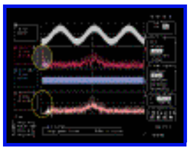
New Digital Filter Package



Example of a high pass filter, used to block power supply hum (60 Hz-frequency component) from a higher frequency signal. The cutoff frequency is set to 1 kHz with a narrow transition region of 1% (very steep). Channel 2 displays the unfiltered signal, while B shows the filtered result. The FFT analysis of the signal before and after the filtration is displayed by traces A and C. Notice the disappearance of the 60 Hz component.

Leading Features

- **Wide variety of digital filters:**

  Low Pass
  High Pass
  Band Pass
  Band Stop
  Raised Cosine Raised Root Cosine
  Gaussian
  User Designed

- **Easy to set and configure:**

  Edge (corner, modulation)
  Frequency
  Transition Region Width

- **Can be coupled with other LeCroy analysis packages:**

  Spectral Analysis
  PowerMeasure
  Disk Drive
  Advanced Optical Recording
  Jitter and Timing Analysis
  JitterPro

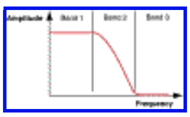
LeCroy's Digital Filter Package (DFP) implements a set of linear-phase Finite Impulse Response (FIR) filters. It enhances your ability to examine important signal components by filtering out undesired spectral components such as noise. With the custom design feature, you can reconstruct corrupted signals by applying matched (mirror) filters to compensate for known distortions.

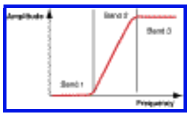
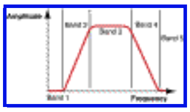
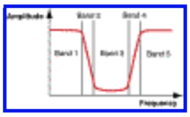
DFP eliminates the need to transfer acquired data to a PC for analysis. It can be used for circuit design: you can view the effects of different filters on your data before implementing the actual filters into your designs. If more complex filters are desired, up to four filters can be cascaded, or new, custom-designed filters can be defined.

The edge (also called corner or modulation) frequency of most filters (specified in Hertz) can be set from a simple menu. The transition region width can be set on the same menu. For Band Pass and Band Stop filters, the width is the same for both transition regions.

Filters are fully programmable over the GPIB, RS-232-C, or LAN connections (when available). Custom filters can be designed and the coefficients loaded into the scope using a spreadsheet and the DSOFilt utility, which can be downloaded from the LeCroy web site at www.lecroy.com.

Filter Types

	**Low Pass** Band 1: Pass Band — signal passes unattenuated, DC to top of the transition region Band 2: Transition Region — edge frequency to edge frequency plus width, increasing attenuation Band 3: Stop Band — above end of transition region, signal is highly attenuated

	**High Pass** Band 1: Stop Band — DC to bottom of the transition region, highly attenuated Band 2: Transition Region — edge frequency minus width to edge frequency, decreasing attenuation Band 3: Pass Band — above edge frequency, signal passes unattenuated
	**Band Pass** Band 1: First Stop Band — DC to bottom of first transition region, highly attenuated Band 2: First Transition Region — lower corner minus width to lower corner, decreasing attenuation. Band 3: Pass Band — signal passes unattenuated Band 4: Second Transition Region — upper corner to upper corner plus width, increasing attenuation Band 5: Second Stop Band — signal highly attenuated
	**Band Stop** Band 1: First Pass Band — DC to bottom of first transition region, signal passes unattenuated Band 2: First Transition Region — lower corner minus width to lower corner, increasing attenuation Band 3: Stop Band — signal is highly attenuated Band 4: Second Transition Region — upper corner to upper corner plus width, decreasing attenuation Band 5: Second Pass Band — signal passes unattenuated

Note: The above filters are optimal FIR filters of less than 1000 taps, according to the Parks-MacLellan algorithm described in "Digital Filter Design and Implementation," by Parks and BUrros, John Wiley & Sons, Inc., 1987.

Communication Channel Filters

Raised Cosine (a low-pass filter)

Band 1: Pass Band -- DC to corner frequency minus half width, signal passes unattenuated
Band 2: Transition Region -- corner minus half width to corner plus half width, attenuation increases in frequency with the rolloff shape of 0.5 * cos (a) + 0.5, where (a) goes from 0 to ź over the transition region. This region is determined by ß, which is specified as a percentage of the Corner Frequency.
Band 3: Stop Band -- above corner frequency plus half width, highly attenuated

The impulse function for the raised cosine filter is:

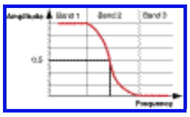
$$h(t) = \frac{\left[\dfrac{\sin\left(\pi \frac{t}{T_s}\right)}{\pi \frac{t}{T_s}}\right] \cos\left(\pi\beta \frac{t}{T_s}\right)}{1-\left(2\beta \frac{t}{T_s}\right)^2}$$

Raised Root Cosine (a low-pass filter)

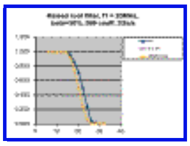
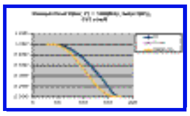
Band 1: Pass Band -- DC to corner frequency minus half width, signal passes unattenuated.
Band 2: Transition Region -- corner minus half width to corner plus half width, attenuation increases with frequency with the rolloff shape of 0.5 * sqrt (cos (a) + 0.5), where (a) goes from 0 to ź over the transition region. This region is determined by ß, which is specified as a percentage of the corner frequency.
Band 3: Stop Band -- above corner frequency plus half width, signal is highly attenuated.

