UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 10 – ANALOG-TO-DIGITAL AND DIGITAL-TO-ANALOG CONVERSION

OBJECTIVES

The purpose of this experiment is to familiarize the student with the aspects of Analog-to-Digital and Digital-to-Analog signal conversion.

INTRODUCTION

There are many analog parameters to deal with in the world of technology and these parameters are increasingly being converted to digital formats. Examples include time, temperature, and audio which are being turned into digital signals in items like digital clocks, digital thermometers, and audio CDs and MP3s. Analog-to-Digital Converters (ADCs) and Digital-to-Analog Converters (DACs) play key roles in the digitizing of analog parameters and the subsequent restoration of digital information to its analog form.

A specific example of the increasing change in technology to digital format is the simple thermometer. An analog thermometer is composed of a glass capillary tube connected to a reservoir of mercury. Put under the tongue of a person, the mercury resorvoir warms up, and expands in volume. The expansion pushes a column of mercury up the thin hollow channel in the glass, and a calibrated scale etched in the glass allows the temperature to be read by the length of the mercury column. These parameters (temperature and length of the mercury column) are pure analog. Mercury is a toxic substance and glass an easily breakable substance, therefore, digital thermometers have replaced these analog thermometers as they are much safer to use. A sensor in the tip of a digital thermometer changes resistance based on temperature, which creates a voltage proportional to temperature. This voltage is input to an analog-to-digital converter, the output of which is converted to base ten and fed to a liquid crystal display (LCD). The temperature is clearly read from the display, 98.6°F or 37°C.

In this experiment, an analog signal will be converted to a digital signal and observed using LEDs. The signal will then be converted from its digital format back to analog and compared with the original input signal to check its accuracy.

PRELAB

1. From the datasheet for an ADC0804 integrated circuit, draw a block diagram showing the pin connections. (Make sure to note the LSB and MSB positions.)
2. From the datasheet for a DAC0808 integrated circuit, draw a block diagram below showing the pin connections. (Make sure to note the LSB and MSB positions.)

PROCEDURE

1. Prepare the power supply for a DC voltage of +5V and use a voltage divider network to achieve as closely as possible, the +2.5V reference.

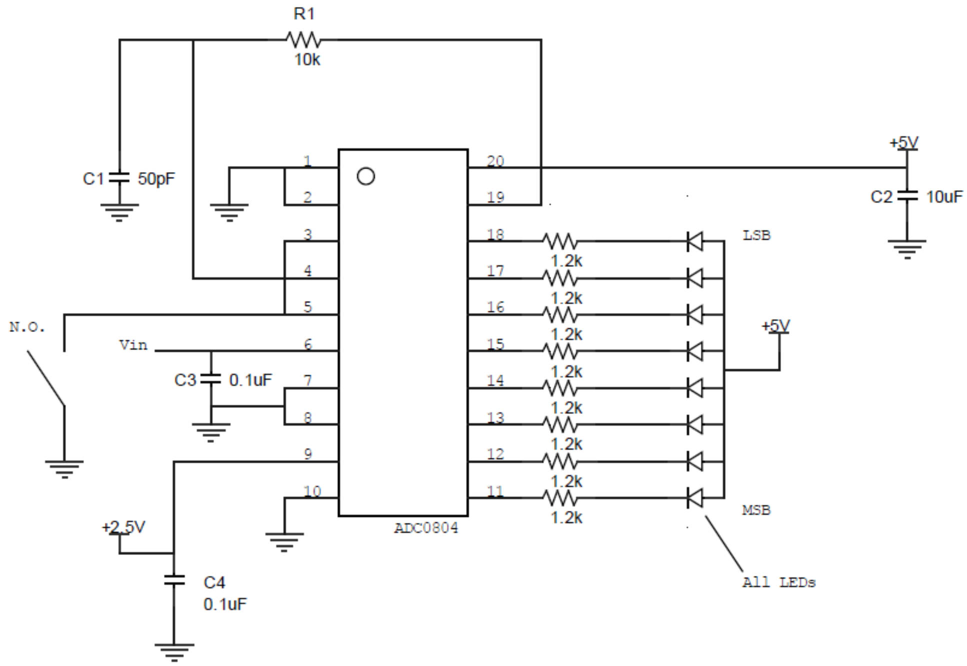

Figure 10-1 ADC0804 Connections

2. Connect the circuit shown in Figure 10-1.
3. Now build the DC input circuit shown below in Figure 10-2.

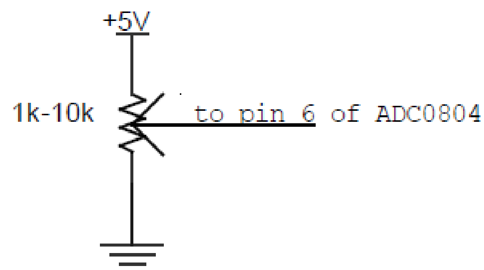

Figure 10-2 DC Input Circuit

NOTE: The digital output of the ADC will not be valid until pins 3 and 5 are momentarily connected to ground via the normally open (NO) switch shown in the circuit diagram.

4. With the wiper of the input circuit potentiometer at ground (analog V_{in} = 0V), 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). All LEDs should be lit at this point.

5. Now move the wiper slowly from 0V to +5V, while observing the LEDs. The LEDs should turn 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**	$= 0000\ 0011_2 = 003_{10}$
etc.	

6. This counting pattern will progress in 255 steps from $0000\ 0000_2$ (all LEDs ON) Until, with the wiper at +5V, the pattern should be $1111\ 1111_2$ (all LEDs off).
7. Construct the DAC circuit shown in Figure 10-3 below.

