

The Liberator is a high-performance, high-accuracy analog data acquisition and analysis instrument for the Universal Serial Bus (USB) and Blue Tooth wireless connectivity. It is specifically designed for demanding portable and stationary dynamic signal acquisition applications requiring a high level of functionality and integration in an ultra portable package.

The Liberator features two 24-bit analog input channels, two digital tachometer inputs, a quadrature decoder and +5 V & +12 V sensor power outputs. In addition to its data acquisition capabilities, the Liberator contains an onboard DSP with built-in dynamic signal analysis functions to process tracking filters, order analysis, RMS conversion and peak detection in real-time.

Liberator is both battery powered and USB port powered. The Liberator was design for low power consumption, drawing less than 1.25 W in active mode and 175 mW in standby mode. Its high level of integration combined with its low power consumption makes the Liberator ideal for mobile notebook PC based data acquisition systems and Windows Mobile 5.

The analog input channels are simultaneously sampled at a maximum rate of 102.4 kS/s with 24-bit resolution and multiple triggering modes, including external digital triggering. Each input channel has an independent software-selectable 2.7 mA excitation current for connecting Integrated Circuit Piezoelectric (ICP<sup>®</sup>) accelerometers and microphone preamplifiers. See Appendix A, *Specifications*, for details.

The analog input circuitry uses oversampling delta-sigma modulating analog-to-digital converters (ADCs). Delta-sigma converters are inherently linear, provide built-in brick-wall anti-aliasing filters, and have specifications that exceed other conventional technology for this application with regard to total harmonic distortion (THD), signal-to-noise ratio (SNR), and amplitude flatness. These features help you acquire signals with high accuracy and high fidelity without introducing noise or out-of-band aliases.

## Features

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The Satellite 402 incorporates the following features into a compact, ultra-portable data acquisition device:

- 2 simultaneously sampled analog input channels
- 24-bit  $\Delta\Sigma$  A/D converters with built-in anti-aliasing protection
- 102.4 kS/s max sample rate
- 120 dB dynamic range
- ICP<sup>®</sup> accelerometer power (software-configurable)
- 2 tachometer/frequency counter inputs
- USB interface – Plug-and-Play hot swappable operation
- 100% USB powered – no external source required
- Onboard DSP with built-in functions:
  - Tracking filters/Lock-in Amplifiers
  - RMS converters
  - Quadrature decoder
  - +5 V & +12 V sensor power outputs
- Low power < 1.25 W @ max sample rate
- 16,384 sample/channel onboard FIFO
- Analog triggering with software-selectable level and slope
- Pre-trigger and Post-trigger sampling capture

# Applications

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- Dynamic balancing
- Sound and vibration
- Modal Data Acquisition
- FRF "Bump testing"
- Predictive maintenance
- Coast down
- Real-time Order Tracking
- Shaft orbits
- Sonar
- Motor current analysis
- Gain Phase testing
- Transformer testing
- Audio testing



# Specifications

## Analog Input

### Channel Characteristics

Number of Channels .....	2, simultaneously sampled
Input configuration.....	Single-ended
Resolution .....	24 bits, nominal
Type of ADC .....	Delta-sigma
Oversampling, for sample rate ( $f_s$ ):	
1.024 kS/s $\ominus$ $f_s$ $\ominus$ 51.2 kS/s .....	128 $f_s$
51.2 kS/s < $f_s$ $\ominus$ 102.4 kS/s .....	64 $f_s$
Sample rates ( $f_s$ ).....	1.024 to 102.4 kS/s in 3.255 &S/s increments for $f_s >$ 51.2 kS/s or 6.510 &S/s increments for $f_s \ominus$ 51.2 kS/s
Frequency accuracy .....	$\pm 25$ ppm
Input signal ranges .....	$\pm 10 V_{\text{peak}}$ , $\pm 1 V_{\text{peak}}$
FIFO buffer size .....	16,384 samples per channel
Data transfers.....	USB 1.1, 2.0; 1 MByte/sec throughput, max

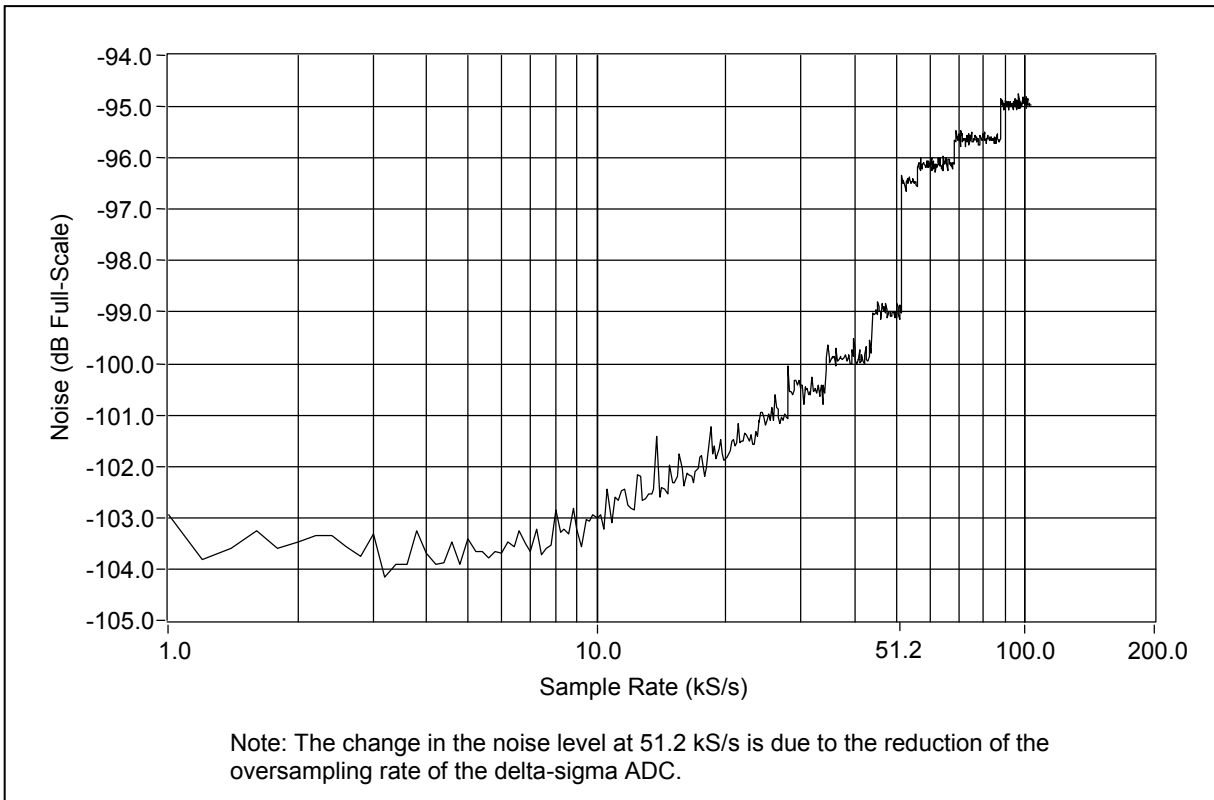
### Transfer Characteristics

Offset (residual DC) .....	$\pm 3$ mV, max
Gain (amplitude accuracy) .....	$\pm 0.02$ dB ( $\pm 0.2$ %), max, $f_{\text{in}} = 1$ kHz
Gain drift (-10 to 70 °C).....	$\pm 50$ ppm/°C

