Geiger Counter BC-1L

Assembly Instructions

Version 1.0

About This Kit

The BC-1L Geiger counter kit is designed as an educational electronics project that can be fully assembled from discrete, through-hole components. All circuitry is implemented using common, but high quality parts.

life with a geiger counter. Radioactivity is way more common than popular belief would suggest.

In addition to the onboard pulse indication circuitry, the kit also features a digital pulse output for connection to external counters or microcontrollers, allowing for further experimentation.

Typical assembly time is approximately 2–3 hours depending on experience level and debugging time.

Kit Information

Version:	1.0
PCB Revision:	1
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Designed for FSAR share-a-skill June 2026.

1 Introduction

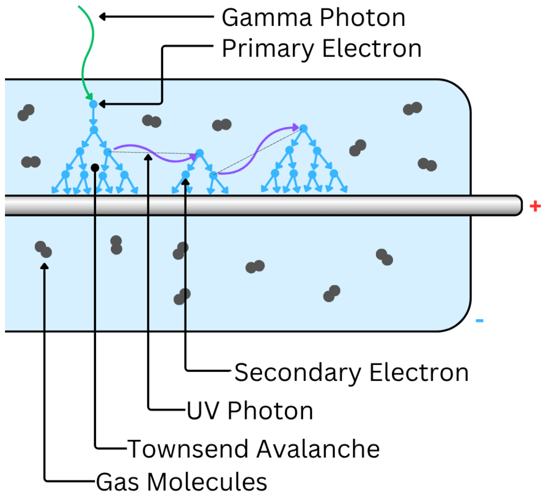
This manual guides you through assembling a fully functional a Geiger–Müller radiation detector from discrete components.

Originally developed in the early 20th century by Hans Geiger and later improved together with Walther Müller, the Geiger counter remains one of the most recognizable scientific instruments ever created. Despite its simplicity, it is capable of detecting ionizing radiation events with remarkable sensitivity.

Hans Geiger, 1928 (public domain image)

The detector's central sensing element is a Geiger–Müller tube. It is filled with a low-pressure gas mixture and operated using a high voltage applied between the cathode and a thin central anode wire.

As a gamma photon or beta particle ionizes a gas molecule inside the tube, a primary electron is released. The strong electric field accelerates the electron toward the anode wire. Along its path, it collides with additional gas molecules



Simplified structure of a Geiger–Müller tube

and frees secondary electrons that also accelerate towards the anode.

A multiplication process known as a *Townsend avalanche* forms. During the avalanche, ultraviolet photons are also emitted and may trigger additional avalanches elsewhere in the tube. A large volume of the tube is eventually ionized, producing a short current pulse as the electrons reach the anode.

A quenching gas inside the tube absorbs UV photons and terminates the discharge, allowing the detector to recover before the next event. Positive ions are accelerated toward the cathode and recombined with electrons. For clarity, this process was omitted from the illustration.

The detector built in this workshop emits the characteristic audible "click" and flashes an LED whenever a current pulse is detected.

Note

Background radiation is always present around us from natural sources such as cosmic rays and radioactive materials in the earth's crust. Even without any radioactive sample nearby, this background radiation can be detected by the counter.

2 Safety

The circuit includes a high-voltage bias supply that generates around 390 V. While the detector operates at very low current, improper handling of the circuit may still result in electric shock. Always exercise caution when working on powered circuits.

Never touch exposed conductors or components while the circuit is powered. Ensure the device is switched off and sufficient time has passed for stored charge to dissipate before working on the circuit.

Warning

Touching the high-voltage section may result in a painful electric shock. The circuit may remain charged for up to 30 seconds after the device has been powered down.

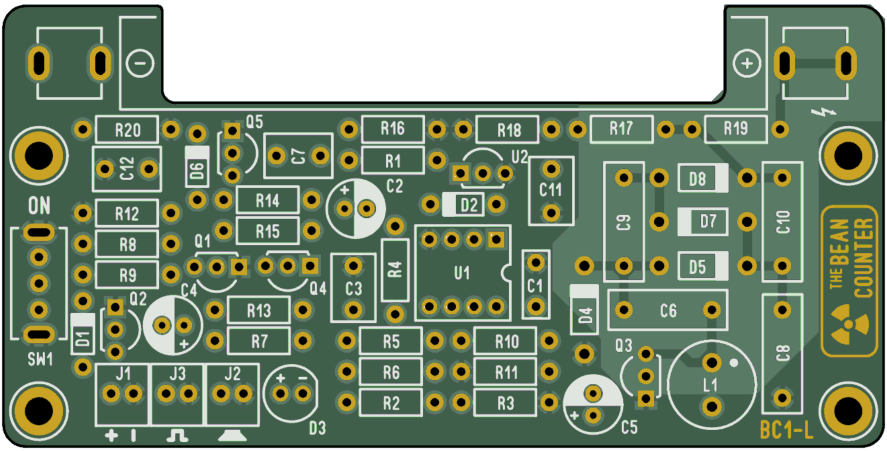
Soldering Safety

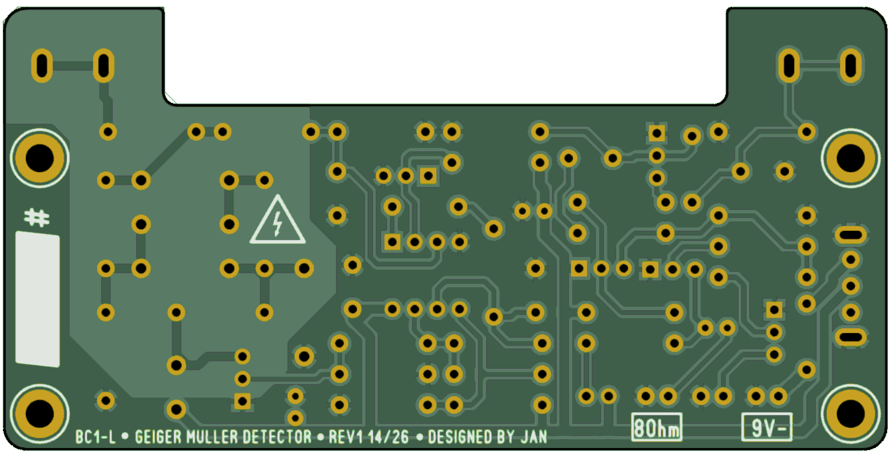
- Do not inhale soldering fumes
- Do not touch the soldering iron tip
- Do not wave the soldering iron around, as molten solder may splatter from the tip
- Be mindful of others while handling the hot iron
- Wash your hands after soldering

Note

Gently blowing the fumes away while soldering is a simple and effective way to reduce inhalation exposure.

3 PCB Overview





The PCB silkscreen (white markings) has printed designators that correspond to specific components. How to identify and mount each component will be explained step by step. Before starting the assembly process, it is recommended to write your name or initials on the textbox on the left of the back side of the board. Use the drawing above if you want to check the reference of a component that has already been installed.

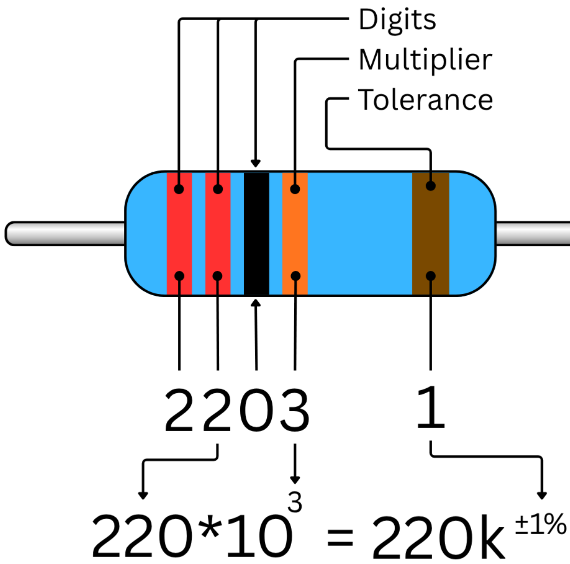
4 PCB Assembly

For ease of assembly, it is strongly recommended to follow the instructions in order. Begin with the lowest-profile components so the PCB can rest flat on the table during soldering without components falling out.

