ELECTRO TECHNIQUE

Rev 1.1 May 2020
electrotechnique.cc

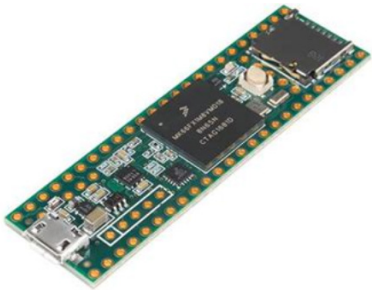
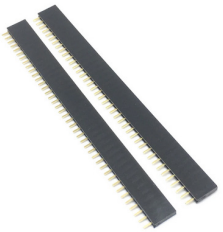
TSYNTH

BUILD GUIDE

TSynth is a DIY programmable polyphonic synthesizer based on the Teensy microcontroller board. It is supplied as a main PCB, a front panel and a 3D printed standoff for mounting the display. It is intended to be easy and enjoyable to build, using easy to obtain and common components.
PLEASE READ THIS GUIDE IN ITS ENTIRIETY BEFORE PURCHASING ANYTHING OR SOLDERING.

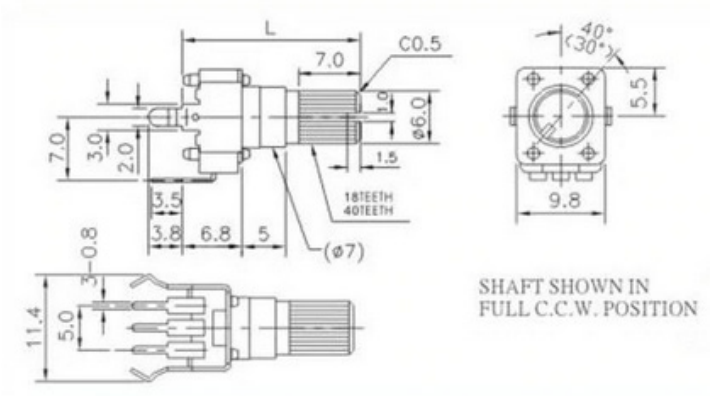
What you need to buy to build TSynth

In addition to the two boards and display standoff from ElectroTechnique, you will need the following to build TSynth:

• Teensy 3.6 **without** headers	
• Audio Board Rev C to fit Teensy 3.6 (**DO NOT** get this confused with the Rev D for the Teensy 4 when ordering)	
• 0.1” pitch pin headers, 15mm pin length • **2** 40 pin strips are sufficient as they can be broken to length	
• **2** 0.1” pitch pin header sockets, 24 pins length • **1** 0.1” pitch pin header socket, 5 pins length • These can be broken to length by removing a pin and using a hack saw, but aren’t designed for this.	

- 0.96” Colour IPS Display 80 x 160 with ST7735 SPI interface, mostly available from AliExpress/Banggood/ Ebay. Ensure the pin out is the same as the picture. If you use a different display, it will not work and you will need to changed the code yourself.

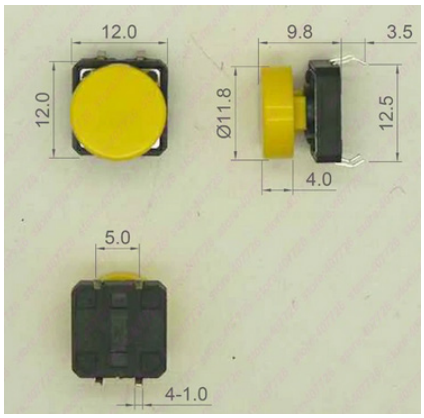
- **33** 10kΩ potentiometers, 9mm square, 15mm long shaft, 6mm splined shaft - Bourns PTV09 / ALPS RV09 type. Available generally as ‘9mm’ potentiometers.

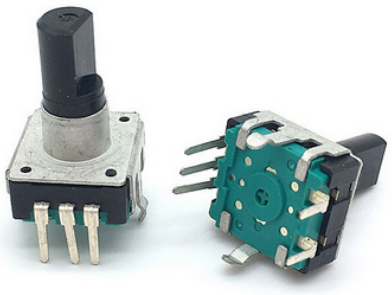


- **33** knobs to fit the potentiometers with 6mm splined shaft

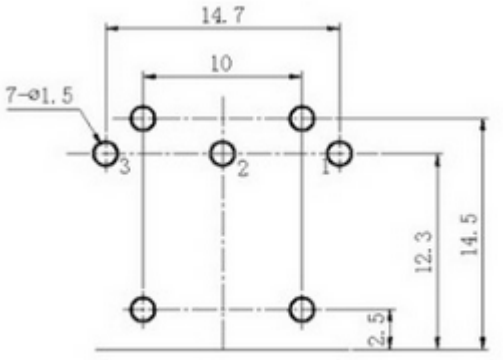
- **7** 12mm x 12mm, 7.3mm high, tactile push buttons

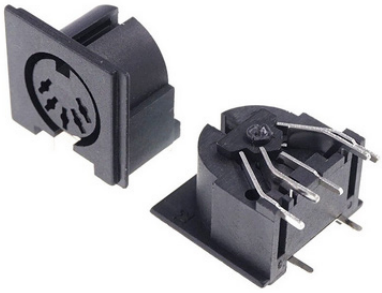
- **7** caps to fit the buttons, these are often included with the buttons if you buy from cheaper sources. Ensure the cap will actually fit onto the button, there are different sizes and styles.



