Using Operational Amplifiers as Multiplexers in Cost-Optimized Designs

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Introduction

Designs often have multiple sensors or input signals that require interfacing to an analog-to-digital converter (ADC). Depending on how many input signals are required for the design and the ADC that is required to meet the performance of the design there may not be enough dedicated ADC channels for each input signal. In that case, the use of a multiplexer (MUX) is required. However, in most cases when using a multiplexer, an operational amplifier is required at both the input and output of the multiplexer for proper operation. The op amp at the input prevents MUX switching/charge injection from reaching the sensor. The output op amp is required to provide a low-impedance output to drive the input of the ADC. Figure 1 displays a typical signal chain design when using a multiplexer.

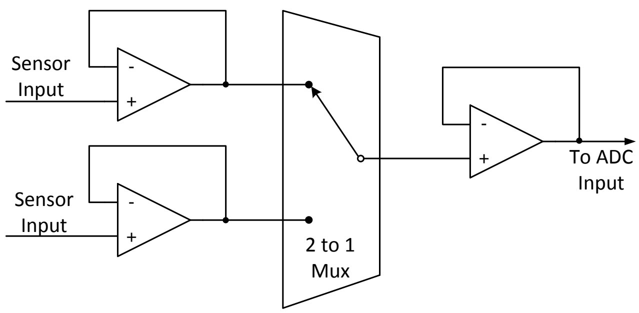

Figure 1. Signal Chain of Multiple Inputs Using Multiplexer

The requirements of additional op amps and a MUX can add significant cost to the design. However, the design can be simplified to use an op amp with shutdown in place of the multiplexer function. Figure 2 displays a typical 2-to-1 MUX and Figure 3 displays how a dual channel amplifier with shutdown can be configured to operate as a 2-to-1 MUX. The dual channel op amps are in a buffer configuration with the output of both channels shorted together. The desired input channel is selected through the use of the SEL signal which connects to the shutdown pin of the op amps. This tech note describes how to configure a dual package amplifier as a MUX and discuss some design considerations.

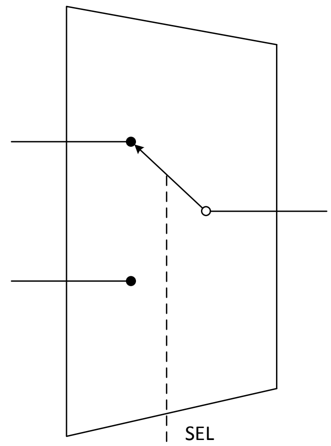

Figure 2. Multiplexer

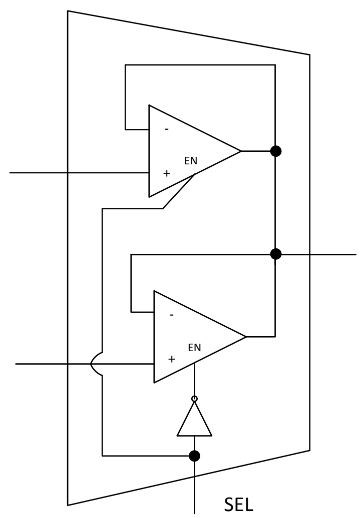

Figure 3. Op Amp as a MUX

Design Considerations

There are two main potential design challenges that must be considered when configuring an amplifier as a MUX, namely: shoot through current and input clamping diodes (back-to-back diodes). The first issue, shoot-through current, occurs when two amplifiers are enabled (on) at the same time. During this condition, one amplifier forces current into the output of another amplifier resulting in large current flows, potentially damaging the devices. To avoid shoot-through current from occurring the timing of the amplifiers must be carefully designed. Figure 4 displays a recommended timing diagram to ensure that shoot-through current does not occur. Notice that the timing diagram uses a “break before make” concept where both amplifiers are disabled (off) for a short period of time before an amplifier is enabled. If the timing of each channel cannot be controlled independently to ensure a “break before make” connection it is important to verify that the disable time of the amplifier is much faster than the enable time. This ensures that the device inherently has a “break before make” connection.

