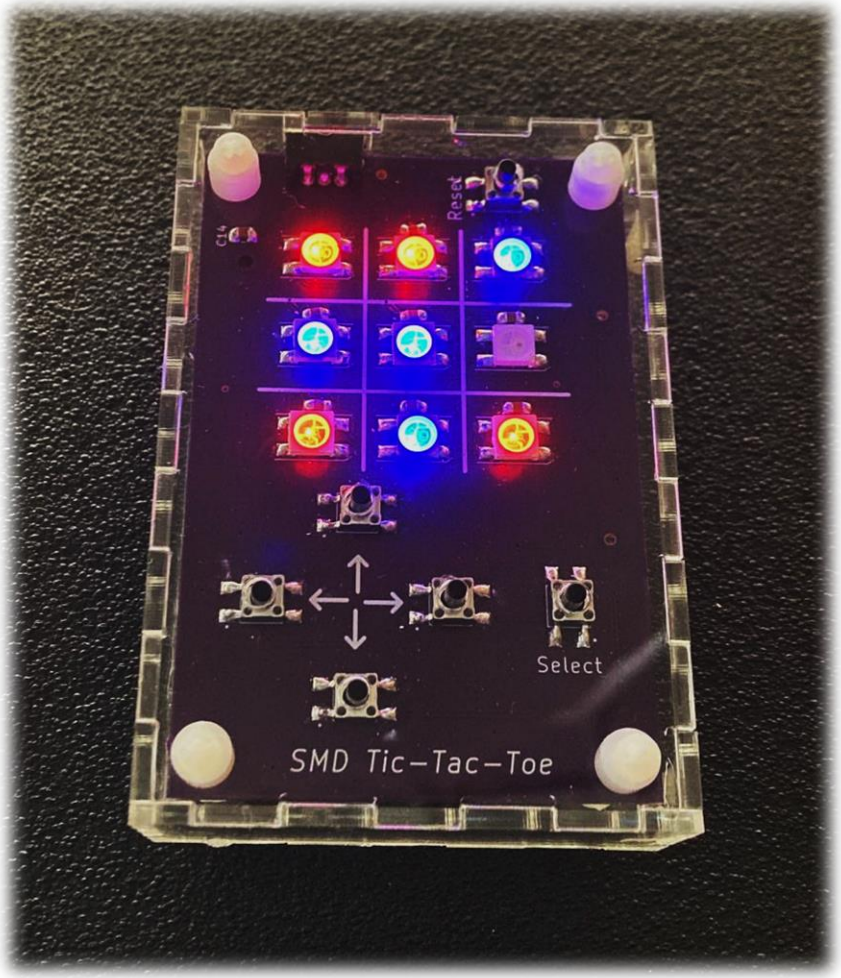
SMD TIC-TAC-TOE SOLDERING KIT



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Do you want to ***learn to solder SMD*** *components by making a* ***fun LED tic-tac-toe*** *that you can show to your friends?!?*
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BPC

Artisans ASYLUM

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M. Beach
Artisan's Asylum
Allston MA
July 2024

SMD TTT

The SMD Tic-Tac-Toe is a kit to learn to solder SMD components. It consists of a Tic-Tac-Toe game displayed on a 3x3 LED matrix, and commanded by 5 pushbuttons (4 directions + select).

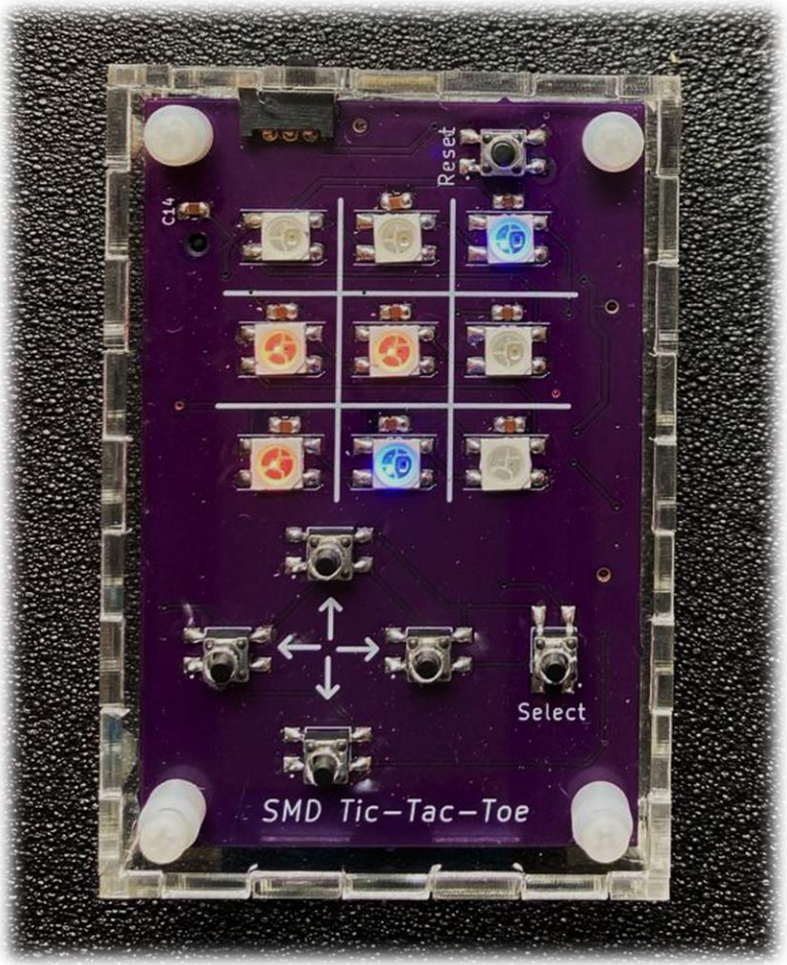
The kit includes different footprints with different soldering difficulty. Most of the components have 0805 packages, and the hardest packages are a SOIC-8 and a SOT-23-5.

The tic-tac-toe includes a transparent acrylic laser-cut enclosure, that can be mount with mounting holes for #4.

Overall, the soldering difficulty of this kit is easy, and it is a good introduction to SMD soldering. This kit is recommended for a didactical use.

The kit includes a clear acrylic enclosure, the components and the PCB

Pictures


Reset
C14
Select
SMD Tic–Tac–Toe


SW2
R8
TP3
D1
F1
R6
C1
U2
C3
JP3
TP5
J2
C2
U1
TP4
JP2
R4
R3
R5
R7
R2
SMD Tic–Tac–Toe
May 2024
F. Vischi (Bored Parrot Co.)
M. Beach (Artisans' Asylum)

Pictures


SMD Tic-Tac-Toe
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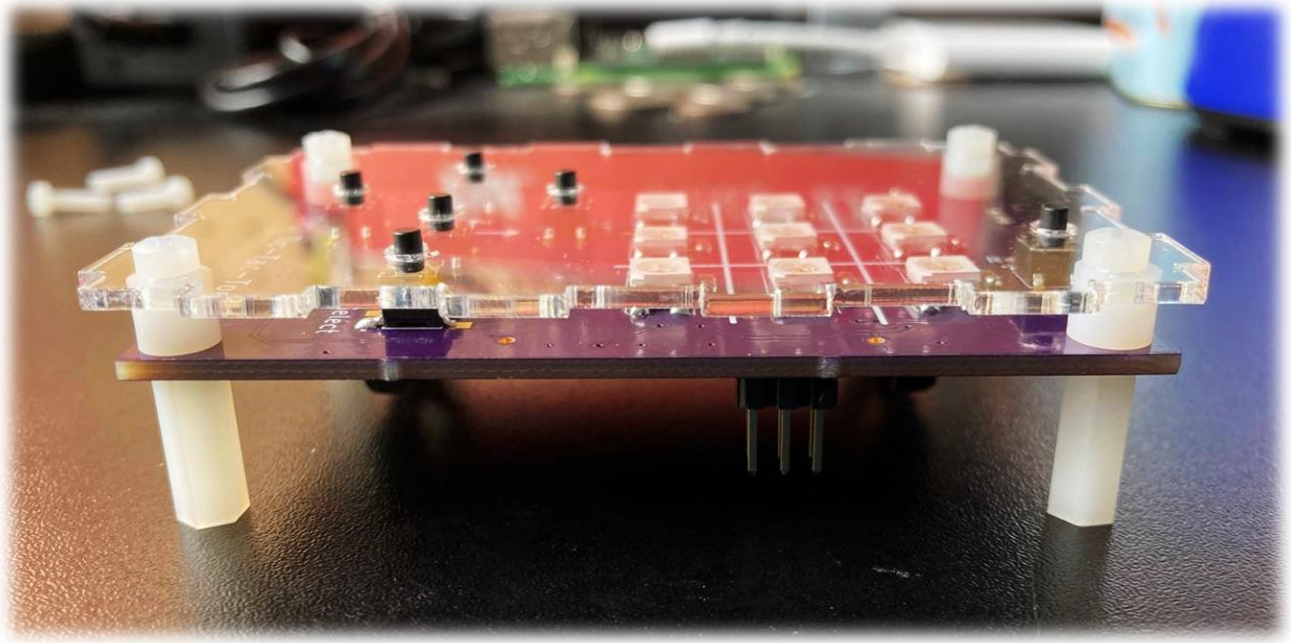


What you need (not included)

- Soldering station / iron
- Wire solder, for example Harimatec Inc. , PN 7333001
- Solder wick, for example Chemtronics , PN 80-2-5
- Fine tweezers

How it works

The SMD TTT is based on a ATTiny85 microcontroller, fused with internal oscillator.

The ATTiny85 drives the 3x3 matrix of daisy-chained addressable LEDs. The LEDs are driven with the *FastLED* library (Garcia and Kriegsman).

The command pushbuttons are connected into a resistor ladder, so that the 5 buttons are connected to a single analog output, where the voltage depends on which button is pushed. This voltage is read by the ATTiny ADC input pin.

The kit includes a 6 pin header for SPI reprogramming of the microcontroller.

Assembly instructions

General suggestions for a good soldering

- Clean the solder tip from non-metallic impurities, by brushing the hot tip against a soldering sponge / tip cleaner. NEVER USE SAND PAPER! It will ruin your tip.
- Wet the tip before soldering, by applying a small amount of solder on the iron tip. A ‘dry’ tip doesn’t conduct heat well
- Set the right temperature. In general should be in the range 600F to 750F, but the right temperature depends on many factors.
- A low temperature can make false contacts or contacts prone to cracking. It also makes soldering slow, requiring more time of iron application, which can damage the component
- A high temperature can damage the component, evaporate faster the flux, or burn it.
- Perform the soldering in a short time. Indeed, while soldering, the flux evaporates making the characteristic smoke. If most of the flux is evaporated, the melt solder is more viscous and doesn’t ‘flow’ well to wet metallic contacts

