I²C on Senseair Sunrise

Senseair
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1. I²C protocol

I²C is a communication protocol invented by Philips Semiconductor for communication between a master (or multiple masters) and a single or multiple slave 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 salves and one master. 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.

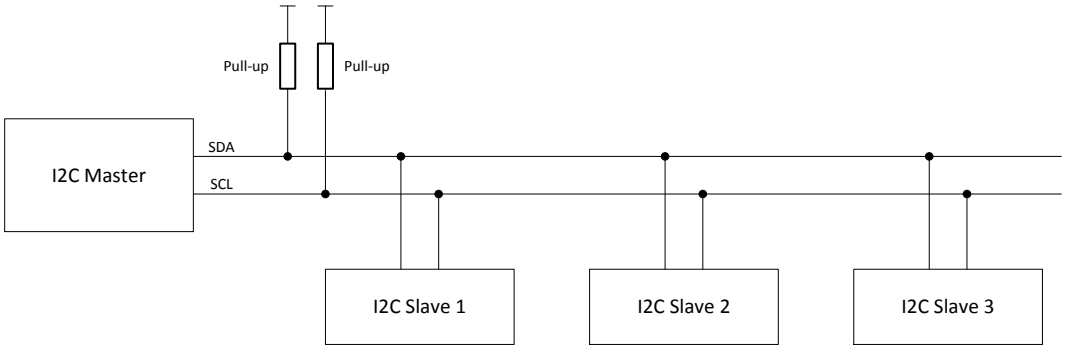


Figure 1, I²C Bus

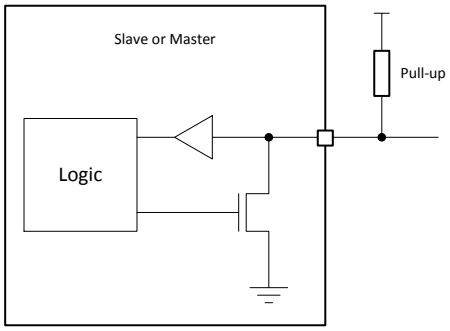


Figure 2, Structure of SDA/SCL ports

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 a master has written 8 bits to a slave the master releases SDA and the slave 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.

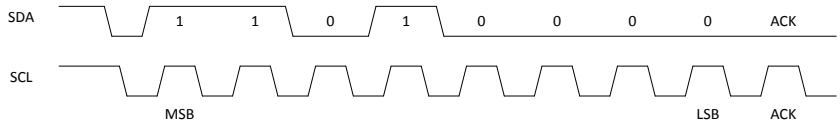


Figure 4, 0xD0 (11010000b) and ACK

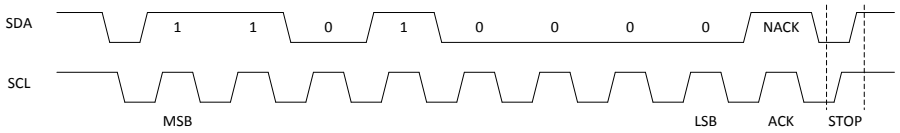


Figure 5, 0xD0 (11010000b), NACK and STOP

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 master wants to write to the slave, if least significant bit is 1 it means that the master wants to read from the slave. When least significant bit is 1 the slave is intended to take control of SDA from next byte, but the master still controls SCL. When the master wants to stop reading from the slave it will NACK last byte sent by the slave and send a STOP condition.

If a receiving device, master or slave, 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.

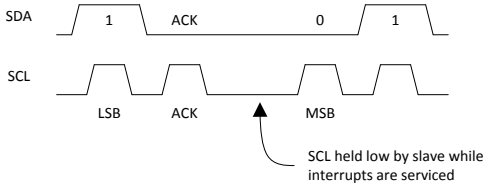


Figure 6, Clock stretching

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 I2C-Bus specification and Manual Rev 6, NXP semiconductors

[2] TDE7318, Sunrise user guideline

2. I²C on Senseair Sunrise

2.1. I²C settings

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

Table 1, Senseair Sunrise I²C settings

Parameter	Value	Description
Master/slave mode	Slave	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
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	<25ms	Writing one register to sensors EEPROM can take up to 25ms, If sensor is powered down when EEPROM write operations are ongoing it may result in corrupt parameters.
Writing time to RAM	<1ms	

Since Senseair Sunrise 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 spend most of its time in deep sleep mode to minimize power consumption, this have the effect that it is necessary to wake up the sensor before it is possible to communicate with it. 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.

Communication sequence:

1) Wake up sensor by sending sensor address (START, sensor address, STOP). Sensor will not ACK this byte.

2) Normal I2C 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.

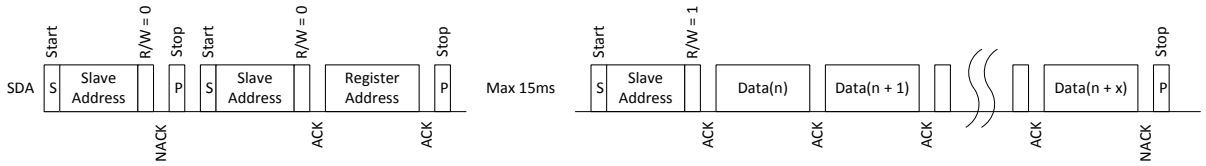


Figure 7, Reading from Senseair Sunrise after wake up

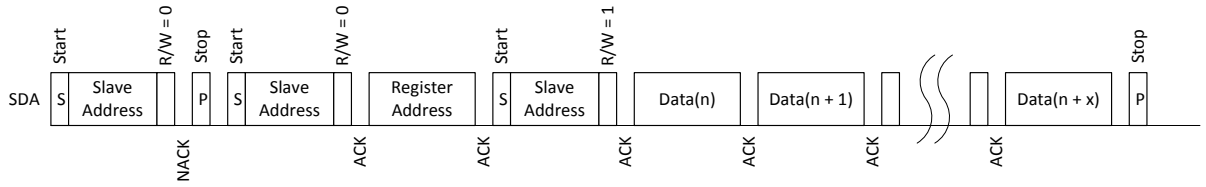


Figure 8, Reading from Senseair Sunrise after wake up using repeated start

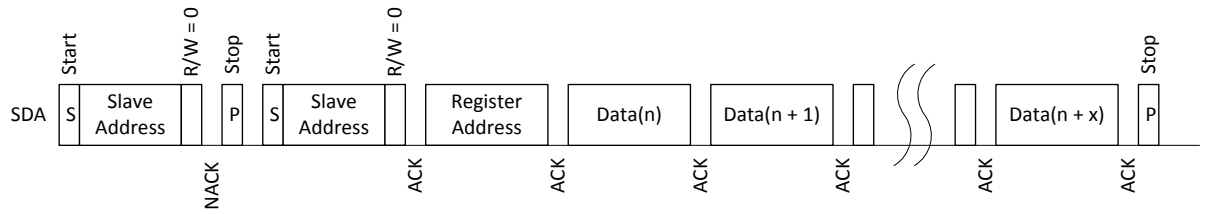


Figure 9, Writing to Senseair Sunrise

2.2. I²C register map

I²C registers are categorised into two groups, which are Table 2 I2C read only registers and Table 3 I2C read/write registers

Table 2 I2C read only registers

Name	Register number / Address	Description (read only registers)		
ErrorStatus	0x00 (MSB)	**Bit**	**Error description**	**Suggested action**
		0	**Low internal regulated voltage** Flag is set if sensors regulated voltage is too low, this means supply voltage is lower than 2.8V.	Check power supply.
		1	**Measurement timeout** Flag is set if sensor is unable to complete the measurement in time.	Flag is cleared after a successful measurement. If flag is set permanently try to restart sensor by power on/off. Contact local distributor.
		2	Reserved	
		3	Reserved	
		4	Reserved	
		5	Reserved	
		6	Reserved	
		7	Reserved	
	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,	Try to repeat calibration. Ensure that the environment is stable during calibration.

<table>
<tr><td></td><td></td><td><table>
<tr><td></td><td>background or target calibration).</td><td></td></tr>
<tr><td>4</td><td>Self-diagnostics error
Indicates internal interface failure.</td><td>Try to restart sensor by power on/off.
Contact local distributor.</td></tr>
<tr><td>5</td><td>Out of range
Indicates that the measured concentration is outside the sensor’s measurement range</td><td>Perform suitable CO_2 calibration (zero, background or target calibration).
Contact local distributor.</td></tr>
<tr><td>6</td><td>Memory error
Error during memory operations</td><td>Try to restart sensor by power on/off.
Contact local distributor.</td></tr>
<tr><td>7</td><td>No measurement completed
Bit set at startup, cleared after first measurement</td><td>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</td></tr>
</table></td></tr>
<tr><td>Reserved</td><td>0x02</td><td></td></tr>
<tr><td>Reserved</td><td>0x03</td><td></td></tr>
<tr><td>Reserved</td><td>0x04</td><td></td></tr>
<tr><td>Reserved</td><td>0x05</td><td></td></tr>
<tr><td rowspan="2">CO_2 Value Filtered & pressure compensated</td><td>0x06 (MSB)</td><td rowspan="2">Filtered pressure compensated CO_2 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)
Pressure compensated value can exceed 10000ppm.
See [2] for details about IIR filtration and pressure compensation</td></tr>
<tr><td>0x07 (LSB)</td></tr>
<tr><td rowspan="2">Temperature</td><td>0x08 (MSB)</td><td rowspan="2">Chip temperature. Signed 16 bit value, unit °C x100. For example, register value = 2223 means 22.23°C.</td></tr>
<tr><td>0x09 (LSB)</td></tr>
<tr><td>Reserved</td><td>0x0A</td><td></td></tr>
<tr><td>Reserved</td><td>0x0B</td><td></td></tr>
<tr><td>Reserved</td><td>0x0C</td><td></td></tr>
<tr><td>Measurement count</td><td>0x0D</td><td>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 CO_2 value was read.</td></tr>
</table>

