Escuela Universitaria Politécnica - La Almunia
Centro adscrito
Universidad Zaragoza

ESCUELA UNIVERSITARIA POLITÉCNICA

DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)

Anexos

Diseño de un Sistema Automático para la Evaluación de la Calidad de la Fruta

424.18.67

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WIKIPEDIA

Plantilla:RGB

#D0D0D0

Documentación de la plantilla

Uso

Las plantilla {{RGB}} es una ayuda para que el editor pueda usar libremente los colores sin conocimiento de los valores RGB.

```
{{RGB|valor}}
```

Esta plantilla devuelve un valor hexadecimal para un color en específico, basta con reemplazar el «valor» con alguno de los colores permitidos y puede agregarse un dígito para aclararlo. La tabla completa de los colores permitidos, se encuentra abajo.

Además de los colores que figuran en la tabla, puede usarse el blanco y el negro.

Por ejemplo:

- `{{RGB|blanco}} devuelve: #FFFFFF`
- `{{RGB|negro}}  devuelve: #000000`
- `{{RGB|uva}}    devuelve: #622989`
- `{{RGB|rojo6}}  devuelve: #D54E4E`
- `{{RGB|cian3}} devuelve: #8DFAE9`
- `{{RGB|gris1}} devuelve: #FCFAFB`
- `{{RGB|gris3}} devuelve: #ECE6E9`
- `{{RGB|gris5}} devuelve: #CBC5C8`
- `{{RGB|gris7}} devuelve: #999496`
- `{{RGB|gris9}} devuelve: #575355`

Para que la plantilla se sustituya completamente encabece la plantilla con **subst:**

- `{{subst:RGB|azul}} devuelve: #0C389E`

50 colores en 11 tonalinades cada uno, además del blanco y el negro										
rojo	rojo9	rojo8	rojo7	rojo6	rojo5	rojo4	rojo3	rojo2	rojo1	rojo0
rosa	rosa9	rosa8	rosa7	rosa6	rosa5	rosa4	rosa3	rosa2	rosa1	rosa0
cereza	cereza9	cereza8	cereza7	cereza6	cereza5	cereza4	cereza3	cereza2	cereza1	cereza0
fuego	fuego9	fuego8	fuego7	fuego6	fuego5	fuego4	fuego3	fuego2	fuego1	fuego0
tampico	tampico9	tampico8	tampico7	tampico6	tampico5	tampico4	tampico3	tampico2	tampico1	tampico0
naranja	naranja9	naranja8	naranja7	naranja6	naranja5	naranja4	naranja3	naranja2	naranja1	naranja0
arenque	arenque9	arenque8	arenque7	arenque6	arenque5	arenque4	arenque3	arenque2	arenque1	arenque0
mandarina	mandarina9	mandarina8	mandarina7	mandarina6	mandarina5	mandarina4	mandarina3	mandarina2	mandarina1	mandarina0
caoba	caoba9	caoba8	caoba7	caoba6	caoba5	caoba4	caoba3	caoba2	caoba1	caoba0
chocolate	chocolate9	chocolate8	chocolate7	chocolate6	chocolate5	chocolate4	chocolate3	chocolate2	chocolate1	chocolate0
cacao	cacao9	cacao8	cacao7	cacao6	cacao5	cacao4	cacao3	cacao2	cacao1	cacao0
bronce	bronce9	bronce8	bronce7	bronce6	bronce5	bronce4	bronce3	bronce2	bronce1	bronce0
centeno	centeno9	centeno8	centeno7	centeno6	centeno5	centeno4	centeno3	centeno2	centeno1	centeno0
amarillo	amarillo9	amarillo8	amarillo7	amarillo6	amarillo5	amarillo4	amarillo3	amarillo2	amarillo1	amarillo0
cromo	cromo9	cromo8	cromo7	cromo6	cromo5	cromo4	cromo3	cromo2	cromo1	cromo0
lirio	lirio9	lirio8	lirio7	lirio6	lirio5	lirio4	lirio3	lirio2	lirio1	lirio0
hiel	hiel9	hiel8	hiel7	hiel6	hiel5	hiel4	hiel3	hiel2	hiel1	hiel0
cerveza	cerveza9	cerveza8	cerveza7	cerveza6	cerveza5	cerveza4	cerveza3	cerveza2	cerveza1	cerveza0
kaki	kaki9	kaki8	kaki7	kaki6	kaki5	kaki4	kaki3	kaki2	kaki1	kaki0
oliva	oliva9	oliva8	oliva7	oliva6	oliva5	oliva4	oliva3	oliva2	oliva1	oliva0
bosque	bosque9	bosque8	bosque7	bosque6	bosque5	bosque4	bosque3	bosque2	bosque1	bosque0
verde	verde9	verde8	verde7	verde6	verde5	verde4	verde3	verde2	verde1	verde0
pasto	pasto9	pasto8	pasto7	pasto6	pasto5	pasto4	pasto3	pasto2	pasto1	pasto0
loro	loro9	loro8	loro7	loro6	loro5	loro4	loro3	loro2	loro1	loro0

kiwi	kiwi9	kiwi8	kiwi7	kiwi6	kiwi5	kiwi4	kiwi3	kiwi2	kiwi1	kiwi0
lima	lima9	lima8	lima7	lima6	lima5	lima4	lima3	lima2	lima1	lima0
manzana	manzana9	manzana8	manzana7	manzana6	manzana5	manzana4	manzana3	manzana2	manzana1	manzana0
liquen	liquen9	liquen8	liquen7	liquen6	liquen5	liquen4	liquen3	liquen2	liquen1	liquen0
turquesa	turquesa9	turquesa8	turquesa7	turquesa6	turquesa5	turquesa4	turquesa3	turquesa2	turquesa1	turquesa0
cian	cian9	cian8	cian7	cian6	cian5	cian4	cian3	cian2	cian1	cian0
mar	mar9	mar8	mar7	mar6	mar5	mar4	mar3	mar2	mar1	mar0
cobalto	cobalto9	cobalto8	cobalto7	cobalto6	cobalto5	cobalto4	cobalto3	cobalto2	cobalto1	cobalto0
noche	noche9	noche8	noche7	noche6	noche5	noche4	noche3	noche2	noche1	noche0
añil	añil9	añil8	añil7	añil6	añil5	añil4	añil3	añil2	añil1	añil0
enlace	enlace9	enlace8	enlace7	enlace6	enlace5	enlace4	enlace3	enlace2	enlace1	enlace0
azul	azul9	azul8	azul7	azul6	azul5	azul4	azul3	azul2	azul1	azul0
rey	rey9	rey8	rey7	rey6	rey5	rey4	rey3	rey2	rey1	rey0
agua	agua9	agua8	agua7	agua6	agua5	agua4	agua3	agua2	agua1	agua0
celeste	celeste9	celeste8	celeste7	celeste6	celeste5	celeste4	celeste3	celeste2	celeste1	celeste0
violeta	violeta9	violeta8	violeta7	violeta6	violeta5	violeta4	violeta3	violeta2	violeta1	violeta0
uva	uva9	uva8	uva7	uva6	uva5	uva4	uva3	uva2	uva1	uva0
lavanda	lavanda9	lavanda8	lavanda7	lavanda6	lavanda5	lavanda4	lavanda3	lavanda2	lavanda1	lavanda0
glicina	glicina9	glicina8	glicina7	glicina6	glicina5	glicina4	glicina3	glicina2	glicina1	glicina0
dulce	dulce9	dulce8	dulce7	dulce6	dulce5	dulce4	dulce3	dulce2	dulce1	dulce0
ciruela	ciruela9	ciruela8	ciruela7	ciruela6	ciruela5	ciruela4	ciruela3	ciruela2	ciruela1	ciruela0
fucsia	fucsia9	fucsia8	fucsia7	fucsia6	fucsia5	fucsia4	fucsia3	fucsia2	fucsia1	fucsia0
fresa	fresa9	fresa8	fresa7	fresa6	fresa5	fresa4	fresa3	fresa2	fresa1	fresa0
nube	nube9	nube8	nube7	nube6	nube5	nube4	nube3	nube2	nube1	nube0
cemento	cemento9	cemento8	cemento7	cemento6	cemento5	cemento4	cemento3	cemento2	cemento1	cemento0
gris	gris9	gris8	gris7	gris6	gris5	gris4	gris3	gris2	gris1	gris0

Esta documentación está transcluida desde Plantilla:RGB/doc.
Los editores pueden experimentar en la zona de pruebas (crear) *y en los casos de prueba* (crear) *de la plantilla.*
Por favor, añade las categorías en la subpágina de documentación. Subpáginas de esta plantilla.

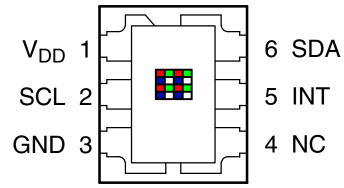
TCS3471
COLOR LIGHT-TO-DIGITAL CONVERTER

TAOS115 – MARCH 2011

Features

- Color Light Sensing
  - Programmable Analog Gain, Integration Time, and Interrupt Function with Upper and Lower Thresholds
  - Resolution Up to 16 Bits
  - Very High Sensitivity — Ideally Suited for Operation Behind Dark Glass
  - Up to 1,000,000:1 Dynamic Range
- Low Power Wait State
  - 65 μA Typical Current
  - Wait Timer is Programmable from 2.4 ms to > 7 Seconds
- I^2C Interface Compatible
  - Up to 400 kHz (I^2C Fast Mode)
- Dedicated Interrupt Pin
- Pin and Register Set Compatible with the TCS3x7x Family of Devices
- Small 2 mm × 2.4 mm Dual Flat No-Lead Package
- Sleep Mode — 2.5 μA Typical Current

PACKAGE FN
DUAL FLAT NO-LEAD
(TOP VIEW)



Package Drawing Not to Scale

Applications

- Color Temperature Sensing
- RGB LED Backlight Control
- Color Display Closed-Loop Feedback Control
- Ambient Light Sensing for Display Brightness Control
- Industrial Process Control
- Medical Diagnostics

End Products and Market Segments

- HDTVs, Mobile Handsets, Tablets, Laptops, Monitors, PMP (Portable Media Payers)
- Medical Instrumentation
- Consumer Toys
- Industrial/Commercial Lighting

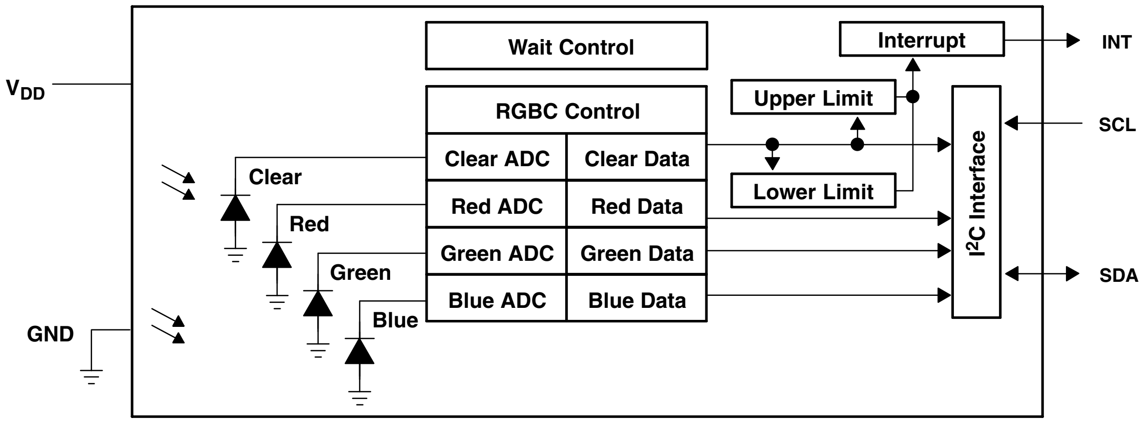
Description

The TCS3471 family of devices provides red, green, blue, and clear light sensing (RGBC) that detects light intensity under a variety of lighting conditions and through a variety of attenuation materials. An internal state machine provides the ability to put the device into a low power mode in between RGBC measurements providing very low average power consumption.

The TCS3471 is directly useful in lighting conditions containing minimal IR content such as LED RGB backlight control, reflected LED color sampler, or fluorescent light color temperature detector. With the addition of an IR blocking filter, the device is an excellent ambient light sensor, color temperature monitor, and general purpose color sensor.

Texas Advanced Optoelectronic Solutions Inc.
1001 Klein Road • Suite 300 • Plano, TX 75074 • (972) 673-0759
www.taosinc.com

Functional Block Diagram



Detailed Description

The TCS3471 light-to-digital device contains a 4 × 4 photodiode array, integrating amplifiers, ADCs, accumulators, clocks, buffers, comparators, a state machine, and an I^2C interface. The 4 × 4 photodiode array is composed of red-filtered, green-filtered, blue-filtered, and clear photodiodes — four of each type. Four integrating ADCs simultaneously convert the amplified photodiode currents to a digital value providing up to 16 bits of resolution. Upon completion of the conversion cycle, the conversion result is transferred to the data registers. The transfers are double-buffered to ensure that the integrity of the data is maintained. Communication to the device is accomplished through a fast (up to 400 kHz), two-wire I^2C serial bus for easy connection to a microcontroller or embedded controller.

The TCS3471 provides a separate pin for level-style interrupts. When interrupts are enabled and a pre-set value is exceeded, the interrupt pin is asserted and remains asserted until cleared by the controlling firmware. The interrupt feature simplifies and improves system efficiency by eliminating the need to poll a sensor for a light intensity value. An interrupt is generated when the value of an RGBC conversion exceeds either an upper or lower threshold. In addition, a programmable interrupt persistence feature allows the user to determine how many consecutive exceeded thresholds are necessary to trigger an interrupt.

Terminal Functions

TERMINAL NAME	TERMINAL NO.	TYPE	DESCRIPTION
GND	3		Power supply ground. All voltages are referenced to GND.
INT	5	O	Interrupt — open drain.
NC	4		Do not connect
SCL	2	I	I^2C serial clock input terminal — clock signal for I^2C serial data.
SDA	6	I/O	I^2C serial data I/O terminal — serial data I/O for I^2C .
V_{DD}	1		Supply voltage.

Available Options

DEVICE	ADDRESS	PACKAGE – LEADS	INTERFACE DESCRIPTION	ORDERING NUMBER
TCS34711†	0x39	FN–6	I^2C Vbus = V_{DD} Interface	TCS34711FN
TCS34713†	0x39	FN–6	I^2C Vbus = 1.8 V Interface	TCS34713FN
TCS34715†	0x29	FN–6	I^2C Vbus = V_{DD} Interface	TCS34715FN
TCS34717	0x29	FN–6	I^2C Vbus = 1.8 V Interface	TCS34717FN

† Contact TAOS for availability.

Absolute Maximum Ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1) . . . . 3.8 V
Digital output voltage range, V_O . . . . –0.5 V to 3.8 V
Digital output current, I_O . . . . –1 mA to 20 mA
Storage temperature range, T_{stg} . . . . –40°C to 85°C
ESD tolerance, human body model . . . . 2000 V

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltages are with respect to GND.

Recommended Operating Conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	2.7	3	3.3	V
Operating free-air temperature, T_A	–30		70	°C

Operating Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{DD}	Supply current	Active		235	330	µA
		Wait mode		65		
		Sleep mode — no I^2C activity		2.5	10	
V_{OL}	INT, SDA output low voltage	3 mA sink current	0		0.4	V
		6 mA sink current	0		0.6	
I_{LEAK}	Leakage current, SDA, SCL, INT pins		–5		5	µA
I_{LEAK}	Leakage current, LDR pin		–1		+10	µA
V_{IH}	SCL, SDA input high voltage	TCS34711 & TCS34715	0.7 V_{DD}			V
		TCS34713 & TCS34717	1.25			
V_{IL}	SCL, SDA input low voltage	TCS34711 & TCS34715			0.3 V_{DD}	V
		TCS34713 & TCS34717			0.54	

Optical Characteristics, V_{DD} = 3 V, T_A = 25°C, GAIN = 16, ATIME = 0xF6 (unless otherwise noted) (see Note 1)

PARAMETER		TEST CONDITIONS	Red Channel			Green Channel			Blue Channel			Clear Channel			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
R_e	Irradiance responsivity	λ_D = 465 nm See Note 2	0%		15%	10%		42%	65%		88%	19.2	24	28.8	(counts/ µW/ cm^2)
		λ_D = 525 nm See Note 3	8%		25%	60%		85%	9%		35%	22.4	28	33.6	
		λ_D = 625 nm See Note 4	85%		110%	0%		15%	5%		25%	27.2	34	40.8	

NOTES: 1. The percentage shown represents the ratio of the respective red, green, or blue channel value to the clear channel value.
2. The 465 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 465 nm, spectral halfwidth $\Delta\lambda½$ = 22 nm, and luminous efficacy = 75 lm/W.
3. The 525 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 525 nm, spectral halfwidth $\Delta\lambda½$ = 35 nm, and luminous efficacy = 520 lm/W.
4. The 625 nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics: dominant wavelength λ_D = 625 nm, spectral halfwidth $\Delta\lambda½$ = 9 nm, and luminous efficacy = 155 lm/W.

RGBC Characteristics, V_{DD} = 3 V, T_A = 25°C, AGAIN = 16, AEN = 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Dark ADC count value	E_e = 0, AGAIN = 60×, ATIME = 0xD6 (100 ms)	0	1	5	counts
ADC integration time step size	ATIME = 0xFF	2.27	2.4	2.56	ms
ADC number of integration steps		1		256	steps
ADC counts per step		0		1024	counts
ADC count value	ATIME = 0xC0 (153.6 ms)	0		65535	counts
Gain scaling, relative to 1× gain setting	4×	3.8	4	4.2	%
	16×	15	16	16.8	
	60×	58	60	63	

Wait Characteristics, V_{DD} = 3 V, T_A = 25°C, Gain = 16, WEN = 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	CHANNEL	MIN	TYP	MAX	UNIT
Wait step size	WTIME = 0xFF		2.27	2.4	2.56	ms
Wait number of steps			1		256	steps

AC Electrical Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

PARAMETER†		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_{(SCL)}$	Clock frequency (I^2C only)		0		400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition		1.3			μs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.		0.6			μs
$t_{(SUSTA)}$	Repeated start condition setup time		0.6			μs
$t_{(SUSTO)}$	Stop condition setup time		0.6			μs
$t_{(HDDAT)}$	Data hold time		0			μs
$t_{(SUDAT)}$	Data setup time		100			ns
$t_{(LOW)}$	SCL clock low period		1.3			μs
$t_{(HIGH)}$	SCL clock high period		0.6			μs
t_F	Clock/data fall time				300	ns
t_R	Clock/data rise time				300	ns
C_i	Input pin capacitance				10	pF

† Specified by design and characterization; not production tested.

