INTEL-IRRIS

Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

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Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

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Building the INTEL-IRRIS LoRa IoT platform Part 1: soil sensor device

(using the latest IRD PCB v4.1)

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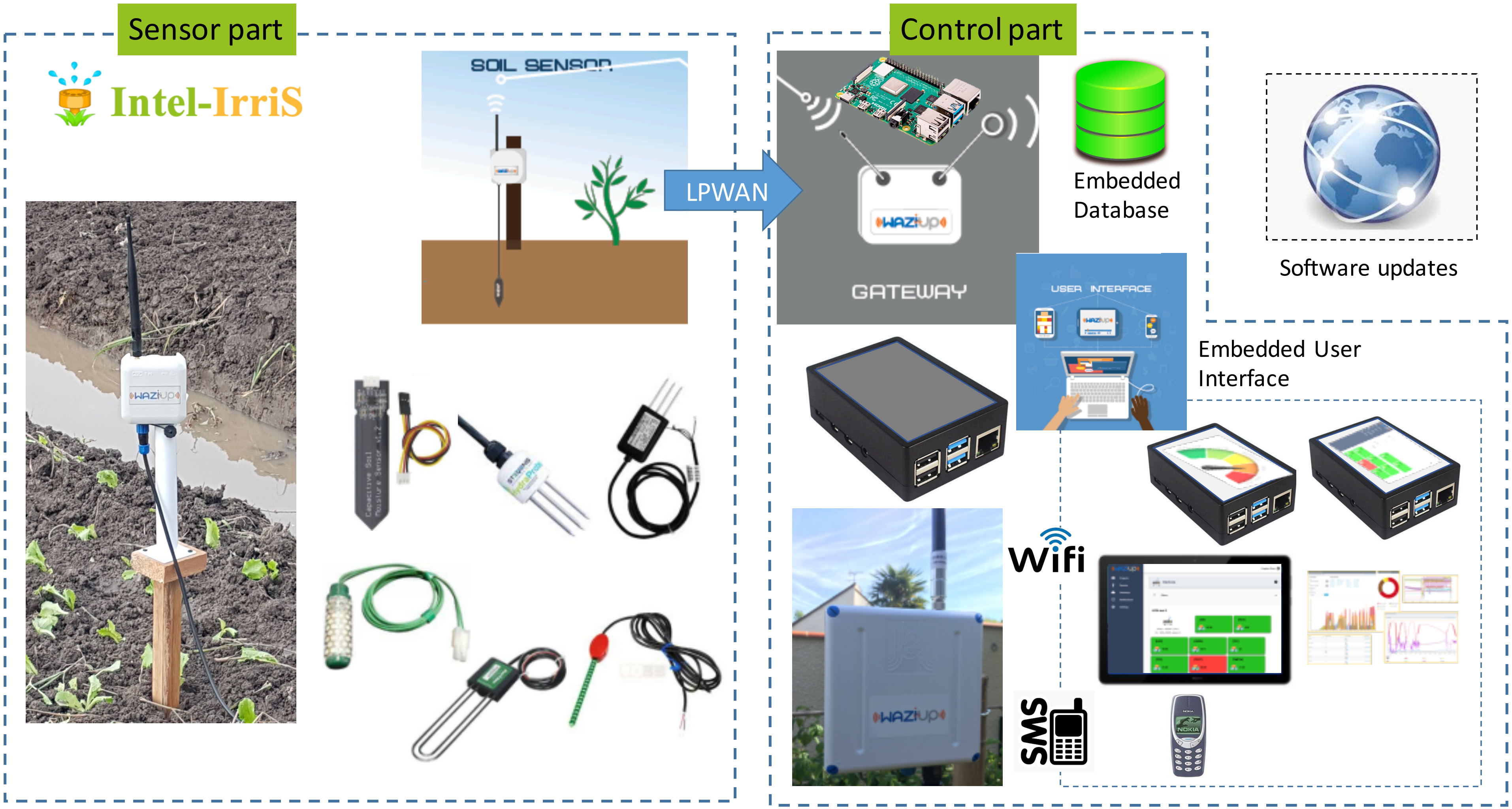
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham
Université de Pau, France

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

LIUPPA

WAZIUP
IoT – from idea to reality
WAZIHUB

Review: Technology components



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Review: Low-cost sensors

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Sensor part

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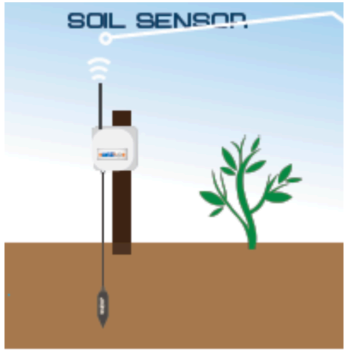

- Build on low-cost, low-power IoT expertise
- Increase accuracy of low-cost sensors by automatic and remotely controlled procedures for advanced calibration
- Enable deployment of several complementary low-cost sensors
- Include agricultural models / knowledge with corrective & predictive analytics

Review: Smart embedded control

- Build on low-cost embedded & open IoT gateway expertise
- Implement the “Intelligent Irrigation in-the-box” with "plug-&-sense" approach
- Model complex water-soil-plant interaction
- Embed Decision Support System (DSS) and disruptive Artificial Intelligence (AI)
- Integration of various knowledge streams
- Fully autonomous

INTEL-IRRIS's starter-kit

- From idea to reality!

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CASING & PARTS

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List of components for IRD PCB

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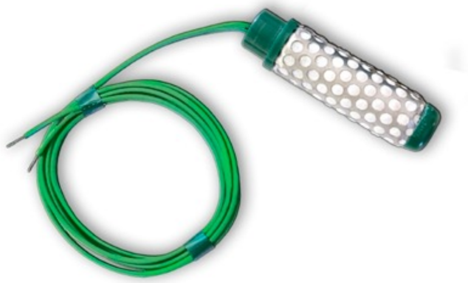

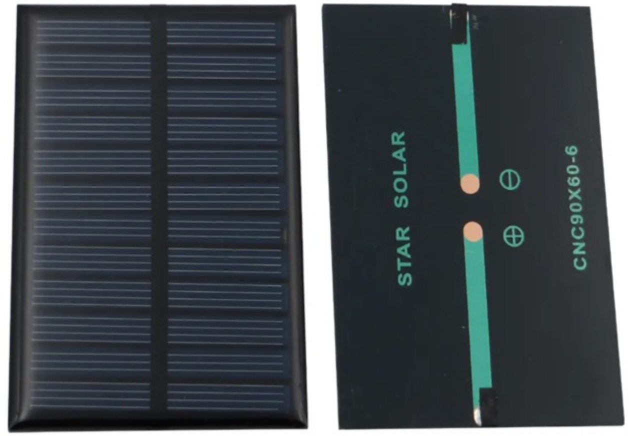

For SOLAR

For AA alkaline batteries

For SOLAR with NiMh

SMA male


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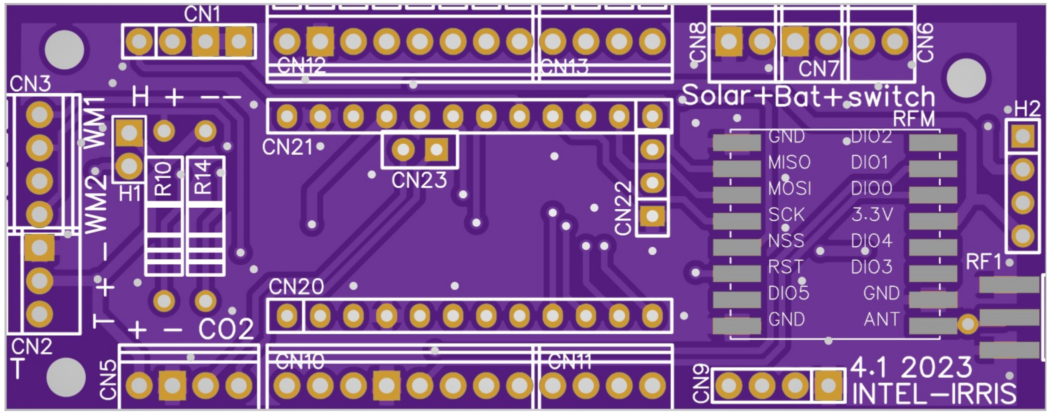
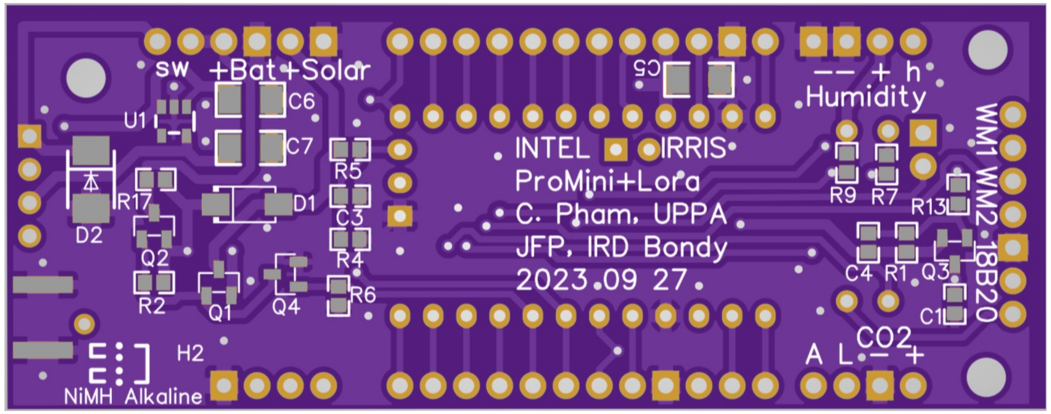
Intelligent Irrigation System for Low-cost Autonomous Water Control
in Small-scale Agriculture
LATEST IRD
PCB V4.1

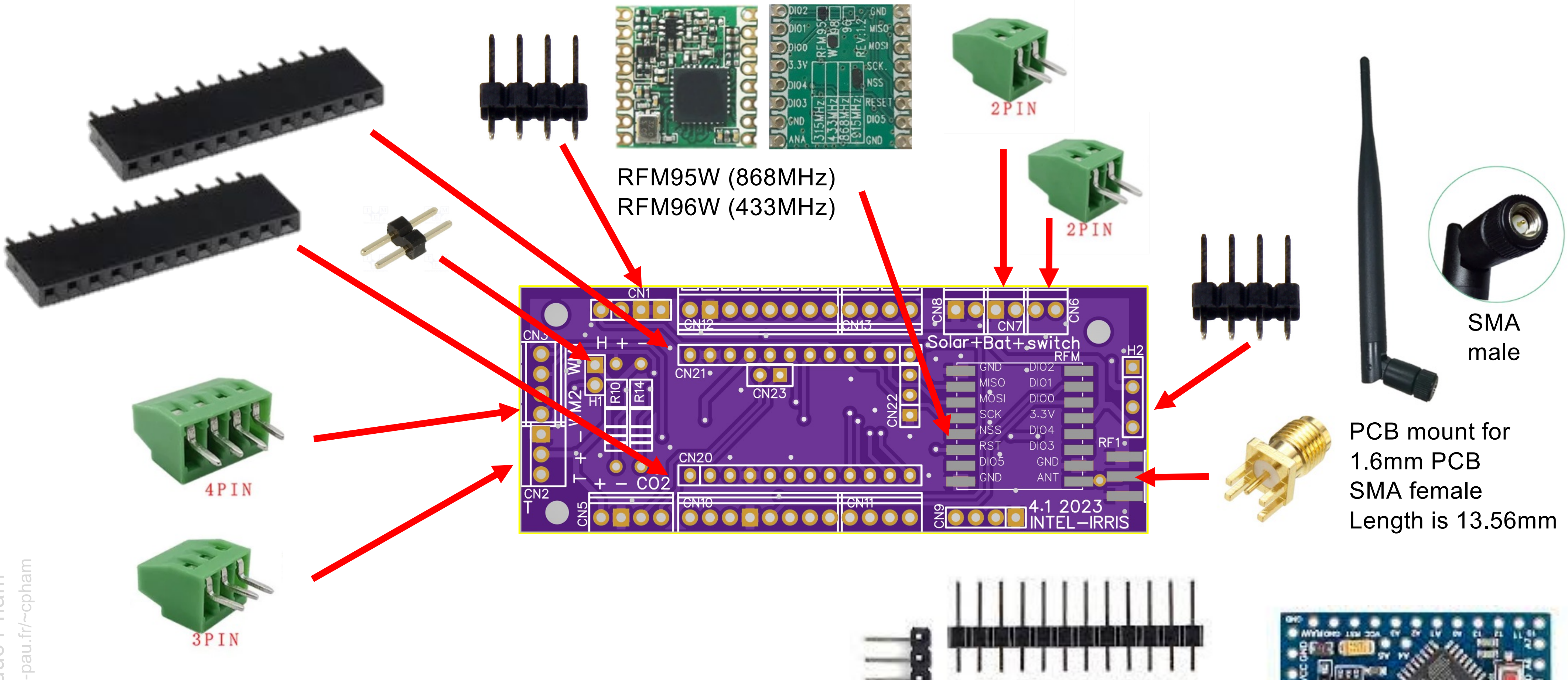
The IRD PCB v4.1 – raw version

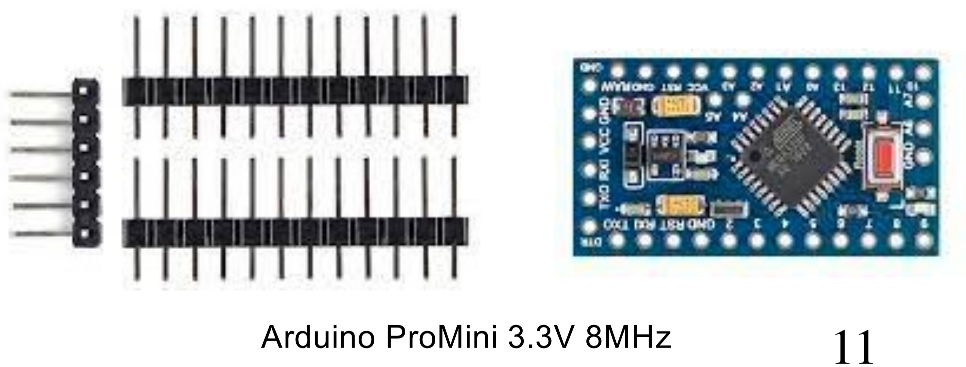
- You can order the raw version of the IRD PCB, which means only the PCB, without any electronic components soldered by the manufacturer
- It is the so-called DIY approach
- The raw version is not intended to have solar charging capabilities





Electronic parts – starter-kit version





https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-IrriS-low-cost-sensor-hardware-parts.pdf

Tutorial video

- This dedicated video will show how to solder all the components
  Video n°1: https://youtu.be/3jdQ0Uo0phQ
- The "old" version of the INTEL-IRRIS PCB is shown on the video but you can easily adapt for the new IRD PCB v4.1

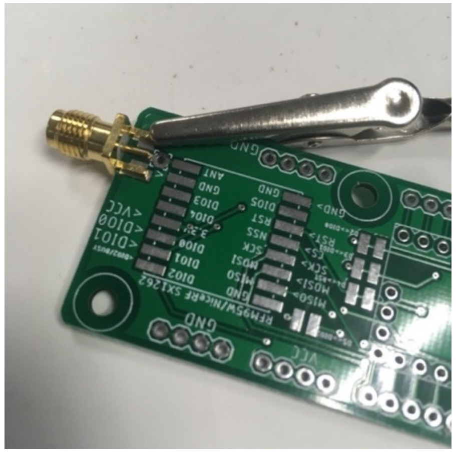
Good soldering

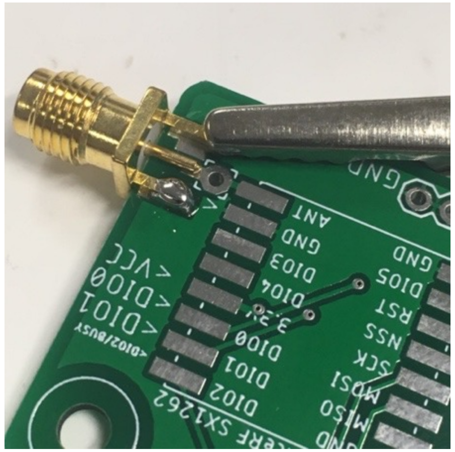
- It is important to have good soldering to avoid any issue when deploying the devices
- Check this great soldering tutorial from Collin's lab
  - https://youtu.be/RB4P1HTmwLc

- Just put the required amount of lead, too much lead is not good!
- It is not a bad idea to train on soldering before making the device and not waste electronic components

Updates on Video n°1

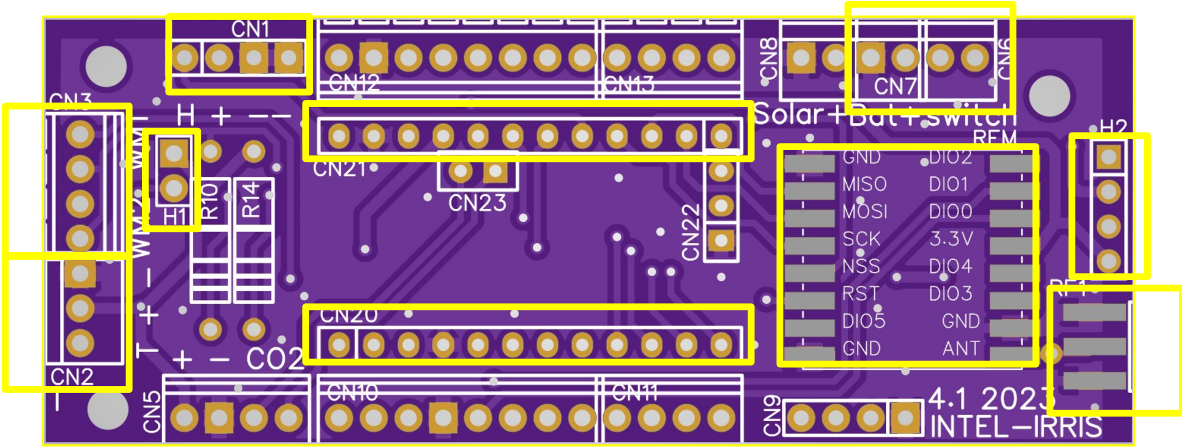
- Clip the SMA connector to the PCB to correctly align the connector before soldering one of the GND pad, then remove clip and finish soldering
- Or, gently press SMA connector pads so that insertion on PCB is harder and SMA connector will not move during soldering
- Make sure that the GND pads and the central pin are not touching each other, in doubt, do a continuity check

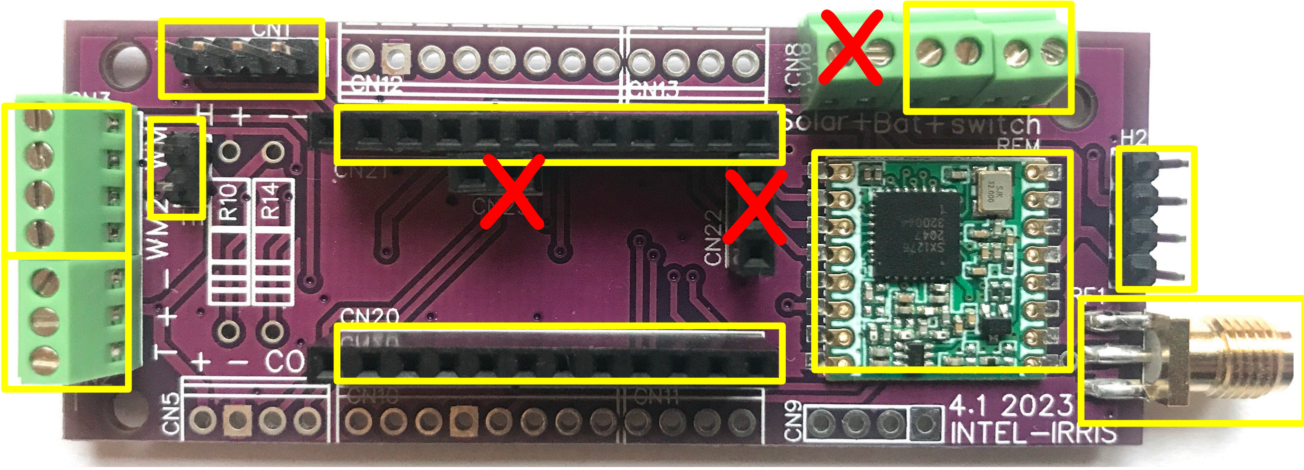




Wiring with IRD PCB v4.1 (raw version)

