



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



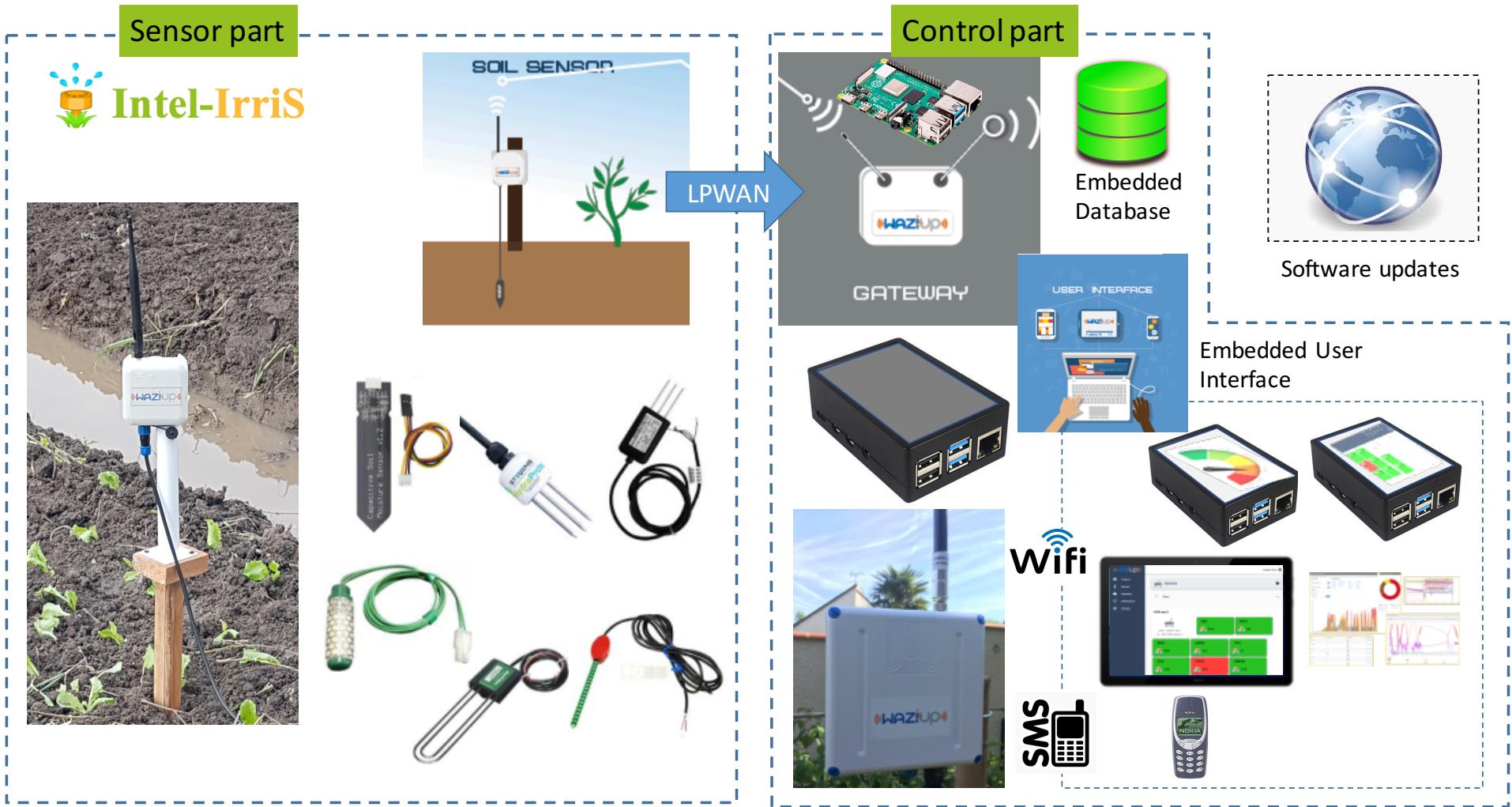
Building the Intel-IrriS LoRa IoT platform Part 1: soil sensor device



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



Review: Technology components



Review: Low-cost sensors



- 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

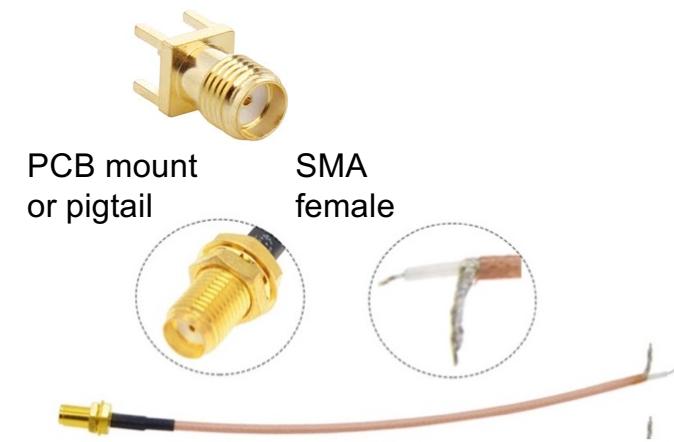
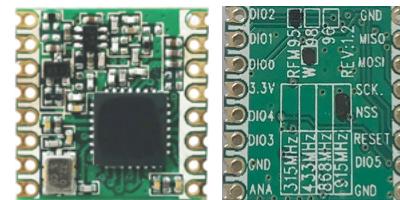
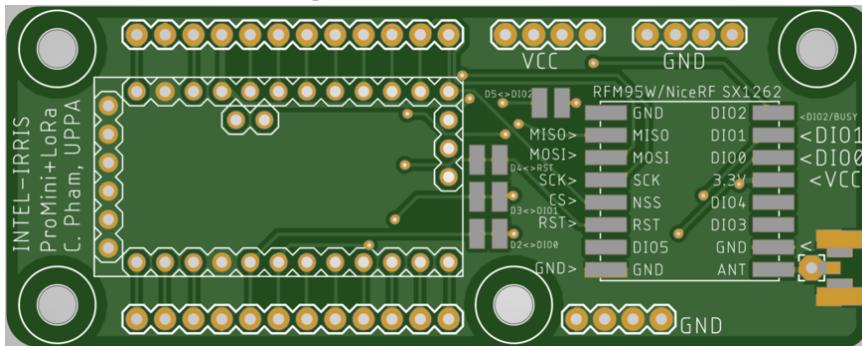


Review: Starter-kits

- "Intelligent Irrigation in-the-box", "plug-&-sense"
- At least 100 starter-kit will be distributed

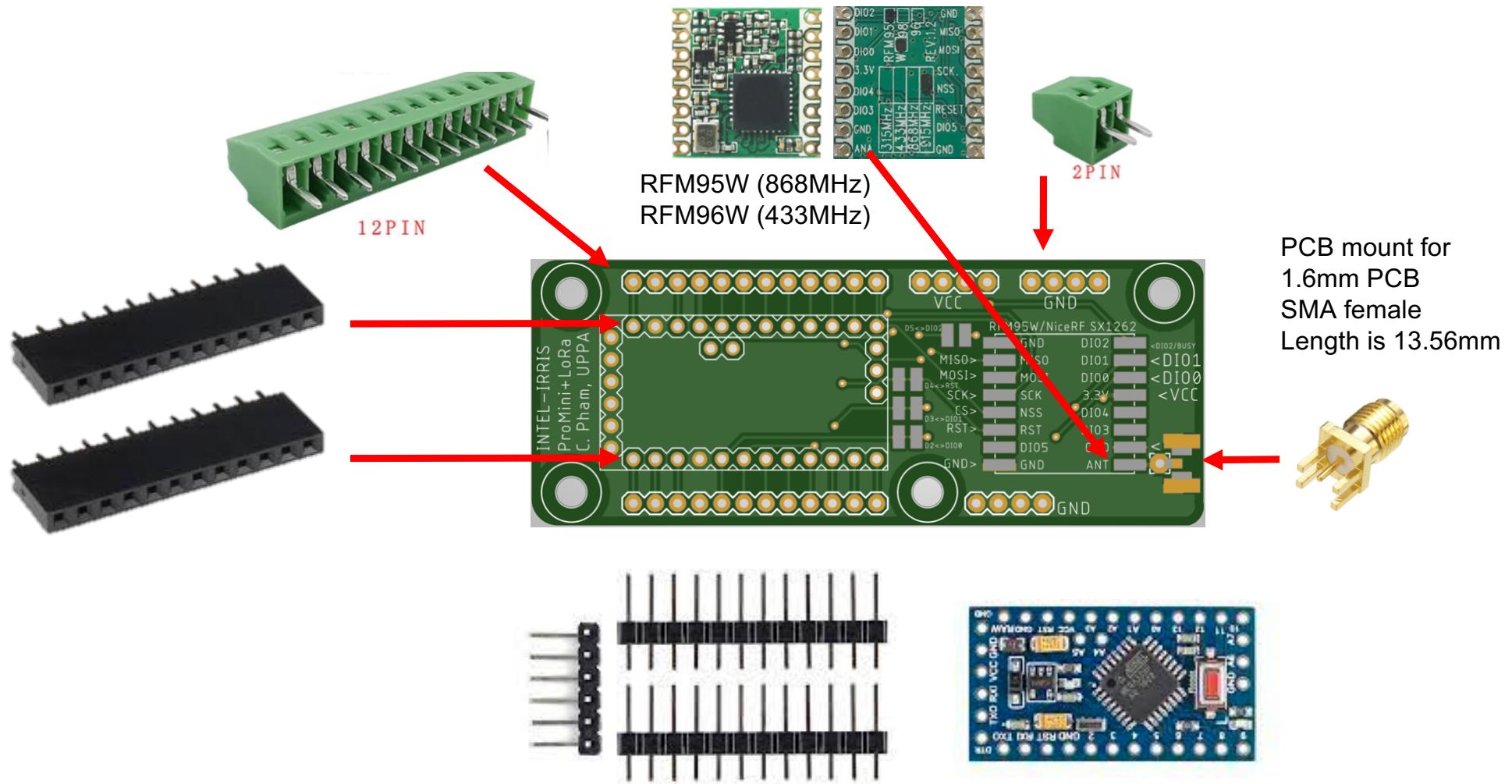


Soil sensor: electronic parts complete version

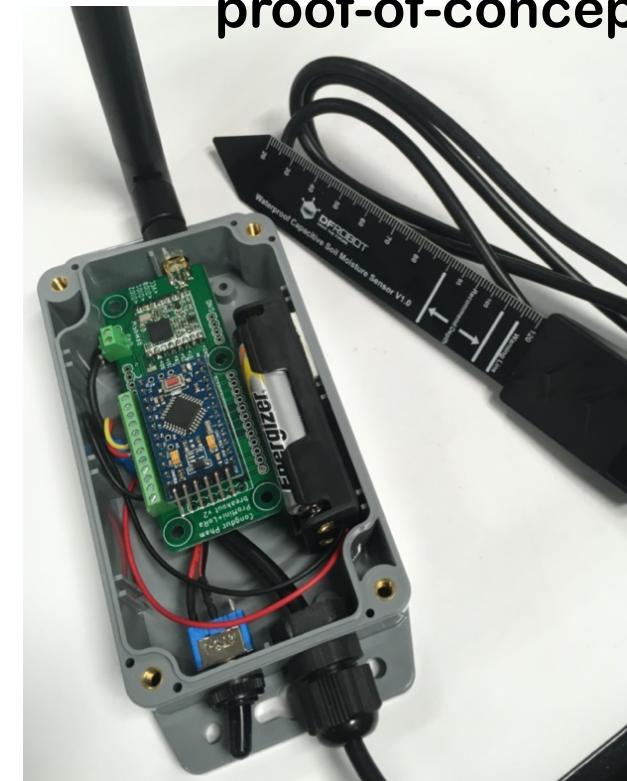
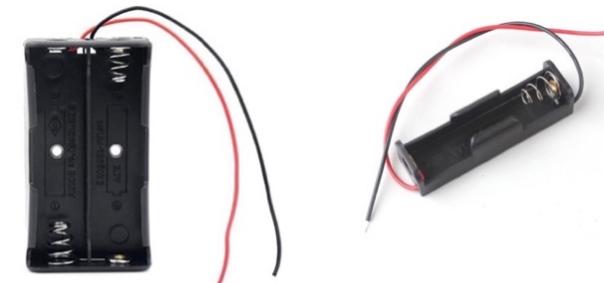


