MLX90601 family

IR thermometer modules

Features and benefits

- Contact-less temperature measurement based on infrared emission by the object;
- Measurement of absolute object temperature over broad object and ambient temperature ranges (see table below);
- Guaranteed absolute object temperature accuracy better than 1°C within specified ambient and object temperature ranges.
- Factory calibration;
- Linearised output;
- Selectable output: analog, digital (SPI) or Pulse Width Modulation (PWM);
- Open drain relay driver output driven by comparator circuit;
- Rigid PCB or flex;
- Automotive protection circuit available on rigid PCB versions;
- EEPROM Error Correction Circuit (ECC) based on Hamming code.

For projects requiring increased accuracy, customer specific temperature ranges, etc., please contact your Melexis sales person.

Ordering Information

Part No	Suffix						
	T_a	Package	Type	Description	Object calibration range	Ambient calibration range	Circuit board
MLX90601	E	ZA	BAA	FOV = 85° - Analog Output	-20°C to +120°C	0°C to 50°C	Rigid
MLX90601	E	ZA	DAA	FOV = 85° - PWM Output	-20°C to +120°C	0°C to 50°C	Rigid
MLX90601	E	ZA	CAA	FOV = 85° - PWM Output + SPI	-20°C to +120°C	0°C to 50°C	Rigid
MLX90601	K	ZA	BKA	FOV = 85° - Analog Output + SPI	-20°C to +120°C	-20°C to 85°C	Flex
MLX90601	K	ZA	CKA	FOV = 85° - PWM Output + SPI	-20°C to +120°C	-20°C to 85°C	Flex
MLX90601	K	ZA	CKD	FOV = 85° - PWM Output + SPI	-40°C to +120°C	-40°C to 125°C	Flex
MLX90601	K	ZA	CLA	FOV = 40° - PWM Output + SPI	-40°C to +150°C	-40°C to 125°C	Flex

Notes:

T_a ambient operating temperature range:

- MLX90601EZA-XXX: -40°C / +85°C
- MLX90601KZA-XXX: -40°C / +125°C

Applications

- Automotive climate control
- Residential/office/industrial climate control
- Medical and bio-instrumentation (contamination avoided through contact-less measurement)
- Industrial process control
- Consumer applications requiring temperature control, such as microwave ovens, toasters, …
- Detection of occupancy or movement

1 Description

The MLX90601 Family modules are versatile IR thermometer modules, which perform signal conditioning, linearization and ambient temperature compensation.

The modules are built around the MLX90313 IR sensor interface, which uses high performance chopper stabilized amplifiers, providing excellent noise performance. Accurate compensation for variations in ambient temperature is based on digital signal processing using the calibration data stored in the on-chip EEPROM. Object and ambient temperature outputs are digitally generated and are perfectly linear over the temperature range.

The sensing element is the MLX90247 discrete IR thermopile sensor. The sensor housing contains a thermopile for measurement of the object temperature, and a thermistor for measurement of the ambient temperature.

The modules are delivered factory calibrated. The output signals are always digitally generated, but can be made available under different forms: analog voltage; PWM coded digital; or digital over bi-directional serial SPI.
All modules feature the 90313 comparator output (open drain relay driver).

Several types of modules are available:

- Modules for automotive applications:

- EZA-BAA (analog voltage output)
- EZA-DAA (digital PWM coded output)
- Rigid FR4 PCB
- 5-pin through-hole connector
- ESD protection circuitry on the PCB

- Modules for industrial or consumer application:

- Always provided with an SPI interface for full programmability
- EZA-CAA: Rigid FR4 PCB with 10-pole connector, PWM output
- KZA-BKA: Flex PCB with analog output
- KZA-CKA: Flex PCB with PWM output
- KZA-CKD: idem as CKA, but with extended calibration temperature range
- KZA-CLA: idem as CKA, but with reduced field of view and even further extended temperature range as CKD.

The modules of type KZA are built on a flexible polyamide substrate, facilitating the mechanical integration.

CONTENTS

2 *Glossary*

ADC: Analog to Digital Converter

Ambient Temperature: the temperature of the IR sensor.

Ambient Compensation: The IR signal captured by a thermopile sensor is not only dependent on the temperature of the object (Tobject) but also on the temperature of the sensor itself. Therefore the IR signal is compensated for this effect by means of the measured sensor temperature (Tambient). This rather complex calculation is performed in the linearisation unit of MLX90313.

ANSI: American National Standards Institute

Chopper Amplifier: Special amplifier configuration aimed at ultra low offset.

DAC: Digital to Analog Converter.

EEPROM: Non-volatile memory that can be electrically erased and rewritten. This type of memory is used to store configuration and calibration data for the module.

ECC: Error Checking and Correction. The EEPROM on board of MLX90313 is equipped with a checking and correction feature based on the Hamming Code method.

Emissivity: The ratio of power radiated by a substance to the power radiated by a blackbody at the same temperature (ANSI definition).

ESD: Electrostatic Discharge

FOV: Field Of View = full opening angle under which the object is viewed by the detector

FR4: Epoxy glass-fiber laminate, Fire Retardant grade 4.

IR: Infrared. Every object emits infrared radiation in relation to its temperature. This effect can be used to measure this temperature without the need for physical contact.

Linearisation: The signal from a thermopile is not linear with the object temperature. MLX90313 is therefore equipped with a digital calculation unit that produces an output that is linear with the object temperature.

LPF: Low Pass Filter of the MLX90313

LSB: Least Significant Bit

MISO: Master In, Slave Out (= SPI-terminology)

MOSI: Master Out, Slave In (= SPI-terminology)

MSB: Most Significant Bit

NETD: Noise Equivalent Temperature Difference

Object (or target): The object the IR module is aimed at.

PCB: Printed Circuit Board

POR: Power-on reset: Reset circuit that starts the digital system in a known state whenever the supply voltage is cycled

PSRR: Power Supply Rejection Ratio: Measure for an amplifier's immunity to disturbances on the supply connections.

PWM: Pulse Width Modulation coding

PTC: See Thermistor

Reflectance: The ratio of reflected power to incident power, generally expressed in dB or percent (ANSI definition).

rms: Root Mean Square

SPI: Serial Peripheral Interface

Ta, Tambient: The temperature of the IR sensor.

Target: or Object: The object the IR module is aimed at.

Thermistor: Temperature dependant resistor. Basically there are 2 types. The types that increase their resistance with rising temperature are PTC (positive thermal coefficient) type. The ones that decrease their resistance with rising temperature we call NTC (negative thermal coefficient) type. The MLX90313 can work with both types. The MLX90601 modules are equipped with sensors that use PTCs.

To, Tobject: The temperature of the object one wishes to measure with the module

3 MLX90601 Electrical Specifications

Electrical specifications are given for V_{DD} = 4.75V to 5.25V.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Supply Voltage and consumption						
Supply voltage range	VDD		4.75	5	6	V
Power consumption	IDD	Ta=25°C		5	5.6	mA
POR threshold voltage	Vpor		1.1	1.3	1.5	V
IR- and TEMP-chain: amplifier and output driver characteristics						
Power supply rejection ratio	PSRR	f ≤ 100kHz	75			dB
Input referred white noise[1]	Vnir	rms-value			25	nV/√Hz
Input referred white noise[2]	Vntemp	rms-value			400	nV/√Hz
Output voltage range		IROUT, TEMPOUT	0		Vdd-0.2	V
Output source current	Iod	IROUT, TEMPOUT	1			mA
Output sink current	Ios	IROUT, TEMPOUT	20			μA
DC Output impedance, drive[3]	rod	IROUT, TEMPOUT			10	Ω
DC Output impedance, sink[4]	ros	IROUT, TEMPOUT			100	Ω
Rel1 open drain relay driver						
Relay driver current					15	mA
Output impedance	Ro			10		Ω
High voltage protections			32		40	V
PWM						
PWM Clock period	Tclk		45	50	55	μs
PWM Total period	T		92.16	102.4	112.64	ms
Leading buffer time	t1	% of T		12.5		%
Trailing buffer time	t5	% of T		12.5		%
Duty cycle high	t2	% of T	0		50	%
Duty cycle low	t3	% of T	0		50	%
Error signal	t4	% of T		25		%
Rise time[5]		10% to 90% of Vh	13.3		100	μs
Fall time[5]		90% to 10% of Vh	13.3		100	μs
Output voltage high	Vh	Ihigh=2mA	4			V
Output voltage low	Vl	Ilow=2mA			1	V

[1] Amplifier-generated noise referred to amplifier input. Does not take into account the noise generated by the thermopile.
[2] Amplifier-generated noise referred to amplifier input. Does not take into account the noise generated by the thermistor.
[3] Output impedance of driver stage of 90313 ASIC. Does not take into account discrete resistors placed on the module circuit board: see functional diagrams in paragraph 5.
[4] Output impedance of driver stage of 90313 ASIC. Does not take into account discrete resistors placed on the module circuit board: see functional diagrams in paragraph 5.
[5] Without external loading.

4 General Description

4.1 Theory of operation

The MLX90601 modules are developed especially to make IR temperature sensing easy. All modules have a linearised output signal. Also they are factory calibrated, so making all modules interchangeable. Also this relieves customers from complex calibration procedures.

All modules have a MLX90247 thermopile sensor as IR sensing element. The output of this sensor is a function of both Object (IR) and ambient temperature. Ideally the output voltage of the thermopile sensor is:

$$Vir = \alpha(To^4 - Ta^4) \qquad [1]$$

Where To is Object temperature in Kelvin, and Ta is the ambient temperature in Kelvin. Alpha is a device constant. It is clear from above equation that the ambient temperature must be known before the object temperature can be calculated. Therefore the MLX90247 thermopile sensor has a thermistor built-in. Melexis has designed a powerful ASIC to perform the signal processing of the thermopile output voltage.
MLX90313 amplifies the signals coming from MLX90247 and converts them to digital by means of two high performance, low noise, chopper stabilized amplifiers and the 12-bit analog to digital converter. The digital unit on the interface then performs the ambient compensation of the IR signal. This results in two temperature signals, one representing the temperature of the object the IR sensor is pointed at (Tobject) and one representing the temperature of the sensor (Tambient). Both signals are then linearised and presented at the outputs in analog of PWM coded form. When using modules that have also SPI, the temperature registers can be read directly through the serial interface.

The linearisation unit can only operate when both Ta (ambient temperature) and To (object temperature) are in a distinct calibrated range. This has an important implication for the ambient temperature.
When the modules are used outside the calibrated ambient temperature, the object temperature is calculated using a false ambient temperature, resulting in an erroneous output signal. If the ambient temperature is below the ambient calibration range, the OVL flag in the SPI register is set and the temperature data bits are all zero. For analog output modules, the output will be zero volts. Alternatively, if the ambient temperature is above the ambient calibration range, the OVH flag in the SPI register is set and the temperature data bits are all one. For analog output modules, the output will be 4.5 volts.
When returning into calibrated ambient temperature range, the module will resume normal operation.

Our standard products have such ranges that they can suit a maximum number of applications. Currently four combinations of ambient and object temperature range are offered.

4.2 Accuracy

IMPORTANT REMARKS:

- *The measurement accuracy indicated in this paragraph can only be realized if the MLX90601 modules are correctly operated. Please read carefully through the important guidelines in paragraph 4.2.3 before starting a design with the MLX90601.*
- *The accuracies given by the formula in paragraph 4.2.1 and the table in paragraph 4.2.2 are only valid for factory calibrated modules and for objects with emissivity of 99.2% (see remark on emissivity in paragraph 4.2.3).*

4.2.1 Accuracy of object temperature

The error Toerr on the object temperature is a function of both object and ambient temperature. It is given by the formula:

Toerr = Taerr + 1.5% * ABS(To - Ta)

where Taerr is:

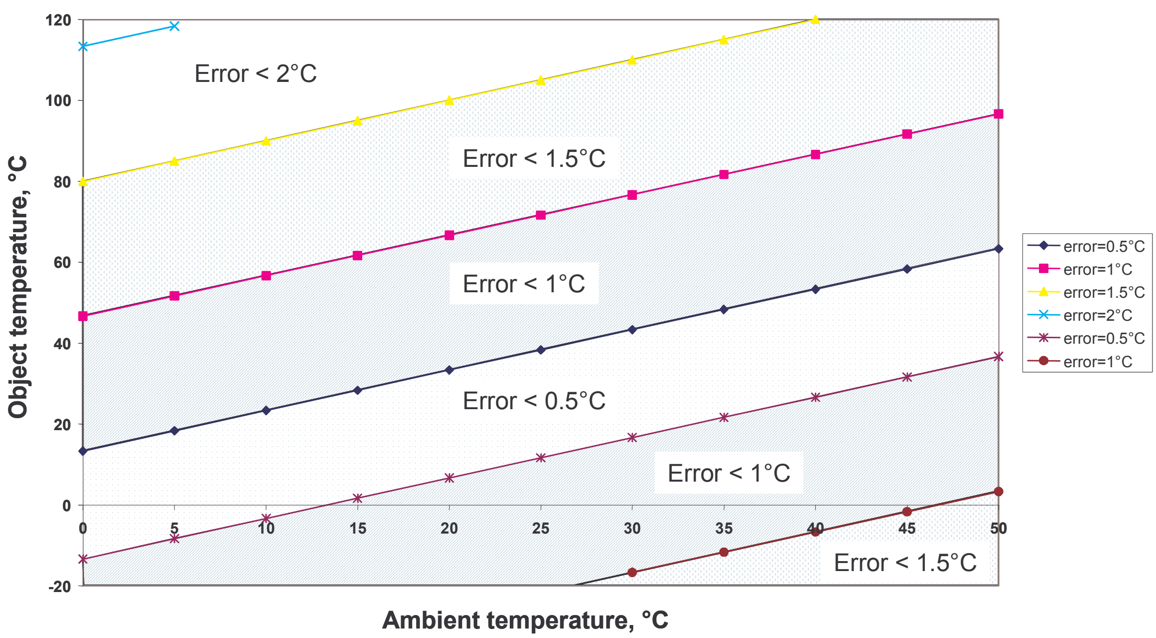
0.3 °C for Ta within the range [0°C,50°C]
1 °C for Ta < 0°C
1 °C for Ta > 50°C

To = object temperature
Ta = ambient temperature
ABS = absolute value

If To is the real object temperature, the measured value will be in the interval [To-Toerr, To+Toerr].

Graphical representation of the error for the range:
Ta : [0°C, 50°C]
To: [-20°C, 120°C]

MLX90601EZA: Error on object temperature measurement



The formula is valid for factory-calibrated modules and for objects with an emissivity of 99.2% (see remark in paragraph 4.2.3.2).

For modules of type KZA, which have an extended calibration range, refer to the details per module.

4.2.2 Accuracy of ambient temperature

Measurements are only possible if Tambient is within the ambient calibration range. See the table in paragraph 1 for an overview of the ambient calibration ranges per type of module.

Tambient	Accuracy of Tambient, °C
< 0°C	1
0°C to 50 °C	0.3
> 50°C	1

4.2.3 Guidelines for optimal measurement accuracy

4.2.3.1 Isothermal conditions

The MLX90601 thermometers are calibrated under isothermal conditions: during the object calibration, all points of the sensor package are at the same temperature within narrow tolerances. The accuracy numbers mentioned in paragraph 4.2.1 are valid if the thermometer module is used under similar isothermal conditions. In many practical situations, the isothermal conditions form no problem: as the sensor package is made of thermally conductive nickel, quite strong external thermal gradients need to be applied to result in temperature gradients over the sensor package that are strong enough to create a measurement error.
Nevertheless, Melexis strongly advises to keep the sensor away from local heat-sources / cooling equipment, in order to avoid the presence of strong thermal gradients, and to have optimal measurement accuracy within the error margins indicated in paragraph 4.2.1.
The error due to a thermal gradient will have a positive sign if the front of the sensor is at higher temperature than the temperature of the thermopile die; it will have a negative sign if the front of the sensor is at a lower temperature than the temperature of the thermopile die.

