Electronic Noise

Use the oscilloscope and the DataCapture.vi program to study electronic noise, bias or offset, drift, and pickup. These terms will be defined as we go along. Here is the syntax for importing a file into Mathematica
Data = Import[``Z:\\teaching\PH315\programs\RCdata”, ``Table”]

1. With the input shorted, set the oscilloscope to 10 mV/div and 1 ms/div. The resulting waveform displays random *noise*, that is, short-term fluctuations with a nearly constant, or *stationary*, average value.

(a) Gather data with the VI, but do not bother saving yet. The measured voltages have only specific, quantized values; why? (Print neatly! If we can’t read it, it is wrong.)

What is the smallest voltage increment you can measure? Explain. This voltage increment is called the *least count* of the instrument and is a source of uncertainty called *quantization error* or *quantization noise*.

Estimate the peak-to-peak value of the noise in millivolts or microvolts. Guesstimate (yes, it’s in the dictionary) the lowest voltage you could measure with the oscilloscope on this setting. Explain how you arrived at this value.

Change the vertical position on the oscilloscope and gather the data again with the VI. Did the vertical position of the LabView waveform change appreciably? Comment.

Now set the oscilloscope to 2 mV/div and 5 ms/div. Describe what you see and how it differs from what you saw at the other time scales. Is the noise stationary? Why not?

(b) Use 1 or 2 ms/div and a number of voltage ranges such as 2, 5, 10, and 50 mV/div. Check visually with the VI and see whether the mean values of the waveform differ from one voltage range to the next. You may get the true zero value by selecting “ground” on one of the buttons to the right of the display on the oscilloscope. The mean value of the waveform with no input is called a *bias* or *offset*. You can correct a measurement for a bias but not for noise. Visually estimate the biases for several voltage ranges and tabulate them below.

(c) Use the VI to capture data at each time base, save the data, and export it to a spreadsheet or Mathematica (or anything else you like). Calculate the means and sample standard deviations, and tabulate them below (see the uncertainty lab for definitions). Are they 0? If not, why not?

(d) If we are going to measure the offset, we need to use the SDOM (not the sample standard deviation) as a measure of uncertainty. Gather several data sets at 5 ns/div and see whether the means are constant within 1 or 2 SDOM's (note that $N = 25{,}000$). If they are not, we would say that there is *drift* at that time scale. Sometimes the distinction between drift and noise is not clear, but generally drift refers to a fluctuation whose period is longer than the observation time. When there is drift during a measurement, the standard deviation of the mean is not a meaningful measure of the total uncertainty.

(i) Why not?

(ii) Tabulate the means and SDOM's of several runs below.

(iii) Do the means differ by more than 2 SDOM's? If they do, then to calculate the offset, you must average the means of the several measurements. What value will you use for the uncertainty of the calculated mean (the mean of the individual means)?

2. Use the power supply from the capacitor lab to apply a voltage around 100 mV to the oscilloscope. Use the VI to acquire the mean and SDOM of the power-supply voltage. (You would not normally use an oscilloscope to measure a steady voltage, but there is no reason you cannot.)

(a) What is the actual, measured value of the power-supply voltage?

(b) Calculate the standard uncertainty of the measurement. Hint: Include the SDOM of the offset voltage.

(c) Can you think of any other sources of uncertainty? Where would you get their values?

3. Put a megohm resistor across the input and observe the resulting waveform with different time bases. What frequencies do you see? What else do you see besides periodic signals? Where do you think these signals come from? What you are seeing is called *pickup*. You will probably not be able to measure the frequencies using the "Measure" function of the oscilloscope because of the noise; rather, you will have to estimate the periods with the scale.

4. If time allows, take one of the stationary data sets you acquired in part 1 and plot the data as a voltage histogram. See whether the data are approximately Gaussian. Random noise is in principle Gaussian; if the noise is not Gaussian, then SDOM has limited meaning.