SMA
male

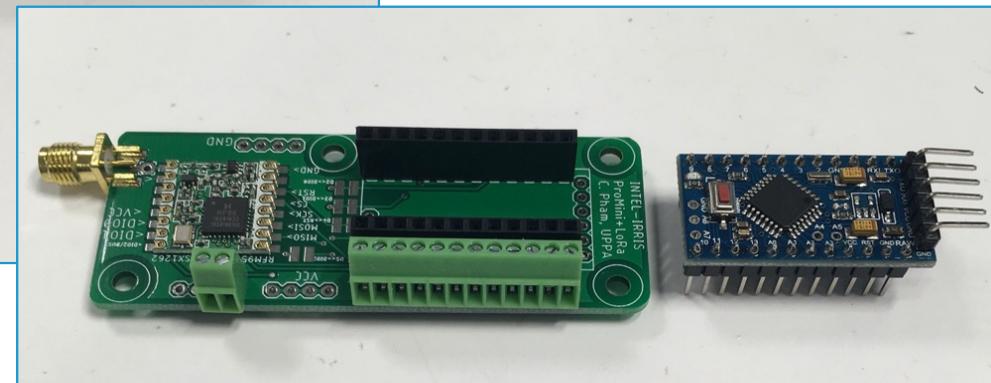
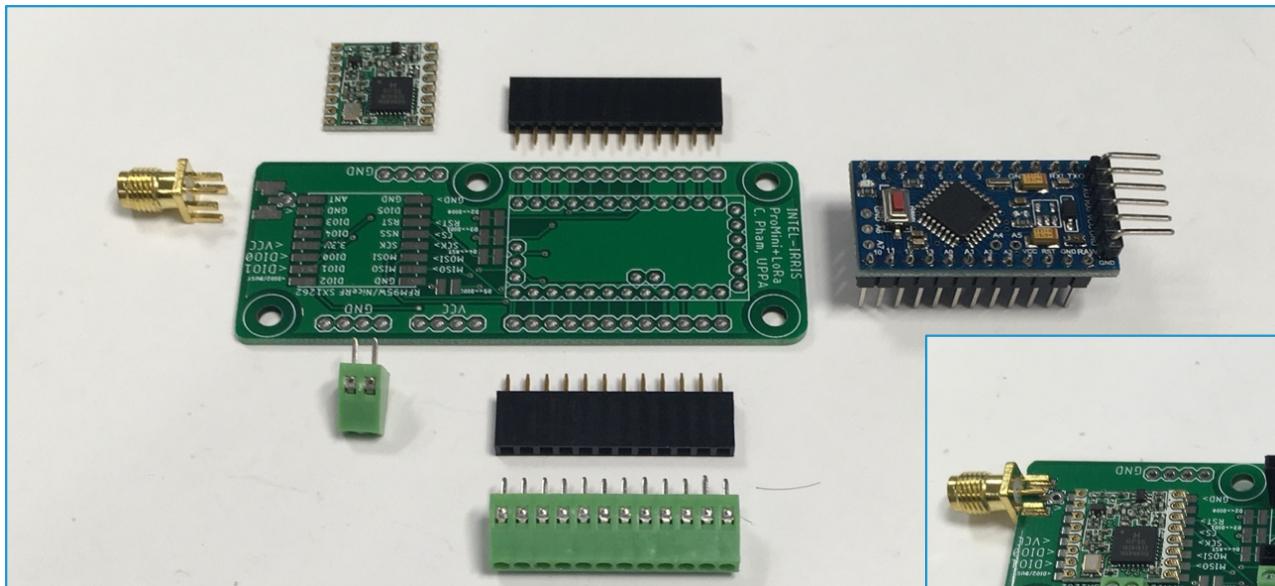
Soil sensor: electronic parts starter-kit version



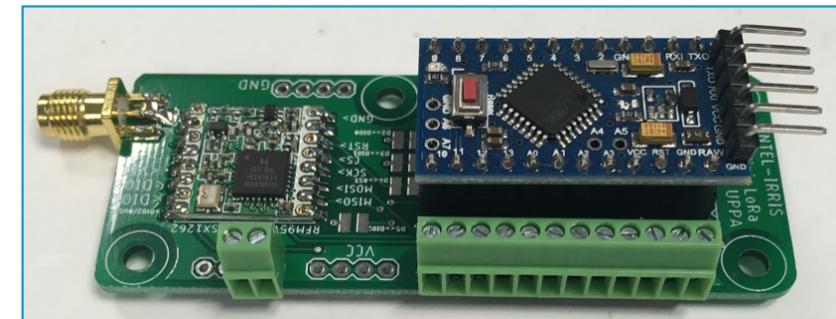
Soil sensor: enclosure & integration



Assembling the PCB board

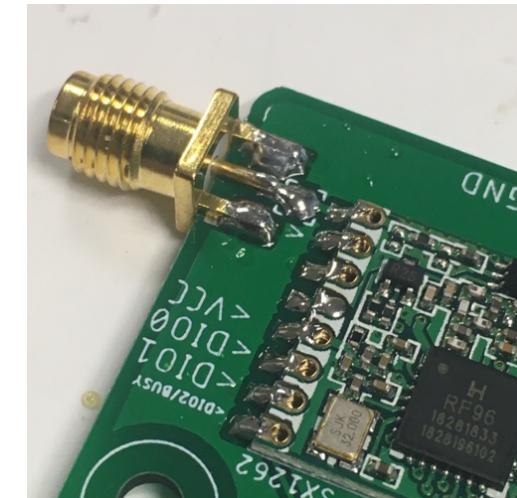
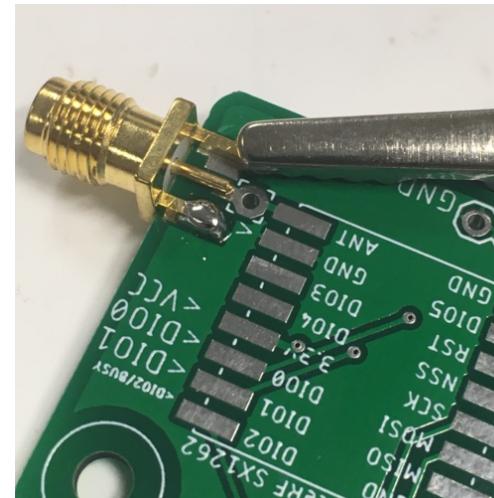
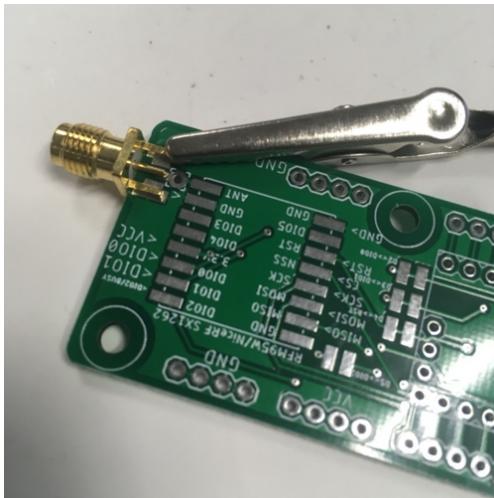


This dedicated video will show
how to solder all the components
Video n°1: <https://youtu.be/3jdQ0Uo0phQ>



Updates

- Here are some updates on Video n°1
- Clip the SMA connector to the PCB to correctly align the connector before soldering one of the GND pad
- Remove clip and finish soldering
- Make sure that the GND pads and the central pin are not touching each other, in doubt, do a continuity check





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>

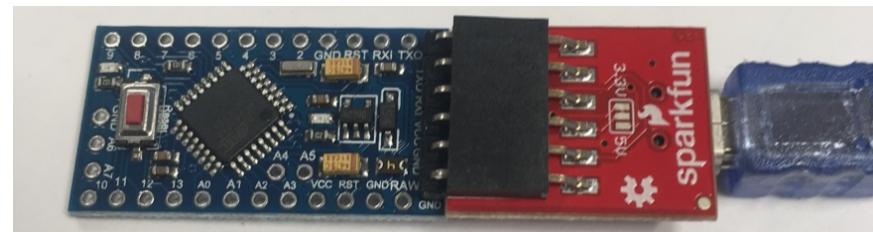
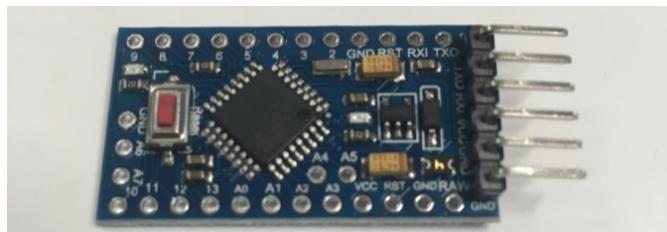


- Just put the required amount of lead, too much lead is not good!
- It is not a bad idea to train on soldering before making the device and not waste electronic components

