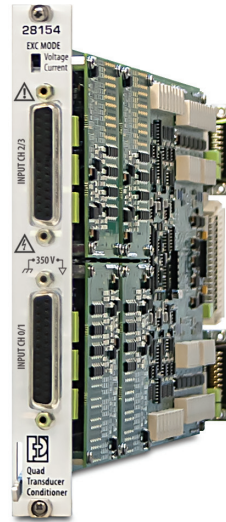




## Precision 28154

### Quad-Channel 350 Vcm Transducer Conditioner with Voltage and Current Excitation

**28154 Quad-Channel 350 V Common-Mode Transducer Conditioner with Voltage and Current Excitation** offers four channels of conditioning to support a wide variety of transducers, including those that require constant voltage excitation or constant current excitation. Balanced constant voltage excitation in a bridge configuration supports applications such as strain gages and pressure transducers. Balanced current excitation accommodates single-arm static or dynamic strain gages, RTDs, and other resistive transducers. Each of three independent outputs can be programmed for filtered or wideband operation, allowing for simultaneous measurement of static and dynamic signals from one transducer.



#### 28154 Applications

- Static, Dynamic or Transient Testing
- Turbine and Rocket Engine Test Stands
- Wind Tunnels
- Energetic Shock, Explosive, Ordinance Testing
- Structural Shock and Vibration Testing

#### Sensor Applications

- Static or dynamic strain gage conditioner
- Full bridge conditioner
- Pressure transducer conditioner
- Piezoresistive accelerometer conditioner
- RTD conditioner
- Thermocouple
- Amplifier
- Load cell conditioner
- MEMS transducer conditioner
- Hot wire anemometry
- AC or DC filter/amplifier (<1 mV to 10 V inputs)

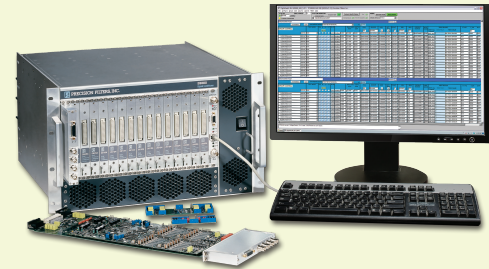
#### Precision 28154 Features

- Four channels per card, 64 channels per 28016 chassis
- Per channel isolation - 350 V channel to channel and channel to earth ground with CMV monitor.
- Three wideband or filtered outputs per channel
- Balanced programmable constant voltage excitation with remote sense—up to 20 V delivered to the bridge
- Balanced differential constant current excitation (0-20 mA/20 V compliance) with AC current cal
- Option HC10 – RTD/Bridge configuration. 4-wire 0-1 mA RTD excitation. RTD substitution, resistive shunt cal.
- Option HC10B – RTD/Bridge/4-20 mA configuration. 4-wire 0-1 mA RTD excitation. Resistive shunt cal. Unipolar excitation mode with 4-20 mA sense resistor.
- Option HC14 – Bridge/Strain/IEPE configuration. Prog. Bridge configuration (1, 2, 4-Arm) or 2-wire/4-wire Constant Current. Prog. completion (120, 350 and 1 kOhm). Programmable precision 255 step bipolar resistive shunt calibration of R1 or R2. IEPE input mode (8 mA constant current source).
- Precision DC voltage substitution (1 mV – 10 V)
- On-the-fly report of measured transducer excitation and resistance
- Transducer open/short indication
- Transducer leakage resistance measurement in constant current excitation mode
- Automatic bridge balance/transducer suppress
- Up to 100 kHz filtered bandwidth or 250 kHz wideband bandwidth
- Programmable AC/DC input coupling
- Programmable gain: x1/16 to x8192 with 0.025% resolution
- 4-pole low-pass filters with programmable pulse/flat characteristics
- Pre-filter overload detectors
- Precise digital calibration

#### Overview

### 28000 Analog Signal Conditioning System

*The new standard for the world's most discriminating test labs.*



The Precision 28000 signal conditioning system provides all the flexibility you need to manage your test measurements.

The Precision 28000 makes it easy to manage a test, with hundreds of channels and a mix of transducers. Choose charge, IEPE w/TEDS, voltage (filter amplifier), strain, thermocouple, RTD, potentiometer, current, frequency, or other transducers.

The built-in test hardware and software (optional) provide quick Go/No-Go tests, which can be run before each test, and rigorous Factory Acceptance Tests to assure you that the 28000 meets your most stringent requirements for critical applications. It won't be long before these tests earn a permanent place in your maintenance routine. And since they are traceable to NIST, they eliminate the need for off-site calibration.

In every phase of your tests—record keeping, installation, design, set-up, operation, maintenance, and upgrading—the Precision 28000 offers ways to help you save time and money over the life of the system.

#### 28000 System Features

- Graphical user interface (GUI) and Ethernet network interface for system control
- Intelligent gain and system scaling algorithms
- Go/No-Go test with diagnostics to be used before tests
- Rigorous Factory Acceptance Test for maintenance
- Field-swappable AC power supplies
- Built-in temperature and power supply monitoring with alarms

# Precision 28154 Description

## Precision 28154 Description

The 28154 is a member of the Precision 28000 family of signal conditioners. The 28154 provides four channels of conditioning for a wide variety of transducers requiring constant current or constant voltage excitation. The 28154 features isolated input and excitation stages for accurate measurement of signals in the presence of high common-mode voltage inputs. Up to 350 volts of isolation, channel to channel and channel to earth ground is provided. Up to sixteen 28154 cards may reside in the 28000 system to provide 64 channels per chassis. In addition, the 28154 may be mixed with other conditioners in the 28000 family to meet your unique signal conditioning requirements.

## Balanced Constant Voltage Excitation

The 28154 provides balanced constant voltage excitation of up to 20 volts and conditioning for 1-, 2-, and 4-arm resistive bridges. The 2- to 10-wire input connection provides 6 wires for the bridge, 3 wires for DC shunt calibration, 1 wire for the shield, and 1 wire for single-arm bridges. Automatic balance of the bridge is accomplished by inserting a voltage ratiometric with the excitation supply to the amplifier input stage. This balance method provides outstanding stability without loading the bridge. A wide range of unbalanced conditions may be accommodated.

Balanced constant voltage excitation offers a number of advantages over single-ended excitation. It enables a true balanced instrumentation amplifier input for outstanding rejection of high frequency common mode signals. Single-ended voltage excitation to balanced bridges produces a relatively large common mode voltage at half the excitation supply. The instrumentation amplifier must reject this signal. Balanced voltage excitation applied to balanced bridges results in lower common mode input voltages to the amplifier input stage.

The excitation supply has automatic amplitude and offset correction that may be run on the unit in place at any time. Dedicated remote sense lines allow the excitation supply regulator to deliver an accurate voltage to the bridge.

## Balanced Constant Current™ Excitation

The 28154 is equipped with Precision Filters' proprietary balanced differential constant current excitation that is optimized for making dynamic strain measurements on single active strain gages. Balanced constant current excitation provides an accurate means of measuring dynamic strain with a single active strain gage using only a two-wire connection. Electrostatic pickup is reduced when compared to single-ended constant current excitation or a quarter bridge configuration with remote completion resistors or unbalanced current sources. The balanced current excitation circuit operates properly even under certain common gage fault conditions such as a direct short of the gage to the test model.

Balanced constant current excitation provides a true balanced input for rejection of common-mode signals. Standard programmable excitation provides 0 to 20 mA of constant current with an "excitation off" mode to detect input cable noise pickup. Gage open/short detection is also provided. Option HC10/HC10B provides 1 mA balanced excitation with enhanced noise and drift characteristics optimized for RTD measurements.

