“The Contactless Badge" designed IR - Thermometer Evaluating Temperature & Social/Physical Distancing by Fabricating the MLX90614 Thermal Sensor during Covid- 19 Global Emergency

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Article

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"The Contactless Badge" designed IR - Thermometer Evaluating Temperature & Social/Physical Distancing by Fabricating the MLX90614 Thermal Sensor during Covid- 19 Global Emergency

Abhijeet Kumar[1] Arpit Kumar[2] Manju Kumari[3]

1.1 Abstract

The study ameliorates the feasibility of IR thermometer, and to introduce a novel design with upgraded applications & functions. The custom compact device (shape illustrates a "Badge") measures the surface temperature of a body and received data processed through a microcontroller (AtMega328P). The device functions in a way that if there is any thermal change from ambient temperature (D-1 m), the mode is activated and triggers a pre-defined alert. For distance measuring, it measures the intensity of IR radiation emitted by a body from a particular direction. It also reads the temperature when it comes across a body. It will provide an optimum way in the primary healthcare instrumentation and helpful for noncontact, quick, and accurate measurement of moving and high temperature body.

Keywords

Social/physical Distancing, Thermal Badge, IR Sensitivity, Infrared Radiation, Ambient Temperature,

1.2 Introduction

Infrared Sensitivity is a process through which we measure the number of infrared rays that are transmitted by any object currently there are lots of applications of infrared sensitivity, measuring temperature is a common application. The sensor that is applied to measure the IR (infrared radiation) is a passive IR sensor (PIR) the sensor measures infrared light is in *[W/ M^2 or Ft^2],* or the energy produced by an infrared light source over a specific area. Infectious disease — one of the cardinal signs of infection is raised body temperature infrared scan of the forehead **[1].** Considers above *100^o* to be a *flu-related fever.* ***The National Institutes of Health*** says an adult with a temperature above *99^o F* "has a fever, depending on the time of day. Fever is one of the most important symptoms **[0]** of COVID-19, but due to the contagious effect, its measurement can become a serious problem, so it is important to perform the temperature detection of patients very quickly and possibly without any contact & generally use infrared thermometers in circumstances when other sorts of thermometers are not practical. ***If an object is extremely fragile or dangerous to be near, for example, an infrared thermometer is a good way to get a temperature from a safe distance***. Infrared thermometers measure temperature from a distance. This distance can be many miles or a fraction of an inch, on the other hand, both epidemiological and laboratory studies have revealed that ambient temperature could affect the survival and spread of Coronavirus **[6],** before the current pandemic, hospitals would assess fever and act upon it in response to individual patients and diagnoses a fever is considered normal body temperature for a typical adult is considered *98.6°F,* but the reality is a "normal" body temperature can range between *97°F and 99°F* **[2].** A range is more accurate because many factors affect body temperature, including the time of day and a person's gender, age, and activity levels. Any temperature over *100.4°F,* which is your body's way of fighting off an illness or infection, high body temperature is one of the first symptoms of illness, and a fever is a sign that your body is fighting off an infection, like the flu virus, so that a continuous monitoring of temperature, regarding body, is an essential task to be performed in the contrast of COVID-19.

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1.3 Literature review

1.3.1 Infrared detection

Infrared thermometers work based on Phenomenon called black body radiation. Anything at a temperature above absolute zero has molecules inside of it moving around. The higher the temperature, the faster the particles move. As the Move, the molecules emit. Infrared radiation-an electromagnetic radiation below the visible spectrum of light. As they get hotter, they emit infrared and even emit visible light. That is why heated metal can glow red or indeed white. Infrared thermometers detect and measure this radiation. The ability to accurately measure the temperature of different materials has always been a challenge for the Instrumentation Engineer. The use of the classic contact type temperature detector such as thermocouples or RTD's (Resistance Temperature Detectors) has not always shown to be the best approach to obtain the expected measurement. When not used carefully in closed environments, thermocouples and RTD's could report the environmental temperature rather than the temperature from the product under examination. They are also temperature limited and when needed for applications above those limits, very expensive and low reliable materials are necessary to do the job. On the whole application of non-contact thermometers has become the preferred choice for such tasks.

1.4 Principle of IR Temperature Measurement

In nature, when the temperature of the object is higher than the absolute zero (-273.15°C), Electromagnetic waves will continue to radiate around due to the thermal motion of molecules. The radiation of the electromagnetic wave contains the infrared radiation of 0.75 ~100μm, the radiation energy density and the temperature of the object are per the law of radiation **[7-8];**

$$A = \alpha\beta(T_2^4 - T_1^4) \qquad (1)$$

Where; A is a radiation degree, the unit is W/m^3; αis the Stephen Pozman constant, $\alpha=5.67\times10^{-8}$W/(m^2 · K^4); β is the radiation rate; T_2 is the absolute temperature of the object, the unit is K; T_1 is the ambient temperature, the unit is K. The numerical value of the radiation rate is 0-1.0, which indicates the ability of the radiation electromagnetic wave. All real objects (including the surface of the human body), β values are less than 1.0.

The main radiation infrared wavelength of the human body is 9 - 10μm, human body surface temperature can be accurately measured by measuring the body's radiation infrared energy. Because the light in the range of 9 to10μm is not absorbed by air, the surface temperature of the human body can be determined by infrared energy. The relationship between the temperature of radiator and detection voltage can be derived by the Planck formula;

$$U = \mu\gamma\beta\alpha(T_2^4 - \rho T_1^4) \qquad (2)$$

Where; ρ=μγβα, T_2 is the absolute temperature of the object to be measured, μ is the sensitivity of the detector, γ is constant which is related with the atmospheric attenuation distance, β is radiation rate, α is the Stefan Boltzmann constant. According to the eqn. (2), the output signal of the detector and the target temperature is nonlinear, and the T_2^4 is proportional to, Therefore, the surface temperature of the object should be linearized, and the radiation rate can be corrected so that the real temperature can be obtained, Correction formula is:

$$T_2 = \frac{T_0}{\sqrt[4]{\beta(T)}} \qquad (3)$$

Where; T_0 is the surface temperature (radiant temperature); β(T) is the radiation rate, its value is 0.1 - 0.9. The real temperature is higher than the ambient temperature after the radiation rate correction due to the influence of the radiation signal, so the ambient temperature is also compensated, that is: The temperature of the ambient temperature plus the actual temperature is the actual temperature of the measured object **[9-10].**

1.5 Method and Materials

The device configuration includes CAD Modeling, Circuitry Plots, Simulation and Programs written and complied, respectively, on *Autodesk (Fusion 360- 2.0.9719)*, *Altium Designer V-20.2.3.* Arduino *CC V-1.8.9.*

