

ETHERNET WEATHER STATION

The objective is to build a little weather station (temperature, atmospheric pressure). The data will be searchable via the Ethernet port. (web page Management). In addition, you will learn about NUCLEO STMicroelectronics cards while using the I²C protocol and Ethernet frame analysis.

1 NUCLEO STM32 cards	<ul style="list-style-type: none"> Discover NUCLEO boards. IDE ARDUINO installation.
2 NUCLEO programming	<ul style="list-style-type: none"> Get started with NUCLEO F429ZI card Leds and keys board control
3 MEMS et I ² C sensors	<ul style="list-style-type: none"> MEMS X-NUCLEO-IKS01A2 structural analysis LPS22HB temperature and pressure sensor implementation I²C analysis
4 Ethernet and WEB server	<ul style="list-style-type: none"> Static IP and DHCP Weather data access (TELNET) and Wireshark analysis WEB server

Work requested & answers to be completed on this document by inserting texts and images (screenshots) under the different questions.

1 NUCLEO STM32 BOARD

Discover NUCLEO boards.

Q1-1 From the document flstm32nucleo.pdf, what are the 3 ranges of NUCLEO cards?

<http://www.st.com/resource/en/flyer/flstm32nucleo.pdf>

Nucleo-64, Nucleo-144, Nucleo-32

Q1-2 What is the role of flash memory in a microcontroller?

https://fr.wikipedia.org/wiki/M%C3%A9moire_flash

La mémoire flash est une mémoire de masse à semi-conducteurs ré-inscriptible, c'est-à-dire une mémoire possédant les caractéristiques d'une mémoire vive mais dont les données ne disparaissent pas lors d'une mise hors tension. La mémoire flash stocke dans des cellules de mémoire les bits de données qui sont conservées lorsque l'alimentation électrique est coupée.

Q1-3 What are the main differences between these three NUCLEO ranges?

The number of I/O, the size of the flash memory and the peripherals differ.

Q1-4 The microcontroller used is a STM32F429ZI. Complete the information below

http://www.st.com/content/st_com/en/products/microcontrollers/stm32-32-bit-arm-cortex-mcus/stm32-high-performance-mcus/stm32f4-series/stm32f429-439.html?querycriteria=productId=LN1806

Caractéristiques	
Operating Frequency (MHz)	180
FLASH Size (kB)	2048
Internal RAM Size (kB)	256
Timers (16 bit)	12
Timers (32 bit)	2
A/D Converters (12bits)	24
D/A Converters (12 bit)	2
I/O	114
i2C	3
SPI	6
USART	4
UART	4
Additional Interfaces	Ethernet, SAI
Supply max Voltage (V)	3,6

IDE ARDUINO Installation

The whole procedure is indicated HERE <https://github.com/stm32duino/wiki/wiki>

Start by installing the Arduino IDE: <https://www.arduino.cc/en/Main/Software>

Finish CORE STM32 installation.

<https://github.com/stm32duino/wiki/wiki/Getting-Started>

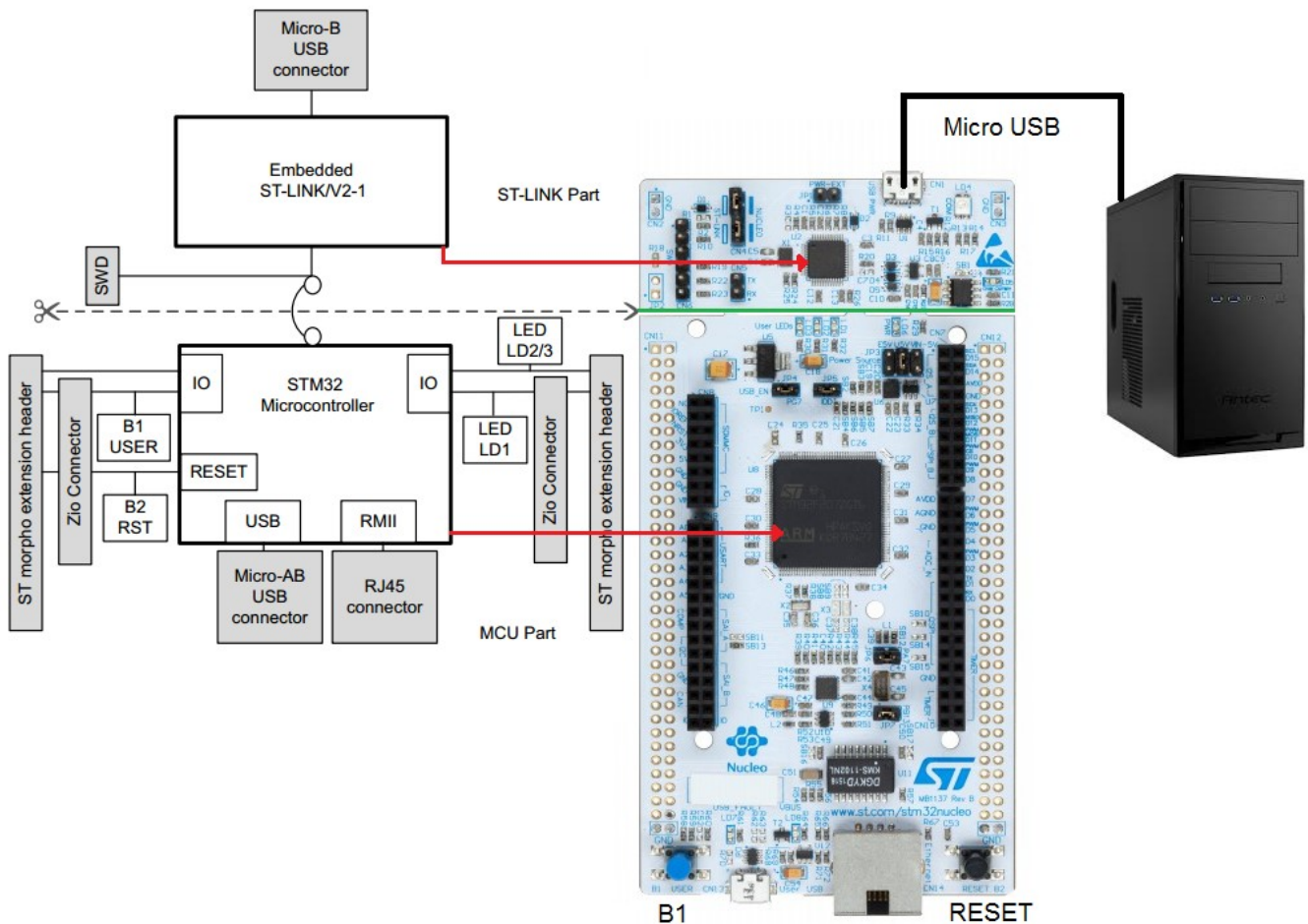
<https://github.com/stm32duino/wiki/wiki/Boards-Manager>

The list of supported NUCLEO cards is listed here:

https://github.com/stm32duino/Arduino_Core_STM32/blob/master/README.md#boards-available

2 NUCLEO programming

Get started with the NUCLEO F429ZI card



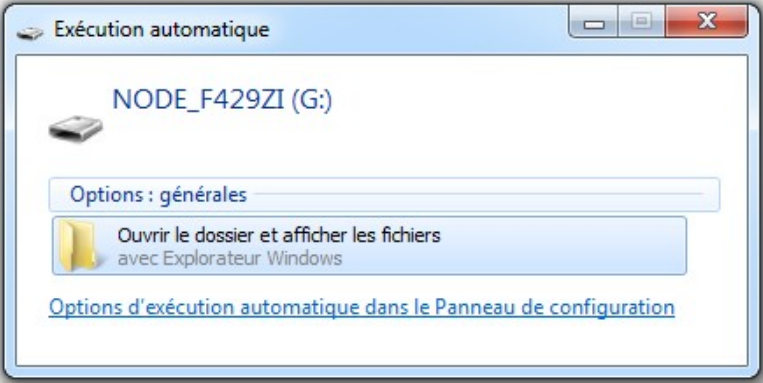
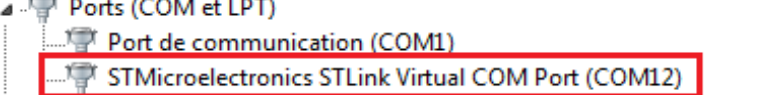
The NUCLEO F429ZI card has a breakable part. This is a programming interface called ST-LINK. It is included on all cards in the NUCLEO range, so there is no need to use a separate programmer.

Note on the nucleo cards drivers

When connecting a NUCLEO card to a PC, two drivers are needed

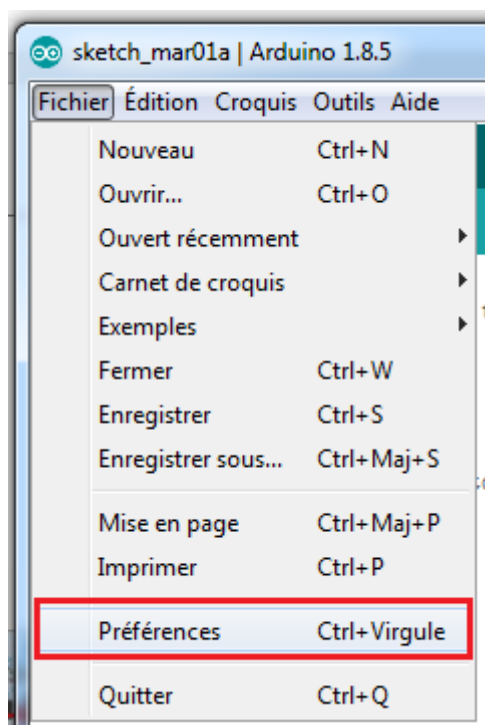
One is installed automatically, it is a USB mass Storage Device as for a USB key.

The other driver is the ST-LINK driver. In this case it will be necessary to install the driver manually.