The impulse function for the square-root raised cosine filter is:

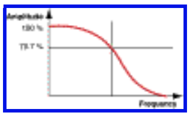
$$h(t) = \frac{4\beta}{\pi\sqrt{T_s}} \frac{\cos\left((1+\beta)\pi \frac{t}{T_s}\right) + \dfrac{\sin\left((1-\beta)\pi \frac{t}{T_s}\right)}{4\beta \frac{t}{T_s}}}{1-\left(4\beta \frac{t}{T_s}\right)^2}$$



Raised Cosine Filter

Two raised root cosine filters with different beta. Applying this filter twice results in a raised cosine response.

	**Gaussian** Band 1: Pass Band — DC to half power bandwidth % * modulation frequency, pass. 3dB down at half power bandwidth. The shape of a Gaussian filter's frequency response is a Gaussian centered at DC. The signal becomes more highly attenuated with increasing frequency. Gaussian filters do not have a Transition Region or Stop Bands. Instead, the width is determined by the product BT, where: B = half power bandwidth expressed as a fraction of the modulation frequency T = bit (or modulation) period

Specifications

- Filters can contain up to 1000 coefficients.
- The number of input data points in memory should exceed that of coefficients by a factor of 10.
- Transition width is limited to 0.3% of the sampling data rate in frequency space.
- Cutoff frequencies for the low pass, high pass, band pass and band stop filters are limited between 0.4% to 49.5% of the sample rate. (It is possible to further reduce the lower limit by using multiple filters and identity -- sparse -- function.)

Applications

The DFP option has a broad range of applications:

System Identification

- Telephone channel identification
- Modem echo cancellation

Prediction

- CDMA interference
- Adaptive CDMA receiver
- Spectral whitening

Noise Cancellation

- ECG noise control
- Background noise

Low-pass filters eliminate the accumulated high-frequency noise and interference, canceling high-frequency background noise.

- Sample applications include datacom, telecom, disk drive, and optical recording analysis, for an accurate RF signal detection.

Band stop filters eliminate a narrow band of frequencies.

- Sample applications include medical equipment such as ECG monitors, where the dominant ripple at 50/60Hz is rejected, leaving the low-energy biological signals intact.
- For digital troubleshooting, the inherent frequency of the switched power supply is blocked, revealing power lines voltage drop and glitches caused by the system clock oscillator.

Band pass filters emphasize a selected frequency band.

- Sample applications include radio channel identification, broadband transmission, ADSL, and clock generators (eliminating the central frequency, displaying harmonics only), and telecom (jitter measurement over a selected frequency range).

High pass filters are useful for eliminating DC and low-frequency components.

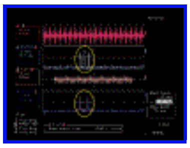
- Some applications include disk drive and optical recording (emulation of the slicing function).

Raised cosine, raised root cosine, and Gaussian filters are low pass filters with unique shapes.

- Raised cosine is one of a class of filters used to minimize intersymbol interference. The time domain impulse response crosses zero at all multiples greater than one of the bit period. Harmonies of the modulation frequencies are therefore canceled.
- Applying raised root cosine twice (or, for example, at the sending and receiving end of a signal) produces the same result as a raised cosine filter.
- Applications include wireless cellular communications such as WCDMA, datacom, telecom, disk drive, and optical drive analysis.

The custom-designed filter feature lets you design filters with virtually any desired characteristics. Typical applications may include areas such as matched (or mirror) filters and modem echo cancellation.

The required custom filter can be designed with a digital filter design or math package such as MATLABŽ or MathcadŽ. Filter coefficients can be downloaded into the oscilloscope with DSOFilt utility. This utility can be downloaded free of charge from LeCroy's web site at www.lecroy.com.



Example of a amplitude modulated high frequency signal (A), a 2MHz carrier modulated with 200KHz . The signal is filtered by a Band Stop Filter, (between 1.95MHz to 2.05MHz with narrow edges - only 25KHz), which removes the 2MHz carrier leaving only the side bands (C). The FFT of the unfiltered signal is shown by B (notice the carrier). The FFT of the filtered signal (D), reveals the absence of the 2MHz carrier.