PARAMETER MEASUREMENT INFORMATION

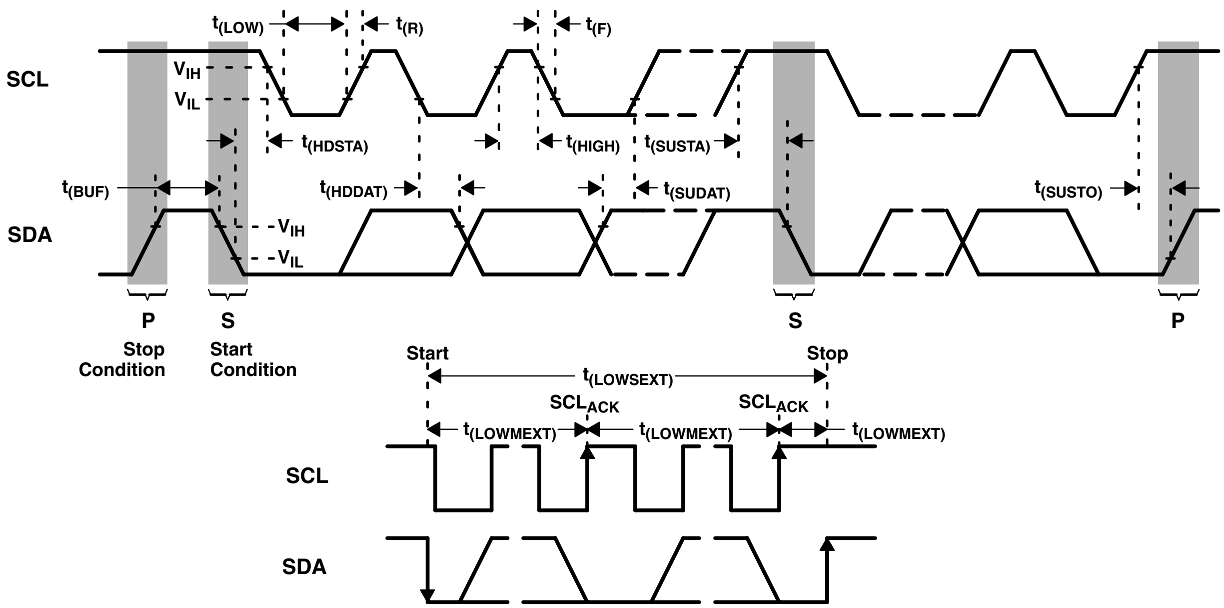


Figure 1. Timing Diagrams

TYPICAL CHARACTERISTICS

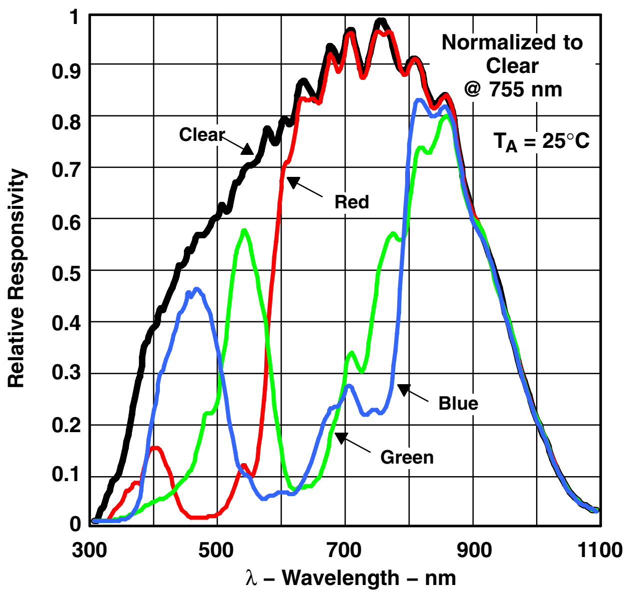


Figure 2

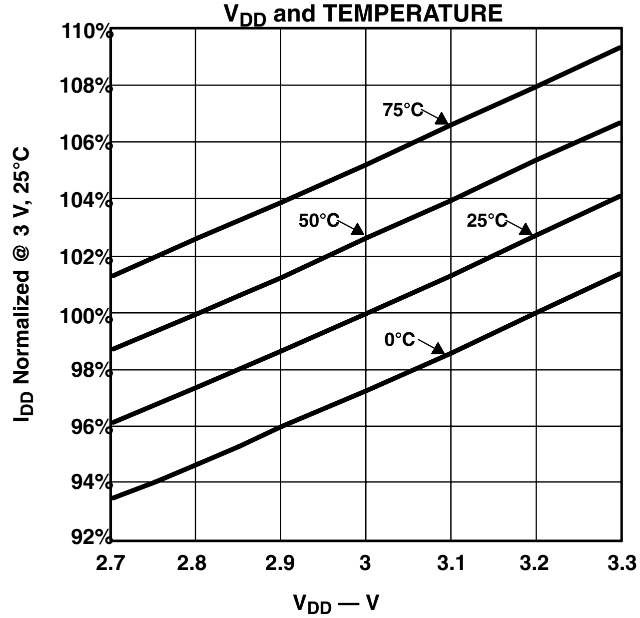


Figure 3

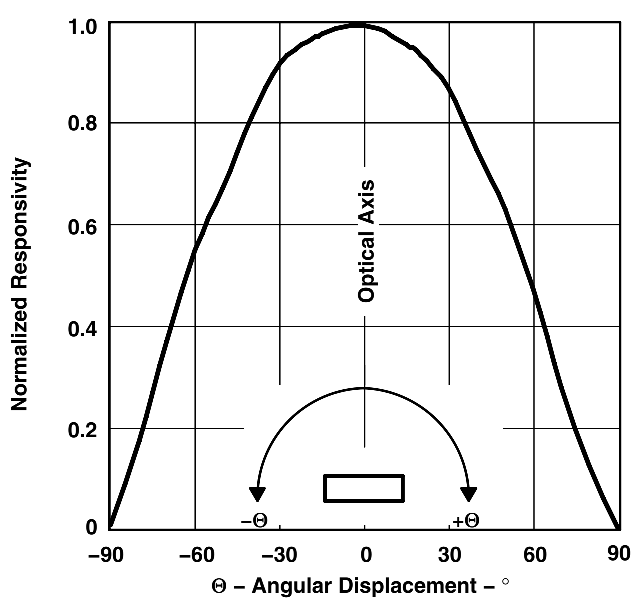


Figure 4

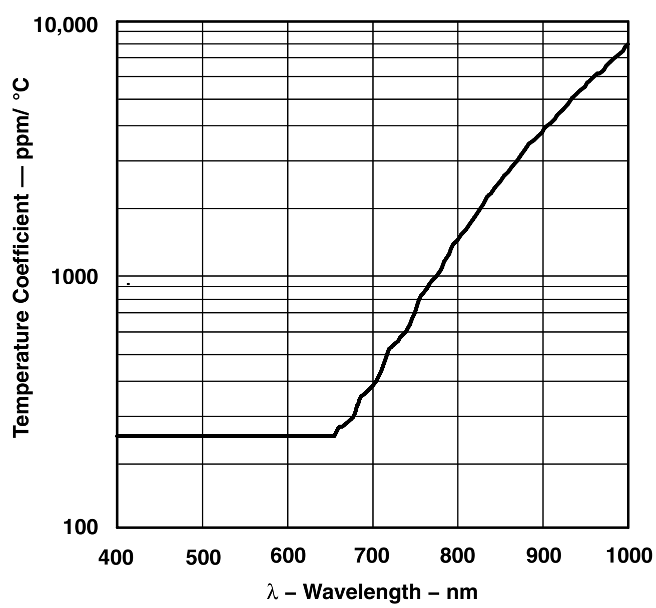


Figure 5

PRINCIPLES OF OPERATION

System State Machine

The TCS3471 provides control of RGBC and power management functionality through an internal state machine (Figure 6). After a power-on-reset, the device is in the sleep mode. As soon as the PON bit is set, the device will move to the start state. It will then continue through the Wait and RGBC states. If these states are enabled, the device will execute each function. If the PON bit is set to 0, the state machine will continue until all conversions are completed and then go into a low power sleep mode.

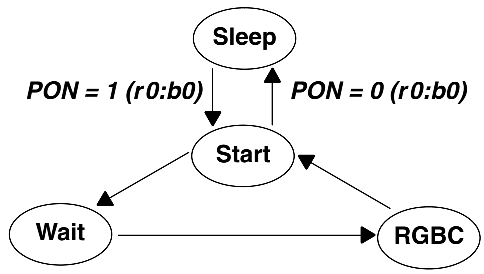


Figure 6. Simplified State Diagram

NOTE: In this document, the nomenclature uses the bit field name in italics followed by the register number and bit number to allow the user to easily identify the register and bit that controls the function. For example, the power on (PON) is in register 0, bit 0. This is represented as *PON (r0:b0)*.

RGBC Operation

The RGBC engine contains RGBC gain control (AGAIN) and four integrating analog-to-digital converters (ADC) for the RGBC photodiodes. The RGBC integration time (ATIME) impacts both the resolution and the sensitivity of the RGBC reading. Integration of all four channels occurs simultaneously and upon completion of the conversion cycle, the results are transferred to the color data registers. This data is also referred to as channel *count*.

The transfers are double-buffered to ensure that invalid data is not read during the transfer. After the transfer, the device automatically moves to the next state in accordance with the configured state machine.

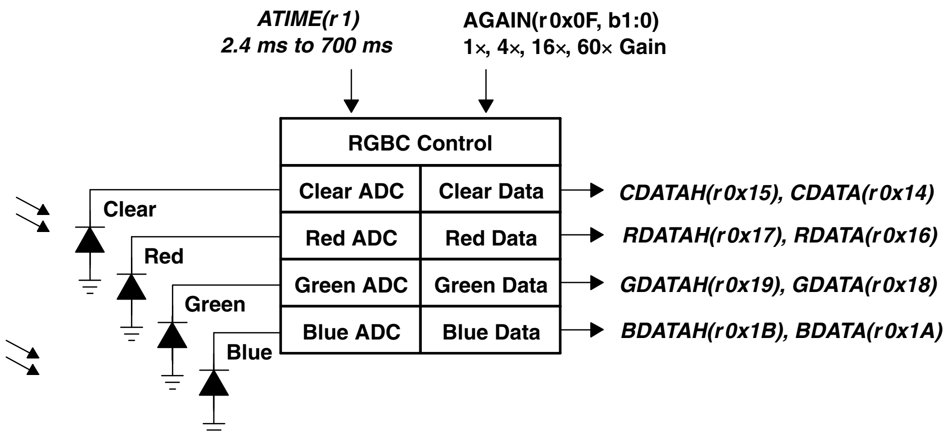


Figure 7. RGBC Operation

The registers for programming the integration and wait times are a 2's compliment values. The actual time can be calculated as follows:

ATIME = 256 − Integration Time / 2.4 ms

Inversely, the time can be calculated from the register value as follows:

Integration Time = 2.4 ms × (256 − ATIME)

For example, if a 100-ms integration time is needed, the device needs to be programmed to:

256 − (100 / 2.4) = 256 − 42 = 214 = 0xD6

Conversely, the programmed value of 0xC0 would correspond to:

(256 − 0xC0) × 2.4 = 64 × 2.4 = 154 ms.

Interrupts

The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for light intensity values outside of a user-defined range. While the interrupt function is always enabled and it's status is available in the status register (0x13), the output of the interrupt state can be enabled using the RGBC interrupt enable (AIEN) field in the enable register (0x00).

Two 16-bit interrupt threshold registers allow the user to set limits below and above a desired light level range. An interrupt can be generated when the RGBC Clear data (CDATA) falls outside of the desired light level range, as determined by the values in the RGBC interrupt low threshold registers (AILTx) and RGBC interrupt high threshold registers (AIHTx). It is important to note that the low threshold value must be less than the high threshold value for proper operation.

To further control when an interrupt occurs, the device provides a persistence filter. The persistence filter allows the user to specify the number of consecutive out-of-range RGBC occurrences before an interrupt is generated. The persistence register (0x0C) allows the user to set the persistence (APERS) value. See the persistence register for details on the persistence filter values. Once the persistence filter generates an interrupt, it will continue until a special function interrupt clear command is received (see command register).

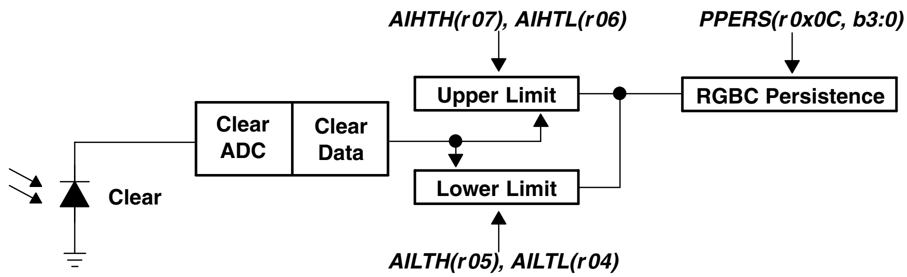


Figure 8. Programmable Interrupt

State Diagram

Figure 9 shows a more detailed flow for the state machine. The device starts in the sleep mode. The PON bit is written to enable the device. A 2.4-ms delay will occur before entering the start state. If the WEN bit is set, the state machine will cycle through the wait state. If the WLONG bit is set, the wait cycles are extended by 12× over normal operation. When the wait counter terminates, the state machine will step to the RGBC state.

The AEN should always be set. In this case, a minimum of 1 integration time step should be programmed. The RGBC state machine will continue until it reaches the terminal count, at which point the data will be latched in the RGBC register and the interrupt set, if enabled.

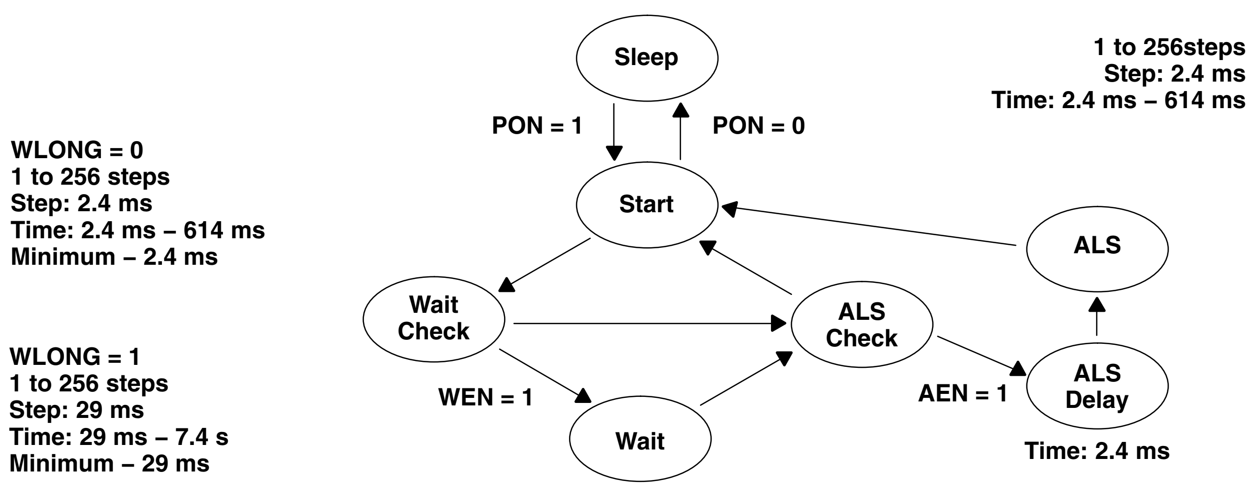


Figure 9. Expanded State Diagram

I²C Protocol

Interface and control are accomplished through an I²C serial compatible interface (standard or fast mode) to a set of registers that provide access to device control functions and output data. The devices support the 7-bit I²C addressing protocol.

The I²C standard provides for three types of bus transaction: read, write, and a combined protocol (Figure 10). During a write operation, the first byte written is a command byte followed by data. In a combined protocol, the first byte written is the command byte followed by reading a series of bytes. If a read command is issued, the register address from the previous command will be used for data access. Likewise, if the MSB of the command is not set, the device will write a series of bytes at the address stored in the last valid command with a register address. The command byte contains either control information or a 5-bit register address. The control commands can also be used to clear interrupts.

The I²C bus protocol was developed by Philips (now NXP). For a complete description of the I²C protocol, please review the NXP I²C design specification at http://www.i2c–bus.org/references/.

A	Acknowledge (0)
N	Not Acknowledged (1)
P	Stop Condition
R	Read (1)
S	Start Condition
Sr	Repeated Start Condition
W	Write (0)
...	Continuation of protocol
▩	Master-to-Slave
☐	Slave-to-Master

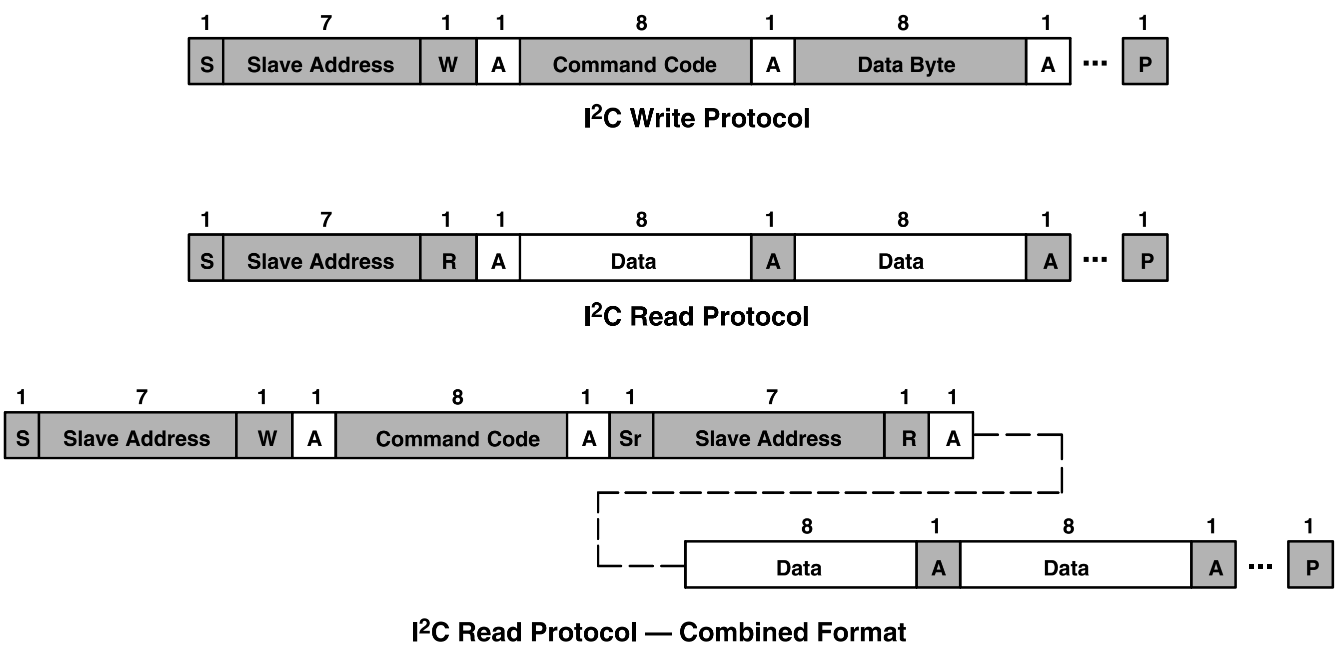


Figure 10. I²C Protocols

Register Set

The TCS3471 is controlled and monitored by data registers and a command register accessed through the serial interface. These registers provide for a variety of control functions and can be read to determine results of the ADC conversions. The register set is summarized in Table 1.

Table 1. Register Address

ADDRESS	RESISTER NAME	R/W	REGISTER FUNCTION	RESET VALUE
−−	COMMAND	W	Specifies register address	0x00
0x00	ENABLE	R/W	Enables states and interrupts	0x00
0x01	ATIME	R/W	RGBC ADC time	0xFF
0x03	WTIME	R/W	Wait time	0xFF
0x04	AILTL	R/W	RGBC interrupt low threshold low byte	0x00
0x05	AILTH	R/W	RGBC interrupt low threshold high byte	0x00
0x06	AIHTL	R/W	RGBC interrupt high threshold low byte	0x00
0x07	AIHTH	R/W	RGBC interrupt high threshold high byte	0x00
0x0C	PERS	R/W	Interrupt persistence filters	0x00
0x0D	CONFIG	R/W	Configuration	0x00
0x0F	CONTROL	R/W	Gain control register	0x00
0x12	ID	R	Device ID	ID
0x13	STATUS	R	Device status	0x00
0x14	CDATA	R	Clear ADC low data register	0x00
0x15	CDATAH	R	Clear ADC high data register	0x00
0x16	RDATA	R	Red ADC low data register	0x00
0x17	RDATAH	R	Red ADC high data register	0x00
0x18	GDATA	R	Green ADC low data register	0x00
0x19	GDATAH	R	Green ADC high data register	0x00
0x1A	BDATA	R	Blue ADC low data register	0x00
0x1B	BDATAH	R	Blue ADC high data register	0x00

The mechanics of accessing a specific register depends on the specific protocol used. See the section on I^2C protocols on the previous pages. In general, the COMMAND register is written first to specify the specific control/status register for the following read/write operations.

Command Register

The command registers specifies the address of the target register for future write and read operations.

Table 2. Command Register

	7	6	5	4	3	2	1	0	
COMMAND	COMMAND	TYPE		ADD					– –

FIELD	BITS	DESCRIPTION	
COMMAND	7	Select Command Register. Must write as 1 when addressing COMMAND register.	
TYPE	6:5	Selects type of transaction to follow in subsequent data transfers:	
		FIELD VALUE	**INTEGRATION TIME**
		00	Repeated byte protocol transaction
		01	Auto-increment protocol transaction
		10	Reserved — Do not use
		11	Special function — See description below
		Byte protocol will repeatedly read the same register with each data access. Block protocol will provide auto-increment function to read successive bytes.	
ADD	4:0	Address field/special function field. Depending on the transaction type, see above, this field either specifies a special function command or selects the specific control-status-register for following write and read transactions. The field values listed below apply only to special function commands:	
		FIELD VALUE	**READ VALUE**
		00000	Normal — no action
		00110	RGBC interrupt clear
		other	Reserved — Do not write
		RGBC Interrupt Clear. Clears any pending RGBC interrupt. This special function is self clearing.	

Enable Register (0x00)

The Enable register is used primarily to power the TCS3471 device on and off, and enable functions and interrupts as shown in Table 3.

Table 3. Enable Register

	7	6	5	4	3	2	1	0	
ENABLE	**Reserved**			**AIEN**	**WEN**	**Reserved**	**AEN**	**PON**	**Address 0x00**

FIELD	BITS	DESCRIPTION
Reserved	7:5	Reserved. Write as 0.
AIEN	4	RGBC interrupt enable. When asserted, permits RGBC interrupts to be generated.
WEN	3	Wait enable. This bit activates the wait feature. Writing a 1 activates the wait timer. Writing a 0 disables the wait timer.
Reserved	2	Reserved. Write as 0.
AEN	1	RGBC enable. This bit actives the two-channel ADC. Writing a 1 activates the RGBC. Writing a 0 disables the RGBC.
PON[1]	0	Power ON. This bit activates the internal oscillator to permit the timers and ADC channels to operate. Writing a 1 activates the oscillator. Writing a 0 disables the oscillator. During reads and writes over the I^2C interface, this bit is temporarily overridden and the oscillator is enabled, independent of the state of PON.

NOTE 1: A minimum interval of 2.4 ms must pass after PON is asserted before an RGBC can be initiated.

RGBC Timing Register (0x01)

The RGBC timing register controls the internal integration time of the RGBC clear and IR channel ADCs in 2.4-ms increments. Max RGBC Count = (256 − ATIME) × 1024 up to a maximum of 65535.

