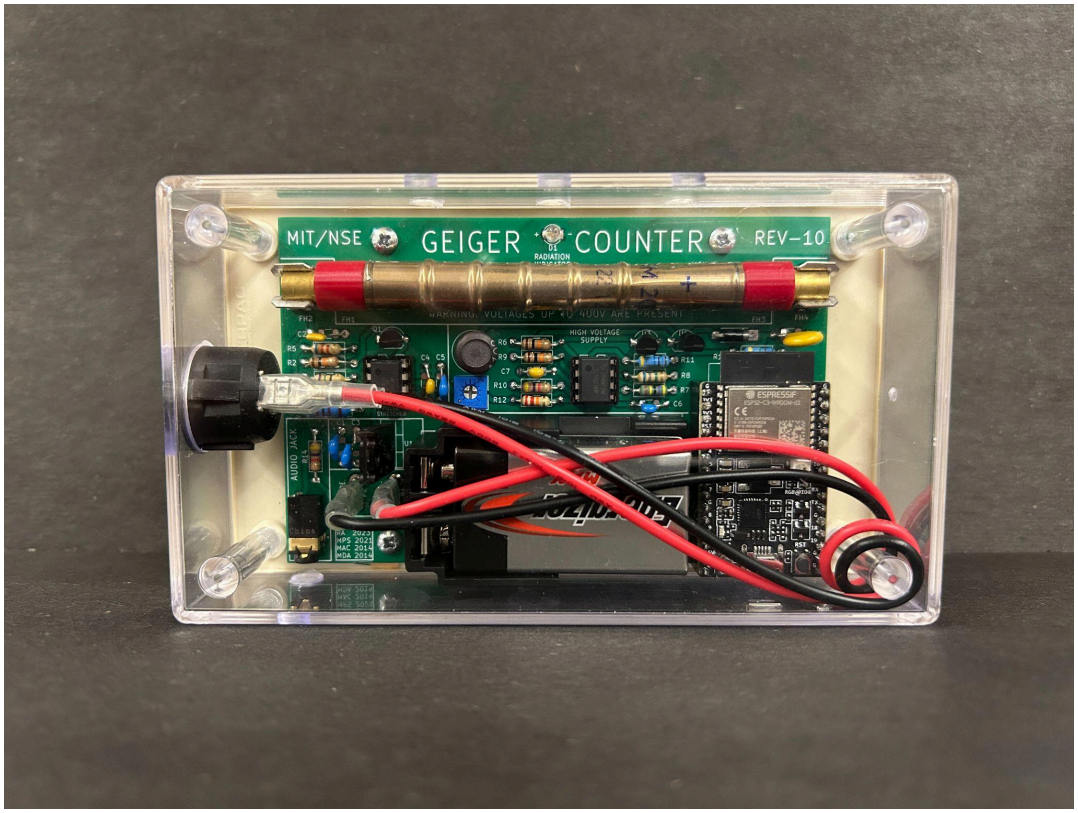
MIT-NSE GEIGER COUNTER ASSEMBLY (REV-10)



By: Rhett Applestone

Introduction:

When opening your MIT-NSE Geiger Counter box you should be greeted with something that looks similar to this.

(fig 1)

The top bag contains all the electronic components that are needed to assemble your own working Geiger-Müller counter. The case contains both your Rev-10 circuit board and your geiger tube. Below that is a small box containing an ESP32-C3-DEVKITC-02. The ESP32-C3-DEVKITC-02 is a programmable microcontroller that we use to communicate with mobile apps, web apps, and conventional software applications for data logging purposes.

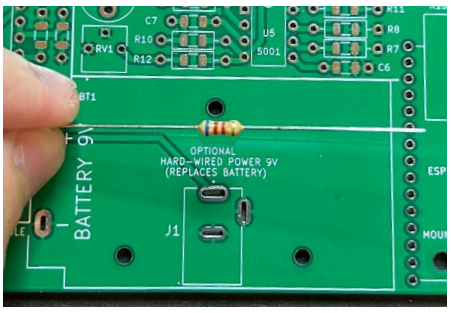
Note: It's a good idea to fully read each individual section before soldering to make sure you understand exactly what to do.

SUGGESTED TOOLS / MATERIALS:

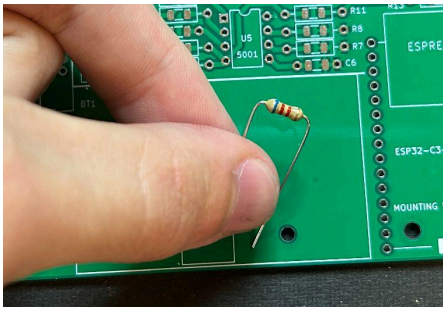
- Soldering iron
- Solder
- Solder flux (if you want)
- Something to clean iron tip (brass shavings, sponge)
- Pliers
- Screwdriver (small philips)

Section 1: The Resistors

This kit has 14 axial resistors. They do not have polarity and can be installed in **either direction**. I will demonstrate how to properly install one resistor, in this case R5. Once Installed solder them to the board from the bottom. The remaining resistors can be installed in any order. Please reference the labels on the individual bags (or bins) to know which resistor goes where.

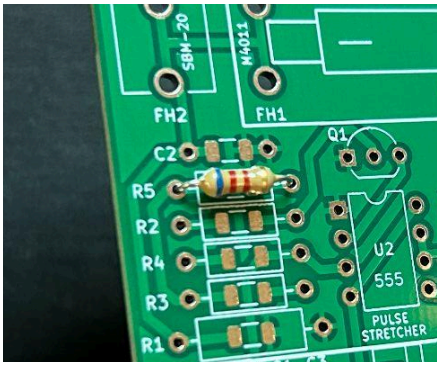


(Fig 2)

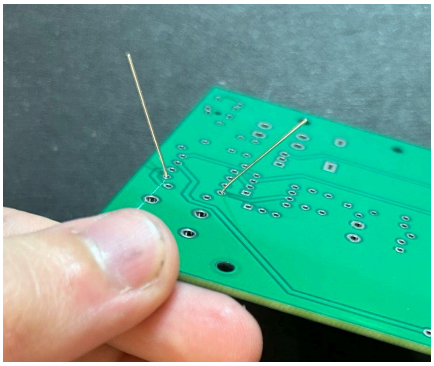


(Fig 3)

First find the correct resistor, in this case R5, then bend the leads as shown in Fig 3.



(Fig 4)



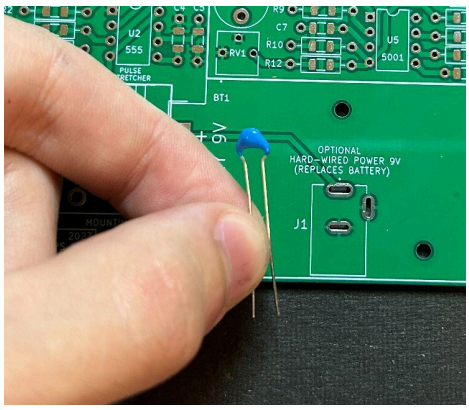
(Fig 5)

Insert the resistor into its correct holes so that it lies flat and then flip the board and flare out the leads so they don't not fall out of the board before you solder them. After this, solder the resistor in and clip the excess leads flush (or close to flush) with the bottom of the board to prevent short circuits.

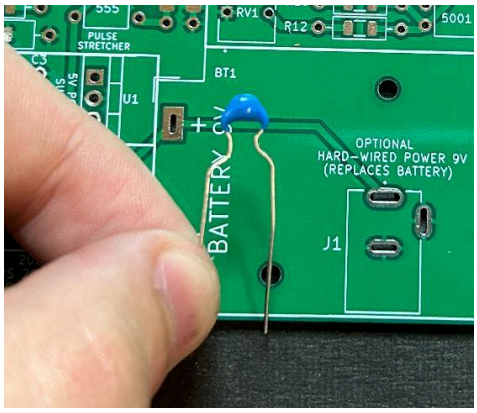
Find the rest of the resistors and solder them in following the same process

Section 2: Soldering The Capacitors

Soldering in the capacitors is much like soldering in the resistors. Our capacitors are all ceramic, and have no polarity (although some other electrolytic capacitors do). This means they can be put in **either direction.** I will demonstrate this with C1

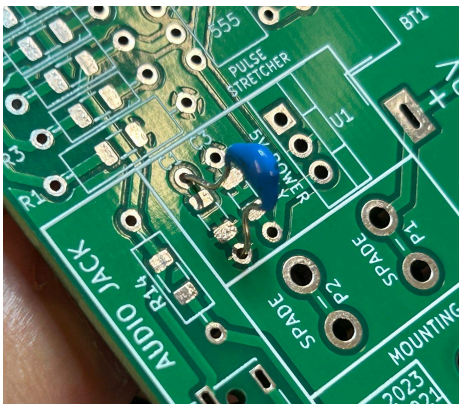


(Fig 6)

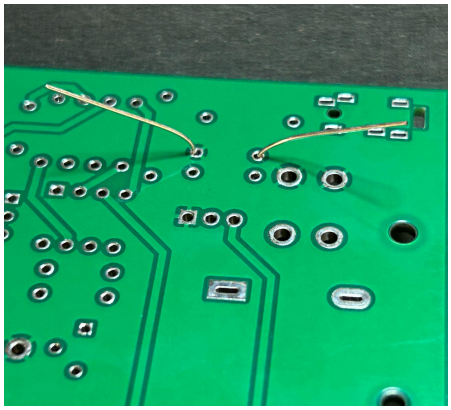


(Fig 7)

First find the correct capacitor (double check), then flare out the leads slightly if needed to fit comfortably in the holes.



