A

PROJECT STAGE -2 REPORT ON

“COVID 19 SAFETY SYSTEM – DOOR HANDLE SANITIZER & TEMPERATURE DETECTION”

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CERTIFICATE

This is to certify that the project report entitled

“COVID 19 SAFETY SYSTEM – DOOR HANDLE SANITIZER & TEMPERATURE DETECTION”

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Has successfully completed Project stage 2 report under the supervision of **Prof. Mrs. S. G. Madhikar** for the partial fulfillment of the requirements of Bachelor of Engineering E&TC of Savitribai Phule Pune University, Pune. This work has not been earlier submitted to any other institute or University for the award of degree or diploma.

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ABSTRACT

Since December 2019 the world is under tremendous tension, the numbers are increasing day by day, and till date no vaccine has been full proved against the pandemic agent. The COVID-19

virus was unknown to us before it cast its outbrake in Wuhan, China. Being from a large family, a continuous mutation is occurring, forbidding the researchers, microbiologist, pharmaceuticals to search for the cure for the vaccine.

Affecting the countries in a chain; China , Italy ,Spain , USA , India , Russia, the virus has proved it’s strength and subservient a technologically enhanced race. The policies taken worldwide has lessen its affect to some extent but could not eradicate it. Lockdown has economically weaken many nations, and testing of different medicines has also not proven to be satisfactory.

The design shows the preventive measure that can be taken during the COVID-19 pandemic in the whole world. Sanitizers have become the most significant commodities right now. By the new rules and regulations given by WHO vigorous sanitization is needed to survive. The design gave the solution for the problem stated. The design introduces an automatic hand sanitizer and temperature sensing system, to keep the hand sanitized whenever a person wants to do it, without a contact with the sanitizing machine. The temperature sensor on touching gives the body temperature of the person.

Keywords: Automatic hand sanitizer, Arduino, ultrasonic sensor, PIR sensors, TMP36, covid-19.

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CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 Introduction

In early 2020, a virus emerged that was spreading rapidly to several countries. The first case related to the virus was reported in Wuhan, Hubei Province. WHO named this disease the 2019 novel coronavirus (2019-nCoV), then changed its name to Coronavirus Disease (COVID-19) which was caused by the virus of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-Cov-2). This virus is zoonotic (a virus that is transmitted between animals and humans) and originates from bats. Besides, this virus can also be transmitted from humans to humans.

Coronavirus can be transmitted either by air, direct contact, or indirectly. However, it is most commonly spread by droplets. Symptoms caused by this virus include the mild flu, namely a cold, sore throat, cough, fever, and difficulty breathing. In severe cases, Covid-19 can manifest as pneumonia. Patients can develop acute respiratory distress syndrome for a short time and die from multiple organ failure. The existence of this disease has a big impact on both socials and economics. WHO has declared this a pandemic disease and many cities around the world are in a lockdown situation. To prevent the cause of this virus, it can be done by keeping a distance at least 1 meter, avoid going to crowded places, avoid touching the eyes, mouth, and nose when outside, and cleaning hands with soap or alcohol-based hand rub.

Providing containers for cleaning fluids in public spaces is a form of Covid-19 prevention, but the provision of containers is currently ineffective because there are parts that are often touched. This could be a point of transmission for Covid-19. Many health actions are carried out using automatic systems including air quality monitoring, hand sanitizers, hand hygiene. Hand sanitizers are an alternative for washing hands during a pandemic. It can be used when and water are not available. Hand sanitizer is also available in several forms such as liquid (spray) or gel. Hand sanitizer is usually made from materials such as alcohol, polyacrylic acid, glycerin, propylene glycol, or plant extracts.

The process of killing germs starts with removing the oil on the skin, then the bacteria in the body will come to the surface. Soap or alcohol will kill bacteria after rubbing to your hand.

Hand sanitizer is effective against Covid-19. So far, most of the available hand sanitizers do not operate automatically.

This project aims to make an automatic hand sanitizer where soap and water can come out automatically. Besides that, automated hand sanitizer will make notification to the owner, if the liquid has run out to the smartphone. The ultrasonic sensor will sense the presence of heat and motion of the object and send data to the microcontroller so that it can activate the pump. If the water height is less than 20 cm, the ultrasonic sensor will send data to controller to the output devices such as smartphones. The results of the hand sanitizer testing that the system can run smoothly with a minimum detection error of transferring data.

1.2 Problem Statement

The motive of the project is, too much hand sanitization is not good for human body as it may cause irritations and can be poisonous if consumed. Instead of hand sanitization if door knobs and objects are automatically sanitized it would increase efficiency to curb the spread of new influenza virus which is transmitted by hand contact.

1.3 Objective

With the above stated aspects, the design has been done for easy installation of the hardware in every possible places across the globe. The design encompasses few parameters to be calculated and taken as priority, such as

- Installation of ultrasonic sensor for object detection.
- Installation of temperature sensor.
- Installation of Pulse oximeter sensor.
- Installation of spray pumps/submersible pumps.
- Synchronizing all the sensors with microcontroller.

The circuit connection should be done minutely to avoid any kind of fault while working of the device. Proper safety measure has been taken to overcome any kind of fault in consideration of over-voltage , short circuit , excessive current flow etc.

1.4 Relevance

In this COVID-19 pandemic period which is a global outbreak, hand hygiene is the core preventive measure in the spread of the disease as advised by WHO (World Health Organization) which includes washing hands with water and soap regularly, hand sanitizing using hand sanitizers, etc.

Hygiene refers to the practices conducive to maintaining health and preventing disease especially through cleanliness such as washing hands, coughing in the elbow etc. Hand washing helps to prevent any diseases that spread through contact. In order to eliminate most of the germs on the hands, we need to apply a good hand washing practice. In most healthcare settings, alcohol-based hand sanitizers are preferable to hand washing with soap and water because it can be easily tolerated and it is also more effective at reducing bacteria. Hand sanitizer is a liquid, gel, or foam generally used to decrease infectious agents on the hands. A sanitizer is designed to kill germs on skin, objects and surfaces.

This project aims to design and implement a low cost smart hand sanitizer dispenser with door controller. It is based on ATMEGA328P Micro-controller, Thermal temperature sensor and Ultrasonic rangefinder sensor (an ultrasonic sensor is used to check the presence of hands below the outlet of the sanitizer machine), that can help to solve the challenges faced by security guards at different stations such as bank doors, school gates, hospital gates etc.

CHAPTER 2
LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

John M. Boyce, M.D.and Didier Pittet, M.D talked about the significance of hand washing with individual cleanliness. For ages, hand washing with cleanser and water has been viewed as a proportion of individual cleanliness. The idea of purging hands with a germicide specialist most likely rose in the mid nineteenth century. As ahead of schedule as 1822, a French drug specialist exhibited that arrangements containing chlorides of lime or soft drink could destroy the foul smells related with human bodies and that such arrangements could be utilized as disinfectants and sterilizers. In a paper distributed in 1825, this drug specialist expressed that doctors and different people going to patients with infectious illnesses would profit by soaking their hands with a fluid chloride arrangement.

R. Monina Klevens, et al., used a multi-step approach and three data sources. The main source of data was the National Nosocomial Infections Surveillance (NNIS) system, data from 19902002, conducted by the Centers for Disease Control and Prevention. Information from the National Hospital Discharge Survey (for 2002) and the American Hospital Association.

Design and Development of Arduino Based Contactless Thermometer Here Arduino UNO, MLX90614 temperature sensor, OLED Display and a battery is used for developing this system. The thermometer built here has a wide range of -70 to 380˚C temperature measurement, has a resolution of 0.02 with an accuracy of 0.5˚C and is accessed by 2 wire serial SM Bus compatible protocol. Unlike traditional thermometers, the proposed thermometer does not need any contact to measure the temperature. When the Arduino is powered on, the MLX90614 measures the temperature of the body/object in its range. The range is provided by a led/IR light for accurate target of desired object or body. This temperature is displayed using OLED.

Automated Social Distancing Gate with Non-Contact Body Temperature Monitoring using Arduino Uno The incoming person’s body temperature is measured using MLX90614ESF-BAA- 000-TU-ND non-contact IR temperature sensor and the temperature is displayed on a 4x20 blue LCD as soon as IR sensor GP2YOA21YK detects the forehead at a distance of 150cm. A buzzer of 0.5 watt, 8 ohms is used to notify the detection of abnormal temperature i.e., 37.5 degree

Celsius or above. Also a speaker is used to indicate the same. MLX90614ESF-DCx versions of the infrared thermometer sensor can be used instead of MLX90614ESF-BAA-000-TUND for better accuracy.

Design of a contactless body temperature measurement system using Arduino Here an Arduino CT uno controller, a type of Arduino mega controller is used to monitor the temperature parameters. Two sensors LM 35 as S1 and MLX-90614 as S2 are used for temperature measurement. LM35 is a contact type sensor and gives a precise output in the range -55 degree C to 150-degree C. Whereas the MLX-90614 is a contactless sensor. The S1 senses the ambience temperature where output voltage is directly converted into temperature in Celsius and S2 senses the human body temperature through PWM output pins. The esp.-WIFI shield is a programmable microcontroller that is used to transfer and monitor the collected temperature data both wired and wirelessly and also displays the data in the online portal.

Design of Automatic Hand Sanitizer with Temperature Sensing Here there are two systems which work simultaneously, the first one is automatic sanitizer and second is the temperature sensing. The ultrasonic sensor PING SEN136B5B is used to detect the range of the human and the PIR sensor is used to monitor the motion of the human. The range of PIR sensors is 5 to 12m. Any detection of humans will activate the sanitizer pump1 and the sanitizer is sprayed and a blower is used to spread the sanitizer to the surroundings. Ultrasound sensor has a range less than 30m, any detection of human hand in that range will activate pump2 which sanitizes the hands using a DC motor. Temperature sensor TMP 36 senses the temperature as soon as the contact is made, the sensor displays the temperature on the LCD display in Fahrenheit. A RGB led is made to glow green when the temperature is normal else it is made to glow red when the temperature is higher than normal and a piezo electric buzzer is used for the same. The system has an efficient automatic sanitizing development but fails to provide a contactless temperature measuring unit, which can lead to spreading of infection.

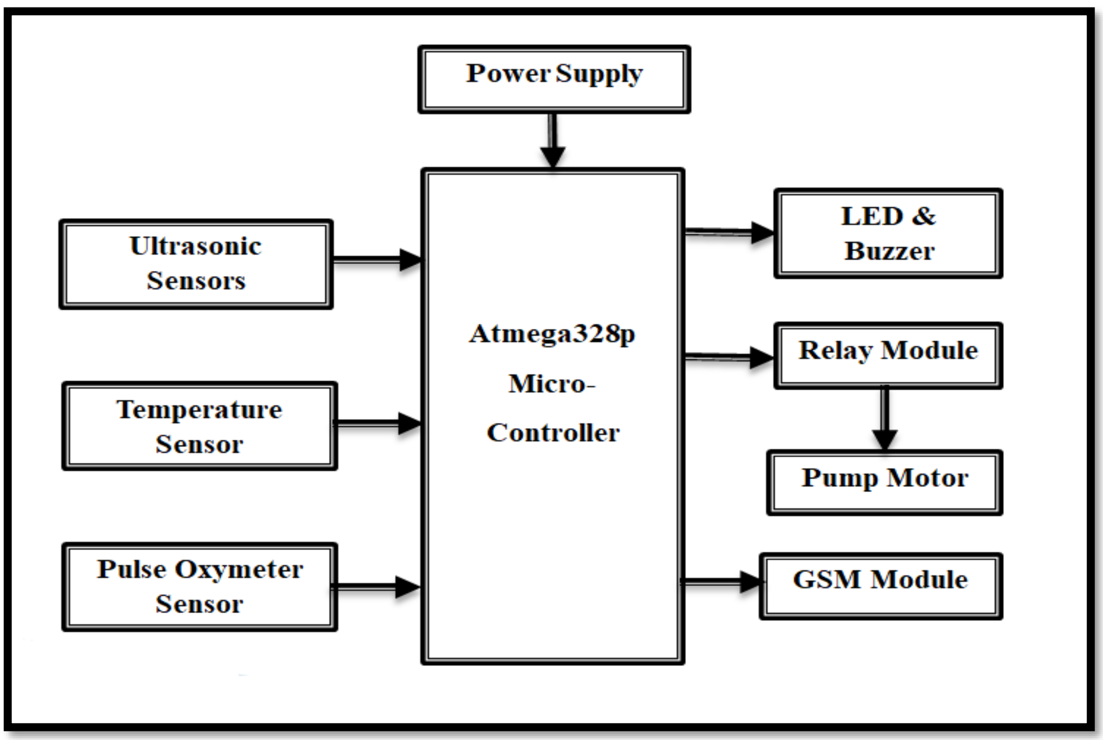
CHAPTER 3
DESIGN DEVELOPMENT & SPECIFICATIONS

CHAPTER 3

DESIGN DEVELOPMENT & SPECIFICATIONS

3.1 Block diagram :-

As we switch on the device , the sensors attached to the controller gets activated. We have two systems to work simultaneously to each other. First the automatic sanitizer and secondly the contacted temperature sensing. The ultrasonic sensor is attached to the controller for detection of human/object ranging. Any detection in the specified range will activate the sanitizer and it will sanitize the surroundings with activation of spray pump 1 accompanied with a blower so that the sanitizer reaches the surrounding . The ultrasonic sensor on the other side has been specified with a range of less than 30cm, any movement especially hand near(<30cm) the device will activate the spray pump 2 and the sanitizer reaches the hand through a small pipe.



.Fig.3.1: Block diagram of system

Description:

3.1.1 Atmega328p microcontroller

It is an open source microcontroller based computing platform used for easy programming and synchronizing of different analog and digital sensors and it is also capable of sending and receiving data over the internet. It is built up with 8-bit Atmel AVR or 32- bit Atmel ARM microcontrollers. It provides a comfortable design platforms for hobbyists, students and professional designers.

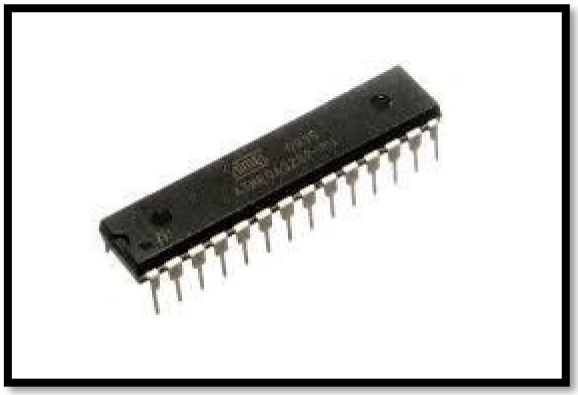


Fig.3.1.1 Microcontroller

3.1.2 Ultrasonic Sensor

The ultrasonic range sensor (HC–SR 04) has a range of 3cm - 400 cm. The sensor operates by transmitting an ultrasound and receiving the echo as it bounces back against an obstacle after a certain time and calculates the distance of the object accordingly. The sensors sends the ultrasound and senses the echo with the same pin SIG.

Fig.3.1.2 Ultrasonic Sensor

3.1.3 Pulse Oximeter Sensor

The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

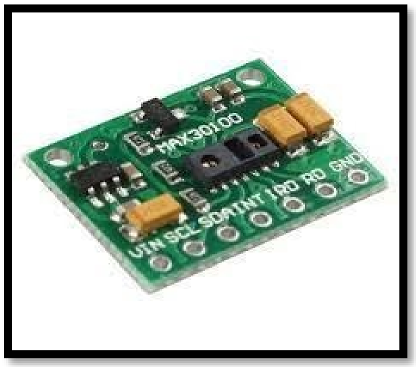


Fig.3.1.3 Pulse Oximeter Sensor

3.1.4 DC Motor/ Submersible Spray Pump

The motor/pump is used to spray the sanitizer on the hand after the sensors give required signal. A submersible pump (or sub pump, electric submersible pump (ESP)) is a device which has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between the pump and the fluid surface. Submersible pumps push fluid to the surface, rather than jet pumps, which create a vacuum and rely upon atmospheric pressure.

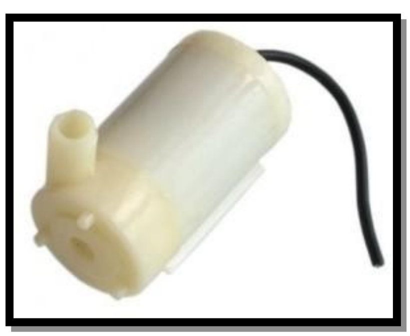


Fig.3.1.4 DC Motor/ Submersible Spray Pump

3.1.5 WIFI Module

The ESP8266EX microcontroller integrates a Tensilica L106 32-bit RISC processor, which achieves extra-low power consumption and reaches a maximum clock speed of 160 MHz. The Real-Time Operating System (RTOS) and Wi-Fi stack allow about 80% of the processing power to be available for user application programming and development

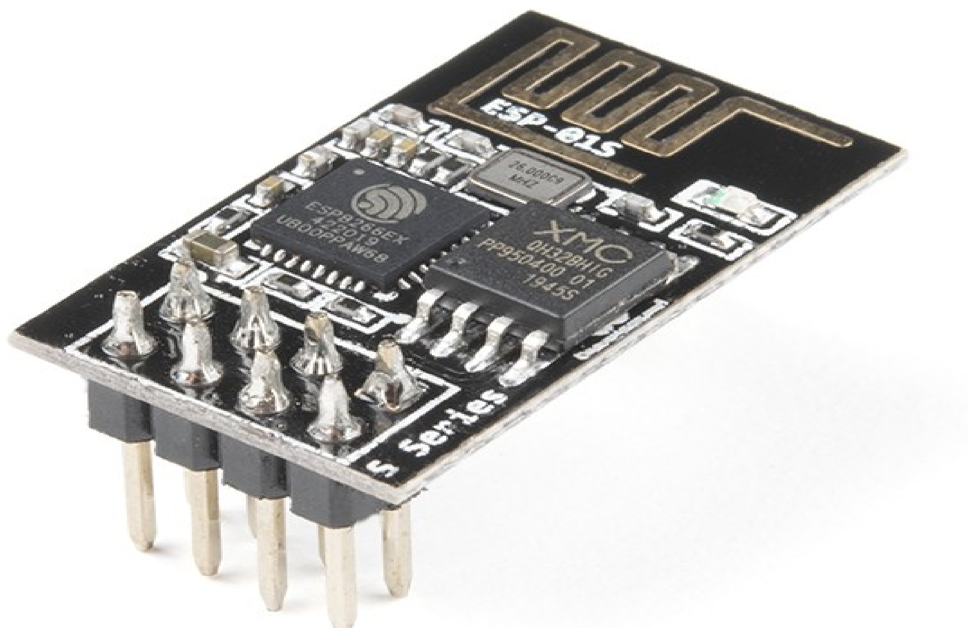


Fig.3.1.5 WIFI Module

The ESP8266 module enables microcontrollers to connect to 2.4 GHz Wi-Fi, using IEEE 802.11 bgn. It can be used with ESP-AT firmware to provide Wi-Fi connectivity to external host MCUs, or it can be used as a self-sufficient MCU by running an RTOS-based SDK.

