Description

The LFO Controller is a versatile analog synthesizer module used to alter audio frequencies, create repetitive patterns, do tremolo effects, and so forth. As an LFO (low frequency oscillator), it puts out control signals such as a sine, triangle, square, gate and trigger in the range of about 0.03Hz to 30Hz. It can also be accurately controlled by keyboard gate or trigger signals to create such effects as delayed vibrato, repetitive envelopes, etc.

This module operates in four basic modes:

- Triggered or delayed mode
- Gated mode
- Footswitch mode
- Free-running mode

In triggered mode, as long as keyboard triggers are appearing, the LFO is quiescent. When the triggers eventually stop, the output signal smoothly ramps up to full amplitude but only after a desired interval. This creates the so-called delayed vibrato effect when used to frequency modulate a VCO (voltage controlled oscillator).

In gated mode the LFO is quiescent as long as no keyboard gates are present. But when a gate is finally detected, again the output ramps up.

Footswitch mode is similar, but now it is an ordinary short-to-ground footswitch which enables or disables the LFO.

Finally, with neither a keyboard trigger nor gate present, the unit behaves as a standard free-running LFO.

All in all, with these basic modes, in addition to a variety of panel knobs, switches and jacks there is hardly a synthesizer control task that can't be accommodated. Experimentation will probably uncover other valuable uses.

How It Works

The schematic is spread out over two pages, Figures 1 and 2. Refer to the first. The heart of the LFO Controller is a Schmitt-trigger/integrator formed around IC1a and IC1b. A triangle is developed at pin 1 while a square is found at pin 7. R57 sets the basic operating frequency, while R1 is there to prevent stalling at very low settings. This arrangement is a little unusual in that the comparator, IC1b, is deliberately biased down by trimmer R28 and resistor R32. This forces the triangle to oscillate between 0V and –5V. The reason for this is to ensure that the unit always commences with a complete cycle and not with some orphaned partial waveform. That will be extremely important when using the LFO Controller in gated mode to create repetitive envelopes; the gates and triggers always accurately follow the onset of keyboard activity. In short, the player will never experience timing errors and can attack the keyboard with his or her usual technique.

Q1, a P-channel FET, is used to halt the LFO by shorting out timing capacitor C3 when needed. In particular, when the gate of Q1 is positive the transistor is essentially out of the circuit and the oscillator is running. But when the gate goes negative, C3 is shorted out and the unit freezes. Incidentally, when stopped, the square wave output at pin 7 of IC1b lies at –15V, which will be central to the timing accuracy business just mentioned.

Let's think about using the LFO Controller in gated mode. A keyboard gate is applied to jack J1. This then feeds the non-inverting comparator built around IC2a. When the keyboard gate is at 0V, the output at pin 1 is negative and hence Q1 is on. The unit has halted. But when a gate arrives (+5V on most synthesizers) pin 1 goes positive turning on the oscillator once more.

Now note IC2c. Yes, this is a comparator too, but even more interesting is that it's acting as an AND gate. (It's perhaps surprising to observe that you can model any logic gate with op-amps.). The two inputs to the AND gate are the keyboard gate just mentioned and the square wave also described above. When both of these go high, indicating that you've just pressed a key with the LFO Controller presently halted, oscillations begin at once with a full cycle. Once more, this is what keeps the unit musically useful and accurate.

The square wave output thus created is developed across voltage divider R16/R12. Its amplitude will be ±5V, a common synthesizer standard. The square is also rectified by D4, creating a 0V to +5V gate signal at jack J4. You would typically use this to drive an envelope generator.

The square is also differentiated by C10 and cleaned up by comparator IC2b. What appears at jack J2 is a nice trigger pulse, about 1 millisecond wide and again 0V to +5V in amplitude. This could also be employed with an envelope generator, but also with sequencers and similar trigger-happy devices.

Finally, LED D8 monitors the square wave providing visual indication of what's going on. Note the way in which the otherwise unused Darlington pair buffer in IC3 (yet to come) is pressed into service here. This keeps the LED from loading down any of the outputs.

That takes care of the rectilinear outputs, so let's focus on the triangle and sine outputs next. Refer to Figure 2. Recall that the triangle wave at pin 1 of IC1a swings from the nonstandard 0V to –5V levels. IC2d takes care of massaging this. First off, the chip buffers the triangle since we're using the non-inverting input at pin 12. Equally important is that the configuration simultaneously amplifies and level shifts the triangle to the usual ±5V value. The triangle is available unmodified at optional jack J6.