(Fig 8)



(Fig 9)

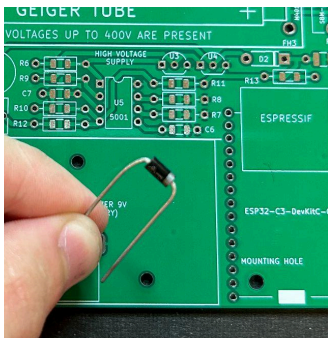
Put the capacitor in so it sits close to the board and then flare out the ends, solder it in, and snip the ends. (Sidenote) The silvery looking pads between each one of the resistor holes makes it possible to use surface mount resistors and capacitors and/or through hole resistors and capacitors (the kind we're using right now)

(Fig 10)

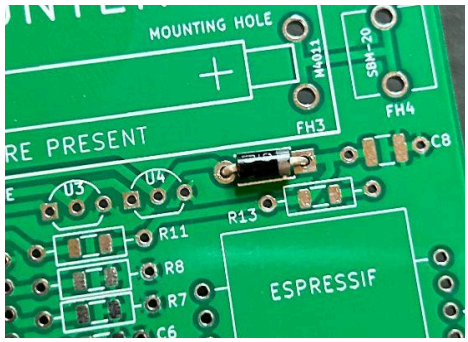
Here's an example of a surface mount resistor for reference
(Source: Digikey HRG3216Q-15R0-D-T1)

Section 3: The Diode

The diode is like a one way valve but for electricity. This means it's polarized and must **only go in one direction**. Our diode's spot on the board is labeled **D2**. Make sure the silver line on the diode overlaps the line on the board's outline of the diode



(Fig 11)



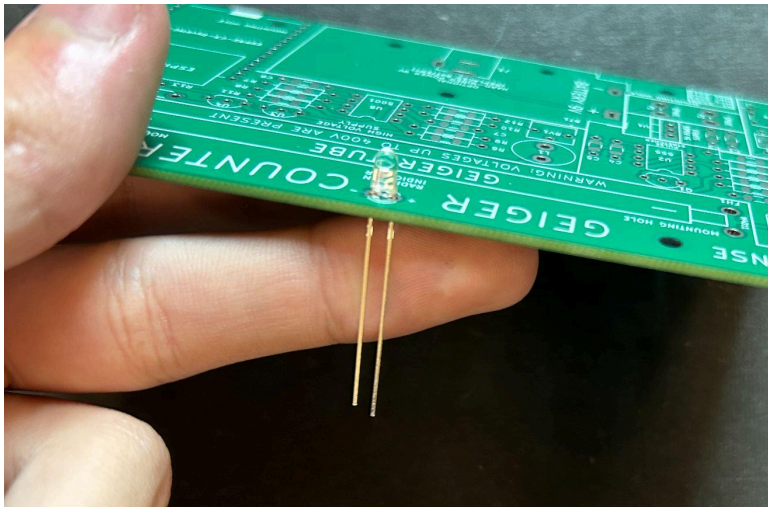
(Fig 12)

From now on, if it's not said, it's implied that you will take the three steps to complete the installation of each component.

1. Bend Leads outward from the bottom to keep component attached to the board
2. Solder the component in to achieve sound electrical connection
3. Snip the excess leads from the bottom of the board

Section 4: The LED

The LED emits light which will be our main use, however it is also a diode (Light Emitting Diode), and therefore may **only go in one direction**.

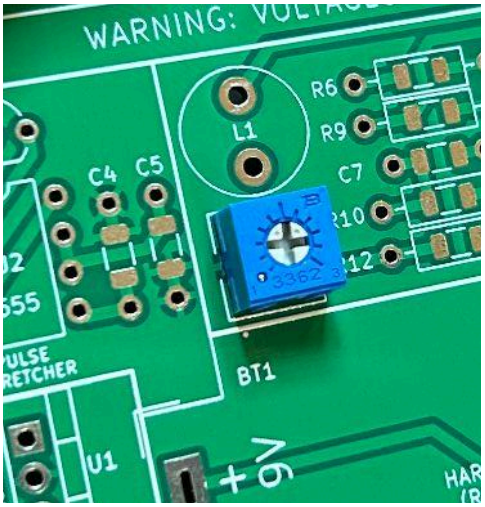


(Fig 13)

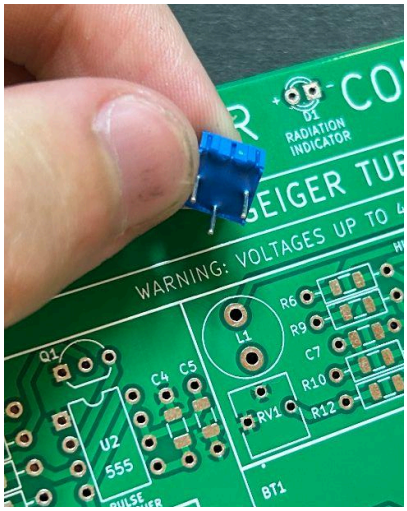
Notice how one lead of the LED is a bit longer. Now notice that there's an + and - sign next to the led hole labeled **D1**. The Longer lead goes into the hole labeled +.

Section 5: The Potentiometer

This is a potentiometer, it has three leads, and in our circuit it will allow us to vary the output high voltage that will bias our geiger tube. This is done by turning the dial on the top with a screwdriver. It's labeled **RV1** on the board



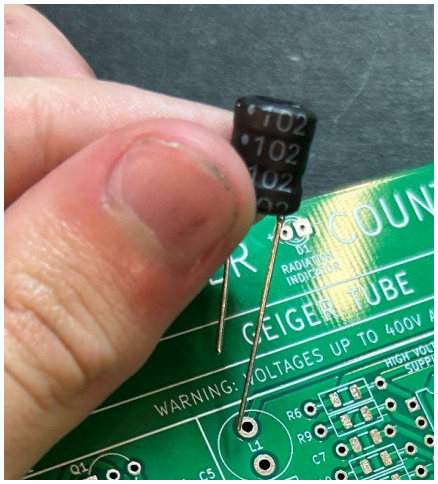
(Fig 14)



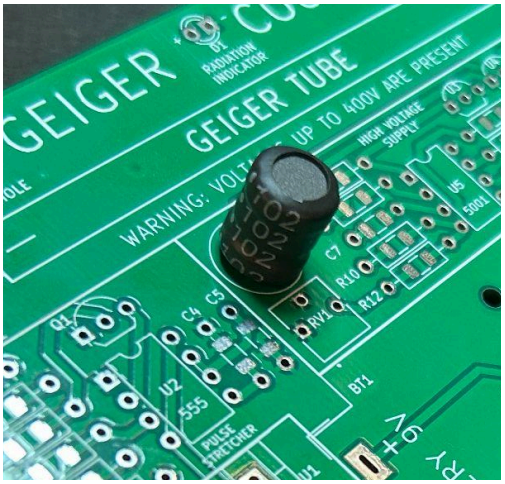
(Fig 15)

Section 6: The Inductor

This is an inductor. It works to store energy in the form of a magnetic field. We use this property to generate our high voltage when switched on/off quickly. It's labeled **L1** on the board. While one of the leads may be longer, the inductor **can go in either orientation**



(Fig 16)



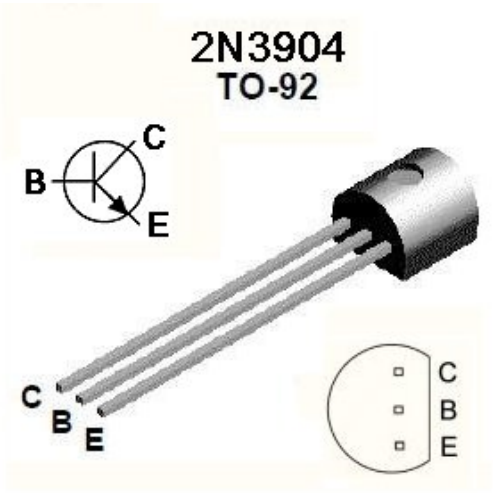
(Fig 17)

Section 7: The 2N3904 NPN Transistor

The transistor is a pretty simple invention. At the most basic level, a transistor is to electricity as a ball valve is to water. When the top is turned water can flow.

(Fig 18)

(Src: Home Depot 1-1/4 in. PVC S x S Ball Valve)



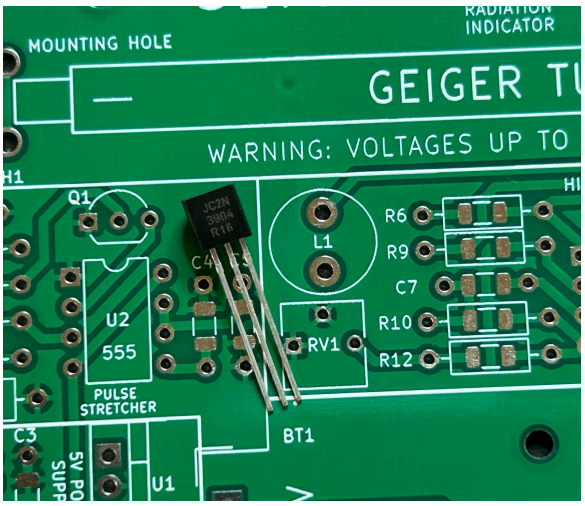
(Fig 19)

(Src: Wikimedia File:2n3904.jpg)

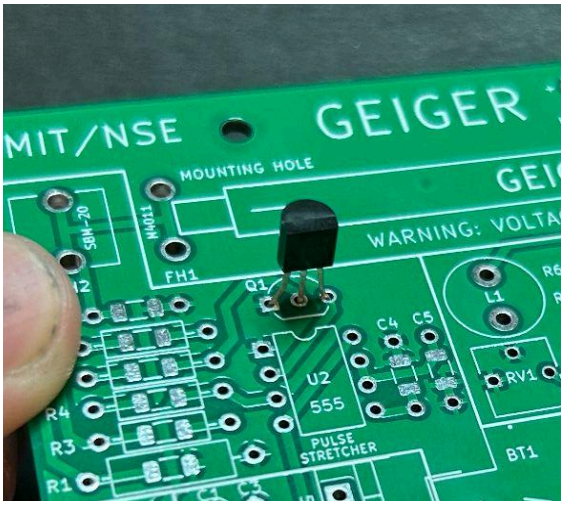
The base (labeled **B**) of the transistor is like the red part of the valve that you twist. When positive voltage is applied to the base of the 2N3904, current is allowed to freely pass from the collector (labeled **C**) to the emitter (labeled **E**). Otherwise, current is not allowed to pass.

There are many types and variants, but they all operate on that same basic principle.

We have one 2N3904 in our geiger counter to help with the pulse detection. The transistor must **only go in one direction**. The circuit board has a white outline of the top of the transistor, line it up. Our 2N3904 is labeled **Q1** on the board. You may want to bend the leads out a bit before inserting it.