3.1.6Temperature Sensor MLX90614

Our latest infrared temperature measurement module is the MLX90614. This sensor measures the surface temperature by detecting infrared radiation energy and wavelength distribution. The IR temperature probe consists of an optical system, photoelectric detector, amplifier, signal processing and output module. The optical system collects the infrared radiation in its field of view and the infrared radiation energy is converted in to corresponding electrical signals when converging on the photoelectric detector. After being processed by the amplifier and signal processing circuit, the signal is converted in to a temperature value. The MLX90614 is self calibrating and has a low noise amplifier integrated in to the signal processing chip. The chip itself is a 17 bit ADC and DSP device, giving accurate and reliable results.

Fig.3.1.6 Temperature Sensor MLX90614

3.2 Circuit Diagram:

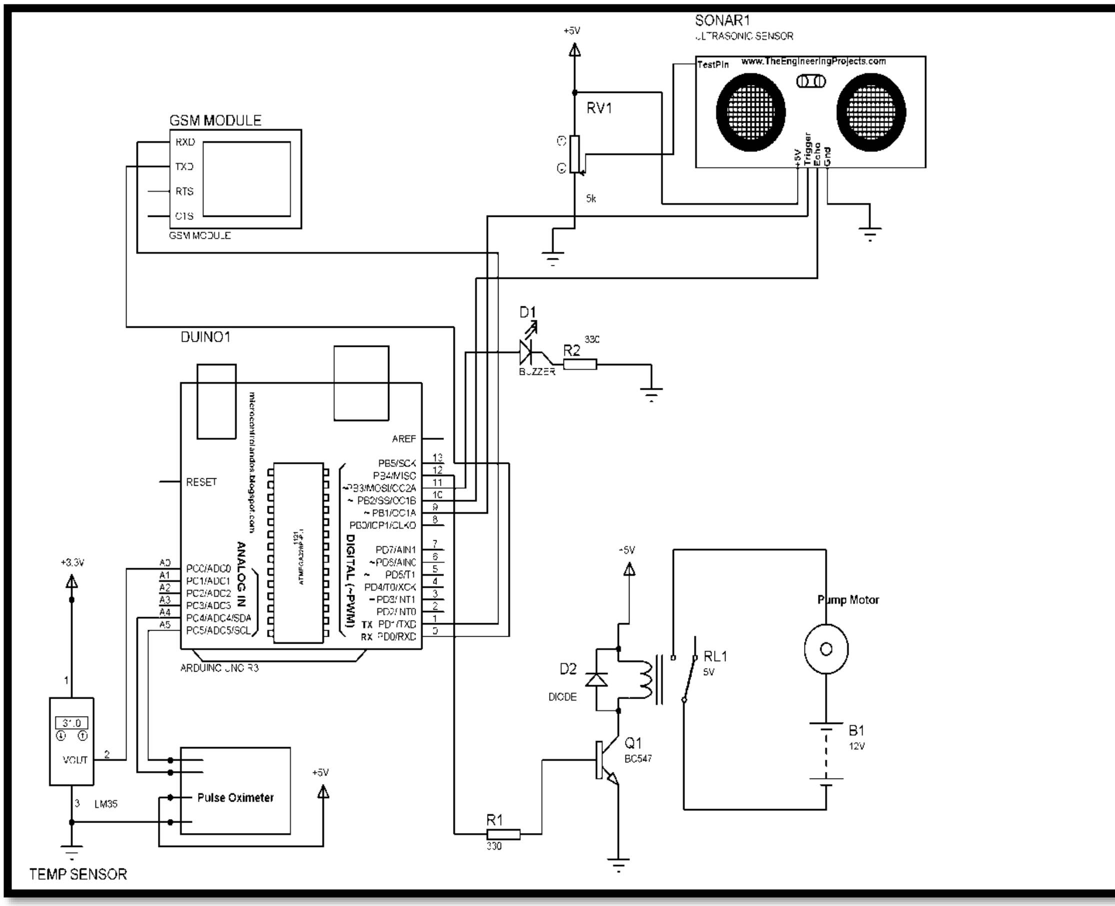
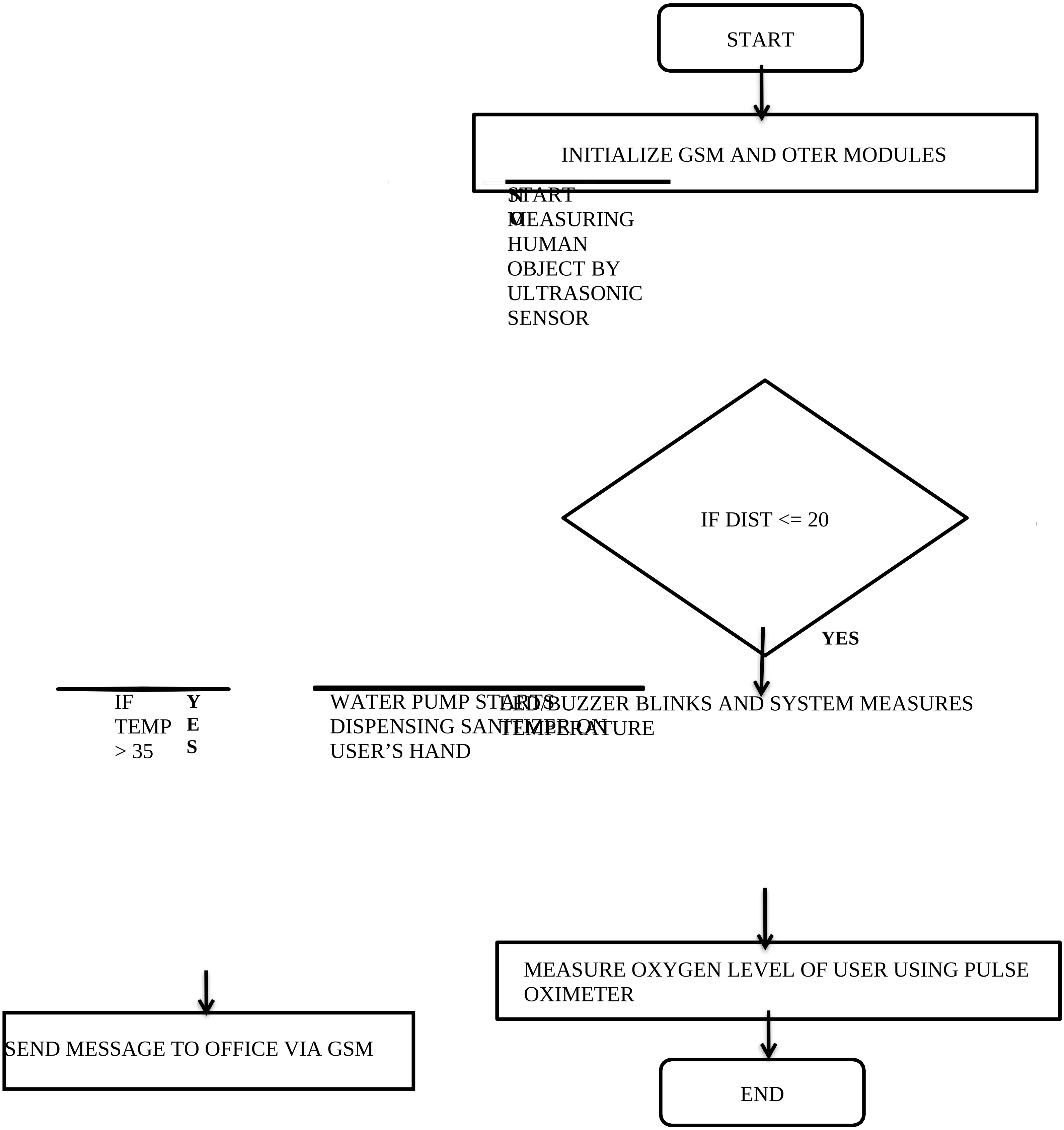


Fig. 3.3: Circuit Diagram of system

3.3 Flow Chart



3.4 Specifications

1. Controller ATMEGA328
2. LED and Buzzer
3. IR Temperature Sensor MLX 90614
4. Pulse Oxi Meter MAX 30100
5. Ultrasonic sensor
6. Sanitizer Pump 12V WATER PUMP
7. WIFI Module: ESP8266EX
8. Relay Module

3.5 Software Platform

1. Arduino IDE
2. Proteus Simulation

CHAPTER 4

IMPLEMENTATION

CHAPTER 4

IMPLEMENTATION

4.1 Software Implementation

1. The following figure is the basic circuitry of assembled components namely: Atmega microcontroller, GSM module, Ultrasonic Sensor, Temperature Sensor, Buzzer and a DC motor pump connected to a relay circuit. It is shortly divided into analog inputs like temperature sensor and digital outputs like GSM module, buzzer, DC motor pump and digital input like Ultrasonic sensor.

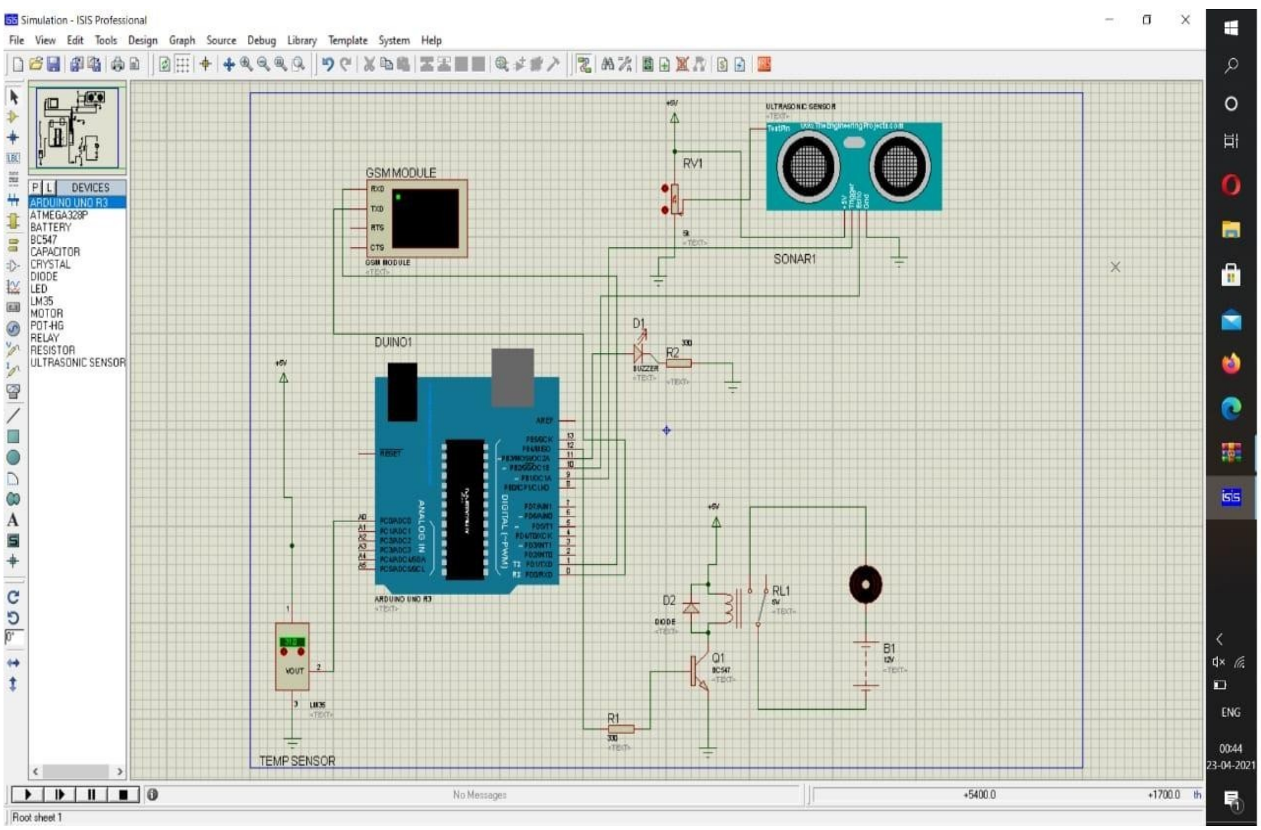


Fig. 4.1 Simulation of Basic Circuit

2. Distance gets printed on GSM module when the simulation is on run mode. Continuous monitoring of obstacle distance is done till threshold value is reached.

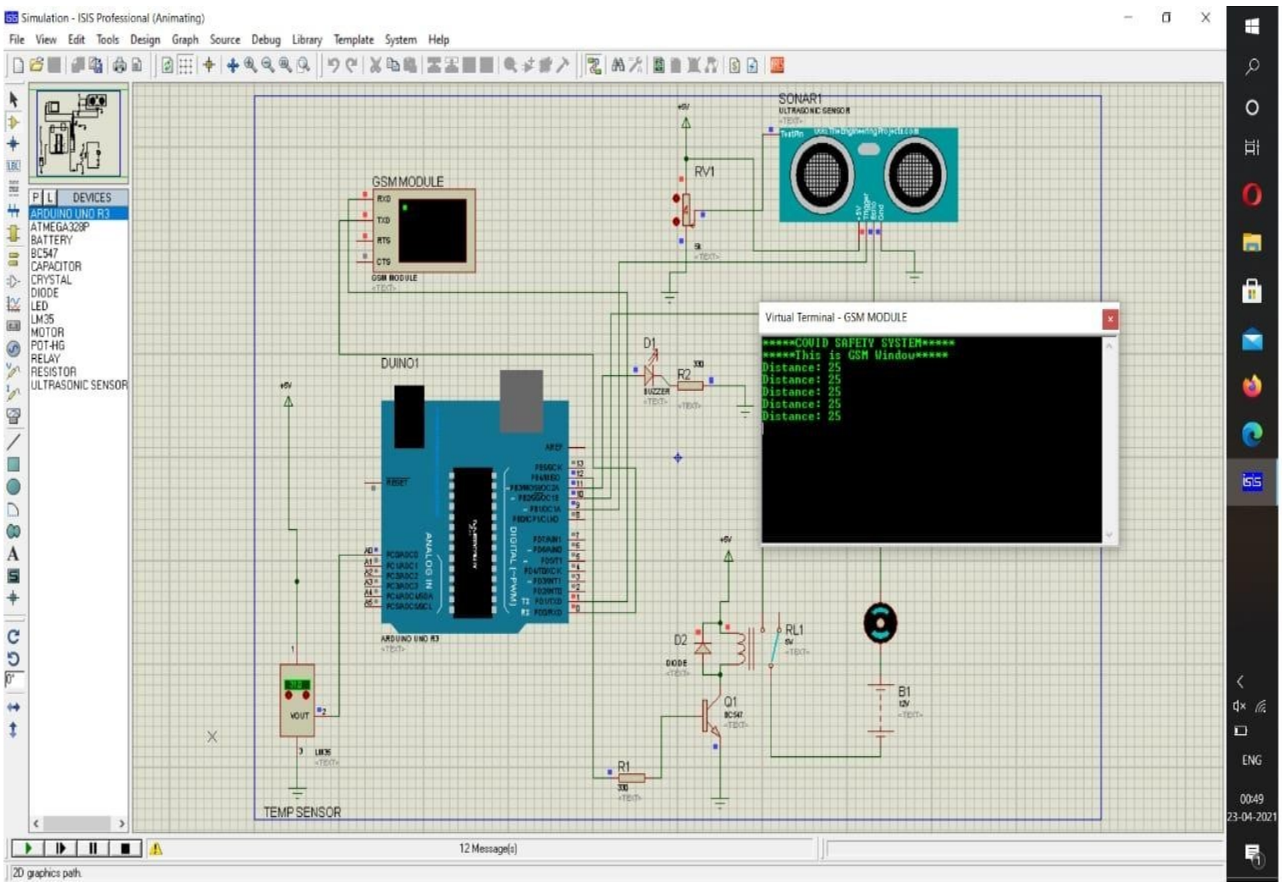


Fig.4.2 Simulation of UV sensor

3. When person’s hand gets detected the GSM module’s visual terminal displays the temperature detected by temperature sensor and a system generated message.