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)	
CO_2 Value Unfiltered pressure compensated	0x10 (MSB)	Unfiltered pressure compensated CO_2 concentration. Signed 16 bit value, unit ppm.
	0x11 (LSB)	Addresses 0x06 2bytes & 0x10 2 bytes are equal if pressure compensation is disabled at 0xA5 (default)
CO_2 Value Filtered	0x12 (MSB)	Filtered CO_2 concentration. Signed 16 bit value, unit ppm. See [2] for details about IIR filtration.
	0x13 (LSB)	
CO_2 Value Unfiltered	0x14 (MSB)	Unfiltered CO_2 concentration. Signed 16 bit value, unit ppm.
	0x15 (LSB)	
Firmware rev.	0x38 (MSB)	Firmware main revision
	0x39 (LSB)	Firmware sub revision
Sensor Id	0x3A (MMSB)	Sensor Id. Unsigned 32 bit value.
	0x3B (MLSB)	
	0x3C (LMSB)	
	0x3D (LLSB)	
Reserved	0x3E	
Reserved	0x3F	

Table 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. After having performed the calibration all following measurements will use the adjusted calibration parameters
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></td><td></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 CO_2 as calibration target.</td></tr>
</table></td></tr>
<tr><td>0x83 (LSB)</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 rowspan="2">CO_2 Value Override</td><td>0x86 (MSB)</td><td rowspan="2">Default value = 32767 (no override). If a value lower than default is written to the register both filtered and unfiltered CO_2 value will be set to this value after next measurement.</td></tr>
<tr><td>0x87 (LSB)</td></tr>
</table>

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 increment this value every hour.**
	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. A system reset is required after changing measurement mode.
Measurement Period (EE)	0x96 (MSB)	Measurement period in seconds (range from 2 to 65534). Odd numbers will be rounded up to nearest even number. A system reset is required after changing configuration. Default value is 16. Note: Measurement period is only used in continuous measurement mode
	0x97 (LSB)	
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. A system reset is required after changing configuration. Default is 8 samples. One sample takes < 200ms, this means that “Number of samples” * 0.2s should be less than or equal to time between measurements. If time for executing all samples in a measurement is longer than time between measurements, sensor will execute all samples and after that start a new measurement. This means that actual time between measurements will be longer than expected.
	0x99 (LSB)	
ABC period (EE)	0x9A (MSB)	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.
	0x9B (LSB)	
Reserved	0x9C	
Clear ErrorStatus	0x9D	Write any numbers to this register to clear the ErrorStatus

<table>
<tr><td rowspan="2">ABC Target (EE)</td><td>0x9E (MSB)</td><td rowspan="2">Target value for background and ABC calibrations (ppm CO_2). Default value is 400 (400 ppm CO_2).</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>
<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></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/I2C 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</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<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 respective read 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>
<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 increment this value every hour.</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="6">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 sensor after each power on (enable) before a new measurement is trigged.</td></tr>
<tr><td>0xCF (LSB)</td></tr>
<tr><td rowspan="2">Filter Par1</td><td>0xD0 (MSB)</td></tr>
<tr><td>0xD1 (LSB)</td></tr>
<tr><td rowspan="2">Filter Par2</td><td>0xD2 (MSB)</td></tr>
<tr><td>0xD3 (LSB)</td></tr>
</table>

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)	
Reserved	0xDE	
Reserved	0xDF	

Registers with (EE) after their names use sensors EEPROM, this means that to 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. All new written data to register (EE) can be read back after a sensor reset is completed.

It can take up to 25ms to write one (EE) register (one or two bytes). When write operations are ongoing 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. It is very important that the sensor is not powered down when write operations are ongoing, doing so may result in corrupt parameters.

Writing several bytes to sensors EEOPROM it’s important to wait until all bytes are written.

Write time for registers mapped to sensors RAM (all registers not marked with EE) is less than 1ms.

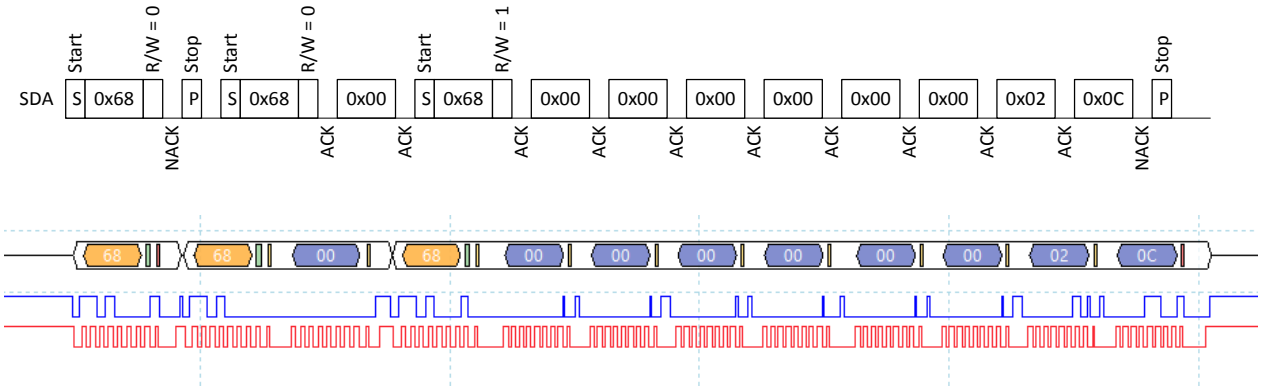
Registers marked as “Reserved” can be read and written, however it is strongly recommended to not use these registers.

3. Examples

3.1. Read Error Status and CO_2

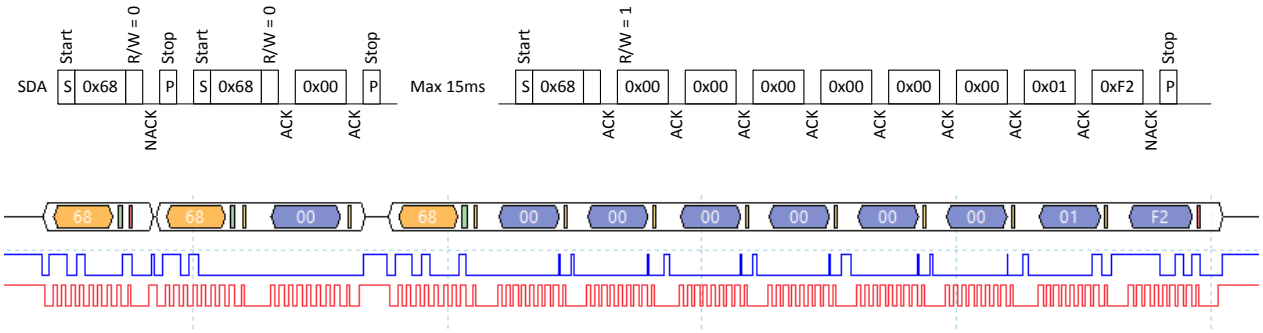
Reading Error Status and filtered CO_2 value (Error Status, 4 reserved bytes, CO_2).

3.1.1 **Example using repeated start:**



In example Error Status = 0 (no error flags set) and CO_2 = 0x020C (524d).

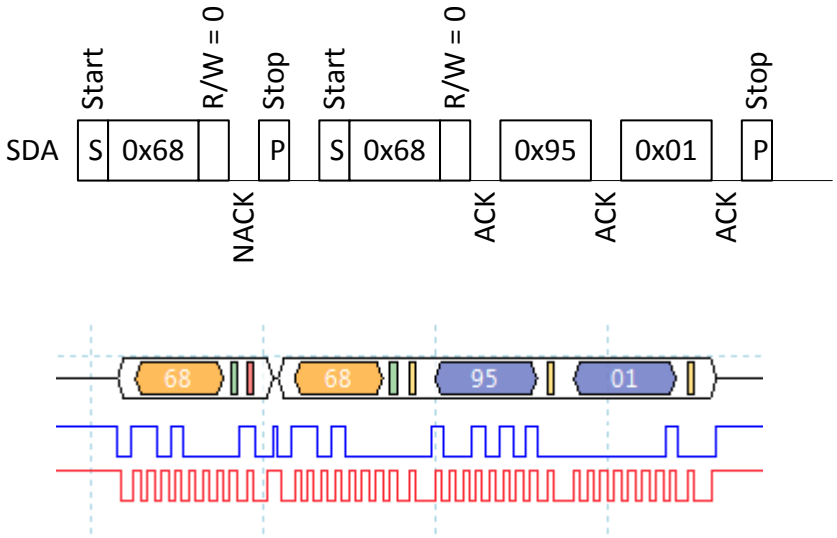
3.1.2 **Example not using repeated start:**



In example Error Status = 0 (no error flags set) and CO_2 = 0x01F2 (498d).

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.

