INTEL-IRRIS

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

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

Intel-IrriS

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

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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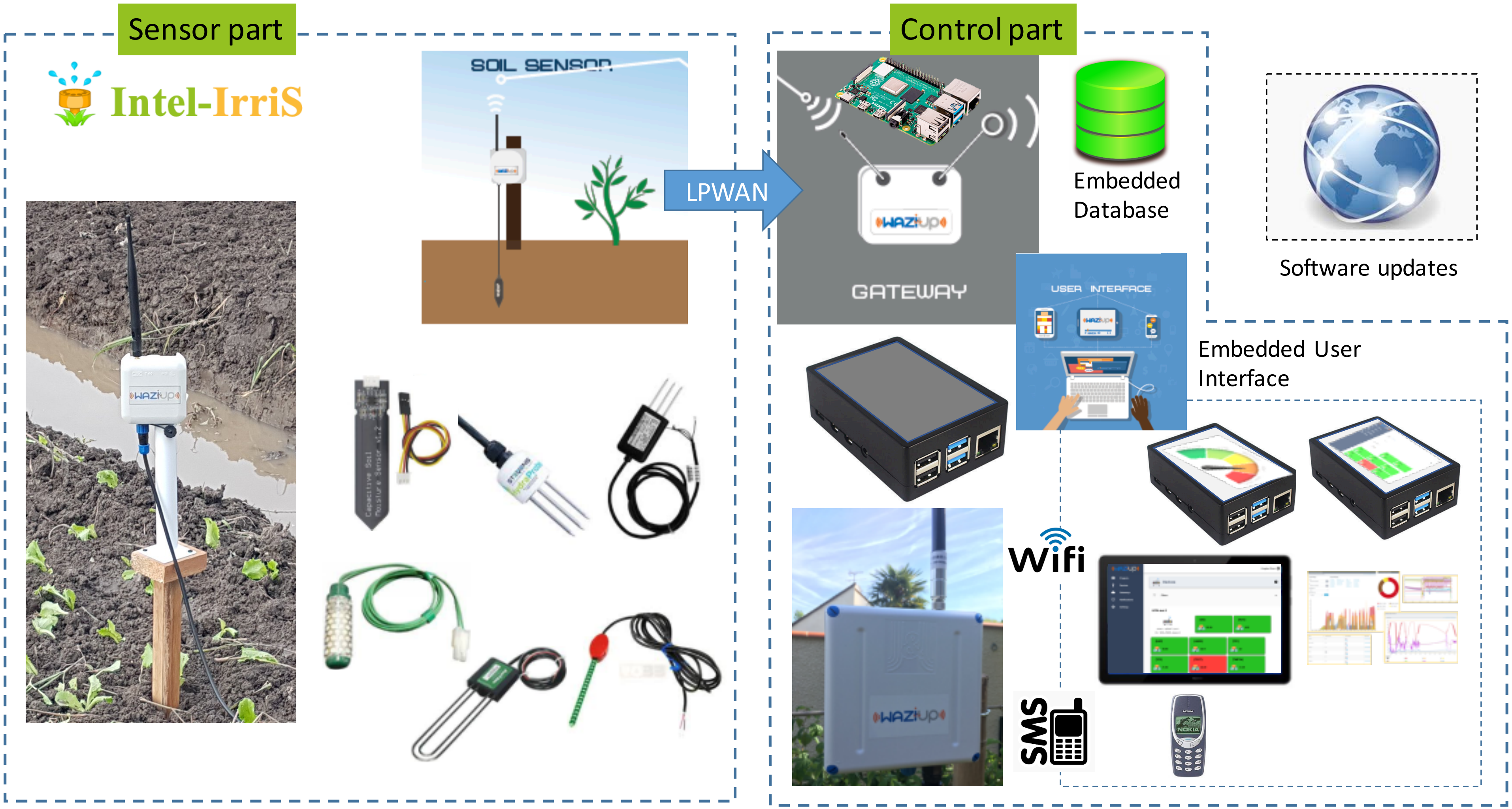
UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

LIUPPA

WAZIUP
IoT – from idea to reality
WAZIHUB

Review: Technology components



Review: Low-cost sensors

Sensor part

- 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

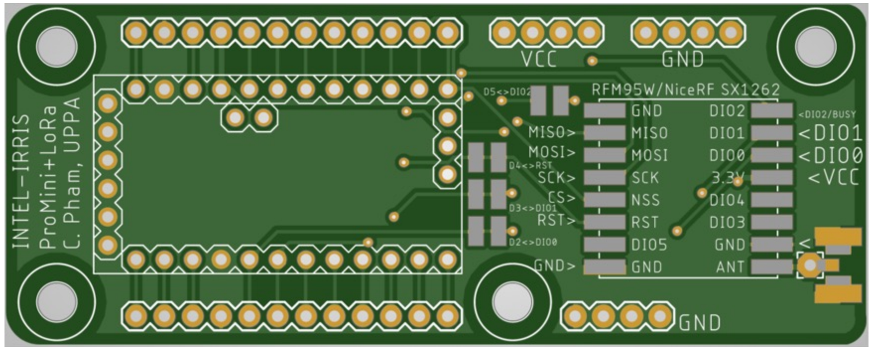
INTEL-IRRIS's starter-kit

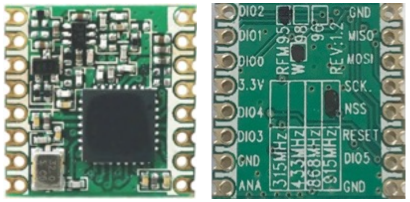
- **From idea to reality!**


INTEL-IRRIS
Intelligent Irrigation System for Low-cost Autonomous Water Control
in Small-scale Agriculture
SIMPLE PCB v1

Soil sensor: electronic parts

complete version

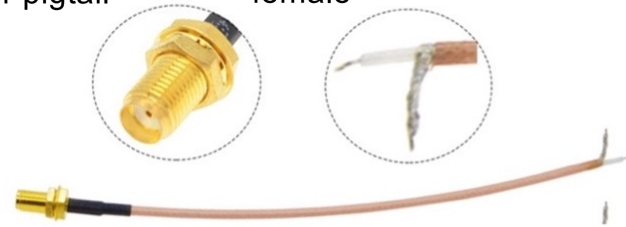


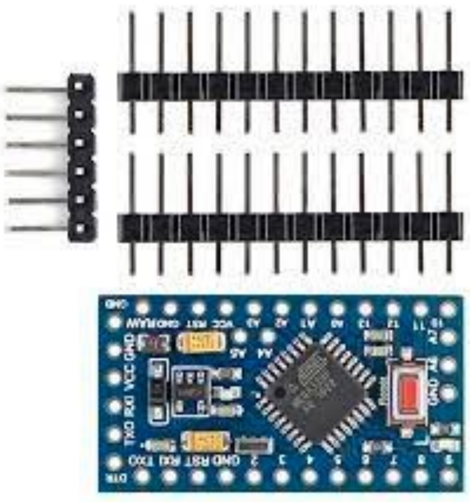


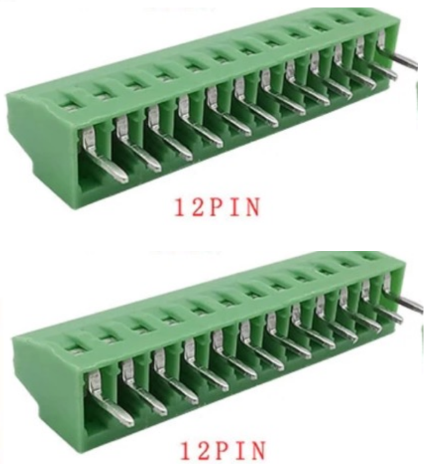
RFM95W (868MHz)
RFM96W (433MHz)
NiceRF SX1262 (868MHz)
NiceRF SX1268 (433MHz)
NiceRF SX1280 (2.4GHz)

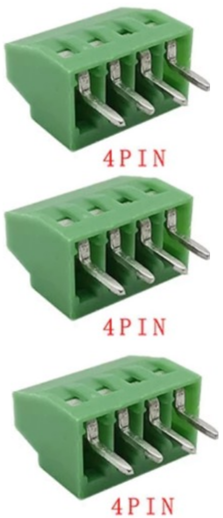
PCB mount or pigtail

SMA female



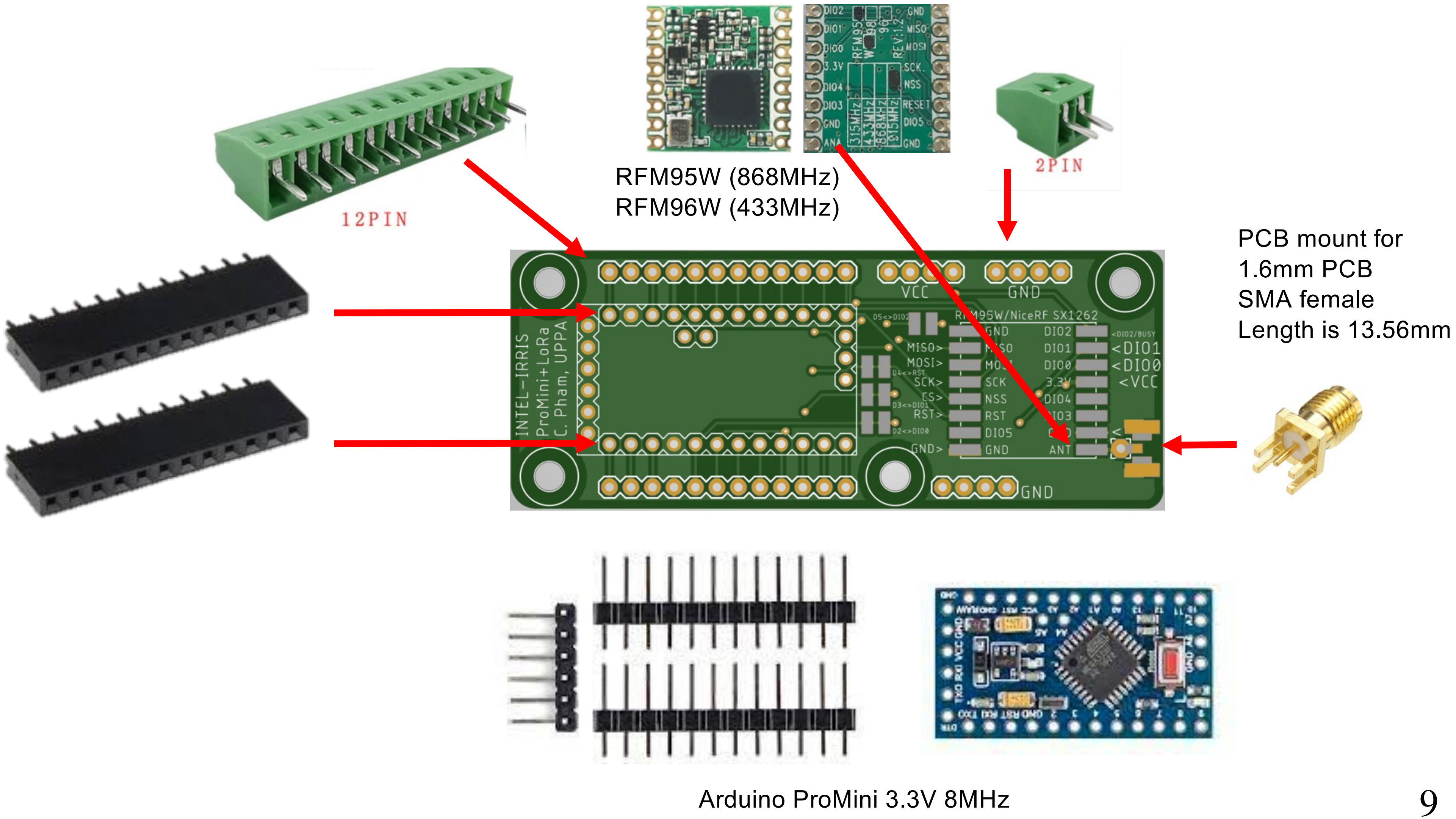






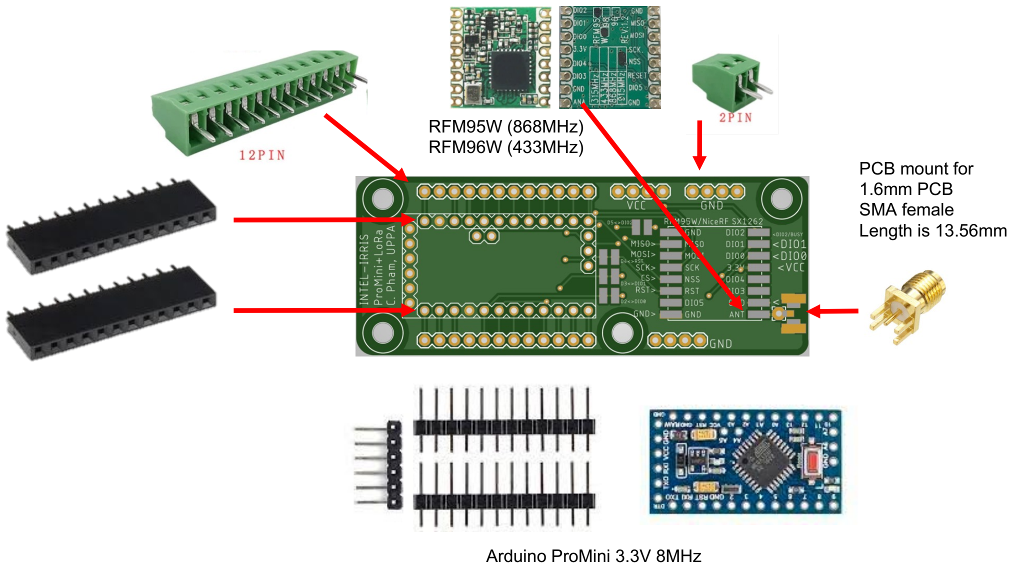
SMA male

Soil sensor: electronic parts
starter-kit version



List of components

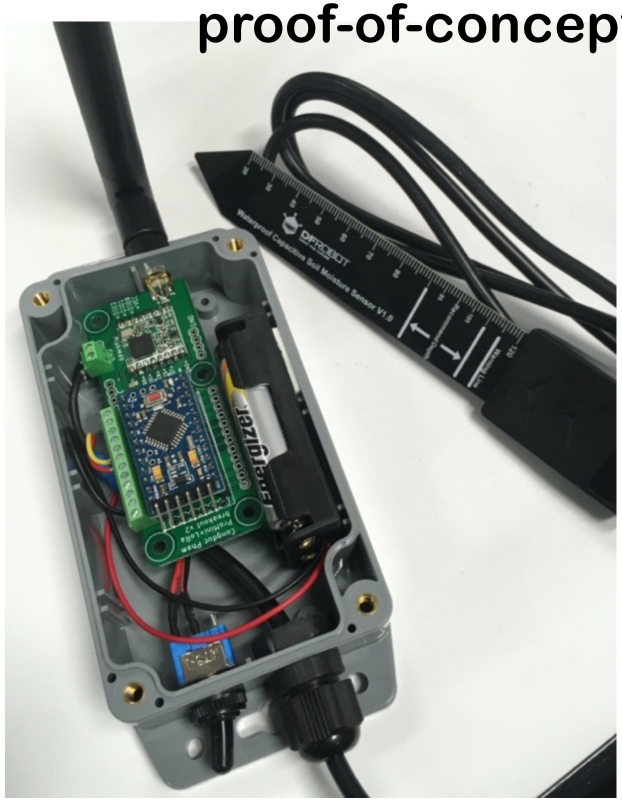
- https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-IrriS-low-cost-sensor-hardware-parts.pdf



- 12-pin and 2-pin screw terminal block
  https://fr.aliexpress.com/item/4000867583795.html
- 12-pin female header
  https://fr.aliexpress.com/item/32970948352.html
- RFM95W (868MHz) or RFM96W (433MHz)
  https://fr.aliexpress.com/item/32844406764.html
- SMA female PCB connector
  https://fr.aliexpress.com/item/32955045280.html
- Arduino ProMini 3.3v 8MHz
  https://fr.aliexpress.com/item/1005001621723982.html
- Flat-face seal for outer antenna junction (6x11x0.8mm), left
  https://fr.aliexpress.com/item/4000368310126.html
- Flat-face seal for inner antenna junction (14x5x0.5 mm), right
  https://fr.aliexpress.com/item/1005004643934924.html

Soil sensor: enclosure & integration

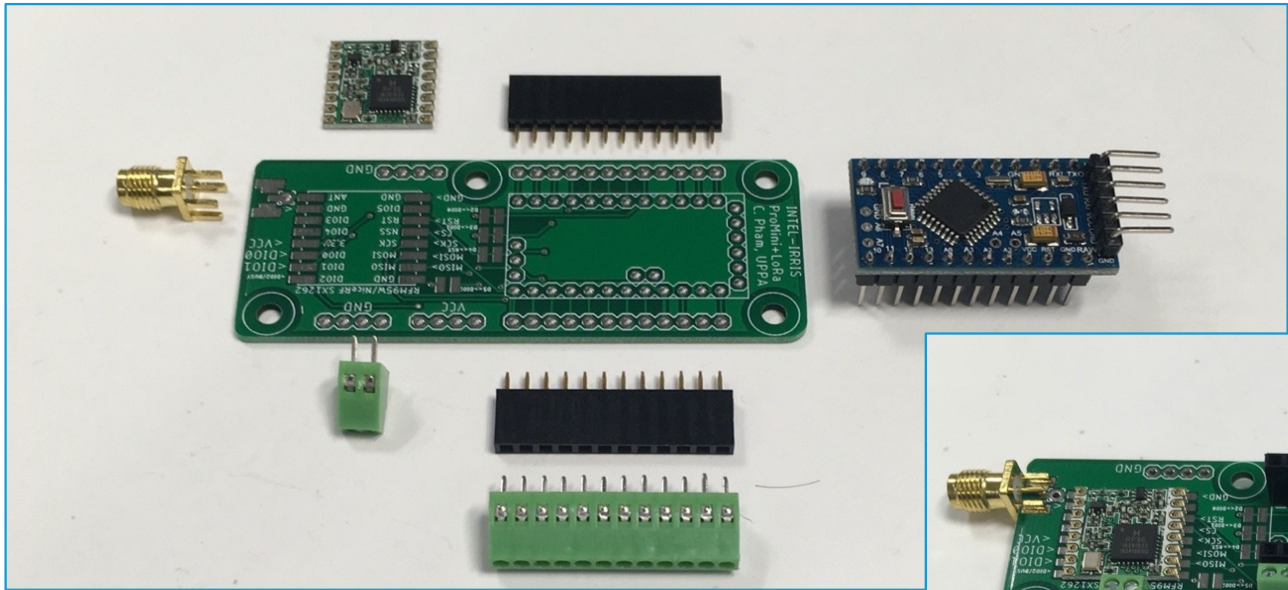
proof-of-concept

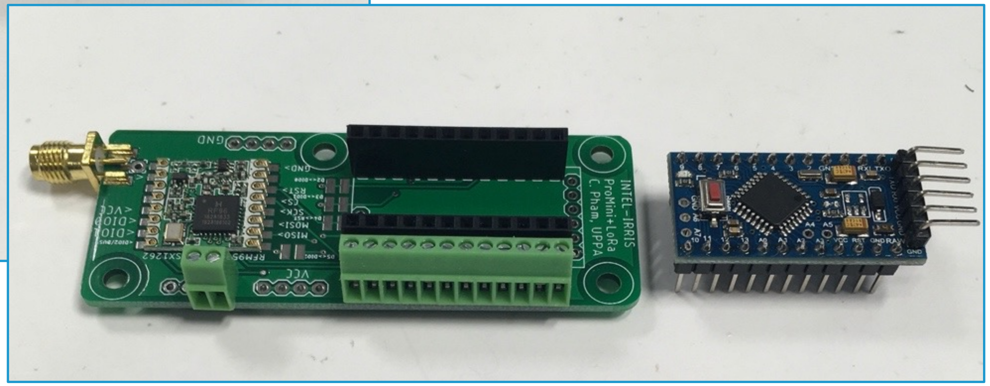


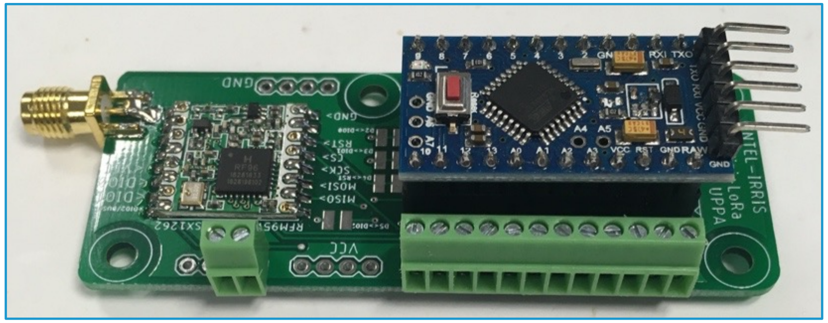
List of components

- ABS waterproof enclosure
  https://www.gotronic.fr/art-boitier-abs-etanche-g304m-17977.htm
- SEN0308 capacitive soil sensor
  https://www.gotronic.fr/art-capteur-d-humidite-capacitif-gravity-sen0308-32249.htm
- DS18B20 temperature sensor for soil temperature
  https://fr.aliexpress.com/item/32827810300.html
  you will need a 4.7 kOhm resistor
- Irrometer Watermark water tension sensor
  https://www.challenge-agriculture.fr/en/product/makers-space/watermark-sensors-for-makers/
  you will need a resistor from 7kOhm to 14kOhm (we use 10kOhm)
- 2-AA battery holder
  https://fr.aliexpress.com/item/4001008150456.html
- switch with pre-soldered wires
  https://fr.aliexpress.com/item/4000286754686.html
- waterproof cap for the switch (select just the cap)
  https://fr.aliexpress.com/item/33022608497.html
- Cable gland PG7 (select PG7)
  https://fr.aliexpress.com/item/10000132999214.html
- 3dBi 868MHz or 3dBi 433MHz antenna
  868MHz: https://fr.aliexpress.com/item/32964912902.html
  433MHz: https://fr.aliexpress.com/item/32963197821.html

