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# Skin and Body Temperature Parameter Calibration of MAX30100 Sensor Module Based on Arduino-Uno

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**Abstract**: The aim of this research is to process the temperature parameter's Arduino digital output and convert it into skin and body temperature through calibration effort. Firstly, we compare the characteristic of temperature change's aspect with DS18B20 temperature sensor in skin temperature reading. The calibration effort's process has four leading stages sequencingly: averaging, filtering, fitting (nearing) towards skin temperature's reading, and lastly nearing the result to body thermometer as calibrator. The fitting result respectively has ammount of 6.02°C for skin temperature and 1.34°C for body temperature. According to these following results, the error rate is ±0.27% towards body thermometer.

Keywords: skin temperature; body temperature; calibration; MAX30100; averaging; filtering; fitting

## 1. Introduction

MAX30100 is opted for the sensor module as it can read these three following parameters altogether: heartrate, oxygen saturation and temperature. Rather, not any researcher has attempted the calibration for neither skin nor body temperature parameter on MAX30100 sensor module. Yet, the oxygen saturation's result is the function of body temperature[1)]. So is the heartrate parameter which data processing output has the correlation with body temperature reading[2)].

On the datasheet, there is just a statement mentioning that MAX30100 sensor module does apparently have the role to measure heartrate and oxygen saturation parameter[3)]. The novelty aspect we want to promote is how to process the temperature output to represent both skin and body temperature as well. But further testing highly need be carried out in order to ensure the sensor reading's validity. Thus is the importance of doing calibration effort.

After being through a sequence of calibration's stages, the use of MAX30100 sensor module can be integrated with a diagnostic medical device called patient monitor. And for the future onwards, MAX30100's utilization is intended to provide the manufacture of patient monitor at affordable cost named Low Cost Mini Patient Health Monitor[4)] with four parameters as leading preferences: heartrate, oxygen saturation, skin temperature and body temperature.

## 2. Literature Review

### 2.1 Skin and Body Temperature

The difference between skin and body temperature parameter lies at their data measurement's source. When the central spot of skin temperature's measurement is the body's peripheral part (namely skin on the fingers), body temperature's data result originates from the heat production and loss of our body. Here is the illustration for skin and body temperature's origin at Fig. 1.

Use the following table format in the manuscript. Note that all the tables and figures should be cited in the paragraph as Table 1 and Fig. 1 where appropriate.

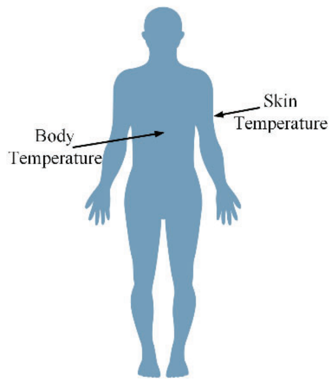



**Fig. 1:** Skin and Body Temperature Illustration.

As for body temperature parameter, it has the normal range between 36 – 37,4 °C[5)]. Then the range of skin temperature occurs at 2 – 4 °C below body temperature[6]. The obvious impact beyond the aforementioned range is having fever's symptoms in which it might even lead into tissues and organs' failure; not to mention death. Another evident sign that does likely come is hypothermia which occurs when body temperature drastically drops under normal range (36 °C)[7].

### 2.2 MAX30100's Infrared and Red LED

The infrared and red LED light emitted by MAX30100 sensor module become the central component that represent the entire MAX30100's functional work. From the signal reading, then following by signal processing, later on altering the signal into a digital one, and eventually the latter is to convert the temperature reading to parameters. The infrared LED'S emitted light does enable the signal reading at particular wavelength[8]. Moreover, the red LED light has a substantial role to correct the parameter reading's result that has been interpreted during the signal processing by the infrared LED component on sensor module[3].