For dynamic strain conditioning applications, the 28154 can provide accurate measurements with only two wires by AC coupling the input. For best AC or DC measurements (required for RTD type transducers), the 28154 provides a 4-wire Kelvin connection for remote sense. Constant current excitation may be applied to full bridge applications with the advantage that excitation delivered to the bridge is unaffected by excitation supply lead wire resistance.

Suppression of the gage DC operating point is performed automatically using the zero suppress feature of the 28154. Zero suppress allows the use of more gain to emphasize small gage fluctuations. Zero suppress also provides the user with an accurate means to balance a full bridge.

The excitation current source output may be modulated to allow AC current injection in the loop. The frequency of the AC current is user controlled. This allows the user to simulate changes in gage resistance in the loop and provides direct AC input stimulation to the signal conditioner for end-to-end system calibration.

## 28154 Sensor Configuration

The high degree of modularity of the 28154 allows the card to be easily configured to condition a particular sensor type. Two sensor configuration options are available to support a wide range of transducer conditioning applications.

**Bridge/Strain/IEPE Configuration:** The HC14 configuration option supports measurements of strain in a ¼ or ½ or full bridge configuration or 2-wire/4-wire constant current measurements. Precise low drift (0.2 PPM) completion resistors are included for 120, 350 or 1000 ohm bridges. 255-step bipolar shunt calibration provides programmable shunt cal resistance values ranging from 7.5 kΩ to 1.92 MΩ. Shunt calibration can be applied internally to the 28154 card or remotely at the actual bridge using dedicated shunt calibration connections. Single shunt of R1 or R2 bridge arms is supported.

The HC14 also supplies an 8mA current source for measurements with IEPE transducers. An AC coupling capacitor removes the sensor bias and connects to the amplifier input stage. Sensor Bias and fault conditions are monitored in real time to alert the user to a fault condition.

### Bridge/RTD Configuration:

The HC10 Bridge/RTD/Configuration Module supports full-bridge and RTD measurements. A 1mA precision constant current excitation is supplied to the RTD. Current drive and signal sense terminals are available on the input connector to allow a 4-wire Kelvin connection to the RTD. Precision 0.01% RTD substitution resistors are supplied for calibration purposes.

For full bridge measurements, programmable single-step bipolar shunt of R1 or R2 is supported for the HC10 option. In addition, relay contacts are used to connect the sensor internal cal resistor to + or – excitation.

The option HC10B adds a unipolar excitation mode with a 250 Ω sense resistor for sensors with 4-20 mA outputs.

## Input Stage

The 28154 input stage provides outstanding common-mode rejection and may be either AC or DC coupled. AC coupling is useful for dynamic applications where the DC bias on the transducer, which can limit dynamic range, can be coupled out of the signal. With the input DC coupled, low drift and ultra low noise is provided by the 28154 input stage. The input stage may be shorted under program control to verify signal conditioner channel noise and DC offsets. A switch at the input stage is provided to connect the amplifier to the 28000 system test bus. The test bus is used to inject signals for performance verification.

An on-board precision DC calibration source may be injected at the input to simulate engineering unit inputs. The level of the calibration source may be controlled on a per-channel basis, allowing for simultaneous full span outputs on every channel, even at different programmed channel gains.

For applications requiring maximum bandwidth, the standard configuration has direct coupled barrier stage with programmable filtering to 100 kHz and 100 k $\Omega$  of isolation resistance.

## Amplifier and Filter

Programmable pre- and post-filter amplifiers provide an overall gain of x8192. Gain is distributed across the filter to provide protection from large out-of-band energy or transients that could cause clipping before the filter, distorting the data. The input overload detector reports overloads by out-of-band signals which could cause in-band distortion. The Gain Wizard in the GUI allows the user to set a gain reserve and then apportions the gain between the input and output. This provides input gain for best noise performance yet conforms to the limitations of the user's worst case estimate of out-band signals. Pre-filter overload detectors alert the user to over-voltage conditions that would otherwise be masked by the filter. A fully buffered output having over 25 mA of drive capability may be used to drive long output cable runs.

The 28154 is specified with a 4 -pole low-pass filter with cutoffs programmable from 1 Hz to 100 kHz and programmable "flat" or "pulse" mode. The "flat" mode provides pass-band characteristics nearly identical to a Butterworth filter while providing a much sharper roll-off. This mode is a good choice for applications such as spectral analysis. The "pulse" mode has time domain response similar to the Bessel filter yet provides superior

amplitude response characteristics. The "pulse" mode is ideal for time domain applications including transient (shock) measurements and waveform analysis.

## Output Stage

The 28154 has three independently buffered outputs. A single-ended rear panel output is intended to drive the primary data acquisition hardware. Two sets of auxiliary outputs are available at the rear of the chassis via two 15-pin D connectors that are integral to the 28154 card. Each of the three outputs may be selected for filtered or wideband operation under program control. This allows the 28154 to measure both AC (dynamic) and DC (static) signals coming from one transducer. The gain ratio between the filtered and wideband output may be set between 0.1 and 1 to prevent overdriving the wideband output on signals whose broad band energy is significantly larger than the filtered component.

Option O provides a bank isolated output stage for the AUX1 output to drive distant loads that may be at different ground potentials.

### 28154 Programmable Features

- Bipolar or unipolar constant voltage excitation
- Bipolar constant voltage excitation level: 0 to 20.475 V in 5 mV steps
- Constant current excitation level: 0 to 20.475 mA in 5  $\mu$ A steps
- RTD Constant current excitation level (Option HC10/HC10B): 0 to 1 mA in 0.25  $\mu$ A steps
- IEPE current source (Option HC14): 0 or 8 mA
- Expected transducer resistance thresholds
- Transducer leakage resistance thresholds
- Voltage excitation sense: instrument or gage
- Current excitation input interface: 2-wire or 4-wire
- Bridge configuration: 1-arm (2-wire), 1-arm (3-wire), 2-arm or 4-arm (HC14)
- Bridge resistance: 120  $\Omega$ , 350  $\Omega$  or 1 k $\Omega$  (HC14)
- DC shunt cal: instrument or gage (HC10/HC10B/HC14)
- DC shunt cal resistance and shunt arm: R1 or R2 (HC10/HC10B/HC14)
- Automatic balance/suppress
- AC/DC input coupling
- Test modes: amp short, 10 V DC CAL, excitation off, test bus, voltage substitution, DC shunt calibration, AC current, excitation monitor

- RTD resistor substitution (HC10)
- Precision DC voltage substitution
- Output monitor
- Gain: x1/16 to x8192 with 0.025% resolution
- Filter type: pulse or flat
- Cutoff frequency:
  - 2 Hz to 100 kHz
- Wide-band (250 kHz) or filtered operation

### 28154 Graphical User Interface Display

All programmable features in addition to:

- On-the-fly excitation monitor
- On-the-fly sensor resistance monitor with pass/fail status
- Sensor open or short indication
- Configuration read back
- Balance/Suppress status
- Input wiring
- Transducer sensitivity
- System scaling in engineering units
- Overload status
- Intelligent gain algorithm
- Group control

# 28154 Details and Specifications

## Verification of Cables and Sensor Health:

Large changes in sensor impedance or sensor excitation can indicate that data from this sensor is no longer meaningful. The unique transducer health monitor circuits of the 28154 provide an “on-the-fly” report of measured sensor excitation and resistance. Measured gage resistance is compared to user specified limits and flagged if out of tolerance. Also, the 28154 alerts the user to a transducer open or short condition.

