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Design, Fabrication and Performance Analysis of a Peltier Module-Based CPU Cooling System

A report submitted to the Department of Mechanical, Sonargaon University of Bangladesh, in partial fulfilment of the requirements for the award of the degree of Bachelor of Science in mechanical engineering.

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APPROVAL

This is to certify that the project work entitled, “Design, Fabrication and Performance Analysis of a Peltier Module-Based CPU Cooling System” has been carried out by Sayed Shajib (ID: ME2203028269), Saiful (ID: ME2203028227), and Md. Osman Prodhan (ID: BME1503007129), Sabbir Ahamad (ID: ME2102024147), Most. Kohinur Pervin Mimi (ID: ME2203028242) thereby declared that the work presented here is original work done by me and has not been published or submitted elsewhere for the requirement of a degree of Bachelor of Science (B.Sc.) in Mechanical Engineering in the year of 2025 Program in the Department of Mechanical Engineering, Sonargaon University of Bangladesh (SU) has been carried out under by supervisor.

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DECLARATION

We do hereby solemnly declare that the work presented here in this project report has been carried out by us and has not been previously submitted to any University Organization for the award of any degree or certificate.

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ABSTRACT

This project presents the design and implementation of a Design, Fabrication and Performance Analysis of a Peltier Module-Based CPU Cooling System combined with a water-cooled heat sink for efficient thermal management. Modern CPUs generate excessive heat during continuous operation, which can affect performance, stability, and lifespan. To solve this issue, a thermoelectric cooling method is used where the Peltier module transfers heat from the CPU surface to the cooling system based on the Peltier effect. One side of the Peltier cools the CPU, while the hot side is attached to a water-cooled heat sink system to dissipate heat effectively without using any cooling fan. Water circulation through the heat sink helps in maintaining a stable and uniform temperature, improving overall heat removal efficiency. A temperature monitoring system is used to observe real-time CPU temperature and ensure safe operation. This setup provides a quiet, compact, and efficient cooling solution compared to traditional air-cooling systems. The main goal of this project is to maintain optimal CPU temperature, enhance system reliability, and prevent overheating issues in high-performance computing applications.

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LIST OF ABBREVIATIONS

SD	Storage device
LCD	Liquid crystal display
AVR	Automatic voltage regulation
IC	Internal circuit
USB	Universal Serial Bus
PWM	Pulse width modulation
AC	Alternating current
DC	Direct current
I/O	Input output
IC	Internal circuit
USB	Universal Serial Bus
SMPS	Switch Mode Power Supply
IDE	Integrated Development Environment
CPU	Central Processing Unit

CHAPTER 1

INTRODUCTION

1.1 Introduction

For the past two decades, the miniaturization of electronic devices has been the electronics industry's primary research focus. Consequently, smaller devices have higher power densities and operate at elevated temperatures, which drastically undermine their performance and reduce safety and reliability. Pedram and Nazarian reported that more than 50% of integrated circuit failures are related to thermal issues. Thermoelectric cooling can provide enhanced cooling rates and address the thermal management challenges of compact electronics. Although Peltier modules are available in the market, the current commercial external Computer cooling systems (cooler pads) do not employ them and instead rely on only a set of axial fans, which cause an inadequate decrement in CPU/GPU junction temperatures. This study aimed to develop an effective and practical TEC-based cooling system for laptop computers.

Research on the application of TECs for thermal management of electronics began with mathematical modeling of TECs and their subsequent performance assessment and optimization depending on various parameters. However, little effort has been dedicated to incorporating TECs in physically confined electronic devices such as laptops and computers. BouRabee et al. used a TEC to cool air and supply it to the fan inlet of a laptop. Temperatures of various components in the laptop and Computer were measured at several ventilation conditions, with and without the TEC in conjunction. However, since the air cooled by TEC was passed through an enclosed ducting, it resulted in a large pressure drop and thereby poor convection, resulting in only 1°C temperature drop in the GPU relative to a commercial external cooling system. Khan et al. attached a TEC directly to the CPU die, and a secondary heat pipe is used to cool the hot side of the module. The final cooling load of the secondary heat pipe is borne by the laptops and computers' existing forced convection-cooled heat sink. This restricts the TEC from operating at higher cooling capacities, and consequently, the CPU junction temperature drop witnessed was only 2.3°C as compared to the stock cooling system.

In the present study, a TEC is physically integrated with the stock cooling system, and its performance is gauged by the temperature drop produced in CPU/GPU junctions.

1.2 Problem Statement

Modern computer processors (CPUs) generate a significant amount of heat during high-speed and continuous operations. Excessive heat can lead to performance degradation, system instability, and permanent hardware damage if not properly managed. Conventional air-cooling systems that rely on fans often face limitations such as noise, inefficient heat dissipation under heavy load, dust accumulation, and reduced cooling performance over time.

