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# Room Temperature Control using Voltage Controller for Miniature Powder Milk Storage

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**ABSTRAK**

*Suhu ruang penyimpanan Susu Bubuk akan mempengaruhi kualitasnya, dengan kemungkinan bakteri dan virus yang dapat mengkontaminasi produk, suhu yang direkomendasikan pada ruangan penyimpanan berdasarkan penelitian sebelumnya yaitu 20-25°C, dengan tujuan untuk menghambat pertumbuhan bakteri asam laktat. Berdasarkan permasalahan tersebut, dirancang ruang penyimpanan Susu Bubuk dengan kapasitas volume 220 liter dengan tidak menggunakan ventilasi melainkan ruang kedap udara, dengan menggunakan empat buah Peltier melalui pengaturan tegangan yang akan mempengaruhi temperatur. Pada saat menggunakan Peltier diperlukan tegangan yang sesuai dan konstan dari keluaran Buck Converter untuk mencapai suhu yang ditargetkan, sehingga digunakan kontrol Proportional Integral untuk mempercepat sistem ke tegangan yang diharapkan untuk suhu target 23°C. Pada hasil penerapan kontrol dengan Kp= 5 dan Ki= 22.32 pada tegangan 12 Volt didapatkan temperatur 23.2°C lebih mendekati suhu target dibandingkan dengan tegangan 11 volt dan 10 volt dengan suhu yang dihasilkan 23.5°C dan 23.8°C.*

***Kata kunci****: Buck Converter, Peltier, Proportional Integral, Susu Bubuk*

**ABSTRACT**

*The temperature of the Milk Powder storage room will affect its quality, with the possibility of bacteria and viruses that can contaminate the product, the recommended temperature for storage rooms based on previous research is 20-25°C, to inhibit the growth of lactic acid bacteria. Based on these problems, a powder milk storage room was designed with a volume capacity of 220 liters without using ventilation but in an airtight chamber, using four Peltiers through a voltage regulation that would affect the temperature. When using Peltier, an appropriate and constant voltage is required from the output of the Buck Converter to reach the target temperature, so that the Proportional Integral control is used to accelerate the system to the expected voltage for the target temperature of 23°C. In the results of applying control with Kp = 5 and Ki = 22.32 at 12 Volts, a temperature of 23.2°C is closer to the target temperature than the 11 volts and 10 volts with the resulting temperature being 23.5°C and 23.8°C.*

***Keywords****: Buck Converter, Peltier, Proportional Integral, Powder Milk*

## 1. INTRODUCTION

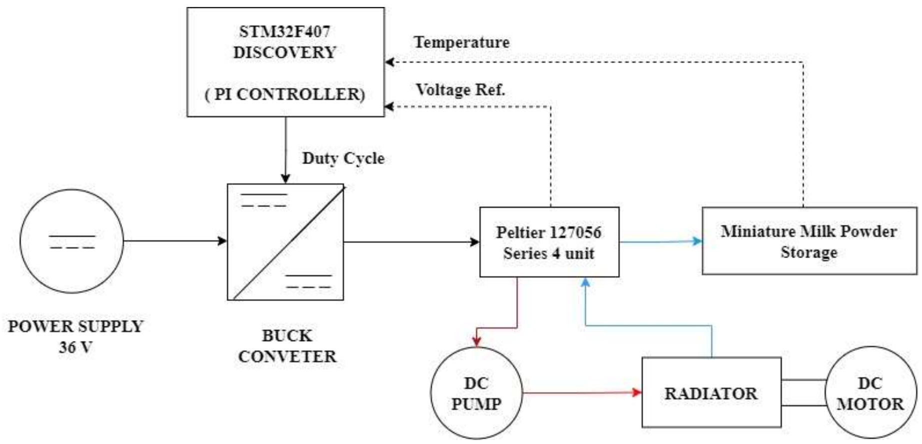
Refrigeration equipment in developing industries, it generally uses a compressor combined with freon gas. The cooling system called thermoelectric cooling (TEC)/ Peltier can be used in cooling an object **(Sulaiman, et al., 2018)**, where the gas chemical produced is not environment friendly, with freon gas can damage the ozone layer and potentially have negative impact on the environment and endanger humans health, so there is an alternative replacement that is being developed, namely coolers with thermoelectric modules (Peltier) (**Ab, et al., 2022**), which are easy to use by adjusting the DC voltage, with a combination of control methods and a DC-DC converter that will maximize the performance of the Peltier.

Research that already has settings for cooling temperatures in powdered milk storage rooms still uses freon gas which can damage the environment, so in this study, a thermoelectric (Peltier) functions with temperature regulation using voltage and must meet the standards the aim was to make a miniature milk powder storage room to prevent the possibility of bacteria and viruses that could contaminate the product, the recommended temperature with the aim of inhibiting the growth of lactic acid bacteria, a miniature powder milk storage room will be made with the target of reducing the temperature in the area of 20 – 25$^{o}$C **(Rawat, et al., 2022)**, by setting the appropriate voltage (setting point) with the help of Proportional Integral control to accelerate the release of hot air at Peltier. So as to be able to reach the recommended room temperature target. The cooling process occurs in the Peltier which functions as an evaporator that will distribute cooling through the heatsink so that the cooling distribution is maximized, and the release of heat generated by the Peltier is done by flowing water through a DC pump, where the circulating water will be passed to a radiator which has a cooling lattice, and the radiator gets airflow from a modified fan so that the water that will flow back to Peltier will be at normal temperature.

