Electric Druid Tap Tempo LFO

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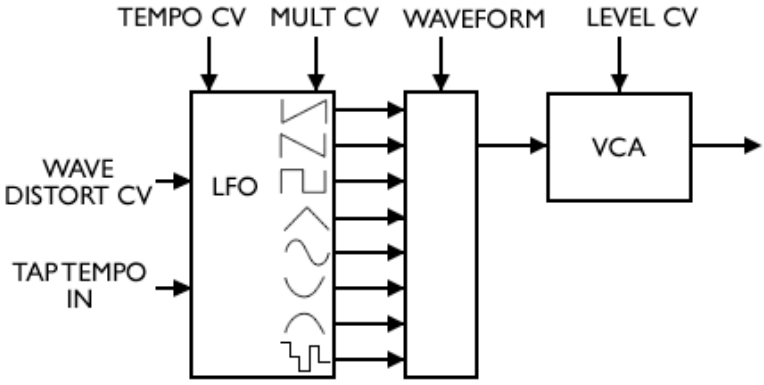
Introduction

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 16 waveforms including "random levels" and "random slopes" waveforms. 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

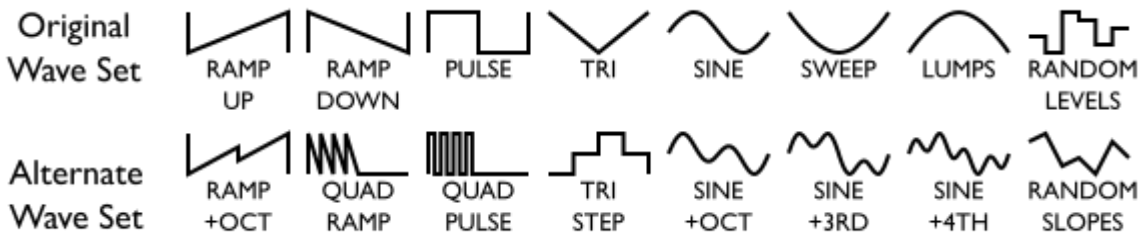
The TAP TEMPO input can also accept 0-5V pulses. This allows the LFO to be synchronized to an external clock. The chip also produces a CLOCK OUT which can synchronise other TAPLFOs.

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 50Hz.

Sixteen output waveforms, in two sets

The chip can produce 16 output waveforms, shown below. These are selected by the voltage on Pin 12 (WAVEFORM) and the digital level on Pin 6 (the WAVE SET selection input).



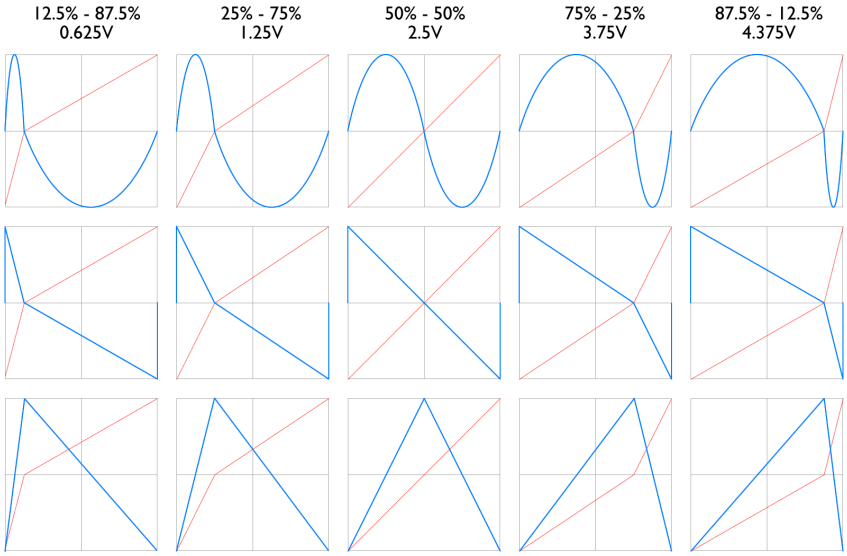
Half-speed, Double-speed, and Triplets

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
x0.5		1/2 note, minim
x1		1/4 note, crotchet
x1.5		Triplet 1/4 note, triplet crotchet
x2		1/8th note, quaver
x3		Triplet 1/8th note, triplet quaver
x4		1/16th 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 LEVELS) are affected similarly.

16-bit waves and 10-bit LFO output resolution

The internal waveforms and calculations have been improved beyond the TAPLFO2D's 8-bit waves. This version uses 16-bit wave data with interpolation to give the smoothest possible result. The final PWM output is 10-bit.

