Application Note

Datalogging application with the MLX90129

Scope

This application note gives some guidelines to use the MLX90129 as a RFID datalogger. All the features of the MLX90129 and several options for datalogger configuration are explained. Also, two examples based on the EVB90129 are provided to allow a quick start.

Applications

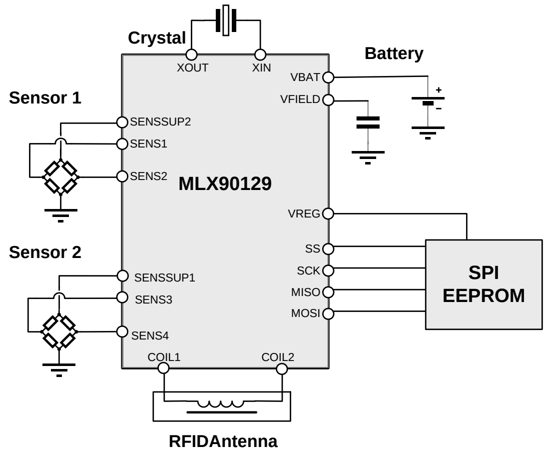
- Cold chain monitoring
- Asset management and monitoring (security and integrity)
- Industrial, medical and residential control and monitoring

Related Melexis Products

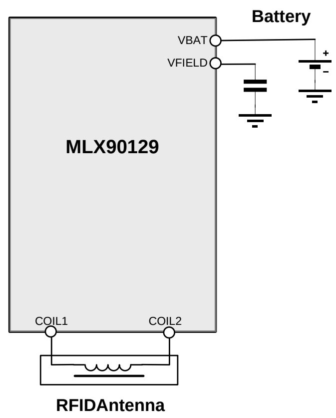
Part No.	Temperature suffix	Package Code	Option code
MLX90129RGO	R (-40°C to 105°C)	GO [TSSOP 20]	-

Typical Circuit

Multi sensors and extended memory device



Low cost temperature logger



Description

The MLX90129 can be easily used as a wireless datalogger because of its RFID interface and standalone operating mode. The MLX90129 is very flexible and its large number of features allows its configuration as required for your application. In a full featured configuration up to 3 sensor values can be recorded in the internal or external memory. Measurements can be sequenced to occur from every millisecond up to every day with a precise timing based on an external oscillator. In its most basic configuration, the MLX90129 when supplied by a battery and connected to an antenna is an RFID temperature datalogger. For example the system can monitor the temperature of goods during one week and the information can be read by a basic RFID reader. Data recovered at the end of the week indicate if the temperatures went over or under a determined threshold. This application note puts together all the necessary information, such as options description and basic configuration, in order to allow a quick and easy implementation of the MLX90129 as a datalogger.

Contents

1.Introduction

A datalogging application is based on a sensing system which monitors the environment and saves environmental measurements in an autonomous way. A well known application is cold chain monitoring. The temperature of a perishable product must be maintained within a limited temperature range is monitored during the transportation from the production site to the retailer. On delivery of the product the temperature history during transport is read with a RFID reader without opening the package and the product is accepted or not depending upon the history. The MLX90129 features allow for implementing a datalogger system with only a few external components. It is recommended to test the different features step by step. For example in the case of datalogger with 3 sensors and external memory, the first step should consist of finding the configuration of each sensor and testing it. During the second step, the external memory implementation can be tested by writing and reading data by RFID. Once the sensor configuration is verified and the external memory implementation validated, the datalogger configuration can be tested. In this documentation all the commands are RFID commands. However it is possible to configure the MLX90129 as datalogger through a SPI interface. In this case, the sequence of commands is similar with RFID commands only the command code and the syntax change.

Note: The RFID commands described in this document use the Dual Subcarrier not addressed mode (=> flag =0x03) and the letters ‘crc’ means the CRC (cyclic redundancy check) has to be computed and added at the end of the command.

2.Datologging modes

Before configuring the MLX90129 it is necessary to define the parameters of the datalogger depending on the kind of application. The following table summarizes the configuration options for the MLX90129. List what you need for your application and report to the next paragraphs for more information.

Features	Options	Comments	Page
Sensors used	1 sensor 2 sensors 3 sensors		Page 6
Time stamp	Timestamp added	Give chronological information about the measure but add one data (16 bits) by sensing sequence	Page 7
	Timestamp Not added	No chronological information	Page 7
Memory	Internal memory	Amount of storage limited but no external components needed	Page 9
	External memory	Amount of storage up to 1Mbit	Page 13
Storage condition	Without threshold	Whatever the condition, the data are saved	Page 6
	With threshold	Only relevant data are saved. The use of the amount of storage is optimized.	Page 6
	Loop enable	Store only the last N data	Page 10
Clock Source	Internal LFO	No external components needed but less precise than XLFO clock	Page 12
	External XLFO	The interval between two measurements is very precise but the power consumption is increased	Page 12
Power management	Vreg is continuously ON	An external device is supplied continuously	Page 13
	Vreg is active only when data are saved in the external memory	Minimize the power consumption.	Page 13
	Automatic stand by mode	Minimize the power consumption at the end of the datalogging	Page 15
Datalogging Start up	As soon as the MLX90129 is supplied		Page 17
	By a RFID command in a short time after the MLX90129 has been supplied	The power consumption before the start command is not optimized	Page 17
	MLX90129 in standby mode then the datalogging is started by a RFID command	When the battery has to be connected at the factory but the datalogging should start later	Page 18

3.MLX90129 configuration

The following paragraphs describe the configuration of the MLX90129 according to the modes selected for the datalogging.

3.1. The sensors thresholds

This application note does not describe the way to condition the external or internal sensors using gain and offset. The following assumes the sensor configuration has been validated. The only option available for the datalogging concerns the "Sensor control word" for each sensor (EEPROM #15 for sensor 0, EEPROM #1B for sensor 1 and EEPROM #21 for sensor 2).

The bits 4, 5 and 6 of the "Sensor control word" allow selecting the condition for saving the measured data from the sensor. The threshold low and high values are defined in EEPROM #16 - #17 for sensor 0, EEPROM #1C - #1D for sensor 1 and EEPROM #22 - #23 for sensor 2.

- If bit 4 of "Sensor control word" is set to '1' the measured values below the low threshold are saved.
- If bit 5 of "Sensor control word" is set to '1' the measured values between the high and low threshold are saved.
- If bit 6 of "Sensor control word" is set to '1' the measured values above the high threshold are saved.

In case the application does not use threshold, the threshold words are set to 0x0000 and bit 4, 5, 6 of "Sensor control word" have to be set to '1' which means measured values are saved whatever the threshold value.

Example:

The MLX90129 is configured to save the value of the internal temperature sensor every minute in the internal memory. The application is the cold chain monitoring and the temperature has to be saved only when it is above a determined threshold such as 4°C. The EEPROM of the MLX90129 is configured as follows:

Address	Value	Comments
#15	0xC043	Only the sensor values above the threshold are saved
#16	0x0000	Low threshold value
#17	0xA450	High threshold value corresponding to 5°C (after calibration of the internal temperature sensor)

If the output of the ADC corresponding to the measured temperature is 0x9236, the data is not stored in the internal memory (0x9236 < 0xA450). If the measured value is 0xB568, it is above the high threshold, consequently the data is saved.

