullaly	ALL
5	3/20/97	Alice Loy	[illegible]	DJ Mullaly	1-7; 2-1; 2-2; 2-3; 2-4; 2-5; 2-6; 2-7; 2-8; 2-9

TABLE OF CONTENTS

TABLE OF CONTENTS Continued.....

LIST OF FIGURES

LIST OF TABLES

1. GENERAL

1.1 INTRODUCTION

The Technology for Energy (TEC) Model 156 Series of Analog Signal Isolators are used in applications where it is necessary to isolate Class 1E circuits from non-Class 1E circuits. The TEC Model 156 Isolators are designed to meet the isolation requirements set forth in IEEE Standard 384-1981. Its small size, ease of mounting, and simple termination make the Model 156 Isolator an excellent field isolation device. These qualities make the Model 156 ideal for retrofitting isolation capabilities into existing plant circuits.

Another area where this type of isolator can be used is for Emergency Response Facilities (ERFs). NUREG-0696 describes the systems and facilities in a nuclear power plant that improve the response to abnormal plant conditions such as ERFs. Many of the parameters monitored by the ERFs are not classified 1E, but their signals are obtained from 1E sensors. Safety grade isolation of 1E sensors must be provided when signals are used by non-1E devices.

The TEC Model 156 isolators are fully qualified for harsh environments according to the guidelines set forth in IEEE Standards 323-1974, 344-1975, 381-1977, and 472-1974. TEC maintains a disciplined quality assurance program that ensures a quality product. This program includes quality control standards for design, qualification, and production.

1.2 DESCRIPTION

The TEC Model 156 (Figure 1-1) is a small sealed unit enclosed in a stainless steel case which provides better than 120 dB isolation at 60 Hz. The isolation capability of the Model 156 has been designed and tested for up to 2000 V dc (peak). The internal electronics are potted to prevent moisture problems when the isolators are located in harsh environments and to ensure physical integrity when the isolators are subjected to mechanical or seismic stresses. The stainless steel case is spot-welded to the baseplate after potting. These construction features make the isolator a durable unit with a 20-year qualified lifetime for a service temperature of 135° F or less with a DBA (Design Basis Accident) of 100 days at 146° F. Engineering analysis can be provided to calculate qualified lifetimes at various customer-specified service temperatures.

The TEC Model 156 has been designed for field mounting on any flat surface. For applications where multiple isolators and train separation are required, qualified NEMA enclosures are available for housing the isolators. Mounting in an enclosure also protects the isolator from water spray and corrosive chemicals. Dimensions for the module are shown in Figure 1-2. Refer to Section 3 for more details on mounting.

Input and output connections are mounted on barrier terminal strips on opposite sides of the module. The 1E input side has no connections other than the input signal, and the non-1E output side contains both the output termination and the power connection. The separation of the input and output terminations helps ensure isolation integrity.