- First, solder the various components



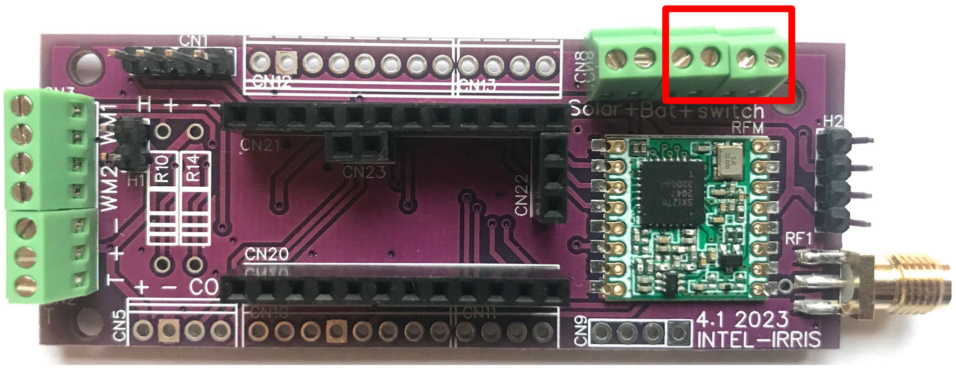


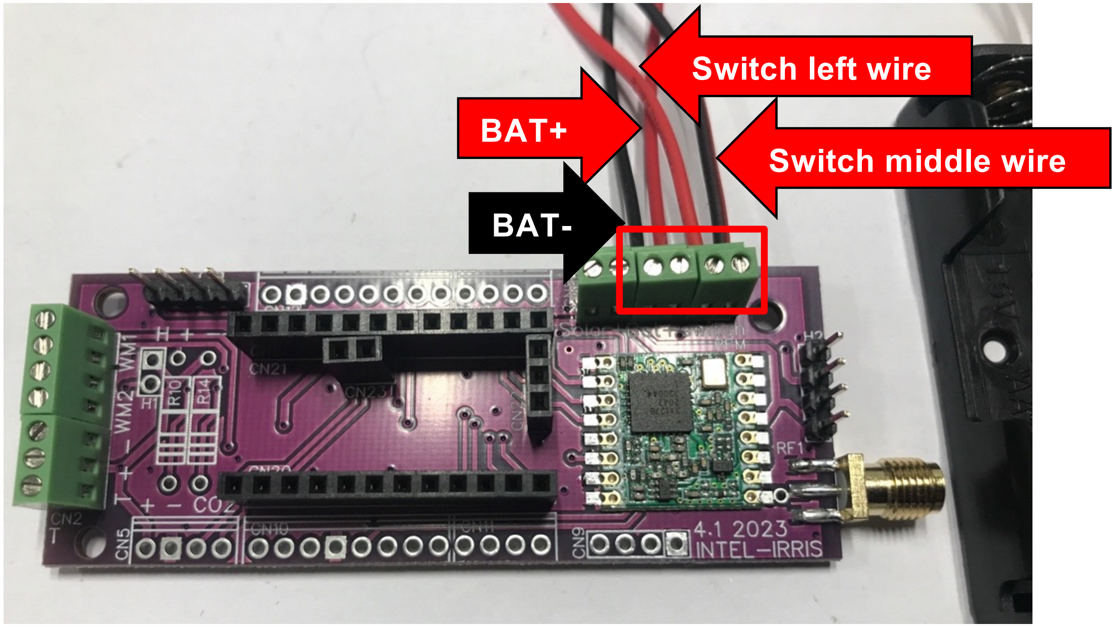
The raw version is not intended to have solar charging capabilities. For solar charging, the full version (see later) is the dedicated PCB

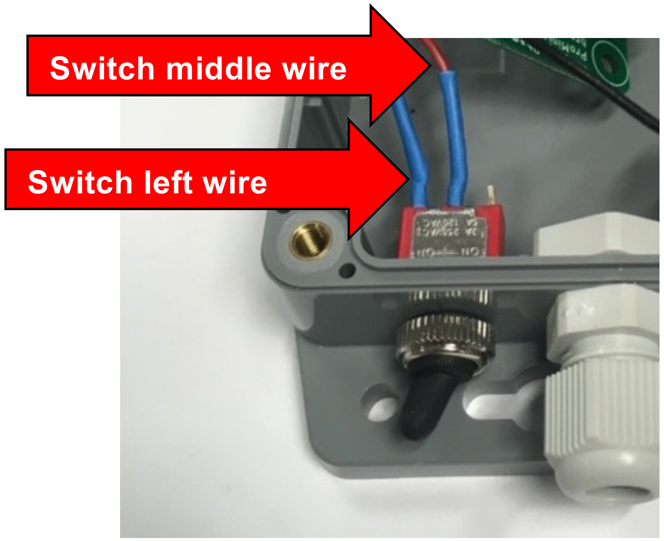
X Not needed for the raw PCB which is not designed to have the solar circuit manually soldered

Wiring with IRD PCB v4.1 (raw version)

- Power wires (from AA alkaline battery)

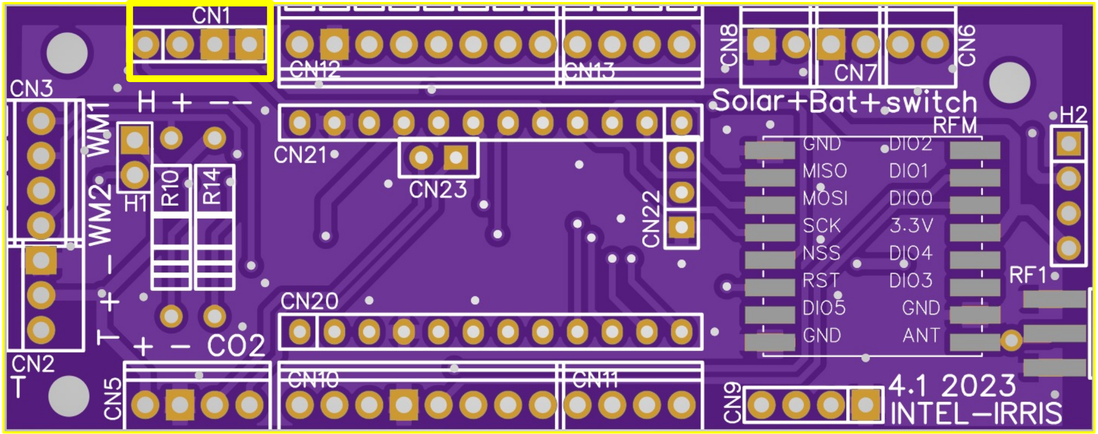


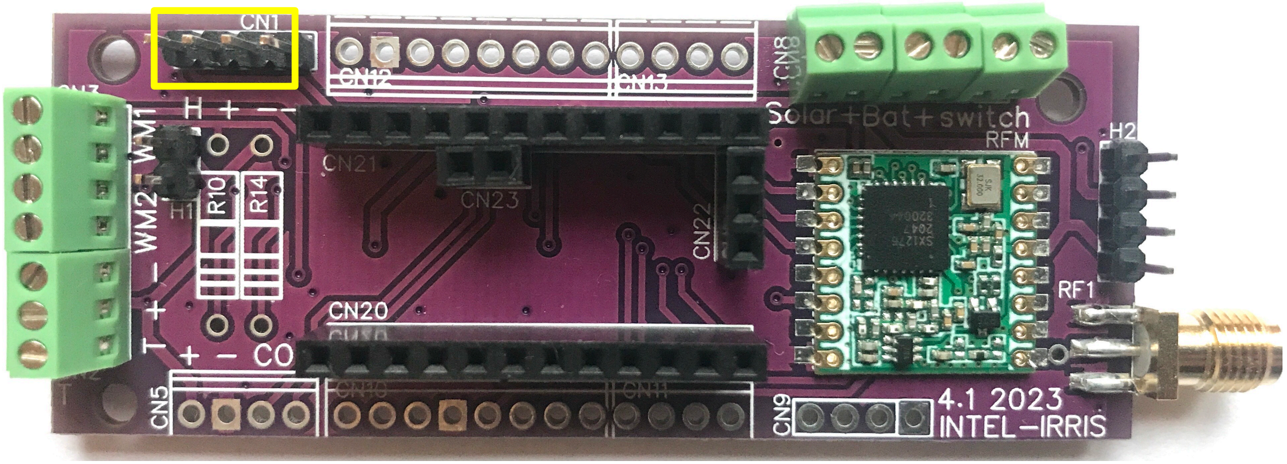




Wiring with IRD PCB v4.1 (raw version)

- SEN0308 capacitive

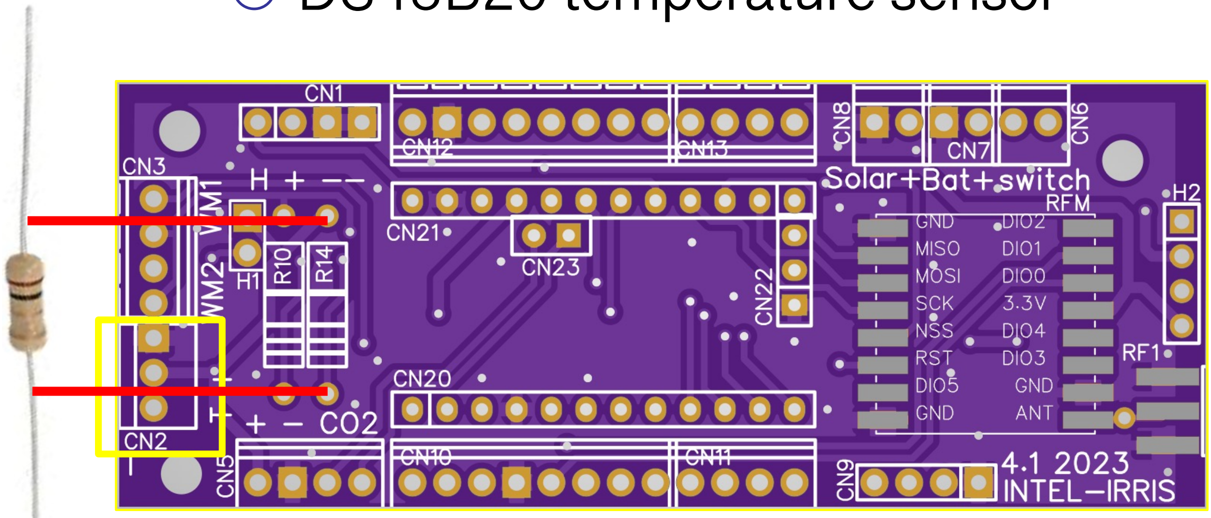


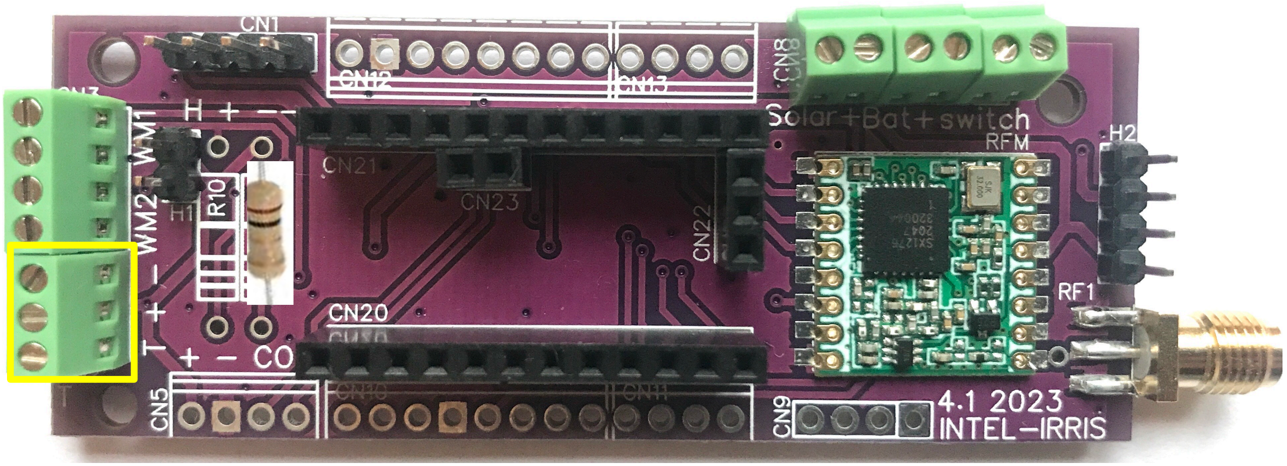


Just connect the sensor in the dedicated header
– – are the 2 black wires
+ is red and H is yellow

Wiring with IRD PCB v4.1 (raw version)

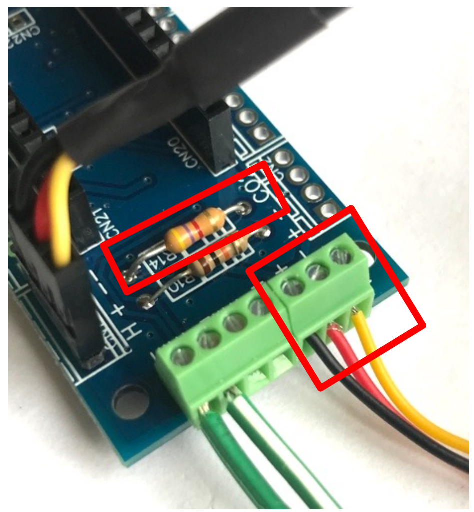
- DS18B20 temperature sensor





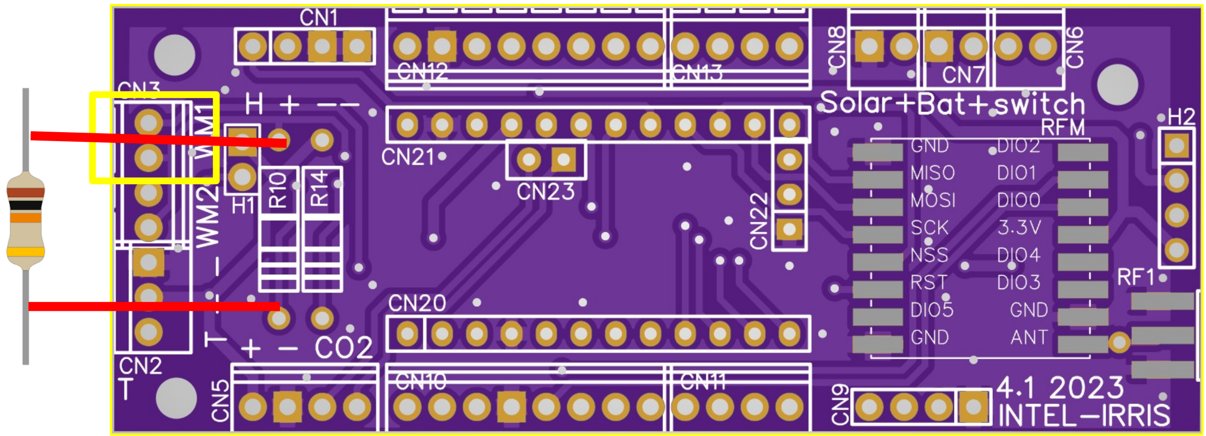
Solder a 4.7kOhms resistor then wire in the dedicated terminal block

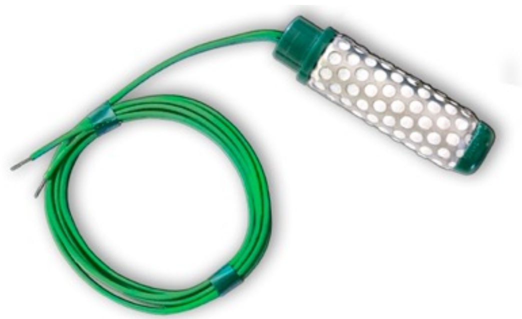
T+ – : Yellow, Red, Black wires



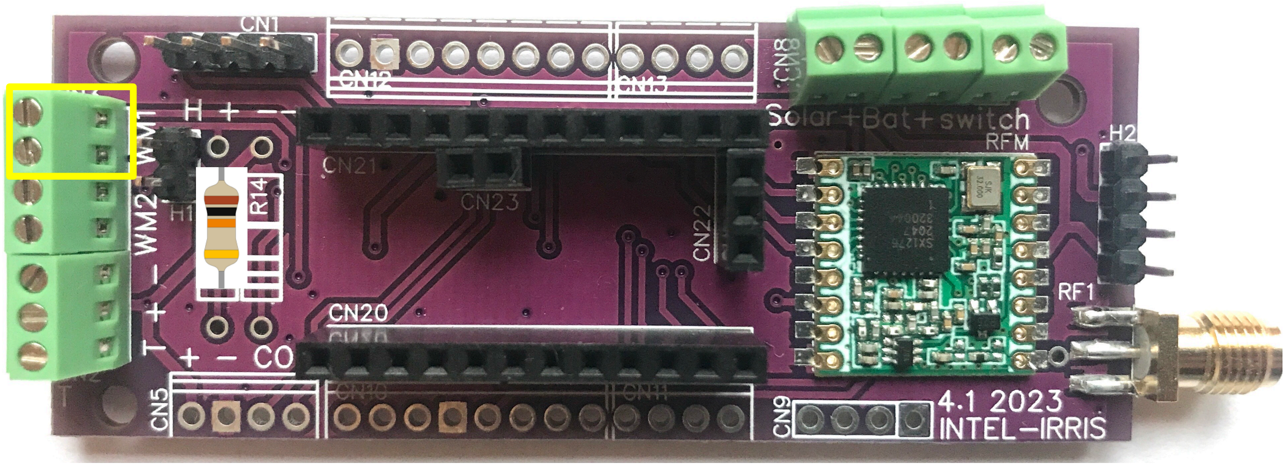
Wiring with IRD PCB v4.1 (raw version)

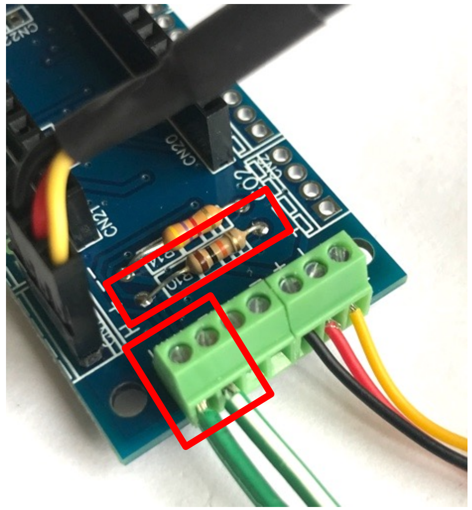
- First Watermark





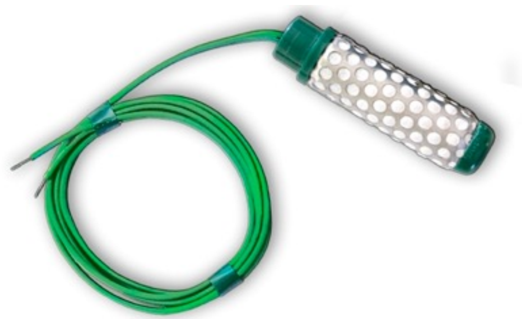
Solder a 10kOhms resistor then wire in the dedicated WM1 terminal block

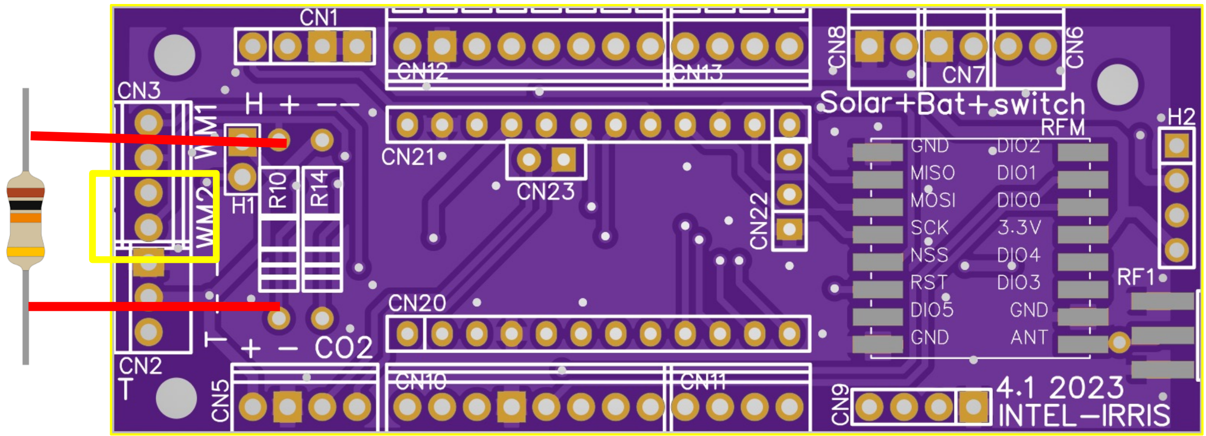




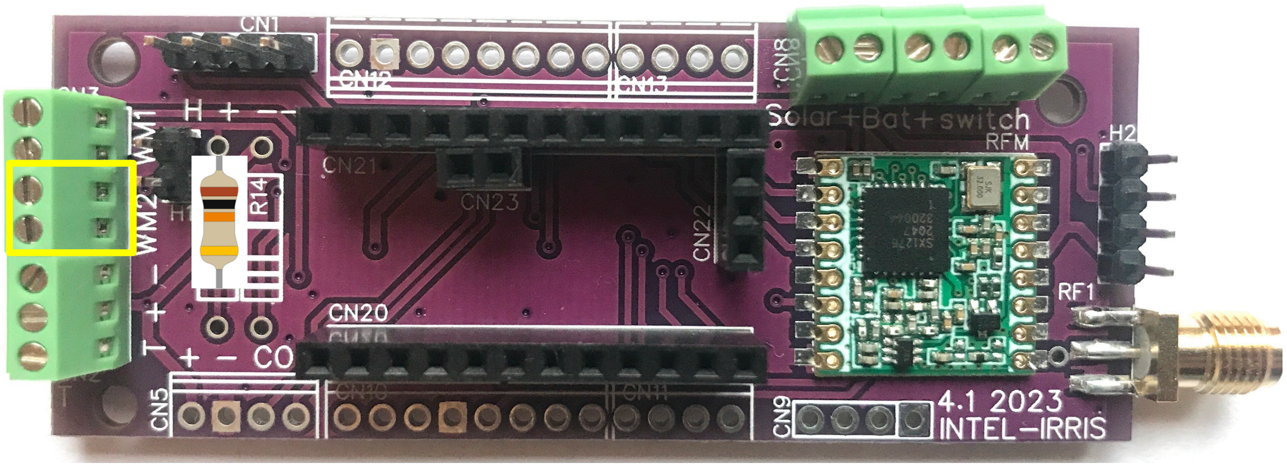
Wiring with IRD PCB v4.1 (raw version)