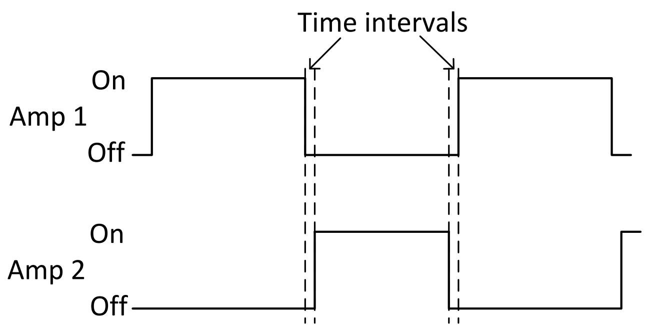

Figure 4. Amplifier Time Intervals

The second design issue that must be considered is if an amplifier has input clamping diodes. Input clamping diodes can turn on and short the output voltage of the enabled amplifier to the input voltage of a disabled amplifier. Figure 5 displays how the input clamping diodes can turn on and conduct. If the input clamping diodes turn on two conditions can occur: the enabled amplifier output overdrives the input signal of a disabled amplifier or the input signal of a disabled amplifier is the output signal. Therefore an amplifier without input clamping diodes is required. See the *MUX-friendly Precision Operational Amplifiers Tech Note* for more information on the challenges and solutions to input clamping diodes.

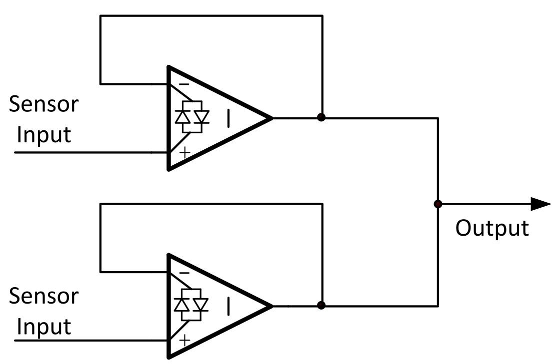

Figure 5. Input Clamping Diodes

The TLV9062S is a dual channel device that does not have input clamping diodes and has a disable time that is faster than the enable time. Therefore each shutdown pin does not have to be independently controlled. Figure 6 displays the TLV9062S configured as a MUX. Notice that since the disable time of the amplifier is faster than the enable time an inverter can be used to control the shutdown pin of the amplifier instead of controlling each shutdown pin independently.