In some musical applications, a sine wave is a more natural tool for modulating various sound parameters. So, the triangle is next applied to an OTA (operational transconductance amplifier). But here we're using IC3b in a nonlinear fashion. It can be shown that the differential pair inputs of an OTA when slightly overdriven by a triangle wave produce a decent facsimile of a sine. That's what we're doing here. The triangle is applied to the inverting input of IC3b via R38 while the control current at pin 16 is locked into place. That control current can be adjusted by trimmer R33 to warp the triangle at its extremes, giving a nice roundness to the wave. Trimmer R53 modifies the symmetry, ensuring that the positive and negative halves of the sine wave are indeed identical in appearance. Trimmer R34 then sets the final amplitude allowing you to match it exactly to the triangle wave. Finally, trimmer R54 tweaks the offset to make certain the wave is centered on ground. One final detail, R31 provides a feedforward path which has the excellent property of squashing the pips that would otherwise occur at the extremes. What comes out at jack J7 is a very reasonable approximation to a sine wave.

Switch S2 lets you select any of the triangle, sine or square waves for your main controller output. Again, note that these signals are all a nominal ±5V in amplitude. Whichever is chosen is routed to the second OTA, IC3a. In this case, we're using the chip in its usual fashion as a VCA (voltage controlled amplifier). As the current into pin 1 is altered, the waveform will smoothly increase from no signal at all to the full output. The signal is buffered by the second Darlington pair inside the LM13700 and then finally presented to jack J8. By the way, the Darlington pair in this chip has an offset of two diode drops below ground which is pretty annoying. Trimmer R55 deliberately feeds in an offset voltage to counteract this. Finally, remember that an OTA like this one is a current-out device. Thus R39 and trimmer R56 to ground convert the current to a voltage, with the trimmer letting you nudge the amplitude as needed.

Let's focus on how the delay circuitry works next. IC4, which is the LMC555, a CMOS version of the well known timer, is pressed into service. Here it's configured as a one-shot or monostable. Delay pot R61 along with R7 and C13 set the "on" time. This ranges from nearly instantaneous on up to about six seconds.

Back up to jack J5 for a moment. When keyboard triggers are present here (indicating that someone is twiddling the musical keyboard), the one-shot is repeatedly fired. But since IC4 responds to negative going triggers, we must first invert them and that is the purpose of Q2 and its associated components. C1 differentiates the trigger, making it quite narrow to avoid any obvious latency. The transistor, besides inverting this pulse, also boosts it to the full +15V level. Most keyboards put out a +5V trigger, so it's important to be able to accommodate this lower level. D5 is simply there to dump the negative transitions to ground keeping Q2 happy.

Observe that the cleaned up trigger is applied to both pin 2 and pin 4 of IC4. The former is the actual one-shot input. But the latter is a master reset which overrides anything else that may be happening in the circuit. This implies that the output at pin 3 will go high and stay there as long as person is playing the keys. But when our musician lifts his or her fingers completely, IC4 will time out according to the setting of pot R61, eventually forcing pin 3 low again.

You'll realize that the sense of this is the reverse of what we want. So Q3 simply inverts the control signal. This is then applied to the lag processor by means of S1b and D7. R62 and C12 slow the transition down so that this voltage moves smoothly and continuously from off to on. Between the Delay pot and the Lag pot, you have a lot of versatility here to create musically useful passages.

The control voltage on C12 is buffered by IC1c, and then converted to a control current by PNP transistor Q4. This current is finally applied to IC3a as described earlier.

One last thing. It doesn't make any sense to try to control this module with both a gate and trigger simultaneously. So, switch S1 (which is actually a two pole affair) either chooses delay mode or gate mode. You'll note that the second pole of the switch, S1b, gives you the option of driving the thing under gate mode, should that prove useful to you. Keep in mind that the gate input at J1 can also be used with a footswitch in gated mode, opening up more possibilities for musical expression.

How to Calibrate the LFO Controller

Begin by putting the unit into free running mode (no keyboard gate or trigger applied). Monitor the triangle wave at jack J6 and adjust trimmer R28 for a centered waveform. This should be very close to 10Vpp. Make a note of that value, say, 10.2V or whatever it is. That will be our measuring stick for what follows.

Monitor the sine wave at jack J7. Begin by adjusting R33 for a nicely rounded wave. Then adjust R53 for ideal symmetry. Next, tweak R34 for an amplitude that matches the value you noted for the triangle wave in the previous step. Finally, adjust R54 so the sine is centered on ground. The exact amplitudes of the triangle and sine are not so important, as long they are reasonably close to 10Vpp and more importantly are identical to each other.

Monitor the control output at jack J8. Adjust R56 to give the same value you noted earlier, and then touch up the centering with R55. These last two trimmers may interact a bit, so you'll want to go back and forth a few times until you get the desired result.

You're ready to start playing!