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*Research article*

# Contactless temperature and distance measuring device: A low-cost, novel infrared -based "Badge"- shaped structural model for measuring physical distance and body temperature

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**Abstract:** This work eases the feasibility of infrared thermometer application and reliability to introduce a novel design with upgraded applications & functions. The custom-designed compact device "Badge" structured comprises the operative methods through the electronic packages of an optimal level. The physical and social distance measured by the ToF (Time of Flight) infrared laser sensor within 1 m from the subject and the measuring equipment (MLX90632 SMD QFN and VL530LX ToF). When the distance is not maintained, or the physical distance condition is not met, the flashing LED, or vibration should trigger an indication (warning for physical distancing and alteration for pyrexia warning, respectively). Statistical analysis and simulation-based studies criticized the accuracy of ±0.5$^{o}$F and relational model of the independent and dependent variable for this device with significant $R^2 = 0.99$ and $P <= 1$; values with the lowest accuracy error of ±0.2$^{o}$F and least residual sum of squares 0.01462 values. The portable, lightweight, and dynamic body temperature monitoring altered the application from static to continuous, complete structural design. This alternative provides the best technique to combine worn (personnel) medical devices with primary healthcare instruments to help body temperature measurements that are not contactable, fast, and accurate. It builds a way of processing through the protocol Covid-19.

**Keywords:** social/physical distancing; thermal badge; infrared sensitivity, infrared radiation; distance measurement; temperature measurement

## 1. Introduction

Body temperature indicates human physiological activity and health, especially in paediatrics, surgery, and general emergency department [5]. Most of the early methods of measuring body temperature used contact mercury thermometers. Advances in electrical technology mean that contact-type electronic thermometers have become widely used. The measurement sites are the sublingual mouth, the rectum, the axillary, and the base of the urethra. Some medical reports show that contact thermometers accurately measure body temperature [3]. For Illness screening, many individuals' body temperature must be measured, so non-contact type infrared thermometers (IRT) are used to measure the tympanic (ear) and forehead temperature. These IRTs are fast, convenient, and safe to use. Medical IRTs for ear temperature and forehead temperature are used in medicine. Infrared Sensitivity is a process through which we measure the number of infrared rays transmitted by any object; currently, there are many infrared sensitivity applications; measuring temperature is expected. 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 that raised body temperature, infrared scan of the forehead [8], considers above $100^o$ a flu-related fever [8]. Fever is one of the most acute symptoms [9] of COVID-19; The National Institutes of Health says an adult with a temperature above $99^o$F has a fever, depending on the time of day. However, its measurement can become a serious problem due to the contagious effect, so it is important to perform the temperature detection of patients very quickly and possibly without any contact & generally use infrared thermometers when other sorts of thermometers are not practical. If an object is extremely fragile or dangerous to be near, an infrared thermometer is a good way to get a temperature from a safe distance. Infrared thermometers measure temperature from a short distance. However, both epidemiological and laboratory studies revealed that ambient temperature could affect Coronavirus survival and spread [12]; before the current pandemic, hospitals would assess fever and act on it in response to individual patients and diagnoses a fever (Insider magazine) A average adult's body temperature is 98.6 degrees Fahrenheit. However, a "normal" body temperature range can range between 97 ℉ and 99 ℉ [6]. The field is more accurately predictable because many factors affect body temperature, including the time of day and gender, age, and activity levels, any temperature over 100.4 ℉, which is a person body's way of fighting off an illness or infection, high body temperature is one of the first symptoms of the disease. A fever is a sign that a person's body is fighting off an illness, like the flu virus, so that continuous monitoring of temperature regarding the body is an essential task to be performed in contrast to COVID-19. The adoption of thermo- alerting systems in the framework of pandemic situations, such as COVID-19, can be decisive for initial temperature assessment devoted to medical purposes, namely:

- During the triage process in a public health emergency, initial human temperature screening is conducted to determine the significance of fever and elevated temperature concerning possible affection to personnel health or the community.
- Temperature monitoring in high-throughput areas such as offices, airports, and schools.

This paper describes an integrated solution input to tackle the pandemic easily and modified with novelty and much affordability in the existing infrared thermometers. The novel engineered shape of the Badge intensifies the portability, lightweight & dynamic body systematically for temperature monitoring also transformed the application from static to continuous and preventive measures functions. Whereas the Social /Physical Distance - alert us to the potential of COVID - Since people can spread the virus before they know they are sick, or even after vaccination, people can transmit the SARS-CoV-2 to somebody else. It is essential to stay at least ~ 3 ft. away from others even if they do not have any symptoms. Social distancing is especially important for people at a higher risk of severe illness from COVID-19. The measurement data is analyzed using statistical techniques and accurate – time testing of prototypes to validate the accuracy and precision of the device to be an implementable commercial product to resolve existing social issues conveniently and effectively.

## 2. Literature review

### *2.1. IR-sensitivity*

Infrared thermometers work based on a phenomenon called black body radiation. Anything at a temperature above absolute zero has molecules inside it moving around. The higher the temperature, the faster the particles move. The molecules emit infrared radiation as they travel beyond the visible spectrum of light; when they heat up, they release infrared and even 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. Using 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 standard 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, costly and low reliable materials are necessary to do the job. The application of non-contact thermometers has become the preferred choice for such tasks.

### *2.2. Principle of IR temperature measurement*

In nature, when the object’s temperature is higher than the absolute zero (-273.15℃), Electromagnetic waves continue to radiate around due to the thermal motion of molecules. The electromagnetic wave radiation contains the infrared radiation of 0.75~100 μm, the radiation energy density and the temperature of the object are per the law of radiation [1]

$$A = \alpha\beta(T_2^4 - T_1^4) \tag{1}$$

Where; A is a radiation degree, the unit is $W/m^3$; α is the Stephen Pozman constant, $\alpha = 5.67\times10^{-8}\ W/(m^2 \cdot K^4)$; 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 electromagnetic radiation wave. For all-natural objects (including the surface of the human body), β values are less than 1.0. The primary radiation infrared wavelength of the human body is 9–10 μm; the human body’s surface temperature can be accurately measured by measuring the body’s radiation infrared energy. Because the light in the range of 9 to10 μm is not absorbed by air, the surface temperature of the human body can be determined by infrared energy. The Planck formula can derive the relationship between the temperature of radiator and detection voltage;

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

Where; $\rho = \mu\gamma\beta\alpha$, $T_2$ 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 Eq (2), the output signal of the detector and the target temperature is nonlinear, and the $T_2^4$ is proportional too. Therefore, the surface temperature of the object should be linearized, and the radiation rate can be corrected so that the absolute temperature can be obtained; Correction formula is:

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

Where; $T_0$ is the surface temperature (radiant temperature); β (T) is the radiation rate, its value is 0.1–0.9. The absolute 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: The temperature of the ambient temperature plus the actual temperature is the actual temperature of the ambient temperature measured object [1].