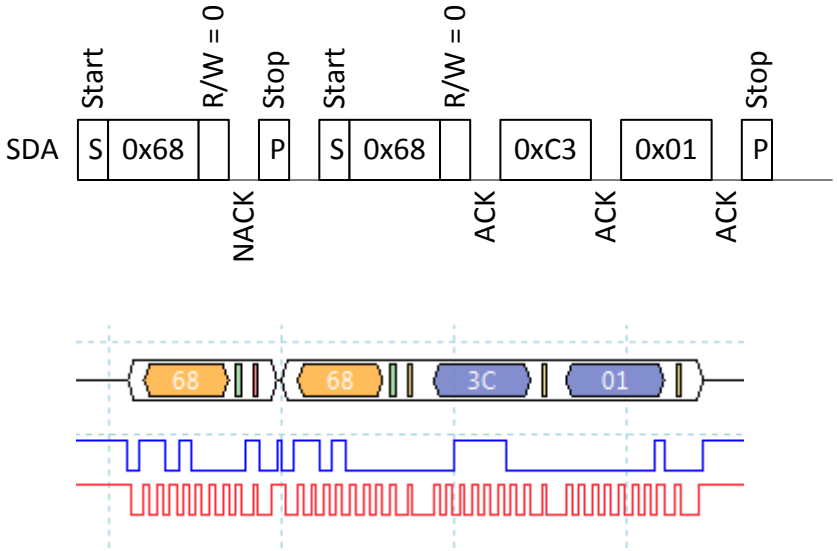


3.3. Start single measurement

The single measurement command can be used if a host wants to control when Senseair Sunrise 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.

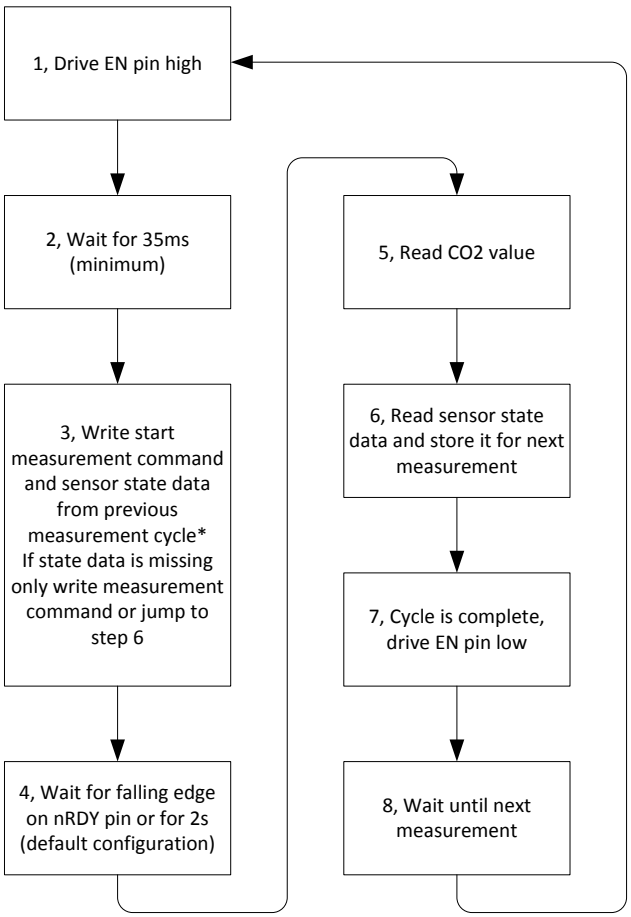
Write 1 to register Start Single Measurement (0xC3 or 0x93).



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

To minimize power consumption one can power down Senseair Sunrise between measurements 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 before it is powered down and to write these registers back after it is powered on.

Following sequence can be used when powering down/disable the sensor between measurements.



*If start measurement command and state data is written in two separate write sequences, state data must be written before start measurement command

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

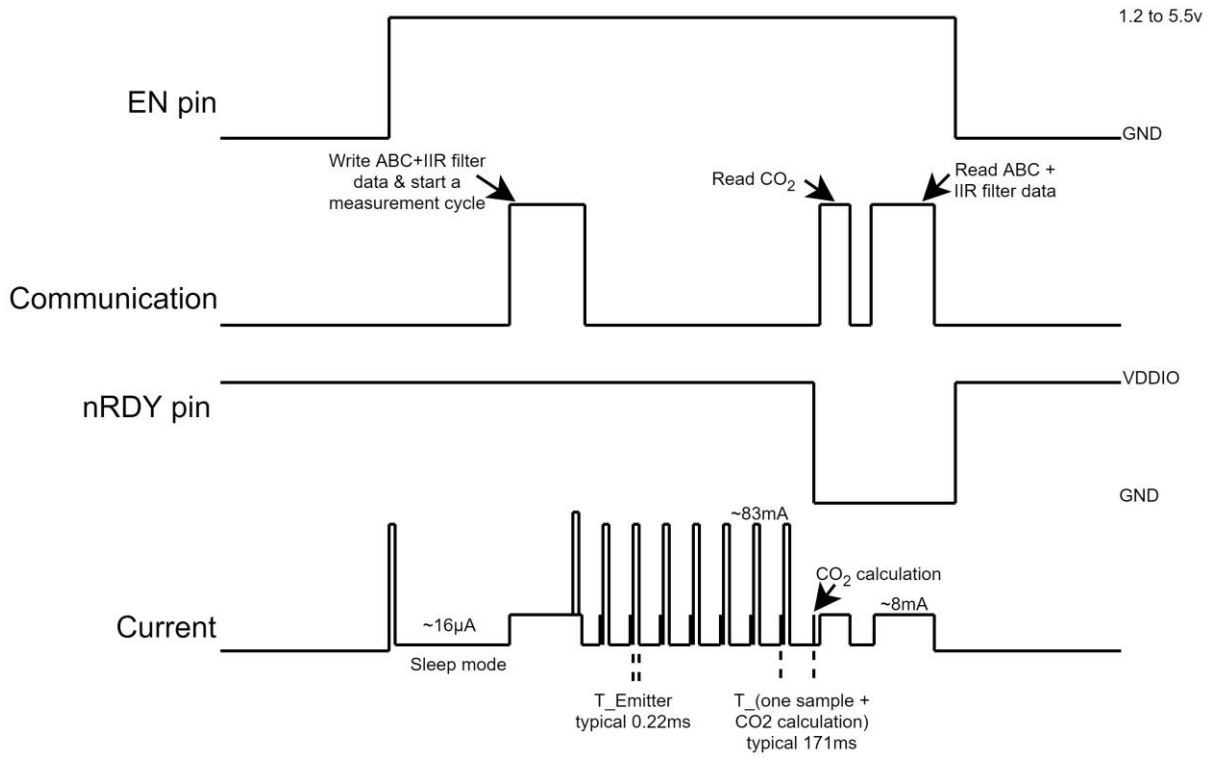


Figure 11, Timing diagram for single measurement mode

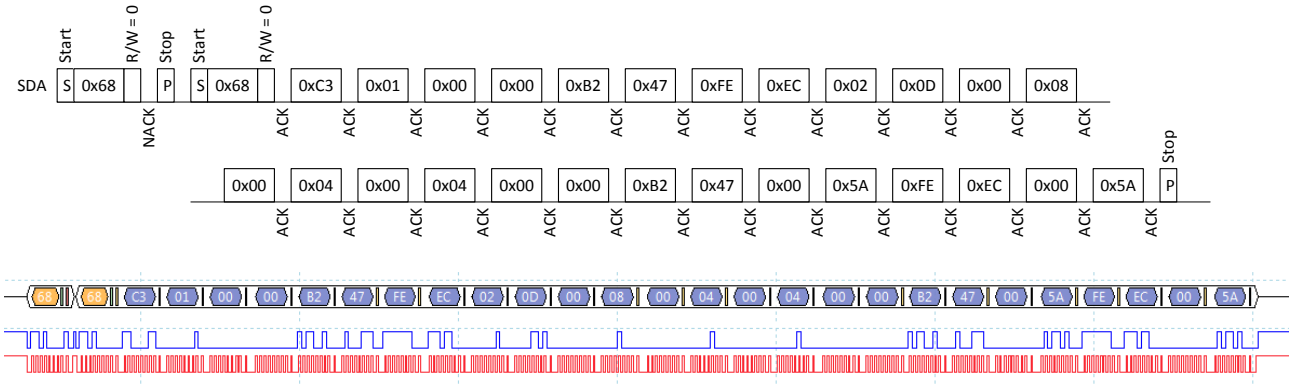
1 Drive EN pin high (>1.2V)

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

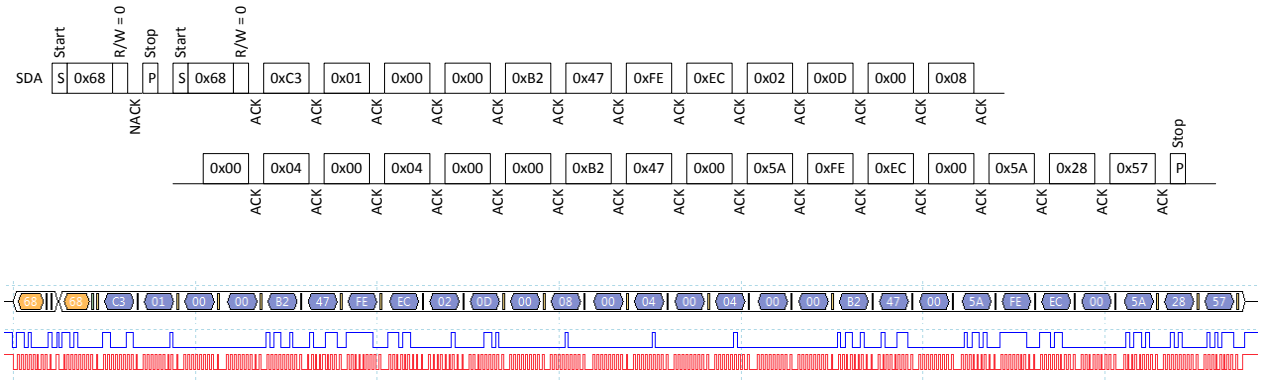
3 If state data exist go to point 3.1, otherwise go to point 3.2

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).



