Application Note

MLX90381 I2C Communication Protocol for EoL Calibration

Melexis
INSPIRED ENGINEERING

Contents

Application Note

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1. Scope

This document describes the I²C communication protocol to read and write the output transfer curve parameters in the memory of the MLX90381 sensor. This enables the user to perform an End of Line (EoL) calibration of the MLX90381 sensor embedded in the module/microcontroller. The application note describes the circuit, the activation of the I²C interface, the commands of the protocol and the procedure to access the sensors register and Multi Time Programmable (MTP) memory.

2. Related Melexis Products

Related Products

- MLX90381 - Triaxis® pico-resolver

Related Documents

- Datasheet MLX90381
- Application Note Example MLX90381 I²C Communication Protocol
- Application Note MLX90381 End of Line Calibration

3. I²C Unique Slave Circuit

The MLX90381 is a Hall effect resolver sensor for high speed angle measurements targeting embedded applications. The MLX90381 can be supplied at PCB level or/and by the (MLX8133x) motor driver regulator (3.3V typically). OUT1 and OUT2, (SIN and COS) are connected to the ADC of the microcontroller.

The MLX90381 is EoL (End of Line) programmable (limited to customer memory area) through the OUT1 and OUT2 pins of the sensor. The communication protocol is derived from I²C (100kHz standard speed). The I²C SCL and SDA pins are shared with normal application pins OUT1 and OUT2. The double function of the output pins requires the MLX90381 be a unique slave in the circuitry, Figure 1.

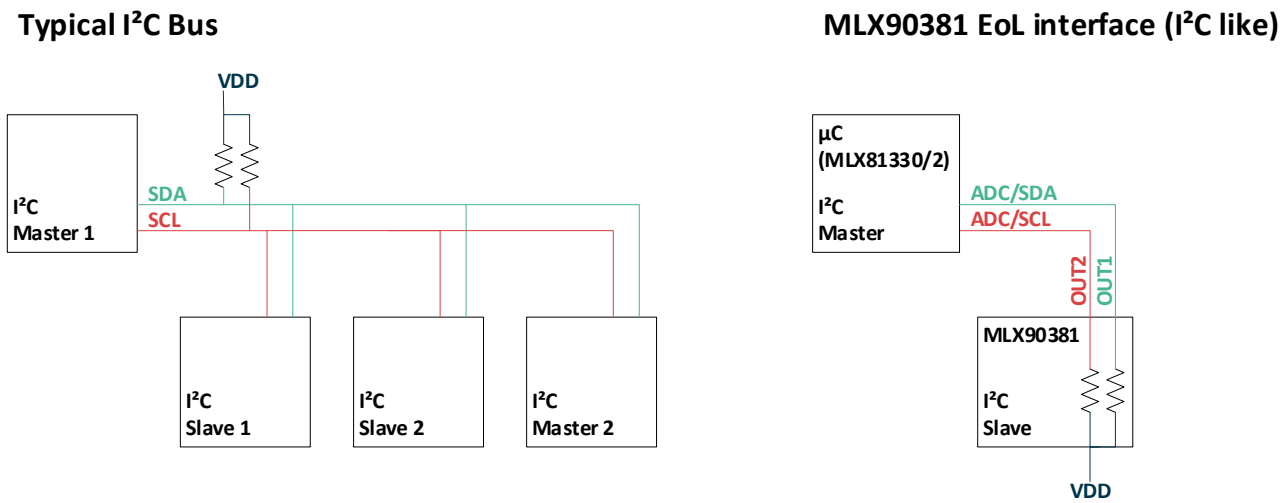
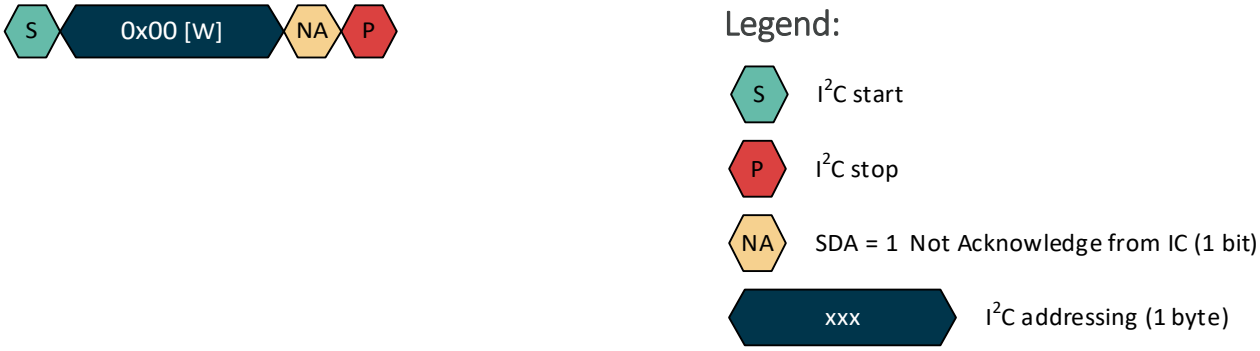


Figure 1: Typical I²C and MLX90381 EoL (I²C like)

4. Activate I²C Interface

The Activation sequence of the I²C interface resembles an addressing write cycle to I²C address 0x00.



The difference is found in the start bit which requires a delay to allow the output drivers of the MLX90381 sensor to switch off and turn to listening mode. And the acknowledge of the slave to the master which is a high acknowledge and not a low acknowledge. The address 0x00 is set by the 100kΩ pull-down resistors and should not be forced by the microcontroller.

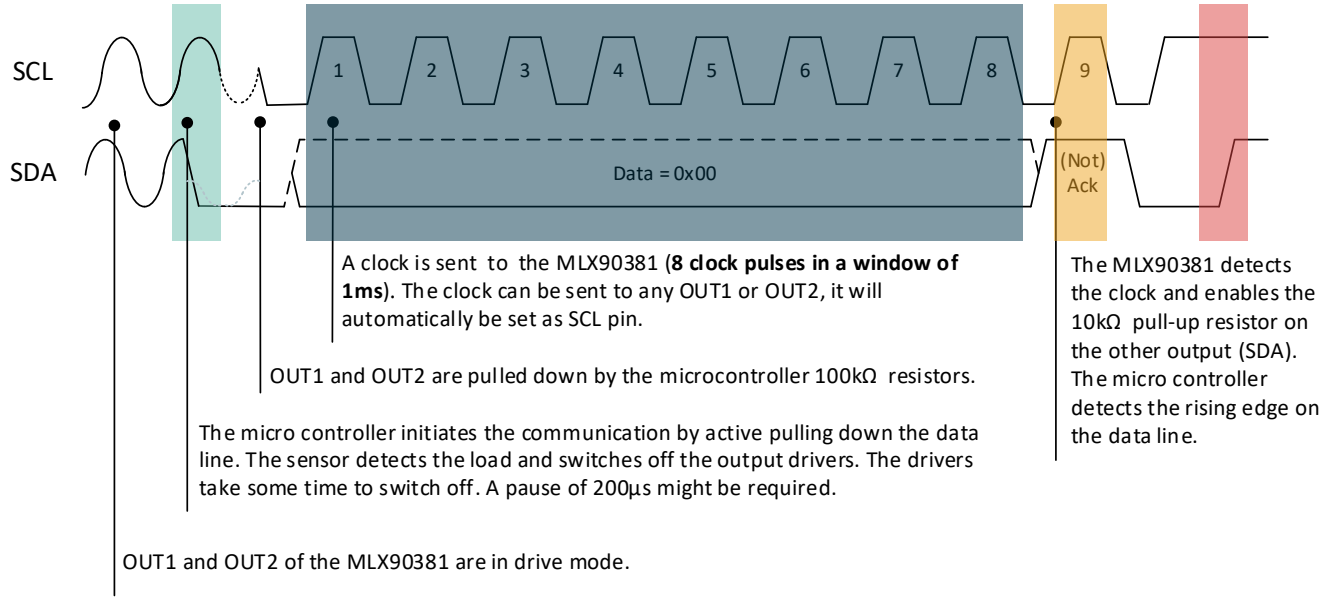


Figure 2: Activation I2C interface

The I²C activation mechanism uses the overcurrent diagnostic failure detection circuit to switch the drivers OUT1 & OUT2 in High-Z.