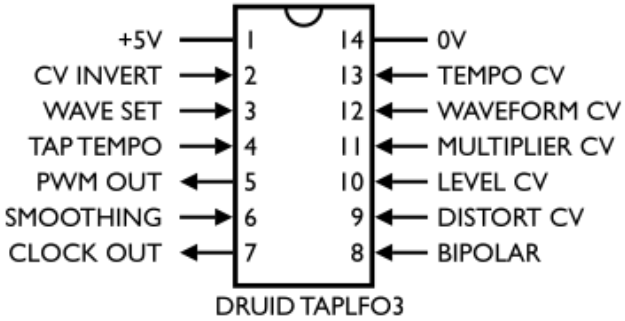
31.25KHz sample output rate

The PWM output frequency is 31.25KHz., a big increase on the 19.5KHz of the previous generation chip. This allows the PWM output to be heavily filtered for a smooth analogue output, even with just a simple RC filter.

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. The fact that this input is logarithmic means the TEMPO CV input can use linear pots and still have a musical feel.

Pinout Diagram



Pin	Function	Details	Notes
1	+5V	Power supply	
2	CV INVERT	0-5V digital input	Selects whether the input CVs are inverted. 0V = CVs inverted, 5V/NC = Not inverted
3	WAVE SET	0-5V digital input	Selects which set of eight waveforms is used. 0V = Alternate wave set, 5V/NC = original waveset
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 LFO output at 31.25KHz
6	SMOOTHING	0-5V digital input	Selects whether the wave smoothing filter is applied. 0V = Smoothing on
7	CLOCK OUTPUT	0-5V digital output	Provides a 0-5V signal at the current LFO frequency
8	BIPOLAR	0-5V digital input	Selects Bipolar or Unipolar output
9	WAVE DISTORT CV	0-5V analogue input	8 bit, values from 0 to 255 Alters waveshape of LFO waveforms. Does not affect RANDOM LEVELS 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 CV	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	

NC = Not connected

Differences from TAPLFO2D

Whilst efforts have been made to ensure the TAPLFO3 is compatible with the TAPLFO2D in most application circuits, some significant changes have been made. This section details those changes and how they affect existing circuits.

Four new option selection inputs

The pins that previously were used by the clock crystal are now used for selecting CV inversion and the alternate waveform set. In addition, the little-used "Next Multiplier" input and "Tempo timing LED" output have been replaced with BIPOLAR output selection and an output smoothing filter.

All four of these inputs have internal pull-ups on the chip, so if left unconnected they default to a high state. The chip has been arranged so that this gives the same behaviour as the previous chip to maintain compatibility. If switches to select these options are required, they can be a simple SPST from the pin to ground.

CV Inversion

Pin 2 is now the CV INVERT selection input. If you're adding inverting op-amp mixers to the CV inputs, this can save the use of an extra op-amp to re-invert the CVs. An example circuit demonstrates this.

Wave Set selection

The WAVE SET input allows the user to select a second alternate set of eight waveforms.

With the pin left unconnected (or connected to 5V), the original waves are used. With the pin connected to ground, the alternate wave set is selected.

Smoothing Filter

Pin 6 is now the SMOOTHING filter selection input. This applies the digital equivalent of a single pole RC filter to the waveform before it is output. The filtering removes the abrupt edges that tend to give clicks in some applications and gives the waveforms a softer rise and fall (about 20msecs).

With the pin left unconnected, the filter is not applied. With the pin connected to ground, the filtering is applied.

Bipolar Output

The TAPLFO2D produced a bipolar output around a bias level of 2.5V. Pin 8/BIPOLAR is now used to select this behaviour.

With the pin left unconnected, the output is bipolar around 2.5V. With the pin connected to ground, the output is unipolar from 0V up to 5V.

Tap Tempo Input has an internal pull-up

The tap tempo input now has an internal pull-up. This saves an external resistor. If you're using a PCB designed for the TAPLFO2D that includes the external 10k pull-up, you can simply leave this resistor unpopulated.

There are no other significant changes.

Application Notes

Schematics for the example circuits are shown at the back of the datasheet.

