The Electric Compress Lowers Body Temperature During Fever Using The PID Control System

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ABSTRACT

Compressing is a physical method for lowering the body temperature for those who are experiencing a fever. It can be done by using fluids or tools that can cause warmth and coolness to related parts of the body. The aim of developing this tool is to add a cold temperature selection mode and PID control to reduce the possibility of errors in setting the temperature with the resulting temperature in the compress, as well as getting a more stable and faster temperature adjusment. This research used an ATmega328P microcontroller as a data processor, a PID control system as a temperature controller for the heating element, an LM35 temperature sensor as a temperature detector, two heaters as hot and cold media, an I2ºC LCD as a display and a buzzer as a marker for the completion of the compress therapy process. Measurements were carried out at a hot temperature setting of 37ºC, 39ºC, and 41ºC, and a cold temperature setting of 20ºC and 25ºC. From these temperature measurements, the difference in temperature measurements between the measurements on the proposed tool module and the measurements on the thermometer at each point was, on average, below 1ºC. Therefore, this electric compressor is proven capable of operating like a real therapeutic tool.

Keywords: Fever, Heating and Cooling Elements, Electric Compress, LM35, PID.

ABSTRAK

Kompres adalah salah satu metode fisik untuk menurunkan suhu tubuh anak yang sedang mengalami demam dengan menggunakan cairan atau alat yang dapat menimbulkan hangat dan dingin pada bagian tubuh yang memerlukan. Tujuan dari pengembangan alat ini dengan menambahkan mode pemilihan temperatur dingin dan kontrol PID untuk mengurangi kemungkinan terjadinya kesalahan pada setting suhu dengan suhu yang dihasilkan pada kompres, serta mendapatkan suhu yang lebih stabil dan lebih cepat dalam mencapai suhu setting pada media kompres elektrik. Penelitian ini menggunakan microcontroller ATmega328P sebagai pengolah data, menggunakan sistem kontrol PID sebagai pengontrol suhu pada elemen pemanas, sensor suhu LM35 sebagai pendeteksi suhu, menggunakan dua Heater sebagai media panas dan dingin, LCD I2C sebagai display dan Buzzer sebagai penanda proses terapi kompres selesai. Pengukuran dilakukan pada dua mode suhu yaitu suhu panas dan suhu dingin pada setting suhu panas 37ºC, pada suhu panas 39ºC, pada suhu panas 41ºC dan untuk suhu dingin pada suhu 20ºC, dan pada suhu 25ºC untuk suhu dingin. Dari pengukuran suhu ini maka selisih pengukuran suhu antara pengukuran pada modul alat yang diusulkan dengan pengukuran pada alat pembanding yaitu thermometer pada masing-masing titik rata-rata di bawah 1ºC. Maka, dapat disimpulkan bahwa alat kompres elektrik ini mampu beroperasi layaknya alat terapi sesungguhnya.

***Kata Kunci**: Demam, Elemen Pemanas dan Dingin, Kompres Elektrik, LM35, PID.*

1. INTRODUCTION

Maintaining a healthy body is very important for humans, especially during the change of seasons, which usually accompany the development of various diseases. Not only in certain circles, but, of course, everyone has experienced and is experiencing abnormal temperatures. These various diseases tend to become more prevalent during transitional seasons, from the dry season to the rainy season and vice versa. Climate changes affect changes in a person's health condition. A person's condition, from being healthy to being sick, causes the body's reaction to an increase in temperature, which is usually called fever [1][2][3][4].

Fever is a condition where the body temperature is higher than normal body temperature, due to an increase in the temperature-regulating center in the hypothalamus. Most fevers in children are caused by changes in the heat center in the hypothalamus (thermoregulation). Diseases characterized by fever can attack the immune system [5][6][7][8]. Apart from that, fever also plays a role in increasing the production of specific and non-specific immunity to help cure or protect against infection [9][10][11][12]. Fever is a symptom, not a disease. Fever occurs when the body's immune system is fighting an infection. Medically, fever is defined as a temperature above 37.4 ºC. On the other hand, high fever (hyperpyrexia) is defined as an increase in body temperature above 41 ºC[13][14][15][16].

