Lab 1: Positive feedback and oscillators

Objectives:
- see how positive feedback can be used to make a trigger or oscillator
- use a special-purpose IC (a 555) to make a square wave generator

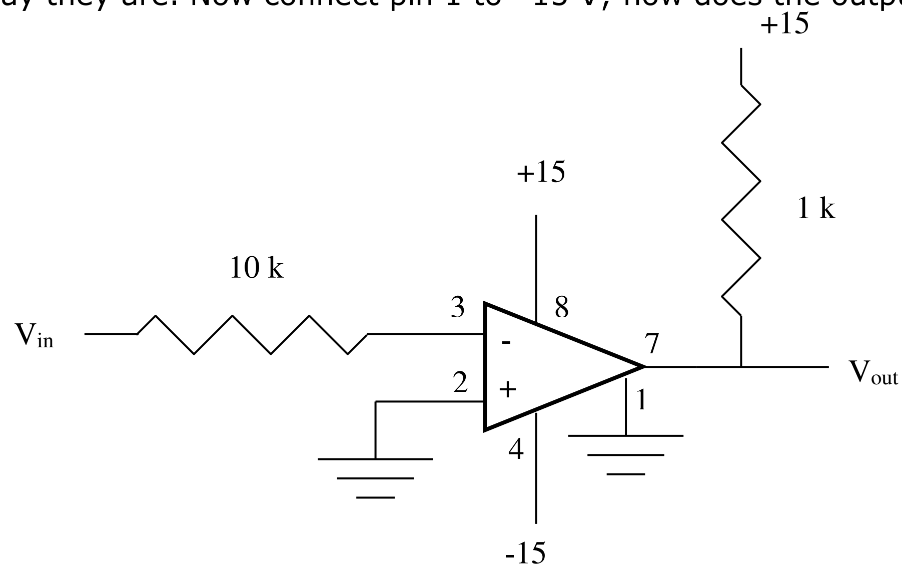
General notes:
- Remember that the DIP (dual in-line package) chips should straddle the trench in the breadboard
- Remember that we don't always show power to the chip on the circuit diagram, but it always needs to be there (usually ±15 V). Check your breadboard supplies and adjust them to be fairly close to ±15V.
- If you see "fuzz" on your output voltages, try putting a small ceramic capacitor (few tenths of a μF) between each of the power supplies and ground (to act as a short for very high frequencies; this will tend to eliminate the oscillations that cause the "fuzz").

7-1 Comparator/Schmitt trigger

In Lab 6-1, you used an LF411 op amp in an open-loop configuration and found that it saturated at about +15 when V+ > V-, and about -15 when V+ < V-. This behavior allows you to use an op amp as a comparator, in which the sign of the output voltage tells you which input voltage is more positive.

Set up an LM311 in the circuit shown below. (The 311 is a special-purpose comparator, which you can think of as being like a very fast op amp.) Note that the output is treated somewhat differently than with a typical op amp. The comparator has an output transistor that needs V_{CC} and V_{EE} set explicitly, which we do here by grounding pin 1 and "pulling up" pin 7 to +15 through a 1 k pull-up resistor. Is there any feedback here?