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



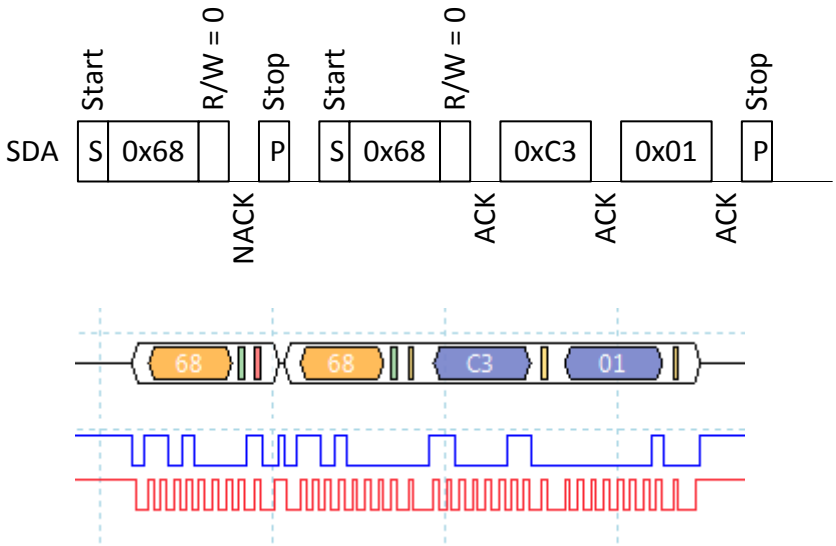
3.2 Sensor state data do not exist.

If host device has no state data, it is very important that host do not write “0” to address 0xC2 - 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).

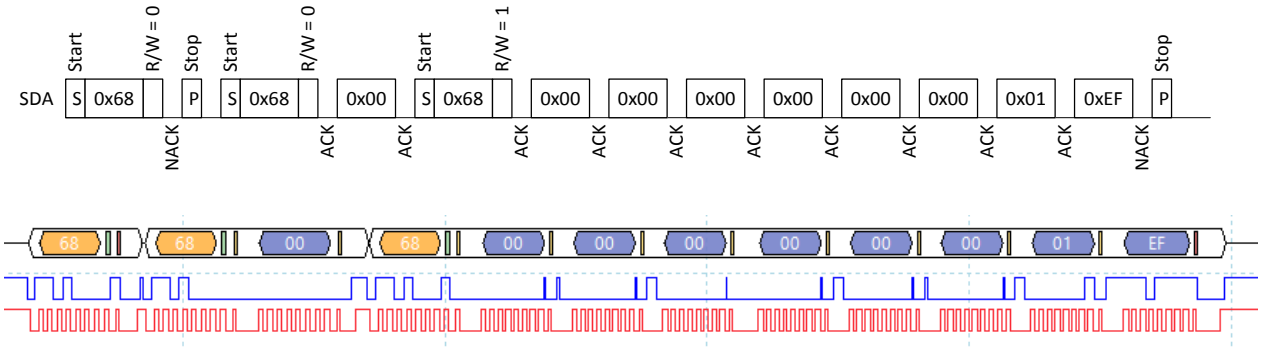
If pressure compensation is enabled write pressure to Barometric air pressure register before writing the start measurement command.



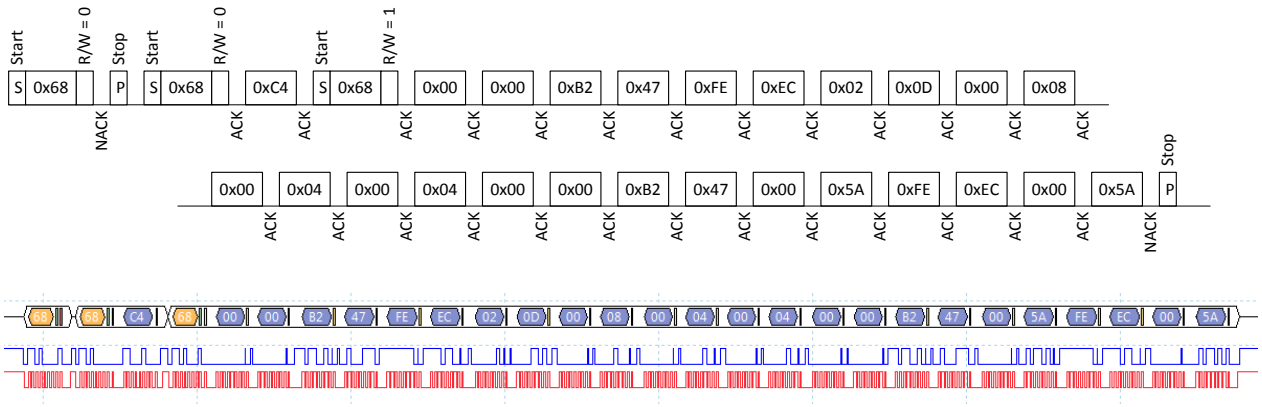
b) Jump to point 6 immediately to read and save state data from the sensor before the initial measurement.

4 Wait until ready pin goes low or 2s (for default configuration)

5 Read eight bytes starting from address 0x00 (first two bytes = Error Status, last two bytes = CO_2 value).



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



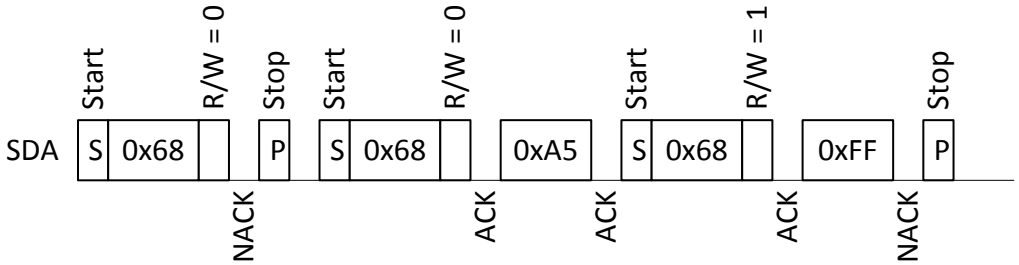
7 Drive EN pin low (<0.4V)

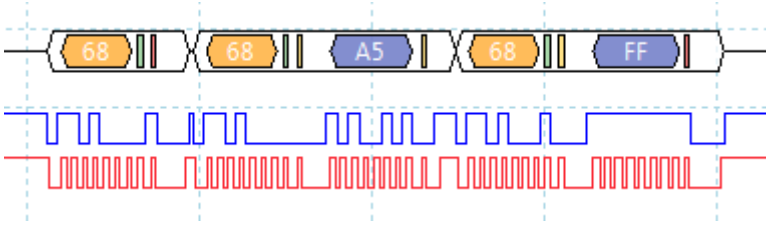
3.5. Enable/Disable ABC

3.5.1 **Enable ABC:**

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

1.1 Start to read address 0xA5.

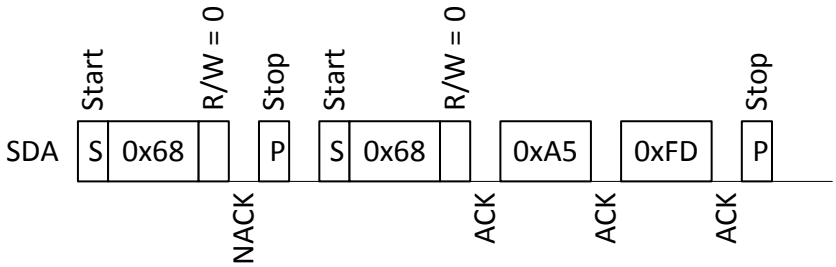


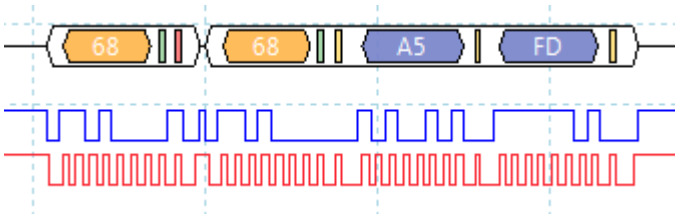


1.2 Clear bit1 in register and write back

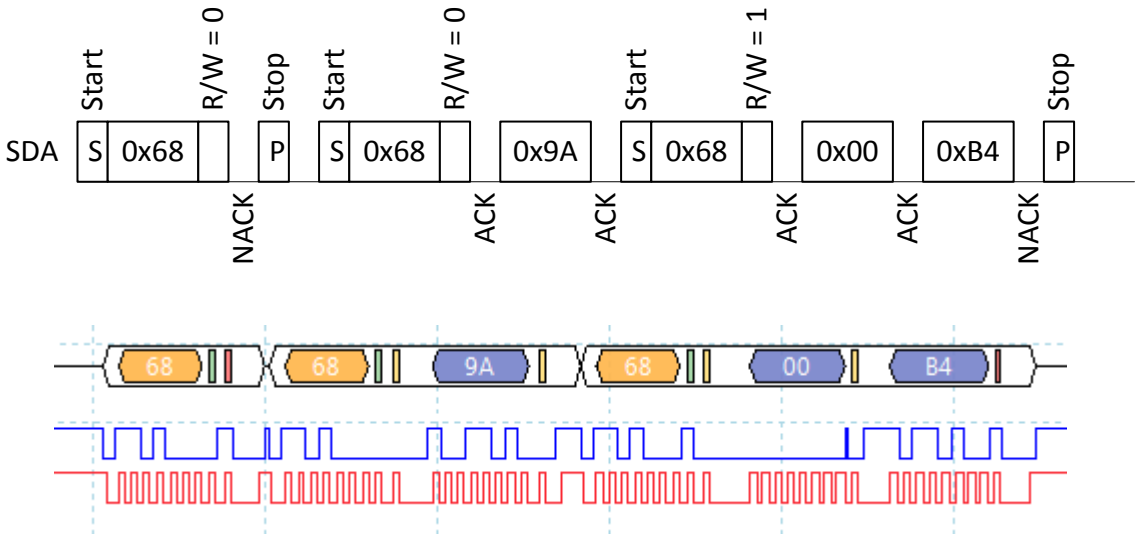
Meter control = 0xFF => new Meter control value = 0xFF & 0xFD = 0xFD