(Fig 20)



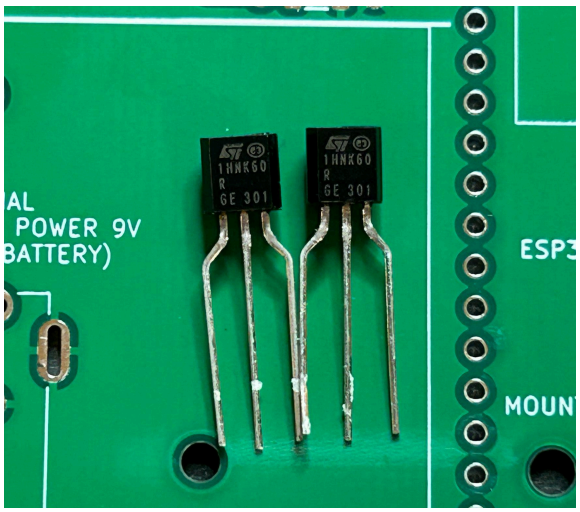
(Fig 21)

Section 8: The N-Channel MOSFET

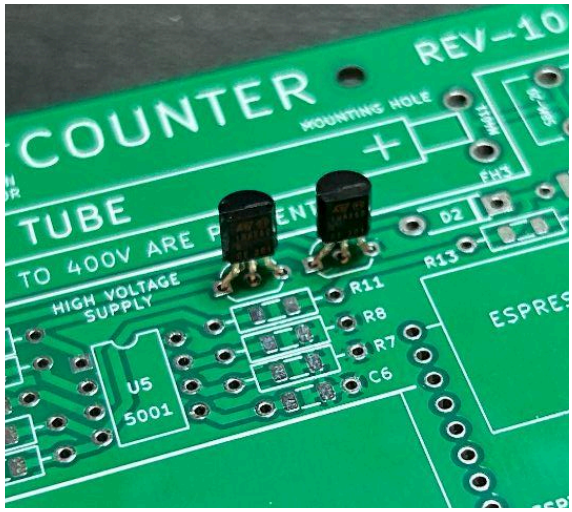
A N-Channel MOSFET (metal-oxide-semiconductor field-effect transistor) really does about the same thing as the classic NPN transistor we just talked about. It's just better at switching on and off quickly and uses less energy.

We have two in our circuit that are responsible for connecting and disconnecting a piece of the circuit that bridges across the output side of the inductor and ground. If you do this really quickly high voltage at the output is generated. That idea is the basis of the boost converter.

They are **U3** and **U4**, and again may **only go in one direction**. Align their tops with the white silkscreen on the board.



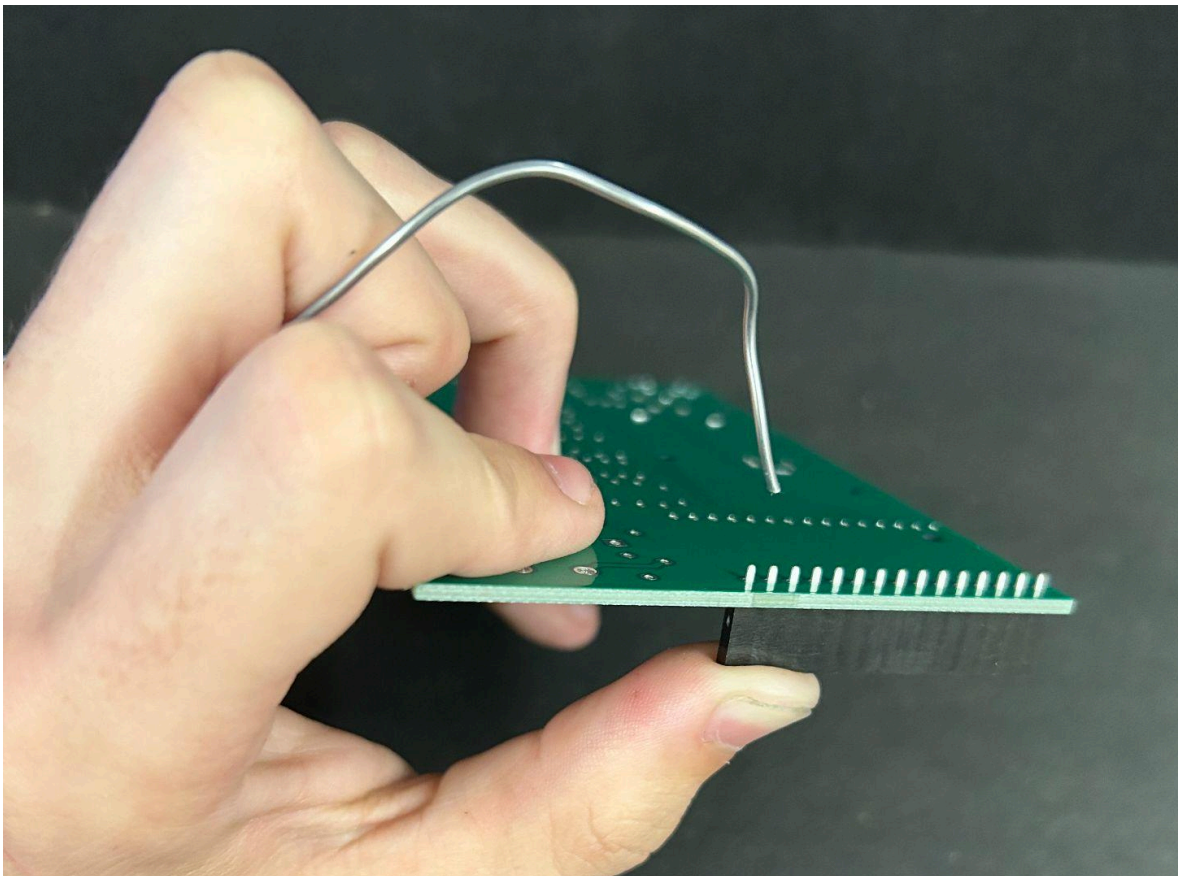
(Fig 22)



(Fig 23)

Section 9: The Header pins

To make it easy to connect and disconnect the ESP32-C3-DEVKITC-02 to the circuit board we use header pins 15 long. It's important that these are soldered onto the board directly up and down so everything fits nicely.

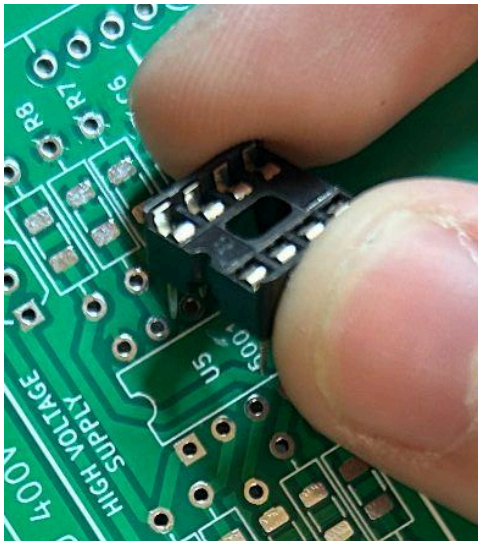


(Fig 24)

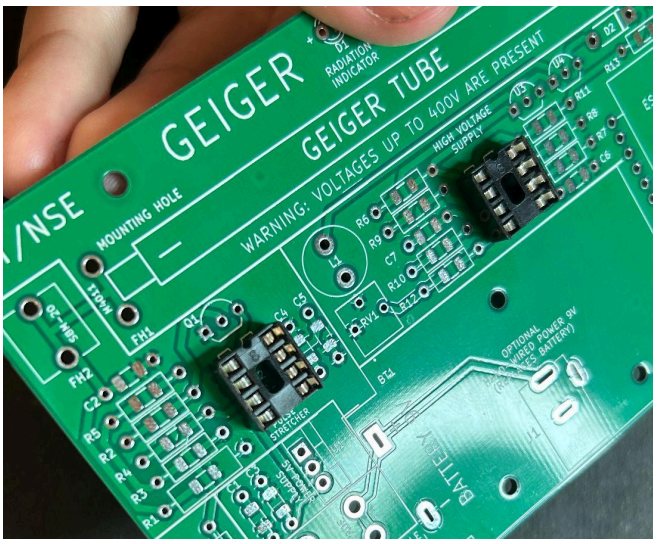
This is not easy, the best way to do this if you don't have helping hands is to hold the header to the board while also holding solder in the same hand. Use your other hand to hold the soldering iron and get two quick soldiers on the first and last pin of the header. Then once stable, solder the pins between the first and last, plus re-doing the ones between to ensure good connection. Do this twice

Section 10: The DIP-8 Sockets

DIP stands for, Dual Inline Package, and 8 signifies how many pins it has in total. We have two DIP-8 sockets. One is for the LMC555 **U2** we use, and another is for the TL5001 **U5**



(Fig 25)



(Fig 26)

Make sure the notch on the top of the DIP-8 socket lines up with the notch on the board for both the 555 and 5001.

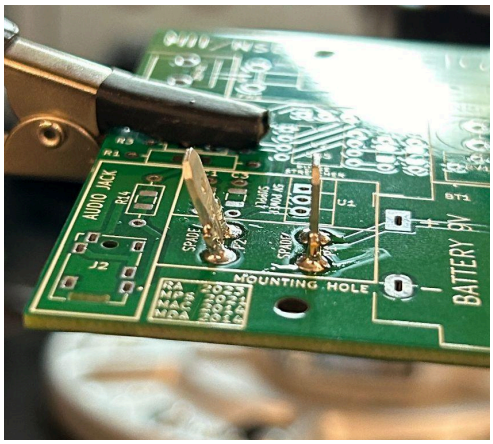
Solder the sockets one by one. If you don't have helping hands to make it easier hold use a similar technique to that discussed in the previous section on the headers.

Please refrain from putting in the 555 or 5001 chip till later so they don't get damaged.

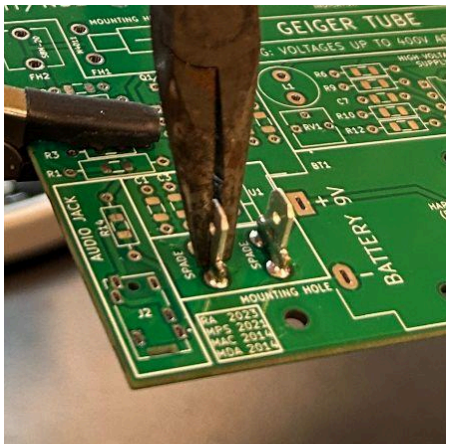
Section 11: The Spades

In this build we use spades to connect the board to a switch. This lets you remove the top case easily to adjust things as you see fit while being able to have a nice case mounted switch.