4.2.3.2 Emissivity of the measured object

Each material is characterized by a certain emissivity, which is the ratio of power radiated by a substance to the power radiated by a (perfect) blackbody at the same temperature.

The emissivity equals the absorption by the surface: a perfect emitter (a perfect black body) is also a perfect absorber. If the emissivity is lower than 1, the absorption also becomes lower than 1, and part of the radiation incident on the object is reflected. As such, the infrared radiation coming from an object with emissivity lower than 1 is a mix of radiation emitted by the object, and radiation reflected by the object.

Materials like human skin, clothes, glass,… typically have an emissivity above 90%. It is easy to measure their temperature using infrared thermometers, as >90% of the radiation coming from these surfaces is emitted by them, and is a measure of their own temperature.

Polished metals have a very low emissivity. For example, cleaned and polished silver has been reported to have an emissivity as low as 2 to 3%. When pointing the infrared thermometer at cleaned and polished silver, only 2 to 3% of the radiation is emitted by the silver, while 97 to 98% of the radiation comes from objects that are reflected by the silver surface. In that case, the temperature of the environment will have a very important influence on the result of the measurement, in particular when the environment is at the same or higher temperature than the object. If the object is at much higher temperature than the environment, the 2% emitted radiation might be stronger than the 98% reflected radiation, which reduces the impact of the environment, and simplifies the measurement.

Melexis makes calibration and final test with a 99.2% emissivity black body that is traceable to NIST (National Institute of Standards). As the calibration is done with a black body of emissivity = 99.2%, the accuracy predicted by the formula in paragraph 4.2.1 will be obtained when measuring objects with the same emissivity of 99.2%.

The following applies when using the MLX90601 to measure objects of emissivity ε lower than 99.2%:

- the MLX90601 module measures a temperature that is a weighted average of the temperature of the object and the temperature of the environment that is reflected by the object. The higher the emissivity of the object, the higher the weight of the object in the measurement.
- If the environment is at a higher temperature than the object, the measured object temperature will be higher than the real object temperature.
- If the environment is at a lower temperature than the object, the measured object temperature will be lower than the real object temperature.

In some cases, a trick can be applied to measure the temperature of a low-emissivity object. For example, the temperature of a polished metal surface can be measured if locally a layer of paint can be applied on the surface. The painted part of the surface will show a high emissivity, and will allow accurate temperature measurement through infrared.

4.2.3.3 Direct sunlight

The measurement of the temperature of a glass surface is a special case. Glass is non-transparent to long-wavelength infrared radiation; at room temperature, smooth glass is reported to have an emissivity in the order of 95%. So, by pointing the MLX90601 to a glass surface, it is perfectly possible to measure the temperature of the surface. As glass is non-transparent to long-wavelength infrared, the temperature of objects behind the glass will have no impact on the measurement (as far as they do not heat the glass).
One special case occurs when measuring the temperature of a glass surface with the sensor looking straight in the sun: see figure 1.

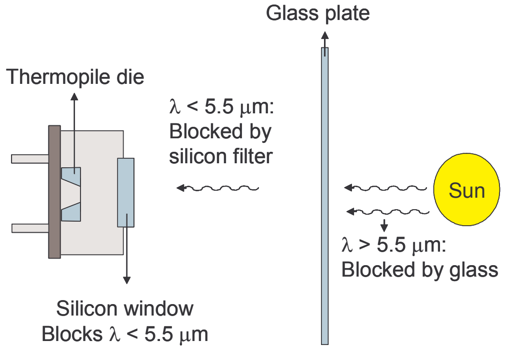


Figure 1: measurement of temperature of glass plate

In an ideal world, the direct incidence of the sun on the sensor should not affect the readings of the MLX90601, as the long wavelengths emitted by the sunlight are blocked by the glass, and the short wavelengths are blocked by the long-wavelength pass filter in the silicon window. In reality, the filtering is not perfect, and some energy passes, causing readout errors up to +1°C.
Melexis advises to avoid direct incidence of the sun on the sensor in case of measurement of the temperature of glass plates.

4.2.3.4 Window cleanliness

If the sensor window is contaminated with a material that is not transparent to long wavelength infrared radiation, the sensor will measure a weighted average of the temperature of the contamination (that has a temperature very close to the ambient temperature of the sensor itself), and the temperature of the object. Before this effect becomes noticeable, the window is already visibly dirty. It can then be cleaned using isopropyl alcohol and a clean lint free cloth.

For correct object temperature measurements, the window should also be kept dry. Water is non-transparent to long wavelength infrared. So, if there is water condensation on the window, the sensor will measure a weighted average of the temperature of the condensation and the temperature of the object.

4.2.3.5 Remark on scratches on the window

Scratch tests were done on the optical window according to MIL-C-48497A. The window was not damaged by this test. Furthermore a test was done on sensors by scratching the window using a pencil eraser and a paper clip metal wire. Only the wire resulted in scratches with a limited effect on the sensor performance.

4.2.3.6 Touching of the cap of the sensor

Touching of the cap of the sensor has to be avoided. As a result of touching, the temperature of part of the cap changes, which results in a change of the infrared radiation level on the thermopile die. The thermopile voltage output changes, which results in errors on the measurement of the object temperature.

The MLX90601 modules are calibrated under isothermal conditions (i.e. all parts of the module are at the same temperature within narrow tolerances). To make measurements with optimal accuracy, the module should be operated also under isothermal conditions. Touching the sensor results in thermal gradients and in a strong deviation of isothermal conditions.

Characteristics of the output

Object and ambient temperature measurements can be made available through following outputs:

Type of output	Resolution
Analog	8 bit
PWM	10 bit
Digital SPI	12 bit

As the analog and PWM outputs use the same physical output pins, they cannot be activated simultaneously, and only following combinations of outputs are available:

- Analog
- PWM
- Analog + Digital SPI
- PWM + Digital SPI

Next to the object and ambient temperature outputs, all modules have a relay driver output (open drain).

The next paragraphs describe the details of each of the outputs.

4.2.4 Analog output

The object temperature information is available as a voltage between the IROUT and VSS pins. The ambient temperature information is available as a voltage between the TEMPOUT and VSS pins. The output voltages are the result of a D/A conversion after digital signal processing for ambient temperature compensation and linearization based on the calibration data. The resolution of the output D/A converter is 8 bit. The output drivers have a maximum output voltage of 4.5V when the maximum calibrated temperature is reached.

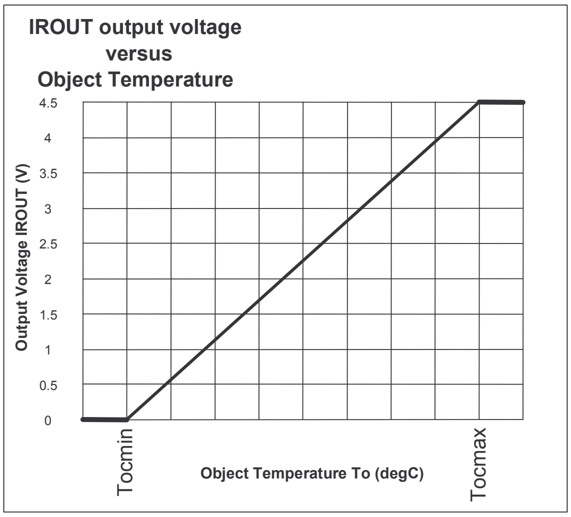
The relation of the output voltage to the temperature is defined as follows:

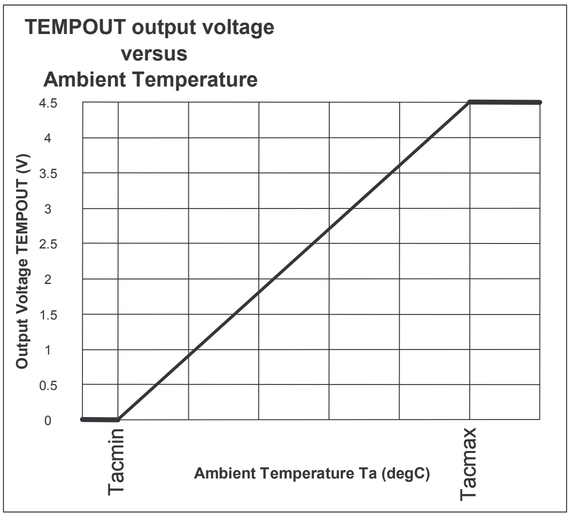
$$T = \frac{Vout}{4.5} * (Tmax - Tmin) + Tmin$$

where:
T measured temperature (object or ambient temperature)
Vout analog output voltage on IROUT (object) or TEMPOUT (ambient) pins.
Tmin minimum calibrated temperature (object or ambient)
Tmax maximum calibrated temperature (object or ambient)

Refer to module details for calibrated object/ambient temperature ranges of each type of module.

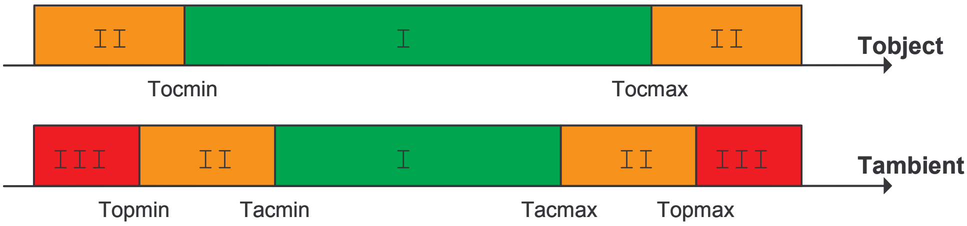
A graphical representation is depicted below.





Where:
Tocmin = minimum calibrated object temperature
Tocmax = maximum calibrated object temperature
Tacmin = minimum calibrated ambient temperature
Tacmax = maximum calibrated ambient temperature

The behavior of the module outside the calibrated ranges is shown below:



Topmin = lower limit of operating temperature range
Topmax = upper limit of operating temperature range

Module operating conditions

T object in range	T ambient in range	Effect on outputs
I	I	Object temperature output is working normal Ambient temperature output is working normal
II	I	Object temperature output will be clamped to 0V (To < Tocmin) or clamped to 4.5V (To > Tocmax). Ambient temperature output is working normal
I or II	II	BOTH temperature outputs will be clamped to 0V (Ta < Tacmin) or clamped to 4.5V (Ta > Tacmax).
I or II	III	The module may be damaged if operated outside the ambient operating temperature range. BOTH temperature outputs will be clamped 0V (Ta < TacminC) or clamped at 4.5V (Ta>TacmaxC).

4.2.5 PWM output

The object temperature information is available at the IROUT pin. The ambient temperature information is available on the TEMPOUT pin. The resolution of the Pulse Width Modulated output is 10 bits.

The relation of the output voltage to the temperature is defined as follows:

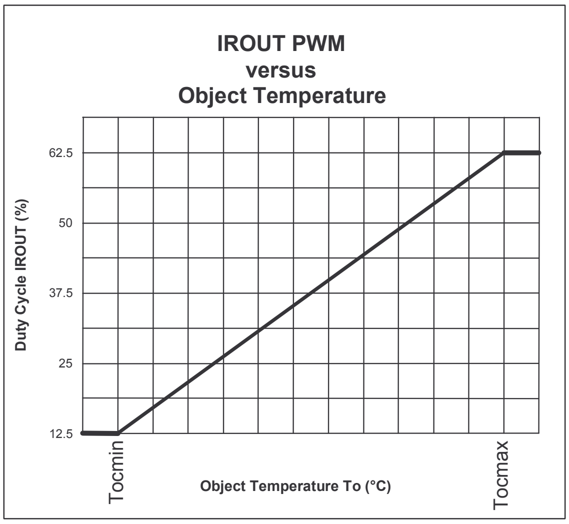
$$T = \frac{DutyCycle - 12.5\%}{50\%} * (Tmax - Tmin) + Tmin$$

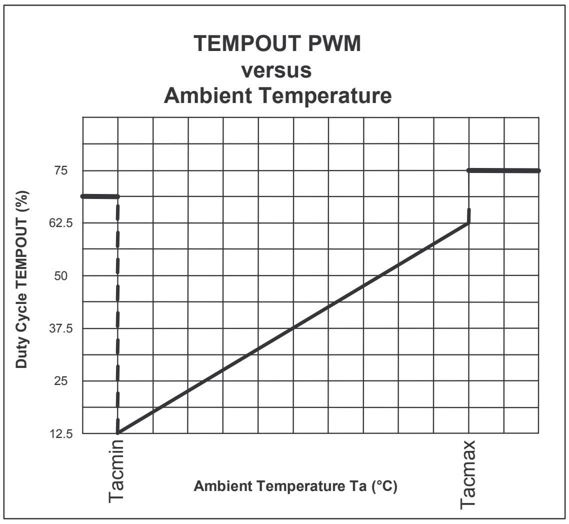
where:

T	measured temperature (object or ambient)
DutyCycle	Duty Cycle of the IROUT or TEMPOUT PWM signals.
Tmin	minimal calibrated temperature (object or ambient)
Tmax	maximum calibrated temperature (object or ambient)

Refer to module details for calibrated ranges info

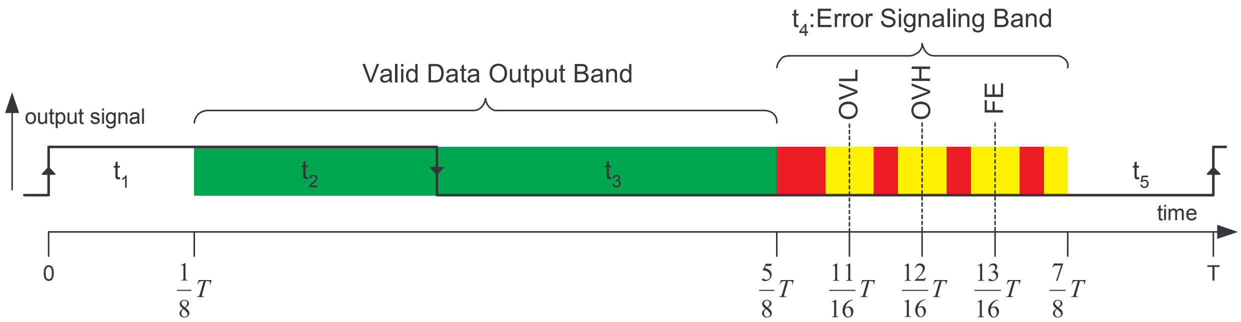
A graphical representation of the PWM signal duty cycle as a function of temperature is depicted below.





Where:
Tocmin = minimum calibrated object temperature
Tocmax = maximum calibrated object temperature
Tacmin = minimum calibrated ambient temperature
Tacmax = maximum calibrated ambient temperature

The next figure shows the full PWM coding format:



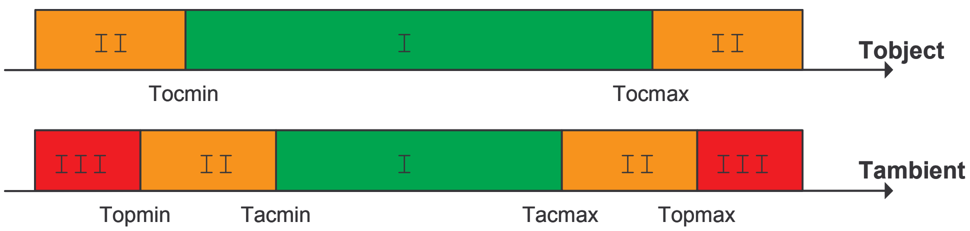
The PWM signal has a period of 102.4ms typical consisting of 2048 clock cycles of 50µs. Every frame starts with a leading buffer time, t_1, during which the signal is always high, as shown in the figure. The leading buffer time is followed by a slot for the useful data signal starting at 1/8T ending at 5/8T, where the ratio t2/(t2+t3) is the representation of the output value.