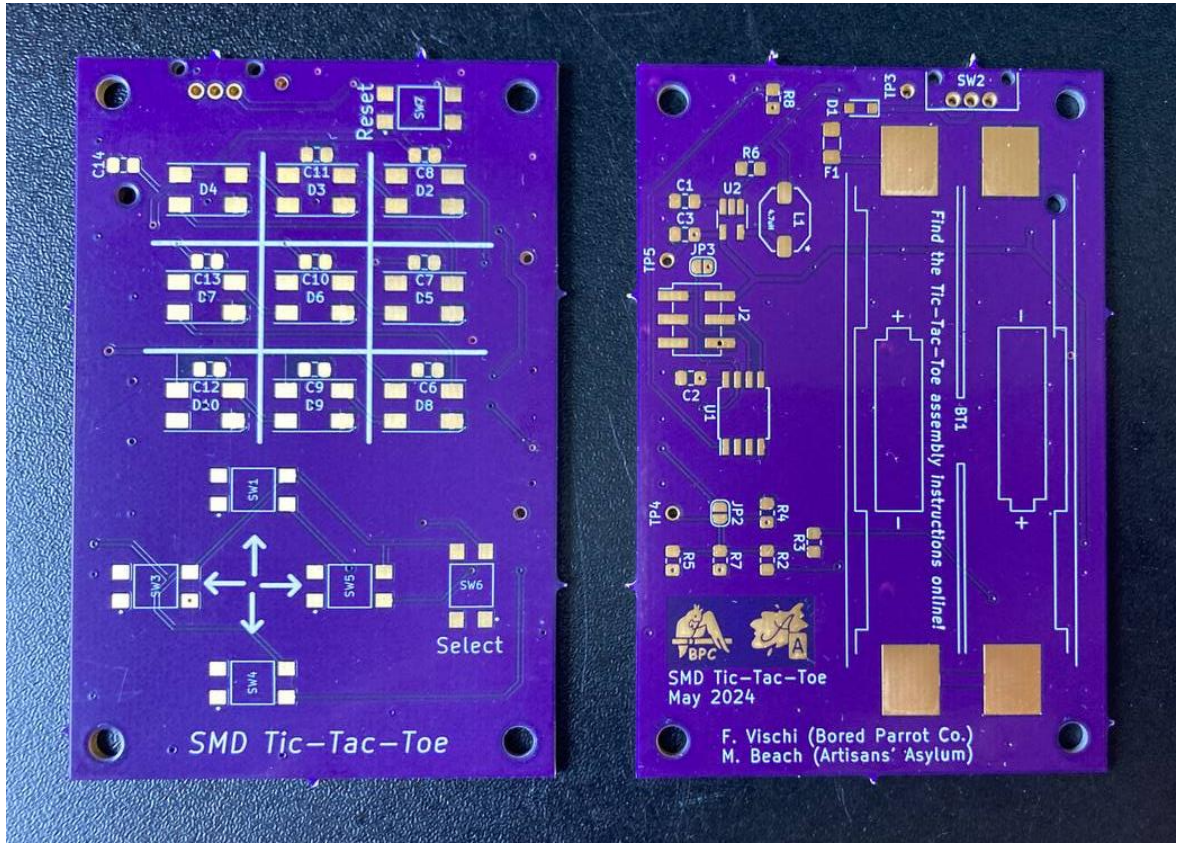
Suggested soldering order

	Ref	Component
1	BT1	Battery holder 2x AAA
2	J2	Pin header 2x3
3:7	R2:5, R7	Resistors 0805
8:16	C6:14	Capacitors 0805
17	D1	Diode SOD-323
18	F1	Polymer fuse 1206
19	R8	Resistor 0805
20:28	D2:10	Addressable LEDs

	Ref	Component
29:34	Sw1, Sw3:7	Momentary switches
35	U1	IC ATTiny85 SOIC-8
36	C2	Capacitor 0805
37	U2	IC SOT-23-5
38	L1	Inductor
39:40	C1, C3	Capacitors 0805
41	R6	Resistor 0805
42	Sw2	THT slide switch

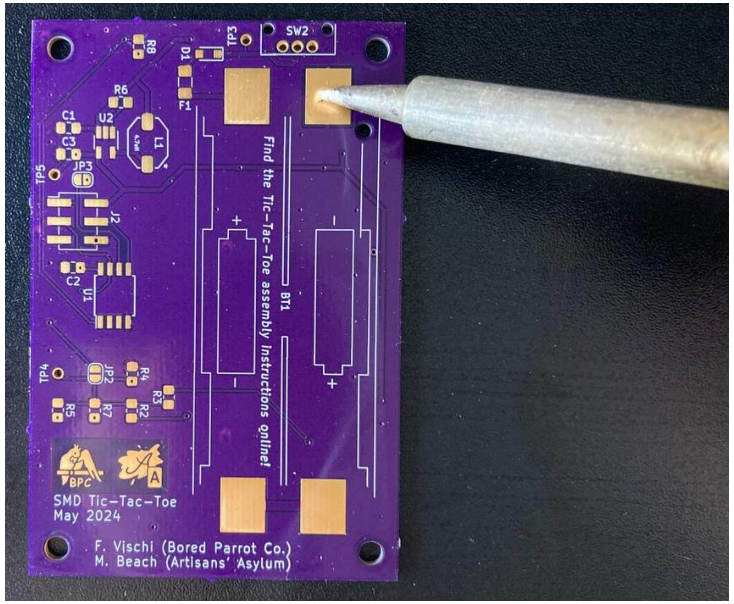
Start: the PCB

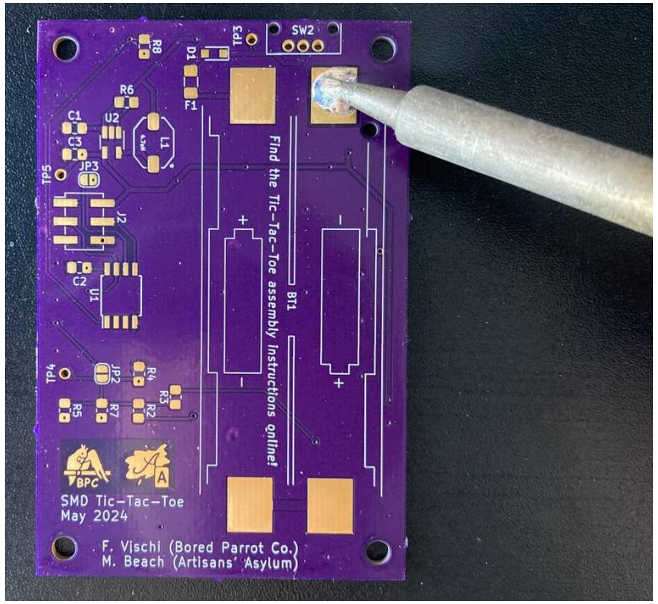
- The PCB before assembly looks like the ones in the figures
- The left figure shows the front side, hosting the LED matrix
- The right figure shows the back side, hosting the voltage booster and microcontroller unit

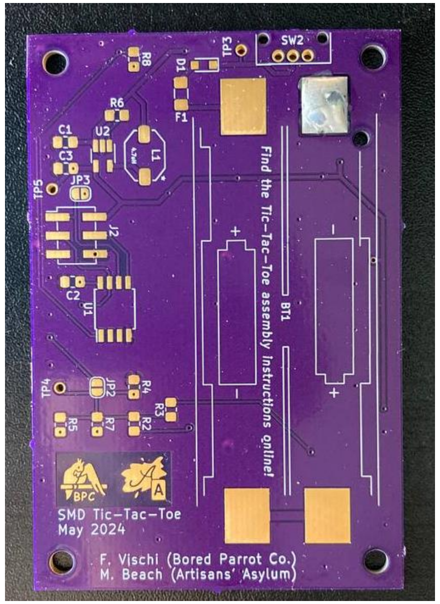


Battery holder

- We get started by soldering the biggest SMD component of our board: the battery holder
- For this component and the others, we generally start by wetting the pad connected to the ground plane (see figure). Indeed, the ground plane pad is the hardest to wet, since the ground plane keeps it cool by thermal dispersion. This implies that it may require a bit more time and heat for a successful wetting, and we want to do this first, without the component, which may be damaged by excessive heat
- The pictures below show, in order from left to right, the ground plane pad procedure

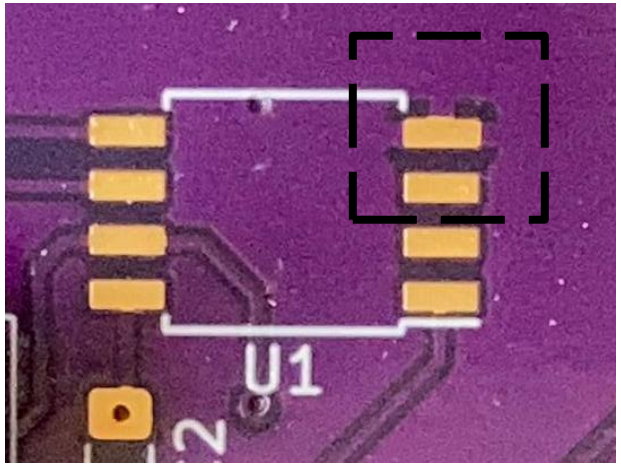


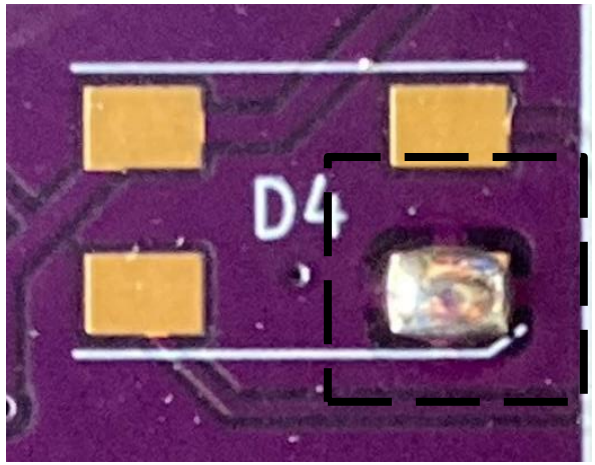


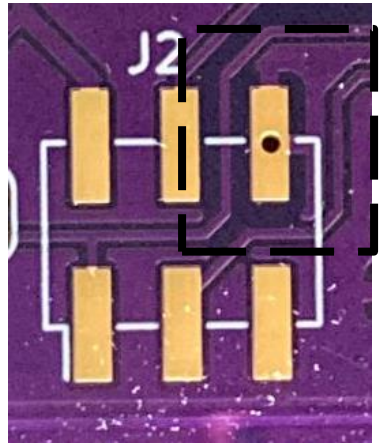


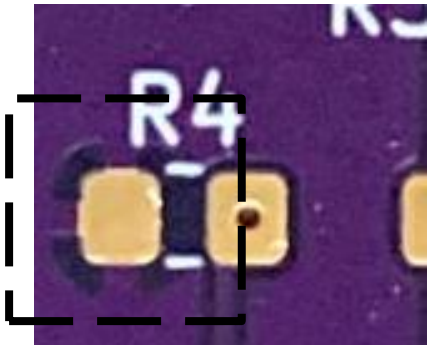
Find the ground plane pad

- On this specific board, ground plane pads can be recognized by the presence of a ‘purple cross’ surrounding the pad.
- This ‘purple cross’ is a cross of copper covered by solder mask. The lighter purple is solder mask on copper, while the dark purple is solder mask on the FR4 substrate.
- This cross is called *thermal relief*, and it’s designed on purpose to avoid thermal dispersion and to ease soldering.
- Attention: the thermal relief may be not present on other PCB layouts



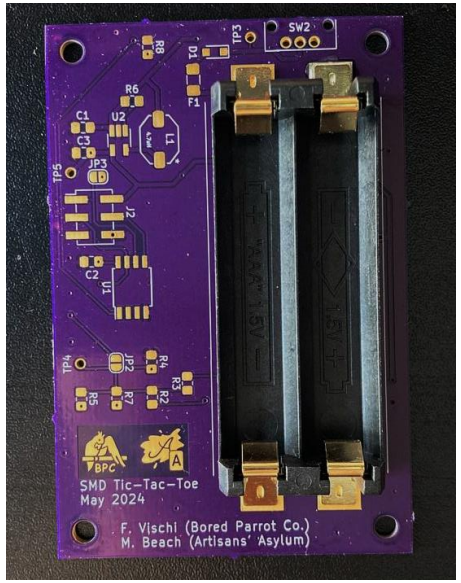


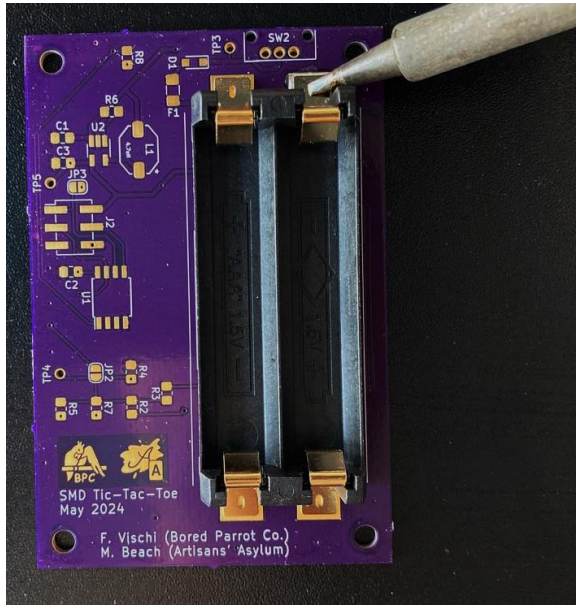


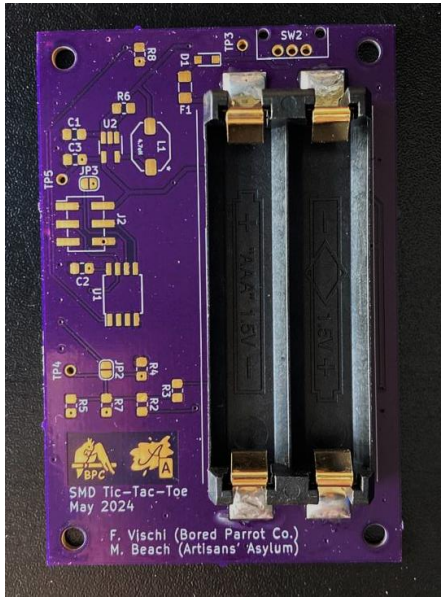


Battery holder

- Now position the battery holder. Take care of the battery holder keying pin on its back: it must fit into the PCB hole next to C14
- With the soldering iron, apply heat to the holder pad on the PCB wetted pad, and add more wire solder, to form a solid electrical contact. A small pressure over the holder body will help the pad to sink into the melt tin
- The final result should look smooth, without cracks, and covering about the whole PCB pad
- Complete the soldering over the other three pads

