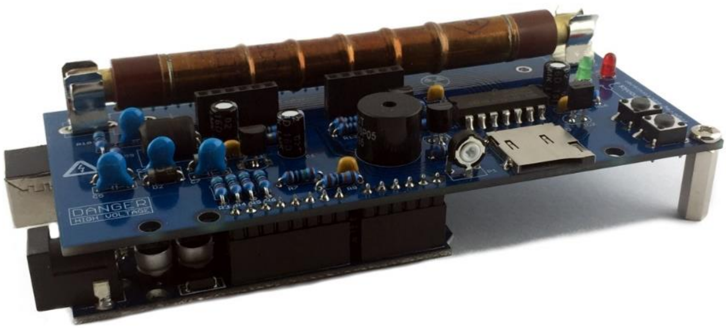
Instructions

Geiger Counter Shield for Arduino

V2.1



Safety Notes

This circuit design includes a step-up converter which can generate voltages up to 500 VDC. You are responsible for the safety during the assembly and operation of this device. DO NOT USE IF YOU DON'T KNOW HOW TO HANDLE HIGH VOLTAGES. All assembly and safety instructions should be read carefully before the device is operated.

We do not guarantee that the radiation readings you may see, or may not see, on the display are correct. You are fully responsible for your safety and health in high radiation areas.

Disclaimer

The information in this document is provided "as is" without any warranty of any kind and is subject to change without notice. You are responsible for the safety during the assembly and operation of this device. "My Electronics" takes no responsibility for any damage to property, personal injury or death. In no event shall "My Electronics" be liable to you or any third parties for any special, indirect, or consequential, or any other damages resulting from assembly or operation of this kit. When you buy the kit you agree with the disclaimer.

All applicable UL, IECEE, VDE and local regulations must be considered.

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Product Description

The Geiger Counter Shield allows you to detect nuclear radiation with your Arduino. The kit is designed for the SBM-20 tube but also supports a variety of other Geiger tubes. The kit has visual and sound indication of radiation and can be used as detector for dangerous radiation levels or radioactive materials. The shield is equipped with an LCD to display a CPS bargraph, averaged CPM and dose-rate readings. Data can be logged via the serial port or to a microSD card via the on-board microSD interface.

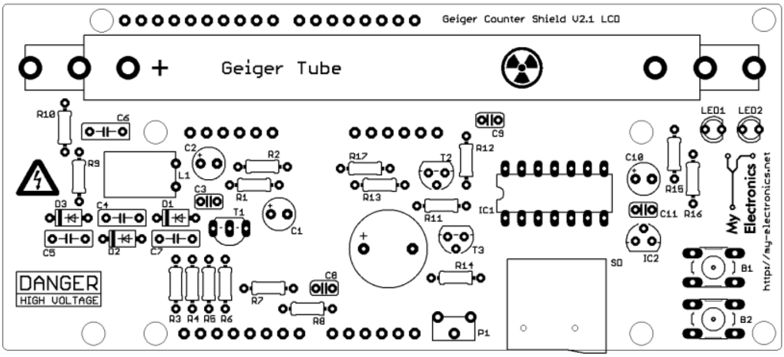
Features

- Compatible with Arduino UNO and MEGA
- Sensitive to beta and gamma radiation
- Support for the most common Geiger tubes: SBM-20, J305, STS-5, …
- HV step-up converter with feedback regulation, adjustable from 300-600 V
- Reliable up to 1 mSv/h
- Buzzer and two LED's for indication of detection events and alerts
- LCD display CPS bargraph, averaged CPM and dose-rate
- Two buttons for controlling the software
- The data can be logged via the serial port or on a microSD card
- Easy to build
- Programmable using the Arduino IDE

Assembly Instructions

To build this kit, you should know how to solder. If you have never soldered before, we recommend the Soldering is Easy tutorial.

