ScioSense


# APC1

## Air Purification Combo ONE

**APC1 datasheet**

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The APC1 is a compact, box-shaped, all-in-one environmental sensor solution to precisely measure particulate matter and aerosols, volatile organic compounds, temperature and humidity. It leverages the ScioSense leading edge sensor technology to provide an accurate, fully calibrated, maintenance-free solution to air quality monitoring.

For maximum flexibility, the APC1 provides up to 20 environmental signal parameters through UART or I²C interfaces. Moreover, it features temperature compensation algorithms to simplify integration on system level, thereby accelerating time to market at minimal overall BOM costs.

The APC1 is a proven, maintenance-free technology, designed for high volumes and reliability.

## Key Features & Benefits

**Calibrated signal outputs in compliance with international standards** (PM1.0, PM2.5, PM10, TVOC, $eCO_2$[1], AQI[2], temperature and relative humidity).

**Matchbox-size, fully orchestrated design** for space-constrained applications and lowest overall BOM costs.

**System level temperature compensation** to expedite integration on system level and time to market.

**Particle detection down to 0.3µm**

**Superior accuracies over wide temperature and humidity ranges**

- Temperature
  - Accuracy: ±0.45°C, typ.
  - Range: 5 to 50°C
- Humidity
  - Accuracy: ±4%RH, typ.
  - Range: 10 to 95%RH

## Applications

- **Home appliances**
  - Air cleaners / purifiers
- **Building Automation / smart home / HVAC**[3]
  - Indoor air quality detection
  - Demand-controlled ventilation
  - Smart thermostats
- **IoT devices & air quality monitors**

## Properties

**Supply voltage**: 4.5 to 5.5V

**UART or I²C** with 3.3V communication interface

**Power consumption**: 75mA

**Short response times**

- Temperature $T_{63}$: <60s
- Humidity $T_{63}$: <18s

**Smallest footprint:** 50 x 38 x 21mm

[1] $eCO_2$ = equivalent $CO_2$ values for compatibility with HVAC ventilation standards
[2] AQI = Air Quality Index
[3] HVAC = Heat, Ventilation and Air Conditioning

# Table of Contents

# 1 Block diagram

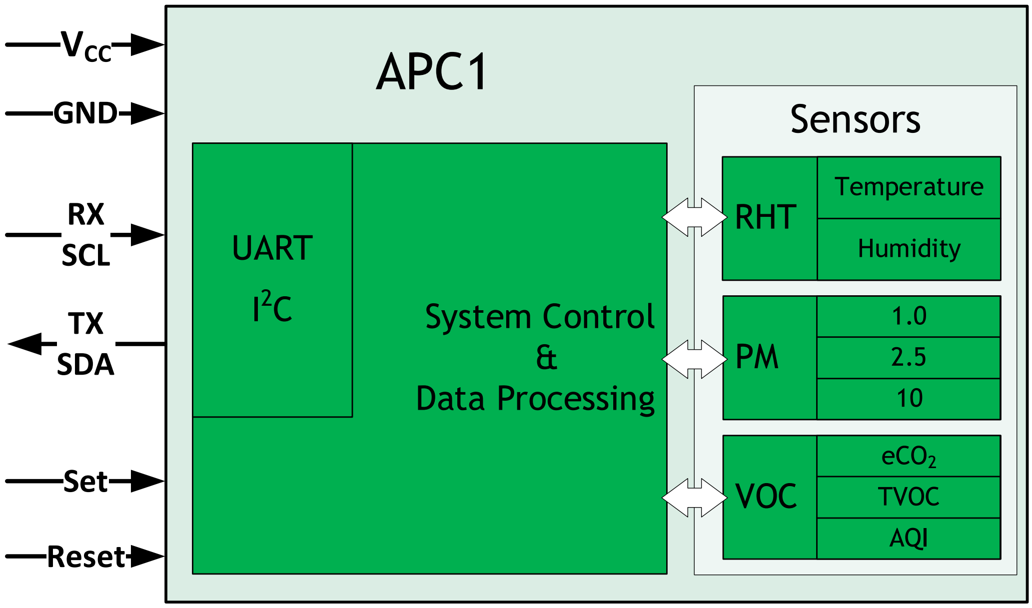


*Figure 1: Functional Blocks*

The APC1 combo module comprises of a temperature and humidity sensor, a multi-particulate matter (PM) sensor and a VOC sensor, providing standardized signal outputs. Equipped with an internal fan and a control CPU, the APC1 autonomously controls the sensor functionality, including full temperature compensation and output via UART or I²C interface.

# 2 Absolute maximum ratings

*Table 1: Absolute Maximum Ratings*

| Symbol | Parameter | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| | **Environmental Operating & Storage Conditions** | | | | | |
| See Table 3 | | | | | | |
| | **Electrical Parameters** | | | | | |
| $V_{DD}$ | Supply Voltage | -0.3 | 5.0 | 6.0 | V | |
| $V_{IO}$ | I/O pins | -0.3 | | 5.5 | V | |
| $I_{IO}$ | Max. current per I/O pin | -18 | | 20 | mA | |
| See Table 7 for further information | | | | | | |

Exposure of the APC1 to conditions outside these ranges may result in reduced performance and accuracy or even permanently damage the APC1. Prolonged operation at these limits can lead to reduced lifetime.

# 3 Intended use

The APC1 sensor combo is intended for use in common indoor environments. It shall be operated in normal indoor air within its specified, non-condensing environmental conditions, with no aggressive or poisonous gases present. Prolonged exposure to environments outside these conditions can affect performance and lifetime of the sensor.

The APC1 is not designed for use in safety-critical or life-protecting applications.

# 4 Functional component specifications

## 4.1 General

*Table 2: Module specifications*[4]

| Parameter | Conditions | Value | Unit |
|---|---|---|---|
| Output data rate | | 1 | Hz |
| Noise Level[5] | 0.2m distance | 24 | dB(A) |
| Noise Level long-term drift | 0.2m distance | 0.5 | dB(A)/a |
| Lifetime | 25 °C; 50% RH | 10 | years |
| Physical Size | | 50 × 38 × 21 | mm |
| Weight | | 36 | g |

## 4.2 Environmental Conditions

*Table 3: Operating & Storage Conditions*

| Symbol | Parameter | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| $T_{AMB}$ | Operating Ambient Temperature | 5 | | 50 | °C | |
| $RH_{AMB}$ | Operating Ambient Rel. Humidity | 10 | | 95 | % | Non-condensing |
| $T_{STRG}$ | Storage Temperature | 10 | | 50 | °C | |
| $RH_{STRG}$ | Storage Relative Humidity | 20 | | 60 | % | Non-condensing |

[4] Default combo conditions in standard measurement mode: 24°C and 5 V supply voltage, unless stated otherwise.
[5] Measured indoors @ background noise <17dB(A).

## 4.3 Sensor specifications

### 4.3.1 Temperature and humidity

The APC1 deploys a highly accurate capacitive humidity and temperature sensor.

*Table 4: Temperature and humidity sensor specifications*

| Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **Temperature** | | | | | |
| Range | @50%RH | 5 | 25 | 50 | °C |
| Accuracy | @50%RH | | 0.45 | 0.7 | °C |
| Resolution | | | 0.1 | | °C |
| Repeatability | @50%RH and 24°C | | | 0.05 | °C |
| Response Time $T_{63}$ | T-step from 23 to 45°C @50%RH | | | <60 | s |
| **Relative Humidity** | | | | | |
| Range | @24°C | 10 | 50 | 95 | %RH |
| Accuracy | @24°C and 25 to 75%RH | | 4 | 6 | %RH |
| Resolution | | | 0.1 | | %RH |
| Repeatability | @24°C and 25 to 75%RH | | | 0.75 | %RH |
| Response Time $T_{63}$ | RH step from 40% to 60% @24°C | | | <18 | s |

### 4.3.2 Particulate matter

The APC1 uses proven laser scattering technology to reliably detect particles down to 0.3 µm.

