with notes.

EE-321 Lab - week 3 - Nonlinear uses of the op-amp.

28th July 2005

1 Purpose

The official purpose of this experiment is to try some nonlinear circuits using an op-amp:

1. Comparator
2. Schmitt Trigger
3. Timer
4. Oscillator

These four circuits are only slightly different from each other. One naturally progresses into the next.

The unofficial purpose is to practice using the oscilloscope and signal generators, in ways you may not have used them before. In particular, you will use the scope in "XY" mode, and the signal generator as a DC sweep generator

2 Overview

You will build several configurations of op-amp circuits, and verify that they work as expected:

Comparator The comparator is a simple op-amp circuit with no feedback. The output will be positive when the non-inverting input has a higher voltage than the inverting input, negative otherwise.

Schmitt Trigger This is a modified version of the comparitor, with a dead zone around which nothing happens. It is used to remove noise from a signal.

Timer Adding an RC network and a switch to the Schmitt Trigger converts it into a timer. Push the button, wait a while, then the state changes. The reset button sets it back.

Oscillator Instead of "buttons", just wire the resistor to the output of the op-amp. You now have a square wave oscillator.

3 Parts needed

- 741 op-amp
- resistors: 1meg, 1k, 4.7k(2)
- capacitors: .1 uf (2), 22 uf
- Scope, signal generator, power supply, all on bench.
- Wire, in 3 colors, about 3 feet.

4 Procedure

4.1 Setup

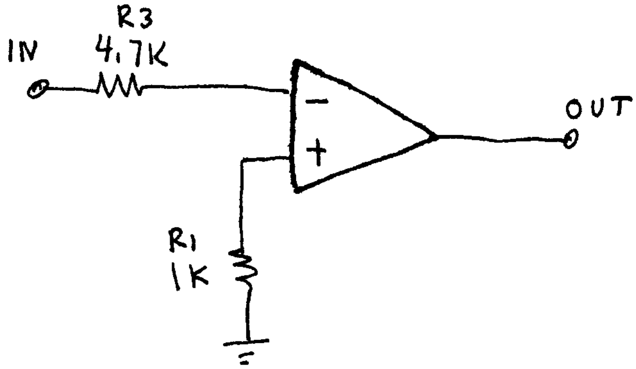
Before beginning, set the equipment to reasonable settings. You must do this before making any connections to your circuit. You cannot rely on the equipment being set in any particular way when you start. Most likely, it will be set up to suit some other experiment that has nothing to do with yours, and has completely different requirements. It is possible that someone else may have set it to a mode that can damage your circuit, or even present a safety hazard. You need to set ALL controls to your needs, including those that don't apply to your work, if only to turn off features that you are not using today.

1. Power supply
   (a) Use the fixed power supply.
   (b) Using the scope, confirm that it has no visible ripple, and that it is approximately ±15 volts, within 1 volt.
   (c) Turn it off before moving on.
2. Scope
   (a) Set to defaults, then:
   (b) XY mode (display, format, XY)
   (c) Intensity: overall=100, text/grat=50, waveform=100.
   (d) Both channel 1 (X) and channel 2 (Y) as follows:
      i. 5 volts/division
      ii. DC coupled
      iii. 20 MHz bandwidth
      iv. Z-in to 1 meg.
      v. Centered, so you get a dot in the middle of the screen. The vertical position control for channel 1 moves it horizontally. The vertical position control for channel 2 moves it vertically.
   (e) Time base for a sample rate of 1 KS/sec or sweep rate of 5 milliseconds per division.

   2
3. Signal generator
   (a) Set to defaults, then:
   (b) Waveform to off.

4.2 The comparator

1. Build the circuit according to this schematic:



2. Connect it to the power supply as you did last week, Have at least one other person check your circuit.

3. Connect the scope, channel 1 (X) to input, channel 2 (Y) to output. Always put a 1K resistor in series with the scope probe. Put the resistor in the breadboard, sticking up. Clip the scope cable to the end of the resistor that sticks up.

4. Connect the signal generator to the input. Initially, the input will be zero. You will see a dot in the middle of the screen.

5. Apply power. Observe the scope. You should still see a dot. It will move to either +14 volts or -14 volts. Make a note of which. Turn power off. Try it again. Does it come back to the same place?

6. Still keeping the waveform off, use the signal generator's DC offset control to vary the DC voltage, above and below zero. You will see the dot on the scope move horizontally in response to it. The horizontal position is a measure of the voltage. Note also the output voltage, as indicated by the vertical position. You should see that for positive input, the output goes full negative, and for negative input it goes full positive. What is the input voltage for the output to switch from positive to negative (rising threshold)? What is the input voltage for the output to switch from negative to positive (falling threshold)?

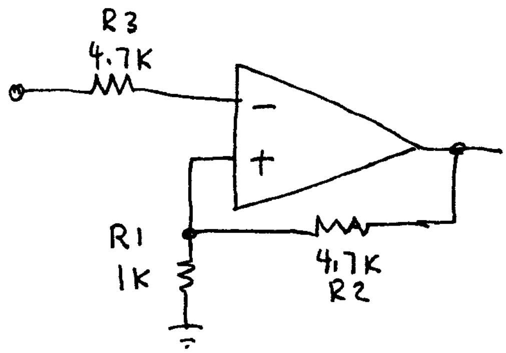
7. Switch off the DC offset. Set the signal generator to a triangle wave at 100 Hz. Increase the level so you get a good image on the scope. Capture the image and include it in your journal. Show what you have to the lab instructor.