Assembling the PCB board





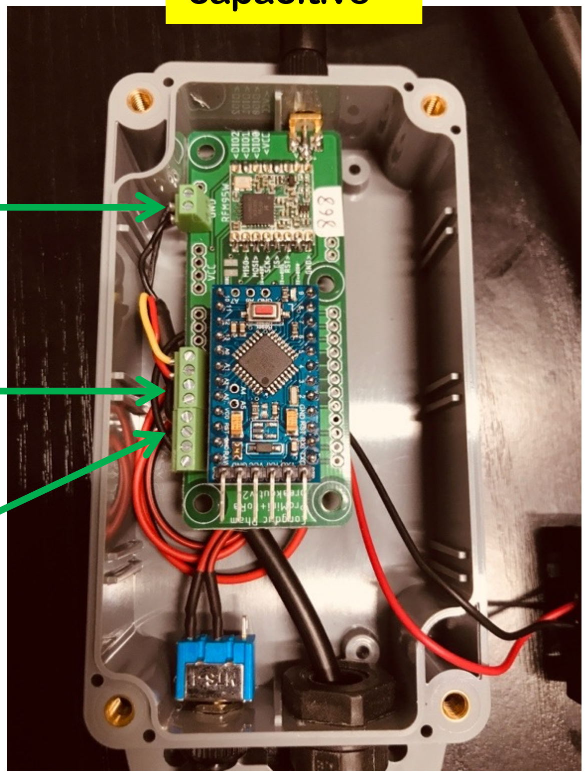


This dedicated video will show
how to solder all the components
Video n°1: https://youtu.be/3jdQ0Uo0phQ

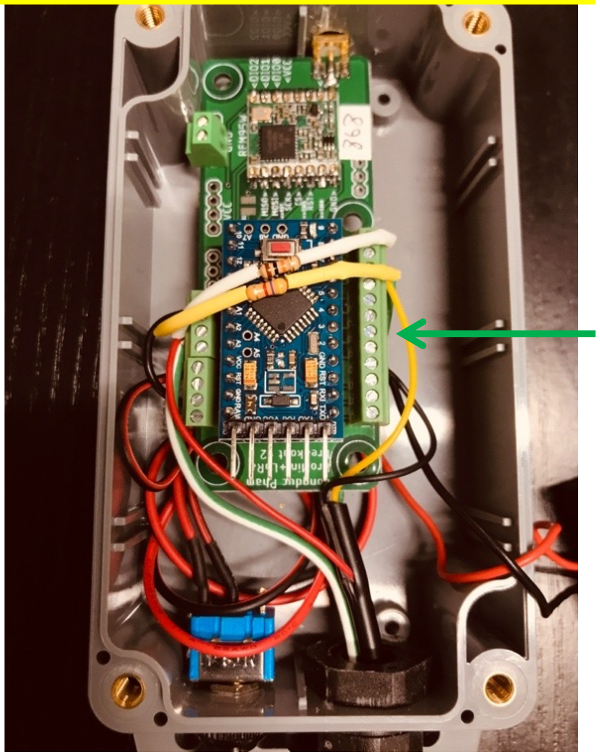
Optimizing usage of terminal blocks

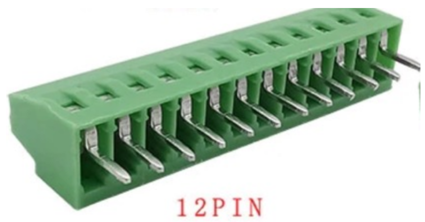
- You can solder all terminal blocks if you have plenty of them, but you can optimize for capacitive or tensiometer device

capacitive



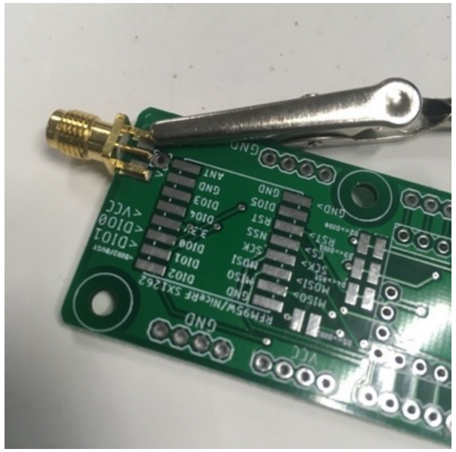
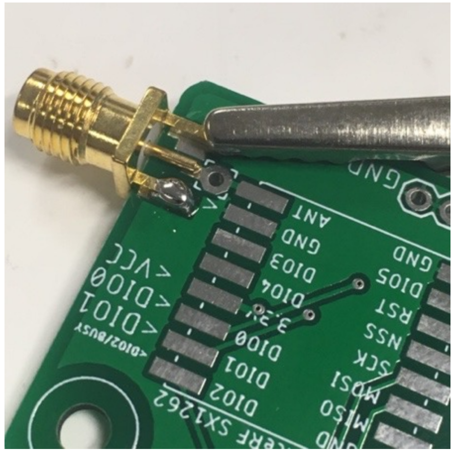
Tensiometer w/soil temperature





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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Good soldering

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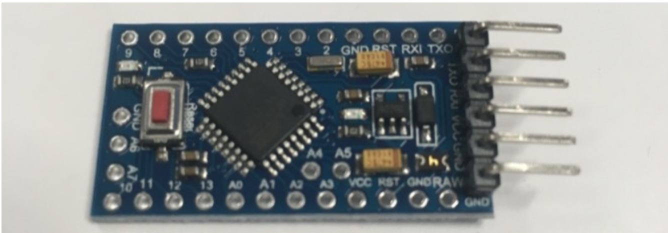
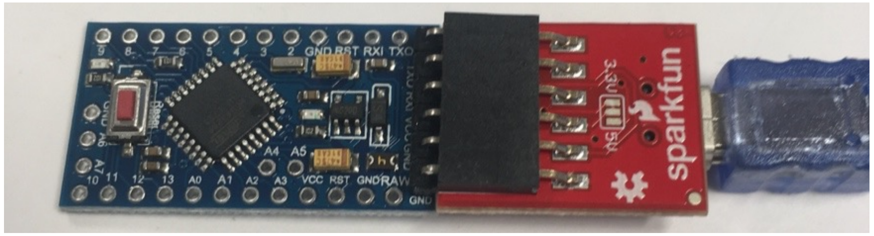
- It is important to have good soldering to avoid any issue when deploying the devices
- Check this great soldering tutorial from Collin's lab
  - https://youtu.be/RB4P1HTmwLc

- 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

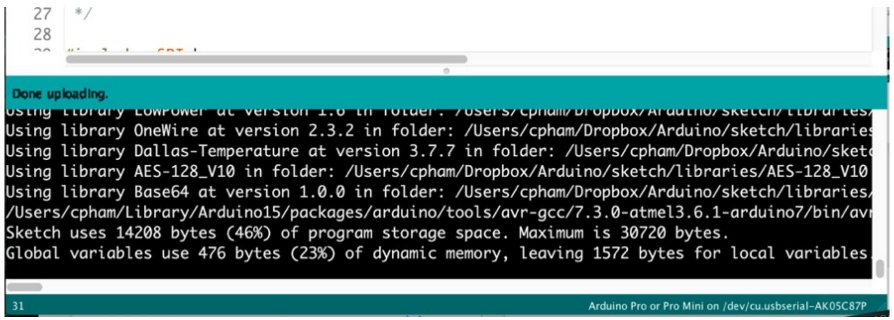
Check the Arduino

- First, just solder the programming header





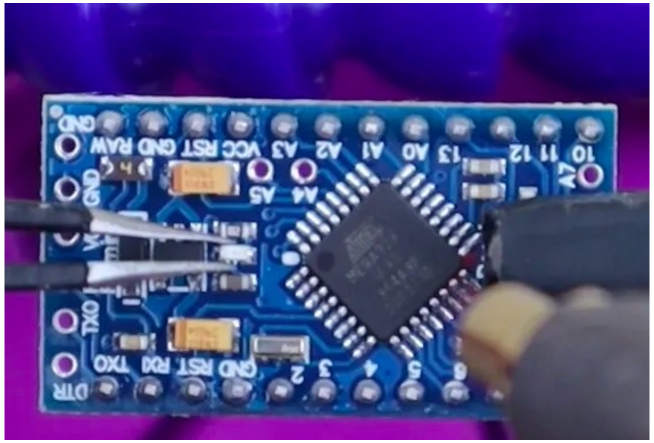
- To flash the Arduino board with the INTEL-IRRIS code
- See slides from "Getting the software: Arduino IDE" to "Uploading to your board"
- If uploading is successful, then you can continue with soldering the remaining header pins, otherwise, take another board as this one may have hardware issue

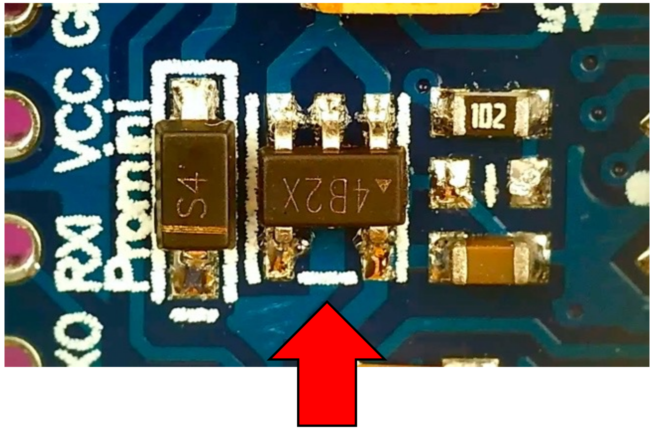


Never transmit without antenna

- 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, 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

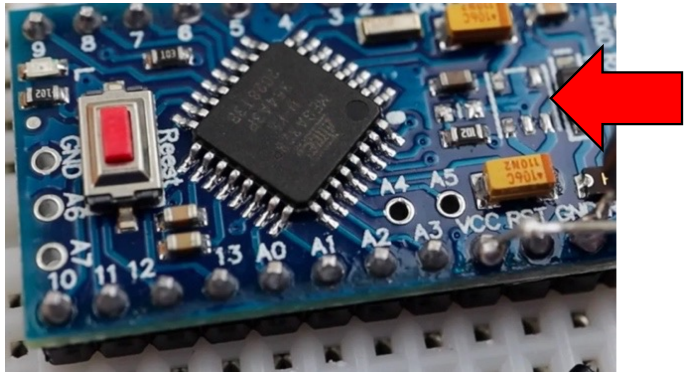
Reduce power consumption





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

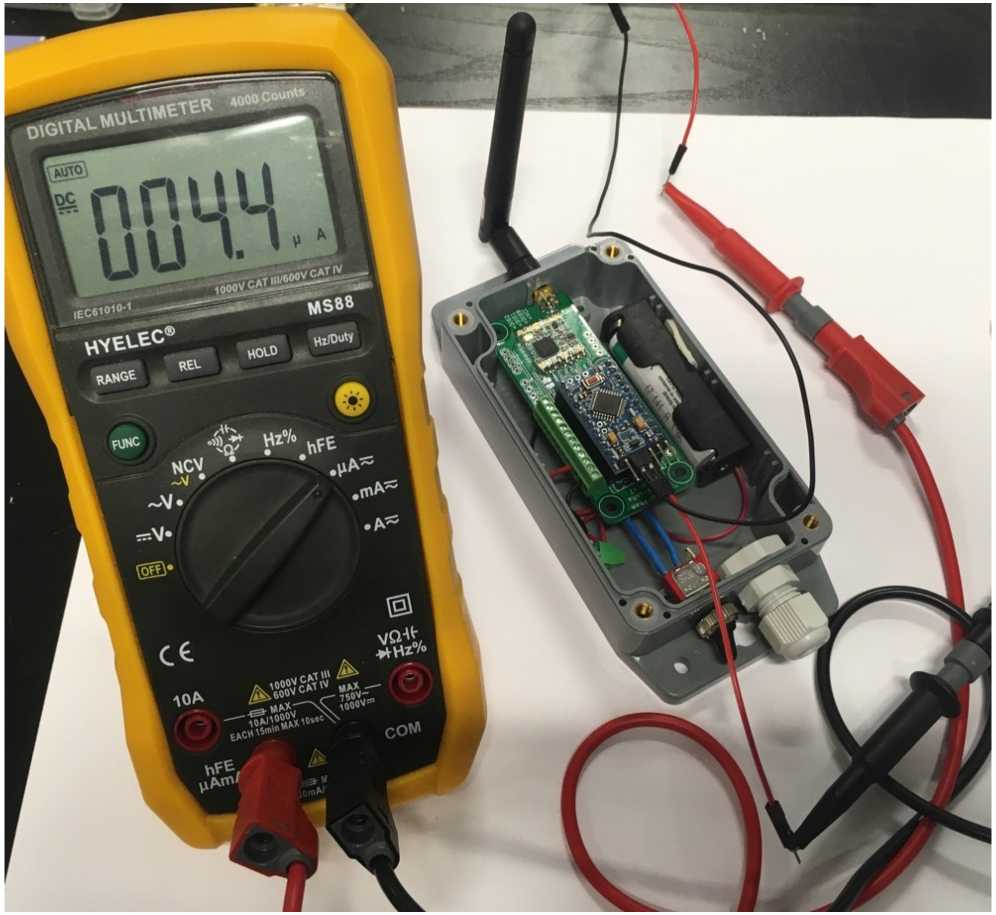
Do not forget **to remove the voltage regulator with a small plier**



Only inject up to 3.6V **through the VCC pin**

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

Power consumption in deep sleep



- Measured below 5uA in deep sleep, between 2 active periods with transmissions
- Expected autonomy with 1 transmission / hour is over 2 years with either 2 AA batteries or 1 AA 3.6V Lithium battery

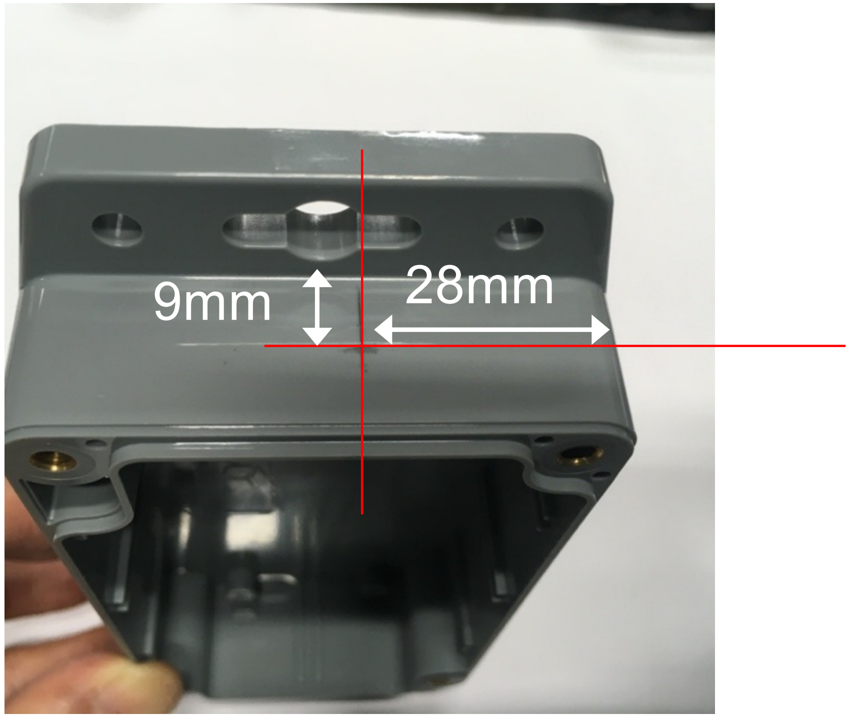
Get an enclosure for outdoor usage

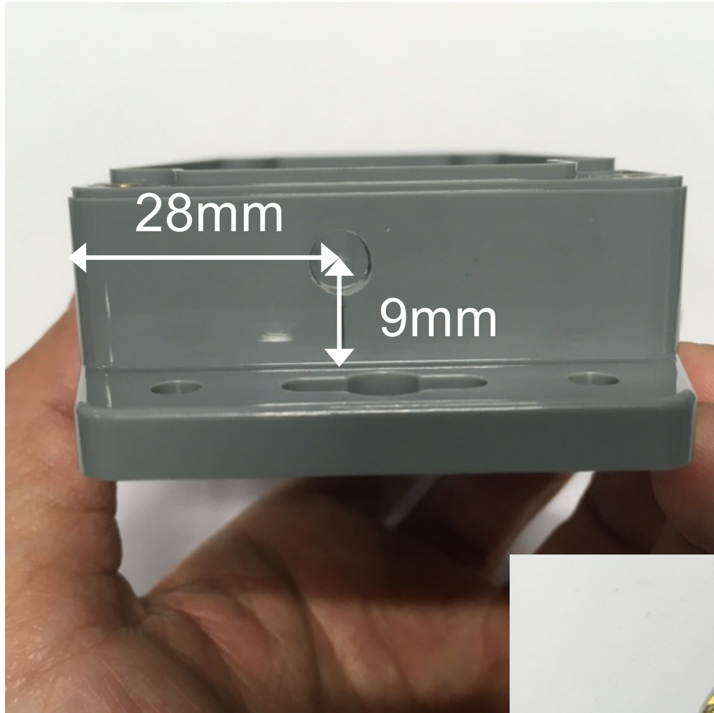
Here, it is an IP65 box which dimension is 115 x 65 x 40mm
https://www.gotronic.fr/art-boitier-abs-etanche-g304m-17977.htm

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

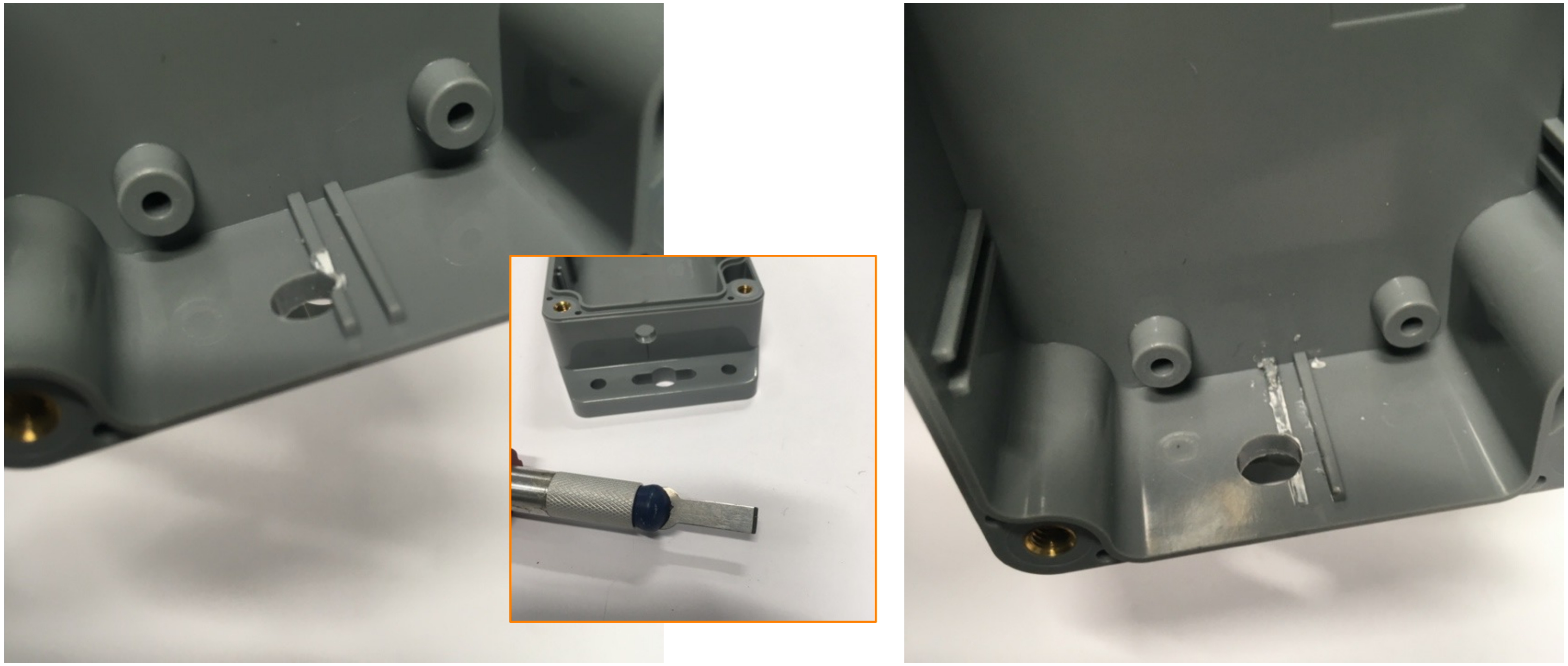
Drill a hole for the SMA connector





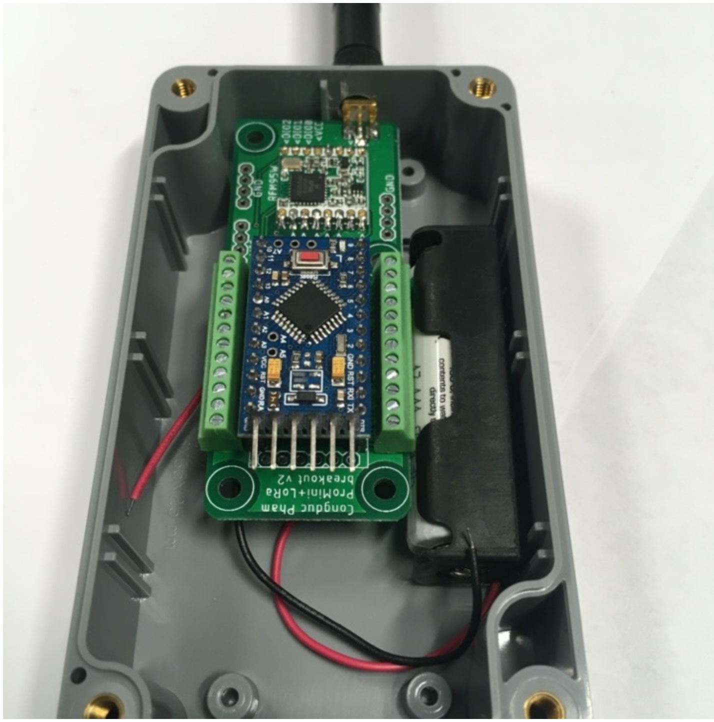
28mm for the right edge:
  - measure from the flat side as the corner is round
9mm from the outside bottom
use a 7mm drill bit for metal, not for wood nor concrete!

