HANDBOOK RELATED TO BUOY SYSTEM FOR FRESHWATER QUALITY MONITORING PLATFORM (TECHNICAL)

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2. PRESENTATION

The system described in this document is part of a social impact project financed by Colciencias - Minciencias, Boyacá Government and Colombia BIO Program; leaded by Santo Tomás Tunja Basic Sciences department in alliance with Andes University and Germán Franco Carbón SAS Company, from the municipality of Samacá. The system has the utility of allowing easy characterization of the state of fresh water by continuous measuring of 5 quality parameters (temperature, pH, oxide-reduction potential, electric conductivity and dissolved oxygen) using a semi-autonomous measurement unit.

3. INTRODUCTION

The importance that hydric resources have for regions' (one of them, Samacá) welfare, health and economy, where it is based on agriculture, livestock and mining [1], and has a high hydric potential [1] and, the fact of the pollution high risk that water can have in these regions, due to different activities [2], are relevant reasons for develop a solution to characterize the water in base of 5 quality parameters measurements, which consists of a system with energy autonomy that has the capacity to carry out measurements and visualize the respective results remotely, making easier monitoring the state of the water and giving to community the possibility of submitting the collected information to subsequent analyzes that indicate possible affections on rivers.

4. HANDBOOK OBJECTIVE

This paper, tries to give you easy instructions for handling this system, called “freshwater quality monitoring platform”. Thus, you can handle it with caution for correct dismounting and mounting processes if you need to fix or replace any device.

The document, also has both a calibration guide section and a connection chart one for showing calibration process for sensors measures reliability and devices connections, as GPS-Raspberry pi and PCB-Raspberry pi.

5. SYSTEM DESCRIPTION

1. Measurement unit

   a. Devices box: rectangular unit of 25 cm x 30 cm with Ingress Protection IP65, where are located the following devices:

      i. Inside (on an acrylic sheet):

         - 3 Li-Po, 1 cell, 3.7 V, 2000 mAh batteries.

         - 3, 5 V solar power manager 5 V for batteries connection with solar panels and the circuit supply output.

         - 1 interconnection board from 3 solar power manager supply outputs to a common output, configured in parallel and connected to Raspberry Pi.

         - 1 Raspberry pi 3 B+.

         - 1 UART GPS NEO-7M module and SMA connector wire.

         - 1 2G/3G/4G/GSM EC21-AU celular module, SMA connector wire and Claro SIM chip (3103915058).

         - 1 Bluetooth HC-05 with USB-TTL board.

- 1 900 MHz XBee Pro S3B with adapter board and USB-USB Micro, A type wire.

- 1 USB 1-4 expander.

- 1 PCB with 5 cards (temperature, pH, oxide-reduction potential, electrical conductivity and dissolved oxygen transducers) with BNC connectors for probes.

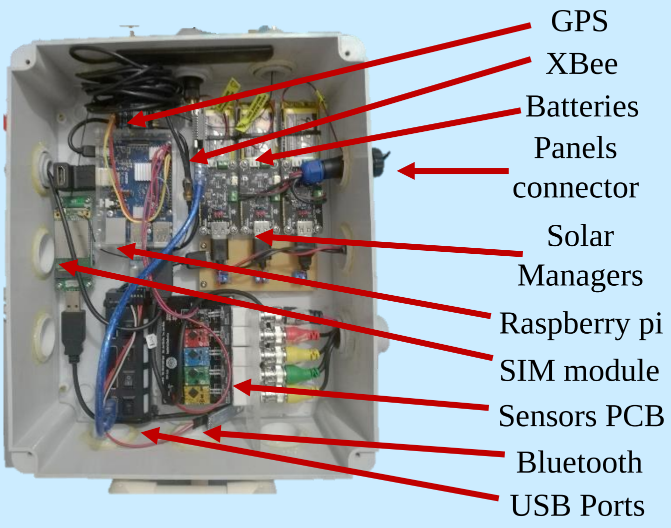


Figure 1. Inside of devices box.

ii. Outside:

- 1 GPS, 1.5 GHz antenna with SMA connector and wire.