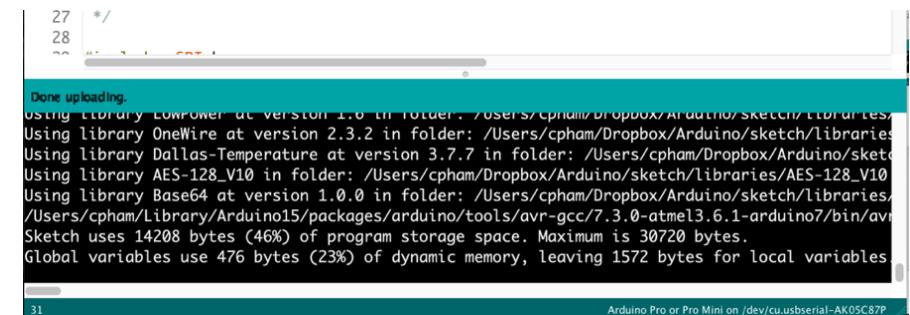


Check the Arduino

- 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



```
27 */  
28  
Done uploading.  
Using library LowPower at version 1.0 in folder: /Users/cpham/Dropbox/Arduino/sketch/libraries/  
Using library OneWire at version 2.3.2 in folder: /Users/cpham/Dropbox/Arduino/sketch/libraries/  
Using library Dallas-Temperature at version 3.7.7 in folder: /Users/cpham/Dropbox/Arduino/sketch/  
Using library AES-128_V10 in folder: /Users/cpham/Dropbox/Arduino/sketch/libraries/AES-128_V10  
Using library Base64 at version 1.0.0 in folder: /Users/cpham/Dropbox/Arduino/sketch/libraries/  
/Users/cpham/Library/Arduino15/packages/arduino/tools/avr-gcc/7.3.0-atmel3.6.1-arduino7/bin/avr  
Sketch uses 14208 bytes (46%) of program storage space. Maximum is 30720 bytes.  
Global variables use 476 bytes (23%) of dynamic memory, leaving 1572 bytes for local variables  
31  
Arduino Pro or Pro Mini on /dev/cu.usbserial-AK05C87P
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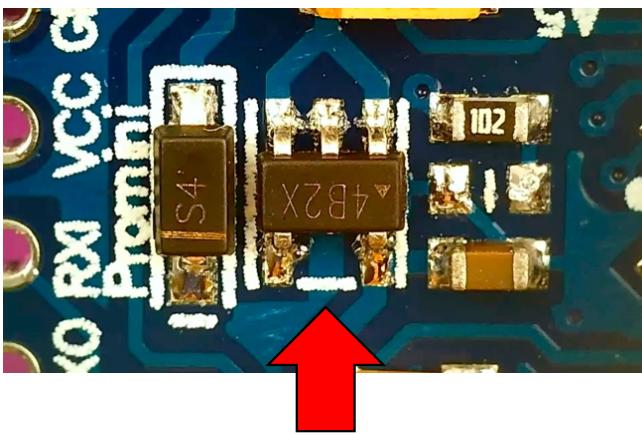
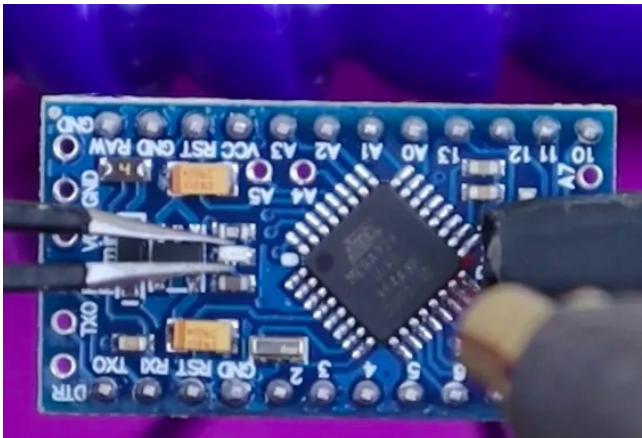


Never transmit without antenna

- 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

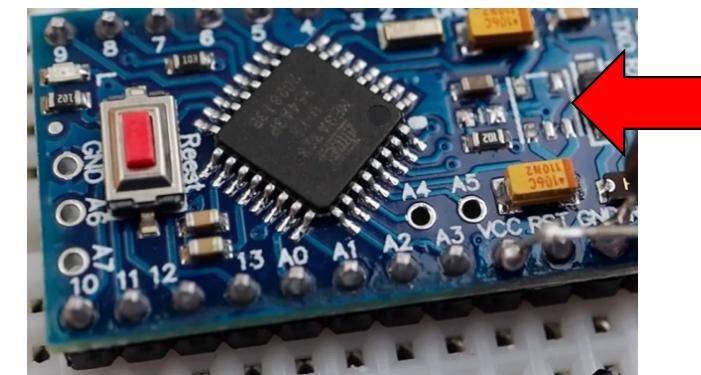


Reduce power consumption



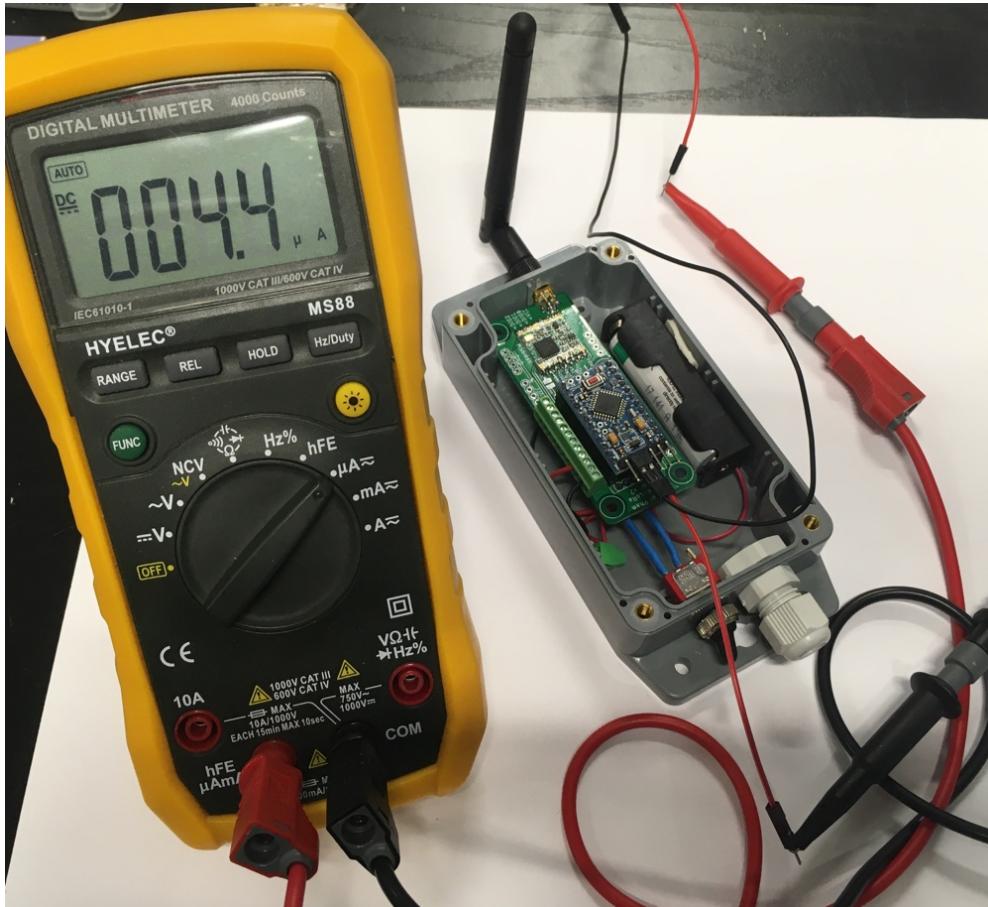
Do not forget to remove the power LED by just clipping it off with some wire cutters

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



Only inject up to 3.6V through the VCC pin

Power consumption in deep sleep



Measured below 5 μ A 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



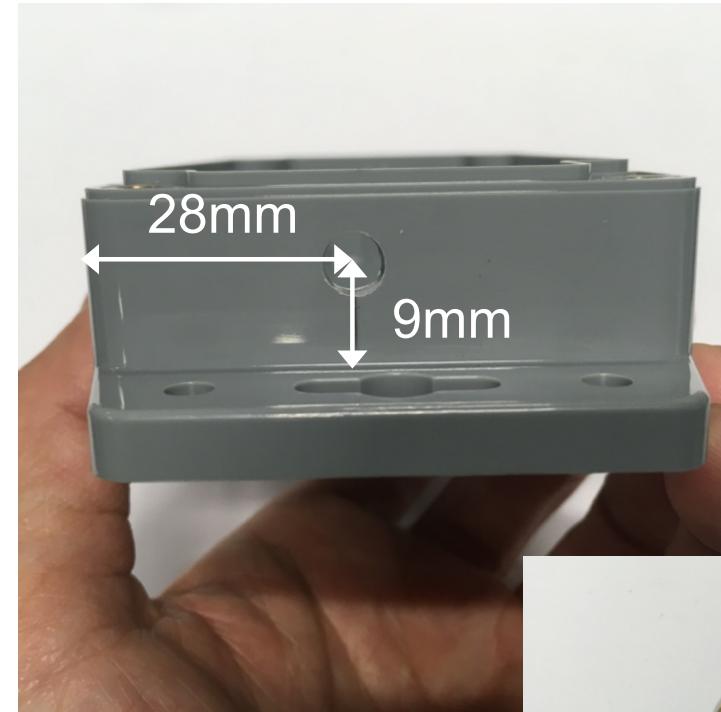
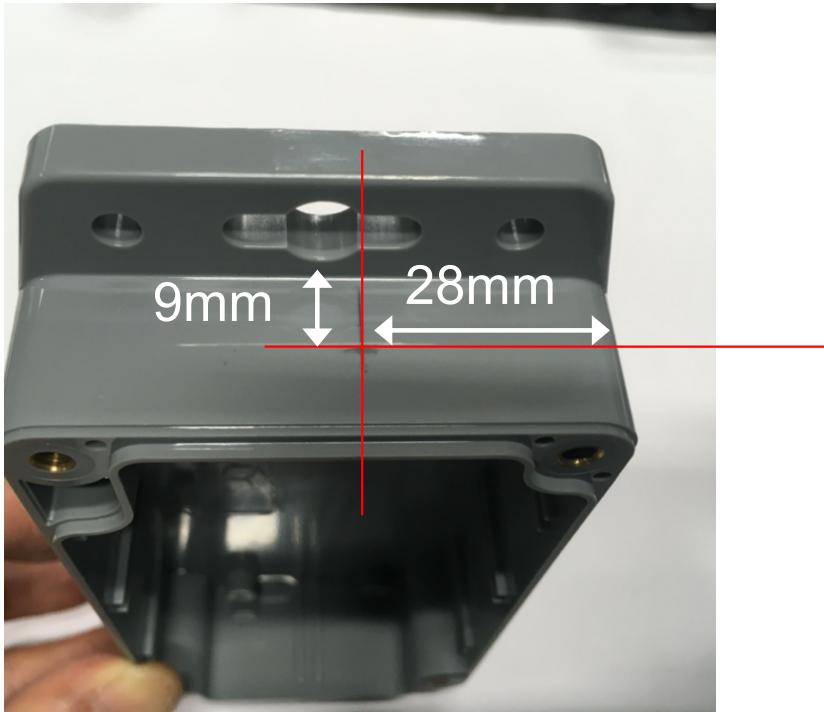
Here, it is an IP65 box which dimension is 115 x 65 x 40mm