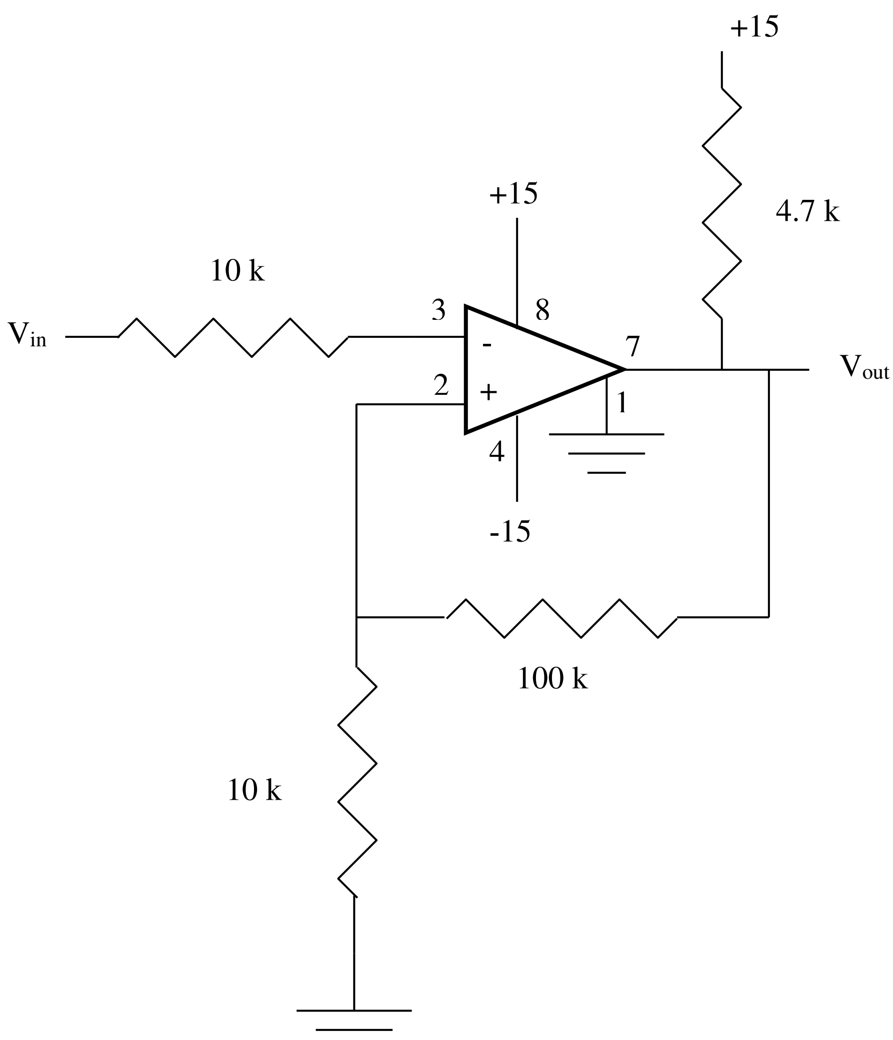
Put in a sine wave of moderate amplitude (1 V or larger) and frequency in the tens of kHz range, and look at (sketch) the input and output voltages. Explain why they are the way they are. Now connect pin 1 to –15 V; how does the output change, and why?



Because the 311 responds very quickly, a small voltage difference between its inputs can easily cause the output to oscillate or bounce between + and -. Give your circuit a sine wave with a very small slope, and try to get it to oscillate.

Now we're going to use positive feedback to eliminate the oscillations. Hook up the feedback as shown below, and change the 1k pull-up resistor to 4.7k (better for power dissipation). This is a Schmitt Trigger. Do the Golden Rules apply here? Why or why not?

Use an input sine wave signal of moderate amplitude (a few volts) and frequency (around 1 kHz). Look at V_{out} and V_{in} on the same time scales and sketch them carefully. At what V_{in} value does V_{out} switch from 0 to 15? At what value does it switch back? Explain this in terms of what's going on at the noninverting input (you might want to look at the noninverting input to verify your explanation). How could you change the amount of hysteresis? What would happen if you connected pin 1 to −15V? (Try it!)