### 2.3 Averaging, Filtering and Fitting

Averaging is an approach utilizing raw data set having been gathered to find the average it has afterwards. The principle is clearly simple: the average is not to be smaller than the least value nor greater than the highest value of the raw data set itself[9]. The objective of averaging approach is to drastically reduce the parameter result's error in data processing from noise during the signal reading[10]. And the mean's result on the averaging approach can optimize the algorithm's performance in existing program[11].

Further, the filtering phase has the role to significantly minimize signal reading's noise by altering the initial reading into the processed one which has been filtered[12]. Entering this stage, sensor reading's result having been through the averaging is accordingly being processed till acquiring the parameter output that has been smoothed[13]. In filtering, there are at least three prime principles we have to regard: not doing any data addition; keeping the acquired data's relevance; and the foremost one is not to change every existing data[14]. Besides, the focus of data filtering is to eliminate data not being filtered by the algorithm's mechanism[15]. Thereupon we do truly obtain the better result of sensor reading.

As for fitting, it is a stage to near the value of data output a parameter has towards its actual reading result. Result of the processed data must be clear at the preceding phase (filtering), so the fitting value's setup for obtained function can generally represent the parameter's measurement result[16]. And the latter function from this fitting phase becomes the reference to optimize the sensor's reading result[17].

The calibration effort through averaging, filtering and fitting approach is highly needed due to various uncertainty in measurement -i.e. environmental turbulence[18][19]. Averaging and filtering stage do apparently give significant enhancement in sensor reading's stability yet accuracy. Also the fitting approach in this paper does enhance the sensor's reading precision by nearing its reading value (result) numerically[20].

Related to averaging, filtering and fitting on MAX30100 in order to calibrate skin and body temperature as well, here are several equations as the followings:

$$T_{MAXAVG} = \frac{\sum_{i=1}^{n} T_{MAX30100_i}}{n} \quad (1)$$

$$T_{FILTER} = \left\{T_{MAXAVG} \middle| \left|T_{MAXAVG} - \frac{\sum_{i=1}^{N} T_{MAXAVG}}{N}\right| \leq \Delta T_{READ}\right\} \quad (2)$$

$$T_{SKIN} = T_{FILTER} \pm \Delta T_{MAX-DS} \quad (3)$$

$$T_{BODY} = T_{SKIN} \pm \Delta T_{SKIN-BODY} \quad (4)$$

## 3. Methodology

### 3.1 Calibration Method

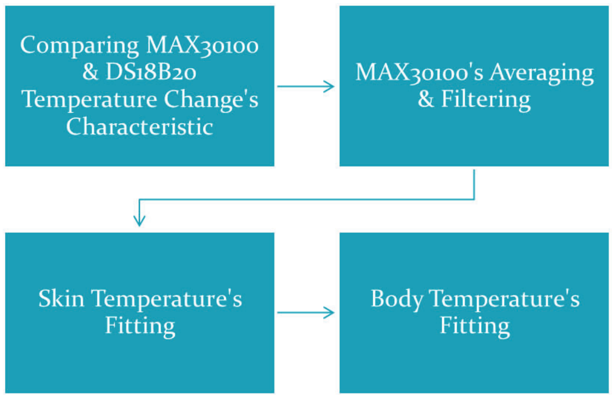



**Fig. 2:** Skin and Body Temperature Calibration on MAX30100's Outline.

Figure 2 explains the outline for skin and body temperature calibration on MAX30100 sensor module. Firstly, the intended objective to be fulfilled was comparing the characteristic of temperature change between MAX30100 and calibrated DS18B20[21]. It is to assure that both sensors have identical characteristic. DS1B280 is chosen to be the comparator because the calibration towards this sensor module has already been done with valid result responsibly[21][22]. The aspect intended to be improved is obviously MAX30100 sensor module's reading stability and accuracy as well.

