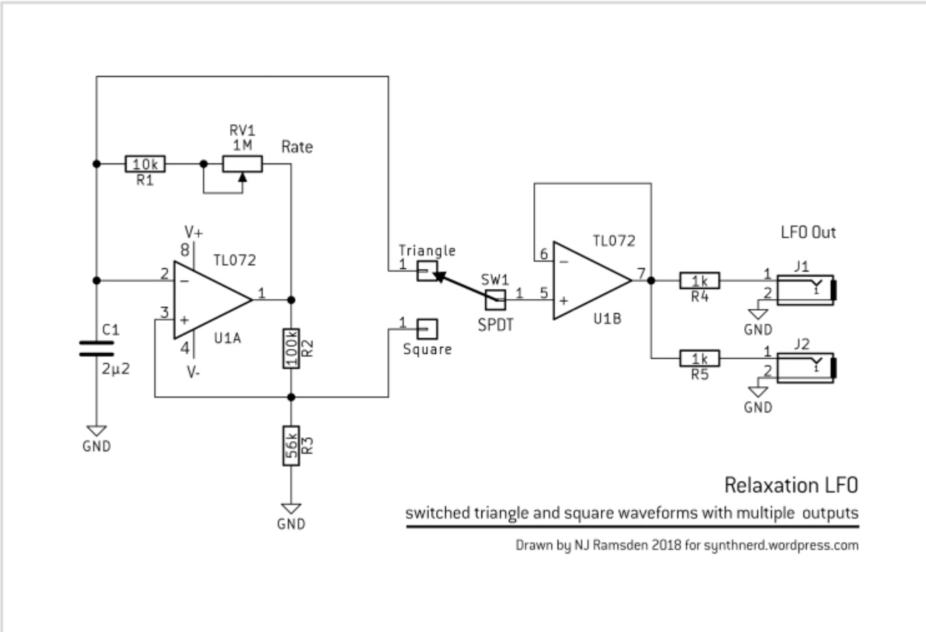
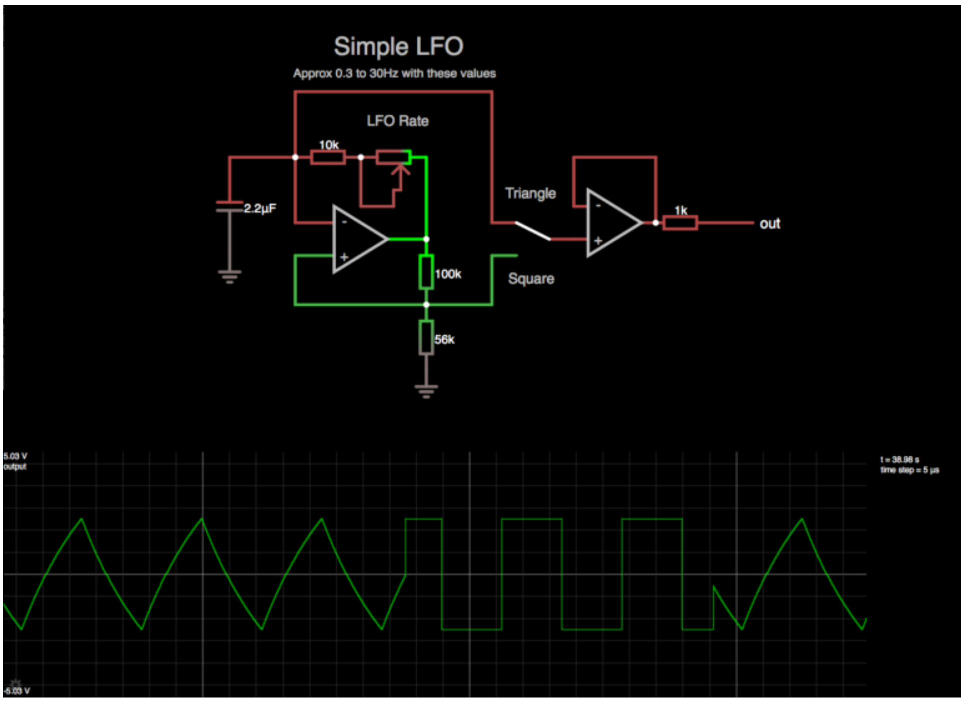
…Synth DIY: the Relaxation LFO

This circuit gets is name from the way it charges, then discharges, a capacitor. Think of it like breathing: inhale, exhale. The charge on the capacitor is the rhythm of the breath.