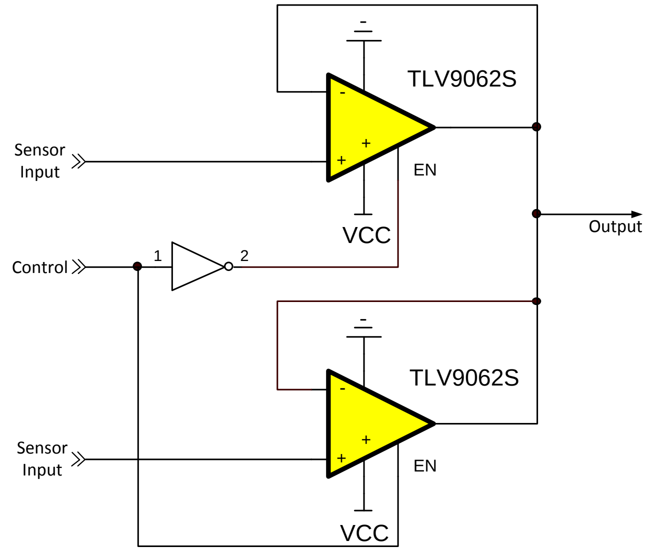

Figure 6. MUX Circuit Using TLV9062S

Figure 7 and Figure 8 displays measurements of the output voltage, output current, and shutdown pins of the TLV9062S configured as a MUX. Channel 1 (blue) is the enable signal, channel 2 (red) is the logic inverter output, channel 3 (green) is the output voltage signal, and channel 4 (purple) is the output current between the two amplifiers. To be able to determine which amplifier is enabled and outputting a signal the input voltage to op amp A is 1 V DC and the input voltage to op amp B is 2 V DC. When op amp A is enabled (on) and op amp B is disabled the output voltage is 1 V. When op amp A is disabled (off) and op amp B is enabled (on) the output voltage is 2 V. Notice that when the control switch transitions from low to high or high to low, the op amp output goes low to approximately 0V indicating that the op amp disables before it enables. During this transition period, there is a spike of current flowing between the two amplifiers. The peak current between the two amplifiers is 400 µA for less than 200 ns and does not affect operation of the circuit.

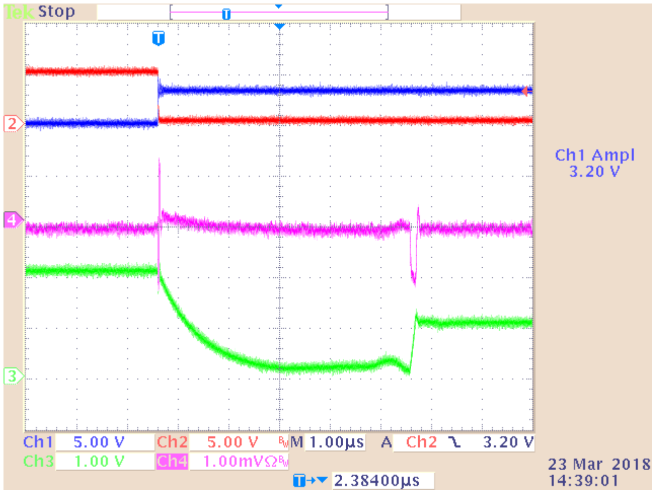

Figure 7. Op Amp A On, Op Amp B Off

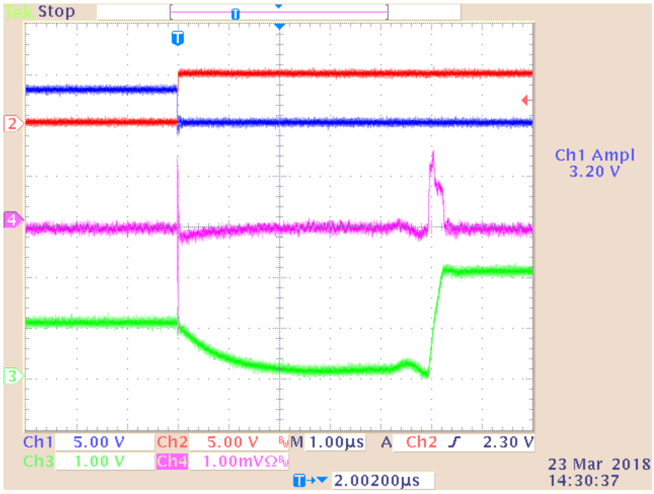

Figure 8. Op Amp A Off, Op Amp B On

Conclusion

Multiplexers are widely used in many applications that require several input signals to interface with a single ADC. Using a multi-channel op amp with shutdown capabilities as a MUX circuit is a simple yet effective way to reduce the cost of a design and still meet the performance goals of the design. By carefully designing the circuit the two main design challenges, shoot-through current and input-clamping diodes, can be avoided. TLV9062S is a solution that avoids both design challenges by having a disable time that is faster than the enable time and does not have input clamping diodes.

Table 1. Recommended Amplifiers for MUX Circuits

DEVICE	DESCRIPTION
TLV9062S	Low cost, 10 MHz, low noise, RRIO, CMOS amplifier with shutdown
TLV9002S	Low cost, 1 MHz, low noise, RRIO, CMOS amplifier with shutdown
OPA2320S	High precision, 20 MHz, low noise, RRIO, CMOS amplifier with shutdown
OPA2837	Low power, precision, 105 MHz, voltage feedback op amp with shutdown

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