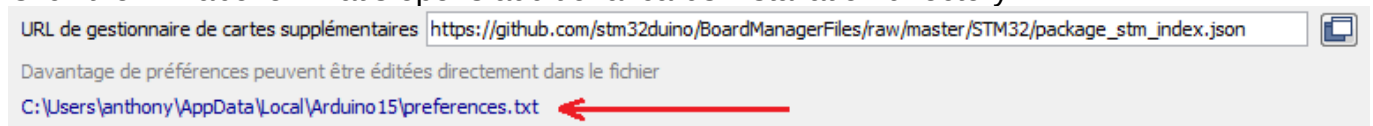
	<p>USB mass Storage Device.</p> <p>Automatic driver installation</p>
	<p>Manual driver installation from the Device Manager.</p>

Where is the ST-LINK driver ?

In the Arduino IDE, go to the "Preferences" menu



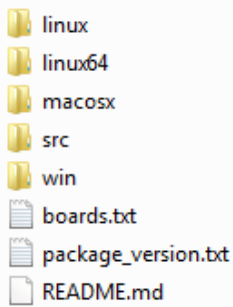
Click the link above. That's opens additional cards installation directory



Continue to browse directories and access tools

C:\Users\name\AppData\Local\Arduino15\packages\STM32\tools\STM32Tools\2017.9.22\tools

At this level, a choice is required depending on your operating system



For Windows:

C:\Users\name\AppData\Local\Arduino15\packages\STM32\tools\STM32Tools\2017.9.22\tools\win\stlink\ST-LINK_USB_V2_Driver

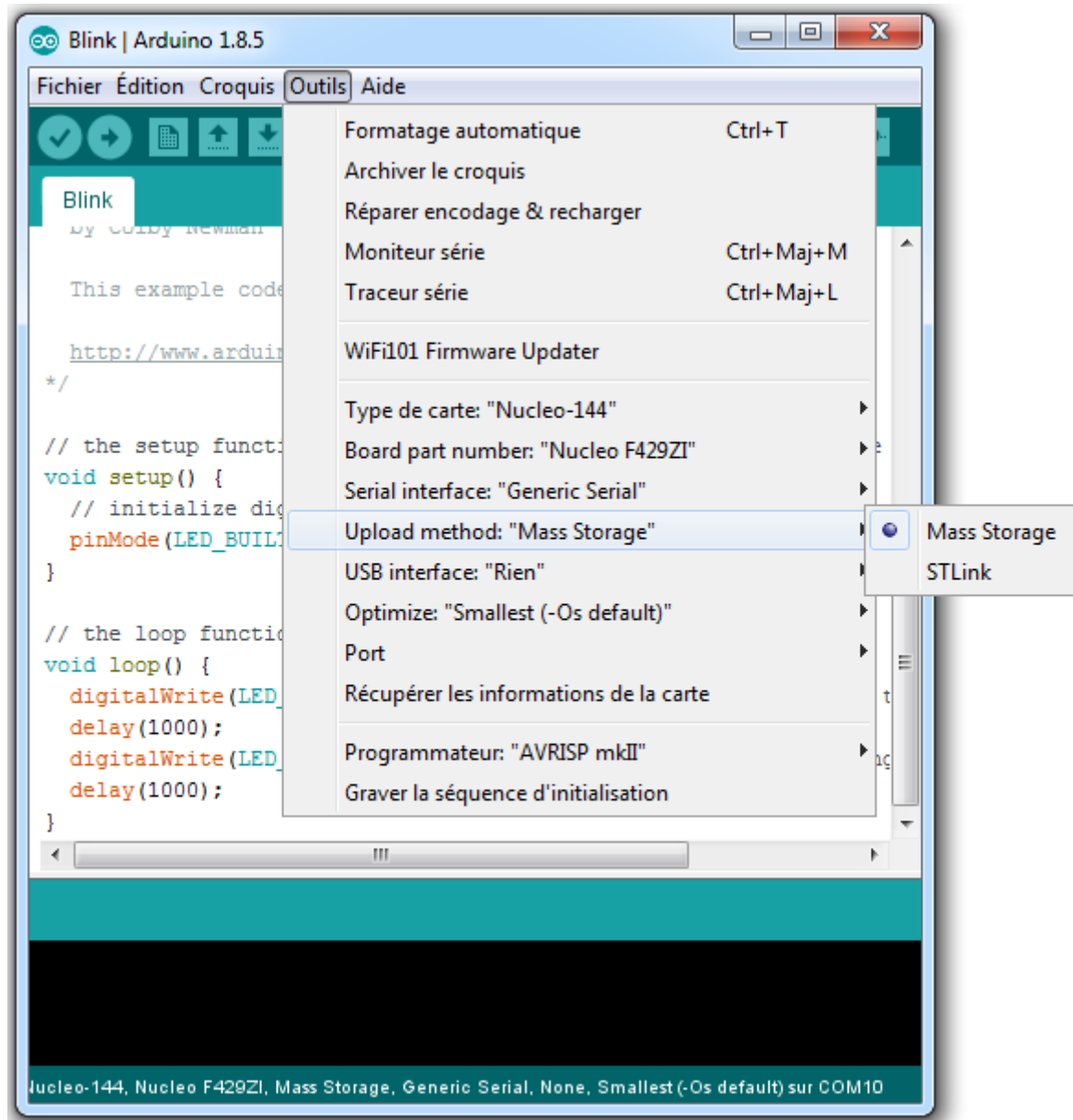
	In Device Manager, perform a manual installation by pointing this directory.
--	--

For Linux:

/home/name/.arduino15/packages/STM32/tools/STM32Tools/2017.9.22/tools/linux64

	<p>Run the install.sh script as root</p> <p>sudo bash install.sh</p>
--	--

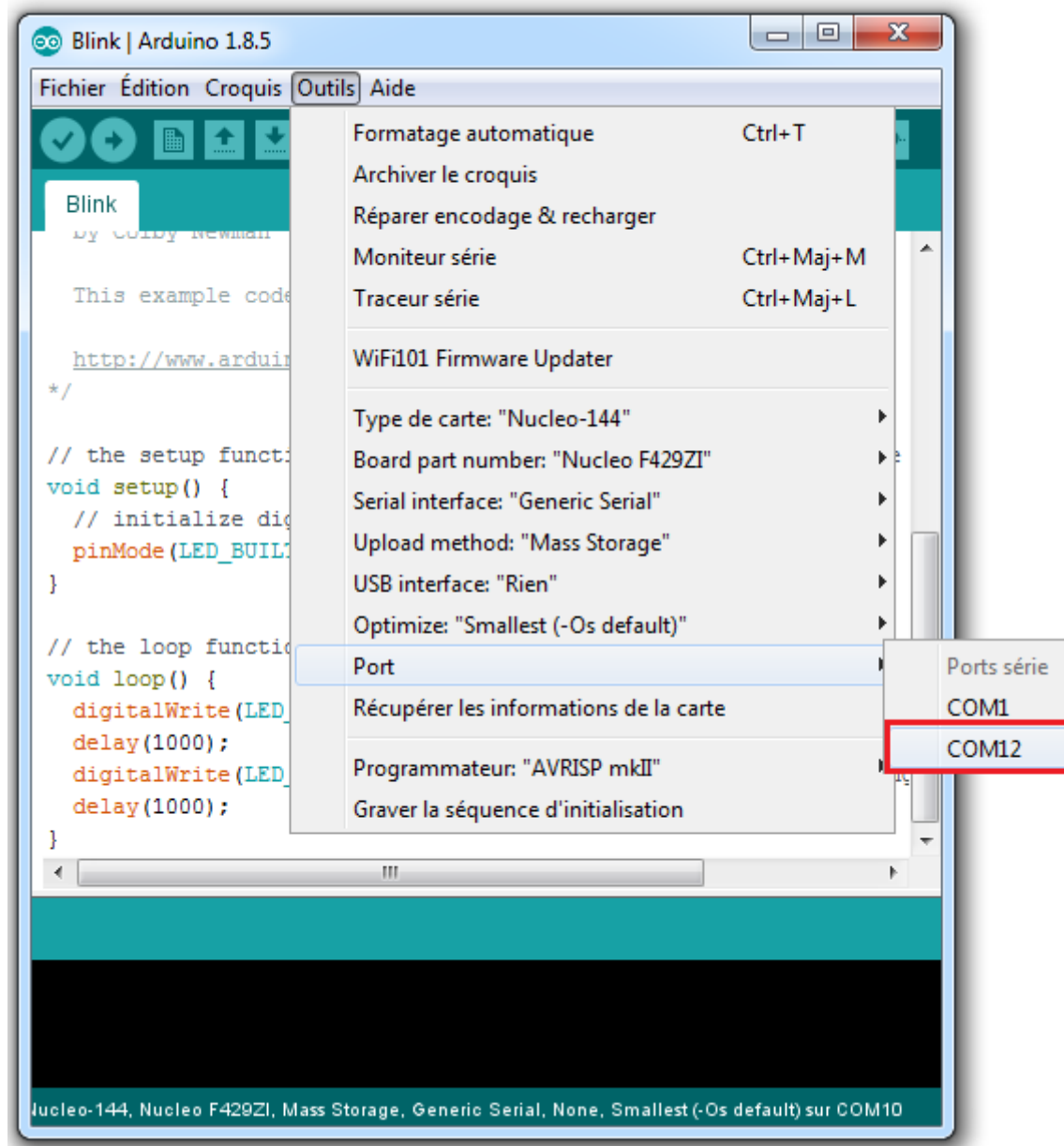
In the Arduino environment, configure the Tool menu as follows:



There are two modes of programming Mass Storage or STLink

Choose **Mass Storage** by default

Check that a communication port is installed correctly. (Other than COM1)



