How Do I Eliminate Ghosting From My Measurements?

Hardware: Multifunction DAQ (MIO)>>E Series>>PCI-6036E

Problem:
I am scanning multiple channels using a multifunction DAQ board but I am seeing the trends of one channel being reflected in the subsequent channel. However when I only measure from a single channel the measurements are correct. How do I eliminate this ghosting effect?

Solution:
To overcome ghosting you have several options:

1. Select a transducer with lower source impedance
2. Reduce sampling rate and increase interchannel delay to allow enough settling time for the amplifier (see KnowledgeBase 292A3QBS)
3. Implement a voltage follower or buffer circuit to decrease source impedance to less than 1 kOhm (see KnowledgeBase 208AD10T)
4. Arrange signals to minimize voltage swings between channels
5. Choose the high-impedance channel as the first channel in the scan list.
6. Avoid multiplexing – sample one channel at a time or switch to a simultaneous sampling DAQ device

Note: This will only help if you are not sampling in round-robin mode.

Why does ghosting occur?

High source impedance on a scanned channel causes its settling time to increase. The small internal capacitance on the analog-to-digital converter (ADC) combines with the high source impedance to create a low pass filter. As the source impedance increases, so does the time constant of this filter and thus its settling time. A simplified diagram is below:

As the multiplexer switches from one channel to the next the capacitor C starts to charge from the voltage of the previous channel to the voltage of the connected channel. If RX is too large C will not be charged (or discharged) to the correct voltage and will show remnants from the previously scanned channel when the measurement is taken by the ADC. This incorrect reading is called ghosting. It is also often incorrectly labeled crosstalk.

Let's take an example: Assume R0 is small (< 1 kOhm) and source 0 is a sine wave with an amplitude of 2 volts with no offset. In addition assume R1 is large ~100 kOhms and source 1 is held at a constant 5 volts. When measuring each signal individually you do not switch between channels of the multiplexer and will see the following:
However, when both channels are scanned the sine wave is reflected onto channel 1:

This same issue will occur if no signal is connected to a channel since RX will essentially become infinite. If source 1 is completely disconnected from ai1 and both ai0 and ai1 are still scanned you will see the following:
It has been incorrectly suggested that scanning a grounded channel before a high-impedance channel will reduce ghosting by allowing the capacitor to discharge to ground. However, the time it takes for the voltage at the ADC to reach the correct level is related to the difference between the previous channel and the current channel, not just the current charge of the capacitor. For this reason it is best to arrange signals to minimize voltage swings between channels.

If ground (0 Volts) is farther away from the voltage of the high-impedance channel than the voltages of the other scanned channels, it will actually take longer for the high-impedance channel to reach the desired level. Grounding the channel before a high-impedance channel is only useful if the high-impedance channel is closer to 0 Volts than the other scanned channels.

In the previous example, grounding the channel scanned before the high-impedance channel does not allow the high-impedance channel to take a correct measurement. Below is a graph of the preceding example with a grounded channel (a12) added between the low-impedance channel and the high-impedance channel. Note that the actual voltage of the high-impedance channel is supposed to read 5 volts.

Related Links:
KnowledgeBase 28MF7JQ0: Troubleshooting Unexpected Voltages, Floating, or Crosstalk on Analog Input Channels
KnowledgeBase 292A3QB5: How do I Increase Interchannel Delay Using NI-DAQmx or Traditional NI-DAQ (Legacy)?
Developer Zone: Using a Unity Gain Buffer (Voltage Follower) with a DAQ Device
KnowledgeBase 2O8AD10T: How Do I Create a Buffer to Decrease the Source Impedance of My Device?