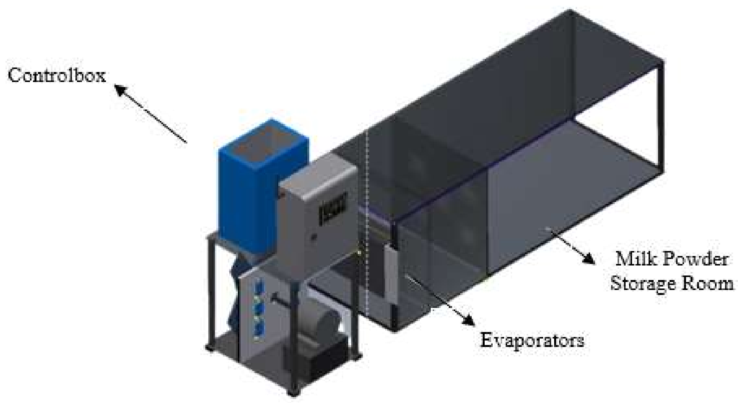
So that there is a formulation of the problem, namely how to implement PI control on voltage regulation for air temperature cooling in a miniature milk powder storage room, and how to design a buck converter circuit that is enabled to regulate the Peltier input voltage. So that from this normal temperature it can take the heat from the Peltier and accelerate cooling, to achieve the desired temperature during the process of cooling a room, stability and cooling must be achieved quickly **(Shekhar & Pandey, 2022)**. To do this, various techniques including PI control can be applied. Temperature drop design can also be done by analyzing first-order differential equations and understanding how the process self-regulates. Boundary characteristics will be determined by FOPDT **(Kaplan & Bodur, 2022) (Khuriati, 2022)**. The purpose of this research is to select the (CO) controller output that will affect the value of the process variable (PV) **(Wahyudi, et al., 2022).** The remainder of this essay is structured as follows. The modeling and design of the control design and the techniques we suggest are described in Section 2. The experimental results and discussion are discussed in Section 3, and the conclusions of the paper are discussed in Section 4.

## 2. METHODS

The focus of this research is to design a miniature powder milk storage by implementing a buck converter as a voltage converter, which will be used as input from the Peltier and implemented voltage regulation which will affect the obtained temperature. At the stage of conducting this research by designing a concept according to the block diagram presented in Figure 1 (a), and in Figure 1 (b) illustrating a three-dimensional image of a miniature milk powder storage room with a capacity of 220 liters, then it will facilitate data analysis and collection as well as drawing conclusion.




**(a)**




**(b)**

**Figure 1. (a) Overall System Block Diagram (b) Three-Dimensional Design of Miniature Space Milk Powder Storage Capacity Of 220 Liters**

## 2.1 Thermo Electric Cooler (Peltier)

In principle, the thermoelectric effect is a direct energy conversion process due to a temperature difference after being given an electric voltage. Figure 2 displays the composition of the Peltier.

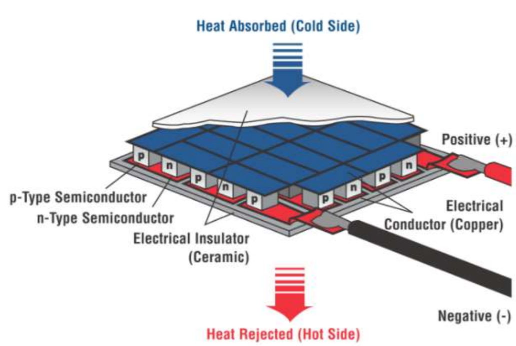



**Figure 2. Peltier Element Arrangement (Alim, et al., 2020)**

The cooling system called thermoelectric cooling (TEC)/ Peltier can be used in cooling an object **(Sulaiman, et al., 2018)**, Peltier has a relationship between the electrical conductivity and the heat conductivity of the material. Thermoelectricity, especially the Peltier concept, can be a useful alternative for cooling (refrigeration) systems. The current cooling system is based on a vapor compression cycle which is less environmentally friendly **(Ab, et al., 2022)**, by utilizing a thermoelectric cooling method, which is used to optimize work on electrical equipment such as laboratory incubators which require the temperature to be controlled accurately within the desired range. Cooling on thermoelectric is affected by a current which is regulated by voltage, explains that voltage regulation with a set point of 40 volt and 48 volt in a series-parallel connection difference gets cooling 3°C **(Alim, et al., 2020)**, so that the application of Peltier in the cooling process is very possible to use. The thermoelectric relationship in this study is to enable the Peltier for cooling in a miniature milk powder storage room with a predetermined cooling standard, setting the Peltier voltage input using a converter by adjusting the voltage according to the setting point.

### 2.2 Milk Powder

Industrial products that reach consumers will experience storage, perishable products which are prone to getting spoiled quickly at room temperature such as (milk powder), milk powder storage will affect the quality and quantity of the milk powder, and the duration of milk powder storage will also affect the milk powder particles **(Kang, et al., 2022)**. To achieve success in storing milk powder, the surrounding objects that affect it must be considered, namely microorganisms **(Renner, 1988)**. To avoid contamination, a sterilization process must be carried out, so that microbiological reactions can be avoided and the nutritional value of powdered milk is maintained.

In powdered milk storage rooms, it is recommended for refrigerator temperatures (20–25°C) **(Rawat, et al., 2022)**. At the recommended storage temperature, oxygen levels increased. 34 times for incomplete packaging and only 5 with intact packaging, and at 40°C the oxygen level increases 200 times with a high increase in peroxide value which can cause physical damage to the explosion, color, and impurities of the milk powder **(Immaningsih, 2013)**. Then a miniature milk powder storage room was designed with a capacity of 220 liters with a design that fits a maximum of 11 packs of powdered milk.

### 2.3 Buck Converter

The buck converter is used to change the system input voltage to be lower or equal to the input voltage, by adjusting the system requirements according to the **(Ichsan, et al., 2017)**, increasing the duty cycle value, the higher the output voltage and current value in the system resulting in power efficiency derease due to the determination of the duty cycle value that has been calculated previously does not match the value of the output voltage parameter. So that the design of the buck converter consists of several components including high-frequency inductors, capacitors as filters, diodes as rectifiers, MOSFET as electrical switches, and resistors as load modeling as shown in Figure 3.