**Strain Gage Loop Resistance Measurement:** Strain measurements often require complicated wiring schemes. Long cable runs, multiple connection points, high-temperature high-impedance very small diameter wire and slip rings combine to cause uncertainty in the strain gage connection. Often a sudden increase in gage resistance is a predictor of gage failure. The Precision 28154 gives continual real time monitoring of the total “Loop Resistance” of the gage and cable circuit. This loop resistance reading can be compared to preset limits to alert the user of unexpected resistance shifts as well as gross gage short and gage open conditions.

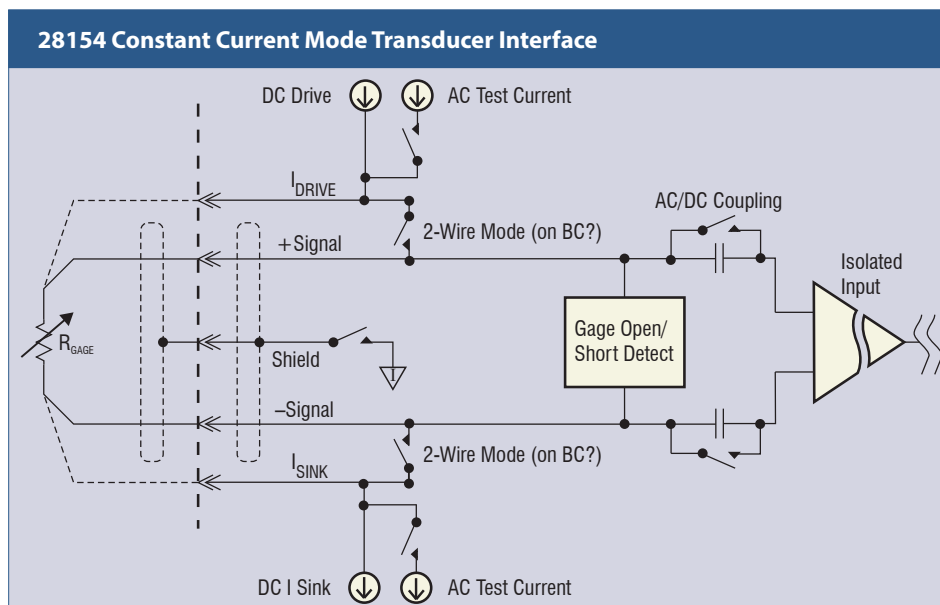
**Cable Roll-off:** One often asked question of many measurements engineers is “How will my cable capacitance affect my high frequency strain measurement”? This question can be answered quickly and easily and all from the convenience of the control room. The AC current “chopper cal” feature of the 28154, in balanced constant current excitation mode, adds a small AC current square wave at a user selected frequency on top of the DC excitation current to stimulate an AC signal across the actual strain gage sensing element. Since the stimulus signal is based at the sensor, it will exhibit the same roll-off characteristics as a signal resulting from actual dynamic strain. The test frequency of the AC signal can be increased as necessary to chart the cable roll-off characteristics and validate the cable circuit for use at the desired measurement frequencies.

**Gage Leakage Measurements:** In extremely hot sections of a test article, such as a gas turbine engine, it is impossible to use standard insulating materials in gage wiring. Often a rigid section of a stainless steel or Inconel sheath encloses high temperature inner conductor wires. The inner core of the sheath is filled with magnesium oxide (MGO) as a high temperature insulating material. The insulating properties of the MGO are affected by moisture absorption at damage points or improperly sealed cable terminations. In extreme conditions, insulation breakdown can cause a leakage path to ground and

corrupt a gage reading. Other causes of cable leakage are fatigue or failure at extension wire tie-down points, or in the strain gage itself. The leakage detection feature of the 28154 continually monitors leakage and compares readings to preset threshold limits. Sensors which show higher than normal leakage can be quickly identified prior to or during the test run.

## Muting Faulty Sensors:

Depending on the sensor type, various techniques must be used to quiet the channel's input and output circuits and ensure that no noise coupling occurs. For example, an intermittent gage will create a gage chatter condition whereby the connecting wires continually switch between the high voltage fault level and the proper low voltage operational level. This chatter condition creates a hostile noise source to any other gage extension wires in the vicinity of the hostile cable. Precision 28154 signal conditioning channels have a “MUTE” feature, which places the channel in its quietest quiescent state and minimizes the possibility of coupling noise to properly functioning channels.





# 28154 Details and Specifications

## 28154 Conditioner Cards

Unless stated, specifications apply for ambient temperature of 25°C.

The detailed description and specifications for the 28154 are organized as follows in the sections below:

- Programmable Sensor Configuration Options
- Test Modes
- Bridge Wiring
- Excitation Supply
- Input Characteristics
- Amplifier Characteristics
- Filter Type Characteristics
- Output Characteristics
- General Characteristics
- Accessories
- Ordering Information

## Programmable Sensor Configuration Options

The 28154 optional sensor configuration modules provide versatility to condition a wide variety of transducers. The HC10, HC10B, and HC14 options are factory configured and support bridge, strain, IEPE, RTD and thermocouple configurations.

The HC10, HC10B, and HC14 support programmable 2-wire/4-wire (Kelvin) constant current input connections.

### HC10 Full-Bridge/RTD Configuration Module

#### RTD Substitution Cal (Constant Current Mode, 2-wire or 4-wire Kelvin)

**Values:** 62.5, 125, 250, 500, 1 k and 2 k $\Omega$ , programmable

**Accuracy\*:**  $\pm 0.01\%$ , 5 ppm/°C

#### DC Shunt Calibration (Constant Voltage Excitation Mode Only):

3-Step Bipolar Shunt Cal

#### DC Shunt Selection:

R1 or R2 bridge arms

#### Shunt Sensitivity:

$\pm 1$  mV per volt of programmed excitation for 120, 350 and 1 k $\Omega$  bridges

#### Shunt Resistance:

Selectable:  
29.940 k $\Omega$ ,  
87.325 k $\Omega$ ,  
249.5 k $\Omega$

*\*These specifications are guaranteed by design but are not testable to these limits with the 28000 Factory Acceptance Test (FAT)*

**Resistor Accuracy:**  $\pm 0.1\%$ , 10 ppm/°C

#### Sensor Cal:

Contact closure provided to connect sensors equipped with internal cal resistors to + or – excitation.

### HC10B Full-Bridge/RTD/4-20 mA Configuration Module

The HC10B adds a unipolar excitation mode to the HC10 for 4-20 mA output sensors and sensors with internal electronics that require a unipolar supply. *The HC10B does not support RTD substitution.*

#### Unipolar Excitation Mode:

27 V  $\pm$  2 V @ 35 mA/per channel

#### 4-20 mA Sense Resistor:

250  $\Omega$   $\pm 0.1\%$ , 2-, 3-, and 4-wire sense connections supported

### HC14 Bridge/Strain/IEPE Bridge/IEPE Configuration Module

#### Bridge Configuration:

1-arm, 1-arm w/ 3 wires, 2-arm or 4-arm, (programmable)

#### Constant Current Mode:

2-wire or 4-wire (Kelvin)

#### Completion Resistors:

120  $\Omega$ , 350  $\Omega$  and 1 k $\Omega$ , programmable

#### Resistor Temperature Coefficient:

$\pm 0.2$  ppm / °C

#### Resistor Accuracy: $\pm 0.02\%$

#### DC Shunt Calibration:

255-Step Bipolar Shunt Cal

#### DC Shunt Selection:

R1 or R2 bridge arms

#### Shunt Resistance:

7.5 k $\Omega$  to 1.92 M $\Omega$

#### Settings:

Shuntcal resistance can be set to 1.92 M $\Omega$  /n where n=1 to 255

#### Resistor Accuracy: $\pm 0.1\%$ , 10 ppm/°C

#### IEPE Input Mode:

**Level:** 8 mA,  $\pm 5\%$

#### Compliance Voltage:

26 V, Nominal

#### AC Coupling Frequency w/ IEPE

**Selected:** 0.32 Hz  $\pm 5\%$

#### Fault Monitor:

Sensor open/short

**IEPE Bias Monitor:** Bias voltage continuously monitored and compared to user defined limits

## Bridge Wiring

### Input Connector:

25-pin D-shell (2 ea.)