*Table 5: Particulate matter sensor specifications*

| Parameter | Condition | Value | Unit |
|---|---|---|---|
| Size ranges | PM1.0 | 0.3 - 1.0 | µm |
| | PM2.5 | 0.3 - 2.5 | µm |
| | PM10 | 0.3 - 10 | µm |
| Resolution | | 1 | µg/m³ |
| Standard volume | | 0.1 | L |
| Effective concentration range | PM2.5<br>PM10 | 0 – 500<br>0 – 500 | µg/m³<br>µg/m³ |
| Maximum Upper Limit of Range | PM2.5<br>PM10 | ≥1000<br>≥1500 | µg/m³<br>µg/m³ |
| Maximum Consistency Error | **PM2.5**<br>100 – 1000 µg/m³<br>0 – 100 µg/m³ | <br>±10<br>±10 | <br>%<br>µg/m³ |
| | **PM10**<br>100 – 1000 µg/m³<br>0 – 100 µg/m³ | <br>±15<br>±15 | <br>%<br>µg/m³ |
| Counting Efficiency | @ 0.3 µm<br>≥0.5 µm | 50<br>98 | %<br>% |
| Laser Wavelength | | 650 | nm |
| Laser Class | DIN EN 60825-1 | 1 | |
| Start-Up Time[6] | typical | 30 | s |

[6] Determined by fan rev up after powering.

### 4.3.3 VOC

The APC1 deploys a multi-gas sensor solution based on metal-oxide (MOX) technology. Outputs are provided in standard TVOC or $eCO_2$ concentrations or as AQI values[7].

*Table 6: VOC sensor specifications*

| Parameter | Description | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Signals | TVOC | Total VOC concentration | 0 | | 65,000 | ppb |
| | $eCO_2$ | Equivalent $CO_2$ | 400 | | 65,000 | ppm $CO_2$-equiv. |
| | AQI-UBA[8] | Air Quality Index<br>Classification of TVOC value | 1 | | 5 | - |
| Start-Up Time[9] | Initial Start-Up | After first power up | | 60 | | min |
| | Warm-Up | After every power up | | 3 | | min |

[7] TVOC = Total Volatile Organic Compounds; $eCO_2$ = equivalent $CO_2$; AQI = Air Quality Index
[8] Classified TVOC output signal according to the indoor air quality levels by the German Federal Environmental Agency (UBA, 2007).
[9] Device is not designed for power-cycling.

# 5 Electrical specifications

*Table 7: Electrical specifications*

| Symbol | Parameter | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | 4.5 | 5.0 | 5.5 | V | |
| $I_{Op}$ | Operating Current | - | 75 | ≤120[10] | mA | Active measurement & fan |
| $I_{Idle}$ | Idle Current | - | 9 | ≤10 | mA | Idle mode |
| $I_{DeepSleep}$ | Deep Sleep Current | - | 1.7 | ≤2 | mA | Deep Sleep mode (via SET pin) |
| $V_{IH}$ | I/O Input HIGH level voltage | 2.7 | | | V | @ 3.3V |
| $V_{IL}$ | I/O Input LOW level voltage | | | 0.6 | V | @ 3.3V |

Default combo conditions in standard measurement mode: 24°C and normal ambient air, unless stated otherwise.

*Table 8: ESD / EMC ratings*

| | Electrostatic Discharge | | | |
|---|---|---|---|---|
| $ESD_{HBM}$ | Electrostatic Discharge HBM | ±2,000 | V | JS-001-2014 |

[10] Only during short / extreme conditions e.g. start-up of fan.

# 6 Hardware interface specifications

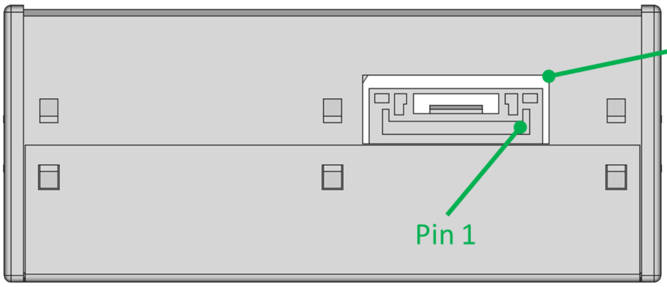


*Figure 2: Connector type and pin orientation on device*

*Table 9: Pin assignment*

| Pin ID | Pin Name | Pin Type | Description |
|---|---|---|---|
| 1 | $V_{DD}$ | Supply | 5V (Supply voltage) |
| 2 | GND | Supply | Ground |
| 3 | SET | Input | LOW: Deep Sleep mode.<br>HIGH or floating: resume previous operating mode (Idle or Measurement mode).<br>Internally pulled-up. |
| 4 | UART_RX / I2C_SCL | Input | UART RX or I²C SCL.<br>Internally pulled-up. |
| 5 | UART_TX / I2C_SDA | Output | UART TX or I²C SDA.<br>Internally pulled-up. |
| 6 | RESET | Input | Set LOW to Reset device.<br>Internally pulled-up. |
| 7 | NC | | Internal use only. Do not connect. |
| 8 | NC | | Internal use only. Do not connect. |

# 7 Host communication

## 7.1 UART interface

The Universal Asynchronous Receiver/Transmitter (UART) protocol is an asynchronous serial interface.

### 7.1.1 UART application circuitry

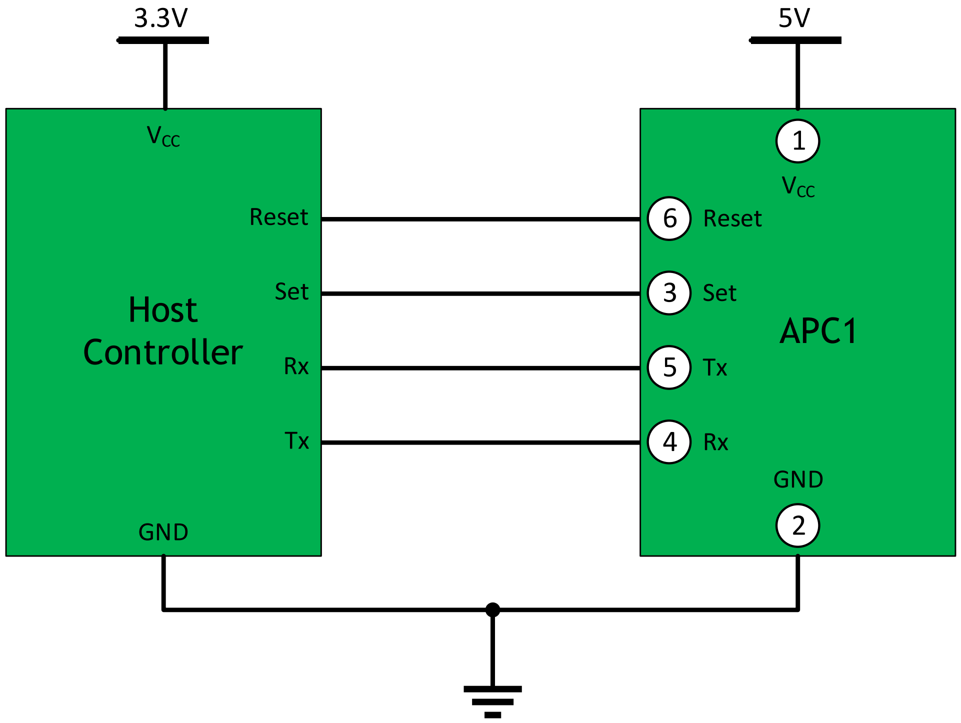


*Figure 3: Recommended UART application circuitry*

**Important notes:**

1. While a 5V DC supply voltage is required to drive the fan. The communication interfaces run at 3.3V TTL level.
2. Pins 3, 4, 5 and 6 are pulled-up internally
3. Do not connect SET (pin 3) and RESET (pin 6) when not used.
4. Do not connect pins 7 and 8.
5. The outer metal shell is connected to GND.
   Do not connect to any other live component or parts of circuitry except GND.
6. Do not remove the outer metal shell of the APC1.
7. Do not open the module.

