Precision 28154
Quad-Channel 300 V Common-Mode Transducer Conditioner with Voltage and Current Excitation

28154 Quad-Channel 300 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 Features
- Four channels per card, 64 channels per 28016 chassis
- Per channel isolation - 300 V channel to channel and channel to earth ground.
- Three wideband or filtered outputs per channel
- Optional isolated output (Option O)
- 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/Thermocouple Configuration. 4-Wire 0-1 mA RTD excitation. RTD substitution, resistive shunt cal.
- 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 – 100 mV)
- 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 0.01% resolution
- 4-pole low-pass filters with programmable pulse/flat characteristics
- Pre-filter overload detectors
- Precise digital calibration

### 28154 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)

### Sensor Applications
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### Precision 28000 Analog Signal Conditioning System

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**

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 300 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 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/Thermocouple Configuration:** The HC10 Bridge/RTD/Thermocouple Configuration Module supports full bridge, RTD and thermocouple 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 Thermocouple measurements it is assumed that a third party UTR is used with isothermal block temperature read and processed by external means to compensate the 28154 output for a reference junction and to perform linearization.

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.
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, that 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.

Amplifier and Filter
Programmable pre- and post-filter amplifiers provide an overall gain of 8192. Gain is distributed both before and after 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 time domain 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 on the front panel of the 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
- 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): 0 to 1 mA in 0.25 μA 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/HC14)
- DC shunt cal resistance and shunt arm: R1 or R2 (HC10/HC14)
- Automatic balance/suppress
- AC/DC input coupling
- Test modes: amp short, 10 V DC CAL, excitation off, test bus (voltage substitution, Option V), DC shunt calibration, AC current, excitation monitor
- RTD resistor substitution (HC10)
- Precision DC voltage substitution

28154 Graphical User Interface Display
All programmable features in addition to:
- Output monitor
- Gain: x1/16 to x8192 with 0.01% resolution
- Filter type: pulse or flat
- Cutoff frequency:
  - 2 Hz to 100 kHz, flat mode
  - 1 Hz to 100 kHz, pulse mode
- Wide-band (250 kHz) or filtered operation

- 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 Constant Current Mode Transducer Interface
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
- Bridge Wiring
- Excitation Supply
- Input Characteristics
- Amplifier Characteristics
- Test Modes
- 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 and HC14 options are factory configured and support bridge, strain, IEPE, RTD and thermocouple configurations.

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

HC10 Full-Bridge/RTD/Thermocouple Configuration Module

RTD Substitution Cal
Values: 62.5, 125, 250, 500, 1 k and 2 kΩ, programmable
Accuracy: ±0.01%, 5 ppm/°C
Thermocouple cal via prog. voltage substitution
Range: 1 mV - 100 mV w/ 100 μV resolution of setting
Accuracy: ±0.02%, ±3 μV, ±15 ppm/°C
DC Shunt Calibration (Constant Voltage Excitation Mode Only):
3-Step Bipolar Shunt Cal
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
Resistor Accuracy: ±0.1%, ±10 ppm/°C

HC14 Bridge/Strain/IEPE Bridge/IEPE Configuration Module

Bridge Configuration:
1-arm, 1-arm w/ 3 wires, 2-arm or 4-arm, (programmable)
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 256
Resistor Accuracy: ±0.1%, 10 ppm/°C
IEPE Input Mode:
Level: 8 mA, ±1%
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 continuously monitored and compared to user defined limits

Bridge Wiring

Input Connector:
26-pin high-density D-shell (2 ea.)
Input Wires:
±EXCITATION (2)
±SENSE (2)
±SIGNAL (2)
SHUNT CAL (3)
¼ Bridge RTN (1) Single-Arm Bridge SHIELD (1)
28154 Details and Specifications

Diagram with HC10 Bridge/RTD/Thermocouple Configuration Module

Truth Table

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28154 with HC10 Bridge Configuration Module
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¹ One switch selected at a time.
28154 Details and Specifications

28154 Excitation Supply

28154 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%, ±500 µV

Noise:
100 µVrms, 3 Hz to 200 kHz

Temperature Drift:
±0.0025%/°C of setting or ±50 µV/°C, whichever is greater

Sense Leakage Current:
Less than 10 µA

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 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%, 5 µA

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

Noise:
65 pA/√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 level is 0.1% of programmed excitation current.

Frequency:
1 kHz to 100 kHz in 1 kHz steps

Frequency Accuracy: ±5%

HC10 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 µA steps

Total Gage Voltage:
20 – I x 14E3 minimum

Input Impedance:
2 MΩ nominal per side

Initial Accuracy: 0.05%, 500 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

28154 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 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. 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 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.