Board Layout



Parts List

Qty.	Part	Value/Description
1	R1	10 Ω
4	R2, R12, R15, R16	1 kΩ
6	R3-R7, R10	10 MΩ
2	R8, R9	100 kΩ
3	R11, R13, R14	10 kΩ
1	R17	220
4	D1-D3	UF4007
1	T1	MPSA44
2	T2, T3	2N3904
1	L1	10 mH
3	C1, C2, C10	100 µF, 10 V
2	C3, C11	100 nF
4	C4-C7	10 nF, 1 kV
2	C8, C9	100 pF
2	B1, B2	Button
1	LED1, LED2	3 mm LED
1	IC1	3.3 V Voltage Regulator
1	IC2	74HC125 Quad Buffer
1	P1	10 kΩ, Potentiometer
1	SD	microSD Socket
1		16x2 HD44780 LCD
2		6.3 mm Fuse Holder
1		Buzzer
3		Pin Header 1x6
2		Pin Header 1x8
1		Pin Header 1x10
2		Female Header 1x6
2		Standoff 15 mm, M3
4		Standoff 12 mm, M3
10		Pan-Head Screw, M3
1		Piece of Electrical Tape

First, check if all listed parts are included in your package. Note that the diodes D1-D3, the LEDs, the capacitors C1, C2, C10 and the buzzer have polarity and need to be soldered in the right direction. We recommend to start soldering the flat components. Start with the resistors R1-R17 and the diodes D1-D3 followed by the capacitors C3, C8, C9, C11. Then solder the microSD socket, the buttons B1, B2 and the LEDs. Then solder IC1, the transistors T1-T3, IC2 followed by the capacitors C4-C7, C1, C2, C10 and the inductivity L1. Finally solder the headers for the LCD, the buzzer and the fuse holders for the Geiger tube.

The table below lists the required resistors and their corresponding color codes:

Part	Value	1st	2nd	3rd	4th	5th
R1	10 Ω	Brown	Black	Black	Gold	Brown
R2, R12, R15, R16	1 kΩ	Brown	Black	Black	Brown	Brown
R3-R7, R10	10 MΩ	Brown	Black	Black	Green	Brown
R8, R9	100 kΩ	Brown	Black	Black	Orange	Brown
R11, R13, R14	10 kΩ	Brown	Black	Black	Red	Brown
R17	220 Ω	Red	Red	Black	Black	Brown

The assembled PCB is shown below

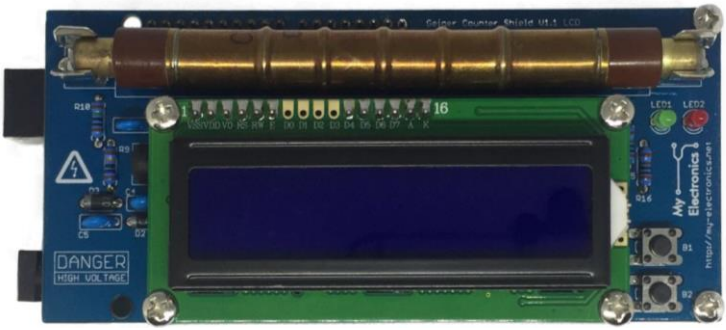
Assembled PCB

To prevent shorts, cover the USB connector of the Arduino board with the piece of electrical tap included in the kit.

Operation

To operate the shield, mount the LCD and a compatible Geiger tube as shown below:

Assembled PCB with mounted LCD and SBM-20 tube



Note that the Geiger tube needs to be mounted with its positive pole connected to the fuse holder marked with “+”. Then, mount the shield on top of an Arduino UNO or MEGA board.

IMPORTANT: Before operating the shield, connect a 9 to 12 V external power supply to the Arduino board.

Then, connect the Arduino to your computer via USB as usual and upload the sample sketch using the Arduino IDE. The sample sketch is available on our GitHub repository: [Download Sample Sketch](). If you are using the Arduino IDE for the first time, we recommend to take a look at the [Getting Started with Arduino]() guide.

