Gas Concentration Readings

SCS V3 // Bryn Parrott // Spec Sensors

THE SCS V3 system will send to the host system digital representations of raw ADC values of voltage measurements derived from each sensor's TIA amplifier connection. The gas concentrations are calculated from readings sent to the host system during the data acquisition stage and made available for viewing on the platform in the form of graphs of gas concentration.

FablabsBCN team (Oscar) will have responsibility to make necessary changes to the host system software to implement the necessary conversion calculations in software. However calibration data for each sensor is needed to make accurate calculations. **Here in this document I have provided all of the parameters and formulae in one place** to make it easy to implement the required calculations. It will be necessary to include temperature values taken at the same time as the Gas Sensor Readings to give effect to the temperature compensation calculation.
I comment that the overall calculation method for SpecSensors data should be similar to AlphaSense data because the two types of sensors work in the same way. Each sensor measures gas concentration via an electrochemical plate; producing a current. The current is transformed into a voltage using a proprietary Trans-Impedance Amplifier and measured by the same 16 bit ADC chip. However the characterisation data for the two types of sensor will be different because of different gas concentration sensitivity ranges and different manufacturing techniques. ***In theory*** *implementation should be a case of input the appropriate characterisation parameters.*

(A) Bar codes from sensors : (Factory Calibration data**)**
Unique serial no, part no, target gas, date code, **sensitivity code**

040821010923 110102 CO 2104 4.38

032921020504 110601 SO2 2104 42.86

100820021155 110303 H2S 2010 232.08

051721011203 110406 O3 2106 -32.20

032521010719 110507 NO2 2103 -25.69

(A.1) **I2C Connection to 4 port ADC BOARD(s) (x2):**
[Handy table to refer to All Factors]
For temperature Compensation please refer to Page 5

I2C Addr	ADC Chan.	Sensor Type	Measure. Property	Serial #	Manuf. Part No/Date	Sensitivity Code nA/ppm	TIA Gain kV/A	Calib Factor M V/ppm
0x48	0	SO_2	V_{gas}	032921020504	110601/2104	42.86	100	0.00042860000
0x48	1	SO_2	V_{ref}			42.86	100	0.00042860000
0x48	2	NO_2	V_{gas}	032521010719	110507/2103	-25.69	499	-0.00128193100
0x48	3	NO_2	V_{ref}			-25.69	499	-0.00128193100
0x49	0	O_3	V_{gas}	051721011203	110406/2106	-32.20	499	-0.00160678000
0x49	1	O_3	V_{ref}			-32.20	499	-0.00160678000
0x49	2	n/c						0.00000000000
0x49	3	n/c						0.00000000000
0x49	0	CO	V_{gas}	040821010923	110102/2104	4.38	100	0.00004380000
0x4A	1	CO	V_{ref}			4.38	100	0.00004380000
0x4A	2	H_2S	V_{gas}	100820021155	110303/2010	232.08	49.9	0.00115807920
0x4A	3	H_2S	V_{ref}			232.08	49.9	0.00115807920
0x4A	0	n/c						0.00000000000
0x4B	1	n/c						0.00000000000
0x4B	2	n/c						0.00000000000
0x4B	3	n/c						0.00000000000

Gas Sensor Physical Layout (representation); Viewed from top.

<table>
<tr><td>ADC Board 2</td><td>ADC Board 1
(Nearest MCU Stack)</td><td>Cable
Void</td><td></td></tr>
<tr>
<td>Bottom of Encl.
<table>
<tr><td>CO</td><td>ADC
0x4A</td><td>C0,C1
(Ch 0,1)</td></tr>
<tr><td>H2S</td><td>ADC
0x4A</td><td>C2,C3
(Ch 2,3)</td></tr>
<tr><td colspan="3">CO2 (SCD41) [Not connected to ADC]</td></tr>
</table>
</td>
<td>Bottom of Encl.
<table>
<tr><td>ADC
0x48</td><td>C0,C1
(Ch 0,1)</td><td>SO2</td></tr>
<tr><td></td><td>C2, C3
(Ch 2,3)</td><td>NO2</td></tr>
<tr><td>ADC
0x49</td><td>C4, C5
(Ch 0,1)</td><td>O3</td></tr>
</table>
</td>
<td>ADC to Gas Sensor Cables

USB Power Cables

Reset Button

I2C Wires</td>
<td>Top to Bottom
<table>
<tr><td>GPS</td></tr>
<tr><td>PM Brd 2</td></tr>
<tr><td>PM Brd 1</td></tr>
<tr><td>Void (Coiled Cable)</td></tr>
<tr><td>Data Brd</td></tr>
<tr><td>Urban Brd
(Bottom of Encl)</td></tr>
</table>
</td>
</tr>
<tr><td>OLED</td><td>OLED</td><td></td><td>PM Sensors x 2</td></tr>
<tr><td colspan="2">I2C 8 Ch MUX (0x70)</td><td></td><td></td></tr>
<tr><td>Pwr Distrib + INA219</td><td></td><td></td><td></td></tr>
</table>

(C) Calculating Target Gas Concentration (from manufacturer documentation) :

The target gas concentration is calculated by the following method:
Cx =1/M x (V_{gas} − V_{gas0}),

where :

- Cx is the gas concentration (ppm),
- V_{gas} is the voltage output gas signal (V),
- V_{gas0} is the voltage output gas signal in a clean-air environment (free of analyte gas)
- M is the sensor calibration factor (V/ppm).