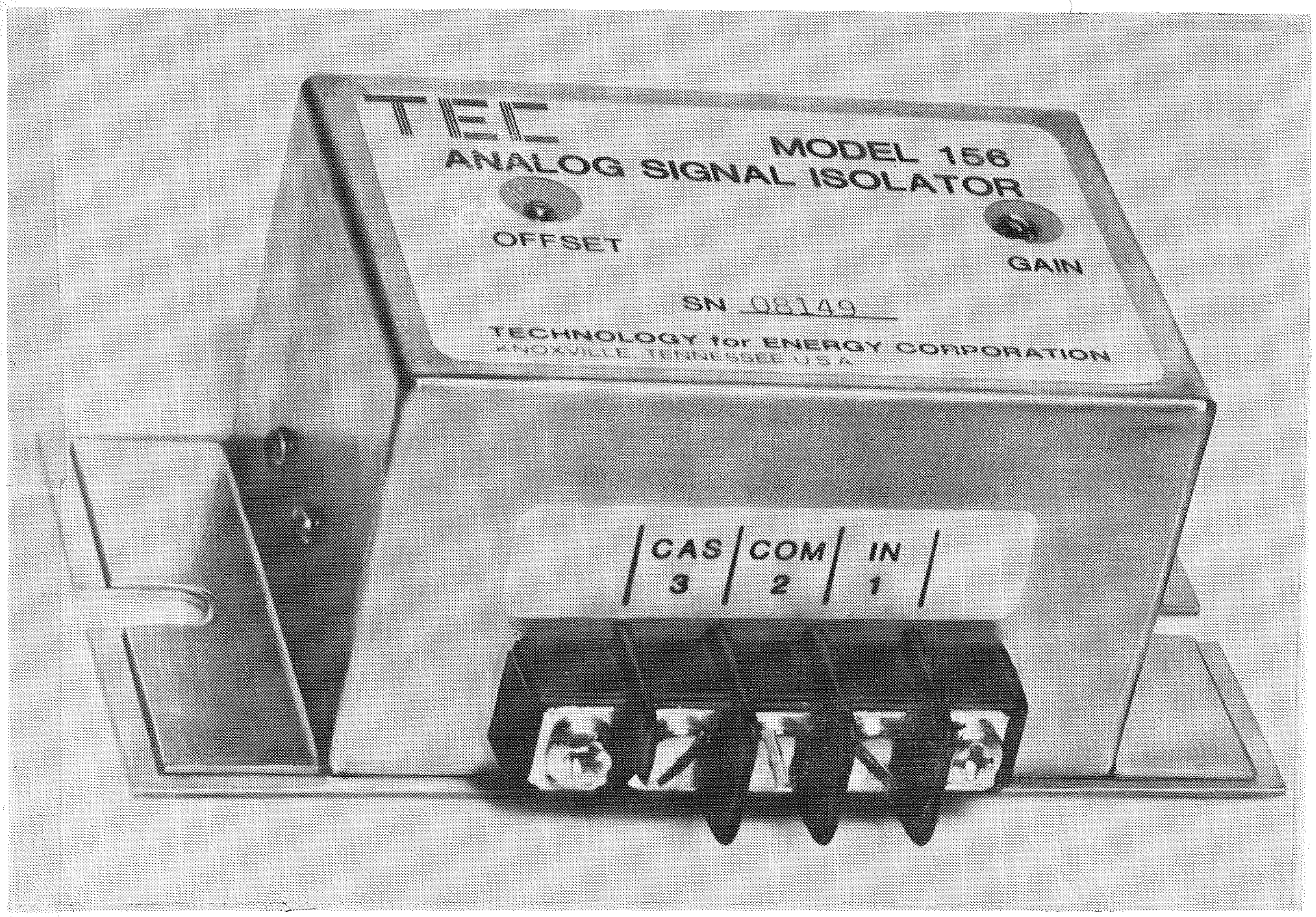

Figure 1-1. TEC Model 156 Digital Signal Isolator.

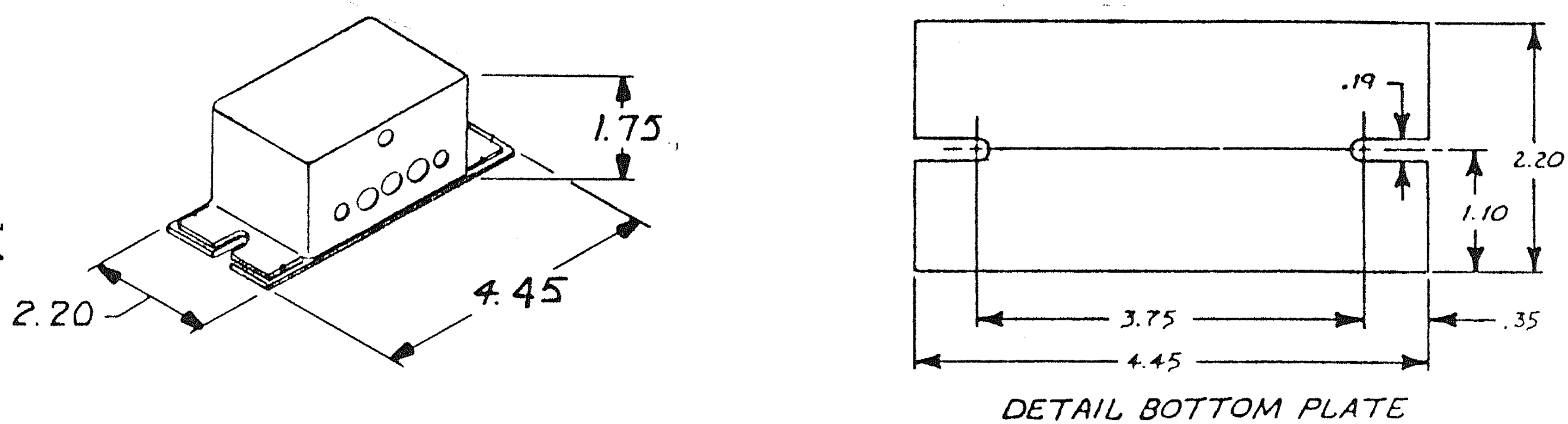

FIGURE 1-2. TEC MODEL 156 DIMENSIONS

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Figure 1-3 contains a block diagram of the TEC Model 156 Isolator which shows the input, output, and power connections. Power requirements are +24 V dc nominal, +18 (+20 for 156S) to +30 V dc operating at less than 60 mA (for 4 - 20 mA output units), 90 mA (for 10 - 50 mA output units and the Model 156S), 40 mA (for 0-1 mA and 0-10 V output units except the 156S).