3.2. The Direct Memory Access configuration

The Direct Memory Access unit (DMA) manages the datalogger application. This block controls the standalone application, without any external microcontroller. It handles the start-up operations, and sends the data from a programmed source towards a programmed destination. Typically, it may get the data from the sensor interface and store it in an EEPROM. It works on defined time periods controlled by a timer which is defined later in this document.

The "DMA configuration word" (EEPROM #09) allows configuring several options of the standalone application. The functionality of the bits of this register which are not detailed in this paragraph will be addressed in the next part of this document. In the following example the not detailed bits are set to '0'.

3.2.1. Sensors and Time stamp

The bits from 12 to14 allow selecting the sensors used in the datalogging.

- If bit 12 of "DMA configuration word" is set to '1' the value of sensor 0 will be saved. The sensor 0 configuration is defined from EEPROM #15 to #1A.
- If bit 13 of "DMA configuration word" is set to '1' the value of sensor 1 will be saved. The sensor 1 configuration is defined from EEPROM #1B to #20.
- If bit 14 of "DMA configuration word" is set to '1' the value of sensor 2 will be saved. The sensor 2 configuration is defined from EEPROM #21 to #26.

In order to know when the sensor value has been saved, a time stamp can be added before each sequence of measure.

- If bit 15 of "DMA configuration word" is set to '1' the time stamp is added

When more than one sensor is selected as a source of automatic logging, the DMA stores subsequently all the sensor output data in the selected memory. The stored data have a prefix to identify them as shown in the following table.

Bit	15:14	13:0
Definition	Prefix	ADC output code

The prefix code is defined in the following table:

Prefix code	Related sensor or parameter
00	Sensor 0
01	Sensor 1
10	Sensor 2
11	Iteration index (Time stamp)

When only one sensor is selected, the DMA stores subsequently the sensor output data in the selected memory without prefix as shown in the following table.

Bit	15:0
Definition	ADC output code

<u>Example:</u>

If only the sensor 0 data are saved and its value without prefix is 0x6904 then this value, when the standalone application uses multiple sensors, will be shifted two bits on right and prefix '00' will be added on MSbit. The steps to shift the value and add the time stamp are shown in the following table:

Hexadecimal	0x6904
binary	0b0110 1001 0000 0100
Shifted value	0b01 1010 0100 0001
with prefix	0b0001 1010 0100 0001
New hexadecimal	0x1A41

In case of datalogging with 3 sensors and time stamp the memory contents are as follows:

Memory address	Value (hex)	MSbyte (bin)	Prefix	Value without prefix (hex)
0000	C000	1100 0000	Time stamp	0000
0001	25DB	0010 0101	Sensor 0	976C
0002	5BFA	0101 1011	Sensor 1	6FE8
0003	A2B2	1010 0010	Sensor 2	8AC8
0004	C001	1100 0000	Time stamp	0001
0005	25DB	0010 0101	Sensor 0	976C
0006	5BFB	0101 1011	Sensor 1	6FEC
0007	A2B3	1010 0010	Sensor 2	8ACC
0008	C002	1100 0000	Time stamp	0002
0009	25DB	0010 0101	Sensor 0	976C
000A	5BFA	0101 1011	Sensor 1	6FE8
000B	A2B1	1010 0010	Sensor 2	8AC4
000C	C003	1100 0000	Time stamp	0003
000D	25DB	0010 0101	Sensor 0	976C
000E	5BFA	0101 1011	Sensor 1	6FE8
000F	A2B2	1010 0010	Sensor 2	8AC8

Same data as previous table but re-arranged for clarity:

Memory value				Data with prefix removed			
Timestamp	Sensor 0	Sensor 1	Sensor 2	Time stamp	Sensor 0	Sensor 1	Sensor 2
C000	25DB	5BFA	A2B2	0000	976C	6FE8	8AC8
C001	25DB	5BFB	A2B3	0001	976C	6FEC	8ACC
C002	25DB	5BFA	A2B1	0002	976C	6FE8	8AC4
C003	25DB	5BFA	A2B2	0003	976C	6FE8	8AC8

In case of datalogging with only sensor 0 and without time stamp, there is no prefix and the memory content is as follow:

Memory address	Memory value
0000	976C
0001	976C
0002	976D
0003	976C

3.2.2. LSB and MSB Masks

In order to identify the start and the end of a sequence of measurements stored in the external memory two options are available.

- If bit 8 of "DMA configuration word" is set to '1' the MSByte of the first word in the datalogging sequence in the external EEPROM is NOT copied.
- If bit 9 of "DMA configuration word" is set to '1' the LSByte of the last word in the datalogging sequence in the external EEPROM is NOT copied.

Example:
For a datalogging application with one sensor and 4 iterations:

Memory address	Initial value	With Option disabled	With b8='1'	With b9='1'	With b8='1' and b9='1'
0000	FFFF	9884	FF84	9884	FF84
0001	FFFF	9885	9885	9885	9885
0002	FFFF	9885	9885	9885	9885
0003	FFFF	9884	9884	98FF	98FF
0004	FFFF	FFFF	FFFF	FFFF	FFFF

A datalogging application with two sensors with timestamp and 4 iterations"

With no option: (b8 and b9 reset to '0')

Memory value		
Timestamp	Sensor 0	Sensor 1
C000	25DB	5BCA
C001	25DB	5BCB
C002	25DB	5BCA
C003	25DB	5BCA
FFFF	FFFF	FFFF

With option "remove LSByte" and "remove MSbyte" enabled (b8 and b9 set to '1')

Memory value		
Timestamp	Sensor 0	Sensor 1
FF00	25DB	5BCA
C001	25DB	5BCB
C002	25DB	5BCA
C003	25DB	5BFF
FFFF	FFFF	FFFF

3.2.3. Source and destination selection

Basically a DMA unit copies data from a source to a destination. For a datalogging application, data from the sensor are copied to a memory. The MLX90129 allows this basic configuration but also other DMA operations such as copying register file to external memory. These other configurations which are not about datalogging are not detailed in this document. The bits 4 and 5 of "DMA configuration word" allow selecting the source. The code '11' is for selecting the sensor value after conversion by the ADC as a source. In this case there is no address to be defined for the source. Consequently the EEPROM #0A "DMA source start address" is filled with 0x0000.

The destination of the data is selected with the bits 6 and 7 of "DMA configuration word".

- The code '01' selects the internal memory of the MLX90129 as a destination of the data.
- The code '10' selects the external memory as a destination of the data.

Once the destination is selected, the start address and also the number of iterations have to be chosen according to the following recommendations.

The start address is the address where the DMA unit will copy the first word of a DMA sequence. It is defined in the EEPROM #0B "DMA destination start address". Care should be taken when the internal memory of the MLX90129 is selected as destination. Indeed in case of wrong configuration, the EEPROM allowed for MLX90129 configuration (from address #00 to #28) could be overwritten. For this reason the minimal value for the DMA destination start address in case of internal memory selected is 0x0029.

