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1 Description

Enviro Station is a device built around the Pimoroni Enviro+ board, an add-on for Raspberry Pi computers. The Enviro Station uses a Raspberry Pi Zero W. The software should run on other Raspberry Pi models from 2 on upwards, however, it would be necessary to tweak some Raspberry Pi Zero specific settings in the MEMS microphone driver.

Enviro Station uses all of the sensors provided by the Pimoroi Enviro+ board and the extra particulate sensor, with the exception of the temperature reading provided by the BME280 chip. This temperature reading is not the ambient temperature as confirmed by the chip's manufacturer and therefore a separate precision temperature sensor in the form of the MCP9808 has been added. The BME280 temperature is however processed and included in the Enviro Station data set and statistics and can be easily enabled for display and recording instead of the MCP9808.

As built by me, the Enviro Station has the following specs:

Table 1: Basic specs

Measurement	Range	Sensor	Notes
Ambient Temperature	-40 to +125ºC or -40 to 257F	MCP9808 0.25ºC typical accuracy	Selectable unit for display but recorded always in Celsius
Barometric Pressure	300 to 1100 mb or 225 to 825 mmHg 8.86 to 32.48 inchHg 4.36 to 15.95 PSI	BME280 ±1 % (0.. 65ºC)	Selectable unit for display but recorded always in millibar
Humidity	0 to 100%	BME280 ±3 % (0.. 65ºC)	
Harmful Gasses:	Carbon monoxide CO Nitrogen dioxide NO_2 Ethanol Hydrogen Ammonia Methane Propane Iso-butane	MICS-6814 - RED sensor (ohm or ratio) - OX sensor (ohm or ratio) - NH3 sensor (ohm or ratio)	The 3 sensors values can be displayed in Ohm. For each a R0 = clean air value should be configured and then the unit can be switched to ratio (Ohm / R0) instead (possibility of conversion to actual gas concentrations in ppm is still under investigation) Recording format follows display format (ohm or ratio)
Light Intensity	0.01 to 64000 lux	LTR-559ALS-01	
Noise	0 to 120 dbSPL or 0 to 131071 (raw) PCM	SPH0645LM4H-B	The quiet floor PCM needs to be configured to get reasonable dbSPL values. Recording format follows display format (dbSPL or PCM)

Measurement	Range	Sensor	Notes
Particulate Matter (by weight)	(in µg/m^3) PM1 PM2.5 PM10	PMS5003 PM2.5: 0..500 ± 10%	Particle concentration under atmospheric environment
Particulate Matter (by size)	(in µm/L) >0.3 µm diameter >1 µm diameter >2.5 µm diameter >10 µm diameter	PMS5003	Sensor reports per 0.1L, but values are displayed and recorded *10 to report per L values

For convenience, some sensors are grouped together, for example all GAS sensors. The groups are shown in Table 2. The effect of grouping is that some settings apply to all elements of a group. For example, recording of the GAS group will always include all three elements, OX, RED and NH3.

Table 2: Sensor Groups

Sensor Group	Containing:
Temperature	Temperature
Baro+Hum	Barometric pressure and Humidity
Gas	OX, RED, NH3
PM (weight)	PM1, PM2.5, PM10 ug/m3
Light	Light
Noise	Noise
PM (size)	0.3, 1, 2.5, 10 um/L
Time	System Time, Run Time, recording status (not actually a sensor but useful…)

Unless notes, the following functions can be selected individually for each Sensor Group. All selectable options apart from min/max display can be saved in a setup file and automatically loaded at startup.

To simplify the code, it is currently possible to choose some options for the “Time” sensor but they are ignored.