<https://www.gotronic.fr/art-boitier-abs-etanche-g304m-17977.htm>

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)

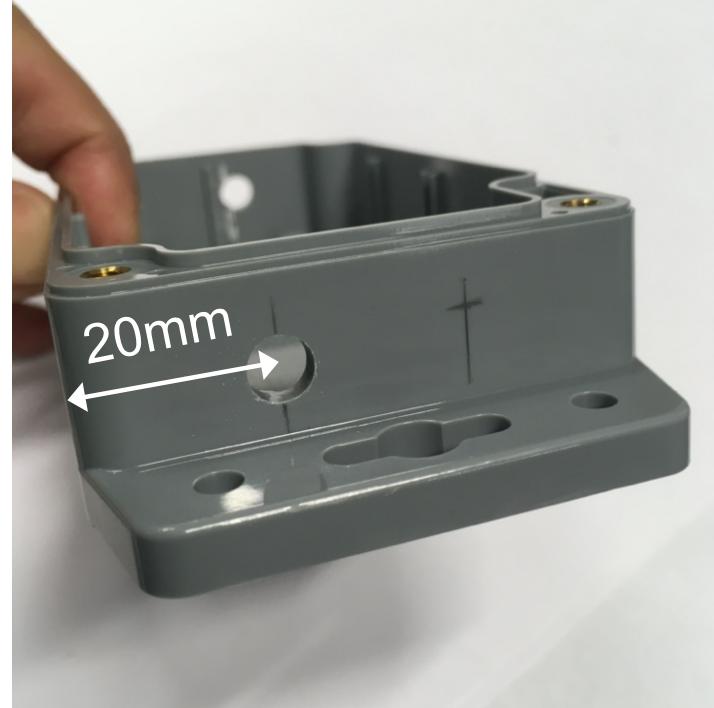
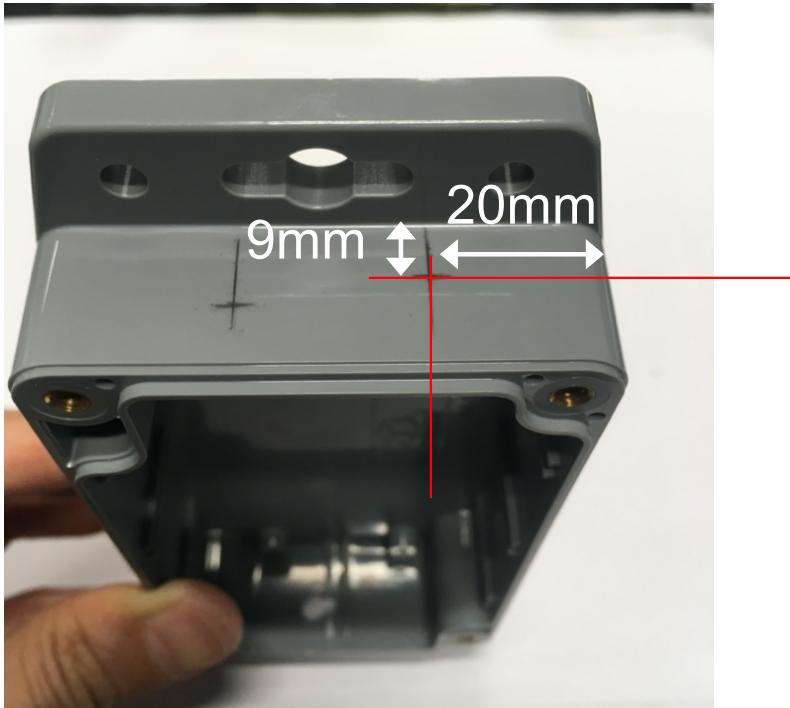
Placing the PCB board



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

Drill a hole for the cable gland



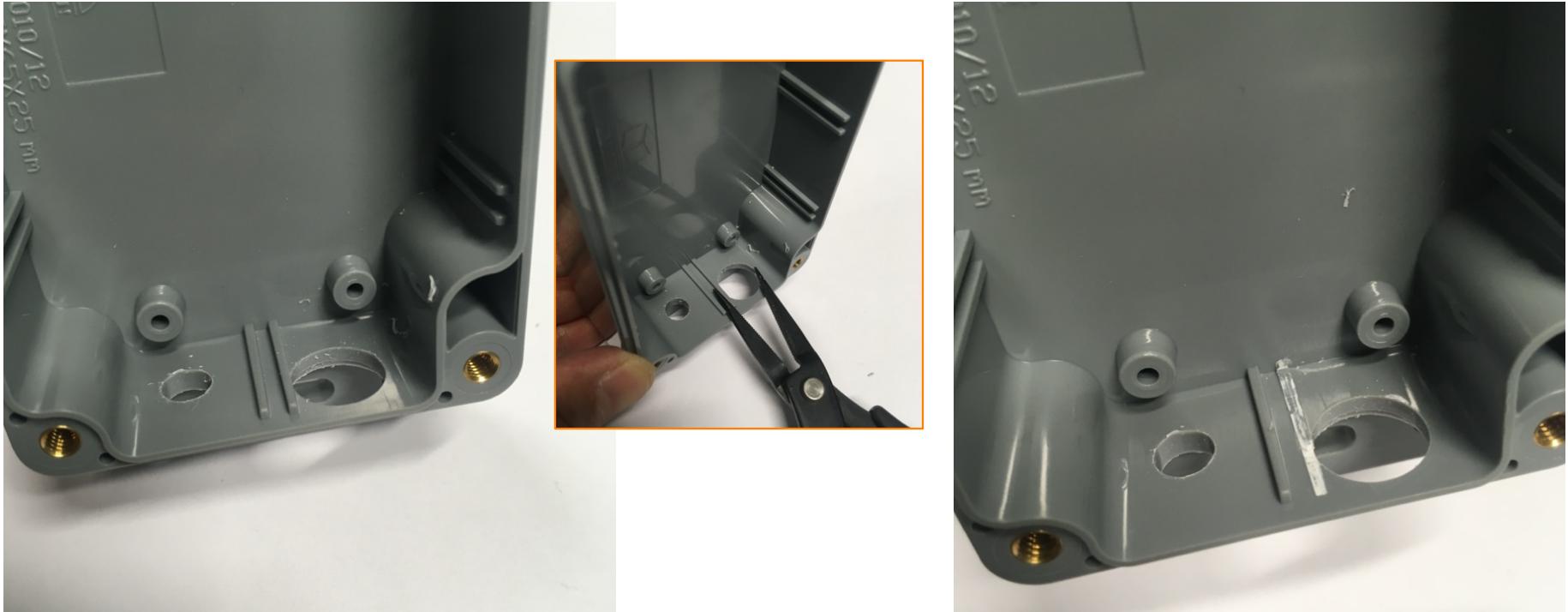
41mm for the right edge:

- measure from the flat side as the corner is round

9mm from the outside bottom

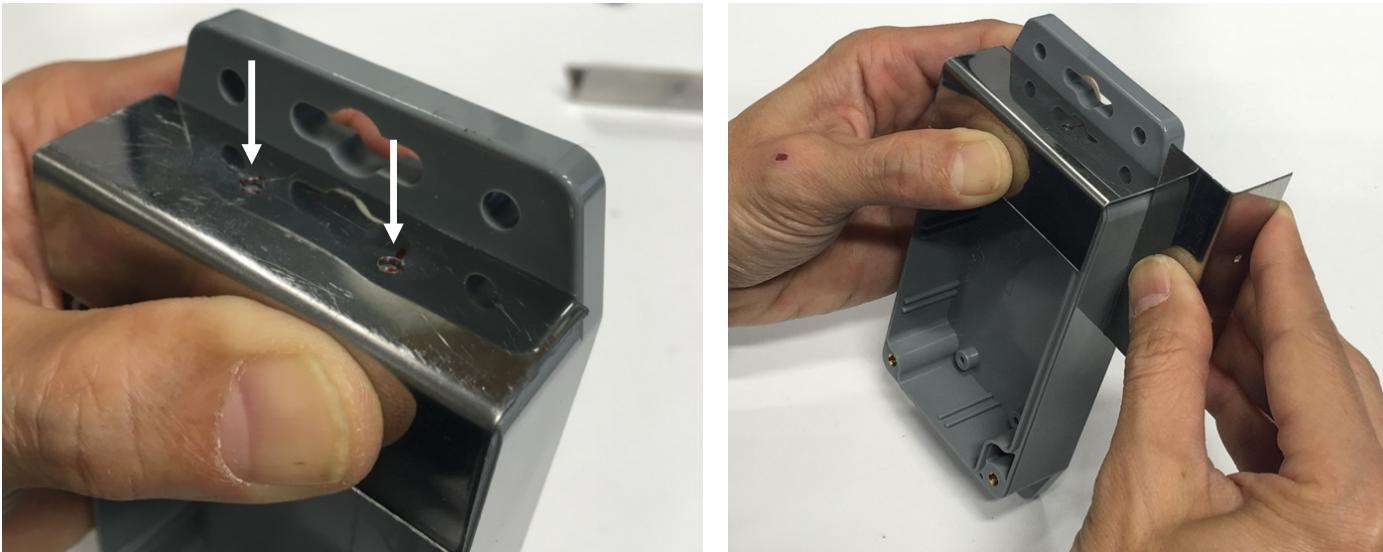
use a 13mm drill bit for metal

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

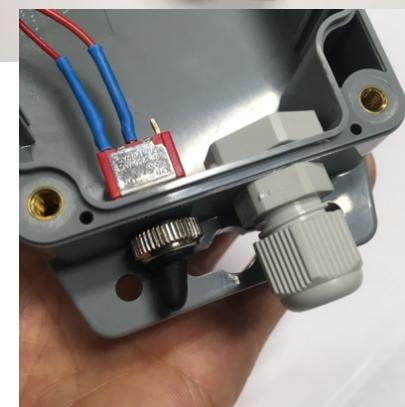
But be sure to precisely align the edge of the jig with the edge of the enclosure

Placing switch and cable gland

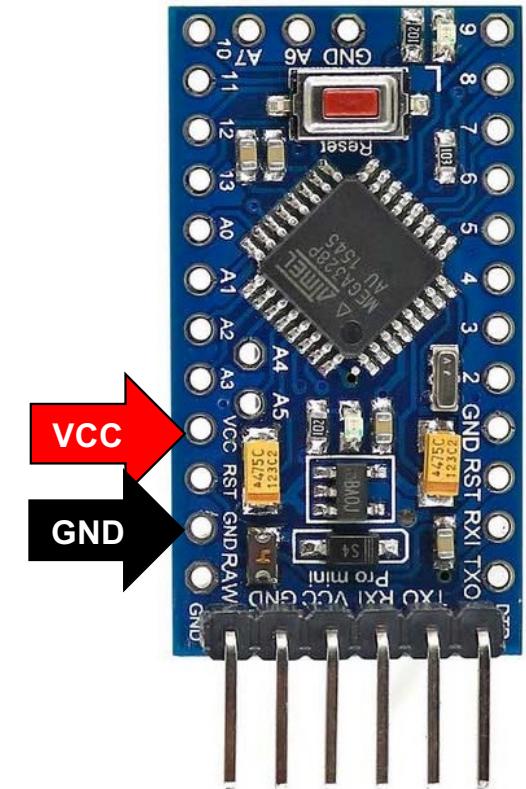
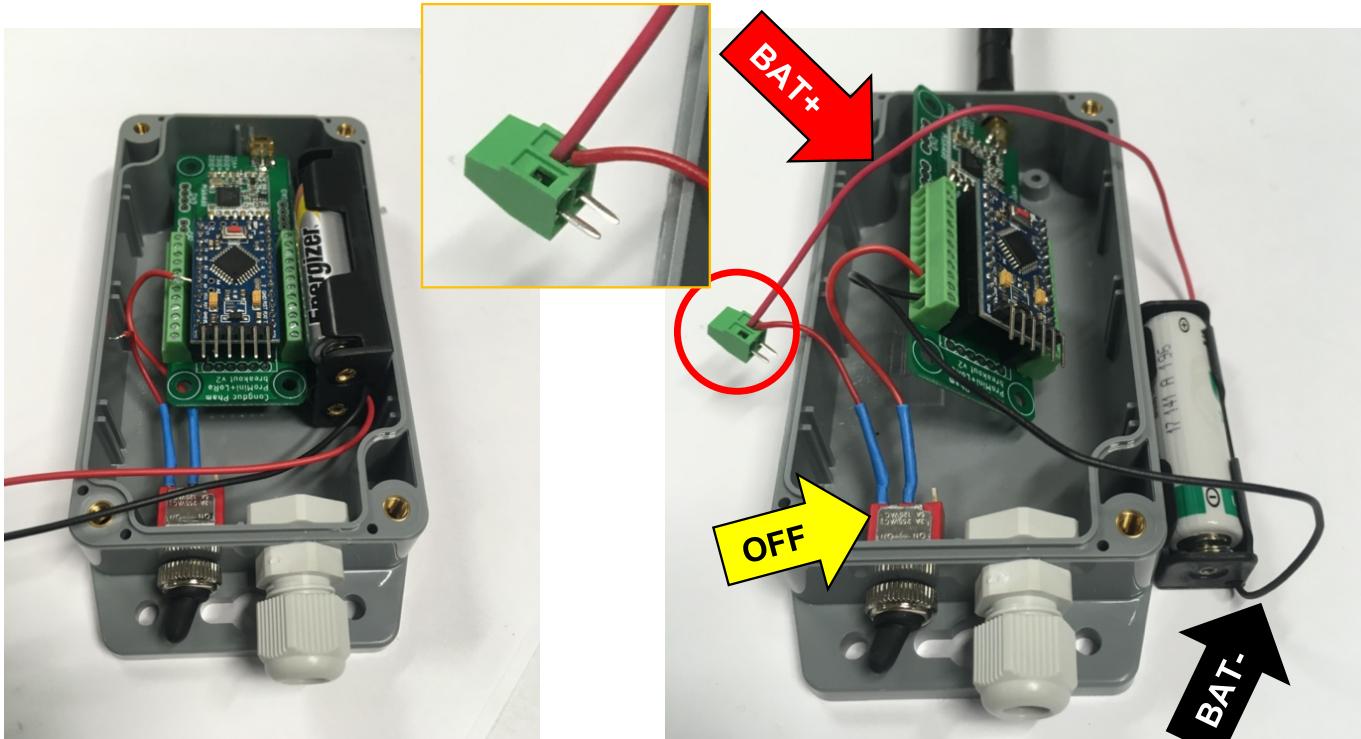


test that everything is OK

the switch has a water-proof cap

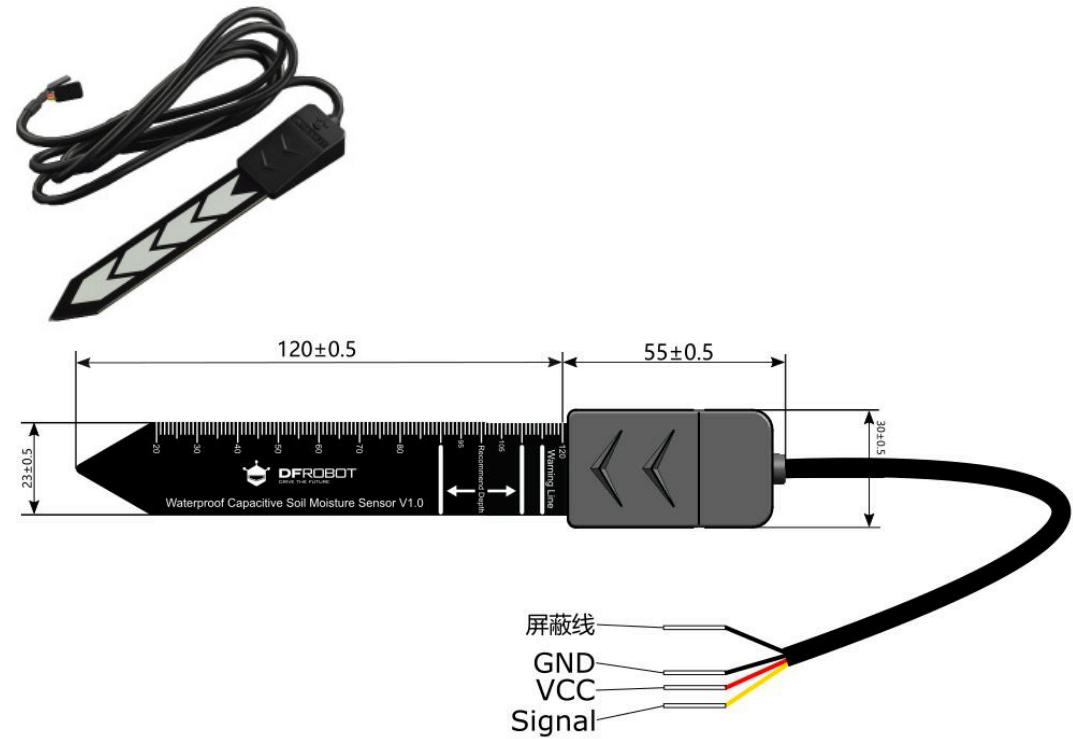


Connecting switch, battery & board



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

Wire the SEN0308 sensor

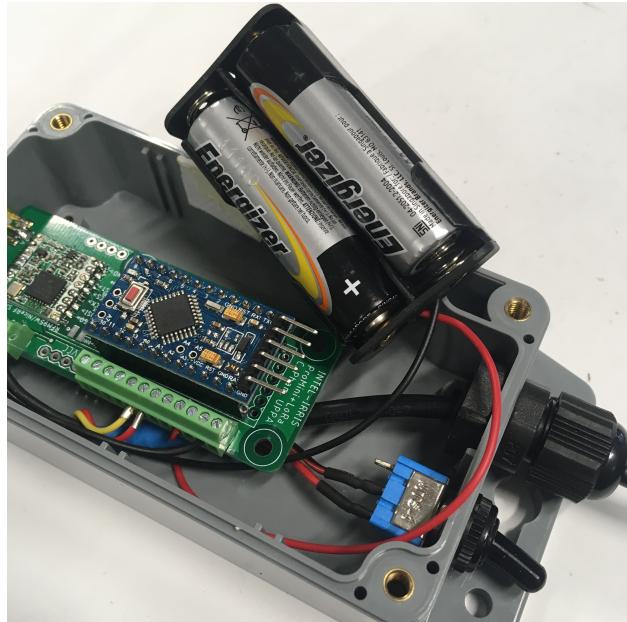


Insert sensor's wire through cable gland

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

Putting it altogether



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

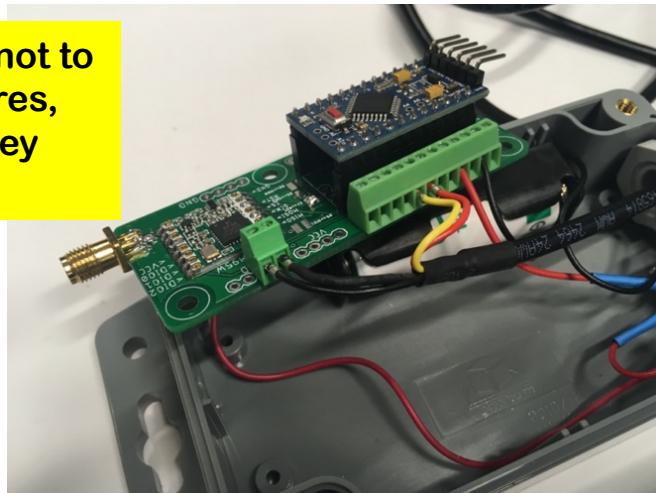
You can also use a 3.6V lithium battery with a 1-AA battery holder

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

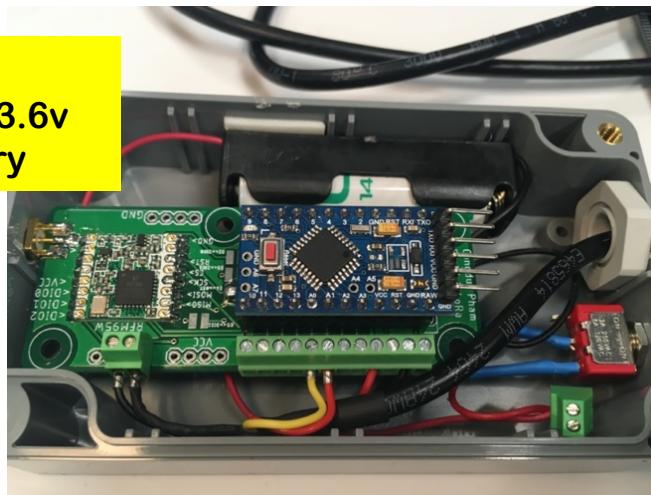


The complete soil sensor device

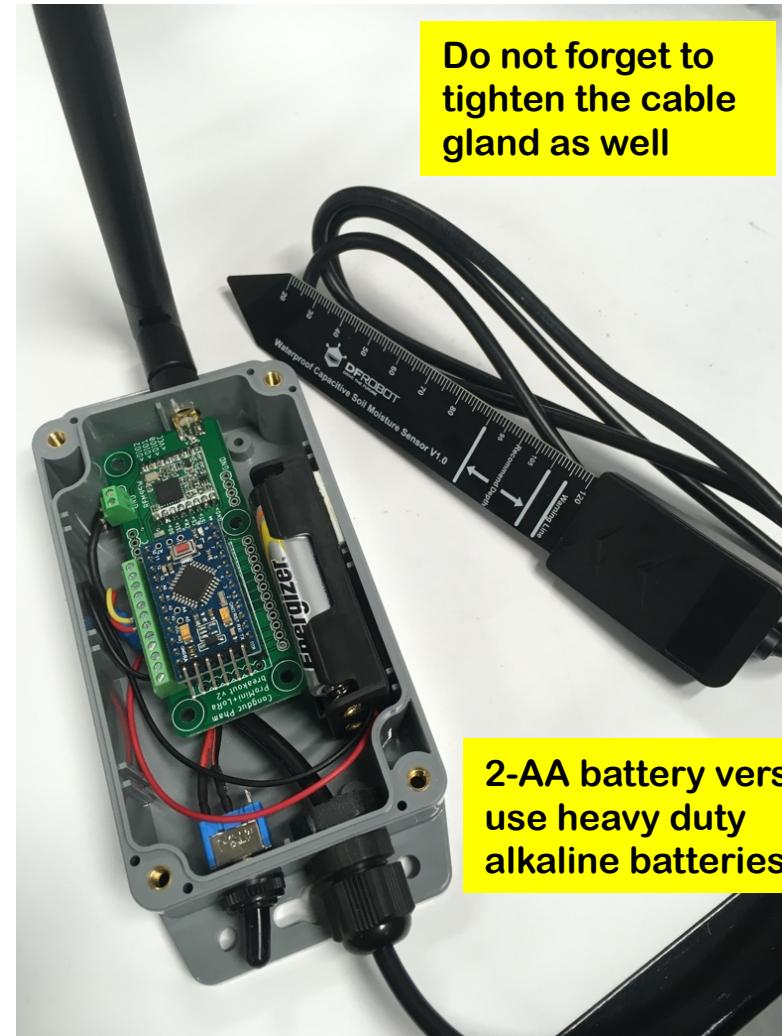
Tighten (but not too much!) all wires, check that they are not loose



1-AA battery version, use 3.6v lithium battery

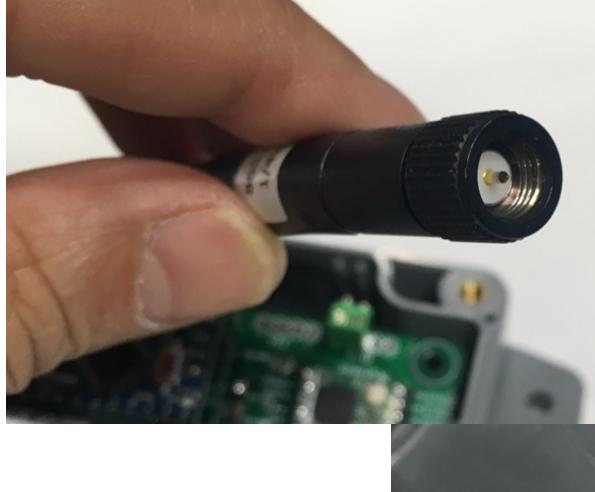


