# MultiGeiger

***Release V1.15.0***

**Mar 21, 2021**

# Contents

CHAPTER 1

# Overview

## 1.1 What is MultiGeiger?

The MultiGeiger is a radioactivity measurement device.

### 1.1.1 Main features

**multiple use cases supported**

- fixed location stations (data transfer via network)
- mobile operations (using the OLED display and speaker)
- (more are planned)

**multiple 400V Geiger-Mueller tubes supported**

- big, sensitive tubes, like the Si21g or Si22g (for measurement stations)
- smaller, less sensitive tubes, like the SBM21 (good for finding hot spots)

**Hardware**

- low parts count, simple to assemble
- inexpensive, but still good parts
- using ESP32, a modern and fast 32bit micro controller
- with WiFi (WPA2) or with WiFi + LoRA
- with OLED display

**Firmware**

- implemented in C
- using the popular arduino API

- over-the-air firmware updates

**Network and Community**

- this is an Ecocurious citizen science project
- web-based geo map for publishing measurements
- web-based archive of historic radiation data

**Free and Open**

- GPL v3 licensed
- open development and issue tracking on GitHub

## About

The **MultiGeiger** is a project of Ecocurious, your community for environment, nature and technology, see https://ecocurious.de/projekte/multigeiger/.

The goal is to establish a citizen measurement network for radioactivity in Germany.

The **MultiGeiger** hardware and software was designed by Jürgen Böhringer (http://www.boehri.de).

Reinhard/rexfue has further developed the software, the board, and is taking care of the integration of the sensors into our map https://ecocurious.de/multigeiger-karte/.

We have started the first workshops where you can assemble the components and the case with our support.

**Workshop dates can be found here:**

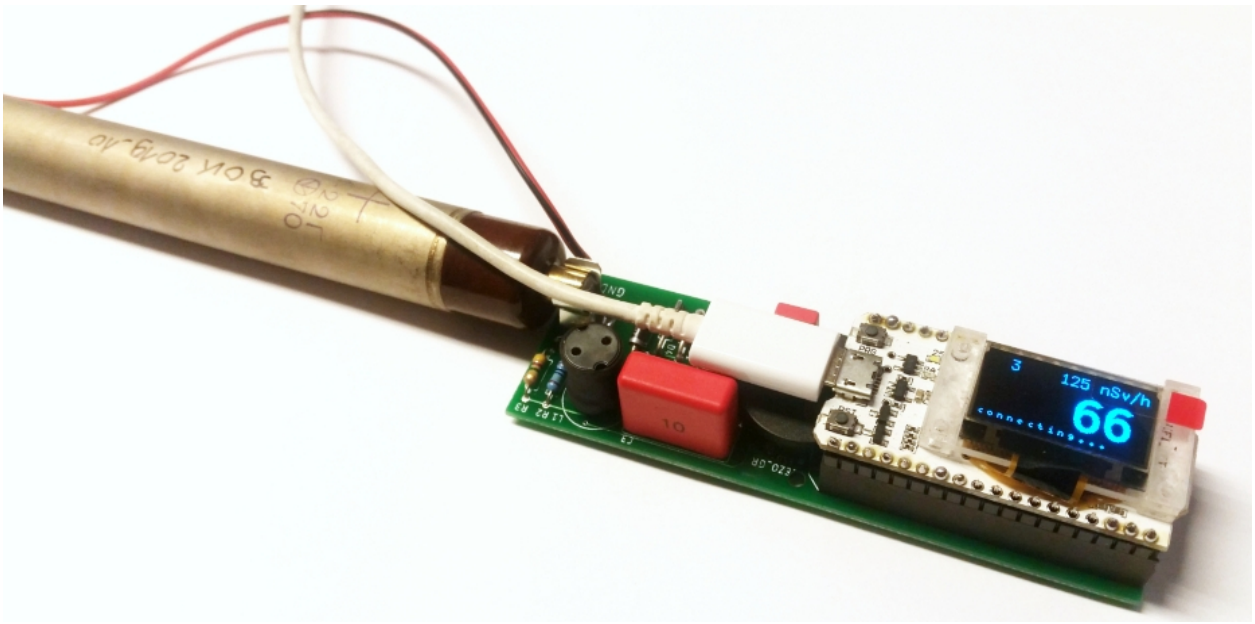
- https://www.meetup.com/de-DE/Ecocurious-deine-Umwelt-Natur-und-Technik-Community/
- https://ecocurious.de/events/

Does this sound interesting to you? Then join us, we cordially invite you!

## Assembly

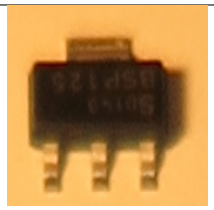
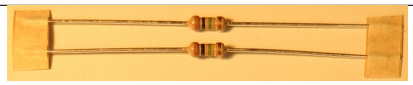
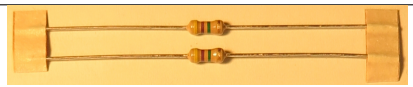
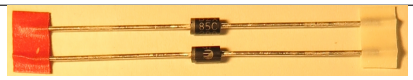
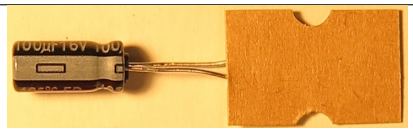
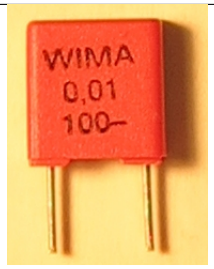
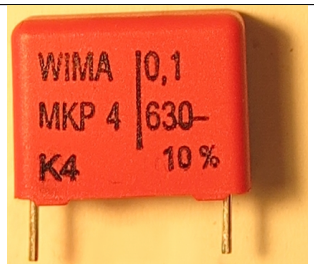
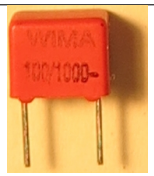
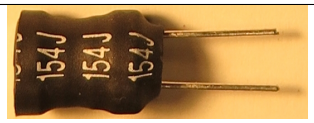
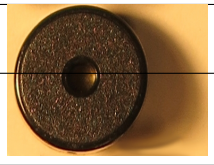
## Ergebnis

Das Multigeigerprojekt ist eine Idee der Ecocurious-Initiative. Das dazugehörige Open-Source Multigeigermessgerät zum Messen radioaktiver Gammastrahlung wird von der Community entwickelt. Die Echtzeitdaten der stationären Geräte werden per LoRaWAN oder WiFi/WLAN an einen Server gefunkt und auf einer Karte visualisiert. So entsteht ein Radioaktivitätsmessnetz in Bürgerhand, das wir hiermit aufbauen wollen. Herzliche Einladung zum Mitmachen!




### Bauteile

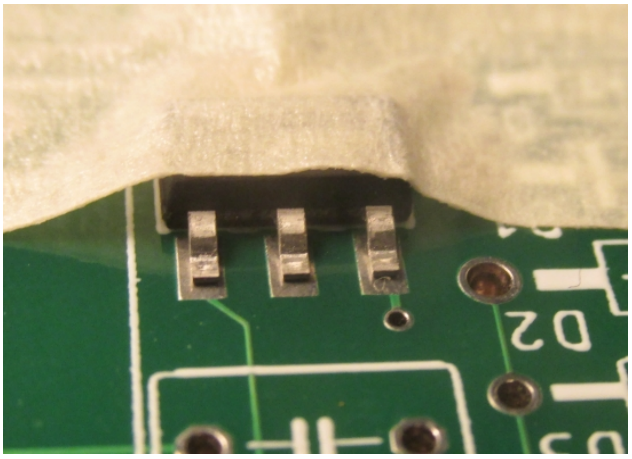
Elektronikbauteile aus (s. Stückliste) zunächst sortieren und auf Vollständigkeit prüfen:

| ID(s) | # | Bild | Typ |
|---|---|---|---|
| T1 | 1 |  | N-MOS-Transistor BSP125 |
| R1 | 1 |  | 10K Widerstand braun-schwarz-orange-gold |
| R2 R5 | 2 |  | 1,0M Widerstand braun-schwarz-grün-gold |
| R3 R4 | 2 |  | 4,7M Widerstand gelb-violett-grün-gold |
| D1 D2 | 2 |  | Z-Diode ZY 200 |
| D3 | 1 |  | Z-Diode BZX55C3V3 |
| D4 | 1 |  | Gleichrichterdiode BYV 26E |
| D6 | 1 |  | Gleichrichterdiode GP10Y |
| C1 | 1 |  | ELKO Elektrolytkondensator 100 uF, 16 V |
| C2 | 1 |  | Folienkondensator 10nF, 100V 0.01 100- |
| C3 | 1 |  | Folienkondensator 100nF, 630V 0.1 630- |
| C4 | 1 |  | Folienkondensator 100pF, 1000V 100/1000- |
| L1 | 1 |  | Spule 150uH 154J |
| Pz1 | 1 |  | Piezo-Lautsprecher |
| | |  | |

### Lötarbeiten

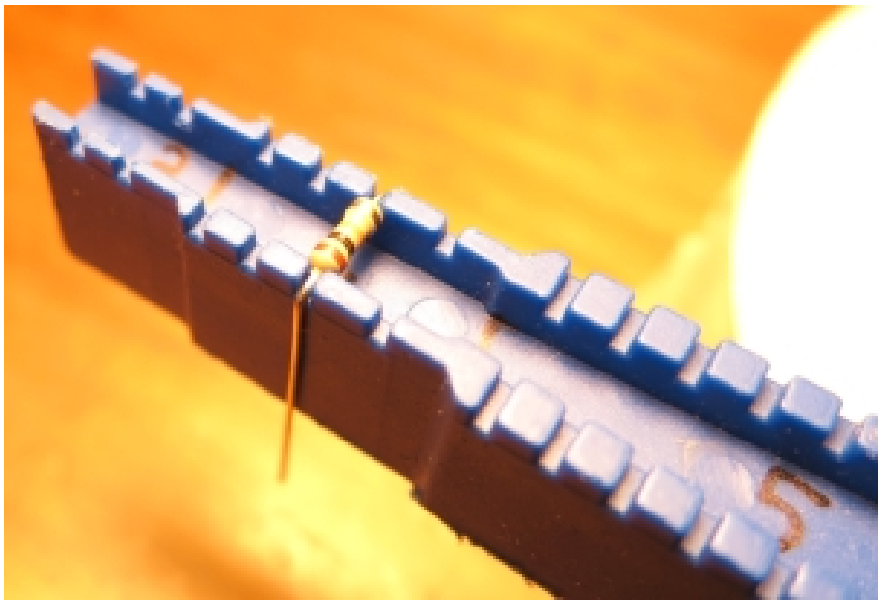
#### Feldeffekt-Transistor T1

Als erstes Bauteil wird das einzige Bauteil im SMD-Bauform montiert. Mit Klebeband (Kreppband hat sich bewährt) wird er so auf die Platine geklebt, so dass die drei Pins sichtbar sind. Dann werden die vorderen Anschlüsse verlötet, das Klebeband vorsichtig entfernt und der hintere Anschluss verlötet.