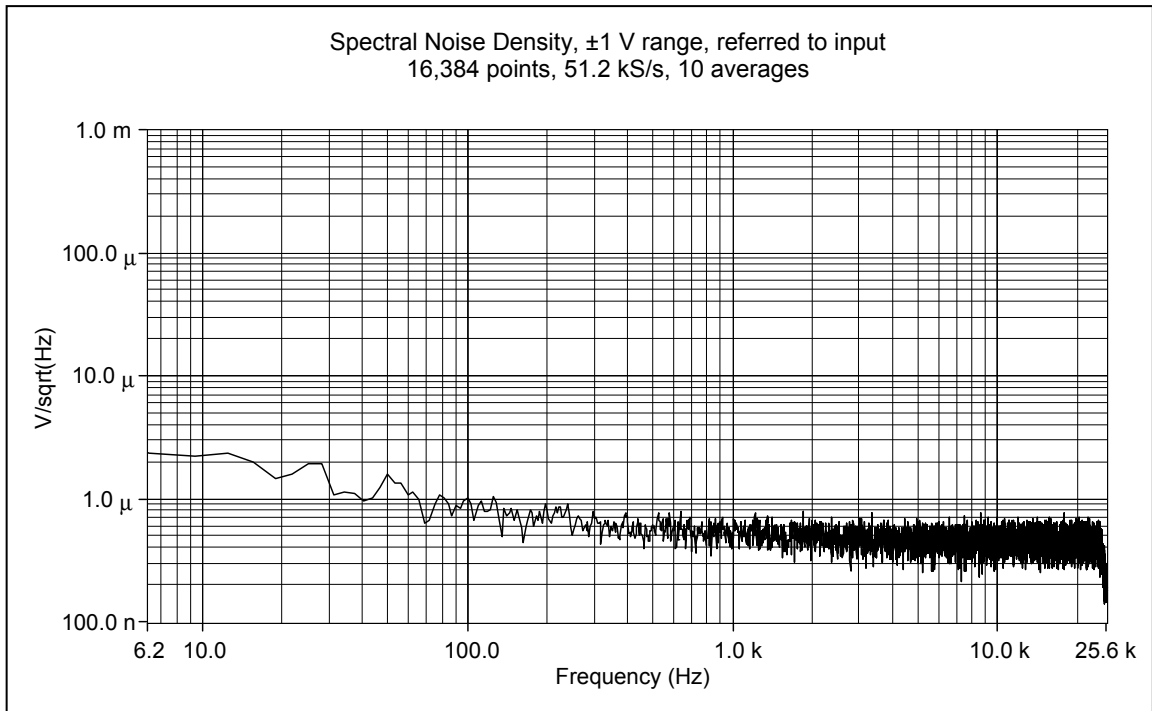
### Amplifier Characteristics

Input impedance (ground referenced)	
Positive input.....	1 M $\Omega$ in parallel with 60 pF
Negative input (shield) .....	1 $\Omega$ in parallel with 0.02 &F
Flatness (relative to 1 kHz) .....	$\pm 0.04$ dB, 3 Hz to 0.4535 $f_s$ , max
-3 dB bandwidth .....	0.4863 $f_s$

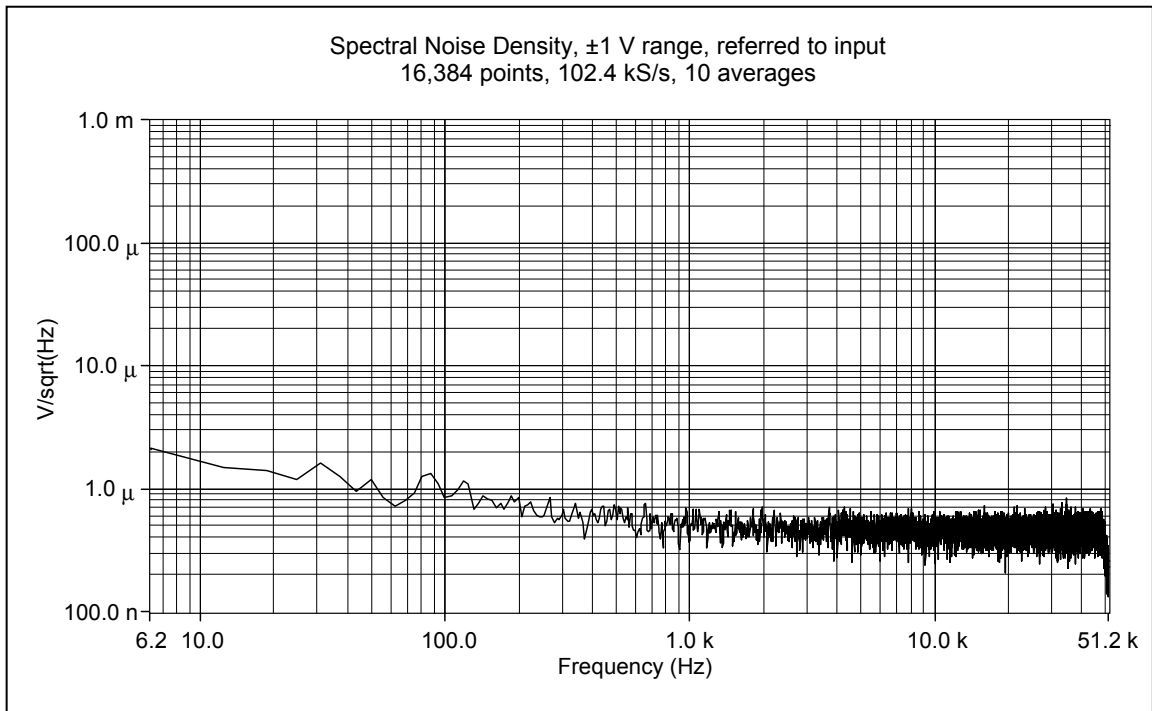
Input coupling .....AC  
AC -3 dB cutoff frequency .....0.16 Hz  
Overvoltage protection  
Positive input ..... $\pm 40$  V  
Positive inputs protected .....CH0, CH1  
Negative input (shield) .....Not protected  
Noise .....Refer to Figures A-1 through A-5



