COLLEGE OF ENGINEERING
SUNY POLYTECHNIC INSTITUTE

ECE 260
Name:____

Date:____

Laboratory 7 – Applications of Op-Amps

Purpose: In this lab, you will examine an op-amp circuit design and gain experience in op-amp circuit analysis

Equipment Required

- Breadboard and variable power supply
- FLUKE Hand-held Digital Multimeter (DMM)
- 1 741 Op-Amp
- 4-10kΩ Resistors
- 2-5kΩ Resistors
- Other resistors as needed for your op-amp circuit

Optional Equipment

- 1-470Ω Resistor
- 4-1.2kΩ Resistors
- 1-11kΩ Resistor
- 3-1kΩ Resistor
- 1 LM339 Quad Comparator
- 4 Red LEDs

Learning Objectives

1. Apply an op-amp circuit to a real design
2. Build and analyze a D/A converter
3. Build and analyze an A/D converter

<u>Theory</u>

In this lab you will build a Digital-to-Analog Converter (DAC) that will accept three bits in and output an analog voltage, varying from 0 to 7 volts and feed the analog voltage to an LED display that will light up a series of LEDs based on the voltage level.

This circuit is broken up into two parts. The first circuit you will build will decode the digitial signal and generate an appropriate output voltage. In other words, a 1 V increase in the signal on the conductor, e.g., an input of 001_2 produces 1V, and a 101_2 produces 5 V, up to 111_2 which will produce a 7V output.

You will implement this using an R-2R ladder circuit. A schematic of the circuit is given in Figure 1 below.

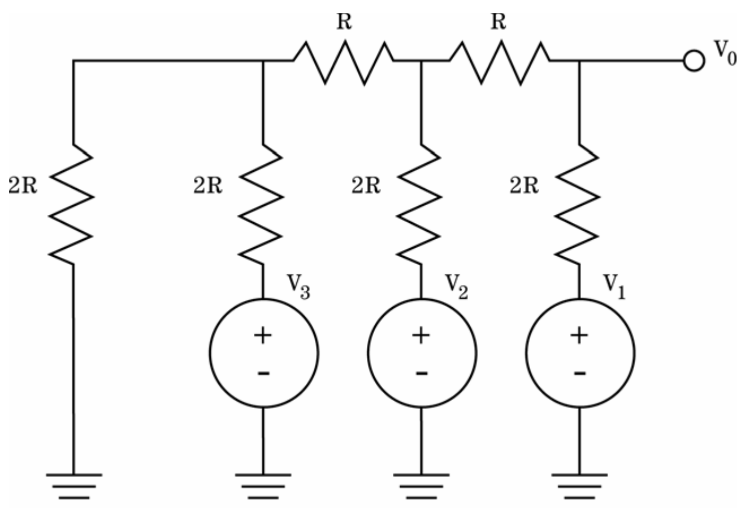

Figure 1

Analysis:

In the Notes section of this lab handout, provide a detailed circuit analysis that shows that the Thevenin equivalent of the circuit of Figure 1, defined at V_0 s defined as:

$$\boldsymbol{V_{TH}} = \left(\frac{\boldsymbol{V_1}}{\mathbf{2}} + \frac{\boldsymbol{V_2}}{\mathbf{4}} + \frac{\boldsymbol{V_3}}{\mathbf{8}}\right) \qquad \textbf{Eq. 1}$$

And

$$\boldsymbol{R_{TH} = R} \qquad \textbf{Eq. 2}$$

Hint: The best way to show this is to analyze the circuit using superposition.

Design:

Let the resistance, R, in Figure 1 equal 5kΩ. In this lab, you will design an op-amp interface, attached to the output of the circuit that will properly scale the signal voltage to the octal voltage value associated with the binary input from (V_1 V_2 V_3). Your results will be recorded in Table 1 below.

Table 1

V_1	V_2	V_3	Expected Value of V_0	V_0 Calculated From Eq. 1	V_0 Measured Without Op-Amp Interface	V_0 Corrected With Op-amp Interface
0	0	0	0			
0	0	5	1			
0	5	0	2			
0	5	5	3			
5	0	0	4			
5	0	5	5			
5	5	0	6			
5	5	5	7			

Question: Which voltage represents the most significant bit of the digital input? The least significant?

____

____

____

Procedure:

Design and Build a D/A Converter

1. Calculate the output voltage V_0 of the circuit in Figure 1 based on the Thevenin Equivalent given in Equation 1. Record your answers in column 5 in Table 1.
2. Build the circuit in Figure 1 and measure V_0 for every possibility given in Table 1. Simulation of the two TTL signal levels (0 and 1) for V_1, V_2, and V_3 is accomplished by applying either 0V or 5V to the appropriate inputs to the circuit. Connect the three inputs so that when power is applied, all three will be at 5V. When your circuit is working, verify the circuit performance by recording the data for all of the combination of inputs into column 6 of Table 1. Do not take this circuit apart.
3. The correct output voltage levels for a D/A converter is shown in the 4th column of Table 1. If your output voltage does not match these values, you will need to design an op-amp circuit that will be attached to V_0 so that your circuit produces the correct output voltage
    - Design and build an op-amp circuit to produce the required output voltage (output values should be 0,1,2,3,…,7). If you recall, the diagram for a non-inverting op-amp is given in Figure 2 below. Show all your calculations for designing the op-amp circuit. Be sure to use large enough resistors for R_1 and R_2 so that your circuit doesn't produce too much current ($R_i > 1k\Omega$). Select proper values for $\pm V_{cc}$ so that saturation does not occur.
    - Build the circuit and connect the output (V_0) of your ladder circuit in Figure 1 to the input of your op-amp circuit in Figure 2. V_{in} of your op-amp circuit should be replaced by V_0 of your ladder circuit
    - Verify the performance of your circuit and record your results in the last column of Table 1