Under linux the communication port is named **tttyACM0**

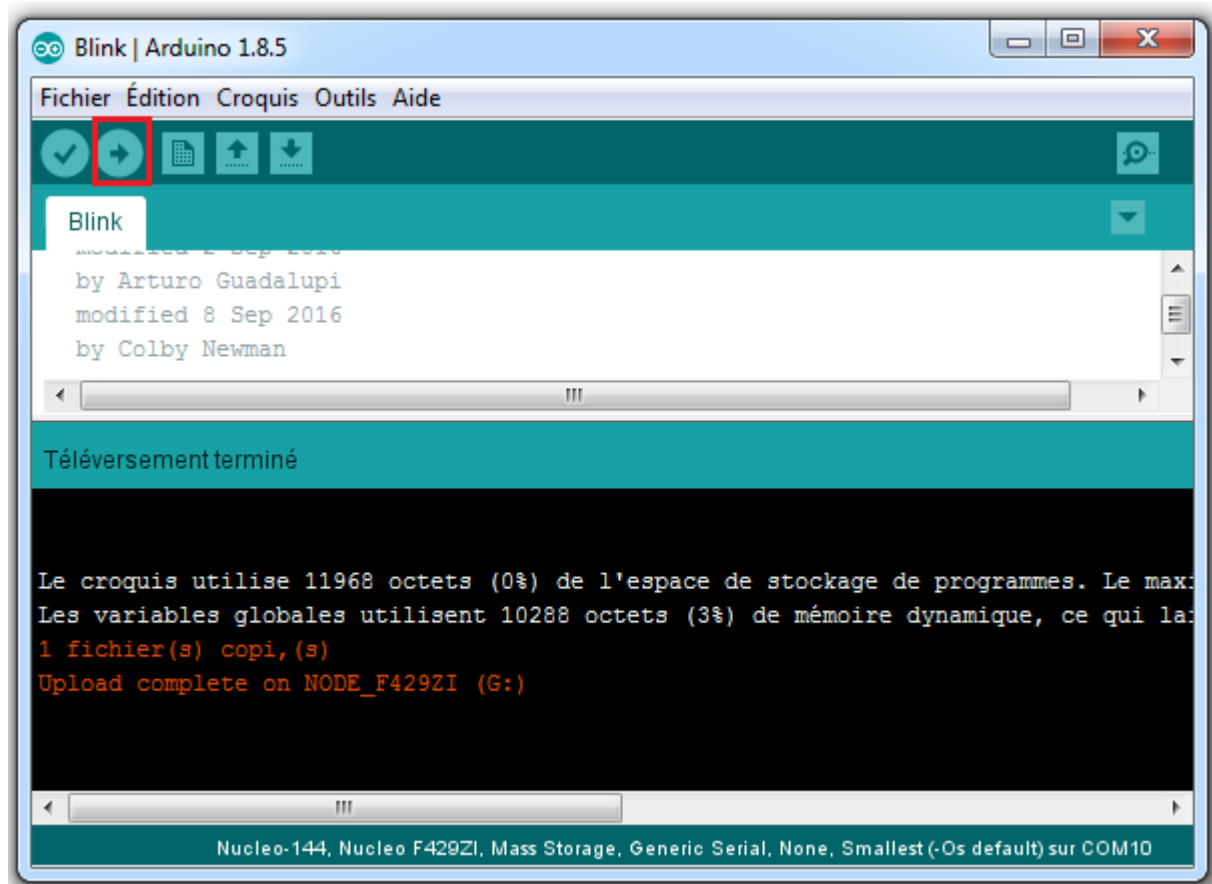
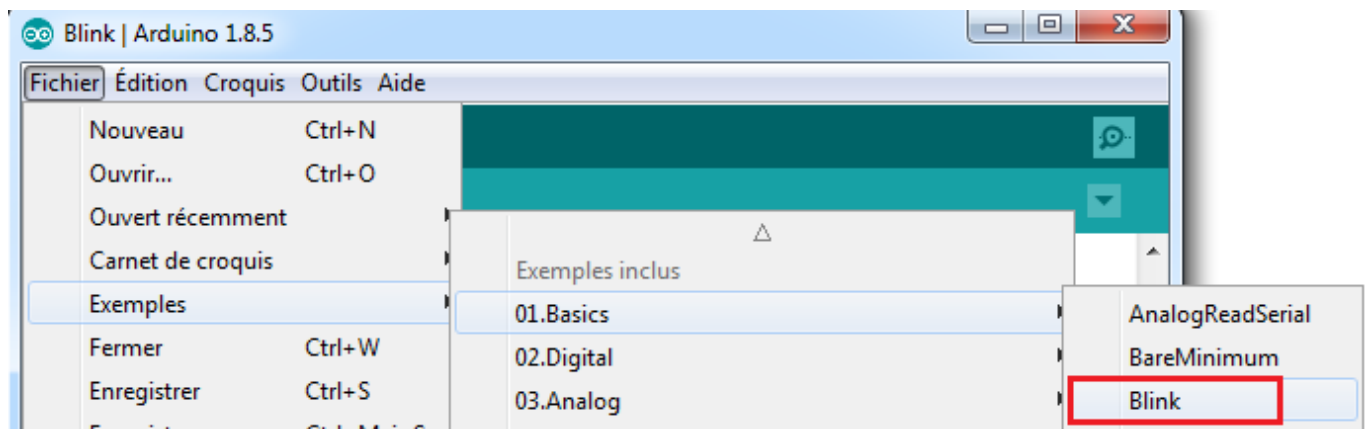
Dans la console taper :

ls /dev/ttyA*

/dev/ttyACM0 should appear.

LED and push button management

Load the "Blink" program from the examples

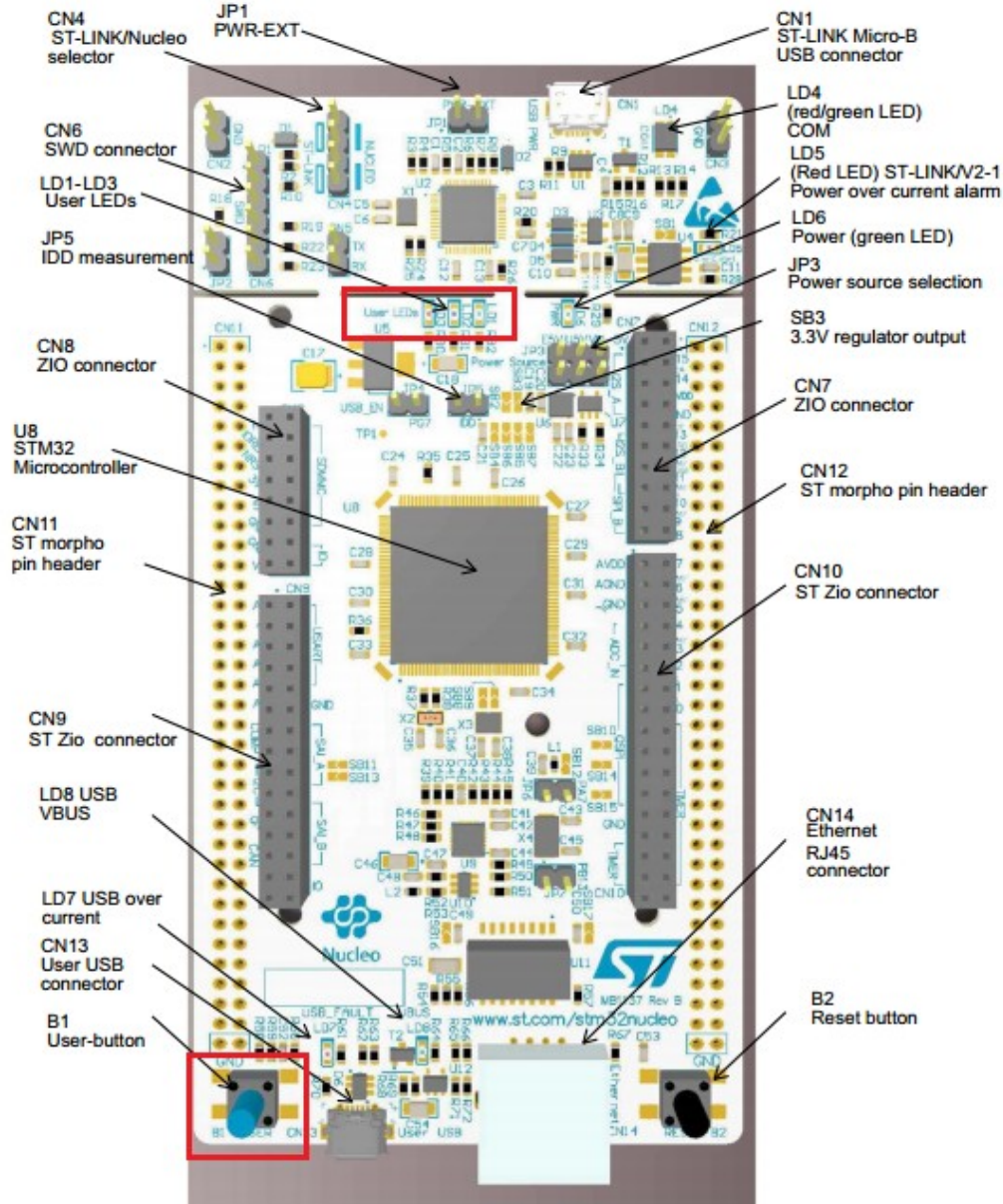


Led LD1 should flash every second.

Replace the `LED_BUILTIN` constant with `PB0`.

Once the program is uploaded. There must be no change.

Locate the LD1, LD2, LD3 LEDs and the User pushbutton on the board



Q2-1 Complete the following table:

Pxx : STM32 NUCLEO 144 input / output port, from the document en.DM00244518.pdf, pages 30-31 or in annex 1

http://www.st.com/resource/en/user_manual/dm00244518.pdf

Active level: low or high

	LD1	LD2	LD3	BP USER
Pxx	PB0	PB7	PB14	PB13
Active level	haut	haut	haut	haut
Led color	vert	bleu	rouge	

Q2-2 Find the 3 Leds and the push button in the structural diagram of the NUCLEO board

http://www.st.com/resource/en/schematic_pack/nucleo_144pins_sch.zip

Q2-3 Complete the following program to scroll through the 3 Leds

```
/*
scrolling leds
*/
#define LD1 PB0
#define LD2 PB7
#define LD3 PB14

void setup() {

    pinMode(LD1, OUTPUT);
    pinMode(LD2, OUTPUT);
    pinMode(LD3, OUTPUT );
}

void loop() {

    digitalWrite(LD1, HIGH);
    delay(100);
    digitalWrite(LD1, LOW);

    digitalWrite(LD2, HIGH);
    delay(100);
    digitalWrite(LD2, LOW);

    digitalWrite(LD3, HIGH);
    delay(100);
    digitalWrite(LD3, LOW);
}
```

Q2-4 What does the following program do?

```
/*
Bp user test
*/
#define LD1 PB0
#define BPUSER PC13

byte bpUserState;

void setup() {
    pinMode(LD1, OUTPUT);
    pinMode(BPUSER, INPUT);
}

void loop() {
    bpUserState = digitalRead(BPUSER);
    if (bpUserState == 1) {
        digitalWrite(LD1, HIGH);
    }
    else
    {
        digitalWrite(LD1, LOW);
    }
}
```

If the push button is pressed, LED LD1 light on

Q2-5 Modify the previous program in order to scroll LD1, LD2 and LD3 LEDs in the green, blue, red direction when the USER pushbutton is released then in the red, blue, green direction when the USER push button is pressed.