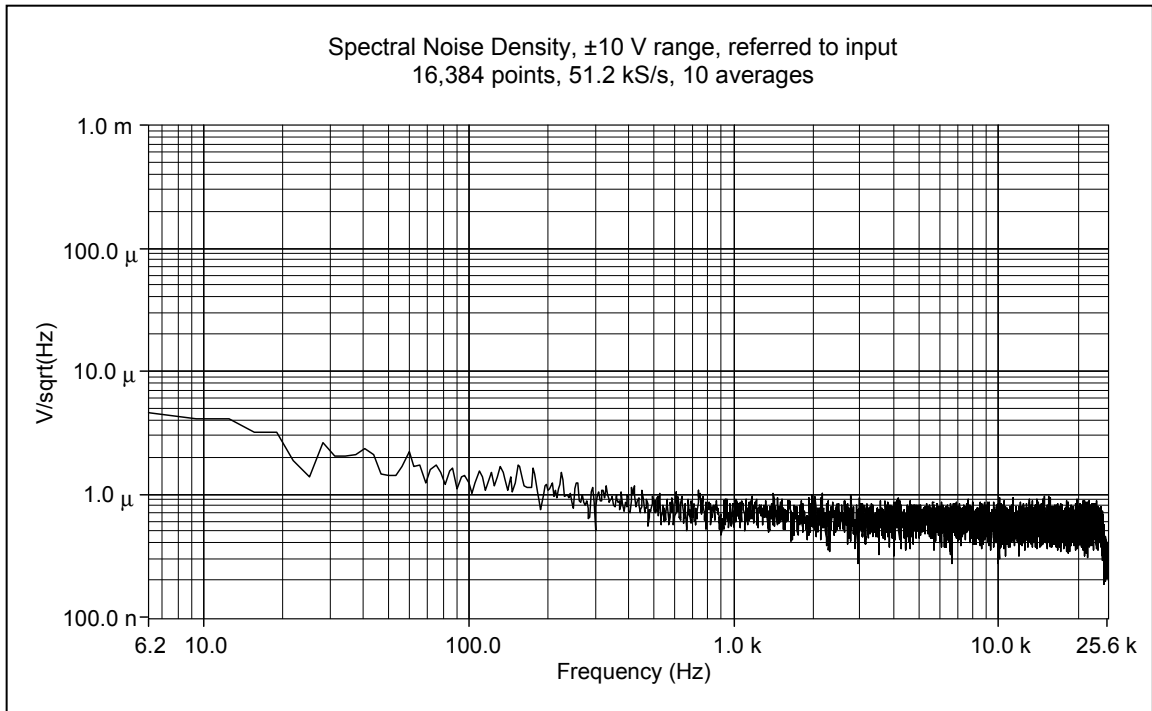
**Figure A - 1. Idle Channel Noise**



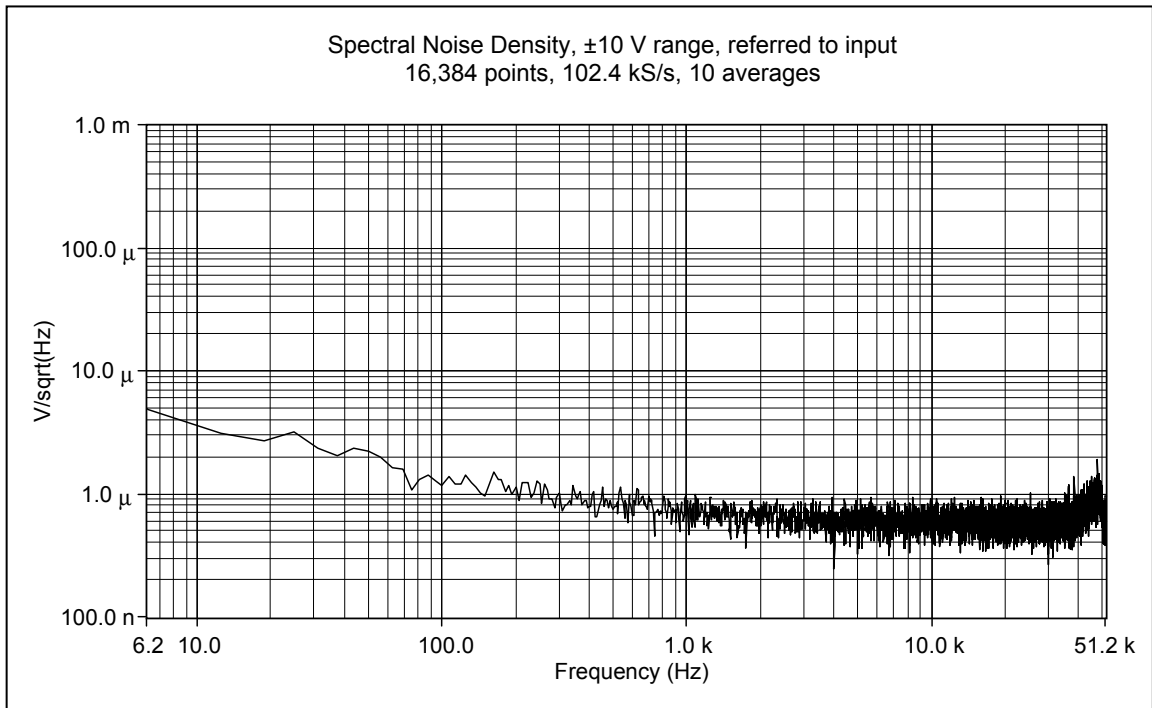
**Figure A - 2.** Input Noise Spectral Density at 128-Times Oversampling,  $\pm 1$  V Range



**Figure A - 3.** Input Noise Spectral Density at 64-Times Oversampling,  $\pm 1$  V Range



**Figure A - 4.** Input Noise Spectral Density at 128-Times Oversampling,  $\pm 10$  V Range



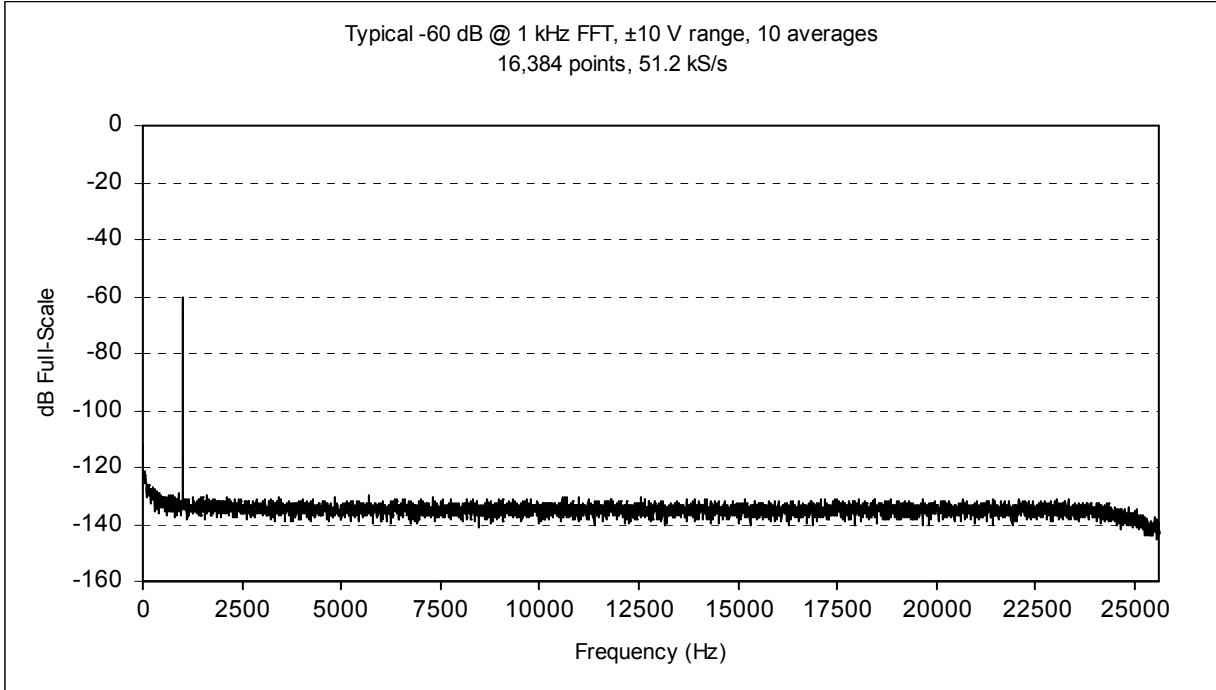
**Figure A - 5.** Input Noise Spectral Density at 64-Times Oversampling,  $\pm 10$  V Range

