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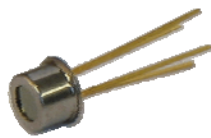
Features and Benefits

- Small size, low cost
- Easy to integrate
- Factory calibrated in wide temperature range:
-40 to 85 °C for sensor temperature and
-40 to 115 °C for object temperature.
- High accuracy of 0.5°C over wide temperature range (0..+50°C for both Ta and To)
- High (medical) accuracy calibration
- Measurement resolution of 0.02°C
- SMBus compatible digital interface
- Power saving mode
- Customizable PWM output for continuous reading
- Embedded emissivity compensation
- 3V supply voltage

Applications Examples

- High precision non-contact temperature measurements;
- Hand-held thermometers
- Ear thermometers
- Home appliances with temperature control;
- Healthcare;
- Livestock monitoring;
- Multiple zone temperature control – up to 100 sensors can be read via common 2 wires

Ordering Information



Part No.
MLX90615

Temperature Code
E (-40°C to 85°C)

Package Code
SG (TO-46)

Accuracy grade
Medical –DAA

Example :
MLX90615ESG-DAA

1 Functional diagram

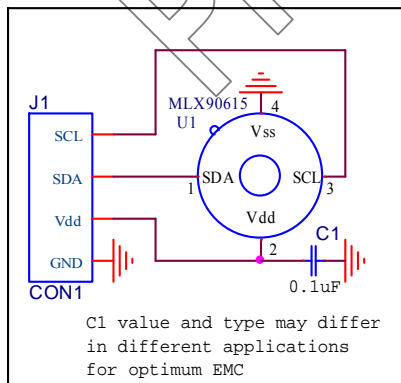


Figure 1 Typical application schematics – MLX90615 connection to SMBus

2 General Description

The MLX90615 is an Infra Red thermometer for non contact temperature measurements. Both the IR sensitive thermopile detector chip and the signal conditioning chip are integrated in the same TO-46 can package.

Thanks to its low noise amplifier, 16-bit ADC and powerful DSP unit, a high accuracy and resolution of the thermometer is achieved.

The thermometer comes factory calibrated with the digital SMBus compatible interface enabled. Readout resolution is 0.02°C.

General description (continued)

The MLX90615 is built from 2 chips, the Infra Red thermopile detector and the signal conditioning chip MLX90325, specially designed by Melexis to process the output of IR sensor. The device is available in an industry standard TO-46 package.

Thanks to the low noise amplifier, high resolution 16-bit ADC and powerful DSP unit of the MLX90325, Melexis is able to deliver a high accuracy and high resolution infrared thermometer. The calculated object and ambient temperatures are available in the RAM memory of the MLX90325 with a resolution of 0.02 °C. The values are accessible by 2 wire serial SMBus compatible protocol with a resolution of 0.02°C or via a 10-bit PWM (Pulse Width Modulated) signal from the device.

The MLX90615 is factory calibrated in standard temperature ranges from: -40 to 85°C for the ambient temperature and from -40 to 115°C for the object temperature.

As a standard, the MLX90615 is delivered with a programmed object emissivity of 1. It can be easily customized by the customer for any other emissivity in the range 0.1-1.0 without the need of recalibration with a black body.

The MLX90615 can be battery powered.

An optical filter (5.5µm to 14µm long-wave pass) that cuts off the visible and near infra-red radiant flux is integrated in the package to make the sensor insensitive to visible light.

PRELIMINARY

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4 Glossary of Terms

PTAT	Proportional To Absolute Temperature sensor (package temperature)
POR	Power On Reset
HFO	High Frequency Oscillator (RC)
DSP	Digital Signal Processing
FIR	Finite Impulse Response. Digital filter
IIR	Infinite Impulse Response. Digital filter
IR	Infra-Red
DC	Direct Current (for settled conditions specifications)
LPF	Low Pass Filter
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
TBD	To Be Defined

5 Maximum ratings

Parameter.	MLX90615
Supply Voltage, V_{DD} (over voltage)	5V
Supply Voltage, V_{DD} (operating)	3.6 V
Reverse Voltage	0.5 V
Operating Temperature Range, T_A	-40...+85°C
Storage Temperature Range, T_S	-40...+125°C
ESD Sensitivity (AEC Q100 002)	2kV
DC sink current, SDA pin	25 mA
DC clamp current, SDA pin	10 mA
DC clamp current, SCL pin	10 mA

Table 1: Absolute maximum ratings for MLX90615

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

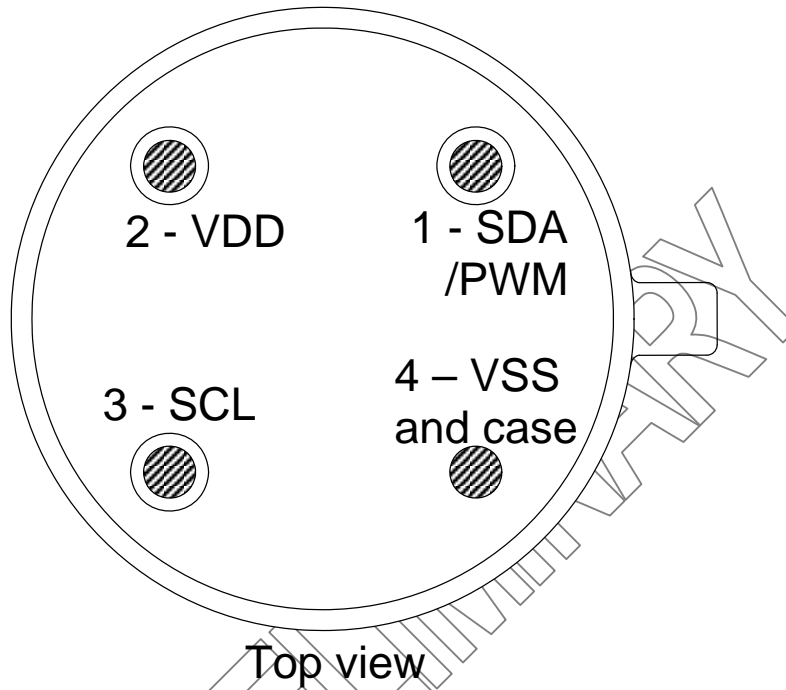


Figure 2: Pin description MLX90615

Pin Name	Function
VSS	Ground. The metal can is also connected to this pin.
SCL	Serial clock input for 2 wire communications protocol. Weak pull-up (300kΩ typ) is present on this pin.
SDA/PWM	Digital input / output open drain NMOS. In SMBus mode (factory default) Serial Data I/O. In PWM mode – PWM output. Weak pull-up (300kΩ typ) is present on this pin.
VDD	External supply voltage.

Table 2: Pin description MLX90615

Notes:

For EMC and isothermal conditions reasons, it is highly recommended not to use any electrical connection to the metal can except by the Vss pin.

The SDA pin is an input Schmidt trigger when the thermometer is operated in the 2-wire SMBus interface mode.

