Name ______________________________

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

6.091 Hands-On Introduction to EE Lab Skills

Laboratory No. 2 BJT, Op Amps

IAP 2008

1 Objective

In this laboratory, you will become familiar with a simple bipolar junction transistor (BJT) circuit, a comparator, an oscillator and various op-amp circuits.

1.1 BJT

1.1.1 Exercise

Build the circuit below using parts from the parts bin in the lab. Resistors, if needed are available from the drawers in the center of the lab in 38-600. The pin out for the 2N2222 BJT is shown below. Note that the collector (pin 3) is connected electrically to the case!

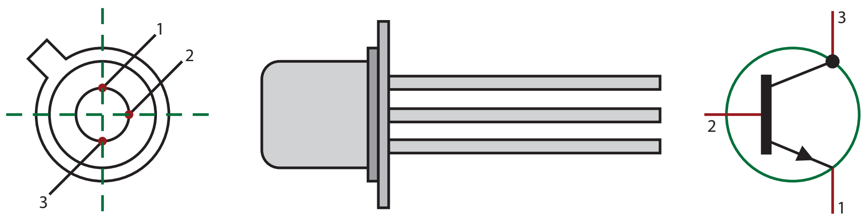
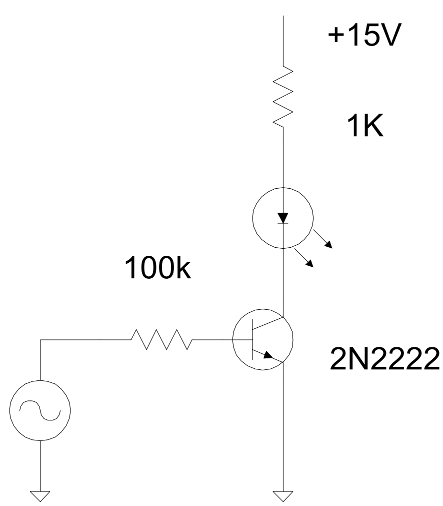


Figure by MIT OpenCourseWare.



Turn on function generator and using a ramp signal try to get a pulsing light. Set the frequency low enough so that your eyes can see the pulse. You will also need to adjust the amplitude.

What is the peak current through the LED?

1.2 Operational Amplifiers (Op-amps)

Op-amps can be used as comparators. This mode of operation is called open-loop, i.e. no feedback. In this mode, the output voltage will be very high (the plus rail) or very low (the negative rail).   Applications with negative feedback are generally used for amplification, signal processing and conditioning.

1.2.1 Exercise - Comparators

Wire up a comparator on the proto-board using 741 op-amp. The 741 pin out is shown below. The offset null pins are used to fine tune the 741 so that a zero input will result in an actual zero output.

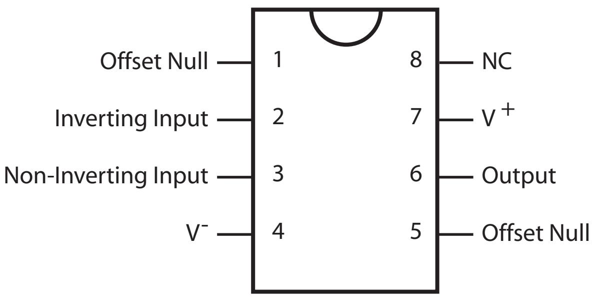
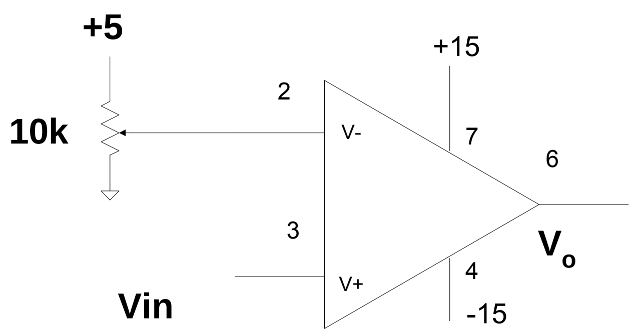


Figure by MIT OpenCourseWare.



Be sure to supply power and ground. Set V- to 1.0v. Turn on function generator using a ramp waveform.

a) Display both the input and the output on an oscilloscope. Describe what is happening. What happens as you vary the potentiometer?

b) Using the measurement features of the oscilloscope, measure the threshold of the comparator.

c)   What is the maximum output voltage (the plus rail)?

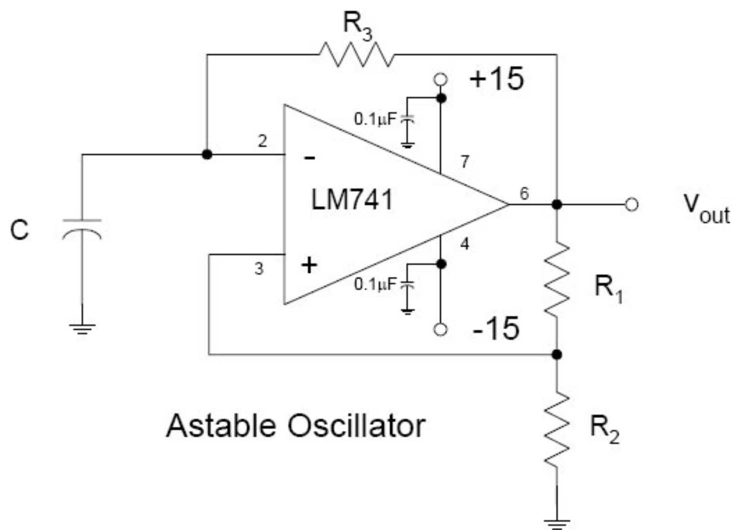
d)   What is the minimum output voltage (negative rail)?