### Dynamic Characteristics

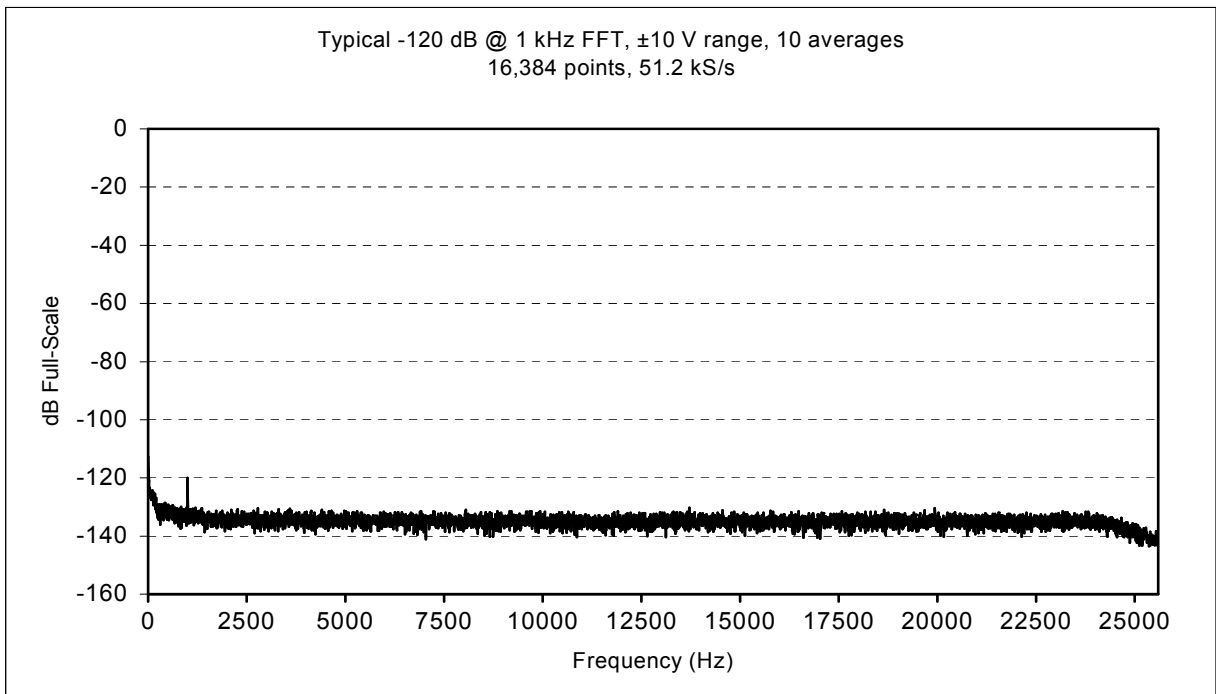
Alias-free bandwidth (passband) .....	0.16 Hz to $0.4535 f_s$
Stop band .....	$0.5465 f_s$
Alias rejection .....	110 dB
Delay through ADC anti-aliasing filter .....	38.8 sample periods
Digital High Pass Filter <sup>1</sup> (software controlled), $f_s = 51.2$ kS/s	
-3 dB stop band .....	$1.07$ Hz, $f_s$ (in kS/s) x $0.02083$ Hz
-0.1 dB stop band .....	$6.93$ Hz, $f_s$ (in kS/s) x $0.1354$ Hz
Spurious-Free Dynamic Range .....	Refer to Figures A-6 through A-9
$1.024$ kS/s $\odot f_s \odot 51.2$ kS/s .....	125 dB
$51.2$ kS/s $< f_s \odot 102.4$ kS/s .....	116 dB
THD, $f_{in} = 1$ kHz	
0 dBFS input .....	$< -90$ dB
20 dBFS input .....	$< -100$ dB
IMD .....	$< -100$ dB
Crosstalk <sup>2</sup> (channel separation), $f_{in} = 0$ to 45 kHz	
Shorted input .....	$< -102$ dB
1 k $\Omega$ load .....	$< -100$ dB
Phase linearity .....	$< \pm 0.4$ deg
Interchannel phase mismatch	
Same input range on both channels .....	$< f_{in}$ (in kHz) x 0.015 deg + 0.03 deg
Different input ranges on both channels ....	$< f_{in}$ (in kHz) x 0.060 deg + 0.06 deg
Interchannel gain mismatch .....	$\pm 0.01$ dB ( $\pm 0.12$ %)

<sup>1</sup> Stop band frequencies scale with sample rate ( $f_s$ ).

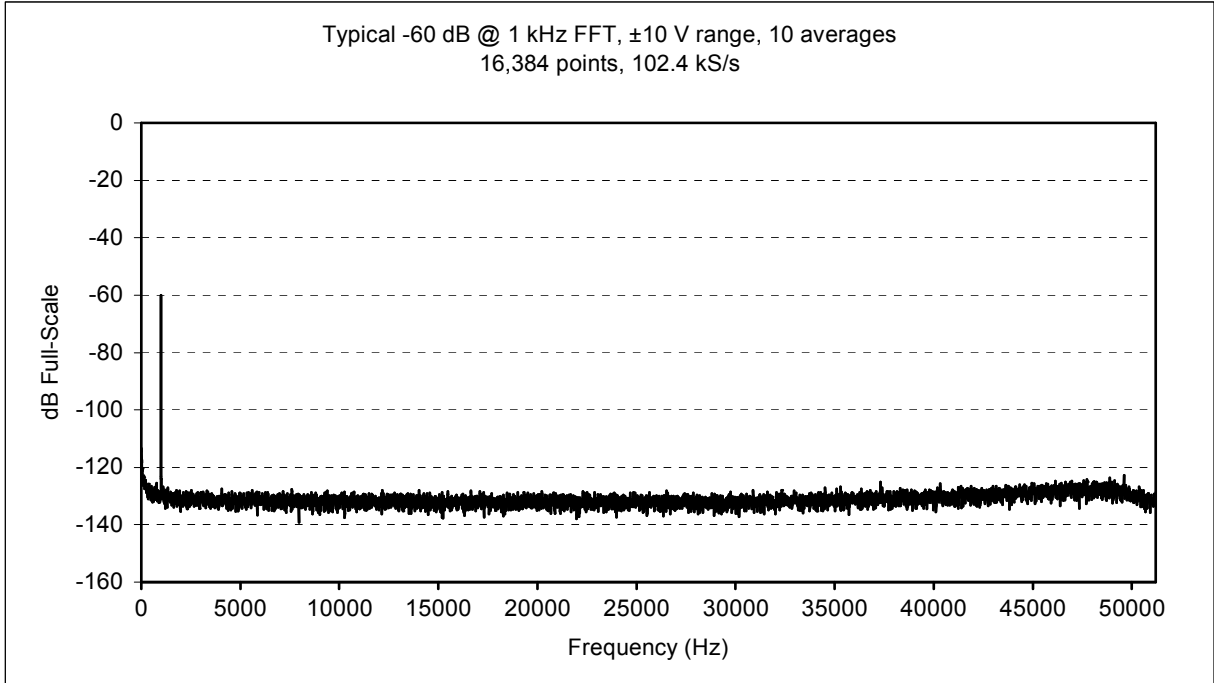
<sup>2</sup> Measured with full-scale ( $\pm 10$  V,  $\pm 1$  V) input