Q2-6 What does the following program do?

Do not forget to open the serial monitor  on the right port (COMx ou ttyACM0)

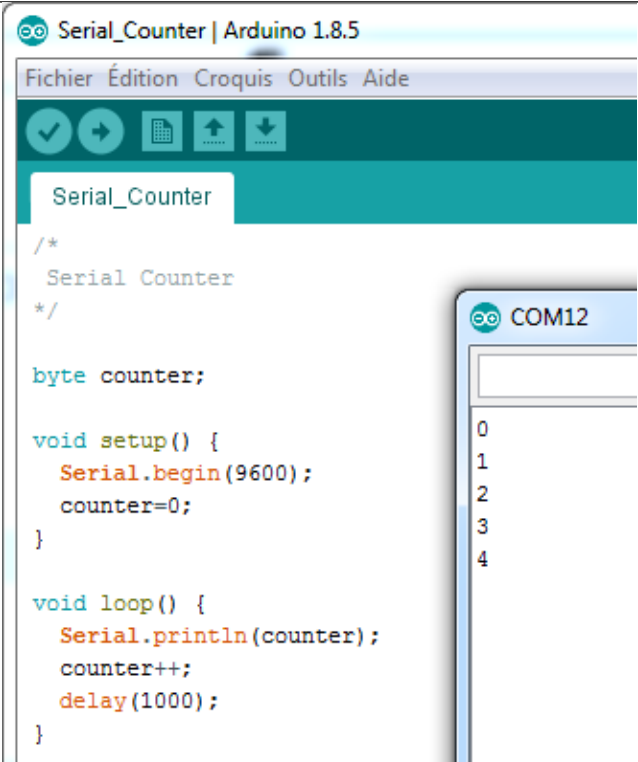
Moniteur série

```
/*
Serial Counter
*/

int counter;

void setup() {
  Serial.begin(9600);
  counter=0;
}

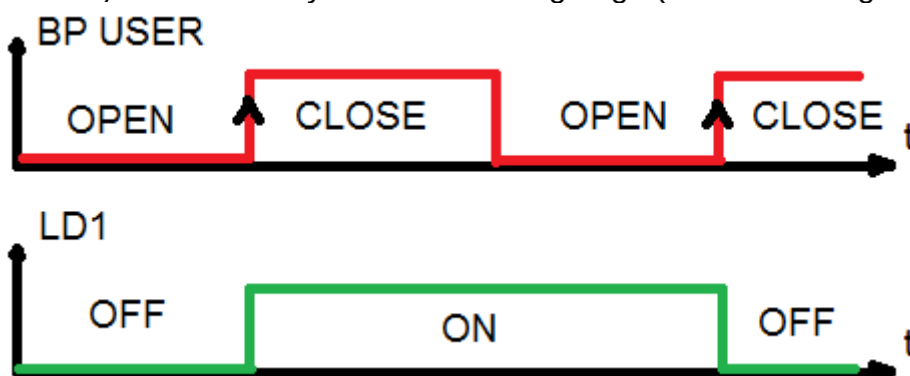
void loop() {
  Serial.println(counter);
  counter++;
  delay(1000);
}
```



The program increment a counter variable every second and displays this variable one the serial monitor.

Q2-7 Modify the previous program to increment the variable when pressing the USER pushbutton. Then display this variable on the serial monitor. Each time the push button is pressed, the LED LD1 changes state.

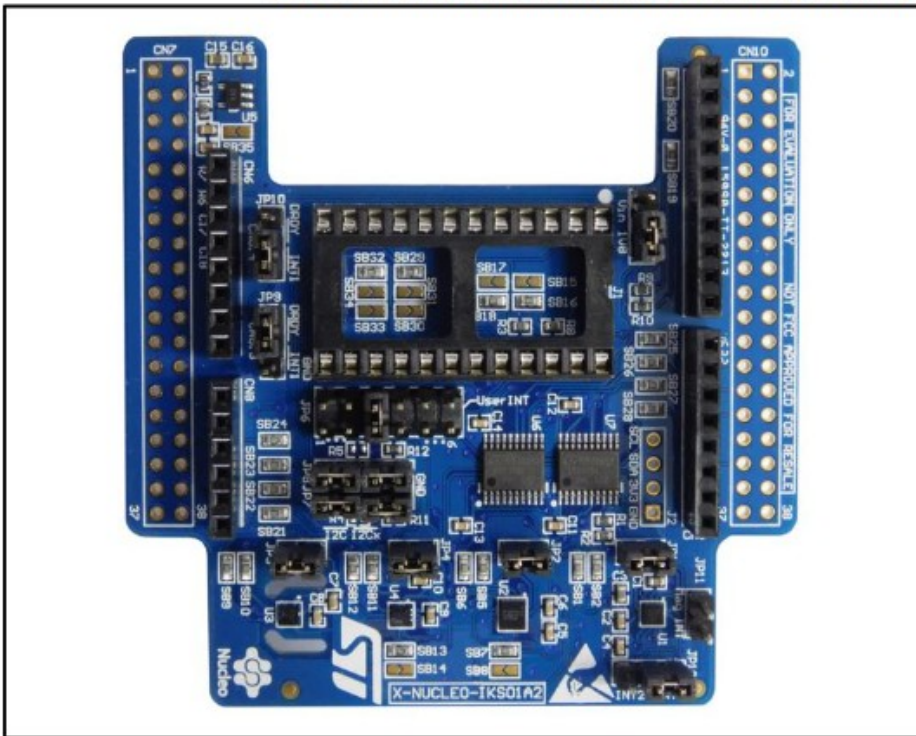
Beware, it is necessary to detect a rising edge (low level to high level)



3 MEMS et I²C Senor

x-nucleo-iks01a2 Shield board

X-NUCLEO-IKS01A2 expansion board (sheild)



Q3-1 Define a **MEMS** using the following links

https://players.brightcove.net/618591172001/rydXtRRN_default/index.html?videoId=2289006872001

<http://www.st.com/en/mems-and-sensors.html>

https://fr.wikipedia.org/wiki/Microsyst%C3%A8me_%C3%A9lectrom%C3%A9canique

the term microelectromechanical systems is the French version of the acronym MEMS (microelectromechanical systems). A MEMS is a microsystem comprising one or more mechanical elements, using electricity as a source of energy, in order to perform a sensor function.

MEMS X-NUCLEO-IKS01A2 structural analysis

Q3-2 From dm00333132.pdf (page1), what are the 4 sensors used on the Sheild map? Specify their functions.

http://www.st.com/resource/en/user_manual/dm00333132.pdf

- LSM6DSL accelerometer and 3D gyroscope
- LSM303AGR 3D accelerometer and 3D magnetometer
- HTS221 humidity and temperature sensor
- LPS22HB pressure sensor

Q3-3 From the document x-nucleo-iks01a2_schematic.pdf, associate the reference of the 4 sensors with U1, U2, U3 and U4. Locate the sensors on the schematic.

http://www.st.com/resource/en/schematic_pack/x-nucleo-iks01a2_schematic.pdf

U1	U2	U3	U4
LSM303AGR	LSM6DSL	HTS221	LPS22HB

Q3-4 What is the role of jumper JP1, JP2, JP3 and JP4? justify.

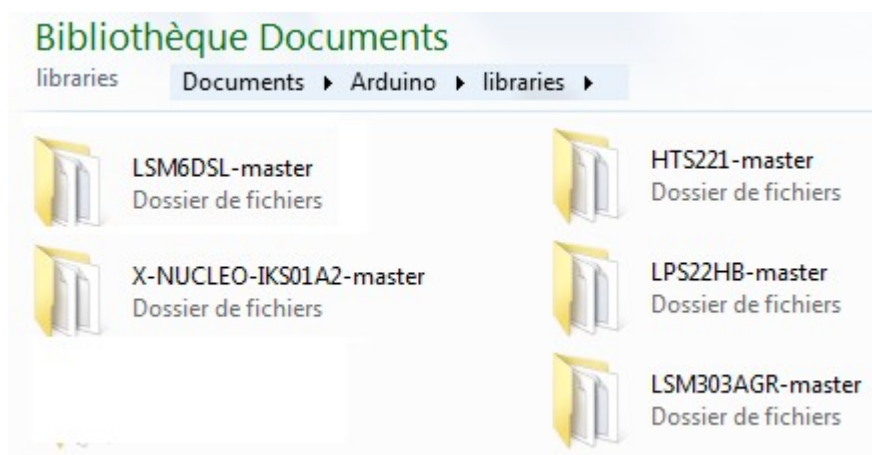
The rôle of the jumpers is to feed or not the integrated circuits U1, U2, U3 and U4. This will reduce the consumption of the shield card if not all sensors are used

Libraries Installation

Ci-dessous les liens vers les librairies ainsi que les documentations STM des 4 capteurs.

https://github.com/stm32duino/LSM6DSL	www.st.com/resource/en/datasheet/lsm6dsl.pdf
https://github.com/stm32duino/LSM303AGR	www.st.com/resource/en/datasheet/lsm303agr.pdf
https://github.com/stm32duino/HTS221	www.st.com/resource/ja/datasheet/hts221.pdf
https://github.com/stm32duino/LPS22HB	www.st.com/resource/en/datasheet/dm00140895.pdf
https://github.com/stm32duino/X-NUCLEO-IKS01A2	

Directory Content C:\Users\name\Documents\Arduino\libraries



Temperature and pressure sensor LPS22HB Implementation

Q3-5 What does the following program do?