The EEPROM #0C "DMA processing length" corresponds to the number of words to be copied in the destination. It is not similar to the number of datalogging sequences or number of iterations. The number of datalogging sequences is the number of wake up to measure sensor(s) values. For example, one iteration could include up to three sensor measurements and the time stamp.

DMA sequence include	Number of words copied
One sensor	1
Two sensors	2
Three sensors	3
One sensor + Time stamp	2
Two sensors + Time stamp	3
Three sensors + Time stamp	4

For example a datalogging with 3 sensors and time stamp with 100 iterations corresponds to 400 words to be saved. Consequently the EEPROM #0C is filled with 0x190 (corresponds to 400 in decimal basis)

Care should be taken when the internal memory of the MLX90129 is selected as destination. Indeed if the number of words saved exceeds the amount of physical memory available, the EEPROM allowed for MLX90129 configuration (from address #00 to #28) could be overwritten. For this reason the maximum number of words for a datalogging application in the internal memory is 0x00D7.

3.2.4. Loop features

In the "DMA configuration word" (EEPROM #09) the bit 3 allows the enabling of an eternal loop of datalogging. In this case, after having copied the number of words defined in "DMA processing length", the DMA unit does not stop its operation but sets its address to the initial one ("DMA destination start address") and goes on copying data. The timestamp could allow for characterizing the measurement chronologically.

Example:
Datalogging with one sensor plus timestamp with "DMA processing length" equal to 0x0008 and "DMA destination start address" equal to 0x0000 in the external memory. Once the address 0x0008 has been reached, the DMA unit starts storing values from address 0x0000 as shown in the following memory content

Memory address	Memory value	
	Time stamp	Sensor value
0000	C00C	261B
0002	C00D	261B
0004	C00A	261B
0006	C00B	261B
0008	FFFF	FFFF

3.2.5. DMA configuration example

The following paragraph gives basic EEPROM DMA configuration for the most common applications. They can be implemented as is.

Configuration for a datalogging with one sensor, such as internal temperature sensor, and full MLX90129 internal memory used (215 measures):

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Configuration	09	1070	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0
source start address	0A	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
destination start address	0B	0029	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
processing length	0C	00D7	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	1

Configuration for a datalogging with one sensor plus time stamp and full MLX90129 internal memory used (107 measures):

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Configuration	09	9070	1	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0
source start address	0A	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
destination start address	0B	0029	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
processing length	0C	00D7	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	1

Configuration for a datalogging with one sensor plus time stamp, full MLX90129 internal memory used and loop enabled. Infinite number of measurements but only the 107 last measurements are kept:

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
configuration	09	9078	1	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0
source start address	0A	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
destination start address	0B	0029	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
processing length	0C	00D7	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	1

Configuration for a datalogging with one sensor plus timestamp and EVB90129 external memory used. 4095 measurements are saved in the external memory:

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
configuration	09	90B0	1	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0
source start address	0A	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
destination start address	0B	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
processing length	0C	1FFF	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1

Configuration for a datalogging with three sensors plus time stamp and full external 128kbits memory used. 2047 measures for each sensor are saved in the external memory:

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
configuration	09	F0B0	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	0
source start address	0A	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
destination start address	0B	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
processing length	0C	1FFF	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1

3.3. Timer configuration

The timer configuration determines the time between consecutive sensor measurements in a datalogging sequence. Depending on the application, the measurement from the sensor(s) can be done every millisecond, second, minute or hour. The MLX90129 embeds a low frequency oscillator (LFO) with very low power consumption which can be selected as timer clock source. However the precision of the LFO is +/- 15% which does not allow highly precise timing intervals between measurements. In case of timing precision requirements, the MLX90129 allows connecting an external real time oscillator (XLFO) at the frequency of 32,748 kHz. In compensation to the high precision timing the power consumption in sleep mode is higher than with the LFO. The selection between the LFO and XLFO as clock source for the timer is done by the bit 14 of the EELatch word 0 (#03) in the internal device memory domain. Care should be taken to not over-write the trimming bits in this EELatch.

- If the bit 14 of the EELatch word 0 (#03) is set to ‘0’ the LFO is selected as source clock for the timer.
- If the bit 14 of the EELatch word 0 (#03) is set to ‘1’ the XLFO is selected as source clock for the timer.

The EEPROM #0F “Timer period” defines the period between two measurements according to the time units defined in the EEPROM #10 “Timer control”.
The bits 4 and 5 define the unit according to the following table. The N is the value in hexadecimal in the “Timer period” register.

b5 b4	Time unit	Timer period precision
00	Period in milliseconds	N * 0.9765625 ms
01	Period in seconds	N * 1 second
10	Period in minutes	N * 1 minute
11	Period in hours	N * 1 hour

Care should be taken that the sensor initialization time in addition to the ADC conversion time is not longer than the timer period.

The time of the measurement is included in the period. That means there is exactly the required period between measurements. Knowing the time when the datalogging started, Time stamps allow deducing the time when a specific measurement happened.

Example:
Device configured to do one sensor acquisition every 10 minutes. The datalogging has started at 2 pm (this value can be coded and saved in the MLX90129 memory). The time stamp combined with the measure is 0xC023. That means it is the 35^{th} sequence. 35 multiplied by 10 minutes gives the time elapsed since the start. 350 minutes equals to 5 hours and 50 minutes. Consequently the measurement happened at 7:50 pm.

The functionality of the bits of EEPROM #10 “Timer control” which are not detailed in this paragraph will be addressed in the next part of this document. In the following example the not detailed bits are set to ‘0’.

3.3.1. Timer Configuration example

- Sensor acquisition every 10 seconds with LFO as source clock

EEPROM configuration

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Timer period	0F	000A	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Timer control	10	0010	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Internal device memory domain configuration

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EELATCH word 0	03	XXXX	0	0	T	T	T	T	T	T	0	T	T	T	T	T	T	T

'T' are Factory defined bit values. Spurious results may occur if values are altered from their factory set value.

- Sensor acquisition every 4 minutes with XLFO as source clock

EEPROM configuration

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Timer period	0F	0004	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Timer control	10	0020	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Internal device memory domain configuration

Content	#	Hexa	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EELATCH word 0	03	XXXX	0	1	T	T	T	T	T	T	0	T	T	T	T	T	T	T

'T' are Factory defined bit values. Spurious results may occur if values are altered from their factory set value.

3.4. External memory configuration

In order to extend the amount of data saved, an external memory can be connected to the MLX90129 through the SPI interface. The External memory can be up to 1Mbits. The external regulated output of the MLX90129 can be used as power supply for the external memory. The bit 6 and 7 of "DMA configuration word" being set to code '10' selects the external memory as a destination of the data.

The external memory available on the EVB90129 is a 128Kbits SPI memory. The characteristics and the following configuration are common for most of the 128kbits memory on the market.
In order to enable the communication between the MLX90129 and the external memory, the following configuration has to be set in the EEPROM at address #0D and #0E:
#0D = 0x0629
#0E = 0x0203
Also, the bit 0 of the register #05 has to be set to '1' in order to put the MLX90129 in master mode.