Patients with high body temperatures cannot be left alone because prolonged high temperatures can cause seizures. Various actions that can be taken to treat fever are by carrying out various interventions, including providing sufficient fluids, providing external cooling, and administering fever-reducing drugs. External cooling is a method of reducing body temperature through various methods based on the principles of radiation and conduction by providing warm clothing. Do warm compresses and evaporate. In QS Al-Anbiya verse 69, it tells about healing hot diseases or fever. This understanding is taken from the story of Prophet Ibrahim, who was burned alive, and when Prophet Ibrahim (as) was burned, he didn't feel the slightest heat, where We (Allah) said, "O fire! Be you cool, savior for Abraham. (QS Al-Anbiya: 69).

Compresses are divided into two categories: warm and cold compresses [17]. People still make warm and cold compresses in ways that are still considered too complicated. A warm compress is done by boiling water first and then soaking the cloth in the boiled water. The process for cold compresses is almost the same as warm compresses, namely by soaking a cloth in cold water or water with ice cubes in it. Only after that can it be used on patients. This method is considered less effective because the process is very time-consuming and must be done repeatedly. Considering that the temperature of the fabric cannot be maintained for a long time, the result is a rapid release of heat because it is in an open space. And the compress will always return to normal temperature quickly [18][19][20][21].

The modern era now offers many innovations in compresses in this case, one of which is the fever patch product, which is a compress in the form of a fever-reducing plaster for children, which is practical and can be used for emergency treatment when a child has a fever. This plaster is commonly used by anyone, especially babies and children who have a fever. The way to use it is by attaching the fever patch plaster to the child's forehead, and the fever patch plaster will start working to reduce the child's fever. Even though this product is considered practical, it can overcome inefficiencies. However, this product is still unable to provide effective results, just as traditional plaster compresses also cannot last long because the cold only lasts up to 10 minutes. This plaster is considered less effective and less economical because it is only used once, so it requires more than one plaster. The use of plaster compresses can increase waste because the system for using this compress is only used once [4].

Based on the description of the problem above, the author has the idea to create an innovative electric compressor device, where previously someone had already innovated this device, namely an electric compressor based on the AVR ATmega8 microcontroller as a working controller for the tool and a NTC (Negative Temperature Coefficient) temperature sensor to detect temperature on the compress and temperature on the body [5]. The author here wants to develop this innovative tool by using a PID control system with two temperatures used, namely warm temperature and cold temperature, and a PID control system, which is used to control the temperature of the heater used so that the temperature is more stable. The temperature sensor used is the LM35 temperature sensor, which functions to detect the temperature of the compress, which is used to control the working process of the heater to produce stable warm and cold temperatures in the electric compress.

2. RESEARCH METHODS

The tool testing method and data collection for the proposed module to lower body temperature during fever using the PID control system for this research includes several test parameters, including testing at cold temperatures, hot temperatures, and timers.

2.1. Hardware Design

The hardware design of the proposed module uses several circuit modules, including Arduino Nano, a button circuit, a sensor circuit, a buzzer circuit, an LCD circuit, an SSR driver circuit, and a heater circuit. The picture below is a block diagram of the tool.