Table 4. RGBC Timing Register

FIELD	BITS	DESCRIPTION			
ATIME	7:0	**VALUE**	**INTEG_CYCLES**	**TIME**	**MAX COUNT**
		0xFF	1	2.4 ms	1024
		0xF6	10	24 ms	10240
		0xD5	42	101 ms	43008
		0xC0	64	154 ms	65535
		0x00	256	700 ms	65535

Wait Time Register (0x03)

Wait time is set 2.4 ms increments unless the WLONG bit is asserted, in which case the wait times are 12× longer. WTIME is programmed as a 2’s complement number.

Table 5. Wait Time Register

FIELD	BITS	DESCRIPTION			
WTIME	7:0	**REGISTER VALUE**	**WAIT TIME**	**TIME (WLONG = 0)**	**TIME (WLONG = 1)**
		0xFF	1	2.4 ms	0.029 sec
		0xAB	85	204 ms	2.45 sec
		0x00	256	614 ms	7.4 sec

RGBC Interrupt Threshold Registers (0x04 – 0x07)

The RGBC interrupt threshold registers provides the values to be used as the high and low trigger points for the comparison function for interrupt generation. If the value generated by the clear channel crosses below the lower threshold specified, or above the higher threshold, an interrupt is asserted on the interrupt pin.

Table 6. RGBC Interrupt Threshold Registers

REGISTER	ADDRESS	BITS	DESCRIPTION
AILTL	0x04	7:0	RGBC clear channel low threshold lower byte
AILTH	0x05	7:0	RGBC clear channel low threshold upper byte
AIHTL	0x06	7:0	RGBC clear channel high threshold lower byte
AIHTH	0x07	7:0	RGBC clear channel high threshold upper byte

Persistence Register (0x0C)

The persistence register controls the filtering interrupt capabilities of the device. Configurable filtering is provided to allow interrupts to be generated after each integration cycle or if the integration has produced a result that is outside of the values specified by the threshold register for some specified amount of time.

Table 7. Persistence Register

	7	6	5	4	3	2	1	0	
PERS	**Reserved**				**APERS**				**Address 0x0C**

FIELD	BITS	DESCRIPTION		
Reserved	7:4	Reserved		
APERS	3:0	Interrupt persistence. Controls rate of interrupt to the host processor.		
		FIELD VALUE	**MEANING**	**INTERRUPT PERSISTENCE FUNCTION**
		0000	Every	Every RGBC cycle generates an interrupt
		0001	1	1 clear channel value outside of threshold range
		0010	2	2 clear channel consecutive values out of range
		0011	3	3 clear channel consecutive values out of range
		0100	5	5 clear channel consecutive values out of range
		0101	10	10 clear channel consecutive values out of range
		0110	15	15 clear channel consecutive values out of range
		0111	20	20 clear channel consecutive values out of range
		1000	25	25 clear channel consecutive values out of range
		1001	30	30 clear channel consecutive values out of range
		1010	35	35 clear channel consecutive values out of range
		1011	40	40 clear channel consecutive values out of range
		1100	45	45 clear channel consecutive values out of range
		1101	50	50 clear channel consecutive values out of range
		1110	55	55 clear channel consecutive values out of range
		1111	60	60 clear channel consecutive values out of range

Configuration Register (0x0D)

The configuration register sets the wait long time.

Table 8. Configuration Register

	7	6	5	4	3	2	1	0	
CONFIG	Reserved						WLONG	Reserved	Address 0x0D

FIELD	BITS	DESCRIPTION
Reserved	7:2	Reserved. Write as 0.
WLONG	1	Wait Long. When asserted, the wait cycles are increased by a factor 12× from that programmed in the WTIME register.
Reserved	0	Reserved. Write as 0.

Control Register (0x0F)

The Control register provides eight bits of miscellaneous control to the analog block. These bits typically control functions such as gain settings and/or diode selection.

Table 9. Control Register

	7	6	5	4	3	2	1	0	
CONTROL	Reserved						AGAIN		Address 0x0F

FIELD	BITS	DESCRIPTION	
Reserved	7:2	Reserved. Write bits as 0	
AGAIN	1:0	RGBC Gain Control.	
		FIELD VALUE	**RGBC GAIN VALUE**
		00	1× gain
		01	4× gain
		10	16× gain
		11	60× gain

ID Register (0x12)

The ID Register provides the value for the part number. The ID register is a read-only register.

Table 10. ID Register

	7	6	5	4	3	2	1	0	
ID	ID								Address 0x12

FIELD	BITS	DESCRIPTION	
ID	7:0	Part number identification	0x14 = TCS34711 & TCS34715
			0x1D = TCS34713 & TCS34717

Status Register (0x13)

The Status Register provides the internal status of the device. This register is read only.

Table 11. Status Register

	7	6	5	4	3	2	1	0	
STATUS	Reserved			AINT	Reserved			AVALID	Address 0x13

FIELD	BIT	DESCRIPTION
Reserved	7:5	Reserved.
AINT	4	RGBC clear channel Interrupt.
Reserved	3:1	Reserved.
AVALID	0	RGBC Valid. Indicates that the RGBC channels have completed an integration cycle.

RGBC Channel Data Registers (0x14 – 0x1B)

Clear, red, green, and blue data is stored as 16-bit values. To ensure the data is read correctly, a two-byte read I^2C transaction should be used with a read word protocol bit set in the command register. With this operation, when the lower byte register is read, the upper eight bits are stored into a shadow register, which is read by a subsequent read to the upper byte. The upper register will read the correct value even if additional ADC integration cycles end between the reading of the lower and upper registers.

Table 12. ADC Channel Data Registers

REGISTER	ADDRESS	BITS	DESCRIPTION
CDATA	0x14	7:0	Clear data low byte
CDATAH	0x15	7:0	Clear data high byte
RDATA	0x16	7:0	Red data low byte
RDATAH	0x17	7:0	Red data high byte
GDATA	0x18	7:0	Green data low byte
GDATAH	0x19	7:0	Green data high byte
BDATA	0x1A	7:0	Blue data low byte
BDATAH	0x1B	7:0	Blue data high byte

APPLICATION INFORMATION: HARDWARE

Typical Hardware Application

A typical hardware application circuit is shown in Figure 11. A 1-μF low-ESR decoupling capacitor should be placed as close as possible to the V_{DD} pin.

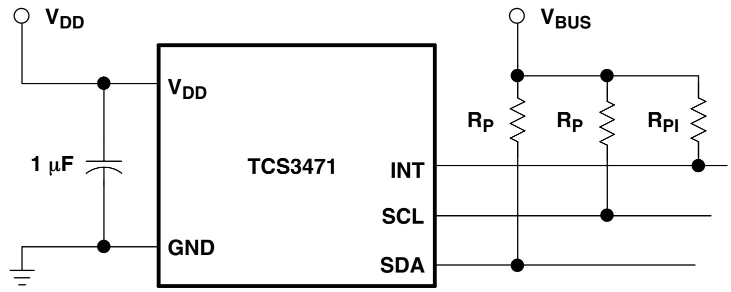


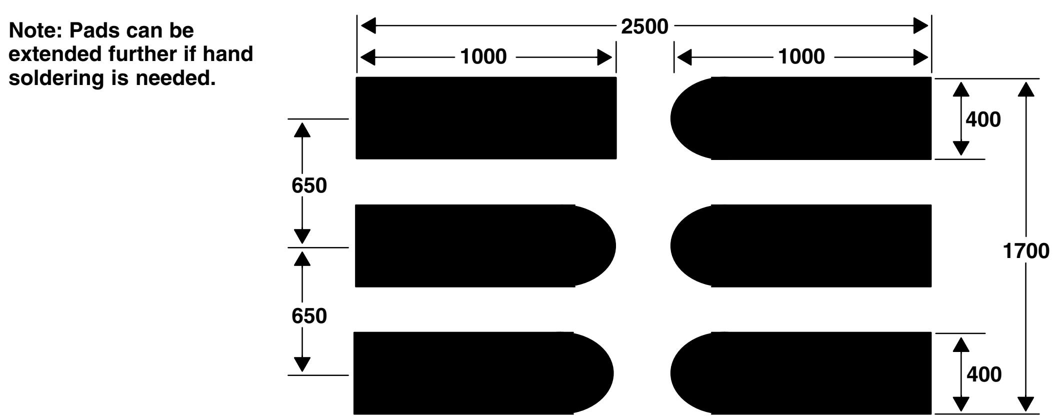
Figure 11. Typical Application Hardware Circuit

V_{BUS} in Figure 11 refers to the I²C bus voltage, which is either V_{DD} or 1.8 V. Be sure to apply the specified I²C bus voltage shown in the Available Options table for the specific device being used.

The I²C signals and the Interrupt are open-drain outputs and require pull-up resistors. The pull-up resistor (R_P) value is a function of the I²C bus speed, the I²C bus voltage, and the capacitive load. The TAOS EVM running at 400 kbps, uses 1.5-kΩ resistors. A 10-kΩ pull-up resistor (R_{PI}) can be used for the interrupt line.

PCB Pad Layout

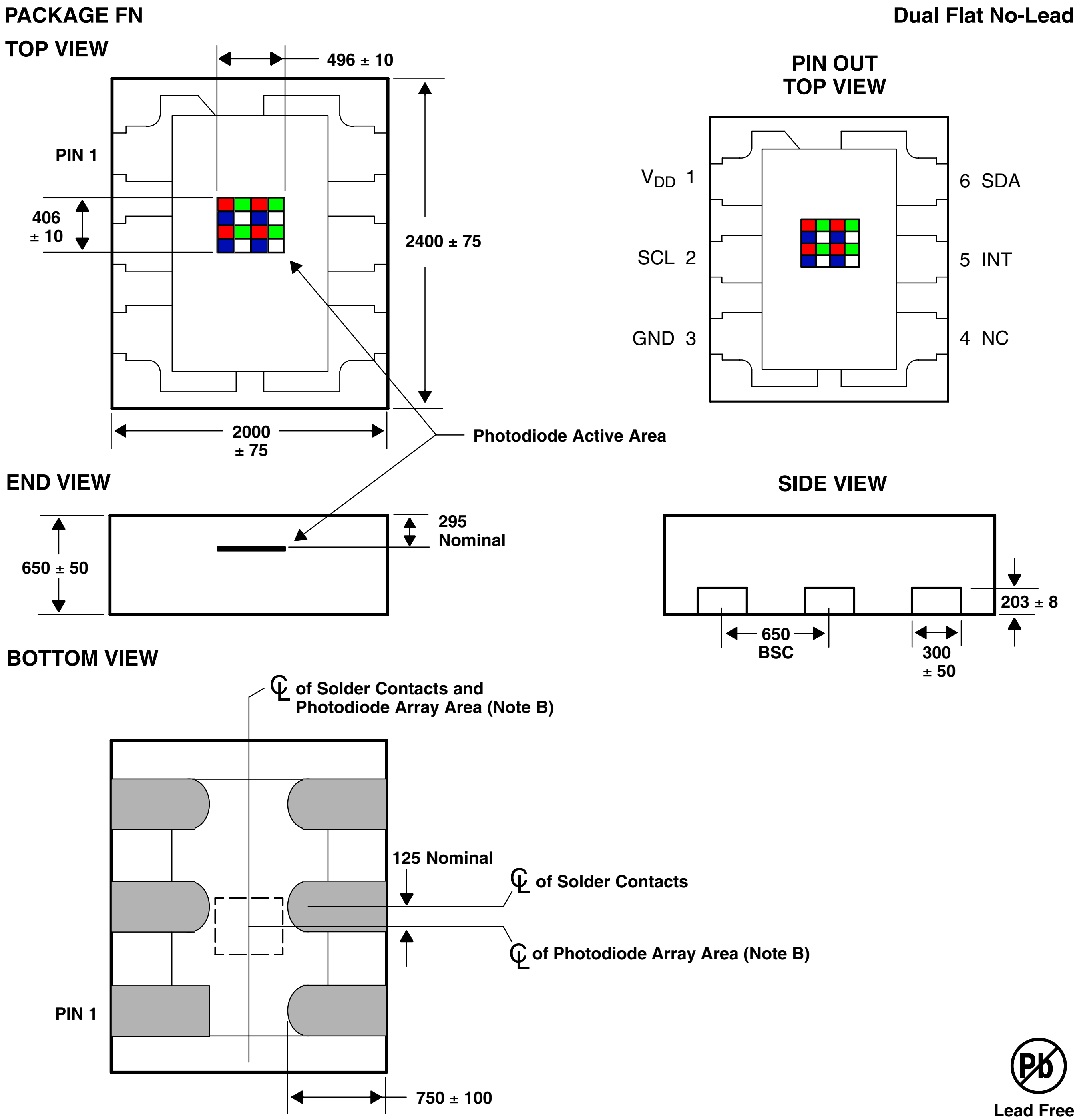
Suggested PCB pad layout guidelines for the Dual Flat No-Lead (FN) surface mount package are shown in Figure 12.



NOTES: A. All linear dimensions are in micrometers.
B. This drawing is subject to change without notice.

Figure 12. Suggested FN Package PCB Layout

MECHANICAL DATA

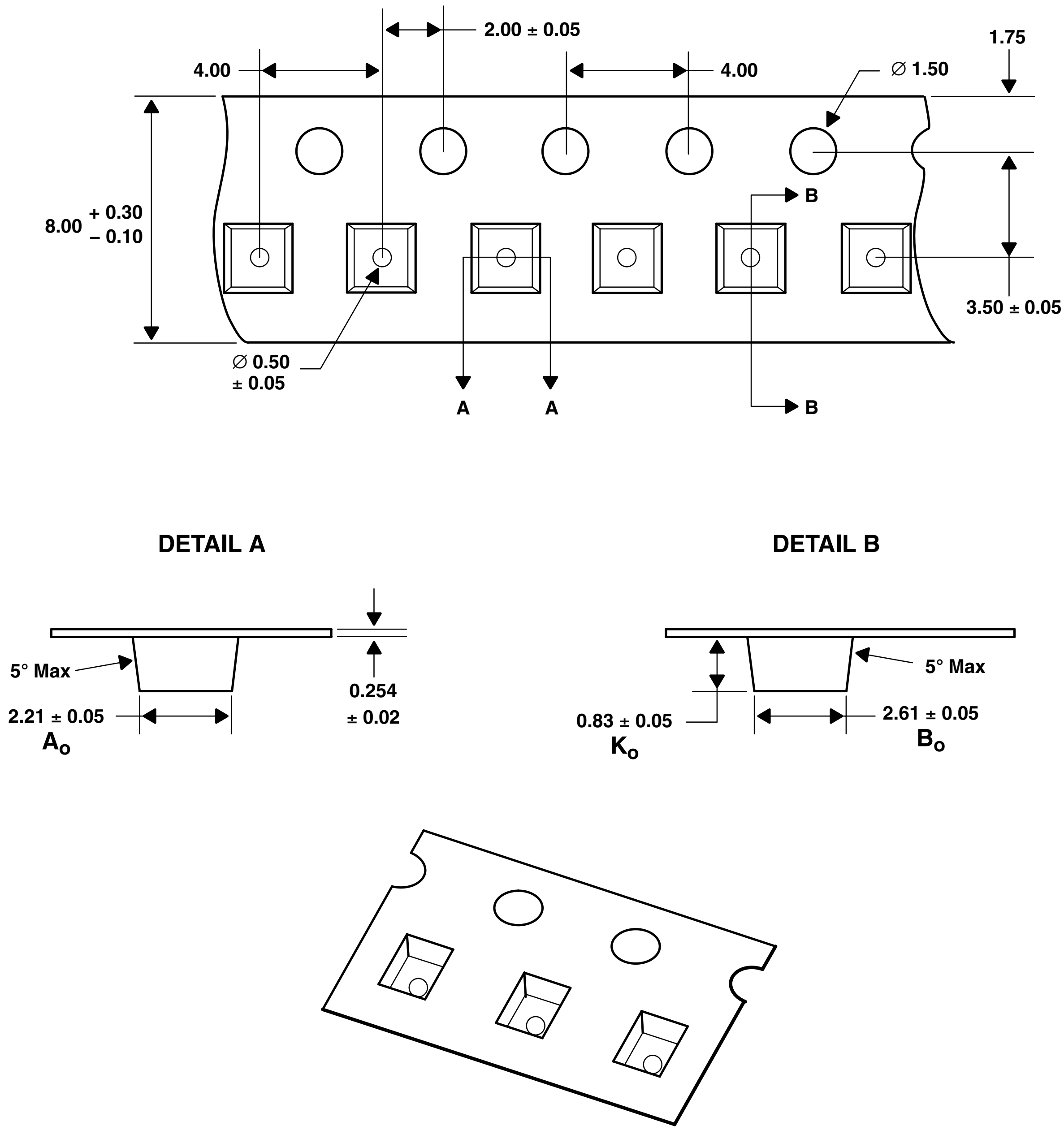


NOTES: A. All linear dimensions are in micrometers.
B. The die is centered within the package within a tolerance of ± 75 μm.
C. Package top surface is molded with an electrically nonconductive clear plastic compound having an index of refraction of 1.55.
D. Contact finish is copper alloy A194 with pre-plated NiPdAu lead finish.
E. This package contains no lead (Pb).
F. This drawing is subject to change without notice.

Figure 13. Package FN — Dual Flat No-Lead Packaging Configuration

MECHANICAL DATA

TOP VIEW



NOTES:
- A. All linear dimensions are in millimeters. Dimension tolerance is ± 0.10 mm unless otherwise noted.
- B. The dimensions on this drawing are for illustrative purposes only. Dimensions of an actual carrier may vary slightly.
- C. Symbols on drawing A_o, B_o, and K_o are defined in ANSI EIA Standard 481−B 2001.
- D. Each reel is 178 millimeters in diameter and contains 3500 parts.
- E. TAOS packaging tape and reel conform to the requirements of EIA Standard 481−B.
- F. In accordance with EIA standard, device pin 1 is located next to the sprocket holes in the tape.
- G. This drawing is subject to change without notice.

Figure 14. Package FN Carrier Tape

MANUFACTURING INFORMATION

The FN package has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate.

The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The components should be limited to a maximum of three passes through this solder reflow profile.

Table 13. Solder Reflow Profile

PARAMETER	REFERENCE	TCS3471
Average temperature gradient in preheating		2.5°C/sec
Soak time	t_{soak}	2 to 3 minutes
Time above 217°C (T1)	t_1	Max 60 sec
Time above 230°C (T2)	t_2	Max 50 sec
Time above T_{peak} −10°C (T3)	t_3	Max 10 sec
Peak temperature in reflow	T_{peak}	260°C
Temperature gradient in cooling		Max −5°C/sec

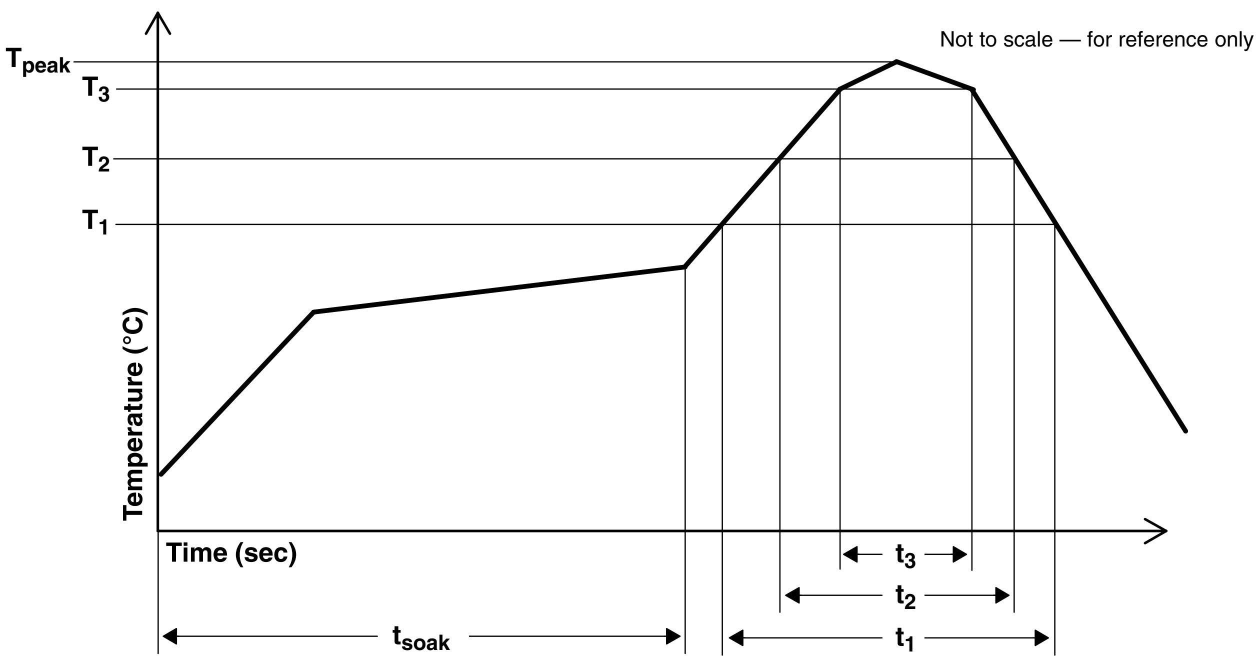


Figure 15. Solder Reflow Profile Graph

MANUFACTURING INFORMATION

Moisture Sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package. To ensure the package contains the smallest amount of absorbed moisture possible, each device is dry-baked prior to being packed for shipping. Devices are packed in a sealed aluminized envelope called a moisture barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

The FN package has been assigned a moisture sensitivity level of MSL 3 and the devices should be stored under the following conditions:

Temperature Range	5°C to 50°C
Relative Humidity	60% maximum
Total Time	12 months from the date code on the aluminized envelope — if unopened
Opened Time	168 hours or fewer

Rebaking will be required if the devices have been stored unopened for more than 12 months or if the aluminized envelope has been open for more than 168 hours. If rebaking is required, it should be done at 50°C for 12 hours.

