EE 210: CIRCUITS AND DEVICES
A/D AND D/A Conversion

The objectives of this laboratory experience are double. First, students will become familiar with using Analog-to-Digital Converters (ADC). Secondly, students will design a basic Digital-to-Analog Converter (DAC).

ADCs and DACs are commonly used in electronic systems. ADCs are typically used to convert analog signals into digital signals (for example music) that can be further stored and processed, for example in the commonly used MP3 format. DACs are used to create an analog signal from a digital signal in order to restore the information; that is, in this example, the DAC will convert the digital MP3 signal into a continuous wave that will drive the headphones or speakers in your MP3 player.

PART 1 – ANALOG TO DIGITAL CONVERSION

The figure below describes the ADC process. Given an analog input signal, the ADC generates a number of digital signals (0 or 5 V) that is equal to the number of bits in the converter. In our case, we will use an 8-bit Analog-to-Digital converter. The bits or digital signals at the output of the converter can be generated and transmitted all at the same time (parallel) or sequentially (series). The ADC needs two other critical signals: a signal that tells the ADC to start converting and a clock signal that controls when the conversions happen. The clock can be an external TTL signal or can be generated internally by the ADCs that have this capability.
In this lab we will used the ADC0804 or ADC0805 that are 8-bit parallel Analog-to-Digital Converters manufactured by National Instruments. This ADC features an internal clock, thus avoiding the need for an external clock signal.

1.1 Analog Signal. Configure the function generator for a sine signal, frequency of 20 Hz and 5 \( V_{pp} \). Modify the offset of the generator so the resulting signal is between 10 V and 0 V. Verify with the oscilloscope that the analog signal does not have any negative voltages.

1.2 Analog-to-Digital Converter circuit. Build the circuit shown in the figure below. Make the switch that connects pins 3 and 5 to ground with a wire so you can connect it and disconnect it.

Connect Channel 1 of the oscilloscope to the input voltage (pin 6) and Channel 2 to the MSB at the output of the ADC (pin 11). You should see the AC signal in Channel 1 and a constant, flat signal in Channel 2. This indicates that the conversion has not started yet.

Open the switch that created by the wire. At this point the ADC should start converting.

1.2.1 Describe the signal in pin 11. Measure its frequency. What is the meaning of this signal?
Verify the correct operation of the ADC by visualizing the different signals at pins 12 through 18.

1.2.2 Describe the signal in pin 18. Measure its frequency. What is the meaning of this signal?

The set of digital signals found at pins 11 through 18 are digital words that represent the voltage of the analog signal for each time that the ADC samples it. These digital words can be stored in memory, connected at the input of a microprocessor or undergo any other digital signal processing function.

PART 2 – DIGITAL-TO-ANALOG CONVERSION

After the analog signal has been digitized and processed, it needs to be converted again into an analog signal. To simplify the design process, we will start with the design of a 4-bit Digital-to-Analog Converter (DAC).

2.1 Design a 4-bit Digital-to-Analog Converted based on a single Operational Amplifier. The output signal should have an amplitude anywhere between 5 Vpp and 10 Vpp.

2.2 Connect Ch1 to the original analog signal (pin 6 of ADC0804) and Ch2 at the output of your DAC converter. Ch2 should show the reconstructed analog signal

2.2.1 Describe the signal in Ch2. How many levels does this signal have? What is the voltage step between consecutive levels? Sketch the signal at the output of the DAC. Include the voltage values of each step.

2.3 Expand the 4-bit DAC to a 8-bit DAC

2.3.1 Compare the reconstructed signal with the reconstructed signal from a 4-bit converter. What are the main differences? What is the voltage step between consecutive levels now?