

Low Power CO₂ Sensor

DESCRIPTION

The CozIR®-LP3 is a low power NDIR CO₂ sensor using state-of-the-art solid-state LED optical technology. The low power LEDs are manufactured in-house, giving GSS complete control of the CO₂ sensor signal chain.

The CozIR®-LP3's low power consumption is compatible with battery powered operation, allowing the sensor to be used in a wide variety of applications including wirelessly connected equipment.

The CozIR®-LP3 operation is configurable depending on user requirements. On power-up, the CozIR®-LP3 automatically starts taking measurements. Measurements can be streamed or output on request.

The CozIR®-LP3 also features a built-in auto-zero function that maintains CO₂ measurement accuracy over the lifetime of the product.

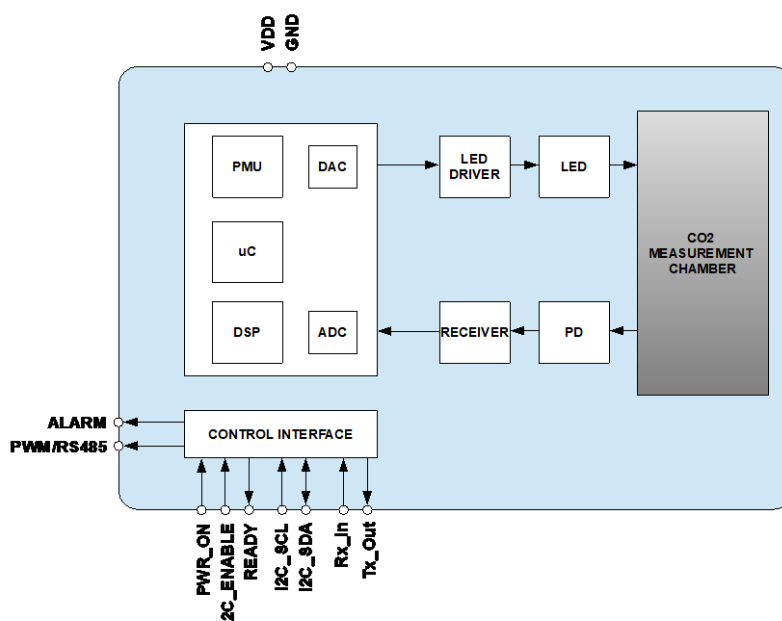
FEATURES

- Low power <3mW average
- 30ppm typical measurement accuracy
- Solid state NDIR LED optical technology
- UART or I²C control and data interface
- Analogue or digital CO₂ measurements
- Built-in auto-zeroing
- Altitude pressure compensation
- Programmable alarm output

APPLICATIONS

- Air Quality and HVAC
- Building management systems (BMS)
- Demand-Controlled Ventilation (DCV) systems
- IoT and Smart Technology wireless equipment
- Indoor Air Quality (IAQ) equipment

BLOCK DIAGRAM



Low Power CO₂ Sensor

TABLE OF CONTENTS

| | |
|--|----|
| DESCRIPTION..... | 1 |
| BLOCK DIAGRAM..... | 1 |
| FEATURES..... | 1 |
| APPLICATIONS..... | 1 |
| ORDERING INFORMATION..... | 4 |
| PACKAGE DRAWING..... | 5 |
| PIN-OUT DESCRIPTION – CozIR®-LP3..... | 6 |
| ABSOLUTE MAXIMUM RATINGS..... | 8 |
| RECOMMENDED OPERATING CONDITIONS..... | 8 |
| PERFORMANCE CHARACTERISTICS..... | 9 |
| ELECTRICAL CHARACTERISTICS – RX_IN, TX_OUT, SDA, SCL, I2C_ENABLE, READY..... | 10 |
| ELECTRICAL CHARACTERISTICS – PWM_RS485, ALARM Outputs..... | 10 |
| ELECTRICAL CHARACTERISTICS – PWR_ON Input..... | 10 |
| POWER CONSUMPTION..... | 11 |
| METHOD OF OPERATION..... | 12 |
| POWER ON DATA READY..... | 12 |
| MEASUREMENT CYCLE..... | 14 |
| MEASUREMENT CYCLE - I ² C INTERFACE MODE..... | 15 |
| MEASUREMENT CYCLE - UART INTERFACE MODE..... | 15 |
| MEASUREMENT PROCESS..... | 15 |
| DIGITAL FILTER..... | 16 |
| PWM_RS485 - DIGITAL OUTPUT..... | 18 |
| PWM Output Configuration..... | 18 |
| High/Low Configuration..... | 18 |
| ALARM OUTPUT..... | 19 |
| BUILT-IN SELF TEST..... | 19 |
| ZERO POINT SETTING..... | 20 |
| ZERO IN A KNOWN GAS CONCENTRATION..... | 20 |
| ZERO IN NITROGEN..... | 20 |
| ZERO IN FRESH AIR..... | 20 |
| AUTO-ZERO FUNCTION..... | 21 |
| AUTO-ZERO INTERVALS..... | 21 |
| AUTO-ZERO LEVEL..... | 22 |
| ALTITUDE PRESSURE COMPENSATION..... | 23 |
| SELECTION OF CONTROL INTERFACE..... | 24 |
| CONTROL INTERFACE TIMING - I ² C MODE..... | 24 |
| I ² C INTERFACE MODE..... | 25 |
| WRITING TO AN I ² C REGISTER..... | 26 |
| READING FROM AN I ² C REGISTER..... | 26 |
| I ² C REGISTER MAP SUMMARY..... | 27 |
| MEASUREMENT CONTROL..... | 29 |
| CO ₂ LEVEL MEASUREMENT VALUE WITH STATUS BYTE..... | 29 |

Low Power CO₂ Sensor

| | |
|--|----|
| CO ₂ LEVEL MEASUREMENT VALUE ONLY..... | 29 |
| DIGITAL FILTER | 29 |
| ZERO CONTROL SETTINGS..... | 30 |
| AUTO-ZERO INITIAL INTERVAL PERIOD | 31 |
| AUTO-ZERO INTERVAL PERIOD | 31 |
| AUTO-ZERO TARGET VALUE | 31 |
| ZERO IN FRESH AIR..... | 32 |
| CONTROL VALUE | 32 |
| SERIAL NUMBER..... | 32 |
| ALARM LEVEL | 32 |
| PWM CONTROL..... | 33 |
| AUTO-ZERO CONTROL | 33 |
| SELF-TEST | 34 |
| RUN TIME | 34 |
| ALTITUDE PRESSURE SETTING..... | 34 |
| CONNECTION DIAGRAM FOR I ² C INTERFACE..... | 35 |
| UART INTERFACE MODE | 36 |
| CONTROL INTERFACE TIMING - UART MODE | 36 |
| UART COMMAND PROTOCOL..... | 36 |
| UART OPERATION | 36 |
| METHOD OF OPERATION | 37 |
| K0 COMMAND MODE (K=0) | 37 |
| K1 STREAMING MODE (K=1) | 37 |
| K2 POLLING MODE (K=2)..... | 37 |
| K COMMAND..... | 37 |
| K COMMAND (0x4B) | 38 |
| MEASUREMENT DATA OUTPUTS | 38 |
| UART INTERFACE SUMMARY | 39 |
| CO ₂ LEVEL MEASUREMENT VALUE - Z INFORMATION (0x5A) | 42 |
| CO ₂ LEVEL MEASUREMENT VALUE - z INFORMATION (0x7A) | 42 |
| CO ₂ MEASUREMENT Z SCALING FACTOR – UART MODE..... | 42 |
| ‘.’ COMMAND (0x2E)..... | 42 |
| DIGITAL FILTER COMMANDS | 43 |
| A COMMAND (0x41) | 43 |
| a COMMAND (0x61)..... | 43 |
| ZERO SETTING COMMANDS – UART MODE | 44 |
| G COMMAND (0x47) | 45 |
| U COMMAND (0x55)..... | 45 |

Low Power CO₂ Sensor

| | |
|---|----|
| X COMMAND (0x58) | 45 |
| P COMMAND - CO ₂ Level for Auto-Zeroing | 45 |
| P COMMAND – CO ₂ Level for Zero-Point Setting..... | 46 |
| SENSOR STATUS AND CONFIGURATION COMMANDS – UART MODE | 47 |
| i COMMAND..... | 47 |
| J COMMAND (0x4A) | 47 |
| j COMMAND (0x6A) | 47 |
| ALTITUDE PRESSURE COMPENSATION | 48 |
| [COMMAND (0x5B) | 48 |
|] COMMAND (0x5D) | 48 |
| AUTO-ZERO INTERVALS..... | 49 |
| @ COMMAND (0x2E) | 49 |
| SERIAL NUMBER AND FIRMWARE VERSION – UART MODE..... | 50 |
| Y COMMAND (0x59)..... | 50 |
| c COMMAND (0x63)..... | 50 |
| CONNECTION DIAGRAM FOR UART INTERFACE | 51 |
| IMPORTANT NOTICE | 52 |
| ADDRESS | 53 |
| REVISION HISTORY | 53 |
| ERRATA..... | 54 |

ORDERING INFORMATION

CozIR®-LP3-X

| X | Measurement Range |
|------|-------------------|
| 2000 | 2000ppm |
| 5000 | 5000ppm |
| 1 | 10,000ppm (1%) |

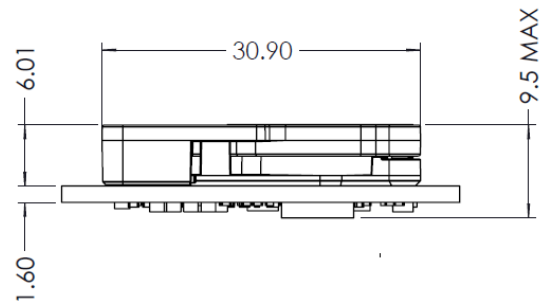
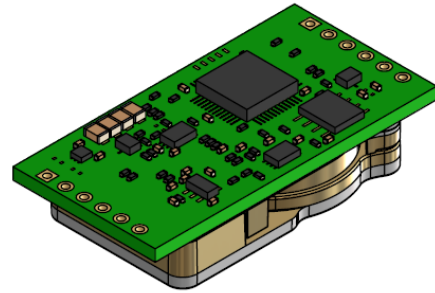
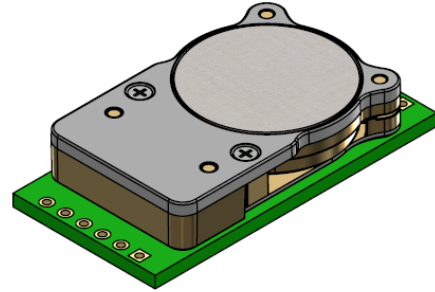
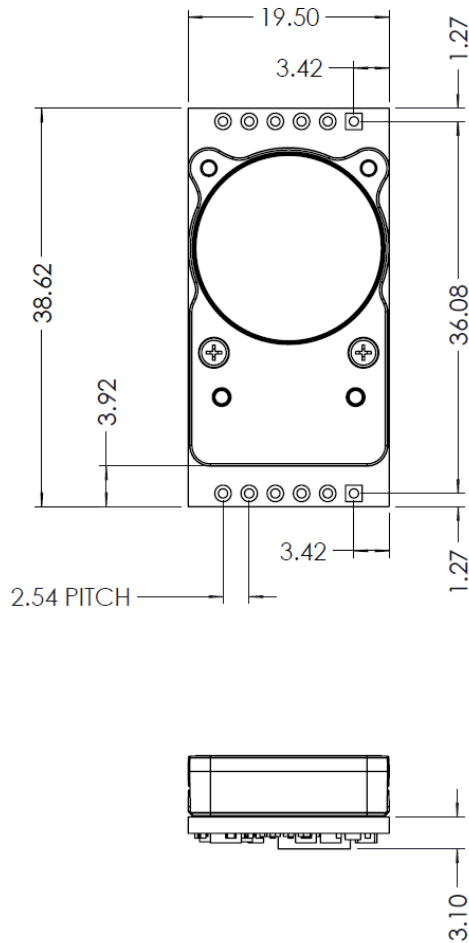
See separate data sheet for CozIR®-LP3 evaluation kit options.