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
Supplies						
External supply	V_{DD}		2.6	3	3.6	V
Supply current	I_{DD}	No load		0.8	1.5	mA
Supply current (programming)	I_{DDpr}	No load, erase/write EEPROM operations		1.5		mA
Power-down supply current	I_{sleep}	No load, SCL and SDA high		1.1	3	μA
Power On Reset						
POR level	V_{POR}	Power-up, power-down and brown-out	0.8	1.5	1.9	V
V_{DD} rise time	T_{POR}	Ensure POR signal			20	ms
Output valid	T_{valid}	After POR		0.5		s
EEPROM						
Data retention		$T_a = +85^\circ\text{C}$	10			years
Erase/write cycles		$T_a = +25^\circ\text{C}$	100,000			Times
Erase/write cycles		$T_a = +85^\circ\text{C}$	40,000			Times
Erase cell time	T_{erase}			5		ms
Write cell time	T_{write}			5		ms
Pulse width modulation						
PWM resolution	PWMres	Data band		10		bit
PWM output period	$PWM_{T,H,def}$	Factory default high frequency PWM, HFO factory calibrated		1.024		ms
PWM output period	$PWM_{T,L}$	Low frequency PWM, HFO factory calibrated		102.4		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-15		+15	%
Output low Level	PWM_{LO}	$I_{sink} = 2\text{ mA}$			0.2	V
Output sink current	$I_{sink_{PWM}}$	$V_{out,L} = 0.5\text{V}$		10		mA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
SMBus compatible 2-wire interface						
Input high voltage	V_{IH}		1.6	2	2.4	V
Input high voltage	$V_{IH}(Ta,V)$	Over temperature and supply	1.2	2	2.8	V
Input low voltage	V_{IL}		0.7	1.0	1.3	V
Input low voltage	$V_{IL}(Ta,V)$	Over temperature and supply	0.5	1.0	1.5	V
Output low voltage	V_{OL}	Over temperature and supply, $I_{sink} = 2mA$			0.2	V
SCL,SDA leakage	I_{leak}	$V_{SCL}=V_{DD}, V_{SDA}=V_{DD}, Ta=+85^{\circ}C$			0.25	μA
SCL capacitance	C_{SCL}				10	pF
SDA capacitance	C_{SDA}				10	pF
Slave address	SA	Factory default		5Bh		hex
SMBus Request	t_{REQ}	SCL low	21		39	ms
Timeout, low	$T_{imeout,L}$	SCL low	27	32	39	ms
Timeout, high	$T_{imeout,H}$	SCL high	52	64	78	μs
Acknowledge setup time	$T_{suac}(MD)$	8-th SCL falling edge, Master		TBD		μs
Acknowledge hold time	$T_{hdac}(MD)$	9-th SCL falling edge, Master		TBD		μs
Acknowledge setup time	$T_{suac}(SD)$	8-th SCL falling edge, Slave		TBD		μs
Acknowledge hold time	$T_{hdac}(SD)$	9-th SCL falling edge, Slave		TBD		μs

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

*SMBus compatible interface is described in details in the SMBus detailed description section. Maximum number of MLX90615 devices on one bus is 127, higher pullup currents are recommended for higher number of devices, faster bus data transfer rates, and increased reactive loading of the bus.

MLX90615 is always a slave device on the bus. MLX90615 can work in both low-power and high-power SMBus communication.

All voltages are with respect to the V_{ss} (ground) unless otherwise noted.

8 Detailed description

8.1 Block diagram

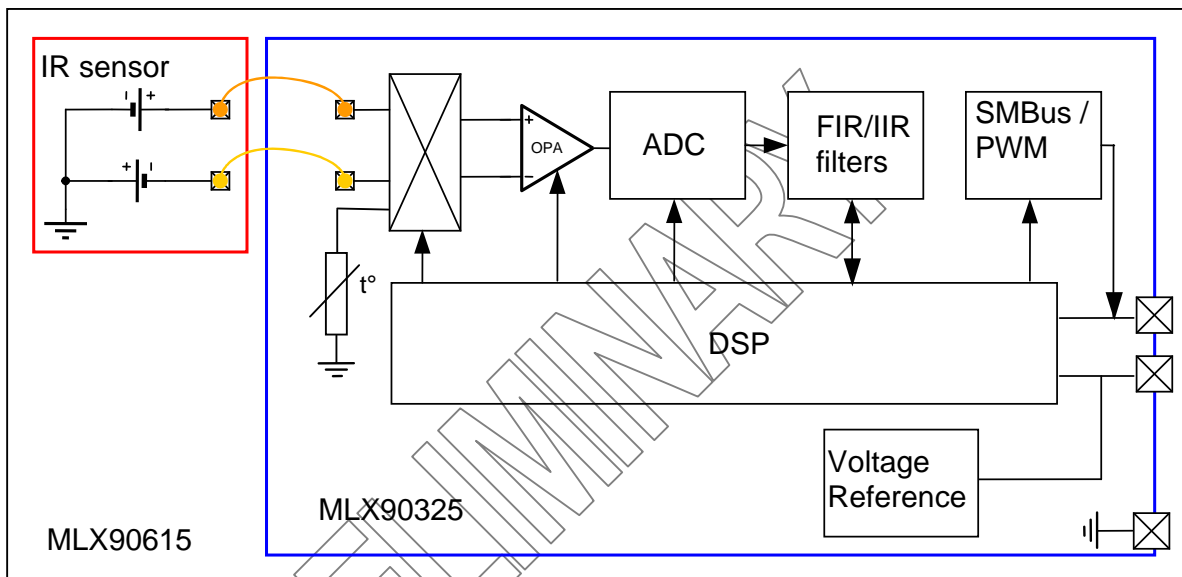


Figure 3: block diagram

8.2 Signal processing principle

A DSP embedded in the MLX90615 controls the measurements, calculates object and ambient temperatures and does the post-processing of the temperatures to output them through SMBus compatible interface or PWM (whichever activated).

The output of the IR sensor is amplified by a low noise, low offset chopper amplifier with programmable gain, then converted by a Sigma Delta modulator to a single bit stream and fed to the DSP for further processing. The signal passes a FIR low pass filter. The output of the FIR filter is the measurement result and is available in the internal RAM. Based on results of the above measurements, the corresponding ambient temperature T_a and object temperatures T_o are calculated. Both calculated temperatures have a resolution of 0.02 °C. An additional IIR LPF is programmable in EEPROM and allows customization of the thermometer output in order to trade-off noise versus measurement speed. The IIR filter can also limit effect of spurious objects that may appear in the FOV in some applications.

The PWM output can be enabled in EEPROM as the POR default. Linearized temperatures (T_o or T_a , selectable in EEPROM) are available through the free-running PWM output.

8.3 Block description

8.3.1 Amplifier

A low noise low offset amplifier with programmable gain is implemented for amplification of the IR sensor voltage. With a carefully designed input modulator and balanced input impedance, an offset as low as 0.5 μ V is achieved.

8.3.2 Power-On-Reset (POR)

The Power On Reset (POR) is connected to the Vdd supply. The on-chip POR circuit provides an active level of the POR signal when the Vdd voltage rises above approximately 0.5V and holds the entire MLX90615 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 a weak open drain (active high) at the SDA pin. After the MLX90615 exits the POR state, the functions programmed in the EEPROM take control of that pin.

8.3.3 EEPROM

A limited number of addresses in the EEPROM memory are of interest for the customer. The whole EEPROM can be read and written with the SMBus interface. The entire EEPROM content between addresses 4h and Dh must be kept unaltered or the factory calibration of the device will be lost.