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Melexis
Microelectronic Integrated Systems

MLX90614 family

Single and Dual Zone
Infra Red Thermometer in TO-39

Features and Benefits

- ❑ Small size, low cost
- ❑ Easy to integrate
- ❑ Factory calibrated in wide temperature range:
  -40 to 125 ˚C for sensor temperature and
  -70 to 380 ˚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 optional
- ❑ Measurement resolution of 0.02°C
- ❑ Single and dual zone versions
- ❑ SMBus compatible digital interface
- ❑ Customizable PWM output for continuous reading
- ❑ Available in 3V and 5V versions
- ❑ Simple adaptation for 8 to 16V applications
- ❑ Power saving mode
- ❑ Different package options for applications and measurements versatility
- ❑ Automotive grade

Applications Examples

- ❑ High precision non-contact temperature measurements;
- ❑ Thermal Comfort sensor for Mobile Air Conditioning control system;
- ❑ Temperature sensing element for residential, commercial and industrial building air conditioning;
- ❑ Windshield defogging;
- ❑ Automotive blind angle detection;
- ❑ Industrial temperature control of moving parts;
- ❑ Temperature control in printers and copiers;
- ❑ Home appliances with temperature control;
- ❑ Healthcare;
- ❑ Livestock monitoring;
- ❑ Movement detection;
- ❑ Multiple zone temperature control – up to 100 sensors can be read via common 2 wires
- ❑ Thermal relay/alert
- ❑ Body temperature measurement

Ordering Information

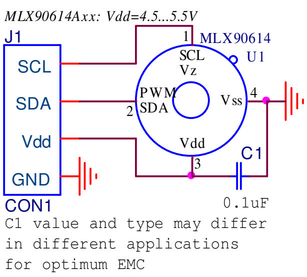
Part No. MLX90614 X X X
(1) (2) (3)

(1) Supply Voltage:
A - 5V power
(adaptable for 12V)
B - 3V power

(2) Number of thermopiles:
A – single zone
B – dual zone

(3) Package type:
A – Filter inside
B – Filter outside

1 Functional diagram



MLX90614 connection to SMBus

Figure 1 Typical application schematics

2 General Description

The MLX90614 is an Infra Red thermometer for non contact temperature measurements. Both the IR sensitive thermopile detector chip and the signal conditioning ASSP are integrated in the same TO-39 can.
Thanks to its low noise amplifier, 17-bit ADC and powerful DSP unit, a high accuracy and resolution of the thermometer is achieved.
The thermometer comes factory calibrated with a digital PWM and SMBus output.
As a standard, the 10-bit PWM is configured to continuously transmit the measured temperature in range of -20 to 120 ˚C, with an output resolution of 0.14 ˚C.
The POR default is SMBus interface

General description (continued)

The MLX90614 is built from 2 chips developed and manufactured by Melexis:
The Infra Red thermopile detector MLX81101.
The signal conditioning ASSP MLX90302, specially designed to process the output of IR sensor.
The device is available in an industry standard TO-39 package.

Thanks to the low noise amplifier, high resolution 17-bit ADC and powerful DSP unit of MLX90302 high accuracy and resolution of the thermometer is achieved. The calculated object and ambient temperatures are available in RAM of MLX90302 with resolution of 0.01 ˚C. They are accessible by 2 wire serial SMBus compatible protocol (0.02°C resolution) or via 10-bit PWM (Pulse Width Modulated) output of the device.

The MLX90614 is factory calibrated in wide temperature ranges: -40 to 125 ˚C for the ambient temperature and -70 to 382.2 ˚C for the object temperature. The 10-bit PWM is as a standard configured to transmit continuously the measured object temperature for an object temperature range of -20 to 120 ˚C with an output resolution of 0.14 ˚C. The PWM can be easily customized for virtually any range desired by customer by changing the content of 2 EEPROM cells. This has no effect on the factory calibration of the device.

The PWM pin can also be configured to act as a thermal relay (input is To), thus allowing for an easy and cost effective implementation in thermostats or temperature (freezing/boiling) alert applications. The temperature threshold is user programmable. In an SMBus system this feature can act as a processor interrupt that can trigger reading all slaves on the bus and to determine the precise condition.

As a standard, the MLX90614 is calibrated for an 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 thermometer is available in 2 supply voltage options: 5V compatible or 3V (battery) compatible. The 5V can be easily adopted to operate from a higher supply voltage (8-16V, for example) by use of few external components (refer to “Applications information” section for details).

An optical filter (long-wave pass) that cuts off the visible and near infra-red radiant flux is integrated in the package to provide sunlight immunity.

Table of Contents

3 Glossary of Terms

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

Note: sometimes the MLX90614xxx is referred to as "the module".

4 Maximum ratings

Parameter.	MLX90614AAA MLX90614ABA	MLX90614BAA MLX90614BBA	MLX90614AAB MLX90614ABB	MLX90614BAB MLX90614BBB
Supply Voltage, V_{DD} (over voltage)	7V	5V	7V	5V
Supply Voltage, V_{DD} (operating)	5.5 V	3.6V	5.5V	3.6V
Reverse Voltage	0.4 V			
Operating Temperature Range, T_A	-40 to +125°C		-40…+85°C	
Storage Temperature Range, T_S	-40…+125 °C		-40…+105°C	
ESD Sensitivity (AEC Q100 002)	2kV			
DC current into SCL/Vz (Vz mode)	2 mA			
DC sink current, SDA /PWM pin	25 mA			
DC source current, SDA/PWM pin	25 mA			
DC clamp current, SDA/PWM pin	25 mA			
DC clamp current, SCL pin	25 mA			

Table 1: Absolute maximum ratings for MLX90614

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

5 Pin definitions and descriptions

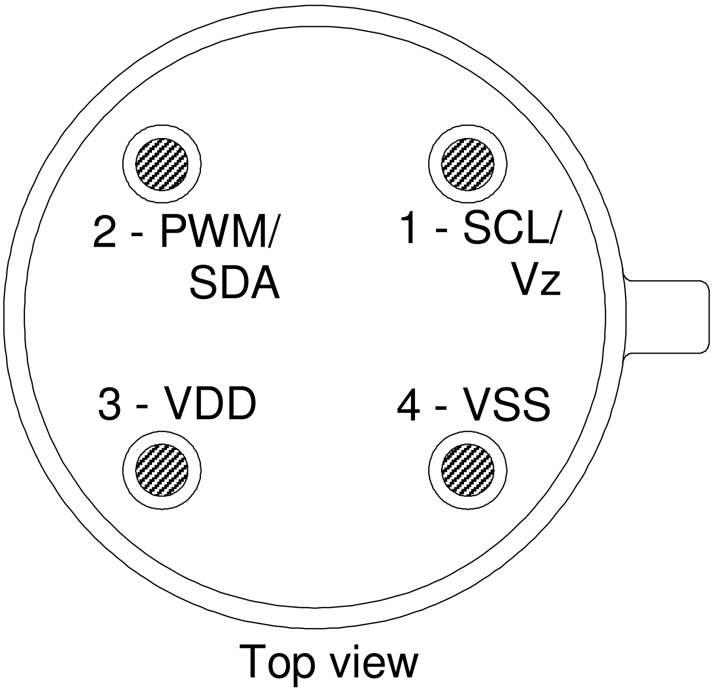


Figure 2: Pin description

Pin Name	Function
VSS	Ground. The metal can is also connected to this pin.
SCL / Vz	Serial clock input for 2 wire communications protocol. 5.7V zener is available at this pin for connection of external bipolar transistor to MLX90614A to supply the device from external 8 -16V source.
PWM / SDA	Digital input / output. In normal mode the measured object temperature is available at this pin Pulse Width Modulated.
VDD	External supply voltage.

Table 2: Pin description MLX90614

Note: for +12V (+8…+16V) powered operation refer to the Application information section. 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.
With the SCL/Vz and PWM/SDA pins operated in 2-wire interface mode, the input Schmidt trigger function is automatically enabled.

6 Electrical Specifications

6.1 MLX90614Axx

All parameters are preliminary for T_A = 25 ˚C, $\mathbf{V_{DD}}$ **=5V** (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	V_{DD}		4.5	5	5.5	V
Supply current	I_{DD}	No load			1	mA
Supply current (programming)	I_{DDpr}	No load, erase/write EEPROM operations			1.5	mA
Zener voltage	Vz	Iz = 75…400 uA	5.6	5.75	5.8	V
Zener voltage	Vz(Ta)	Iz=70…400uA, full temperature range	5.15	5.75	6.24	V
Power On Reset						
POR level	V_{POR}	Power-up, power-down and brown-out	2.7	3.0	3.3	V
V_{DD} rise time	T_{POR}	Ensure POR signal			3	ms
Output valid (result in RAM)	Tvalid	After POR		0.15		s
Pulse width modulation[1]						
PWM resolution	PWMres	Data band		10		bit
PWM output period	$PWM_{T,def}$	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-4		+4	%
Output high Level	PWM_{HI}	I_{source} = 2 mA	V_{DD}-0.2			V
Output low Level	PWM_{LO}	I_{sink} = 2 mA			V_{SS}+0.2	V
Output drive current	$Idrive_{PWM}$	Vout,H = V_{DD} - 0.8V		20		mA
Output sink current	$Isink_{PWM}$	Vout,L = 0.8V		20		mA
Output settling time	Tset	100 pF capacitive load, full operating Ta range		500	TBD	ns
Output settling time	$Tset_{RC}$	220 Ohm in series with 47nF load on the wire, full Ta operating range	20		50	us

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
SMBus compatible 2-wire interface[2]						
Input high voltage	V_{IH}		1.8	2	2.2	V
Input high voltage	V_{IH}(Ta,V)	Over temperature and supply	1.6		2.4	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		1.5	V
Output low voltage	V_{OL}	SDA pin in open drain mode, over temperature and supply, Isink = 2mA			0.2	V
SCL leakage	I_{SCL},leak	V_{SCL}=4V, Ta=+85°C			30	uA
SDA leakage	I_{SDA},leak	V_{SDA}=4V, Ta=+85°C			0.3	uA
SCL capacitance	C_{SCL}				10	pF
SDA capacitance	C_{SDA}				10	pF
Slave address	SA	Factory default		5Ah		hex
SMBus Request	t_{REQ}	SCL low	1.024			ms
Timeout, low	$T_{imeout,L}$	SCL low			30	ms
Timeout, high	$T_{imeout,H}$	SCL high			50	us
Acknowledge setup time	Tsuac(MD)	8-th SCL falling edge, Master	0.5		1.5	us
Acknowledge hold time	Thdac(MD)	9-th SCL falling edge, Master	1.5		2.5	us
Acknowledge setup time	Tsuac(SD)	8-th SCL falling edge, Slave	2.5			us
Acknowledge hold time	Thdac(SD)	9-th SCL falling edge, Slave	1.5			us
EEPROM						
Data retention		Ta = +85°C	10			years
Erase/write cycles		Ta = +25°C	100,000			Times
Erase/write cycles		Ta = +125°C	10,000			Times
Erase cell time	Terase			5		ms
Write cell time	Twrite			5		ms

Notes: All the communication and refresh rate timings are given for the nominal calibrated HFO frequency and will vary with this frequency's variations.
1. All PWM timing specifications are given for single PWM output (factory default for MLX90614xAx). For the extended PWM output (factory default for the MLX90614xBx) each period has twice the timing specifications (refer to the PWM detailed description section). With large capacitive load lower PWM frequency is recommended. Thermal relay output (when configured) has the PWM DC specification and can be programmed as push-pull, or NMOS open drain. PWM is free-running, power-up factory default is SMBus, refer to 7.6, "Switching between PWM and SMBus communication" for details..
2. For SMBus compatible interface on 12V application refer to Application information section. SMBus compatible interface is described in details in the SMBus detailed description section. Maximum number of MLX90614xxx 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.
MLX90614xxx is always a slave device on the bus. MLX90614xxx can work in both low-power and high-power SMBus communication.
All voltage are with respect to the Vss (ground) unless otherwise noted.

Power saving mode is not available on the 5V version (MLX90614Axx).

6.2 MLX90614Bxx

All parameters are preliminary for T_A = 25 ˚C, $\mathbf{V_{DD}}$ **=3V** (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	V_{DD}		2.4	3	3.6	V
Supply current	I_{DD}	No load			1	mA
Supply current (programming)	I_{DDpr}	No load, erase/write EEPROM operations			1.5	mA
Power-down supply current	Isleep	no load	1	2.5	5	uA
Power-down supply current	Isleep	Full temperature range	1	2.5	6	uA
Power On Reset						
POR level	V_{POR}	Power-up, power-down and brown-out	1.6	1.85	2.1	V
V_{DD} rise time	T_{POR}	Ensure POR signal			1	ms
Output valid	Tvalid	After POR		0.15		s
Pulse width modulation[1]						
PWM resolution	PWMres	Data band		10		bit
PWM output period	$PWM_{T,def}$	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-4		+4	%
Output high Level	PWM_{HI}	I_{source} = 2 mA	V_{DD}-0.25			V
Output low Level	PWM_{LO}	I_{sink} = 2 mA			V_{SS}+0.25	V
Output drive current	$Idrive_{PWM}$	Vout,H = V_{DD} - 0.8V		15		mA
Output sink current	$Isink_{PWM}$	Vout,L = 0.8V		15		mA
Output settling time	Tset	100 pF capacitive load, full operating Ta range			150	ns
Output settling time	$Tset_{RC}$	220 Ohm in series with 47nF load on the wire, full Ta operating range		500	TBD	ns

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
SMBus compatible 2-wire interface[2]						
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}	SDA pin in open drain mode, over temperature and supply, Isink = 2mA			0.25	V
SCL leakage	I_{SCL},leak	V_{SCL}=3V, Ta=+85℃			20	uA
SDA leakage	I_{SDA},leak	V_{SDA}=3V, Ta=+85℃			0.25	uA
SCL capacitance	C_{SCL}				10	pF
SDA capacitance	C_{SDA}				10	pF
Slave address	SA	Factory default		5Ah		hex
SMBus Request	t_{REQ}	SCL low	1.024			ms
Timeout,low	$T_{imeout,L}$	SCL low			30	ms
Timeout, high	$T_{imeout,H}$	SCL high			50	us
Acknowledge setup	Tsuac(MD)	8-th SCL falling edge, Master	0.5		1.5	us
Acknowledge hold	Thdac(MD)	9-th SCL falling edge, Master	1.5		2.5	us
Acknowledge setup	Tsuac(SD)	8-th SCL falling edge, Slave	2.5			us
Acknowledge hold	Thdac(SD)	9-th SCL falling edge, Slave	1.5			us
EEPROM						
Data retention		Ta = +85℃	10			years
Erase/write cycles		Ta = +25℃	100,000			Times
Erase/write cycles		Ta = +125℃	10,000			Times
Erase cell time	Terase			5		ms
Write cell time	Twrite			5		ms

Note: refer to MLX90614Axx notes.

7 Detailed description

7.1 Block diagram

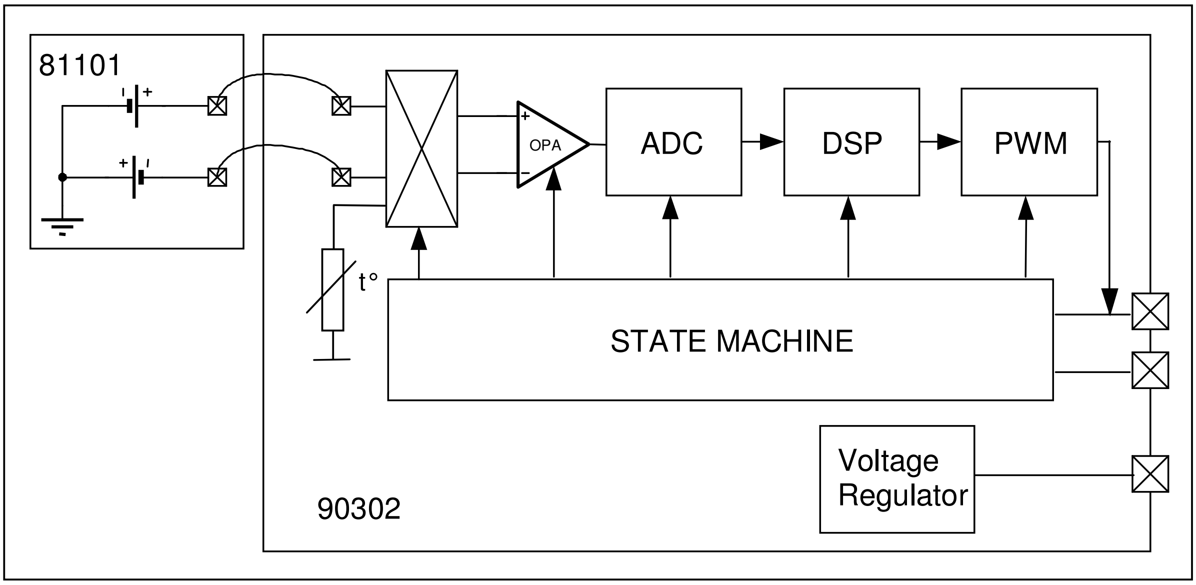


Figure 3: block diagram

7.2 Signal processing principle

The operation of the MLX90614 is controlled by an internal state machine, which controls the measurements and calculations of the object and ambient temperatures and does the post-processing of the temperatures to output them through the PWM output or the SMBus compatible interface.
The ASSP supports 2 IR sensors (second one not implemented in the MLX90614xAx).The output of the IR sensors is amplified by a low noise low offset chopper amplifier with programmable gain, converted by a Sigma Delta modulator to a single bit stream and fed to a powerful DSP for further processing. The signal is treated by programmable (by means of EEPROM contend) FIR and IIR low pass filters for further reduction of the band width of the input signal to achieve the desired noise performance and refresh rate. The output of the IIR filter is the measurement result and is available in the internal RAM. 3 different cells are available: One for the on-board temperature sensor (on chip PTAT or PTC) and 2 for the IR sensors.
Based on results of the above measurements, the corresponding ambient temperature Ta and object temperatures To are calculated. Both calculated temperatures have a resolution of 0.01 ˚C. The data for Ta and To can be read in two ways: Reading RAM cells dedicated for this purpose via the 2-wire interface (0.02℃ resolution, fixed ranges), or through the PWM digital output (10 bit resolution, configurable range).
In the last step of the measurement cycle, the measured Ta and To are rescaled to the desired output resolution of the PWM) and the recalculated data is loaded in the registers of the PWM state machine, which creates a constant frequency with a duty cycle representing the measured data.

7.3 Block description

7.3.1 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 0.5µV is achieved.

7.3.2 Supply regulator and POR

The module can operate from 2 different supplies:
VDD= 5V => MLX90614Axx
VDD=3.3V => MLX90614Bxx (battery or regulated supply)
Refer to "Applications information" section for information about adopting higher voltage supplies.

The Power On Reset (POR) is connected to Vdd supply. The on-chip POR circuit provides an active (high) level of the POR signal when the Vdd voltage rises above approximately 0.5V and holds the entire MLX90614xxx in reset until the Vdd is higher than the specified POR threshold V_{POR} (note that this level is different for MLX90614Axx and MLX90614Bxx). During the time POR is active, the POR signal is available as an open drain (active high) at the PWM/SDA pin. After the MLX90614xxx exits the POR condition, the function programmed in EEPROM takes precedence for that pin.

7.3.3 EEPROM

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

EEPROM (32X16)		
Name	Address	Write acces
To_{max}	000h	Yes
To_{min}	001h	Yes
PWMCTRL	002h	Yes
Ta range	003h	Yes
Ke	004h	Yes
Config Register1	005h	Yes
Melexis reserved	006h	No
...	...	...
Melexis reserved	00Dh	No
SMBus address	00Eh	Yes
Melexis reserved	00Fh	Yes
Melexis reserved	010h	No
...	...	...
Melexis reserved	018	No
Melexis reserved	019h	Yes
Melexis reserved	01Ah	No
Melexis reserved	01Bh	No
ID number	01Ch	No
ID number	01Dh	No
ID number	01Eh	No
ID number	01Fh	No

The addresses To_{max}, To_{min} and Ta range are for customer dependent object and ambient temperature ranges. For details see point 7.5.3 below in this document

The address **PWMCTRL** consists of control bits for configuring the PWM/SDA pin:

Bit 0	Select the type of PWM mode:	1 - Single PWM, factory default for MLX90614xAx	0 – Extended PWM, factory default for MLX90614xBx
Bit 1	Enable/disable the PWM:	1 - Enable PWM, disable SMBus	0 - Disable PWM (Enable SMBus), Factory default
Bit 2	Configuration of the pin PWM:	1 - Push-Pull,	0 – OpenDrain NMOS, factory default
Bit 3	Mode selection	1 - ThermoRelay,	0 - PWM, Factory default
Bits[8:4]	Extemded PWM definition	Number of repetitions divided by 2 of sensor 1 and 2 in Extended PWM mode. The number of repetitions can vary from 0 to 64 times.	
Bits[15:9]	PWM clock configuration	2MHz divided by number written in this place. (128 in case the number is 0.) A single PWM period consists of 2048 clocks and extended PWM of 4096 clocks for each period (2T in figure 6). The 2 MHz clock is valid for the nominal HFO frequency.	