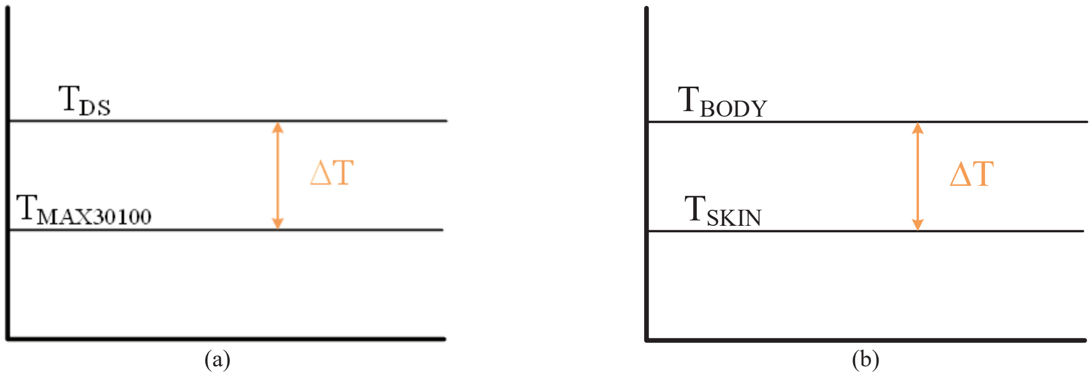



**Fig. 3:** Illustration of MAX30100 Sensor's Difference Reading Result with Its Calibrator (a) Skin Temperature (with DS18B20) (b) Body Temperature (with body thermometer).

Next is to convert the temperature reading result into skin temperature parameter. Precision is the aspect being focused for improvement[23)]. The approach was done by acquiring reference from (temperature) reading difference of MAX30100 ($T_{MAX30100}$) and DS18B20 ($T_{DS}$) as the calibrator (see Fig. 3(a)). Rather, the work on this stage has an aim to ascertain the validity of skin temperature's reading result on MAX30100 and near the reading value afterwards.

Later, the following measure is to perform the calibration of skin temperature ($T_{SKIN}$) to body temperature parameter ($T_{BODY}$) in order to enhance the body temperature reading's precision on MAX30100 sensor. At this latter phase, we preferred to use digital body thermometer as the calibrator due to its valid reading accuracy (± 0,1 °C). Besides, the body thermometer's use has already been allocated for public and there is a plenty of its availability[24)]. More, the calibration at this stage was being carried out by nearing MAX30100's skin temperature reading result to body thermometer according to the difference of reading value between them (see Fig. 3(b)).

Figure 3(a) illustrates temperature reading's fitting from MAX30100 to calibrated DS18B20 on skin parameter temperature; as for Fig. 3(b) MAX30100 skin temperature's result towards body temperature referring to body thermometer being the calibrator.

### 3.2 Experimental Setup

Figure 4 gives the illustration of skin temperature reading's calibration effort on MAX30100 sensor module to DS18B20. The procedure is being run by putting both sensors at palm. Patient does only need to respectively place his/her finger[24)] on MAX30100, and grab the DS18B200 sensor with hand. And the calibration's result itself is applied to near skin temperature's reading value on MAX30100 to DS18B20 from the temperature difference that occurs.

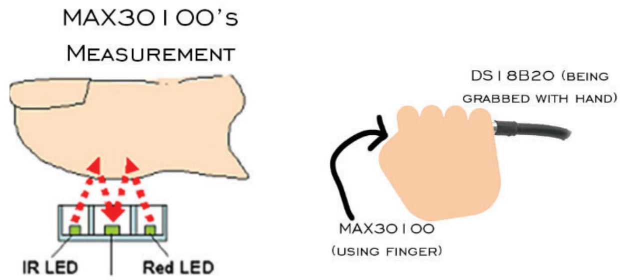



**Fig. 4:** Gathering Data at Patient's Palm with MAX30100 and DS18B20.

And for Fig. 5, the illustration has purpose to portray the calibration effort for body temperature on MAX30100's sensor module. In the beginning, two sensors are placed at tested patient's arm -particularly in elbow- in order to prevent turbulence from environment at temperature reading's result. Then patient will be asked to pin them by flexing the elbow till not any change body thermometer's reading value. The result from such effort will then be used to near the skin temperature's reading from MAX30100 towards body thermometer as calibrator.