The following sequence helps validate the configuration of the external memory. For the EVB90129 the jumper CON3 "memory enable" as to be set in order to supply the external memory. The jumper of the SS Selector has to be set between SS_29 and SS_MEM in order to connect the SPI bus from MLX90129 to the external memory SPI bus.

Action	RFID commands request	Response	Comments
Write EEPROM #0D	43210D2906 crc	0078F0	No error
Write EEPROM #0E	43210E0302 crc	0078F0	No error
Update Register from EEPROM	03C01F crc	0078F0	No error
Read Register #05	03A01F05 crc	00F03FB073	#05 data =0x3FF0
Write Register #05	03A11F05F13F crc	0078F0	Set MLX90129 as SPI master
Write External Memory #0000 with ABCD	03A51F0000CDAB crc	0078F0	No error
Read External Memory #0000	03A41F0000 crc	00CDABC7A7	Read 0xABCD => Correct

In order to minimize the power consumption in a datalogging application, the external memory can be supplied only when needed. To set this option the bit 13 of the EEPROM #12 has to be set.

In order to choose the size of the external memory, the following parameters have to be taken into consideration:

MLX90129 data are 16 bits long (2 bytes or one word). MLX90129 timestamps are 16 bits long and should be added in the calculus. MLX90129 manages automatically the conversion from 16 bits data to the 8 bits data compatible with the external memory. More information is provided in a dedicated application note.

Example:
Area available in a 128kbit memory: 128kbit memory: = 16Kbyte => 8K words = 8*1024 = 8192 words
This memory can store 8192 data from the MLX90129 which means:

- 8192 acquisitions of one sensor
- 4096 acquisitions of two sensors
- 2730 acquisitions of three sensors
- 4096 acquisitions of one sensor plus timestamp
- 2730 acquisitions of two sensors plus timestamp
- 2048 acquisitions of three sensors plus timestamp

Area available in a 1Mbit memory: 1Mbit memory: = 128Kbyte => 64K words = 64*1024 = 65536 words
This memory can store 8192 data from the MLX90129 which means:

- 65536 acquisitions of one sensor
- 32768 acquisitions of two sensors
- 21845 acquisitions of three sensors
- 32768 acquisitions of one sensor plus timestamp
- 21845 acquisitions of two sensors plus timestamp
- 16384 acquisitions of three sensors plus timestamp

For information, a MLX90129 sensing its internal temperature sensor every minute and storing data in a 1Mbit external SPI memory, is autonomous in terms of data storage during more than 45 days. In case the acquisition is every hour, the autonomy is more than 7 years.

More information about external SPI memory and its configuration is provided in a dedicated application note.

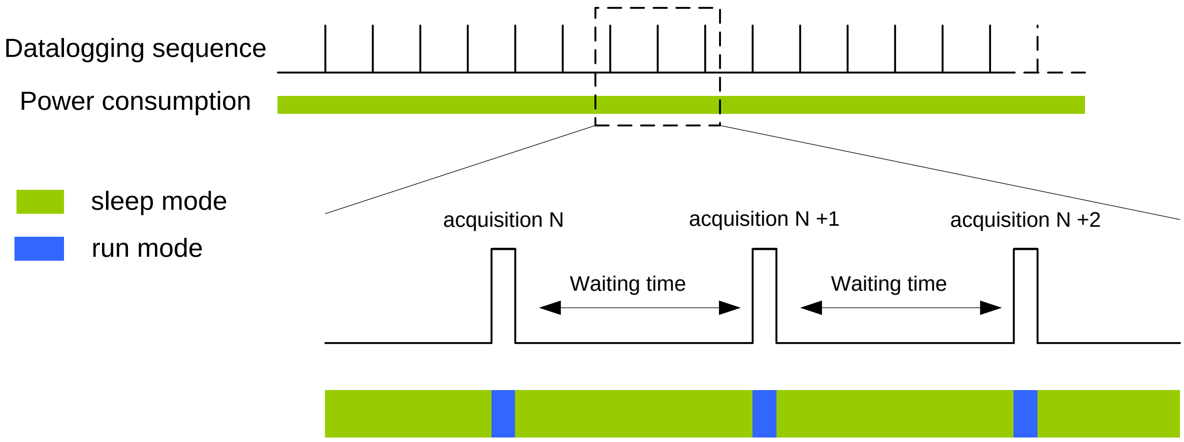
4.Power management

The MLX90129 power management includes 4 modes:

- ❑ Watchful (initial state at power on ~ 100uA)
- ❑ Run (memory / internal sensor access ~ 500uA)
- ❑ Sleep (only wake-up timer works ~ 1.5uA) *
- ❑ Standby (all MLX90129 blocks are in standby ~ 0.5uA)*

* The external memory is not supplied by the regulator (to save power).

The power modes are managed automatically during datalogging. The MLX90129 is in “Run” mode during the sensor value acquisition and most of the time it is in “Sleep mode” waiting for the next acquisition. During the waiting time it is not necessary to supply an eventual external SPI memory through the MLX90129 regulator (Vreg). Consequently, the bit 13 of the EEPROM #12 has to be set to ‘1’. The regulator supplies the external device only in “Run” mode. However, if requested, Vreg can be continuously enabled by setting the bit 13 of the EEPROM #12 to ‘0’.
In most of the applications, the ratio between the sensor acquisition time and the waiting time allows considering the power consumption in “run” mode as negligible. The acquisition time depends on the sensor and the ADC configuration. It can vary between 2.3 milliseconds and 1 second. Once the datalogging has been started the power consumption corresponds to the following schematic.



The average power consumption is given by the following formula:

$$I_{avg} = \frac{(I_{sleep} * T_{sleep} + I_{sensing} * T_{sensing})}{(T_{sleep} + T_{sensing})}$$

Example:
A MLX90129 low cost temperature logger senses temperature every minute (T_cycle) during 5 days. That means 7200 acquisitions.

The system parameters for one cycle are:

- ❑ I_sensing = 500uA
- ❑ Tcycle_sensing = 2.3 ms
- ❑ I_sleep = 1.5uA
- ❑ Tcycle_sleep = Tcycle – T_sensing = 59997.7ms

The parameters for the whole sequence are:

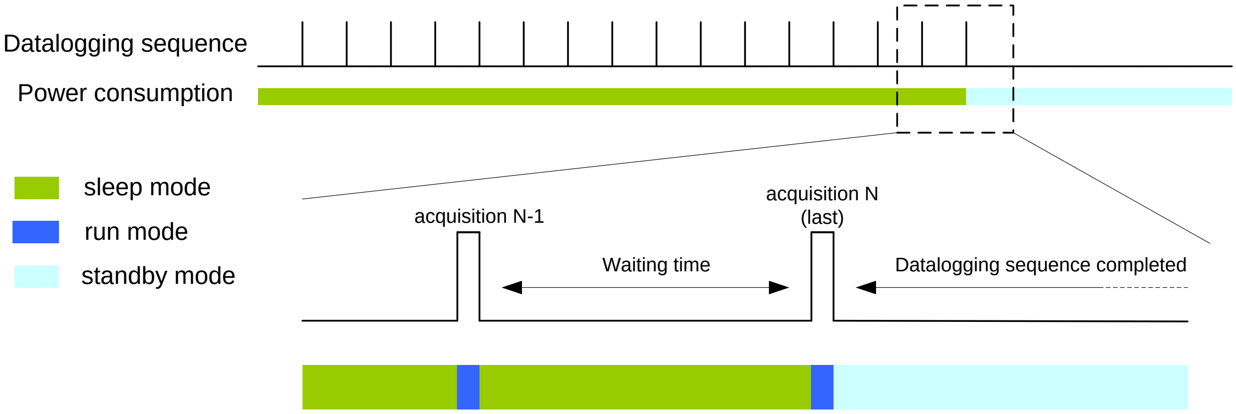
- ❑ Total T_sensing = 2.3ms * 7200 = 16,56 s
- ❑ Total T_sleep = 59997.7ms * 7200 = 431 983.44 s

The average power consumption is

$$I_{avg} = \frac{(500uA*16.56s + 1.5uA*431983.44s)}{(16.56s + 431983.44s)} = 1.519uA$$

In case the power consumption during sensing time is considered as negligible the average power consumption is 1.5uA.
If we consider a 225mAh cell battery, the life time of the device is about 17 years.

At the end of a datalogging sequence it is advised to switch the MLX90129 into “Standby” mode in order to save power. This option is available through the bit 2 of the EEPROM #10. By setting this bit to ‘1’, the standby mode is automatically selected once the datalogging sequence is finished. The end of the datalogging sequence with the standby mode option selected is described in the following schematic.



The whole average power consumption is given by the following formula:

$$I_{avg} = \frac{(I_{sleep} * T_{sleep} + I_{sensing} * T_{sensing} + I_{standby} * T_{standby})}{(T_{sleep} + T_{sensing} + T_{standby})}$$

<u>Example:</u>
A MLX90129 low cost temperature logger senses temperature every minute during 5 days of the week and is inactive during the two-day weekend. The power consumption during sensing time is considered as negligible. The system parameters are:

- I_sleep = 1.5uA
- T_sleep = 5 days
- I_standby = 0.5uA
- T_standby = 2 days

During the week the power consumption corresponds to the sleep mode (I_sleep) and during the weekend power consumption corresponds to the standby mode (I_standby). The average power consumption of the whole week is the addition of both modes:

$$I_{avg} = \frac{(1.5uA*5days + 0.5uA*2days)}{(5days + 2days)} = 1.214uA$$

If we consider a 225mAh cell battery, the life time of the device is about 21 years.

5. Datalogging sequences

5.1. Datalogging start up

Once the sensors, the DMA, the SPI and the timer have been configured the datalogging sequence is initiated by starting the timer. The timer starts when the bit 2 of the Register #10 “Timer Control” is set. Depending on the application there are several possibilities to start the datalogging sequence:

- The timer can be started automatically after the device has been power
- The timer can be started by a RFID command (after power on)
- The MLX90129 can be put in very low power mode until the datalogging sequence is started by a RFID command.

5.1.1. Datalogging sequence started from power on

As soon as the MLX90129 is powered, the configuration is loaded from the EEPROM to the register and as soon as the bit 2 of the register #10 is set to ‘1’ the timer starts. To start the datalogging immediately after the MLX90129 is powered, this bit has to be set in EEPROM. Care should be taken for systems using external memory. Indeed the b0 of the EEPROM / Register #05 has to be set before the timer starts.

Actions	RFID commands	Comments
Field ON		The MLX90129 is powered only by the electromagnetic field from the RFID reader
EEPROM configuration	…	Ex: DMA, SPI master …
Timer Configuration	4321101C00 crc	Timer every second
EEPROM configuration	…	Ex: Sensors…
Field OFF		The MLX90129 is switched off
When the datalogger is in situation to start the datalogging sequence:		
The battery is plugged		The datalogging sequence starts
The datalogging sequence is running		

5.1.2. Datalogging sequence started by a RFID command

In this case the timer is disabled by default in the EEPROM. That means, once powered, the MLX90129 loads the register file from EEPROM but the timer does not start because the bit 2 is not set. In order to start the datalogging sequence a RFID command to start the timer is sent. Care should be taken for systems using external memory, the bit 0 of the EEPROM / Register #05 has to be set before the timer start.

Actions	RFID commands	Comments
Field ON		The MLX90129 is powered only by the electromagnetic field from the RFID reader
EEPROM configuration	…	Ex: DMA, SPI master …
Timer Configuration	4321101800 crc	Timer every seconds
EEPROM configuration	…	Ex: Sensors…
Field OFF		The MLX90129 is switched off
The battery is plugged		The registers are loaded but the timer does not start /!\ during this time the power consumption correspond to the Watchful mode (~ 100uA)
When the datalogger is in situation to start the datalogging sequence:		
Write Register file #05	03A11F05F13F crc	Put the MLX90129 as SPI master (only if an external memory is used)
Read Register file #10	03A01F10 crc	Read the timer control register
Write Register file #10	03A11F101C00 crc	Add a mask at the read value to set b2 and then start the timer and the datalogging sequence
The datalogging sequence is running		

5.1.3. MLX90129 in low power before the datalogging sequence

This case corresponds to a datalogger for which the battery will be connected at the factory but the datalogging sequence has to start later. During the time where the MLX90129 is not used, it is interesting to put it in the lowest power consumption mode. The idea is to start a datalogging of one unit without saving data which at the end will put the MLX90129 in standby mode (~ 0.5uA). The device can stay in this state as long as necessary. It can be woken up and the datalogging can be started by RFID commands.

Actions	RFID commands	Comments
Field ON The battery is connected		The MLX90129 is powered by the battery but the battery could be connected at the end of the configuration.
EEPROM configuration	…	Classic configuration without taking care of a specific behavior
Timer Configuration in EEPROM	4321101800 crc	The timer has to be disabled in EEPROM
EEPROM configuration	…	End of the complete configuration
Update of the register file	03C01F crc	The application configuration is loaded in the register file but the timer does not start
Write Register file #09	03A11F09B000 crc	No sensors are selected for the datalogging to go in low power mode
Write Register file #0F	03A11F0F0100 crc	The shortest time of the timer is selected (1 ms)
Write Register file #10	03A11F100C00 crc	The timer starts counting for 1ms then the MLX90129 goes in standby mode
Field OFF		During this time the MLX90129 is in standby mode
When the datalogger is in the situation to start the datalogging sequence		
Field ON		
Update of the register file	03C01F crc	The application configuration is loaded in the register file but the timer does not start
Write Register file #05	03A11F05F13F crc	Put the MLX90129 as SPI master (only if an external memory is used)
Read Register file #10	03A01F10 crc	Read the timer control register
Write Register file #10	03A11F101C00 crc	Add a mask at the read value to set b2 and then start the timer and the datalogging sequence
The datalogging sequence is running		

5.2. Datalogging on hold

During the datalogging several actions from the user are allowed. The datalogging can be put on hold, the address of the current iteration can be checked, data can be read then the datalogging sequence can be restarted.