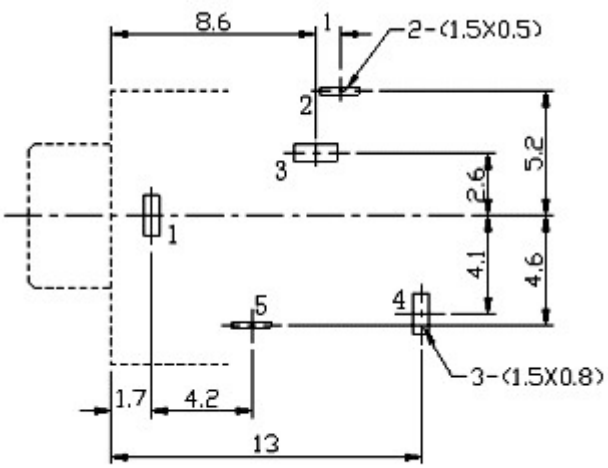
• **4** 3mm Red or Yellow LEDs, low current 1-2mA type. Don't get ones that require 20mA, because they won't receive enough current to illuminate.	
• **1** Rotary incremental encoder with push switch, 15mm long shaft, no bushing (no screw thread), 24 pulses per rotation - Bourns PEC12 type - these can be found with 6mm splined shafts and plastic D shape shafts, a detented (click) type is best. • Buying a named brand like ALPS or Bourns pays off here, as the better quality can be felt when rotating and increments are reliably made on each click. • Encoders often have pins swapped, meaning that a a clockwise rotation produces decrements instead of increments. This is easily fixed in the code - please contact electrotechnique if you have this problem after assembly.	
• **1** Knob for the encoder, for either D shape or 6mm spined shaft depending on what you bought - a 3D printable model is available from the website	
• **1** USB type A socket, right angle	
• **1** USB type B socket, right angle - *optional, see notes*	

- **1** 5 pin DIN 180° right angle socket - MIDI socket

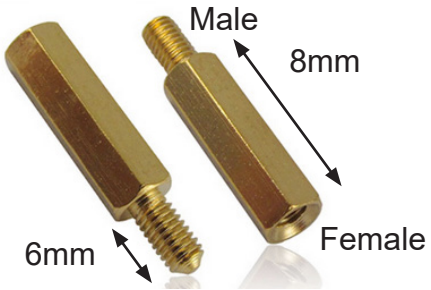




- **1** 3.5mm stereo jack socket - *optional, see notes*



- **7** 8mm brass standoffs *female-male*



- **7** 22mm brass standoffs *female-female*
- ***or*** **7** 12mm *female-female* and **7** 10mm *female-male* screwed together

- **23** M3 hex bolts 8mm (thread) length
- **4** M3 hex bolts 10mm (thread) length
- 19 of these are for the suggested enclosure, the other 7 (all 8mm) are for the front panel and display standoff.

• **13** M3 nuts for attaching display standoff (1), end cheeks (8) and side panel columns (4)	
• Some short lengths of flexible hook-up wire to connect the USB host and optional stereo jack	

Notes The Teensy 3.6 and Audio Board Rev C can be ordered directly from the manufacturer PJRC (pjrc.com) or from other suppliers - Sparkfun, Adafruit, Digikey, Mouser... a list of distributers is on PJRC. You might find it better to order the Teensy along with other components from Mouser or Digikey and take advantage of free DHL delivery for orders over $50. A BOM file for Mouser is available with most of the components on the website.

The low-cost display is mostly available from Banggood/AliExpress/Ebay. It must be a colour 80 x 160 IPS ST7735 SPI interface type to work with the PCB and firmware. Adafruit displays look similar but may not work properly with the firmware. If you opt for a different display, you will probably need to change the code to support it.

The rest of the components are very common and can be ordered from well known suppliers such as Digikey, Mouser, Conrad, Rapid, RS, Farnell... or from cheaper bulk suppliers like Ali Express, Banggood, Ebay. The quality is often no different, although see the note on the encoder. Cheaper potentiometers can sometimes feel a bit loose or tight.

Be careful with the connectors, the MIDI 5-pin DIN and 3.5mm jack socket in particular can have pins in slightly different positions. Look at the footprints carefully. USB sockets usually follow a standard, just ensure they are the right type and designed to mount horizontally on the board - see the pictures.

There is the option of soldering a USB type B socket and a 3.5mm stereo jack socket, which replicate the micro USB socket on the Teensy and the headphone jack on the Audio Board, which will probably not withstand repeated insertions everytime TSynth is used. They are highly recommended.

To make the suggested enclosure you will need access to a 3D printer and a laser cutter, or access to a service that has these. You can of course, put TSynth in any kind of enclosure you like, such as a wooden one. The brass hex standoffs are also much cheaper in quantity from AliExpress etc.