1.3 Write back new Meter control value.



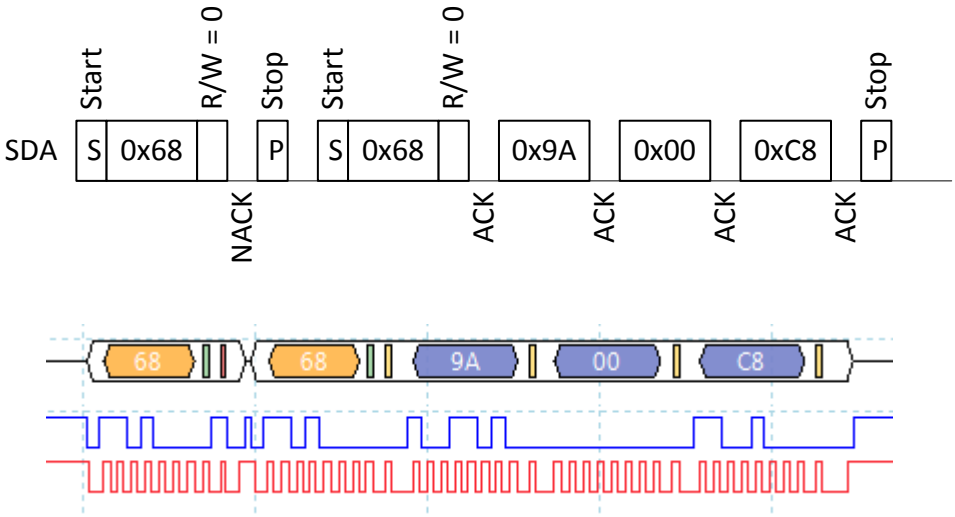


2. Read register ABC period (0x9A, 0x9B) and verify that it is desired ABC period.



ABC period = 0x00B4 = 180 hours

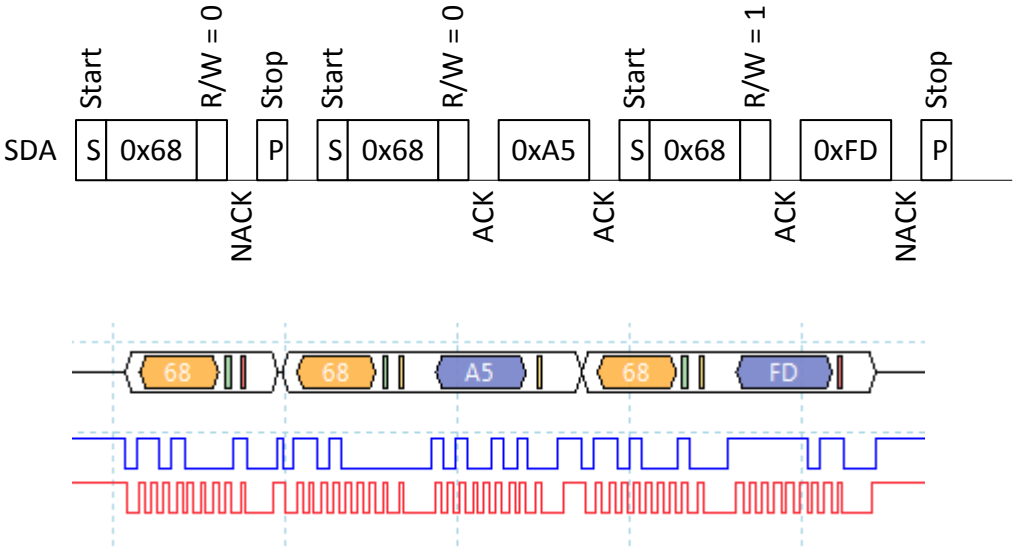
3. If ABC period needs to be changed write wanted ABC period in hours to register ABC period (0x9A, 0x9B), in this example ABC period is set to 200 hours.



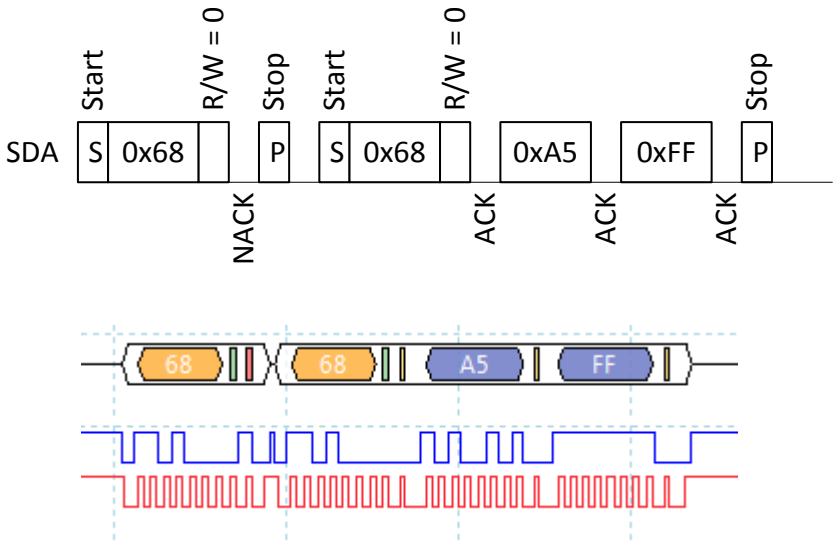
3.5.2 **Disable ABC:**

Set bit1 in register Meter control (0xA5)

1. Start to read 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.



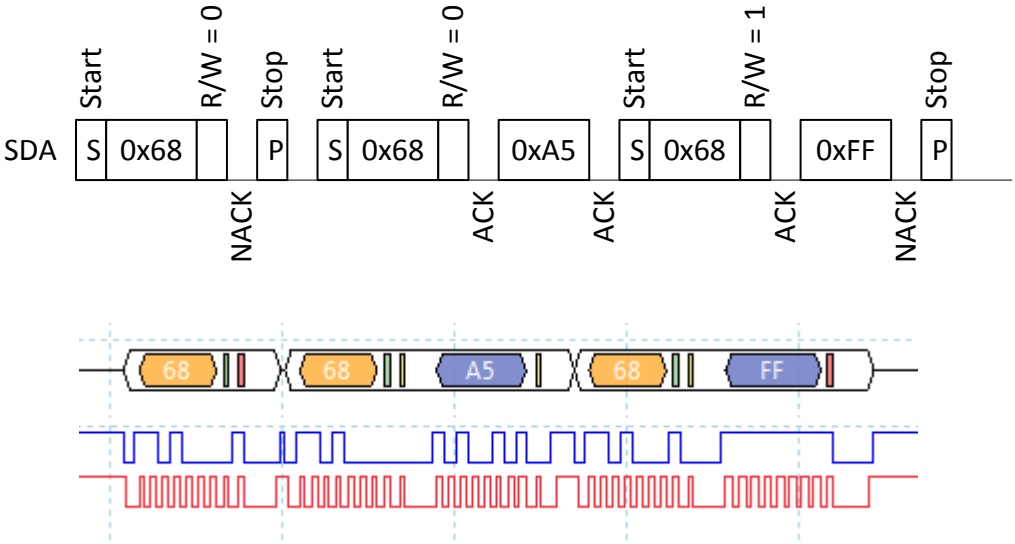
A possible alternative is to set register ABC period to zero, but then information about what ABC period to use must be saved to be able to enable ABC in future.

