

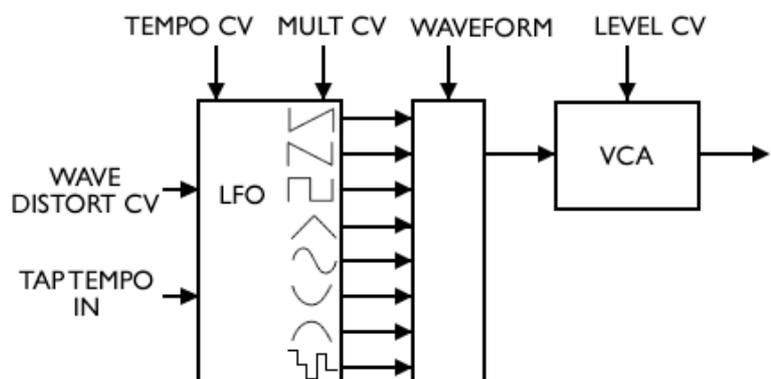
# Electric Druid Tap Tempo LFO

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## Introduction

This low frequency oscillator uses a PIC microprocessor to create a versatile tap tempo LFO. All LFO parameters are controlled by 0-5V control voltages.

The chip can produce 8 waveforms including a random (sample-and-hold) waveform. The basic LFO tempo is controlled by TEMPO CV or TAP TEMPO IN. The final output frequency is based on this setting and the MULTIPLIER CV, which allows you to set a basic tempo, and then produce an LFO output at a multiple of this speed.



The WAVEFORM voltage selects one of the 8 waveforms. The LFO waveforms can be modified by the WAVE DISTORT CV. Finally, the LEVEL CV sets the output level.

## Features

### Simple “Tap Tempo” control

The TAP TEMPO input can measure the time between two taps of a momentary switch or button, and uses this time to set the LFO’s basic tempo.

### Ability to synchronize LFO to external clocks

The TAP TEMPO input can also accept 0-5V pulses. This allows the LFO to be synchronized to an external clock.

### LFO range from 0.025Hz to above 50Hz

The basic range of the TEMPO CV allows the LFO to produce frequencies between 0.05Hz (a 20 second cycle) and 12.8Hz. However, in conjunction with the MULTIPLIER CV, this range is extended to 0.025Hz (a 40-second cycle) to 100Hz.

### 8 output waveforms

The chip can produce 8 output waveforms, shown below. These are selected by the voltage on Pin 12 (WAVEFORM).



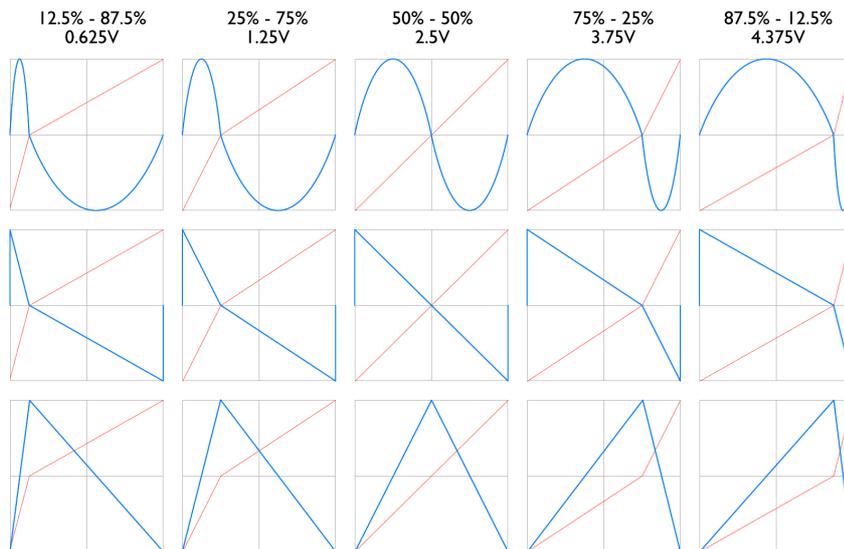
### Half-speed, Double-speed, and Triplets