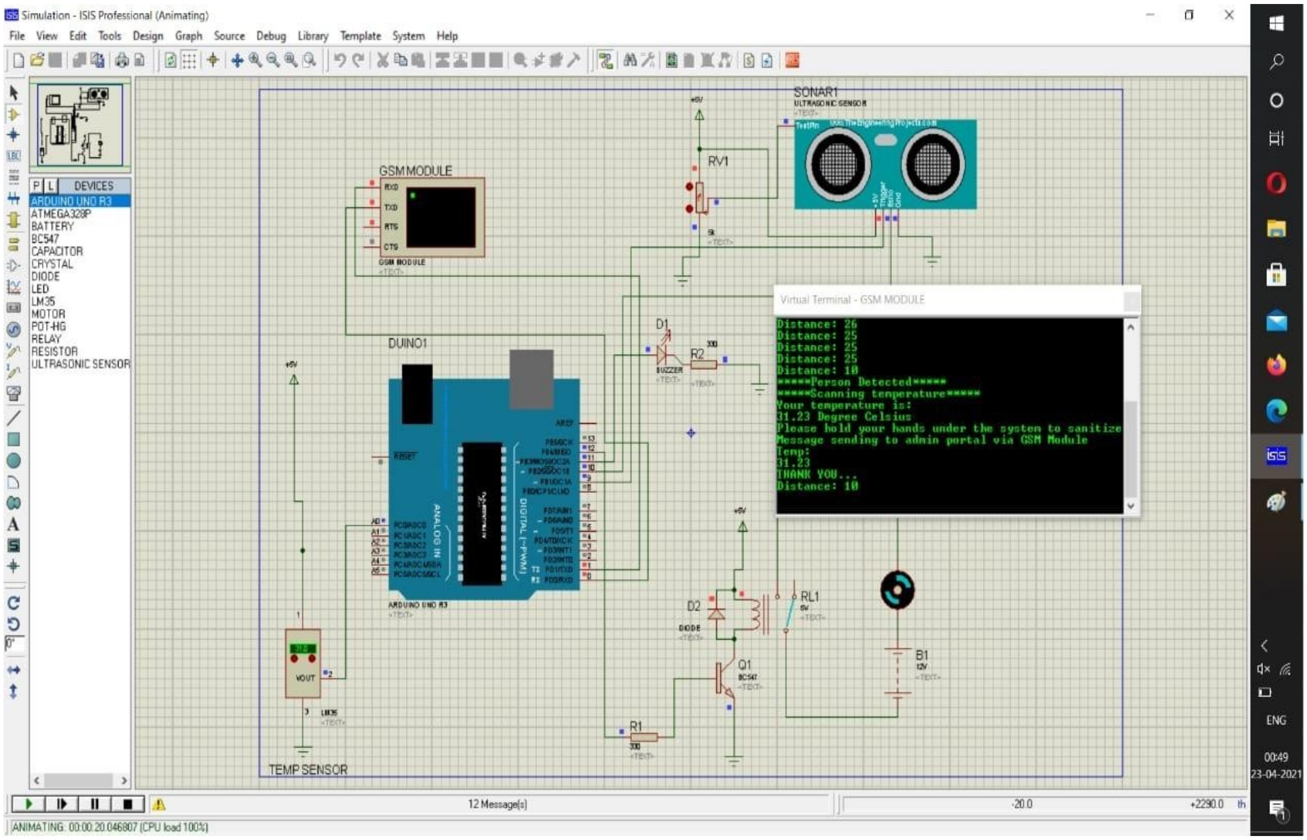


Fig.4.3 Final Simulation

CHAPTER 5

RESULTS

CHAPTER 5

RESULTS

5.1 Result

The following figure is the basic circuitry of assembled components namely: Atmega microcontroller, GSM module, Ultrasonic Sensor, Temperature Sensor, Buzzer and a DC motor pump connected to a relay circuit. It is shortly divided into analog inputs like temperature sensor and digital outputs like GSM module, buzzer, DC motor pump and digital input like Ultrasonic sensor. Distance gets printed on GSM module when the simulation is on run mode. Continuous monitoring of obstacle distance is done till threshold value is reached. When person’s hand gets detected the GSM module’s visual terminal displays the temperature detected by temperature sensor and a system generated message.

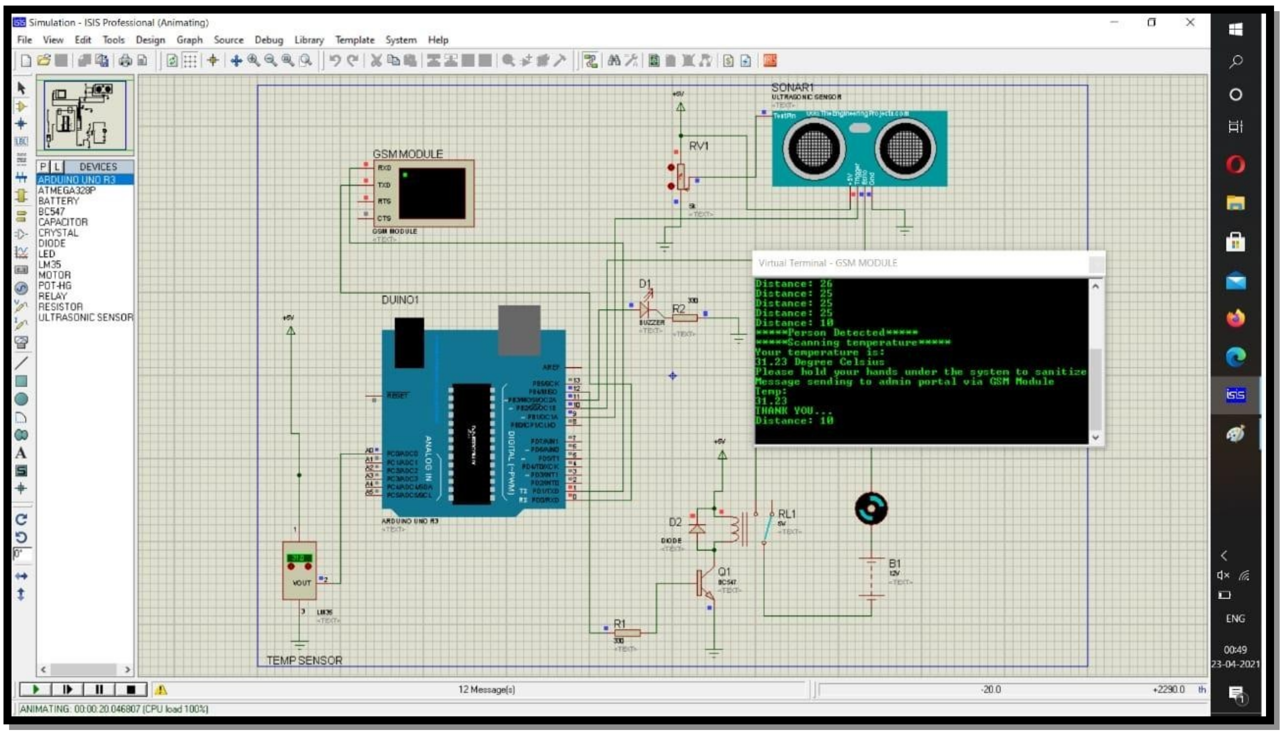


Fig. 5.1 Result

5.2 Hardware result

As per the block diagram we have interfaced temperature sensor MLX60915, Pulse sensor max30100, ultrasonic sensor HC-SR 04, GSM Module and led with arduino microcontroller as shown in below fig. 5.2

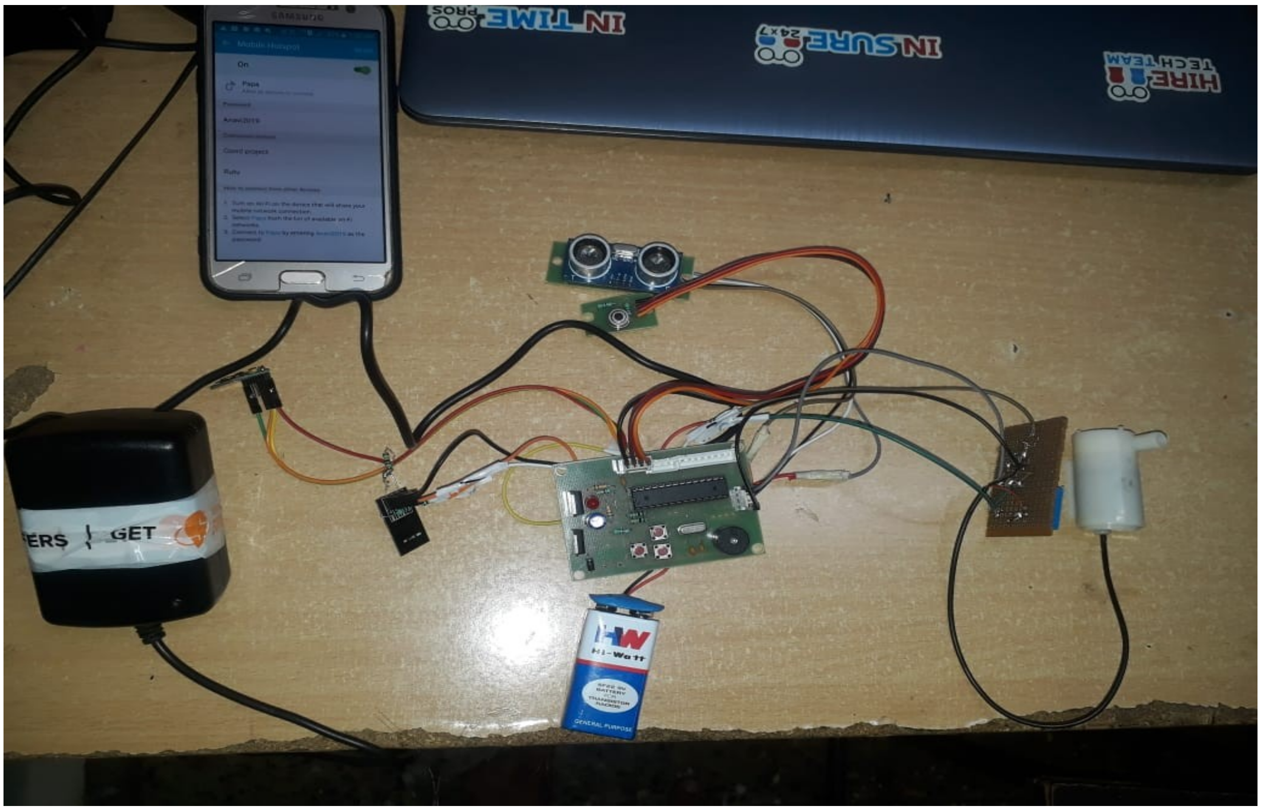


Fig. 5.2: Output image of hardware COVID kit

MLX sensor senses temperature of human and without any physical touch and microcontroller senses those signals and gives output of hand’s temperature over I2C protocol. Ultrasonic sensor is mainly used to detect any object or person is detected in front of system to start the process. Pulse sensor senses the oxygen level of user and stores this all information in local variable and then start to dispense sanitizer by turning pump motor on. When sanitization is completed and if temperature and oxygen level of user is beyond threshold level then this information will be sent to the Admin department via SM module. For this admins mobile number should be loaded in controller’s code.

If you want to wash your hands, place your hands within 15 cm from the ultrasonic sensor. According to Arduino program, this will switch on the relay module. The submersible water pump is connected to the relay module and an external power supply. The external power supply can be adjusted to provide the appropriate voltage. The water pump is switched on and the water is pumped from the container to your hands through a tube, which is modeled as the faucet in this prototype.

5.3 Voltage and current specification:

5.3.1 ATMEgA328P

• Operating Voltage:

– 1.8 - 5.5V for ATmega328P

• Temperature Range:

– -40°C to 85°C

• Low Power Consumption at 1 MHz, 1.8V, 25°C for

– Active Mode: 0.3 mA

– Power-down Mode: 0.1 µA

– Power-save Mode: 0.8 µA (Including 32 kHz RTC)

5.3.2 MAX30100

- Ultra-Low Shutdown Current: (0.7µA, typ)
- Continuous Input Current into Any Terminal: ±20mA
- VDD = 1.8V, VIR_LED+ = VR_LED+ = 3.3V, TA = +25°C

5.3.3 MLX90615

- Factory calibrated in wide temperature range:
- 40…85˚C for sensor temperature and
- 40…115˚C for object temperature
- High accuracy of 0.5°C over wide temperature range (0...+50°C for both TA and TO)
- High (medical) accuracy calibration
- Measurement resolution of 0.02°C

5.3.4 Ultrasonic

- Supply voltage: 5V (DC)
- Supply current: 15mA.
- Modulation frequency: 40Hz.
- Output: 0 – 5V (Output high when obstacle detected in range).

5.3.5 Relay 5V

- Trigger Voltage (Voltage across coil): 5V DC.
- Trigger Current (Nominal current) : 70mA.
- Maximum AC load current: 10A @ 250/125V AC.
- Maximum DC load current: 10A @ 30/28V DC.

CHAPTER 6

ADVANTAGES AND APPLICATION

ADVANTAGES AND APPLICATIONS

6.1 Advantages:

1. The most significant advantage of sanitizer dispenser is the hands-free usage.
2. This machine is user-friendly.
3. This machine does not require any high-end skills nor does it require massive amount of strength for operation purpose.
4. Almost all parts required for the manufacturing of this dispenser can be obtained from the industrial waste discarded by fabrication, construction, production, manufacturing factories.
5. This machine is portable and does not require much space. It can easily be placed in cramped-up places.

6.2 Limitations:

1. Storage of liquid sanitizer might be a limitation for our system.
2. Poor metallic storage container is very armful for user.

6.3 Applications:

1. Medical observance Devices
2. Fitness Assistant Devices
3. Wearable Devices
4. This system is used at many places like schools, Restaurants, Offices, Religious places, Industries, etc.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion:

Our model 'Temperature monitoring system with built in sanitising system' is proposed considering the human life at risk of the covid-19 infection spreads. This is fully automatic, use of this hybrid system at the entrance of the various crowded places can reduce the man work who is also subjected to risk. Spread of infection is under control due to no contact. Since controlling the doors are also automated, it is ensured that every individual follows the rules accordingly.

Generally 75 and 100 millimeters of mercury (mm Hg) is the range of blood oxygen level. The pulse oximeter generally shows the reading between 95 and 100 percent. If the blood level of oxygen saturation on the device is less than 90 per cent, then it is considered harmful. As shortness of breath is considered a key symptom of coronavirus infection, people are using a pulse oximeter to check the level of oxygen in their blood.

This is a cost efficient and an all-in-one model and hence does not require any multiple systems to support the model. This model suits the need for every organization to maintain the temperature record of the employees daily along with automatic intimation to the higher authority in case of increased temperature of any individual through the GSM module which is a great advantage.

7.2 Future Scope:

In future, we can use IOT concept to store large amount of people's data on server which is needed in offices, institutes, etc.

By providing camera interfacing to tis system, we can also store user's image along with his/her temperature and oxygen reading to the server.

CHAPTER 7

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DATA SHEETS

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

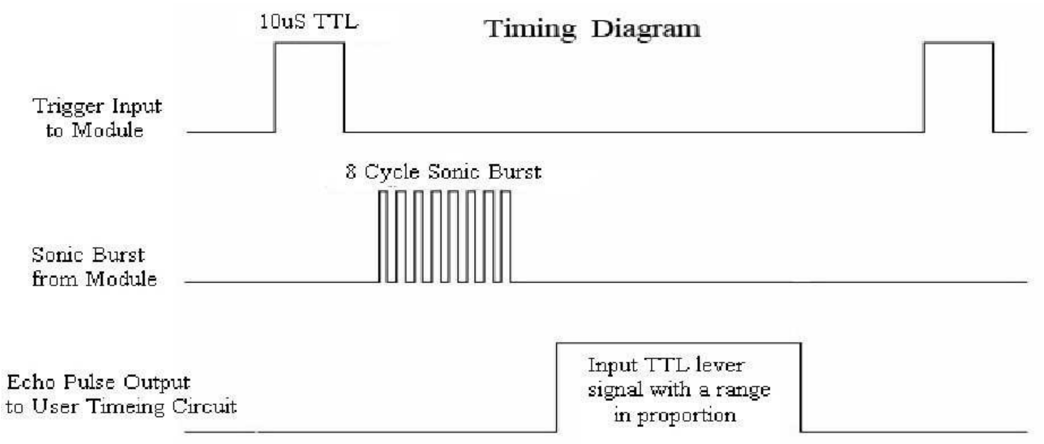
Electric Parameter

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**

VccTrigEchoGND

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.