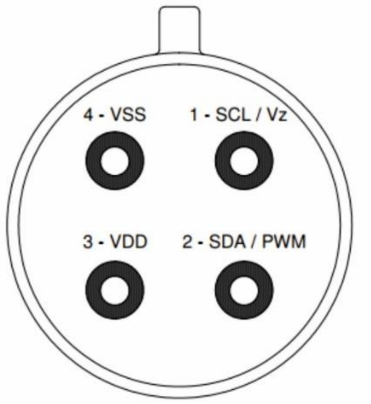
The proposed hardware consists of 4 components: 1) Microcontroller, 2) MLX90614 (Thermal Sensor, 3) Alert & Notification System, and 4) Power supply & BMS units – Function as the management of the power supply and over discharge & overcharge protection; the required voltage input of device is 5 V and minimum operating voltage is 3 V. These four components are assembled in a single module (Fig) and fabricated under the outer body that 3D printed body of this novel device, which shapes referred as Badge *(a **small piece of metal, plastic, or cloth bearing/ wearable/hanging design*** [Fig] with acrylonitrile butadiene styrene (ABS) material. Especially, this case is designed to provide better optimum performance integrity Portable and compact structure leads to an ordinary and simple device that's easily fits in our day-to-day life without taking extra effort and attention.

1.5.1 Description of MLX90614 (Thermal Sensor)

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 with the same TO-39 can.
Integrated with its low noise amplifier, 17-bit ADC, and powerful DSP unit, high accuracy and resolution of the thermometer are achieved.
The thermometer comes factory calibrated with a digital PWM and SMBus (System Management Bus) output. As a standard, the 10-bit PWM is configured to continuously transmit the measured temperature in the range of -20-120˚C, with an output resolution of 0.14˚C. The factory default POR setting is SMBus. The PWM pin can also be configured to act as a thermal relay (input is T_A), thus allowing for easy and cost-effective implementation in thermostats or temperature factor based alert applications as in this study. The temperature threshold in this sensor was programmable. In a 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. An optical filter (long-wave pass) that cuts off the visible and near infrared radiant flux is integrated in the package to provide ambient and sunlight immunity. The wavelength pass band of this optical filter is from 5.5-14µm (except for xCH and xCI type of devices which incorporate uncoated Silicon lens).

1.5.2 Pin definition and description of MLX90614

SCL/ Vz; Serial clock input for 2 wire communications protocol. 5.7V. **SDA / PWM -** Digital input / output. In normal In SMBus compatible mode, the pin is automatically configured as open drain NMOS. Mode the measured object temperature is available at this pin Pulse Width Modulated. **VDD-** External supply voltage; **VSS-** Ground. The metal can also connect to this pin [.



Fig; Pin definition of MLX90614

Electrical Specification of **MLX90614 Bxx [SMBus compatible 2-wire interface[2]]** Dual Zone Infrared Thermometer in TO-39

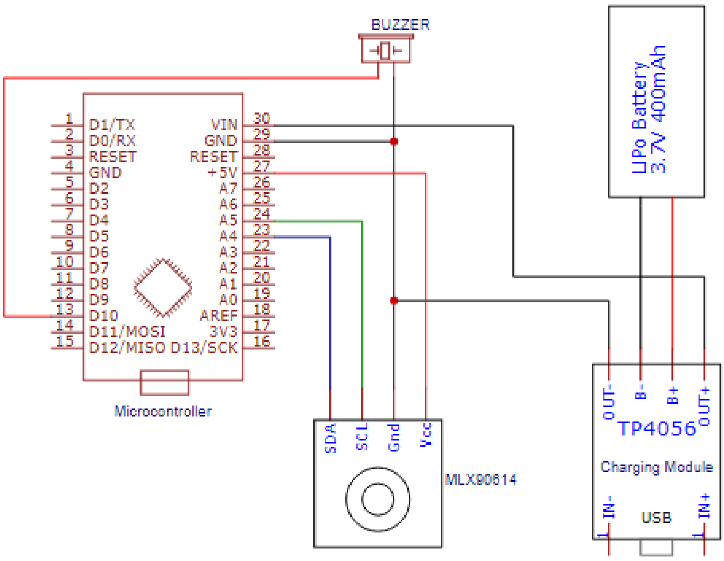
Parameters	*Symbol*	*Test condition*	*Min*	*Type*	*Max*	*Units*
		SMBus compatible 2-wire interface[2]				
Input high voltage	VIH(Ta,V)	Over temperature and supply	VDD-0.1			V
Input low voltage	VIL(Ta,V)	Over temperature and supply			0.6	V
Output low voltage	VOL	Over-temperature and supply, Isink = 2mA			0.25	V
SCL leakage	ISCL,leak	VSCL=3V, Ta=+85°C			20	µA
SDA leakage	ISDA,leak	VSDA=3V, Ta=+85°C			0.25	µA
SCL capacitance	CSCL	10			10	pF
SDA capacitance	CSDA	10			10	pF
Slave address	SA	Factory default		5A		hex
Wake up request	twake	SDA low	33			ms
SMBus Request	tREQ	SCL low	1.44			ms
Timeout,low	Timeout,L	SCL low	27	33		ms
Timeout, high	Timeout,H	SCL high	45	55		Ms
Acknowledge setup time	Tsuac(MD)	8-th SCL falling edge, Master		1.5		Ms
Acknowledge hold time	Thdac(MD)	9-th SCL falling edge, Master		1.5		Ms
Acknowledge setup time	Tsuac(SD)	8-th SCL falling edge, Slave		2.5		Ms
Acknowledge hold time	Thdac(SD)	9-th SCL falling edge, Slave		1.5		Ms

Table: Electrical specification MLX90614Bxx, (of I2C interface)

Assembling the sensor in the device for experimentation **PIR** Sensor (MLX90614) to evaluate the temperature. The sensor is covered with a metallic hood to get the constant temperature (T_o) value of the object.

Microcontroller (ATmega328P ;) installed on the device for the processing of input data collected by the sensor and to produce output functions;

1.5.3 Circuitry Plots



Fig; Schematics of the device

The statistical trial of the device function configured electronically on the software (Arduino CC V 1.8.9); Programs of the device classified into two stages are stated below-

Pre-calibration and Processing

In the MLX90614 the calibration function is pre factory calibrated, & in the device the $(T_A - T_{OBJ.})$ sensor calibrated in the-

```
{ float AmbientTemp = 0; //ambeint temperature
float ObjectTemp = 0, stemp = 0, temp = 0; // Object temperature
unsigned char readcount = 0;
float threshold = AmbientTemp-(-10.5) ; // calibrating the mlx sensor for correct temperature
int dtime = 10;}
```

