# 431 Lab 8
## Analog/Digital Converters
March 28, 2009

**Note: This is a demonstration lab and is not to be handed in**. Learn all you can from it. This lab uses the spreadsheet, a2dsim.xls (on the EE431 web site), to simulate analog to digital conversion and digital to analog conversion.

**General experiments:**

1. Set the parameters to 1V peak sine wave at 1083 Hz, 8-bit and 2 Volt span, 16,000 Hz sampling, and smooth at 3000 Hz. Set the display over-sampling choice to 3.

2. Observe chart 1. Also try smoothing at 4000 and 1000 Hz. Note that for smoothing at 1000 Hz that the peak amplitude of the output waveform is a little less than 0.7 Volts –3 dB down from 1 Volt peak which would be expected.

3. Change the sampling to 8,000 Hz and then 4,000 Hz. Note how the waveform becomes coarser.

**Alias experiments:**

4. Set the parameters to the same as in step 1 except sample at 2,000 Hz. Note that the output frequency is lower than the input frequency since aliasing has occurred.

5. Change the display over-sampling setting to 2 and then 1. It appears (falsely) that the output signal is modulated. Actually, what you are observing is the summation of multiple output frequencies produced by aliasing.

6. Set the sampling frequency to 1,000 Hz (display over-sampling to 1). Note that the low frequency alias occurs at a frequency represented by approximately every 12 samples. What frequency is this?

7. With the display over-sampling set to 1, set the sample frequency to 2,166 and then 1,083 Hz. Why is the output exactly zero for every sample? Note that with synchronous sampling, phase makes a difference. In this case the relative phase is zero.

8. Observe the waveform with a sampling frequency of 1,115 Hz and 1,051 Hz (display over-sampling set to 1). Measure the resulting low-frequency alias and relate that to the sampling frequency.

**Low resolution experiments:**

9. Set all parameters to the same as in step 1 and observe Chart 1 as a reference.

10. Observe the waveform when the resolution is changed to 4, 3, and 2 bits. Note that the discrete levels are visible.

**Over-range experiments:**

11. Set all parameters to the same as in step 1 and observe Chart 1 as a reference.

12. Change the voltage span to 1 Volt and note the clipping that occurs. The output of the analog-to-digital converter saturates at the input maximum and minimum values.

**Practical A/D application:**

13. Set the parameters to 60.2 Hz, 1 volt peak signal, 10 Hz sampling, 2 volt span, 8 bit resolution, and display over-sampling to 1. The chart will show the effect of a very low frequency alias that often occurs in real instruments where the sample frequency is a sub-multiple of the AC power line frequency.

14. Change the sample frequency to 11 Hz and observe that the alias is at a higher frequency that could probably be eliminated with appropriate digital filtering.

15. Change the sample frequency to 15 Hz and observe a similar low frequency alias as in step 13.

16. Change the sample frequency to 22 Hz and observed that the alias frequency is 6 Hz. Change the signal frequency to 50 Hz and note that the alias frequency remains at 6 Hz. Why is the alias frequency the same in both cases?

17. One conclusion from the above observations is that it is bad to sample at a frequency that is a sub-multiple of the AC line frequency since a near DC alias results. Identify all sample frequencies between 10 and 30 Hz that are poor choices for 60 Hz and 50 Hz power line frequencies.

18. Derive all sample frequencies between 10 and 30 Hz for which the resulting alias frequency for either 60 or 50 Hz power line frequency is identical and away from DC. Also identify the resulting alias frequency for each. List the frequencies in descending order of the resulting alias frequency – i.e. highest alias frequency to lowest. This derivation takes a little thought but is not hard. The result is very practical for use in industrial situations where it is frequently not practical to put low-pass anti-alias filters on many analog signals to be digitized. Frequently the desired signals are very near DC and a relatively high frequency (several Hz) alias of the power line frequency can be easily removed with digital filters (typically a simple notch filter based on FIR methods). A low frequency alias of the power line frequency near DC is impossible to remove and often causes many problems.