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

<table>
<tr><td>Bits[2:0]</td><td>– Configure coefficients of IIR digital filter:</td><td colspan="2">
<table>
<tr><th>Bit 2</th><th>Bit 1</th><th>Bit 0</th><th>a_1</th><th>b_1</th></tr>
<tr><td>0</td><td>x</td><td>x</td><td>0.5</td><td>0.5</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0.571428571</td><td>0.428571428</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0.666(6)</td><td>0.333(3)</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0.8</td><td>0.2</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0 (IIR bypassed)</td></tr>
</table>
</td></tr>
<tr><td>Bit 3</td><td>– Configure the type of ambient temperature sensor:</td><td>1 - PTC,</td><td>0 – PTAT.</td></tr>
<tr><td>Bits[5:4]</td><td>– Configure the type of data transmitted through PWM:</td><td colspan="2">
<table>
<tr><th>Bit 5</th><th>Bit 4</th><th>Data 1</th><th>Data 2</th></tr>
<tr><td>0</td><td>0</td><td>Ta</td><td>IR 1</td></tr>
<tr><td>0</td><td>1</td><td>Ta</td><td>IR 2</td></tr>
<tr><td>1</td><td>1</td><td>IR 1</td><td>IR 2</td></tr>
<tr><td>1</td><td>0</td><td>IR 2</td><td>Undefined*</td></tr>
</table>
</td></tr>
<tr><td>Bit 6</td><td>– Define the number IR sensors:</td><td>1 – 2 sensors,</td><td>0 -1 sensor.</td></tr>
<tr><td>Bit 7</td><td>– Define the sign Ks (Ks=dAlpha/dTobj) :</td><td colspan="2">Factory calibration, do not alter</td></tr>
<tr><td>Bits[10:8]</td><td>– Configure coefficient N of FIR digital filter:</td><td colspan="2">
<table>
<tr><th>Bit 10</th><th>Bit 9</th><th>Bit 8</th><th>N</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>8</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>16</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>32</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>64</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>128</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>256</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>512</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1024</td></tr>
</table>
</td></tr>
<tr><td>Bits[13:11]</td><td>– Configure the gain of amplifier:</td><td colspan="2">
<table>
<tr><th>Bit 13</th><th>Bit 12</th><th>Bit 11</th><th>Gain</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1 (preamplifier bypassed)</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>3</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>6</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>12.5</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>25</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>50</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>100</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>100</td></tr>
</table>
</td></tr>
<tr><td>Bit 14</td><td colspan="3">Unused</td></tr>
<tr><td>Bit 15</td><td>– Define the sign of thermo-shock compensation:</td><td>1 - negative,</td><td>0 – positive.</td></tr>
</table>

Note: The following bits/registers should not be altered (except with special tools – contact Melexis for such tools availability) in order to keep the factory calibration relevant:
Ke [15..0] ; Config Register1 [13..11;7;3] ; addresses 00Fh and 019h.
** not recommended for extended PWM mode*

7.3.4 RAM

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

RAM (32x17)		
Name	Address	Read access
Melexis reserved	000h	Yes
...	...	...
Melexis reserved	005h	Yes
T_A	006h	Yes
T_{OBJ1}	007h	Yes
T_{OBJ2}	008h	Yes
Melexis reserved	009h	Yes
...	...	...
Melexis reserved	01Fh	Yes

7.4 SMBus compatible 2-wire protocol

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

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

7.4.1 Functional description

The SMBus interface is a 2-wire protocol, allowing communication between the Master Device (MD) and one or more Slave Devices (SD). In the system only one master can be presented at any given time [1]. The MLX90614 can only be used as a slave device.

Generally, the MD initiates the start of data transfer by selecting a SD through the Slave Address (SA).

The MD has read access to the RAM and EEPROM and write access to 9 EEPROM cells (at addresses 0x20h, 0x21h, 0x22h, 0x23h, 0x24h, 0x25h*, 0x2Eh, 0x2Fh, 0x39h). If the access to the MLX90614 is a read operation it will respond with 16 data bits and 8 bit PEC only if its own slave address, programmed in internal EEPROM, is equal to the SA, sent by the master. The SA feature allows connecting up to 127 devices with only 2 wires, unless the system has some of the specific features described in paragraph 5.2 of reference [1]. In order to provide access to any device or to assign an address to a SD before it is connected to the bus system, the communication must start with zero SA followed by low RWB bit. When this command is sent from the MD, the MLX90614 will always respond and will ignore the internal chip code information.
Special care must be taken not to put two MLX90614 devices with the same SD addresses on the same bus as MLX90614 does not support ARP[1].
The MD can force the MLX90614 into low consumption mode "sleep mode" (3V version only).
Read flags like "EEBUSY" (1 – EEPROM is busy with executing the previous write/erase), "EE_DEAD" (1 – there is fatal EEPROM error and this chip is not functional**).
Note: This address is readable and writable. Bit 3 should not be altered as this will cancel the factory calibration.*
*Note**: EEPROM error signalling is implemented in automotive grade parts only.*

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

There are eleven command protocols for standard SMBus interface. The MLX90614 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

7.4.3 Detailed description

The PWM/SDA pin of MLX90614 can operate also as PWM output, depending on the EEPROM settings. If PWM is enabled, after POR the PWM/SDA pin is directly configured as PWM output. The PWM mode can be avoided and the pin can be restored to its Data function by a special command. That is why hereafter both modes are treated separately.

7.4.3.1 Bus Protocol

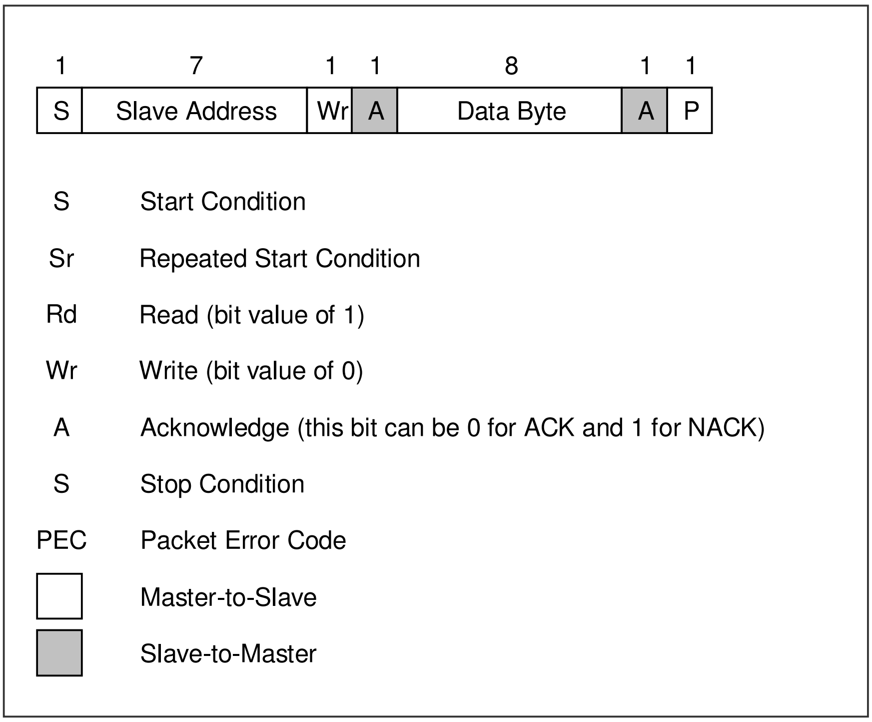


Figure 4: SMBus packet element key

After every 8 bits received by the SD an ACK/NACK takes place. When a MD initiates communication, it first sends the address of the slave and only the SD which recognizes the address will ACK the rest will remain silent. 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 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 X8+X2+X1+1. The Most Significant Bit of every byte is transferred first.

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

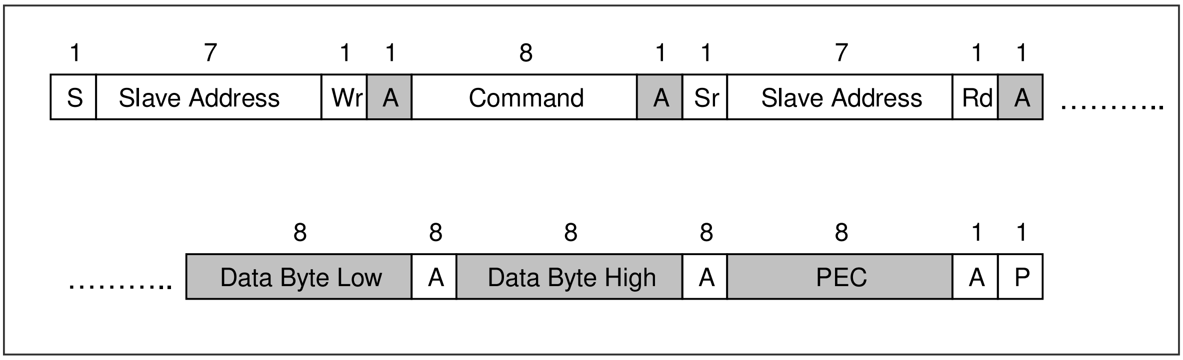


Figure 5: SMBus read word format

7.4.3.1.2 Write Word (depending on the command – RAM or EEPROM)

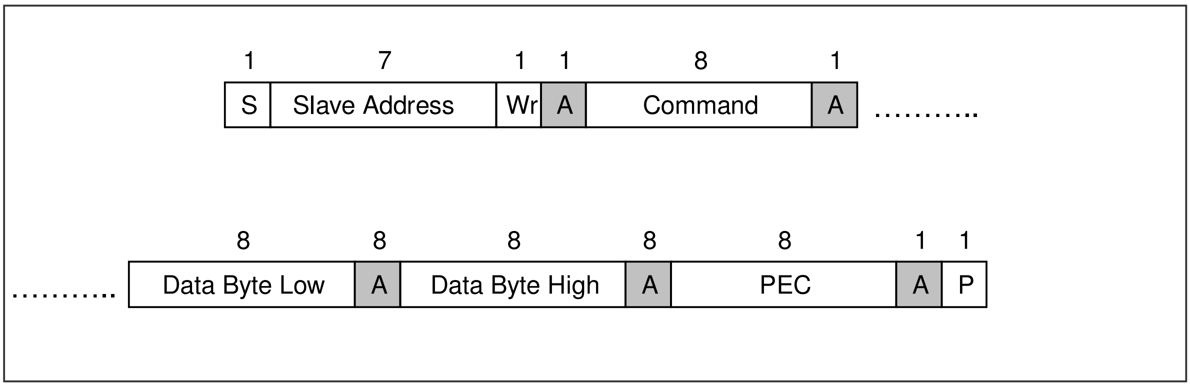


Figure 6: SMBus write word format

7.4.4 AC specification for SMBus

7.4.4.1 Timing

The MLX90614 meets all the timing specifications of the SMBus [1]. The maximum frequency of the MLX90614 SMBus is 100KHz and the minimum is 10KHz.
The specific timings in MLX90614's SMBus are:
SMBus Request (t_{REQ}) is the time that the SCL should be forced low in order to switch MLX90614 from PWM mode to SMBus mode;
Timeout L is the maximum allowed time for SCL to be low. After this time the MLX90614 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 MLX90614 will reset its communication block assuming that the bus is idle (according to the SMBus specification).
Tsuac(SD) is the time after the eighth falling edge of SCL that MLX90614 will force PWM/SDA low to acknowledge the last received byte.
Thdac(SD) is the time after the ninth falling edge of SCL that MLX90614 will release the PWM/SDA (so the MD can continue with the communication).
Tsuac(MD) is the time after the eighth falling edge of SCL that MLX90614 will release PWM/SDA (so that the MD can acknowledge the last received byte).
Thdac(MD) is the time after the ninth falling edge of SCL that MLX90614 will take control of the PWM/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 acknowledge; SD when the slave device is making acknowledge). For other timings see [1].

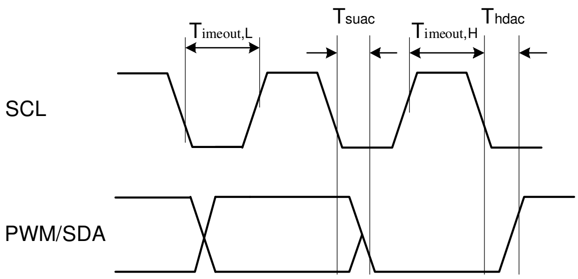


Figure 7: SMBus timing

7.4.5 Bit transfer

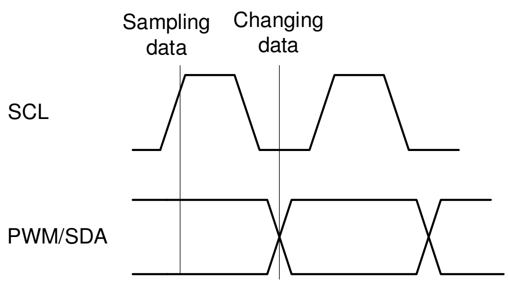


Figure 8: Bit transfer on SMBus

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

7.4.6 Commands

In application mode RAM and EEPROM can be read both with 32x16 sizes. If the RAM is read, the data are divided by two, due to a sign bit in RAM (for example, T_{OBJ1} - RAM address 0x07h will sweep between 0x27ADh to 0x7FFF as the object temperature rises from -70.01℃ to +382.19℃). The MSB read from RAM is an error flag (active high) for the linearized temperatures (T_{OBJ1}, T_{OBJ2} and T_a). The MSB for the raw data (e.g. IR sensor1 data) is a sign bit (sign and magnitude format).

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

Note: The xxxxx are the 5 LSBits of the memory map address to be read/written.*
*Note**: Behaves like read command. The MLX90614 returns PEC after 16 bits data of which only 4 are meaningful and if the MD wants it, it can stop the communication after the first byte. The difference between read and read flags is that the latter does not have a repeated start bit.*
Flags read are:

Data[15] – EEBUSY – the previous write/erase EEPROM access is still in progress. High active.
Data[14] – Unused
Data[13] - EE_DEAD – EEPROM double error has occurred. High active.
Data[12] – INIT – POR initialization routine is still ongoing. High active.
Data[11] – not implemented..
Data[10..0] – all zeros.

Flags read is a diagnostic feature. The MLX90614 can be used regardless of these flags.

7.4.7 Sleep Mode

MLX90614 can enter Sleep Mode via command “Enter SLEEP mode” sent via the SMBus interface. This mode is not available for the 5V supply version. To limit the current consumption to 2.5uA (typ), the SCL pin should be kept low during sleep. MLX90614 goes back into power-up default mode (via POR reset) by setting SCL pin high and then PWM/SDA pin low for at least t_{DDq}=13ms. **If EEPROM is configured for PWM (EN_PWM is high), the PWM interface will be selected after awakening and if PWM control [2], PPODB is 1 the MLX90614 will output a PWM pulse train with push-pull output.**

7.4.7.1 Enter Sleep Mode

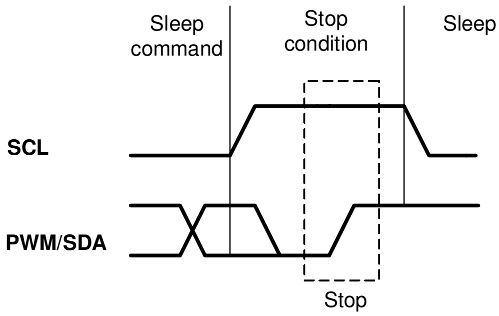


Figure 9: Enter sleep

7.4.7.2 Exit from Sleep Mode

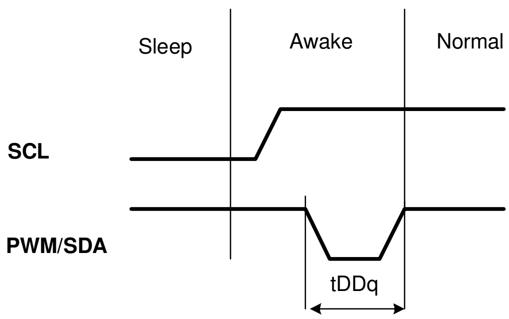


Figure 10: Exit Sleep Mode

7.5 PWM

The MLX90614 can be read via PWM or SMBus compatible interface. Selection of PWM output is done in EEPROM configuration (factory default is PWM). PWM output has two programmable formats, single and dual data transmission, providing single wire reading of two temperatures (dual zone object or object and ambient). The PWM period is derived from the on-chip oscillator and is programmable.

Config Register[5:4]	PWM1 data	PWM2 data	*Tmin,1*	*Tmax,1*	*Tmin,2*	*Tmax,2*
00	Ta	T_{obj1}	Ta_{range},L	Ta_{range},H	To_{min}	To_{max}
01	Ta	T_{obj2}	Ta_{range},L	Ta_{range},H	To_{min}	To_{max}
11	T_{obj1}	T_{obj2}	To_{min}	To_{max}	To_{min}	To_{max}
10*	T_{obj2}	Undefined	To_{min}	To_{max}	*N.A.*	*N.A.*

Note: Serial data functions (2-wire / PWM) are multiplexed with a thermal relay function (described in the "Thermal relay" section).
** not recommended for extended PWM format operation*

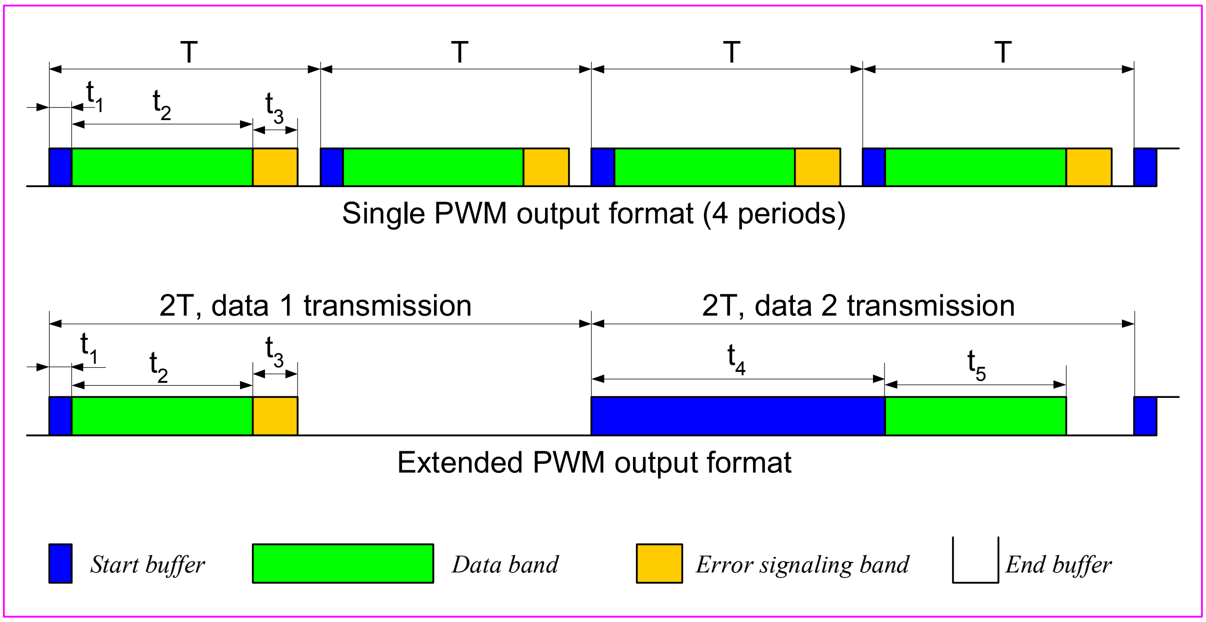


Figure 11: PWM timing

7.5.1 Single PWM format

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

$$Tout = \left[\frac{2t_2}{T} * (Tmax - Tmin)\right] + Tmin\ ,$$

where Tmin and Tmax are the corresponding rescale coefficients in EEPROM for the selected temperature output (Ta, object temperature range is valid for both Tobj1 and Tobj2 as specified in the previous table) and T is the PWM period. Tout is T_{obj1}, T_{obj2} or T_a according to Config Register [5:4] settings.

The different time intervals t_1-t_3 have the following functions:
t_1: Start buffer. During this time the signal is always high. t_1 = 0.125*T (T is the PWM period, refer to fig. 11).
t_2: Valid Data Output Band, 0 to 1/2T. PWM output data resolution is 10 bit.
t_3: Error band – information for Fatal error in EEPROM (double error detected, not correctable). t_3 = 0.25 * T.
Therefore a PWM pulse train with a duty cycle of 0.875 will indicate a fatal error in EEPROM (for single PWM format).

Example:
T_{obj1} => Config Reg[5:4] = 11'b
To_{min} = 0℃ => To_{min} [EEPROM] = 100 * (to_{min} + 273.15) = 6AB3h
To_{max} = +50℃ => To_{max} [EEPROM] = 100 * (to_{max} + 273.15) = 7E3Bh
Captured PWM high duration is 0.495*T => t_2=(0.495 – 0.125)*T=0.370*T =>
measured object temperature = 2X0.370* (50℃ -0℃)+0℃ = +37.0℃.