- 1 GSM module antenna with SMA connector and wire.

- 1 XBee, 900 MHz, 5 dB antenna.

- 1 lateral solar panels connector.

- 1 key switch.

- 1 extension (main probe) with the 5 sensors probes.

- 1 weather station SEN0186.


Figure 2. Devices box and sensors' probes.

Weather station is shown in figures 3 and 4.

Figure 3. Weather station which is placed above devices box.

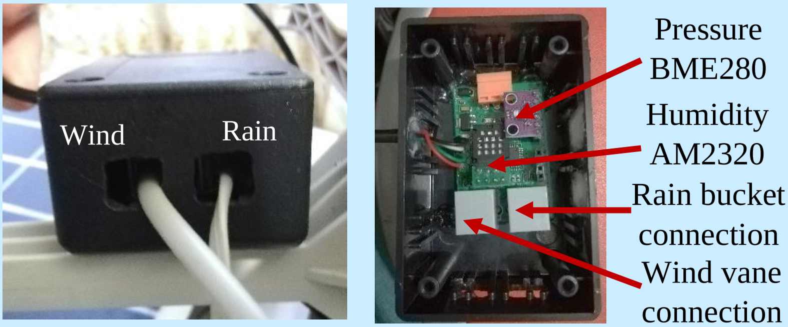


Figure 4. Weather sensors and connections.

Sensors's specifications are below:

Sensor	Communication protocols*	Readings (Unit)	Operation voltage	Probe Material
EZO-RTD™	UART, USB, I2C	Temperature (°C)	3.3 V- 5 V	Class A platinum
EZO-pH™	UART, USB, I2C	pH (dimensionless)	3.3 V- 5 V	KCL reference, silver wire and EXR glass tip
EZO-ORP™	UART, USB, I2C	Oxide-Reduction Potential (mV)	3.3 V- 5 V	KCL reference, silver wire and platinum tip
EZO-EC™	UART, USB, I2C	Electric Conductivity (µS)	3.3 V- 5 V	Graphite electrodes
EZO-DO™	UART, USB, I2C	Dissolved Oxygen (mg/l)	3.3 V- 5 V	PTFE membrane, silver rod, zinc anode and electrolyte

Table 1. Sensors' specifications.

* Sensors are configured on I2C mode.

b. Solar panels: 3 photovoltaic monocrystalline cell units of 28 cm x 28 cm and 5 V, 2 A, 10 W capacity. Each one has a couple of wires (positive and negative) which end in a common connector for devices box of measurement unit connection. Furthermore, each panel is set on an H, which is removable from the main structure.

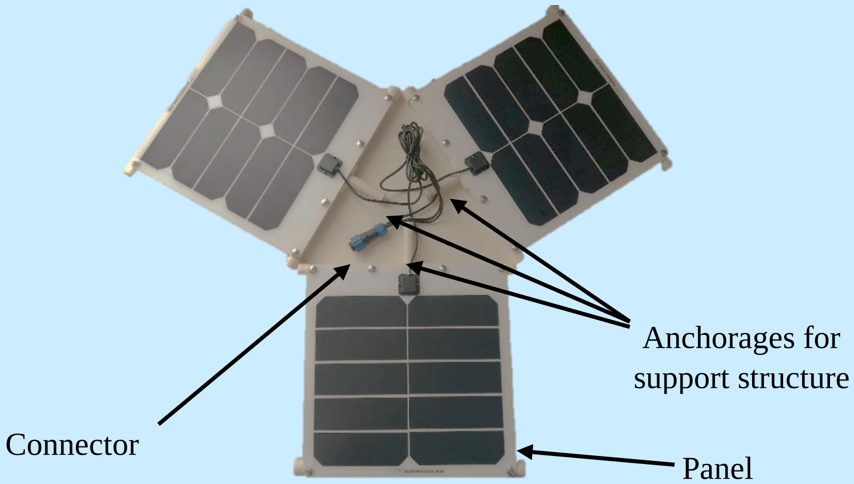


Figure 5. Power distribution solar panels' system.

