# Precision 28164

Quad-Channel 500 Vcm Galvanically Isolated Transducer Conditioner with *Voltage and Current Excitation*

28164 Quad-Channel 500 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.
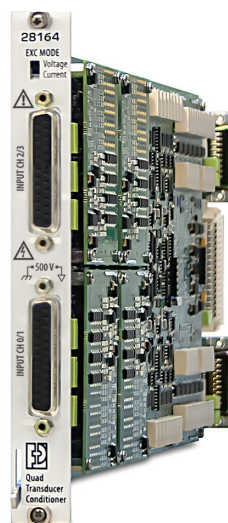
28164 Applications

- 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 28164 Features

- Four channels per card, 64 channels per 28016 chassis
- Per channel isolation - 500 V channel to channel and channel to earth ground
- Three wideband or filtered outputs per channel
- Galvanically isolated input
- 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 10 kHz filtered bandwidth or 25 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

Overview

28000 Analog Signal Conditioning System

The new standard for the world's most discriminating test labs.
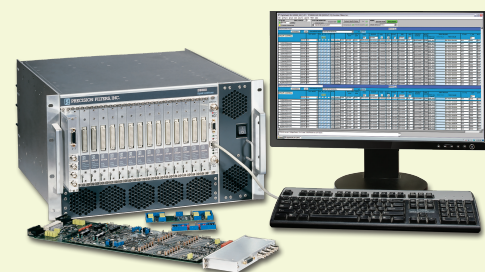
The Precision 28000 signal conditioning system provides all the flexibility you need to manage your test measurements.

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 28164 Description

Precision 28164 Description

The 28164 is a member of the Precision 28000 family of signal conditioners. The 28164 provides four channels of conditioning for a wide variety of transducers requiring constant current or constant voltage excitation. The 28164 features isolated input and excitation stages for accurate measurement of signals in the presence of high common-mode voltage inputs. Up to 500 volts of isolation, channel to channel and channel to earth ground is provided. Up to sixteen 28164 cards may reside in the 28000 system to provide 64 channels per chassis. In addition, the 28164 may be mixed with other conditioners in the 28000 family to meet your unique signal conditioning requirements.

Balanced Constant Voltage Excitation

The 28164 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 28164 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. Options HC10 and HC10B provide 1 mA balanced excitation with enhanced noise and drift characteristics optimized for RTD measurements.

For dynamic strain conditioning applications, the 28164 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 28164 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 28164. 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.

28164 Sensor Configuration

The high degree of modularity of the 28164 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 28164 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 28164 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 28164 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.

The 28164 is designed for applications requiring large isolation impedance between the input stage and the channel output. The isolated barrier stage provides more than 1000 MΩ of isolation between the isolated input ground and the output signal ground for each channel.

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 28164 is specified with a 4 -pole low-pass filter with cutoffs programmable from 2 Hz to 10 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 waveform analysis.

Output Stage

The 28164 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 28164 card. Each of the three outputs may be selected for filtered or wideband operation under program control. This allows the 28164 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.

28164 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 µA steps
- RTD Constant current excitation level (Option HC10/HC10B):
  0 to 1 mA in 0.25 uA 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 Ω, 350 Ω or 1 kΩ (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 10 kHz
- Wideband (25 kHz) or filtered operation

28164 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

28164 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 28164 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 28164 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 28164 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 28164, 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 28164 continually monitors leakage and compares readings to preset threshhold 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 28164 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.