1.5.4 Processing of Input

```
 temp = stemp / 5;        // get the average reading of temp
 stemp = 0;

 if ((temp >= 96) && (temp < 107)) {              /// high temp //alert
   digitalWrite(buzpin, HIGH); delay(1000);

 }else {
   digitalWrite(buzpin, LOW ); // infected person


 if ((temp >= 90) && (temp < 96)) {
   digitalWrite(buzpin, HIGH); delay(100);            // for ir intensity  //distance measuring approx//
   digitalWrite(buzpin, LOW); delay(200);
 }else{
 }


 if ((temp >= 90) && (temp < 96)) {
   digitalWrite(buzpin, HIGH); delay(100);            // for ir intensity  //distance measuring approx//
   digitalWrite(buzpin, LOW); delay(200);

 }else{
   digitalWrite(buzpin, LOW ); // infected person

 }
 }
```

1.5.5 Output processing function

```
void setup() {
  Serial.begin(9600);
  pinMode(buzpin, OUTPUT);
  delay(100);
  Serial.println("Adafruit MLX90614 test");
```

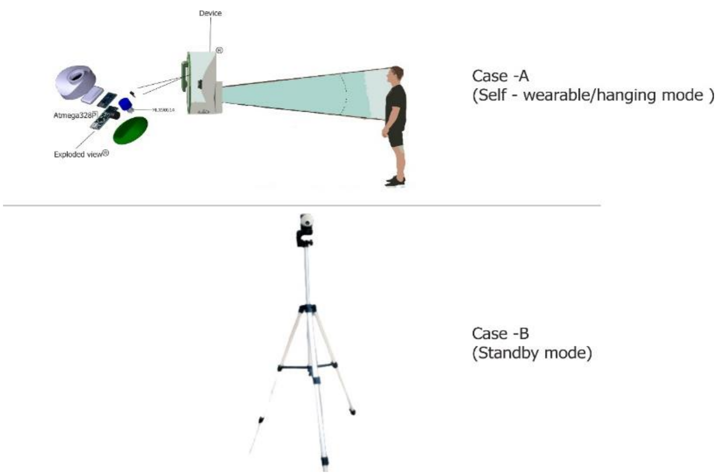
```
  mlx.begin();
}

Void loop() {
  // reading object and ambeint tempreature
  ObjectTemp = threshold + mlx.readObjectTempF();
  AmbientTemp = mlx.readAmbientTempF();


  Adafruit_MLX90614 ("IR1 ");
  Serial.print("IR1: ");
  Serial.print("Ambient = ");
Serial.print((String)AmbientTemp);
  Serial.print("*F\tObject = ");
Serial.print((String)ObjectTemp);
Serial.println("*F");

  if (readcount < 5) { //after reading 5 consecutive time
    stemp = stemp + ObjectTemp;
    readcount ++;
    dtime = 20; // until approx. 5 x 20 ms = 100 msec
  }
  else {
    disptemp();
    dtime = 10;
    readcount = 0;
  }
  delay(dtime);
  Serial.println("count  :" + String(readcount));
}
```

The device configured in two case setups were the observation done upon respective attachment shown in **fig;**



Fig; attachment option of the proposed device

1.6 Result and Discussion

All unit circuit are simulated on the Serial Monitor and Plots platform of Arduino CC V-1.8.9, the PCB board and the body of the device produce after simulation results, the distance versus temperature accuracy were simulated in ambient temperature exposure, time, consecutive counts, respectively, calculated in simulation **[*Figure c*],** where the threshold values are configured pre simulation steps. Relates that the accurate calibration of the mlx sensor for appropriate output.

X[ambient]	Y[D= .5m]	Y[D=1m]
92.64	93.48	89.81
92.61	93.77	89.77
92.57	93.45	89.77

Table – Variation of temperature in distance at the float threshold = T_A- [-10.5] of ambient temperature. Value is in [°**F**]

The device consists of two functions mode which [1] Physical/Social Distancing [2] High-temperature alert mode. Observed that any thermal change is noticed in a comparison of the ambient temperature in the surrounding environment (D-1m) the mode1 activated and perform the function of alert (buztone= 100µs high and 100µs low as buzzer output signal). In any thermal change in a comparison of the ambient temperature (99>°**F**) in the surrounding environment (D-1m) the mode is activated and performs the function of alert (buztone=1000µs high & low signal (k)) defined in the section processing of input.

1.6.1 Determination Mechanism of Device

The field (90^0) view of a sensor is determined by the angle in with the sensor is sensitive to thermal radiation this means that the sensor will detect all object in the field of view, the sensor returns the average of all objects in the field of view & whether it is important to that the measured object fills the field of view if this is of the case, the sensor can detect objects that are to supposed to be measured resulting in an incorrect measurement in this way good understanding of the field of view.

Therefore, in this device, this configured to take the field of view into account to determine the distance between sensor and object, because the field of view and object dimension is knowing the derivation for the distance between sensor and object with simple geometry.

$$D = \frac{S}{2} * \tan\frac{(FoV)}{2} \qquad (4)$$

The principle of measuring (**FoV** *[Error! Reference source not found.*is based on the object that is fixed and the sensor panning left to Right or from $+90^0 to - 90^0$*[Figure [a.3, 4, 5]* and the T_D between the fixed print and the background kept to be assigned possible. Panning the sensor from $+90^0 to - 90^0$the sensor will show the peak value

At 0^0 (Fig); at this point, the sensor is straight across the hotspots. In considering normalized the graph of the dataset, here the maximum response at 0^0; a normalized graph shows the intensity from 0 to 100% versus the angle of the measured from$+90^0 to - 90^0$ the field of view is now defined at 50% in the curve (Fig).

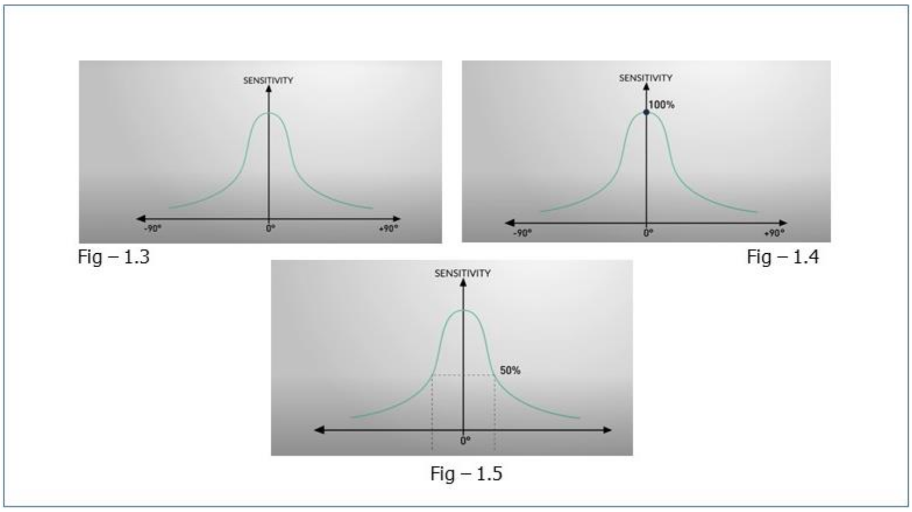


Figure [a.3, 4, 5, 6] ***(Panning of sensor, normalize graph (intensity) from 0 to 100% defined at 50% curve respectively)***

1.6.2 Physical Overview of device

The device refers to the BADGE shape (a compact structure), with high accuracy of 0.5°C in a wide temperature range (0°C…+50°C. for both T_A and T_O), considering the physical appearance of the device the portability and small size because it is easy to carry and accessible in personnel use applications such as (for cloth wear, Like we are hanging ordinary badges as same, also hanging an IR badge & the badge Shape because it does not make feel that an additional thing carries throughout the day in along does not take much attention in day-to-day life).