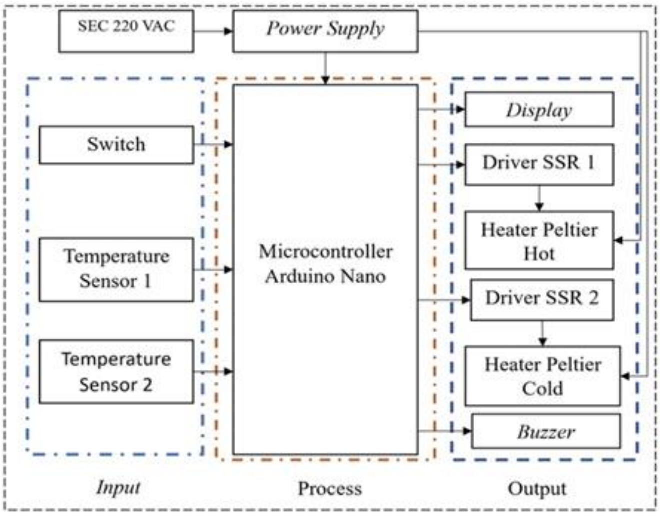

Figure 1. Block Diagram

Based on Figure 1 above, it can be explained that the voltage source is 220 VAC, which will be reduced and directed to become DC voltage to provide voltage supply to the entire circuit of the device. At input, the button and two temperature sensors will send input data in the form of analog data, which will be processed by the Arduino Nano microcontroller (ATmega328p) in the processing section. The processing results will produce an output on the buzzer as a marker of the completion of the compress therapy process and a display in the form of a 20 x 4 LCD with a display in the form of selecting hot or cold temperature settings and setting a timer. After determining the temperature settings and timer settings and then pressing the Start button, the Arduino Nano will process it, where the temperature detection value will be forwarded to the heater to control hot or cold according to the settings. This automatic control is the output of the SSR (solid state relay), which is implemented on the microcontroller. The output of this compressor is two heaters; one heater is for cold temperatures, and the second heater is for hot temperatures, and for the SSR (solid state relay) as the driver, there are also two for each heater. Where the output from the SSR (solid state relay) is applied to the device's microcontroller; where if the temperature has reached the specified set point value, then the current to the heater or cooler will be cut off, and when the temperature value is less than the set point then the current will flow again to turn on the heater or cooler to work again, this process will continue to repeat until the temperature remains at a predetermined set point value.

2.2. Software Design

The software design in this research is to process the reading results from the LM35 temperature sensor. The system flow diagram can be seen in Figure 2 below:

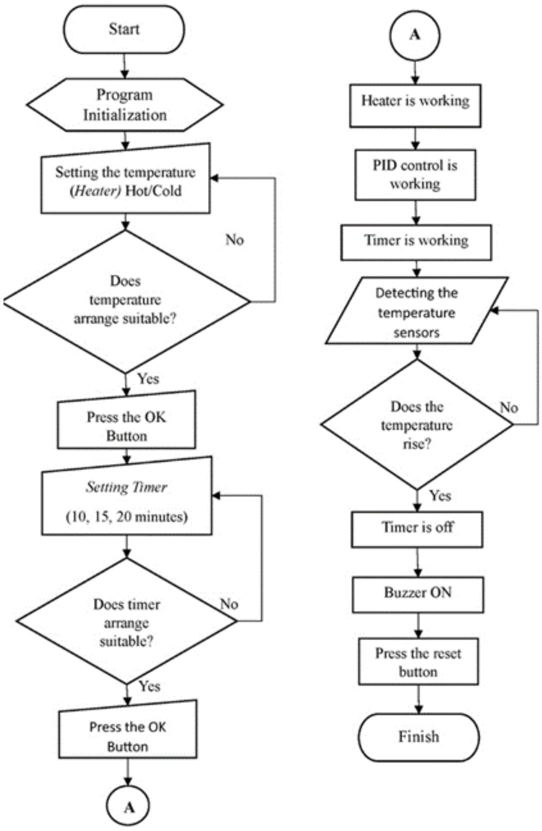

Figure 2. The Flowchart

Based on Figure 2 above, it can be seen that when the proposed module starts working, there is an initialization program on the proposed module. After the initialization is complete, it is asked to determine the desired hot or cold temperature setting value, then press the OK button to continue setting the desired timer after completing the temperature setting, and the timer has been set, then press the OK/Start button to run the proposed module. When the proposed module is working, the temperature sensor will detect the temperature of the heater, which will also work according to the settings. Then, the PID system starts working to regulate the work of the Peltier heater, and the timer also works according to the settings. If the temperature has been reached, the process is complete, the timer is OFF, and the buzzer lights up to indicate that the compress therapy process has been completed.

3. RESULTS AND DISCUSSION

In this final assignment research, the author tested the proposed module by comparing it with a comparison module. The data was taken using a thermometer and stopwatch comparison module. The data taken was 15 for each warm and cold temperature setting, as well as a timer.

3.1. Test Result of PID Control

The author's PID control testing pays attention to the transient response to the given PID control. This aims to determine the difference between the percentage of overshoot and the set point temperature value (maximum overshoot), the first time required to reach the set point temperature (rise time), the time required first to reach the peak value (peak time) and the time when the value returns to the set temperature point after overshoot (settling time). Table 1 shows the results of the transient response of PID control at temperature settings of 37 ℃, 39 ℃, and 40 ℃.

