Destination Weather Station v4.5

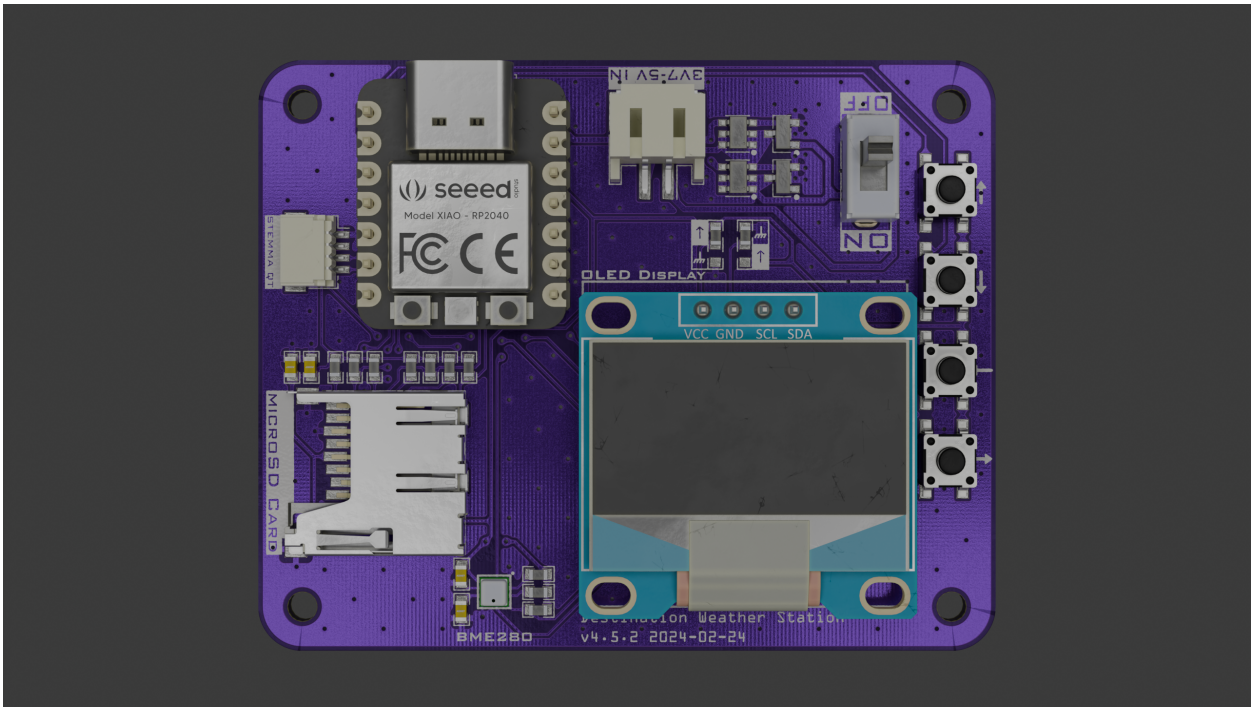
Release 0.2.0

Destination SPACE Inc.

Mar 14, 2024

CONTENTS

An Open Source Remote Sensing Platform for National Taiwan Normal University



CHAPTER

ONE

GETTING STARTED

1.1 What is in the Kit?

1.1.1 Kit Contents

- Destination Weather Station v4.5.2
- Seeeduino XIAO RP2040 microcontroller w/ headers
- 128x64px OLED display w/ headers
- SPDT power switch
- AAA battery case
- 8GB micro-SD card
- USB-A to USB-C cable

1.2 Destination Weather Station v4.5 Assembly

The Destination Weather Station v4.5 is preassembled with the majority of the circuit components.

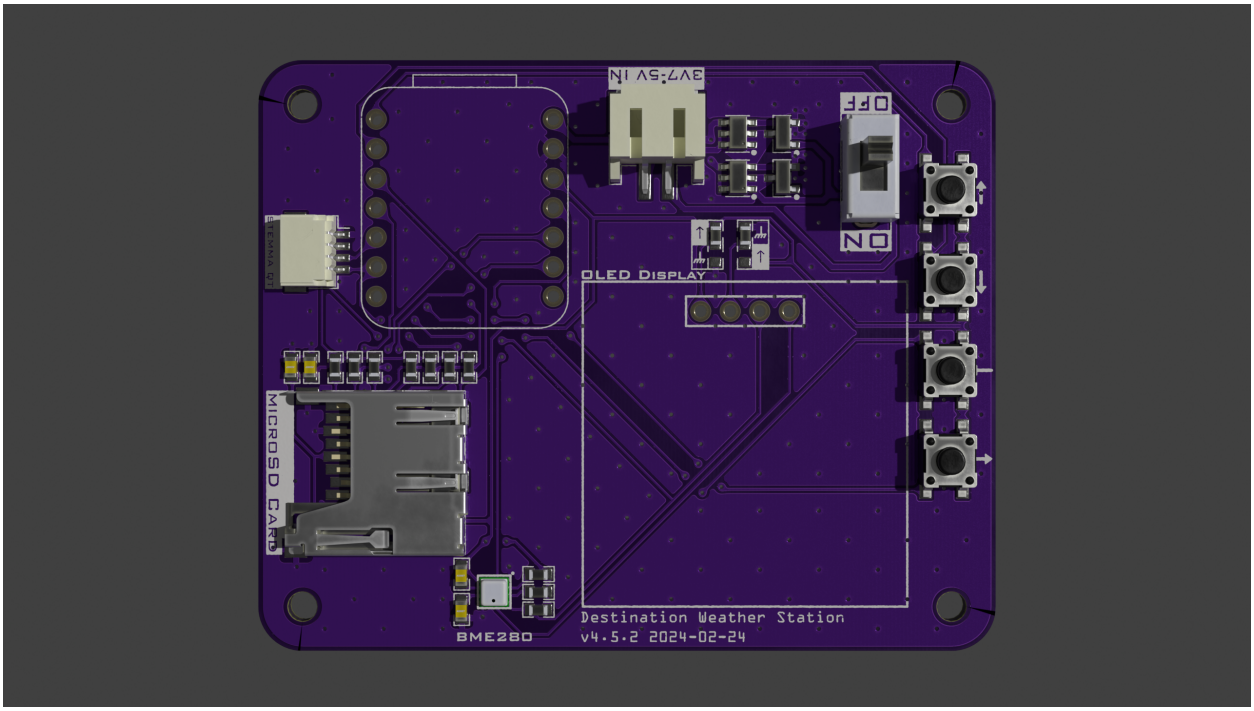
Before using the weather station, you will need to *solder* the *XIAO RP2040 microcontroller*, *OLED display*, and power switch. Follow the instructions below to solder your weather station. You can then *connect the batteries* and insert the microSD card.

1.2.1 Soldering

To solder the weather station, follow the instructions below. Tools required to complete these steps are:

- Soldering iron
- Solder wire

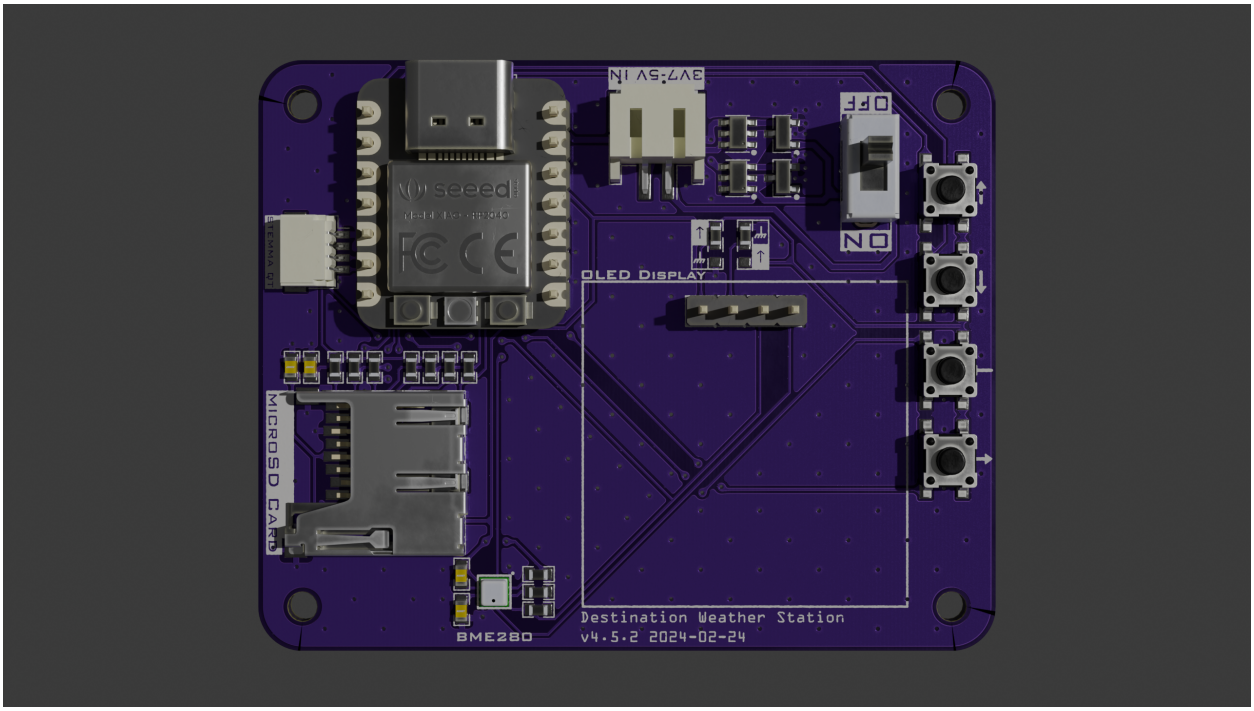
Power Switch



To solder the power switch to the weather station, insert it into the front side of the board. Flip the board over and solder the pins, starting with the two outer ones.

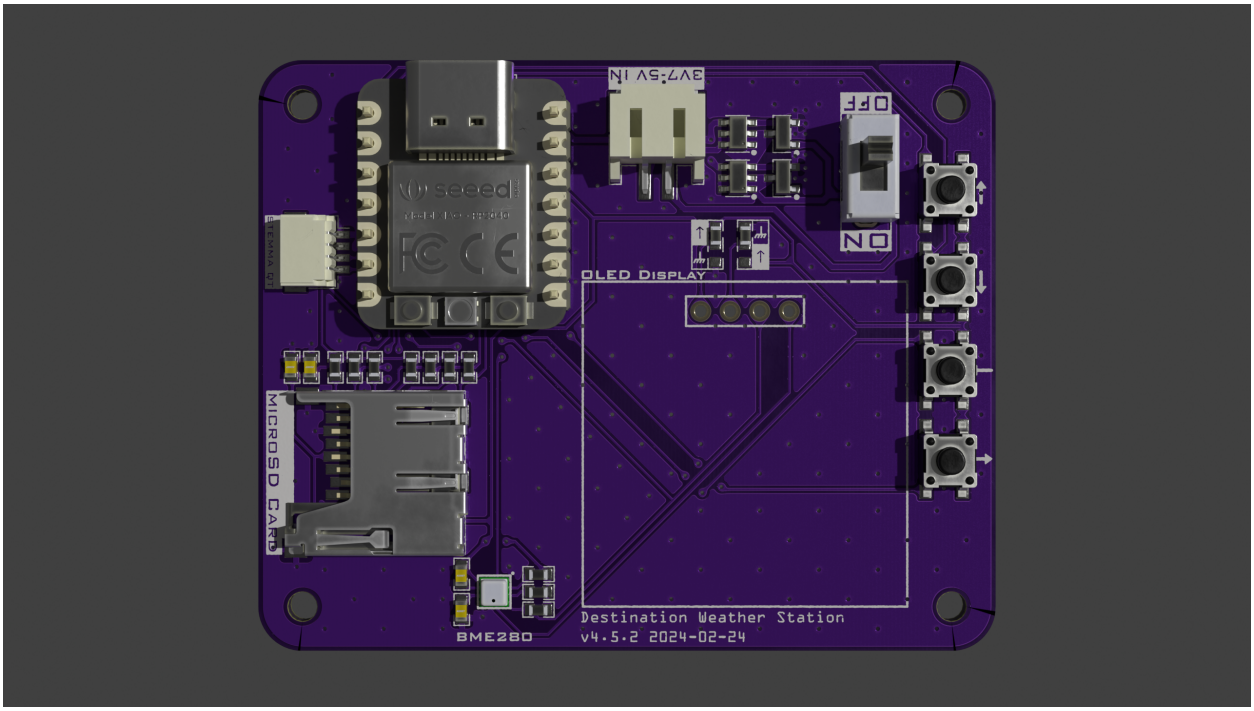
XIAO RP2040

To solder the XIAO RP2040 to the weather station, begin by inserting the long side of the 1x7 header pins into the weather station board as shown below.



