Anti-Alias Filter & FFT Spectrum Analyzer with DC Excitation

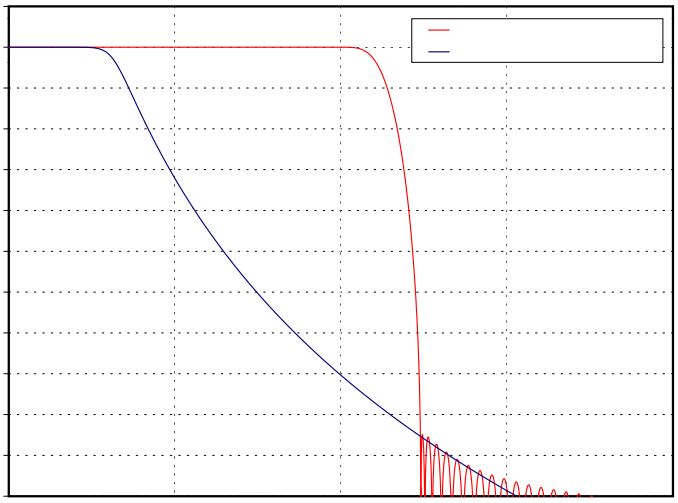
Model CR9052DC

The CR9052DC is a high-performance anti-alias filter and Fast Fourier Transform (FFT) spectrum analyzer that extends the capabilities of the CR9000 Measurement and Control System. Together, the CR9052DC and CR9000 form a rugged, portable, dc-powered system that rivals the performance of larger, laboratory-based, ac-powered data acquisition systems. Each CR9052DC occupies one slot in a CR9000 or CR9000C system chassis. Up to four CR9052s can be used in a system (consult with a Campbell Scientific applications engineer for application-specific requirements).

The CR9052DC's (at right) anti-alias and FFT capabilities add new functionality to the CR9000 Measurement and Control System—a powerful, yet portable 12 Vdc-powered system (left).

Each CR9052 module has six differential analog measurement channels with programmable input ranges from ±20 mV to ±5 V. Each channel has its own programmable-gain instrumentation amplifier, pre-sampling analog filter, and sigma-delta analog-to-digital converter. All CR9052DC channels in a single CR9000 chassis are sampled simultaneously.

The CR9052DC 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, selectable from 5 Hz to 50 kHz. The CR9052DC 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's main processor.



The CR9052DC can burst measurements to its on-board, 8-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 100,000 measurements per second.

The CR9052DC filter's pass-band ripple is less than ±0.01 dB (0.1 percent), 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

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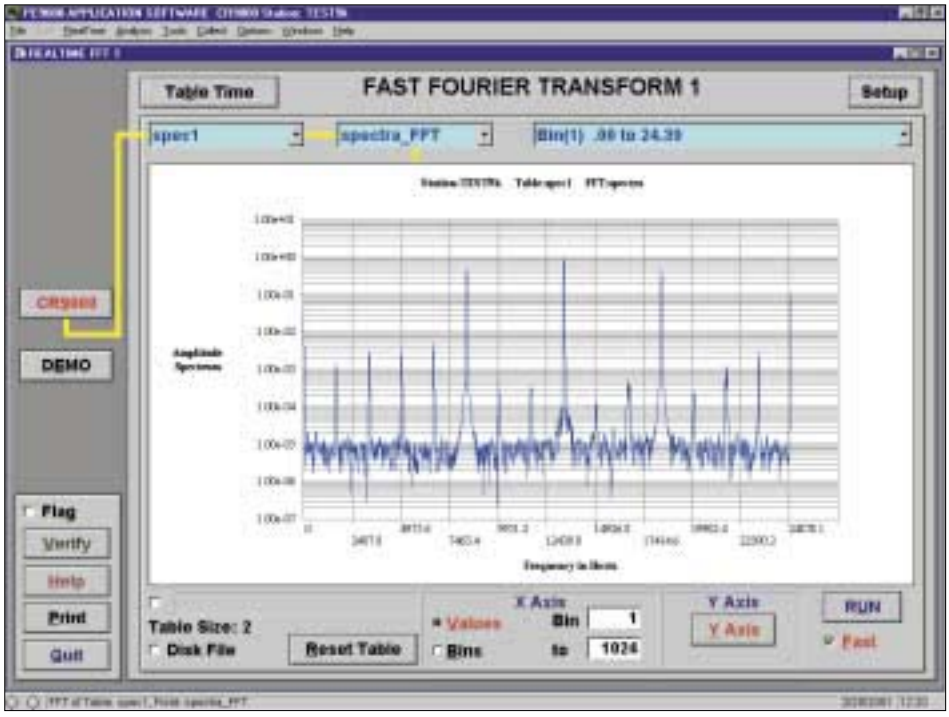
Butterworth filter with the same ripple and attenuation starts a factor of 5.81 above its pass-band frequency. The digital implementation of the CR9052DC FIR filters maintains a group delay that is independent of frequency (linear phase response). In addition, the digital filter performance does not 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.).



