I²C
on Senseair
Sunrise and Sunlight

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1. I²C protocol

I²C is a communication protocol invented by Philips Semiconductor for communication between a controller (or multiple controllers) and a single or multiple target devices. It is commonly used for intra-board low speed communications [1].

1.1. I²C bus

I²C requires only two bus lines, serial data line (SDA) and serial clock line (SCL), Figure 1 is an example of an I²C bus with three targets and one controller. Both SDA and SCL are bidirectional lines that should be connected to a positive voltage via a current source or pull-up resistors. The output stages of devices connected to the bus must have an open-drain or open-collector to perform the wired AND logic, an example is shown in Figure 2.

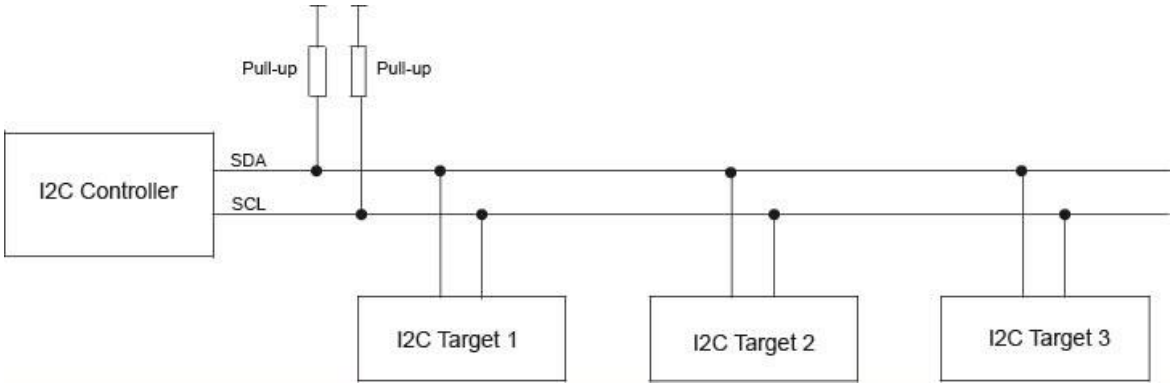

Figure 1. I²C Bus

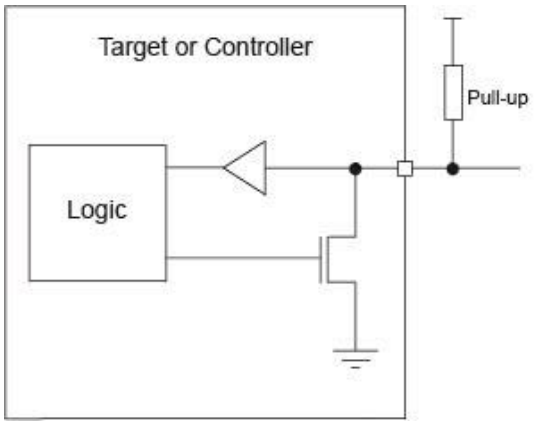

Figure 2. Structure of SDA/SCL ports

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1.2. I²C data transfer

Every I²C transmission starts with a START condition and ends with a STOP condition, however a transmission can contain repeated START conditions. A high to low transition on SDA line while SCL is high defines a START condition. A low to high transition on the SDA line while SCL is high defines a STOP condition. Figure 3 shows both a START and a STOP condition.

Figure 3. START and STOP conditions

One data bit is transferred each clock pulse of SCL. Reading of SDA is done when SCL is high and SDA is only allowed to change when SCL is low. Every data byte is followed by one ACK/NACK bit. It is always the receiving device that does the ACK/NACK, for example when controller a has written 8 bits to a target the controller releases SDA and the target should drive SDA low before SCL goes high to ACK the transmission.
Figure 4 and
Figure 5 show examples of transmissions with ACK and NACK bits.

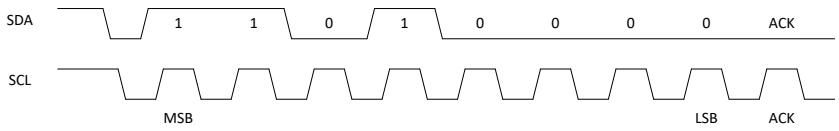

Figure 4. 0xD0 (11010000b) and ACK

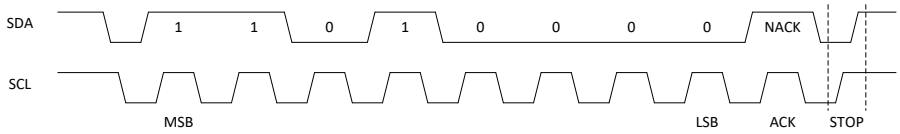

Figure 5. 0xD0 (11010000b), NACK and STOP

The first byte sent after a START condition is always an address byte, the address itself is 7 bits (10 bits address mode exist but is not covered in this document) and the least significant bit is used as direction bit (R/W). If the least significant bit is 0 it means the controller wants to write to the target, if least significant bit is 1 it means that the controller r wants to read from the target. When least significant bit is 1 the target is intended to take control of SDA

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from next byte, but the controller still controls SCL. When the controller wants to stop reading from the target it will NACK last byte sent by the target and send a STOP condition.

If a receiving device, controller or target, needs additional time to for example evaluate a received byte it can pause the data transfer by holding SCL low, this is called clock stretching. An example of clock stretching is shown in
Figure 6.

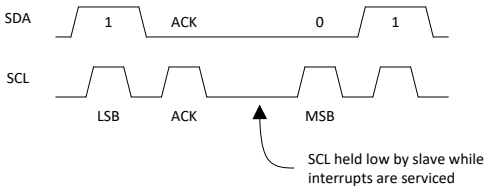

Figure 6, Clock stretching

1.3. Abbreviations

Term	Description
LLSB	least least significant byte
LMSB	least most significant byte
LSB	least significant byte
MLSB	most least significant byte
MMSB	most most significant byte
MSB	most significant byte

1.4. References

[1] UM10204 I^2C-Bus specification and Manual, NXP semiconductors

[2] TDE7318, Sunrise user guideline

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2. I²C on Senseair Sunrise and Sunlight

2.1. I²C settings

The sensor acts as a target device on the I²C bus.

2.1.1 Senseair Sunrise and Sunlight I²C settings

Parameter	Value	Description
Controller/target mode	Target	Sensor will never initiate communication
Data rate	Up to 100kbit/s (standard mode)	
Addressing mode	7 bit	
Address range	0 – 127	Default address is 0x68
Clock stretch	Yes	If sensor needs time to evaluate a received byte it will hold SCL low. **Note**: For articles 006-0-0002, 006-0-0007 please refer to “Writing time to EE” and “Writing time to RAM” as timeout intervals which sensor can hold SCL to evaluate a received byte.
SCL pull-up	100kΩ	
SDA pull-up	-	
Wake-up		Wake up needed
Timeout	15ms	After any activity on the SDA line sensor will wake up, sensor will enter sleep again after 15ms without activity on the SDA line or after a completed read or write cycle.
Writing time to EE	Articles 006-0-0002, 006-0-0007: <25ms	Write operations into (EE) registers require relative long to process. If sensor is powered down while EEPROM write

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	Article 006-0-0008: < 107ms	operations are ongoing it may result in corrupt parameters.
Writing time to RAM	<1ms	

Table 1. Senseair Sunrise and Sunlight I^2C settings

Since Senseair Sunrise/Sunlight only provides a 100kΩ pull-up resistor on the SCL line an external pull-up resistor must be used for SDA. To be able to use data rates up to 100kbit it is in most cases suitable to use pull-up resistors in the range 5kΩ - 15kΩ on both SCL and SDA. Information about how to calculate appropriate pull-up resistor values can be found in [1]

Senseair Sunrise/Sunlight spend most of its time in deep sleep mode to minimise power consumption, this have the effect that it is necessary to wake up the sensors before it is possible to communicate with them. Sensor will wake up on a falling edge on SDA, it is recommended to send sensors address to wake it up. When sensors address is used to wake up the sensor, the sensor will not acknowledge this byte if it in sleep mode and will acknowledge it if sensor is already activated to process a measurement or a previous communication attempt.

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Communication sequence:

1) Wake up sensor by sending sensor address (START, sensor address, STOP).
Sensor will not ACK this byte. **Note**: Sensor will ACK the address if it was not in sleep mode (for example, during measurements).

2) Normal I^2C read/write operations. I2C communication must be started within 15ms after the wake-up byte, each byte sent to or from the sensor sets the timeout to 15 ms. After a complete read or write sequence sensor will enter sleep mode immediately.

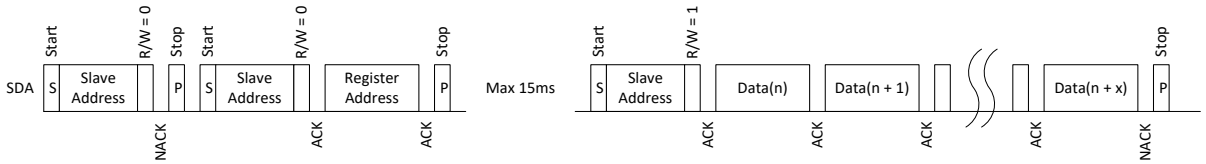

Figure 7. Reading from Senseair Sunrise/Sunlight after wake up

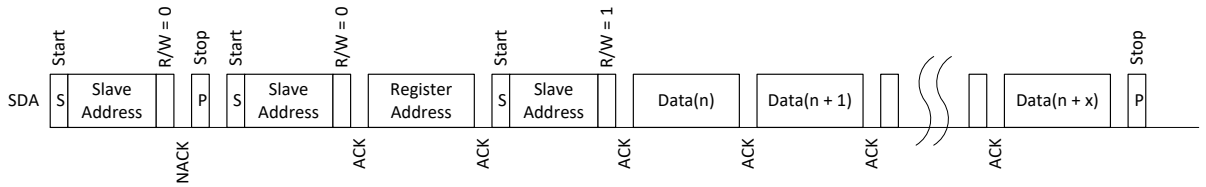

Figure 8. Reading from Senseair Sunrise/Sunlight after wake up using repeated start

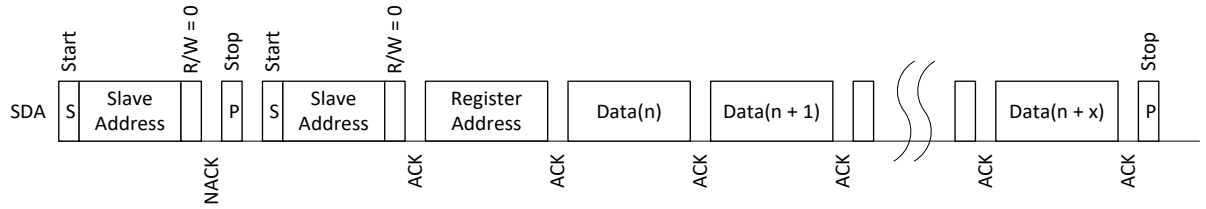

Figure 9. Writing to Senseair Sunrise/Sunlight

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I²C register map

I²C registers are categorised into two groups: I2C read only registers (see table 2) and I²C read/wright registers (see table 3.

2.1.2 I²C read only registers

Name	Register number / Address	Description (read only registers)		
		Bit	Error description	Suggested action
ErrorStatus	0x00 (MSB)	0	Low internal regulated voltage For article 006-0-0007: Flag is set if sensor's internal regulated voltage is too low, this means supply voltage is lower than 2.8V. Flag is cleared after internal voltage normalization. For article 006-0-0008: Flag is set if sensor's internal regulated voltage dropped below 2.8V and sensor's reset occurred. Flag shall be cleared by proper power-off/on sequence, reset command or by writing into "Clear ErrorStatus" register.	Check power supply. This means output voltage from internal regulator is lower than 2.8V or due too low input sensor's voltage or due internal regulator malfunction. Measurement data is not valid.