Next, flip the weather station over and solder all 14 pins to the weather station.

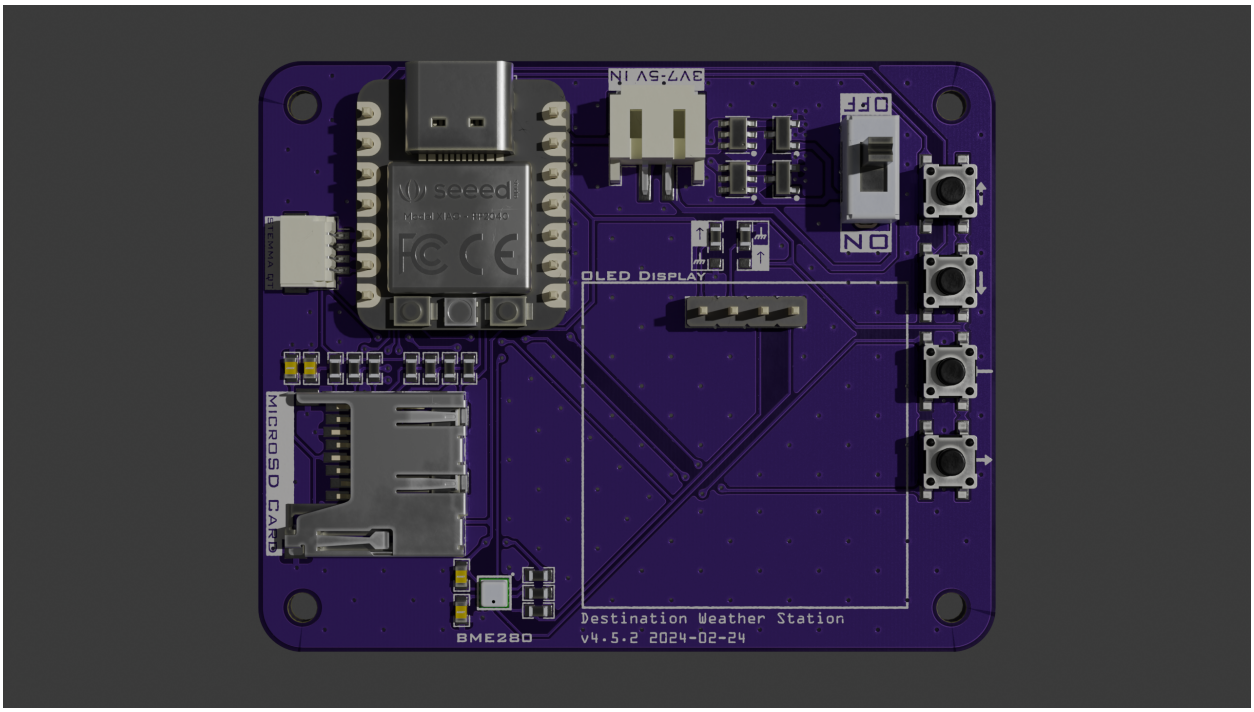
Finally, flip the weather station back over and solder the XIAO to the short side of the header pins. After you are done, it should look like the image below.



OLED Display

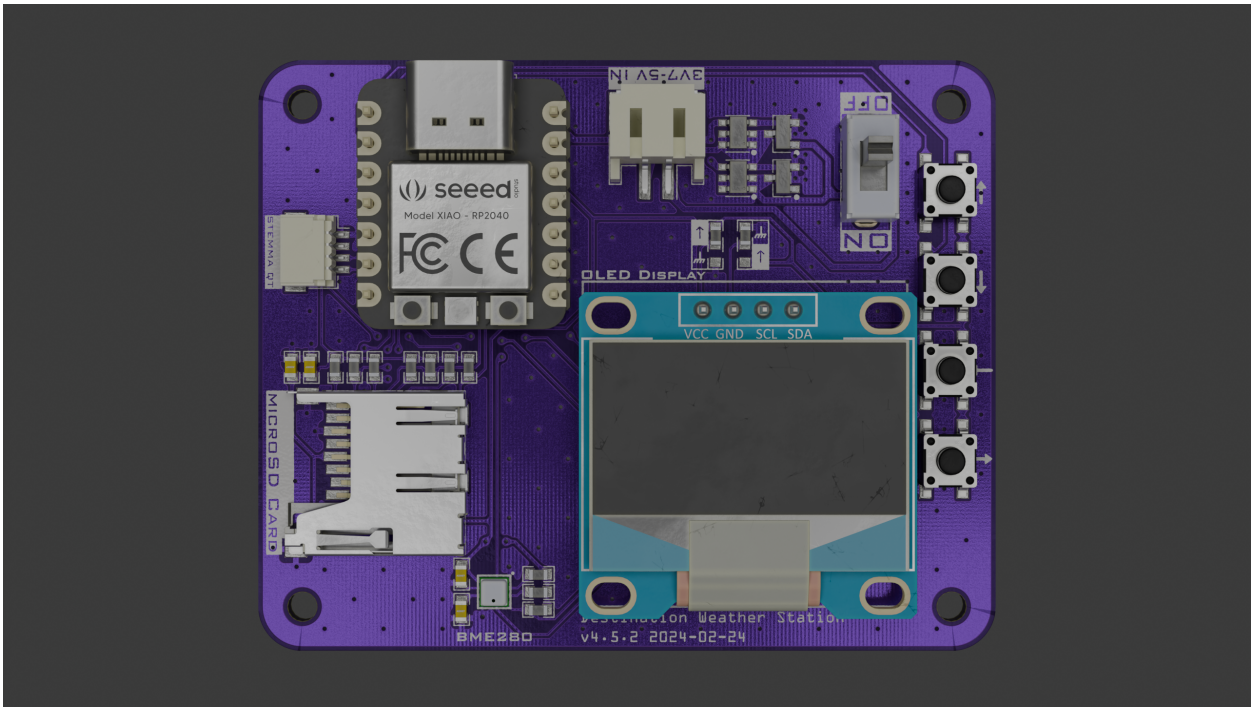
To solder the OLED display to the weather station, you will follow similar procedures to the steps above to solder the XIAO.

Begin by inserting the long side of the 1x4 header into the weather station board as shown below.

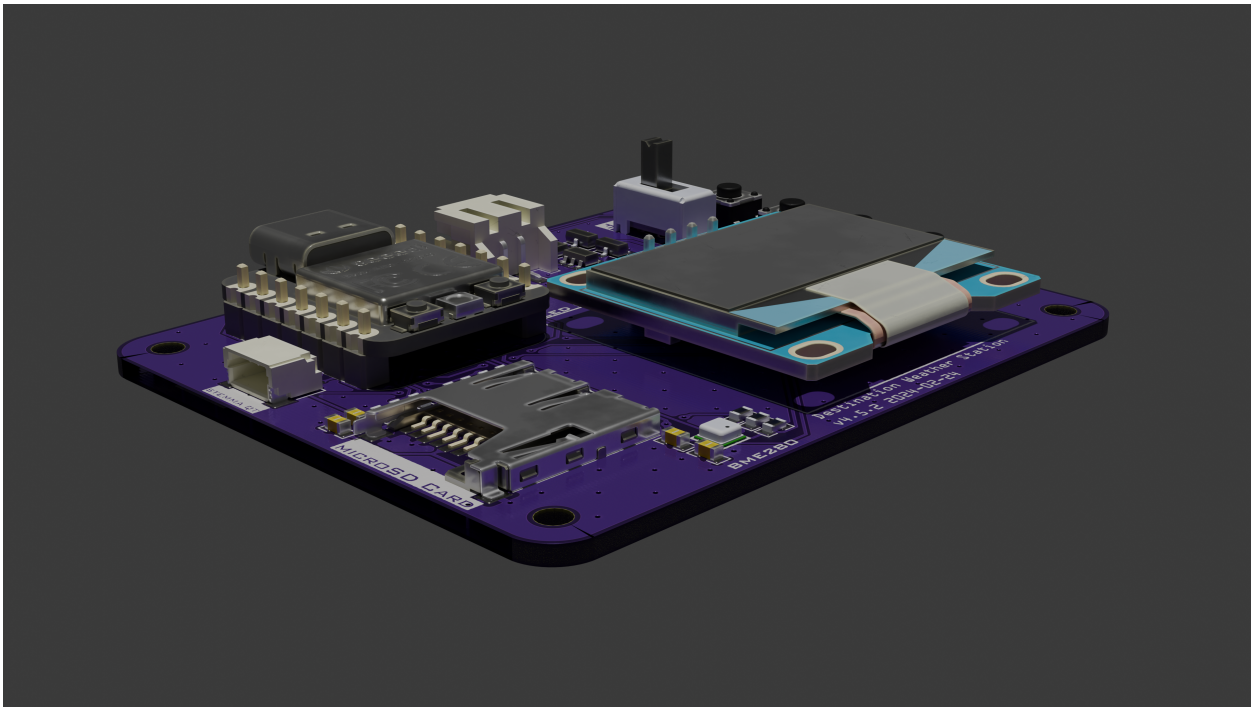


Next, flip the board over and solder the pins to the back.

Similarly, flip the board back over and solder the display to the front.



1.2.2 Final Assembly



Batteries

Insert three (3) AAA batteries into the battery pack. Connect the JST-PH connector to the matching connector on the weather station.

CHAPTER

TWO

CONFIGURATION

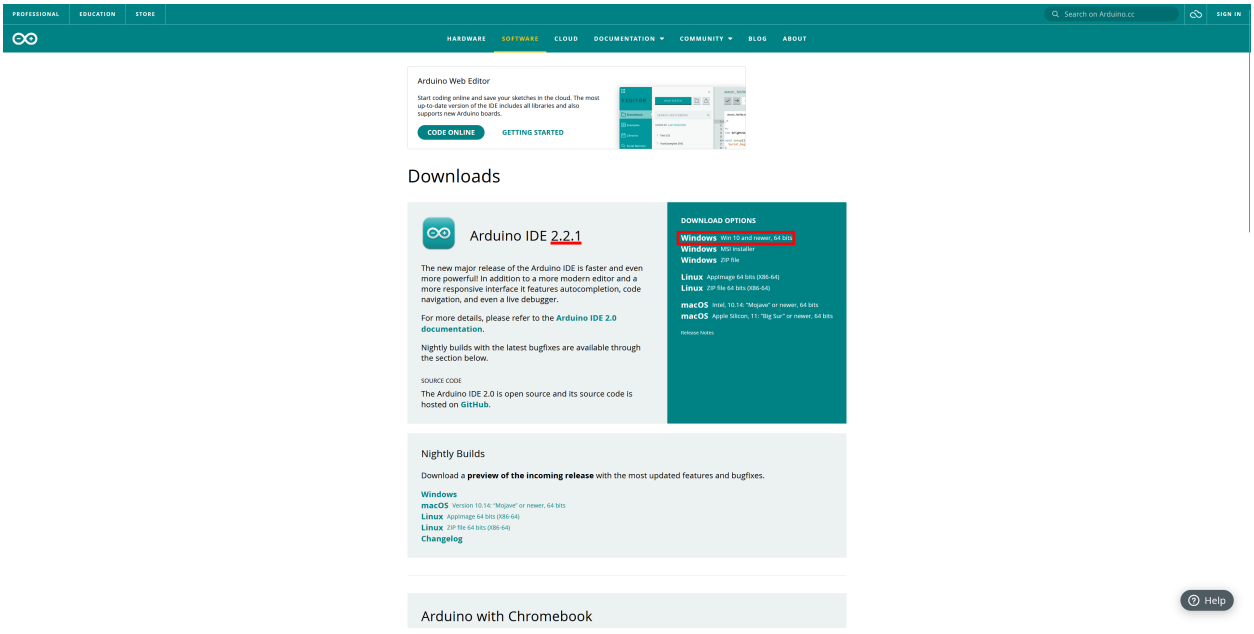
2.1 Installing Arduino IDE

To program the Destination Weather Station, you will need to download and install Arduino IDE.