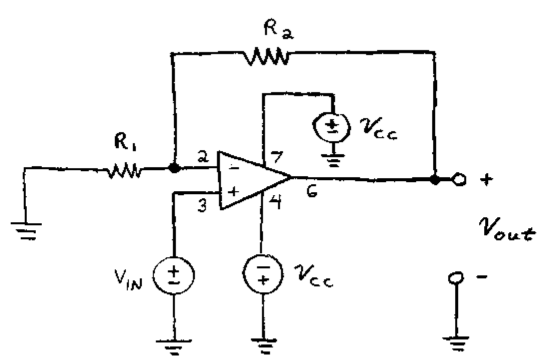

Figure 2 – Non-inverting Amplifier (LM 741)

OPTIONAL

4. Build an A/D Converter
   - The design of one half of the A/D converter is given in Figure 3 below. The circuit is designed such that an Octal 0 is indicated when all the LEDs are off. Each increment in the octal number will light an additional LED. The design consists of two LM339s, (quad comparators), with the pin-out shown in Fig. 4. You will verify the design by constructing the first half of her circuit as shown in Fig. 3. Conduct a system test by connecting your D/A converter from Part 1 to the A/D converter of Part 2 to ensure the entire system works.
   - Breadboard the circuit in and verify the performance with the circuit in Part 1. Note that this is only half of circuit, so it should only operate for octal numbers from 0 to 4. Note the $\pm V_{cc}$ for the LM339 is $\pm 15\ V_{DC}$

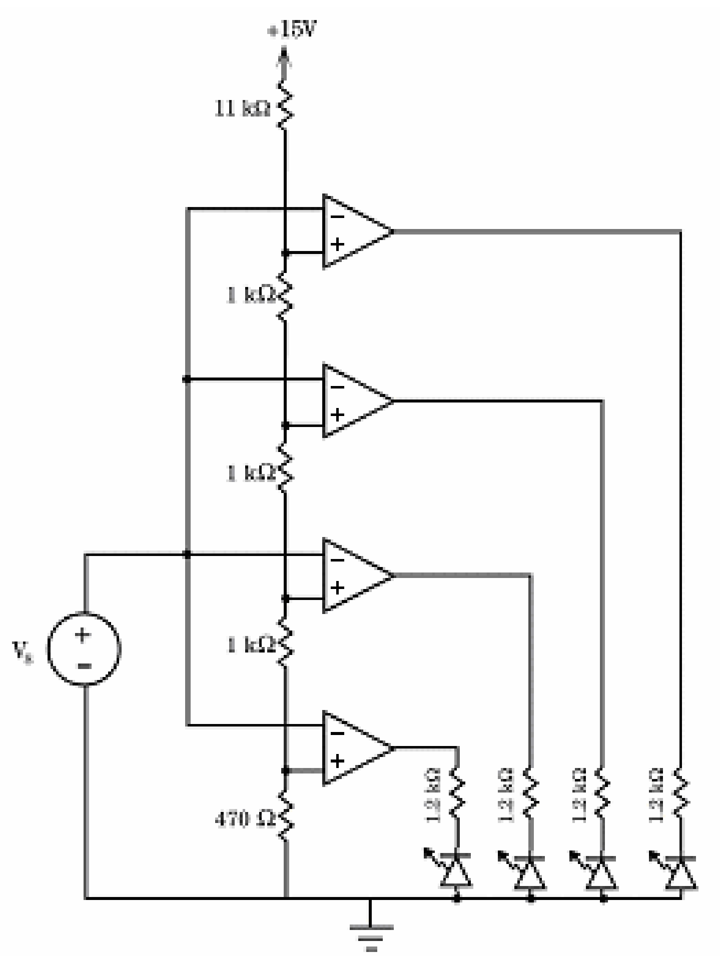

Figure 3

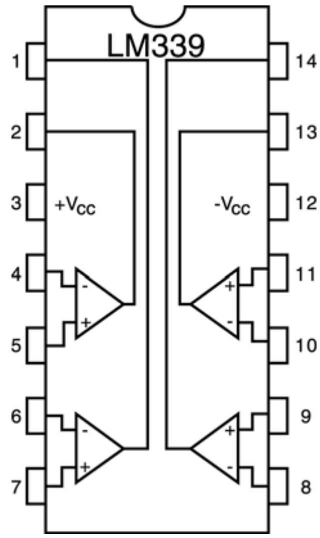

Figure 4

NOTES and CALCULATTIONS