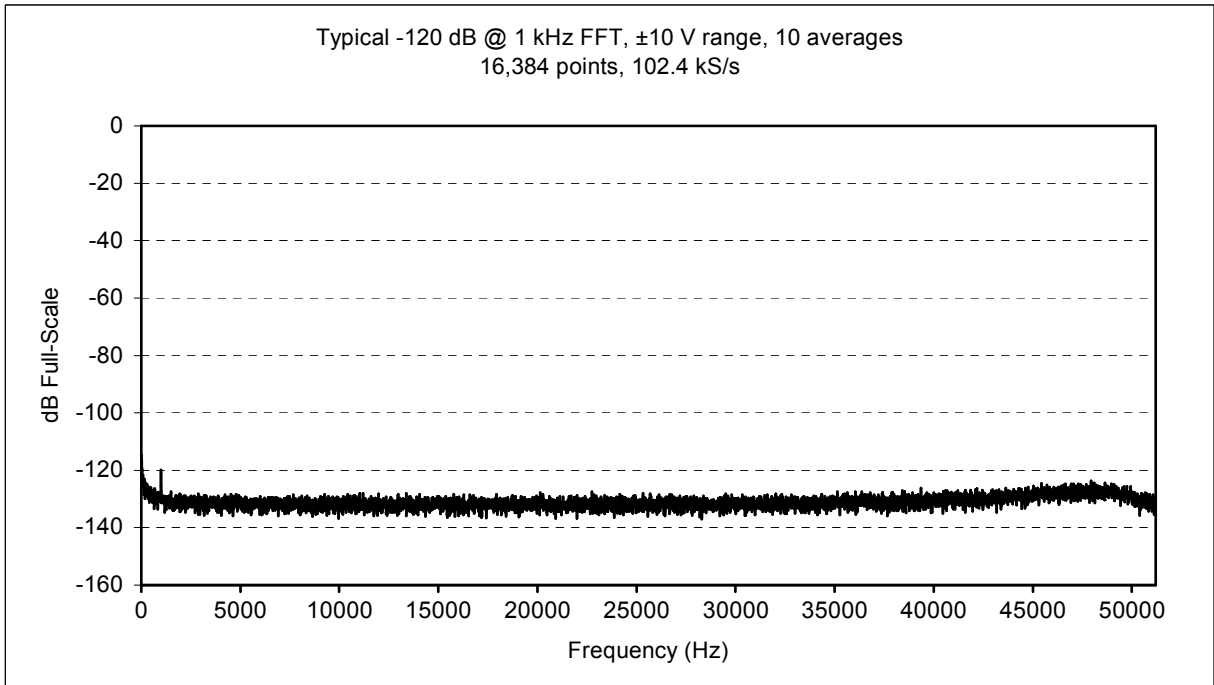
**Figure A - 6.** Spurious-Free Dynamic Range at 51.2 kS/s, -60 dB



**Figure A - 7.** Spurious-Free Dynamic Range at 51.2 kS/s, -120 dB



**Figure A - 8.** Spurious-Free Dynamic Range at 102.4 kS/s, -60 dB



**Figure A - 9.** Spurious-Free Dynamic Range at 102.4 kS/s, -120 dB

## ICP<sup>®</sup> Signal Conditioning

Constant current source (software controlled)

Current .....	2.7 mA, $\pm 10\%$
Compliance .....	24 V, $\pm 5\%$
Output impedance .....	> 250 k $\Omega$ at 1kHz
Current noise .....	< 500 pA/ $\sqrt{\text{Hz}}$

## Triggers

### *Analog Trigger*

Source .....	CH0, CH1
Level .....	-10 to +10 V, programmable
Slope .....	Positive or negative (software selectable)
Resolution .....	24 bits, nominal

### *Digital Trigger*

Source .....	EXT TRIG input
Compatibility .....	3 V / 5 V TTL, CMOS, NPN (4.7 k $\Omega$ pull-up to 3.3V)
High-level input voltage .....	2.4 V minimum
Low-level input voltage .....	0.8 V maximum
Response .....	Rising or falling edge (software selectable)
Pulse width .....	250ns, min

### *Manual Trigger*

Source .....	TRIG button
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### *Timing*

Pre/Post triggering delay .....	up to 16,384 samples before to 8,388,607 ( $2^{23}$ ) samples after trigger (programmable)
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## Digital Input

### Tachometer Input

Source .....	EXT TRIG input
Compatibility .....	3 V / 5 V TTL, CMOS, NPN (4.7 k $\Omega$ pull-up to 3.3V)

High-level input voltage.....	2.4 V minimum
Low-level input voltage.....	0.8 V maximum
Measurement range .....	0.5 Hz to 100 kHz (30 CPM to 6.0 Million CPM)
Response time .....	1 input period
Averaging .....	1 or 8 input periods (software selectable)
Frequency accuracy (averaging = ON)	
0.5 Hz to 20 kHz .....	±0.01 %
20 kHz to 50 kHz .....	±0.02 %
50 kHz to 100 kHz .....	±0.04 %

### Aux Tachometer Input

Source.....	QUAD_A input
Compatibility.....	3 V / 5 V TTL, CMOS, NPN (4.7 kΩ pull-up to 3.3V)
High-level input voltage.....	2.4 V minimum
Low-level input voltage.....	0.8 V maximum
Measurement modes .....	frequency, pulse width
Frequency measurement range.....	2.34 Hz to 100 kHz (140 CPM to 6.0 Million CPM)
Frequency response time.....	1 input period
Frequency accuracy	
2.34 Hz to 4 kHz .....	±0.01 %
4 kHz to 20 kHz .....	±0.05 %
20 kHz to 50 kHz .....	±0.13 %
50 kHz to 100 kHz .....	±0.26 %
Pulse width measurement range .....	10 uSec to 427 mSec
Pulse width measurement resolution .....	25.4 nS

### Encoder Input

Quadrature sources .....	QUAD_A, QUAD_B inputs (quadrature signals)
Index source.....	EXT TRIG input
Compatibility.....	3 V / 5 V TTL, CMOS, NPN (4.7 kΩ pull-up to 3.3V)
High-level input voltage.....	2.4 V minimum

Low-level input voltage.....	0.8 V maximum
Maximum frequency.....	2 x $f_s$ (ADC sample rate)
Maximum count.....	$\pm 8,388,607$ ( $2^{23}$ )

## Sensor Power Output

### +5V Output

Output voltage.....	+5 VDC, $\pm 10\%$
Current.....	100 mA, max
ON/OFF control.....	software selectable

### +12V Output

Output voltage.....	+12 VDC, $\pm 5\%$
Current.....	80 mA, max
ON/OFF control.....	software selectable

## Onboard DSP Measurement Functions

All output values are calculated simultaneously and continuously on both input channels. All DSP routines are factory preprogrammed.