The MULTIPLIER CV input selects a tempo multiplier which is used to determine the final LFO frequency. This allows the LFO to produce changes at double or half-speed, or produce triplet times. The available multipliers are shown below:

Multiplier	Musical symbol	Note name
0.5		1/2 note, minim
1		1/4 note, crotchet
1.5		Triplet 1/4 note, triplet crotchet
2		1/8 <sup>th</sup> note, quaver
3		Triplet 1/8 <sup>th</sup> note, triplet quaver
4		1/16 <sup>th</sup> note, semiquaver

## Wave Distort CV input

The selected waveform can be distorted using the WAVE DISTORT input. This modifies the duty cycle of all LFO waveforms. Examples are shown below.



The top row shows the effect of the WAVE DISTORT CV on the SINE wave, whilst the following rows show the effect on the RAMP DOWN and TRIANGLE waveforms. Other waves (excepting RANDOM) are affected similarly.

## 10-bit LFO output resolution

The internal waveforms and calculations are 8-bit, but the chip interpolates between the given values to provide a 16-bit output, of which 10 bits are fed to the PWM module.

## 19.5KHz sample output rate

The PWM frequency is around 19.5KHz. This allows the PWM output to be heavily filtered for a smooth analogue output. The two-stage 24dB Bessel filter provides the best-possible pulse filtering.

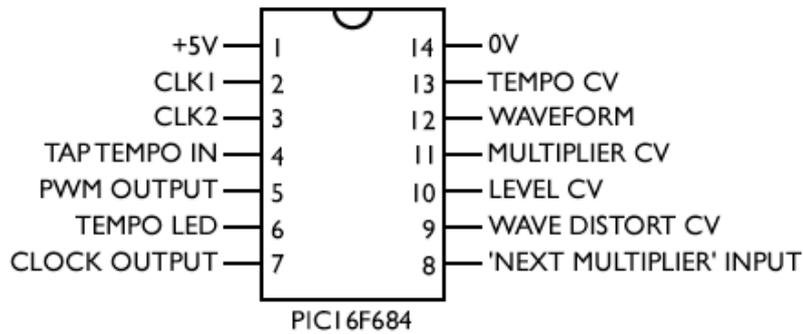
## 8-bit resolution on the control voltages

The Sequential Prophet 5 used a 7-bit control resolution, so this is going slightly better. Whether a standard potentiometer actually has the accuracy to directly produce an 8 bit resolution is another question. The inputs are sampled at over 6KHz.

## Logarithmic control response over 1:256 range

The Tempo CV gives the full range from 0.05 Hz to 12.8 Hz in eight even octaves, eg 0.05-0.1Hz, 0.1-0.2Hz, 0.2-0.4Hz, 0.4-0.8Hz, 0.8-1.6Hz, 1.6-3.2Hz, 3.2-6.4Hz, 6.4-12.8Hz.

## Pinout Diagram



Pin	Function	Details	Notes
1	+5V	Power supply	
2	CLK1	Connect to Xtal	20MHz Clock
3	CLK2	Connect to Xtal	20MHz Clock
4	TAP TEMPO IN	5-0V digital input	Sets basic tempo of LFO. Note that this input expects negative-going pulses.
5	PWM OUTPUT	0-5V digital output	PWM output at 19.5KHz
6	TEMPO LED	0-5V digital output	Indicates tap timing (on when timing)
7	CLOCK OUTPUT	0-5V digital output	Provides a 0-5V signal at the current LFO frequency
8	NEXT MULTIPLIER	0-5V digital input	Steps through Multiplier values 0-5. Expects negative-going pulses.
9	WAVE DISTORT CV	0-5V analogue input	8 bit, values from 0 to 255 Alters waveshape of LFO waveforms. Does not affect RANDOM wave.
10	LEVEL CV	0-5V analogue input	8 bit, values from 0 to 255 Controls overall output level
11	MULTIPLIER CV	0-5V analogue input	3 bit, values from 0-5 Note that values 6 & 7 are not used (set to x1) so the maximum useful CV is 3.75V
12	WAVEFORM	0-5V analogue input	3 bit, values from 0 to 7
13	TEMPO CV	0-5V analogue input	8 bit, values from 0 to 255 0.05 Hz to 12.8 Hz for LFO
14	0V	Power supply	

# Application Notes

## Modular synth LFO with tap tempo and sync input

This circuit diagram shows most of the features of the chip.