Remove unwanted plastic part



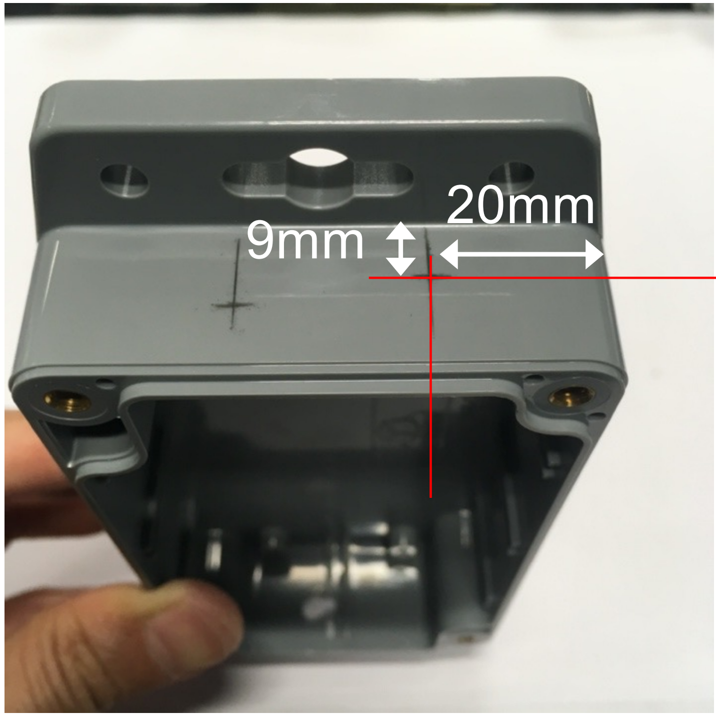
- we need to remove the plastic reinforcement part for this particular enclosure
- use a flat cutter for instance to remove and smooth the inside part (a small plier can be used first to remove most of the part)

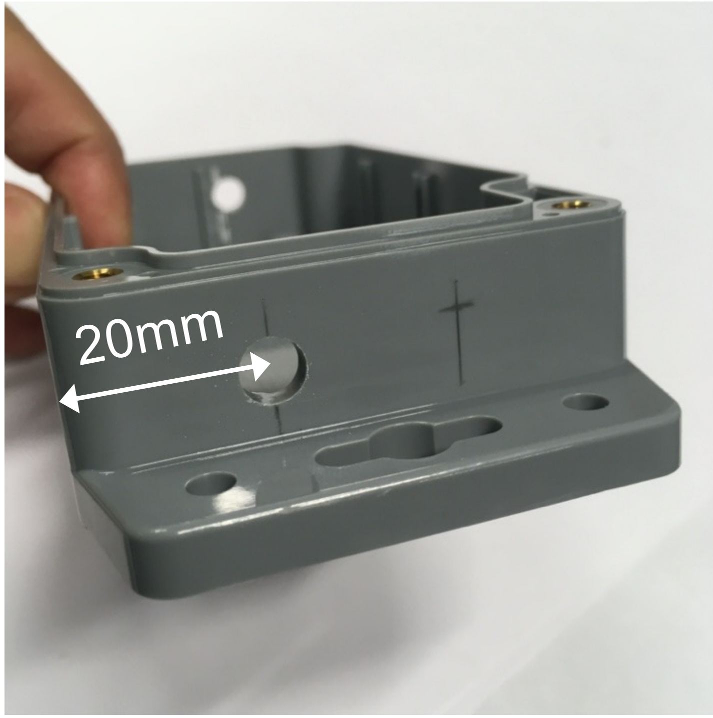
Placing the PCB board



- the PCB board can be placed, with the SMA connector going through the hole
- both 2-AA (left) and 1-AA (right) battery holder can be used

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

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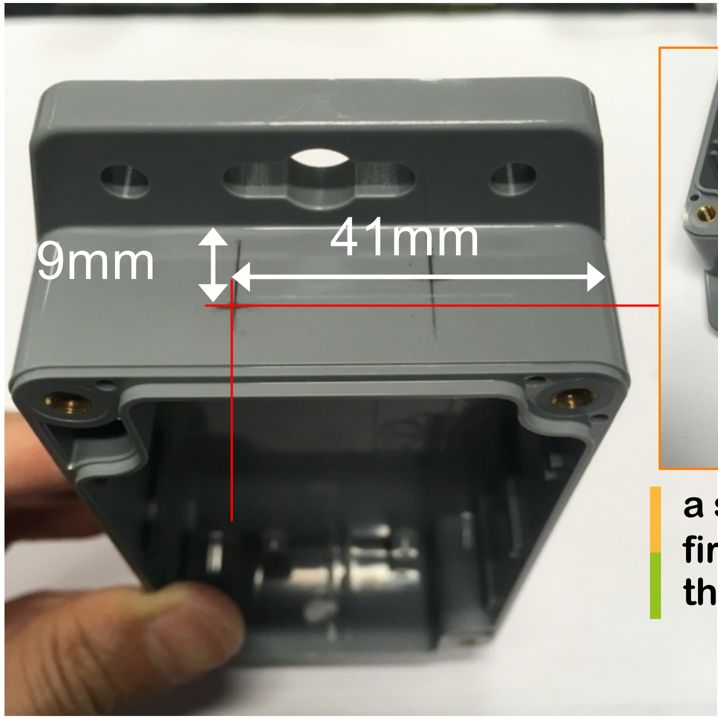
http://www.univ-pau.fr/~cpham

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

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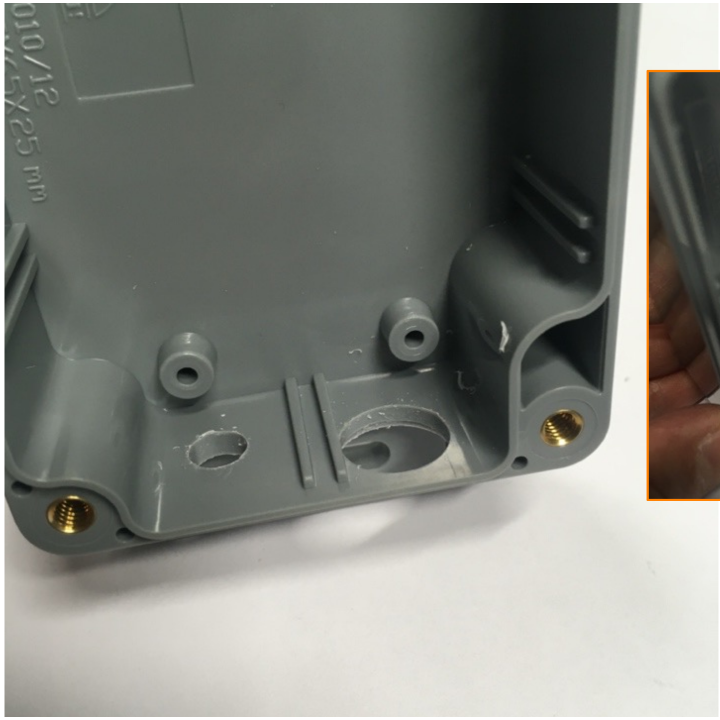
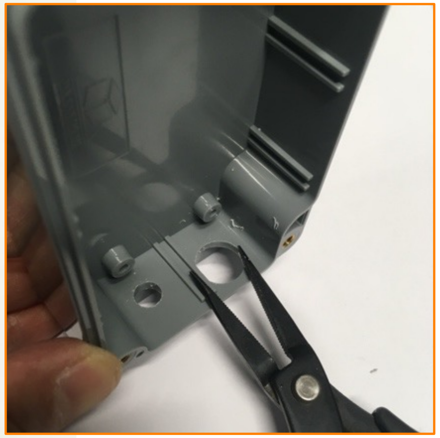
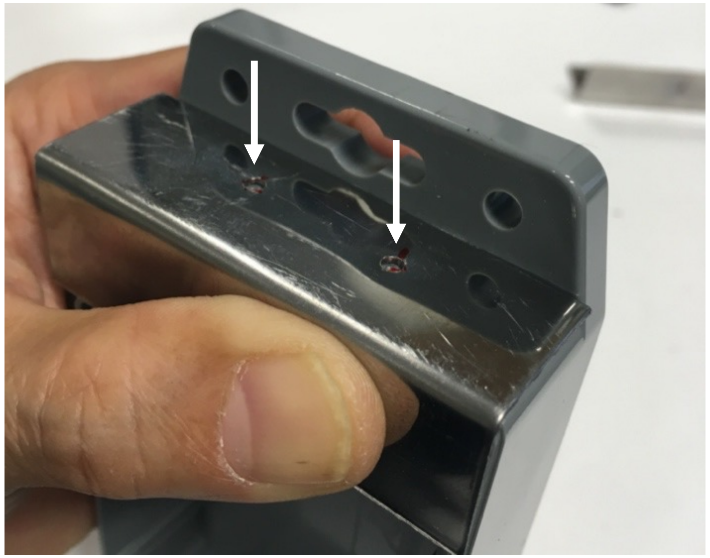
Remove unwanted plastic part

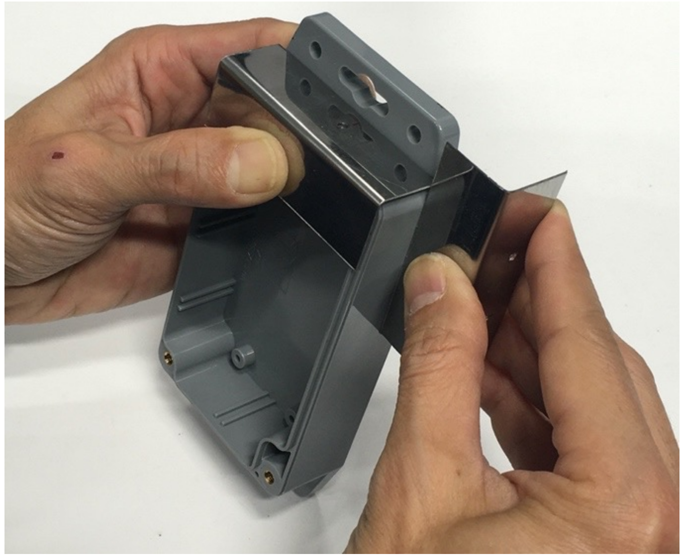




- again, we need to remove the plastic reinforcement part for this particular enclosure
- use a flat cutter for instance to remove and smooth the inside part (a small plier can be used first to remove most of the part)

Going for larger production

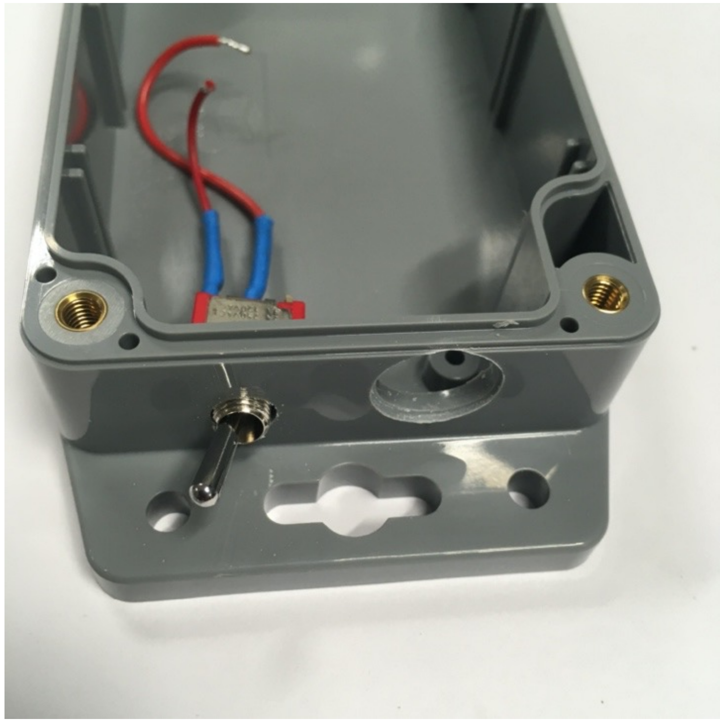




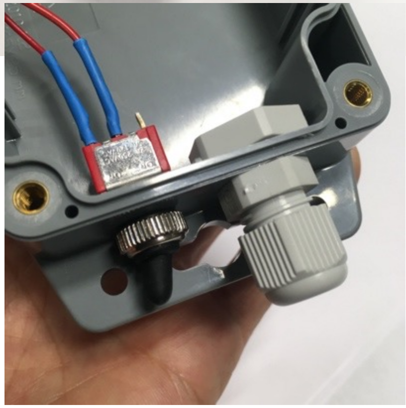
If you need to prepare many enclosures, it may be faster to first make an assembly jig (here a piece of metal) for marking the holes

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

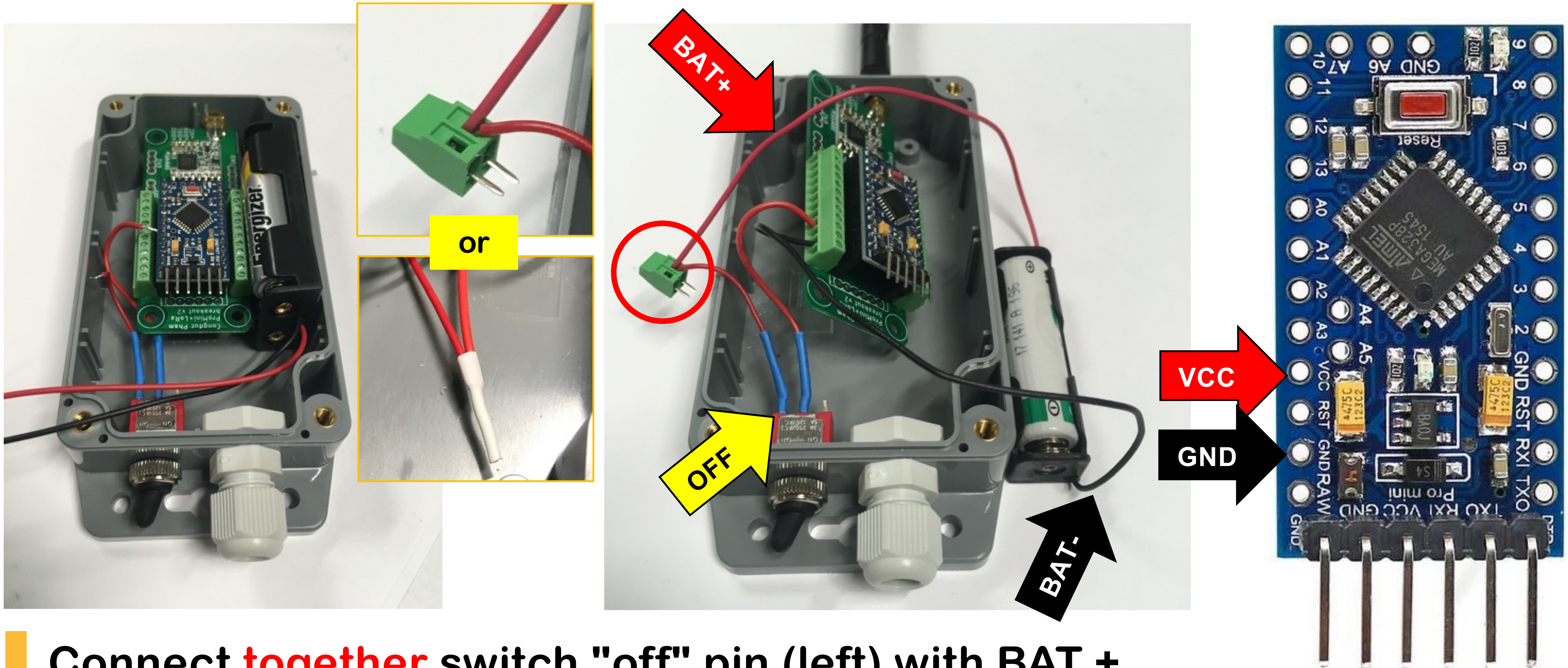
Placing switch and cable gland



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



Connecting switch, battery & board



Connect together switch "off" pin (left) with BAT +
Connect directly switch "on" pin (middle) to board's VCC
Connect directly BAT – to board's GND
Toggling the switch to the right will then power the board

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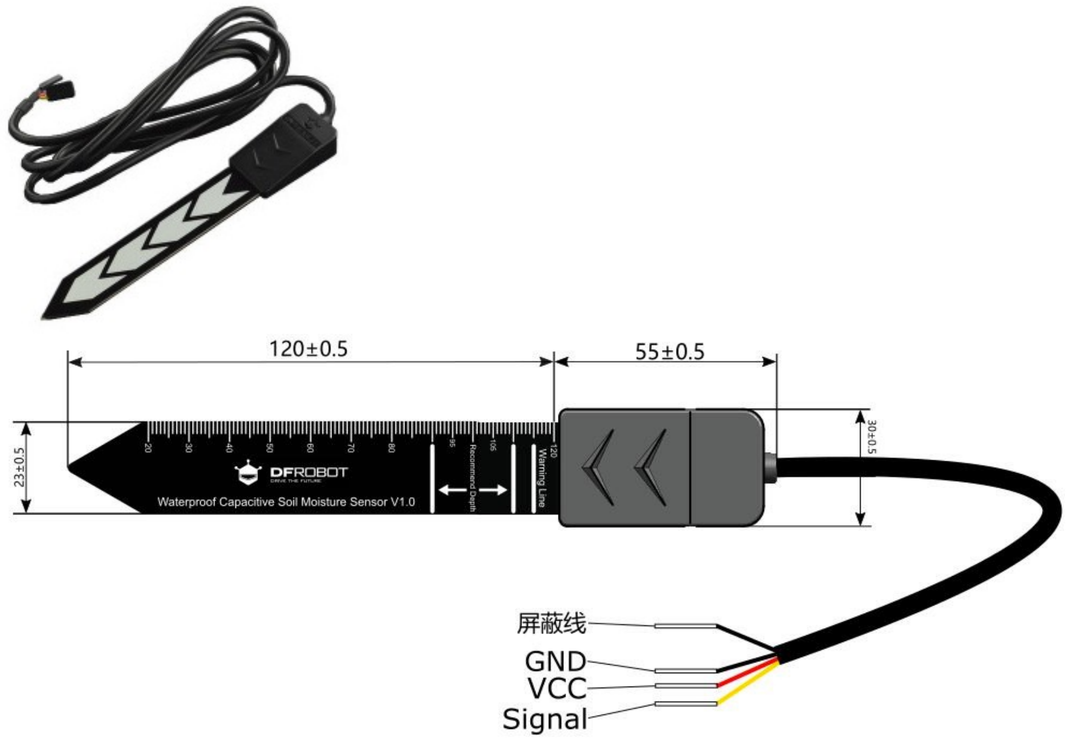
Wire the SEN0308 sensor