Do not forget to tighten the cable gland as well



2-AA battery version, use heavy duty alkaline batteries

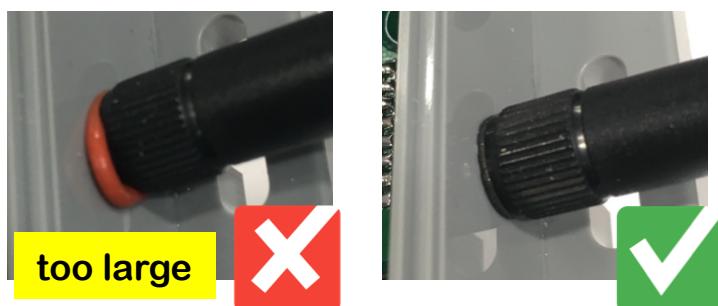
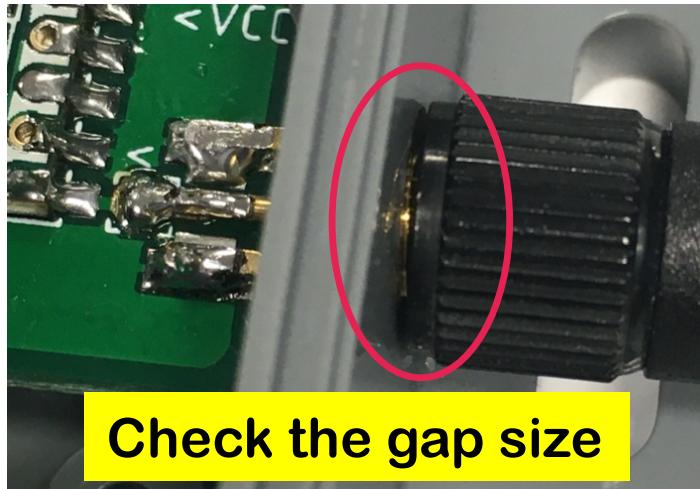
Connecting antenna



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

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 an o-ring 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!

There are o-ring for SMA connector but the gap size is an indication

Do not have or can not use o-ring?

Maybe the gap is too big? Use silicon joint sealant



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



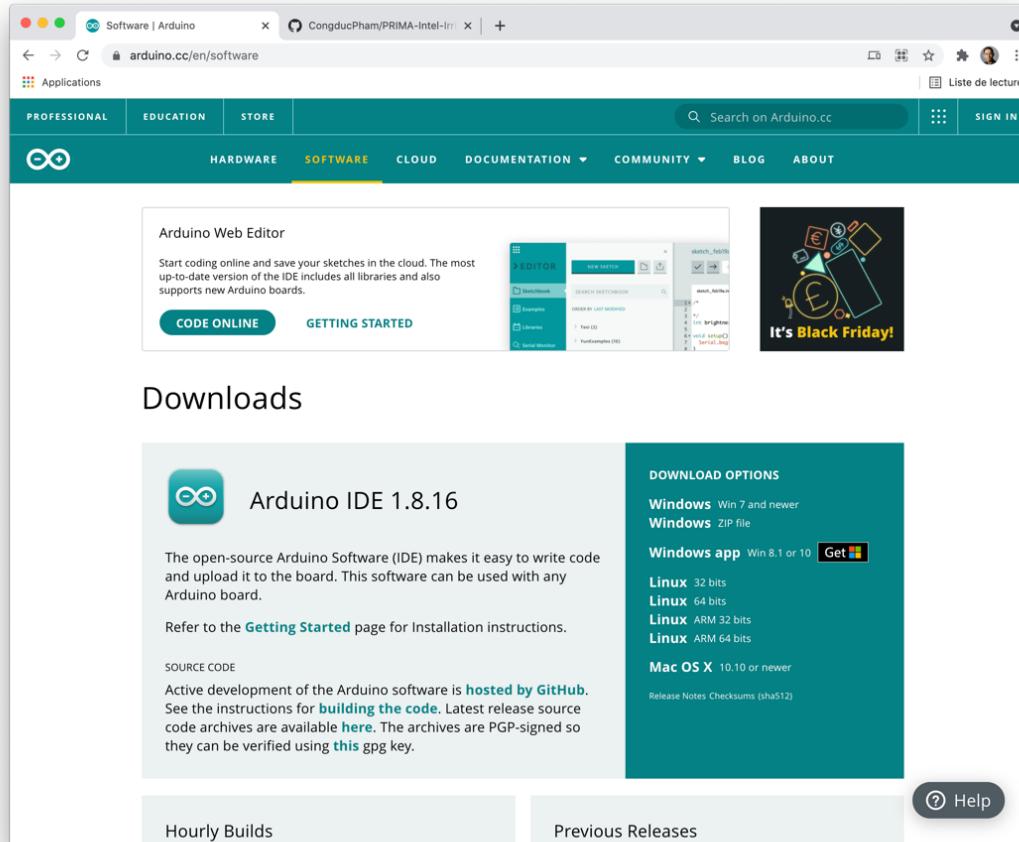
Use a wet toothpick to finish and clean the silicon all around the antenna junction



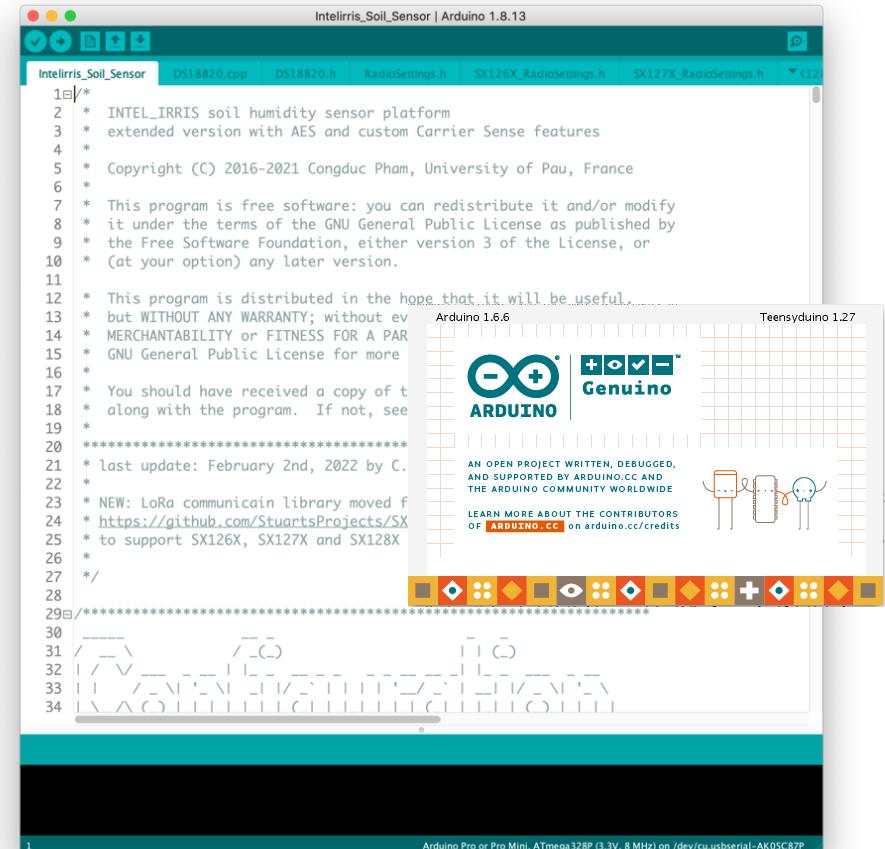
check especially
the back side

Even with o-ring, it is good to add silicon!

Getting the software: Arduino IDE



The screenshot shows the Arduino website's download section for the Arduino IDE 1.8.16. It features a large image of the IDE interface with a "It's Black Friday!" promotion. Below the image, there are two main download options: "CODE ONLINE" and "GETTING STARTED". The "GETTING STARTED" option leads to the installation instructions. On the right, there is a "DOWNLOAD OPTIONS" section with links for Windows (Win 7 and newer, ZIP file), Windows app (Get Microsoft Store), Linux (32 bits, 64 bits, ARM 32 bits, ARM 64 bits), and Mac OS X (10.10 or newer). There are also links for "Release Notes" and "Checksums (sha512)". At the bottom, there are links for "Hourly Builds" and "Previous Releases", and a "Help" button.



The screenshot shows the Arduino IDE interface with the sketch "Intelirris_Soil_Sensor" open. The code editor displays the following C++ code:

```

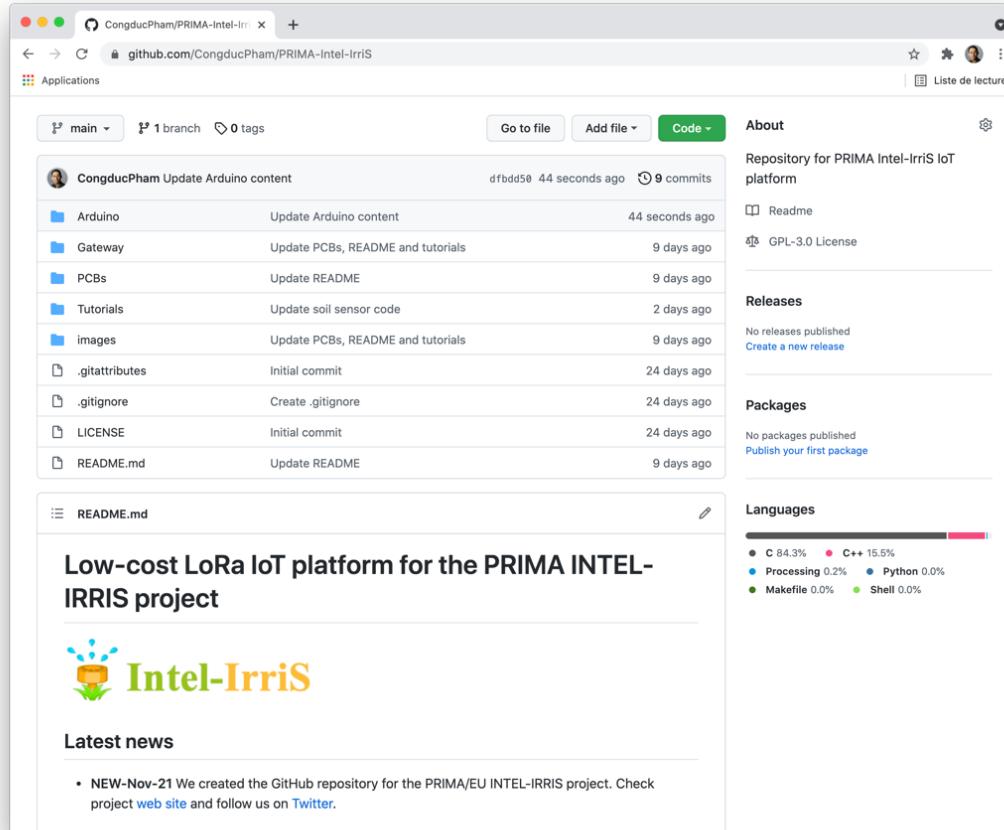
1 /*
2 * INTEL_IRRIS soil humidity sensor platform
3 * extended version with AES and custom Carrier Sense features
4 *
5 * Copyright (C) 2016-2021 Congduc Pham, University of Pau, France
6 *
7 * This program is free software: you can redistribute it and/or modify
8 * it under the terms of the GNU General Public License as published by
9 * the Free Software Foundation, either version 3 of the License, or
10 * (at your option) any later version.
11 *
12 * This program is distributed in the hope that it will be useful,
13 * but WITHOUT ANY WARRANTY; without even
14 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
15 * See the GNU General Public License for more details.
16 *
17 * You should have received a copy of the GNU General Public License
18 * along with the program. If not, see
19 *
20 */
21 * last update: February 2nd, 2022 by C.
22 *
23 * NEW: LoRa communication library moved from
24 * https://github.com/StuartsProjects/SX
25 * to support SX126X, SX127X and SX128X
26 *
27 */
28
29 */
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31 /--\ /--\
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34 | | | / \ | / \ |

```

The IDE interface includes tabs for "Intelirris_Soil_Sensor", "DS18B20.cpp", "DS18B20.h", "RadioSettings.h", "SX126X_RadioSettings.h", and "SX127X_RadioSettings.h". The status bar at the bottom indicates "Arduino Pro or Pro Mini, ATmega328P (3.3V, 8 MHz) on /dev/cu.usbserial-AK05C87P".

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

Getting the software: Intel-IrriS code

The screenshot shows the GitHub repository page for CongducPham/PRIMA-Intel-IrriS. The repository has 1 branch and 0 tags. The main commit is by CongducPham, updating Arduino content. The repository is described as a "Repository for PRIMA Intel-IrriS IoT platform". It includes a Readme, a GPL-3.0 License, and no releases or packages published. The Languages section shows C at 84.3%, C++ at 15.5%, Processing at 0.2%, Python at 0.0%, Makefile at 0.0%, and Shell at 0.0%. The README.md file describes the Low-cost LoRa IoT platform for the PRIMA INTEL-Irris project. The Intel-IrriS logo is present on the page.