5.2.1. Current address destination

At any time during the datalogging, the address of the memory block used to store the data currently being processed, can be read. This address is available by reading the internal device register #05 "DMA current destination address".

Example:

RFID commands	RFID response	Comments
03A21F05 crc	001B00F5B7	The response is 0x001B when no datalogging sequence has been started
When datalogging sequence has been started:		
03A21F05 crc	0022004FD6	Means the current destination address is 0x0022
03A21F05 crc	01A11CA2	Means the internal device is busy, current address is not available.
03A21F05 crc	0024009F82	Means the current destination address is 0x0024

Care should be taken that the current destination address does not correspond to the number of iterations of the datalogging sequence. Indeed, if more than one sensor is saved the destination address is incremented by more than one unit for each iteration. However if the number of data saved is known (else read register file #09) it is easy to determine the iteration number.

Example:

For a datalogging sequence with one sensor and timestamp, the destination address will be twice the iteration number.

iteration	Destination address
0	0x0000
1	0x0002
2	0x0004
…	….
38	0x004C

For a datalogging sequence with three sensors and timestamp, the destination address will be four times the iteration number.

iteration	Destination address
0	0x0000
1	0x0004
2	0x0008
…	….
30	0x0078

5.2.2. On hold process

At any moment the datalogging sequence can be put on hold by the RFID reader and data can be read. To put on hold the datalogging, the bit 1 of the Register file #09 "DMA configuration" has to be set. Then data already saved can be read, IRQ can be checked, etc. In order to restart the datalogging sequence, the bit 1 has to be reset.

Example:

Actions	RFID commands	RFID response	Comments
Read Register #09	03A01F09 crc	00B0902B68	The current configuration of the register file #09 is 0x90B0
Write Register #09	03A11F09B290 crc	0078F0	Bit 2 of register #09 is set, the datalogging is on hold
Read internal device #01	03A21F01 crc	000000CCC6	No interruption detected (facultative)
Read current address	03A21F05 crc	001A002DAE	The current destination address is 0x001A
Read last data, time stamp	03A41F1800 crc	000CC060A9	Timestamp is 0xC00C => thirteen iterations
Read last data, sensor value	03A41F1900 crc	001C25528C	Data = 0x251C (prefix included)
Write Register #09	03A11F09B090 crc	0078F0	Datalogging restarted
Read current address	03A21F05 crc	0024009F82	Means the current destination address is now 0x0024, the datalogging sequence continues

5.3. Datalogging end sequence and data recovery

The datalogging sequence is either automatically stopped when the number of iterations configured has been reached or could be stopped by a command. By resetting the bit 2 (WUT_Autolog_EN) of the register #10, the wake up timer stops and so does the datalogging sequence. Once stopped, data stored in the internal or external memory can be read by RFID with the classic read EEPROM or read external Memory commands.

Example:

Actions	RFID commands	RFID response	Comments
Write Reg#10	03A11F100000 crc		Stop DMA
Read internal device #01	03A21F01 crc	000000CCC6	No interruption detected (optional)
Read current address	03A21F05 crc	004C000A29	Means the last destination address used is 0x004C => last data in 0x004B
Read external memory	03A41F0000 crc	0000C0C000	Timestamp is 0xC000 = iteration 0
Read external memory	03A41F0100 crc	002225E0A0	Data = 0x2522 (prefix included)
..	…	…	…
Read external memory	03A41F4A00 crc	0025C04B5D	Timestamp is 0xC025 = iteration 37
Read external memory	03A41F4B00 crc	002225E0A0	Data = 0x2522 (prefix included)

5.4. Delays for data recovery (memory access delay)

The commands “Read Single Block”, “Read Multiple Blocks” and “Read External Memory” are used to recover data from the MLX90129 internal memory or from the external SPI memory. The following tables allow to evaluate the time needed to recover the data by RFID.

5.4.1. Data in the MLX90129 internal EEPROM

The command “Read Single Block” returns 16 bits. The command “Read Multiple Blocks” allows reading several blocks with only one request. The number of blocks returned is specified in the request. The limit is not defined by the ISO15693 standard but by the buffer size of the RFID reader that is used. In the following example, the buffer is limited to 95 blocks.

Operation	Time of the RFID communication (request + answer)
Read Single Block	3.74 ms
Read Multiple Blocks (20 blocks)	15.5 ms
Read Multiple Blocks (40 blocks)	27.5 ms
Read Multiple Blocks (60 blocks)	39.5 ms
Read Multiple Blocks (72 blocks)	47 ms
Read Multiple Blocks (95 blocks)	60 ms
Read full MLX90129 data memory (216 blocks) *	141 ms

*The value is theoretical. It is based on the time to read 3 times 72 blocks which corresponds to the full MLX90129 data memory (216 blocks). It does not take into account the limitation due to the RFID reader processing and communication delay. For example, with the DVK90121, which processes an RS232 communication between each RFID request, the total time is 455 ms.

5.4.2. Data in the external SPI memory

The command “Read External Memory” allows to read data stored in the SPI memory connected to the MLX90129. The time to read 1 block is 4.34 ms. The minimum time between two ISO15693 subsequent requests is 310us. According to these parameters the following table gives the theoretical delay to read data.

Operation with the external SPI memory	Theoretical delay
Read one block (2 bytes)	3.74 ms
Read 512 bytes	1.1 s
Read 1 Kbytes	2.2 s
Read 8 Kbytes	17.8 s
Read 16 Kbytes	35.6 s
Read 32 Kbytes	1 min 11 s
Read 64 Kbytes	2 min 22 s
Read 128 Kbytes	4 min 44 s

6.Datalogging Examples

Two examples are provided to illustrate the options and the sequence of a datalogging application. The first example, the weather station, uses all the features of the EVB90129 in order to monitor the weather during 24 hours. The second example is a cold chain monitoring datalogger based on a minimalist hardware.

6.1. The weather station based on EVB90129

This example is based on the EVB90129. The goal is to monitor the temperature and the luminosity during one day as done by a weather station. The EVB90129 is packaged in a transparent hermetic box. Temperature is monitored twice, once by the MLX90129 internal temperature sensor and then by the external temperature sensor. The luminosity is monitored by the external ambient light sensor. The button battery is used to power the system and the external 32,768 KHz oscillator is used as a precise reference for the sequence. The MLX90129 senses the weather parameters every minute during 24 hours. That corresponds to a total of 1440 times 4 words of data to store. The external 128Kbit memory of the EVB90129 fulfills this requirement. As the battery has to be connected before the packaging, the MLX9029 will be put in very low power mode after the configuration. The Datalogging sequence will be started on site by a mobile RFID reader.