### Tracking Filter/Lock-in Amplifier

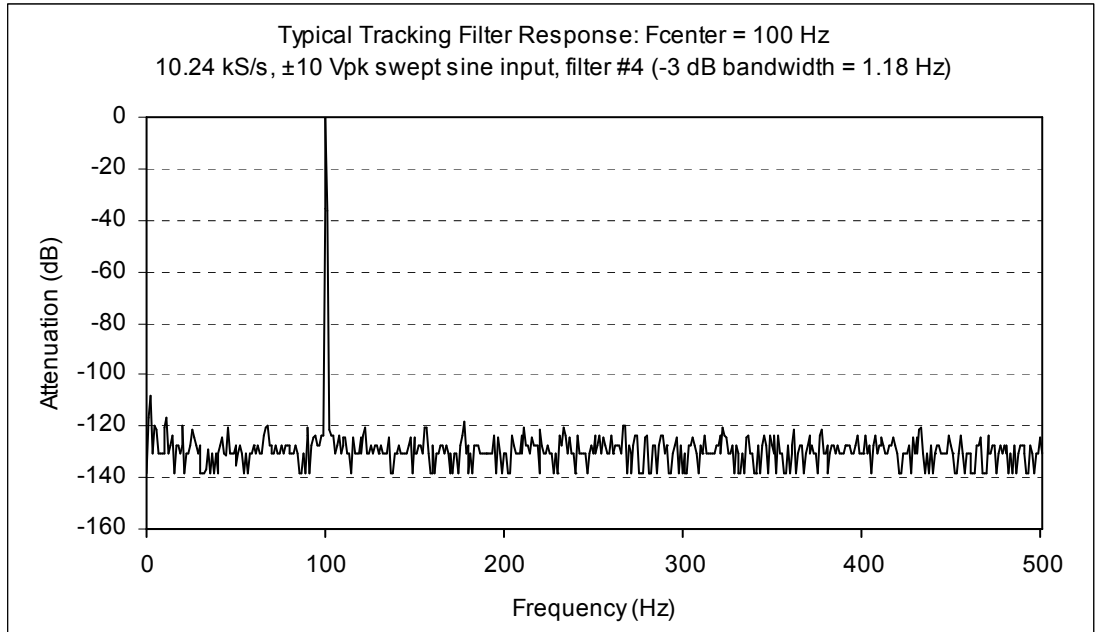
Output.....	Amplitude and Phase ( $V_{\text{peak}}$ and degrees)
Tracking filter bandwidth (-3 dB).....	0.0073 Hz to 189.3 Hz, software selectable
Tracking filter stop band rejection.....	120 dB Refer to Figures A-11 through A-12
Response time to full accuracy.....	80 ms to 2048 s ( $2^{13}$ to $2^{21}$ samples) software selectable, Refer to Figure A-10
Frequency range.....	0.5 Hz to 45 kHz
Tracking source.....	EXT TRIG input, or fixed frequency
Tracking ratio.....	0.001 to 1000.0 (Integer values required for phase)
Averaging.....	2 to 255 point moving average, software selectable
Averaging measurement period	
Continuous mode.....	10 ms to 16,320 s

Cyclic mode.....	2 to 8,388,607 ( $2^{23}$ ) EXT TRIG input periods
Amplitude accuracy (Phase Lock = OFF)	
0.5 Hz – 0.43 x sample rate ( $f_s$ ) .....	$\pm 0.2$ % reading
Amplitude accuracy (Phase Lock = ON) <sup>2</sup> .....Refer to Figure A-13	
0.5 Hz – 2 kHz .....	$\pm 0.2$ % reading
2 kHz – 3 kHz.....	$\pm 0.5$ % reading
Phase accuracy (EXT TRIG referenced) <sup>2</sup> .....Refer to Figures A-14 through A-16	
0.5 Hz – 5 Hz .....	$< \pm 0.3$ deg
5 Hz – 2 kHz.....	$< \pm 0.1$ deg
2 kHz – 8 kHz.....	$< \pm 0.3$ deg
Inter-channel phase mismatch (CH0 range = CH1 range) <sup>2</sup>	
5 Hz – 10 Hz .....	$< \pm 0.06$ deg
10 Hz – 1 kHz.....	$< \pm 0.01$ deg
1 kHz – 5 kHz.....	$< \pm 0.04$ deg
5 kHz – 8 kHz.....	$< \pm 0.06$ deg
Inter-channel phase mismatch (CH0 range different from CH1 range) <sub>2</sub>	
5 Hz – 10 Hz .....	$< \pm 0.06$ deg
10 Hz – 200 Hz .....	$< \pm 0.01$ deg
200 Hz – 1 kHz .....	$< \pm 0.1$ deg
1 kHz – 8 kHz.....	$< \pm 0.8$ deg

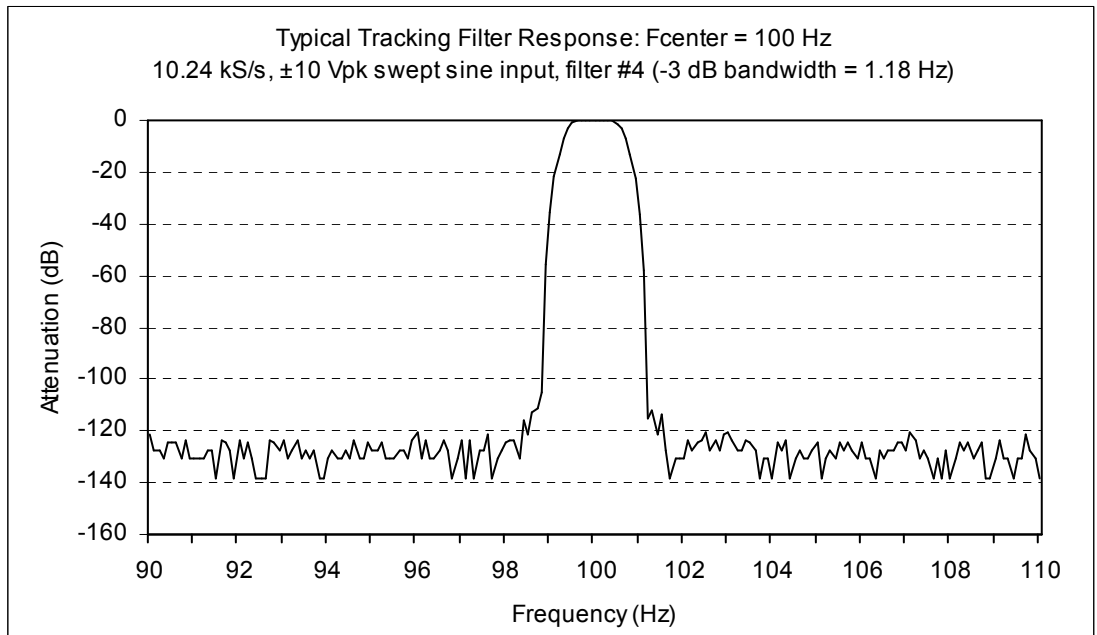
<sup>2</sup> Sample rate ( $f_s$ ) = 51.2 kS/s,