28164 Constant Current Mode Transducer Interface
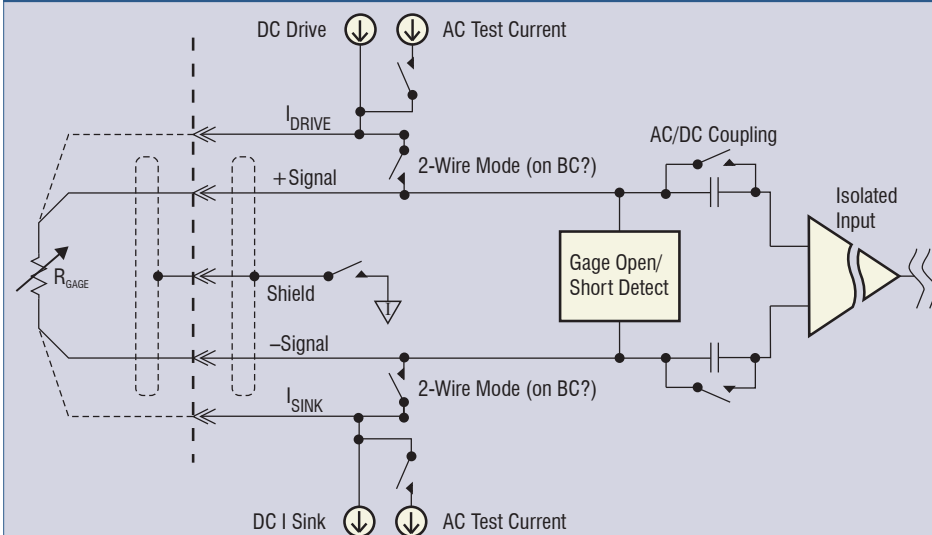
28164 Details and Specifications

28164 Conditioner Cards

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

The detailed description and specifications for the 28164 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 28164 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 thermo-couple configurations.

The HC10, HC10B, and HC14 support pro-grammable 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 kΩ, programmable
>
> **Accuracy*:** ±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:**
> ±1 mV per volt of programmed excitation for 120, 350 and 1 kΩ bridges

> **Shunt Resistance:**
> Selectable:
> 29.940 kΩ,
> 87.325 kΩ,
> 249.5 kΩ

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

Resistor Accuracy*: ±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:
> 26 V ± 1 V @ 35 mA/per channel

4-20 mA Sense Resistor:
> 250 Ω ±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 Ω, 350 Ω and 1 kΩ, programmable

Resistor Temperature Coefficient:
> ±0.2 ppm / °C

Resistor Accuracy: ±0.02%

DC Shunt Calibration:
> 255-Step Bipolar Shunt Cal

> **DC Shunt Selection:**
> R1 or R2 bridge arms

> **Shunt Resistance:**
> 7.5 kΩ to 1.92 MΩ

> **Settings:**
> Shuntcal resistance can be set to 1.92 MΩ /n where n=1 to 255

> **Resistor Accuracy:** ±0.1%, 10 ppm/°C

IEPE Input Mode:

> **Level:** 8 mA, ±5%

> **Compliance Voltage:**
> 26 V, Nominal

> **AC Coupling Frequency w/ IEPE Selected:** 0.32 Hz ±5%

> **Fault Monitor:**
> Sensor open/short

> **IEPE Bias Monitor:** Bias voltage continu-ously monitored and compared to user defined limits

Bridge Wiring

Input Connector:
> 25-pin D-shell (2 ea.)

Input Wires:
> ±EXCITATION (2)
> ±SENSE (2)
> ±SIGNAL (2)
> SHUNT CAL (3)
> ¼ Bridge RTN (1) Single-Arm Bridge
> SHIELD (1)
> ISOLATED GROUND (1)
> SIGNAL GROUND (1)

28164 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: ±1 mV to ±100 mV in 100 µV steps ±0.02%, ±10 µV
> High Range: ±0.1 V to ±10V in 10 mV steps ±0.02%, ±1 mV
> Stability: ±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 measure-ment 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 ampli-fier output. Excitation monitor gain is x0.5.

