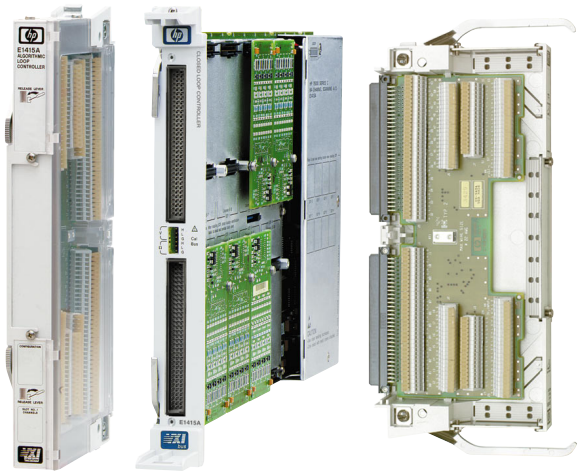
Algorithmic Closed Loop Controller
HP E1415A

Technical Specifications

- **1 to 32 control loops**
- **Multiple inputs and outputs per loop**
- **2.5 kz maximum update rate**
- **User-written "C" code control algorithms or default PID**
- **On-the-fly change of coefficients and algorithms**



Description

The HP E1415A is a **C-size, 1-slot, VXI closed loop control module.** It bridges the gap between standard PID controllers and custom control systems. And, it is complete on a single module! More powerful than PID controllers and easier to implement than custom systems, the HP E1415A is the perfect solution to tough monitoring and control applications. These applications consist of:

- Linear control of multiple loops of temperature, position, velocity, acceleration, rpm, and other parameters;
- Complex control requiring nested or interconnected loops, or loops with multiple inputs or multiple outputs of mixed type;
- Independent loops with multi-level alarms and watchdog requirements.

The HP E1415A can also be used in various other modes for applications requiring general-purpose multifunction input and output capability. The algorithms are flexible enough and the timing is deterministic enough to be used for hardware-in-the-loop simulation of many types of new product designs. And it can be used solely for data acquisistion with the ability to capture multiple channels of analog, digital, or frequency-based signals all with a single VXI module.

Refer to the HP Website for instrument driver availability and downloading instructions.

Compact Packaging with Signal Conditioning

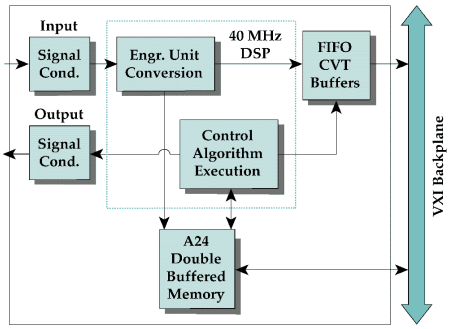
It also provides for configurable signal conditioned I/O with up to eight individual plug-ons for analog, digital, and frequency needs. More specifically the capabilities of the HP E1415A with SCPs are:

- HP E1501A direct input (>100 kHz BW)
- HP E1502A 10 Hz two-pole low-pass filter
- HP E1503A programmable gain/filter per channel; gains of X1, X8, X64, and two-pole low-pass filters of 10 Hz, 100 Hz, and 1000 Hz
- HP E1504A breadboard circuit card
- HP E1505A dual-level current source for resistance and temperature
- HP E1506A, E1507A, E1511A bridge completion and excitation for strain, (sample and hold on E1511A)
- E1510A Sample and Hold with 5 programmable Bessel low-pass filters
- HP E1508A, E1509A fixed gain (16 kHz or 64 kHz) and 10 Hz, 2-pole, low pass filter per channel
- HP E1512A 25 Hz two-pole low-pass filter
- HP E1513A attenuator input with 10 Hz, 2-pole, low-pass filter for signals up to 60 VDC
- HP E1514A, E1515A isolated input with 10 Hz or 100 Hz two-pole low-pass filter
- HP E1516A, E1517A isolated input with X64 gain and 10 Hz or 100 Hz two-pole low-pass filter
- HP E1531A non-isolated voltage output up to ±16 V
- HP E1532A non-isolated current output up to ±10 mA source
- HP E1533A digital I/O with 16 TTL-level compatible bits
- HP E1534A frequency, totalize, and pulse width modulation input or output
- HP E1535A watchdog timer with algorithm language control

The on-board calibration reference is automatically routed to the input of the signal conditioning during the calibration cycle, thus eliminating the need to remove the module for calibration.

Flexibility with Deterministic Control

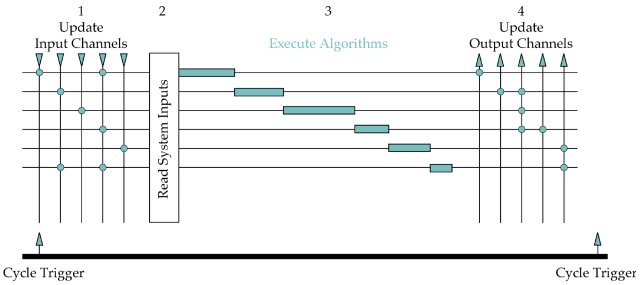
The HP E1415A is a digital sampling closed loop control system which is complete on a single module. All signal conditioning, process monitoring, control calculations, and control signals are handled on board without the need for computer supervision. Once setup is done, the module is essentially free-running.



Digital Sampling Closed Loop Control System

The HP E1415A combines flexibility with deterministic control. Control algorithms for each of the loops can be the default PID calculation or a user-defined, downloaded, custom algorithm. The loop update rate is deterministically controlled by an internal clock so that variations in the algorithm execution times do not affect the loop cycle time.

There are four steps to each control cycle: 1.) Input channels are measured, 2.) System inputs are updated, 3.) Control algorithms are executed, and 4.) Output signals are updated.



Four Steps to Control Cycle

The inputs are updated at the beginning of each cycle and the outputs are updated at a later deterministic time in the cycle so that various paths in the control algorithm do not affect the loop timing. These steps are executed automatically and deterministically without need for intervention from a system computer.

Powerful Control Capability

The control algorithm for each loop is easily developed by the user from a list of algebraic expressions and flow constructs such as IF, THEN, ELSE. Tuning is simplified because all of the constants in the algorithm as well as the algorithm itself can be updated on-the-fly. New values are double-buffered so there is no need to stop scanning the inputs or halt the algorithm execution.

The on-board 40 MHz pipelined DSP provides highly deterministic execution, making it easy to accurately predict cycle times. Engineering unit conversions for temperature, strain, resistance, and voltage measurements are made automatically without slowing down the algorithm execution speed.

Wide Choice of Inputs/Outputs

The inputs to the loop algorithm can be measured values from multiple channels, operator input values, outputs from other loops, or values from other subsystems.

The HP E1415A has a variety of signal conditioning plug-ons for making measurements of:

- Temperature, strain
- Voltage, current, resistance
- Rpm, frequency, totalize
- Discrete levels, TTL, contact closures

In addition, the measured input values and the calculated output values can be stored in a 64 thousand sample FIFO buffer and efficiently transferred to the controlling computer in blocks of data. With this feature, it is no longer necessary to waste resources by dedicating a data acquisition channel to monitor each control loop input and output. The result of any algorithm calculation can be an input for use by another loop or subsystem, or it can be a direct output of several different types. Among the choices of output are:

- Analog voltage
- Analog current
- Discrete levels (TTL)
- Pulse width modulation (TTL)

As an example of output flexibility, the pulse width modulation output has several modes. In the PWM free run mode, the frequency or pulse width output is independent of the loop update rate and can be changed once per loop update cycle. The square wave mode provides a variable frequency, fixed 50% duty cycle output signal. The pulse-per-update mode provides a variable width pulse synchronized to the loop update cycle.