If the sketch was uploaded correctly and the kit was assembled properly, the LCD will display “Geiger Counter Shield” and enter followed by one of the below:

CPS Mode

```
3            CPS
███-------------
```

CPM Mode

```
19           CPM
0.11        µSv/h
```

If you run the shield for the first time, you might have to adjust the contrast of the LCD using the potentiometer P1.

With the shield operating correctly, you should hear a click sound indicating detection events every few seconds, also visualized by the green LED (LED1). Button B1 is used to switch between the CPS and CPM mode. Button B2 is used to mute or unmute the sound. The CPS mode displays the counts per second (CPS) value and a CPS bargraph. For CPS larger than 16 the bargraph is scaled logarithmically, e.g., 121 CPS will be displayed as 12 bars. If the CPS exceeds 1000 the red LED (LED2) is lit for warning. The CPM display shows the counts per minute (CPM) value and the corresponding dose rate in µSv/h. The dose rate is calculated using the conversion factor given in the datasheet of the Geiger tube. The table below lists the conversions factors and operating voltages for some common Geiger tubes.

Tube Type	Operating Voltage	CPM to µSv/h
SMB-20	400 V	0.0057
J305	400 V	0.0081
STS-5	400 V	0.0060

If you operate the shield with a Geiger tube other than the SBM-20 you have to change the `DOSE_RATE_FACTOR` in the Arduino sketch accordingly.

To enable the SD logger the `SD_LOGGER` define in the Arduino sketch needs to be set to true:

```
#define SD_LOGGER true
```

With a SD cards inserted and the SD logger enabled the LCD will display “SD Card Detected” upon startup as well as the file name the data will be logged to, e.g., “Data_001.txt”. If no SD card is inserted “No SD Card Detected” will be displayed. The CPM value will be continuously logged every 10 s. A new file with incremented file number is created when restarted.

The serial logger is enabled by default and can be disabled by setting `SERIAL_LOGGER` in the Arduino sketch to false.

WARNING: The assembled kit generates HIGH VOLTAGES. If you buy the kit, you are fully responsible for the safety during the assembly and operation of this device.