Spades are also tricky to solder in place correctly upright. Find the spades included in your kit, and the set of holes labeled **spade** .



(Fig 27)

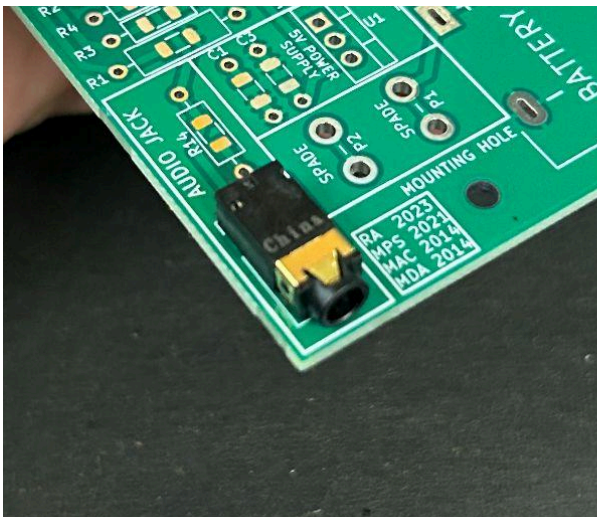


(Fig 28)

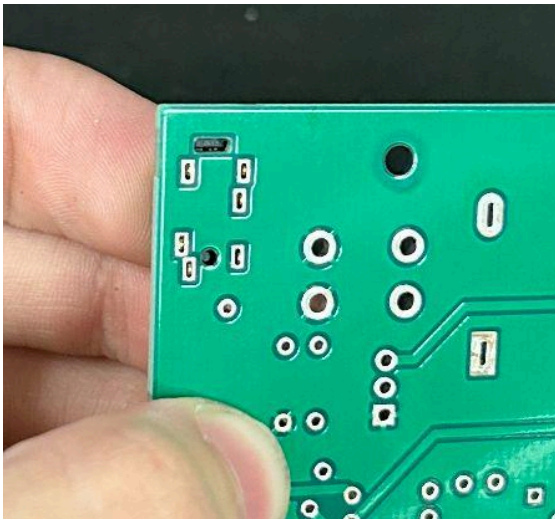
I would recommend first soldering in the spades just lying in the holes without any help and then going back and re melting both all the solder at the same time while holding the spade with pliers. After the solder is liquid orient the spade up and wait for it to solidify before letting go of the spade. Feel free to try other methods if you would like.

Section 12: The Headphone Jack

If you want to hear geiger pulses through headphones you can! We'll be soldering on an audio jack to let us do this. The holes are quite small, however not impossible by any means. Find the audio jack and corresponding board position (**J2**) and solder it from the bottom.



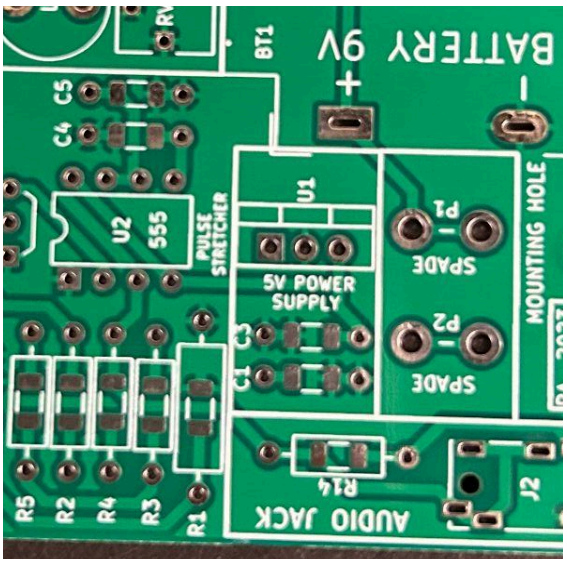
(Fig 29)



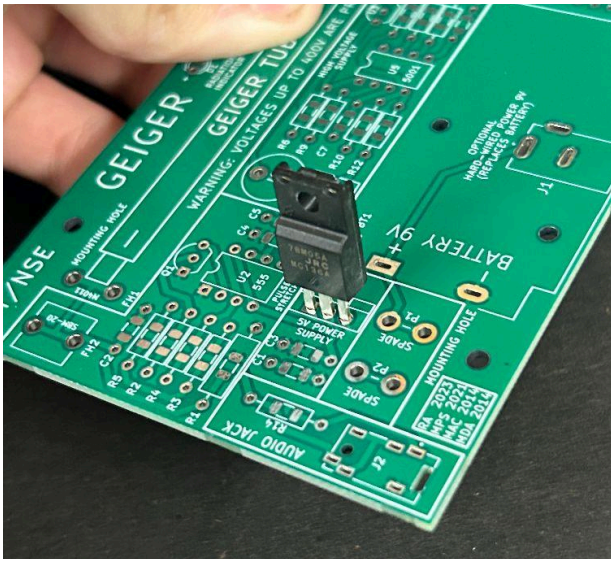
(Fig 30)

Section 13: The Voltage Regulator

To run the 555 chip and the ESP32-C3-DEVKITC-02 we use a 5v 500mA linear voltage regulator to turn the 9v into 5v. The only thing tricky here is orientation. The linear voltage regulator must **only go in one direction**. The regulator has the denotation of **U1** on the board



(Fig 31)



(Fig 32)

As shown in Fig 32 the regulator needs to have its flat side facing the part of the white silkscreen that has three rectangles next to each other.

Section 14: Picking a Geiger tube

You may be thinking “I only have the tube that came with the kit” which is true, however if you would like to learn about the tubes you are able to run with this counter, read this section. There are two main choices that this board was designed for. Those being the classic SBM-20 soviet era geiger tube (top), and the modern M4011 geiger tube (bottom).

(Fig 33)

The M4011 was chosen because of its wide availability and the fact that it’s being actively manufactured.
(sidenote) the M4011 may also be sold as the J321 or other variants. The most important thing is that the tube is around 88-90mm long, 10mm diameter, and has similar working voltage.

Both tubes work quite well however if you decide to choose the M4011 there are some additional considerations

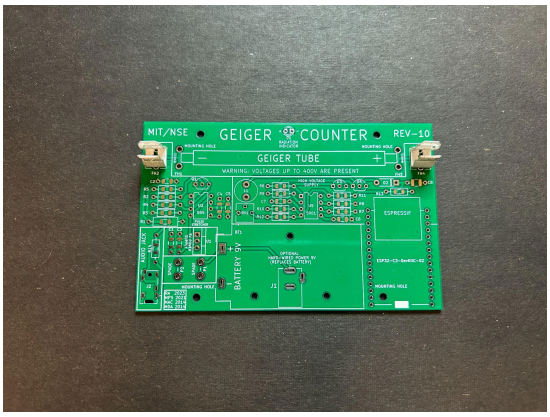
Section 15: Additional M4011 Considerations

One of the main reported disadvantages to the M4011 is that it **may or may not** be light sensitive. It has therefore been advised to cover the tube in heat shrink to block the majority of the light that comes in contact with the tube. Be sure to mark the + and - sides so you don't forget

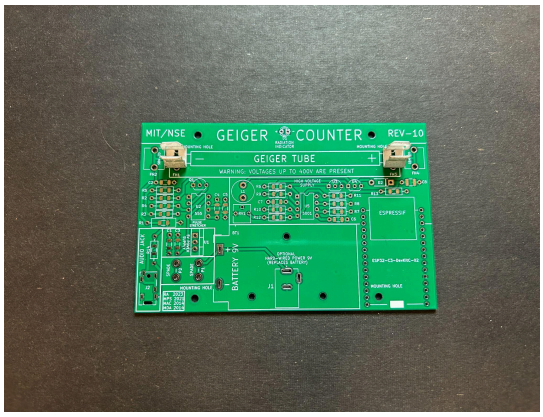
(Fig 34)

(Fig 35)

Section 16: The Tube Clips

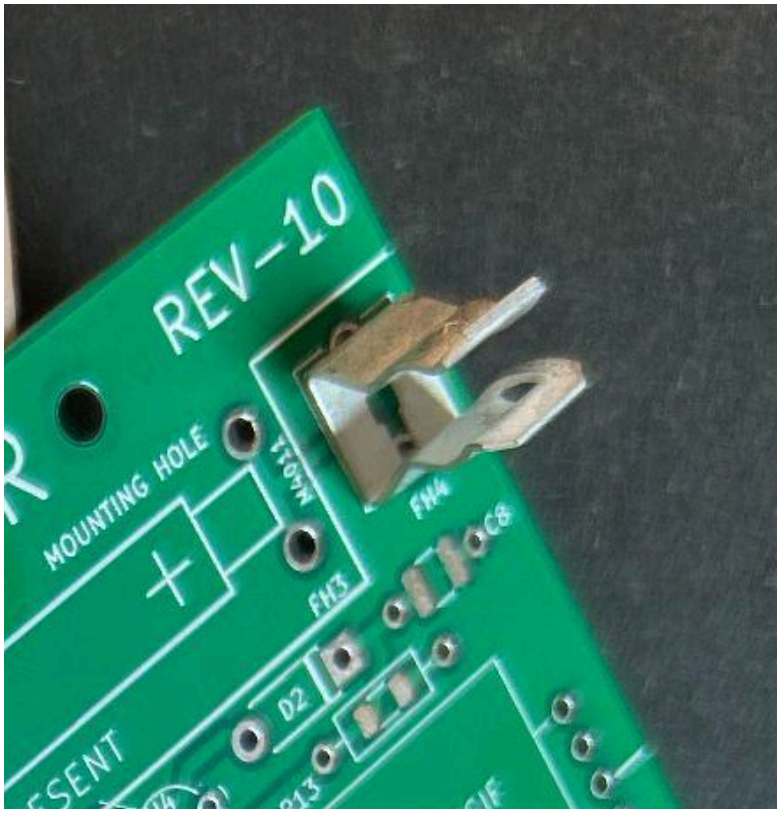


(Fig 36)(**SBM-20**)



(Fig 37)(**M4011**)

Fig 36 displays the conventional SBM-20 configuration and Fig 37 shows how they should be put in for the M4011. The Tube clips must **only go in one direction** or else they will not be able to accept the tube