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		1	Measurement timeout Flag is set if sensor is unable to complete the measurement in time. For article 006-0-0008: This flag is set in combination with the Self-diagnostic flag.	Flag is cleared after a successful measurement. If flag is set permanently, try to restart sensor by power on/off. Contact local distributor.
			For article 006-0-0008: Abnormal signal level Flag is set if an invalid measurement sample is detected. This flag is set in combination with the Self-diagnostic flag.	Flag is cleared after a successful measurement. If flag is set permanently, try to restart sensor by power on/off. Contact local distributor.
		3	Reserved	
		4	Reserved	
		5	Reserved	
		6	Reserved	
		7	For firmware revision 4.10 and above: Scale factor error Flag is set if current scaling factor defined by 0xA8...0xAB registers is not correct	Flag is cleared after writing correct scaling factor value and following reset of the sensor

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	0x01 (LSB)	Bit	Error description	Suggested action
		0	Fatal error Indicates that initialization of analog front end failed	Try to restart sensor by power on/off. Contact local distributor.
		1	I2C error Attempt to read or write to not exiting addresses/registers detected.	Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. Contact local distributor.
		2	Algorithm error Corrupt parameters detected.	Try to restart sensor by power on/off. Contact local distributor.
		3	Calibration error Indicates that calibration has failed (ABC, zero, background or target calibration).	Try to repeat calibration. Ensure that the environment is stable during calibration.
		4	Self-diagnostics error Indicates internal failure. For articles 006-0-0008: Detailed information of the failure can be found in MSB bits 1-2.	Try to restart sensor by power on/off. Contact local distributor.
		5	Out of range Indicates that the measured	Ensure that the environment is within the

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			concentration, temperature, or set pressure are outside the sensor's measurement range	sensors operating range (see Product specification) If pressure compensation is enabled, provide valid pressure value for pressure compensation. Perform suitable gas calibration (zero, background or target calibration). Contact local distributor.
		6	Memory error Error during memory operations	Try to restart sensor by power on/off. Contact local distributor.
		7	No measurement completed Bit set at startup, cleared after first measurement	0 – First measurement cycle completed 1 – No measurement completed If sensor is used in single measurement mode and powered down between measurements this bit can be used to verify started measurement cycle has finished
Reserved	0x02			
Reserved	0x03			
Reserved	0x04			
Reserved	0x05			

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Measured concentration Filtered & pressure compensated	0x06 (MSB)	Filtered pressure compensated gas concentration. Signed 16 bit value, unit ppm. Addresses 0x06 2bytes and 0x12 2 bytes are equal if the pressure compensation is disabled at 0xA5 (default) See [2] for details about IIR filtration and pressure compensation
	0x07 (LSB)	
Temperature	0x08 (MSB)	Chip temperature. Signed 16 bit value, unit °C x100. For example, register value = 2223 means 22.23°C.
	0x09 (LSB)	
Reserved	0x0A	
Reserved	0x0B	
Reserved	0x0C	
Measurement count	0x0D	Counter incremented after each measurement, range 0 – 255. The counter wraps around after the maximum value is reached. Counter value can for example be used by the host system to ensure that the sensor has done a measurement since last time measurement concentration was read.
Measurement cycle time	0x0E (MSB)	Measurement cycle time shows current time in present measurement cycle, incremented every 2 seconds. For example, Measurement cycle time = 3 means 6 seconds has passed in current measurement cycle. Value is set to 0 when sensor starts a new measurement. This value can be used by the host system to synchronize readings with sensor measurements.
	0x0F (LSB)	
Measured concentration Unfiltered pressure compensated	0x10 (MSB)	Unfiltered pressure compensated gas concentration. Signed 16 bit value, unit ppm. Addresses 0x10 2bytes & 0x14 2 bytes are equal if pressure compensation is disabled at 0xA5 (default)
	0x11 (LSB)	
Measured concentration Filtered	0x12 (MSB)	Filtered gas concentration. Signed 16 bit value, unit ppm. See [2] for details about IIR filtration.
	0x13 (LSB)	

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Measured concentration Unfiltered	0x14 (MSB) 0x15 (LSB)	Unfiltered gas concentration. Signed 16 bit value, unit ppm.
Reserved		
Scaled measured concentration Filtered Pressure Compensated	0x1A (MSB) 0x1B (LSB)	Measured concentration (0x06…0x07) scaled by scale factor defined by 0xAA…0xAB registers. Signed 16 bit value. Note: For firmware revision 4.10 and above
Reserved		
ETC	0x2A (MMSB) 0x2B (MLSB) 0x2C (LMSB) 0x2D (LLSB)	Elapsed time counter: counts while the sensor is powered up. Unsigned 32 bit value, unit hours. Note: For firmware revision 4.10 and above
Reserved		
Firmware type	0x2F	Firmware type. Unsigned 8 bit value.
Reserved		
Firmware rev.	0x38 (MSB) 0x39 (LSB)	Firmware main revision Firmware sub revision
Sensor Id	0x3A (MMSB) 0x3B (MLSB) 0x3C (LMSB) 0x3D (LLSB)	Sensor Id. Unsigned 32 bit value.
Reserved	0x3E	
Reserved	0x3F	
Product Code	0x70 – 0x7F	Note: These registers require firmware revision 4.08 or later.

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<table>
<tr>
<td></td>
<td></td>
<td>They contain information about the sensors Product code. Each register is a character in ASCII format, and the end character is 0x00. Below is an example for Sunrise with product code “006-0-0008”.

<table>
<tr><th>Register Address</th><th>Hex data</th><th>ASCII character</th></tr>
<tr><td>0x70</td><td>0x30</td><td>0</td></tr>
<tr><td>0x71</td><td>0x30</td><td>0</td></tr>
<tr><td>0x72</td><td>0x36</td><td>6</td></tr>
<tr><td>0x73</td><td>0x2D</td><td>-</td></tr>
<tr><td>0x74</td><td>0x30</td><td>0</td></tr>
<tr><td>0x75</td><td>0x2D</td><td>-</td></tr>
<tr><td>0x76</td><td>0x30</td><td>0</td></tr>
<tr><td>0x77</td><td>0x30</td><td>0</td></tr>
<tr><td>0x78</td><td>0x30</td><td>0</td></tr>
<tr><td>0x79</td><td>0x38</td><td>8</td></tr>
<tr><td>0x7A</td><td>0x00</td><td>null</td></tr>
</table>

After the first null character, the remaining in this address range is also null.</td>
</tr>
</table>

Table 2. I^2C read only registers

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2.1.3 I²C read/write registers

<table>
<tr><th>Name</th><th>Register number / Address</th><th>Description (read/write registers)</th></tr>
<tr><td>Reserved</td><td>0x80</td><td></td></tr>
<tr><td>Calibration Status</td><td>0x81</td><td>These bits are set after successful calibrations. The bits need to be cleared/reset by host system; it is recommended to do this before starting a calibration.
<table>
<tr><th>Bit</th><th>Description</th></tr>
<tr><td>0</td><td></td></tr>
<tr><td>1</td><td></td></tr>
<tr><td>2</td><td>Factory calibration restored</td></tr>
<tr><td>3</td><td>ABC calibration</td></tr>
<tr><td>4</td><td>Target calibration</td></tr>
<tr><td>5</td><td>Background calibration</td></tr>
<tr><td>6</td><td>Zero calibration</td></tr>
<tr><td>7</td><td></td></tr>
</table></td></tr>
<tr><td rowspan="2">Calibration Command</td><td>0x82 (MSB)</td><td rowspan="2">Calibration is initiated by the commands in the table below. See [2] for description of the different calibration modes.

The sensor will perform a calibration based on the first measurement immediately after the calibration command was received. Host system should trig a measurement after writing the calibration command in single measurement mode. After having performed the calibration, all following measurements will use the adjusted calibration parameters</td></tr>
<tr><td>0x83 (LSB)</td></tr>
</table>

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<table>
<tr><td></td><td></td><td>It is recommended that Calibration status is cleared before initiating a calibration.

<table><tr><th>Command</th><th>Name and description</th></tr><tr><td>0x7C02</td><td>Restore factory calibration.

Restores calibration parameters to factory calibration values.</td></tr><tr><td>0x7C03</td><td>Forced ABC calibration.

Sensor will perform an ABC calibration after receiving this command if sensor has valid ABC data. The command can be used if one for some reason wants to do an ABC adjustment before one ABC period has passed (when a normal ABC calibration is done).

This command only works if ABC is enabled, see ABC period (addr 0x9A & 0x9B) and MeterControl (addr 0xA5).</td></tr><tr><td>0x7C05</td><td>Target calibration.

Calibration using Calibration target (addr 0x84, 0x85) value as calibration target.</td></tr><tr><td>0x7C06</td><td>Background calibration

Calibration using ABC target as calibration target.</td></tr><tr><td>0x7C07</td><td>Zero calibration.

Calibration using 0 ppm gas as calibration target.</td></tr></table></td></tr>
<tr><td rowspan="2">Calibration Target</td><td>0x84 (MSB)</td><td rowspan="2">Calibration target used by target calibration

(0x82..0x83- 0x7C05 command).</td></tr>
<tr><td>0x85 (LSB)</td></tr>
<tr><td></td><td>0x86 (MSB)</td><td></td></tr>
</table>

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Measured concentration Override	0x87 (LSB)	Default value = 32767 (no override). If a value lower than default is written to the register both filtered and unfiltered measured concentration will be set to this value after next measurement.
ABC Time	0x88 (MSB)	Time passed since last ABC calibration in hours. If ABC is enabled when sensor is used in single measurement mode and powered down between measurements, the host system must read this register from the sensor after each measurement, increment its value every hour and write back to the sensor after each power on (enable) before a new measurement is trigged.
	0x89 (LSB)	
ABC Par0	0x8A (MSB)	If ABC is enabled when sensor is used in single measurement mode and powered down between measurements, these registers must be read from the sensor after each measurement and written back to the sensor after each power on (enable) before a new measurement is trigged.
	0x8B (LSB)	
ABC Par1	0x8C (MSB)	
	0x8D (LSB)	
ABC Par2	0x8E (MSB)	
	0x8F (LSB)	
ABC Par3	0x90 (MSB)	
	0x91 (LSB)	
Reserved	0x92	
Start Single Measurement	0x93	Writing 1 initiates a measurement if the sensor is configured for single measurement mode.
Reserved	0x94	
Measurement Mode (EE)	0x95	There are two measurement modes to choose between. Value = 0, continuous measurement mode (default) Value = 1, single measurement mode.

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		Note: A system reset is required after changing measurement mode. New written data to the register can be read back after a sensor reset is completed.
Measurement Period (EE)	0x96 (MSB)	Measurement period in seconds (range from 2 to 65534). Odd numbers will be rounded up to nearest even number.
	0x97 (LSB)	Note: A system reset is required after changing configuration. New written data to the register can be read back after a sensor reset is completed. Default value is 16. Note: Measurement period is only used in continuous measurement mode
Number of samples (EE)	0x98 (MSB)	Number of samples in one measurement (range from 1 to 1024). A higher number leads to a better accuracy but also a higher power consumption.
	0x99 (LSB)	Note: A system reset is required after changing configuration. New written data to the register can be read back after a sensor reset is completed. Default is 8 samples. Note: One sample takes max 300ms, this means that (Number of samples * 0.3s) should be less than or equal to time between measurements. If time for executing all samples in a measurement is longer than measurement period, sensor will execute all samples and after that start a new measurement. This means that actual measurement period will be longer than measurement period specified in HR12. Note (not applicable for 006-0-0007): Odd numbers will be internally rounded down to nearest even number and values below 2 will be replaced with 2.

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<table>
<tr><td rowspan="2">ABC period (EE)</td><td>0x9A (MSB)</td><td rowspan="2">Period for ABC cycle in hours (range from 1 to 65534). Default is 180 hours.

ABC enabled by writing 1 to 65534 to addr 0x9A, 0x9B and bit 1 = 0 at addr 0xA4, 0xA5

ABC disabled by writing 0 or 65535 to addr 0x9A, 0x9B or bit 1 = 1 at addr 0xA4, 0xA5.</td></tr>
<tr><td>0x9B (LSB)</td></tr>
<tr><td>Reserved</td><td>0x9C</td><td></td></tr>
<tr><td>Clear ErrorStatus</td><td>0x9D</td><td>Write any numbers to this register to clear the ErrorStatus</td></tr>
<tr><td rowspan="2">ABC Target (EE)</td><td>0x9E (MSB)</td><td rowspan="2">Target value for background and ABC calibrations (ppm gas).</td></tr>
<tr><td>0x9F (LSB)</td></tr>
<tr><td>Reserved</td><td>0xA0</td><td></td></tr>
<tr><td>Static IIR filter parameter (EE)</td><td>0xA1</td><td>Parameter for static IIR filter, range from 2 – 10. A higher value corresponds to a harder filtration. See [2] for details about IIR filtration.</td></tr>
<tr><td>Reserved</td><td>0xA2</td><td></td></tr>
<tr><td>SCR</td><td>0xA3</td><td>The SCR register can be used to reset the sensor

Register value = 0xFF, sensor will reset/restart itself.</td></tr>
<tr><td>Reserved</td><td>0xA4</td><td></td></tr>
<tr><td>Meter control (EE)</td><td>0xA5</td><td>Bit field used to enable/disable sensor functions
<table>
<tr><th>Bit</th><th>Description</th></tr>
<tr><td>0</td><td>0 - nRDY enabled (default)

1 - nRDY disabled</td></tr>
<tr><td>1</td><td>0 - ABC enabled (default)

1 - ABC disabled</td></tr>
<tr><td>2</td><td>0 – Static IIR filter enabled (default)

1 - Static IIR filter disabled</td></tr>
</table>
</td></tr>
</table>

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<table>
<tr><td></td><td></td><td>
<table>
<tr><td>3</td><td>0 – Dynamic IIR filter enabled (default)
1 – Dynamic IIR filter disabled
To enable dynamic IIR filter both static IIR filter (bit2) and dynamic IIR filter (bit3) must be enabled</td></tr>
<tr><td>4</td><td>0 – Pressure compensation enabled
1 – Pressure compensation disabled (default)</td></tr>
<tr><td>5</td><td>0 – nRDY pin invert enabled, low during measurement
1 – nRDY pin invert disabled (default), high during measurement</td></tr>
<tr><td>6</td><td></td></tr>
<tr><td>7</td><td></td></tr>
</table>
EEPROM mapped register.
</td></tr>
<tr><td>Reserved</td><td>0xA6</td><td></td></tr>
<tr><td>MB/I^{2}C address (EE)</td><td>0xA7</td><td>Sensor address, range 1 – 127 (0x01 – 0x7F). Default value is 104 (0x68). A sensor reset is needed to activate the new address.
EEPROM mapped register
Note: Sensor does not check validity of the I^{2}C address, do not set reserved or invalid I^{2}C addresses.</td></tr>
<tr><td rowspan="2">Concentration scale factor, nominator part (EE)</td><td>0xA8 (MSB)</td><td rowspan="4">Registers 0xA8…0xAB are used to scale “Measured concentration Filtered & pressure compensated” register value to calculate “Scaled measured concentration” (registers 0x18...0x19) register value:
“Scaled measured concentration” = “Measured concentration Filtered & pressure compensated” *” Concentration scale factor, nominator part”/” Concentration scale factor, denominator part”
The registers are unsigned 16 bit.
If both registers are equal to 0xFFFF, the scaling is disabled and “Scaled measured concentration” registers value is just a</td></tr>
<tr><td>0xA9 (LSB)</td></tr>
<tr><td rowspan="2">Concentration scale factor, denominator part (EE)</td><td>0xAA (MSB)</td></tr>
<tr><td>0xAB (LSB)</td></tr>
</table>

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<table>
<tr><td></td><td></td><td>copy of “Measured concentration Filtered & pressure compensated” registers.