Additionally, standard cooling methods may not provide sufficient temperature control for high-performance or compact systems. Therefore, there is a need for an alternative cooling solution that is more efficient, reliable, and compact.

This project addresses the problem by implementing a Peltier-based thermoelectric cooling system combined with a water-cooled heat sink, eliminating the need for traditional cooling fans. The system aims to provide better heat transfer, stable temperature control, and silent operation. However, challenges such as heat dissipation from the hot side, power consumption, and system efficiency must also be considered and optimized for effective performance.

1.3 Objectives

The objectives of this project are:

- To design and develop an efficient CPU cooling system using a Peltier (thermoelectric) module
- To reduce CPU temperature and prevent overheating during high-performance operation
- To achieve a compact and noise-free cooling solution compared to traditional air cooling

1.4 Project plan

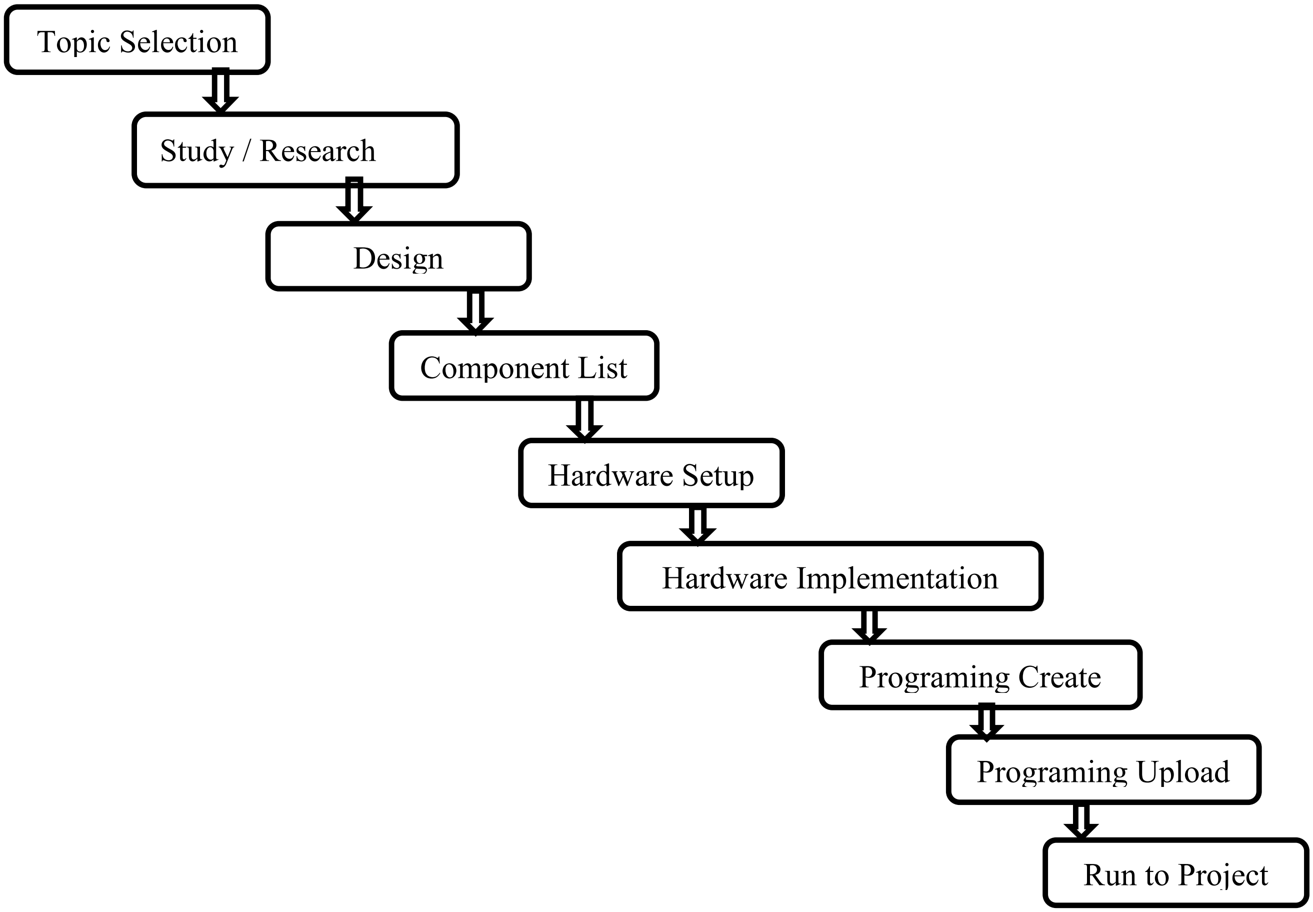

Figure 1.1 Project Implementation Chart

1.5 Methodology

Our methodology for the project:

- Design and construction of a "**Design, Fabrication and Performance Analysis of a Peltier Module-Based CPU Cooling System**" and designing a block diagram & circuit diagram to know which components are needed to construct it.
- Collecting all components and programming for the microcontroller to control the system.
- Setting all components in a PCB board & soldering. Then assembling the whole block on a board and finally running the system & checking.