EEPROM (16X16)		
Name	Address	Write acces
SMBus slave address (SA) / PWM T min	0h	Yes
PWM T range	1h	Yes
Config	2h	Yes
Emissivity	3h	Yes
Melexis reserved (factory calibration)	4h	Yes
...
Melexis reserved (factory calibration)	Dh	Yes
ID number	Eh	No
ID number	Fh	No

SMBus slave address: 7 LSBs (6..0) contains the SMBus slave address that the MLX90615 will respond to. Note that all MLX90615 will respond to SA 00h and therefore this value is useless in a network. Factory default is 5Bh.

PWM T min: 15 bit limit for the PWM signal minimum temperature – right justified (factory default is 355Bh, which corresponds to +0.03°C)

PWM T range: 15 bit range for the PWM signal temperature (Tmax – Tmin) – right justified (factory default is 09C3h, which corresponds to a PWM range +0.03...+50.01°C).

The **Config** register consist of control bits to configure the thermometer at POR:

Bit number	Factory default value	Function
Bit 0	1	SMBus/ PWM mode select 1 – SMBus 0 - PWM
Bit 1	0	PWM frequency (doesn't matter in SMBus mode) 1 - Low 0 - High
Bit 2	0	PWM output temperature 1 - Ta 0 - To
Bit [11:3]	Device specific	Factory calibration do not alter
Bits [14:12]	001b	IIR settings*
Bit [15]	0	Must be kept 0

IIR setting at EEPROM address 02h [binary]	Settling time [samples]	Spike response %
001	1	100
010	10	50
011	18	33.(3)
100	24	25
101	31	20
110	38	16.(6)
111	45	14.286

*Note: IIR setting 000b must be avoided

Emissivity: Contains the value for object emissivity correction. The MLX90615 will compensate for the emissivity of the object measured with respect to that value. The equation for that register is

$$\text{Emissivity} = \text{dec2hex}[\text{round}(16384 \times \epsilon)]$$

,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 $\epsilon = 0 \dots 1$. For details about the emissivity factor in IR measurements refer to the FAQ section of the current document.

Factory default is 4000h, which sets the thermometer to an emissivity of 1.0 (emissivity correction off).

8.3.4 RAM

RAM can be read through SMBus interface. Limited number of RAM registers, summarized below are of interest to the customer.

RAM (16x16)		
Name	Address	Read access
Melexis reserved	0h	Yes
...
Melexis reserved	4h	Yes
Raw IR data	5h	Yes
T _A	6h	Yes
T _O	7h	Yes
Melexis reserved	8h	Yes
...
Melexis reserved	Fh	Yes

T_A is the MLX90615 package (ambient) temperature and T_O is the object temperature. The output scale is 0.02°K/LSB. To convert a read object temperature into degrees Celsius the equation is

$$T_o [^{\circ}\text{C}] = \text{RAM}(7\text{h}) * 0.02 - 273.15.$$

Raw IR data is in sign (1 bit, the MSB) and magnitude (15 bits) format.

8.4 SMBus compatible 2-wire protocol

The chip supports a 2 wires serial protocol, build with pins SDA and SCL.

- SCL – digital input, used as the clock for SMBus compatible communication. A low pulse on that pin with duration t_{REQ} switches to the SMBus mode in case the PWM is selected in EEPROM. In case PWM operation is desired, the SCL pin should be kept high. SMBus is the factory default (via EEPROM settings).
- SDA/PWM – Digital input/ NMOS open drain output, used for both PWM and input/output for the SMBus. (SMBus is factory default function).

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 present at any given time [1]. The MLX90615 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 14 EEPROM cells (at addresses 0..Dh). If the access to the MLX90615 is a read operation, it will respond with 16 data bits and 8 bit PEC only if its own slave address, programmed in the internal EEPROM, is equal to the SA, sent by the master. The SA feature allows connecting up to 127 devices with 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 MLX90615 will always respond and will ignore the internal chip code information.

Note that EEPROM addresses 4h...Dh contain the factory calibration and should not be altered.

Special care must be taken not to put two MLX90615 devices with the same SD addresses on the same bus as MLX90615 does not support ARP[1].

The MD can force the MLX90615 into low consumption mode “sleep mode”.

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

There are eleven command protocols for the standard SMBus interface. The MLX90615 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 SDA pin of the MLX90615 can operate also as a PWM output, depending on the EEPROM settings. If PWM is enabled, after POR the SDA pin is directly configured as a PWM output. The PWM mode can be avoided and the pin can be restored to its Serial Data function by issuing SMBus request condition. If SMBus is the POR default, the request does not have to be sent.

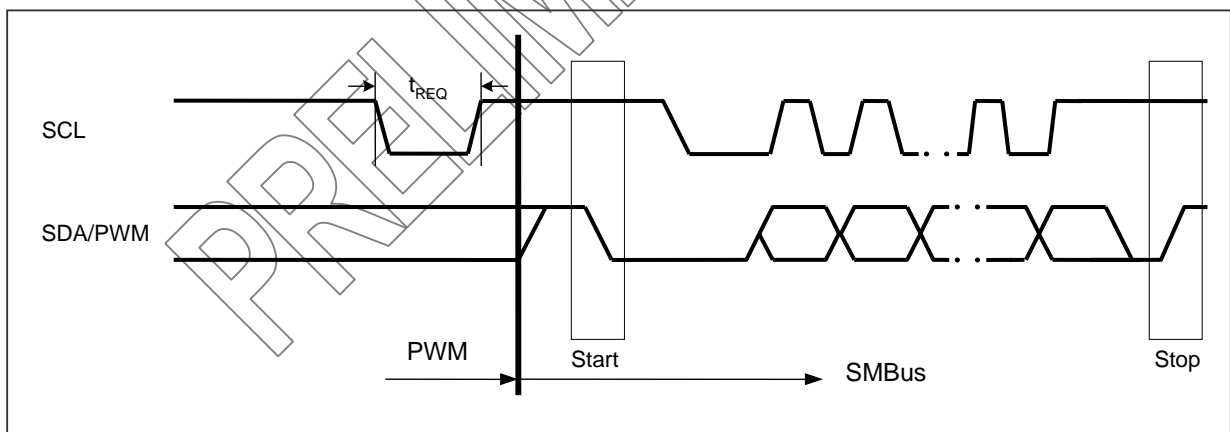


Figure 4: SMBus request, start and stop conditions

All conditions on the SCL and SDA/PWM lines are described in detail below.

