LP8 CO_2 engine for battery-powered applications

User's Guide
Rev 1.16

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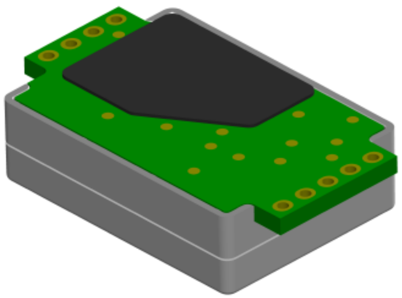
Sensors for Life

Standard Specifications



Charge per measurement:

Total	3.6 mC
IR source (lamp)	2.4 mC
Electronics	1.2 mC

Achieving RMS noise in CO2 measurements:

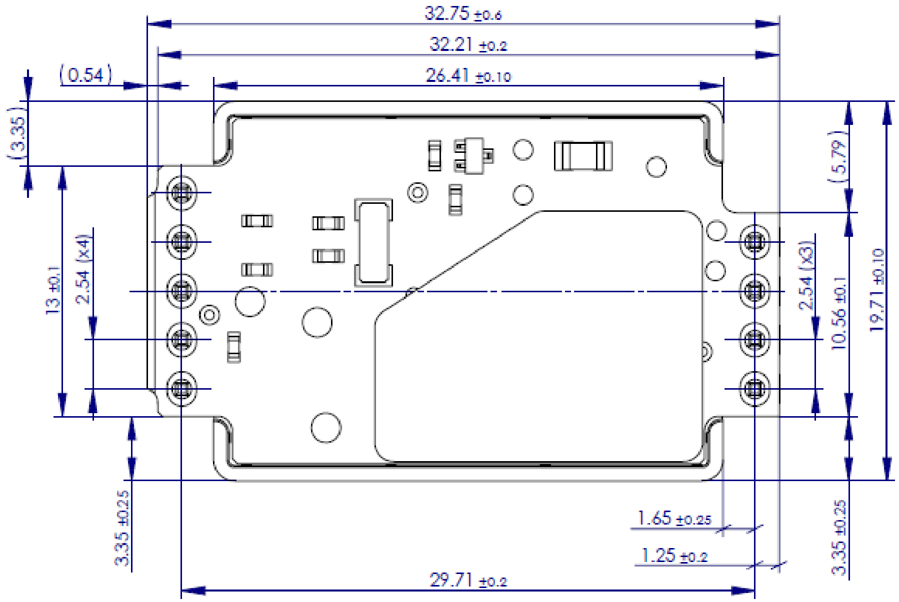
@400ppm	14 ppm
@1000ppm	25 ppm

STANDARD SPECIFICATIONS

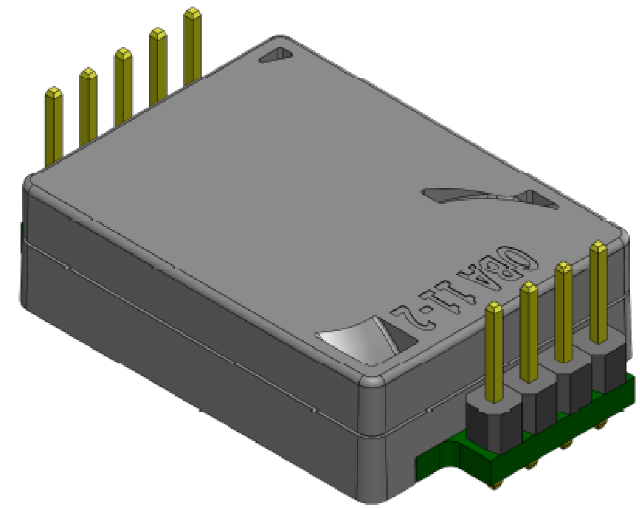
Measured gas	Carbon dioxide (CO_2)
Operating principle	Non-dispersive infrared (NDIR)
Measurement range	0 - 2000ppm
Accuracy CO_2	±50ppm ±3% of reading [1,4]
RMS noise CO_2	**14 ppm @ 400 ppm** **25 ppm @ 1000 ppm**
Accuracy Temperature	±0.7°C
Power supply	**2.9 – 5.5V**
Peak current	140 mA max. (125 mA typ. @ 25°C)
Shutdown current	1 µA [2,3]
Charge per measurement	**3.6 mC**
Energy per measurement	11.9 mJ @ 3.3V
Average current having	
16 s meas. period	225 µA [2,3]
60 s meas. period	61 µA [2,3]
120 s meas. period	31 µA [2,3]
Measurement period	≥16 s
Dimensions	**8 mm x 33mm x 20mm**
Life expectancy	>15 years
Operation range	0 - 50°C, 0 - 95% RH (non-condensing)
Communication	UART (host-slave protocol)

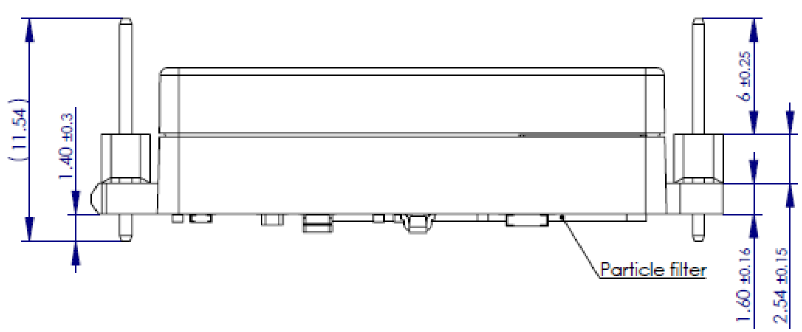
Note 1: 10 – 40°C, 20 – 60 % RH, after at least three 8 days periods, each followed by ABC command set in the Calculation Control byte
Note 2: Resistor network for measuring VCAP voltage adds 14 µA @5.5V
Note 3: External super-capacitor leakage is not considered
Note 4: Spec is ref. to uncertainty of calibration gas mixtures ±1%

Dimensions

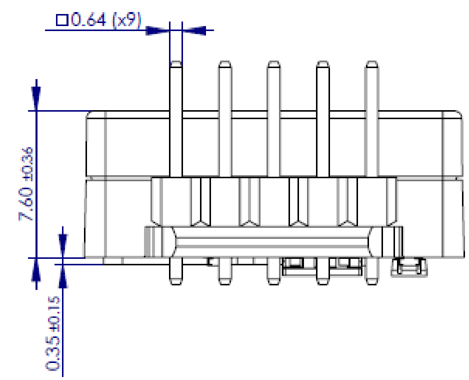


32.75 ±0.6
32.21 ±0.2
26.41 ±0.10
(0.54)
(3.35)
13 ±0.1
2.54 (x4)
(5.79)
2.54 (x3)
10.56 ±0.1
19.71 ±0.10
3.35 ±0.25
1.65 ±0.25
1.25 ±0.2
29.71 ±0.2
3.35 ±0.25





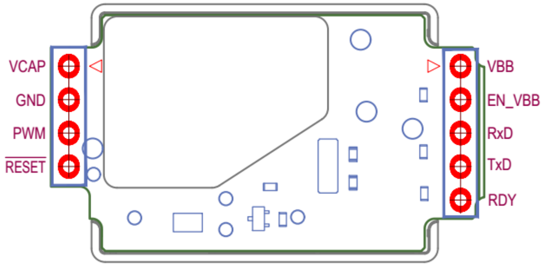
(11.54)
1.40 ±0.3
6 ±0.25
Particle filter
1.60 ±0.16
2.54 ±0.15



□0.64 (x9)
7.60 ±0.36
0.35 ±0.15

Signal description and specifications

Bottom Layer



Pin #	Name	Type	Description	Abs. max. voltage, V	Other relevant specifications
JP1 (4-pin header)					
1	VCAP	Power	Lamp driver supply voltage. Sensor monitors this voltage using a 500k resistor network connected to the MCU ADC.	6.5	
2	GND	Power	Ground	-	
3	PWM	Output	I/O pin. Reserved for PWM functionality in other models.	3.6 [1,2]	$I_{PULL-UP}$ = 10 to 80 µA
4	RESET#	Input	Reset. Shall be left floating in LP8 because sensor is powered-up every measurement cycle – brownout MCU reset works.	2.5	$R_{PULL-UP}$ = 10 kΩ Pull-up resistor is connected to 2.5V
JP2 (5-pin header)					
1	VBB	Power	Supply voltage of the MCU voltage regulator.	5.5	
2	EN_VBB	Input	Enable pin of the voltage regulator. When in the logic low state VBB draws maximum 2µA of current.	VBB	V_{IL} max. = 0.4V (disable regulator) V_{IH} min. = 0.9V (enable regulator)
3	RxD	Input	UART receive of sensor MCU	3.6	V_{IL} max. = 0.4V V_{IH} min. = 2.0V
4	TxD	Output	UART transmit of sensor MCU	3.6 [1,2]	$I_{PULL-UP}$ = 10 to 80 µA Otherwise CMOS push-pull 2.5V output
5	RDY	Output	Signal is used to synchronize sensor with a host system.		

Note 1: Values are referred to the periods when the outputs are set as weak pull-ups.
Note 2: Signals are configured as outputs and not allowed to be driven by another push-pull output.