There were no technical advantages if this device defined in the shape of a "Badge" instead of a handheld IR Gun thermometer, as drawbacks, it is inaccurate as much as possible outdoor because of the limitation of the sensor, this sensor is sensitive it takes T_A and T_O, So in the outdoors, the data will be meshed up between ambient and body temperature cause high exposure of sunlight also due the shape and size of the sensor presently it's In *[Can type through-hole sensor]* have large openings.

In further R&D the SMD IR thermal sensor will apply in this device along with implementing a metallic hood to prevent any outdoor exposure for IR rays & to gauge the body temperature and physical and social distancing.

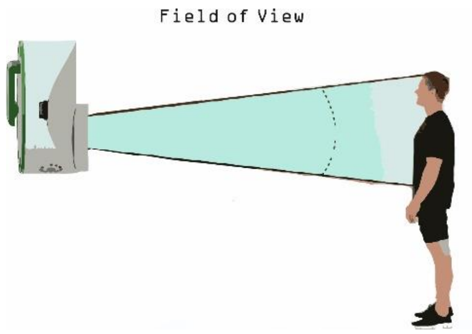


Figure b-s FoV MLX90614

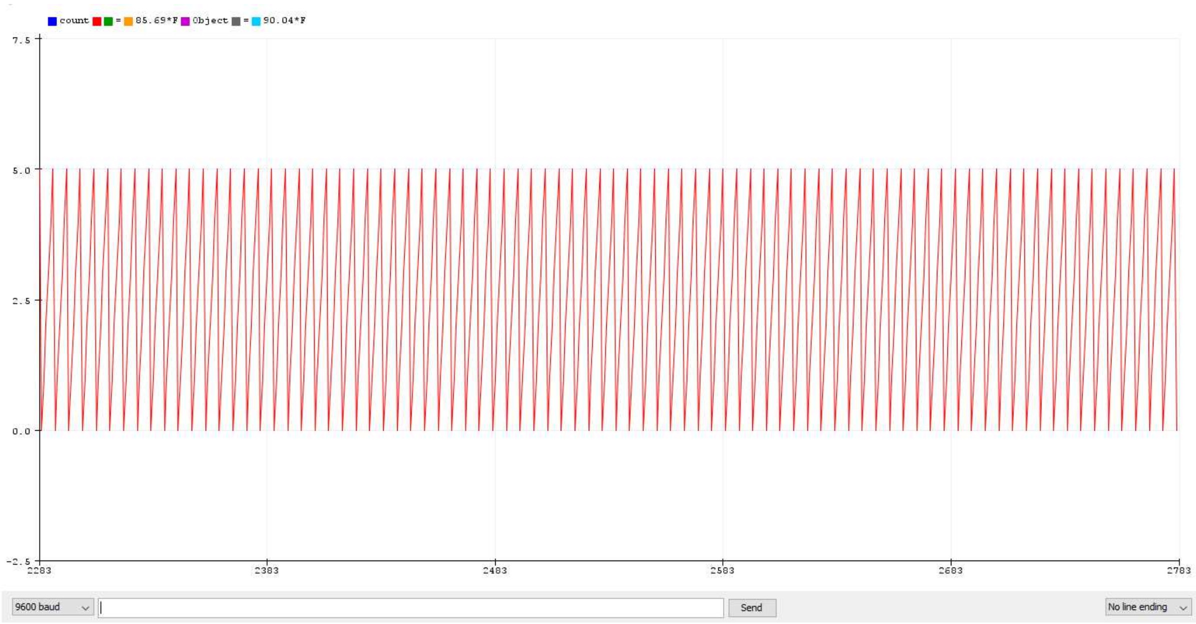


Figure c; Serial plot consider to ambient & body temperature at [D-1m]
Reading; 5 consecutive time
Until approx. 5 x 20 ms = 100 msec}

1.7 Conclusion

An infrared thermometer that infers temperature from a portion of thermal radiation called black-body radiation emitted by the object being measured. Using non-contact thermometers has become the preferred choice for such applications. They have also come as a solution for the difficulties involved in the temperature measurements of moving objects. The industry has used portable and spot type infrared thermometers for some time, but the demand for better and more precise measurements has brought an incredible number of new products & are available in the market are in various variants such as Gun type, wearable and many more consider all the affordability in comparison of accuracy is not available at low cost. In concerning that larger research has been mainly focusing on the adaptation of sophisticated solutions for fever monitoring and contact tracing, therefore in this study, the same will be evaluated at tiny-scale with novel and compact & much affordability at low cost with high accuracy in suggested exposure (indoor, hospitals, airports, personnel use all (crowd-sourced places) & interpreted as the device for where the primary need is dedicated for distance and noncontact temperature evaluation tasks on moving objects, sophisticated with many options for customization with upcoming parts and will be a better replacement of existing consider the same applications. The shapes of the devices come with much uniqueness and not prior, therefore in this study are appraised as Intellectual property and registered IN -332413-001.

1.8 Acknowledgment

We owe much to Bihar Bal Bhawan Kilkari Patna, (Under Education Deptt. Govt. Of Bihar) India for R&D funding's of this applied research project during the pandemic. We are also grateful for the guidance of *Mr. Jai Mangal Singh (B. tech Mech. Engineering) CEO Redtron Education LLP Bangalore, India,* CSIR - *CEERI (Central Electronics and Research Institute Pilani), Dr. Sai Krishna Sir, (Sr. Principal Scientist, CSIR – CEERI) & Institutional Mentor Mrs. Manju Kumari (M.sc Environmental Science and Management)* Bihar Bal Bhawan Kilkari.