3.6. Enable/Disable dynamic IIR filter

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

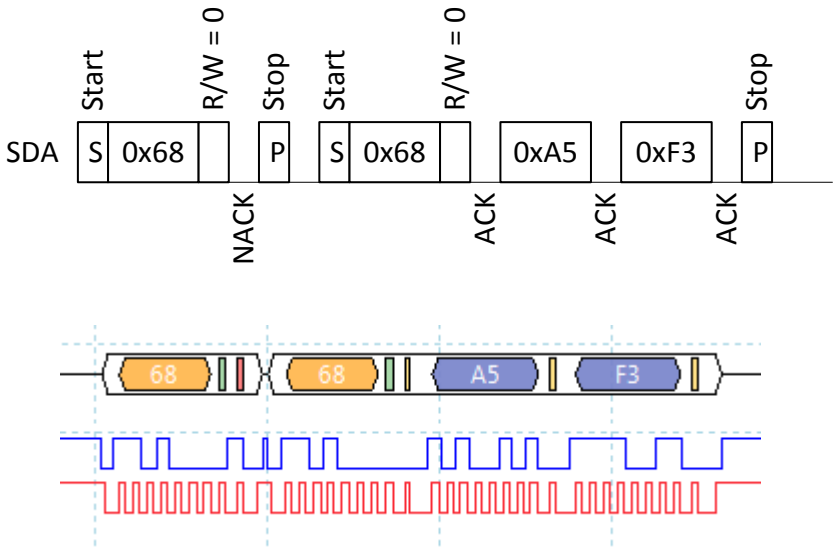
3.6.1 **Enable dynamic IIR filter.**

1. Start to read Meter control.



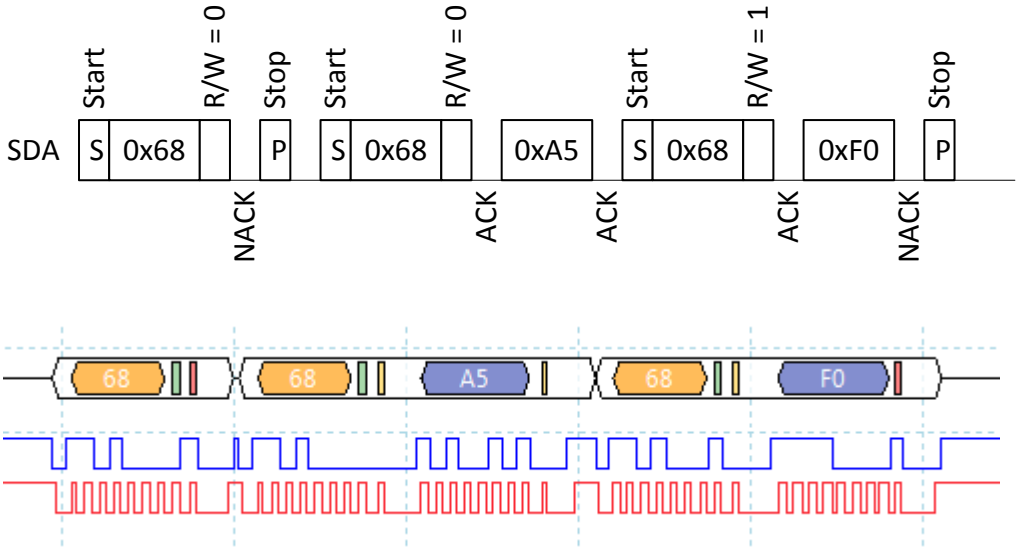
2. Clear bit2 and bit3 in register and write back

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

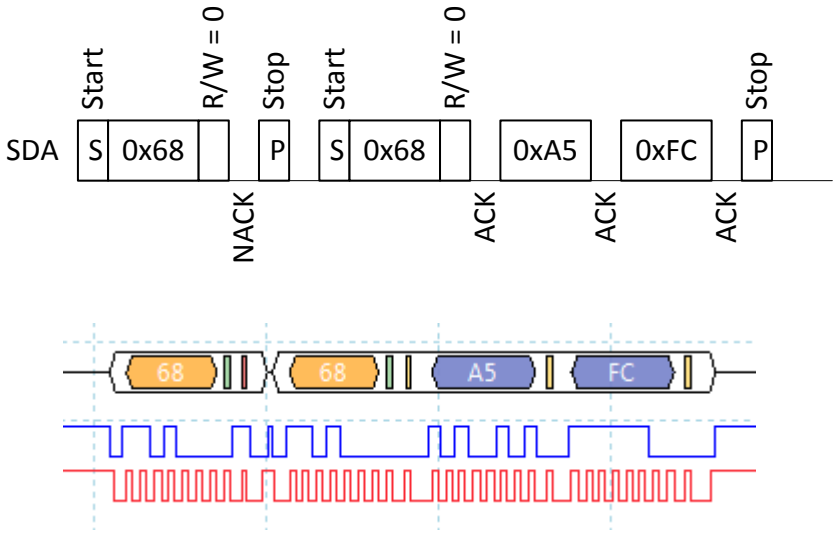


3.6.2 **Disable static and dynamic IIR filter.**

1. Start to read 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

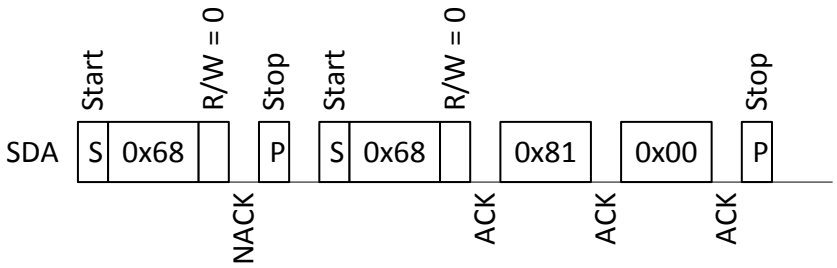


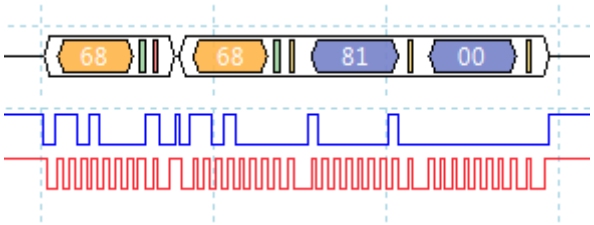
3.7. Calibration

3.7.1 **Background Calibration**

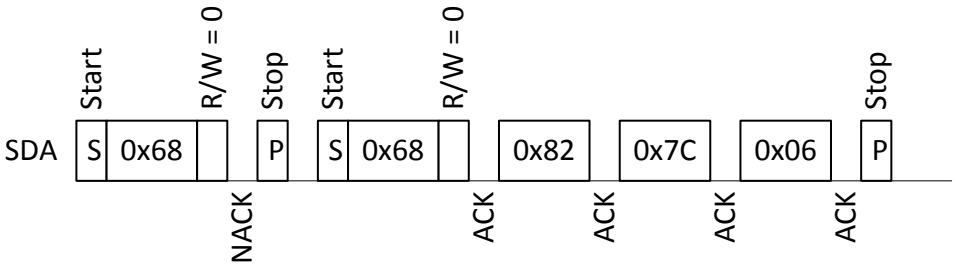
Example how to background calibrate against fresh air or 400ppm CO_2 concentration by trigging the background calibration, read calibration status and CO_2 value after calibration.

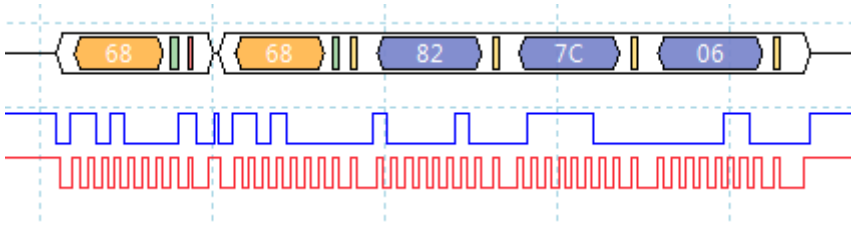
1. Start to clear register Calibration Status (0x81)



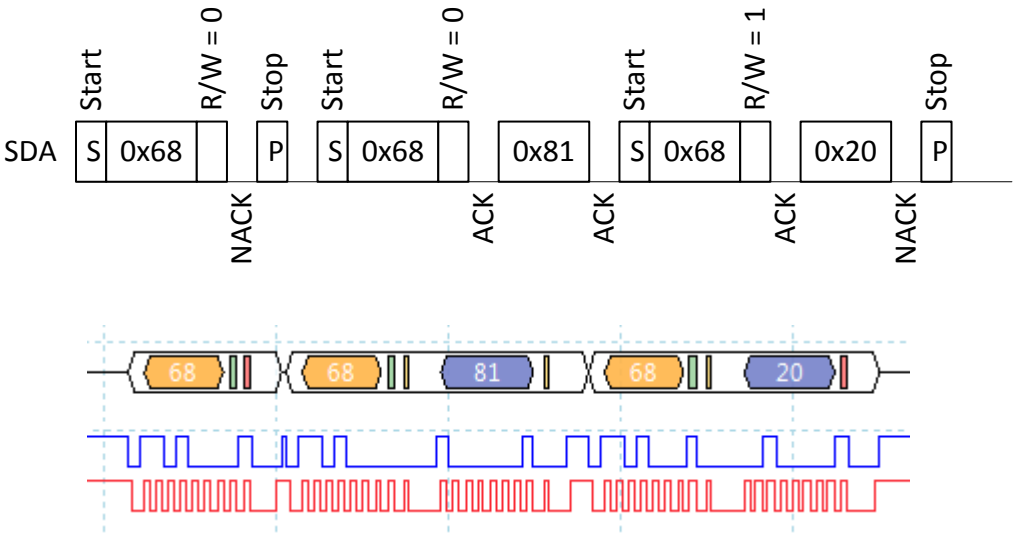


2. Write background calibration command (0x7C06) to register Calibration Command (0x82)





3. Read register Calibration Status (0x81)



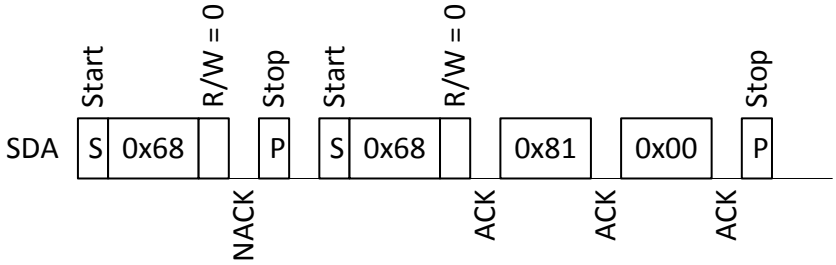
Calibration status register = 0x20 means background calibration succeeded.

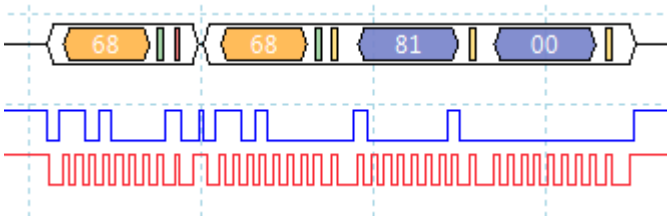
To achieve best possible result from a calibration it is important that the sensor is in a stable environment.

