

# DESIGN NOTES

## Free FilterCAD 3.0 Software Designs Filters Quickly and Easily

Design Note 245

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Analog filters must satisfy multiple design specifications (i.e., gain, phase and time response) and implementation constraints (i.e., component tolerance, IC package and power supply voltage and current limitations). The design of a complex filter network requires substantial mathematical work and experience in an available technology (i.e., integrated circuits or op amps and discrete components). Linear Technology's FilterCAD™ 3.0 (FCAD) automates and simplifies the process of analog filter design and implementation. FCAD is a Microsoft Windows®-based program. FCAD reduces the lengthy process of selecting and designing an optimal filter to a sequence of mouse clicks. Based on a user's input of filter parameters, FCAD designs a filter response and then implements that response as a practical circuit using a Linear Technology active RC or switched-capacitor filter IC. FCAD can realize lowpass, highpass, bandpass and notch filters with a variety of responses, including Butterworth, Bessel, Chebyshev, elliptic and minimum Q elliptic. In addition, with FCAD, a custom filter can be designed to meet an arbitrary set of specifications. FCAD features two distinct paths, Quick Design/Implement for quick answers to filter questions and Enhanced Design/Implement for comprehensive filter design and implementation choices. FilterCAD can be downloaded from [www.linear-tech.com](http://www.linear-tech.com).

### Linear Phase Lowpass Filters

In data acquisition and data communication systems, a lowpass filter with a linear phase response in its passband is often required to process a signal with minimum waveform distortion. In classic filter design, a Bessel approximation produces a linear phase lowpass filter. A lowpass Bessel filter has a very low overshoot response to a pulsed input signal. However, a Bessel filter has very low stopband selectivity. Nonstandard linear phase filters can be designed with higher selectivity than a Bessel filter. The following examples will describe how to use FCAD's Quick Design/Implement to obtain standard Bessel and nonstandard linear phase lowpass filter circuits.

### Example 1: Design a 256kHz Linear Phase Lowpass Filter for a Single 5V Power Supply

The first time FCAD is opened, it defaults to the Quick Design window. Clicking on the "Next" button, FCAD advances through a series of windows with simple questions on filter design specifications. In the first window, select Lowpass; in the next, enter 20dB in the Attenuation box, 256kHz in the Passband ( $f_C$ ) box and twice  $f_C$  (512kHz) in the Stopband ( $f_S$ ) box; in the following two windows, select Linear Phase and 5V Power Supply. One more click on the "Next" button displays a Quick Implement window of Linear Technology filter ICs. The Quick Implement window offers a choice of two linear phase lowpass filters that can provide a 256kHz cutoff while operating with a single 5V power supply: the LTC1569-7 (a self-contained switched capacitor) and the LTC1563-3 (an active RC). Placing the mouse pointer on the device name and clicking causes FCAD to display the filter's gain response. The LTC1563-3 has a standard fourth order Bessel response and the LTC1569-7 has a very selective elliptic response with linearized phase in the passband. Click on the "Next" button to view the device package, then click again to enter a design title; finally, click on the "Done" button to view the filter's schematic, gain and time response to a step input. Selecting the time response window allows for the choice of a filter signal input (step, pulse or sine-burst input). Figure 1 shows the filter schematic and 10 $\mu$ s pulse response of the LTC1563-3 and Figure 2 shows the same for the LTC1569-7. Choosing the optimum filter IC from the list offered by FCAD depends on the filter application. Specific application requirements can favor one device only or allow a choice of either one. The LTC1569-7 has high selectivity and is tunable (changing an external resistor sets the cutoff frequency), whereas the LTC1563-3 has low pulse overshoot and is not tunable (six equal external resistors must change to set the cutoff frequency).