Excitation Current Limit: Current limit protection is provided by the 28154 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.
### 28154 Details and Specifications

#### 28154 Input Characteristics

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

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

**Common Mode Voltage**
±300 V peak, AC or DC operating

**Max Differential Signal Level (AC + DC)**
±10 Vpk

**Slew Rate:**
20 V/µs, min

**Input Protection (Power On):**
30 V continuous, 100 Vpk for 1mS, 10% duty cycle

**Offset Drift:**
1 µV/°C, typical

**Noise:**
10 nV/√Hz at 1 kHz and prefilter gain > 64, typical

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

**CMRR (DC Coupled):**
110 dB, DC to 440 Hz and input gain > x16

**CMRR (AC Coupled):**
100 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.

**Range:**
Bridge balance algorithm selects the most appropriate range to achieve balance with finest resolution.

**32 mV/V Mode Auto-Balance Ranges:**
- ±0.001 mV/V to ±32 mV/V in ±0.976 µV/V steps

**512 mV/V Mode Auto-Balance Ranges**
- (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 Ranges:**
±0.001 mV to ±640 mV in ±19.53 µV steps

**10.24 V Suppress Ranges**
- (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

**Auto Suppress Time:**
Less than 60 seconds per system of 64 channels

#### 28154 Amplifier Characteristics

**Prefilter Gain:**
x1 to x512 in binary steps with overload detection (10.5 Vpk threshold)

**Postfilter Gain:**
x1/16 to x16 in binary steps with vernier adjustment

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

**Gain Setability:**
- 0.0125% steps for POG ≥ 0.5X
- 0.0125%/POG for POG < 0.5X

**DC Gain Accuracy:**
- 0.01% typical, 0.1% maximum for POG ≥ 0.5X
- 0.1%/POG maximum for POG <0.5X

**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:**
±0.02% for 6 months

**Temp Coef.:** ±0.004%/°C

**DC Linearity:**
±0.005% re full scale, 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 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 (Option V):** 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. Option V enables user control of the test bus. 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:**
Programmable from 1 mV to 100 mV in 100 µV steps

**Accuracy:**
± 0.02%, ±3 µV, ±15 ppm/°C

**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 excitation 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.
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
Flat Mode:
- 2 Hz to 2.046 kHz in 2 Hz steps
- 2.2 kHz to 100 kHz in 200 Hz steps

Pulse Mode:
- 1 Hz to 1.023 kHz in 1 Hz steps
- 1.1 kHz to 100 kHz in 100 Hz steps

Amplitude Accuracy:
- ±0.1 dB max, DC to 0.8 Fc
- ±0.2 dB max, 0.8 Fc to Fc

Amplitude Match:
- ±1° max, DC to 0.8 Fc
- ±2° max, 0.8 Fc to Fc

Phase Match:
- Bypasses filter but not amplifier stages

Bypass Bandwidth:
- 250 kHz, typical

<table>
<thead>
<tr>
<th>Specification</th>
<th>LP4F Maximally Flat Low-Pass Filter</th>
<th>LP4P Constant Time Delay Low-Pass Filter</th>
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<tr>
<td>Cutoff Frequency Amplitude</td>
<td>−3.01 dB</td>
<td>−3.01 dB</td>
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<tr>
<td>DC Gain</td>
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<tr>
<td>Pass-Band Ripple</td>
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<td>0.00 dB</td>
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<td>Stop-Band Frequency</td>
<td>5.9465 Fc</td>
<td>11.863 Fc</td>
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<td>&lt; 3.7 deg</td>
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<tr>
<td>Zero Frequency Group Delay</td>
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<td>0.2920/Fc</td>
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<tr>
<td>Percent Overshoot</td>
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<td>1% Settling Time</td>
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<tr>
<td>−80 dB Frequency</td>
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<td>11.8629 Fc</td>
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</tbody>
</table>
Output Characteristics

Primary (Rear Panel) Output: 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 available on the front panel of the 28154 card.

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 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 + 150 μV/°C RTO

Noise:
2.8 μV rms RTI + 60 μV rms RTO,
3 Hz to 100 kHz

Crosstalk:
−90 dB, DC to 100 kHz

Option O:
Bank isolated AUX1 output

Isolation Voltage:
90 V peak, AC or DC operating

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

Level vs. Frequency:
±10 Vpk for f ≤ 30 kHz;
±10 Vpk x (30 kHz/f) for f > 30 kHz

Noise:
2.8 μV rms RTI + 100 μV rms RTO,
3 Hz 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.
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 40°C (operating); -20°C to 70°C (storage)

Connectors:
The input connectors are integral to the 28154 card. Cutouts on the 28000 frames allow the input connector to pass through the backplane and to mate directly with the input cables.

Two 26-pin high-density D connectors are utilized for the 4 inputs (2 inputs per connector). Connectors have high-quality machined gold-plated pins/sockets.

28154 output connectors are integral to the 28000 system chassis. Three wires per output are provided to accommodate twisted/shielded cables. Two additional auxiliary outputs with ground sense capability are available via 15-pin DB connectors the front panel.

28154 Accessories and Ordering

Ordering Information

28154-<LP4FP>-<HC10/14>-O V

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

User Test Bus Control*
Optional Bank Isolated AUX1 Output
Optional Configuration Modules

* WARNING: Application of the test bus defeats the input stage isolation. Improper use of the test bus with high CMV signals present at the input may result in damage to the amplifier.

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-26D**: High-density 26-pin D-shell mating input connector with machined crimp pins and metal backshell with strain relief

**CONN-IN-26D-SC**: High-density 26-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

**CONN-OUT-26D-SC**: High-density 26-pin D-shell mating output connector with machined solder cup pins and metal backshell with strain relief

**CONN-OUT-15D**: 15-pin D-shell mating output connector with machined crimp pins and metal backshell with strain relief

**CONN-OUT-15D-SC**: 15-pin D-shell mating output connector with machined solder cup pins and metal backshell with strain relief

**CONN-OUT-50D-A**: 50-pin D-shell mating output connector with crimp pins and backshell with strain relief

**CONN-OUT-50D-SC-A**: 50-pin D-shell mating connector with solder cup pins and backshell with strain relief.

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 164 64x64 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.

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