

## Assembly Manual for UKRAA Cosmic Watch Muon Detector

### Introduction

A. These instructions should be read in conjunction with:

- Dr Spencer Axani's videos at
  - <https://www.youtube.com/watch?v=e4IXzNiNxgU>
  - [https://www.youtube.com/watch?v=zdVC8EL\\_Xt8&t=956s](https://www.youtube.com/watch?v=zdVC8EL_Xt8&t=956s)
  - <https://www.youtube.com/watch?v=yFgin5wlw4I&t=3s>
  - <https://www.youtube.com/watch?v=Ck24HGrijBfY&t=378s>
- The CosmicWatch Instruction Manual at <https://github.com/spenceraxani/CosmicWatch-Desktop-Muon-Detector-v2/blob/master/Instructions.pdf>

B. The pcbs supplied by UKRAA are a later version than those described in the videos and Manual referred to above. The principal changes are as follows:

- The 0 Ohm resistors on the version described in the videos/Manual have been replaced by tracking in the UKRAA supplied version so are not shown on the pcbs;
- There are a number of unused components shown on the version described in the videos/Manual. These do not appear on the version supplied by UKRAA.
- The metal filling shown in the Instruction Manual on the SiPM pcb is not provided in the later version supplied by UKRAA.
- Metric screws and spacers have been supplied in the UKRAA kit in place of the imperial screws and spacers described in the Instruction Manual.
- The scintillator blocks supplied by UKRAA have been polished, drilled and tapped. The procedures described in section 4.4 of the Instruction Manual should be ignored.

C. All of the components required to make the Muon Detector are included in the kit, so section 3.1 of the Instruction Manual can be ignored. You will need to supply the following items, where required:

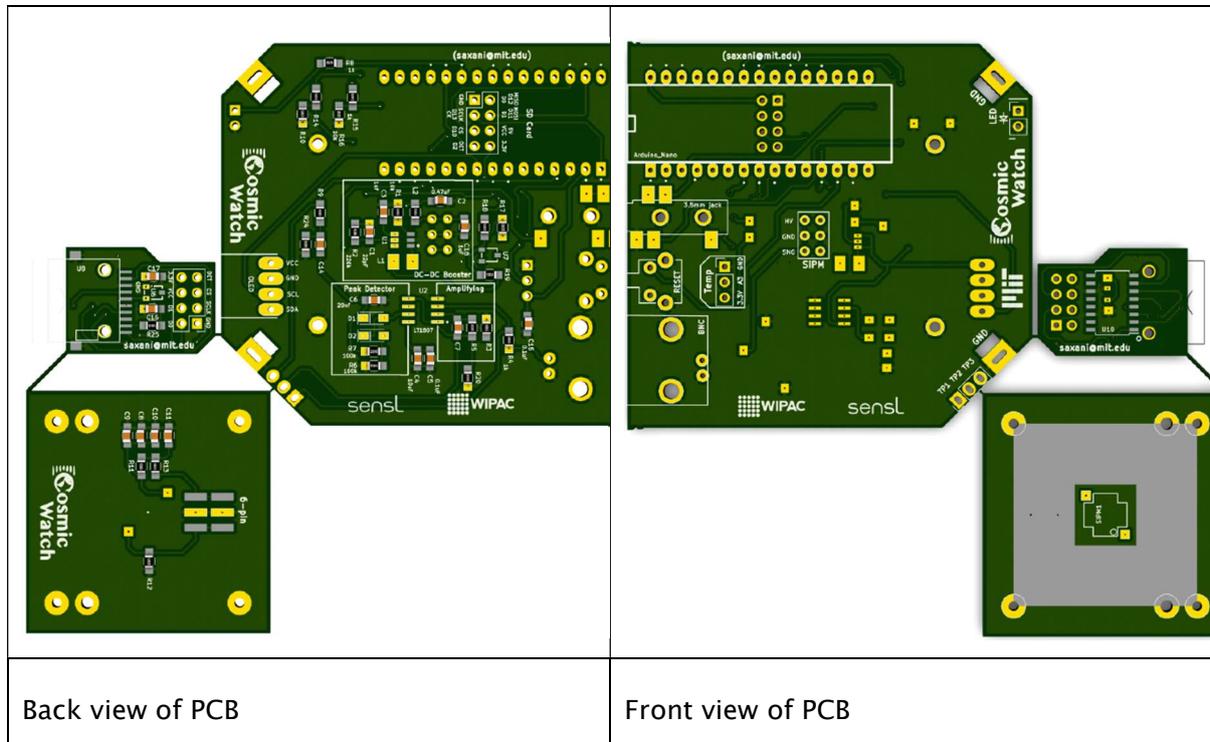
- Aluminium foil for wrapping the Plastic scintillator – the 18u (quality GB4806.9-2016) Al foil is best;
- Black electrical tape for making the Plastic scintillator light-tight;
- A microSD Card (capacity at least 200 Mb);
- A short 3.5mm male to male audio cable if two detectors are being used in coincidence mode;
- A BNC Cable to connect to an oscilloscope for testing purposes;
- An Enclosure – available from UKRAA (part no UKR086).