### 7.1.2 UART communication

UART communication between the APC1 and a host system is based on transmitter (Tx) and receiver (Rx) connected to the host system as depicted in Figure 3 with the following settings:

*Table 10: APC1 UART communication settings*

| Parameter | Value | Unit | Description |
| --- | --- | --- | --- |
| Baud rate | 9,600 | bit/s | - |
| Data bits | 8 | bit | - |
| Parity | None | - | - |
| Stop bit | 1 | bit | - |

The data byte structure looks as follows:

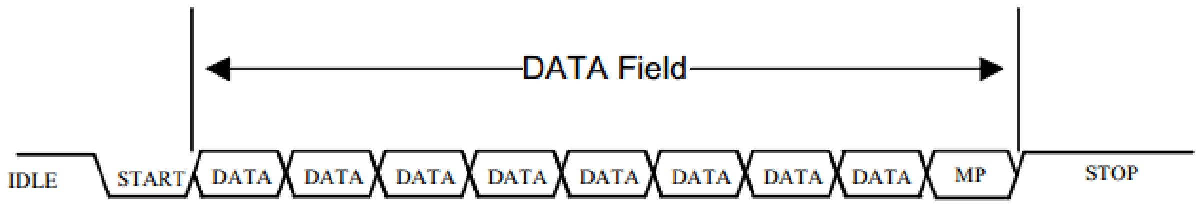


*Figure 4: APC1 data byte structure*

## 7.2 I2C interface

The Inter-Integrated Circuit (I2C) is a synchronous multi-controller/multi-target serial communication bus interface.

### 7.2.1 I2C application circuitry

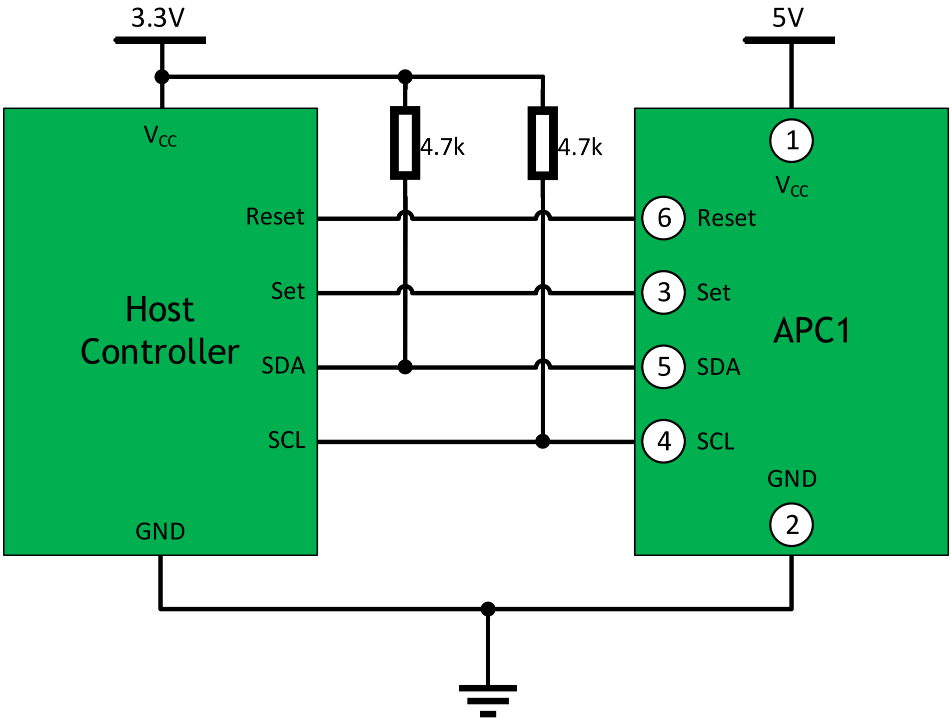


*Figure 5: Recommended I2C application circuitry*

**Important notes:**

1. While a 5V DC supply voltage is required to drive the fan. The communication interfaces run at 3.3V TTL level.
2. While pins 3 and 6 are pulled-up internally, pins 4 and 5 require pull-ups as depicted.
3. Do not connect SET (pin 3) and RESET (pin 6) when not used.
4. Do not connect pins 7 and 8.
5. The outer metal shell is connected to GND.
   Do not connect to any other live component or parts of circuitry except GND.
6. Do not remove the outer metal shell of the APC1.
7. Do not open the module.

### 7.2.2 I2C communication

I2C communication between the APC1 and a host system is based on the 100kbit/s standard mode with SDA and SCL connected to the host system as depicted in Figure 5 with the following settings:

*Table 11: APC1 I2C communication settings*

| Parameter | Value | Unit | Description |
|---|---|---|---|
| Slave Address | 0x12 | - | Device's I2C address (7 bit) |
| SCLK frequency | 100 | Kbit/s | I2C standard mode |

*Table 12: APC1 I2C timing parameters*

| Parameter | Symbol | Value | | Unit |
|---|---|---|---|---|
| | | Min | Max | |
| Hold time (repeated) START condition.<br>After this period, the first clock pulse is generated | $t_{HD\_STA}$ | 4 | - | µs |
| LOW period of the SCLK clock | $t_{LOW}$ | 4.7 | - | µs |
| HIGH period of the SCLK clock | $t_{HIGH}$ | 4.0 | - | µs |
| Data hold-time | $t_{HD\_DAT}$ | 5.0 | - | µs |
| Data set-up time | $t_{SU\_DAT}$ | 250 | - | ns |
| Set-up time for a repeated START condition | $t_{SU\_STA}$ | 4.7 | - | µs |
| Set-up time for STOP condition | $t_{SU\_STO}$ | 4.0 | - | µs |
| Bus free time between a STOP and START condition | $t_{BUF}$ | 4.7 | - | µs |

The timing sequences look as follows with the timings defined in table 12:

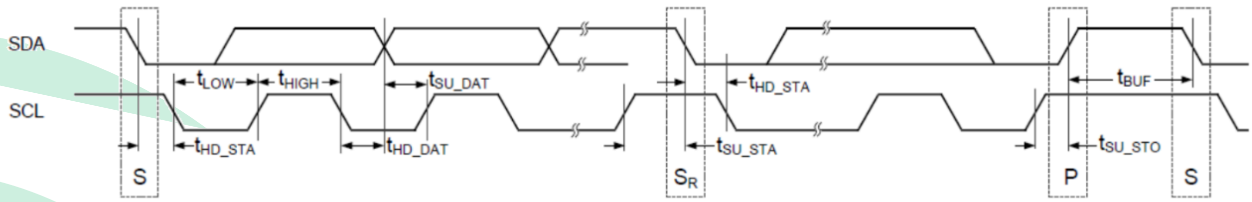


*Figure 6: I2C timings*

There are two possible command sequences:

1. Master reads slave (APC1) continuously.
2. Master reads specific slave (APC1) register.

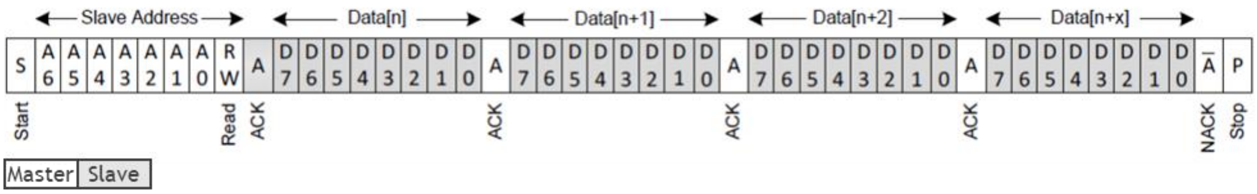


*Figure 7: I2C command sequence for continuous reading*

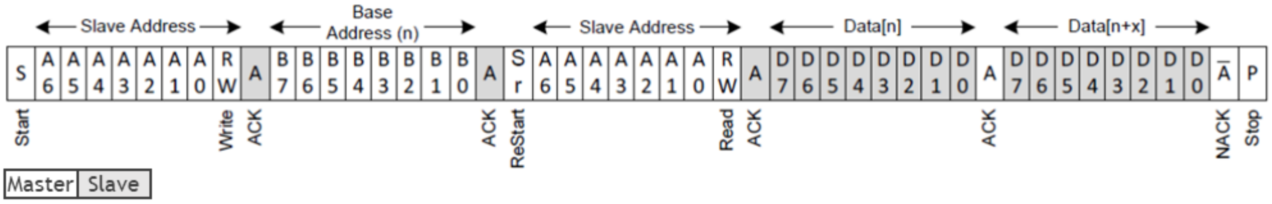


*Figure 8: I2C command sequence for specific register reading*

# 8 Operation

## 8.1 Operating modes

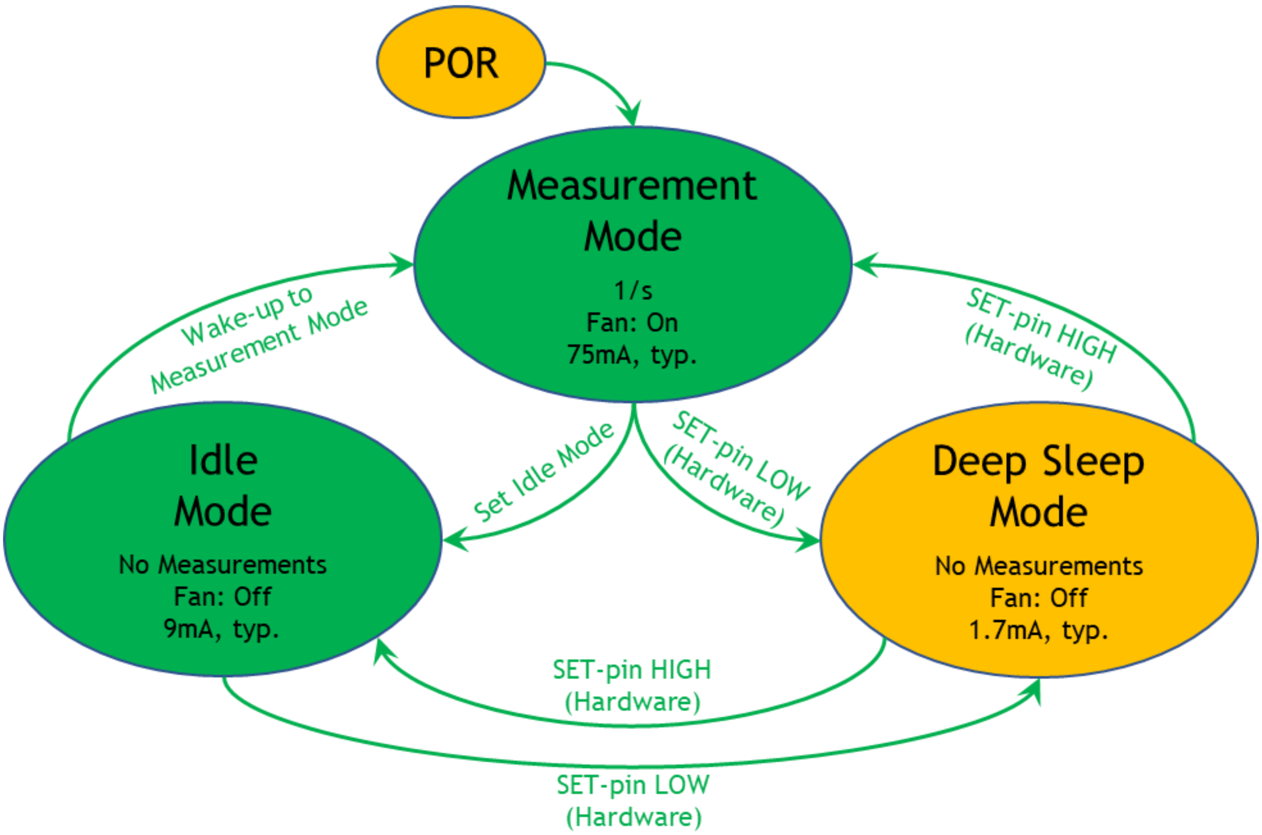


*Figure 9: Operating Modes*

After Power-on (POR) the APC1 enters its default operating mode: Measurement Mode, carrying out a new set of measurement data every second.

For power savings and to stop the fan, the device can be set to Idle Mode. Moreover, it can be put into Deep Sleep by hardware (see Section 8.3.5). No measurements or measurement data can be executed or obtained in Idle or Deep Sleep Mode.

See Section 8.3 for further information on how to set commands and to obtain measurement data from the device.

## 8.2 Output data

### 8.2.1 64-byte output structure

When in Measurement mode, the following structure of measurement data is provided and updated every second.