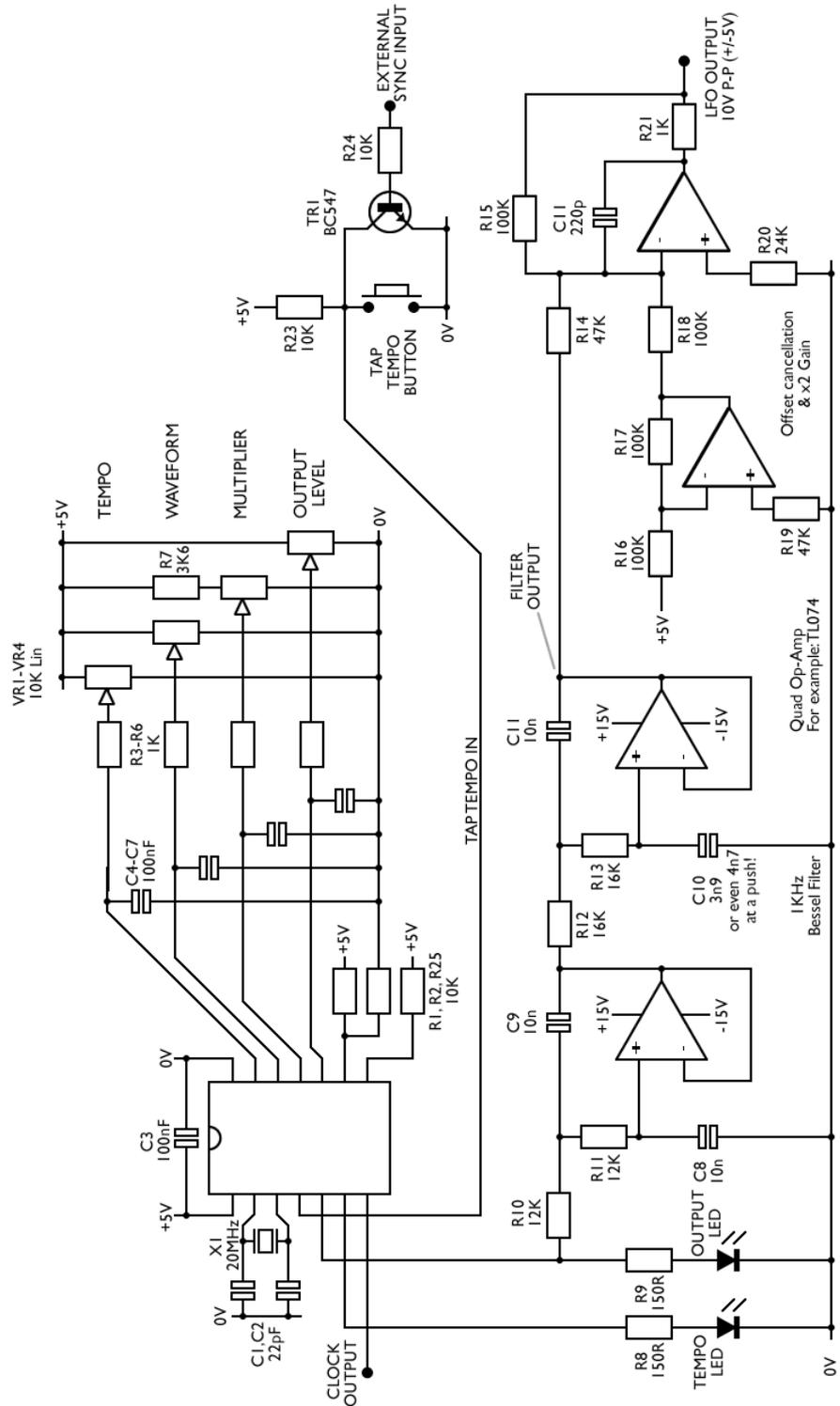
Only WAVE DISTORT CV is disabled, being tied to 2.5V to give a square wave.