The slot t4 allows flagging of special conditions:

- OVL: Ambient temperature underflow
- OVH: Ambient temperature overflow
- FE: Fatal Error EEPROM: The module has an on-board ECC (Error Check and Correction, based on a Hamming-code). ECC can detect errors and can correct single-bit errors in the stored calibration constants and settings. In case of multiple bit errors, automatic correction is not possible, and the output will flag Fatal Error EEPROM.

If the ambient temperature is out of the calibrated temperature range, both PWM signals will flag this condition, and the object and ambient temperatures will not be available until the ambient temperature is back in the calibrated temperature range.

The behavior of the module outside the calibrated ranges is shown below:



Topmin = lower limit of operating temperature range
Topmax = upper limit of operating temperature range

Module operating conditions

T object in range	T ambient in range	Effect on outputs
I	I	Object temperature output is working normal Ambient temperature output is working normal
II	I	Object temperature output duty cycle will be 12.5% if To < Tocmin, or 62.5% if To > Tocmax. Ambient temperature output is working normal
I or II	II	BOTH temperature outputs duty cycle will be 68.75% if Ta < Tacmin (OVL), or 75% if Ta > Tacmax (OVH).

I or II	III	The module may be damaged if operated outside the ambient temperature range. BOTH temperature outputs duty cycle will be 68.75% if Ta < Tacmin (OVL), or 75% if Ta > Tacmax (OVH).

The next table summarizes the PWM duty cycle:

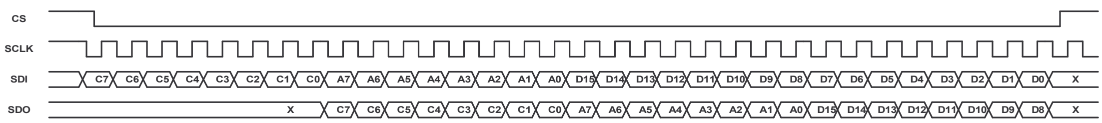
PWM duty cycle overview

Condition	Duty cycle	nominal timing
Normal operation	12.5% - 62.5%	12.8 ms - 64 ms
OVL: Tambient underflow	68.75 %	70.4 ms
OVH: Tambient overflow	75 %	76.8 ms
FE: Fatal Error EEPROM	81.25%	83.2 ms

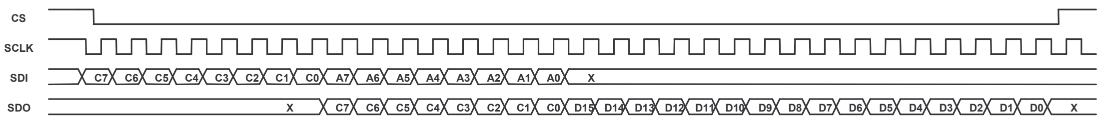
4.2.6 Digital SPI output

Protocol

The digital interface implemented in MLX90313C is SPI-compatible[1]. It can be used to access the on-chip EEPROM and all internal registers. The chip will always work as a slave device. The format of any command is always 32 bits: 8 bits for the operation code, 8 bits for the address and 16 bits of data. The communication protocol is presented below.



write command



read command

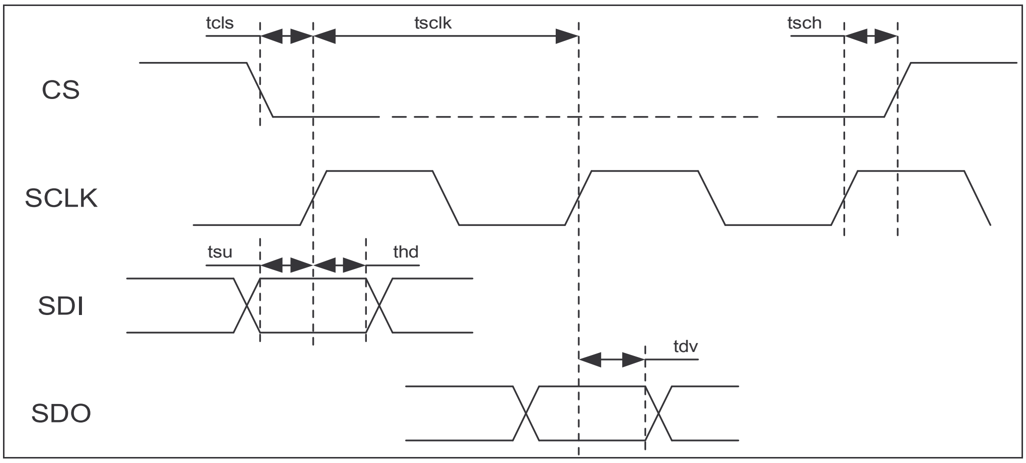
Every write command starts with a high-to-low transition of CS and ends with a low-to-high transition of CS after 32 periods of the serial data clock (SCLK). MLX90313C reads the data present on SDI on the rising edge of the clock. With a delay of 8 periods of the serial clock, the 90313 SPI interface will repeat the opcode, address and the first 8 bits of data on pin SDO. This allows the external master to check command and address and terminate the operation in case of an error by forcing CS high before the end of the complete command cycle, i.e. before the end of the 32 clock periods.
The read command is built up similarly, except that no data has to be passed of course. On SDO the opcode will be followed directly by the requested data, the address is not returned in this case.

The data on SDO is valid on the rising edge of the clock. In case of a read command, the SPI will output the data on SDO starting on the 25th rising edge of the clock (after CS low) as indicated in the figure above.

Timing/speed

[1] The 90313 implements SPI with following restrictions: fixed command length of 32 bits; fixed transition edges of data and clock; operation in slave mode only; no support of software addressing; only hardware addressing through CS. The 90313 SPI interface has one known bug: the tristate function of the SDO pin does not work; see appendix B for a solution.

The baud-rate depends on the serial data clock (SCLK) supplied by the master controller and is limited to 125kb/s. The timing requirements are given in the figure and table below



SPI timing

SPI timing requirements

Symbol	Parameter	Value	Unit
tsclk	Sclk period	min 8	µs
tcls	CS low to SCLK high	min 50	ns
tsch	SCLK low to CS high	min 50	ns
tsu	data in setup time	min 200	ns
thd	data in hold time	min 200	ns
tdv	data out valid	min 1	µs

Operation codes

The operation code is the first series of 8 bits in a command, C[7:0] in the figure on the protocol above. Below table summarizes the operations available in MLX90313C.

Operation Codes

mnem.	C[7:0]	Command
WR	X101X0XX	Write internal register
RD	X10010XX	Read internal register
WEPR	0001XXXX	Write EEPROM
ER	001XXXXX	Erase EEPROM
REPR	X0001XXX	Read EEPROM
BLWR	1001XXXX	Block Write EEPROM
BLER	101XXXXX	Block erase EEPROM

Temperature registers

The object and ambient temperatures are stored into internal registers.
A table containing the most interesting internal register addresses is included below:

Address list internal registers

Register	Function	Address
Irout	Tobject (lin)	09h
Tout	Tambient (lin)	0Ah

These registers keep the linearised (lin) object and ambient temperature.

Register format:

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Name	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	OVH	OVL	FE	Res

D11..D0 : 12 bit temperature data
OVH: Overflow flag for Tambient measurement, Ta>Tamax, D[11:0] set to FFFh
OVL: Underflow flag for Tambient measurement, Ta<Tamin, D[11:0] set to 000h
FE: Fatal Error in EEPROM.
Res Not used, always zero.

A digital SPI output is always combined with an analog or a PWM output. Depending on the nature of this second output, the measured temperature can be obtained from the register content as follows:

For a PWM / digital SPI module:

$$T = \frac{Rt}{2^{12} - 1}(Tmax - Tmin) + Tmin$$

Where:
Rt register value (12 bit, 0x000 to 0xFFF)
Tmax maximum calibrated temperature
Tmin minimum calibrated temperature

For an analog / digital SPI module:

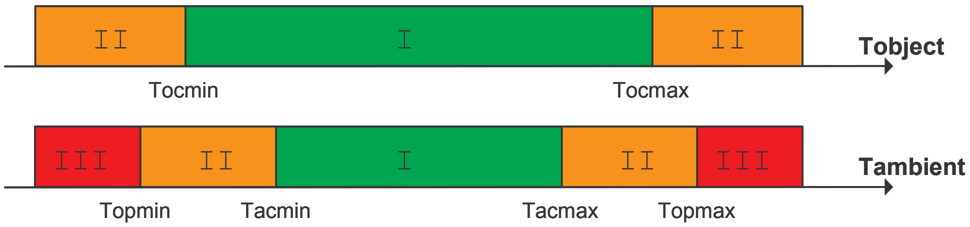
The MLX90601 KZA-BKA has been calibrated to have absolute voltage outputs. Therefore there is a difference between the temperature information of the analog outputs and the internal register values. Before calculation of the temperature for the internal register content is possible, it is necessary to measure the VREF voltage, available at pin 5. This voltage will be slightly different for each module so it must be measured for every module. A correction factor must be included in the calculation.

The measured temperature can be obtained from the register content as follows:

$$T = \frac{Rt * \frac{Vref}{4.5}}{2^{12} - 1} \bullet (Tmax - Tmin) + Tmin$$

Where:
T measured temperature
Rt register value (12 bit, 0x000 to 0xFFF)
Vref Reference voltage (to be measured)
Tmax maximum calibrated temperature
Tmin minimum calibrated temperature

The behavior of the module outside the calibrated ranges is shown below:



Tocmin = minimum calibrated object temperature
Tocmax = maximum calibrated object temperature
Tacmin = minimum calibrated ambient temperature
Tacmax = maximum calibrated ambient temperature
Topmin = lower limit of operating temperature range
Topmax = upper limit of operating temperature range

Module operating conditions

T object in range	T ambient in range	Effect on outputs
I	I	Object temperature output is working normal Ambient temperature output is working normal
II	I	SPI IROUT register data bits 0x000 if To < Tocmin, or 0xFFF if To > Tocmax. SPI TOUT register operating normal
I	II	SPI IROUT register data bits 0x000 if Ta < Tacmin, or 0xFFF if Ta > Tacmax. Corresponding overflow flags will be set.
I	III	The module may be damaged if operated outside the ambient temperature range. SPI IROUT register data bits 0x000 if Ta < Tacmin, or 0xFFF if Ta > Tacmax. Corresponding overflow flags will be set.

EEPROM reprogramming

The configuration constants are stored in EEPROM non-volatile memory. Note that also the linearization constants are stored in EEPROM, and erasing or over-writing these will irreversible destroy the modules' proper operation. Reprogramming the EEPROM must be done with care.

Here's how to rewrite a specific EEPROM address.

1. Write 0xB200 to register address 0x10. This unlocks EEPROM control registers. The module now stops updating it's output
2. Write 0x0065 to register address 0x18. Enables charge pump for programming.
3. Erase the address you want to rewrite
4. Write the new data in the EEPROM address
5. Repeat steps 3 and 4 for any further programming
6. You now can cycle the power for restarting the chip in normal operation, with new settings

Be sure never to use the Block Write or Block Erase commands, as they completely erase the EEPROM.

4.3 Relay driver output

Next to the temperature outputs, each of the standard modules also has a relay driver output. The relay driver has an open drain output stage. For the electrical characteristics: see table under paragraph 3.

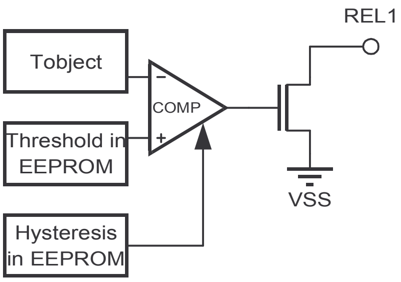
Parameter	Value	Units
Resolution of digital comparator	12	Bit
Default source	Object temperature	
Default input polarity*	Inverting	
Treshold	Version dependent	
Hysteresis	Version dependent	

These settings can be changed by factory programming on request.

*Note: Comparator input polarity:
- Inverting: relay switches OFF if temperature is above the threshold.
- Non-inverting: relay switches ON if temperature is above the threshold.

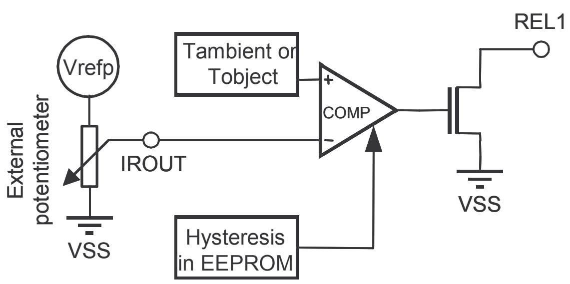
The comparator can be used in two configurations:
- threshold voltage programmed in EEPROM
- treshold voltage set by potentiometer

4.3.1 Treshold voltage programmed in EEPROM



The comparator is a 12 bit digital comparator; threshold and hysteresis registers are 16 bit registers of which the 11 MSBs are used in the comparator circuit.

4.3.2 Treshold voltage set by potentiometer



The potentiometer is inserted between the VSS and VREF pins, to ensure that the voltages offered at the IROUT pin match the input range of the analog to digital converter (ADC). The IROUT pin is used as an input pin, and gives access to an 8 bit ADC. In case of potentiometer use, the linearised analog output signal is no longer available on IROUT. The pin Vrefp must be configured for 3 Volt (bits ENDREFDIV and SELDR[2:0] in EEPROM memory).

5 Overview of the standard modules

5.1 MLX90601EZA-BAA

5.1.1 Key properties EZA-BAA

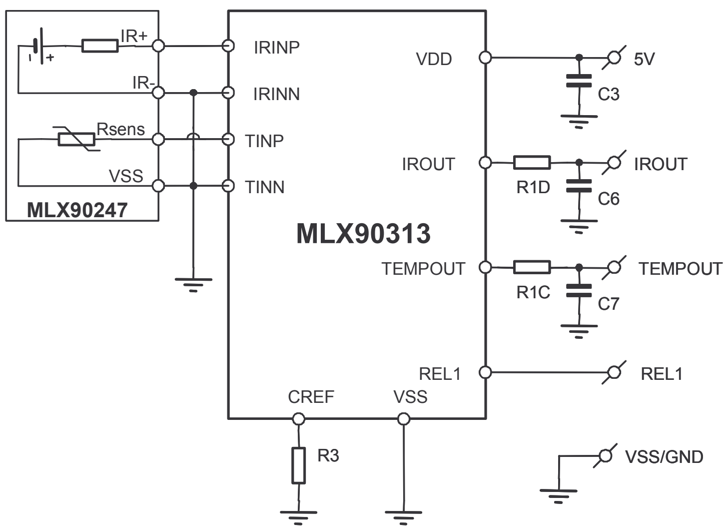
- automotive use
- analog output signals with 8 bit resolution
- comparator with relay driver output
- only 5 connection pins

5.1.2 General description EZA-BAA

The MLX90601EZA-BAA is targeted at automotive applications. In order to allow application in automotive environments, the module has been equipped with RC protection circuits on the IROUT and TEMPOUT pins.