EVALUATION KIT AVAILABLE

MAX30100

Pulse Oximeter and Heart-Rate Sensor IC for Wearable Health

General Description

The MAX30100 is an integrated pulse oximetry and heart- rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

The MAX30100 operates from 1.8V and 3.3V power sup- plies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Applications

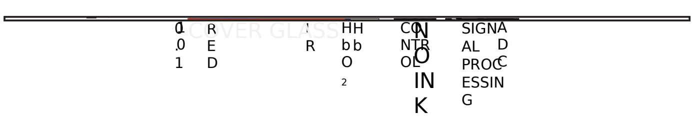
- Wearable Devices
- Fitness Assistant Devices
- Medical Monitoring Devices

Benefits and Features

- Complete Pulse Oximeter and Heart-Rate Sensor Solution Simplifies Design
  - Integrated LEDs, Photo Sensor, and High-Performance Analog Front - End
  - Tiny 5.6mm x 2.8mm x 1.2mm 14-Pin Optically Enhanced System-in-Package
- Ultra-Low-Power Operation Increases Battery Life for Wearable Devices
  - Programmable Sample Rate and LED Current for Power Savings
  - Ultra-Low Shutdown Current (0.7µA, typ)
- Advanced Functionality Improves Measurement Performance
  - High SNR Provides Robust Motion Artifact Resil- ience
  - Integrated Ambient Light Cancellation
  - High Sample Rate Capability
  - Fast Data Output Capability

***Ordering Information* appears at end of data sheet.**

System Block Diagram



19-7065; Rev 0; 9/14

Absolute Maximum Ratings

V_{DD} to GND..V to +2.2V
GND to PGND..V to +0.3V
x_DRV, x_LED+ to PGND...V to +6.0V
All Other Pins to GND...V to +6.0V
Output Short-Circuit Current Duration.......................Continuous
Continuous Input Current into Any Terminal....................±20mA

Continuous Power Dissipation (T_A = +70°C)
OESIP (derate 5.8mW/°C above +70°C)...................464mW
Operating Temperature Range.......................... -40°C to +85°C
Soldering Temperature (reflow)......................................+260°C
Storage Temperature Range........................... -40°C to +105°C

Package Thermal Characteristics (Note 1)

OESIP
Junction-to-Ambient Thermal Resistance (θ_{JA})........150°C/W
Junction-to-Case Thermal Resistance (θ_{JC})............170°C/W

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Power-Supply Voltage	V_{DD}	Guaranteed by RED and IR count tolerance		1.7	1.8	2.0	V
LED Supply Voltage (R_LED+ or IR_LED+ to PGND)	V_{LED+}	Guaranteed by PSRR of LED Driver		3.1	3.3	5.0	V
Supply Current	I_{DD}	SpO_2 and heart rate modes, PW = 200µs, 50sps			600	1200	µA
		Heart rate only mode, PW = 200µs, 50sps			600	1200	
Supply Current in Shutdown	I_{SHDN}	T_A = +25°C, MODE = 0x80			0.7	10	µA
SENSOR CHARACTERISTICS							
ADC Resolution					14		bits
Red ADC Count (Note 3)	RED_C	Propriety ATE setup RED_PA = 0x05, LED_PW = 0x00, SPO2_SR = 0x07, T_A = +25°C		23,000	26,000	29,000	Counts
IR ADC Count (Note 3)	IR_C	Propriety ATE setup IR_PA = 0x09, LED_PW = 0x00, SPO2_SR = 0x07, T_A = +25°C		23,000	26,000	29,000	Counts
Dark Current Count	DC_C	RED_PA = IR_PA = 0x00, LED_PW = 0x03, SPO2_SR = 0x01			0	3	Counts
DC Ambient Light Rejection (Note 4)	ALR	Number of ADC counts with finger on sensor under direct sunlight (100K lux) LED_PW = 0x03, SPO2_SR = 0x01	RED LED		0		Counts
			IR LED		0		

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
IR ADC Count—PSRR (V_{DD})	$PSRR_{VDD}$	Propriety ATE setup 1.7V < V_{DD} < 2.0V, LED_PW = 0x03, SPO2_SR = 0x01, IR_PA = 0x09, IR_PA = 0x05, T_A = +25°C		0.25	2	%
		Frequency = DC to 100kHz, 100mV$_{P-P}$		10		LSB
RED/IR ADC Count—PSRR (X_LED+)	$PSRR_{LED}$	Propriety ATE setup 3.1V < X_LED+ < 5V, LED_PW = 0x03, SPO2_SR = 0x01, IR_PA = 0x09, IR_PA = 0x05, T_A = +25°C		0.05	2	%
		Frequency = DC to 100kHz, 100mV$_{P-P}$		10		LSB
ADC Integration Time	INT	LED_PW = 0x00		200		µs
		LED_PW = 0x03		1600		µs
IR LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C	870	880	900	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C		30		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C		1.4		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		6.5		mW
RED LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C	650	660	670	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C		20		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C		2.1		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		9.8		mW
TEMPERATURE SENSOR						
Temperature ADC Acquisition Time	T_T	T_A = +25°C		29		ms
Temperature Sensor Accuracy	T_A	T_A = +25°C		±1		°C
Temperature Sensor Minimum Range	T_{MIN}			-40		°C
Temperature Sensor Maximum Range	T_{MAX}			85		°C

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL CHARACTERISTICS (SDA, SDA, INT)						
Output Low Voltage SDA, INT	V_{OL}	I_{SINK} = 6mA			0.4	V
I²C Input Voltage Low	V_{IL_I2C}	SDA, SCL			0.4	V
I²C Input Voltage High	V_{IH_I2C}	SDA, SCL	1.4			V
Input Hysteresis	V_{HYS}	SDA, SCL		200		mV
Input Capacitance	C_{IN}	SDA, SCL		10		pF
Input Leakage Current	I_{IN}	V_{IN} = 0V, T_A = +25°C (SDA, SCL, INT)		0.01	1	µA
		V_{IN} = 5.5V, T_A = +25°C (SDA, SCL, INT)		0.01	1	µA
I²C TIMING CHARACTERISTICS (SDA, SDA, INT)						
I²C Write Address				AE		Hex
I²C Read Address				AF		Hex
Serial Clock Frequency	f_{SCL}		0		400	kHz
Bus Free Time Between STOP and START Conditions	t_{BUF}		1.3			µs
Hold Time (Repeated) START Condition	$t_{HD,START}$		0.6			µs
SCL Pulse-Width Low	t_{LOW}		1.3			µs
SCL Pulse-Width High	t_{HIGH}		0.6			µs
Setup Time for a Repeated START Condition	$t_{SU,START}$		0.6			µs
Data Hold Time	$t_{HD,DAT}$		0		900	ns
Data Setup Time	$t_{SU,DAT}$		100			ns
Setup Time for STOP Condition	$t_{SU,STOP}$		0.6			µs
Pulse Width of Suppressed Spike	t_{SP}		0		50	ns
Bus Capacitance	C_B				400	pF
SDA and SCL Receiving Rise Time	t_R		20 + 0.1C_B		300	ns
SDA and SCL Receiving Fall Time	t_{RF}		20 + 0.1C_B		300	ns
SDA Transmitting Fall Time	t_{TF}		20 + 0.1C_B		300	ns

Note 2: All devices are 100% production tested at T_A = +25°C. Specifications over temperature limits are guaranteed by Maxim Integrated's bench or proprietary automated test equipment (ATE) characterization.

Note 3: Specifications are guaranteed by Maxim Integrated's bench characterization and by 100% production test using proprietary ATE setup and conditions.

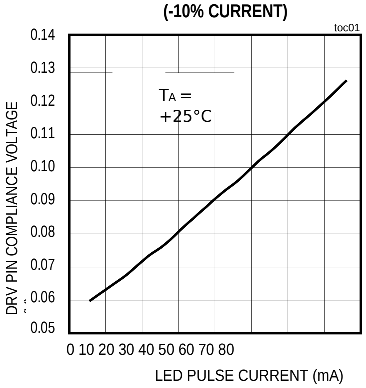
Note 4: For design guidance only. Not production tested.

Figure 1. I²C-Compatible Interface Timing Diagram

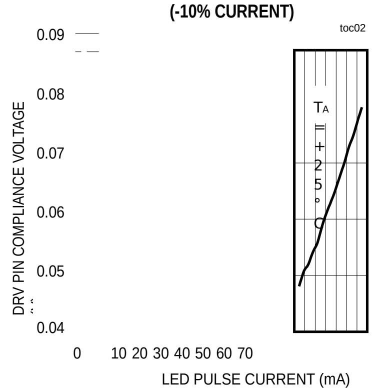
Typical Operating Characteristics

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, unless otherwise noted.)

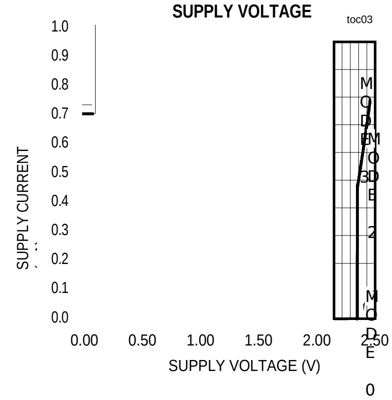
RED LED SUPPLY HEADROOM
(-10% CURRENT)



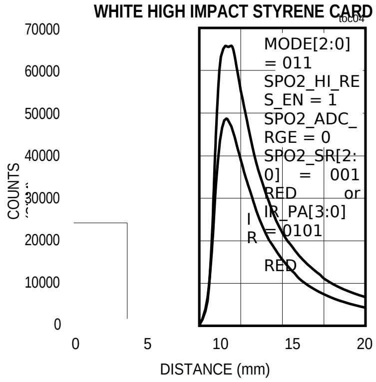
IR LED SUPPLY HEADROOM
(-10% CURRENT)



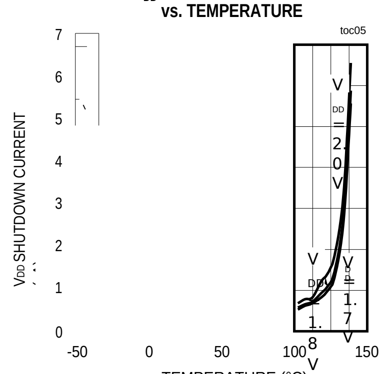
V_{DD} SUPPLY CURRENT vs.
SUPPLY VOLTAGE



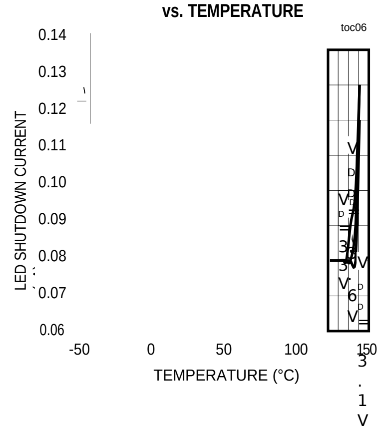
DC COUNTS vs. DISTANCE FOR
WHITE HIGH IMPACT STYRENE CARD



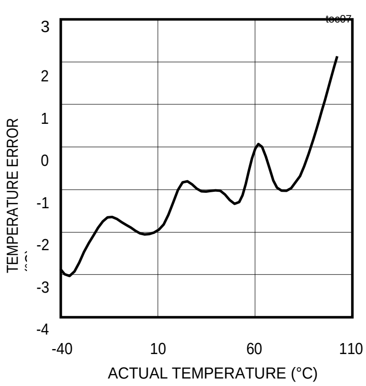
V_{DD} SHUTDOWN CURRENT
vs. TEMPERATURE



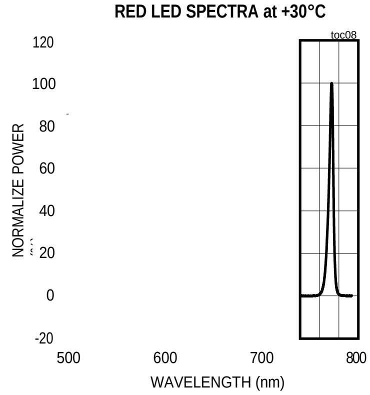
LED SHUTDOWN CURRENT
vs. TEMPERATURE



ON-BOARD TEMPERATURE vs. ERROR

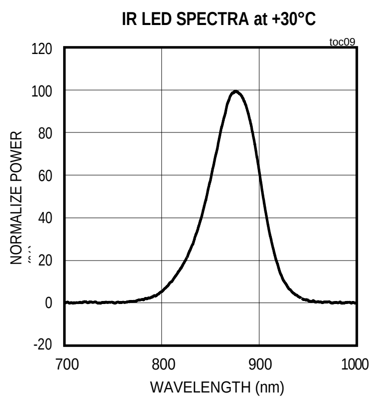


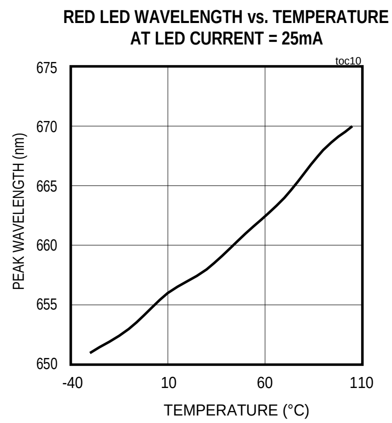
RED LED SPECTRA at +30°C

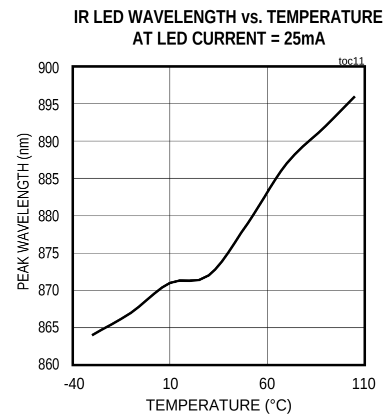


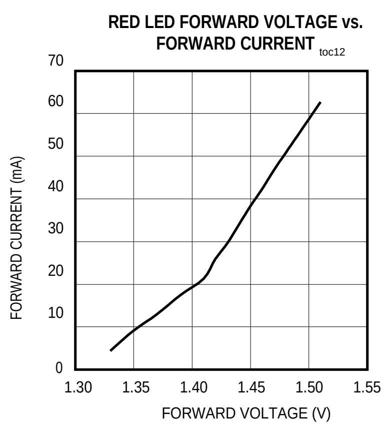
Typical Operating Characteristics (continued)

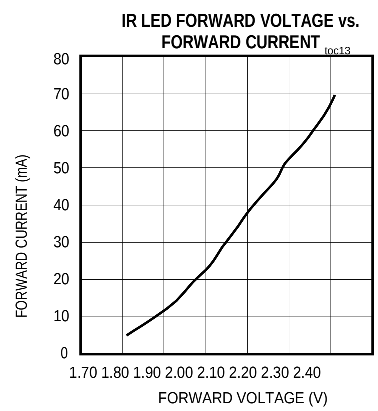
(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, unless otherwise noted.)



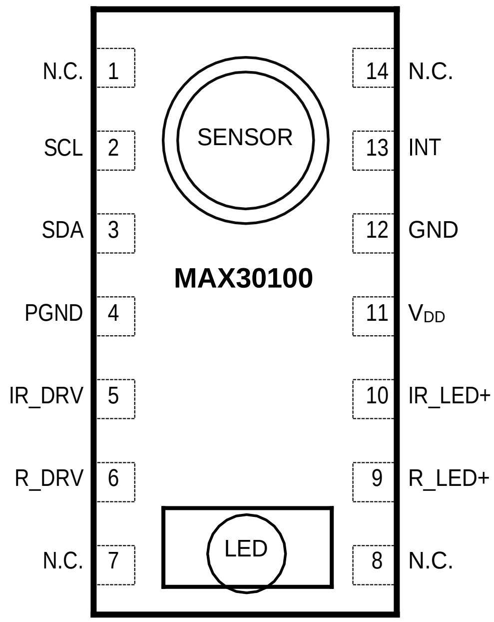








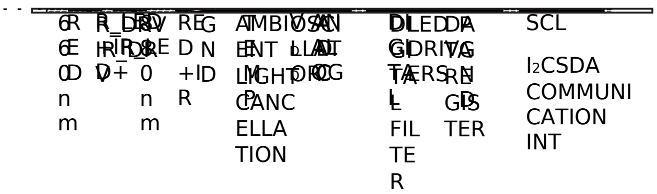
Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1, 7, 8, 14	N.C.	No Connection. Connect to PCB Pad for Mechanical Stability.
2	SCL	I^2C Clock Input
3	SDA	I^2C Clock Data, Bidirectional (Open-Drain)
4	PGND	Power Ground of the LED Driver Blocks
5	IR_DRV	IR LED Cathode and LED Driver Connection Point. Leave floating in circuit.
6	R_DRV	Red LED Cathode and LED Driver Connection Point. Leave floating in circuit.
9	R_LED+	Power Supply (Anode Connection) for Red LED. Bypass to PGND for best performance. Connected to IR_LED+ internally.
10	IR_LED+	Power Supply (Anode Connection) for IR LED. Bypass to PGND for best performance. Connected to R_LED+ internally.
11	V_{DD}	Analog Power Supply Input. Bypass to GND for best performance.
12	GND	Analog Ground
13	INT	Active-Low Interrupt (Open-Drain)

Functional Diagram



Detailed Description

The MAX30100 is a complete pulse oximetry and heart-rate sensor system solution designed for the demanding requirements of wearable devices. The MAX30100 provides very small total solution size without sacrificing opti- cal or electrical performance. Minimal external hardware components are needed for integration into a wearable device.

The MAX30100 is fully configurable through software reg- isters, and the digital output data is stored in a 16-deep FIFO within the device. The FIFO allows the MAX30100 to be connected to a microcontroller or microprocessor on a shared bus, where the data is not being read continu- ously from the device's registers.

SpO_2 Subsystem

The SpO_2 subsystem in the MAX30100 is composed of ambient light cancellation (ALC), 16-bit sigma delta ADC, and proprietary discrete time filter.

The SpO_2 ADC is a continuous time oversampling sigma delta converter with up to 16-bit resolution. The ADC output data rate can be programmed from 50Hz to 1kHz. The MAX30100 includes a proprietary discrete time filter to reject 50Hz/60Hz interference and low-frequency residual ambient noise.

Temperature Sensor

The MAX30100 has an on-chip temperature sensor for (optionally) calibrating the temperature dependence of the SpO_2 subsystem.

The SpO_2 algorithm is relatively insensitive to the wavelength of the IR LED, but the red LED's wavelength is criti- cal to correct interpretation of the data. The temperature sensor data can be used to compensate the SpO_2 error with ambient temperature changes.

LED Driver

The MAX30100 integrates red and IR LED drivers to drive LED pulses for SpO_2 and HR measurements. The LED current can be programmed from 0mA to 50mA (typical only) with proper supply voltage. The LED pulse width can be programmed from 200µs to 1.6ms to optimize measurement accuracy and power consumption based on use cases.

Table 1. Register Maps and Descriptions

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
STATUS											
Interrupt Status	A_FULL	TEMP_RDY	HR_RDY	SPO2_RDY				PWR_RDY	0x00	0X00	R
Interrupt Enable	ENB_A_FULL	ENB_TEP_RDY	ENB_HR_RDY	ENB_SO2_RDY					0x01	0X00	R/W
FIFO											
FIFO Write Pointer					FIFO_WR_PTR[3:0]				0x02	0x00	R/W
Over Flow Counter					OVF_COUNTER[3:0]				0x03	0x00	R/W
FIFO Read Pointer					FIFO_RD_PTR[3:0]				0x04	0x00	R/W
FIFO Data Register	FIFO_DATA[7:0]								0x05	0x00	R/W
CONFIGURATION											
Mode Configuration	SHDN	RESET			TEMP_EN	MODE[2:0]			0x06	0x00	R/W
SPO2 Configuration		SPO2_HI_RES_EN	RESERVED	SPO2_SR[2:0]			LED_PW[1:0]		0x07	0x00	R/W
RESERVED									0x08	0x00	R/W
LED Configuration	RED_PA[3:0]				IR_PA[3:0]				0x09	0x00	R/W
RESERVED									0x0A – 0x15	0x00	R/W
TEMPERATURE											
Temp_Integer	TINT[7:0]								0x16	0x00	R/W
Temp_Fraction					TFRAC[3:0]				0x17	0x00	R/W
RESERVED									0x8D	0x00	R/W
PART ID											
Revision ID	REV_ID[7:0]								0xFE	0xXX*	R
Part ID	PART_ID[7]								0xFF	0x11	R/W

*XX denotes any 2-digit hexidecimal number (00 to FF). Contact Maxim Integrated for the Revision ID number assigned for your product.

Interrupt Status (0x00)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Interrupt Status	A_FULL	TEMP_ RDY	HR_RDY	SPO2_ RDY				PWR_ RDY	0x00	0X00	R

There are 5 interrupts and the functionality of each is exactly the same: pulling the active-low interrupt pin into its low state until the interrupt is cleared.