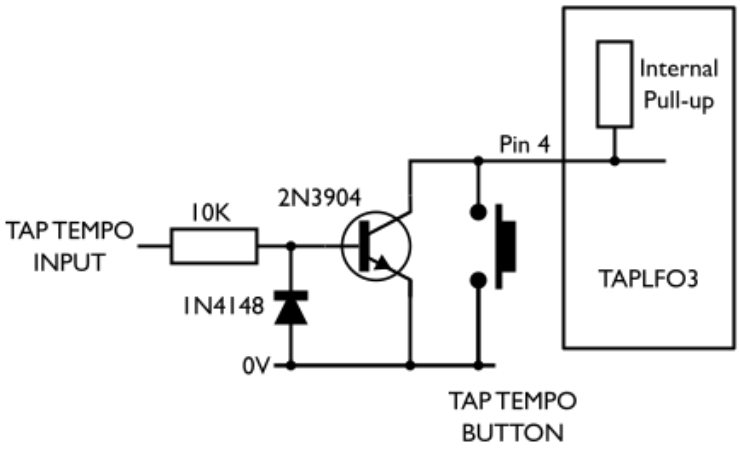
Example circuit: Modular synth LFO with tap tempo and sync input

The circuit on the following two pages shows many of the features of the chip and introduces many useful circuit elements.

The chip is configured with pin 2 tied low, so all CV inputs are inverted. All the inputs except for Multiplier CV have inverting mixers attached that allow modulation of the pot setting by an external control voltage. The Multiplier input is wired simply with a pot.

The circuit uses a two-stage filter giving a 4-pole response for excellent PWM frequency suppression. The second filter stage applies a gain of two to boost the level to the typical 10V p-p used in many modular synths. It also allows the signal offset to be adjusted to ensure the waveform is centred around zero.

The TAP TEMPO input on the TAPLFO3 chip expects a "short-to-ground" signal, and times the period between the falling edges of consecutive pairs of pulses to set the frequency. If another device provides 0-5V clock signal, this can be fed to the TAP TEMPO input and the LFO will synchronize to the clock.



The circuit shown (as appears in the Modular Synth LFO schematic) can be used to provide an input that protects against negative voltages and is safe for positive-going sync pulses up to about 20V.

Example circuit: Single supply tap tempo stompbox LFO

This example circuit shows how the chip can be used with a 9V single supply, as typically found in stompbox circuits. The circuit uses a single filter stage which offsets the output to the midpoint 4.5V level. This is 2V to 7V output is what would usually be provided by a op-amp based LFO. However, it is possible to replace the op-amp filter with a simple passive filter (see "The simplest possible PWM output filter" below), in which case the output voltage will be from 0V to 5V. This may be just what is required for some circuits.

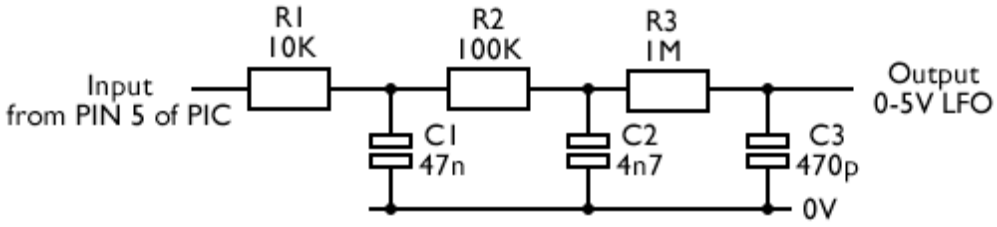
Example circuit: Tap tempo tremolo circuit

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 PIC VCLFO.

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. Furthermore, an LDR's slow response means that no extra filtering is required and the PWM signal can be fed directly to the vactrol. This makes a very simple circuit for something that has so many options.

The simplest possible PWM output filter

Whilst the 2 stage 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 two or 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. If you don't need three stages, simply leave off R3/C3.

Note that the output is unbuffered, so will need a high impedance input following it.

Disabling unwanted CV inputs

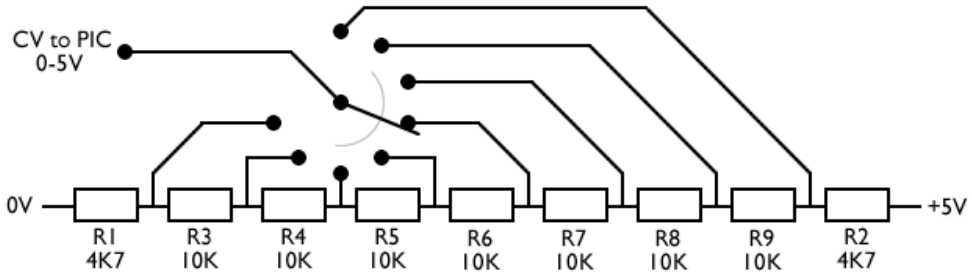
If the WAVE DISTORT CV input is not required, it can be tied to a fixed voltage. For a square wave output, this should be 2.5V. This can be produced by a pair of 10K resistors wired as a potential divider between 0V and +5V.

