Improve Stability Issues with Low C_{ON} Multiplexers

A common issue encountered during system design is poor transient performance of the signal chain. This transient behavior can frequently be attributed to stability problems in an amplifier circuit. Op Amp stability issues can create large overshoots and ringing and are often caused by too much capacitance on the output or inverting input of the amplifier. While a system designer may not intentionally add capacitance to a design, the on-capacitance (C_{ON}) of a multiplexer (mux) may be large enough to impact the system. Selecting a mux with low C_{ON} can help minimize issues caused from these common circuit challenges.

The C_{ON} of a mux represents the equivalent capacitance to ground seen by the system when a mux channel is conducting. Typical values of C_{ON} for analog multiplexers range from 10's of pF to over 400pF. However, newer multiplexers can have C_{ON} as low as 1.5pF.

Stability: Driving Capacitive Loads

An amplifier can become unstable when there is too much delay between the amplifier output and the inverting feedback node. This delay can be formed by the combination of a load capacitor and the amplifier open loop output impedance. Figure 1 shows a typical system where an amplifier will need to drive the capacitive load of the mux C_{ON}.

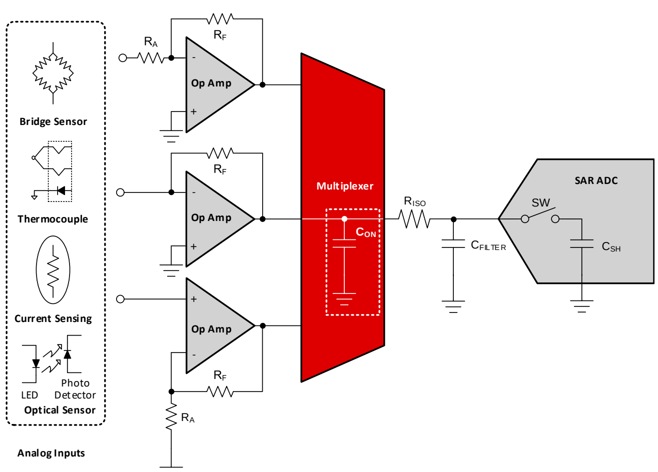

Figure 1. Op Amp Driving Mux Capacitive Load

In this example, one must understand how much capacitive load the amplifier can drive in order to select the correct multiplexer for the circuit. Figure 2 shows the capacitive drive strength if using a general purpose Op Amp such as the TLV9061.

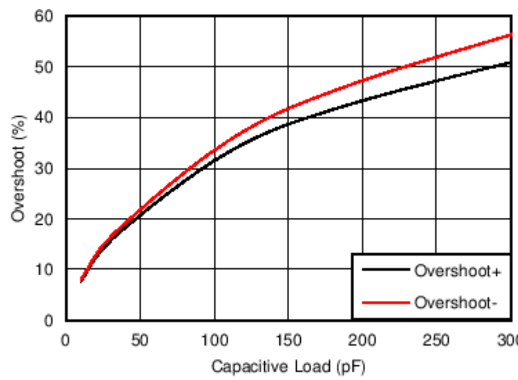

Figure 2. Overshoot vs. Capacitive Load

By referencing the datasheet of the amplifier, it is easy to see increasing overshoot in output response with regard to an increase in load capacitance. Selecting a multiplexer with low C_{ON} becomes critically important to reduce overshoot in the system and ensure stability under the closed loop frequency.

Stability: Capacitance on Inverting Input

Stability issues can also arise from the interaction of the feedback resistance, R_F, with capacitance on the inverting node of the op amp. A transimpedance amplifier circuit with configurable gain control is a common example where the C_{ON} of the mux can cause oscillations if special attention is not given to stability analysis. Figure 3 shows a mux being used to switch-in different feedback elements for configurable gain of a transimpedance amplifier circuit.

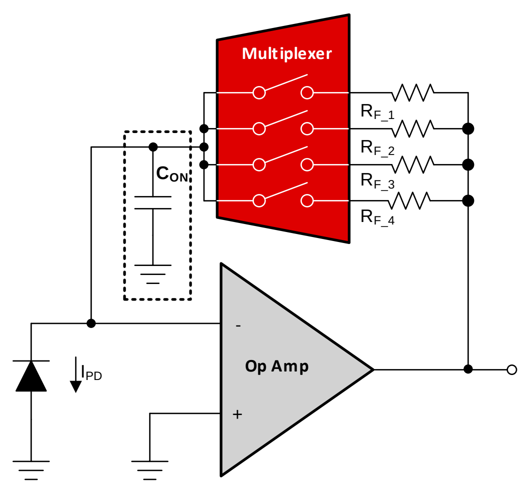

Figure 3. Configurable Gain Control

If using a 1:1 4-channel switch such as TMUX1511 for configurable gain control as shown, each individual channel has its own C_{ON} which will be placed in parallel when all channels are conducting. If a mux is not selected to optimize on capacitance, a single channel of a 1:1 switch can typically have 40pF of capacitance. Therefore with all 4 channels conducting the total C_{ON} of the feedback path would be 160pF. Conversely, using a mux with 2.5pF of C_{ON} would lead to a total feedback capacitance of only 10pF with all channels conducting. The C_{OFF} specification should also be included for any channels that are not conducting.