Table 1. PID Control Transient Response

Temperature (°C)	MP (%) (Maximum Overshoot)	TR (second) (Rise Time)	TP (second) (Peak Time)	TS (Second 2) (Settling Time)
37	2.70	27	63	36
39	2.30	36	72	48
41	1.95	42	75	54

Based on measuring and testing the transient response of the PID control from the proposed module, as shown in Table 1, using a digital thermometer for testing and measuring warm temperatures, data results were obtained at a temperature of 37°C producing an MP (%) (maximum overshoot) value of 2.70, TR (Rise Time) at 27 seconds, TP (peak Time) at 63 seconds and TS (Settling Time) at 36 seconds. At a temperature of 39 °C, it produces an MP value (%) (maximum overshoot) of 2.30, TR (Rise Time) at 36 seconds, TP (peak Time) at 72 seconds, and TS (Settling Time) at 48 seconds. At a temperature of 41 °C, it produces an MP value (%) (maximum overshoot) of 1.95, TR (Rise Time) at 42 seconds, TP (peak Time) at 75 seconds, and TS (Settling Time) at 54 seconds.

3.2. Test Result of Hot Temperature at 37 °C

The results of temperature measurements at a temperature setting of 37 ℃ can be seen in Table 2. These measurement results will be taken into data when the temperature value begins to stabilize. The data collection was carried out 15 times.

Table 2. Test Results of Setting the temperature at 37 ℃

No	The Proposed *Module* (℃)	*The Thermometer* (℃)
1	36.8	36.6
2	36.9	36.9
3	37.1	36.9
4	37.1	37
5	37	37
6	37	37.1
7	37	37.2
8	37.1	37.1
9	37.2	37.2
10	37.1	37.1
11	37	37.3
12	37.1	37.1
13	36.9	39.9
14	36.9	36.9
15	36.9	36.9
Mean	36.03	36.09
Deviation	0.06	
Error (%)	0.16	

Table 2 above is a recap of data collection at a temperature setting of 37 ℃, using the comparison measuring method between the proposed tool and a comparison measuring tool that is a mini digital thermometer. For fifteen repetitions, the average temperature value obtained on the proposed module was 36.3, whereas the average temperature value on the comparison tool was 37. From the two average values, the deviation value obtained is 0.7, and the error value obtained is 1.9%. The error value obtained is caused by several factors, including differences in sensor specifications used on the proposed module, as well as different sensor placement on the proposed module. The comparison can also affect this.

3.3. Test Result of Hot Temperature at 39 °C

The results of temperature measurements at a temperature setting of 39 ℃ can be seen in Table 3. The measurement results are taken into data when the temperature value begins to stabilize. The data collection was carried out 15 times.

Table 3. Test Results of Setting the temperature at 39 ℃

No	The Proposed *Module* (℃)	*The Thermometer* (℃)
1	38.6	38.8
2	38.6	38.9
3	39	38.9
4	39	39
5	39.1	39
6	39.1	39.1
7	39	39
8	39.1	39.1
9	39.1	39.2
10	39.1	39.2
11	39	39.4
12	38.8	39.3
13	39.1	39.1
14	39.1	39.1
15	39.1	39.1
Mean	38.98	39.08
Deviation	0.1	
Error (%)	0.25	

Based on the measurements and testing of the proposed module in Table 3 above, which is a recap of data collection at a temperature setting of 39 ℃, using a comparison measuring method between the proposed module and a comparison measuring tool that is a mini digital thermometer, fifteen times repeated, the average value of the temperature on the proposed module was obtained namely 38.98, while the average temperature value on the comparison tool is 39.08. From these two average values, the deviation value obtained is 0.1, and the error value obtained is 0.25%. The error value obtained is caused by several factors, including differences in sensor specifications used on the proposed module, as well as different sensor placement on the proposed module. The comparison can also influence this.

3.4. Test Result of Hot Temperature at 41 °C

The results of the heat temperature test at a temperature setting of 41 ℃ can be seen in Table 4. The measurement results will be taken into data when the temperature value begins to stabilize.

Table 4. Test Results of Setting the Temperature at 41 ℃

No	The Proposed *Module* (℃)	*The Thermometer* (℃)
1	40.6	40.9
2	41.1	40.9
3	41.2	41.1
4	41	41.1
5	41.1	41.2
6	40.9	41
7	41	41
8	41	40.9
9	40.9	41.1
10	41.1	40.9
11	41.5	41.2
12	41.1	41.1
13	41.2	41.1
14	41.1	40.9
15	41.1	40.9
Mean	41.07	41.02
Deviation	0.06	
Error (%)	0.12	

It is based on the measurements and testing of the proposed module, as shown in Table 4 above, which is a recap of data collection at a temperature setting of 41 ℃, using a comparison measuring method between the proposed module and a comparison measuring tool that is a mini digital thermometer, fifteen times repeated, the average value of the temperature on the proposed module was obtained namely 41.07, while the average temperature value on the comparison tool is 41.02. From these two average values, the deviation value obtained is 0.06, and the error value obtained is 0.12%. The error value obtained is caused by several factors, including differences in sensor specifications used on the proposed module, as well as different sensor placement on the proposed module. The comparison can also influence this.

