

Function specific amplifier products improve system capabilities

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Operational amplifiers (op amps) have been around a long time – longer, in fact than semiconductor integrated circuits. Even so, IC designers continue to innovate creating smaller, faster, more accurate, and lower power op amps. Perhaps more significantly, op amps are increasingly being used as building blocks in more highly integrated IC products, each targeted at a specific class of applications.

Some of these amplifier based categories are familiar to most electrical engineers. Comparators, instrumentation amplifiers, and difference amplifiers are widely accepted op amp based integrated products which perform valuable functions, and typically perform their task faster, more accurately, and use less board space than the equivalent discrete op amp circuit would require. This article focuses on a set of high speed amplifier product types that enhance new instrumentation, medical, and communications applications. These products have been optimised to provide functional and performance advantages beyond what can be achieved by individual op amp circuits.

Fully differential high speed amplifiers

As signal bandwidths increase, so too does the challenge of amplifying and driving these signals, especially when there is a need to digitise that signal. A high speed pipelined a/d converter presents a complex capacitive load which needs to be driven without adding significant noise or distortion to the signal. Most high speed a/d converters also now have differential inputs to maximise SNR on a limited input voltage range associated with smaller semiconductor process geometries.

Traditionally, high speed open loop RF style amplifiers have been used to drive these a/d converters. But they are typically single ended, power hungry, and require a 5 to 12V power supply. Recently, fully differential amplifiers have been developed, which drive a/d converters at high speed and achieve excellent noise and distortion performance. These amplifiers are often manufactured on advanced complementary bipolar Silicon Germanium (SiGe) processes. Because Germanium atoms are larger than Silicon atoms, selectively adding some Germanium to an otherwise Silicon process causes strains within the material's crystalline structure. This strain actually results in beneficial electrical properties which allow for faster transistors. One such silicon germanium fully differential amplifier is the LTC6404. This amplifier can be used to drive differential signals, or to convert from single ended as shown in figure 1.

