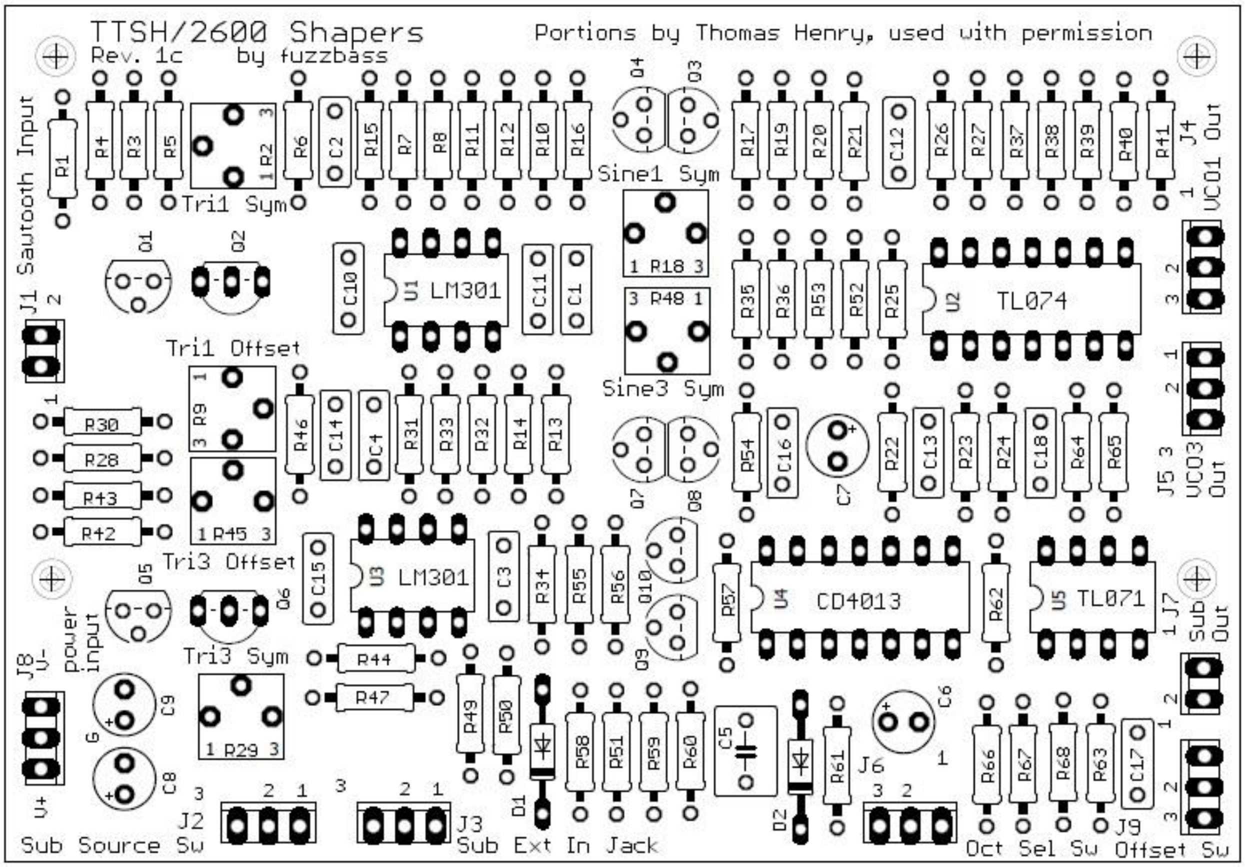
TTSH / ARP 2600 Shapers

Supplemental Outputs for VCOs 1 and 3 + Sub-Oscillator

Install Guide



Version 1c

By Fuzzbass

Features

- Triangle wave (+/- 5V p-p) output tracking VCO1 sawtooth core
- Sine wave (+/- 5V p-p) output tracking VCO1 sawtooth core
- Triangle wave (+/- 5V p-p) output tracking VCO3 sawtooth core
- Sine wave (+/- 5V p-p) output tracking VCO3 sawtooth core
- Sub-oscillator / divider circuit with assignable source and suitable for audio, CV or gate/clock operation.
- Mounts to existing supports in all versions of TTSH
- Powered by existing TTSH power supply

Disclaimer – Consider….

- Builder assumes all risks.
- This is a complicated modification and should not be undertaken by a novice or non-builder. It is assumed that person performing this modification is the one who built the TTSH. Therefore this person has the requisite tools on hand, and overall familiarity with the synthesizer.
- If errors are committed during the panel drilling, the results are generally irreparable, and replacement panels are not available.
- Care should be taken to properly support the main PCB during the installation and testing phases and while the PCB is separated from the panel. M3x50mm M-F spacers (qty:8) are recommended to place the PCB on stilts (front and rear) while it is separated from the panel. These spacers are not required for the Shaper, and so are not in the BOM.
- The electrical load of the Shaper is borne by the TTSH power supply. Prior to panel drilling, test to ensure that your power supply can handle it.

Attributions

I can't claim to have invented any of this. I took the ideas of some clever and generous people, and put them together here, tweaking them a bit along the way. My contribution was developing the circuits so they may be manufactured and added to your synthesizer with some confidence of success.

Here is where I picked up these ideas:

1. The sawtooth to triangle shaper design is directly out of VCO2 on the ARP2600, and is presented here unchanged, in all its bedraggled glory. It is simple, works acceptably, and it does not contain any rare parts.
2. The triangle to sine shaper design is from Thomas Henry. This is the same shaper that shows up in most of Thomas' VCO designs. I made a few changes to accommodate the source signals, and to streamline the design by way of eliminating some trimmers. Thomas has gracefully given his permission for use here. Thank you Thomas!
3. The core of the sub-oscillator section was observed in a schematic for the Roland SH101. This has been used in other synthesizers; it's a well known technique documented in the chip's datasheet. The original SH101 design does not work anymore due to changes over time in the

CD4013 chip involved. However, the chip "improvements" were easily negated by addition of some capacitors, restoring the original [dys]function. I learned about this trick by scouring hobbyist websites frequented by people who build DIY clocks and such.

4. The utility of the sub-oscillator is greatly improved by adding some conditioning components at its front end, thereby allowing it to be used to divide a variety of audio, CV or timing signals. The SH101 sub-oscillator circuit expected an audio rate square wave input. I have added a Schmitt Trigger and a gate to trigger converter in series at the input. The Schmitt Trigger acts as comparator and converts any type of alternating signal into unipolar gate pulses. The comparator is protected by a diode in front of it to shunt any negative voltage before it damages the transistors. The resulting pulse wave is then converted into short impulses to drive the divider in the core of the sub-oscillator. The Schmitt Trigger and its protective diode came from Yves Usson's divider module. The subsequent gate to trigger converter I learned about from Ken Stone, and was also used in my TTSH Gate Booster.

General

The ARP 2600 and the TTSH synthesizers show some economizing in their designs. The VCO2 section contains shapers to produce triangle and sine wave outputs, in addition to the pulse and sawtooth wave outputs. The VCO1 and VCO3 sections do not have outputs for sine and triangle waves. The typical rub is that when you want an LFO, it's usually VCO2. What if you want an LFO with a triangle wave to modulate pulse width? Who would ever want that, right? Oh well…

Another frustration comes in with the FM. All three VCOs have multiple FM inputs ranging from near linear to exponential in response. FM is the most fun using an audio rate sine wave to modulate another audio rate sine wave. But there is only one sine wave available. Oh well…

And the same exact thing with AM (i.e. the Ring Modulator).

The TTSH Shapers module was created to add triangle and sine wave outputs that track the VCO1 and VCO3 cores. These are fully compatible and identical in function and phase to the triangle and sine wave outputs of VCO2. These new waveform outputs create all kinds of new timbre capabilities when used for modulation, be it FM, AM or both.

In addition to these waveform outputs, a sub-oscillator is also included. The sub-oscillator includes many options for the builder, depending on desired functionality. In addition to providing an audio output, the sub-oscillator may also be used as a clock/gate/event divider to drive the envelope generators.

Install Considerations

Before you decide to install this module, you should consider what will be required of your current system to support it. This section will help you work through those considerations.

1. You will, at minimum, need to allocate space for, and drill, five new jacks, to support the new waveform outputs. <u>This requires complete disassembly of the instrument – a non trivial operation that brings its own set of risks.</u> The sub-oscillator section has optional features, and a fully tricked out install adds three switches and one additional jack. If you wish to make use of

these features, you will need to allocate and drill space for these. Since all of these features are optional, you may elect to defeat them during the install by way of adding jumpers to the board. In this case there will just be five jacks consisting of the shaper outputs, and one sub oscillator audio output.

2. There is panel wiring involved.
3. Trimming requires use of an oscilloscope.
4. If you have a V1 TTSH, you will also be dismounting your speakers.
5. You will need to apply +/- 15V bipolar power to the board from your existing power supply. The board demands 40ma on the V+ supply, and around 30ma on the V- supply. Using the DC-DC converters and an external AC-DC 12V supply, the additional load on the +12V supply was measured at 90ma. Methods for tapping power in all TTSH versions are presented below. The board has been successfully tested with V1-3 TTSH using standard power supply implementations. An ARP 2600 has not been evaluated for this.
6. The board has four mounting screw holes intended for M3 machine screws. The spacing of these holes is compatible with TTSH versions V1 – V3, so you won't have to improvise here. If your case is a custom type that is very shallow at the top, you should verify that you have 1 3/16" / 30mm clearance available. There are detailed mounting instructions for the TTSH in subsequent sections. The board has not been evaluated for installation in an ARP 2600 case, but should be simple to mount to wood surfaces inside the case.
7. You will need to connect the VCO1 and VCO3 core module outputs to the inputs on this board. This is a simple and straightforward process for TTSH, but this may be a complicating factor with ARP 2600, particularly in the case where the VCO core modules are encased or potted. The circuit points required for connection are exposed in all versions of TTSH and ARP 2600. However, if you have an ARP 2600, you may need to trace the circuits or have this module installed by your trusted service technician. [I do not own an ARP 2600].