CHAPTER 2

THEORY AND BACKGROUND STUDY

2.1 Introduction

This chapter presents the theoretical background of the Peltier-based CPU cooling system, including its working principles and key concepts. It also reviews previous research and existing cooling technologies. The literature review helps to understand system design improvements, efficiency challenges, and the role of thermoelectric cooling in modern CPU temperature management.

2.2 Principle of the Peltier Module

One of the connections created by the two dissimilar materials may heat up while the other cools down when an electric current passes between them. This is referred to as the Peltier effect, which is the Seebeck effect in reverse. The Peltier coefficients and the current passing through the materials determine how much heat is produced or absorbed. Thus, the Peltier effect can be employed as a silent refrigerator without any moving fluid and to pump heat from one place to another. Thermoelectric refrigerators are small, green, and safe because they don't use dangerous refrigerants. Applications for satellites, spacecraft, dehumidifiers, and fiber optics can all benefit from the Peltier effect's cooling properties.

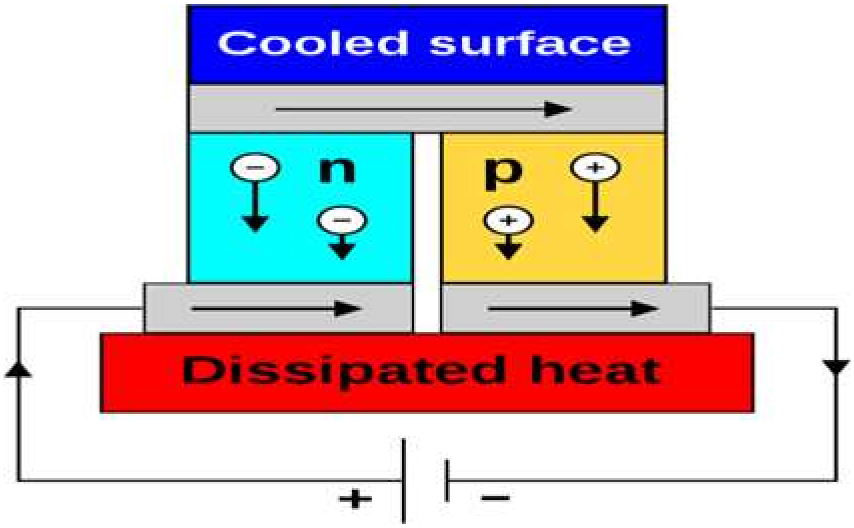

Figure 2.1 Peltier Effect

A longer lifespan and less maintenance are provided by the absence of mechanical wear and moving parts. Since no refrigerants are utilized, there is no issue with leaks. The size and shape of the thermoelectric coolers will be flexible. By regulating current, the TEC coolers offer precise control over the heat produced or dissipated. Its poor coefficient of performance and high cost for a given cooling capacity are its key drawbacks.

2.3 Peltier-Based CPU Cooler

A Peltier CPU cooler, also known as a thermoelectric cooler, is a device specifically designed to dissipate heat generated by a CPU. It utilizes the Peltier effect, discovered by Jean Charles Athanase Peltier in 1834, to create a temperature difference between two junctions when an electric current flows through two dissimilar materials. This temperature difference allows for efficient heat transfer, cooling down the CPU and preventing overheating.

The main component of a Peltier CPU cooler is the Peltier module itself. This module is made up of a set of thermoelectric materials, such as bismuth telluride, sandwiched between two ceramic plates. When an electric current is applied to the module, one side becomes cold while the other becomes hot, creating the desired temperature difference.

One side of the Peltier module, also known as the cold side, is in direct contact with the CPU heat source. This side absorbs the heat generated by the CPU, causing the thermoelectric materials to cool down. The hot side of the module, on the other hand, faces the external environment. It dissipates the absorbed heat into the surroundings using passive or active cooling methods, such as a heatsink and a fan, or even liquid cooling systems.

With the Peltier effect at work, the hot side of the Peltier module increases in temperature, while the cold side decreases in temperature. This temperature difference allows for efficient heat transfer from the CPU to the cold side, ensuring that the CPU operates within safe temperature limits.

It’s worth noting that while Peltier CPU coolers can effectively cool down CPUs, they also have some limitations. Peltier modules consume a significant amount of electrical power, as they require an electric current to operate. Additionally, Peltier coolers can create a substantial amount of heat on the hot side, which needs to be dissipated effectively to prevent temperature build-up.

2.4 Literature Review

Thermoelectric cooling technology is based on the Peltier effect, where heat transfer occurs due to electric current flow. This method is widely used for small-scale cooling applications because it has no moving parts, operates silently, and requires low maintenance. Researchers highlight that thermoelectric modules are compact and environmentally friendly compared to traditional refrigeration systems. However, their lower efficiency and high-power consumption limit large-scale use. Recent advancements in semiconductor materials have improved their performance. This study provides a foundation for applying thermoelectric cooling in CPU systems where compact and reliable cooling is required.