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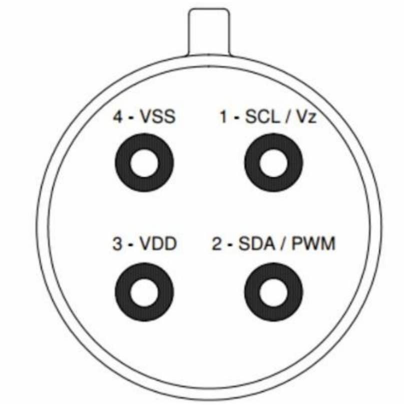
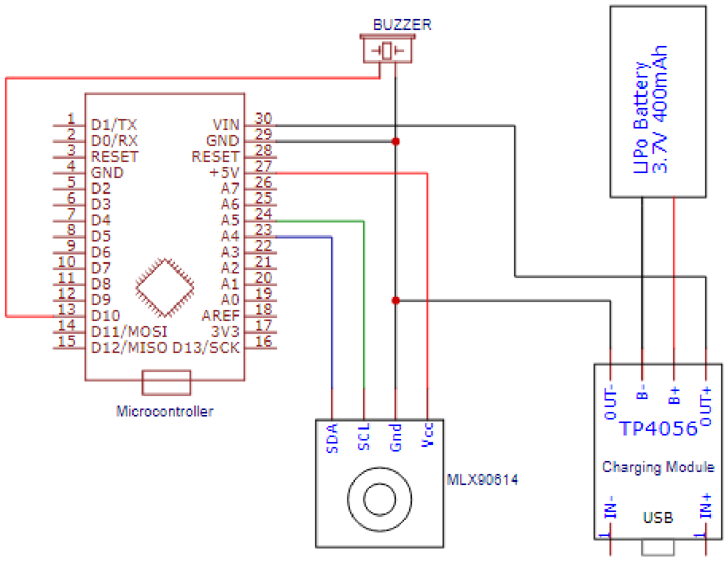
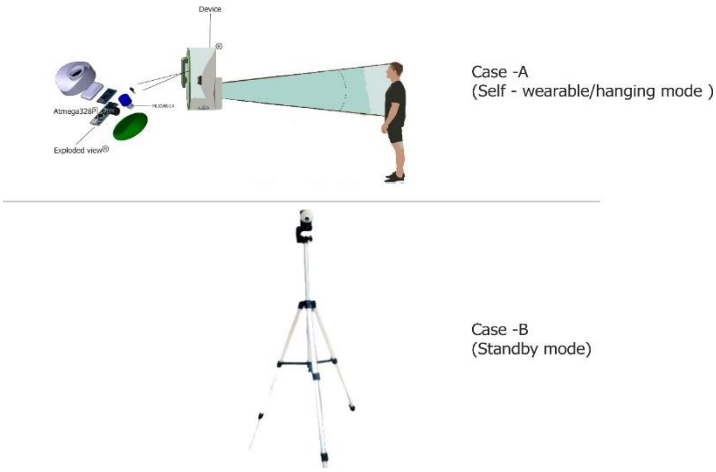
Figures



Fig; Pin definition of MLX90614



Fig; attachment option of proposed device



Fig; attachment option of proposed device

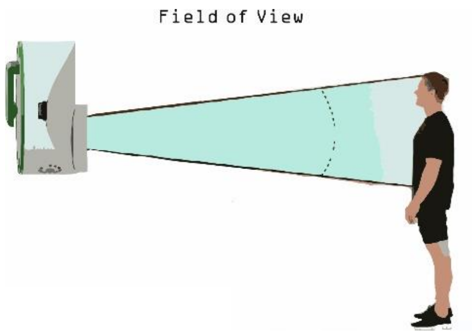


Figure d FoV MLX90614

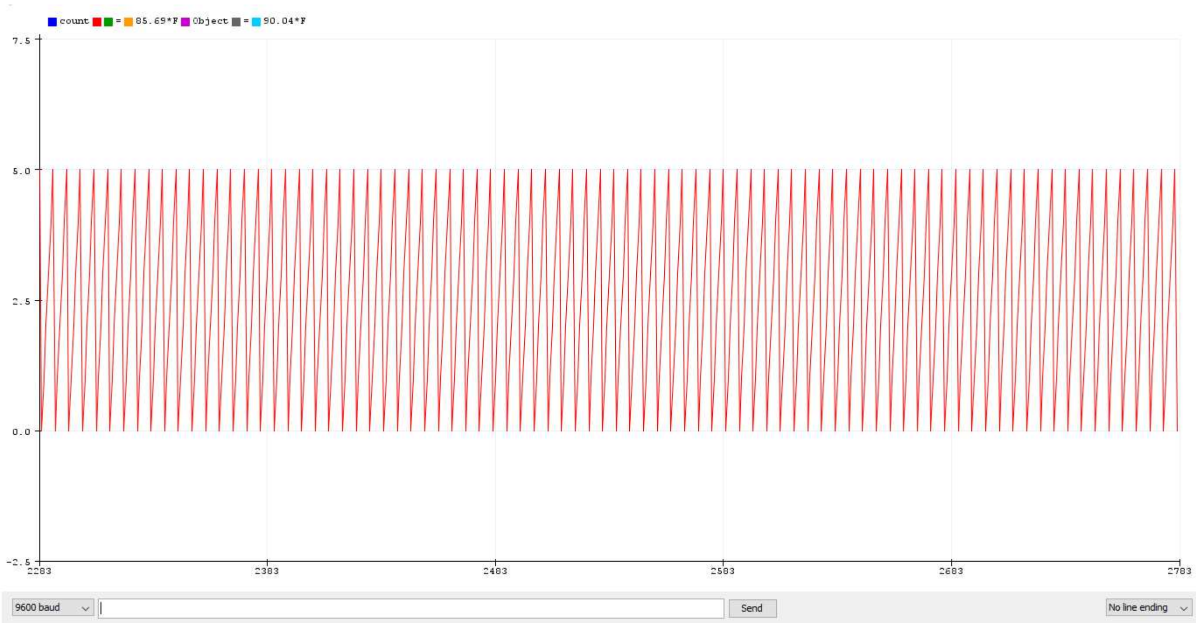


Figure e; Serial plot consider to ambient & body temperature at [D-1m]
Reading; 5 consecutive time
Until approx. 5 x 20 ms = 100 msec}

