An amp for every occasion

Despite the trend towards integration, the choice of op amps available to designers has never been wider. By **Chris Edwards**.

Originally developed to support analogue computers, the op amp has an elegantly simple core design. Simply by wiring in different feedback configurations using passives, it can be massaged into roles that include buffers and integrators as well has high-gain amplifiers. It is little wonder the op amp has been as successful as it has been.

Because the op amp is so readily tuneable, we might expect a few core parts to do almost any job, and for the circuit to be ripe for integration. In practice, the choice of discrete op amps has never been wider.

Steve Logan, executive business manager for Maxim Integrated's core products groups, says: "If you don't need terribly high bandwidth, high voltage for industrial systems or very low voltage for portable designs, those are times when op amps can be integrated."

Op amps often interface electronics to the outside world, so they need to take account of numerous subtly different edge cases, which pushes designers to discrete options. Each variant uses a specific choice of process and circuit topology to take on a job. Logan cites the wrist-worn heart rate monitor, which measures the light reflected back from a green LED. In these systems, input current noise has a large effect on signal quality, calling for op amps that can deliver much lower levels than generic options.

Signal-conditioning of systems can turn out to be more complex than first appears, Logan says. "One application that's not immediately obvious is driving a high-speed, high-resolution SAR A/D converter; it can be pretty demanding circuitry. The difference between a SAR and sigma-delta is in how it takes a big gulp of current. The op amp has to settle quickly, so you are talking settling time, slew rate and total harmonic distortion. You may need multiple stages to get the settling time, along with an input buffer, plus a gain stage and filter stage in front of that. You might think at first: how tough can it be? Then it turns into a two- or three-stage op-amp circuit."

Dwight Byrd, marketing manager at Texas Instruments, says: "As demand for further sensors and signals increases, better conditioning and amplification of the sensor becomes paramount, thus making the proliferation of op amps possible."

Art Eck, senior product marketing manager at Microchip Technology, adds: "We see a trend toward more designer op amps: op amps that are built for a particular application or set of applications."

"Previously, an SC-70 package was considered one of the smallest one-channel op amps available."
Dwight Byrd

Microchip product marketing manager Kevin Tretter notes changes in application needs are creating new problems for op-amp components to address. "With the rapid expansion of wireless capabilities the industry has seen over the years, the presence of electromagnetic interference is becoming a larger issue. Sensitive analogue sensor circuits commonly sit next to wireless communication

modules. More and more amplifier manufacturers are trying to combat the adverse effects by implementing on-chip filtering."

Increased noise is partly a by-product of the shrinking size of many designs, as well as the recent focus on making systems more aware of their surrounding environment. "A lot of designs call for sensors to be added, but for boards to be shrunk," Logan says.

Byrd notes: "Where the biggest driver in further technology trends comes in is package size. Previously, an SC-70 package was considered one of the smallest one-channel op amps available. Now, SOT553 is becoming commonplace."

Logan says the trend continues all the way to wafer-level packages, measuring just more than 1mm on the longer side. Such tiny packages support the idea of an 'analogue insurance policy', where op amps and similar parts provide additional conditioning and protection such as buffering to integrated mixed-signal SoCs. "For a little extra size and cost, you can add these functions and make them more robust. The wafer-level package lets you do that."

Tom Kugelstadt, principal applications engineer at Renesas subsidiary Intersil, says there is potential for circuit-level advances that could reduce the need for op-amp proliferation and so aid integration. "The biggest inevitable tradeoff is between low-power and high-bandwidth, or high-speed. In general, high-speed amplifiers require the fast charging and discharging of the gate capacitances of the internal transistors. This requires increases in bias and supply currents, which often leads to increased offset current and voltages. While high-speed op amps have improved significantly in these parameters, they still tower a magnitude above their low-speed, precision counterparts.

"However, there are circuit topologies that aim for increased precision while trading only a minute portion of their high-speed performance. These designs, known as composite amplifiers, consist of a precision amp in open-loop and a high-speed amp in a closed-loop differentiator configuration."

The multiple novel circuit topologies that have appeared over the past few decades to deal with problems such as temperature drift and power consumption can have unexpected side effects that designers need to take into account. That adds to the complexity of picking the right op amp.

Logan points to the use of chopper-stabilised amplifiers. "These are great for low offsets, but push the noise out to a single frequency. One that pushes it out to 60kHz is great for DC, but if you have signals that reach 50kHz, you start to get into the noise skirt. These are nuanced things you might not see immediately from the datasheet."

Frequency-related interactions often need careful examination, says Byrd, and datasheets should show them. "If the output impedance is relatively low and unchanging over a frequency range, it is normally indicative that the op amp will be more stable than one that does have a wide varying output impedance. The output impedance will be interacting directly with the op amp load, and normally a capacitor, it would create various filters as the frequency and therefore the output impedance changes."

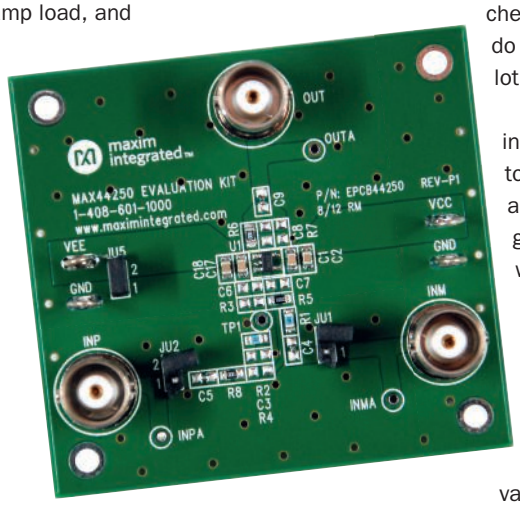
Kugelstadt says interactions with manufacturing choices at the PCB level can introduce unforeseen issues. "High-precision designs using auto-zeroing amplifiers can suffer in precision from asymmetric circuit design. Here, the solder joints around the amplifier form thermocouples that contribute more differential input voltage than the specified offset in the data sheet. Customers unfamiliar with this pitfall blame the device manufacturer for overstating its device performance. The remedy is good application support, such as including layout guidelines in the application section of the data sheet."

"'Mux friendly' versions of op amps [are] more suitable for use as comparators." Ying Zhou

Ying Zhou, TI marketing manager. points out the need to consider how the op amp is designed, particularly if the op amp is being co-opted for a secondary purpose. "If a dual- or quad-channel op amp is already used elsewhere on the board, sometimes the engineers would assign the left channels for comparator functions," she says.

Although many op amps have input clamping diodes to protect the input transistors but these can affect their behaviour as comparators. Zhou says 'mux friendly' versions of op amps that remove the clamps make them more suitable for use as comparators.

Logan notes: "Getting an evaluation kit and putting it on the board is a great thing to do. There is a lot of pin compatibility out there, so you can easily drop another one in to check its performance. But, you do have the issue of having a lot to choose from."



Below: The MAX44250 evaluation kit, one of many such kits available to design engineers

Tretter concludes: "The industry continues to strive to create the 'ideal op amp' and, although we continually get closer to that ideal, there will always be design trade-offs among speed, noise, power usage, size, et cetera. These trade-offs, coupled with continually growing application specific needs, will continue to drive a variety of amplifier types."