### *2.3. IR-contactless thermometry advanced applications*

Recently, research on the application of infrared thermography. Thermometry on human body temperature measurement has been carried out. Rodriguez-Lozano FJ, et al [9] proposed a novel method to segment the human beings' forehead region and calculate the mean temperature of this area. This simple and accurate method presents the thermal face images in different features. Chaglla EJ, et al [2] introduced an ear-based device to measure the ear temperature continuously. The novel design involved coating graphene platelets on the lens of an infrared thermopile sensor, and the performance of this device was validated by comparing it with other commercial ear thermometers. Craig JV et al. [3] evaluated three types of infrared thermal detection systems for fever screening in tropical conditions and found that the devices with video monitoring had very high specificity. The handheld thermograph could not be used for fever screening. Many factors affect the temperature measurement of the human body [4,11]. Measuring the temperature of the forehand using an IRT is convenient, but some studies show that the measurements are not accurate. There are three forehead thermometers: a thermistor probe, a liquid crystal strip, and an IR thermometer. The thermistor probe and the liquid crystal strip are contact-type thermometers. The thermistor probe is a deep body thermometer because it is inserted into the forehead tissue. Measuring body temperature is an effective technique for screening SARS and other flu cases. The Coronavirus (COVID-19) has spread globally, and temperature measurement is used to screen people rapidly. Handheld forehead IRTs are easy to use, rapid, non-contact, and inexpensive, so they are widely used. These IRTs were reported to measure wrist temperature and forehead temperature. However, these devices have unproven reliability [13]. Many studies compare temperature measurements for different parts of the human body using different thermometers. Most of the forehead thermometers are contact-type. The body temperature measurements depend on the type of thermometer, the sensing elements, and the manufacturers' claimed performance for each thermometer or thermal sensor, either SMD or THT.

## 3. Method and materials

### *3.1. Constructional methods and simulation-based studies*

The device configuration includes CAD Modeling was developed to construct a badge form enclosure following circuits related to aesthetics Cloud Powered 3D CAD/CAM Software for Product Design (Autodesk Fusion 360 © 2020 Autodesk, Inc.) *[Licensed to Arpit Kumar]*. Circuitry Plots, Simulation, and Programs written and complied, respectively, on Cloud-based Commercial Electronic design automation software (EasyEDA) *[Subscription Free –Membership to Abhijeet Kumar]*, The open-source Arduino Software (IDE) (Arduino CC V-1.8.9.).

### *3.2. Hardware description and schematics*

The hardware mainly consists of 1. Single Dual Layered FR-4 PCB Board 2. ATmega 328p-AU (Microcontroller Chip Sensor), 3. TP4056 - BMS (Battery Management Chip), 4. VL53L0X - SMD (Time-of-Flight ranges and gesture detection sensor), 5. MLX90632 –SMD QFN (FIR-Sensor), 6. Lithium Polymer Battery – (with power rating 3.6 V 600 mAh), 7. Micro – 60dB (piezo buzzer/micro vibration motor), 8. SPDT - MHSS1104 (Micro Switch), with mainly other peripheral components for the efficient and reliable working of the circuit board.

**MLX90632 – Thermal Sensor [SMD QFN]**

The MLX90632 is a medical-grade accuracy non-contact infrared temperature sensor in a small SMD QFN package. The SMD QFN package is factory calibrated with calibration constants stored in the EEPROM memory. A significant strength of the MLX90632 is that these temperature differences around the sensor package will be reduced to a minimum. However, some extreme cases will influence the sensor. Temperature differences can affect the accuracy of the thermometer in the package induced by causes like (among others): hot electronics behind the sensor, heaters/coolers behind or beside the sensor, or by a hot/cold object very close to the sensor that heats not only the sensing element in the thermometer but also the thermometer package.

In the same way, localized thermal variations -like turbulence in the air- will not generate thermal noise in the output signal of the thermopile. This MLX90632 with medical accuracy is calibrated at ambient temperatures ranging from -20 to 85˚C. Initially, the factory calibrated with a precision of ±0.2˚C within the narrow object temperature range from 35 to 42˚C for the present purposes With FoV (Field of View 50$^{o}$). Allows extended-range operation. This measurement type option is implemented to give additional range to the medical devices. The object temperature range is limited from -20 to 100˚C. The typical supply voltage of the MLX90632 is 3.3 V. For the I2C communication with the master microcontroller.

- In this document, RAM used for measurement data is mainly referred to as ‘storage memory’.
- EEPROM used to store the trimming values, calibration constants, and device/measurement settings