2. Receiver box

a. Receiver box: rectangular unit of 13 cm x 17 cm, with Ingress Protection IP55. This consolidates a backup of the measurement unit information and allows data to be shown on a graphical interface.

The receiving box has the following electronic devices:

i. Inside (on an acrylic sheet):

- 1 Raspberry pi 3 B+.

- 1 GSM EC21-AU module and SMA connector wire.

- 1 XBee Pro S3B with adapter board and USB-USB Micro, A type wire.

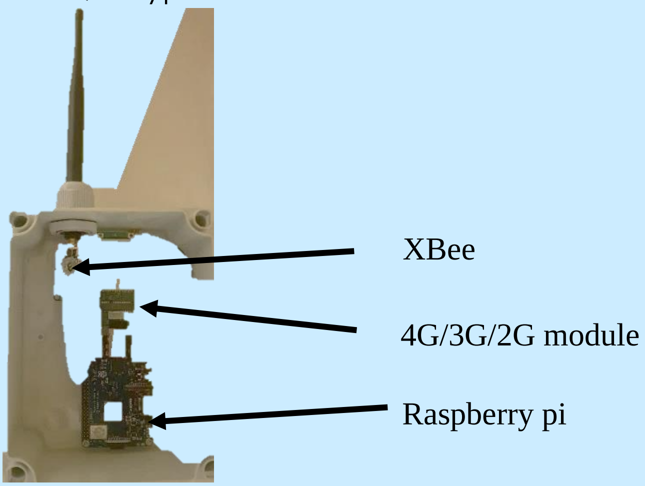


Figure 6. Inside of receiver box.

ii. Outside:

- 1 XBee de 900 MHz, 5 dB antenna.

- Charger for Raspberry pi 3 B+ supply.

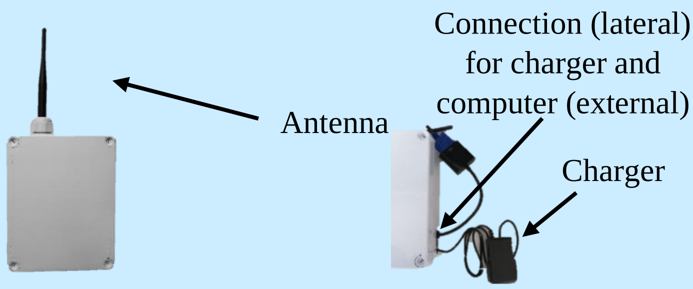


Figure 7. Receiver box.

Figure 8. Receiver's unit Graphic User Interface for data display.

6. CONNECTION CHARTS

Raspberry pi – PCB

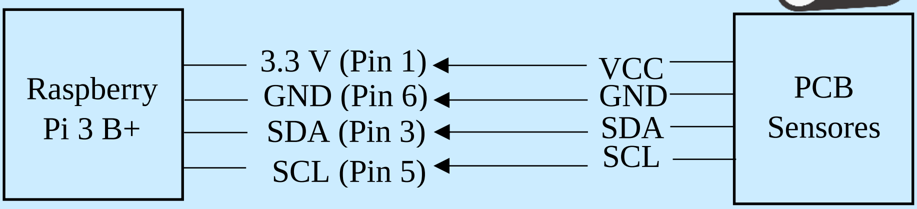


Chart 1. Raspberry pi-PCB connection.

Raspberry pi – GPS

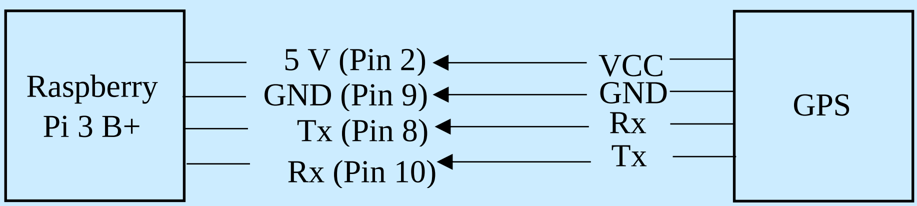


Chart 2. Raspberry pi-GPS connection.