3.7.2 **Target Calibration**

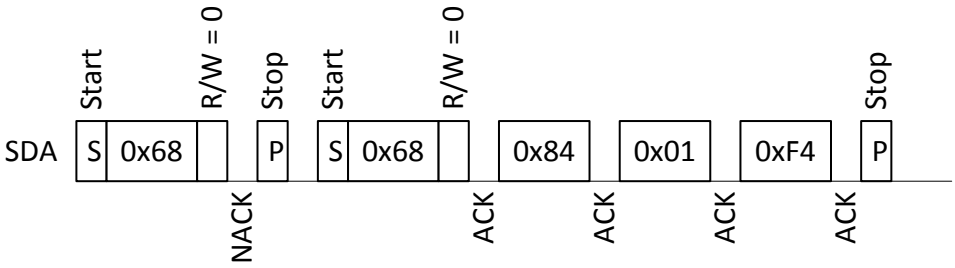
Example how to calibrate against target 500 ppm.

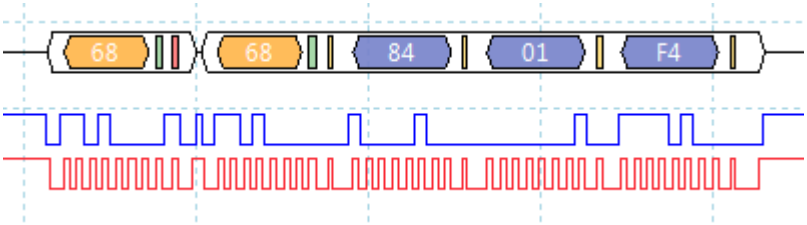
1. Start to clear register Calibration Status (0x81)



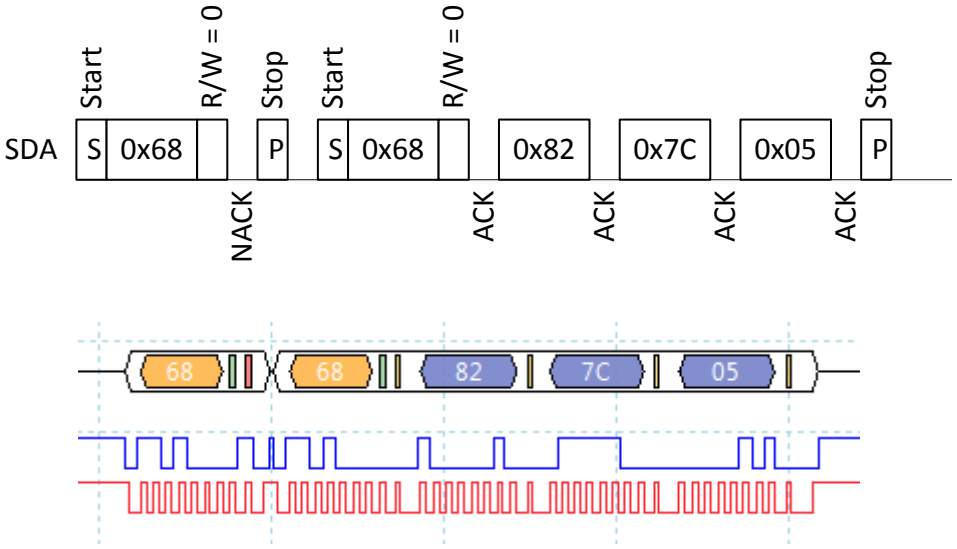


2. Write calibration target 500 to register Calibration Target (0x84)

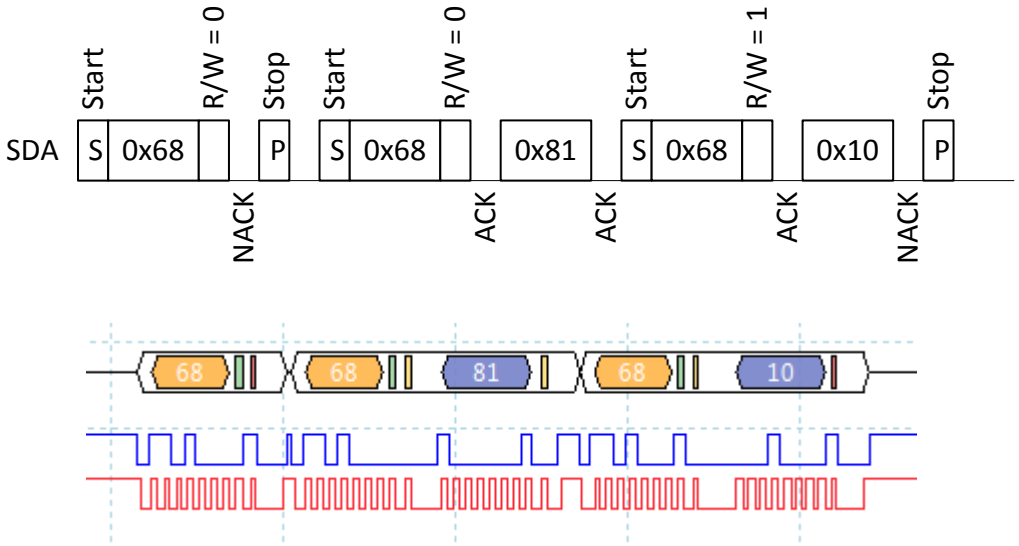




3. Write calibration command (0x7C05) to register Calibration Command (0x82)



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

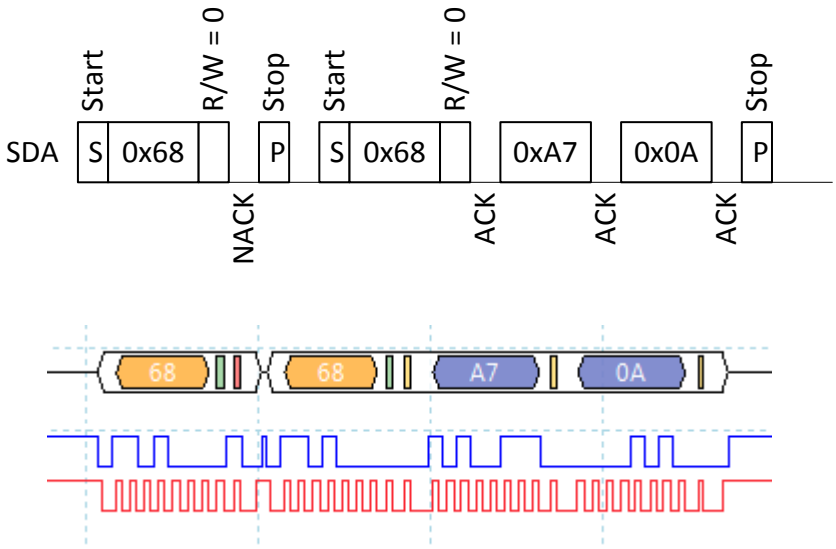


Calibration status register = 0x10 means target calibration succeeded.

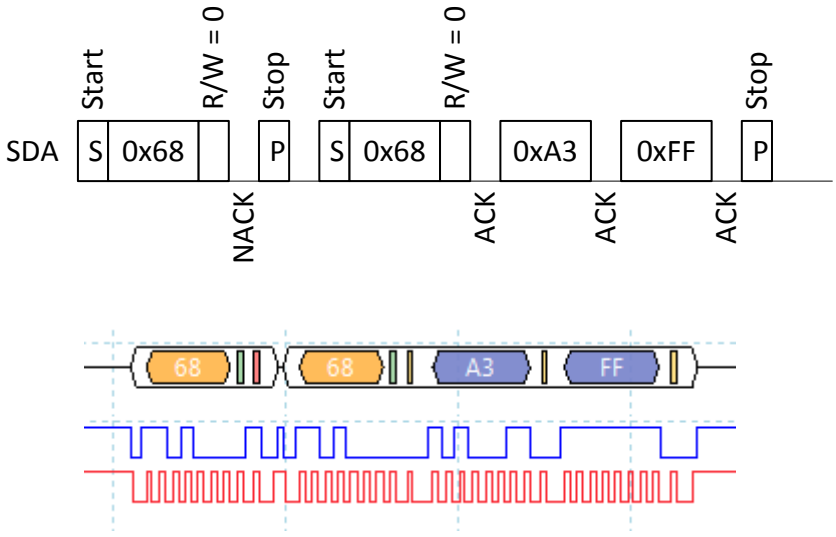
3.8. I²C address

Set sensors I2C address to 10.

