

## Features and Benefits

- Easy to integrate
- Factory calibrated in wide temperature range  
-40...+85 °C for sensor temperature
- Measurement range -70°C to 1030°C
- Measurement resolution of 0.02°C
- Built in thermal gradient compensation sensor for fast, stable readings
- SMBus compatible digital interface
- Customizable PWM output for continuous reading
- 3V supply voltage;
- Sleep mode for reduced power consumption
- 8-14um spectral sensitivity

## Applications Examples

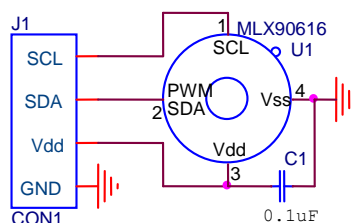
- Sensor element for high temperature thermometer guns

## Ordering Information



Part No.	Temperature Code	Package Code	-Option Code	Standard Part	Packing Form
MLX90616	E:(-40°C to 85°C)	SF (TO-39)	- X X X (1) (2) (3)	-000	- TU
(1) Supply Voltage/ Accuracy H - 3V , no IR calibration		(2) Number of thermopiles C – gradient compensated: <b>See page 2</b>		(3) Package options: A – Standard package	
<b>Example:</b> MLX90616ESF-HCA-000-TU					

## 1 Functional diagram



**MLX90616 connection to SMBus**

**Figure 1: Typical application schematics**

## 2 General Description

The MLX90616 is an Infra Red thermopile sensor for high temperature non-contact thermometers. Both the IR sensitive thermopile detector chip and the signal conditioning ASSP are integrated in the same TO-39 can. A low noise amplifier, 17-bit ADC and powerful DSP unit, result in a high accuracy and resolution of the thermometer. The ambient temperature sensor in the MLX90616 is calibrated in the factory. The digital interface of the sensor is SMBus compatible.

The MLX90616 is intended to be used in applications where the user places a lens in front of the sensor to adjust the FOV to his application. **The sensor-lens combination temperature measurement has to be calibrated by the customer.** Melexis provides the necessary software to do this in an engineering controlled environment.

The MLX90616 consists of a chipset developed and manufactured by Melexis:

- The Infra Red thermopile detector MLX81101
- The signal conditioning ASSP MLX90302, specially designed to process the output of IR sensor.

The device is available in an industry standard TO-39 package.

## ***General description (continued)***

An optical filter (long-wave pass) that cuts off the visible and near infra-red radiant flux is integrated in the package to provide ambient and sunlight immunity. The wavelength pass band of this optical filter is between 8 and 14 $\mu$ m.

A low noise amplifier, high resolution 17-bit ADC and powerful DSP unit in the MLX90302 enables high accuracy and resolution of the thermometer. The calculated object and ambient temperatures are available in RAM of MLX90302 with resolution of 0.02 °C. They are accessible by 2 wire serial SMBus compatible protocol (0.02°C resolution) or via 10-bit PWM (Pulse Width Modulated) output of the device.

The MLX90616 is factory calibrated to allow operation in wide ambient temperature ranges from -40 to 85 °C.

As a standard, the MLX90616 is supplied with a programmed object emissivity of 1. It can be easily changed by the customer for any other emissivity in the range 0.1...1.0 without the need for recalibration with a black body.

The PWM can be easily customized for virtually any range desired by the customer by changing the content of 2 EEPROM cells. This has no influence on the calibration of the device and temperature calculations in the device. Only the PWM output is adjusted.

**It is a common issue with infrared thermometer guns that they are sensitive to ambient temperature variations. It has therefore often been required to let the thermometer stabilize for a long period (20 minutes) before achieving accurate measurements.**

**The MLX90616ESF-HCA incorporates a secondary thermopile sensor to sense thermal gradients in the package and in the optical assembly. The signal of this secondary sensor is used to compensate for the adverse effect these thermal gradients have on the measurement. In this way it is possible to make a thermometer gun which stabilizes very quickly (seconds) and gives accurate results in demanding environments.**

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## 4 Glossary of Terms

PTAT	Proportional To Absolute Temperature sensor (package temperature)
PTC	Positive Temperature Coefficient sensor (package temperature)
POR	Power On Reset
HFO	High Frequency Oscillator (RC type)
DSP	Digital Signal Processing
FIR	Finite Impulse Response. Digital filter
IIR	Infinite Impulse Response. Digital filter
IR	Infra-Red
PWM	Pulse With Modulation
DC	Duty Cycle (of the PWM) ; Direct Current (for settled conditions specifications)
FOV	Field Of View
SDA,SCL	Serial DATA, Serial CLock – SMBus compatible communication pins
Ta	Ambient Temperature measured from the chip – (the package temperature)
To	Object Temperature, 'seen' from IR sensor
ESD	Electro-Static Discharge
EMC	Electro-Magnetic Compatibility
ASSP	Application Specific Standard Product
TBD	To Be Defined

Note: sometimes the MLX90616xxx is referred to as "the module".

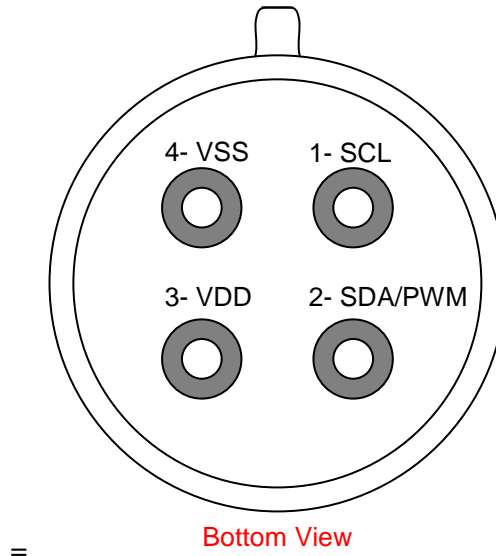
## 5 Maximum ratings

Parameter	MLX90616
Supply Voltage, V <sub>DD</sub> (over voltage)	5V
Supply Voltage, V <sub>DD</sub> (operating)	3.6V
Reverse Voltage	0.4 V
Operating Temperature Range, T <sub>A</sub>	-40...+85°C
Storage Temperature Range, T <sub>S</sub>	-40...+125°C
ESD Sensitivity (AEC Q100 002)	2kV
DC sink current, SDA / PWM pin	25 mA
DC source current, SDA / PWM pin	25 mA
DC clamp current, SDA / PWM pin	25 mA
DC clamp current, SCL pin	25 mA

**Table 1: Absolute maximum ratings for MLX90616**

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

## 6 Pin definitions and descriptions



**Figure 2: Pin description**

Pin Name	Function
SCL	Serial clock input for 2 wire communications protocol.
SDA / PWM	Digital input / output. In normal mode the measured object temperature is available at this pin Pulse Width Modulated. In SMBus compatible mode automatically configured as open drain NMOS.
VDD	External supply voltage.
VSS	Ground. The metal can is also connected to this pin.

**Table 2: Pin description MLX90616**

With the SCL and PWM / SDA pins operated in 2-wire interface mode, the input Schmitt trigger function is automatically enabled.

## 7 Electrical Specifications

All parameters are preliminary for  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 3\text{V}$  (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
<b>Supplies</b>						
External supply	$V_{DD}$		2.6	3	3.6	V
Supply current	$I_{DD}$	No load		1	2	mA
Supply current (programming)	$I_{DDpr}$	No load, erase/write EEPROM operations		1.5	2.5	mA
Sleep mode supply current	$I_{sleep}$	no load	1	2.5	5	$\mu\text{A}$
Sleep mode supply current	$I_{sleep}$	Full temperature range	1	2.5	6	$\mu\text{A}$
<b>Power On Reset</b>						
POR level	$V_{POR\_up}$	Power-up (full temp range)	1.4	1.75	1.95	V
POR level	$V_{POR\_down}$	Power –down (full temp range)	1.3	1.7	1.9	V
POR hysteresis	$V_{POR\_hys}$	Full temp range	0.08	0.1	1.15	V
$V_{DD}$ rise time (10% to 90% of specified supply voltage)	$T_{POR}$	Ensure POR signal			20	ms
Output valid	$T_{valid}$	After POR		0.15		s
<b>Pulse width modulation<sup>1</sup></b>						
PWM resolution	PWMres	Data band		10		bit
PWM output period	$PWM_{T,def}$	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-4		+4	%
Output high Level	$PWM_{HI}$	$I_{source} = 2\text{ mA}$	$V_{DD}-0.25$			V
Output low Level	$PWM_{LO}$	$I_{sink} = 2\text{ mA}$			$V_{SS}+0.25$	V
Output drive current	$I_{drive_{PWM}}$	$V_{out,H} = V_{DD} - 0.8\text{V}$		4.5		mA
Output sink current	$I_{sink_{PWM}}$	$V_{out,L} = 0.8\text{V}$		11		mA

Continued next page.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
<b>SMBus compatible 2-wire interface<sup>2</sup></b>						
Input high voltage	$V_{IH}(Ta,V)$	Over temperature and supply	VDD-0.1			V
Input low voltage	$V_{IL}(Ta,V)$	Over temperature and supply			0.6	V
Output low voltage	$V_{OL}$	SDA pin in open drain mode, over temperature and supply, $I_{sink} = 2mA$			0.25	V
SCL leakage	$I_{SCL,leak}$	$V_{SCL}=3V, Ta=+85^{\circ}C$			20	$\mu A$
SDA leakage	$I_{SDA,leak}$	$V_{SDA}=3V, Ta=+85^{\circ}C$			0.25	$\mu A$
SCL capacitance	$C_{SCL}$				10	pF
SDA capacitance	$C_{SDA}$				10	pF
Slave address	SA	Factory default		5A		hex
Wake up request	$t_{wake}$	SDA low	33			ms
SMBus Request	$t_{REQ}$	SCL low	1.44			ms
Timeout,low	$T_{timeout,L}$	SCL low	27		33	<b>ms</b>
Timeout, high	$T_{timeout,H}$	SCL high	45		55	<b>us</b>
Acknowledge setup	$T_{suac}(MD)$	8-th SCL falling edge, Master	0.5		1.5	us
Acknowledge hold	$T_{hdac}(MD)$	9-th SCL falling edge, Master	1.5		2.5	us
Acknowledge setup	$T_{suac}(SD)$	8-th SCL falling edge, Slave	2.5			us
Acknowledge hold	$T_{hdac}(SD)$	9-th SCL falling edge, Slave	1.5			us
<b>EEPROM</b>						
Data retention		$Ta = +85^{\circ}C$	10			years
Erase/write cycles		$Ta = +25^{\circ}C$	100,000			Times
Erase/write cycles		$Ta = +125^{\circ}C$	10,000			Times
Erase cell time	$T_{erase}$			5		ms
Write cell time	$T_{write}$			5		ms

**Table 3: Electrical specification MLX90616BXX**

Notes: All the communication and refresh rate timings are given for the nominal calibrated HFO frequency and will vary with this frequency's variations.

1. All PWM timing specifications are given for single PWM output. With large capacitive loads, a lower PWM frequency is recommended. Thermal relay output (when configured) has the PWM DC specification and can be programmed as push-pull, or NMOS open drain. PWM is free-running; power-up factory default is SMBus.

2. For SMBus compatible interface on 12V application refer to Application information section. SMBus compatible interface is described in details in the SMBus detailed description section. The maximum number of MLX90616xxx devices on one bus is 127, higher pull-up currents are recommended for higher number of devices, faster bus data transfer rates, and increased reactive loading of the bus.

The MLX90616 is always a slave device on the bus. The MLX90616 can work in both low-power and high-power SMBus communication.

All voltages are referred to the  $V_{SS}$  (ground) unless otherwise noted.