8.4.3.1 Bus Protocol

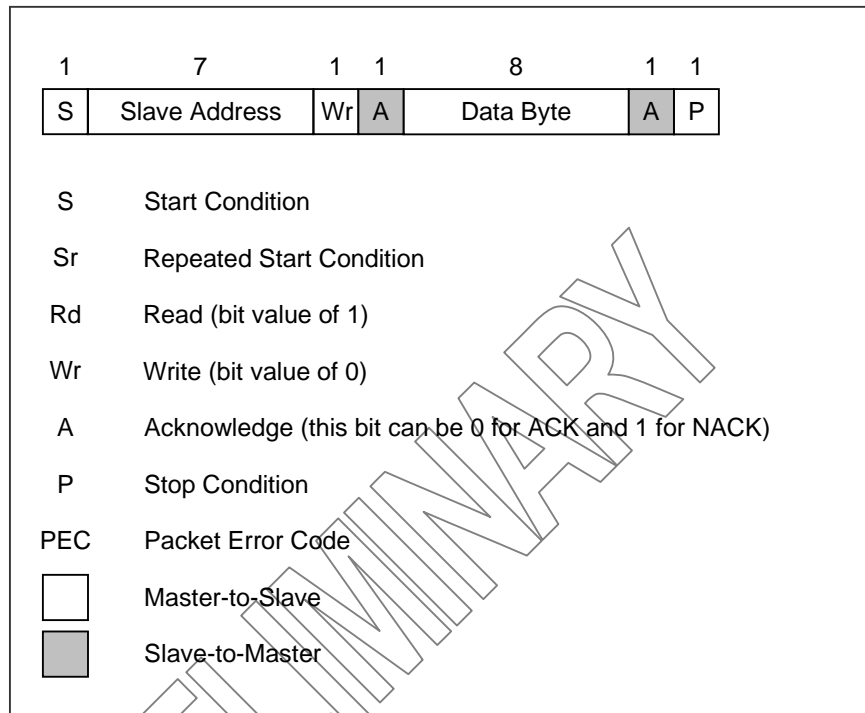


Figure 5: SMBus packet element key

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. If 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 transmitted first.

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

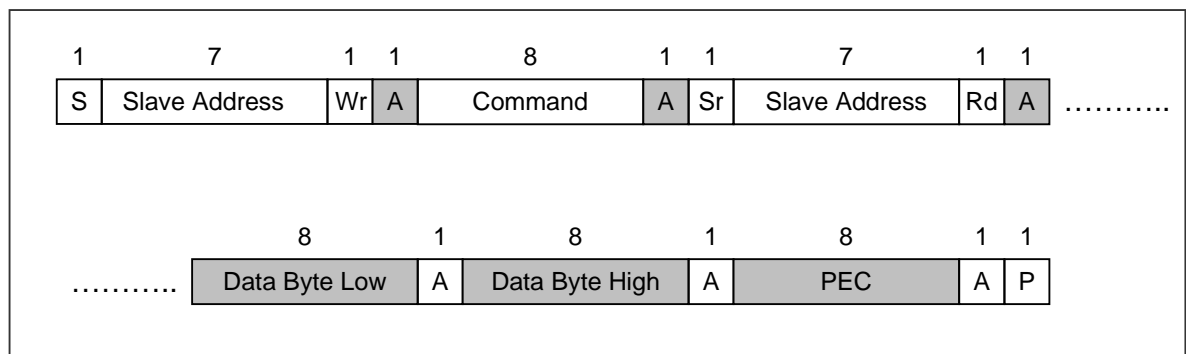


Figure 6: SMBus read word format

8.4.3.1.2 Write Word (EEPROM only)

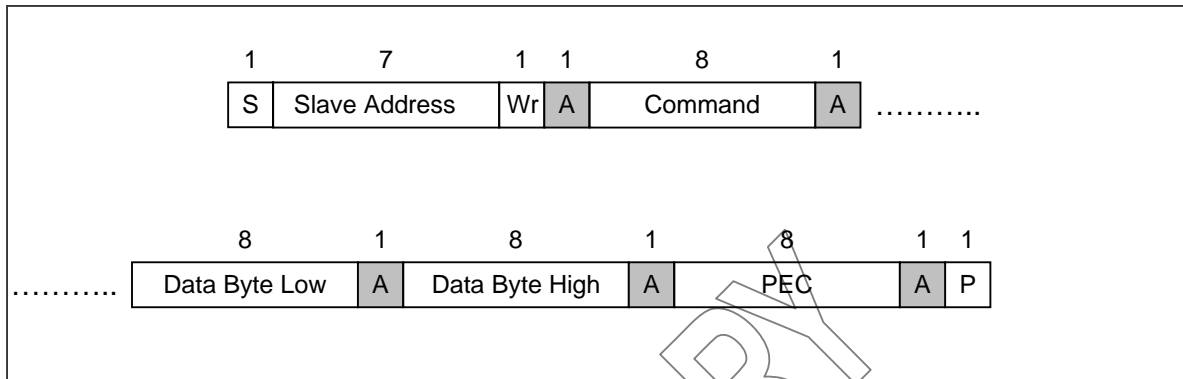


Figure 7: SMBus write word format

Note: Before a write operation takes place, the EEPROM cell needs to be erased. An erase operation is simply a write of 0000h at the same EEPROM address. Care needs to be taken not to alter factory calibration (EEPROM addresses 4...Dh).

8.4.4 AC specification for SMBus

8.4.4.1 Timing

The MLX90615 meets all the timing specifications of the SMBus [1] except the values given in the Electrical specifications section. The maximum frequency of the MLX90615 SMBus clock is 100kHz and the minimum is 10kHz.

The specific timings for the MLX90615's SMBus are:

SMBus Request (t_{REQ}) is the time that the SCL should be forced low in order to switch MLX90615 from thermal relay mode to SMBus mode;

Timeout L is the maximum allowed time for SCL to be low. After this time the MLX90615 will reset its communication block and will be ready for new communication;

Timeout H is the maximum time for which it is allowed for SCL to be high during communication. After this time MLX90615 will reset its communication block assuming that the bus is idle (according to the SMBus specification).

$T_{suac}(SD)$ is the time after the eighth falling edge of SCL during which the MLX90615 will force SDA low to acknowledge the last received byte.

$T_{hdac}(SD)$ is the time after the ninth falling edge of SCL during which the MLX90615 will release the SDA (so the MD can continue with the communication).

$T_{suac}(MD)$ is the time after the eighth falling edge of SCL during which the MLX90615 will release SDA (so that the MD can acknowledge the last received byte).

$T_{hdac}(MD)$ is the time after the ninth falling edge of SCL during which the MLX90615 will take control of the SDA (so it can continue with the next byte to transmit).

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

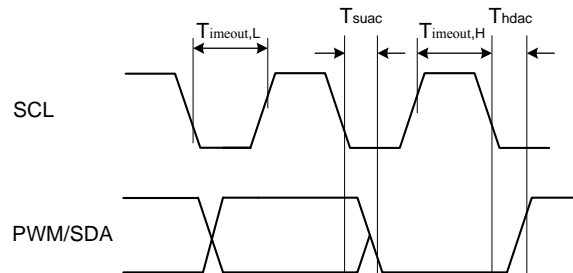


Figure 8: SMBus timing

8.4.5 Bit transfer

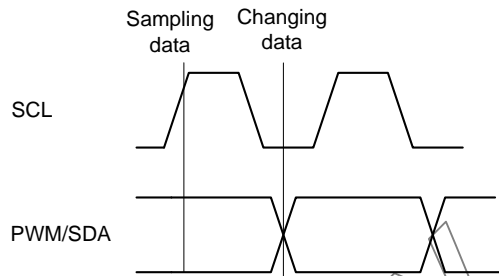


Figure 9: Bit transfer on SMBus

The data on 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.

8.4.6 Commands

In application mode RAM and EEPROM can be read both with 16x16 sizes. (For example, T_{OBJ} - RAM address 0x07h will sweep between 0x2D8Ah to 0x4BD0h as the object temperature rises from -40°C to +115°C). The MSB read from RAM is an error flag (active high) for the linearized temperatures (T_{OBJ} and T_a).

