Physics 120 Lab 9 (2019 - incomplete): Positive (Destabilizing) Feedback

9.1 Three Comparators and positive feedback

Comparators work best with positive feedback. But before we show you these good circuits, let’s look at two poor comparator circuits: one using an op amp, the other using a special-purpose comparator chip. These circuits will perform poorly; they will help you to see what’s good about the improved comparator that does use positive feedback.

Open-loop op amp as comparator

![Figure 9.1: Op amp as simple comparator.](image)

You will recognize this as the very first op amp circuit you wired (exercise 4.1), where the point was to highlight the high gain of the device. In that exercise the excessive gain was factored out of the circuit equations and the input/output was linear. Here we view the circuit as a comparator and the very high gain and the “pinned” output are desired.

Drive the circuit with a sine wave with a 100 mV (or less) amplitude at around 100 Hz and notice that the output is close to a "square wave"; document with a SCREENSHOT. Now drive the circuit at 100 kHz, and document with a SCREENSHOT that the “square wave” output is not as square as it was for 100 Hz. Why not?

Special-purpose comparator IC

![Figure 9.2: 311 comparator and no feedback.](image)

Now substitute a LM311 comparator for the LF411 (or AD711); the pin-outs are not the same. You will notice that the output stage looks funny: it is not like an op amp’s, which is always a push-pull; instead, two pins are brought out, and these are connected to the collector (pin 7) and emitter (pin 1) of the output transistor, respectively. These pins let the user determine both the top and bottom of the output swing (e.g., one can use +5 V and ground to make the output compatible with standard digital logic).

Here, you will keep the top of the swing at +15 V and set the bottom of the swing to ground. Does the LM311 perform better than the LF411? How so? Document the improvement in gain(s) with a SCREENSHOT.
A side-effect of the LM311’s fast response is its readiness to oscillate when given a small and/or voltage difference between its inputs. Tease your LM311 into oscillating near the transition using a sine wave with a gentle slope. You may need to use the "expansion settings" of the oscilloscope. Document your output with a SCREENSHOT that shows rapid transitions near the threshold.

**Special-Purpose Comparator IC configured with positive feedback as a Schmitt Trigger**

The positive feedback used in the circuit of Figure 9.6 provides hysteresis that will eliminate the harmful oscillations by shifting the threshold immediately after a transition. Predict the thresholds of the circuit above (see class handout as a guide but derive the expression for this simplified case); they try it out and document your a functioning circuit with a SCREENSHOT.

![Schmitt trigger circuit diagram]

Figure 9.3: Schmitt trigger: comparator with positive feedback

Notice that triggering stops for sine waves smaller than some critical amplitude. Explain this.

Measure and report the hysteresis. Observe the rapid transitions at the output, independent of the input waveform or frequency. Look at both the "-" and "+" comparator terminals and document with a SCREENSHOT of the V- and V+ inputs and the output.

Reconnect the so-called “Ground” pin of the 311 to -15 V; this pin is not necessarily ground, rather it is the emitter of the output transistor. Perhaps you can now see why the chip’s designers brought out this pin, as well as why they provided an open-collector output.

9.2 Relaxation oscillator

![RC relaxation oscillator circuit diagram]

Figure 9.4: RC relaxation oscillator
A comparator is used with positive feedback to construct a free-running oscillator. Build the circuit of Figure 9.7 and show, with a SCREENSHOT, that $V_{\text{out}}$ oscillates. What are the expected and measured frequencies (see, e.g., class notes)? Record from both the output and point "X" and explain, documenting with a SCREENSHOT, what you see. Repeat, including SCREENSHOT, with the 10 kΩ resistor replaced with 1 MΩ.

**9-3 7555 IC oscillator (square wave)**

The 555 and its derivatives have made the design of moderate-frequency oscillators easy through the use of a monolith device. The 7555 runs up to 500 kHz and its very high input impedances and rail-to-rail output swings can simplify designs.

![Figure 9.5: 7555 relaxation oscillator.](image)

Connect a 7555 in the classic relaxation oscillator configuration, as shown above. Look at the output and document with a SCREENSHOT. The frequency is given by:

$$f_{\text{oscillation}} = \frac{1.4}{(R_A + 2R_B)C}$$

Look at the waveform on the capacitor ($C$). What voltage levels does it run between? Document with a SCREENSHOT. Does this make sense?

Replace $R_B$ with a short circuit. What do you expect to see at the capacitor? At the output? Document your conclusions with SCREENSHOTs.

**9-4 A small recurrent neural network**

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