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

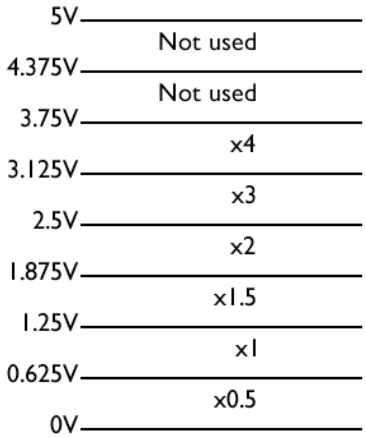
If the MULTIPLIER CV input is not required, it can be tied to a fixed voltage. Since multiplier CVs above 3.75V default to 'x1', the input can be disabled by tying it to the +5V rail with a 10K resistor.

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 (R1 and R2 in the diagram) should be roughly half the other value.



The diagram on the right shows the CV "boundary voltages" for the eight options, and the multiplier that is applied for voltages between those levels. The top two options are not used for the Multiplier (they give x1 if used). The waveform CV uses the same boundaries, but uses all eight options.

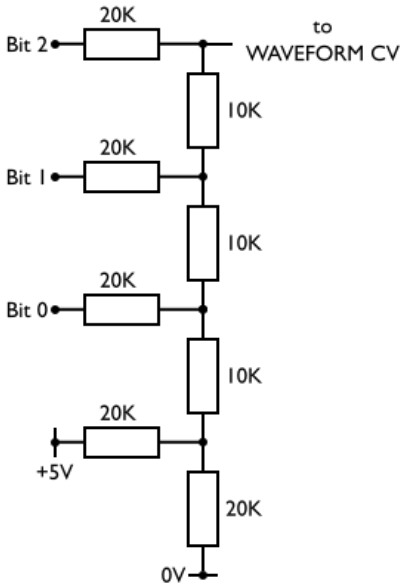


Using digital signals to select waveform or multiplier

In a programmable system, it is convenient to be able to select waveforms and multipliers using digital signals. This can be done by converting them to a CV using a simple R-2R DAC.

Although we only require eight options, we use a 4-bit R-2R DAC design with the lowest bit tied high to ensure the output falls in the middle of the voltage range for each option.

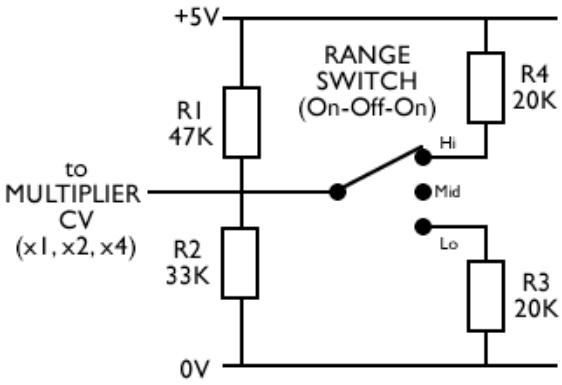
Again, for the Multiplier CV, only inputs 0-5 are used, and values 6 and 7 just give x1.

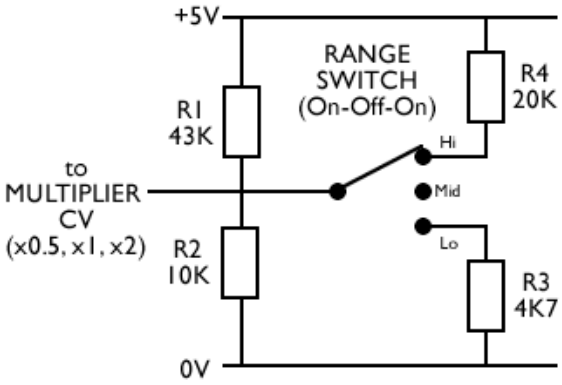


Using the Multiplier CV as a Range switch

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.