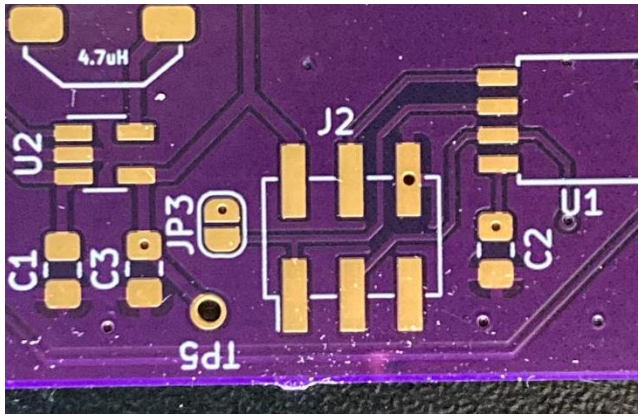


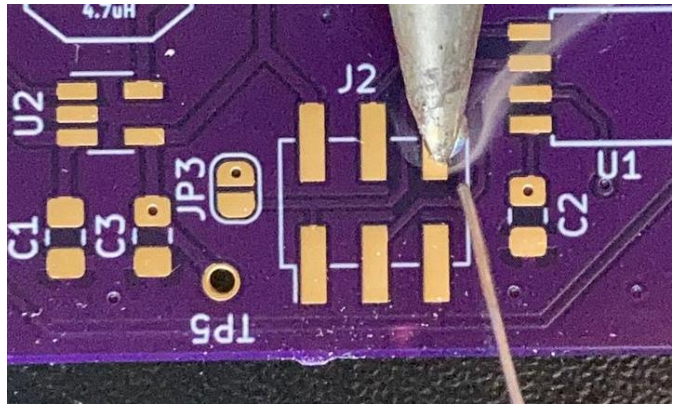


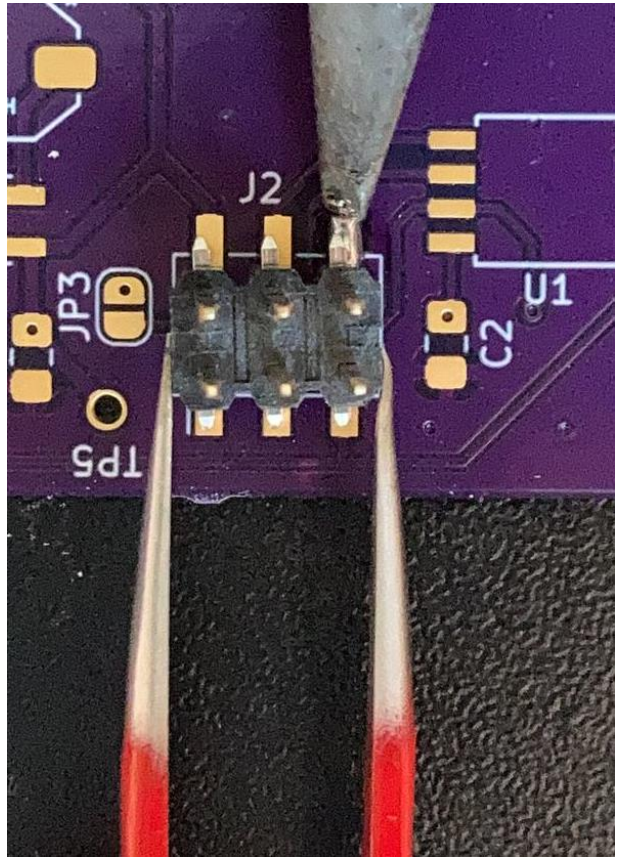


Pin header J2

- Wet the ground plane pad first.
- Position the header next to its footprint, holding it with tweezers.
- Apply heat again to the wetted pad. While the solder is melt, push the header lead into the solder, caring of aligning the other leads to the other pads. Check that the melt solder is sticking to the lead surface. Remove the iron, without moving the component until the melt is solid.

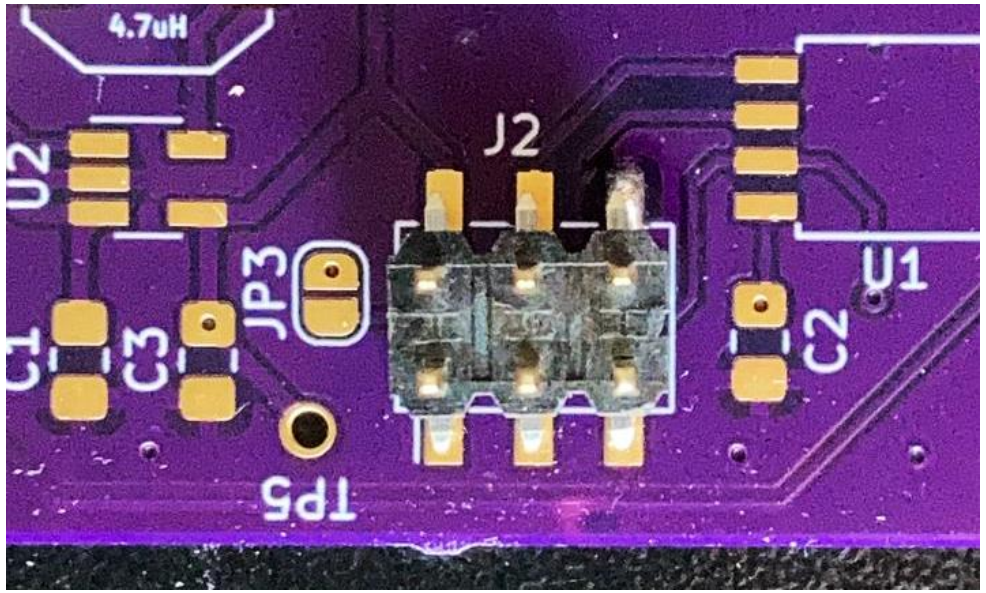


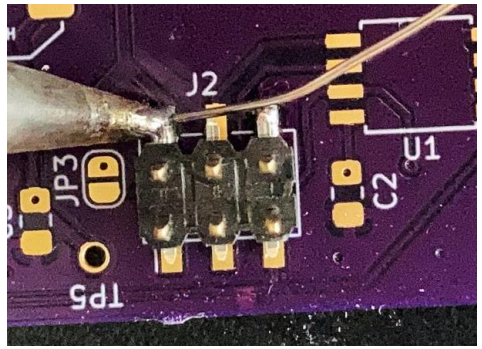


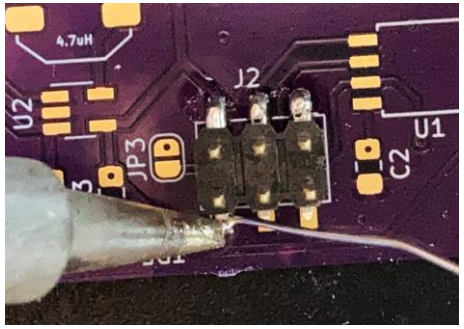


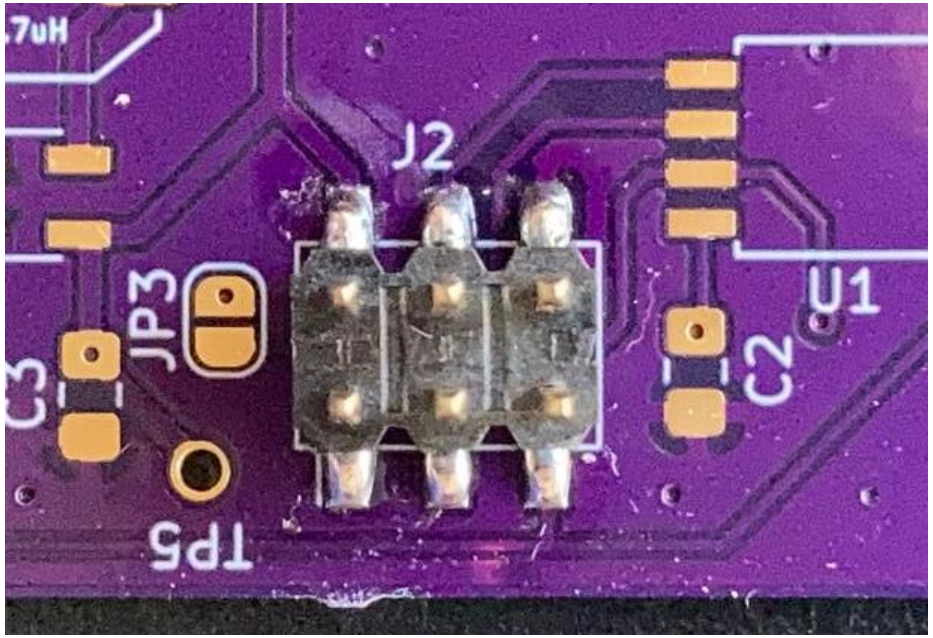
Pin header J2

- If the component is not aligned, repeat the procedure above until a good alignment
- Solder the other pads
- It can happen that some pads don't look well done. Just 'rework' them, applying a bit more of tin
- In case pads are shorted, you can use the solder wick. See the integrated circuits soldering below



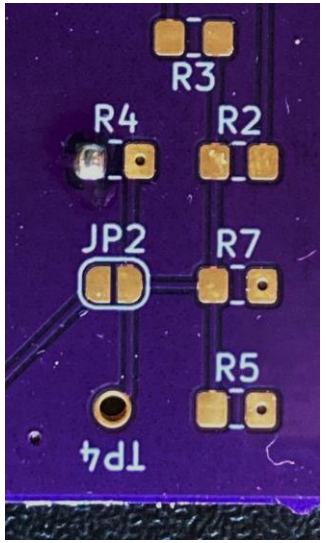


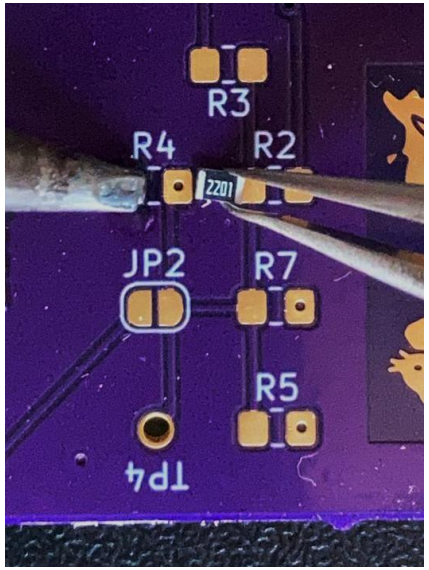


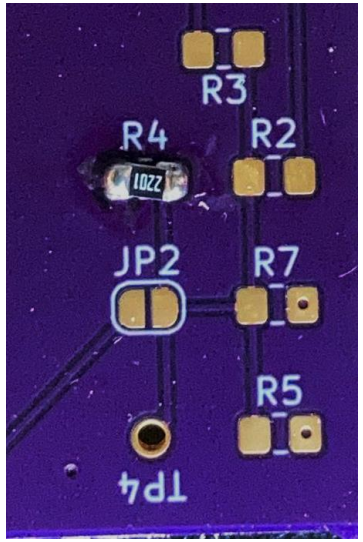


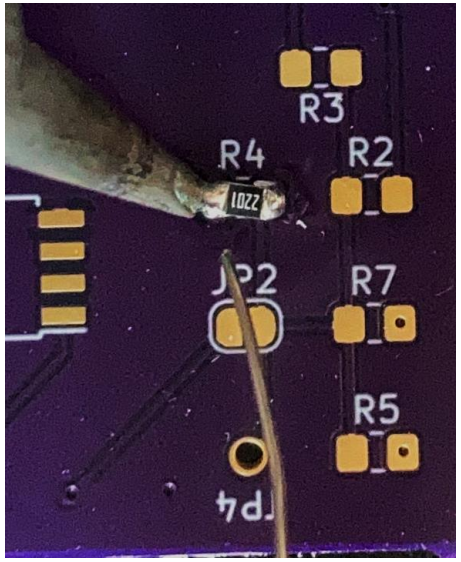
Resistor ladder R2:R5, R7

- Let’s go down in component size. Let’s start with R4, a 2.2kR resistor, 0805 package.
- First wet the ground plane pad
- Then, melt the wetted pad, and push the resistor, so that one pad is into the melt solder. Remove the iron without moving the component, and wait that the melt is solid.
- Now apply solder to the other pad, to make resistor-PCB electrical contact.
- Rework the first ground plane pad, if needed