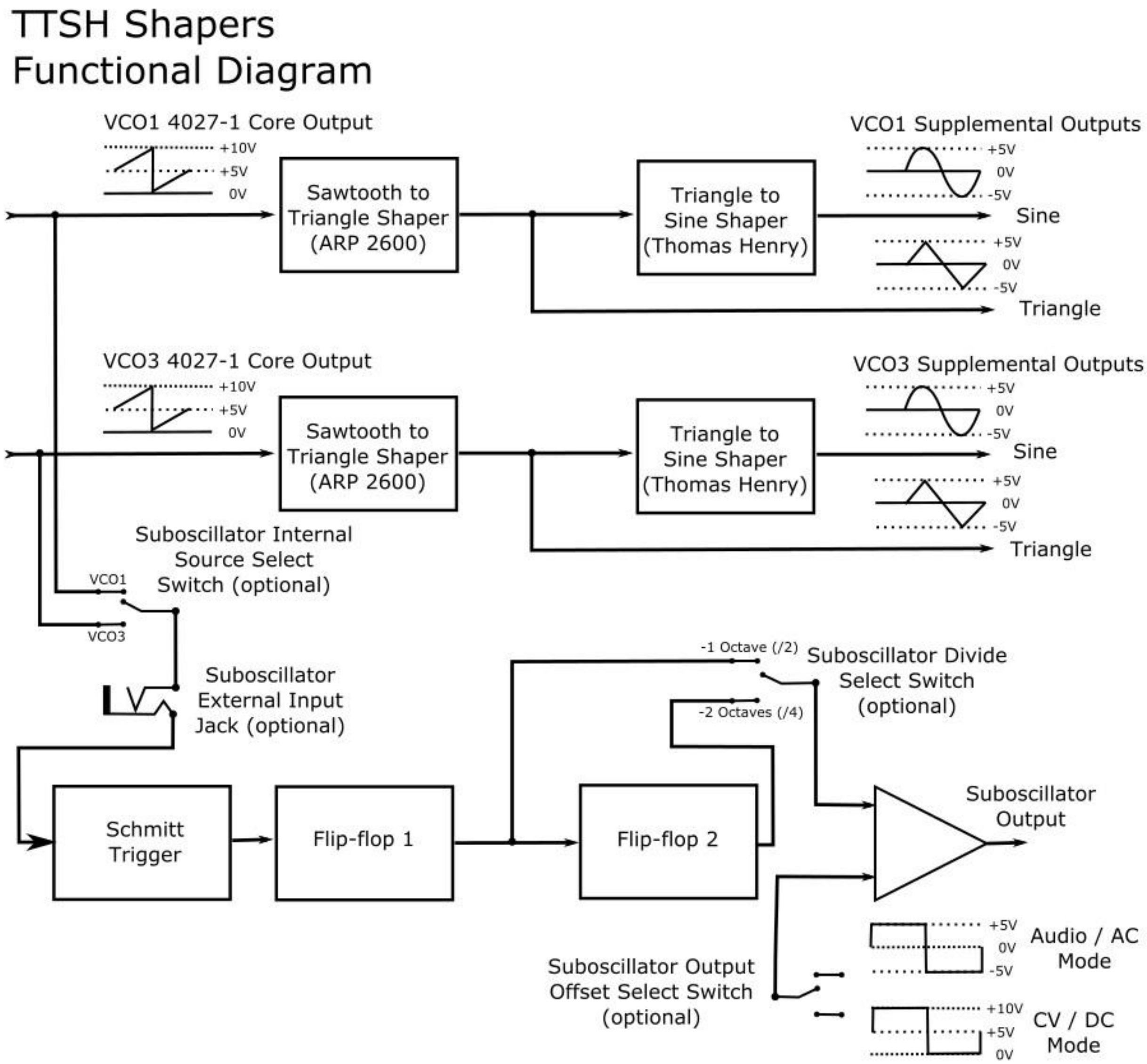
Caveat:

In TTSH Versions 2-3, the loudspeakers and attendant amplifiers are not well matched. Without the shaper installed, if you crank the speakers up to full, the system becomes unstable. The speakers buck inductive spikes back onto the power rails, and the PSU is taxed at or beyond capacity. It is not recommended that a V2-3 TTSH be operated with the internal speakers running at maximum. The added load of the Shaper does nothing to improve this condition; in fact, the Shaper makes it slightly worse.

In either case, don't crank the speakers in your V2-3 TTSH, and don't obsess about the fact that they shouldn't be cranked. The speakers are a useful utility item, but are no way at all to hear the synth. Another way to say it: <u>expect the speakers to suck, and you won't be disappointed</u>.

Structure

It's probably best to describe how this works by way of a picture.



Triangle Shaper

There are two identical shaper sections, one for VCO1 and the other for VCO3. The input is taken directly from the VCO core modules, which put out a unipolar sawtooth wave 0 to +10V p-p. The first stage is a sawtooth to triangle converter. The resulting output is a bipolar triangle wave, -5V to +5V p-p.

> As with the 2600 and TTSH, there is a little funkiness with this triangle wave. At the point where the source sawtooth wave drops from peak to 0V, the triangle wave shows some instability, and there is a little glitch. This appears on the scope as a notch. As you increase the frequency of the VCO, this notch becomes more pronounced. It was found that the best practice to keep this from becoming an audible problem is to be sure to use the specified LM301 op amp in this

section. The comparatively slow response of the LM301 helps to smooth out this glitch, and keep it from being apparent to the ear.
At low frequencies, there is not much of a glitch, and therefore not a lot of harmonics added by it. At higher frequencies, there is more a glitch, but the resulting harmonics are shifted up into supersonic frequencies, so not apparent, and likely to be removed subsequently by the VCF anyway.

The triangle wave output is taken directly to the output of the module via a 2k2 load resistor, and also feeds the input of the subsequent triangle to sine wave shaper.

Sine Shaper

This circuit was not taken from the 2600 / TTSH. The sine shaper in the 2600 / TTSH VCO2 section is, well… less than desirable. It is impossible to trim all the overtones out of the resulting wave in VCO2, and the best that can be achieved could be described as a rounded off triangle. And it requires an aftermarket part (dual JFET).

Instead, a more updated and sophisticated shaper, designed by the great Thomas Henry, is used.

There are a few twists and turns with the sine shaper implementation. Thomas design includes gain (Thomas calls this one roundness) and offset trimmers. His shaper also expects the offset and output impedance of his triangle source, not that of the TTSH / 2600 triangle circuit. So there are a few tweaks.

One design choice made was to eliminate the gain and offset trimmers. The triangle shapers already included four trimmers. The original sine shapers would include six trimmers. Ten trimmers on the board seemed excessive. I had in mind a certain maximum size of the board so that it could be mounted using the existing fasteners on the TTSH PCB. Ten trimmers pushed the board dimension beyond what would fit in a V1-2 TTSH.

It was found that if matched pairs of transistors are used in the sine shapers, fixed values of resistors can be reliably substituted for the gain [roundness] and offset trimmers. It's worth noting that the values I came up with were not standard resistor values. My guess is that Thomas uses trimmer here because he rightly sees the need of transistor matching as an obstacle to be overcome. I overcome this obstacle for the builder by providing the matched pairs in the kit. The sine symmetry trimmers from Thomas design are included, rendering a total of six trimmers – and it all fits in the footprint I wanted.

The matched transistor pairs sold with the kit have been tested to ensure a good round sine wave with minimal DC offset.

Sub-Oscillator

The sub-oscillator is a simple mathematical divider, and produces a square wave output. This section has many install options. In fact, the entire section is optional. At minimum, this section may be installed with hard wired input to either VCO1 or VCO3, with fixed division of -1 Octave (/2), and audio output (-5V to +5V p-p). In this bare bones implementation, the only panel space required is a single output jack. There is detailed information below. All of these options may be defeated or hard set by application of jumpers to the board.

During experiments with the sub-oscillator circuit, I found that if you feed it supersonic frequencies, it will at some point lock up at one of its output states (-5V, 0V, +5V, +10V). Locking up at any DC voltage other than 0V is undesirable behavior, when being used in audio mode. This happens when the input frequency is above ~30 KHz. To dampen this, I could have put a filtering capacitor in series with the output. However this would cause distortion of the output signal. Running the sub-oscillator at 30 KHz is not normal use, so this behavior was not worked out of the circuit. If you mistakenly cause it to happen while using the sub-oscillator in audio mode, it is unlikely to cause problems down the line. The only reason I mention it here is because the TTSH/ 2600 VCOs can be driven all the way up to ~95 KHz.

Bill of Materials

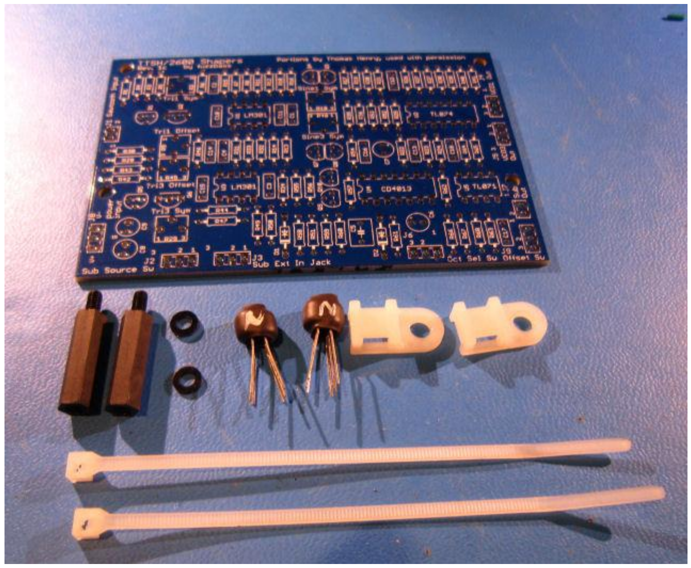
Qty	Value	Part	Description
		Resistors - Fixed	
1	220r	R57	Resistor, 1/4 watt, Through Hole, 1%
2	390r	R17, R35	Resistor, 1/4 watt, Through Hole, 1%
5	1k	R4, R27, R41-42, R65	Resistor, 1/4 watt, Through Hole, 1%
12	2k2	R1, R13-14, R16, R22, R28, R49-51, R54, R61-62	Resistor, 1/4 watt, Through Hole, 1%
1	4k7	R67	Resistor, 1/4 watt, Through Hole, 1%
2	4k53	R23, R37	Resistor, 1/4 watt, Through Hole, 1%
2	5k6	R21, R53	Resistor, 1/4 watt, Through Hole, 1%
10	10k	R6, R19-20, R25-26, R36, R39-40, R44, R52	Resistor, 1/4 watt, Through Hole, 1%
2	10k5	R24, R38	Resistor, 1/4 watt, Through Hole, 1%
1	13k	R68	Resistor, 1/4 watt, Through Hole, 1%
4	15k	R5, R12, R33, R43	Resistor, 1/4 watt, Through Hole, 1%
1	18k	R66	Resistor, 1/4 watt, Through Hole, 1%
2	22k	R58-59	Resistor, 1/4 watt, Through Hole, 1%
6	30k1	R7, R10-11, R31-32, R47	Resistor, 1/4 watt, Through Hole, 1%
2	39k	R3, R30	Resistor, 1/4 watt, Through Hole, 1%
1	47k	R64	Resistor, 1/4 watt, Through Hole, 1%
1	62k	R63	Resistor, 1/4 watt, Through Hole, 1%
2	68k	R8, R46	Resistor, 1/4 watt, Through Hole, 1%
2	75k	R15, R34	Resistor, 1/4 watt, Through Hole, 1%
1	100k	R60	Resistor, 1/4 watt, Through Hole, 1%
1	1m	R56	Resistor, 1/4 watt, Through Hole, 1%
1	1m2	R55	Resistor, 1/4 watt, Through Hole, 1%
		Resistors - Trimmer	
2	50k	R18, R48	Bournes Trimmer, Single Turn, 3362P Series
4	100k	R2, R9, R29, R45	Bournes Trimmer, Single Turn, 3362P Series
		Capacitors	
2	30p	C2, C4	Capacitor, MLCC, C0G, 5mm LS (33p suitable)