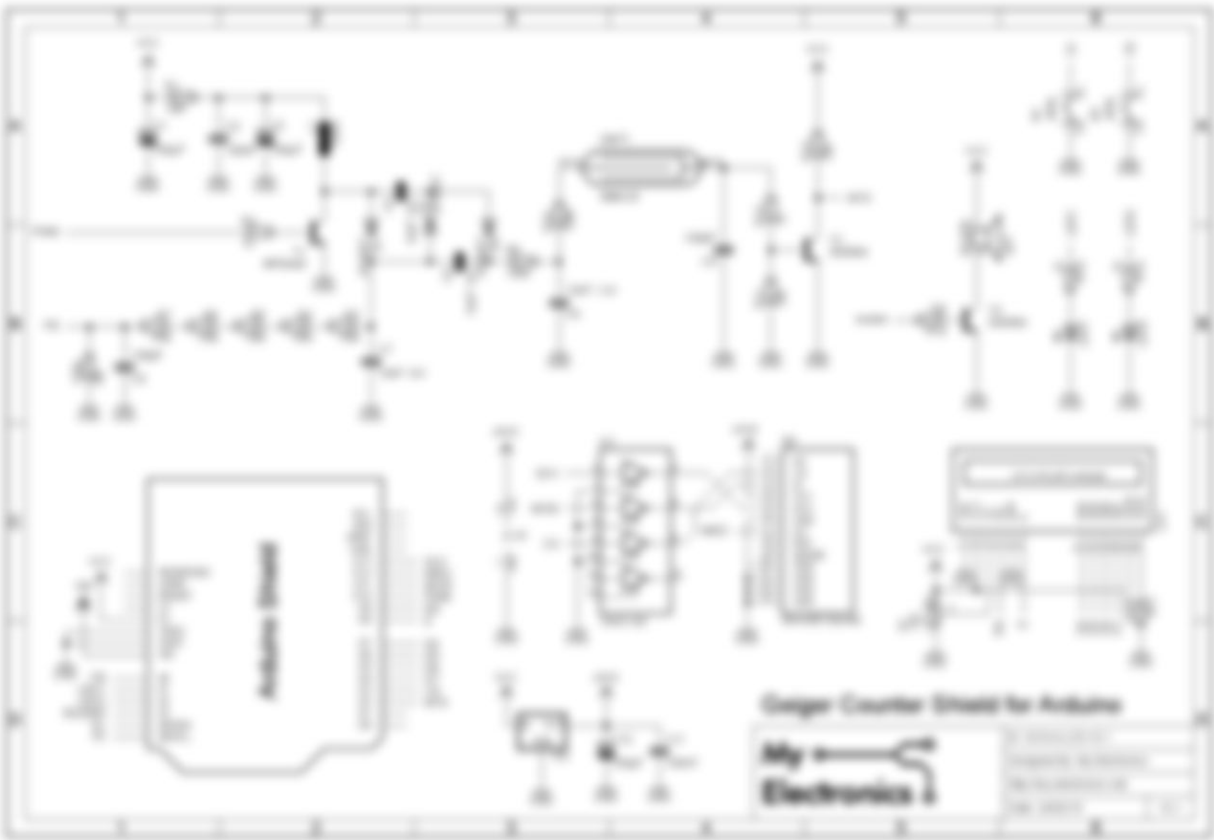
Troubleshooting

If the kit does not operate, please perform the following tests before sending a support request:

1. Check if all components are soldered properly and installed in the right position and direction
2. Check if the required external power supply is connected to your Arduino.
3. In the Arduino IDE, check if the sketch was uploaded properly.

Need help with the DIY Kit? Please send a support request with your order number or eBay ID: support@my-electronics.net

Schematics


Arduino Shield
Geiger Counter Shield for Arduino
My Electronics

Functional Description

A Geiger tube consists of a chamber filled with a gas mixture at a low pressure of about 0.1 bar. The chamber contains two electrodes with potential difference of several hundred volts. The walls of the tube are either metal or have their inside surface coated with a conducting material, while the anode is a wire mounted axially in the center of the chamber. When ionizing radiation strikes the tube, some molecules of the fill gas are ionized. This creates positively charged ions and free electrons in the gas.

Working Principle of a Geiger Tube

The high voltage across the tube electrodes accelerates the positive ions towards the cathode and the electrons towards the anode. Due to the high electric field strength, free electrons gain sufficient energy to ionize additional gas molecules by collision and create a large number of electron avalanches. This multiplication effect gives the tube its key characteristic of being able to produce a significant output pulse from a single original ionizing event.

The voltage range in which a Geiger tube operates correctly is called Geiger plateau. If the tube voltage is increased from zero, the count rate will be zero up to a starting voltage, where very high energetic radiation starts to be detected. Further increasing the voltage results in rapidly rising count rates until a plateau is reached. This is where the tube voltage is sufficient to allow a complete discharge along the anode for each detected radiation count, and the effect of different radiation energies are equal. At the end of the plateau the count rate begins to increase rapidly again, until the onset of continuous discharge where the tube cannot detect radiation, and may be damaged.

HV Power Supply

The 400 - 500 V required to drive a Geiger tube are generated by the HV power supply unit of the shield. The unit comprises a feedback controlled step up converter and a subsequent voltage double stage. The simplified working principle of the step up converter is sketched below.