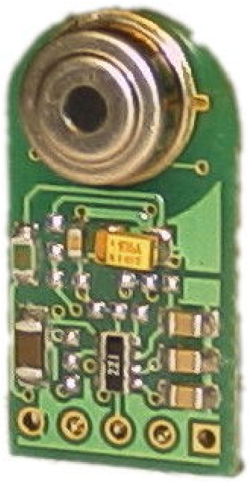
Note that this module has no SPI interface connector available. User reconfiguration of this type of module can be done with the Melexis EVB90601 (evaluation board) and a special test clip. Refer to appendix A for details.

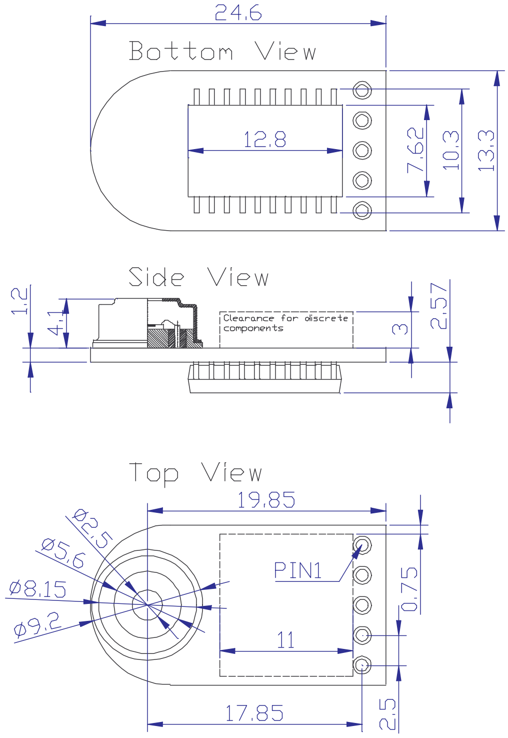
5.1.3 Functional diagram



MLX90601EZA-BAA	R3 = 100kΩ
MLX90601EZA-DAA	C3 = 10µF/100nF
	R1D = R1C = 220Ω
	C6 = C7 = 47nF

5.1.4 Physical outline EZA-BAA





5.1.5 Pin descriptions EZA-BAA

pin-out information

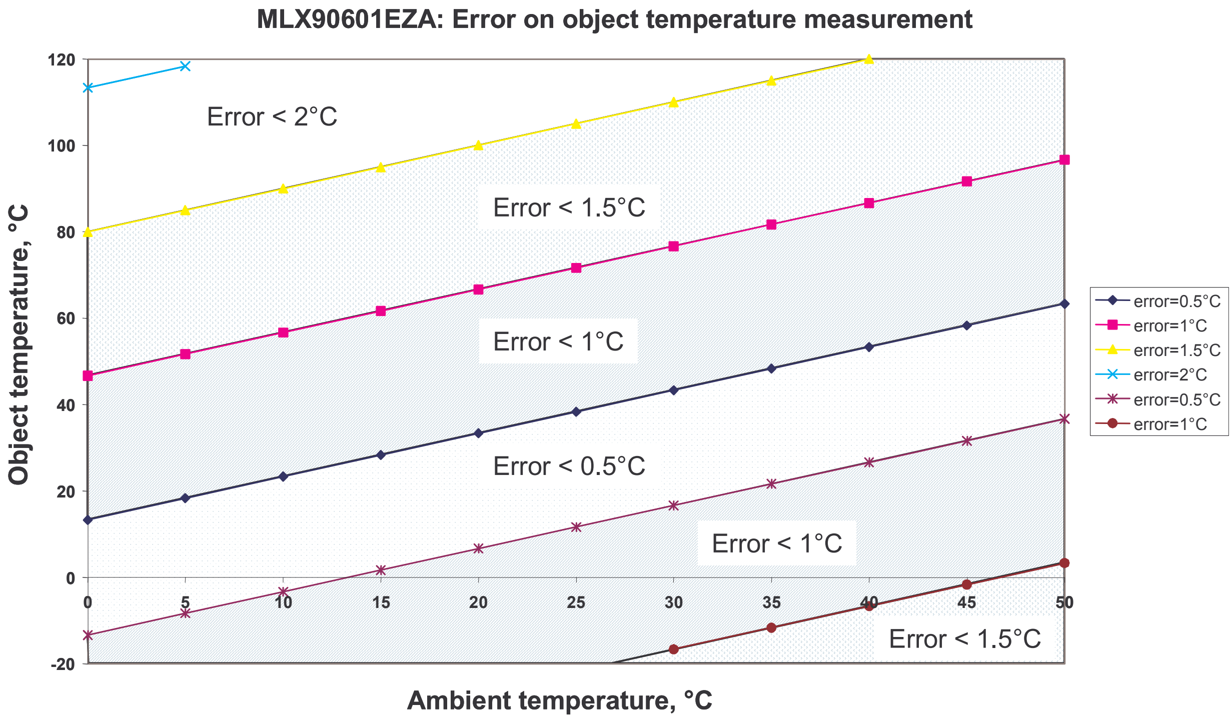
pin	name	Function
1	IROUT	Analog output infrared temperature. The output voltage is a linear representation of the object temperature.
2	TEMPOUT	Analog output ambient temperature The output voltage is a linear representation of the ambient (=detector) temperature, as measured by the PTC thermistor inside the IR sensor.
3	VDD	Supply voltage
4	REL1	Relay driver output
5	VSS	Ground connection and reference for voltage measurements.

5.1.6 Specific characteristics EZA-BAA

Parameter	Symbol	Condition	min	typ	max	unit
Absolute maximum ratings*						
Supply voltage	VDD		-0.3		6	V
Operating temperature range	Ta		-40		+85	°C
ESD Sensitivity		AEC Q100 002			4	kV
Analog outputs IROUT/TEMPOUT						
Capacitive load	Cmax				100	nF
Calibration settings						
Calibrated object temperature range	[Tocmin, Tocmax]	Emissivity = 0.99	-20		+120	°C
Calibrated ambient temperature range	[Tacmin, Tacmax]		0		+50	°C
Comparator settings						
Treshold temperature	Tth			50		°C
Hysteresis	Thy			5		°C

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

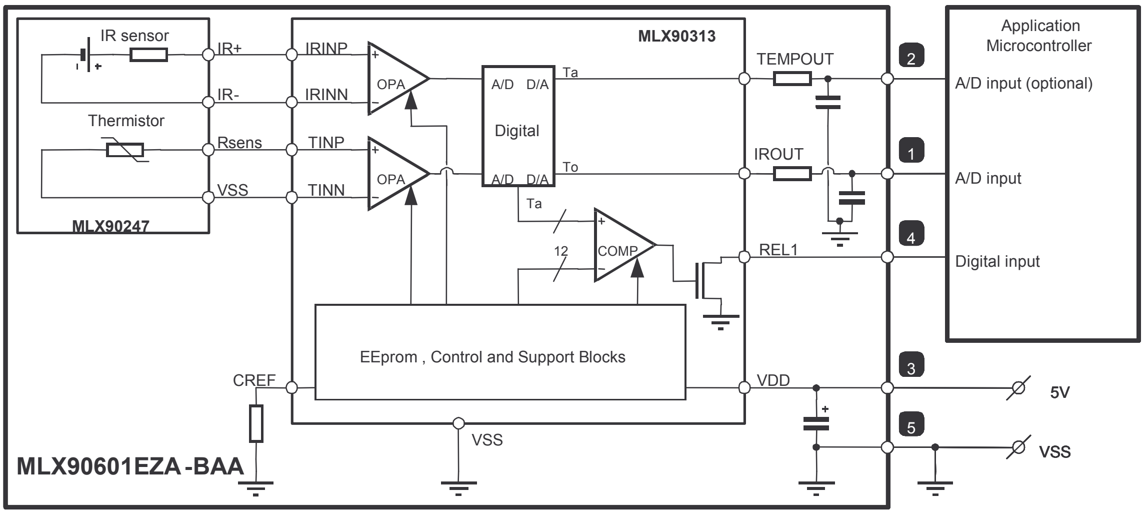
5.1.7 Object temperature accuracy matrix EZA-BAA



See also 4.2 on accuracy of the measurements.

5.1.8 Applications information

Connection of the MLX90601 module into an application is straightforward. The 5V regulated supply should be connected between pin 3 (VDD) and pin 5 (VSS).
The outputs can be measured relative to VSS at pin 1 (IROUT) for Tobject and pin 2 (TEMPOUT) for Tambient, e.g. by means of a voltmeter. In an actual application the module outputs can be directly connected to the A/D inputs of a microcontroller, e.g. as a replacement for a conventional temperature sensor.
In many applications, the ambient temperature of the sensor is not needed. In this case, pin 2 can simply be left open.
The REL1 signal at pin 4 can be used as input for a digital I/O or to drive a relay (not shown). In case of a digital input the microcontroller must have internal pull-up resistors or an external pull-up resistor must be added.



5.2 MLX90601EZA-DAA

5.2.1 Key properties EZA-DAA

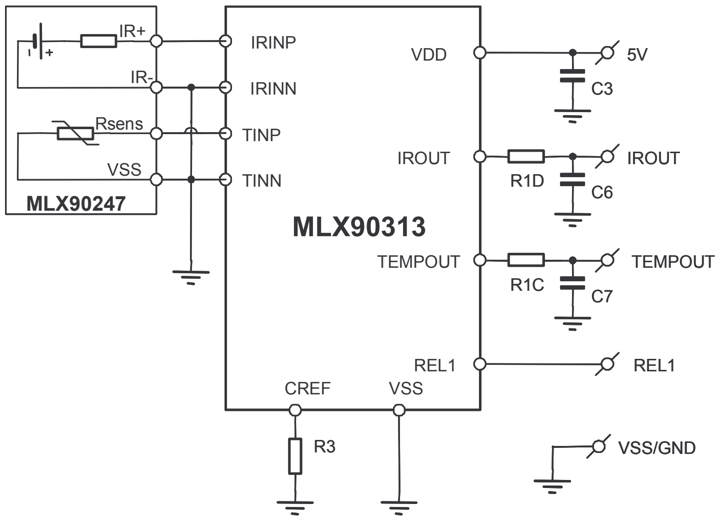
- automotive use
- PWM coded output signals with 10 bit resolution
- ambient temperature underflow and overflow flagging
- comparator with relay driver output
- only 5 connections

5.2.2 General description EZA-DAA

The MLX90601EZA-BAA is targeted at automotive applications. In order to allow application in automotive environments, the module has been equipped with RC protection circuits on the IROUT and TEMPOUT pins.

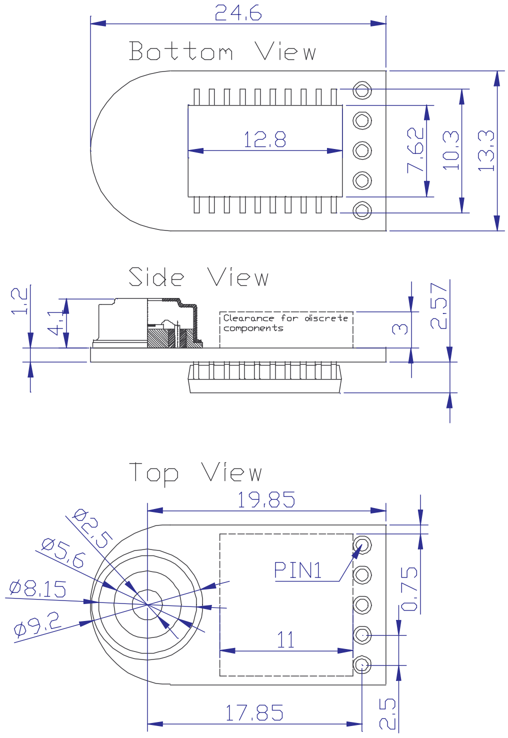
Note that this module has no SPI interface connector available. User reconfiguration of this type of module can be done with the Melexis EVB90601 (evaluation board) and a special test clip. Refer to appendix A for details.

5.2.3 Functional diagram EZA-DAA



MLX90601EZA-BAA	R3 = 100kΩ
MLX90601EZA-DAA	C3 = 10µF/100nF
	R1D = R1C = 220Ω
	C6 = C7 = 47nF

5.2.4 Physical outline EZA-DAA



5.2.5 Pin descriptions EZA-DAA

pin-out information

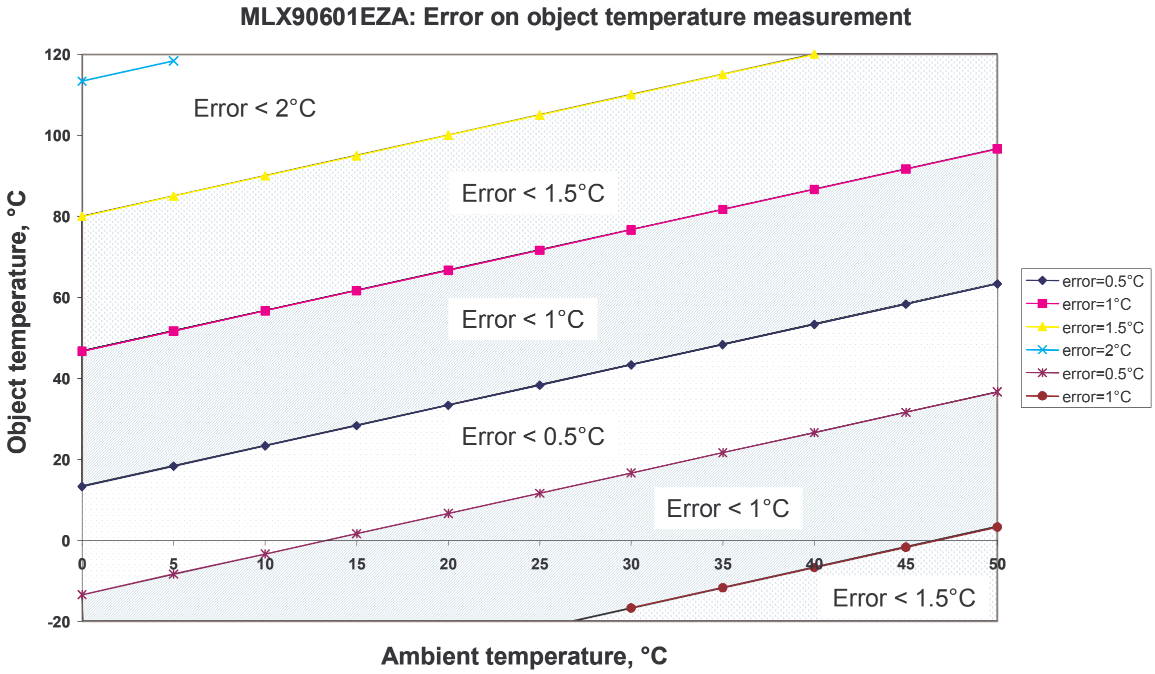
pin	name	Function
1	IROUT	PWM-coded output infrared temperature.
2	TEMPOUT	PWM-coded output ambient temperature
3	VDD	Supply voltage
4	REL1	Relay driver output
5	VSS	Ground connection and reference for voltage measurements.