Filter #	Tracking Filter Bandwidth (-3dB Hz)	RMS Converter Lowpass (-3 dB Hz)	Settling Time (samples)
0	$7.158 \times 10^{-6} \times \text{scan rate}$	$3.579 \times 10^{-6} \times \text{scan rate}$	$2,097,152 = 2^{21}$
1	$1.438 \times 10^{-5} \times \text{scan rate}$	$7.190 \times 10^{-6} \times \text{scan rate}$	$1,048,576 = 2^{20}$
2	$2.885 \times 10^{-5} \times \text{scan rate}$	$1.443 \times 10^{-5} \times \text{scan rate}$	$524,288 = 2^{19}$
3	$5.778 \times 10^{-5} \times \text{scan rate}$	$2.889 \times 10^{-5} \times \text{scan rate}$	$262,144 = 2^{18}$
4	$1.156 \times 10^{-4} \times \text{scan rate}$	$5.780 \times 10^{-5} \times \text{scan rate}$	$131,072 = 2^{17}$
5	$2.311 \times 10^{-4} \times \text{scan rate}$	$1.156 \times 10^{-4} \times \text{scan rate}$	$65,536 = 2^{16}$
6	$4.622 \times 10^{-4} \times \text{scan rate}$	$2.311 \times 10^{-4} \times \text{scan rate}$	$32,768 = 2^{15}$
7	$9.245 \times 10^{-4} \times \text{scan rate}$	$4.623 \times 10^{-4} \times \text{scan rate}$	$16,384 = 2^{14}$
8	$1.849 \times 10^{-3} \times \text{scan rate}$	$9.245 \times 10^{-4} \times \text{scan rate}$	$8,192 = 2^{13}$