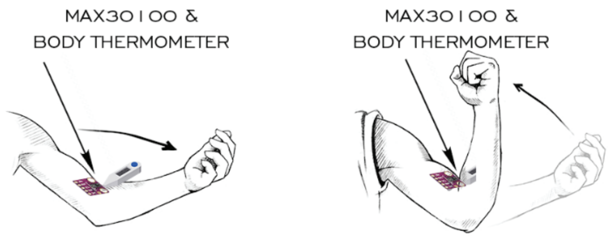



**Fig. 5:** Gathering Data at Patient's Palm with MAX30100 and DS18B20.

### 3.3 Statistical Approach

From statistical aspect, the starting approach is to average every data set consisting of twenty five temperature output results (n=25) in which each is collected per 200 ms ($T_{MAX30100_i}$). The next is to choose filtering value. The filtering value itself ($T_{FILTER}$) is acquired if the difference of the average temperature ($T_{MAXAVG}$) and its own averaging result from 20 obtained outputs (N=20) has value less than or equal to already settled constant ($\Delta T_{READ}$). Then the further step is to near the skin temperature's reading result of MAX30100 module sensor to DS18B20 with an amount of $\Delta T_{MAX\text{-}DS}$. Averaging, filtering and fitting option at the skin temperature reading is already written in equation (1), (2) and (3).

There does enter the latter stage, namely calibration effort from skin to body temperature. Thus means for nearing the skin temperature ($T_{SKIN}$) to body temperature reading result ($T_{BODY}$) from temperature reading's difference[25] of the calibrator, body thermometer, and MAX30100's skin temperature ($\Delta T_{SKIN\text{-}BODY}$). And the mechanism on this phase can be described in equation (4).

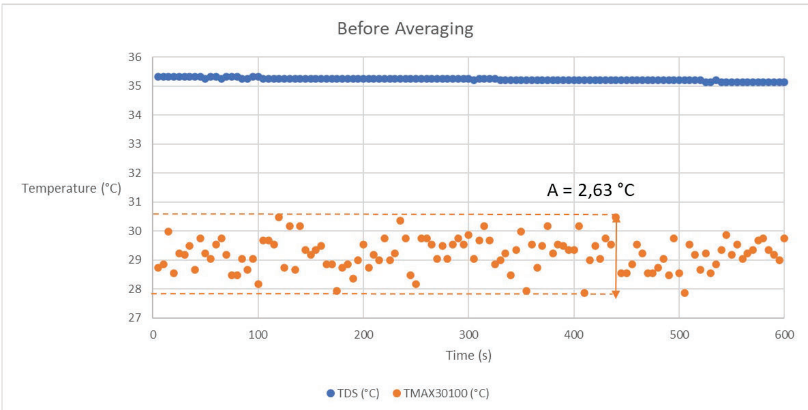
## 4. Results and Discussion

Figure 6 represents the difference prior and subsequent to averaging processing on MAX30100 sensor module towards DS18B20. From Figure 6(a), it is obvious that MAX30100's temperature reading ($T_{MAX30100}$) had not reached stability yet before applying averaging processing. Temperature reading then significantly enhanced after having adjustment by averaging (Fig. 6 (b)) in which MAX30100 ($T_{MAXAVG}$) has more stable reading than the foregoing one.