D. You can construct the detector by following the procedures described in the videos and Instruction Manual, subject to the comments above or by following the steps described below.

E. If you are new to surface mount soldering, see one of the online tutorial videos such as: <https://www.youtube.com/watch?v=EW9Y8rDm4kE>. A good magnifier, a set of narrow

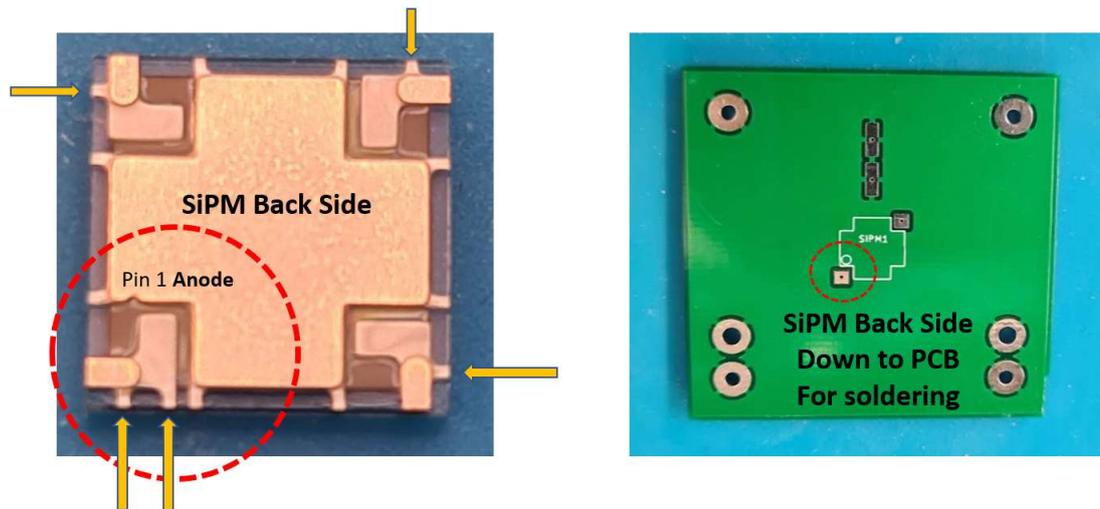
point tweezers, a thin tip (about 1.5mm) soldering iron and 22 SWG 0.7mm solder wire are recommended.

## PCB Orientation



## Stage 1: smd components

1. Solder smd components onto pcbs in the following order:
  - Resistors (all pcbs).
  - Capacitors (all pcbs).
  - Shottky diodes (back side of the main pcb) – NB observe polarity.
  - L1 & L2 inductors (back side of the main pcb).
  - U2 (LT1807) op amp (back side of the main pcb) – NB observe polarity.
  - U1 (LT3461) (back side of the main pcb) – NB observe polarity.
  - U6 (3.3V regulator) (back side of the SD card pcb) – NB observe polarity.
  - SD card socket (back side of the SD card pcb).
  - U10 (the logic level converter) (front side of the SD card pcb) – the line at the top of the IC is at the same end as the pin 1 mark on the pcb.
  - The SiPM (Front side of the scintillator pcb). The corner of the SiPM which has an extra tab is at the corner marked pin 1 on the pcb, as shown below. Warning, do not use metal tweezers to handle the SiPM.



If you are unsure of the orientation of U1 (Analog Devices LT-3461) or U2 (Analog Devices LT-1807), please see the IC manufacturer's data sheet.

