Report of GroGenesis V2 Testing

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GroGenesis V2 prototype

GroGenesis V2 Sensor Selection

Each sensor was carefully selected such that its detection range was suitable for the targeted analyte and that the sensor could operate in a greenhouse's humid environment. The list of selected sensors added to the board are listed in Table along with its specifications.

Table 1. Overview and Analysis of Sensors on GroGenesis v2 Board.

Part #	Sensor	Price	Detection Range	Accuracy	Response Time
403-SCD30	CO2	$75	400- 10,000ppm	±(30 ppm + 3%)	20 s
SHTC3	RH/Temp.	$4.63	0 - 100% RH	±1.8 %RH ±0.1 °C	15 s
BMMP388	Pressure [kPa]	$15.68	30-110	0.05 ppm	0.1 s
SPEC-110-205	Ethanol	$31.51	0-10000 ppm	5 ppm	180 s
SPEC-110-304	Hydrogen Sulfide	$31.51	0-50 ppm	0.005 ppm	15 s
SPEC-110-401	Ozone	$31.51	0-5 ppm	0.02 ppm	15 s
SPEC-110-602	Sulfur Dioxide	$31.51	0-20 ppm	0.02 ppm	15 s
SPEC-110-109	Carbon Monoxide	$31.51	0.5-1000 ppm	0.1 ppm	30 s
SPEC-110-502	Nitrogen Dioxide	$31.51	0-5 ppm	0.02 ppm	15 s
SCIENOC 4C2H4-0.5	Ethylene	USD $134	0-0.5 ppm	0.01 ppm	30 s
SCIENOC 4NOX-10	Oxynitride	USD $134	0-10 ppm	0.1 ppm	40 s
SCIENOC 4NO-1	Nitric Oxide	USD $134	0-1 ppm	0.01 ppm	25 s
SPEC-110-902	Irritants	$31.51	0-20 ppm	30 ppm	60 s
BH1730	Light [kLux]	$7.55	0.001-100 kLux	0.83 ppm	15 s

1. GroGenesis v2 Design

The GroGenesis v2 circuit schematic and PCB board comprising the sensors was designed using Kicad PCB design software. The following section outlines the sensors functions, operating circuit, communication protocols and the PCB design of the GroGenesis v2.

2. Schematic Design

The schematic design of the GroGuardian circuit comprises the master microcontroller unit, slave microprocessors, analog and digital sensors with distinct operating/biasing circuits, passive elements such as resistors, capacitors, switches and auxiliary ports.

