MLX90130

13.56MHz RFID Transceiver

Features and Benefits

- ❑ Conforms with ISO/IEC 14443 A[1] and B[2],
- ❑ Conforms with ISO/IEC 15693
- ❑ Conforms with ISO/IEC 18000-3 mode 1
- ❑ Standard SPI/UART interfaces with 528 Bytes of buffer
- ❑ High speed communication (848kbit/s)
- ❑ Embedded RF field and TAG detectors

Application Examples

- ❑ Medical applications such as post-surgery monitoring, glucose metering and drug identification
- ❑ Access control readers
- ❑ Industrial automation. Monitoring of goods during manufacturing and work-in-progress

[1] Purchase of MLX90130 doesn't imply any grant of any ISO14443A license. Customers are advised to sign patent licensing agreements with all third parties, especially those companies listed in the introduction of the corresponding standard.
[2] RATP/Innovatron Technology

Ordering Information

Part Code	Temperature Code	Package Code	Option Code	Packing Form Code
MLX90130	S (-20°C to 85°C)	LQ (Lead free QFN 5x5 32 leads)	ADA-000	RE
MLX90130	S (-20°C to 85°C)	LQ (Lead free QFN 5x5 32 leads)	ADA-000	TU
MLX90130	R (-40°C to 105°C)	LQ (Lead free QFN 5x5 32 leads)	ADA-000	RE
MLX90130	R (-40°C to 105°C)	LQ (Lead free QFN 5x5 32 leads)	ADA-000	TU

Functional Diagram

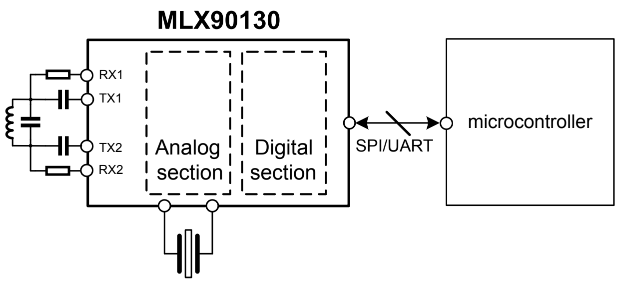


Figure 1: MLX90130 functional diagram

The dual driver architecture of the MLX90130 requires minimal external support components and allows the transmitter to provide up to 300 milliwatts RF power to an appropriate antenna load. This delivered power is suitable for most short to mid range applications.

The digital section of the MLX90130 handles the low protocol layers from API to physical layer using advanced bit and frame encoding/decoding functions. It contains a digital demodulator based on sub-carrier detection and a programmable bit/symbol encoder/decoder. It also encodes and decodes the start and stop bits, parity bits, extra guard time (EGT), start and end of frame (SOF/EOF) and CRC.

Its 528 bytes buffer allows buffering of an entire RFID frame. The SPI/UART communication ports guarantee easy interface with the majority of microcontrollers, especially the low cost ones.

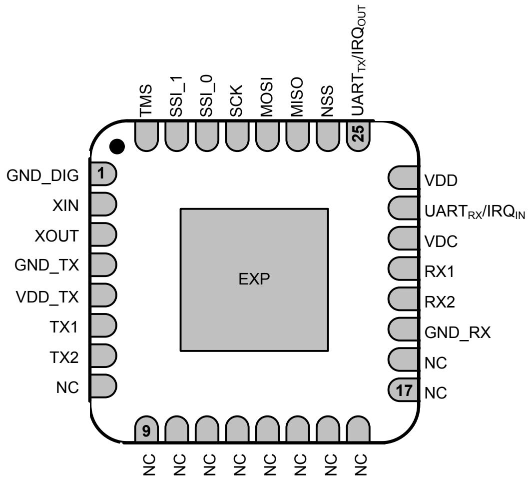
Description

The MLX90130 is a 13.56MHz, fully integrated, multi-protocol RFID transceiver IC. It has been designed to handle sub-carrier frequencies from 106 to 848 kHz and baud rates up to 848kbit/s.

Table of Contents

1 Pin and signal descriptions

The device is packaged in a 32 pin lead free QFN package.



Pin	Symbol	Pin Type	Description
1	GND_dig	Supply	Ground (Digital)
2	XIN	Analog	Xtal oscillator input
3	XOUT	Analog	Xtal oscillator output
4	GND_TX	Supply	Ground (Drivers)
5	VDD_TX	Supply	Drivers Power Supply
6	TX1	Analog	Driver output_1
7	TX2	Analog	Driver output_2
8-18	NC		Not connected
19	GND_RX	Supply	Ground (analog)
20	RX2	Analog	Receiver input_2
21	RX1	Analog	Receiver input_1
22	VDC	Analog	Melexis Reserved
23	UART_RX / IRQ_in	Digital I	UART Receive pin / Interrupt input
24	VDD	Supply	Main Power Supply
25	UART_TX / IRQ_out	Digital O	UART Transmit pin / Interrupt output
26	NSS	Digital I	SPI Slave Select
27	MISO	Digital O	SPI data output
28	MOSI	Digital I	SPI data input
29	SCK	Digital I	SPI clock
30	SSI_0	Digital I	Select serial communication interface
31	SSI_1	Digital I	Must be set to GND
32	TMS	Digital I	Must be set to VDD
EXP		Exposed Pad	Must be set to GND

Table 1: Pin definitions and descriptions

2 General Description

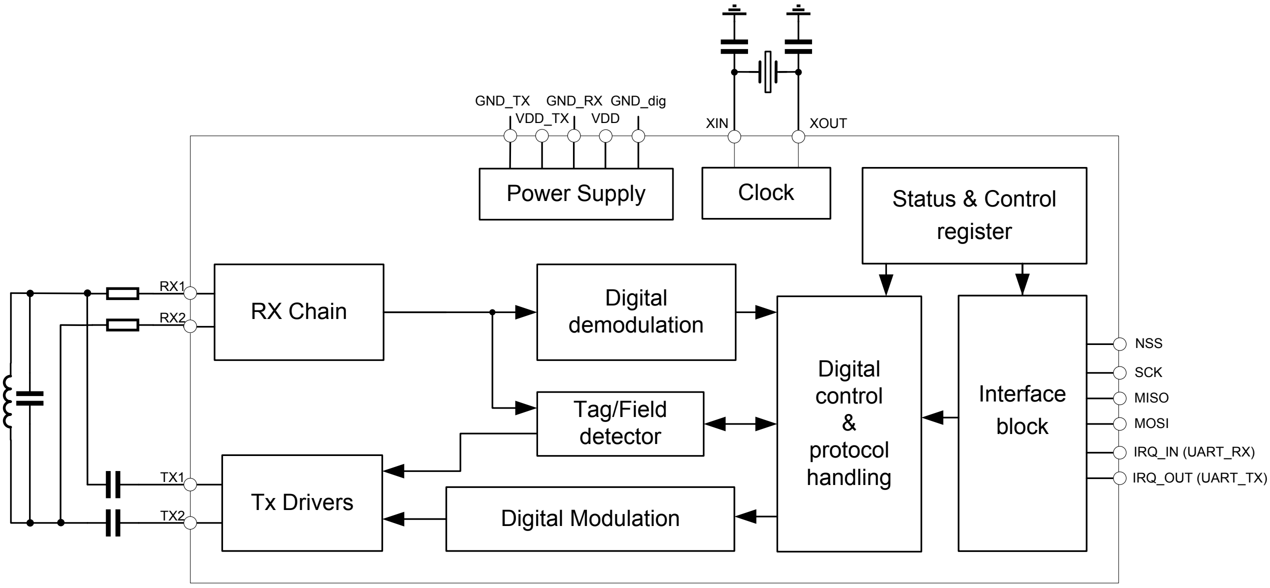


Figure 2: MLX90130 simplified block diagram

Power supply

The MLX90130 requires a nominal stable external power supply from 2.7 to 5.5 volt. The current drain depends on the antenna impedance and on the output matching network configuration.

TX Drivers

The transmission drivers are each composed of a differential D class output stage and a programmable modulation index control block. They drive the antenna according to some dual buffer output architecture. The drivers provide modulation index depth capability. They require minimal external support components and allow the transmitter part to provide up to 300 mW RF power to a suitable antenna load.

RX Chain

This chain performs analog demodulation, filtering, amplification and digitizing operations. The receiver inputs are typically connected to the antenna through 2 external attenuation resistors to avoid saturation of the internal detector. The received signal is demodulated, filtered and finally digitized to provide a digital output signal. It is then fed to the digital section for further processing. The complete receiver chain is automatically configured according to the characteristics of the received information and the protocol in use.

Digital control & protocol handling

This block handles the control of the device and the frame coding and decoding parts of the protocols supported by the MLX90130. The MLX90130 provides to the external application, pure payload information after removing frame related information (such as SOF, EOF, EGT …). It can be configured to calculate the CRC for each communication protocol.

Interface Block

The MLX90130 is addressed through SPI or UART interfaces with a specific and simple set of commands making the life of application programmers easier. A 528 bytes buffer allows minimum interaction with the external low cost microcontroller. This reduces the burden of the microcontroller whose resources can be fully dedicated for the application.

TAG/FIELD Detector

This block manages the enhanced Tag/Card detection capabilities, as well as Field detection. It generates detection signal that is available for the application microcontroller through the interrupt pin (IRQ_OUT). It allows the use of the MLX90130 with low power consumption constraints. An internal state machine handles the RF timings field generation burst.

Reference clock and internal oscillator

The built-in reference oscillator works with a reference crystal of 27.12MHz while, the internal nominal system clock frequency (HFO) is 13.56 MHz. An internal low frequency RC oscillator (LFO) at 32 kHz is also implemented. This block provides the low frequency clock to manage programmable wake-ups in Tag/Card detection as well as in Field detection modes.