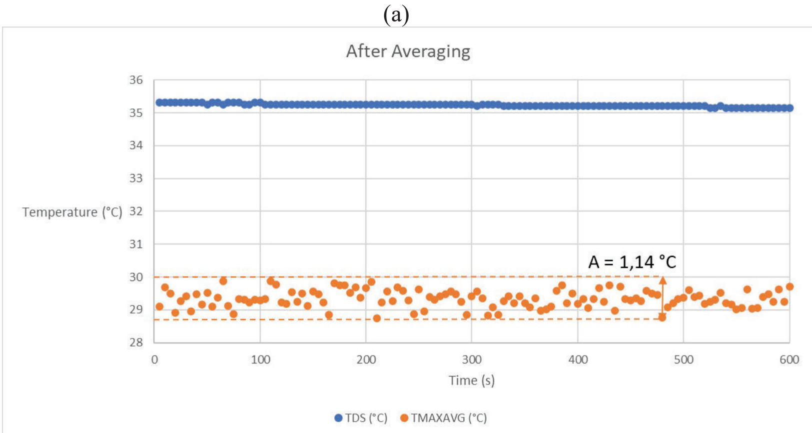
But the accuracy was not fully obtained. Referring to temperature reading on Fig.7(a), MAX30100's reading ($T_{MAXAVG}$) could not have portrayed temperature's real change. Thus did engage the filtering phase. We opted a filtering value of 0,15 °C ($\Delta T_{READ}$ = 0,15 °C), to drastically improve MAX30100 sensor's reading accuracy itself. As the result, MAX30100 ($T_{FILTER}$) did have identical characteristic with DS18B20 sensor in reading ongoing temperature change. The acquired data can be seen at Fig. 7(b) below.

And next was to process this MAX30100's filtering result ($T_{FILTER}$) to later near the reading result itself to skin temperature. The reference came from the difference of MAX30100 ($\overline{T_{FILTER}}$) and DS18B20 ($\overline{T_{DS}}$) reading's average. Average reading's difference between both sensors ($\Delta T_{MAX\text{-}DS}$) reached up to an amount of 6,02 °C referring to already processed data on Fig. 8 below. Therefore, the difference value became reference in fitting stage of MAX30100 sensor module's skin temperature reading.

$$\Delta T_{MAX-DS} = \overline{T_{DS}} - \overline{T_{FILTER}}$$
$$\Delta T_{MAX\text{-}DS} = 35{,}23 - 29{,}21$$
$$\Delta T_{MAX\text{-}DS} = 6{,}02 \text{ °C}$$

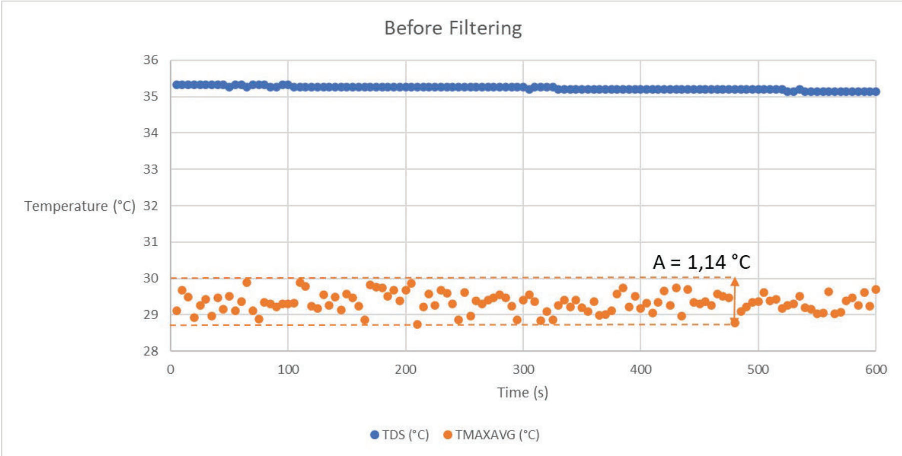



(a)