1.2.2 Exercise - Oscillator

Wire up an oscillator on the proto-board using 741 op-amp. Be sure to supply power and ground.

Use R1=10k, R2=4.7k, R3=10k, C=.33μf

Display V- and V_o on the scope. Describe what is happening. Now replace R3 with a 4.7k resistor. Predict what the change is in the frequency. (The phrase astable oscillator is redundant. Oscillators by definition are not stable.)



Astable Oscillator

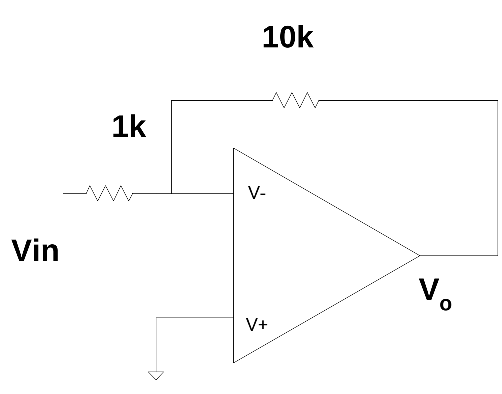
1.2.3 Exercise – Inverting Amplifier

Wire up a comparator on the proto-board using 741 op-amp. Be sure to supply power and ground. Turn on function generator using a 5 volt ramp. Display both the input and the output on an oscilloscope. How is the output related to the input?

What is the peak output voltage? This is also referred to as saturation.

What is the minimum output voltage**?**

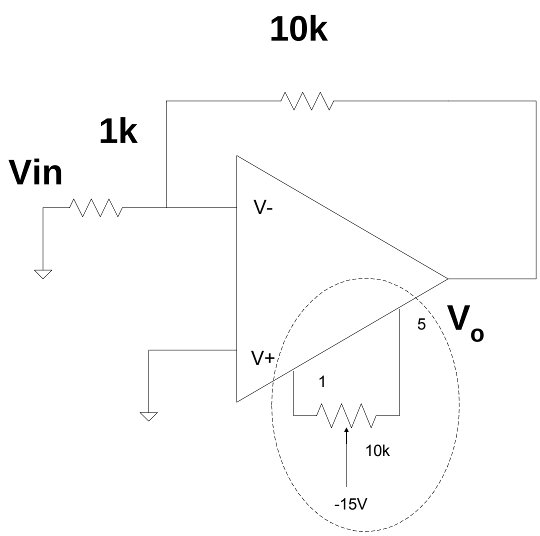
Increase the input frequency until the gain begins to decrease. You have reached the gain bandwidth limitation of the op-amp.



Real World Constraints – Input offset voltage

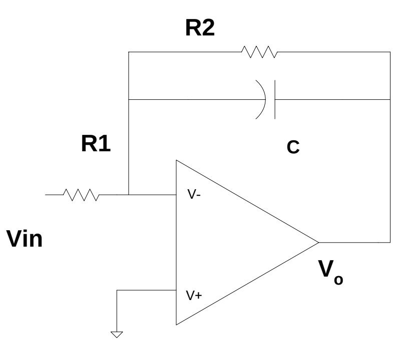
Up to now, the lab exercises have assumed that the op-amps are ideal. This makes the lab exercises more fun and less stressful. However, in the real world, op-amps are not ideal. For example, if $V_+ = V_-$ the output should be zero. In actuality, it is not.

The real world op-amp has a very small offset voltage between V_+ and V**-**. This is typically 2-5 mv. To cancel out or null out this offset voltage, the op-amp provides two pins (pins 1 and 5) to "null" out the offset voltage. **Set Vin=0.** Measure the output with a DMM. Most likely it is not zero. Now add the null adjustment (dotted section) to your circuit and adjust the pot until the output is zero with both inputs grounded.



1.2.4 Exercise – Integrator

Op-amps are frequently used as integrators. For example, when an input is triggered, i.e. turned on, the integral of the input signal is directly proportional to the on time. Wire up an integrator on the proto-board, this time using a 356 op-amp. Use R1=4.7k, C=0.1μf, R2 = 1m. R2 provides a path for the input bias current and can be almost ignored in the circuit.

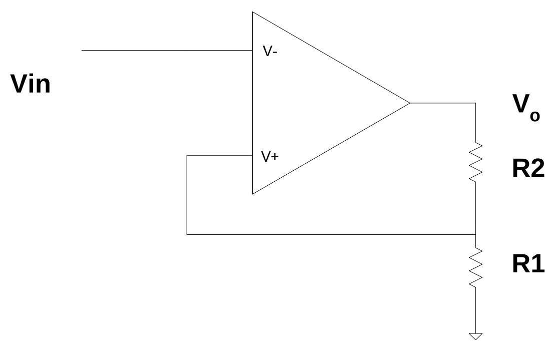


Input a square wave to the integrator. As you decrease the frequency, the output no longer looks like an integral of the input signal. Explain qualitatively why that occurs.

Display both the input and the output on an oscilloscope. Notice that for a square wave, the output voltage is proportional to the "on" time.

1.2.5 Exercise Schmitt Trigger (Optional)

A Schmitt trigger has different thresholds for rising edge and falling edge signals. Among other uses, it can be used to trigger on slowly changing signals. The rising edge trigger point is $\sim \frac{R1}{R1+R2}\left(V^{+}\right)$. V^{+} is the positive supply voltage. The falling edge trigger point is $\sim \frac{R1}{R1+R2}\left(V^{-}\right)$ In actuality, the output voltage is never able to reach V+ or V- but something less. Measure the max and min voltage. Using R1=1K, R2=10K, input a ramp into the Schmitt trigger and predict the trigger points. What are the measured trigger points?



Note the polarity of the input pins!