Each assembly step includes a table listing the component references and corresponding values populated during that stage.

Step 1 – Resistors

Resistors are identified using colored bands that encode their value. Each band corresponds to either a digit, a multiplier or the tolerance of the part. An example of a 220 kΩ resistor is shown below.



The digits and multipliers associated with each color are listed below.

Color	Digit	Multiplier	Color	Digit	Multiplier
Black	0	10^0	Green	5	10^5
Brown	1	10^1	Blue	6	10^6
Red	2	10^2	Violet	7	10^7
Orange	3	10^3	Grey	8	10^8
Yellow	4	10^4	White	9	10^9

Note

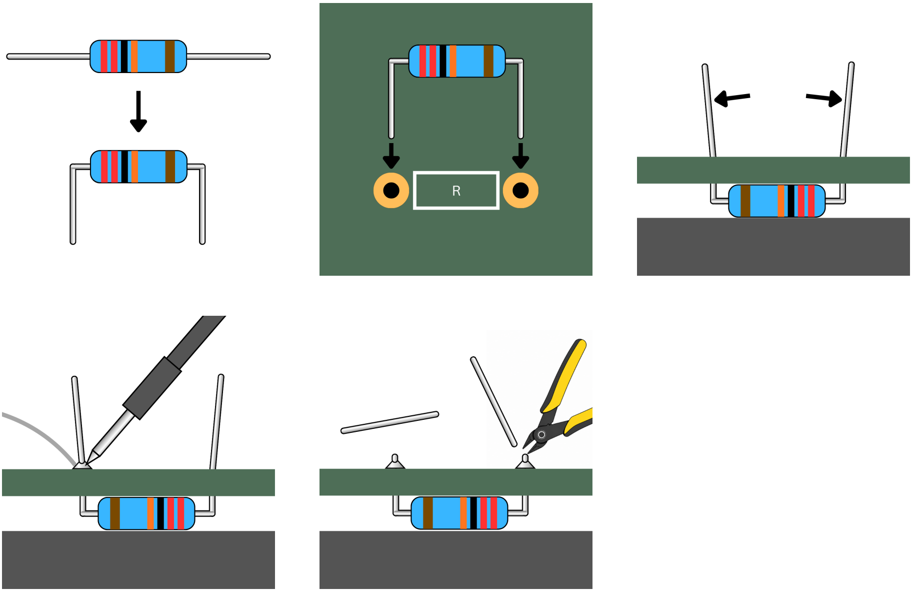
The tolerance band is the final ring and is printed slightly wider than the other rings. All resistors in this kit have a tolerance of $\pm 1\%$ and are identified by a brown tolerance band.

The resistors used in this kit feature three value bands, followed by a multiplier band and a tolerance band. Read the first three bands as digits, then multiply the result using the multiplier band to obtain the resistance value.

The resistor values used throughout the kit are listed below.

Reference	Value	Color Code
R4, R7–R11, R14	1kΩ	Brown Black Black Brown Brown
R12	10kΩ	Brown Black Black Red Brown
R2, R3, R13, R15, R16	100kΩ	Brown Black Black Orange Brown
R1, R5, R6	220kΩ	Red Red Black Orange Brown
R18	649kΩ	Blue Yellow White Orange Brown
R19	4.7MΩ	Yellow Violet Black Yellow Brown
R17	100MΩ	Brown Black Black Blue Brown
R20	1MΩ	Brown Black Black Yellow Brown

Before inserting the resistors, bend the leads to match the spacing of the PCB holes. Insert the resistor from the top side of the PCB and ensure that it sits flat against the board surface.



When inserting multiple resistors, it can be helpful to slightly bend the leads outward on the underside of the PCB to prevent components from falling out during soldering.

For soldering, place the PCB flat on the table so that all resistors remain firmly pressed against the PCB surface. Once soldered, trim the excess leads.

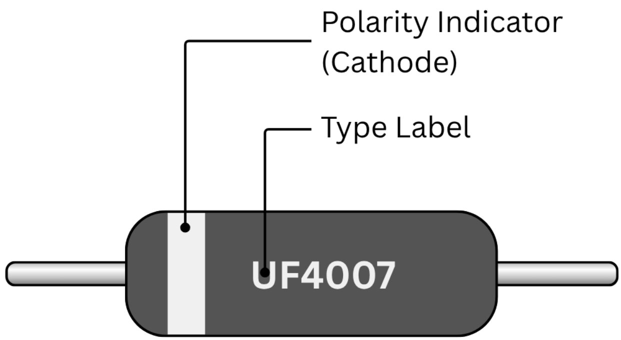
Note

Always melt fresh solder directly at the joint. Do not pre-melt solder on the iron tip, as the flux inside the solder wire will evaporate and may result in an unreliable (cold) joint.

Note

Avoid cutting through the solder joint when trimming leads, as this may weaken the connection.

Step 2 – Diodes



This board uses only two diode types, which can be distinguished easily by the color of their package without reading the printed markings.

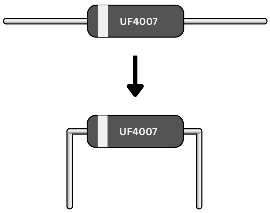
Reference	Value	Body Color
D1, D2, D6	1N4148	Brown glass body
D4, D5, D7, D8	UF4007	Black plastic body

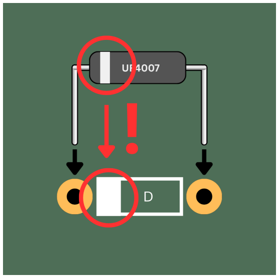
Diodes are installed in the same manner as resistors. Unlike resistors, however, diodes are polarized components and must be inserted with the correct orientation.

Before inserting a diode, align the polarity stripe on the diode body with the corresponding stripe shown on the PCB silkscreen.

Note

Double-check the diode orientation before soldering. The stripe on the diode must align with the stripe shown on the PCB silkscreen.


UF4007
UF4007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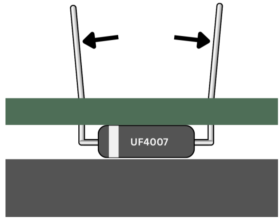
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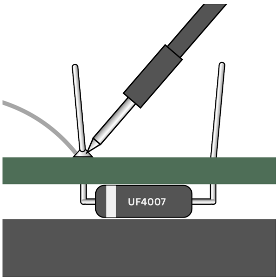
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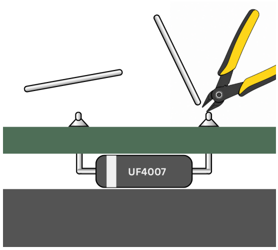

UF4007

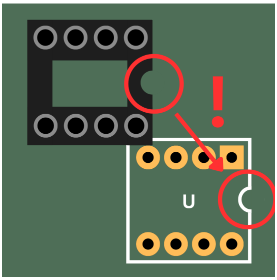
Step 3 – DIP–8 Socket

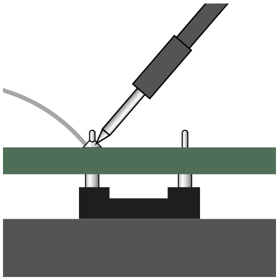
A socket is provided for IC U1. Install the socket now, but do not insert the IC until all soldering has been completed.

Reference	Value
U1	DIP–8 Socket
	MCP6542 (do not insert yet)

The DIP–8 socket features a notch on one side indicating the orientation of the IC. Align this notch with the corresponding notch shown on the PCB silkscreen before soldering.