Power management

The MLX90130 offers 2 modes and 5 different states of operation allowing ultra low power consumption of the whole system. In hibernate state; the device consumes typically 1µA, while the current consumption in sleep state is of 20µA. In ready state (RF field OFF), the current consumption is typically of 2.5mA and in TAG detection state, the current consumption is typically of 50µA.

Note: *In Active mode and TAG detection states, power consumption depends on the antenna load and on the operating conditions. For more information on power consumption in tag detection, please refer to the chapter* *Tag Detector*.

3 Power Management and Operating modes

The MLX90130 features 2 main operating modes: Idle and Active, with 6 different states of operation, as described on the table below:

Mode	State	Description
Idle	Hibernate	Lowest power consumption, the MLX90130 wakes-up with low level pulse on IRQ_IN pin
	Sleep	Low Power consumption: Wake-up source to exit from this mode is configurable: - Timer - IRQ_in pin (low-level) - NSS pin (low-level) - Field detector
	Tag detection	Low power consumption: Tag detection feature, wake up source is configurable - Timer - IRQ_in pin (low level) - NSS pin (low level) - Tag detector (mandatory)
Active	Ready	High frequency oscillator (HFO) is running. In this mode the MLX90130 is in reader mode with its HF turned OFF. The MLX90130 waits for a command from external application, through the selected serial interface (SPI or UART).
	Reader	High frequency oscillator (HFO) is running. In this mode the MLX90130 is selected in RFID reader mode with its HF field set ON. The MLX90130 is able to receive and execute commands through the selected serial interface (SPI or UART) and is able to communicate with RFID transponders, according to the selected protocol. In Reader mode, the command “SendRecv” is used to send and receive information from an RFID transponder

Table 2: MLX90130 Operating modes & States

Entering in Hibernate, Sleep and Tag detector states requires a dedicated command called Idle. As soon as one of these states is activated, an appropriate source signal is required to wake-up the device (see description above). The wake-up time from Sleep or Hibernate to Ready state is typically 2ms, this time is mainly due to settling time of XTAL oscillator (HFO).

In Reader mode, the MLX90130 is able to communicate with Transponders (TAG). This state is entered using the command Protocol_select. In Ready state, the MLX90130 is fully enabled but waiting for the Protocol_select command to enter the Reader state, without settling time penalty.

The following diagram describes the different working modes' capabilities

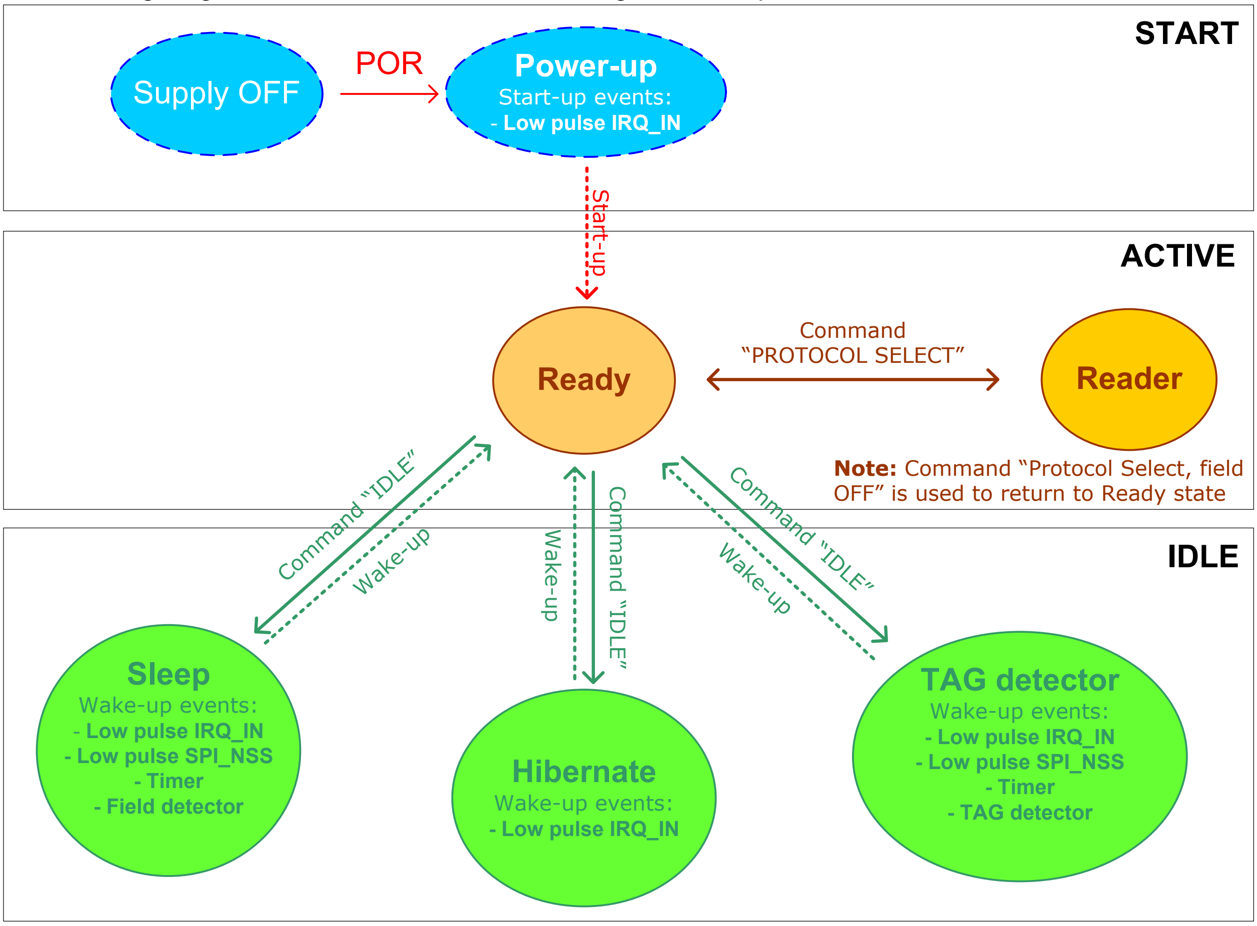


Figure 3: MLX90130 Power modes transitions

4 Start-up sequence

Once powered-up, the MLX90130 waits for a low pulse on the pin IRQ_IN (greater than 10µs) before automatically selecting the external interface (SPI or UART) and entering Ready state after a delay of approximately 2ms.

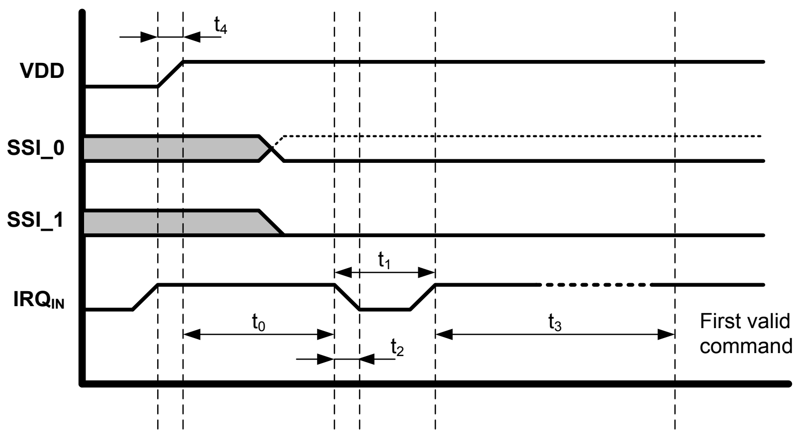


Figure 4: MLX90130 operating states transition figure

Figure 4 above shows the power-up sequence for a MLX90130 device where:

- t_0 is the initial wake-up delay[1)] 100µs (minimum)
- t_1 is the minimum pulse width in IRQ_{IN} pin[1)] 10µs (minimum)
- t_2 is the delay for the serial interface selection[1)] 250ns (typical)
- t_3 is the delay before the MLX90130 could accept commands[1)] 10ms (minimum)
- t_4 is the V_{DD} ramp-up time[1)] 10ms (maximum)

1) Value specified by design

The following configuration at power on reset (POR) is required to select the interface to be used.

Interface/Pin	SSI_1	SSI_0
SPI	0	1
UART	0	0

Table 3: Selection of the serial communication interface

Notes:

- *The Serial Interface is selected after the following falling edge of pin IRQ_IN when leaving from POR or Hibernate states.*
- *When the MLX90130 leaves the IDLE mode following an UART_RX/IRQ_{IN} low level pulse, this pulse is NOT interpreted as the UART start bit character.*

5 Communication Interface & protocol

Whatever the communication protocol selected (SPI or UART), the principle of communication is always the same: The application sends a command to the MLX90130 and waits for the appropriate answer. A simple and specific set of command allows the configuration and control of the MLX90130.

Application		MLX90130
Select protocol (e.g. ISO15693, Single Sub-carrier)	→	
	←	Protocol selected, ready for communicate
Send protocol related data, CRC automatically added (e.g. “022000” + CRC)	→	
	←	Return TAG answer (e.g. “001234ABCD”, CRC correct)
Select another protocol (e.g. ISO14443A, 7-bit mode)	→	
	←	Protocol selected, ready for communicate
Send protocol related data, CRC automatically (e.g. “26”)	→	
	←	Return TAG answer (e.g. “0400” , Parity is OK, CRC ignored)
Turn field OFF	→	
	←	Field is OFF

Figure 5: Example of communication with MLX90130

In order to start RFID communication, the application has to choose the protocol and specify some parameters. When the protocol is selected, the application sends data and parses response until the next protocol is selected or a specific parameter is changed.

5.1 UART

The default baud rate is 57.600 kbps and the maximum allowed baud rate is 2 Mbps.