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

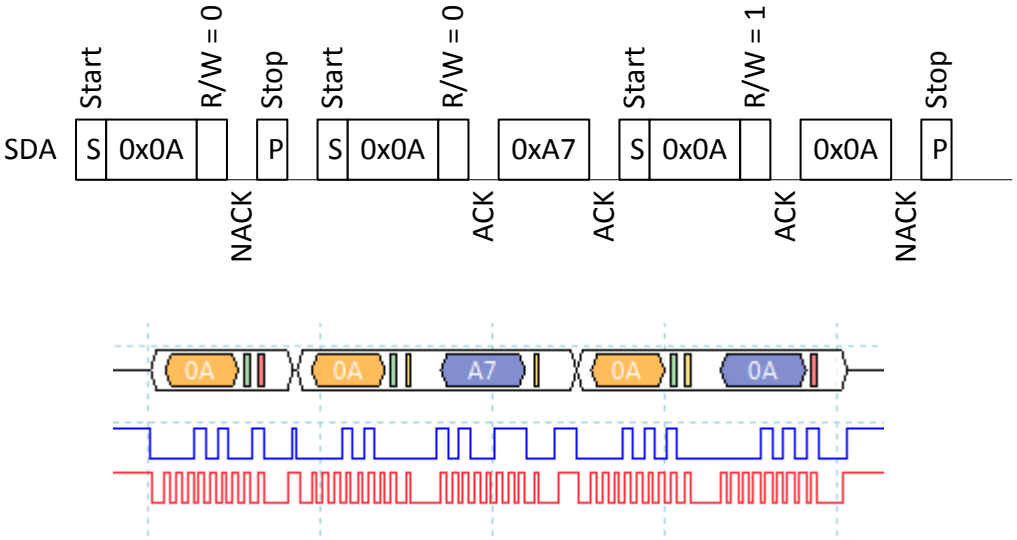


2. Write 0xFF to register SCR (0xA3) to reset sensor (still use address 0x68)



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

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

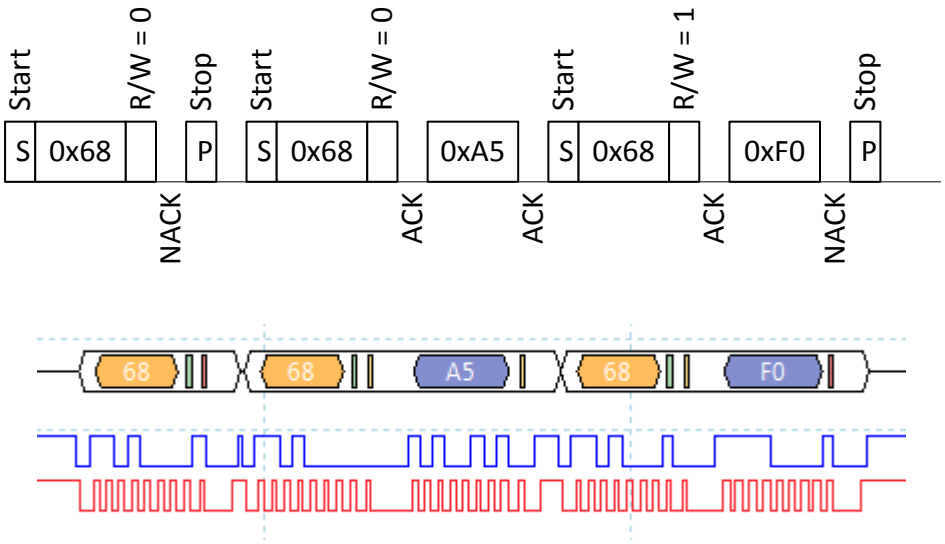


3.9. Enable/Disable pressure compensation

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

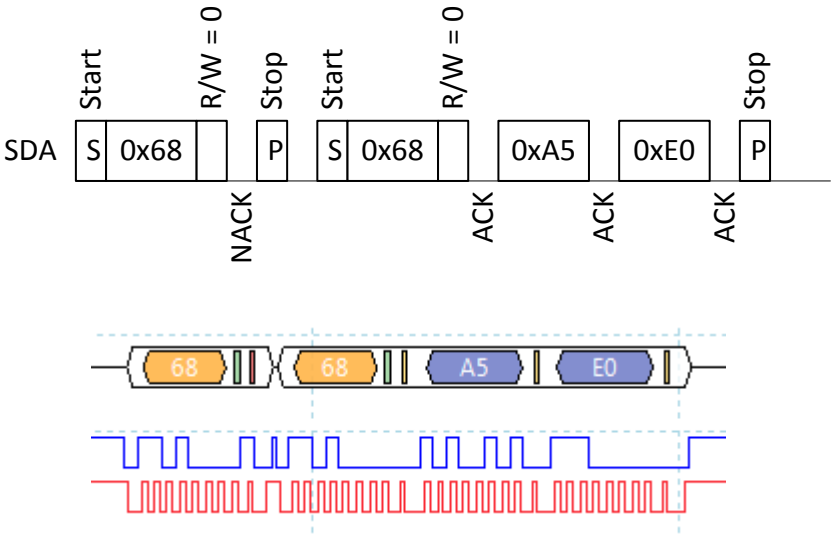
3.9.1 **Enable pressure compensation.**

1. Start to read Meter control.



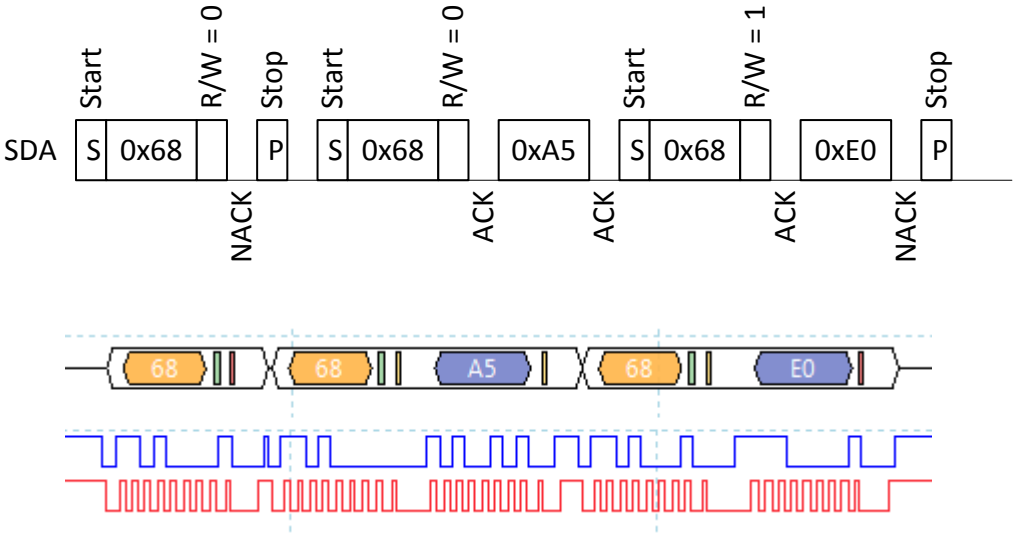
2. Clear bit4 in the register and write back

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

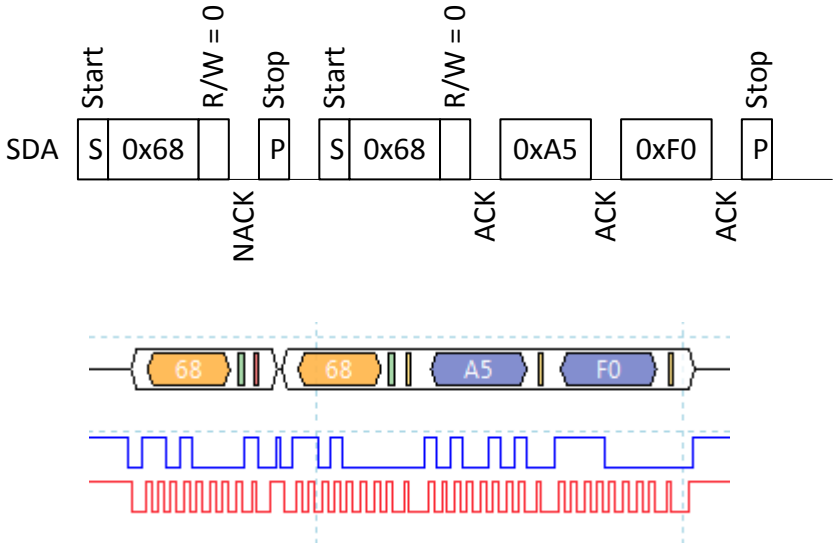


3.9.2 **Disable pressure compensation.**

3. Start to read register Meter control (0xA5).



4. Set bit 4 in register Meter control (0xA5).
   Meter control = 0xE0 => new Meter control = 0xE0 | 0xF0 = 0xF0

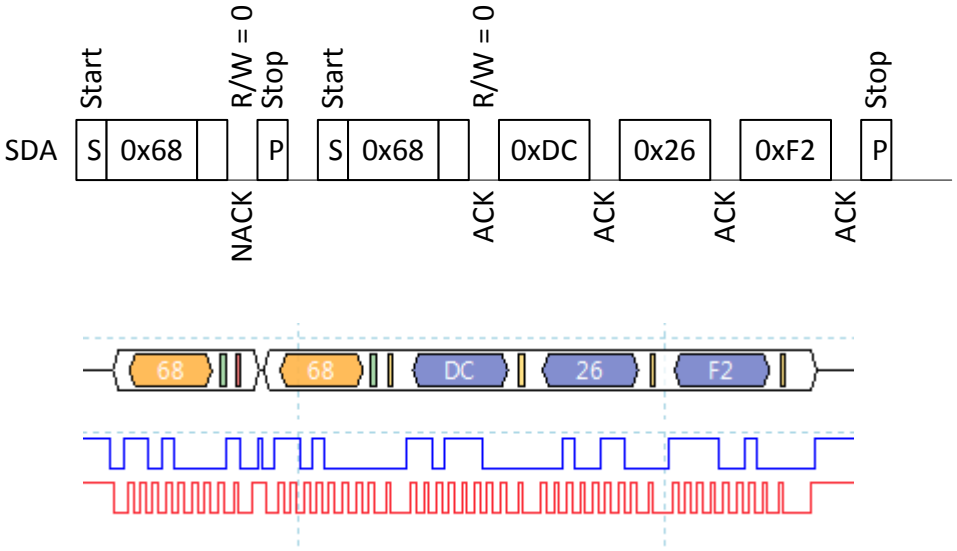


3.10. Write pressure to sensor

Write pressure 997 hPa to sensor. Sensor works with pressure unit 0.1 hPa so first 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 sensor will pressure compensate CO_2. If value written to sensor is not in the range 3000 – 13000 sensor will use 3000 or 13000 for the pressure compensation.

Pressure value written to the sensor will be used in the next CO_2 calculation. In continuous measurement mode this means that it can take up to one measurement period before pressure compensated CO_2 value is based on the new pressure value