Physics 323

Experiment # 4 - Op-Amps II(Positive Feedback)

Purpose: In this lab we will look at two important uses for positive feedback: trigger circuits and oscillators.

References: Storey pp. 522-524, pp. 666-670
Wallbank, Barry *PHYS 323 Course Notes* pp. 29-32

1. Comparators and Schmitt Triggers

Prelab- Comparators and Schmitt Triggers

Predict the behaviour of the comparator in Fig. 1 and predict the voltage thresholds for the Schmitt trigger circuit in Fig. 2. Before you answer these questions read through the lab to learn more about the operation of the 311 comparator and the circuits.

Lab Intro- Comparators and the 311 chip

We saw in Experiment #3 that negative feedback could be used with a very high open loop gain forward path to design a very useful, stable amplifier among other circuits. Negative feedback moderates the circuit's performance and tends to prevent saturation of the output.

As you might expect positive feedback has the opposite effect. It forces the output quickly to extremes. Consider the following use for this decisive behaviour. When you build a system a frequent operation is to know which of two signals is larger, or to know when a given signal exceeds a predetermined value (like the IF… THEN… statements of computer programming). Such a sub-circuit is a *comparator*, which in its simplest form is a high-gain differential amplifier i.e. an op-amp with no feedback which goes either into positive or negative saturation (i.e. hits the power rails) depending on the relative magnitude of the inputs (remember exercise 1 in Experiment #3). However, a 741 op-amp would make a slow comparator; it is better to use a special purpose comparator e.g. the 311. (I will set up a 741 circuit for you to observe and compare.)

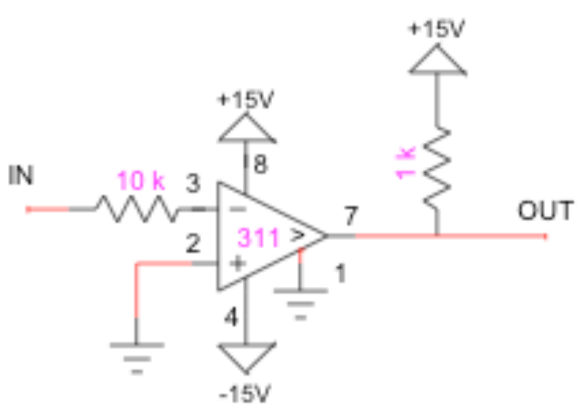

Figure 1: Basic Comparator Circuit with 311

The 311 is *not* an op-amp (note the '>' symbol). Instead its output acts as a high-speed switch. The connections mimic some of those of the 741 op-amp. When the '-' input is greater than the '+' input the switch "opens" and OUT goes to the 15V that is provided through the 1 kΩ resistor (you will need to explain this effect in the ***Prelab***). When '+' is greater than '-' the switch closes to ground and OUT drops to zero. The 1 kΩ resistor prevents a large current from being drawn from the power supply. The 10 kΩ resistor connected to pin 3 likewise prevents current from being drawn through the virtual ground provided at pin 2.

Lab Procedure - Comparator

Connect the circuit in Figure 1 and drive it with a 10 kHz sine wave.

Observe and record the input and output waveforms. Does it match your ***Prelab*** prediction?

Turn the frequency up. Can you observe a breakdown of the behaviour?

(There is one more part to this procedure so don't disassemble the comparator yet.)

Lab Intro- Schmitt Trigger

If an input waveform is noisy a comparator may switch several times as it passes through the threshold. (If you have ever driven in a car where the backlights for the dash come on automatically when it gets dark you may have notice times they flip back and forth when it is close to twilight. ***Procedure:*** Simulate this effect by turning down the AC amplitude from the WG (this is the noise) and then adjust the "signal" by changing the DC offset. You should find two stable regions, separated by a noisy interval.

We require a circuit that can ignore the noise and make the output more decisive (and stable) by introducing positive feedback. Consider the following circuit

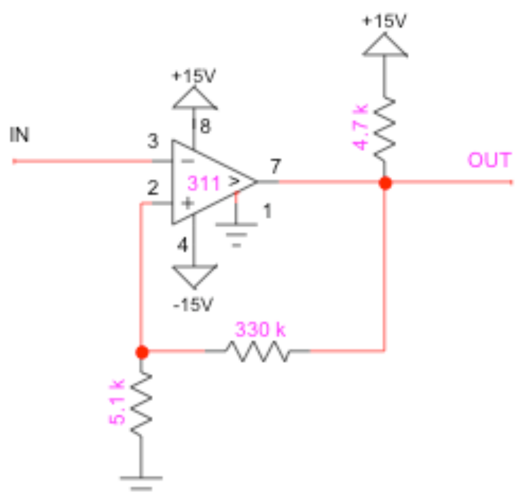

Figure 2: Schmitt trigger with 311

The effect of the feedback voltage divider is to make the circuit have two thresholds, depending on the output state i.e. hysteresis has been introduced. This makes the comparator less likely to "switchback" on a noisy input. Also the positive feedback ensures a rapid output transition regardless of the speed of the input waveform. A comparator connected as shown is known as a *Schmitt trigger*.

Note: when you are trying to predict the voltage thresholds (i.e. an effect at the input) you need to make assumptions about the *current* output state. You know how the 311 acts so you can predict the two output states. *Then* you need to predict the effect of changing the input in the two cases when these output are the initial states.

Lab Procedure- Schmitt trigger

Connect up the Schmitt trigger and measure the threshold voltages. Is the circuit behaving as you have predicted?

Prelab- Wien-bridge sinusoidal oscillator

Calculate the output frequency for the Wien-bridge oscillator.

Calculate the amplitude and phase (relative to the output) of the signal at the non-inverting input. What is the approximate resistance of the lamp for stable operation?

If the gain of the inverting network (i.e. lamp and 330 Ω resistor) is too high or too low what would happen?

Lab Procedure- Wien-bridge

At low to moderate frequencies the Wien-bridge oscillator is a good source of low distortion sinusoidal signals - this is much more difficult to do than producing a square wave.

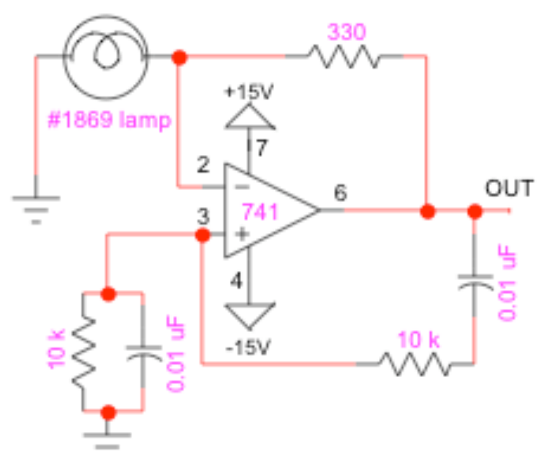

Figure 3: Wien-bridge oscillator

Connect up the circuit of Fig. 3 as shown (so you need to use a 741 and the appropriate pin assignment). Measure the output frequency (look Mom! No input!). How much distortion is there in the output? What, no waves? Make sure you have the correct balance. You might substitute in a potentiometer (variable resistor) so you can trim the gain until you get it just right.

What is the purpose of the lamp?