*Table 13: 64 byte output registers*

| Byte | Field Name | Size (byte) | Range | | Resolution | Unit | Access (R/W) | Description |
|---|---|---|---|---|---|---|---|---|
| | | | Data | Physical | | | | |
| 0x00 | Frame header | 2 | 0x42 0x4D | - | - | - | R | Frame header |
| 0x02 | Frame length | 2 | 0x00 0x3C | - | - | - | R | Frame length (60 byte) |
| 0x04 | PM1.0 | 2 | 0-500 | 0-500 | 1 | ug/m3 | R | PM1.0 mass concentration |
| 0x06 | PM2.5 | 2 | 0-1,000 | 0-1,000 | 1 | ug/m3 | R | PM2.5 mass concentration |
| 0x08 | PM10 | 2 | 0-1,500 | 0-1,500 | 1 | ug/m3 | R | PM10 mass concentration |
| 0x0A | PM1.0 in air | 2 | 0-500 | 0-500 | 1 | ug/m3 | R | PM1.0 mass concentration in atmospheric environment |
| 0x0C | PM2.5 in air | 2 | 0-1,000 | 0-1,000 | 1 | ug/m3 | R | PM2.5 mass concentration in atmospheric environment |
| 0x0E | PM10 in air | 2 | 0-1,500 | 0-1,500 | 1 | ug/m3 | R | PM10 mass concentration atmospheric environment |
| 0x10 | # particles >0.3µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 0.3µm in 0.1L of air |
| 0x12 | # particles >0.5µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 0.5µm in 0.1L of air. To determine # of PM0.5 particles subtract field 0x12 from field 0x10. |
| 0x14 | # particles >1.0µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 1.0µm in 0.1L of air. To determine # of PM1.0 particles subtract field 0x14 from field 0x10. |
| 0x16 | # particles >2.5µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 2.5µm in 0.1L of air. To determine # of PM2.5 particles subtract field 0x16 from field 0x10. |
| 0x18 | # particles >5.0µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 5.0µm in 0.1L of air. To determine # of PM5 particles subtract field 0x18 from field 0x10. |
| 0x1A | # particles >10µm | 2 | 0-65,535 | 0-65,535 | 1 | Particle count | R | Number of particles with diameter > 10µm in 0.1L of air. To determine # of PM10 particles subtract field 0x1A from field 0x10. |
| 0x1C | TVOC | 2 | 0-65,000 | 0-65,000 | 1 | ppb | R | TVOC output |
| 0x1E | $eCO_2$ | 2 | 400-65,000 | 400-65,000 | 1 | ppm | R | Output in ppm $CO_2$ equivalents |

| Byte | Field Name | Size (byte) | Range | | Resolution | Unit | Access (R/W) | Description |
|---|---|---|---|---|---|---|---|---|
| | | | Data | Physical | | | | |
| 0x20 | Reserved | 2 | - | - | - | - | - | Reserved |
| 0x22 | T-comp. | 2 | 0-500 | 0-50 | 0.1 | °C | R | Compensation only valid for detached module operation according to orientation 4 (figure 10). See Section 9.3.2 for temperature and humidity compensation on system level. |
| 0x24 | RH-comp. | 2 | 0-1,000 | 0-100 | 0.1 | % | R | |
| 0x26 | T-raw | 2 | 0-500 | 0-50 | 0.1 | °C | R | Uncompensated temperature |
| 0x28 | RH-raw | 2 | 0-1,000 | 0-100 | 0.1 | % | R | Uncompensated humidity |
| 0x2A | $RS_0$ | 4 | 100 - 50M | (100) 1k - 10M (50M) | 1 | Ω | R | Gas sensor raw resistance value RSi. ($RS_1$ not used) Values show specified range. Values in brackets show total / measurement range. |
| 0x2E | $RS_1$ | 4 | | | | | | |
| 0x32 | $RS_2$ | 4 | | | | | | |
| 0x36 | $RS_3$ | 4 | | | | | | |
| 0x3A | AQI | 1 | 1-5 | 1-5 | 1 | - | R | Air Quality Index according to UBA Classification of TVOC value |
| 0x3B | Reserved | 1 | - | - | - | - | - | Reserved |
| 0x3C | Version | 1 | - | - | - | - | R | Firmware version |
| 0x3D | Error code | 1 | - | - | - | - | R | See Section 8.2.2 for details |
| 0x3E | Checksum | 2 | - | - | - | - | R | Frame (0x00 – 0x3D) checksum |
| **Total bytes:** | | **64** | | | | | | |

Note: First byte: MSB; last byte: LSB; valid for all multi-byte data strings of 64-byte output structure.

### 8.2.2 Error codes

The error codes can be obtained from the 64 byte output structure (byte 0x3D).

*Table 14: Error codes*

| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|
| X | **RHT**[11] | **VOC**[12] | **Laser** | **Fan** stopped | **Photodiode** | **Fan**-speed low | Too many **Fan** restarts |

No error: error code = 0x00 (= default condition)

[11] Temperature and humidity sensor
[12] VOC Sensor

### 8.2.3 Module type, ID and firmware version

Using the 0xE9 command the following structure containing the module type, its ID and firmware version.

*Table 15: Module type, ID & FW registers*

| Byte | Field Name | Size (byte) | Data | Access (R/W) | Description |
|---|---|---|---|---|---|
| 0x00 | Frame header | 2 | 0x42 0x4D | R | Frame header |
| 0x02 | Frame length | 2 | 0x00 0x13 | R | Frame length (19 byte) |
| 0x04 | Module name & type | 6 | 0x41 0x50 0x43 0x31 0x2D 0x55 | R | Example ASCII code: "A" "P" "C" "1" "-" "U" ("U" for UART, "I" for I2C interface) |
| 0x0A | Serial number | 8 | 0x11 0x22 0x33 0x44 0x55 0x66 0x77 0x88 | R | Example ID: 1122334455667788 |
| 0x12 | Delimiter | 1 | 0x2D | R | Example ASCII code: "-" |
| 0x13 | FW version | 2 | 0x00 0x22 | R | Example: Firmware version 0x22 |
| 0x15 | Checksum | 2 | 0x04 0xBE | R | Frame (0x00 – 0x14) checksum |
| **Total bytes:** | | **23** | | | |

Note: First byte: MSB; last byte: LSB; valid for all multi-byte data strings of structure.

The example data of above structure creates the following output string:

**0x41 0x50 0x43 0x31 0x2D 0x55 0x11 0x22 0x33 0x44 0x55 0x66 0x77 0x88 0x2D 0x00 0x22**

or

**APC1-U1122334455667788-22**

where green text represents original hex-values and black text the appropriate ASCII interpretation.

## 8.3 Commands

The APC1 requires the following command protocol:

*Table 16: Host to device command structure*

| StartByte1 | StartByte2 | Command | ModeH | ModeL | ChecksumH | ChecksumL |
|---|---|---|---|---|---|---|
| 0x42 | 0x4D | **Command** | **ModeH** | **ModeL** | LRCH | LRCL |

After successful execution of a command, the APC1 answers within 200ms as follows:

*Table 17: Device to host answer protocol structure*

| StartByte1 | StartByte2 | FrameLengthH | FrameLengthL | Command | Data | ChecksumH | ChecksumL |
|---|---|---|---|---|---|---|---|
| 0x42 | 0x4D | 0x00 | **FrameLengthL** | **Command** or **Data** | **ModeL** or **Data** | LRCH | LRCL |

The **Checksum** is the sum of the values of all bytes sent (not considering Checksum itself) with

- ChecksumH = LRCH = High byte
- ChecksumL = LRCL = Low byte

This is valid for both, host-to-device and device-to host communication.

### 8.3.1 UART Commands

The following UART commands are available:

*Table 18: APC1 UART host commands*

| Command | ModeH | ModeL | Description |
|---|---|---|---|
| **0xE1** | X | 0x00 Set passive mode<br>0x01 Set active mode | Toggle measurement result communication mode:<br>**Passive:** Device to send 64-byte structure on request (Default).<br>**Active:** Device to send 64-byte structure every second |
| **0xE2** | X | 0x00 Request new meas. data | Once in passive mode, this command requests the device to send a 64-byte data structure containing the latest measurement results. |
| **0xE4** | X | 0x00 Set to Idle mode<br>0x01 Wake-up to Meas. mode | Toggle between Idle and Measurement mode (Default). |
| **0xE9** | X | X | Read module type, ID & FW version |

### 8.3.2 UART communication examples

#### 8.3.2.1 Read module type, ID & FW version

This command requests the APC1 to send the module type, ID and firmware version.