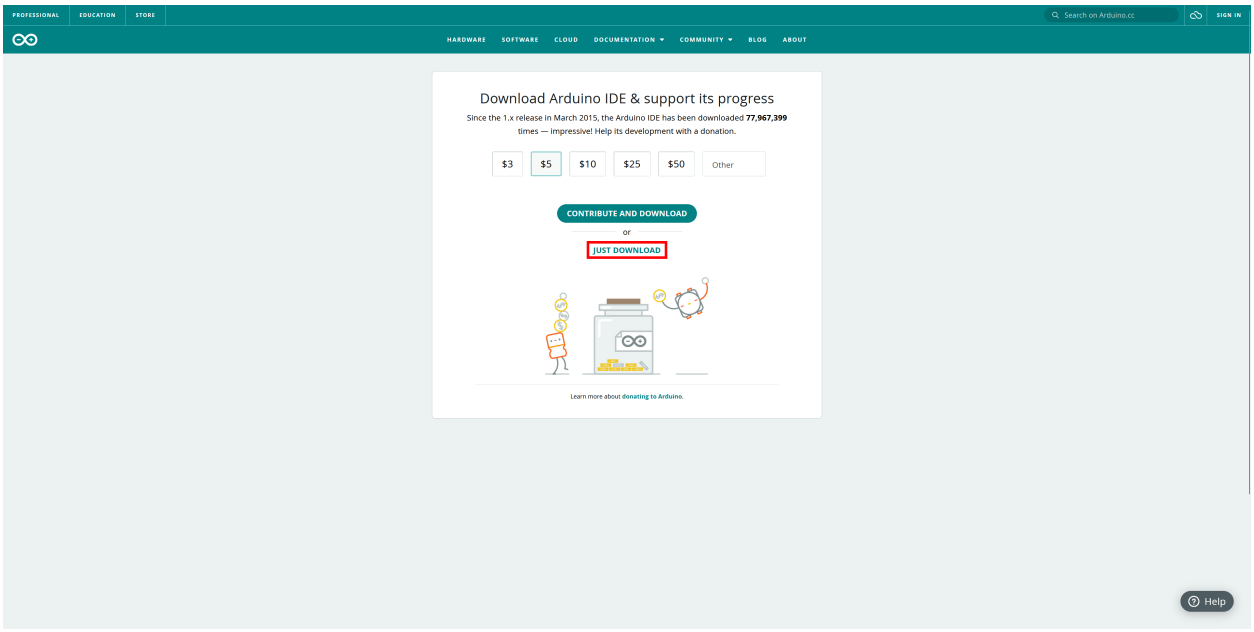
2.1.1 Download

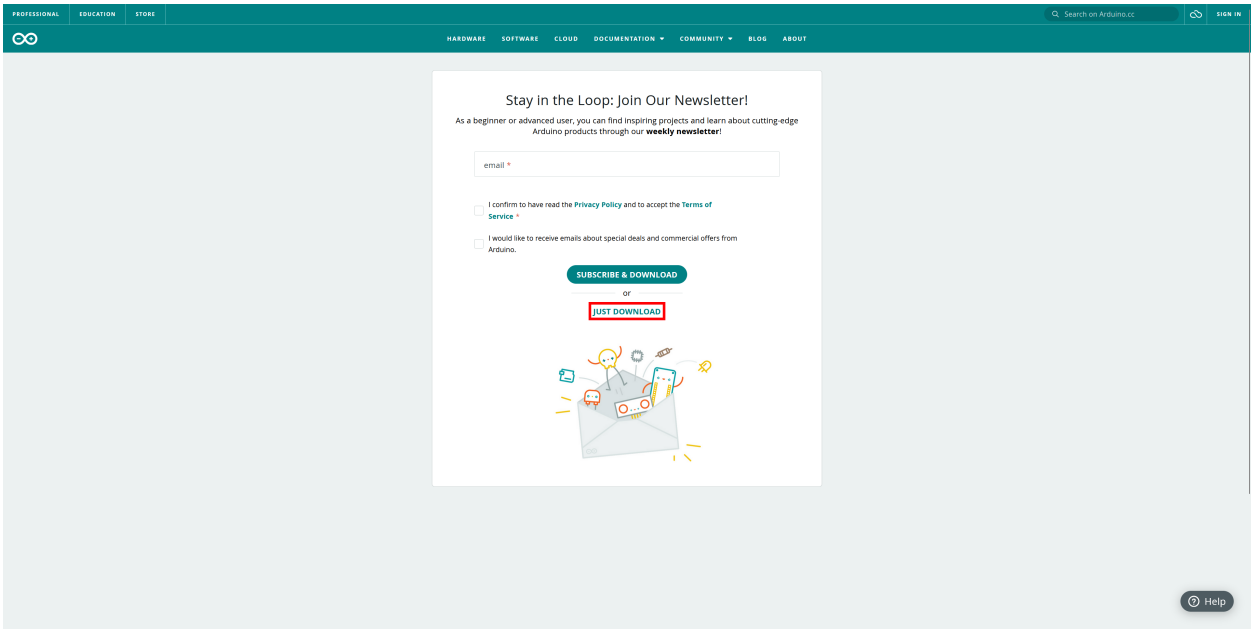
To begin, navigate to https://www.arduino.cc/en/software.

Click `Windows Win 10 and newer, 64 bits` under the most recent version of IDE. This may be different than the screenshot below



When the page loads, click next





2.1.2 Installation

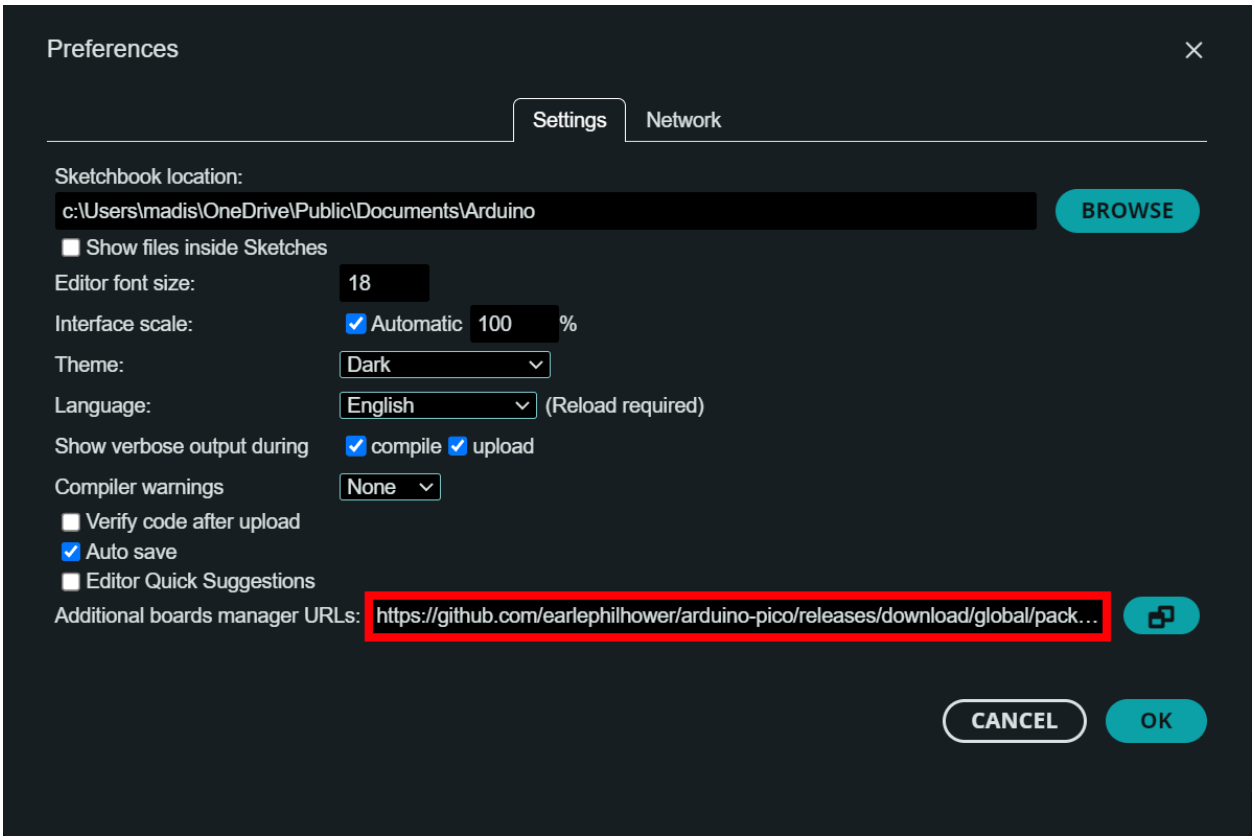
To install Arduino IDE, navigate to where you saved your `arduino-ide_2.x.x_Windows_64bit.exe` file and follow the instructions in the install.

2.2 Software Configuration

2.2.1 Board Manager

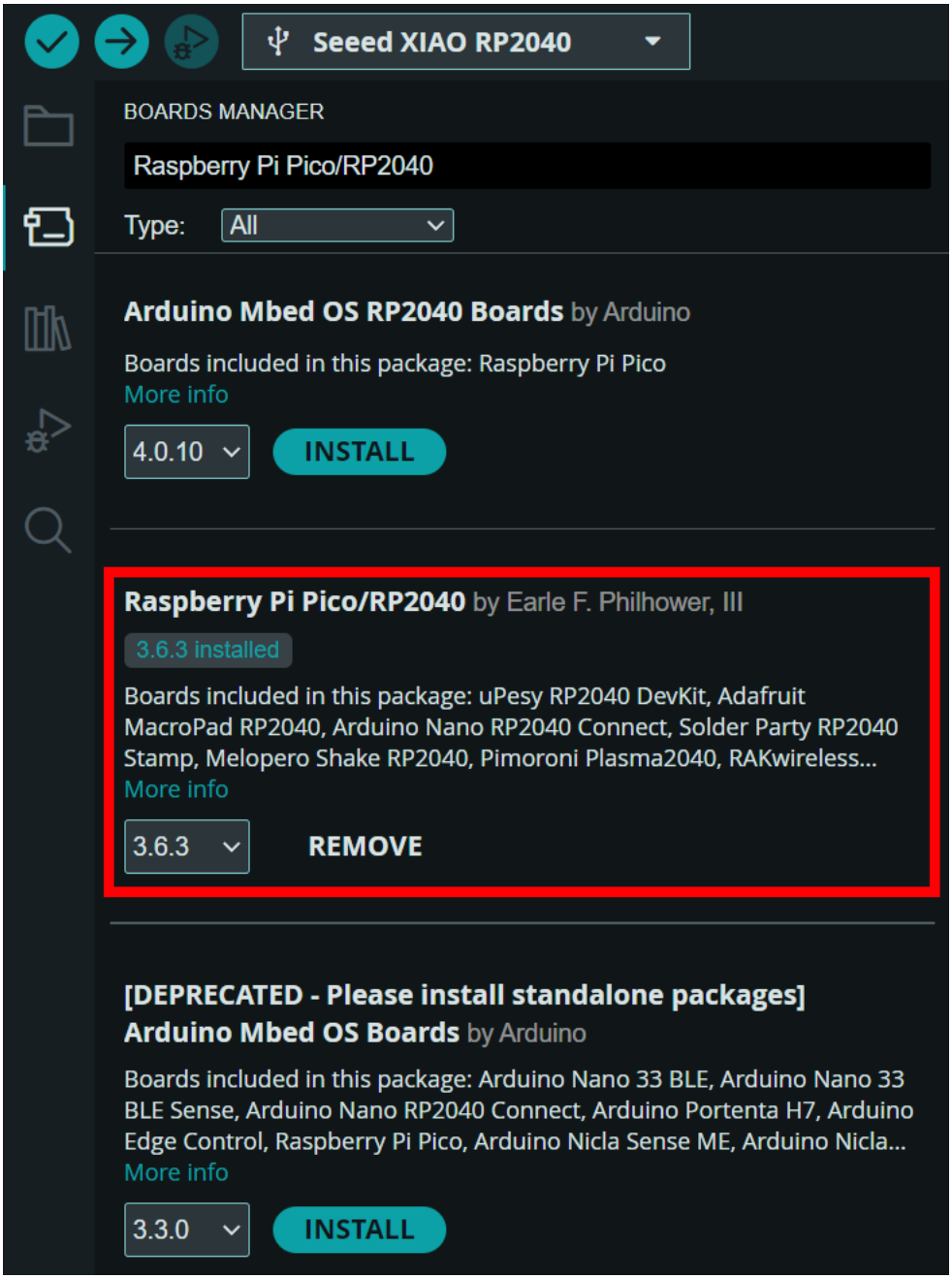
To properly configure IDE, the board manager for the XIAO RP2040 needs to be installed.