The first two op-amp stages are a Bessel filter which averages the PWM output from the chip and turns it back into an analogue signal.

The following two op-amp stages remove the 2.5V offset on the output, and boost the level to the typical 10V p-p used in many modular synths.

If exact adjustment of offset or output level is required, R16 (level) and/or R20 (offset) can be replaced with trimmers of approximately twice the marked values.

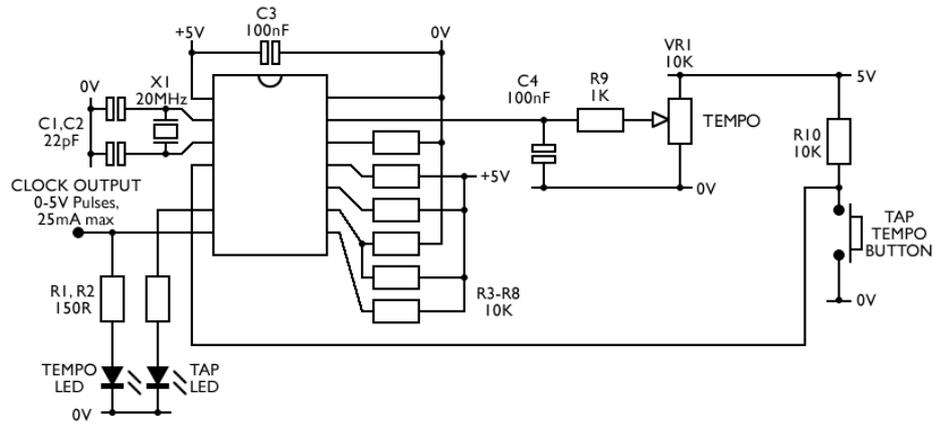
The output from the filter is a 5V p-p LFO output centred around 2.5V. For some applications, this might be suitable, in which case the two offset cancellation and x2 gain op-amp stages can be ignored.



## Simple tap tempo drum machine or sequencer clock

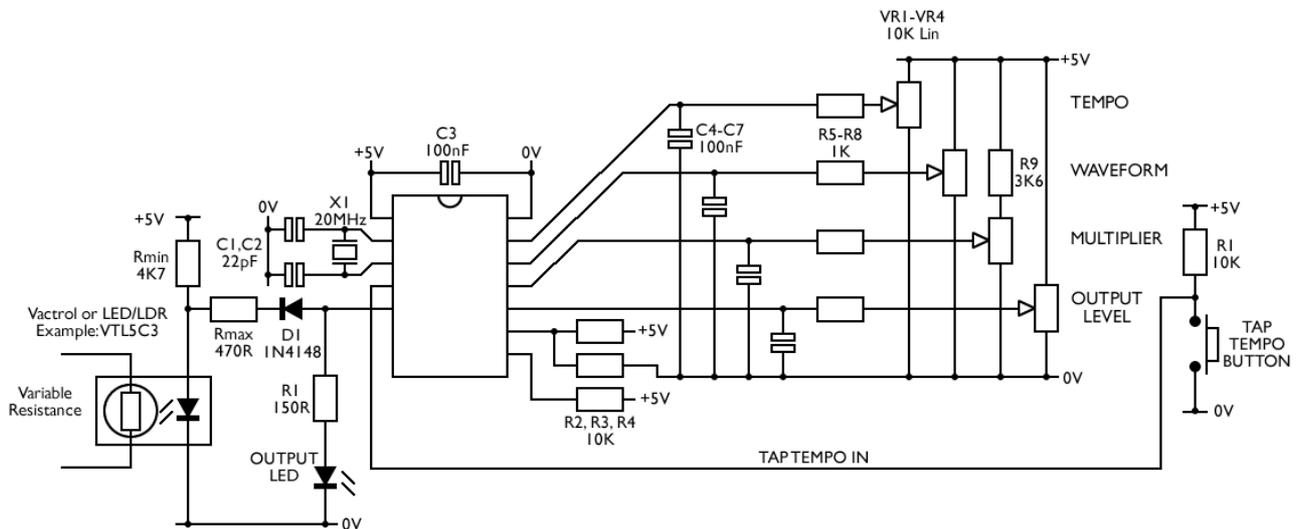
This example circuit provides tap-tempo +5V clock pulses for driving analogue sequencers or drum machines.