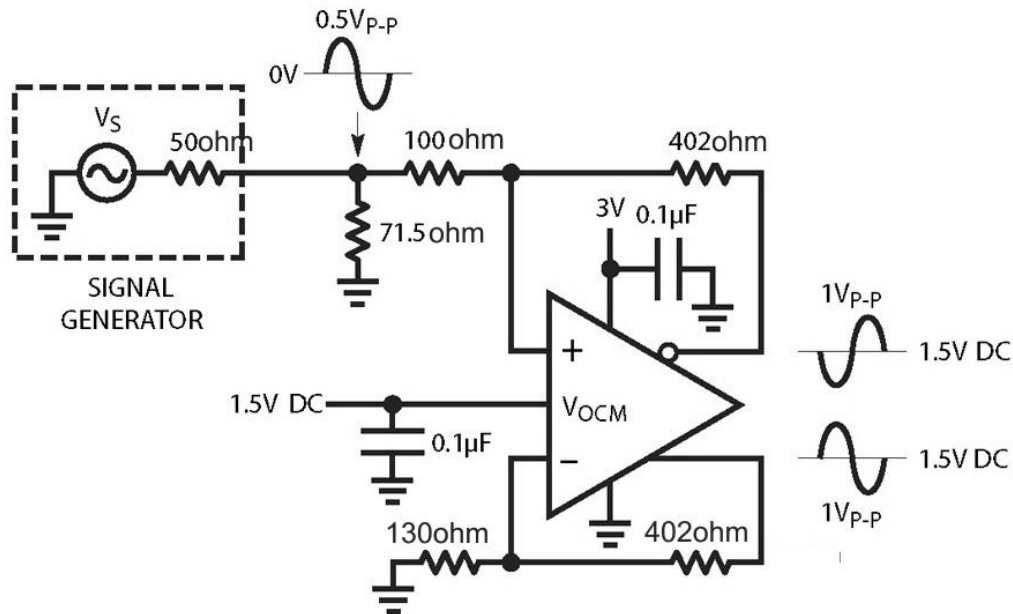


Figure 1: LTC6404 block diagram

The LTC6404 is targeted for 14bit to 18bit applications with signal bandwidths of DC to 10MHz. It achieves better than 90dB distortion and less than $1.5\text{nV}/\sqrt{\text{Hz}}$ noise for input signals of up to 10MHz, making the part suitable for high performance instrumentation. A critical internal component of any amplifier is its compensation circuitry which sets the minimum gain for which the part is stable. The IC designer can trade off stability at lower gains for better performance at higher frequencies. The LTC6404 is available in three versions: the unity gain stable LTC6404-1, and decompensated LTC6404-2 and LTC6404-4 which achieve better speed and distortion characteristics with minimum gains of 2 and 4 respectively. The LTC6404 operates on a single 2.7 to 5.25V supply and has rail to rail outputs allowing the system designer to maximise output swing. A wider temperature (-40 to 125°C) range version of the LTC6404 is available for use in rugged instrumentation applications.

Further integration can offer additional benefits. At high frequencies, system stability can become a significant challenge primarily due to parasitic capacitance associated with routing high speed signals around the board. By integrating gain and feedback resistors into the amplifier, there are fewer discrete components on the board and thus less stray capacitance. Also, the critical feedback node is moved on chip making the circuit less sensitive to bond wire inductance. The LTC6400 is one such product that achieves stability and high performance for high frequency signals up to around 300MHz. The LTC6420-20 goes one step further by integrating two channels onto a single die, making it possible to achieve better phase and gain matching between them.

High speed variable gain amplifiers

An even higher level of integration is achieved by taking a fully differential high speed amplifier and incorporating gain control as a variable gain amplifier (VGA). VGAs are available both as digital control or analogue control devices and are especially useful for automatic gain control and for temperature compensation. The LTC6412 (see figure 2) is an example of a fully differential analogue control VGA with exceptional stability and consistency across its entire frequency, temperature and gain ranges.