Insert sensor's wire through cable gland

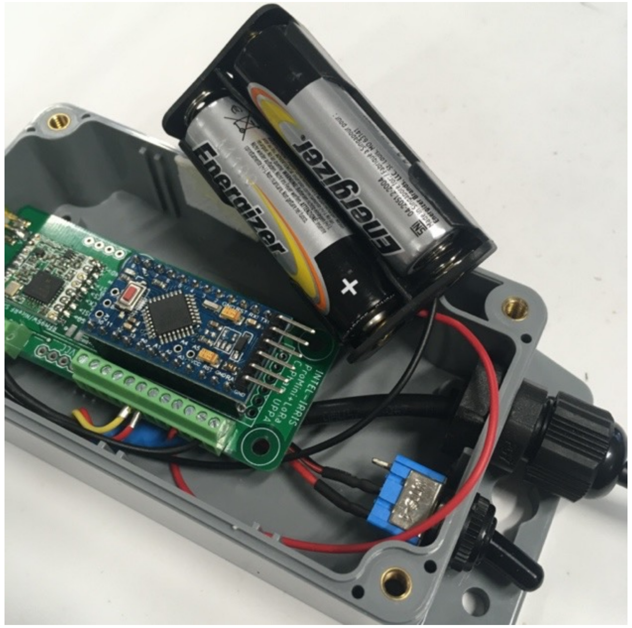
Connect SEN0308's wires to board:

- **VCC to board's A1**
- **GND to board's GND (there are 2 GND wires)**
- **Signal to board's A0**

PRIMA
IN THE MEDITERRANEAN AREA

Putting it altogether

Intel-IrriS



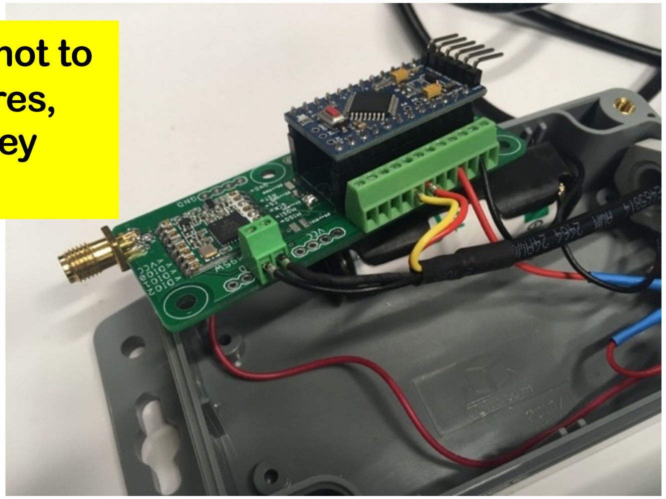
You can fix the battery pack with double-side tape, e.g. those used to fix mirrors on wall

You can also use a 3.6V lithium battery with a 1-AA battery holder

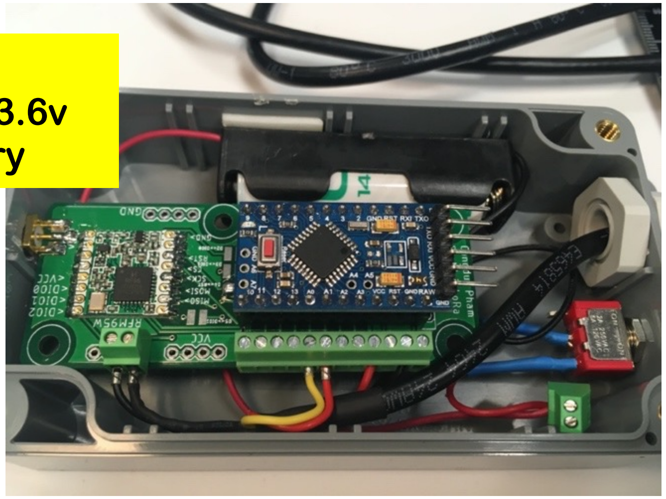
This dedicated video will show how to build the outdoor soil device
Video n°2: https://youtu.be/zcazzDbXvHk

The complete soil sensor device

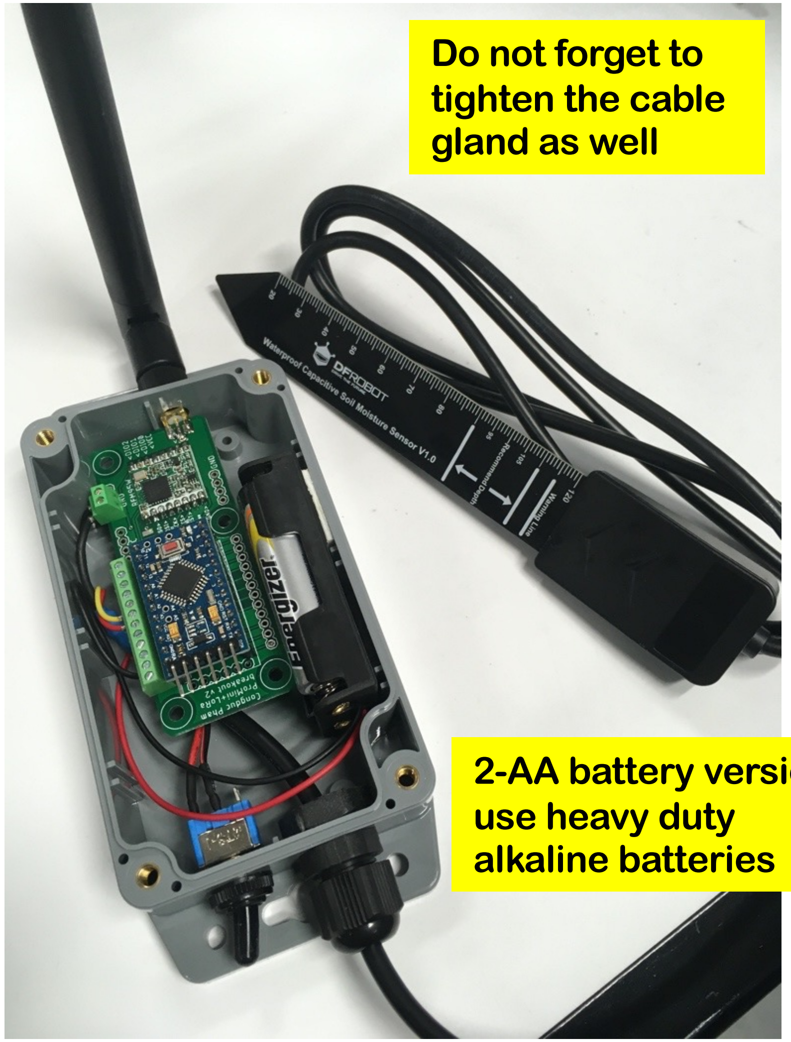
Tighten (but not to much!) all wires, check that they are not loose



1-AA battery version, use 3.6v lithium battery

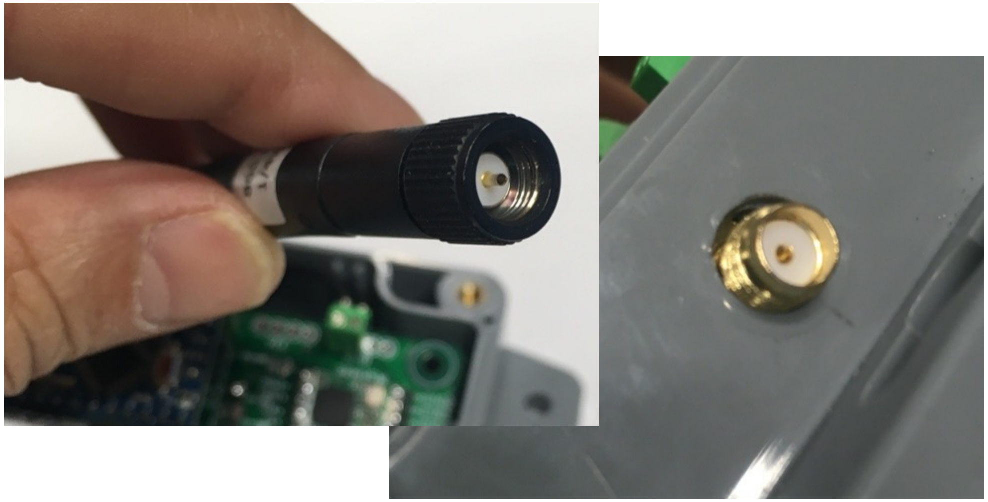


Do not forget to tighten the cable gland as well



2-AA battery version, use heavy duty alkaline batteries

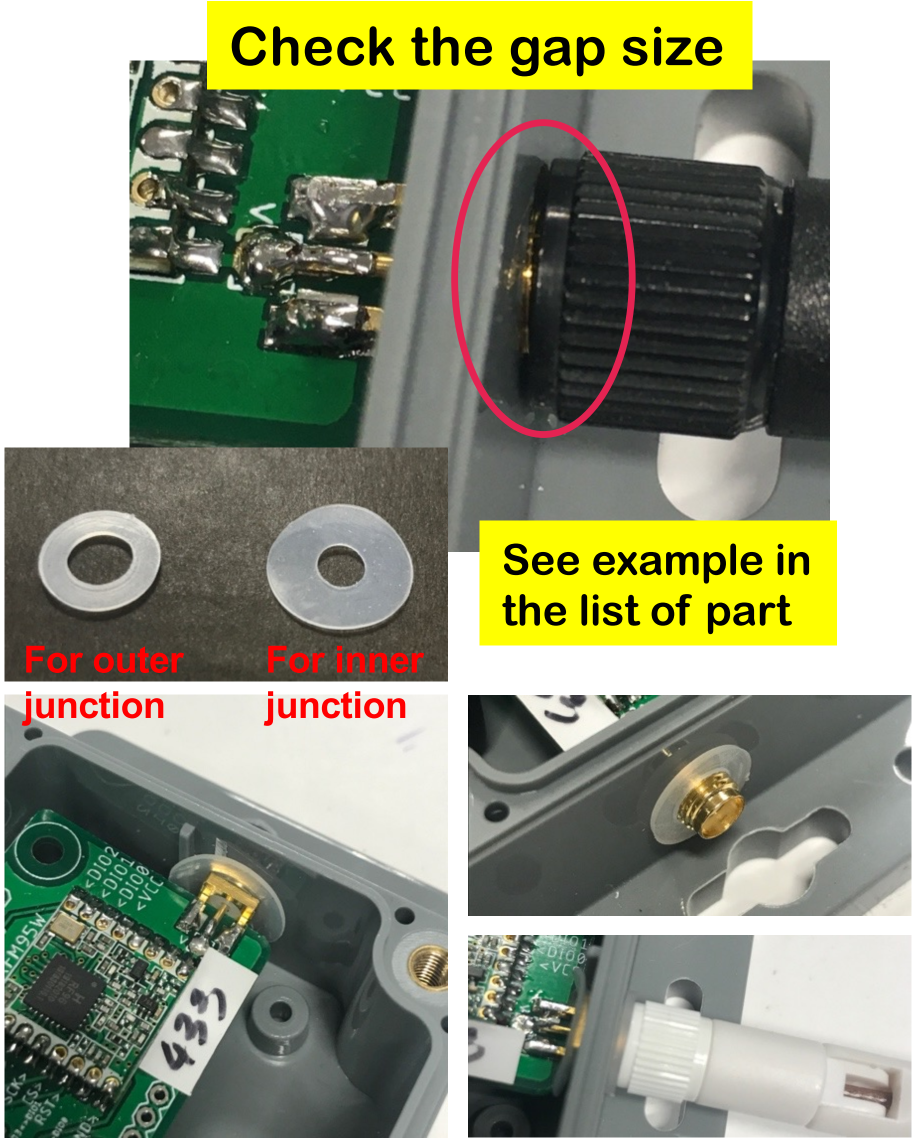
Connecting antenna



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



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!

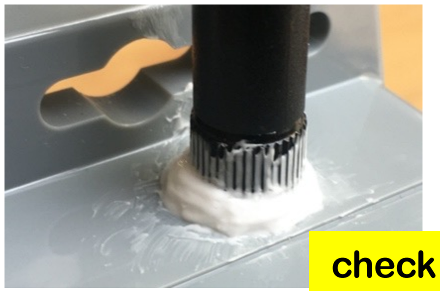
Do not have or can not use flat seal ?

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

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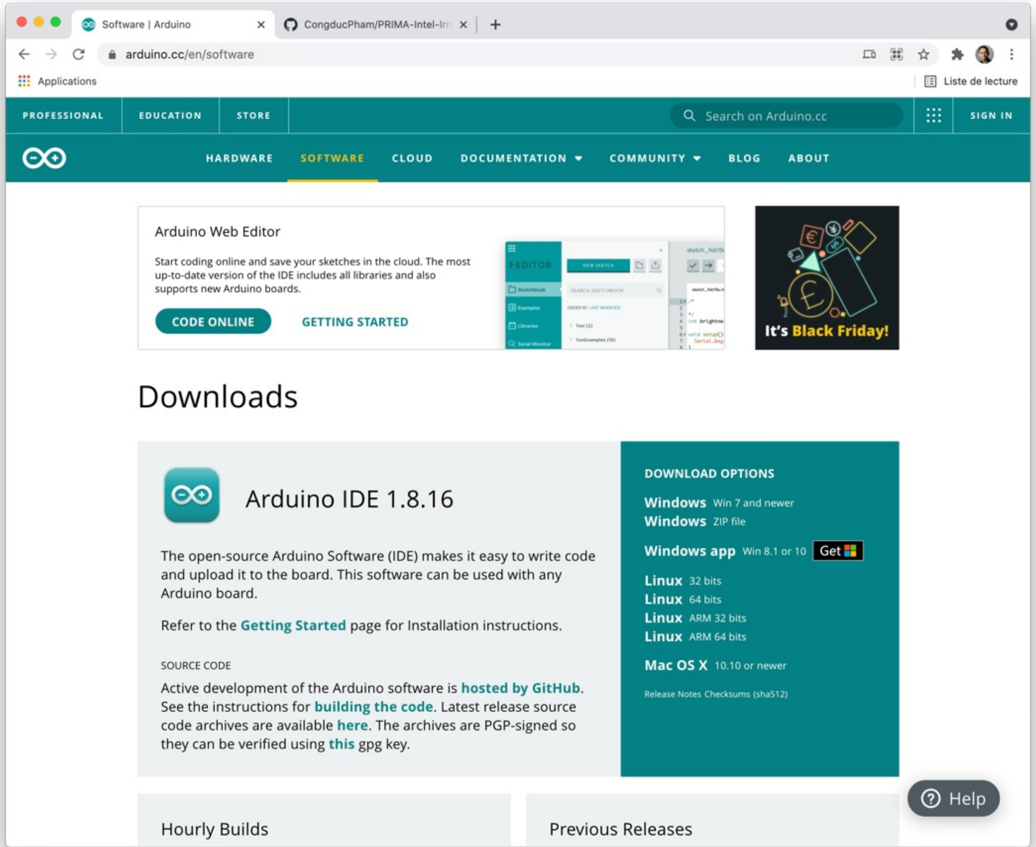
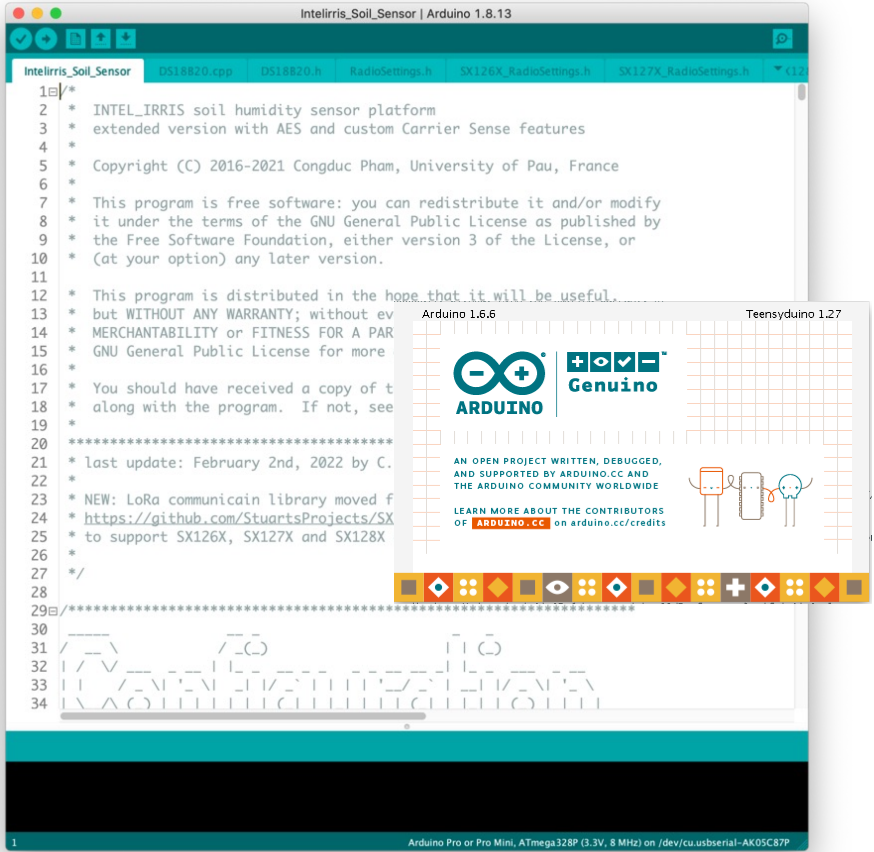
http://www.univ-pau.fr/~cpham

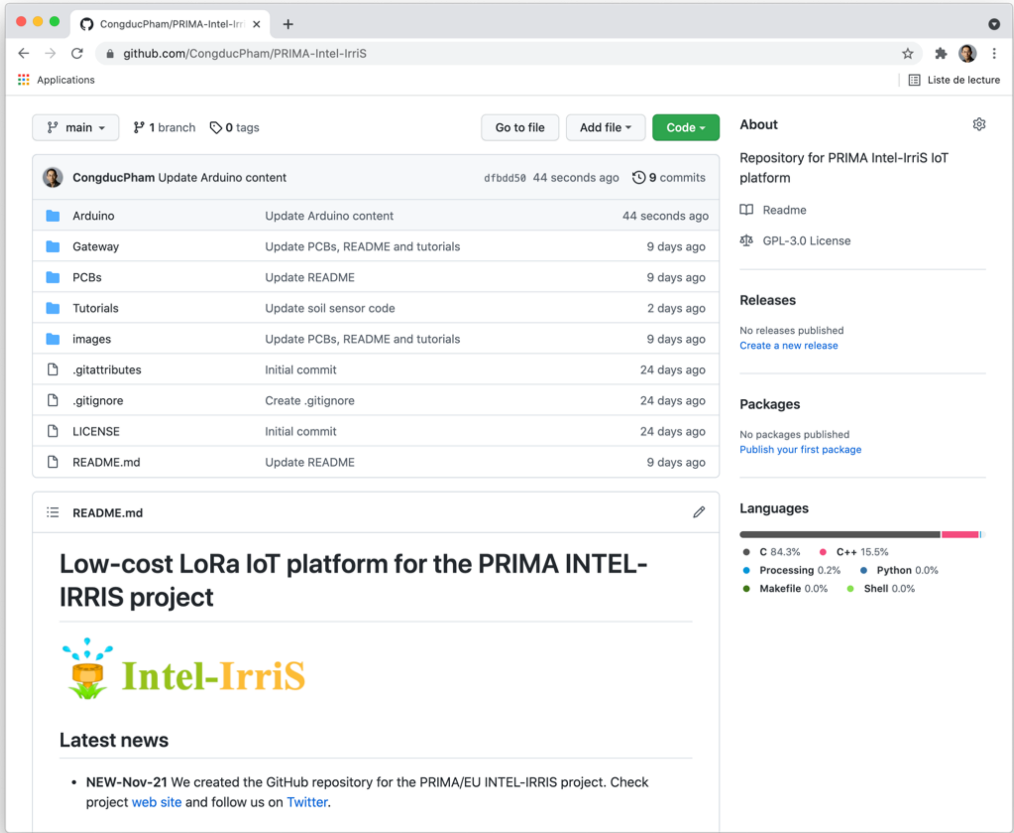
Getting the software: Arduino IDE





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

Getting the INTEL-IRRIS code



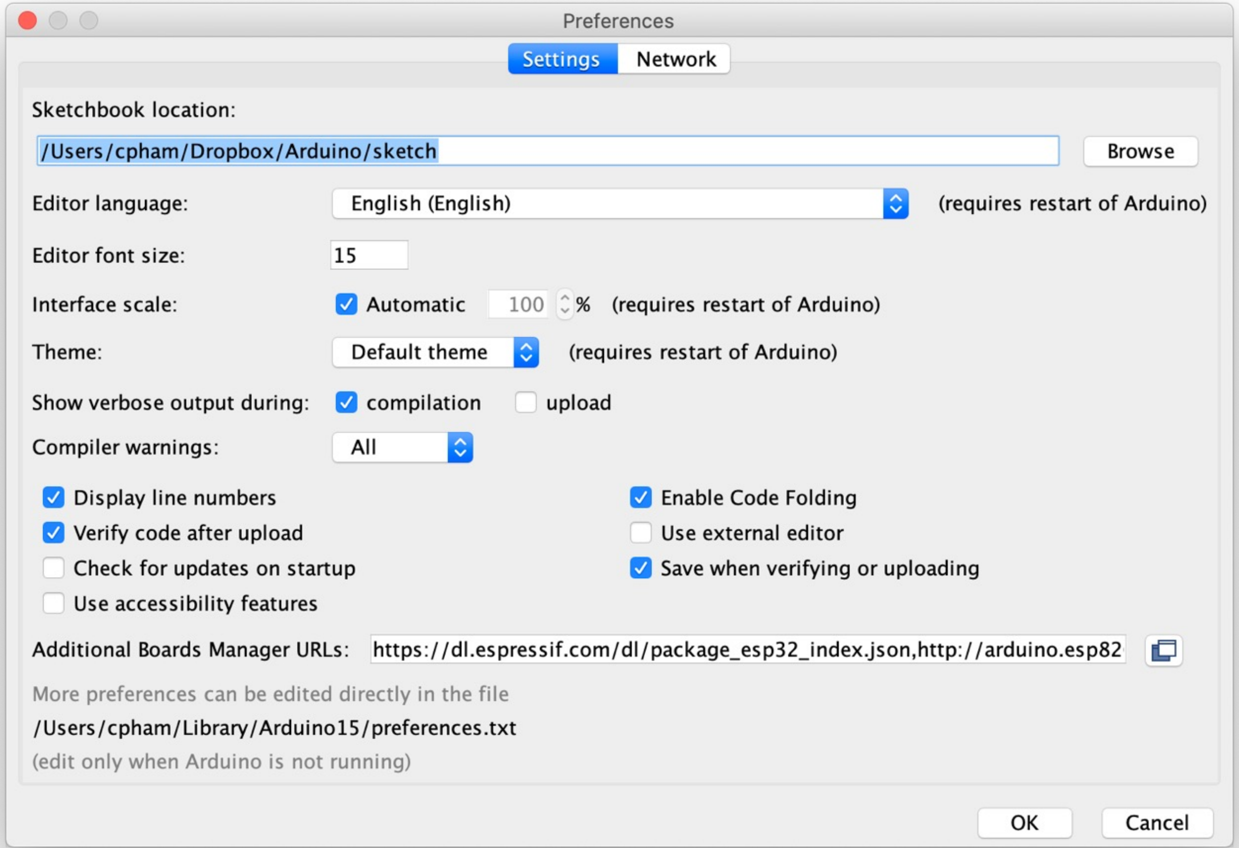
On your computer, create a `sketch` folder

