

Precision Op Amp Enables Fast Multiplexing at Low Power

Design Note 536

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Introduction

If you are designing a system that measures a number of analog voltages, but not all at the same time, you can reduce downstream circuitry by multiplexing the measurements into a single output signal, then serially process and digitize the original voltage levels using shared components. The benefit is that the number and size of signal chain components is a fraction of that required by a per-channel design. Properly implementing a multiplexing solution requires attention to a few details, especially if you want to quickly switch between channels, measure accurately and maintain low power consumption.

Respond Quickly

Multiplexing increases the frequency content of the combined signal, since every time the multiplexer switches channels, the multiplexed signal changes value. Even if the input signals do not change quickly, the multiplexed signal does, so any circuitry after the multiplexer must respond quickly to these transitions. For instance, if the output signal does not fully settle to the target accuracy before the next channel is read, then the measured value of a given channel can depend on the value of the previous channel, equivalent to channel-to-channel crosstalk.

Because a multiplexer has non-zero on-resistance, it is often necessary to buffer the output using an op amp. Figure 1 shows a multiplexed circuit, with per-channel op amps before the MUX, and one shared op amp after. It's the performance of the shared downstream op amp that we consider here.

Op amps with low power consumption tend to be slow. In particular, op amp slew rate is typically closely related to op amp supply current. This is because the current available to charge internal capacitors is a fixed proportion of the op amp total supply current.

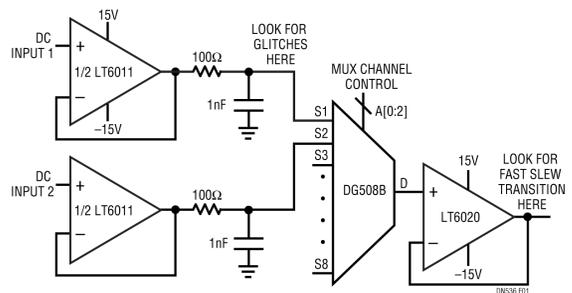


Figure 1. Multiplexed system. LT6011 buffers at inputs have high input impedance. The LT6020 after the MUX can slew fast when MUX changes channel. LT6020 special input circuitry avoids voltage glitches at MUX inputs.

The LT[®]6020 op amp, on the other hand, has a much higher slew rate than you would expect for its low supply current. It performs this feat by adjusting the slew rate based on the size of the input step, so large input steps are processed just as fast as small input steps.

Figures 2a and 2b show the impact on transient step response of the LT6020 compared to a conventional op amp of similar power consumption. For conventional op amps, the large-signal response is much slower than the small-signal response. The LT6020, however, responds just as cleanly to a 10V step as to a $\pm 200\text{mV}$ step. This ability to slew fast and settle quickly to a new value, while still drawing only $100\mu\text{A}$ of supply current, makes the LT6020 a good choice as a buffer after a multiplexer.

Avoid Glitches

Even if the op amp following the multiplexer is fast enough, there is another important detail that is often overlooked. Most precision op amps have internal protection diodes across the input stage to avoid reverse biasing sensitive bipolar transistors at the input stage.

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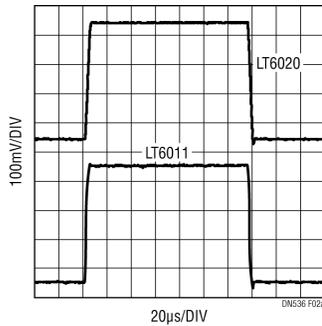


Figure 2a. For small output signals, the LT6020 performs similarly to other op amps of the same power level. The response is dominated by gain bandwidth.

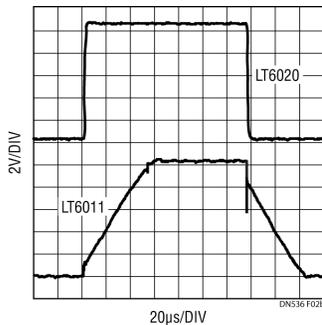


Figure 2b. For large output signals, the LT6020 preserves signal fidelity compared to other op amps of similar power level. The response is dominated by slew rate.

When the multiplexer switches from one channel to the next, the input voltage at one terminal changes quickly, with the output (and therefore the feedback node) not yet changed. This causes a large current spike to flow through the internal protection diodes. Where does that current come from? It must come from the circuitry connected to the input of the multiplexer. If that circuitry is high impedance, or slow, then this current spike causes a voltage glitch. The output of the system then tries to follow that input voltage glitch, so that the output cannot settle accurately until after that voltage glitch has resolved itself.

The **LT6020** op amp provides a unique solution to this problem. Its input devices are very accurate, but also robust enough to allow more than 5V reverse bias. Therefore, rather than internal protection diodes, a pair of back-to-back Zeners protects the input. As a result, no current spikes occur for input steps of 5V or less. Figures 3a and 3b show that the LT6020 op amp

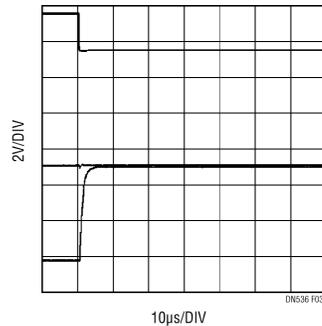


Figure 3a. As soon as the control signal (top trace) changes the MUX channel, the LT6020 output (bottom trace) transitions from the voltage on the previous channel to the next channel. The middle trace shows the input to the multiplexer, with almost no voltage glitch.

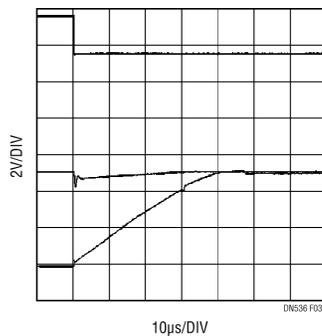


Figure 3b. Same setup as 3a, but with a conventional op amp after the multiplexer (**LT6011**). The signal at the input to the multiplexer (middle trace) shows a noticeable glitch due to current flowing through the multiplexer into the protection diodes of the op amp.

causes almost no voltage glitches at the output of the sensor, while a traditional precision op amp (**LT6011** shown as example) causes a large voltage glitch.

Conclusion

Correctly multiplexing precision signals into one output signal requires careful attention to detail. The **LT6020** op amp simplifies the design of multiplexed solutions with a set of unique features. For instance, its slew rate is much faster than other op amps at this low supply current level, allowing it to respond quickly to channel changes. Also, its unique input protection scheme avoids current spikes that would otherwise cause upstream glitches during channel changeover using a traditional precision op amp.

Data Sheet Download

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