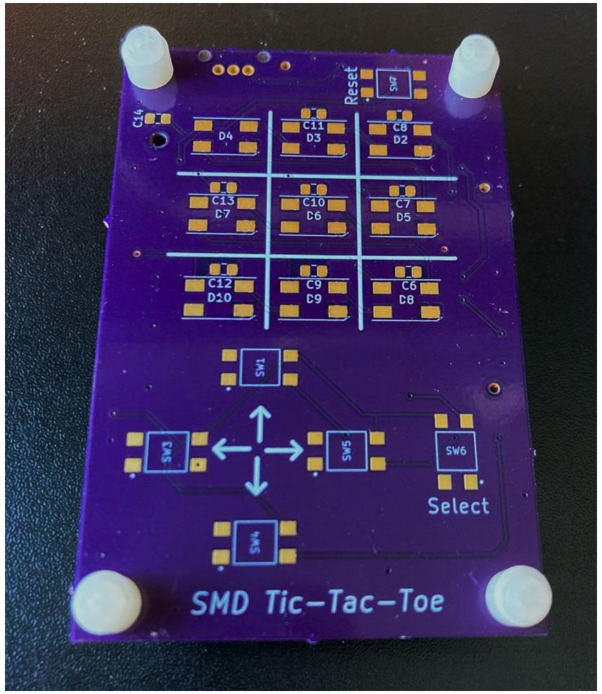


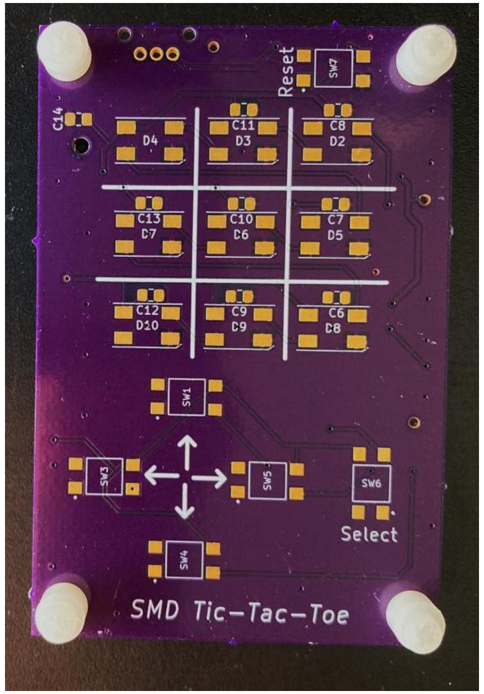


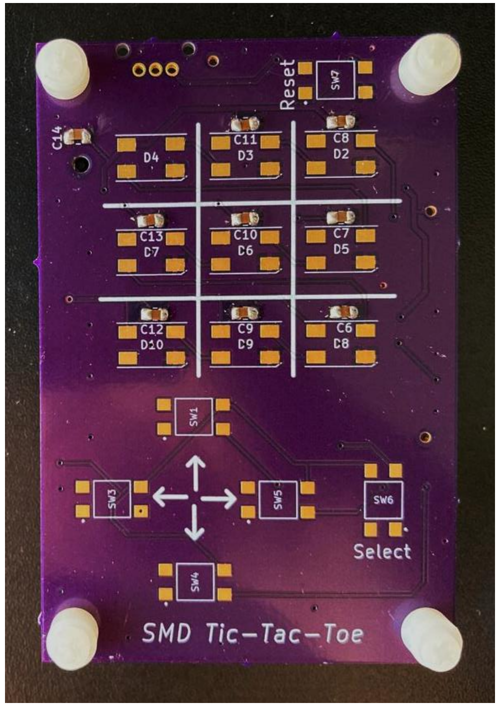


Front PCB capacitors

- To get some practice, let’s solder now the 100nF capacitors, package 0805, on the PCB front
- For mechanical stability, place the ½’’ screws + 4mm spacer + standoff, as in the figures
- Solder the capacitors to the PCB front. As usual, it’s convenient to wet the ground plane pad first

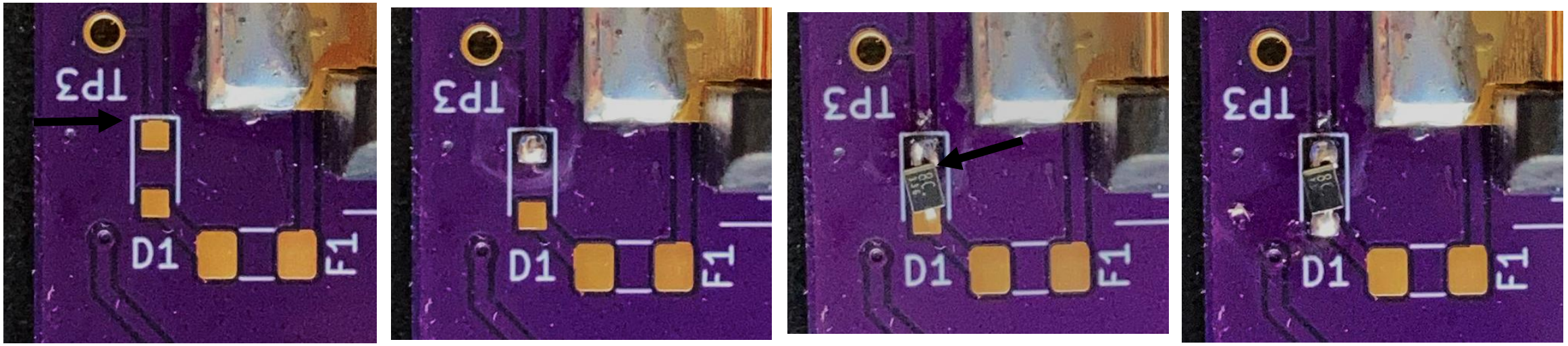






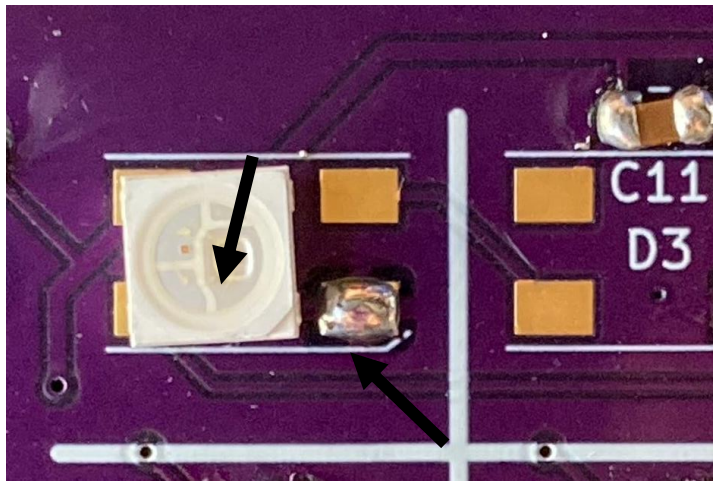
Diode D1, fuse F1, resistor R8

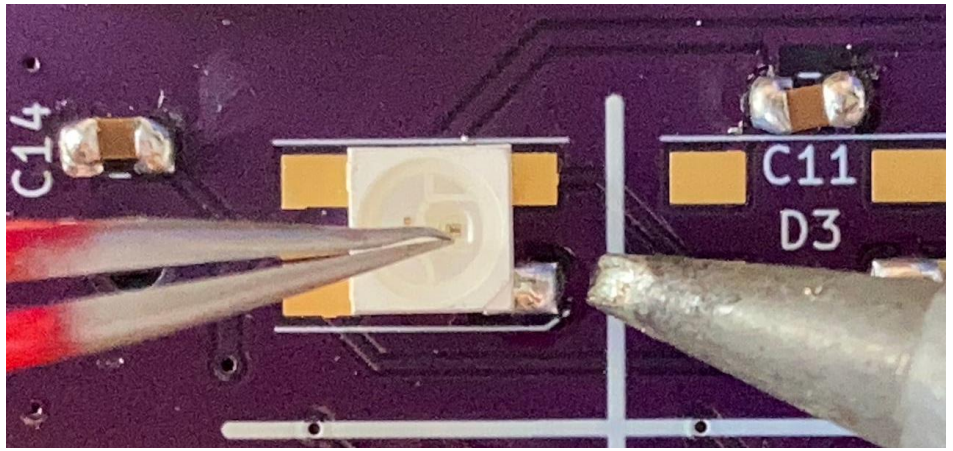
- Let's further go down in component size, for a diode with SOD-323 package
- ATTENTION: a diode is a component with polarity: it's necessary that the component is in the right position / rotation, so that the cathode lead is soldered to the cathode pad, and the anode lead is soldered to the anode pad.
- In most of the diodes, the cathode is marked by a band on the component (see picture).
- On the TTT PCB, the cathode is marked by a three-sided rectangle on the silkscreen (see picture)
- Follow the same procedure: wet one pad, then push one of the component lead into the melt to fix it, solder the other lead(s), and rework the first lead if needed. Solder also F1 and R8

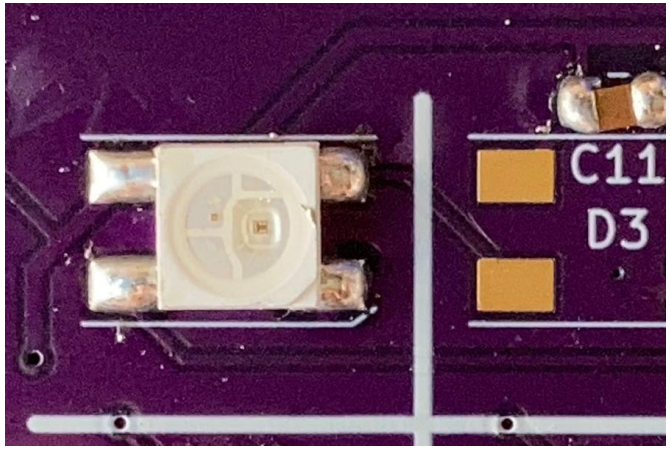


LED matrix D2:D10

- Let's move to the LED matrix, made of nine addressable LEDs.
- ATTENTION to the component direction / rotation. Place the LED notch in correspondence of the PCB silkscreen diagonal marker, see arrows in figure
- ATTENTION: LEDs and optical components are delicate against heat. When soldering, try to limit the time of soldering. We suggest a temperature of 700F (370C). To limit the time of soldering, it is important to wet the ground plane pad first
- If the component is crooked, fix it by applying a small pressure with the tweezers, and melting the pad again.
- This component has J leads, with less overlap on the pads. Make sure the contact happens. It can help to push the solder against the lead, by brushing kindly with the iron