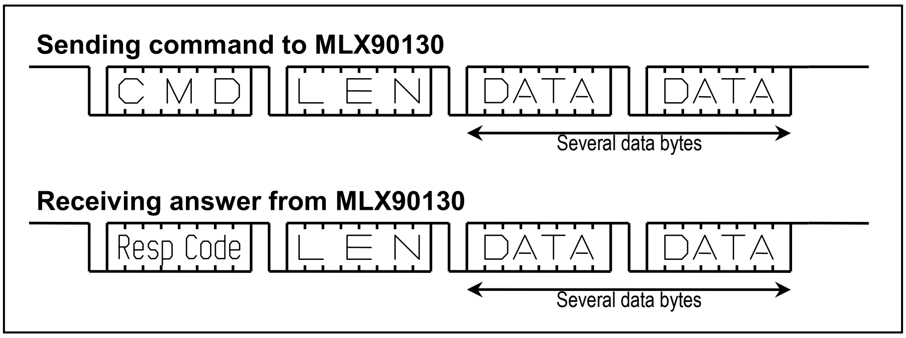


Figure 6: UART communication

Notes: *Length of data field can be zero, in this case no data is sent.*

5.2 SPI

5.2.1 Polling mode

In order to send commands and receive answers, the application software has to pass 3 stages:

1. Send the command to the MLX90130
2. Poll the MLX90130 until it is ready to transmit the response.
3. Read the response.

The application software should never read the MLX90130 without being sure that the device is ready to send its response.

A Control byte is used to specify the communication type and direction (see pictures below):
– 00: Send command to the MLX90130
– 11: Poll the MLX90130
– 10: Read data from the MLX90130
– 01: Reset the MLX90130

The SPI_NSS line is used to select a device on the common SPI bus. The SPI_NSS active level is LOW.

When the SPI_NSS line is inactive, all data sent by the application will be ignored and the SPI_MISO line will be kept in high impedance state.

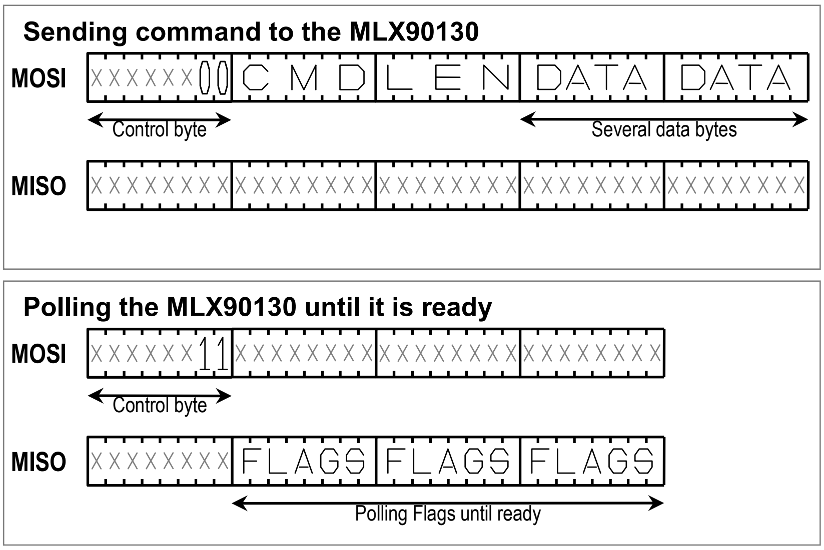


Figure 7: SPI communication, sending command & polling method

The following table shows the meaning of the flags returned by the MLX90130 device.

Bit	Description
[4:7]	RFU, will be set to “0000”
3	Data can be read from MLX90130 when set
2	Data can be sent to MLX90130 when set
[1:0]	MLX Reserved

Table 4: Interpretation of SPI flags

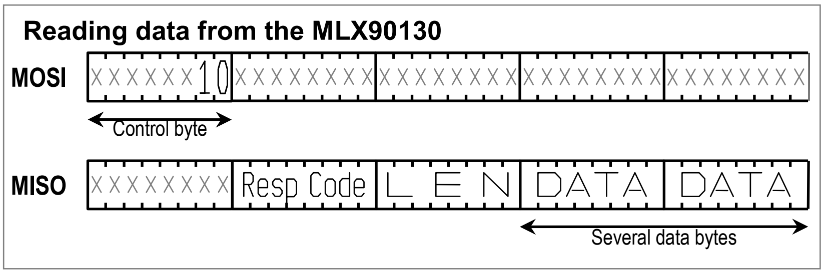


Figure 8: SPI communication, reading data from the MLX90130

The maximum allowed communication speed is 2Mbps and data must be sampled by the rising edge of the SCK signal. The SPI communication is most significant bit (MSB) first.

'Sending', 'Polling' and 'Reading' commands must be separated by a high level of the SPI_NSS line. For example, when the application needs to wait for data from the MLX90130, it asserts the SPI_NSS line to low and issues a 'Polling' command.
By keeping the SPI_NSS line low, the application can continuously read the Flags waiting for the bit indicating that the MLX90130 is ready (the flags will be automatically updated, no need to send several polling commands). Then, the application has to assert the SPI_NSS line high to finish the polling sequence. The application asserts the SPI_NSS line low again to issue a 'Reading' command to read data. When all data is read, the application asserts the SPI_NSS line high.

The MLX90130 can issue as many 'Polling' commands as necessary. For example, the application asserts SPI_NSS low, issues a 'Polling' commands and reads the flags. If the MLX90130 is not ready, the application can assert the SPI_NSS high and continue its algorithm (measuring temperature, communication with something else). Then, the application can assert SPI_NSS low again and again issues a 'Polling' commands, and so on, as many times as necessary, until the MLX90130 is ready.

Note that at the beginning of the communication, the application does not need to check flags to start the transmission. The MLX90130 is assumed to be ready to receive a command from the application.

Figure 9: SPI communication reset the MLX90130

Control byte 0x01 resets the MLX90130 and places the device in Ready state, so a wake-up sequence is not necessary.

5.3 IRQ mode

When the MLX90130 is configured to use the SPI serial interface, the pin IRQ_OUT is used to give additional information to the application. When the MLX90130 is ready to send back a reply it sends an Interrupt request by setting a low level on pin IRQ_OUT, which remains low until the application reads the data. The application can use the IRQ mode to skip the polling stage.

6 Commands

6.1 Command format

The structure of the command sent by the application is almost identical to the structure of the answer from the MLX90130, as shown below:

- **Command:** [CMD] + [LEN] + [DATA]
- **Answer:** [RESPCODE] + [LEN] + [DATA]

- [CMD] = Command (**1byte**)
- [LEN] = Length including only the field DATA, zero if no data sent (**1byte**)
- [RESPCODE] = Response code, depends on the command (**1byte**)
- [DATA] = Data information, depends on the command (**0 to 528bytes**)

6.2 List of commands

Code	Command	Description
0x01	IDN	Requests short information about device and its FW version
0x02	Protocol Select	Selects communication protocol and specifies some protocol-related parameters
0x03	Poll field	Returns the current value of the field detector flag (“FieldDet”)
0x04	SendRecv	Sends data using previously selected protocol and receives the response of the TAG.
0x07	Idle	Switches device into Idle/Sleep/Hibernate mode and specifies which condition is used to exit from these modes
0x0A	BaudRate	Sets UART baud rate
0x55	Echo	MLX90130 replies with an Echo of 0x55 to this command. In this specific case, the command format is not respected as the data is only 0x55
Other codes		MELEXIS reserved

Table 5: MLX90130 list of commands

6.3 IDN command (0x01)

The IDN command gives information about the MLX90130 and the internal firmware version

IDN **0x01**			
Direction	Data	Comments	Example
MCU – device	01	Command code	**0100**
	00	Length of data	
Device - MCU	00	Result code	000F4E4643204653324A4153543300B3EE In this example: 4E4643204653324A4153543300= Device ID B3EE = CRC of internal ROM (real CRC can differ from the example above)
	<Len>	Length of data	
	<Device ID>	Data in ASCII format	
	<ROM CRC>	CRC calculated for ROM content	

Table 6: "IDN" command description

Note: *It takes about 6ms to calculate the CRC for the entire ROM. Application must allow sufficient time before waiting for an answer to this command.*

6.4 Protocol select command (0x02)

The "Protocol Select" command automatically configures the internal registers of the MLX90130 for the best communication performances of the selected protocol. It also prepares the MLX90130 by automatically setting the HF field ON. The field will be automatically set OFF when the MLX90130 returns to Idle mode using the Idle command or by sending a Protocol Select/Field OFF command (the device then returns in Ready state).