**Figure A - 10.** Tracking filter/RMS converter bandwidths and settling times.



**Figure A - 11.** Tracking Filter Response at 10.24 kS/s,  $F_{center} = 100$  Hz



**Figure A - 12.** Tracking Filter Bandpass Detail at 10.24 kS/s,  $F_{center} = 100$  Hz

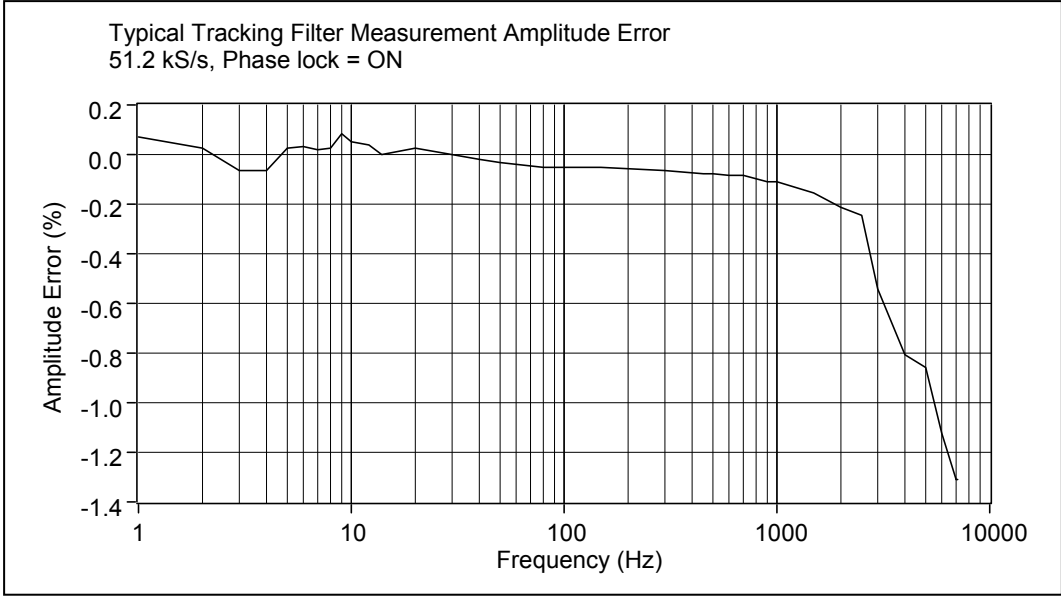


Figure A - 13. Tracking Filter Amplitude Error at 51.2 kS/s, Phase lock = ON

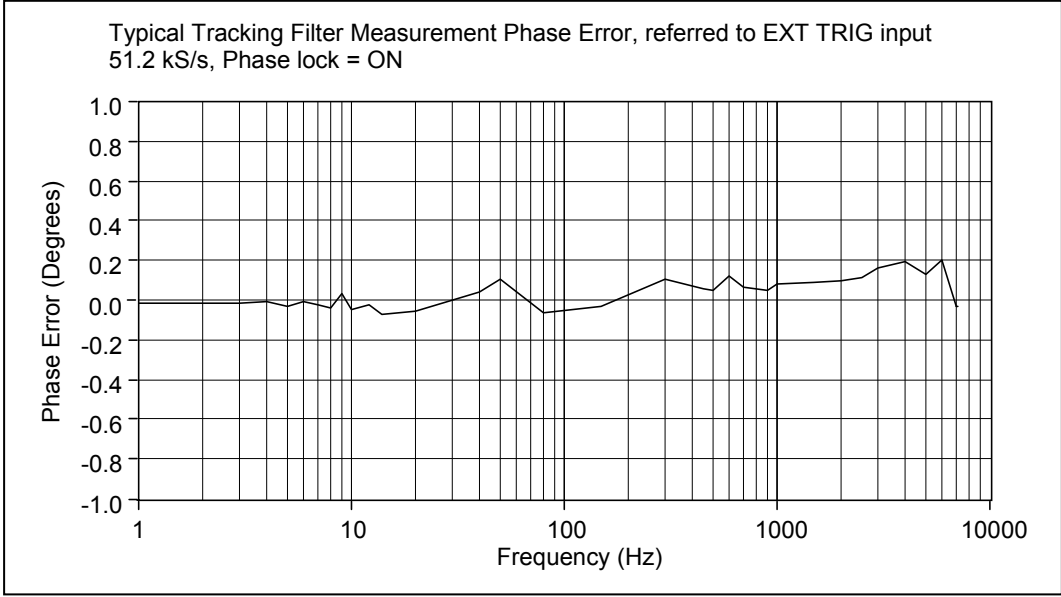
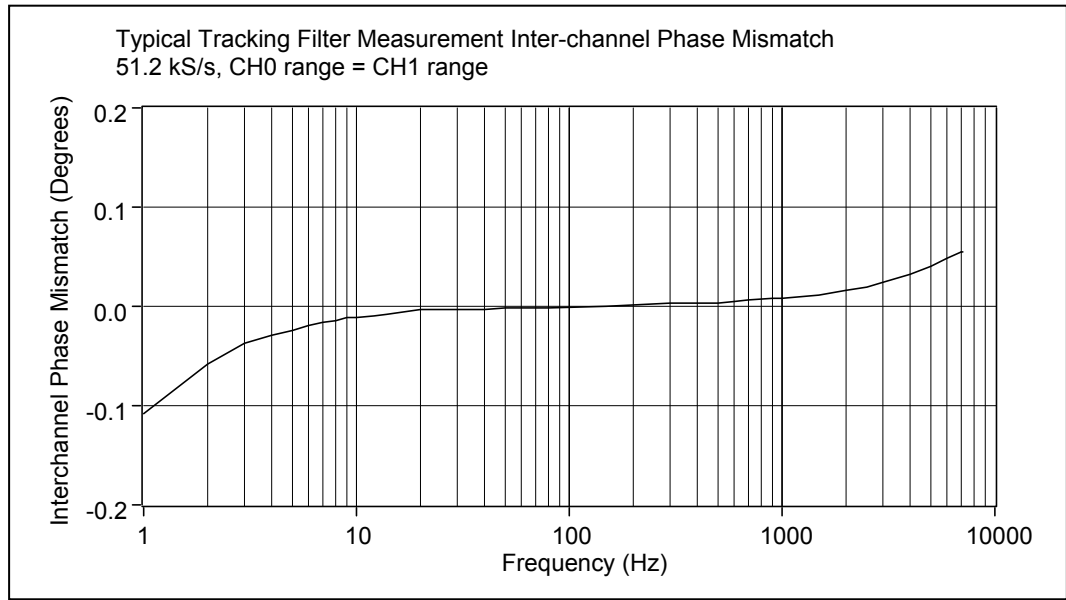
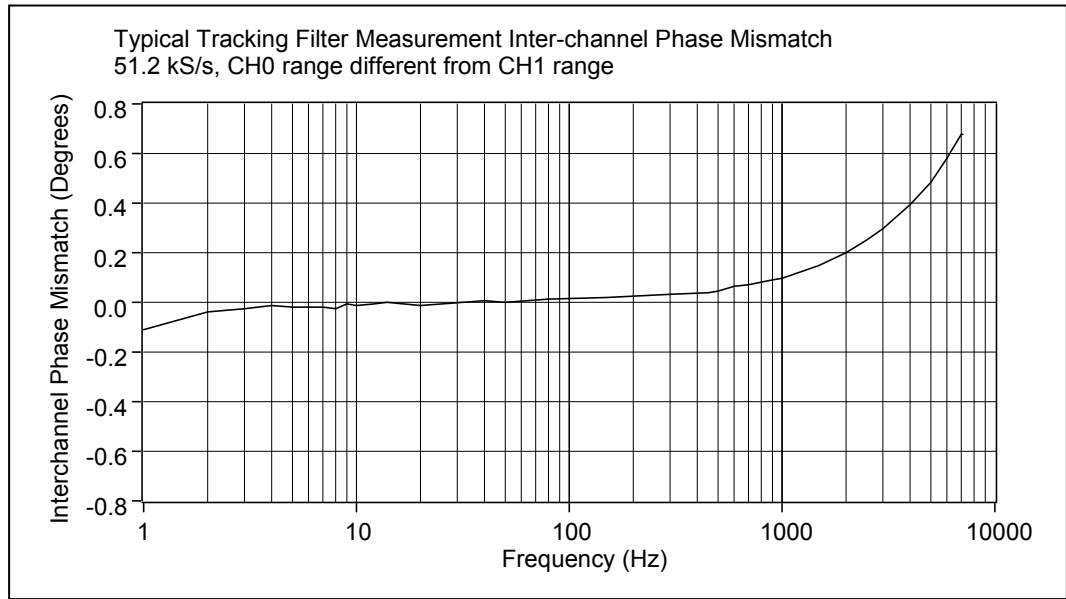


Figure A - 14. Tracking Filter Phase Error at 51.2 kS/s, Phase lock = ON



**Figure A - 15.** Tracking Filter Inter-Channel Phase Mismatch at 51.2 kS/s, CH0 Range = CH1 Range



**Figure A - 16.** Tracking Filter Inter-Channel Phase Mismatch at 51.2 kS/s, CH0 Range different from CH1 Range

## RMS Converter

Output.....	Volts, True RMS
Measurement bandwidth (-3 dB).....	$0.4863 f_s$
Low frequency limit (-3 dB) .....	0.16 Hz to 47.33 Hz, software selectable
Response Time to Full Accuracy .....	80 ms to 2048 s, software selectable
Accuracy (10 Hz to 30 kHz) .....	$\pm 0.2$ % reading
Accuracy (3 Hz to 45 kHz) .....	$\pm 0.5$ % reading

## Peak Hold

Response time .....	$1/f_s$ (1/sample rate)
Measurement .....	$V_{\text{peak}}$ (magnitude absolute value)

## Bus Interface

Type .....	USB 1.1 (USB 2.0 compatible)
Data transfers.....	1 MByte/sec throughput, max
Instrument Driver.....	Plug-n-Play
Operating Systems.....	Windows™ 98SE / Me / NT 4.0 / 2000 / XP

## Power Requirements

All power is supplied via the USB interface +5 V.

Active.....	1.2 watts (240 mA) + sensor power
Standby .....	175 mW (35 mA) + sensor power
Sleep .....	175 mW (35 mA)
USB Suspend.....	1.5 mW (300 $\mu$ A)
Total power limit .....	< 2.5 watts (500 mA), maximum

## Physical

Dimensions (not including connectors).....	7.0 x 2.9 x 11.3 cm (2.75 x 1.13 x 4.45 in.)
Weight .....	200 gm (7.0 oz.)

Enclosure material .....extruded aluminum  
Analog input connectors.....BNC female  
Digital input/sensor power connector .....6-pin mini DIN socket  
(PS/2 cable type)

## Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common mode voltage.

Channel-to-earth ..... 10 V, installation category I  
Channel-to-channel ..... 10 V, installation category I

## Environmental

Operation temperature .....0 to 50 °C  
Storage temperature .....-20 to 70 °C  
Relative humidity ..... 10 to 90%, noncondensing  
Altitude .....2,000 m  
Pollution degree (indoor use only) .....2

## Calibration

All gain and offset correction calibration values are recalled from nonvolatile memory on power-up.

Recalibration Interval .....1 year  
Warm-up time.....15 minutes