Once inserted, place the PCB upside down on the table so the socket rests flat against the surface. Then solder all pins.





Caution

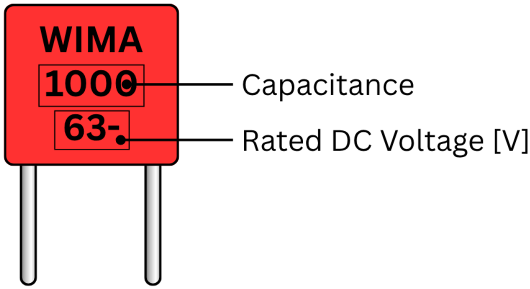
Double-check the orientation of the socket before soldering. The notch on the socket must align with the notch shown on the PCB silkscreen.

Note

Do not insert the MCP6542 into the socket yet. Wait until all soldering has been completed.

Step 4 – Film Capacitors

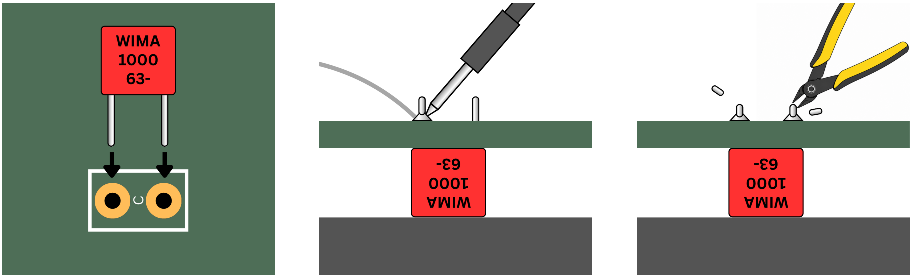
The red WIMA film capacitors used in this kit may display their values using different units depending on their capacitance.



Values below 1 nF are typically written directly in picofarads. Values containing `n` are specified in nanofarads, while values containing a decimal point without a unit are specified in microfarads.

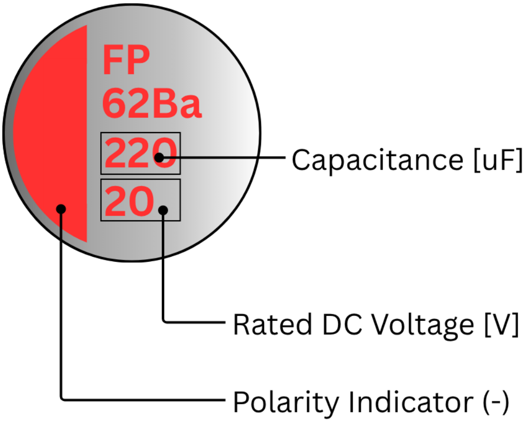
Reference	Value	Printing
C1	0.1 μF, 63V-	0.1/63-
C3, C7	1 nF, 63V-	1000/63-
C11, C12	220 pF, 63V-	220/63-
C6, C8, C9, C10	3.3 nF, 1000V-	3300/1000-

Insert the film capacitor into the PCB footprint. These capacitors are not polarized and may be inserted in any direction. Place the board on the table so the components remain pressed against the table while soldering. Trim the excess leads afterwards.



Step 5 – Polymer Capacitors

Unlike film capacitors, polymer capacitors are polarized and must be installed with the correct orientation. The polarity markings and value indicators are shown below.



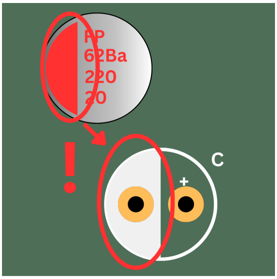
Note

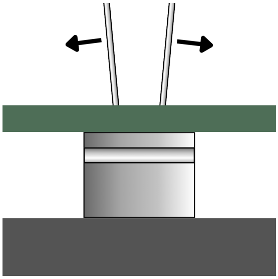
The third digit in the capacitance code is a multiplier that specifies how many zeros to add to the first two digits.

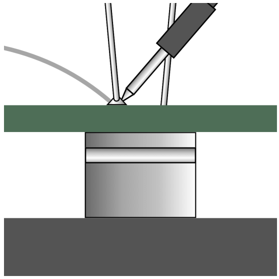
Only one polymer capacitor type is used in this build. See the value and references below.

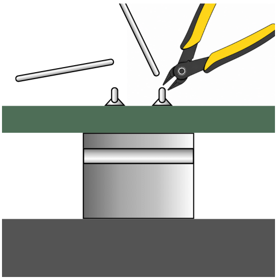
Reference	Value	Printing
C2, C4, C5	22 μF, 20V-	220 20

Install the polymer capacitors as shown below. Ensure that the polarity stripe on the capacitor aligns with the polarity marking printed on the PCB silkscreen.









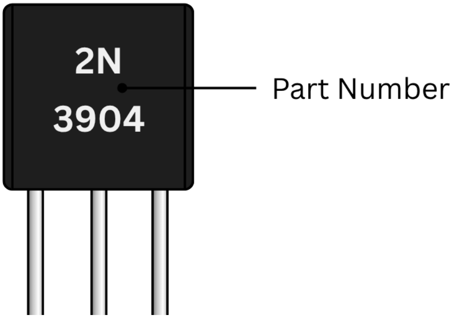
As with resistors and diodes, it can be helpful to slightly bend the wires after inserting the component, so it does not fall out while soldering.

Caution

Installing a polymer capacitor with incorrect polarity may damage the component.

Step 6 – Transistors and Voltage Reference

This build uses three transistor types as well as a voltage reference in the same TO–92 package. All devices are identified by markings printed on the flat side of the package. If you have trouble reading the marking, taking a picture with your phone may be helpful.



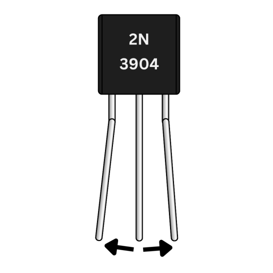
Populate the following components during this assembly step:

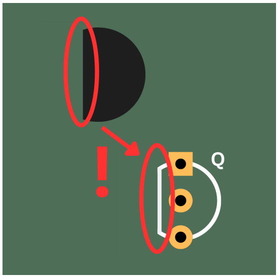
Reference	Value	Printing
Q1, Q2, Q5	2N3904	2N3904
Q4	2N3906	2N3906
Q3	MPSA42	CMPS42
U2	LM385BZ–2.5	LM385

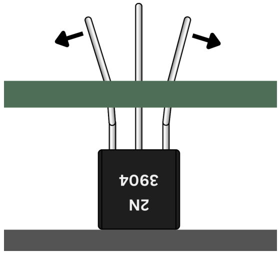
Before insertion, gently bend the leads to match the footprint on the PCB. Insert the devices from the top side of the PCB and ensure that the package sits close to the board surface, but not completely flush against it.

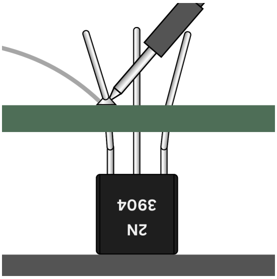
Caution

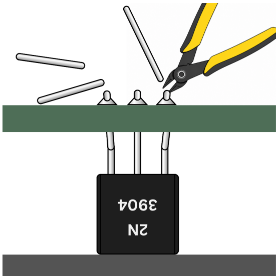
Although these components share the same package, they are not interchangeable. Inserting the wrong part may damage the component.











Ensure that the flat side of the package aligns with the silkscreen marking. Slightly bending the leads after insertion can help with holding the component in place while soldering. Trim the excess wires afterwards.

Caution

Align the flat side of the package with the outline printed on the PCB silkscreen. Installing a device backwards may damage it.