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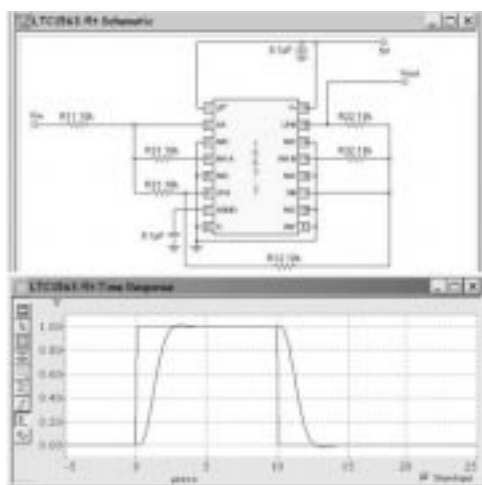


Figure 1. LTC1563-3 Schematic and Pulse Response

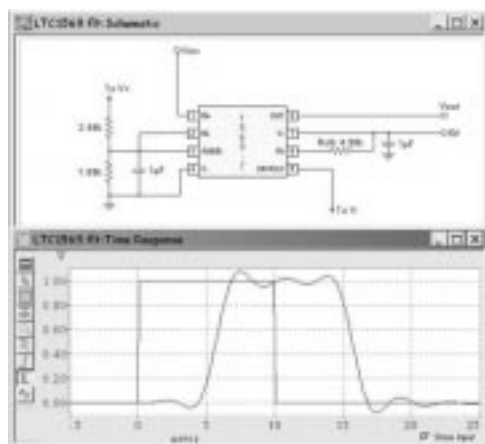


Figure 2. LTC1569-7 Schematic and Pulse Response

Consult the IC's data sheet for additional information (i.e., the LTC1563-3 has a rail-to-rail input and output voltage range and the LTC1569-7 can be tuned with an external clock to a cutoff frequency as low as 100Hz).

Both the LTC1563-3 and the LTC1569-7 are available in a surface mount package with identical dimensions (the LTC1563-3 in a 16-pin narrow SSOP and the LTC1569-7 in a 8-pin narrow SO package).

### Example 2. Design a 10kHz Low Power Linear Phase Lowpass Filter for a Single 3V Power Supply

Following the procedure described in Example 1, sequentially select Lowpass, enter 20dB in the Attenuation box,

#### Data Sheet Download

<http://www.linear-tech.com/go/dnLTC1563-3>  
<http://www.linear-tech.com/go/dnLTC1569-7>  
<http://www.linear-tech.com/go/dnLTC1565-31>

10kHz in the Passband ( $f_C$ ) box and twice  $f_C$  (20kHz) in the Stopband ( $f_S$ ) box, then select Linear Phase, 3V Power Supply and Low Power. Click on "Next" to view FCAD's Quick Implement window of three low power linear phase lowpass filters that can operate with a 3V power supply: The LTC1569-6 and LTC1569-7 (switched capacitor) and the LTC1563-3 (active RC). Of the three ICs, the LTC1563-3 has the lowest power supply current (1mA) for cutoff frequencies ( $f_C$ ) less than 25.6kHz and may be operated to cutoff frequencies as low as 256Hz. The LTC1569-6 has lower power supply current than the LTC1569-7 for cutoff frequencies ( $f_C$ ) less than 20kHz and it can be clock tuned to a frequency as low as 25Hz.

### Example 3: Design a 650kHz Linear Phase Lowpass Filter for a Single 5V Power Supply

Following the procedure described in Example 1, sequentially select Lowpass, enter 20dB in the Attenuation box, 650kHz in the Passband ( $f_C$ ) box and twice  $f_C$  (1300kHz) in the Stopband ( $f_S$ ) box, then select Linear Phase and 5V Power Supply. FCAD's Quick Implement window shows the LTC1565-31 as an active RC filter. The LTC1565-31 has differential inputs and outputs. The "dash 31" of LTC1565 denotes a passband frequency equal to 650kHz. For applications requiring specific cutoff frequencies other than that provided by the LTC1565-31, contact LTC Marketing.

FilterCAD 3.0 can provide a variety of filter design solutions. In the event that the program is unable to offer a filter to a set of specifications, Linear Technology's filter applications staff is available to assist in the design of an optimum filter.

For a tutorial on FilterCAD 3.0, please refer to Linear Technology's archived online seminar at [www.linear-tech.com/seminar](http://www.linear-tech.com/seminar).

The following books are excellent sources in filter design and signal processing:

"Filtering in the Time and Frequency Domains," Herman J. Blinichikoff and Anatol I. Zverev. Robert E. Krieger Publishing Company.

"Filter Design For Signal Processing Using MATLAB and Mathematica." M. D. Lutovac, D. V. Tošić and B. L. Evans. Prentice Hall Inc.

For literature on our Filters,  
 call **1-800-4-LINEAR**. For applications help,  
 call (408) 432-1900, Ext. 2156