Measuring Channel Switching Error in Data Acquisition Systems

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Summary – The switching between channels when performing multi-channel data acquisition originates errors in the result of the analog to digital conversion due to the non-ideal behavior of multiplexers. Here we discuss the test methods required to quantify those errors, presenting the shortcomings of existing ones and proposing new testing procedures.

Keywords – Multiplexer, ADC Testing, Switching.

I. State-of-the-art

The new IEC 85/227/NP recommend test method "*Channel Switching Error*" [1] is performed using DC voltage sources to produce two voltages, one 10% lower than the maximum and the other 10% higher than the minimum ADC input range. Those voltages are applied to two channels of the data acquisition board (DAQ) (CH1 and CH2). First, a certain number of samples of CH1 only is acquired and the mean of the output codes is computed, then samples of CH2 only are acquired and the mean computed. Finally, samples from both channels are simultaneously acquired and the mean of the output codes obtained in each channel is computed. The next step is to determine the error of each channel by subtracting the mean of the output codes when that channel was the only one acquired and the mean of the same channel when it was acquired together with the other channel. The higher of the two errors (in absolute value) is the channel switching error.

In Figure 1 the histogram of the output codes obtained is represented when using a National Instruments 6023E DAQ to acquire 100,000 samples at 200kS/s in the 50mV bipolar input range. A Fluke 5700A calibrator was used to generate voltages of 45mV and −45mV. It can be clearly seen that acquiring both channels simultaneously causes the sampled voltages to be different from when the channels were acquired separately. In the case depicted the channel switching error was 113 LSB.

The charge injection [2], due to the switching of the multiplexer, is a transient disturbance that affects the circuit connected to the DAQ input. In this case the DC power supply is momentarily affected by the switching and may fail to recover completely before the next sample. This causes the sampled voltages to be different from the ideal value. The faster the sampling rate the greater the error because the signal source will have less time to recover. This can be seen in Figure 2 were the channel switching error is represented as a function of the sampling frequency for four different input ranges.

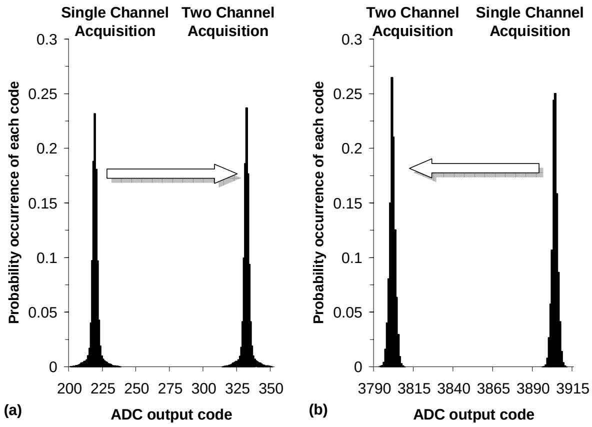

Figure 1 – Histogram of the output codes obtained from sampling two channels individually and at the same time. (a) lower voltage values and (b) higher voltage values.

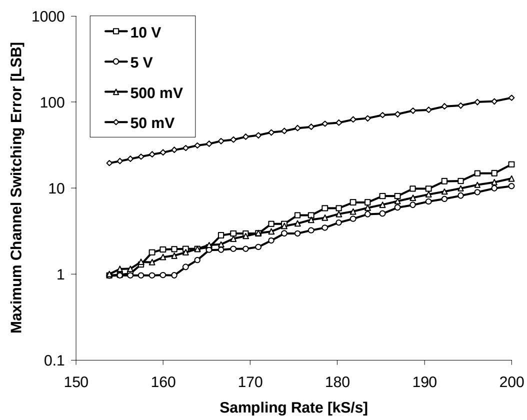

Figure 2 – Channel switching error for different sampling frequencies and input ranges.

II. OUR CONTRIBUTION

In our opinion the IEC 85/227/NP test method does not completely describe the channel switching error. A test was carried out by connecting the floating output of a DC power supply (ITT Instruments AX322) with 10V to a voltage divider made of 4 resistors in series (R_1, R_2, R_3 and R_4) with values 10kΩ, 90kΩ, 90kΩ and 10kΩ. One of the DAQ channels was connected to R_2 and the other to R_3. The ground and the negative terminal of both channels were connected between R_2 and R_3. This way one channel had a voltage of 4.5V and the other a voltage of –4.5V. The result can be seen in Figure 3 where the sampled voltages are represented by circles for both channels.

