17.368 Data Conversion and Lab
Lab 4
Fall 2013

Digital to Analog Conversions

Objective

- o To construct and operate a binary-weighted DAC
- o To construct and operate a Digital to Analog Converters
- o Testing the ADC and DAC With DC Input
- o Testing the ADC and DAC With A Sinusoidal Input
- o Integrated Digital to Analog Converter Signal Generator

References

(a) Agilent Technologies "EducatorsCorner.com" Experiment on A/D and D/A

Materials

o	1	Breadboard	
o	1	Oscilloscope	
o	1	Dual Power Supply (+18 V and –18 V)	
o	1	5 V DC Supply	
o	1	Oscillator of Function Generator for signal source	
o	1	741 Linear IC	
o	1	DAC0800LCN (Digital to Analog Converter)	
o	1	DIP Switch (8 switches minimum)	
o	1	1 k Ohm Resistor Pack (8 Resistors, minimum) or (8) 1 K Ohm Resistors (Brown Black Red)	
o	2	7493 Synchronous 4-Bit Up/Down Counters	
o	1	10 V Zener Diode	
o	1	LM78L05 voltage regulator	
o	1	470 Ohm Resistor	(Yellow Violet Brown)
o	2	5.1 k Ohm Resistors	(Green Brown Red)
o	2	10 k Ohm Resistors	(Brown Black Orange)
o	1	16 k Ohm Resistor	(Brown Blue Orange)
o	1	20 k Ohm Resistor	(Red Black Orange)
o	1	39 k Ohm Resistor	(Orange White Orange)
o	1	82 k Ohm Resistor	(Grey Red Orange)
o	1	100 k Ohm Potentiometer	
o	1	0.01 μF Capacitors	(103)
o	3	0.1 μF Capacitor	(104)
o	1	10 μF Capacitor	

WARNINGS AND PRECAUTIONS

1. Never install or remove the components from an energized circuit

2. Do not construct circuits while energized

3. Follow electrical safety precautions

Background Information

None.

Pre-Lab Preparation

1. Download the component Data Sheets available on the course web page.

Procedure

Experiment 1. (Binary-Weighted D/A Converter)

a. Assemble the circuit shown in Figure 1.

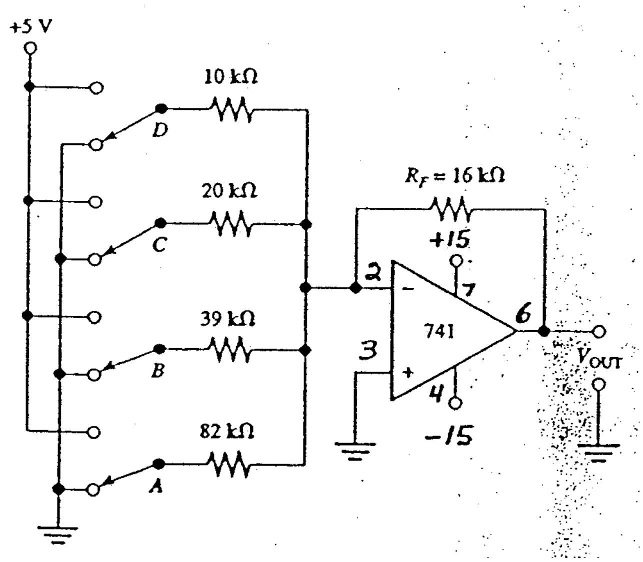


FIGURE 1
Binary-weighted D/A Converter

b. Calculate the values of V_{OUT} for the circuit shown in Figure 1 for each input specified in Table 1.

What formula did you use?

Why?

Table 1 Function Table		
DCBA	Vout	
Inputs	Calculated	Measured
0000		
0001		
0011		
0101		
1000		
1011		
1100		
1111		

c. Measure V_{OUT} for the circuit shown in Figure 1 for each input specified in Table 1 by positioning the switches in the circuit to the binary numbers listed in the input section. Record results in Table 1. How do the measured values compare to the calculated values?