Do not forget to open the serial monitor  on the right port (COMx ou ttyACM0)

Moniteur série

and at the right speed.

```
/**
 * temp_Pressure_LPS22HB
 */

#include <LPS22HBSensor.h>
#define sync 13

LPS22HBSensor *PressTemp;

void setup() {
  // Led.
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(sync, OUTPUT);

  // Initialize serial for output.
  Serial.begin(115200);

  // Initialize I2C bus.
  Wire.begin();

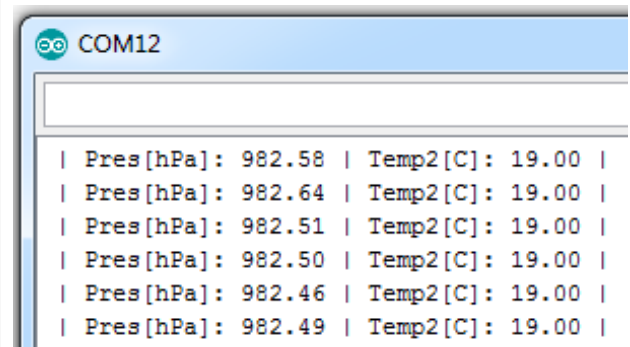
  // Initialize components.

  PressTemp = new LPS22HBSensor (&Wire);
  PressTemp->Enable();
}

void loop() {
  // Led blinking.
  digitalWrite(LED_BUILTIN, HIGH);
  delay(250);
  digitalWrite(LED_BUILTIN, LOW);
  delay(250);

  // Read pressure and temperature.
  float pressure, temperature;
  digitalWrite(sync, HIGH);
  PressTemp->GetPressure(&pressure);
  PressTemp->GetTemperature(&temperature);
  digitalWrite(sync, LOW);

  // Output data.
  Serial.print(" | Pres[hPa]: ");
  Serial.print(pressure, 2);
  Serial.print(" | Temp[C]: ");
  Serial.print(temperature, 2);
  Serial.println(" |");
}
```



Pres[hPa]	Temp2[C]
982.58	19.00
982.64	19.00
982.51	19.00
982.50	19.00
982.46	19.00
982.49	19.00

This program

I²C communication analysis

In order to understand the I²C bus communication, it is necessary to obtain a logic analyzer.

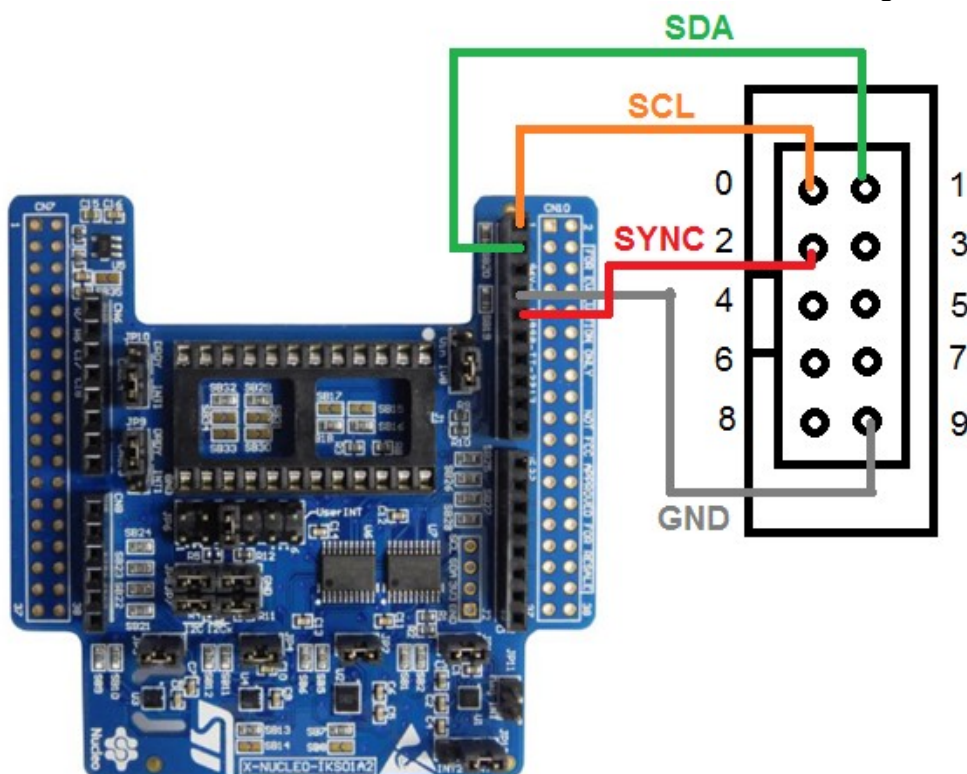


The Saleae analyzer is available on ebay

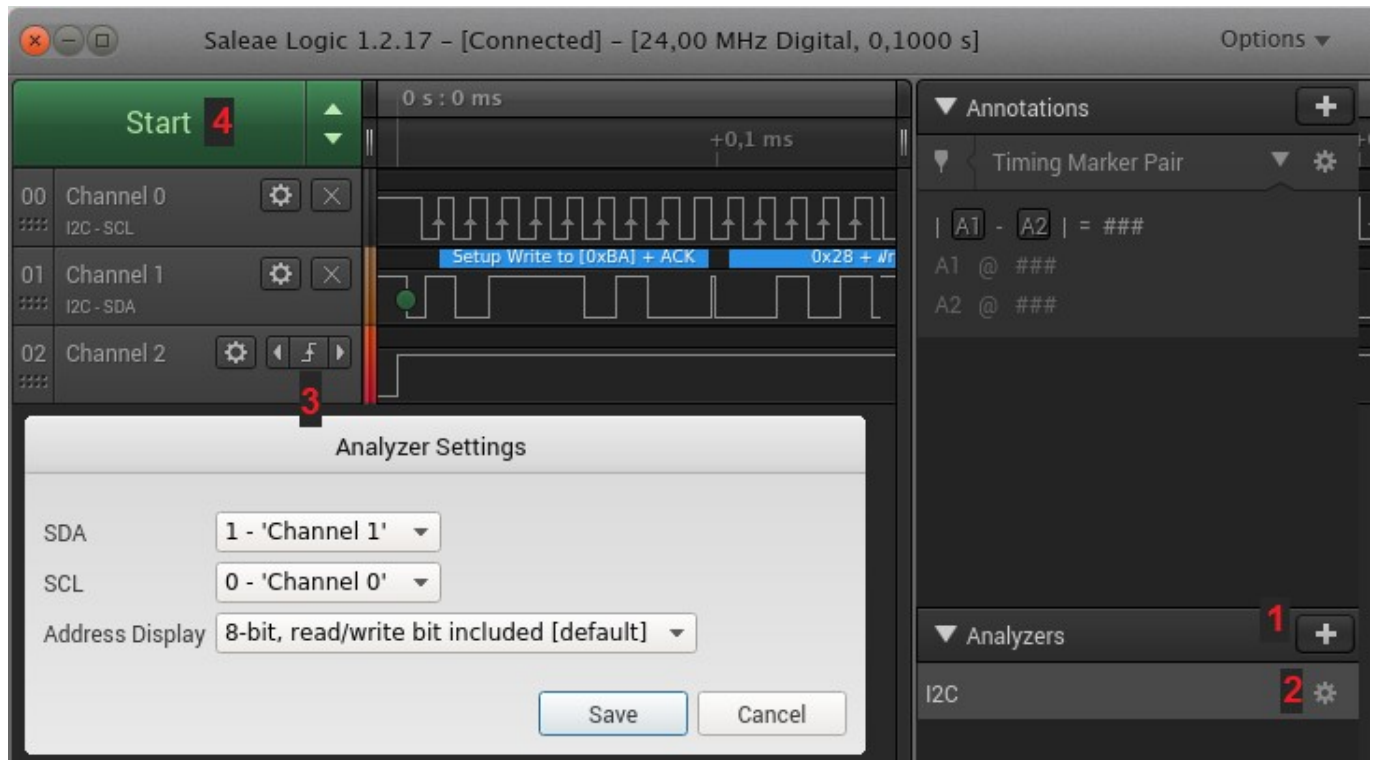
<https://www.ebay.fr/itm/24MHz-8CH-USB-Logic-Analyzer-8-Channel-Logic-Analyzer-Compatible-to-Saleae/172316908968>

The software is downloadable at the following address: <https://www.saleae.com/fr/downloads>

The I²C bus is on the CN5 shield card connector. **Connect** the logic analyzer as follows:



Configure the Saleae software as shown in the screenshot below:



- 1- Add the I²C analysis protocol
- 2- Configure the I²C bus on channel 0 for SCL, 1 for SDA.
- 3- Set a rising edge on channel 2
- 4- Start an acquisition (Start)

Q3-6 What is the logical level of the U4 CS input, cavalier SB13 (LPS22HB) ?

http://www.st.com/resource/en/schematic_pack/x-nucleo-iks01a2_schematic.pdf

Q3-7 Quel est le rôle de la broche CS ? (Page 9 hts221.pdf)

www.st.com/resource/ja/datasheet/hts221.pdf

Q3-8 What is the role of pin SD0 / SA0? (page 9 hts221.pdf) Give the logical level on the schématics

www.st.com/resource/ja/datasheet/hts221.pdf

Q3-9 Then give the two hexadecimal values of the read and write command on the I²C bus.? (Page 26 hts221.pdf)

www.st.com/resource/ja/datasheet/hts221.pdf

Table 11. SAD+Read/Write patterns

Command	SAD[6:1]	SAD[0] = SA0	R/W	SAD+R/W
Read	101110	0	1	10111001 (B9h)
Write	101110	0	0	10111000 (B8h)
Read	101110	1	1	10111011 (BBh)
Write	101110	1	0	10111010 (BAh)

Q3-10 Deduce the 7-bit I²C address of the component in hexadecimal.

Q3-11 The following questions will be about the hts221.pdf constructor document (page 32) related to the following screenshots if the logic analyzer is not used. Otherwise, analyze the received frames.