Modern CPUs generate localized hotspots due to uneven workload distribution. This study explains how thermoelectric coolers can directly target these hotspots for efficient cooling. By placing Peltier modules close to the heat source, rapid heat removal is possible. The research shows improved CPU performance and reduced thermal stress. However, challenges include increased energy consumption and integration complexity. The findings suggest that thermoelectric cooling is suitable for high-performance processors when combined with effective heat dissipation techniques, such as liquid cooling.

This research reviews both on-chip and off-chip thermoelectric cooling methods used in electronic devices. On-chip cooling offers fast response and localized temperature control, while off-chip systems are easier to implement. The study highlights that thermoelectric cooling has been researched for many years, but is now gaining importance due to advancements in nanotechnology. Despite its benefits, efficiency remains a major concern. The paper concludes that combining thermoelectric cooling with other cooling methods can improve overall performance in CPU applications.

This study focuses on combining thermoelectric cooling with a water-cooling heat sink. The results show that liquid cooling significantly improves heat removal from the hot side of the

Peltier module. It ensures stable operation and prevents overheating of the system. The experiment also indicates that coolant flow rate and heat exchanger design play an important role in performance. This hybrid approach is more efficient than air cooling alone and is highly suitable for CPU cooling systems.

This research analyzes a hybrid system combining thermoelectric and liquid cooling methods. The system provides rapid heat dissipation and maintains stable CPU temperature under heavy load conditions. Optimization techniques are applied to improve cooling efficiency and reduce power consumption. The study concludes that proper system design, including a heat sink and water flow control, is essential for achieving the best performance. This approach is effective for modern computing systems.

This study presents a thermoelectric cooling system designed for multicore processors. It uses multiple Peltier modules arranged in an array to cool different regions of the CPU. The system dynamically adjusts cooling based on temperature variations. Results show improved thermal management and reduced power usage. The research emphasizes the importance of smart control systems in improving cooling performance. This method is suitable for advanced CPU cooling applications.

Recent research highlights improvements in thermoelectric materials used in Peltier modules. New semiconductor materials increase efficiency and cooling capacity. These advancements make thermoelectric cooling more practical for electronic devices such as CPUs. The study also discusses design improvements and future challenges in thermoelectric systems. It suggests that continued research will enhance performance and reduce limitations.

This study explores transient cooling techniques using pulsed current in thermoelectric modules. It shows that temporary cooling below normal limits can be achieved. This method is useful for handling sudden temperature spikes in CPUs. However, continuous operation at such levels is difficult due to energy limitations. The research highlights potential improvements in cooling efficiency for short-duration high-load conditions.

This research discusses the real-world implementation of Peltier cooling systems. It shows that combining thermoelectric cooling with water cooling can achieve low temperatures effectively. However, the system requires careful design to handle heat from the hot side. High power consumption and system complexity are major challenges. The study provides practical insights into designing efficient cooling systems.

This study focuses on the limitations of thermoelectric cooling systems. It explains that low efficiency and high energy consumption are major drawbacks. The heat generated on the hot side must be properly dissipated to maintain performance. Without effective cooling, the system may fail. The study emphasizes the need for improved design and hybrid cooling techniques.

CHAPTER 3

SYSTEM ARCHITECTURE

3.1 Introduction

The project objectives, methods, Peltier Concept, literature evaluation, and other details were all clarified in the preceding chapter. The block diagram, circuit diagram, working principle, Hardware Implementation, and final project instrument cost analysis will all be covered in this chapter.

3.2 Block Design

Here is the block diagram of the "**CPU Cooling System using Peltier**" with all the essential components. All of the components are shown below as a block in this diagram. Here we use the Arduino nano Micro-controller of our project. Other equipment is attached to this microcontroller and works together to perform as our desired outcome.