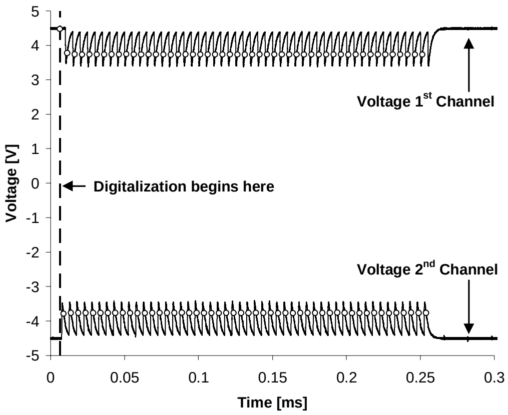

Figure 3 – Samples obtained when acquiring two channels (circles) and the input voltage measured with a digital oscilloscope (solid lines). Resistances of 10kΩ and 90kΩ were used. The sampling frequency is 200kS/s and the input range is ±5V.

It can be seen that only the first sample of the first channel has the correct value (4.5V) but the following samples are lower (in absolute value) than 4.5V. This is because the input signal at the time of sampling, represented by the dark solid line (obtained with an oscilloscope), is not 4.5V but suffers a decrease (in absolute value) due to MUX switching. After switching the input voltage recovers "slowly" toward the correct value (4.5V) but never actually reaches it due to the next sampling.

This effect is worst when the resistance values are higher as can be seen in Figure 4 where resistances 10 times greater were used.

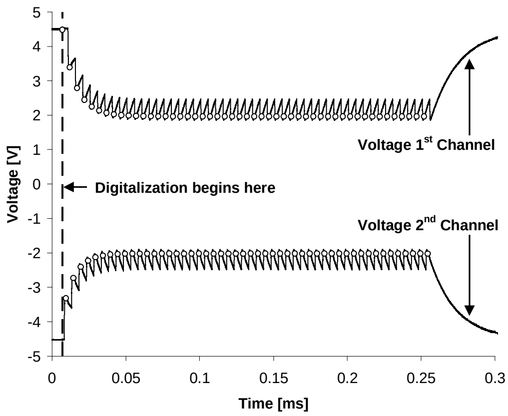

Figure 4 – Samples obtained when acquiring two channels (circles) and the input voltage measured with a digital oscilloscope (solid lines). Resistances of 100kΩ and 900kΩ were used. The sampling frequency is 200kS/s and the input range is ±5V.

It is thus demonstrated that the value of the input circuit impedance, as "seen" by the DAQ, will affect greatly the switching error. This fact is known by some DAQ manufacturers, namely by National Instruments that states in the 6023E manual [2] that the simultaneous sampling should only be performed when the input impedance is below 1kΩ.

In Figure 5 the switching error is plotted as a function of sampling frequency with the voltage dividers. The error in these cases is much greater than the error determined with the IEC method (Figure 2).

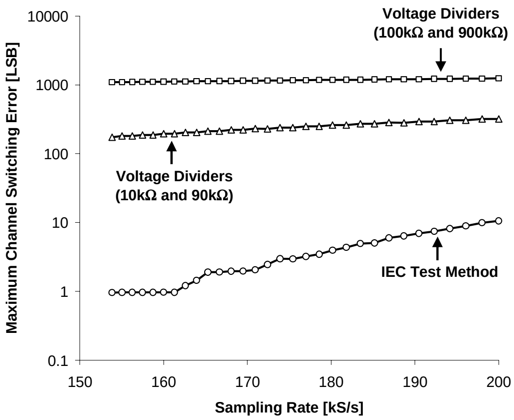

Figure 5 – Channel switching error for different sampling frequencies using resistance dividers and the IEC method. The ADC input range is ±5V.

III. Conclusions

In this paper the test method proposed by IEC 85/227/NP [1] to measure switching error was analyzed. The method shortcomings were pointed out, namely the fact that the results obtained are highly dependent on the impedance of the input circuit.

To that effect DAQ manufacturers should perform the test using different impedances. They should also present information regarding switching error as a function of sampling frequency and input range.

The influence of the impedance in the switching error should be studied in more detail, namely the effect of impedances with capacitors and inductors. Also a modeling of the effect of switching on the input circuit may enable the development of a better test method.

IV. References

[1] International Standard IEC 85/227/NP, "Performance Characteristics and Calibration Methods for Digital Data Acquisition Systems and Relevant Software", International Electrotechnical Commission.

[2] National Instruments, "6023E / 6024E / 6025E User Manual", December 2000.