Figures

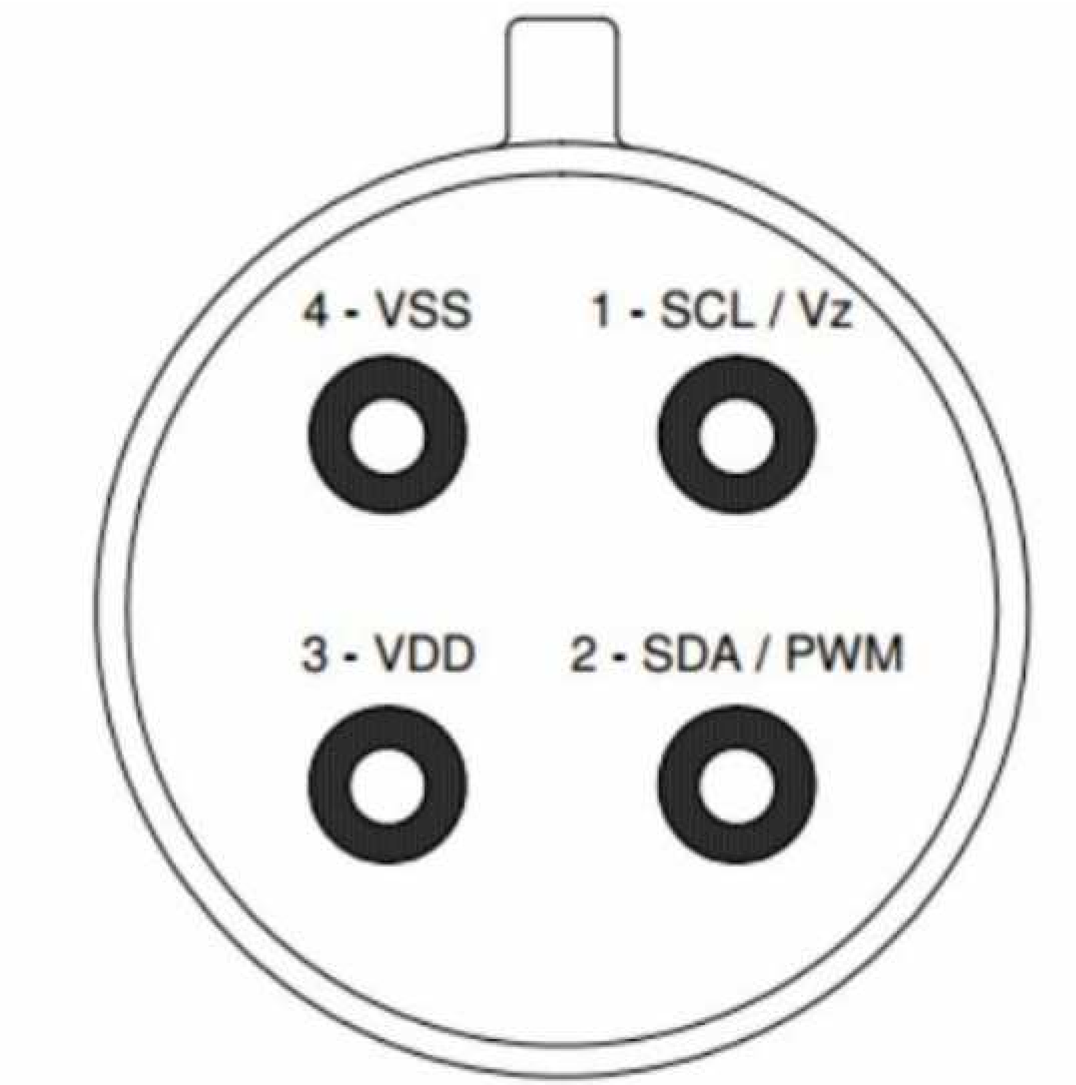


Figure 1

Pin definition of MLX90614

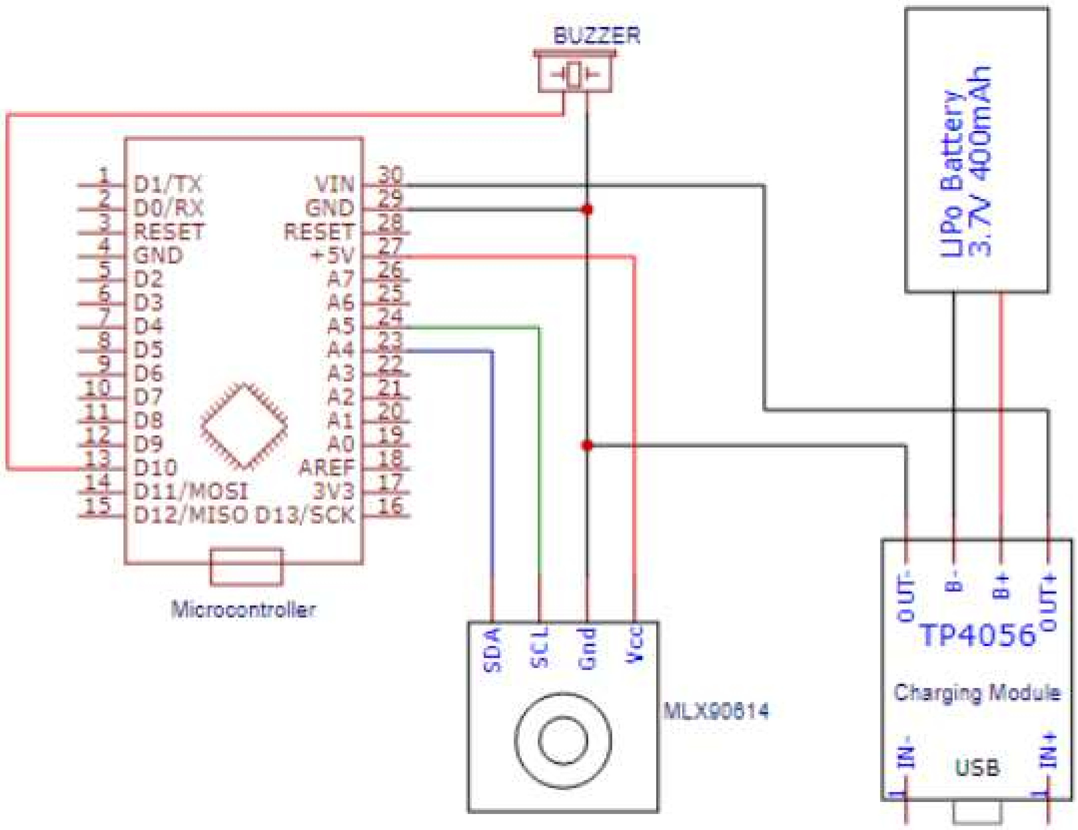


Figure 2

Schematics of the device

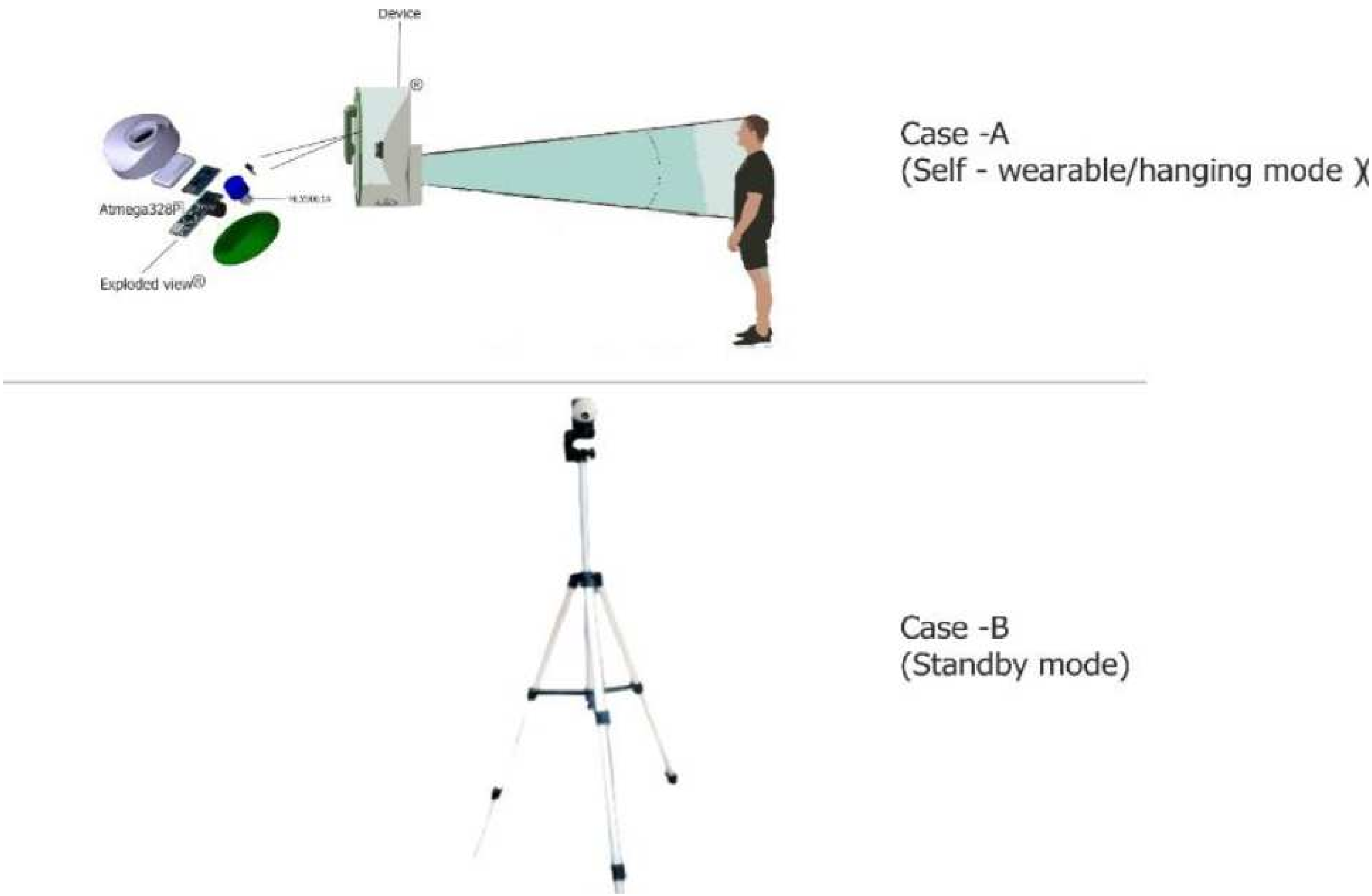