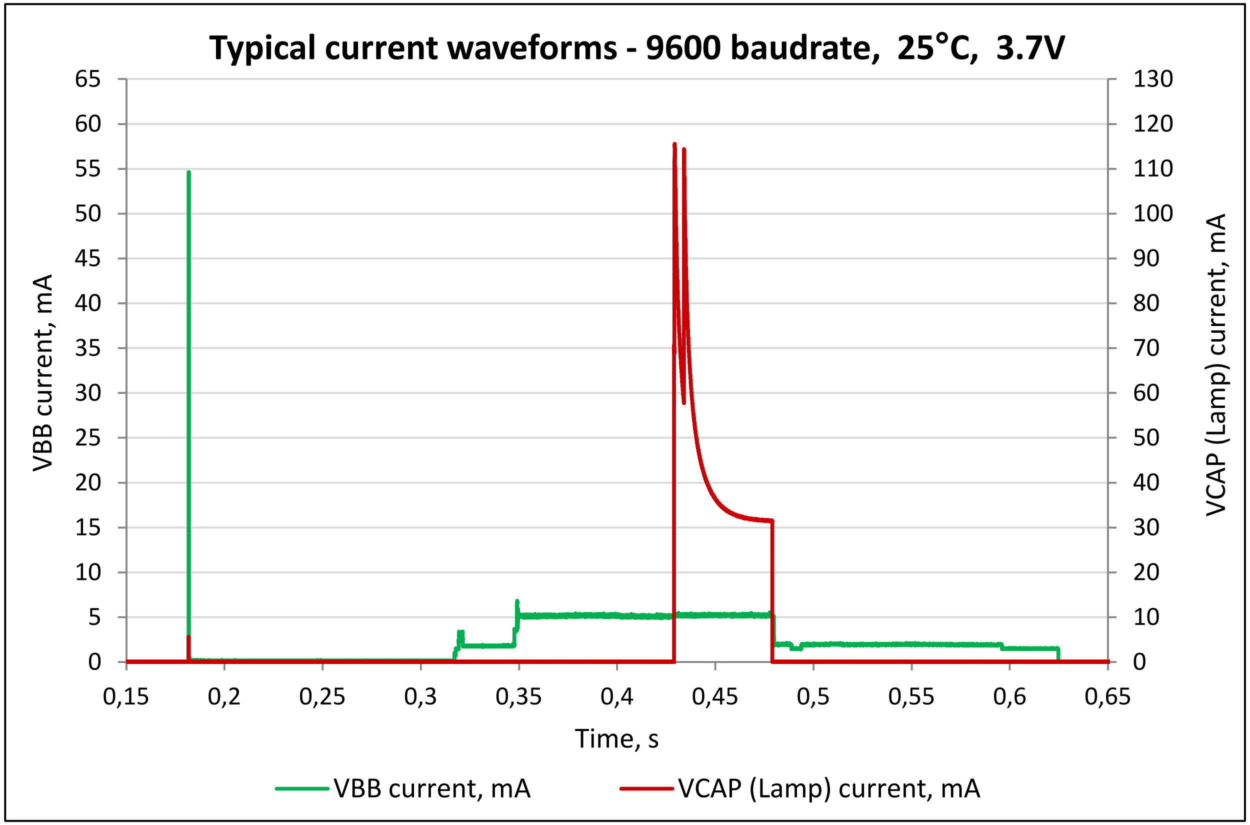
Power specifications

Parameter	Min	Typ	Max	Unit	Test conditions
Power supply voltage:					
VBB (sensor electronics)	2.9		5.5	V	
VCAP (lamp)	2.9		6.5	V	
Peak current					VBB = VCAP = 2.9 - 5.5V
VBB (sensor electronics) [1]		5.4	6	mA	T_{amb} = 0 - 50°C
VCAP (lamp) [2]		119	129	mA	T_{amb} = 25 °C
VCAP (lamp) [2]			134	mA	T_{amb} = 0°C (peak current decreases with increasing temperature)
Total (VBB + VCAP) [1,2]		125	140	mA	T_{amb} = 0 - 50°C
Shutdown current					
VBB (sensor electronics) [3]		1	2	µA	T_{amb} = 25°C
VCAP (lamp) with 400kΩ resistor network		14	15	µA	T_{amb} = 25°C, VCAP = 5.5V
VCAP (lamp) w/o voltage monitoring		0.1	0.2	µA	T_{amb} = 25°C, VCAP = 5.5V
Charge per measurement cycle					T_{amb} = 0 - 50°C, VBB = VCAP = 2.9 - 5.5V
VBB (sensor electronics)		1.1	1.2	mC	9600 baudrate
		1.0	1.1	mC	19200 baudrate
VCAP (lamp)		2.2	2.4	mC	

Note 1: Charging of 20 µF decoupling capacitance is not considered
Note 2: Charging of 220 nF decoupling capacitance is not considered
Note 3: Without pull-down resistor 100k on VBB_EN (mounted on request)

Typical current profile

"Subsequent" measurement cycle of LP8 sensor requires less than 460 ms using 9600 UART communication baudrate.
If inrush current required for charging decoupling capacitors is excluded then typical values of peak current @25°C are:
VBB (electronics) – 5.4 mA; VCAP (lamp) – 119 mA; total – 125 mA.

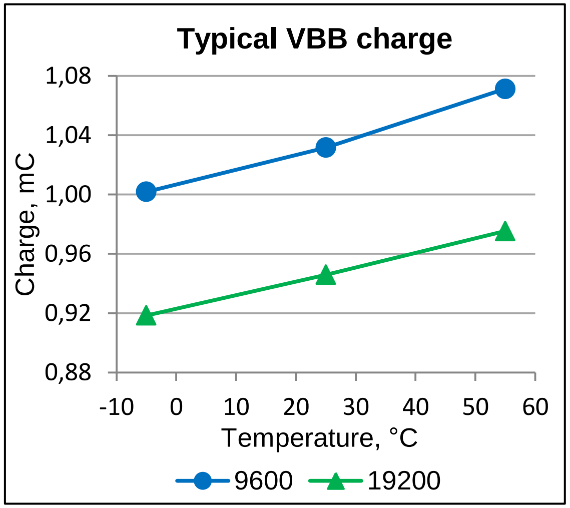


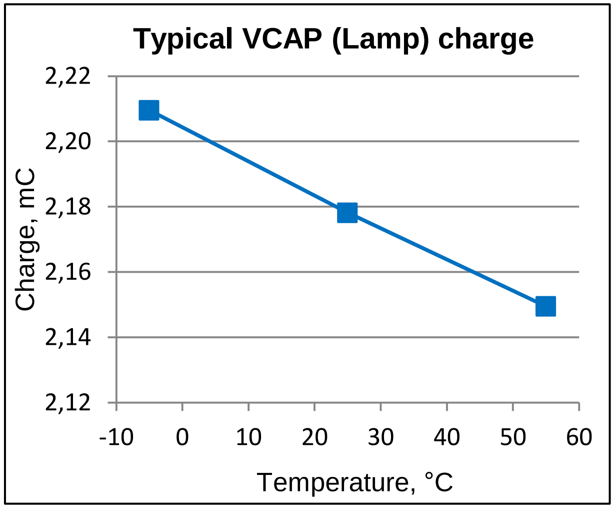
Measured charge for the waveforms

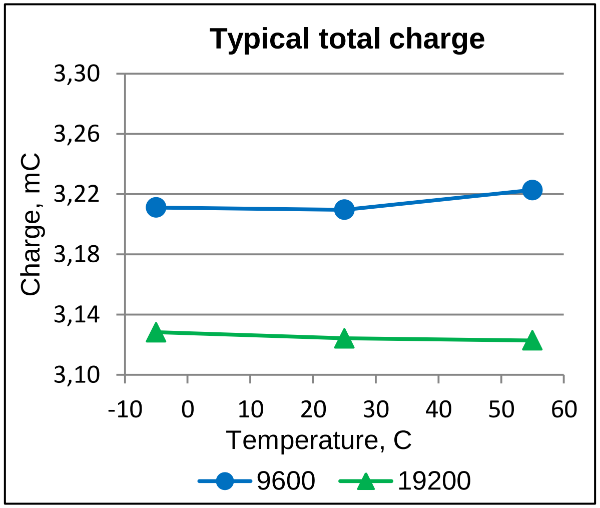
Power pin	Charge, mC
VBB (Electronics)	1,03
VCAP (IR source)	2,19
Total	3,23

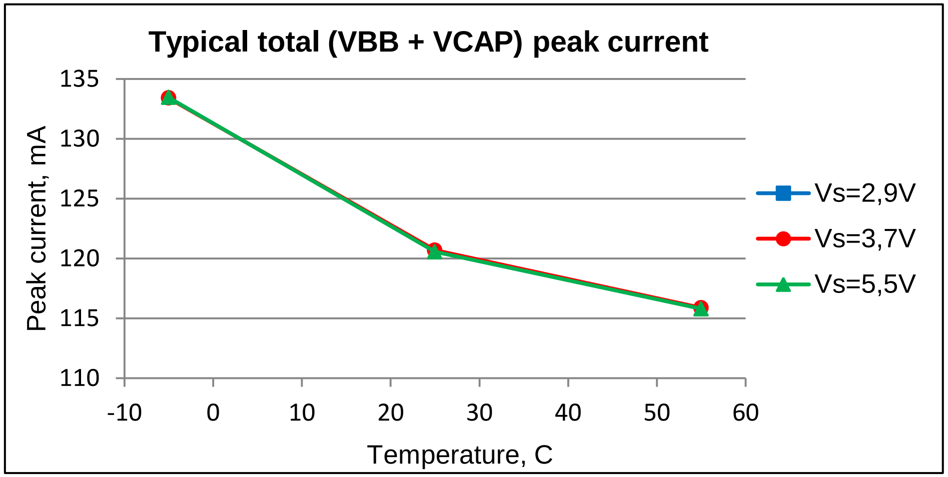
Typical consumption

The parameters below are tested in the whole supply voltage range of 2.9-5.5V. There is no significant dependence of the charge and peak current parameters on the supply voltage.

