University of Utah
Electrical Engineering Department
EE 2100
Experiment No. 3

Nonlinear Op Amp Circuits

A. Stolp, 2/1/00
rev, 1/26/03

Minimum required points = 50 Grade base, 100% = 71 points
Recommend parts = 64 points

Lab Objectives

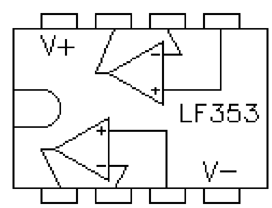
Learn about non-linear op amp applications.

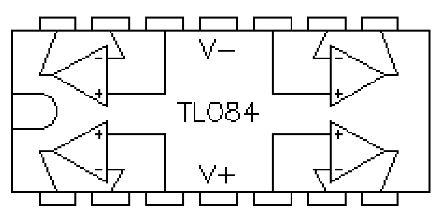
Check out from stockroom:

- Wire kit
- Two 10x scope probes
- Interrupter and test slide
- Other parts if and when needed, see text

Parts	Experiments
Parts from labs 1 & 2	all
TLO84 op amp (or as a second choice: LF353)	all
0.001 µF capacitor	3
Two 1 kΩ, two 6.8 kΩ, five 10 kΩ, 30 kΩ, 33 kΩ, and 47 kΩ resistors	mixed
IR emitter (May only be available for check-out)	3
Small signal or switching diode (like 1N914 or 1N4148)	3

General

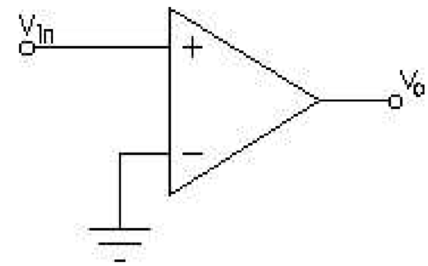




It's time to graduate from the LM741, use the TLO80 or LF353 op amps in this lab. You need something with a respectable slew rate. A 741 is good as an educational tool because it so aptly demonstrates the limitations of op amps. A 741 *isn't* so good for anything *else* because it so aptly demonstrates the limitations of op amps. There are plenty of better op amps available for little or no extra money.

If an op amp circuit has no negative feedback, assume that it is not operating in its active, or linear region. Assume instead that its output is at one of the two output limits.
You can determine which of the two limits by determining which of the two input voltages is greater than the other. If the non-inverting input voltage is greater than the inverting input voltage, then the output will be at its positive limit. If the inverting input voltage is greater, then the output will be at its negative limit. Circuits that operate this way are called non-linear circuits and can be very useful.

Connect the op amp to the power supply.

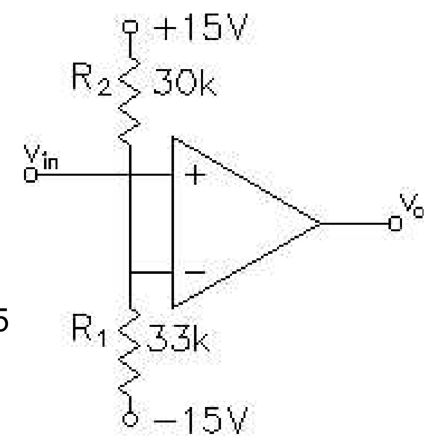


Experiment 1, Comparator (26 points, Recommended)
(3 pts) Probably the simplest non-linear application of the op amp is the voltage comparator. The one shown at right simply compares the input voltage against zero. If $V_{in} > 0$, $V_o = L+$. If $V_{in} < 0$, $V_o = L-$. (See textbook, section 2.8, p.97) Build this circuit.

(3 pts) Hook the function generator to the input. Select a reasonable frequency (say 1 kHz) sine wave and voltage and observe both the input and output of your circuit with the scope. You should easily observe its switching action. (Most easily observed if both traces are set to the same zero level and scale.) The output will look like a square wave, high whenever the input voltage goes over zero and low whenever the input voltage goes under zero. Comment and/or sketch waveforms in your notebook. Try to turn down the input to the point where the op amp behaves as a linear amplifier. Can't do it, can you?

(2 pts) Play with the DC offset feature of the function generator and note the effect on the output. What happens when the offset is so big that the input voltage no longer crosses the zero line? (Note: Trigger the scope on the input signal and use AC coupling for the trigger, otherwise you may lose triggering.)

All right, that was riveting, but what if we don't want to compare the input to zero? How do I modify this circuit so that I can set my comparing level to something other than zero?



(3 pts) Use a 3 kΩ resistor and a 27 kΩ resistor to set the comparing level to about 1.5 V, as shown. It should be obvious here that you could set the comparing level to almost anything you want. (Note: crossing lines on a schematic do not indicate a connection unless there's a dot.)