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

28164 Details and Specifications

Diagram with HC10 Bridge/RTD Configuration Module
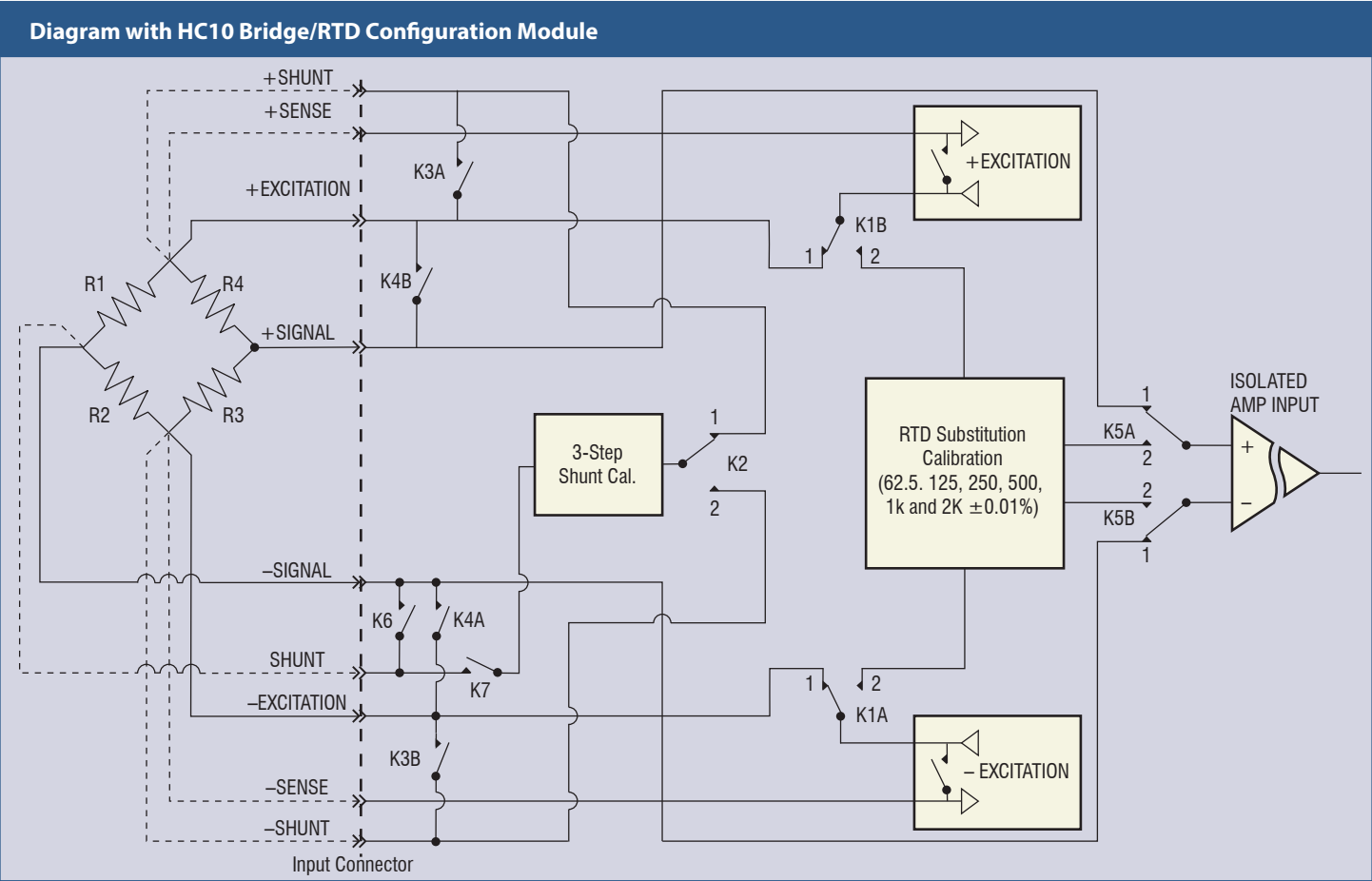
Truth Table