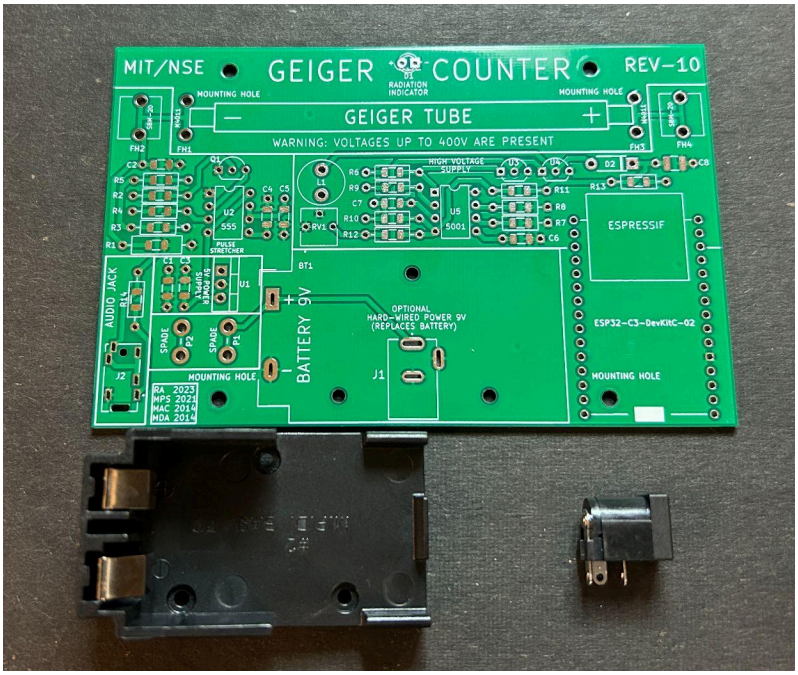


(Fig 38)

Here’s a close up of the correct orientation of the fuse clips. Flip the other fuse clip 180 degrees so both can accept the tube.

Section 17: Picking a Power Source

This geiger counter is designed to be able to run off battery power or wall power if the user so-chooses. However, you can only pick one so choose wisely. If you choose wall power you **must use a power brick rated at 9V 500mA**. If you try to use a 5V brick it will not work at all. Running the geiger counter fully transmitting data from the ESP32-C3-DEVKITC-02 you will get around 4 hrs 45 mins of battery life, removing the ESP will increase this drastically.

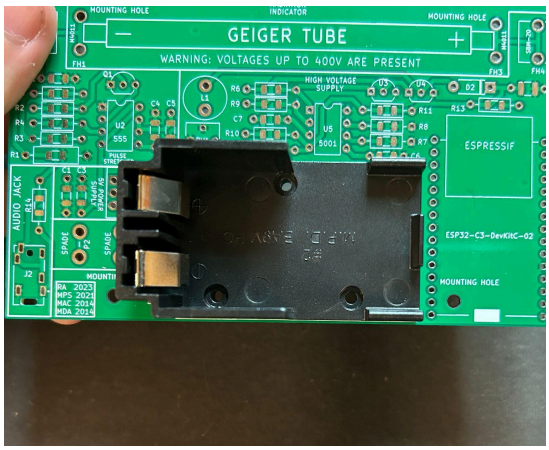


(Fig 39)

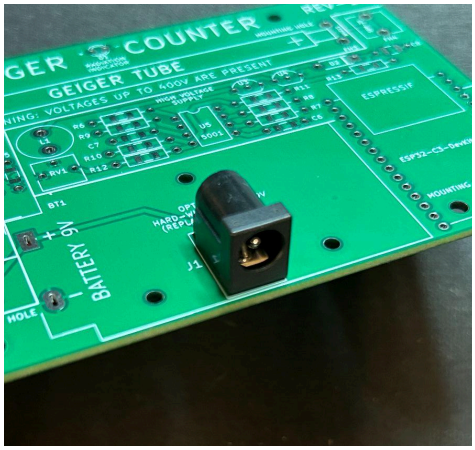
The Battery holder is shown on the left, and the 9V barrel jack option is shown on the right.

Section 18: Power Source Installation

After you've chosen if you’d like to run the geiger counter with the battery or the 9V barrel connector it’s time to install and solder it in



(Fig 40)



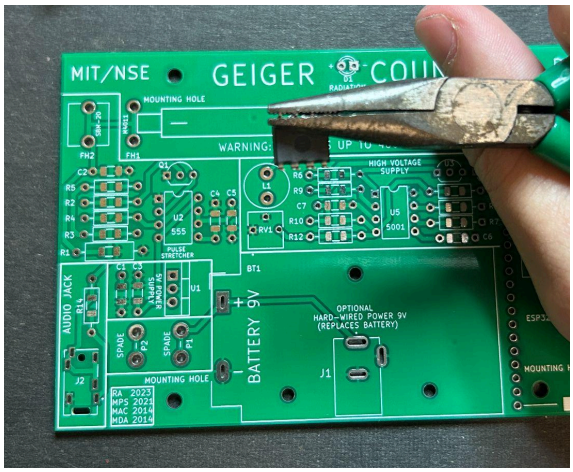
(Fig 41)

If choosing the battery holder make sure to snip off the leads on the bottom to make sure it can fit nicely on the case's base plate.

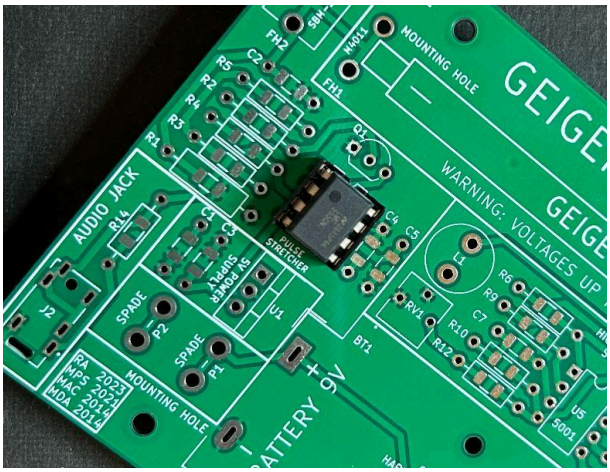
Section 19: Putting in Chips

Both the LMC555 and TL5001 go in the same way which I will explain now

First the **LMC555 (Left)**



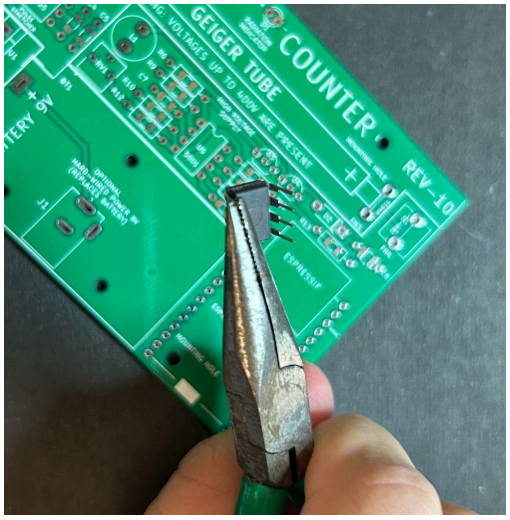
(Fig 42)



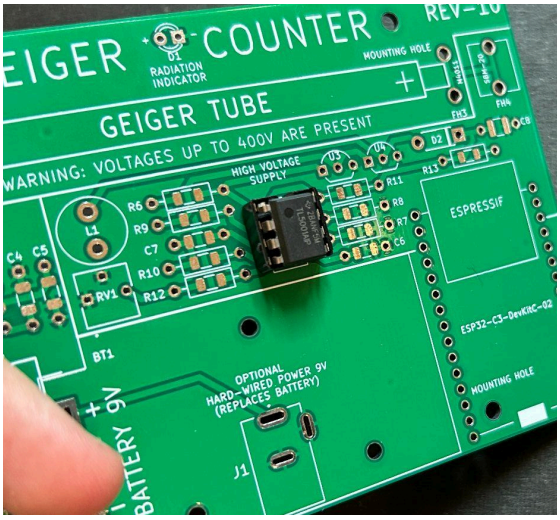
(Fig 43)

Bend the chip's legs ever so slightly inward so that they fit into the DIP-8 socket better, then align the circle on the top of the chip with the **circle in the top left**, then press in carefully making sure to not bend the legs of the chip.

Next with the **TL5001 (Right)**



(Fig 44)



(Fig 45)

Same thing, Bend the chip's legs in ever so slightly so that they fit into the DIP-8 socket better, then align the circle on the top of the chip to the top left **circle in the top left**.

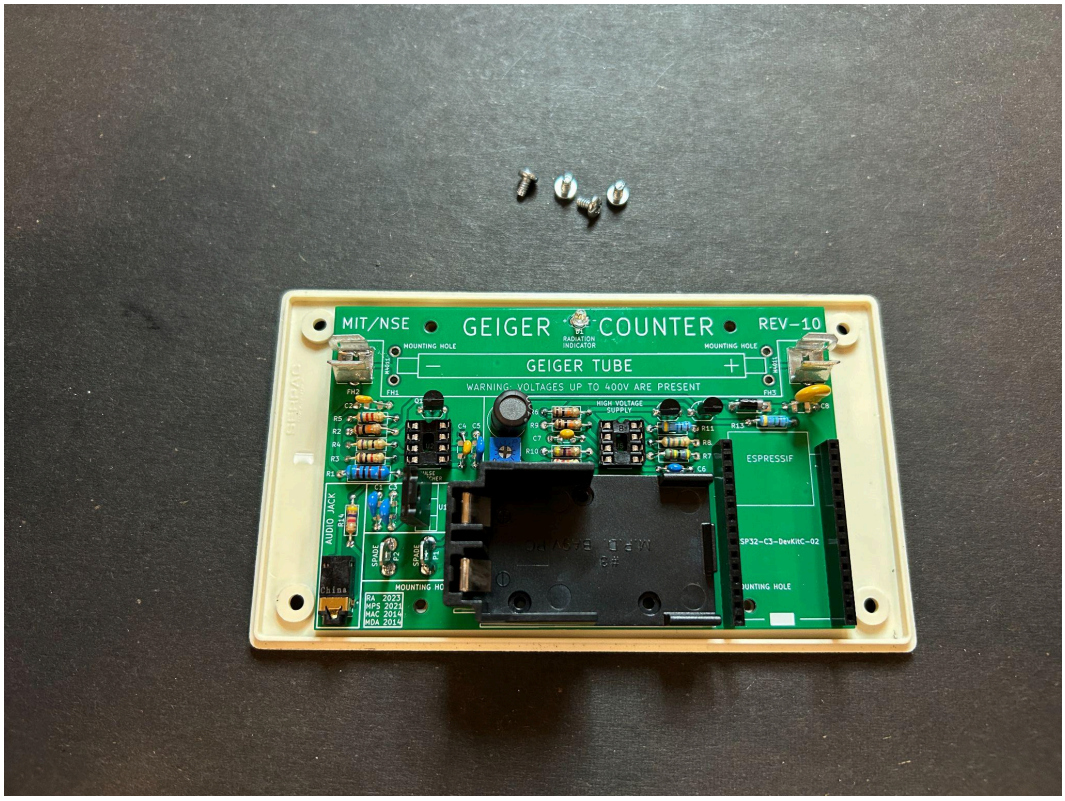
The LMC555 is a really cool chip and has three operating modes (monostable, bistable, and astable). We're using it in monostable mode, which means when we send in a pulse it sends out a pulse, but the pulse it sends out is longer.