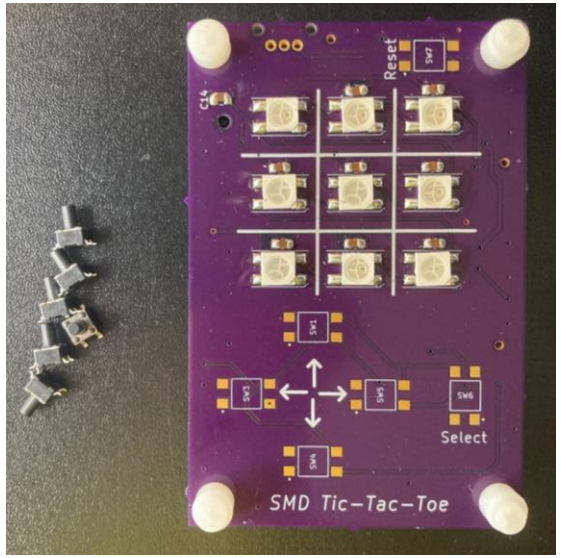


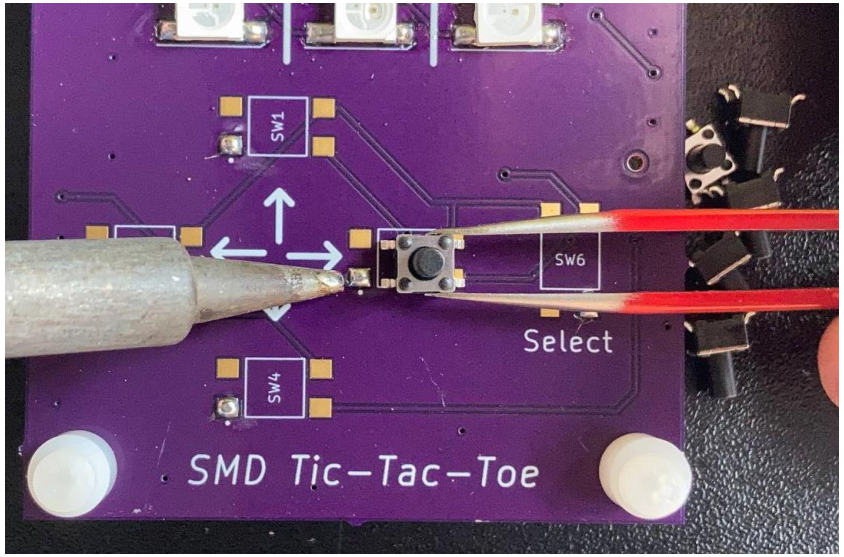




Momentary switches SW1:6

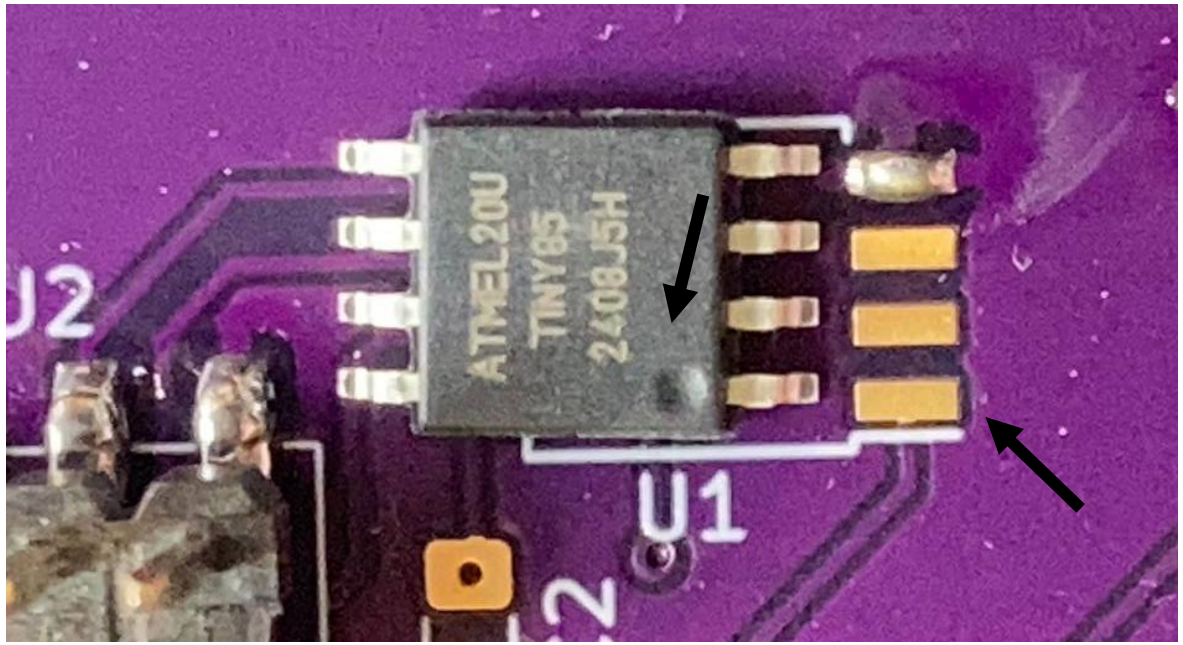
- When soldering these components, it is important that the switches are well aligned to the footprint, to be aligned with the plexiglass enclosure opening.
- Wet one pad for all the switches footprints (for example, the one with a silkscreen marker)
- Place all the switches, without soldering the other pads
- Check they are well-aligned, by placing the front plexiglass panel, pushing them and feeling them clicking (see figure)
- If alignment is poor, correct it. If it is good, complete the soldering of all the pads





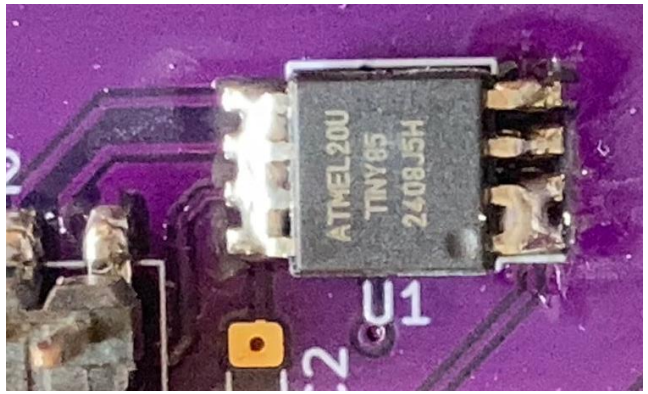
Microcontroller U1

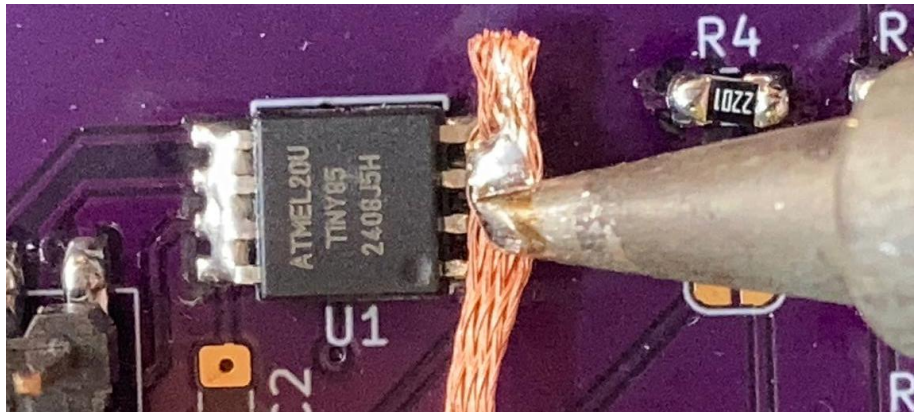
- Let’s solder the first Integrated Circuit (IC) of our board, an ATTiny85, with SOIC-8 package
- ATTENTION to the position / direction of the IC. Make sure the IC marker corresponds to the silkscreen marker (see arrows in figure)
- Solder the first pad. We suggest starting by the usual ground plane pad.

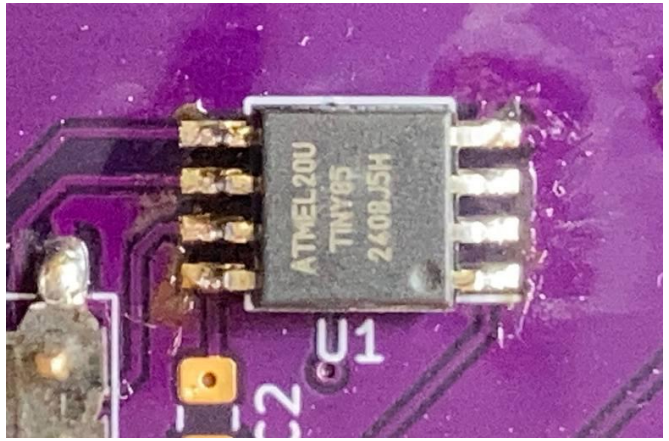


Microcontroller U1, capacitor C2

- There are two ways to solder the SOIC-8. One is to solder lead by lead, like the other components. If solder bridges happen, you can use the solder wick.
- Another, quicker way is to pour enough solder to make a solder blob over the pins, without caring for the bridges. Then, these can be removed using the solder wick.
- NOTE: when using the solder wick, the iron should be at a higher temperature, since the wick itself disperses the iron heat.
- Solder C2

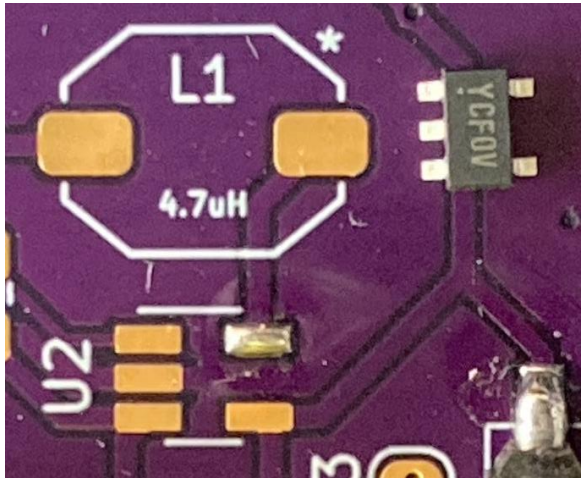


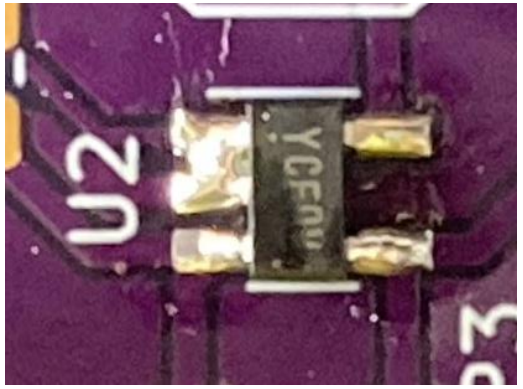


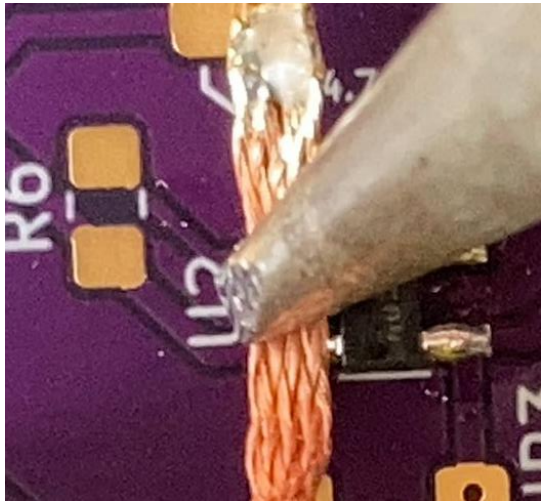


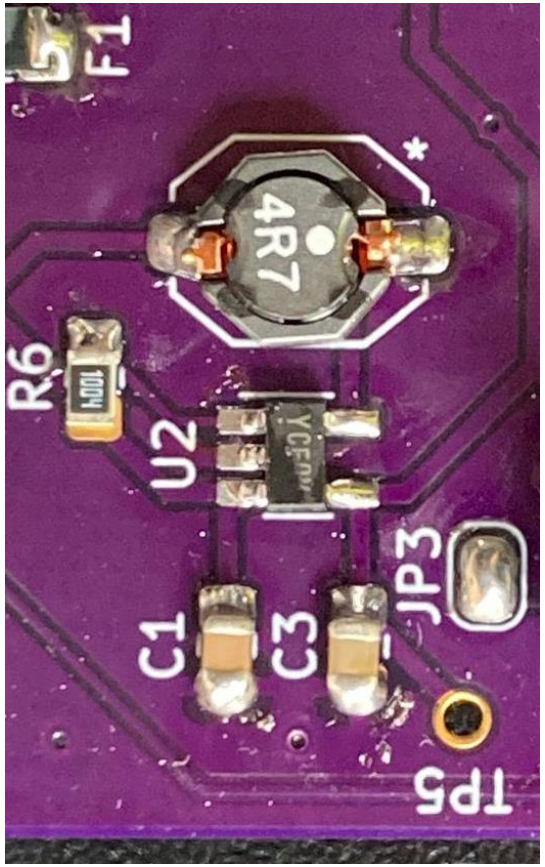
Voltage regulator U2

- The voltage regulator XC9142B33CMR comes in a SOT-753 package
- It can be convenient here to use the ‘solder blob’ technique: apply a solder blob over the leads and the pads, and remover the bridges with the solder wick.
- Solder also C1, C3, R6, L1



