

Digital to Analog Conversion (DAC) and Analog to Digital Conversion (ADC) Simulation using Electronics Workbench (EWB)

Name _____

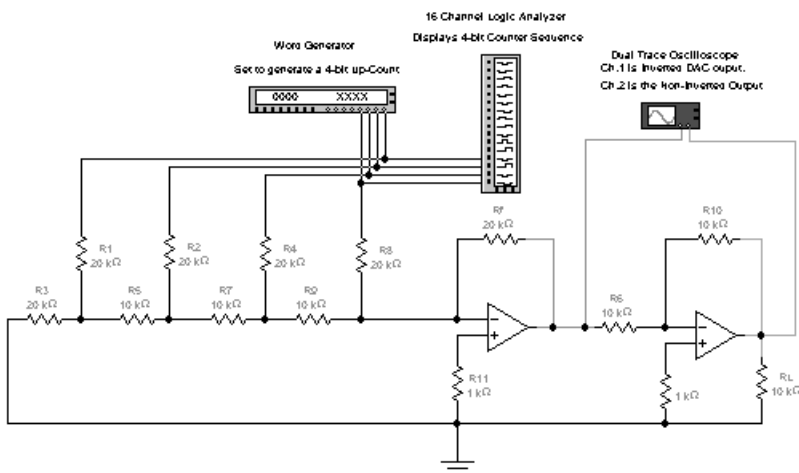
This exercise will make use of Electronics Workbench to investigate ADC and DAC circuits. A pdf version of this lab and the two EWB files are available on the Forums at cset.stcc.edu/forums in the 2016 Spring EET-250 Lab area, Week #4 . Do not attempt to construct these EWB files on your own.

Analog to Digital Converters (ADCs) and Digital to Analog Converters (DACs) form the bridge between the human analog and the computer's digital world. Your mp3 player is a dedicated DAC, converting digitally encoded music into an analog form which can drive headphones or speakers. Somewhere earlier in the process, there was an ADC that converted analog sound waves into binary ones & zeroes (digital) which ultimately would become your mp3 song. As computers became more powerful and less expensive the demand for ADC and DAC circuits rose proportionately.

The circuits that will be investigated here are some basic examples of how digital signals can be converted to analog, and then how analog signals can be converted to digital. Note that anytime a conversion is performed, there are always opportunities for errors and inaccurate conversion. For any application, it's important to choose the ADC or DAC that will provide the level of accuracy and speed necessary.

The first circuit is an R-2R DAC circuit with an inverting amplifier on the output to generate a positive analog output voltage. The resistors R1, R2, R4 and R8 are numbered such that they show the weight of the binary input that they represent, from LSB to MSB. The word generator is configured to generate a 4-bit up-count from binary 0000 to 1111 and then repeat. The logic analyzer is designed to monitor up to 16 logic lines simultaneously and put the display on an oscilloscope-like screen. The dual-trace oscilloscope is similar to the units that you are familiar with in our lab. On your EWB file, you should notice that the input channels of the

oscilloscope are blue (Ch. 1) and red (Ch. 2). This will cause the displays on the oscilloscope to be blue and red, respectively. Keep in mind that when printing on a laser printer, the displays will both be black. To energize this circuit, you must "click" on the power button (0 / 1) in the upper right-hand corner of the display. After sufficient time has elapsed, you can stop the analysis and study the displays generated on the logic analyzer and the oscilloscope.



PROCEDURE (Digital to Analog Conversion):

- 1.) Load the file for the R-2R DAC circuit. Energize the circuit and study the logic analyzer output and the oscilloscope display. Items to note: the logic analyzer showing the 4-bit binary count applied to the DAC, the inverted DAC output and the "righted" analog output.

How many "steps" are there in the analog output?

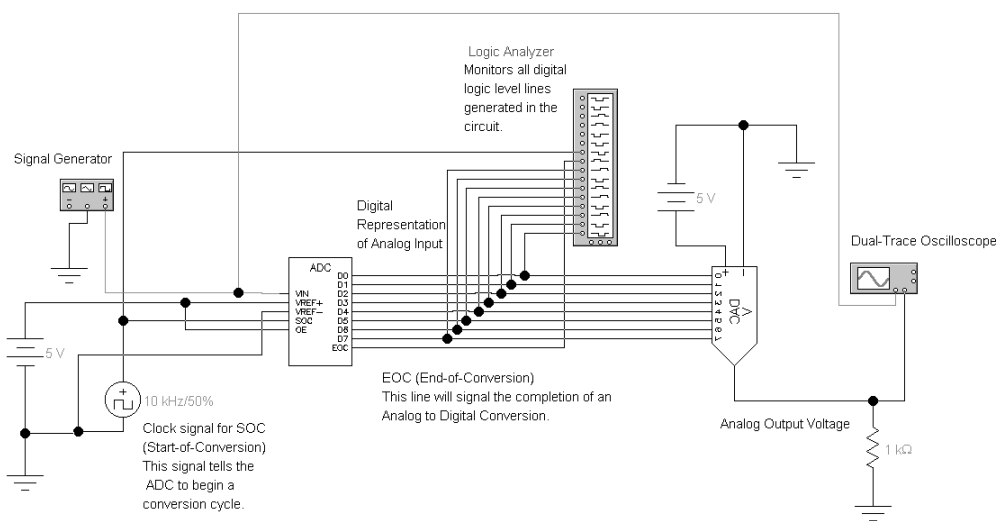
What is the resolution of this DAC in percent?