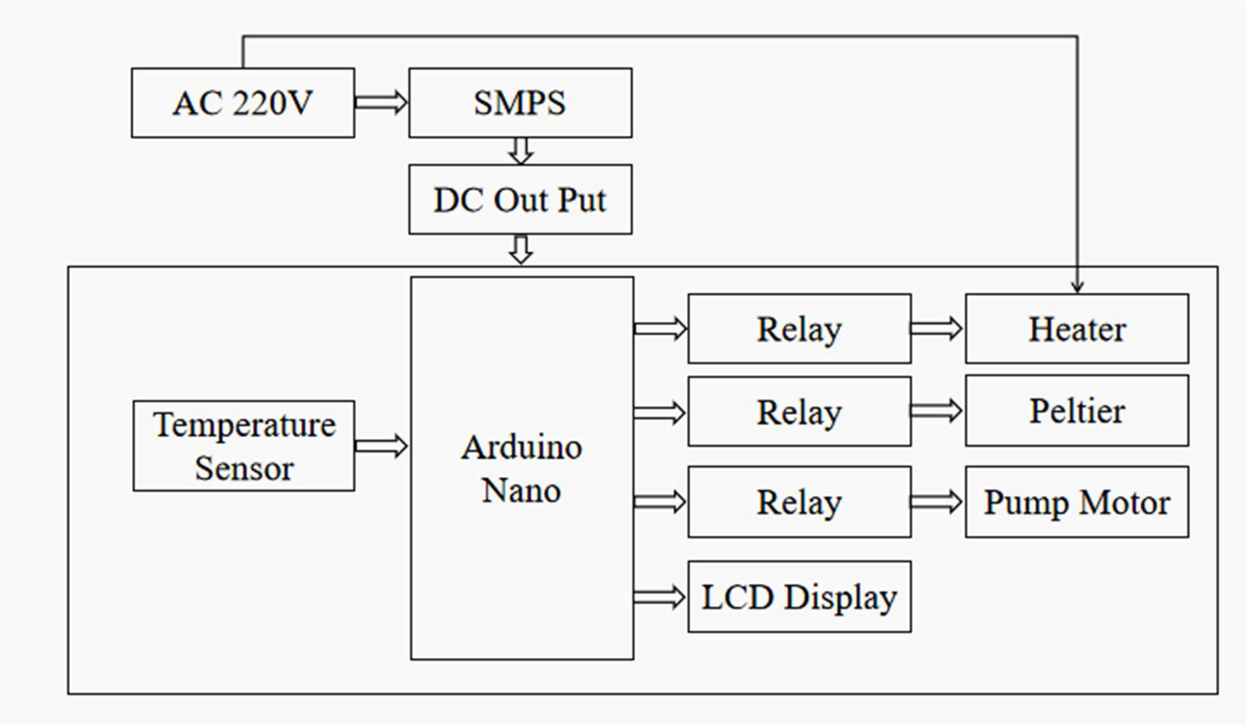

Figure 3.1: Block Diagram of CPU Cooling System using Peltier

3.3 Schematic Design

The schematic diagram here represents the electrical circuit and the components of the project. Here we have used standardized symbols and lines.

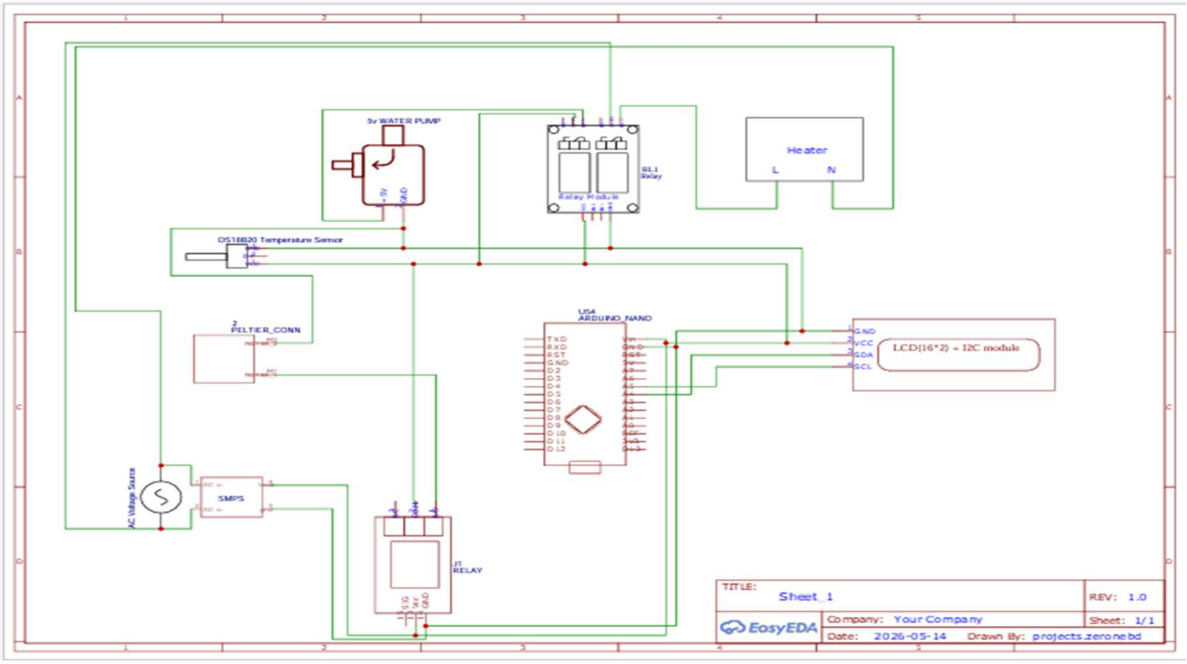

Figure 3.2: Circuit Diagram CPU Cooling System using Peltier

3.4 Working Principle

- The system is powered by an SMPS, which supplies a stable DC voltage to all components, including the Arduino Nano, Peltier module, sensors, relay, and pump motor.
- A temperature sensor continuously measures the CPU temperature and sends real-time data to the Arduino Nano, which acts as the main controller.
- The Arduino Nano processes the temperature data and displays it on the LCD for user monitoring.
- When the temperature exceeds a preset limit, the Arduino activates the relay module, which switches ON the Peltier module and pump motor.