Raspberry pi – Raspberry pi-Power Supply, Bluetooth, 4G Module

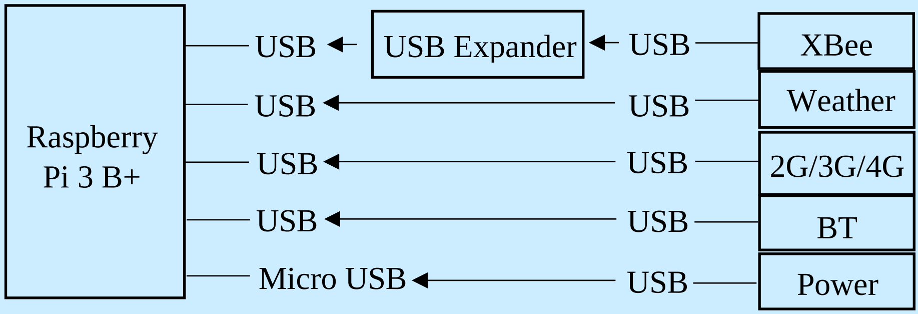


Chart 3. Raspberry pi-Power Supply, Bluetooth (BT), XBee, 4G/3G/2G module connection.

7. RECOMMENDATIONS

- Read carefully whole manual.

- For normal operation be sure of bring an Internet data plan for both measuring unit (3103915058 of Claro) and receiver unit (3218986965 of Claro).

- If you need to uncover the box of the measuring unit, be sure to do it out of the water, with the switch off and with the panels disconnected. Then, remove the 4 corner screws and lift up the box cap.

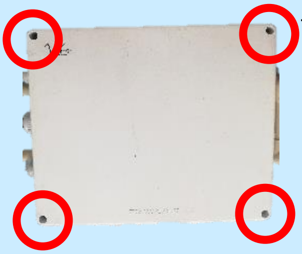


Figure 9. Measurement unit screws (cap).

- If you need to remove any electronic component from the acrylic sheet, for cleaning, repair or replacement, remember to do it with the system turned off and with the batteries and panels disconnected.

- When you need to remove any electronic component, check that all their respective connectors are disconnected. Then carefully remove the component by unscrewing its 4 support screws, using a 2 mm Bristol key, and save the screws.

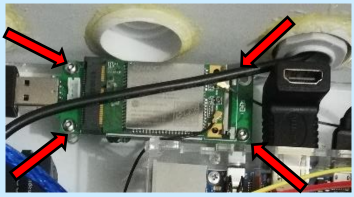


Figure 10. Bristol screws (EC21 module).

- If you have disconnected some components, remember how they were initially (see connection diagrams) to avoid erroneous connections and system damages.

- Handle the solar panels with caution.

- Do not remove the acrylic sheet, unless absolutely necessary. If required, ensure that no external components are connected to the internal components, before removing the sheet.

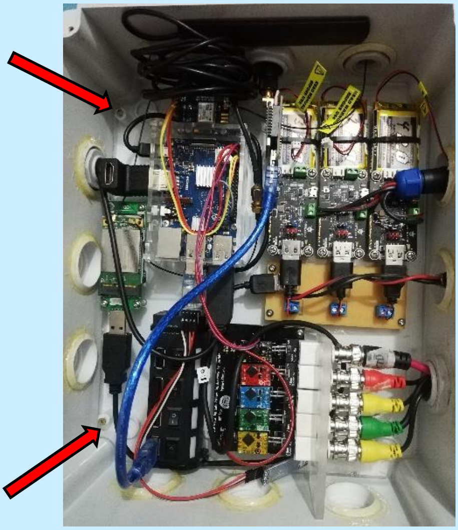


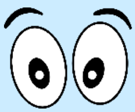
Figure 11. Acrylic sheet screws.