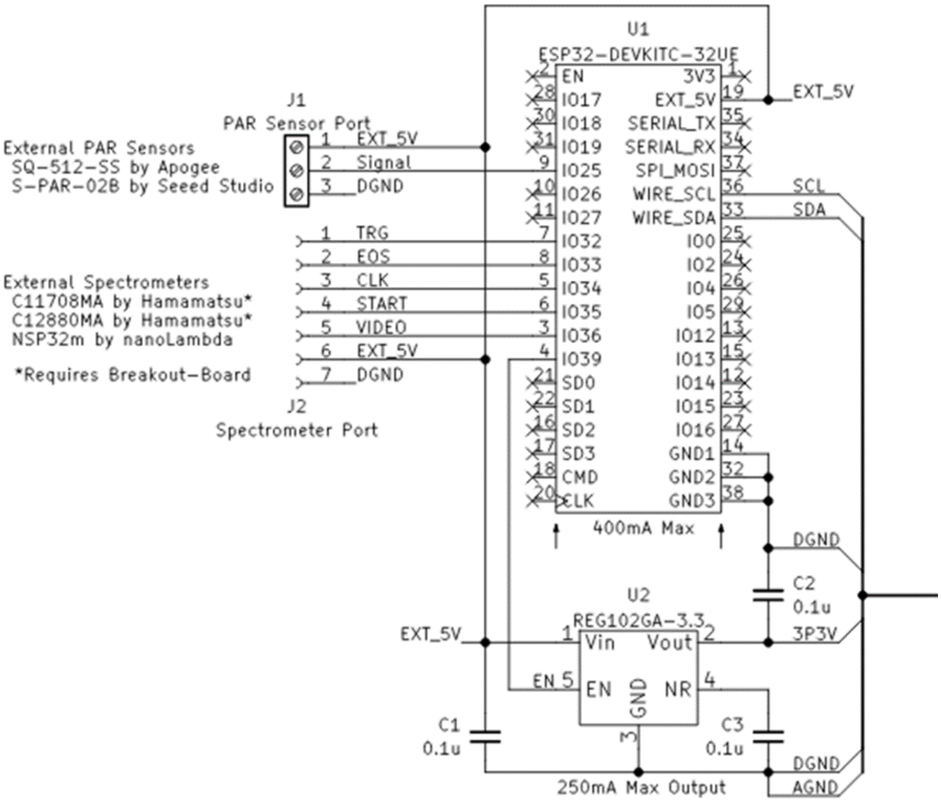

Figure 1. ESP32 microcontroller schematic circuit

In the GroGenesis v2, the ESP32 microcontroller is used as the master unit to power, communicate and program the onboard sensors and slave microprocessors. The GroGenesis v2 uses a combination of communication protocols including a data bus, i2c communication and analog communication. The ESP32 communicates with the analog sensors via the ADUCM355 microprocessors which act as slave units that connect to two analog sensors each. The schematic circuit for the ESP32 microcontroller is depicted in Figure .

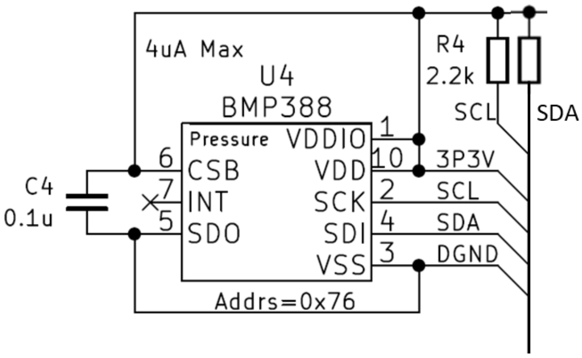

Figure 2. Schematic circuit of BMP388 pressure sensor

The BMP388 sensor is a pressure sensor that operates via i2c communication directly interfaced with the ESP32 microcontroller using the i2c address 0x76.

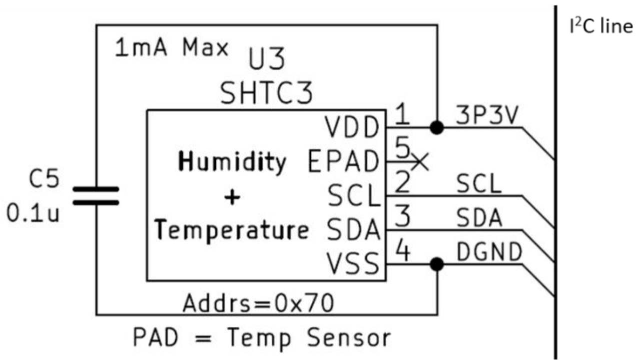

Figure 3. SHTC3 humidity and temperature sensor

The SHTC3 sensor reports both humidity and temperature value and operates via i2c communication directly interfaced with the ESP32 microcontroller unit using the i2c address 0x70.

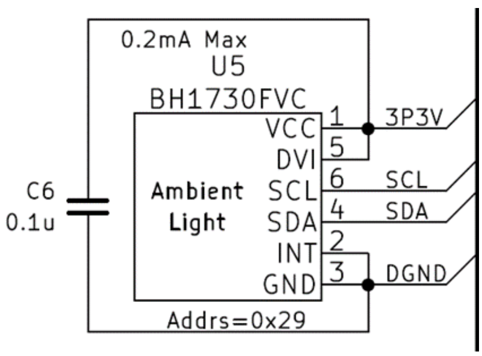

Figure 4. Schematic circuit of BH1730FVC ambient light sensor

The BH1730FVC sensor reports ambient light value in kLux and operates via i2c communication directly interfaced with the ESP32 microcontroller unit using the i2c address 0x29.

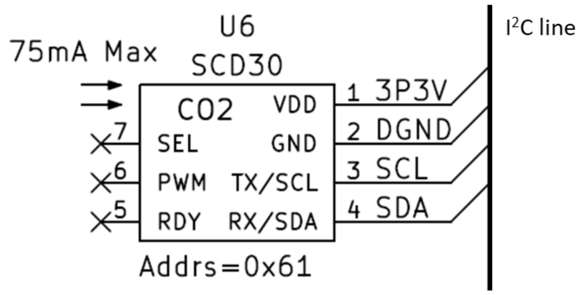

Figure 5. Schematic diagram of SCD30 CO2 sensor

The SCD30 sensor reports the CO_2 values in ppm and also comprises of an onboard reference temperature and humidity sensor which reports in °C and % RH respectively. The SCD30 operates via i2c communication with the ESP32 using the i2c address 0x61.