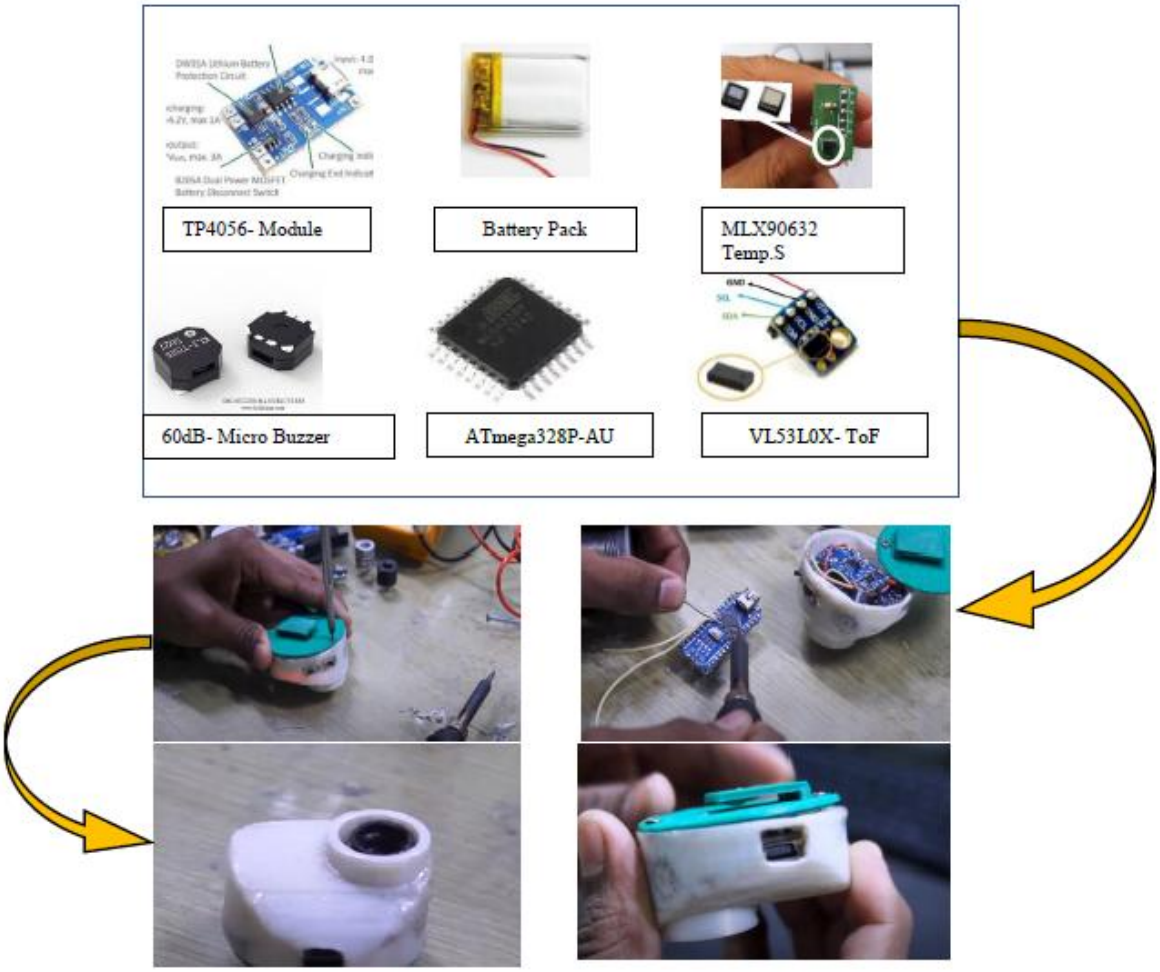



**Figure 1.** Components installation insider enclosure of prototype.

Based on this data, its external microcontroller can calculate the object temperature and, if needed, the sensor temperature. An optical filter (long-wave pass) that cuts off the visible and near-infrared radiant flux is integrated with the sensor to provide ambient light immunity. The wavelength passband of this optical filter is from 2 to 14 µm [7].

**Table 1.** Electrical characteristics.

| Parameters | Min | Type | Max | Unit |
|---|---|---|---|---|
| Extemal supply | 3 | 3.3 | 3.6 | V |
| Supply current | 0.5 | 1 | 1.4 | mA |
| $I^2C$ voltage | 1.65 | 1.8 | 1.95 | V |
| Input high voltage | $0.7*V_{I2C}$ | | $V_{I2C} + 0.5$ | V |
| Input low voltage | -0.5 | | $0.3*V_{I2C}$ | V |
| Output low voltage | 0 | | 0.4 | V |

All parameters are valid for $T_A$ = 25 °C, VDD = 3.3 V (unless otherwise specified).

### VL53L0X - SMD (ToF)

The VL53L0X Time-of-Flight (ToF) laser-ranging module is housed in the smallest package with accurate distance measurement whatever the target reflectance, unlike conventional technologies. It can measure absolute distances up to 2 m. The VL53L0X integrates a leading-edge SPAD array (Single Photon Avalanche Diodes) and embeds ST's second-generation Flight Sense technology. The VL53L0X's 940 nm VCSEL emitter (Vertical-Cavity Surface-Emitting Laser) is invisible to the human eye, coupled with internal physical infrared filters, enabling longer-ranging distances, higher immunity to ambient light, and better robustness to cover glass optical crosstalk. The (FoV) of laser transmitter 25° and receiver 35° [10].

**Table 2.** Technical specification.

| Feature | Detail |
|---|---|
| Package | Optical LGA12 |
| Size | 4.40 x 2.40 x 1.00 mm |
| Operating voltage | 2.6 to 3.5 V |
| Operating temperature: | -20 to 70 ℃ |
| Infrared emitter | 940 nm |
| $I^2C$ | Up to 400 kHz (FAST mode) serial bus Address: 0x52 |

### Schematics –For Circuit / PCB Board

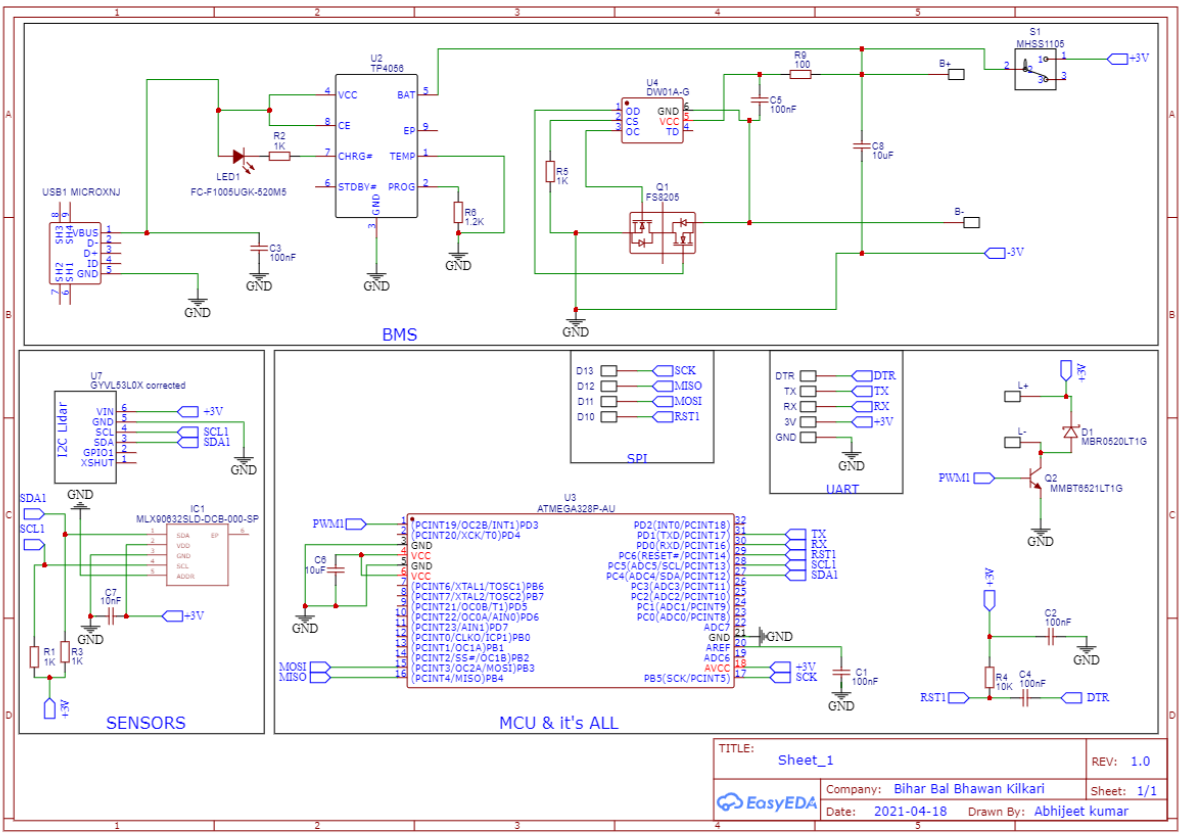



**Figure 2.** PCB – layouts.

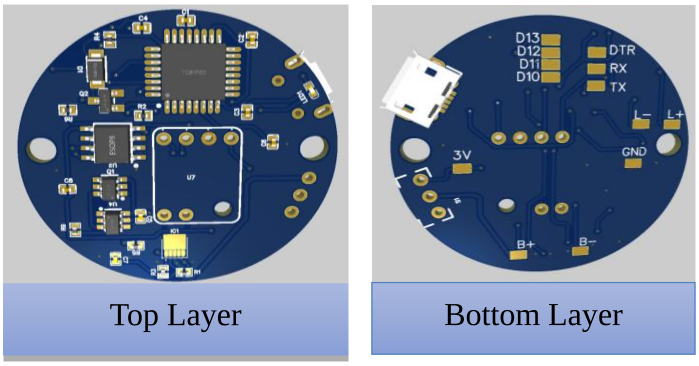



**Figure 2.** Continued.

The PCB board is one of its types for present purpose due to its compact form factor and an 8-bit microcontroller with all the necessary functions. The contactless temperature and distance measurement with onboard battery charging and management circuits feature constant voltage, constant current for charging purposes and overcharge –discharge protection.