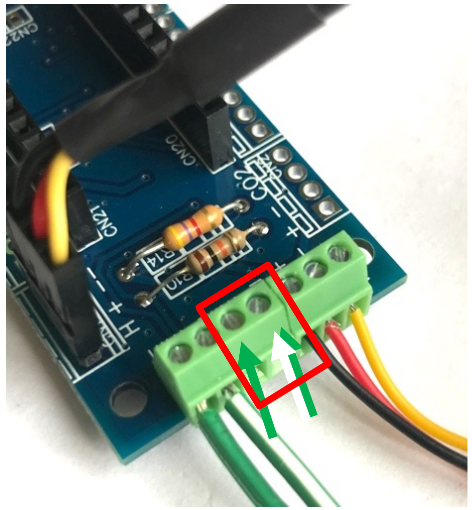
- Second Watermark





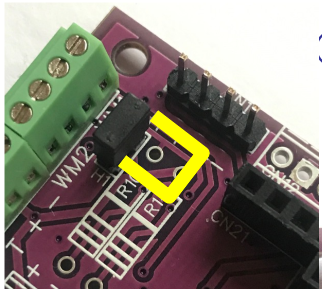
No additional resistor needed just wire in the dedicated WM2 terminal block

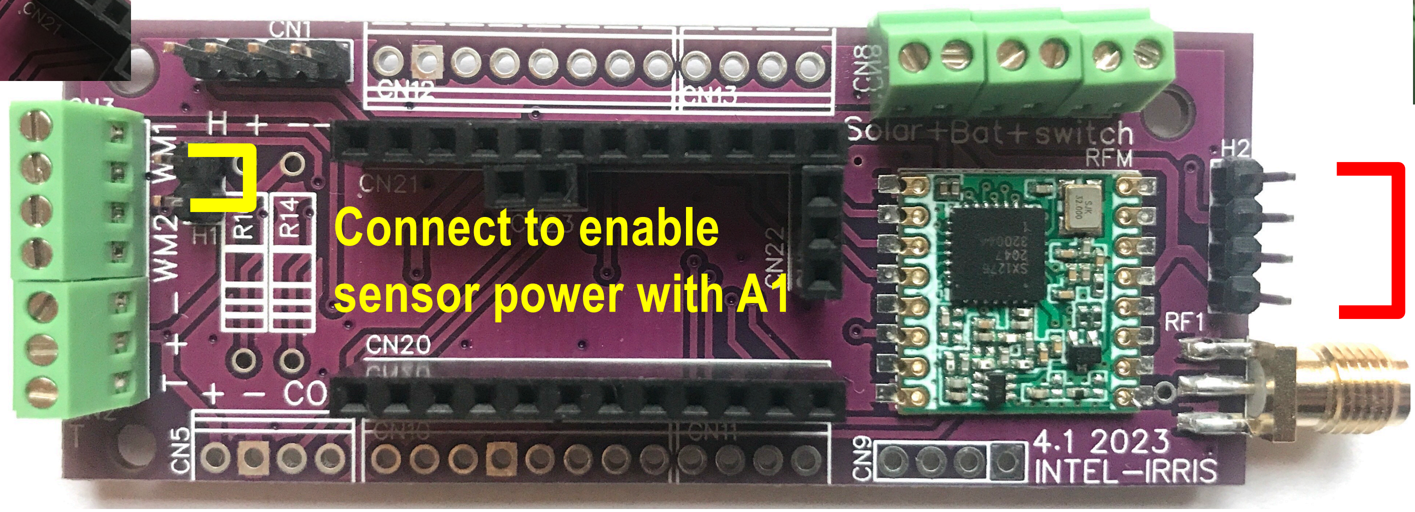




Wiring with IRD PCB v4.1 (raw version)

- The raw version is not intended to have the solar circuit soldered manually on the back side
  - 2 alkaline AA batteries will be used similar to the simple PCB v2
  - It is necessary to short the 2 external pins of H2 connector and the 2 pins of H1 connector





Connect
for alkaline
batteries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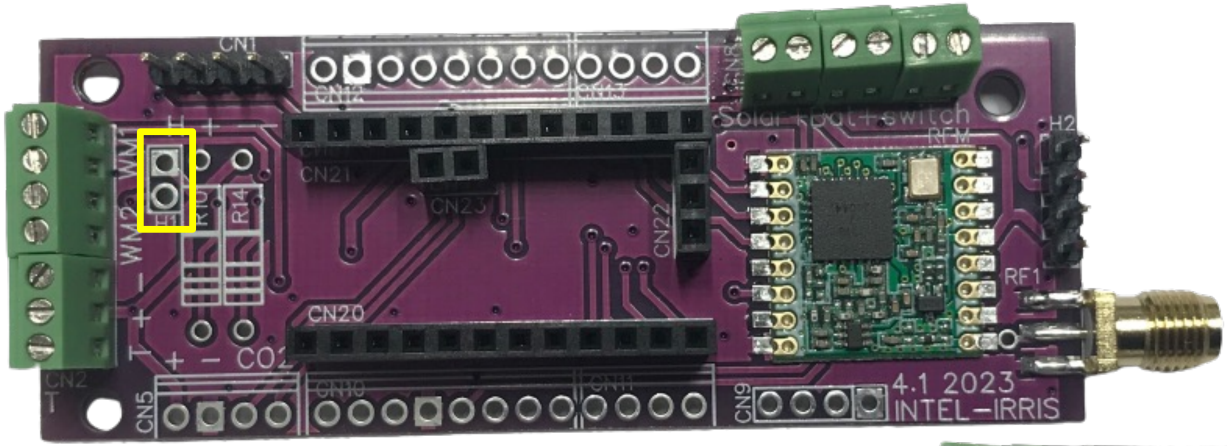
in Small-scale Agriculture
LATEST IRD
PCBA V4.1

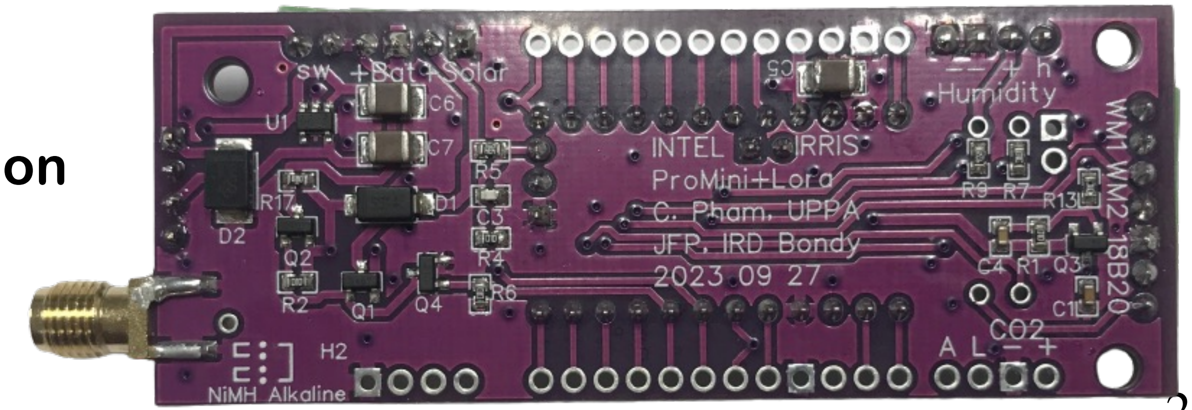
Wiring with IRD PCB v4.1 (PCBA)

- The PCBA is already fully assembled, including the resistors for the temperature and watermark sensors (on the back side)



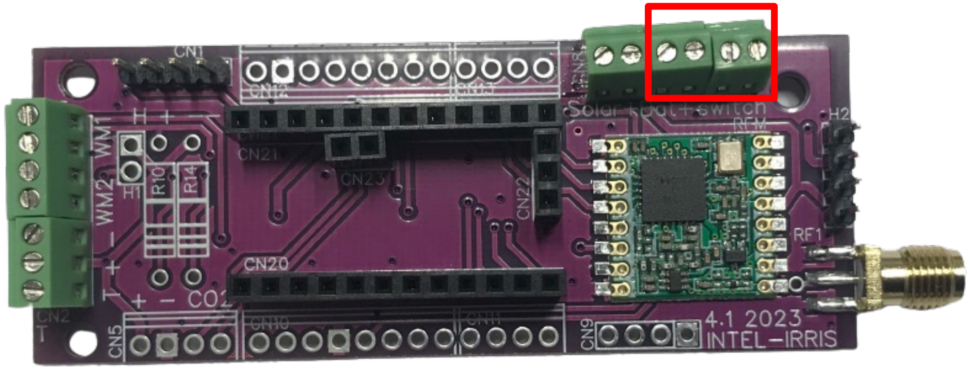
The full version does not need to have header for H1

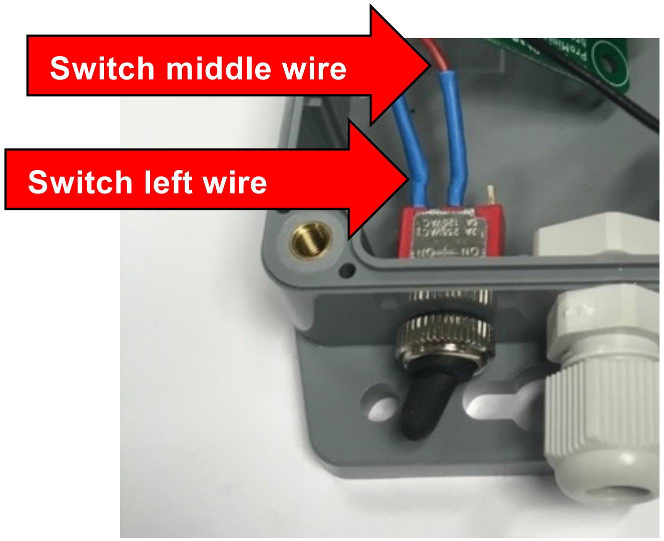
The solar circuit is on the back side

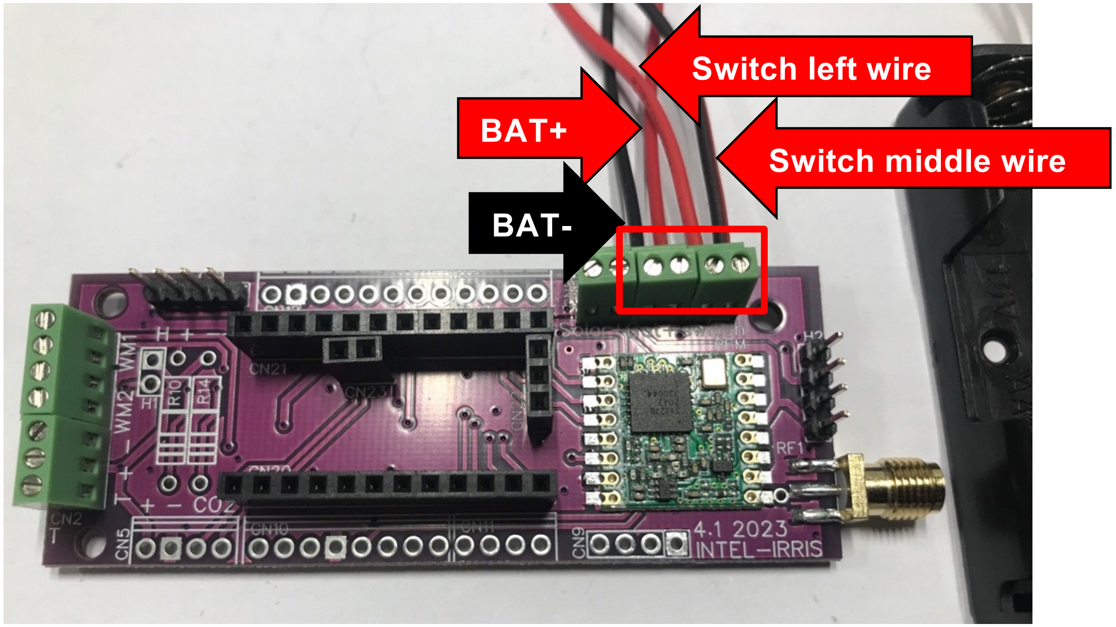


Wiring with IRD PCB v4.1 (PCBA)

- Power wires (from NiMh batteries or AA alkaline batteries)

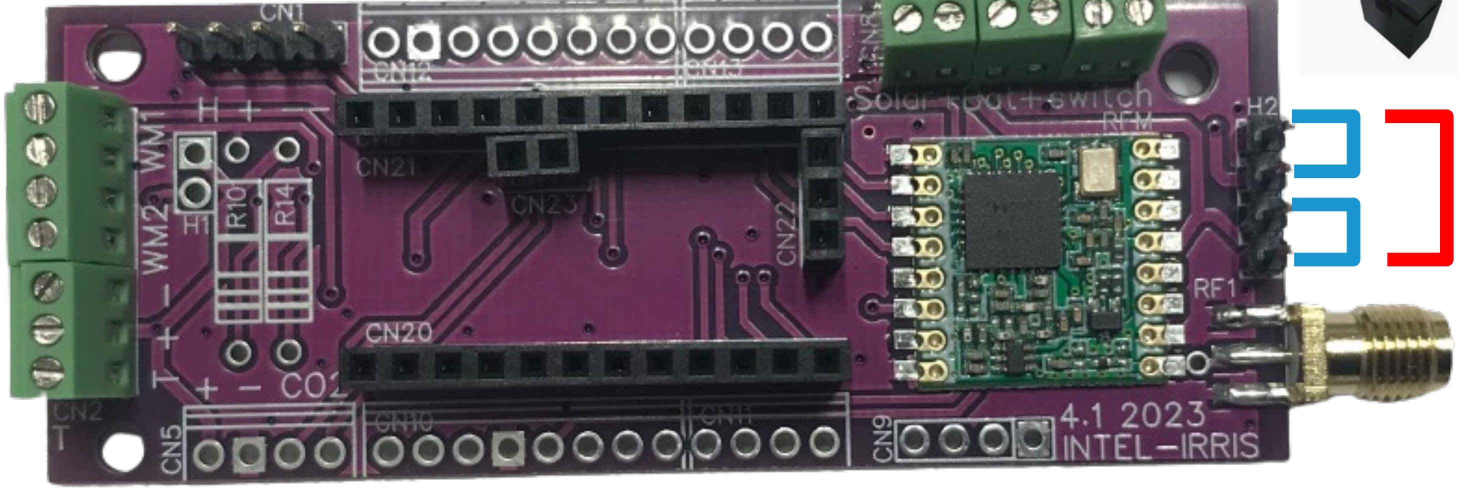




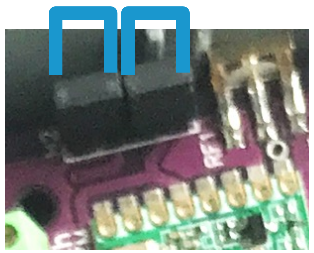


Wiring with IRD PCB v4.1 (PCBA)

- The full version (PCBA) comes with the solar charging circuit
- **BUT** you can still power it with 2 alkaline AA batteries without using a solar panel to avoid external fragile parts
- You can select between solar charging with NiMh batteries or no solar charging with 2 alkaline AA batteries



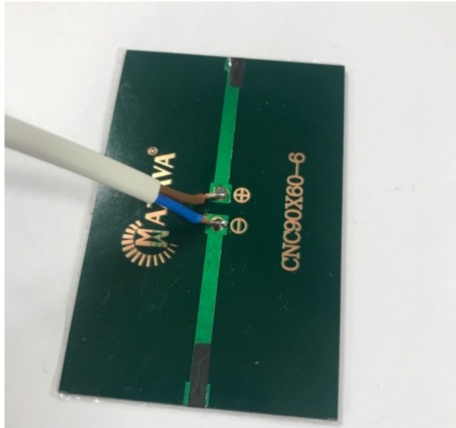
Connect for SOLAR with NiMh



Connect for alkaline batteries

PCBA: Installing solar panel (1)

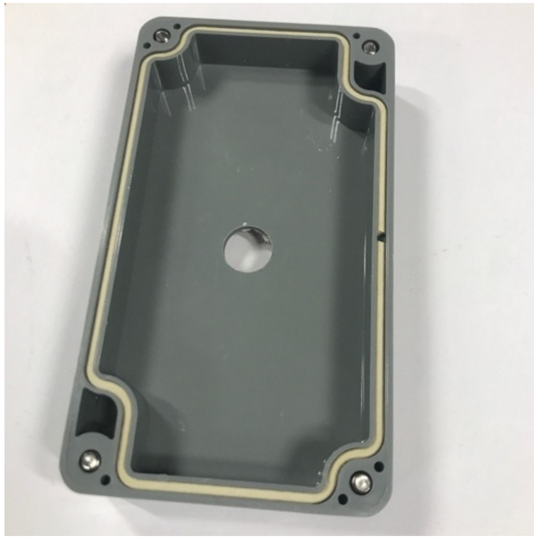
- Mini solar panel
  6 V 0.6 W 100 mA 60x90mm

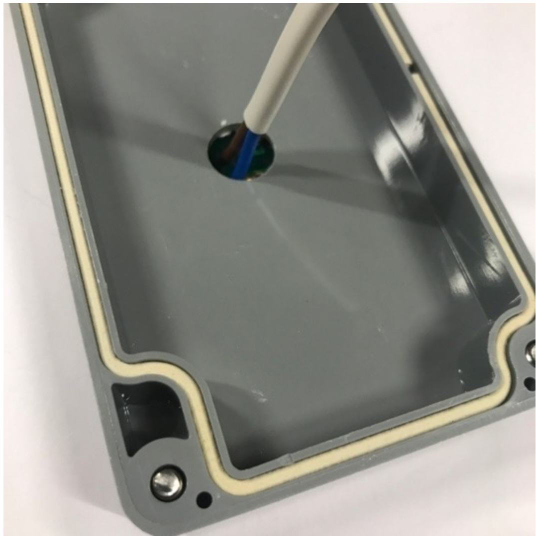


Solder 2 wires on + and -

The case cover has a mark indicating the center

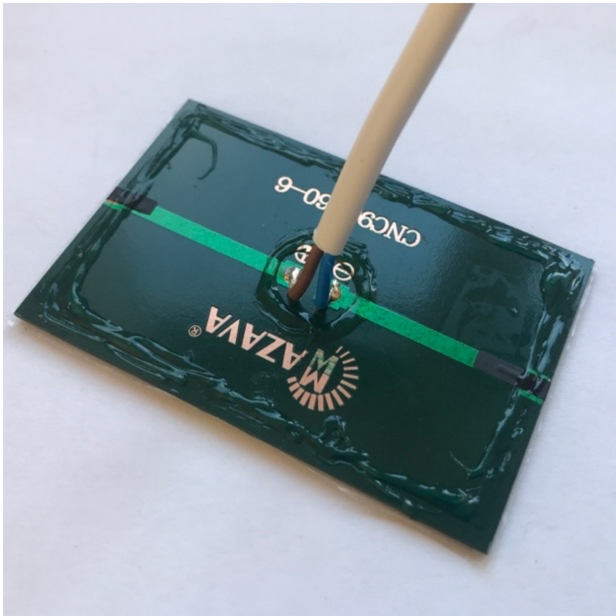
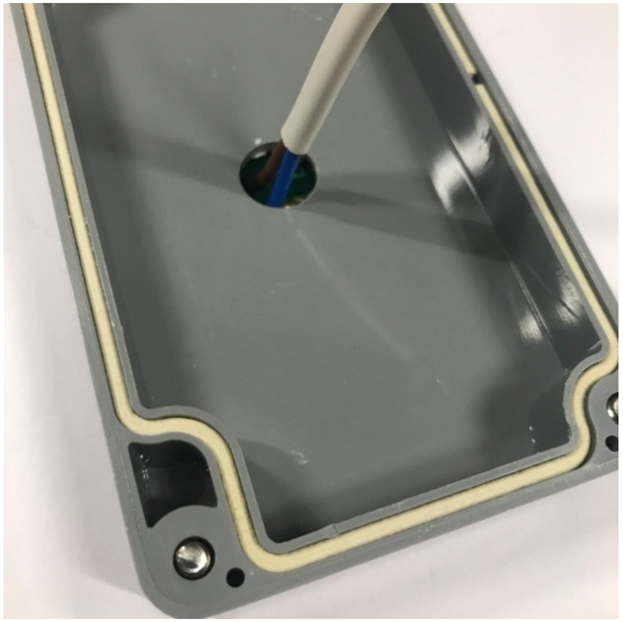
Drill a hole with a 10mm to 12mm drill bit for metal





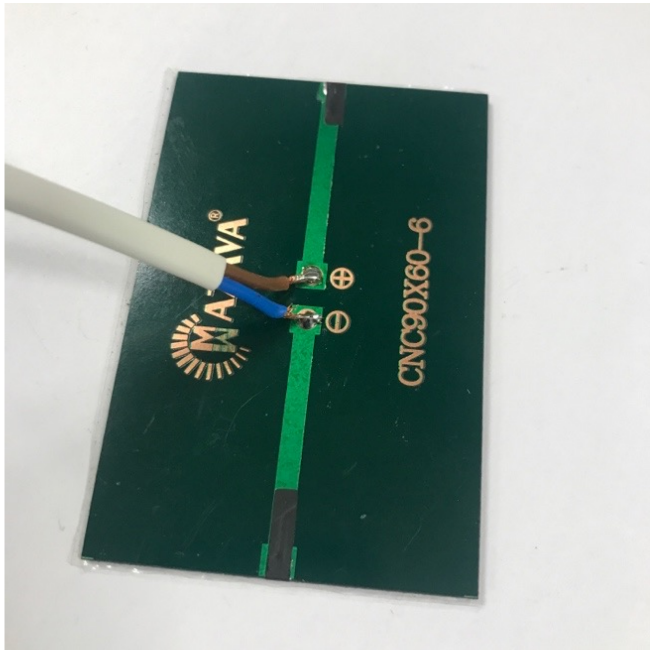
PCBA: Installing solar panel (2)