Protocol Select **0x02**			
Direction	Data	Comments	Example
MCU – device	02	Command code	Refer to examples in table Table 8 below
	<Len>	Length of data	
	<Protocol>	Protocol codes (Reader) 00 = Field OFF 01 = ISO/IEC15693 02 = ISO/IEC14443-A 03 = ISO/IEC14443-B	
	<Parameters>	Depends on protocol selected, refer to Table 8	
Device - MCU	00	Result code	**0000 -** Protocol is successfully selected
	00	Length of data	
Device - MCU	82	Error code	**8200-** Invalid command length
	00	Length of data	
Device - MCU	83	Error code	**8300 -** Invalid protocol
	00	Length of data	

Table 7: "Protocol select" command description

Parameter list for different protocols					
Protocol (Reader)	Code	Parameters			Examples of commands
		Byte	Bit	Function	
Field OFF	00	0	7:0	RFU, set to '0'	**02020000**
ISO15693	01	0	7:6	RFU, set to '0'	**02020101** – Select ISO/IEC15693, SSC, 26kbps, modulation of 100%, CRC automatically added **02020107** – Select ISO/IEC15693, DSC, 26kbps, modulation 10%, CRC automatically added
			5:4	00 – 26kbps 01 – 52kbps 10 – 6kbps 11 – RFU	
			3	0 – Respect delay 312us 1 – Wait for SOF	
			2	0 - 100% modulation 1 – 10% modulation	
			1	0 – Single Sub-Carrier (SSC) 1 – Dual Sub-Carrier (DSC)	
			0	0 – No CRC added 1 – CRC auto. added	
ISO14443 A	02	0	7:6	Transmission data rate 00 – 106kbps 01 – 212kbps 10 – 424kbps 11 – 847kbps	**02020200** – ISO/IEC14443A, 106kbps transmission & reception, Frame Delay Time (FDT) of 86/90µs Note that anti-collision commands REQA, WUPA, Select20 and Select70 use fixed FDT of 86/90us. Other commands use variable FDT with fixed granularity. Refer to ISO/IEC14443A standard for more information.
			5:4	Reception data rate 00 – 106Kbps 01 – 212Kbps 10 – 424Kbps 11 – 847Kbps	
			3:0	RFU, set to '0'	
		1	7:0	PP (max 14, i.e. 0x0E)	**Frame Delay Time (FDT) definition:** These 3 bytes are optional. When PP, MM and DD are not specified or set to 0x00, the default value corresponds to FDT of 86/90us, used during anti-collision process. Otherwise, the following formula applies: $FDT = \frac{2^{PP} \cdot (MM+1) \cdot (DD+128) \cdot 32}{13.56} [\mu s]$ If PP is defined, MM must be also set, but DD still remains optional
		2	7:0	MM (max 255, i.e. 0xFF)	
		3	7:0	DD (max 127, i.e. 0x7F)	
		4	7:0	NEmd	**Optional RFU, this byte should be omitted or set to '0'**
		5	7:0	NEmdRes	**Optional RFU, this byte should be omitted or set to '0'**

Table 8: Parameter values for "Protocol select" command

Parameter list for different protocols					
Protocol (Reader)	Code	Parameters			Examples of commands
		Byte	Bit	Function	
ISO14443 B	03	0	7:6	Transmission data rate 00 – 106kbps 01 – 212kbps 10 – 424kbps 11 – 847kbps	**02020301** – ISO/IEC14443B, 106kbps transmission & reception, Frame Waiting Time (FWT) of 302µs, CRC automatically added **020403010400** – ISO/IEC14443B, 106kbps transmission & reception, Frame Waiting Time (FWT) of 4.8ms, CRC automatically added
			5:4	Reception data rate 00 – 106kbps 01 – 212kbps 10 – 424kbps 11 – 847kbps	
			3:1	RFU, set to '0'	
			0	0 – No CRC added 1 – CRC auto. added	
		1	7:0	PP (max 14, i.e. 0x0E)	**Frame Waiting Time (FWT) definition:** These 2 bytes are optional. The default value corresponds to a FWT of 4949ms, answer to ATTRIB. $FWT = \frac{2^{PP} \cdot (MM+1) \cdot (DD+128) \cdot 32}{13.56} [\mu s]$ If PP is defined, MM must be also set, but DD still remains optional
		2	7:0	MM (max 255, i.e. 0xFF)	
		3	7:0	DD (max 127, i.e. 0x7F)	
		5:4	15:0	TTTT	Timing: TR0 = TTTT/13.56 us Coded with LSB first, default value 1023 = 0x3FF
		6	7:0	YY	Timing: Min_TR1 = 128 * YY / 13.56us. Default value: 0
		7	7:0	ZZ	Timing: Max_TR1 = 128 * ZZ / 13.56us. Default value:26 , i.e. 0x1A
		8	7:0	NEmd	**Optional RFU, this byte should be omitted or set to '0'**
		9	7:0	NEmdRes	**Optional RFU, this byte should be omitted or set to '0'**

Table 9: Parameter values for "Protocol select" command (Reader)

6.5 PollField command (0x03)

The “PollField” command will be used to detect the presence of an HF field by monitoring the flag “FieldDet”. This command returns the current value of the flag “FieldDet”. The parameters <Presc> and <Timer> can also be used to define a time during which the MLX90130 continuously scans for the presence or none presence of the field. The answer to the “*PollField*” command is available after the scanning period, with the flag <FieldDet> updated accordingly,

PollField **03**			
Direction	Data	Comments	Example
MCU – device	03	Command code	**0300** – Check if Field is ON or OFF
	<Len>	Length of data	
	<Flags>	Timer flag (Optional) 01 – Wait for field appearance 00 – Wait for field disappearance	**0303010FFF**– Wait for field appearance during (16*256)/13.56=302µs
	<Presc>	Timer prescaler (Optional)	
	<Timer>	Timer time-out (Optional)	Parameters Flags, Presc and Timer are optional. They must be specified if application has to wait for field appearance or disappearance. The time to wait is: $\text{Time} = \frac{(\text{Presc}+1)\cdot(\text{Timer}+1)}{13.56}[\mu s]$
Device - MCU	00	Result code	**000101 – HF field is detected**
	01	Length of data	
	<FieldDet>	[7:1] – RFU [0] – 0 : No HF field detected 1 : HF field detected	

Table 10: “PollField” command

Note: *When the MLX90130 is selected in reader mode (protocol select command), the HF field will be automatically turned ON and the flag “FieldDet” will be set to ‘1’ (the MLX90130 detects its own field). Consequently, the PollField command should be used in Tag/Card Emulation state or in Reader state with the HF field set OFF.*

6.6 SendRecv command (0x04)

This command is used to send specific protocol data and receives corresponding answer. Before sending this command, the application must select a protocol using the Protocol select command. If the response of the Transponder is successfully received and decoded, the field <Data> will contain additional information which is protocol specific. This is explained in the Table 12 below.

SendRecv 0x04			
Direction	Data	Comments	Example
MCU – device	04	Command code	**Depends on protocol previously selected!**
	<Len>	Length of data	**0403022012** – Command “Read single block 12” (ISO/IEC15693 protocol)
	<Data>	Data to be sent	
Device - MCU	80, A0, C0	Result code	**8008000000000077CF00 -** The response of the TAG is successfully decoded. This is an example of response from an ISO15693 TAG. For result code 0xA0, 0xC0, please refer to paragraph “support of extended frames” below.
	<Len>	Length of data	
	<Data>	Data received. Interpretation depends on protocol	
Device - MCU	90, B0, D0	Result code	The response of the TAG is decoded, but the number of bytes is not integer. Used only for Iso14443-A protocol. For result code 0xB0, 0xD0, please refer to paragraph “support of extended frames” below.
	<Len>	Length of data	
	<Data>	Data received. Interpretation depends on protocol	
Device - MCU	86	Error code	**8600-** Hardware Communication error
	00	Length of data	
Device - MCU	87	Error code	**8700-** Frame wait timeout (no valid reception) or no TAG
	00	Length of data	
Device - MCU	88	Error code	**8800 -** Invalid SOF
	00	Length of data	
Device – MCU	89	Error code	**8900 -** Receive buffer overflow (too many bytes received)
	00	Length of data	
Device – MCU	8A	Error code	**8A00 -** Protocol Framing error: - ISO14443A (106kbps) : Mod. Miller, wrong symbol sequence - ISO14443B: Start/Stop bit polarity
	00	Length of data	
Device – MCU	8B	Error code	**8B00 -** EGT time out (ISO14443B)
	00	Length of data	
Device – MCU	8C	Error code	**8C00 -** Invalid length received during Felica communication (2 < Length < 255)
	00	Length of data	
Device – MCU	67	Error code	**6700 –**TR1 set by card too long in case of protocol **ISO14443B**
	00	Length of data	
Device - MCU	68	Error code	**6800 –** TR1 set by card too short in case of protocol **ISO14443B**
	00	Length of data	
Device - MCU	8E	Error code	**8E00 -** Reception lost without EOF received
	00	Length of data	

Table 11: “SendRecv" command description

Note: In case of SendRecv command, the returned error code might be 8 bytes long. In this case, only the first byte has to be taken into account.

Data format for transmission

Protocol	Explanation	Response example	Comments
ISO15693	Send example: 04 03 022000 04 – Command code 03 – Length of entire data field 022000 – Data		If length of data is Zero, only EOF will be sent. This can be used for anti-collision procedure
ISO14443A	Send example: 04 07 9370800F8C8E 28 04 – Command code 07 – Length of entire data field 9370800F8C8E – Data 28 – Transmission flags: 7 – RFU, must be set to '0' 6 – SplitFrame if set 5 – Append CRC if set 4 – Auto. add the parity bit in if set to '0'[1)] 3:0 – Number of significant bits in last byte		For bit oriented protocol, frames could be split by setting the bit **SplitFrame** to one. In this case, the MLX90130 will send the last byte of the command with no integer number of bits, according to the field **number of significant bits in last byte**. In reception, the MLX90130 expects to receive the complement (**8 – "number of significant bits in last byte"**). This option is used during anti-collision procedure.
ISO14443B	Send example: 04 03 050000 04 – Command code 03 – Length of entire data field 050000 – Data		

Table 12: Parameter values for "SendRecv" command

[1)]The process of automatically calculate and add the parity bit by the MLX90130 can be disabled by setting the bit 4 of the flags to '1'. In this case, the applicative MCU must add one byte to the data with the most significant bit corresponding to the parity bit. The other bits of these additional bytes are not considered and can be set to '0' or '1'. The datastream will then look like: <DataByte><Parity><DataByte><Parity>.