*Table 19: Communication protocol to request module type, ID & FW version*

| | |
|---|---|
| **Host command** | 0x42 0x4D **0xE9** 0x00 0x00 0x01 0x78 |
| **Device answer** | 0x42 0x4D FrameLengthH/L Module name & type Serial number Delimiter FW version ChecksumH/L |

The device responds by sending a 23-byte structure (see “Device answer”) according to table 15.

#### 8.3.2.2 Read measurement data from device

This command requests the APC1 to send the latest set of measurement results (64-byte output structure).

As this command is not possible in active mode, make sure the device is in Measurement mode with passive communication.

*Table 20: Communication protocol to request the latest set of measurement results*

| | |
|---|---|
| **Host command** | 0x42 0x4D **0xE2** 0x00 **0x00** 0x01 0x71 |
| **Device answer** | 0x42 0x4D FrameLengthH/L PM1.0H/L PM2.5H/L … Version ErrorCode ChecksumH/L |

The device responds by sending the 64-byte output structure with the latest measurement results.

Repeat this command whenever there is a need for new measurement data. Note that the maximum update rate of the 64-byte structure is 1Hz.

#### 8.3.2.3 Set Passive communication mode

This command sets the APC1 to passive (single shot) communication.

*Table 21: Communication protocol to set passive communication mode*

| | |
|---|---|
| **Host command** | 0x42 0x4D **0xE1** 0x00 **0x00** 0x01 0x70 |
| **Device answer** | 0x42 0x4D 0x00 0x04 **0xE1** **0x00** 0x01 0x74 |

The device responds by sending the above device answer.

#### 8.3.2.4 Set Active communication mode

This command sets the APC1 to active (continuous) communication / data update (default after POR).

*Table 22: Communication protocol to set active communication mode*

| | |
|---|---|
| **Host command** | 0x42 0x4D **0xE1** 0x00 **0x01** 0x01 0x71 |
| **Device answer** | 0x42 0x4D 0x00 0x04 **0xE1 0x01** 0x01 0x75 |

The device responds by sending the above device answer.

#### 8.3.2.5 Set Idle mode

This command sets the device to Idle mode, resulting in:

- No measurements
- No updates of the 64-byte output register structure
- Fan: Off
- Low power consumption: 9mA

*Table 23: Communication protocol to set device to Idle mode*

| | |
|---|---|
| **Host command** | 0x42 0x4D **0xE4** 0x00 **0x00** 0x01 0x73 |
| **Device answer** | 0x42 0x4D 0x00 0x04 **0xE4 0x00** 0x01 0x77 |

#### 8.3.2.6 Set Measurement mode

This command sets the device from Idle to Measurement mode (default after POR), resulting in:

- Active measurements, updated every second
- Fan: On
- Average power consumption: 75mA

*Table 24: Communication protocol to set device to Measurement mode*

| | |
|---|---|
| **Host** | 0x42 0x4D **0xE4** 0x00 **0x01** 0x01 0x74 |
| **Device** | …0x4D FrameLengthH/L PM1.0H/L PM2.5H/L … Version ErrorCode ChecksumH/L… |

When communication mode is “active”, the device responds by continuously sending the updated 64-byte output structure (see “Device answer”) containing the latest measurement results.

### 8.3.3 I2C Commands

The following I2C commands are available:

*Table 25: APC1 I2C host commands*

| Command | ModeH | ModeL | Description |
|---|---|---|---|
| **0xE4** | X | 0x00 Set to Idle mode<br>0x01 Set to Measurement mode<br>0x0F Reset | Toggle between Idle and Measurement mode (Default). |
| **0xE9** | X | X | Read module type, ID & FW version |

Above commands must be written to Write Register Address 0x40 - 0x46.

### 8.3.4 I2C communication examples

#### 8.3.4.1 Read module type, ID & FW version

This command requests the APC1 to write the module type, ID and firmware version to response address 0x47 - 0x5D.

*Table 26: Communication protocol to request module type, ID & FW*

| | |
|---|---|
| **Host command** | Write 0x42 0x4D **0xE9** 0x00 0x00 0x01 0x78 to address 0x40 – 0x46 |
| **Device answer** | 0x42 0x4D FrameLengthH/L Module name & type Serial number Delimiter FW version ChecksumH/L |

The device answer can be found in response address 0x47 - 0x5D and is interpreted according to table 15.

#### 8.3.4.2 Set Idle mode

This command sets the device to Idle mode, resulting in:

- No measurements
- No updates of the 64-byte output register structure
- Fan: Off
- Low power consumption: 9mA

*Table 27: Communication protocol to set device to Idle mode*

| | |
|---|---|
| **Host command** | Write 0x42 0x4D **0xE4** 0x00 **0x00** 0x01 0x73 to address 0x40 – 0x46 |
| **Device answer** | 0x42 0x4D 0x00 0x04 **0xE4 0x00** 0x01 0x77 |

The device answer can be found in response address 0x47 - 0x4E.

#### 8.3.4.3 Set Measurement mode

This command sets the device from Idle to measurement mode (default after POR), resulting in:

- Active measurements, updated every second
- Fan: On
- Average power consumption: 75mA

*Table 28: Communication protocol to set device to Measurement mode*

| | |
|---|---|
| **Host** | Write 0x42 0x4D **0xE4** 0x00 **0x01** 0x01 0x74 to address 0x40 – 0x46 |
| **Device** | 0x42 0x4D FrameLengthH/L PM1.0H/L PM2.5H/L … Version ErrorCode ChecksumH/L |

The device responds with the 64-byte structure according to table 13.

#### 8.3.4.4 Reset device

This command resets the device resulting in a POR / restart:

*Table 29: Communication protocol to reset device*

| | |
|---|---|
| **Host** | Write 0x42 0x4D **0xE4** 0x00 **0x0F** 0x01 0x82 to address 0x40 – 0x46 |
| **Device** | Reset |

Besides a power-on / reset there is no device answer.

### 8.3.5 Hardware command - Deep Sleep

Besides power on/off there is a hardware command available to set the module into Deep Sleep mode. The power-saving Deep Sleep mode can be invoked using hardware pin 3 (SET). It can be set at any operating mode (Idle or Measurement mode) by putting the SET pin to LOW (GND), resulting in:

- No measurements
- No updates to the 64-byte output register structure
- Fan: Off
- Lowest power consumption: 1.7mA

To resume the previous operating mode (Idle or Measurement), put the SET pin HIGH again.

# 9 Integration and operation

## 9.1 General

- Do not remove the outer metal shell of the APC1.
- Do not attempt to open the module.
- Protection must be added if the sensor is used in the following conditions:
  - PM concentrations ≥300µg/m³ for more than 50% of combo lifetime
  - PM concentrations ≥500µg/m³ for more than 20% of combo lifetime
  - Kitchen environment
  - Occasional water mist conditions such as in bathroom environments.
- Refer to Section 3 "Intended Use" for further details.