Actions	RFID commands	Comments
The battery is plugged, the jumpers for the power supply, the sensors and the external memory are set correctly		
The EVB90129 is packaged in the hermetic box		
RFID reader for configuration is enabled, field is on		
Write EEPROM #09	432109B0F0 crc	Select 3 sensors plus time stamp. Take data from the ADC and store it in the external memory
Write EEPROM #0A	43210A0000 crc	
Write EEPROM #0B	43210B0000 crc	Data storage in the external memory start at the address 0x0000
Write EEPROM #0C	43210C2616 crc	1440 iteration with 4 words stored each time correspond to 5670 words =>0x1626 in hexadecimal
Write EEPROM #0D	43210D2506 crc	External memory configuration
Write EEPROM #0E	43210E0302 crc	External memory configuration
Write EEPROM #0F	43210F0100 crc	Timer wake up every minute
Write EEPROM #10	4321102800 crc	Timer disabled
Write EEPROM #12	432112FF00 crc	Default configuration
Write EEPROM #15	4321157300 crc	Internal temperature sensor configuration
Write EEPROM #16	4321160000 crc	
Write EEPROM #17	4321170000 crc	
Write EEPROM #18	4321180080 crc	
Write EEPROM #19	4321193102 crc	
Write EEPROM #1A	43211A0080 crc	
Write EEPROM #1B	43211B73D0 crc	External temperature sensor configuration
Write EEPROM #1C	43211C0000 crc	
Write EEPROM #1D	43211D0000 crc	
Write EEPROM #1E	43211E0080 crc	
Write EEPROM #1F	43211F2301 crc	
Write EEPROM #20	4321204000 crc	
Write EEPROM #21	43212173D0 crc	Light sensor configuration
Write EEPROM #22	4321220000 crc	
Write EEPROM #23	4321230000 crc	
Write EEPROM #24	4321240080 crc	
Write EEPROM #25	4321250000 crc	
Write EEPROM #26	4321260200 crc	
Read Internal device #03	03A21F03 crc	Read trimming value previous to set XLFO bit
Write Internal device #03	03A31F03XXXX crc	Select XLFO as clock source by setting bit 14 of the previous reading

Continuing		
Actions	RFID commands	Comments
Update of the register file	03C01F crc	The application configuration is loaded in the register file but the timer does not start
Write Register file #09	03A11F09B000 crc	No sensors are selected for the datalogging to go in low power mode
Write Register file #0F	03A11F0F0100 crc	The shortest time of the timer is selected (1 ms)
Write Register file #10	03A11F100C00 crc	The timer starts counting for 1ms then the MLX90129 goes in standby mode
RFID reader for configuration is disabled, field is off		
The MLX90129 is now in standby mode		

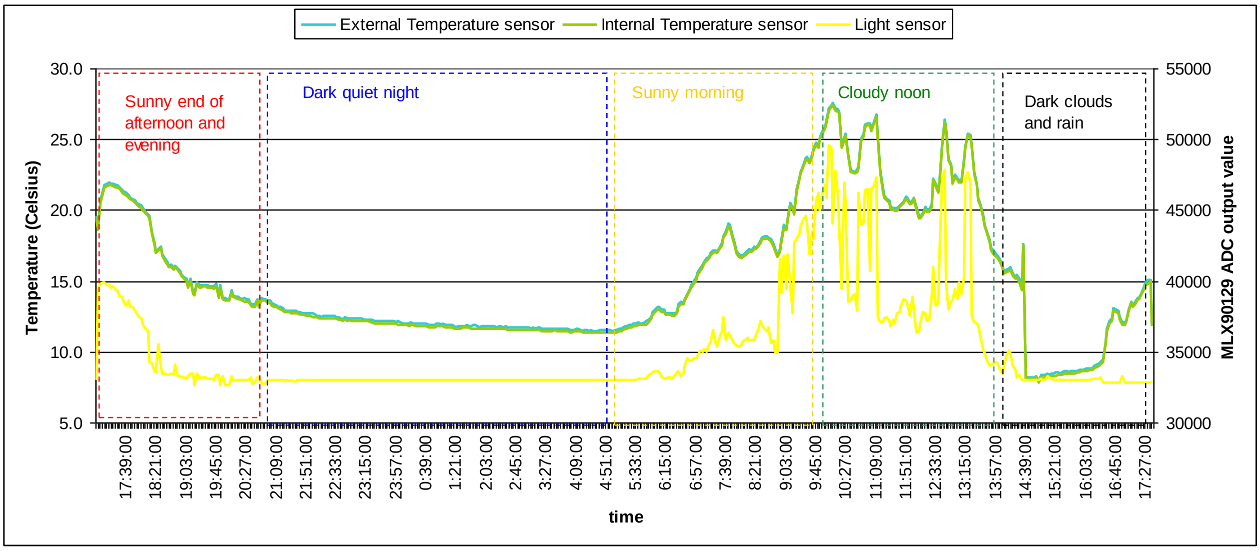
When the datalogger is in a situation to start the datalogging sequence the following commands have to be sent by a RFID reader. In our case the box has been put on the roof of Melexis' facility in Switzerland.

Actions	RFID commands	Comments
Mobile RFID reader is enabled, field is on		
Update of the register file	03C01F crc	The application configuration is loaded in the register file but the timer does not start
Write Register file #05	03A11F05F13F crc	Put the MLX90129 as SPI master (only if an external memory is used)
Read Register file #10	03A01F10 crc	Read the timer control register
Write Register file #10	03A11F102C00 crc	Add a mask at the read value to set b2 and then start the timer and the datalogging sequence
Mobile RFID reader is disabled, field is off		
The datalogging sequence is running		

After 24 hours the results are loaded using a RFID reader. The following commands have to be sent.

Actions	RFID commands	Comments
Mobile RFID reader is enabled, field is on		
Read internal device #01	03A21F01 crc	No interruption detected (this action is optional)
Read current address	03A21F05 crc	Check the memory address of the last transaction to be sure data have been recorded till the end of the sequence
Read external memory #0000	03A41F0000 crc	Read the first time stamp
Read external memory #0000	03A41F0100 crc	Read the first data
…	….	All the data are read till the final memory address
Mobile RFID reader is disabled, field is off		

The following graph shows the results from the EVB90129 sensors:



6.2. Cold chain monitoring based on the low cost temperature logger architecture

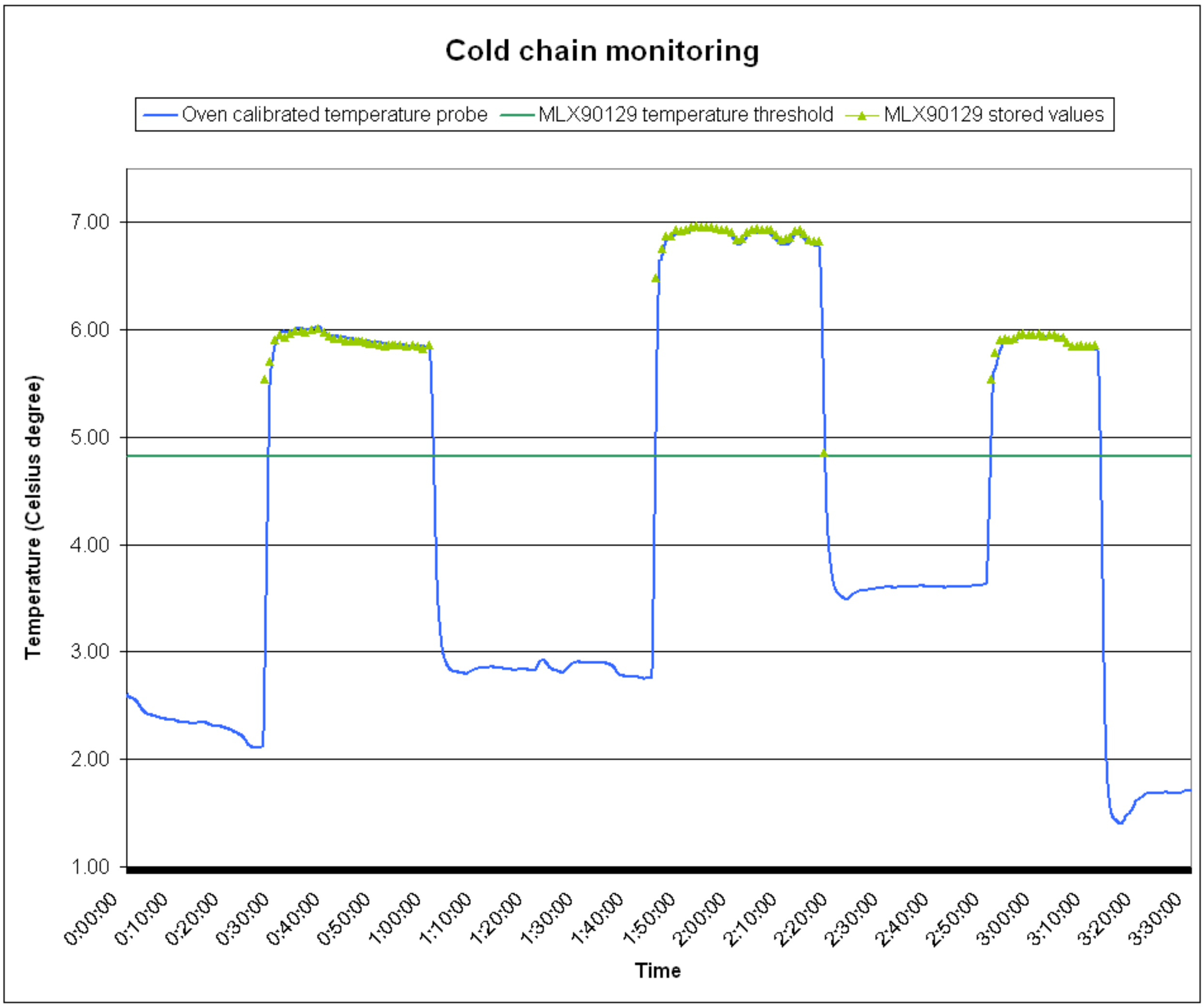
This example could also be based on the EVB90129 but thanks to the MLX90129 embedded features, only a very few external elements are needed. The example consists of implementing a professional cold chain monitoring based on the MLX90129. The temperature value is sensed with the MLX90129 internal temperature sensor and values are stored in the internal EEPROM. The number of stored values is optimized with the "threshold" feature of the Melexis device. Indeed, temperature values are stored only when they have crossed the high threshold value which is defined by the user (4.8ºC in the example). This threshold can be the temperature maximum defined by health authorities for the specific monitored goods. When the temperature has crossed the defined threshold, an interruption bit is set. This bit or the full stored data can be read wirelessly through the RFID interface. Only the RFID loop antenna, a capacitor and the battery from the EVB90129 are used. The datalogging will be started automatically when the system is going to be powered by the battery. In order to simulate the cold chain monitoring application, the EVB90129 is put in an oven for 3h30m and the temperature is monitored every minute. During the configuration, the following commands are sent:

Actions	RFID commands	Comments
RFID reader for configuration is enabled, field is on		
Write EEPROM #09	4321099070 crc	Select 1 sensor plus time stamp. Take data from the ADC and store it in the internal memory
Write EEPROM #0A	43210A0000 crc	
Write EEPROM #0B	43210B2900 crc	Data storage in the MLX90129 memory starts at the address 0x0029 (after the configuration area)
Write EEPROM #0C	43210CD700 crc	Address shall not exceed the last EEPROM address
Write EEPROM #0F	43210F0100 crc	Timer wake up every minutes
Write EEPROM #10	4321102D00 crc	Timer enabled
Write EEPROM #12	432112FF00 crc	Default power configuration
Write EEPROM #15	4321157300 crc	Internal temperature sensor configuration
Write EEPROM #16	4321160000 crc	
Write EEPROM #17	4321170000 crc	
Write EEPROM #18	4321180080 crc	
Write EEPROM #19	4321193102 crc	
Write EEPROM #1A	43211A0080 crc	
RFID reader for configuration is disabled, field is off		

Now, to start the datalogging sequence, the battery has to be connected. The EVB90129 is exposed to several temperatures around the threshold value by an oven. The temperature of the oven is also constantly recorded in order to check the results and the behavior of the threshold. After 3h30m the sequence is stopped by a RFID command and the data are saved through the same way.

Actions	RFID commands	Comments
Mobile RFID reader is enabled, field is on		
Read internal device #01	03A21F01 crc	Detect if the threshold value have been crossed or not
Read current address	03A21F05 crc	Check the memory address of the last transaction in order to read back the correct data
Read internal memory #29	032029 crc	Read the first time stamp
Read external memory #2A	03202A crc	Read the first data
…	….	All the data are read till the final memory address
Mobile RFID reader is disabled, field is off		

The timestamps allow matching data with the time line of the oven temperature. The results are shown in the following graph.



The graph shows that only temperatures above the threshold have been saved which reduces the amount of data to store.

7.Trouble shooting notes

In case of failure in the implementation of a datalogging application the following list has to be checked in order to identify the issue.

<u>The timer does not start:</u>
Check if the bit 2 of register file #10 is set to '1'.
Check if the bit 0 of the register file #09 is equal to '0'.
Check if there is a value in the timer period register #0F.

<u>No data are stored in the internal memory:</u>
Check if the source and destination registers are well configured (EEPROM #09).
Check if at least one sensor is selected (EEPROM #09).
Check if the conditions with threshold are respected (bits 4,5,6 EEPROM #15, #1B, #21).
Check if the security register configuration allows the writing in EEPROM.

<u>No data are stored in the external memory (in addition to internal memory):</u>
Implement a basic Write / Read external EEPROM test (without datalogging).
Check the SPI bus lines connections (MISO with MISO, SS with SS …).
On the EVB90129, check if the jumpers "Memory enable" and "SS selector" are in place.
Check the power supply of the external memory.
Check if the MLX90129 configuration is compliant with the external memory.
Check if the MLX90129 in master mode (bit 0 EEPROM #05 = '1').

8.Conclusion

This application note allows a fast implementation of a datalogger based on the MLX90129. Due to the embedded features, a datalogger needs only a few external components in addition to the MLX90129. The examples provided in this document could be used as a base to develop a custom application. In case of troubleshooting they can be used to validate the hardware. All the available options for a datalogging application can be found in the MLX90129 datasheet.

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