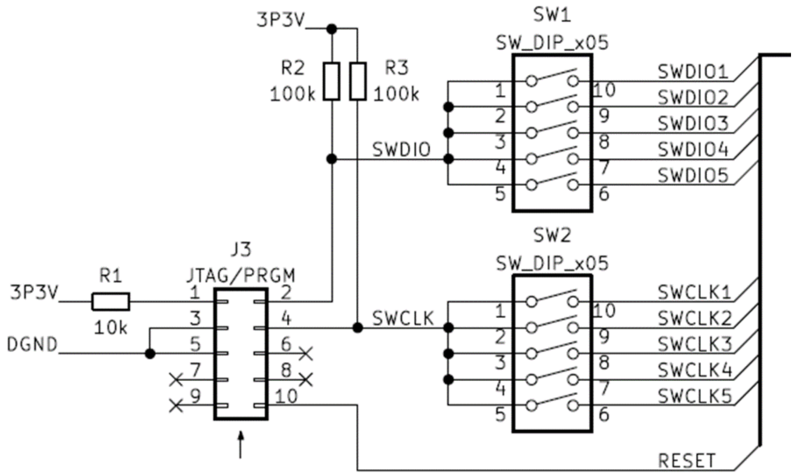

Figure 6. Physical switches and JTAG input slot

The JTAG input slot is used for programming the onboard ADUCM355 microprocessor units to retrieve the data measured by the respective analog sensors and report it back to the ESP32 microcontroller. Each of the ADUCM355 is selected for programming using 2 physical switches placed on the backside of the GroGenesis v2 board. The 2 switches namely SWDIO and SWCLK are used to provide data and clock signals respectively to the microprocessors. It is imperative to ensure that the same pin number is selected on both the switches while programming the ADUCM355 to ensure that the microprocessor is flashed properly with the appropriate program for its respective sensors.

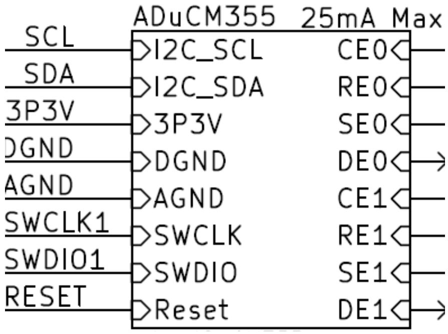

Figure 7. ADUCM355 microprocessor unit

The ADUCM355 microprocessors are used to communicate to two analog sensors, each report back to the ESP32 via i2c communication using the data bus. Each ADUCM355 is connected to two individual analog sensors. The ADUCM355 is programmed using C language with the Keil µvision software GUI.