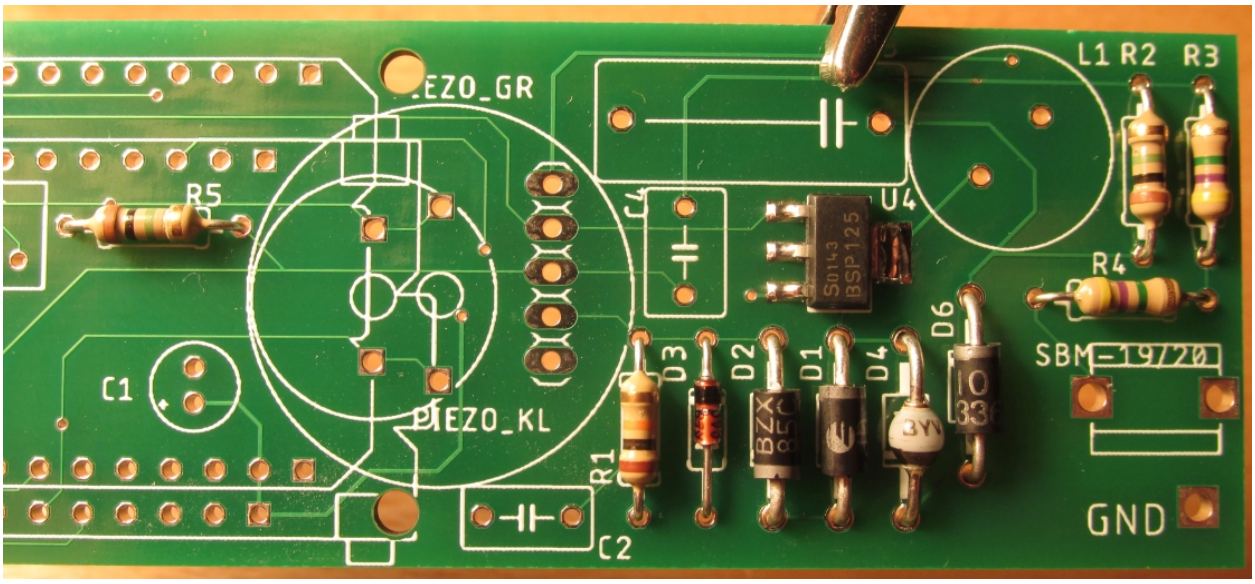


#### Widerstände und Dioden

Die Widerstände und Dioden werden alle in einer Abbiegevorrichtung (oder entsprechend mit der Hand oder einer kleinen Zange) gebogen. Die Breite ist immer vier Einheiten – sprich ca. 10 mm.

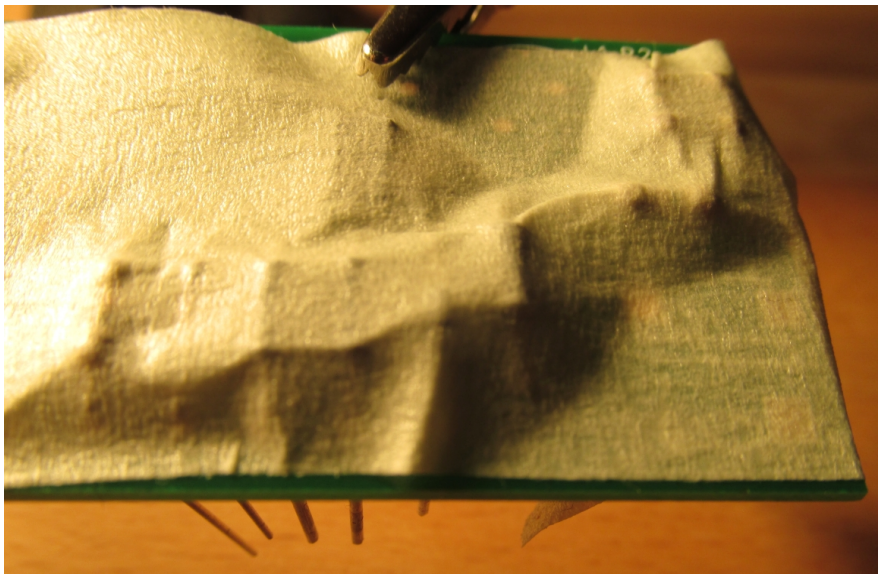


Anschließend wird die Platine mit den Widerständen und Dioden bestückt. Bei den Dioden unbedingt auf die Polarität achten! Die Kathode (Minus-Pol) ist mit einem Strich auf Platine und Bauteil markiert.




Vor dem Löten der Unterseite werden die Bauteile auf der Oberseite mit Klebeband fixiert, oder die Beinchen der Bauteile durch leichtes Auseinanderbiegen verklemmt. Dann Bauteile anlöten, Klebeband entfernen und überschüssigen Draht abschneiden.

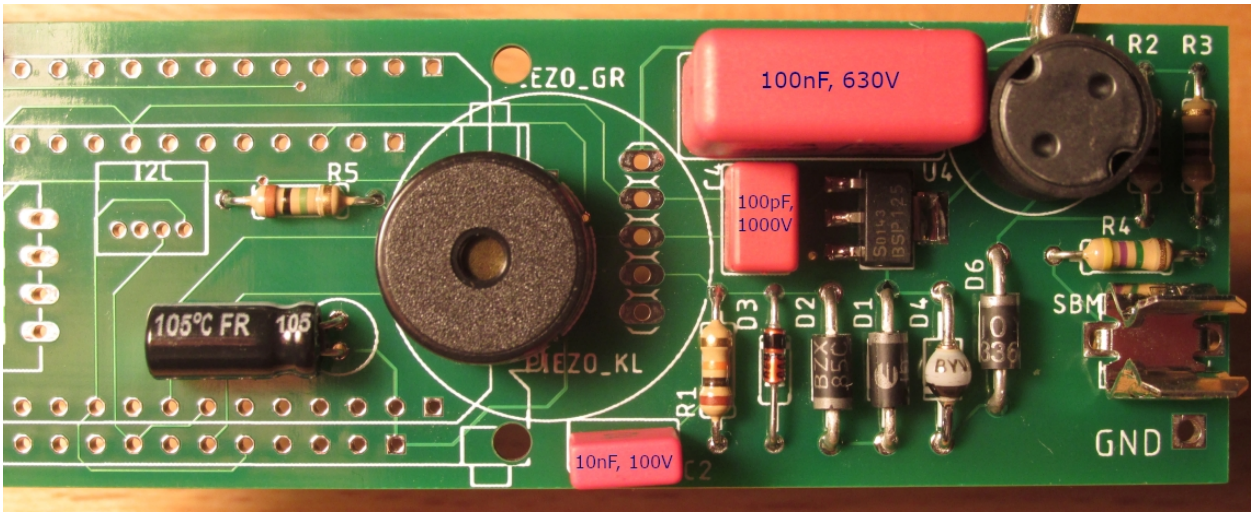
**Note:** Verletzungsgefahr: Beim Abschneiden darauf achten, dass der davonfliegende Draht niemanden verletzten kann. Möglichst festhalten beim Abschneiden!



### Kondensatoren und restliche Bauteile

Der Elektrolytkondensator (Elko) wird vorher mit einer Flachzange angewinkelt. Beim Elko unbedingt auf die Polung achten: Auf dem Elko ist der „–“-Pol markiert, auf der Platine der „+“-Pol. Die Beschriftungen müssen sich gegenüber liegen. Der Zählrohrhalter muss so herum eingesetzt werden, dass das Zählrohr nach außen steht kann – am besten testen! Dann die Bauteile mit Klebeband fixieren, anlöten und den überschüssigen Draht abschneiden.

Kondensatoren, Zählrohrhalter, Spule, Piezo-Lautsprecher sind bestückt:




### Buchsenleisten und Mikrocontroller-Modul

Die Buchsenleiste muss vorher evtl. noch gekürzt werden.

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**Note:** Dabei muss der Seitenschneider genau auf dem **letzten nicht mehr benötigten Kontakt** angesetzt werden – **nicht dort wo man ihn eigentlich kürzen will** – ansonsten kann sie splittern. Beim Abschneiden wegfliegende Teile möglichst festhalten!

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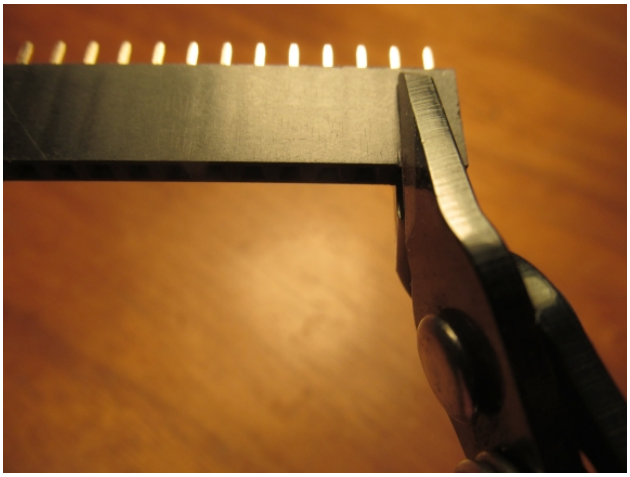
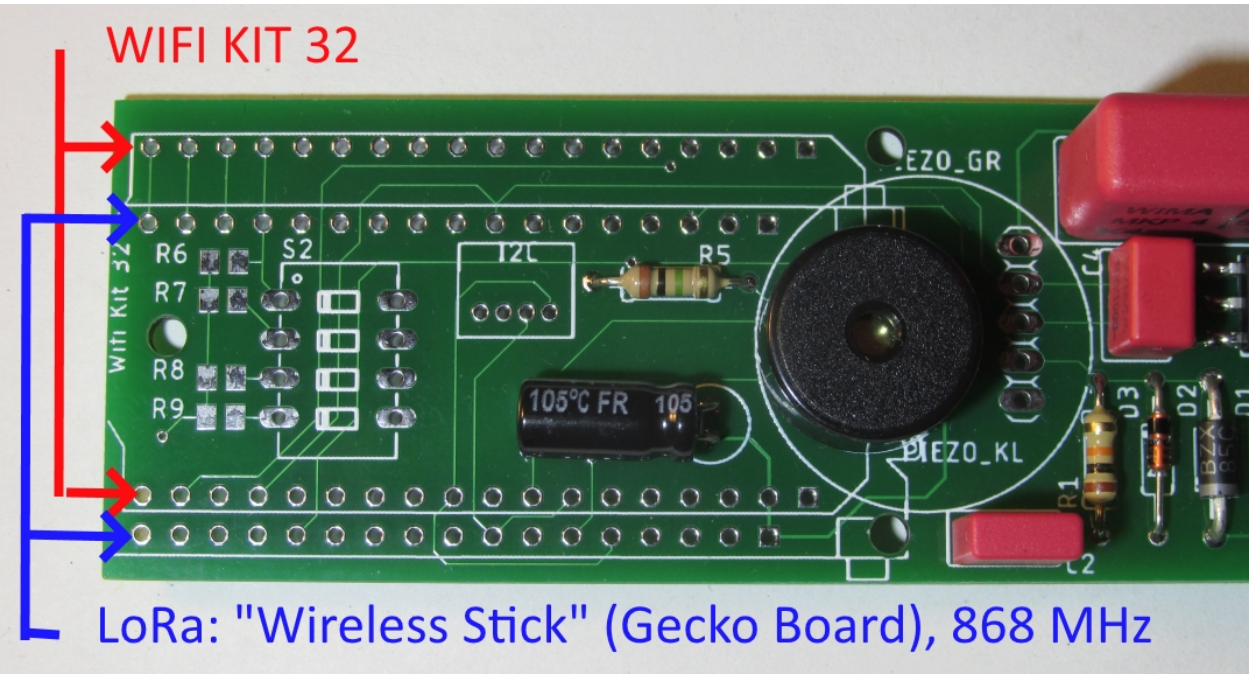