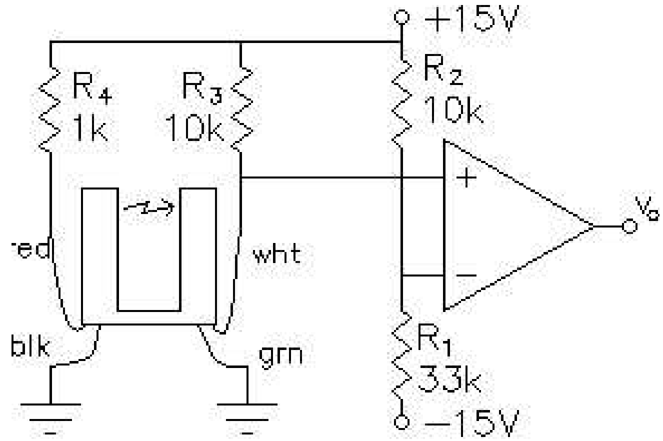
(2 pts) Play with the function generator and note the output. Note that the output stays low unless the input is higher than 1.5 V.

(2 pts) Increase the frequency of the input until you note problems in the output. What is limiting the useful frequency of the comparator, that is, what is causing the problems? With an LM741, the slew rate would limit the useable frequency. With a faster op amp it could be slew rate or the high frequency gain limitations of the op amp. See if you can see either or both of these effects. Turn the frequency back down.

(2 pts) Push and hold the sine-wave button on the function generator until the display shows DC V. Now the output is DC only and is controlled by the offset. Adjust the DC offset until you find the switching voltage. (Don't rely on the HP's display. Remember it's off by a factor of two). Get the voltage as close as you can— so that a very small change of the input makes the output switch. Measure this voltage and record it as the switching voltage. If a little noise were added to the input DC, what would happen to output?

Interrupter

(3 pts) An Interrupter shines a light beam (usually infrared) from a sender to a detector. It can then be used to detect when something interrupts the light beam. Hook the interrupter to the comparator as shown. (Note that R_2 has changed.)

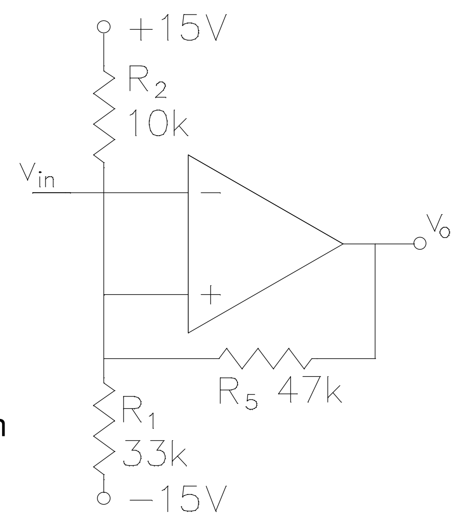


(2 pts) Measure the voltage at the white lead of the interrupter as you move the test side within the beam. If you use the fuzzy side of the test slide you'll see that it's not clear from this voltage exactly when the beam is "interrupted" and when it is not. That's why you'd use a comparator in this situation— to provide a positive switching action at some level of beam interruption. (Some interrupters have comparators built in.) Observe the comparator output with the scope as you move the test slide. Comment in your notebook.

(2 pts) Try the fuzzy side of the slide and try to move the slide to a position just where the switching occurs. You'll find that the slightest movement will make the output switch up and down. Comment in your notebook. This shows how sensitive the output is to noise or slight variations of the input. This hyper-sensitivity is not good. Consider, for instance, if the comparator were hooked to a counter to count the bills coming out of an automatic teller machine. Miscounts might not be too cool. The next circuit will cure this problem by adding some toggling effect.

Experiment 2, Schmitt trigger (19 points, Recommended)

The Schmitt trigger is just a comparator with some toggle action (hysteresis). It can be made in several ways, but all involve some positive feedback.



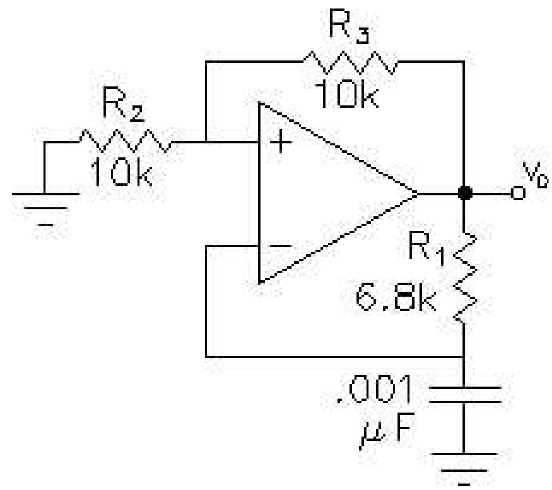
(7 pts) Temporarily remove the interrupter and make the circuit shown at right. (Notice that you'll also have to change the R_1 and R_2 connections to the two op amp since they are now hooked to the noninverting input.) Check this circuit with a DC input and determine the two switching levels with some accuracy. (One for switching low-to-high, and one for switching high-to-low.)