R3 to R8 disable the waveform output (fixed to Ramp Up), the multiplier (fixed to x1), the output level (fixed to max), the pulse width (fixed to 2.5V, square), and the 'Next multiplier' input (tied high). The main LFO output isn't used. Tempo can be set either by the Tempo knob VR1 or by tapping the button.



## Tap tempo LFO control of vactrols or LED/LDRs

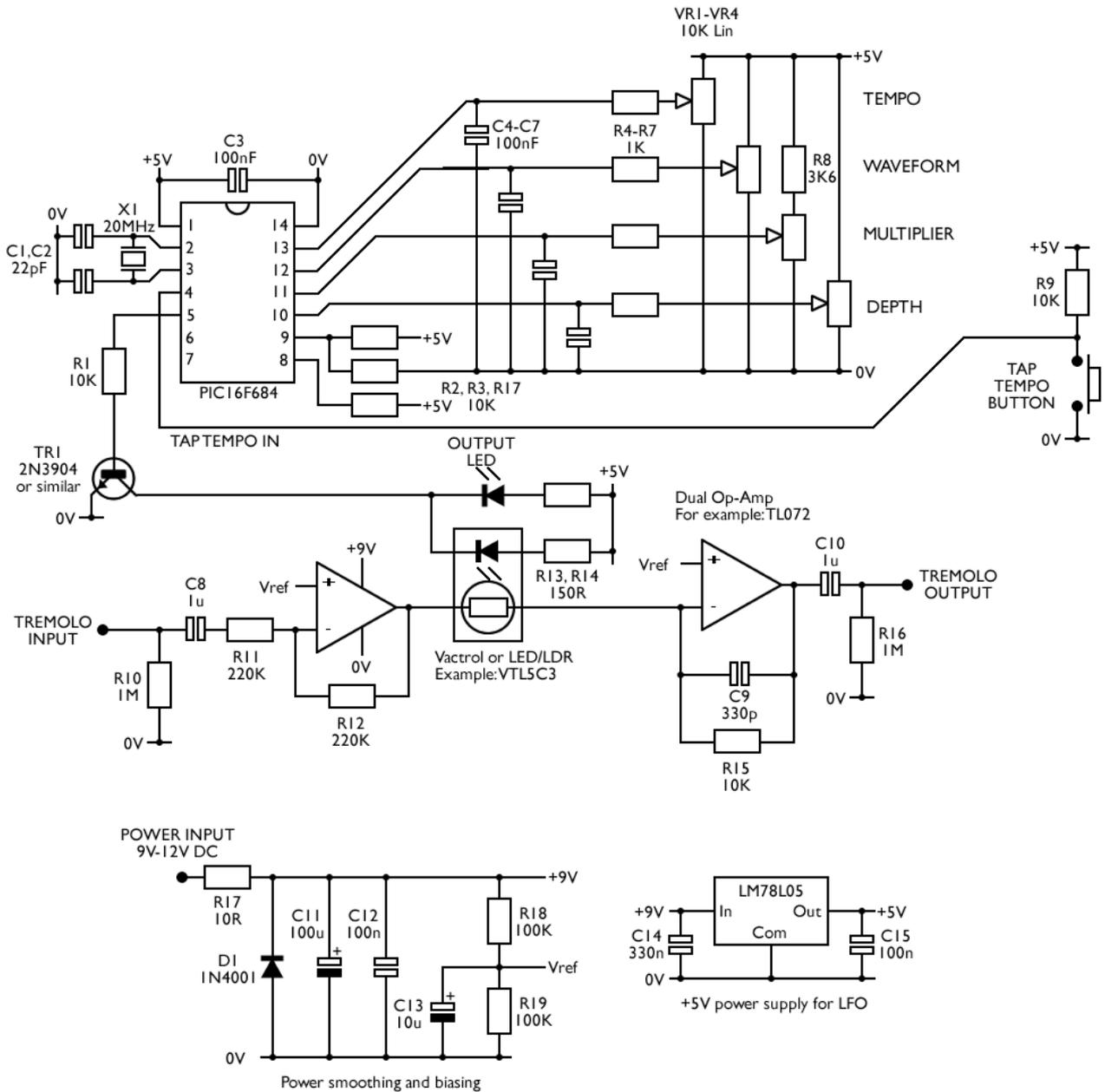
The PWM output from the chip is ideal for controlling the LED in a vactrol. LEDs don't have a linear current/brightness response, which means controlling them with a typical voltage-output LFO via a resistor gives poor results. Controlling the LEDs brightness with PWM provides much better linearity.