- You can remotely monitor and adjust the operation of the software of both units through VNC (you must have it on your computer or your cellular device).

- Make sure that the sensors that need liquid protection (pH and ORP) have enough. If not, pour a small amount into its jars.

- Do the calibration of the sensors at least once a year (see calibration guide).

8. DATA DISPLAY



Data display can be done in different ways, making it easier for the user to be actually the final destination of the information of the measurement results. One of the methods is the box of the receiving unit through the graphical interface shown in Figure 8 of section 5, "System description". Similarly, data can be viewed in the email inbox of the assigned addresses. It's also possible to access the information through a mobile application or the WEB server http://monitoreoaguas.ustatunja.edu.co/.

When measurement data cannot be displayed, it may be due to a system failure associated with any of the following cases:

- The device will not send information to email or the WEB server if it has run out of mobile data. Therefore, you must ensure that both units (measurement and receiver) have an internet (data) plan.

- The interface will not receive information if it is not within the range of the measurement unit. Verify that measurement data are displayed on the interface when you are close to the measurement unit. Then locate the receiver box where you will be receiving information, at a much greater distance.

- The unit of measurement may lose the configuration established for the connection ports of the devices and may need to be verified or adjusted. To do this, uncover the box of the measurement unit and connect an HDMI cable to Raspberry Pi and a monitor. Then connect a mouse and keyboard to the Raspberry Pi module or USB port expander. Turn on the device and run the command terminal (figure 12).

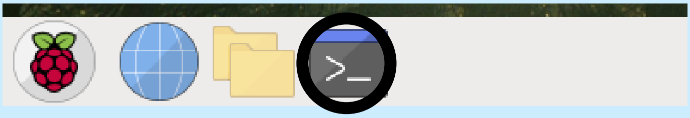


Figure 12. LX (command) Terminal.

Type *ls /dev* command (figure 13) and press enter.

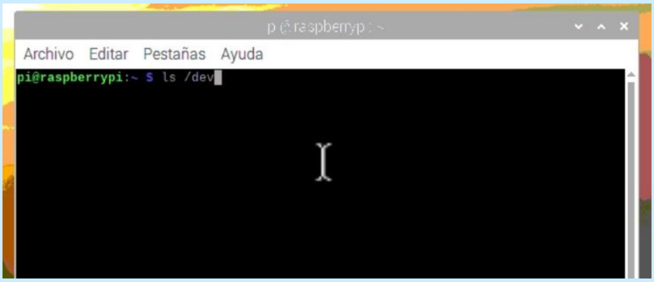


Figure 13. ls /dev command for ports configuration.

Al ejecutarlo obtendrá la lista de puertos utilizados por el dispositivo. Fíjese en la sección *ttyUSB* (figura 14).

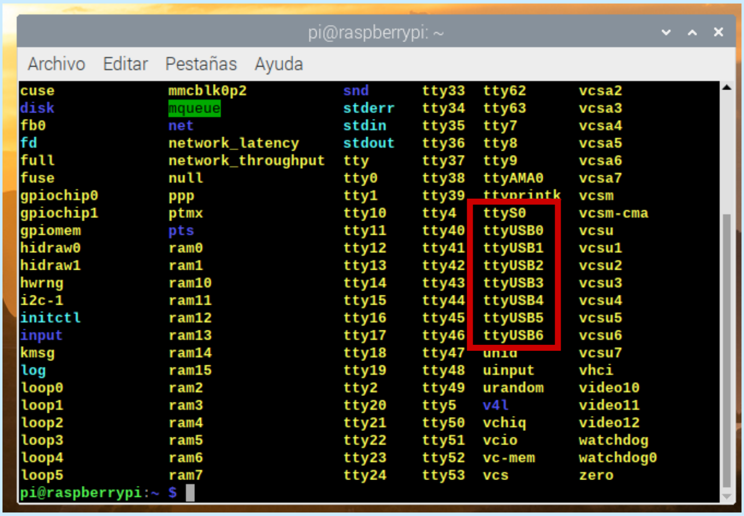


Figure 14. Devices ports on LX Terminal.