## 9.2 Combo orientation

To ensure proper functioning throughout the entire lifetime, the following guidelines for combo orientation must be met:

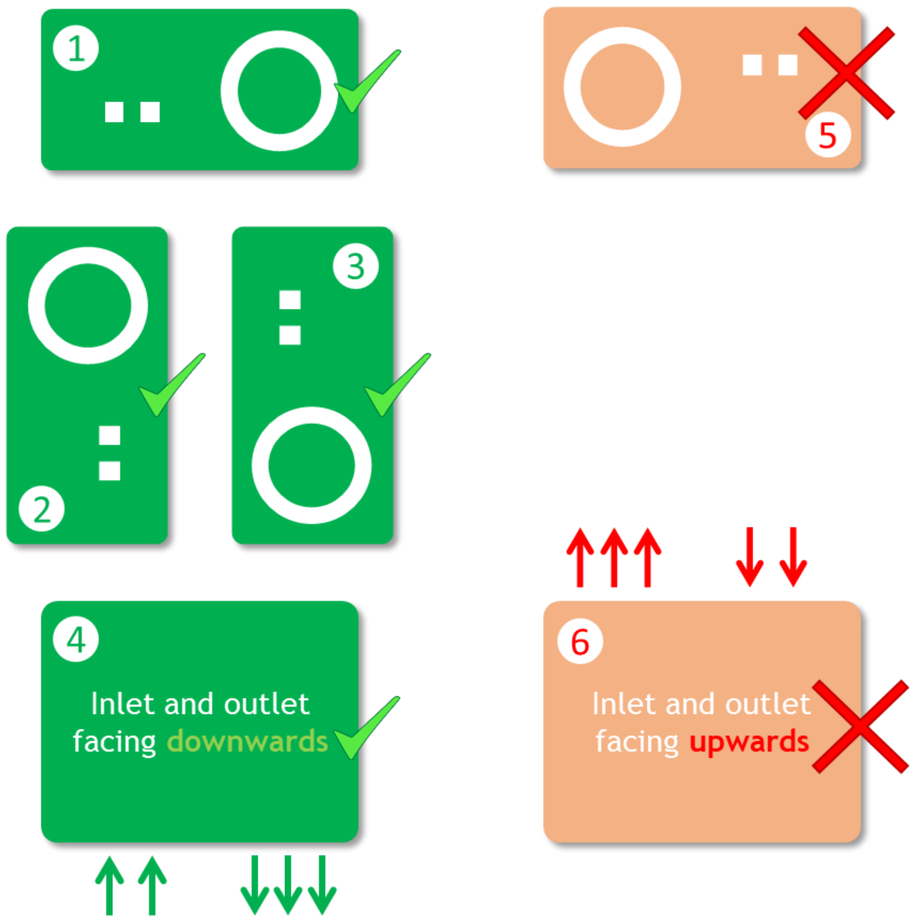


*Figure 10: Recommended combo orientation*

## 9.3 Integration into a host system

### 9.3.1 Mechanical Integration

- Keep inlet and outlet plane of both, APC1 and host system as close as possible to each other. If required, use suitable air guides and/or ductwork with sealants to avoid short-circuits of air flows.
- Host system inlet and outlet must not be smaller than APC1 inlet and outlet.
- To avoid false results, protect/shield inlet and outlet from output air flow of ventilation system or air cleaner.
- Install APC1 at least 20 cm above the floor in order to prevent blocking by larger particles or flock dust. Protect inlet by metal mesh, if required.

### 9.3.2 Temperature and humidity compensation on system level

For precise temperature and humidity readings, the APC1 is equipped with a temperature and humidity compensation algorithm on module level. Due to excess heat from external/host components, some integrations require further temperature and humidity compensation.

This section describes how to determine and compensate such offsets and correct for consequential humidity errors.

#### 9.3.2.1 Determining and compensating the temperature offset

The following procedure uses a single temperature measurement point to determine the APC1 temperature offset, induced by a host system.

**Required items:**

- A temperature reference $T_{Ref}$ (e.g. ScioSense ENS210 evaluation kit on flex-foil).
- A system with an integrated APC1, logging the device's temperature reading $T_{Sys}$. **Important Note:** As the device's temperature reading $T_{Sys}$, it is recommended to use the compensated temperature value T-comp from the 64-byte data structure (see Table 13, Register 0x22). Do not use T-raw.

**T compensation equation:**

$$T_{Ref} = T_{Sys} + T_{Offset}$$

**Compensation procedure:**

1. Setup the temperature reference and system under calibration in a *thermally stable* environment at a typical environmental / operating temperature.
2. Wait for the temperature readings to stabilize (APC1 and reference); thereafter start recording.

Note: For the sake of highest accuracy, it is advisable to carry out a series of experiments and/or log the data for a longer duration while stable.

3. For highest precision, average the recorded temperature values before calculating the difference between system and reference with the following equation:

$$\Delta T = T_{Offset} = T_{Ref} - T_{Sys}$$

with

$T_{Ref}$: Averaged temperature value of the temperature reference

$T_{Sys}$: Averaged temperature value of the system under calibration

4. Compensate the temperature reading by subtracting the determined offset:

$$T_{Comp} = T_{Sys} + T_{Offset} = T_{Sys} + (T_{Ref} - T_{Sys})$$

**Example T-Compensation**

Assuming the above experiment shows the following results:

$$T_{Ref} = 21°C;\ T_{Sys} = 25°C \ \rightarrow \ \Delta T = T_{Offset} = T_{Ref} - T_{Sys} = -4°C$$

Meaning that the host system causes a temperature offset of an additional 4°C on the APC1, which needs to be compensated for by subtracting said 4°C from the APC1's $T_{Sys}$ reading:

$$T_{Comp} = T_{Sys} + T_{Offset} = T_{Sys} + (T_{Ref} - T_{Sys}) = 25°C + (21°C - 25°C) = 21°C$$

#### 9.3.2.2 Correcting the temperature-offset induced humidity error

Since (per definition) the relative humidity output is a temperature-dependent signal, it requires a temperature-offset-dependent correction, provided the temperature offset is other than zero.

Once the T-compensation is done, the humidity correction only requires an additional calculation according to the following equation:

$$RH_{Comp} = RH_{Sys} * (273.15 + T_{Comp})/(273{,}15 + T_{Sys}) * 10 \wedge (a * T_{Sys}/(b + T_{Sys}) - a * T_{Comp}/(b + T_{Comp}))$$

with

$T_{Sys}$: T-raw temperature reading of the APC1 (see register 0x26 Table 13)

$T_{Comp}$: Compensated $T_{Sys}$ temperature reading

$RH_{Sys}$: RH-raw relative humidity reading of the APC1 (see register 0x28 Table 13)