7.5.2 Extended PWM format

The PWM format for extended PWM is shown in Figure 11. Note that with bits DUAL[5:1]>00h each period will be repeated 2N+1 times, where N is the decimal value of the number written in DUAL[5:1] (*DUAL[5:1] =PWM control & clock [8:4]*), like shown on Figure 12.

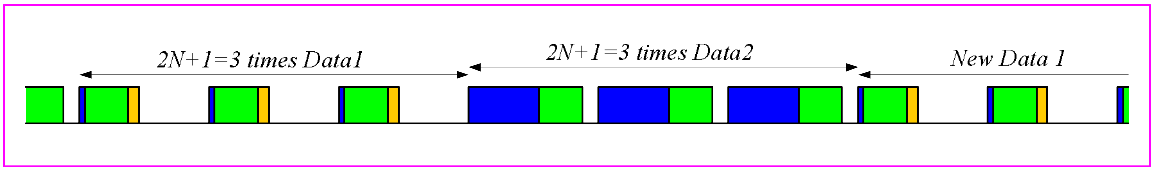


Figure 12: Extended PWM format with DUAL[5:1] = 01h (2 repetitions for each data)

The temperature transmitted in Data 1 field can be calculated using the following equation:

$$Tout_1 = \left[\frac{2t_2}{T} * (Tmax_1 - Tmin_1)\right] + Tmin_1$$

For Data 2 field the equation is:

$$Tout_2 = \left[\frac{2t_5}{T} * (Tmax_2 - Tmin_2)\right] + Tmin_2$$

Where $Tmin_1$,$Tmax_1$,$Tmin_2$ and $Tmax_2$ are given in Table 9, t_2=t_{high1}-t_1, and t_5=t_{high2}-t_4.
Time bands are: t_1=0.125*T, t_3=0.25*T and t_4=1.125*T. As shown in Figure 11, in extended PWM format the period is twice the period for the single PWM format. All equations provided herein are given for the single PWM period T. The EEPROM Error band signalling will be 43.75% duty cycle for Data1 and 93.75% for Data2.
Note:EEPROM error signalling is implemented in automotive grade parts only.

Example:
Configuration: Ta : T_{obj1} @ Data1 : Data2 => Config Reg[5:4] = 00b,
Ta_{min} = -5℃ => Ta_{range}, L [EEPROM] = 100*(Ta_{min}+38.2)/64 = 33h,
Ta_{max} = +105℃ => Ta_{range},H [EEPROM] = 100*(Ta_{max}+38.2)/64 = DFh,
Ta_{range} [EEPROM]=DF33h
To_{min} = 0℃ => To_{min} [EEPROM] = 100 * (To_{min} + 273.15)/64 = 6AB3h
To_{max} = +50℃ => To_{max} [EEPROM] = 100 * (To_{max} + 273.15)/64 = 7E3Bh
Captured high durations are 0.13068*(2T) and 0.7475*(2T), where 2T is each captured PWM period. Time band t_4 is provided for reliable determination between Data1 and Data2 data fields. Thus Data1 is represented by 0.13068*(2T) and Data2 – by 0.7475*(2T), and the temperatures can be calculated as follows:
t_2/T=(t_{high1}/T)-0.125=0.13636 => Ta=+25.0℃,
t_5/T=(t_{high2}/T)-1.125=0.370 => T_{obj1}=+37.0℃.

7.5.3 Customizing the temperature range for PWM output

The calculated ambient and object temperatures are stored in RAM with a resolution of 0.01 °C (16 bit). The PWM operates with a 10-bit word so the transmitted temperature is rescaled in order to fit in the desired range.
For this goal 2 cells in EEPROM are foreseen to store the desired range for To (To_{min} and To_{max}) and one for Ta (Ta_{range}: the 8MSB are foreseen for Ta_{max} and the 8LSB for Ta_{min}).
Thus the output range for To can be programmed with an accuracy of 0.01 °C, while the corresponding Ta range can be programmed with an accuracy of 2.56 °C.

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

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

The T_{RAM} is the linearised Tobj, 16-bit (0000…FFFFh, 0000 for -273.15°C and FFFFh for +382.2°C) and the result is a 10-bit word, in which 000h corresponds to To_{MIN}[°C], 3FFh corresponds to To_{MAX}[°C] and 1LSB corresponds to $\frac{To_{MAX} - To_{MIN}}{1023}$ [°C]

$$T_{MIN_{EEPORM}} = T_{MIN} * 100 \text{ LSB}$$

$$T_{MAX_{EEPORM}} = T_{MAX} * 100 \text{ LSB}$$

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

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

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

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

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

7.6 Switching Between PWM and SMBus communication

7.6.1 PWM is enabled

The diagram below illustrates the way of switching to SMBus if PWM is enabled (factory programmed POR default for MLX90614 is SMBus, PWM enabled). Note that the SCL pin needs to be kept high in order to use PWM.

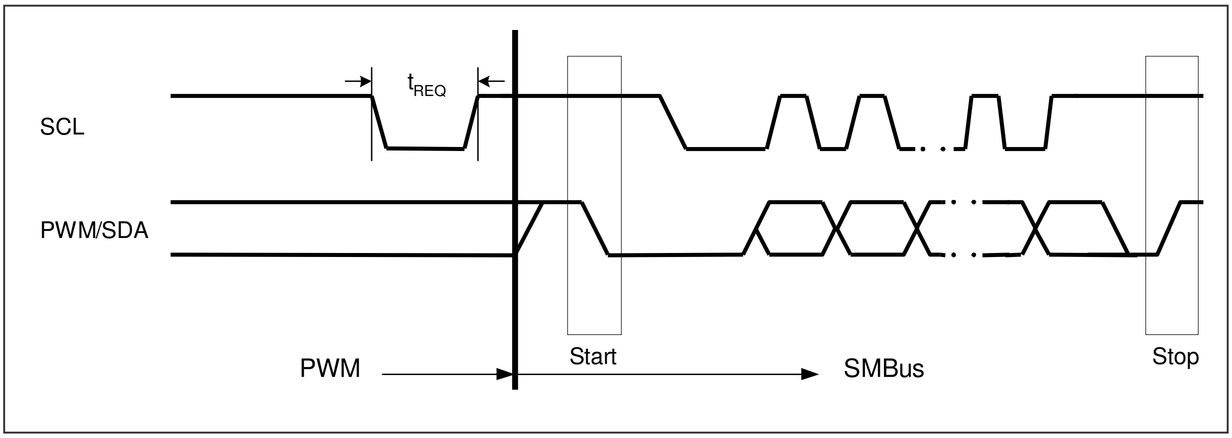


Figure 13: Switching from PWM mode to SMBus

7.6.2 Request condition

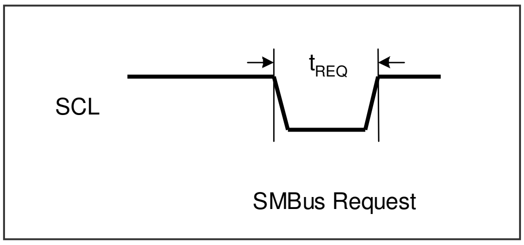


Figure 14: Request (switch to SMBus) condition

If PWM is enabled, the MLX90614's SMBus Request condition is needed to disable PWM and reconfigure PWM/SDA pin before starting SMBus communication. Once disabled PWM, it can be only enabled by switching Off-On of the supply or exit from Sleep Mode. The MLX90614's SMBus request condition requires forcing LOW the SCL pin for period longer than the request time (t_{REQ}). The SDA line value is ignored in this case.

7.6.3 PWM is disabled

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

7.7 Computation of ambient and object temperatures

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

$$V_{ir}(Ta,To) = A.(To^4 - Ta^4),$$

Where To is the object temperature absolute (Kelvin) temperature, Ta is the sensor die absolute (Kelvin) temperature, and A is the overall sensitivity.
An additional temperature sensor is needed for measuring the temperature of 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.

7.7.1 Ambient temperature Ta

The Sensor die temperature is measured with a PTC or a PTAT element. All the sensors' conditioning and data processing is handled on-chip and the linearized sensor die temperatureTa is made available in memory.
The resolution of the calculated Ta is 0.01 ˚C. The sensor is factory calibrated for the full automotive range (-40 to 125 ˚C). In RAM cell ,006h, 0000h corresponds to -40 ˚C and 4074h (16500d) corresponds to 125 ˚C. The conversions from RAM contend to real Ta is easy using the following relation:

$Ta[°K] = Tareg \times 0.01$ Note that via SMBus Ta is read divided by 2, or Ta,SMBus[°K]=Tareg x 0.02

7.7.2 Object temperature To

The result has a resolution of 0.01 ˚C and is available in RAM. To is derived from RAM as:

$To[°K] = Toreg \times 0.01$ Note that via SMBus To is read divided by 2, or To,SMBus[°K]=Toreg x 0.02

7.7.3 Calculation flow

The measurement, calculation and linearization are held by core, which executes a program form ROM. After POR the chip is initialized with calibration data from EEPROM. During this phase the number of IR sensor is selected and which temperature sensor will be used. Measurements, compensation and linearization routines run in a closed loop afterwards.

Processing ambient temperature includes:

- Offset measurement with fixed length FIR filter
- Additional filtering with fixe length IIR filter. The result is stored into RAM as T_{OS}
- Temperature sensor measurement using programmable length FIR *.
- Offset compensation
- Additional processing with programmable length IIR **. The result is stored into RAM as T_D.
- Calculation of the ambient temperature. The result is stored into RAM as T_A

Processing of the object temperature consists of three parts. The first one is common for both IR sensors, the third part can be skipped if only one IR sensor is used.

- IR offset:
  - Offset measurement with a fixed length FIR
  - Additional filtering with a fixed length IIR. The result is stored into RAM as IR_{OS}.

Gain measurement with fixed length FIR filter
Offset compensation
Additional gain filtering with fixed length IIR, storing the result into RAM as IR_G.
Gain compensation calculation, the result is stored into RAM as K_G

Object temperature:

IR1 sensor:

IR sensor measurement with programmable length FIR filter *.
Offset compensation
Gain compensation
Filtering with programmable length IIR filter**, storing the result into RAM as $IR1_D$.
Calculation of the object temperature. The result is available in RAM as T_{OBJ1}.

IR2 sensor:

IR sensor measurement with programmable length FIR filter *.
Offset compensation
Gain compensation
Filtering with programmable length IIR filter**, storing the result into RAM as $IR2_D$
Calculation of the object temperature. The result is available in RAM as T_{OBJ2}.

PWM calculation:

Recalculate the data for PWM with 10 bit resolution
Load data into PWM module

Note: The measurements with programmable filter length for FIR filter use the same EEPROM's sell for N.*
*Note**: The IIR filter with programmable filter length uses the same EEPROM's sell for L.*

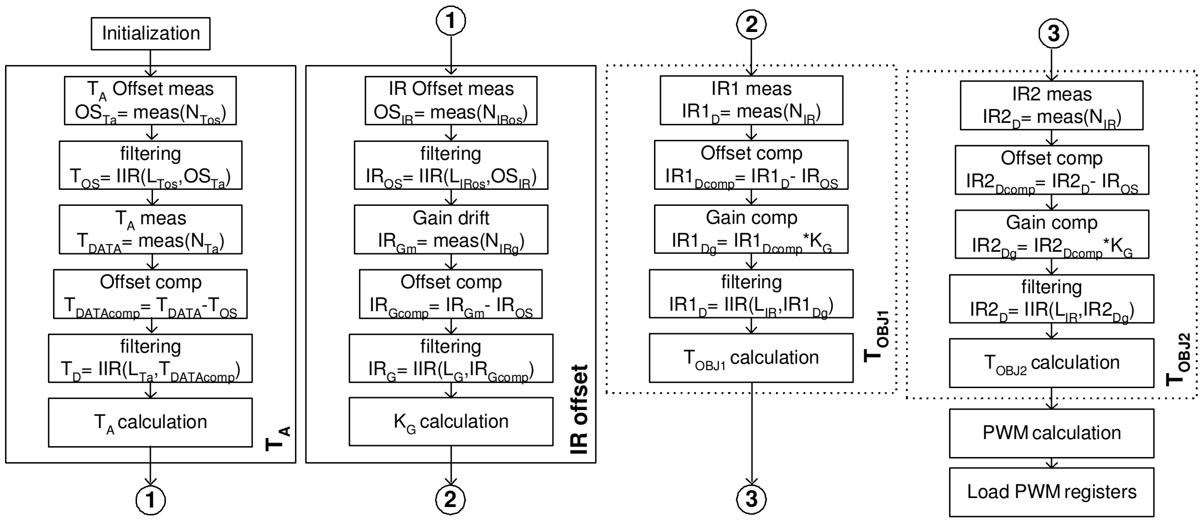


Figure 15: Software flow

7.8 Thermal relay

The MLX90614 can be configured to behave as a thermo relay with programmable threshold and hysteresis on the PWM/SDA pin. The input for the comparator unit of the relay is the object temperature from sensor 1
The output of the MLX90614 is NOT a relay driver but a logical output which should be connected to a relay driver if necessary.
In order to configure the MLX90614 to work as thermal relay two conditions must be met:

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

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

PWM/SDA pin is high if $T_{obj}1 \geq threshold + hysteresis$

PWM/SDA pin is low if $T_{obj}1 \leq threshold - hysteresis$

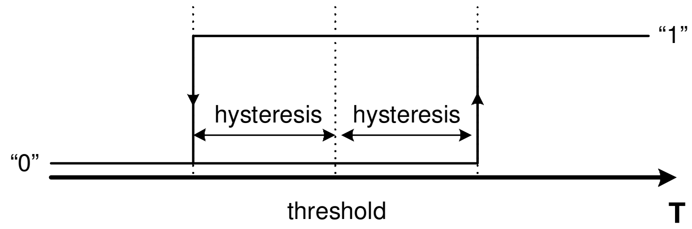


Figure 16: Thermal relay : "PWM" pin versus Tobj

The MLX90614 preserves its normal operation when configured as a thermal relay (PWM configuration and specification applies as a general rule also for the thermal relay) and therefore it can be read using the SMBus (entering the SMBus mode from both PWM and thermal relay configuration is the same).
For example, the MLX90614 can generate a wake-up alert for a system upon reaching a certain temperature and then be read as a thermometer. A reset condition (enter-and exit Sleep, for example) will be needed in order to return to the thermal relay configuration.

Example: threshold 5 °C => (5 + 273.15)*100 = 27815 = 6CA7h
hysteresis is 1°C => 1 * 100 = 100 = 64h
PWM/SDA pin will be low at object temperature below 4 °C
PWM/SDA pin will be high at object temperature higher that 6 °C

8 Unique Features

The MLX90614 is a ready-to use low-cost non contact thermometer provided from Melexis with output data linearly dependent on the object temperature with high accuracy and extended resolution.
It supports versatile customization to a very wide range of temperatures, power supplies and refresh rates.
The user can program the internal object emissivity correction for objects with a low emissivity. An embedded error checking and correction mechanism provides high memory reliability.
The sensors is housed in an industry standard TO39 package for both single- and dual-zone IR thermometers. The thermometer is available in automotive grade and can use two different packages for wider applications' coverage.
The low power consumption and sleep mode make the thermometer ideally suited for handheld mobile applications.
The digital sensor interface can be either a power-up-and-measure PWM or an enhanced access SMBus compatible protocol. Systems with more than 100 devices can be built with only two signal lines. Dual zone non contact temperatures measurements available via a single line (extended PWM).
A built-in thermal relay function further extends the easy implementation of wide variety of freezing/boiling prevention and alert systems, as well as thermostats (no MCU is needed).

9 Performance Graphs

9.1 Temperature accuracy of the MLX90601AAA

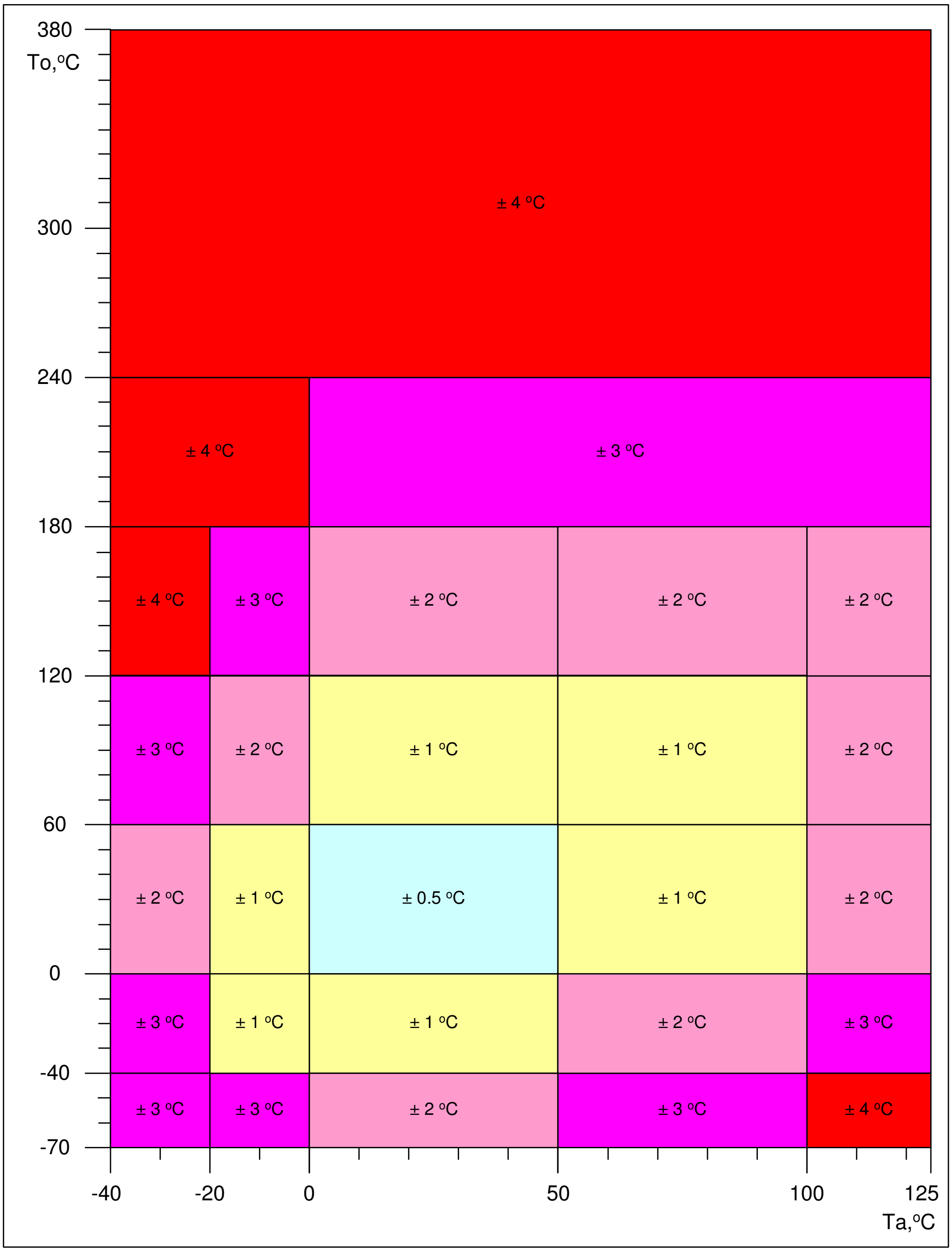


Figure 17: Preliminary accuracy of MLX90601AAA (Ta,To)

All accuracy specifications apply under settled isothermal conditions only.

A version of the MLX90614 with accuracy suited for medical applications is available upon request. The accuracy in the range Ta 10ºC - 40ºC and To 32ºC - 42ºC is shown in diagram below. The accuracy for the rest ranges is same as in previous diagram.

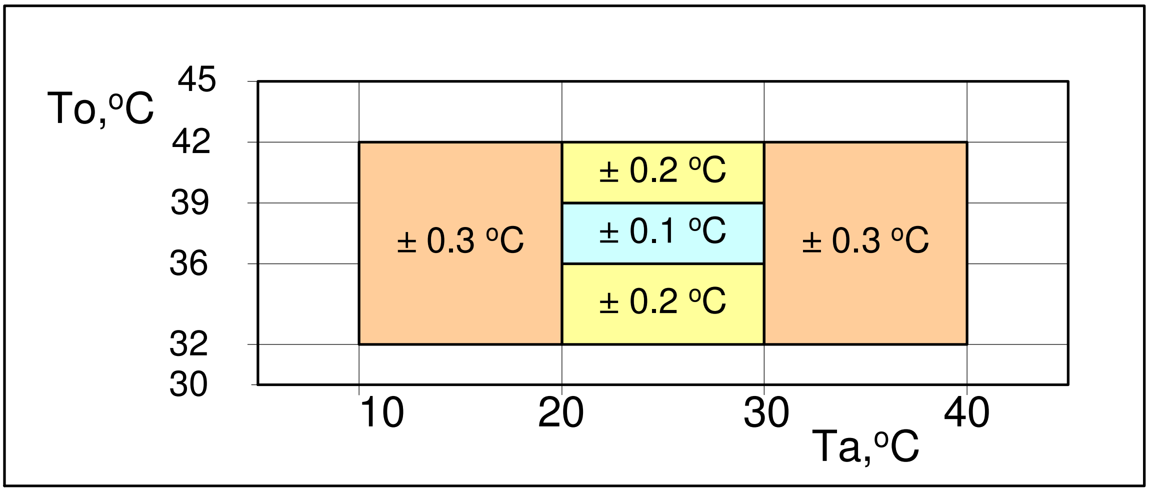


Figure 18: Preliminary accuracy of MLX90601BAA (Ta,To) for medical applications.