## 8 Detailed description

### 8.1 Block diagram

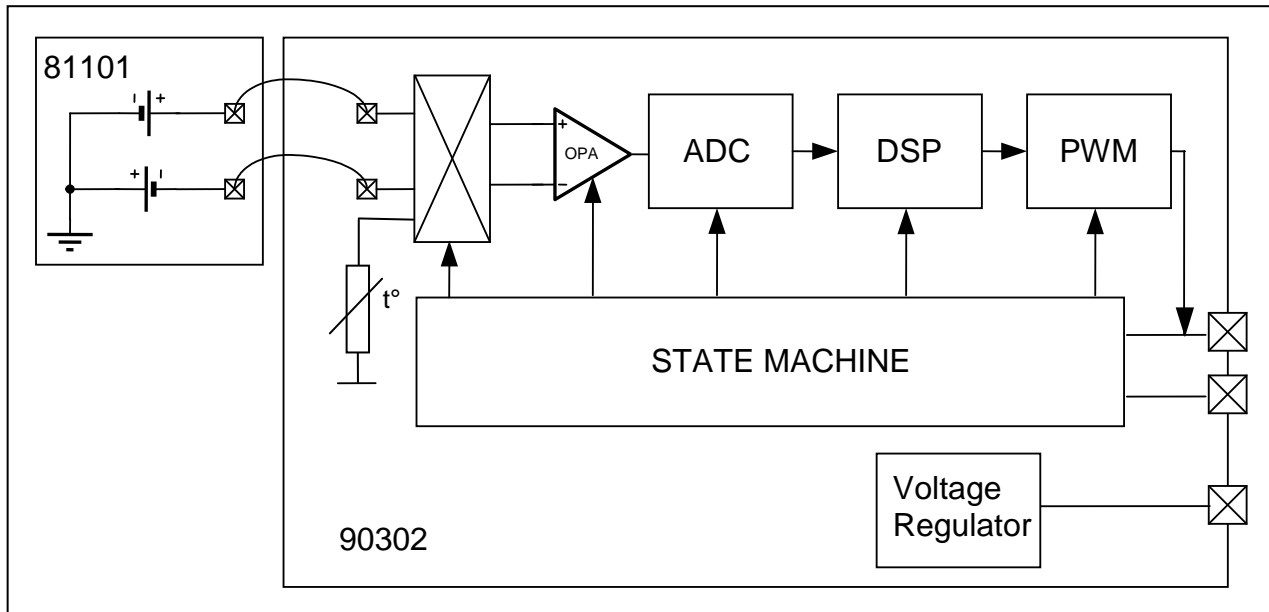


Figure 3: block diagram

### 8.2 Signal processing principle

The operation of the MLX90616 is controlled by an internal state machine, which controls the measurements and calculations of the object and ambient temperatures and does the post-processing of the temperatures to output them through the PWM output or the SMBus compatible interface.

The output of the IR sensors is amplified by a low noise low offset chopper amplifier with programmable gain, converted by a Sigma Delta modulator to a single bit stream and fed to a powerful DSP for further processing. The signal is treated by programmable (by means of EEPROM content) FIR and IIR low pass filters for further reduction of the bandwidth of the input signal to achieve the desired noise performance and refresh rate. The output of the IIR filter is the measurement result and is available in the internal RAM. 3 different cells are available: One for the on-board temperature sensor (on chip PTAT or PTC) and 2 for the IR sensors.

Based on results of the above measurements, the corresponding ambient temperature  $T_a$  and object temperature  $T_o$  are calculated. Both calculated temperatures have a resolution of  $0.02\text{ }^\circ\text{C}$ . The data for  $T_a$  and  $T_o$  can be read in two ways: Reading RAM cells dedicated for this purpose via the 2-wire interface ( $0.02\text{ }^\circ\text{C}$  resolution, fixed ranges), or through the PWM digital output (10 bit resolution, configurable range).

In the last step of the measurement cycle, the measured  $T_a$  and  $T_o$  are rescaled to the desired output resolution of the PWM) and the recalculated data is loaded in the registers of the PWM state machine, which creates a constant frequency with a duty cycle representing the measured data.

### 8.3 Block description

#### 8.3.1 Amplifier

A low noise, low offset amplifier with programmable gain is used for amplifying the IR sensor voltage. By carefully designing the input modulator and balanced input impedance, an offset below  $0.5\mu\text{V}$  is achieved.



### 8.3.2 Supply regulator and POR

The Power On Reset (POR) is connected to Vdd supply. The on-chip POR circuit provides an active (high) level of the POR signal when the Vdd voltage rises above approximately 0.5V and holds the entire MLX90616 in reset until the Vdd is higher than the specified POR threshold  $V_{POR}$ . During the time POR is active, the POR signal is available as an open drain at the PWM/SDA pin. After the MLX90616 exits the POR condition, the function programmed in EEPROM takes precedence for that pin.

### 8.3.3 EEPROM

A limited number of addresses in the EEPROM memory can be changed by the customer. The whole EEPROM can be read through the SMBus interface.

EEPROM (32X16)		
Name	Address	Write access
<b>To<sub>max</sub></b>	<b>0x000</b>	<b>Yes</b>
<b>To<sub>min</sub></b>	<b>0x001</b>	<b>Yes</b>
<b>PWMCTRL</b>	<b>0x002</b>	<b>Yes</b>
<b>Ta range</b>	<b>0x003</b>	<b>Yes</b>
<b>Emissivity correction coefficient</b>	<b>0x004</b>	<b>Yes</b>
<b>Config Register1</b>	<b>0x005</b>	<b>Yes</b>
<b>Calibration coefficients</b>	<b>0x006</b>	<b>Calibration mode</b>
...	...	...
<b>Calibration coefficients</b>	<b>0x00D</b>	<b>Calibration mode</b>
<b>SMBus address</b>	<b>0x00E</b>	<b>Yes</b>
<b>Calibration coefficients</b>	<b>0x00F</b>	<b>Yes</b>
<b>Calibration coefficients</b>	<b>0x010</b>	<b>Calibration mode</b>
...	...	...
<b>Calibration coefficients</b>	<b>0x018</b>	<b>Calibration mode</b>
<b>Config Register2</b>	<b>0x019</b>	<b>Yes</b>
<b>Melexis reserved</b>	<b>0x01A</b>	<b>No</b>
<b>Melexis reserved</b>	<b>0x01B</b>	<b>No</b>
<b>ID number</b>	<b>0x01C</b>	<b>No</b>
<b>ID number</b>	<b>0x01D</b>	<b>No</b>
<b>ID number</b>	<b>0x01E</b>	<b>No</b>
<b>ID number</b>	<b>0x01F</b>	<b>No</b>

**Table 4: EEPROM table**

The addresses  $To_{max}$ ,  $To_{min}$  and Ta range are for customer dependent object and ambient temperature ranges. For details see section 8.5.2 below in this document

The address **Emissivity** contains the object emissivity (factory default 1.0 = 0xFFFF), 16 bit.

$$\text{Emissivity} = \text{dec2hex}[\text{round}(65535 \times \epsilon)]$$

Where  $\text{dec2hex}[\text{round}(X)]$  represents decimal to hexadecimal conversion with round-off to nearest value (not truncation). In this case the physical emissivity values are  $\epsilon = 0.1 \dots 1.0$ .

Erase (write 0) must take place before write of desired data is made.

**PWM period configuration:**

The period in extended PWM mode is twice the period in single PWM mode.

In single PWM mode period is  $T = 1.024 * P$  [ms], where P is the number, written in bits 15...9 PWMCTRL.

Maximum period is then 131.072 ms for single and 262.144 ms for extended. These values are typical and depend on the on-chip RC oscillator absolute value. The duty cycle must be calculated instead of working only with the high time only in order to avoid errors from the period absolute value deviations.

The address **PWMCTRL** consists of control bits for configuring the PWM/SDA pin as shown in Table 5:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	<b>PWM control bit meaning</b>
															0	- PWM extended mode
															1	- PWM single mode
															0	- PWM mode disabled (EN_PWM)
															1	- PWM mode enabled (EN_PWM)
															0	- SDA pin configured as Open Drain (PPODB)
															1	- SDA pin configured as Push-Pull (PPODB)
															0	- PWM mode selected (TRPWMB)
															1	- Thermal relay mode selected (TRPWMB)
																- PWM repetition number 0...62 step 2
																- PWM period 1.024*ms (Single PWM mode) or 2.048*ms (Extended PWM mode) multiplied by the number written in this place (128 in case the number is 0)

\* Values are valid for nominal HFO frequency

**Table 5: PWM control bits**

The address **ConfigRegister1** consists of control bits for configuring the analog and digital parts:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Config register bit meaning
													1	0	0	- IIR (100%) a1=1, b1=0
													1	0	1	- IIR (80%) a1=0.8, b1=0.2
													1	1	0	- IIR (67%) a1=0.666, b1=0.333
													1	1	1	- IIR (57%) a1=0.571, b1=0.428
													0	0	0	- IIR (50%) a1=0.5, b1=0.5
													0	0	1	- IIR (25%) a1=0.25, b1=0.75
													0	1	0	- IIR (17%) a1=0.166(6), b1=0.83(3)
													1	1	1	- IIR (13%) a1=0.125, b1=0.875
													0			- Repeat sensor test "OFF"
													1			- Repeat sensor test "ON"
													0	0		- Ta on PWM channel 1, Tobj1 on PWM channel 2
													0	1		Not Valid
													1	0		Not Valid
													1	1		- Tobj1 on PWM channel 1
													1			- This bit should always be set to '1'
													M			- Melexis reserved - Do not change
					0	0	0									- FIR = 8 not recommended
					0	0	1									- FIR = 16 not recommended
					0	1	0									- FIR = 32 not recommended
					0	1	1									- FIR = 64 not recommended
					1	0	0									- FIR = 128
					1	0	1									- FIR = 256
					1	1	0									- FIR = 512
					1	1	1									- FIR = 1024
					0	0	0									- GAIN = 1 - Amplifier is bypassed
					0	0	1									- GAIN = 3
					0	1	0									- GAIN = 6
					0	1	1									- GAIN = 12,5
					1	0	0									- GAIN = 25
					1	0	1									- GAIN = 50
					1	1	0									- GAIN = 100
					1	1	1									- GAIN = 100
					M											- Melexis reserved - Do not change
					0											- Enable sensor test
					1											- Disable sensor test

*Note: The following bits/registers should not be altered (except with special tools – contact Melexis for tools availability) in order to keep the factory calibration relevant: Ke [15..0]; Config Register1 [13..11;7;3]; addresses 0x00F and 0x019.*

**Table 6: Configuration register 1**

### 8.3.4 On-chip filtering and settling time:

The MLX90616 features configurable on-chip digital filters. They allow customization for speed or noise. Details on the filters are given in the application note “Understanding MLX90616 on-chip digital signal filters” available from [www.melexis.com](http://www.melexis.com).

The available filter settings and the settling times they give are listed below. Settling time depends on two configurations: IIR filter settings and FIR filter settings. The FIR filter has a straightforward effect on noise (a 4 times decrease of settling time increases the noise 2 times and vice versa). The IIR filter provides an additional, spike limiting, feature. Spike limit is also listed and defines to what level the magnitude of a spike would be limited – for example, 25% denotes that if a 20°C temperature delta spike is measured the temperature reading by the MLX90616 will spike only 5°C. More details are available in the application notes from [www.melexis.com](http://www.melexis.com).

IIR setting	FIR setting	Settling time (s)	Spike limit
xxx	000...011		
100	100	0.06	100.0%
100	101	0.07	100.0%
100	110	0.10	100.0%
100	111	0.14	100.0%
101	100	0.20	80.0%
101	101	0.24	80.0%
101	110	0.34	80.0%
101	111	0.54	80.0%
110	100	0.38	66.7%
110	101	0.48	66.7%
110	110	0.67	66.7%
110	111	1.10	66.7%
111	100	0.42	57.0%
111	101	0.53	57.0%
111	110	0.75	57.0%
111	111	1.20	57.0%
000	100	0.47	50.0%
000	101	0.60	50.0%
000	110	0.84	50.0%
000	111	1.33	50.0%
001	100	1.10	25.0%
001	101	1.40	25.0%
001	110	2.00	25.0%
001	111	3.20	25.0%
010	100	1.80	16.7%
010	101	2.20	16.7%
010	110	3.20	16.7%
010	111	5.00	16.7%
011	100	2.40	12.5%
011	101	3.00	12.5%
011	110	4.30	12.5%
011	111	7.00	12.5%

**Table 7: possible IIR and FIR settings**

Note: Settling time is in seconds and depends on internal oscillator absolute value. 100% spike limit appears with the IIR filter bypassed, and there is no spike limitation.