### Input Wires:

$\pm$ EXCITATION (2)  
 $\pm$ SENSE (2)  
 $\pm$ SIGNAL (2)  
SHUNT CAL (3)  
¼ Bridge RTN (1) Single-Arm Bridge  
SHIELD (1)  
ISOLATED GROUND (1)  
SIGNAL GROUND (1)

## 28154 Test Modes

**Amplifier Short:** A switch at the amplifier input is utilized to ground the input stage for measurement of noise and DC offset.

**Test Bus:** Test bus input allows for injection of a test signal at the amplifier input. An external test signal or the 28000-?-TEST test subsystem may be connected to the test bus input. Application of the test bus defeats the isolation of the input stage. The 28000-?-TEST prompts the user during Factory Acceptance Test to remove inputs that may be a source of high common mode voltage to ensure safe application of the test bus signal. The GUI and LCS appropriately warn the user that isolation will be defeated before the test bus is applied. Improper use of the test bus with high CMV signals at the input may result in damage to the amplifier.

### Precision DC Voltage Substitution:

A calibrated programmable DC voltage is connected to the amplifier input.

#### Level:

Low Range:  $\pm 1$  mV to  $\pm 100$  mV in 100  $\mu$ V steps  $\pm 0.02\%$ ,  $\pm 10$   $\mu$ V  
High Range:  $\pm 0.1$  V to  $\pm 10$  V in 10 mV steps  $\pm 0.02\%$ ,  $\pm 1$  mV  
Stability:  $\pm 20$  ppm/°C of setting

**10 VDC CAL:** A calibrated 10 VDC reference is connected to the amplifier input. The NIST traceable measured error (in percent) is stored in non-volatile memory on the card. Subsequent NIST traceable field measurement of the 10 VDC reference requires the 28000-?-TEST test subsystem.

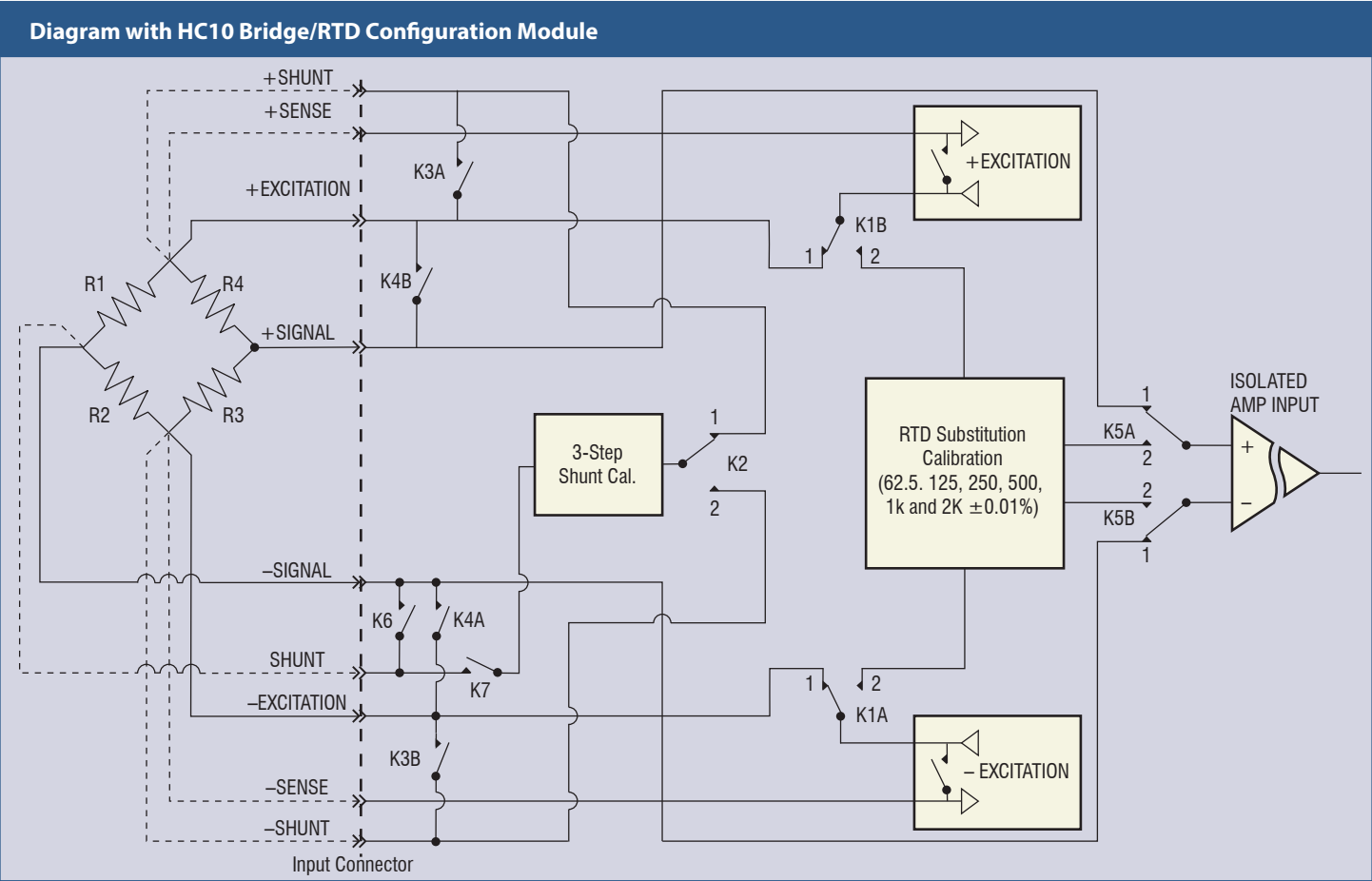
**DC Shunt Cal:** Applies resistive shunt across bridge arm.

### Excitation Monitor (Constant Voltage

**Mode Only):** The amplifier input is switched from the bridge to the excitation supply to monitor the excitation voltage at the amplifier output. Excitation monitor gain is x0.5.