If scaling factor is invalid, the “Scale factor error” bit will be set in “ErrorStatus” register at startup.

EEPROM mapped registers.

A sensor reset is needed to activate the new setting and readback new values.

Note: For firmware revision 4.10 and above</td></tr>
<tr><td rowspan="2">Scaled Calibration Target</td><td>0xAC (MSB)</td><td rowspan="2">Scaled calibration target used by target calibration (0x7C05 command).

Note: For firmware revision 4.10 and above</td></tr>
<tr><td>0xAD (LSB)</td></tr>
<tr><td rowspan="2">Scaled Measured concentration Override</td><td>0xAE (MSB)</td><td rowspan="2">Default value = 32767 (no override). If a value lower than default is written to the register, both the gas filtered and unfiltered registers will be set to this value.

Note: For firmware revision 4.10 and above</td></tr>
<tr><td>0xAF (LSB)</td></tr>
<tr><td rowspan="2">Scaled ABC Target (EE)</td><td>0xB0 (MSB)</td><td rowspan="2">Target value for background and ABC calibrations.

Note: For firmware revision 4.10 and above</td></tr>
<tr><td>0xB1 (LSB)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Registers from address 0xC0 to 0xCD are mirrors of registers at addresses 0x80, 0x81, 0x92, 0x93, and 0x88 to 0x91. The reason for this is to make it possible to only write and read respectively one block of read/write registers when sensor is used in single measurement mode and powered down between measurements. See example at 3.4 for details.</td></tr>
<tr><td>Reserved</td><td>0xC0</td><td></td></tr>
<tr><td>Calibration Status</td><td>0xC1</td><td>These bits are set after successful calibrations. The bits need to be cleared/reset by host system; it is recommended to do this before starting a calibration.
<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0</td><td></td></tr><tr><td>1</td><td></td></tr></table></td></tr>
</table>

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<table>
<tr><td></td><td></td><td><table>
<tr><td>2</td><td>Factory calibration restored</td></tr>
<tr><td>3</td><td>ABC calibration</td></tr>
<tr><td>4</td><td>Target calibration</td></tr>
<tr><td>5</td><td>Background calibration</td></tr>
<tr><td>6</td><td>Zero calibration</td></tr>
<tr><td>7</td><td></td></tr>
</table></td></tr>
<tr><td>Reserved</td><td>0xC2</td><td></td></tr>
<tr><td>Start Single Measurement</td><td>0xC3</td><td>Writing 1 to this register initiates a measurement if the sensor is configured for single measurement mode.</td></tr>
<tr><td rowspan="2">ABC Time</td><td>0xC4 (MSB)</td><td rowspan="2">Time passed since last ABC calibration in hours.
If ABC is enabled when sensor is used in single measurement mode and powered down between measurements, the host system must read this register from the sensor after each measurement, increment its value every hour and write back to the sensor after each power on (enable) before a new measurement is trigged.</td></tr>
<tr><td>0xC5 (LSB)</td></tr>
<tr><td rowspan="2">ABC Par0</td><td>0xC6 (MSB)</td><td rowspan="8">If ABC is enabled when sensor is used in single measurement mode and powered down between measurements, these registers must be read from the sensor after each measurement and written back to the sensor after each power on (enable) before a new measurement is trigged.</td></tr>
<tr><td>0xC7 (LSB)</td></tr>
<tr><td rowspan="2">ABC Par1</td><td>0xC8 (MSB)</td></tr>
<tr><td>0xC9 (LSB)</td></tr>
<tr><td rowspan="2">ABC Par2</td><td>0xCA (MSB)</td></tr>
<tr><td>0xCB (LSB)</td></tr>
<tr><td rowspan="2">ABC Par3</td><td>0xCC (MSB)</td></tr>
<tr><td>0xCD (LSB)</td></tr>
<tr><td rowspan="2">Filter Par0</td><td>0xCE (MSB)</td><td rowspan="3">If the sensor is used in single measurement mode with IIR filter enabled and powered down between measurements, these registers must be read from the sensor after each measurement and written back to the</td></tr>
<tr><td>0xCF (LSB)</td></tr>
<tr><td>Filter Par1</td><td>0xD0 (MSB)</td></tr>
</table>

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	0xD1 (LSB)	sensor after each power on (enable) before a new measurement is trigged.
Filter Par2	0xD2 (MSB)	
	0xD3 (LSB)	
Filter Par3	0xD4 (MSB)	
	0xD5 (LSB)	
Filter Par4	0xD6 (MSB)	
	0xD7 (LSB)	
Filter Par5	0xD8 (MSB)	
	0xD9 (LSB)	
Filter Par6	0xDA (MSB)	
	0xDB (LSB)	
Barometric air pressure value	0xDC (MSB)	Barometric air pressure value. Signed 16 bit, unit 0.1 hPa. Range from 3000 – 13000 (300 – 1300 hPa). For values outside pressure range, error flag “out of range” will be set and compensation will be done with min or max pressure value.
	0xDD (LSB)	
ABC barometric pressure value	0xDE	**If pressure compensation and ABC are both enabled** when sensor is used in single measurement mode and powered down between measurements, this register must be read from the sensor after each measurement and written back to the sensor after each power on (enable) before a new measurement is trigged.
	0xDF	

Table 3 I^2C read/write registers

Registers with (EE) after their names use sensors EEPROM, this means that too frequent writes to these registers will lead to a corrupt EEPROM. Total number of EEPROM write cycles should be less than 10000.

When writing multiple (EE) registers in one sequence then this write cycle will be counted as just ONE write cycle out of the 10000 that are allowed writes to the EEPROM.

Write operations into (EE) registers require relative long to process (see Senseair Sunrise and Sunlight I2C settings).

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Note: For articles 006-0-0002 and 006-0-0007: When write operations are ongoing, the sensor will not respond to communication. This means that for example if Measurement Mode (EE), Measurement Period (EE), Number of samples (EE) and ABC period (EE) registers are written in one I2C write sequence, the sensor can be unresponsive for up to 100ms.
Note: Do not use sensors capability to respond on communication as an indication of finished writing process.

It is very important that the sensor is not powered down when write operations are ongoing, doing so may result in corrupt parameters.

When writing several bytes to sensors EEPROM, it's important to wait until all bytes are written.

Registers marked as "Reserved" can be read and written, however it is strongly recommended to not use these registers.

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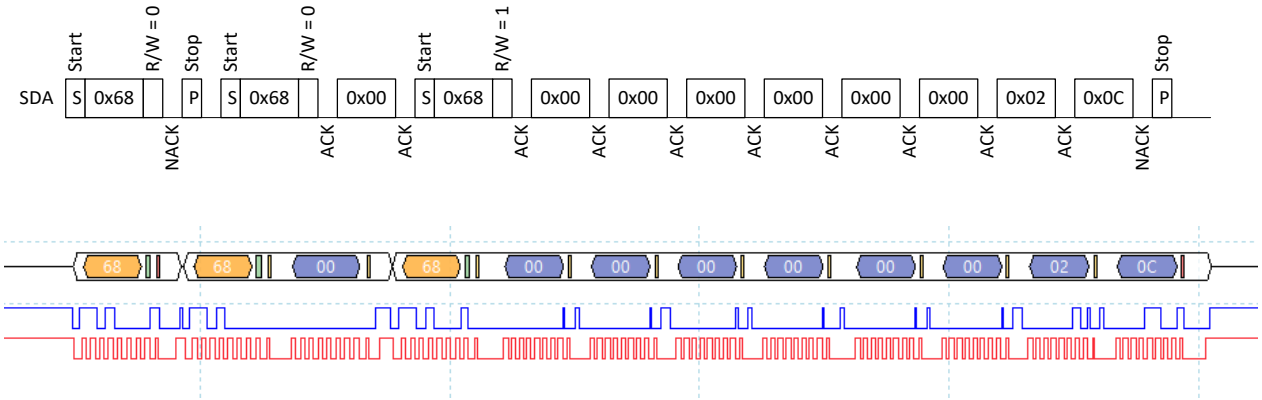
3. Examples

3.1. Read Error Status and gas concentration

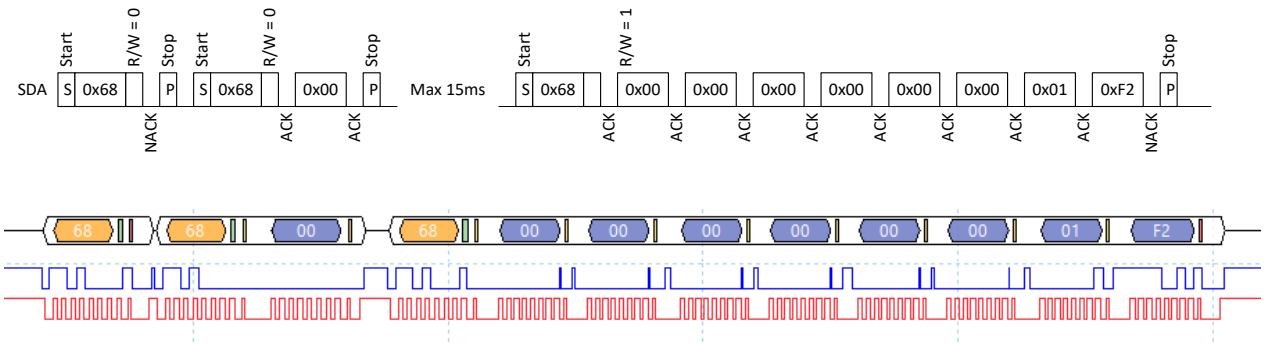
Reading Error Status and filtered measured gas concentration (Error Status, 4 reserved bytes, measured concentration).

3.1.1 **Example using repeated start:**



In example Error Status = 0 (no error flags set) and measured concentration = 0x020C (524d).

3.1.2 **Example not using repeated start:**



In example Error Status = 0 (no error flags set) and measured concentration = 0x01F2 (498d).

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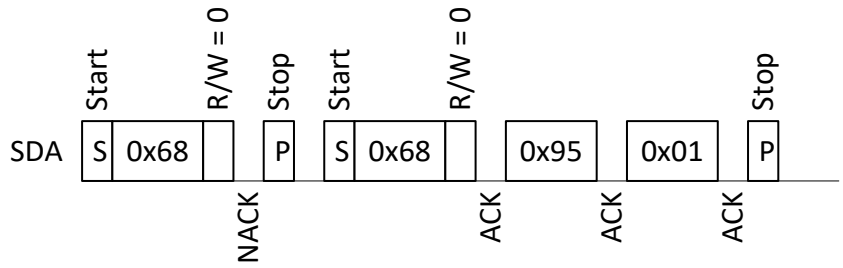
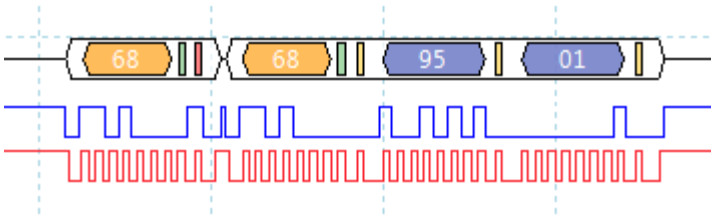
3.2. Set measurement mode to single measurement mode

Write 1 to register Measurement Mode (0x95). Note that after measurement mode has been written to the sensor it has to be restarted before it will change to the new measurement mode.



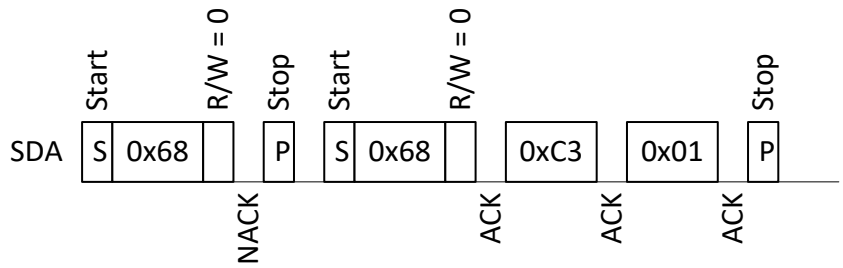


3.3. Start single measurement

The single measurement command can be used if a host wants to control when Senseair Sunrise/ Sunlight measures, for example if one wants to use different measurement periods depending on time of day or weekday.

If ABC is enabled, it is very important to ensure that measurements are performed when the sensor is exposed to fresh air.

Write 1 to register Start Single Measurement (0xC3 or 0x93).