The value, M, is calculated by the following method:
M (V⁄ppm) = Sensitivity Code (nA⁄ppm) × TIA Gain (kV/A) × 10^−9 (A/nA) × 10^3 (V/kV),

where

- the Sensitivity Code is provided on the sensor label (see Para. A) and
- the TIA Gain is the gain of the trans-impedance amplifier (TIA) stage of the ULPSM circuit. Standard gain configurations are listed in the table (See Para D.1) below.

The value V_{gas0} can also be represented by: V_{gas0} = V_{ref} + V_{offset},
where:

❖ V_{ref} is the voltage output reference signal (V)

➢ *The Vref output acts as the reference voltage for zero concentration even as the battery voltage decreases. Measuring V_{ref} in-situ compensates for variations in battery or supply voltage, minimizing these effects on Cx. A difference amplifier or instrumentation amplifier can be used to subtract V_{ref} from V_{gas}. Alternatively, when measuring V_{ref} directly, always use a unity gain buffer.*

❖ V_{offset} is a voltage offset factor.

➢ **V_{offset}**, *accounts for a small voltage offset that is caused by a normal sensor background current and circuit background voltage.* ***To start, V_{offset} = 0 is an adequate approximation****. To achieve higher-precision measurements,* **V_{offset}** *must be quantified. Once the sensor has been powered-on and allowed to stabilize in a clean-air environment (free of the analyte gas) and is providing a stable output within your application's measurement goals, the value of V_{gas} may be stored as V_{gas0} and used in subsequent calculations of gas concentration, Cx.*

(D) **References**:

(D.1) **TIA (Trans Impedance Amplifier)** Gains:

Target Gas	TIA Gain (kV/A)
Carbon Monoxide	100
Hydrogen Sulfide	49.9
Nitrogen Dioxide	499
Sulfur Dioxide	100
Ozone	499
Ethanol	249
Indoor Air Quality	100
Respiratory Irritants	499

(D.2) **Temperature Compensation:**

NOTE:Sensors are factory calibrated at 20 Degrees C.

When implementing temperature compensation, first correct the temperature effect on the zero (offset) and then correct the temperature effect on the span (sensitivity) of the sensor. [See V_{offset}, above]

These corrections can be done in software by implementing one of the following:

- Curve fit
- Look up table
- A set of linear approximations, as outline in the following table(s)

Please note: in the tables below I observe that there is inconsistent depiction of the offsets either as percentages (%) per Deg C or as ppm per Deg C. **Please take Care** !

(D.2.1) SO2:

Temperature Coefficient of Span (%/°C) ***(Typical)***	-20 °C to 20 °C	-0.33%/°C
	20 °C to 40 °C	0.26%/°C
Temperature Coefficient of Zero Shift (ppm/°C) ***(Typical)***	-20 °C to 0 °C	0.012 ppm/°C
	0 °C to 25 °C	0.056 ppm/°C
	25 °C to 40 °C	0.46 ppm/°C

(D.2.2) CO:

Temperature Coefficient of Span (%/°C) ***(Typical)***	-20 °C to 20 °C	-0.33%/°C
	20 °C to 40 °C	0.26%/°C
Temperature Coefficient of Zero Shift (ppm/°C) ***(Typical)***	-20 °C to 0 °C	0.012 ppm/°C
	0 °C to 25 °C	0.056 ppm/°C
	25 °C to 40 °C	0.46 ppm/°C

(D.2.3) NO2

Temperature Coefficient of Zero Shift (ppm/°C) ***(Typical)***	-20 °C to 30 °C	0 ppm/°C
	30 °C to 50 °C	0.0066 ppm/°C
Temperature Coefficient of Span (%/°C) ***(Typical)***	-20 °C to 50 °C	0.3%/°C

Temperature Compensation Data: (continued)

(D.1.4) H2S

Temperature Coefficient of Span (%/°C) ***(Typical)***	-20 °C to 20 °C	-0.33%/°C
	20 °C to 40 °C	0.05%/°C
Temperature Coefficient of Zero Shift (ppm/°C) ***(Typical)***	-20 °C to 0 °C	0.002 ppm/°C
	0 °C to 25 °C	0.0 ppm/°C
	25 °C to 40 °C	0.003 ppm/°C

(D.1.5) O3

Temperature Coefficient of Zero Shift (ppm/°C) ***(Typical)***	-20 °C to 30 °C	0 ppm/°C
	30 °C to 50 °C	0.0066 ppm/°C
Temperature Coefficient of Span (%/°C) ***(Typical)***	-20 °C to 50 °C	0.3%/°C