3.5. Test Result of Cold Temperature at 20 °C

The temperature measurement results for setting a temperature of 20 ℃ can be seen in Table 5. The measurement results will be taken into data when the temperature value begins to stabilize. The data collection was carried out 15 times.

Table 5. Test Results of Setting the Temperature at 20 ℃

No	The Proposed *Module* (℃)	*The Thermometer* (℃)
1	19.8	19.9
2	19.9	19.9
3	20	20
4	20	20
5	20	20.1
6	20.1	20.1
7	20.2	20.2
8	20.3	20.3
9	20.2	20.4
10	20.1	20.5
11	20.3	20.6
12	20.6	20.9
13	20.4	20.6
14	20.1	20.2
15	20.1	20.1
Mean	20.31	20.54
Deviation	0.23	
Error (%)	1.13	

Based on the measurements and testing of the proposed module in Table 5 above, which is a recap of data collection at a temperature setting of 20 ℃, using a comparison measuring method between the proposed module and a comparison measuring tool that is a mini digital thermometer, for fifteen repetitions, the average value of the temperature on the proposed module was obtained, namely 20.08, while the average temperature value on the comparison tool is 20.16. From these two average values, the deviation value obtained is 0.04, and the error value obtained is 0.39%. The error value obtained is caused by several factors, including differences in sensor specifications used on the proposed module, as well as different sensor placement on the proposed module. The comparison can also influence this.

3.6. The Test Result of the Cold Temperature at 25 °C

The results of the cold temperature test at a temperature setting of 25 ℃ can be seen in Table 6. The measurement results will be taken into data when the temperature value begins to stabilize. The data collection was carried out 15 times.

Table 6. The Test Results of Setting the temperature at 25 ℃

No	The Proposed *Module* (℃)	*Thermometer* (℃)
1	24.8	24.8
2	24.9	24.9
3	25.1	24.9
4	25.2	25
5	25	25
6	25	25.1
7	25	25.2
8	25.2	25.1
9	25.1	25.1
10	25	25
11	25.4	25.3
12	25	25.4
13	25	25.2
14	25	25.1
15	25	25.1
Mean	25.04	25.08
Deviation	0.04	
Error (%)	0.15	

Based on the measurements and the testing of the proposed module, Table 6 above is a recap of data collection at a temperature setting of 25 ℃, using a comparison measuring method between the proposed module and a comparison measuring tool that is a mini digital thermometer, for fifteen repetitions, the average temperature value obtained on the proposed module was 25.04, while the value the average temperature on the comparison tool is 25.08, from the two average values, the deviation value obtained is 0.04 and the error value obtained is 0.15 %. The error value obtained is caused by several factors, including differences in sensor specifications used on the proposed module, as well as different sensor placement on the proposed module. The comparison can also influence this.

3.7. The Test Result of Timer with 10-Minute Setting

The results of testing the timer with a timer setting of 10 minutes can be seen in Table 7. The measurement results will be taken into data when the timer value is stable. The data collection was carried out 15 times.

Table 7. The Test Results of 10 Minutes Timer Setting

No.	The Proposed *Module* *(minutes)*	*Stopwatch* *(minutes)*
1	10.00	10.00
2	10.00	10.00
3	10.00	10.00
4	09.59	10.00
5	10.00	10.00
6	10.00	10.00
7	10.00	10.00
8	10.00	10.00
9	10.00	10.00
10	09.59	10.00
11	10.00	10.00
12	10.00	10.00
13	10.00	10.00
14	10.00	10.00
15	10.00	10.00
Mean	9.94	10
Deviation	0.06	
Error	0.6%	

Based on measurements and tool testing, Table 7 above is a recap of data collection at a timer setting of 10 minutes, using the comparison measuring method between the proposed module and the comparison measuring tool that is the stopwatch, for fifteen repetitions. The average value of the timer on the proposed module was 9.94, while the average value of the timer on the comparison tool was 10. From the two average values, the deviation value is 0.06, and the error value is 0.6%. The error value obtained was caused by several factors, including differences in the timer specifications used on the proposed module, and when measuring and pressing the start button between the proposed module and the comparison tool, it did not coincide. This could also influence this.