Notes:

1. Sensors are shipped individually or in trays
2. Tray quantity = 50

Low Power CO₂ Sensor

PACKAGE DRAWING



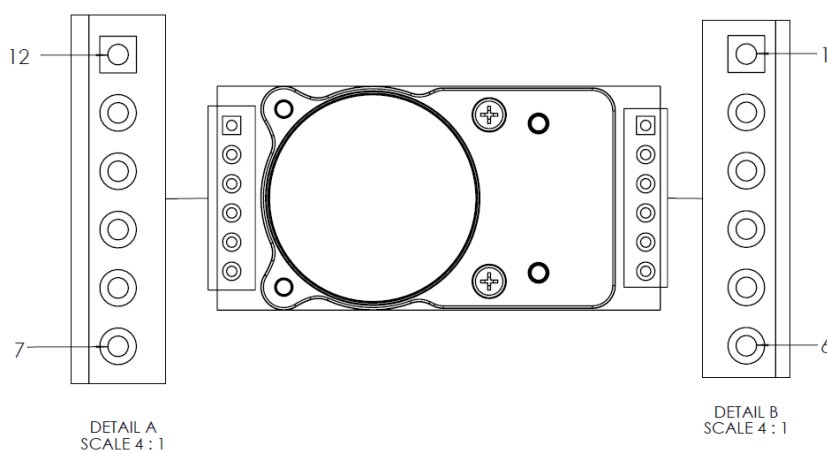
Weight = ~5g

Low Power CO₂ Sensor

PIN-OUT DESCRIPTION – CozIR®-LP3

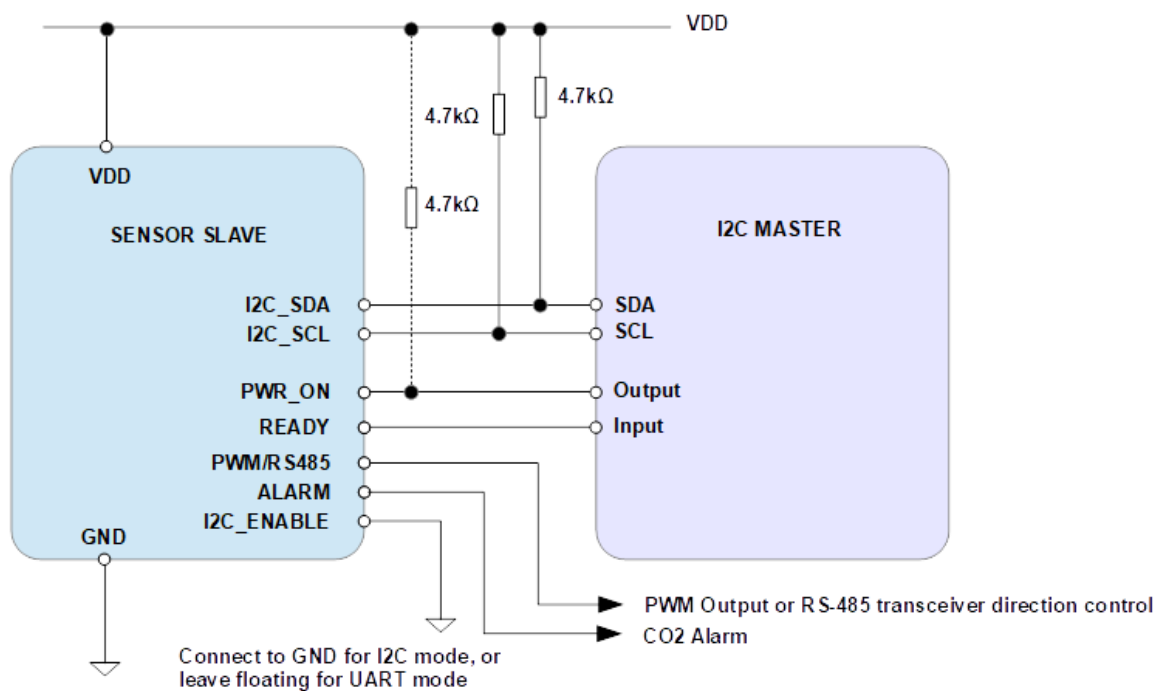
| PIN | NAME | TYPE | DESCRIPTION |
|-----|------------|----------------------|---|
| 1 | GND | Supply | Sensor ground |
| 2 | VDD | Supply | Sensor supply voltage |
| 3 | NC | Unused | Do not connect (For internal use only) |
| 4 | PWR_ON | Digital Input | Sensor Power on Enable pin. - Power on – High - Power off – Low If unused, connect to VDD |
| 5 | ALARM | Digital Output | Alarm Output |
| 6 | READY | Digital Output | Data ready pin. Pulsed high when data ready |
| 7 | PWM_RS485 | Digital Output | PWM Output Or Direction control to drive external half duplex RS485 transceiver |
| 8 | I2C_ENABLE | Digital Input | Set low for I ² C interface mode. Leave floating to select UART interface mode. Pin status detected at power on. |
| 9 | I2C_SCL | Digital Input | I ² C serial clock input. Open drain, external 4.7kΩ resistor pulled high to VDD required |
| 10 | I2C_SDA | Digital Input/Output | I ² C serial data input/output. Open drain, external 4.7kΩ resistor pulled high to VDD required |
| 11 | Tx_Out | Digital Output | UART Transmit Output |
| 12 | Rx_In | Digital Input | UART Receive Input |

Top View



Low Power CO₂ Sensor

CONNECTION DIAGRAM



Notes

1. The power on status of the sensor can be controlled with the PWR_ON pin. If this function is not required, the pin must be pulled high to VDD

Low Power CO₂ Sensor

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings are stress ratings only. Permanent damage to the CozIR®-LP3 may be caused by continuously operating at or beyond these limits. The CozIR®-LP3 functional operating limits and guaranteed performance specifications are given at the test conditions specified.



ESD Sensitive Device. This sensor uses ESD sensitive components. It is therefore generically susceptible to damage from excessive static voltages. Proper ESD precautions must be taken during handling and storage of this device.

| CONDITION | MIN | MAX |
|---|-----------|-------|
| Supply Voltages | -0.3V | +6.0V |
| Voltage Range Digital Inputs | GND -0.3V | 5V |
| Operating Temperature Range (T _a) | 0°C | +50°C |
| Storage Temperature Range | -40°C | +70°C |
| Humidity Range (RH), non-condensing | 0 | 95% |
| Operating Pressure Range | 500mbar | 2bar |

RECOMMENDED OPERATING CONDITIONS

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT |
|-----------|--------|------|-----|-----|------|
| Supply | VDD | 3.25 | 3.3 | 5.5 | V |
| Ground | GND | | 0 | | V |

Low Power CO₂ Sensor

PERFORMANCE CHARACTERISTICS

Test Conditions Unless Otherwise Specified

VDD = 3.3V, GND = 0V. CO₂ = 450ppm, RH = 0% non-condensing, T= 25°C, Pressure = 1013mbar

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--------|--|-----|---------------------------|-----------------------|------|
| CO ₂ measurement range | | | 0 | | 2,000 | ppm |
| | | | 0 | | 5,000 | ppm |
| | | | 0 | | 10,000 | ppm |
| Accuracy | | @25°C | | ±(30, +3% of reading) | ±(45, +3% of reading) | ppm |
| | | 0°C to +50°C, after auto-zero @25°C | | ±(30, +3%), +0.14% per °C | | ppm |
| CO ₂ RMS Noise | | Digital filter setting 16 | | 6 | | ppm |
| Time to Valid Measurement After Power-On | | Dependent on filter setting, typ @ 16 | 0.8 | 8.3 | | secs |
| Response Time | | From 0ppm to T ₉₀ (half full-scale), default settings, limited by diffusion through membrane window | | 30 | | secs |
| Repeatability | | | | ±(30, +3%) | | ppm |
| Pressure Dependence | | Per mbar deviation from 1013mbar, 750-1050mbar | | 0.14 | | % |
| Current Consumption | | Peak current when sampling | | 15 | | mA |
| | | Peak at turn-on | | 40 | | mA |
| | | SLEEP Mode | | 0.01 | | mA |

Low Power CO₂ Sensor

ELECTRICAL CHARACTERISTICS – RX_IN, TX_OUT, SDA, SCL, I2C_ENABLE, READY

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------|--------|------------------------|-----|-----|-----|------|
| Digital Input/Output | | | | | | |
| Input HIGH Level | | | 1.8 | | | V |
| Input LOW Level | | | | | 1.0 | V |
| Output HIGH Level | | I _{OH} = +1mA | 2.6 | | | V |
| Output LOW Level | | I _{OL} = -1mA | | | 0.4 | V |

ELECTRICAL CHARACTERISTICS – PWM_RS485, ALARM Outputs

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------|--------|------------------------|-----|-----|-----|------|
| Digital Input/Output | | | | | | |
| Output HIGH Level | | I _{OH} = +1mA | 2.6 | | | V |
| Output LOW Level | | I _{OL} = -1mA | | | 0.4 | V |

ELECTRICAL CHARACTERISTICS – PWR_ON Input

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------|--------|-----------------|-----|-----|-----|------|
| Digital Input/Output | | | | | | |
| Input HIGH Level | | | 0.9 | | | V |
| Input LOW Level | | | | | 0.4 | V |

Low Power CO₂ Sensor

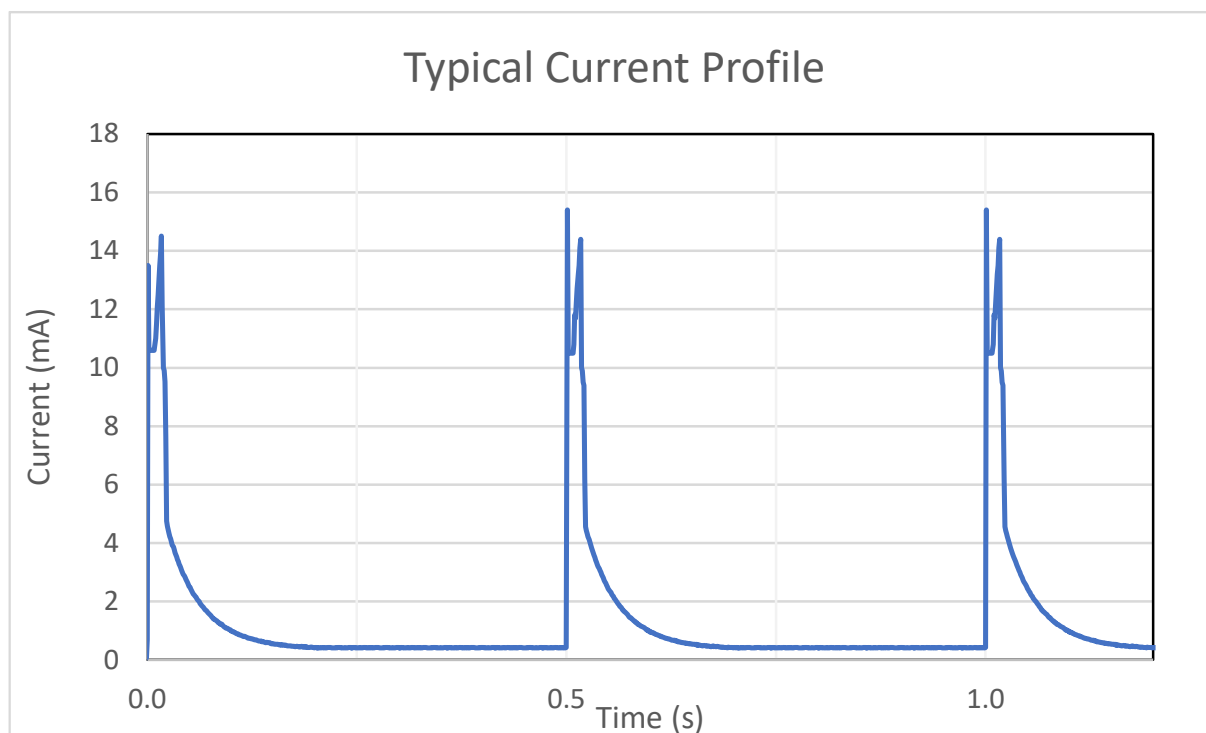
POWER CONSUMPTION

Test Conditions Unless Otherwise Specified

VDD = 3.3V, GND = 0V. CO₂ = 450ppm, RH = 0% non-condensing, T= 25°C, Pressure = 1013mbar

| SETTING | SYMBOL | TEST CONDITIONS | VDD | | Average Power |
|-------------------------------------|--------|------------------|-----|--------|---------------|
| | | | V | I (mA) | mW |
| Active OFF | | PWR_ON held low | 3.3 | 0.001 | 0.003 |
| Active, SLEEP mode, no measurements | | | 3.3 | 0.01 | 0.03 |
| Active, taking measurements | | Default settings | 3.3 | 1 | 3.5 |