In Arduino IDE, navigate to **File > Preferences**. In the window, enter `https://github.com/earlephilhower/arduino-pico/releases/download/global/package_rp2040_index.json` into the **Additional boards manager URLs:** text box.



Click **OK**

Next, navigate to **Tools > Board: > Boards Manager...**. Search for `Raspberry Pi Pico/RP2040` and click **INSTALL** on the option published by Earle F. Philhower, III.



2.2.2 Code Libraries

Several libraries are needed to upload code to the weather station.

To install these libraries, navigate to **Tools > Manage Libraries...**

In the search box enter the following library names and install each including any required dependancies.

- `Adafruit BME280 Library`
- `Adafruit LTR390 Library`
- `Adafruit SSD1306`

- Adafruit VEML7700 Library
- ENS160 - Adafruit Fork
- Sensirion I2C SCD4x

CHAPTER

THREE

SENSORS

3.1 Destination Weather Station - Sensors

The Destination Weather Station is equipped with a *Bosch BME280 combined humidity and pressure sensor*.

In the expansion sensor kit, several more environmental sensors are provided to measure a wide variety of parameters. These include:

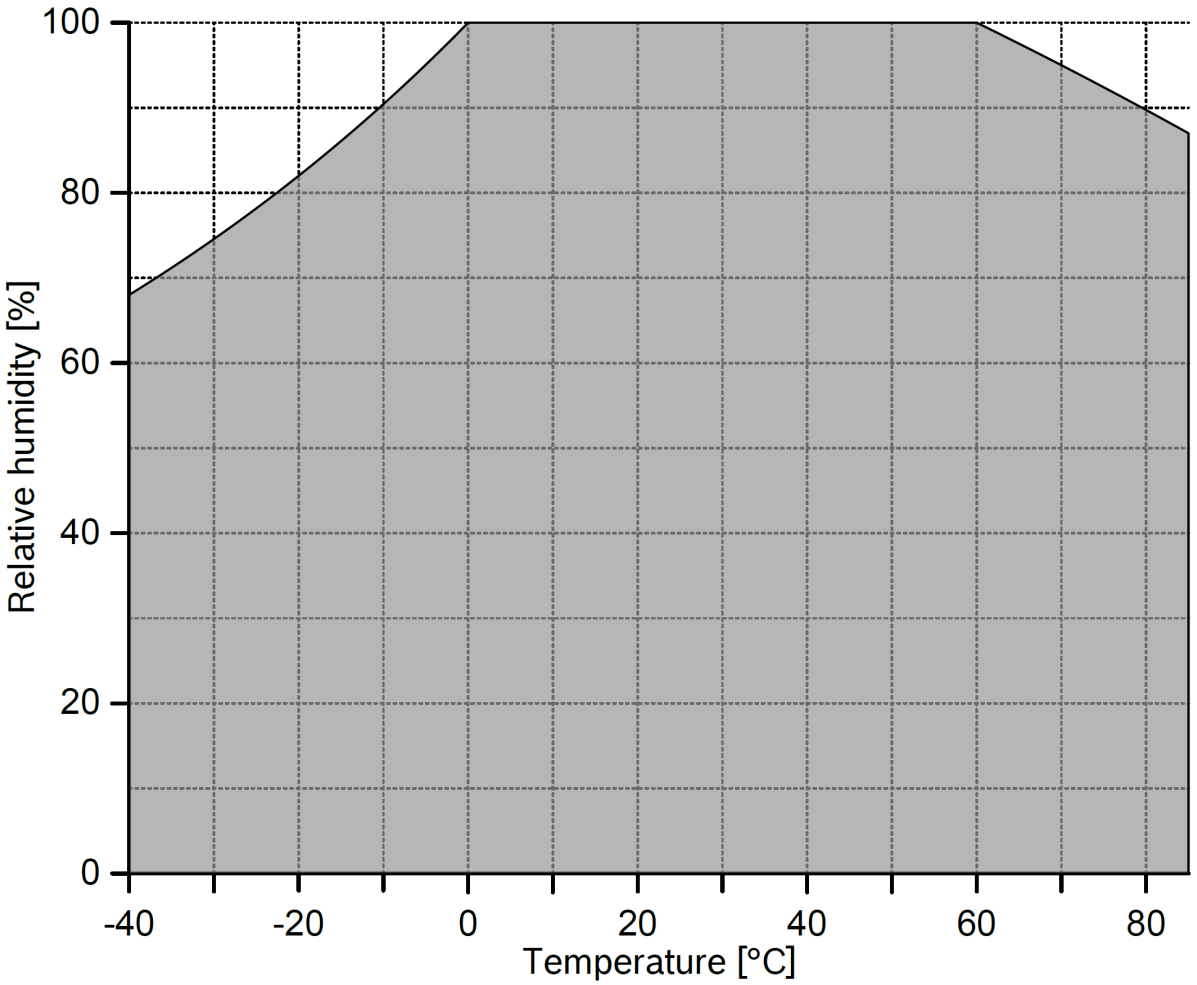
- *ScioSense ENS160 - Digital metal-oxide multi-gas sensor*
- *Lite-On LTR390 - Ambient light and ultravoiolet light sensor*
- *Sensirion SCD40 - Miniature CO2 sensor*
- *Vishay VEML7700 - High accuracy ambient light sensor*

3.2 BME280

The BME280 combined humidity and pressure sensor is a classic device used for accuratly measureing temperature, pressure, and humidity.

3.2.1 Humidity

Parameter	Specifications
Operating Range	0 - 100 %RH
Absolute Accuracy	±3 %RH
Hysteresis	± %RH



3.2.2 Pressure

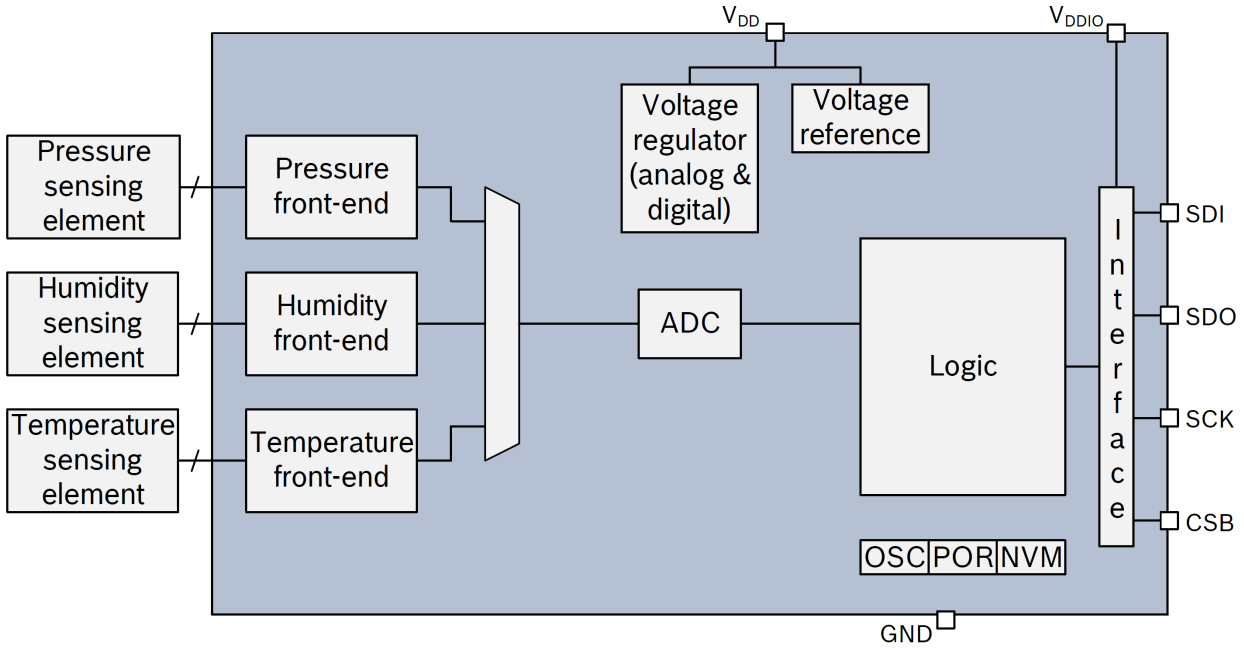
Parameter	Specifications
Operating Range	0 - 1100 hPa
Absolute Accuracy	± 1.0 hPa
Relative Accuracy (700 - 900 hPa & 25 - 40 °C)	± 0.12 hPa

3.2.3 Temperature

Parameter	Specifications
Operating Range	0 - 65 °C
Absolute Accuracy	0.5 °C

3.2.4 Functional Block Diagram

Below is a functional block diagram for how the BME280 sensor works. The data for each parameter (humidity, pressure, and temperature) are measured using an analog sensor. The data is then converted from an analog voltage signal to a digital data signal. This data is then passed to the logic side of the sensor which sends and recieves data to/from the host device.



3.3 ENS160

The ENS160 digital metal-oxide multi-gas sensor measures volitile organic compounds (VOCs), which can be used to measure total VOC content (TVOC), air quality index (AQI), and calculate an approximate value for carbon-dioxide concentration (eCO2).

3.3.1 Specifications

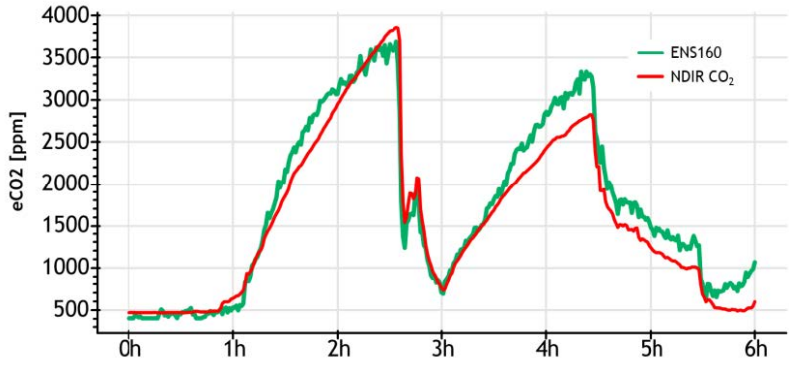
Parameter	Range	Resolution	Units
TVOC	0 - 65,000	1	ppb
eCO2	400 - 65,000	1	ppm CO2 equivalent
AQI-UBA	1 to 5	1	•
AQI-EPA	0 - 500	1	•

3.3.2 TVOC

Total Volitile Organic Compounds (TVOC) is a useful parameter used to determine the quality of the air in a given area. This is incredibly important for urban environments and in indoor settings. This is typically measured in parts-per-billion (ppb), but in polluted environments, can reach into the parts-per-million (ppm) range.

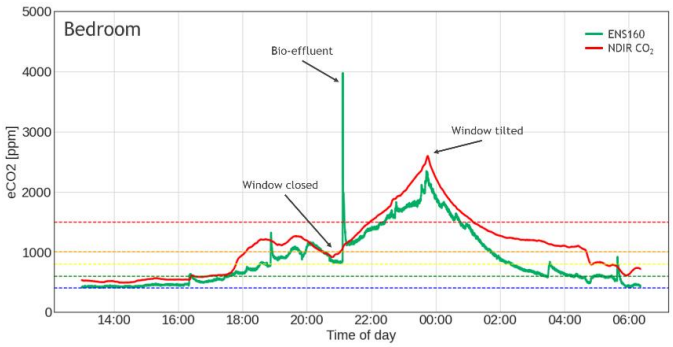
3.3.3 eCO2

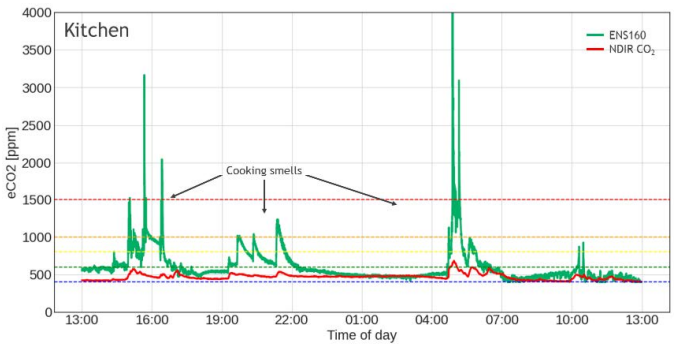
The ENS160 sensor uses an algorythm to calculate an approximate value for carbon-dioxide (CO2) concentration. While the sensor cannot directly measure CO2, it's algorythm can closely approximate this value, as seen in the graph below.