To switch off the output drivers the sensor needs to detect an overcurrent OC > 500µA.

There is 4-5µs de-bounce circuit on the overcurrent detection.

At least 8 SCL pulses have to be sent to activate I²C interface.

Once I²C is activated the internal 4.7kΩ pull-up resistor is enabled on the I²C data bus.

There is a 20-30ms timeout in case there is no I²C communication after activation. Upon timeout the sensor returns to application mode. The MTP memory lock has no influence on this timeout.

By default the assignment of the SCL and SDA to OUT1 and OUT2 is done automatically by the pin which received the 8 clocks. But there is an option to fix the selection which application output pin is SCL and which one is SDA in the MLX MTP area.

Note that the communication can be enabled by a pull up instead of pull down resistor (overcurrent works in both sink and source direction). This can be useful when the magnet is positioned so that both the OUT1 and OUT2 output level are in the low side.

The oscilloscope plots beside show the I²C interface activation of the MLX90381.

OUT1 and OUT2 as analog signals:
Yellow: SCL
Blue: SDA

OUT1 and OUT2 as digital signals:
0: SCL
1: SDA

The 2 plots show the same I²C interface activation sequence. Only the analog level before the activation is executed is different.

STEP 1. SDA is pulled low.

STEP 2. Monitor SCL to detect when the output driver is switched off. There is 4-5µs de-bounce circuit on the overcurrent detection.

STEP 3. Send 8 SCL pulses. When the 8 pulses are detected, the internal 10 kΩ pull-ups will become active between the 8th clock and the Not-Acknowledge of the MLX90381 sensor.

STEP 4. When the Not- Acknowledge is detected, the sensor is in communication mode.

STEP 5. Set the I²C STOP to complete the I²C interface activation.

STEP 6. Send the first command to the sensor.

STEP 7. Etc…

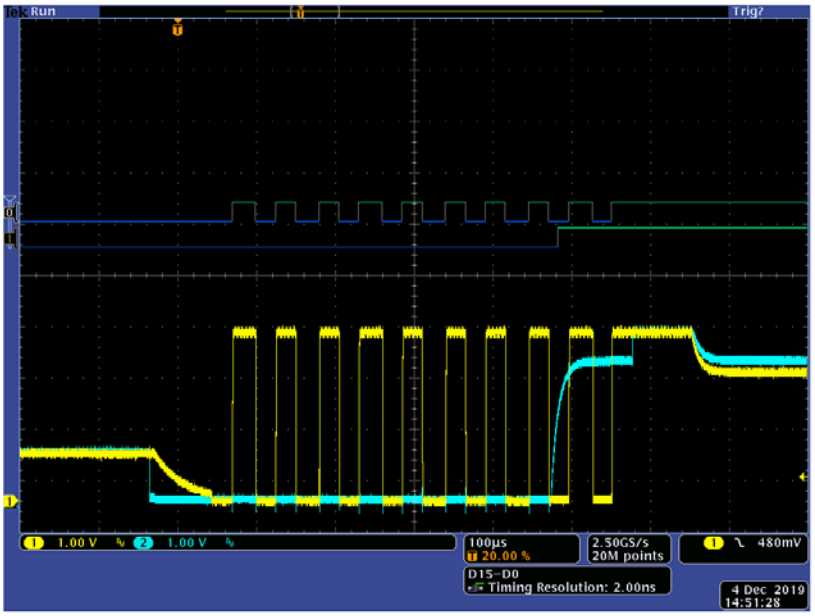


Figure 3: Oscilloscope plots of the I²C interface activation

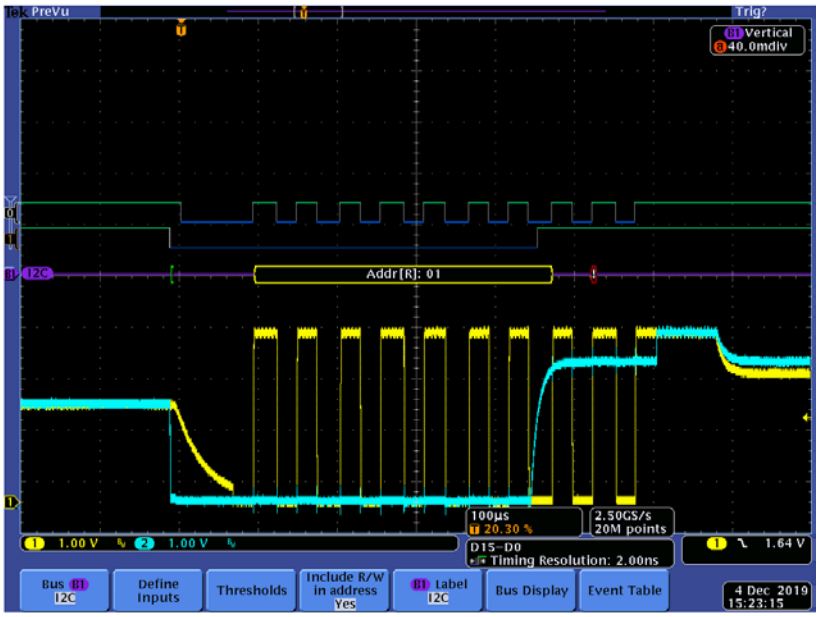


Figure 4: Oscilloscope plots of the I²C interface activation

4.1. Activation I²C Interface Pin Requirements

The MLX90381 is a unique I²C slave of the microcontroller, as the I²C pins are shared with the 2 outputs for the analogue SIN/COS signals that represent the magnetic angle.

In normal operation mode there are 100kΩ resistors placed on the output pins to detect when the sensor goes in diagnostic mode. The 4.7kΩ resistors, required for the I²C communication, are only needed during the I²C communication. To avoid conflict with the normal operation mode, the pull-up resistors are integrated in the sensor and switched on when the sensor is in I²C mode.

During the I²C interface activation, the 4.7kΩ pull-up resistors are not yet active. Due to this SCL pin needs to have a push-pull driver to set the 8 clock pulses to activate the I²C interface. The SDA pin needs a low-side driver (or push-pull) that can create an overcurrent OC > 500µA on the output driver to switch the drivers off. Both SCL and SDA need to be disabled / disconnected in normal operation mode for the SIN/COS signals.