2	100p	C1, C3	Capacitor, MLCC, C0G, 5mm LS
1	100p	C5	Capacitor, Film, 5mm LS
9	100n	C10-18	Capacitor, MLCC, X7R, 5mm LS
2	100n	C6-7	Capacitor, Polarized, 50V, 2.5mmLS
2	2u2	C8-9	Capacitor, Polarized, 50V, 2.5mmLS
		Active Components	
2	1N4148	D1-2	General Purpose Diode, DO35
1	CD4013B	U4	Dual D-type Flip-Flop, DIL14
4	2N3904	Q3-4 and Q7-8	NPN TRANSISTOR - Matched pair, TO92*
2	2N3904	Q9-10	NPN TRANSISTOR, TO92
2	2N5172	Q2, Q6	NPN TRANSISTOR, TO92
2	LM301H	U1, U3	Single OP AMP, DIL08
1	TL071P	U5	Single OP AMP, DIL08
1	TL074P	U2	Quad OP AMP, DIL14
2	2N3906	Q1, Q5	PNP Transistor, TO92
		Misc.	
3	PDIP08	IC Socket, Machined	IC Socket, DIP08 (optional)
2	PDIP14	IC Socket, Machined	IC Socket, DIP14 (optional)
2	MTA02-100	J1, J7	MTA-100 header, friction lock, 2P, tin contacts
8	MTA03-100	J2-6, J8-9, TTSH Power Header	MTA-100 header, friction lock, 3P, tin contacts
2	MTA02-100	J1, J7	MTA-100 wire housing, closed end, friction lock, 2P, IDC, 22AWG, tin contacts
8	MTA03-100	J2-6, J8-9, TTSH Power Header	MTA-100 wire housing, closed end, friction lock, 3P, IDC, 22AWG, tin contacts
1	MTA03-100	TTSH Power Header V1 only	MTA-100 wire housing, feed thru, friction lock, 3P, IDC, 22AWG, tin contacts
2	MTA02-100 Cover	J1, J7	DUST COVER 2P Closed End (optional)
8	MTA03-100 Cover	J2-6, J8-9, TTSH Power Header	DUST COVER 3P Closed End (optional)
1	MTA03-100 Cover	TTSH Power Header V1 only	DUST COVER 3P Feed Thru (optional)
6	PJ138	sub ext in, all signal outputs	Kobiconn 3.5mm jack, switched, panel mount, knurled round nut
3	SPDT ON-ON	sub source sel., sub div sel., sub offset sel.	Mountain Toggle Switch, subminiature, solder pins
2	Mount		Hex Standoff M3x20mm Male-Female Nylon*
2	Washer		Nylon washer M3 *
2	Cable Tie		Nylon cable tie 4 inches *
2	Cable Tie Anchor		Panel Mount for nylon cable tie*

* included in kit.

What's included in the partial kit

The partial kit includes the PCB, two NPN matched pairs, and mounting hardware – the last four items on the BOM. All other items are included in the shared Mouser BOM.



1 Contents of the partial kit

It is recommended that the following parts from the Mouser Shared BOM **not** be substituted:

100p	C5	505-FKP2100/100/2.5
CD4013B	U4	595-CD4013BE
PJ138	sub ext in, all signal outputs	16PJ138

You will also need:

- Hook up wire, 22 or 24 AWG, stranded, at least three colors
- Epoxy (recommended) or other adhesive
- Heat shrink tubing 1/8 inch or 3mm
- Solder with no-clean flux. (most of the board assembly may be done with washable flux solder)
- MTA 100 IDC termination tool.

Build Guide

READ THIS FIRST:

Drilling holes in your panel should be approached with caution. Once the holes are drilled, they cannot be filled back in. The panel you have is the only one you get; there are no replacements available. The process described below tries to approach this conservatively, testing at each step to ensure that shaper is going to work with your TTSH before any non-reversible changes are made. It is highly recommend that you follow this routine, and not jump straight away to drilling your panel.

Programming the Sub-Oscillator

Prior to construction, decide which sub-oscillator options you wish to implement. You may implement all three switches, and one additional jack, or simply program them at the board level. To program at board level, replace the associated header with a wire jumper, as shown in the table below. The BOM includes all parts for option 3. Otherwise, use resistor trimmings for jumpers. You can also install all the headers and defeat some using MTA100 shorting jumpers, but these are not included in the BOM.

If you follow straight down the Program Option 1 column, you will have a bare-bones install, where the sub-oscillator is hard wired to track VCO1 for -1 octave audio use. In this form, the sub-oscillator will only require one panel instance, the output jack. Fully tricked out, you can use the sub oscillator as an audio sub, or a gate divider. When reading the table, it will probably help to refer back to the block diagram, above.

Sub-oscillator Implementation Options

Header	Function	Program Option 1	Program Option 2	Option 3
J2	Source Select Switch (VCO1 or VCO3). **This option becomes redundant if you install the external input jack.**	VCO1; omit header at J2 and switch; jumper pins 2-1	VCO3; omit header at J2 and switch; jumper pins 2-3	Wire to SPDT on-on switch, pin 2 is common
J3	External Input Jack.	No external input; omit header at J3 and jack; jumper pins 2-1	n/a	Wire to switched mono jack. Pin 1: T, Pin 2: TS, Pin 3: ground
J6	Octave/Division Select Switch. The output of the first flip-flop is taken to the second flip-flop. This switch selects where the output of the flip flops is tapped, either at /2 or /4 divisions of the input waveform.	-1 Octave or /2 division; omit header at J6 and switch; jumper pins 2-3	-2 Octaves or /4 division; omit header at J6 and switch; jumper pins 2-1 **(not recommended)**	Wire to SPDT on-on switch, pin 2 is common
J9	Offset Select Switch. Sets the bias applied to the output buffer. The first option results in a bipolar output, and is suitable for operation as an audio sub-oscillator. The second option results in a unipolar output, and is suitable for modulation, clock or gate division.	Audio / AC mode; omit header at J9 and switch; jumper pins 2-3. You can use the first Voltage Processor to add +5V DC offset for CV use, but the result will be inverted.	CV / DC mode; omit header at J9 and switch; jumper pins 2-1. You can use the second Voltage Processor to add -5V DC offset for audio use. **(not recommended)**	Wire to SPDT on-on switch, pin 2 is common

The recommended implementation is J2: Program Option 1, and Option 3 for all others. This presents on the panel as two jacks and two switches, and all functionality is supported, In this implementation, the sub oscillator functions as a new stand alone section of the TTSH.

Board Construction

The PCB construction procedure specifies cutting component leads before soldering, which is considered the “proper” way. I’ll leave that to the builder decide if this is necessary. My own experience is that this technique allows for:

- Speedier assembly
- Better wetting of the pads and components
- Improved solder flowing
- Reduced errors, goobers and bridges due to better visibility of the work, and accessibility of the pads.
- Less solder ending up in your waste bin. <u>This alone is worth thinking about if you use leaded solder.</u>

However, using this approach, it is easier to overlook a joint during soldering and leave it cold. Extra time should therefore be spent on the inspection following soldering.

Board Construction Steps:

1. Inspect the board for obvious defects.
2. Trace the profile of the PCB on corrugated cardboard and cut out. The cardboard should be rigid, flat and free of creases or holes. Corrugated is best for this due to its springiness and heat insulation.
3. Install min 2 inch spacers to back side of the board to raise it from the work surface, or support in a Panavise.
4. Pick all parts and lay out in BOM order
5. Clean both sides of the board with isopropyl alcohol.
6. Install all axial lead passive components. These are the items that hug the board (fixed resistors, diodes, possibly capacitors). Go down the BOM list, and stuff each value in order.
7. Take the precut cardboard form and place over the components. Secure with painters tape. Flip the board over and press down firmly onto your work surface. Don’t place it in the Panavise. You want the cardboard sandwiched between your work surface and the components, and the components sandwiched between the cardboard and PCB.
8. Working your way across the board, bend all leads out (away from the component body). Clip these at the outer edge of the solder pad. If you have done this correctly, you could in theory remove the cardboard, lift the board, and nothing would fall out. But don't remove the cardboard yet.

9. Solder all connections.
10. Inspect carefully for missed solder joints, and then flip the board over and remove the cardboard.
11. Install the IC sockets and C0G caps with formed (radial) leads. Both of these have roughly the same profile.
12. Tape the cardboard back on, flip the board over.
13. Bend out and trim the capacitor leads, as before.
14. Solder all connections. When soldering the DIP sockets, tack solder one leg. With that leg heated, press down lightly on the board to bring the socket fully into contact with the board. Then, remove the iron, and let that joint cool. Solder the remaining legs.
15. Inspect carefully for missed solder joints, and then flip the board over and remove the cardboard.
16. Stuff the film capacitor, and single transistors. Affix the cardboard, flip and tack solder only one lead of each component. Remove the cardboard and correct seating of each component. You want the caps to be firmly down on the board and upright. Double check orientation of the transistors. You want the transistors to all have uniform height and be upright. Once you are satisfied, flip the board. Bend out and trim all leads, and solder remaining joints. You are done with the cardboard now.
17. Stuff electrolytic caps, flip the board, bend the leads out, cut and solder.
18. Install matched transistors to sine shaper section, and the headers. Flip and tack solder only one lead of each component. Correct seating of each component. Once you are satisfied, flip the board. Bend out and trim all leads, and solder remaining joints. Do this in a rotary fashion, one pin on each transistor at a time.
19. If you are using washable flux, stop here, wash the board, blow out the nooks and crannies with compressed air, and allow the board to dry before proceeding. You should now be able to inspect your work under magnification.
20. Install trimmers using no-clean flux. Once the trimmers are on, the board must not be immersed.
21. Install ICs U1 – U5.