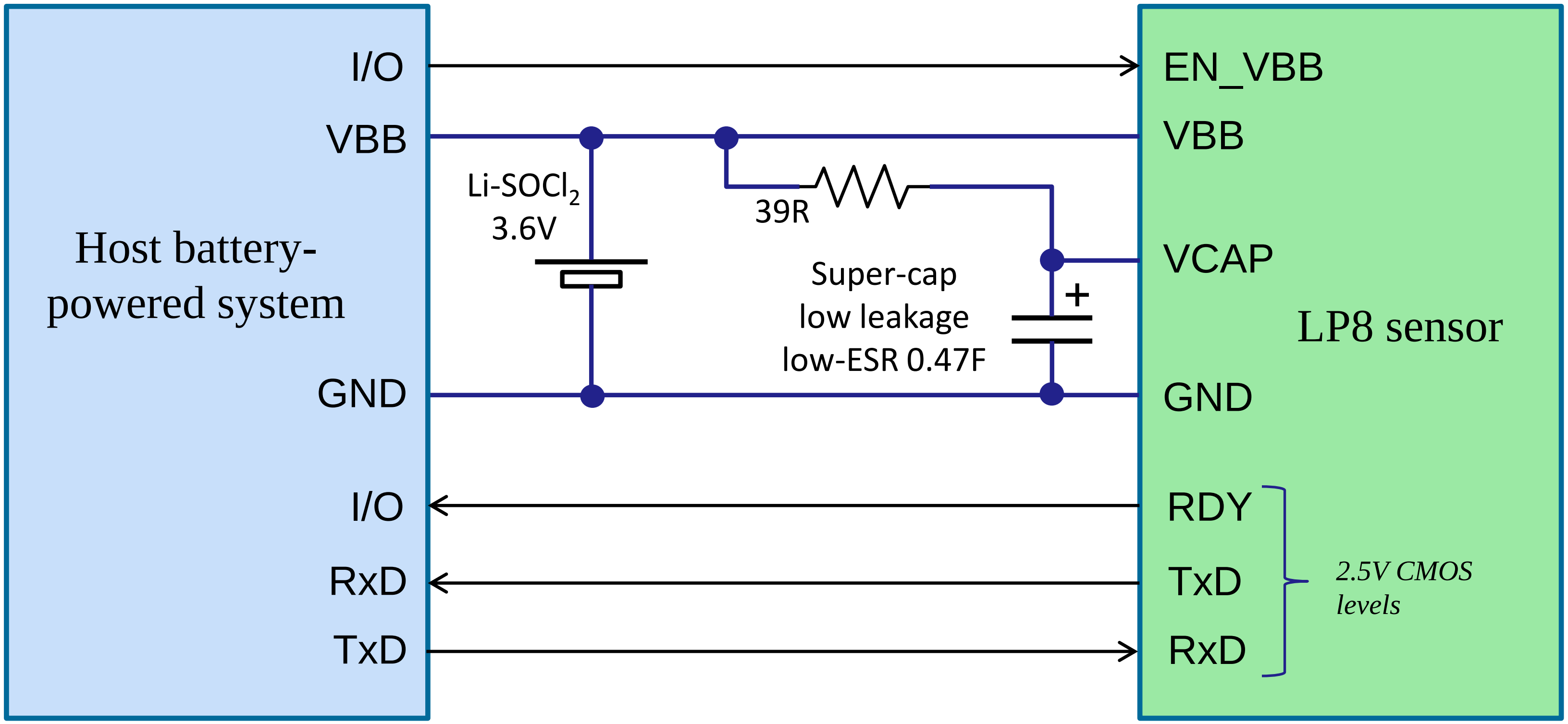








Simple host connection



- In some battery-powered systems current limiter can be simply a 5Ω resistor.
- Suggested super-cap type is Eaton Bussman PM-5R0H474-R (0.47F 5V). It is specified for 8µA leakage current @5V, 20°C and 500mΩ ESR.
- Customer can use its own low-leakage switch (for example TPS22907) to switch off both VCAP and VBB between measurements. VBB can be supplied from super-cap.

Calculating average current consumption

$$I_{avg} = \frac{Q_{MCU} + Q_{lamp}}{T_{MEAS}} + I_{SHDN} + I_{C\_leak}$$

where:

I_{avg} – average current consumption
T_{MEAS} – measurement period set by customer
Q_{MCU} – MCU-part (VBB) charge per measurement
Q_{lamp} – lamp (VCAP) charge per measurement
I_{SHDN} – sum of shutdown currents of electronics and lamp driver (if customer uses its own switch the parameter is obtained from the switch specs)
I_{C_leak} – leakage current of super-capacitor

An example:

Measurement period is 30 seconds, sensor is configured with VCAP voltage monitor, super capacitor leakage current is 8 µA.

$$I_{avg} = \frac{1000\ [\mu A \cdot s] + 2200 [\mu A \cdot s]}{30\ [s]} + 15\ [\mu A] + 8\ [\mu A] = 130\ [\mu A]$$

Average current consumption can be reduced by:

- Increasing measurement period.
- Using an external low-leakage switch (for example TPS22907) for both VBB and VCAP.
- Using super capacitor with lower leakage current.

Low consumption hints

- ✓ VCAP pin has a 400kΩ resistor-divider network connected to MCU ADC used for measuring voltage supplied to the lamp driver. Monitoring that this voltage does not drop below allowed threshold during lamp pulse insures sensor measurement accuracy. Use a switch for VCAP voltage to eliminated excess current consumed by the network between measurements.

- ✓ A current source instead of resistor reduces time needed for charging the super-capacitor.

- ✓ Super-capacitor can be charged only for a small fraction of time prior measurement. To keep a voltage equilibrium on the super-capacitor one need to supply the same charge as consumed by single measurement, 3.6 mC. For example:

  Power supply voltage is 3.3V

  Desired voltage equilibrium on the super-capacitor is 3.1V

  Under these circumstances a 100Ω resistor will provide (3.3V-3.1V)/100Ω = 2mA current, enough to charge the capacitor during 3.6mC / 2mA = 1.8 seconds.

- ✓ Host MCU shall hold IO pins connected to TxD, RxD and RDY signals in Hi-Z or Low state when LP8 power is off. Leakage current on these pins of LP8 module in the power-off state is not specified.

- ✓ Using external switches on both VBB and VCAP with sub-microampere leakage current can help to reduce average current consumption further.

- ✓ SN74AUP2G34 dual buffer is recommended for interfacing 2.5V CMOS TxD and RDY outputs of the sensor to a 3..3V or 3V powered host MCU with CMOS input levels $V_{IH} = 0{,}7 \times V_{CC}$, $V_{IL} = 0.3 \times V_{CC}$. A switched pull-down can be arranged for the buffer to avoid leakage current when the sensor power is off.

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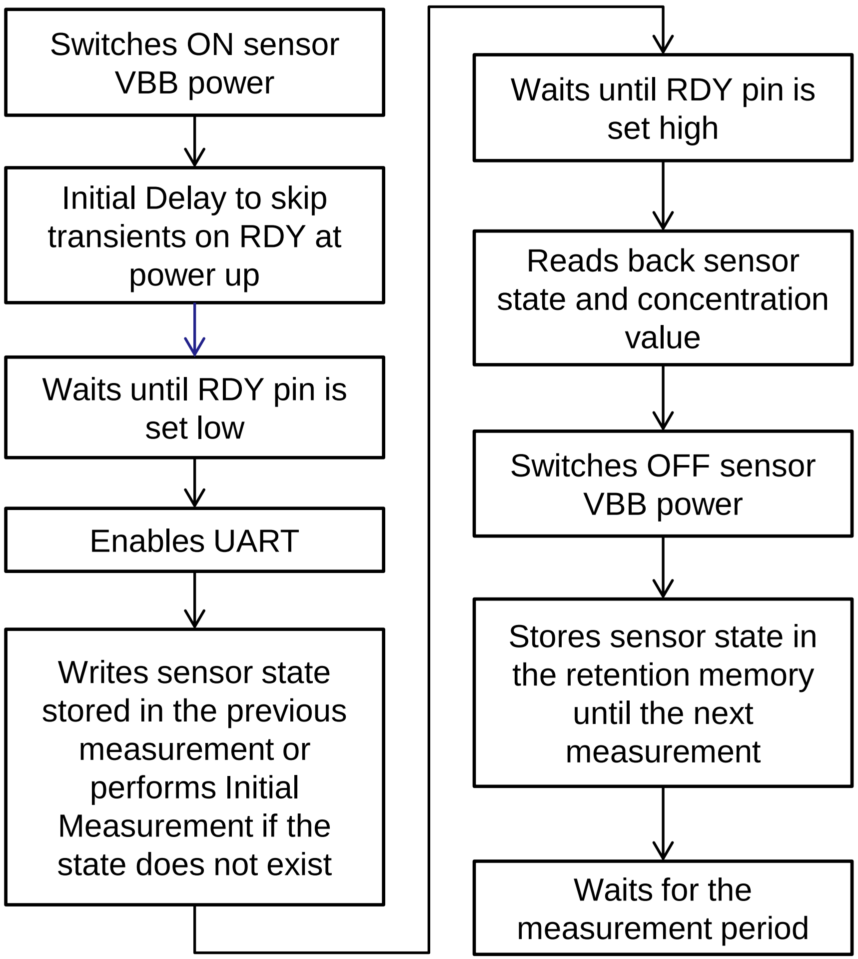
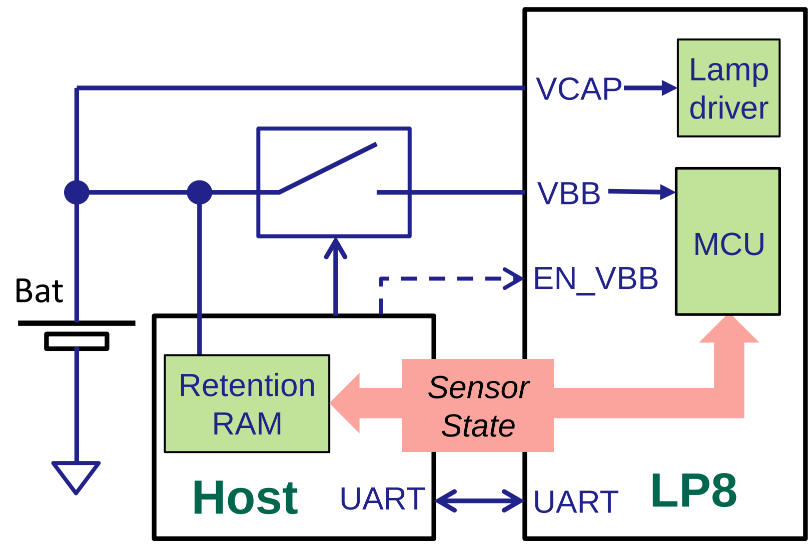
Sensor control by a host MCU system