On your computer, create a sketch folder

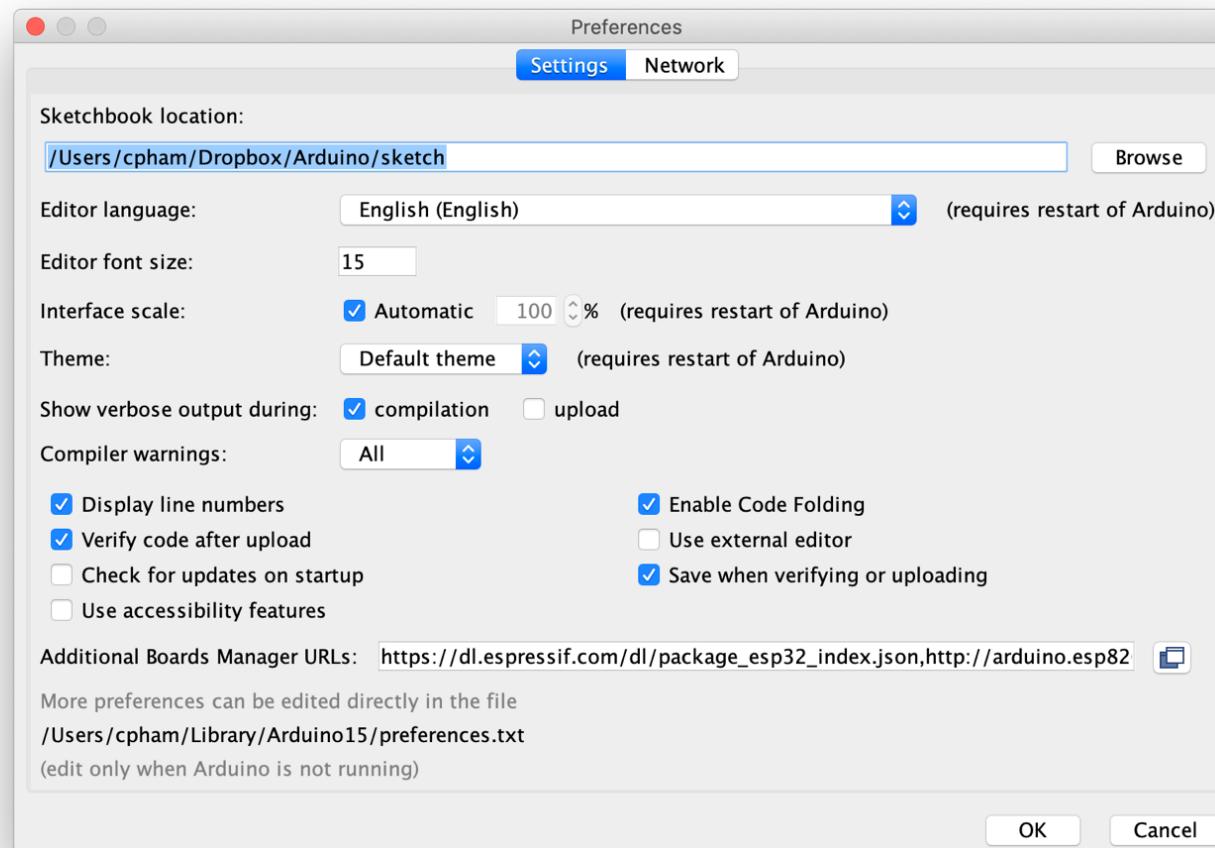
Then download the whole repository as ZIP file

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>

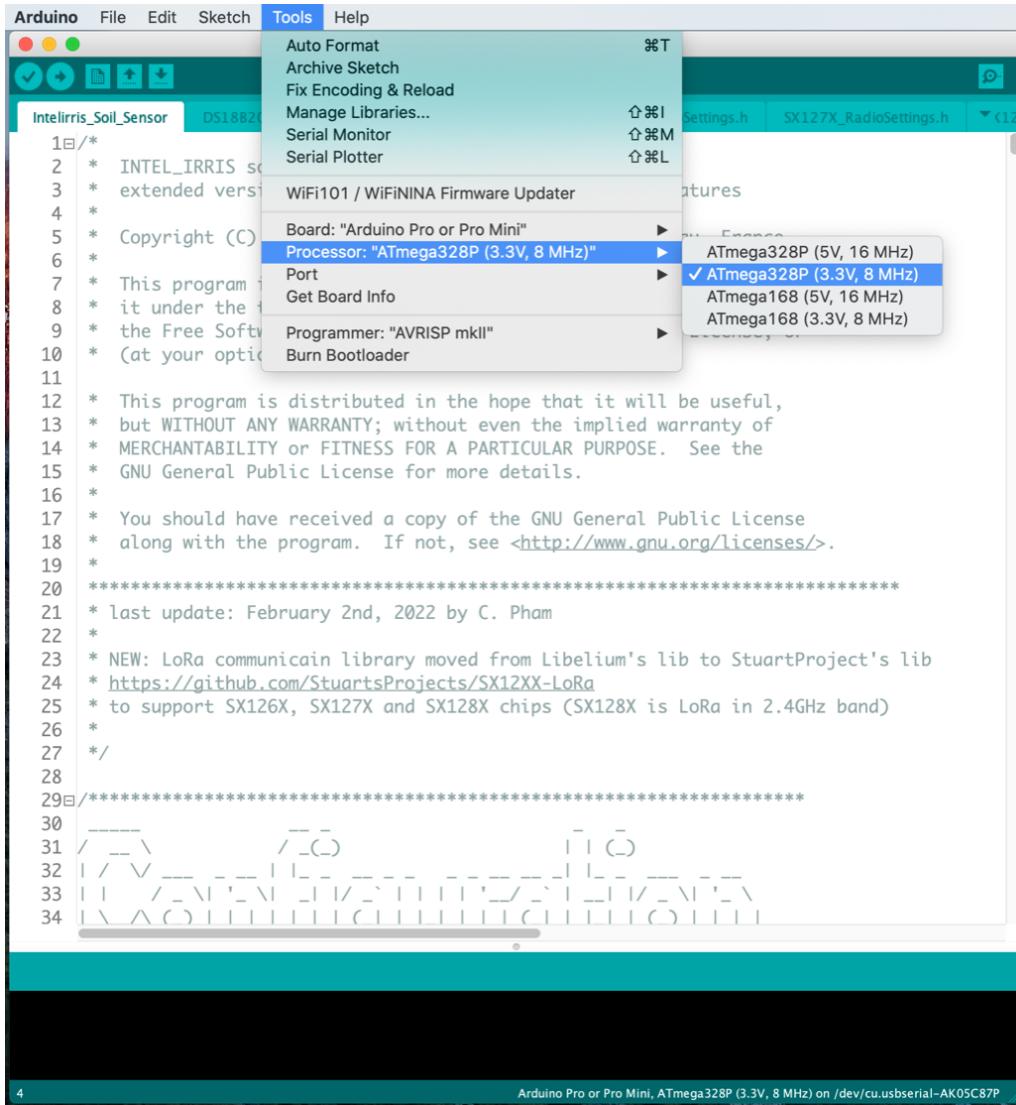


Setting your Arduino IDE



Run Arduino IDE, open Preferences
 Indicate your sketch folder in Sketchbook location

Compiling the soil sensor code

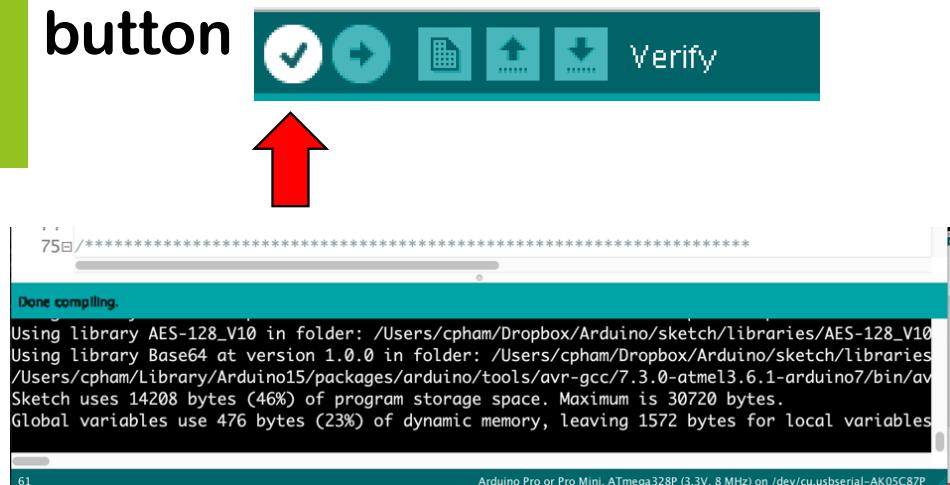


The screenshot shows the Arduino IDE interface. The sketch titled "Intelirris_Soil_Sensor" is open. The "Tools" menu is pulled down, showing various options like Auto Format, Archive Sketch, and Board selection. Under Board selection, it lists "Board: Arduino Pro or Pro Mini" and "Processor: ATmega328P (3.3V, 8 MHz)". This option is selected, indicated by a blue highlight and a checked checkbox. Other options shown include ATmega328P (5V, 16 MHz), ATmega168 (5V, 16 MHz), and ATmega168 (3.3V, 8 MHz). The main code area displays the source code for the soil sensor sketch, which includes comments about the ATmega328P processor and its 8MHz clock speed.

Open Intelirris_Soil_Sensor sketch – no change required

**Select the ProMini board,
3.3V and 8MHz version**

**Then click on the "verify"
button**

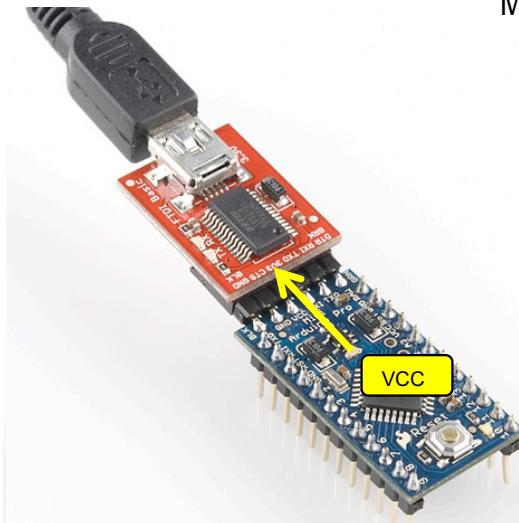




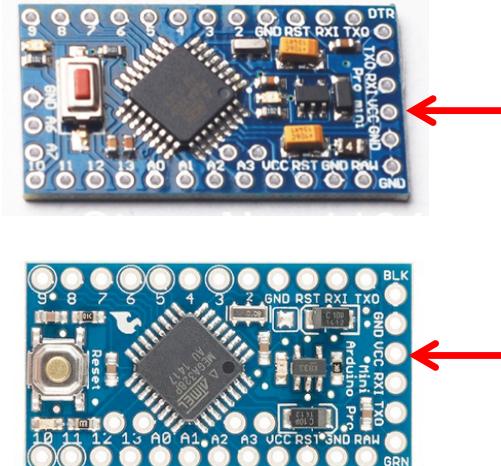
Never transmit without antenna

- 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

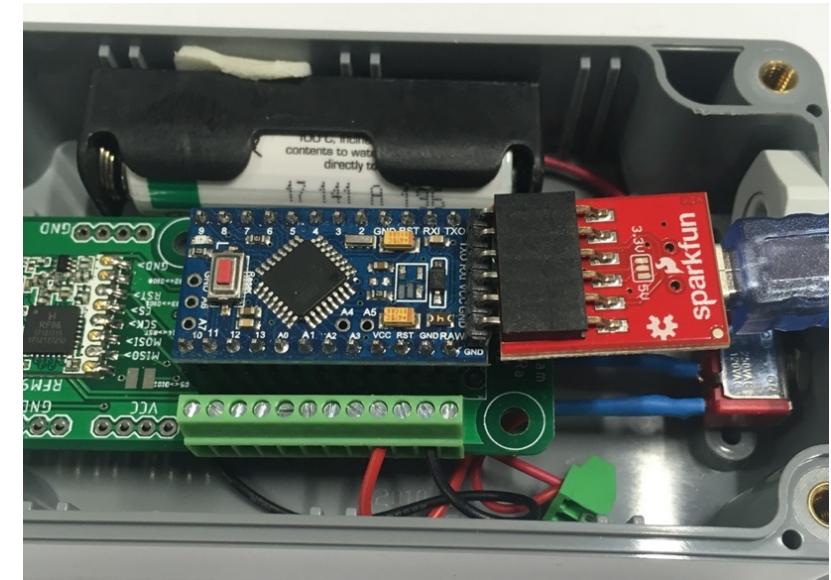
Connecting with an FTDI cable



Most Chinese clone version, check the VCC pin



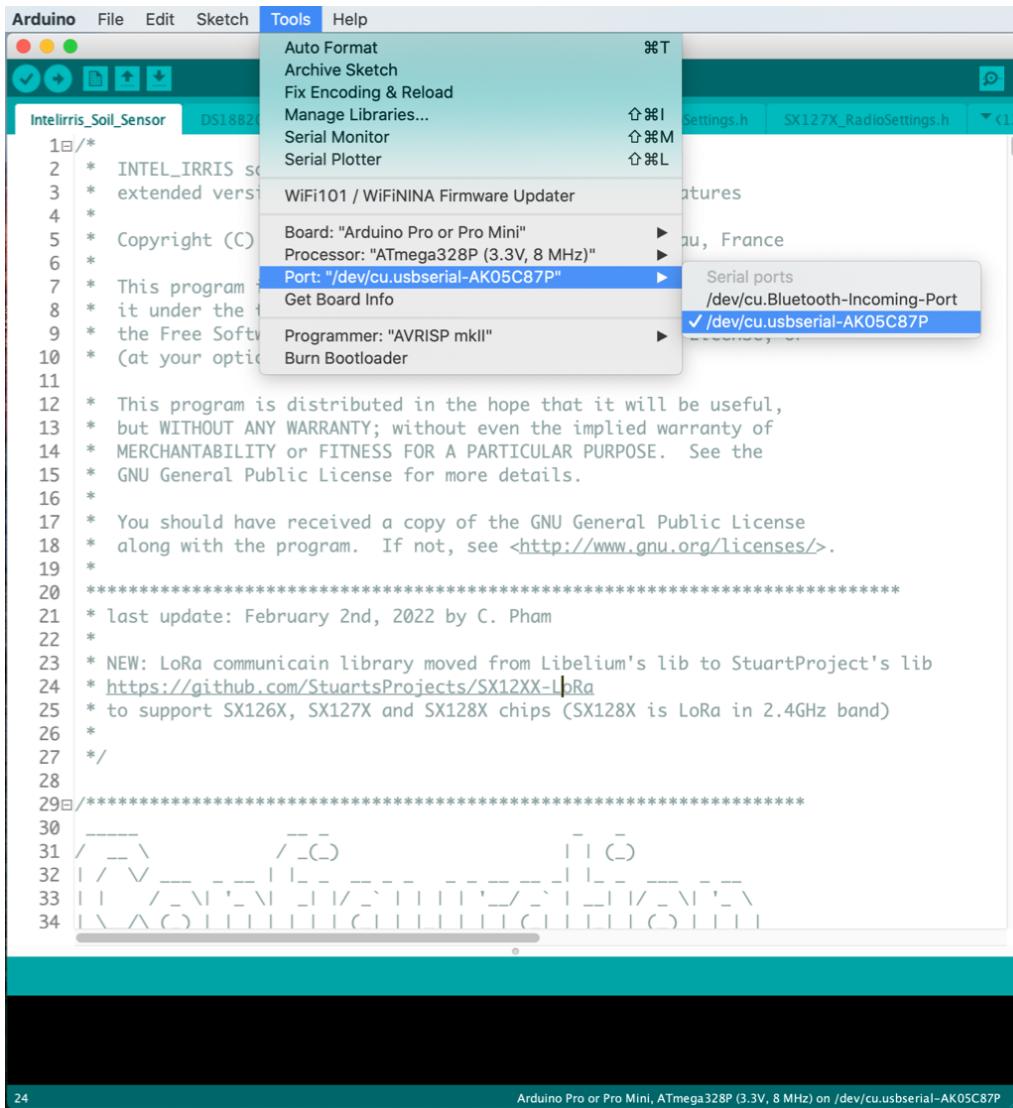
Original Sparkfun
version



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.

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>

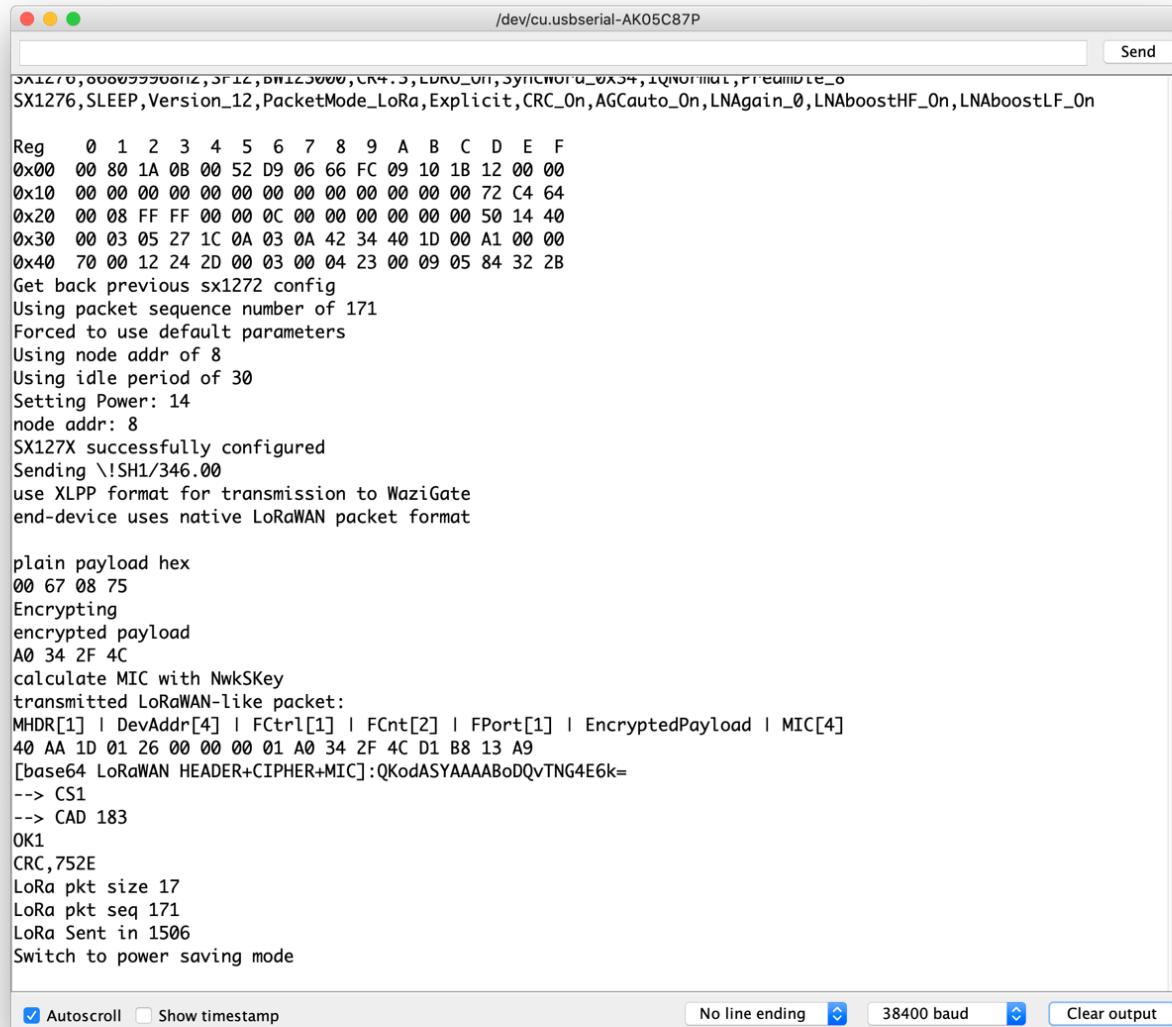
Click on the "upload" button



And wait until upload is completed

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```

Checking that device is operational



The screenshot shows a terminal window titled '/dev/cu.usbserial-AK05C87P'. The output displays the following information:

```

SX1276,0000000000000000,3F12,B0123000,CR4.5,LDRU_0H,SYNCHRO_0X34,TQNormal,Preamble_0
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 00 72 C4 64
0x20 00 08 FF FF 00 00 0C 00 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]:QKodASYAAABoDQvTNG4E6k=
--> 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 
  Clear output

```

Open serial monitor

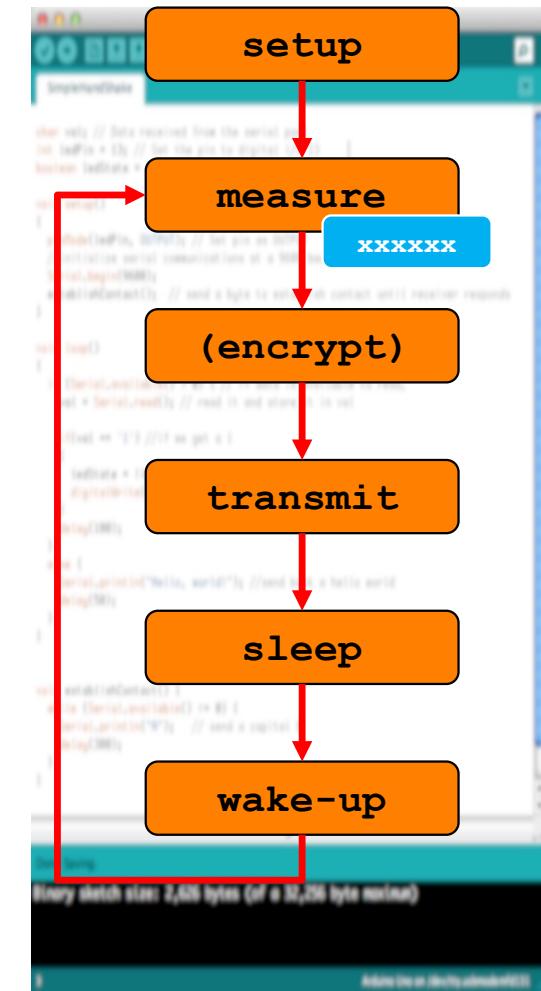
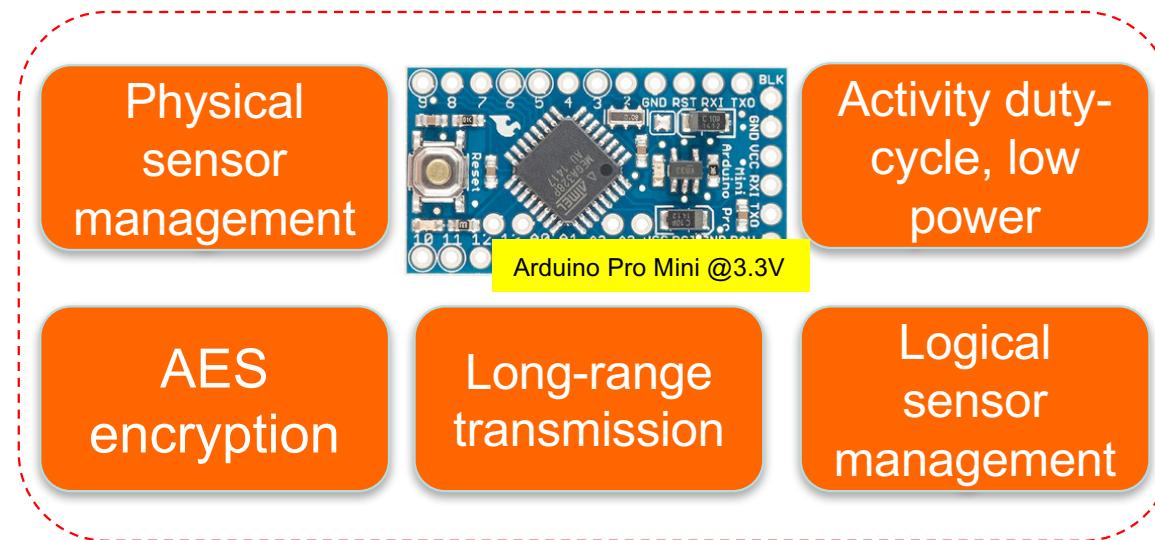
Set baud rate to 38400

See output from board

Check that transmission is OK

Generic & cyclic behavior

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



Transmission to WaziGate



Parameters for
INTEL-IRRIS WaziGate



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

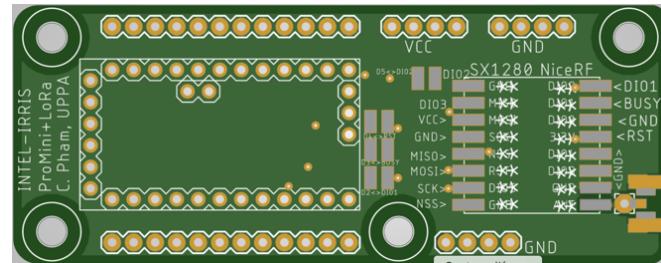


This dedicated video will show all these steps, from connecting the SEN0308 to testing transmission to the WaziGate
Video n°4: <https://youtu.be/j-1Nk0tv0xM>



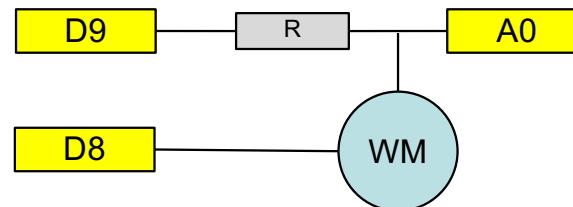
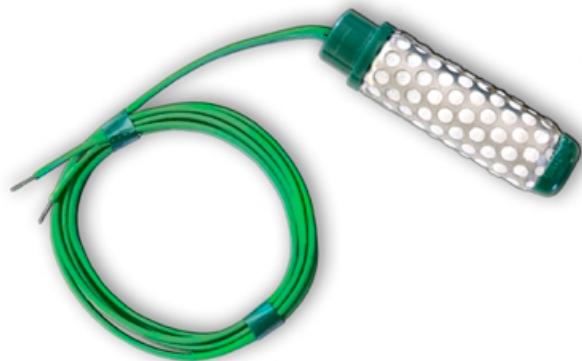
Advanced options

- 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

A0 will be used to read signal from sensor

R is a resistor from 7kOhms to 14kOhms

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

```
11 #define WATERMARKANALOG_SCALE _BOARD_MVOLT_SCALE
12 //put here the resistor value, in Ohms
13 #define WM_RESISTOR 10000
14 //we defined WM_MAX_RESISTOR=32760 because the transmitted value would be 32760/10=3276
15 //and currently a bug in WaziGate XLPP decoding code will limit the maximum value to 3276
16 #define WM_MAX_RESISTOR 32760
17
```

- 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 26011**DB1**
 1 msg/60mins
 1 sensor
 XLPP data



Soil temperature with the WM sensor

- Without a real temperature sensor, the Arduino code uses a default soil temperature set to 28°C to convert the resistance value into centibars

```
//////////  
// 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

2 versions of the soil device





Starter-kit

Autonomous

Intelligent Irrigation

Plug-&-Sense

In-the-box