Lab 8: Digital-Analog Conversion

Physics 327

Spring 2025

Goals

Gain experience with frequently-used mixed-signal devices that convert from analog voltages to digital values (ADCs) and from digital to analog (DACs).

Pre-Laboratory Exercises

To prepare for this laboratory:

1. Read about DACs and ADCs in Faissler Chapter 35–36.
2. Read the datasheets for the DAC0808 and ADC0809.

Introduction

Lab Procedure For this lab, *team up with another group* at the beginning of the lab session. Assign one group to complete Part A (building the DAC circuit) and the other group to complete Part B (the ADC circuit). Once these are built, work together using both circuits to complete Part C. Share your findings among the two groups and discuss this in your report.

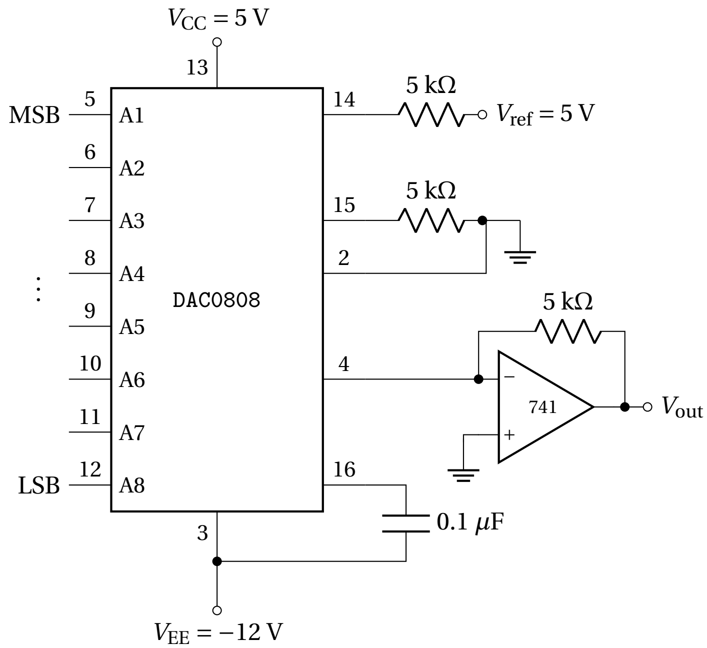
In this lab, you will set up and examine an Analog to Digital Converter (ADC) and a Digital to Analog Converter (DAC). The ADC takes an analog input voltage within a certain range (usually 0 to a reference voltage) and converts it to a binary number with a given number of bits. For example, an 8-bit ADC with $V_{\mathrm{ref}} = 5$ V maps the input range 0–5 V to the output range 0–255 (binary 00000000–11111111). These devices are commonly used in data acquisition systems, to digitally record voltage measurements in an experiment.

A DAC does just the opposite: you input a binary number and it outputs a corresponding analog voltage. A DAC often cannot supply much current, so it is common to use an op amp on the output to connect to a load. These devices are commonly used for digital control of the voltages in circuits. The analog voltage output necessarily takes discrete jumps, corresponding to the increment of the least significant bit (LSB). For better precision, one uses more bits: a 14-bit DAC with a 5 V *dynamic range* has smaller increments than an 8-bit DAC with the same range.

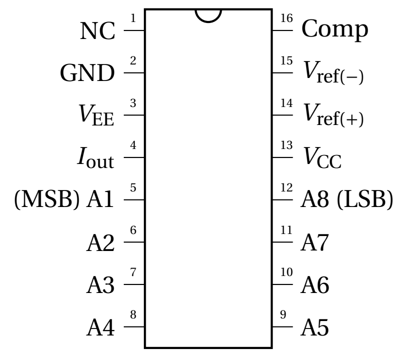
Note that for this lab you will need several power supply voltages: ± 12 V and $+5$ V supply voltages. Pay careful attention to the wiring diagrams and the absolute maximum values specified in the datasheets to avoid damaging these sensitive devices; for example, never input a negative value to the ADC0809. If powered incorrectly, the chips can also become extremely hot.

A Digital to Analog Conversion

A diagram of the **MC1408** (DAC0808) digital to analog converter circuit is given in Fig. 1a, along with the pinout in Fig. 1b. Refer to the datasheet available on Canvas for details. Set up the circuit as shown, including the LM741 op amp. With the power inputs at the top, build this circuit on the *left side* of the breadboard. Connect all input pins 5–12 to ground, and measure V_{out} from the op amp. If it is not close to zero, adjust a 10 kΩ trim pot to minimize it,



(a) DAC0808 circuit setup.



(b) DAC0808 pinout.

Figure 1: The DAC0808 (MC1408) D/A converter.

following the same offset nulling procedure as in earlier labs. For the digital input, the most significant bit (MSB) is pin 5 and the least significant bit (LSB) is pin 12. The reference voltage V_{ref} should be +5 V. The output is given by

$$V_{out} = V_{ref}\left[\frac{A1}{2} + \frac{A2}{4} + \ldots + \frac{A8}{256}\right] \tag{1}$$

where An is either 0 (for logic low, or ground) or 1 (for logic high, or 5 V).