Note

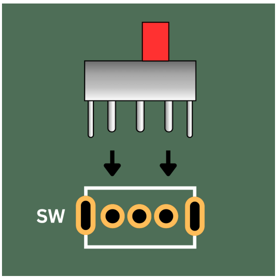
Avoid heating the leads for more than a few seconds at a time. If additional soldering is required, please allow the component to cool briefly before reheating.

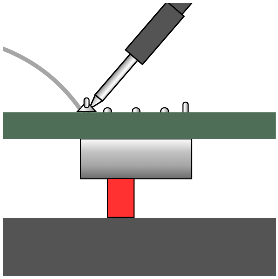
Step 7 – Switch

The slider switch serves as the main power switch for the Geiger counter. Insert the switch from the top side of the PCB and verify that all pins are fully seated before soldering.

Reference	Value
SW1	SPDT Slider Switch

To prevent mechanical damage from operating the switch, it should sit flush against the PCB surface. It is also helpful to double check correct seating of the component after soldering the first joint.





The switch is not polarized and may be inserted in any orientation.

Note

Ensure the switch sits flat against the PCB before soldering, as correcting the alignment afterwards can be difficult.

Note

You may use the flat side of the iron tip against the wider side legs of the switch to deliver more heat while soldering.

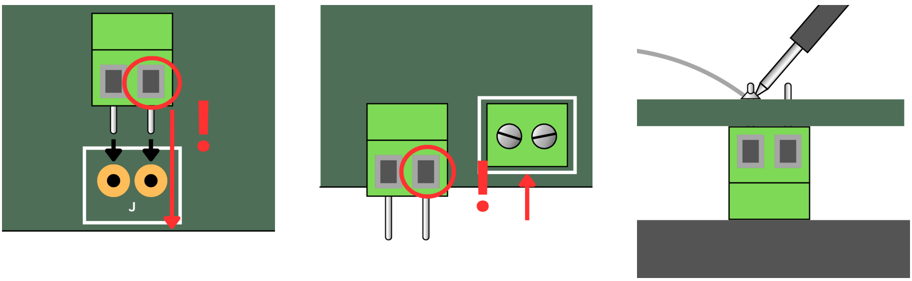
Step 8 – Terminal Blocks

Terminal blocks are used to connect the PCB to external circuitry. There are three terminal blocks on the PCB:

Reference	Value
J1, J2, J3	2–Pin 2.54mm Terminal Block

Mount the terminal blocks in the locations marked J1, J2, and J3 as shown below. Pay close attention to their orientation before soldering: the side used to insert and tighten the wires should face toward the outer edge of the PCB.

Ensure that each terminal block sits flat against the PCB with both pins fully inserted through the board. A good approach is to solder one pin first, check that the connector is straight and properly aligned, and then solder the remaining pin.



Note

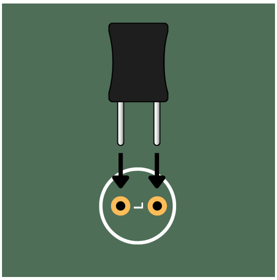
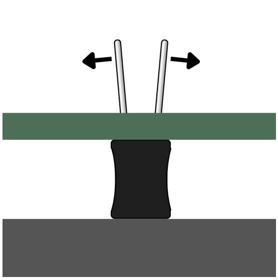
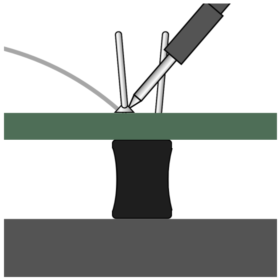
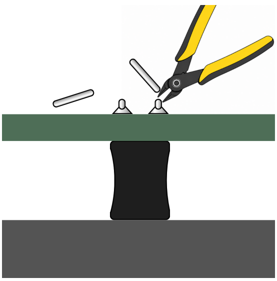
Double check correct orientation, as terminal blocks can be difficult to remove once soldered.

Step 9 – Inductor

The inductor is part of the high-voltage power supply used to generate the Geiger tube bias voltage. The inductor is not polarized and may be inserted in either orientation.

Reference	Value	Printing
L1	22mH	223

Insert the inductor from the top side of the PCB and ensure that it sits close to the board surface before soldering. You may find it helpful to slightly bend the leads to lock it into place while soldering.

Note

The inductor body is mechanically more fragile than most other components. Avoid applying excessive force when bending the leads.

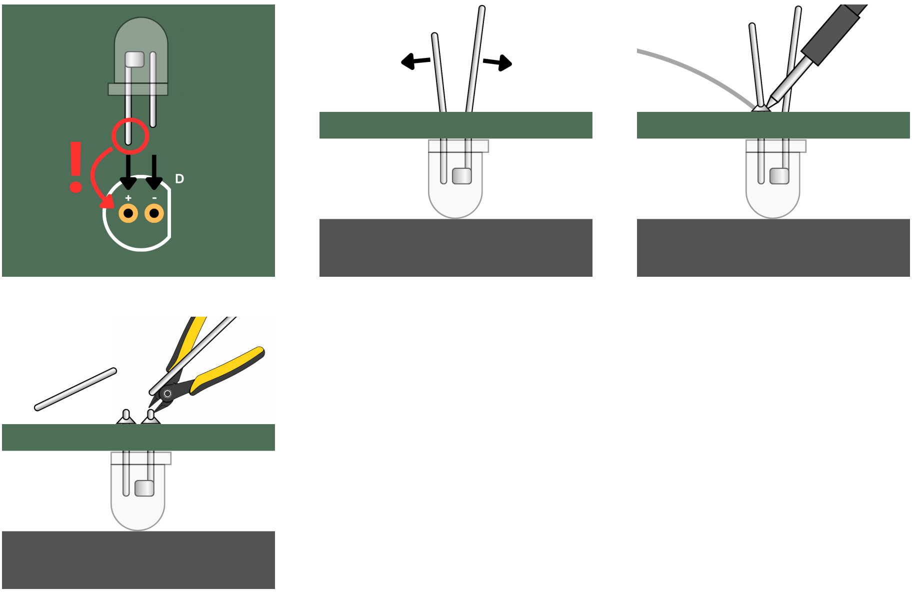
Step 10 – LED

A LED is used to visually indicate radiation events. Install the LED in the position marked D3. Only one type of LED is used.

Reference	Value
D3	LED, amber, clear body

LEDs are polarized components, so orientation is important. The long lead (anode) should align with the + mark on the PCB silkscreen, while the short lead (cathode) should align with the - side. The flat edge of the LED body also indicates the cathode side and should match the flat edge shown in the silkscreen outline.

Insert the LED so that it sits flush with the PCB, then gently bend the leads outward on the underside of the board to hold it in place during soldering. Once aligned, solder both leads and trim the excess wire close to the solder joints.

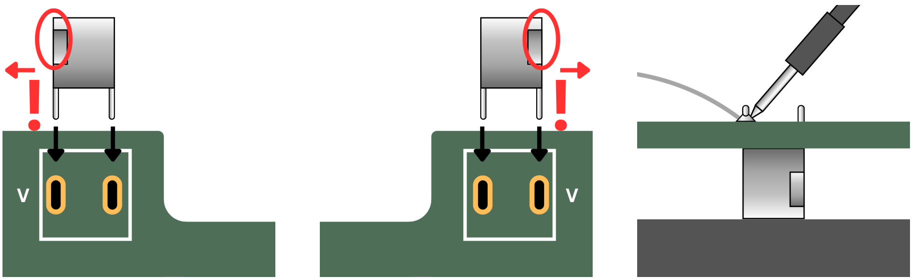


Step 11 – Geiger Tube

It is now time to install the heart of the geiger counter – the Geiger–Müller tube. The tube itself is mounted using two spring socket holders.

Reference	Value
V1	J321

Begin by installing the two tube holders into the PCB. Pay careful attention to their orientation before soldering. The indent on each holder should face toward the outer edge of the PCB, away from both the tube outline and the PCB cutout. Ensure that both holders sit fully flush against the board before soldering the pins in place.