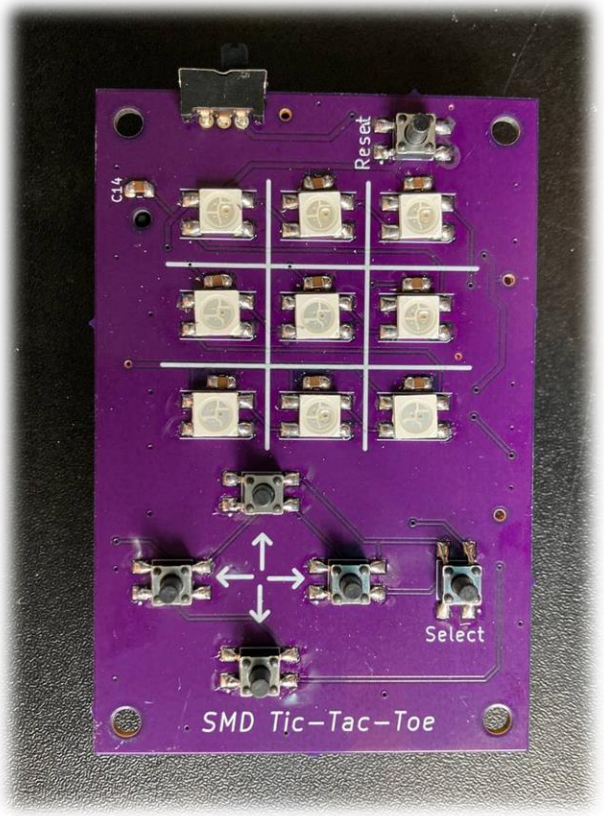


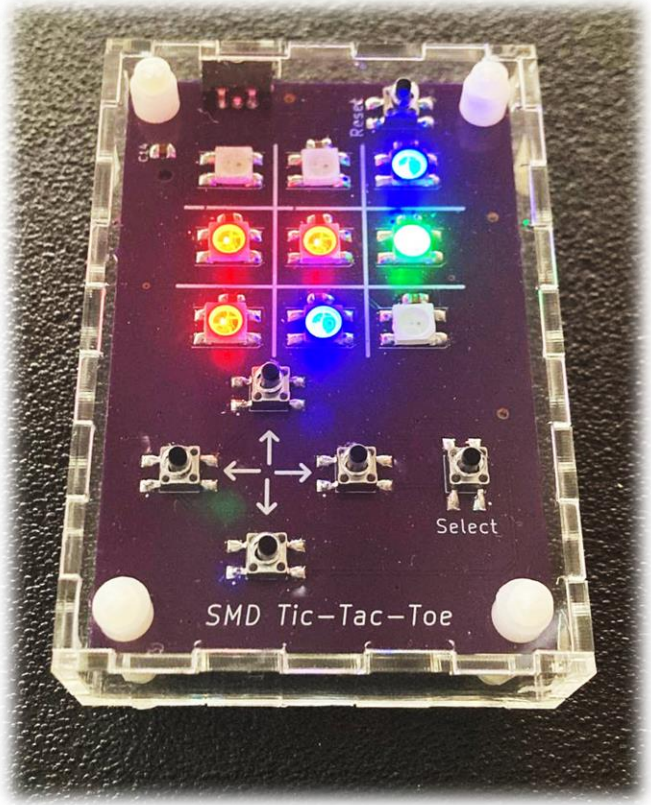




Final steps

- Bridge jumpers JP2 and JP3
- Solder the through hole component SW2
- GOOD JOB! All the components are placed!
- Insert two AAA in the battery holder and test it. If it works… ***CONGRATULATIONS!*** You can place it in the acrylic holder, using the spacer and the standoffs



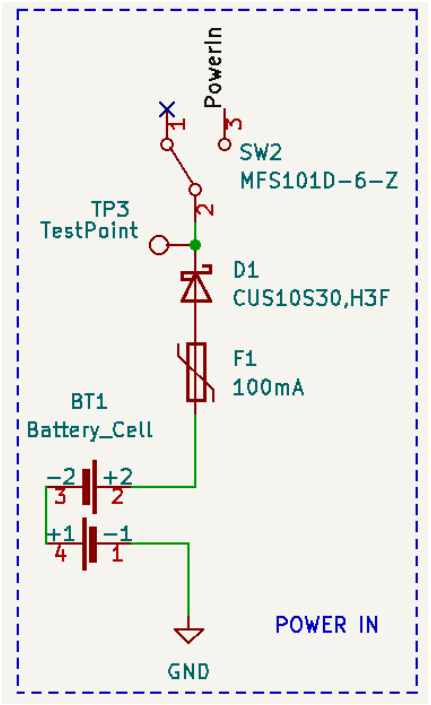


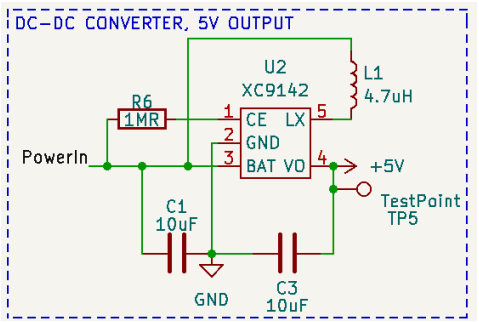
What if it doesn’t work?

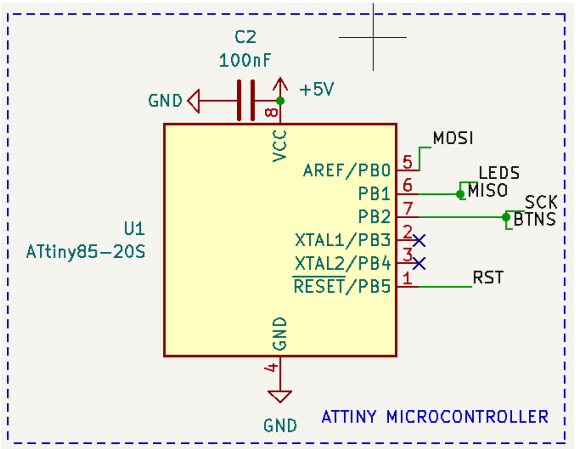
- First of all, visually inspect all the components and look for solder bridges, especially on U1 or U2.
- Also look for components place with the wrong rotation. Check that the components notches/markers correspond to the silkscreen notches/markers
- The PCB has jumpers and testpoints for debugging. JP2 can disconnect the pushbutton resistor ladder. JP3 can disconnect the LED matrix
- Voltages to ground are expected to be: ~3V on TP3, 5V on TP5.
- Voltage on TP4 depends on the pushbutton status. When no push-button is pressed, it is expected to be 0.
- 5V can be supplied through the J2 header. If the TTT works only when power is supplied through J2, then the *power in* and *DC-DC converter* stages are likely the issue.

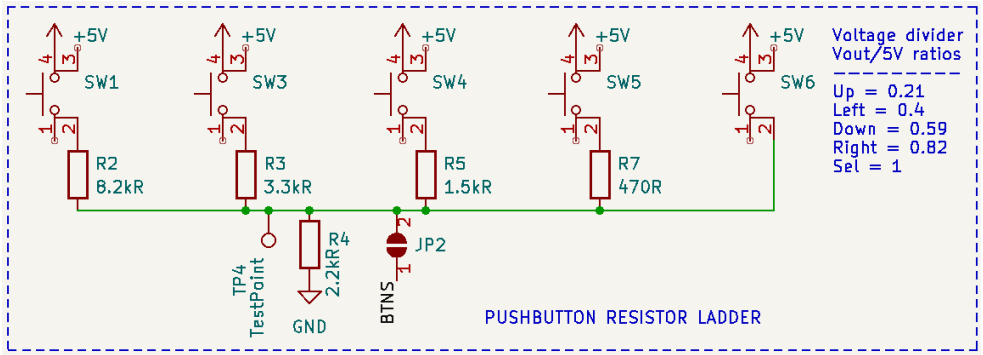
SMD TTT circuit design

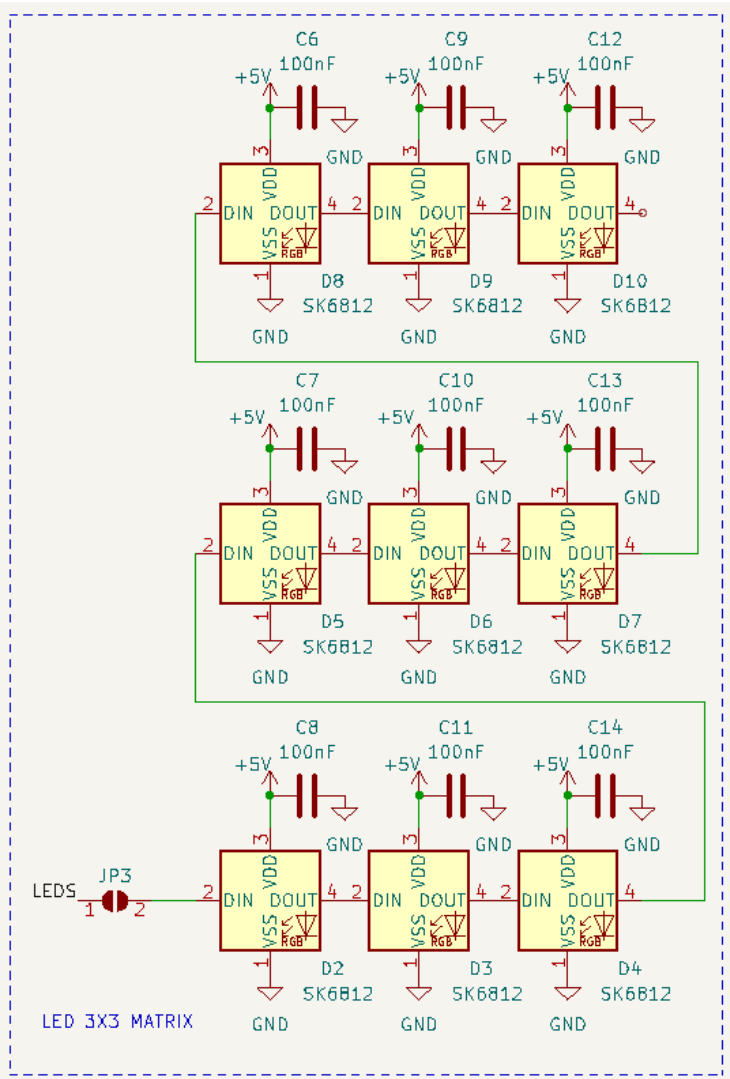
Schematic

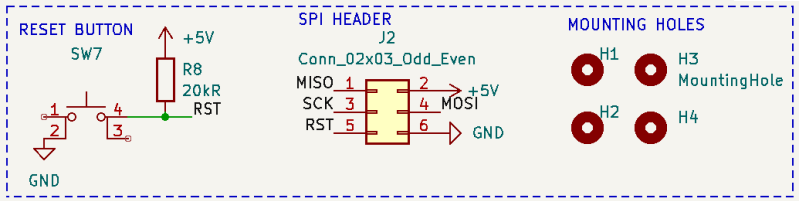

PowerIn
SW2
MFS101D-6-Z
TP3
TestPoint
D1
CUS10S30,H3F
F1
100mA
BT1
Battery_Cell
POWER IN
GND


DC-DC CONVERTER, 5V OUTPUT
U2
XC9142
L1
4.7uH
R6
1MR
CE
LX
GND
BAT
VD
PowerIn
+5V
TestPoint
TP5
C1
10uF
C3
10uF
GND


C2
100nF
GND
+5V
VCC
U1
ATtiny85-20S
AREF/PB0
PB1
PB2
XTAL1/PB3
XTAL2/PB4
RESET/PB5
MOSI
LEDS
MISO
SCK
BTNS
RST
GND
ATTINY MICROCONTROLLER