Interpretation of <Data> field for different protocols			
Protocol	Explanation	Response example	Comments
ISO15693	Response example	80 | 08 | 0000000000 | 77CF | 00	**000000000077CF** - this is a response on Read Single Block command for Iso15693 TAG. Other fields are added by the device
	Result code	80	
	Length of entire data field	08	
	Data received from TAG	0000000000	
	Original (received) value of CRC	77CF	
	7:2 – RFU 1 – CRC error if set 0 – Collision is detected if set	00	
ISO14443A	Response example	80 | 09 | 80B30B8DB500 | 00 | 00 | 00	ISO/IEC14443A is bit oriented protocol, and non-integer amount of bytes can be received. **Number of significant bits in the 1st byte** is the same as indicated in Send command. To calculate a position of a collision, application has to take **index of byte** first. **Index of bit** indicates a position inside this byte. Note that both indices start from 0 and bit index can be 8, meaning that collision could also affect the parity bit. Note that collision information is only present when protocol ISO/IEC14443A with a data rate of 106kbps for transmission and reception is selected. When others protocols are selected, the two additional bytes are not transmitted.
	Result code	80	
	Length of entire data field	09	
	Data received from TAG	80B30B8DB500	
	7 – Collision is detected 6 – RFU 5 – CRC error 4 – parity error 3:0 – shows how many significant bits are there in the first byte	00	
	7:0 – Index of the first byte where collision is detected	00	
	7:4 – RFU 3:0 – Index of the first bit where collision is detected	00	
ISO14443B	Response example	80 | 0F | 5092036A8D00000000007171 | 3411 | 00	
	Result code	80	
	Length of entire data field	0F	
	Data received from TAG	5092036A8D00000000007171	
	Original (received) value of CRC	3411	
	7:2 – RFU 1 – CRC error if set 0 – RFU	00	

Table 13: "SendRecv" command, interpretation of <data> field for different protocol

6.6.1 Support of extended frames

In reader mode it is possible to receive up to 528 bytes of frame data. The extended size is included in the command code as follows:

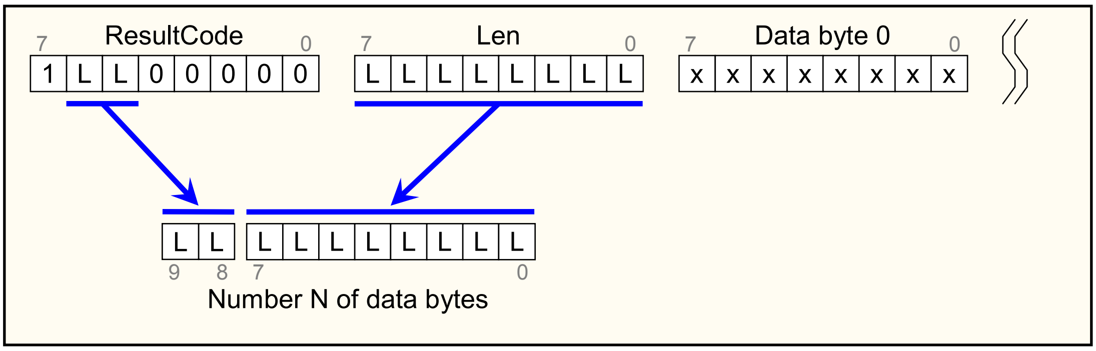


Figure 10: Coding of Length of extended frames

Consequently, the *ResultCode* returned depends on the length of the decoded frame received by the Transponder.

ResultCode	Len	Length of data	Comment
0x80	0x00 – 0xFF	0 – 255 bytes	
0xA0	0x00 – 0xFF	256 – 511 bytes	
0xC0	0x00 – 0x0F	512 – 528 bytes	
0x90	0x00 – 0xFF	0 – 255 bytes	In ISO/IEC14443A only with a none integer number of bytes
0xB0	0x00 – 0xFF	256 – 511 bytes	
0xD0	0x00 – 0x0F	512 – 528 bytes	

Table 14: Coding of Length of extended frames

6.7 Idle command (0x07)

This command would be used to switch the MLX90130 into low-power Idle mode. Several sub-modes or states could be selected as shown in the table below. Please note that except when an error occurs (the answer is then directly sent), the response to an Idle command is sent only when the MLX90130 exits the Idle mode.

Idle **0x07**			
Direction	Data	Comments	Example
	07	Command code	
	0E	Length of data	
	<WUFlags>	Specifies wake-up sources and LFO frequency. Refer to Table 16	
	<EnterCtrlL>	2 bytes: Settings to enter Idle mode, refer to Table 17	
	<EnterCtrlH>		
	<WUCtrlL>	2 bytes: Settings to wake-up from Idle mode (**recommended value = 0x3800**), refer to Table 17 below	
	<WUCtrlH>		
	<LeaveCtrlL>	2 bytes: Settings to leave Idle mode (**recommended value = 0x1800**), refer to Table 17 below	
	<LeaveCtrlH>		**0x070E0221003801180008606054603F00**– Tag detector with LFO set at 32kHz
	<WUPeriod>	Period of time between two TAG detection bursts. Also used to specify the duration before timeout. Refer to Equation 1	
MCU – device	<OscStart>	Waiting time for the HFO to stabilize (based time: LFO) (**recommended value = 0x60**)	**0x070ECB21003801180008606054603F10** – Tag detector with LFO set at 4kHz + possibility to WU on low level on RX and time out set with MaxSleep = 10
	<DacStart>	Waiting time for the DAC to stabilize (based time: LFO) (**recommended value = 0x60**)	
	<DacDataL>	Lower compare value for TAG detection. Note: Only the **6 MSB bits** are available	
	<DacDataH>	Higher compare value for TAG detection. Note: Only the **6 MSB bits** are available	
	<SwingsCnt>	Number of HF periods during TAG detection. Refer to Equation 2**.**	
	<MaxSleep4:0>	Maximal number of TAG detection trials before timeout. Value set to 0 during TAG detection calibration. **0x00 < MaxSleep < 0x1F (bit 7 to 5 are RFU and must be set to 0)** Also used to specify duration before timeout, refer to Equation 3**.**	
Device – MCU	0x00	Result code	**0x0001XX** - Here XX is a value of WUFlags, **please note that this response is sent only when device exits idle mode**
	0x01	Length of data	
	<WUFlags>	Content of WUFlags, please refer to Table 16 below	
Device – MCU	0x82	Error code	**0x8200** - Invalid command length
	0x00	Length of data	

Table 15: "Idle" command description

Meaning of Wake-up settings <**WUFlags**>			
A	Register	Bit	Function
2	WUFlags	7:6 LfoPresc	LFO prescaler. Divides LFO for state machine. 00 – 32 KHz 01 – 16 KHz 10 – 8 KHz 11 – 4 KHz
		5 RFU, set to ‘0’	
		4:0 WUFlags	Specifies the possible source on which to exit from idle mode, in case of SLEEP state is selected. Each bit corresponds to one wake-up source which are updated and returned when the MLX90130 leaves the Idle routine without error bit4 – Low level on SPI_NSS bit3 – Low level on UART_RX, must be set to ‘1’bit2 – Field Detector bit1 – TAG Detector bit0 – WakeUp (WU at the end of MaxSleep cycles even if no event detected)

Table 16: Field <WUFlags> definition in “Idle” command

Meaning of power settings <**EnterCtrlH:EnterCtrlL**>, <**WUCtrlH:WUCtrlL**> and <**LeaveCtrlH:LeaveCtrlL**>		
A	Register	Comment
0	CtrlL	7 – Initial DAC compare index (‘0’ = DacDataL, ‘1’ = DacDataH used for the 1st comparison) 6 – RFU, must be set to ‘0’ 5 – LFO enable (needs to be set to ‘1’ in WUCtrl) 4 – HFO enable (needs to be set to ‘1’ in WUCtrl) 3 – VDDA enable (needs to be set to use HFO, see recommended values in Table 15 above) 2 – Hibernate enable 1 – RFU, must be set to ‘0’ 0 – Sleep mode enable
1	CtrlH	7:2 – RFU, must be set to ‘0’ 1 – Field detector enable 0 – IREF (needs to be set to ‘1’ in WUCtrl, otherwise must be put to ‘0’)

Table 17: Fields <EnterCtrl>, <WUCtrl> and <LeaveCtrl> definition in “Idle” command

Notes:

- *The bytes <EnterCtrl> define the configuration when entering the IDLE mode. The bytes <WUCtrl> define the configuration when the device wakes-up from the IDLE mode (recommended value 0x3801). The bytes <LeaveCtrl> define the configuration when leaving the IDLE mode, after wake-up.*
- *The Hibernate state is entered by setting the “Hibernate state enable” flag to ‘1’ and the Sleep state is entered by setting the “sleep state enable” flag to ‘1’, both in the <WUFlags> register.*

Equation 1: Sleep period

$$t_{Sleep\_Tagdet} = 256 \cdot t_L \cdot (WUPeriod_{10} + 2)$$

Equation 2: HF ON period

$$t_{HFon\_Tagdet} = \frac{SwingCnt}{f_{carrier}}$$

Equation 3: Duration before Timeout

$$t_{MaxSleep_{Tagdet}} = (t_{HFon_{Tagdet}} + t_{Sleep_{Tagdet}}) \cdot (MaxSleep + 1)$$

With:

$$t_L = \frac{1}{f_{LFO}} \quad \text{and} \quad t_{carrier} = \frac{1}{f_{HFO}}$$

6.8 BaudRate command (0x0A)

This command is used to change the UART baud rate. The device acknowledges the new UART baud rate with the answer 0x55.

Set UART baud rate **0x0A**			
Direction	Data	Comments	Example
MCU – device	0A	Command code	
	01	Length of data	
	<BR_Ratio>	New BR ratio = <BR_Ratio>*2+2 See following table: Baud rate ratio 255 – 13.56/512 ~26.48kbps 254 – 13.56/510 ~26.59kbps 253 – 13.56/508 ~26.7kbps . . . 117 – 13.56/236 ~57.7kbps (default value) . . . 2 – 13.56/6 ~2.26Mbps 1:0 – Not used	
Device - MCU	55	"Echo" code of 0x55	**55 -** New baud rate is used to reply

Table 18: "Baudrate" command description

7 Modifying internal settings for optimal performances

7.1.1 Example: How to modify the ARC_B register

The internal registers of the MLX90130 are automatically set when the protocol is selected with the command protocol select. To get optimal performances, the internal register ARC_B containing the modulation index of the RFID request and the analog gain for the reception chain can be modified. The following example shows the specific commands to be sent to read/write the register ARC_B:

Use the "Protocol Select" command (0x02) to select the appropriate communication protocol.