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	

28164 with HC10 Bridge Configuration Module

Diagram with HC14 Bridge/Strain/IEPE Configuration Module

Input Connector
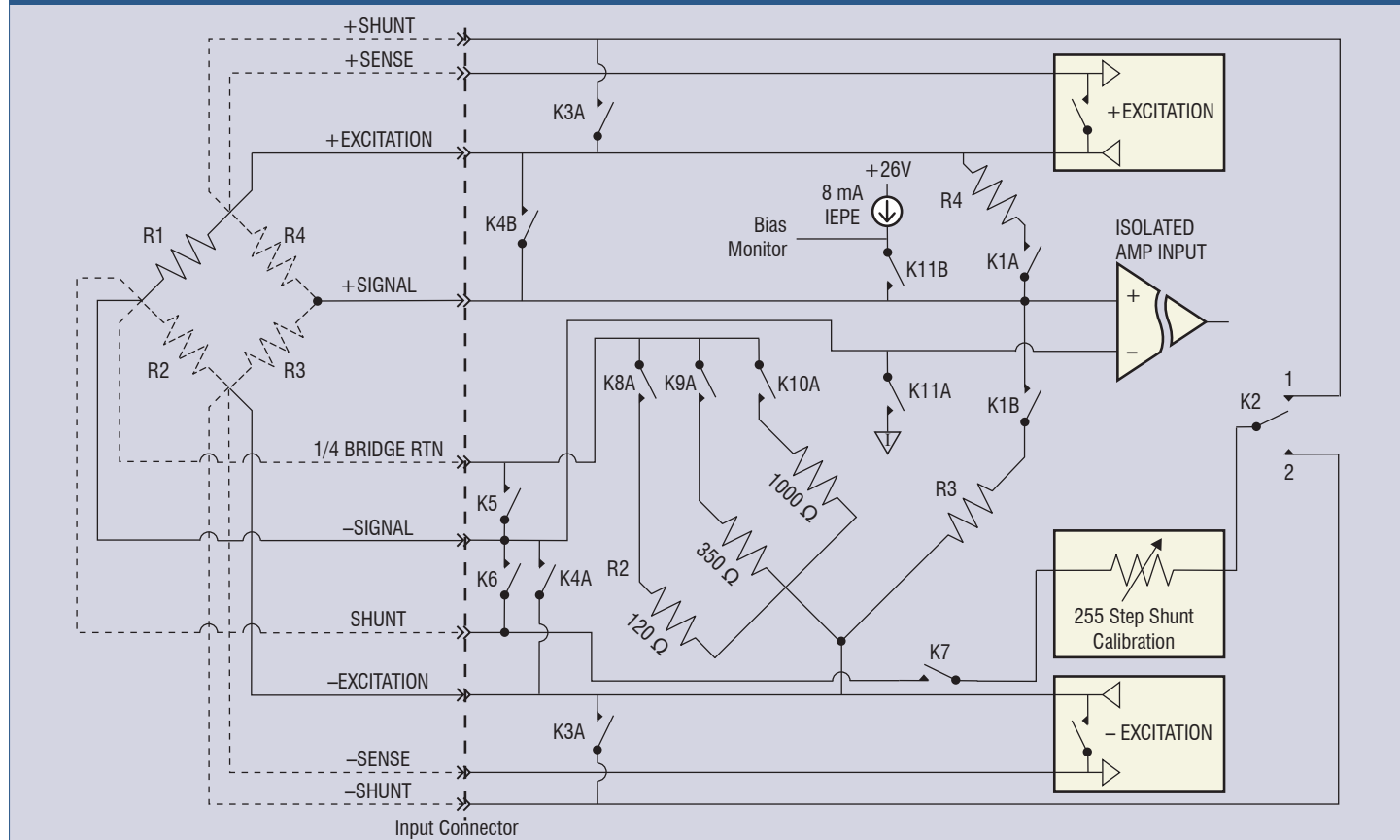
Truth Table

Configuration	K1	K2	K3, K6	K4	K5	K7	K8	K9	K10	K11
¼ Bridge, 2-Wire	IN				IN		IN[1]	IN[1]	IN[1]	IN
¼ Bridge, 3-Wire	IN				OUT		IN[1]	IN[1]	IN[1]	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

[1] One switch selected at a time.