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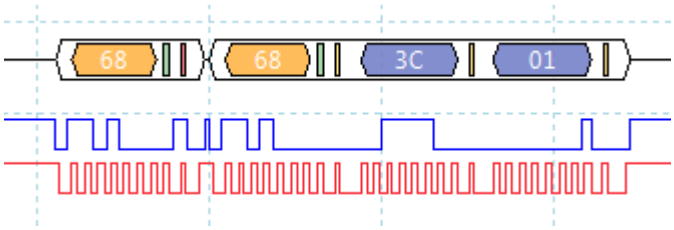

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3.4. Sequence for single measurement mode, sensor enabled/disabled by EN pin

To minimise power consumption, one can power down Senseair Sunrise/Sunlight between measurements, or alternatively drive its EN pin low (powers down active circuits). When the sensors circuits are powered down, data needed for ABC and IIR filter will be lost. Therefore, it is necessary to read a few registers from Senseair Sunrise/Sunlight before it is powered down and to write these registers back after it is powered on.

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Following sequence can be used when powering down/disable the sensor between measurements in single measurement mode.

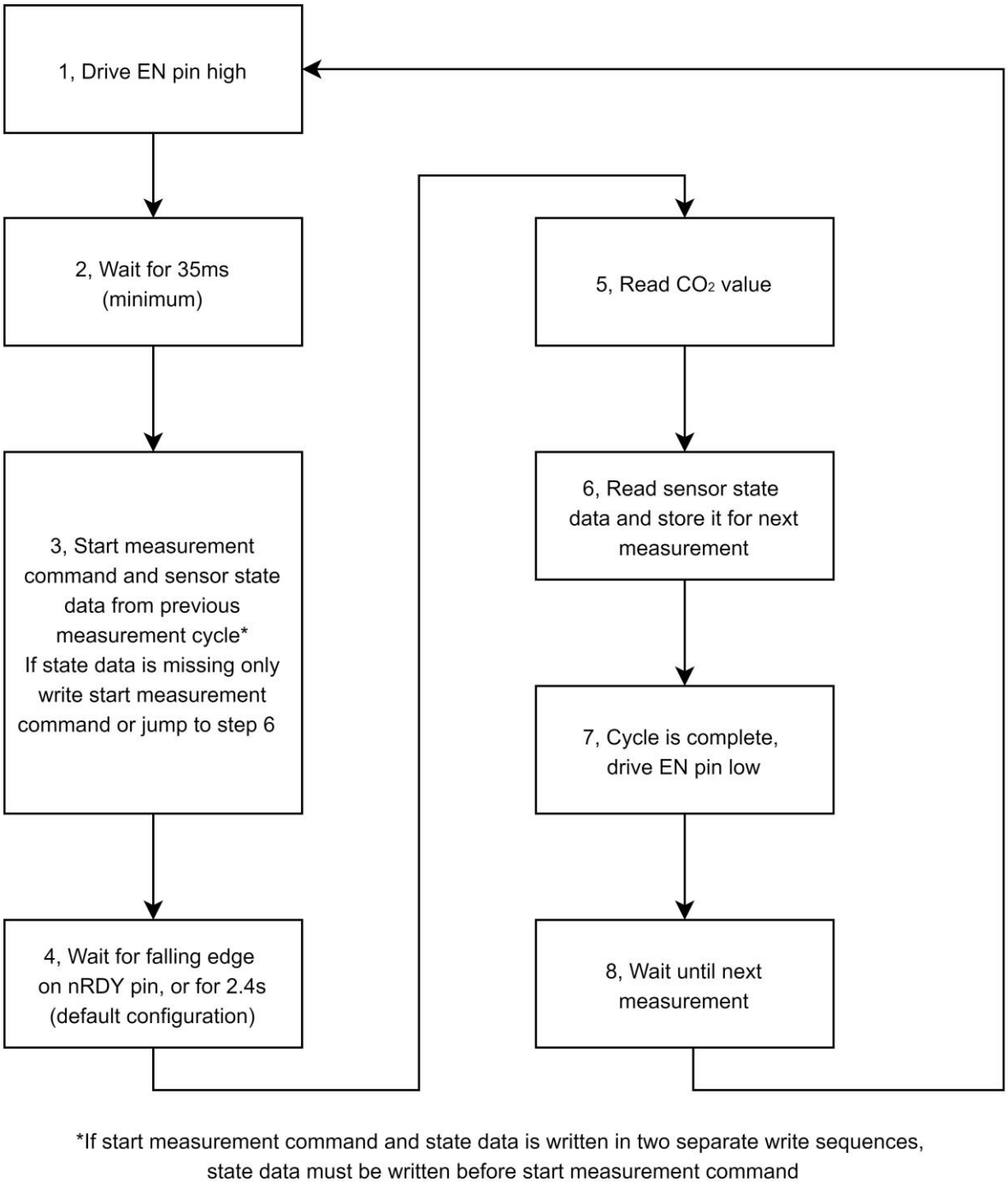

Figure 10, Sequence for single measurement mode, sensor enabled/disabled by EN pin

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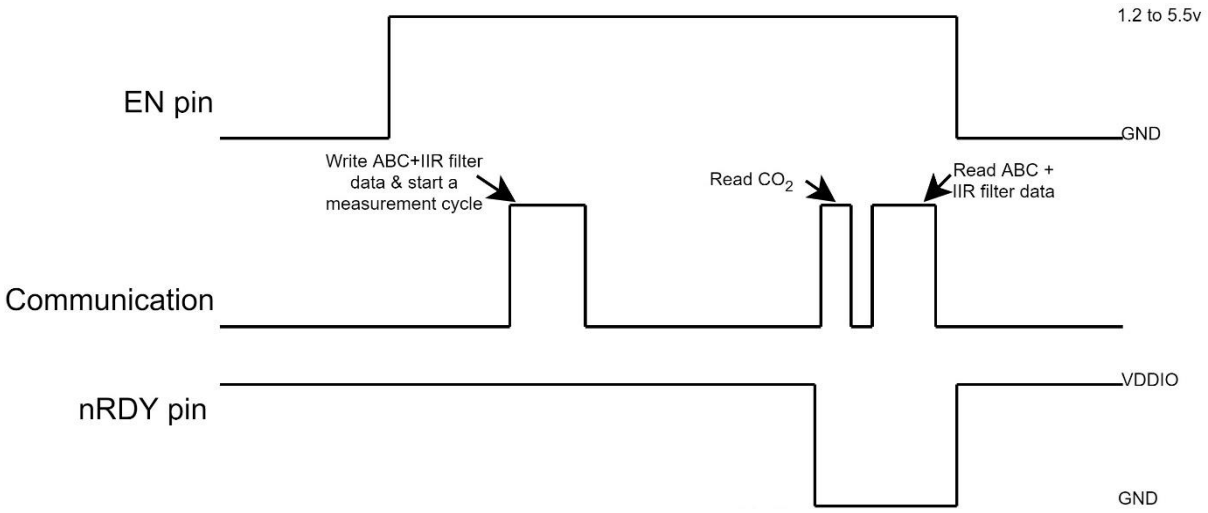


Figure 11, Timing diagram for single measurement mode

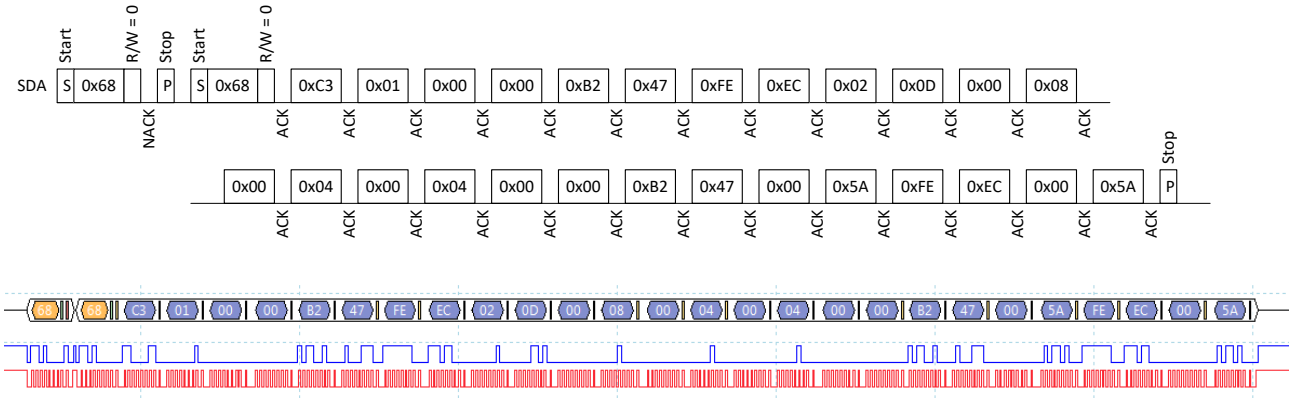
1 Drive EN pin high (>1.2V)

2 Wait for minimum 35ms for sensor start-up and stabilisation

3 If state data exist go to point 3.1, otherwise go to point 3.2

3.1 Sensor state data exist

If pressure compensation is not used write start measurement command and state data to register Start Single Measurement – Filter Par6 (0xC3 – 0xDB).



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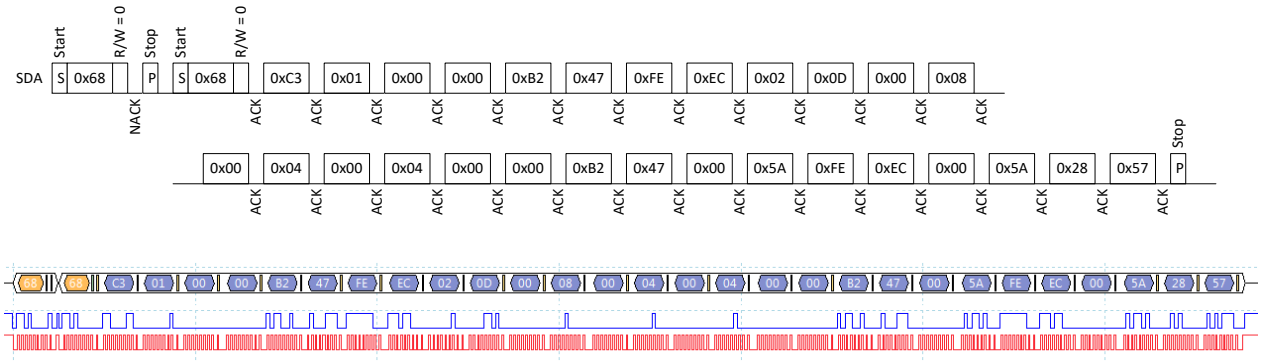
If pressure compensation is used, write measurement command, state data and pressure to registers Start Single Measurement – Barometric air pressure (0xC3 – 0xDD). In this example barometric air pressure 1032.7 hPa is written to the sensor.



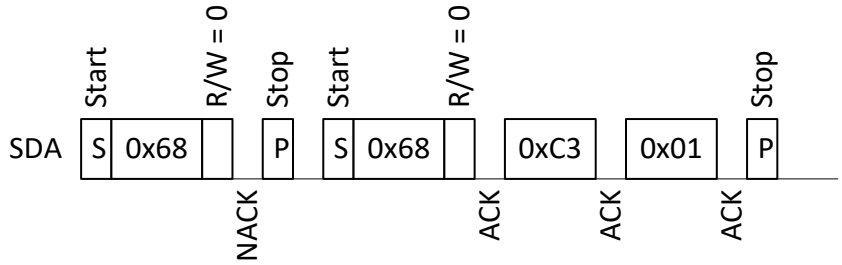
3.2 Sensor state data do not exist.

If host device has no state data, it is very important that host do not write “0” or any arbitrary data to address 0xC6 - 0xDB (ABC Par0 to Filter Par6) the first time it starts a measurement.

There are 2 options for this condition:

a) Write 1 (start measurement command) to register Start Single Measurement (0xC3).

If pressure compensation is enabled write pressure to Barometric air pressure register before writing the start measurement command.



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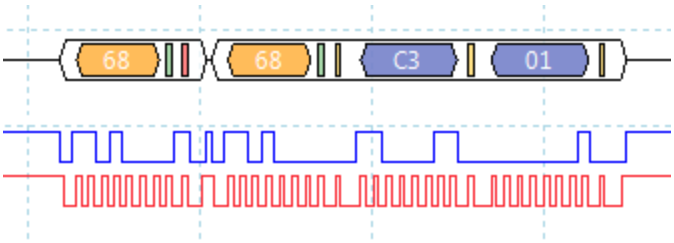

b) Jump to point 6 immediately to read and save state data from the sensor before the initial measurement.