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

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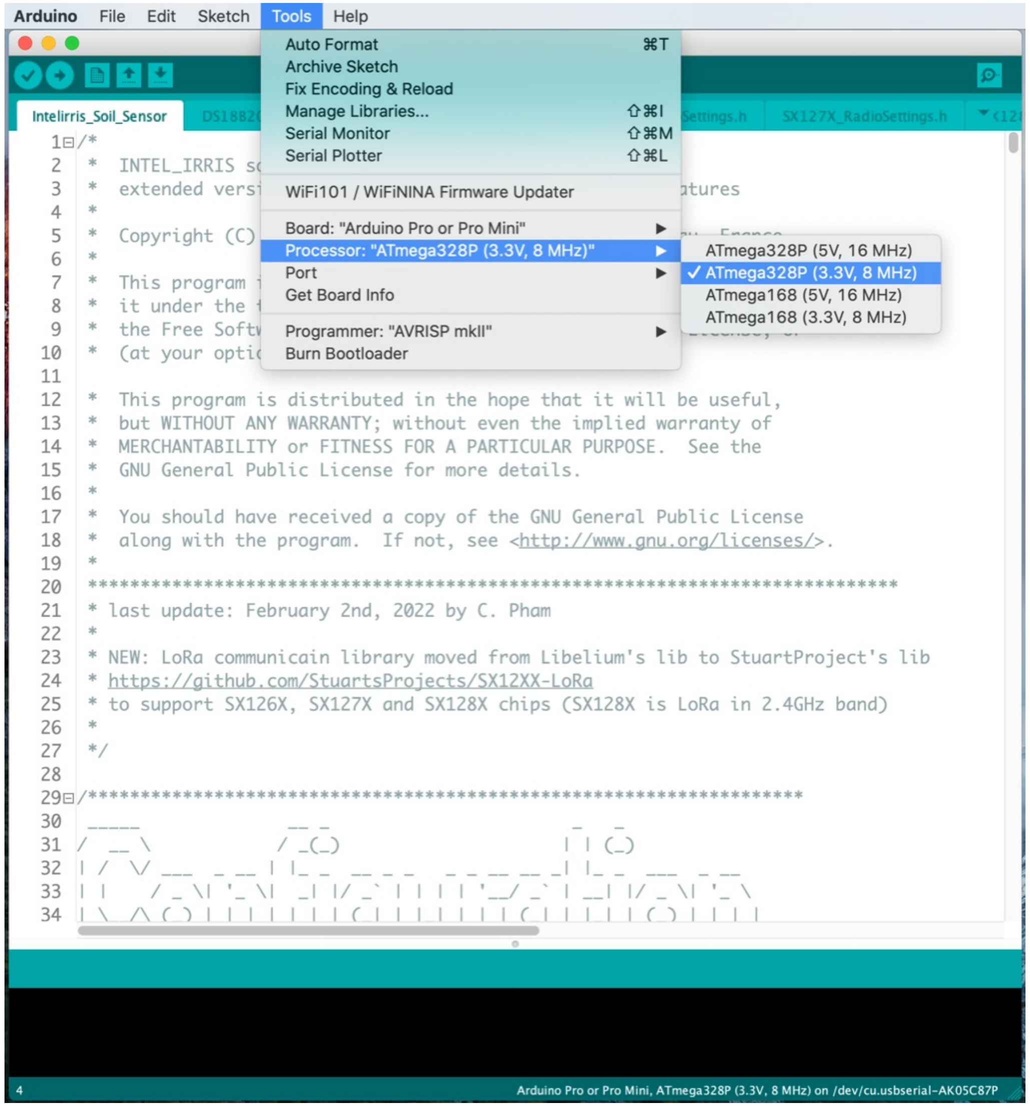
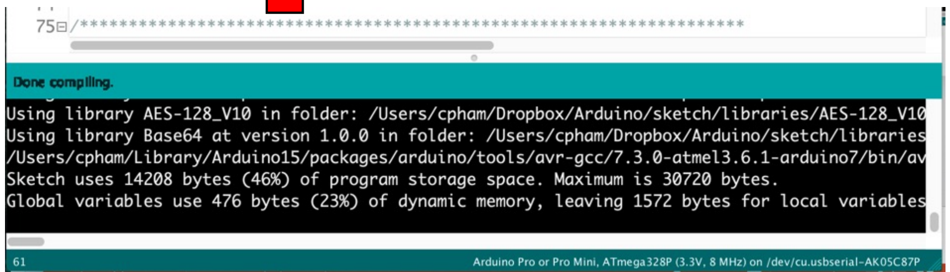
Compiling the soil sensor code



Open Intelirris_Soil_Sensor sketch – no change required for default capacitive sensor

Select the ProMini board, 3.3V and 8MHz version

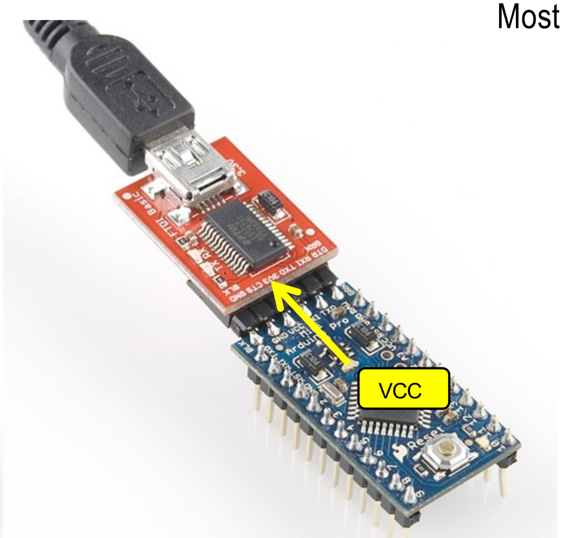
Then click on the "verify" button



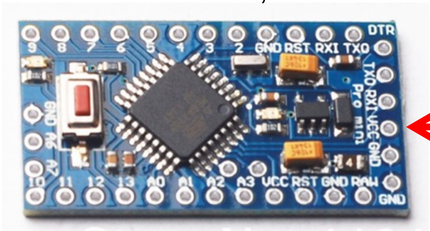
Never transmit without antenna

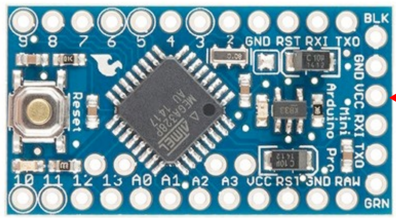
- NEVER, NEVER transmit without an antenna
- Doing so can damage the radio module
- If your board is already connected to the radio module and you need to flash the board, connect the antenna
- If you need to update the existing code and your device already run a code that transmit data, connect the 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

Connecting with an FTDI cable

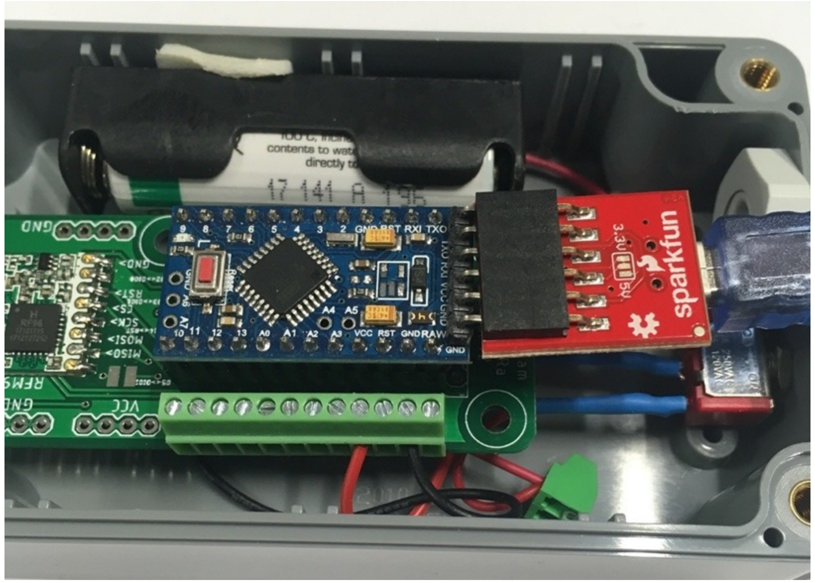


Most Chinese clone version, check the VCC pin





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.

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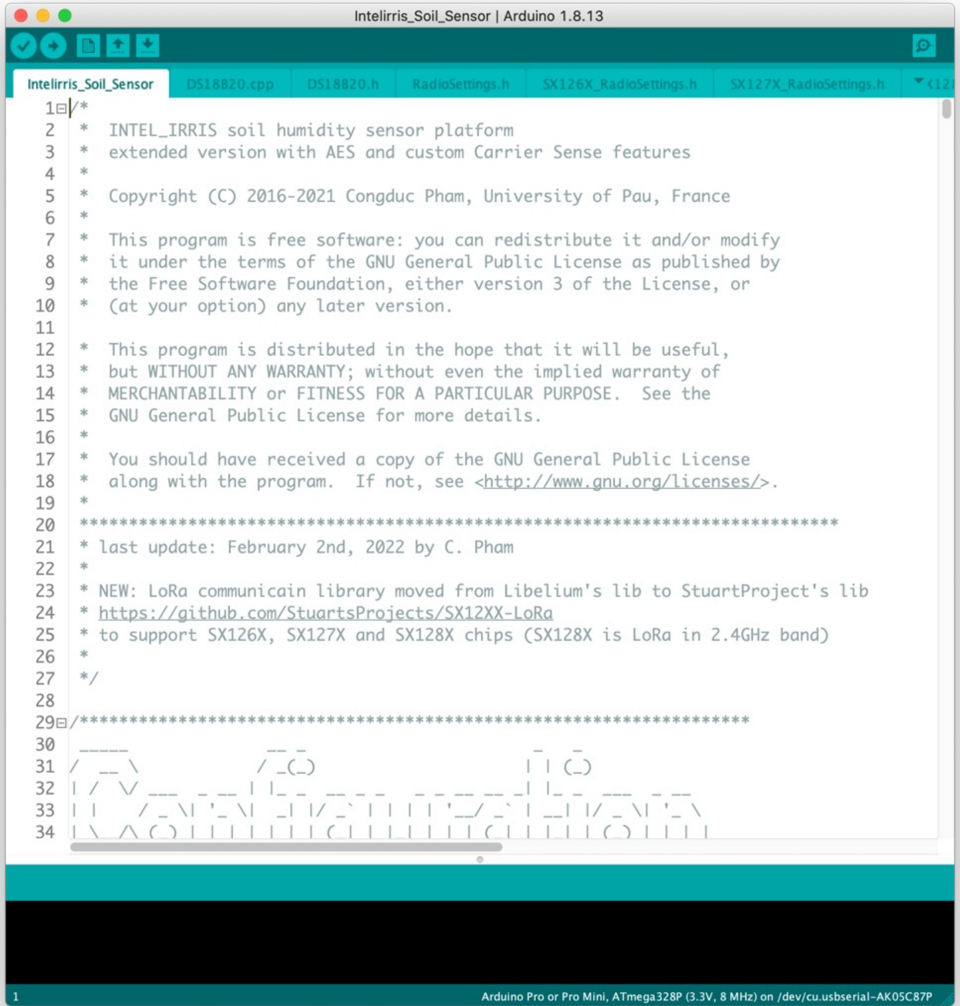
Select serial port for uploading

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

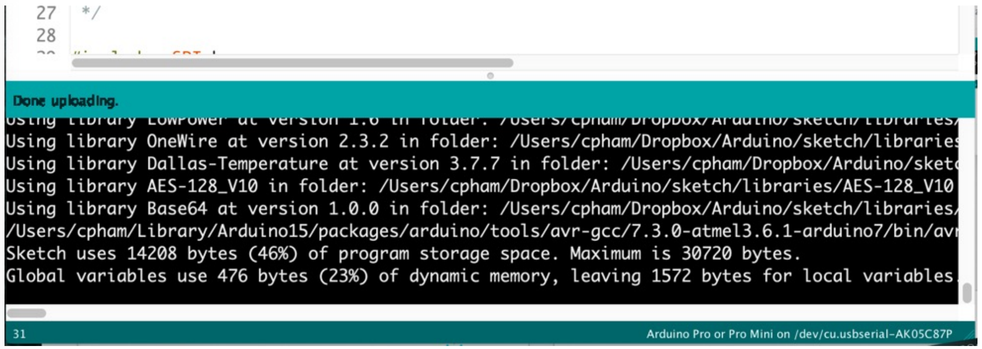
https://learn.sparkfun.com/tutorials/how-to-install-ch340-drivers/all

