

Physics 364, Fall 2014, Lab #11 **Name:** _____
(comparators)

Monday, October 6 (section 401); Tuesday, October 7 (section 402)

Course materials and schedule are at positron.hep.upenn.edu/p364

So far we have used opamps mainly in their linear mode of operation (where V_{out} is linearly related to the inputs, rather than being saturated near $\pm V_S$), and we have used them always with *negative feedback*. Today we'll look at **comparators**, which are like opamps that are optimized for non-linear use, where V_{out} is intended to be saturated at its maximum or minimum value. In this context, we'll see where **positive feedback** can be useful.

Our intent is for this lab to use only about half of today's lab time, so that you can go back to finishing up Lab 9 (opamp imperfections) once you're done. Also remember that **today is this week's only lab** due to Fall Break.

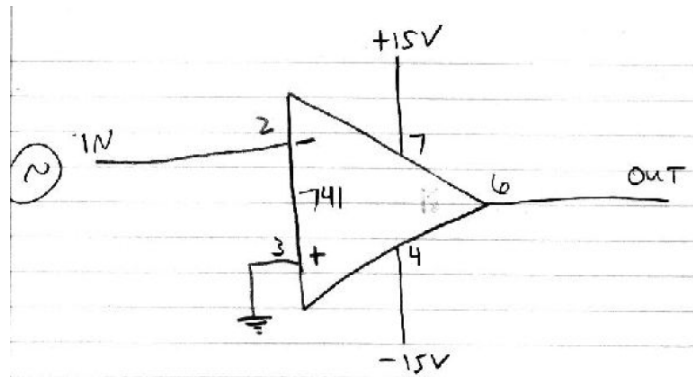
Part 1

Start Time: _____

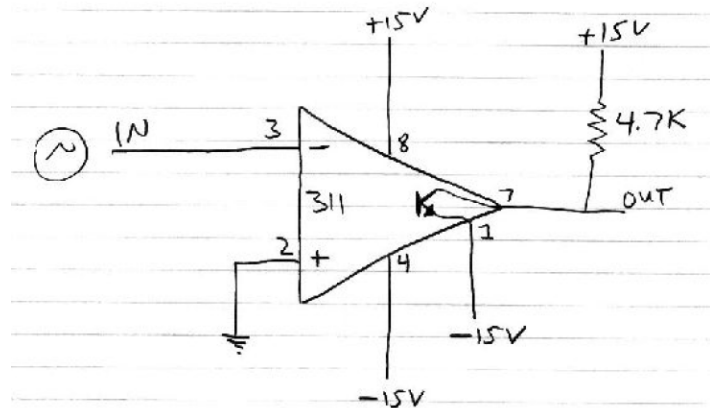
opamp vs. comparator

(time estimate: 45 minutes)

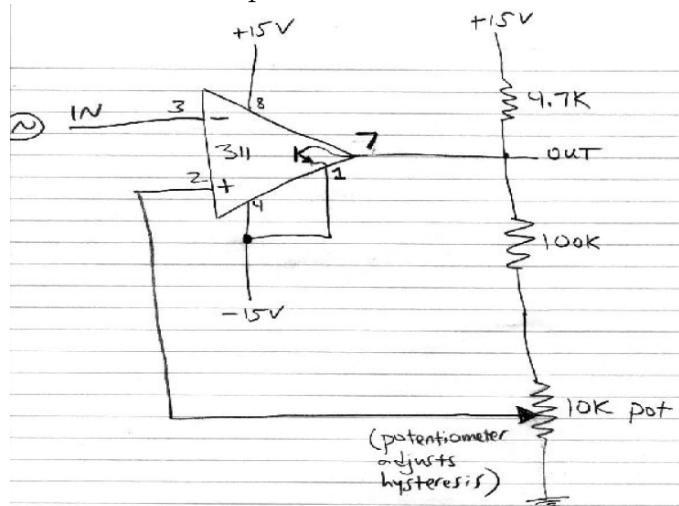
1.1 How well does your '741 opamp work as a comparator? Try a 10 kHz, 1 V_{pp} sine wave (also try a triangle wave) as input to the circuit shown below. Ideally, V_{out} should be +15 V whenever $V_{in} > 0$ and should be -15 V whenever $V_{in} < 0$. How "square" does $V_{out}(t)$ look? Why is it not especially square (i.e. what feature of the opamp is limiting the squareness of V_{out})?



1.2 Now try the same measurement with a '311 comparator, as shown below. (**Note that the '311 has a different pinout from that of the '741.**) What is the slew rate? After you've tried the 10 kHz sine and triangle, try an input with a very small slope near the zero-volt threshold (for instance, a sine with a DC offset) and see if you can catch the open-loop comparator's indecisiveness illustrated in last weekend's notes. (When $V_{in}(t)$ approaches the threshold voltage with a very small slope (or with some noise added), it should transition back and forth several times between the ± 15 V output states before settling down.)



1.3 Now try a comparator with positive feedback. Use the $10\text{ k}\Omega$ potentiometer to adjust the amount of hysteresis. Analyze the $0\text{ k}\Omega$ and $10\text{ k}\Omega$ cases (extreme values of the potentiometer setting) along the lines of the reading notes, as well as values in between. Do you see the effect of the different up-going and down-going thresholds? Does more hysteresis make it more difficult for the comparator to show multiple transitions near threshold? (Try a small-slope input as you did in part 1.2.) If you watch V_{in} , V_{out} , and the also non-inverting input with three separate scope probes, you should see the two separate thresholds at work.