Experiment 2. (8-Bit D/A Converter - Basic Bipolar Output Operation)

a. Review the DAC0800 Data Sheets for the features of this device.

b. The supply voltages will be the +15 and the –15 volts D.C., the reference voltage will be +10 volts D.C. (use a **10 volt Zener diode** with a resistor to make a 10 volts D.C. source OR use a potentiometer and adjust to 10 V). Pin 14 (the reference) voltage is critical. You need to be as close to 10 volts as you can. **NOTE: The 10 volts is measured on the left side of the 5k resistor.**

   1. The digital input will be the standard **TTL 5 volt** signal levels (use a voltage regulator to get +5 volts for TTL levels, **LM78L05**, 100 ma. Output max. or you can use a power supply).

c. A DIP Switch will be used for the Digital Signal input control with 1 K Ohms pull-up SIP resistor pack or you can use (8) 1 K Ohm resistors. The schematic will be the same as in the DAC0800 Data Sheet Figure 1 on page 1 and as modified by Figure 2 of this Lab.

d. When the circuit is working measure the output voltages for the seven switch input configurations on page 7 (figure 7) of the DAC0800 Data Sheets and record in a similar table.

e. Choose one digital input. Record the output voltage. Vary the reference voltage to Pin 14. Note the effect on the output voltage as you vary the reference. What effect, if any, do you see at the output? How much of a change to the reference voltage is required to see an effect on the output, if any?

