Interface and Data Format Specification for sensors

(v2 sensor boards)

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Waggle Sensor Array

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Contents

1 Physical Connections and Interfaces

'v2 sensor boards' means a set of sensors which includs a v2.08 Airsense board, a v2 Lightsense board, and a Chemsense board.

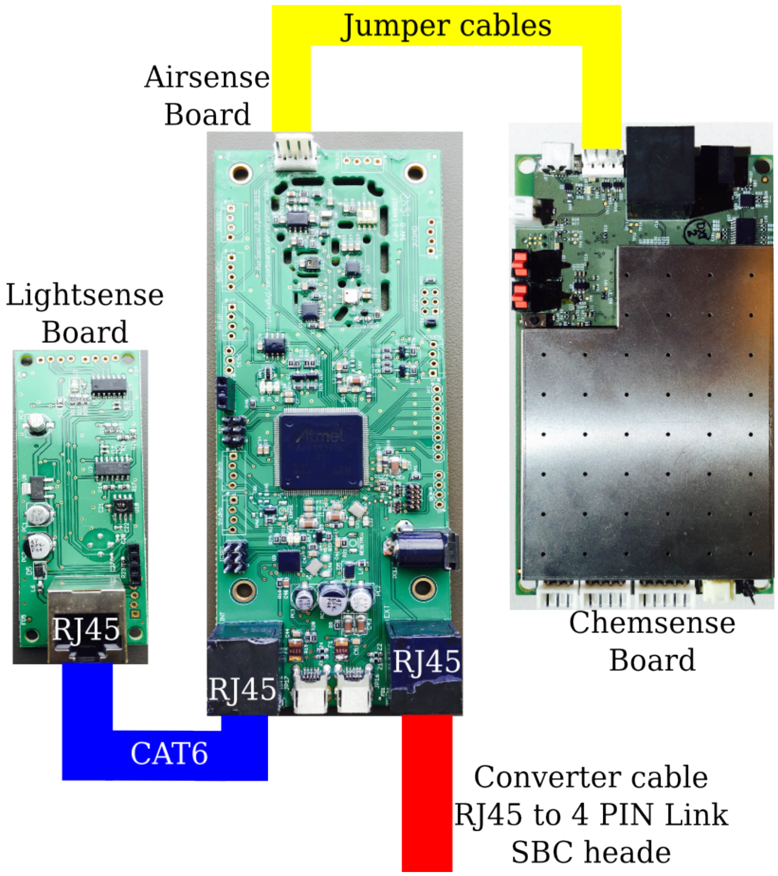

Figure 1: Connections between the sensor boards and the sensor

Physical connections between sensor boards and sensors are shown in the Figure 1. Airsense board is connected to lightsense board through CAT6 cable, and chemsense board is connected to lightsense board through jumper cables. Airsense and lightsense deliver data through I2C communication, and chemsense board delivers data through serial3 communication. All sensor data from airsense, lightsense, and chemsense board are delivered to nodecontroller thourgh converter cable attached on airsense board using I2C communication.

2 Data Transmission

The data from the sensor boards is sent as a formatted unit of data — a transmission packet. A transmission packet is composed of several data sub-packets, each of which carries information pertaining to the parameter listed in the sub-packet. The transmission packet format and the data sub-packets are described here.

2.1 Transmission Packet

A transmission packet can be broken down into 6 segments. The structure of the transmission packet (and the data sub-packet) relies on byte positions and predefined values for some segments. The first segment is the start byte or the preamble. The preamble is followed by the packet sequence number and protocol version, each of which are 4 bits long and are together packed into a single byte. Next, a one byte field that reports the length of the data which follows it immediately. The data segment is followed by a single CRC byte, and finally the packet ends with a one byte postscript. The table below lists the packet and the static values, if any, for each of the segments.

Field	**Value**	**Segment**	**Length**
Preamble	0xAA	1	1 Byte
Packet Sequence Number	Variable	2	1 Nibble
Protocol version	0x00	2	1 Nibble
Length of data (not whole packet)	Variable	3	1 Byte
Data	Variable	4	Variable
CRC of data (not whole packet)	Variable	5	1 Byte
Postscript	0x55	6	1 Byte

Table 1: Transmission Packet Segments

The table below illustrates how the segments are organized in a transmission packet.