Table 3 Functions

Functions	Details	Notes
Measurement frequency	Every 1 second	Fixed, applies to each sensor
Average value display Average value recording	Exponential Moving Average Values older than 1h fade to less than 0.1%	per sensor group per sensor group
Min value display Max value display Min/Max reset	min/max selection is not saved in setup	per sensor group per sensor group reset only for all sensor groups together
Trend History Depth	Based on averages 1 hour, 1 day, or 7 days ago.	per sensor group
Trend display		per sensor group
Recording interval	Off 1s, 10s, 30s, 1m, 5m, 10m, 15m, 1h	global, all selected sensors are recording at the same interval
Recording selection	Actual values and/or Average values	per sensor group
Unit selection		only for: • Temperature, • Barometric Pressure, • Gas • Noise
Automatic cycle between displays	Cycle time fixed to 10 seconds	global on/off toggle
Display sleep time	Off, 30s, 1m, 5m	global setting

2 Operation

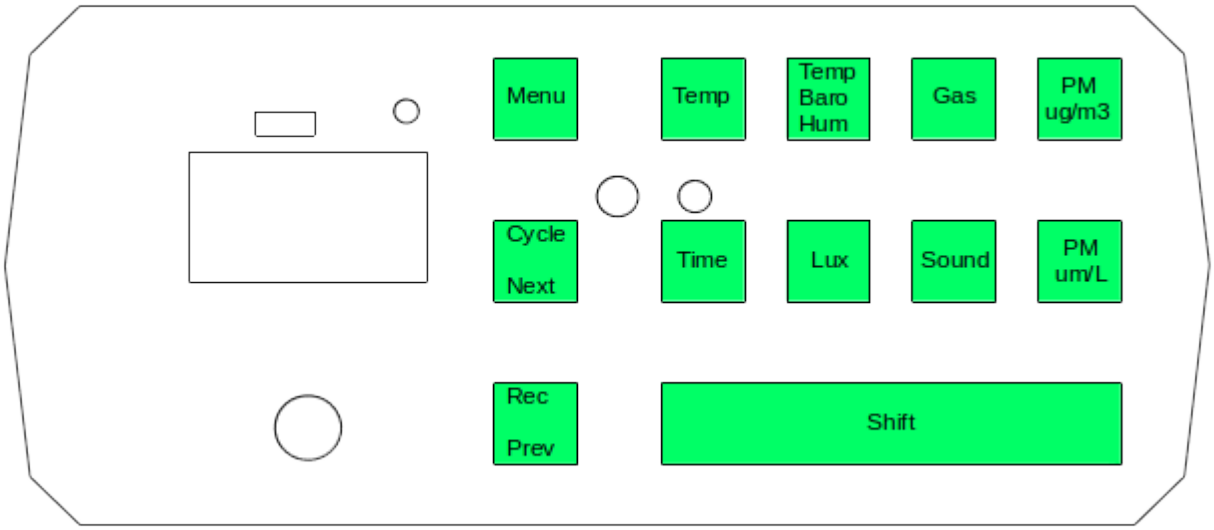

Figure 1: Enviro Station Front Panel

The front panel has 12 touch-sensitive areas (buttons) shown in green in Figure 1. The 8 smaller buttons above the large “Shift” bar are for the 8 sensor groups.

2.1 Display mode

During normal operation, the display shows one of the 8 sensor groups. Touching one of the 8 sensor group buttons, selects that group for display. Touching the cycle button enables or disables the automatic cycling through all 8 groups.

The display uses the last selected or loaded setup values to show:

1. Selected unit format (where applicable)
2. The colour of the unit text indicates:
   (a) white: the value is real-time
   (b) green: the value shown is the average value
   (c) blue: the value shown is the minimum

(d) red: the value shown is the maximum

3. The colour of the value indicates:

(a) red: the trend is increasing or maximum value

(b) blue: the trend is decreasing or minimum value

(c) white: trend is disabled or the trend is flat (no change)

To recognise whether trend or min/max are displayed, look at the colour of the unit text.