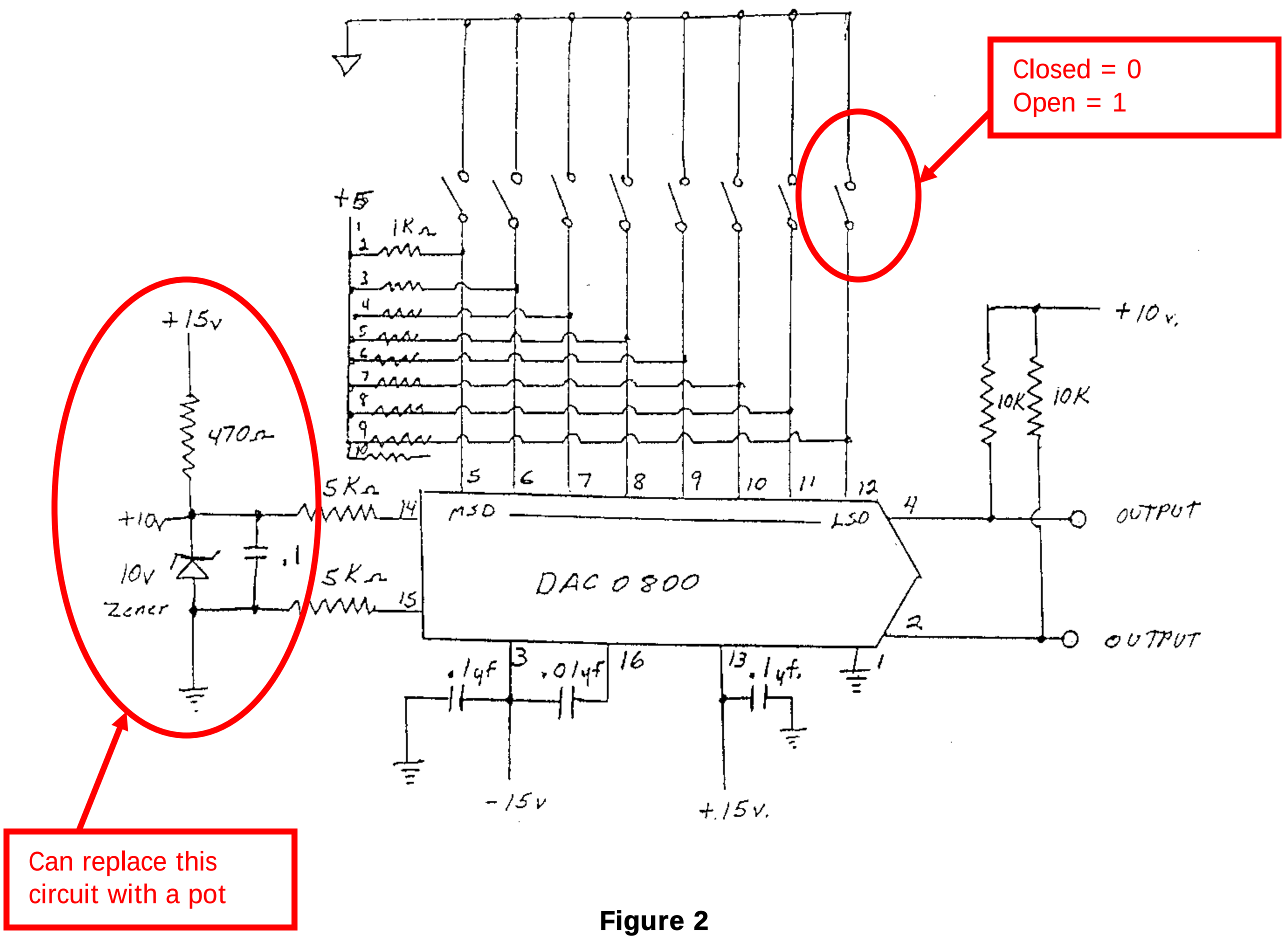

Closed = 0
Open = 1
+5
1KΩ
+15v
470Ω
+10v
10v
Zener
.1
5KΩ
5KΩ
MSD
LSD
DAC 0800
+10v.
10K
10K
OUTPUT
OUTPUT
.1µf
.01µf
.1µf.
-15v
+.15v.
Can replace this circuit with a pot

Figure 2

Experiment 3. <u>(Testing the ADC and DAC With DC Input)</u>

Background Information

This experiment requires that you tie the Analog to Digital circuit from lab #3 (also shown in Figure 3) to the input of the Digital to Analog circuit, Figure 4.

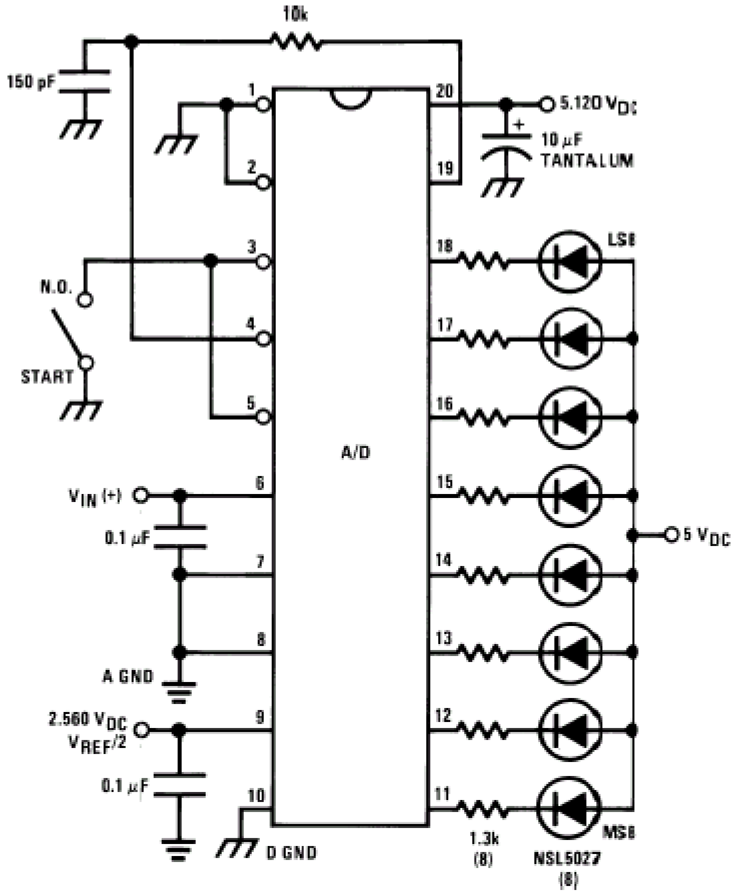
The 8-bit output of the ADC, Figure 3, gets connected to the 8-bit input of the DAC0800, Figure 4. Do this as follows: connect the MSB of the ADC (pin 11 of the ADC0804), to the MSB of the DAC (pin 5 = A1 of the DAC0800). Next, connect pin 12 above to pin 6. Do this for each bit, ending with the LSB, so that pin 18 (LSB output of the ADC) is connected to pin 12 (LSB input of the DAC).

NOTE: Steps “a” through “d” has already been accomplished in Lab # 3 and are shown below just to build upon the remainder of the experiment.

a. Construct the ADC circuit shown in Figure 3 (this is the same circuit used in Lab #3). Do not connect the circuit to the DC power supply, or to an input signal at this time. Make the MSB LED on the left, and the LSB LED on the right.

   Be VERY careful to include all needed components and wires, and to NOT put in wires that aren't needed.

   It's much easier to build it correctly, even if it takes a bit longer to do so, than it is to make a mistake and have to troubleshoot it later.



This circuit is from page 24 of National Semiconductors document : *http://www.national.com/ds/AD/ADC0801.pdf*

IMPORTANT NOTES for the ADC0804:

1. Separate grounds must be used: one for analog, and one for digital. This is a VERY important concept, to avoid digital noise from getting into the analog input circuit. Use a separate bus for each ground, and bring them together only at a single point: the negative terminal of the 5 V power supply.