**Excitation Off:** The excitation supply is programmed to zero volts or zero mA.

# 28154 Details and Specifications

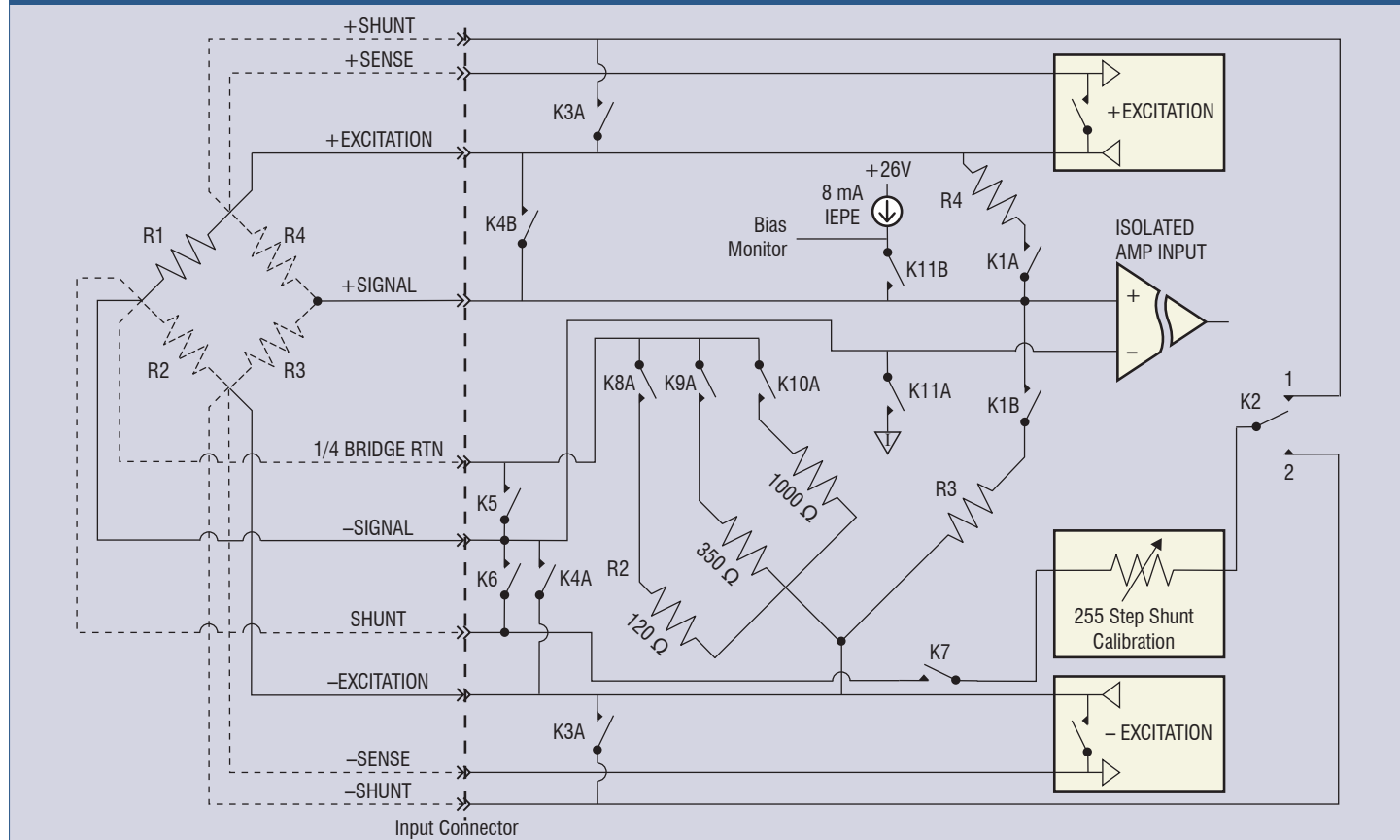


Truth Table

Configuration	K1	K2	K3, K6	K4	K5	K7
Shunt Cal Gage	1		OUT		1	IN
Shunt Cal Instrument	1		IN		1	IN
Shunt R1	1	1			1	IN
Shunt R2	1	2			1	IN
Constant Current 2-Wire	1			IN	1	
Constant Current 4-Wire	1			OUT	1	
DC Voltage Substitution	2				2	
RTD Substitution	2				2	

28154 with HC10 Bridge Configuration Module

**Diagram with HC14 Bridge/Strain/IEPE Configuration Module**



**Truth Table**

Configuration	K1	K2	K3, K6	K4	K5	K7	K8	K9	K10	K11
¼ Bridge, 2-Wire	IN				IN		IN <sup>1</sup>	IN <sup>1</sup>	IN <sup>1</sup>	IN
¼ Bridge, 3-Wire	IN				OUT		IN <sup>1</sup>	IN <sup>1</sup>	IN <sup>1</sup>	IN
½ Bridge	IN						OUT	OUT	OUT	OUT
Full Bridge	OUT						OUT	OUT	OUT	OUT
120 Ohm Completion							IN	OUT	OUT	IN
350 Ohm Completion							OUT	IN	OUT	IN
1000 Ohm Completion							OUT	OUT	IN	IN
Shunt Cal Gage			OUT			IN				
Shunt Cal Instrument			IN			IN				
Shunt R1		1				IN				
Shunt R2		2				IN				
Constant Current 2-Wire				IN						
Constant Current 4-Wire				OUT						
8 mA IEPE Current Source	OUT		OUT	OUT	OUT	OUT				IN

<sup>1</sup> One switch selected at a time.

# 28154 Details and Specifications

## 28154 Excitation Supply

### Programmable Constant Voltage Excitation

#### Maximum Output:

20.475 V, 30 mA (balanced)

#### Steps:

Programmable from 0 to 20.475  
in 5 mV steps

#### Excitation Sense:

Programmable (instrument or  
gage sense)

#### Accuracy:

$\pm 0.03\%$  of setting  $\pm 1$  mV

#### Noise:

100  $\mu$ Vrms, 3 Hz to 200 kHz

#### Temperature Drift:

$\pm 0.0025\%/^{\circ}\text{C}$  of setting or  $\pm 50$   $\mu$ V/ $^{\circ}\text{C}$ ,  
whichever is greater

#### Sense Leakage Current:

Less than 10 nA

#### Calibration:

Automatically calibrated for gain and  
offset. Calibration initiated at the GUI  
panel.

#### Excitation Off:

The excitation supply is programmed  
to 0 volts.

## 28154 Constant Current Excitation Supply

#### Type:

Balanced differential constant current  
excitation

#### Excitation:

0 to 20.475 mA in 5  $\mu$ A steps

#### Total Gage Voltage (Volts):

20 – I x 700 minimum

#### Input Impedance:

100 k $\Omega$  nominal per side

#### CMRR (DC to 1 kHz):

80 dB for 120  $\Omega$  gage  
70 dB for 350  $\Omega$  gage  
60 dB for 1 k $\Omega$  gage

#### Initial Accuracy:

0.05% of setting  $\pm 5$   $\mu$ A

#### Temperature Drift:

30 nA + 0.0024% of setting per  $^{\circ}\text{C}$

#### Noise:

65 pA/ $\sqrt{\text{Hz}}$  at 1 kHz

#### Bandwidth:

$\pm 0.2$  dB to 200 kHz (RGAGE < 1 k $\Omega$ )

#### AC Current:

An AC current square wave, 50% duty  
cycle at the programmed frequency is  
injected into the current loop to evaluate  
system span and end-to-end system  
frequency response. The AC current  
peak-peak level is 0.2% of programmed  
excitation current.

#### Frequency:

1 kHz to 100 kHz in 1 kHz steps

#### Frequency Accuracy: $\pm 5\%$

#### Push-Push BCC (Option P):

Balanced Push-Push BCC mode optimized  
for static and static/dynamic half bridge  
measurements. Specs are equivalent to  
standard BCC except as indicated.

#### Gage Voltage (per side):

11-I x 350 minimum

#### Input Impedance:

10 M $\Omega$  nominal per side

## HC10/HC10B RTD Excitation

The HC10 option provides excitation levels  
optimized for RTD measurements.

#### Type:

Balanced differential constant current  
excitation

#### Level:

0 to 1.02375 mA in 0.25  $\mu$ A steps

#### Total Gage Voltage:

20 – I x 14E3 minimum

#### Input Impedance:

2 M $\Omega$  nominal per side

#### Initial Accuracy: 0.05% of setting $\pm 250$ nA

#### Drift:

1.5 nA + 0.0024% of setting per  $^{\circ}\text{C}$

#### Noise:

3.5 pA per rt Hz at 1 kHz

#### Bandwidth:

$\pm 0.2$  dB to 200 kHz

## 28154 Mute Mode

In harsh test environments, a sensor or  
input cable can become faulty or intermit-  
tent during a critical test. With high gain  
signal conditioning, this can be troublesome  
if large signal swings on input or output  
cabling cross-couple to other channels. The  
28154 Mute control places the channel in the  
quietest operational state to minimize system  
noise in the event of a failed sensor. Mute  
mode is also useful to terminate unused  
channels in a safe and quiet state.