Note

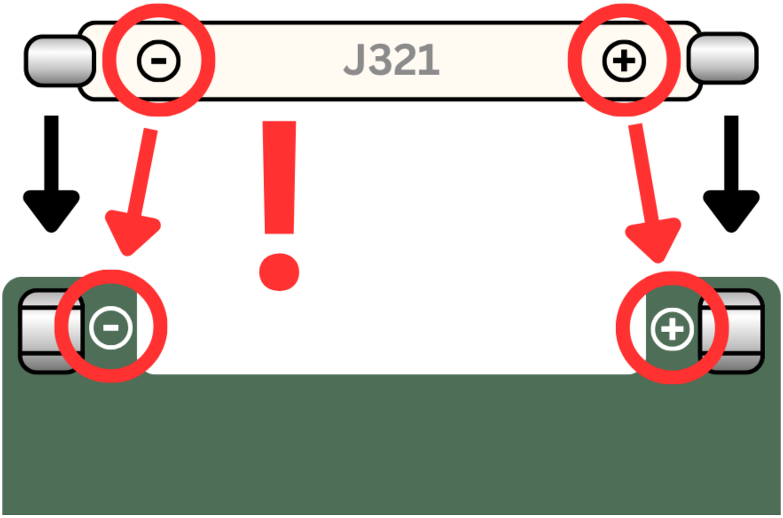
Double check the orientation of the tube holders before soldering. Removing them after installation can be extremely difficult without damaging the PCB.

Once the holders are soldered, install the Geiger tube by gently pressing it into the sockets as shown below. Apply light and even pressure while inserting the tube. Avoid twisting it during installation. If necessary, the socket contacts can be gently bent outward beforehand to reduce insertion force.

Caution

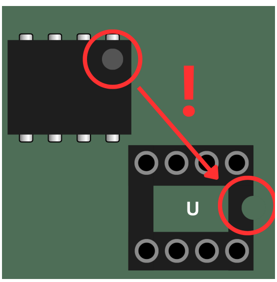
The glass body of the tube is fragile and can crack if excessive force is applied. Press on the metal end contacts and use gentle, even pressure during installation. If the tube does not snap into place easily, do not force it.

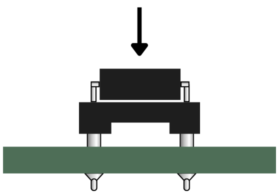
The Geiger tube itself is polarized. The cathode and anode ends must align with the markings on the PCB silkscreen as shown below.



Step 12 – Install DIP-8 IC

Insert the MCP6542 dual comparator IC (U1) into the previously mounted socket. Ensure to align the dot on the device with the notch on the socket. Gently push the chip into place. If the pins initially don't line up, you may gently bend them by positioning the pins on a flat surface and rotating the device.





Caution

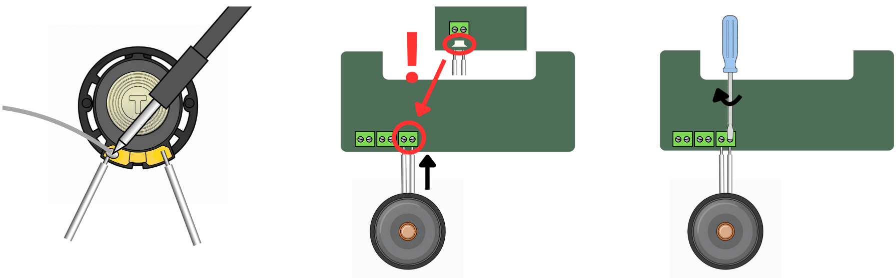
Double check that the chip was inserted with correct polarity. Inserting it in reverse order can destroy the chip.

Step 13 – Loudspeaker

The loudspeaker is connected to the PCB using the pre-tinned wires included with the kit. Begin by soldering the wires to the speaker terminals as shown below. Only solder to the outer connection pads of the speaker terminals — applying heat to the inner pads can desolder the delicate voice coil wires inside the speaker and permanently damage it.

Note

Avoid heating the speaker excessively. If additional soldering is required, allow the component to cool briefly before reheating.



Once the wires are attached, insert the wire ends into terminal block J2 (identified on the PCB silkscreen with a speaker icon) and tighten the screws using a small flat-head screwdriver. Tighten the screws gently — do not overtorque the terminal block. After tightening, gently tug each wire to confirm that it is securely clamped in place.

Note

The back of the loudspeaker is magnetic and may attract the soldering iron. You may want somebody to hold the speaker in place while soldering.

Caution

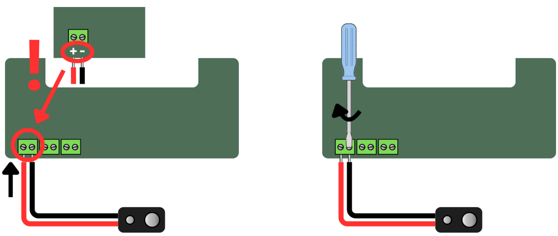
Only solder on the outside connection pads of the speaker terminals. Soldering on the inside can desolder the speaker coil wires and cause permanent damage.

Step 14 – Battery

Connect the battery clip by inserting the wire ends into terminal block J1. Ensure that the red wire is connected to the terminal marked with the + icon on the PCB silkscreen, while the black wire is connected to the terminal marked with the - icon.

Once the wires are fully inserted, fasten them in place by tightening the screws on the top side of the terminal block using a small flat-head screwdriver. Tighten the screws gently until the wires are securely clamped – avoid overtightening.

After tightening, gently tug each wire to confirm that it is properly secured.



Note

Double check polarity before connecting the battery. The red wire should connect to + and the black wire to -. If polarity is reversed the device will not turn on.

5 Bring-Up and Testing

It is now time to test the Geiger counter circuit for the first time. Connect the 9V battery to the battery clip and move the power switch to the ON position.

After a short moment, the circuit should begin operating. You should observe occasional flashes from the LED accompanied by corresponding clicks from the loudspeaker. Depending on background radiation levels, the click rate may vary from one environment to another. If the circuit does not appear to function, switch the board off and refer to the troubleshooting suggestions below before continuing.

Warning

Danger of electric shock. The Geiger counter generates high voltage during operation. Always switch the board off and wait a minimum of 30 seconds before performing rework, allowing the capacitors time to discharge.

Note

If you are struggling to find an issue, feel free to ask for debugging assistance.

Common Issues

If the board does not power up correctly, carefully inspect the following:

- Check that all solder joints are properly wetted (no cold solder joints).
- Inspect the PCB for solder bridges between joints.
- Ensure the battery clip wiring polarity is correct.
- Verify the orientation of all polarized components, including diodes, electrolytic capacitors, transistors, and the Geiger tube (see page 6).
- Double check resistor and capacitor values against the bill of materials.

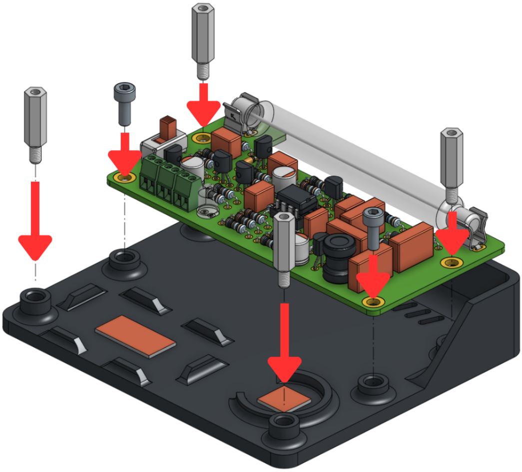
Caution

If you notice that any component starts to heat up, immediately disconnect the battery and ask for debugging assistance.