Rmin and Rmax control the minimum and maximum brightness of the LED. Rmin sets the current through the LED when the LFO output is at its lowest level. When the LFO output is at its highest level, the voltage on pin 5 is +5V, so Rmin and Rmax are effectively in parallel. The example VTL5C3 vactrol gives a variable resistance from 60K to 3K3 with the values given.

The variable resistance output can be used instead of, or in parallel with, potentiometers to control parameters in a wide range of circuits. For example, across the 'delay time' pot in a PT2399-based delay for LFO-modulated delay effects.

## Tap tempo tremolo circuit

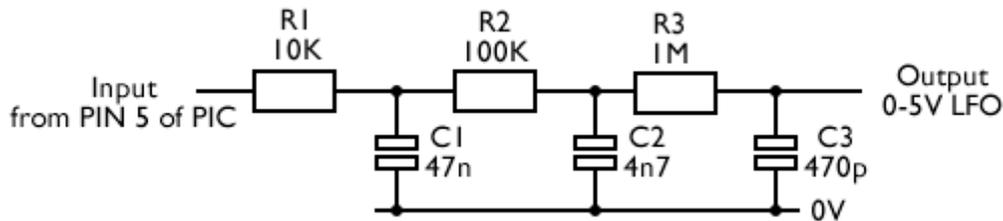


This example circuit shows a complete tremolo effect based on the tap tempo LFO. The tremolo audio path is a clean, simple design based on the classic Tremulus Lune. Thanks to Mike for his work designing this with my original PICVCLFO.

The 'Next Multiplier' input on Pin 8 is here shown disabled by being tied high with 10K. It can also be connected up in the same way as the TAP TEMPO button.

## The simplest possible PWM output filter

Whilst the 2 stage bessel filter in the Modular Synth LFO circuit above provides good filtering performance, it is fairly complicated, requiring two op-amps and associated components. Can it be done with less? Yes, it can. You can use a three stage passive filter like this:



You can experiment with the values a bit (The values above give 338Hz cutoff) but be sure to maintain the x1, x10, x100 relationship of R1, R2, R3 and C3, C2, C1. This helps limit loading between the stages.

Note that the output is not bipolar (the LFO runs from 0V up to nearly 5V) and is unbuffered, so will need a high impedance input following it.

## Disabling unwanted CV inputs

If the WAVE DISTORT CV input is not required, it can be tied to a fixed voltage. For a square wave output, this should be 2.5V. This can be produced by a pair of 10K resistors wired as a potential divider between 0V and +5V.

If the LEVEL CV input is not required, it can be disabled by tying the input to the +5V rail with a 10K resistor.

If the MULTIPLIER CV input is not required, it can be tied to a fixed voltage. Since multiplier CVs above 3.75V default to 'x1', the input can be disabled by tying it to the +5V rail with a 10K resistor.

If the NEXT MULTIPLIER input is not required, it should be tied to +5V with a 10K resistor. It functions in exactly the same way as the TAP TEMPO input.

## Using rotary switches to select waveform or multiplier

Rotary switches can be used to select waveforms or multipliers by replacing the CV potentiometer with a resistor string that provides the correct voltages, as shown. Since the CV range for each option is fairly wide, exact values are not crucial, but the top and bottom resistors should be roughly half the other value.