## 28154 Transducer Health Monitor

**Sensor Excitation Monitor:** Transducer  
excitation voltage or current is monitored  
and reported to the user on the fly. Mea-  
sured excitation is compared to factory-set  
tolerance, and GUI indicators report if out of  
tolerance.

**Sensor Resistance Monitor:** Transducer  
resistance is monitored on the fly and com-  
pared to user-defined limits. GUI indicators  
report if sensor resistance is out of user  
tolerance.

**Sensor Open/Short Monitor:** Transducer  
open or short condition is monitored and  
reported to the user via GUI indicators.

**Transducer Leakage Resistance Measure-  
ment:** The 28154 monitors gage bias levels  
in order to detect constant current excitation  
leakage conditions in the external current  
loop. Transducer leakage status is monitored  
and reported via the GUI.

#### Common Mode Voltage (CMV) Monitor:

The CMV may be monitored via the 28000  
system monitor bus to assess CMV levels at  
the channel input.

**CMV Monitor Gain:** x1/30

**CMV Monitor BW:** 1 kHz (-3 dB)

**Excitation Current Limit:** Current limit  
protection is provided by the 28154 exci-  
tation supply. Possible causes of current  
limit are an incorrect excitation setting or a  
shorted transducer. Current limit indicators  
are provided in the GUI.

**Excitation Thermal Shutdown:** The excita-  
tion supply regulator die temperature is  
continuously monitored and will shut down  
should the temperature reach a level where  
damage to the excitation supply may occur.  
Thermal shutdown indicators are provided  
in the GUI.



# 28154 Details and Specifications

## 28154 Input Characteristics

### Type:

Balanced differential w/ programmable AC/DC input coupling

### Isolation:

Input stage and excitation are referenced to a common isolated ground. 100 kOhm impedance between isolated ground and signal ground for each channel.

**Input Impedance:** 10 MΩ //100 pF per side

### Common Mode Voltage:

±350 V peak, AC or DC operating

### Max Differential Signal Level (AC + DC):

±10 Vpk for  $f \leq 250$  kHz ±10 Vpk x (250 kHz/f) for  $f > 250$  kHz

**Slew Rate:** 15 V/μs, min

### Input Protection (Power On):

30 V continuous, 100 Vpk for 1mS, 10% duty cycle

**Offset Drift:** 1 μV/°C, typical

### Input Noise (typical)

<2.8 μVrms, 100 kHz BW; <1 μVrms and 10 μVpp 10 kHz BW; <5 μVpp 1 kHz BW; <3 μVpp 100 Hz BW; <2 μVpp 10 Hz BW

**Bias Current:** <200 pA @ 25° C ±10 pA/° C

### THD:

<0.01% for 1 kHz, 20 Vpp sinewave input

**AC Coupling Frequency:** 0.25 Hz (3.01 dB)

**CMRR (Pre-filter gain = x512, CMV applied to ±SIGNAL & Isolated Gnd):**

**DC Coupled:** 150 dB at DC; 130 dB at 60 Hz; 110 dB at 440 Hz; 65 dB at 10 kHz typ.

**AC Coupled:** 100 dB, 10 Hz to 440 Hz

**CMRR (Pre-filter gain ≥ x32, CMV applied to ±SIGNAL w/ Isolated Gnd tied to Signal Gnd):**

**DC Coupled:** 100 dB, DC to 440 Hz

**AC Coupled:** 80 dB, 10 Hz to 440 Hz

### Auto Bridge Balance Mode:

The bridge is automatically balanced utilizing voltage insertion at the input amplifier when bridge balance mode is selected. The inserted voltage is derived from and thus tracks the excitation supply. A successive approximation A/D converter mechanization is used for rapid bridge balance.

### 32 mV/V Mode Auto-Balance Range:

±0.001 mV/V to ±32 mV/V in  
±0.976 μV/V steps

### 512 mV/V Mode Auto-Balance Range:

(gain limited to x512):  
±0.016 mV/V to ±512 mV/V in  
±15.625 μV/V steps

### Accuracy:

±0.1% of setting ±0.1% of F.S. range

**Stability:** ±25 ppm / °C of setting

### Drift (RTI):

±0.3 μV / °C for 32 mV/V range;  
±5 μV / °C for 512 mV/V range

### Auto Balance Time:

Less than 60 seconds per system of 64 channels

### Auto Suppress Mode:

A programmable DC offset derived from a precision 10 V reference is injected at the channel input stage to suppress the gage DC operating voltage. Manual or automatic suppression modes are supported.

### 640 mV Suppress Range:

±0.001 mV to ±640 mV in ±19.53 μV steps

### 10.24 V Suppress Range:

(gain limited to x512):  
±0.3125 mV to ±10.24 V in ±312.5 μV steps

### Accuracy:

±0.1% of setting ±0.1% of F.S. range

**Stability:** ±25 ppm / °C of setting

**Drift (RTI):** ±0.3 μV / °C for 640 mV range;  
±5 μV / °C for 10.24 V range

### Long Term Zero Stability (6 months):

± 5 μvolts RTI ±1 mV RTO, 32 mV/V range

### Auto Suppress Time:

Less than 60 seconds per system of 64 channels

## 28154 Amplifier Characteristics

### Pre-filter Gain:

x1 to x512 in binary steps with overload detection (10.5 Vpk threshold)

### Post-filter Gain:

x1/16 to x16 with vernier adjustment

**Overall Gain:** x1/16 to x8192

### Gain Resolution:

0.025% steps for POG ≥1X  
0.025%/POG for POG <1X

### DC Gain Accuracy:

0.01% typical, 0.1% maximum for POG ≥1X  
0.1%/POG maximum for POG <1X

### Gain Ratio of Wideband (Unfiltered) to the Filtered Outputs:

Each of the three 28154 outputs may be selected for wideband or filtered operation under program control. The ratio of the gain on the wideband output to the filtered output may be set from 0.1000 and 1.0000 with 0.1% resolution. All GUI Gain Wizard calculations are based on filtered output.

**Stability:** ±0.01% for 6 months

**Temp Coef.:** ±0.004%/°C

### DC Linearity:

±0.005% re fullscale, relative to the best straight line

### Frequency Response:

DC to 100 kHz, 0 dB ±0.1 dB  
-3 dB typical @ 250 kHz

**High Frequency Rolloff:** 18 dB/octave

# 28154 Details and Specifications

## 28154 Filter Type Characteristics

### Flat/Pulse Low-Pass Filters

Our LP4FP 4-pole flat/pulse low-pass filters provide you with the versatility to address applications in either the time or the frequency domain.

### Flat Mode Low-Pass Filters

Precision LP4F flat mode characteristics are specified to have outstanding passband flatness equivalent to the Butterworth yet deliver very sharp roll-off characteristics.

The LP4F is a good choice as an anti-aliasing filter and for applications such as spectral analysis. The LP4F has zero passband ripple and roll-off superior to the Butterworth.

### Pulse Mode Low-Pass Filters

For the time domain, we offer the LP4P pulse mode low-pass filters. These filters have excellent transient response and phase linearity, making them ideal filters for time-domain applications, including transient (shock) measurements and time domain waveform analysis—all with roll-off characteristics superior to their Bessel filter counterparts.

