Physics 334
Notes for Lab 8 – Positive Feedback and Oscillators

February 25, 2009

Lab manual sections **10-1, 10-2, 10-3, 10-4, Suggested: 10-8, Optional 10-6**.

10-1. ***Be careful of the difference in the pinouts between the '411 and '311!*** To get the open-loop '311 to oscillate, apply a 10Hz sine wave to the input and slowly decrease its amplitude.

To predict the thresholds of the Schmitt trigger, find the voltage at pin 2 as defined by the voltage divider made of the 10k, 100k and 4.7k resistors. When the output is HI, pin 7 is "open"—the transistor at the output is off. When the output is LO, pin 7 is "grounded"—the transistor at the output is on so its collector sees the potential at pin 1, which is ground here.

Note what changes when you connect pin 1 to -15V.

10-2. Use the circuit from 10-1. All you need to do is connect the R and C to the input. To predict the frequency of oscillation, recall from the class notes that an estimate based on linear charging gives $f = 1/(4\lambda RC)$ where $\lambda = 10\text{k}/(10\text{k} + 100\text{k})$. A more complete calculation gives $1/f = 2RC \ln[(1+\lambda)/(1-\lambda)]$. Try both formulas. Note: capacitor tolerances are not very good – typically 20 %.

10-3. ***Note: Many people are tempted at this point to think the 7555 (or or varients) is an OpAmp. It is not. It is a special purpose chip designed specifically to be an easy to use oscillator. There are many specialty purpose chips that do just about every job imaginable. To use them, always look up, read and understand the data sheet. The 555 is a very famous chip, but there are many others.***

Do as stated. Draw the waveforms you get at the output and at pin 6 (top of the cap). Are the trigger and threshold points at 1/3 and 2/3 V_{CC}? When you remove R_B, you will have to look hard at the output waveform; it is *not* a constant!

To make a 50% duty-cycle oscillator, remove resistors R_A and R_B and the connect a 10k resistor between the output (pin 3) and the threshold pins (pins 2 and 6). Explain why this works. Ignore the question about how the output differs from the output of the traditional '555.

10-4 The 3906 makes a simple current source. The voltage divider at the base sets the base to about 2.7 or so volts... Or two volts (fixed) across the 2 k resistor, giving 1 mA current. Since

$I = C\frac{dV}{dt}$, a constant current onto a capacitor gives a constant $\frac{dV}{dt}$... or a ramp. This ramp continues it's upward climb until it hits the threshold voltage, whence it discharges (rapidly) through Pin 7 (D).

10-8. ***Suggested if you have time***

The op amp has a number of gain stages, each of which has some inherent phase shift. As you learned in class, if these phase shifts add to 180, it can lead to oscillation. Op Amps are always (though not always) rolled off for gain so that they are stable all the way to unity gain. Usually just barely so. So if we add some additional capacitance in the feedback path (and hence a bit more phase shift), we can sometimes get an oscillation.

After you insert the 10k pot into the circuit, and find the point where oscillation ceases, measure the gain, and calculate the value of B, the amount fed back into the input. Note, gain $\propto 1/B$. You may find that the point at which the oscillation stops is hard to pin down.

10-6 Optional

This is a clever and fun circuit. Try it if you can. It uses both positive feedback to make an oscillator, and negative feedback to limit the gain sufficiently to make a "nice" sine wave without clipping. It was one of the first ways to make a sine wave oscillator. In fact it's how Hewlett and Packard got their start... with the HP200 - a nice piece of instrumentation to produce low distortion audio frequency sine waves.

Use the #334 lamp. This lamp is the red lamp with two wire leads. The lamp's resistance increases as the filament gets hotter (recall Lab 1!). *Note:* the lamp should not glow (very much). Try replacing the 560Ω resistor with 1k, 510Ω and 390Ω, and comment on your results.

When you poke the lamp with your finger, remember that it acts as both a resistor and a capacitor (with capacitance increasing due to the proximity of your fingertip). The circuit uses a lamp because the the temperature variation of the lamp is slow compared to the oscillation period.