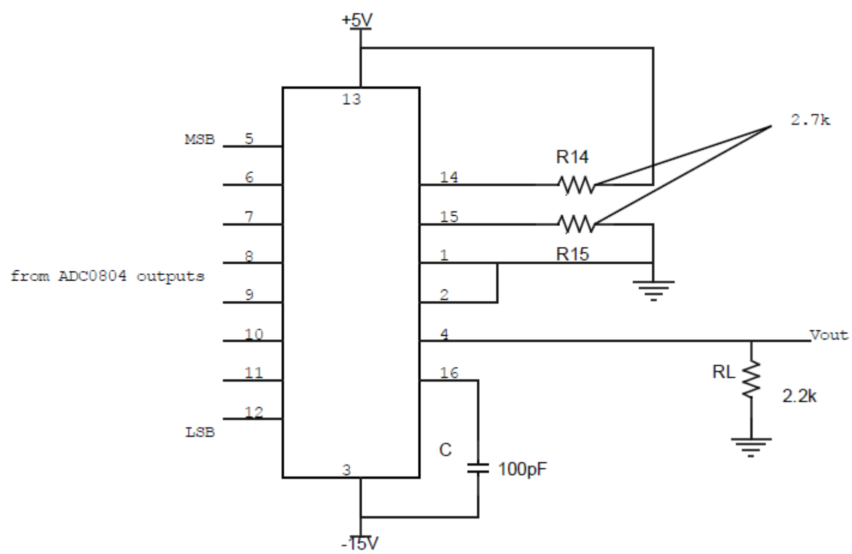

Figure 10-3 DAC0808 Circuit Connections

8. Connect the eight outputs of the ADC to the eight-bit input of the DAC. Be sure to connect the inputs such that they are in matching order (i.e. the connections match from LSB to MSB on the ADC and DAC).
9. You should observe that the outputs of the ADC are active low while the inputs of the DAC are active high. This will cause a 180 deg. phase shift between the original analog signal and the DAC output.
10. Using Table 10-1, fill in the appropriate voltages corresponding to the given conditions. The input voltage to the ADC should decrease from about 5V to 0V from the top of the table to the bottom. Likewise, the output voltage from the DAC changes from about -4.2V to 0V as you go from the top of the table to the bottom.

Table 10-1: Voltage Values for the ADC and DAC

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		

11. Prepare a function generator to produce a sinusoidal waveform at 20Hz with a magnitude of $5V_{p\text{-}p}$.
12. Turn off the power to the ADC/DAC circuit.
13. Build the circuit shown in Figure 10-4 below, which will allow for connection of the function generator.

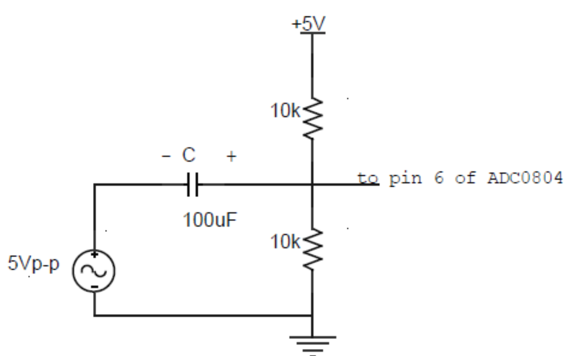

Figure 10-4 Sinusoidal Input Circuit

14. Turn on the power and connect the sinusoidal input circuit to the ADC/DAC circuit. At this point the capacitor C3 located between pin 6 and ground should be removed. If not it will act as a low pass filter, causing attenuation that will increase with the frequency of the sinusoidal input.
15. Use channel 1 of the oscilloscope to display the input to the ADC and channel 2 to display the output of the DAC. The waveforms should be approximately 180° out of phase. Measure and record the input and output values of voltage and frequency. Save the input and output waveforms.
16. Increase the frequency of the function generator to 100Hz, while maintaining the original voltage level. Measure and record the input and output values of the voltage and frequency. Make notes on the shape of the output waveform, it should appear slightly different than the input. Save the input and output waveforms.
17. Increase the frequency of the function generator to 200Hz, while maintaining the original voltage level. Measure and record the input and output values of the voltage and frequency. Make notes on the shape of the output waveform, it should appear slightly more different than the input as observed at 100Hz. Save the input and output waveforms.
18. Now increase the frequency of the function generator to 2kHz. Measure and record the input and output values of the voltage and frequency. Now the output should not look like a clean sine wave; it should appear as a step shaped approximation to a sine wave with approximately 3 to 4 steps per cycle. This is due to the decreased period of the input signal, now being only 3 to 4 times larger than the time between samples. Save the input and output waveforms.

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. From Table 10-1, calculate the "resolution" in volts for the ADC0804 and the DAC0808. Show how you determine your answer (there are several ways). Do the values calculated seem reasonable? What is the dynamic range for the ADC?
2. Include the waveforms obtained Steps 15-18 of the experiment in the report. Compare the input and output values for the voltage and frequency. How did the differences change as the frequency increased? Comment on the differences between the waveforms.
3. Calculate the percent error in the input and output waveforms (voltage and frequency) for steps 15-18. How does the percent error change as the frequency is increased, is the error large enough to be considered unacceptable?
4. Shannon's sampling theorem says that when sampling at the Nyquist rate or higher (twice the input frequency or greater), the input waveform can be recovered exactly with an ideal low-pass of cutoff frequency equal to ½ the Nyquist rate . Is the circuit sampling at the Nyquist rate or higher? If so, why are the output waveforms from steps 17 and 18 not the same as the input waveform?

Be sure to include all items from the post-lab exercise above in your written lab report.