2. A "START" switch *may* be needed. As shown, the ADC is in "free-running" mode. At the end of one conversion, another starts. Under certain conditions, the circuit may not begin the analog-to-digital conversion process unless pins 3 & 5 are momentarily grounded. This may be done manually, or may be done with a series R-C circuit (a power-on "start" circuit): 10k Ω to =5 V, 0.1µF to ground, junction to pins 3 & 5. Every time power is applied, the 0.1µF will hold pins 3 & 5 low, until it charges through the 10k Ω.

Figure 3

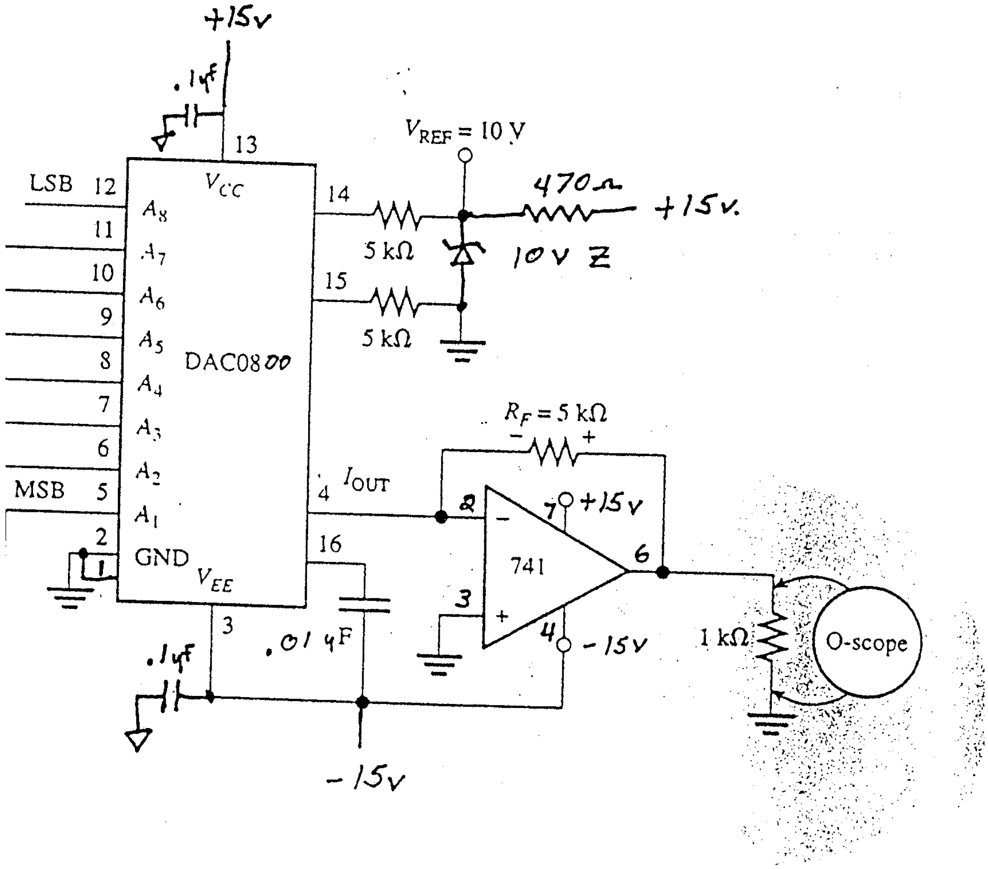


Figure 4

b. Now build the DC input circuit shown in Figure 5. The value of the potentiometer is quite unimportant; anything from a 1k to a 100k will be fine.

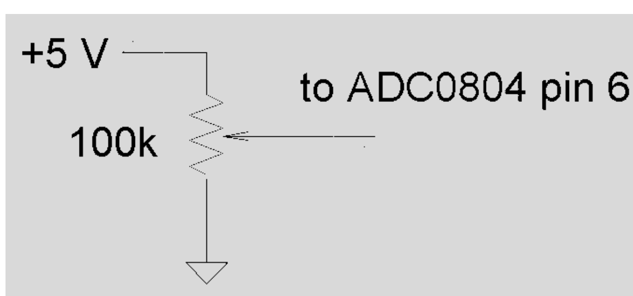


Figure 5

c. Set the current limit controls on both of your power supplies to about 50 mA (proper use of current limiting can prevent an LED from becoming an SED [smoke-emitting diode]). Now turn on the DC power (for the +5 V and the -15 V supply).

d. With the wiper of the input circuit potentiometer at ground (analog V_{in} = 0 V), the 8-bit output of the ADC should be all zeros ($0000\ 0000_2$).