In Figure 3, the steps for the configuration and programming of the MLX90632 temperature and VL53L0X Time-of-Flight (ToF) sensor on Arduino software are reported. When an object is found under a distance of 100 cm, the object temperature lies between 95 to 99$^{o}$F (human body temperature range), measured by VL53L0X (laser sensor) and MLX90632 thermal sensor. An indication in flashing LED should trigger (warning for physical distancing), No alert for pyrexia symptomatic. If the measured temperature ranges up to 99$^{o}$F; assumed to be higher (waring for high temperature or pyrexia symptomatic).

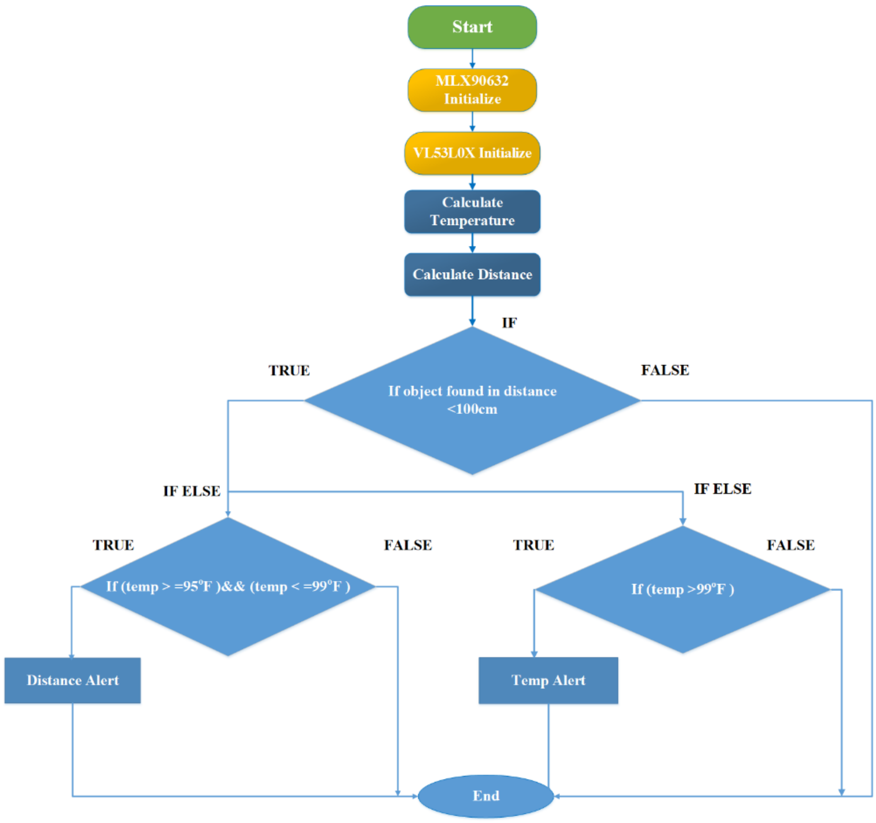



**Figure 3.** Schematic of the algorithm for the operational function of the device.

**Illustrations of the device**

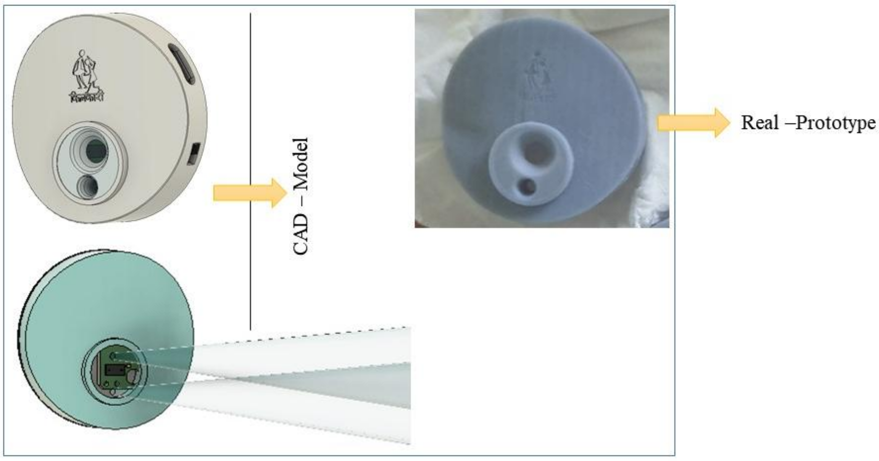



**Figure 4.** Represent the structural illustrations of both CAD model and Real –Prototype. The Real-Prototype Printed with SLA Printing (resin printed), with respective size of 40 x 15mm disc shape.

*3.3. Real time – prototyping testing and calibration methods*

**Phase –I**

The MLX90632 is factory calibrated with an accuracy of ±0.2˚C, and the secondary Calibration was done to achieve the same reference ROMSONS PDT (digital probe thermometer) readings. It was done at once.

**Relational Variance of Distance and Temperature Values**

The IR radiation emitted by the body is absorbed or lost in the ambient environment due to its radiating nature. It was necessary to have a feedback system to accurately get the temperature from a distant body and fulfil the temperature loss over the distance; in this case, an object could be measured at any point under the range of 1 meter—the feedback system concurrently producing offset value according to the change in measured distance. The value is being added to the initial temperature reading, and it generates a final temperature reading that will be accurate and reliable to its applications.

**Phase –II**

The ROMSONS PDT (digital probe thermometer) measures the body temperature of these objects with much accuracy and stability. The test used 132 people aged from ~12-60 years. The temperature measurement is done to ensure the aimed application of the device (personnel use, crowdsource places, so forth so).

For the same subjects, the prototype – IR badge device used Integrated with Melexis MEMS thermopile technology SMD QFN package (FIR- MLX90632) to measure subjects' accurate and stable body temperature at a meter (at any point). For distance, calculation the (VL53L0X) SMD-Time-of-Flight ranging and gesture detection sensor was used for accurate distance measurement between subject and device. Both studies were conducted with perspective to quantify the ambient's accuracy and physical distance alert system.