Operator Control

Manual control can be implemented through a software user interface or external hardware, such as a potentiometer. Bumpless transfer from auto to manual mode, or manual to auto is handled automatically by a set-point-tracking routine in the default PID algorithm code.

The following temperature accuracy graphs include instrument and firmware linearization errors. The linearization algorithm used is based on the IPTS-68 (78) standard transducer curves. Add your transducer accuracy to determine total measurement error.

Loop Control Specifications

General

Number of loops:	1 to 32
Default control algorithm type:	PID
Maximum loop update rate (for default PID algorithm):	
1 loop:	3 kHz
8 loops:	1 kHz
32 loops:	250 Hz

Custom Algorithm Development

Language:	subset of C, programming language including if-then-else, most math and comparison operations.
Variable types:	scalar local and global variables, array local and global variables
Intrinsic functions:	interrupt (), writefifo(), writecvt(), writeboth(), min(), max(), abs().
Other functions:	create own custom functions to handle transcendental operations.

I/O General

A total of eight (8) Signal Conditioning Plug-ons (SCP's) can be installed in most combinations of input or output configurations on a single HP E1415A.

Summary Specifications

The following specifications include the SCP and scanning A/D performance together as a unit. Accuracy is stated for a single sample, averaging multiple samples will improve accuracy by reducing noise of the signal. The basic E1415A scanning A/D has a full scale range of ±16 V and five autoranging gains of X1, X4, X16, X64, and X256. An SCP must be used with each eight channel input block to provide input protection and signal conditioning.

Measurement resolution:	16 bits (including sign)
Maximum reading rate:	100 kSamples/s divided by the number of channels in the scan
Memory:	64 kSa
Maximum input voltage:	Normal mode plus common mode
Operating:	< ±16 V peak
Damage level:	> ±42 V peak
Maximum common mode voltage:	
Operating:	±16 V peak
Damage level:	> ±42 V peak
SCP input impedance:	>100 MOhm differential
Maximum tare cal offset:	62.5 mV range ±75% of full scale other ranges ±25% of full scale
Jitter:	
Phase jitter scan-to-scan:	80 pS RMS
Phase jitter card-to-card:	41 nS peak 12 nS RMS
Measurement accuracy:	90 days ,23 ±/1° C (with *CAL done after 1 hr warm-up and CALZERO done within 5 min)

Note: *Beyond the 5 min. limitation and CALZERO not done, apply the following drift error:*
Drift = 10 μV/°C ÷ SCP gain, per °C change from CALZERO temperature

Using accuracy data: Below are listed data needed to calculate accuracy. Many definitions of accuracy are possible. Here we use two:
1) Single-shot, 3 sigma and
2) Worst Case. To calculate accuracy assuming temperature is held constant within ± 1 degree C of the temperature at calibration, the following formulas apply:

Single Shot, $3\sigma = \pm\sqrt{(GainError–\mu V)^2 + (OffsetError–\mu V)^2 + (Noise–3\sigma)^2}\ \mu V$

Correcting for temperature: To calculate accuracy over temperature range outside the ±1°C range, results after *CAL are given by replacing each of the above error terms as follows:
Replace $(GainError–\mu V)^2$
with $(GainError–\mu V)^2 + (GainTempco–\mu V)^2$.
Replace $(OffsetError–\mu V)^2$
with $(OffsetError–\mu V)^2 + (OffsetTempco–\mu V)^2$.

Timing Signals

Timing: scan-to-scan timing and sample-to-sample timing can be set independently.

Scan triggers: can be derived from a software command or a TTL level from other VXI modules, internal timer, or external hardware. Typical latency 17.5 µs.

Synchronization: multiple HP E1415A modules can be synchronized at the same rate using the TTL trigger output from one HP E1415A to trigger the others.

Alternate synchronization: multiple HP E1415A module can be synchronized at different integer-related rates using the ALG:SCAN:RATIO mode and the TTL trigger output from one HP E1415A module to trigger the others.

Scan triggers:

Internal	Resolution	Trigger count
100 µsec to 6.5536 sec	100 µsec	1 to 65,535 or infinite

Sample timer:

Range	Resolution
10 µsec to 32768 msec	0.5 µsec

Note: *For detailed information on noise characteristics and reduction techniques for the HP E1415A, refer to the product note: HP E1413A/B/C, E1313A, and E1415A Recommended Wiring and Noise Reduction Techniques, pub. no. 5965-1653E.*

Analog Specifications

Voltage Measurements
HP E1501A Direct Input SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset error	Noise 3σ	Noise* 3σ
62.5 mV	0.01%	5.3 µV	18 µV	8 µV
256 mV	0.01%	10.3 µV	45 µV	24 µV
1.0 V	0.01%	31 µV	110 µV	90 µV
4.0 V	0.01%	122 µV	450 µV	366 µV
16.0 V	0.01%	488 µV	1.8 mV	1.5 mV

***A/D filter ON (min sample period ≥145µS: ≤100 Hz scanrate 64 Ch)**

Normal mode rejection	Common mode rejection	Input Capacitance
0 dB	>105 dB (0 to 60 Hz)	80 pF typical

Temperature coefficients:

Gain	Offset	
10ppm/°C	(0-40°C) 0.14 µV/°C	(40-55°C) 0.38 µV/°C+ .8 µV

HP E1502A Low Pass Filter SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset error	Noise 3σ	Noise* 3σ
62.5 mV	0.01%	7.2 µV	34 µV	15 µV
256 mV	0.01%	12.2 µV	60 µV	28 µV
1.0 V	0.01%	33 µV	110 µV	92 µV
4.0 V	0.01%	122 µV	450 µV	366 µV
16.0 V	0.01%	488 µV	1.8 mV	1.5 mV

***A/D filter ON (min sample period ≥145µS: ≤100 Hz scanrate 64 Ch)**

Normal Mode Rejection			Common Mode Rejection		Typical Min
10 Hz	10 Hz:	−6 dB	0 to 60Hz	>108 dB	>100 dB
LP filter	50 Hz:	>23 dB			
	60 Hz:	>25 dB			

Temperature coefficients:

	Tempco	Temp Range
Gain:	10 ppm/°C	
Offset:	No additional error	(0-30 °C)
	0.1 µV/°C	(30-40 °C)
	0.27 µV/°C+02.4 µV	(40-55 °C)

HP E1512A Low Pass Filter SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset error	Noise 3σ	Noise* 3σ
62.5 mV	0.01%	7.2 µV	34 µV	15 µV
256 mV	0.01%	12.2 µV	60 µV	28 µV
1.0 V	0.01%	33 µV	110 µV	92 µV
4.0 V	0.01%	122 µV	450 µV	366 µV
16.0 V	0.01%	488 µV	1.8 mV	1.5 mV

***A/D filter ON (min sample period ≥145µS: ≥100 Hz scanrate 64 Ch)**

HP E1508A Fixed Filter/Amplifier SCP

Accuracy:
Fixed gain x16:

Range ±FS	Gain % of rdg	Offset error	Noise 3σ	Noise* 3σ
3.906 mV	0.01%	3.8 µV	3.4 µV	2.9 µV
15.63 mV	0.01%	4.2 µV	4.1 µV	3.5 µV
(at ≥40C)			4.4 µV	3.8 µV
62.5 mV	0.01%	4.9 µV	7.5 µV	6.3 µV
256 mV	0.01%	8.0 µV	28 µV	23 µV
1.0 V	0.01%	31 µV	113 µV	94 µV