4 Wait until ready pin goes low or 2.4s (for default configuration)

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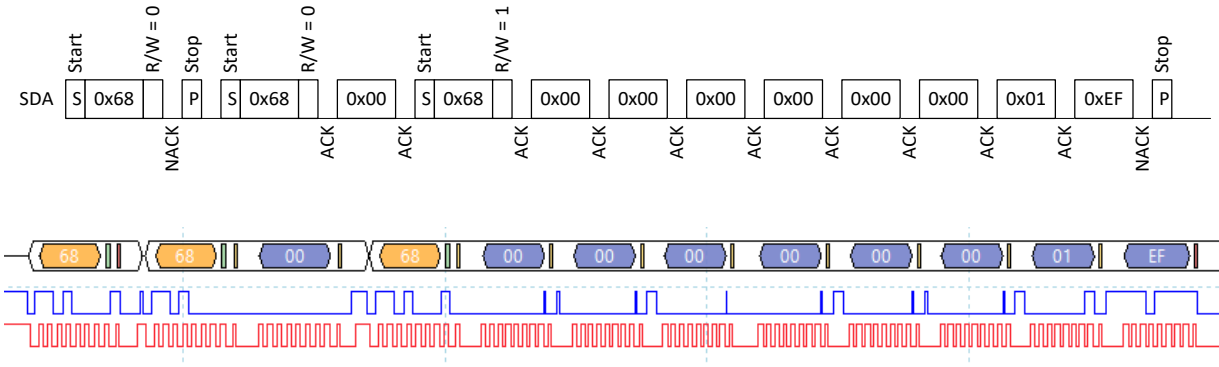
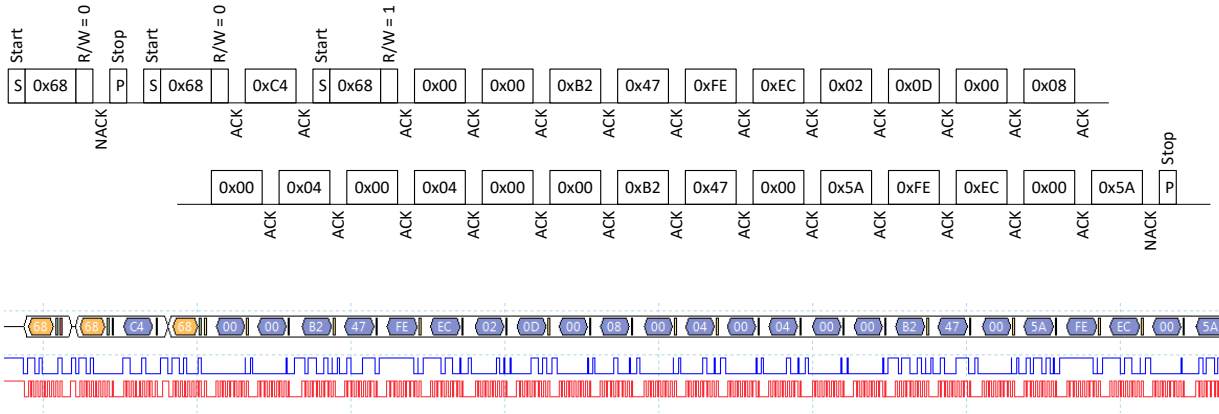
5 Read eight bytes starting from address 0x00 (first two bytes = Error Status, last two bytes = measured concentration).



6 Read sensor state data from address 0xC4 – 0xDB and save it for next measurement.



7 Drive EN pin low (<0.4V)

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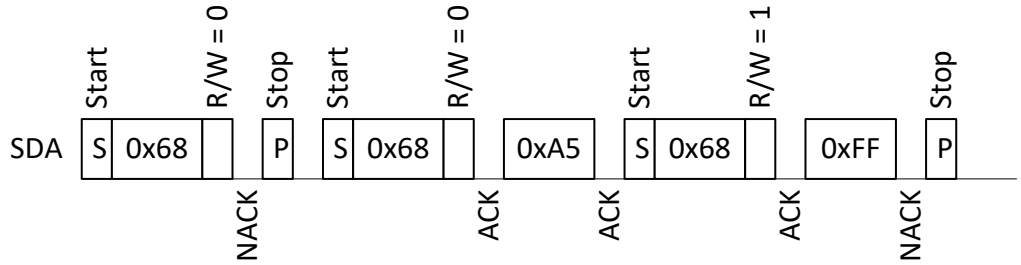
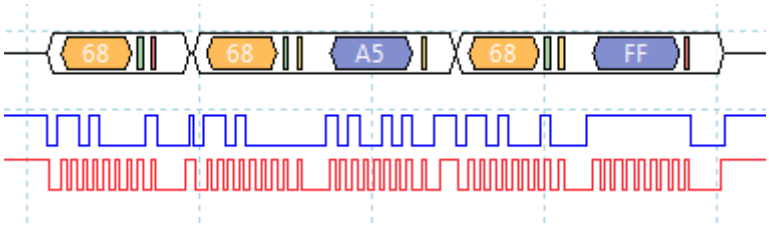
3.5. Enable/Disable ABC

3.5.1 **Enable ABC:**

1. Clear bit1 in register Meter control (0xA5)

1.1 Start by reading current register value from address 0xA5.

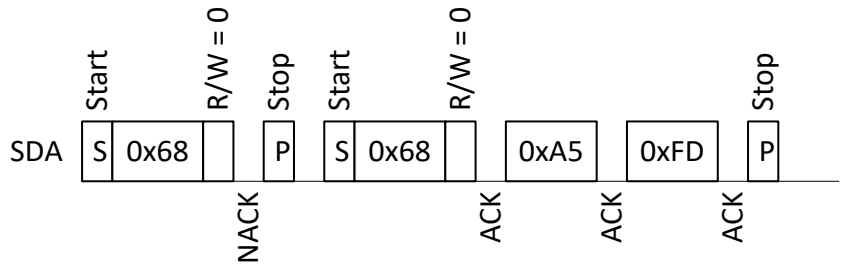


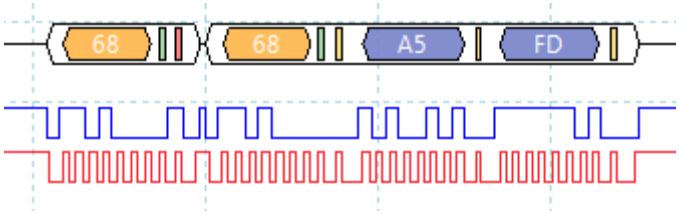


1.2 Clear bit1 in register and write back

Meter control = 0xFF => new Meter control value = 0xFF & 0xFD = 0xFD

1.3 Write back new Meter control value.





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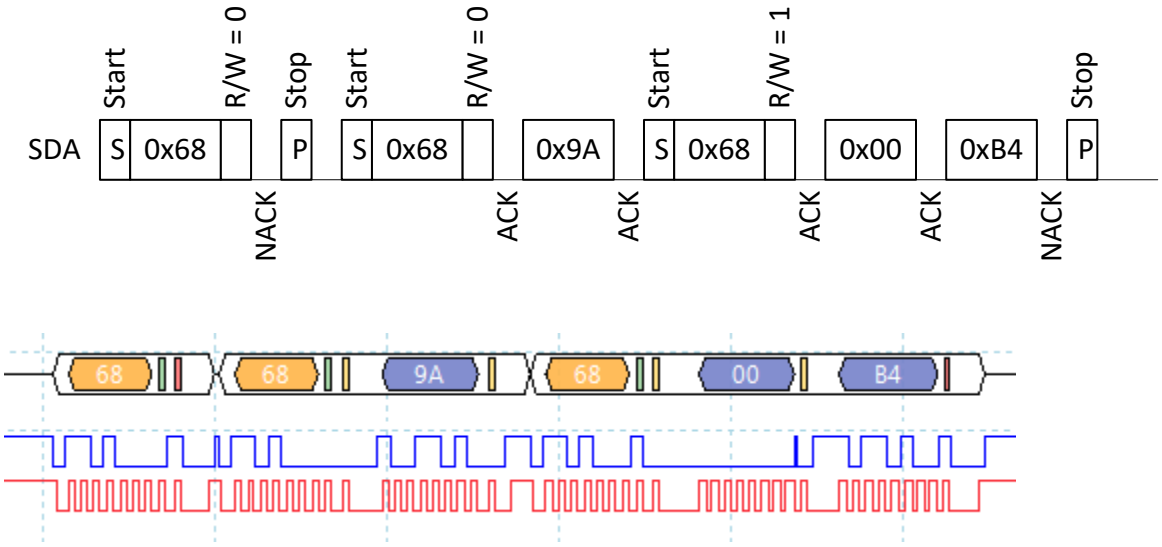
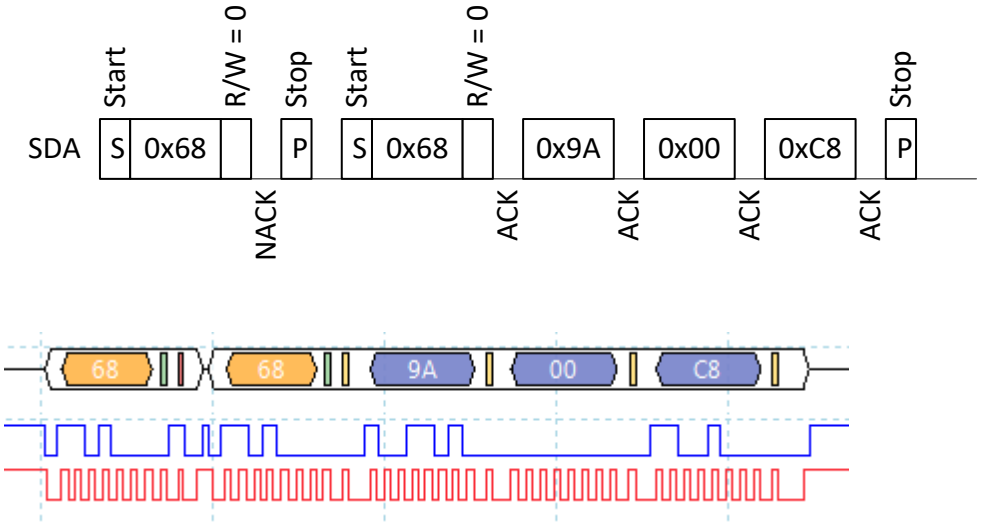
2. Read register ABC period (0x9A, 0x9B) and verify that it is desired ABC period.



ABC period = 0x00B4 = 180 hours

3. If ABC period needs to be changed, write wanted ABC period in hours to register ABC period (0x9A, 0x9B). In this example ABC period is set to 200 hours.



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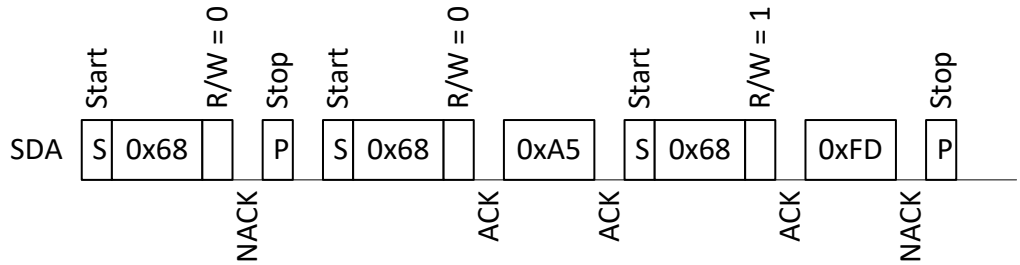
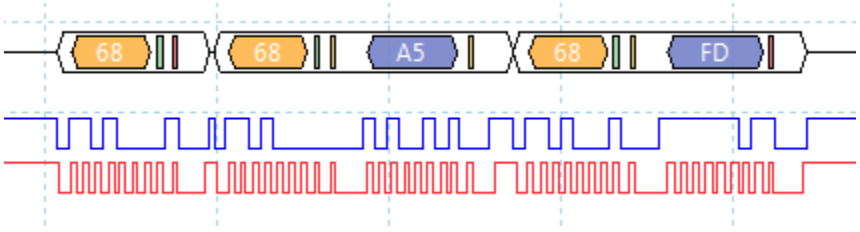
3.5.2 **Disable ABC:**

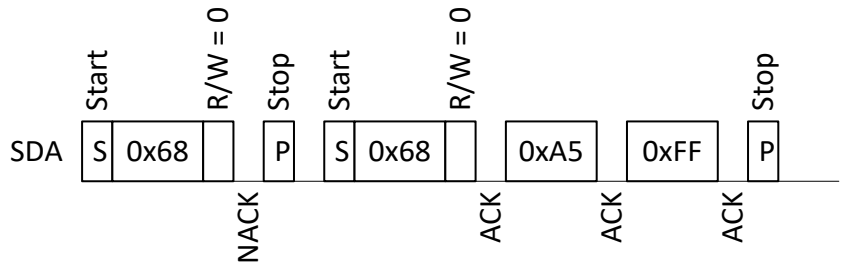
Set bit1 in register Meter control (0xA5)

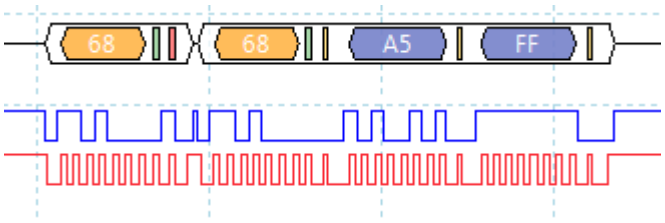
1. Start by reading register Meter control.





2. Set bit1 in register and write back.
3. Meter control = 0xFD => new Meter control = 0xFD | 0x02 = 0xFF
4. Write back new Meter control value.





A possible alternative is to set register ABC period to zero, but then information about what ABC period to use must be saved to be able to enable ABC in future.

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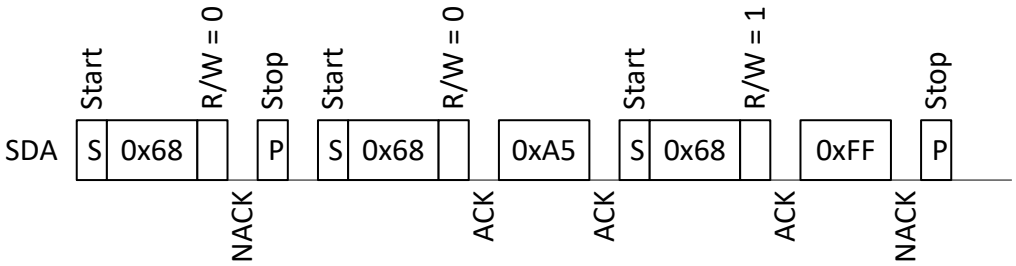
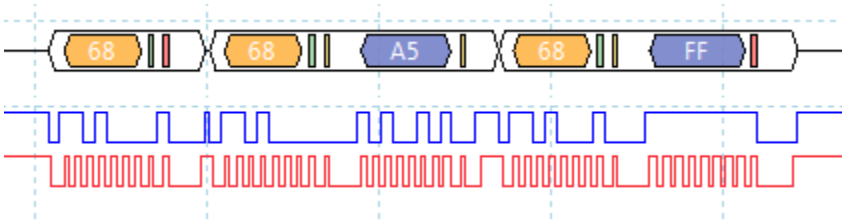
3.6. Enable/Disable dynamic IIR filter

Enable and disable dynamic IIR filtration by writing to register Meter control (0xA5).