The design of the buck converter is required to obtain the appropriate output results because the filter is a low-pass filter with high-frequency harmonics, and the converter output is not completely pure dc wave **(Shekhar & Pandey, 2022).** Table 1 contains the buck converter design specifications comparison with Peltier (TEC 12706) to calculation in Equation (1)-(3). This study uses MOSFET type IRFP460 with a drive voltage ($V_{DS}$) of 10 volts, by including variations in duty cycle which will affect the value of the output voltage.

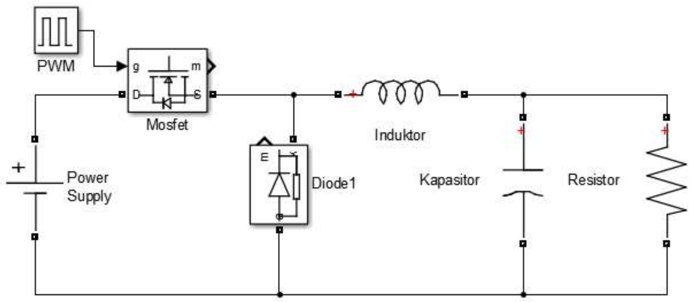



**Figure 3. Buck Converter Circuit**

$$Vo = Vs \times D \tag{1}$$

$$L = \frac{(1-D)}{Vo\ \Delta IL \times f} \tag{2}$$

$$C = \frac{(1-D)}{8L(\Delta Vo/_{Vo})f^2} \tag{3}$$

**Table 1. Results of Buck Converter Component Calculations and Supporting Components**

| **Hardware** | | **Specification** |
|---|---|---|
| **Buck Converter** | Switching Frequency (F) | 40 kHz |
| | Input Voltage (Vs) | 36 V |
| | Output Voltage (Vo) | 16 V |
| | Inductor (L) | 45 μH |
| | Capacitor (C) | 868 μF |
| | Power (P) | 300 W |
| **Microcontroller** | | ARM STM32F4VGTX |
| **Display** | | LCD 4x20 |
| **Communication** | | USB TTL |
| **Peltier** | | TEC 12706 Series 4 Unit |

## 2.4 First Order Plus Dead Time (FOPDT)

Utilizing system identification techniques, it is possible to identify the system as a model of the process when the inputs and outputs are known and it is clear that the system closely resembles the process **(Kaplan & Bodur, 2022)**. By using tried-and-true controller tuning methods, its related FOPDT model makes this work simpler **(Khuriati, 2022)**, one of the characteristics of the problems in industrial control processes can be modeled mathematically, one of which is self-regulating process modeling, where the process is stable, and in modeling it can be approximated using FOPDT (first order plus dead time) mathematical model **(Belwal, et al., 2023)**, which is a function of first order with the addition of a dead time, characterized by a parameter (L) transportation delay, processing time constant (T), and process static gain (K). Testing integration without control and observing changes in the manipulated variable (MV) to the process variable (PV) will get the characteristics of a plan can be seen in Figure 4.

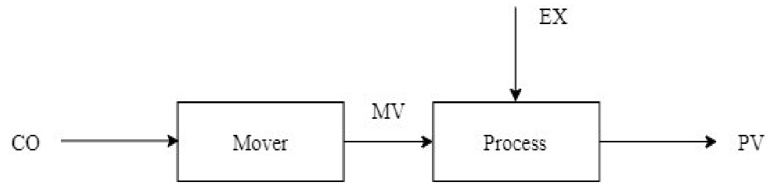
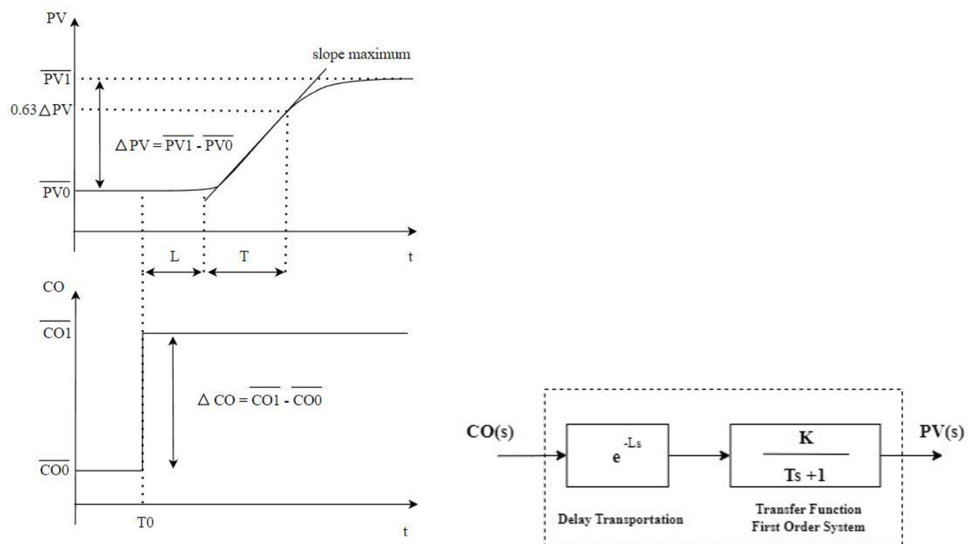



**Figure 4. Process Model Block Diagram**

An operator and an exogenous variable is an input variables that cannot be controlled by an operator/disturbances in the system. In the self-regulating process modeling, problems arise in temperature control (heat exchanger) and fluid level control. With the three parameters process transport delay, process time constant, and process static gain, it becomes a representative of the system and becomes an auxiliary control material in a simple system test process (bump test), which is a signal response test without manual mode. By providing a step response signal at the output controller (CO) which is carried out by the operator by setting it at a fixed value and will display the response on the system (PV) until a steady state.