The top two options are not used for the Multiplier. The diagram below shows the CV “boundary voltages” and the multiplier that is applied for voltages between those levels.

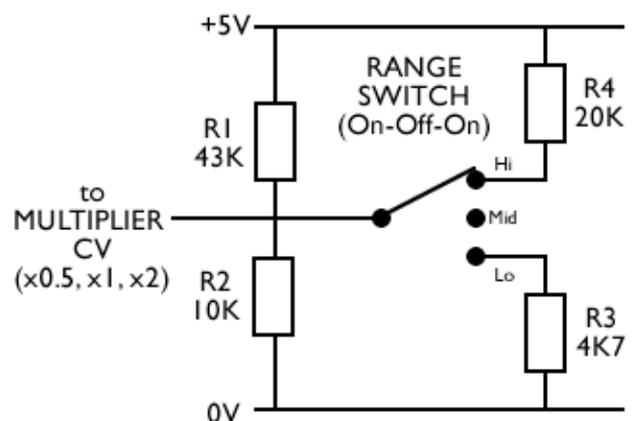
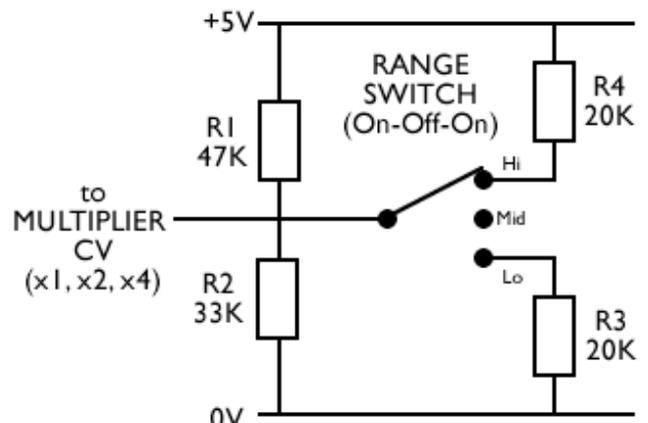
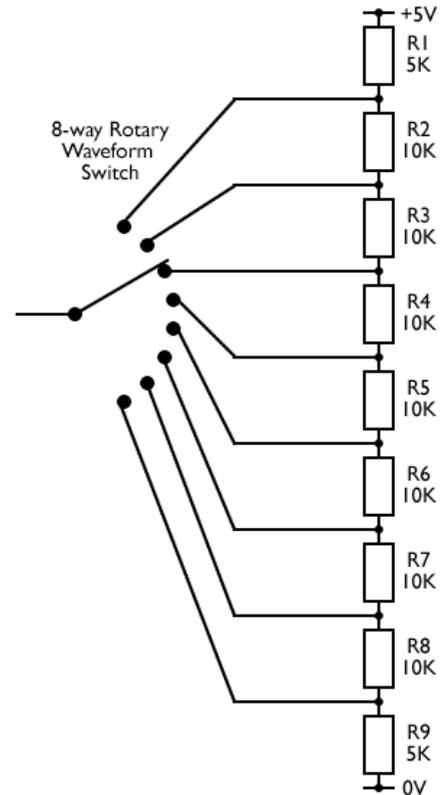
5V	Not used
4.375V	Not used
3.75V	x4
3.125V	x3
2.5V	x2
1.875V	x1.5
1.25V	x1
0.625V	x0.5
0V	

The waveform CV uses the same boundaries, but uses all eight options.

## Using the Multiplier CV as a Range switch

If the Multiplier CV is not required, it can be used to increase the frequency range of the LFO.

Either of the arrangements shown provide a switchable voltage which changes the range of the LFO over three octaves.



## Using the Tap Tempo LFO as a synchronizable LFO

The TAP TEMPO input accepts negative-going 5-0V pulses, and times the period between the falling edges of consecutive pairs of pulses to set the frequency. If another device provides a 0-5V clock signal, this can be fed to the TAP TEMPO input and the LFO will synchronize to the clock.

The circuit shown can be used to provide an input that is safe for sync pulses up to about 20V.