Input and output ranges for the TEC Model 156 Series have been designed to meet industry requirements. Table 1-1 lists the input/output characteristics of currently available models. Other models with different input and output specifications can be designed and manufactured upon request.

During normal operation, the TEC Model 156 Series of Analog Isolators perform their function without operator interaction. The Model 156 uses an inherently fail-safe principle which ensures isolation even if all power is removed from the isolator.

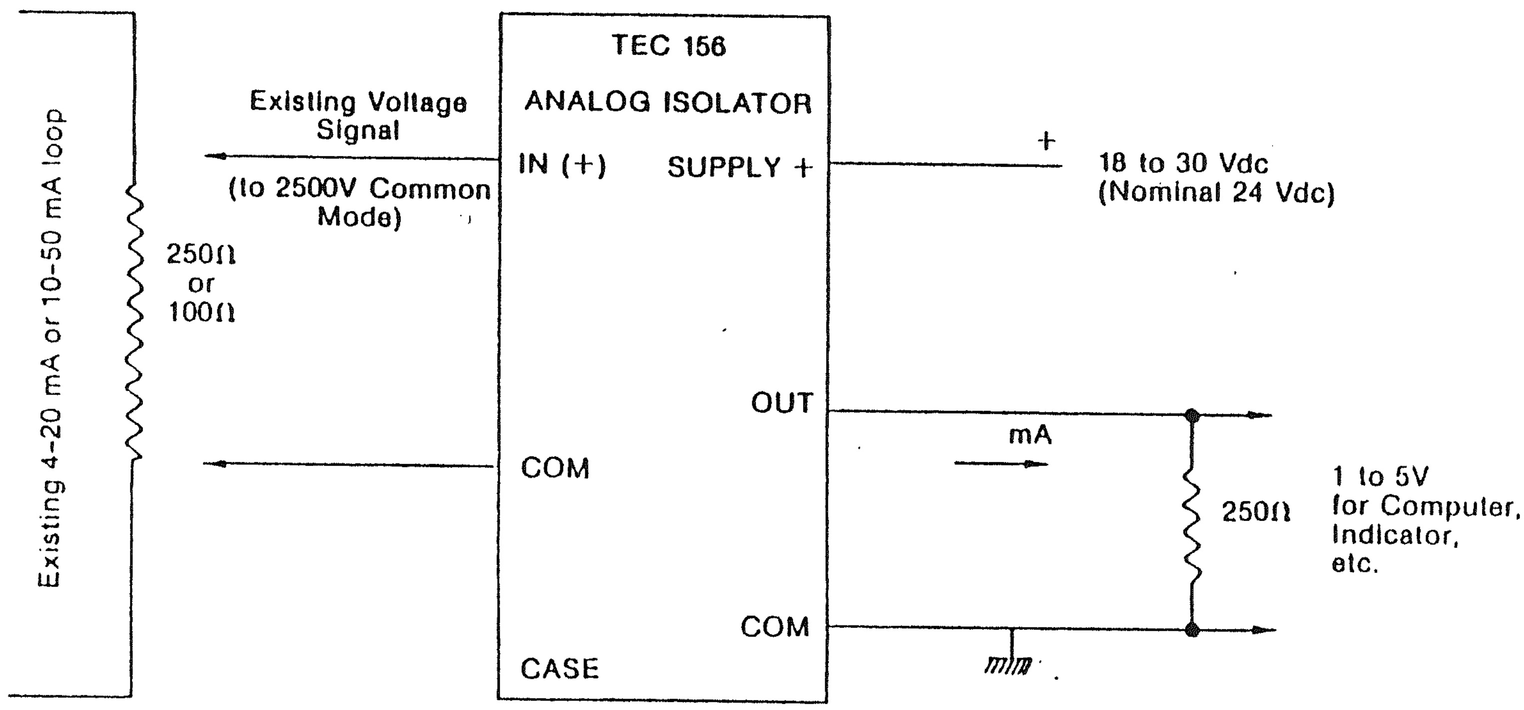

Figure 1-3. Block Diagram for the TEC Model 156

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Table 1-1

TEC Model 156 ANALOG ISOLATOR INPUTS AND OUTPUTS

Model No.	Input	Output
156A	1 - 5 V dc	4 - 20 mA
156B	0 - 5 v dc	4 - 20 mA
156C	0 - 10 V dc	4 - 20 mA
156D	4 - 20 mA	4 - 20 mA
156E	10 - 50 mA	4 - 20 mA
156F	0 - 1 mA	4 - 20 mA
156G	0 - 50 mA	4 - 20 mA
156H	40 - 200 V dc	4 - 20 mA
156I	0 - 20 V dc	4 - 20 mA
156J	0 - 1 V dc	4 - 20 mA
156K	0.2 - 1 V dc	4 - 20 mA
156L	4 - 20 mA	10 - 50 mA
156M	1 - 5 V dc	10 - 50 mA
156N	(−5) - (+5) V dc	4 - 20 mA
156P	0 - 80 mV	4 - 20 mA
156Q	0 - 1 mA	0 - 1 mA
156R	0 - 1 V	0 - 1 mA
156S	0 - 10 V	0 - 10 V *
156T	0 - 10 V	0 - 1 mA
156U	0 - 10 V	0 - 10 V *

* See Section 2.1.16 and 2.1.17 for input/output impedances.

2. SPECIFICATIONS

2.1 PERFORMANCE CHARACTERISTICS

(Reference ANSI/IEEE Standard 381-1977, Section 4.2)

2.1.1 Input Signal Range

Model	Input
156A,M	1 - 5 V
156B	0 - 5 V
156C	0 - 10 V
156D,L	4 - 20 mA
156E	10 - 50 mA
156F	0 - 1 mA
156G	0 - 50 mA
156H	40 - 200 V
156I	0 - 20 V
156J	0 - 1 V
156K	0.2 - 1 V
156N	(-5) - (+5) V
156P	0-80 mV
156Q	0-1 mA
156R	0-1 V
156S	0-10 V
156T	0-10 V
156U	0-10 V

All inputs are dc signals.

2.1.2 Output Signal Range

Model	Output Current	Allowable Output Voltage
156A - K,N	4 - 20 mA Source	0 V < V_{out} < Vcc -6 V