3.6.1 **Enable dynamic IIR filter.**

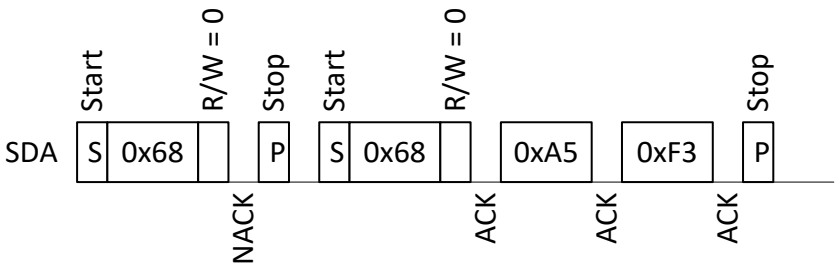
1. Start by reading Meter control.

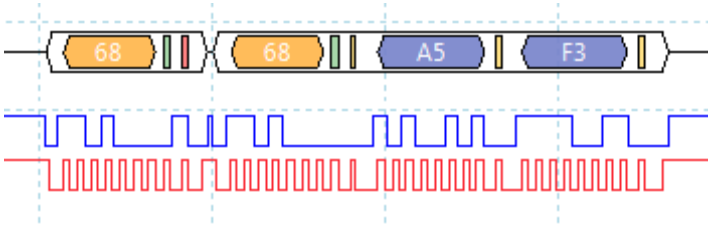




2. Clear bit2 and bit3 in register and write back

Meter control = 0xFF => new Meter control value = 0xFF & 0xF3 = 0xF3





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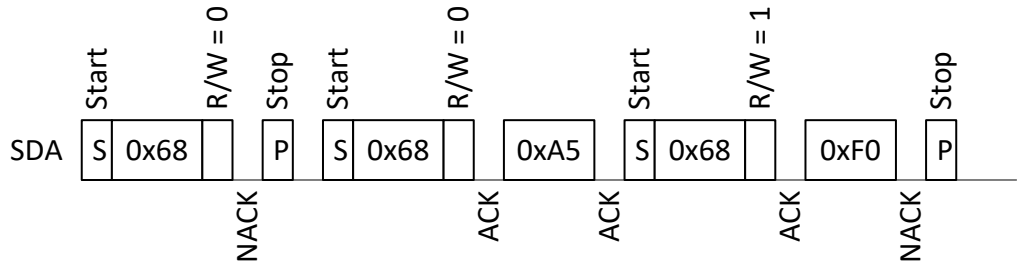
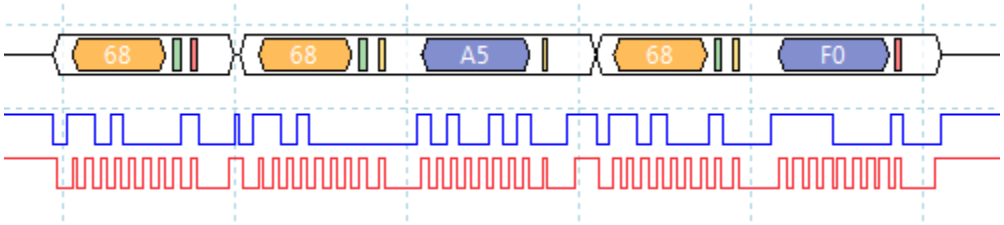
3.6.2 **Disable static and dynamic IIR filter.**

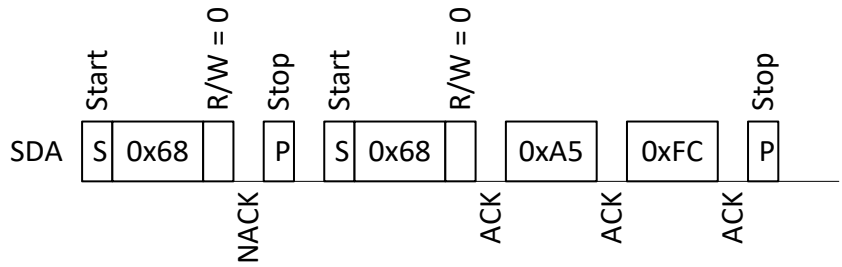
1. Start by reading register Meter control (0xA5).

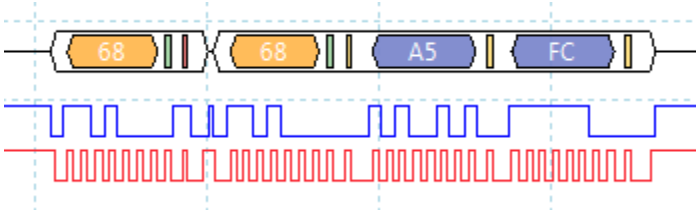




2. Set bit 2 and bit 3 in register Meter control (0xA5).

Meter control = 0xF0 => new Meter control = 0xF0 | 0xFC = 0xFC





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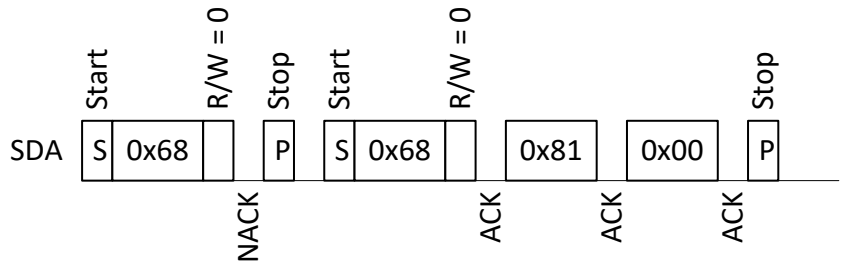
3.7. Calibration

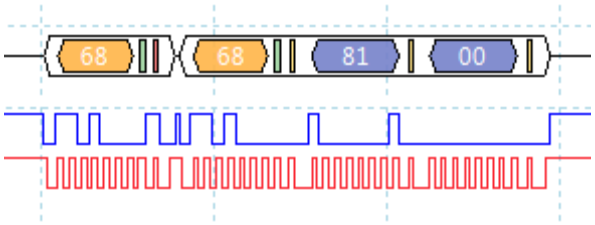
3.7.1 **Background Calibration**

Example how to background calibrate against gas of concentration specified in the ABC Target register (for CO_2: against fresh air or 400ppm CO_2) by trigging the background calibration and read calibration status after calibration.

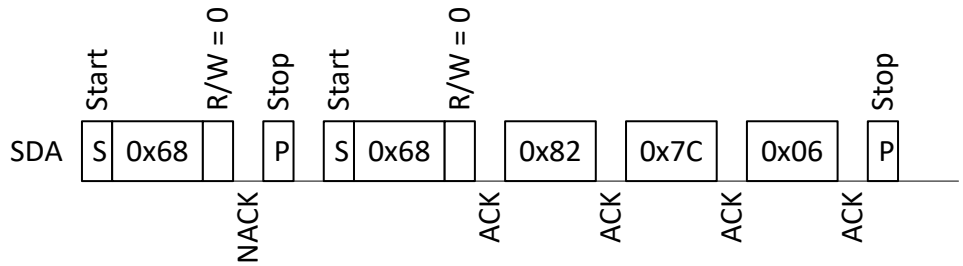
3.7.1.1. Continuous measurement mode

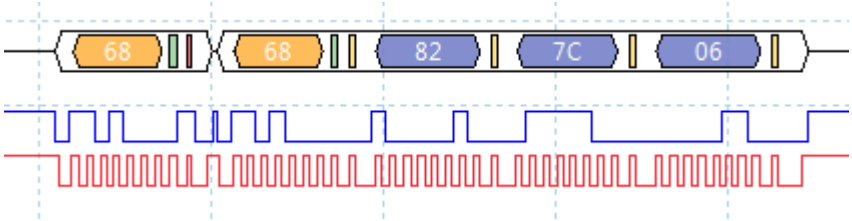
1. Start by clearing register Calibration Status (0x81)





2. Write background calibration command (0x7C06) to register Calibration Command (0x82)





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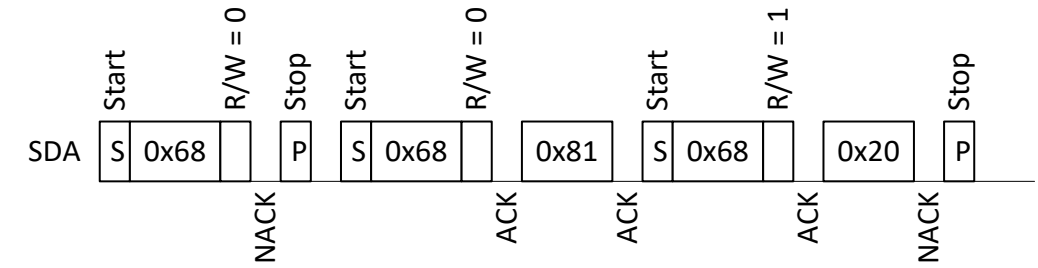
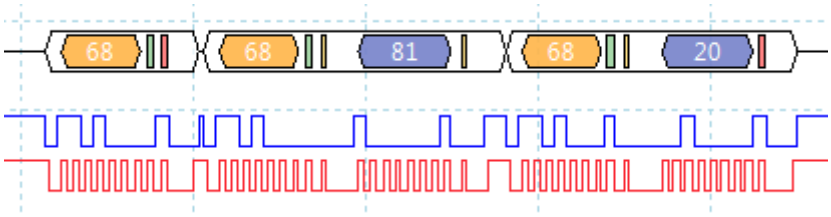
3. Read register Calibration Status (0x81)





Calibration status register = 0x20 means background calibration succeeded.

To achieve best possible result from a calibration it is important that the sensor is in a stable environment.

3.7.1.2. Single measurement mode

Flowchart presents the calibration sequence in single measurement mode.

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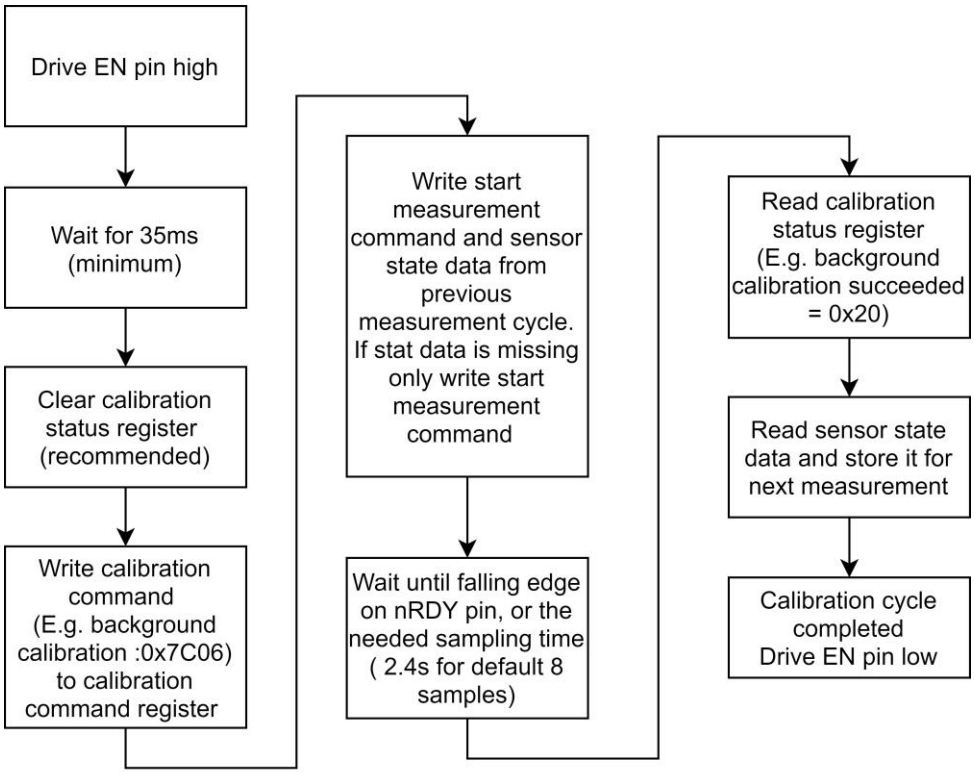

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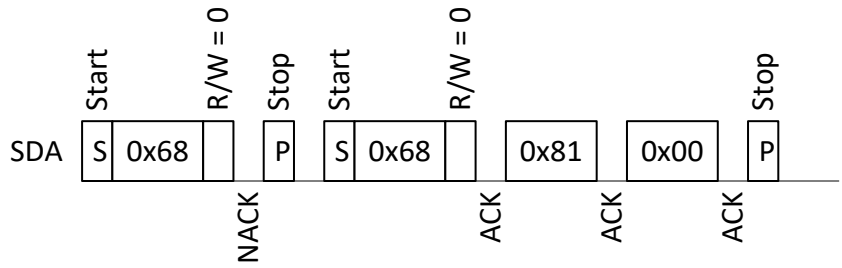
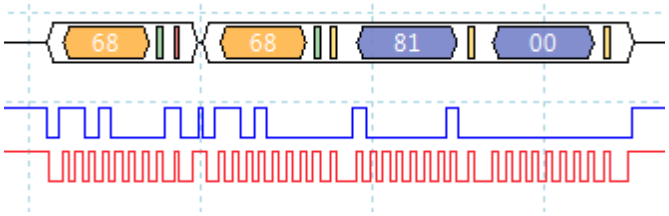
Target Calibration

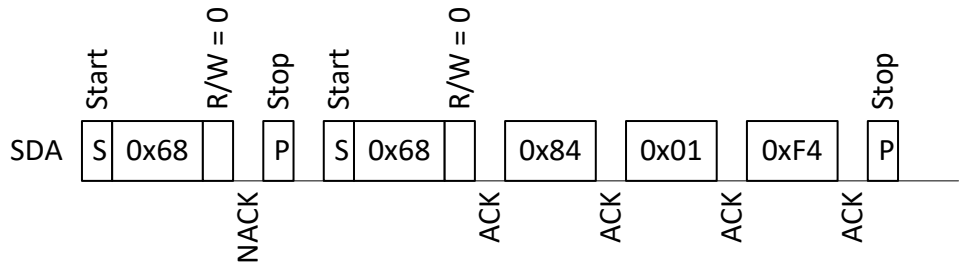
Example how to calibrate against target 500 ppm.