Uploading to your board

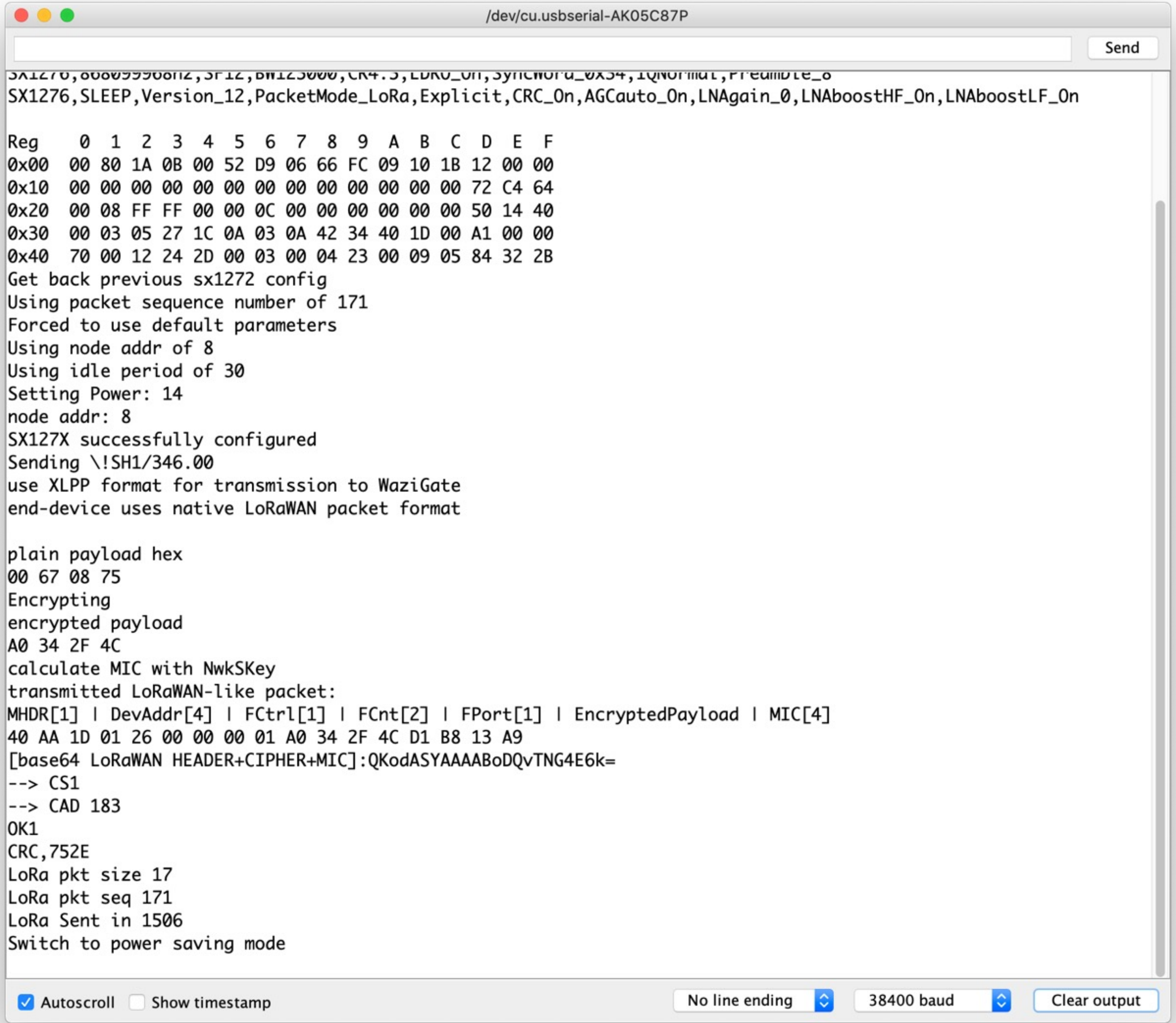


Click on the "upload" button

And wait until upload is completed



Checking that device is operational



Open serial monitor

Set baud rate to 38400

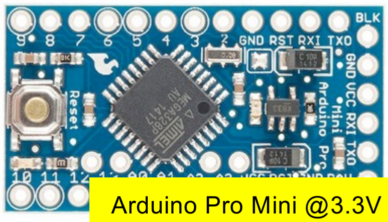
See output from board

Check that transmission is OK

Generic & cyclic behavior

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

Physical sensor management



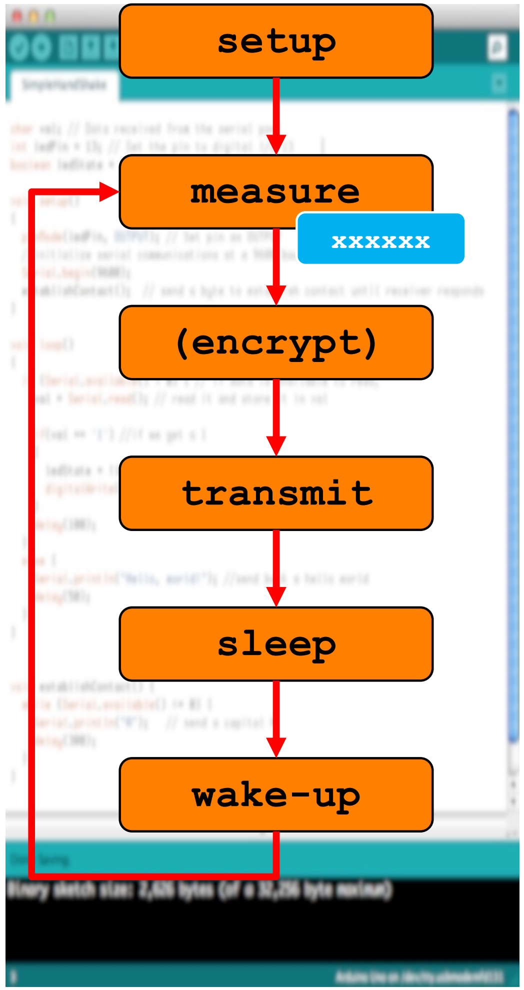
Arduino Pro Mini @3.3V

Activity duty-cycle, low power

AES encryption

Long-range transmission

Logical sensor management



Transmission to WaziGate

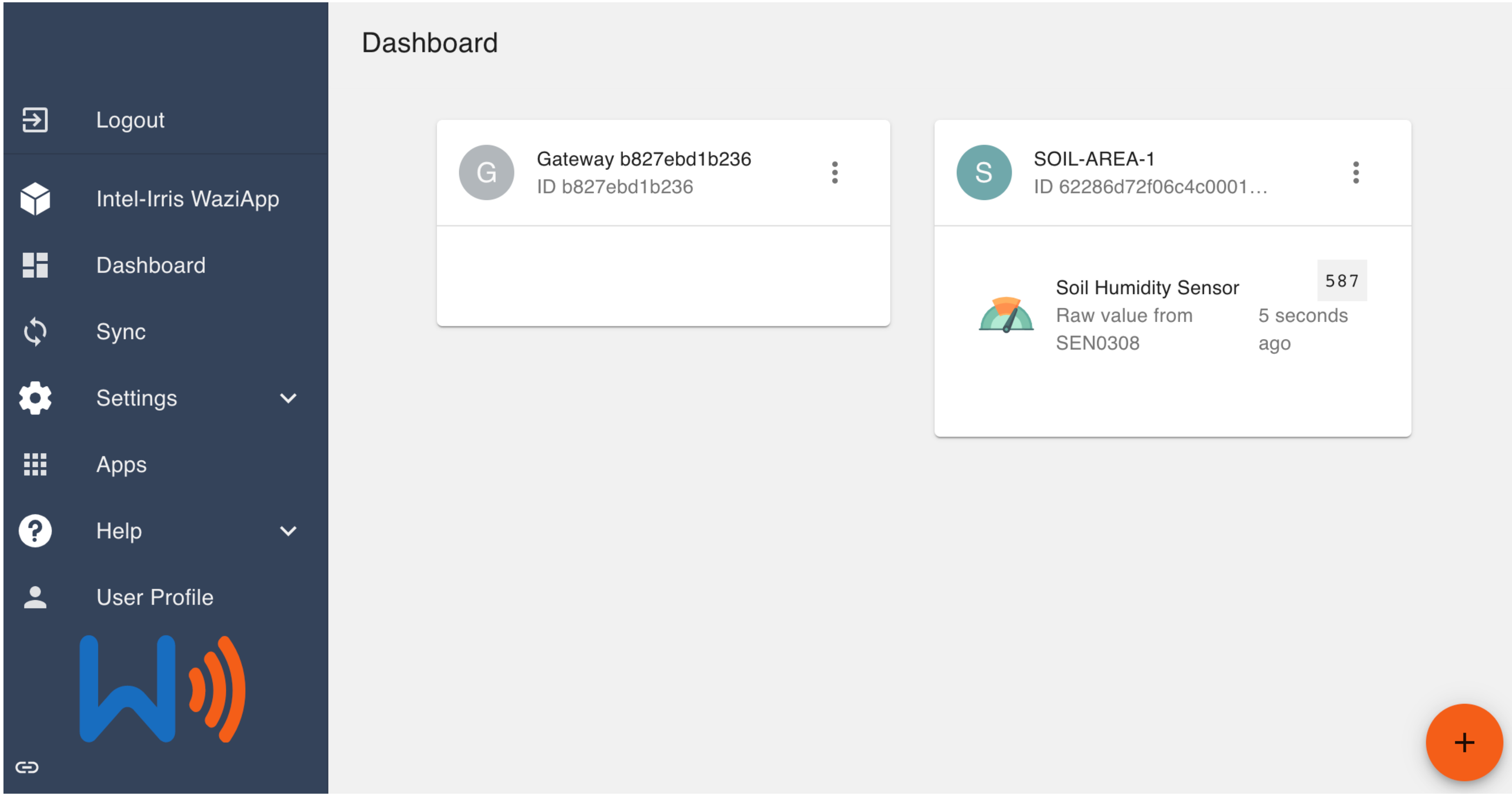
Parameters for INTEL-IRRIS WaziGate

LoRaWAN

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

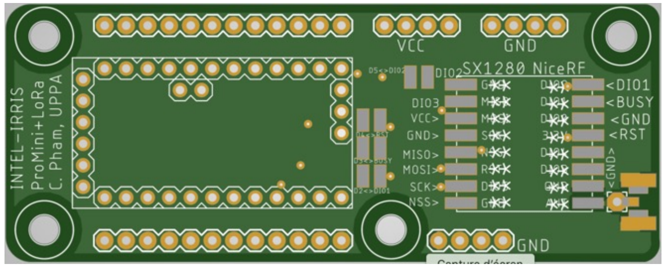
This dedicated video will show all these steps, from connecting the SEN0308 to testing transmission to the WaziGate
Video n°4: https://youtu.be/j-1Nk0tv0xM

See it on the dashboard



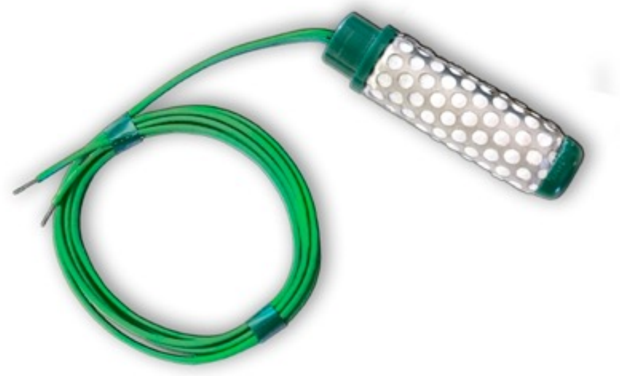
Advanced options

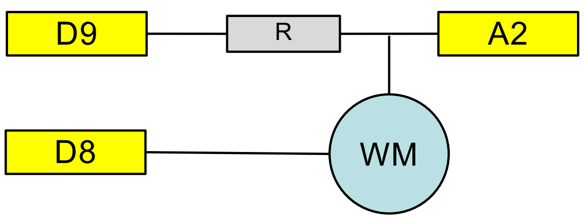
- The Intelirris_Soil_Sensor sketch can
  - Drive SX127X, SX126X and SX128X LoRa chips
    - SX128X requires a dedicated PCB for NiceRF SX1280

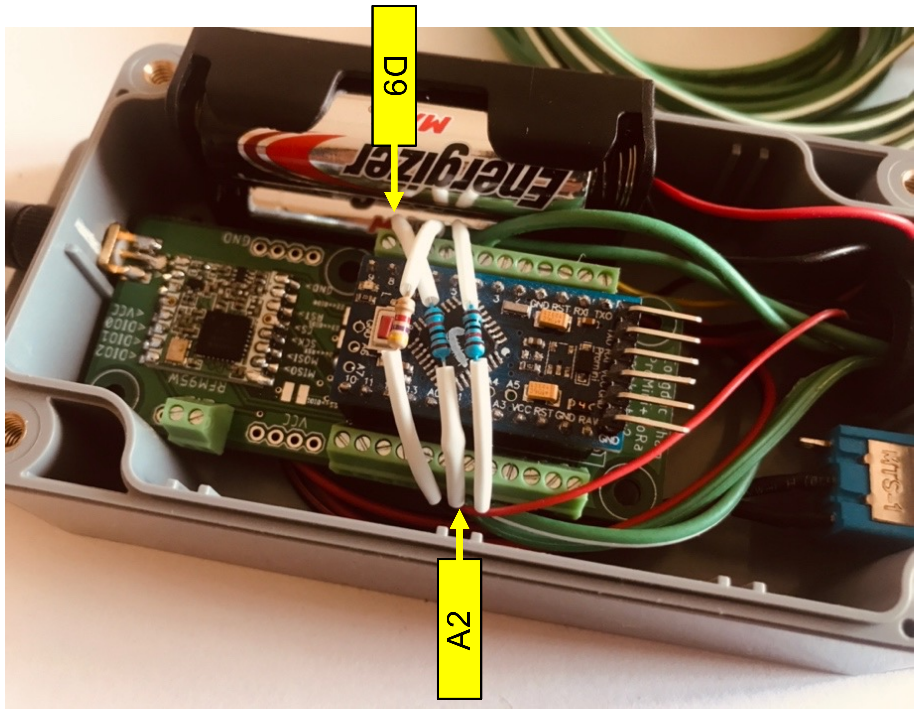


  - Send AES 128-bit encrypted packet
  - Send uplink LoRaWAN packet (encrypted)
  - Receive downlink LoRaWAN packet
  - Can read from a Watermark water tension sensor
  - Can read additionally from a DS18B20 soil temperature sensor
  - Support WaziSense and WaziDev boards specific features

With a Watermark sensor







- with a Watermark sensor, the "pseudo-AC Short Pulse" method will be used – see https://www.irrometer.com/200ss.html
- D9 and D8 will be used to alternating power the sensor
- A2 will be used to read signal from sensor
- R is a resistor from 7kOhms to 14kOhms – default is 10kOhms

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

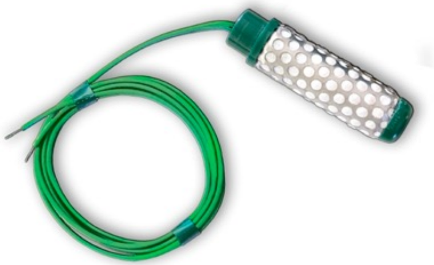
```
//put here the resistor value, in Ohms
#define WM_RESISTOR 10000
//we defined WM_MAX_RESISTOR=32760 because the transmitted value would be 32760/10=3276
//and currently a bug in WaziGate XLPP decoding code will limit the maximum value to 3276
#define WM_MAX_RESISTOR 32760
```

- Uncomment in main program `WITH_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
```

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

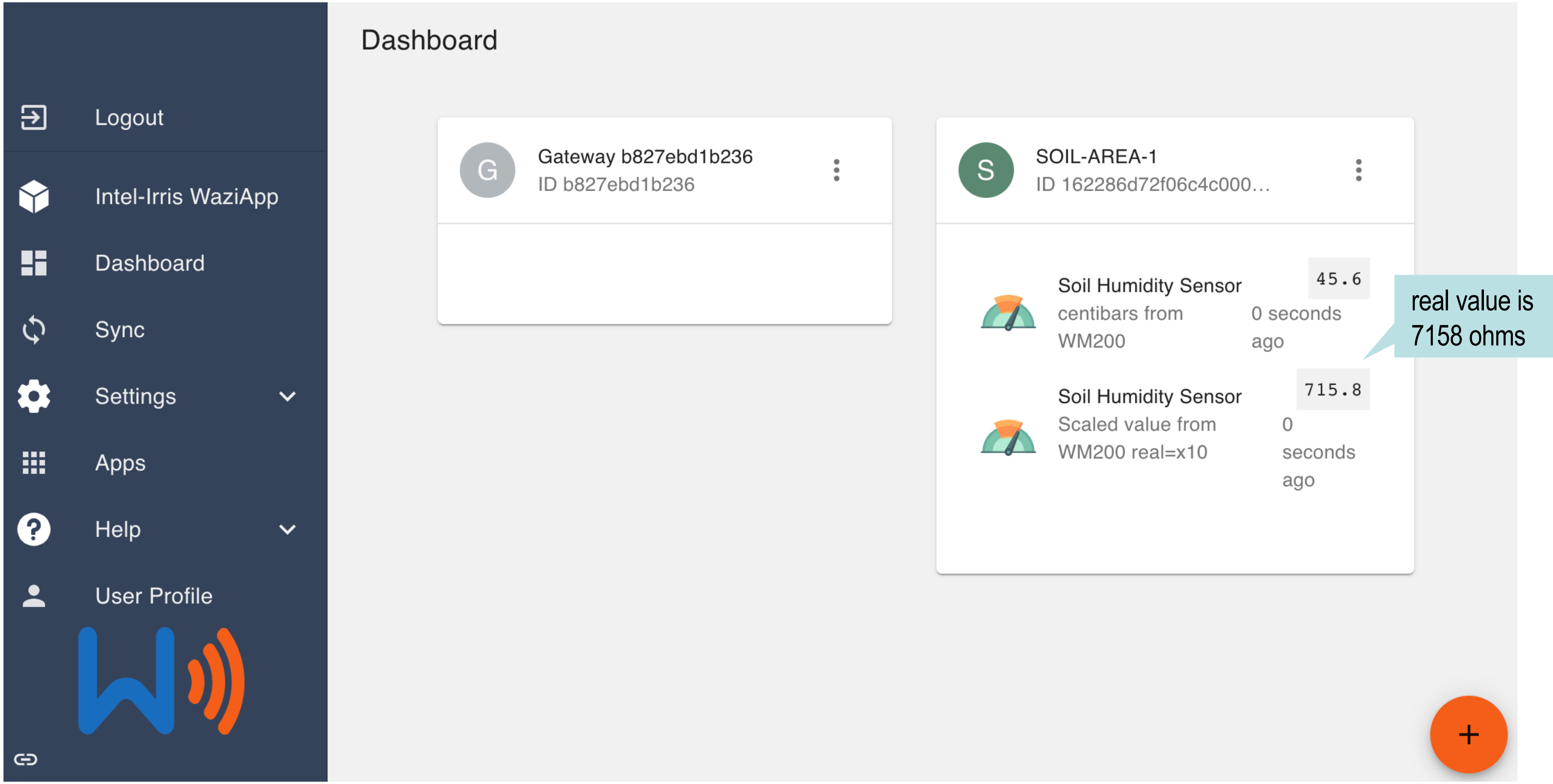


Parameters for
INTEL-IRRIS WaziGate

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)

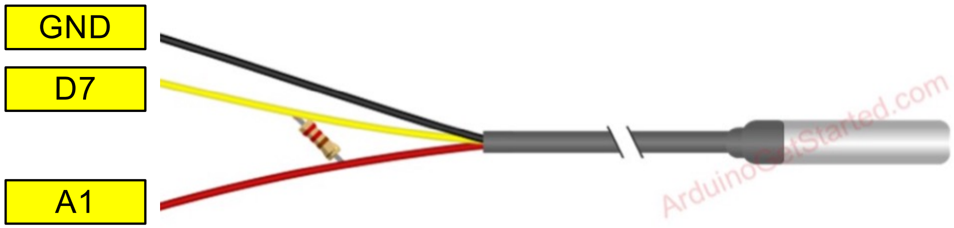
- Without a real temperature sensor, the INTEL-IRRIS code uses a default soil temperature set to 28°C to convert the resistance value into centibars (see https://www.irrometer.com/200ss.html)

```
/////////////////////////////////////////////////////////////////////
// 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)