Preamble	Seq. Number | Prot. Ver.	Data Length	Data	CRC	Postscript
1st Byte	2nd Byte	3rd Byte	up to 255 Bytes	Penultimate Byte	Final Byte

Table 2: Transmission Packet structure

2.2 Data Packer CRC

To validate the data transmitted from the sensor board, a CRC value for the data is calculated and transmitted as part of the data packet. The Maxim 1-Wire CRC polynomial is used for calculating the CRC. On receiving the data packet, the CRC of the data packet is recalculated and compared with the value transmitted as part of the packet. If the two CRC values match, the transmission is error-free. The equivalent polynomial function of the CRC is:

$CRC = x^8 + x^5 + x^4 + 1.$

Further description of the Maxim 1-Wire CRC is available in Maxim Application Note 27. Below are the Python and C implementations of the CRC calculator. The CRC implementations below take a data byte and the previous CRC as inputs, and return the new CRC as return value.

Python Code:

```
def calc_crc (data_byte,CRC_Value)
```

```
    CRC_Value = ord(data_byte) ^ CRC_Value
    for j in range(8):
    if (CRC_Value  & 0x01):
        CRC_Value  = (CRC_Value  >> 0x01) ^ 0x8C
    else:
        CRC_Value  =  CRC_Value  >> 0x01
return CRC_Value
```

C Code:

```
unsigned char  CRC_CALC (unsigned char data, unsigned char crc)
{
        unsigned char i;
        crc ^= data;
        for (i=0x00; i < 0x08; i++)
        {
                if (crc & 0x01)
                        crc = (crc >> 0x01) ^ 0x8C;
                else
                        crc =  crc >> 0x01;
        }

        return(crc);
}
```

2.3 Data Sub-packets

The data segment of the transmission packet is further broken down into many sub-packets. The sub-packet starts with a source identifier. One bit validity field and seven bits "length of the sub-packet" field are packed together as the next byte. The length field counts the number of bytes following it which make up the sub-packet. The table below shows the organization of a sub-packet. The validity bit is set to 0 if the sensor represented in the sub-packet is dead, disabled, unconnected, unresponsive or if data could not be collected from the sensor in the time window. Instead of recreating the full packet in the buffer, the particular sub-packet which is the sensor segment is marked as invalid is not packed into a whole packet. If the field is set to 1, it indicates a valid measurement/reading. The seven bits length field restricts the size of the sub-packet to 127 bytes.

Source ID	1-bit Validity [0: invalid, 1: valid]| 7-bits Data Length	Data
One Byte	One Byte	up to 127 Bytes

3 Data Formats

The data sent in each sub-packet is encoded in one or more formats. Currently we define eight formats for various types of data including integers, bytes, and floating point numbers. The numerical range of these representations is restricted to within the bounds of values that we expect from the various sensors and other sources. Thus the encoding schemes are specifically designed to effectively and efficiently encode the values expected in the sensor streams. The eight formats, and the encoding schemes are listed below.

Format	**Number of Bytes Used**	**Value Represented**	**Value Range**
1	2	unsigned int_16 input	0 – 65535
2	2	int_16 input	$\pm\{0 - 32767\}$
3	6	byte input[6]	0x00 – 0xffffffffffff
4	3	unsigned long_24 input	0 – 16777215
5	3	long_24 input	$\pm\{0 - 8388607\}$
6	2	float input	$\pm\{0 - 127.99\}$
7	4	byte input[4]	0x00 – 0xffffffff
8	2	float input	$\pm\{0 - 31.999\}$

Table 3: Data formats

3.1 Format 1

This 2 byte format is used to transmit an integer between 0 and 65535. The number is split and serialized as follows –

8 Most Significant Bits	8 Least Significant Bits
Byte[0]	Byte[1]

3.2 Format 2

This 2 byte format is used to transmit an integer between -32767 and 32767. The number is split and serialized as follows –

Sign Bit | 7 Most Significant Bits	8 Least Significant Bits
Byte[0]	Byte[1]