Opcode	Command
0001 aaaa*	EEPROM Access
0010 aaaa*	RAM Access
1100 0110	Enter SLEEP mode

Note*: The aaaa are the 4 LSBits of the memory map address to be read/written.

8.4.7 Sleep Mode

Sleep mode is available in SMBus mode only.

MLX90615 can enter Sleep Mode via command “Enter SLEEP mode” sent via the SMBus interface. MLX90615 goes back into power-up default mode by forcing the SCL pin low for at least t_{DDQ} = 50 ms. Exit from Sleep is always in SMBus mode. Valid data will be available typically 0.3 seconds after the device has woken up.

Note: The previous generation IR thermometer, MLX90614 wakes up through a low pulse on the SDA line, not SCL.

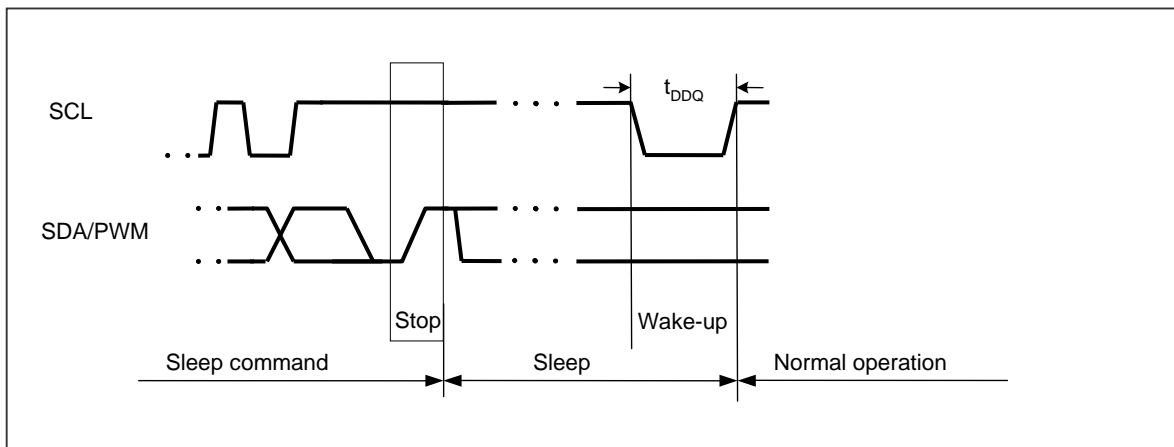


Figure 10: Enter and exit Sleep

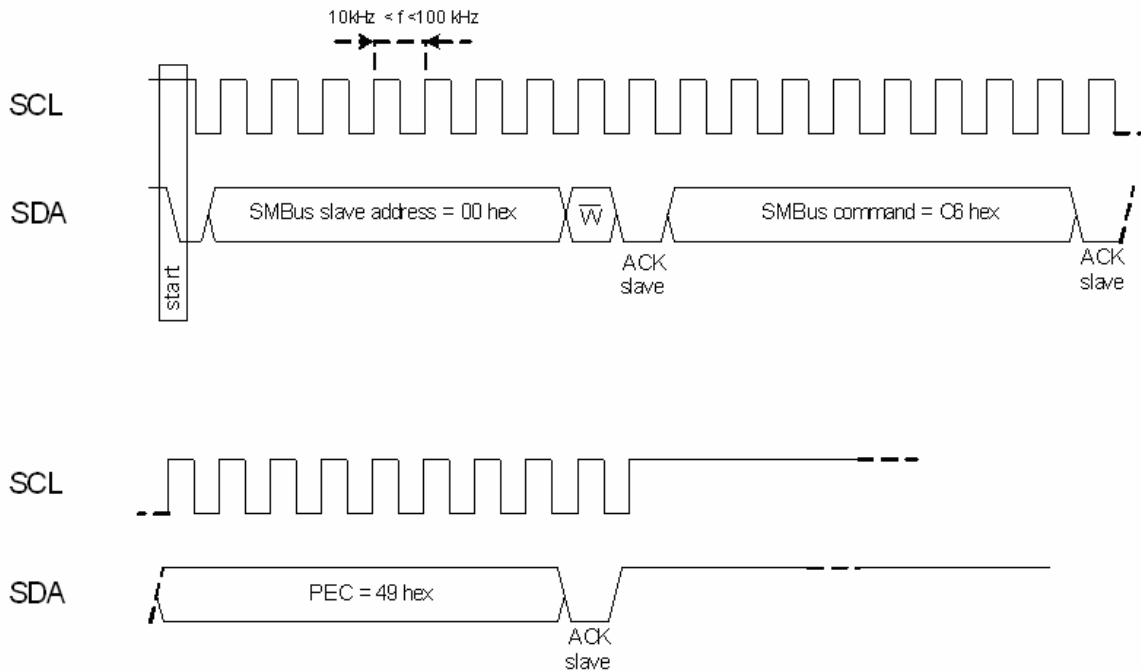


Figure 11: Detailed Sleep command

SCL needs to be high during Sleep. SDA can idle in each state at the same time, but the high state is recommended as the pull-up does not add current drain. There are weak pull-ups on both SCL and SDA pins.

8.5 Switching between PWM and SMBus

8.5.1 PWM is enabled

The diagram below illustrates how to switch to SMBus if PWM is enabled. Note that the SCL pin needs to be kept high in order to use the PWM function. The SCL pin has on-chip a weak pull-up.

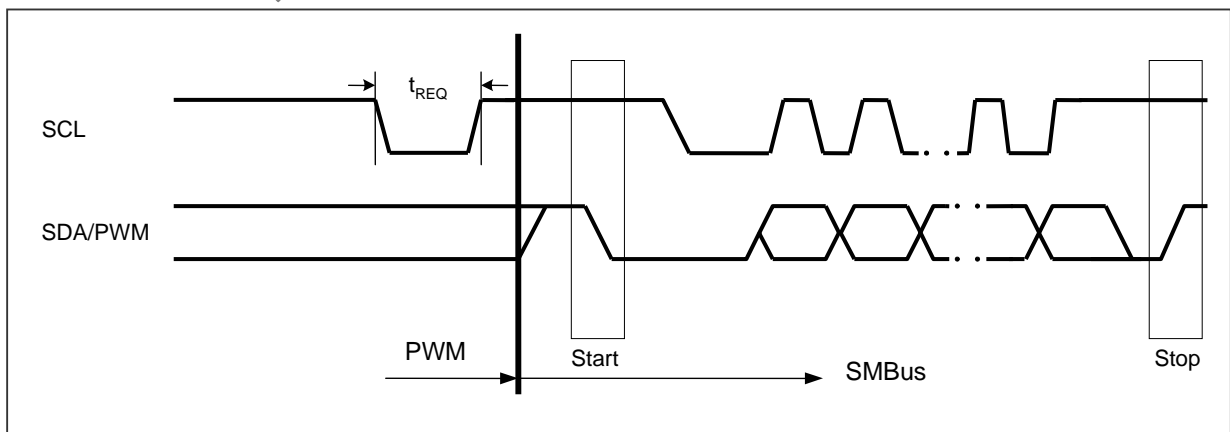


Figure 12: Switching from PWM mode to SMBus

8.5.2 Request condition

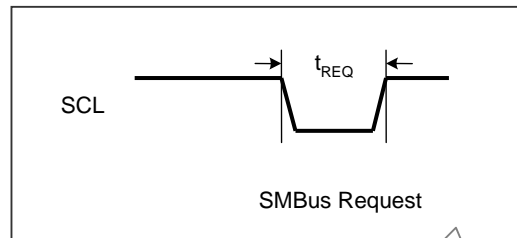


Figure 13: Request (switch to SMBus) condition

If PWM is enabled, the MLX90615's SMBus Request condition is needed to disable PWM and reconfigure SDA/PWM pin before starting SMBus communication. Once disabled, PWM can only be enabled by switching the supply Off-On. The MLX90615's SMBus request condition requires forcing the SCL pin LOW for a period longer than the request time (t_{REQ}). The SDA/PWM line value is ignored in this case.