5.2.6 Specific characteristics EZA-DAA

Parameter	symbol	condition	min	typ	max	Unit
Absolute maximum ratings*						
Supply voltage	VDD		-0.3		6	V
Operating temperature range	Ta		-40		+85	°C
ESD Sensitivity		AEC Q100 002			4	kV
Calibration settings						
Calibrated object temperature range	[Tocmin, Tocmax]	Emissivity = 0.99	-20		+120	°C
Calibrated ambient temperature range	[Tacmin, Tacmax]		0		+50	°C
Comparator settings						
Treshold temperature	Tth			50		°C
Hysteresis	Thy			5		°C

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

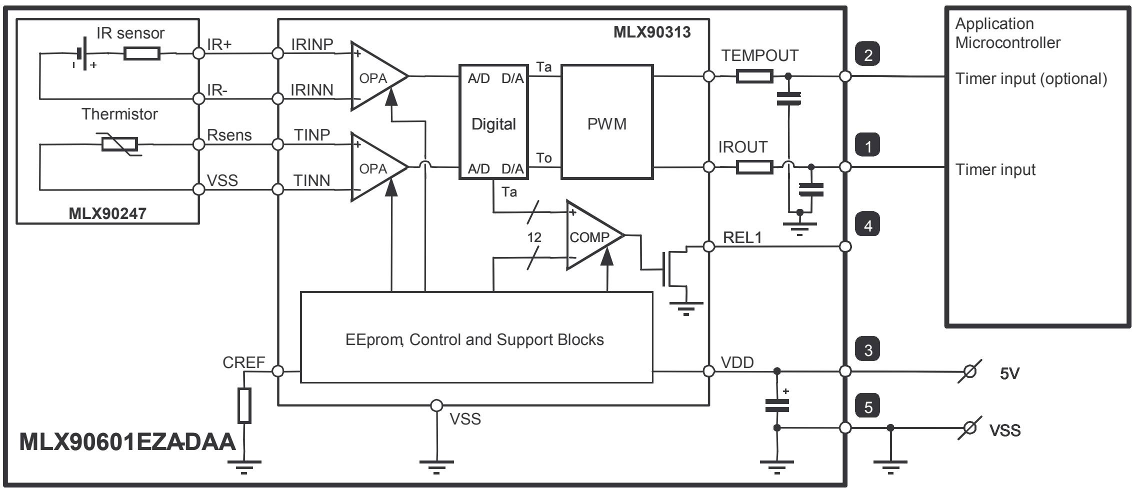
5.2.7 Object temperature accuracy matrix EZA-DAA



See also 4.2 on accuracy of the measurements.

5.2.8 Applications information

Connection of the MLX90601 module into an application is straightforward. The 5V regulated supply should be connected between pin 3 (VDD) and pin 5 (VSS).
In an actual application the module outputs can be directly connected to a timer or IRQ inputs of a microcontroller. In many applications, the ambient temperature of the sensor is not needed. In this case, pin 2 can simply be left open.
The REL1 signal at pin 4 can be used as input for a digital I/O or to drive a relay (not shown). In case of a digital input the microcontroller must have internal pull-up resistors or an external pull-up resistor must be added.



5.3 MLX90601EZA-CAA

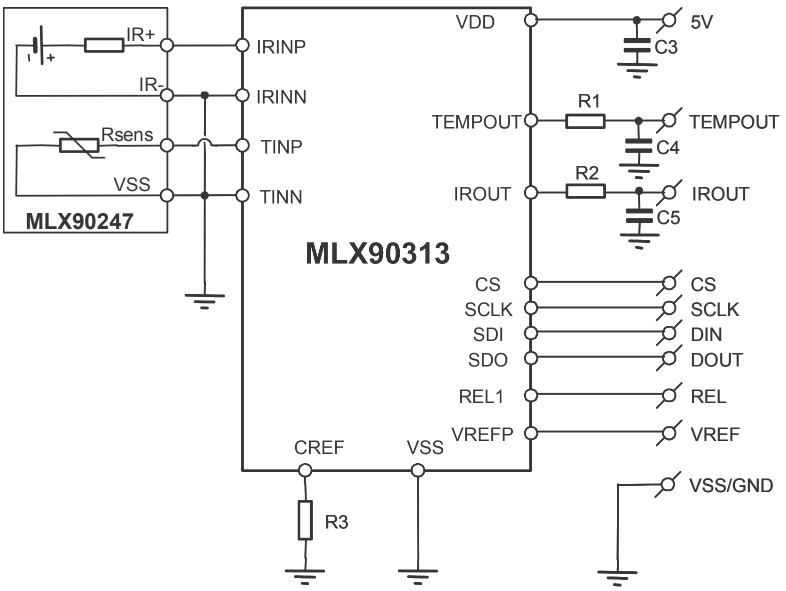
5.3.1 Key properties EZA-CAA

- consumer and industrial use
- PWM output signals with 10 bit resolution
- SPI interface available
- comparator with relay driver output and reference voltage
- 10-pole connector, mating to a 1mm-pitch flat cable connector

5.3.2 General description EZA-CAA

The MLX90601EZA-CAA is a module that is targeted at industrial and consumer applications. The sensor and the MLX90313 ASIC are placed on a rigid PCB. The module has a 10-pole connector, which has all relevant interconnections to the ASIC.
The CAA type module has the SPI interface available. Next to reading the temperature information, the SPI interface also allows changing the module's settings and calibration.

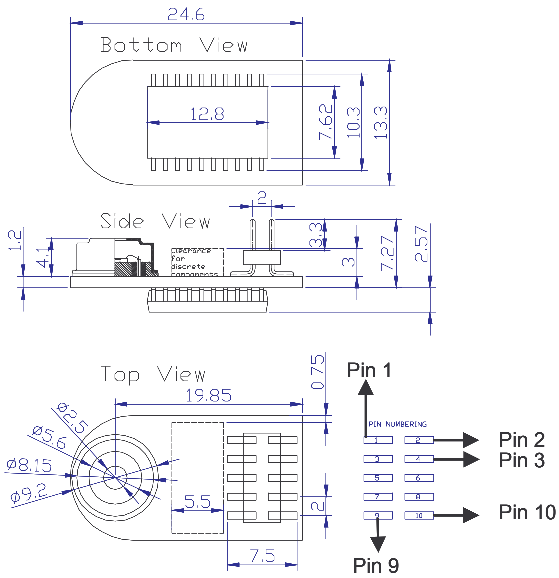
5.3.3 Functional diagram EZA-CAA



MLX90601EZA-CAA

R3 = 100kΩ
C3 = 10µF/100nF
R1 = R2 = 220Ω
C4 = C5 = 47nF

5.3.4 Physical outline EZA-CAA



5.3.5 Pin descriptions EZA-CAA

pin-out information

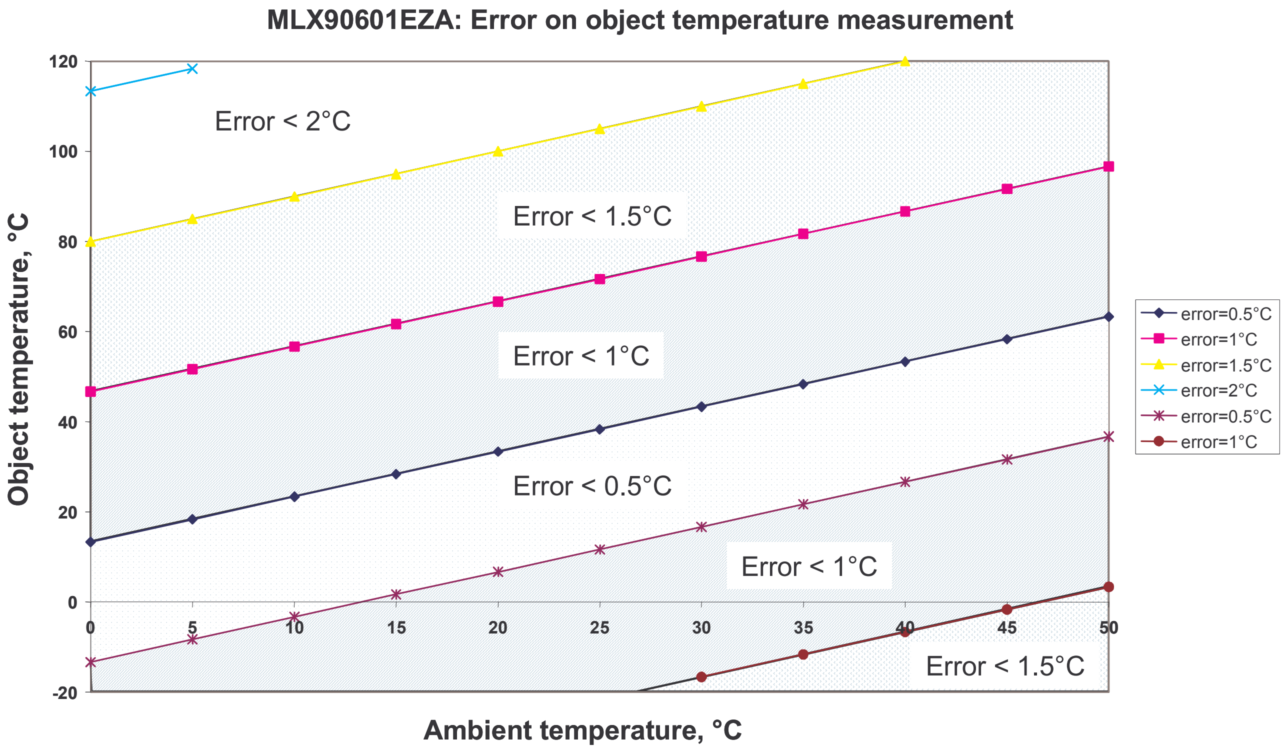
pin	name	Function
1	REL1	Relay output
2	VSS	Ground connection
3	VDD	Supply voltage
4	SDI	SPI data in (MOSI)
5	SDO	SPI data out (MISO)
6	CSB	SPI chip select; active low
7	SCLK	SPI clock
8	IROUT	PWM coded output infrared temperature
9	VREF	ADC reference voltage. Use: see paragraph 4.3.2.
10	TEMPOUT	PWM coded output ambient temperature

5.3.6 Specific characteristics EZA-CAA

Parameter	symbol	condition	min	typ	max	Unit
Absolute maximum ratings*						
Supply voltage	VDD		-0.3		6	V
Operating temperature range	Ta		-40		+85	°C
ESD Sensitivity		AEC Q100 002			1	kV
Calibration settings						
Calibrated object temperature range	[Tocmin, Tocmax]	Emissivity = 0.99	-20		+120	°C
Calibrated ambient temperature range	[Tacmin, Tacmax]		0		+50	°C
Comparator settings						
Treshold temperature	Tth			50		°C
Hysteresis	Thy			5		°C

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

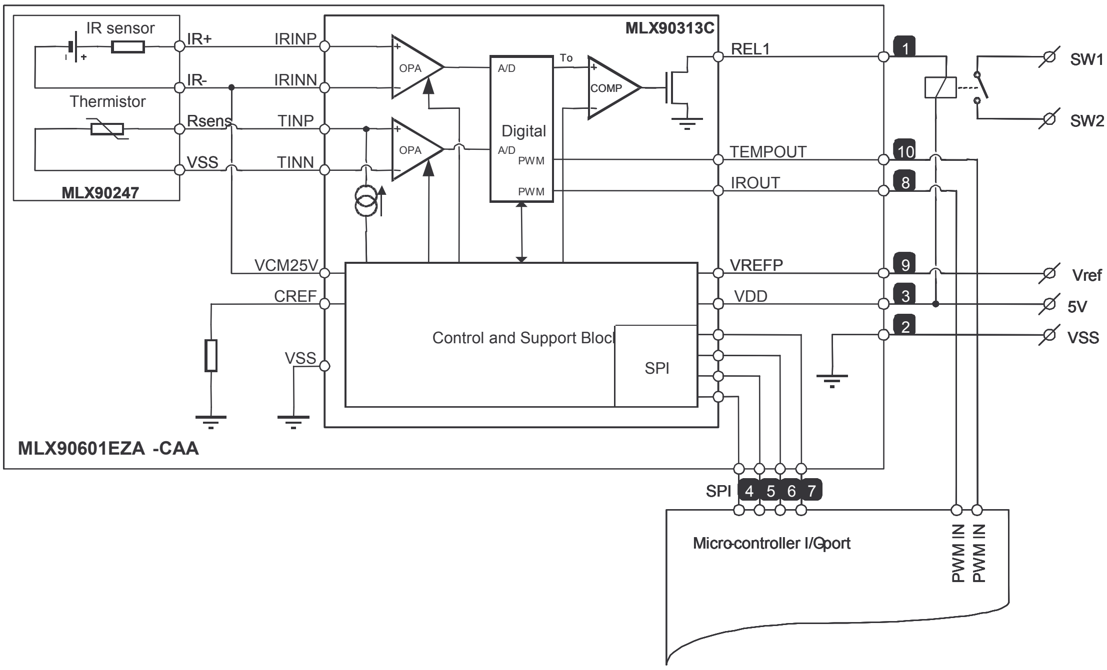
5.3.7 Object temperature accuracy matrix EZA-CAA



See also 4.2 on accuracy of the measurements.

5.3.8 Applications information

Connection of the MLX90601EZA-CAA module into an application is straightforward. The 5V regulated supply should be connected between pin 3 (VDD) and pin 2 (VSS). There are numerous possibilities for the I/O of which one example is shown below. Here the default configuration is used. In the example a relay is switched with the REL1 output. The threshold for this comparator is programmed in the EEPROM. Once the micro-controller has set the threshold through the SPI, the MLX90601 controls the alarm standalone. The SPI connection to the host microcontroller can be a permanent connection in the application or just a means for in-circuit programming of the device. Through this connection full access to the internal registers and configuration settings is achieved. The SPI connection can be used to directly read output data from the module in digital form and process them in the application in real time. An interesting feature is in-circuit programming of the calibration constants. It is possible to change the range or emissivity, or whatever setting needs to be user adjustable.



5.4 MLX90601KZA-BKA

5.4.1 Key properties KZA-BKA

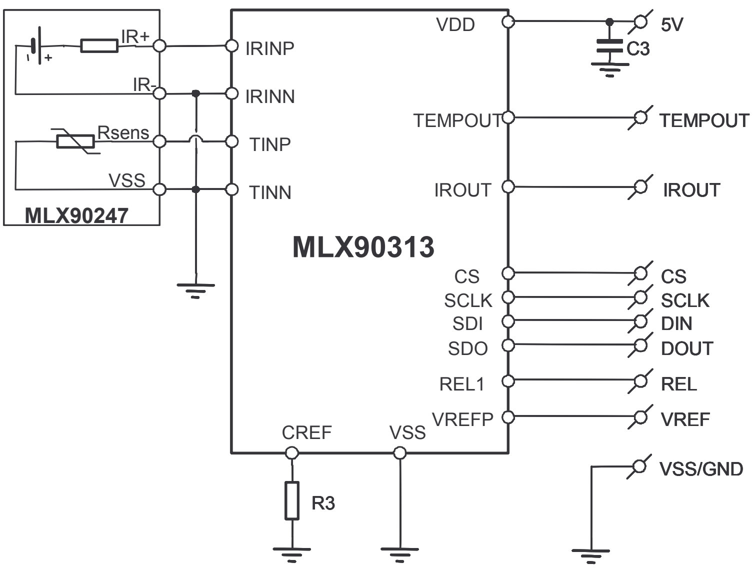
- flex circuit for consumer and industrial use
- analog output signals with 8 bit resolution
- SPI interface available
- comparator with relay driver output and reference voltage
- 10-pole flex connector

5.4.2 General description KZA-BKA

The MLX90601KZA-BKA is a module that is targeted at industrial and consumer applications. The sensor and the MLX90313 ASIC are placed on a flexible substrate. The flexible substrate allows the sensor to be bent in any direction, which may greatly simplify the mechanical of the module.