The Sign Bit which is the most significant bit in Byte 0 is set as follows —

Positive Integer	0
Negative Integer	1

3.3 Format 3

This 6 byte format is used to transmit an array of 6 bytes. The array is serialized as follows –

Array[0]	Array[1]	Array[2]	Array[3]	Array[4]	Array[5]
1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte

3.4 Format 4

This 3 byte format is used to transmit an integer between 0 and 16777215. The number is split and serialized as follows –

8 Most Significant Bits	Bits 15 – 8	8 Least Significant Bits
Byte 0	Byte 1	Byte 2

3.5 Format 5

This 3 byte format is used to transmit an integer between -8388607 and 8388607. The number is split and serialized as follows –

Sign Bit | 7 Most Significant Bits	Bits 15 – 8	8 Least Significant Bits
Byte 0	Byte 1	Byte 2

The Sign Bit which is the most significant bit in Byte 0 is set as follows —

Positive Integer	0
Negative Integer	1

3.6 Format 6

This 2 byte format is used to transmit a floating point number between -127.99 and 127.99. Only 2 fractional places are allowed in this format and the number is serialized as follows –

Sign Bit| 7 bit representation of Integer part	0 | 7 bit representation of the Fractional part
Byte 0	Byte 1

As shown above, the leading bit of the Byte 1 is always set to 0, and the Sign Bit which is the most significant bit of Byte 0 is set as follows —

Positive Number	0
Negative Number	1

3.7 Format 7

This 4 byte format is used to transmit an array of 4 bytes. The array is serialized as follows –

Array[0]	Array[1]	Array[2]	Array[3]
Byte 0	Byte 1	Byte 2	Byte 3

3.8 Format 8

This 2 byte format is used to transmit a floating point number between -31.999 and 31.99. Only 3 fractional places are allowed in this format and the number is serialized as follows –

Sign Bit| 5 bit representation of Integer | 2 most significant bits of fraction	8 least significant bits of the fraction
Byte 0	Byte 1

As shown above, the format uses 5 bits for representing the integer part and 10 bits to represent the fractional part. The Sign Bit which is the most significant bit of Byte 0 is set as follows —

Positive Number	0
Negative Number	1

4 Sub-packets

As shortly explained in document section 2.3, data sub-packets are generated depending on its designated data format and length. The first byte of the sub-packet is sensor ID for each parameter, and the second byte means validity of the packet and length of the sensor data. The packet validity is initially 0, and it will be changed to 1 when each sub-packet gets sensor value from sensor. And after a transmission packet is trasmitted, the validity becomes 0 again. The form of sub-packet is shown below.

Source ID	1-bit Validity | 7-bits Sensor Data Length	Data
One Byte	One Byte	up to 127 Bytes

4.1 Parameters

The sensor boards output a set of parameters which are identified by a unique ID. Each parameter has a set of values associated with it which are encoded in an appropriate data format. The table below lists the various parameters produced by the sensor boards, the unique source ID used to identify them, the values produced by them and the format in which the value is encoded.

Table 4: Data sub-packet structure (each row is a "chunk")

Parameter	**Source ID**	**Values and Formats**
	Airsense board	
Airsense/Lightsense MAC address	0x00	MAC Address – Format 3
TMP112	0x01	Temperature – Format 6
HTU21D	0x02	Temperature and Humidity – Format 6
BMP180	0x04	Temperature – Format 6 & Pressure – Format 4
PR103J2	0x05	Temperature – Format 1
TSL250RD	0x06	Visible Light – Format 1
MMA8452Q	0x07	Three Accelerations and Vibration – Format 6
SPV1840LR5H-B	0x08	RMS Sound Level – Format 1
TSYS01	0x09	Temperature – Format 6
	Lightsense board	
HMC5883L	0x0A	Three Magnetic Fields – Format 8
HIH6130	0x0B	Temperature and Humidity – Format 6
APDS-9006-020	0x0C	Visible Light – Format 1
TSL260RD	0x0D	IR Light – Format 1
TSL250RD	0x0E	Visible Light – Format 1
MLX75305	0x0F	Light – Format 1
ML8511	0x10	Light – Format 1
TMP421	0x13	Temperature – Format 6
SPV1840LR5H-B	0x14	RMS Sound Level – Format 1