- Send Protocol Select command (for example ISO/IEC14443A): 0x02020200
- MLX90130 reply: 0x0000

Read Analog Configuration register (ARC_B) value

- Write the ARC_B register index to 0x01: 0x0903680001
- MLX90130 reply: 0x0000
- Read the ARC_B register value: 0x0803690100
- MLX90130 reply: 0x01DF[1]

Modify the value of Analog Register Configuration (ARC_B) to 0x23

- Write the ARC_B register: 0x090468010123
- MLX90130 reply: 0x0000

Read back the Analog Configuration register (ARC_B) value

- Write the ARC_B register index to 0x01: 0x0903680001
- MLX90130 reply: 0x0000
- Read the ARC_B register value: 0x0803690100
- MLX90130 reply: 0x0123

[1]In this example, the ARC_B register = 0x5F with 'D' = Modulation Index & 'F' = Rx amplifier gain.

The content of the register ARC_B is shown in Table 19 below with the default values in Table 20:

ARC_B register of the MLX90130			
A	Register	Bit	Function
69	ARC_B	7:4 ModIdx[1]	ASK Modulation Index : Code 1 = 10% Code 2 = 14% Code 3 = 18% Code 4 = 21% Code 5 = 24% Code 6 = 26% Code 7 = 30% Code 8 = 35% Code 9 = 39% Code A = 40% Code B = 43% Code C = 45% Code D = 96%
		3:0 Rx Gain[2]	Reception chain amplifier Gain: Code 0 = 34dB Code 1 = 32dB Code 3 = 27dB Code 7 = 20dB Code F = 8dB

Table 19: Register ARC_B description

(1) Characterized using ISO/IEC10373-6 set setup and DVK90130 antenna matching
(2) Defined by design simulations

Communication protocol	Default value
ISO/IEC14443 Type A	0xDF
ISO/IEC14443 Type B	0x20
ISO/IEC 15693 – 10%	0x50
ISO/IEC15693 – 100%	0xD3

Table 20: Default value of ARC_B per protocol (Reader mode)

7.1.2 Example how to read back WUFlags content

WUFlags byte (refer to Table 16) is automatically updated after the MLX90130 wakes-up from an Idle command. In SPI mode, this byte is available to read in the FIFO register while, in UART mode, this byte is asynchronously sent after wake-up. In some cases, it is useful to check the WUFlags separately, the example below shows how to do it:

Read WUFlags register value

- Read the WUFlags register value: 0x0803620100
- MLX90130 reply: 0x0001XX[1]

[1] XX equal the WUFlags register value

8 Tag Detector

8.1 Operating Principle

The objective of the TAG detector function is to be able to detect the presence of an RFID label/tag or an NFC device emulating a tag in front of the reader's antenna, with reduced power consumption.

The TAG detector function is based on the detection of any variation of the HF field. If an RFID transponder or an NFC device in tag emulation mode approaches from the reader's antenna, it influences the amplitude of the generated HF by a loading effect. This variation can be monitored by the MLX90130 to inform the external host microcontroller that an RFID transponder or an NFC device in tag emulation mode is approaching the antenna.

When set in TAG detector state, the MLX90130 periodically generates a few periods (pulses) of HF carrier frequency and measure the amplitude's field. This value is then compared to reference levels DacDataH[7:0] and DacDataL[7:0] defined by the user.

If the measured level is above DacDataH[7:0] or below DacDataL[7:0], - i.e. a change in the amplitude of the HF field occurs - the MLX90130 automatically informs the external application MCU by: either generating an IRQ on the pin IRQ_{OUT} (SPI interface), or directly sending the WUFlag register value (UART interface).In the same time it enters to Ready state and wait for a protocol select command.
Therefore, either the application MCU takes the control of the MLX90130 by sending a command protocol select and can decide to start communicating with the TAG, or the MLX90130 goes back in idle (tag detector) mode.This mechanism is repeated until a new object is detected in the field or another kind of event appears (e.g. max number of trials reached, wake-up from host MCU …).
Before using this feature it is necessary to perform a calibration by using the MCU

The TAG detector state is entered using the Idle command. The values of DacDataH/DacDataL[7:0] are defined in this command, as well as the number of HF pulses and the time between two HF bursts with respectively the bytes SwingsCnt[7:0] and WUPeriod[7:0]. The MLX90130 can be forced to wake-up after a certain number of trials, even if no TAG has been detected. This number of trials is set using the bits MaxSleep[4:0].

The bit "initial DAC compare index" in register EnterCtrlL is used to select the first comparison to be performed when starting the TAG detector state. When set to '0', the TAG detector feature is started with a comparison to DacDataL[7:0]. If set to '1', the TAG detector feature is started with a comparison to DacDataH[7:0]. Please note that the IREF bit in EnterCtrlH byte has to be set to allow a proper functionality of the TAG detector feature.

The following picture illustrates the TAG detector operation describes above.
The objective of the TAG detector function is to be able to detect the presence of an RFID label/tag in front of the reader's antenna, with reduced power consumption. The TAG detector function is based on the detection of any variations of the HF field. If an RFID transponder approaches from the reader's antenna, it influences the amplitude of the generated HF by a loading effect. This variation can then be monitored by the MLX90130 to inform the external host microcontroller that an RFID transponder is approaching the antenna.

When put in TAG detector state, the MLX90130 periodically generates a few periods of HF carrier frequency to monitor the maximum generated amplitude. This value is then compared to two reference levels DacDataH/DacDataL[7:0] defined by the user. If the monitored level is above DacDataH[7:0] or below DacDataL[7:0], the MLX90130 asserts the IRQ_{OUT} pin low, to wake-up the external application microcontroller, and returns to Ready state waiting for a protocol select command. If a protocol select command is not issued by the MCU, the MLX90130 goes in sleep mode during a certain waiting period selected by the user and this mechanism is repeated until a TAG is detected or another event appears (e.g. max number of trials reached, wake-up from host MCU …).

The TAG detector state is entered using the Idle command, the value of DacDataH/DacDataL[7:0] is defined in this command, as well as the number of HF pulses and the time between two HF bursts with respectively the bytes SwingsCnt[7:0] and WUPeriod[7:0]. The MLX90130 can be forced to wake-up after a certain number of trials, even if no TAG has been detected. This number of trials is set using the bits MaxSleep[4:0].

When the MLX90130 detects a change in the amplitude of the HF field, it makes the assumption that an object is placed near the antenna. The device is able to detect any HF field variation with a very short period of field presence. After a field change has been detected (decrease or increase), the MLX90130 informs the external application microcontroller by generating an IRQ on the pin IRQ_{OUT} (SPI interface) or directly sending the WUFlag register value (UART interface). Then, the host microcontroller takes the control of the MLX90130 and tries communication with the TAG. Before using the TAG detection feature it is necessary to perform a calibration as shown in the chapter Calibration procedure below.

The bit "initial DAC compare index" in register EnterCtrlL is used to select the first comparison to be performed when starting the TAG detector state. When set to '0', the TAG detector feature is started with a comparison to DacDataL[7:0]. If set to '1', the TAG detector feature is started with a comparison to DacDataH[7:0]. Please note that the Iref bit in EnterCtrlH byte has to be set to allow a proper functionality of the TAG detector feature.

The following picture illustrates the TAG detector operation describes above.

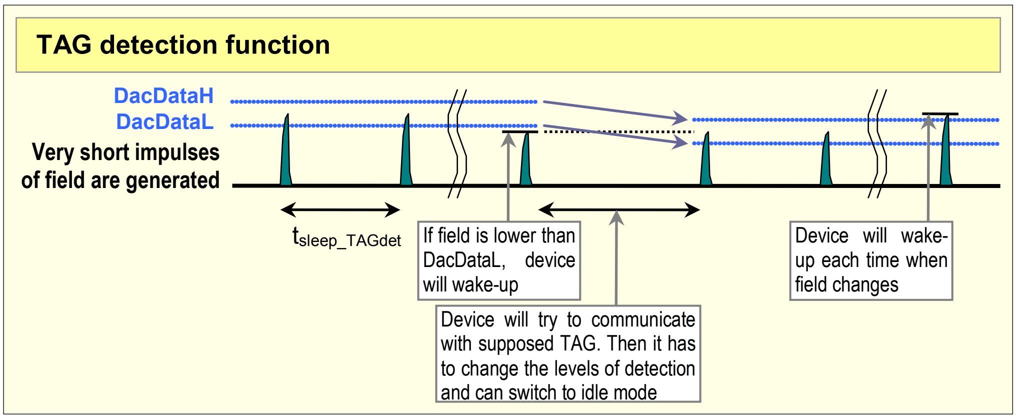


Figure 11: MLX90130 TAG detection principle

8.2 Calibration procedure

The calibration process should be performed with no tag in its near environment. It consists of executing a successive tag detection sequence using a well-known configuration, in order to establish the two specific reference thresholds: DacDataL and DacDataH which will be programmed in the device before entering Tag Detector Mode. These both thresholds are coded in 6 bits.

During the calibration process, DacDataH value is fixed to 0xFC and the software will vary the DacDataL value from its minimum value (0x00) to its maximum value (0xFC). At each step, the WUflags byte is read to know if the HF level is above or below the low threshold ("tag detected flag" set or not).

At the end of the calibration process, the reference level DacDataRef is found and corresponds to the value of DacDataL for which the wake-up event switches from "WakeUp at the end of MaxSleep cycles" (no tag in the RF field) to "tag detected".

To avoid too much sensitivity in the tag detection process, the use of a guard band is recommended. This value should correspond to at least 2 DAC steps (Guard = 0x08).