The CozIR®-LP3 current consumption varies in time over the measurement cycle. The LED is pulsed, which results in a peak current when taking measurements of approximately 15mA. A typical current consumption profile after power-on is shown below.



Low Power CO₂ Sensor

METHOD OF OPERATION

The CozIR®-LP3 is designed for low power applications where power is often at a premium.

Power-on is controlled by setting the state of the PWR_ON pin. This pin controls the on-board sensor power. If held low, the sensor will remain in a quiescent state. The sensor will not respond to any commands in this state. To turn the sensor on, set PWR_ON pin high. If unused, connect the PWR_ON pin permanently to VDD.

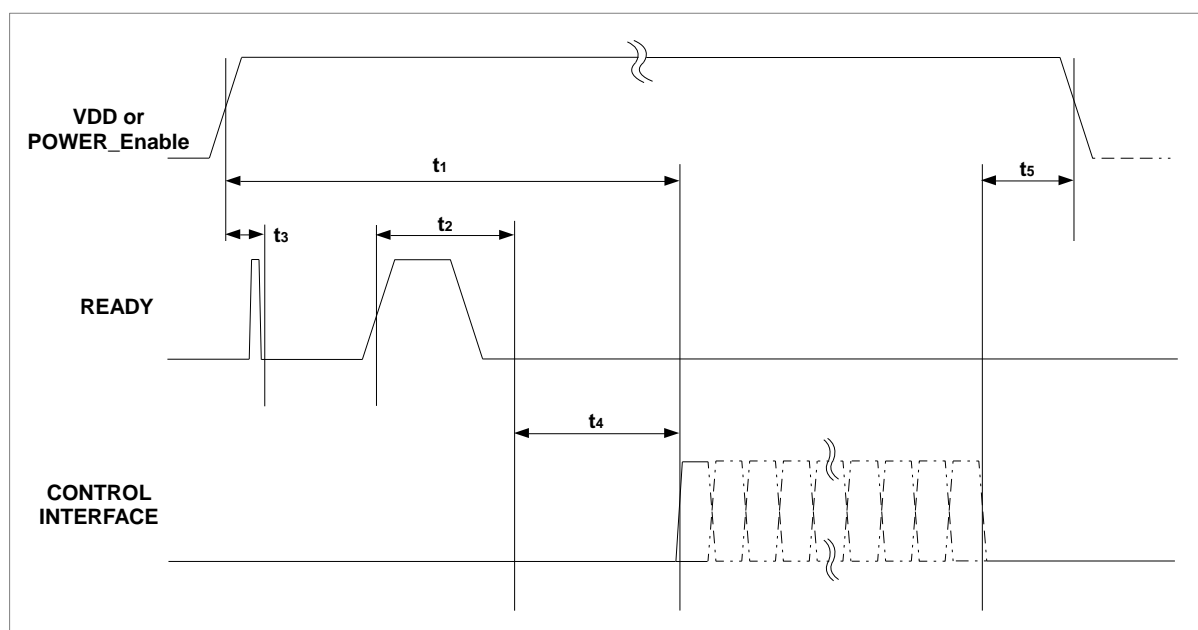
When the sensor is switched on, and the PWR_ON pin connected to VDD or set high, the state of the I2C_ENABLE pin is sampled. Setting the I2C_ENABLE pin low puts the CozIR®-LP3 into I²C interface mode. Leaving the I2C_ENABLE pin floating puts the CozIR®-LP3 into UART interface mode.

In either mode, after power on, the sensor automatically starts to take measurements, 2 readings per second. Readings can be read out once the READY pin is pulsed high in either UART or I²C interface mode.

POWER ON DATA READY

After power is applied to the CozIR®-LP3, the sensor will automatically start to take CO₂ measurements using the configured settings. Once the initial READY flag has been pulsed high, the sensor will respond to requests for CO₂ data. The control interface is available approximately 14ms after the falling edge of a valid READY pulse.

The data READY time is determined by the digital filter setting.



Low Power CO₂ Sensor

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT |
|---|----------------|-----|------|-----|------|
| READY Data Valid from Power On | t ₁ | 0.8 | 8.3 | | s |
| READY High Pulse-Width | t ₂ | | 16.5 | | ms |
| READY Low from Power On | t ₃ | | | 100 | ms |
| Control Interface Setup Time | t ₄ | 14 | | | ms |
| Control Interface Active to Safe Shutdown Time ¹ | t ₅ | 80 | 5.8 | | ms |

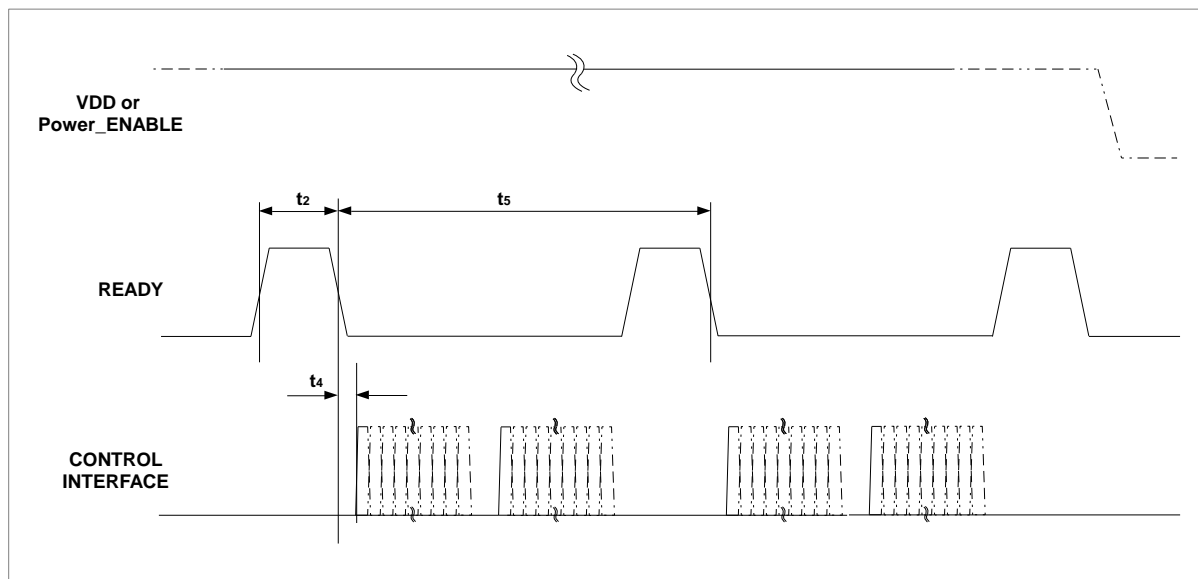
Notes

1. Time needed for the sensor to safely shut down after the user has written to or read from memory.

Low Power CO₂ Sensor

MEASUREMENT CYCLE

Writing to or reading from the CozIR®-LP3 sensor is gated by the status of the READY pin. In both UART and I²C interface mode, the sensor will not respond when the READY pin is high. The READY pin is set high for approximately 16.5ms when the sensor is taking measurements every 0.5 seconds. The control interface is available approximately 14ms after the falling edge of a valid READY pulse. The sensor will only respond correctly when the READY pin is low.



| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT |
|------------------------------|--------|-----|------|-----|------|
| READY High Pulse-Width | t_2 | | 16.5 | | ms |
| Control Interface Setup Time | t_4 | 14 | | | ms |
| READY Pulse Period | t_5 | | 0.5 | | s |

Low Power CO₂ Sensor

MEASUREMENT CYCLE - I²C INTERFACE MODE

- Apply power to the Sensor and set PWR_ON high
- The sensor will automatically start taking measurements.
- The data READY flag is set low within 5ms of power on.
- The data READY flag will be pulsed high for approximately 16.5ms with data available 14ms after the falling edge of the data READY flag
- Data can be read out at any rate up to the maximum I²C read rate
- Measurement data is updated every 0.5 seconds
- Note when auto-zero is used, the auto-zero trigger event will extend the measurement time by ~2s

MEASUREMENT CYCLE - UART INTERFACE MODE

- Apply power to the Sensor and set PWR_ON high
- The sensor will automatically start taking measurements.
- The sensor takes a measurement at 2 readings per second
- The data READY flag is set low within 5ms of power on.
- The data READY flag will be pulsed high for approximately 16.5ms with data available 14ms after the falling edge of the data READY flag
- The UART baud rate is fixed at 9600 baud
- Measurement data is updated every 0.5 seconds
- Note when auto-zero is used, the auto-zero trigger event will extend the measurement time by ~2s