Continued on next page

Table 4 – continued from previous page

Parameter	Source ID	Values and Formats
Chemsense board		
Total reducing gases	0x15	Raw Concentration – Format 5
Nitrogen dioxide	0x17	Raw Concentration – Format 5
Ozone	0x18	Raw Concentration – Format 5
Hydrogen sulphide	0x19	Raw Concentration – Format 5
Total oxidizing gases	0x1A	Raw Concentration – Format 5
Carbon monoxide	0x1B	Raw Concentration – Format 5
Sulfur dioxide	0x1C	Raw Concentration – Format 5
SHT25	0x1D	Temperature & Humidity – Format 2
LPS25H	0x1E	Temperature – Format 2 & Pressure – Format 4
Si1145	0x1F	UV intensity – Format 1
Chemsense MAC address	0x20	MAC Address – Format 3
CO ADC temp	0x21	ADC temperature – Format 2
IAQ IRR ADC temp	0x22	ADC temperature – Format 2
O3 NO2 ADC temp	0x23	ADC temperature – Format 2
SO2 H2S ADC temp	0x24	ADC temperature – Format 2
CO LMP temp	0x25	ADC temperature – Format 2
Accelerometer	0x26	Three Accelerations – Format 2 & Vibration – Format 4
Gyro	0x27	Three Orientation – Format 2 & Orientation Index – Format 4

Each parameter and its values are composed into a sub-packet based on the format described in document section 2.3. In the case of parameters with 2 or more values, the encoded values are arranged in the sub-packets sequentially. The context of each parameter, its utility and the arrangement of its values is described below. In all the tables below, the validity bit is set to 1. The parameter descriptions below are aggregated based on the sensor-board they are situated on - Airsense, Lightsense and Chemsense.

4.2 Airsense:

4.2.1 Airsense/Lightsense MAC address

This is a six byte ID that uniquely identifies each Airsense board. This MAC address is also applied to each Lightsense board which has the same board number. The ID is provided by a DS2401 1-Wire DSN chip. The 1-byte family ID and CRC provided by the DSN chip are omitted, and the rest six bytes are used as the Unique ID. The Unique ID uses Format 3 for encoding and the arrangement is listed below.

0x00	0x86	ID in Format 3
Byte[0]	Byte[1]	Bytes[2 – 7]

4.2.2 TMP112

TMP112 is a digital temperature sensor, which provides the temperature values in centigrade.

0x01	0x82	Temperature in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None

4.2.3 HTU21D

HTU21D is a digital temperature and humidity sensor, which provides relative humidity value (%RH) and temperature value in centigrade.

0x02	0x84	Temperature in Format 6	%RH in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes [4 – 5]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None
Relative Humidity	%RH	None	None

4.2.4 BMP180

BMP180 is an digital temperature and barometric pressure sensor, which provides temperature in centigrade and pressure in hectopascals.

0x04	0x85	Temperature in Format 6	Pressure in Format 4
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes [4 – 6]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None
Atmospheric Pressure	Pa	None	None

4.2.5 PR103J2

PR103J2 is an analog temperature sensor whose resistance changes with change in temperature. The sensor is implemented in a voltage divider circuit, and the center-tap voltage is converted and packed into Format 1 using a 10-bit ADC.

0x05	0x82	Temperature in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	raw integer	Bulk Curve Fitting	°C

4.2.6 TSL250RD

TSL250RD is an analog visible light sensor that produces an analog voltage that is representative of the irradiance measured in μW/cm^2. The output voltage of the sensor is converted and packed into Format 1 using a 10-bit ADC.

0x06	0x82	Light intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Light Intensity	raw integer	Bulk Curve Fitting	μW/cm^2

4.2.7 MMA8452Q

MMA8452Q is a digital three-axis accelerometer. The accelerations in three orthogonal directions, x, y and z, as a multiple of acceleration due to gravity (g) are obtained from the sensor, and a vibration value (represented as multiple of g) is calculated using high-frequency time series data from the three axis.