The way the LEDs are connected, each LED will light up when the bit it represents is ***low = 0_2***. So, all LEDs should be lit at this time.

Now move the wiper slowly from 0 V to +5 V, while observing the LEDs. The LEDs should turn on and off in a binary counting order. For example, the LED pattern should follow the following pattern:

MSB							**LSB**	
ON	ON	ON	ON	ON	ON	ON	ON	$= 0000\ 0000_2 = 000_{10}$
ON	ON	ON	ON	ON	ON	ON	**OFF**	$= 0000\ 0001_2 = 001_{10}$
ON	ON	ON	ON	ON	ON	**OFF**	ON	$= 0000\ 0010_2 = 002_{10}$
ON	ON	ON	ON	ON	ON	**OFF**	**OFF**	$= 0000\ 0011_2 = 003_{10}$
ON	ON	ON	ON	ON	**OFF**	ON	ON	$= 0000\ 0100_2 = 004_{10}$
ON	ON	ON	ON	ON	**OFF**	ON	**OFF**	$= 0000\ 0101_2 = 005_{10}$
:								:
:								:
OFF	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	$= 1111\ 1111_2 = 255_{10}$

This counting pattern above is in 255 steps from $0000\ 0000_2$ (all LEDs ON) until, with the wiper at +5 V, the pattern should be: = $1111\ 1111_2$ (all LEDs OFF):

e. Now construct the DAC circuit shown in Figure 4. Connect the eight bits at the output of the ADC to the eight-bit input of the DAC. Remember that the way the LEDs are connected, each LED will light up when the bit it represents is low = 0_2.

f. We will now test the ADC and the DAC as a system, using different DC input voltages (set by you using the potentiometer) so that one bit at a time is tested.

MSB LED	**LED**	**LED**	**LED**	**LED**	**LED**	**LED**	**LSB LED**	**Vin (V)** to the ADC	**Vout (V)** from the

									DAC
Off	Off	Off	Off	Off	Off	Off	Off		
Off	ON	ON	ON	ON	ON	ON	ON		
ON	Off	ON	ON	ON	ON	ON	ON		
ON	ON	Off	ON	ON	ON	ON	ON		
ON	ON	ON	Off	ON	ON	ON	ON		
ON	ON	ON	ON	Off	ON	ON	ON		
ON	ON	ON	ON	ON	Off	ON	ON		
ON	ON	ON	ON	ON	ON	Off	ON		
ON	ON	ON	ON	ON	ON	ON	Off		
ON	ON	ON	ON	ON	ON	ON	ON		

In the table above, you should see that the input voltage to the ADC decreases from about 5 V to 0 V as you go from the top row to the bottom row. Likewise, the output voltage from the DAC changes from about +4.2 V to 0 V as you go from the top row to the bottom row.

Based on the data in the table above, what is the "resolution", in volts, of the ADC? Show how you determine the answer (there are several ways).

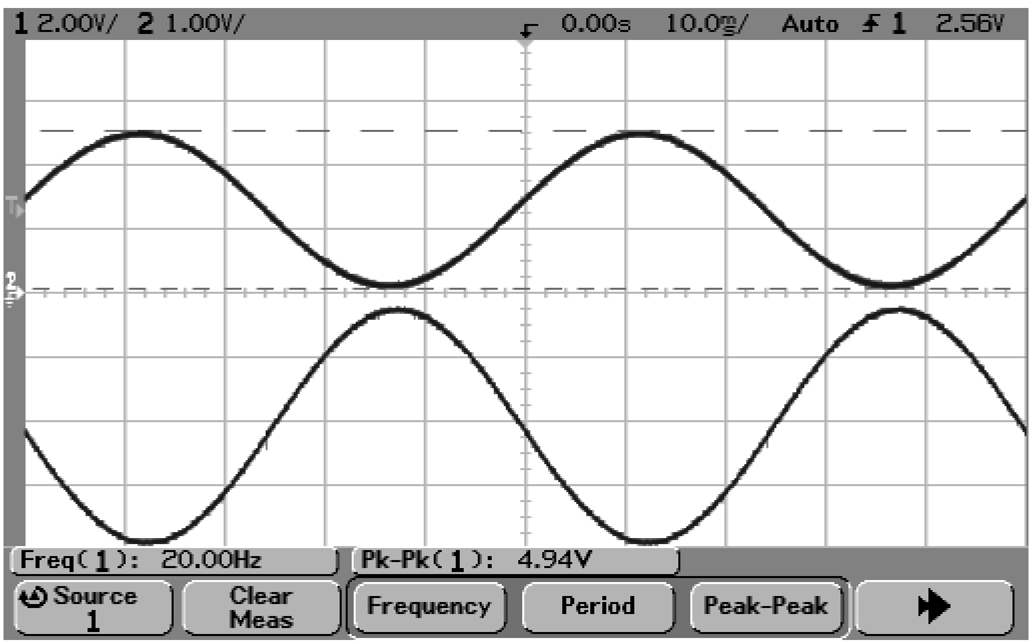
Based on the data in the table above, what is the "resolution", in volts, of the DAC? Show how you determine the answer (there are several ways).