The geiger tube makes the pulse which we need the 555 to stretch for us to send it to our LED, ESP, and Audio Jack.

The TL5001 is a Pulse Width Modulator chip (PWM). This means that it sends a high signal then a low signal in a consistent pattern again and again. This high and low turns on and off our MOSFETs from earlier to create a changing current in our inductor which in turn leads to our high voltage output via a boost converter topology.

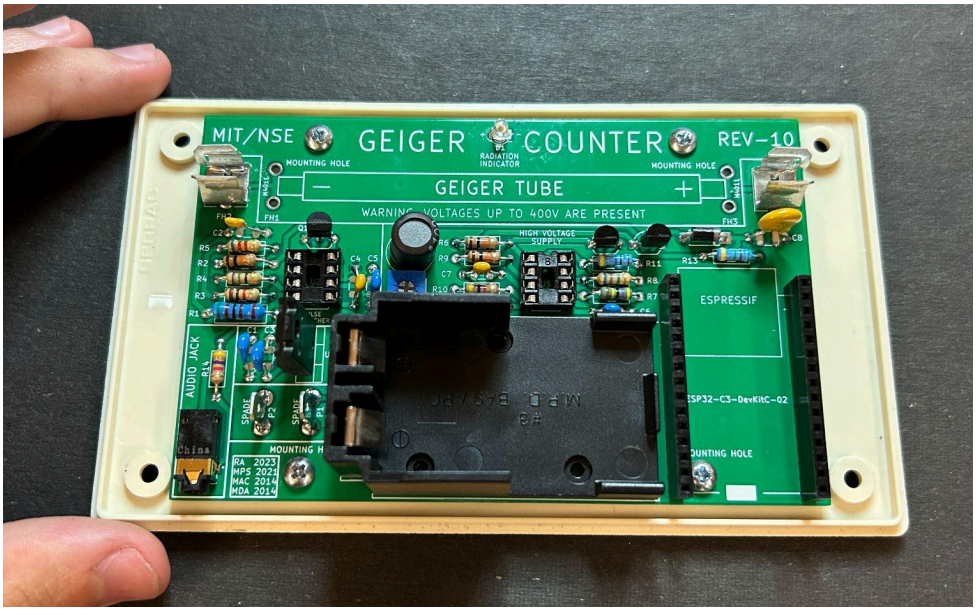
Section 20: Mounting The Board to Case

It's finally time to mount the board to the case! Find the four small mounting screws included with the kit and get the bottom base plate and line up the holes



(Fig 46)

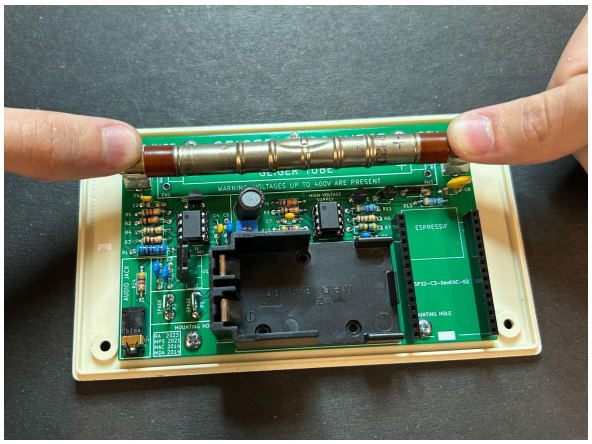
It doesn't matter which way around the board is, they will both work.



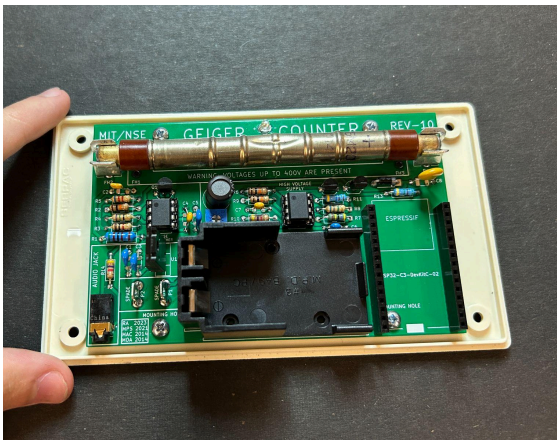
(Fig 47)

Screw each screw in incrementally to make sure everything lines up good and **do not over tighten the screws**. When they're flush with the circuit board, stop tightening.

Section 21: Installing The Tube, ESP, and Battery

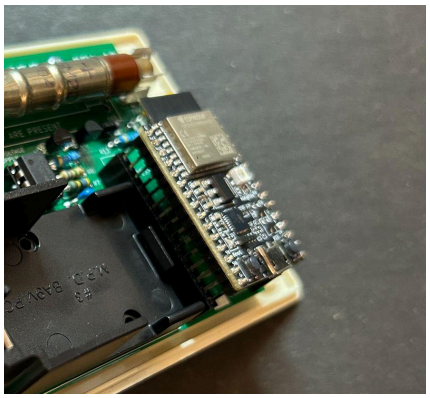


(Fig 48)

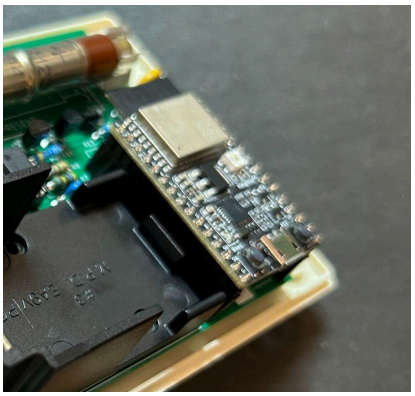


(Fig 49)

It's now time to pop in the tube and the ESP! Line the + side of the tube up with the + on the circuit board and use both thumbs to firmly press the geiger tube into the clips. Tube must **only go in one direction**

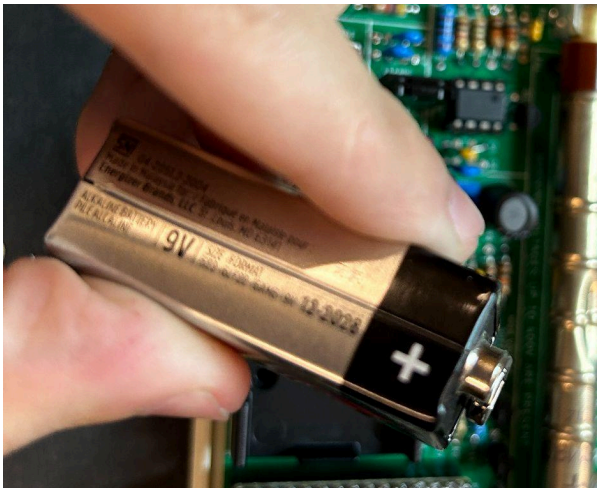


(Fig 50)

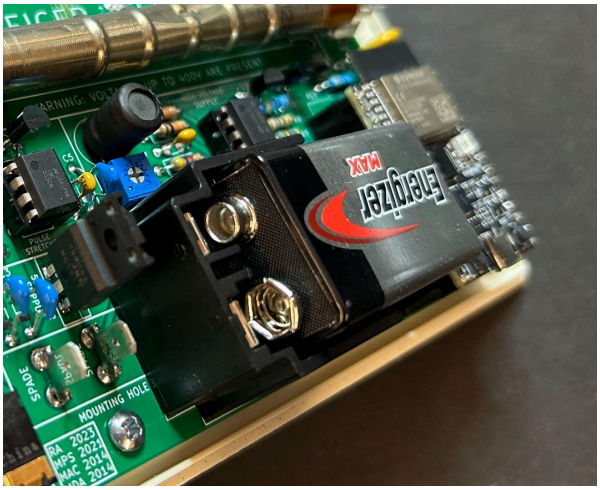


(Fig 51)

This step is optional, and your battery will drain faster if using the ESP. Line up the esp making sure all the pins slide in nicely then press down firmly. ESP may **only go in one direction**



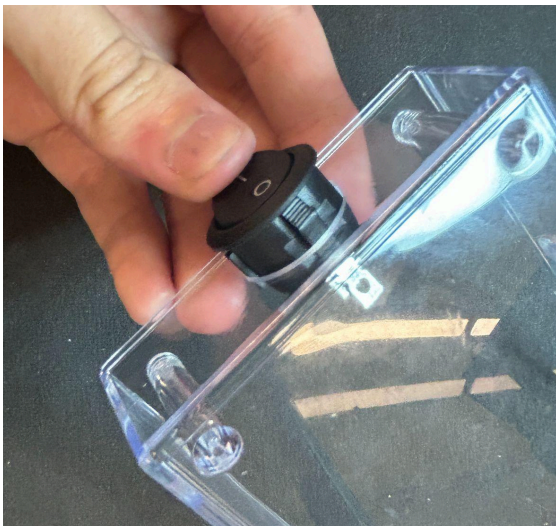
(Fig 52)



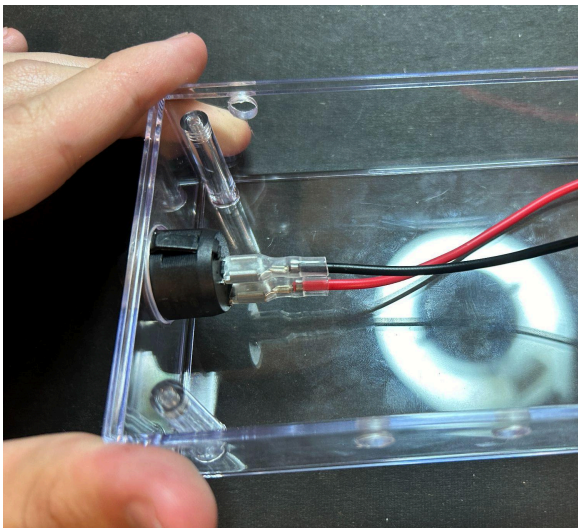
(Fig 53)