The interrupts are cleared whenever the interrupt status register is read, or when the register that triggered the interrupt is read. For example, if the SpO_2 sensor triggers an interrupt due to finishing a conversion, reading either the FIFO data register or the interrupt register clears the interrupt pin (which returns to its normal high state), and also clears all the bits in the interrupt status register to zero.

Bit 7: FIFO Almost Full Flag (A_FULL)

In SpO_2 and heart-rate modes, this interrupt triggers when the FIFO write pointer is the same as the FIFO read pointer minus one, which means that the FIFO has only one unwritten space left. If the FIFO is not read within the next conversion time, the FIFO becomes full and future data is lost.

Bit 6: Temperature Ready Flag (TEMP_RDY)

When an internal die temperature conversion is finished, this interrupt is triggered so the processor can read the temperature data registers.

Bit 5: Heart Rate Data Ready (HR_RDY)

In heart rate or SPO_2 mode, this interrupt triggers after every data sample is collected. A heart rate data sample consists of one IR data point only. This bit is automatically cleared when the FIFO data register is read.

Bit 4: SpO_2 Data Ready (SPO2_RDY)

In SpO_2 mode, this interrupt triggers after every data sample is collected. An SpO_2 data sample consists of one IR and one red data points. This bit is automatically cleared when the FIFO data register is read.

Bit 3: RESERVED

This bit should be ignored and always be zero in normal operation.

Bit 2: RESERVED

This bit should be ignored and always be zero in normal operation.

Bit 1: RESERVED

This bit should be ignored and always be zero in normal operation.

Bit 0: Power Ready Flag (PWR_RDY)

On power-up or after a brownout condition, when the supply voltage V_{DD} transitions from below the UVLO voltage to above the UVLO voltage, a power-ready interrupt is triggered to signal that the IC is powered up and ready to collect data.

Interrupt Enable (0x01)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Interrupt Enable	ENB_A_FULL	ENB_TEP_RDY	ENB_HR_RDY	ENB_SO2_RDY					0x01	0X00	R/W

Each source of hardware interrupt, with the exception of power ready, can be disabled in a software register within the MAX30100 IC. The power-ready interrupt cannot be disabled because the digital state of the MAX30100 is reset upon a brownout condition (low power-supply voltage), and the default state is that all the interrupts are disabled. It is important for the system to know that a brownout condition has occurred, and the data within the device is reset as a result.

When an interrupt enable bit is set to zero, the corresponding interrupt appears as 1 in the interrupt status register, but the INT pin is not pulled low.

The four unused bits (B3:B0) should always be set to zero (disabled) for normal operation.

FIFO (0x02–0x05)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
FIFO Write Pointer					FIFO_WR_PTR[3:0]				0x02	0x00	R/W
Over Flow Counter					OVF_COUNTER[3:0]				0x03	0x00	R/W
FIFO Read Pointer					FIFO_RD_PTR[3:0]				0x04	0x00	R/W
FIFO Data Register	FIFO_DATA[7:0]								0x05	0x00	R/W

FIFO Write Pointer

The FIFO write pointer points to the location where the MAX30100 writes the next sample. This pointer advances for each sample pushed on to the FIFO. It can also be changed through the I^2C interface when MODE[2:0] is nonzero.

FIFO Overflow Counter

When the FIFO is full, samples are not pushed on to the FIFO, samples are lost. OVF_COUNTER counts the number of samples lost. It saturates at 0xF. When a complete sample is popped from the FIFO (when the read pointer advances), OVF_COUNTER is reset to zero.

FIFO Read Pointer

The FIFO read pointer points to the location from where the processor gets the next sample from the FIFO via the I^2C interface. This advances each time a sample is popped from the FIFO. The processor can also write to this pointer after reading the samples, which would allow rereading samples from the FIFO if there is a data communication error.

FIFO Data

The circular FIFO depth is 16 and can hold up to 16 samples of SpO_2 channel data (Red and IR). The FIFO_DATA register in the I^2C register map points to the next sample to be read from the FIFO. FIFO_RD_PTR points to this sample. Reading FIFO_DATA register does not automatically increment the register address; burst reading this register reads the same address over and over. Each sample is 4 bytes of data, so this register has to be read 4 times to get one sample.

The above registers can all be written and read, but in practice, only the FIFO_RD_PTR register should be written to in operation. The others are automatically incremented or filled with data by the MAX30100. When starting a new SpO_2

or heart-rate conversion, it is recommended to first clear the FIFO_WR_PTR, OVF_COUNTER, and FIFO_RD_PTR registers to all zeros (0x00) to ensure the FIFO is empty and in a known state. When reading the MAX30100 registers in one burst-read I^{2}C transaction, the register address pointer typically increments so that the next byte of data sent is from the next register, etc. The exception to this is the FIFO data register, register 0x05. When reading this register, the address pointer does not increment, but the FIFO_RD_PTR does. So the next byte of data sent will represent the next byte of data available in the FIFO.

Reading from the FIFO

Normally, reading registers from the I^{2}C interface autoincrements the register address pointer, so that all the registers can be read in a burst read without an I^{2}C restart event. In the MAX30100, this holds true for all registers except for the FIFO_DATA register (0x05).

Reading the FIFO_DATA register does not automatically increment the register address; burst reading this register reads the same address over and over. Each sample is 4 bytes of data, so this register has to be read 4 times to get one sample.

The other exception is 0xFF, reading more bytes after the 0xFF register does not advance the address pointer back to 0x00, and the data read is not meaningful.

FIFO Data Structure

The data FIFO consists of a 16-sample memory bank that stores both IR and RED ADC data. Since each sample consists of one IR word and one RED word, there are 4 bytes of data for each sample, and therefore, 64 total bytes of data can be stored in the FIFO. Figure 2 shows the structure of the FIFO graphically.

The FIFO data is left-justified as shown in Table 1; i.e. the MSB bit is always in the bit 15 position regardless of ADC resolution.

Each data sample consists of an IR and a red data word (2 registers), so to read one sample requires 4 I^{2}C byte reads in a row. The FIFO read pointer is automatically incremented after each 4-byte sample is read.

In heart-rate only mode, the 3rd and 4th bytes of each sample return zeros, but the basic structure of the FIFO remains the same.

Write/Read Pointers

Table 2. FIFO Data

ADC RESOLUTION	IR [15]	IR [14]	IR [13]	IR [12]	IR [11]	IR [10]	IR [9]	IR [8]	IR [7]	IR [6]	IR [5]	IR [4]	IR [3]	IR [2]	IR [1]	IR [0]
16-bit																
14-bit																
12-bit																
10-bit																

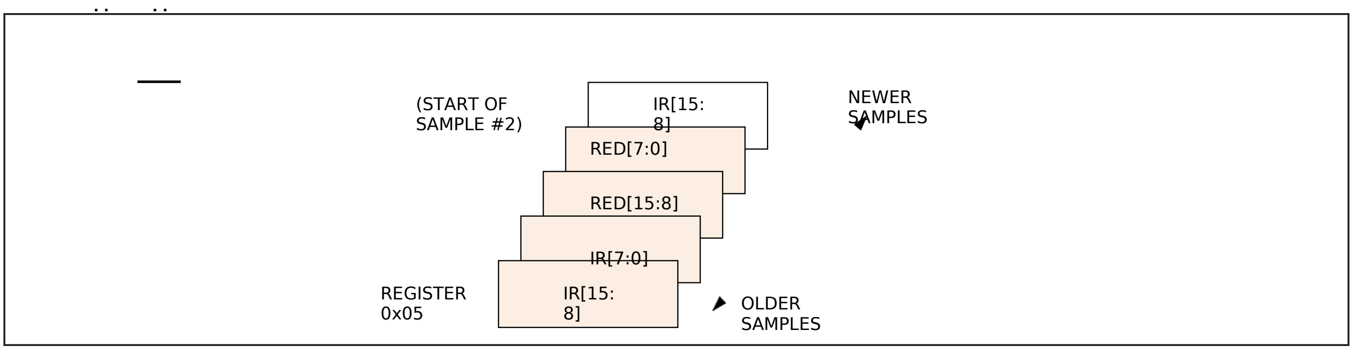


Figure 2. Graphical Representation of the FIFO Data Register

The locations to store new data, and the read pointer for reading data, are used to control the flow of data in the FIFO. The write pointer increments every time a new sample is added to the FIFO. The read pointer is incremented automatically every time a sample is read from the FIFO. To reread a sample from the FIFO, decrement its value by one and read the data register again.

The SpO_2 write/read pointers should be cleared (back to 0x0) upon entering SpO_2 mode or heart-rate mode, so that there is no old data represented in the FIFO. The pointers are not automatically cleared when changing modes, but they are cleared if V_{DD} is power cycled so that the V_{DD} voltage drops below its UVLO voltage.

Pseudo-Code Example of Reading Data from FIFO

First transaction: Get the FIFO_WR_PTR:

```
START;
Send device address + write mode
Send address of FIFO_WR_PTR;
REPEATED_START;
Send device address + read mode
Read FIFO_WR_PTR;
STOP;
```

The central processor evaluates the number of samples to be read from the FIFO:

```
NUM_AVAILABLE_SAMPLES = FIFO_WR_PTR – FIFO_RD_PTR
(Note: pointer wrap around should be taken into account)
NUM_SAMPLES_TO_READ = < less than or equal to NUM_AVAILABLE_SAMPLES >
```

Second transaction: Read `NUM_SAMPLES_TO_READ` **samples from the FIFO**:

```
START;
Send device address + write mode
Send address of FIFO_DATA;
REPEATED_START;
Send device address + read mode
for (i = 0; i < NUM_SAMPLES_TO_READ; i++)
{ Read FIFO_DATA;
Save IR[15:8];
Read FIFO_DATA;
Save IR[7:0];
Read FIFO_DATA;
Save R[15:8];
Read FIFO_DATA;
Save R[7:0];
     }
STOP;
```

Third transaction: Write to FIFO_RD_PTR register. If the second transaction was successful, FIFO_RD_PTR points to the next sample in the FIFO, and this third transaction is not necessary. Otherwise, the processor updates the FIFO_RD_PTR appropriately, so that the samples are reread.

```
START;
Send device address + write mode
Send address of FIFO_RD_PTR;
Write FIFO_RD_PTR;
STOP;
```

Mode Configuration (0x06)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Mode Configuration	SHDN	RESET			TEMP_EN	MODE[2:0]			0x06	0x00	R/W

Bit 7: Shutdown Control (SHDN)

The part can be put into a power-save mode by setting this bit to one. While in power-save mode, all registers retain their values, and write/read operations function as normal. All interrupts are cleared to zero in this mode.

Bit 6: Reset Control (RESET)

When the RESET bit is set to one, all configuration, threshold, and data registers are reset to their power-on-state. The only exception is writing both RESET and TEMP_EN bits to one at the same time since temperature data registers 0x16 and 0x17 are not cleared. The RESET bit is cleared automatically back to zero after the reset sequence is completed.

Bit 3: Temperature Enable (TEMP_EN)

This is a self-clearing bit which, when set, initiates a single temperature reading from the temperature sensor. This bit is cleared automatically back to zero at the conclusion of the temperature reading when the bit is set to one in heart rate or SpO_2 mode.

Bits 2:0: Mode Control

These bits set the operating state of the MAX30100. Changing modes does not change any other setting, nor does it erase any previously stored data inside the data registers.

Table 3. Mode Control

MODE[2:0]	MODE
000	Unused
001	Reserved (Do not use)
010	HR only enabled
011	SPO_2 enabled
100–111	Unused

SpO2 Configuration (0x07)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
SPO_2 Configuration		SPO2_HI_ RES_EN	Reserved	SPO2_SR[2:0]			LED_PW[1:0]		0x07	0x00	R/W

Bit 6: SpO_2 High Resolution Enable (SPO2_HI_RES_EN)

Set this bit high. The SpO_2 ADC resolution is 16-bit with 1.6ms LED pulse width.

Bit 5: Reserved. Set low (default).

Bit 4:2: SpO_2 Sample Rate Control

These bits define the effective sampling rate, with one sample consisting of one IR pulse/conversion and one RED pulse/ conversion.

The sample rate and pulse width are related, in that the sample rate sets an upper bound on the pulse width time. If the user selects a sample rate that is too high for the selected LED_PW setting, the highest possible sample rate will instead be programmed into the register.

Bits 1:0: LED Pulse Width Control

These bits set the LED pulse width (the IR and RED have the same pulse width), and therefore, indirectly set the integra- tion time of the ADC in each sample. The ADC resolution is directly related to the integration time.

Table 4. SpO_2 Sample Rate Control

SPO2_SR[2:0]	SAMPLES (PER SECOND)
000	50
001	100
010	167
011	200
100	400
101	600
110	800
111	1000

Table 5. LED Pulse Width Control

LED_PW[1:0]	PULSE WIDTH (µs)	ADC RESOLUTION (BITS)
00	200	13
01	400	14
10	800	15
11	1600	16

LED Configuration (0x09)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
LED Configura-tion	RED_PA[3:0]				IR_PA[3:0]				0x09	0x00	R/W

Bits 7:4: Red LED Current Control

These bits set the current level of the Red LED as in Table 6.

Bits 3:0: IR LED Current Control

These bits set the current level of the IR LED as in Table 6.

Table 6. LED Current Control

Red_PA[3:0] OR IR_PA[3:0]	TYPICAL LED CURRENT (mA)*
0000	0.0
0001	4.4
0010	7.6
0011	11.0
0100	14.2
0101	17.4
0110	20.8
0111	24.0
1000	27.1
1001	30.6
1010	33.8
1011	37.0
1100	40.2
1101	43.6
1110	46.8
1111	50.0

*Actual measured LED current for each part can vary widely due to the proprietary trim methodology.

Temperature Data (0x16–0x17)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Temp_Integer	TINT[7:0]								0x16	0x00	R/W
Temp_Fraction					TFRAC[3:0]				0x17	0x00	R/W

Temperature Integer

The on-board temperature ADC output is split into two registers, one to store the integer temperature and one to store the fraction. Both should be read when reading the temperature data, and the following equation shows how to add the two registers together:

$$T_{MEASURED} = T_{INTEGER} + T_{FRACTION}$$

This register stores the integer temperature data in two's complement format, where each bit corresponds to degree Celsius.

Table 7. Temperature Integer

REGISTER VALUE (hex)	TEMPERATURE (°C)
0x00	0
0x00	+1
...	...
0x7E	+126
0x7F	+127
0x80	-128
0x81	-127
...	...
0xFE	-2
0xFF	-1

Temperature Fraction

This register stores the fractional temperature data in increments of 0.0625NC (1/16th of a degree).

If this fractional temperature is paired with a negative integer, it still adds as a positive fractional value (e.g., -128°C + 0.5°C = -127.5°C).

Applications Information

Sampling Rate and Performance

The MAX30100 ADC is a 16-bit sigma delta converter. The ADC sampling rate can be configured from 50sps to 1ksps. The maximum sample rate for the ADC depends on the selected pulse width, which in turn, determines the ADC resolution. For instance, if the pulse width is set to 200µs, then the ADC resolution is 13 bits and all sample rates from 50sps to 1ksps are selectable. However, if the pulse width is set to 1600µs, then only sample rates of 100sps and 50sps can be set. The allowed sample rates for both SpO_2 and HR mode are summarized in Table 8 and Table 9.

Power Considerations

The LEDs in MAX30100 are pulsed with a low duty cycle for power savings, and the pulsed currents can cause ripples in the LED power supply. To ensure these pulses do not translate into optical noise at the LED outputs, the power supply must be designed to handle peak LED current. Ensure that the resistance and inductance from the power supply (battery, DC/DC converter, or LDO) to the device LED+ pins is much smaller than 1Ω, and that there is at least 1µF of power-supply bypass capacitance to a low impedance ground plane. The decoupling capacitor should be located physically as close as possible to the MAX30100 device.

In the heart-rate only mode, the red LED is inactive, and only the IR LED is used to capture optical data and determine the heart rate. This mode allows power savings due to the red LED being off; in addition, the IR_LED+ power supply can be reduced to save power because the forward voltage of the IR LED is significantly less than that of the red LED.

The average I_{DD} and LED current as function of pulse width and sampling rate is summarized in Table 10 to Table 13.

Table 8. SpO_2 Mode (Allowed Settings)

(Allowed Settings)

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	O	O	O	O
100	O	O	O	O
167	O	O	O	
200	O	O	O	
400	O	O		
600	O			
800	O			
1000	O			
Resolution (bits)	13	14	15	16

Table 9. Heart-Rate Mode

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	O	O	O	O
100	O	O	O	O
167	O	O	O	
200	O	O	O	
400	O	O		
600	O	O		
800	O	O		
1000	O	O		
Resolution (bits)	13	14	15	16

Table 10. SpO_2 Mode: Average IDD Current (µA) R_PA = 0x3, IR_PA = 0x3

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	628	650	695	782
100	649	691	776	942
167	678	748	887	
200	692	775	940	
400	779	944		
600	865			
800	952			
1000	1037			

Table 11. SpO_2 Mode: Average LED Current (mA) R_PA = 0x3, IR_PA = 0x3

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	0.667	1.332	2.627	5.172
100	1.26	2.516	4.96	9.766
167	2.076	4.145	8.173	
200	2.491	4.93	9.687	
400	4.898	9.765		
600	7.319			
800	9.756			
1000	12.17			

Hardware Interrupt

The active-low interrupt pin pulls low when an interrupt is triggered. The pin is open-drain and requires a pullup resistor or current source to an external voltage supply (up to +5V from GND). The interrupt pin is not designed to sink large currents, so the pullup resistor value should be large, such as 4.7kΩ.

The internal FIFO stores up to 16 samples, so that the system processor does not need to read the data after every sample. Temperature data may be needed to properly interpret SpO_2 data, but the temperature does not need to be sampled very often—once a second or every few seconds should be sufficient. In heart-rate mode tem- perature information is not necessary.