Experiment 4. **(Testing the ADC and DAC With A Sinusoidal Input)**

a. Don't connect the function generator to the circuit yet. Set it to produce a sinusoid as follows: 2.5 Vp = 5.0 Vpp, at 20 Hz. Do this with only the generator connected to the oscilloscope.

b. Turn off the power to the ADC/DAC circuit. Apply a 5 Vpp sinusoid signal to pin 6 of the ADC.

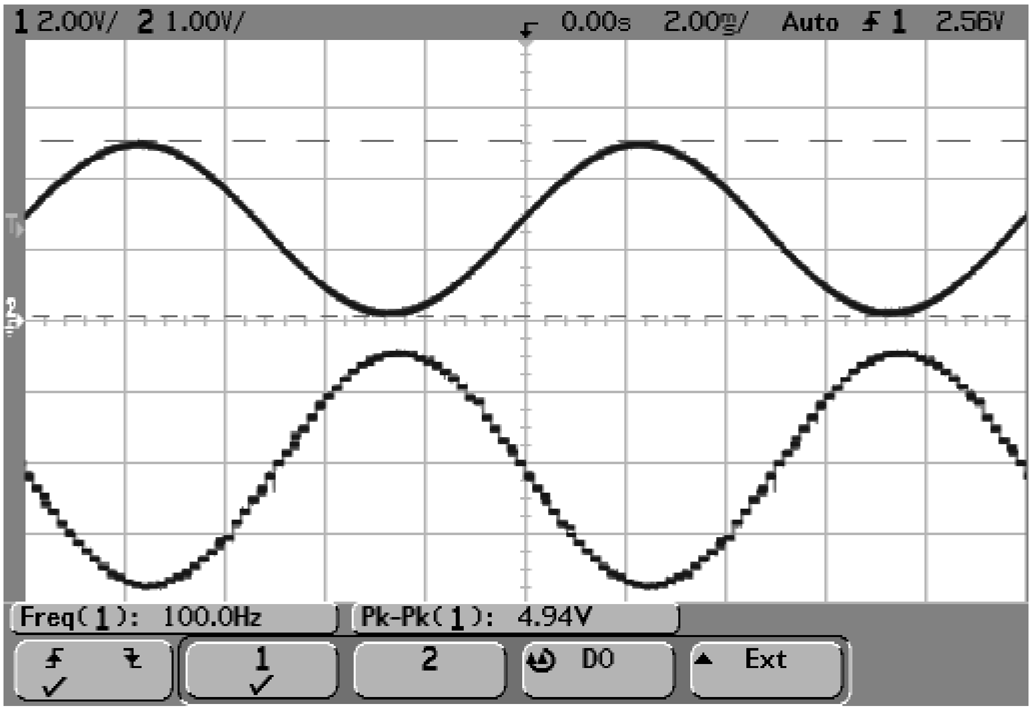
c. Turn on power. Using two 10X probes, connect Channel 1 to the input to the ADC, and Channel 2 to the output of the DAC. The display should look similar to the one below. Notice that Vin and Vout are 180° out of phase.



The input sinewave (top trace) is at 20 Hz., and is the input signal to the ADC.

The bottom trace is the output from the DAC. While it's hard to see, it is made up of 255 steps of voltage.