9.2 Field Of View (FOV)

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

Parameter	MLX90614xAA	MLX90614xAB	MLX90614xBA	MLX90614xBB
Peak zone 1	±0°	±0	-25°	-30°
Width zone 1	72°	80°	70°	70°
Peak zone 2	Not applicable		-25°	+30°
Width zone 2			70°	70°

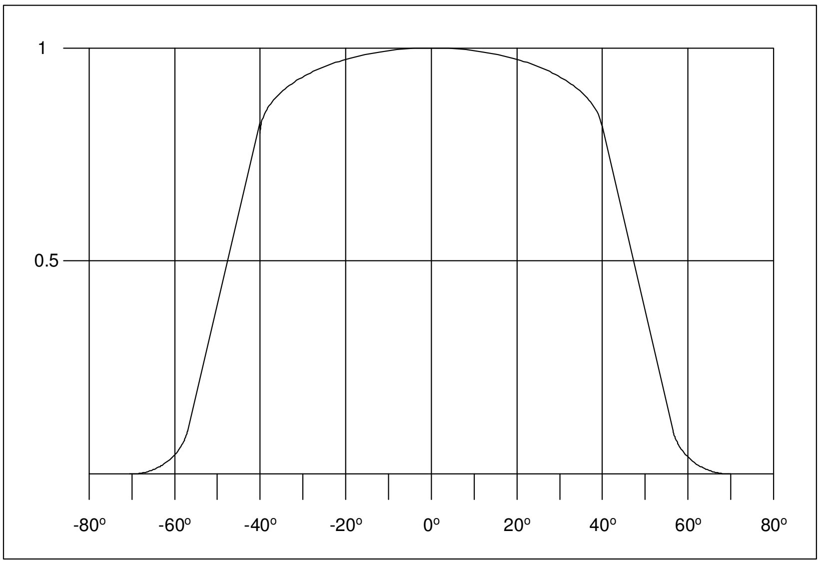


Figure 19: FOV of MLX90614xAA

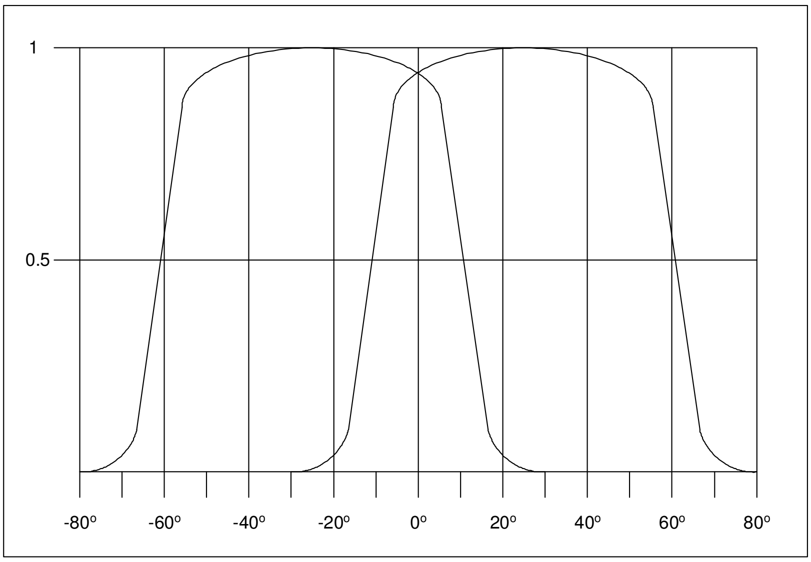


Figure 20: FOV of MLX90614xBA

Figure 21: identification of zone 1&2 relative to alignment tab.

10 Applications Information

10.1 Use of the MLX90614 thermometer in SMBus configuration

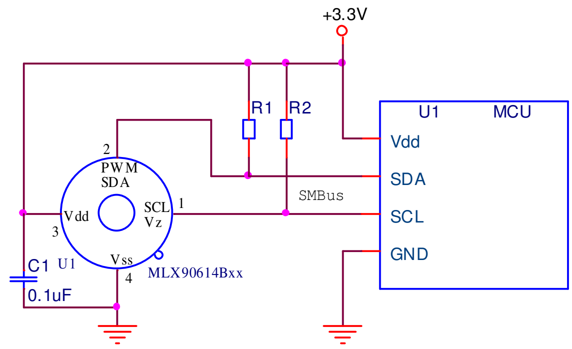


Figure 22: Connection of MLX90614 to SMBus, 3.3V power supply.

The MLX90614 has diode clamps SDA/SCL to Vdd so it is necessary to provide MLX90614 with power in order not to load the SMBus lines.

10.2 Use of multiple MLX90614s in SMBus configuration

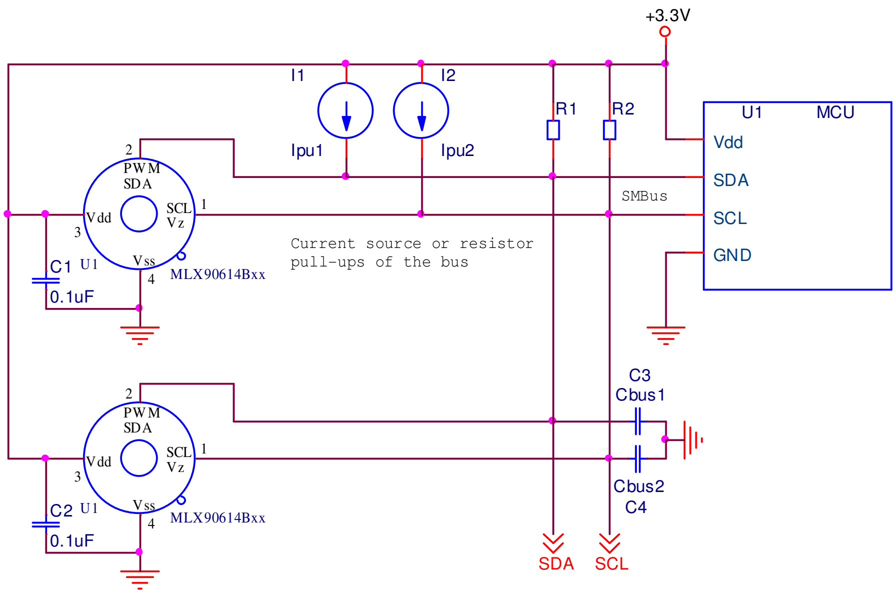


Figure 23: SMBus configuration of multiple sensors.

The MLX90614 supports a 7-bit slave address in EEPROM, thus allowing up to 127 devices to be read via two common wires. With the MLX90614BBx this results in 254 object temperatures measured remotely and an additional 127 ambient temperatures which are also available. 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.

10.3 Thermal alert / thermostat

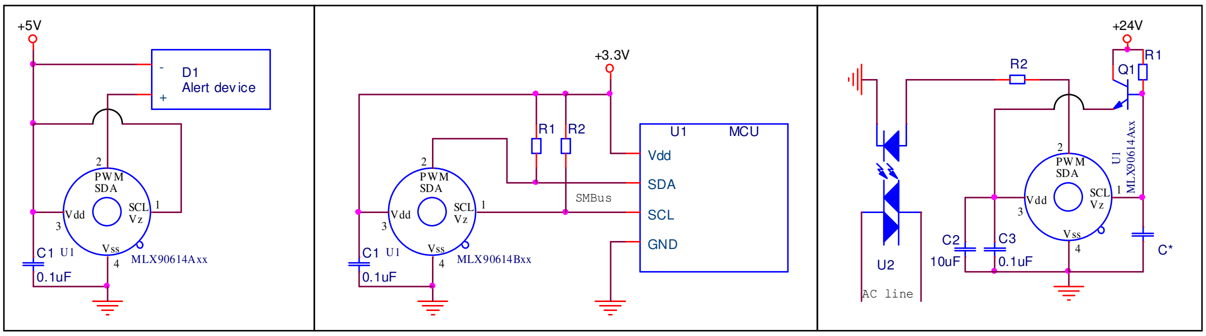


figure 24: Possible thermal relay configurations.

The MLX90614 can be configured in EEPROM to operate as a thermal relay. A non contact freezing or boiling prevention with 1 mA quiescent current can be built with two components only – the MLX90614 and a capacitor. The PWM/SDA pin can be programmed as a push-pull or open drain NMOS, which can trigger external device, such as a relay (refer to electrical specifications for load capability), buzzer, RF transmitter or a LED. This feature allows very simple thermostats to be built without the need of any MCU and zero design overhead required for firmware development. In conjunction with a MCU, this function can operate as a system alert that wakes up the MCU. Both object temperature and sensor die temperature can be also read in this configuration.

10.4 High voltage source operation

As a standard, the module MLX90614Axx works with a supply voltage of 5Volt. In addition, thanks to the integrated internal reference regulator available at pin SCL/Vz, this module can easily be powered from higher voltage source (like VDD=8…16V). Only a few external components as depicted in the diagram below are required to achieve this.

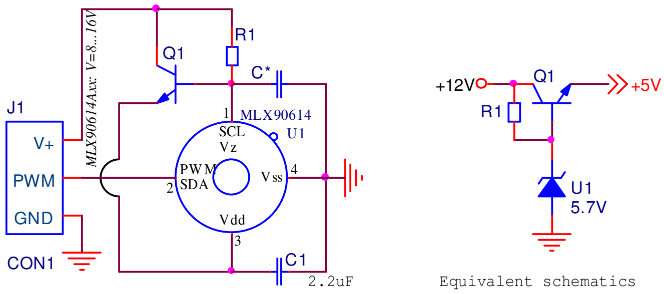


Figure 25: 12V regulator implementation

With the second (synthesized zener diode) function of the SCL/Vz pin used the 2-wire interface function is available only if the voltage regulator is overdriven (5V regulated power is forced to Vdd pin).
When the zener diode function of the SCL/Vz pin is used, the 2-wire SMBus function is only available if the voltage regulator is overdriven (5V regulated power is forced to the VDD pin).

11 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 MLX90614xxx, it is recommended not to subject the MLX90614 to heat transfer and especially transient conditions.

Upon **power-up** the MLX90614 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 MLX90614xxx 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 MLX90614xxx 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 MLX90614xxx 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 MLX90614 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.

In **12V powered systems SMBus usage is constrained** because the SCL pin is used for the zener diode function. Therefore, higher than 5V applications are likely to use PWM output or external regulator. Nevertheless, in the 12V powered applications MLX90614 can be programmed (configured and customized) by forcing the Vdd to 5V externally and running the SMBus communication.

Sleep mode is available in MLX90614Bxx. This mode is entered and exited via the SMBus compatible 2-wire communication. On the other hand, the extended functionality of the SCL pin yields in increased leakage current through that pin. As a result, this pin needs to be forced low in power-down mode and the pull-up on the SCL line needs to be disabled in order to keep the overall power drain in power-down really small.

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

It is possible to use the MLX90614xxx 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 MLX90614xxx in that way.

Power dissipation within the package may affect performance in two ways: by heating the "ambient" sensitive element significantly beyond the actual ambient temperature, as well as by causing gradients over the package that will inherently cause thermal gradient over the cap. Loading the outputs also causes increased power dissipation. In case of using the MLX90614Axx internal zener voltage feature, the regulating external transistor should also not cause heating of the TO39 package.

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

Check www.melexis.com for most current application notes about MLX90614.

Standard information regarding manufacturability of Melexis products with different soldering processes
Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to following test methods:

Reflow Soldering SMD's (Surface Mount Devices)

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

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

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

Iron Soldering THD's (Through Hole Devices)

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

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

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

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

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

Melexis 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 MLX90614 is RoHS compliant

12 ESD Precautions

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

13 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

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

where
$\boldsymbol{\varepsilon_1}$ and $\boldsymbol{\varepsilon_2}$ are the emissivities of the two objects,
$\boldsymbol{\alpha_1}$ is the absorptivity of the sensor (in this case),
$\boldsymbol{\sigma}$ is the Stefan-Boltzmann constant,
$\mathbf{A_1}$ and $\mathbf{A_2}$ are the surface areas involved in the radiation heat transfer,
$\mathbf{F_{a\text{-}b}}$ is the shape factor,
$\mathbf{T_1}$ and $\mathbf{T_2}$ 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 MLX90614 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 MLX90614 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 MLX90614 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 MLX90614AAA 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 MLX90614. 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.

14 Package Information

The MLX90614 is packaged in an industry standard TO – 39 can.

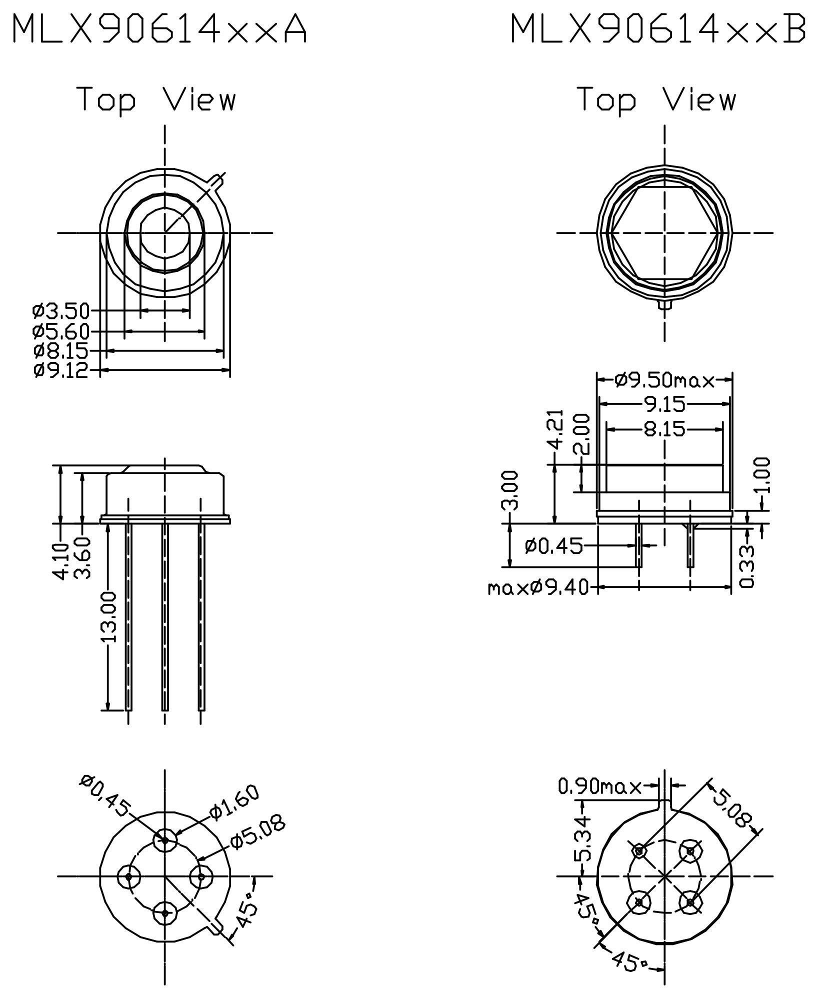


Figure 26: Packaging options

15 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.

16 Disclaimer

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ISO/TS 16949 and ISO14001 Certified

24-Bit Analog-to-Digital Converter (ADC) for Weigh Scales

DESCRIPTION

Based on Avia Semiconductor's patented technology, HX711 is a precision 24-bit analog-to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor.

The input multiplexer selects either Channel A or B differential input to the low-noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, corresponding to a full-scale differential input voltage of ±20mV or ±40mV respectively, when a 5V supply is connected to AVDD analog power supply pin. Channel B has a fixed gain of 32. On-chip power supply regulator eliminates the need for an external supply regulator to provide analog power for the ADC and the sensor. Clock input is flexible. It can be from an external clock source, a crystal, or the on-chip oscillator that does not require any external component. On-chip power-on-reset circuitry simplifies digital interface initialization.

There is no programming needed for the internal registers. All controls to the HX711 are through the pins.

FEATURES

- **Two selectable differential input channels**
- **On-chip active low noise PGA with selectable gain of 32, 64 and 128**
- **On-chip power supply regulator for load-cell and ADC analog power supply**
- **On-chip oscillator requiring no external component with optional external crystal**
- **On-chip power-on-reset**
- **Simple digital control and serial interface: pin-driven controls, no programming needed**
- **Selectable 10SPS or 80SPS output data rate**
- **Simultaneous 50 and 60Hz supply rejection**
- **Current consumption including on-chip analog power supply regulator:**
  normal operation < 1.5mA, power down < 1uA
- **Operation supply voltage range: 2.6 ~ 5.5V**
- **Operation temperature range: -40 ~ +85℃**
- **16 pin SOP-16 package**

APPLICATIONS

- **Weigh Scales**
- **Industrial Process Control**

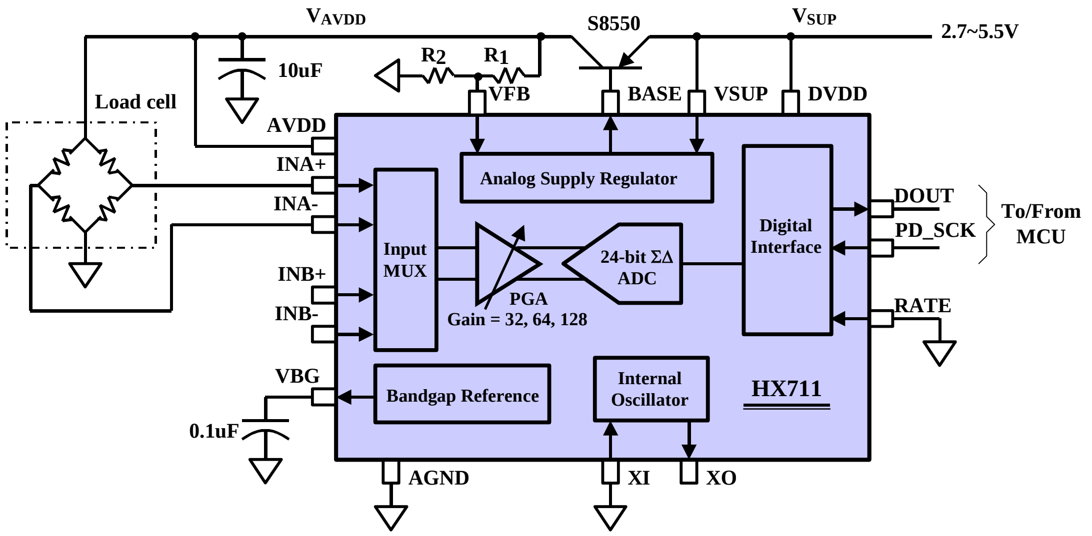
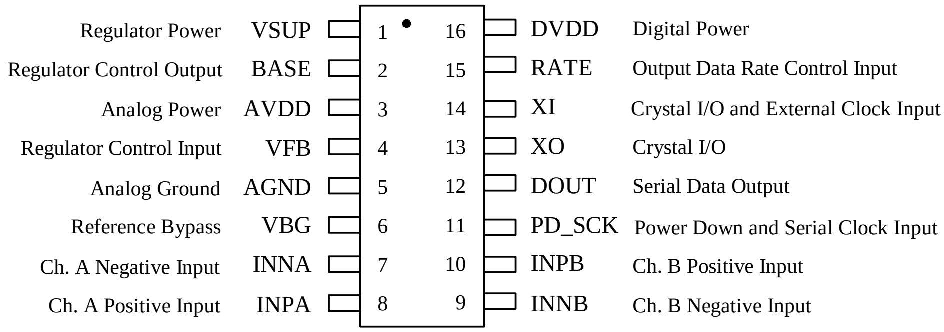


Fig. 1 Typical weigh scale application block diagram

Pin Description



SOP-16L Package

Pin #	Name	Function	Description
1	VSUP	Power	Regulator supply: 2.7 ~ 5.5V
2	BASE	Analog Output	Regulator control output（NC when not used）
3	AVDD	Power	Analog supply: 2.6 ~ 5.5V
4	VFB	Analog Input	Regulator control input（connect to AGND when not used）
5	AGND	Ground	Analog Ground
6	VBG	Analog Output	Reference bypass output
7	INA-	Analog Input	Channel A negative input
8	INA+	Analog Input	Channel A positive input
9	INB-	Analog Input	Channel B negative input
10	INB+	Analog Input	Channel B positive input
11	PD_SCK	Digital Input	Power down control (high active) and serial clock input
12	DOUT	Digital Output	Serial data output
13	XO	Digital I/O	Crystal I/O (NC when not used）
14	XI	Digital Input	Crystal I/O or external clock input, 0: use on-chip oscillator
15	RATE	Digital Input	Output data rate control, 0: 10Hz; 1: 80Hz
16	DVDD	Power	Digital supply: 2.6 ~ 5.5V

Table 1 Pin Description

KEY ELECTRICAL CHARACTERISTICS

Parameter	Notes	MIN	TYP	MAX	UNIT
Full scale differential input range	V(inp)-V(inn)		±0.5(AVDD/GAIN)		V
Common mode input		AGND+1.2		AVDD-1.3	V
Output data rate	Internal Oscillator, RATE = 0		10		Hz
	Internal Oscillator, RATE = DVDD		80		
	Crystal or external clock, RATE = 0		f_{clk}/1,105,920		
	Crystal or external clock, RATE = DVDD		f_{clk}/138,240		
Output data coding	2's complement	800000		7FFFFF	HEX
Output settling time (1)	RATE = 0		400		ms
	RATE = DVDD		50		
Input offset drift	Gain = 128		0.2		mV
	Gain = 64		0.4		
Input noise	Gain = 128， RATE = 0		50		nV(rms)
	Gain = 128， RATE = DVDD		90		
Temperature drift	Input offset（Gain = 128）		±6		nV/℃
	Gain（Gain = 128）		±5		ppm/℃
Input common mode rejection	Gain = 128， RATE = 0		100		dB
Power supply rejection	Gain = 128， RATE = 0		100		dB
Reference bypass（V_{BG}）			1.25		V
Crystal or external clock frequency		1	11.0592	20	MHz
Power supply voltage	DVDD	2.6		5.5	V
	AVDD，VSUP	2.6		5.5	
Analog supply current (including regulator)	Normal		1400		µA
	Power down		0.3		
Digital supply current	Normal		100		µA
	Power down		0.2		

（1）Settling time refers to the time from power up, reset, input channel change and gain change to valid stable output data.