4.2. Detailed Description Activate I²C Interface

The interface between MLX90381 and MLX81330/2 is shown in Figure 5 to Figure 8. It can be extended to an interface with a microcontroller.

The first figure shows the MLX90381 and microcontroller in application mode.

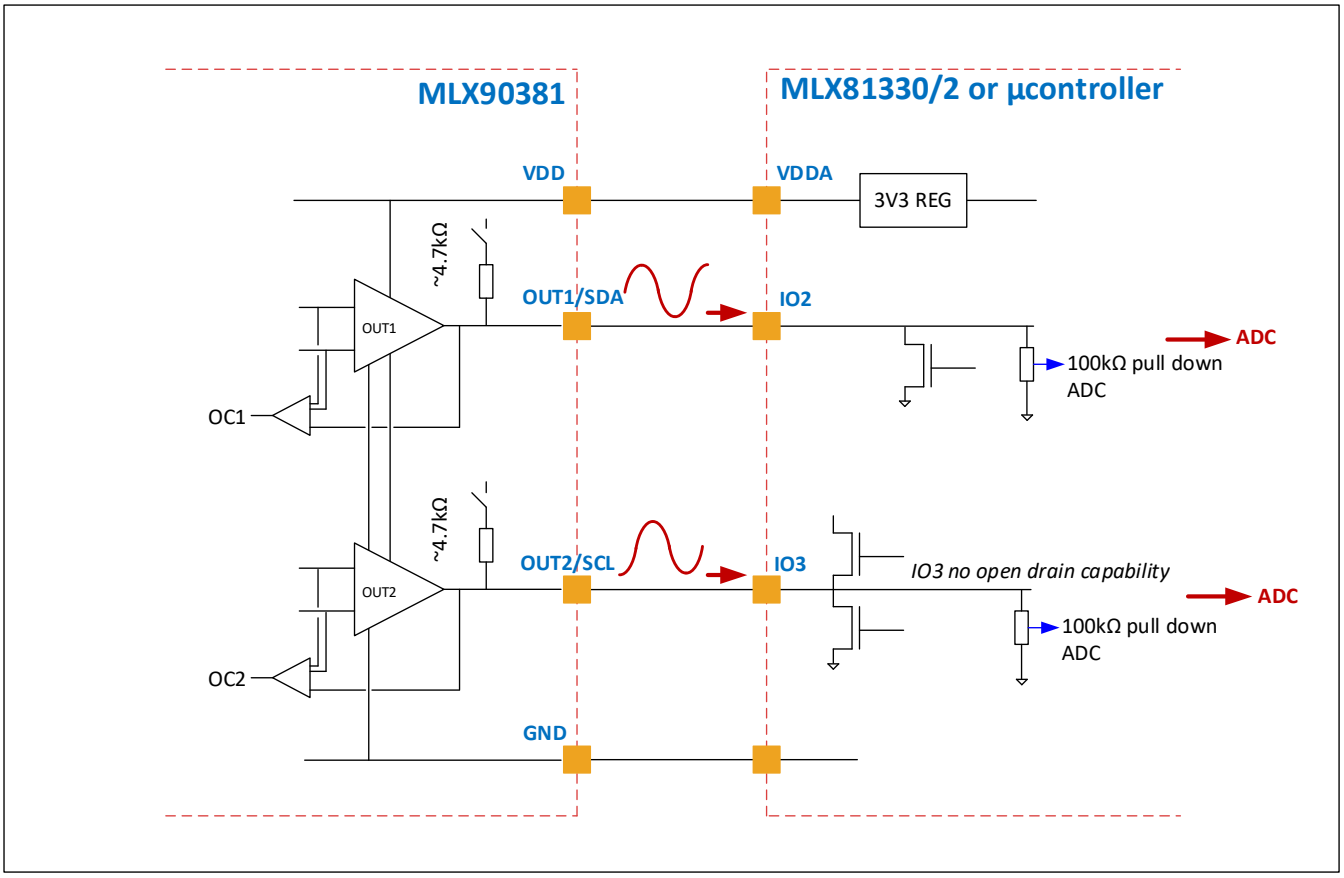


Figure 5: Application case: MLX90381 OUT1 and OUT2 go to the MLX81330/2 ADC

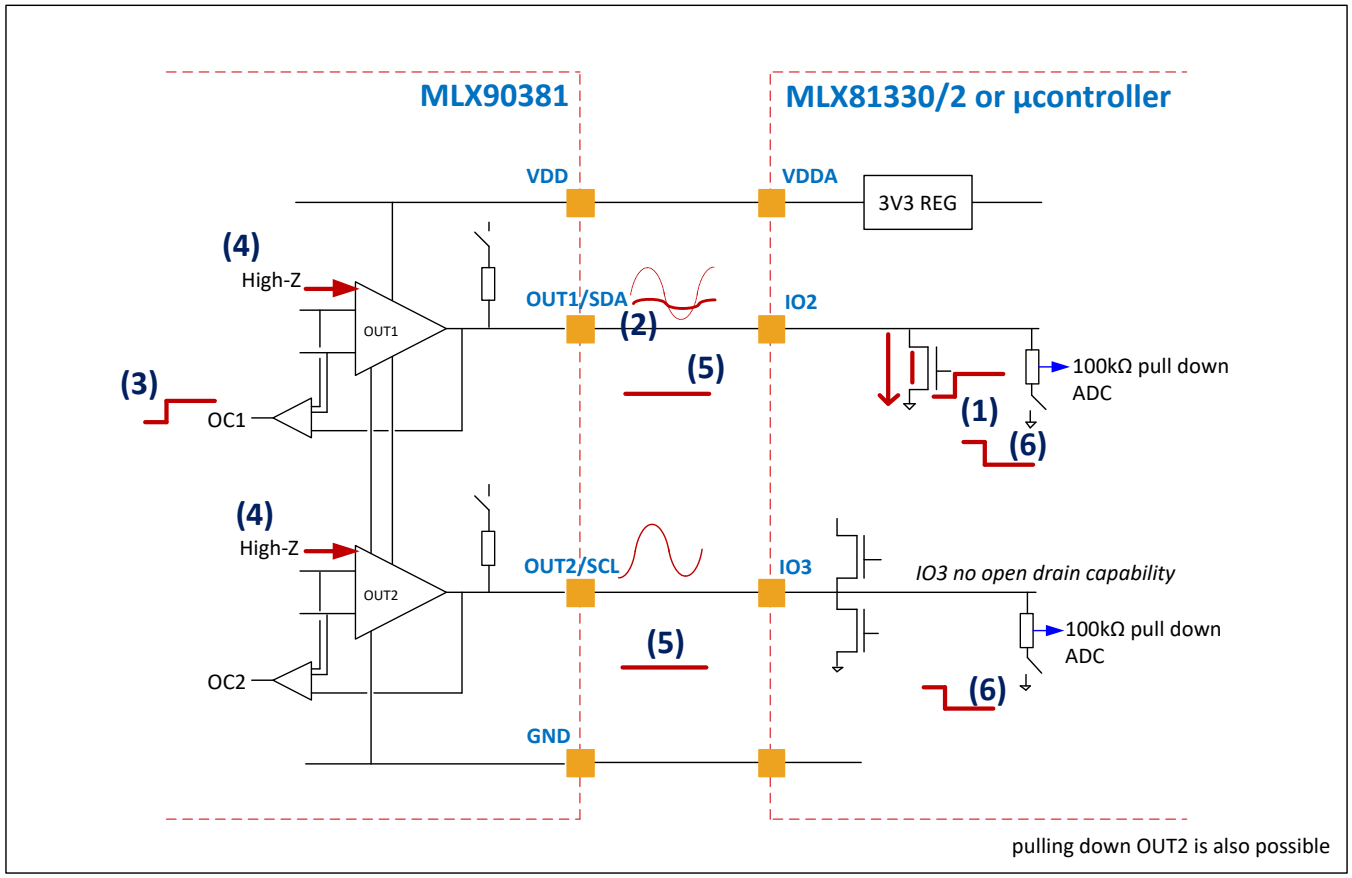


Figure 6: MLX81330/2 initiates I²C communication with MLX90381

Initiation of EoL/I²C communication:

Step (1): MLX81330/2 (or a microcontroller) initiates the communication by active pulling down (or up) on IO2 (**or** IO3),

Step (2): As a consequence, OUT1 (or OUT2) drops, but not fully since the two drivers are still providing SIN/COS information.

Step (3): MLX90381 detects the load on OUT1 (or OUT2) **with the overcurrent diagnostic** (DIAG_OC1 or DIAG_OC2)

Step (4): both OUT1 and OUT2 are switched off (high-z). **(Fail safe state mode.)**

Step (5): OUT1 and OUT2 are pulled down by MLX81330/2 or microcontroller 100kΩ resistors. The voltage drop can be detected on the 2nd pin IO3 (resp. IO2).

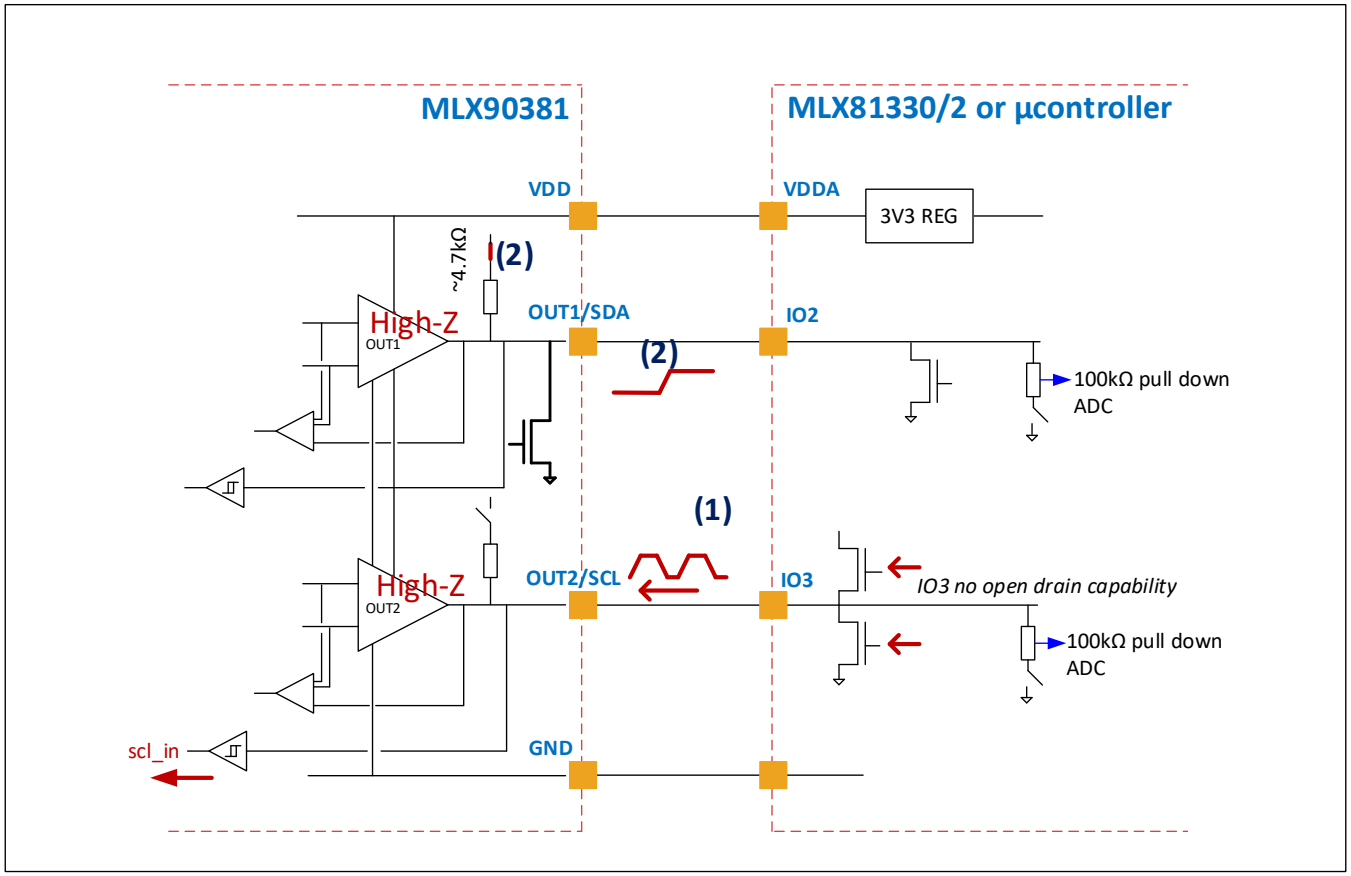


Figure 7: I²C communication between MLX90381 and MLX81330/2

Step (1): A clock is sent to MLX90381 (**8 clock pulses in a window of 1ms**). The clock can be sent to any OUT1 or OUT2; it will automatically be set as SCL pin. (Unless automatic pin swap is disabled in the MTP.)

Step (2): MLX90381 detects the clock, enables the 4.7kΩ pull-up on the other output. The microcontroller detects the rising edge on OUT1.