***A/D filter ON (min sample period ≥145µS: ≤100 Hz scanrate 64 Ch)**

HP E1509A Fixed Filter/Amplifier SCP

Accuracy:
Fixed gain x64:

Range ±FS	Gain % of rdg	Offset error	Noise 3σ	Noise* 3σ
3.906 mV	0.01%	2.3 µV	1.7 µV	1.4 µV
15.63 mV	0.01%	2.4 µV	2.2 µV	1.9 µV
(≥40 °C)			2.5 µV	2.2 µV
62.5 mV	0.01%	3.0 µV	7.0 µV	5.7 µV
256 mV	0.01%	8.0 µV	28 µV	23 µV

***A/D filter ON (min sample period ≥145 µS: ≤100 Hz scanrate 64 Ch)**

Normal Mode Rejection			Common Mode Rejection		Typical Min
10 Hz	10 Hz	−6 dB	0 to 60 Hz	>136 dB	>120 dB
LP filter	50 Hz	> 23 dB			
(2 pole)	60 Hz	> 25 dB			

HP E1503A Programmable Filter/Gain SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset 2 Hz	Offset 10 Hz	Offset 100 Hz
62.5 mV	0.01%	12 μV	8.8 μV	6.8 μV
256 mV	0.01%	15 μV	12.5 μV	11.2 μV
1.0 V	0.01%	33 μV	31.8 μV	31.3 μV
4.0 V	0.01%	123 μV	122 μV	122 μV
16.0 V	0.01%	488 μV	488 μV	488 μV

Range ±FS	Filt Off	Noise 3σ	Noise* 3σ
62.5 mV	6.3 μV	45 μV	26 μV
256 mV	10.8 μV	63 μV	31 μV
1.0 mV	31.2 μV	112 μV	93 μV
4.0 mV	122 μV	450 μV	366 μV
16.0 V	488 μV	1.8 mV	1.5 mV

***A/D filter ON (min sample period ≥145 μS: ≤100 Hz scanrate 64 Ch)**

Temperature coefficients:

Gain: 15ppm/°C after *CAL

Offset: Add tempco error plus fixed offset to above table

Temp.	Tempco	2 Hz	10 Hz	100 Hz	Filt Off
(0-30)	.16 μV/° C	0 μV	0 μV	0 μV	0 μV
(30-40)	.18 μV/° C	13 μV	9 μV	1.1 μV	0.2 μV
(40-55)	.39 μV/° C	31 μV	22 μV	6.4 μV	1.1 μV

Accuracy:
Gain of x8:

Range ±FS	Gain % of rdg	Offset 2 Hz	Offset 10 Hz	Offset 100 Hz
7.8 mV	0.01%	4.6 μV	3.6 μV	3.2 μV
31.3mV	0.01%	4.7 μV	3.8 μV	3.3 μV
125 mV	0.01%	6.0 μV	5.3 μV	5.0 μV
0.50 V	0.01%	16 μV	16 μV	16 μV
2.0 V	0.01%	61 μV	61 μV	61 μV

Range ±FS	Filt Off	Noise 3σ	Noise* 3σ
3.9 mV	3.6 μV	5.3 μV	4.5 μV
15 mV	5 μV	6.9 μV**	5.9 μV**
62 mV	14 μV	14 μV	12 μV

***A/D filter ON (min sample period ≥145 μS: ≤100 Hz scanrate 64 Ch)**
****7.4 μV and 6.3 μV when temp≥ 40 °C**

Temperature coefficients:

Gain: 15ppm/°C after *CAL

Offset: Add tempco error plus fixed offset to above table

Gain of x8:

Temp.	Tempco	2 Hz	10 Hz	100 Hz	Filt Off
(0-30)	.16 μV/° C	0 μV	0 μV	0 μV	0 μV
(30-40)	.18 μV/° C	13 μV	9 μV	1.1 μV	0.2 μV
(40-55)	.39 μV/° C	31 μV	22 μV	6.4 μV	0.8 μV

Accuracy:
Gain of x64:

Range ±FS	Gain % of rdg	Offset 2 Hz	Offset 10 Hz	Offset 100 Hz
3.9 mV	0.01%	2.9 μV	2.3 μV	2.1 μV
15 mV	0.01%	3.0 μV	2.4 μV	2.2 μV
62 mV	0.01%	3.5 μV	3.0 μV	2.9 μV
256 mV	0.01%	8.2 μV	8.0 μV	8.0 μV

Range ±FS	Filt Off	Noise 3σ	Noise* 3σ
3.9 mV	2.1 μV	1.6 μV**	1.3 μV*
15 mV	2.2 μV	2.2 μV***	1.9 μV***
62 mV	2.9 μV	7.0 μV	5.7 μV
256 mV	8.0 μV	28 μV	23 μV

***A/D filter ON (min sample period ≥145 μS: ≤100 Hz scanrate 64 Ch)**
****1.9μV and 1.7 μV for 100 Hz filter**
*****2.5 μV and 1.9 μV when temp ≥ 40 °C**

Temperature coefficients:

Gain: 15ppm/°C after *CAL

Offset: Add tempco error plus fixed offset to above table

Temp.	Tempco	2 Hz	10 Hz	100 Hz	Filt Off
(0-30)	.16 μV/° C	0 μV	0 μV	0 μV	0 μV
(30-40)	.18 μV/° C	1.1 μV	0.2 μV	0.1 μV	0.1 μV
(40-55)	.39 μV/° C	6 μV	1.4 μV	0.6 μV	0.6 μV

Normal mode rejection:

2 Hz lowpass (2 pole)	10 Hz lowpass filter (2 pole)	100 Hz lowpass filter (2 pole)
2 Hz −3 dB	10 Hz −3 dB	100 Hz −3 dB
50 Hz >44 dB	50 Hz >18 dB	400 Hz >15 dB
60 Hz >45 dB	60 Hz >20dB	

Common mode rejection (0 to 60 Hz):

	Typical	Min
X1 gain	108 dB	>100 dB
X8 gain	115 dB	>110 dB
X64 gain	130 dB	>120 dB

HP E1513A Divide by 16 Attenuator SCP

Accuracy:

Range ±FS	Linearity % of rdg	Offset error	Noise 3σ	Noise* 3σ
62.5 mV**	0.02%	100 μV	700 μV	288 μV
256 mV**	0.02%	175 μV	860 μV	430 μV
1.0 (16 V)	0.02%	500 μV	1.8 mV	1.4 mV
4.0 (60 V)	0.02%	1.95 mV	7.0 mV	5.8 mV

***A/D filter ON (min sample period ≥145 μS: ≤100 Hz scanrate 64 Ch)**
**** These ranges are not recommended.**

HP E1514A Isolated Fixed/Filter Amplifier SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset error	Noise mV 3σ	Noise mV*σ
16	0.015	976 μV	2.1	1.7

***Max. scan rate - 100 rdgs/s/channel**

General:

Max. input voltage	Max. common mode voltage	Input Impedance	Max. tare call offset	Measurement range
<±60VDC, 42V pAC	<±60VDC, 42V pAC	1 MΩ ± 2%	3.2213 V	0-±16V FS (DC volts)