MEASUREMENT PROCESS

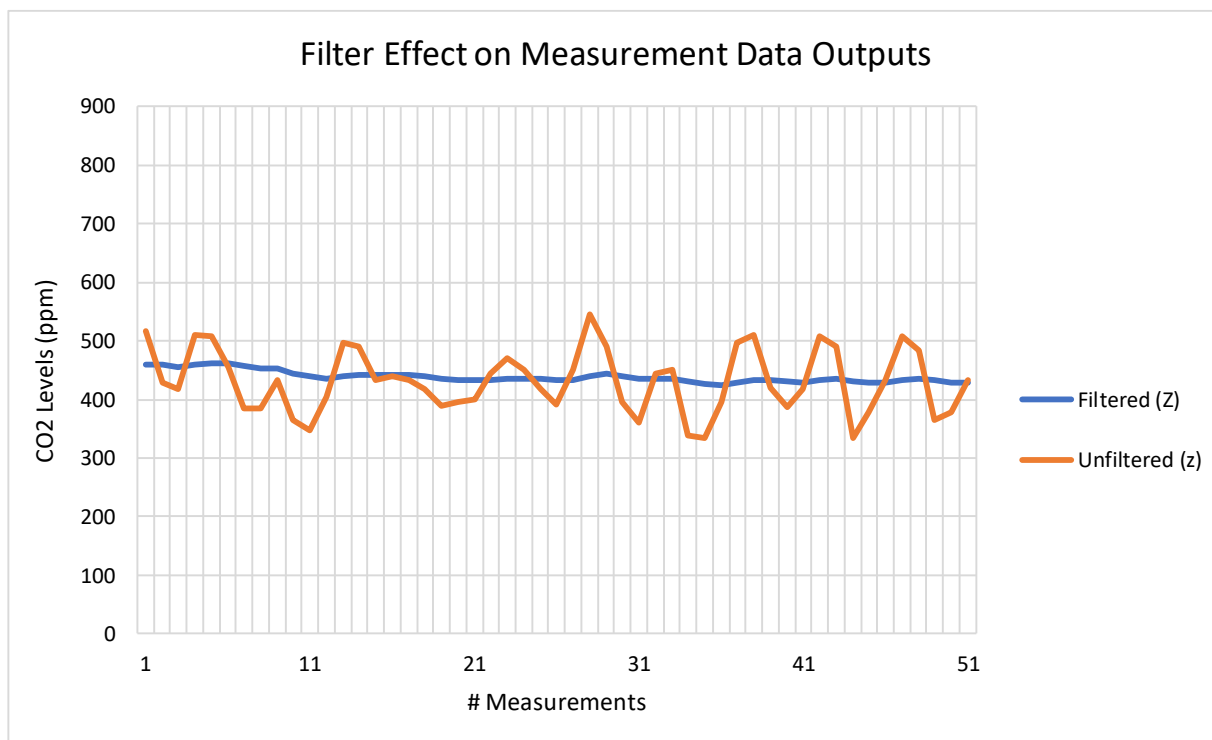
The CozIR®-LP3 sensor takes readings at a fixed rate of two per second. The measurement process is set on by default but can be switched off to save power. If the measurement process is switched off, the user can still write to control registers to configure the sensor. The sensor will report the last active measurement until the measurement process is switched back on. The time to a valid measurement will depend on the sensor filter configuration.

Low Power CO₂ Sensor

DIGITAL FILTER

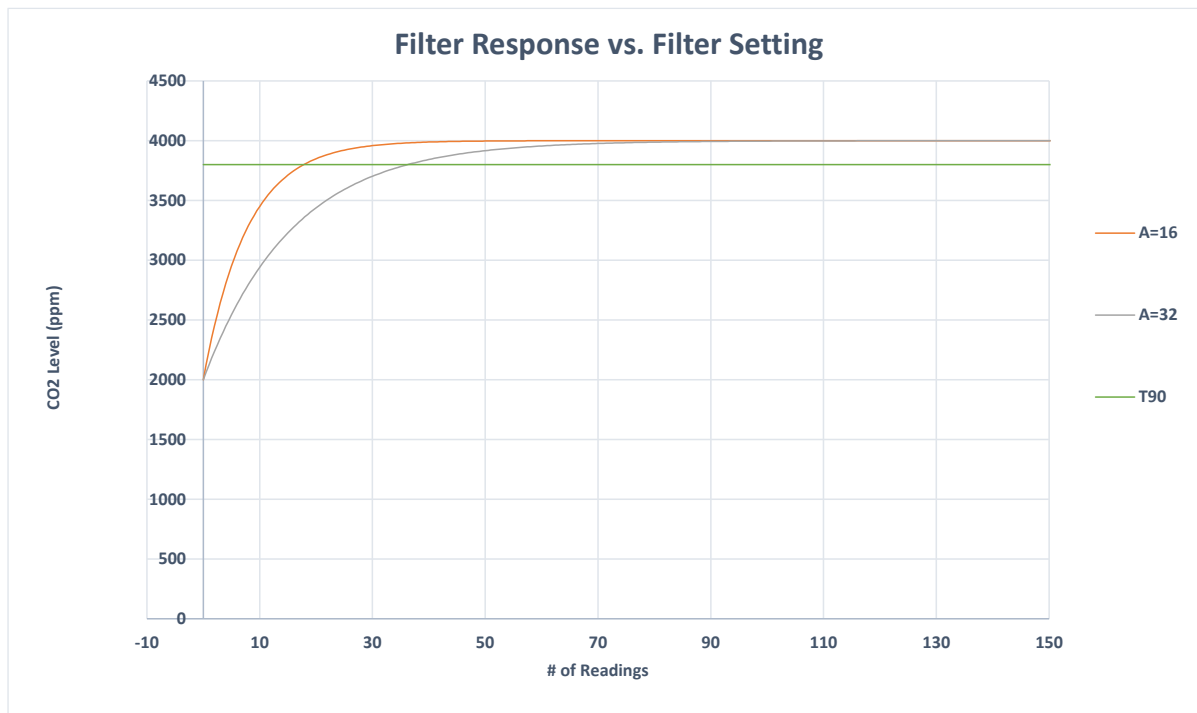
The CO₂ gas chamber is illuminated with a nominal 4.25um wavelength LED and the signal received using a photo-diode. The signal from the photo-diode is processed and filtered by the sensor to remove noise and provide an accurate CO₂ reading. High frequency noise coming from the sampling process is removed using a proprietary lowpass filter. The digital filter setting can be varied from 1-255, allowing the user to reduce measurement noise at the expense of the measurement response time. Filter = 1 is the same as unfiltered.

The ideal digital filter setting is application specific and is normally a balance between CO₂ reading accuracy and response time. Filter settings are variable between The CozIR®-LP2 sensor will also output the raw unfiltered CO₂ measurement data. This data can be post processed using alternative filter algorithms.



The graph above shows the effects of the filter on the CO₂ measurement data (Z). The unfiltered output (z) is shown in orange and the filtered output (Z) shown in blue.

Low Power CO₂ Sensor



The graph above shows the effect of the filter on response times. Increasing the filter setting increases the measurement output response time. T_{90} is the time to 90% of reading. The CozIR®-LP3 takes 2 readings per second. The CozIR®-LP3 sensor will also output the raw unfiltered CO₂ measurement data. This data can be post processed using alternative filter algorithms.

Low Power CO₂ Sensor

PWM_RS485 - DIGITAL OUTPUT

PWM/RS485 is an independently controlled digital output. The PWM_RS485 pin can be configured in two different ways, selectable by the user.

PWM Output Configuration

This mode must be selected by the user. The PWM output is OFF by default. Once selected, the digital output is configured as a PWM output with the duty cycle proportional to the CO₂ concentration, from 0 to full scale.

The PWM output is only operational when the sensor is active. The default PWM master clock rate is 8MHz. Provision is made to divide the master clock by powers of 2 up to 128. The PWM resolution may be set to 8 or 10 bits.

The PWM signal can be programmed to be continuously on or pulsed on to save power.

In pulsed mode, the user can set the PWM output to pulse on after every measurement cycle. The number of pulses is programmable from 2 pulses to 8 pulses.

If the measured CO₂ concentration is lower than 1 bit of output, the PWM pin will stay low. If the measured CO₂ concentration is higher than all bits set, the PWM pin will stay high.

| Clock Speed | 8-bit PWM frequency (kHz) | 10-bit PWM frequency (kHz) |
|-------------|---------------------------|----------------------------|
| Min | 0.244 | 0.061 |
| Max | 31.25 | 7.81 |

The PWM configuration is retained after the sensor is power cycled.

High/Low Configuration

This mode must be selected by the user. Once selected, this digital output can be set high or low and can be used for a variety of functions including for example setting the direction control for an external RS-485 physical layer transceiver.

Low Power CO₂ Sensor

ALARM OUTPUT

The sensor comes with a CO₂ level alarm function. The ALARM pin goes high if the detected CO₂ level exceeds the alarm threshold value. The alarm threshold detection can be enabled or disabled. It is disabled by default.

If enabled, the alarm is triggered when the measured CO₂ reading exceeds the alarm threshold value. The alarm is cleared if the measured CO₂ reading falls below 80% of the alarm threshold value.

The alarm is off if the CO₂ level alarm level is set to zero. The default setting is zero.

The alarm value is retained after the sensor is power cycled.

BUILT-IN SELF TEST

The sensor has a built-in test function that automatically checks if it is operating correctly at power-on and during a measurement cycle. The sensor will store an error condition if any of the following are triggered.

| ERROR FLAG | ERROR CONDITION |
|------------------------------|--|
| Sensor Lifetime | If the total power-on time exceeds 20000 hours |
| LED optical output value | If LED output is out of range |
| CO ₂ out of range | If the temperature compensated CO ₂ value is out of range |
| ADC input value | If the ADC input signal is out of the expected range |

The sensor will return a self-test decimal value of 85 if operation is nominal or 170 if any of the error conditions are flagged.

Low Power CO₂ Sensor

ZERO POINT SETTING

The performance of an NDIR sensor can be compromised by the build-up of contaminants in the measurement chamber of the sensor, as well as other degradations in the optical components. The effect of these degradations can be fully eliminated by using one or more of the GSS zeroing routines. Zero-point setting is the process of modifying the CO₂ measurement value read by the sensor and align it with an external reference set point.

In all cases, the best zero is obtained when the gas concentration is stable, and the sensor is at a stabilised temperature. Zero-point settings are not cumulative and only the latest zero-point setting is effective. For example, there is no benefit in zeroing in nitrogen, and then zeroing in a calibration gas. The sensor will store only the latest zero point regardless of what method is used. There are several different methods available to the user to set the zero point of the sensor.

ZERO IN A KNOWN GAS CONCENTRATION

Place the sensor in a known gas concentration and allow time for the sensor temperature to stabilise, and for the gas to be fully diffused into the sensor.

Power up the sensor, wait for the READY pin to indicate the sensor interface is active. Write the known concentration level to the sensor, then initiate the Zero in a Known Gas calibration method. The concentration must be in ppm.

ZERO IN NITROGEN

Place the sensor in the nitrogen gas and allow time for the sensor temperature to stabilise, and for the gas to be fully diffused into the sensor. Power up the sensor, wait for the READY pin to indicate the sensor interface is active. Initiate the Zero in Nitrogen command. The sensor is zeroed assuming a 0ppm CO₂ environment.

ZERO IN FRESH AIR

If there is no calibration gas or nitrogen available, the sensor zero point can be set in fresh air. Ambient CO₂ concentrations in fresh air are typically 400ppm. This level is programmable over a range from 0ppm to the full scale of the sensor.

Place the sensor in a fresh air environment and allow time for the sensor temperature to stabilise, and for the fresh air to be fully diffused into the sensor. Power up the sensor, wait for the READY pin to indicate the sensor interface is active.

The user can initiate a Zero in Fresh Air setting cycle. The sensor can use the default fresh air CO₂ concentration value (400ppm), or the user can write a different fresh air value to the sensor if desired. The concentration must be in ppm.

Low Power CO₂ Sensor

AUTO-ZERO FUNCTION

The sensor has a built-in auto-zeroing function. To function correctly, the sensor must be exposed to typical background levels (400-450ppm) at least once during the auto-zero period. For example, many buildings will drop quickly to background CO₂ levels when unoccupied overnight or at weekends. The auto-zero function uses the information gathered during these periods to re-zero. The sensor will reset the 'zero' level every time it does an auto-zero. Auto-zeroing is enabled by default. If the sensor is powered down, the auto-zero is reset to default values.

The auto-zero function works in the same way as the **ZERO IN FRESH AIR** command. Auto-zeroing is enabled by default. It is enabled to operate automatically but can be disabled or it can be forced. The user can also independently adjust the CO₂ level used for auto-zeroing.

The CozIR®-LP3 keeps a record of the lowest measured CO₂ value in memory (Z_{lowest}). The sensor also keeps a record of the last CO₂ measurement. Every time the CozIR®-LP3 takes a new measurement, the previous and current values are filtered to create a new value (Z_{new}).

$$Z_{\text{new}} = \frac{Z_{\text{cur}} - Z_{\text{prev}}}{2} + Z_{\text{prev}}$$

If the value of Z_{new} is lower than the stored Z_{lowest} , Z_{lowest} is updated.