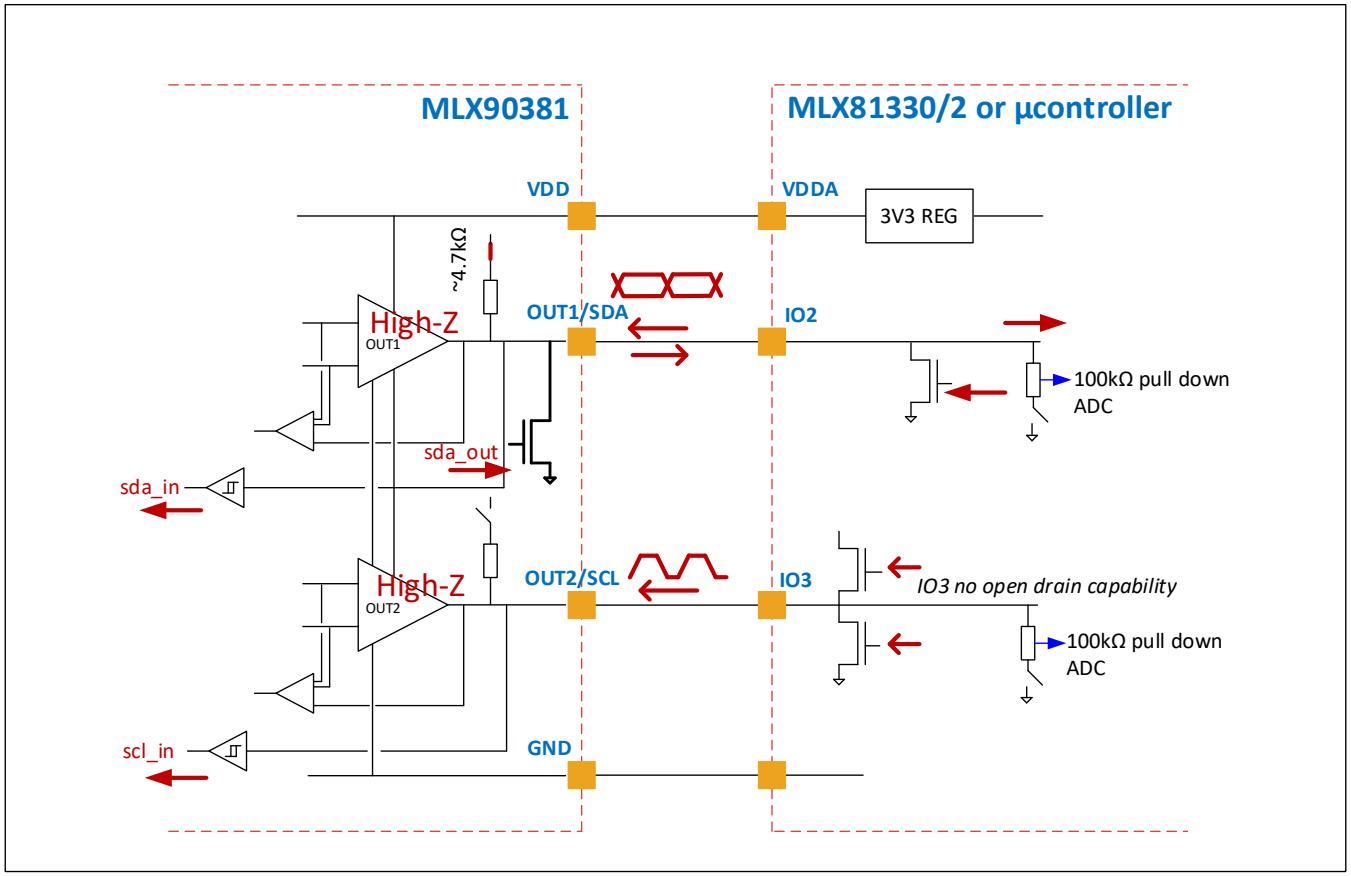


Figure 8: I²C communication between MLX90381 and MLX81330/2

Calibration/program MTP:

Step (1): The communication starts.

Step (2): Memory (or ports) are filled.

Step (3): Communication stops. MLX90381 returns to application mode filled with new trimmings stored on ports or memory.

Loop Step (1), Step (2), and Step (3) until the right settings are found.

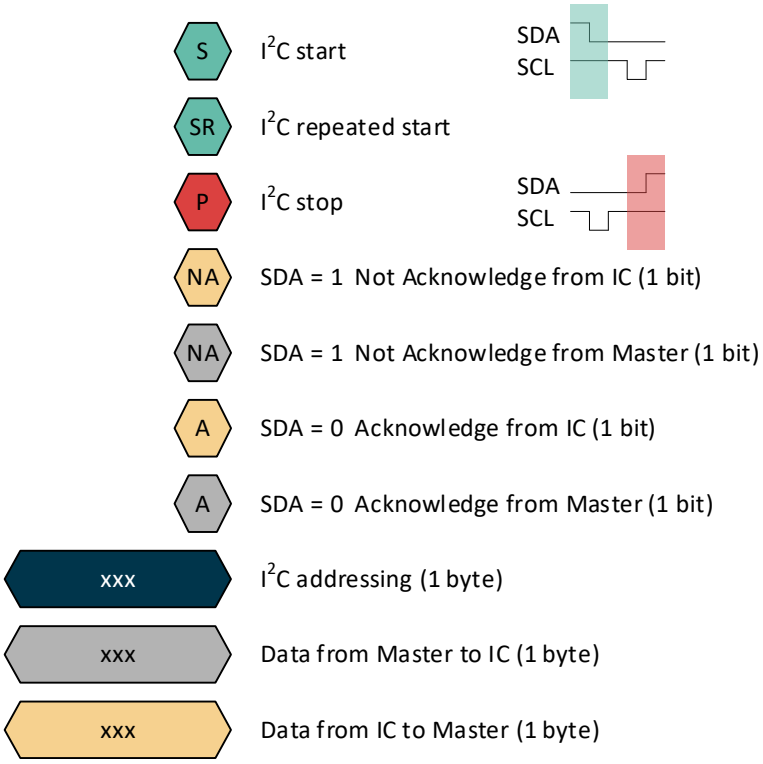
See Chapter 7: EoL Calibration Procedure

At the end of the cycle, a lock bit inside the memory can be set; the chip can no longer be programmed through the output pins.

5. I²C Communication Protocol

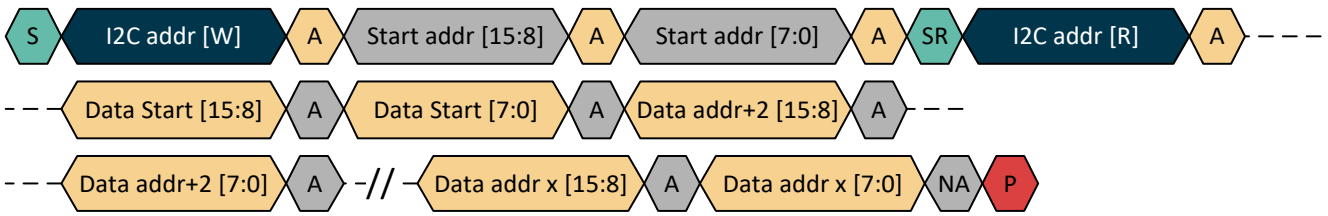
The MLX90381 sensor uses an I²C derived communication interface to read/write Customer configuration register as well as Customer MTP area. The I²C communication protocol with the MLX90381 consists of three basic communication commands to read and write the memory of the sensor. The MLX90381 is an I²C slave. The 7-bit slave address is hard coded to 0x32, so 8-bit 0x64[W] 0x65[R].

Legend:



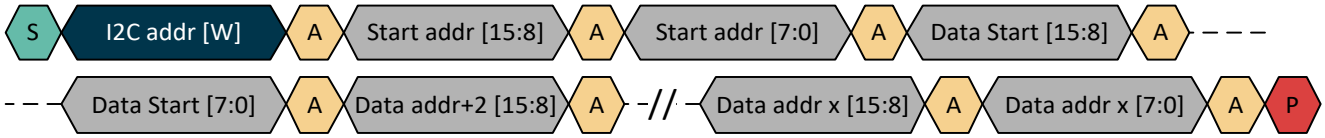
5.1. Memory Read MTP & Register

The read command starts with the (start) address of the first memory address to be read. The data for the sequential addresses is read in incremental order for the number of clock frames sent. Multiple read commands need to be used for non-sequential reading of data addresses.