Final recommended values with guard band:
- DacDataL = DacDataRef – Guard
- DacDataH = DacDataRef + Guard

The parameters used to define the tag detection calibration sequence (clocking, set-up time, burst duration, etc.) must be the same as those used for the future tag detection sequences. MaxSleep has to be set to '0' for the calibration.

Another and faster way (binary search: 6 steps) to calibrate the Tag Detector is described in the application note AN2_MLX90130_32_TagDetector.

9 Field Detector

The MLX90130 embeds a field detector block to measure the field level of an external HF RFID reader. This can be used to be able to monitor the availability of the channel before switching ON the HF field of the MLX90130.

The command Poll field can be used to monitor the HF field, the device directly returns a bit indicating that an HF field has been detected or not. The field detector can also be configured as an option to wake-up from "Idle" mode.

10 Application Information

10.1 External Antenna network

RF communication performance depends on the external system antenna network and resonance conditions.

The antenna matching of the MLX90130 is reduced to a minimal component count, composed of two serial capacitors Cs and one parallel capacitor Cp. A parallel resistor Rp can also be added to adjust the antenna damping thus reducing detuning effect provoked by the presence of TAGs or Readers in front of the MLX90130. Two serial resistors R_{RX} have to be adjusted in order to avoid entering the clamping region (see Table 24 below). Finally, depending on EMC constraints, an EMI filter composed of two serial inductors and two parallel capacitors can be added at the transmitting outputs.

Figure below gives the composition of the external matching network. For more information, please refer to the application note AN1_MLX90130_32_AntennaDesignGuidelines available on the Melexis web-site.

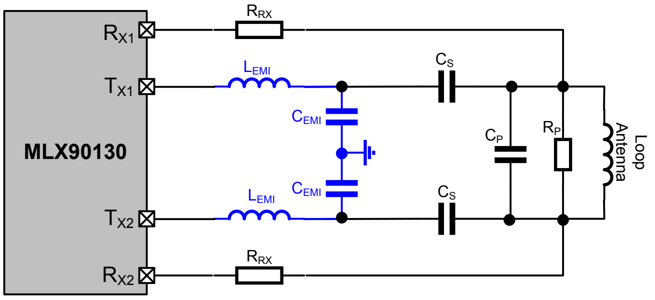


Figure 12: External antenna matching network

10.2 Application schematic

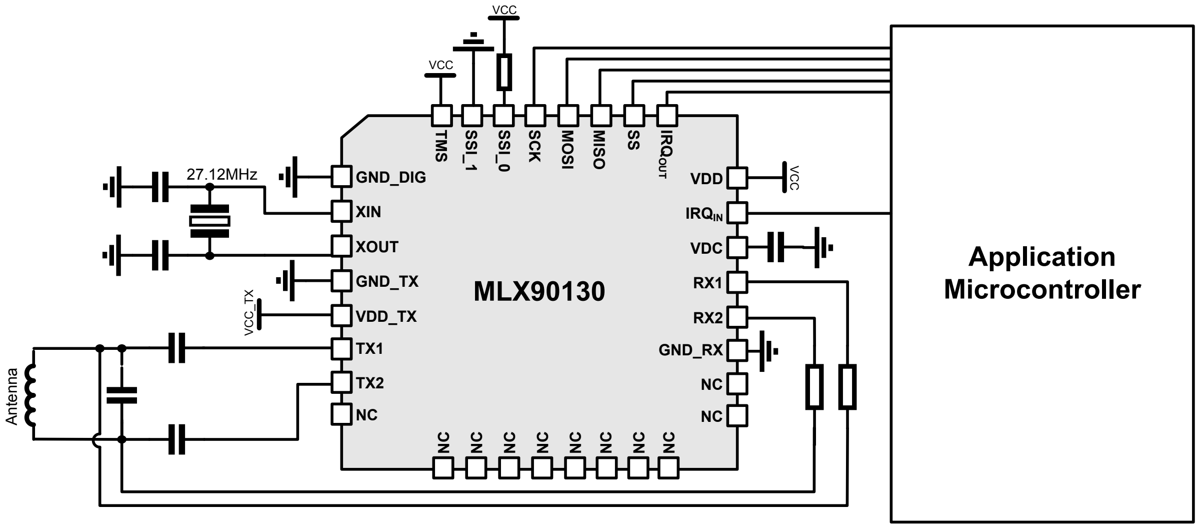


Figure 13: MLX90130 application schematic in SPI mode

11 Electrical Specifications

11.1 Absolute Maximum Ratings

Parameter	Symbol	Value	Units
Supply Voltage	V_{DD}	-0.3 to 7.0	V
Supply Voltage	V_{DD_TX}	-0.3 to 7.0	V
Input or Output voltage relative to Ground	VIO	-0.3 to VDD+0.3	V
Operating Temperature Range	T_A	-20 to 85	°C
Storage Temperature Range	T_S	-40 to 150	°C
Electrostatic discharge according to AEC-Q100-002 Human Body Model	V_{ESD_HBM}	2	kV

Table 21: Absolute maximum ratings

Note: *Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.*

11.2 DC Characteristics

Operating Parameters T_A = -20°C to 85°C

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Supply voltage	V_{DD}		2.7	5	5.5	V
Supply voltage of TX driver	V_{DD_TX}		2.7	5	5.5	V

Table 22: DC characteristics

11.3 Power Consumption Characteristics

Operating Parameters T_A = -20°C to 85°C (2.7 < VDD/VDD_TX <5.5V)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Supply current in Hibernate state	Icc Hibernate			1	8	µA
Supply current in Sleep state	Icc Sleep			20	30	µA
Supply current in Ready State	Icc Ready			2.5	3	mA
Supply current in RF Reader ON	Icc RF Reader ON			100[1]		mA
Supply current in Tag Detection state	ICC Tag Det			50[1,2]		µA

Table 23: Power consumption characteristics

1. Parameter measured at applicative level only, using recommended output matching network
2. Following specific conditions for TAG detection: T_A = 25°C, WUPeriod = 0x1A (4x per seconds), OscStart= 0x60, DACStart= 0x10, SwingCnt = 0x1F

11.4 RF Characteristics

Operating Parameters T_A = -25°C to 85°C (2.7 < VDD/VDD_TX <5.5V)

Symbol	Parameter	Min	Typ	Max	Units
f_C	Frequency of operating field (carrier frequency)	13.553	13.56	13.567	MHz
Carrier modulation index[3]	ISO/IEC14443A ISO/IEC14443B ISO/IEC15693 (10% modulation) ISO/IEC15693 (100% modulation)	 8 10 80		100 14 30 100	%
Transmitter specifications					
R_{ON_3V}	Equivalent resistor of driver output TXn[2]		13		Ω
R_{ON_5V}	Equivalent resistor of driver output TXn[2]		8		Ω
P_{OUT_3V}	Output power for 3V operation [2]		70		mW
P_{OUT_5V}	Output power for 5V operation [2]		317		mW
Receiver specifications					
Z_{OUT}	Differential. input resistance between RX1/RX2[2]		80		kΩ
C_{INPUT}	Differential. input capacitance between RX1/RX2 [2]		22		pF
V_{SENS}	Sensitivity[3]		6		mVp
V_{RXMAX}	Clamping voltage on RX1 (RX2) relative to Ground[2]	9.5	11	13.2	Vp

Table 24: Reader characteristics

Symbol	Parameter	Min	Typ	Max	Units
$H_{Threshold}$	HF field level of detection[2,3]	0.1875			A/m

Table 25: Field detection characteristics

1. Parameter measured using recommended output matching network
2. Value based on design simulation and/or characterization results, and not tested in production
3. Based on ISO/IEC 10373-6 protocol measurements

11.5 SPI Characteristics

Symbol	Parameter	Min	Typ	Max	Units
f_{SCK}	SPI clock frequency			2	MHz
V_{IL}	Input low voltage			$0.3*V_{DD}$	V
V_{IH}	Input high voltage	$0.7*V_{DD}$			
V_{OL}	Output low voltage			$0.4*V_{DD}$	
V_{OH}	Output high voltage	$0.7*V_{DD}$			
$t_{SU(NSS)}$ (1)	NSS setup time		70		ns
$t_{h(NSS)}$ (1)	NSS hold time		0		
$t_{CH(SCKL)}$ (1)	Clock low time		200		
$t_{CH(SCKH)}$ (1)	Clock high time		200		
$t_{SU(SI)}$ (1)	Data slave Input setup time		20		
$t_{h(SI)}$ (1)	Data slave Input hold time			80	
$t_{v(SO)}$ (1)	Data slave output valid time		150		
$t_{h(SO)}$ (1)	Data slave output hold time		280		
$C_{b\_SPI\_IN}$	Capacitive load for input pins NSS, CLK, MOSI			3	pF
$C_{b\_SPI\_OUT}$	Capacitive load for input pins MOSI			20	

Table 26: SPI interface characteristics

1. Values based on design simulation and/or characterization results, not tested in production

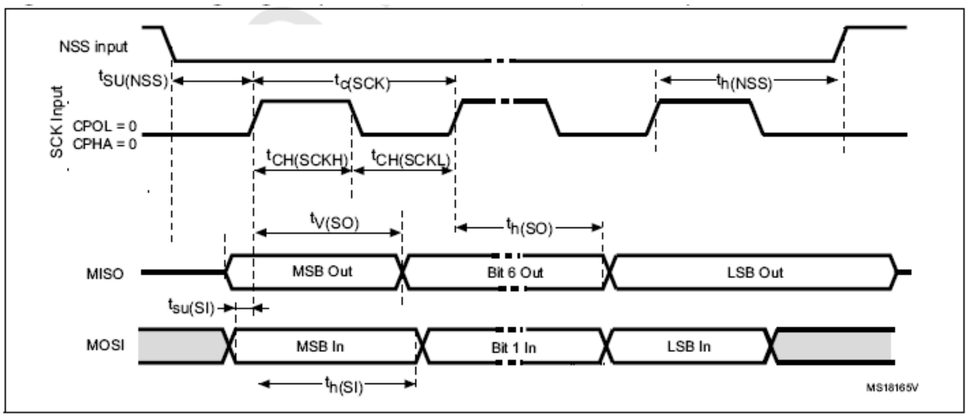


Figure 14: SPI timing diagram (Slave mode and CPOL = 0, CPHA = 0)