Figure 3

attachment option of the proposed device

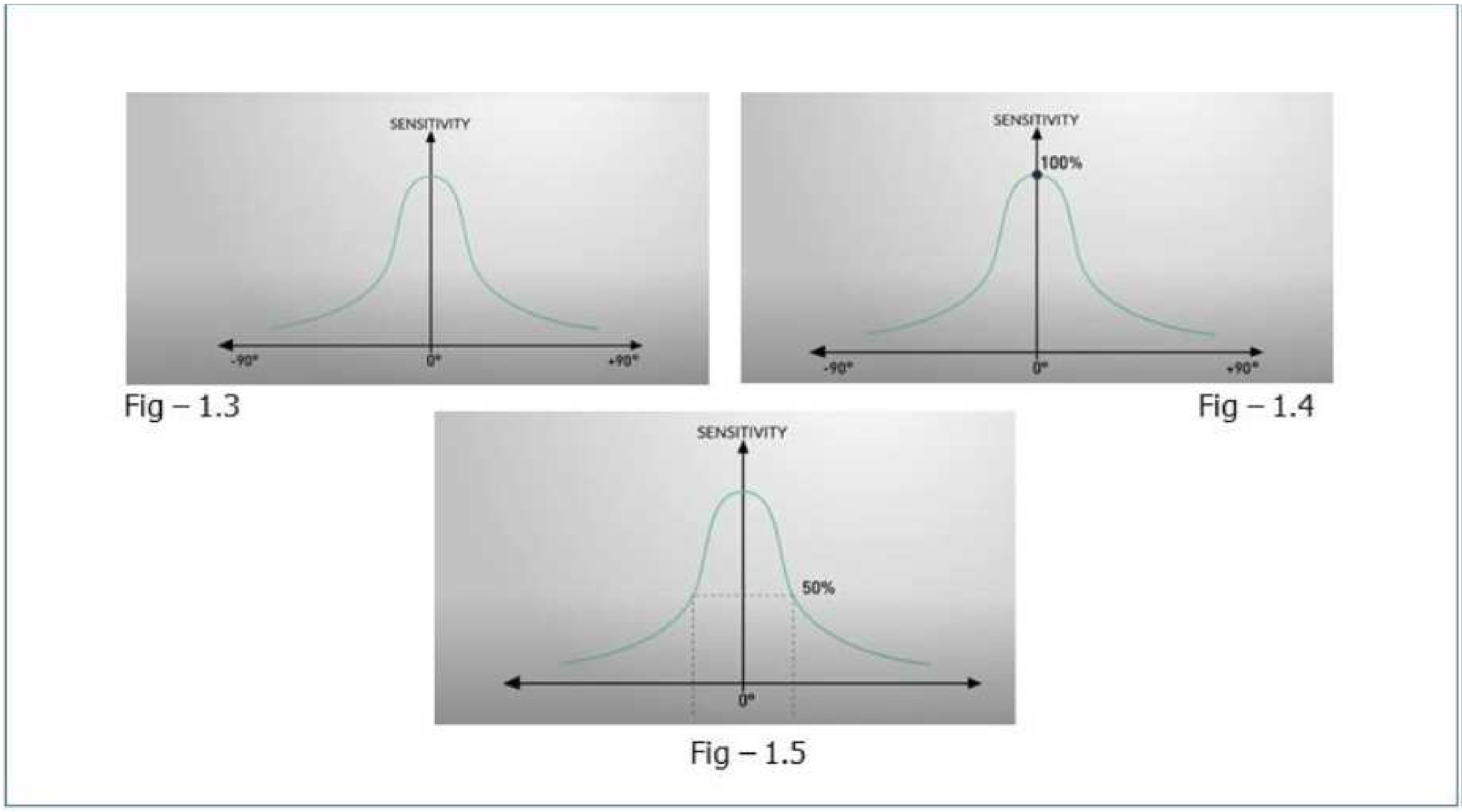


Figure 4

Panning of sensor, normalize graph (intensity) from 0 to 100% defined at 50% curve respectively