156L,M	10 - 50 mA Source	
156Q, R, T	0 - 1 mA Source	
156S, U	0 - 10 V	

Vcc is the supply voltage powering the isolation amplifier, nominally 24 V dc.

2.1.3 Accuracy

Parameter	Models	Accuracy
Gain @ 25@C	All	±1% *, adjustable GAIN trim: ±5%
Offset @ 25@C	156A,M	±5 mV* RTI**, adjustable by OFFSET trim: ±40 mV RTI
	156B	±5 mV* RTI, adjustable by OFFSET trim: ±125 mV RTI
	156C	±10 mV* RTI, adjustable by OFFSET trim: ±250 mV RTI
	156D,L	±20 μA* RTI, adjustable by OFFSET trim: ±160 μA RTI
	156E	±50 μA* RTI, adjustable by OFFSET trim: ±400 μA RTI
	156F	±1 μA* RTI, adjustable by OFFSET trim: ±25 μA RTI
	156G	±50 μA* RTI, adjustable by OFFSET trim: ±1250 μA RTI
	156H	±0.2 V* RTI, adjustable by OFFSET trim: ±1.6 V RTI
	156I	±20 mV* RTI, adjustable by OFFSET trim: ±500 mV
	156J	±2 mV* RTI, adjustable by OFFSET trim: ±25 mV

156K	±2 mV* RTI, adjustable by OFFSET trim: ±8 mV
156N	±5 mV* RTI, adjustable by OFFSET trim: ±250 mV
156P	±0.08 mV* RTI, adjustable by OFFSET trim: ±2 mV RTI
156Q	±1μA* RTI, adjustable by OFFSET trim: ± μA RTI
156R	±1 mV* RTI, adjustable by OFFSET TRIM: ±10mV RTI
156S, T, U	±12.5 mV* RTI, adjustable by OFFSET trim: ±100 mV RTI

*Expected accuracy for a period of two years after calibration of FINE GAIN and OFFSET controls.
**RTI - Reference to Input.

2.1.4 Linearity

256A-U ±0.2% maximum integral nonlinearity

2.1.5 Sensitivity (Gain)

Model	Sensitivity
156A	4 mA/Volt input
156B	3.2 mA/Volt input + 4 mA
156C,N	1.6 mA/Volt input + 4 mA
156D	1 mA/mA input
156E	0.4 mA/mA input
156F	16 mA/mA input + 4 mA
156G	0.32 mA/mA input + 4 mA
156H	100 μA/Volt input
156I	0.8 mA/Volt input + 4 mA
156J	16 mA/Volt input + 4 mA
156K	20 mA/Volt input
156L	2.5 mA/mA
156M	10 mA/Volt input
156P	200 mA/Volt input + 4 mA
156Q	1 mA/mA input
156R	1 mA/Volt input
156S,U	1 Volt/Volt input
156T	0.1 mA/Volt input

See Section 2.1.3 for accuracy, and Section 2.1.10 for drift with temperature.