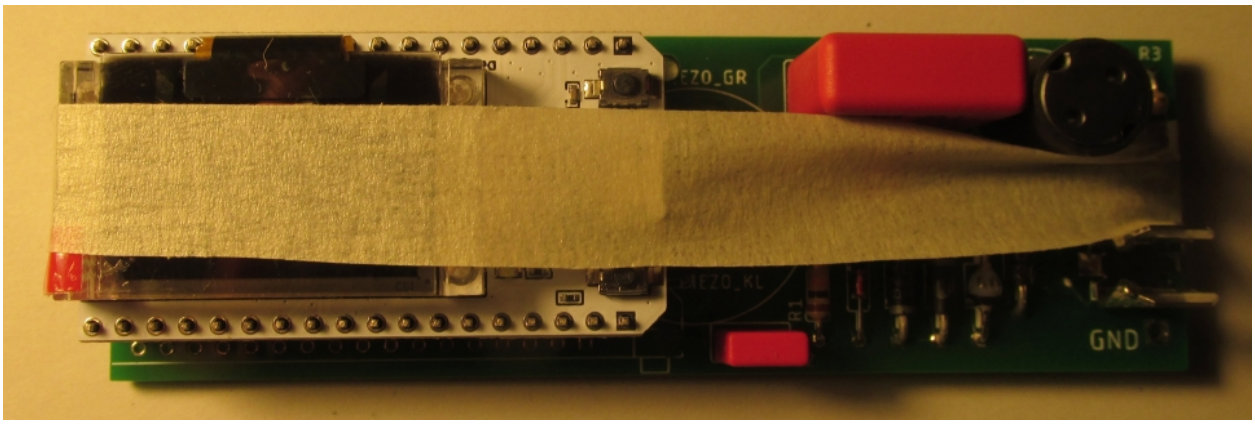
Wird der große Piezo-Lautsprecher verwendet, so sollte die Buchsenleiste mit einer Feile etwas abgefeilt werden (vorher ausprobieren). Am einfachsten geht das an der originalen, nicht bearbeiteten Seite der Buchsenleiste. Je nachdem, welches Mikrocontroller-Board verwendet wird, müssen die Buchsenleisten an den entsprechenden Stellen bestückt werden.




Die Winkel der Buchsenleiste sollten genau stimmen. Daher am besten so vorgehen:

- Die erste Buchsenleiste einstecken.
- Von unten her eine Lötstelle in der Mitte löten, die Lötstelle nochmals heiß machen und gleichzeitig die Buchsenleiste justieren (rechter Winkel, alle Pins richtig).
- Die zweite Buchsenleiste einstecken.
- In beide Buchsenleisten die Stiftleiste aus dem Mikrocontroller-Modul-Set einstecken, so dass deren längerer Teil der Stiftleiste in der Buchsenleiste steckt.
- Das Mikrocontroller-Modul aufstecken, so dass das Display sichtbar ist und die Mikro-USB-Buchse über dem Piezo-Lautsprecher liegt.
- Alles mit einem schmalen Klebeband fixieren (siehe Bild unten), so dass alle Lötstellen zugänglich sind.
- Nun können alle Kontakte gelötet werden.

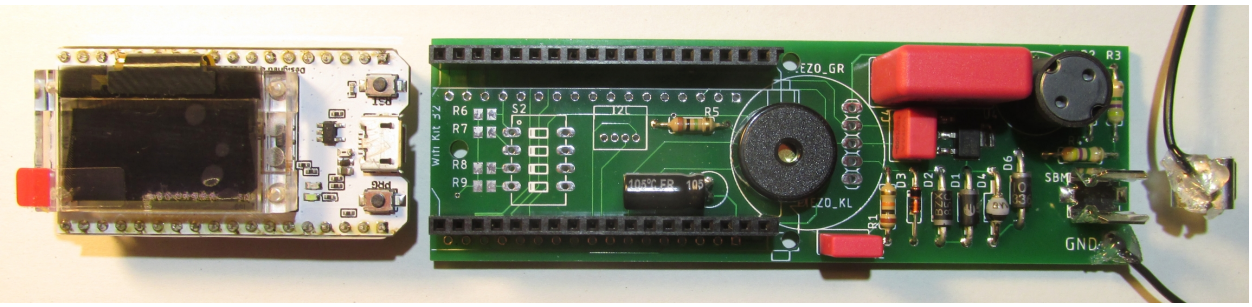
**Note:** Das OLED-Grafikdisplay ist über eine dünne Flex-Leitung angeschlossen, die nicht zu heiß werden darf. Im Zweifel lötet man die Pins in der Nähe der Flex-Leitung nicht an – sie werden nicht benötigt.



Nach dem Löten kann das Mikrocontroller-Modul mit wippenden Bewegungen vorsichtig abgezogen werden.

- Beim Mikrocontroller-Modul sind Pin-Beschriftungsaufkleber mit dabei. Diese können jetzt seitlich aufgeklebt werden. Welcher Pin wo ist, steht auf der Unterseite des Mikrocontroller-Moduls.
- Das Kabel für den Anschluss der Zählrohr-Kathode (Minus-Anschluss) an Klammer und Platine anlöten.
- Kabel mit jeweils einem Tropfen Heißkleber sichern (Zugentlastung).
- Sichtkontrolle (hast du Lötstellen vergessen, sind Lötbrücken entstanden, . . . ).
- Mikrocontroller-Modul wieder aufstecken.
- Zählrohr anklemmen: der Plus-Pol (Anode) ist markiert und muss in Richtung Platine zeigen.
- Eine erste Funktionskontrolle ist nun möglich, s. *Inbetriebnahme*.

Fertige Geigerzähler- und Mikrocontrollerplatine:




**Note:** Das dünne Glas des OLED-Grafikdisplays ist empfindlich. Bitte keine Kraft auf das Display ausüben, sondern nur auf die Mikrocontrollerplatine!

**Warning:** Verletzungsgefahr: Auf der Geigerzählerplatine wird eine **Spannung von 400 Volt** erzeugt. Diese hält sich auch noch längere Zeit **nach dem Ausschalten des Geräts**. Bei Berührung kann es zu kleineren Stromschlägen kommen, die normalerweise harmlos sind. Dennoch sollten sie vermieden werden!

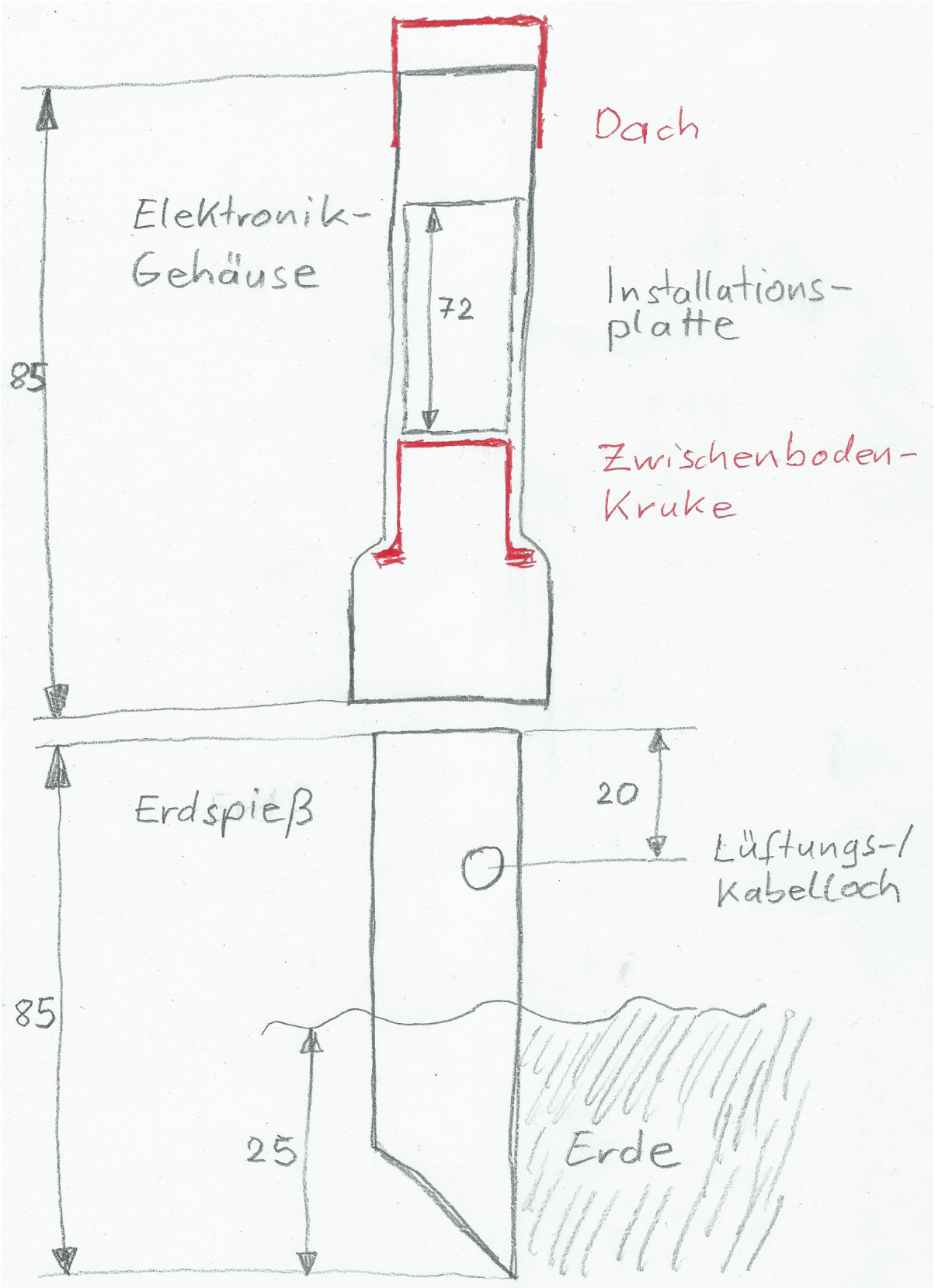

**Man sollte vor dem Arbeiten an der Schaltung den Kondensator entladen.** Am einfachsten macht man dies mit einer zweiten, ca. 30 cm langen Leitung, mit der man Anode und Kathode des Zählrohrs für etwa eine Sekunde kurzschließt. Dies schützt nicht nur vor unangenehmen Stromschlägen, sondern schützt auch die empfindliche elektronische Schaltung.

### Gehäuse

### Funktionen des Gehäuses

- Es schützt die Elektronik vor Umwelteinflüssen (z. B. Regen) und Insekten (daher sollte kein Zugang von außen zur Elektronik größer sein als 0,5 mm).
- Es hält das Zählrohr in einer Höhe von 1 m über der Wiese – somit sind unsere Messwerte (bestmöglich) vergleichbar zu denen des amtlichen ODL-Messnetzes.