### 8.3.5 RAM

It is not possible to write into the RAM memory. It can only be read and only a limited number of RAM registers are of interest to the customer.

RAM (32x17)		
Name	Address	Read access
Melexis reserved	0x000	Yes
...	...	...
Melexis reserved	0x003	Yes
Raw data IR main channel	0x004	
Raw data IR compensation	0x005	
T <sub>A</sub>	0x006	Yes
T <sub>OBJ</sub>	0x007	Yes
Melexis reserved	0x008	Yes
...	...	...
Melexis reserved	0x01F	Yes

**Table 8: Ram addresses**

### 8.4 SMBus compatible 2-wire protocol

The chip supports a 2 wire serial protocol, built with pins PWM/SDA and SCL.

- SCL – digital input, used as the clock for SMBus compatible communication. This pin has the auxiliary function for building an external voltage regulator. When the external voltage regulator is used, the 2-wire protocol is available only if the power supply regulator is overdriven.
- PWM/SDA – Digital input/output, used for both the PWM output of the measured object temperature(s) or the digital input/output for the SMBus. The pin can be programmed in EEPROM to operate as Push/Pull or open drain NMOS (open drain NMOS is factory default). In SMBus mode SDA is forced to open drain NMOS I/O, push-pull selection bit defines PWM/Thermal relay operation.

#### 8.4.1 Functional description

The SMBus interface is a 2-wire protocol, allowing communication between the Master Device (MD) and one or more Slave Devices (SD). In the system only one master can be presented at any given time [1]. The MLX90616 can only be used as a slave device.

Generally, the MD initiates the start of data transfer by selecting a SD through the Slave Address (SA). The MD has read access to the RAM and EEPROM and write access to 9 EEPROM cells (at addresses 0x20h, 0x21h, 0x22h, 0x23h, 0x24h, 0x25h\*, 0x2Eh, 0x2Fh, 0x39h). If the access to the MLX90616 is a read operation it will respond with 16 data bits and 8 bit PEC only if its own slave address, programmed in internal EEPROM, is equal to the SA, sent by the master. The SA feature allows connecting up to 127 devices with only 2 wires, unless the system has some of the specific features described in paragraph 5.2 of reference [1]. In order to provide access to any device or to assign an address to a SD before it is connected to the bus system, the communication must start with zero SA followed by low RWB bit. When this command is sent from the MD, the MLX90616 will always respond and will ignore the internal chip code information.

**Special care must be taken not to put two MLX90616 devices with the same SD addresses on the same bus as MLX90616 does not support ARP [1].**

The MD can force the MLX90616 into low consumption mode “sleep mode” (3V version only).

Read flags like “EEBUSY” (1 – EEPROM is busy with executing the previous write/erase), “EE\_DEAD” (1 – there is fatal EEPROM error and this chip is not functional\*\*).

*Note\*:* This address is readable and writable. Bit 3 should not be altered as this will cancel the factory calibration.

*Note\*\*:* EEPROM error signaling is implemented in automotive grade parts only.

### 8.4.2 Differences with the standard SMBus specification (reference [1])

There are eleven command protocols for standard SMBus interface. The MLX90616 supports only two of them. Not supported commands are:

- Quick Command
- Byte commands - Sent Byte, Receive Byte, Write Byte and Read Byte
- Process Call
- Block commands – Block Write and Write-Block Read Process Call

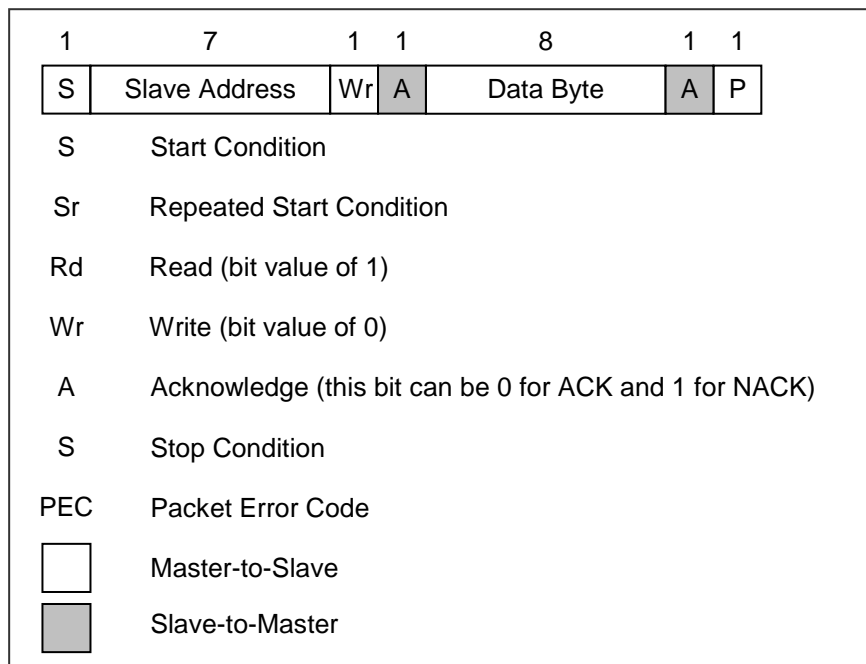
Supported commands are:

- Read Word
- Write Word

### 8.4.3 Detailed description

The PWM/SDA pin of MLX90616 can operate also as PWM output, depending on the EEPROM settings. If PWM is enabled, after POR the PWM/SDA pin is directly configured as PWM output. The PWM mode can be avoided and the pin can be restored to its Data function by a special command. That is why hereafter both modes are treated separately.

#### 8.4.3.1 Bus Protocol



**Figure 4: SMBus packet element key**

After every 8 bits received by the SD an ACK/NACK takes place. When a MD initiates communication, it first sends the address of the slave and only the SD which recognizes the address will ACK, the rest will remain silent. In case the SD NACKs one of the bytes, the MD should stop the communication and repeat the message. A NACK could be received after the PEC. This means that there is an error in the received message and the MD should try sending the message again. The PEC calculation includes all bits except the START, REPEATED START, STOP, ACK, and NACK bits. The PEC is a CRC-8 with polynomial  $X^8+X^2+X+1$ . The Most Significant Bit of every byte is transferred first.

### 8.4.3.1.1 Read Word (depending on the command – RAM or EEPROM)

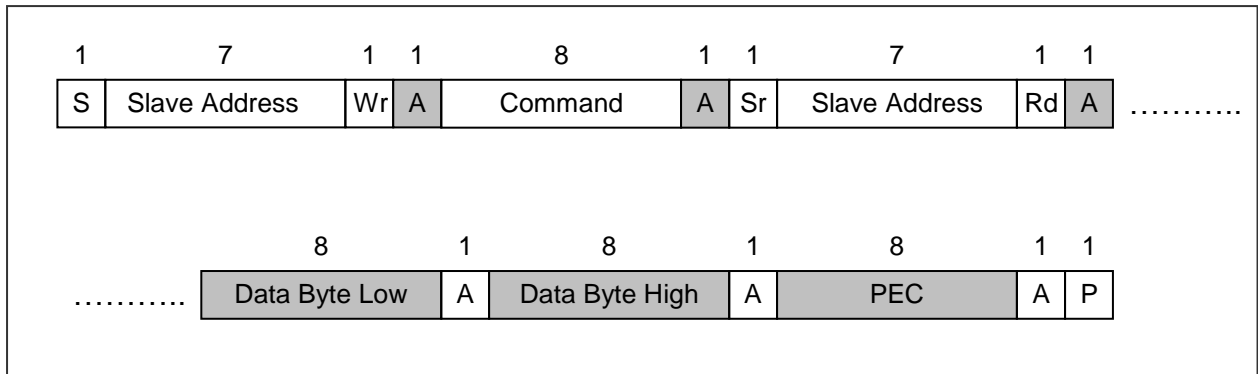


Figure 5: SMBus read word format

### 8.4.3.1.2 Write Word (EEPROM)

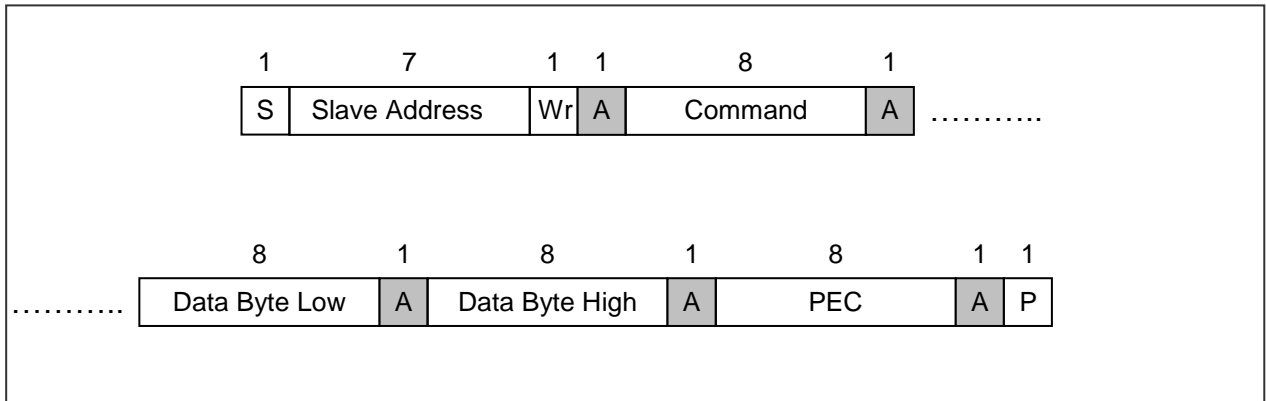
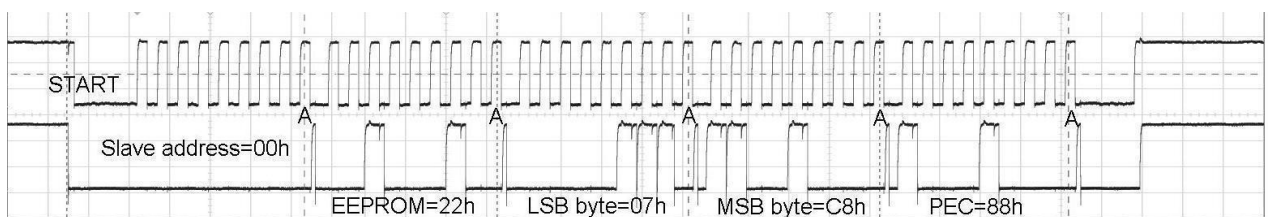
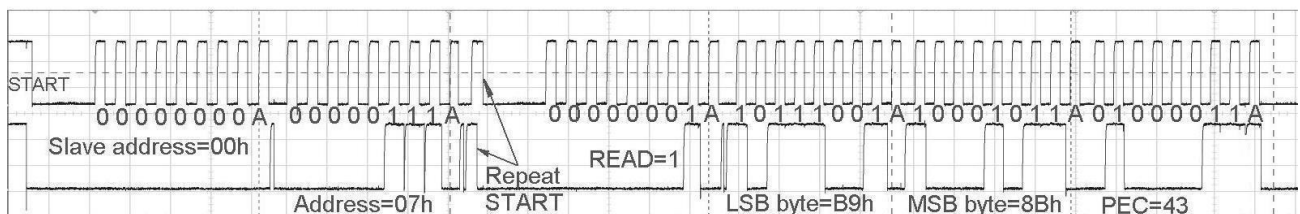


Figure 6 SMBus write word format



Write 0xC807h to EEPROM address 0x22h, PEC=0x88h



Read RAM 0x07h, result = 0x8BB9h, PEC = 0x43h

Figure 7: SMBus communication examples (Read RAM and Write EEPROM)

## 8.4.4 AC specification for SMBus

### 8.4.4.1 Timing

The MLX90616 meets all the timing specifications of the SMBus [1]. The maximum frequency of the MLX90616 SMBus is 100 KHz and the minimum is 10 KHz.