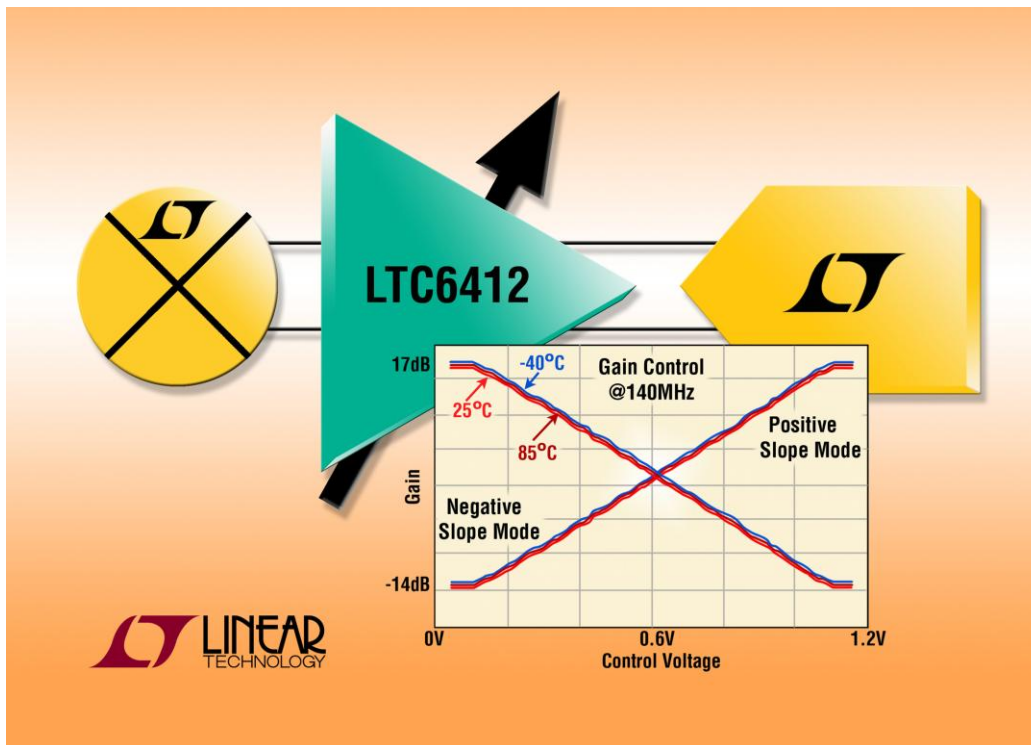


Figure 2: LTC6412

With a -3dB bandwidth of 800MHz, it is optimised for operation with input signals ranging from 1MHz to 500MHz and provides continuous gain adjustment from -14dB to 17dB. It achieves a constant output noise level over the entire gain range with a noise figure (NF) of just 10dB at the maximum gain setting. This results in a constant SFDR characteristic, remaining at greater than 120dB at 240MHz over the full gain control range.

High speed Active Filters

The third example of high speed integrated amplifier based products is high speed active filters. Until recently, most integrated active filters on the market were limited in bandwidth to less than 2MHz. System designers requiring higher cutoff frequencies had no choice but to create discrete designs which are bulky and consume large amounts of board space. This challenge is compounded if the system requires higher order filters or a high degree of filter accuracy. The

same process and design advances which enabled the creation of high performance differential amplifiers and VGAs also make it possible to create higher bandwidth active filters. Like the amplifiers described above, these new filters are often fully differential to enable better SNR on a low supply voltage. Linear Technology has introduced a broad selection of wide bandwidth active filter building blocks intended as drop in solutions to ease the design task. These single and dual matched filters provide integrated, highly accurate filtering capability with exceptional dynamic range performance in small footprint. They are ideal for a wide range of applications such as anti aliasing filters for driving high resolution A/D converters, reconstruction filters for D/A converters in wireless communication receivers and transmitters, industrial and medical signal processing of optical and image processing filters, instrumentation and testing, RFID demodulation baseband filters, and all types of filtering in signal processing applications.

Part Number	Features
LTC6601	Configurable 5MHz to 27MHz, second order differential, low noise, 0.5% tolerance lowpass filter building block
LTC6605	Dual matched 6.5MHz to 25MHz second order differential lowpass filter
LT6604	Dual matched 2.5MHz-15MHz fourth order differential linear phase lowpass filter
LTC6602	Dual matched 900kHz spi programmable ninth order bandpass/lowpass filter
LTC6603	Dual matched 2.5MHz spi programmable ninth order linear phase lowpass filter

Table 1: LTC66xx device features

The LTC6601 contains a low noise, wideband amplifier plus an assortment on chip resistors and capacitors to form a second order differential input and output lowpass filter. The resistors and capacitors are pinned out to allow the user to mix and match different combinations to form a wide range of lowpass response from 5 to 27MHz, as well as filter gain. These internal resistors and capacitors are matched to a tolerance of $\pm 0.5\%$. Additionally the amplifier's bandwidth is also factory trimmed. The combination provides a lowpass filter response with accuracy that is difficult to replicate using discrete components, while ensuring excellent repeatability and saving significant board space. Figure 3 shows the filter topology by pin strapping internal resistors and capacitors to implement different filter responses. Higher order filters with precise response can be easily created by cascading multiple stages of the filter.