### Rohre


Dach
Elektronik-
Gehäuse
72
Installations-
platte
85
Zwischenboden-
Kruke
Erdspieß
20
Lüftungs-/
Kabelloch
85
25
Erde

- Rohr für das Elektronikgehäuse: Zunächst wird das Rohr mit einer Säge auf entsprechende Länge abgesägt. Die Muffe (Aufweitung) zeigt nach unten.
- Rohr für den Erdspieß: Der noch umgesägte Teil des Restes ist das obere Ende des Erdspießes. Unten wird der Erdspieß auf entsprechende Länge abgesägt im 45-Grad-Winkel. Mit diesem schrägen Anschnitt lässt sich der Erdspieß später mit leichten Drehbewegungen gut in die Erde bohren. Alternativ kann man diesen Teil des Rohrs kurzhalten (ca. 15 cm) und in einem verzinkten Sonnenschirmhalter mit Erdspieß (Ø40mm) festklemmen.
- Lüftungs-/Kabelloch bohren: Mit einem Reißnagel o. ä. wird das Loch seitlich im Erdspieß vorgestochen. Anschließend wird es aufgebohrt. Zuletzt wird es mit einem großen Bohrer / Schälbohrer auf etwa 17 mm Durchmesser aufgebohrt.

**Note:** Verletzungsgefahr: Mit der Klinge/dem Bohrer immer nach außen, d. h. vom Körper weg, schneiden oder bohren!

### Dach und Zwischenboden

Für das Dach kann man einen Rohrabschlussstopfen oben vorsichtig über das Rohr schieben, s. Bild rechts.

Als Zwischenboden verwenden wir eine Kruke, also eine Plastikdose, die in Apotheken zum Abfüllen von Salben verwendet wird. Der rote Deckel kann als Material für eine kabeldurchführungsverkleinernde Zwischenbodenauflage dienen.

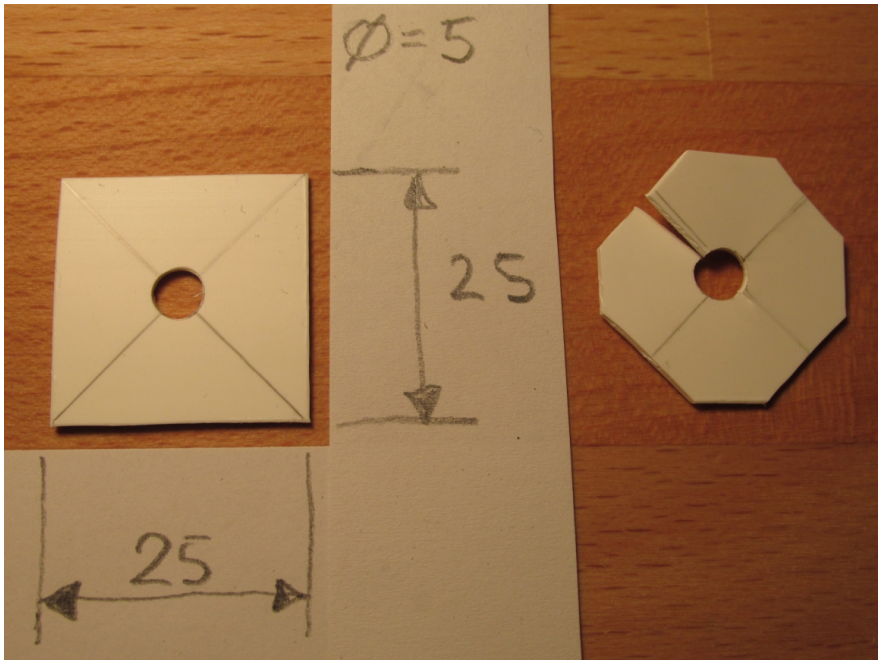
Für den Zwischenboden wird lediglich das Gewinde vorsichtig mit der Säge abgesägt, s. Bild links. Der „Kragen“ muss bestehen bleiben, da er als Anschlag dient.

In den Zwischenboden wird in der Mitte ein Loch zur Kabeldurchführung mit 10 mm gebohrt. Der Stecker des Kabels muss durch das Loch passen.

Eine Zwischenbodenauflage dient zum Schutz vor Insekten, da sie das Loch der Kabeldurchführung verkleinert. Man kann dafür z. B. den roten Deckel der Kruke oder ein ähnliches Stück Kunststoff verwenden.

Es wird die Mitte markiert und dort ein Loch mit dem Durchmesser des Stromkabels (ca. 5 mm) gebohrt. Anschließend werden die Ecken abgeschnitten. Zusätzlich wird ein Verbindungsschlitz von außen zum Loch geschnitten.

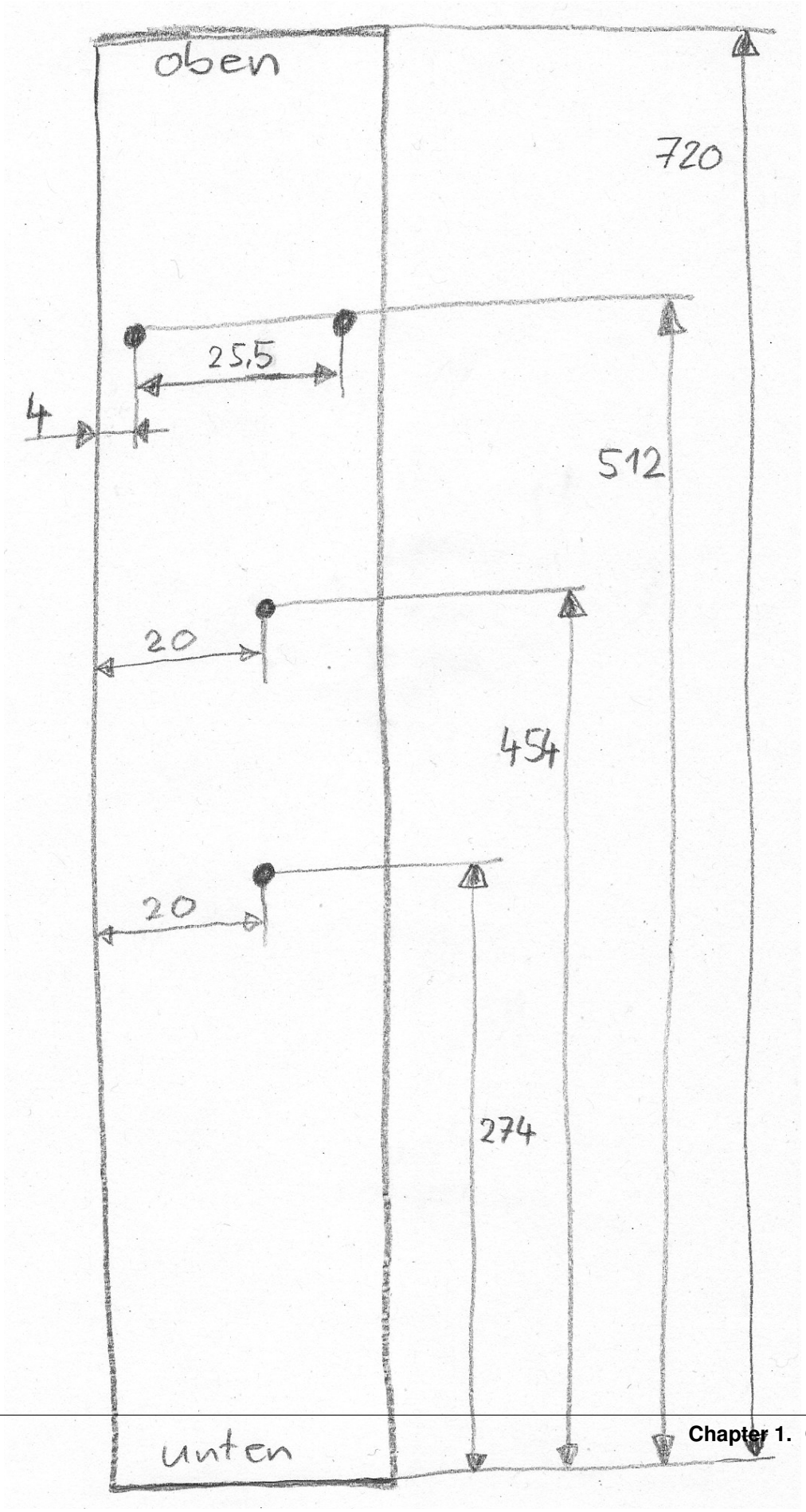
Aufbau der Zwischenbodenauflage (in zwei Arbeitsschritten):




### Installationsplatte

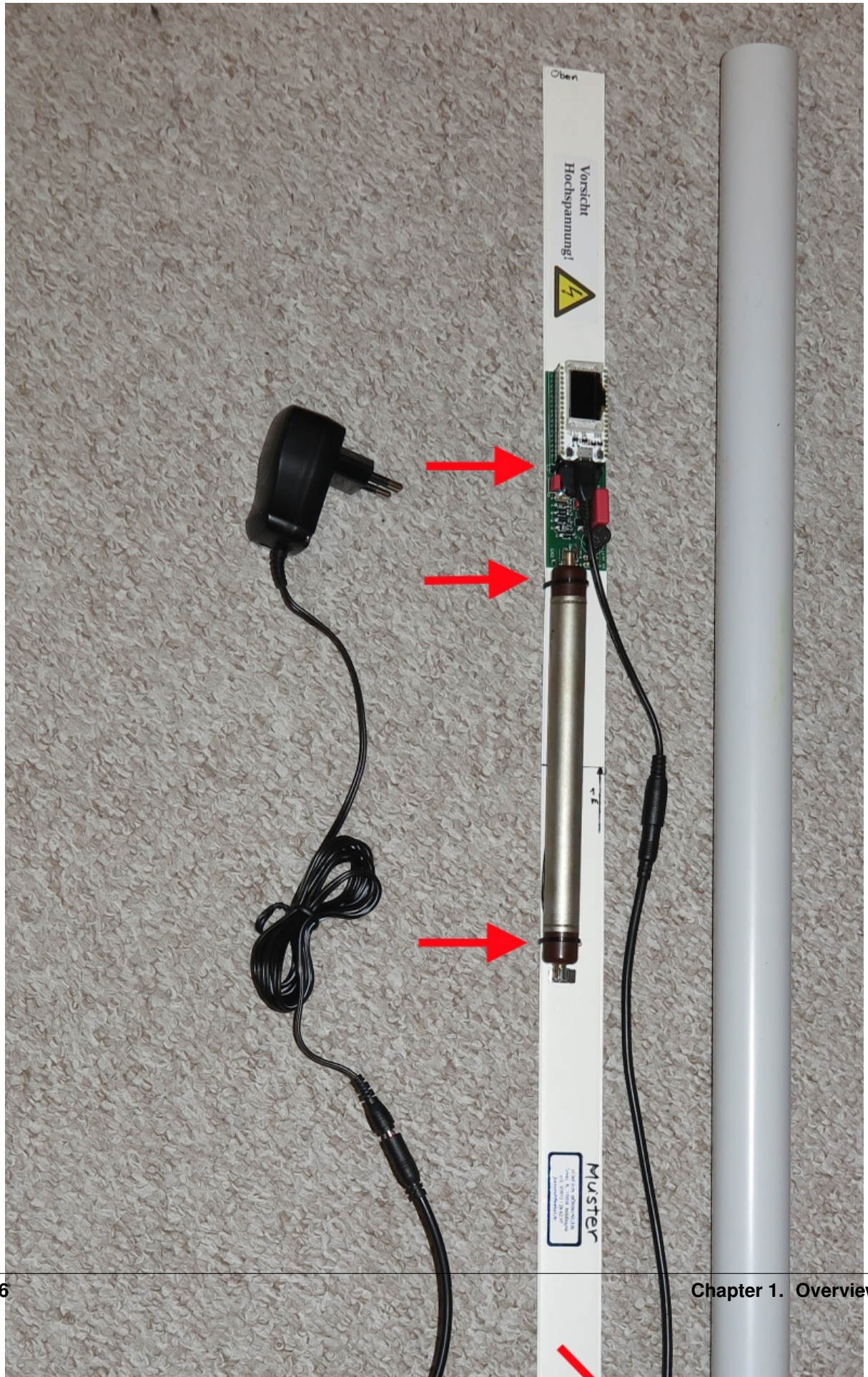
- Die Installationsplatte kann aus dem Ober- oder Unterteil eines Kabelkanals gefertigt werden. Dazu werden die Seitenteile vorsichtig mit einem Messer abgeschnitten. Danach wird der dadurch entstandene, biegsame Kunststoffstreifen auf die richtige Länge gebracht. Hierzu kann eine starke Schere verwendet werden.
- Löcher durch Installationsplatte bohren: Elektronik und Zählrohr werden so mit Kabelbindern auf Installationsplatte fixiert, dass das Zählrohr sich auf 1 m Höhe befindet, wenn der Erdspieß 25 cm in der Erde steckt. Das Zählrohr zeigt nach unten. Die Löcher werden mit dem Reißnagel vorgestochen und dann auf 3 mm aufgebohrt, s. Bild „Bohrplan Installationsplatte“.
- Die Platine wird lediglich mit einem Kabelbinder auf der Platte montiert, der durch beide Löcher gezogen wird. Er verläuft unterhalb des USB-Steckers.