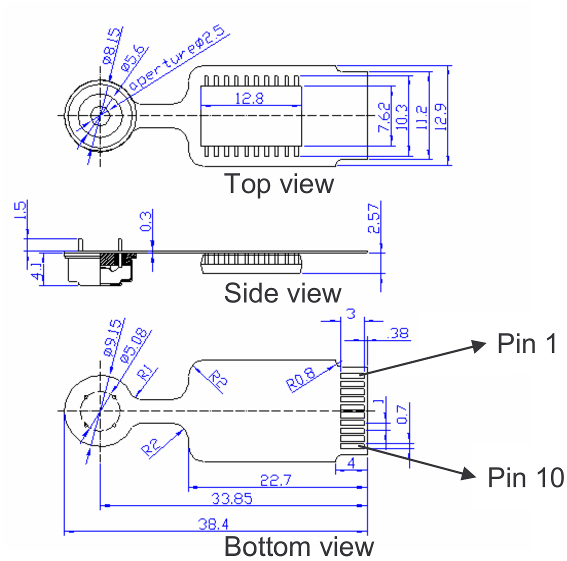
The flex modules all have the SPI interface available. Next to reading the temperature information, the SPI interface also allows changing the module's settings and calibration.

5.4.3 Functional diagram KZA-BKA



MLX90601KZA-BKA R3 = 100kΩ
C3 = 10µF

5.4.4 Physical outline KZA-BKA



5.4.5 Pin descriptions KZA-BKA

pin-out information

pin	name	function
1	VSS	Ground connection
2	REL1	Relay output
3	IROUT	analog output infrared temperature
4	TEMPOUT	analog output ambient temperature
5	VREF	ADC reference voltage. Use: see paragraph 4.3.2
6	VDD	Supply voltage
7	SDI	SPI data in (MOSI)
8	SCLK	SPI clock
9	SDO	SPI data out (MISO)
10	CSB	SPI chip select; active low

5.4.6 Specific characteristics KZA-BKA

Parameter	symbol	condition	min	typ	max	unit
Absolute maximum ratings*						
Supply voltage	VDD		-0.3		6	V
Operating temperature range	Ta		-40		+125	°C
ESD Sensitivity		AEC Q100 002			1	kV
Smallest bending radius of the neck of the flex circuit	Rflex		1.5			mm
Analog outputs IROUT/TEMPOUT						
Capacitive load	Cmax	directly on pin			50	pF
Capacitive load		with 200 ohms series resistance			100	nF

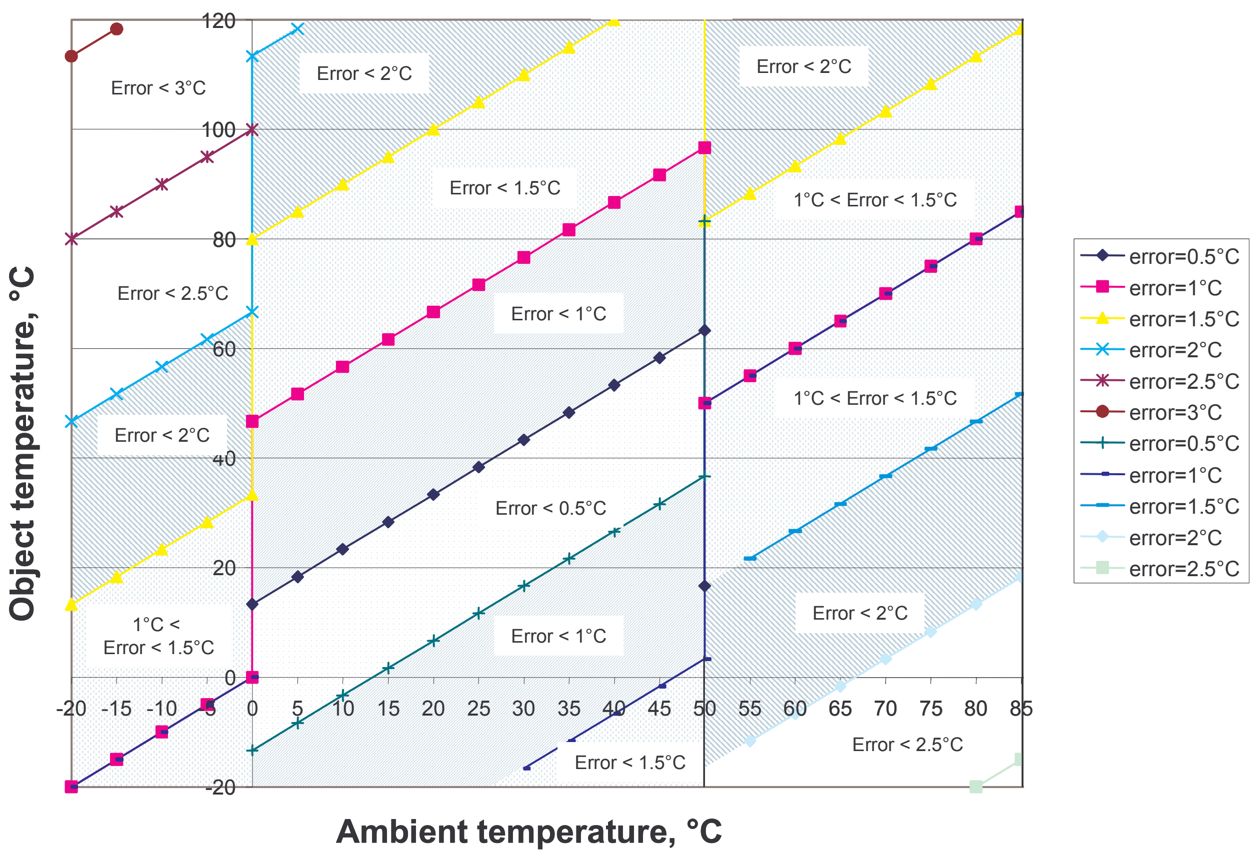
Parameter	symbol	condition	min	typ	max	unit
Calibration settings						
Calibrated object temperature range	[Tocmin, Tocmax]	Emissivity = 0.99	-20		+120	°C
Calibrated ambient temperature range	[Tacmin, Tacmax]		-20		+85	°C
Comparator settings						
Treshold temperature	Tth			95		°C
Hysteresis	Thy			5		°C

When the Cmax value of 50 pF is exceeded, a 200 ohm series resistor must be used to maintain stability !

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

5.4.7 Object temperature accuracy matrix KZA-BKA

MLX90601KZA-BKA: Error on object temperature measurement



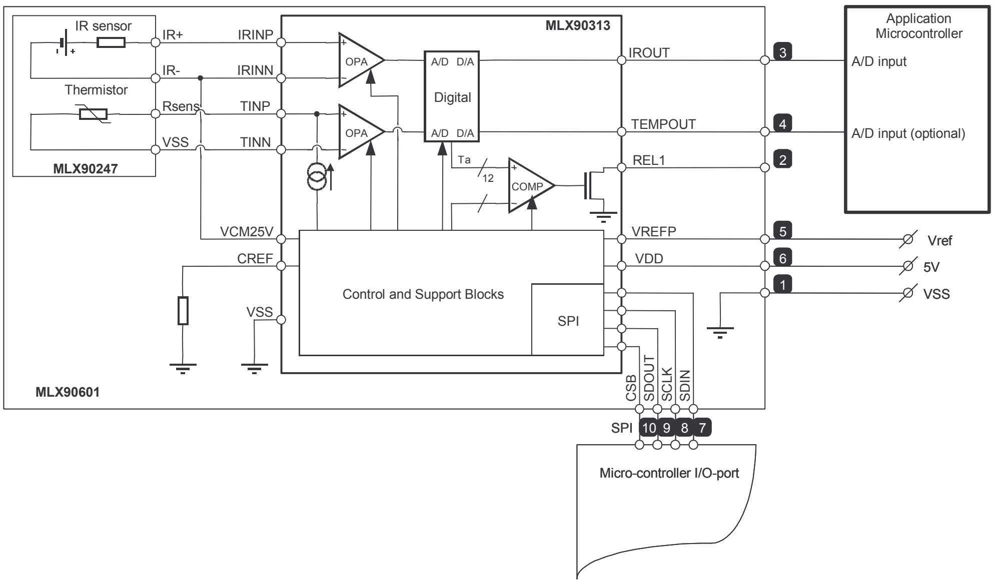
See also 4.2 on accuracy of the measurements.

5.4.8 Applications information

Connection of the MLX90601 module into an application is straightforward. The 5V regulated supply should be connected between pin 6 (VDD) and pin 1 (VSS). The outputs can be measured relative to VSS at pin 3 (IROUT) for Tobject and pin 4 (TEMPOUT) for Tambient, e.g. by means of a voltmeter. In an actual application the module outputs can be directly connected to the A/D inputs of a microcontroller, e.g. as a replacement for a conventional temperature sensor. When large loading capacitances are to be used, a series resistor may be necessary. Refer to electrical specifications.

Although the circuit carrier is flexible, it is only intended to be bent at the neck between the thermopile sensor and the ASIC. Minimal bending radius is 1.5 mm.

In many applications, the ambient temperature of the sensor is not needed. In this case, pin 2 can simply be left open. The REL1 signal can be used as input for a digital I/O or to drive a relay (not shown). In case of a digital input the microcontroller must have internal pull-up resistors or an external pull-up resistor must be added. The microcontroller connection to the SPI interface is purely optional.



5.5 MLX90601KZA-CKA, MLCX90601KZA-CKD and MLX90601KZA-CLA

5.5.1 Key properties KZA-CKA, KZA-CKD, KZA-CLA

- Flex circuit for consumer and industrial use.
- PWM output signals with 10 bit resolution
- SPI interface available
- relay comparator and reference voltage
- 10 pole flex connector

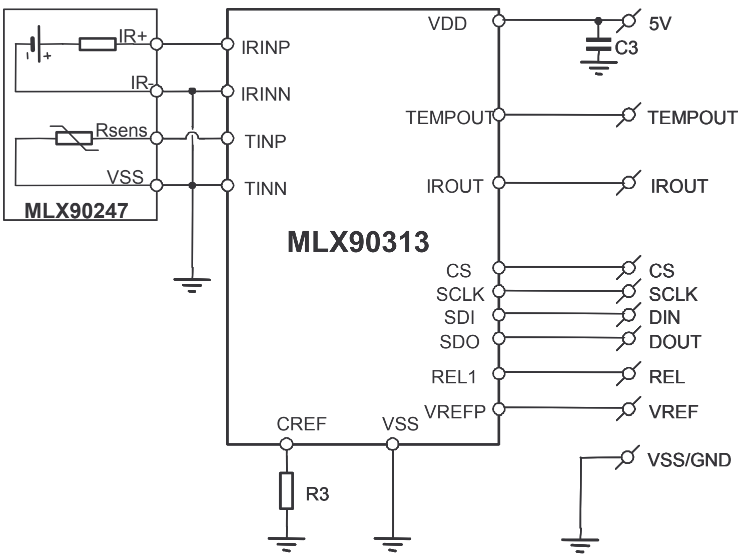
5.5.2 General description KZA-CKA, KZA-CKD, KZA-CLA

The MLX90601KZA-CKA, CKD and CLA modules are targeted at industrial and consumer applications. The sensor and the MLX90313 ASIC are placed on a flexible substrate. The flexible substrate allows the sensor to be bent in any direction, which may greatly simplify the mechanical of the module.

The MLX90601KZA-CLA module has a tube of diameter 3.5 mm and length 4 mm mounted on the sensor TO-can. Application of the tube reduces the FOV to 42°.

The flex modules all have the SPI interface available. Next to reading the temperature information, the SPI interface also allows changing the module's settings and calibration.

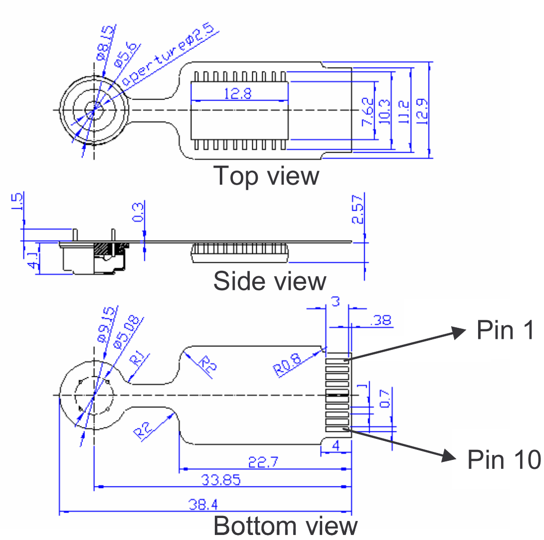
5.5.3 Functional diagram KZA-CKA, KZA-CKD, KZA-CLA



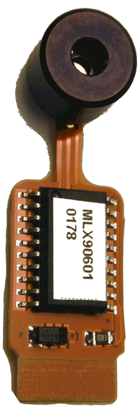
MLX90601KZA-CKA
MLX90601KZA-CKD
MLX90601KZA-CLA

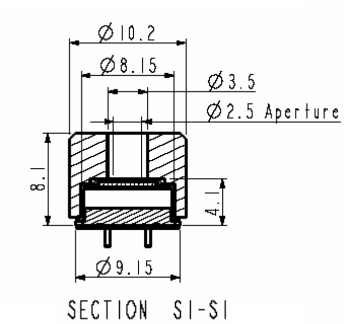
R3 = 100kΩ
C3 = 10µF

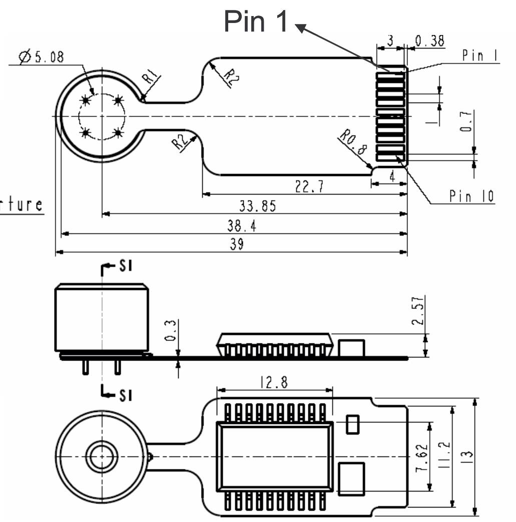
5.5.4 Physical outline KZA-CKA, KZA-CKD, KZA-CLA



MLX90601KZA-CKA
MLX90601KZA-CKD







MLX90601KZA-CLA

5.5.5 Pin descriptions KZA-CKA, KZA-CKD, KZA-CLA

pin-out information

pin	name	function
1	VSS	Ground connection
2	REL1	Relay output
3	IROUT	PWM coded output infrared temperature
4	TEMPOUT	PWM coded output ambient temperature
5	VREF	ADC reference voltage. Use: see paragraph 4.3.2
6	VDD	Supply voltage
7	SDI	SPI data in (MOSI)
8	SCLK	SPI clock
9	SDO	SPI data out (MISO)
10	CSB	SPI chip select; active low