## 4. Statistical analysis

The temperature data readings were analyzed using (Origin Pro - 2021) © Origin Lab Corporation, Northampton, MA, USA) *[Licensed to Arpit Kumar]*. Data are expressed as a Descriptive Analysis. The coefficient of variance (CV %) value is calculated to determine measurement accuracy.

$$CV = (\text{standard deviation})/\text{mean} \tag{4}$$

Significant fittings of data sets were tested using Linear Fitting Models (Polynomial and Linear Fit with 95% Confidence band) along with Mean Comparison also visualized through One–Way Anova. A p-value equal to or less than <0.05 denotes statistical significance. The parametric relationship between measurement values, calibration curves, relational variance distance, and temperature is determined using Line and Scatter plots.

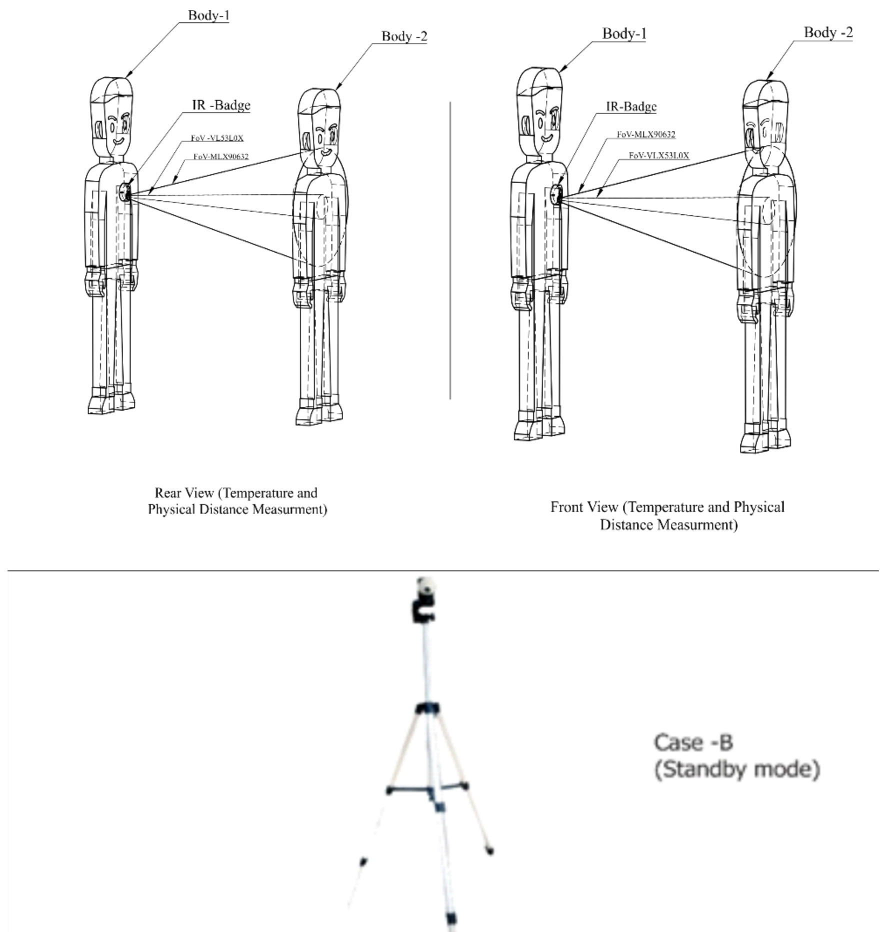



**Figure 5.** Applications of the device /attachment options (Front Side and Rear Side Positions).

## 5. Result

The device's real-time realization was done on simulation-based studies and real-time testing practices to validate the proposed device performance overall. Numerous sets of measurements were performed while the distance versus temperature accuracy was simulated in ambient temperature. The Measured body temperature from the commercial clinical probe-based digital thermometer was used as a reference value for IR thermal badge. In contrast, the accuracy of the clinical thermometer with the IR badge under additive temperature offsets (2) is the first one for the initial measurement temperature variation. The last one is to fulfil the temperature loss according to the measured distances that resulted in accurate and reliable sources for measuring body temperature within a meter's distance at any point in a straight path between device and object. Several variations of the data based on their height are analyzed to ensure the relational variance of distance and temperature that could depend on person to person based on their height and criticize how it is reliable and accurate in a different scenario.

Secondary calibration was used to validate the reference temperature readings with the measured values (ROMSON PDT). It applies as an initial offset that will be additive with device temp data. The method only required a temperature source, which is known.

**Table 3.** Instruments and temperature data.

| SN | Instruments | Temp. Data |
|---|---|---|
| 1. | ROMSONS PDT | 96.3 |
| 2. | IR Badge | 89.8 |
| | Offset Value =ROMSONS PDT-IR Badge = 6.5 | |

The relational variance of distance and temperature values presented by line graphs where the temperature calculation of person was taken from Front and Rear positions. The measurement is initially taken from 2 cm (min. measuring range) thereafter-continuous increases up to 100 cm (max. measuring range). Descriptive statistics were performed to visualize the maximum and minimum deviation and error percentages.

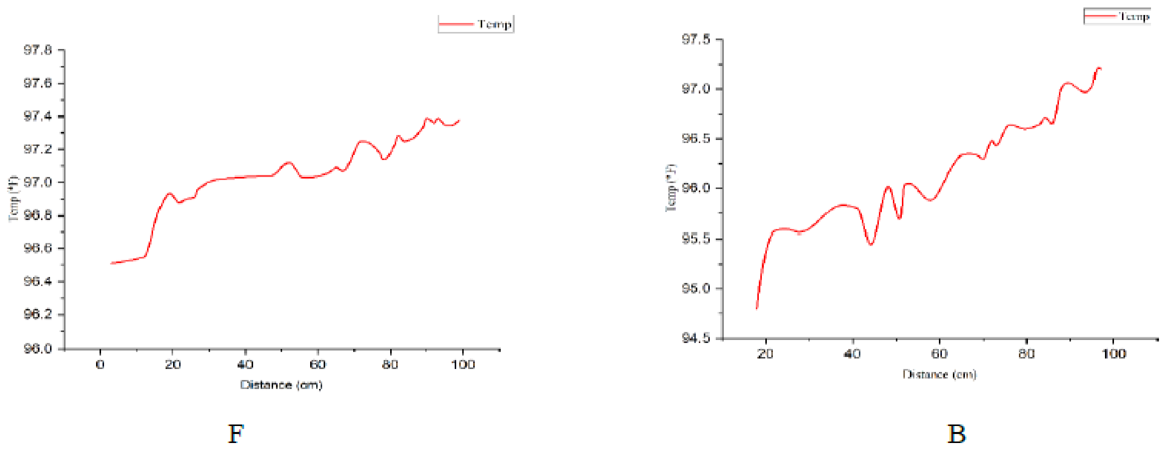
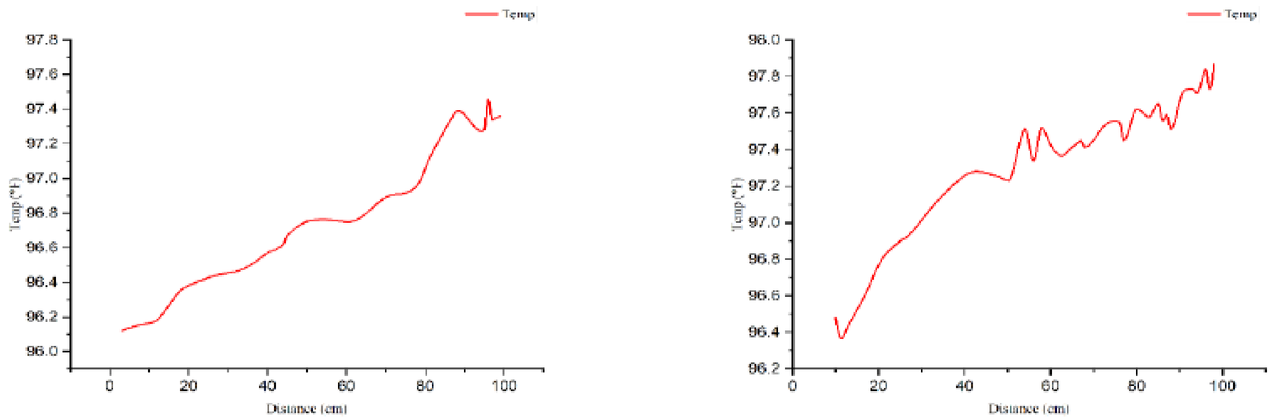