Bohrplan Installationsplatte:


oben
720
25,5
4
512
20
454
20
274
unten

### Einbau

Einbau des Geräts (die roten Pfeile markieren Kabelbinder):


Oben
Vorsicht
Hochspannung!
Muster

- Platine und Zählrohr werden mit Kabelbinder auf die Installationsplatte montiert.
- In die Micro-USB-Buchse wird der passende Adapter gesteckt.
- Das „10 m Verlängerungskabel“ wird richtig herum zunächst durch den Erdspieß und dann durch den Zwischenboden gefädelt. Anschließend wird er mit dem Adapter verbunden.
- Danach wird die Zwischenbodenauflage oberhalb des Zwischenbodens vorsichtig auf das Kabel geschoben.
- Oberhalb der Zwischenbodenauflage wird ein Kabelbinder auf das Kabel gezurrt, so dass eine Zugentlastung entsteht.
- Erster Test des Gehäuses: Wir schieben erst vorsichtig die Installationsplatte in das Elektronikgehäuse. Anschließend folgen Zwischenboden und der Erdspieß.
- Wenn alles passt wird noch die Zwischenbodenauflage mit Silikon-Kleber auf den Zwischenboden geklebt und mit Kreppband (bis zum Aushärten) fixiert.
- Der Warn-Aufkleber „Vorsicht Hochspannung“ wird auf die Installationsplatte geklebt.

### Inbetriebnahme

WLAN-Variante: Das Gerät baut einen eigenen WLAN-Accesspoint (AP) auf. Die SSID des AP lautet ESP32-xxxxxxxx, wobei die xxx die Chip-ID des WLAN-Chips sind (Beispiel: ESP32-51564452). Bitte diese Nummer notieren, sie wird später für die Anmeldung benötigt, z. B. bei https://devices.sensor.community/. Der Access-Point bleibt für 30 s aktiv. Danach versucht das Gerät, sich mit dem (früher) eingestellten WLAN zu verbinden. Dieser Verbindungsversuch dauert ebenfalls 30 s. Kommt keine Verbindung zustande, wird wieder der eigene AP für erzeugt. Das standardmäßig vergebene WLAN-Kennwort ist „*ESP32Geiger*“ und sollte zeitnah geändert werden.

Weitere Informationen: *Deployment* und *Usage*.

**Wir wünschen viel Freude mit dem neu gebauten Gerät und hoffen dass es niemals unnatürliche bzw. gesundheitsschädliche Ausschläge messen wird!**

### Setup

Download and unpack the latest release from GitHub ( https://github.com/ecocurious/MultiGeiger/releases ) as source code (zip) or source code (tar.gz). In the new directory, open the directory *multigeiger* and load the file *multigeiger.ino* with the Arduino IDE.

The board supports two different Heltec devices, different counting tubes and optionally a sensor for ambient temperature, air pressure, and humidity (BME280 or BME680). The software can send data via network to different services.

- **Heltec WiFi Kit 32** This MCU has WiFi, a large display and plugged into the longer female connectors on the board.
- **Heltec Wireless Stick** This MCU has a very small display, and provides LoRa beside WiFi. It must be plugged into the shorter female headers on the board.

To select the Heltec boards in the Arduino IDE, the following steps must be taken:

- Add the file: https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_dev_index.json in Preferences->Additional Boards Manager URLs.
- Then, the ESP32 boards (name “esp32 by Espressif Systems”) can be installed under Tools->Board->Boards Manager. Choose the correct Heltec board under Tools->Board.
- Select the **Heltec wireless Stick** for **both** boards.

- If you use arduino-esp32 >= 1.0.5, you might need to apply a patch to get back the "partition scheme" menu needed in the next step, see the `misc/arduino-esp32/paritition-menu-*.*` files in our git repo.
- Select under Tools **Flash size: "4MB(32Mb)"** and **Partition Scheme: "Minimal SPIFFS (Large APPS with OTA)"**. The software recognizes automatically which board is equipped.

Various software settings can be made via the following files (see comments inside):

- **./multigeiger/userdefines.h** (always necessary, an example is provided in userdefines-example.h)
- **./platformio.ini** (only for platformio, an example is provided in platformio-example.ini)

All external libraries are required, which are listed in the file

```
platformio-example.ini
```

under the section

```
lib-deps =
```

Please install the latest version via platform.io / Libraries.

**Caution:** If the Arduino IDE is used, please check that in the file project_config/lmic_project_config.h (in the top level in this library) the correct configurations are set. The file must look like this:

```
// project-specific definitions
#define CFG_eu868 1
//#define CFG_us915 1
//#define CFG_au921 1
//#define CFG_as923 1
// #define LMIC_COUNTRY_CODE LMIC_COUNTRY_CODE_JP /* for as923-JP */
//#define CFG_in866 1
#define CFG_sx1276_radio 1
//#define LMIC_USE_INTERRUPTS
```

The specified versions of the libraries are the minimum requirements. We always test with the latest versions too, so please always install and use the latest versions. If the compiler reminds other libraries, please install them in the Arduino IDE via *Sketch -> Include Library -> Manage Libraries ...*

### Procedure after startup

The device establishes its own WiFi access point (AP). The SSID of the AP is **ESP32-xxxxxx**, where the xxx are the chip ID (or MAC address) of the WiFi chip (example: **ESP32-51564452**). **Please write down this number, it will be needed later.** This access point remains active for 30 sec. After that the device tries to connect to the (previously) defined WiFi netwword. This connection attempt also takes 30sec. If no connection could be established, the own AP is created again and the process starts again and again.

### Configuring the device via WiFi

After the WiFi AP of the device appears on your cell phone or computer, connect to it. The connection asks for a password, it is **ESP32Geiger**. The start page of the device opens usually **automatically**. If the start page does not appear, you have to call the address **192.168.4.1** with a browser. The start page appears, where you can't miss the link to the **configure page** , click on it and you enter the settings page.

The settings page has the following lines:

- Geiger accesspoint SSID This is the SSID of the built-in AP and can be changed. If the sensor was already registered with this number at sensor.community, a new registration is mandatory.

- Geiger accesspoint password This is the password for the built-in AP. It **MUST** be changed the first time. If desired, the default password **ESP32Geiger** can be used again. The field must not be left blank. Save the password to your favourite password manager.
- WiFi client SSID Here you have to enter the SSID of the WLAN you want to connect for network/internet access.
- WiFi client password And here the corresponding password.

For more security, it is recommended to use a separate WiFi network (e.g. guest network) to ensure an isolated communication from the normal network.

If everything is entered, press **Apply** and the data are stored in the internal EEPROM. Leave this page via **Cancel**, because only in this way the program closes the Config-Mode and connects to the local WiFi network. If there is no **Cancel** Button, go back to the WiFi settings of the device and type in the normal home network parameters again.

**CAUTION**. **When updating to version 1.13, the WiFi settings must be re-entered**. In future versions this step shall become obsolete.

Furthermore, the following options can be defined on the settings page:

- Start melody, speaker tick, LED tick and display on/off.
- Send data to sensor.community or/and to madavi.de
- If LoRa hardware is available: the LoRa parameters (DEVEUI, APPEUI and APPKEY) can be entered here.

The firmware on the MultiGeiger can be updated with the link **Firmware update** at the End of the settings page. Download the .bin file, select it via **Browse...** and click **Update**. It will take roughly 30sec for uploading and flashing the firmware. If you see **Update Success! Rebooting...**, the MultiGeiger will reboot and the new firmware will be active.

If **Update error: ...** appears, the update did not work. The previous firmware is still active.

The settings page can be called up from your own WiFi at any time. To do this, just enter in the address bar of the browser: http://esp32-xxxxxxx (xxxxx is the chip ID – see above). If it does not work with this hostname, use the IP address of the Geiger counter instead. The Ip address can be found in the devices list in your router. If successful, the login page appears. Enter **admin** as username and the chosen password (see above). Now you will see the settings page as described.

### Server for measured data

The pulses are counted for one measuring cycle at a time, from which the "counts per minute" (cpm) are calculated. After each cycle the data is sent to the servers at *sensor.community* and at *madavi.de*.

At *sensor.community* the data is stored and made available for retrieval the next day as CSV file. This file can be found at http://archive.sensor.community/DATE/DATE_radiation_si22g_sensor_SID.csv), where DATE = date in format YYYY-MM-DD (both times equal) and SID is the sensor number of the sensor (**not** the ChipID). For other sensors, replace the counting tube name **si22g** with the corresponding name (e.g.: sbm-20 or sbm-19).

At *madavi* the data is stored in a RRD database and can be accessed directly as a graph via this link: https://www.madavi.de/sensor/graph.php?sensor=esp32-CHIPID-si22g. Here CHIPID is the ChipId (the digits of the SSID of the internal access point).

During the transmission of the data to the servers, the name of the server is briefly shown in the status line (bottom line) of the display.

### Login to sensor.community

In order to send the measuered data to sensor.community, it is mandatory to have a valid account and the sensor is registered. Both can be done at https://devices.sensor.community. Create an account if you do not have one via the *Register* button and log in. To register a new sensor click *Register new sensor*. Fill in the form:

- Sensor ID: Enter the number (only the numbers) of the SSID of the sensor (e.g. for the sensor ESP-51564452 enter 51564452).
- Sensor Board: Select *esp32* (by the small arrows on the right)
- Basic information: Enter the address and the country. The internal name of the sensor can be assigned arbitrarily, but must be entered. Please check **Indoor sensor** as long as the sensor operates not outdoor.
- Additional information: Can be left blank, but its nice to provide further information.
- Hardware configuration: Select the sensor type **Radiation Si22G** (or accordingly). The value for the second sensor can remain DHT22, as it is irrelevant in this context.
- Position: Please enter the coordinates as accurate as possible. You can use the right button to calculate the coordinates. They are needed to show your sensor on the map.

Finish the settings by clicking *Save settings*. At the overview page for this sensor go to *Data*. Here you see amongst others the ID of the sensor. Please remember: the ID mandatory for the queries at sensor.community or multigeiger.citysensor.de.