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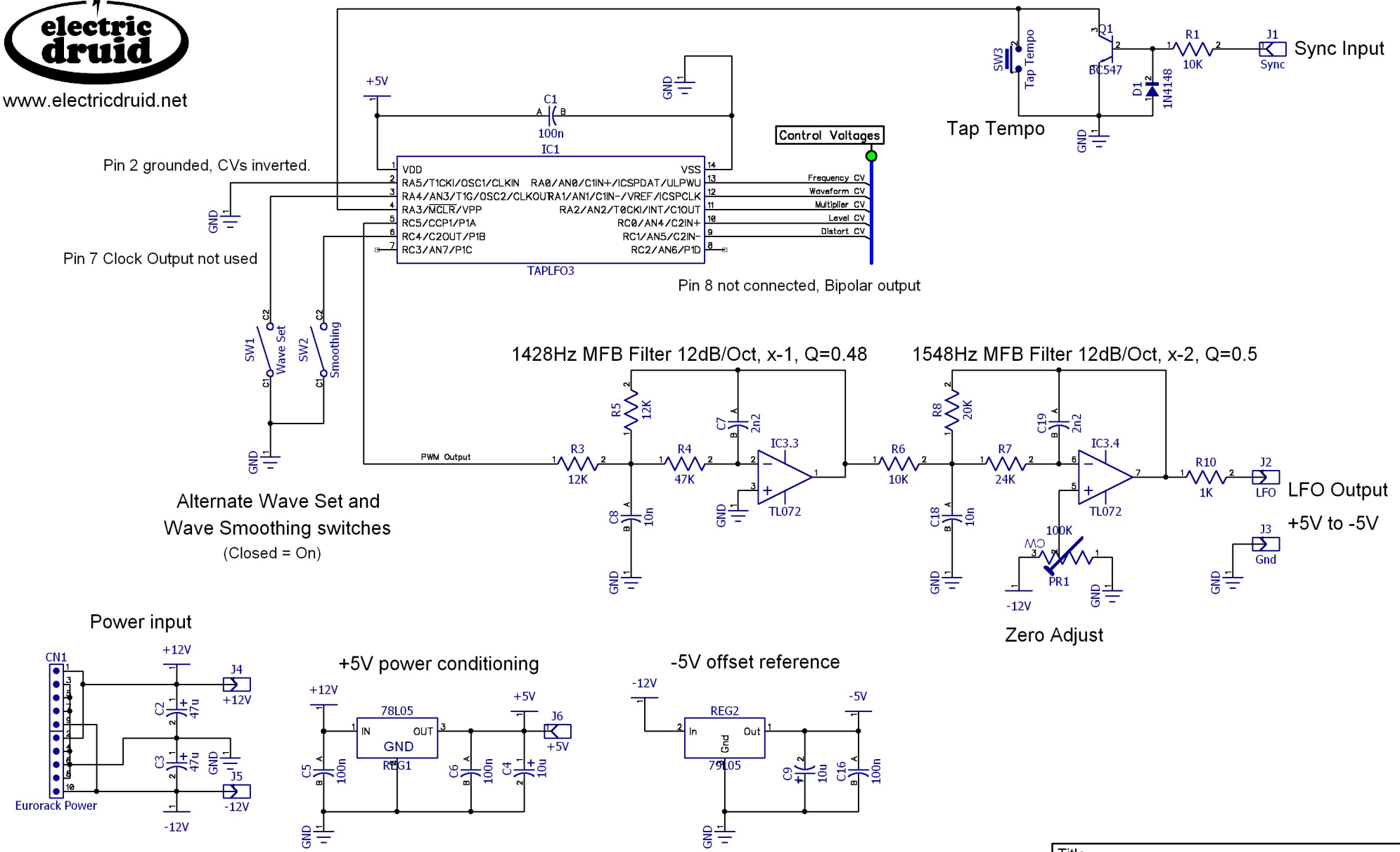