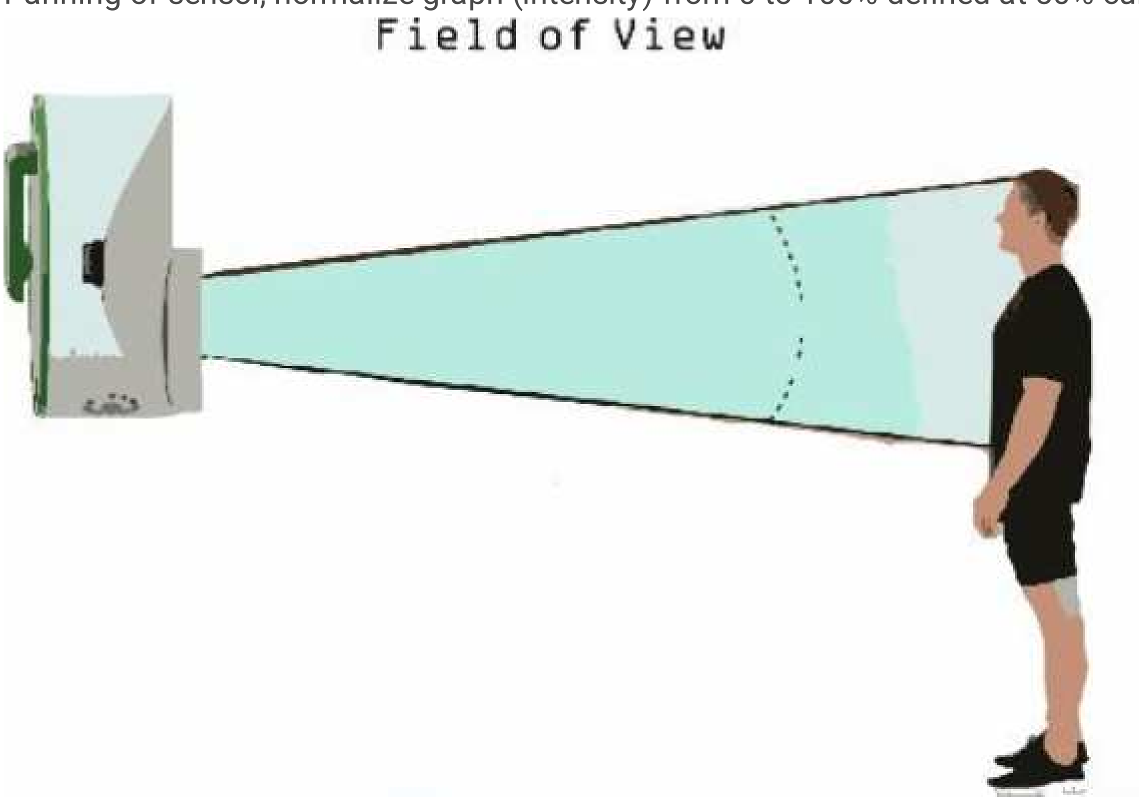


Figure 5

FoV MLX90614

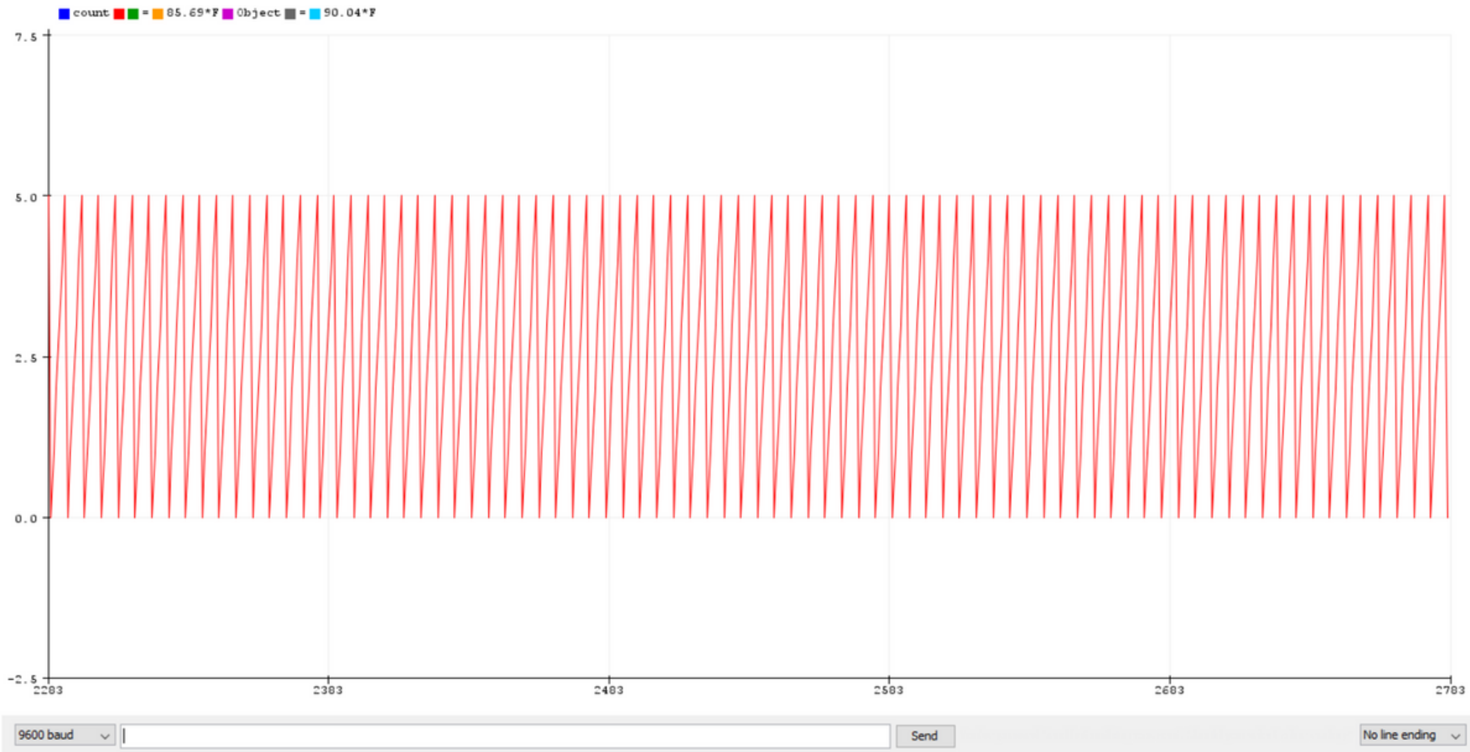


Figure 6

Serial plot consider to ambient & body temperature at [D-1m] Reading; 5 consecutive time Until approx. 5 x 20 ms = 100 msec}