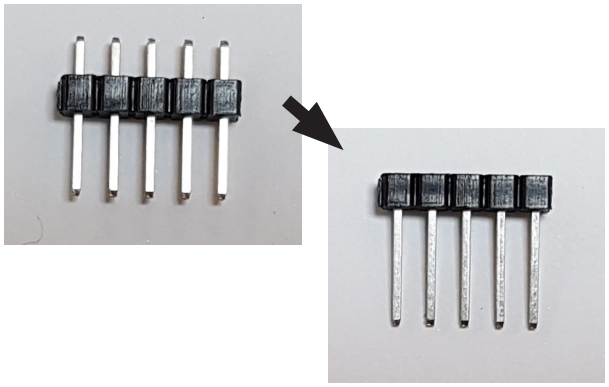
1. Assembling Teensy 3.6 and Audio Board

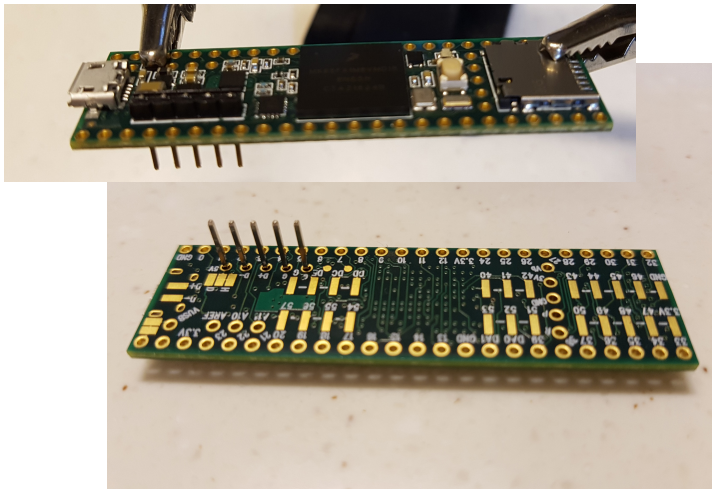
You can, and this is highly advised, test the Teensy 3.6 with the TSynth firmware before soldering the Audio Board on or the Teensy onto the main PCB. After flashing the firmware (see **Firmware** section), you can use the USB connection to send MIDI from a computer and use the USB digital audio to listen to the output. Be aware that the controls are not connected and you will probably get very random noises! It does show that it's working in preparation for the assembly.

The first task is to solder the pin headers onto the Teensy 3.6. This is probably the most challenging part of building, although not difficult. It is critical however, to get the pin headers positioned correctly, so the Audio Board can be soldered on top and the whole thing placed onto the PCB. Take your time and refer

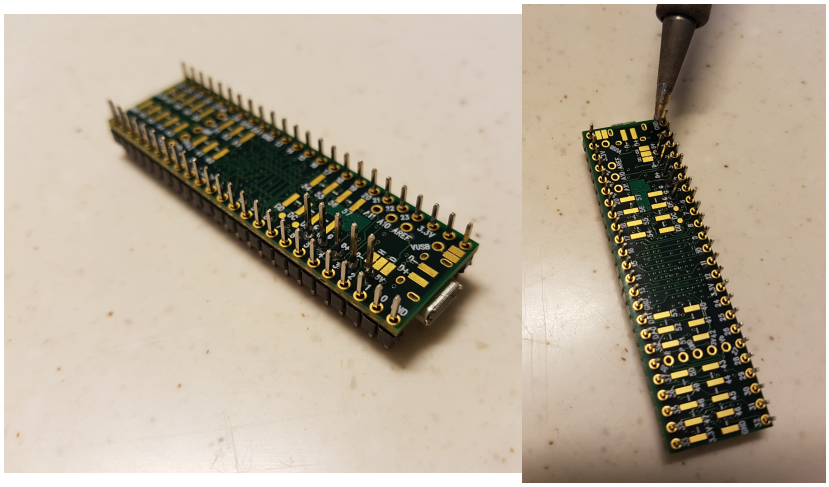
to the pictures.

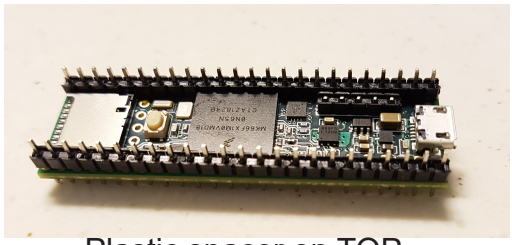
The pin header for the USB Host comes first. This needs to be modified. Simply push them through the plastic spacer, on a hard surface. The tops of the pins must be flush with the plastic spacer. This is so that the top of the pin header doesn't touch the bottom of the Audio Board when it is soldered on top of the Teensy. See pictures. Solder the pin header onto the Teensy with the plastic spacer on top.



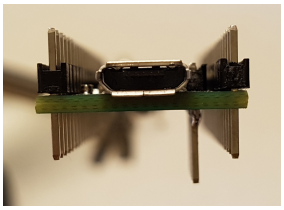


Take two 24 pin strips and push them into the top of the Teensy so the plastic spacer is on top. Solder the pins on the underside starting from the first pins at opposite ends. Ensure the headers sit flush and tight with the top of the Teensy PCB. Then solder the pins in between. Ensure you get a good solder joint but use minimal solder. Big blobs down the legs will make it difficult to insert into the pin header sockets or (if you are choosing not to use sockets) the main PCB holes. Make sure the pin headers are straight when soldering.