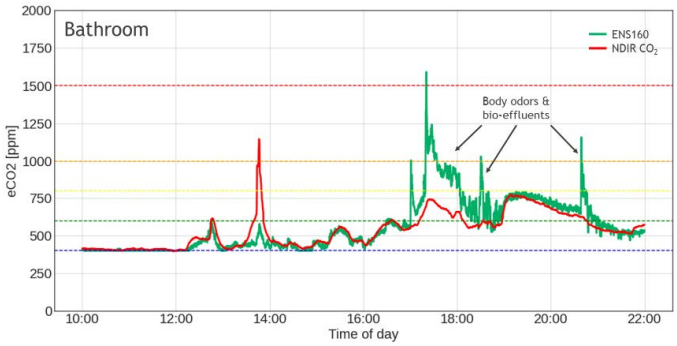


In the graph, the calculated eCO2 measurment is being compared to a nondispersive infrared CO2 sensor. It can closely approximate the CO2 concentration, but it is not perfect.

In the graphs below, ScioSense has provided eCO2 measurments for different environments, such as in a bedroom, kitchen, and bathroom. These graphs show that different conditions, such as closing a window, cooking, or being in a room can increase CO2 concentrations.







3.3.4 AQI

Air Quality Index (AQI) is the typical parameter used to judge the quality of air and how polluted it is. There are several different scales used to measure this value, but they are all based on the concentration of VOCs. For example, the United States uses the NowCast algorythm developed by the Environmental Protection Agency (EPA) ranging from 0 to 500, the European Union's European Environment Agency (EEA) uses a scale ranging from 0 to 1250, and Taiwan's Ministry of Environment uses a similar scale to the United States, ranging from 0 to 500. The figures below show each of these indexes.

Environmental Protection Agency (EPA)

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	**Good**	**0 to 50**	**Air quality is satisfactory, and air pollution poses little or no risk.**
Yellow	**Moderate**	**51 to 100**	**Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.**
Orange	**Unhealthy for Sensitive Groups**	**101 to 150**	**Members of sensitive groups may experience health effects. The general public is less likely to be affected.**
Red	**Unhealthy**	**151 to 200**	**Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.**
Purple	**Very Unhealthy**	**201 to 300**	**Health alert: The risk of health effects is increased for everyone.**
Maroon	**Hazardous**	**301 and higher**	**Health warning of emergency conditions: everyone is more likely to be affected.**

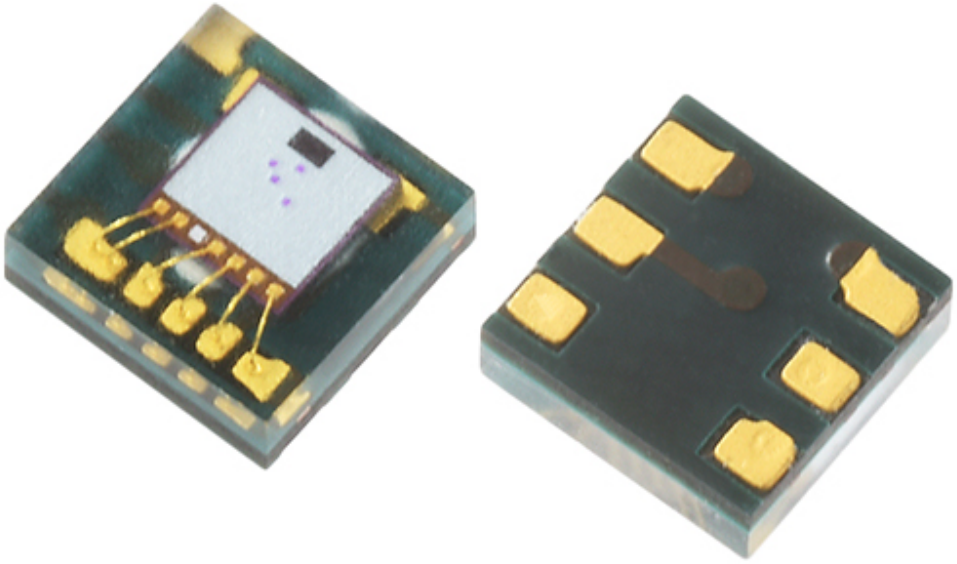
European Environment Agency (EEA)

Pollutant	Index level (based on pollutant concentrations in µg/m3)					
	Good	Fair	Moderate	Poor	Very poor	Extremely poor
Particles less than 2.5 µm ($PM_{2.5}$)	0-10	10-20	20-25	25-50	50-75	75-800
Particles less than 10 µm (PM_{10})	0-20	20-40	40-50	50-100	100-150	150-1200
Nitrogen dioxide (NO_2)	0-40	40-90	90-120	120-230	230-340	340-1000
Ozone (O_3)	0-50	50-100	100-130	130-240	240-380	380-800
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-750	750-1250

Ministry of Environment

Air Quality Index (AQI)							
AQI	O_3 (ppm) 8h	O_3 (ppm) 1-h [1]	$PM_{2.5}$ (µg/m³) 24-h	PM_{10} (µg/m³) 24-h	CO (ppm) 8-h	SO_2 (ppb) 1-h	NO_2 (ppb) 1-h
Good 0 ~ 50	0.000 - 0.054	-	0.0 - 15.4	0-50	0 - 4.4	0-20	0-30
Moderate 51 ~ 100	0.055 - 0.070	-	15.5 - 35.4	51-100	4.5 - 9.4	21-75	31-100
Unhealthy for Sensitive Groups 101 ~ 150	0.071 - 0.085	0.125 - 0.164	35.5 - 54.4	101-254	9.5 - 12.4	76-185	101-360
Unhealthy 151 ~ 200	0.086 - 0.105	0.165 - 0.204	54.5 - 150.4	255-354	12.5 - 15.4	186-304 [3]	361-649
Very Unhealthy 201 ~ 300	0.106 - 0.200	0.205 - 0.404	150.5 - 250.4	355-424	15.5 - 30.4	305-604 [3]	650-1249
Hazardous 301 ~ 400	(2)	0.405 - 0.504	250.5 - 350.4	425 - 504	30.5 - 40.4	605-804 [3]	1250-1649
Hazardous 401 ~ 500	(2)	0.505 - 0.604	350.5 - 500.4	505-604	40.5 - 50.4	805-1004 [3]	1650-2049

3.4 LTR390



The LTR390 optical sensor is a combined digital ambient light (ALS) and UVA sensor.

3.4.1 Ambient Light Specifications

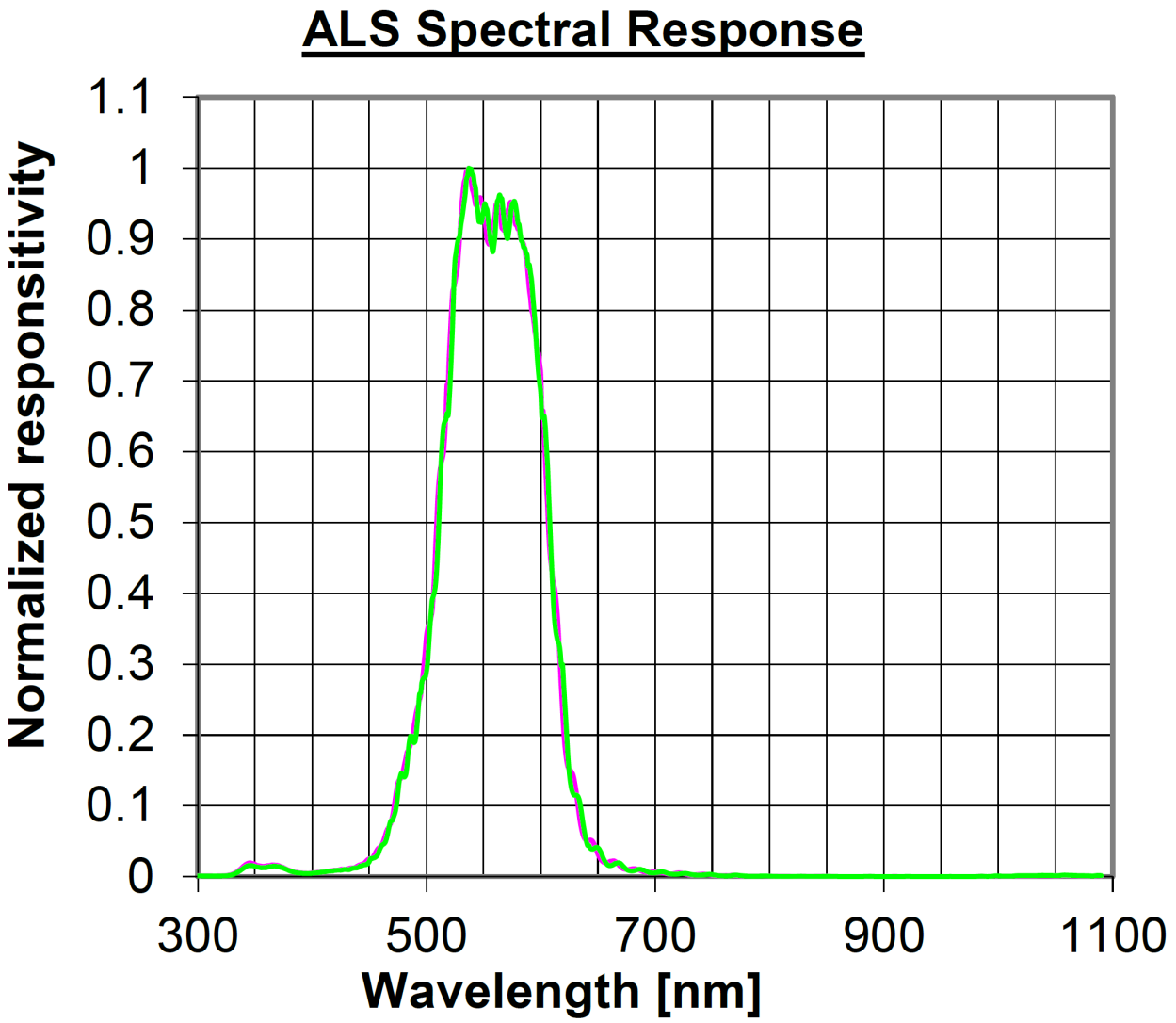
Parameter	Minimum	Typical	Maximum	Units	Condition
ALS Output Resolution	13	18	20	Bit	Programable for 13, 16, 17, 18, 19, 20 bit
Dark Level Count	•	0	5	count	0 Lux, T_ope=25°C, 18-bit range
Calibrated Lux Error In Gain Range 3	-10	•	10	%	While LED, 5000K, T_ope=25°C
ALS Accuracy	-25	•	25	%	Across different light sources