Normal mode rejection	Common mode rejection
10 Hz: −6dB	DC @ 60 V: −105dB
60 Hz: > −25dB	DC-1KHz @ 42 Vp: −100dB
	DC-10KHz @ 10 Vp: −80dB
	DC-100KHz @ 2 Vp: −65dB

HP E1515A Isolated Fixed/Filter Amplifier SCP

Accuracy:

Range ±FS	Gain % of rdg	Offset error	Noise mV 3σ	Noise mV*σ
16	0.015	976 μV	2.1	1.7

***Max scan rate — 100 rdgs/s/channel**

General:

Max. input voltage	Max. common mode voltage	Input Impedance	Max. tare call offset	Measurement range
<±60 VDC, 42V pAC	<±60 VDC, 42V pAC	1 MΩ ± 2%	3.2213 V	0-16 V FS (DC volts)

Normal mode rejection	Common mode rejection
10 Hz: −6 dB	DC @ 60 V: −105dB
60 Hz: > −15 dB	DC-1 KHz @ 42 Vp: −100dB
	DC-10 KHz @ 10 Vp: −80dB
	DC-100 KHz @ 2 Vp: −65dB

HP E1516A Isolated Fixed/Filter Amplifier SCP

Accuracy:
Gain x64:

Range ±FS	Gain % of rdg	Offset error	Noise mV 3σ	Noise mV*3σ
0.0625	0.015	3.8 μV	10	8

***Max. scan rate - 100 rdgs/s/channel**

General:
DC volts: 0-±0.0625 V FS
Temperature: −200 to +1700 °C

Max. input voltage	Max. common mode voltage	Input Impedance	Max. tare cal offset
<±60 VDC, 42 V peak AC	<± VDC, 42 V peak AC	1 MOhm ±2%	0.0122 V

Normal mode rejection	Common mode rejection
10 Hz: −6 dB 60 Hz: >−25 dB	DC @ 60 V: −145 dB DC-1 kHz @ 42 Vp: −120 dB DC-10 kHz @ 10 Vp: −120 dB DC-100 kHz @ 2 Vp: −110 dB

HP E1517A Isolated Fixed/Filter Amplifier SCP

Accuracy:
Gain x64:

Range ±FS	Gain % of rdg	Offset error	Noise mV 3σ	Noise mV*3σ
0.0625	0.015	3.8 μV	1.5	10

***Max. scan rate - 100 rdgs/s/channel**

General:
Measurement range:
DC volts: 0−±0.0625 V FS
Temperature: −200 to +1700 °C

Max. input voltage	Max. common mode voltage	Input Impedance	Max. tare call offset
<±60 VDC, 42 V peak AC	<±60 VDC, 42 V peak AC	1 MΩ±2%	0.0122 V

Normal mode rejection	Common mode rejection
100 Hz: −6 dB 200 Hz: >−15 dB	DC @ 60 V: −145 dB DC -1 KHz @ 42 Vp: −105 dB DC -10 KHz @ 10 Vp: −105 dB DC -100 KHz @ 2 Vp: −105 dB

Temperature Measurements

Any of the input SCPs can be used to make temperature measurements with thermocouples, thermistors, or RTDs, but the HP E1503A/E1508A/E1509A provide higher accuracy with thermocouples. One internal current source is supplied to bias the thermistor located on the terminal block and is used to establish the temperature reference. Jumpers are supplied for connecting the current source to external thermistors or RTDs. Please note, the reference thermistor cannot be read through the HP E1509A SCP. Thermistors and RTD's require an input SCP and a Current Source SCP for excitation. Engineering units conversion to degrees C are made on-card at full speed.

Temperature accuracy:

Call specifications for the following were measured with the A/D filter off. The thermocouple graphs following this description include the errors due to measuring the voltage output of the thermocouple, and the algorithm errors due to converting the thermocouple voltage to temperature or the Measurement/Conversion Error (MCE). To this error the Reference Junction Measurement error (RJME) must be added due to measuring the reference junction temperature with an RTD or a 5K thermistor. See the following graphs for the RTD or the 5K thermistor to determine this additional error. Also, the Isothermal Reference Gradient errors (IRGE) must be added due to gradients across the isothermal reference. If an external isothermal reference panel is used, consult the manufacturer's specifications. If HP termination blocks are used as the isothermal reference, see the notes below.

$$\text{Total Temperature Error} = [(\text{MCE})^2 + (\text{RJME})^2 + (\text{IRGE})^2]^{1/2}$$

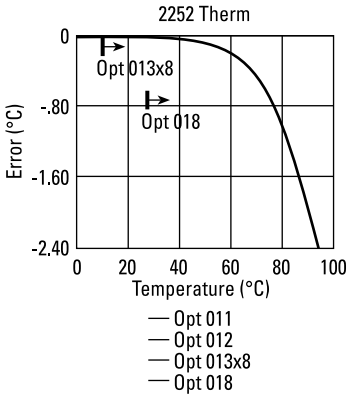
Note:

1) When using the Terminal Module as the isothermal reference, add ±0.6 °C to the thermocouple accuracy specs to account for temperature gradients across the Terminal Module. The ambient temperature of the air surrounding the Terminal Module must be within ±2 °C of the temperature of the inlet cooling air to the VXI mainframe.
2)When using the E1586A Rack Mount Terminal Panel as the isothermal reference, add ±0.2 °C to the thermocouple accuracy specs to account for temperature gradients across the E1586A. The E1586A should be mounted in the bottom part of the rack, below and away from other heat sources for best performance.

The following temperature accuracy graphs include instrument and firmware linearization errors. The linearization algorithm used is based on the IPTS-68 (78) standard transducer curves. Add your transducer accuracy to determine total measurement error.

Conversion Chart

Opt 011 = E1501A
Opt 012 = E1502A
Opt 013 = E1503A
Opt 014 = E1504A
Opt 015 = E1505A
Opt 016 = E1506A
Opt 017 = E1507A
Opt 018 = E1508A
Opt 019 = E1509A
Opt 020 = E1510A
Opt 021 = E1511A



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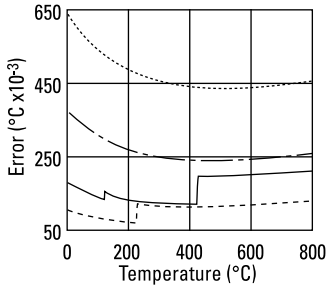
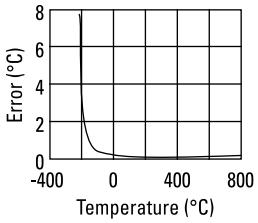


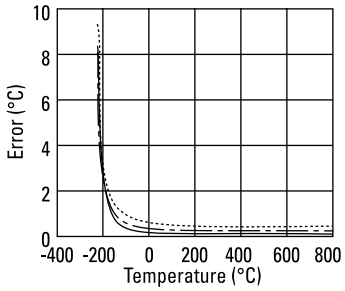
— Opt 011
···· Opt 012
— Opt 013x8
- - Opt 013x64

