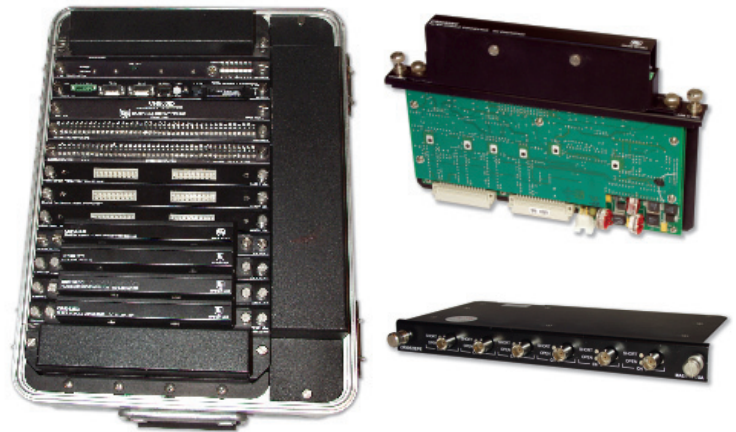


# Anti-Alias Filter & FFT Spectrum Analyzer Modules

## Models CR9052IEPE & CR9052DC

Campbell Scientific's CR9052IEPE and CR9052DC modules provide a high-performance anti-alias filter and a Fast Fourier Transform (FFT) spectrum analyzer that extend the capabilities of the CR9000(X) Measurement and Control System. Use of these CR9052 modules allow the CR9000(X) to perform digitally filtered, alias free simultaneous measurements. Triaxial accelerometers, microphones, and strain gages all benefit from the CR9052's superior noise performance. With the CR9052 in the CR9000(X), the user has a rugged, portable, and accurate dc-powered system that rivals the performance of larger laboratory-based, ac-powered data acquisition systems. Each CR9052 occupies one slot in a CR9000(X) system chassis.

Both the CR9052IEPE and CR9052DC modules have six analog differential channels with programmable input ranges. Each channel has its own programmable-gain instrumentation amplifier, pre-sampling analog filter, and sigma-delta analog-to-digital converter. All of the channels in a single CR9000(X) chassis are sampled simultaneously.

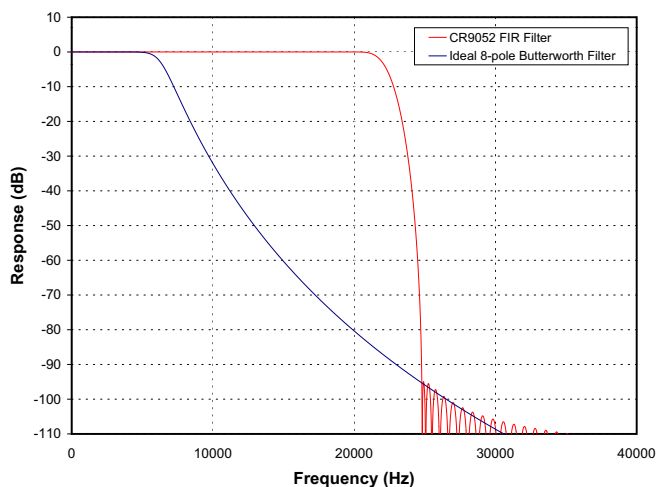


The CR9052DC (top right) and CR9052IEPE (bottom right) provide anti-alias and FFT capabilities to the CR9000X Measurement and Control System—a powerful, yet portable 12 Vdc-powered system (left).

## Anti-aliasing Filter

The CR9052 implements anti-aliasing with programmable, real-time, finite impulse response (FIR) filters. An on-board digital signal processor (DSP) collects alias-free, 50 kHz samples from each of the module's sigma-delta converters, and then applies real-time, programmable low-pass filtering and decimation to anti-alias and down-sample the data to the desired measurement rate. The CR9052 can also accumulate snapshots of anti-aliased time-series, Fourier transform them into frequency spectra, and send the resulting real-time spectra to the CR9000(X)'s main processor.

The CR9052 can burst measurements to its on-board, eight million sample buffer at 50,000 measurements per second for each channel. Using the FFT spectrum analyzer mode, the module's DSP can provide real-time spectra from "seamless," anti-aliased, 50 kHz, 2048-point time-series snapshots for each of its six analog input channels. The decimated data can be downloaded to an appropriate PC card at an aggregate rate of up to 300,000 measurements per second.