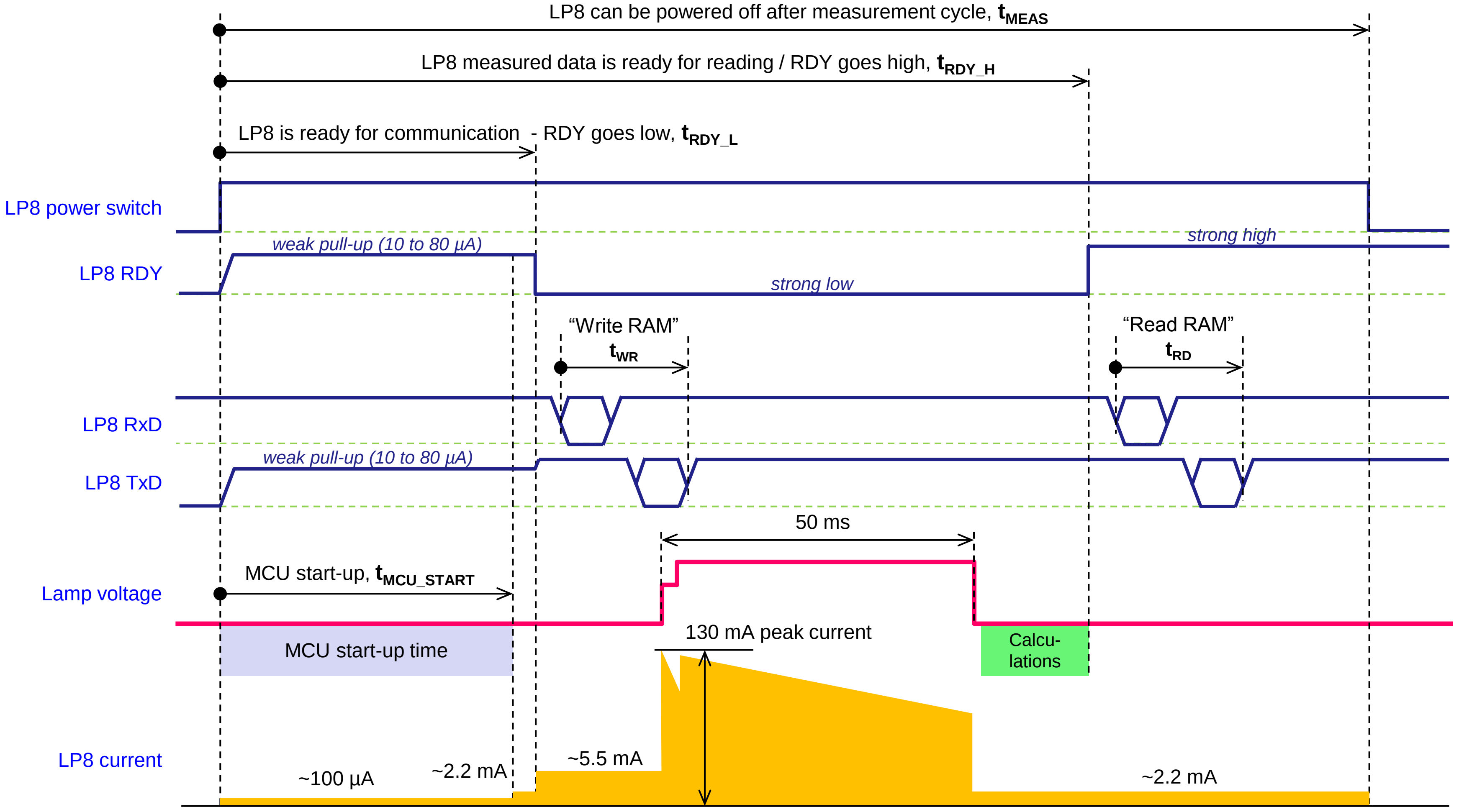
Host loop sequence



Measurement period of the sensor is determined by customer host system and may vary without degrading measurement accuracy.
Minimum allowed measurement period is 16 seconds (below 16 seconds accuracy is not guaranteed).



Time diagram



Timing parameters

Parameter	FW Rev 1.07 and lower			FW Rev 1.08 and higher			Calculation Control command	Test conditions
	Min	Typ	Max	Min	Typ	Max		
t_{MCU_START} , ms		134 [1]			134 [1]		-	T_{amb} = 25°C; VBB = VCAP = 3.7V
t_{RDY_L} , ms	180	185	205	145	150	175	Initial, Subsequent	t_{MCU_START} = 125 - 140 ms; T_{amb} = 25°C; VBB = VCAP = 3.7V
	180	185	205	145	150	175	Zero, Background calibrations, ABC	
t_{RDY_H} , ms	310	325	355	285	290	320	Initial, Subsequent	
	395	410	430	350	365	385	Zero, Background calibrations, ABC	
t_{MEAS} , ms	430	460	500	400	430	470	Initial, Subsequent	t_{MCU_START} = 125 - 140 ms; T_{amb} = 25°C; VBB = VCAP = 3.7V; SenseAir LabVIEW host emulation on PC, 9600 baud
	530	540	580	490	500	540	Zero, Background calibrations, ABC	
t_{WR} , ms	52	57	62	52	57	62	-	Host writes 26 bytes; SenseAir LabVIEW host emulation on PC, 9600 baud
t_{RD} , ms	72	77	83	72	77	83		Host reads 44 bytes; SenseAir LabVIEW host emulation on PC, 9600 baud

Note 1: Typical value is specified by the MCU producer

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Polling RDY pin or not

Standard RDY polling

Weak pull-up (10µA min.) on RDY pin before it goes low shall be considered in satisfying host V_{IH}

1. Turn on VBB
2. Initial Delay 4 ms [1]
3. Wait until RDY = low
   timeout = 210 ms
4. UART "Write RAM"
5. Wait until RDY = high
   timeout = 250 ms
6. UART "Read RAM"
7. Turn off VBB

Note 1: Initial delay is needed for turning on VBB regulator, external switches and then establishing pull-up on RDY. If a slow external switch is used then this delay will be necessary to increase.

Polling only transition to high level on RDY

Weak pull-up state on RDY is desired to be omitted in polling

1. Turn on VBB
2. Delay 210 ms
3. UART "Write RAM"
4. Wait until RDY = high
   timeout = 250 ms
5. UART "Read RAM"
6. Turn off VBB

No RDY polling, delays

RDY pin is not used by the host

1. Turn on VBB
2. Delay 210 ms
3. UART "Write RAM"
4. Delay 250 ms
5. UART "Read RAM"
6. Turn off VBB

FW Rev.	Typical measurement cycle time T_{MEAS} (between power ON an OFF) for the Subsequent Measurement, ms		
	Standard RDY polling	Polling only transition to high on RDY	No RDY polling
<=1.07	460	460	700
>=1.08	430	430	700

UART communication

MODBUS UART settings for SenseAir sensors:

- Device address – 0x68 or 0xFE
- Baudrate – 9600
- Parity – No
- Stop bits – 2

<table>
<tr><th colspan="4">MODBUS ADU (Application Data Unit)</th></tr>
<tr><td rowspan="2">Address field (1 byte)</td><td>Function Code</td><td>Data</td><td rowspan="2">CRC (Low byte first then High byte)</td></tr>
<tr><td colspan="2">MODBUS PDU</td></tr>
</table>

Function Code 65 (0x41) Write to RAM MCU

Request PDU

Function code	1 byte	0x41
Starting Address Hi	1 byte	Address Hi
Starting Address Lo	1 byte	Address Lo
Number of bytes to write	1 byte	N
Data to write	N bytes	