### Setup (LoRA)

The MultiGeiger can be connected with the followng steps to TTN ("The Things Network"):

- Create the TTN device in your profile at *The Things Network*
- Transfer the parameters to the multi-pointer
- Login at *sensor.community* (former luftdaten.info)
- HTTP integration

### Creating a TTN device

The device must be registered with TTN. To do this, an account must first be created at TTN (if one does not already exist).

### Create TTN account

At https://account.thethingsnetwork.org/register you have to enter a **USERNAME**, the **EMAIL ADDRESS** and a **PASSWORD**. Then right down over **Create account** create the account. After that you can log in to the console with the new data (https://account.thethingsnetwork.org/users/login).

### Create application

After you have logged in successfully, create the new application via **APPLICATIONS** and **add applications**. The following fields must be filled in:

- **Application ID:** Any name for this application, but it must not yet exist in the network (e.g.: geiger_20200205).

- **Description:** Any description of the application can be entered here.
- **Application EUI:** Remains empty, the number is generated by the TTN system.
- **Handler registration:** The pre-filled value (ttn-handler-eu) is already correct and remains.

Now add the application with **Add application** in the lower right corner.

### Create device

Finally, the device has to be created. To do this, select the newly created application in the overview of applications (click). Then in the middle area at **DEVICES** start the creation of a new device via **register device**. The following fields must be filled in:

- **Device ID:** Any name for the device. It must be unique within the application (e.g.: geiger_01) and consist only of lower-case letters.
- **Device EUI:** Click once on the symbol on the far left of the line, then the text appears that this number is generated by the system. We don't have to enter anything else.
- **App Key:** No input necessary
- **App EUI:** Stays like this

Click on **Register** in the lower right corner. Congratulations, the device is created.

### Modifying the LoRa parameters

- After the registration was completed, the LoRa parameters can be transferred to the program.
- They can be set up at the configuration site of the Geiger counter (see above).
- Go through the configuration site until the settings of the LoRa parameters are displayed. Type in the 3 parameters from the TTN console (**APPEUI, DEVEUI, APPKEY**). They can be found in your TTN account for each device (see above). The HEX values must be entered **without** spaces as they appear in the TTN.

Example: | The TTN console reads

```
Device EUI 00 D0 C0 00 C3 19 7C E8
```

Then the following must be entered:

```
00D0C000C3197CE8
```

This is also applies to **APPEUI** and **APPKEY** .

### Logging data into sensor.community (formerly luftdaten.info)

If you want the MultiGeiger to pass recorded data to *sensor.community* via TTN, you have to register it. The registration is similar to the TTN registration described above. In the following, only the changes are explained:

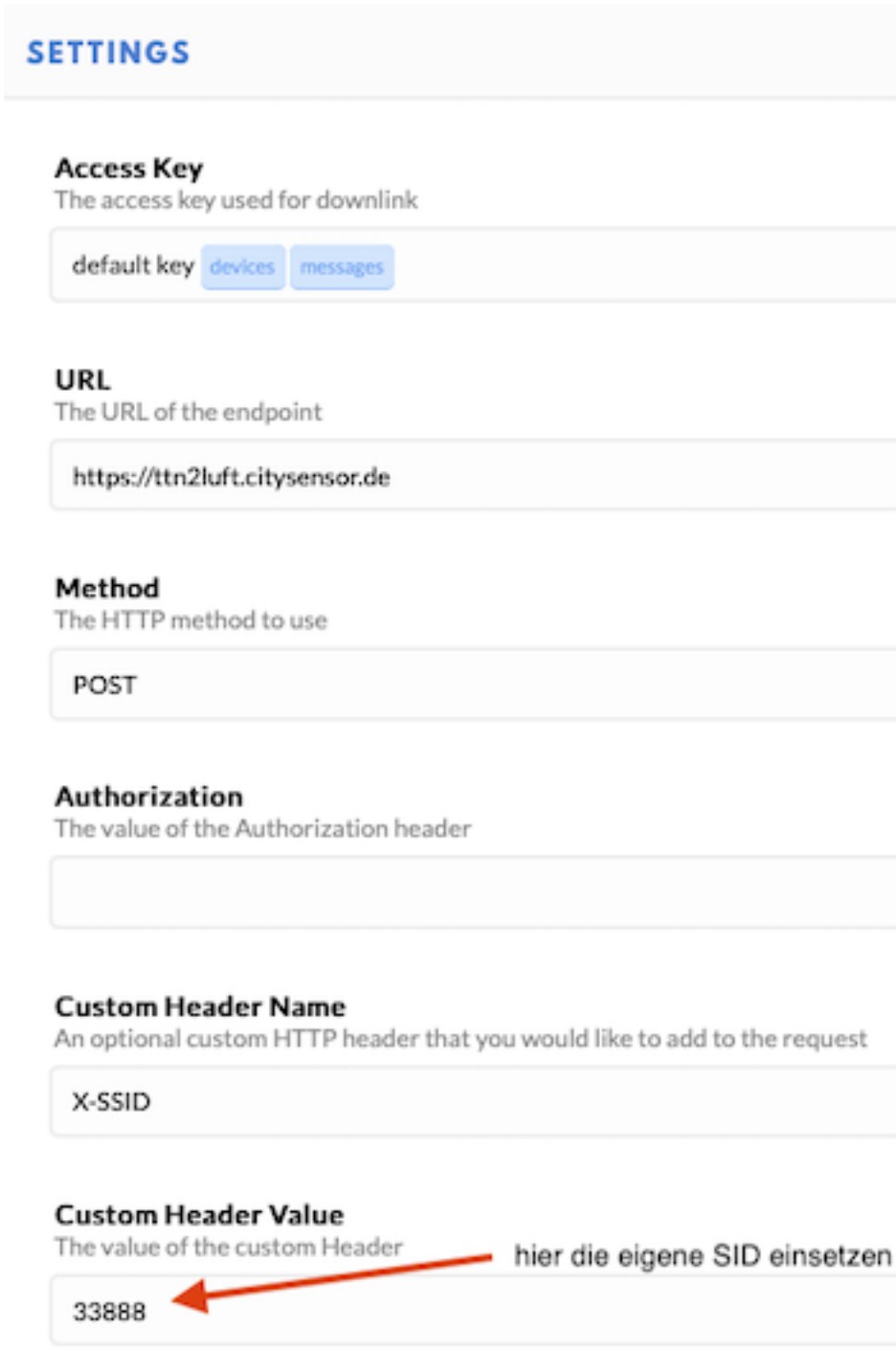
- Sensor ID: Enter the last 4 bytes of the DEVEUI in left to right order (e.g. if the DEVEUI is *00 D0 C0 00 C3 19 7C E8*, so enter *C3197CE8*), but converted to decimal, not in HEX (finally: 3273227496).
- Sensor Board: Select **TTN**, using the small arrows on the right.

### HTTP integration

To get the data from TTN to *sensor.community* you have to enable the HTTP integration at TTN. In the TTN console click *Applications* and then click on the application of the GeigerCounter (e.g. *geiger_20200205*). On the top right in the bar with *Overview*, *Devices*, *Payload Formats*, *Integrations*, *Data*, *Settings* click **Integrations**. Then select **HTTP Integration** via **add integration**.

**Now fill in the displayed fields:**

- **Process ID** Enter any name for this integration here **Access Key:** Click here once and select the *default key*
- **URL:** Enter the URL for the ttn2luft program: https://ttn2luft.citysensor.de
- **Method:** If it reads already *POST*, don't touch it
- **Authorization:** remains empty
- **Custom Header Name:** here comes the text **X-SSID** pure
- **Custom Header value:** Enter the SSID of the sensor (the number you got when you registered at sensor.community, *NOT* the chip ID).
- Click **Add integration** in the lower right corner to confirm the changes.




See this example how the form should look like:

### TTN payload (example)

In order to get readable values in the TTN console instead of solely data bytes, a small script can be inserted as payload decoder. Go to the TTN website, log in, click **Applications** to find the application you created above. Select the tab **Payload Formats** in the menu bar and paste the following code into the field. Existing code will be overwritten):

```
function Decoder(bytes, port) {
  // Decode an uplink message from a buffer
  // (array) of bytes to an object of fields.
  var decoded = {};
  if(port == 1) {
  decoded.counts = ((bytes[0]*256 + bytes[1]) * 256 + bytes[2]) * 256 + bytes[3];
  decoded.sample_time = (bytes[4] * 256 + bytes[5]) * 256 + bytes[6];
  decoded.tube = bytes[9];
  var minor = (bytes[7]&0xF)+(bytes[8]>>4) ;
  decoded.sw_version="" + (bytes[7]>>4) + "." + minor + "." + (bytes[8]&0xF);
  }
  if (port === 2) {
    decoded.temp = ((bytes[0] * 256 + bytes[1]) / 10) + "°C";
    decoded.humi = bytes[2] / 2 + "%";
    decoded.press = ((bytes[3] * 256 + bytes[4]) / 10) + "hPa";
  }
  return decoded;
}
```

### Usage

### OLED display

### Top line

Left: Time since power-on (not shown on small displays).

Right: Overall average radiation since power-on.

### Middle area

Current CPM (counts per minute) displayed using a rather big font.

### Bottom line

This is a status display with 8 positions, numbered 0..7:

Rules of thumb:

- `.` usually means “off” or “unused”.
- if you see some *number* (`0` .. `7`) within the status display line, something went wrong.

Positions:

- 0: WiFi
  - `A`: AccessPoint active
  - `w`: WiFi client trying to connect
  - `W`: WiFi client connected
  - `0`: some error happened
- 1: sensors.community transmission

  - `.`: off (not configured, not enabled)
  - `?`: init (enabled, before 1st transmission)
  - `S`: sending
  - `s`: idle (shown after successful sending)
  - `1`: sending failed (shown after trying to send)
- 2: madavi transmission
  - `.`: off (not configured, not enabled)
  - `?`: init (enabled, before 1st transmission)
  - `M`: sending
  - `m`: idle (shown after successful sending)
  - `2`: sending failed (shown after trying to send)
- 3: TTN ("The Things Network")
  - `.`: off (not configured, not enabled, no LoRa hardware)
  - `?`: init (enabled, before 1st transmission)
  - `T`: sending
  - `t`: idle (shown after successful sending)
  - `3`: sending failed (shown after trying to send)
- 4: BLE (Bluetooth® Low Energy)
  - `.`: off (not enabled)
  - `?`: init (enabled, before setup of BLE service)
  - `B`: connected and sending notifications, if requested by connected device
  - `b`: connectable (advertising and ready to connect)
  - `4`: BLE error
- 5: unused
- 6: unused
- 7: High-Voltage Capacitor charging
  - `H`: OK
  - `7`: failure to charge HV capacitor

### ESP32 buttons

The MultiGeiger ESP32 microcontroller board has 2 buttons:

- RST: reset (restarts device)
- PRG: program (press and hold PRG, press RST momentarily, upload firmware)

Often, using PRG is not needed for flashing firmware, because it "just works" when using the right tools.

### DIP Switches

Optionally, the MultiGeiger can be equipped with a 4-contact DIP switch under the ESP32 microcontroller board.