2.1.1 Functions in Display Mode

Table 4: Functions in Display Mode

Button	Function
<any Sensor Button>	Selects that sensor group for display
SHIFT+ <any Sensor Button> except TIME	Toggles the display for that sensor group between: • normal = real-time or average with or without trend colouring • min = shows the minimum value(s) • max = shows the maximum value(s)
SHIFT+ TIME	Resets the min/max values for all sensors to current real-time value.
CYCLE	Toggles the automatic cycling of the display between all 8 sensor groups.
REC	If not recording, pressing REC mounts an external USB drive and starts recording with content and frequency based on current recording settings. If recording was already in progress, pressing REC stops recording and unmounts the external USB drive.
MENU	Starts the MENU

2.2 Menu mode

Note that sensor processing and recording continues normally while the MENU is shown.

There are 10 sub-menus to allow extensive configuration of the Enviro Station

- Unit: allows changing of units for some of the sensors
- Average: selecting display of average instead of real-time value

- Trend: selecting display of trend colouring
- Trend-History: selecting the length of the history used for trend
- Recording-values: selecting which real-time values are included in the recording
- Recording-average: selecting which average values are included in the recording
- Recording-time interval: selecting how often the values are recorded
- Sleep Time: selecting if the display should be turned off after some time of inactivity
- Save: saves the current selection in a file to be automatically restored at start-up
- Load: restore the selection from a file

2.2.1 Functions in Menu Mode

Table 5: Functions in Menu Mode

Button	Function
MENU	Leave the Menu mode. Any changes are active for the current run but unless they have been explicitly saved, will be lost when the unit is turned-off. You can go back into Menu and select Save to avoid that.
NEXT	Moves to the next sub-menu in a cyclic manner
PREV	Moves to the previous sub-menu in a cyclic manner
<any Sensor Button> except TIME	Shows the current setting for that Sensor Group and enables changing using SHIFT
SHIFT (by itself!)	Cycles through the options for the currently selected sensor based on the current sub-menu

3 Calibration

There are two sensors that need some form of calibration: GAS and NOISE.

3.1 Gas Sensor: R0

The Gas sensor has three different substrates that each produce a resistance value in Ohm which changes with the presence of gasses to which that substrate is particular sensitive. The Ohm value is also very sensitive to temperature. The sensor itself is heated and needs to come up to operating temperature first. It must also be protected from air flow which would cool it down

Normally, the factory would deliver a R0 value for each of the 3 substrates, giving its Ohm value at a standard temperature in a standard (clean) atmosphere. For the Enviro+, these values are not available and since the values vary in production, taking R0 values from another chip is not an option.

Having R0 would allow showing the ratio of the measured resistance over R0 which in turn could be used to get an idea of the gas concentration based on the graphs (normalized to the ratio) in the data sheet.

In the absence of any R0 data, the following procedure can be used to get maybe a reasonable approximation:

1. Select the unit OHM “Ω” for the Gas sensor. This means the values shown and recorded are the raw resistance values.
2. Put the unit into an environment that you assume is having the cleanest air that you can find. The Enviro-Station can be powered from a USB powerbank, so going outdoors into a park or wood-land is a possibility.
3. Let the unit run and observe the average values reported. Recording on a USB stick may be useful here. We hope the shown resistance approach a more or less steady value and take these as R0.
4. Use a text editor to edit the SETUP.TXT file and overwrite the R0 values in there.
5. When the file is reloaded, switch the Gas Unit to ratio “/” to use the new R0 values.

3.2 Noise floor

I observed that even in total silence, the PCM value delivered by the MEMS microphone has a significant noise signal which pushes the dbSPL values into unrealistic high values.

1. To have any chance of getting realistic-looking dbSPL values, the system noise signal must be determined and then subtracted using the following procedure:
2. Select the unit PCM for the Sound sensor. This means the values shown and recorded are the raw PCM values reported by the microphone
3. Put the unit into an environment that is as quiet as possible
4. Let the unit run and observe the average PCM values reported. Recording on a USB stick may be useful here. We hope the shown PCM values approach a more or less steady value and take these as noise floor level.