When the auto-zero function is run, the sensor will reset the fresh-air zero point using Z_{lowest} . The value the sensor uses for this fresh-air zero-point is user programmable. The sensor default value for CO₂ in fresh air is 400ppm. When the auto-zero function is run, the sensor sets the Z_{lowest} value of CO₂ of the fresh air to 400ppm. Typically, it is set to the same value as the **ZERO IN FRESH AIR** value, but it can also be set at a different level if desired.

AUTO-ZERO INTERVALS

The auto-zero period can be programmed by the user. The sensor can be programmed to undertake an initial auto-zero after power-on. Thereafter, the auto-zero period can be set independently of the start-up auto-zero time. Note, the auto-zero settings are reset if the sensor is powered down.

The minimum and maximum interval time for either the initial or ongoing auto-zero period depends on the interface mode.

Low Power CO₂ Sensor

UART Mode

| Auto-Zero Period | Minimum Value | Maximum Value | Default Value | Resolution |
|--------------------|---------------|---------------|---------------|------------|
| Initial Auto-Zero | 0.1 days | 37.9 | 7 days | 0.1 day |
| On-Going Auto-Zero | 0.1 days | 37.9 | 8 days | 0.1 day |

I²C Mode

| Auto-Zero Period | Minimum Value | Maximum Value | Default Value | Resolution |
|--------------------|---------------|---------------|---------------|------------|
| Initial Auto-Zero | 0 | 65535 | 12096 | 1 |
| On-Going Auto-Zero | 0 | 65535 | 13824 | 1 |

In I²C mode, the time period is calculated as follows.

Auto-Zero (hours) = Auto-Zero Value/72

Initial Auto-Zero (default) = 12096/72 = 168 hours (7 days)

On-Going Auto-Zero (default) = 13824/72 = 192 hours (8 days)

In all cases, it is recommended the subsequent auto-zero period is set to >1 day and the initial auto-zero period set to less than the subsequent auto-zero period.

AUTO-ZERO LEVEL

The background concentration will depend on sensor location. Ambient levels are typically in the range of 400ppm - 450ppm. The factory default is set to 400ppm. The user can change the background ambient level used for auto-zeroing. The value is stored in the sensor.

Low Power CO₂ Sensor

ALTITUDE PRESSURE COMPENSATION

NDIR gas sensors detect the concentration of gas by measuring the degree of light absorption by the gas analyte. The degree of light absorption is then converted into a concentration reported by the sensor.

The absorption process is pressure dependent, and a change in pressure will cause a change in the reported gas concentration. As the pressure increases, the reported gas concentration also increases. As the pressure decreases, the reported concentration decreases. This effect takes place at a molecular level and is common to all NDIR gas sensors.

GSS sensors are calibrated at 1013mbar. The reading from the sensor will vary from the nominal output if the mean barometric pressure is different from the calibration setting.

It is possible to configure the sensor to correct for this effect by writing the actual or reference mean barometric pressure in mbar to the sensor. This can be done as part of the initial set up process or updated at any time during use.

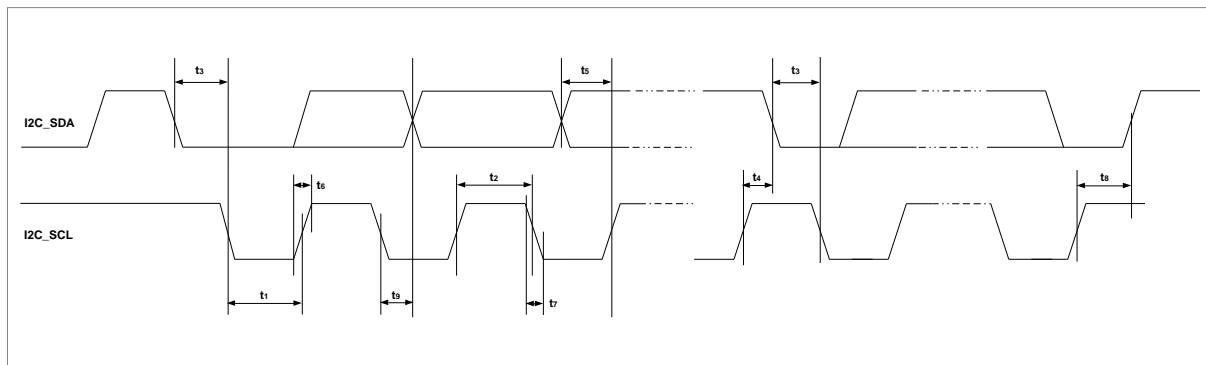
Low Power CO₂ Sensor

SELECTION OF CONTROL INTERFACE

The CozIR®-LP3 is controlled by writing to registers through a serial control interface. The control interface can be configured as a UART or 2-wire I²C interface.

Selection of the control interface is done via the I2C_ENABLE pin. The state of the I2C_ENABLE pin is sampled at power up only. The status cannot be changed after power up. Setting the I2C_ENABLE pin low puts the CozIR®-LP3 into I²C interface mode. Leaving the I2C_ENABLE pin floating puts the CozIR®-LP3 into UART control interface mode.

CONTROL INTERFACE TIMING - I²C MODE



| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT |
|-----------------------------------|----------------|-----|-----|------|------|
| I2C_SCL Frequency | | 0 | | 100 | kHz |
| I2C_SCL Low Pulse-Width | t ₁ | 4.7 | | | us |
| I2C_SCL High Pulse-Width | t ₂ | 4.0 | | | us |
| Hold Time (Start Condition) | t ₃ | 4.0 | | | us |
| Setup Time (Start Condition) | t ₄ | 4.7 | | | us |
| Data Setup Time | t ₅ | 250 | | | ns |
| I2C_SDA, I2C_SCL Rise Time | t ₆ | | | 1000 | ns |
| I2C_SDA, I2C_SCL Fall Time | t ₇ | | | 300 | ns |
| Setup Time (Stop Condition) | t ₈ | 4.0 | | | us |
| Data Hold Time | t ₉ | 0 | | 5.0 | us |
| Capacitive load for each bus line | - | | | 400 | pF |

Low Power CO₂ Sensor

I²C INTERFACE MODE

The CozIR®-LP3 supports software control via a 2-wire serial bus. Many devices can be controlled by the same bus, and each device has a unique 7-bit address (this is not the same as the 8-bit address of each register in the CozIR®-LP3). The CozIR®-LP3 operates as a slave only device.

The controller indicates the start of data transfer with a high to low transition on I2C_SDA while I2C_SCL remains high (I²C Start condition). This indicates that a device address will follow. All devices on the 2-wire bus respond to the start condition and shift in the next eight bits on I2C_SDA (7-bit address + Read/Write bit, MSB first). If the device address received matches the address of the CozIR®-LP3 and the R/W bit is '0', indicating a write, then the CozIR®-LP3 responds by pulling I2C_SDA low on the next clock pulse (ACK). If the address is not recognised or the R/W bit is '1', the CozIR®-LP3 returns to the idle condition and waits for a new start condition and valid address.

The CozIR®-LP3 acknowledges the correct address by pulling I2C_SDA low for one clock pulse. The master then sends the address of the register it wishes to read from or write to. Data is either read from or written to in 1 - 4 bytes, most significant byte (MSB) first.

The transfer of data is complete when there is a low to high transition on I2C_SDA while I2C_SCLK is high. After receiving a complete address and data sequence the CozIR®-LP3 returns to the idle state and waits for another start condition. If a start or stop condition is detected out of sequence at any point during data transfer (i.e. I2C_SDA changes while I2C_SCL is high), the device jumps to the idle condition.

The CozIR®-LP3 supports clock stretching. In an I²C communication, the master device determines the clock speed. The I²C bus provides an explicit clock signal running at a pre-defined rate. However, there are situations where an I²C slave is not able to co-operate with the clock speed given by the master and needs to slow down a little. This is done by a mechanism referred to as *clock stretching*.

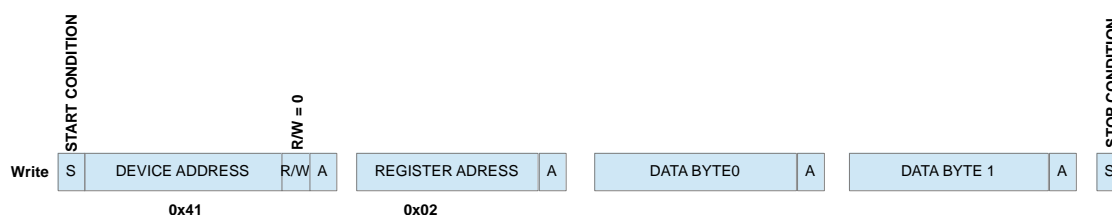
An I²C slave is allowed to hold down the clock if it needs to reduce the bus speed. The CozIR®-LP3 operates at up to 100kHz, and maximum stretch is never more than 500µsecs.

The CozIR®-LP3 device address is 0x41.

Low Power CO₂ Sensor

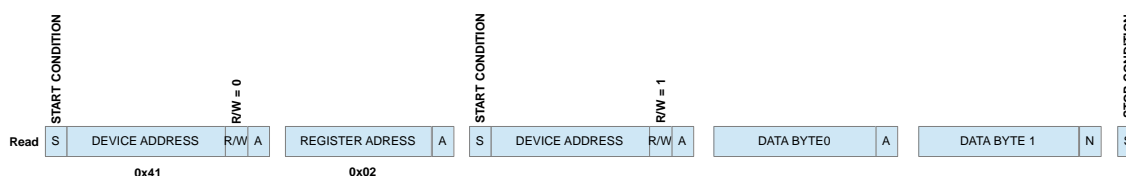
WRITING TO AN I²C REGISTER

The controller (Master) sends a START condition to the sensor. The sensor acknowledges the controller by setting the R/W bit low, indicating it is expecting the controller to write to a register. The controller sends the register address that it wants to write to, and then 1-4 data bytes. Once the controller has completed the operation, it sends the STOP condition.



READING FROM AN I²C REGISTER

The controller (Master) sends a START condition to the sensor. The sensor acknowledges the controller by setting the R/W bit high, indicating it is expecting the controller to read from a register. The controller (Master) must send another START condition to the sensor and the sensor address with R/W bit set to read. Then read out 1-4 data bytes. Once the controller has completed the operation, it sends the STOP condition.