3.4.2 UVS Specifications

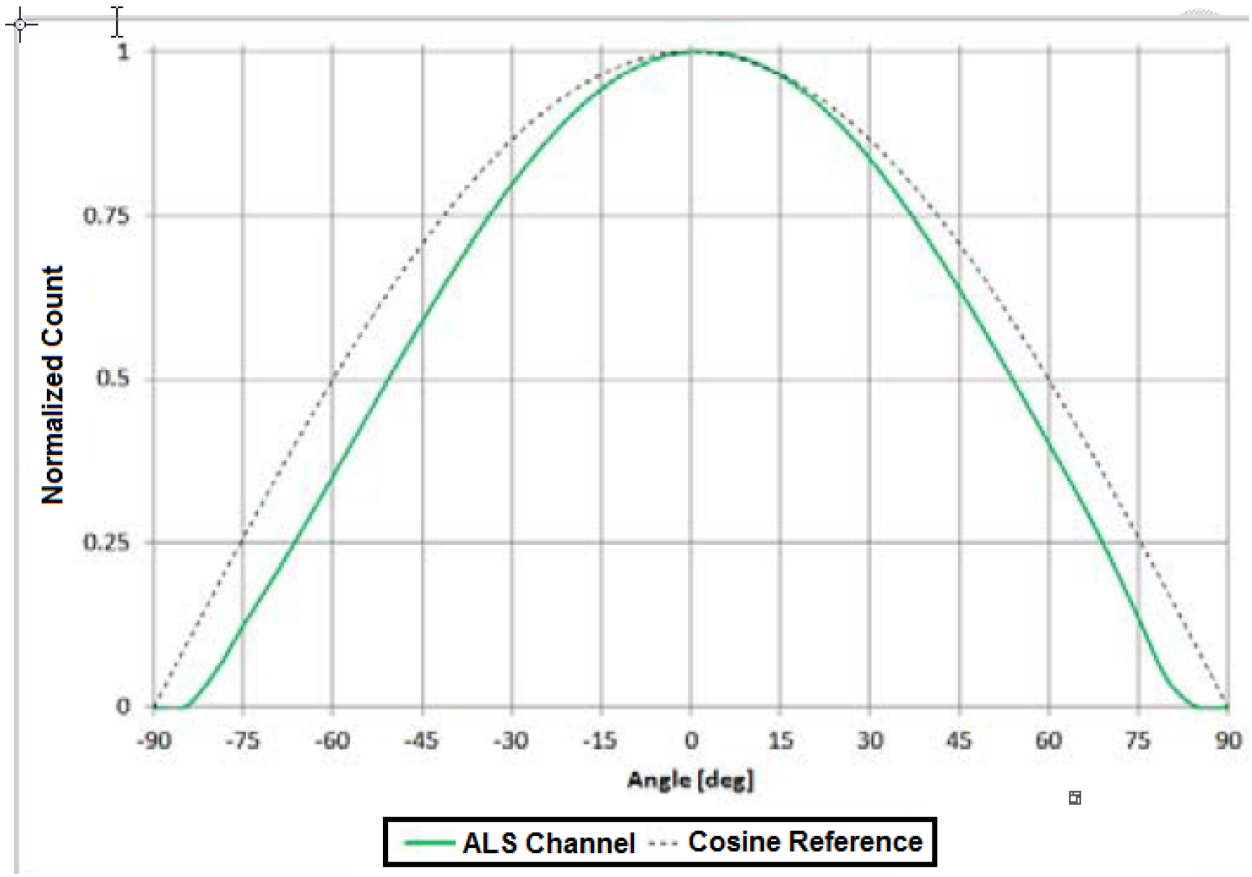
Parameter	Minimum	Typical	Maximum	Unit	Condition
UVS Output Resolution	13	18	20	Bit	Programmable for 13, 16,17, 18, 19, 20 bit
UV Count	•	160	•	count	UV LED 310nm, T_ope=25°C, 18-bit, Gain range = 18, Irradiance = 70uW/cm2
UV Sensitivity	•	2300	•	Counts/UVI	Gain range = 18, 20-bit
UVI Accuracy (UVI>5)	-20	•	20	%	Gain Range = 18, 20bit
UVI Accuracy (UVI<5)	-1	•	1	%	Gain Range = 18, 20bit

3.4.3 ALS Sensor

The ambient light sensor is sensitive to a range of 450nm - 650nm and is centered at 535nm as seen in the graph below.

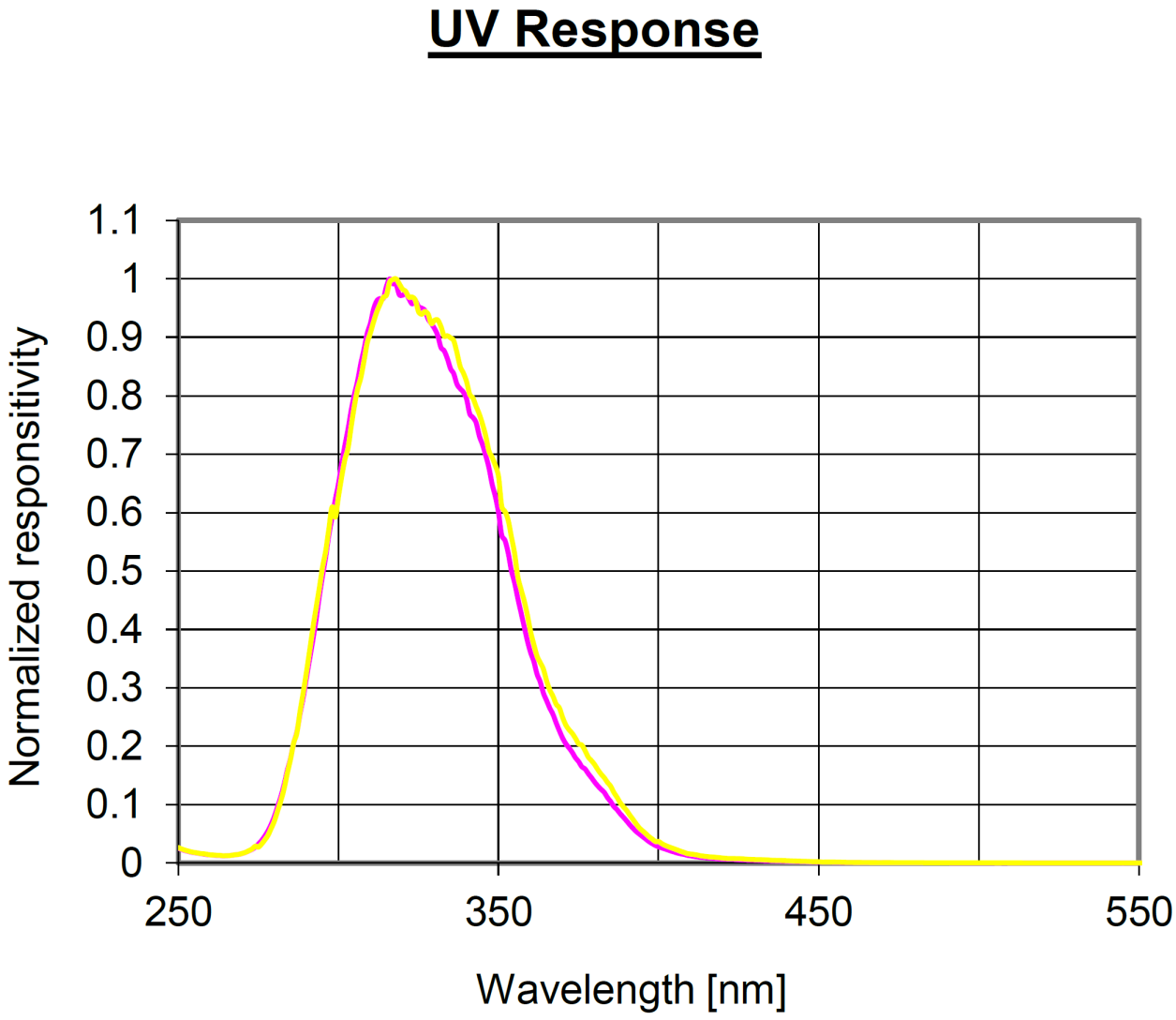


Additionally, below is a graph showing the angle of incidence of the sensor, where a normalized count of 1 indicates full sensitivity.



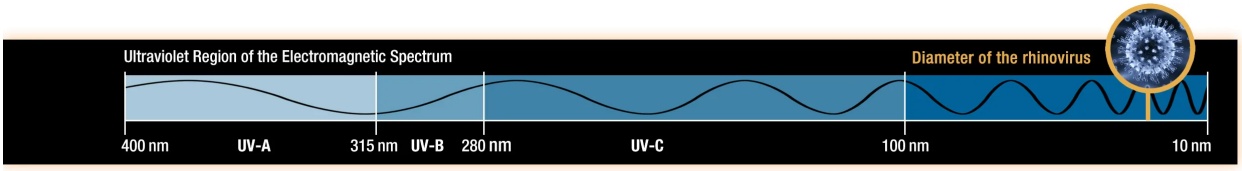
3.4.4 UVS Sensor

The UVS sensor peaks in sensitive for UVA wavelengths (315-400) with some moderate sensitivity to low-energy UVB wavelengths. The graph below indicates the the response of the UVS sensor, which has a range of 275nm - 400nm and is centered at 320nm.



3.4.5 The Ultra-Violet Spectrum

The ultra-violet spectrum ranges from 10nm to 400nm. This is further subdivided into different bands of intensity, which are used in remote sensing and to indicate their danger.



3.4.6 UVA

UVA is the longest wavelength of the UV spectrum, ranging from 400nm to 315nm. UVA is the primary cause of sunburns encountered from being in the sun too long. This is because the longer wavelength allows it to penetrate deeper into the skin.

3.4.7 UVB

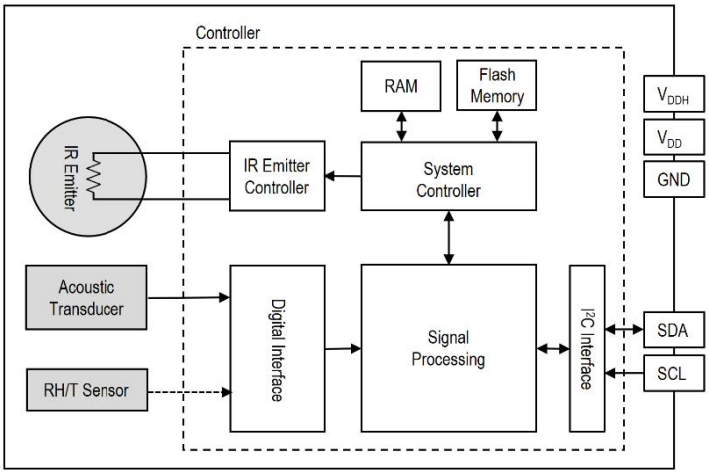
UVB is a the middle band of the UV spectrum and ranges from 315nm to 280nm. UVB is mostly absorbed by the ozone layer, but can still reach the earth's surface. This is primarily seen at higher latitudes and elevations. Because UVB has a shorter wavelength, this is the primary cause of skin cancer and blistering from sunburns.

3.4.8 UVC

UVB is the highest energy band in the UV spectrum, ranging from 280nm to 100nm. UVC is entrily filtered out by the Earth's atmosphere, so is no danger to life on the surface, but can become a risk durring air travel or in space. UVC is a type of ionizing radiation, meaning it easily kills cells. This is useful for UV disinfection lights.

3.5 SCD40

THe SCD40 CO2 sensor uses photoacoustic nondispersive infrared (NDIR) technology to measure actual CO2 concentration, unlike the eCO2 measurement on the *ENS160*. This works by measuring the attenuation of an infrared light shining through the gas onto an accoustic transducer. Along with the sample chamber there is a reference nitrogen sample used to compare the CO2 measurement to the known gas. This process works according to Beer-Lambert law which is this attenuation of the gas.