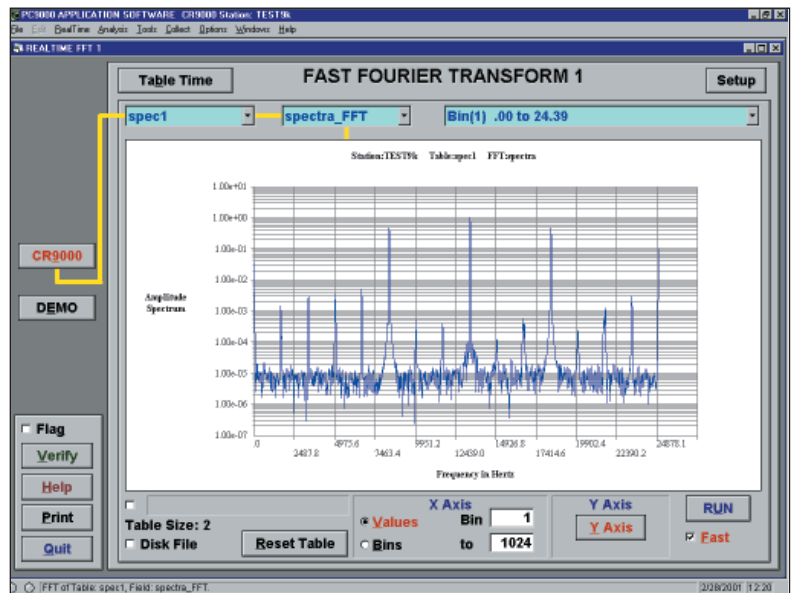
The CR9052 filter's pass-band ripple is less than  $\pm 0.01$  dB (0.1%), and the stop-band attenuation exceeds 90 dB (1/32,000). The FIR filter's transition band has a steep roll-off (graph at left), with the stop-band frequency starting a factor of 1.24 above the pass-band frequency. In comparison, the stop-band frequency of an ideal eight-pole Butterworth filter with the same ripple and attenuation starts a factor of 5.81 above its pass-band frequency. The digital implementation of the CR9052 FIR filters maintains a group delay that is independent of frequency (linear phase response). In addition, the digital filter performance does not change with time, temperature, or component tolerances. The on-board DSP automatically chooses the appropriate low-pass filter to anti-alias the input data for the user's desired measurement rate. If desired, users may load their own coefficients into the on-board DSP to tailor the FIR filter's frequency response to their own needs (band pass, band reject, etc.).



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The FFT option allows radix-two ( $2^n$ , where  $n = 5, 6, \dots, 16$ ) transform lengths ranging from 32 to 65,536 samples. Users can optionally apply a Hanning, Hamming, Blackman-Harris, Kaiser-Bessel window function to their time series before transforming them. The CR9052 offers a variety of spectrum normalizations, including real and imaginary, amplitude and phase, power, power spectral density (PSD), and decibels (dB). In addition, the CR9052 can combine adjacent spectral bins into a single bin to decrease the size of the final spectrum. A built-in function selects an exponentially increasing spectral bin width to give 1/n octave analyses, where  $n$  can vary from 1 to 12. A single programming step with either the CRBasic programming language, or the CR9000(X) program generator configures the FFT spectrum analyzer options. Class A, B, and C spectral weighing options are supported with the CR9052.



*Real-time amplitude spectrum is measured by the CR9052DC, then displayed using PC9000 software. The time-series sample rate is 50 kHz, and the FFT length is 2048 samples.*

The module has superior noise performance, with an input-referred noise of  $8 \text{ nV Hz}^{-1/2}$  for the  $\pm 20 \text{ mV}$  input range. On the  $\pm 20 \text{ mV}$  input range, the total noise for a 20 kHz bandwidth is less than  $1.4 \text{ }\mu\text{V}$ , and for a 1 Hz bandwidth,  $250 \text{ nV}$  (see noise performance in specification table). The programmable anti-alias filter allows users to trade bandwidth for noise, or vice versa. The DSP's floating-point numeric implementation of the FIR anti-alias filters and Fourier transforms preserve this low-noise performance. A 2048-point FFT gives an instantaneous dynamic range exceeding 126 dB (an amplitude ratio of  $2 \times 10^6$ ), and the 65,536-point FFT gives an instantaneous dynamic range exceeding 140 dB (an amplitude ratio of  $1 \times 10^7$ ). Real-time digital temperature compensation ensures gain accuracy ( $\pm 0.03\%$  of reading) and offset accuracy ( $\pm 0.03\%$  of full-scale) throughout the  $-40^\circ$  to  $70^\circ\text{C}$  operating temperature range.