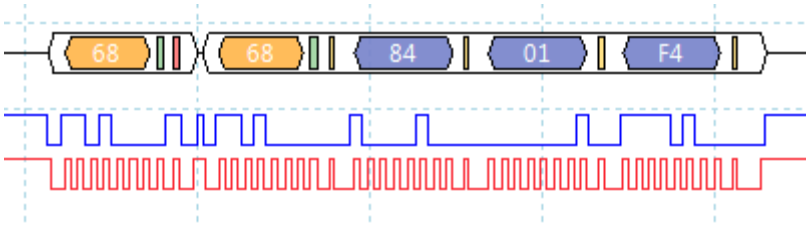
1. Start by clearing register Calibration Status (0x81)





2. Write calibration target 500 to register Calibration Target (0x84)





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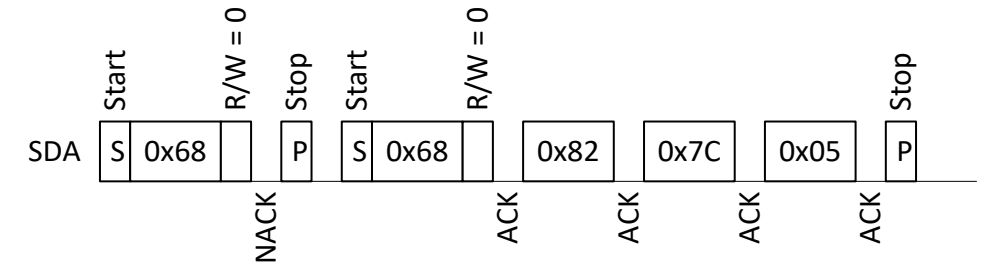
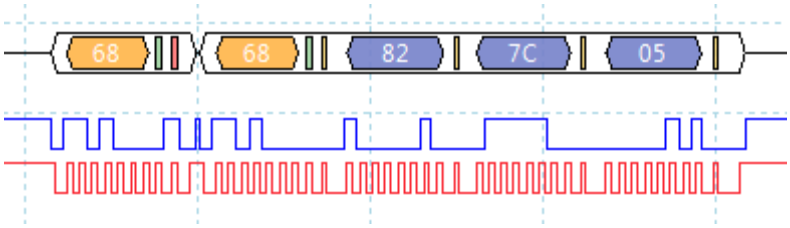
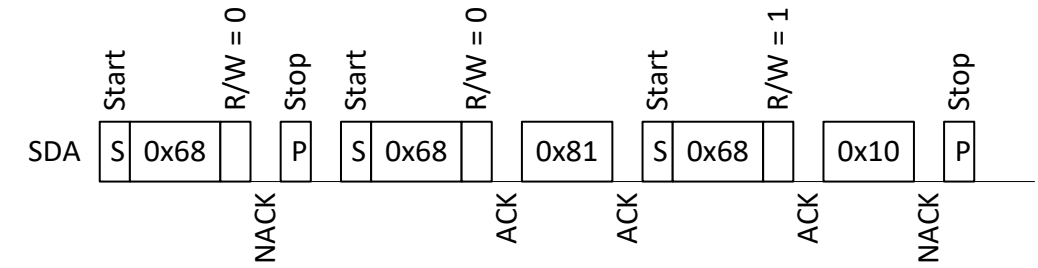
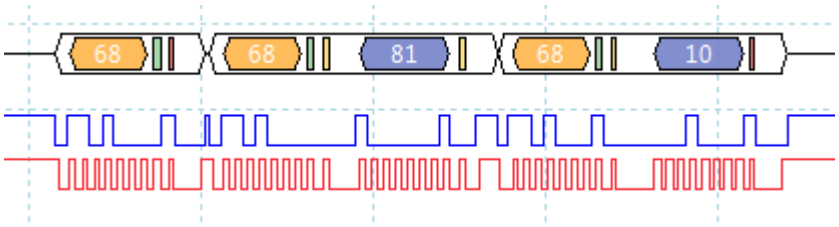
3. Write calibration command (0x7C05) to register Calibration Command (0x82)





4. Read status from register Calibration Status (0x81).





Calibration status register = 0x10 means target calibration succeeded.

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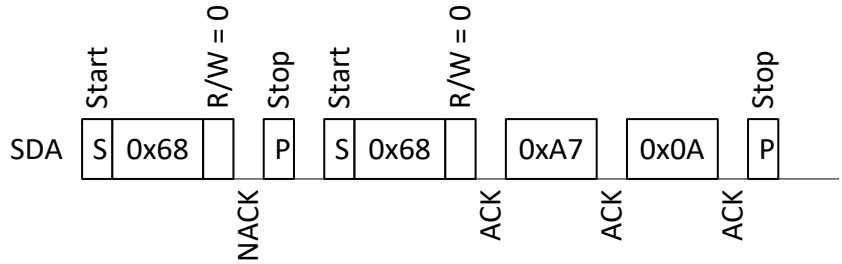
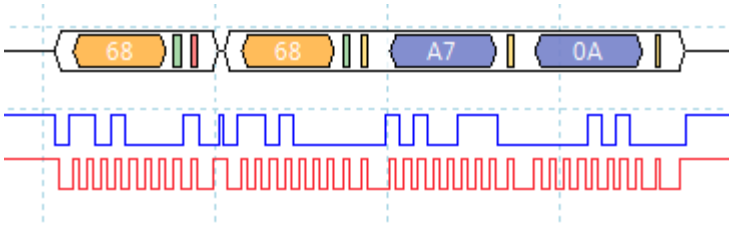
3.8. I²C address

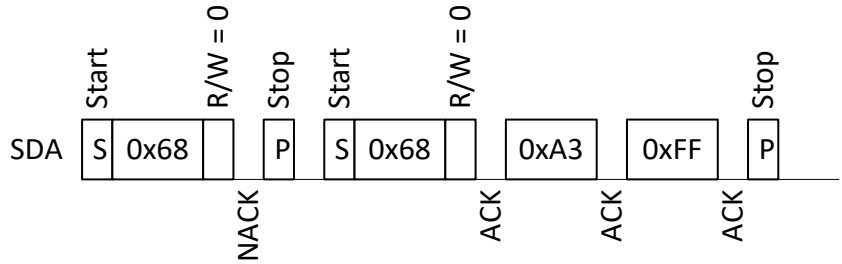
Set sensors I2C address to 10.

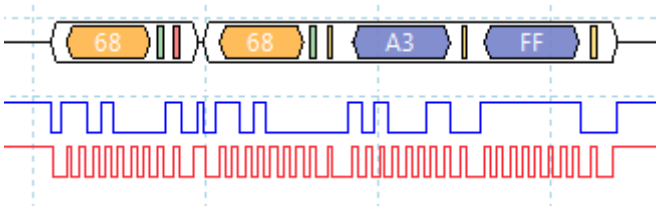
1. Write 10 to register MB/I2C (0xA7)





2. Write 0xFF to register SCR (0xA3) to reset sensor (still use address 0x68)





An alternative to write reset command is to power off/on the sensor.

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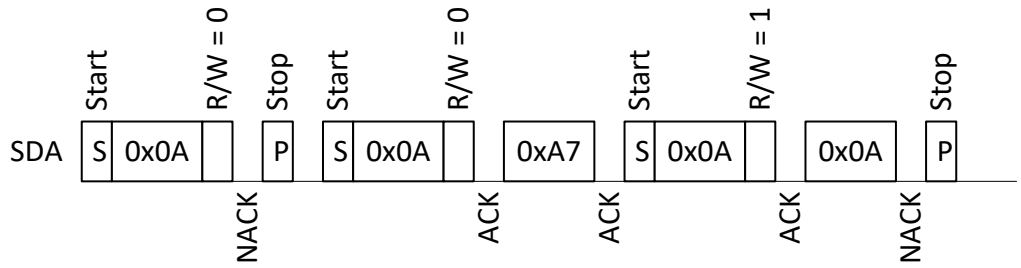
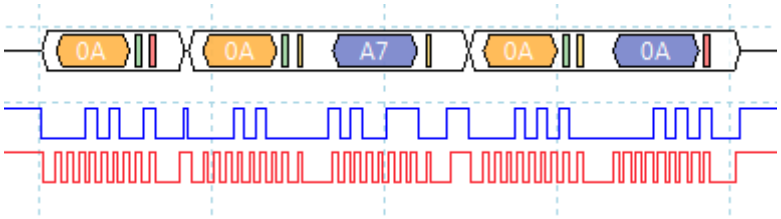
3. Read register MB/I2C (0xA7) using address 10.





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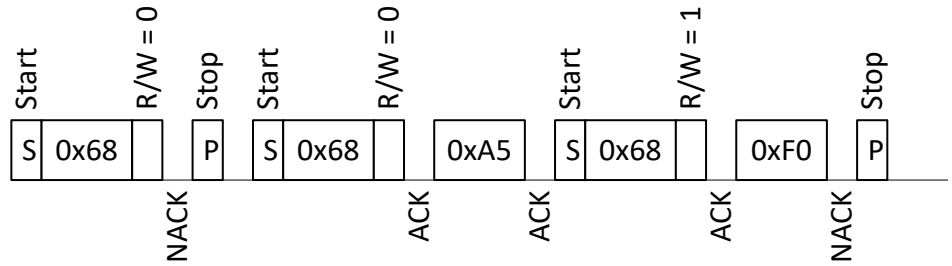
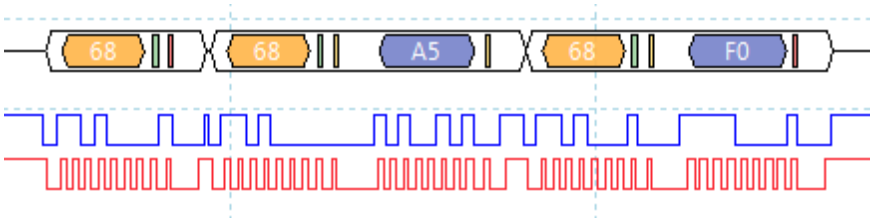
3.9. Enable/Disable pressure compensation

Enable and disable pressure compensation by writing to register Meter control (0xA5).

3.9.1 **Enable pressure compensation.**

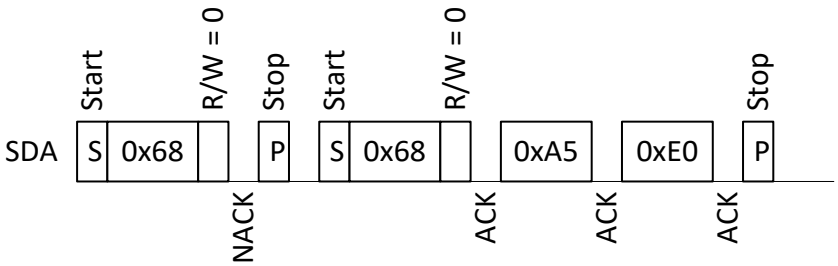
1. Start by reading Meter control.