Instability in the circuit can be identified through Phase Margin or Rate of Closure analysis. A general rule of thumb states that a design should have > 45° of phase margin for optimal stability. The Rate of Closure method uses the magnitude plots of A_{OL} and $1/\beta$ where the absolute value of the difference in each slope must be 20dB for optimal stability. While the phase margin and rate of closure methods work in simulations, the phase margin must be indirectly measured on the bench by analyzing output percent overshoot with a step response on the input. The circuit shown in Figure 3 will be used in the following circuit simulation. Figure 4 shows the small signal analysis with varying values for mux C_{ON} in the time domain.

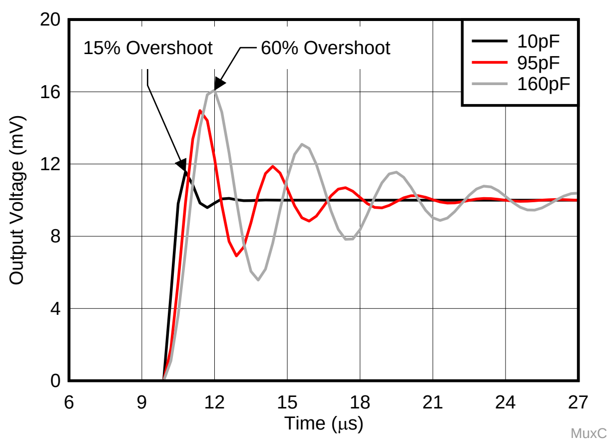

Figure 4. Op Amp Instability

Expecting a 10mV output from the transient response simulations, the percent overshoot can be recorded and the phase margin can be obtained. In the simulation with C_{ON} of 10pF, the 15.3% overshoot results in a phase margin of 53°, whereas the C_{ON} of 160pF has 60% overshoot resulting in 19° of phase margin. Additionally, the sustained oscillations of the C_{ON} with 160pF is another way to visually identify stability issues. While most applications will include a feedback capacitor for stability purposes, minimizing mux C_{ON} provides similar benefits. Since the frequency of the pole and zero are derived using C_{ON} and C_F, lower C_{ON} allows for a smaller feedback capacitor which allows higher system bandwidth. Figure 5 shows the relationship of phase margin and percent overshoot for a second-order system, please reference TI's Analog Engineer's Pocket Reference for more information.

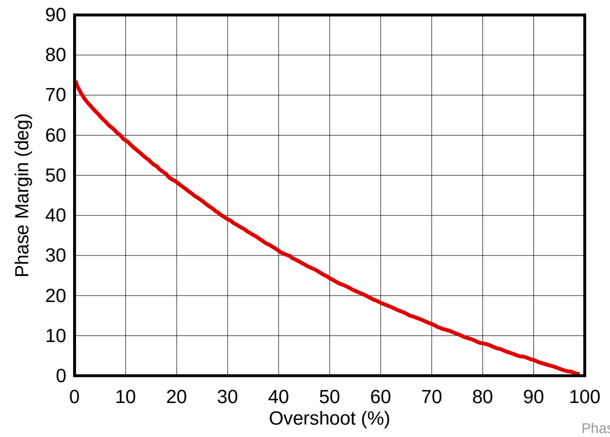

Figure 5. Phase Margin vs. Percent Overshoot

Low C_{ON} System Importance

Stability issues can be encountered in amplifier circuits when special attention is not paid to device parasitic capacitances. System designers should understand mux capacitance specifications in order to select the correct multiplexer for their application. Selecting a mux with low capacitance can help minimize stability concerns and reduce system complexity.

Additional Resources

- TI Precision Labs - Multiplexers
- TI Precision Labs - Op Amps: Stability
- TI Analog Pocket Reference Guide

Table 1. Alternative Device Recommendations

Device	Optimized Parameters
TMUX1511	1:1 4-channel switch, low C_{ON} = 3.3 pF, BW = 3 GHz
TMUX1574	2:1 4-channel switch, low C_{ON} = 7.5 pF, BW = 2 GHz
TMUX136	2:1 2-channel switch, low C_{ON} = 1.4 pF, BW = 6.1 GHz
TMUX1072	2:1 2-channel switch, low C_{ON} = 6.2 pF, BW = 1.2 GHz
TLV9002	Low cost, 10MHz, low noise, RRIO, CMOS Amplifier

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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