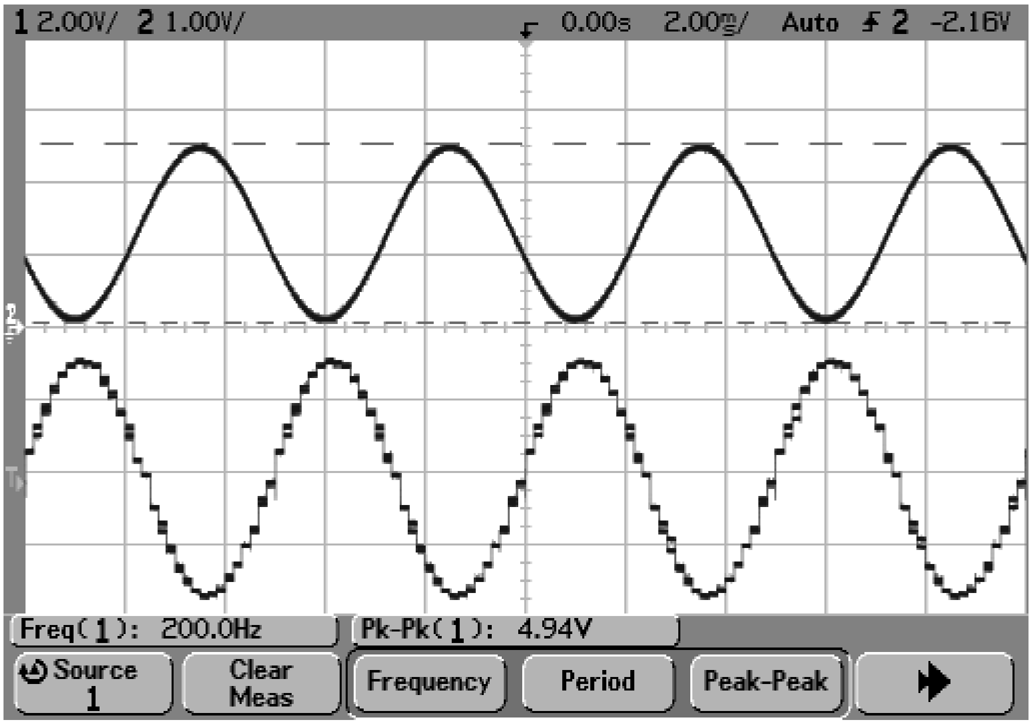
d. Now increase the frequency of the function generator to 100 Hz. The output (shown below) now doesn't look like a clean sine wave; clearly it is a step approximation to a sine wave.



The input sinewave (top trace) is at 100 Hz., and is the input signal to the ADC.

The bottom trace is the output from the DAC. It is easier to see, at this frequency, that the output waveform is made up of steps of voltage (and far fewer than 255 steps - Why?).

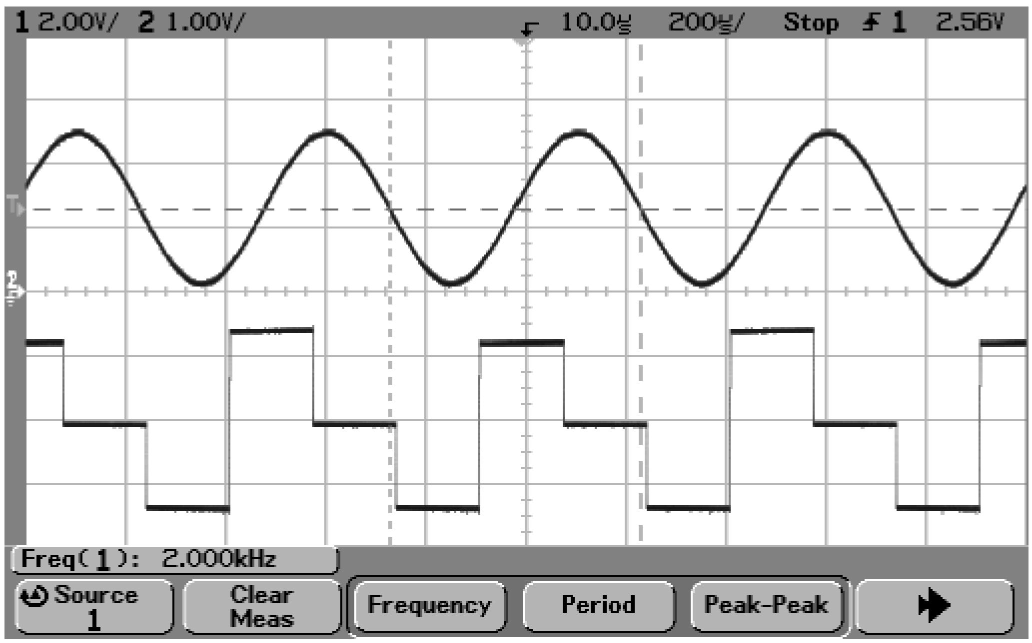
e. Now increase the frequency of the function generator to 200 Hz. The output (shown below) now doesn't look like a clean sine wave; clearly it is a step approximation to a sine wave.