**(a)** **(b)**

**Figure 5. (a) Bump Test Response Graph on The FOPDT (b) Block Diagram of The FOPDT Process Model**

From the response of the graph in Figure 5 (a), the time constant (T), and the gradient (maximum slope) that occurs during the transient process can be obtained. In determining the processing time constant determines the response speed, if the time constant is smaller then the system response time is faster. The static gain of the process is the ratio of the change in (PV) to the change in (CO) in its steady state **(Aguiar, et al., 2022)**. The gain value of this process directly shows the sensitivity of the process, the greater the static gain, the more sensitive the process is, a small change in (CO) will result in a relatively large (PV) deviation. In system design and analysis, the differential equation represents the behavior of the system process, which is modeled in the form of a transfer function with the following equation in Figure 5 (b). So that in differential modeling the system characteristic response is obtained which will be used for control analysis. Figure 6 shows a bump test on system, using an input voltage of 12 Volt and an initial temperature of 29°C. For FOPDT will calculation in Equation (4)-(6).

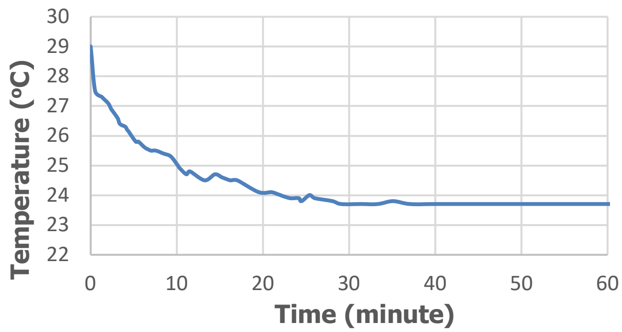



**Figure 6. Graph Function of Temperature Drop Against Time With 12 Volt CO Output**

$$\Delta PV = PV_1 - PV_0 \quad (4)$$

$$\Delta CO = CO_1 - CO_0 \quad (5)$$

$$K = \frac{\Delta PV}{\Delta C} \quad (6)$$

**Table 2. Results of Fist Order Plus Dead Time (FOPDT)**

| Parameters | Symbol | Value | Units |
|---|---|---|---|
| **Gain (reverse)** | K | - 0.441 | - |
| **Controler Output** | ΔCO | 12 | Volt |
| **Proses Variabel** | ΔPV | 5.3 | ºC |
| **Delay Transpotation** | L | 0.2 | m |
| **Time konstan** | T | 7.6 | m |

## 2.5 Proportional Integral (PI)

In applying Proportional Integral, it is used to control processes that have relatively fast dynamics, such as flow, pressure, and so on. By using proportional and integral controllers, it will produce the same response as the setting point which has zero offsets **(Ajangnay & Adam, 2022)**. In proportional control to a system error, integral control responds to the size and length of time of the error signal so that the planned output signal from the integral control is the integral result of the mathematical error signal. An error signal will appear when there is a change between the resulting output value and the setting point presented, the effect of the integral will cause the process output to change until there is no error in the system in the process, Figure 7 presents an image of the PI block diagram.

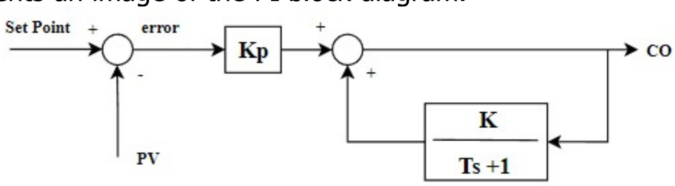



**Figure 7. PI Alternative Block Diagram**

## 2.6 LM35 Temperature Sensor

The LM35 sensor in this study is used to perform conversions when the temperature changes every 1ºC the temperature will show a voltage of 10 mV. In its placement, LM35 can be affixed to the surface but the temperature will decrease slightly by around 0.01ºC because it is absorbed at the surface temperature.

$$A = \frac{\mathrm{Rf}}{\mathrm{Rin}} + 1 \tag{7}$$

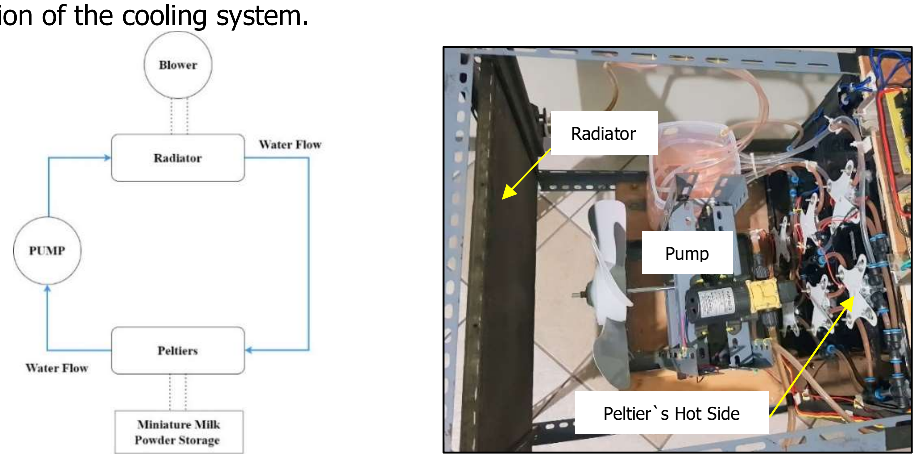
In the temperature measurement, the non-inverting amplifier circuit is used with the formulation in Equation 7, with a sensor reference voltage of 3.3 Volts, Rf 10k Ω, and Rin 2.2k Ω and, and it will get an amplification of 5.54 times. This series of reinforcement is carried out so that the temperature measurement converted by the microcontroller becomes more precise.

