ME 511 Mechatronics @ UIC

Operational Amplifiers and Timer

This lab is to be done in a group of two during lab hours

1 Prelab (not graded)

1.1 Motivation

The goals of the lab are to introduce you to integrated circuits, the LM741 operational amplifiers (op-amps for short) and the 555 Timer. The LM741 will be used to build and test the following op-amp circuits; an inverting amplifier, a differentiator, and a summer. The 555 Timer will be used to turn a LED ON-OFF at a prescribed time interval.

1.2 Assigned Reading

This part of the Lab needs to be done before you come to the lab. Assigned reading from the textbook is listed below

1. Class notes on operational amplifiers (Lectures 10 and 11)
2. Timers on Wikipedia https://en.wikipedia.org/wiki/555_timer_IC

1.3 Questions based on reading (not graded)

1. Which of the following are ideal features of an amplifier
   (a) small input impedance.
   (b) large input impedance.
   (c) small output impedance.
   (d) large output impedance.
2. Which of the following are TRUE for the LM741 op amp
   (a) Pin 7 needs to be connected to +15 V.
   (b) Pin 4 needs to be connected to -15 V.
   (c) The inverting pin 2 and non-inverting pin 3 are interchangeable
   (d) The pins 1, 5, and 8 are not normally used.
3. A/An ________ op-amp circuit can be used to convert angular speed measured in rad/s to angle measured in rad.
   (a) inverting
   (b) non-inverting
   (c) integrating
   (d) differentiating

4. There are multiple temperature sensors in a room. You want to use an op-amp to find the room temperature at a particular instant of time by averaging the sensor measurements. Which of the following op-amp circuit will you use?

   (a) summer
   (b) difference amplifier
   (c) integrator
   (d) differentiator

5. For a real amplifier follower circuit, if you input a signal that instantaneously jumps from 0 to V voltage (i.e., a step input), the output will

   (a) instantaneously jump from 0 to V volts
   (b) instantaneously jump from 0 to -V volts
   (c) gradually increase from 0 to V volts
   (d) gradually decrease from 0 to -V volts

Answers 1 b,c; 2 a,b,d; 3 c; 4 a; 5 c.

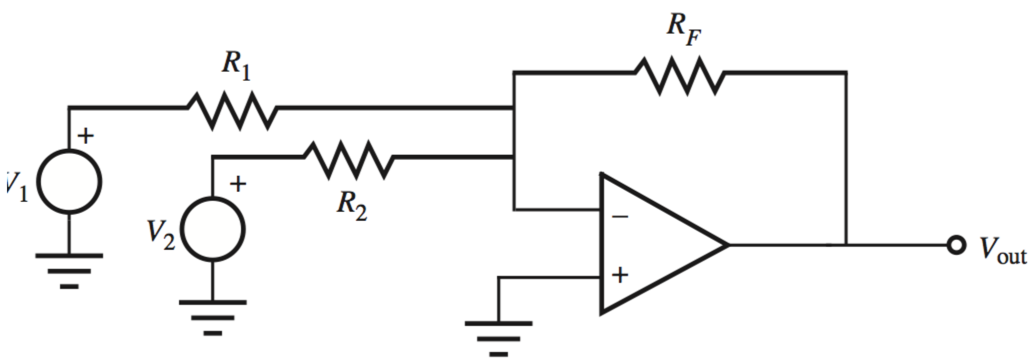
2 Labwork (To be done during the lab)

Equipment list

1. 3 resistors of value $1k\Omega$ and 1 resistor of value $10k\Omega$.
2. Capacitor $0.1\mu F$.
3. 1 LM 741 op-amp
4. 1 555 Timer
5. Breadboard.
6. Multimeter.
7. Hantek2D72 Oscilloscope/Digital Multimeter/Function Generator
8. DC voltage supply. (please return this back after the lab is done)

2.1 (20 pts) Summing amplifier (TinkerCAD)

You will do this circuit in TinkerCAD. The remaining exercises should be done in hardware.



1. For the summing amplifier shown above, derive a formula for

$$\frac{V_{out}}{V_{in}} =$$

2. Build the circuit above using $R_1 = R_2 = R_F = 1k\Omega$. Now input the following voltages: $V_1 = 5V$ and $V_2 = 2V$. Measure the output voltage V_{out}. Do the simulated values agree with the theoretical values you calculated earlier? Show the circuit and result to the teaching assistant.

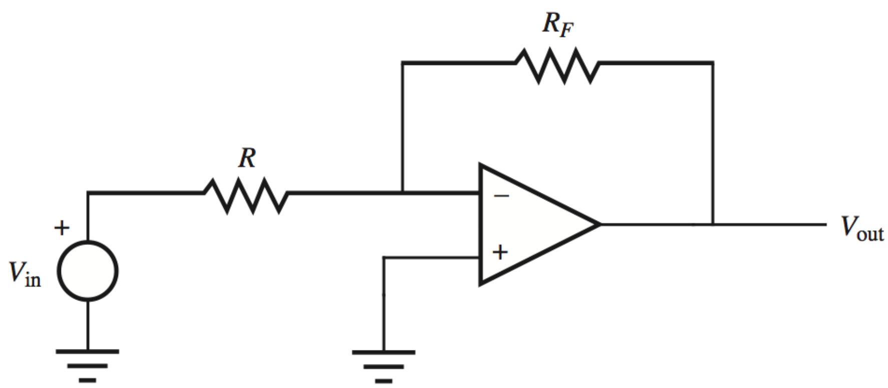
3. Now input the following voltages: $V_1 = 5V$ and V_2 should be a sinusoidal wave with an amplitude of $1V$ and frequency of 2 kHz. Record the inputs and outputs on the same plot and show this to the teaching assistant.