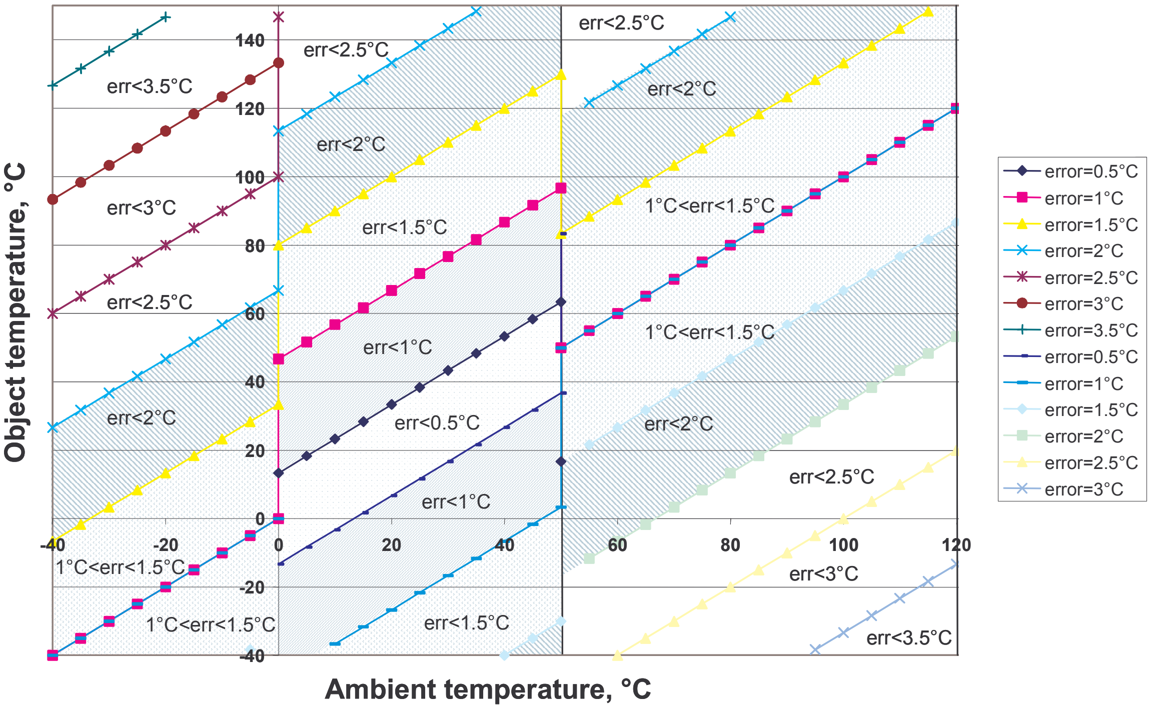
5.5.6 Specific characteristics KZA-CKA, KZA-CKD, KZA-CLA

Parameter	symbol	condition	min	typ	max	unit
Absolute maximum ratings						
Supply voltage	VDD		-0.3		6	V
Operating temperature range	Ta		-40		+125	°C
Smallest bending radius of the neck of the flex circuit	Rflex		1.5			mm
ESD Sensitivity		AEC Q100 002			1	kV
Calibration settings						
Calibrated object temperature range						
MLX90601 KZA-CKA	[Tocmin, Tocmax]	Emissivity = 0.99	-20		+120	°C
MLX90601 KZA-CKD	[Tocmin, Tocmax]	Emissivity = 0.99	-40		+120	°C
MLX90601 KZA-CLA	[Tocmin, Tocmax]	Emissivity = 0.99	-40		+150	°C
Calibrated ambient temperature range						
MLX90601 KZA-CKA	[Tacmin, Tacmax]		-20		+85	°C
MLX90601 KZA-CKD	[Tacmin, Tacmax]		-40		+125	°C
MLX90601 KZA-CLA	[Tacmin, Tacmax]		-40		+125	°C
Comparator settings						
Treshold temperature	Tth			95		°C
Hysteresis	Thy			5		°C

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

5.5.7 Object temperature accuracy matrix KZA-CKA, KZA-CKD, KZA-CLA

MLX90601KZA-CKA, CKD, CLA: Error on object temperature Measurement

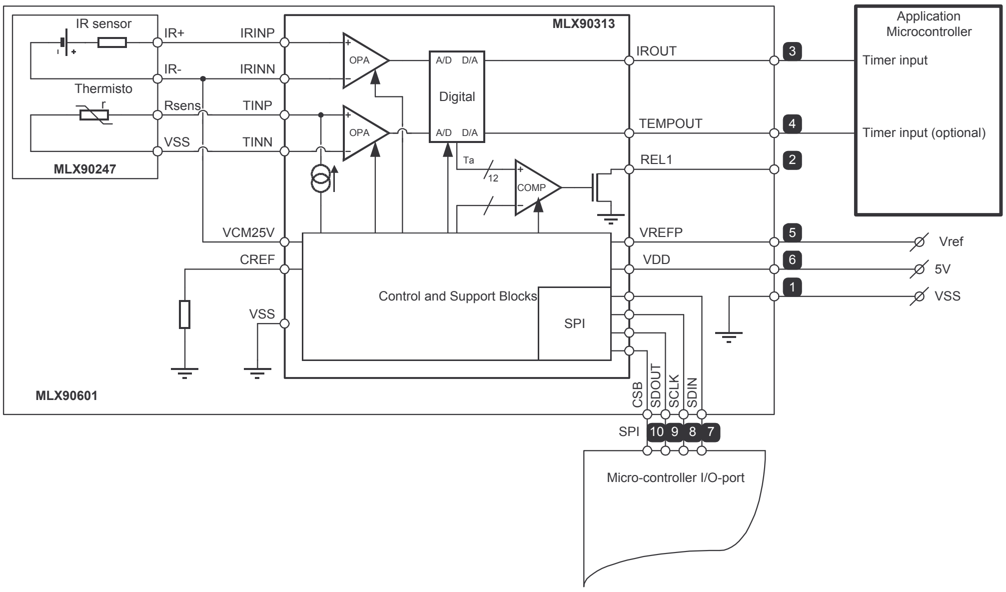


See also 4.2 on accuracy of the measurements.

5.5.8 Applications information

Connection of the MLX90601 module into an application is straightforward. The 5V regulated supply should be connected between pin 6 (VDD) and pin 1 (VSS).

In many applications, the ambient temperature of the sensor is not needed. In this case, pin 4 can simply be left open.
The REL1 signal can be used as input for a digital I/O or to drive a relay (not shown). In case of a digital input the microcontroller must have internal pull-up resistors or an external pull-up resistor must be added. Here of course the microcontroller connection to the SPI interface is purely optional.



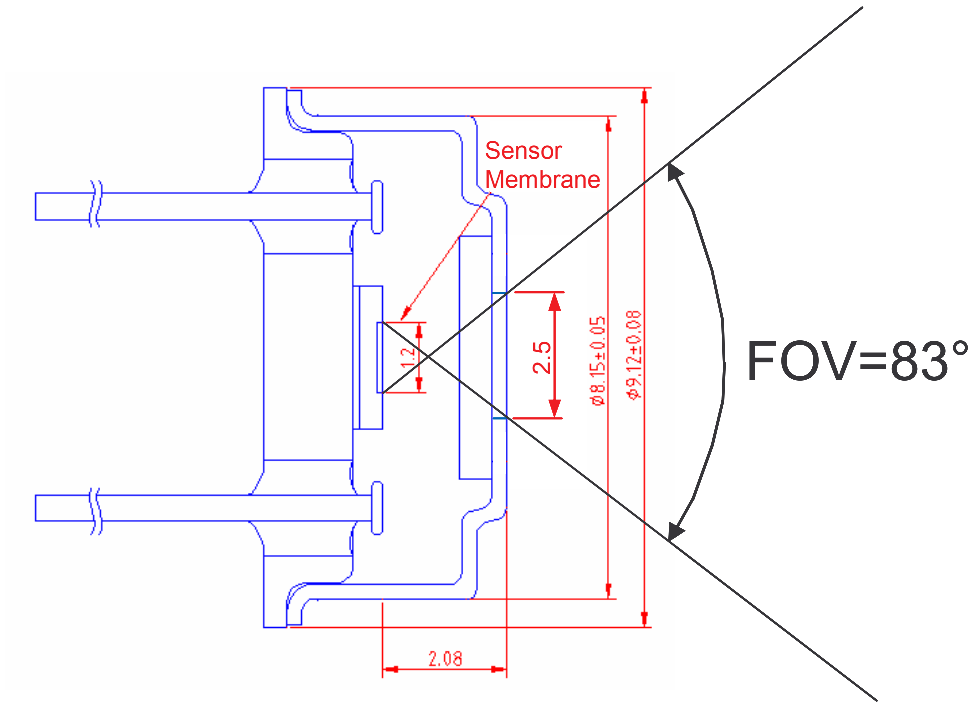
6 Detailed technical information

6.1 Sensor characteristics

All modules have the same thermopile sensor **MLX90247ESF-DSL**. For detailed specification we refer to the datasheet on MLX90247, available from the Melexis web site (www.melexis.com). In a calibrated module the linearization unit of MLX90313 takes all characteristics of the sensor into account, including all process variations they are subject to.
The remainder of this paragraph concerns the characteristics of the **MLX90247ESF-DSL**, as part of the MLX90601 modules.

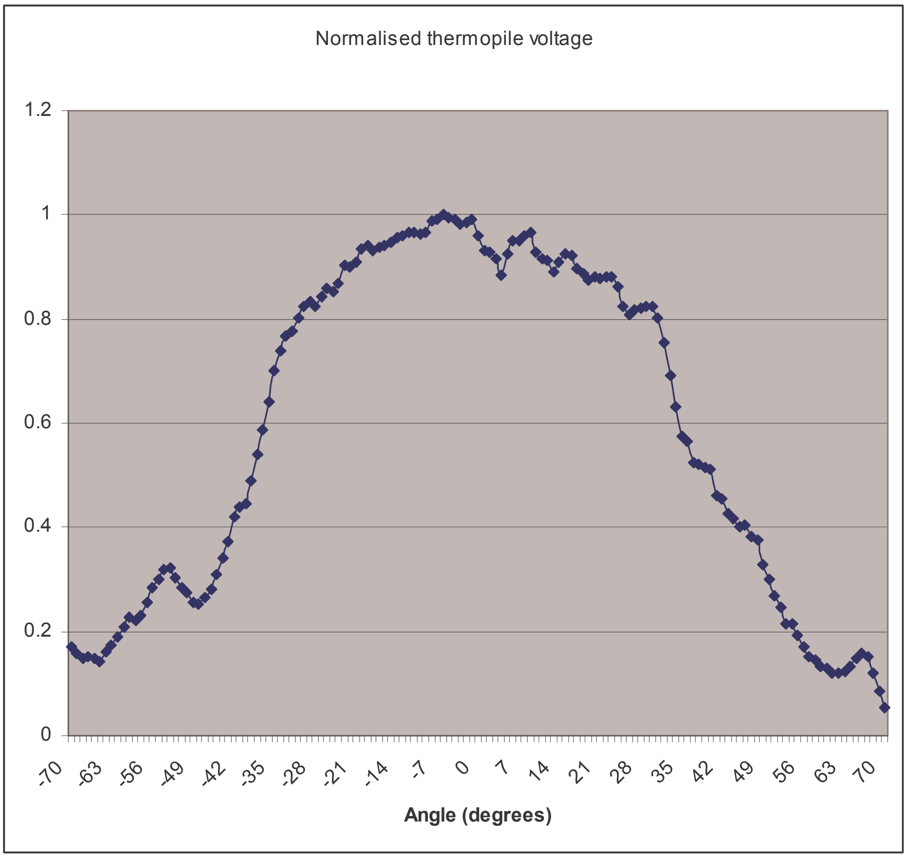
Field of View

The TO-39 sensor housing of the thermopile integrated in the 90601 modules has a 2.5mm diameter aperture, resulting in an 83° full angle field of view, for 100% of the IR energy. The drawing below illustrates the meaning of the 83°:
83° = 2 x arctg ((half side of the sensor membrane + half diameter of the aperture)/distance membrane to aperture) = 2x arctg ((0.6+1.25)/2.08)



The FOV can be reduced by placing a tube over the sensor housing. The MLX90601 KZA-CLA is a standard module with FOV=40°, using a tube.

The figure below shows a typical field of view measurement on a sensor as used in the modules of the MLX90601 family (ripples in the curve are due to noise in the measurement setup).



Spectral behaviour

The silicon filter used as IR-window is treated with an antireflective coating to optimize transmission of long infrared wavelengths (above 5.5 µm), and to cut off the transmission of visible light and of the short infrared wavelengths that are used in communication devices.
The spectral characteristics of the silicon filter optimize the 90601 modules for temperature measurements in the range [-40°C, +150°C].

The spectral characteristics are:

Wavelength interval (µm)	Transmission (%)
λ < 5 µm	< 0.5 %
7.5 µm < λ < 13.5 µm	> 75 %

Sensor Sensitivity

The variation of the thermopile output voltage V_{TP} with object and ambient temperatures is well approximated by the expression $V_{TP} = \alpha \, . \, (T_o^4 - T_a^4)$, where:

- α = a technological constant, valid for a fixed FOV, detector geometry and materials
- To = object temperature, Kelvin
- Ta = ambient (or sensor) temperature, Kelvin

Sensitivity is a convenient way to compare thermopile sensors. It is the output voltage of the sensor for 1°C of difference between T_o and T_a. In practice, it is measured at room-temperature:

$S = \alpha.(299^4 - 298^4)$ = the thermopile output voltage caused by a temperature difference of 1 K between radiating object and detector, at room temperature.

S is an approximation of the derivative of the infrared output voltage V_{TP} to temperature:

S □ dV_{TP}/dT_o

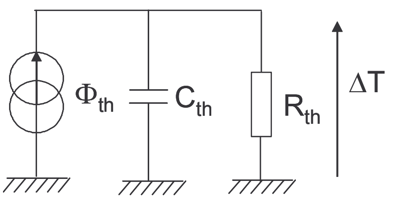
The thermopile sensor used in the MLX90601 infrared thermometer modules (**MLX90247ESF-DSL)** has a sensitivity of typically 30 μV/K, and a typical value of α = 0.28 pV/K^4.

6.2 Dynamic behavior of the module - timing

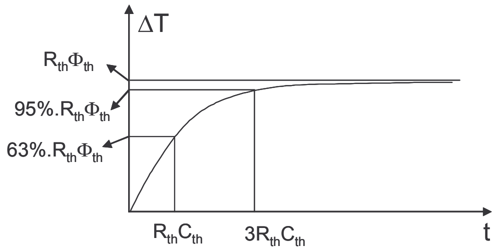
This paragraph discusses:

- Dynamic behavior of the module: thermal reaction speed
- Signal processing time

Thermal reaction speed:



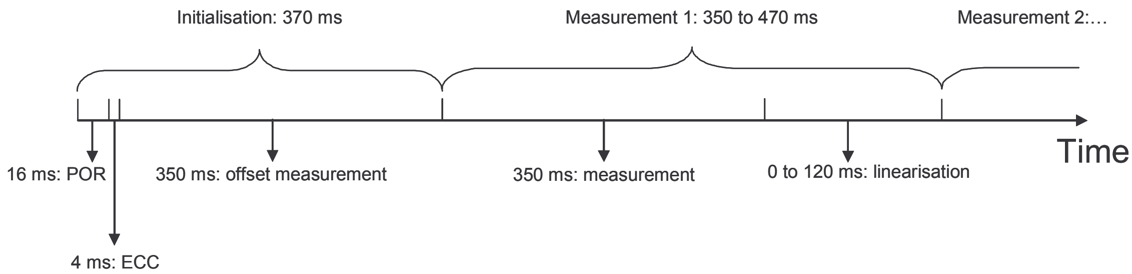
Thermal model of sensor membrane



Membrane step-response

Estimated time constant $\tau_{th} = R_{th}C_{th} \approx 30$ ms

Signal processing time:



- POR = Power On Reset
- ECC = EEPROM Error Check and Correction (4 ms if no errors are detected; add 8 ms per word

to be corrected, with a maximum of 128 words). In most situations, there are no errors to correct.

- Offset measurement: measurement of ambient and infrared offset signals; averaging over 1024 samples (factory setting).
- Measurement: measurement of ambient and infrared temperatures. By default, the modules average over 1024 samples, which takes 175 ms per channel.
- Linearization: 0 to 50 ms for ambient linearization, and 0 to 70 ms for infrared linearization. The exact value depends upon ambient and object temperatures.

The output is refreshed every cycle of 1024 samples; the output refresh rate is between 350 and 470 ms, depending on ambient and object temperatures.