(4 pts) Hook the interrupter back to the input and play with the fuzzy side of the slide again. Move the slide back and forth where the switching occurs. You'll find that it always takes a significant movement to make the output switch. Comment in your notebook. Does this circuit have better noise immunity?

(6 pts) Figure out how the circuit works and exactly what the two switching levels *should* be (hint: use superposition and L- and L+. Or, for crude calculations, assume that L- $\simeq$ -15 V

and L+ ~ +15 V, now you can work out two voltage dividers, one where R_5 is in parallel with R_1 and one where R_5 is in parallel with R_2.) Compare to the values that you measured earlier. (Note: most calculation steps like this one may be completed after lab. In rare cases you'll need the numbers to complete the lab, but not today.)

Experiment 3, Multivibrator (30 points, first two parts Recommended,)

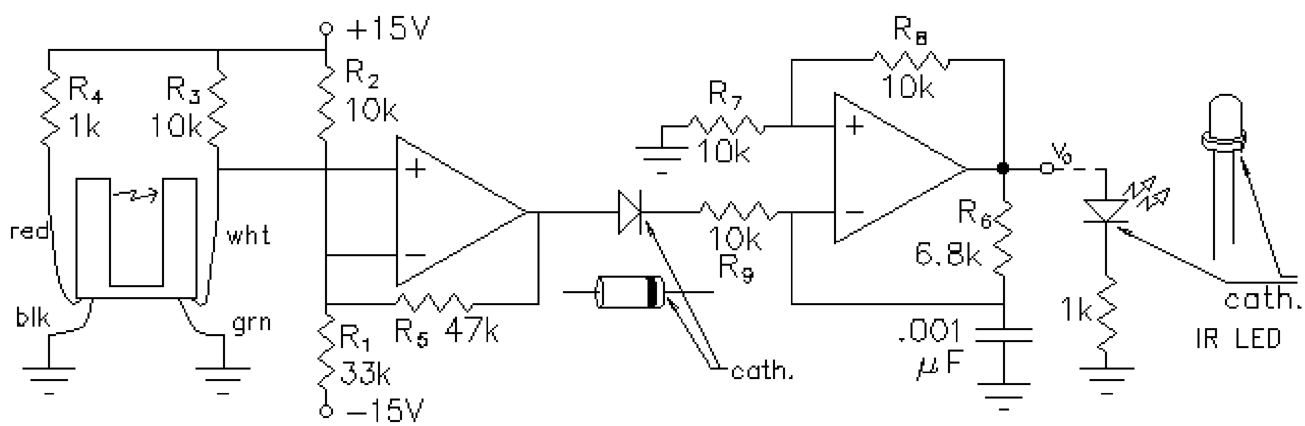


(13 pts) Leave the Schmitt trigger hooked up for now and make the oscillator circuit shown with another op amp in your IC. Use the scope to look at various waveforms at different locations in the circuit. Draw a large schematic in your notebook and include small sketches of the nodal waveforms next to the nodes where you measured them. Describe how this oscillator works. (Hint: you can consider R_2, R_3, and the op amp as a Schmitt trigger which will switch at about ⅓ and ⅔ of V+.)

(4 pts) Hypothesize in your notebook how to change one resistor and halve the frequency. Write down your guess <u>before</u> you try it. Try it to explain why it didn't (did) work. Replace any resistors that you changed.

Controlled Oscillation

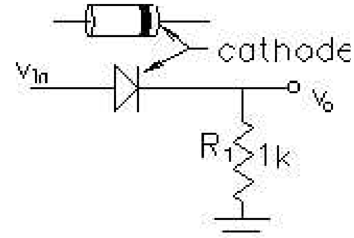
(11 pts) Hook your Schmitt trigger to your oscillator as shown below. Leave off the IR LED for now.



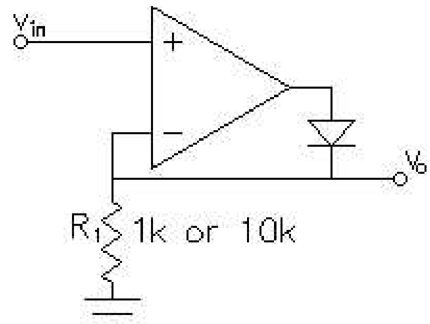
The comparator turns the oscillator on and off. This is modulation. The oscillator is set to run at about 56 kHz, which is a common frequency used by infrared remote controls. Observe the output of the oscillator with the scope while moving the test slide through the interrupter beam. Sketch the wave form in your notebook showing how the output changes as the beam is interrupted. Show the working circuit to your TA. Your TA may have a circuit utilizing a commercially available IR remote receiver and a counter which will work with your circuit if you add the IR LED.