6 Enclosure Assembly

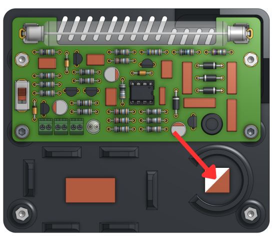
Install the PCB

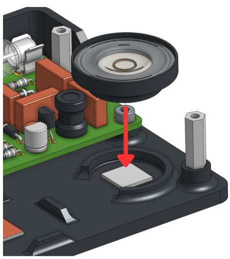
Place the assembled PCB onto the standoffs inside the enclosure. Secure it using two hex bolts and two hex standoffs, as shown in the image below. Then install the remaining two hex standoffs into the threaded inserts at the back of the enclosure.

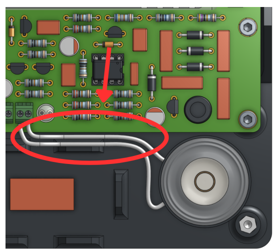


Install the Loudspeaker

Remove the protective film from the adhesive pad in the mounting area. Press the loudspeaker into place as shown below. Align the speaker terminals with the cut out section. Route the speaker wires along the edge of the PCB.

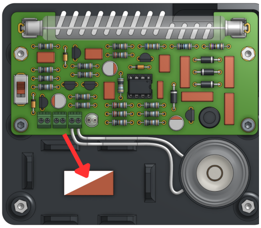


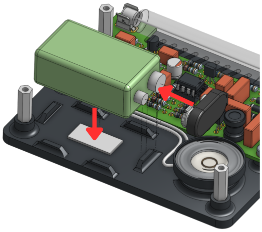


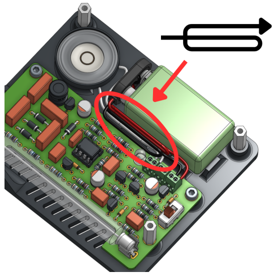


Install the Battery

Remove the protective film from the adhesive strip on the battery mount. Connect the battery to the PCB, then place it onto the adhesive pad as shown below. Create a single loop in the battery wires and route them along the edge of the PCB.

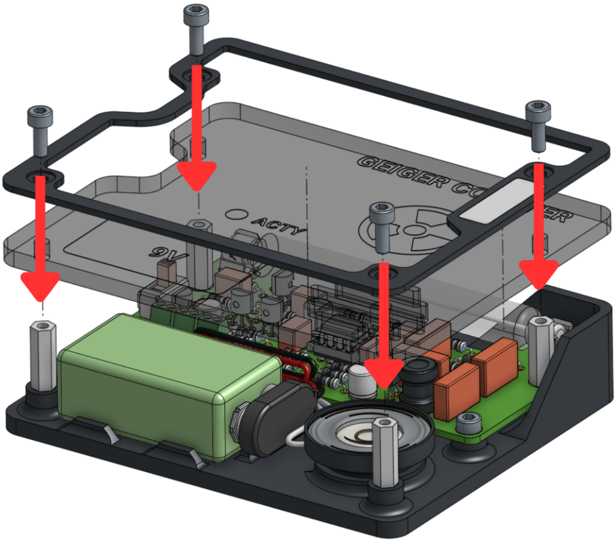






Complete the Assembly

Place the acrylic cover and frame onto the four standoffs. Secure the assembly using four hex bolts, as shown below. Avoid overtightening the bolts.



7 Experiments

Background Radiation

Measure the background radiation by counting the radiation events over time. A good approach is to measure over multiple one minute intervals and then compute the mean counting rate.

Background radiation is usually specified in equivalent dose rate and typically around $0.12\,\mu\text{Sv/h}$. Compute the equivalent dose rate from your measurement.

Note

Equivalent dose rate depends strongly on the type and energy of the radiation. Commercial detectors are commonly calibrated using gamma radiation emitted by a ^{137}Cs source at 661.7 keV.

Note

For ^{137}Cs gamma radiation, the J321 tube used in this kit has an approximate sensitivity of 154 CPM (counts per minute) per $\mu\text{Sv/h}$.

You may find that background radiation can fluctuate strongly depending on where you measure it. Particularly interesting may be:

- Basements
- Granite rock formations
- An airplane at altitude
- Eastern Saxony and western Czech Republic

Radioactive Antiques

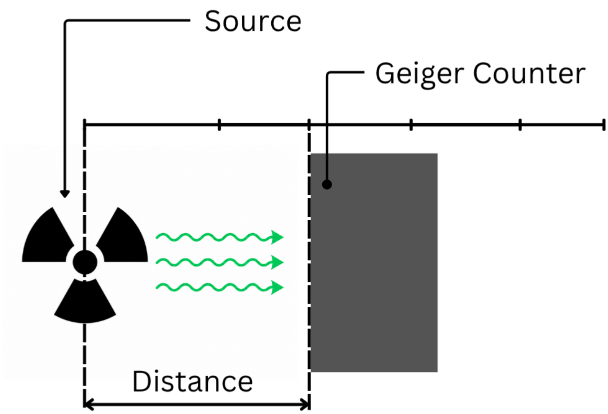
A Geiger counter can make visits to antique shops and flea markets particularly interesting. Certain vintage items may contain naturally radioactive materials that can be detected easily with the kit. Common examples include green uranium glass, orange or red ceramic glaze and old camera lenses.

Warning

Use extreme caution when encountering antique radioactive watch dials, instrument gauges or compasses. Those items may expose you to a significant radiation dose and can release toxic radioactive dust when opened.

Attenuation by Distance

Place a weak radioactive object, such as a piece of uranium glass, near the Geiger tube and measure the count rate over one minute. Repeat the measurement while gradually increasing the distance between the object and the detector. Plot count rate over distance.



You should see the measured intensity I decrease approximately according to the *inverse square law* with respect to the distance r from the source.

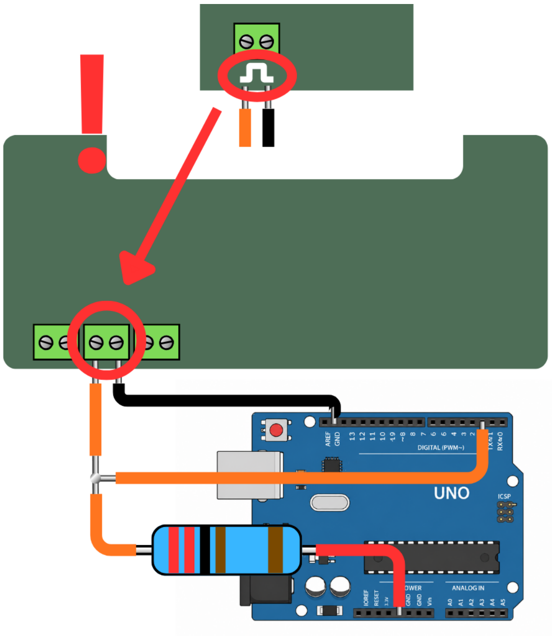
$$I \propto \frac{1}{r^2} \qquad \text{Inverse square law}$$

8 Expansion

The circuit features an open-collector pulse output for connecting auxiliary circuitry. This allows the Geiger counter to interface with devices such as microcontrollers.

An example connection to an Arduino UNO-type controller board is shown below. Connect a 2.2 kΩ pull-up resistor between the +5 V supply and the pulse output. The open-collector output is then connected to digital pin 2 of the Arduino UNO. Also ensure that the grounds of both systems are connected together.

Each detected radiation event generates a short pulse that pulls the output low for approximately 100 µs.