Highlighted addresses USB0, USB1 and USB2 must correspond respectively to the Weather Station, XBee and Bluetooth devices. Verify that these addresses correspond, disconnecting one of the mentioned devices and running the *ls /dev* command again. The address associated with the disconnected device should disappear (and appear after reconnection). If any of the addresses do not correspond, it may have problems with the subsequent display of the measurement information.

- The battery system may limit the delivery of energy to the system. Eventually, it may require to press the Boot button on the Solar manager cards (Figure 15) for make charge-discharge energy cycle stable.

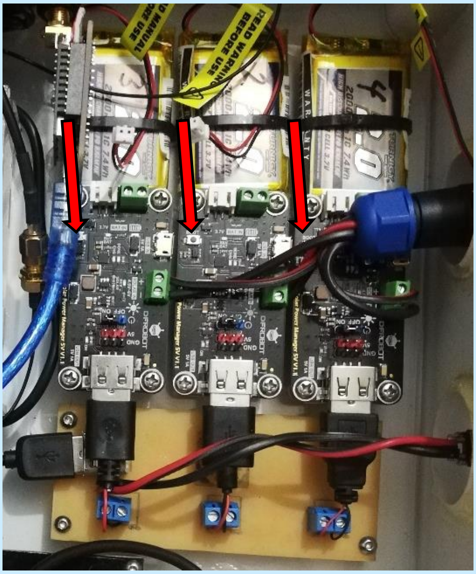


Figure 15. Solar managers Boot buttons.

9. CALIBRATION GUIDE

In this section, the considerations for the calibration of the sensors are briefly detailed, which is recommended to be done once per year.

Calibration liquids	Sensors	Variables	Values
	-	pH y ORP (liquid protection)	Don't applies
		pH	4, 7 and 10
		Oxide-Reduction Potential (ORP)	225 mV
		Electric Conductivity (EC)	12880 µS and 80000 µS
		Dissolved Oxygen (DO)	0 mg/L
Don't needs		Temperature (RTD)	Don't applies

Table 2. Sensors and calibration liquids [3].

Calibration

Once the prototype has been implemented; it must be calibrated following the steps established by the sensors manufacturer, atlas-scientific. The following are the recommendations and procedures to take into account for this calibration:

The most important thing in calibration is the continuous observation of the data that is acquired through any sensors. A constant value should be evidenced if the probe is in the calibration process.

To start the calibration process, it is required to connect the Raspberry pi to a screen or monitor, through the HDMI port. Then, using a mouse execute the User Terminal, indicated in figure 16.

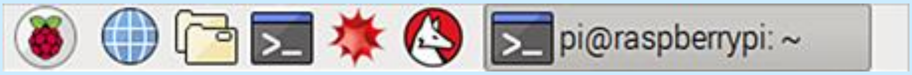


Figure 16. Command-User Terminal [4].

Once started, the following commands should be executed, one by one, and pressing enter after each one (if the first command does not work, please try since second one or write them two (first and second one) on a single line):

- cd~

- git clone https://github.com/AtlasScientific/Raspberry-Pi-sample-code.git

- cd ~/Raspberry-Pi-sample-code

- sudo python i2c.py

Steps for starting calibration process are shown at figure 17.

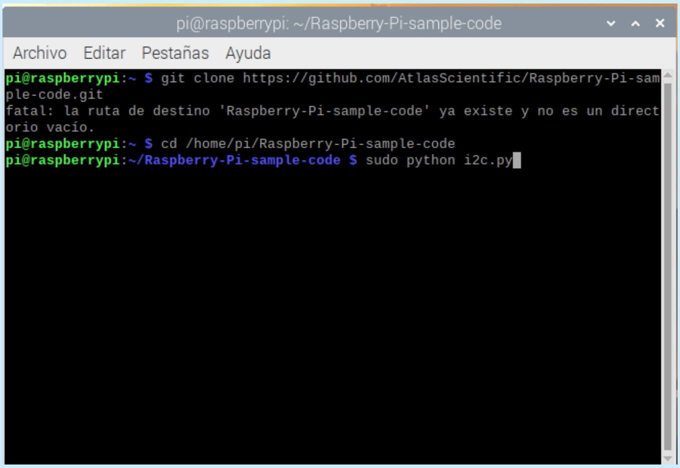


Figure 17. Steps for running calibration code.