Working Principle of a Step-Up Converter

When the switch S1 is closed, current flows through the inductor and generates a magnetic field. When the switch is open, the magnetic field previously generated will be destroyed to maintain the current flow (Lenz's law). As a result, the induced voltage will be in series with the power supply voltage causing a higher voltage to charge the capacitor through the diode. While the switch is opened, the capacitor is charged to the combined voltage. When the switch is closed again the right hand side is shortened out from the left hand side and the capacitor is able to provide energy to the load. During this time the diode prevents the capacitor from discharging through the switch. On the shield L1, D1 and C7 are implementing the step up converter. T1 and R1 are representing the switch S1. For an ideal step up converter operating is DCM mode[1] the output voltage is given as [1]:

$$V_{out} = \frac{V_{in}}{2}\left(1 + \sqrt{1 + \frac{2D^2 \cdot R \cdot T}{L}}\right),$$

where V_{in} is the input voltage (5 V), D is the duty cycle, T the inverse switching frequency, L the inductivity of the inductor and R the output resistance.

In the Arduino sketch the PWM frequency is set to f = 4 kHz with a initial duty cycle of D = 29/255 = 0.11. Using L = 10 mH (L1) and R = 10 MΩ (R10) we get:

$$V_{out} = \frac{5\ V}{2}\left(1 + \sqrt{1 + \frac{2 \cdot (29/255)^2 \cdot 10\ M\Omega \cdot 1/(4\ kHz)}{10\ mH}}\right) = 203.6\ V.$$

The output of the step up converter stage runs in a feedback loop with the analog digital converter (ADC) of the Arduino. The ADC reads the HV through voltage divider 50 MΩ : 100 kΩ (R5 – R6), 200 V will give 0.4 V at the ADC input. The ADC has 10-bit resolution (ADC values from 0 – 1023) and uses the internal 1.1 V reference, i.e., 0.4 V will lead to a ADC reading of 372. Depending on the ADC reading the Arduino then increases or decreases the duty cycle D to adjust the output voltage.
The capacitors C1-C3 and the resistor R1 decouple the switching noise of the step up converter from the power supply lines.

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[1] Step up converters can operate in two distinct modes, continuous conduction mode (CCM) and discontinuous conduction mode (DCM). CCM occurs when the inductor current does not reach zero, whereas in DCM it does reach zero. Each mode is appropriate for different applications. Since the required output current is small (400 V / 10 MΩ = 40 µA) DCM is selected as the operating mode. DCM has the benefit of being able to produce higher output voltages with smaller inductor values but has the downside of producing higher peak currents which can result in switching noise of the power supply lines.

The output of the step up converter stage is then doubled by a voltage doubler stage (C4, C5, D2, D3). The simplified working principle of the voltage double is sketched below.

Working Principle of a Voltage Doubler

The negative peak charges the capacitor C4 via the diode D2 to 200 V. During the positive peak the 200 V of C4 is added to the input voltage 200 V and the capacitor C5 is charged through D3 to 400 V. The resulting voltage is then filtered by the low-pass filter R9 and C6. R10 is the Geiger tubes anode resistor that limits the current through the tube to a safe value.

Detection

In idle mode the Geiger tube will pass only a small leakage current, but when ionizing radiation strikes the tube some of the gas inside the tube is ionized which will allow a higher current through the tube. This current will raise voltage at the base of transistor T2 through a voltage divider 10 kΩ - 1 kΩ (R11, R12) turning it on which pulls INT0 pin to low. The Arduino interrupts at the pin change and counts one event.

SD Card Interface

The SD card interface comprises a 3.3V voltage regulator (IC2, C10, C11) and a level shifter (IC1). The built in 3.3 V regulator on the Arduino board is not used because it only supplies up to 50 mA while some SD cards require more power when writing. The miniSD card socket is connected to the SPI interface of the Arduino through IC1. IC1 is a level shifter, converting the 5 V signals of the Arduino into 3.3 V signals for the SD card.

References

[1] Understanding Boost Power Stages in Switch Mode Power Supplies, Application Report, Texas Instruments