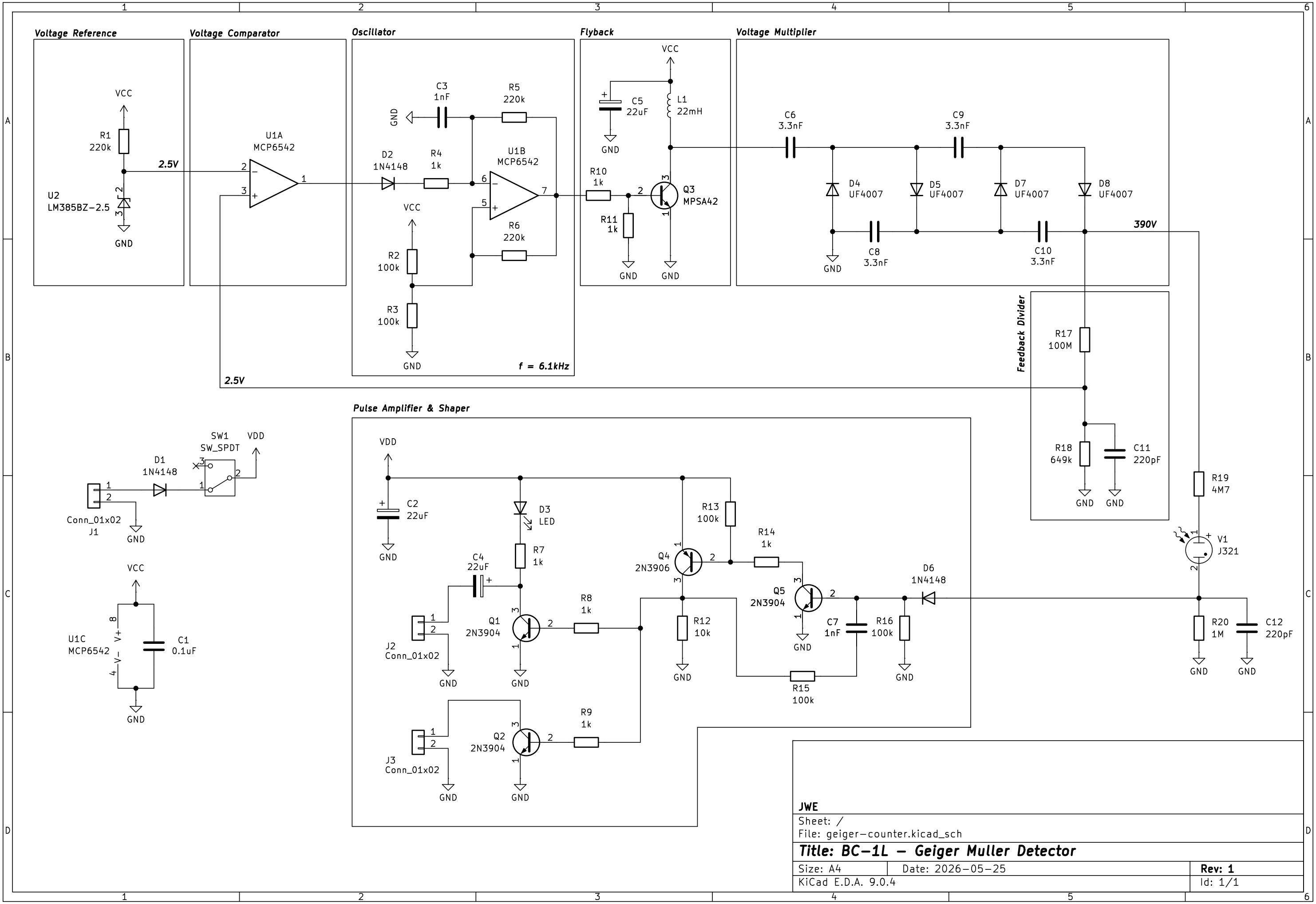


A simple example program using the Arduino IDE is shown below. The code counts incoming pulses using a hardware interrupt and prints the number of detected events every 10 seconds.

```
volatile unsigned int counts = 0;

void pulseISR() {
    counts++;
}

void setup() {
    Serial.begin(9600);

    pinMode(2, INPUT_PULLUP);

    attachInterrupt(
        digitalPinToInterrupt(2),
        pulseISR,
        FALLING
    );
}

void loop() {
    static unsigned long lastPrint = 0;

    if (millis() - lastPrint >= 10000) {
        lastPrint = millis();

        Serial.print("Counts per minute: ");
        Serial.println(counts*6);

        counts = 0;
    }
}
```

9 Appendix

The complete circuit diagram and bill of materials are shown on the next pages.


Voltage Reference
Voltage Comparator
Oscillator
Flyback
Voltage Multiplier
Feedback Divider
Pulse Amplifier & Shaper
VCC
R1
220k
2.5V
U2
LM385BZ-2.5
GND
U1A
MCP6542
C3
1nF
R5
220k
D2
1N4148
R4
1k
U1B
MCP6542
R6
220k
R2
100k
R3
100k
f = 6.1kHz
C5
22uF
L1
22mH
R10
1k
R11
1k
Q3
MPSA42
C6
3.3nF
C9
3.3nF
D4
UF4007
D5
UF4007
D7
UF4007
D8
UF4007
C8
3.3nF
C10
3.3nF
390V
R17
100M
R18
649k
C11
220pF
R19
4M7
V1
J321
R20
1M
C12
220pF
D1
1N4148
SW1
SW_SPDT
VDD
J1
Conn_01x02
U1C
MCP6542
C1
0.1uF
C2
22uF
D3
LED
R7
1k
C4
22uF
Q1
2N3904
R8
1k
J2
Conn_01x02
Q2
2N3904
R9
1k
J3
Conn_01x02
Q4
2N3906
R13
100k
R14
1k
Q5
2N3904
R12
10k
R15
100k
C7
1nF
R16
100k
D6
1N4148
JWE
Sheet: /
File: geiger-counter.kicad_sch
Title: BC-1L - Geiger Muller Detector
Size: A4
Date: 2026-05-25
Rev: 1
KiCad E.D.A. 9.0.4
Id: 1/1

Reference	Count	Part	Value	Part Number	Supplier
C1	1	Capacitor (Film)	0.1uF, 63V-	MKS2C031001A00KSSD	WIMA
C2, C4, C5	3	Capacitor (Polymer)	22uF, 35V-	RNS1D220MDS1	Nichicon
C3, C7	2	Capacitor (Film)	1nF, 63V-	FKP2C011001D00HSSD	WIMA
C6, C8, C9, C10	4	Capacitor (Film)	3.3nF, 1000V-	MKS4O113303C00KSSD	WIMA
C11, C12	2	Capacitor (Film)	220pF, 63V-	FKP2C002201D00JSSD	WIMA
D1, D2, D6	3	Silicon Diode	100V-, 0.3A	1N4148	Diotec
D3	1	LED	587–593nm	C503B-AAN-CA0C0342	CREE
D4, D5, D7, D8	4	Silicon Diode	1000V-, 1A	UF4007	DC Comp.
J1, J2, J3	3	Connector	2.54mm 2 Pos	XY308-2P 2.54MM GREEN	Xinya
L1	1	Inductor	22mH, 110mA	RLB9012-223KL	Bourns
Q1, Q2, Q5	3	NPN Transistor	60V-, 200mA	2N3904	CDIL
Q3	1	NPN Transistor	300V-, 500mA	MPSA42	CDIL
Q4	1	PNP Transistor	40V-, 200mA	2N3906	CDIL
R1, R5, R6	3	Resistor	220k, 0.6W	MBB02070C2203FCT00	Vishay
R2, R3, R13, R15, R16	5	Resistor	100k, 0.6W	MBB02070C1003FCT00	Vishay
R4, R7–R11, R14	7	Resistor	1k, 0.6W	MBB02070C1001FCT00	Vishay
R20	1	Resistor	1M, 0.6W	MBB02070C1004FCT00	Vishay
R12	1	Resistor	10k, 0.6W	MBB02070C1002FCT00	Vishay
R17	1	Resistor	100M, 1.2W	HVA12FA100M	Stackpole
R18	1	Resistor	649k, 0.6W	MRS25000C6493FCT00	Vishay
R19	1	Resistor	4.7M, 0.6W	MBB02070C4704FC100	Vishay
SW1	1	Switch	SPDT, 0.5A, 50V-	SLW-121586-5A-D	Same Sky
U1	1	Dual Comparator	—	MCP6542	Microchip
U1-SKT	1	Socket	DIP-8	PZ8AW	ECON
U2	1	Voltage Reference	2.5V, 1.5%	LM385BZ-2.5	TI
V1	1	Geiger Tube	360–440V	J321	—
V1-SKT	2	Socket	6mm	3517	Keystone

Circuit Description

The Geiger–Müller tube requires several hundred volts to operate. To generate this bias voltage, a burst-mode boost converter topology was implemented.