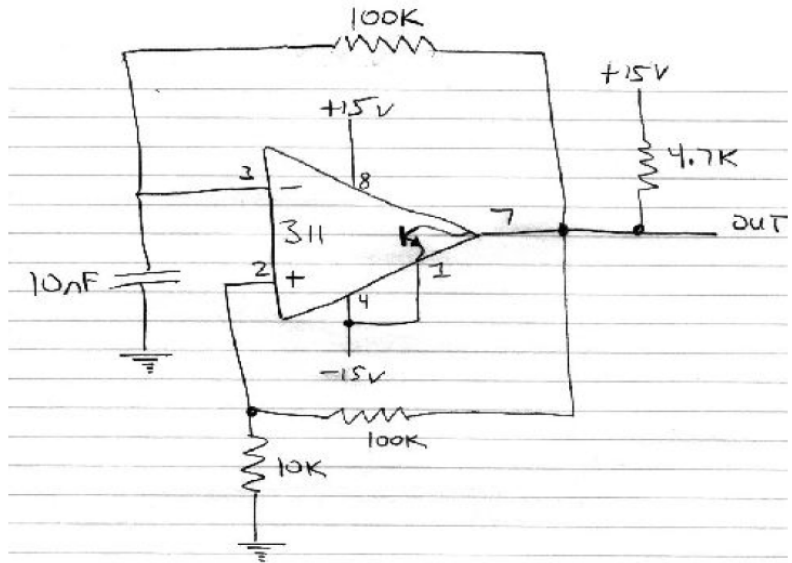
Part 2

Start Time: _____

“relaxation” oscillator

(time estimate: 30 minutes)

2.1 Build the oscillator drawn in the figure below, and measure its oscillation period. Look both at V_{out} and at the voltage on the capacitor vs. time. Can you understand how the circuit works? (My apologies for having forgotten to draw the $100\text{ k}\Omega$ positive-feedback resistor at the bottom of the diagram in the reading!)



2.2 Now choose components and modify the circuit to make it output a 1 kHz square wave. Draw the updated schematic diagram.

Part 3
finish up Lab 9

Start Time: _____
(time estimate: 60 minutes)

There is no part 3. Finish up any remaining parts of Lab 9 from last week. If you still have time left after finishing up Lab 9, you can try the optional Part 4 on the next page.

Part 4

Start Time: _____

optional — active lowpass filter

(time estimate: 30 minutes)

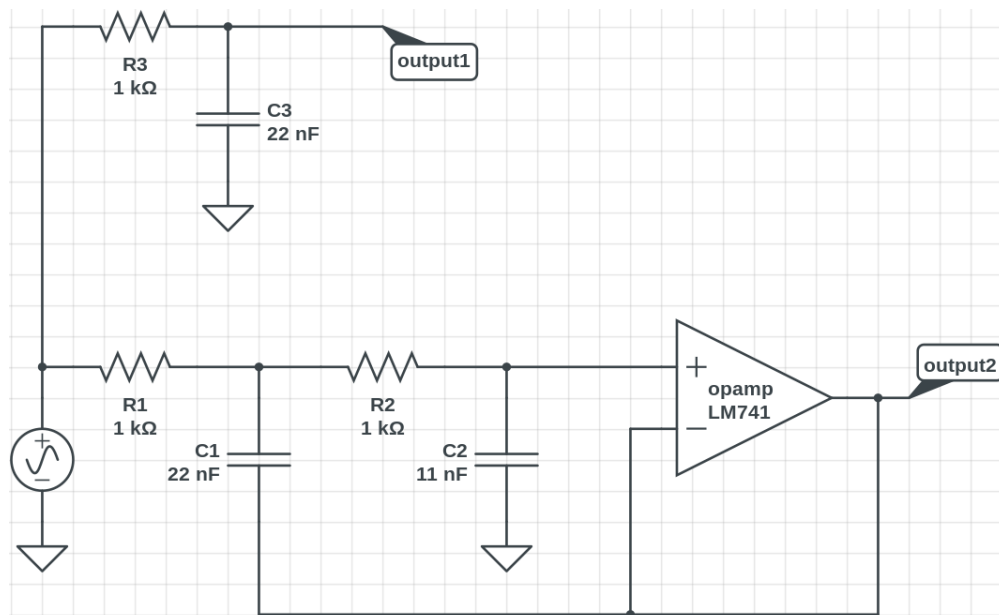
The diagram below shows two low-pass filters driven by the same input signal. The top one is the familiar RC filter. The bottom one is a Sallen-Key “active filter,” implementing a second-order Butterworth filter.

en.wikipedia.org/wiki/Sallen-Key_topology

en.wikipedia.org/wiki/Butterworth_filter

You can use two 22 nF capacitors in series to make 11 nF. Observe the frequency response of each filter. What is its gain at DC? At what frequency does its response drop to 0.707 of its DC value? How rapidly does the response fall, well above this frequency? You should find that the second filter’s response (a) is much flatter in the low-frequency “pass band” than the first; and (b) falls off like $1/f^2$ instead of the usual $1/f$ behavior at high frequency.

Instead of measuring this tediously by hand, use the FG’s *sweep* function to sweep the frequency of V_{in} from well below f_{3dB} up to well above f_{3dB} . Look simultaneously at V_{out1} and V_{out2} . Use the *sync* output on the back of the FG to trigger the scope at the start of each sweep.



The point here is that sometimes you want a filter that cuts off more sharply than a simple RC, so that you can cleanly separate wanted from unwanted frequencies. You don’t need to remember the circuit diagrams for higher-order filters, but you may want to remember that they exist so that you can look them up if you need them.

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