Table 12. Heart-Rate Mode: Average IDD Current (µA) IR_PA = 0x3

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	608	616	633	667
100	617	634	669	740
167	628	658	716	831
200	635	670	739	876
400	671	740	878	
600	707	810		
800	743	881		
1000	779	951		

Table 13. Heart-Rate Mode: Average LED Current (mA) IR_PA = 0x3

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	0.256	0.511	1.020	2.040
100	0.512	1.022	2.040	4.077
167	0.854	1.705	3.404	6.795
200	1.023	2.041	4.074	8.130
400	2.042	4.074	8.123	
600	3.054	6.089		
800	4.070	8.109		
1000	5.079	10.11		

Table 14. Red LED Current Settings vs. LED Temperature Rise

RED LED CURRENT SETTING	RED LED DUTY CYCLE (% OF LED PULSE WIDTH TO SAMPLE TIME)	ESTIMATED TEMPERATURE RISE (ADD TO TEMPERATURE SENSOR MEASUREMENT) (°C)
0001 (3.1mA)	8	0.1
1111 (35mA)	8	2
0001 (3.1mA)	16	0.3
1111 (35mA)	16	4
0001 (3.1mA)	32	0.6
1111 (35mA)	32	8

Timing for Measurements and Data Collection

Timing in SpO_2 Mode

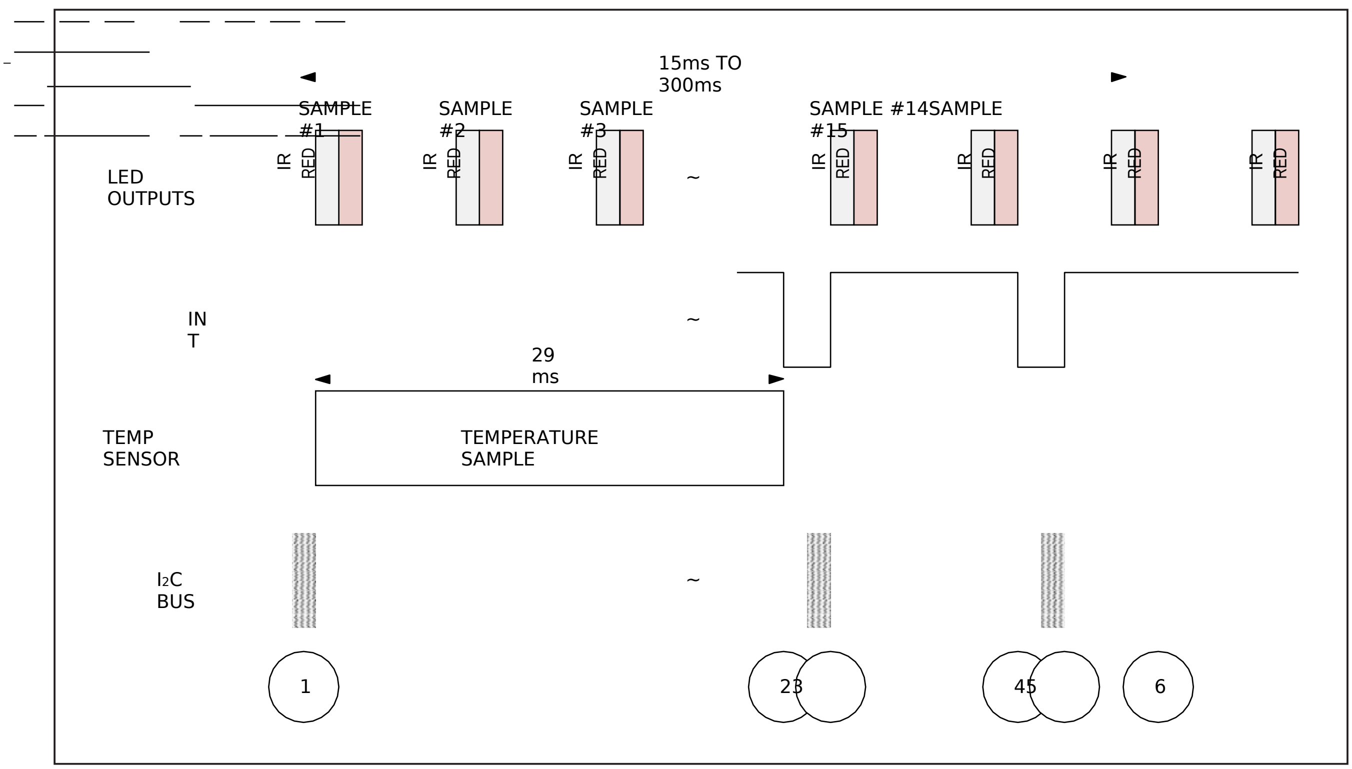


Figure 3. Timing for Data Acquisition and Communication When in SpO_2 Mode

Table 15. Events Sequence for Figure 3 in SpO_2 Mode

EVENT	DESCRIPTION	COMMENTS
1	Enter into SpO_2 mode. Initiate a temperature measurement.	I^2C Write Command Sets MODE[2:0] = 0x03. At the same time, set the TEMP_EN bit to initiate a single temperature measurement. Mask the SPO2_RDY Interrupt.
2	Temperature measurement complete, interrupt generated	TEMP_RDY interrupt triggers, alerting the central processor to read the data.
3	Temp data is read, interrupt cleared	
4	FIFO is almost full, interrupt generated	Interrupt is generated when the FIFO has only one empty space left.
5	FIFO data is read, interrupt cleared	
6	Next sample is stored	New sample is stored at the new read pointer location. Effectively, it is now the first sample in the FIFO.

Timing in Heart-Rate Mode

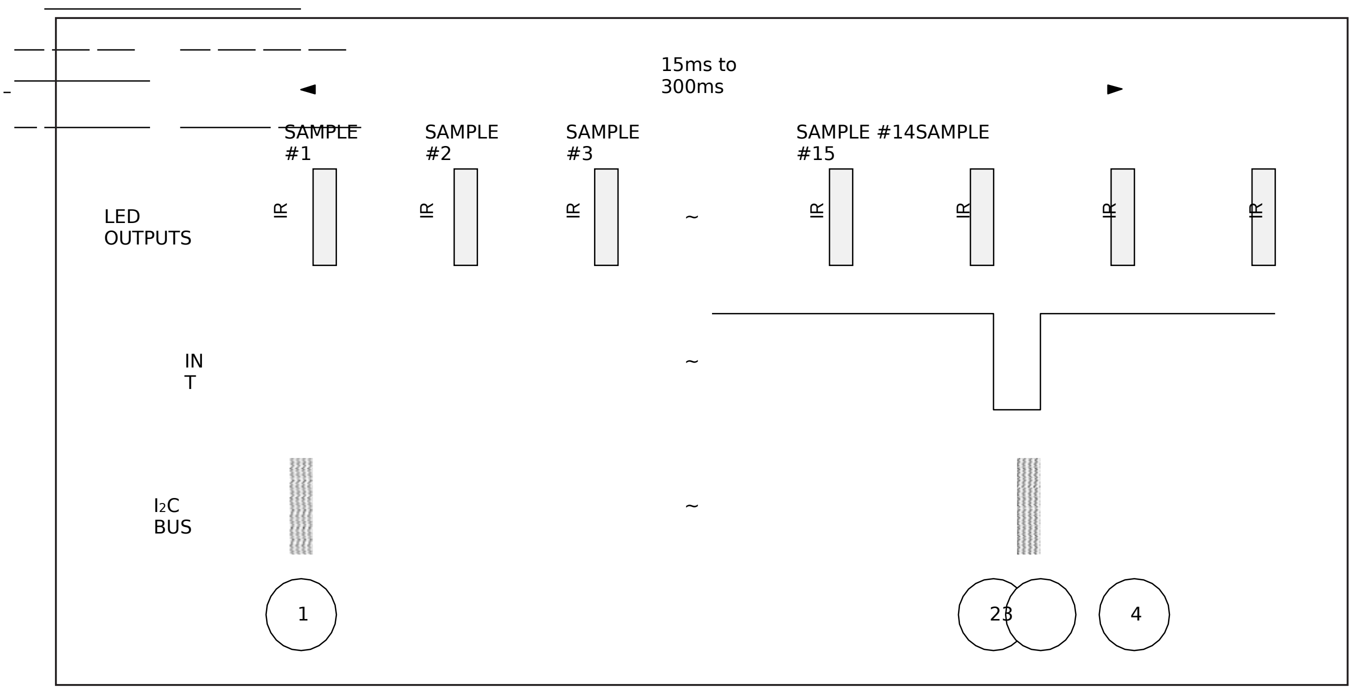


Figure 4. Timing for Data Acquisition and Communication When in Heart Rate Mode

Table 16. Events Sequence for Figure 4 in Heart-Rate Mode

EVENT	DESCRIPTION	COMMENTS
1	Enter into heart rate mode	I^2C Write Command Sets MODE[2:0] = 0x02. Mask the HR_RDY interrupt.
2	FIFO is almost full, interrupt generated	Interrupt is generated when the FIFO has only one empty space left.
3	FIFO data is read, interrupt cleared	
4	Next sample is stored	New sample is stored at the new read pointer location. Effectively, it is now the first sample in the FIFO.

Power Sequencing and Requirements

Power-Up Sequencing

Figure 5 shows the recommended power-up sequence for the MAX30100.

It is recommended to power the V_{DD} supply first, before the LED power supplies (R_LED+, IR_LED+). The interrupt and I^2C pins can be pulled up to an external voltage even when the power supplies are not powered up.

After the power is established, an interrupt occurs to alert the system that the MAX30100 is ready for operation. Reading the I^2C interrupt register clears the interrupt, as shown in Figure 5.

Power-Down Sequencing

The MAX30100 is designed to be tolerant of any power-supply sequencing on power-down.

I^2C Interface

The MAX30100 features an I^2C/SMBus-compatible, 2-wire serial interface consisting of a serial data line (SDA) and a serial clock line (SCL). SDA and SCL facilitate communication between the MAX30100 and the master at clock rates up to 400kHz. Figure 1 shows the 2-wire interface timing diagram. The master generates SCL and initiates data transfer on the bus. The master device writes data to the MAX30100 by transmitting the proper slave address followed by data. Each transmit sequence is framed by a START (S) or REPEATED START (Sr) condition and a STOP (P) condition. Each word transmitted to the MAX30100 is 8 bits long and is followed by an acknowledge clock pulse. A master reading data from the MAX30100 transmits the proper slave address followed by a series of nine SCL pulses.

The MAX30100 transmits data on SDA in sync with the master-generated SCL pulses. The master acknowledges receipt of each byte of data. Each read sequence is framed by a START (S) or REPEATED START (Sr) condition, a not acknowledge, and a STOP (P) condition. SDA operates as both an input and an open-drain output. A pullup resistor, typically greater than 500Ω, is required on SDA. SCL operates only as an input. A pullup resistor, typically greater than 500Ω, is required on SCL if there are multiple masters on the bus, or if the single master has an open-drain SCL output.

Bit Transfer

One data bit is transferred during each SCL cycle. The data on SDA must remain stable during the high period of the SCL pulse. Changes in SDA while SCL is high are control signals. See the *START and STOP Conditions* section.

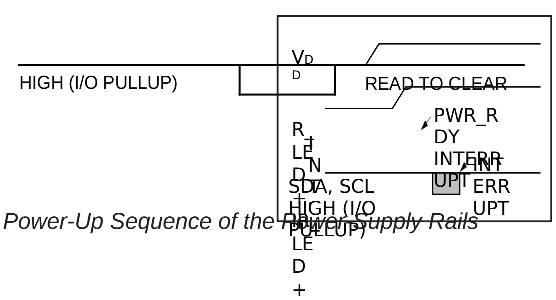


Figure 5. Power-Up Sequence of the Power-Supply Rails

START and STOP Conditions

SDA and SCL idle high when the bus is not in use. A mas- ter initiates communication by issuing a START condition. A START condition is a high-to-low transition on SDA with SCL high. A STOP condition is a low-to-high transition on SDA while SCL is high (Figure 6). A START condition from the master signals the beginning of a transmission to the MAX30100. The master terminates transmission, and frees the bus, by issuing a STOP condition. The bus remains active if a REPEATED START condition is gener- ated instead of a STOP condition.

Early STOP Conditions

The MAX30100 recognizes a STOP condition at any point during data transmission except if the STOP condition occurs in the same high pulse as a START condition. For proper operation, do not send a STOP condition during the same SCL high pulse as the START condition.

Slave Address

A bus master initiates communication with a slave device by issuing a START condition followed by the 7-bit slave ID. When idle, the MAX30100 waits for a START condition followed by its slave ID. The serial interface compares each slave ID bit by bit, allowing the interface to power down and disconnect from SCL immediately if an incor- rect slave ID is detected. After recognizing a START condition followed by the correct slave ID, the MAX30100 is ready to accept or send data. The LSB of the slave ID word is the Read/Write (R/W) bit. R/W indicates whether the master is writing to or reading data from the MAX30100. R/W = 0 selects a write condition, R/W = 1 selects a read condition). After receiving the proper slave ID, the MAX30100 issues an ACK by pulling SDA low for one clock cycle.

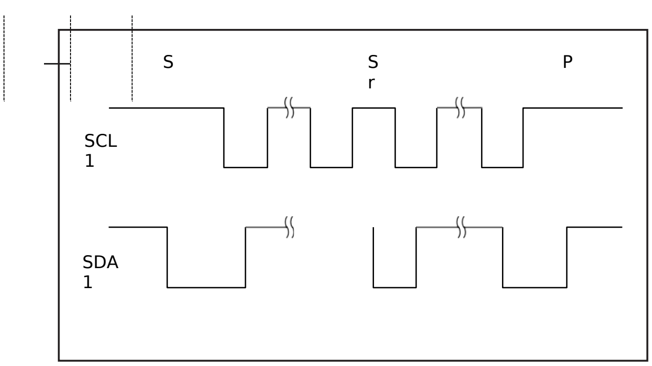
The MAX30100 slave ID consists of seven fixed bits, B7–B1 (set to 0b1010111). The most significant slave ID bit (B7) is transmitted first, followed by the remaining bits. Table 18 shows the possible slave IDs of the device.

Acknowledge

The acknowledge bit (ACK) is a clocked 9th bit that the MAX30100 uses to handshake receipt each byte of data when in write mode (Figure 7). The MAX30100 pulls down SDA during the entire master-generated 9th clock pulse if the previous byte is successfully received. Monitoring ACK allows for detection of unsuccessful data transfers. An unsuccessful data transfer occurs if a receiving device is busy or if a system fault has occurred. In the event of an unsuccessful data transfer, the bus master will retry communication. The master pulls down SDA during the 9th clock cycle to acknowledge receipt of data when the MAX30100 is in read mode. An acknowledge is sent by the master after each read byte to allow data transfer to continue. A not-acknowledge is sent when the master reads the final byte of data from the MAX30100, followed by a STOP condition.

Table 17. Slave ID Description

B7	B6	B5	B4	B3	B2	B1	B0	WRITE AD-DRESS	READ AD-DRESS
1	0	1	0	1	1	1	R/W	0xAE	0xAF



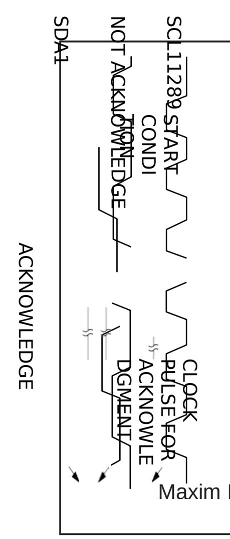


Figure 6. START, STOP, and REPEATED START Conditions

Figure 7. Acknowledge

Write Data Format

For the write operation, send the slave ID as the first byte followed by the register address byte and then one or more data bytes. The register address pointer increments automatically after each byte of data received. For example, the entire register bank can be written by at one time. Terminate the data transfer with a STOP condition. The write operation is shown in Figure 8.

The internal register address pointer increments automatically, so writing additional data bytes fill the data registers in order.

Read Data Format

For the read operation, two I^{2}C operations must be performed. First, the slave ID byte is sent followed by the I^{2}C register that you wish to read. Then a REPEATED START (Sr) condition is sent, followed by the read slave ID. The MAX30100 then begins sending data beginning with the register selected in the first operation. The read pointer increments automatically, so the MAX30100 continues sending data from additional registers in sequential order until a STOP (P) condition is received. The exception to this is the FIFO_DATA register, at which the read pointer no longer increments when reading additional bytes. To read the next register after FIFO_DATA, an I^{2}C write command is necessary to change the location of the read pointer.

An initial write operation is required to send the read register address.

Data is sent from registers in sequential order, starting from the register selected in the initial I^{2}C write operation. If the FIFO_DATA register is read, the read pointer does not automatically increment, and subsequent bytes of data contain the contents of the FIFO.

S	1	0	1	0	0	0	1	R/W = 0	ACK	A7	A6	A5	A4	A3	A2	A1	A0	ACK

SLAVE ID REGISTER ADDRESS

D7	D6	D5	D4	D3	D2	D1	D0	ACK	P

Figure 8. Writing One Data Byte to the MAX30100

SLAVE ID S = START CONDITION Sr = REPEATED START CONDITION P = STOP CONDITION ACK = ACKNOWLEDGE BY THE RECEIVER NACK = NOT ACKNOWLEDGE REGISTER ADDRESS SLAVE ID DATA

S	1	0	1	0	0	0	1	R/W = 0	ACK	A7	A6	A5	A4	A3	A2	A1	A0	ACK	
S	1	0	1	0	0	0	1	R/W = 0	ACK	D7	D6	D5	D4	D3	D2	D1	D0	NACK	P

Figure 9. Reading One Byte of Data from the MAX30100

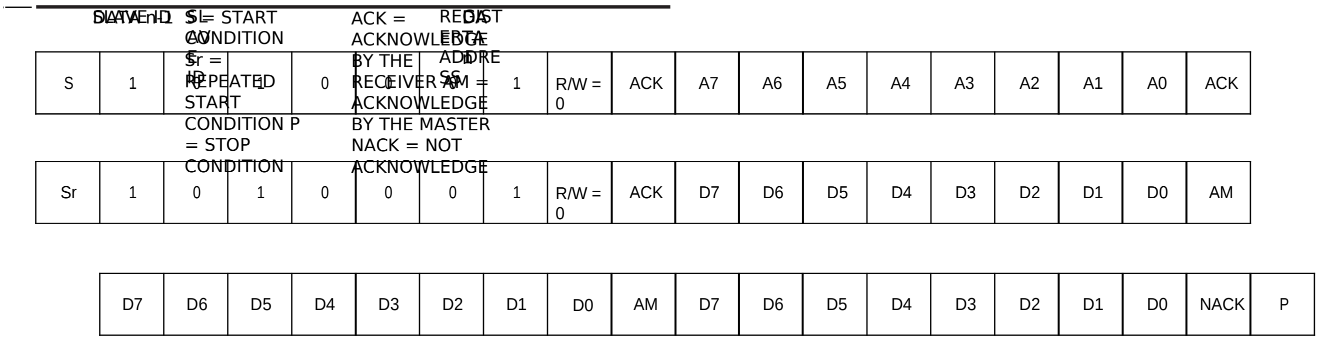


Figure 10. Reading Multiple Bytes of Data from the MAX30100

Typical Application Circuit

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX30100EFD+	-40°C to +85°C	14 OESIP (0.8mm pitch)

+Denotes a lead(Pb)-free/RoHS-compliant package.