- The Peltier module works on the thermoelectric effect: one side becomes cold (placed on the CPU) and absorbs heat, while the backside becomes hot.
- To remove this heat, a water-cooling heat sink is attached to the hot side. The pump motor circulates water through the heat sink, carrying away heat and cooling the hot surface.
- The system may also use a heater (for testing or control purposes) to simulate temperature rise.
- Once the temperature drops below the set limit, the Arduino turns OFF the relay, stopping the Peltier and pump, maintaining efficient and controlled cooling.

3.5 Project Experimental Setup

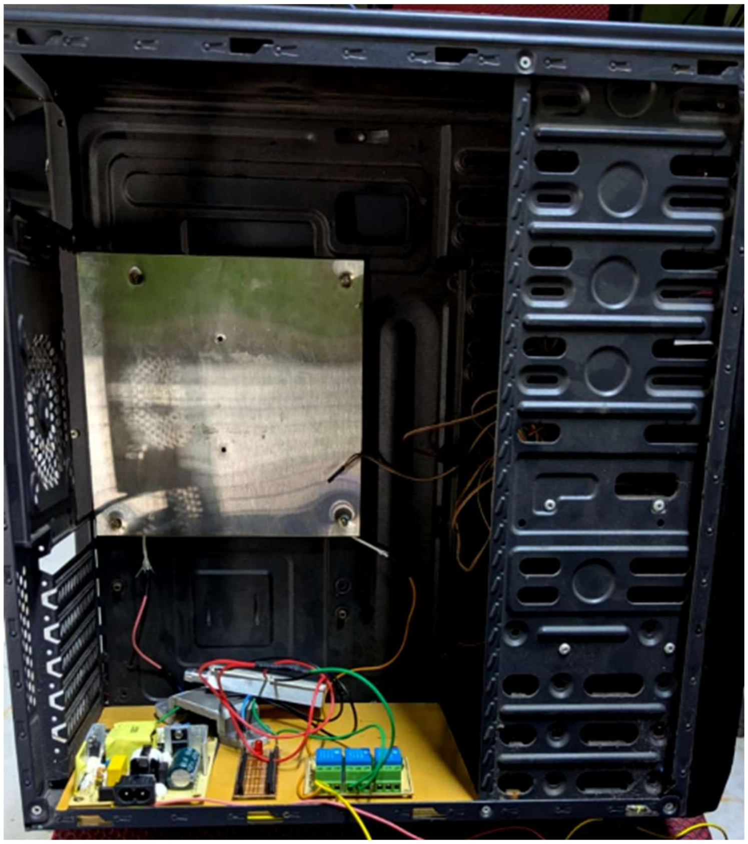

Figure 3.3: Hardware and Instrument Setup

3.6 Cost Management

Table 01: Cost Analysis

No.	Product Name	Specification	Qty. Price	Unit Price (Taka)	Total Price (Taka)
01	SMPS	5V 7Amp	1	600	600
02	Heater	220V 200W	1	700	700
03	Peltier	TEC1-12706	2	400	800
04	Water Cooling Heat Sink	Aluminium 40*80*12mm	1	600	600
05	Relay	5V	3	150	450
06	Arduino Nano	ATmega328p	1	700	700
07	LCD Display	16*2	1	450	450
08	Pump Motor	6v DC	1	250	250
09	Temperature Sensor	DS18B20	1	300	300
10	Others				2000
				Total =	6850/=

CHAPTER 4

HARDWARE AND SOFTWARE ANALYSIS

4.1 Introduction

In this section, we will discuss elaborately about “CPU Cooling System using Peltier” and the component description, features, and working procedure of all equipment. The system hardware fabricates composed of micro-controller unit, a power unit, a source unit, power store unites, a sensor unit, and many more related components.

4.2 Hardware Instrument

- SMPS
- Arduino Nano
- Peltier Module
- Water Cooling Heat Sink
- Pump Motor
- Heater
- LCD Display
- Temperature Sensor
- Relay

4.3 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high-dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply.

Figure 4.1: Switch Mode Power Supply (SMPS)

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size, or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter, where it is turned on and off at high frequencies of between 20 KZ and 200 KZ by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned on. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator, followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pinouts, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer. There are different circuit configurations known as topologies, each having unique characteristics, advantages, and modes of operation, which determine how the input power is transferred to the output. Most of the commonly used topologies, such as flyback, push-pull, half bridge, and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer, and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density

Disadvantages

- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment, such as computers, sensitive electronics, battery-operated devices, and other equipment requiring high efficiency.