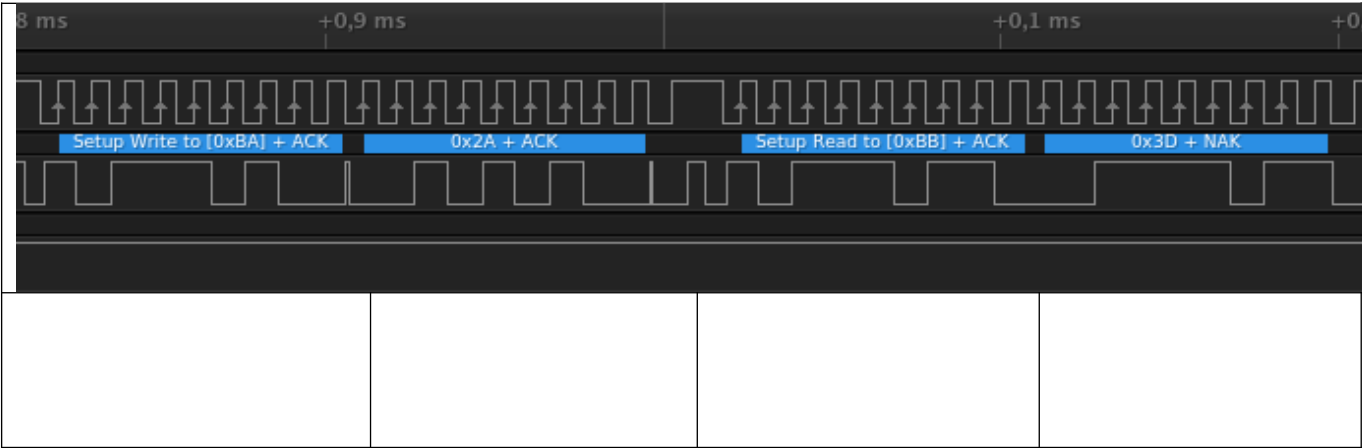
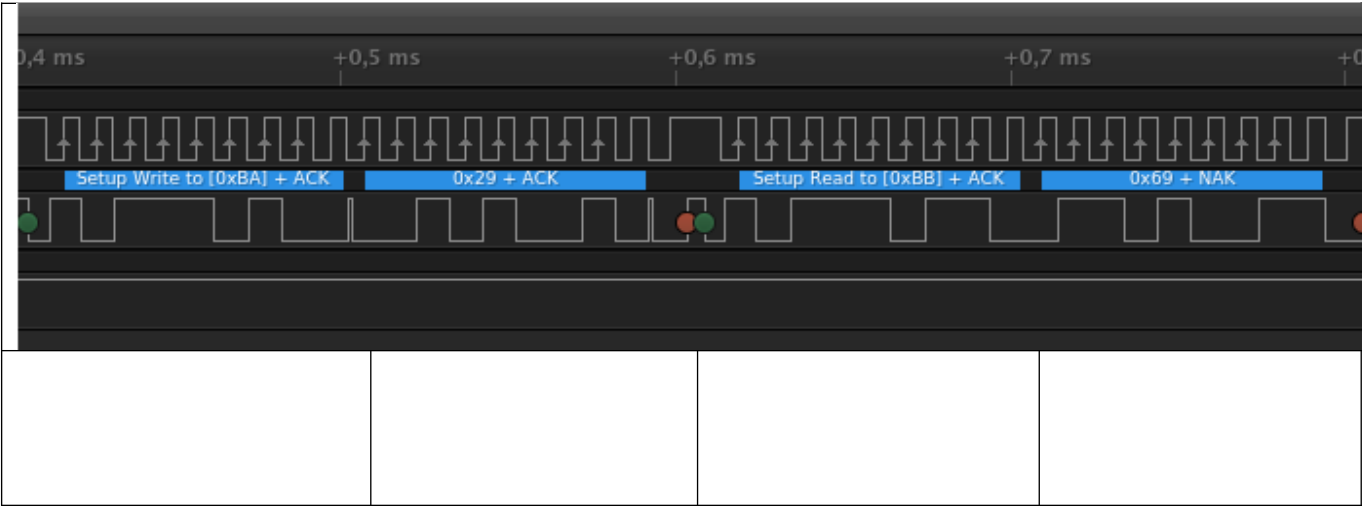
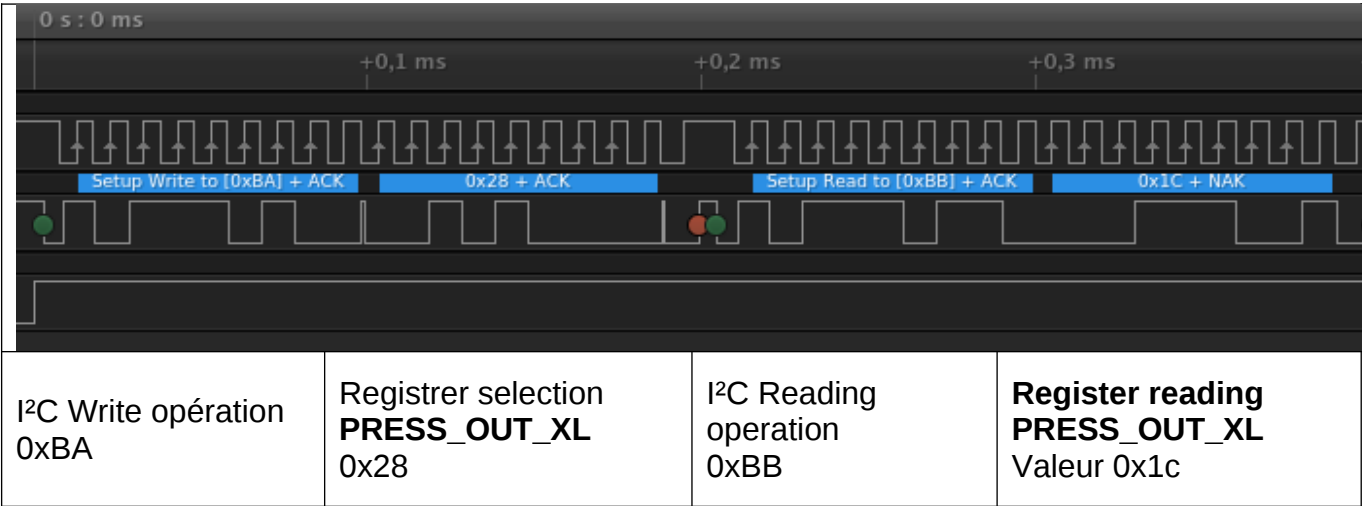
www.st.com/resource/ja/datasheet/hts221.pdf

The hts221 sensor library uses a 4-byte frame to read the contents of a one-byte register. The frame breaks down as follows:

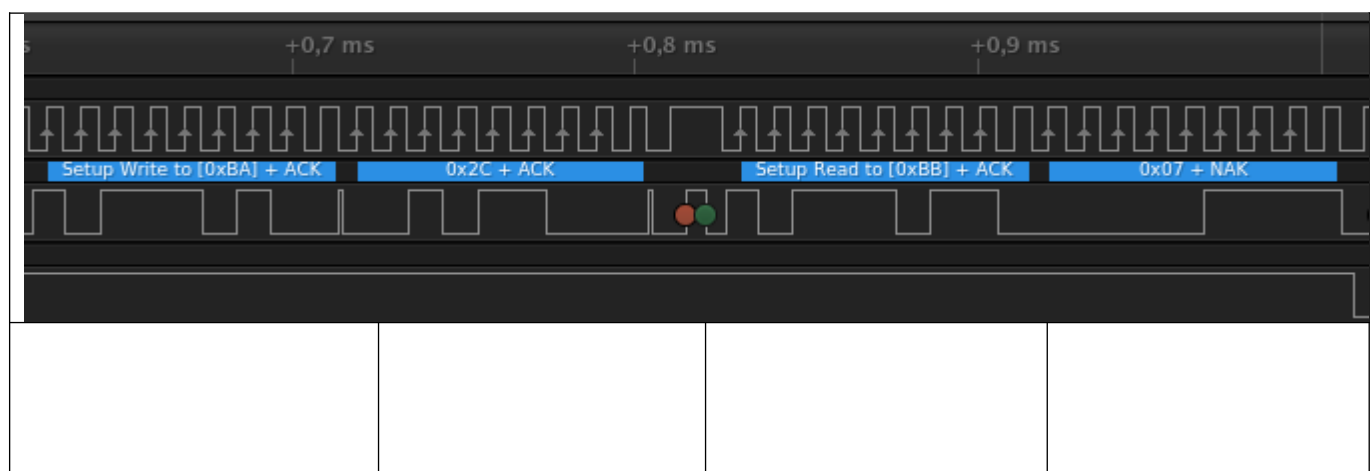
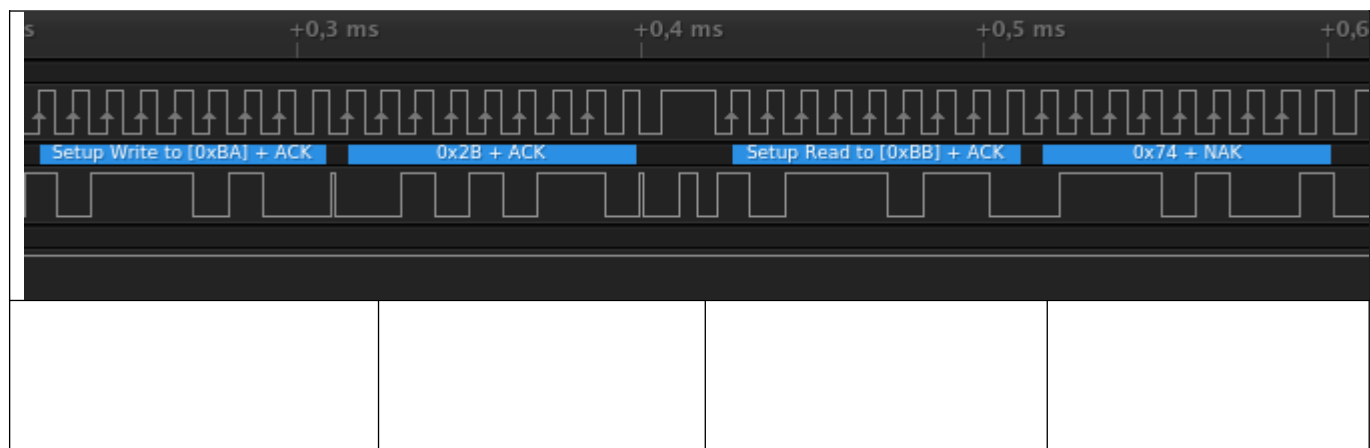
I ² C write operation	Register selection	I ² C reading operation	Reading the register
----------------------------------	--------------------	------------------------------------	----------------------