Testing the Board

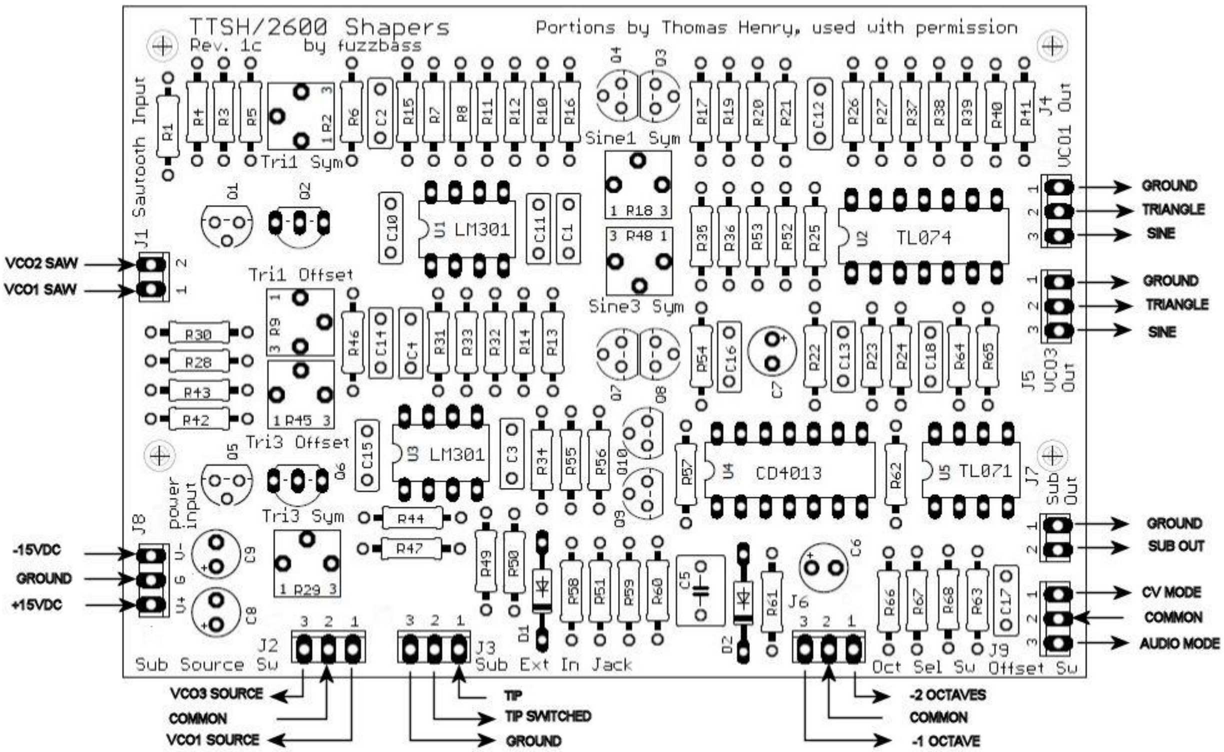
If you have the ability to power the board on your bench, you should do so and test it. It will be much easier to troubleshoot and/or repair your build outside of your synth. You can test the board using the sawtooth output from any VCO on the TTSH (the triangle shaper is expecting a rising ramp 0V to +10V). Remember to bring a ground connection over from the synth. You can attach this ground, along with your scope's ground reference, to J4 pin 1 during testing. While you have the board powered up on the bench, you can perform calibration (documented below), although you may have to repeat this once the board is installed.

To test the sub-oscillator, you will need to install shorting jumpers or test leads between pins on any of the option headers you included, indicated in the table in olive green. Without some test jumpers, the sub oscillator will not function on the bench.

Header Pin Outs

Jumper	Function	Pin	Pin out
J1	**Sawtooth Wave Inputs**	1	VCO-1 Sawtooth Input
	(wire to 4027-1 points)	2	VCO-3 Sawtooth Input
J2	**Sub-Oscillator Source Select**	1	VCO-1 Source
	(wire to SPDT On-On toggle switch)	2	Common
	Test: short pins 1-2	3	VCO -3 Source
J3	**Sub-Oscillator External Input**	1	Tip
	(wire to switched mono 3.5mm jack)	2	Tip-Switched
	Test: short pins 1-2	3	Ground
J4	**VCO-1 Triangle and Sine Outputs**	1	Ground
	(wire to mono 3.5mm jacks)	2	Tip (VCO-1 Triangle Out)
		3	Tip (VCO-1 Sine Out)
J5	**VCO-3 Triangle and Sine Outputs**	1	Ground
	(wire to mono 3.5mm jacks)	2	Tip (VCO-3 Triangle Out)
		3	Tip (VCO-3 Sine Out)
J6	**Sub-Oscillator Octave Select**	1	-2 Octaves (/4)
	(wire to SPDT On-On toggle switch)	2	Common
	Test: short pins 2-3, then 1-2	3	-1 Octaves (/2)
J7	**Sub-Oscillator Output**	1	Ground
	(wire to mono 3.5mm jack)	2	Tip (Sub-Oscillator Out)
J8	**Power Input**	1	+15V DC
	(wire to TTSH Power Distribution)	2	Ground
		3	-15V DC
J9	**Sub-Oscillator Offset Select**	1	CV (+5V DC Offset)
	(wire to SPDT On-On toggle switch)	2	Common
	Test: short pins 1-2, then 2-3	3	Audio (No DC Offset)

Here is a pin out diagram:



Testing Compatibility

Before making any changes to your panel, test the shaper with your synth, to ensure your power supply will support it, and your VCO cores will tolerate it. You will need to have your TTSH removed from the case, and supported so it can be powered and operated.

Now we move inside your synth.

Connecting to Power

In the V1 TTSH, we will make use of an existing power header, by way of making a new jumper cable for it. In the V2-3 TTSH, there is no existing power header, so one must be added, along with a new jumper.

It is time now to separate your panel from the main PCB. Remove everything (repeat EVERYTHING) from the panel. You will need the panel to lay perfectly flat on your work surface and/or drill press table. I won't go into the details here, which vary by which TTSH version you have. You put it together, and you should know what is involved in taking it apart. Be gentle. Be patient. Removing the power switch will be a headache. There are 82 jacks with nuts on them.

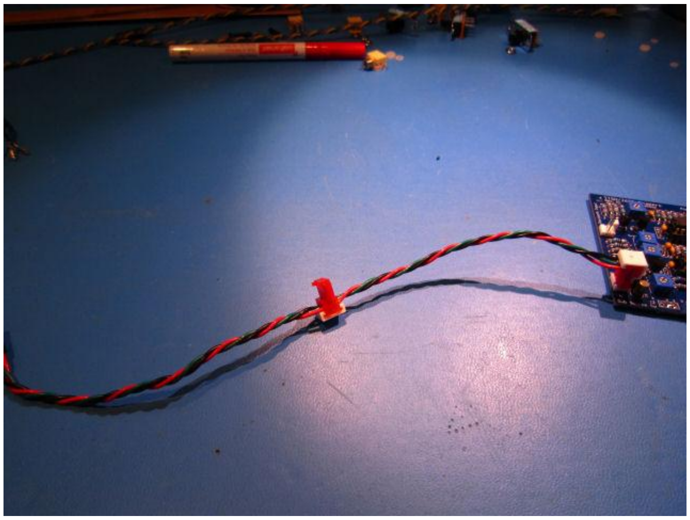
> **Suggestion 1**: While the main PCB is isolated from the panel, protect it by installing M3x50mm M-F standoffs, both sides, as stilts. These can run through four of the five points used to mount the panel to the PCB.

Suggestion 2: If you end up desoldering connections to remove panel components, consider adding headers, wire housings and jumpers for these while the board and PCB are apart. This will remove some dread of separating these two in the future. On V1 TTSH, there is a little single pin pad for a ground connection at the bottom right of the PCB. Use this to construct a removable ground connection to the panel mounted KBD CV and Multiples jacks. On V2-3 TTSH, add some extra MTA100 friction lock headers to other sections (each has a 2x3 pad that will accept a power header) so you can add more powered options later if you wish.

Power - TTSH V1

The V1 power distribution was off-board. One of these power runs will be replaced here with a new run extending the power to the Shaper. This assumes you used MTA100 friction lock headers and IDC type wire housings. If you soldered these wires in, you should desolder and remove the connection. There are sufficient parts in the BOM to install headers and wire housings no matter how you started out.

1. Remove the power jumper feeding the VCF section.
2. Cut three lengths of new hookup wire (different colors), 12 inches (30cm). Be consistent with whatever wire color convention you used for power. On the V1 main board, the polarity of the power headers is printed.
3. Rebuild your power jumper assembly for the VCF using three wire housings, with pass-through housing at the VCF power input (the middle position on the wire assembly). Double check power polarity before making terminations! <u>The polarity of the headers may not be consistent at all three locations.</u>
4. Extend this power wiring assembly to the Shapers board.

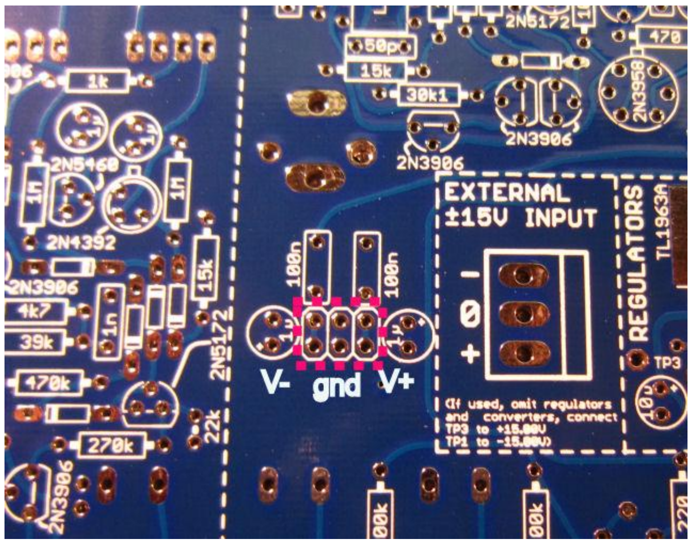


2 New power jumper with pass through housing in line

TTSH V2 and V3

In TTSH V2 and V3, the pads that supported power connections in V1 live on as vias connecting each section to the power distribution layer. Thankfully the dimensions remain the same so these can also function as tap points where power can be accessed by installing a new MTA friction lock header. I recommend using the one in the VCF section to power the Shapers board. You will need to solder this header in. Be careful to observe the polarity for this header location, which is not marked on the board. See the diagrams below.