### Stage 2: test – part 1

2. Check the resistance in both directions at the back of the SiPM, with the SiPM face placed on a cloth surface which will exclude light. It should be a finite value (typically several MOhm) in one direction and infinity (open circuit) in the other direction.

### Stage 3: through hole components – part 1

3. Solder components onto the pcbs in the following order:
  - 4-pin header (back side of the main pcb).
  - 4 x 2-pin SD card header (back side of the main pcb).
  - temperature sensor (front side of the main pcb).
  - 2 x 3 socket (front side of the main pcb) – take care to align the connector accurately. This will ensure that the stand-offs on the scintillator board align with the screw holes on the main pcb.
  - BNC connector (front side of the main pcb) – careful alignment is needed for subsequent Enclosure end panel alignment.
  - reset button (front side of the main pcb).
  - 3.5mm jack socket (front side of the main pcb) – careful alignment is needed for subsequent Enclosure end panel alignment.
  - Arduino headers (front and rear sides of the main pcb) – NB the short legs of the 15-pin headers are soldered into the front side of the pcb and the 2x4 header is soldered into the rear side of the pcb, again with the short legs soldered into the pcb.
  - Clip off any protruding wires on the pcbs.

#### Stage 4: Arduino programming

4. The Arduino IDE should first be installed on your PC. Take care to select the correct version for your OS. <https://www.arduino.cc/en/software>
5. If you do not already have them on your PC, Install the following libraries from <https://www.arduino.cc/en/guide/libraries>:
  - Adafruit ssd1306 -- Version 1.1.2
  - Adafruit GFX Library -- Version 1.0.2
  - TimerOne -- Version 1.1.0
  - SPI -- Version 1.0.0
  - SD -- Version 1.0.9
  - EEPROM -- Version 2.0.0
6. If you do not already have them on your PC, download the following files from GitHub at <https://github.com/spenceraxani/CosmicWatch-Desktop-Muon-Detector-v2>:
  - Naming.ino;
  - OLED.ino.
7. Edit Naming.ino to change the name of the detector to the desired name.
8. As the supplied Elegoo Nano uses the ATmega328P and CH340 chip instead of the FT232 chip, it is necessary to download and install the driver from [www.elegoo.com](http://www.elegoo.com).
9. Connect the Arduino Nano to your PC using a USB/USB mini cable, select Arduino Nano in the Arduino IDE, and tell the IDE which USB port it is plugged into.
10. Upload naming.ino and run. Check that there are no errors.
11. Upload OLED.ino and run. Check that there are no errors.

#### Stage 5: through hole components – part 2

12. Solder the remaining components onto the pcbs in the following order:
  - the Arduino Nano, with the mini-USB socket facing outwards (front side of the main pcb).
  - the SD Card pcb (back side of the main pcb) – ensure the pcbs are kept parallel. Careful alignment is needed for subsequent Enclosure end panel alignment.
  - the LED – observe polarity (longer leg is +ve). If you have purchased a UKRAA enclosure find the LED bezel, remove the grommet and put the legs through the grommet before soldering. Keep the legs full length to allow alignment with the hole in the UKRAA enclosure end panel, the longer +ve leg should be clipped back after soldering.

### Stage 6: test – part 2

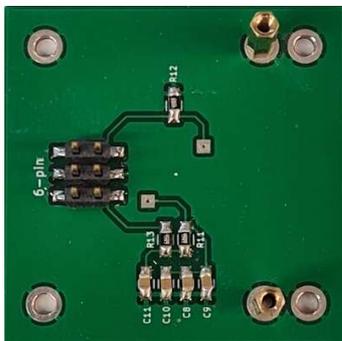
13. Plug a suitable power source into the mini-USB socket on the detector. Connecting the detector to a PC via a USB to mini-USB cable will provide sufficient power.
14. Check that the Arduino LED illuminates. Remove the power cable.
15. Plug the OLED screen into the front of the main pcb. Re-apply power.
16. The OLED screen should display:
  - the Cosmic Watch splash screen, followed by:
  - a screen showing the total count (0), the uptime (0) and the detector name, followed by:
  - a screen showing the total count (1), the uptime (incrementing) the level of the most recent hit (maximum) and the count rate (incrementing).

The white LED should illuminate once between the last two steps.