(https://synthnerd.files.wordpress.com/2018/12/LFO-for-synthnerd.jpg)
Relaxation LFO



(https://synthnerd.files.wordpress.com/2018/12/example-circuit.png)
Relaxation LFO simulation

Watch this in action here: Relaxation LFO simulator (http://tinyurl.com/y745b6xq)

Download a PDF of the schematic here: Relaxation LFO schematic (https://synthnerd.files.wordpress.com/2018/12/LFO-for-synthnerd.pdf)

This example uses two op-amp stages, run from dual supply rails. Let's consider just the first op-amp for now.

It has something in common with a comparator (https://www.electronics-tutorials.ws/opamp/op-amp-comparator.html) – the output will flip high or low depending on which input is higher. Here we're using feedback to control this operation.

Imagine the output of the op-amp is high. From this, feedback charges the capacitor. The capacitor takes time to charge up through the feedback resistor, with the charging being faster with less resistance (actually here we're using one fixed resistor and one variable resistor so the user can change the charging rate). When the voltage present at the inverting input (-) goes higher than the voltage at the non-inverting input (+), the output flips low.

Now, the capacitor slowly ramps *down* because of the negative feedback from the low output. When the voltage at (-) drops *below* the voltage at (+), the output flips high and the cycle repeats.

With the values shown, the LFO ranges from about 0.3Hz to 30Hz, or 30 milliseconds to 3 seconds per cycle. This is a good starting point for experimentation.

Some Technical Detail

Looking at the simulation, we can see a square wave at the output of the first op-amp, and a triangle wave at the top of the capacitor. Ignore the second op-amp for now.

The output voltage of the op-amp will vary depending on your supply rails and which device you use. The popular TL07x devices, for example, will not swing fully to either rail.

If you take your 'square' LFO wave from this point, it will likely be hotter than you need. Using a TL07x on 15V rails, your LFO output would be in the region of 27V peak-to-peak, which is silly. We could add a few more parts to drop it down to something more practical.

The two resistors connecting the output of the op-amp to its (+) input act as a divider to determine the level at which the signal flips direction. If they are equal, the flip point will be half the op-amp's output voltage, etc. You should adjust these values to get the right output level for your needs. A typical modular LFO might be +5V to -5V, for example. Useful resistor values might be in the range 10k to 100k or thereabouts, but absolute values are not critical. It's the ratio that counts. For example, if your rails are +/-12V, and your op-amp thereby swings to +/-11V, you could use a 12k resistor from output to (+), and a 10k resistor from (+) to ground, which would give you a +/-5V LFO output (11V*10k/10k+12k = 11*10/22 = 5).

We can take the square LFO output from the junction of these two resistors, instead of directly from the op-amp output, and it will be the same peak voltage as the triangle. We just need to buffer it to prevent problems arising from connecting it to some other input somewhere.

The 'triangle' wave available at the capacitor is not really a true triangle, as the rise and fall are both slightly curved. This will be more pronounced the closer to the rails your flip point is. It probably won't matter, and you might not even notice, if you've got something like a 5V flip point on 12V or 15V rails.

We can't take the triangle wave directly from the cap; we need to use a buffer so as not to load it. This is the second op-amp.

We can use one buffer for both waveforms, and just add a switch to select them. You can then use the output of this buffer to feed multiple destinations without trouble. Doing it this way means we can have a useful LFO with just one dual op-amp chip and a handful of extra parts. It's a small circuit that is cheap to build, and with only one knob, one switch, and one socket required, you can fit them into a small panel space. Of course, you could omit the switch and use separate buffers for each waveform, or just tap off one waveform if you don't need the other. You should be easily able to adapt this circuit to your own needs.

Finally, how do we change the speed range of the LFO? Once we know the peak voltage level, we can change the values of the capacitor and the negative feedback resistor/s. We can use a variable resistor here, though we'll still need a small fixed resistor at one end to give a limit to the maximum speed. A higher resistance means a slower LFO. A 10k resistor and a 1M pot give a 1:100 range; if you keep the 1M pot but make the fixed resistor only 1k, for example, your range will be 1:1000, with the slow time more or less the same – the smaller fixed resistor sets the fast limit. When you've decided on your speed range, pick a suitable capacitor to determine the absolute speeds. A higher capacitance means a slower rate. With the aforementioned resistor values, something in the low microfarad range is a good starting point.

The capacitor should be non-polarised, as it will be charged above and below 0V. You can get non-polarised electrolytics easily enough, and the little polyester film caps are fine too, though they are less common in the >1µF range. Make sure the voltage rating of the cap is more than the voltage swing you'll be giving it.

Next time I'll talk about integrating LFOs.