Type E



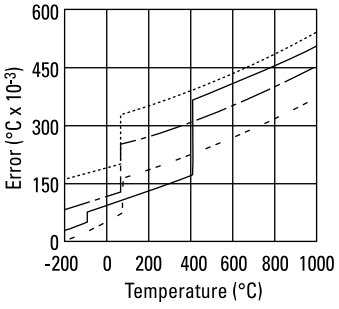
— Opt 018
— Opt 019

Type E



— Opt 011
···· Opt 012
— Opt 013x8
— Opt 013x64

RTD

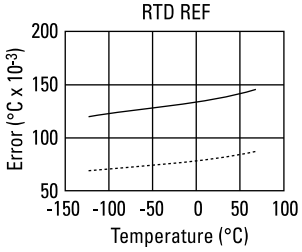


— Opt 011
···· Opt 012
— Opt 013x8
- - Opt 013x64

Conversion Chart

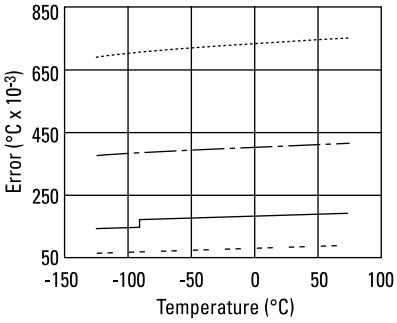
Opt 011	=	E1501A
Opt 012	=	E1502A
Opt 013	=	E1503A
Opt 014	=	E1504A
Opt 015	=	E1505A
Opt 016	=	E1506A
Opt 017	=	E1507A
Opt 018	=	E1508A
Opt 019	=	E1509A
Opt 020	=	E1510A
Opt 021	=	E1511A

RTD REF



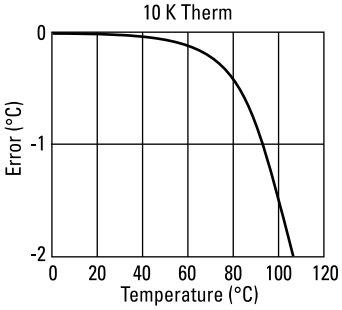
— Opt 018
···· Opt 019

RTD REF



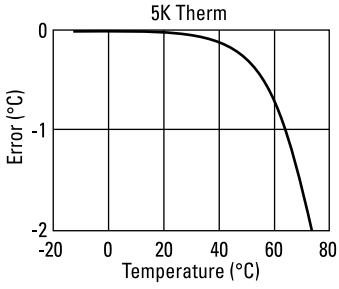
— Opt 011
···· Opt 012
— Opt 013x8
- - Opt 013x64

10 K Therm

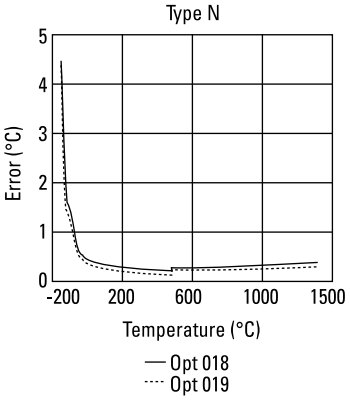


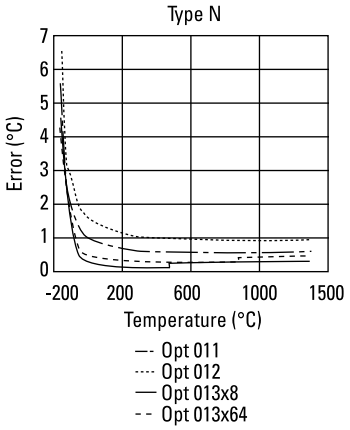
— Opt 011
— Opt 012
— Opt 013x8
— Opt 018

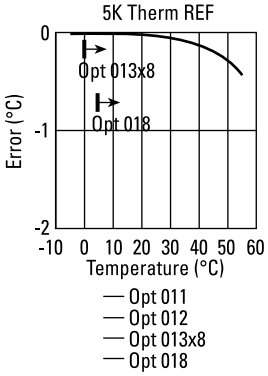
5K Therm

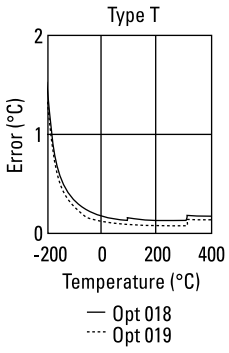


— Opt 011
— Opt 012
— Opt 013x8
— Opt 018



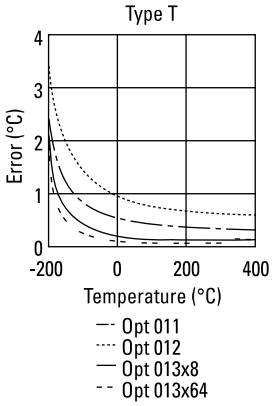


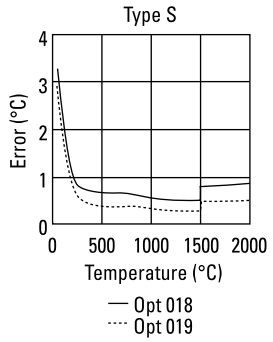


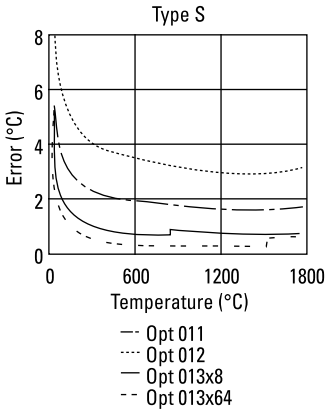


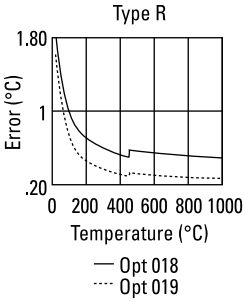
Conversion Chart

Opt 011	=	E1501A
Opt 012	=	E1502A
Opt 013	=	E1503A
Opt 014	=	E1504A
Opt 015	=	E1505A
Opt 016	=	E1506A
Opt 017	=	E1507A
Opt 018	=	E1508A
Opt 019	=	E1509A
Opt 020	=	E1510A
Opt 021	=	E1511A

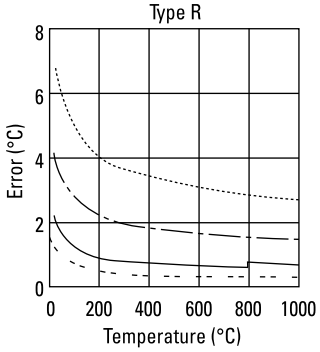






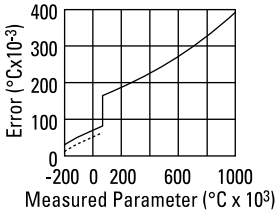


Type R



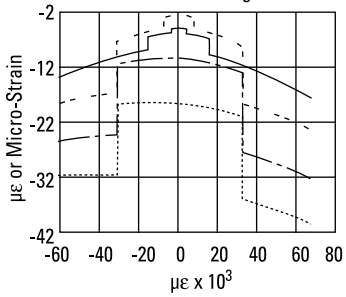
Opt 011
Opt 012
Opt 013x8
Opt 013x64

RTD



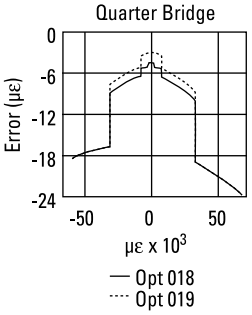
Opt 018
Opt 019

Quarter Bridge



Opt 011
Opt 012
Opt 013x8
Opt 013x64

Quarter Bridge

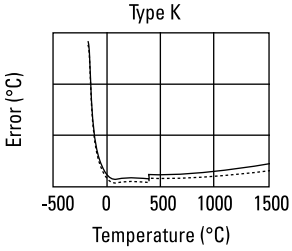


Opt 018
Opt 019

Conversion Chart

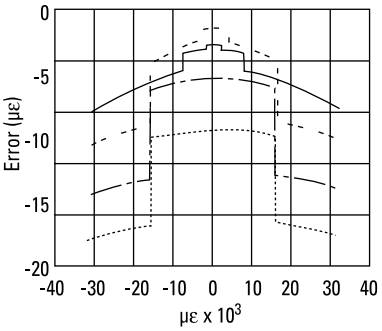
Opt 011	=	E1501A
Opt 012	=	E1502A
Opt 013	=	E1503A
Opt 014	=	E1504A
Opt 015	=	E1505A
Opt 016	=	E1506A
Opt 017	=	E1507A
Opt 018	=	E1508A
Opt 019	=	E1509A
Opt 020	=	E1510A
Opt 021	=	E1511A