2.1.6 Deadband (All Models)

None

2.1.7 Repeatability

Within Accuracy Limits (see Section 2.1.3 for Accuracy)

2.1.8 Drift and Stability

Gain vs Temperature - all models ±0.05%/°C Maximum

Offset vs Temperature -	156A,M	±150 μV/@C Maximum
(RTI)	156B	±260 μV/°C Maximum
	156C,N	±540 μV/°C Maximum
	156D,L	±0.6 μA/°C Maximum
	156E	±1.5 μA/°C Maximum
	156F	±0.052 μA/°C Maximum
	156G	±2.6 μA/°C Maximum
	156H	±6 mV/°C Maximum
	156I	±1 mV/°C Maximum
	156J	±85 mV/°C Maximum
	156K	±30 μV/°C Maximum
	156P	±4 μV/°C Maximum
	156Q	±0.75 μA/°C Maximum
	156R	±75 μV/°C Maximum
	156S,T,U	±375 μV/°C Maximum

2.1.9 Hysteresis (All Models)

None

2.1.10 Reproducibility (Same as repeatability)

2.1.11 Transfer Function (All Models)

$$\text{Output(s)} = \text{Input(s)} \times G \left[\frac{1}{1 + \frac{s}{2\pi F_L}} \right]$$

G is the sensitivity (gain) of the module. It is specifically the ratio of output to input as given in Section 2.1.5, excluding any constant output offset factor, K.

F_L is the -3 dB lowpass corner frequency (Hz) as specified in Section 2.1.12.

s is the complex frequency variable.

2.1.12 Frequency Response (All Models)

dc - 500 Hz minimum (-3 dB)

2.1.13 Response Time (All Models)

Rise time: 700 μs maximum
(10 - 90%)

2.1.14 Saturation Characteristics (All Models) $V_{Supply} = 24V$

Time: 50 ms (maximum) recovery from input overload to <0.02% full scale error

Output: 2.4 mA minimum, 33 mA maximum (4-20 mA output units)
6 mA, 83 mA maximum (10-50 mA output units)
0 mA, 1.7 mA maximum (0-1 mA output units)
0 V minimum, 17 V maximum (0-10 V output units)

2.1.15 Input Overrange Constraints

Model	
156A,B,C,H,I,J,K,M,N,P,R,S,T,U	±500 V pk maximum
156D, L	±45 mA pk maximum
156E	±70 mA pk maximum
156F	±7 mA pk maximum
156G	±70 mA pk maximum

2.1.16 Input Impedance

Model	
156A, B, J, K, M,R	10 MΩ ±5%, 1.5 MΩ overload
156C, N, S, T, U	10 MΩ ±5%, 5.76 MΩ overload
156D, L	249 Ω ±2%
156E, G	100 Ω ±2%
156F, Q	4.99 KΩ ±2%

156H	102 MΩ ±2%
156I	10 MΩ ±5%, 8 MΩ overload
I56P	1 MΩ ±10%, 150 KΩ overload

2.1.17 Output Impedance

> 10 M Ω 1000 pF (±10%) for 156 a through R and T
200Ω 1000 pF (±10%) for 156S
250Ω 1000 pF (±10%) for 156U

2.1.18 Load Capability (All Models)

Any load resistance that will not cause output voltage to exceed limits in Section 2.1.2.

2.1.19 Pulse Characteristics (All Models)

Step Response:
Output (t) = (output steady state)($l-e^{-t/\tau}$)
Time constant (τ) = 318 μs minimum

2.1.20 Ripple Output (All Models)

Less than 320 μA p-p (4-20 mA output units)
Less than 800 μA p-p (10-50 mA output units)
Less than 16 μA p-p (0-1 mA output units)
Less than 200 mV p-p (0-10 V output units)

2.1.21 Common Mode Rejection (All Models)
See isolation below

2.1.22 Isolation (All Models)

Maximum Common Mode Voltage: 2000 V dc pk continuous
(inputs to outputs) 2000 V rms 60 Hz, 1 minute maximum

Common Mode Input Impedance: $5x10^{10}$ Ω | | 20 pF minimum
Case should be grounded to output side ground potential

2.1.23 Range and Adjustments

GAIN Trim: (all) ±5% min

OFFSET Trim:

Model	Adjustment Range
156A, M	±40 mV RTI*
156B	±125 mV RTI
156C, N	±250 mV RTI

156D, L	±160 μA RTI
156E	±400 μA RTI
156F	±25 μA RTI
156G	±1250 μA RTI
156H	±1.6 V RTI
156I	±500 mV RTI
156J	±25 mV RTI
156K	±8 mV RTI
156P	±2 mV RTI
156Q	±8 μA RTI
156R	±10 mV RTI
156S, T, U	±100 mV RTI

GAIN trim and OFFSET trim adjustments should be set under laboratory conditions and rarely, if ever, require readjustment. These adjustments are factory set during manufacture.

2.1.24 Thermal and Electrical Insulating Properties (All Models)

Electrical: Input and input common to output common - 5 x $10^{10}\Omega$ minimum. Case floats and should be grounded to output side potential.

Thermal: N/A

2.1.25 Power Requirements (All models)
Voltage: +24V dc nominal
+18 to 30

Current Operating Max	
Model Suffix	mA
Q, R, T	40
A, B, C, D, E, F, G, H, I, J, K, N, P	60
L, M, S, U	90

Only the output side is powered.

2.1.26 Contact Ratings (All Models)

All connections by barrier terminal strips with connection resistance 1 Ω maximum.

No relay type contacts inside.

2.1.27 Warm-Up Time

10 seconds for signal transfer; isolation is not dependent upon unit being powered.

2.1.28 Signal-to-Noise Ratio (All Models)

dc S/N: N/A
ac S/N: N/A

NOISE: 120 nA rms 0.05 Hz - 500 Hz (output)

2.1.29 Heat Rejection Rate (All Models)

	4-20 mA output units	10-50 mA output units	0-1 mA output units
V cc = 18 V	1.1 W maximum	1.7 W maximum	0.7 W maximum
V cc = 24 V	1.5 W maximum	2.3 W maximum	1 W maximum
V cc = 30 V	1.8 W maximum	2.7 W maximum	1.2 W maximum

	0-10 V output units
V cc = 18 V	1.7 W maximum
V cc = 24 V	2.3 W maximum
V cc = 30 V	2.7 W maximum

2.2 ENERGY SUPPLY AND ENVIRONMENT SPECIFICATIONS

Reference ANSI/IEEE Standard 381-1977, Section 4.3

2.2.1 Temperature

Operating: 0 - 70@C (158@F)
Storage: -55@C to 125@C

2.2.2 Pressure

-0.1 to 1 atmospheres

2.2.3 Relative Humidity (Operating and Storage)

0 - 100% Non-condensing

2.2.4 Power Source

Voltage: +24 V dc nominal, 18 V - 30 V dc
Current: less than 40 mA for 156Q, R, T
less than 60 mA for A, B, C, D, E, F, G, H, I, J, K, N, P
less than 90 mA for L, M, S, U
Ripple: less than 250 mV p-p

2.2.5 Electromagnetic Interference

Case should be grounded to output side ground potential. Unit believed to operate without serious degradation in 1 V per meter electric fields. EMI - Surge testing in accordance with TEC Document 156-QP-04.

2.2.6 Vibration

Operating - Unit is vibration free.
Seismic - See seismic spectra in qualification report (TEC 156-TR-04)

2.2.7 Spray and Jet (Water or Chemical)

Water or chemical sprays are not part of the environment.

2.2.8 Chemicals (Atmospheric)

Chemicals are not part of the environment.

2.2.9 Radiation Type - Gamma

2.2.10 Irradiation (Gamma; Rads, Carbon)

	Dose Rate	Total
Normal	0.0025 R/hr	880 R
Post-Accident	1400 R/hr	1100 R

2.2.11 Radiation Energy Spectrum

Gamma Energy	% Field Distribution
1.17 MeV	99.9
1.33 MeV	100.0

2.2.12 Mounting Constraints

Securely mount to flat surface in spray-proof enclosure.

Securely mount 1E and non-Class 1E wiring to unit.

2.2.13 Weight

0.78 lbs.