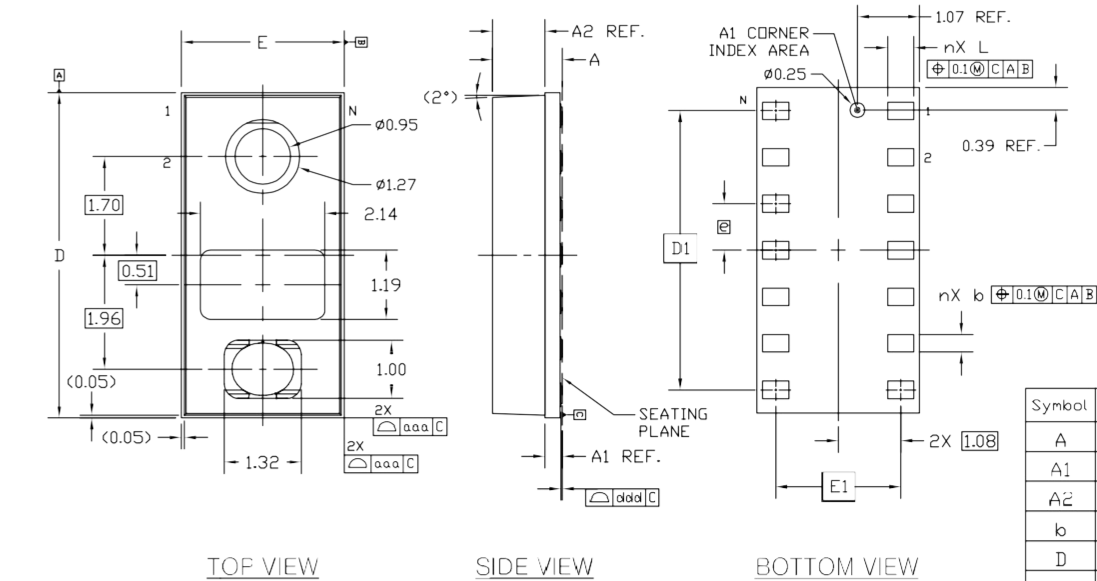
Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
14 OESIP	F142D5+2	21-0880	90-0461



Symbol	MIN	NOM	MAX
A	1.1	1.2	1.3
A1	0.3 REF.		
A2	0.9 REF.		
b	0.25	0.30	0.35
D	5.5	5.6	5.7
D1	4.8 BSC		
E	2.7	2.8	2.9
E1	2.15 BSC		
e	0.8 BSC		
L	0.40	0.45	0.50
N	14		
aaa	0.1		
ddd	0.08		

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
2. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M–1994.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. MATERIAL MUST BE COMPLIANT WITH MAXIM SPECIFICATION 10-0131 FOR SUBSTANCE CONTENT, MUST BE EU ROHS COMPLIANT WITHOUT EXEMPTION AND PB-FREE.
5. ALL DIMENSIONS APPLY TO Pb FREE (+) PARTS.
6. PACKAGE CODE: F142D5+2

maxim integrated

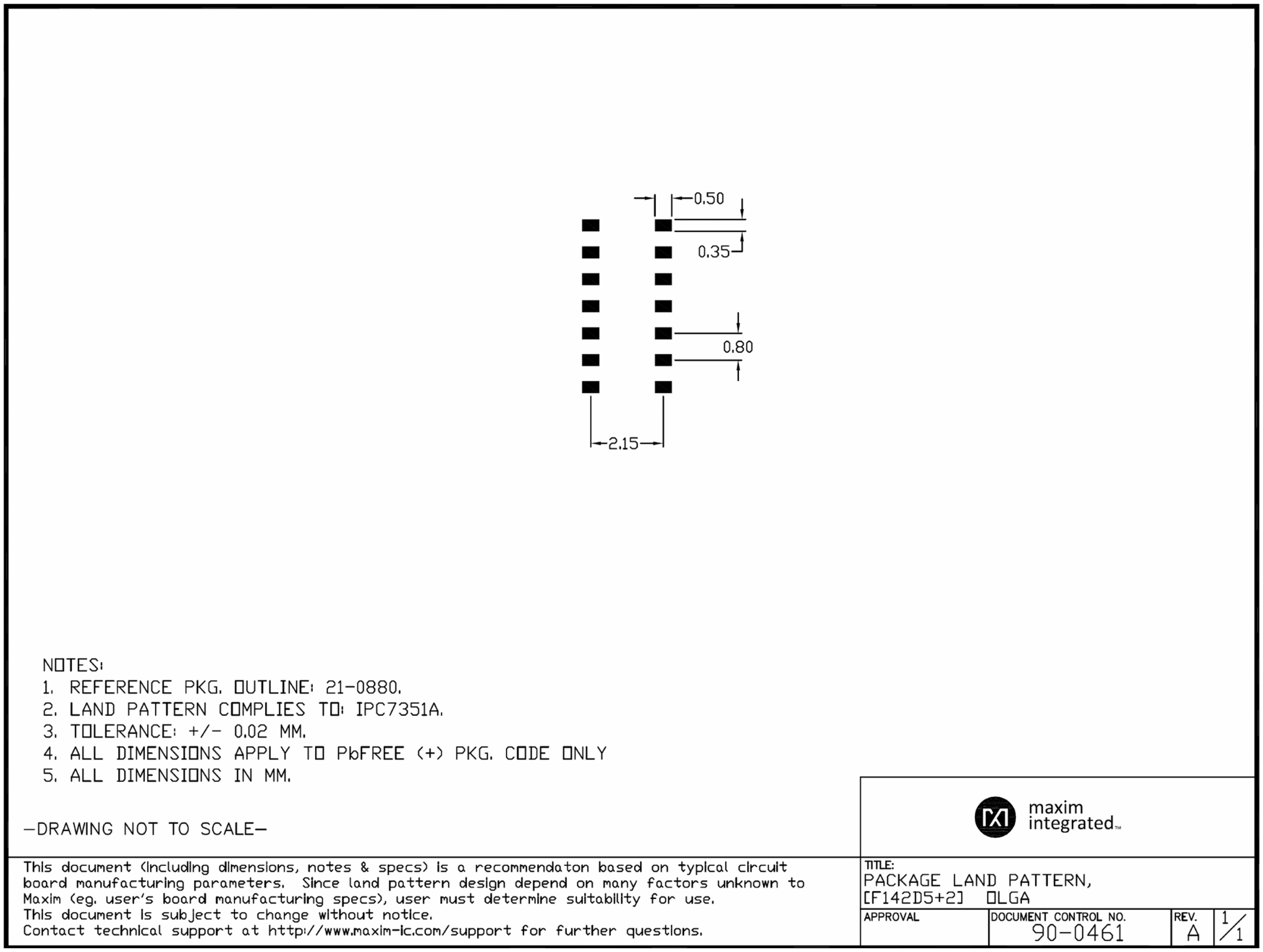
TITLE: PACKAGE OUTLINE, 14L OLGA, 2.8x5.6x1.2mm

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0880	B	1/1

–DRAWING NOT TO SCALE–

Package Information (continued)

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.



Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	9/14	Initial release	—

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at www.maximintegrated.com.

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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

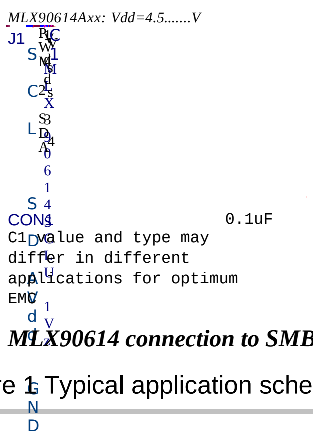
Part No. MLX90614 X X X
(1) (2) (3)

(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.

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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, VDD (over voltage)	7V	5V	7V	5V
Supply Voltage, VDD (operating)	5.5 V	3.6V	5.5V	3.6V
Reverse Voltage	0.4 V			
Operating Temperature Range, TA	-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

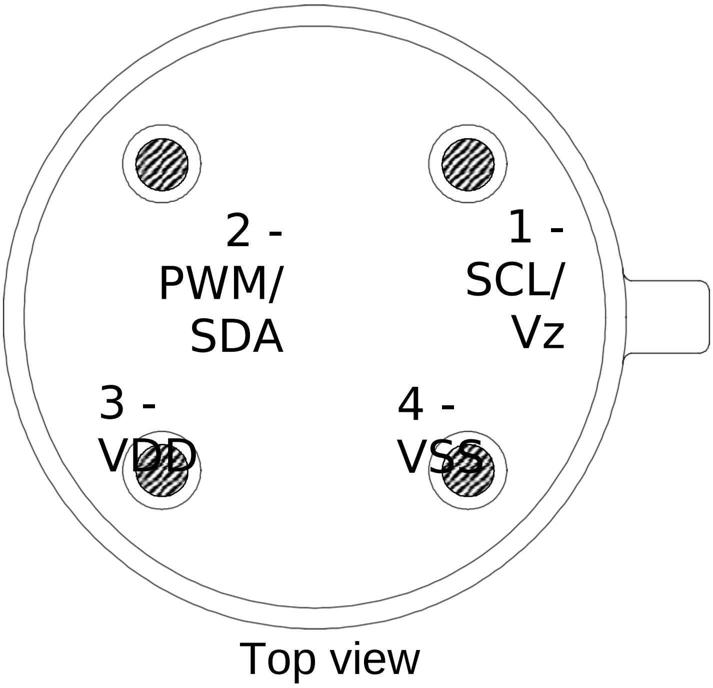

Figure 2: Pin description

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, V_{DD} **=5V** (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	VDD		4.5	5	5.5	V
Supply current	IDD	No load			1	mA
Supply current (programming)	IDDpr	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	VPOR	Power-up, power-down and brown-out	2.7	3.0	3.3	V
VDD rise time	TPOR	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	PWMT,def	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	dPWMT	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-4		+4	%
Output high Level	PWMHI	I_{source} = 2 mA	VDD-0.2			V
Output low Level	PWMLO	Isink = 2 mA			VSS+0.2	V
Output drive current	IdrivePWM	Vout,H = VDD - 0.8V		20		mA
Output sink current	IsinkPWM	Vout,L = 0.8V		20		mA
Output settling time	Tset	100 pF capacitive load, full operating Ta range		500	TBD	ns
Output settling time	TsetRC	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	VIH		1.8	2	2.2	V
Input high voltage	VIH(Ta,V)	Over temperature and supply	1.6		2.4	V
Input low voltage	VIL		0.7	1.0	1.3	V
Input low voltage	VIL(Ta,V)	Over temperature and supply	0.5		1.5	V
Output low voltage	VOL	SDA pin in open drain mode, over temperature and supply, Isink = 2mA			0.2	V
SCL leakage	ISCL,leak	VSCL=4V, Ta=+85°C			30	uA
SDA leakage	ISDA,leak	VSDA=4V, Ta=+85°C			0.3	uA
SCL capacitance	CSCL				10	pF
SDA capacitance	CSDA				10	pF
Slave address	SA	Factory default		5Ah		hex
SMBus Request	tREQ	SCL low	1.024			ms
Timeout, low	Timeout,L	SCL low			30	ms
Timeout, high	Timeout,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, **V_{DD} =3V** (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	VDD		2.4	3	3.6	V
Supply current	IDD	No load			1	mA
Supply current (programming)	IDDpr	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	VPOR	Power-up, power-down and brown-out	1.6	1.85	2.1	V
VDD rise time	TPOR	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	PWMT,def	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	dPWMT	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-4		+4	%
Output high Level	PWMHI	I_{source} = 2 mA	VDD-0.25			V
Output low Level	PWMLO	Isink = 2 mA			VSS+0.25	V
Output drive current	IdrivePWM	Vout,H = VDD - 0.8V		15		mA
Output sink current	IsinkPWM	Vout,L = 0.8V		15		mA
Output settling time	Tset	100 pF capacitive load, full operating Ta range			150	ns
Output settling time	TsetRC	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	VIH		1.6	2	2.4	V
Input high voltage	VIH(Ta,V)	Over temperature and supply	1.2	2	2.8	V
Input low voltage	VIL		0.7	1.0	1.3	V
Input low voltage	VIL(Ta,V)	Over temperature and supply	0.5	1.0	1.5	V
Output low voltage	VO L	SDA pin in open drain mode, over temperature and supply, Isink = 2mA			0.25	V
SCL leakage	ISCL,leak	VSCL=3V, Ta=+85°C			20	uA
SDA leakage	ISDA,leak	VSDA=3V, Ta=+85°C			0.25	uA
SCL capacitance	CSCL				10	pF
SDA capacitance	CSDA				10	pF
Slave address	SA	Factory default		5Ah		hex
SMBus Request	tREQ	SCL low	1.024			ms
Timeout,low	Timeout,L	SCL low			30	ms
Timeout, high	Timeout,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°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

Note: refer to MLX90614Axx notes.

7 Detailed description

7.1 Block diagram

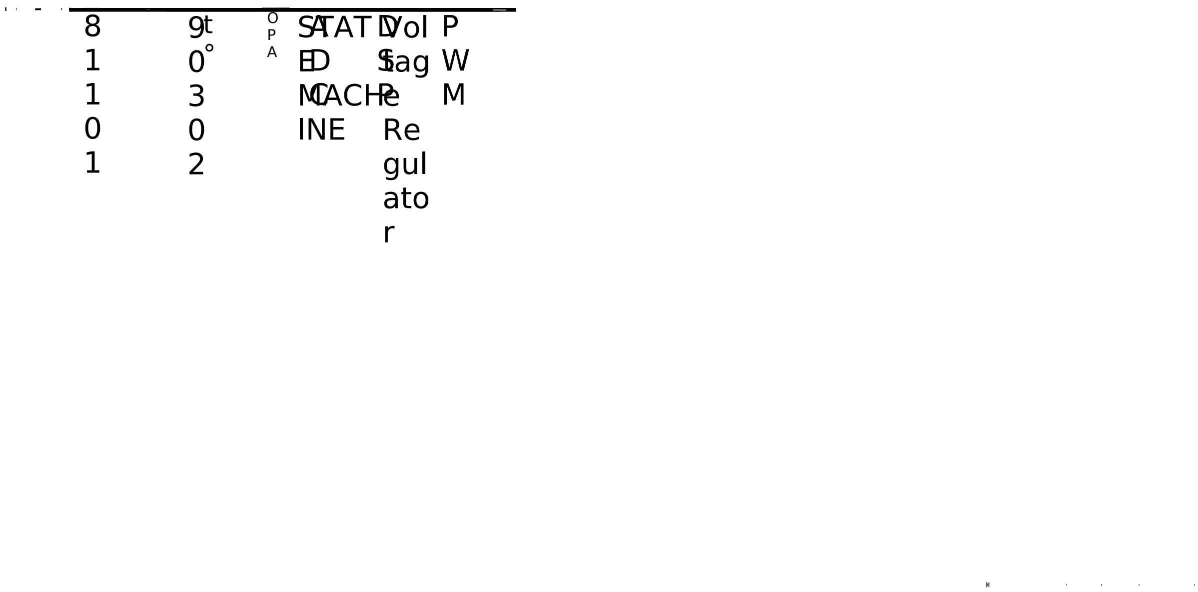

Figure 3: block diagram

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°C resolution, fixed ranges), or through the PWM digital output (10 bit resolution, configurable range).
In the last step of the measurement cycle, the measured 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**
Tomax	**000h**	**Yes**
Tomin	**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
TA	006h	Yes
TOBJ1	007h	Yes
TOBJ2	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

1	7	1	1	8	1	1
S	Slave Address	Wr	A	Data Byte	A	P

SStart Condition

SrRepeated Start Condition RdRead (bit value of 1)
WrWrite (bit value of 0)

AAcknowledge (this bit can be 0 for ACK and 1 for NACK)

SStop Condition
PECPacket Error Code

Master-to-Slave Slave-to-Master

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)

1	7	1	1	8	1	1	7	1	1	
S	Slave Address	Wr	A	Command	A	Sr	Slave Address	Rd	A	………..

	8	8	8	8	8	1	1
………..	Data Byte Low	A	Data Byte High	A	PEC	A	P

Figure 5: SMBus read word format

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

1	7	1	1	8	1	
S	Slave Address	Wr	A	Command	A	………..

	8	8	8	8	8	1	1
………..	Data Byte Low	A	Data Byte High	A	PEC	A	P

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 (tREQ) 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].