The combined capabilities of the CR9052 and the CR9000(X) offer numerous measurement and data processing possibilities. For example, this combination allows users to mix high-speed, anti-aliased measurements with slower measurements. The general-purpose programmability of the CR9000(X) allows users to process their data before saving it to data tables. For example, users may save measured data only if the amplitude of a specific acoustic frequency exceeds some threshold, or only if an acoustic spectral component correlates to measurements from other sensors.

## **CR9052IEPE and CR9052DC Differences**

The CR9052IEPE and CR9052DC use the same anti-alias motherboard but have different daughterboards that allow measurement of different sensor types. The CR9052IEPE's daughterboard provides current source excitation and ac coupling that allow the direct connection of Internal Electronics Piezoelectric (IEPE) accelerometers and microphones. An external IEPE power supply is not needed because the CR9052IEPE has an on-board 34 V, high efficiency, low noise, charge pump power supply that supplies a 2 mA, 4 mA, or 6 mA constant current excitation. The CR9052IEPE interfaces with sensors via BNC connectors.

The CR9052DC module includes six independent dc excitation channels that are programmable for 10 V, 5 V, or 10 mA. This module measures accelerometers, strain gages, and microphones. Sensor connections use CR9052EC Easy Connectors for the CR9052DC. The Easy Connectors consist of a terminal strip that is easily disconnected from the CR9052. Customers needing to monitor several locations intermittently have found it useful to buy several CR9052ECs and simply move the CR9000(X) and on-board CR9052DC(s) between monitoring locations.

Prior to April 2005, only the CR9052DC was available. Customers with a CR9052DC may send it to Campbell Scientific to convert it to a CR9052IEPE. The conversion consists of adding the IEPE daughterboard and a recalibration. Once converted, the customer can swap back and forth between the DC and IEPE excitation boards.

# Specifications

**Operating temperature range is -40° to +70°C (specifications valid over this range unless otherwise specified). Non-condensing environment required. To maintain specifications, yearly recalibrations are recommended.**

Over-voltage protection on all inputs and outputs:  
+ 50 V, -40 V

Current consumption (at 12 V input): 500 mA + 1.5\*[ $I_{ex}$ ],  
where  $I_{ex}$  is the sum of excitation currents provided by all channels

Current consumption for complete CR9000(X) system:  
must be less than 4 A

## Differential Inputs

Number of channels: 6

Gain accuracy: ±0.03% of reading

Offset accuracy: ±0.03% of full-scale input range

Input resistance: 1 × 10<sup>9</sup> Ω

Input time constant: 1 kΩ × 100 pF = 100 nsec

Input offset current: ≤ 35 nA

Common-mode input range: +15 to -5 V

## Programmable anti-aliasing implemented with finite-impulse-response filters

$f_{SAMPLE}$  = Output sample rate that is programmable from 50 ksamples s<sup>-1</sup> to 5 samples s<sup>-1</sup>

$f_{SAMPLE}/f_{PASS}$  = Sample ratio that is programmable (2.5, 5, 10, or 20)

$f_{PASS}$  = Top of the pass band

$f_{STOP}$  = Bottom of the stop band

$f_{PASS}/f_{STOP}$  = Transition band rolloff

Sample Ratio	$f_{PASS}$	$f_{STOP}$	$f_{PASS}/f_{STOP}$
2.5	$f_{SAMPLE}/2.5$	$f_{SAMPLE}/2.01$	1.24
5	$f_{SAMPLE}/5$	$f_{SAMPLE}/3.37$	1.48
10	$f_{SAMPLE}/10$	$f_{SAMPLE}/5.08$	1.97
20	$f_{SAMPLE}/20$	$f_{SAMPLE}/6.81$	2.94

Linear phase response: group delay is independent of frequency

Pass band ripple: ≤0.01 dB

Stop band attenuation: ≥90 dB

Group delay: 36/ $f_{SAMPLE}$

Channel-to-channel sampling simultaneity: ≤ 100 nsec

## Measurement rates

Non-burst: 15 ksamples s<sup>-1</sup>, aggregate\*

Bursting to PC FLASH card: 50 ksamples s<sup>-1</sup>, aggregate\*

Bursting to rotating media PC card: 100 ksamples s<sup>-1</sup>, aggregate\*

Bursting to 8 M sample buffer on filter module:  
300 ksamples s<sup>-1</sup>, aggregate per module\*\*

\*The aggregate rate is the sum of the measurement rates on all channels

\*\*The aggregate per module rate is the sum of measurement rates on all channels of a single filter module.