V2



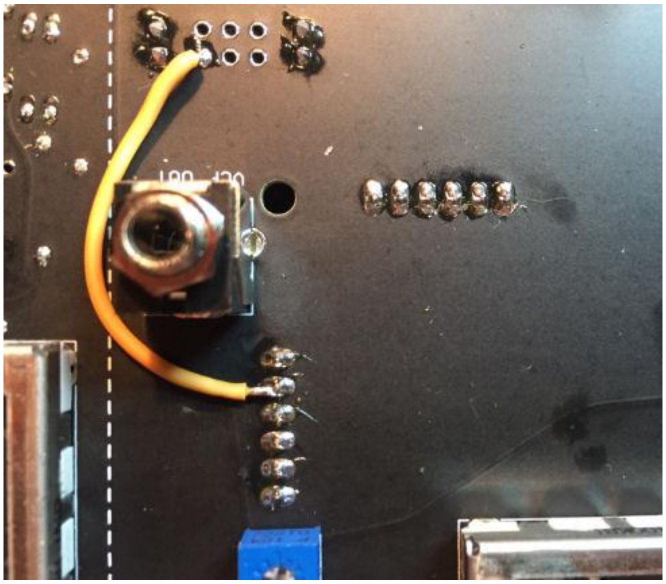
3 VCF Location for power header, TTSH V2

Install the new header with its friction lock oriented toward the top edge of the PCB, consistent with the power header on the Shapers board. Then the wire housings on your power jumper can be terminated same both ends and the risk of a power error will be reduced.

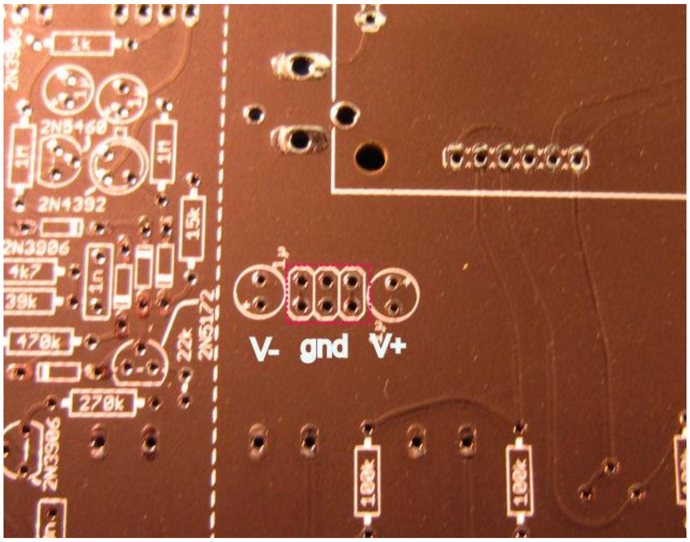
Build a power jumper using two MTA100x3 wire housings, length: 5 inches / 13cm.

V3

There is a bug in the VCF in V3 where the trace for V- rail connection to the VCF sub board was missing. The recommended fix involves a wire jumper from the VCF power header location, installed on the other side of the board, as shown below:



Be cognizant of this fix as you install the header on the other side of the board, here:



4 VCF location for power header, TTSH V3

Install the new header with its friction lock oriented toward the top edge of the PCB, consistent with the power header on the Shapers board. Then the wire housings on your power jumper can be terminated same both ends and the risk of a power error will be reduced.

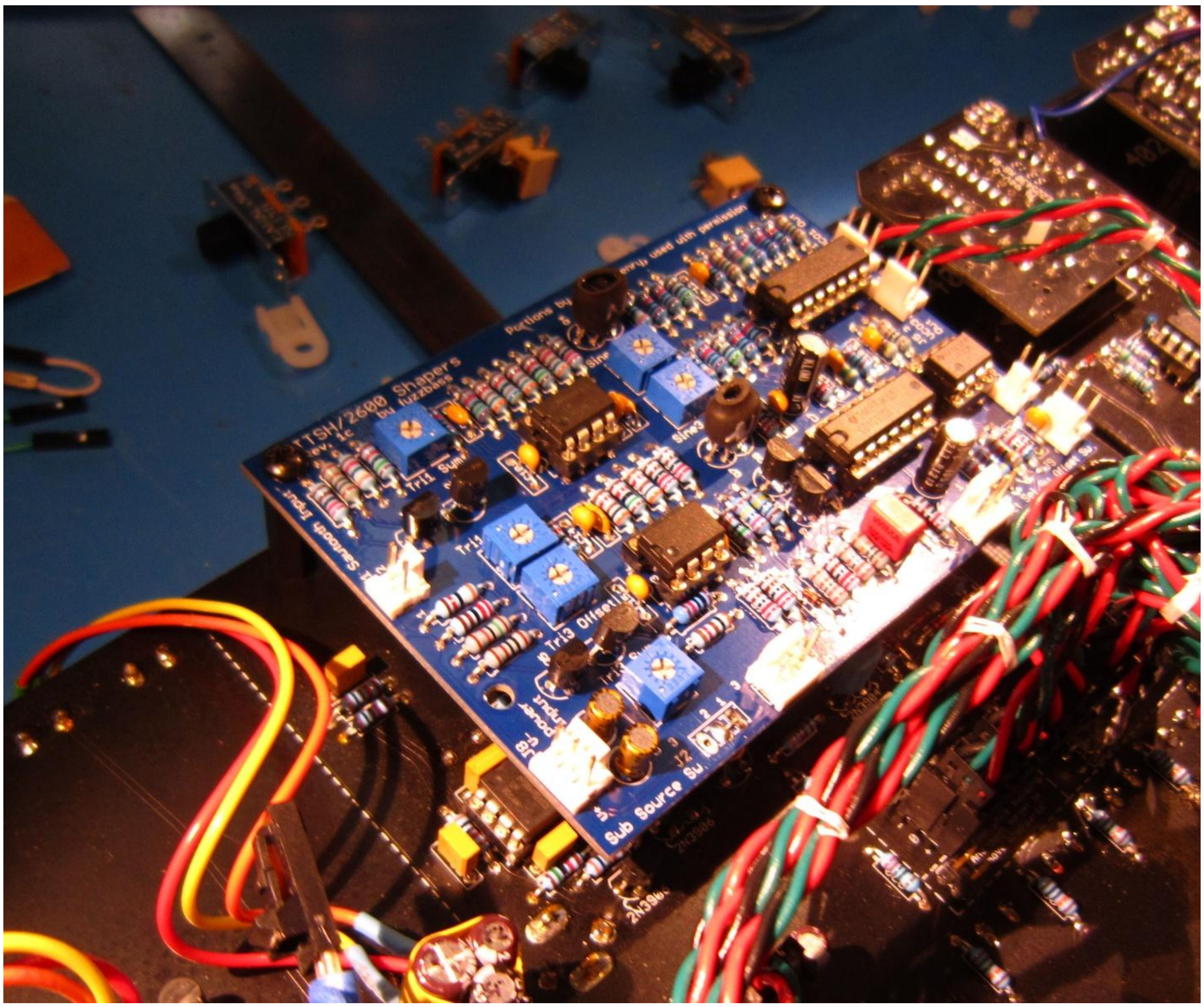
Build a power jumper using two MTA100x3 wire housings, length: 5 inches / 13cm.

Mounting your Shaper

> **Note:** photographs below show a V1 TTSH, and the main PCB has black solder mask on both sides, as does the V3 TTSH. The V2 TTSH has blue solder mask on the component side. If you have a V2 TTSH, don't let this confuse you as to which side of the board is shown.

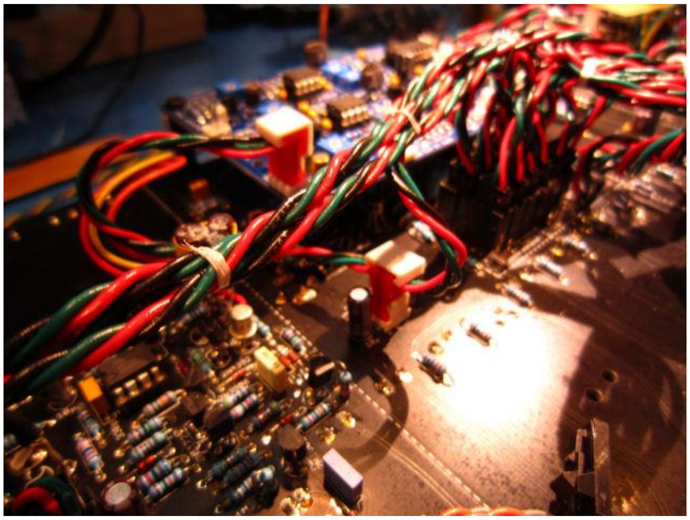
TTSH V1-2: Remove the M3 screws connecting the two center top 12mm spacers (above the VCF and Power sections. Install 20mm black nylon M-F spacers (provided). Install the Shaper board with components facing away from the main TTSH PCB. Using the nylon washers provided, install the M3 screws previously removed, to complete the mounting.

TTSH V3: The shaper piggy-backs on top of the VCF sub-module. Remove the M3 screws securing the VCF sub-module, keeping the sub-module in place. Install 20mm black nylon M-F spacers (provided). Install the Shaper board with components facing away from the main TTSH PCB. Using the nylon washers provided, install the M3 screws previously removed, to complete the mounting.



5 Shaper mounted to TTSH Version 1

Connect the power headers using the jumper you made. TTSH V1 shown below:



6 VCF Power connection in V1 TTSH

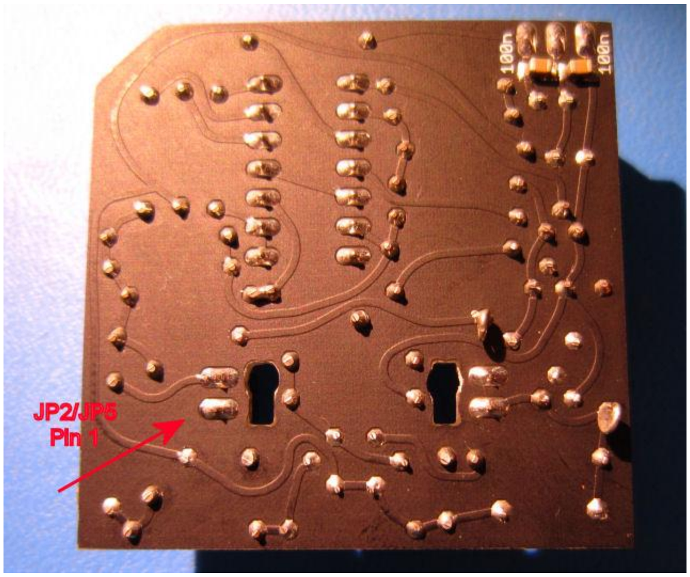
Connecting TTSH Sawtooth outputs to Shaper inputs.