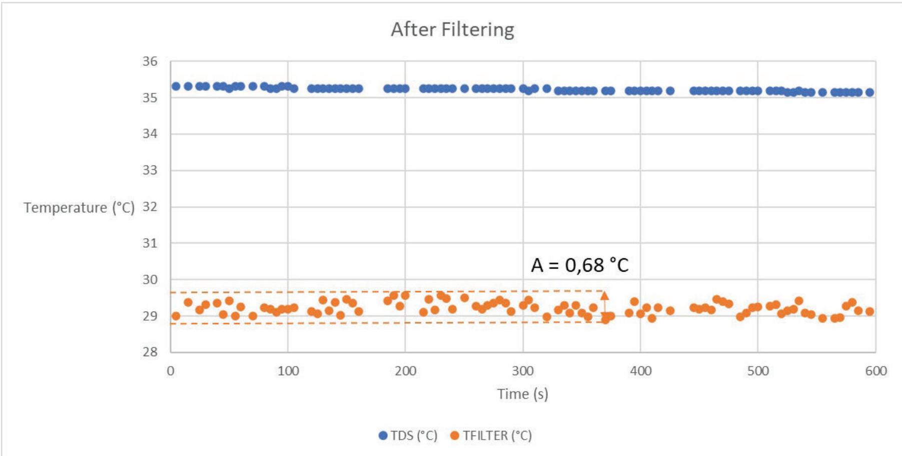



(b)

**Fig. 6:** Averaging Processing on MAX30100 Sensor Module
(a) Before Averaging (b) After Averaging.




(a)




(b)

**Fig. 7:** Filtering Processing on MAX30100 Sensor Module
(a) Before Filtering (b) After Filtering.

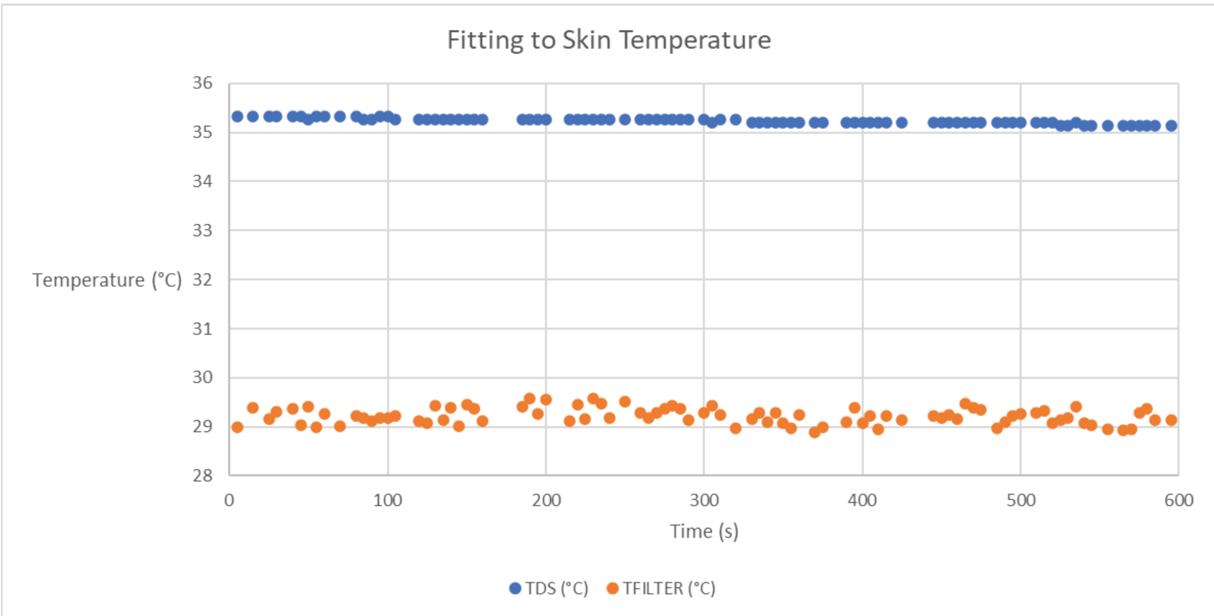
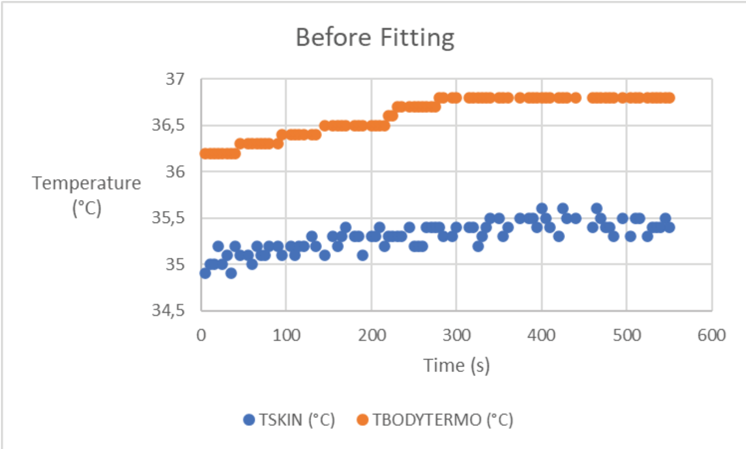
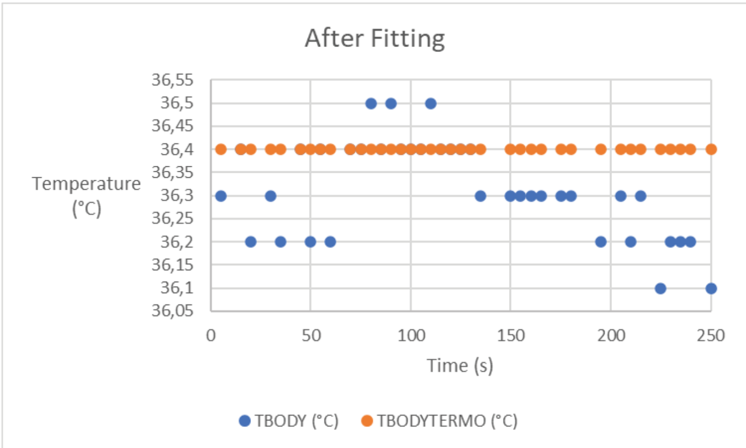