0x07	0x88	Acc. X in Format 6	Acc. Y in Format 6	Acc. Z in Format 6	Vibration in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 5]	Bytes[6 – 7]	Bytes[8 – 9]

Value	Board Output	Post-Processing Mode	Post-processed Output
Acc. X	g	none	none
Acc. Y	g	none	none
Acc. Z	g	none	none
Vibration	g	none	none

4.2.8 SPV1840LR5H-B

SPV1840LR5H is a MEMS microphone that is sampled at high frequency to obtain the peaks and calculate the sound intensity for a time window. The raw calculated intensity is represented as a 16-bit integer value using Format 1.

0x08	0x82	Sound Intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Sound Intensity	raw integer	Bulk Curve Fitting	dB

4.2.9 TSYS01

TSYS01 is a digital temperature sensor, which provides the temperature values in centigrade.

0x09	0x82	Temperature in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None

4.3 Lightsense:

4.3.1 HMC5883L

HMC5883L is a digital three-axis magnetometer. The magnetic field strengths in three orthogonal directions, x, y and z are obtained from the sensor.

0x0A	0x88	Field strength X in Format 8	Field strength Y in Format 8	Field strength Z in Format 8
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 5]	Bytes[6 – 7]

Value	Board Output	Post-Processing Mode	Post-processed Output
Mag. Field X	Gauss	none	none
Mag. Field Y	Gauss	none	none
Mag. Field Z	Gauss	none	none

4.3.2 HIH6130

HIH6130 is a digital temperature and humidity sensor, which provides relative humidity value (%RH) and temperature value in centigrade.

0x0B	0x84	Temperature in Format 6	%RH in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 5]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None
Relative Humidity	%RH	None	None

4.3.3 APDS-9006-020

APDS-9006-020 is an analog visible light sensor that produces an analog voltage that is representative of the general luminance. The output voltage of the sensor is converted and packed into Format 1 using a 16-bit ADC.

0x0C	0x82	Raw luminance in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Ambient Light Intensity	raw integer	Bulk Curve Fitting	μW/cm^2

4.3.4 TSL260RD

TSL260RD is an analog Near-infrared light sensor that produces an analog voltage that is representative of the irradiance measured in μW/cm^2. The output voltage of the sensor is converted and packed into Format 1 using a 16-bit ADC.

0x0D	0x82	Near-infrared intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Nera-infrared Intensity	raw integer	Bulk Curve Fitting	μW/cm^2

4.3.5 TSL250RD

TSL250RD is an analog visible light sensor that produces an analog voltage that is representative of the irradiance measured in μW/cm^2. The output voltage of the sensor is converted and packed into Format 1 using a 16-bit ADC.

0x0E	0x82	Light intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Ambient Light Intensity	raw integer	Bulk Curve Fitting	μW/cm^2

4.3.6 MLX75305

MLX75305 is an visible light sensor that produces an analog output that is representative of the light intensity. The output voltage of the sensor is converted and packed into Format 1 using a 16-bit ADC.

0x0F	0x82	Light intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Ambient Light Intensity	raw integer	Bulk Curve Fitting	$\mu W/cm^2$

4.3.7 ML8511

ML8511 is an ultra-violet light sensor that produces an analog output that is representative of the ultra-violet light intensity. The output voltage of the sensor is converted and packed into Format 1 using a 16-bit ADC.

0x10	0x82	UV intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
UV Light Intensity	raw integer	Bulk Curve Fitting	$\mu W/cm^2$

4.3.8 TMP421

TMP421 is a digital temperature sensor, which provides the temperature values in centigrade.

0x13	0x82	Temperature in Format 6
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C	None	None

4.3.9 SPV1840LR5H-B

SPV1840LR5H is a MEMS microphone that is sampled at high frequency to obtain the peaks and calculate the sound intensity for a time window. The raw calculated intensity is represented as a 16-bit integer value using Format 1.