Response PDU

Function code	1 byte	0x41

Error Response PDU

Function code	1 byte	0xC1
Error code	1 byte	Error code

Function Code 68 (0x44) Read from RAM MCU

Request PDU

Function code	1 byte	0x44
Starting Address Hi	1 byte	Address Hi
Starting Address Lo	1 byte	Address Lo
Number of bytes to read	1 byte	N

Response PDU

Function code	1 byte	0x44
Number of bytes to read	1 byte	N
Data	N bytes	

Error Response PDU

Function code	1 byte	0xC4
Error code	1 byte	Error code

Sensors for Life

Read / write sensor state and measurement result

Sensor RAM address space dedicated to the communication with host

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0x8x	Calculation control	Sensor State has to be written before measurement and read back by host after the measurement. To be stored in the host retention memory when sensor power if off between measurements.														
0x9x	Sensor State								Host_Pressure (S16, 0.1 hPa)		Conc (S16) *unfiltered		ConcPC (S16) *unfiltered		Space_Temp (S16, 0.01°C)	
0xAx	VCAP1 (S16, mV)		VCAP2 (S16, mV)		Error Status3	Error Status2	Error Status1	Error Status0	Conc_filtered (S16)		ConcPC_filtered (S16)		*Reserved*			

Communication sequence

Write prior measurement		
Write 26 bytes to the RAM area **0x80-0x99**		
Calculation control	Sensor State	Host_Pressure (S16, 0.1 hPa)

Read back after measurement			
Read 44 bytes from the RAM area **0x80-0xAB**			
	Sensor State		Measured Date and Error Status

If host system is not equipped with a pressure sensor and sensor pressure compensation by external pressure value is not used then it is recommended to omit writing to Host_Pressure, write only to the address range 0x80-0x97.

Parameters

Parameter	Length, bytes	RAM Starting Address	Format	Units	Description
Calculation Control	1	0x80	Bit structure	N/A	Command which determines calculation flow in the sensor
Sensor State	23	0x81	Structure	N/A	23 bytes proprietary data structure which comprises filter memory and ABC sampling data. It has to be saved in the host retention memory of the host and passed to the next measurement.
Host_Pressure	2	0x98	S16	10 Pa = 0.1 hPa	Pressure measured by host. If pressure is not measured, then host has to write the default value of 10124 (1012.4 hPa) which assumes no pressure correction applied or omit writing the parameter.
Conc	2	0x9A	S16	ppm	Non pressure-corrected unfiltered concentration value
ConcPC	2	0x9C	S16	ppm	Pressure-corrected unfiltered concentration value
Conc_filtered	2	0xA8	S16	ppm	Non pressure-corrected filtered concentration value
ConcPC_filtered	2	0xAA	S16	ppm	Pressure-corrected filtered concentration value
Space_Temp	2	0x9E	S16	0.01 °C	Temperature measured by sensor NTC
VCAP1	2	0xA0	U16	mV	VCAP voltage measured by sensor prior lamp pulse
VCAP2	2	0xA2	U16	mV	VCAP voltage measured by sensor at the end of lamp pulse
Error Status	4	0xA4	Bit Structure	N/A	Error bit structure

S16 – signed integer 16 bits
U16 – unsigned integer 16 bits

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Calculation Control byte

Calculation Control, 0x80	Description of Calculation Control command	Sensor State, 0x81-0x97
0x10	Initial measurement (filters reset, ABC sample reset and other initial actions) – Sensor State is initialized by the sensor itself	Any values or skip writing Sensor State
0x20	Subsequent measurement	Values read from the address range 0x81-0x97 in the previous measurement and saved in the retention memory of the host
0x40	Zero calibration using unfiltered data	
0x41	Zero calibration using filtered data	
0x42	Zero calibration using unfiltered data + reset filters	
0x43	Zero calibration using filtered data + reset filters	
0x50	Background calibration using unfiltered data	
0x51	Background calibration using filtered data	
0x52	Background calibration using unfiltered data + reset filters	
0x53	Background calibration using filtered data + reset filters	
0x70	ABC (based on filtered data)	
0x72	ABC (based on filtered data) + reset filters	

A host system counts ABC period itself (suggested period is 7,5 – 8 days) and has to write ABC command to the “Calculation Control byte” when ABC period expires.

Sensor recalibration

The LP8 sensor works as a slave and totally relies on host commands applied through the “Calculation Control” byte. The differences between three types of calibration used in LP8 are:

1) ABC (**A**utomatic **B**aseline **C**orrection) – sensor uses for recalibration the lowest concentration value treated as 400 ppm (together with remembered accompanying parameters) found during the period starting from the last “Initial state” / “ABC” / “Background / Zero calibration” commands written into the “Calculation Control” byte.
2) Background calibration – environment is treated as 400 ppm (for instance fresh air environment)
   a) Using unfiltered channel – sensor considers current unfiltered measurement values to provide recalibration
   b) Using filtered channel – sensor consider filtered values to provide recalibration (sensor has to be exposed for fresh air >40 blinks)
3) Zero calibration - environment is treated as 0 ppm (for instance Nitrogen environment)
   a) Using unfiltered channel – sensor considers current unfiltered measurement values to provide recalibration
   b) Using filtered channel – sensor consider filtered values to provide recalibration (sensor has to be exposed for zero gas >40 blinks)

Background Calibration is intended to be performed either in ”fresh air” background environment or by using a calibration gas mixture of 400 ppm CO_2 and nitrogen in an encapsulated enclosure. A ”fresh air” environment can be achieved in a crude way by placing the sesnor in direct proximity to outdoor air, free of combustion sources and human presence, preferably during either by open window or fresh air inlets or similar.

Zero Calibration is typically performed by placing the sensor in an encapsulated enclosure, e.g. plastic bag, and flashing a nitrogen calibration gas into it. It is the most accurate recalibration routine, which is not affected performance-wise by having an available pressure sensor on host for accurate pressure-compensated references.

Filtered and unfiltered concentrations

Concentration parameters

Unfiltered - Conc, ConcPC	Noise in readings, immediate response limited only by gas diffusion into the optical cell
Filtered - Conc_filtered, ConcPC_filtered	Only small noise in readings, slow response

Important: Filtering is performed on raw signals, so that filtered and unfiltered concentrations are calculated from the raw signals in parallel as independent channels.

Zero-/Background calibration *

Using unfiltered data	Poor accuracy of recalibration, calibration environment shall persist only during single measurement
Using filtered data	Good accuracy of recalibration, calibration environment shall persist during > 40 measurements to insure filter settling

* - ABC commands use only filtered signals because it is assumed that sensor is exposed to fresh air for a enough long time having 7,5 - 8 days ABC period

Sensor program algorithm flow of measurement cycle:

Measuring raw signals → Filtering / [Reset filters if Initial Measurement or some error types occur] → [Recalibration] → [Reset filters for the commands with codes 42,43,52,53,73] → Calculating Concentrations

Reset filters ≡ update raw-signals filter memory with measured values from the actual cycle

Filtered and unfiltered concentrations

Calculation Control, 0x80	Description of Calculation Control flow command	Values read in the meas. cycle	
		ConcPC	**ConcPC_filtered**
0x10	Initial measurement	Measured value	Measured value
0x20	Subsequent measurement	Measured value	Measured value + Δnoise
0x40	Zero calibration using unfiltered data	0 ppm	0 ppm + Δnoise
0x41	Zero calibration using filtered data	0 ppm + Δnoise	0 ppm
0x42	Zero calibration using unfiltered data + reset filters	0 ppm	
0x43	Zero calibration using filtered data + reset filters	0 ppm + Δnoise	
0x50	Background calibration using unfiltered data	400 ppm	400 ppm + Δnoise
0x51	Background calibration using filtered data	400 ppm + Δnoise	400 ppm
0x52	Background calibration using unfiltered data + reset filters	400 ppm	
0x53	Background calibration using filtered data + reset filters	0 ppm + Δnoise	

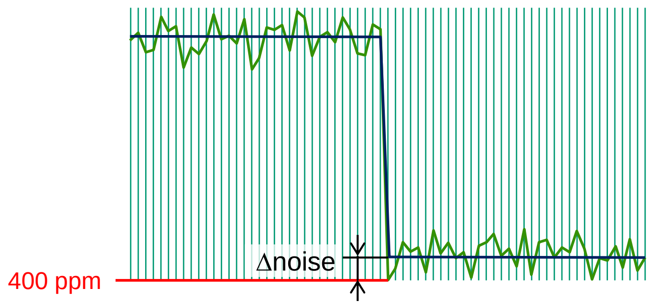
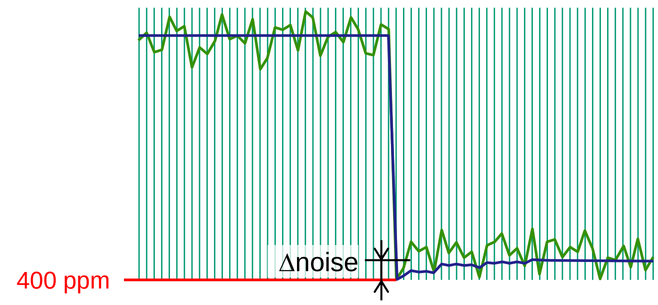
Δnoise – signed difference between unfiltered concentration and filtered one. Refer the noise specifications on the page 2 of the document where RMS value is given (standard deviation).

The above table is valid only if no error occurs and calibrations are performed under valid conditions, i.e. Nitrogen is purged if zero calibration is performed, concentration is close to 400 ppm if background calibration is performed.