Complete the following acquisition tables as shown in the first example:

Pressure reading



Temperature reading



Results analysis

Q3-12 Complete the following table with regard to the pressure sensor

Registers	PRESS_OUT_H	PRESS_OUT_L	PRESS_OUT_XL
Hexadécimal 8 bits			
Décimal (24 bits)			

Q3-13 Deduce the pressure in hectopascal hts221.pdf (page 16) What is the measuring range of the sensor?

www.st.com/resource/ja/datasheet/hts221.pdf

--

Q3-14 Compléter le tableau suivant pour le capteur de température

Registers	TEMP_OUT_H	TEMP_OUT_L
Hexadécimal 8 bits		
Décimal (16 bits)		

Q3-15 What is the variable type for the previous decimal value? (strike out the mention of useless) Why? [hts221.pdf](#) (page 46)

unsigned int	int
---------------------	------------

Q3-16 The temperature is calculated by dividing by 10 the 16-bit decimal value. Calculate the temperature

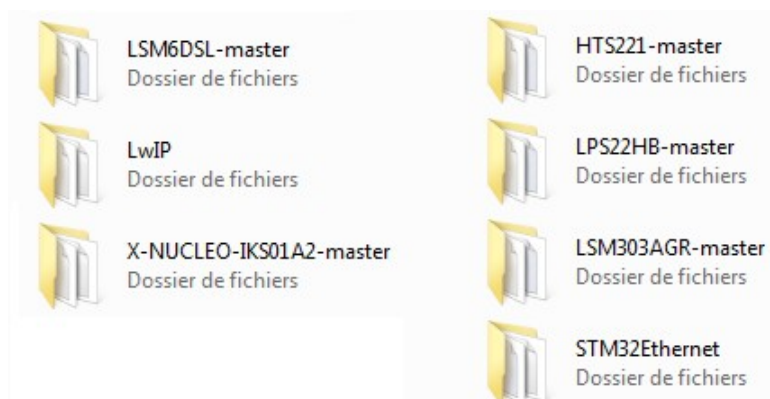
4 Ethernet and WEB server

libraries Installation

Below links to libraries

https://github.com/stm32duino/STM32Ethernet
https://github.com/stm32duino/LwIP

Directory Content C:\Users\name\Documents\Arduino\libraries



The STM32 Ethernet library is equivalent to Arduino Ethernet and described here:

<https://www.arduino.cc/en/Reference/Ethernet>

DHCP addressing and IP address display

Q4-1 From the following page, complete the program to display the address mask, gateway, and DNS.

Use the following methods:

Ethernet.subnetMask()

Ethernet.gatewayIP()

Ethernet.dnsServerIP()

```
/*
  DHCP-based IP printer
*/

#include <LwIP.h>
#include <STM32Ethernet.h>

// Enter a MAC address for your controller below.
byte mac[] = {0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xE5}; //Le dernier chiffre du dernier hexa est
                                                    //changer selon l'adresse mac

void setup() {
  // Open serial communications and wait for port to open:
  Serial.begin(9600);
  // start the Ethernet connection:

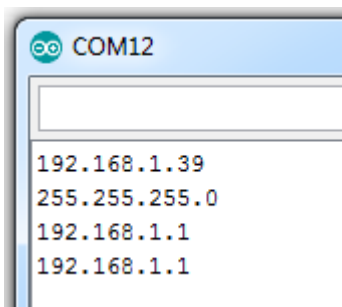
  if (Ethernet.begin(mac) == 0) {
    Serial.println("Failed to configure Ethernet using DHCP");
    while (1) {}
  }
  // print your local IP address:
  Serial.println(Ethernet.localIP());
  Serial.println(Ethernet.subnetMask());
  Serial.println(Ethernet.gatewayIP());
  Serial.println(Ethernet.dnsServerIP());

}

void loop() {

}
```

To see the IP address displayed in the serial monitor, make a RESET of the card once the program has been uploaded. (The serial monitor must be open beforehand)



Static IP address

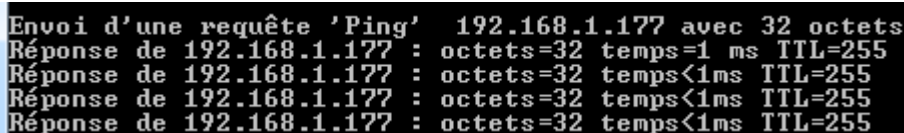
Q4-2 See the link below. Modify the previous program to perform static IP address.

<https://www.arduino.cc/en/Reference/EthernetIPAddress>

```
/*  
  Fixed IP printer  
*/  
  
#include <LwIP.h>  
#include <STM32Ethernet.h>  
  
// Enter a MAC address for your controller below.  
byte mac[] = {0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED};  
  
IPAddress ip(    );  
  
void setup() {  
  // Open serial communications and wait for port to open:  
  Serial.begin(9600);  
  // start the Ethernet connection:  
  
  Ethernet.begin(    );  
  
  // print your local IP address:  
  Serial.println(Ethernet.localIP());  
  
}  
  
void loop() {  
  
}
```

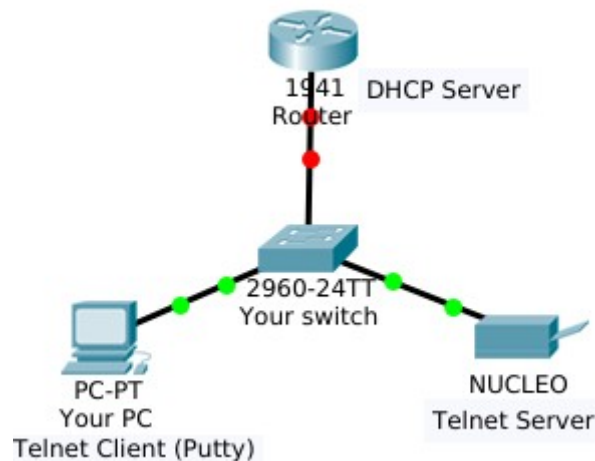
Check the connection with a ping command from console

ping 192.168.1.177



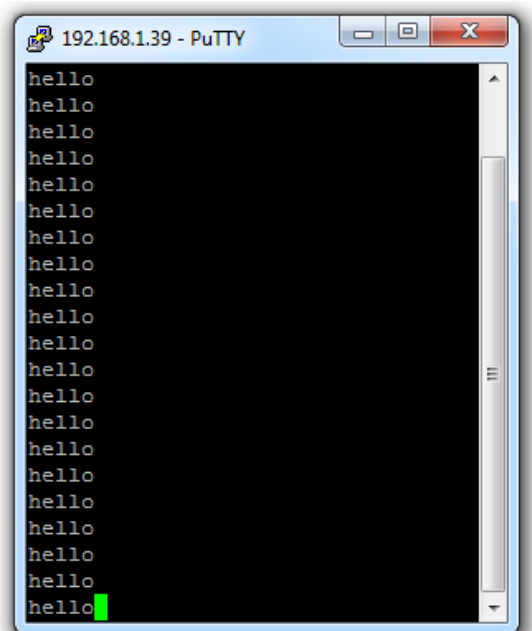
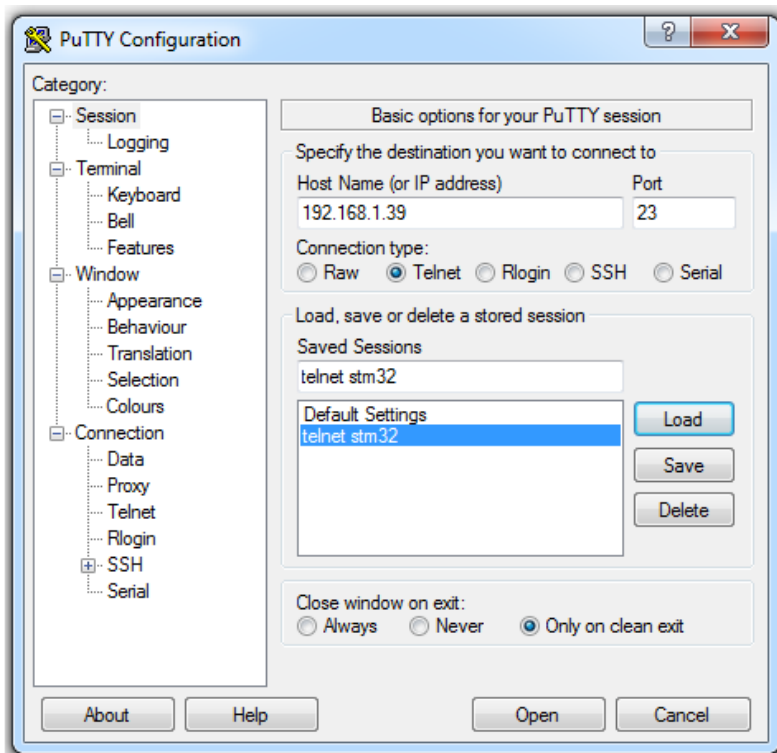
```
Envoi d'une requête 'Ping' 192.168.1.177 avec 32 octets  
Réponse de 192.168.1.177 : octets=32 temps=1 ms TTL=255  
Réponse de 192.168.1.177 : octets=32 temps<1ms TTL=255  
Réponse de 192.168.1.177 : octets=32 temps<1ms TTL=255  
Réponse de 192.168.1.177 : octets=32 temps<1ms TTL=255
```

Telnet access



Upload the program on the next page, Check with putty the communication with the server