Experiment 4, Precision diode (16 points)

Normally you loose 0.7 V across a diode when it's biased in the forward bias direction. Sometimes that can be a problem, particularly in measurement applications. The precision diode circuit performs the action of a diode without the voltage drop.

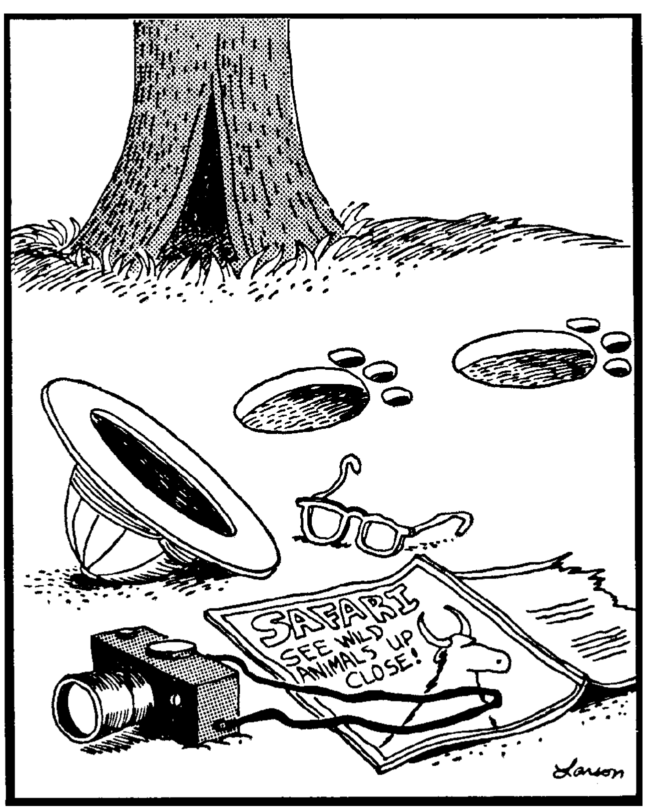


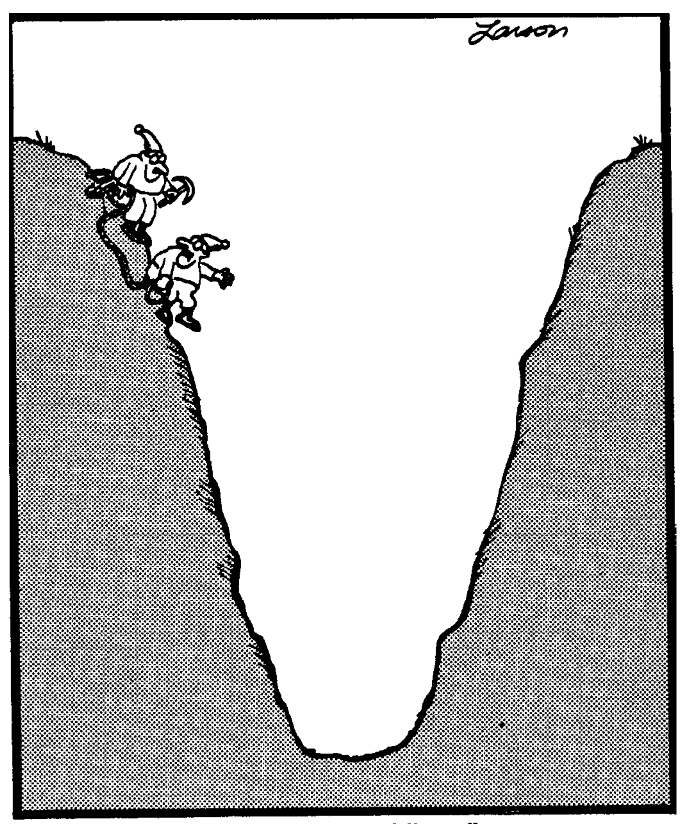
(6 pts) First build the simple rectifier circuit shown to see the problem.
Set the function generator to about 4 Vpp (shown as 2 Vpp on the HP) and 1 kHz. Observe the V_{in} and V_o with the scope. Set both traces to the same zero level and scale. Note the rectification action as well as the voltage loss across the diode. Quickly sketch the input and output waveforms in your notebook.



(4 pts) Now try the precision diode circuit at right and note the differences. You'll see much better rectification, but there are limitations. Turn up the frequency until the becomes a little "late" in turning on. What's going on here? Hook the scope up to the actual output pin of the op amp. That'll probably give you the clue you'll need to identify our old nemesis.

(4 pts) Quickly sketch the input and output waveforms in your notebook.





"Because it's not there."