Then, calibration code will start displaying commands and instructions, including the *poll* command to take readings from all the sensors or *r* to receive data from the selected sensor (figure 18).

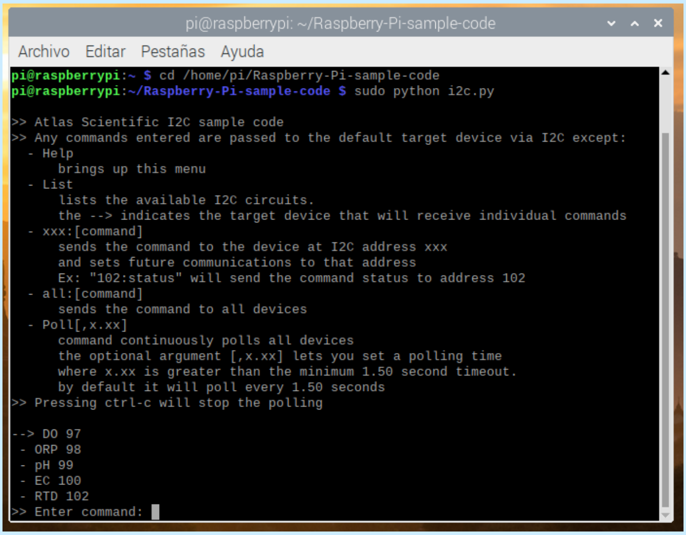
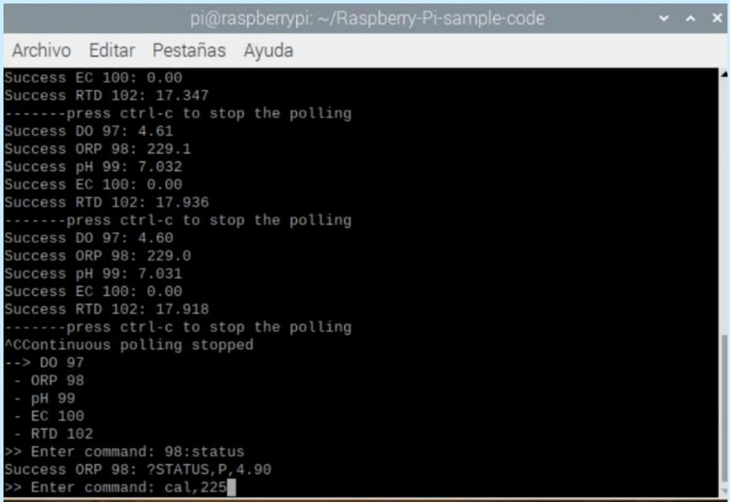


Figure 18. Instructions list for Atlas sensors.

It is noteworthy that the calibration must be done one sensor at a time. Therefore, when you want to select a sensor, you must write its address, followed by the word status (eg *98:status*), according to the respective addresses displayed at the start of the program (or indicated by the *list* command).