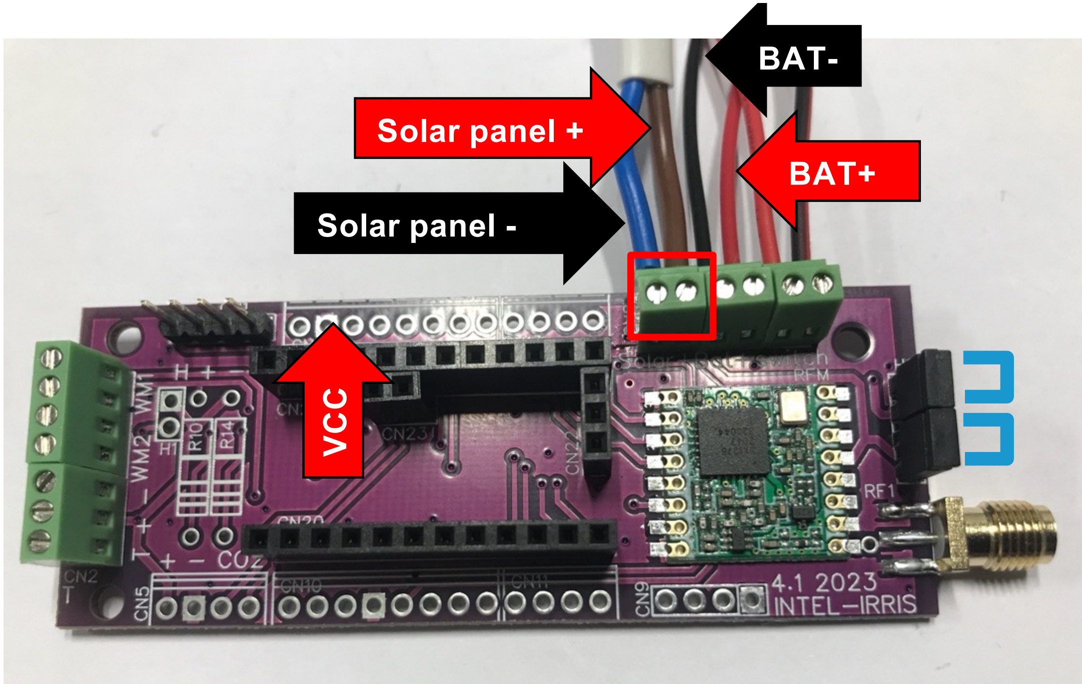
- Use silicon or glue to assemble the solar panel on the case cover
- Make sure there is no discontinuity of glue, also add glue around the centered hole surrounding the wires

Wiring with IRD PCB v4.1 (PCBA)

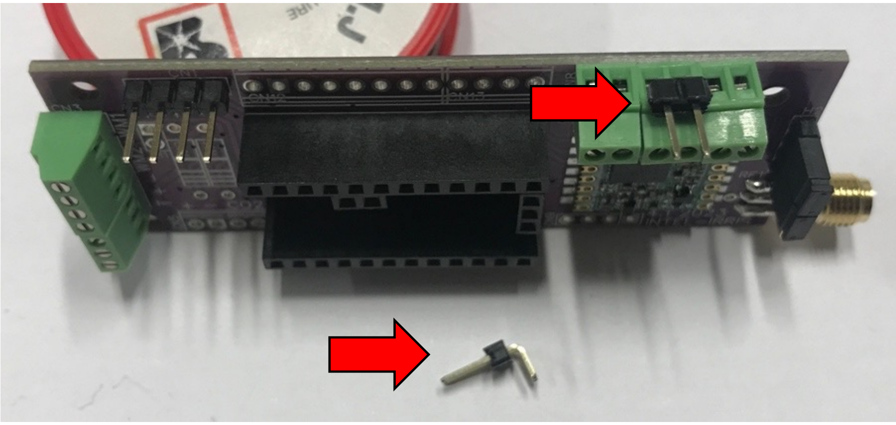
- Solar panel wires

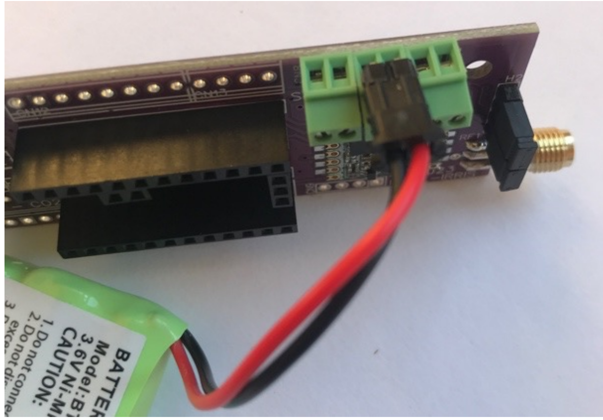




Wiring with IRD PCB v4.1 (PCBA)

- Connect NiMh batterie packs with a 2-pin female connector
- You can screw in a 2-pin male 90° header



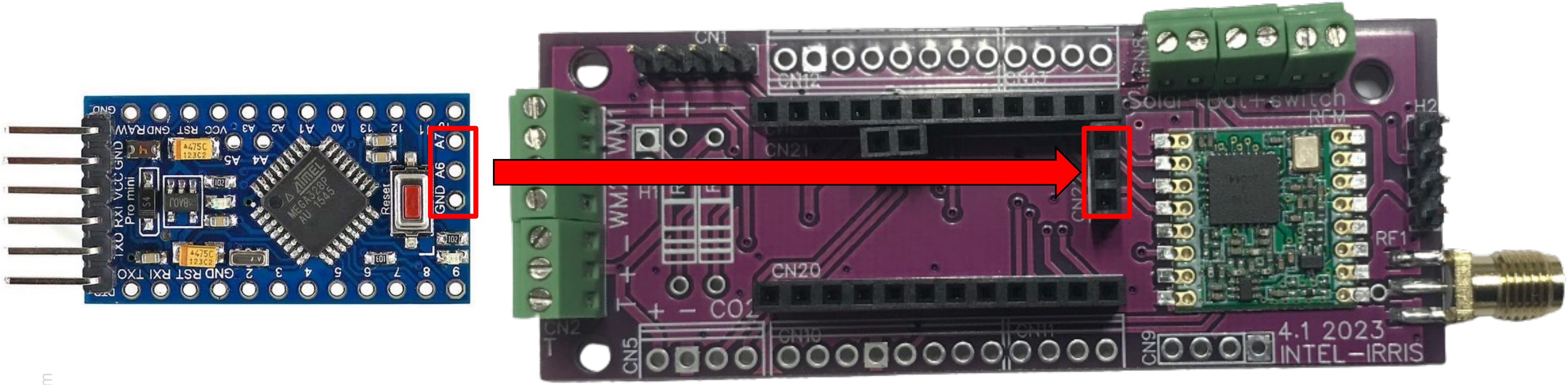


You can buy NiMh battery packs with a 2 pin connector that can be used for fast connection

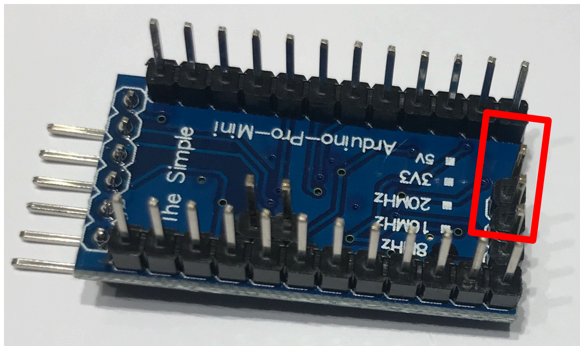
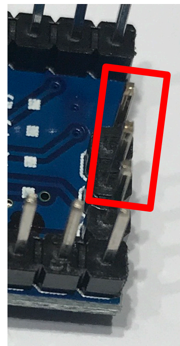
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

IMPORTANT: Arduino ProMini

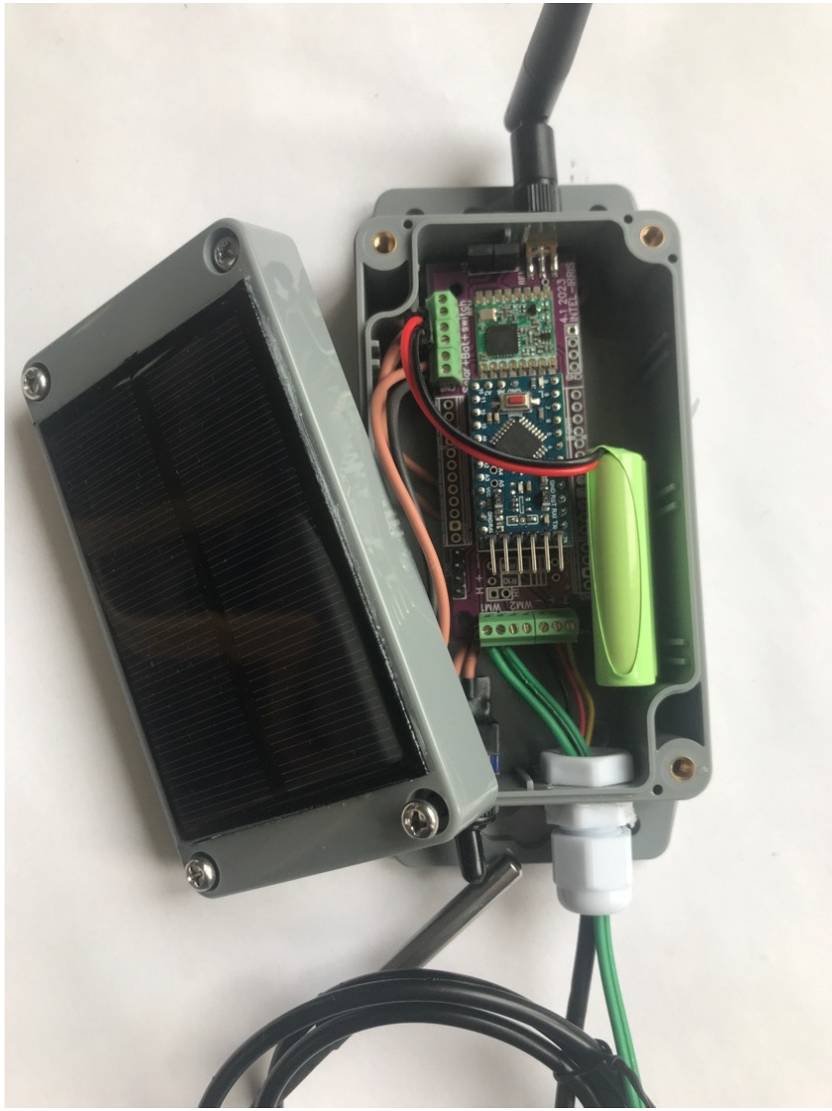
- For solar charging, using the IRD PCBA v4.1, the Arduino ProMini MUST have pin A7 connected!

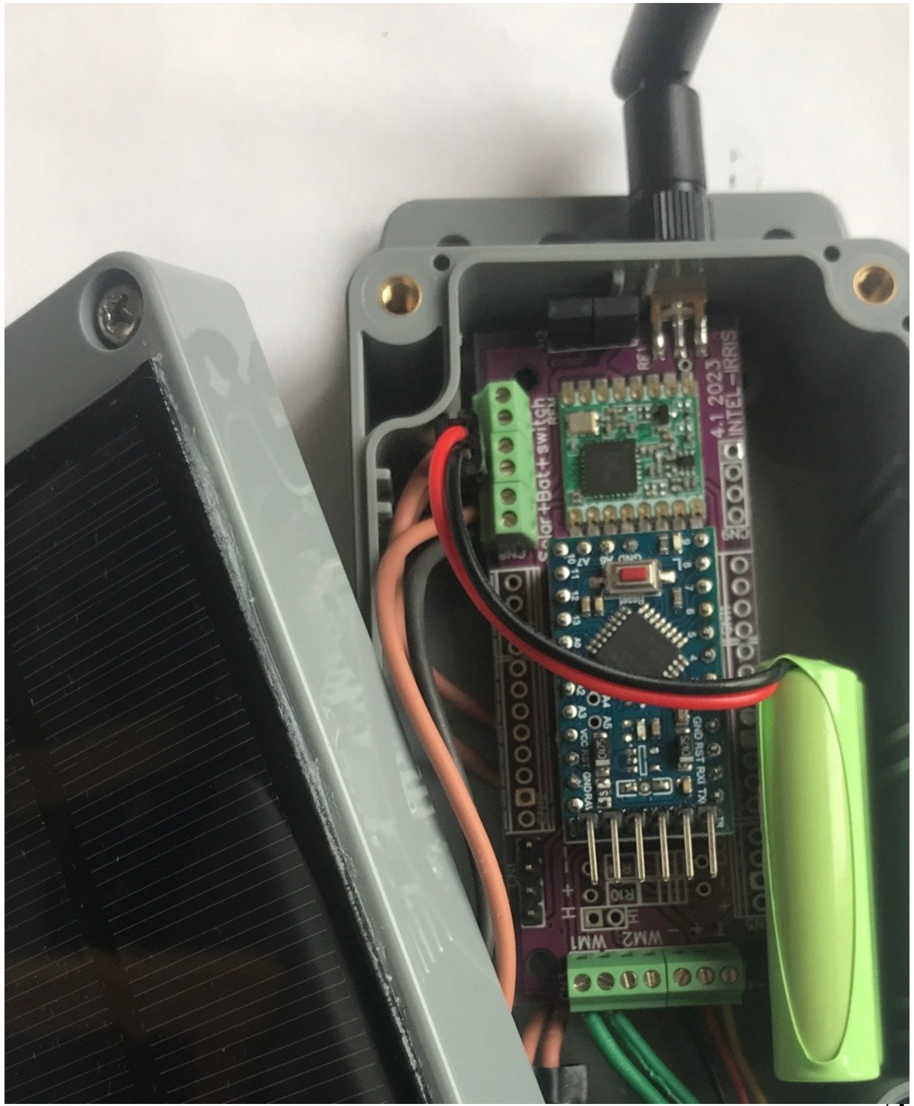


- So, it is MANDATORY to solder a 3-pin header for GND, A6 & A7 on the Arduino ProMini board

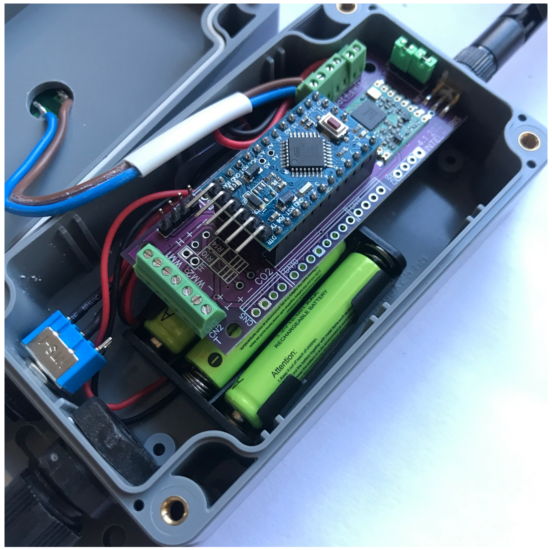
Soil device with PCBA v4.1, final result

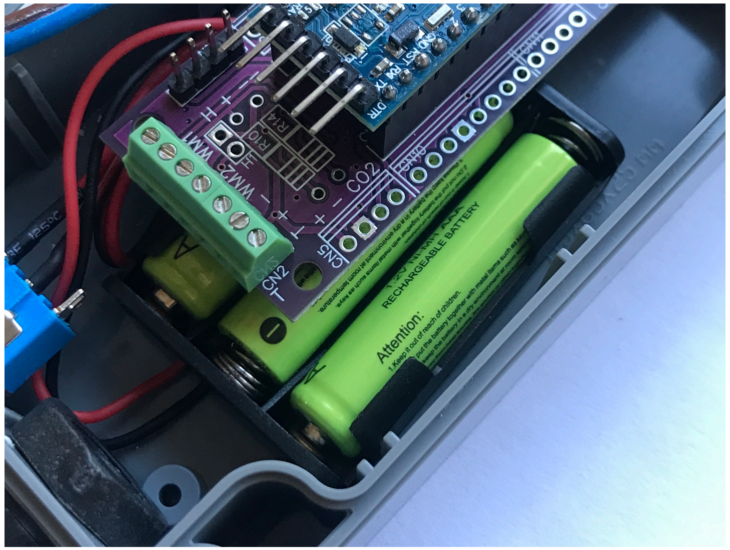




Using 3xAAA batteries

- You can alternatively use 3xAAA NiMh rechargeable batteries with a battery holder
- If this is the case, you need to adjust the antenna hole on the external casing described in slide 36
- This would allow you to slip the 3xAAA battery holder under the PCBA board



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INTEGRATION
& CASING

Get an enclosure for outdoor usage

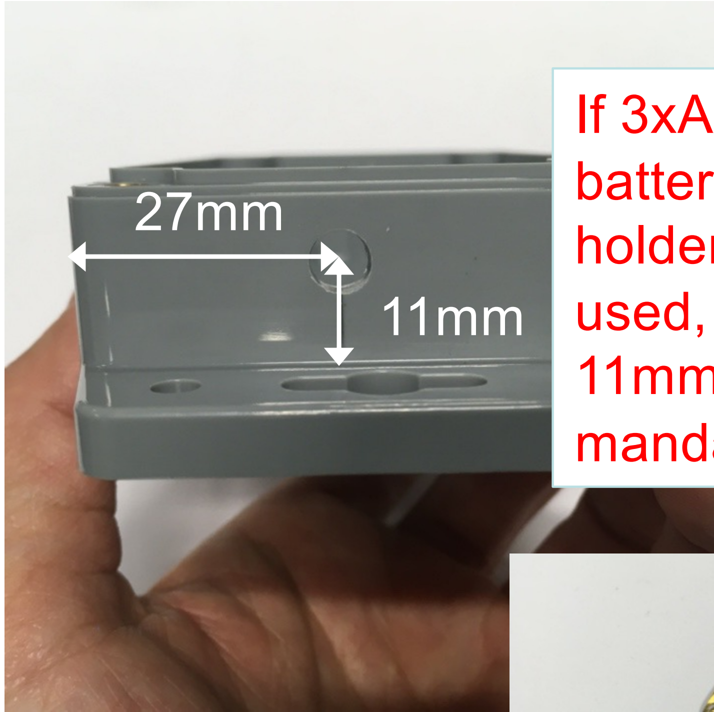
Here, it is an IP65 box which dimension is 115 x 65 x 40mm

https://www.gotronic.fr/art-boitier-abs-etanche-g304m-17977.htm

Drilling machine and drilling bits

At least a simple cordless drilling machine is necessary
If you have a (small) bench drilling machine it is of course better
Then you need an assortment of drilling bits for metal, not for wood nor concrete! Here, you will mainly need 7mm and 13mm bits
It is also interesting to have step drill bits

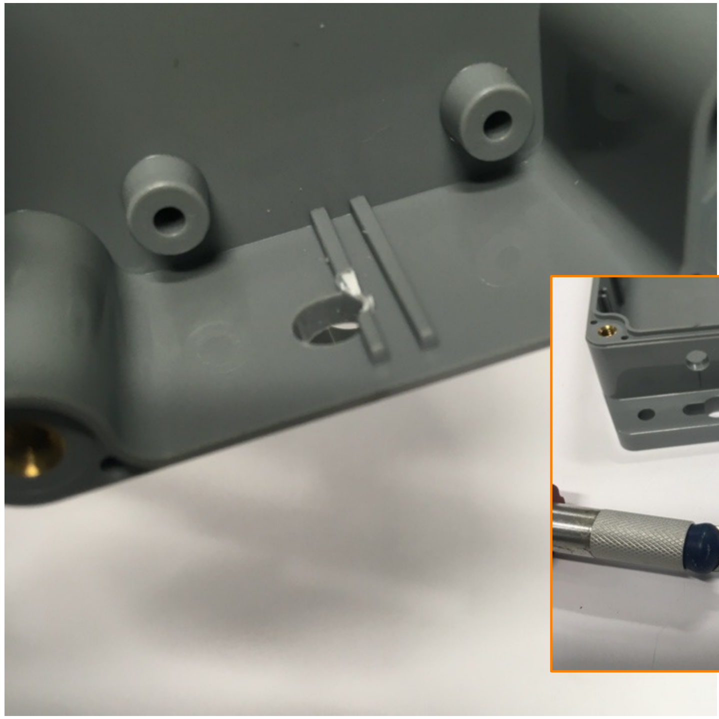
Drill a hole for the SMA connector



If 3xAAA battery holder is used, having 11mm is mandatory!

27mm for the right edge:
- measure from the flat side as the corner is round
11mm from the outside bottom
use a 7mm drill bit for metal, not for wood nor concrete!