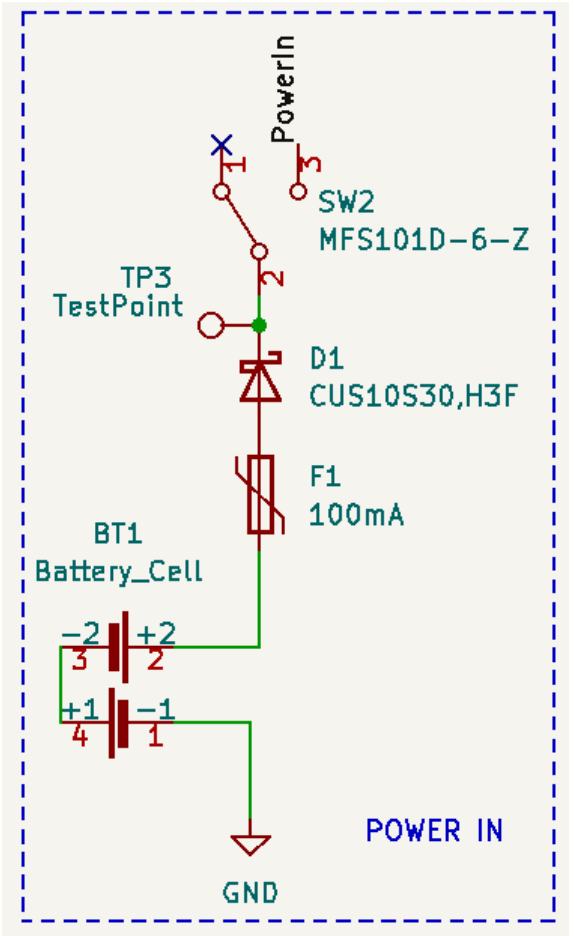

SW1
SW3
SW4
SW5
SW6
+5V
R2
8.2kR
R3
3.3kR
R5
1.5kR
R7
470R
R4
2.2kR
JP2
TP4
TestPoint
BTNS
GND
Voltage divider
Vout/5V ratios
Up = 0.21
Left = 0.4
Down = 0.59
Right = 0.82
Sel = 1
PUSHBUTTON RESISTOR LADDER


C6
C9
C12
C7
C10
C13
C8
C11
C14
100nF
+5V
GND
DIN
DOUT
VDD
VSS
D8
D9
D10
D5
D6
D7
D2
D3
D4
SK6812
LEDS
JP3
LED 3X3 MATRIX


RESET BUTTON
SW7
R8
20kR
RST
+5V
GND
SPI HEADER
J2
Conn_02x03_Odd_Even
MISO
SCK
RST
MOSI
MOUNTING HOLES
H1
H2
H3
H4
MountingHole

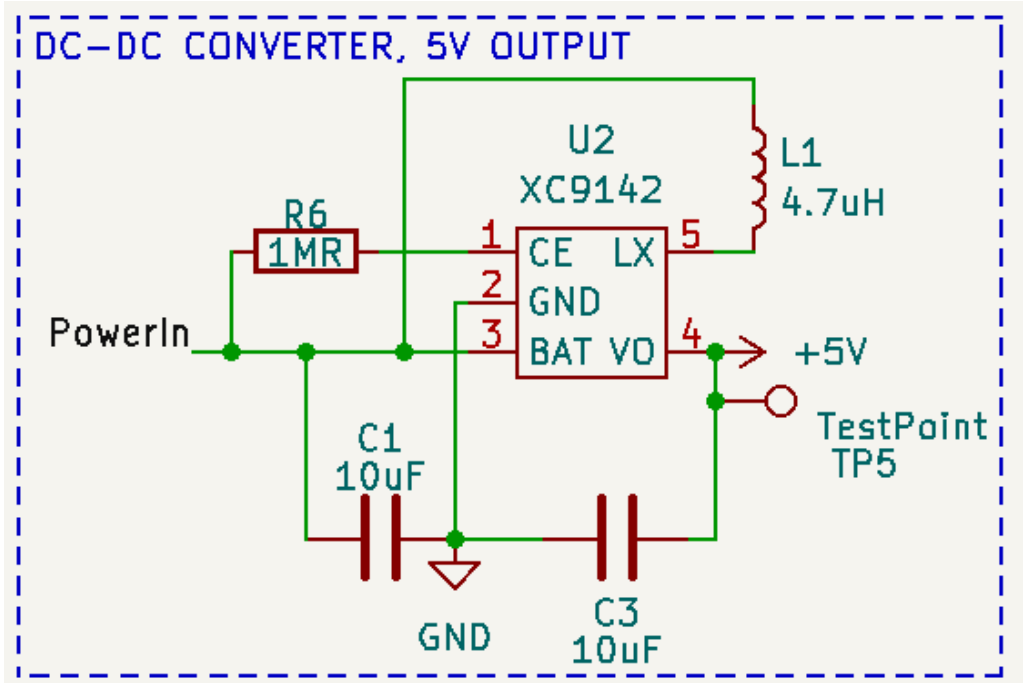
Power in

- Two AAA batteries are in series in a holder, yielding maximum 3V
- The battery power is supplied through a resettable fuse, which limits the max allowed current, and a Schottky diode for reverse bias protection.
- The switch allows to turn the TTT on or off



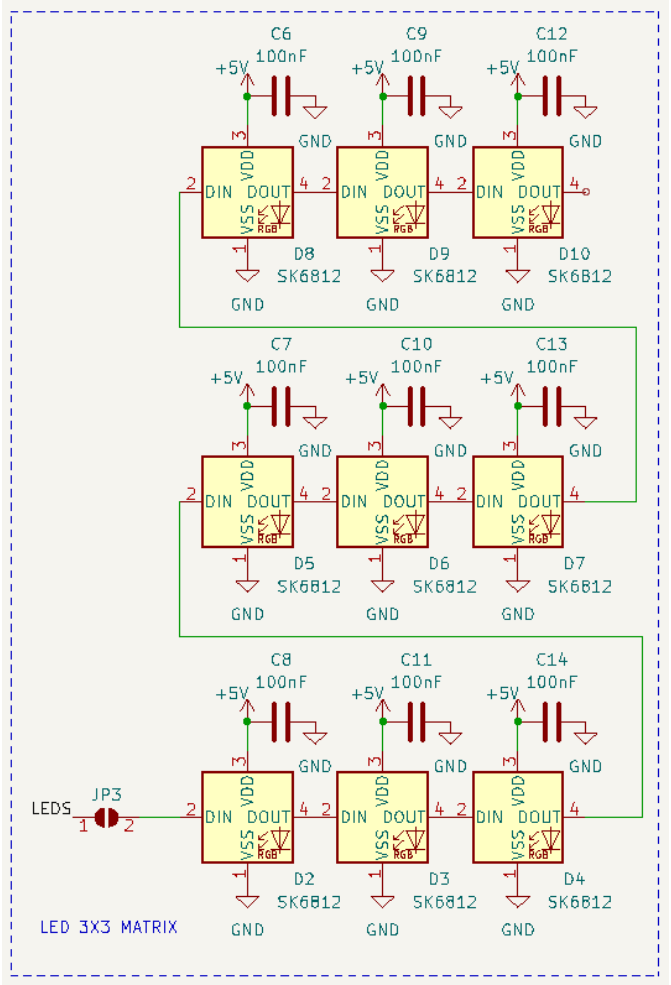
Voltage boosting

- The microcontroller and the LEDs work at 5V
- The XC9142 is a DC-DC switching regulator, which increases the battery voltage (3V) to the needed 5V



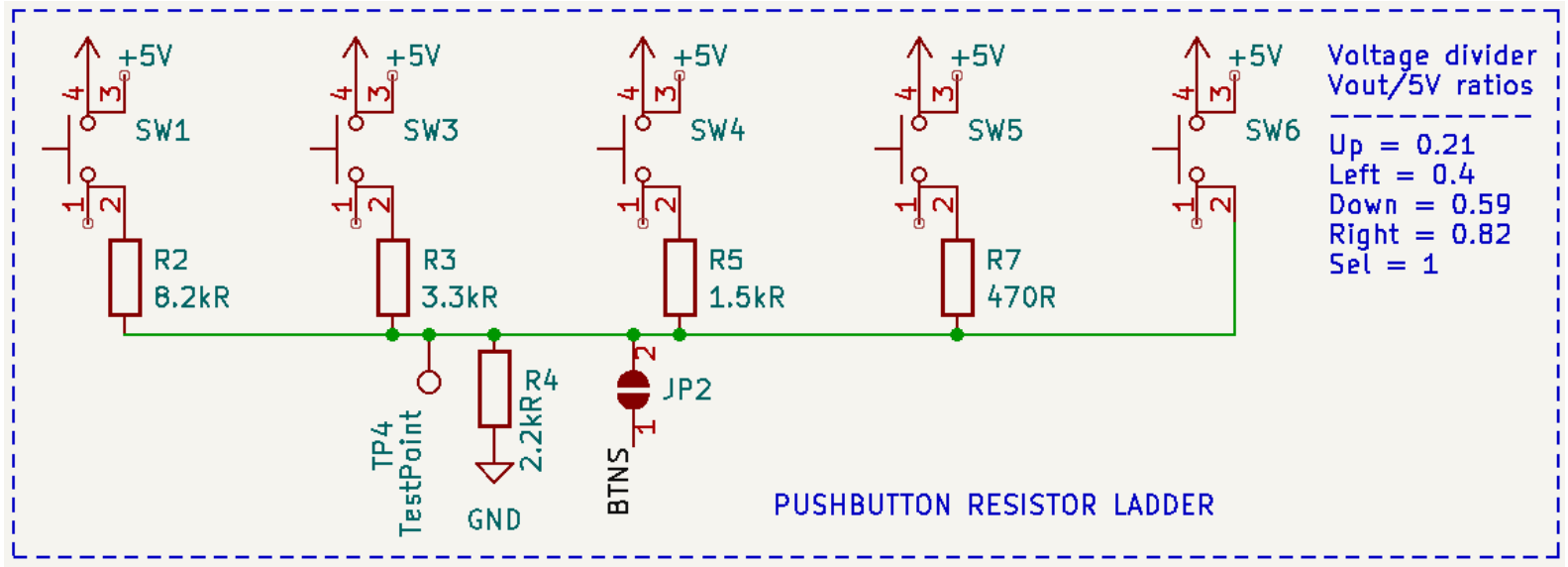
LED matrix

- Addressable LEDs are opto-components that include RGB LEDs and an integrated circuit driver
- The driver allows to easily change color and brightness, but importantly allows to address the wanted LEDs, just by daisy-chaining the DataIn-DataOut pins



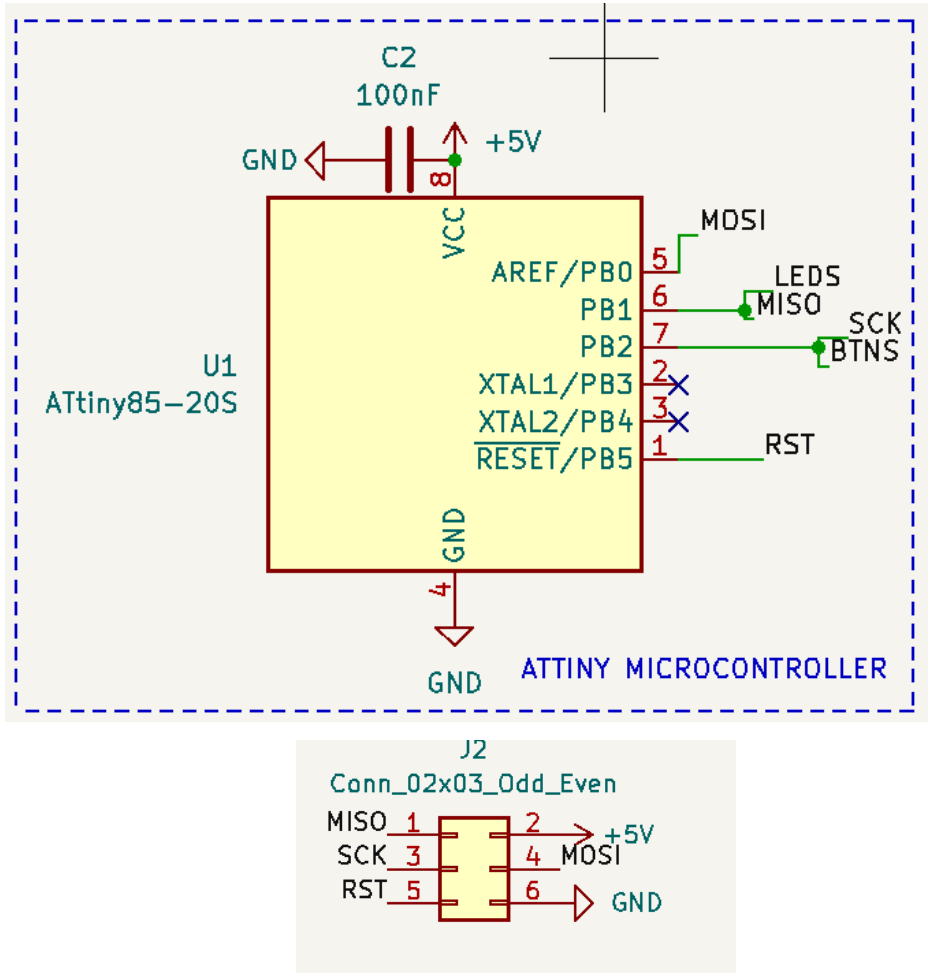
Pushbutton resistor ladder

- The ATTiny85 microcontroller doesn't have enough pins to digitally read the status of all the switches
- However, it supplies an analog ADC input, which can read the voltage to it
- The switches resistor ladder works as a voltage divider, where ratio depends on the switch is pressed