pi@raspberrypi: ~/Raspberry-Pi-sample-code

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```
Success EC 100: 0.00
Success RTD 102: 17.347
-------press ctrl-c to stop the polling
Success DO 97: 4.61
Success ORP 98: 229.1
Success pH 99: 7.032
Success EC 100: 0.00
Success RTD 102: 17.936
-------press ctrl-c to stop the polling
Success DO 97: 4.60
Success ORP 98: 229.0
Success pH 99: 7.031
Success EC 100: 0.00
Success RTD 102: 17.918
-------press ctrl-c to stop the polling
^CContinuous polling stopped
--> DO 97
 - ORP 98
 - pH 99
 - EC 100
 - RTD 102
>> Enter command: 98:status
Success ORP 98: ?STATUS,P,4.90
>> Enter command: cal,225
```

Figure 19. ORP sensor selection (numerical address 98) for its calibration. The cal calibration command is used when the sensor is ready for this procedure.

After selecting the sensor, you can proceed with the calibration. Remember that this process is independent for each sensor and is performed using the *cal* command, followed by the reference value. However, this reference value is associated with a standard solution, so you must introduce the sensor probe in the respective solution before executing the *cal* command of figure 19.

The considerations for the calibration of each sensor are indicated below. Remember to wash each probe with pure water before and after each calibration point.

- pH: In small containers (one per liquid), pour a small amount of each liquid. Make the calibration at each point, immersing the end of the probe in each container (it is necessary to stabilize the measurements in each case) in the following order:

1. pH 7 (middle point). Command: *cal,mid,7*.
2. pH 4 (low point). Command: *cal,low,4*.
3. pH 10 (high point). Command: *cal,high,10*.

Three point calibration provides high precision over the full pH range, these three values 4.00, 7.00 and 10.00 should be considered as calibration standards. The relationship of the calibrated points to the total pH range is shown below.

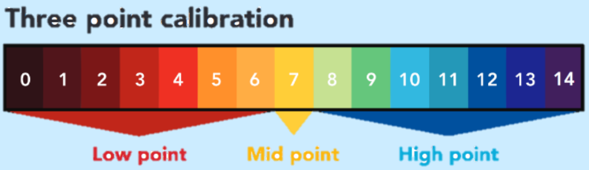

Figure 20. pH range with three point calibration [5].

- ORP (Oxide-Reduction Potential): The ORP probe calibration protocol indicates that its calibration depends on a single verification point, for which purpose a 225 mV calibration solution is used, where the probe is immersed until stabilizing the measurements obtained (Command: *cal,255*). It is recommended to perform this calibration at least once a year.

Figure 21. ORP probe calibration process [6].

- EC (Electric Conductivity): For the calibration of this sensor, there are three steps. For the first, the calibration is performed with the probe exposed to air. For the rest, in small containers (one per liquid), pour a small amount of each liquid and shake the probe to avoid air bubbles accumulated in the sensor area. Make the calibration at each point, immersing the end of the probe in each container, it is necessary to stabilize the measurements in each case with a maximum range of 40% in the following order:

1. 0 µS Air calibration. Command: *cal,dry*.
2. 12,880 µS (low point). Command: *cal,low,12880*.
3. 80,000 µS (high point). Command: *cal,high,80000*.

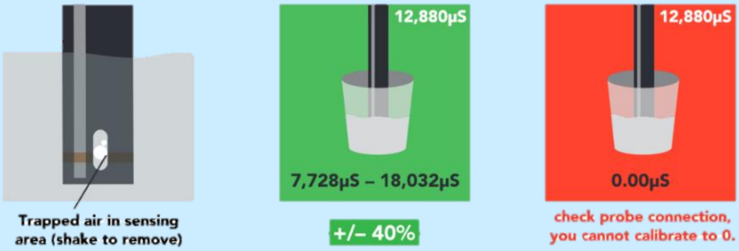

Figure 22. EC probe calibration process [7].

- DO (Dissolved Oxygen): For the calibration process, the probe must first be exposed to air until data stabilization (air calibration. Command: *cal*). Then insert the probe into the container until the measurements stabilize. It must be set by programming to 0 mg / L (liquid calibration. Command: *cal,0*).

Figure 23. DO probe calibration process [8].

10. REFERENCES

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[7] Atlas-Scientific. Env-Sds-Kit, EC Datasheet. Recovered from: https://www.atlas-scientific.com/files/EC_EZO_Datasheet.pdf

[8] Atlas-Scientific. Env-Sds-Kit, DO Datasheet. Recovered from: https://www.atlas-scientific.com/files/DO_EZO_Datasheet.pdf

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