The specific timings in MLX90616's SMBus are:

**SMBus Request ( $t_{REQ}$ )** is the time that the SCL should be forced low in order to switch MLX90616 from PWM mode to SMBus mode – at least 1.44ms;

**Timeout L** is the maximum allowed time for SCL to be low. After this time the MLX90616 will reset its communication block and will be ready for new communication – not more than 45us;

**Timeout H** is the maximum time for which it is allowed for SCL to be high during communication. After this time MLX90616 will reset its communication block assuming that the bus is idle (according to the SMBus specification) – not more than 27ms.

**$T_{suac}(SD)$**  is the time after the eighth falling edge of SCL that MLX90616 will force PWM/SDA low to acknowledge the last received byte – not more than 2.5 $\mu$ s.

**$T_{hdac}(SD)$**  is the time after the ninth falling edge of SCL that MLX90616 will release the PWM/SDA (so the MD can continue with the communication) – not more than 1.5 $\mu$ s.

**$T_{suac}(MD)$**  is the time after the eighth falling edge of SCL that MLX90616 will release PWM/SDA (so that the MD can acknowledge the last received byte) – not more than 0.5 $\mu$ s.

**$T_{hdac}(MD)$**  is the time after the ninth falling edge of SCL that MLX90616 will take control of the PWM/SDA (so it can continue with the next byte to transmit) – not more than 1.5 $\mu$ s.

The indexes MD and SD for the latest timings are used – MD when the master device is making acknowledge; SD when the slave device is making acknowledge. For other timings see [1].

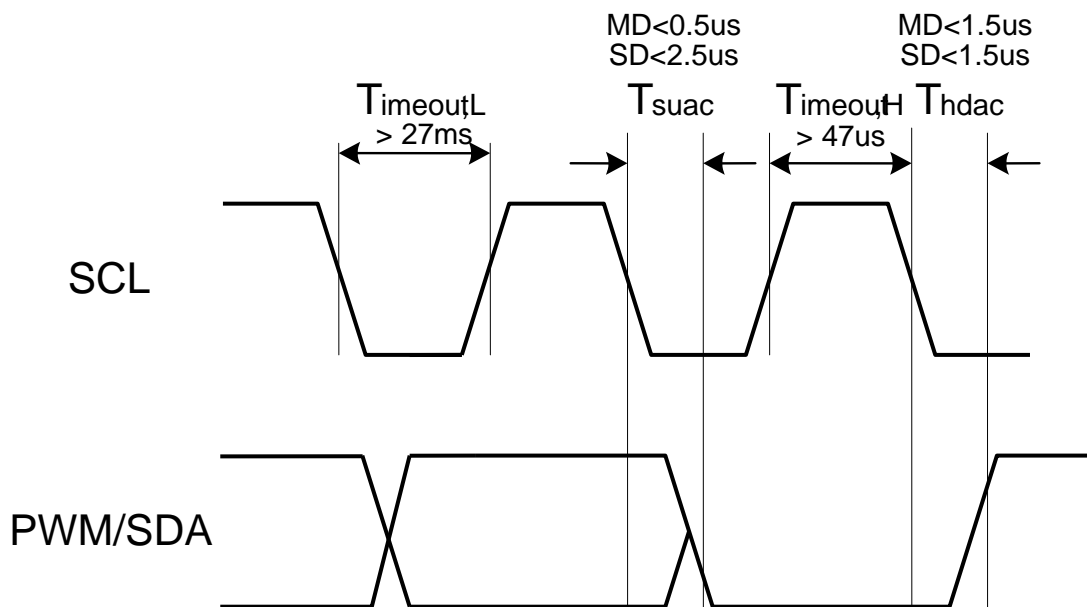


Figure 8: SMBus timing



### 8.4.5 Bit transfer

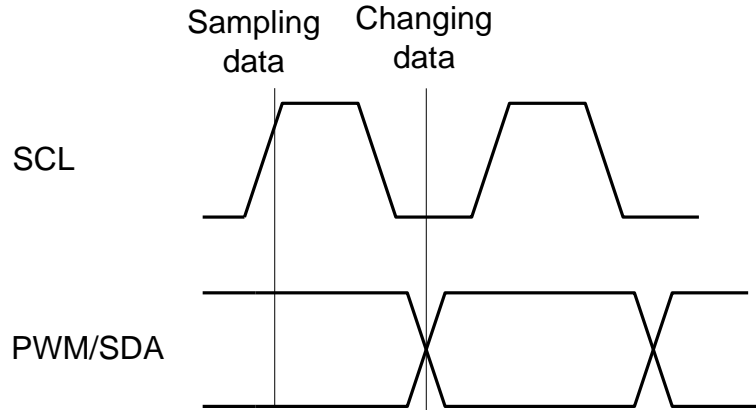


Figure 9: Bit transfer on SMBus

The data on PWM/SDA must be changed when SCL is low (min 300ns after the falling edge of SCL). The data is fetched by both MD and SDs on the rising edge of the SCL. The recommended timing for changing data is in the middle of the period when the SCL is low.

### 8.4.6 Commands

RAM and EEPROM can be read both with 32x16 sizes. If the RAM is read, the data are divided by two, due to a sign bit in RAM (for example,  $T_{OBJ}$  - RAM address 0x07h will sweep between 0x27ADh to 0xFFFF as the object temperature rises from -70.01°C to +1037.55°C). The MSB for the raw data (e.g. IR sensor1 data) is a sign bit (sign and magnitude format). A write of 0x0000 must be done prior to writing in EEPROM in order to erase the EEPROM cell content. Refer to EEPROM detailed description for factory calibration EEPROM locations that need to be kept unaltered.

Opcode	Command
000x xxxx*	RAM Access
001x xxxx*	EEPROM Access
1111_0000**	Read Flags
1111_1111	Enter SLEEP mode

Table 9: SMBus commands

Note\*: The xxxxx represent the 5 LSBits of the memory map address to be read/written.

Note\*\*: Behaves like read command. The MLX90616 returns PEC after 16 bits data of which only 4 are meaningful and if the MD wants it, it can stop the communication after the first byte. The difference between read and read flags is that the latter does not have a repeated start bit.

Flags read are:

Data[7] - EEBUSY - the previous write/erase EEPROM access is still in progress. High active.

Data[6] - Unused

Data[5] - EE\_DEAD - EEPROM double error has occurred. High active.

Data[4] - INIT - POR initialization routine is still ongoing. Low active.

Data[3] - Not implemented.

Data[2..0] and Data[8..15] - All zeros.

Flags read is a diagnostic feature. The MLX90616 can be used regardless of these flags.

For details and examples for SMBus communication with the MLX90616 check the [www.melexis.com](http://www.melexis.com)

## 8.4.7 Sleep Mode

The MLX90616 can enter in Sleep Mode via the command “Enter SLEEP mode” sent via the SMBus interface. This mode is not available for the 5V supply version. To limit the current consumption to 2.5uA (typical), the SCL pin should be kept low during sleep. MLX90616 goes back into power-up default mode (via POR reset) by setting SCL pin high and then PWM/SDA pin low for at least  $t_{DDq}=80ms$ . If EEPROM is configured for PWM (EN\_PWM is high), the PWM interface will be selected after awakening and if PWM control [2], PPODB is 1 the MLX90616 will output a PWM pulse train with push-pull output.

### 8.4.7.1 Enter Sleep Mode

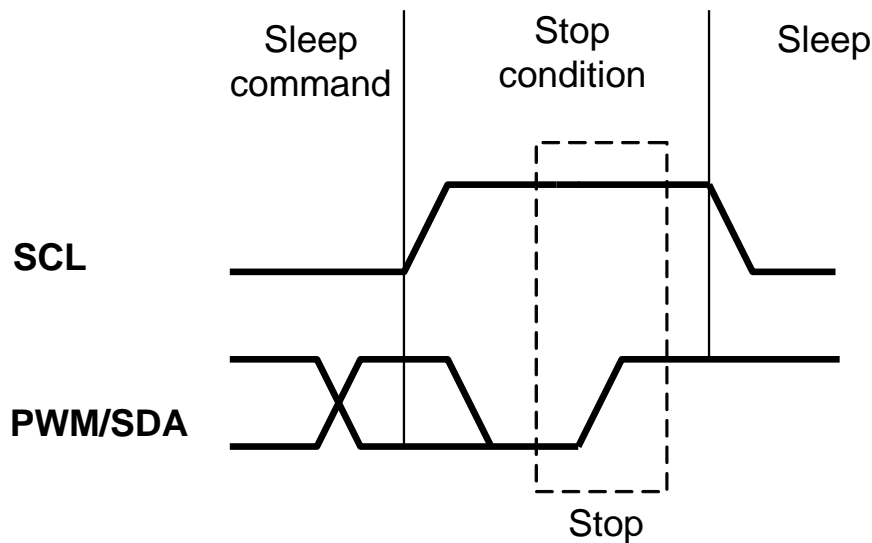


Figure 10: Enter sleep

### 8.4.7.2 Exit from Sleep Mode

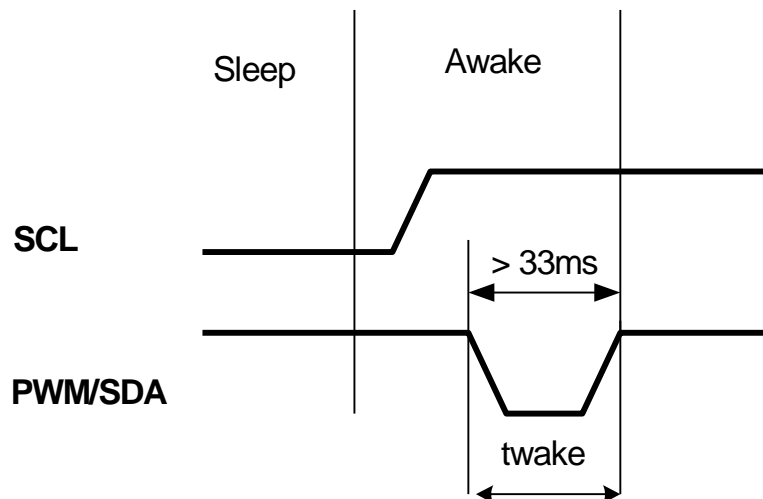


Figure 11: Exit Sleep Mode

First data is available 0.25 seconds (typ.) after exit from Sleep is done. On-chip IIR filter is skipped for the very first measurement. All measurements afterwards pass the embedded digital filtering as configured in EEPROM. Details on embedded filtering are available in application note "Understanding MLX90616 on-chip digital signal filters", available from [www.melexis.com](http://www.melexis.com)

SCL line is kept low in order to reduce current leakage through the pin (artificial Zener diode is connected to that pin).

#### **8.4.8 MLX90616 SMBus specific remarks**

Continuous SMBus readings can introduce an error. As the SCL line inside TO39 package is passing relatively close to the sensor input and error signal is induced to the sensor output. The manifestation of the problem is wrong temperature readings. This is especially valid for narrow FOV devices. Possible solution is to keep SDA and SCL line quiet for period longer than refresh rate and settling time defined by internal settings of MLX90616 prior to reading the temperature or switch to PWM signal and completely disconnect from SDA and SCL line.

## 8.5 PWM

The MLX90616 can be read via PWM or SMBus compatible interface. Selection of PWM output is done in EEPROM configuration (factory default is SMBus). PWM output has two programmable formats, single and dual data transmission, providing single wire reading of two temperatures (dual zone object or object and ambient). The PWM period is derived from the on-chip oscillator and is programmable.

Config Register[5:4]	PWM1 data	PWM2 data	$T_{min,1}$	$T_{max,1}$	$T_{min,2}$	$T_{max,2}$
00	$T_a$	$T_{obj}$	$T_{range,L}$	$T_{range,H}$	$T_{Omin}$	$T_{Omax}$
01	Undefined	Undefined	N.A.	N.A.	N.A.	N.A.
11	Undefined	Undefined	N.A.	N.A.	N.A.	N.A.
11	$T_{obj1}$	$T_{obj2}$	$T_{Omin}$	$T_{Omax}$	$T_{Omin}$	$T_{Omax}$

Table 10: PMW configuration table

Note: Serial data functions (2-wire / PWM) are multiplexed with a thermal relay function (described in the "Thermal relay" section).