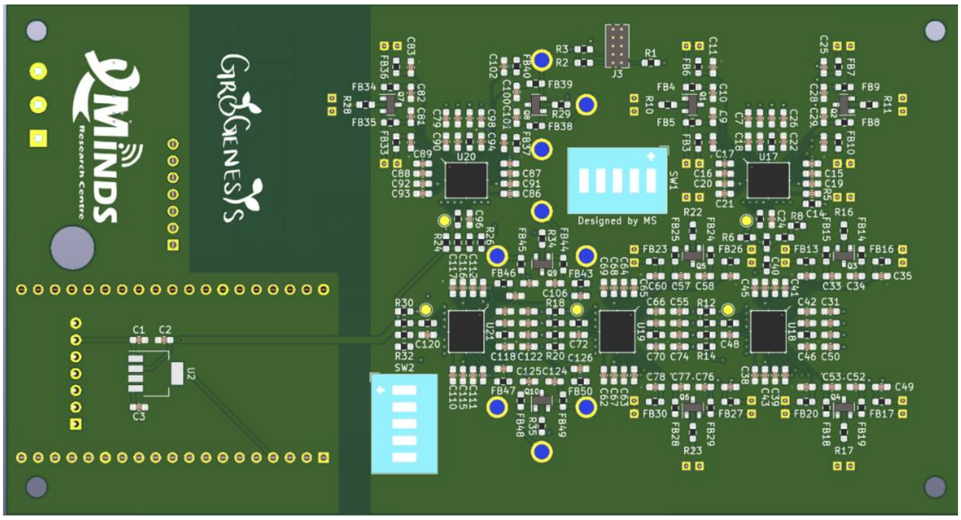

Figure 8. GroGenesis v2 PCB bottom view

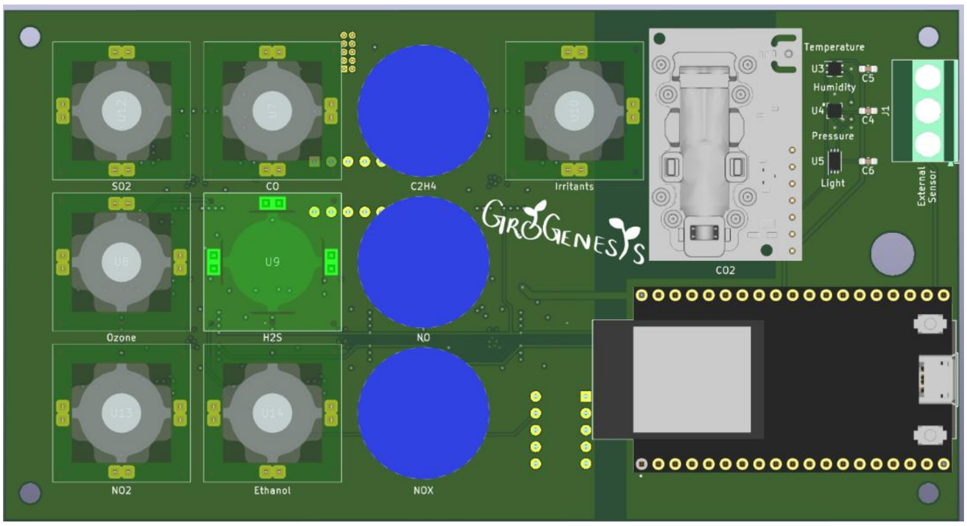

Figure 9. GroGenesis v2 PCB top view

3. PCB Fabrication

The GroGenesis v2 boards comprises SMD components which have been initially soldered on to the PCB using reflow oven technique and through-hole components which have been hand-soldered to the board. The electrochemical sensors of the GroGenesis v2 board have been through-hole soldered on the top side of the board. Similar to the GroGenesis v1, the ESP32 was not soldered directly onto the PCB, but rather, it was replaced into header pins to allow for interchanging convenience. Similarly, the SCD30 sensor has also been placed into header pins as per the datasheet instructions. The through-hole components were fabricated after the surface-mounted components located on the bottom of the board were fabricated by placing inside the reflow oven. This has been done to ensure that the analog sensors and other SMD components are not exposed to temperatures exceeding the maximum temperature limit reported in their datasheets.