5. Use a text editor to edit the SETUP.TXT file and overwrite the noise level value in there.
6. When the file is reloaded, switch the Sound sensor to dbSPL to use the new noise floor value.

4 Installation

4.1 Pre-requisites:

Raspberry Pi Zero W with up-to-date Raspberry Pi OS (Raspbian) BUSTER

Internet access to be able to download packages

User Pi

4.2 Prep:

1. Create home folder	Create folder: `/home/pi/EnviroStation`

2. USB mount point	Create a mount point for USB sticks:
	`sudo mkdir /mnt/usb_stick`
	`sudo chmod a=rw /mnt/usb_stick`

3. Turn off auto-mount	Turn off all auto-mount options in file manager. These don't work when Enviro-Station is auto-started and interfere when running interactively. `File → Edit → Preferences → Volume Management` (untick all auto-mount options)
4. Raspberry Pi configuration	Use the Raspberry Pi configuration menu INTERFACES to • enable SSH and/or VNC depending how you want to use it. • Enable: SPI, I2C, Serial Port • Disable: Serial Console, 1-Wire, Remote GPIO If the Configuration program asks you to reboot, do it
5. Go to home folder	Change to home folder `/home/pi/EnviroStation` and open console window there
6. Update PIP	Ensure PIP is up-to-date `sudo pip3 install --upgrade setuptools`
7. Setup adafruit stuff	`pip3 install adafruit-circuitpython-ads1x15`

	`pip3 install adafruit-circuitpython-bme280`
8. MPR121	If you want to use the stock MPR121 driver from Adafruit (but I don't recommend it because it is less responsive): `pip3 install adafruit-circuitpython-MPR121`
9. Setup Pimoroni stuff	`sudo pip3 install st7735`

4.3 Sound:

10. Setup sounddevice	`python3 -m pip install sounddevice –user`
	
	`sudo apt-get install libportaudio2`

11. Follow Adafruit MEMS mic instructions Note: this will take better part of 1h	`cd ~`
	`wget https://raw.githubusercontent.com/adafruit/Raspberry-Pi-Installer-Scripts/master/i2smic.sh`
	`chmod +x i2smic.sh`
	`sudo ./i2smic.sh`
	
	(select Raspberry Pi Zero and autoload)
	Reboot

12. Go to home folder	Change to home folder `/home/pi/EnviroStation` and open console window there
13. Get Paul's driver	`git clone https://github.com/PaulCreaser/rpi-i2s-audio`

14. Configure it and compile	`cd rpi-i2s-audio`
	edit my_loader.c with
	`nano my_loader.c`
	
	and change the two lines
	`.platform = "3f203000.i2s" to .platform = "20203000.i2s"`
	and
	`.name = "3f203000.i2s" to .name = "20203000.i2s"`
	save changes and compile:
	
	`make -C /lib/modules/$(uname -r )/build M=$(pwd) modules`

	load it: `sudo insmod my_loader.ko`

15. Make it autoload at boot	`sudo cp my_loader.ko /lib/modules/$(uname -r)`
	`echo 'my_loader' | sudo tee --append /etc/modules > /dev/null`
	`sudo depmod -a`
	`sudo modprobe my_loader`

Install Enviro-Station

16. Go to home folder	Change to home folder `/home/pi/EnviroStation` and open console window there
17. Copy	Copy Enviro-Station_vx_x.zip from Github and extract files
18. Check that it runs	`python3 EnviroStation.py`
19. Install as service	`sudo cp EnviroStation.service /lib/systemd/system/` `sudo chmod 644 /lib/systemd/system/EnviroStation.service`