0x08	0x82	Sound Intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Sound Intensity	raw integer	Bulk Curve Fitting	dB

4.4 Chemsense:

4.4.1 Total reducing gases

This parameter provides the current output of the electrochemical ToR sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x15	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.2 Nitrogen dioxide

This parameter provides the current output of the electrochemical NO_2 sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x17	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.3 Ozone

This parameter provides the current output of the electrochemical O_3 sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x18	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.4 Hydrogen sulphide

This parameter provides the current output of the electrochemical H_2S sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x19	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.5 Total oxidizing gases

This parameter provides the current output of the electrochemical ToX sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x1A	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.6 Carbon monoxide

This parameter provides the current output of the electrochemical CO sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x1B	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.7 Sulfur dioxide

This parameter provides the current output of the electrochemical SO_2 sensor. The cell current is quantified using an AFE that uses a 24-bit ADC to convert it into a signed digital value. This value is represented in Format 5.

0x1C	0x83	Raw current value in Format 5
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Concentration	raw integer	per-sensor	PPM

4.4.8 SHT25

SHT25 is a temperature and humidity sensor. The temperature and humidity raw values are encoded in Format 2.

0x1D	0x84	Raw temperature value in Format 2	Raw humidity value in Format 2
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 5]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	raw integer	Bulk Curve Fitting	°C
Humidity	raw integer	Bulk Curve Fitting	%RH

4.4.9 LPS25H

LPS25H is a temperature and pressure sensor. The temperature and pressure raw values are encoded in Format 2 and Format 4 respectively.

0x1E	0x85	Raw temperature value in Format 2	Raw pressure value in Format 4
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 6]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	raw integer	Bulk Curve Fitting	°C
Atmospheric Pressure	raw integer	Bulk Curve Fitting	hPa

4.4.10 Si1145

Si1145 is an Ultra-violet sensor. The raw output from the sensor is encoded Format 1.

0x1F	0x86	Raw UV intensity in Format 1
Byte[0]	Byte[1]	Bytes[2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
UV Intensity	raw integer	Bulk Curve Fitting	$\mu W/cm^2$

4.4.11 Chemsense MAC address

This is a six byte ID that uniquely identifies each Chemsense board. The Unique ID uses Format 3 for encoding and the arrangement is listed below.

0x20	0x86	ID in Format 3
Byte[0]	Byte[1]	Bytes[2 – 7]

4.4.12 ADC Temperatures

Chemsense board measures temperature of sensor ADCs. This includes five parameters which are:

- CO ADC Temp
- IAQ/IRR ADC Temp
- O3/NO2 ADC Temp
- SO2/H2S ADC Temp
- CO CMT Temp

All of them give ADC temperature in 100ths of degree celsious. Format 2 is used for encoding and the arrangement is listed below. No specific descriptions for each sensor data are given for now (July 2016).

Source ID (0x21 ∼ 0x25)	0x82	temperature in Format 2
Byte[0]	Byte[1]	Bytes [2 – 3]

Value	Board Output	Post-Processing Mode	Post-processed Output
Temperature	°C × 100	None	None

4.4.13 Accelerometer

The accelerations in three orthogonal directions, x, y and z, as a multiple of acceleration are obtained from the sensor, and a vibration index is calculated. Acceleration data are encoded in Format 2, and vibration index is encoded in Format 4. No specific descriptions for each sensor data are given for now (July 2016).

0x26	0x89	Acc. X in Format 2	Acc. Y in Format 2	Acc. Z in Format 2	Vibration in Format 4
Byte[0]	Byte[1]	Bytes[2 – 3]	Bytes[4 – 5]	Bytes[6 – 7]	Bytes[8 – 10]

Value	Board Output	Post-Processing Mode	Post-processed Output
Acc. X	raw integer	none	none
Acc. Y	raw integer	none	none
Acc. Z	raw integer	none	none
Vibration Index	raw integer	none	none

4.4.14 Gyro

The gyro in three orthogonal directions, x, y and z, as a multiple of acceleration are obtained from the sensor, and a orientation index is calculated. Gyro data are encoded in Format 2, and orientation index is encoded in Format 4. No specific descriptions for each sensor data are given for now (July 2016).

