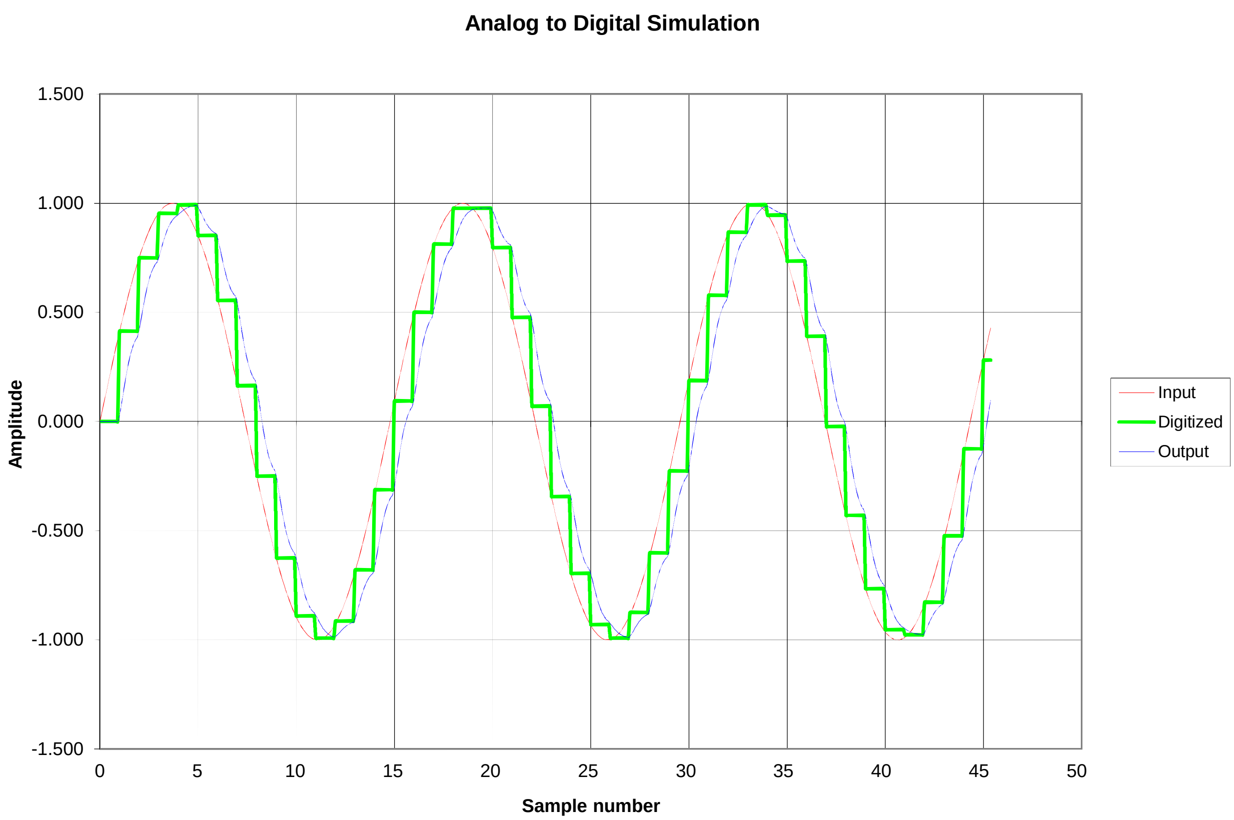
EE431 Lab 8
Analog/Digital Converters

March 30, 2012

This lab uses the spreadsheet, a2dsim.xls (on the EE431 web site), to simulate analog to digital conversion and digital to analog conversion. Paste (as an enhanced metafile works well) each Excel plot into a Word document as a picture sized such that you can put two pictures per page (sometimes perhaps only one per page depending on space required by other text) with captions that clearly indicate what is being shown – a series of unlabeled or poorly labeled pictures is meaningless to you and anyone that reads the report – samples are shown below – there is no need to mention the display oversampling factor as that is not relevant. *Caution: Be careful not to confuse the input sine wave frequency with the sample frequency with filter frequency in the following or your results will be useless.* You enter parameters on Sheet1 of the Excel workbook and observe the resulting plot on Chart1.

General experiments:

1. Set the parameters to 1083 Hz, 1V peak sine wave with 16,000 Hz sample frequency, 2 volt span and 8-bit resolution. Set the output low-pass or smoothing filter to 7500 Hz. Set the display over-sampling choice to 3.



Plot of 1083 Hz 1 volt peak sine wave sampled at 16,000 Hz
A/D has 2 volt span, 8-bit resolution, Output smoothing filter: 7,500 Hz