**Figure 6.** Person - 1 [Front (F), Rear (R)].

Person Height – 5.5ft, Body Temperature Measured by – ROMSON PDT (96.5$^{o}$F), Device Height -140 cm.

**Table 4.** Descriptive statistics.

| | N total | Mean | Standard Deviation | Sum | Coefficient of Variation | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Distance F | 34 | 57.14706 | 30.38853 | 1943 | 0.53176 | 3 | 64 | 99 |
| Distance F | 31 | 60.45161 | 26.31582 | 1874 | 0.43532 | 18 | 68 | 97 |
| Temp R | 34 | 97.08529 | 0.242 | 3300.9 | 0.00249 | 96.51 | 97.08 | 97.39 |
| Temp F | 31 | 96.1629 | 0.70607 | 2981.05 | 0.00734 | 94.78 | 96.33 | 97.2 |



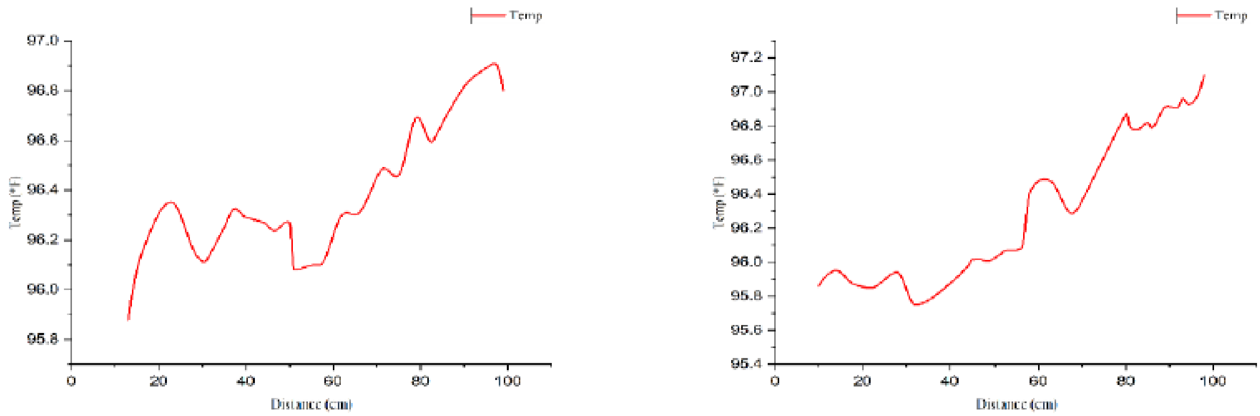

F R

**Figure 7.** Person – 2 [Front (F), Rear (R)].

Person Height – 5.11ft. Body Temperature Measured by – ROMSON PDT (96.3°F), Device Height -140 cm.

**Table 5.** Descriptive statistics.

| | N total | Mean | Standard Deviation | Sum | Coefficient of Variation | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Distance F | 25 | 59 | 32.37926 | 1475 | 0.5488 | 3 | 56 | 99 |
| Distance R | 39 | 63.89744 | 27.99887 | 2492 | 0.43818 | 10 | 68 | 98 |
| Temp R | 25 | 96.8316 | 0.43566 | 2420.79 | 0.0045 | 96.12 | 96.76 | 97.46 |
| Temp F | 39 | 97.37179 | 0.39861 | 3797.5 | 0.00409 | 96.38 | 97.51 | 97.88 |




F R

**Figure 8.** Person – 3 [Front (F), Rear (R)].

Person Height – 4.8ft. Body Temperature Measured by – ROMSON PDT (96.3°F), Device Height -111 cm.

**Table 6.** Descriptive statistics.

| | N total | Mean | Standard Deviation | Sum | Coefficient of Variation | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Distance F | 29 | 62 | 27.42653 | 1798 | 0.44236 | 10 | 68 | 98 |
| Distance R | 30 | 55.2 | 28.8413 | 1656 | 0.52249 | 13 | 53.5 | 99 |
| Temp F | 30 | 96.37 | 0.30478 | 2891.1 | 0.00316 | 95.88 | 96.295 | 96.92 |
| Temp R | 29 | 96.41759 | 0.45976 | 2796.11 | 0.00477 | 95.75 | 96.41 | 97.1 |

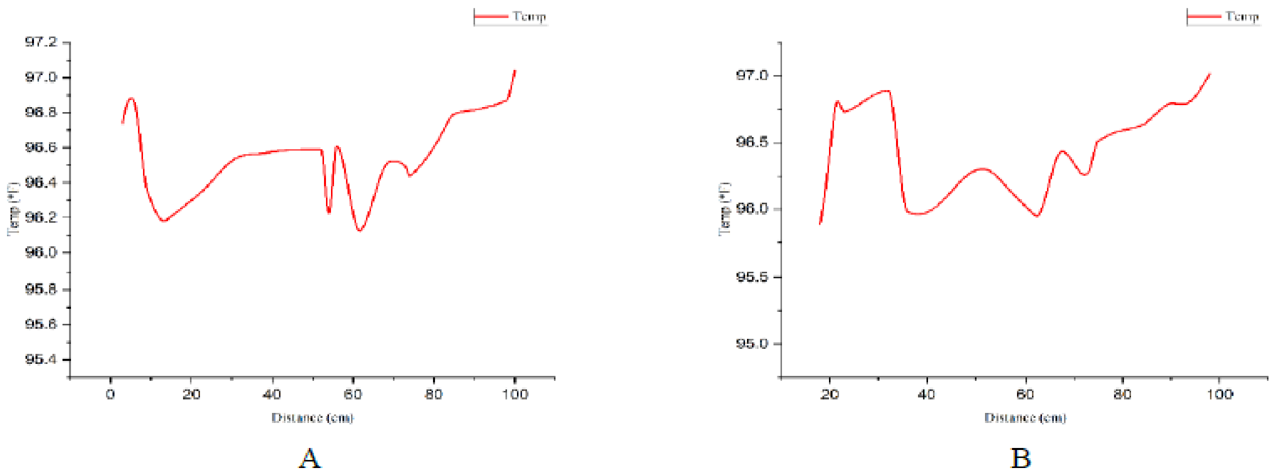



**Figure 9.** Person – 4 [Front (F), Rear (R)].

Person Height – 5.9 ft. Body Temperature Measured by – ROMSON PDT (96.8°F), Device Height -140 cm.