### LP4FP Specifications

4-pole, 4-zero low-pass filter. Programmable for maximally flat pass-band (LP4F) or linear phase with optimized pulse response (LP4P).

**Note:** Other filter types and cutoff ranges are available upon request. Please consult the factory.

### Cutoff Frequencies

- 2 Hz to 1.022 kHz in 2 Hz steps
- 1.2 kHz to 100 kHz in 200 Hz steps

### Pass-Band Accuracy:

- $\pm 0.1$  dB, DC to F  $-0.1$  dB
- $\pm 0.15$  dB to F  $-0.5$  dB

### Phase Match:

- $0.1^\circ$  typical,  $1^\circ$  max, DC to F  $-0.1$  dB;
- $0.15^\circ$  typical,  $1.5^\circ$  max to F  $-0.5$  dB

### Amplitude Match:

- 0.01 dB typical, 0.1 dB max, DC to F  $-0.1$  dB;
- 0.015 dB typical, 0.15 dB max to F  $-0.5$  dB

### Bypass:

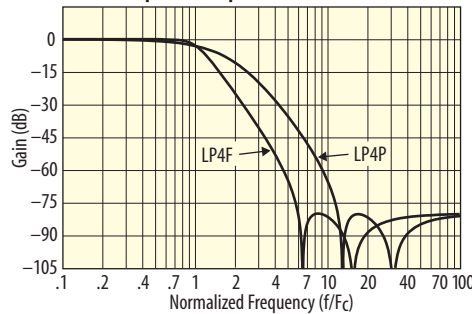
- Bypasses filter but not amplifier stages

### Bypass Bandwidth:

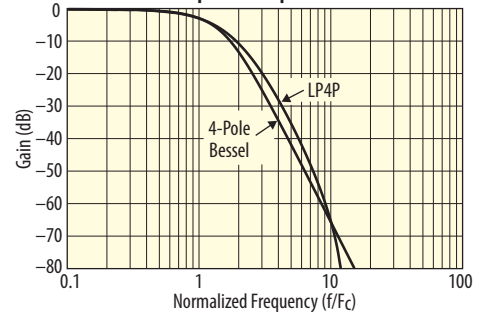
- 250 kHz, typical

Specification	LP4F Maximally Flat Low-Pass Filter	LP4P Constant Time Delay Low-Pass Filter
Cutoff Frequency Amplitude	$-3.01$ dB	$-3.01$ dB
DC Gain	0.00 dB	0.00 dB
Pass-Band Ripple	0.00 dB	0.00 dB
Stop-Band Frequency	$5.9465 F_c$	$11.863 F_c$
Cutoff Frequency Phase	$-180.0$ deg	$-101.5$ deg
Phase Distortion (DC to $F_c$ )	$< 31.8$ deg	$< 3.7$ deg
Zero Frequency Group Delay	$0.4117/F_c$	$0.2920/F_c$
Percent Overshoot	11.1%	0.5%
1% Settling Time	$1.65/F_c$	$0.66/F_c$
0.1% Settling Time	$2.72/F_c$	$0.77/F_c$
$-0.1$ dB Frequency	$0.6348 F_c$	$0.1816 F_c$
$-0.5$ dB Frequency	$0.7747 F_c$	$0.4061 F_c$
$-1$ dB Frequency	$0.8487 F_c$	$0.5742 F_c$
$-2$ dB Frequency	$0.9370 F_c$	$0.8129 F_c$
$-3.01$ dB Frequency	$1.0000 F_c$	$1.0000 F_c$
$-20$ dB Frequency	$1.7412 F_c$	$3.0248 F_c$
$-40$ dB Frequency	$2.9555 F_c$	$5.6932 F_c$
$-60$ dB Frequency	$4.586 F_c$	$9.0980 F_c$
$-80$ dB Frequency	$5.9465 F_c$	$11.8629 F_c$

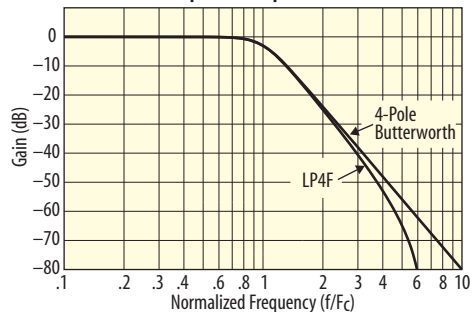
LP4F and LP4P Amplitude Response



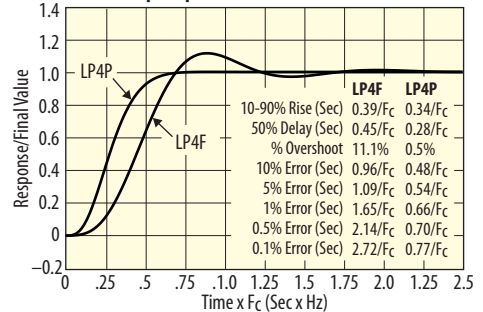
LP4P vs 4-Pole Bessel Amplitude Response



LP4F vs Butterworth Amplitude Response



LP4F and LP4P Step Response



## Output Characteristics

**Primary (Rear Panel) Output:** All outputs configurable for filtered or wideband operation under program control. Output available at rear panel of chassis via 50-pin D connector (M3 chassis) or 26-pin high-density D connector (M5 chassis). For M3 chassis, one 50-pin D accommodates up to 16 primary outputs for four 28154 cards. For chassis with the M5 option, one high-density 26-pin D is available per card slot.

**Auxiliary Outputs:** Two female 15-pin D connectors, one for AUX1 and a second for AUX2 outputs, are accessible via at the rear of the 28000 chassis.

### Type:

**Primary and AUX2:** DC coupled, single-ended output.

**AUX1:** DC coupled, single-ended output with selectable ground sense used for driving grounded single-ended loads. Output is referred to ground at the load. Output sense also reduces ground loop interference by breaking the connection between the load ground and the 28154 channel ground.

### Output Impedance:

$10\ \Omega // 100\ \text{pF}$

### Aux1 Sense Input:

$100\ \Omega // 100\ \text{pF}$  or ground via manual card switch

### Max Output:

$\pm 10\ \text{Vpk}, \pm 10\ \text{mA pk}$

### Offset:

$< 5\ \text{mV}$  after auto-adjust at any gain setting

### Offset Drift:

$1\ \mu\text{V}/^\circ\text{C}$ , RTI +  $100\ \mu\text{V} / ^\circ\text{C}$  RTO

### Noise:

$2.8\ \mu\text{V rms RTI} + 100\ \mu\text{V rms RTO}$ ,  
3 Hz to 100 kHz

### Crosstalk:

$-100\ \text{dB}$ , DC to 10 kHz  
 $-80\ \text{dB}$ , 10 kHz to 100 kHz

### Output Monitor:

A switch at the output of each channel allows for multiplexed connection to the 28000 chassis output monitor bus BNC connector for viewing the channel output with an external device.

### Protection:

Unconditionally short circuit proof

### Overload Recovery:

$< 30\ \mu\text{sec}$  to 0.01% of final value, filter bypassed and DC coupled

### Option O:

Bank isolated AUX1 output

### Isolation:

90 V peak, AC or DC operating.  $25\ \text{k}\Omega$  between output isolated ground and signal ground per card.

### Max Output:

$\pm 10\ \text{Vpk}, \pm 10\ \text{mApk}$  referred to isolated output ground.