Microcontroller

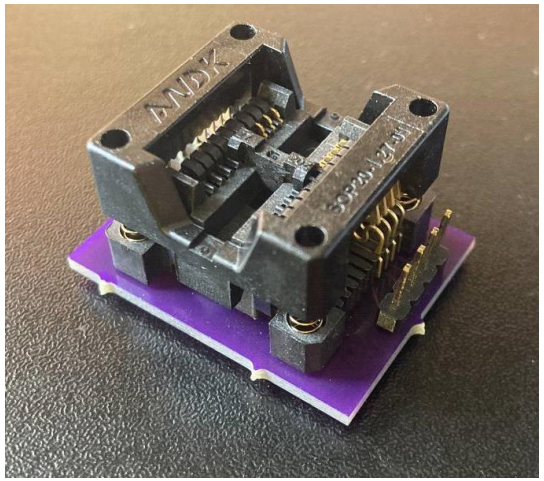
- The ATTiny85 microcontroller is the core of our device
- Pin PB2 is the analog input that reads the voltage from the pushbutton divider, to interpret it as a pushbutton status
- The LEDs matrix first DataIn is connected to PB1. The *FastLED* library on the ATTiny program can speak to these components
- The ISP programming pins (MISO, MOSI, SCK, RST, 5V, GND) are connected to the header J2, to allow the more expert maker to reprogram the ATTiny85 and explore it!

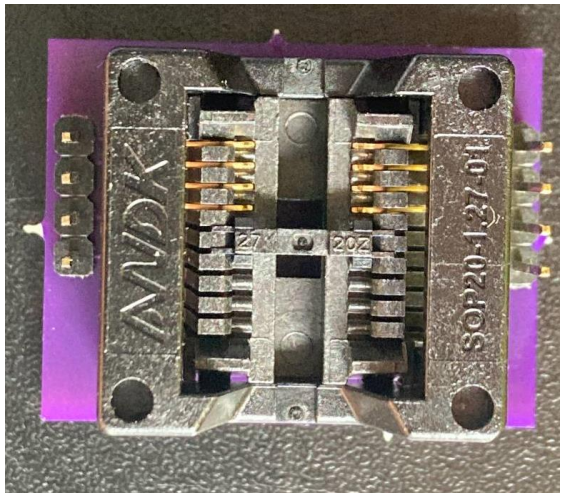


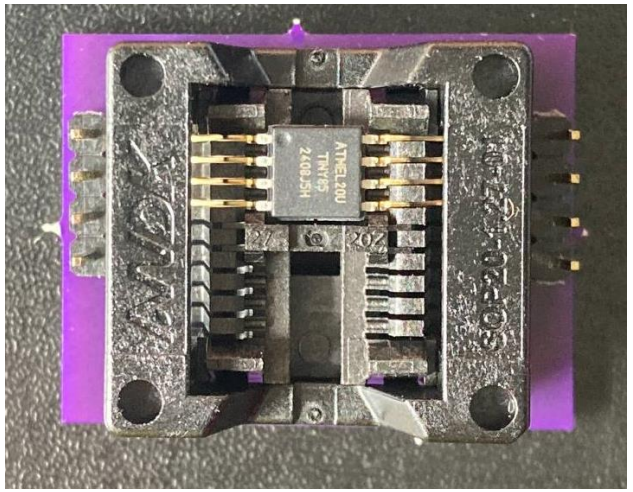
Appendix: programming of the Attiny85

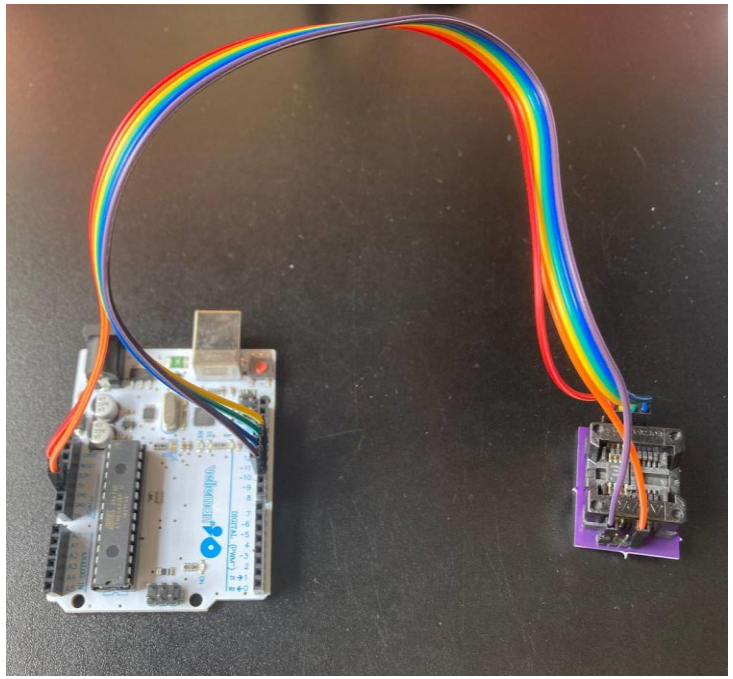
Attiny 85 programmer

The Attiny85 is programmed before packaging by using a Zero Insertion Force (ZIF) socket for 8-SOIC. The ZIF is soldered on a PCB to provide connections with pin headers. The latter can be connected to Arduino Uno R3 or equivalent using jumper wires. Then, using on-line libraries, the Arduino can be programmed as ISP programmer, to upload a bootloader and the Tic-Tac-Toe code on the Attiny 85









BOM, mechanical

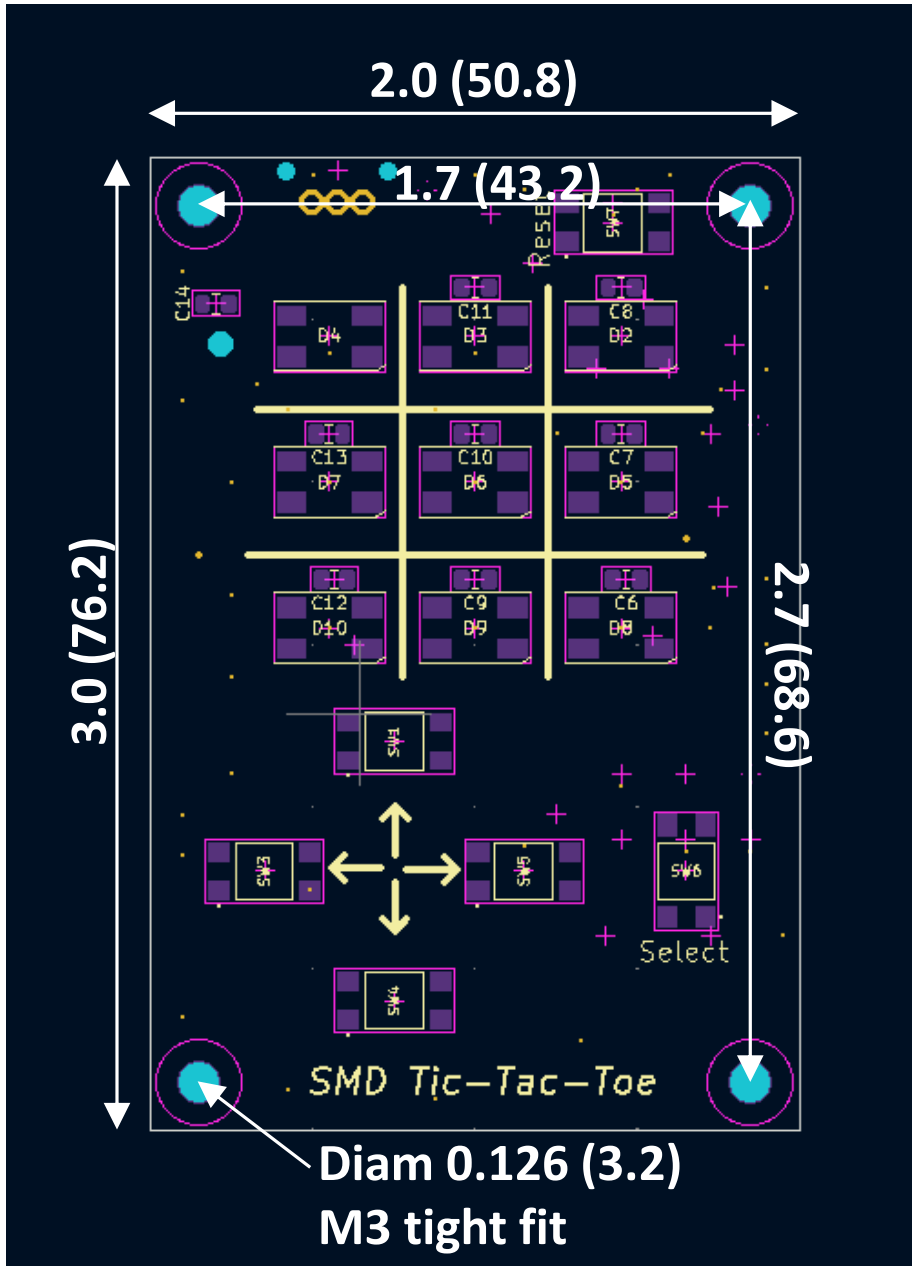
Bill of materials

Reference number	Part	Manufacturer	Part Number
BT 1	Battery holder	Adam Tech (or Keystone)	BH-102B-5 (or Keystone 1022)
D1	D, Schottky	Toshiba Semiconductor and Storage	CUS10S30,H3F
D2-D10	Addressable LED SK6812	Adafruit Industries LLC	1655
F1	PTC fuse 100mA	Bel Fuse Inc.	0ZCJ0010FF2E
L1	Ind 22uH	TDK Corporation	LTF5022T-220MR98-LC
SW2	SPDT	Nidec Components Corporation	MFS101D-6-Z
SW1, SW3-SW7	SPST	C&K	PTS 647 SK70 SMTR2 LFS
U1	Microcontroller	Microchip Technology	ATTINY85-20SU
U2	DC-DC step-up Boost	Torex Semiconductor Ltd	XC9142B33CMR-G

Reference number	Part	Manufacturer	Part Number
C1, C3	C, 10 uF, 0805	KEMET	C0805C106K8PAC7800
C2, C6-C14	C, 100nF, 0805	YAGEO	CC0805KRX7R9BB104
J2	2x3 pin header	Harwin Inc.	M20-8760342
R2	8.2kR, 0805, 1%	Stackpole Electronics	RMCF0805FT8K20
R3	3.3kR, 0805, 1%	YAGEO	RC0805FR-073K3L
R4	2.2kR, 0805, 1%	YAGEO	RC0805FR-072K2L
R5	1.5kR, 0805, 1%	YAGEO	RC0805FR-071K5L
R6	1MR, 1%	Stackpole Electronics	RMCF0805FT1M00
R7	470R, 1%	YAGEO	RC0805FR-07470RL
R8	22kR, 1%	TE Connectivity Passive Product	CRGP0805F22K
Mechanical mount parts			
N/A	Space #4, 4MM	Essentra Components	005371600014
N/A	Standoff, #4-40, 1/2''	Essentra Components	14HTSP103
N/A	Screw 4-40 TH, 3/8''	Essentra Components	010440WF037
N/A	Screw 4-40 TH, 1/2''	Essentra Components	010440WF050

Mechanical Drawing

Units are displayed in : Inches (mm)



Acknowledgments

- The SMD TTT is a project by Francesco Vischi and Mike Beach
- Completed May 2024
- The Bored Parrot Co. is a fictious company for small electronics projects by FV
- Artisans' Asylum, maker space, 96 Holton St., Boston, MA 02135