Remove unwanted plastic part



- we need to remove the plastic reinforcement part for this particular enclosure
- use a flat cutter for instance to remove and smooth the inside part (a small plier can be used first to remove most of the part)

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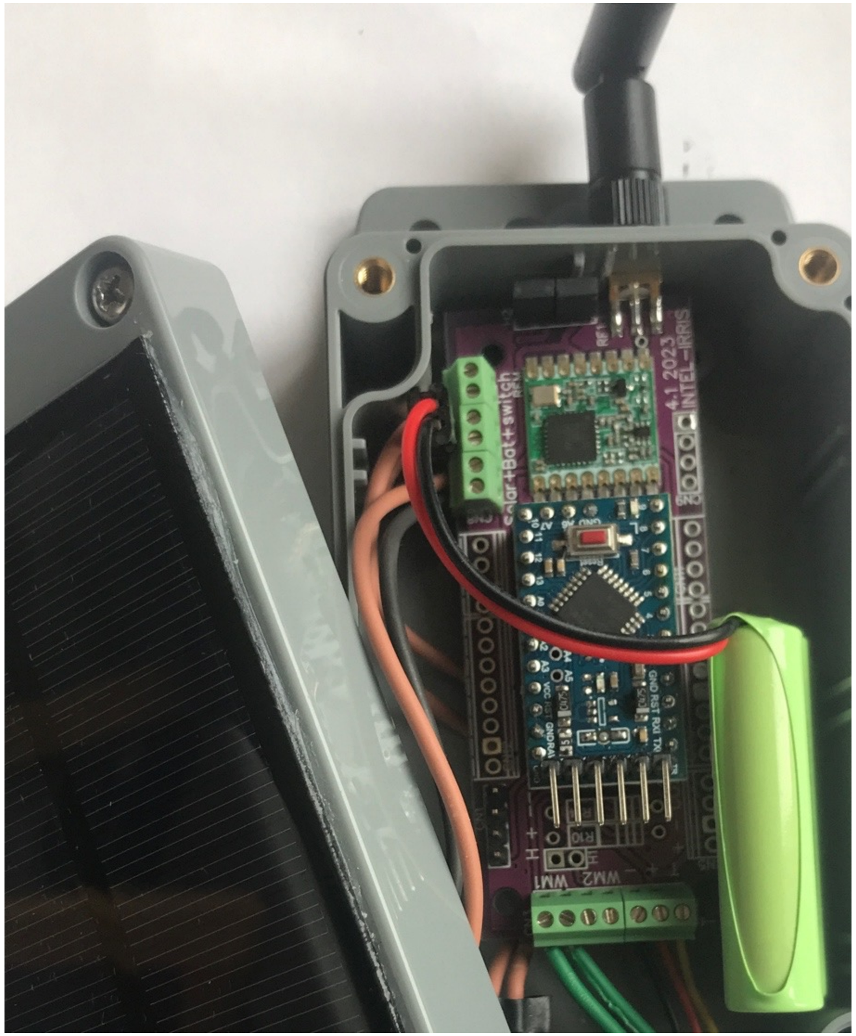
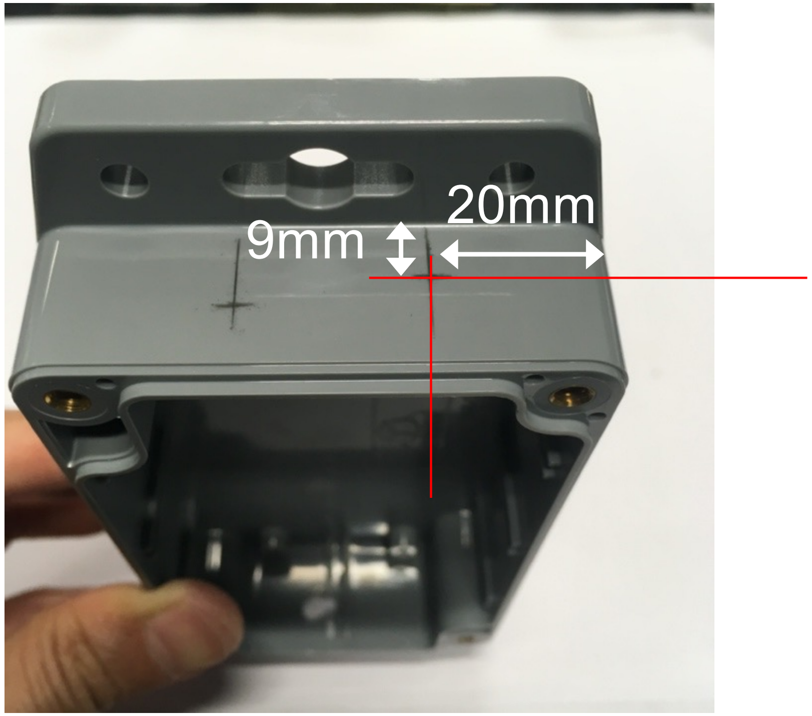
Placing the PCB board

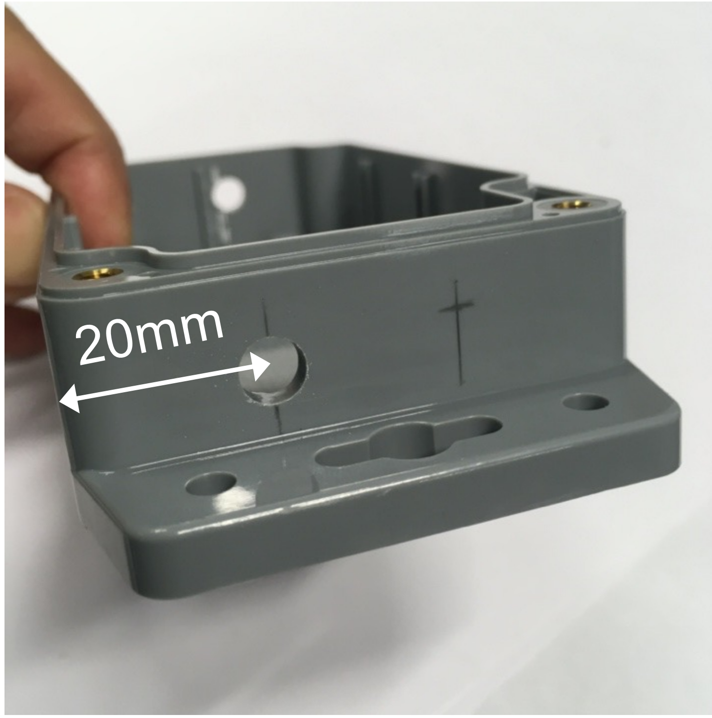
Intel-IrriS



the PCB board can be placed with the SMA connector going through the hole

Drill a hole for the external switch



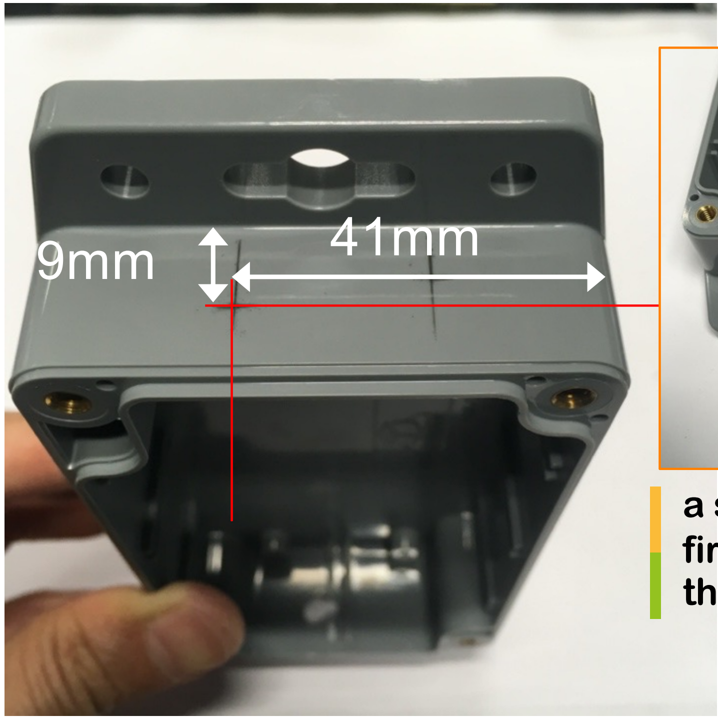


20mm for the right edge:
- **measure from the flat side as the corner is round**

9mm from the outside bottom

use a 7mm drill bit for metal

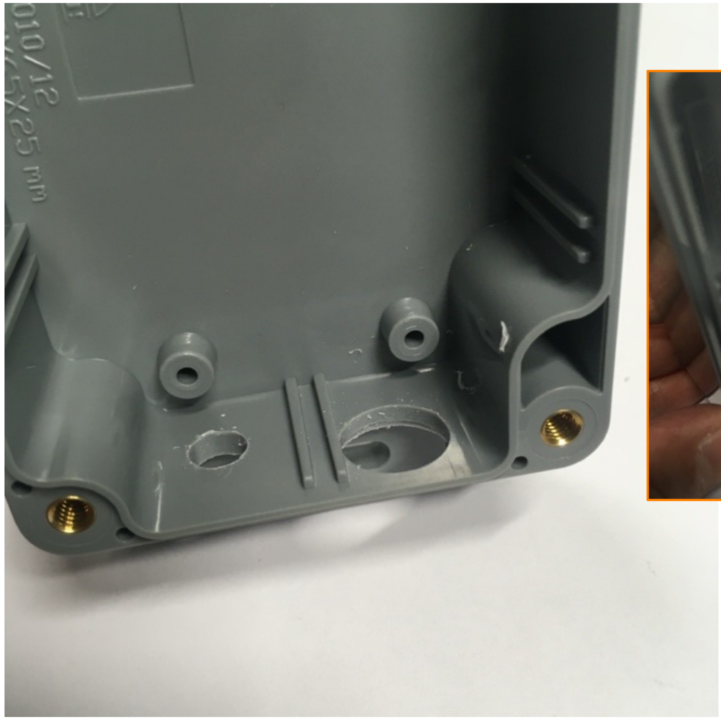
Drill a hole for the cable gland

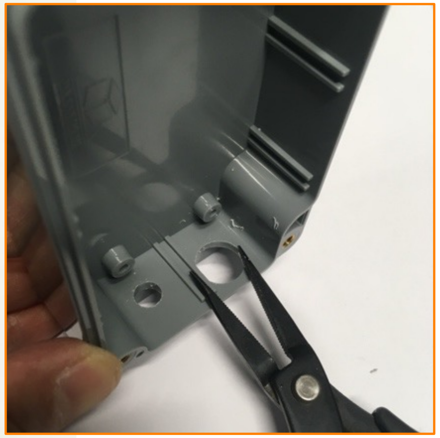


a step drill bit can be used first, drill to 12mm
then use a 13mm drill bit

41mm for the right edge:
- measure from the flat side as the corner is round
9mm from the outside bottom
use a 13mm drill bit for metal, but it is recommended to use a step drill bit to first get a 12mm hole before using the 13mm drill bit

Remove unwanted plastic part

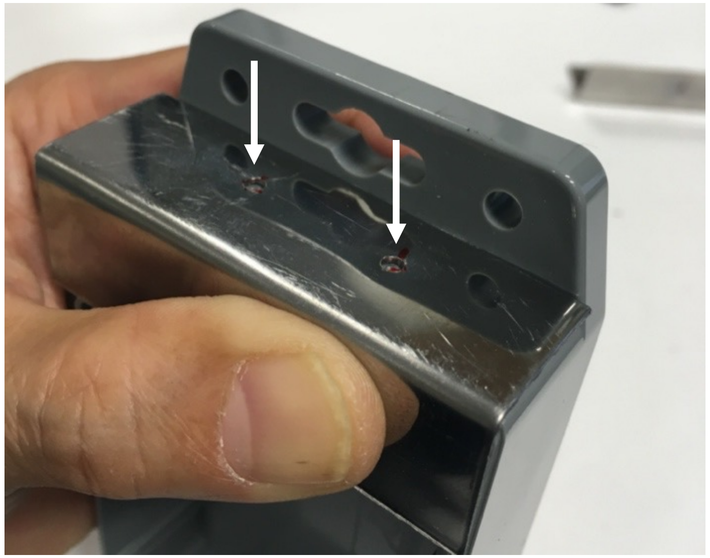
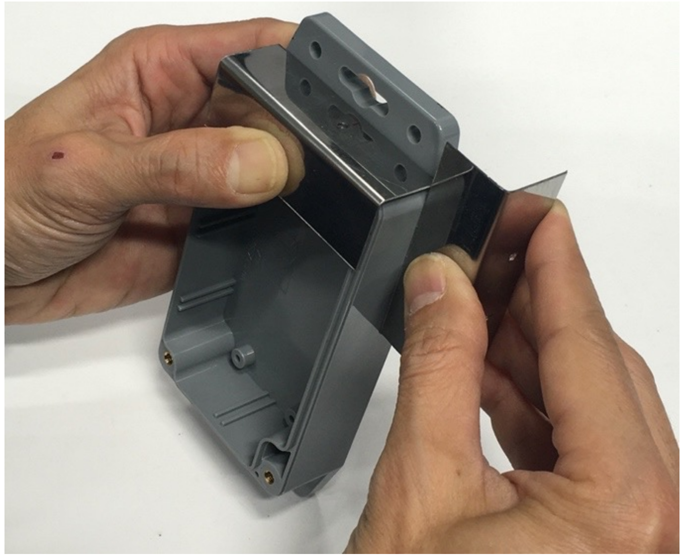




again, we need to remove the plastic reinforcement part for this particular enclosure

use a flat cutter for instance to remove and smooth the inside part (a small plier can be used first to remove most of the part)

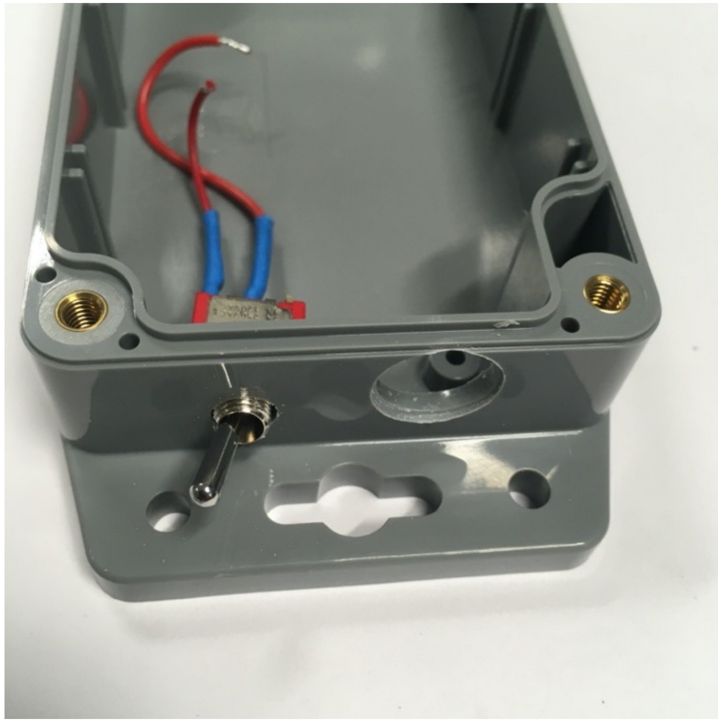
Going for larger production

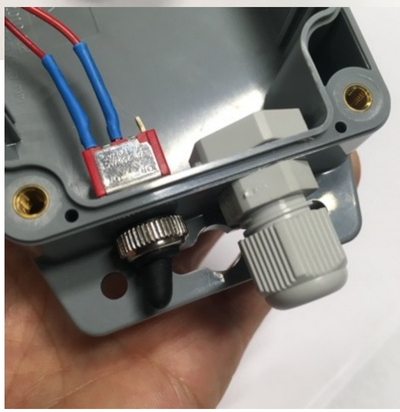
If you need to prepare many enclosures, it may be faster to first make an assembly jig (here a piece of metal) for marking the holes

But be sure to precisely align the edge of the jig with the edge of the enclosure

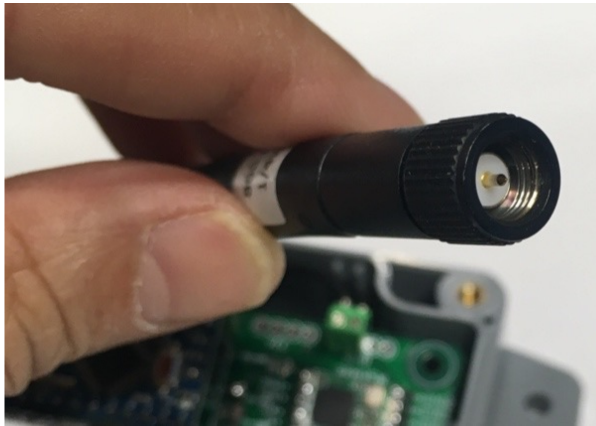
Placing switch and cable gland

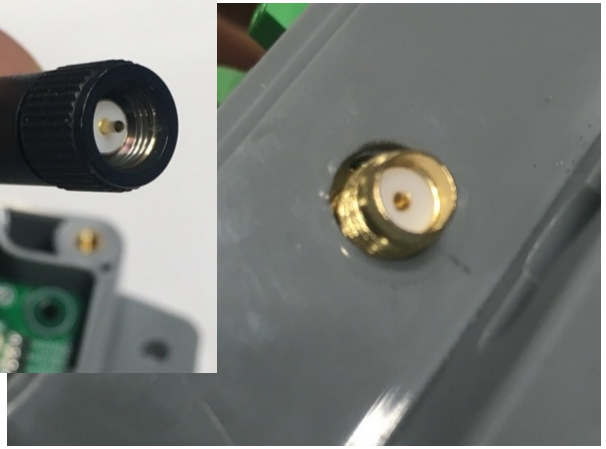


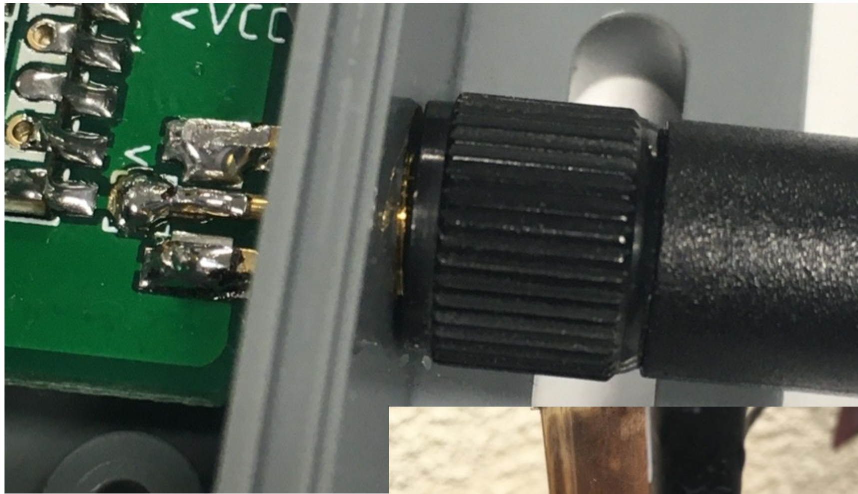
- test that everything is OK
- the switch has a water-proof rubber cap which should be carefully tighten



Connecting antenna



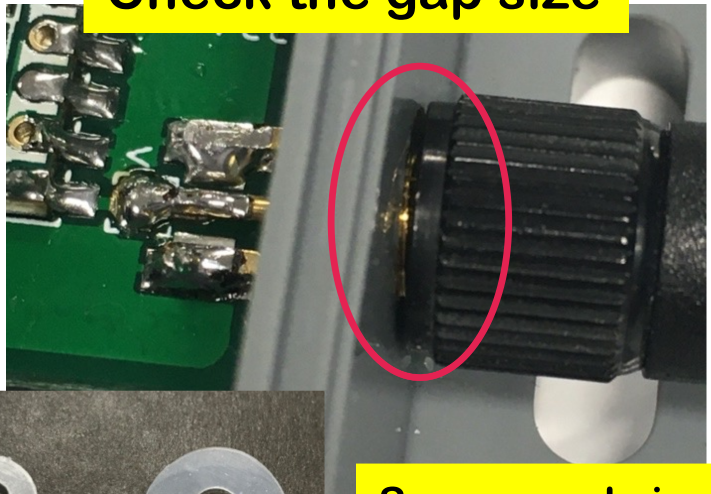


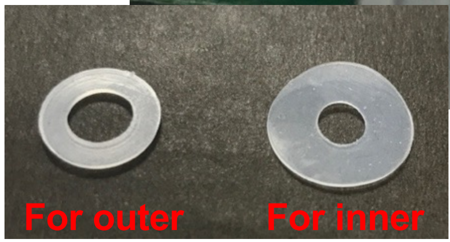


Be sure to connect the matching antenna
Here, SMA female with SMA male antenna
Need to screw the antenna in <u>all the way</u>

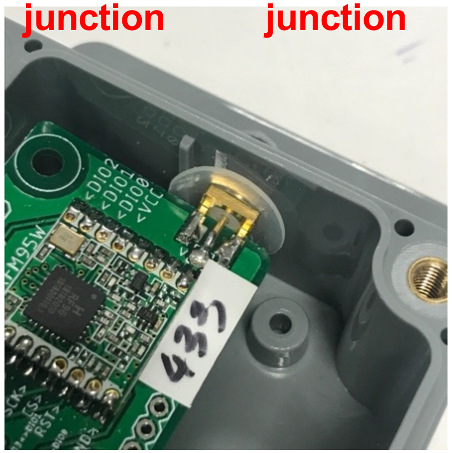
The antenna junction is **critical because this is where rain water can come in**

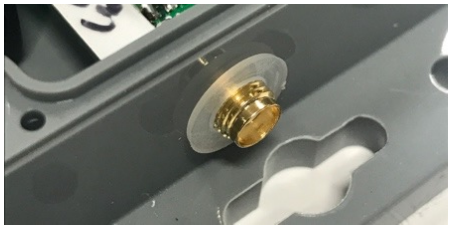
Waterproofing the antenna junction





See example in the list of part





Even when the antenna is screwed in all the way, there might still be a gap

Even with no apparent gap, it is necessary to waterproof the junction

Take flat silicon seals for that purpose, but do not take it too thick or too large!

Too thick: the antenna will not be screwed in all the way!

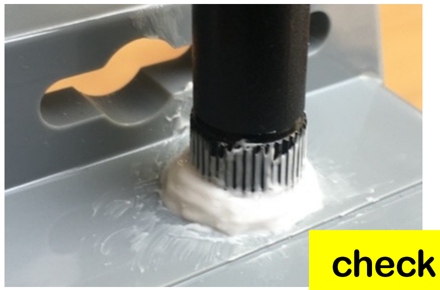
Do not have or can not use flat seal ?