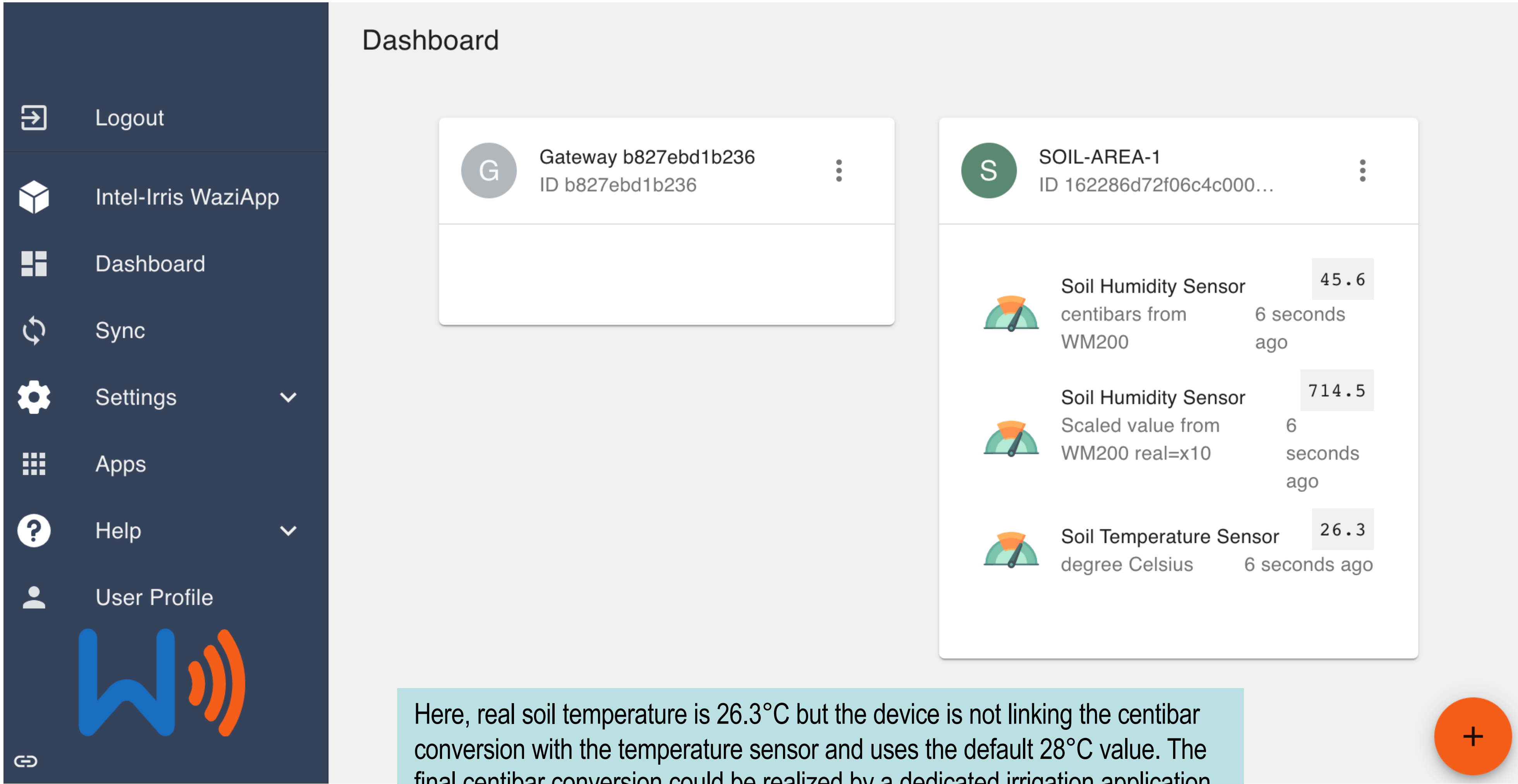
- A DS18B20 temperature sensor can be connected to the device. A 4.7kOhms must be added as illustrated, connecting D7 and A1



```
//////////////////////////////////////////////////////////////////////
// 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.

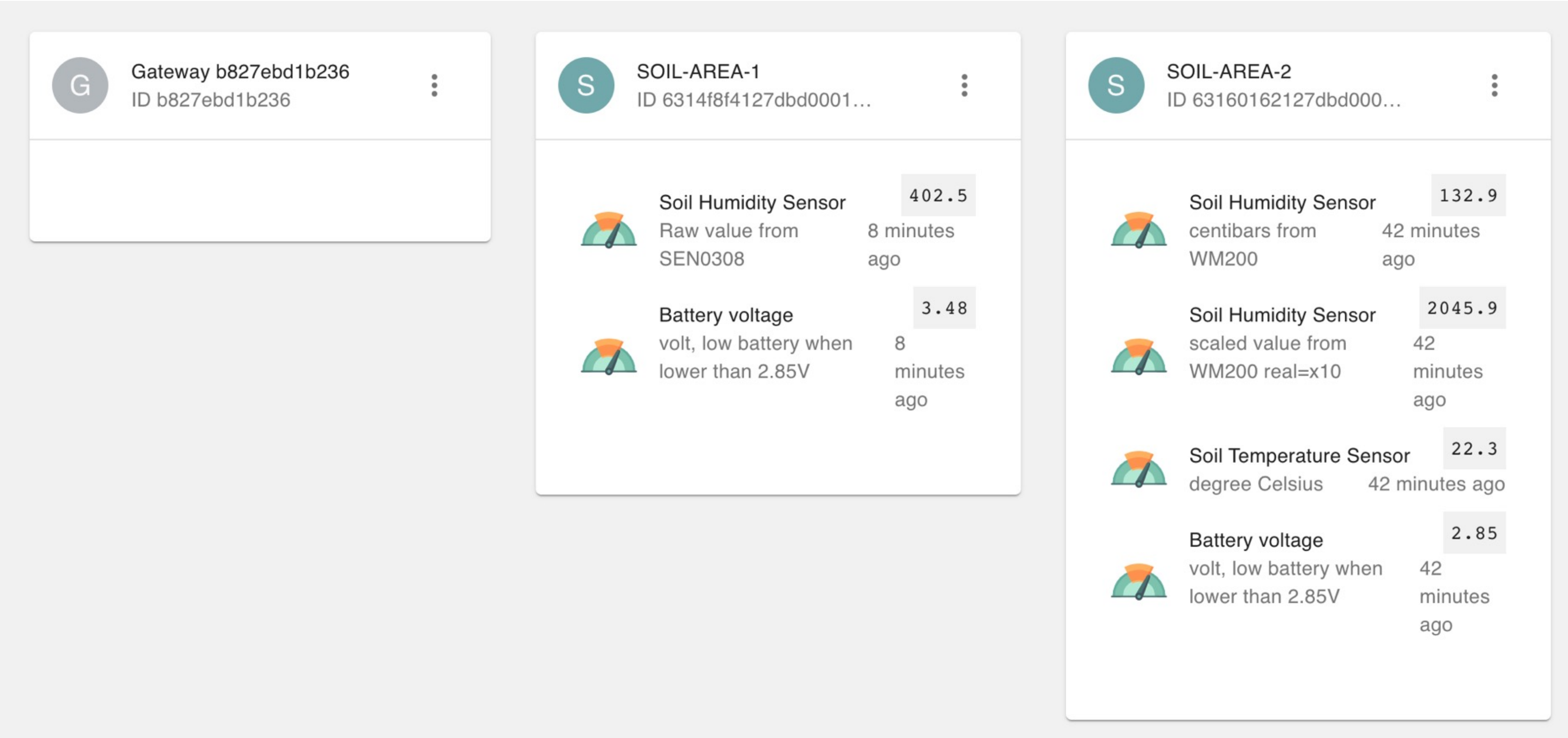
Low battery voltage indication

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

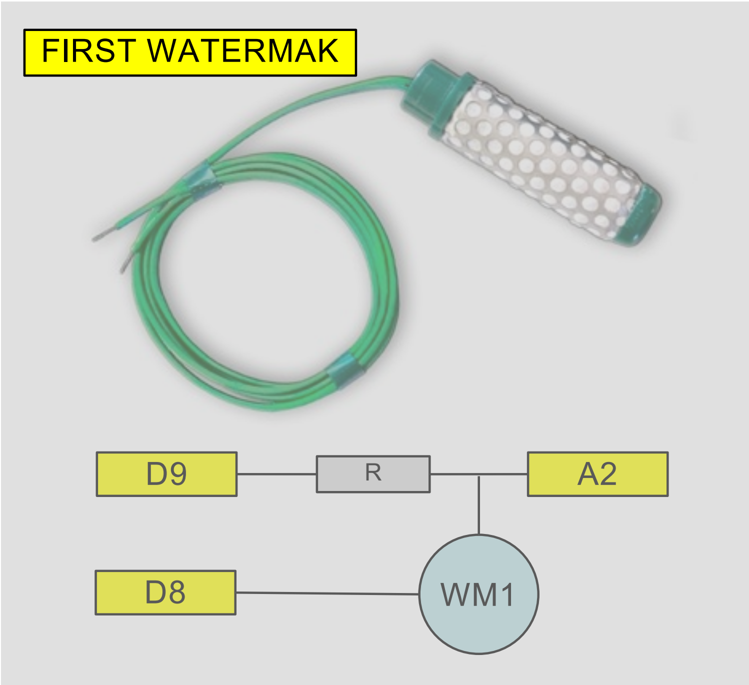
```
#ifdef WITH_WATERMARK
//the ATMega328P reboots at about 2.65 - 2.75
#define VCC_LOW                     2.85
#else
//capacitive sensors can be impacted by low voltage, especially for very dry soil conditions
#define VCC_LOW                     2.85
#endif
```

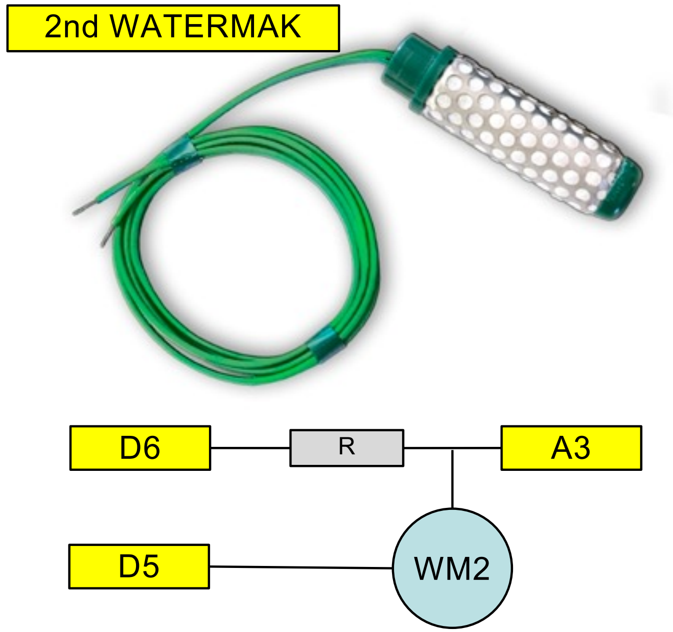
- The battery voltage will be transmitted to the gateway as well and will appear on the WaziGate's dashboard to warn end-user
- When low battery voltage is detected, the measure & transmission time interval will increase from 1h to 4h to preserve battery

See it on the dashboard



Add a second Watermark sensors





a second Watermark sensor can be connected: the purpose is to determine the water movement in the soil

D6 and D5 will be used to alternating power the sensor

A3 will be used to read signal from sensor

R should be identical for both Watermark

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

Software configuration for 2 WM

Intel-IrriS

- Uncomment in main program `TWO_WATERMARK`

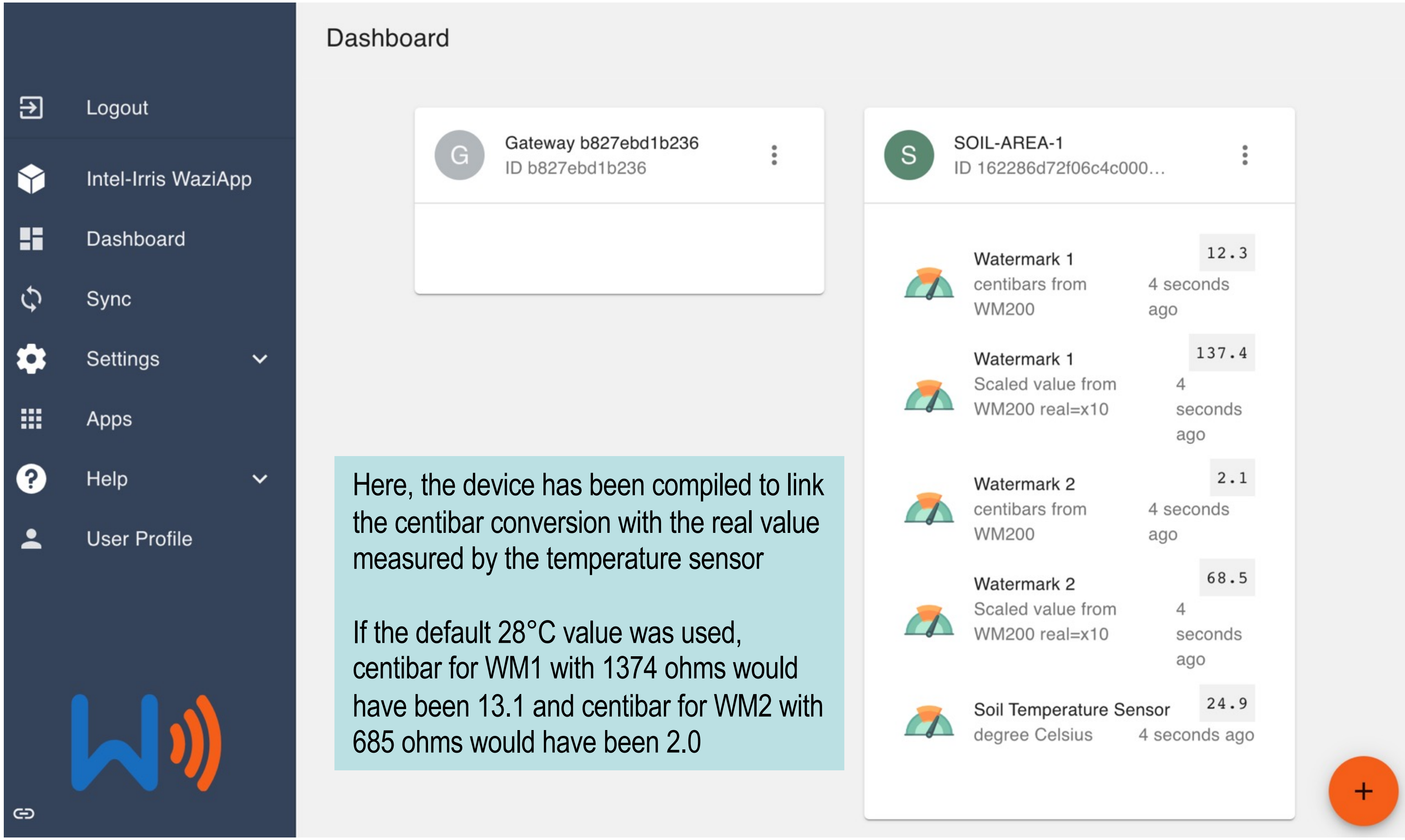
```
////////////////////////////////////////////////////////////////////
// uncomment to have a soil tensiometer watermark sensor
#define WITH_WATERMARK
#define WM_REF_TEMPERATURE 28.0

////////////////////////////////////////////////////////////////////
// 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 add a soil temperature sensor

See it on the dashboard

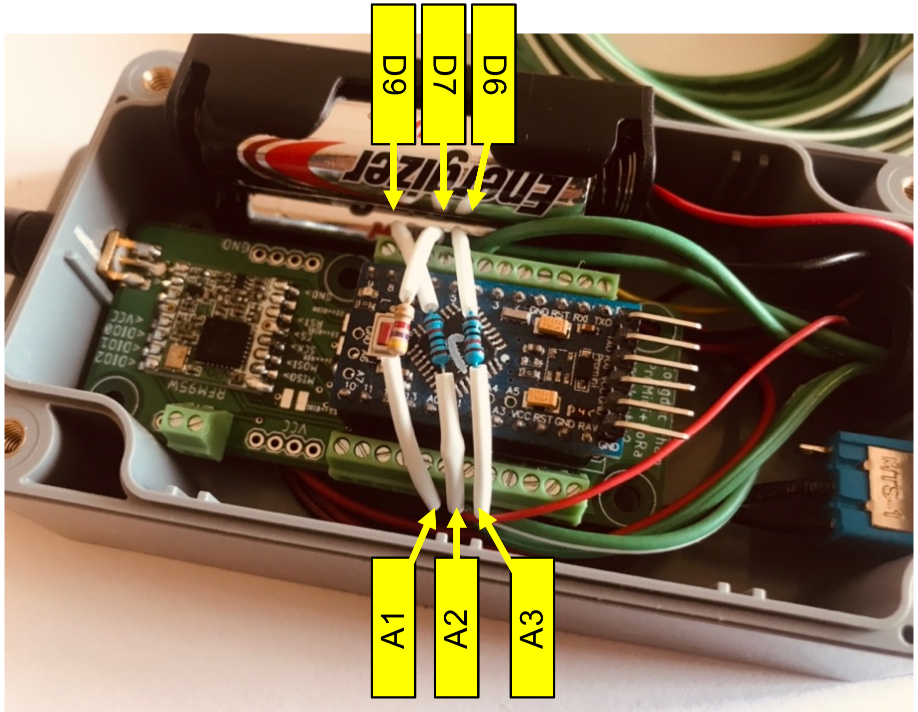


Here, the device has been compiled to link the centibar conversion with the real value measured by the temperature sensor

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

Experimental INTEL-IRRIS soil device

- 2 Watermark sensors (D9-D8-A2 & D6-D5-A3) – 10kOhms
- 1 soil temperature sensor (D7-A1) – 4.7kOhms



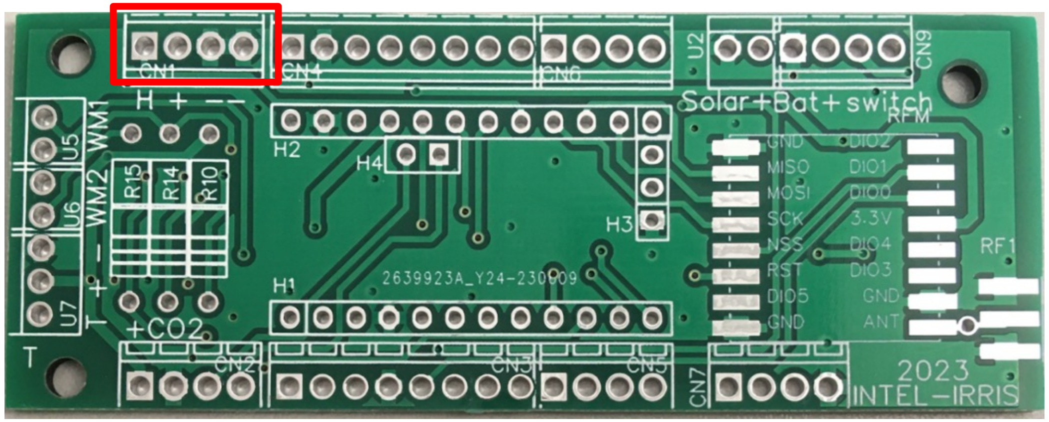
PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

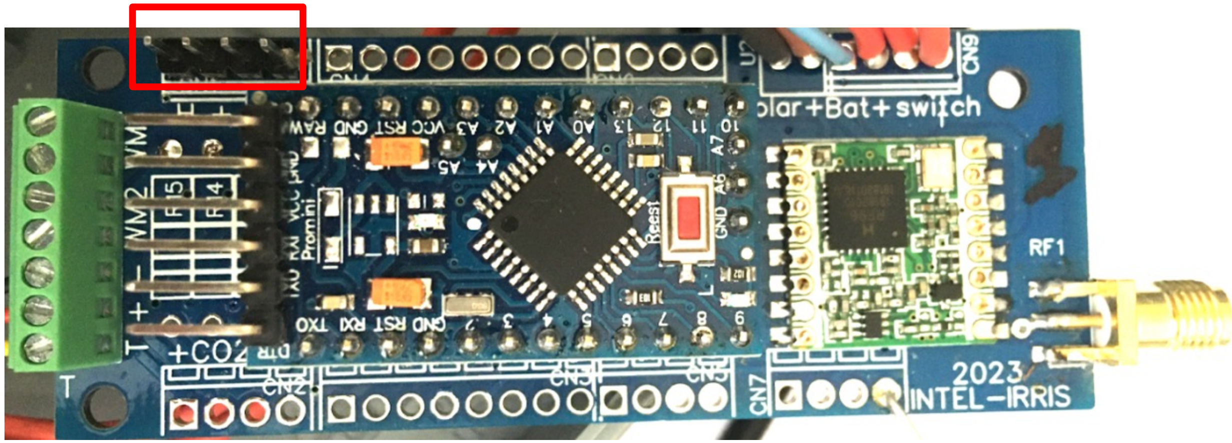

INTEL-IRRIS
Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture
NEW PCBs

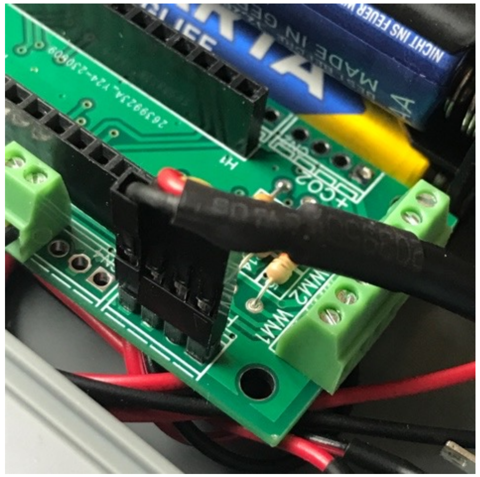
Wiring with new IRD PCB

- SEN0308 capacitive



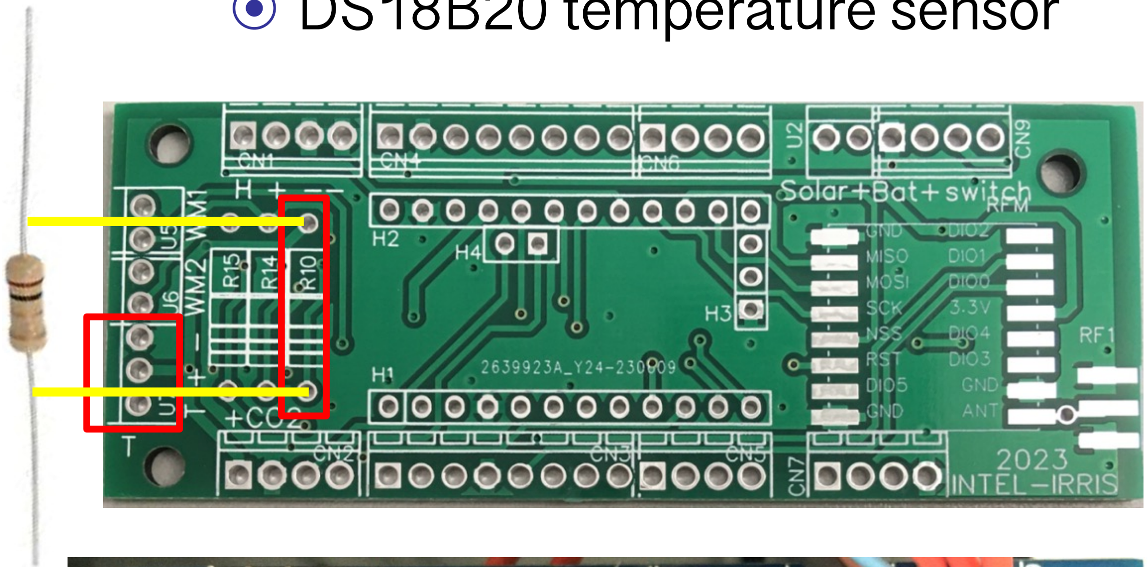
Just connect the sensor in the dedicated header – – are the 2 black wires



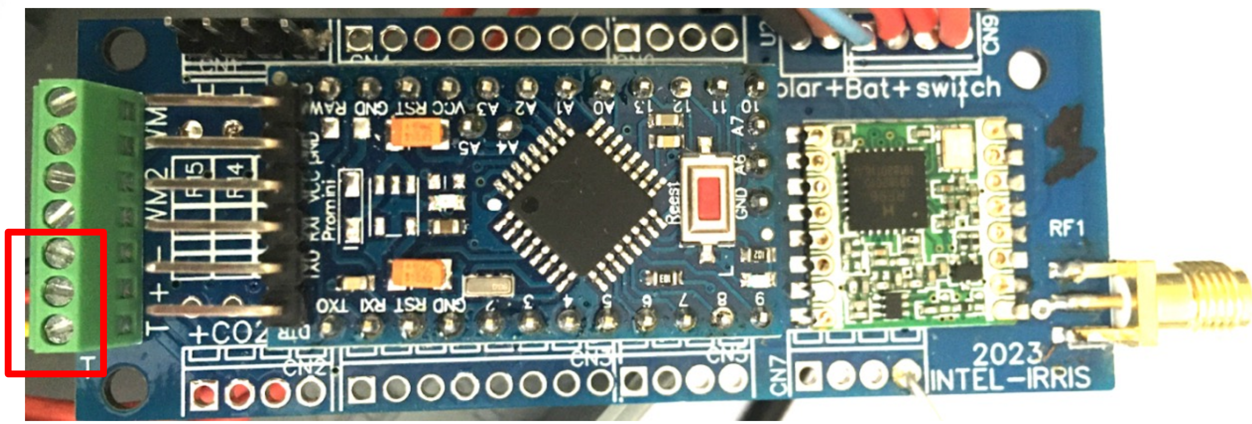


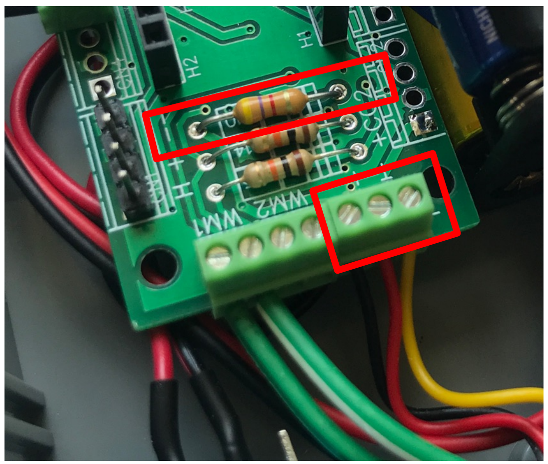
Wiring with new IRD PCB

- DS18B20 temperature sensor



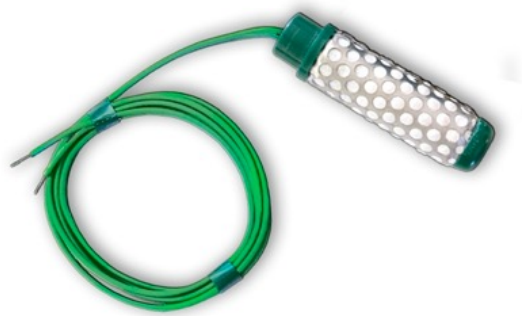
Solder a 4.7kOhms resistance then wire in the dedicated terminal block
T+ – : Yellow, Red, Black wires