**Table 7.** Descriptive statistics.

| | N total | Mean | Standard Deviation | Sum | Coefficient of Variation | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Distance R | 25 | 56.4 | 34.68189 | 1410 | 0.61493 | 3 | 62 | 100 |
| Distance F | 24 | 55.20833 | 28.79308 | 1325 | 0.52154 | 18 | 55 | 98 |
| Temp F | 25 | 96.6132 | 0.27127 | 2415.33 | 0.00281 | 96.13 | 96.59 | 97.09 |
| Temp R | 24 | 96.49125 | 0.3479 | 2315.79 | 0.00361 | 95.89 | 96.545 | 97.02 |

**Table 8.** Descriptive statistics of Temp. measurements.

| | N total | Mean | Standard Deviation | Variance | Sum | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Ref. device Romsons PDT | 132 | 97.79697 | 1.79056 | 3.2061 | 12909.2 | 91.2 | 98 | 101.8 |
| IR Badge | 132 | 97.96212 | 1.801 | 3.24359 | 12931 | 91.3 | 98.15 | 102.2 |

**Table 9.** Coefficient covariance.

| Mean | S.D | C.V (%) |
|---|---|---|
| 97.797 | 1.791 | 0.018 |
| 97.962 | 1.801 | 0.018 |

The CV value is 0.018% for IR badge (1 m) measurement data. The CV value Ref. Device ROMSON PDT is 0.018%. That indicates the lower relative dispersion of data points in a data series around the mean. A CV of 5% shows good precision. The distributions CV < 1 (such asErlang distribution) are considered low-variance, while those with CV > 1 (such as a hyper-exponential distribution) are considered high-variance.

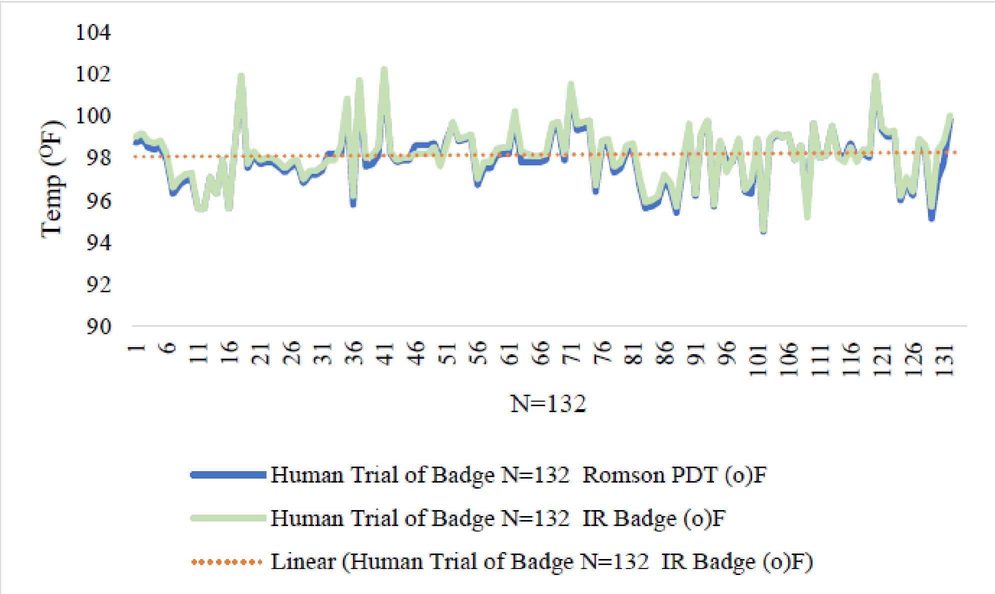
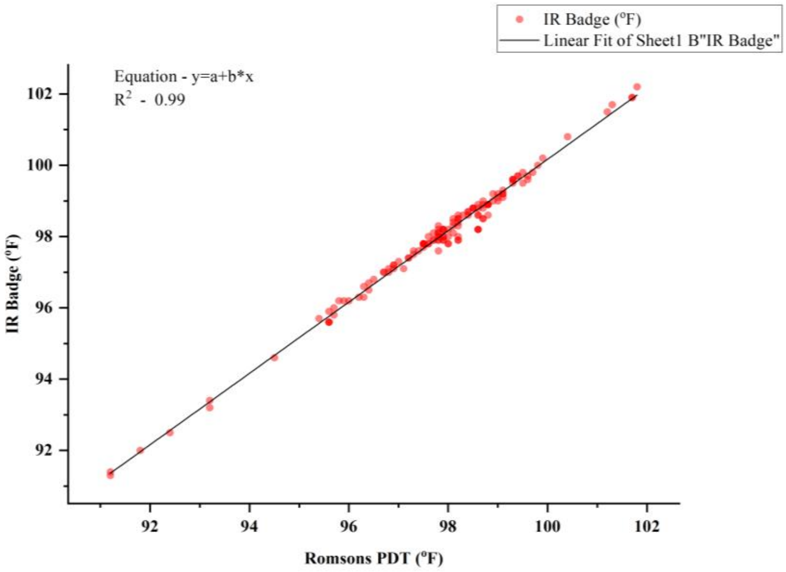



**Figure 10.** Line plot relationship between the Temp. measurements data and their frequency – N = 132.

The relationship between Temp. Data IR ROMSON PDT and Temp Data IR Badge (Dist-1 meter) are shown in Figure 10. These frequency line plots illustrate that not much significance in the data value of both devices, either considering the distancing factor of 1 meter or 15 cm. Accuracy is much higher compared to the existing alternative devices.

**Regression Models Linear Fit**

The Linear fit model was applied to identify the relationship between a Reference Device Temp. Data and IR Badge Measured Data to validate the accuracy and error values. Below the Figure 11 – of Linear Fit and Table where the values summarized fit Values. One-way ANOVA was applied to determine any statistically significant differences between the mean at t; a p-value equal to or less than <0.05 denotes statistical significance.