You may use standard hookup wire (22 or 24 AWG stranded copper) for these connections, but don't twist or drill the wires, let them have a bit of space between each other. It won't hurt if they contact each other once or twice, but they should not run the distance in close proximity.

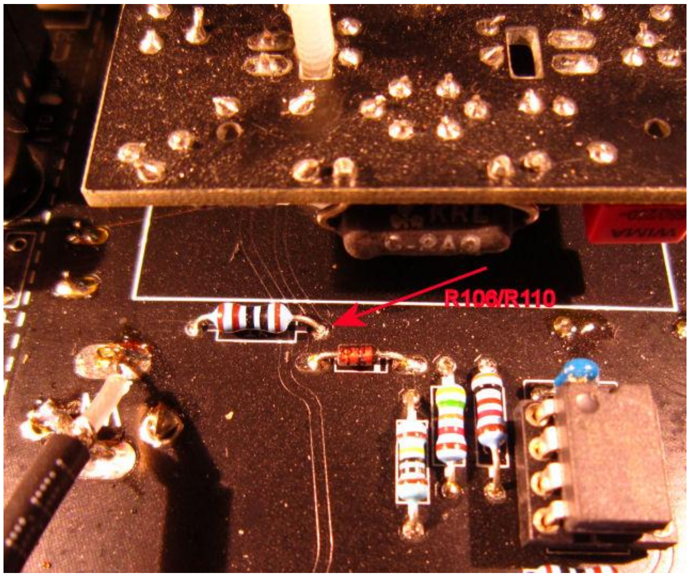
The recommended tapping points are:

VCO1: JP2, pin 1 on the 4027-1 sub module. This is identified on the schematic as test point VCO1-5. An alternative location is on the right side of R106 (1K) resistor on the main board, which is common to the recommended location. Connect to shapers board J1-Pin1.

VCO3: JP5, pin 1 on the 4027-1 sub module. This is identified on the schematic as test point VCO3-5. An alternative location is on the right side of R110 (1K) resistor on the main board, which is common to the recommended location. Connect to shapers board J1-Pin2.



7 Recommended Tapping Point for Sawtooth Wave



8 Alternate Tapping Point for Sawtooth Wave (R110 in VCO3 shown, but R106 in VCO1 is in similar location)

Testing with your TTSH

For testing, connect the power and shaper inputs to VCOs 1 and 3, and leave in place the test shorting jumpers for the sub oscillator, as described above.

Connect your scope's ground reference to J4 pin 1. If you wish to monitor the input with a dual trace scope, you may connect the triggering probe to the alternate connection point for VCO1 (R106) as pictured above. Connect your [second] scope probe to J4, pin 2 (VCO1 Triangle). Power up your TTSH, you should see the triangle output.

Trimming:

Adjust trimmers TRI1 SYM and TRI1 Offset for correct shape and zero DC offset. Move your scope probe to J4, pin 3 (VCO1 Sine). Adjust trimmer Sine1 Sym for good sine shape. Note there may be a very small amount of DC offset but nothing problematic.

Move your scope to J5, pin 3 (VCO3 Triangle). If you are monitoring the sawtooth input, move your triggering probe to VCO3 R110. Repeat checks and adjustments as above.

If you intend to implement the sub oscillator, move your scope to J7 pin 2 (sub out). You should see a square wave, -5V to +5V (10Vp-p), one half the frequency of the input sawtooth. This is a signal suitable for audio use. To validate the octave select function, move the test jumper on J6 to pins 1-2. The output should now be one quarter the frequency of the input sawtooth. To validate the function of the Audio / CV (AC/DC) selector, move the test jumper on J9 to pins 2-3. The output should now be 0V to +10V (10Vp-p). This is a signal suitable for driving the Envelope Generators.

If all these tests succeed, you are ready to proceed with modifying your panel to accept the new jacks.

Panel Drilling

Presented below is a method for positioning the triangle and sine outputs in the control fields of VCO1 and VCO3, in approximately the same location these outputs are located in VCO2. This involves installing jacks between the panel and PCB. If you choose to substitute jacks for those specified in the BOM, make sure they have equal or lesser profile, and are panel mount types. <u>The standard TTSH jacks are not suitable for mounting in this location.</u>

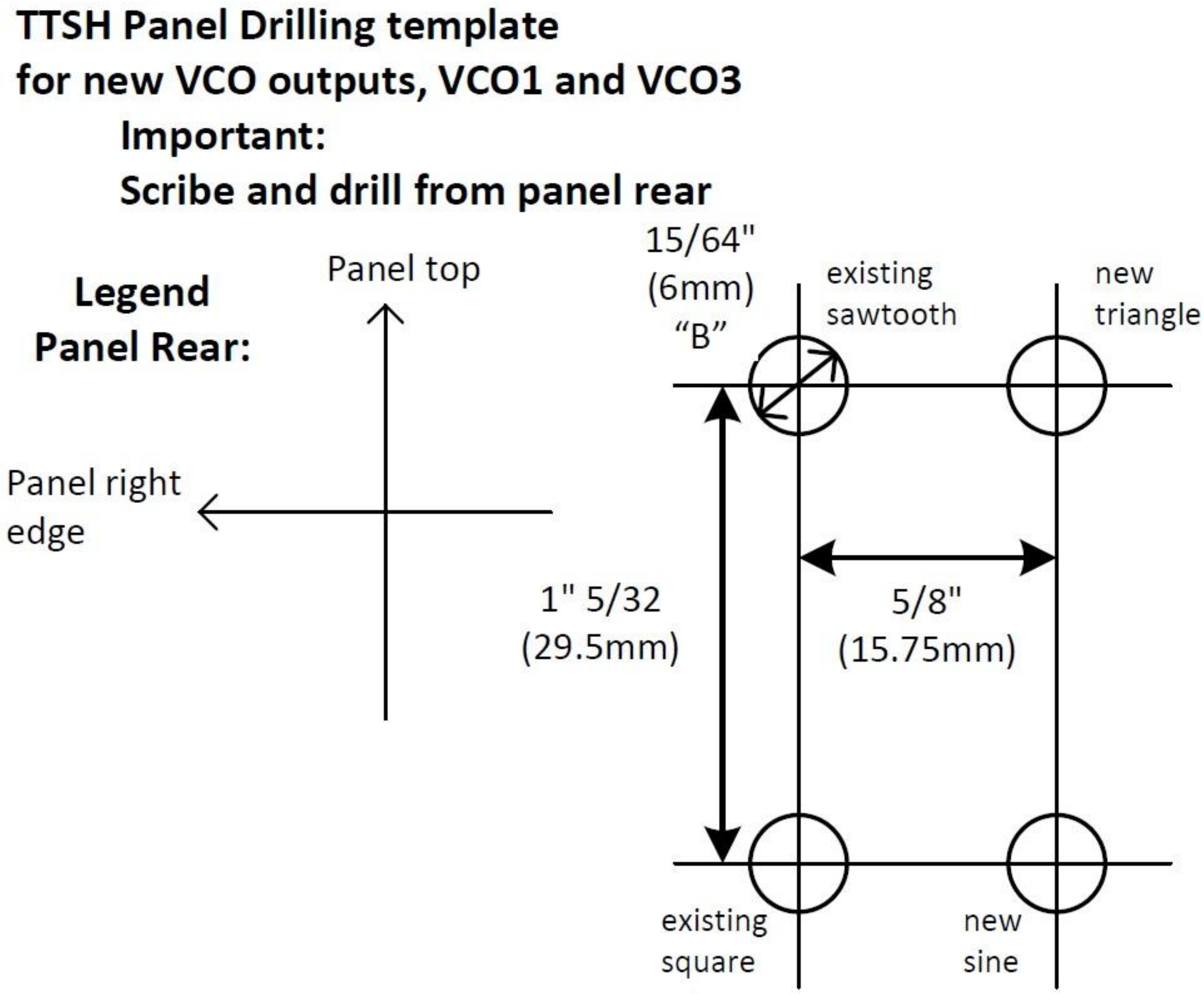
Make sure your work surfaces are clean and free of debris which may scratch the panel face. You will need:

- Metal scribe
- Center punch and hammer.
- Drill Press (preferably) or hand held drill. The drill press method is described below.
- 15/64 or 6mm drill bit. A ¼ inch drill bit will also work but there will be some wiggle room and the nuts holding the jacks will not be as strong.
- Calipers (preferably) or ruler. The caliper method is described below.
- Straight edge
- Cutting lubricant such as 3 in 1 oil or similar.
- Deburring tool (preferably) or needle files.
- Scrap plywood

While you are marking, put something soft under your panel, such as a towel or anti static mat. Try to avoid sliding your panel around while it lays face down, to avoid scratching the face.

The following is a cutting guide, and not a template. <u>You should not cut this out and use it to position your drill</u>.

Work with your panel face down, and the top of the panel facing away from you.



1. Using the straight edge, scribe the two horizontal lines bisecting the existing saw and square output jacks drills on VCO1 and VCO3, running to right approximately one inch. Make sure these are parallel to the panel top and bottom edges and each other.
2. Set your caliper to metric units, close and zero it. Open the caliper until the display reads 18.75mm, then lock. (18.75mm = 15.75 + ½ diameter of existing hole, which is used as a reference)
3. Using the inside dimension caliper, and the left side of existing hole as reference, measure to the right on the horizontal line, and scribe a cross mark. Do this for both the saw and square jack holes.
4. Check by unlocking, closing and zeroing the caliper. Now measure from the center of the existing hole to the mark for the center of the new holes. It should be 15.75mm.
5. You can also now check the vertical spacing between your new locations, which should be 29.5mm.

6. When you are sure these are as accurate as possible, use the center punch to mark a guide for the new drills. When punching, use a backing board such as scrap plywood. You want to make a small dimple on the rear of the panel that is clearly visible on the front. Do not center punch with something soft or pliable under the work - you will bend your panel. Also don't do it on your nice cherry wood dining table. Your wife WILL kill you.