Make sure if using the battery it is installed like is shown in the Fig 53 with the leed + closer to the top and the - closer to the bottom. Battery may **only go in one direction**

Section 22: Final Assembly

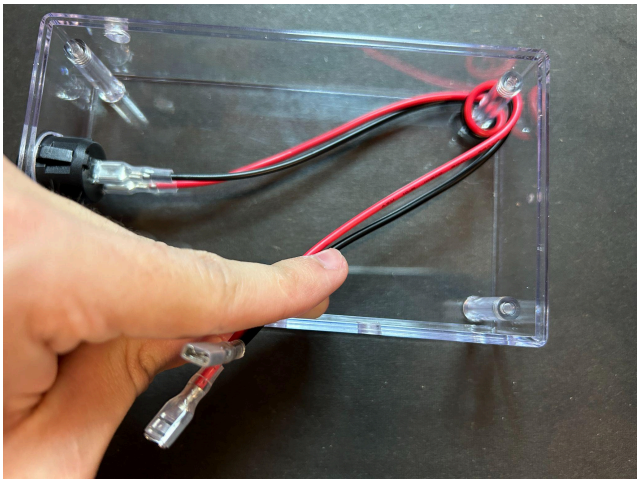


(Fig 54)

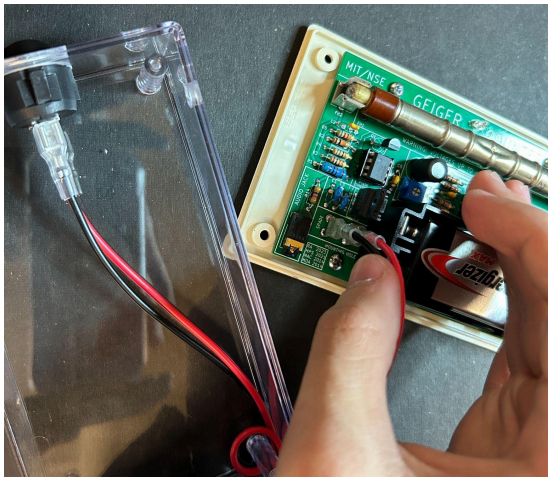


(Fig 55)

Push the switch into the large hole at the end of the clear part of the case. Make sure the “0” on the switch is facing towards the closed face, and the “1” is towards the open face (like is shown in Fig 54). Then attach the wires to the on/off switch (with the red on the bottom).

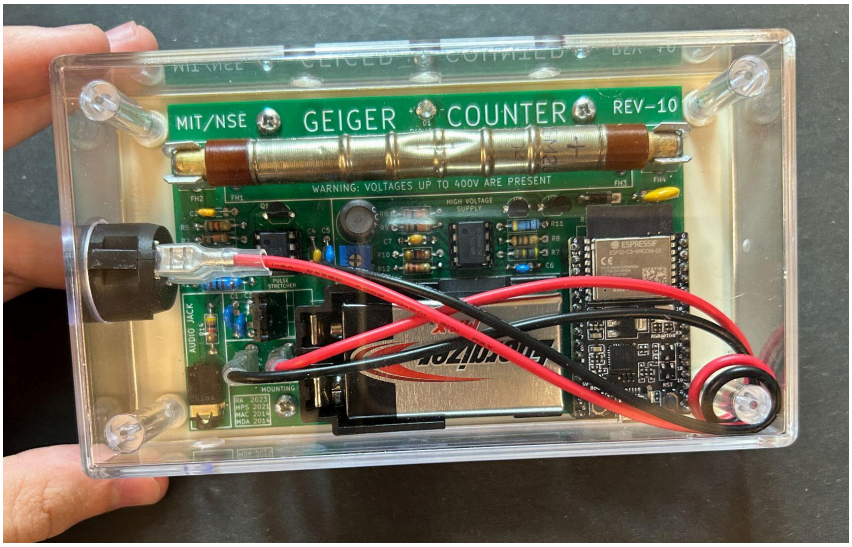


(Fig 56)



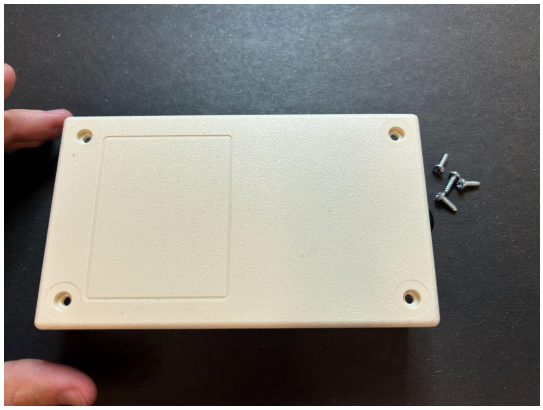
(Fig 57)

Wrap the wires tightly around the top right post and connect the ends of the wires to the spades on the board (with the red wire on the right).

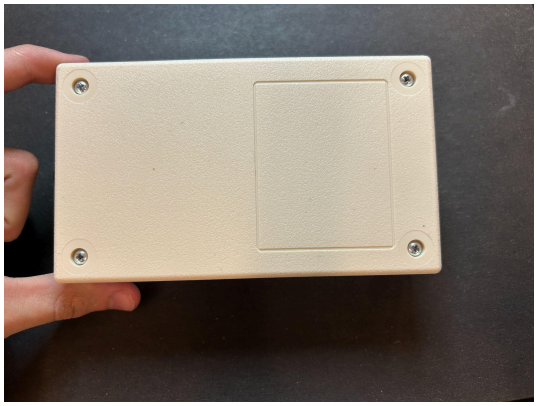


(Fig 58)

Flip the top part of the case over the board and line the pillars up with the holes on the bottom of the board as shown in (Fig 58)



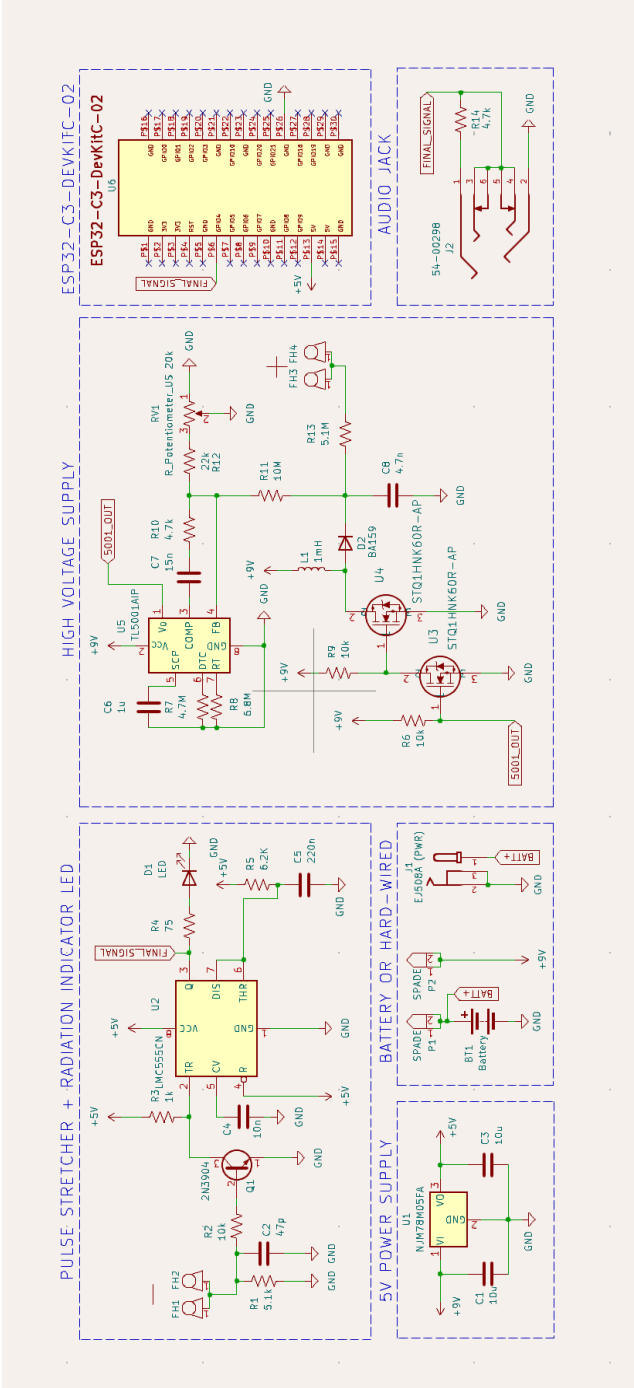
(Fig 59)



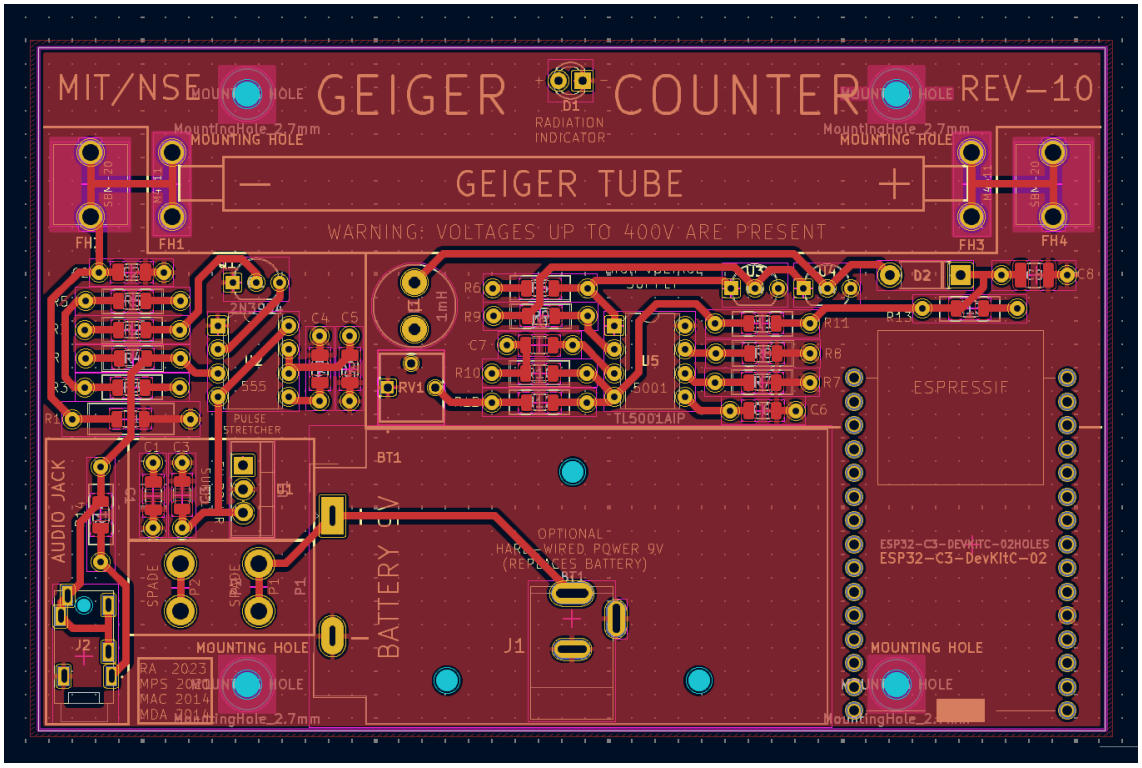
(Fig 60)