Type K



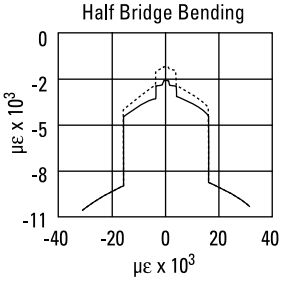
Opt 018
Opt 019

Half Bridge Bending



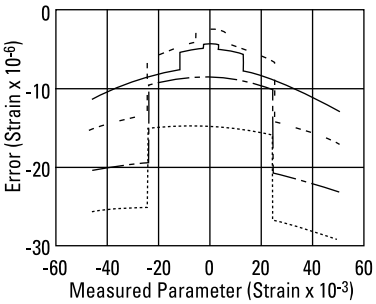
Opt 01
Opt 012
Opt 013x8
Opt 013x64

Half Bridge Bending

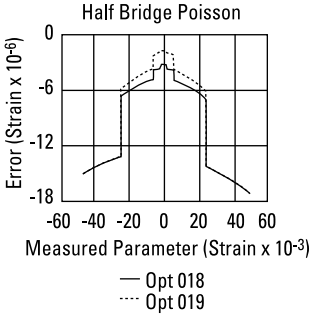


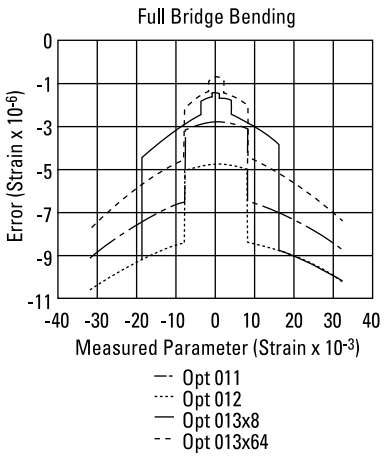
Opt 018
Opt 019

Half Bridge Poisson



Opt 011
Opt 012
Opt 013x8
Opt 013x64





Reference

One of the 64 channels can be used to measure the reference, or the known reference temperature can be downloaded to the HP E1415A.

Thermistors and RTDs: all require an input SCP and the HP E1505A Current Source SCP for excitation.

Engineering units: conversion to degrees C are made on-card at full speed.

Transducer types:

Thermocouples	Thermistors	RTD's
E, E ext, J, K, N, R, S, T (linearized to ITS90 per NIST Monograph 175)	2250, 5 kΩ, 10 KΩ	100 Ω, type 85 and 92

Measurement range: −200 to +1500 °C (depending on transducer type)

Accuracy: 0.003 °C to 3 °C total error (not including transducer error)

Resistance Measurements

Resistance is measured using the HP E1505A Current Source SCP. Measurements are made by applying a DC current to the unknown and measuring the voltage drop across the unknown. The current source is provided through the HP E1505A. The recommended application is using 4-wire connections. Two-wire Ω measurement is possible but not recommended since two 150 Ω series resistors protecting the input FET multiplexer are included in the measurement. The HP E1505A provides eight independently programmable current sources.

HP E1505A Current Source SCP

Resistance:

MIN current source 30.5 μA ± 9 nA

MAX current source 488.3 μA ± 60 nA

Range Ωs FS	Current Amplitude (μA)	A/D Range (Vdc)	Max. Resolution (Ω)
131.1 K	30.518	4	4
32.77 K	30.518	1	1
8.192 K	30.518	.25	.25
8.192 K	488.28	4	.25
2.048 K	488.28	1	.0625
512	488.28	.25	.015
128	488.28	.0625	.0039

Gain		Offset (Ω)	Noise (Ω)
Current amplitude	**Resistance accuracy**	**V (offset of input SCP)/Amps (current source value)**	**V (noise of input SCP)/Amps (current source value)**
30.518 μA	.035% of rdg		
488.28 μA	.02% of rdg		

Static Strain Measurements

Note: *SCPs are available for making both static (the HP E1506A and E1507A) and dynamic strain (the HP E1510A and E1511A) measurements.Two SCPs are required to make static strain measurements. The HP E1506A and E1507A provide excitation and completion for 120 and 350 Ω gages, respectively. The second SCP makes the measurement connection, e.g., the HP E1503A, E1508A, and E1509A. The HP E1506A and E1507A provide strain excitation and completion for a total of 8 channels. Excitation can be external or internal. Excitations and completions are configured by jumpers.*

HP E1506A Strain Completion/Excitation SCP

Accuracy:

Gain + offset error: 40 με

Noise error: 27 με (A/D filter off)
20 με (A/D filter off)

HP E1507A Strain Completion/Excitation SCP

Accuracy:

Gain + offset error: 40 με

Noise error: 27 με (A/D filter off)
20 με (A/D filter off)

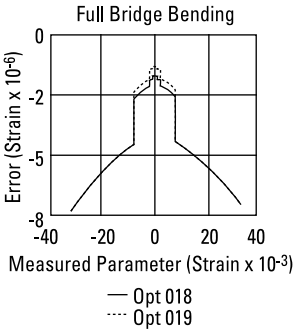
HP E1506A/E1507A

Strain Bridge SCP: internal excitation voltage source: 3.9 V ±512 μV. Externally supplied voltages are supported.

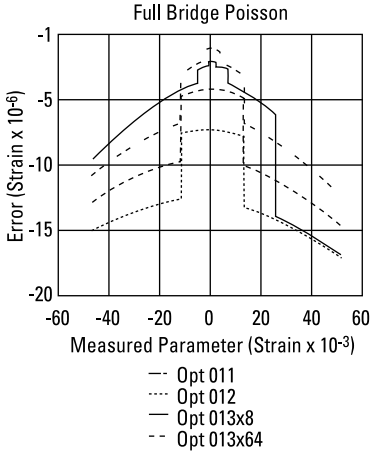
Completion resistors: HP E1506A, 120 Ω ±0.05%. HP E1507A, 350 Ω ±0.05%

Conversion Chart

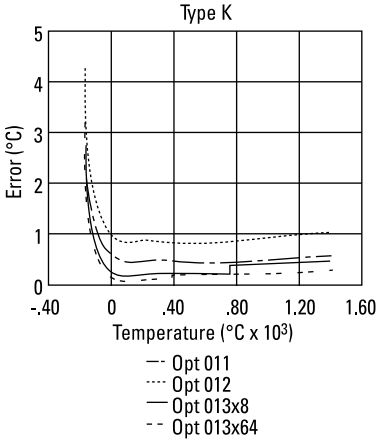
Opt 011 = E1501A
Opt 012 = E1502A
Opt 013 = E1503A
Opt 014 = E1504A
Opt 015 = E1505A
Opt 016 = E1506A
Opt 017 = E1507A
Opt 018 = E1508A
Opt 019 = E1509A
Opt 020 = E1510A
Opt 021 = E1511A