Filtered and unfiltered concentrations

Filtered and unfiltered concentrations on example of Background Calibration command

In the example below sensor shows higher concentration level then it is expected in 400 ppm environment and its accuracy is corrected by applying Background Calibration command to the Calculation Control. Green – ConcPC, blue – ConcPC_filtered.

<table>
<tr><th>Background calibration</th><th>no reset filters</th><th>“+ reset filters”</th></tr>
<tr><td>Using unfiltered data</td><td>
</td><td>
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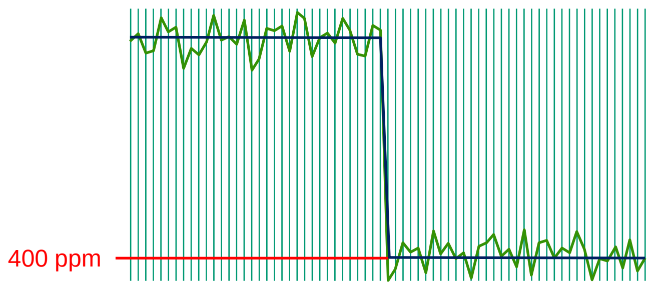
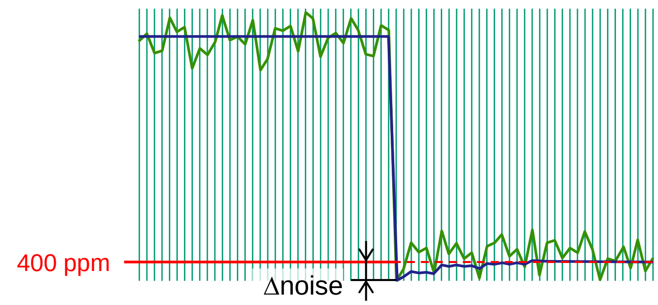
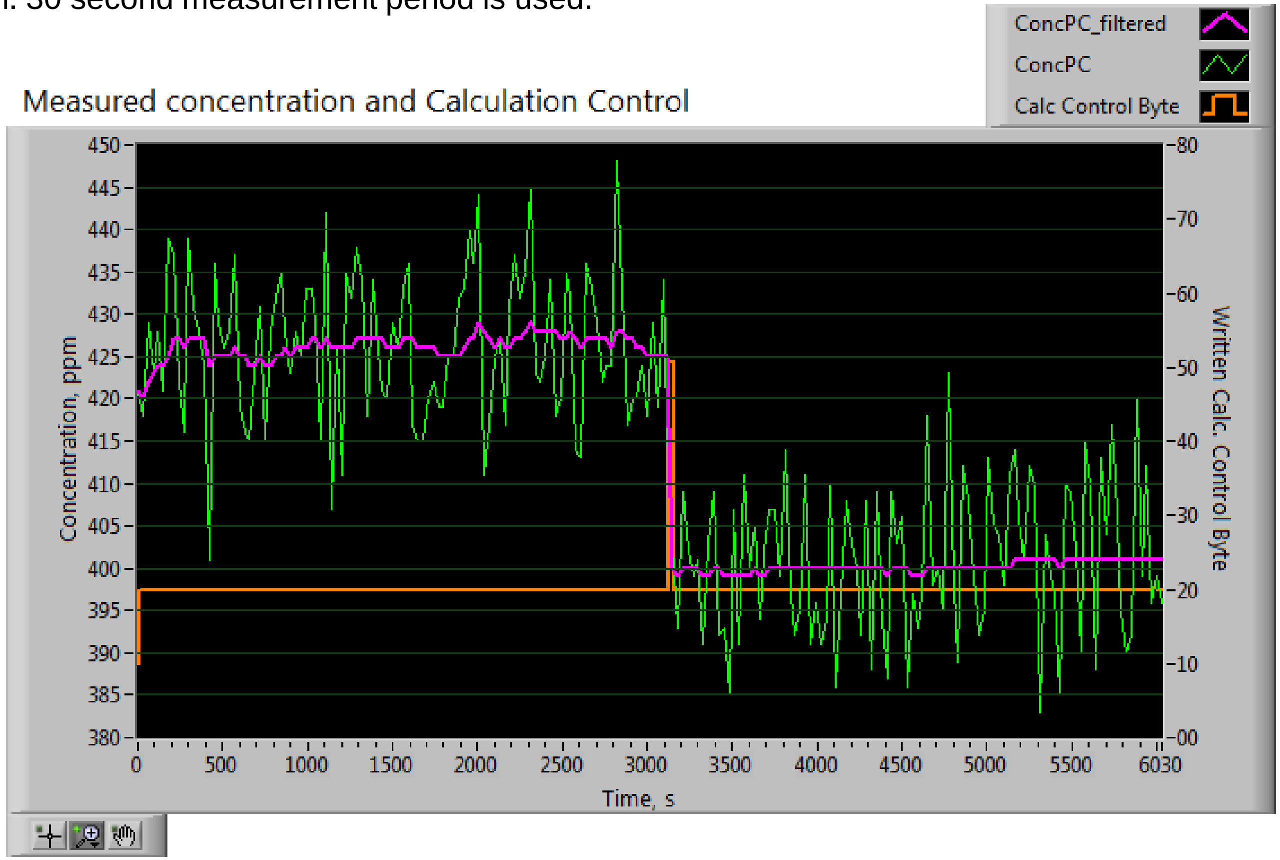
<tr><td>Using filtered data</td><td>
</td><td>
</td></tr>
</table>

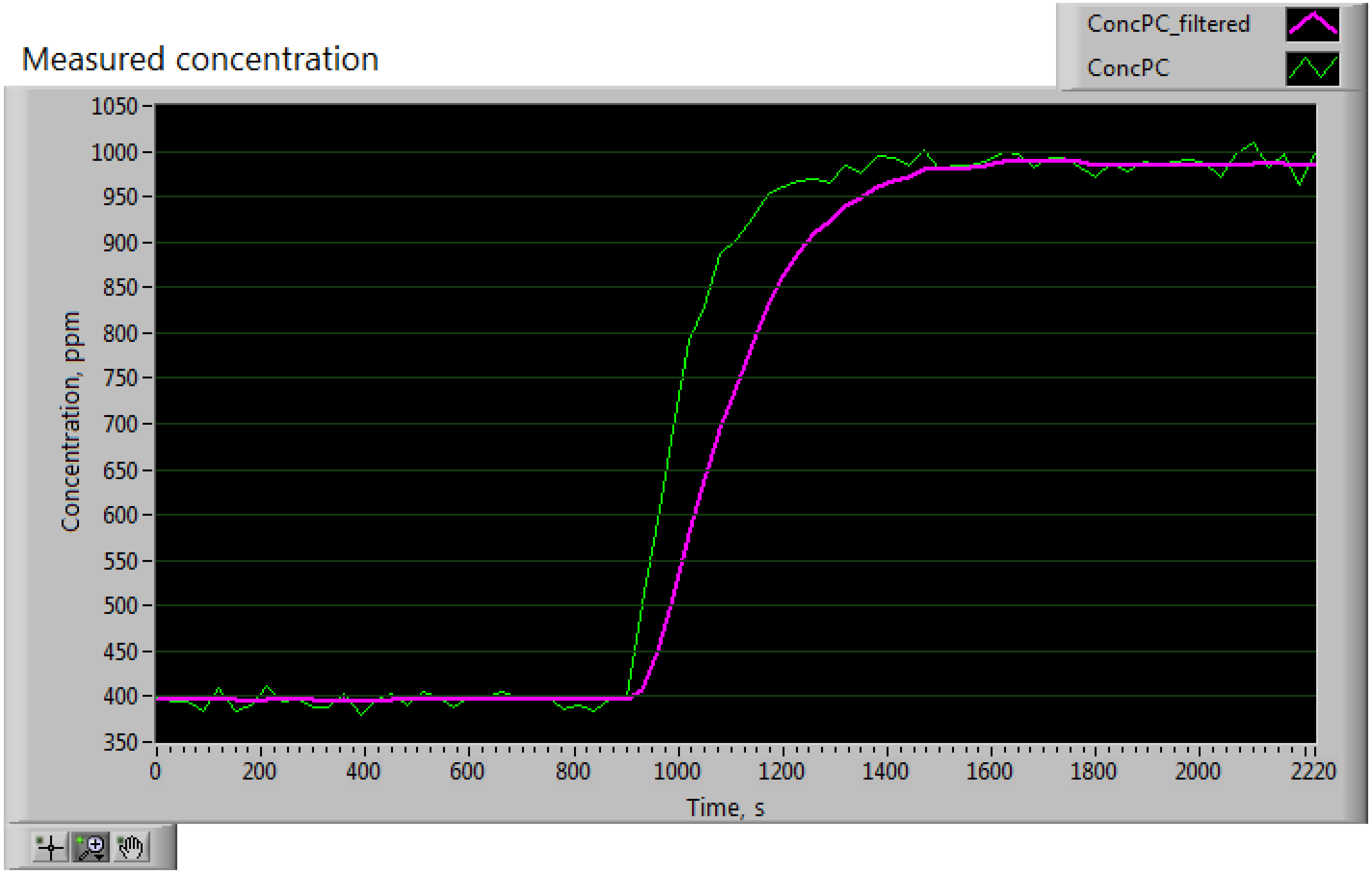
Filtered and unfiltered concentrations

A real example of filtered and unfiltered concentration behavior when implementing Background Calibration command (0x51) in the Calculation Control.
400 ppm environment is created and the sensor shows 25 ppm higher which is corrected by the Background Calibration. 30 second measurement period is used.