## 3. RESULTS AND DISCUSSION

The author discusses the results of system testing and analysis of test findings on open loop and simulation results, and for this purpose, the purpose of testing is to ensure system functionality on hardware and determine its level of success in meeting predetermined requirements.

### 3.1.1 Water Circulation Test For Peltier Heat Transfer

This test was carried out to determine the circulation of water that is used to distribute heat generated by the Peltier when working, because the Peltier has two characteristics with a hot side and a cold side, with the cold side being able to work optimally if the hot side of the Peltier must be removed. In this study, water is the medium for distributing heat generated from the Peltier, using flowing water into a radiator and the water discharge is set at a value of 3.5 liters per minute so that the variable discharge is constant. Figure 8 will present a representation of the cooling system.




**(a)** **(b)**

**Figure 8. (a) Cooling System Illustration, (b) Cooling System Hardware**

In the hot side cooling system, the Peltier utilizes a radiator to cool water which absorbs heat from the Peltier, the heat will be absorbed by the grille on the radiator and the grille of the radiator will be given a gust of wind from the fan, so it is expected that the water coming out of the radiator will have a temperature lower to absorb heat from the Peltier while working.

### 3.1.2 Open Loop Test of Buck Converter

In this study, the buck converter is used to provide input voltage to the Peltier, which will affect the output temperature value, so the converter must have a good efficiency value. In testing the buck converter, this is a reference for obtaining a voltage of 10 V, 11 V, and 12 V.

Table 3 presents a test on the buck converter with an average efficiency value of 86.17%, with tests carried out at a duty cycle of 5 – 90 %.

**Table 3. Buck Converter Test**

| Duty (%) | Vin (V) | Vout (V) | Iin (V) | Iout (A) | Pin (W) | Pout (W) | Efficiency (%) |
|---|---|---|---|---|---|---|---|
| 5 | 36 | 1.495 | 0.02 | 0.33 | 0.72 | 0.49335 | 68.52083 |
| 10.5 | 36 | 3.09 | 0.08 | 0.68 | 2.88 | 2.1012 | 72.95833 |
| 15.3 | 36 | 4.65 | 0.16 | 1.01 | 5.76 | 4.6965 | 81.53646 |
| 20.5 | 36 | 6.35 | 0.29 | 1.37 | 10.44 | 8.6995 | 83.32854 |
| 25.3 | 36 | 7.95 | 0.45 | 1.72 | 16.2 | 13.674 | 84.40741 |
| 30.2 | 36 | 9.58 | 0.63 | 2.07 | 22.68 | 19.8306 | 87.43651 |
| 35.6 | 36 | 11.3 | 0.88 | 2.48 | 31.68 | 28.024 | 88.4596 |
| 40.9 | 36 | 13 | 1.16 | 2.85 | 41.76 | 37.05 | 88.72126 |
| 45.8 | 36 | 14.62 | 1.46 | 3.2 | 52.56 | 46.784 | 89.01065 |
| 50 | 36 | 16 | 1.73 | 3.5 | 62.28 | 56 | 89.91651 |
| 55.7 | 36 | 17.78 | 2.14 | 3.89 | 77.04 | 69.1642 | 89.777 |
| 60 | 36 | 19.14 | 2.49 | 4.2 | 89.64 | 80.388 | 89.67871 |
| 65.5 | 36 | 20.8 | 2.95 | 4.58 | 106.2 | 95.264 | 89.70245 |
| 70.1 | 36 | 22.26 | 3.38 | 4.94 | 121.68 | 109.9644 | 90.37179 |
| 75.5 | 36 | 24.05 | 3.92 | 5.29 | 141.12 | 127.2245 | 90.15342 |
| 80.7 | 36 | 25.55 | 4.49 | 5.62 | 161.64 | 143.591 | 88.83383 |
| 85.4 | 36 | 27 | 4.99 | 5.95 | 179.64 | 160.65 | 89.42886 |
| 90.4 | 36 | 28.36 | 5.57 | 6.29 | 200.52 | 178.3844 | 88.9609 |

### 3.1.3 parameter controller PI

In Figure 9 shows the response of the system in an open loop with steady-state voltage in 12 V, adjustments are made to the duty cycle and will get the transfer function as a system model. Mathematical analytic model calculations to determine Kp and Ki value parameters on the controller, to calculation in Equation (7)-(14).

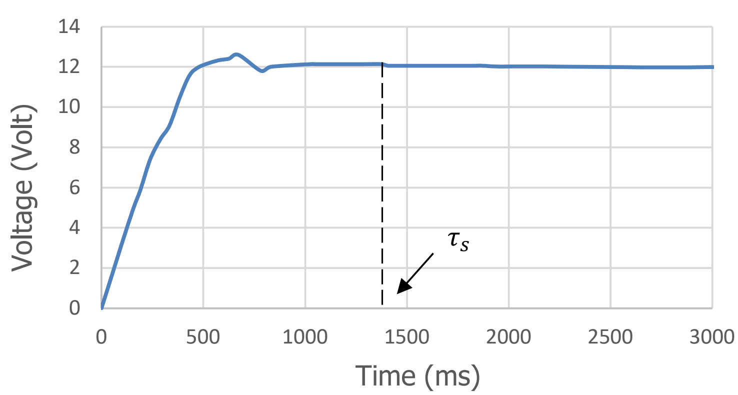



**Figure 9. Open Loop Response System**

Time steady state (ts) = 1.4 s
Volt steady state (Yss) = 12 Volt
Volt set point (Xss) = 10, 11, 12 Volt

To determine Kp and Ki, it is necessary to find the following parameters:

Calculate gain overall

$$K = \frac{Yss}{Xss} \tag{7}$$

Calculate time constant (t)

$$\tau_s = 5\tau \tag{8}$$

Analytic Method

$$\tau_s = \tau_s^* \tag{9}$$

$$\tau_s^* = 5\tau^* \tag{10}$$

$$\tau_i = \tau \tag{11}$$

$$\tau^* = \frac{\tau_i}{K_p \times K} \tag{12}$$

Calculate Gain Proportional (Kp)

$$K_p = \frac{\tau_i}{\tau^* \times K} \tag{13}$$

Calculate Gain Integral (Ki)

$$K_i = \frac{K_p}{\tau_i} \tag{14}$$

In equation (7) is intended to find the constant K as an open Loop transfer function (OLTF) parameter, and the time constant value is the value of 1/5 settling time equation (8), in PI control the analytical method can determine a new time constant, in research it uses 1/5 the old time constant, thereby accelerating the system in reaching the set point so that the new Close loop transfer function (CLTF) has a zero-error value so that the Kp and Ki values are obtained in equations (13) and (14). Table 4 displays the PI control parameters at the set point voltage of 10 Volts, 11 Volts and 12 Volts.

**Table 4. PI Control Parameters**

| **Value steady** | **12 Volt** | | |
|---|---|---|---|
| **Setting Point** | **12 Volt** | **11 Volt** | **10 Volt** |
| $K$ | 1 | 4.58 | 4.16 |
| $\tau$ | 0.28 s | 0.28 s | 0.28 s |
| $\tau s*$ | 0.28 s | 0.28 s | 0.28 s |
| $\tau*$ | 0.056 | 0.056 | 0.056 |
| $Kp$ | 5 | 4.58 | 4.16 |
| $Ki$ | 22.32 | 16.35 | 14.86 |

### 3.3 Simulation Test

Figure 10 shows a system simulation at the Peltier input voltage setting, by looking at the response from the open loop it is used as a transfer function, by modeling the set point voltage according to the plan in chapter 3.2.

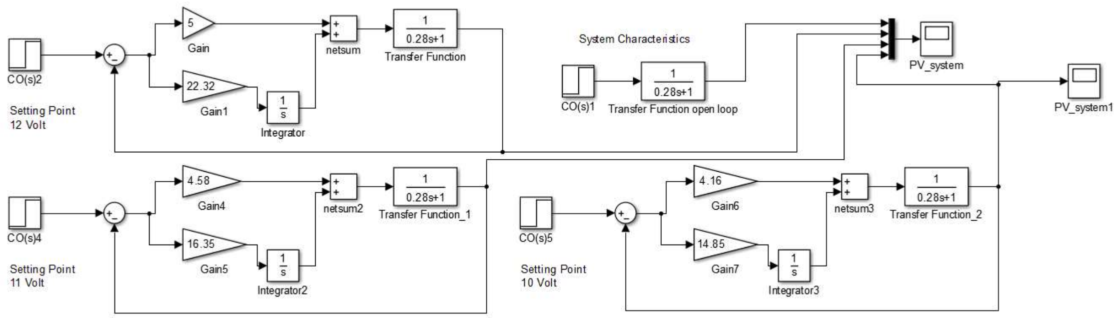
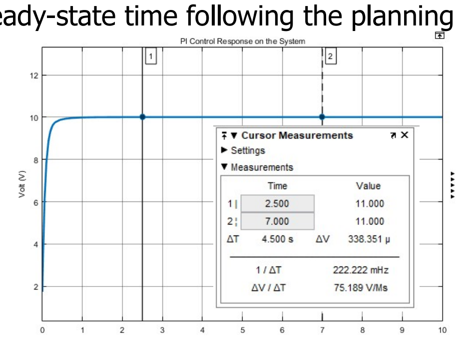



**Figure 10. PI Control Simulation on Simulink PI**

The simulation is carried out on Simulink by entering Kp and Ki parameters so that it can be observed in Figure 11 that the output response according to Kp and Ki has been determined. The simulation results show that the steady-state error is below 0.5%, for each system output result, will have a certain steady state time, this is because the PI control parameters affect the steady-state time following the planning in the PI Control analytic tunning method.

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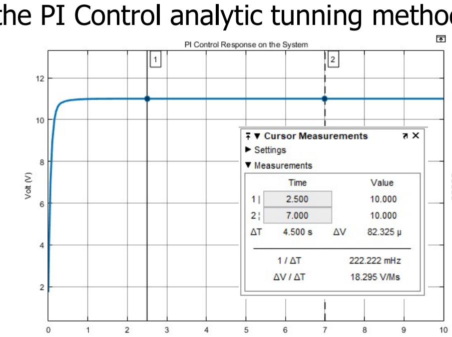


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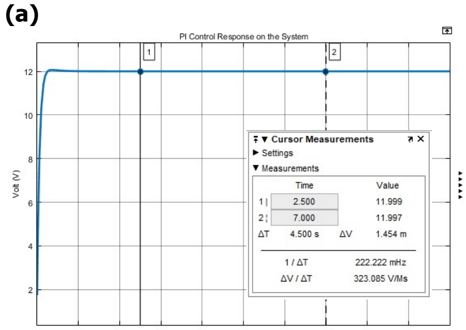


**(c)**

**Figure 11. (a) Control Response in Systems with 10 Volt Set Point (b) Control Response in Systems with 11 Volt Set Point (c) Control Response in Systems with 12 Volt Set Point**

The results of closed-loop response for the set point voltage 12 volt have a steady state time at 1.04 seconds, steady state 11 volt at 1.66 seconds, and steady-state 10 volt at 1.18 seconds, the acceleration system to reach the set point is a benchmark in cooling the storage room.