\* not recommended for extended PWM format operation

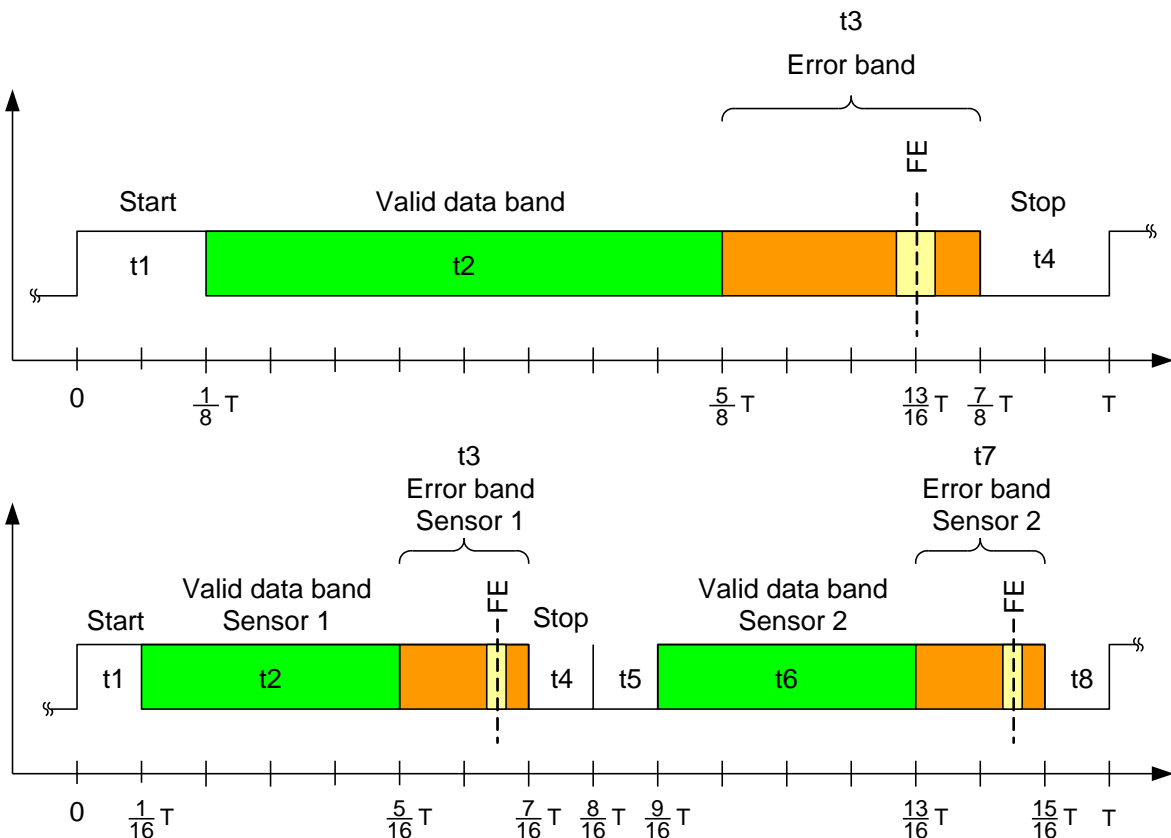


Figure 12: PWM timing single (above) and extended PWM (below)

PWM type	t1	t2	t3	t4	t5	t6	t7	t8
Single	1/8 – high	4/8 - var	2/8	1/8 – low	NA	NA	NA	NA
Extended - S1	1/16 - high	4/16 - var	2/16	1/16 - low	1/16 - low	4/16 – low	2/16 - low	1/16 - low
Extended - S2	1/16 - high	4/16 - high	2/16 - high	1/16 - high	1/16 - high	4/16 - var	2/16	1/16 - low

Table 11: PMW timing

### 8.5.1 Single PWM format

In single PWM output mode only the settings for PWM1 data are used. The temperature reading can be calculated from the signal timing as:

$$T_{OUT} = \left( \frac{2t_2}{T} (T_{O\_MAX} - T_{O\_MIN}) \right) + T_{O\_MIN}$$

where Tmin and Tmax are the corresponding rescale coefficients in EEPROM for the selected temperature output (Ta, object temperature range is valid for Tobj as specified in the previous table) and T is the PWM period. Tout is Tobj or Ta according to Config Register [5:4] settings.

The different time intervals t1...t4 have the following meaning:

t1: Start buffer. During this time the signal is always high. t1 = 0.125\*T (T is the PWM period, refer to fig. 13).

t2: Valid Data Output Band, 0...1/2T. PWM output data resolution is 10 bit.

t3: Error band – information for fatal error in EEPROM (double error detected, not correctable). t3 = 0.25 \* T. Therefore a PWM pulse train with a duty cycle of 0.875 will indicate a fatal error in EEPROM (for single PWM format). FE means Fatal Error.

Example:

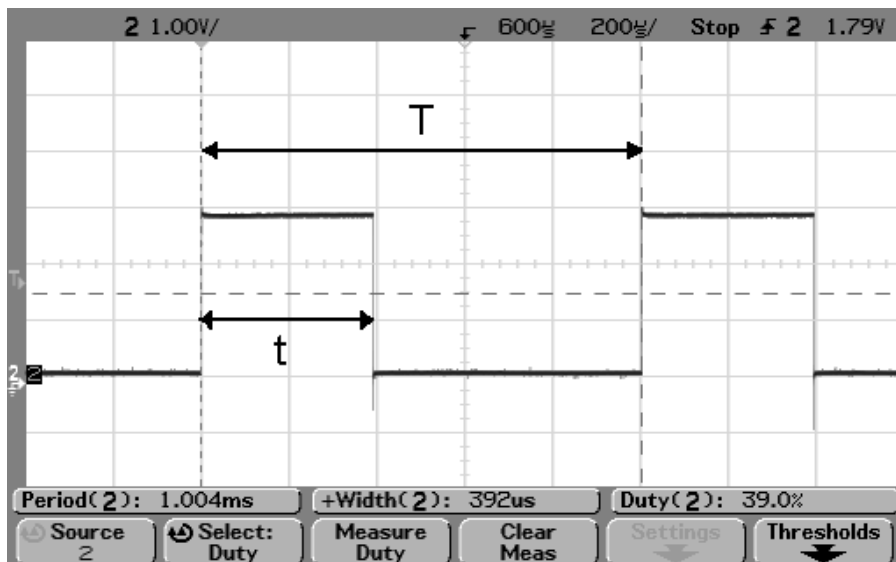


Figure 13: PWM example single mode

To\_min = 0°C => To\_min [EEPROM] = 100 \* (to\_min + 273.15) = 0x6AB3

To\_max = +50°C => To\_max [EEPROM] = 100 \* (to\_max + 273.15) = 0x7E3B

Captured PWM period is T = 1004µs

Captured high duration is t = 392 µs

Calculated duty cycle is:

$$D = \frac{t}{T} = \frac{392}{1004} = 0.3904 \text{ or } 39.04\%$$

The temperature is calculated as follows:

$$T_o = 2 * (0.3904 - 0.125) * (50 - 0) + 0 = 2 * 0.2554 * 50 = 26.54^\circ\text{C}$$

## 8.5.2 Customizing the temperature range for PWM output

The calculated ambient and object temperatures are stored in RAM with a resolution of 0.02 °C (16 bit). The PWM operates with a 10-bit word so the transmitted temperature is rescaled in order to fit in the desired range.

For this goal 2 cells in the EEPROM are foreseen to store the desired range for To ( $T_{o_{min}}$  and  $T_{o_{max}}$ ) and one for Ta ( $T_{a_{range}}$ : the 8MSB are foreseen for  $T_{a_{max}}$  and the 8LSB for  $T_{a_{min}}$ ).

Thus the output range for To can be programmed with an accuracy of 0.02 °C, while the corresponding Ta range can be programmed with an accuracy of 0.64 °C.

The **object** data for PWM is rescaled according to the following equation:

$$T_{PWM_{obj}} = \frac{T_{RAM} - T_{MIN_{EEPROM}}}{K_{PWM_{obj}}}, K_{PWM_{obj}} = \frac{T_{MAX_{EEPROM}} - T_{MIN_{EEPROM}}}{1023}$$

The  $T_{RAM}$  is the linearized  $T_{obj}$ , 16-bit (0x0000...0xFFFF, 0x0000 for -273.15°C and 0xFFFF for +1037.55°C) and the result is a 10-bit word, in which 0x000h corresponds to  $T_{o_{MIN}}$ [°C], 0x3FFh corresponds to  $T_{o_{MAX}}$ [°C]

and 1LSB corresponds to  $\frac{T_{o_{MAX}} - T_{o_{MIN}}}{1023}$  [°C]

$$T_{MIN_{EEPROM}} = T_{MIN} * 50 \text{ LSB}$$

$$T_{MAX_{EEPROM}} = T_{MAX} * 50 \text{ LSB}$$

The **ambient** data for PWM is rescaled according to the following equation:

$$T_{PWM_{ambient}} = \frac{T_{RAM} - T_{MIN_{EEPROM}}}{K_{PWM_{ambient}}}, K_{PWM_{ambient}} = \frac{T_{MAX_{EEPROM}} - T_{MIN_{EEPROM}}}{1023}$$

The result is a 10-bit word, where 000h corresponds to -38.2 °C (lowest Ta that can be read via PWM), 3FFh corresponds to 125 °C (highest Ta that can be read via PWM) and 1LSB corresponds to  $\frac{T_{MAX} - T_{MIN}}{1023}$  [°C]

$$T_{MIN_{EEPROM}} = [T_{MIN} - (-38.2)] * \frac{100}{64} \text{ LSB}$$

$$T_{MAX_{EEPROM}} = [T_{MAX} - (-38.2)] * \frac{100}{64} \text{ LSB}$$

## 8.6 Switching Between PWM and SMBus communication

### 8.6.1 PWM is enabled

The diagram below illustrates the way of switching to SMBus if PWM is enabled (factory programmed POR default for MLX90616 is SMBus, PWM disabled). Note that the SCL pin needs to be kept high in order to use PWM.

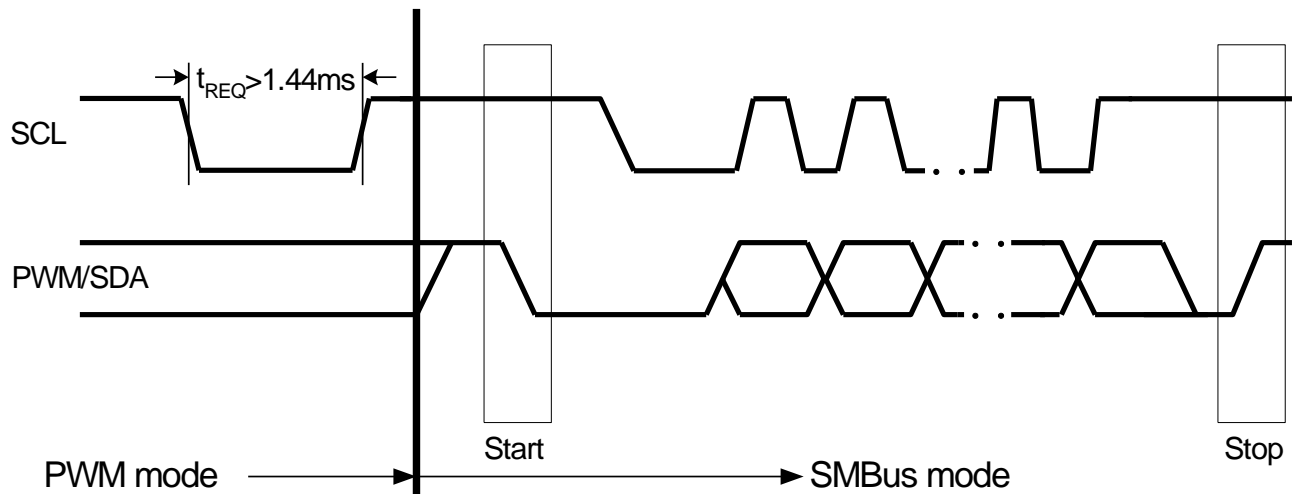


Figure 14: Switching from PWM mode to SMBus

### 8.6.2 Request condition

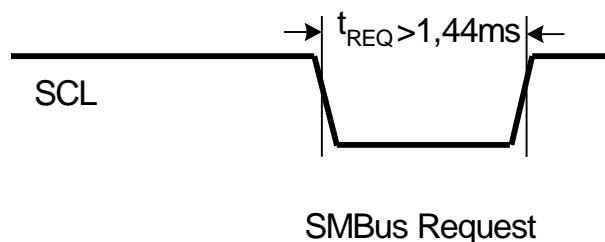


Figure 15: Request (switch to SMBus) condition

If PWM is enabled, the MLX90616's SMBus Request condition is needed to disable PWM and reconfigure PWM/SDA pin before starting SMBus communication. Once PWM is disabled, it can only be enabled by switching the supply OFF – ON or exit from Sleep Mode. The MLX90616's SMBus request condition requires forcing LOW the SCL pin for period longer than the request time ( $t_{REQ}$ ) >1,44ms. The SDA line value is ignored in this case.