8.5.3 PWM is disabled

If PWM is disabled by means of EEPROM the SDA/PWM pin is directly used for the SMBus communication after POR.

PRELIMINARY

8.6 PWM

The MLX90615 can be read via PWM or SMBus compatible interface. Selection of PWM output is done in EEPROM configuration (factory default is SMBus). Object or ambient temperature can be read through PWM. The PWM period is derived from the on-chip oscillator and is programmable in a low or high frequency.

Config Register[2:0]	PWM data	PWM frequency
000	To	High
010	To	Low
100	Ta	High
110	Ta	Low
xx1	SMBus, PWM disabled	

Temperature ranges for the PWM output are written in EEPROM 0x0, 0x1 – PWM Tmin and PWM Trange (Tmax-Tmin), scale is 0.02°K/LSB. Note that in SMBus mode the EEPROM 0x0 is used for Slave address SA.

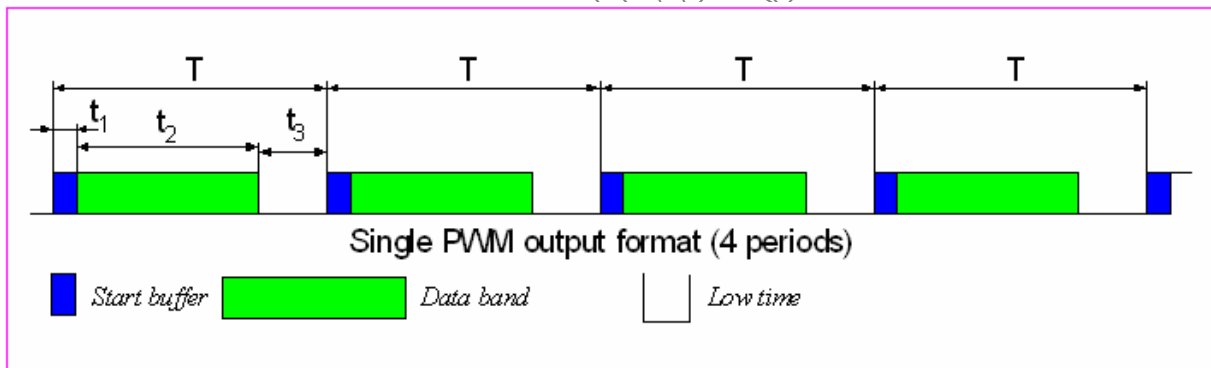


Figure 14: PWM format

8.6.1 PWM format

The temperature reading can be calculated from the signal timing as:

$$T_{out} = \left[\frac{2t_2}{T} * T_{range} \right] + T_{min},$$

where Tmin and Trange are the corresponding rescale coefficients in EEPROM for the selected temperature output and T is the PWM period. Tout is To or Ta according to bit Config Register, 2.

The different time intervals t₁, t₂ and t₃ have the following functions:

t₁: Start buffer. During this time the signal is always high. t₁ = 0.125*T (T is the PWM period, refer to fig. 14).

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

t₃: Low time. The maximum duty cycle is limited to t₁+ t₂ = 0.625 This means that the PWM line will never go static, allowing detection of fault on the line (disconnected device, short on the line).

Example:

To => Config Reg,2 = 0

To_{min} = 0°C

=> PWM T_{min} [EEPROM] = 50 * (to_{min} + 273.15) = 355Bh

To_{max} = To_{min} + T_{range} = +50°C

=> PWM T_{range} [EEPROM] = 50 * (to_{range}) = 09C3h

Captured PWM high duration is 0.495*T => t₂=(0.495 - 0.125)*T=0.370*T =>

measured object temperature = 2X0.370* (50°C -0°C)+0°C = +37.0°C.

8.6.2 Customizing the temperature range for PWM output

The calculated ambient and object temperatures are stored in RAM with a resolution of 0.02 °C (15 bit). The PWM operates with a 10-bit number so the transmitted temperature is rescaled in order to fit in the desired range.

For this goal 2 cells in EEPROM are foreseen to store the desired temperature range, PWM T min and PWM T range.

Thus the output range can be programmed with an accuracy of 0.02 °C.

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

$$T_{PWM} = \frac{T_{RAM} - T_{MIN_{EEPROM}}}{K_{PWM}}, K_{PWM} = \frac{T_{RANGE_{EEPROM}}}{1023}$$

The T_{RAM} is the linearized temperature, 15-bit (2D8A...4BD0h, 2D8A for -40°C and 4BD0h for +115°C) and the result is a 10-bit word, in which 000h corresponds to PWM T_{MIN} [°C], 3FFh corresponds to PWM T_{MAX} [°C]

and 1LSB corresponds to $\frac{T_{MAX} - T_{MIN}}{1023}$ [°C], ($T_{MAX} = T_{MIN} + T_{RANGE}$)

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

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

PRELIMINARY

8.7 Principle of operation

The IR sensor consists of series 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

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

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 additional sensor is needed for 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 PTAT element. All the sensors' conditioning and data processing is handled on-chip and the linearized sensor die temperature T_a is available in RAM. The resolution of the calculated T_a is 0.02 °C. The sensor is factory calibrated for the range -40 to +85 °C. In RAM cell, 6h, 2D89h corresponds to -40 °C and 45F3h corresponds to +85 °C. Conversion RAM content to real T_a is easy:

$$T_a[^\circ K] = T_{areg} \times 0.02$$

8.7.2 Object temperature T_o

The result has a resolution of 0.02 °C and is available in RAM (address 7h). T_o is derived from RAM as:

$$T_o[^\circ K] = T_{oreg} \times 0.02$$

9 Unique Features

The MLX90615 is a ready-to use low-cost non contact thermometer provided by Melexis with output data linearly dependent on the object temperature with high accuracy and extended resolution. The user can program the internal object emissivity correction for objects with a low emissivity. The MLX90615 is housed in standard TO46 package. The low power consumption and sleep mode make the thermometer ideally suited for handheld mobile applications. The digital sensor interface can be either a PWM or an enhanced access SMBus compatible protocol. Systems with more than 100 devices can be built with only two signal lines.