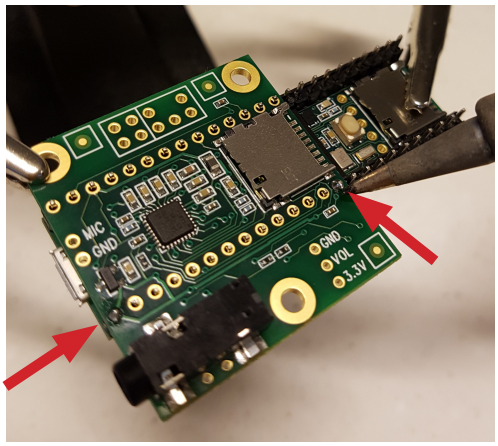
Plastic spacer on TOP



Finally, solder the Audio Board on to the top of the Teensy. Ensure it is the correct way round, the headphone socket faces the front, the same as the micro USB. See the pictures. Start with the first pins at each end and then the pins in between to ensure the board is on correctly and not angled. Ensure the solder joints are good and there are no shorts between pins.

Again it is possible to test both boards, this time using the headphone socket on the Audio Board.

Important Note - the SD card socket on the Audio Board must not be used and the optional memory chip must not be fitted, as these share pins via the Teensy, on the main PCB with several panel controls.

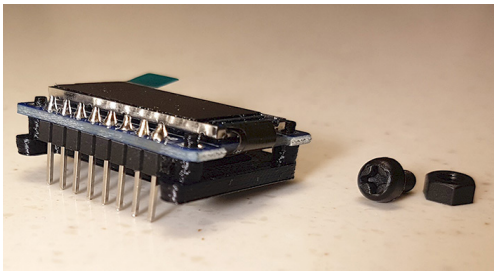


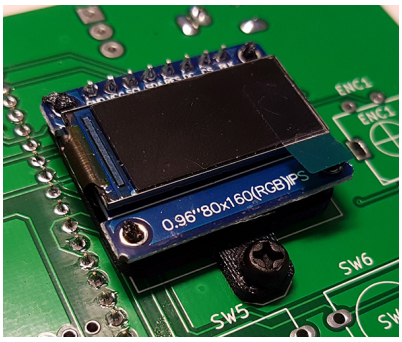
Solder end pins first

2. Soldering the display

Before attaching the Teensy/Audio Board, you may want to solder the display because the Audio Board partially covers the display module pins, making it awkward to get a soldering iron in.

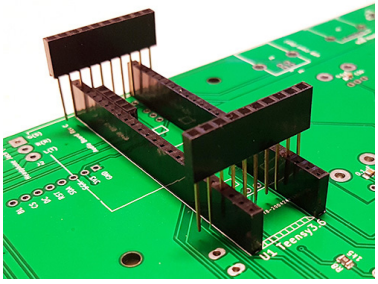
Firstly, place the display module on the 3D printed stand off. Place the assembly on the **TOP SIDE** of the main PCB where the silkscreen says 'SPI Display'. At this point, push an M3 screw through the hole and secure with a nut the other side. Solder the pins to the PCB. The display should be at the correct height from the PCB and sit close to the underside of the front panel when this is attached.

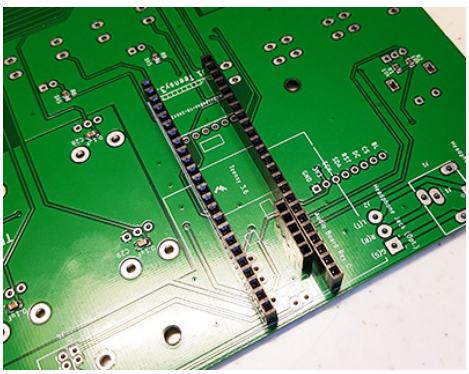


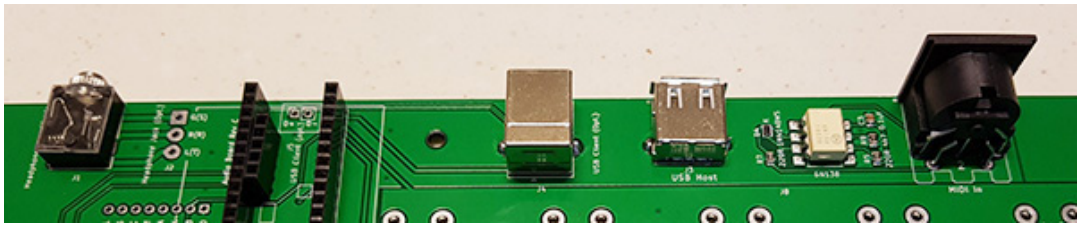


3. Soldering the connectors

Now is the best time to start soldering the connectors onto the **BOTTOM SIDE** of the board. Start with the USB(s), then the MIDI socket, the (optional) headphone socket and then (if you choose to use sockets) the two rows of 24 pin header sockets and single 5 pin header socket for the Teensy. Ensure the pin header sockets are not angled and are perpendicular to the board. It is a good idea to use pin headers pushed into the two 24 pin sockets to ensure they are right-angled to the PCB - see picture. Again, solder the end pins first and then you can re-melt the solder and push the sockets if they are not flush with the PCB.