Residual Plot

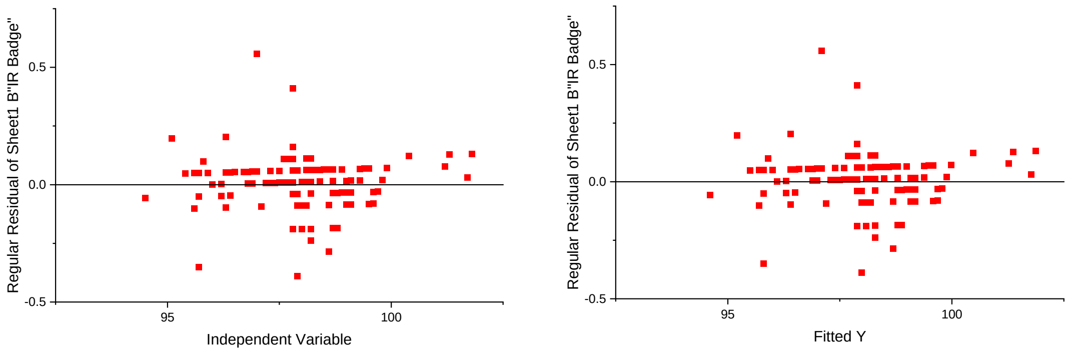



**Figure 11.** Linear fit of IR badge of social experiment trials temperatures values.

**Table 10.** Statistical summary of linear fit.

| | IR Badge |
|---|---|
| Number of Points | 132 |
| Degrees of Freedom | 130 |
| Residual sum of squares | 1.9006 |
| Pearson's r | 0.99598 |
| R-Square (COD) | 0.99198 |
| Adj. R-Square | 0.99192 |

**Table 11.** ANOVA analysis.

| | | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|---|
| IR Badge | Model | 1 | 235.14001 | 235.14001 | 16083.40761 | 4.07702E-138 |
| | Error | 130 | 1.9006 | 0.01462 | | |
| | Total | 131 | 237.04062 | | | |
| At the 0.05 level, the slope is significantly different from zero. | | | | | | |

**Table 12. Parameters.**

| | | Value | Standard Error | t-Value | Prob>\|t\| |
|---|---|---|---|---|---|
| IR Badge | Intercept | 0.58834 | 0.76874 | 0.76534 | 0.44546 |
| | Slope | 0.9949 | 0.00784 | 126.82038 | 4.06957E-138 |

The slope is significantly different from zero (See ANOVA Table).
Standard Error was scaled with the square root of reduced Chi-Sqr.

This Regression model has a significant fitting R2 value – 0.99, and Pearson's; P <= 1, which derive an optimum level relationship between Temp data and the RMSE- 0.01462. In addition, here, the slope of the regression line is significantly different from zero; it concludes that there is a significant relationship between the independent and dependent variables and leads to further implementation of these models – of devices for society and transforming it much more effectively.

The predicted outcomes were visualized most of the scattering data saturation at the Figure 12.

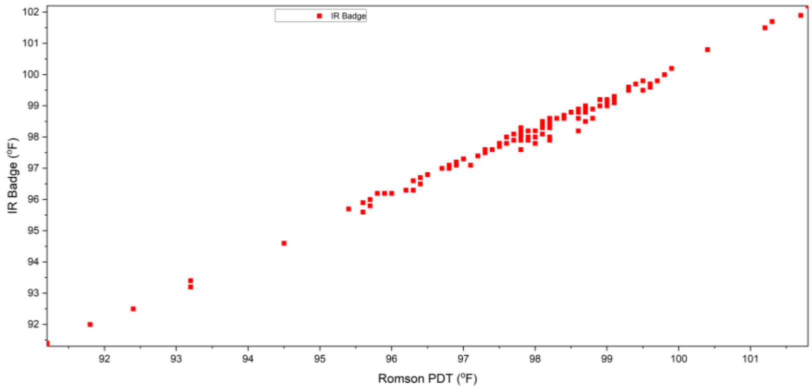



**Figure 12.** Scatter plot to visualize the pattern of IR badge – Temp data values regarding distance.

Coordinates from Y-Axis – ~96-100$^{o}$F and in X-axis - ~96-100$^{o}$F, its shows the optimum accuracy variation of the temperature. Measurement data of temperature IR badge under 1 meter; -50 to +50$^{o}$ FoV window.

## 6. Discussion

The closed loop measurement algorithm, which utilizes a distance sensor to provide feedback to the primary sensor. It does not measure any item mindlessly, as conventional devices do; it also has an eye to maintain track of and adjust temperature readings. Because infrared radiation diminishes with increasing distance. This study highlights that the gadget has two modes of operation defined: physical/social distance, measured using a ToF infrared laser sensor at a distance of one meter between the subject and the measuring equipment that measured by VL53L0X (laser sensor) at the angle of 25$^{o}$ (Transmittance and Receiving) [10]; MLX90632 thermal sensor. The angle at which a sensor is sensitive to heat radiation determines its field of view (50$^{o}$), which indicates that the detector detects all objects in the field of vision. If the measured item fills the field of view, the sensor reports the average of all objects in the field of view. Here, the sensor detects objects that need to be measured, resulting in an inaccurate and improved understanding of the field of view the 50 °are measured at the 50% level of sensitivity.

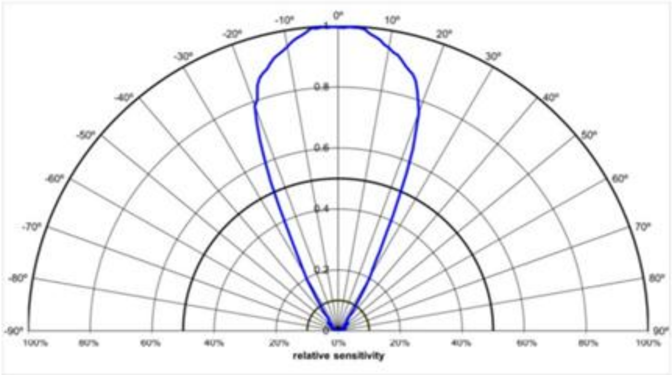



**Figure 13.** FOV (MLX90632)- [7].

For high accuracy applications, the field of view is not obstructed by the enclosure of the application; this needs to be taken care that no obstruction is in a cone of at least 70 °comprehensive (MLX90632 SMD QFN Package). Therefore, considering the FOV device is configured to determine the distance between sensors and objects because the field of view and object dimension derives the distance between the sensor and object with simple geometry.

$$D = \frac{S}{2} * \tan\frac{(FoV)}{2} \tag{5}$$

## 7. Conclusions

This applied innovative study on an enhanced version of IR thermometry application is an integrated solution input to combat the pandemic in a modified and straightforward approach with novelty and great affordability in the current Infrared thermometers. Furthermore, the form turns its practicality and a wider domain into a separate portion with a more accessible price range. Because people can transfer the virus before they realize they are sick or even after immunization, SARS-CoV-2 can be transmitted from one person to another. Even if they do not have any symptoms, it's critical to keep at least 3 feet away from them. Social separation is essential for persons at a higher risk of severe disease from COVID-19. The comprehensive parametric and structural analysis, including the IR dynamic study, illustrates its methodologies and accuracy – with time testing of prototypes to demonstrate the device’s accountability and precision as a commercially viable solution to current societal challenges.

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## Conflict of interest

The authors declare that there is no conflict of interest.

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