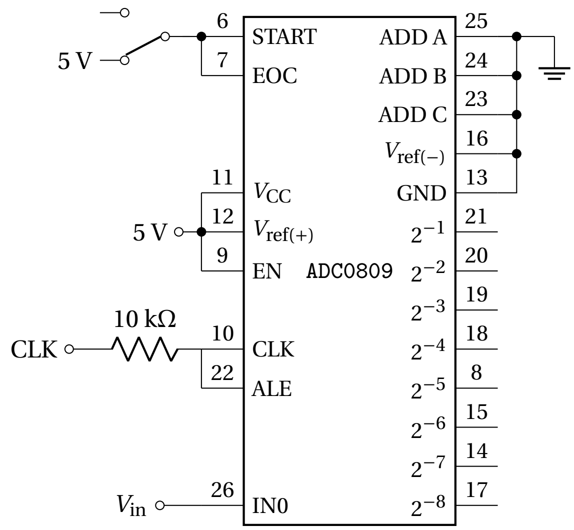
Ground all the digital inputs and record the output. Then connect A1 to +5 V and measure V_{out}. Then, ground A1, connect A2 to +5 V, and measure V_{out} again. Repeat this process for each pin and record your results, including a table and graph in your report. With only A8 (LSB) connected, measure the difference between zero and $V_{ref}/256$ corresponding to the resolution. Try a few other combinations (e.g. pins 5/6, or 5/6/7) and confirm that the output agrees with Eq. 1.

Finally, ground all inputs except pin 5 (A1). Configure the function generator with square pulse with a frequency of 1 kHz, a low level (LoLevel) of 0 V, and a high level (HiLevel) of 5 V. Connect this to pin 5 (A1) and observe this signal and V_{out} on the oscilloscope. Now, decrease the high level to find the threshold voltage required to cause the output to change. This should be around 1.35 V. Is the output shape a good square pulse? Describe the shape of the output and the behavior near the threshold point in your report, and include a photo or sketch. Keep this circuit set up for use later in Part C.

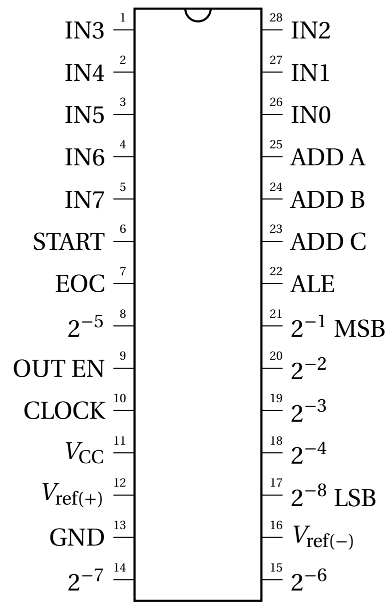
B Analog to Digital Conversion

Set up the circuit shown in Fig. 2a, using an analog to digital converter (ADC).[1] With the power inputs at the top, build this circuit on the *right side* of the breadboard. Set up the function generator to provide a 500 kHz square wave ranging from 0–5 V to the clock input (CLK), using the LoLevel and HiLevel settings on the FG. Note that all input voltages to the ADC must be positive, as negative voltages can damage the device. Before applying the clock signal to the ADC, use a (DC coupled) oscilloscope to confirm that the signal is between 0 and +5 V.

[1] You will only use one input (IN0) but the device actually has a built-in eight-channel multiplexer, with inputs IN0 through IN7 selectable with three address bits (ADD A/B/C). The ALE pin, for Address Latch Enable, causes the chip to read the address bits and select the input.



(a) ADC0809 circuit setup.



(b) ADC0809 pinout.

Figure 2: The ADC0809 A/D converter.

Apply a DC voltage of about 0.5 V to IN0, pin 26, and measure the states of the digital output pins.[2] If the chip did not perform a conversion when you turned the power on, momentarily apply +5 V to the START pin, then leave it open. Connecting EOC (end of conversion) to start as shown in the diagram will cause the chip to continuously convert once it has been started.

Repeat this process for at least four other input voltages to check linearity, and include a table in your report. Next, choosing an input voltage then adjust it slightly to determine what voltage change corresponds to a change of one unit in the LSB. Report this value and explain how you did this in your lab report.

Next, measure the conversion time of the ADC. Disconnect EOC from START. Set up a 555 timer to put a ~ 1 kHz square pulse into START, and monitor this square wave and EOC on the oscilloscope. The time difference between logic low to high of EOC is the conversion time. Repeat this measurement using a clock (CLK) frequency of 200 kHz from the FG, and record your findings for both frequencies. What is the relationship between the clock frequency and conversion time?

C Round Trip

Finally, you will combine the ADC and DAC circuits. First, configure a 555 timer to produce a square wave (0–5 V) with a frequency of about 100 kHz and connect this to the CLK input (replacing the FG). Set up the ADC for continuous conversion again, reconnecting EOC to START.

Next, connect the 8 ADC output pins to the 8 DAC inputs, maintaining the ordering from LSB to MSB. Connect all devices to one power supply, ensuring that both circuits share the same ground and DC voltages.

Set the function generator to output a sine or triangle wave with about 100 Hz frequency, setting a DC offset such that the output is always positive and confirming this on the (DC coupled) oscilloscope. Then connect this signal to IN0 on the ADC. Using the oscilloscope, compare the input wave from the FG with the DAC op amp output. Include a photograph and explain your observations in your lab report.

[2] You can check them with a multimeter, or set up an LED block like in the previous lab.