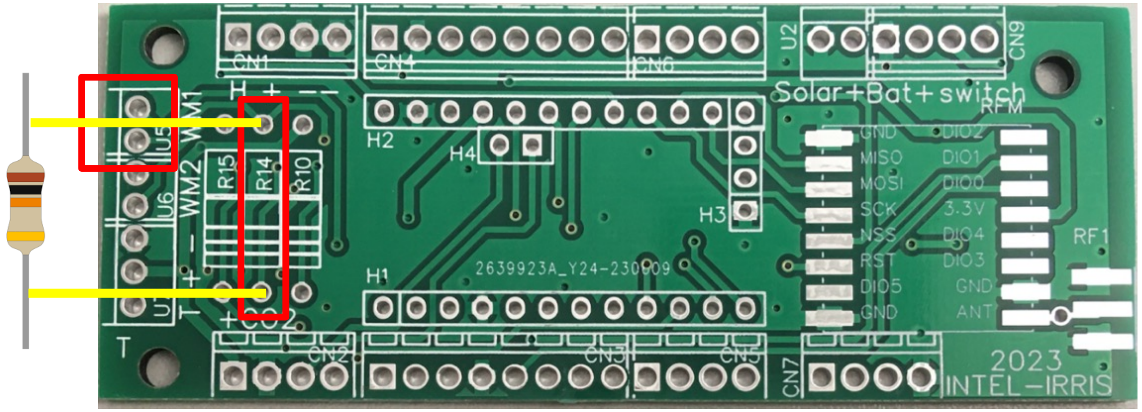




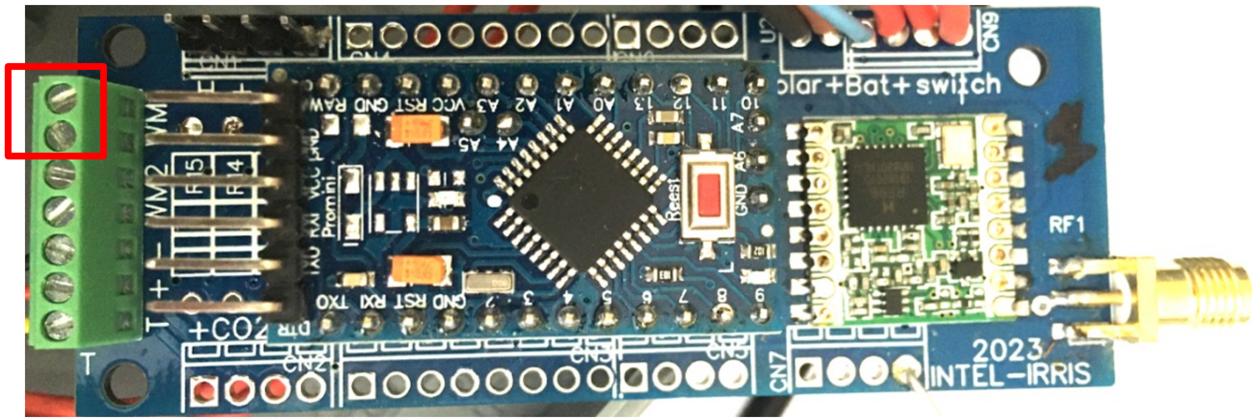
Wiring with new IRD PCB

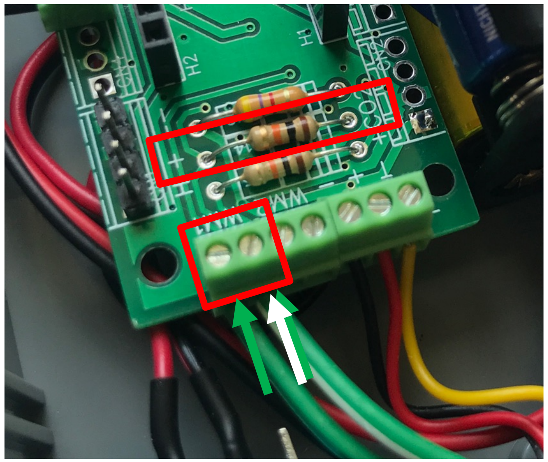
- First Watermark





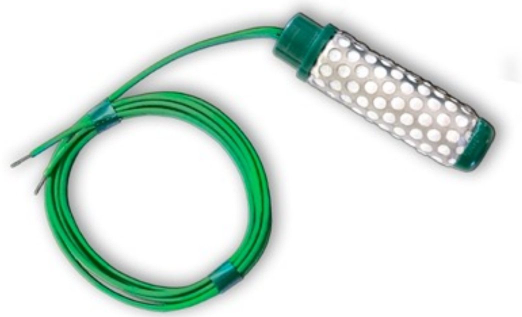
Solder a 10kOhms resistance then wire in the dedicated WM1 terminal block

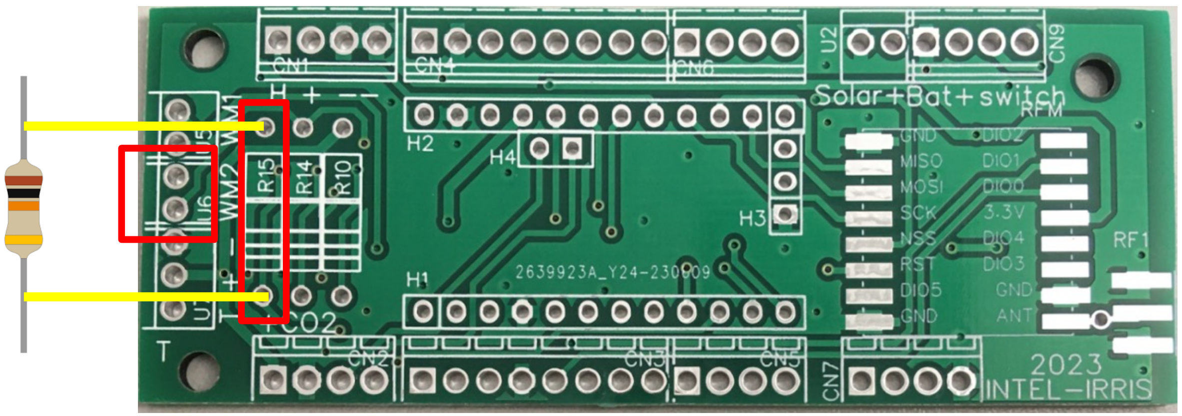




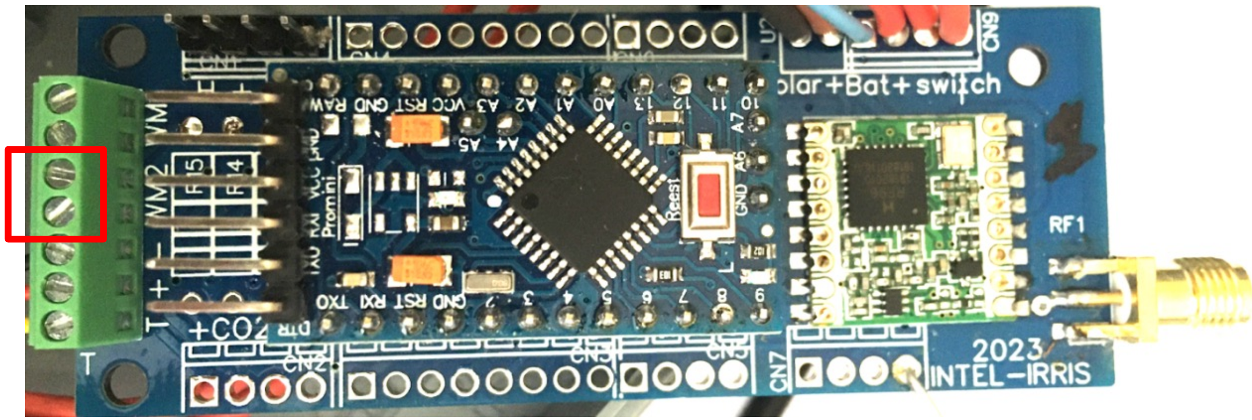
Wiring with new IRD PCB

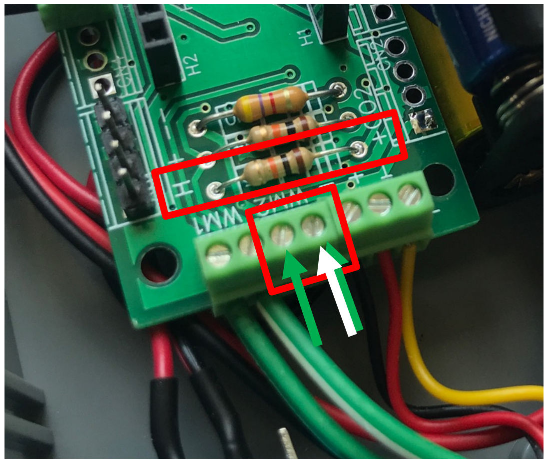
- Second Watermark





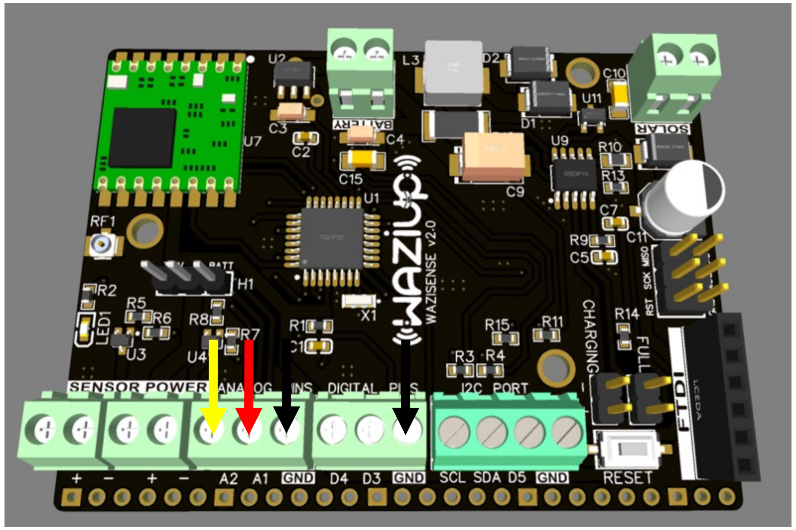
Solder a 10kOhms resistance then wire in the dedicated WM2 terminal block

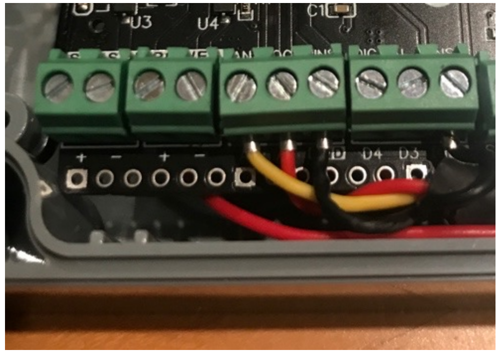


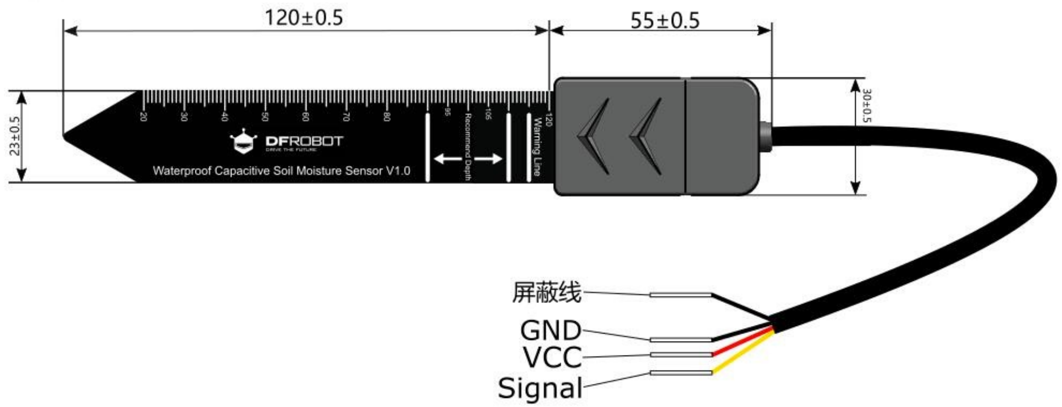


Wiring with WaziSense v2

- SEN0308 capacitive







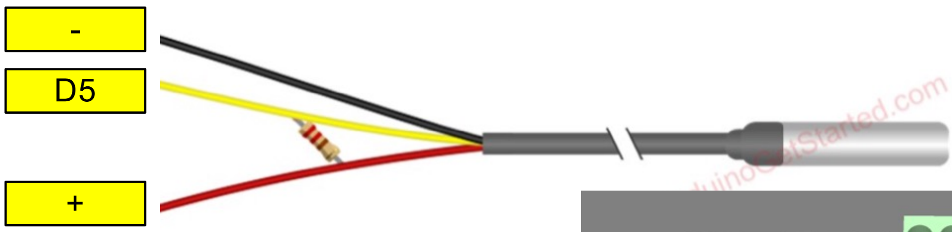
Insert sensor's wire through cable gland

Connect SEN0308's wires to board:

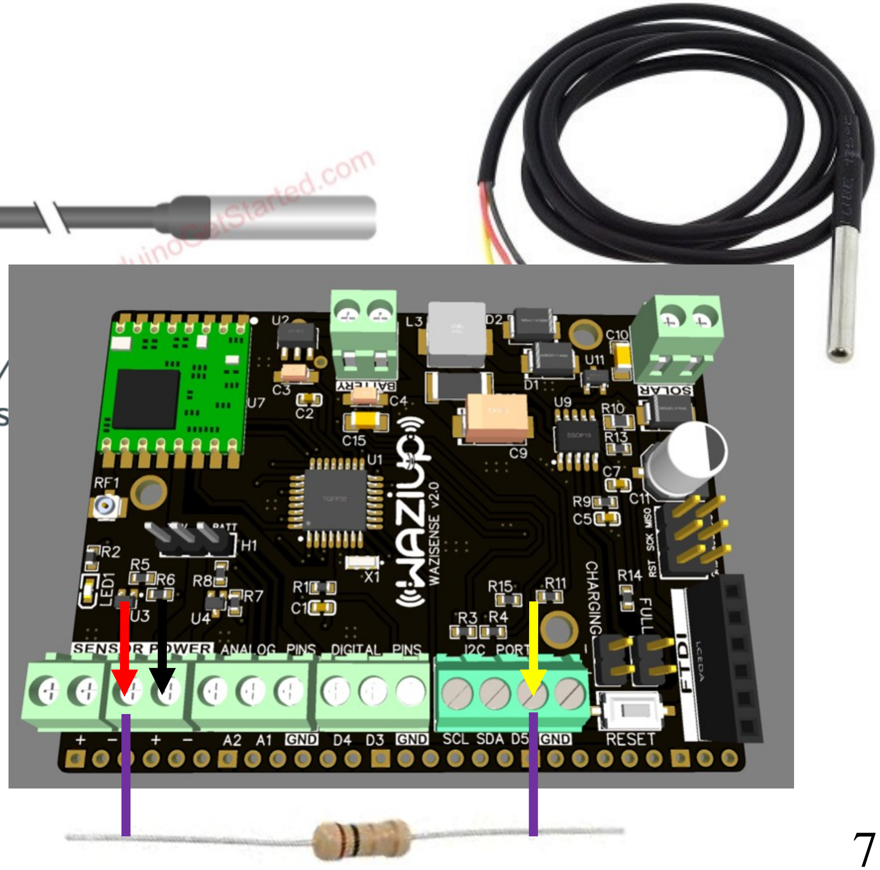
- **VCC to board's A1**
- **GND to board's GND (there are 2 GND wires)**
- **Signal to board's A2**

Wiring with WaziSense v2

- A DS18B20 temperature sensor can be connected to the device. A 4.7kOhms must be added as illustrated, connecting D5 and +

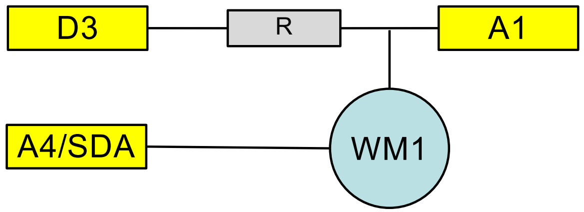


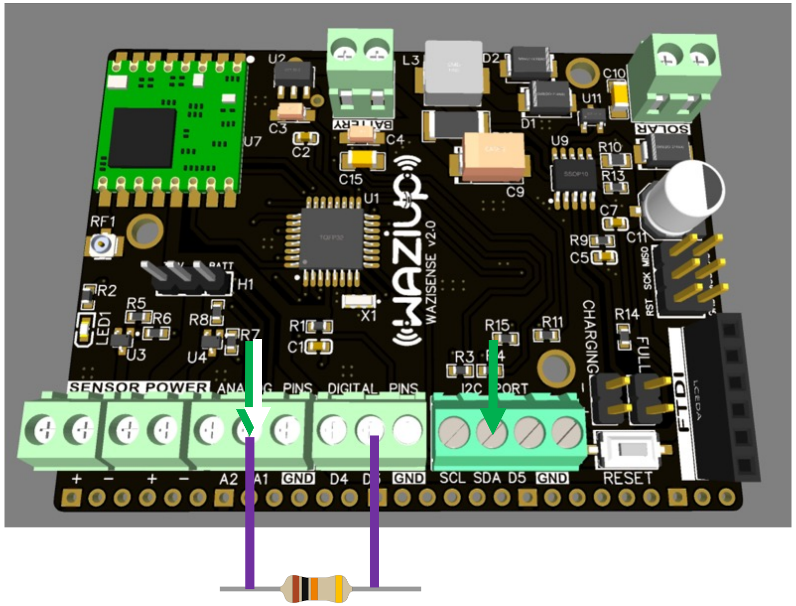

```
////////////////////////////////////////////
// uncomment to have 1 soil temperature sens
// using a one-wire DS18B20 sensor
#define SOIL_TEMP_SENSOR
//#define LINK_SOIL_TEMP_TO_CENTIBAR
```



Wiring with WaziSense v2

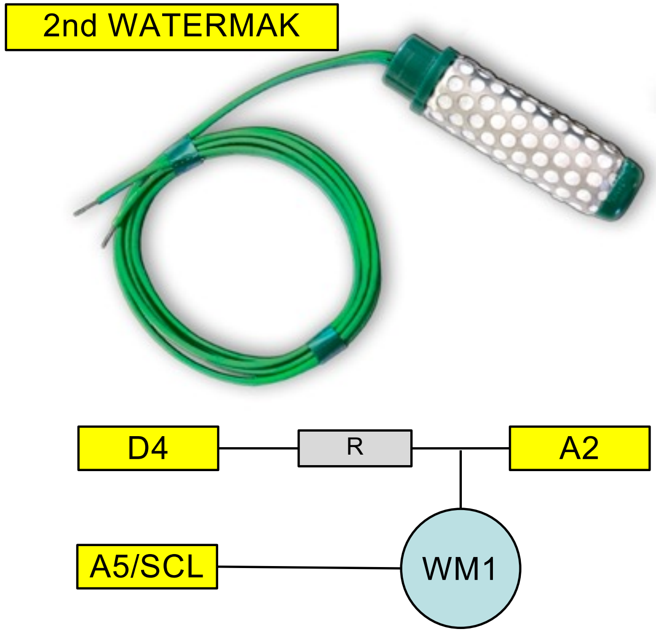
FIRST WATERMAK

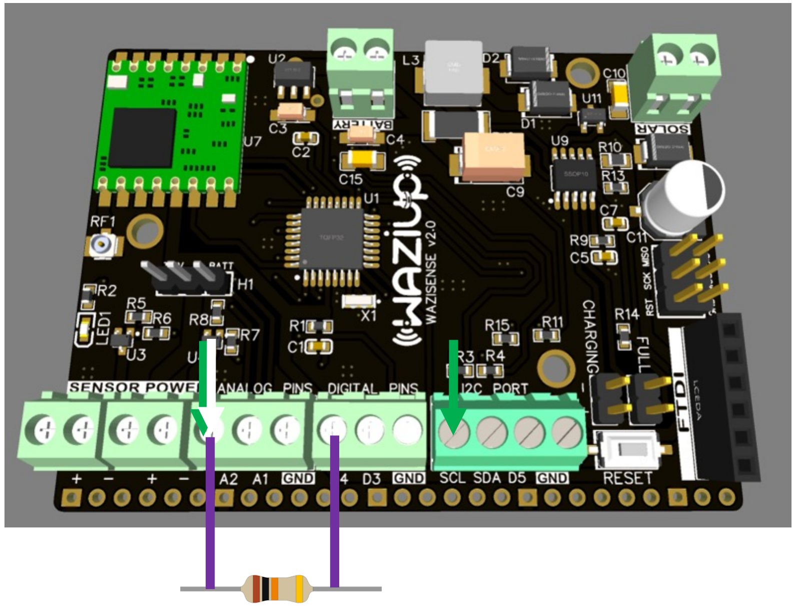




with a Watermark sensor, the "pseudo-AC Short Pulse" method will be used – see https://www.irrometer.com/200ss.html
D3 and A4/SDA will be used to alternating power the sensor
A1 will be used to read signal from sensor
R is a resistor from 7kOhms to 14kOhms – default is 10kOhms

Wiring with WaziSense v2





- a second Watermark sensor can be connected: the purpose is to determine the water movement in the soil
- D4 and A5/SCL will be used to alternating power the sensor
- A2 will be used to read signal from sensor
- R should be identical for both Watermark