The input sinewave (top trace) is at 200 Hz., and is the input signal to the ADC.

The bottom trace is the output from the DAC. It is easier to see, at this frequency, that the output waveform is made up of steps of voltage, some of them quite large. Recall that the resolution of our DAC is 16.1 mV; some of the steps above are over 200 mV!

f. Now increase the frequency of the function generator to 2,000 Hz. The output (shown below) now doesn't look like a clean sine wave; clearly it is a 2-step 3-level approximation to a sine wave.



The input sinewave (top trace) is at 2,000 Hz., and is the input signal to the ADC.

The bottom trace is the output from the DAC. At this frequency the output waveform is made up of **TWO** steps of voltage, and three levels. The width of each step is the conversion time of the ADC0804 analog-to-digital converter (about 166 μs).

Experiment 5. (Integrated Digital to Analog Converter Signal Generator)

NOTE: This Experiment is optional. Those that are interested in exploring other circuitry used with DACs can perform this Experiment. Whether you do this Experiment or not will not result in any points being deducted or added to your final lab grade for Lab #4.

a. Assemble the circuit shown in Figure 6.

b. Turn on the power and apply a clock frequency of 10 kHz to the cascade counters.

c. Observe the analog output with an oscilloscope. NOTE: The clock must be TTL Signal (zero to five volts).

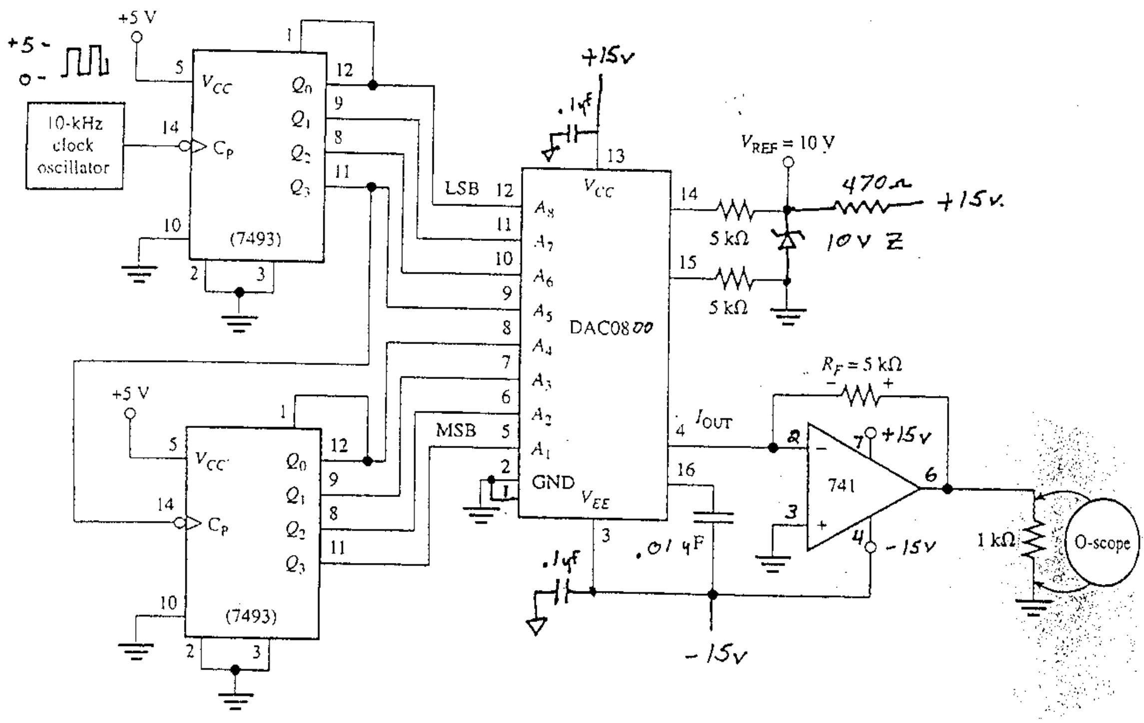


Figure 6