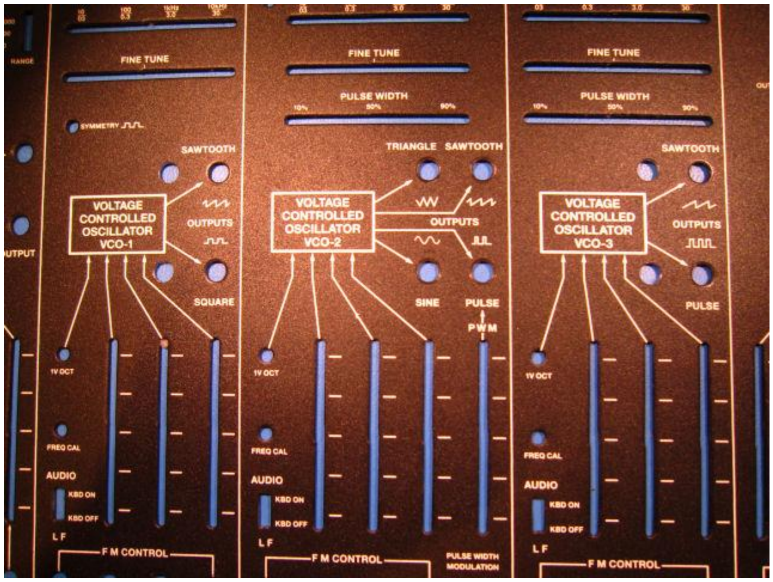
If you are new to the drill press, read the following:

- Drill at moderate speed.
- Wear eye and ear protection!
- Use a backing board of scrap plywood so that you drill through the panel and into the board. This will avoid metal shavings spinning on the other side of the panel and scratching it or your panel being deformed by the pressure from the drill press.
- When repositioning the panel on your drill table, move the backing board, not the panel. <u>Don't slide the panel across whatever is beneath it, because there will be metal shavings present.</u>
- Do not use clamps or a fence on your drill press to immobilize the panel; you need it to move freely. The dimply made with the center punch will guide the panel into final position for the cut.
- As you start a cut on the drill press, bring the bit down just so it makes contact with the dimple from the center punch. Let the bit grab the dimple and move the panel into the final position. Drill just enough to slightly deepen the dimple. With your hand, apply down pressure on the panel to keep it in place, raise the bit, shut off the press, maintaining pressure on the panel until the drill rotation fully stops and the table stops vibrating. Add a drop of cutting oil to the dimple, press down again on the panel, start the drill and complete the cut. It will prolong the life of your drill bit if you make a few passes, raising the bit and allowing it to cool for a few seconds between cuts. If you see smoke from the cutting oil, you need to cool down and proceed more slowly.

Deburr the holes or file the rough edges using needle files, working from the back side of the panel.

Remove cutting oil residue with isopropyl alcohol, <u>nothing stronger</u>.

When you are done your panel should look like this:



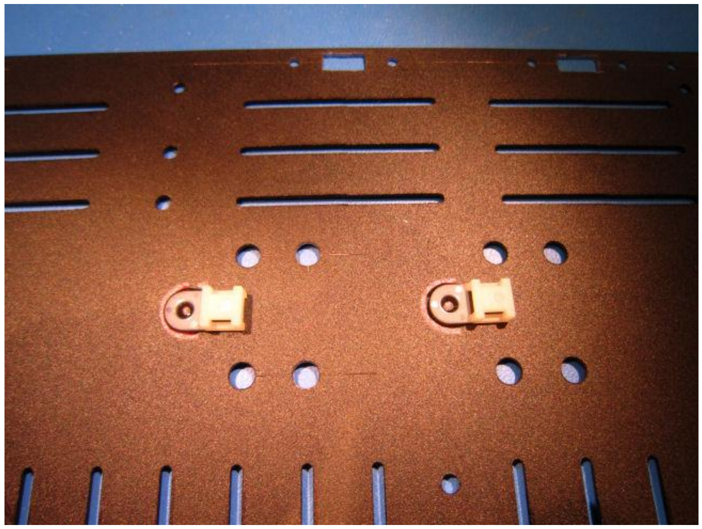
Mounting the new jacks

In addition to wiring up the new jacks, you will be dressing the cables using anchored cable ties, so that these don’t become an obstruction when you bring the panel and PCB back together, and will remain clear of the slide potentiometers.

The wires will travel horizontally across the panel toward the VCF, and then turn and run up in the space along the edge of the VCO sections. At the point where they turn, a cable tie anchor will prevent them from straying out of the path.

> In the example presented below, the VCO3 wiring travels up in the space between the VCO3 and VCF sections. The VCO1 wiring travels across VCO2, and up in the space between the VCO2 and VCO3 sections. This choice was made due to congestion of switches and jacks on my panel, above VCO1. There is not sufficient clearance to exit at the top between VCO1 and VCO2, due to other options I have installed. If your panel is not congested in this area, it would probably be better to transit the VCO1 wires up in the space between VCO1 and VCO2. <u>This change would affect the location of one of the cable tie anchors</u>.

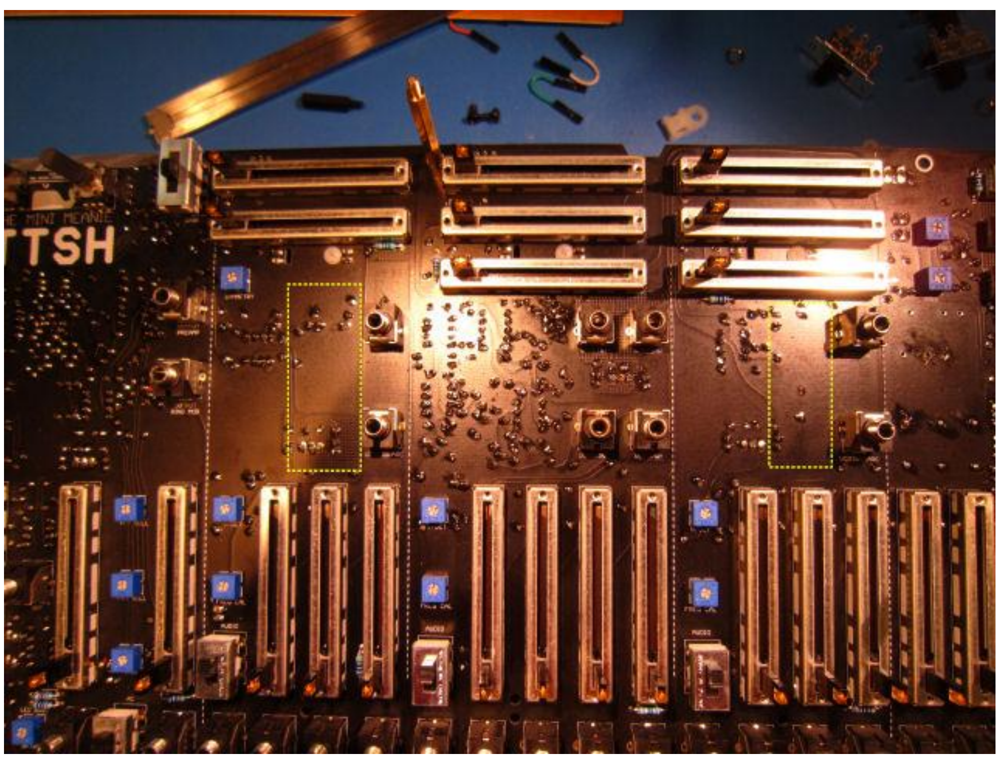
Start by installing the cable tie anchors. Epoxy glue is recommended over other types of adhesives or pressure sensitive film. Tapes and films will dry over time and fail. Hot melt glues do not bond well to this surface. Before gluing, use a wire brush or sandpaper to rough the surface (both the panel and the anchor) to accept epoxy. Apply the cable tie anchors as shown:



9 Cable Tie anchors glued down, VCO2 and VCO3 sections shown.

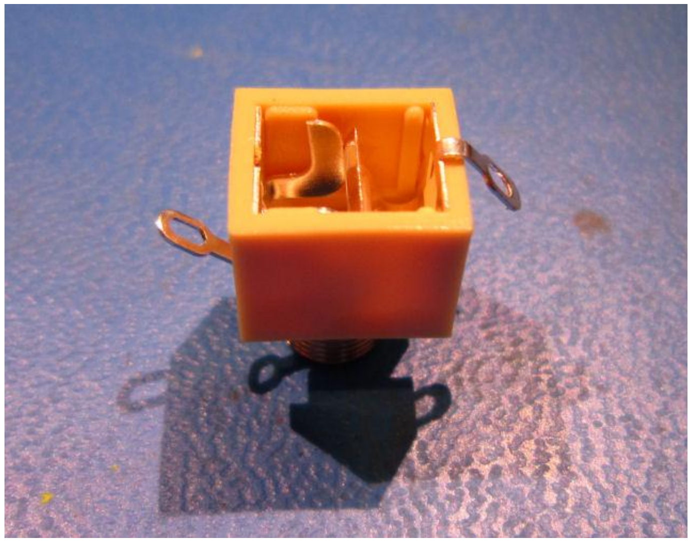
While the glue dries, drill twist a couple of three-wire assemblies, in three colors. One of these will be a ground lead, so use green for that if you have it. One wire set should be 18 inches / 46cm in length, and the other 12 inches / 31cm.