28164 with HC14 Bridge Configuration Module

28164 Details and Specifications

28164 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:
±0.03% of setting ±1 mV

Noise:
100 µVrms, 3 Hz to 200 kHz

Temperature Drift:
±0.0025%/ºC of setting or ±50 µV/ºC, 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.

28164 Constant Current Excitation Supply

Type:
Balanced differential constant current excitation

Excitation:
0 to 20.475 mA in 5 µA steps

Total Gage Voltage (Volts):
20 – I x 700 minimum

Input Impedance:
100 kΩ nominal per side

CMRR (DC to 1 kHz):
80 dB for 120 Ω gage
70 dB for 350 Ω gage
60 dB for 1 kΩ gage

Initial Accuracy:
0.05% of setting ±5 µA

Temperature Drift:
30 nA + 0.0024% of setting per °C

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

Bandwidth:
±0.2 dB to 200 kHz (RGAGE <1 kΩ)

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 10 kHz in 1 kHz steps

Frequency Accuracy: ±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 MΩ nominal per side

HC10/HC10B RTD Excitation

The HC10 and HC10B options provide excitation levels optimized for RTD measurements.

Type:
Balanced differential constant current excitation

Level:
0 to 1.02375 mA in 0.25 µA steps

Total Gage Voltage:
20 – I x 14E3 minimum

Input Impedance:
2 MΩ nominal per side

Initial Accuracy: 0.05% of setting ±250 nA

Drift:
1.5 nA + 0.0024% of setting per °C

Noise:
3.5 pA per rt Hz at 1 kHz

Bandwidth:
±0.2 dB to 200 kHz

28164 Mute Mode

In harsh test environments, a sensor or input cable can become faulty or intermittent 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 28164 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.

28164 Transducer Health Monitor

Sensor Excitation Monitor: Transducer excitation voltage or current is monitored and reported to the user on the fly. Measured 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 compared 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 Measurement: The 28164 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.

Excitation Current Limit: Current limit protection is provided by the 28164 excitation 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 excitation 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.

28164 Details and Specifications

28164 Input Characteristics

Type:
Balanced differential w/ programmable AC/DC input coupling

Input Impedance: 10 MΩ //100 pF per side

Isolation:
Galvanically isolated input. Input stage and excitation are referenced to a common isolated ground. 1000 MΩ minimum impedance between isolated ground and signal ground for each channel.

Common Mode Voltage:
±500 V peak, AC or DC operating

Max Differential Signal Level (AC + DC):
±10 Vpk for f ≤25 kHz ±10 Vpk x (25 kHz/f) for f > 25 kHz

Slew Rate: 2 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 µVrms, 25 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, 1 Vrms 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

28164 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 28164 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:
±0.05% re fullscale, relative to the best straight line

Frequency Response:
DC to 10 kHz, 0 dB ±0.1 dB
–3 dB typical @ 25 kHz

High Frequency Rolloff: 18 dB/octave

28164 Details and Specifications

28164 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 10 kHz in 200 Hz steps

Pass-Band Accuracy:
±0.1 dB, DC to F $_{-0.1\ dB}$
±0.15 dB to F $_{-0.5\ dB}$

Phase Match:
0.1° typical, 1° max, DC to F $_{-0.1\ dB}$;
0.15° typical, 1.5° 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:
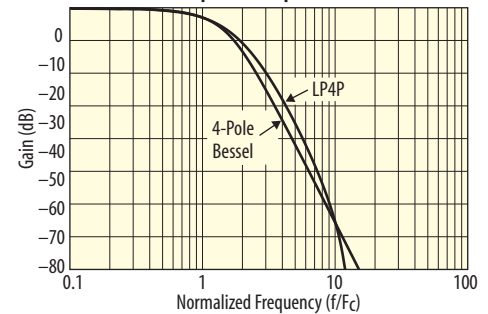-3 dB at 25 kHz, typical

