

LAB 8

Positive Feedback and Oscillators

Reading: Malvino, Sections 21-2, 21-3, 21-9, chapter 22

Hayes and Horowitz, Class 10, Lab 10 and Ch. 4 worked examples on pp 227ff.

1. Comparators

a) Connect a LF411 or a TL071 op amp as a comparator. Drive the input with a sine wave and observe the output. You are just using the high open loop gain of the op amp and swinging between positive and negative saturation. Op amps that are intended to be used as an amplifier have a slow response time which is caused by the internal compensating capacitor used to avoid high frequency oscillations. See if you can measure this limited response time.

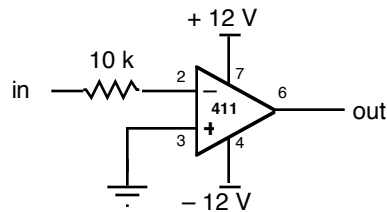


Fig 10.1

b) The LM311 is an op amp that is designed to be used as a comparator. Unlike most op amps, it has a faster response and you can change the voltage levels of the output. With this op amp you get -12 V if $V_{\text{in}} < V_{\text{ref}}$ and $+12\text{ V}$ otherwise. The open collector output of the 311 allows you to change these output levels independently of the power supply that runs the op amp. Pin 1 comes from the emitter of the i.c.'s output transistor. It is not connected inside the chip. Whatever voltage level you connect this pin to becomes the output if $V_{\text{in}} > V_{\text{ref}}$. Often this pin is connected to ground. Similarly pin 7 goes to the output transistor's collector. This collector is not connected in the chip either—that's why it's called an open collector. You connect this pin to a voltage that you want when $V_{\text{in}} < V_{\text{ref}}$, for example, 5 V . Open collector outputs are commonly used if logic voltage levels representing "true" or "false" are different in one part of the circuit from another part.

Connect the LM311 as a comparator and observe its improved performance. *Note that some of the pin numbers of the LM311 are different from the 411 or 741 op amps.*

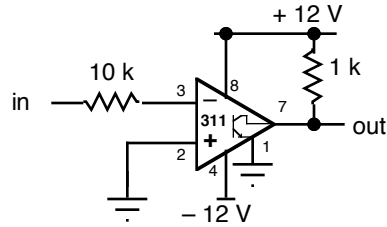


Fig 10.2

2. The Schmitt Trigger

a) Because of its fast response, the 311 comparator can “chatter” if V_{in} hovers indecisively near the comparison point. In this case, the output will swing erratically between the positive and negative output levels as the input drifts up and down by very small amounts.

The Schmitt trigger uses positive feedback to reinforce the comparator’s decision. Immediately after the input voltage crosses the trip point, the trip point (threshold level) changes so that the input must significantly retrace its path in order to reverse the decision. This means that there are two trip points: one for rising input signals, and another, lower one, for falling input signals.

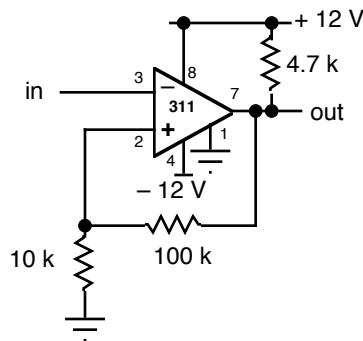


Fig 10.3

Calculate the trip points of the circuit in Fig. 10.3 Build it and see if it operates like it should. Put a sine wave on the input and note the “hysteresis.” Also note that the triggering stops for sine waves below certain amplitudes.

3. R.C. Relaxation Oscillator

The next circuit in Fig. 10.4 shows how to build a square wave generator called a relaxation oscillator. What you do here is remove the input to the Schmitt trigger and reconnect it to one end of a capacitor. The other end of the capacitor is at ground and the capacitor is allowed to charge through a resistor coming from the output of the comparator. After the capacitor charges to the upper trip point, the comparator output goes low to ground. Now the capacitor will discharge until it reaches the lower trip point. The comparator output goes high again and the charging cycle continues. The output oscillates between high and low with a frequency determined by the RC time constant of the resistor and capacitor.

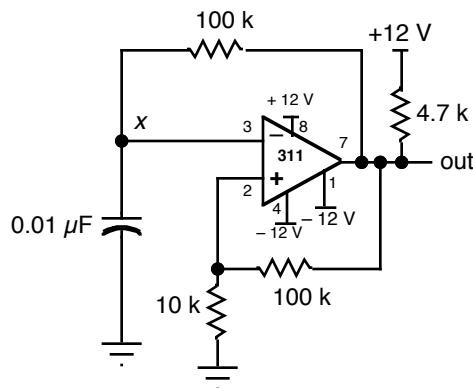


Fig 10.4

Predict the frequency of the circuit. Build it and

- measure the frequency,
- measure the peak-to-peak voltage of the output and the voltage of the low level,
- observe the inverting point x and explain its behaviour, and
- try to change the frequency by changing the capacitor and resistor combination.

4. The Wien Bridge Oscillator

Generating a sine wave is more difficult than a generating a square wave. The Wien bridge circuit uses the parallel-series, lead-lag, circuit to maximize positive feedback for its critical frequency, $f_c = 1 / (2\pi RC)$. The tungsten lamp in the negative feedback loop limits oscillations when they grow past a certain limit. As the current through the lamp increases at higher output voltages, then its resistance increases and cuts down the gain of the amplifier. Thus

a stable frequency is maintained by the lead-lag circuit in the positive feedback loop, and a stable amplitude is established by the self-regulating effect of the tungsten lamp in the negative feedback.

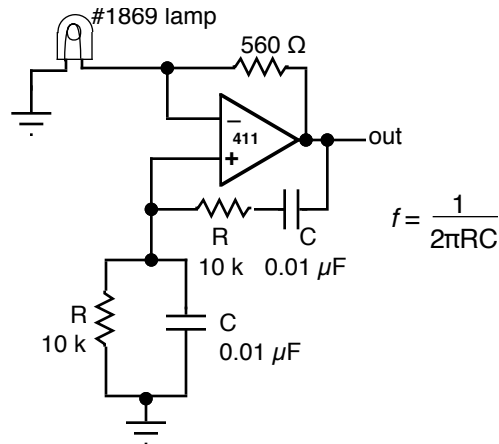


Fig 10.5

Build the circuit in Fig 10.5 and check if its frequency is . When you first turn it on you'll see the amplitude grow larger until the negative feedback increases after the lamp warms up. When you poke the noninverting input with your finger the output will wobble. If you sweep the scope slowly and poke the noninverting input, you can see the envelope of the oscillation bob up and down. Can you explain this?

You can use this oscillator for radio frequencies. Using $R=470\ \Omega$, $C=220\ \text{pF}$ in the lead-lag circuit will give $1/2\pi RC = 1.5\ \text{MHz}$. When I tried it, though, I got a frequency of about 500 kHz. The shift is probably because of stray capacitances and inductances in the circuit. You will have to experiment yourself to get a frequency in the AM radio band. We also found that increasing the 560 Ω feedback resistor to 1 k Ω improved the output amplitude. This way you can use the oscillator for the carrier frequency of the AM transmitter of the FET experiment.

Homework

1. Find the trip points of the Schmitt trigger in Fig. 10.3.
2. Find the oscillation frequencies of the relaxation oscillator and Wien bridge oscillator shown in Figs. 10.4 and 10.5.