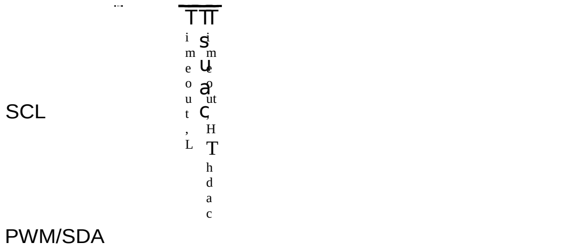

Figure 7: SMBus timing

7.4.5 Bit transfer

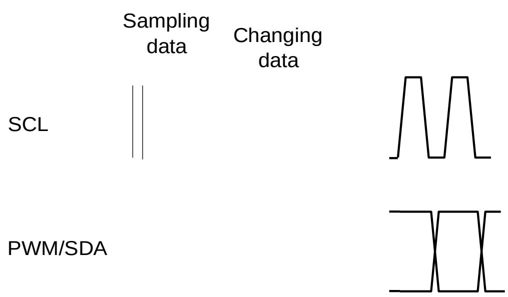

Figure 8: Bit transfer on SMBus

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, **TOBJ1** - RAM address 0x07h will sweep between 0x27ADh to 0x7FFF as the object temperature rises from -70.01°C to +382.19°C). 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

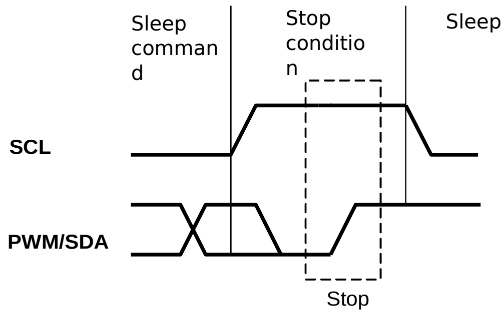

Figure 9: Enter sleep

7.4.7.2 Exit from Sleep Mode

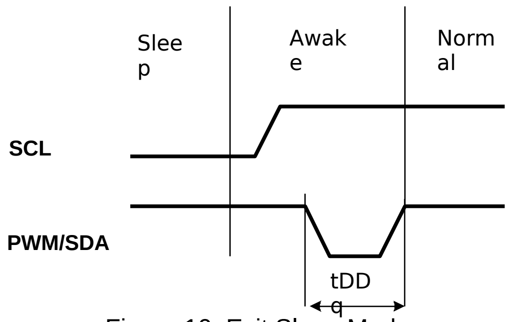

Figure 10: Exit Sleep Mode

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:

$$T_{out} = \frac{2t_2}{T} \cdot (T_{max} - T_{min}) + T_{min},$$

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:
Tobj1 => Config Reg[5:4] = 11'b
Tomin = 0°C => Tomin [EEPROM] = 100 * (tomin + 273.15) =
6AB3h Tomax = +50°C => Tomax [EEPROM] = 100 * (tomax +
273.15) = 7E3Bh
Captured PWM high duration is 0.495*T => t2=(0.495 – 0.125)*T=0.370*T =>
measured object temperature = 2X0.370* (50°C -0°C)+0°C = +37.0°C.

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.

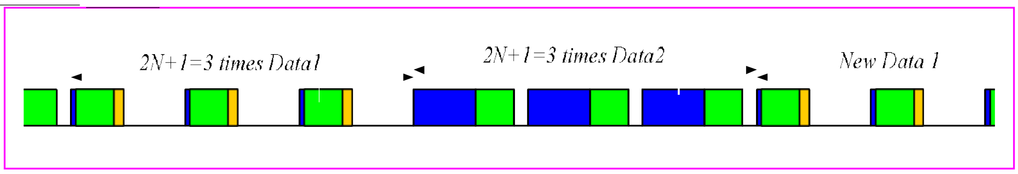

Figure 12: Extended PWM format with DUAL[5:1] = 01h (2 repetitions for each data)

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

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

For Data 2 field the equation is:

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

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 : Tobj1 @ Data1 : Data2 => Config Reg[5:4] = 00b,
Tamin = -5°C => Tarange, L [EEPROM] = 100*(Tamin+38.2)/64 =
33h, Tamax = +105°C => Tarange,H [EEPROM] =
100*(Tamax+38.2)/64 = DFh,
Tarange [EEPROM]=DF33h
Tomin = 0°C => Tomin [EEPROM] = 100 * (Tomin + 273.15)/64 =
6AB3h Tomax = +50°C => Tomax [EEPROM] = 100 * (Tomax +
273.15)/64 = 7E3Bh
Captured high durations are 0.13068*(2T) and 0.7475*(2T), where 2T is each captured PWM period. Time band t4 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:
t2/T=(thigh1/T)-0.125=0.13636 =>
Ta=+25.0°C, t5/T=(thigh2/T)-1.125=0.370
=> Tobj1=+37.0°C.

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:

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

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]

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

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

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

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

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]

$$T_{MIN_{EEPORM}} = \left(T_{MIN} - (-38.2)\right) \times \frac{100}{64} \text{ LSB}$$

$$T_{MAX_{EEPORM}} = \left(T_{MAX} - (-38.2)\right) \times \frac{100}{64} \text{ LSB}$$

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.

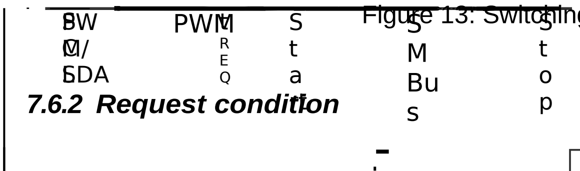

Figure 13: Switching from PWM mode to SMBus

7.6.2 Request condition

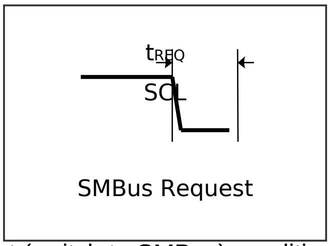

Figure 14: Request (switch to SMBus) condition

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.*

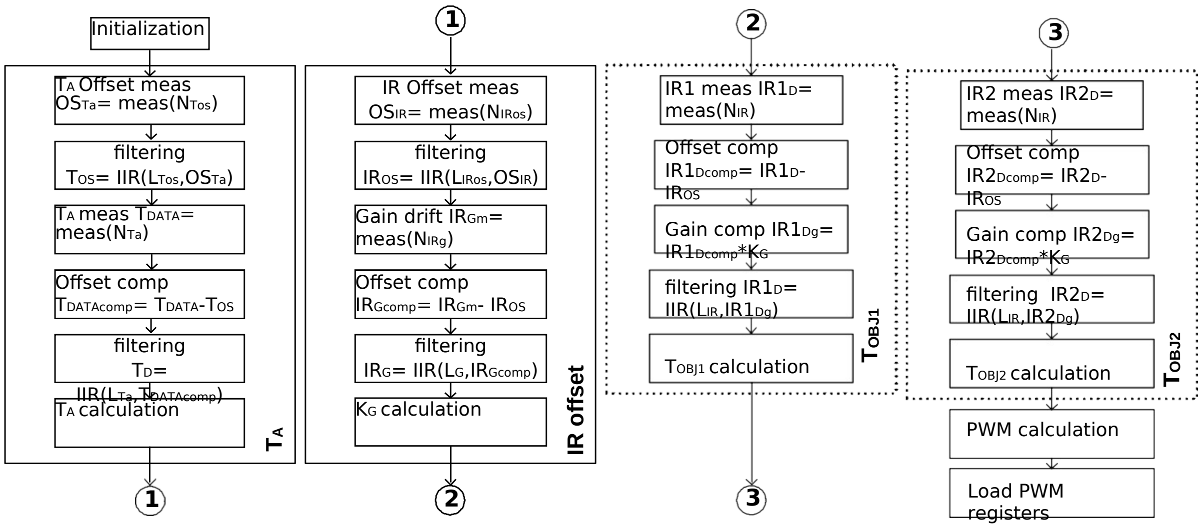

Figure 15: Software flow

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:

- o Set bit TRPWMB high at address 002h in EEPROM
- o 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 $T_{obj} > threshold + hysteresis$

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

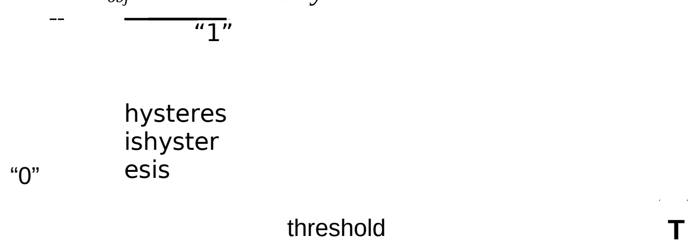

Figure 16: Thermal relay : “PWM” pin versus Tobj

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

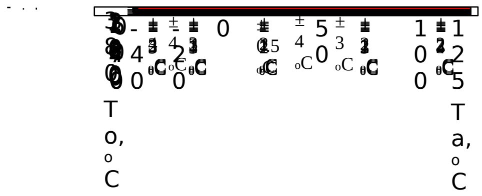

Figure 17: Preliminary accuracy of MLX90601AAA (Ta,To)

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.

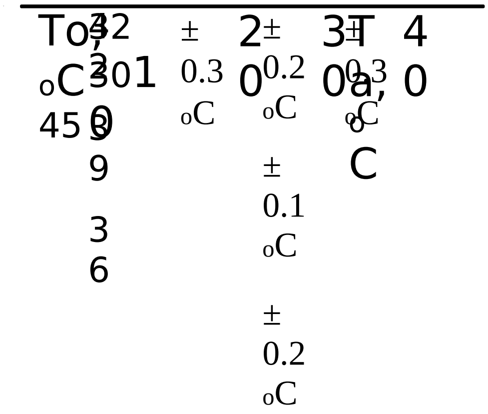

Figure 18: Preliminary accuracy of MLX90601BAA (Ta,To) for medical applications.

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°

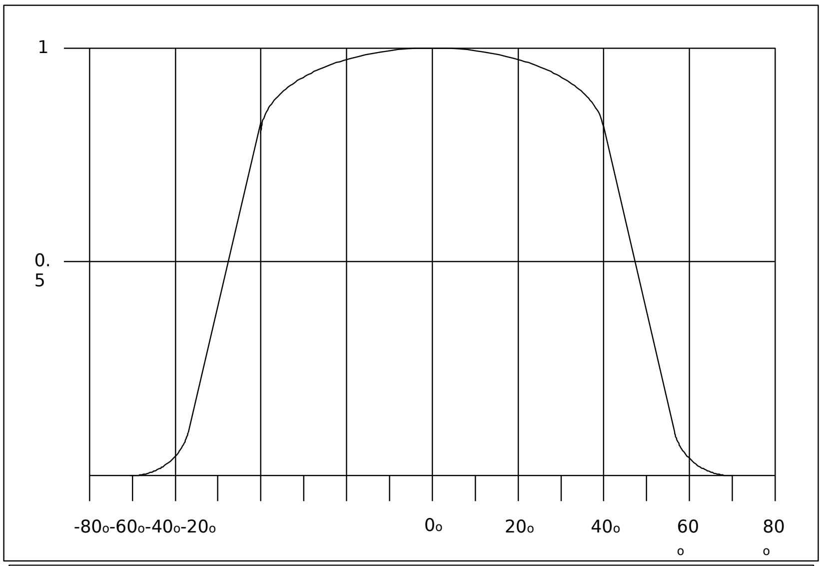

Figure 19: FOV of MLX90614xAA

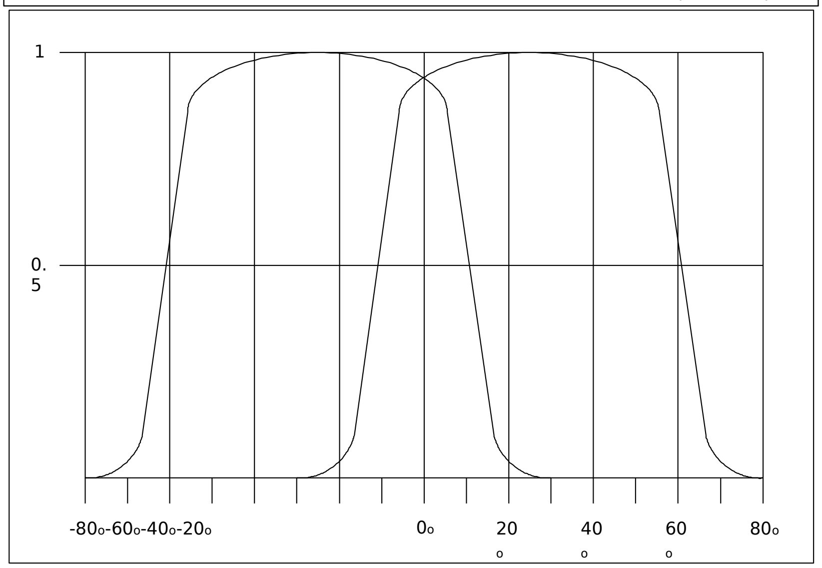

Figure 20: FOV of MLX90614xBA

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

10 Applications Information

10.1 Use of the MLX90614 thermometer in SMBus configuration

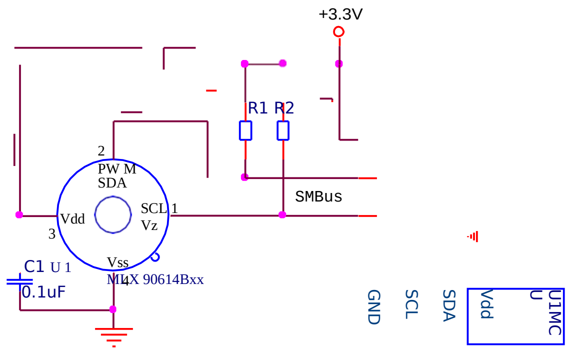

Figure 22: Connection of MLX90614 to SMBus, 3.3V power supply.

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

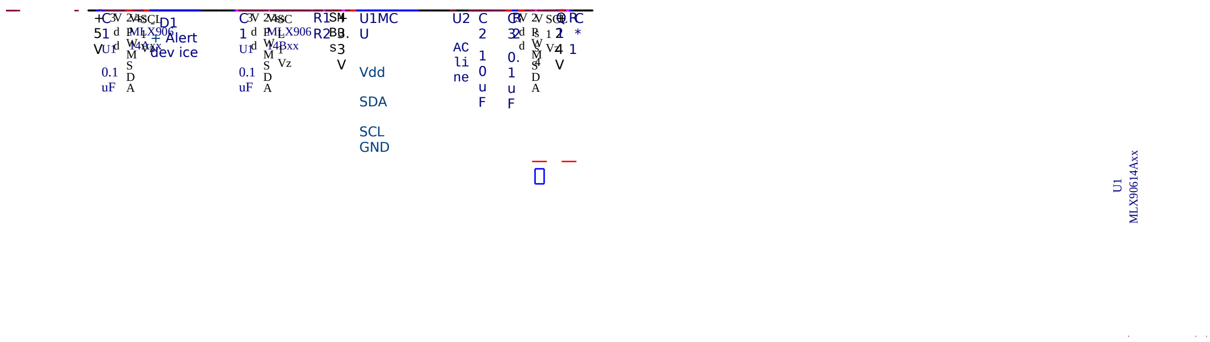

figure 24: Possible thermal relay configurations.

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.

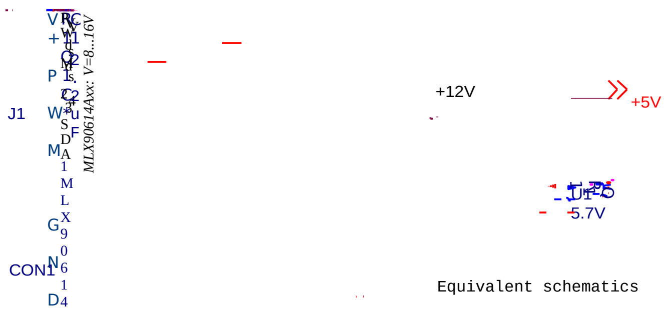

Figure 25: 12V regulator implementation

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

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

where
s_1 and s_2 are the emissivities of the two objects,
a_1 is the absorptivity of the sensor (in this case),
o is the Stefan-Boltzmann constant,
$\mathbf{A_1}$ and $\mathbf{A_2}$ are the surface areas involved in the radiation heat transfer,
$\mathbf{F_{a-b}}$ 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.

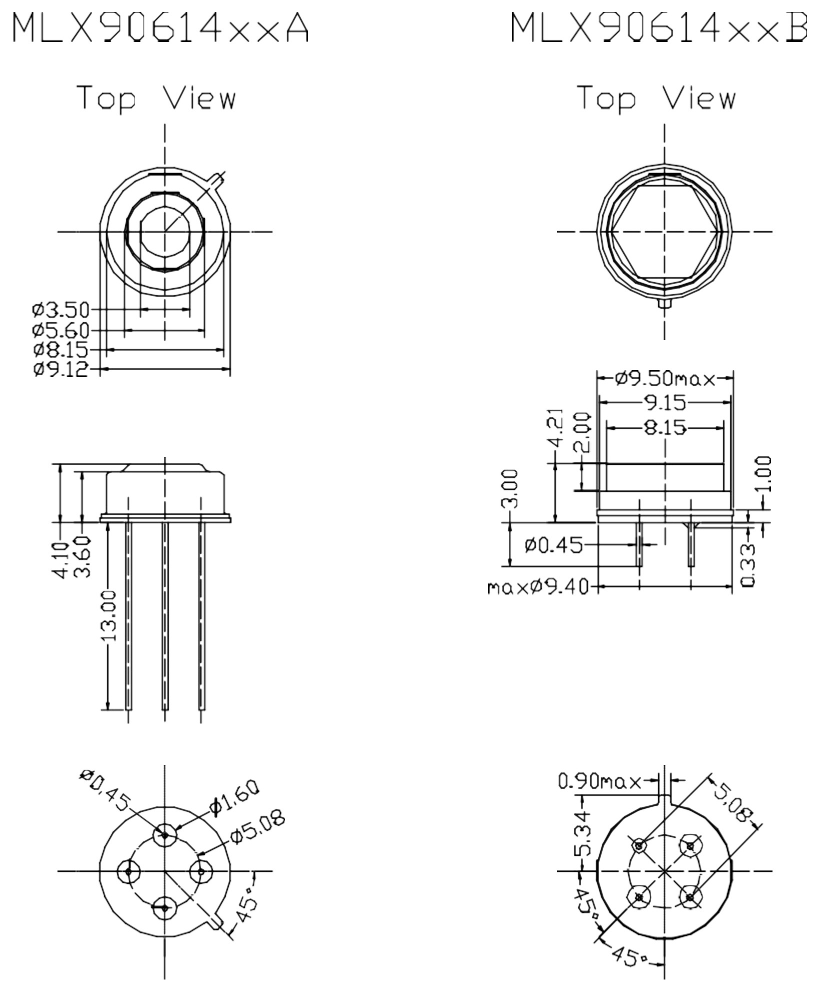

Figure 26: Packaging options

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.

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