A relaxation oscillator generates a 6.2 kHz square-wave signal that drives the MPSA42 transistor. When the transistor turns on, current flows through inductor L1, storing energy in its magnetic field. When the transistor switches off, the magnetic field collapses and the stored energy is released as a high-voltage pulse. This pulse is applied to a Cockcroft–Walton voltage multiplier, increasing the voltage to approximately 390 V.

The multiplier output voltage is monitored using a high-impedance divider formed by R17 and R18. Comparator U1A compares the sensed voltage against a fixed 2.5 V reference generated by U2. Once the output exceeds the desired threshold, the comparator output goes high. Through diode D2, this applies a voltage to the timing capacitor of the relaxation oscillator, forcing it inactive and temporarily disabling the converter.

As the output voltage falls below the threshold, the comparator output returns low and the oscillator resumes operation. This effectively implements a bang-bang style control loop. Capacitor C11 introduces hysteresis into the control law, increasing delay between bursts and improving conversion efficiency. Hysteresis is acceptable because the bias voltage stays in the tubes plateau region, therefore not strongly affecting sensitivity.

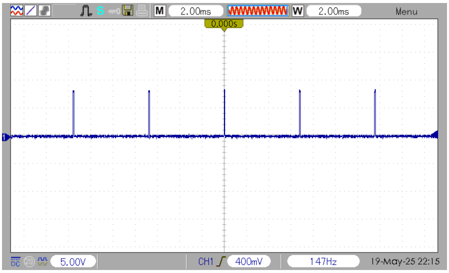
When the Geiger–Müller tube detects ionizing radiation, it briefly conducts and produces a current pulse through resistor R19. The voltage across the tube drops sharply as the current through R19 increases, extinguishing the avalanche inside the tube. The current pulse is integrated on C12.

The transistor Q5 then begins to conduct as base current is supplied, which in turn switches on Q4. Current now flows through Q4, charging C7 through R15. This causes additional current to flow through the base of Q5, keeping it conducting. The counting event is extended to approximately 100 μs.

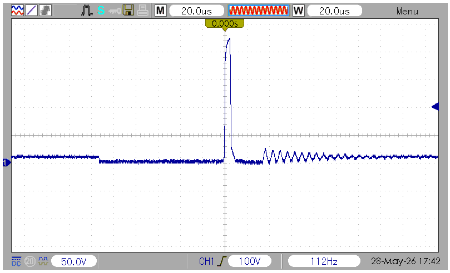
As C7 charges, the base current into Q5 gradually decreases until the transistor stops conducting. Capacitor C7 then discharges through R12. This produces a negative voltage across R16, rapidly turning off both Q5 and Q4, generating a falling edge.

When Q4 is conducting, it also allows base current to flow into Q1 and Q2. Transistor Q1 discharges C4 through the loudspeaker, generating an audible click. Capacitor C4 is then recharged through D3, lengthening the visible LED flash. Transistor Q2 provides the open-collector digital pulse output.

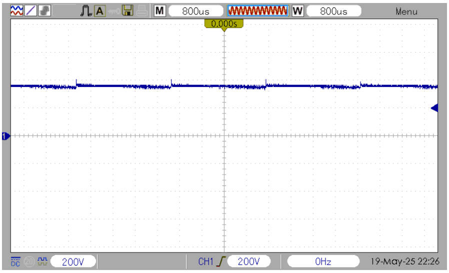
Flyback Waveforms



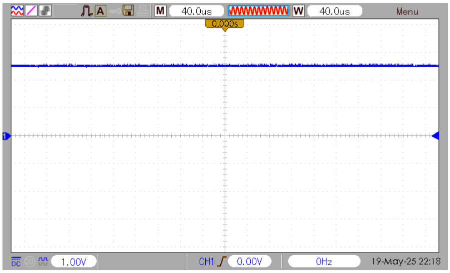
Oscillator Output (U1B)



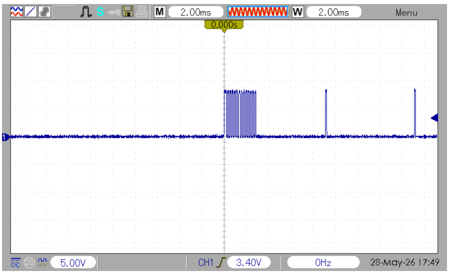
Flyback Node Voltage (Q3 Collector)



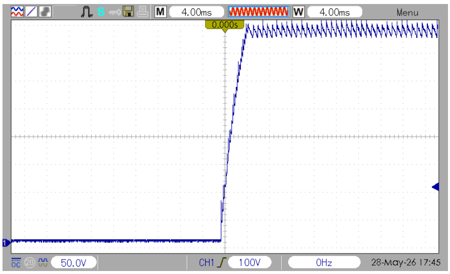
Multiplier Output Voltage (D8)



Feedback Voltage (U1A Non–Inv. Input)

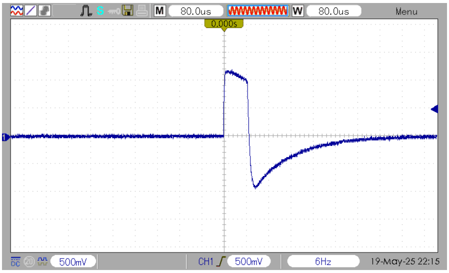


Oscillator Startup (U1B)

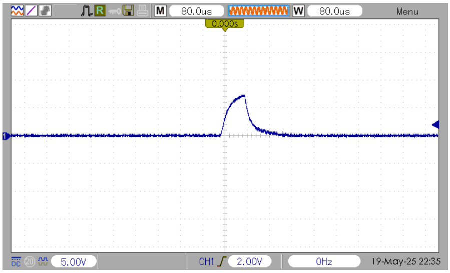


High-Voltage Startup (D8)

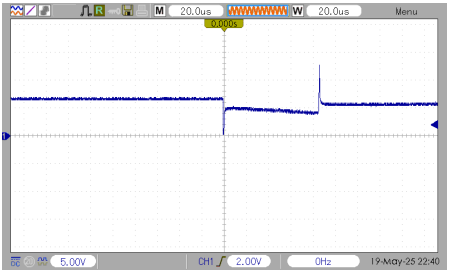
Impulse Waveforms



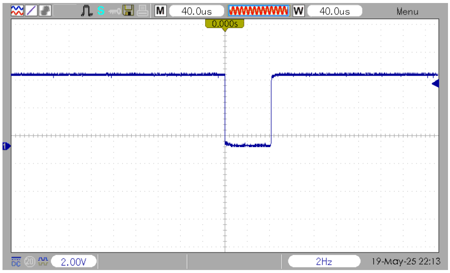
Pulse Integrator Voltage (C12)



Monostable Timing Voltage (C7)



Clicker Drive Voltage (Q1 Collector)



Digital Pulse Output (Q2 Collector)

A 2.2 kΩ pull-up resistor was connected between the Q2 collector and an external +5 V supply to obtain the digital pulse output waveform.

Caution

Never connect a 1:1 oscilloscope probe directly to the high-voltage section of the circuit. Always use an attenuating probe (e.g. 10:1 or 100:1) and verify that neither the probe nor the oscilloscope input rating will be exceeded.

Notes

"One never notices what has been done;

one can only see what remains to be done."

– Marie Curie