$RH_{Comp}$: Compensated $RH_{Sys}$ relative humidity reading

$a$: 7.5 (T ≥ 0°C); factor, defined by physical laws

$b$: 237.3 (T ≥ 0°C); constant, defined by physical laws

# 10 Package drawings & markings

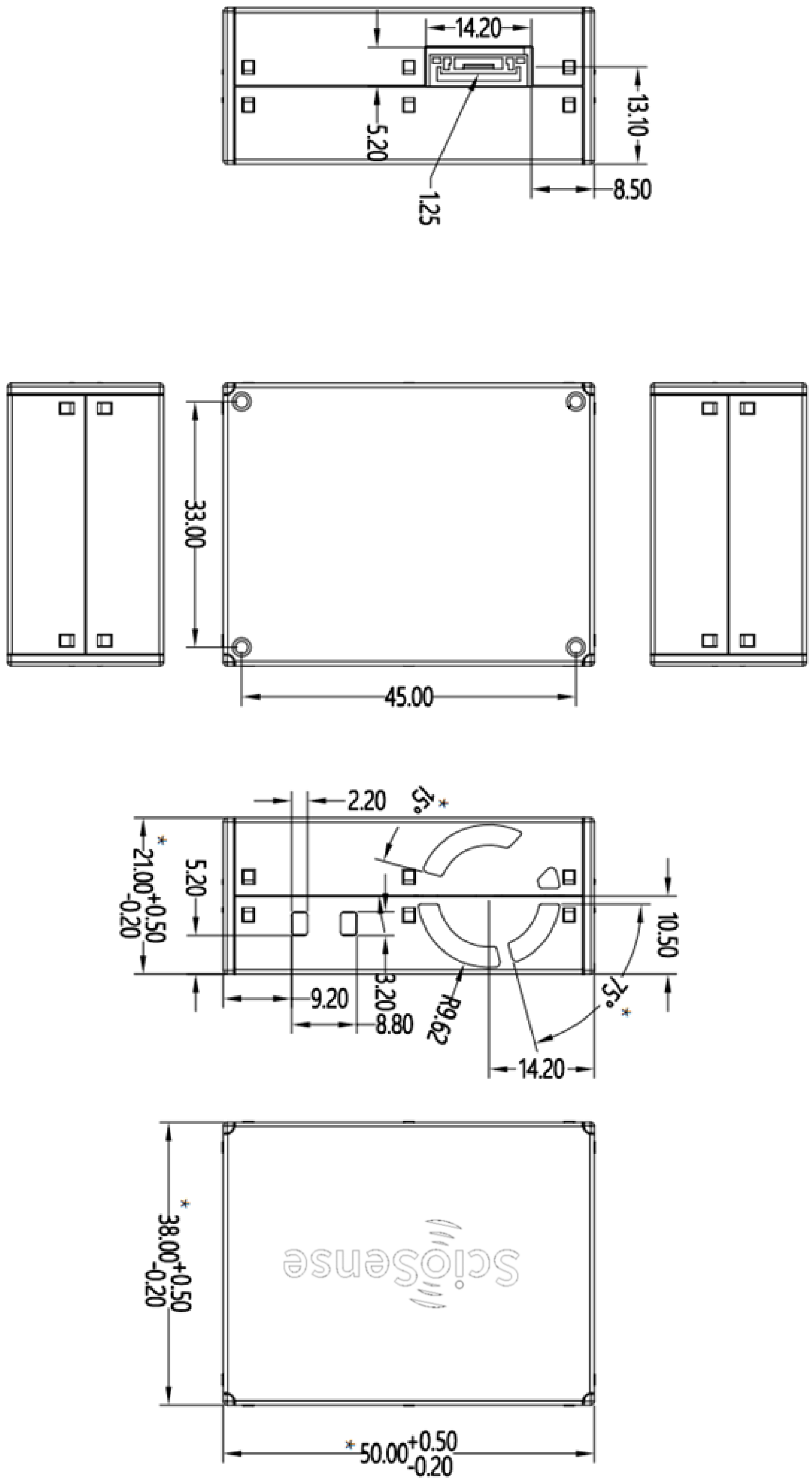


*Figure 11: Technical Drawings (all dimensions in mm)*


*Figure 12: Product label -example of UART version*

## 11 Ordering information

*Table 30: Ordering information*

| Ordering Code | Material ID | Delivery Form | Delivery Quantity | Description |
|---|---|---|---|---|
| APC1001U | 503700201 | Box | 200 | UART interface |
| APC1001J | 503700202 | Box | 200 | I2C interface |
| APC1001U_EK_ST V1 | 503700204 | Box | 1 | UART Evaluation Kit |

## 12 Shipment & Packaging

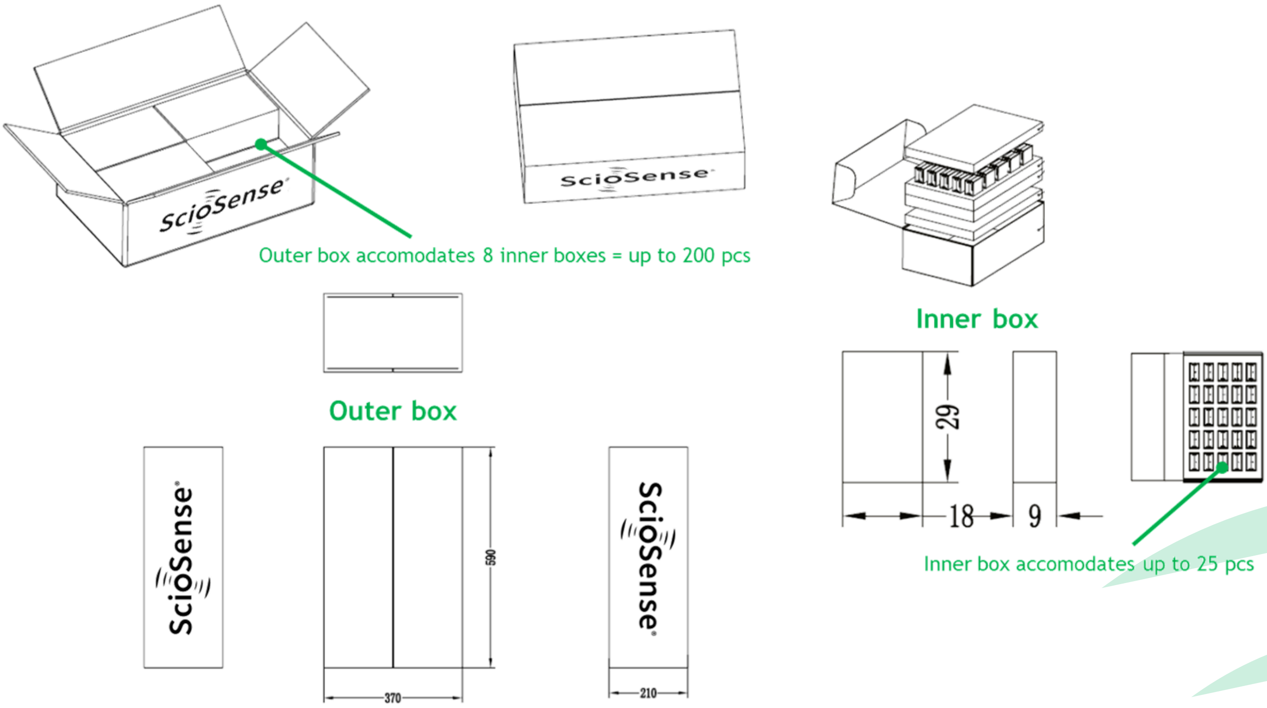


*Figure 13: Packaging Information*

## 13 RoHS Compliance & ScioSense Green Statement

**RoHS**: The term RoHS compliant means that Sciosense B.V. products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead does not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.

**ScioSense Green (RoHS compliant and no Sb/Br)**: ScioSense Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

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# 15 Document status

*Table 31: Document status*

| Document Status | Product Status | Definition |
|---|---|---|
| Product Preview | Pre-Development | Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice. |
| Preliminary Datasheet | Pre-Production | Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice. |
| Datasheet | Production | Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade. |
| Datasheet (Discontinued) | Discontinued | Information in this datasheet is based on products which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs. |

# 16 Revision information

*Table 32: Revision history*

| Revision | Date | Comment | Page |
|---|---|---|---|
| 2.0 | 2023-03-09 | Fully revised version: Added I2C product version. Added I2C Interface description. Amend temperature and humidity compensation sources. Amend disclaimer. | All |
| 1.1 | 2022-05-15 | Add readout of module ID, code examples & further error codes | |
| 1.0 | 2022-04-11 | Official release | All |
| 0.9.1 | 2022-02-23 | Typos and beautification<br>Amend table 14; add note | All<br>14, 15 |
| 0.9 | 2021-11-30 | Preliminary Version | All |

**Note(s) and/or Footnote(s):**

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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