SAFE SHUTDOWN EARTHQUAKE (SSE)
HORIZONTAL ACCELERATION
VERTICAL ACCELERATION IS 2/3
OF HORIZONTAL ACCELERATION
OPERATING BASIS EARTHQUAKE = 1/2 SSE

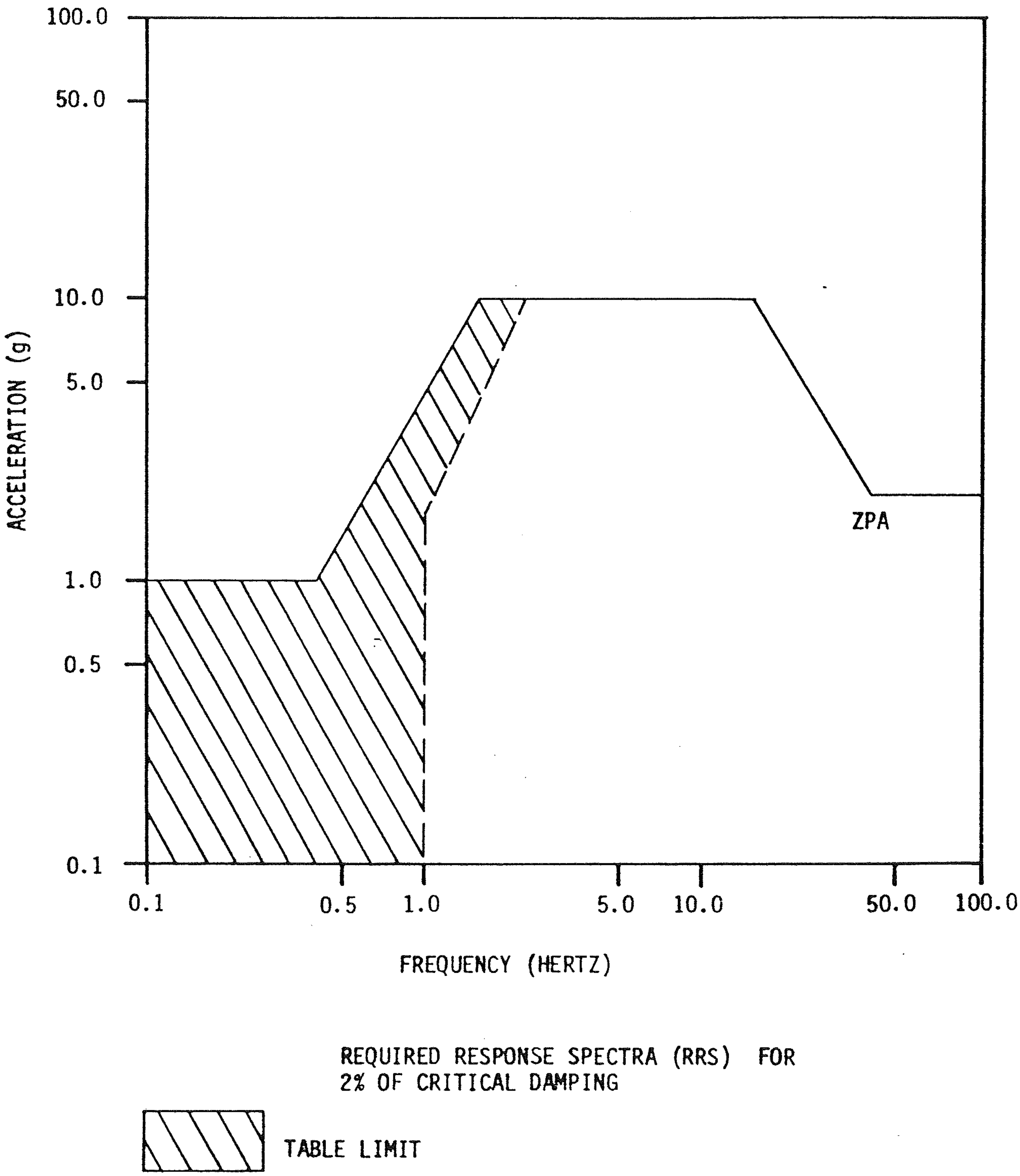

FIGURE 2-1. SEISMIC SPECTRA

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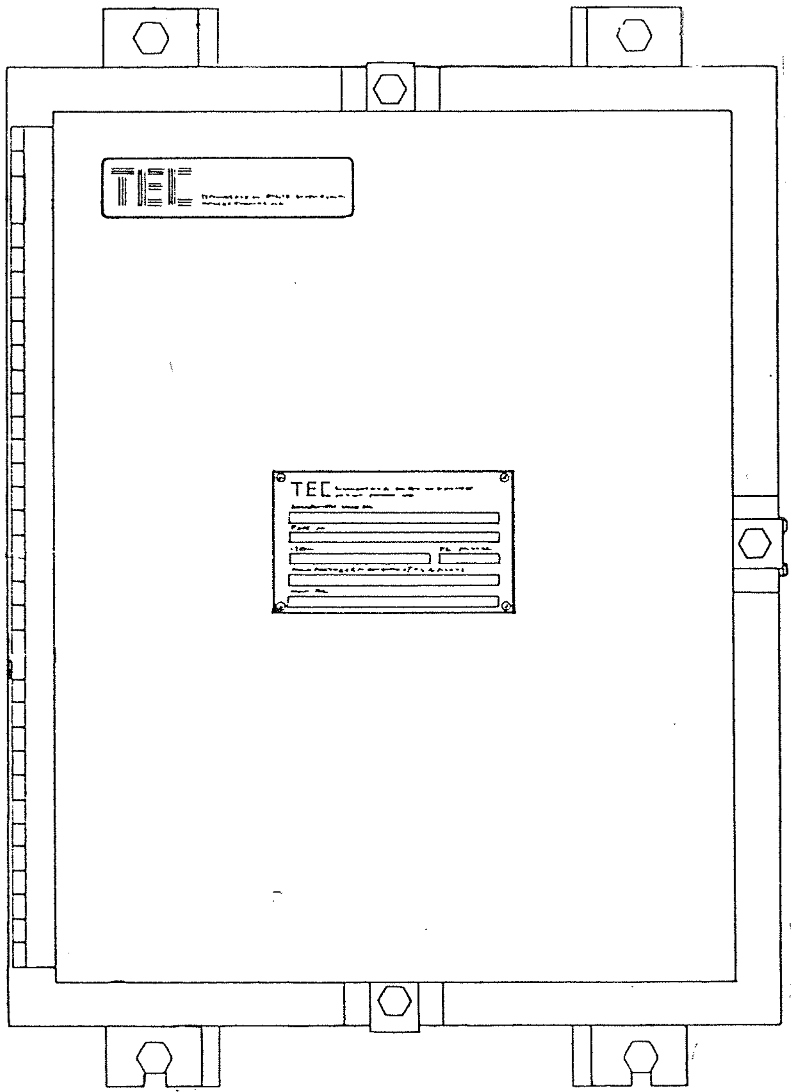
3. MOUNTING

The TEC Model 156 Isolators have been designed specifically for field mounting. The only mounting constraints necessary to maintain qualifi- cation are that it must be securely fastened to a flat surface in a moisture-proof enclosure and that Class 1E and non-1E wiring must be separated.

The small size of the isolators permits them to be mounted individually, in NEMA-12 enclosures, or in cabinets. For applications that require the use of multiple isolators, sixteen of the TEC Model 156 Series Isolators can be mounted in the TEC Model 157 Series NEMA-12 Isolator Enclosures. Figure 3-1 contains a pictorial of this enclosure. The enclosure is designed to be wall-mounted and will protect the isolators from water spray and corrosive chemicals.

Each TEC Model 157 enclosure houses a separate isolator train. These enclosures can also be supplied with a qualified manual switch or an automatic relay system to verify calibration and isolation capability while the system is online. This requirement satisfies Section 4.9, "Capability for Test and Calibration", of IEEE Standard 603-1977, Trial-Use Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