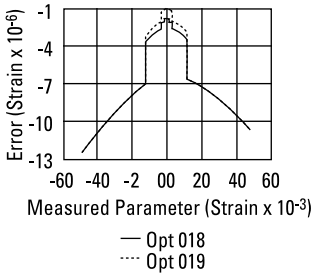
Full Bridge Poisson



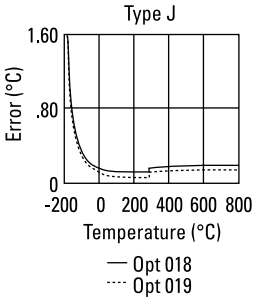
Type K



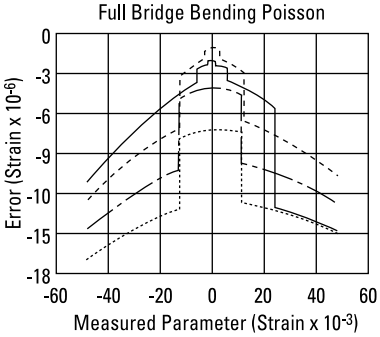
Full Bridge Bending Poisson



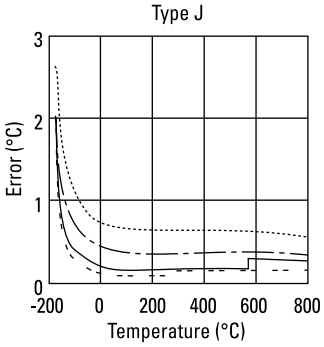
Type J



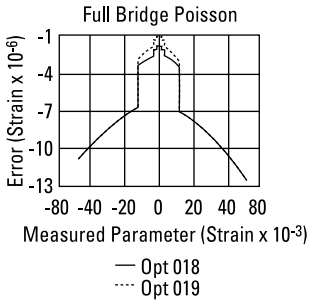
Full Bridge Bending Poisson



Type J



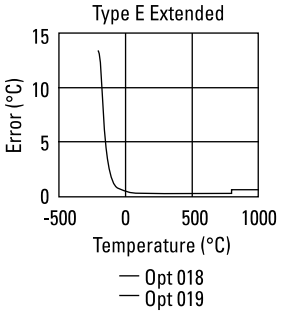
Full Bridge Poisson

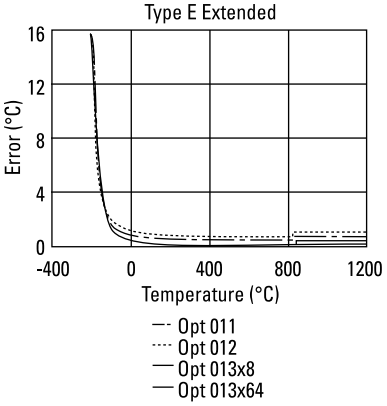


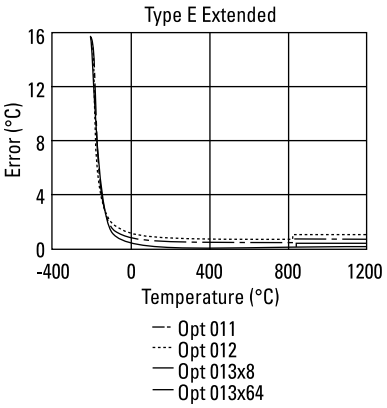
Conversion Chart

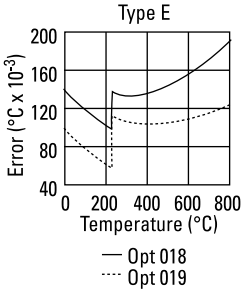
Opt 011	=	E1501A
Opt 012	=	E1502A
Opt 013	=	E1503A
Opt 014	=	E1504A
Opt 015	=	E1505A
Opt 016	=	E1506A
Opt 017	=	E1507A
Opt 018	=	E1508A
Opt 019	=	E1509A
Opt 020	=	E1510A
Opt 021	=	E1511A

Type E Extended









Conversion Chart

Opt 011	=	E1501A
Opt 012	=	E1502A
Opt 013	=	E1503A
Opt 014	=	E1504A
Opt 015	=	E1505A
Opt 016	=	E1506A
Opt 017	=	E1507A
Opt 018	=	E1508A
Opt 019	=	E1509A
Opt 020	=	E1510A
Opt 021	=	E1511A

Transient Measurements

When making higher speed measurements, a vital issue often is the time skew between channels. Ideally, in many applications, the sampled data is needed at essentially the same instant in time. While the intrinsic design of the E1415A provides scanning of 64 channels, with maximum skew of 640 μS between them, far less than most sampled data systems, this still may not be small enough skew for some applications.

Transient Voltage Measurements

The HP E1510A provides basic sample and hold capability on four channels; the other four are standard direct input connections as in the HP E1501A. 6-pole Bessel filters provide alias and alias-based noise reduction while giving excellent transient response without overshoot or ringing. The HP E1510A can be used in strain applications primarily where the bridge is external.

HP E1510A Sample/Hold SCP

Inputs: four simultaneous sample-and-hold channels with programmable gain and Bessel filters and four direct input channels per SCP. Thirty-two (32) channels of each per HP E1415A module

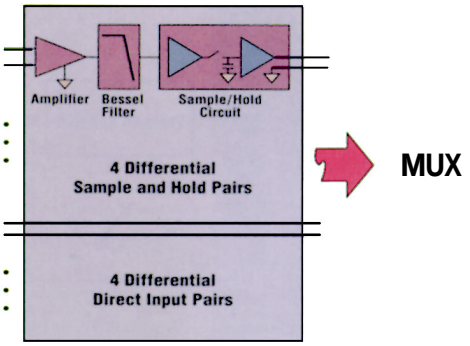
Range: full scale input ranges for each channel are: ±8 V; ±500 mV; ±62.5 mV; and ±7.8 mV

Gain: programmable to 0.5, 8, 16

Filters: 6-pole Bessel filters for alias and alias-based noise rejection, independently programmable 3 dB bandwidths of 1 kHz, 500 Hz, 250 Hz, 100 Hz, or 15 Hz

Usage per HP E1415A module: eight HP E1510A single wide SCPs provide up to 32 channels of signal conditioning for general sample-and-hold or strain measurements using external bridges

Usage with static strain SCPs: the HP E1510A may also be used with the existing HP E1506A and E1507A strain completion SCPs to achieve 20 channels of strain input with excitation and completion in a single HP E1415A module.



HP E1510A Simplified Sample and Hold Block Diagram

Accuracy:

Gain x0.5:

Range ±FS	% Gain error	Offset error	Noise 3σ
125 mV	0.02	488 μV	1.5 mV
0.5 V	0.02	488 μV	1.5 mV
2.0 V	0.02	488 μV	1.5 mV
8.0 V	0.02	488 μV	1.5 mV

Gain of x8:

Range ±FS	% Gain error	Offset error	Noise 3σ
7.8 mV	0.02	30.5 μV	95 μV
31.25 mV	0.02	30.5 μV	95 μV
125 mV	0.02	30.5 μV	95 μV
0.5 V	0.02	30.5 μV	95 μV

Gain of x64:

Range ±FS	% Gain error	Offset error	Noise 3σ
3.9 mV	0.02	15.0 μV	12 μV
15.6 mV	0.02	15.0 μV	12 μV
62.5 mV	0.02	15.0 μV	12 μV

Transient Strain Measurements

The HP E1511A, a double-wide SCP, has all the capabilities of the HP E1510A plus, on-board bridge excitation and completion functions. The four direct input channels are used for monitoring the bridge excitation. A maximum of four SCP's (16 channels) can be installed on an HP E1415A.