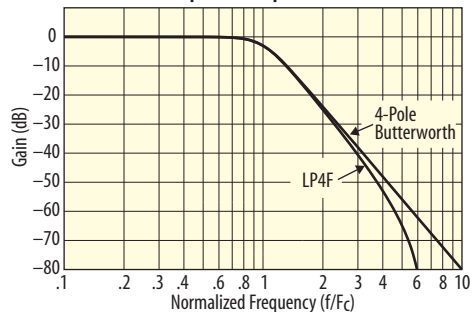| Specification	LP4F Maximally Flat Low-Pass Filter	LP4P Constant Time Delay Low-Pass Filter
Cutoff Frequency Amplitude	–3.01 dB	–3.01 dB
DC Gain	0.00 dB	0.00 dB
Pass-Band Ripple	0.00 dB	0.00 dB
Stop-Band Frequency	5.9465 Fc	11.863 Fc
Cutoff Frequency Phase	–180.0 deg	–101.5 deg
Phase Distortion (DC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

LP4F and LP4P Amplitude Response
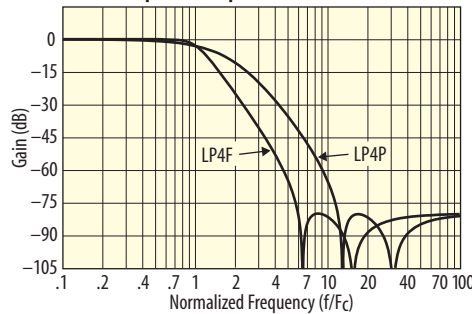
LP4P vs 4-Pole Bessel Amplitude Response

LP4F vs Butterworth Amplitude Response

LP4F and LP4P Step Response

	LP4F	LP4P
10-90% Rise (Sec)	0.39/Fc	0.34/Fc
50% Delay (Sec)	0.45/Fc	0.28/Fc
% Overshoot	11.1%	0.5%
10% Error (Sec)	0.96/Fc	0.48/Fc
5% Error (Sec)	1.09/Fc	0.54/Fc
1% Error (Sec)	1.65/Fc	0.66/Fc
0.5% Error (Sec)	2.14/Fc	0.70/Fc
0.1% Error (Sec)	2.72/Fc	0.77/Fc
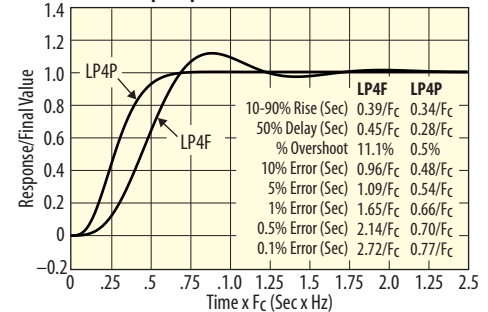
Output Characteristics

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 28164 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 28164 channel ground.

Output Impedance:
10 Ω // 100 pF

Aux1 Sense Input:
100 Ω // 100 pF or ground via manual card switch

Max Output:
±10 Vpk, ±10 mA pk

Offset:
<5 mV after auto-adjust at any gain setting

Offset Drift:
1 µV/°C, RTI + 200 µV / °C RTO

Noise:
2 µV rms RTI + 100 µV rms RTF + 100 µV rms RTO, 3 Hz to 25 kHz

Crosstalk:
–100 dB, DC to 10 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 µsec 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 kΩ between output isolated ground and signal ground per card.

Max Output:
± 10 Vpk, ±10 mApk referred to isolated output ground.