Electric Druid Modular Synth Tap Tempo LFO

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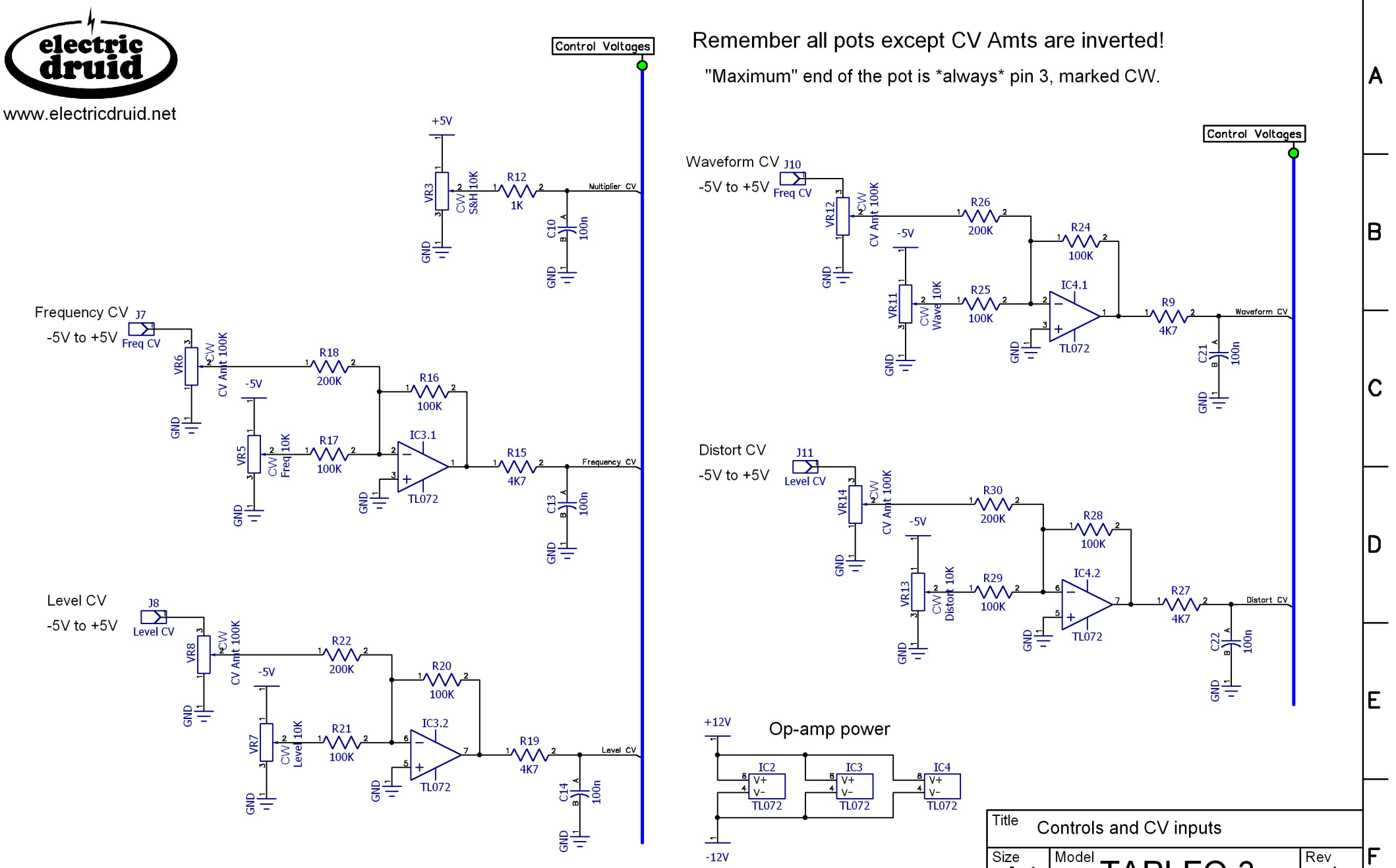
Title	Power, Processor, & Output stages		
Size A4	Model TAPLFO 3		Rev 1
Date	17 Feb 2018	Drawn by	TMW
File	ModSynthTAPLFO3.dch	Sheet	1 of 2