Maybe the gap is too big? Use silicon joint sealant

First, screw in the antenna <u>all the way</u>

Put small amount of silicon around the antenna junction (use a flat screw driver or other flat tool)

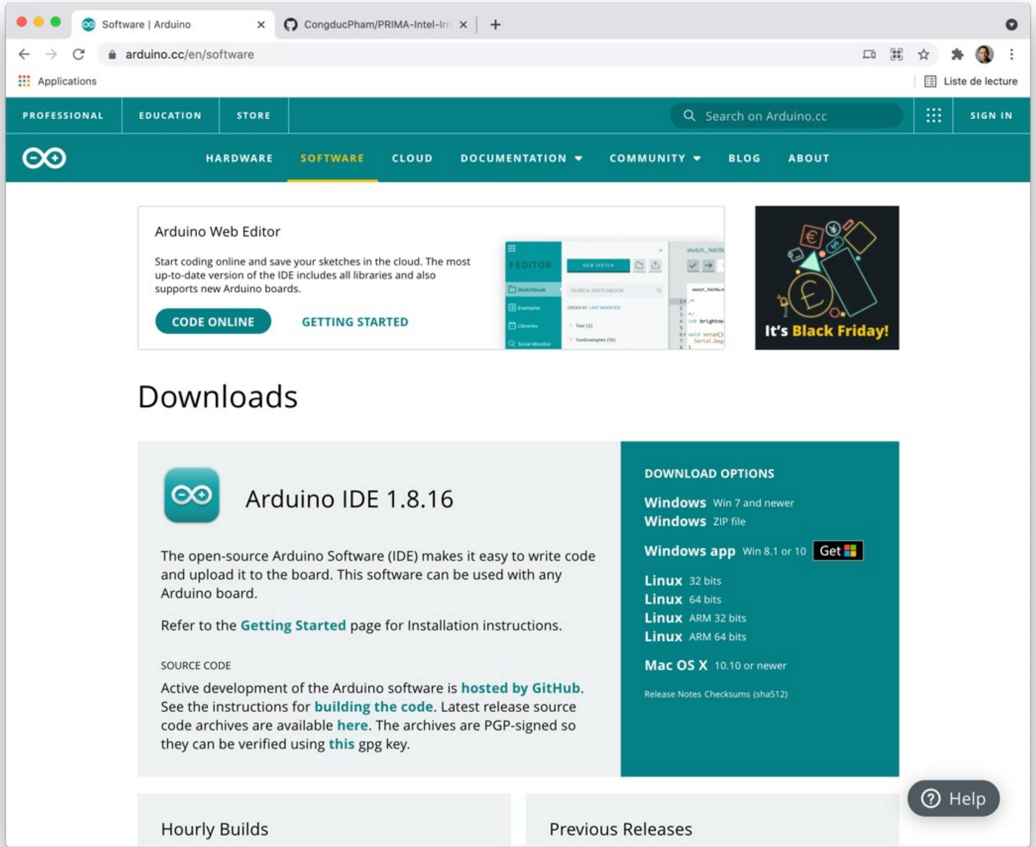
Use a <u>wet</u> toothpick to finish and clean the silicon all around the antenna junction

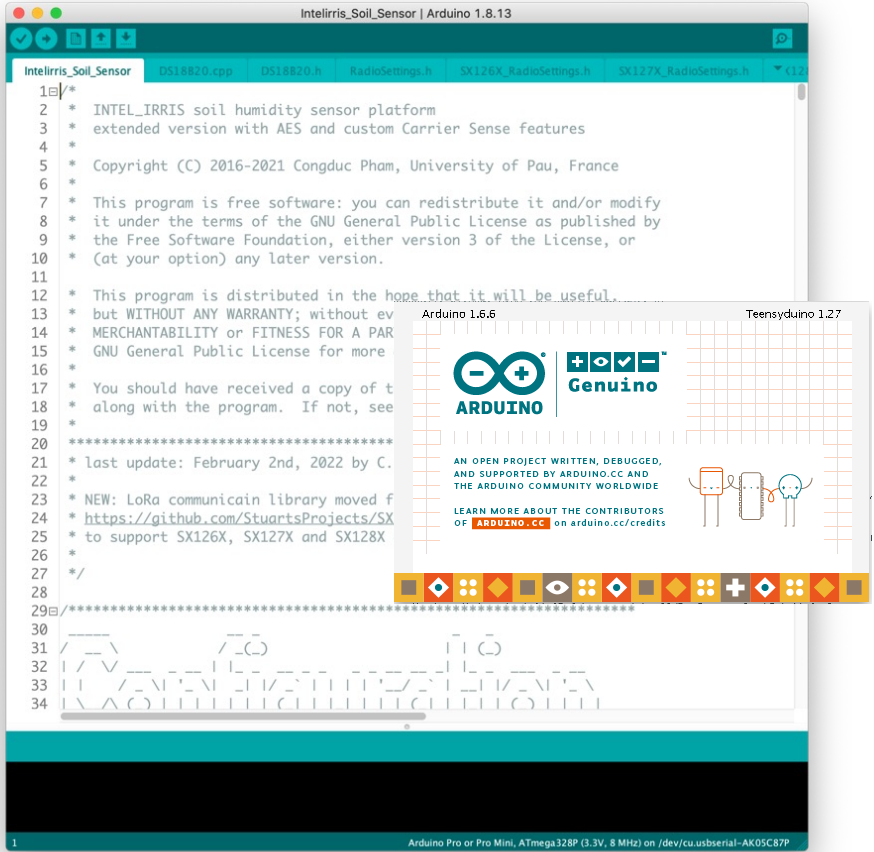


check especially the back side


INTEL-IRRIS
Intelligent Irrigation System for Low-cost Autonomous Water Control
in Small-scale Agriculture
PROGRAM
THE
ARDUINO

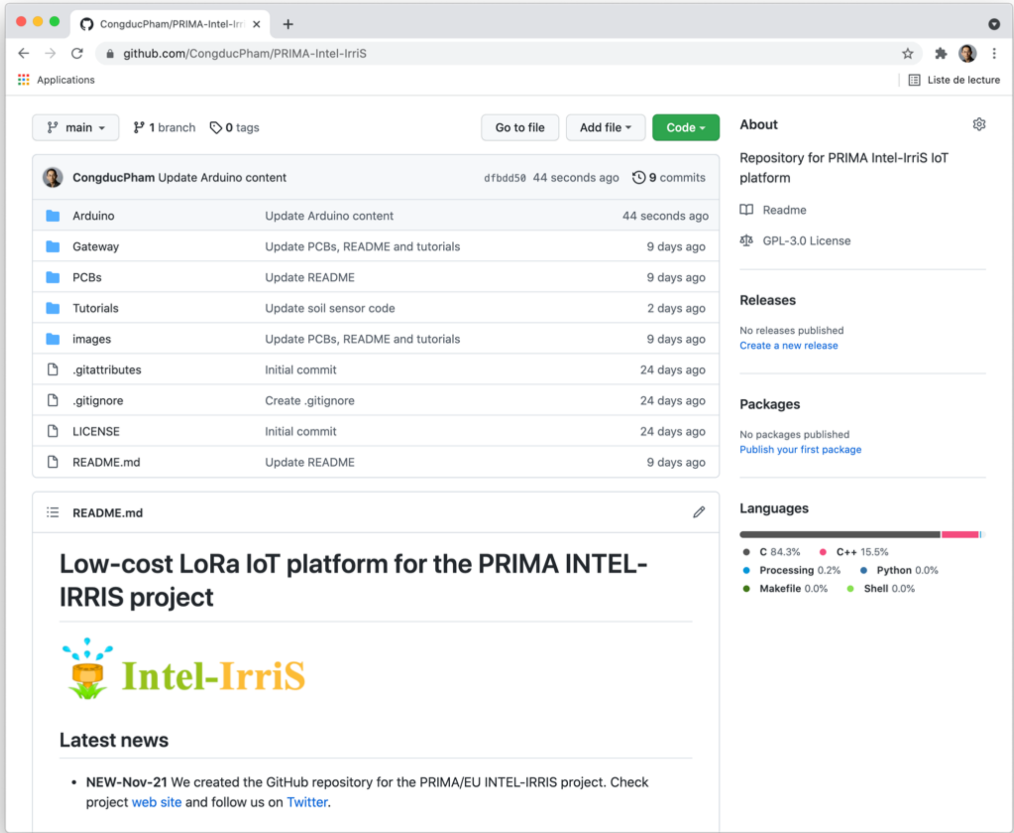
Getting the software: Arduino IDE





Install latest version of Arduino IDE from https://www.arduino.cc/en/software

Getting the INTEL-IRRIS code



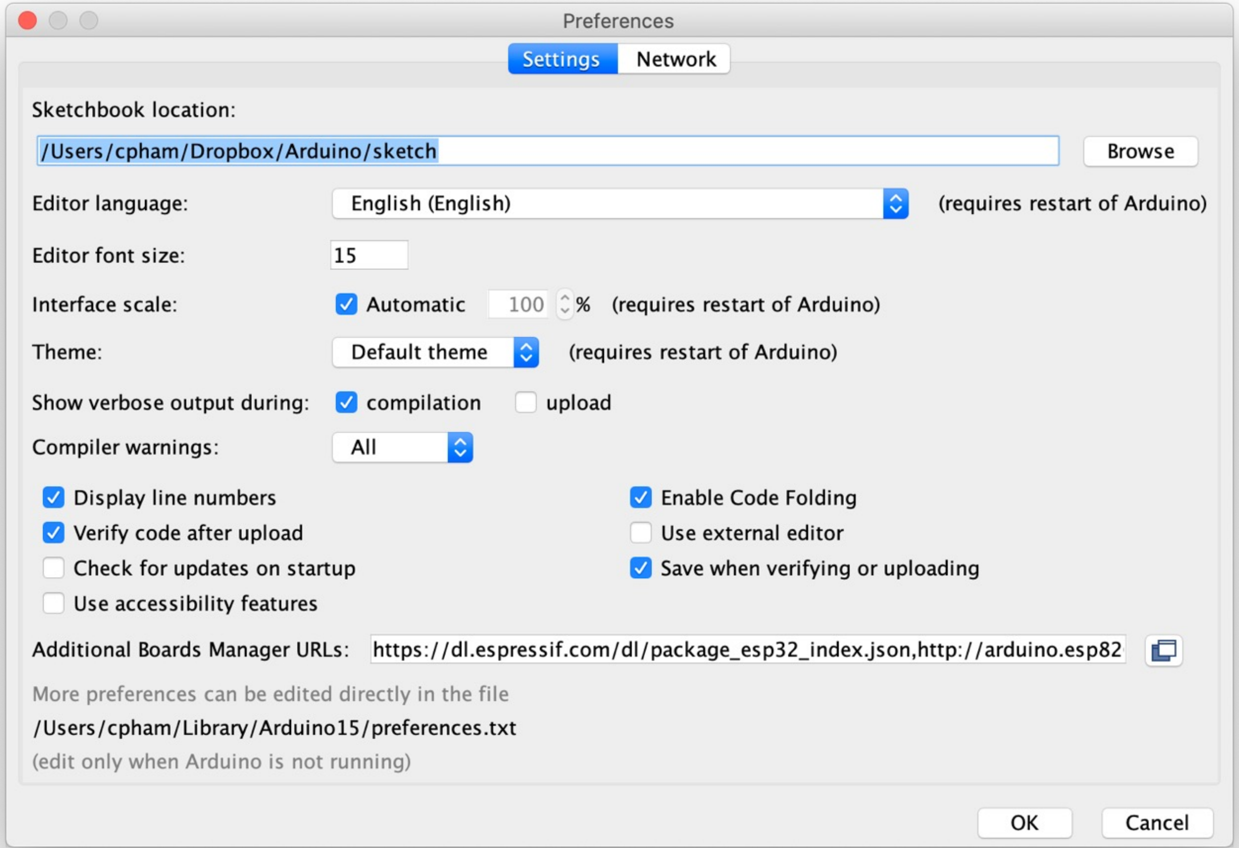
On your computer, create a `sketch` folder

Then download the whole repository as ZIP file

Unzip the file and copy the content of `Arduino` folder into your `sketch` folder

The entire Intel-IrriS GitHub repository is hosted here
https://github.com/CongducPham/PRIMA-Intel-IrriS

Setting your Arduino IDE



Run Arduino IDE, open Preferences

Indicate your `sketch` folder in Sketchbook location

Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

Config for IRD PCB v4.1

- Uncomment `IRD_PCB` in BoardSettings.h

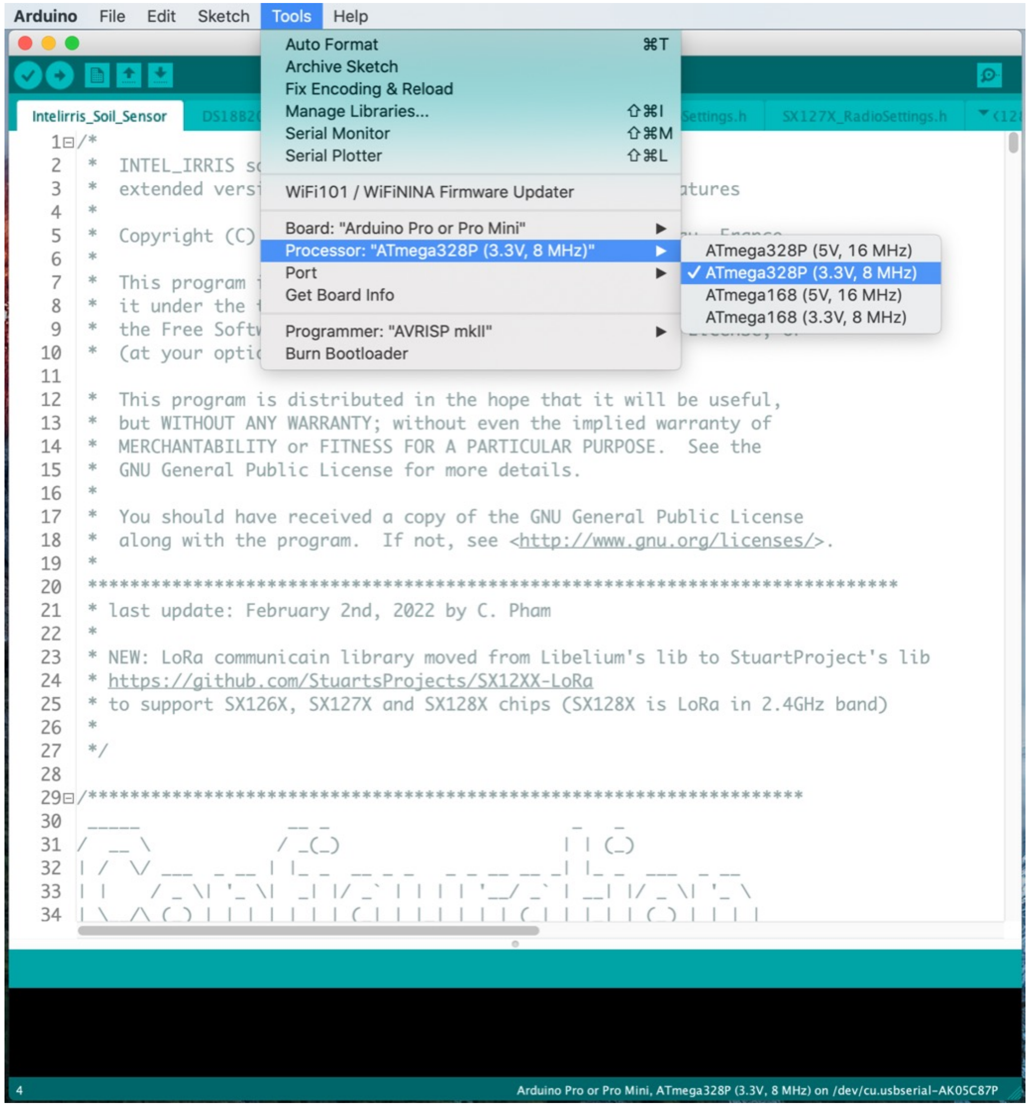
```
//uncomment for WAZISENSE v2 board
//#define WAZISENSE

//uncomment for IRD PCB board
#define IRD_PCB
```

- ONLY for solar version, uncomment `SOLAR_BAT` in BoardSettings.h

```
////////////////////////////////////////////////////////////////////////////////////
// uncomment only if the IRD PCB is running on solar panel
// MUST be commented if running on alkaline battery
// code for SOLAR_BAT has been written by Jean-François Printanier from IRD
#define SOLAR_BAT
// do not change if you are not knowing what you are doing
#define NIMH
```

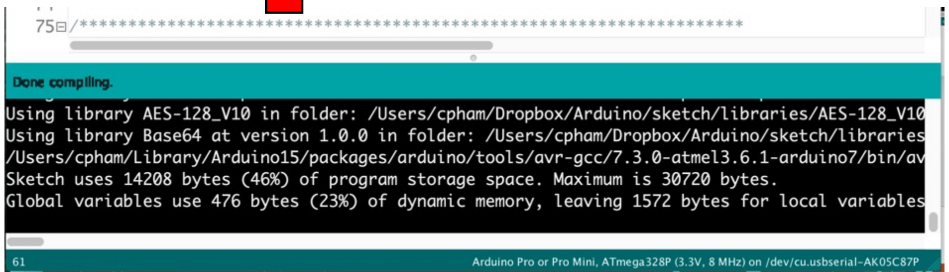
Compiling the soil sensor code



Open Intelirris_Soil_Sensor sketch – no change required for default capacitive sensor

Select the ProMini board, 3.3V and 8MHz version

Then click on the "verify" button



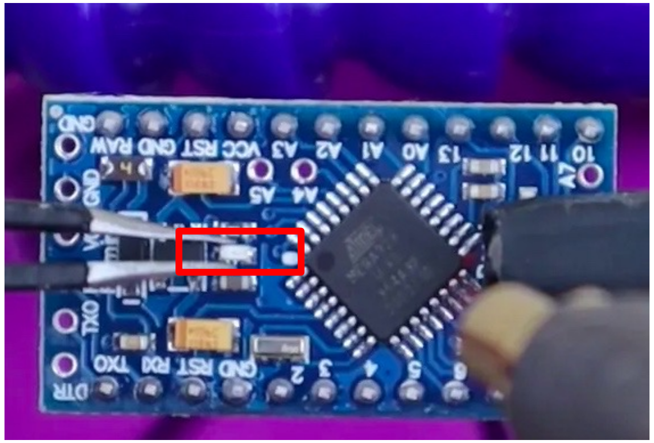
Never transmit without antenna

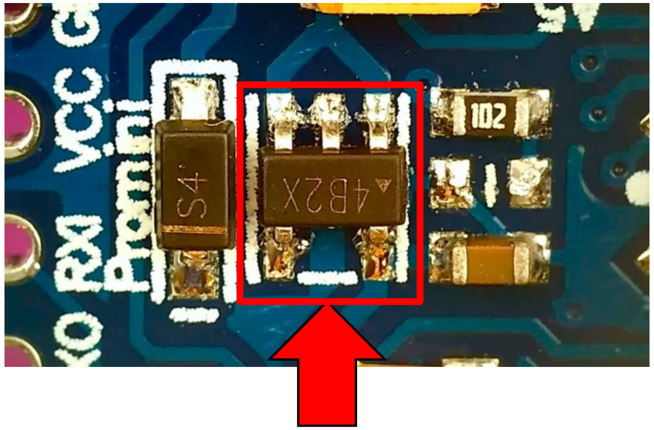
- NEVER, NEVER transmit without an antenna
- Doing so can damage the radio module
- If your board is already connected to the radio module and you need to flash the board, then connect the antenna
- If you need to update the existing code and your device already run a code that transmit data, connect the antenna
- It is safer when programming the device to remove the Arduino board from the female header and program it disconnected from the radio module
- If you deploy a device, make sure that the antenna is correctly connected before powering on the device and realizing any transmission test

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

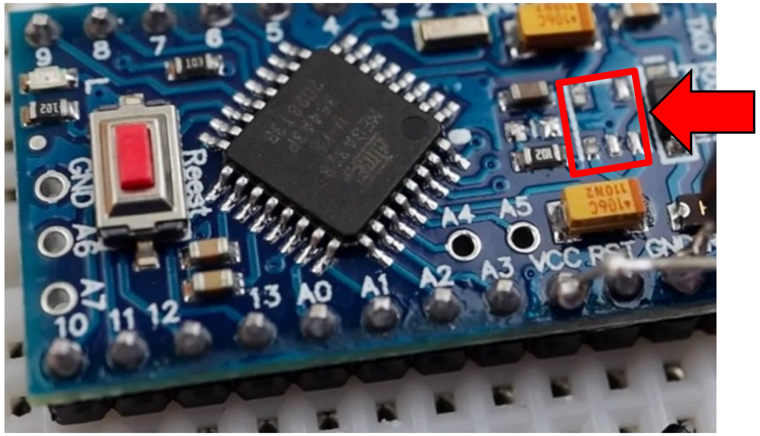
Reduce power consumption

Intel-IrriS





Do not forget to remove the power LED by just clipping it off with some wire cutters



