Blocks bring benefits

Function specific amplifiers improve system capabilities.
By **Brian Black**.

Operational amplifiers (op amps) are increasingly being used as building blocks in more highly integrated ics, each targeted at a specific class of applications.

Some of these amplifier based categories – comparators, instrumentation amps and difference amps – are familiar to most engineers, performing tasks faster, more accurately and with less board space than the equivalent discrete op amp circuit. But a set of high speed amplifier product types enhances new instrumentation, medical, and communications applications beyond what can be achieved by individual op amps.

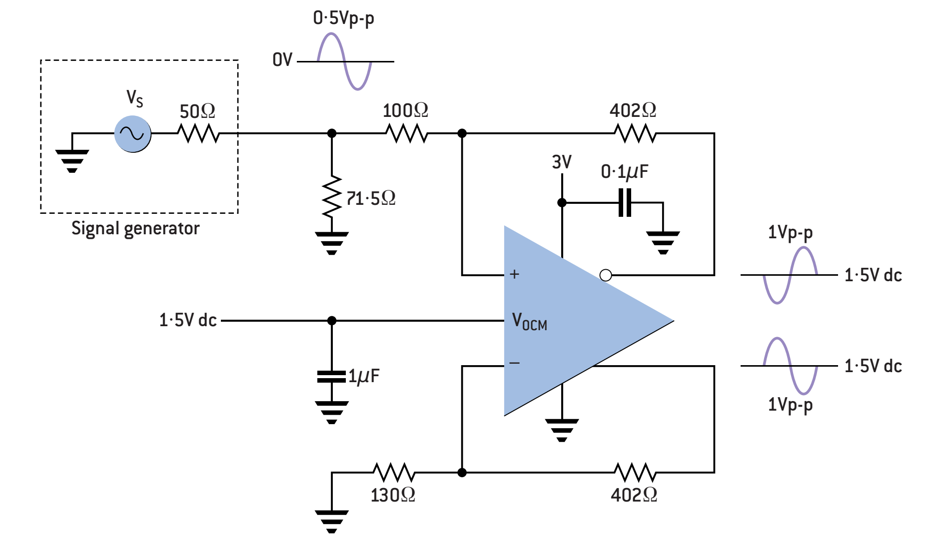
As signal bandwidths increase, so too does the challenge of amplifying and driving these signals, especially when there is a need to digitise that signal. A high speed pipelined a/d converter presents a complex capacitive load which needs to be driven without adding significant noise or distortion. Most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

Traditionally, high speed open loop rf style amplifiers have been used to drive these a/ds. But they are typically single ended, power hungry and require a 5V to 12V power supply. Recently, fully differential amplifiers have been developed, which drive a/ds at high speed and achieve excellent noise and distortion performance. These amplifiers are often manufactured on advanced complementary bipolar SiGe processes.

Selectively adding germanium to a silicon process causes strain, which results in faster transistors. The LTC6404 is a SiGe based fully differential amp which can be used to drive differential signals or to convert from single ended (see figure 1). The part is targeted for 14 to 18bit applications with signal bandwidths of dc to 10MHz.

Compensation circuitry is a critical internal component of any amplifier, setting 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 LT6404 is available in three versions: unity gain stable; and gains of 2 and 4. Operating from a single 2.7 to 5.25V supply, the part has rail to rail outputs, allowing output swing to be maximised.

Fig 1: The LTC6404 block diagram



Further integration can offer additional benefits. At high frequencies, system stability can become a significant challenge primarily due to the parasitic capacitance associated with routing high speed signals. By integrating gain and feedback resistors into the amplifier, there are fewer discrete components on the board and thus less stray capacitance. The critical feedback node is also moved on chip, making the circuit less sensitive to bond wire inductance.