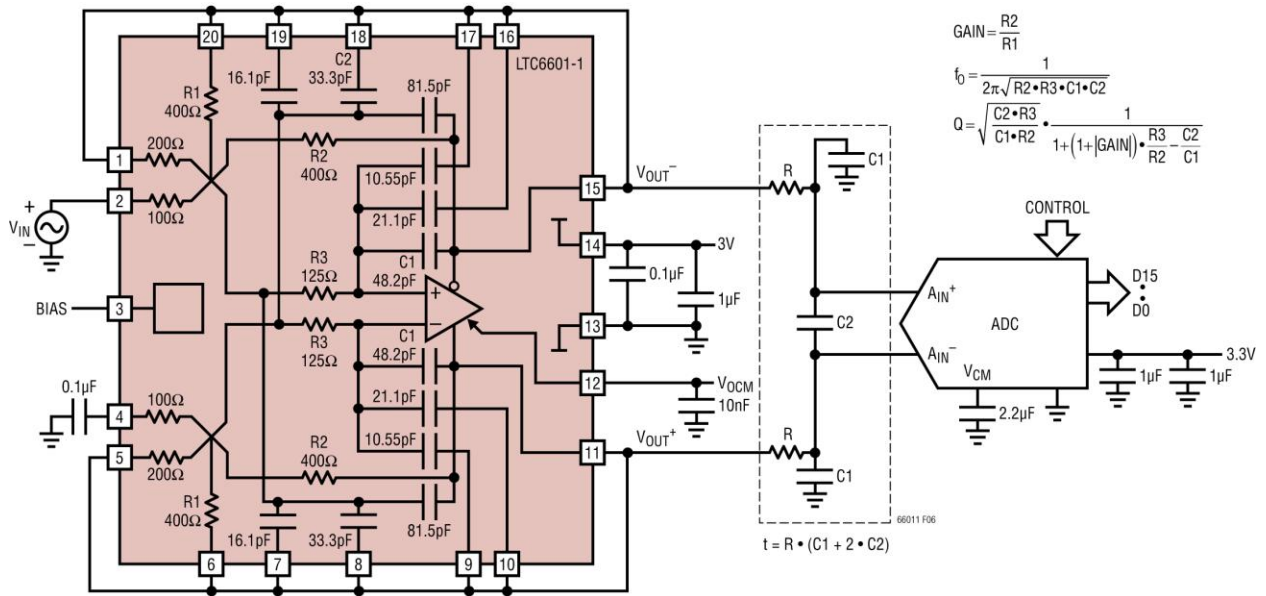


Figure 3: Filter topology

As with the example of the LTC6420 dual high speed amplifier, integrated active filters can also be designed with multiple channels in the same package to provide matched gain and phase in multi channel systems. The LTC6605 is such a dual filter based on the LTC6601. Three versions enable cutoff frequencies ranging from 6.5MHz to 25MHz. These dual channel filters have guaranteed gain and phase matching specifications. They are designed to be drop in, small form factor solutions with minimum external components.

The LT6604 family is another example of dual broadband filters designed to provide tight matching of phase and amplitude performance over its rated frequency bandwidth. The family is available in fixed 2.5, 5, 10 and 15MHz cut off bandwidths and can be powered from 3, 5 or $\pm 5V$ supplies. Their responses have a fourth order approximate Chebyshev roll off skirt while maintaining a tight 0.6dB gain flatness in the passband up to the specified cutoff frequencies. The frequency response is not affected by the gain setting which is controlled by two external resistors. The LT6604 is designed for today's new generation of advanced communications receivers, instrumentation, and signal processing equipment requiring exacting multichannel filtering and matching characteristics. Higher order dual channel filters are also possible as demonstrated by the LTC6602 and LTC6603. The LTC6602 combines a fifth order lowpass cascaded with a fourth order highpass to form a bandpass response. Gain and cutoff frequencies are programmed using either pin strapping or an SPI interface. The highpass filter can be bypassed under software control, providing a lowpass only function. Maximum operating frequency is 900kHz, suitable for RFID readers and lower frequency communications receivers. In contrast, the LTC6603 has higher bandwidth with maximum cutoff up to 2.5MHz. It is a true ninth order lowpass dual channel filter, providing more than 45dB rejection at one octave above the corner frequency.

Summary

Advances in semiconductor process technology and integrated circuit design have made possible a whole new class of amplifier products optimised for high frequency applications. High speed silicon germanium processes enable higher performance at higher bandwidths. By adopting a differential architecture for these amplifier products, the dynamic range is maximised for a given supply range. Well matched on chip resistors and capacitors provide excellent noise and distortion performance while providing excellent matching over temperature variations. And finally, multiple channels can be integrated to provide channel to channel matching that is very difficult to achieve with individual amplifiers at the board level.

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