### 8.6.3 PWM is disabled

If PWM is disabled by means of EEPROM the PWM/SDA pin is directly used for the SMBus purposes after POR. **Request condition should not be sent in this case.**

## 8.7 Computation of ambient and object temperatures

The IR sensor consists of serial connected thermo-couples with cold junctions placed at thick chip substrate and hot junctions, placed over thin membrane. The IR radiation absorbed from the membrane heats (or cools) it. The thermopile output signal is:

$$V_{ir}(T_a, T_o) = A \cdot (T_o^4 - T_a^4),$$

Where  $T_o$  is the object temperature absolute (Kelvin) temperature,  $T_a$  is the sensor die absolute (Kelvin) temperature, and  $A$  is the overall sensitivity.

An on board temperature sensor is needed to measure the chip temperature. After measurement of the output of both sensors, the corresponding ambient and object temperatures can be calculated. These calculations are done by the internal DSP, which produces digital outputs, linearly proportional to measured temperatures.

### 8.7.1 Ambient temperature $T_a$

The Sensor die temperature is measured with a PTC or a PTAT element. All the sensors conditioning and data processing is handled on-chip and the linearized sensor die temperature  $T_a$  is made available in memory.

The resolution of the calculated temperature is 0.02 °C. The sensor is factory calibrated for the full automotive range (-40...+125 °C). In RAM cell 006h, 2DE4h corresponds to -38.2 °C (linearization output lower limit) and 4DC4h (19908d) corresponds to 125 °C. The conversions from RAM content to real  $T_a$  is easy using the following relation:

$$T_a[^\circ K] = T_{areg} \times 0.02, \text{ or } 0.02 \text{ } ^\circ K / \text{LSB}.$$

### 8.7.2 Object temperature $T_o$

The result has a resolution of 0.02 °C and is available in RAM.  $T_o$  is derived from RAM as:

$$T_o[^\circ K] = T_{oreg} \times 0.02, \text{ or } 0.02 \text{ } ^\circ K / \text{LSB}.$$

Example:

1. 0x0000 => -273.15°C (- min possible value returned by MLX90616)
2. 0x0001 => -273.13°C
3. 0x0002 => -273.11°C and so on
4. 0x3AF7 => 28.75°C
5. 0x7FFF => 382.19°C - max possible value returned by MLX90616
6. 0xFFFF => 1037.55 - max possible value returned by MLX90616

The result is calculated by using the following expressions:

1. Convert it to decimal value i.e 0x3AF7 = 15095d
2. Divide by 50 (or multiply by 0.02) i.e. 15095/50=301.9K (result is in Kelvin)
3. Convert K -> °C i.e. 301.9-273.15=28.75°C

### 8.7.3 Calculation flow

The measurement, calculation and linearization are held by core, which executes a program from ROM. After POR the chip is initialized with calibration data from EEPROM. Measurements, compensation and linearization routines run in a closed loop afterwards.



## 8.8 Thermal relay

The MLX90616 can be configured to behave as a thermo relay with programmable threshold and hysteresis on the PWM/SDA pin. The input for the comparator unit of the relay is the object temperature from sensor 1  
**The output of the MLX90616 is NOT a relay driver but a logical output which should be connected to a relay driver if necessary.**

The output driver is one and the same for PWM and Thermal relay.

In order to configure the MLX90616 to work as thermal relay two conditions must be met:

- Set bit TRPWMB high at address 002h in EEPROM
- Enable PWM output i.e. EN\_PWM is set high

The PWM/SDA pin can be programmed as a push-pull or open drain NMOS (via bit PPODB in EEPROM PWMCTRL), which can trigger an external device. The temperature threshold data is determined by EEPROM at address 021h ( $T_{min}$ ) and the hysteresis at address 020h ( $T_{max}$ ).

The logical state of the PWM/SDA pin is as follows:

PWM/SDA pin is high if  $T_{obj} \geq threshold + hysteresis$

PWM/SDA pin is low if  $T_{obj} \leq threshold - hysteresis$

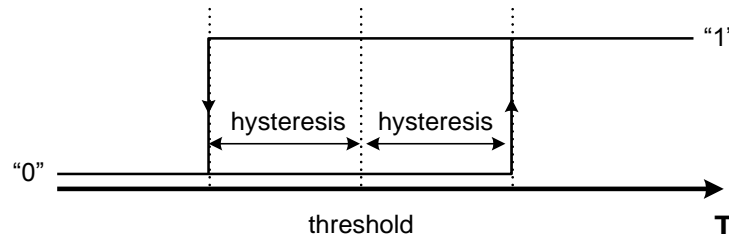


Figure 16: Thermal relay : "PWM" pin versus  $T_{obj}$

The MLX90616 preserves its normal operation when configured as a thermal relay (PWM configuration and specification applies as a general rule also for the thermal relay) and therefore it can be read using the SMBus (entering the SMBus mode from both PWM and thermal relay configuration is the same).

For example, the MLX90616 can generate a wake-up alert for a system upon reaching a certain temperature and then be read as a thermometer. A reset condition (enter and exit Sleep, for example) will be needed in order to return to the thermal relay configuration.

Example:

Threshold = 5 °C  $\rightarrow (5 + 273.15) * 50 = 13908 \rightarrow$  EEPROM 0x0001= 0x3654

Hysteresis = 1°C  $\rightarrow 1 * 50 = 50 \rightarrow$  EEPROM 0x0000= 0x0032 (smallest possible hysteresis is 0,02°C or 0x0001)

PWM/SDA pin will be low at object temperature below 4 °C

PWM/SDA pin will be high at object temperature higher than 6 °C

## 9 Unique Features

- The MLX90616 is a non contact thermometer which can be calibrated by the user for an output linearly dependent on the object temperature with high accuracy and high resolution.
- The high thermal stability of the MLX90616-HCA makes this part highly suited in applications where secondary heat sources can heat up the sensor. These sensors also have a very short stabilization time compared to other types of thermopile sensors, which is of importance if one needs an accurate measurement in conditions where the ambient temperature can change quickly.
- The MLX90616 supports versatile customization to a very wide range of temperatures and refresh rates.
- The user can program the internal object emissivity correction for objects with a low emissivity. An embedded error checking and correction mechanism provides high memory reliability.
- The sensors are housed in an industry standard TO39.
- The low power consumption during operation and the low current draw during sleep mode make the thermometer ideally suited for handheld mobile applications.
- The digital sensor interface can be either a power-up-and-measure PWM or an enhanced access SMBus compatible protocol. Systems with more than 100 devices can be built with only two signal lines.
- A build-in thermal relay function further extends the easy implementation of wide variety of freezing/boiling prevention and alert systems, as well as thermostats (no MCU is needed).

## 10 Performance Graphs

### 10.1 Temperature accuracy of the MLX90616

All accuracy specifications apply under settled isothermal conditions only.

#### 10.1.1 Ambient temperature accuracy

The factory calibrated **T<sub>ambient</sub>** accuracy is  $\pm 0.5^{\circ}\text{C}$ , 0 to  $50^{\circ}\text{C}$ .  
It is  $\pm 1^{\circ}\text{C}$  outside that range.

#### 10.1.2 Object temperature accuracy, using the internal temperature calculation algorithm

The **T<sub>object</sub>** linearization calculation error is less than  $\pm 0.2^{\circ}\text{C}$  or 0.2% of the measurement value, whichever is bigger.

The **T<sub>object</sub>** accuracy after calibration by the customer can be better than  $\pm 0.5^{\circ}\text{C}$  or 1.5% of measured value, whichever is bigger. This depends on the calibration scheme and care taken during the calibration by the customer. To achieve this result, Melexis recommends the use of specific object temperature calibration points. Other reference temperatures can be used, but the accuracy has to be evaluated in that case.

Please consult Melexis for more information on the calibration procedure of the MLX90616.

#### 10.1.3 Object temperature accuracy, with external calculation

The user has the option to use custom linearization algorithms using the raw IRdata information in the RAM memory.

## 10.2 Sensitivity

The sensitivity of the MLX90616 is 100 LSbits,  $T_{\text{object}} = 80^{\circ}\text{C}$ ,  $T_{\text{ambient}} = 25^{\circ}\text{C}$ .

### 10.3 Noise

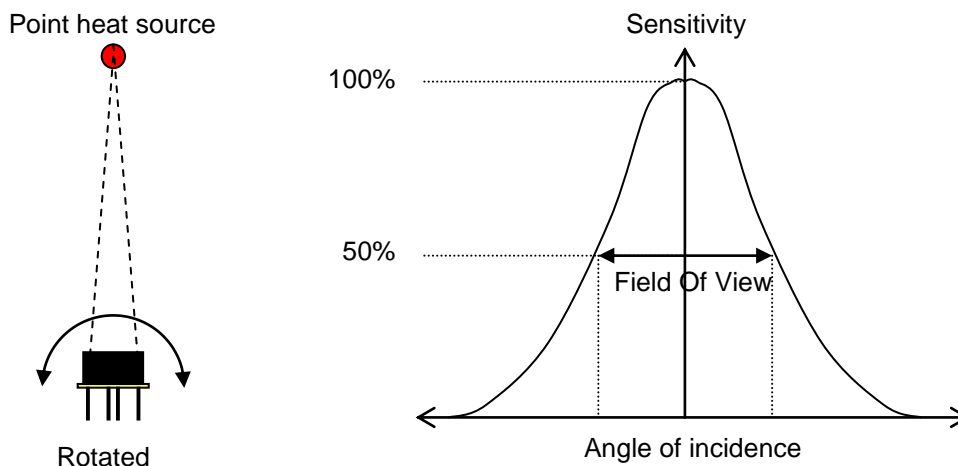
The noise of the MLX90616 is 15bits/ $\sqrt{\text{Hz}}$  peak to peak,  $T_{\text{ambient}} = 25^{\circ}\text{C}$ .

Parameter		Test Conditions	Min	Typ	Max	Units
Ambient temperature accuracy		0 to 50°C	-0.5°C		+0.5°C	
		-40°C < $T_{\text{amb}}$ < 0°C or 50°C < $T_{\text{amb}}$ < 85°C	-1.0°C		+1.0°C	
Object temperature accuracy	Internal calculation error	°C or % of measured value, whichever is greater	-0.2°C, -0.2%		0.2°C, 0.2%	
	Error after calibration with external optics		-0.5°C -1.5%		+0.5°C +1.5%	
Sensitivity		$T_{\text{ambient}} = 25^{\circ}\text{C}$ , $T_{\text{object}} = 80^{\circ}\text{C}$		100		LSBits
Noise		$T_{\text{ambient}} = 25^{\circ}\text{C}$ ,		15		bits/ $\sqrt{\text{Hz}}$

### 10.4 Sensing element size

The size of the sensitive element is  $\square 0.58\text{mm}$ .