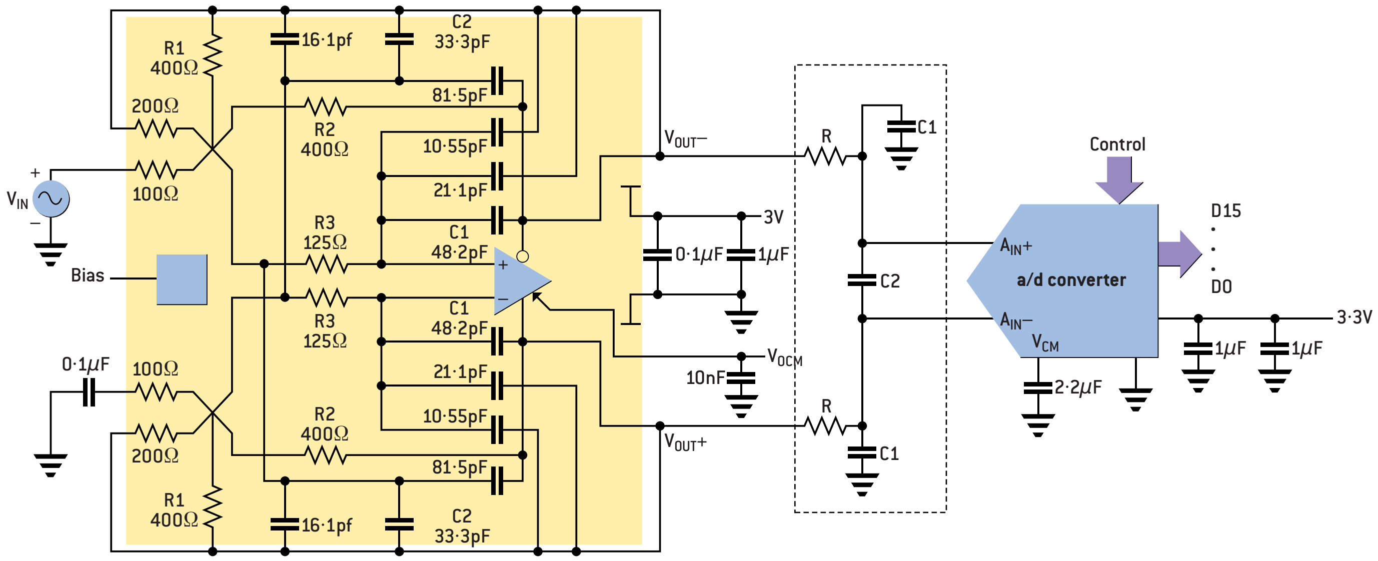
The LTC6400 achieves stability and high performance at frequencies of up to 300MHz. The LTC6420-20 goes one step further, integrating two channels onto one die, making it possible to achieve better phase and gain matching.

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 as digital or analogue control devices and are useful for automatic gain control and for temperature compensation. The LTC6412 is an example of a fully differential analogue control VGA with stability and consistency across its frequency, temperature and gain ranges.

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 gain range with a noise figure of 10dB at the maximum gain setting. This results in a spurious free dynamic range of more than 120dB at 240MHz over the full gain control range.

Another example of high speed integrated amplifier based products is the high speed active filter. Until recently, most integrated active filters were limited in bandwidth to less than 2MHz.

Fig 2: The LTC6601 used in a filter topology



System designers requiring higher cutoff frequencies had no choice but to create bulky discrete designs. This challenge is compounded if the system requires higher order filters or a high degree of filter accuracy.

The same process and design advances described above also make it possible to create higher bandwidth active filters. These filters are often fully differential to enable a better SNR on a low supply voltage. Linear Technology has introduced a selection of wide bandwidth active filter building blocks, intended as drop in solutions. These single and dual matched filters provide integrated, accurate filtering with wide dynamic range in small footprint.

The LTC6601 contains a low noise wideband amplifier, plus an assortment of 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 range of lowpass response from 5MHz to 27MHz, as well as filter gain. Internal resistors and capacitors are matched to a tolerance of ±0.5% and the amplifier's bandwidth is factory trimmed. The combination provides a lowpass filter response with accuracy that is difficult to replicate using discrete components.

Integrated active filters can also be designed with multiple channels in the same package to provide matched gain and phase in multichannel systems. The LTC6605, a dual filter based on the LTC6601, is available in three versions enabling cutoff frequencies ranging from 6.5MHz to 25MHz.

The LT6604 family is another example of a dual broadband filter 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 cutoff bandwidths and can be powered from 3, 5, or ±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. Frequency response is not affected by the gain setting, which is controlled by two external resistors.

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, making it 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.

Black: "By integrating gain and feedback resistors into the amplifier, there are fewer discrete components on the board and thus less stray capacitance."

Advances in semiconductor process technology and ic design have made possible a new class of amplifier products optimised for high frequencies. High speed SiGe processes enable higher performance at higher bandwidths and, by adopting a differential architecture for these amplifier products, dynamic range is maximised.

Well matched on chip resistors and capacitors provide good noise and distortion performance, while providing matching over temperature variations. Finally, multiple channels can be integrated to provide channel to channel matching, difficult to achieve with individual amplifiers at the board level.

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