On the front face of the main PCB, and using angled flush cutters, trim all solder leads down to flush with the board, in the zones indicated:



10 Trim soldered leads flush with board in these zones.

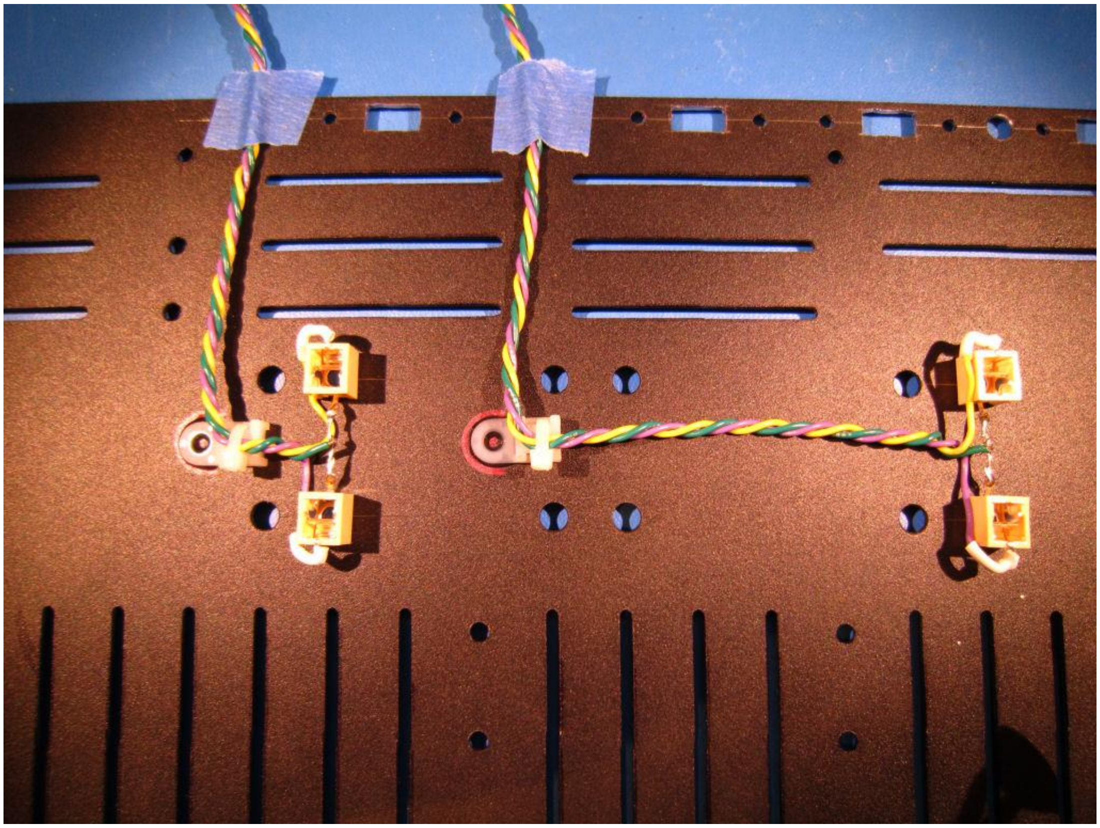
Next, prep your PJ138 jacks. Snip off the switched, tip-normal terminal. Bend the ground lead up away from the panel, and the tip terminal over and downward, as shown:



11 PJ138 jack prepped for installation

Install the jacks with the ground pins of each pair facing each other. Make sure you tighten the nuts firmly. Unlike the other jacks, these can loosen over time and spin – fixing that is hairy. Tie these grounds together with a bit of resistor lead trimmings. When you are sure the epoxy is set, wire up as shown, applying 1/8 inch heat shrink tubing at the tip pin terminations. Dress the cable using zip ties through the anchors. Make sure nothing is encroaching into the areas where the sawtooth and square wave jacks are located, then zip the cable ties up tight. Rout the wires up and temporarily secure at the top using removable tape.

Using the depth gauge of your calipers, make sure nothing will contact the PCB when reassibled. Total clearance here is 12mm. 10mm total height is what you should aim for.



12 Panel wiring for shapers. Here Green=ground, Yellow = Triangle out, Violet = Sine out. The routing of the wires from VCO1 is crossing VCO2 due to the switch I will install above VCO1. There is no path for the wires to exit in the area of this switch. If your TTSH is different, you can route the VCO1 wires as shown for VCO3.

You should now be able to test fit the panel to your main PCB and check for obstructions. Secure the panel with four screws and a few jack nuts at the corners and center.

With the shaper board in place, you can now cut the output wires to length and terminate on MTA100 wire housings, and as shown in the pin outs table, above, and connect them to J4, and J5.

If you are not installing the sub oscillator, you are done and can reassemble your TTSH.

Sub Oscillator wiring.

This section is a bit vague because builders will have varying opinions of what sub oscillator options to use, and where this is best implemented, either on-panel, or off-panel. Instead, I will show you what I did.

My TTSH is mounted in a wooden case that I built, and which is a near replica to the original ARP 2600 case. Because of this, there is small gap between the top of the panel and the case. There is room here to install options. I began with TTSH VCO synch switches already installed in this location, above VCOs 2 and 3.

The switches I chose are APEM PM13B012 SPDT on-on slide types. The bodies of these switches are 9mm tall, but these are really too tall to install between the panel and PCB. The actuators are about twice the size of the ones on the existing TTSH switches. I like the way these switches look and feel, which is very close the switches on the original ARP Odyssey. Because they are big, cutting and filing rectangular holes for them in the panel is a chore! The switches panel mount and are tapped to accept M3 mounting screws. They are also low cost.

These are not the switches included in the shared Mouser BOM. The switches included in the BOM are toggle types, much easier to install, and take up less space. The switches in the BOM also do not fit between the panel and PCB. The correct drill bit for the BOM switches is 3/16" / 5mm.

> If you want slide switches that may fit between the panel and PCB, investigate Switchcraft part number 56206L2X. These come from the same line as the TTSH switches, and so they look and feel identical, but have solder lugs and panel mounts. The profile is 7.5mm; probably 8.5mm with the lugs bent over. These have a 26x9mm panel footprint so there are limited zones on the panel where these will fit. They are expensive. I have not experimented with them.

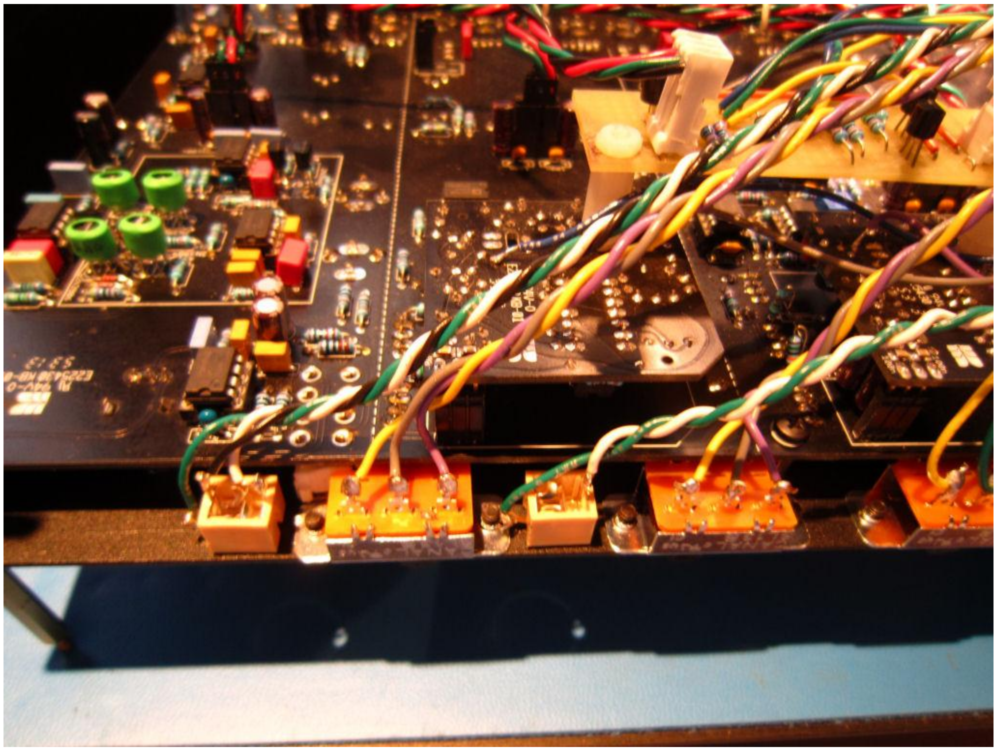
My preference for sub oscillator options is to hard wire the source select to VCO1, and install all other options:

- External Input Jack
- Octave Select Switch
- Output Jack
- Output Offset (AC or DC) Select Switch

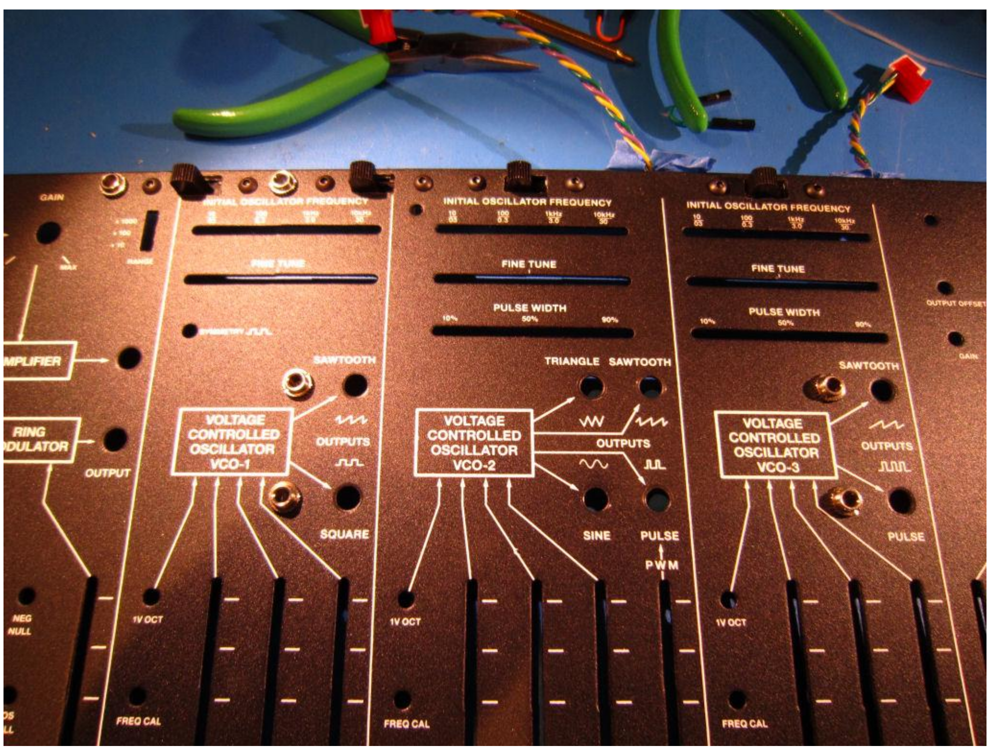
Before you simply follow my lead here, make sure:

1. These switches and jacks will fit in your case and synth panel-pcb.
2. Do you have adequate clearance above the Preamp 3-way switch? I ended up with a conflict here and had to Dremel two switches to make them co-exist.
3. These switches must be fit while the PCB and Panel are apart. They can be soldered after the PCB and Panel are back together.
4. These same switches work for the VCO sync option.

Here are some pictures of the completed installation. I have not yet added any legends to the panel.



13 Sub panel wiring, left to right: ext in jack, octave select switch, sub out, AC/DC switch. Notice the cramped quarters around the Preamp three-way switch.



14 How it looks from the front. Top panel edge left to right: Ext in jack, octave select switch, sub out jack, AC/DC switch, VCO2 sync switch; VCO3 sync switch.