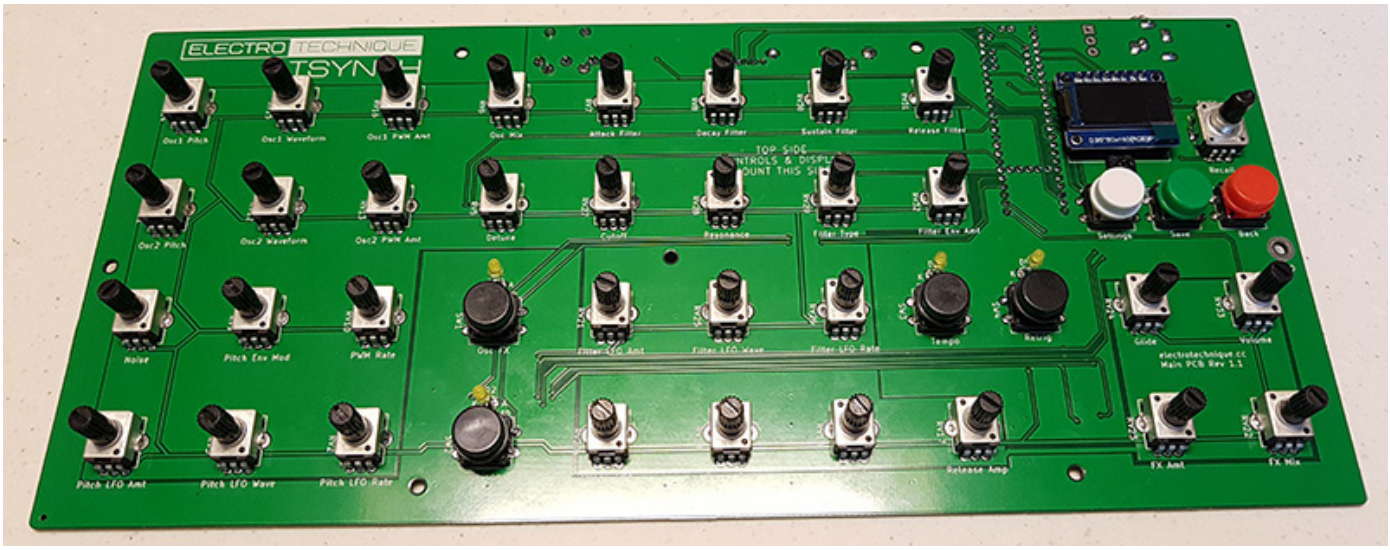






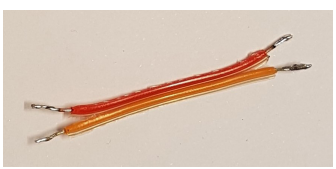
4. Soldering the controls and LEDs

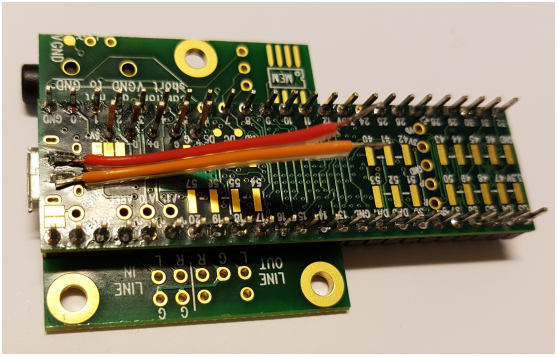
The controls are straight-forward to solder. These go on the **TOP SIDE** of the main PCB where the silkscreen shows what goes where. Start with the potentiometers. These might require a firm push as the metal tabs each side are sprung. Try not to bend these or the pins! Then the encoder and the tactile switches. After soldering these, place the caps on top of the switches and then solder the LEDs. These should be soldered with the tops level with the top of the switch caps. You could use a small length of a drinking straw to get the height right. The anode and cathode (short leg) are marked on the board as A and K. **NOTE** - If you find the front panel doesn't sit flat over the controls, the culprit will be an LED that is too high,