Electric Druid Modular Synth Tap Tempo LFO

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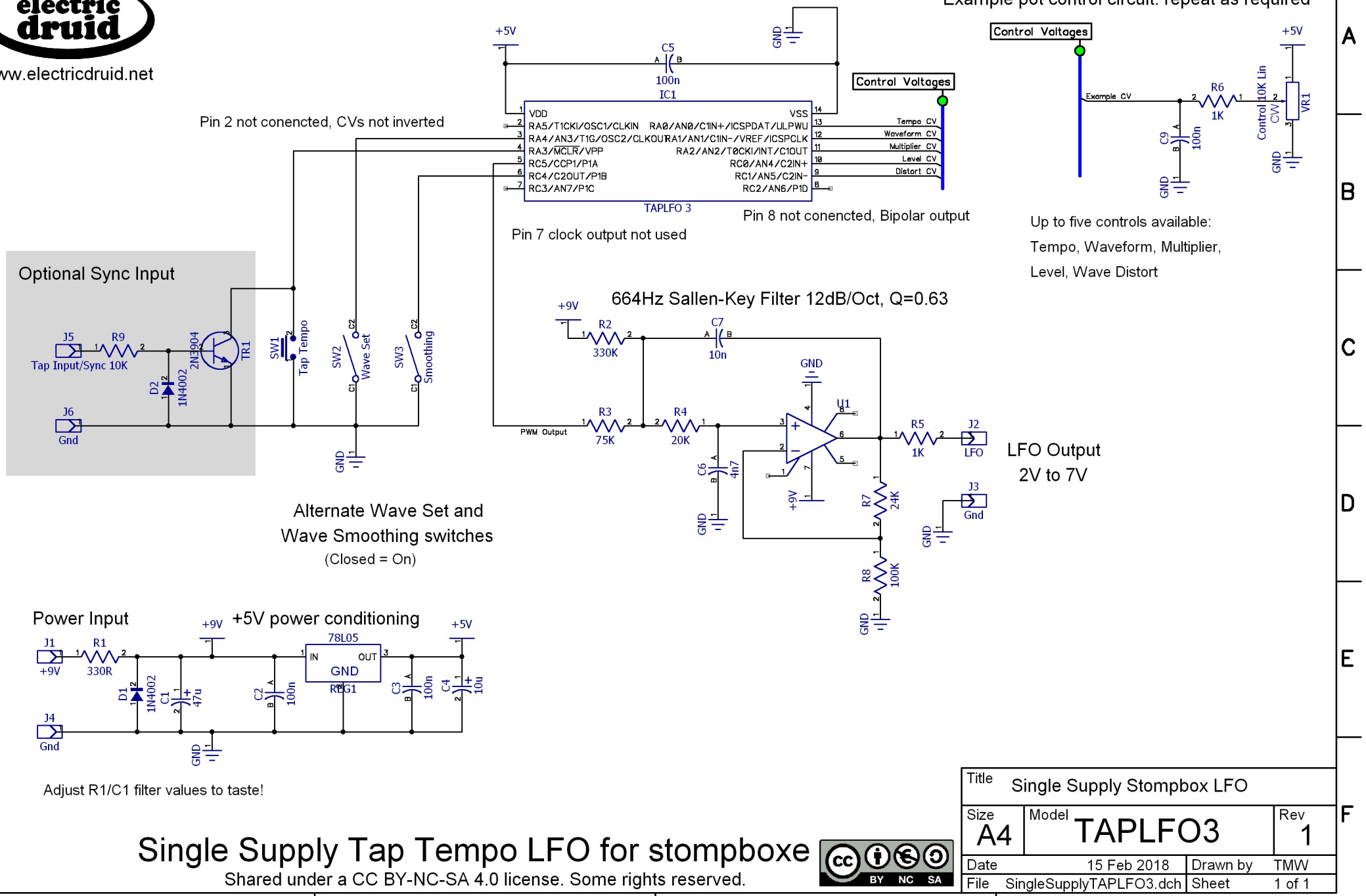
Single Supply Tap Tempo LFO for stompboxe



Title	Single Supply Stompbox LFO		
Size A4	Model TAPLFO3		Rev 1
Date	15 Feb 2018	Drawn by	TMW
File	SingleSupplyTAPLFO3.dch	Sheet	1 of 1