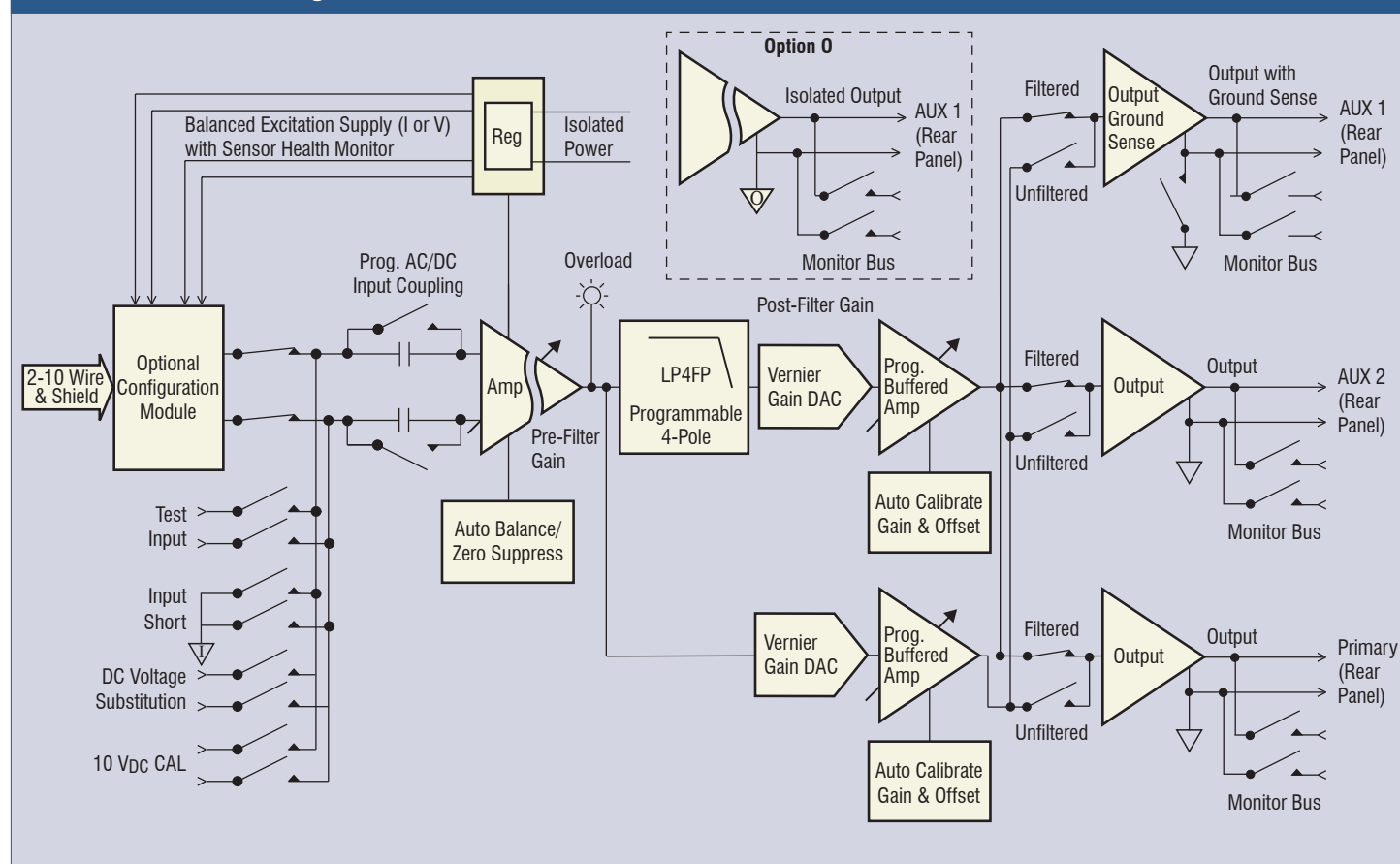
### Level vs. Frequency:

$\pm 10\ \text{Vpk}$  for  $f \leq 30\ \text{kHz}$ ;  
 $\pm 10\ \text{Vpk} \times (30\ \text{kHz}/f)$  for  $f > 30\ \text{kHz}$

### Noise:

$2.8\ \mu\text{V rms RTI} + 100\ \mu\text{V rms RTO}$ ,  
3 Hz to 100 kHz

28154 Channel Block Diagram



# 28154 Accessories and Ordering

## 28154 General Characteristics

### 28154 Card Size:

6.63 x 17.5 x 0.75 inches

### Card Weight:

1.4 lb. net

### Temperature:

0°C to 50°C (operating);

-20°C to 70°C (storage)

### Connectors:

The input connectors are integral to the front panel of the 28154 card. Two 25-pin D connectors are utilized for the 4 inputs (2 inputs per connector). Connectors have high-quality machined gold-plated pins/sockets.

The 28154 primary output connectors are integral to the 28000 system chassis. Three wires per output are provided to accommodate twisted/shielded cables. Two additional auxiliary outputs (AUX1 and AUX2) are available via 15-pin D connectors at the rear panel.

## Accessories

### Mating Connectors

Precision Filters mating connectors accommodate up to 22-AWG wire and are supplied with high-quality metal backshells and gold-plated screw machined contacts for highly reliable connections and long service life.

**CONN-IN-25D:** 25-pin D-shell mating input connector with machined crimp pins and metal backshell with strain relief

**CONN-IN-25D-SC:** 25-pin D-shell mating input connector with machined solder cup pins and metal backshell with strain relief

**CONN-OUT-26D:** High-density 26-pin D-shell mating output connector with machined crimp pins and metal backshell with strain relief. Used for primary outputs on M5 equipped mainframes.

**CONN-OUT-26D-SC:** High-density 26-pin D-shell mating output connector with machined solder cup pins and metal backshell with strain relief. Used for primary outputs on M5 equipped mainframes.

**CONN-OUT-15D:** 15-pin D-shell mating output connector with machined crimp pins and metal backshell with strain relief. Used for AUX1 or AUX2 outputs.

**CONN-OUT-15D-SC:** 15-pin D-shell mating output connector with machined solder cup pins and metal backshell with strain relief. Used for AUX1 or AUX2 outputs.

**CONN-OUT-50D-A:** 50-pin D-shell mating output connector with crimp pins and backshell with strain relief. Used for primary outputs on M3 equipped mainframes.

**CONN-OUT-50D-SC-A:** 50-pin D-shell mating connector with solder cup pins and backshell with strain relief. Used for primary outputs on M3 equipped mainframes.

## Ordering Information

28154-<LP4FP>-<HC10|HC10B|HC14>- O P<sup>1</sup>

Option P: Push-Push BCC

Option O: Bank Isolated AUX1 Output

Optional Configuration Modules

Filter Specification: 4-pole low-pass (LP4FP)

<sup>1</sup>Option P cannot be combined with the HC10/HC10B

## Precision PF-1U-FA Multi-Channel Programmable Filter/Amplifier System



### Exceptional desktop performance.

Ideal for conditioning low-level voltage inputs in front of high-resolution digital data acquisition systems. Fully programmable 8-channel and 16-channel configurations are available, both offering a choice of either 4- or 8-pole low-pass filters with programmable gain.

## High-Density Programmable Switch Systems

Computer-controlled analog signal switching replaces tedious manual patch panels.



### Precision 4164 64x64 Switch Matrix System



### Precision 464kB Switch Matrix System

Precision switch systems are reliable solid-state switch matrix systems, providing computer-controlled connection between input and output signals. Configure the 464kB with up to 256 inputs and 256 outputs, all in a single mainframe, or choose the compact 4164 system with 64 inputs and 64 outputs. Save time and reduce errors on test system setup. Download switch configurations from the host computer over the network. Built-in self-test with fault diagnostics.