DESIGN NOTES

Replace Discrete Lowpass Filters with the LTC1563 Zero Design Effort, Two Item BoM and No Surprises – Design Note 251

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The LTC®1563 family of continuous time, monolithic filter products reduces lowpass filter design to a simple resistor value calculation:

$\quad$ R = 10k • (256kHz/f_C)

where

$\quad$ R = the resistor value in Ohms
$\quad$ f_C = the filter's cutoff frequency in Hertz
$\quad$ (256Hz ≤ f_C ≤ 256kHz)

It's that simple. With the help of any basic calculator (or slide rule), filters are designed in a few seconds.

With the LTC1563, not only is the design process painless, but the end result is an easy-to-build circuit that has been fully specified for its performance as a filter—not just an op amp, a resistor or a capacitor. Additionally, layout sensitivity is minimized and *you only need to specify one passive component—a resistor.*

Lowpass Filters—the Traditional Approach

Filter design is often viewed as a mysterious, intimidating mathematical process. Complex differential equations and elliptic integrals are usually avoided by using filter books with design tables followed by frequency and impedance scaling. Expensive CAD programs can help with much of this effort but these tools are not always available. The final design requires op amps and several resistor and capacitor values.

Once the filter is designed, there are still several component, performance and layout issues to resolve. Which capacitor type is best? How much dynamic range will the circuit have? What are the effects of layout parasitics? All of these questions must be answered to create a finished and robust design.

Lowpass Filters—the LTC1563 Approach

Designing lowpass filters with the LTC1563 is a snap. There are presently two parts in the LTC1563 family—the LTC1563-2 and the LTC1563-3. The LTC1563-2 is configured to give a unity gain, 4th order Butterworth lowpass filter where the cutoff frequency (f_C) is set by a single

resistor value (six resistors are required to form the filter, but they are all the same value). Similarly, the LTC1563-3 gives a unity gain, 4th order Bessel lowpass filter where the cutoff frequency is also set by a single resistor value. The resistor value is calculated by the simple formula above.

Figure 1 shows the schematic for a typical single-supply application using the LTC1563-X. The frequency responses of the LTC1563-2 (Butterworth) and the LTC1563-3 (Bessel) with a cutoff frequency of 100kHz are shown in Figure 2. The step responses are shown in Figure 3. The Butterworth response is often chosen for its flat passband gain (from DC to near the cutoff frequency)

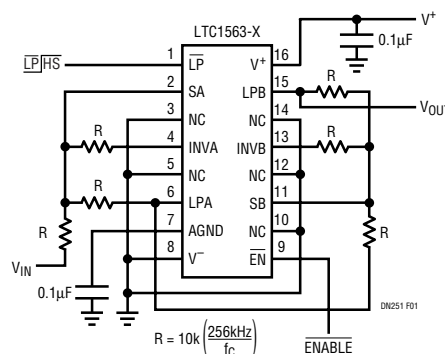*LT*, LTC and LT are registered trademarks of Linear Technology Corporation.

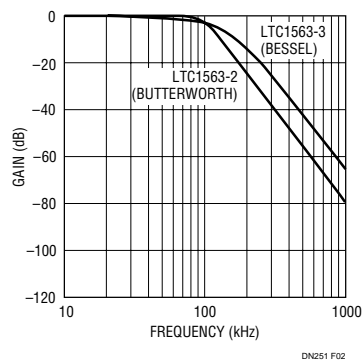**Figure 1. Typical LTC1563-X Single Supply Application**

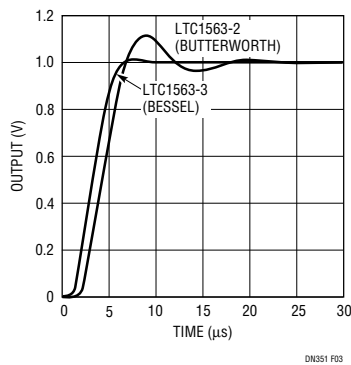**Figure 2. Frequency Response of 100kHz Bessel and Butterworth Filters**

Figure 3. Step Response of 100kHz Bessel and Butterworth Filters

and reasonably sharp corner. The Bessel trades off the corner sharpness for a perfect step response without overshoot and ringing.

Easy Design without Sacrificing Performance

Just because the LTC1563-X design process is easy does not mean that the filter's performance suffers. These parts are fully characterized filter products, ensuring that the filter's noise, distortion and dynamic range performance are all well known. Depending on the signal level and bandwidth, the LTC1563-X delivers a dynamic range of about 90dB, making these parts suitable for use in 16-bit data acquisition systems. Furthermore, the LTC1563-X supports rail-to-rail input and output operation on supply voltages from 2.7V to ±5V. The LTC1563-X also has a typical output DC offset of 1.5mV with an output DC offset drift of 10µV/°C. Lower frequency applications ($f_C \leq$ 25.6kHz) can take advantage of the part's low power mode where supply current is reduced to about 1mA.

The LTC1563-X comes in the narrow 16-lead SSOP package (SO-8 footprint). The part's pinout makes layout easy so that trace parasitics are essentially eliminated. These features, coupled with the LTC1563-X's 2% frequency accuracy, lead to a compact, consistent and robust filter. In the end, you get the filter that you wanted with a known dynamic range and minimal production variation—no surprises.

Also Included, Chebyshev Filters with Gain

Although the configuration of the LTC1563-X leads to the easily designed filters described above, the parts' topology allows for full transfer function freedom by simply using unequal valued resistors.

Data Sheet Download

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The LTC1563-X is composed of two cascaded 2nd order sections to form a 4th order filter (the sections are similar but not identical). A 2nd order section is mathematically defined by three parameters: gain, f_O frequency and Q value. Each section of the LTC1563-X requires three resistors to form the 2nd order section. Every gain, f_O and Q triplet corresponds to a unique 3-resistor solution. With this design flexibility, virtually any all-pole filter is obtainable. The LTC1563-X is also cascadable to form 8th order filters. Additionally, with one extra resistor and a capacitor, odd-order filters can be constructed (for example, a 5th order filter with one part).

Figure 4 shows the schematic for a 0.1dB ripple Chebyshev filter with a cutoff frequency of 150kHz and a passband gain of 10dB. This is just one example of the wide range of filter designs possible with the LTC1563-X. The design of these other transfer functions (not unity gain, 4th order Butterworth or Bessel) is a bit complex. *The best method of getting a good, solid design is to use Linear Technology's FilterCAD™ filter design software (version 3.0 or higher).* FilterCAD runs on the Windows® 95 or higher operating system and is available free of charge from our web site at www.linear-tech.com. A free FilterCAD CD-ROM is also available by calling Linear Technology.
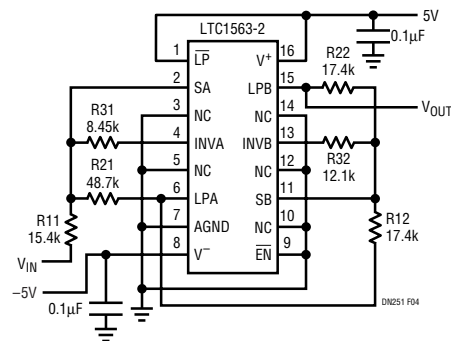

Figure 4. 0.1dB, 150kHz, Chebyshev Lowpass Filter with a DC Gain of 10dB

Conclusion

The LTC1563 family of filter products provides worry-free results with minimal design effort. With its ease of use, consistent results and design flexibility, the LTC1563 may be the only part needed for all of your filter applications.

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