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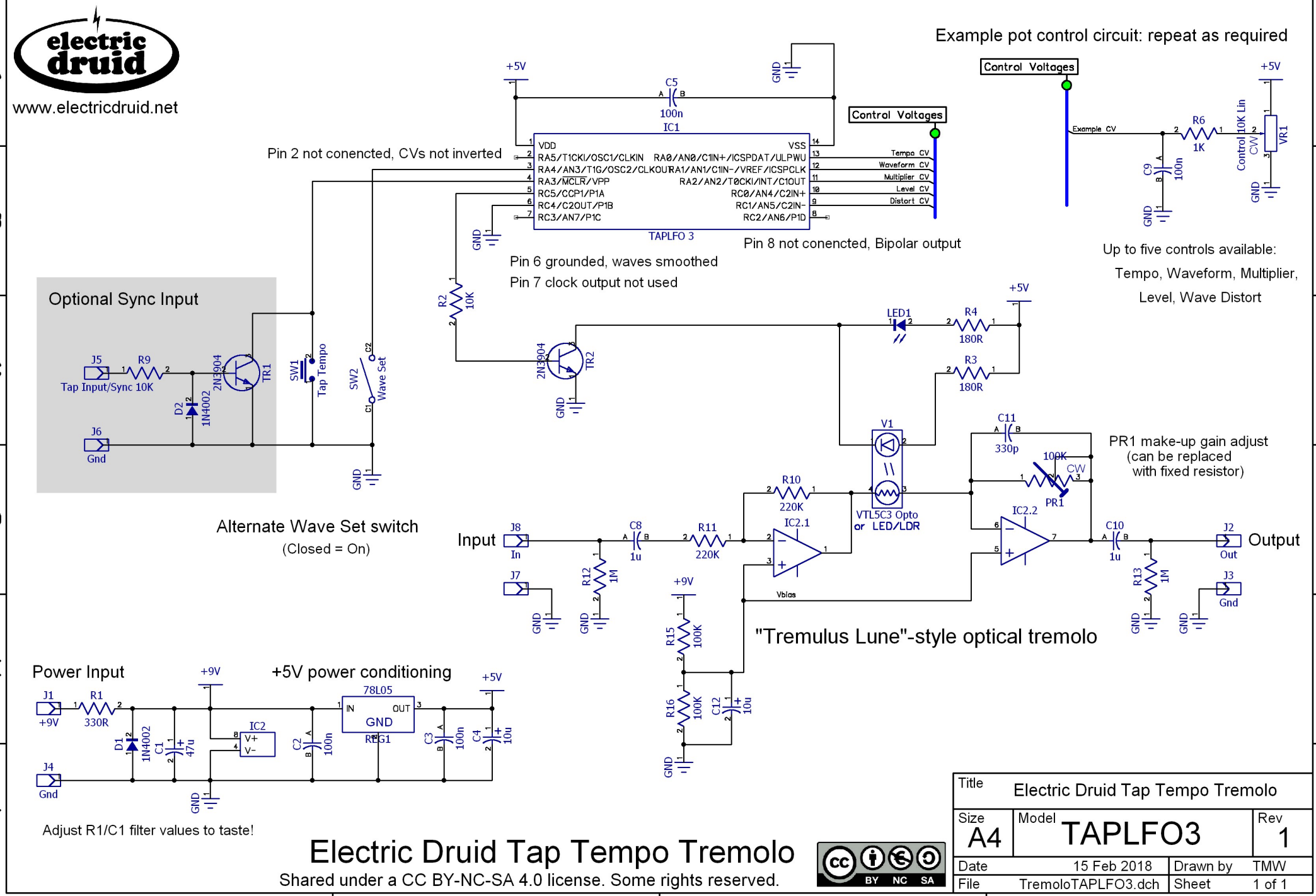
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Example pot control circuit: repeat as required
Control Voltages
Example CV
R6
1K
C9
100n
Control 10K Lin CW
VR1
Up to five controls available:
Tempo, Waveform, Multiplier,
Level, Wave Distort
Pin 2 not conencted, CVs not inverted
Pin 8 not conencted, Bipolar output
Pin 6 grounded, waves smoothed
Pin 7 clock output not used
IC1
TAPLFO 3
VDD
VSS
RA5/T1CKI/OSC1/CLKIN
RA0/AN0/C1IN+/ICSPDAT/ULPWU
RA4/AN3/T1G/OSC2/CLKOUT
RA1/AN1/C1IN-/VREF/ICSPCLK
RA3/MCLR/VPP
RA2/AN2/T0CKI/INT/C1OUT
RC5/CCP1/P1A
RC0/AN4/C2IN+
RC4/C2OUT/P1B
RC1/AN5/C2IN-
RC3/AN7/P1C
RC2/AN6/P1D
Tempo CV
Waveform CV
Multiplier CV
Level CV
Distort CV
C5
100n
Optional Sync Input
J5
Tap Input/Sync 10K
R9
D2
1N4002
J6
Gnd
SW1
Tap Tempo
SW2
Wave Set
Alternate Wave Set switch
(Closed = On)
R2
10K
TR2
2N3904
LED1
R4
180R
R3
180R
V1
VTL5C3 Opto
or LED/LDR
R10
220K
C11
330p
100K
CW
PR1
PR1 make-up gain adjust
(can be replaced
with fixed resistor)
Input
J8
In
C8
1u
R11
220K
IC2.1
IC2.2
R12
1M
J7
Vbias
C10
1u
J2
Out
Output
R13
1M
J3
Gnd
"Tremulus Lune"-style optical tremolo
R15
100K
R16
100K
C12
10u
Power Input
J1
+9V
R1
330R
D1
1N4002
C1
47u
J4
Gnd
+5V power conditioning
IC2
78L05
REG1
C2
100n
C3
100n
C4
10u
Adjust R1/C1 filter values to taste!
Electric Druid Tap Tempo Tremolo
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Title
Electric Druid Tap Tempo Tremolo
Size
A4
Model
TAPLFO3
Rev
1
Date
15 Feb 2018
Drawn by
TMW
File
TremoloTAPLFO3.dch
Sheet
1 of 1