### 10.5 Field Of View (FOV) without external optics



**Figure 17: Field Of View measurement**

Parameter	MLX90616xxA
Peak zone 1	$\pm 0^\circ$
Width zone 1	$90^\circ$

Table 12: FOV summary table

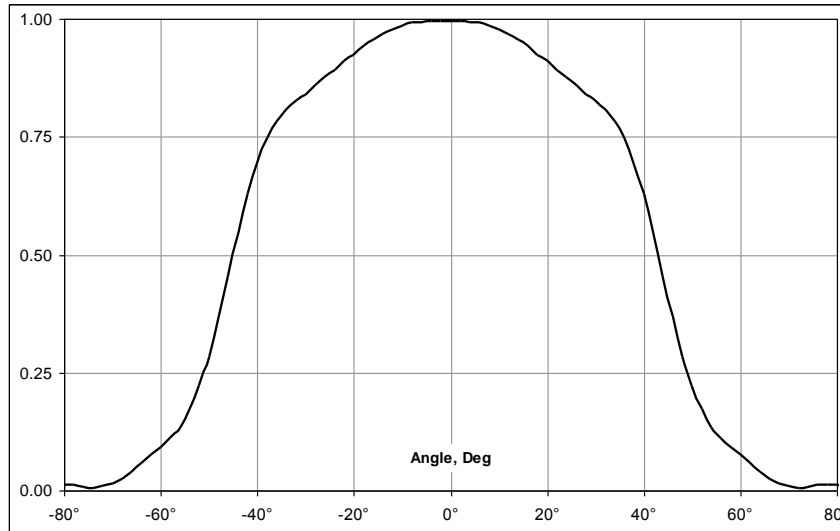


Figure 18: Typical FOV of MLX90616

## 10.6 Spectral Filter

The MLX90616 uses a filter with a transmission region between 8 and 14µm.

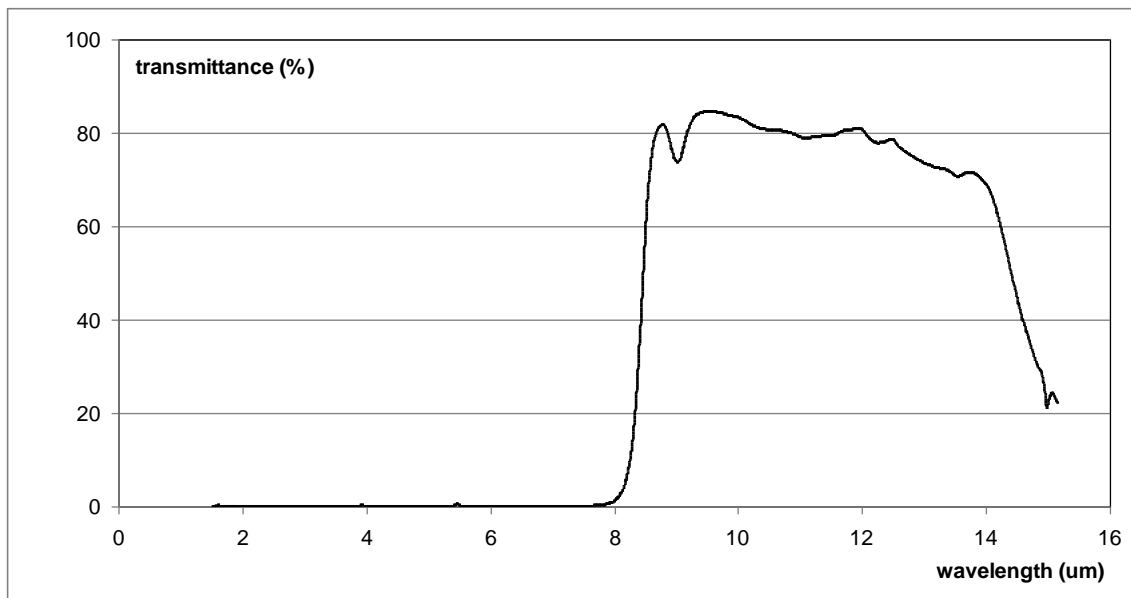


Figure 19: Transmission spectrum of the filter integrated in the MLX90616

## 11 Applications Information

### 11.1 Use of the MLX90616 thermometer in SMBus configuration

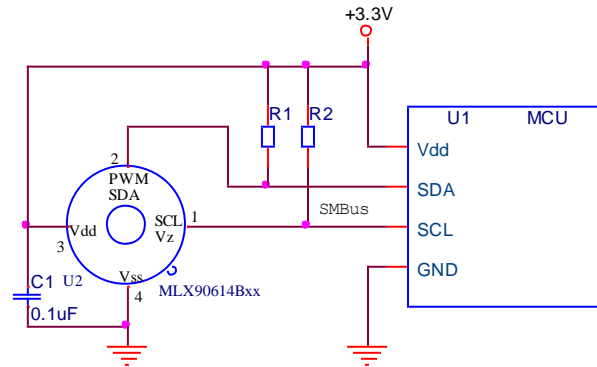


Figure 20: MLX90616 SMBus connection

Figure 20 shows the connection of a MLX90616 to a SMBus with 3.3V power supply. The MLX90616 has diode clamps SDA/SCL to Vdd so it is necessary to provide MLX90616 with power in order not to load the SMBus lines.

### 11.2 Use of multiple MLX90616s in SMBus configuration

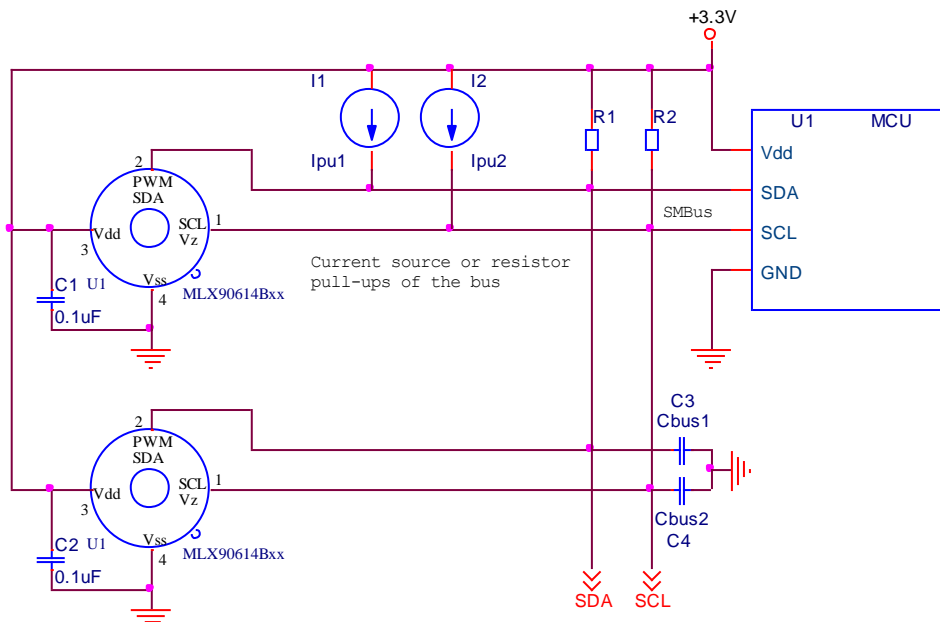
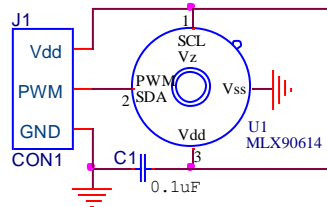


Figure 21: Use of multiple MLX90616 devices in SMBus network

The MLX90616 supports a 7-bit slave address in EEPROM, thus allowing up to 127 devices to be read via two common wires. Current source pull-ups may be preferred with higher capacitive loading on the bus (C3 and C4 represent the lines' parasitics), while simple resistive pull-ups provide the obvious low cost advantage.

### 11.3 PWM output operation

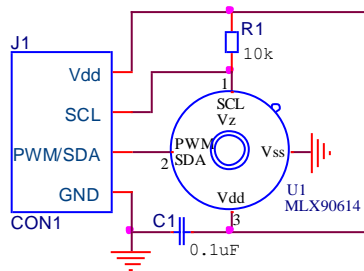
Using the PWM output mode of the MLX90616 is very simple, as shown in Figure 22.



**Figure 22: Connection of MLX90616 for PWM output mode**

The PWM mode is free-running after POR when configured in EEPROM. The SCL pin must be forced high for PWM mode operation (can be shorted to V<sub>DD</sub> pin).

A pull-up resistor can be used to preserve the option for SMBus operation while having PWM as a default as is shown on Figure 23.



**Figure 23: PWM output with SMBus available**

Again, the PWM mode needs to be written as the POR default in EEPROM. Then for PWM operation the SCL line can be high impedance, forced high, or even not connected. The pull-up resistor R1 will ensure there is a high level on the SCL pin and the PWM POR default will be active. SMBus is still available (for example – for further reconfiguration of the MLX90616, or sleep mode power management) as there are pull-up resistors on the SMBus lines anyway.

PWM can be configured as open drain NMOS or a push-pull output. In the case of open drain external pull-up will be needed. This allows cheap level conversion to lower logic high voltage. Internal pull-ups present in many MCUs can also be used.

## 11.4 Thermal alert / thermostat

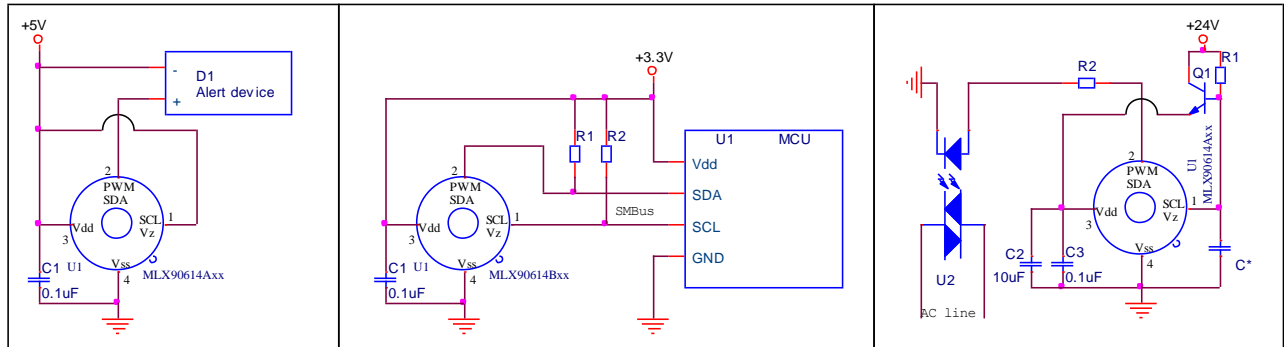


Figure 24: Thermal alert/thermostat applications of MLX90616

The MLX90616 can be configured in EEPROM to operate as a thermal relay. A non contact freezing or boiling prevention with 1 mA quiescent current can be built with two components only – the MLX90616 and a capacitor. The PWM/SDA pin can be programmed as a push-pull or open drain NMOS, which can trigger an external device, such as a relay (refer to electrical specifications for load capability), buzzer, RF transmitter or a LED. This feature allows very simple thermostats to be built without the need of any MCU and zero design overhead required for firmware development. In conjunction with a MCU, this function can operate as a system alert that wakes up the MCU. Both object temperature and sensor die temperature can also be read in this configuration.

## 12 Application Comments

Significant **contamination** at the optical input side (sensor filter) might cause unknown additional filtering/distortion of the optical signal and therefore result in unspecified errors.

IR sensors are inherently susceptible to errors caused by **thermal gradients**. There are physical reasons for these phenomena and, in spite of the careful design of the MLX90616xxx, it is recommended not to subject the MLX90616 to heat transfer and especially transient conditions.

Upon **power-up** the MLX90616 passes embedded checking and calibration routines. During these routines the output is not defined and it is recommended to wait for the specified POR time before reading the module. Very slow power-up may cause the embedded POR circuitry to trigger on inappropriate levels, resulting in unspecified operation and this is not recommended.