Low Power CO₂ Sensor

I²C REGISTER MAP SUMMARY

| REGISTER | ADDRESS | DESCRIPTION | DEFAULT | RANGE | SIZE (bytes) | READ/WRITE |
|------------|---------|--|---------|-----------------|-----------------|-------------|
| R0 (0x00) | 0000000 | Measurement Control | 2 | | 1 | READ/WRITE |
| R2 (0x02) | 0000010 | CO ₂ Level (ppm), filtered, with sensor Global Self-Test byte | N/A | 0 – 65535 | 3 | READ |
| R4 (0x04) | 0000100 | Digital Filter Setting | 16 | 0 - 255 | 1 | READ/WRITE* |
| R5 (0x05) | 0000101 | Zero Control Settings | | | 1 | WRITE |
| R6 (0x06) | 0000110 | Auto Zero Initial Interval Period | 12096 | 0 - 65535 | 2 | READ/WRITE |
| R8 (0x08) | 0001000 | Auto Zero Interval Period | 13824 | 0 - 65535 | 2 | READ/WRITE |
| R12 (0x0C) | 0001100 | Auto-Zero Target Level | 400ppm | 0 to full scale | 2 | READ/WRITE |
| R18 (0x12) | 0010010 | Target value for CO ₂ in fresh air (in ppm) | 400ppm | 0 to full scale | 2 | READ/WRITE |
| R20 (0x14) | 0010100 | New target value in fresh air in ppm (for zero settings) | | | 2 | WRITE |
| R38 (0x26) | 0100110 | Serial Number | N/A | | 4 | READ |
| R44 (0x2C) | 0101100 | Alarm Level | 0 | 0-20000 | 2 | READ/WRITE |
| R46 (0x2E) | 0101110 | PWM Control | 0 | 0-255 | | READ/WRITE |
| R52 (0x34) | 0110100 | CO ₂ Level (ppm), filtered | N/A | 0 – 65535 | 2 | READ |
| R78 (0x4E) | 1001110 | Auto-Zero Control | | | 1 | READ/WRITE |
| R80 (0x50) | 1010000 | Global Self-Test | | | 1 | READ/WRITE |
| R90 (0x5A) | 1011010 | Reports Total Number of Hours | N/A | 0-65535 | 2 | READ |

Low Power CO₂ Sensor

| | | | | | | |
|----------------|---------|------------------------------|------|---------------|---|------------|
| | | Run by Sensor Powered Up | | | | |
| R118 (0x76) | 1110110 | Altitude pressure in mbar | 1013 | 697 – 1050 | 2 | READ/WRITE |

Notes

* indicates a sensor zero should be performed after the default values are changed.

Low Power CO₂ Sensor

MEASUREMENT CONTROL

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|-----|-------------|--|----------|------------|
| R0 (0x00) | 00000000 | 7:0 | MEASUREMENT | CO ₂ measurement 00000010 = On 00000000 = Off | 00000010 | READ/WRITE |

If measurements are switched off, all zero setting commands are automatically disabled.

CO₂ LEVEL MEASUREMENT VALUE WITH STATUS BYTE

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|------|-------|-------------------------------|---------|------------|
| R2 (0x02) | 00000010 | 15:0 | | CO ₂ level, in ppm | N/A | Read only |

The measured CO₂ level is read from Register R2. The first two 8-bit bytes are CO₂ measurement data, MSB first. The value is CO₂ level in ppm. Byte 3 can be read as the global self-test error status value or the status can be read from register 80.

CO₂ LEVEL MEASUREMENT VALUE ONLY

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|---------|------|-------|-------------------------------|---------|------------|
| R52 (0x34) | 0110100 | 15:0 | | CO ₂ level, in ppm | N/A | Read only |

The measured CO₂ level is read from Register R52, 2 bytes, MSB first. The value is CO₂ level in ppm

DIGITAL FILTER

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|-----|--------|------------------------|----------|------------|
| R4 (0x04) | 00000100 | 7:0 | FILTER | Digital filter setting | 00010000 | READ/WRITE |

Low Power CO₂ Sensor

ZERO CONTROL SETTINGS

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|-----|---------------|--|---------|------------|
| R5 (0x05) | 00000101 | 0 | Air Zero | Sets the zero point assuming the sensor is in 400ppm CO ₂ . If using a different CO ₂ value, write the CO ₂ level into Register 18 prior to initiating the zero process. 000000000: No Zero 000000001: Zero | N/A | Write |
| | | 1 | Nitrogen Zero | Sets the zero point assuming the sensor is in 100% nitrogen. 000000000: No Zero 000000010: Zero in Nitrogen | N/A | Write |
| | | 2 | X Zero | Sets the zero point with the sensor in a known concentration of CO ₂ . Write the target ppm concentration into Register 20 prior to initiating the zero process. 00000000: No X Zero 00000010: X Zero | N/A | Write |

The control register 5 enables the user to transfer the value stored in register 18 or register 20 into sensor memory. Once the new target value has been written into register 18 or register 20, write to register R5 to complete the data transfer.

Once the new data has been written to memory, register 5 is cleared.

Low Power CO₂ Sensor

AUTO-ZERO INITIAL INTERVAL PERIOD

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|------|-------|---|----------------|------------|
| R6 (0x06) | 00000110 | 15:0 | | Sets the auto-zero initial interval count period. Each count is 0.5s. | 10111101000000 | READ/WRITE |

The default initial auto-zero period value 12096, equivalent to 7 days.

AUTO-ZERO INTERVAL PERIOD

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|-----------|----------|------|-------|------------------------------------|----------------|------------|
| R8 (0x08) | 00001000 | 15:0 | | Sets the auto-zero interval period | 11011000000000 | Read/Write |

The default auto-zero period value 13824, equivalent to 8 days.

AUTO-ZERO TARGET VALUE

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|----------|------|-------|--|-----------|------------|
| R12 (0x0C) | 00001100 | 15:0 | | Sets the target value for CO ₂ level when doing an auto-zeroing | 110010000 | Read/Write |

The user can independently set the target value for CO₂ used for an auto-zero event. The default is 400ppm.

Low Power CO₂ Sensor

ZERO IN FRESH AIR

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|----------|------|-------|---|-----------|------------|
| R18 (0x12) | 00010010 | 15:0 | | Target value for CO ₂ in fresh air | 110010000 | |

The target value for CO₂ in fresh air is stored in register 18. The default is 400ppm.

CONTROL VALUE

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|----------|------|---------|------------------|---------|------------|
| R20 (0x14) | 00010100 | 15:0 | CONTROL | New target value | | Write |

Stores the new target value. All CO₂ values are in ppm. Number is a two-byte value, MSB first.

SERIAL NUMBER

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|----------|------|---------------|--|---------|------------|
| R38 (0x26) | 00100110 | 31:0 | SERIAL NUMBER | Unique sensor serial number, 32-digit code | | Read only |

ALARM LEVEL

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|------------|----------|------|-------------|---|---------|------------|
| R44 (0x2C) | 00101100 | 15:0 | ALARM LEVEL | CO ₂ threshold for alarm. Sets alarm threshold level between 0 -20,000ppm. 0 turns off the alarm. Alarm value retained after power cycle. | 0ppm | READ/WRITE |

Low Power CO₂ Sensor

PWM CONTROL

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|---------------|---------|-----|------------|--|---------|------------|
| R46 (0x2E) | 0101110 | 2:0 | PRESCALAR | Sets clock pre-scaler, in powers of 2. | 00 | Read/Write |
| | | 3 | RESOLUTION | 0 = 8-bit 1 = 10-bit | 0 | Read/Write |
| | | 4 | MODE | 0 = Pulsed 1 = Always on | 0 | Read/Write |
| | | 6:5 | OUTPUT | 00 = Continuous Output 01 = 2 pulses, then sleeps 10 = 4 pulses, then sleeps 11 = 8 pulses, then sleeps | 00 | Read/Write |
| | | 7 | ON/OFF | Controls the state of the PWM output | 0 | Read/Write |

AUTO-ZERO CONTROL

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|---------------|----------|-----|----------|--|----------|------------|
| R78 (0x4E) | 01001110 | 7:0 | AUTO CAL | Auto-zero control 00000000 = Disabled 00000010 = Enabled | 00000010 | Read/Write |

To force an auto-zero sequence, do the following.

- Set R78 to Enabled
- Set R12 auto-zero to target level, or leave at its default setting
- Set R8 interval period to zero

Low Power CO₂ Sensor

SELF-TEST

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|---------------|---------|-----|---------------------|---|---------|------------|
| R80 (0x50) | 1010000 | 7:0 | GLOBAL SELF TEST | Sensor automatic self-test result 01010101 = Sensor is nominal (decimal value 85) 10101010 = Sensor error (decimal value 170) | | Read/Write |

RUN TIME

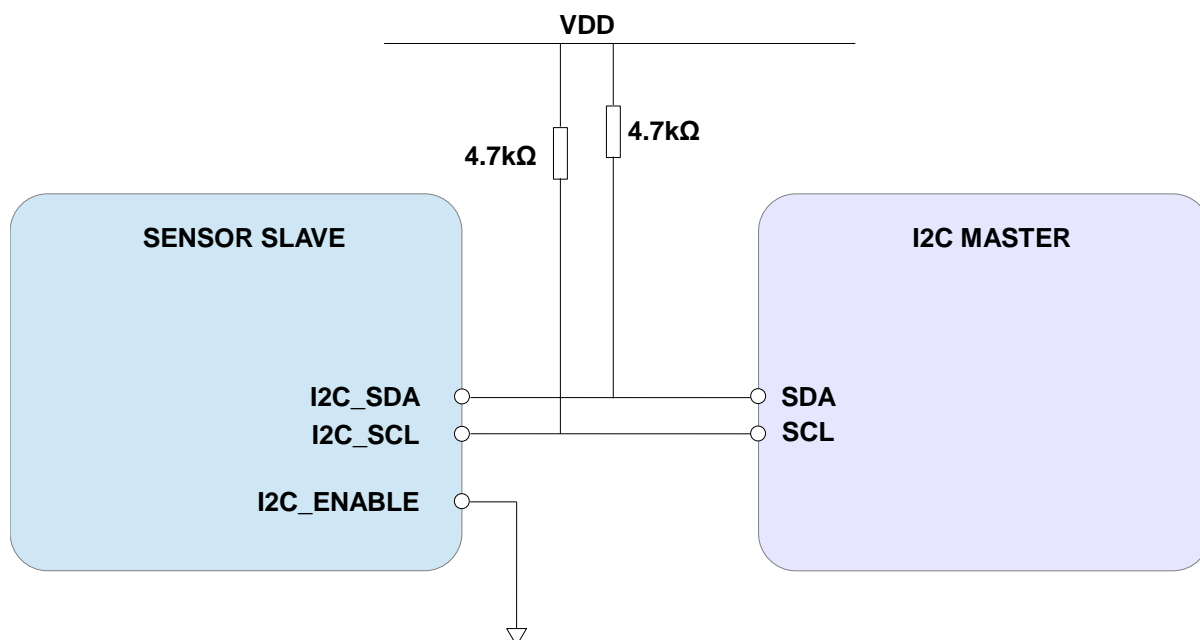
| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|---------------|---------|------|-------|--|---------|------------|
| R90 (0x5A) | 1011010 | 15:0 | HOURS | Reports total number of hours sensor powered-up. | N/A | Read |

ALTITUDE PRESSURE SETTING

| REGISTER | ADDRESS | BIT | LABEL | DESCRIPTION | DEFAULT | READ/WRITE |
|----------------|---------|------|----------|-------------------|---------|------------|
| R118 (0x76) | 1110110 | 15:0 | PRESSURE | Pressure in mbar. | 1013 | Read/Write |

Low Power CO₂ Sensor

CONNECTION DIAGRAM FOR I²C INTERFACE



Low Power CO₂ Sensor

UART INTERFACE MODE

Leaving the I2C_ENABLE pin floating puts the CozIR®-LP3 into UART control interface mode. The status of the I2C_ENABLE is only sampled at power up.

The **Rx_In** and **Tx_Out** pins are normally high, suitable for direct connection to a UART. If the sensor is to be read by a true RS232 device (e.g. a PC), it is necessary to use a level converter to step up/down the voltage and invert the signal.

CONTROL INTERFACE TIMING - UART MODE

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT |
|-----------------------|--------|------|-------|-----|--------|
| Baud Rate (Fixed) | | | 9,600 | | Bits/s |
| Data Bits | | 8 | | | |
| Parity | | None | | | |
| Stop Bits | | 1 | | | |
| Hardware Flow Control | | None | | | |

UART COMMAND PROTOCOL

All UART commands must be terminated with a carriage return and line feed <CR><LF>, hex 0x0D 0x0A. In this document, this is shown as '\r\n'. UART commands that take a parameter always have a space between the letter and the parameter. The sensor will respond with a '?' if a command is not recognised. The two most common causes are missing spaces or missing <CR><LF> terminators.