The firmware makes use of these 4 switches as defined in the `Switches` data type in `switches.h`:

- SW0: Speaker on
- SW1: Display on
- SW2: LED on
- SW3: BLE on

### BLE - Bluetooth® Low Energy

### BLE Heart Rate Service

The MultiGeiger provides a Bluetooth® Low Energy (BLE) service to allow the collection of the Geiger-Mueller count rate via a GATT Heart Rate Service (Service UUID 0x180D). The following characteristics are used:

- 0x2A37 ('Heart Rate Measurement Characteristic'):
  - The first byte is a collection of status flags, according to the service's standard
  - 'Heart Rate Measurement' as 16 bit value (little endian), corresponds to Geiger-Mueller counts per minute (CPM)
  - 'Energy Expenditure' as 16 bit value (little endian), represents a rolling packet counter
- 0x2A38 ('Heart Rate Sensor Position Characteristic')
  - 'Sensor Position' as 8 bit value, corresponds to TUBE-TYPE, allowing the conversion of CPM to radiation rate
- 0x2A39 ('Heart Rate Control Point Characteristic')
  - Write characteristic, required by service's standard to reset Energy Expenditure to 0. Writing 0x01 resets the rolling packet counter to 0.

### Testing BLE

Any decent Bluetooth® scanning app should be able to connect to the device and show the notification values. Known to work well is the nordic® nRF Connect app, which should be available for iOS and Android. More infos about the Android app can be found here on github.

Any heart monitor app / device should be able to connect to the MultiGeiger, too, but that was not tested yet. Any input is appreciated.

- Figure 1: Connect to the MultiGeiger with the name 'ESP32-<id>', where <id> should be the same ID (7 to 8 digits) as with the access point to set the device up initially.
- Figure 2: Find the correct service (UUID 0x180D) and, if needed, load / open characteristics.
- Figure 3: Find the Heart Rate Measurement Characteristic (UUID 0x2A37) and click on the icon to start notifications.

While testing, please keep in mind that an update packet is sent only every ~10s (along with a display refresh, if enabled). If a WiFi transmission is blocking display and BLE updates, the interval may be even longer. So it might take a while until a reaction with actual data can be seen in the app.

*Fig. 1*

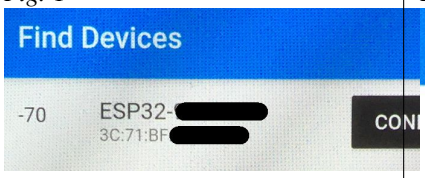



*Fig. 2*

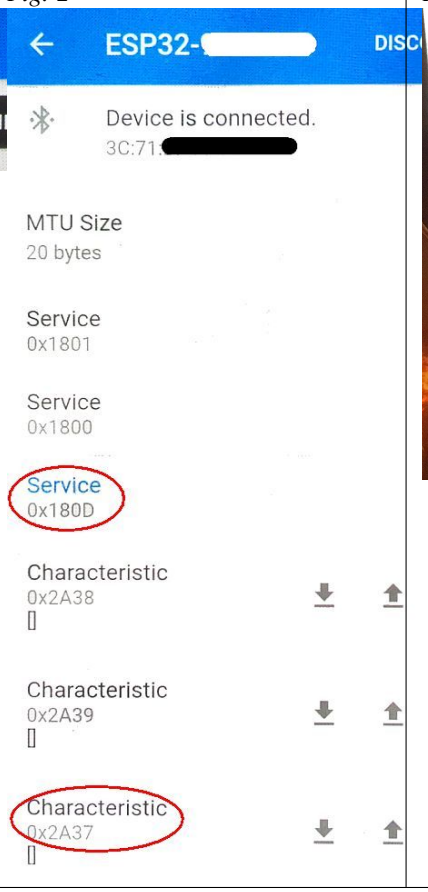
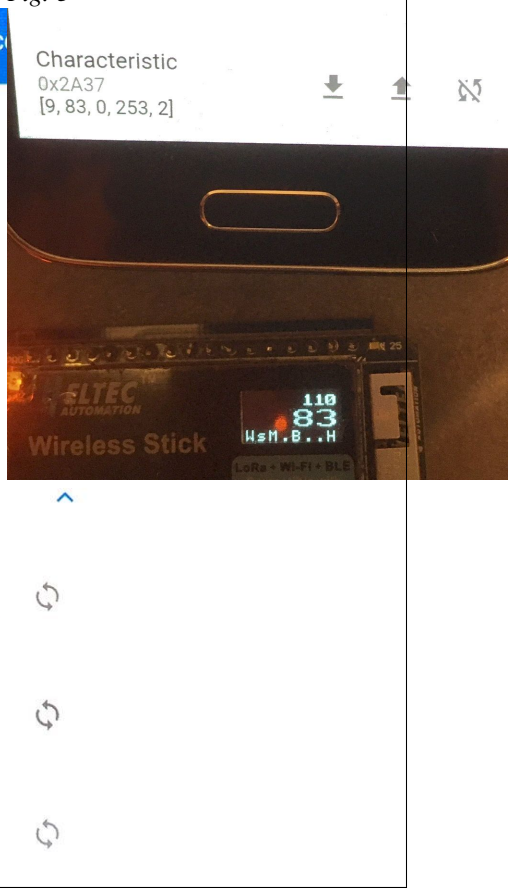



*Fig. 3*




### Deployment

When deploying the MultiGeiger measurement station, you need to consider some things.

Of course, for us private persons, there rarely will be a 100% perfect deployment place. But still, we can be aware of the parameters which may have a negative impact.

### Requirements for the deployment place

### Choosing a deployment place

We want to measure radioactive substances (dust), also known as "fallout". They come from e.g. nuclear explosions or reactor desasters.

In a very weak variant, they also naturally come from the atmosphere due to the decay of the radioactive noble gas radon. This "radon fallout" causes a small, but measurable peak on our devices, which degrades with a half life of 45 minutes.

With the help of these "radon peaks", we can see whether our device is deployed to a good place and is sensitive also for "real" fallout.

### Irrigation area

We need a bigger irrigation area in the direct vicinity of the measurement station. This area should also have the capability to hold and store radioactive particles.

A lawn or a meadow is perfect for this.

On the other hand, some asphalt can not do that, because particles are washed away directly after raining down.

### Wind direction

The area should be unobstructed from the main wind direction by other buildings, bushes or trees.

### Sun light

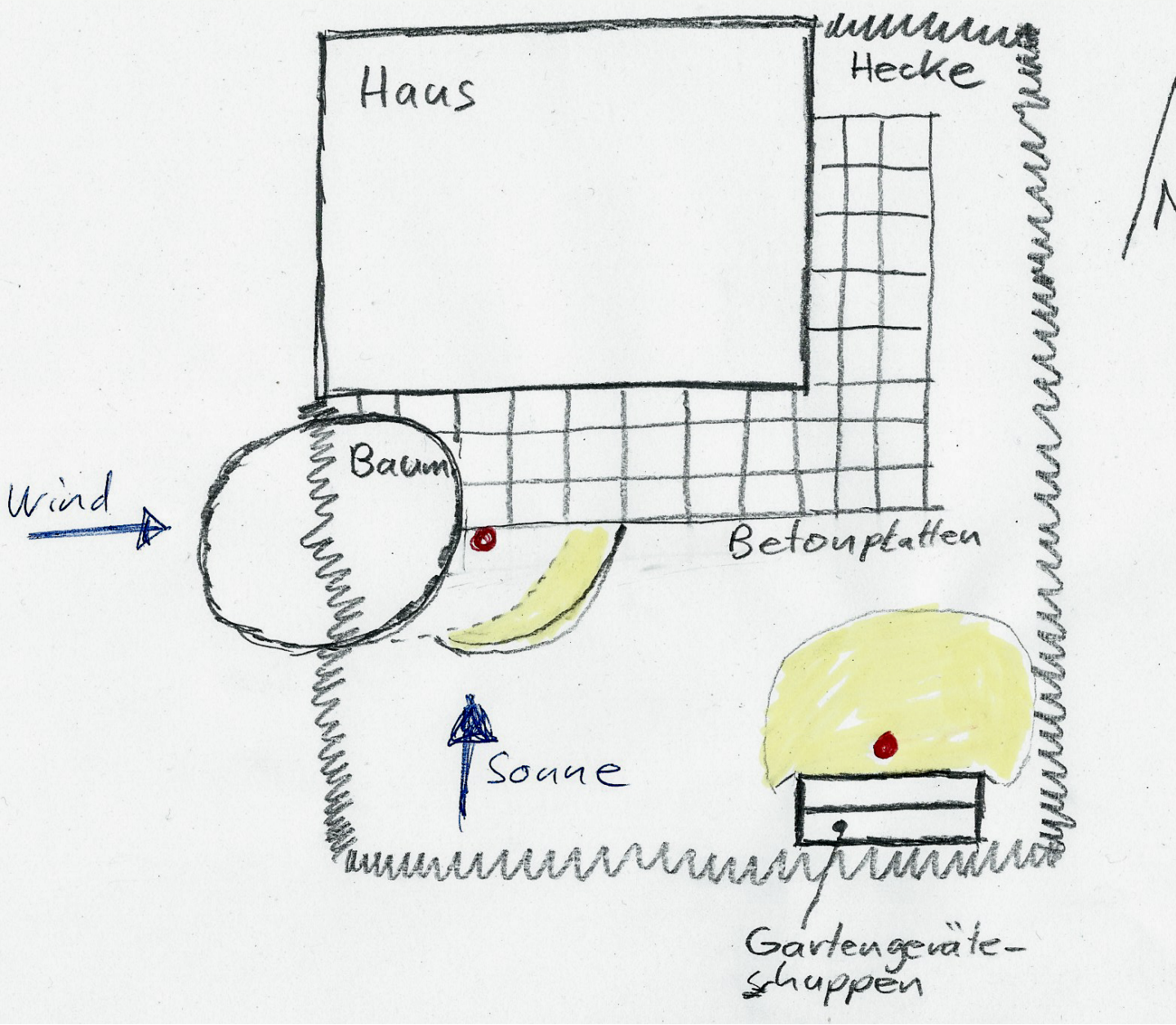
The power supply cable as well as the MultiGeiger device itself, should be in the shadows most of the time.

Direct sunlight can have two negative influences:

- Heat: The temperature inside the device can rise to up to 60 deg celsius in direct sunshine (45 deg celsius in the shadows). We did practical temperature tests showing that the device works ok up to 70 deg celsius. But the GM tube is only specified to up to 50 deg celsius.
- UV damage: Over time, the cable and case can be damaged by UV radiation and get porous.

### Examples

Examples of good and bad deployment places:




Comparison of two deployment places. Yellow is the “usable irrigation area”.

Bad deployment place (red dot at the left)

Reasons:

- Meadow: a bit part of the area around the GM device is made of concrete platter. Incapable of holding/storing fallout.
- Wind: the main wind direction is from the west and the tree obstructs fallout raining down close to the device.
- Sun: Sunlight comes primarily from the south and strongly shines on the devices.

Good deployment place (red dot at the right)

Reasons:

- Meadow: a big part of the area around the GM device is meadow, which can hold/store fallout.

- Wind: no obstruction
- Sun: the GM device is in the shadow due to the garden shack.

#### More Information

Description of the BFS-ODL measurement network (german):

- Messnetz
- ODL-Sonde

Video interview about the BFS-ODL measurement network (german):

- Interview über das BFS-ODL-Netzwerk

### Frequently Asked Questions

#### General

#### Radiation doses, are there practical examples?

There's a great XKCD about that, see there:

https://xkcd.com/radiation/

### Resources

This is a collection of additional resources that are somehow related to MultiGeiger.