Note: *For field wiring the use of shielded twisted pair wiring is highly recommended*

HP E1511A Transient Strain SCP

Bridge completion: jumper selectable 120/350 Ω resistors for ¼ configuration

Programmable excitation: 10 V, 5 V, 2 V, 1 V, and Off

Shunt cal: programmable: 29.4 kΩ

Accuracy:

Gain x0.5

Range ±FS	% Gain error	Offset error	Noise 3σ
125 mV	0.02	488μV	1.5 mV
0.5 mV	0.02	488μV	1.5 mV
2.0 mV	0.02	488μV	1.5 mV
8.0 mV	0.02	488μV	1.5 mV

Temperature coefficients:

Gain: 10 ppm/° C (after *CAL)

Offset: add tempco error to above table

Temp	Tempco
(0-30)	0 μV/° C
(30-55)	.75 μV/° C

Gain of x8:

Range ±FS	% Gain error	Offset error	Noise 3 σ
7.8 mV	0.02	30.5 μV	95 μV
31.25 mV	0.02	30.5 μV	95 μV
125 mV	0.02	30.5 μV	95 μV
0.5 V	0.02	30.5 μV	95 μV

Temperature coefficients:

Gain: 10 ppm/° C (after *CAL)

Offset: add tempco error to above table

Temp	Tempco
(0-30)	0 μV/° C
(30-55)	.75 μV/° C

Gain of x64:

Range ±FS	% Gain error	Offset error	Noise 3 σ
3.9 mV	0.02	15.0 μV	12 μV
15.6 mV	0.02	15.0 μV	12 μV
62.5 mV	0.02	15.0 μV	12 μV

Temperature coefficients:

Gain: 10 ppm/° C (after *CAL)

Offset: add tempco error to above table

Temp	Tempco
(0-40)	.14 μV/° C
(40-55)	.38 μV/° C

Breadboard SCP

The HP E1504A Breadboard SCP provides six square inches of board space for user-supplied custom circuitry. Up to eight FET mux channels can be accessed. Includes +5 V and ±19 V supplies and overvoltage protection.

Analog Output General

Up to eight (8) input channels are available on each SCP. A maximum of four (4) SCP's can be installed on an E1415A due to power limitations.

DC voltage: The HP E1531A voltage output has eight (8) non-isolated channels.

Resolution	Range	Accuracy	Compliance current
16 bits	±16 V full scale	±0.03% (≥ 100 k | lead)	5 mA

DC current: The HP E1532A Current Output SCP has eight (8) non-isolated channels.

Resolution	Range	Accuracy	Compliance voltage
16 bits	± 10 mA full scale (two channels can be connected in parallel to provide ±20 mA)	±0.1%	15 V

Digital Specifications

The HP E1533A Digital I/O SCP has two channels. Each channel provides an 8-bit word which is programmable as input or output.

Digital Input

TTL compatible: 5 V max (non-isolated; use industry standard optisolators for isolation)

Digital Output

TTL compatible: 5 V max or open collector, 48 ma max (non-isolated; use industry standard optisolators for isolation)

Frequency Specifications

The HP E1534A Freq/Totalize/PWM SCP provides eight (8) channels per SCP which can be individually configured as a frequency or totalizer input, or as a pulse width modulated output.

Frequency Input

The HP E1534A Freq/Totalize/PWM SCP provides eight (8) channels per SCP which can be individually configured as a frequency or totalizer input, or as a pulse width modulated output.

Minimum pulse width: 500 ns
Range: 1 Hz to 100 kHz
Input level: Non-isolated TTL compatible
Accuracy: ±0.1% at 0.001s gate time (worst case situation)

Totalize Input

Totalize applications permit counting slow or fast moving events since there is not timeout consideration. The counter can continuously accumulate counts or be reset to 0 at each new scanning cycle.

Minimum pulse width: 500 ns
Range: 24 bit maximum (16,777,216)
Input level: Non-isolated TTL compatible

Frequency Output

Generates user-definable fixed width pulses at variable frequency.

Range: 128 Hz to 40 kHz (64 Hz, if pulse width set at 50% duty cycle)
Output level: TTL, 5 V max
Accuracy: ±0.1%
Resolution: 240 ns

Pulse Width Modulation

Generates variable width pulses at fixed frequency. Typically used for DC motor control.

Range: 128 Hz to 40 kHz
Output level: TTL, 5 V max
Pulse width: 10 μs minimum to one period minus 10 μsec maximum
Accuracy: ±0.1%
Resolution: 240 ns

Other I/O Characteristics

Watchdog timer: The E1535A Watchdog Timer SCP provides four channels of one-shot circuit controlled by software which can be used to open an external relay on various levels of fault.
Holding current: 20 mA maximum

General Characteristics

Module Timing Signals Multiple HP E1415A modules can be synchronized by using the TTL trigger output from one HP E1415A to trigger the others.

VXI Characteristics

VXI device type: A16, slave only, register-based
Size: C
Slots: 1
Connectors: P1/2
Shared memory: n/a
VXI busses: TTL Trigger Bus (T)
C-size compatibility: Yes

Instrument Drivers

Rfer to HP's Website (http://www.hp.com/go/inst__drivers) for driver availability and downloading.

Command module firmware: Downloadable
Command module firmware rev: A.08
I-SCPI Win 3.1: No
I-SCPI Series 700: No
C-SCPI LynxOS: Yes
C-SCPI Series 700: Yes
HP VEE Drivers: No
VXIplug&play *Win Framework:* No
VXIplug&play *Win95/NT Framework:* Yes
VXIplug&play *HP-UX Framework:* No (not available at time of publication)

Module Current

	I_{PM}	I_{DM}
+5 V:	1.0	0.02
+12 V:	0.06	0.01
−12 V:	0.01	0.01
+24 V:	0.1	0.01
−24 V:	0.1	0.01
−5.2 V:	0.15	0.01
−2 V:	0	0

(without SCPs installed)

Cooling/Slot

Watts/slot: 14
ΔP mm H_2O: 0.08
Air Flow liter/s: 0.08

Ordering Information

Product No.	Description
HP E1415A	Algorithmic Closed Loop Controller
HP E1415A A3F	Interface to rack mount terminal panel
HP E1415A W01	3 yr. retn. to HP to 1 yr. OnSite warr.
HP E1501A	Direct Input SCP
HP E1502A	Low Pass Filter SCP
HP E1503A	Gain/filter SCP
HP E1508A	8-channel fixed gain/filter SCP
HP E1509A	8-channel fixed gain/filter SCP (16x)
HP E1510A	4-channel Sample and Hold SCP
HP E1513A	Attenuator Input SCP
HP E1514A	Isolated X1, 10 Hz Low Pass SCP
HP E1515A	Isolated X1, 100 Hz Low Pass SCP
HP E1516A	Isolated X64, 10 Hz Low Pass SCP
HP E1517A	Isolated X64, 100 Hz Low Pass SCP
HP E1531A	8-Channel Voltage Output SCP
HP E1532A	8-Channel Current Output SCP
HP E1533A	16-Bit Digital I/O SCP
HP E1534A	8-Bit Frequency/Totalize/PWM SCP
HP E1535A	Watchdog Timer SCP

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