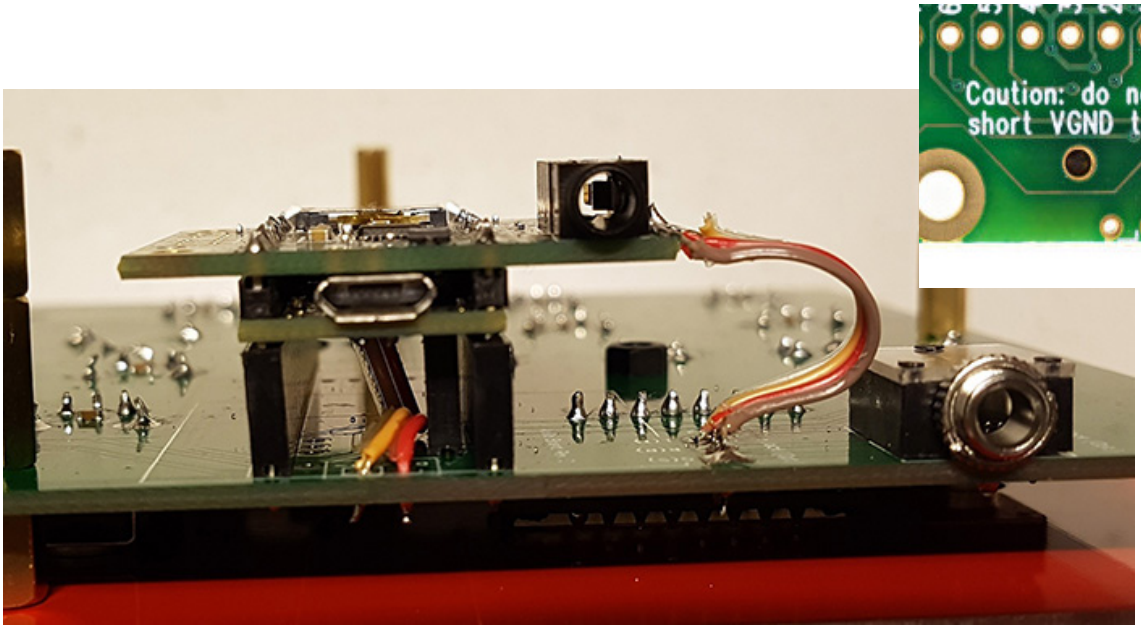
5. Attaching the Teensy

The Teensy can now be attached to the board. If you are using the optional type B USB client socket, you will need to solder two wires from the D+ and D- pads under the micro USB on the Teensy to the two through-hole pads marked *USB Client* directly underneath. Don't mix them up!





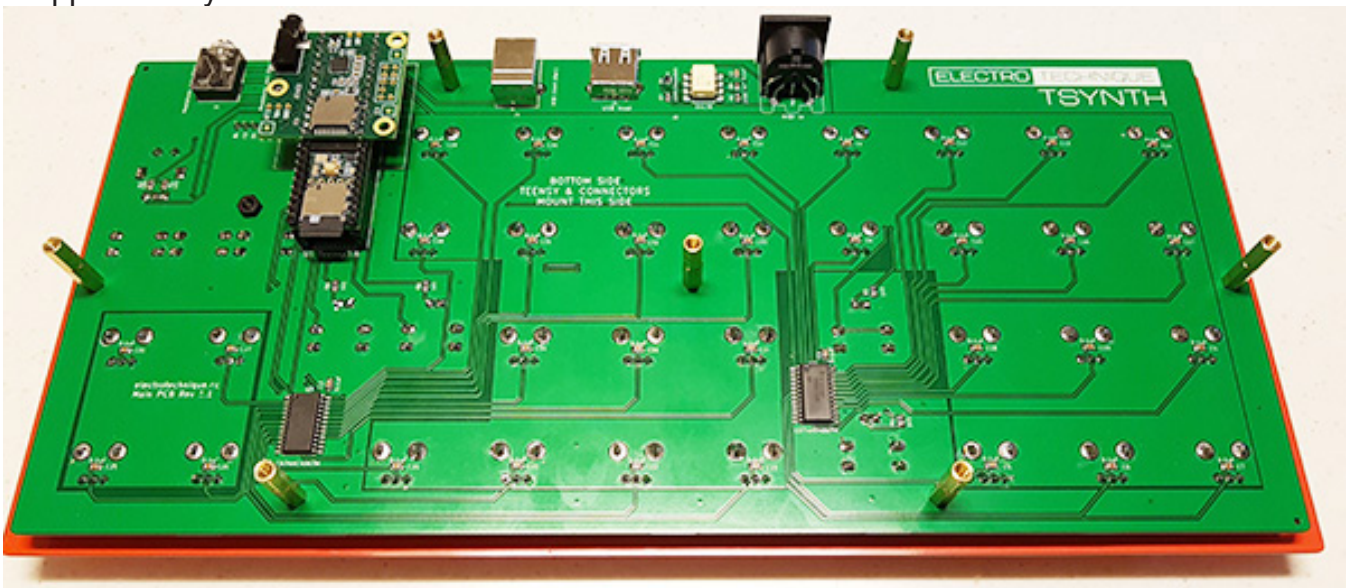
The Teensy can now be pushed onto the pin header sockets or permanently soldered on if you decided to do this. The optional USB client wires should be soldered onto the PCB pads directly underneath, first. If you have used the optional headphone socket on the PCB, you can now solder three wires from the Audio Board to the PCB. There are three pads on the Audio Board to solder to.



At this stage, you should have a fully working TSynth! If the firmware is flashed, you can plug in the USB client into a power supply or computer, headphones into the socket and if you have a MIDI controller, plug that into the USB Host. Be careful to avoid ground loops that will cause hum - plugging both USB and audio into a computer is one such cause. Put a FAT formatted SD card into the Teensy SD card slot (NOT the Audio Board SD slot!) Preset patches are available from the website and you can copy these onto your card first if you want some patches to test. The display should work and all the control should function.

6. Attaching the front panel

The front panel should easily attach to the PCB. Use seven 8mm standoffs (brass are best) to set the correct distance between the two panels. Use the M3 bolts on the front to secure it. 22mm (or 12mm + 10mm) standoffs are added to the bottom panel to secure the PCB and provide something to support the synth.