#### Hardware / Parts

MultiGeiger supported ESP32 boards:

- Heltec WiFi Kit 32 (WiFi-only, infos from board manufacturer) https://heltec.org/project/wifi-kit-32/
- Heltec Wireless Stick (WiFi+LoRa, infos from board manufacturer) https://heltec.org/project/wireless-stick/

#### Software

- Windows driver for the USB -> UART chip CP2102: http://esp32.net/usb-uart/#SiLabs

### Changelog

#### V1.15.0 2021-03-21

New features:

- add bluetooth (BLE) support, #78

Fixes:

- improve LoRaWAN stability (work around LMIC bug #677, add LMIC polling from loop()), #373

- do async NTP/clock setup, #316
- speaker: init "duty_mode" member in MCPWM config
- avoid using IotWebConf 3.0.0 for now, #357, PR #370

Other changes:

- patch: restore partition scheme menu for arduino-esp32 1.0.5
- move CI from travis CI to github workflow
- start screen cleanups, #335
- code / naming style fixes
- remove dates in file names, commit relevant versions to git
- add drill files, #354
- docs:
  - use transifex / sphinx / readthedocs.org for translatons (en/de for now)
  - document docs/translation workflow in development docs
  - added assembly and deployment guide
  - document esp32 board buttons, #129
  - document dip switch usage, #128
  - move README-{de,en}.* contents into the .rst docs
  - BLE usage documentation update with some images, #338
  - added links to map, ecocurious, assembly room
  - markup, rendering, spelling fixes, cleanups
  - fix unclear version / date in Aufbauanleitung, #110
  - moved links to docs -> resources, #223
  - add xkcd about radiation doses to FAQ, #310

### V1.14.0 2020-05-16

New features:

- implement status line on OLED display (see docs), #257
- also support BME680 sensor for temperature, humidity, pressure
- display time up to 60s / 60m / 24h / 99d, then roll over
- speaker/LED: timer-driven sequencer, hw PWM sound, #35
- TLS support
  - add clock module, use NTP to set the clock
  - use persistent per-server HTTPClient instances
  - use connection: keep-alive for web requests
  - add https capability (can be used for sending data)
  - note: transmission to sensors.community and madavi is still using http!

Fixes:

- fixed GM pulse debouncing, #248
- pulse counting: deal with microseconds uint32 overflow, #273
- check WiFi status before trying to transmit
- fix race condition, #286

Other changes:

- dip switches: only read once at boot time, #207
- new font (u8x8 uses 8px width anyway)
- slow down main loop
- toilet -> custom server, add comments about toilet usage, #214
- refactor/simplify pulse counting ISR, bookkeeping in main loop, #220
- refactor big main loop into smaller functions with local bookkeeping.
- misc. other code cleanups
- loraWan: removed unused/not needed code, #212, #234
- removed meeting notes, #294
- docs:
  - README improvements (board name, flash size, partition scheme, passwords, LoRa)
  - update development/release docs (create/test binaries, IDE settings, . . . )

### V1.13.0 2020-04-14

- auto-detect hardware (STICK vs. WIFI) by hardware pin
- use config web page for more values (userdefines.h has the defaults), #140
- try both adresses of BME280
- LoRa payload changes, e.g. to fulfill 'TTN Fair Access Policy'
- send additional data to servers
- send to MADAVI in one single request both geiger and thp data
- new logging with DEFAULT_LOG_LEVEL configuration
- integrated travis-ci:
  - for compile checks (platformio, wifi and stick build)
  - for style checks (using the "astyle" CPP checker)
- source: modularization, cleanups, less globals, . . . (quite huge internal changes, please help testing!)
- building:
  - platformio-based build: suppress lmic_project_config.h usage
  - arduino-ide-based build: you still need to edit that file
- use bump2version tool for project version bumps, #169
- docs:

  - added upgrade hints for 1.13 in README on github
  - https://multigeiger.readthedocs.io/ == the beginning of new (sphinx / reST-markup based) online docs, #163
  - add a basic, short README in English (also for online docs)
  - include infos about project name, #121
  - moved changelog.md to docs/source/changes.rst
  - updated/fixed development docs, #46
  - update docs about new 5V power supply / cabling, #122
  - description of LoRa Payload updated
  - other docs improvements / fixes

### V1.12.0 2020-01-18

- simple OTA (Over-The-Air) updates via web browser based upload, #120
- use less charge pulses in loop() for timing, more in setup() for initial charging, #134
- output error msg on Serial if HV charging fails
- tag log output with "GEIGER: ", #85
- add TUBE_UNKNOWN 0 to have a specific value for experimenting
- adapted platformio.ini to pull all dependencies
- send CR and LF on serial
- changed default tube from sbm-20 to si22g
- semantic versioning, version numbers now like x.y.z
- changed building of revString and lora_version
- docs updated / improved
- explain SBM-19/SBM-20 conversion factor
- removed IotWebconf bundled&patched code, used as a lib now.

### V1.11.1 2019-12-16 rxf

- change luftdaten.info to sensor.community

### V1.11.0 2019-12-16 rxf

- defaults in userdefines-example.h changed
- Software version for LoRa now 2 Bytes
- Display start screen for Wireless stick fixed
- changed to semantic versioning

### V1.10 2019-12-13

- conversion factor for Si22G tube fixed
- char variables changed to int
- isr routines shielded with portMUX
- debug serial out formatting improved
- sequence of counting and dispaying and hv charging improved
- speaker and led tick fixed
- many calls to millis() consolidated

### V1.9 2019-11-12

- structure for different counter tubes
- LoRa payload changed again
- hv pulse every second
- calculate and display cpm value every 10 seconds
- fixed div by 0 if there's no tube
- Readme corrected

### V1.8 2019-11-04

- indentation/spacing, refactor OLED functions, fix conversion factor
- MEASUREMENT_INTERVAL 150sec
- changed LoRa payload

### V1.7 2019-10-21

- PINs rearranged, so we can use new Wifi-Kit-32 and WiFi Stick Light
- Hardware-Layout V1.4 and up
- use switch for speaker tick and display off

### V1.61 2019-09-30

- default measuring interval is now 2.5min

### V1.6 2019-09-13

- some rearrangement of files
- userdefine.h for user changable #defines
- test with dip-switch (needs pullup resistors!)

- Hardware layout V1.3 and lower - OLD Wifi-Kit-32!

### V1.5 2019-09-11

- added BME280 (uses same I2C as display)
- Support for display on Wireless Stick
- For LoRa-Devices added LoRa functionality

### V1.4 2019-09-03

- default configuration with measurement interval of 10min

### V1.3 2019-09-03

- building of ESP-ID out of MAC address is now identical to 'Feinstaubsensor'

### V1.2 2019-09-02

- sending to madavi corrected

### V1.1 2019-09-01

- Library IoTWebConfig changed -> function 'setThingName' added
- Move this (IoTWebConfig) library to source path
- building the SSID from the MAC corrected: first 3 Bytes of MAC build SSID
- LoRa autodetection removed

### V1.0 2019-08-19 rxf

- added detection of LoRa device
- WiFiManager to enter WLAN data and other configs
- send to luftdaten.info every 2.5 min

### V0.3 2019-05-12 jb

- added bug fix for the "Double-Trigger-Problem". This was caused by the rising edge falsly triggering an other pulse recording. The Problem is that there is no Schmitt-Trigger available in the controller.
- simplified serial printing modes
- made seconds in Display as inverse to be able to separate it from minutes
- cleaned up the code
- Fixed overflow bug in Minute-Count+

### V0.2 2019-04-26 jb

- added 1 Minute RS232 (USB) logging mode

### V0.1 2019-03-25 jb

- first version for ESP32 board

## Development

This chapter will get you started with MultiGeiger development.

MultiGeiger is written in C using Arduino-ESP32.

## Contributions

. . . are welcome!

Some guidance for contributors:

- discuss about changes on github issue tracker
- make your PRs against the `master` branch
- do clean changesets:
  - focus on some topic, resist changing anything else.
  - do not do style changes mixed with functional changes.
  - run the automatic code formatter before committing
  - try to avoid refactorings mixed with functional changes.
  - if you need to fix something after commit/push:
    - if there are ongoing reviews: do a fixup commit you can merge into the bad commit later.
    - if there are no ongoing reviews or you did not push the bad commit yet: edit the commit to include your fix or merge the fixup commit before pushing.
  - have a nice, clear, typo-free commit comment
  - if you fixed an issue, refer to it in your commit comment
- make a pull request on github and check on the PR page what the CI system tells about the code in your PR
- wait for review by other developers

## Building a development environment

TODO

### Automatic Code Formatter

We use astyle for automated code formatting / formatting checks.

Run it like this:

```
astyle --options=.astylerc 'multigeiger/\*'
```

## Documentation

### Building the docs with Sphinx

Documentation is written in English and translated to other languages from that source (initially German).

The documentation (in reStructuredText format, .rst) is in `docs/source/`, `index.rst` is the starting point there.

To build the docs, you need to have Sphinx installed and run:

```
cd docs/
make html
```

Then point a web browser at `docs/build/html/index.html`.

The website is updated automatically by ReadTheDocs through GitHub web hooks on the main repository.

After changes of the (english) master docs, the translation master files (`*.pot`) need updating (adding/removing/updating strings in there):

```
cd docs/build/gettext
sphinx-build -b gettext ../../source .
```

Then, these changes need to get pushed to transifex, so translators can comfortably translate on the web:

Translation is organised via [transifex](https://www.transifex.com/thomaswaldmann/multigeiger/), you need to have an account or at least login there and fire a "join team" request. Then translate the missing parts and notify the developers (e.g. via issue tracker).

```
tx push --source
```

Later, after translators did their part, updated translations need to get pulled from transifex:

```
tx pull --all
```

Now we have changes in our git workdir and we need to commit them:

```
git add locales/
git commit -m "updated translations"
git push
```

This will trigger a build of the docs and their translation(s) on readthedocs.io.

### Flashing devices / creating binaries

Arduino IDE:

- do a git checkout of the wanted release, e.g. `git checkout V1.13.0`

- use the default userdefines.h (available as userdefines-example.h)
- IDE settings:
  - Device: Heltec WiFi Stick (always use this, even if you have a WiFi Kit 32)
  - Flash size: 4MB (32Mb)
  - Partition scheme: minimal SPIFFS (large APPS with OTA) - this fits onto 4MB devices.
- `Arduino IDE -> Sketch -> Upload`

  This is to test whether the compiled code actually works after USB-flashing to your device.
- `Arduino IDE -> Sketch -> Export compiled binary`

  This creates a .bin file for OTA updating. Test whether OTA updating using that file works.

### Creating a new release

Checklist:

- make sure all issues for this milestone are closed or moved to the next milestone
- check if there are any pending fixes for severe issues
- check whether some CA certificate (see `ca_certs.h`) will expire soon and whether we already can add their next valid cert.
- find and fix any low hanging fruit left on the issue tracker
- close release milestone on Github
- update `docs/source/changes.rst`, based on `git log $PREVIOUS_RELEASE..`
- `bump2version --new-version 1.23.0 release` - this will:
  - update versions everywhere
  - auto-create a git tag
  - auto-create a git commit
- review the automatically generated changeset
- create a github release for this tag:
  - create a binary (see above) and attach to the github release
  - add a link to the relevant `changes.rst` section to the github release

### Authors

- Juergen Boehringer (see www.boehri.de)
- Reinhard X. Fuerst (see feinstaub.rexfue.de)
- Thomas Waldmann <twaldmann@thinkmo.de>
- and others

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  1. Source Code.
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    copy the object code is a network server, the Corresponding Source
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    that supports equivalent copying facilities, provided you maintain
    clear directions next to the object code saying where to find the
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