20. Enable service	`sudo systemctl daemon-reload`
	`sudo systemctl enable EnviroStation.service`
	reboot

21. Optional: reduce wear on SD card	Edit
	
	`/etc/fstab`
	add
	`tmpfs /tmp tmpfs defaults,noatime,nosuid 0 0`
	`tmpfs /var/log tmpfs defaults,noatime,nosuid,size=16m 0 0`
	find line for / that looks like:
	`PARTUUID=<some hex num>-02 / ext4 defaults,noatime 0 1`
	change to
	`PARTUUID=<some hex num>-02 / ext4`
	`defaults,noatime,commit=600,errors=remount-ro 0 1`
	
	credits https://www.raspberrypi.org/forums/viewtopic.php?t=257514
	HawaiianPi & Jahboater

22. Optional if	`curl https://get.pimoroni.com/onoffshim | bash`

you use OnOff SHIM	

Note: By default, EnviroStation.py uses my MPR121 touch pad driver. You can use the stock Adafruit driver instead but it is quite a bit less responsive. I suspect this is because they have not implemented auto-calibration during setup as recommended by the MPR121. Another feature missing in the Adafruit driver is the capability to use a virtual 13th button (based on the capacitance readings from all 12) as a proximity sensor. This is one method used by EnviroStation.py to wake from sleep.

5 Notes for building the Station

Table 6: Bill of Material

No	Qty	Item	Source
1.	1	Enviro+	Pimoroni
2.	1	PMS5003 with cable	Pimoroni
3.	1	Raspberry Pi Zero W	Various
4.	1	MPR21 touch sensor	Ebay, seller: ict2you
5.	1	MCP9808	Ebay, seller: tandy_corporation
6.	1	Buzzer	Ebay, seller: switch_elec
7.	1	270 Ohm resistor	Banggood
8.	1	USB 2.0 A Male to Micro USB 5 pin Male Left Angle Short Cable Adapter converter	Ebay, seller Innov8wholesaleltd
9.	2	Micro usb 5pin male to micro 5pin female with screw panel mount extension cable	Ebay, seller Innov8wholesaleltd
10.	1	OnOff SHIM	Pimoroni
11.	1	Push-button with red LED	RS-Components Stock 820-7521
12.	1	Enclosure 110x149x71MM Project Box Case PCB Housing in Black or Grey Vented KE3	Ebay, seller eltop_electronics
13.	1	Front Panel PCB	JLCPCB

List of I2C addresses in use:

Address (hex)	Device
18	MCP9808 (precision temperature)
23	Enviro+: LTR559ALS (Light & Proximity)
49	Enviro+: AD1015 (Analog to Digital used for Gas sensor
5a	MPR121 (touch sensor)
76	BME280 (barometric pressure & humidity)

Use	GPIO	pin
I2C SDA	GPIO2	3
I2C SCL	GPIO3	5
LCD_CS	GPIO7 (CE1)	26
LCD_DC	GPIO9 (MISO)	21
LCD backlight	GPIO12	32
SHUTDOWN	GPIO4	7
ONOFF_BUT	GPIO17	11
MICS 6814 heater	GPIO24	18
MEMS Microphone Clk	GPIO18	12
MEMS Microphone LRCL	GPIO19	35
MEMS Microphone DOUT	GPIO20	38
PM5003 Enable	GPIO22	15
PM5003 Reset	GPIO27	13
PM5003 TX	GPIO14	8
PM5003 RX	GPIO15	10
Beeper	GPIO21	40

Use	Pin		Use
Power 3V3	01	02	Power 5V

Use	Pin		Use
I2C SDA	03	04	Power 5V
I2C SCL	05	06	GND
SHUTDOWN	07	08	PM5003 TX
GND	09	10	PM5003 RX
ONOFF_BUT	11	12	MEMS Microphone Clk
PM5003 Reset	13	14	GND
PM5003 Enable	15	16	
	17	18	MICS 6814 heater
	19	20	GND
LCD_DC	21	22	
	23	24	
	25	26	LCD_CS
	27	28	
	29	30	GND
	31	32	LCD backlight
	33	34	GND
MEMS Microphone LRCL	35	36	
	37	38	MEMS Microphone DOUT
GND	39	40	Beeper