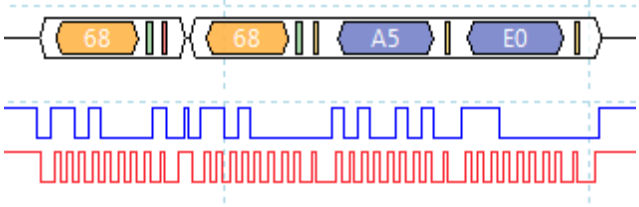




2. Clear bit4 in the register and write back

Meter control = 0xF0 => new Meter control value = 0xF0 & 0xEF = 0xE0





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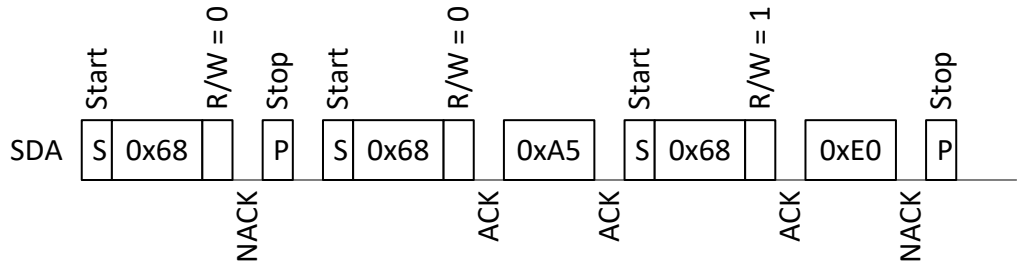
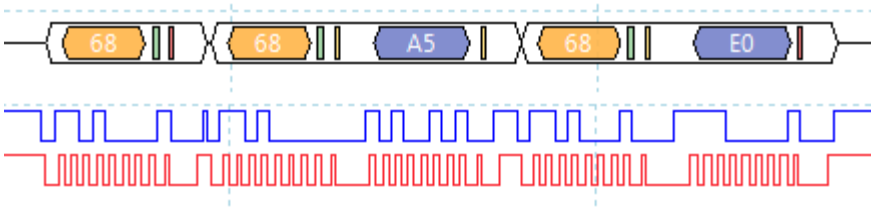
3.9.2 **Disable pressure compensation.**

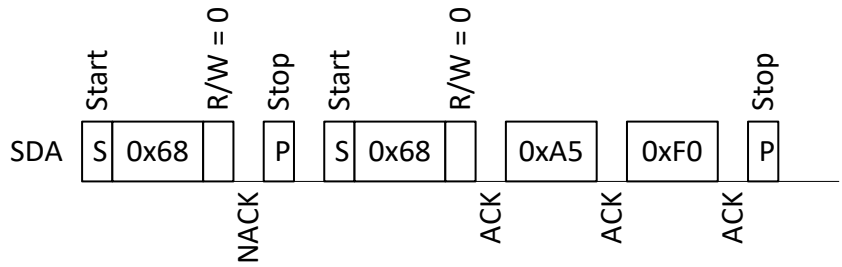
3. Start by reading register Meter control (0xA5).

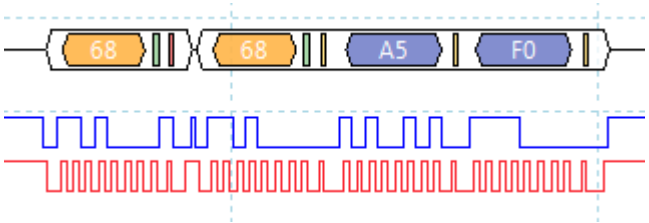




4. Set bit 4 in register Meter control (0xA5).

Meter control = 0xE0 => new Meter control = 0xE0 | 0xF0 = 0xF0





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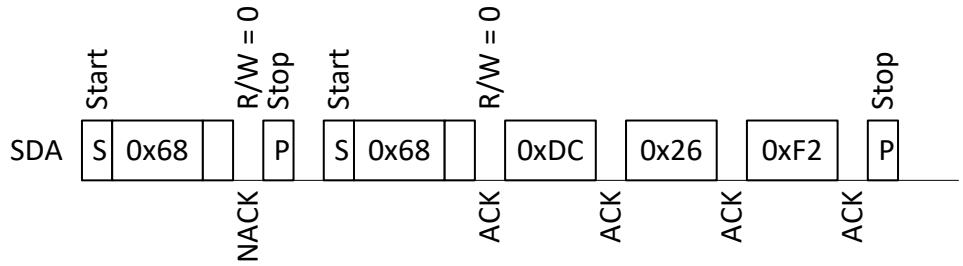
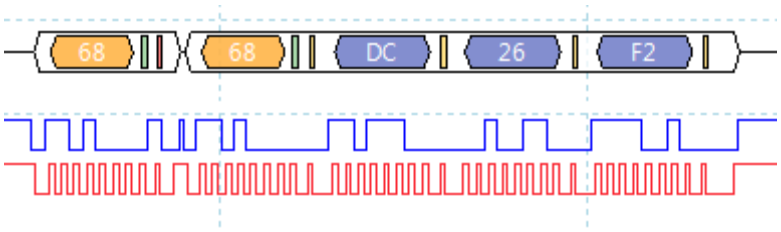
3.10. Write pressure to sensor

Write pressure 997 hPa to sensor. Sensor works with pressure unit 0.1 hPa so value to write to the sensor has to be calculated.

Value to write = 997 * 10 = 9970 = 0x26F2.

Write 9970 to barometric pressure register (0xDC, 0xDD)





If pressure compensation is enabled and a value has been written to address 0xDC 2byte, the sensor will pressure compensate gas. If value written to sensor is not in the range 3000 – 13000, the sensor will use 3000 or 13000 for the pressure compensation.

Pressure value written to the sensor will be used in the next gas calculation. In continuous measurement mode this means that it can take up to one measurement period before pressure compensated measured concentration is based on the new pressure value.

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3.11. Write scaling factor

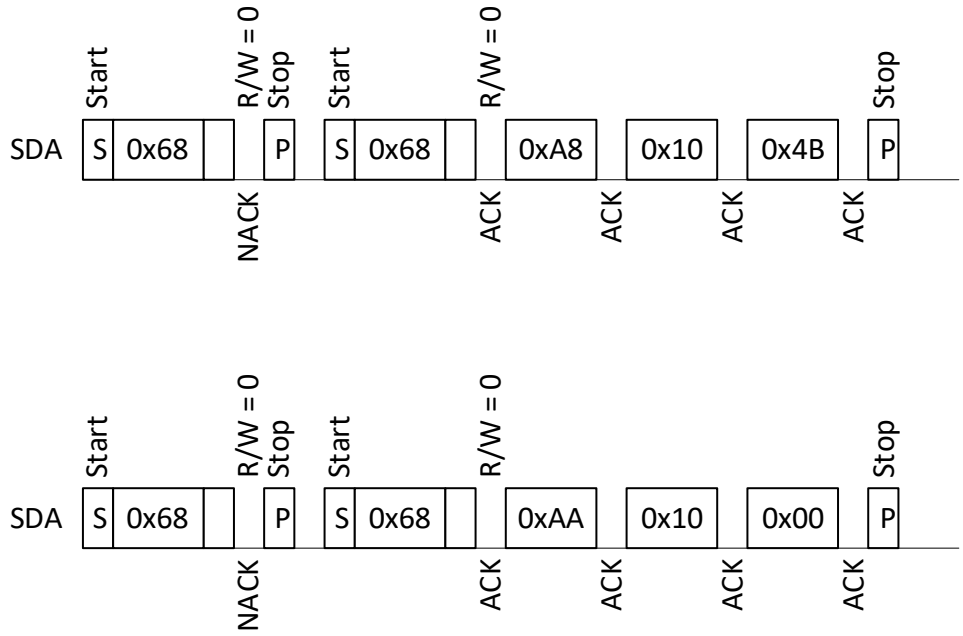
Note: Only applicable for firmware revision equal or above 4.10.

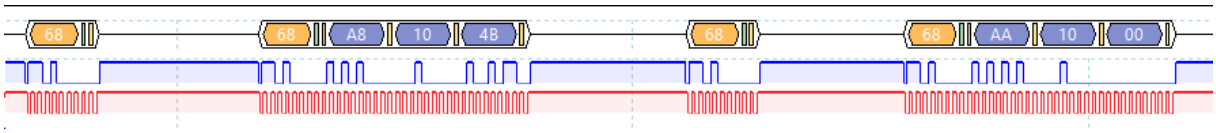
To change scaling factor, one shall write new scaling pair of values into 0xA8…0xAB registers. For example, if one wants to change representation of value in registers 0x1A...0x1B for Sunlight R32 sensor to %LFL for R454B gas (see Scaling factors from ppm to %LFL for common gases):

Values to write:

0xA8...0xA9 = 4171 (0x104B)

0xAA...0xAB = 4096 (0x1000)





Validate the writing after sensor reset (or by software command or by hardware reset):

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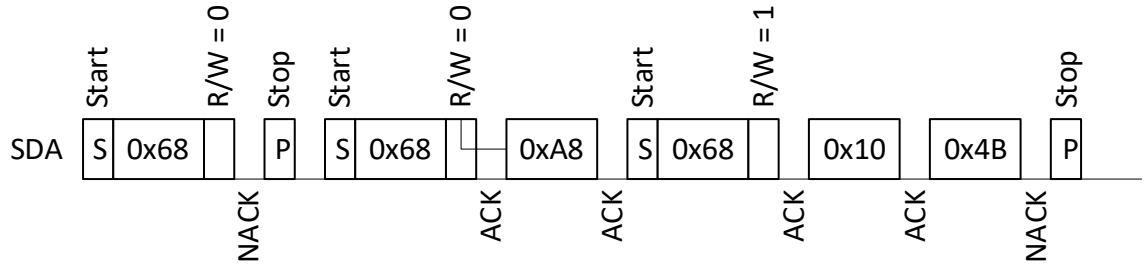

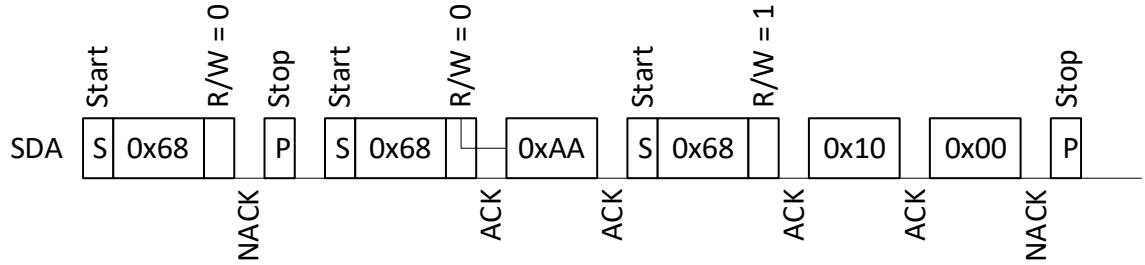

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4. Scaling factors from ppm to %LFL for common gases

The Sunrise/Sunlight sensors family has multiple variants of the articles for different gases and ranges.

To calculate the %LFL or ppm from the sensor reading one can use following formulas:

ppm:

$$ppm = Sensor_{reading} * K_{ppm}$$

%LFL:

$$\%LFL = Sensor_{reading} / K_{\%LFL} * 100\%$$

The sensor resolution in ppm ($Kppm$) and LFL scaling factor ($K\%LFL$) are product depended values, please consult with product specification regarding exact values - the table below shows these values for most common sensors:

Gas	Kppm, sensor resolution in ppm	K%LFL	Recommended concentration scale factor, nominator part (registers 0xA8...0xA9)	Recommended concentration scale factor, denominator part (registers 0xAA…0xAB)	%LFL LSB in registers 0x18…0x19
R32	10	144.4	22756	32768	0.01%
R454A	18.47	45.8	8943	4096	0.01%
R454B	12.06	98.2	4171	4096	0.01%
R454C	26.65	29.6	6919	2048	0.01%
R290	1	210	100	210	0.01%

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5. Revision history

Date	Revision	Page (s)	Description
2019-05-15	1-7	All	Sunrise FW rev. <=2.00, article number 006-0-0002
2021-03-23	17	9, 11, 12 17, 18, 35	Sunrise FW rev. >=3.00, article number 006-0-0007 Page 9 0x2F, Firmware type added Page 11 0x98 & 0x99, sample time changed from max 200ms to 300ms & instead of 0.2 it became 0.3 Page 12 0xA5, nRDY invert added Page 17 Figure10 - point 4 updated from 2s to 2.4s (Max measurement time with default settings). Page 18 Figure 11, - T_ (one sample + gas calculation) typical 180ms - Steady state current during sampling 99mA - MCU active current 10mA Page 35 Revision history added
2021-03-31	9	10, 14, 27	Page 10 0x82 & 0x83, Comments regarding calibration process in single measurement mode Page 14 0xDE & 0xDF, ABC pressure value Page 27 Calibration sequence flowchart in single measurement mode
2021-11-19	10	1, 8, 9,10 11, 12, 15, 17, 20, 26, 34	Page 1, 5, 6, 16, 17 Added “and Sunlight” alt. “/Sunlight”

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			Page 8, 9, 11, 15, 20, 34 — Changed ”CO2 value” to ”measured concentration” (except in figure 10 P 17 and 11 Page 18 = examples) Page 8, 9, 10, 12, 15, 26 — Changed ”CO2” to ”gas” Page 12 — Deleted ” Default value is 400 (400 ppm gas).” Page 26 — Added “for CO_2: against fresh air or 400ppm CO_2)” Changed sidefoot, new logo etc
2021-12-06	11	6 8 8 9 9 13 15 16 20	Update timing for EEPROM operations Description for “Low internal regulated voltage” bit changed Description for “Abnormal signal level” bit added Description for “Self-diagnostic” bit changed Description for “Out of range” bit changed Add note regarding rounding for “Number of samples” register Update description for “ABC Time” register Update description regarding wrirting time for EE registrers Remove “Current” graph from Figure 11
2022-02-11	12	21	Description for “Sensor state data do not exist” changed
2022-03-22	13	All	Modified terminology for inclusive language
2022-05-16	13	11	Updated description of register “CO2 concentration unfiltered”
2022-10-14	14		Changed logo

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2023-09-08	15	13 All	Added read only registers for Product Code, requires FW 4.08 or later. Update Figure references. Figure 2 was not a proper caption, resulting in offset by one for the rest.
2024-04-24	16	15,14 11	Add registers for scaled concentrations and calibration targets New error “Scale factor error” flag
2024-08-21	17	47 49	Example to set scaling factors Common scaling factors table

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