10 Performance Graphs

10.1 Temperature accuracy of the MLX90615

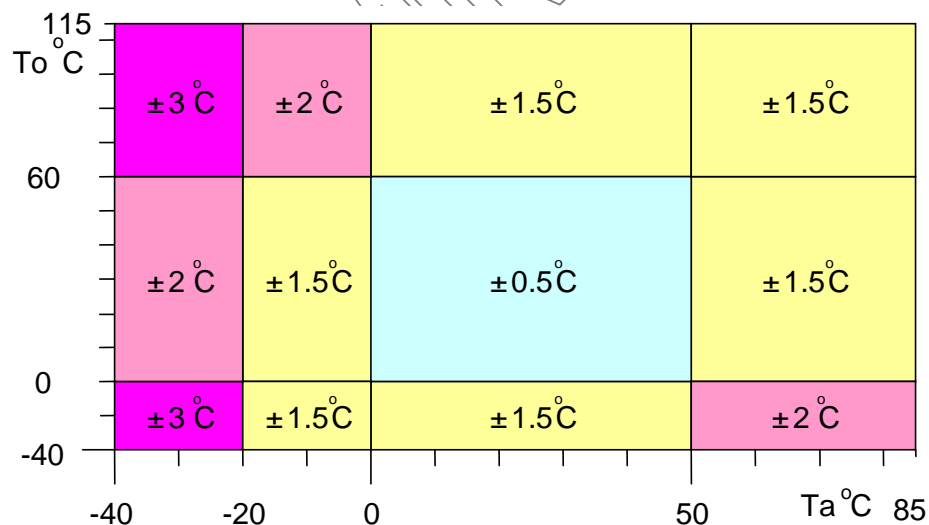


Figure 15: Preliminary accuracy of MLX90615 (Ta, To)

All accuracy specifications apply under settled isothermal conditions only and nominal supply voltage. **The accuracy in the range Ta 10°C - 40°C and To 32°C - 42°C is shown in diagram below. The accuracy for the rest ranges is same as in previous diagram.**

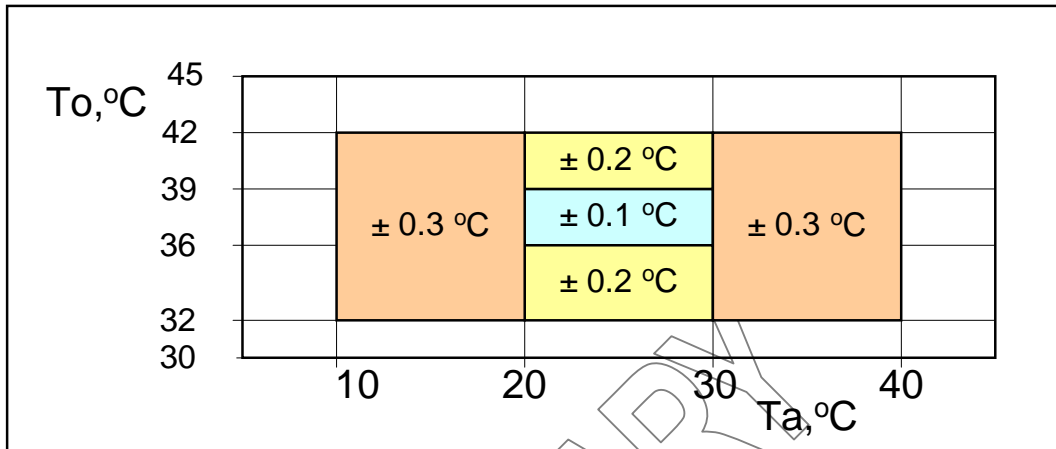


Figure 16: Preliminary accuracy of MLX90615ESG-DAA (Ta, To) for medical applications.

10.2 Field Of View (FOV)

Field of view is determined at 50% thermopile signal and with respect to the sensor main axis.

Parameter	MLX90615
Peak direction	$\pm 0^\circ$
FOV width	100°

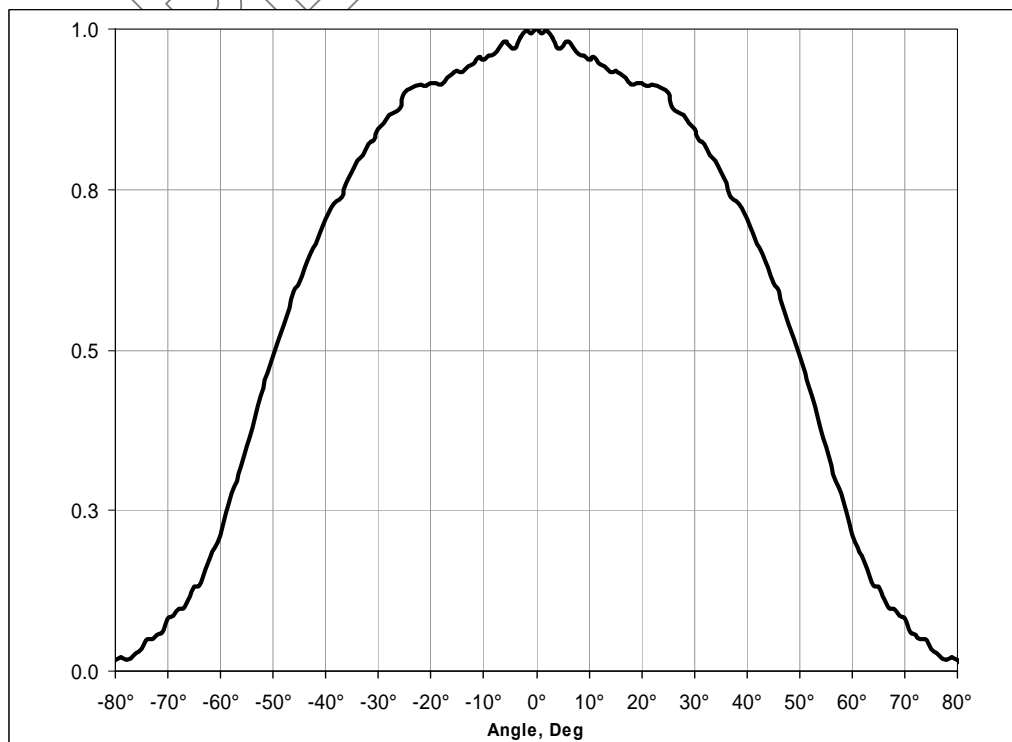


Figure 17: FOV of MLX90615

11 Applications Information

11.1 Use of the MLX90615 thermometer in SMBus configuration

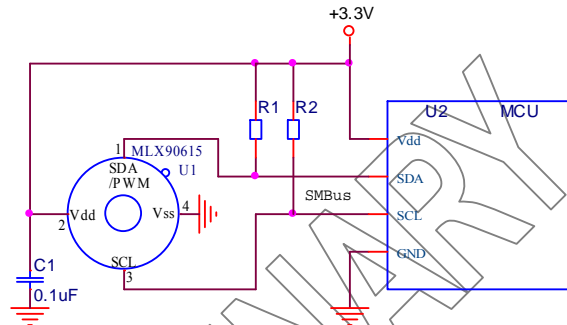


Figure 18: Connection of MLX90615 to SMBus.

MLX90615 has diode clamps SDA/SCL to Vdd so it is necessary to provide MLX90615 with power in order not to load the SMBus lines.