**Fig. 8:** Result of Temperature Reading on DS18B20 and MAX30100 Sensor before Skin Temperature Reading's Fitting towards MAX30100.




(a)




(b)

**Fig. 9:** Fitting Skin Temperature Reading to Body Temperature on MAX30100 (a) Before Fitting (b) After Fitting.

Lastly, the latter step of MAX30100 sensor module's calibration effort was to near the reading value (fitting) from skin temperature ($T_{SKIN}$) to body temperature ($T_{BODY}$) on MAX30100 according to body thermometer's reading result ($T_{BODYTERMO}$) in order to enhance MAX30100's precision. Processed data on Fig. 9(a) already illustrated it all. According to MAX30100 skin temperature ($\overline{T_{SKIN}}$) and body thermometer ($\overline{T_{BODYTERMO}}$) reading result's processing (average), the difference value ($\Delta T_{SKIN\text{-}BODY}$) had an amount of 1,34 °C. And after nearing the reading value (see Fig. 9(b)), we acquired an error of MAX30100's body temperature reading ($\overline{T_{BODY}}$) with 0,27% rate towards body thermometer.

$$\Delta T_{SKIN-BODY} = \overline{T_{BODYTERMO}} - \overline{T_{SKIN}}$$

$$\Delta T_{SKIN\text{-}BODY} = 36{,}59 - 35{,}25$$

$$\Delta T_{SKIN\text{-}BODY} = 1{,}34\ °C$$

$$\varepsilon = \left|\frac{\overline{T_{BODY}} - \overline{T_{BODYTERMO}}}{\overline{T_{BODY}}}\right| \times 100\ \%$$

$$\varepsilon = \left|\frac{36{,}3 - 36{,}4}{36{,}4}\right| \times 100\ \%$$

$$\varepsilon = 0{,}27\ \%$$

## 5. Conclusion

From calibration effort of skin and body temperature on MAX30100 sensor module that already being performed, the error rate is 0,27% for body temperature's reading compared to the calibrator, body thermometer. And this calibration result has already fulfilled measurement principle in which it can be used for skin temperature and body temperature as well towards human responsibly. There, we obtain two additional parameters namely skin and body temperature on one sensor, MAX30100, which is important to truly perceive one's health condition.

### Acknowledgement

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