0x27	0x89	X in Format 2	Y in Format 2	Z in Format 2	Index in Format 4
Byte[0]	Byte[1]	Bytes[2 – 3]	Byte[4 – 5]	Bytes[6 – 7]	Bytes[8 – 10]

Value	Board Output	Post-Processing Mode	Post-processed Output
X Orientation	raw integer	none	none
Y Orientation	raw integer	none	none
Z Orientation	raw integer	none	none
Orientation Index	raw integer	none	none

5 Sensor Data Units

5.1 Raw and Processed

The sensor boards output a set of values which have various units for the data. The table below lists the various units of sensor values. 'Raw Units' in the table means the unit of the packtized data, which is you can get directly from the packet, and 'Processed Units' means the unit which can be used after data conversion through designated equations. The equations will be provided comming subsections.

Table 5: Sensor units both in raw and processed format

Sensor/Parameter	**Raw Units**	**Processed Units**	**Comments**
		Airsense board	
Air/Lightsense MAC	No Units	No Units	
TMP112	°C	°C	
HTU21D	°C, %RH	°C, %RH	
BMP180	°C, Pa	°C, Pa	
PR103J2	integer	°C	
TSL250RD	integer	μw/m^2	
MMA8452Q	g, g, g, g	g, g, g, g	
SPV1840LR5H-B	integer	dB	Pin: PA5(Atmel), A5(Due)
TSYS01	°C	°C	
		Lightsense board	
HMC5883L	G, G, G	G, G, G	
HIH6130	°C, %RH	°C, %RH	
APDS-9006-020	integer	lux	
TSL260RD	integer	μw/m^2	
TSL250RD	integer	μw/m^2	
MLX75305	integer	μw/m^2	
ML8511	integer	UV index	
TMP421	°C	°C	
SPV1840LR5H-B	integer	dB	
		Chemsense board	
Total reducing gases	AFE ADC counts		data not yet processed
Nitrogen dioxide	AFE ADC counts		data not yet processed
Ozone	AFE ADC counts		data not yet processed
Hydrogen sulphide	AFE ADC counts		data not yet processed
Total oxidizing gases	AFE ADC counts		data not yet processed
Carbon monoxide	AFE ADC counts		data not yet processed
Sulfur dioxide	AFE ADC counts		data not yet processed

Continued on next page

Table 5 – continued from previous page

Sensor/Parameter	Raw Units	Processed Units	Comments
Sensirion (SHT25)	100ths of °C, 100ths of %RH	°C, %RH	
LPS25H	100ths of °C, Pa	°C, Pa	
Si1145	fixed value		firmware is not completed
Intel MAC address	No Units	No Units	
CO ADV temp	100ths of °C	°C	
IAQ IRR ADC temp	100ths of °C	°C	
O3 NO2 ADC temp	100ths of °C	°C	
SO2 H2S ADC temp	100ths of °C	°C	
CO LMP temp	100ths of °C	°C	
Accelerometer	Raw register		data not yet processed
Gyro	Raw register		data not yet processed

5.2 conversion processure

5.3 Airsense:

5.3.1 TMP112, HTU21D, BMP180, MMA8452Q, TSYS01

Raw outputs from the sensor boards for the sensors (TMP112, HTU21D, HIH4030, BMP180, MMA8452Q, and TSYS01) are the designated sensor value.

5.3.2 PR103J2

Output of PR103J2 is an interger indicating output voltage from the sensor, which is mapped into integer values between 0 and 1023. The raw integer value can be converted to resistance value through the equations below. The resistance value is needed to find corresponding temperature in a resistance-temperature look-up table (PR103J2 R-T table).

$$\text{resistance } (\Omega) = 47000 \times \left(\frac{1023}{\text{raw integer}} - 1 \right)$$

5.3.3 TSL250RD

Output of TSL250RD in airsense board is an interger indicating output voltage from the sensor, which is mapped into integer values between 0 and 1023. The raw interger value can be converted to irradiance of visible light in micro-watt per square meter through equations below.

$$\text{irradiance } (\mu W/m^2) = \frac{\text{raw integer} \times 5 - 0.09 \times 1023}{0.064 \times 1023}$$