Do not forget to remove the voltage regulator with a small plier

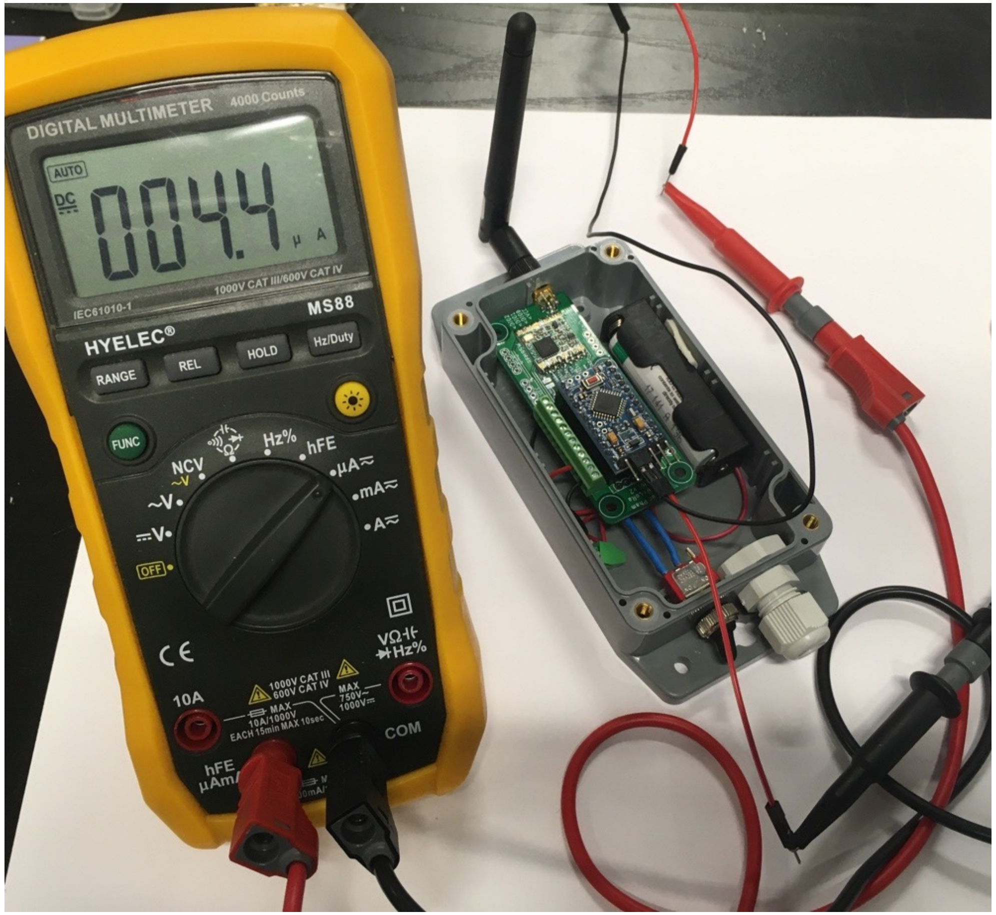
Only inject up to 3.6V through the VCC pin

https://www.the-diy-life.com/making-an-ultra-low-power-arduino-pro/

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Power consumption in deep sleep

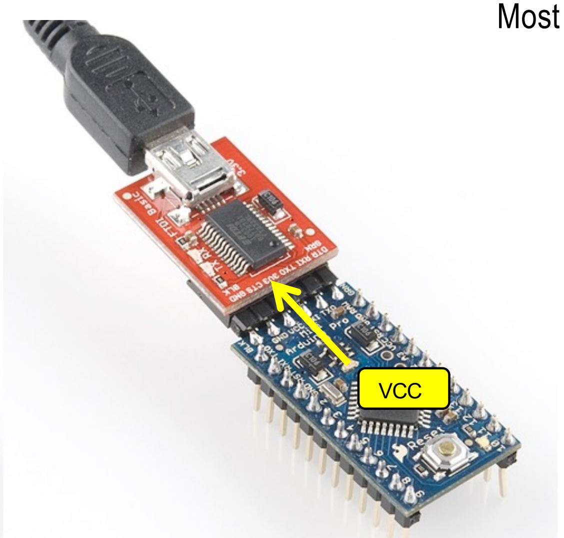
Intel-IrriS



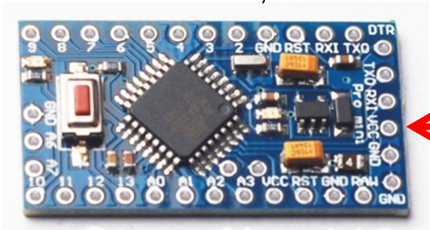
Measured below 5uA in deep sleep, between 2 active periods with transmissions

Expected autonomy with 1 transmission / hour is over 2 years with 2 AA batteries

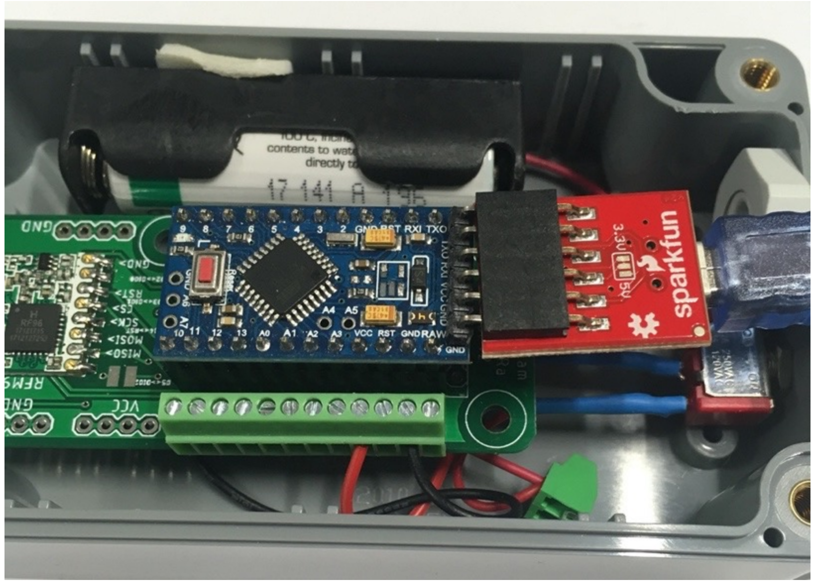
Connecting with an FTDI cable



Most Chinese clone version, check the VCC pin



Original Sparkfun version



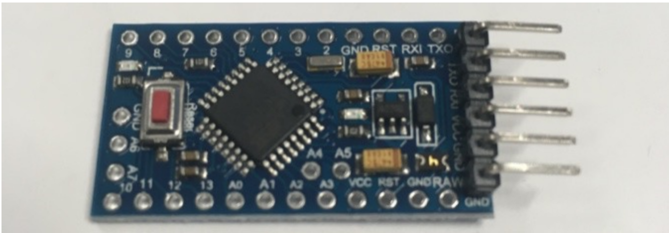
For the ProMini, you need to have an FTDI breakout cable working at 3.3v

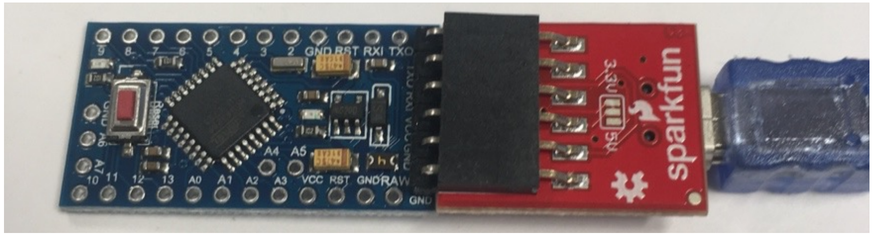
Check the VCC pin position and make it to correspond to the VCC pin of the FTDI breakout.

Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

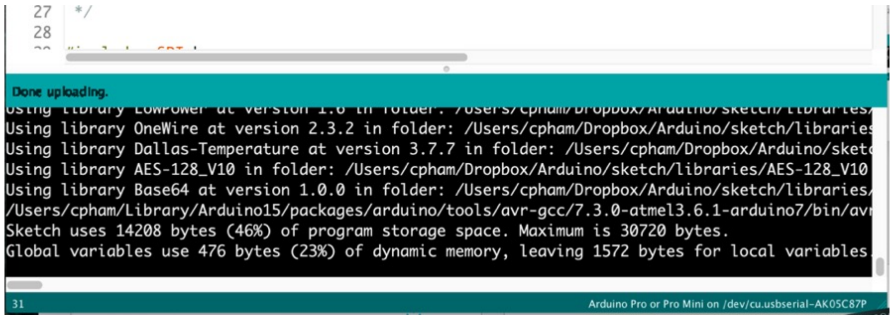
Check the Arduino

- First, just solder the programming header





- To flash the Arduino board with the INTEL-IRRIS code
- See slides from "Getting the software: Arduino IDE" to "Uploading to your board"
- If uploading is successful, then you can continue with soldering the remaining header pins, otherwise, take another board as this one may have hardware issue



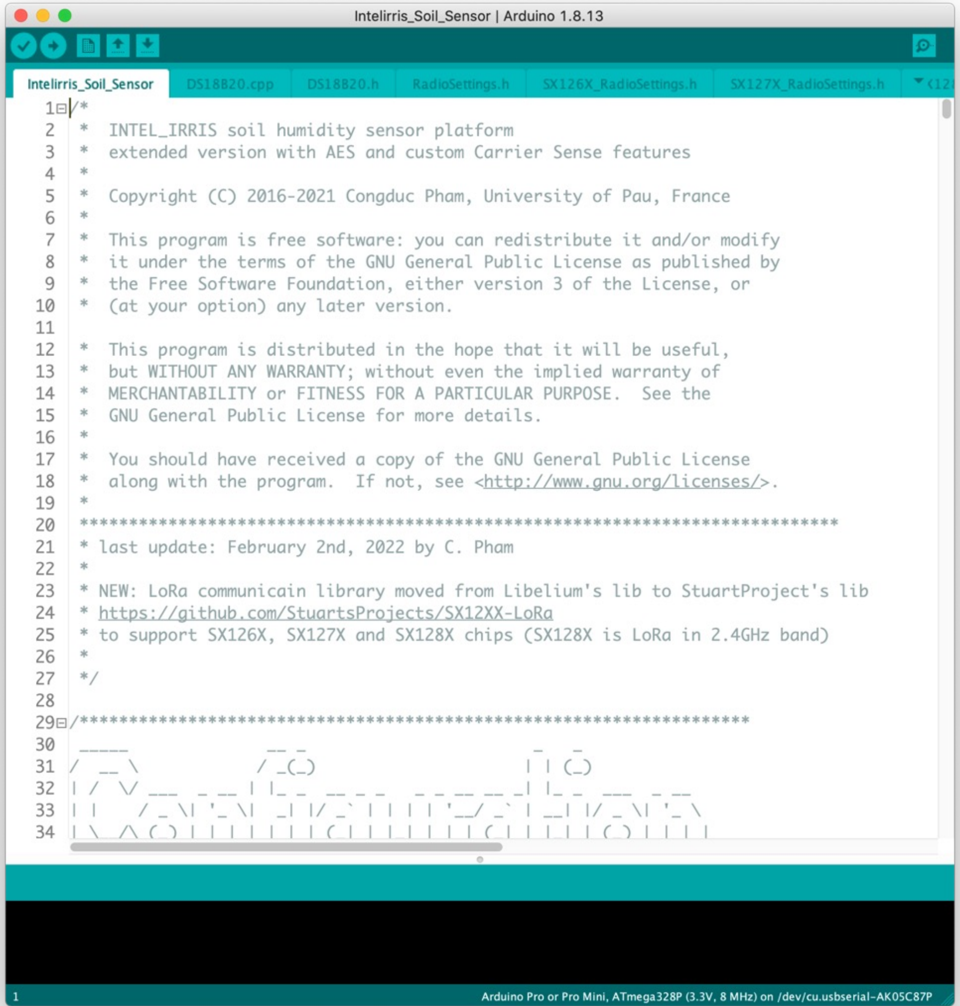
Select serial port for uploading

After connecting the cable to your computer/laptop USB port, try to find the serial port

If you don't find it, you may need to install specific drivers

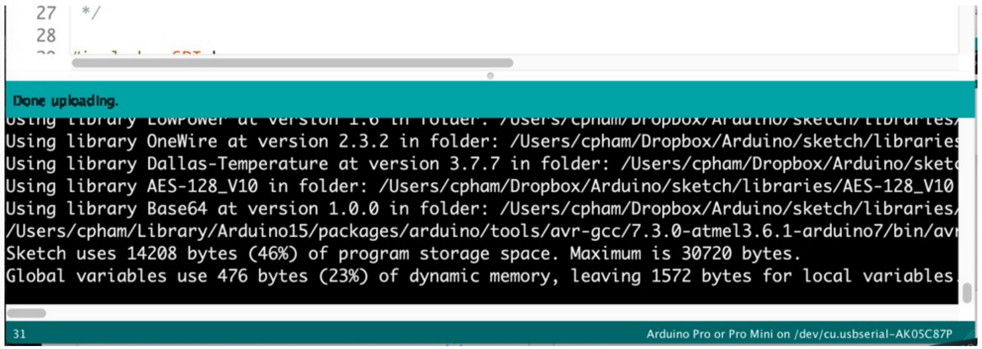
https://learn.sparkfun.com/tutorials/how-to-install-ch340-drivers/all

Uploading to your board



Click on the "upload" button

And wait until upload is completed



PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Checking that device is operational

Intel-IrriS

/dev/cu.usbserial-AK05C87P

Send

```
SX1276,868099968Hz,SF12,BW125000,CR4:5,LDRO_On,SyncWord_0x34,IQNormal,Preamble_8
SX1276,SLEEP,Version_12,PacketMode_LoRa,Explicit,CRC_On,AGCauto_On,LNAgain_0,LNAboostHF_On,LNAboostLF_On

Reg    0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
0x00  00 80 1A 0B 00 52 D9 06 66 FC 09 10 1B 12 00 00
0x10  00 00 00 00 00 00 00 00 00 00 00 00 00 72 C4 64
0x20  00 08 FF FF 00 00 0C 00 00 00 00 00 00 50 14 40
0x30  00 03 05 27 1C 0A 03 0A 42 34 40 1D 00 A1 00 00
0x40  70 00 12 24 2D 00 03 00 04 23 00 09 05 84 32 2B
Get back previous sx1272 config
Using packet sequence number of 171
Forced to use default parameters
Using node addr of 8
Using idle period of 30
Setting Power: 14
node addr: 8
SX127X successfully configured
Sending \!SH1/346.00
use XLPP format for transmission to WaziGate
end-device uses native LoRaWAN packet format

plain payload hex
00 67 08 75
Encrypting
encrypted payload
A0 34 2F 4C
calculate MIC with NwkSKey
transmitted LoRaWAN-like packet:
MHDR[1] | DevAddr[4] | FCtrl[1] | FCnt[2] | FPort[1] | EncryptedPayload | MIC[4]
40 AA 1D 01 26 00 00 00 01 A0 34 2F 4C D1 B8 13 A9
[base64 LoRaWAN HEADER+CIPHER+MIC]:QKodASYAAAABoDQvTNG4E6k=
--> CS1
--> CAD 183
OK1
CRC,752E
LoRa pkt size 17
LoRa pkt seq 171
LoRa Sent in 1506
Switch to power saving mode
```

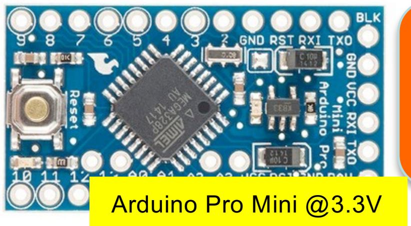
Autoscroll | Show timestamp | No line ending | 38400 baud | Clear output

- **Open serial monitor**
- **Set baud rate to 38400**
- **See output from board**
- **Check that transmission is OK**

Generic & cyclic behavior

SEN0308
capacitive soil humidity
A0 (signal), A1 (power)

Physical sensor management

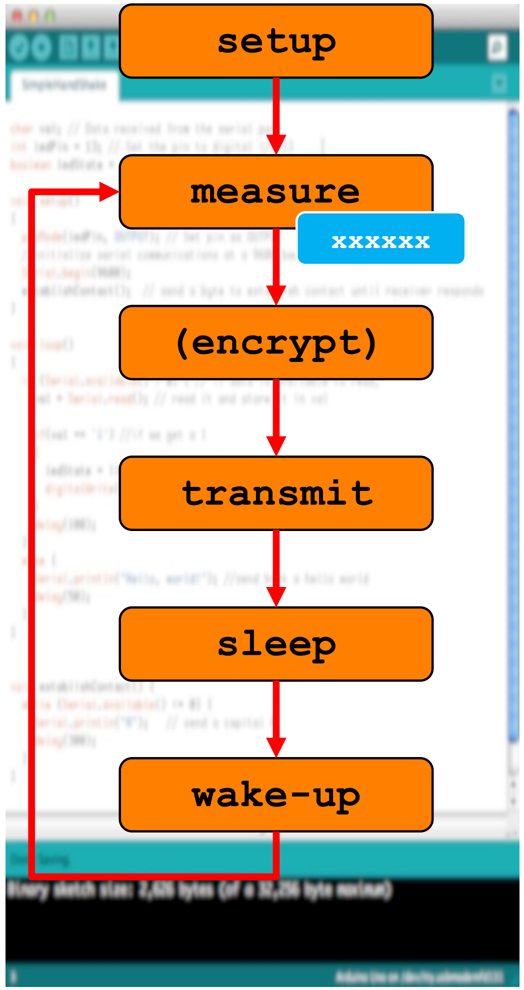


Activity duty-cycle, low power

AES encryption

Long-range transmission

Logical sensor management



Transmission to WaziGate

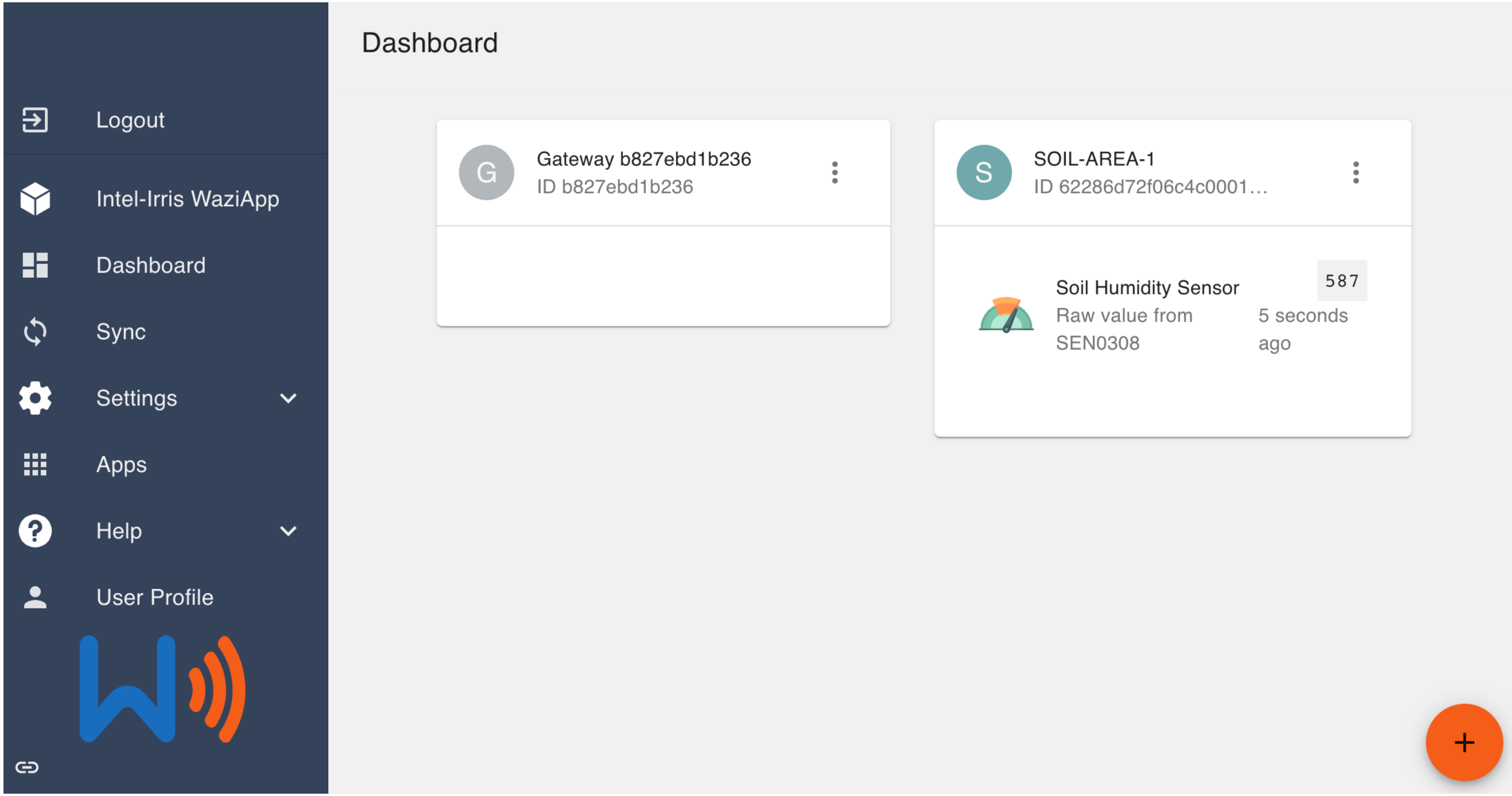
Parameters for
INTEL-IRRIS WaziGate

LoRaWAN

SF12BW125
868.1MHz | 433.175MHz
Node id is 26011DAA
1 msg/60mins
1 sensor
XLPP data

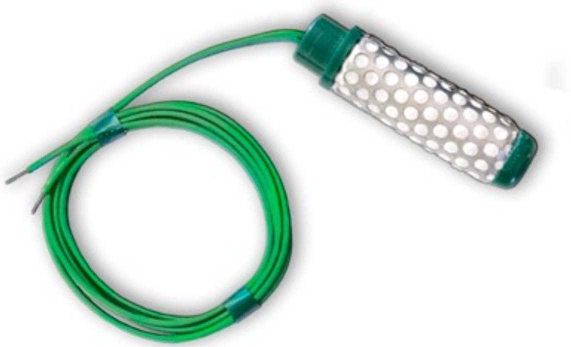
This dedicated video will show all these steps, from connecting the SEN0308 to testing transmission to the WaziGate
Video n°4: https://youtu.be/j-1Nk0tv0xM