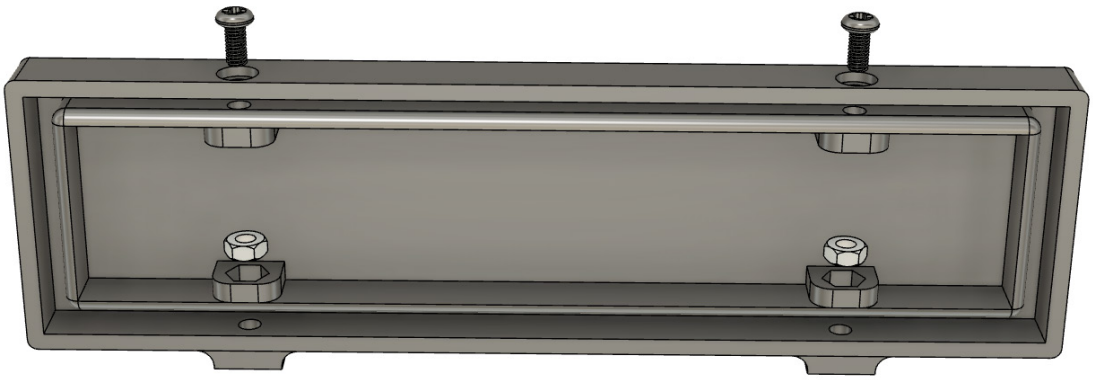


7. Making the enclosure

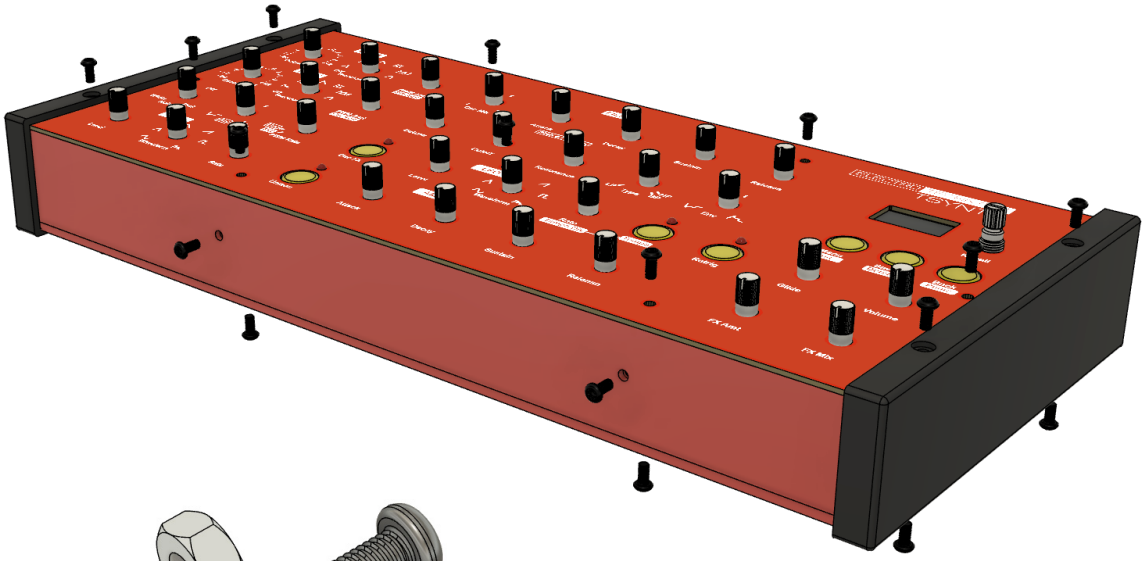
An enclosure finishes the build and this can be your own choice. There is sufficient clearance at the sides to drop the whole assembly into a wooden box with the front panel on top. There are files available on the website to build an enclosure using laser-cut 3mm acrylic and 3D printed side cheeks. You can send the files off and have these made elsewhere if you don't have a 3D printer and / or laser cutter.

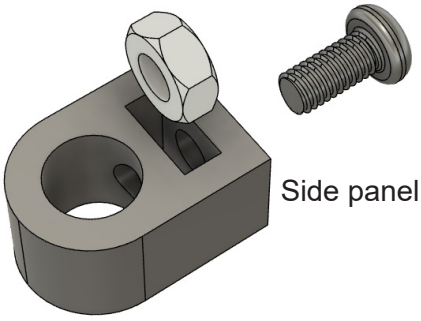
The acrylic is laser cut from a 3mm sheet that needs to be at least 330mm x 220mm. The 3D printed end cheeks need to be printed on a printer with a print bed at least 160mm wide. A mid-red colour will match with the front panel very well. When laser cutting or using a service, ensure you know what lines are cut and what are engraved (rastered), often red lines are cuts.

The sides are attached using four *Side Panel Columns* that the standoffs pass through. These need the M3 nuts to be pushed into the slots. The end cheeks have been designed with the slots for the PCB and 3mm acrylic to be larger to accommodate the shrinkage of the PLA when 3D printed. You may need to alter these and the Fusion 360 model is available on the website. The M3 nuts push into recesses on the inside for the M3 bolts to screw into.