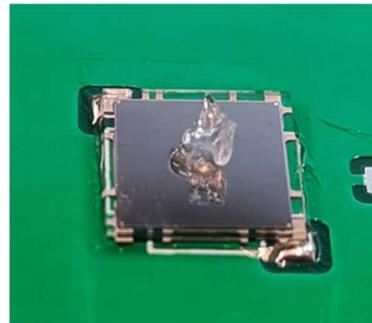
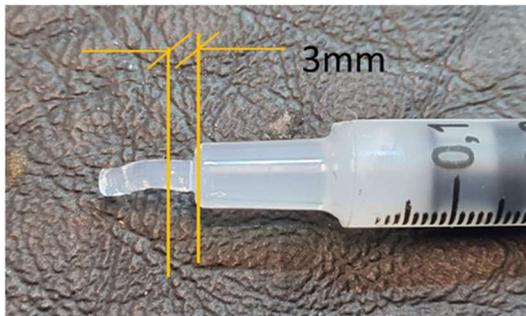
17. Press the red re-set button to check that the OLED screen refreshes.
18. Test the high voltage output as described in section 4.6 of the Instruction Manual. It should be  $29.5V \pm 0.1V$ .
19. Remove the power cable.

### Stage 7: Scintillator module

20. Screw the 2 standoffs to the back of the scintillator pcb with 2 of the standoff screws.



21. Squeeze a small blob of optical gel approximately 3mm long from the syringe. Place the blob of gel on the SiPM and push gently against the scintillator block to align the screw holes. The picture below indicates an appropriate amount of gel to use. Too