The MLX90616xxx is designed and calibrated to operate as a non contact thermometer in **settled conditions**. Using the thermometer in a very different way will result in unknown results.

**Capacitive loading on a SMBus** can degrade the communication. Some improvement is possible with use of current sources compared to resistors in pull-up circuitry. Further improvement is possible with specialized commercially available bus accelerators. With the MLX90616xxx additional improvement is possible by increasing the pull-up current (decreasing the pull-up resistor values). Input levels for SMBus compatible mode have higher overall tolerance than the SMBus specification, but the output low level is rather low even with the high-power SMBus specification for pull-up currents. Another option might be to go for a slower communication (clock speed), as the MLX90616xxx implements Schmitt triggers on its inputs in SMBus compatible mode and is therefore not really sensitive to rise time of the bus (it is more likely the rise time will be an issue than the fall time, as far as the SMBus systems are open drain with pull-up).

For **ESD protection** there are clamp diodes between the Vss and Vdd and each of the other pins. This means that the MLX90616 might draw current from a bus in case the SCL and/or SDA is connected and the Vdd is lower than the bus pull-ups' voltage.

**A sleep mode** is available in the MLX90616Bxx. This mode is entered and exited via the SMBus compatible 2-wire communication. On the other hand, the extended functionality of the SCL pin yields increased leakage current through that pin. As a result, this pin needs to be forced low in sleep mode and the pull-up on the SCL line needs to be disabled in order to keep the overall power drain in sleep mode really small. During sleep mode the sensor will not perform measurements.

The **PWM pin is not designed for direct drive of inductive loads** (such as electro-magnetic relays). Some drivers need to be implemented for higher load, and auxiliary protection might be necessary even for light but inductive loading.

It is possible to use the MLX90616xxx in applications, powered directly from the AC line (transformer less). In such cases it is very important not to forget that **the metal package of the sensor is not isolated** and therefore may become connected to that line and have that electric potential present too. Melexis can not be responsible for any application like this and highly recommends not using the MLX90616xxx in that way.

**Power dissipation** within the package may affect performance in two ways: by heating the "ambient" sensitive element significantly beyond the actual ambient temperature, as well as by causing gradients over the package that will inherently cause thermal gradient over the cap. Loading the outputs also causes increased power dissipation. In case of using the MLX906166xx internal Zener voltage feature, the regulating external transistor should also not cause heating of the TO39 package.

**High capacitive load on a PWM line** will result in significant charging currents from the power supply, bypassing the capacitor and therefore causing EMC, noise, level degradation and power dissipation problems. A simple option is adding a series resistor between the PWM/SDA pin and the capacitive loaded line, in which case timing specifications have to be carefully reviewed. For example, with a PWM output that is set to 1.024 ms and the output format that is 11 bit, the time step is 0.5  $\mu$ s and a settling time of 2  $\mu$ s would introduce a 4 LSB error.

**Power supply decoupling** capacitor is needed as with most integrated circuits. MLX90616 is a mixed-signal device with sensors, small signal analog part, digital part and I/O circuitry. In order to keep the noise low power supply switching noise needs to be decoupled. High noise from external circuitry can also affect noise performance of the device. In many applications a 100nF SMD ceramic capacitor close to the Vdd and Vss pins would be a good choice. It should be noted that not only the trace to the Vdd pin needs to be short, but also the one to the Vss pin. Using MLX90616 with short pins improves the effect of the power supply decoupling.

Severe noise can also be coupled within the package from the SCL (in worst cases also from the SDA) pin. This issue can be solved by using PWM output. Also the PWM output can pass additional filtering (at lower PWM frequency settings). With a simple LPF RC network added also an increase to the ESD rating is possible.

Check [www.melexis.com](http://www.melexis.com) for most recent application notes about MLX90616.



## 13 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:

### Wave Soldering THD's (Through Hole Devices)

- 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 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.

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>

**The MLX90616 is RoHS compliant**

## 14 ESD Precautions

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

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

## 15 FAQ

### When I measure aluminum and plastic parts settled at the same conditions I get significant errors on aluminum. Why?

Different materials have different **emissivity**. A typical value for aluminum (roughly polished) is 0.18 and for plastics values of 0.84...0.95 are typical. IR thermometers use the radiation flux between the sensitive element in the sensor and the object of interest, given by the equation

$$q = \varepsilon_1 \cdot \alpha_1 \cdot (T_1^4) \cdot \sigma \cdot A_1 \cdot F_{a-b} - \varepsilon_2 \cdot (T_2^4) \cdot \sigma \cdot A_2,$$

Where:

$\varepsilon_1$  and  $\varepsilon_2$  are the emissivities of the two objects,

$\alpha_1$  is the absorptivity of the sensor (in this case),

$\sigma$  is the Stefan-Boltzmann constant,

$A_1$  and  $A_2$  are the surface areas involved in the radiation heat transfer,

$F_{a-b}$  is the shape factor,

$T_1$  and  $T_2$  are known temperature of the sensor die (measured with specially integrated and calibrated element) and the object temperature that we need.

Note that these are all in Kelvin, heat exchange knows only physics.

When a body with low emissivity (such as aluminum) is involved in this heat transfer, the portion of the radiation incident to the sensor element that really comes from the object of interest decreases – and the reflected environmental IR emissions take place. (This is all for bodies with zero transparency in the IR band.) The IR thermometer is calibrated to stay within specified accuracy – but it has no way to separate the incoming IR radiation into real object and reflected environmental part. Therefore, measuring objects with low emissivity is a very sophisticated issue and infra-red measurements of such materials are a specialized field. What can be done to solve that problem? Look at paintings – for example, oil paints are likely to have emissivity of 0.85...0.95 – but keep in mind that the stability of the paint emissivity has inevitable impact on measurements.

It is also a good point to keep in mind that not everything that looks black is “black” also for IR. For example, even heavily oxidized aluminum has still emissivity as low as 0.30.

How high is enough? Not an easy question – but, in all cases the closer you need to get to the real object temperature the higher the needed emissivity will be, of course.

With the real life emissivity values the environmental IR comes into play via the reflectivity of the object (the sum of Emissivity, Reflectivity and Absorptivity gives 1.00 for any material). The larger the difference between environmental and object temperature is at given reflectivity (*with an opaque for IR material reflectivity equals 1.00 minus emissivity*) the bigger errors it produces.

### **After I put the MLX90616 in the dashboard I start getting errors larger than specified despite that the module was working properly before that. Why?**

Any object present in the FOV of the module provides IR signal. It is actually possible to introduce error in the measurements if the module is attached to the dashboard with an opening that enters the FOV. In that case the portion of the dashboard opening in the FOV will introduce IR signal in conjunction with constraining the effective FOV and thus compromising specified accuracy. Relevant opening that takes in account the FOV is a must for accurate measurements. Note that the basic FOV specification takes 50% of IR signal as threshold (in order to define the area, where the measurements are relevant), while the entire FOV at lower level is capable of introducing lateral IR signal under many conditions.

### **When a hot (cold) air stream hits my MLX90616 some error adds to the measured temperature I read. What is it?**

IR sensors are inherently sensitive to difference in temperatures between the sensitive element and everything incident to that element. As a matter of fact, this element is not the sensor package, but the sensor die inside. Therefore, a thermal gradient over the sensor package will inevitably result in additional IR flux between the sensor package and the sensor die. This is real optical signal that can not be segregated from the target IR signal and will add errors to the measured temperature.

Thermal gradients with impact of that kind are likely to appear during transient conditions. The sensor used is developed with care for its sensitivity to this kind of lateral phenomena, but the nature of the phenomena demands some care when choosing the place to use the MLX90616 in order to make the effects negligible.

### **I measure human body temperature and I often get measurements that significantly differ from the +37°C I expect.**

IR measurements are true surface temperature measurements. In many applications this means that the actual temperature measured by an IR thermometer will be temperature of the clothing and not the skin temperature. Emissivity (explained first in this section) is another issue with clothes that has to be considered. There is also the simple chance that the measured temperature is accurate – for example, in a cold winter the human hand can appear at temperatures quite different from the well known +37°C.

### **I consider using MLX90616AAA to measure temperature within car compartment, but I am embarrassed about the Sun light that may hit the module. Is it a significant issue?**

Special care is taken to cut off the visible light spectra as well as the NIR (near IR) before it reaches the sensitive sensor die. Even more, the glass (in most cases) is not transparent to the IR radiation used by the MLX90616. Glass has temperature and really high emissivity in most cases – it is “black” for IR of interest. Overall, Sun behind a window is most likely to introduce relatively small errors. Why is it not completely eliminated after all? Even visible light partially absorbed in the filter of the sensor has some heating potential and there is no way to make the sensor chip “blind” for that heating right in front of it.

## 16 Package Information

The MLX90616 is packaged in an industry standard TO – 39 can.

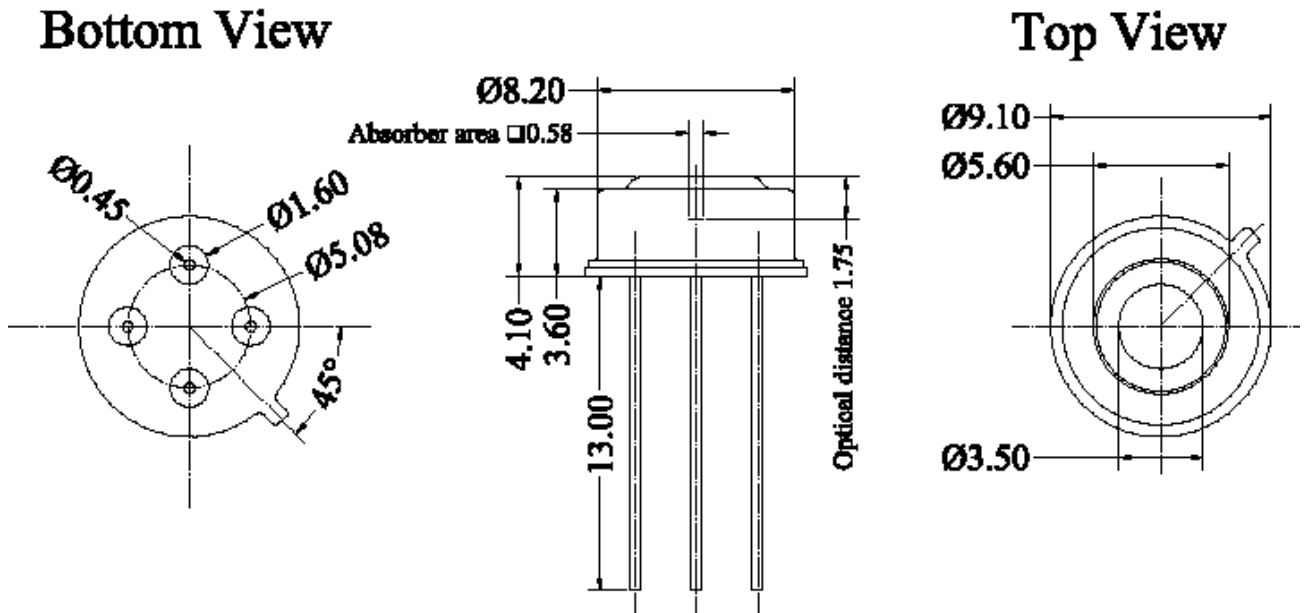


Figure 25: MLX90616 package

Note: All dimensions are in mm

### 16.1 Part marking

The MLX90616 is laser marked with 10 symbols. First 3 letters define device version, and the last 7 are the lot number. Example: "HCA9307308" – MLX90616HCA from lot 9307308.

## 17 References

[1] **System Management Bus (SMBus) Specification** Version 2.0 August 3, 2000  
SBS Implementers Forum Copyright . 1994, 1995, 1998, 2000  
Duracell, Inc., Energizer Power Systems, Inc., Fujitsu, Ltd., Intel Corporation, Linear Technology Inc., Maxim Integrated Products, Mitsubishi Electric Semiconductor Company, PowerSmart, Inc., Toshiba Battery Co. Ltd., Unitrode Corporation, USAR Systems, Inc.

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Europe, Africa, Asia:  
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