See it on the dashboard



Software configuration for WM

- Default resistor value is 10kOhms
- Change in `watermark.h` file the `WM_RESISTOR` value to match the one you are using if needed
- The fully assembled version has a 10kOhms resistor



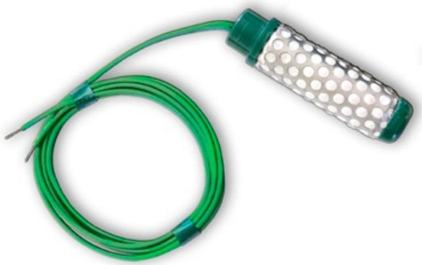
```
//put here the resistor value, in Ohms
#define WM_RESISTOR 10000
//we defined WM_MAX_RESISTOR=32760 because the transmitted value would be 32760/10=3276
//and currently a bug in WaziGate XLPP decoding code will limit the maximum value to 3276
#define WM_MAX_RESISTOR 32760
```

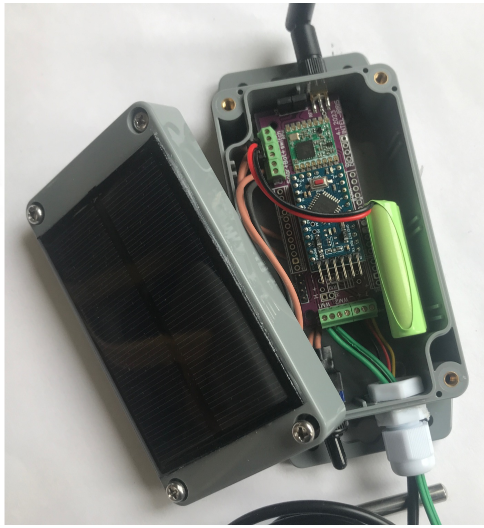
-

```
////////////////////////////////////////////////////////////////////
// uncomment to have a soil tensiometer watermark sensor
#define WITH_WATERMARK
#define WM_REF_TEMPERATURE 28.0
////////////////////////////////////////////////////////////////////
// uncomment to force the watermark to have default device address for WaziGate
//#define WM_AS_PRIMARY_SENSOR
```

Transmission with the WM sensor

- Devices with a WM sensor will have a different default address
  - 26011DB1 instead of 26011DAA for capacitive
- 2 values are transmitted
  - Centibars converted from resistance value
  - Raw resistance value measured for WM sensor, but scaled down by a factor of 10 ➞ 300 = 3000 Ohms



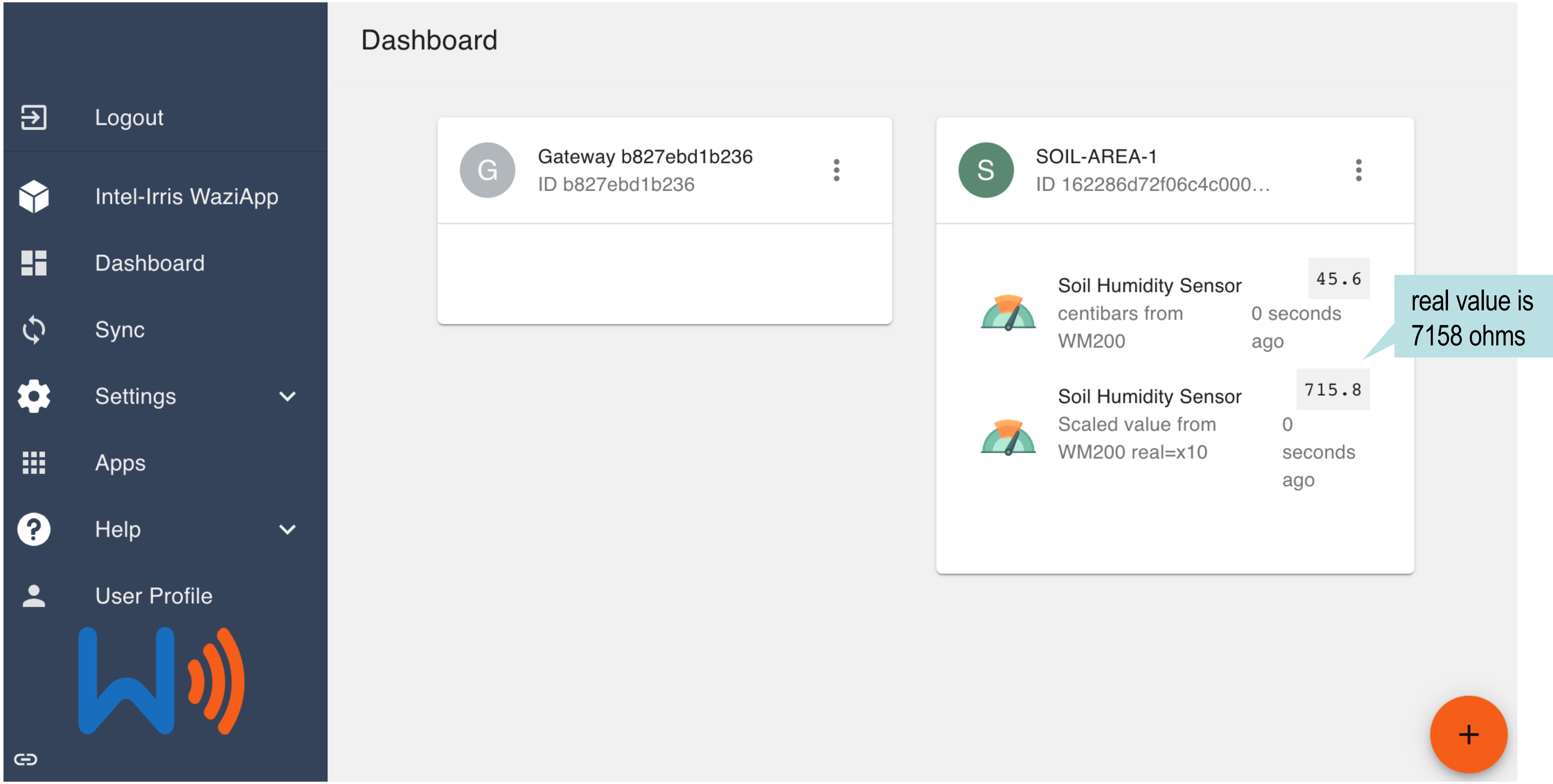


Parameters for INTEL-IRRIS WaziGate

LoRaWAN

SF12BW125
868.1MHz | 433.175MHz
Node id is 26011DB1
1 msg/60mins
1 sensor
XLPP data

See it on the dashboard



2 versions of the soil device

SEN0308 capacitive sensor
Default address is 26011DAA

Watermark WM200
Water tension sensor
Default address is 26011DB1

Soil temperature with WM sensor (1)

- Without a real temperature sensor, the INTEL-IRRIS code uses a default soil temperature set to 28°C to convert the resistance value into centibars (see https://www.irrometer.com/200ss.html)

```
/////////////////////////////////////////////////////////////////////
// uncomment to have a soil tensiometer watermark sensor
#define WITH_WATERMARK
#define WM_REF_TEMPERATURE 28.0
/////////////////////////////////////////////////////////////////////
// uncomment to force the watermark to have default device address for WaziGate
//#define WM_AS_PRIMARY_SENSOR
```

- You can change this setting in the code for testing purposes
- The final objective is to use a real temperature sensor to dynamically get the soil temperature

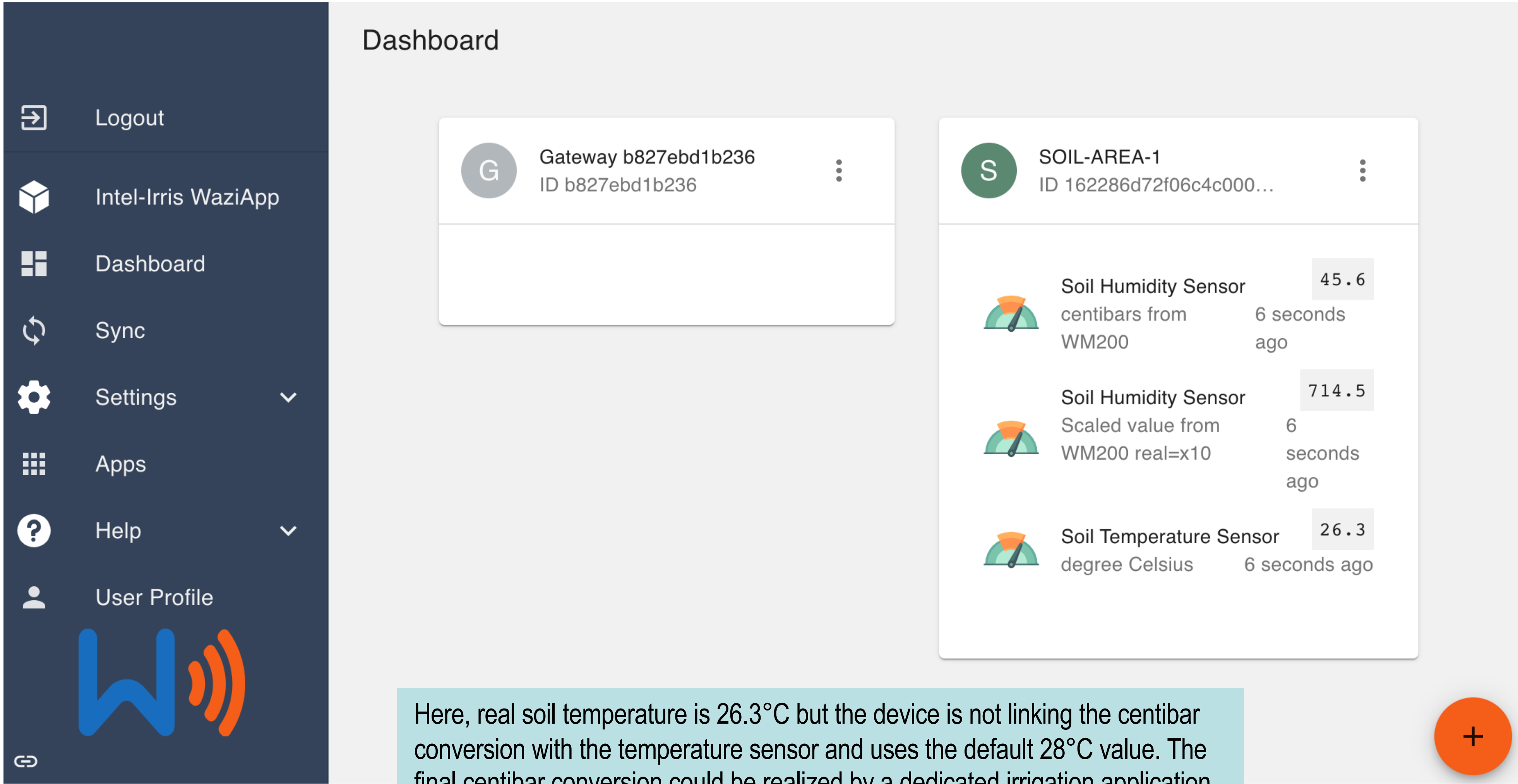
Soil temperature with WM sensor (2)

- A DS18B20 temperature sensor can be connected to the device

```
//////////////////////////////////////////////////////////////////////
// uncomment to have 1 soil temperature sensor ST
// using a one-wire DS18B20 sensor
#define SOIL_TEMP_SENSOR
//#define LINK_SOIL_TEMP_TO_CENTIBAR
```

- In this case, the soil temperature will also be sent to the gateway
- It is also possible to link the measured soil temperature to the centibar calculation performed by the device itself

See it on the dashboard



Here, real soil temperature is 26.3°C but the device is not linking the centibar conversion with the temperature sensor and uses the default 28°C value. The final centibar conversion could be realized by a dedicated irrigation application run on the WaziGate gateway.

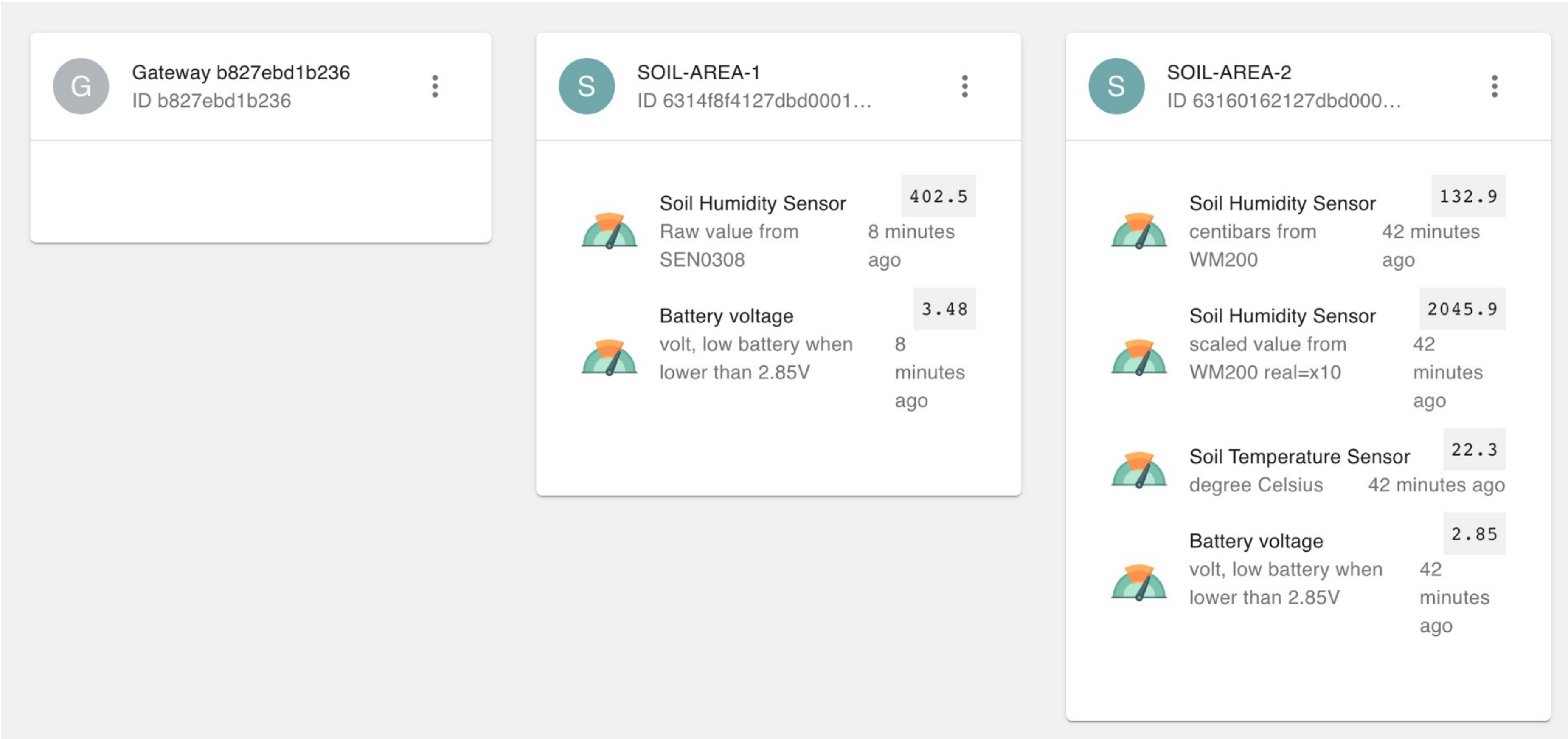
Low battery voltage indication

- The INTEL-IRRIS code has low battery voltage indication feature, by default, low battery voltage threshold is set to 2.85V

```
#ifdef WITH_WATERMARK
//the ATMega328P reboots at about 2.65 - 2.75
#define VCC_LOW                 2.85
#else
//capacitive sensors can be impacted by low voltage, especially for very dry soil conditions
#define VCC_LOW                 2.85
#endif
```

- The battery voltage will be transmitted to the gateway as well and will appear on the WaziGate's dashboard to warn end-user
- When low battery voltage is detected, the measure & transmission time interval will increase from 1h to 4h to preserve battery

See it on the dashboard



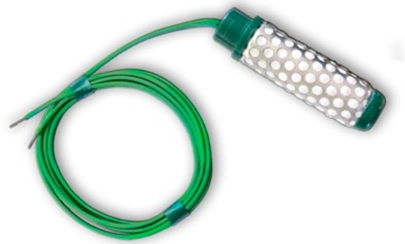
Software configuration for 2 WM

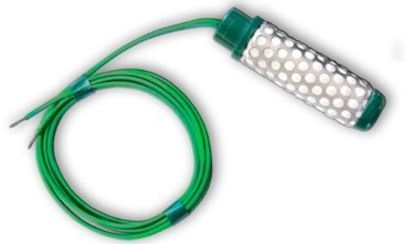
- Uncomment in main program TWO_WATERMARK

```
////////////////////////////////////////////////////////////////////
// uncomment to have a soil tensiometer watermark sensor
#define WITH_WATERMARK
#define WM_REF_TEMPERATURE 28.0

////////////////////////////////////////////////////////////////////
// uncomment to force the watermark to have default device address for WaziGate
//#define WM_AS_PRIMARY_SENSOR

////////////////////////////////////////////////////////////////////
// uncomment to have 2 tensiometer watermark sensor on the same device
#define TWO_WATERMARK
```



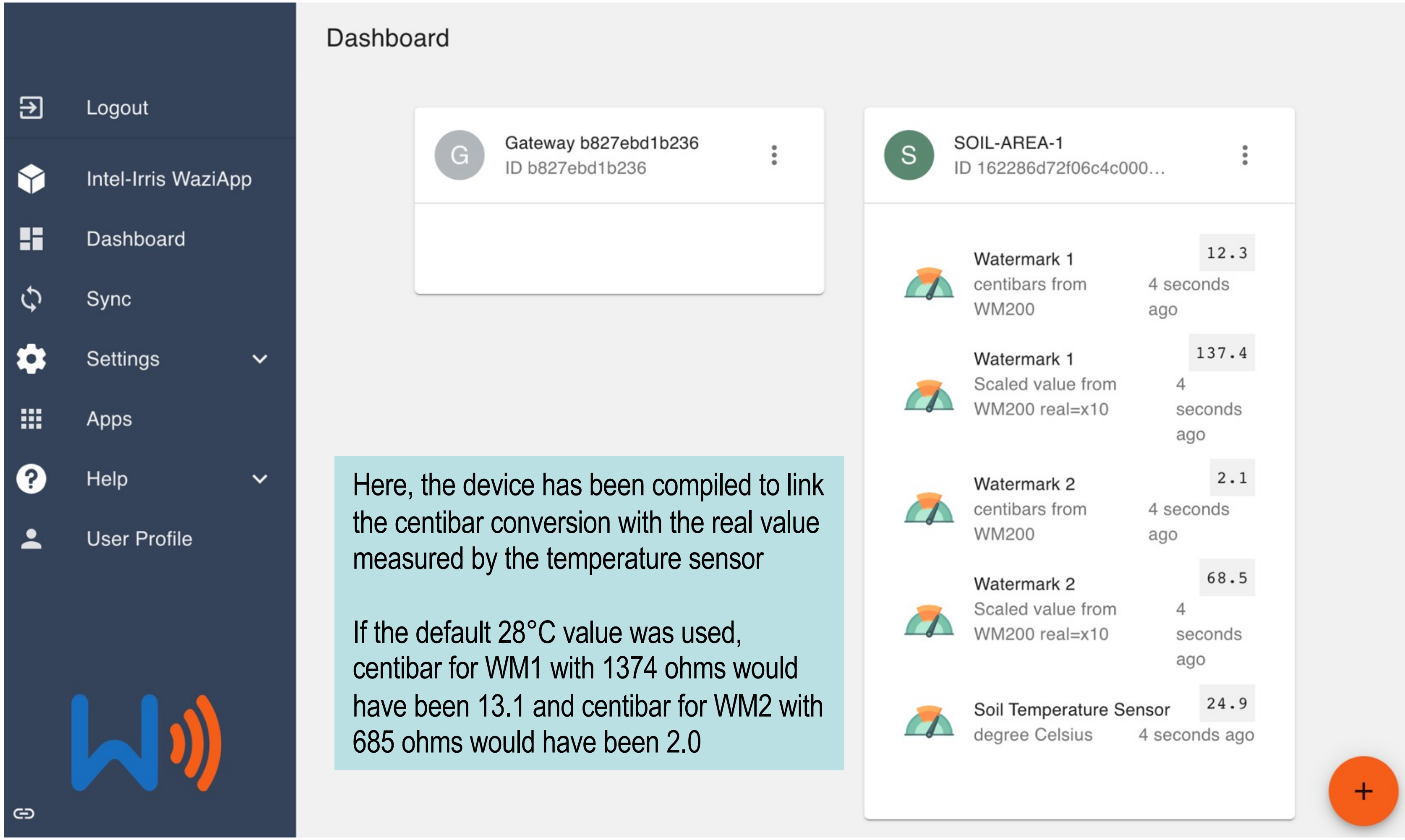


- You can still have a soil temperature sensor

PRIMA
IN THE MEDITERRANEAN AREA

See it on the dashboard

Intel-IrriS



Here, the device has been compiled to link the centibar conversion with the real value measured by the temperature sensor

If the default 28°C value was used, centibar for WM1 with 1374 ohms would have been 13.1 and centibar for WM2 with 685 ohms would have been 2.0