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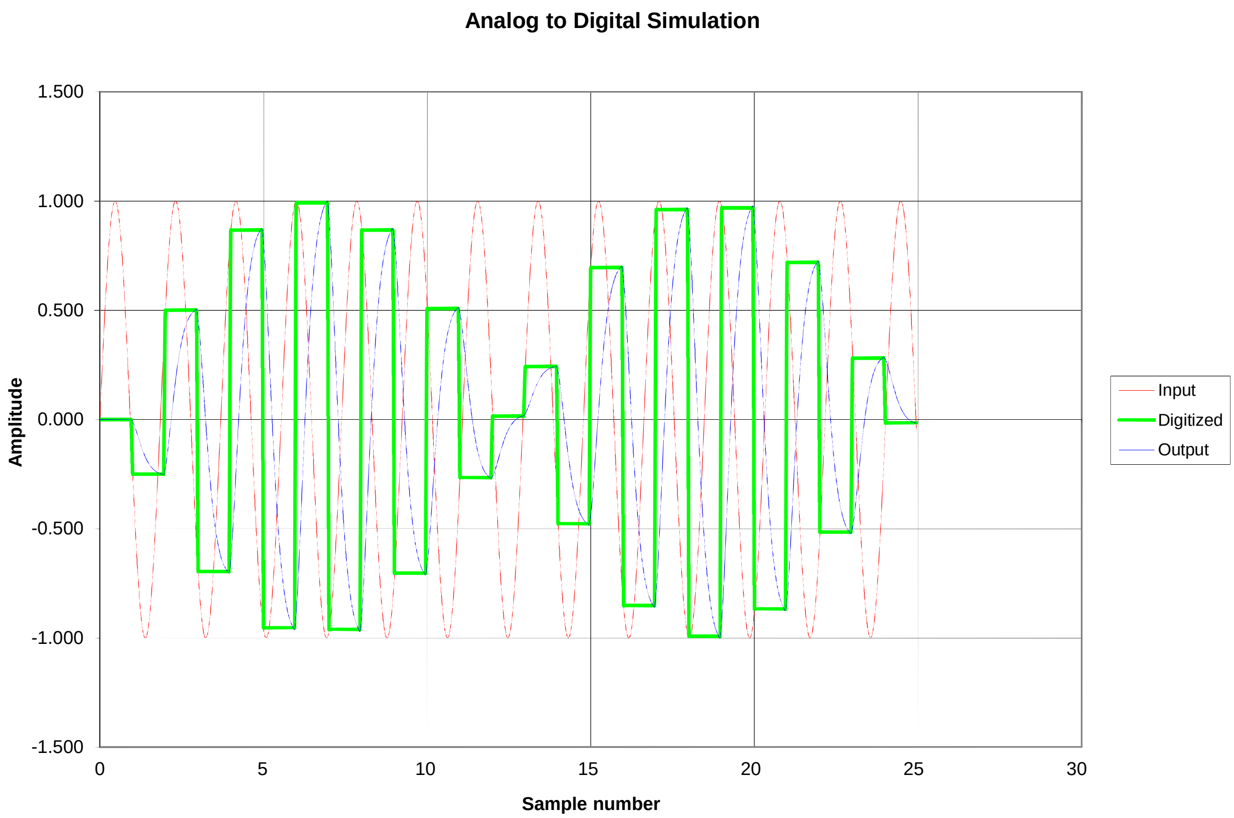
2. Observe chart 1 and note that the smoothed reconstructed sine wave has visible steps. Set the smoothing filter cutoff frequency to 4,000 and note the reconstructed sine wave is smoother.

3. Change the sample frequency to 8,000 Hz and observe how the sampled waveform becomes coarser.

Alias experiments:

4. Set the parameters to 1083 Hz, 1 volt peak sine wave with 2,000 Hz sample frequency, 2 volt span and 8-bit resolution. Set the output low-pass filter to 1,300 Hz and the oversampling choice to 2.



Example of Aliasing: 1083 Hz 1 volt peak sine wave sampled at 2,000 Hz
A/D has 2 volt span, 8-bit resolution, Output smoothing filter: 1,300 Hz

5. Observe that the output frequency is lower than the input frequency since aliasing has occurred (Look carefully – the output frequency is clearly lower than the input frequency). The sampled waveform is the summation of multiple frequencies produced by aliasing.

6. Set the sampling frequency to 1,000 Hz and output filter to 600 Hz leaving everything else the same. 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. This is a situation of synchronous sampling – the sample points happen to all be at the zero crossings of the input sine wave – thus all samples are zero volts. If the phase of the synchronous sampling points was different than the zero crossing points then the output would be a DC voltage related to the phase of the sampling relative to the input sine wave.

8. Observe the sampled 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 the parameters to 1083 Hz, 1V peak sine wave with 64,000 Hz sample frequency, 2 volt span and 8-bit resolution. Set the output low-pass or smoothing filter to 4,000 Hz. Set the display over-sampling choice to 3. Observe the fineness of the samples in the sampled waveform.

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

Over-range experiments:

11. Set the parameters to 1083 Hz, 1V peak sine wave with 16,000 Hz sample frequency, 1 volt span and 8-bit resolution. Set the output low-pass or smoothing filter to 4,000 Hz. Set the display over-sampling choice to 3.

12. Observe that since the input signal exceeds the A/D input range that clipping occurs.

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, 7 Hz low-pass filter, and display over-sampling to 1. The chart will show (only about 90 degrees) the effect of a very low frequency alias (what is the alias frequency) that often occurs in real instruments where the sample frequency is a sub-multiple of the AC power line frequency (the power line frequency averages a very precise 60 Hz over time but at any moment can be off by a few tenths of a Hz). Sub multiples of the power line frequency (or any signal that could alias) are bad sample frequencies to use for this reason – few understand why and spend a long time chasing

phantom low frequency phenomena. The dominant spectrum of the alias in this situation is near DC – the worst possible location.

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. In low frequency sampling the interest is in signals whose spectra is between DC and only a few Hz. An alias is removable if it occupies a different spectrum than desired signals.

15. Change the sample frequency to 15 Hz (another sub-multiple of 60 Hz) and observe a similar low frequency alias as in step 13.

16. Change the signal frequency to 60 Hz and change the sample frequency to 22 Hz and observed that the alias frequency is 6 Hz (it will take a couple of measurements and calculations from the plot). 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? For systems that might have to work in either a 50 or 60 Hz environment it is good to choose a sample frequency that produces an identical alias frequency as far removed from DC as possible – that alias is then easy to remove with digital filtering (often an FIR notch filter). Some good frequencies are 11, 18.333, 22, and 27.5 Hz. The worst case situation is a sample frequency that produces an alias at or near DC – that is impossible to remove.