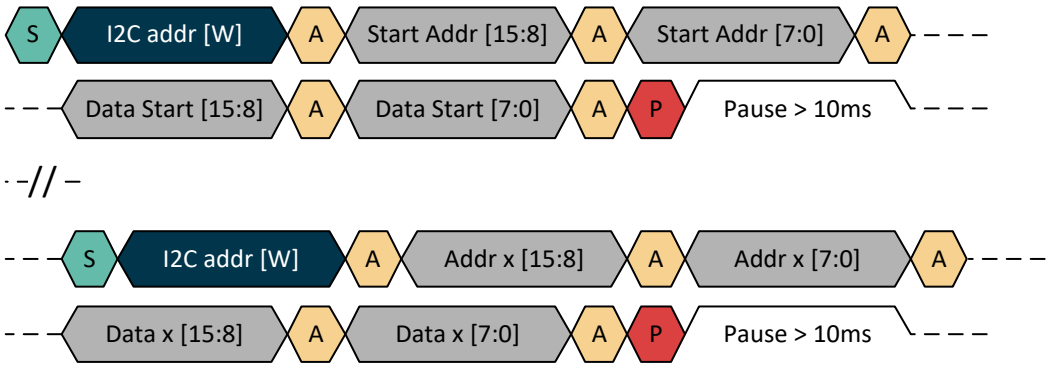
5.2. Memory Write Register

The write register command starts with the (start) address of the first memory address to be written followed by the data to be written to the start address. The data for the sequential addresses is added in incremental order. By this way the customer configuration registers 0x20 to 0x2A can be written using I²C incremental write starting from address 0x20. Multiple write commands need to be used for non-sequential writing of data addresses.



5.3. Memory Write MTP

The write command of the MTP needs to be performed address by address. Between each write command of one address-data frame there is a pause of 10 to 11ms. This pause is mandatory to allow the sensor to charge the MTP cells.



The MTP has a limited number of write cycles for a charge time of 10 to 11 milliseconds. There is no counter in the sensor on the number of write cycles performed on the MTP. For an optimal lifetime performance of the MTP, it is mandatory to limit the write cycles to a single MTP cell to only a few times, see the datasheet of the MLX90381.

6. Customer Configuration Register and MTP

The MLX90381 sensor has a volatile memory, the operating register, and a non-volatile memory, to store the configuration of the sensor. The volatile and non-volatile memory can be written via I²C commands. To gain access to the memory a key needs to be written in the access key register. I²C write access outside customer configuration registers or customer MTP area addresses is automatically rejected.

Unused bits in the MTP have to stay programmed = 0. Changing the contend of these bits to ≠ 0 will result in disabling the functionality of the sensor permanently!

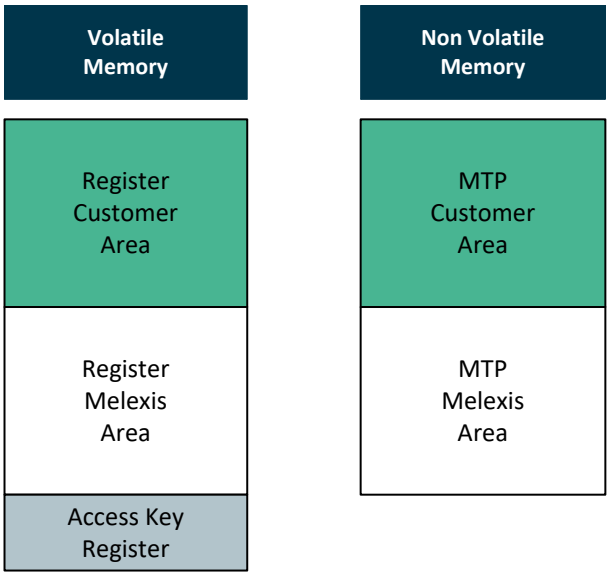


Figure 9: Customer Configuration Register and MTP

6.1. Memory Access Key Register

The first access key register is called i2c_cmd register with address 0x44 which gives calibration mode access:

- Write 0x544E in the i2c_cmd_register to allow entering calibration mode;
- Write 0x944C in the i2c_cmd_register to allow starting SIN/COS generation in normal application mode;
- Write 0x744C in the i2c_cmd_register to allow starting SIN/COS generation in calibration mode;
- Other written content will reset calibration mode.

The second access key register is called ee_shell_ctrl register with address 0x46 which gives you MTP read/write access:

- Write 0x0077 in the ee_shell_ctrl _register to get out of MTP standby mode and enter MTP write mode;
- Write 0x0007 in the ee_shell_ctrl _register to get out of MTP standby mode and enter MTP read mode;
- Write 0x0006 in the ee_shell_ctrl _register to deactivate MTP and reset write mode.

The chip must be in calibration mode to be able to get MTP read/write access.

The I^2C master has to release the I^2C bus within 10µs (1 SCL period) after sending stop bit of the last frame before switching in normal application mode. This is needed to avoid that both the I^2C master and the MLX90381 are driving the I^2C bus when the sensor switches on the output drivers.

The following example flow chart shows which access key(s) to write in the memory access key register to:

- Load sensor output characteristics in registers and verify output
- Program sensor output characteristics in MTP and verify output
- Read MTP
- Program LOCK MTP