4. Give one practical application of the summing amplifier.

2.2 (10 pts) Identifying the leads of the LM 741 op-amp

Search for the specs sheet of the LM 741 op-amp. Draw the LM 741 pin-out in the space below and indicate the leads. Also, check the supply voltage to the op-amp from the spec sheet and indicate the voltage on the diagram you just drew. Get the pin outs and value of the supply voltage checked by the teaching assistant.

2.3 (20 pts) Inverting amplifier (Hardware)



VERY IMPORTANT: Please ensure that you set the supply voltage to the correct value before your connect the op-amp. Also, ensure that you know where to connect the supply voltage before you make the connection. Please ask the teaching assistant if you are not sure. Since we don't have spare op-amps, you might not be able to do this lab if you blow up the op-amp given to you.

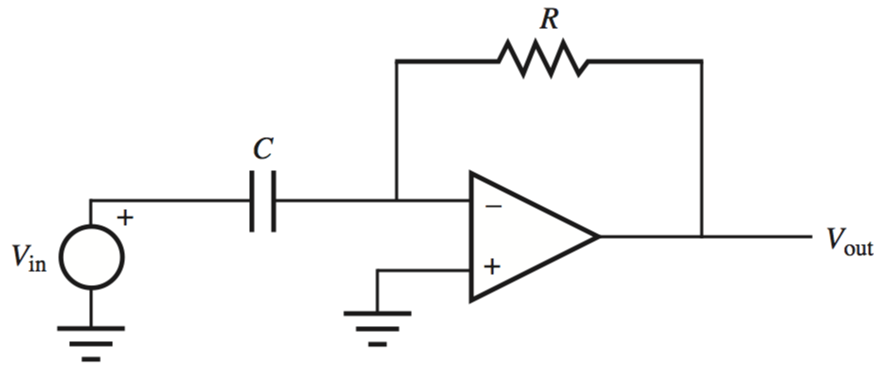
1. For the inverting amplifier shown above, derive a formula for

$$\frac{V_{out}}{V_{in}} =$$

2. Build the circuit above using $R = 1k\Omega$ and $R_F = 10k\Omega$. Now input a sinusoidal wave with amplitude of 0.5 V and frequency of 1 kHz . Measure the output voltage V_{out}. Record the inputs and outputs on the same plot and show this to the teaching assistant.

3. Give one practical application of the inverting amplifier.

2.4 (20 pts) Differentiating amplifier (Hardware)



1. For the differentiating amplifier shown above, derive a formula for

   $$\frac{V_{out}}{V_{in}} =$$

2. We will consider the following three inputs (V_{in}): (i) sinusoidal input, (ii) square wave, (iii) triangular wave. For these three inputs can draw the shape of the output waveform V_{out} below. (HINT: A square wave is made up of vertical and horizontal lines. What is the derivative of a vertical and horizontal line? Use similar logic for sinusoidal wave and triangular wave)

3. Now construct a differentiating amplifier. Use $R = 1k\Omega$ and $C = 0.1\mu F$. Apply the three inputs described above with amplitude of $1V$ and frequency of 2 kHz. Get experimental plots for V_{out} vs time for each of the three cases.

4. Do the measured plots look similar to the ones you drew earlier? What are the differences between actual circuit behavior and the ideal case? Discuss you answers among your group and show all the plots to the teaching assistant.

5. Give one practical application of the differentiating amplifier.

2.5 (30 pts) 555 Timer as an oscillator (Hardware)

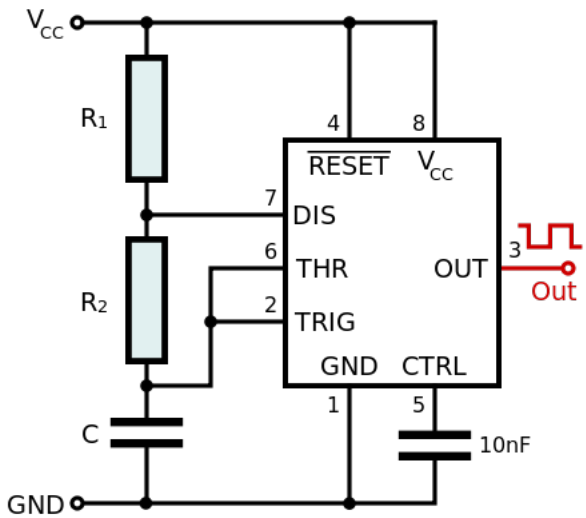


Figure 1: 555 Timer as an astable oscillator from https://en.wikipedia.org/wiki/555_timer_IC

When the 555-timer is connected in the above fashion, it produces an ON-OFF signal. Let t_{ON} and t_{OFF} be the time the output is ON and OFF respectively. Then

$$t_{\mathrm{ON}} = 0.693(R_1 + R_2)C,$$
$$t_{\mathrm{OFF}} = 0.693 R_2 C.$$

Choose R_1, R_2, and C such that, $t_{\mathrm{ON}} = t_{\mathrm{OFF}} = 1$ sec. Connect a LED on the output and confirm that it turns ON-OFF at 1 second interval. (HINT: Choose R's such that $R_2 >> R_1$). Show this to the teaching assistant.