Switch Mode Power Supply

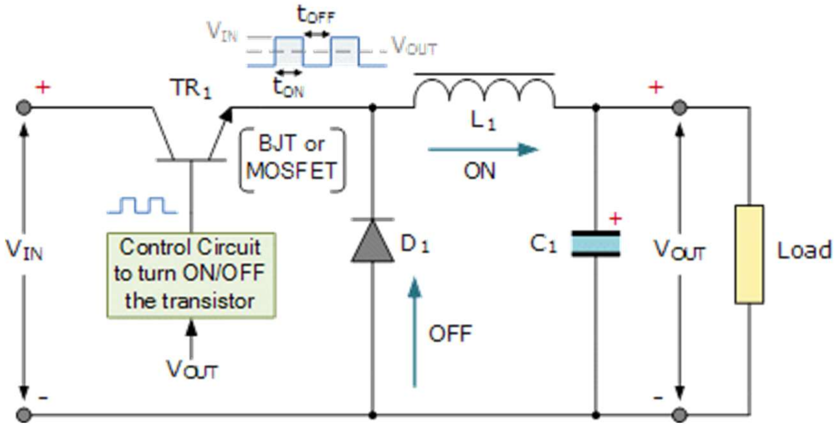

Figure 4.2: SMPS Circuit Diagram

Linear voltage IC regulators have been the basis of power supply designs for many years, as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components, such as a Zener diode and a resistor, or transistors and even op-amps. The most popular linear and fixed output voltage regulator types are, by far, the positive output voltage series and the negative output voltage series. These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits. There is a wide range of these three-terminal fixed voltage regulators available, each with its own built-in voltage regulation and current limiting circuits.

This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well, providing an output voltage that is continually variable from just above zero to a few volts below its maximum voltage output. Most D.C. power supplies comprise a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, and a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabilizer circuit, either linear or switching, to ensure the correct regulation of the power supply's output voltage under varying load conditions. Then a typical d.c. Power supply would look something like this:

Typical DC Power Supply

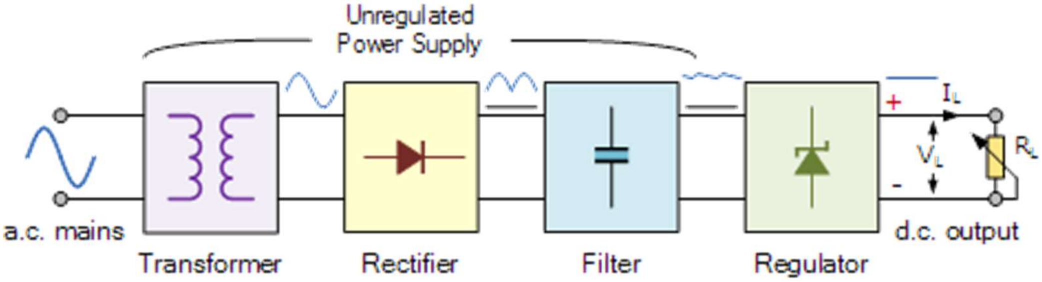

Figure 4.3: DC Power Supply

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single Zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, an output capacitor, and some feedback resistors to set the output voltage.

4.4 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long-distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

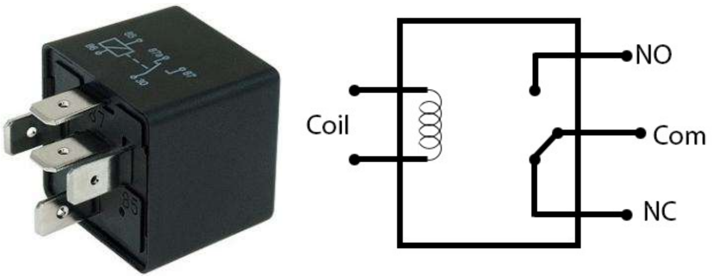

Figure 4.4: Relay

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems, these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not be able to transition the contacts.

Magnetic latching relays can have either single or dual coils. On a single-coil device, the relay will operate in one direction when power is applied with one polarity, and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil, the contacts will transition. AC-controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands.

The relay module is the one in the figure below.

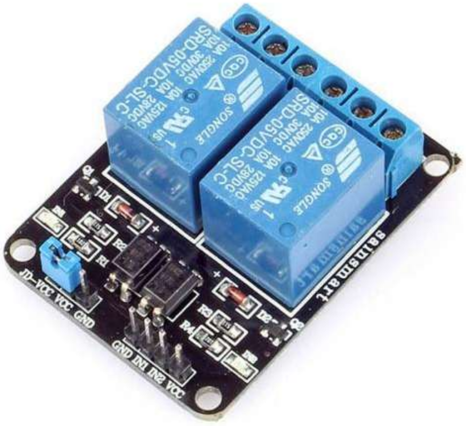

Figure 4.5: Relay Module.