5.3.4 SPV1840LR5H-B

Output value of SPV1840LR5H-B is an interger indicating amplified output voltage from the sensor, which is mapped into integer values between 0 and 1023. The raw output can be converted to sound level in decibel (dB) through equations below.

$$\text{output voltage } (V) = \frac{\text{raw integer} \times 5 - 1.75 \times 1023 \times 454.33}{453.33 \times 1023}$$

$$\text{sound level } (dB) = -20 \times \log_{10}\left(\frac{\text{output voltage}}{3.3}\right)$$

5.4 Lightsense:

5.4.1 HMC5883L, HIH6130, TMP421

Raw outputs from the sensor boards for the sensors (HMC5883L, HIH6130, and TMP421) are the designated sensor value.

5.4.2 APDS-9006-020, TSL260RD, TSL250RD, MLX75305, ML8511 : using MCP3426

Output value of the ligth sensors (APDS-9006-020, TSL260RD, TSL250RD, MLX75305, and ML8511) are raw integer values which are proportional to the output voltage from the sensor. The raw integers can be converted to irradiance through equations below. The calculated output voltage is needed to calculate irradiance for each sensor.

$$\text{output voltage } (V) = \frac{\text{raw integer} \times 2.048 \times 5}{32767 \times 2}$$

a. APDS-9006-020 Raw output value of APDS-9006-020 is an analog current which is proportional to the irradiance. The output current can be converted irradiance in lux through the equation below.

$$\text{irradiance (lux)} = \left(\frac{\text{output voltage}}{0.005} - 0.000156\right) \times 2.5$$

b. TSL260RD Raw output value of TSL260RD is an analog voltage which is inverse proportional to the irradiance. The output voltage can be calculated though the equation below.

$$\text{irradiance } (\mu W/m^2) = \frac{\text{output voltage} - 0.005313}{0.058}$$

c. TSL250RD Raw output value of TSL250RD is an analog voltage which is inverse proportional to the irradiance. The output voltage can be calculated though the equation below.

$$\text{irradiance } (\mu W/m^2) = \frac{\text{output voltage} - 0.005313}{0.064}$$

d. MLX75305 Raw output value of MLX75305 is an analog voltage which is inverse proportional to the irradiance. The output voltage can be calculated though the equation below.

$$\text{irradiance } (\mu W/m^2) = \frac{\text{output voltage} - 0.0996}{0.007}$$

e. ML8511 Raw output value of ML8511 is an analog voltage which is proportional to the irradiance. The output voltage can be calculated though the equation below.

$$\text{UV index } = \frac{\text{output voltage}}{1.489} \times 1.49916$$

f. SPV1840LR5H-B Raw output value of SPV1840LR5H-B is an analog voltage which is proportional to the sound level.

$$\text{sound level } (dB) = -20 \times \log_{10}\left(\frac{\text{output voltage}}{3.3}\right)$$

5.5 Chemsense:

5.5.1 Chemical sensors

Given values of chemical sensors are AFE ADC counts.

- Total reducing gases
- Nitrogen dioxide
- Ozone
- Hydrogen sulphide
- Total oxidizing gases
- Carbon monoxide
- Sulfur dioxide

5.5.2 SHT25, LPS25H

Given values of SHT25 and LPS25H are 100ths of temperature in Celsius and 100ths of humidity value.

$$\text{temperature } (^\circ C) = \frac{\text{output value}}{100}$$
$$\text{humidity } (\%RH) = \frac{\text{output value}}{100}$$

5.5.3 Si1145

Si1145 is a light sensor. Raw values coming from the sensor are three fixed hex integers, however because Chemsense board driver is not completed the values are needed to be ignored (July 2016).

5.5.4 ADC Temperatures

Chemsense board measures temperature of sensor ADCs. All of them give ADC temperature in 100ths of degree Celsius. This includes five parameters which are:

- CO ADC Temp
- IAQ/IRR ADC Temp
- O3/NO2 ADC Temp
- SO2/H2S ADC Temp
- CO CMT Temp

$$\text{temperature } (^\circ C) = \frac{\text{output value}}{100}$$

5.5.5 Accelerometer

5.5.6 Gyro