11.2 Use of multiple MLX90615s in SMBus configuration

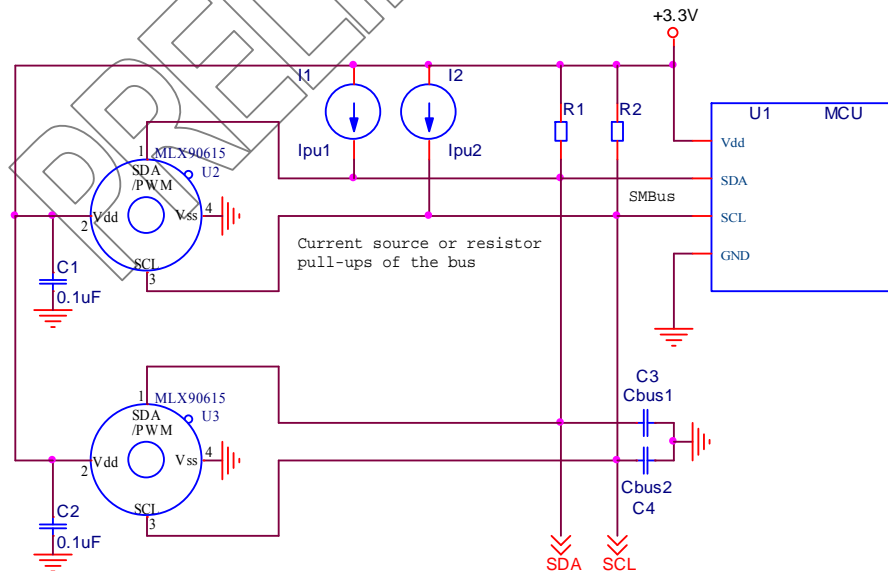


Figure 19: Use of multiple MLX90615 devices in SMBus network

The MLX90615 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

With PWM output configuration MLX90615 can be read via single wire. Output is open drain NMOS (with a weak pull-up, 300 k Ω typ). Therefore external pull-up is required for high level state on the line with longer wires. Simple level shifting is possible with a single resistor. ESD protective clamp on the SDA pin consists of 4 diodes to Vdd, thus allowing high level to go up to 5V disregarding the MLX90615 supply voltage value.

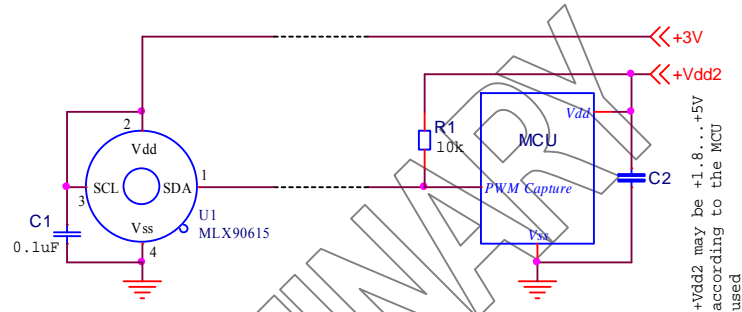


Figure 20: Using MLX90615 PWM output

In EEPROM two PWM periods can be programmed – 102.4 or 1 ms (typ). With remote installation (wires) PWM is recommended as more robust to EMI than the SMBus and the high PWM period would be also preferred. As a factory default, once PWM is enabled, output will cover 0...50°C object temperature range (as 12.5 ... 62.5% duty cycle) at 1kHz frequency.

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 that phenomena and, in spite of the careful design of the MLX90615, it is recommended not to subject the MLX90615 to heat transfer and especially transient conditions.

Upon **power-up** the MLX90615 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 trigger on inappropriate levels, resulting in unspecified operation and is not recommended.

The MLX90615 is designed and calibrated to operate as a non contact thermometer in **settled conditions**. Using the module in 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 MLX90615 additional improvement is possible with 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 MLX90615 implements Schmidt triggers on it's inputs in SMBus compatible mode and is therefore not really sensitive to rise time of the bus (it is more likely the rise time to 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 MLX90615 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.

It is possible to use the MLX90615 in applications, powered directly from the AC line (trasformerless). In such cases it is very important not to forget that **the metal package of the sensor is not isolated** and therefore may occur to be connected to that line, too. Melexis can not be responsible for any application like this and highly recommends not to use the MLX90615 in that way.

Check www.melexis.com for most current application notes about MLX90615.

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:

Reflow Soldering SMD's (Surface Mount Device)s

- 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 Device)s and THD's (Through Hole Device)s

- 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 Device)s

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

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

- 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 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.asp>

The MLX90615 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 aluminium and plastic parts settled at the same conditions I get significant errors on aluminium. Why?

Different materials have different **emissivity**. A typical value for aluminium (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

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

where

ε_1 and ε_2 are the emissivities of the two objects,

α_1 is the absorptivity of the sensor (in this case),

σ 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 aluminium) 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 is a specialised 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 aluminium 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 MLX90615 in the dashboard I start getting errors larger than specified in spite 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 portion of the dashboard opening 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 MLX90615 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 about sensitivity to this kind of lateral phenomena, but their nature demands some care when choosing place to use the MLX90615 in order to make them 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 adequate – for example, in a cold winter human hand can appear at temperatures not too close to the well known +37°C.

I consider using MLX90615 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 MLX90615. 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 that the sensor die will be “blind” for that heating right in front of it.

16 Package Information

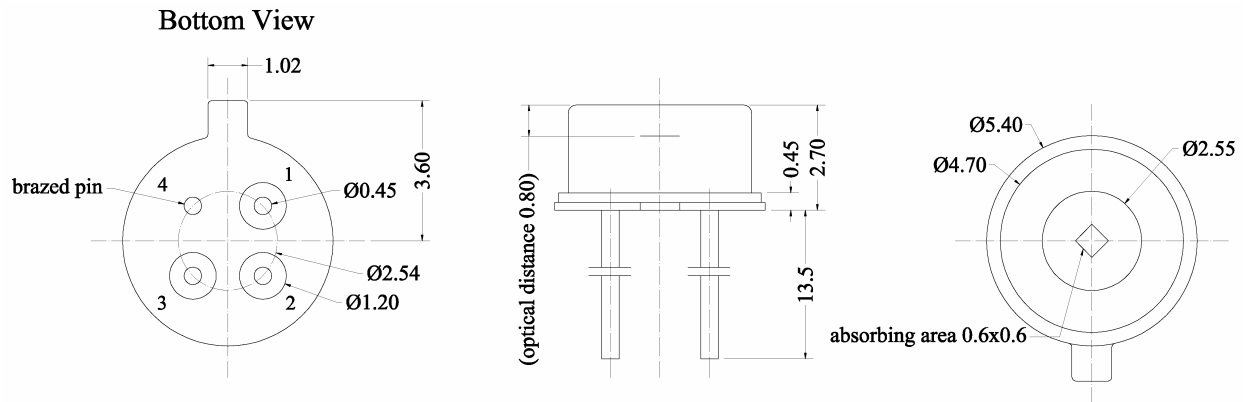


Figure 21: MLX90615 package drawing

PRELIMINARY

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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Revisions Table

Version	Changes	Remark	Date
001		Preliminary Release	Not on doc-server
002	Updates – Sleep mode, packaging, EEPROM	Update	04-Apr-2008
003	Updates – FOV, package, EEPROM, specification, watermark Regenerated as revision 0 for official release Text clarifications, added IRData RAM address, changed Vdd range, added Idd,max, remade package drawing.	Update	25-Apr-2008 24-Jun-2008 21-Jul-2008

PRELIMINARY