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

The FFT option allows radix-two (2^n, where n = 5, 6, ...16) transform lengths ranging from 32 to 65,536 samples. Users can optionally apply a Hanning, Hamming, or Blackman window function to their time series before transforming them. The CR9052DC offers a variety of spectrum normalizations, including real and imaginary, amplitude and phase, power, power spectral density (PSD), and decibels (dB). In addition, the CR9052DC 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 program generator configures the FFT spectrum analyzer options.

The module has superior noise performance, with an input-referred noise of 8 nV $Hz^{-1/2}$ for the ± 20 mV input range. On the ± 20 mV input range, the total noise for a 20 kHz bandwidth is less than 1.4 uV, and for a 1 Hz bandwidth, 250 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 $2x10^6$), and the 65,536-point FFT gives an instantaneous dynamic range exceeding 140 dB (an amplitude ratio of $1x10^7$). Real-time digital temperature compensation ensures gain accuracy (±0.03 percent of reading) and offset accuracy (±0.03 percent of full-scale) throughout the -40° to 70° C operating temperature range.

The module includes six independent dc excitation channels programmable for 10 V, 5 V, or 10 mA. This dc excitation is sourced from a user-replaceable daughter board within the module. Future daughter boards will provide excitation and signal conditioning for piezoelectric accelerometers (ICP® or equivalent).

The combined capabilities of the CR9052DC and the CR9000 offer numerous measurement and data processing possibilities. For example, this combination allows users to mix high-speed, anti-aliased measurements and spectra from accelerometers, strain gages, and microphones with slower measurements from thermocouples, pressure transducers, and serial data streams. The general-purpose programmability of the CR9000 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.

CR9052DC 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.

Inputs

Number of differential input channels: 6

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

Output sample rate	f_{SAMPLE}	programmable: 50 ksamples s^{-1} to 5 samples s^{-1}
Sample ratio	f_{SAMPLE}/f_{PASS}	programmable: 2.5, 5, 10, or 20
Top of the pass band	f_{PASS}	
Bottom of the stop band	f_{STOP}	
Transition band rolloff	f_{PASS}/f_{STOP}	

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

CR9052 measurement rates

Non-burst:	15 ksamples s^{-1}, aggregate*
Bursting to PC FLASH card:	50 ksamples s^{-1}, aggregate*
Bursting to rotating media PC card	100 ksamples s^{-1}, aggregate*
Bursting to 8-Msample buffer on filter module:	300 ksamples s^{-1}, 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*

Analog Input Full-Scale Differential Ranges		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 = common-mode gain / differential-mode gain. CMRR specified from dc to 500 Hz.

Gain accuracy:	± 0.03 percent of reading
Offset accuracy:	± 0.03 percent of full-scale input range
Input resistance:	1 x 10^9 Ω
Input time constant:	1 kΩ x 100 pF = 100 nsec
Input offset current:	≤ 35 nA
Common-mode input range:	+15 to -5 V
Channel-to-channel crosstalk:	≤ -120 dB

CR9052DC Specifications (continued)

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^{-1} to 5 samples s^{-1}
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
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 m (FFT_length/2) where programmable m adjacent bins are combined into a single bin
Logarithmic spectral binning:	1 n 12 where exponentially increasing spectral bin width gives 1/n Octave Analyses

Excitations

Number of continuous excitation channels: 6

Programmable Excitation Levels	Compliance	Accuracy
10 V	85 mA	± 0.03 percent of setting, -25° to 50° C ± 0.05 percent of setting, -40° to 70° C
5 V	85 mA	± 0.03 percent of setting, -25° to 50° C ± 0.05 percent of setting, -40° to 70° C
10 mA	12 V	± 0.06 percent of setting, -25° to 50° C ± 0.08 percent of setting, -40° to 70° C

General

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 system:	must be less than 4 A

Sensor connections use CR9052EC Easy Connectors for 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 and on-board CR9052DC(s) between monitoring locations.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

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