3.5.1 CO2 Sensing Preformance

Parameter	Conditions	Value
Output range	•	0 - 40,000ppm
Accuracy	400ppm - 2,000ppm	±(50ppm + 5% of reading)
Repeatability	Typical	±10ppm

3.5.2 Humidty Sensing Preformance

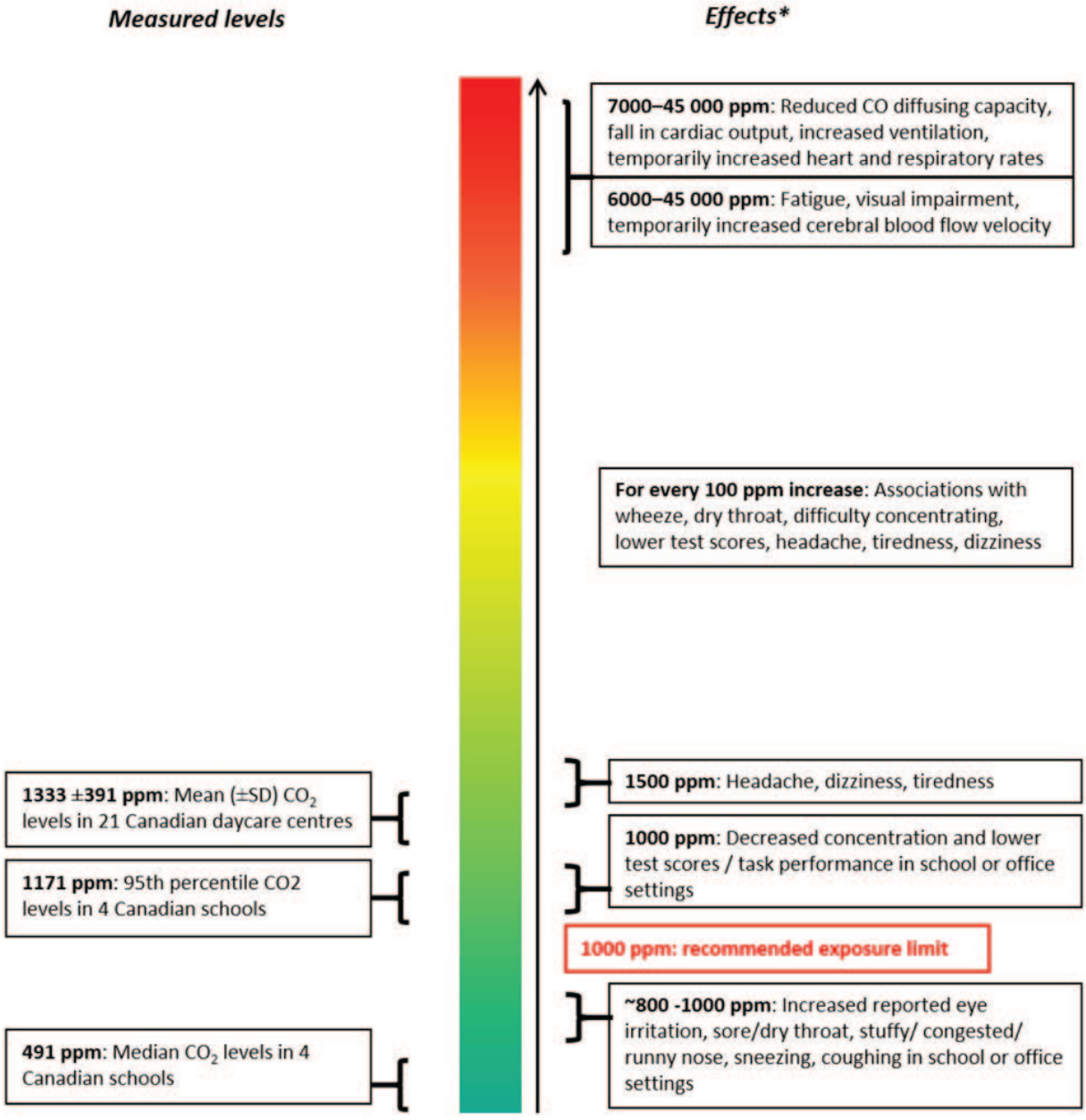
Parameter	Conditions	Value
Range	•	0 %RH - 100 %RH
Accuracy	15°C - 35°C, 20 %RH - 65 %RH	±6 %RH
Accuracy	-10°C - 60°C, 0 %RH - 100 %RH	±9 %RH
Repeatability	Typical	±0.4 %RH

3.5.3 Temperature Sensing Preformance

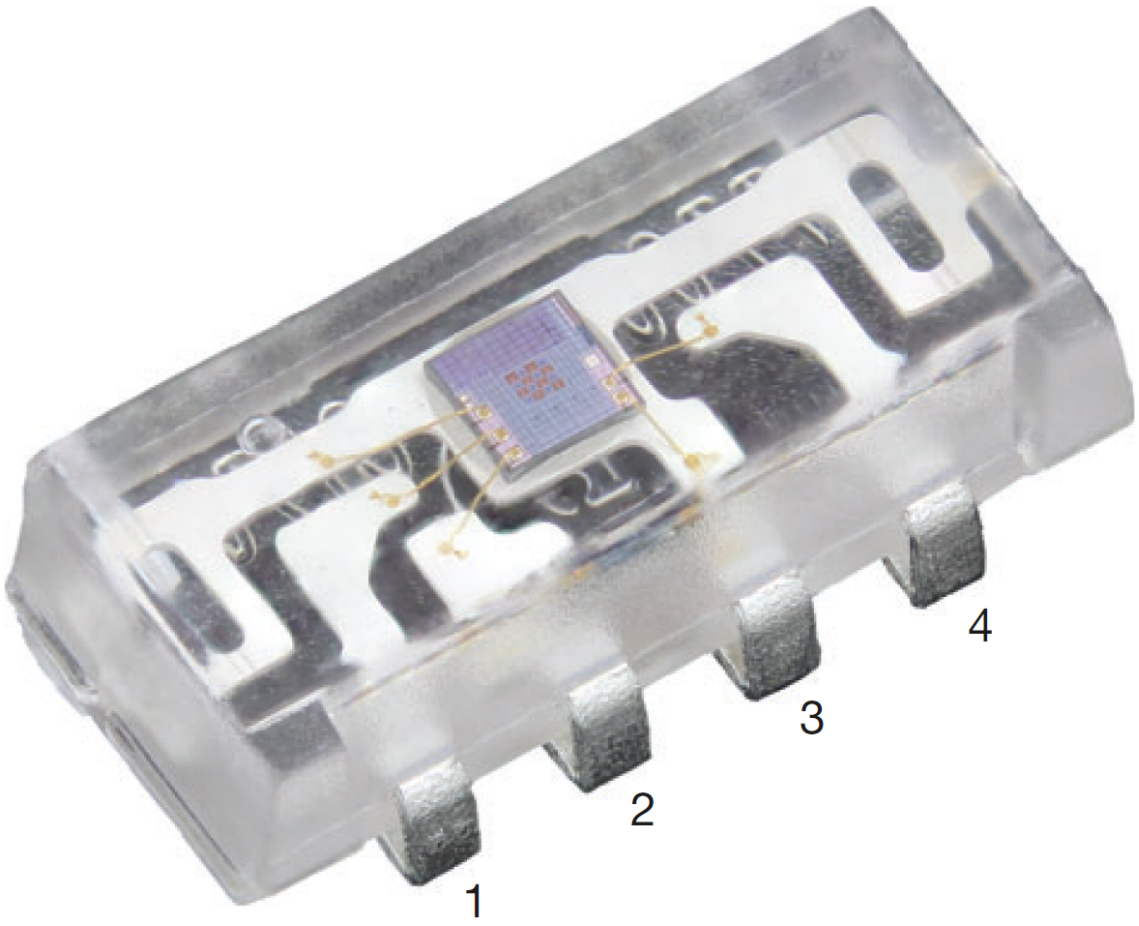
Parameter	Conditions	Value
Range	•	-10°C - 60°C
Accuracy	15°C - 35°C	±0.8°C
Accuracy	-10°C - 60°C	±1.5°C
Repeatability	Typical	±0.1°C

3.5.4 Measuring CO2

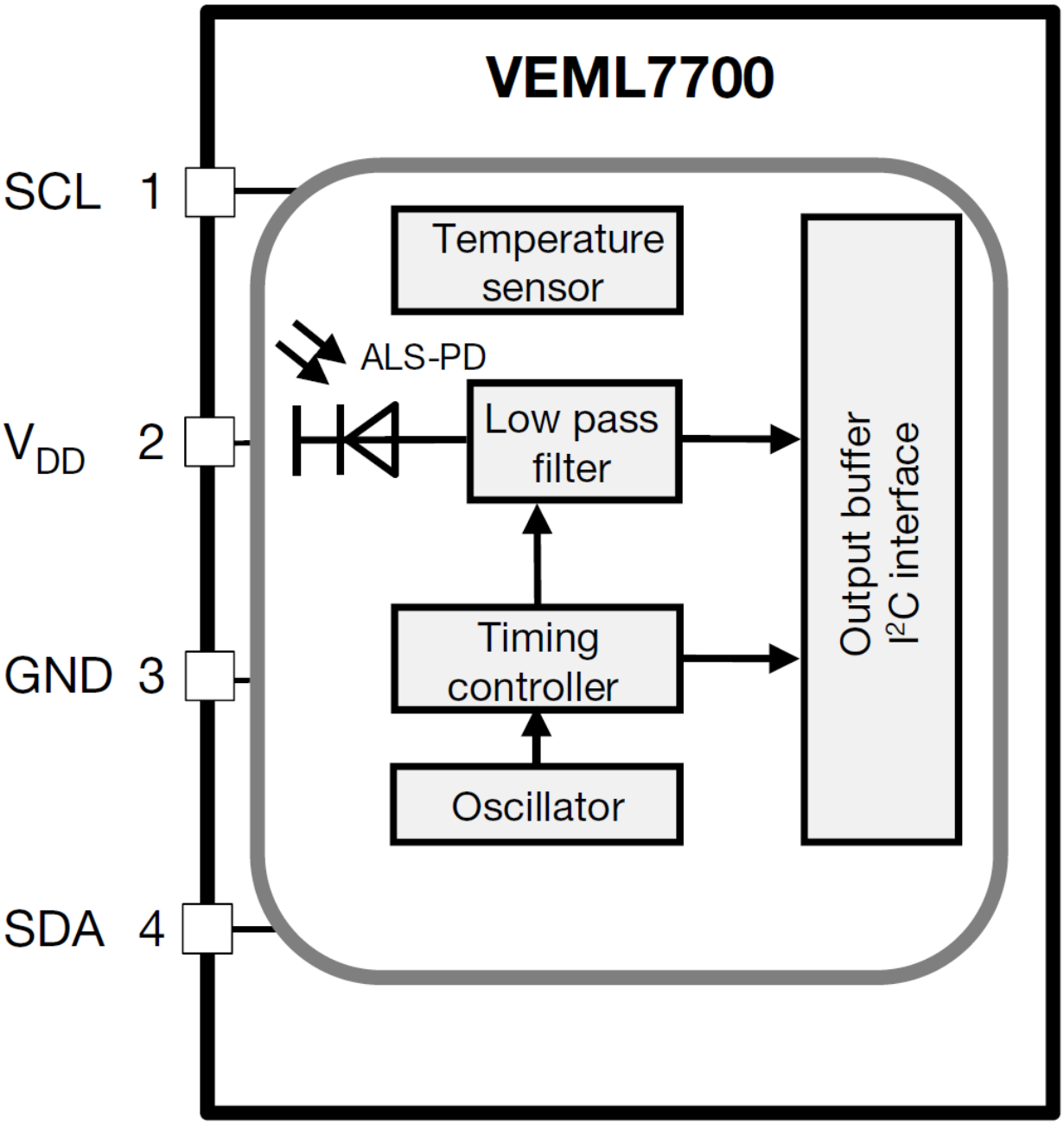
Measuring CO2 is another important parameter for indoor and outdoor air quality. Health Canada reccomends not exceeding 1000ppm of CO2 in a 24 hour period. A high concentration of CO2 can increase the risk of respiratory symptoms, decreased cognitive function, and neurophysiological symptoms such as headaches, tiredness, and dizziness. The graph below shows different concentrations and what effects one may encounter at that concentration.