8. Switch the scope back to normal sweep (YT) mode. You should see two waveforms overlaid, a sine wave and a square wave. Capture the image. Show the lab instructor what you have.

4.3 The Schmitt Trigger.

This modification creates a dead-zone or hysteresis region.

1. Modify your circuit to the following:



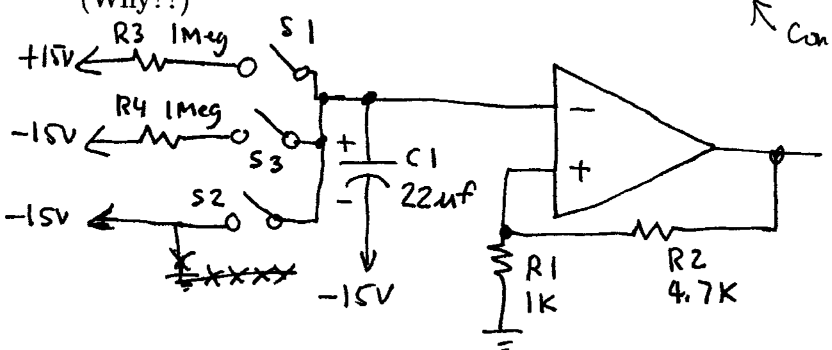
2. Set the scope back to XY mode, and repeat what you did for the comparator.

4.4 The timer.

We start with the Schmitt Trigger. Disconnect the signal generator. You won't need it any more today.

1. Modify your circuit to the following. Where the schematic shows switches, just use a jumper wire. Leave the scope channel 2 connected to the output of the op-amp, leave channel 1 at the input, but change the series resistor to 10 meg, and change the scale to .5 volts/division. (Why??)

Confusing

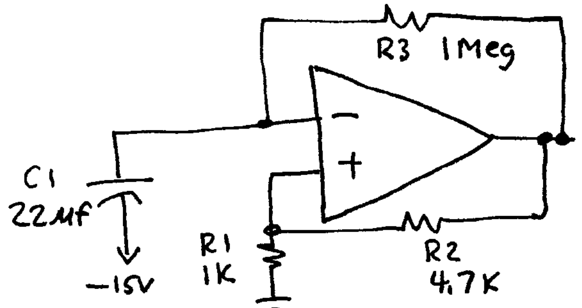


2. Begin with S2 shorted, to discharge the capacitor. What is the output of the op-amp?
3. Open it. What happens to the output of the op-amp?
4. Close S1. Observe the scope. What does it do? How long do you need to wait before something happens at the output? What is the input doing?
5. After a few minutes, open S1 and close S3. What happens now?
6. After a few minutes, open S3 and close S1. It should act like step 4 again.
7. After a few minutes, open S1 and close S2. What happens?
8. You should now understand what the three switches do, and why. You might want to repeat a step to verify it.

4.5 The relaxation oscillator.

We start with the timer. Instead of S1 and S3, connect a 1 meg resistor to the output of the op-amp, so the op-amp changing state will switch it automatically.

Modify your circuit to the following. Leave the scope connected where it is. You will need to set the time base very slow to see the waveform.



It should be an oscillator. What is the frequency? What is the waveform?

5 Report

Please arrange your report in the order listed here.

5.1 Executive summary (on cover) (done individually)

On the cover, show a schematic of each configuration (4 schematics), and its common name. Also supply the following information:

For the Schmitt Trigger, the rising and falling threshold voltages, and an expression for the threshold voltage, in terms of the power supply voltage and resistor values.

For the timer, the delay time, and an expression in terms of R3 and C, assuming R1 and R2 as used in the experiment.

For the oscillator, the frequency, and an expression in terms of R3 and C, assuming R1 and R2 as used in the experiment.

5.2 More detailed summary (individually)

Begin with a paragraph summarizing your experience.

Answer these questions:

1. When you set up for the timer, you were instructed to change the series resistor on channel 1 of the scope to 10 meg. Why? What would have happened if you didn't? Do you expect the performance of the circuit to change when you disconnect the scope?
2. You saw a triangle waveform (or close to one) at the input of the op-amp for the oscillator. Can this be used as an output if you need this waveform? Why or why not? What can you add to the circuit to make it suitable as an output?

5.3 Journal (joint)

Your report should include a journal of what you did, with enough detail that someone else can repeat your experiment, complete with mistakes. Make a copy of the journal so both members of a team can submit it.

5.4 Analysis (individually)

Based on your measured data, try to extract formulas for the threshold voltages of the Schmitt trigger, the time delays of the timer, and the frequency of the oscillator.

5.5 Simulation (individually)

Simulating nonlinear circuits can be tricky. I will give you more information on this, including my simulation of this project. You will get credit if you reproduce my simulation, then comment it to show that you understand it.