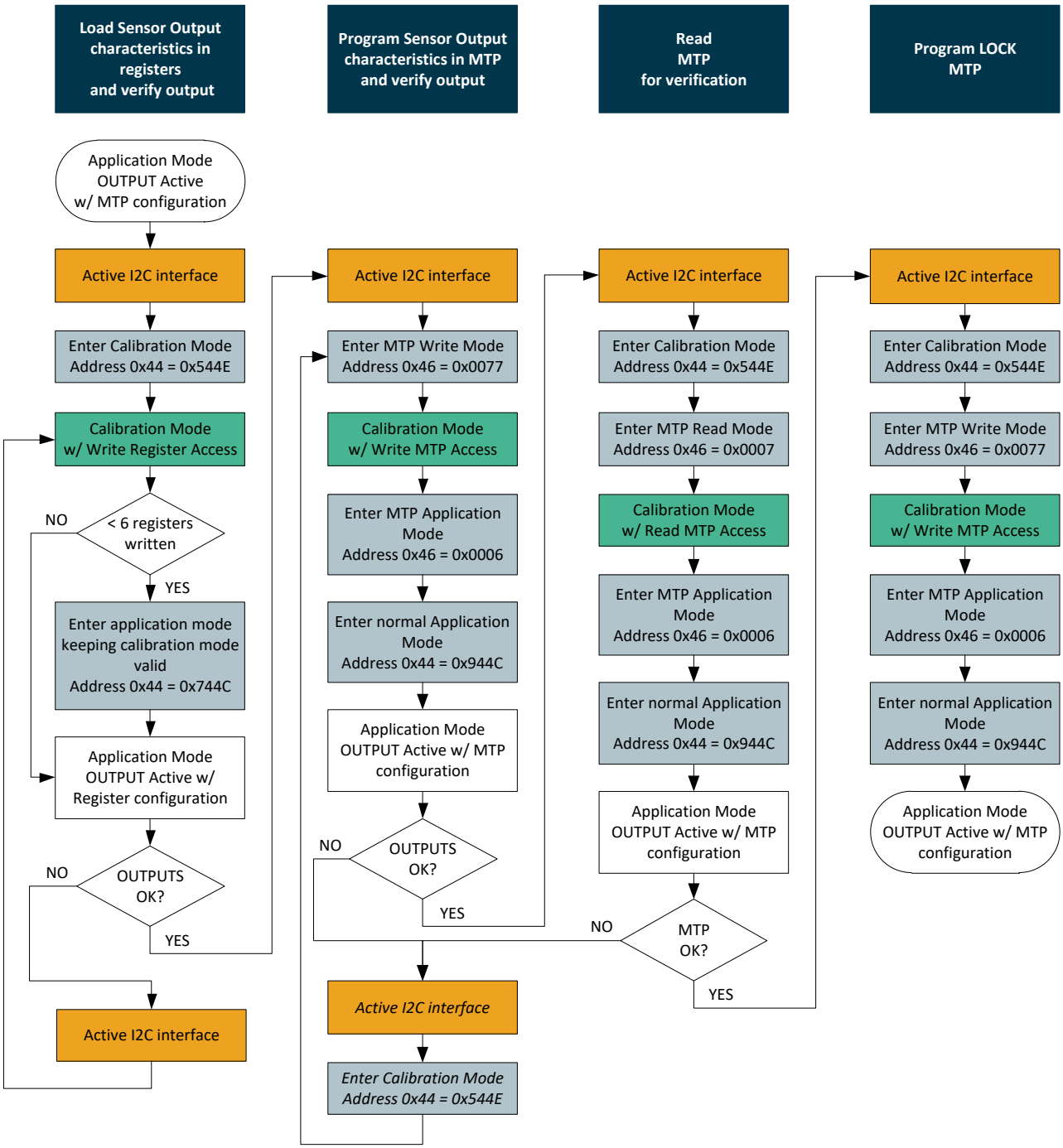


Figure 10: Example flow for memory access key register

6.2. Customer Configuration Register and MTP Map

Please refer to the MLX90381 datasheet for the MTP map and a description of each parameter stored in the MTP.

The MTP customer area, 16 × 16-bit memory, containing the customer programmable parameters of the sensor. The memory is not fully used. In the map, listed in Table 1, the white cells are used for sensor parameters. The red cells are not used for sensor parameters.

The unused bits in the MTP have to stay programmed = 0. For the registers failure detection (CRC), the unused cells are considered = 0. If the data in unused cells is ≠ 0, this safety mechanism will flag an error on the Registers failure detection (CRC).

Changing the content of unused bits to ≠ 0 will result in disabling the functionality of the sensor permanently!

Table 1: Used and Unused bits in the MTP and register.

Address			Word [2 bytes]							
Register [HEX]	MTP [HEX]	Byte	7	6	5	4	3	2	1	0
0x20	0x00	LSB								
		MSB								
0x22	0x02	LSB								
		MSB								
0x24	0x04	LSB								
		MSB								
0x26	0x06	LSB								
		MSB								
0x28	0x08	LSB								
		MSB								
0x2A	0x0A	LSB								
		MSB								
0x2C	0x0C	LSB								
		MSB								
0x2E	0x0E	LSB								
		MSB								

7. EoL Calibration Procedure

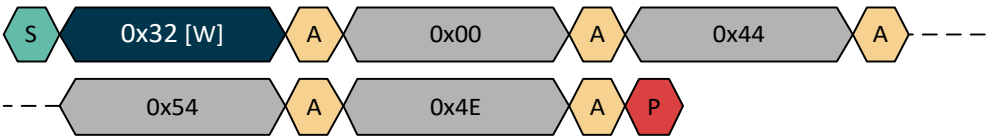
This section describes the general steps that are needed to enable the calibration/programming of the sensitivity and offset of the SIN and COS signal of the MLX90381 sensor.

7.1. Activate I²C Interface

As described in chapter: 4 Activate I2C Interface above.

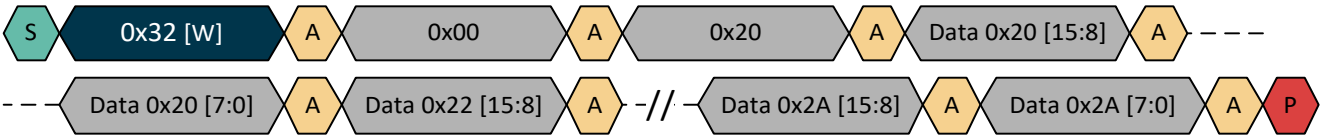
7.2. Enter Calibration Mode

The I²C read/write access is enabled only if calibration mode is entered. Write 0x544E in i2c_cmd register mapped under address 0x44 to enter calibration mode. Being in calibration mode the CRC check is blocked and MTP copy to registers is blocked.



7.3. Program Customer Register

After the calibration mode is entered. 6 words (16 bit) registers, mapped from address 0x20 to 0x2A can be written with a configuration. After 6 valid write accesses to the configuration registers, the sensor automatically switch to the application mode generating sine/cosine on OUT1 and OUT2, and a verification measurement can be done.



If less than 6 words are written, step 0 needs to be executed to enter the application mode while keeping calibration mode valid.

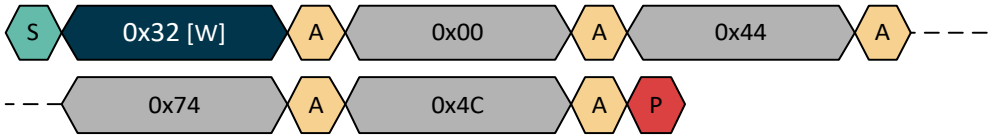
If the value of some of the registers needs to be changed after the measurement of the outputs, the I²C interface has to be activated again, step 7.1, and then only needed registers can be rewritten, step 7.3. As less than 6 words are written, Step 0 needs to be executed to enter the application mode while keeping calibration mode valid. Step 7.2 does not need to be executed as the sensor is still in calibration mode.

Executing step 7.2 when the sensor is already in calibration mode can disrupt the I²C communication. If this occurs, rewrite the register with step 7.3 Program Customer Register, or execute 7.8 Enter Application Mode with MTP Configuration and restart with Step 7.1, 7.2, 7.3 …

7.4. Enter Application Mode Keeping Calibration Mode Valid (with Register Configuration)

After Programming the register, write 0x744C in i2c_cmd register mapped under address 0x44 to switch in the application mode keeping calibration mode valid.

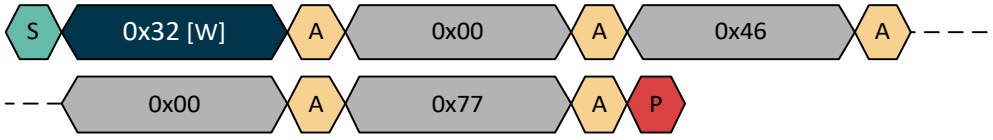
This means that the sensor switches to application mode, but the registers content is not change/loaded with the MTP content.