Table 2 Key Electrical Characteristics

Analog Inputs

Channel A differential input is designed to interface directly with a bridge sensor's differential output. It can be programmed with a gain of 128 or 64. The large gains are needed to accommodate the small output signal from the sensor. When 5V supply is used at the AVDD pin, these gains correspond to a full-scale differential input voltage of ±20mV or ±40mV respectively.

Channel B differential input has a fixed gain of 32. The full-scale input voltage range is ±80mV, when 5V supply is used at the AVDD pin.

Power Supply Options

Digital power supply (DVDD) should be the same power supply as the MCU power supply.

When using internal analog supply regulator, the dropout voltage of the regulator depends on the external transistor used. The output voltage is equal to $V_{AVDD}=V_{BG}*(R1+R2)/R1$ (Fig. 1). This voltage should be designed with a minimum of 100mV below VSUP voltage.

If the on-chip analog supply regulator is not used, the VSUP pin should be connected to either AVDD or DVDD, depending on which voltage is higher. Pin VFB should be connected to Ground and pin BASE becomes NC. The external 0.1uF bypass capacitor shown on Fig. 1 at the VBG output pin is then not needed.

Clock Source Options

By connecting pin XI to Ground, the on-chip oscillator is activated. The nominal output data rate when using the internal oscillator is 10 (RATE=0) or 80SPS (RATE=1).

If accurate output data rate is needed, crystal or external reference clock can be used. A crystal can be directly connected across XI and XO pins. An external clock can be connected to XI pin, through a 20pF ac coupled capacitor. This external clock is not required to be a square wave. It can come directly from the crystal output pin of the MCU chip, with amplitude as low as 150 mV.

When using a crystal or an external clock, the internal oscillator is automatically powered down.

Output Data Rate and Format

When using the on-chip oscillator, output data rate is typically 10 (RATE=0) or 80SPS (RATE=1).

When using external clock or crystal, output data rate is directly proportional to the clock or crystal frequency. Using 11.0592MHz clock or crystal results in an accurate 10 (RTE=0) or 80SPS (RATE=1) output data rate.

The output 24 bits of data is in 2's complement format. When input differential signal goes out of the 24 bit range, the output data will be saturated at 800000h (MIN) or 7FFFFFh (MAX), until the input signal comes back to the input range.

Serial Interface

Pin PD_SCK and DOUT are used for data retrieval, input selection, gain selection and power down controls.

When output data is not ready for retrieval, digital output pin DOUT is high. Serial clock input PD_SCK should be low. When DOUT goes to low, it indicates data is ready for retrieval. By applying 25~27 positive clock pulses at the PD_SCK pin, data is shifted out from the DOUT output pin. Each PD_SCK pulse shifts out one bit, starting with the MSB bit first, until all 24 bits are shifted out. The 25th pulse at PD_SCK input will pull DOUT pin back to high (Fig.2).

Input and gain selection is controlled by the number of the input PD_SCK pulses (Table 3). PD_SCK clock pulses should not be less than 25 or more than 27 within one conversion period, to avoid causing serial communication error.

PD_SCK Pulses	Input channel	Gain
25	A	128
26	B	32
27	A	64

Table 3 Input Channel and Gain Selection

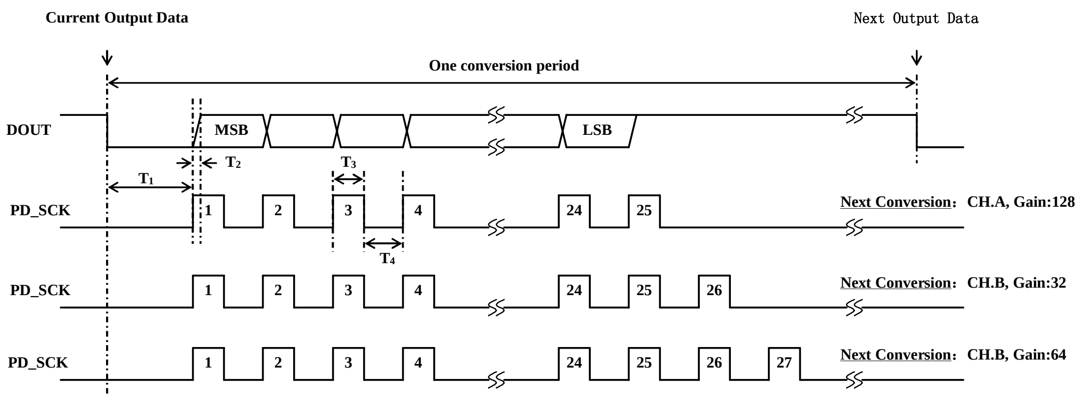


Fig.2 Data output, input and gain selection timing and control

Symbol	Note	MIN	TYP	MAX	Unit
T_1	DOUT falling edge to PD_SCK rising edge	0.1			μs
T_2	PD_SCK rising edge to DOUT data ready			0.1	μs
T_3	PD_SCK high time	0.2	1	50	μs
T_4	PD_SCK low time	0.2	1		μs

Reset and Power-Down

When chip is powered up, on-chip power on rest circuitry will reset the chip.

Pin PD_SCK input is used to power down the HX711. When PD_SCK Input is low, chip is in normal working mode.

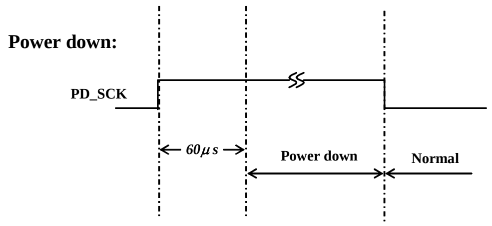


Fig.3 Power down control

When PD_SCK pin changes from low to high and stays at high for longer than 60μs, HX711 enters power down mode (Fig.3). When internal regulator is used for HX711 and the external transducer, both HX711 and the transducer will be powered down. When PD_SCK returns to low, chip will reset and enter normal operation mode.

After a reset or power-down event, input selection is default to Channel A with a gain of 128.

Application Example

Fig.1 is a typical weigh scale application using HX711. It uses on-chip oscillator (XI=0), 10Hz output data rate (RATE=0). A Single power supply （2.7～5.5V） comes directly from MCU power supply. Channel B can be used for battery level detection. The related circuitry is not shown on Fig. 1.

Reference PCB Board (Single Layer)

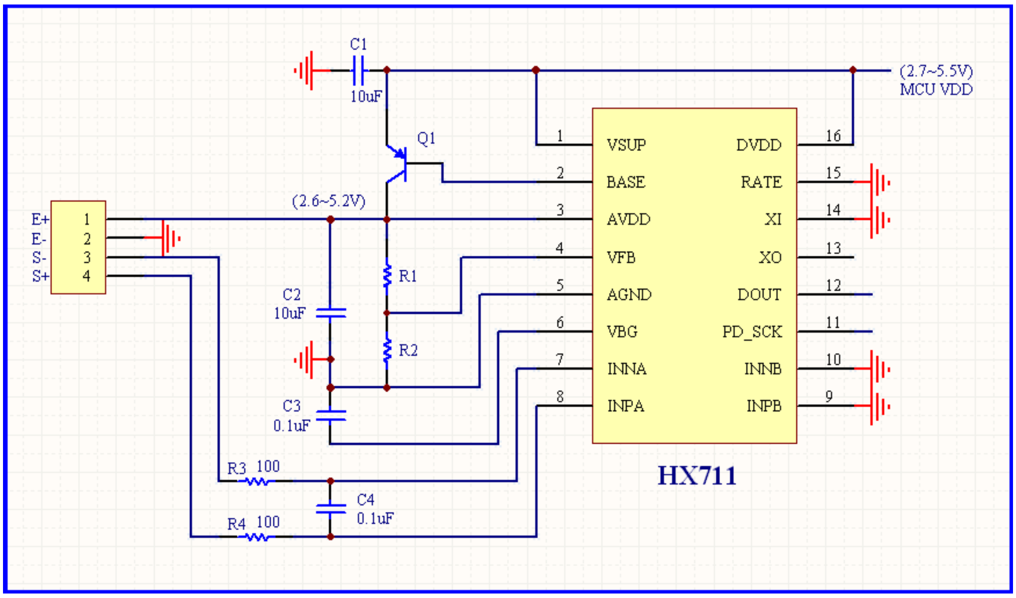


Fig.4 Reference PCB board schematic

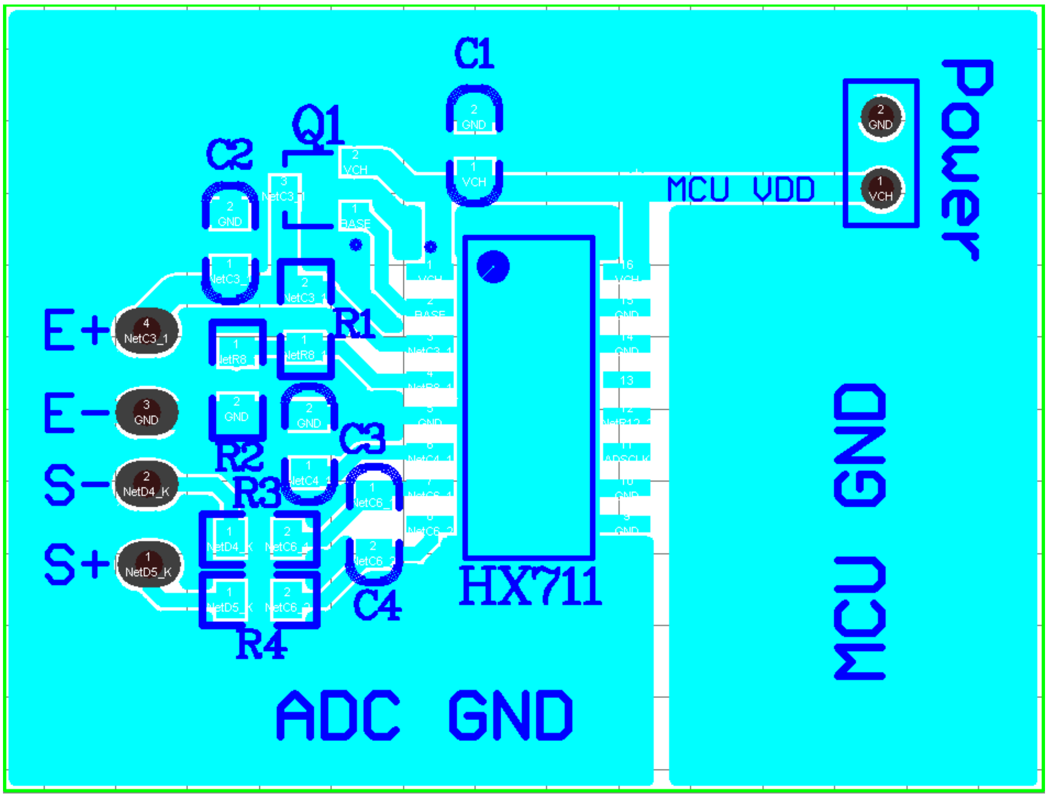


Fig.5 Reference PCB board layout

Reference Driver (Assembly)

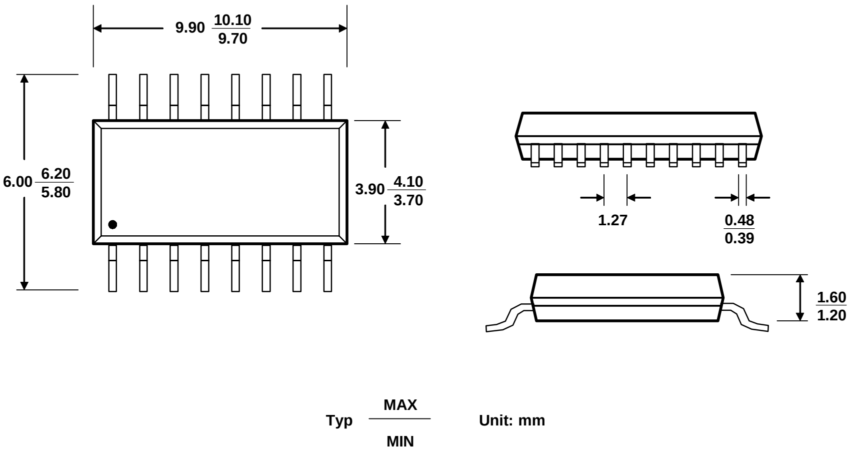
```
/*-------------------------------------------------------------------
Call from ASM:      LCALL   ReaAD
Call from C:    extern unsigned long ReadAD(void);
                  .
                  .
                 unsigned long data;
                 data=ReadAD();
                  .
                  .
---------------------------------------------------------------------*/
PUBLIC          ReadAD
HX711ROM        segment  code
rseg            HX711ROM

sbit            ADDO = P1.5;
sbit            ADSK = P0.0;
/*---------------------------------------------------
 OUT:   R4, R5, R6, R7   R7=>LSB
---------------------------------------------------*/
ReadAD:
    CLR     ADSK                //AD Enable (PD_SCK set low)
    SETB    ADDO                //Enable 51CPU I/0
    JB      ADDO,$              //AD conversion completed?
    MOV     R4,#24
ShiftOut:
    SETB    ADSK                //PD_SCK set high (positive pulse)
    NOP
    CLR     ADSK                //PD_SCK set low
    MOV     C,ADDO              //read on bit
    XCH     A,R7                //move data
    RLC     A
    XCH     A,R7
    XCH     A,R6
    RLC     A
    XCH     A,R6
    XCH     A,R5
    RLC     A
    XCH     A,R5
    DJNZ    R4,ShiftOut          //moved 24BIT?
    SETB    ADSK
    NOP
    CLR     ADSK
    RET
    END
```

Reference Driver（C）

```
//-------------------------------------------------------------------
sbit   ADDO = P1^5;
sbit   ADSK = P0^0;
unsigned long ReadCount(void){
  unsigned long Count;
  unsigned char i;
  ADDO=1;
  ADSK=0;
  Count=0;
  while(ADDO);
  for (i=0;i<24;i++){
    ADSK=1;
    Count=Count<<1;
    ADSK=0;
    if(ADDO) Count++;
  }
  ADSK=1;
  Count=Count^0x800000;
  ADSK=0;
  return(Count);
}
```

Package Dimensions



SOP-16L Package

Ultrasonic Ranging Module HC - SR04

Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:

(1) Using IO trigger for at least 10us high level signal,

(2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.

(3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning.

Test distance = (high level time×velocity of sound (340M/S) / 2,

Wire connecting direct as following:

- 5V Supply
- Trigger Pulse Input
- Echo Pulse Output
- 0V Ground

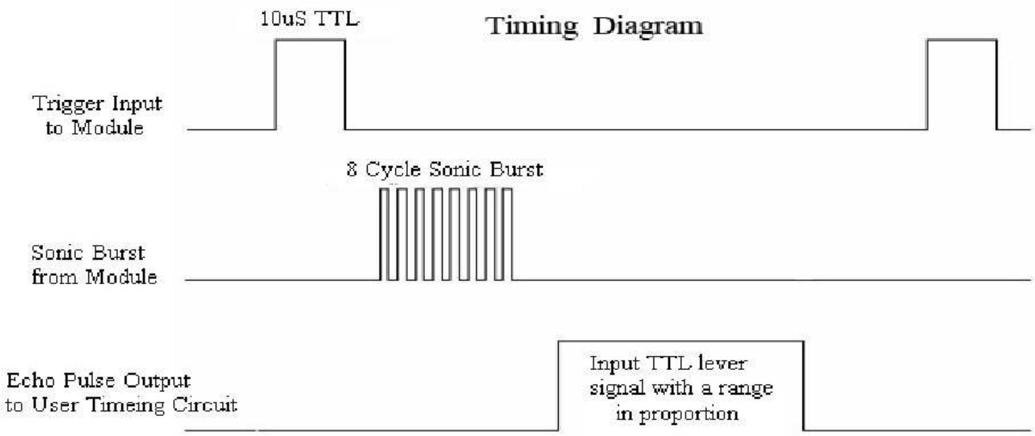
Electric Parameter

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

Vcc Trig Echo GND

Timing diagram

The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can calculate the range through the time interval between sending trigger signal and receiving echo signal. Formula: uS / 58 = centimeters or uS / 148 =inch; or: the range = high level time * velocity (340M/S) / 2; we suggest to use over 60ms measurement cycle, in order to prevent trigger signal to the echo signal.



Attention:

- The module is not suggested to connect directly to electric, if connected electric, the GND terminal should be connected the module first, otherwise, it will affect the normal work of the module.
- When tested objects, the range of area is not less than 0.5 square meters and the plane requests as smooth as possible, otherwise ,it will affect the results of measuring.

www.Elecfreaks.com

Ultrasonic ranging module : HC-SR04

Specifications:

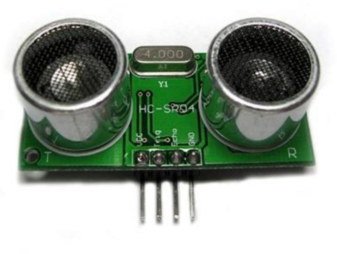
power supply :5V DC

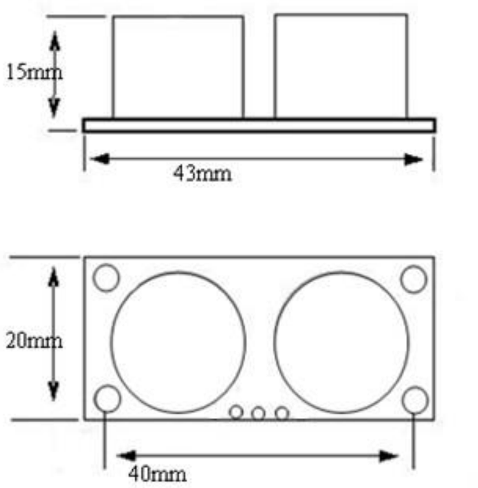
quiescent current : <2mA

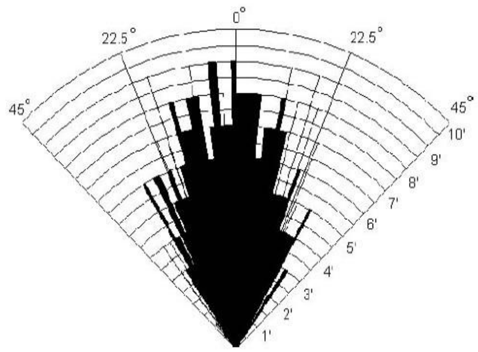
effectual angle: <15°

ranging distance : 2cm – 500 cm

resolution : 0.3 cm

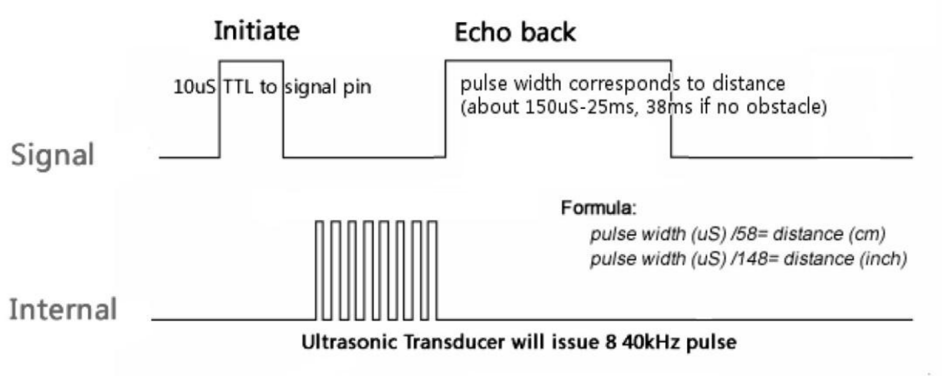






Practical test of performance,
Best in 30 degree angle

Sequence chart



A short ultrasonic pulse is transmitted at the time 0, reflected by an object. The senor receives this signal and converts it to an electric signal. The next pulse can be transmitted when the echo is faded away. This time period is called cycle period. The recommend cycle period should be no less than 50ms. If a 10μs width trigger pulse is sent to the signal pin, the Ultrasonic module will output eight 40kHz ultrasonic signal and detect the echo back. The measured distance is proportional to the echo pulse width and can be calculated by the formula above. If no obstacle is detected, the output pin will give a 38ms high level signal.

Library:
http://iteadstudio.com/store/images/produce/Robot/HCSR04/Ultrasonic.rar