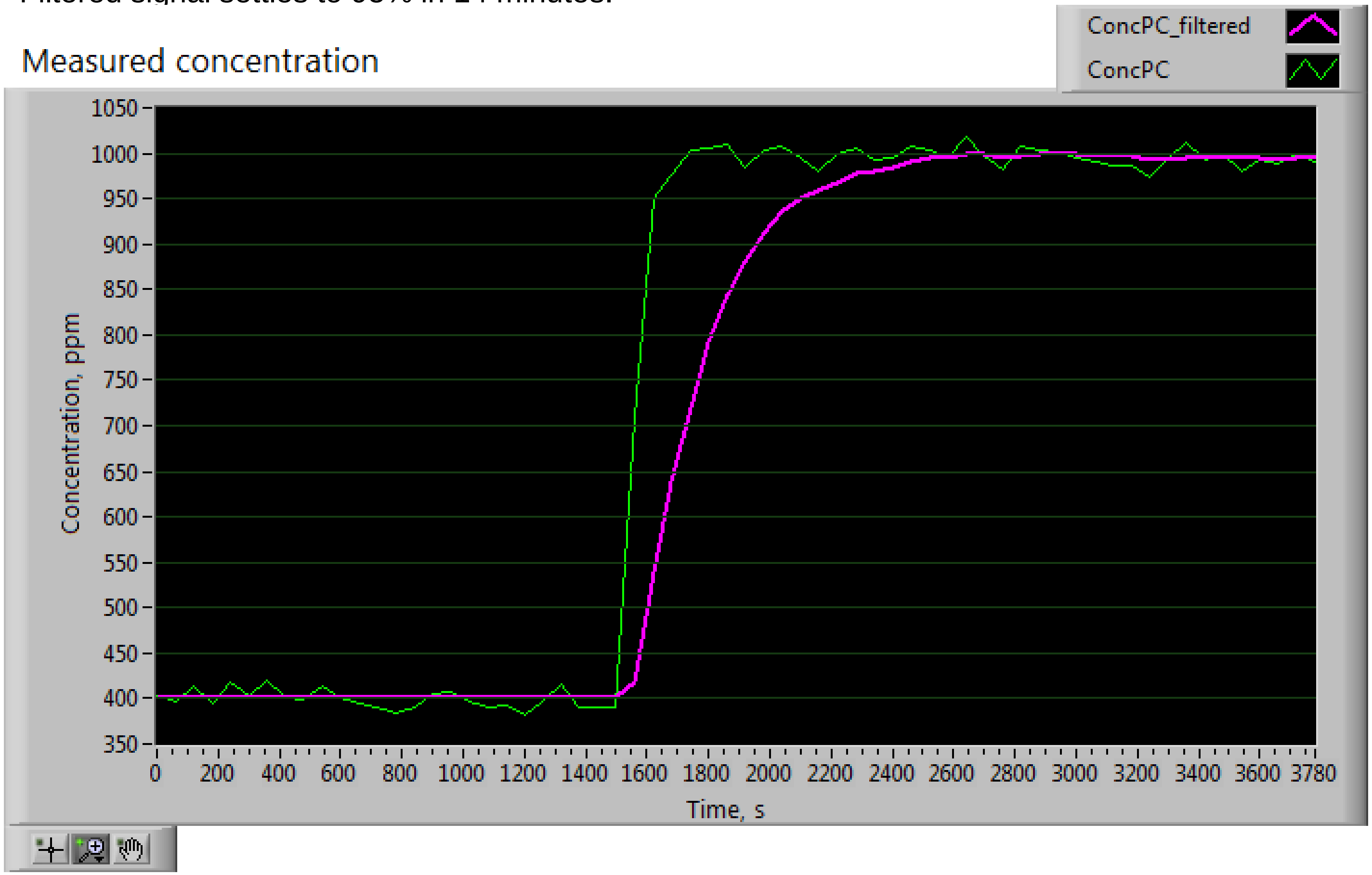
Sensor filter response

Concentration in a plastic bag with LP8 sensor is changed from 400 ppm to 1000 ppm.
Gas flow rate is ~1.5 L/min increased to 4L/min when switching gas, the plastic bag volume is ~1L.
Measurement period is set to **16 seconds**. Settling time of the unfiltered signal is ~5.5 minutes.
Filtered signal settles to 95% in ~8.5 minutes.



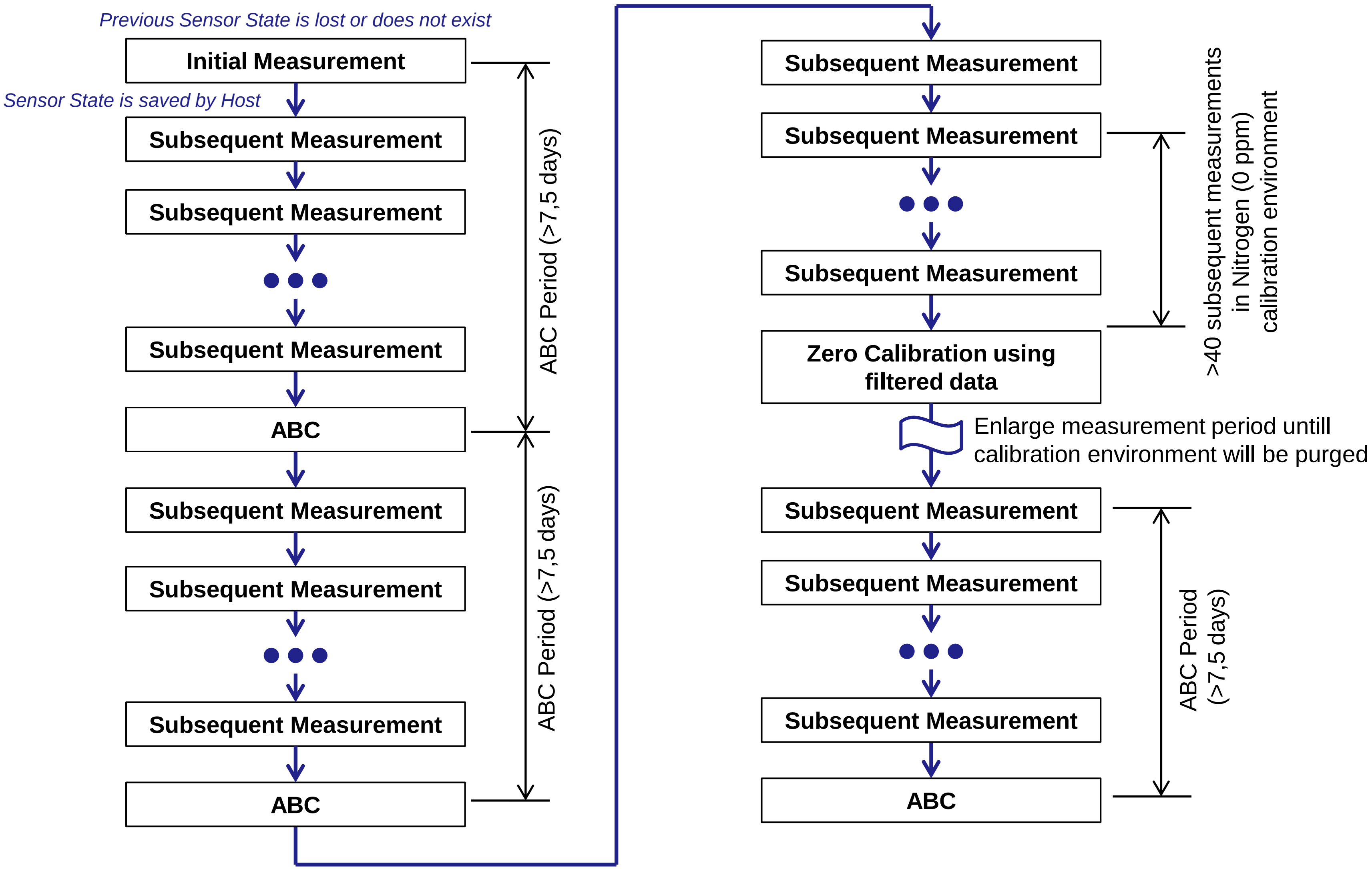
Sensor filter response

Measurement period is set to **60 seconds** (1 minute).
Gas flow rate is ~1.5 L/min increased to 4L/min when switching gas, the plastic bag volume is ~1L.
Settling time of the unfiltered signal takes 4 minutes (4 measurements).
Filtered signal settles to 95% in 14 minutes.



Measurement sequence example

Sensors for Life



Communication sequence in the measurement cycle

Bytes	Description	Corresponding sensor addresses
<CC>	Calculation Control, 1 byte	0x80
<Any1> <Any2> ………… <Any23>	Any values, 23 bytes	
<SS1> <SS2> ………… <SS23>	Sensor State, 23 bytes	0x81 – 0x97
<PP_H> <PP_L>	Host pressure value, 2 bytes Setting this value to 10124 (0x278C) disables pressure compensation in the sensor	0x98 – 0x99
<D1> <D2> ………… <D18>	Measured data and sensor status, 23 bytes	0x9A – 0xAB
<CRC_L> <CRC_H>	CRC, 2 bytes	

LP8 pressure compensation

1) If host is equipped with a pressure sensor it may write pressure value to the addresses 0x98-0x99. Pressure compensation is switched off if written value is 10124 or host omits writing to the addresses 0x98-0x99.
2) If host is not equipped with a pressure sensor there are two options:
   a) Write permanently 10124 to the Host_Pressure, 0x98-0x99
   b) Recommended: omit writing addresses 0x98-0x99 by writing only 24 bytes to the addresses 0x80-0x97.