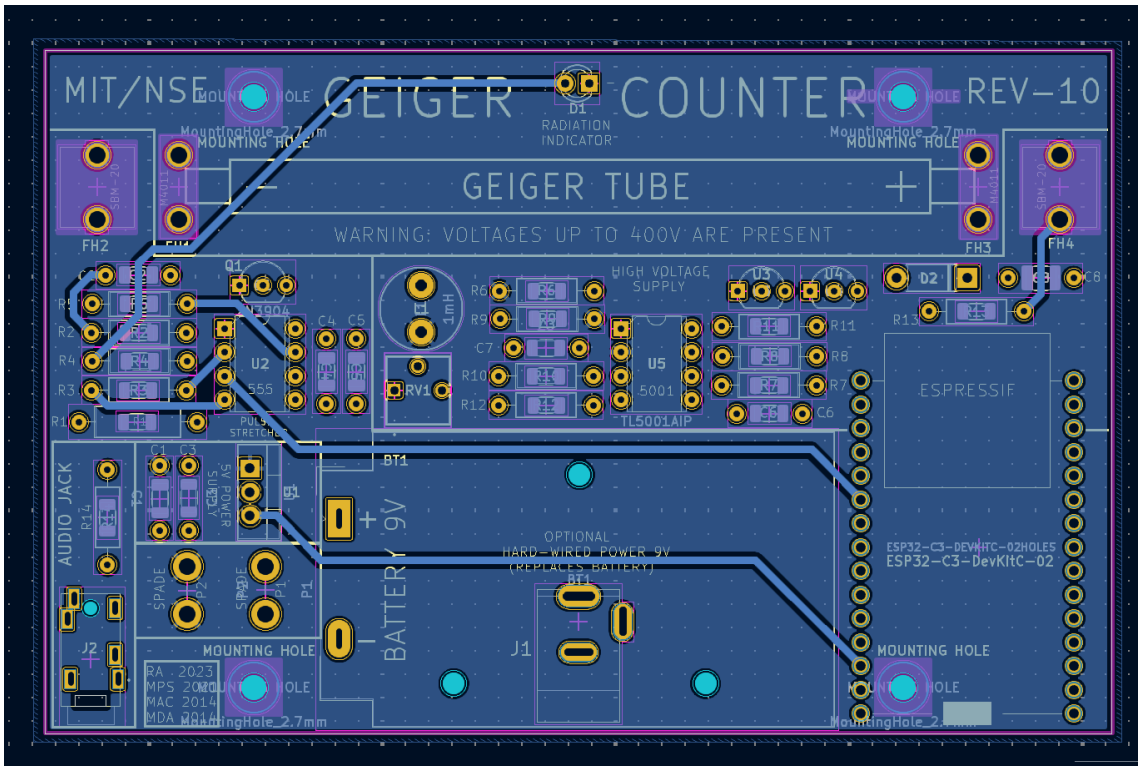
Flip the case over, and find your longer screws. Be sure to screw them in directly up and down to avoid difficulty.

Section 23: CIRCUIT REFERENCES


ESP32-C3-DevKitC-02
U6
FINAL_SIGNAL
+5V
AUDIO JACK
54-00298
J2
FINAL_SIGNAL
R14
4.7k
GND
HIGH VOLTAGE SUPPLY
RV1
R_Potentiometer_US 20k
GND
FH3 FH4
R13
5.1M
R11
10M
C8
4.7n
R10
4.7k
C7
15n
L1
1mH
D2
B4159
U4
STQ1HNK60R-AP
U3
STQ1HNK60R-AP
+9V
S001_OUT
U5
TLS001AIP
SCP
COMP
FB
DTC
RT
GND
C6
1u
R7
4.7M
R8
6.8M
R9
10k
R6
10k
PULSE STRETCHER + RADIATION INDICATOR LED
D1
LED
R4
75
R5
6.2K
C5
220n
U2
LMC555CN
VCC
TR
CV
R
THR
DIS
Q
R3
1k
C4
10n
Q1
2N3904
R2
10k
C2
47p
R1
5.1k
FH1 FH2
+5V
BATTERY OR HARD-WIRED
J1
EJ508A (PWR)
BATT+
SPADE
P1
P2
BT1
Battery
5V POWER SUPPLY
U1
NJM78M05FA
VO
VI
C3
10u
C1
10u

(Fig 61)





(Fig 62 and Fig 63)

QTY	VALUE	PARTS	DESCRIPTION
			RESISTORS (THT)
1	5.1kΩ	R1	1/2W resistor, metal film 700V
3	10kΩ	R2, R6, R9	1/4W resistor, carbon film
1	1kΩ	R3	1/4W resistor, carbon film
1	75Ω	R4	1/4W resistor, carbon film
1	6.2kΩ	R5	1/4W resistor, carbon film
1	4.7MΩ	R7	1/4W resistor, metal film, 1% (not 5%)
1	6.8MΩ	R8	0.6W resistor, carbon film, 1% (not 5%)
2	4.7kΩ	R10, R14	1/4W resistor, carbon film
1	10MΩ	R11	1/4W resistor, metal film 700V
1	22kΩ	R12	1/4W resistor, carbon film
1	5.1MΩ	R13	1/4W resistor, metal film 700V
1	20kΩ	RV1	Potentiometer, 1/2W 1.0 Turn
			CAPACITORS (THT)
2	10uF	C1, C3	MLCC in radial package with 0.1” lead spacing required
1	47pF	C2	MLCC in radial package with 0.1” lead spacing required
1	10nF = 10000pF	C4	Ceramic in radial package 100V 0.2" lead spacing required
1	220n = 0.22uF	C5	Ceramic in radial package with 0.2" lead spacing required
1	1uF	C6	Ceramic in radial package with 0.2” lead spacing required
1	15nF	C7	Ceramic in radial package with 0.15" lead spacing required
1	4.7nF	C8	Ceramic in radial package with 0.2” lead spacing required (CHV)
			INDUCTORS
1	1mH	L1	Inductor, radial package
			DIODES
1	LED	D1	Blue LED 3mm,3 3.3V
1	BA159	D2	Fast switching diode, DO-41 package required
			IC
1	NJM78M05FA	U1	Linear Voltage Regulator 5V at 500mA
1	LMC555	U2	LMC555 CMOS-based 555 timer
2	STQ	U3, U4	N Channel MOSFET 600V 400MA TO92-3
1	TL5001	U5	Power converter control chip
1	2N3904	Q1	NPN Transistor, TO-92 package
			MISC
1	SBM-20		Geiger Tube
2	DIP8		DIP SOCKET 8 pos
2	CLIPS		Fuse clips to hold SBM-20
1	BOARD		MIT-NSE Geiger Counter Board
1	CASE		Serpac enclosure, black, clear top
1	SWITCH		SPST Circular Switch
1	HOLD		9V Battery holder
1	BATT		Energizer Industrial 9V
2	SPADE		Spade Connectors
4	SCREW		#4-40x3/16” pan head thread-cutting screw
2	CONN		Female To Female spade connection wires (4.8mm)
1	AUDIO	J2	Audio Connection Jack (female) 3.5mm
			OPTIONAL
1	ESP32		ESP32-C3-DevKitC-02
2	HEADER		15 POS Female pinheader
1	PWR	J1	9V Connection Power Jack (Female) 2.1X5.5mm
1	M4011		Alternate usable geiger tube

(Fig 64)

Section 24: (Optional) ESP-32 Usage

Your ESP should be pre-loaded with software, however, if it is not, or you'd like to program it yourself, this guide should help you on how to do so. Our GC has the option of running an ESP32-C3-DEVKITC-02. This allows logging of geiger data via android apps, web apps, and desktop apps. There may be workarounds for iPhones, but developing ios apps is difficult because of Apple's policies. The final signal is routed to GPIO 4 of the ESP
To make good detection you will need to use an interrupt (code is example, will not run)

```
const int geigerPin = 4; // Define Geiger pin
pinMode(geigerPin, INPUT); // Set the pinmode of that pin
attachInterrupt(digitalPinToInterrupt(geigerPin), trigger, RISING); //Attach an interrupt to the pin
//Make a function for the interrupt to call, ie
void trigger(){
        txValue++;
}
```

Having an interrupt makes sure that code executes whenever the pin receives a signal. You will also need lots of boilerplate to send the data to whatever medium you choose. ex android. You may also be able to use the ESP as a web server, however this has not been tested thus far.

To upload to the ESP follow this guide
https://randomnerdtutorials.com/installing-esp32-arduino-ide-2-0/

You can either write code or find our examples here and open them with the arduino ide (example android app and web app to receive are also included)
https://github.com/v3ai/ALL-GEIGER-SUMMER-2024/tree/main/Web-and-Andriod

Additional troubleshooting advice:

- Connect your ESP to your computer via micro usb to usb and click Tools > Board > select ESP32C3 Dev Module
- If the board is not automatically recognized click Tools > Port and either figure out which one you're using, or just trial and error upload
- Once you click upload, you may need to hold down the boot button one the ESP until you can see it writing to memory addresses
- You need to set the baud rate to 115200 bps