All command communications are in ASCII and are terminated by carriage return, line feed (0x0D 0x0A). This document uses the protocol "\r\n" to indicate the carriage return line feed. All responses from the sensor, including measurements, have a leading space (ASCII character 32).

The character '#' represents an ASCII representation of a numeric character (0-9). Note there is a space between the first letter and any parameter. For example, the X command reads "X space 2000 carriage return line feed".

UART OPERATION

When initially powered, the sensor will immediately start to transmit a CO₂ reading on receiving any character.

The CO₂ measurement is reported as:

Z #####\r\n

where Z ##### shows the CO₂ concentration.

Note that all outputs from the sensor have a leading space.

Low Power CO₂ Sensor

METHOD OF OPERATION

After power is applied to the CozIR®-LP3, the sensor will automatically start to take CO₂ measurements using the Mode K1 default settings, where the sensor is pre-programmed to send CO₂ measurement data at 2 readings per second. The measurement rate is fixed at 2 readings per second at 9600 baud rate. The sensor will return the previous CO₂ measurement results if the user requests more frequent measurements. The CozIR®-LP3 has 3 potential modes of operation.

K0 COMMAND MODE (K=0)

In this mode, the sensor is in a SLEEP mode, waiting for commands. No measurements are made. There is no latency in command responses. All commands that report measurements or alter the zero-point settings are disabled in Mode 0. Mode 0 is NOT retained after power cycling.

K1 STREAMING MODE (K=1)

This is the factory default setting. Measurements are reported twice per second. Commands are processed when received, except during measurement activity, so there may be a time delay of up to 100ms in responding to commands.

K2 POLLING MODE (K=2)

In polling mode, the sensor only reports readings when requested. The sensor will continue to take measurements in the background, but the output stream is suppressed until data is requested. The sensor will always power up in streaming or polling mode, whichever mode was used before the power cycle.

K COMMAND

| Command | Use | Default | Range | Example | Response | Comments |
|---------|---|---------|-------|---------|----------|------------------|
| K #\r\n | Switches the sensor between different control modes | 1 | | K 1\r\n | K 1\r\n | See 'K' Commands |

Low Power CO₂ Sensor

K COMMAND (0x4B)

| | |
|-------------|--|
| Description | Sets the control interface mode |
| Syntax | ASCII character 'K', SPACE, mode number, terminated by 0x0D 0x0A (CR & LF) |
| Example | K 1\r\n |
| Response | K 00001\r\n (this number is variable) |

MEASUREMENT DATA OUTPUTS

The CozIR®-LP3 sensor can be configured to provide filtered and unfiltered CO₂ data as a single string of data. The number of data sets being sent by the sensor is configurable using the 'M' command.

| UART Command | Use | Default | Range | Example | Response | Comments |
|--------------|---|-------------|-------|---------------------|-------------|--|
| M #####\r\n | Sets the number of measurement data types output by the sensor. Set ##### to the mask value | M 00006\r\n | | See "Output Fields" | M #####\r\n | Sets the number of measurement data types output by the sensor |

| Measurement Parameter | Field Identifier | Mask Value |
|------------------------------|------------------|------------|
| CO ₂ (Filtered) | Z | 4 |
| CO ₂ (Unfiltered) | z | 2 |

The CO₂ measurement string is reported as:

Z ##### z #####\r\n

where

Z ##### shows the CO₂ concentration after digitally filtering

and

z ##### shows the instantaneous CO₂ concentration without any digital filtering.

The required mask value is the sum of the 'Mask Value' for each field required. To output filtered and unfiltered CO₂ data, set M=6.

Low Power CO₂ Sensor

UART INTERFACE SUMMARY

| Syntax | Use | Example | Response | Comments |
|--------------------------|--|--------------------------|--|---|
| A ###\r\n | Set value of the digital filter | A 16\r\n | A 00016\r\n | See “Digital Filter” |
| a\r\n | Return the value of the digital filter | a\r\n | a 00016\r\n | See “Digital Filter” |
| c\r\n | Returns total number of hours the sensor powered up | c\r\n | c 00019 | |
| G\r\n | Zero-point setting using fresh air | G\r\n | G 33000\r\n | See “Zero Point Setting” |
| K #\r\n | Switches the sensor between different modes | K 1\r\n | K 1\r\n | |
| i\r\n | Self-test error condition | i\r\n | i 85\r\n = no error i 170\r\n = error | |
| J ###\r\n | PWM control byte | J ###\r\n | J ###\r\n | See “PWM Control” |
| j\r\n | Read PWM control byte | j\r\n | j ###\r\n | See “PWM Control” |
| M ###\r\n | Sets the number of measurement data types output by the sensor | M 6\r\n | M 6\r\n | See “Output Fields” |
| P 8 ###\r\n P 9 #\r\n | Sets value of CO ₂ background concentration in ppm for auto-zeroing | P 8 1\r\n P 9 144\r\n | | Two byte value, P 8 = MSB P 9 = LSB |

Low Power CO₂ Sensor

| Syntax | Use | Example | Response | Comments |
|----------------------------|---|----------------------------|--------------------------|--|
| | | | | 400ppm in the example |
| P 10 ###\r\n P 11 #\r\n | Sets value of CO ₂ background concentration in ppm used for zero-point zeroing in fresh air. | P 10 1\r\n P 11 144\r\n | | Two-byte value, P 10 = MSB P 11 = LSB 400ppm in the example |
| Q\r\n | Reports the latest measurement data types, as defined by 'M' | Q\r\n | Z 00010\r\n | |
| U\r\n | Zero-point setting using nitrogen | U\r\n | U 33000\r\n | See "Zero Point Setting" |
| V ##### | Set alarm value | V 15000\r\n | V 15000\r\n | See "Alarm Value" |
| v\r\n | Read alarm value | v\r\n | v 15000\r\n | |
| X #####\r\n | Zero-point setting using a known gas calibration | X 2000\r\n | X 32997\r\n | See "Zero Point Setting" |
| Y\r\n | Return firmware version and sensor serial number | Y\r\n | Returns <u>two</u> lines | |
| Z\r\n | Return the most recent filtered CO ₂ measurement in ppm | Z\r\n | Z 00521\r\n | |

Low Power CO₂ Sensor

| Syntax | Use | Example | Response | Comments |
|-------------|--|---------------|---------------|---|
| z\r\n | Return the most recent unfiltered CO ₂ measurement in ppm | z\r\n | Z 00521\r\n | |
| @ ## \r\n | Sets the timing for initial and interval auto-zero periods | @ 1.0 8.0\r\n | @ 1.0 8.0\r\n | See “ Auto-zeroing ” for details |
| @ r\r\n | Returns the Auto-zero configuration | @ 1.0 8.0\r\n | @ 1.0 8.0\r\n | See “ Auto-zeroing ” for details |
| @ #r\r\n | Switch Auto-zero on or off | @ 0\r\n | @ 0\r\n | See “ Auto-zeroing ” for details |
| .\r\n | Returns the scaling factor multiplier required to convert the Z or z output to ppm | .\r\n | . 00001\r\n | Multiply by 1 in the example |
| [#####\r\n | Set pressure value in mbar | [0997\r\n | [0997\r\n | See “Altitude Pressure Compensation” |
|] #####\r\n | Read pressure value in mbar | []\r\n | [0997\r\n | See “Altitude Pressure Compensation” |

Low Power CO₂ Sensor

CO₂ LEVEL MEASUREMENT VALUE - Z INFORMATION (0x5A)

| | |
|-------------|---|
| Description | Reports the latest filtered CO ₂ measurement |
| Syntax | ASCII Character 'Z', terminated by 0x0D 0x0A (CR & LF) |
| Example | Z\r\n |
| Response | Z 00521\r\n |

This value needs to be multiplied by the appropriate multiplier to get the ppm value.

CO₂ LEVEL MEASUREMENT VALUE - z INFORMATION (0x7A)

The sensor is also capable of reporting the real time unfiltered CO₂ measurement value.

| | |
|-------------|--|
| Description | Reports the unfiltered CO ₂ measurement |
| Syntax | ASCII Character 'z', terminated by 0x0D 0x0A (CR & LF) |
| Example | z\r\n |
| Response | z 00521\r\n |

CO₂ MEASUREMENT Z SCALING FACTOR – UART MODE

To calculate the measurement value in ppm, the 'Z' value must be converted into ppm by using the '.' multiplier factor. The multiplier will depend on the full-scale measurement range of the sensor.

| Measurement Range of Sensor | CO ₂ Measurement Scaling Factor (Z) | CO ₂ Measurement Output Units | Example |
|-----------------------------|--|--|------------------|
| 0 – 1% | 1 | ppm | Z 00521 = 521ppm |

'.' COMMAND (0x2E)

To calculate the measurement value in ppm, the 'Z' or 'z' value must be converted into ppm by using the '.' multiplier factor. This multiplier will depend on the full-scale measurement range of the sensor. The multiplier is related to the full-scale range of the sensor. The multiplier must also be used when sending CO₂ concentration levels to the sensor, for example when setting the fresh air CO₂ concentration value. The '.' Command can also be used to read back the scaling factor.

| | |
|-------------|---|
| Description | Returns a number indicating what multiplier must be applied to the Z CO ₂ measurement output to convert it into ppm. |
| Syntax | ASCII character '.', terminated by 0x0D 0x0A (CR & LF) |
| Example | .\r\n |
| Response | . 00001\r\n (this number is always 1 for CozIR®-LP3) |

Low Power CO₂ Sensor

DIGITAL FILTER COMMANDS

| Command | Use | Default | Range | Example | Response | Comments |
|-----------|---------------------------------|---------|---------|----------|-------------|----------|
| A ###\r\n | Set value of the digital filter | 16 | 0 - 255 | A 16\r\n | A 00016\r\n | |
| a\r\n | Return value of digital filter | | 0 - 255 | a\r\n | a 00016\r\n | |

A COMMAND (0x41)

| | |
|-------------|--|
| Description | Set the value of the digital filter |
| Syntax | ASCII character 'A', SPACE, decimal, terminated by 0x0D 0x0A (CR & LF) |
| Example | A 16\r\n |
| Response | A 00016\r\n (this number is variable) |

a COMMAND (0x61)

| | |
|-------------|--|
| Description | Read the value of the digital filter |
| Syntax | ASCII character 'A', SPACE, decimal, terminated by 0x0D 0x0A (CR & LF) |
| Example | A 16\r\n |
| Response | A 00016\r\n (this number is variable) |

Low Power CO₂ Sensor

ZERO SETTING COMMANDS – UART MODE

| Command | Use | Default | Range | Example | Response | Comments |
|----------------------------|---|----------------------------|-------|---|------------------------------|--------------------------|
| G\r\n | Zero-point setting using fresh air | | | G\r\n | G 33000\r\n | See “Zero Point Setting” |
| U\r\n | Zero-point setting using nitrogen | | | U\r\n | U 33000\r\n | See “Zero Point Setting” |
| X #####\r\n | Zero-point setting using a known gas concentration (in ppm) | | | X 1000\r\n | X 32997\r\n | See “Zero Point Setting” |
| P 8 ###\r\n P 9 #\r\n | Sets value of CO ₂ background concentration in ppm for auto-zeroing | P 8 1\r\n P 9 144\r\n | | Two-byte value P 8 = MSB P 9 = LSB 400ppm in the example | P 8 ###\r\n P 9 ###\r\n | |
| P 10 ###\r\n P 11 #\r\n | Sets value of CO ₂ background concentration in ppm used for zero-point setting in fresh air. | P 10 1\r\n P 11 144\r\n | | Two-byte value P 10 = MSB P 11 = LSB 400ppm in the example | P 10 ###\r\n P 11 ###\r\n | |