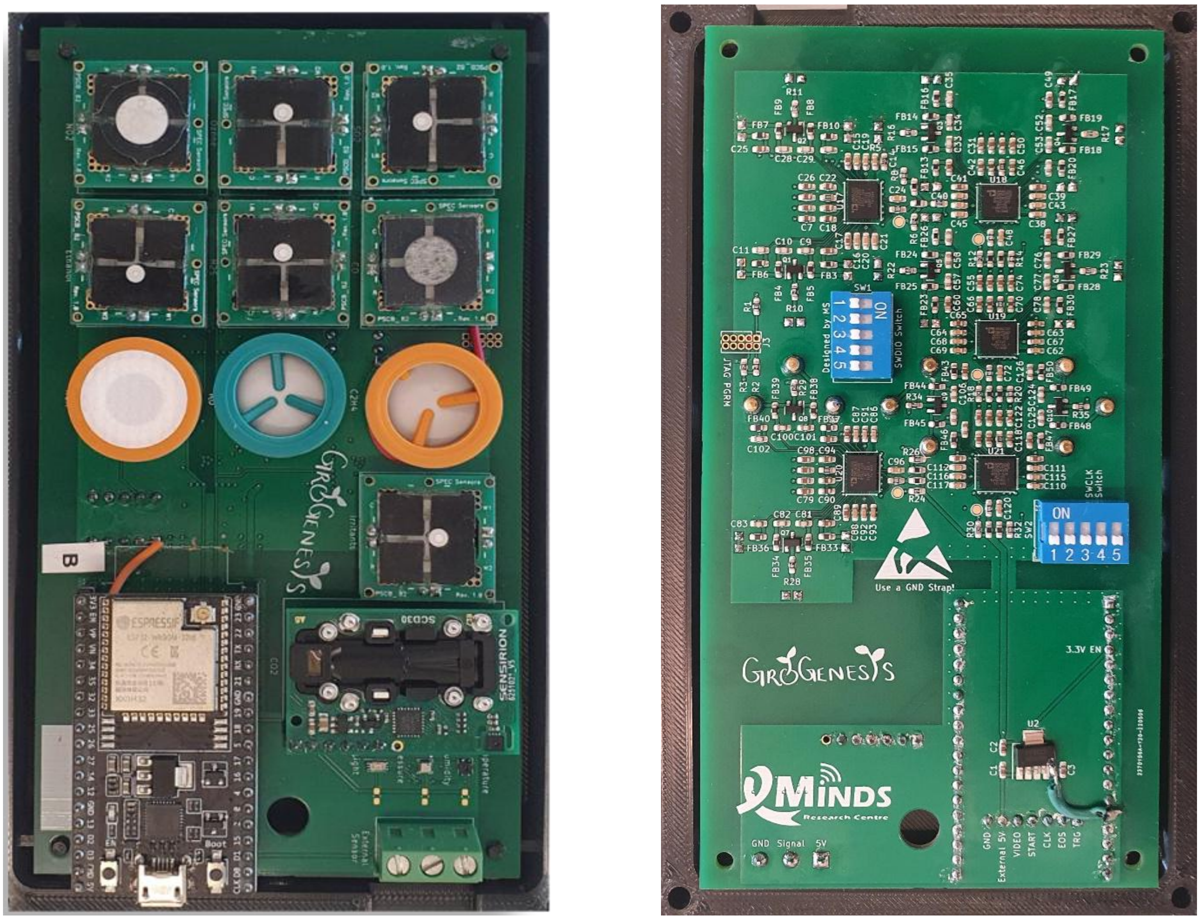

Figure 10. Top view (left) and bottom view (right) of fabricated GroGenesis v2 PCB

a) 3D Enclosure

The GroGenesis v2 board's 3D enclosures, act as a protective shell to protect the onboard components from the harsher greenhouse surroundings (i.e., excess moisture) and avoid potential damage. The 3D enclosures were created using CATIA v5 software and exported as a.STL file for 3D printing. Similar to the GroGenesis v1 board, the top and bottom enclosure parts are put together using four M3 x 0.5 mm thread brasses and screws on each corner. Using a hydraulic press, the brasses are firmly fitted inside a 4 ± 0.2 mm diameter 3D printed hole. Unlike the 3D printed case for the earlier GroGenesis design, the newly printed 3D enclosures comprise of 4 slit holes in the back side enclosure to help mount the board on the Greenhouse pillars using nylon zip-tie cables. The use of magnets from the earlier designed case was avoided due to potential interference that may disrupt the sensor functions.

Figure 11. Front and back view of 3D printed enclosures

4. Baseline Measurement

The GroGenesis v2 board was initially tested in the FLOCON controlled environment test chamber in the absence of contaminants or disruptive factors by subjecting the board to a constant flow of high purity N_2 gas. By this zeroing measurement, the baseline response of the GroGenesis electrochemical sensors were determined, to be used to rectify the offset in values reported by the sensors in real-time. The zeroing test was conducted by extracting 10 values reported by the electrochemical sensors on the GroGenesis board placed in a room temperature environment of 22.1°C with a constant RH of 0.3%. The mean and standard deviation (stdev) of the sensor values was evaluated to analyze the individual sensors performance.

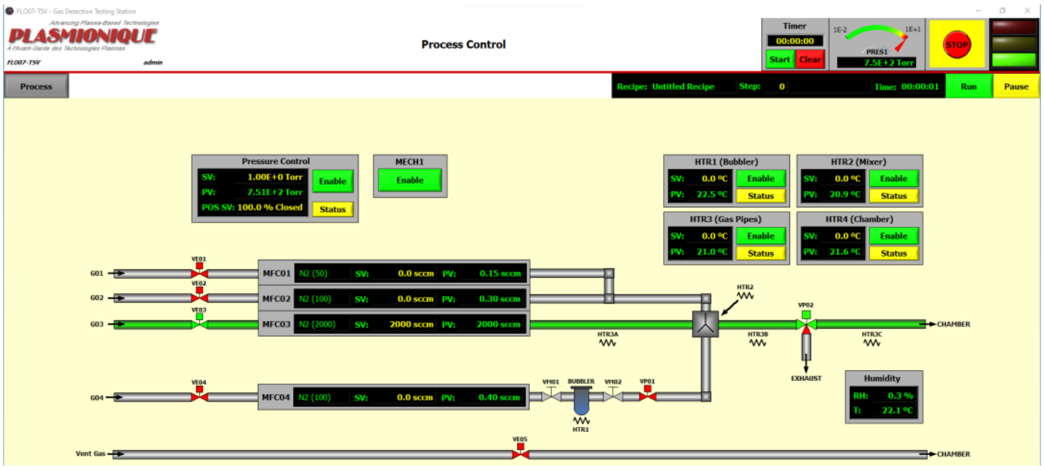

Figure 12. FLOCON GUI depicting Chamber RH of 0.3% and Temperature of 22.1°C