### 3.2 System Integration Hardware Result

The purpose of this test is to ensure the hardware functionality of the system and determine its success rate in meeting predetermined requirements. Figure 12 (a) will show a representation of the system consisting of a cooling system, control system, and a miniature storage room for powdered milk, while Figure 12 (b) shows the loading of wages for powdered milk that weights 50 grams in each pack, with there 11 packs of powdered milk in a room with a capacity of 220 liters there is an additional fan to spread the cold on the heatsink attached to the cold side of the Peltier. The loading on each test set point of the voltage that will affect the temperature is the same value so that from the difference in the set point it can be known the Peltier Sisi Dingintemperature value achieved. Table 5 will present the values and results of system hardware testing with the design that has been done.


**(a)** **(b)**

**Figure 12. (a) Realization Of Milk Powder Storage Miniature Room With A Capacity Of 220 Liters (b) Eleven Packs Of Miniature Space Milk Powder**

**Table 5. PI Control Perfomance Response**

| Initial Temperature ($^OC$) | Set Point (V) | Kp | Ki | Steady State Error (%) | Obtained Temperature ($^OC$) | Delta ΔT($^OC$) | Reach Goal? |
|---|---|---|---|---|---|---|---|
| 28.5 | 10 | 4.16 | 14.68 | 2.74 | 23.8 | 4.7 | yes |
| 28.5 | 11 | 4.58 | 16.35 | 2.72 | 23.5 | 5 | yes |
| 28.5 | 12 | 5 | 22.32 | 2.58 | 23.2 | 5.3 | yes |

In the results shown in Table 5, with an initial temperature of the storage room of 28.5 $^OC$, the 10 Volt set point test obtained a voltage steady state error value of 2.74% with a temperature supply of 23.8$^OC$ with ΔT 4.7 $^OC$, the 11 Volt set point test obtained a voltage steady state error value 2.72% with temperature traders at 23.5 $^OC$ with ΔT 5$^OC$, 12 Volt set point test gets a voltage steady state error value of 2.58% with temperature sales at 23.2$^OC$ with ΔT 5.3$^OC$. The temperature achieved in the system test meets the requirements for a powder milk storage room with a temperature of 20-25 $^OC$ **(Rawat, et al., 2022)**. Figure 13 shows the temperature response output of the cooling system, and Figure 14 shows the voltage regulation with PI control. in this study when testing the system, the power consumption required to obtain cooling at 23.2 $^{o}C$ consumes a large amount of power up to 136 watts with an average current of 11.5 amperes at 4 Peltiers. Because the cooling in the Peltier is influenced by several factors, the first is current consumption, where the greater the current consumed, the greater the cooling potential (ΔT), but the cooling is also affected by the flow of water that absorbs heat on the hot side of the Peltier, so water is sought to come out of the radiator. has a relatively low temperature of ±28 $^{o}C$, so that heat is absorbed properly and makes the Peltier work optimally. From the Peltier specifications used, a value of 3 $^{o}C$ is obtained on the cold side of the Peltier, because ΔT in the specification is 25 $^{o}C$, so the parameter that can be maximized for Peltier cooling is a constant voltage. Where the value of the voltage applied will have an impact on the value of the current flowing into the Peltier, but the resistance value in the Peltier which affects the current flowing is affected by cooling on the hot side of the Peltier.

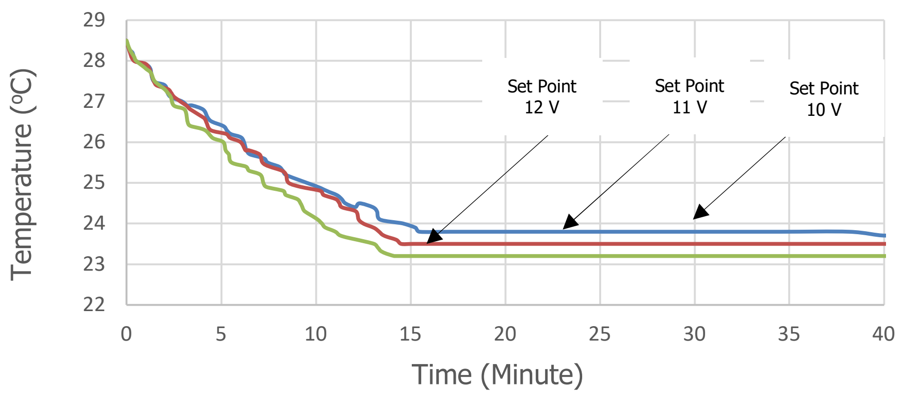


**Figure 13. Temperature Response During Integration Test**

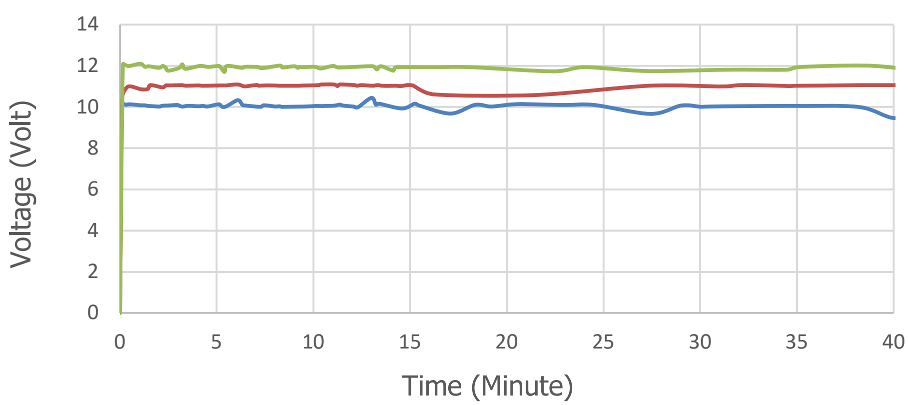


**Figure 14. Peltier Input Voltage Response**

So it refers to the transfer function in Figure 11, with modeling done on Simulink to enable the PI control analytic tuning method with the results of the bump test testing which will be used as a reference, so from these references modeling is carried out by changing the shape to the transfer function and obtaining guidelines for the selection Kp and ki values, which will be implemented in the system. So that in Figure 14 shows the system output response to the voltage regulation which will affect the current and will impact the resulting temperature for a miniature milk powder storage room with a steady state error value in the implementation of controls below 5%. As shown in Figure 13, the temperature obtained is relatively higher in proportion to the increase in the applied voltage value, the selection of the given voltage value is adjusted to the recommendations from the Peltier datasheet used.