Full-Scale Diff. Range	Noise Performance	Dynamic Range ( $f_{PASS}=10$ Hz)	CMRR♦
±5000 mV	50 μV + 600 nV * sqrt( $f_{PASS}$ )	106 dB	-70 dB
±1000 mV	10 μV + 150 nV * sqrt( $f_{PASS}$ )	106 dB	-70 dB
±200 mV	2 μV + 30 nV * sqrt( $f_{PASS}$ )	106 dB	-83 dB
±50 mV	0.5 μV + 12 nV * sqrt( $f_{PASS}$ )	106 dB	-95 dB
±20 mV	0.25 μV + 8 nV * sqrt( $f_{PASS}$ )	103 dB	-103 dB

♦CMRR = common-mode rejection ratio specified from dc to 500 Hz  
= (common-mode gain)/(differential-mode gain)

## FFT Spectrum Analyzer

Fourier transforms applied to anti-aliased inputs described above

Number of channels: 6

Time series sample rates: programmable from 50 ksamples s<sup>-1</sup> to 5 samples s<sup>-1</sup>

FFT length: programmable from 32 to 65,536 samples

Real-time spectral throughput for six channels: 50 kHz or slower, 2048-point or smaller, seamless snapshots

Real-time spectral throughput for two channels: 50 kHz or slower, 65536-point or smaller, seamless snapshots

Optional time series windows: Hanning, Hamming, Blackman

Spectrum options: Real and imaginary, Amplitude and phase, Amplitude, Amplitude rms, Power, Power spectral density, dB

## Optional spectral binning to reduce final spectrum length

Linear spectral binning:  $2 \leq m \leq (\text{FFT\_length}/2)$ , where programmable  $m$  adjacent bins are combined into a single bin

Logarithmic spectral binning:  $1 \leq n \leq 12$ , where exponentially increasing spectral bin width gives 1/n Octave Analyses

# Specifications (continued)

## CR9052DC Excitations

Number of continuous excitation channels: 6

Programmable  
Excitation

Levels	Compliance	Accuracy
10 V	85 mA	±0.03% of setting (-25° to 50°C) ±0.05% of setting (-40° to 70°C)
5 V	85 mA	±0.03% of setting (-25° to 50°C) ±0.05% of setting (-40° to 70°C)
10 mA	12 V	±0.06% of setting (-25° to 50°C) ±0.08% of setting (-40° to 70°C)

## DC excitation noise summary

Input Range at 25°C (mV)	DC Excitation Noise Floor (nV Hz <sup>-0.5</sup> )
±5000	791
±1000	190

## CR9052IEPE Excitations

Number of continuous excitation channels: 6

Channel indicators: one open circuit indicator and one short circuit indicator per channel. Short circuit indicator also indicates when a channel is over-driven or under-driven.

Channel connector type: BNC

Built-in constant current source: each channel's current source is independently software programmable to 0 mA, 1.9 mA, 3.7 mA, or 5.6 mA

Current source compliance range: 0 to 30 Vdc

Signal frequency range: programmable 0.03 Hz to 20 kHz, or 3 Hz to 20 kHz

AC accuracy: ±0.05% over -40° to +70°C

ESD protection: each channel is spark-gap protected

## IEPE conditioning and noise summary

The noise floor is computed from  $1 \times 10^9 \sqrt{\text{PSD}(f)}$ , where PSD(*f*) is the power spectral density function in V<sup>2</sup> Hz<sup>-1</sup>, and 100 Hz ≤ *f* ≤ 20 kHz. The input is shorted through a 4.42 kΩ resistor.

Input Range (mV)	IEPE w/5.6 mA Noise Floor (nV Hz <sup>-0.5</sup> )	IEPE w/3.7 mA Noise Floor (nV Hz <sup>-0.5</sup> )	IEPE w/1.9 mA Noise Floor (nV Hz <sup>-0.5</sup> )
	±5000	1060 at 25°C 1130 at 70°C	980 at 25°C 1060 at 70°C
±1000	600 at 25°C 700 at 70°C	490 at 25°C 580 at 70°C	420 at 25°C 490 at 70°C

If more than four CR9052s are to be used in a single chassis, consult with a Campbell Scientific applications engineer for application-specific requirements. We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.



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815 W. 1800 N. • Logan, Utah 84321-1784 • (435) 753-2342 • FAX (435) 750-9540  
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