What is the output resolution in volts (i.e., the smallest voltage difference possible between steps)? The “1” and “2” marker tabs on the ‘scope display screen might be helpful for this. *Take a screenshot of your computer screen (emphasis on scope display if possible). Post this as a reply on the Forums for this week. Use an editor program to put your name ON the screenshot.*

- 2.) Change the value of R3 to 5k. (This is somewhat of a drastic error, but will demonstrate the effect of inexact resistance values on the DAC output.) Study the output of the DAC now on the ‘scope. What happened? Why? After answering these questions, return the value of R3 to 20K.
- 3.) Use the “Fault” option (Right click on R2) under resistor properties to “open” resistor R2. What happens to the DAC output seen on the ‘scope? Why? Correct this fault and then one at a time, apply an open fault to resistors R1, R4 and R8, noting the effect on the output in each case.

Analog to Digital Conversion and back to Analog

The second circuit we will investigate is a complete ADC and DAC system. The analog input is obtained from a signal generator that will allow us to select either sine, triangle or square wave input. A DC offset is added so that the signal applied to the ADC is all positive. The logic analyzer is used again to display all of the digital logic signals that exist in the system: the 8 data bits representing the analog input, the SOC (start of conversion) and the EOC (end of conversion) signals used by the ADC. The DAC accepts the 8-data bits and converts them to a proportional analog output voltage. The two 5-volt supplies set reference voltage levels for the ADC and the DAC...essentially defining the analog voltage operating ranges for each device.



- 4.) Load the EWB circuit file for the ADC/DAC system. Energize the file as supplied while monitoring the ‘scope display. You can stop the analysis after two cycles of the input. The input is a sinusoidal wave with a frequency of 1kHz. Compare the output to the input.

- 5.) Change the input signal to a triangle wave. How does the output compare to the input? How does it compare to the analog approximation of the sine wave? NOTE: You can switch between sine and triangle wave by using the “PAUSE” feature of EWB...change the generator settings...then click on “RESUME”.

The analog converted signal of the sine and triangle wave should look pretty similar since the sampling rate is relatively low.

- 6.) Increase the SOC clock signal to 50 kHz. The ADC will now sample the signal at five times the rate of the first example. Set the input signal to a sine wave and then the triangle wave. Do the analog outputs more closely resemble the analog input in each case?

Take a screenshot of your computer screen (emphasis on scope display if possible). Post this as a reply on the Forums for this week. Use an editor program to put your name ON the screenshot.

- 7.) Decrease the SOC clock signal to 1500 Hz (something less than 2 kHz, less than twice the sine wave frequency). The Nyquist Sampling Theory states that a signal must be sampled at a rate at least twice as high as the highest frequency component in order to retain all the information in the original signal. This criteria is not met on this step, what do you observe about the output (analog) signal? It should be highly distorted. (With a bit of analysis, it can be shown that the reconstructed analog signal you are viewing has a fundamental frequency of 500 Hz, not the 1000 Hz of the original. The signal has been distorted and information carried in that signal has been lost.) The Nyquist Sampling Theorem must be obeyed for all analog to digital conversion processes.
- 8.) Return the SOC signal to 50 kHz. Change the input to a square wave. Again view the ‘scope display. Do the system input and output look similar?
- 9.) View the logic analyzer output from the square wave input. Observe the binary output of the ADC. How does it relate to the square wave input? What binary values are output from the ADC? Express these numbers in hexadecimal.
- 10.) Keeping the square wave input, reduce it’s amplitude to something less than the current setting and note this amplitude. How are the ADC and DAC outputs effected?

What are the hexadecimal equivalents of the ADC output now?

- 11.) Did these exercises strengthen your understanding of the ADC and DAC processes? What is the most significant concept that these exercises demonstrated to you?