Low Power CO₂ Sensor

G COMMAND (0x47)

| | |
|-------------|---|
| Description | Sets the zero point assuming the sensor is in fresh air (typically 400ppm CO ₂ , but level can be set by user – see P commands.) |
| Syntax | ASCII character 'G' terminated by 0x0D 0x0A (CR & LF) |
| Example | G\r\n |
| Response | G 33000\r\n (the number is variable) |

U COMMAND (0x55)

| | |
|-------------|--|
| Description | Sets the zero point assuming the sensor is in 0ppm CO ₂ such as nitrogen. |
| Syntax | ASCII Character 'U' terminated by 0x0D 0x0A (CR & LF) |
| Example | U\r\n |
| Response | U 32767\r\n(the number is variable) |

X COMMAND (0x58)

| | |
|-------------|---|
| Description | Sets the zero point with the sensor in a known concentration of CO ₂ . Input value is scaled by CO ₂ value multiplier, see '.' command. |
| Syntax | ASCII character 'X', SPACE, then the gas concentration, terminated by 0x0D (CR & LF) |
| Example | X 1000\r\n |
| Response | X 33000\r\n (the number is variable). |

P COMMAND - CO₂ Level for Auto-Zeroing

| | |
|-------------|---|
| Description | Sets the value of CO ₂ in ppm used for auto-zeroing. Input value is scaled by CO ₂ value multiplier, see '.' command. |
| Syntax | ASCII character 'P', SPACE, then 8, SPACE, then MSB terminated by 0x0D 0x0A (CR & LF) ASCII character 'P' then a space, then 9, then a space, then LSB terminated by 0x0D 0x0A (CR & LF) |
| Example | P 8 0\r\n P 9 40\r\n |
| Response | p 8 0\r\n p 9 40\r\n |

The value is entered as a two-byte word, MSB first.

MSB = Integer (Concentration/256)

LSB = Concentration – (256*MSB)

In the above example, target CO₂ background concentration is 400ppm.

MSB = Integer (400/256) = 1

LSB = 400 – 256 = 144

Low Power CO₂ Sensor

P COMMAND – CO₂ Level for Zero-Point Setting

| | |
|-------------|--|
| Description | Sets value of CO ₂ in ppm for zero-point setting in fresh air. |
| Syntax | ASCII character 'P' then a space, then 10, then a space, then MSB terminated by 0x0D 0x0A (CR & LF) ASCII character 'P' then a space, then 11, then a space, then LSB terminated by 0x0D 0x0A (CR & LF) |
| Example | P 10 7\r\n P 11 208\r\n |
| Response | P 00010 00007\r\n P 00011 00208\r\n |

MSB = Integer (Concentration/256)

LSB = Concentration – (256*MSB)

In the above example, target zero-point CO₂ concentration is 2000ppm.

MSB = Integer (2000/256) = 7

LSB = 2000 – (256*MSB) = 208

Low Power CO₂ Sensor

SENSOR STATUS AND CONFIGURATION COMMANDS – UART MODE

i COMMAND

| | |
|-------------|--|
| Description | Reports the result of the sensor self-test. |
| Syntax | ASCII character 'i' terminated by 0x0D 0x0A (CR & LF) |
| Example | i\r\n |
| Response | i ###\r\n (the number is variable) 170 = Sensor error 85 = No sensor error |

J COMMAND (0x4A)

| | | | |
|-------------|---|--------------|--|
| Description | Turns PWM output on and off, and sets the PWM output configuration. | | |
| Syntax | ASCII character 'J', SPACE, decimal, terminated by 0x0D 0x0A (CR & LF) | | |
| Example | J 076\r\n | | |
| | BIT | LABEL | |
| | 2:0 | PRESCALAR | Sets clock pre-scaler, in powers 2. Range from 2 to 128 |
| | 3 | RESOLUTION | 0 = 8-bit 1 = 10-bit |
| | 4 | MODE | 0 = Pulsed 1 = Continuous |
| | 6:5 | OUTPUT | 00 = Continuous Output 01 = 2 pulses, then sleeps 10 = 4 pulses, then sleeps 11 = 8 pulses, then sleeps |
| | 7 | ON/OFF | Controls the state of the PWM output 0 = Off 1 = On |
| | To set PWM output to ON, continuous output (not pulsed), 10-bit resolution, no clock pre-scaler, set value to 1001100 = 076 | | |
| Response | J 076\r\n (the number is variable) | | |

j COMMAND (0x6A)

| | |
|-------------|---|
| Description | Reports the PWM configuration. |
| Syntax | ASCII character 'j' terminated by 0x0D 0x0A (CR & LF) |
| Example | j\r\n |
| Response | j ###\r\n (the number is variable) |

Low Power CO₂ Sensor

ALTITUDE PRESSURE COMPENSATION

| UART Command | Use | Default | Range | Example | Response | Comments |
|--------------|---------------------------------|---------|---------|------------|------------|--------------------------------------|
| [#####\r\n | Sets the pressure value (mbar) | 1013 | 0-65536 | [0990\r\n | [0990\r\n | See "Altitude Pressure Compensation" |
|]\r\n | Returns the pressure value mbar | | | [0990\r\n | [0990\r\n | See "Altitude Pressure Compensation" |

[COMMAND (0x5B)

| | |
|-------------|--|
| Description | Set the altitude pressure value in mbar |
| Syntax | ASCII character '[', SPACE, decimal, terminated by 0x0D 0x0A (CR & LF) |
| Example | [0990\r\n |
| Response | [0990\r\n (the number mirrors the input value) |

] COMMAND (0x5D)

| | |
|-------------|--|
| Description | Reads the altitude pressure value in mbar |
| Syntax | ASCII character ']', SPACE, decimal, terminated by 0x0D 0x0A (CR & LF) |
| Example |]\r\n |
| Response | [0990\r\n (the number mirrors the input value) |

Low Power CO₂ Sensor

AUTO-ZERO INTERVALS

| UART Command | Use | Default | Range | Example | Response | Comments |
|---------------|-----------------------------|---------|-------------|---------------|---------------|-----------------------------|
| @ #.# #.#\r\n | Auto-zero interval settings | 7.0 8.0 | 0.1 to 37.9 | @ 1.0 8.0\r\n | @ 1.0 8.0\r\n | See “Auto-Zero” for details |

@ COMMAND (0x2E)

| | |
|-------------|---|
| Description | Set the ‘Initial Interval’ and ‘Regular Interval’ for auto-zero events. |
| Syntax | ASCII character '@', SPACE, decimal, SPACE, decimal terminated by 0x0D 0x0A (CR & LF) |
| Example | @ 1.0 8.0\r\n |
| Response | @ 1.0 8.0\r\n (the number mirrors the input value) |

Both the initial interval and regular interval are given in days. Both must be entered with a decimal point and one figure after the decimal point. In the above example, the auto-zero interval is set to 8 days, and the initial interval set to 1 day.

To disable auto-zeroing, send @ 0\r\n.

To determine the auto-zero configuration, send @\r\n.

Low Power CO₂ Sensor

SERIAL NUMBER AND FIRMWARE VERSION – UART MODE

| UART Command | Use | Default | Range | Example | Response | Comments |
|--------------|--|---------|-------|---------|--------------------------|----------|
| Y\r\n | Return firmware version and sensor serial number | | | Y\r\n | Returns <u>two</u> lines | |

Y COMMAND (0x59)

| | |
|-------------|---|
| Description | The present version string for the firmware and serial number of the sensor |
| Syntax | ASCII character 'Y', terminated by 0x0d 0x0a (CR & LF) |
| Example | Y\r\n |
| Response | Y,Jan 30 2013,10:45:03,AL17\r\n B 00233 00000\r\n |

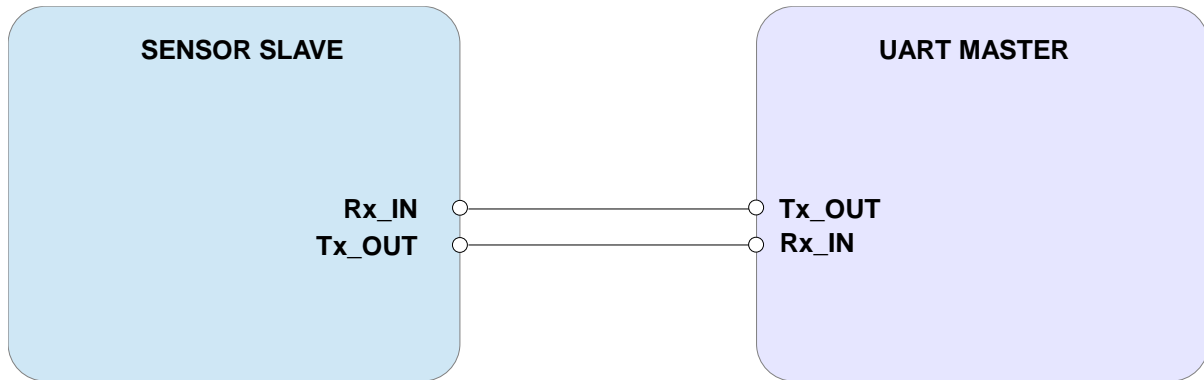
N.B. This command returns two lines split by a carriage return line feed and terminated by a carriage return line feed. This command requires that the sensor has been stopped (see 'K' command).

c COMMAND (0x63)

| | |
|-------------|--|
| Description | Reports the total number of hours sensor powered up |
| Syntax | ASCII character 'c', terminated by 0x0d 0x0a (CR & LF) |
| Example | c\r\n |
| Response | c #####\r\n where ##### is the number of hours ran |

Low Power CO₂ Sensor

CONNECTION DIAGRAM FOR UART INTERFACE



Low Power CO₂ Sensor

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Low Power CO₂ Sensor

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REVISION HISTORY

| DATE | RELEASE | DESCRIPTION OF CHANGES | PAGES |
|------------|---------|---|------------------|
| 13/04/2020 | 1.0 | First revision | All |
| 30/04/202 | 1.1 | Added PWM output, clarified accuracy statements | All |
| 19/05/2020 | 1.2 | Added provisional pin-out | P.6 |
| 04/06/2020 | 1.3 | Separated LP3 from Blink data sheet | All |
| 20/06/2020 | 1.4 | Updated mechanical diagram | P.5 |
| 14/07/2020 | 1.5 | Updated pin-out and register map | All |
| 27/07/2020 | 1.6 | Final register map | All |
| 17/08/2020 | 1.7 | Minor edits | All |
| 26/08/2020 | 2.0 | First revision of preliminary technical data | All |
| 09/09/2020 | 2.1 | Updated READY pulse timing | P.13 |
| 20/09/2020 | 2.2 | Minor edits | All |
| 29/10/2020 | 2.3 | Updated Control Interface Setup Timing | P.12, 13, 14 |
| 03/11/2020 | 3.0 | Removal of some errata | P.50 |
| 08/01/2021 | 3.1 | Power on data ready | P.12 |
| 11/03/2021 | 4.0 | Production release. Updated auto-zero explanation | |
| 10/05/2021 | 4.1 | Updated package drawing | P.5 |
| 14/05/2021 | 4.2 | Updated digital filter settings | P.15, P.26, P.42 |
| 23/06/2021 | 4.3 | @ COMMAND UPDATE | P.48 |
| 18/08/2021 | 4.4 | Updated Control Interface Setup Timing | P.12,13 |

Low Power CO₂ Sensor

ERRATA

| Erratum # | INFORMATION | DESCRIPTION |
|-----------|-------------|---|
| 1 | Bug | PWM_RS485 digital output |
| | Issue | Direction control functionality is not enabled. |
| | Work around | None |
| | Status | To be determined. |