3.8. The Test Result of Timer with 15 Minutes Setting

The measurement results of the 15 minutes timer setting can be seen in Table 8. The measurement results will be taken into data when the timer value is stable. The data collection was carried out 15 times.

Table 8. The Test Results of the 15 Minutes Timer Setting

No.	The Proposed *Module* *(minutes)*	*The Stopwatch* *(minutes)*
1	14.59	15.00
2	15.00	15.00
3	15.00	15.00
4	15.00	15.00
5	15.00	15.00
6	14.59	15.00
7	15.00	15.00
8	15.00	15.00
9	15.00	15.00
10	15.00	15.00
11	15.00	15.00
12	14.58	15.00
13	15.00	15.00
14	15.00	15.00
15	15.00	15.00
Mean	14.91	15
Deviation	0.09	
Error	0.6%	

Based on the measurement and the testing of the proposed module in Table 8 above, which is a recap of data collection at a timer setting of 15 minutes, using a comparison measuring method between the proposed module and a comparison measuring tool that is the stopwatch, for fifteen repetitions, the average value of the timer on the proposed module was obtained, namely 14.91, while the average value of the timer on the comparison tool is 15, from the two average values the deviation value obtained is 0.09 and the error value obtained is 0.6%. The error value obtained was caused by several factors, including differences in the timer specifications used on the proposed module, and when measuring and pressing the start button between the proposed module and the comparison tool, it did not coincide. This could also influence this.

3.9. Test Result of Timer With 20 Minute Setting

The measurement results of the 20-minute timer setting can be seen in Table 9. The measurement results will be taken into data when the timer value is stable. The data collection was carried out 15 times.

Table 9. The Test Results of 20 Minutes Timer Setting

No.	The Proposed *Module* *(minutes)*	*The Stopwatch* *(minutes)*
1	20.00	20.00
2	20.00	20.00
3	19.59	20.00
4	20.00	20.00
5	20.00	20.00
6	20.00	20.00
7	20.00	20.00
8	19.58	20.00
9	19.59	20.00
10	20.00	20.00
11	20.00	20.00
12	20.00	20.00
13	20.00	20.00
14	20.00	20.00
15	20.00	20.00
Average	19.91	20
Deviation	0.09	
Error	0.6%	

Based on the measurement and testing of the proposed module in Table 9 above, which is a recap of data collection at a timer setting of 20 minutes, using a comparison measuring method between the proposed module and a comparison measuring tool that is the stopwatch, for fifteen repetitions, the average value of the timer on the proposed module was obtained, namely 19.91, while the average value of the timer on the comparison tool is 15, from the two average values the deviation value obtained is 0.09 and the error value obtained is 0.6%. The error value obtained was caused by several factors, including differences in the timer specifications used on the proposed module, and when measuring and pressing the start button between the proposed module and the comparison tool, it did not coincide. This could also influence this.

4. CONCLUSION

Based on the results of this research that the author has conducted, it can be concluded that:

a. This research has been carried out on designing an electric compressor with a PID control system to reduce body temperature during fever.
b. The measurement results of the mini digital thermometer showed that the error with the proposed module was 0.16% at a temperature setting of 37 ℃, 0.25% at a temperature setting of 39 ℃, 0.12% at a temperature setting of 41 ℃, 1.13% at a temperature setting of 20℃, 0.15% at a temperature setting of 25℃, 0.6% at a timer setting of 10 minutes, 0.6% at a timer setting of 15 minutes, 0.6% at a timer setting of 20 minutes.
c. The highest maximum peak (MP) or overshoot value is 2.70% at a temperature setting of 37 ℃, and the lowest overshoot value is 1.95% at a temperature of 41 ℃.
d. In the rise time (TR) value, the closer the initial value is to the set point value, the faster the rise time response is given.
e. For peak time (TP) values, the closer the initial value is to the maximum overshoot value, the faster the peak time response will be.

f. Regarding the settling time (TS) value, the greater the set point value given, the greater the upper limit and lower limit values resulting from the settling time response.

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