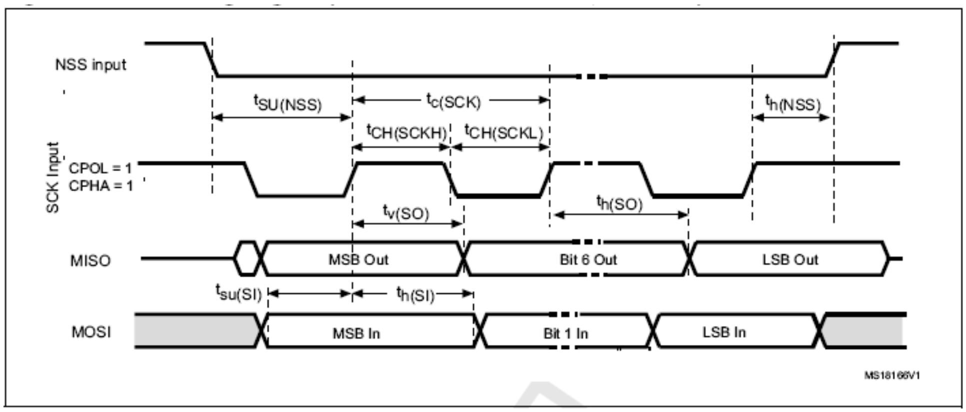


Figure 15: SPI timing diagram (Slave mode and CPOL = 1, CPHA = 1)

11.6 Oscillator Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Low Frequency Oscillator (LFO)						
f_{LFO}	Low-frequency oscillator (LFO)		20	32	43	kHz
XTAL Oscillator						
f_{XTAL}	XTAL Oscillator frequency			27.12		MHz
R_F	Feedback resistor			2		MΩ
C_L	Recommended load capacitance versus equivalent serial resistance of the crystal (RS)(3)	Rs = 30Ω		12		pF
I_2	XTAL driving current(2)	VDD = 3.3V with 12pF load		600	750	µA
g_m	Oscillator transconductance(2)	Start-up	0.04	0.32	1.41	mA/V
$t_{SU(HFO)}$(4)	Oscillator start-up time	VDD is stabilized		2		ms

Table 27: Oscillator characteristics (1) (2)

1. Resonator characteristics given by the crystal/ceramic resonator manufacturer.
2. Based on characterization, not tested in production.
3. The relatively low value of the RF resistor offers a good protection against issues resulting from use in a humid environment, due to the induced leakage and the bias condition change. However, it is recommended to take this point into account if the application is used in tough humidity conditions.
4. tSU(HFO) is the startup time measured from the moment it is enabled (by software) until a stabilized 27.12MHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

For C_{L1} and C_{L2}, it is recommended to use high-quality external ceramic capacitors in the 10 pF to 20 pF range, designed for high-frequency applications, and selected to match the requirements of the crystal or resonator (see Figure 16). C_{L1} and C_{L2} are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2}.

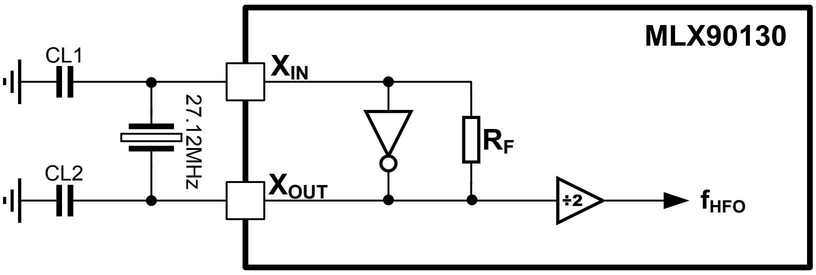


Figure 16: Typical application with a 27.12MHz crystal

13 ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).

Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

14 Standard information regarding manufacturability of Melexis products with different soldering processes

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to following test methods:

Reflow Soldering SMD's (Surface Mount Devices)

- IPC/JEDEC J-STD-020
  Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
  (classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113
  Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing
  (reflow profiles according to table 2)

Wave Soldering SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EN60749-20
  Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Iron Soldering THD's (Through Hole Devices)

- EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Solderability SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EIA/JEDEC JESD22-B102 and EN60749-21
  Solderability

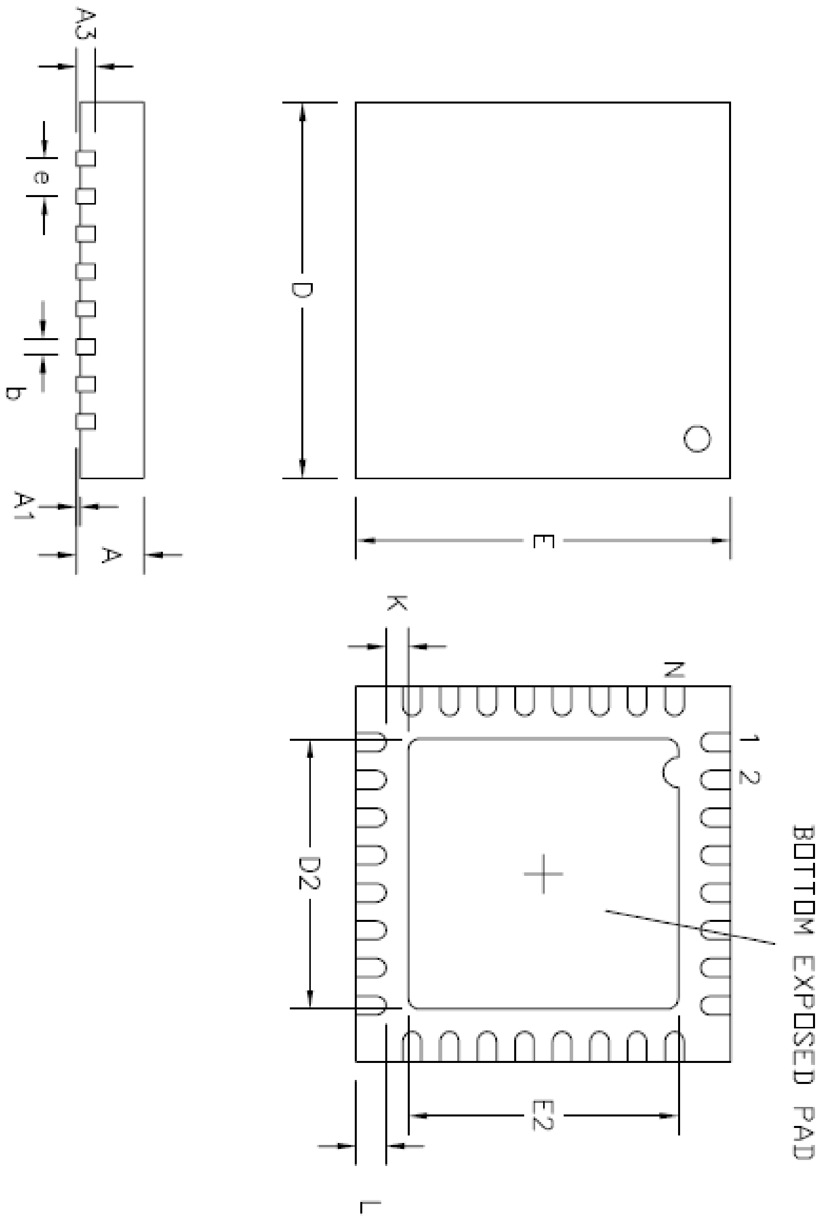
For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile etc) additional classification and qualification tests have to be agreed upon with Melexis.

The application of Wave Soldering for SMD's is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.

Melexis recommends reviewing on our web site the General Guidelines soldering recommendation (http://www.melexis.com/Quality_soldering.aspx) as well as trim&form recommendations (http://www.melexis.com/Assets/Trim-and-form-recommendations-5565.aspx).

Melexis is contributing to global environmental conservation by promoting lead free solutions. For more information on qualifications of RoHS compliant products (RoHS = European directive on the Restriction Of the use of certain Hazardous Substances) please visit the quality page on our website: http://www.melexis.com/quality.aspx

15 Package Information



Moisture Sensitivity Level is MSL3, according as per IPC/JEDEC J-STD-20.

This table in mm

Type	D x E	N	e		A	A1	A3	D2	E2	L	K	b
quad	5 x 5	32 (Opt B)	0.50	min	0.80	0.00	0.20 REF	3.00	3.00	0.35	0.20	0.18
				max	1.00	0.05		3.20	3.20	0.45	–	0.30

Tolerance of D, E: +/- 0.1mm

16 Disclaimer

Devices sold by Melexis are covered by the warranty and patent indemnification provisions appearing in its Term of Sale. Melexis makes no warranty, express, statutory, implied, or by description regarding the information set forth herein or regarding the freedom of the described devices from patent infringement. Melexis reserves the right to change specifications and prices at any time and without notice. Therefore, prior to designing this product into a system, it is necessary to check with Melexis for current information. This product is intended for use in normal commercial applications. Applications requiring extended temperature range, unusual environmental requirements, or high reliability applications, such as military, medical life-support or life-sustaining equipment are specifically not recommended without additional processing by Melexis for each application.
The information furnished by Melexis is believed to be correct and accurate. However, Melexis shall not be liable to recipient or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interrupt of business or indirect, special incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data herein. No obligation or liability to recipient or any third party shall arise or flow out of Melexis' rendering of technical or other services.

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