When mounting the isolators in a control room environment, the TEC Model 157 Enclosure(s) can be mounted in a qualified TEC Model 158 Series Seismic Cabinet. The TEC Model 158 cabinet can accommodate up to six TEC Model 157 enclosures with up to three trains per cabinet. The separation requirements demanded by IEEE Standards are fulfilled by the design of the TEC Model 157 and 158 assemblies. Wiring for Class 1E and non-1E circuits is located in separate steel conduit, and each isolator train is contained in a separate steel conduit in the TEC Model 157 enclosure.



REFERENCE TEC DWG. 157D2001,
REV. E, FOR DETAILS.

FIGURE 3-1. TEC MODEL 157 SERIES ISOLATOR ENCLOSURE

4. QUALIFICATION AND ISOLATION INTEGRITY

The TEC Model 156 Series Analog Signal Isolators are qualified to meet the requirements of IEEE Standards 323-1974, 344-1975, and 381-1977. The qualification program included

- Baseline functional testing;
- Thermal aging;
- Irradiation aging;
- Seismic testing; and
- Functional testing after each type test.

TEC has performed isolation integrity testing on the Model 156 Isolator. Such testing consisted of the following:

- Shorts, opens, and 120 V ac at 20 A fault (with input fuses shorted) applied to the non-1E side.
- 2000 V dc at 20 mA (with input fuses shorted) applied to the non-1E side.

The modules are manufactured by TEC under its Quality Assurance Program in accordance with 10 CFR Part 50. If additional information is required on the isolation integrity or qualification of the TEC Model 156 Isolator, copies of pertinent reports are available from the Manager of Specialty Products.