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Host with pressure sensor

Initial Measurement (previous Sensor State is lost or does not exist)

1) Host powers up sensor
2) Host waits until RDY signal is set low
3) Host writes command “*Write 26 bytes starting from the address 0x0080, Calculation Control = 0x10*”:
   <FE> <41> <00> <80> <1A> <10> <Any1> <Any2> ……. <Any23> <PP_H> <PP_L> <CRC_L> <CRC_H>
4) Host reads response if now communication error occurs:
   <FE> <41> <81> <E0>
5) Host waits until RDY signal is set high
6) Host writes command “*Read 44 bytes starting from the address 0x0080*”:
   <FE> <44> <00> <80> <2C> <CRC_L> <CRC_H>
7) Host reads response if no communication error occurs:
   <FE> <44> <2C> <00> <SS1> <SS2> …… <SS23> <PP_H> <PP_L> <D1> <D2> …… <D18> <CRC_L> <CRC_H>
8) Host powers down sensor

Subsequent Measurement, ABC, … (Sensor State is saved from the previous measurement)

1) Host powers up sensor
2) Host waits until RDY signal is set low
3) Host writes command “*Write 26 bytes starting from the address 0x0080, Calculation Control = CC*”:
   <FE> <41> <00> <80> <1A> <CC> <SS1> <SS2> ……. <SS23> <PP_H> <PP_L> <CRC_L> <CRC_H>
4) Host reads response if now communication error occurs:
   <FE> <41> <81> <E0>
5) Host waits until RDY signal is set high
6) Host writes command “*Read 44 bytes starting from the address 0x0080*”:
   <FE> <44> <00> <80> <2C> <CRC_L> <CRC_H>
7) Host reads response if no communication error occurs:
   <FE> <44> <2C> <00> <SS1> <SS2> …… <SS23> <PP_H> <PP_L> <D1> <D2> …… <D18> <CRC_L> <CRC_H>
8) Host powers down sensor

Host w/o pressure sensor

Initial Measurement (previous Sensor State is lost or does not exist)

1) Host powers up sensor
2) Host waits until RDY signal is set low
3) Host writes command “*Write 24 bytes starting from the address 0x0080, Calculation Control = 0x10*”:

   <FE> <41> <00> <80> <18> <10> <Any1> <Any2> ……. <Any23> <CRC_L> <CRC_H>
4) Host reads response if now communication error occurs:

   <FE> <41> <81> <E0>
5) Host waits until RDY signal is set high
6) Host writes command “*Read 44 bytes starting from the address 0x0080*”:

   <FE> <44> <00> <80> <2C> <CRC_L> <CRC_H>
7) Host reads response if no communication error occurs:

   <FE> <44> <2C> <00> <SS1> <SS2> …… <SS23> <PP_H> <PP_L> <D1> <D2> …… <D18> <CRC_L> <CRC_H>
8) Host powers down sensor

Subsequent Measurement, ABC, … (Sensor State is saved from the previous measurement)

1) Host powers up sensor
2) Host waits until RDY signal is set low
3) Host writes command “*Write 24 bytes starting from the address 0x0080, Calculation Control = CC*”:

   <FE> <41> <00> <80> <18> <CC> <SS1> <SS2> ……. <SS23> <CRC_L> <CRC_H>
4) Host reads response if now communication error occurs:

   <FE> <41> <81> <E0>
5) Host waits until RDY signal is set high
6) Host writes command “*Read 44 bytes starting from the address 0x0080*”:

   <FE> <44> <00> <80> <2C> <CRC_L> <CRC_H>
7) Host reads response if no communication error occurs:

   <FE> <44> <2C> <00> <SS1> <SS2> …… <SS23> <PP_H> <PP_L> <D1> <D2> …… <D18> <CRC_L> <CRC_H>
8) Host powers down sensor

Host w/o pressure sensor

As an alternative for the host without a pressure sensor one can even omit writing any values to the Sensor State in the Initial Measurement:

Initial Measurement (previous Sensor State is lost or does not exist) – option w/o writing any values

1) Host powers up sensor
2) Host waits until RDY signal is set low
3) Host writes command "*Write 1 byte starting from the address 0x0080, Calculation Control = 0x10*":
   <FE> <41> <00> <80> <01> <10> <28> <7E>
4) Host reads response if now communication error occurs:
   <FE> <41> <81> <E0>
5) Host waits until RDY signal is set high
6) Host writes command "*Read 44 bytes starting from the address 0x0080*":
   <FE> <44> <00> <80> <2C> <CRC_L> <CRC_H>
7) Host reads response if no communication error occurs:
   <FE> <44> <2C> <00> <SS1> <SS2> …… <SS23> <PP_H> <PP_L> <D1> <D2> …… <D18> <CRC_L> <CRC_H>
8) Host powers down sensor

Error Handling

ErrorStatus structure

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
ErrorStatus0	WarmUp	Memory	OutOfRange	SelfDiag	Calibration	AlgError	*Reserved*	FatalError
ErrorStatus1	Parameters override bits				*Reserved*	ADC Error	VCAP2 low	VCAP1 low
ErrorStatus2	*Reserved*				Unfiltered concentration channel OOR bits			
ErrorStatus3	*Reserved*				Filtered concentration channel OOR bits			

Error Handling

ErrorStatus0 byte description

Bit	Bit Name	Error Description	Suggested Action
0	FatalError	**Fatal Error** The bit is a joint bit for different error sources when sensor can not provide correct operation, among them: • Configuration EEPROM parameters are out of range or corrupted • Virtual EEPROM memory read/write error • Error in VCAP measurements	Switch off/on sensor power and start with “Initial Measurement” in the Calculation Control byte. Contact local distributor.
2	AlgError	**Algorithm Error** Configuration EEPROM parameters are out of range or corrupted	
3	Calibration	**Calibration Calculation Error** Out of range error at Zero-/Background calibration and ABC	Repeat recalibration or wait until next ABC event.
4	SelfDiag	**Self Diagnostics Error** Hardware error is detected or important EEPROM parameters are corrupted	Contact local distributor.
5	OutOfRange	**Out Of Range Error (OOR)** Indicates an error which occurs at different stages of concentration calculation algorithm. Resets automatically after source of error disappears.	Try sensor in fresh air. Perform sensor zero or background calibration. Check sensor temperature readings.
6	Memory	**Memory Error** Virtual EEPROM read/write error: page checksum error during read or write verification, FLASH operation error.	Contact local distributor.
7	WarmUp	**WarmUp bit** Bit is not set in customer mode	-

Error Handling

ErrorStatus1 byte description

Bit	Bit Name	Error Description	Suggested Action
0	VCAP1 low	**VCAP1 voltage low** Voltage measured prior lamp pulse is below preset threshold. The threshold is 2.8V±3%.	Check battery. Sensor supply voltage is below specified operational limit of 2.9V.
2	VCAP2 low	**VCAP2 voltage low** Average voltage measured at the beginning of lamp pulse (during inrush steps) is below preset threshold. The threshold is 2.7V±3%.	Equivalent series resistance of the sensor power supply source (a battery or super-capacitor) is not enough to provide low-voltage drop during 125mA lamp inrush step.
3	ADC Error	**ADC Error** MCU ADC out-of-range error has occurred.	Switch off/on sensor power and apply “initial measurement” to the Calculation Control byte. Contact local distributor.
4-7	Parameters override bits	This bits indicate which parameter is forced to a predefined value in the debug mode. Should not appear during normal operation.	-

Bits 3-0 of the **ErrorStatus2** and **ErrorStatus3** bytes decode on what algorithm stage an ”Out Of Range Error” (OOR) has occurred in unfiltered and filtered calculation channel respectively.

WARRANTY
This sensor comes with a 90 day warranty starting from the date the sensor was shipped to the buyer.

During this period of time, CO2Meter, Inc. warrants our products to be free from defects in materials and workmanship when used for their intended purpose, and agrees to fix or replace (at our discretion) any part or product that fails under normal use. To take advantage of this warranty, the product must be returned to CO2Meter, Inc. at your expense. If, after examination, we determine the product is defective, we will repair or replace it at no additional cost to you.

This warranty does not cover any products that have been subjected to misuse, neglect, accident, modifications or repairs by you or by a third party. No employee or reseller of CO2Meter, Inc.'s products may alter this warranty verbally or in writing.

LIABILITY
All liabilities under this agreement shall be limited to the actual cost of the product paid to CO2Meter, Inc. In no event shall CO2Meter, Inc. be liable for any incidental or consequential damages, lost profits, loss of time, lost sales or loss or damage to data, injury to person or personal property or any other indirect damages as the result of use of our products.

RETURNS
If the product fails under normal use during the warranty period an RMA (Return Material Authorization) number must be obtained from CO2Meter, Inc. After the item is received, CO2Meter will repair or replace the item at our discretion.

To obtain an RMA number, call us at (386) 256-4910 or email us at Support@CO2Meter.com. When requesting an RMA number, please provide the reason for return and the original order number.

If we determine that the product has failed because of improper use (water damage, dropping, tampering, electrical damage, etc.) or if it beyond the warranty date, we will inform you of the cost to fix or replace the product.

For more information visit our website: www.CO2Meter.com/pages/faq

CONTACT US
Support@CO2Meter.com
(386) 256-4910 Technical Support