## 4. CONCLUSION

In the final results of the study through the design of a miniature powder milk storage room using 4 Peltiers which are controlled by the buck converter voltage by loading 11 packs of powdered milk, using PI control on the input voltage setting the Peltier gets control with Kp = 5 and Ki = 22.32 at 12 Volt voltage obtained a temperature of 23.2 °C, at Kp = 4.58 and Ki = 16.35 from 11 Volts a temperature of 23.5 °C was obtained, and at Kp = 4.16 and Ki = 14.68 at 10 Volts a temperature of 23.8 °C was obtained. With an average steady-state error of 2.58%, 2.72%, and 2.74%. being able to lower the temperature of the 220-liter capacity room from 28.5 °C to a set point of 23 °C, this is following the recommendations for powdered milk storage rooms, and by enabling the buck converter to adjust the Peltier input voltage, a buck converter efficiency of 86.17% is obtained so that the implemented buck converter can work properly as planned. Changes in the Peltier input voltage value can affect the speed of temperature reduction in the mini room, but the allowable voltage for Peltier monitoring has a certain range, according to the type of Peltier used, in the bump test process on the system to obtain the transfer function on the system, which is intended to determine system characteristics, FOPDT modeling can be used as a guide for the determining features before integration, so it is hoped that the temperature setting in the mini milk powder storage room can maintain the nutrition of powdered milk and prevent microorganism contamination. Peltier is not recommended for use in large cooling capacities, because it consumes a lot of power, but it can be developed by manipulating the cooling on the hot side of the Peltier with other methods, for maximum cooling and relatively low power consumption.

## REFERENCES

Ab, R. R., Mohamad, M. A., Kaamin, M., Batcha, M. F., Mazian, M. D., Rosli, M. L., & Aziz, M. A. (2022). Experimental study of Peltier-Based Thermoelectric. *Journal of Advanced Research in Applied Mechanics*, *94*(1), 1-6.

Aguiar, R. T., de Lima, B. S., & Maia, A. T. (2022). Comparative study of tuning techniques for fractional PID controllers for FOPDT systems. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *4*(5), 1-20.

Ajangnay, M. O., & Adam, G. P. (2022). Steady-State and transient assessments of integral back-stepping current controllers in high-Voltage direct current transmission systems. *International Journal of Electrical Power & Energy System*, *142*, 108242.

Alim, M. W., Windarko, N. A., & Rakhmawati, R. (2020). Fuzzy Logic Control Design on Buck Converter for Thermo Electric Air Cooler Power Supply. *JAREE (Journal on Advanced Research in Electrical)*, *4*(2), 111-116.

Belwal, N., Kumar Juneja, P., Kumar Sunori, S., Singh Jethi, G., & Maurya, S. (2023). Modeling and Control of FOPDT Modeled Processes. *Cyber Technologies and Emerging Sciences*, 255-260.

Ichsan, A. R., Effendy, M., & Suhardi, D. (2017). Studi Analisa Synchronous Rectifier Buck Converter Untuk Meningkatkan Efisiensi Daya Pada Sistem PhotoVoltaic. *Kinetik: Game*

*Technology, Information System, Computer Network, Computing, Electronics, and Control*, *2*(3), 151-164.

Immaningsih, N. (2013). Pengaruh suhu ruang penyimpanan terhadap kualitas susu bubuk. *Jurnal Teknologi Industri Pertanian*, *7*(1), 1-5.

Kang, R., Wang, X., Zhao, M., Henihan, L. E., & O'Donnell, C. P. (2022). A comparison of benchtop and micro NIR spectrometers for infant milk formula powder storage time discrimination and particle size prediction using chemometrics and denoising methods. *Journal of Food Engineering*, *329*, 111087.

Kaplan, O., & Bodur, F. (2022). Second-order sliding mode controller design of buck converter with constant power load. *International Journal of Control*, 1-17.

Khuriati, A. (2022). FOPDT Model Based on Experimental Data from Municipal Solid Waste Incineration Process Temperature Control in Fixed Bed. *Journal of Physics and Its Applications*, *4*(2), 33-36.

Rawat, K., Kumari, A., Kumari, R., Ahlawat, P., & Ahlawat, S. C. (2022). Process optimisation using RSM and physicochemical properties during . *International Dairy Journal*, *131*, 105374.

Renner, E. (1988). Storage stability and some nutritional aspects of milk powders and ultra high temperature products at high ambient temperatures. *Journal of Dairy Research*, *55*(1), 125-142.

Shekhar, A., & Pandey, R. R. (2022). *Development of Converter Controlled Thermo-Electric Based Portable Water Purifier.* Tamil Nadu: SRM Institute of Science and Technology.

Sulaiman, A. C., Amin, N. M., Basha, M. A., Majid, M. A., bin, M. F., & Zaman. (2018). Cooling performance of thermoelectric cooling (TEC) and applications. *MATEC Web of Conferences*, (pp. 03021).

Wahyudi, M. Z., Pratama, D. W., Fitrian, A., & Setiadi, H. (2022). Temperature Control using PI Controller. *Journal of Emerging Supply Chain, Clean Energy, and Process Engineering*, *1*(1), 75-83.

Wu, Z., Yuan, J., Li, D., Xue, Y., & Chen, Y. (2021). The proportional-integral controller design based on a Smith-like predictor for a class of high order systems. *Transactions of the Institute of Measurement and Control*, *43*(4), 875-890.