<https://www.putty.org/>



Warning Telnet server only accepts one client at a time


```
/*
telnet Server
*/

#include <LwIP.h>
#include <STM32Ethernet.h>

// Enter a MAC address for your controller below.
byte mac[] = {0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED};

// telnet defaults to port 23
EthernetServer server(23);
EthernetClient client;

boolean alreadyConnected = false; // whether or not the client was connected previously

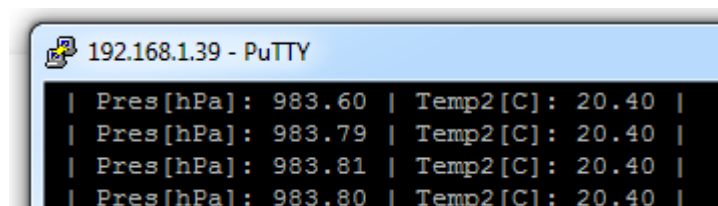
void setup() {
  // Open serial communications and wait for port to open:
  Serial.begin(9600);
  // start the Ethernet connection:
  if (Ethernet.begin(mac) == 0) {
    Serial.println("Failed to configure Ethernet using DHCP");
    while (1) {}
  }
  // start listening for clients
  server.begin();

  Serial.print("Telnet server address: ");
  Serial.println(Ethernet.localIP());
}

void loop() {
  // wait for a new client
  client = server.available();

  // when the client connected, say hello every second:
  if (client) {
    server.println("hello");
    delay(1000);
  }
}
```

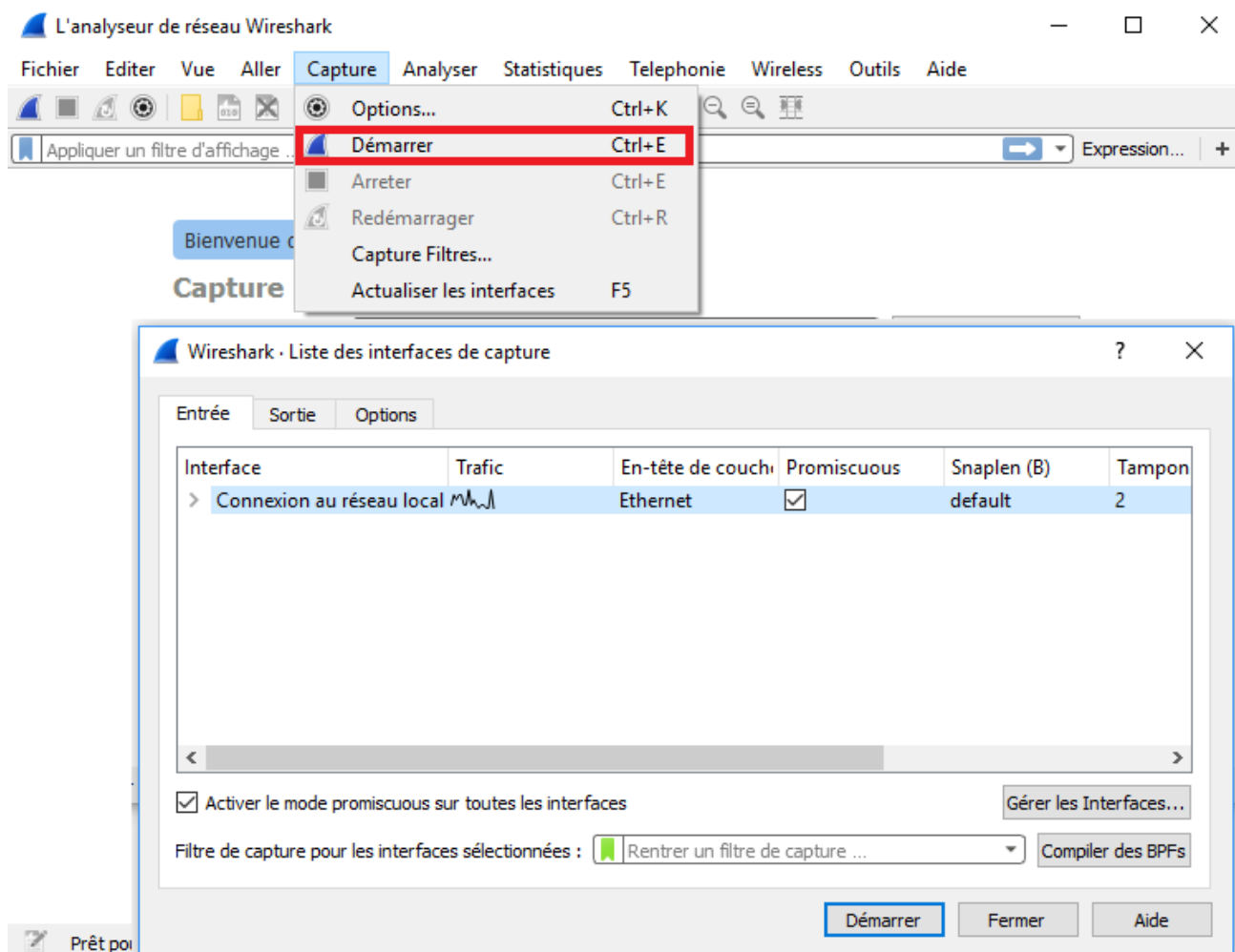
Q4-3 Using question **Q3-5** and the previous program, display the hts221 sensor data with TELNET



Wireshark analysis

<https://www.wireshark.org/>

Install and run the Wireshark program



*Connexion au réseau local

Fichier Editer Vue Aller Capture Analyser Statistiques Telephonie Wireless Outils Aide

ip.addr == 192.168.1.39 && telnet 1

No.	Time	Source	Destination	Protocol	Length	Info
12	8.201961	192.168.1.35	192.168.1.39	TELNET	75	Telnet
16	8.703778	192.168.1.39	192.168.1.35	TELNET	94	Telnet
23	9.205792	192.168.1.39	192.168.1.35	TELNET	94	Telnet
25	9.707795	192.168.1.39	192.168.1.35	TELNET	94	Telnet
29	10.209806	192.168.1.39	192.168.1.35	TELNET	94	Telnet
31	10.711808	192.168.1.39	192.168.1.35	TELNET	94	Telnet
33	11.213838	192.168.1.39	192.168.1.35	TELNET	94	Telnet

Internet Protocol Version 4, Src: 192.168.1.39, Dst: 192.168.1.35

- 0100 = Version: 4
- 0101 = Header Length: 20 bytes (5)
- > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
- Total Length: 80
- Identification: 0x0023 (35)
- > Flags: 0x00
- Fragment offset: 0
- Time to live: 255
- Protocol: TCP (6)
- Header checksum: 0x37ea [validation disabled]
- [Header checksum status: Unverified]
- Source: 192.168.1.39 2
- Destination: 192.168.1.35
- [Source GeoIP: Unknown]
- [Destination GeoIP: Unknown]
- > Transmission Control Protocol, Src Port: 23, Dst Port: 50128, Seq: 1, Ack: 22, Len: 40
- > Telnet
 - Data: Pres[hPa]: 983.93 | Temp[C]: 20.80 \n 3

0000 e0 3f 49 44 29 00 de ad be ef fe ed 08 00 45 00 .?ID)... ..E.

0010 00 50 00 23 00 00 ff 06 37 ea c0 a8 01 27 c0 a8 .P.#.... 7....'..

0020 01 23 00 17 c3 d0 00 00 19 8c 3a 8d 28 1c 50 18 .#..... :.(.P.

0030 0b 53 bd 1d 00 00 7c 20 50 72 65 73 5b 68 50 61 .S...| Pres[hPa]

0040 5d 3a 20 39 38 33 2e 39 33 20 20 7c 20 54 65 6d]: 983.9 3 | Tem

0050 70 5b 43 5d 3a 20 32 30 2e 38 30 20 0a 0d p[C]: 20 .80 ..

Frame (frame), 94 octets | Paquets: 37 · Affichés: 9 (24.3%) · Perdus: 0 (0.0%) | Profil: Default

- 1- Use a filter on server IP analysis and telnet,
- 2- Source and destination IP addresses,
- 3- data
- 4- Pack of data

Q4-4 Is the data sent encrypted?

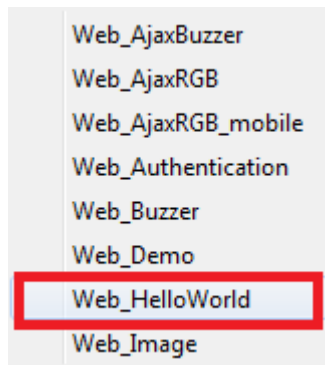
WEB Server

In order to facilitate the management of a WEB server in the NUCLEO card, it is necessary to add the following library:

<https://github.com/f4goh/Webduino>

Or in zip file joined

Start by loading the program **Web_HelloWorld.ino**



Do not forget to use a static IP address

Set up your ip address

IPAddress ip(192, 168, 1, 177);

Then use this method

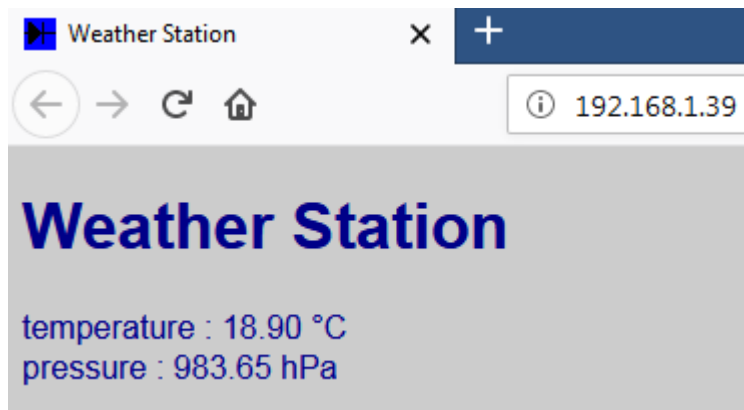
Ethernet.begin(mac, ip);

It is possible to specify the gateway, DNS and mask as **Q4.1** question

Q4-5 Implement the following web page instead of HelloWorld

It will be necessary to add the character \ at the end of each line and just before the " of the code HTML

```
<!DOCTYPE html>
<html>
  <head>
    <title> Weather Station</title>
    <meta charset="UTF-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0"/>
    <meta http-equiv='refresh' content='5'/>
    <style>
      body { background-color: #cccccc; font-family: Arial, Helvetica, Sans-Serif; Color:
#000088; }
    </style>
  </head>
  <body>
    <h1> Weather Station</h1>
  </body>
</html>
```

Q4-6 Finally, add the pressure and temperature information to the previous web page

Annex 1