7.5. Enter MTP Write Mode

If measure result is OK, proceed to calibration finalization by writing needed content to MTP custom area mapped from addresses 0x00 to 0x0A. As the I²C is not active you first need to set I²C to be activated, see 7.1.

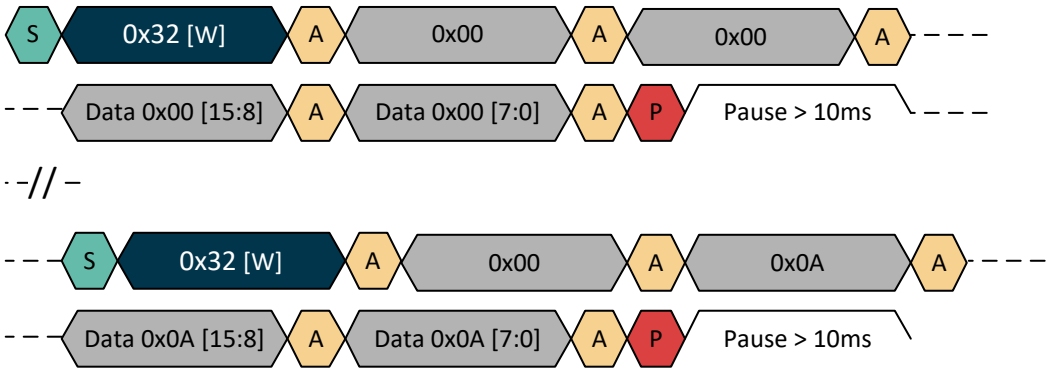
In order to write in MTP, the ee_shell_ctrl register mapped on address 0x46 has to be written by 0x0077 to get out of MTP standby mode and enter MTP write mode.



Note: If the previous command was not a program customer register, then the calibration mode has to be entered again see 7.2

7.6. Program Customer MTP

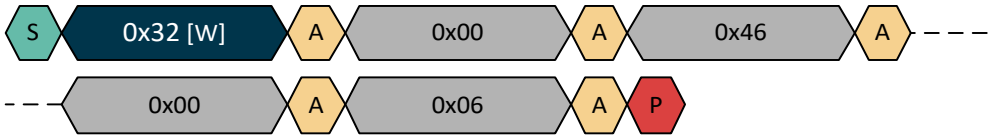
After the MTP write mode is entered, the defined values of 6 configuration registers can be written in MTP. For this you need to use the one data word I²C frame to write in the MTP as the MTP write cycle takes 10ms (5ms for erase and 5ms for write). Thus, a pause of 10-11ms between I²C frames is mandatory.



There is a lock bit (MEMLOCK) mapped under 0x0C address in MTP. If this bit is written by “1” the I²C write access to MTP is forbidden. It is advised to leave the MEMLOCK at “0” until the output functionality is verified after writing the MTP.

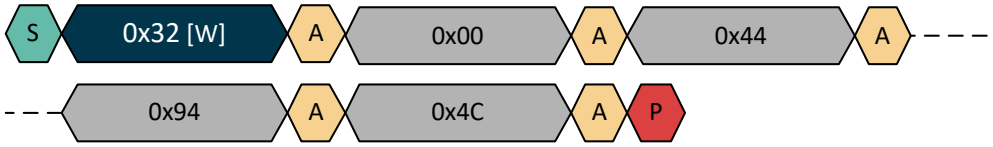
7.7. Reset MTP Read/Write Access

Write the ee_shell_ctrl register mapped on address 0x46 with 0x0006 data to deactivate MTP and reset read/write mode.



7.8. Enter Application Mode with MTP Configuration

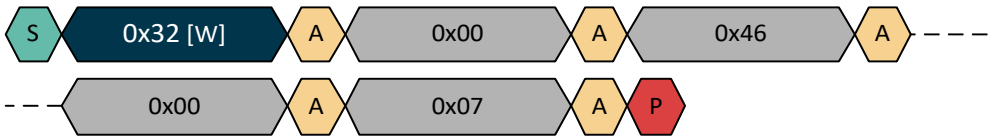
In order to switch in application mode after writing the MTP memory, write 0x944C in i2c_cmd register mapped under address 0x44. Calibration mode will be deactivated and chip behaves as in normal operation mode. Thus data from MTP are copied to configuration registers and Customer can perform output measurements to verify MTP content.



7.9. Enter MTP Read Mode

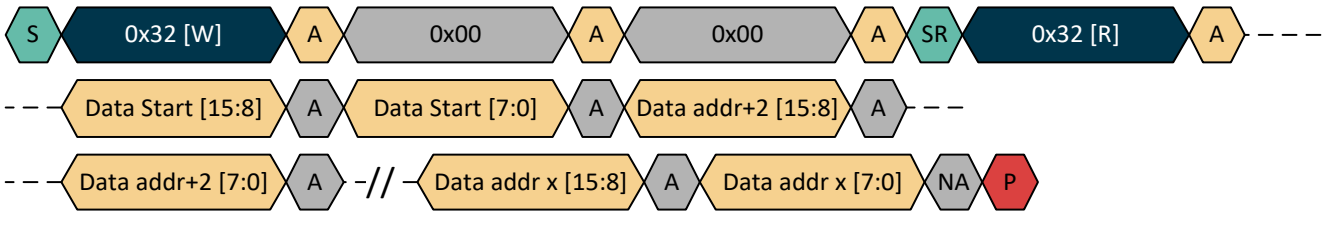
With the Memory Read MTP & Register command, see 5.1, the MTP content of the sensor can be compared with the desired MTP setting. As the I^2C and calibration mode are not active you first need to set I^2C to be activated, see 7.1, and calibration mode has to be entered, see 7.2.

In order to read in MTP, the ee_shell_ctrl register mapped on address 0x46 has to be written by 0x0007 to get out of MTP standby mode and enter MTP read mode.



7.10. Read Customer MTP for Verification

After entering the MTP read mode, the content from the MTP can be read.

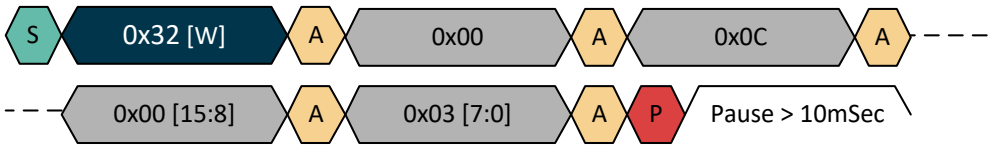


To activate the outputs, write ee_shell_ctrl register by 0x06 data to deactivate MTP write mode, see 7.7 and write the i2c_cmd register by 0x944C data to activate the outputs, see 7.8.

7.11. Program MTP Lock

If the MTP content is OK, Customer can lock it by writing “1” in MEMLOCK bit. In order to do that, I²C has to be activated, see 7.1, calibration mode has to be entered, see 7.2, and ee_shell_ctrl register has to be written by 0x0077, see 7.5.

Then write 0x0001 under 0x0C address (or write 0x0003 under 0x0C address if diagnostic needs to be disabled).



Then write ee_shell_ctrl register by 0x06 data to deactivate MTP write mode, see 7.7 and write the i2c_cmd register by 0x944C data to activate the outputs, see 7.8.

8. Disclaimer

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