3.6 VEML7700



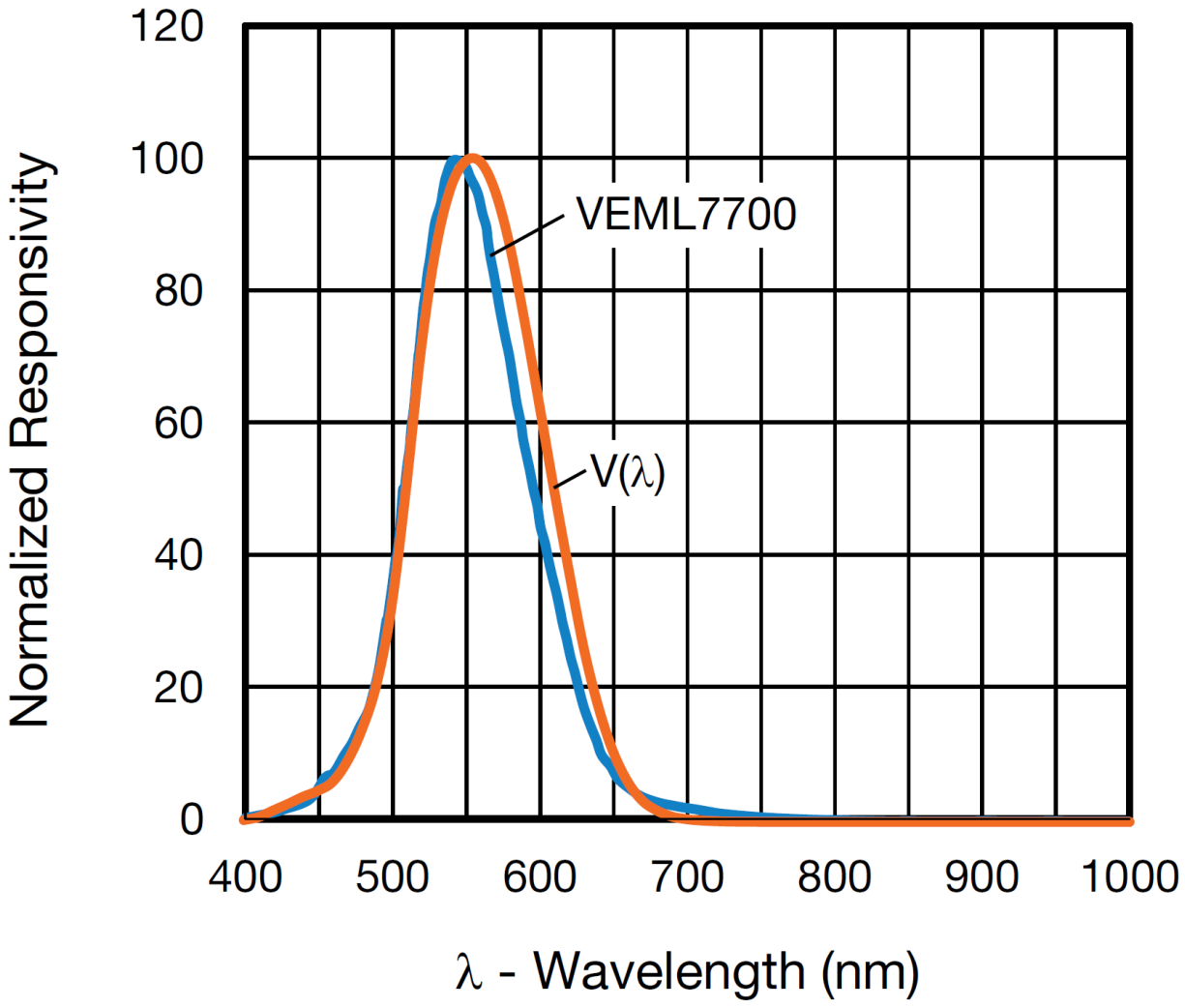
The VEML7700 high accuracy 16-bit light sensor can be used to precisely measure ambient light. Below is a functional block diagram of the device, where the sensor is an ALS photodiode.


VEML7700
SCL 1
VDD 2
GND 3
SDA 4
Temperature sensor
ALS-PD
Low pass filter
Timing controller
Oscillator
Output buffer I2C interface

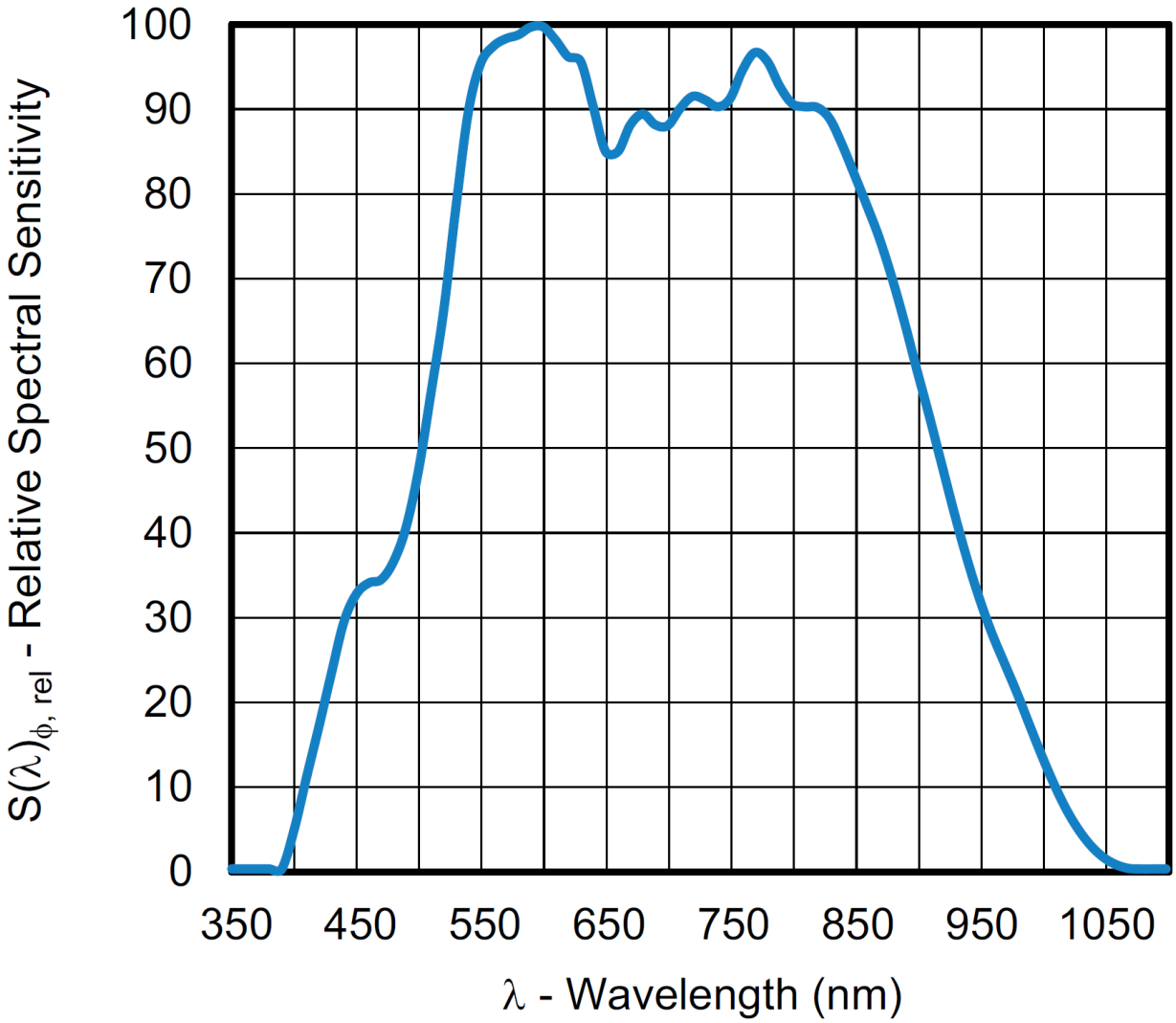
3.6.1 Specifications

Parameter	Typical Value	Units
Digital resolution	0.0036	lux/bit
Detectable minimum illuminance	0.0072	lux
Detectable maximum illuminance	120,000	lux
Dark offset	3	steps

Below is a graph showing the spectral response of the sensor. It is sensitive to wavelengths ranging from 450nm - 650nm, normalized at 550nm.



Additionally, below is a graph showing the sensitivity of the white light channel on the sensor.


100
90
80
70
60
50
40
30
20
10
0
S(λ)φ, rel - Relative Spectral Sensitivity
350
450
550
650
750
850
950
1050
λ - Wavelength (nm)

CHAPTER

FOUR

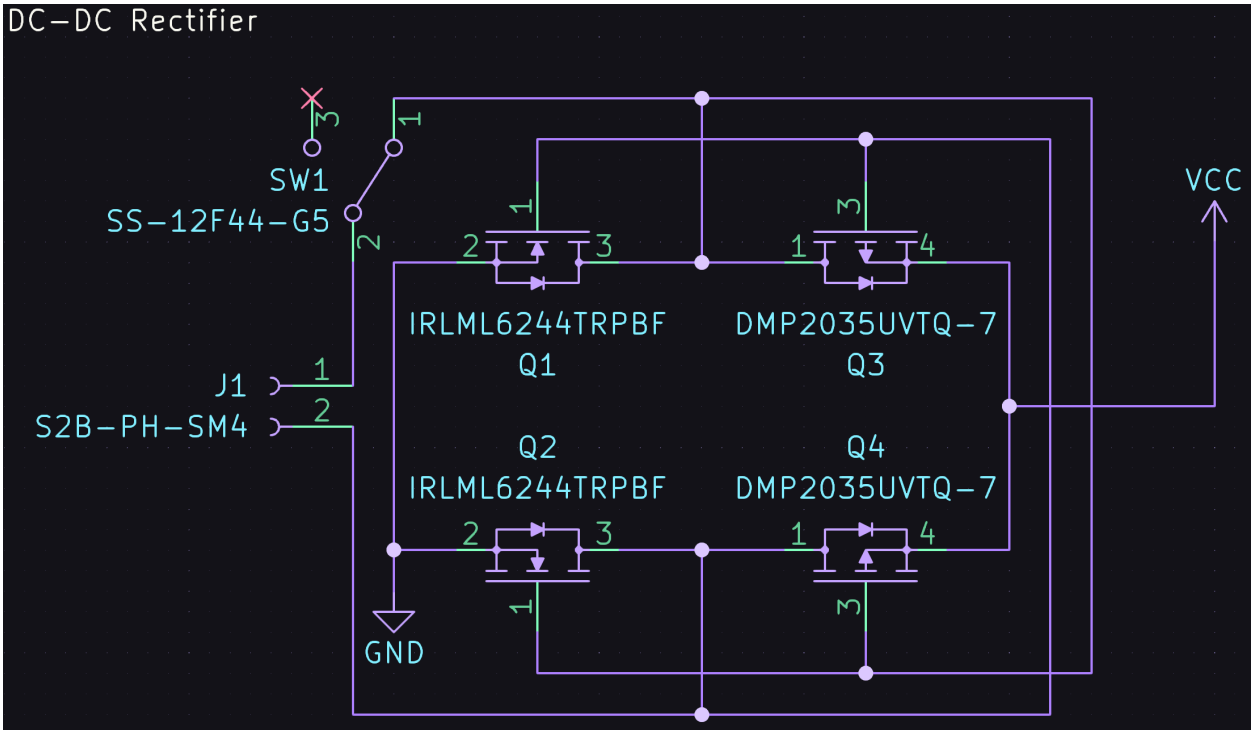
HARDWARE

4.1 Destination Weather Station - Hardware

The Destination Weather Station was designed in KiCad and assembled by hand. the weather station includes several features that improve user experiance. These are:

4.1.1 Power

The power subsystem of the weather station was designed with reverse voltage protection in mind. Typically, if a battery is connected to a circuit backwards, it will not work, or worse, fry the entire system. This is why reverse current protection is often added to circuits to prevent such user error. This allows the user to not have to worry about the polarity of their LiPo battery. On the Destination Weather Station v4.5 we have taken this one step further, by not only having reverse voltage/polarity protection, but also correcting this polarity. This works using the same principal as an AC rectifier circuit. This DC rectifier consists of two N-Channel MOSFETs and two P-Channel MOSFETs. These MOSFETs combine to essentially create a rectifier circuit, which will only allow the correct polarity to pass through the FETs. A schematic of this circuit can be found below.



Note: There is no over-current protection, so make sure to not exceed 5V in.

4.1.2 Storage

The storage on the Destination Weather station is simply a microSD card slot to store recorded sensor data for further evalulation. There is also chip-detect functionality which allows the code to know if a card has been inserted or not.

4.1.3 Human Interface Devices

On the Destination Weather Station there are 4 buttons, which are the primary way to interact with the device. These buttons are each labeled with arrows ↑, ↓, ←, →. These buttons are used to scroll through the menus and to switch between the different data displays.

4.2 Troubleshooting

Coming soon!

CHAPTER

FIVE

SOFTWARE

5.1 Software

Software for the Destination Weather Station v4.5.

5.1.1 Blink Sketch

The Blink sketch is used as a beginners program and to test the on-board RGB LED and NeoPixel.

5.1.2 Sensor Test Sketch

The Sensor Test sketch is used to make sure the sensors on the weather station are working correctly. Use this sketch as the first program to upload after the Blink sketch.

5.1.3 Demo Sketch

The Demo sketch is used as an introductory program to most of the features on the weather station. This includes scrollable menus for all sensors.

5.1.4 Full Code Sketch

The Full Code sketch incorporates all of the components of the weather station, including data recording. This has all the menus of the Demo sketch as well as a menu used to start and stop data recording.

CHAPTER

SIX

MISCELLANEOUS

6.1 Frequently Asked Questions

Coming soon!