At the cost of reduced measurement accuracy, the refresh rate can be sped up by reducing the number of samples per measurement for both ambient and object. The number of samples per measurement can be programmed to the values 64, 128, 256, 512 and 1024. Averaging over 1024 samples gives the best noise performance and is the factory setting. Averaging over a lower number of samples will lead to higher noise levels and reduced accuracy. Measurement times for lower number of samples are as follows:

# samples ambient channel	# samples infrared channel	Refresh rate (ms)
1024	1024	350 to 470
512	512	175 to 295
256	256	100 to 220
128	128	60 to 180
64	64	40 to 160

Refer to the MLX 90313 datasheet for more info on programming the MLX90601 module.

6.3 Noise

Following sources contribute to the noise of the module:

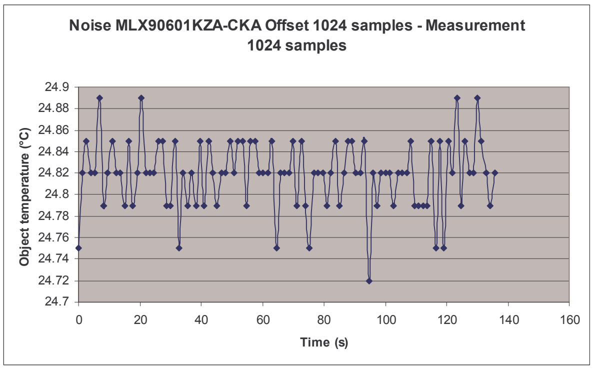
- Thermopile Johnson noise;
- Thermistor Johnson noise;
- Amplifier noise of the infrared signal processing chip;
- Digital switching noise of the infrared signal processing chip.

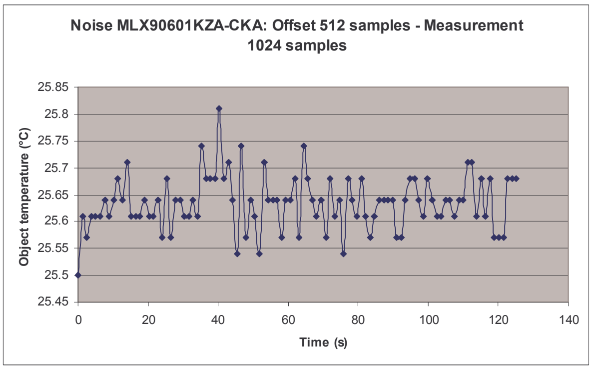
Amplifier offset of the ambient and object channels is measured at regular intervals (every 19 seconds according to factory setting) and is subtracted from the measurements. As such, the noise on the measured object temperature results from the noise on 4 measurements:

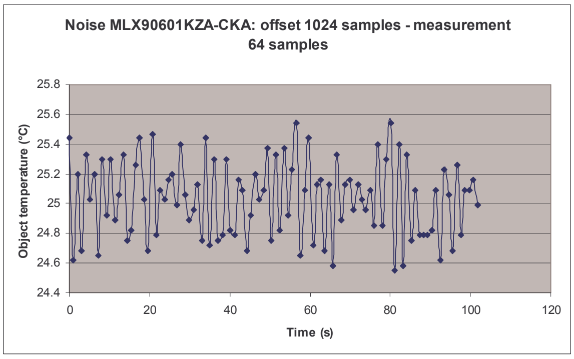
- amplifier offset of ambient channel;
- amplifier offset of object channel;
- thermistor voltage;
- thermopile voltage.

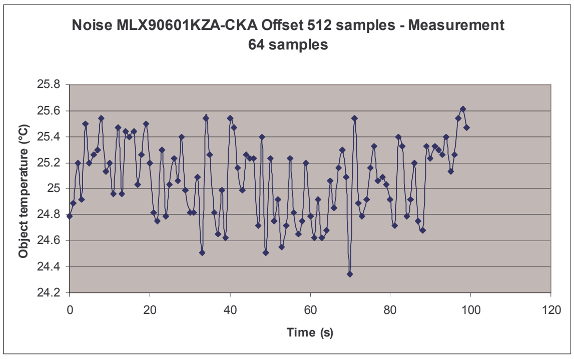
To improve the measurement accuracy, the weak sensor signals are digitally averaged. The averaging is implemented as a digital Low Pass Filter. For the thermistor and thermopile measurements, the digital Low Pass Filter can be programmed to average over 64, 128, 256, 512 or 1024 samples. For the offset measurements, the user can select between 512 and 1024 samples per measurement. By programming the Low Pass Filter, the user can trade speed for accuracy (see also paragraph 6.2).

The impact of the Low Pass Filter settings on the noise is illustrated by following typical measurements on a module of type MLX90601KZA-CLA:









The following table gives an overview of the noise measurements in the 4 figures:

LPF setting: offset	1024	512	1024	512
LPF setting: measurement	1024	1024	64	64
Standard deviation measured To values, °C	0.03	0.05	0.26	0.29
6 x standard deviation (peak-to peak value), °C	0.19	0.30	1.53	1.75

6.4 EMC sensitivity

Measurements were carried out on two typical modules of the family of MLX90601.
The measurements were carried out in a mini-TEM (Transverse Electro-Magnetic field) cell.
RF (Radio Frequency) field strengths of 100 V/m were applied.
The module was oriented inside the cell in such a way that:

- The electrical field lines run along the longitudinal axis of the thermometer module.
- The magnetic field is perpendicular to the electrical field and in the plane of the printed wiring board of the module.

It was found that the sensitivity of the modules to RF radiation was highest for this orientation of the module in the TEM cell.
The RF frequency was swept from 1 to 1000 MHz.

Results:

- Tambient is not sensitive to the applied RF fields, except for a small effect between 950 MHz and 1000 MHz.
- Tobject is quite sensitive to frequencies above 825 MHz. The two samples measured (two different circuit board designs) showed maximum errors of -9°C respectively +25°C.
- It has to be noted that the impact of RF radiation depends very strongly on the board design. The measurement results here indicated should be interpreted as typical results.

7 ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

8 FAQ

Q: Does absolute accuracy of the temperature measurement increase when the temperature range is decreased?
A: No. The main error on absolute accuracy comes from the limited precision of the calibration. Calibration accuracy is the same for all modules of the MLX90601 family.

Q: Can the temperature ranges be changed?
A: Yes, the MLX90313 is a programmable device. Melexis selected a limited set of standard ranges that will fit the majority of applications in order to limit delivery times. However, if necessary, the ranges can be adapted for particular applications. Starting from a standard factory-calibrated module, the temperature range can be reduced without re-calibration, using the Melexis EVB90601 (Evaluation Board). In order to increase the temperature range, re-calibration is needed. Small volumes of modules can be re-calibrated by the customer using the EVB90601, if the customer disposes over a precision bath (ambient calibration) and a precision black body (object calibration). In case of large volumes, Melexis can develop a custom calibration process. Please contact Melexis customer support.

Q: Can the Field of View (FOV) be made smaller?
A: Yes. The MLX90601KZA-CLA is a standard factory-calibrated product with narrow FOV equal to 40°. In this standard product, the FOV has been reduced by the application of a tube over the sensor window. Reduction of FOV below 40° requires infrared optical elements (lenses or mirrors). If the field of view of a factory-calibrated module is changed by adding a lens or a mirror, the module will be out of calibration. For small volumes, a customer can re-calibrate using the Melexis EVB90601 (Evaluation Board). For high volumes, Melexis can provide custom calibrated devices. Please contact Melexis customer support.

Q: IR radiation is comparable to light. Does the object have to be black?
A: No, the optical behavior of materials in the visible spectrum differs considerably from the optical behavior in the infrared spectrum. Water and glass are opaque to infrared, and thus it is perfectly possible to measure their temperature using an infrared sensor. Air is transparent to infrared and does not influence the measurement.

Q: Can the MLX90601 thermometers be used to measure high temperatures (>180°C) ?
A: The MLX90601 thermometers are optimized for measurements in the range [-40°C, +150°C]. In order to have the most correct measurements, non-influenced by sun-light, the silicon window is equipped with a long-wavelength pass filter having a cut-on wavelength of 5.5 micrometer. This filter blocks visible light and near-infrared emitted by the sun. At the same time, the filter strongly limits the possibilities to measure high temperatures. As the object temperature rises, the peak wavelength of the infrared emission spectrum shifts to shorter wavelengths, and an increasing part of the emitted energy is blocked by the long wavelength pass-filter. A peak wavelength of 5.5 micrometer is reached at 250°C; the accuracy of the measurement will be impacted already below 250°C, as a quite important part of the energy emitted by the object gets blocked. The conclusion is that the standard modules of the MLX90601 family are not suited for measurement of temperatures above 180°C.

9 Appendix A: Digital Interfacing to "non-flex" IR modules

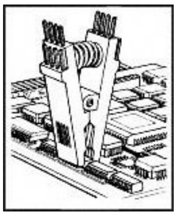
The MLX90601EZA-BAA and MLX90601EZA-DAA do not have a 10 pin connector with the SPI interface signals. To digitally communicate with the module, an SOIC clip can be mounted directly onto the back of the 90313 ASIC. The SOIC clip itself can be connected to the EVB board by means of a flat cable.

Melexis does not supply these cables; references to the components are given below so the user can build a cable himself.

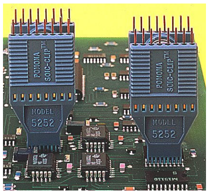
9.1 Component references

9.1.1 SOIC-20 clip

Manufacturer: 3M
Products: - 3M[T] SOIC Wide Test Clip, 20-pin, alloy, order code 923665-18
- 3M[T] SOIC Wide Test Clip, 20-pin, gold, order code 923665-20



Manufacturer: Pomona
Product: Pomona SOIC clip, 20 pin, model 5253



Attention: when the clip is mounted onto the ASIC, temperature measurement values will be influenced, and the module may be out of specification. Measured values when using the SOIC test clip must be interpreted purely indicative.

9.1.2 Flat cable

10 Conductors, 28 AWG, Stranded, 1mm Pitch, Gray Color, Round Conductor Flat Cable

Manufacturer: 3M
Order code: 3625/10

9.1.3 Connector mating 1mm pitch flat cable and EVB board connector

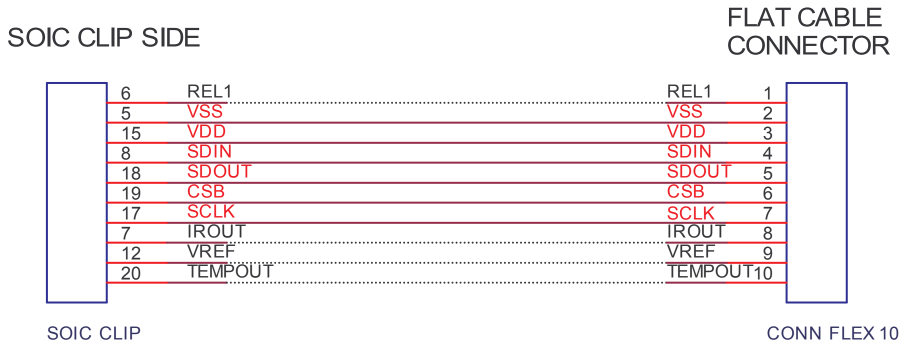
Manufacturer : 3M
Order code : 3M™ 2mm X 2mm Wire mount Socket, 152210-0100-GB, or equivalent.

9.1.4 Flexible circuit board module connector

Manufacturer Molex
Order Code Connector FFC/FPC 1mm 10 Position R/A SMT 52207-1090

Additional flex connectors are available by Molex and others in various configurations, i.e. 90 degree angle, through hole, surface mount etc.

9.2 SPI Communication cable pin-out



Note: dashed connections are purely optional. They are not necessary to establish SPI communication.

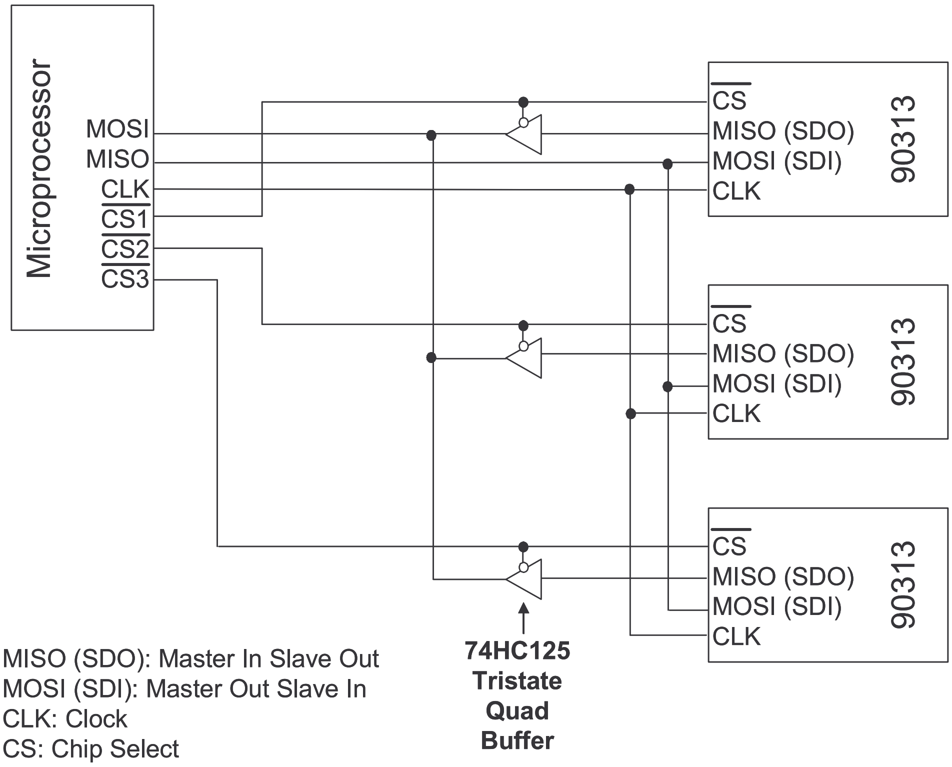
10 Appendix B: List of known bugs

10.1 Solution to SDO tristate function bug

The tristate-function of the SDO line of the modules does not function: this is a known bug in the design of the 90313 interface chip. The next generation of the chip, the 90321, which is foreseen to be brought in production by end 2005, will have solved the problem.

In the meantime, the problem can be solved by using a tristate buffer circuit, such as the 74HC125 tristate quad buffer.

The diagram below shows how to use this circuit with the Melexis modules.



10.2 Indication of "fatal error" when using the module MLX90601with the evaluation-board EVB 90601

A “fatal error” indication can appear on the output (SPI temperature output as well as PWM temperature output) if one reads the EEPROM while reading out temperature. This error is the consequence of a small bug in the design. To avoid the problem during the use of the evaluation board, it is required to turn of “Automatically download EEPROM” in the menu Configuration/Preferences/Miscellaneous of the evaluation board EVB 90601.

10.3 Sensitivity to rest-voltage on the supply line when module is turned off

The phenomenon occurs under following conditions:

- when turned off, there is a rest-voltage on the power supply line of the module;
- AND the module is used at high ambient temperature (>60°C).

After power on, the SPI readout of the temperature gives “ambient underflow”. The error remains until the power is cycled.

The problem is due to a bug in the hardware of the MLX90313 infrared signal conditioning ASIC. In particular when used at high ambient temperature, the ASIC is sensitive to rest-voltages on the supply line during power off. By reducing the rest-value to a very low voltage (order of 10 mV), the problem can be avoided.

10.4 Remark on power-on

During power-on, it is best to keep the CS pin at high level (inactive). Details on power-on timing can be found in paragraph 6.2 on timing of the MLX90601.

11 Disclaimer

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