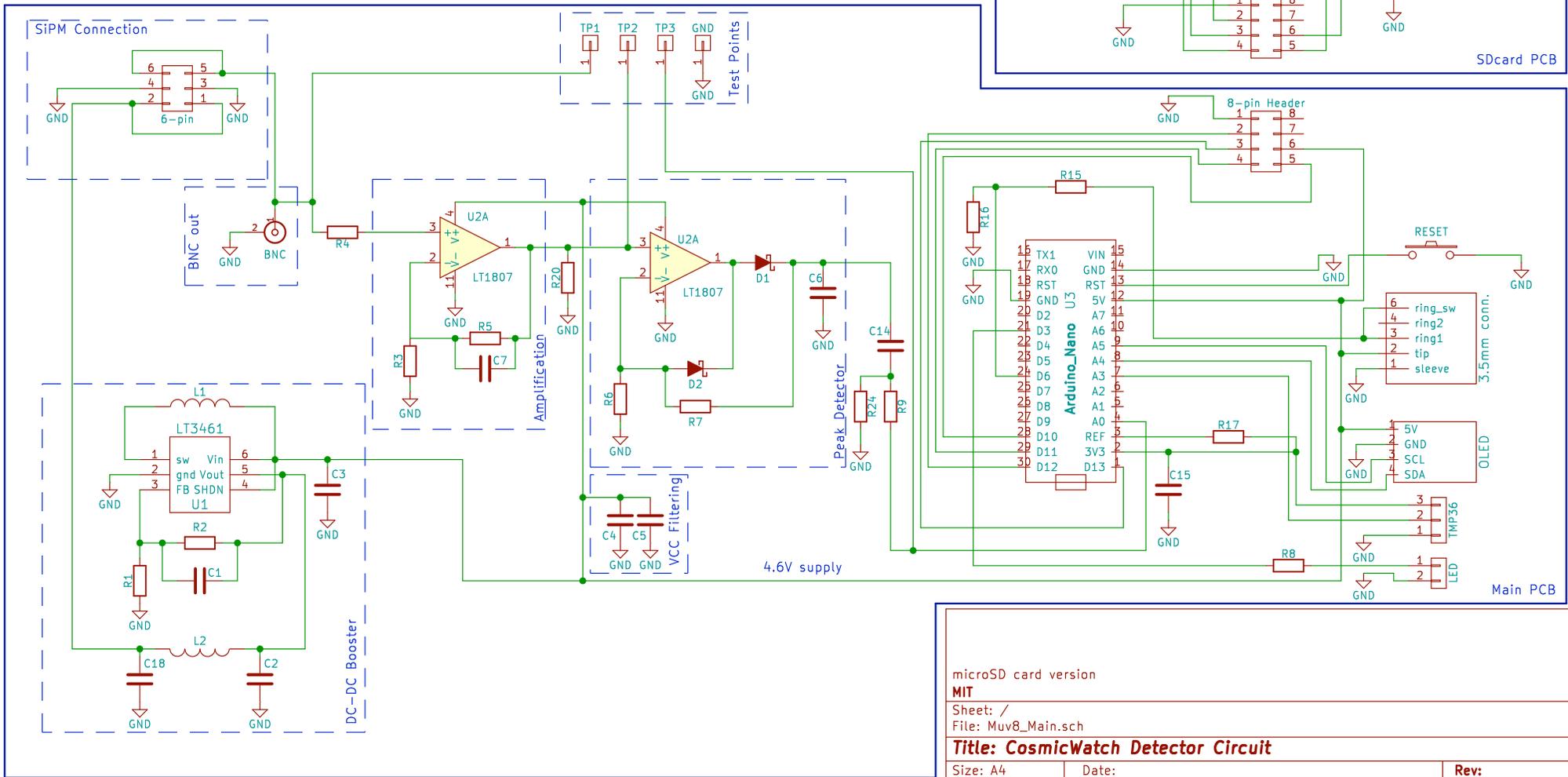
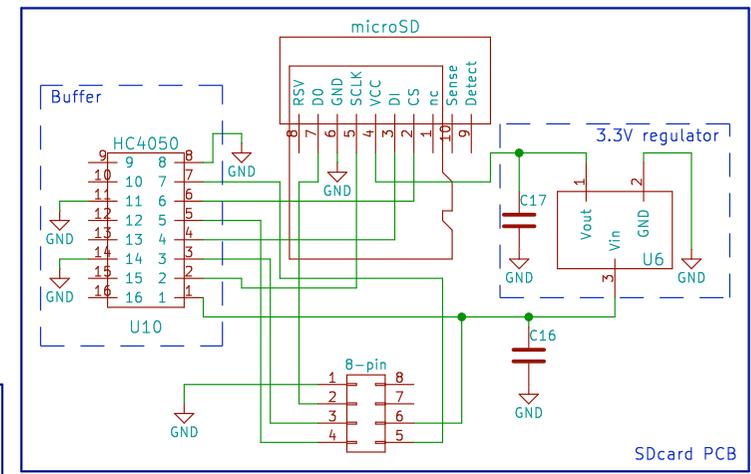
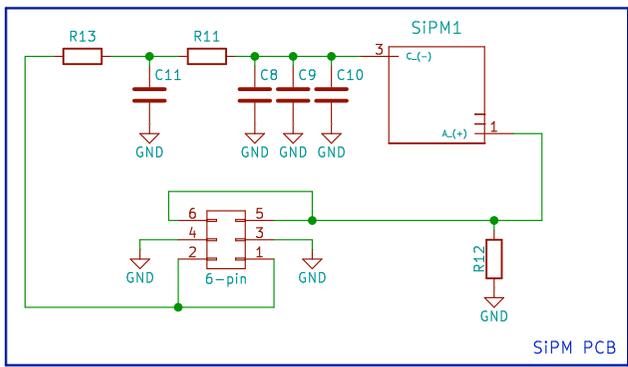
little and the SiPM will not be covered, too much and it will come out around the SiPM and make a mess.

22. Screw the scintillator pcb to the scintillator with the 4 scintillator screws, taking care not to put undue pressure on the SiPM.
23. Tape up the scintillator as shown on the video at <https://www.youtube.com/watch?v=yFgin5wlw4I&t=3s>. Take care not to stretch the tape when applying otherwise it will relax and possibly compromise the light exclusion.
24. Attach the scintillator pcb to the detector pcb by the 6-pin connector and the remaining 2 standoff screws.

### Stage 9: test – part 3

25. Apply power. Depending on various factors (setting of the threshold in the Arduino code, version of the detector, gamma ray background, altitude etc), you should be able to see a count rate of about 0.5 – 1.5 cps at sea level.

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microSD card version  
**MIT**  
 Sheet: /  
 File: Muv8\_Main.sch  
**Title: CosmicWatch Detector Circuit**  
 Size: A4 Date:  
 KiCad E.D.A. eeschema 4.0.2-stable  
 Rev:  
 Id: 1/1