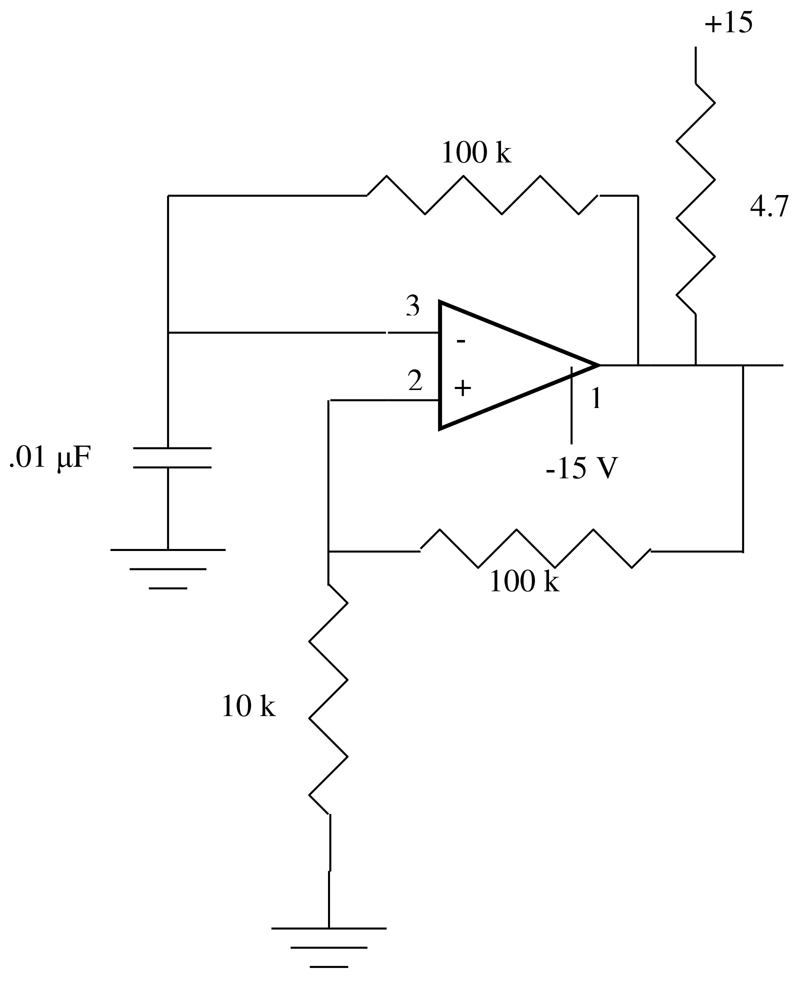


7-2 RC relaxation oscillator

If we modify the Schmitt trigger by replacing V_{in} with the voltage across a capacitor in an RC circuit, and using negative feedback to let the capacitor charge or discharge according to what V_{out} is, we can make use of the hysteresis of the Schmitt trigger to produce an oscillator.

Add the RC network in negative feedback as shown below, and remove the function generator so that your circuit has no signal input(!). Look at V_{out}. Describe or sketch what it's doing. Between what voltage values does the output oscillate? What's the measured frequency of oscillation? Also describe or sketch (on the same time scale) what's happening at the inverting input. Between what values does the inverting input oscillate, and why?

Explain how this circuit produces an output square wave with no input ("magic" is an appealing, but not sufficient, explanation). Figure out what the approximate frequency of the output square wave should be and compare it to what you measured.



7-3 555 timer in astable operation (square-wave generator)
Build the circuit shown in Fig. 9.6 in Kaplan and White. Make R_A and R_B both 10k, and make C=0.1 μF.

Look at V_{out} and at the voltage across the capacitor. Carefully sketch both on the same time scale, labeling voltages and times (duration that the output signal is high, and duration that it's low). What is the capacitor doing when the output is high? What is it doing when the output is low?

From the circuit's component values, predict the duty cycle of the output waveform and then measure it. Predict the frequency of the output waveform and then measure it.

What do you expect to happen to V_{out} and the voltage across the capacitor if R_2 is shorted out? Try it. Sketch or describe the results, and explain why they make sense. What's the duty cycle of this waveform? What's the frequency?

Change the power supply voltage to +10 V. Does that affect the amplitude of the square wave? Does it affect the frequency?

Optional: Use the output of the 555 to make an LED blink on and off (you'll need to change R and/or C values to make the blinking slow enough to see). Show me your design before actually turning it on.

Optional: Come up with a design that would allow a 50% duty cycle square wave to be output. Show me your design before actually turning it on. Sketch a schematic design of your circuit and describe or sketch the results, and comment on how well your design works and why.