Level vs. Frequency:
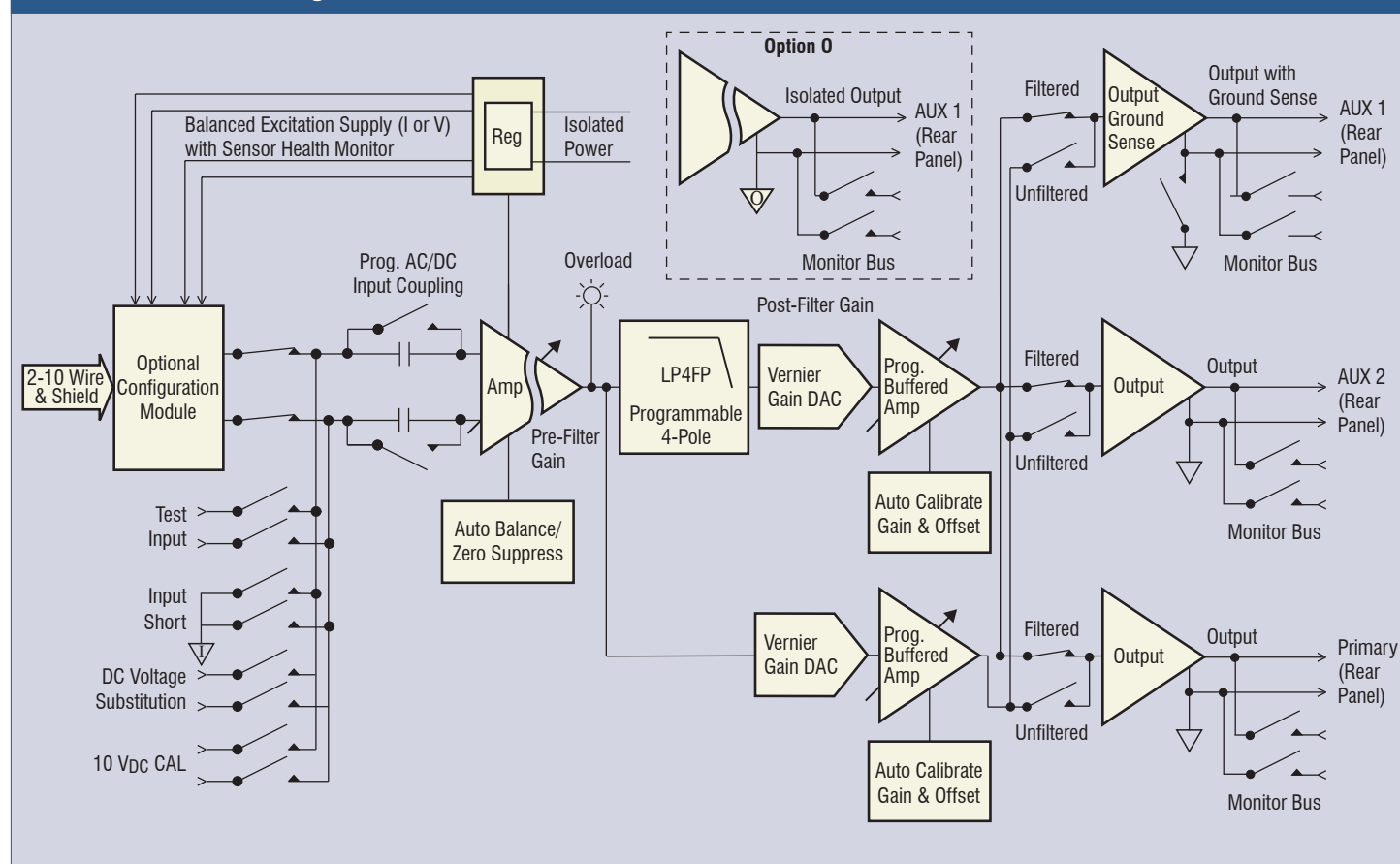±10 Vpk for f ≤ 25 kHz;
±10 Vpk x (25 kHz/f) for f > 25 kHz

Noise:
2.8 µV rms RTI + 250 µV rms RTO, 3 Hz to 25 kHz

28164 Channel Block Diagram

PRECISION FILTERS, INC.

28164 General Characteristics

28164 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 28164 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 28164 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

28164-<LP4FP>-<HC10|HC10B|HC14>- O P[1]

Option P: Push-Push BCC

Option O: Bank Isolated AUX1 Output

Optional Configuration Modules

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

[1]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 464*k*C 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.

™ Balanced Constant Current and BCC are Trademarks of Precision Filters, Inc.