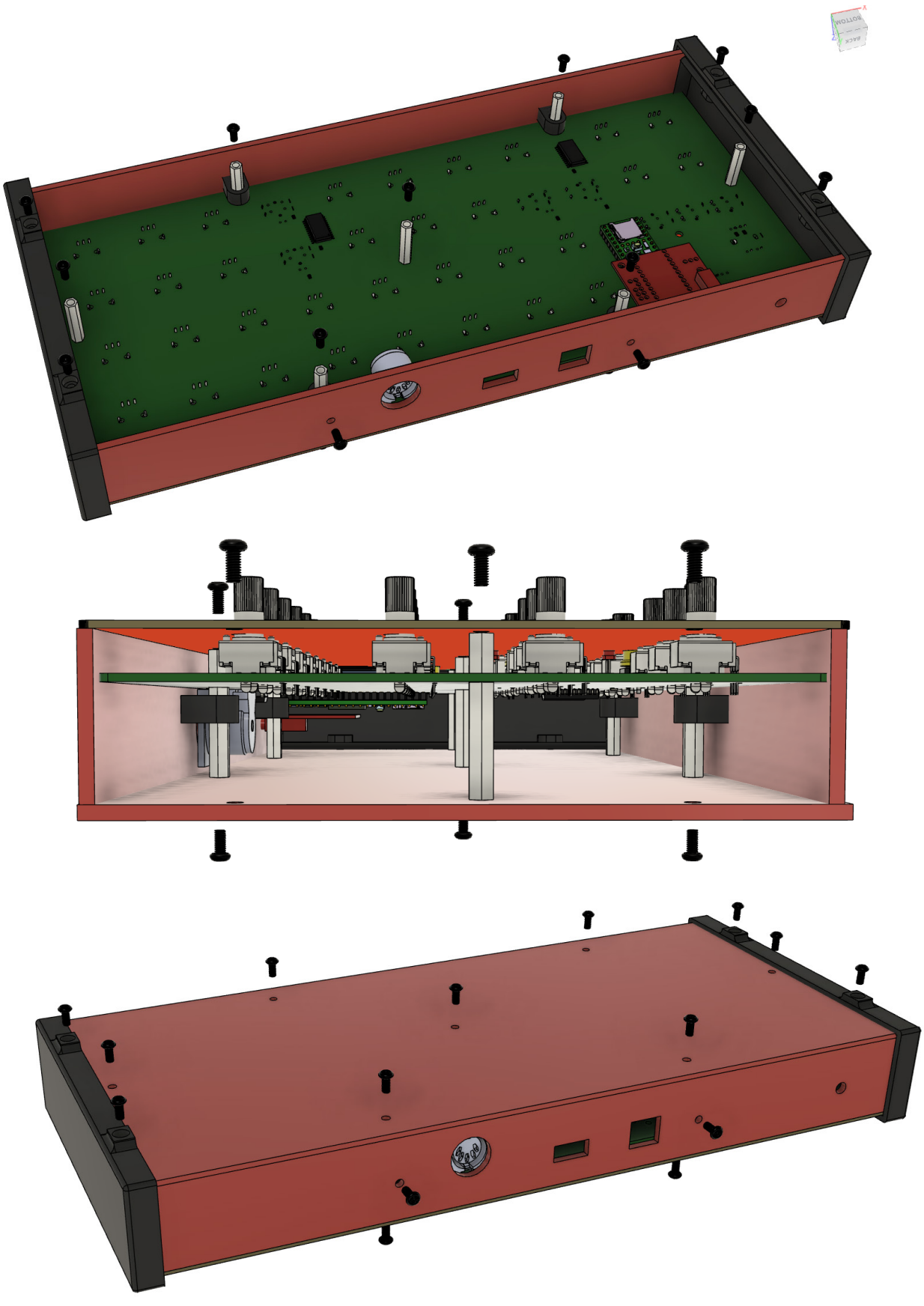


End cheek





Side panel column



Firmware

The firmware is a *hex* file that contains the entire code for the Teensy. The latest version is always available from the website, including the code to build it. The firmware is flashed onto the Teensy by plugging the USB client port into your computer and running the Teensy Loader program available from PJRC - www.pjrc.com/teensy/loader.html **Note** You usually need to press the button on a new Teensy the first time you flash code onto it - instructions are on the PJRC website.

Final Notes

Often, encoders produce pulses on their two outputs that differ from other encoders. This results in decrementing instead of incrementing when turning clockwise. This can be fixed by going into the **Settings** on TSynth and setting the **Encoder** direction to **Type 1** or **Type 2**.

If your display shows 'noisy' lines on the sides, you may need to change the code as the displays sometimes use slightly different screens. Contact info@electrotechnique.cc for assistance.

There is the possibilty of replacing the MIDI DIN socket with a 3.5mm MIDI TRS socket and attaching this to the side panel, making TSynth thinner. This modification is up to you and you'll need to alter the laser cut enclosure plans.

Important Note - the SD card socket on the Audio Board must not be used and the optional memory chip must not be fitted, as these share pins via the Teensy, on the main PCB with several panel controls.

Further work

So now you should have a fully functional TSynth and can explore the range of sounds it is capable of, from just one ARM Cortex M4F microcontroller! The code is open source and available for you to explore and modify. You will need the Arduino IDE and Teensyduino from PJRC to build and flash your code. The synth relies on the PJRC Audio Library with a few modifications, so anything related to sound will involve their code. Be aware that changes are often made to Teensyduino that may break some or all the code. If you decide to make additions to TSynth's functionality, please consider sharing them. The PJRC Audio Library in particular is in need of some expertise in improving the waveforms to band-limit them and some better quality effects. There are a few spare ADC and GPIO pins on the Teensy which could be used for further hardware modification, such as gate and cv input - see the schematic on the website.