This module has two channels (those blue cubes). There are other varieties with one, four, and eight channels.

Main’s voltage connections.

In relation to mains voltage, relays have 3 possible connections:

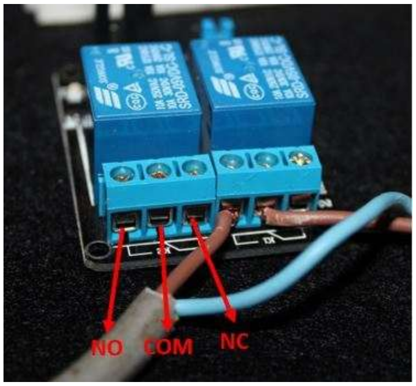

Figure. 4.6: Main’s voltage connections.

- **COM**: common pin
- **NO (Normally Open):** There is no contact between the common pin and the normally open pin. So, when you trigger the relay, it connects to the COM pin, and a supply is provided to a load
- **NC (Normally Closed):** There is contact between the common pin and the normally closed pin. There is always a connection between the COM and NC pins, even when the relay is turned off. When you trigger the relay, the circuit is opened, and there is no supply provided to a load.

Pin wiring

The connections between the relay module and the Arduino are really simple:

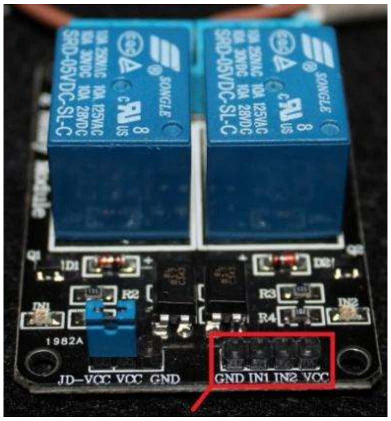

Figure 4.7: voltage connections

- **GND**: goes to ground
- **IN1**: controls the first relay (it will be connected to an Arduino digital pin)
- **IN2**: controls the second relay (it should be connected to an Arduino digital pin if you are using this second relay; otherwise, you don’t need to connect it)
- **VCC**: goes to 5V

4.5 LCD Display

The LCD (liquid crystal display) screen is an electronic display module and looks for various applications. A 16x2 LCD is a very basic module, and it is very commonly used in various devices and circuits. These modules are preferred over seven sections and many other segments.

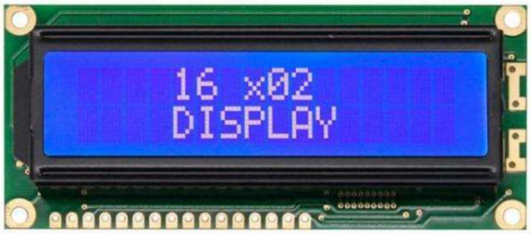

Figure 4.8: 16*2 LCD Display

The reasons for having LCD are economic; Easily programmable, special, and even custom characters (different in seven sections), there are no restrictions on displaying animations. A 16x2 LCD means it can display 16 characters per line and contains 2 lines. Each character on this LCD is displayed in a 5x7 pixel matrix.

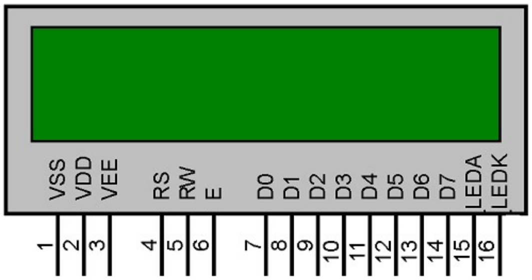

Figure 4.9: Pin out of 16*2 LCD Display

This LCD contains two articles called Command and Data. The command register stores the command instructions on the LCD. The command is a command given to the LCD to perform a predefined task, such as starting it, clearing its screen, locating the cursor, controlling the display, etc.

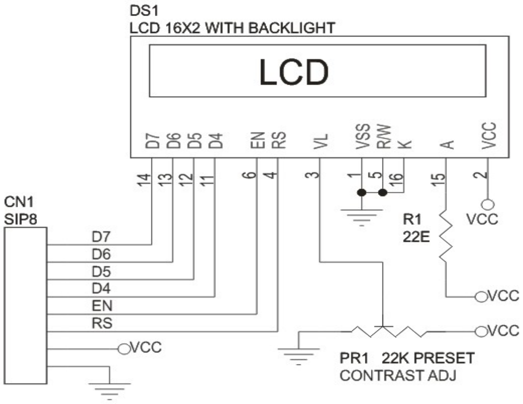

Figure 4.10: 16*2 LCD Display interfacing with Arduino

Feature

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8-pixel box
- The alphanumeric LCDs' alphabet & numbers

4.6 Arduino Nano

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling Lights, motors, and other actuators.

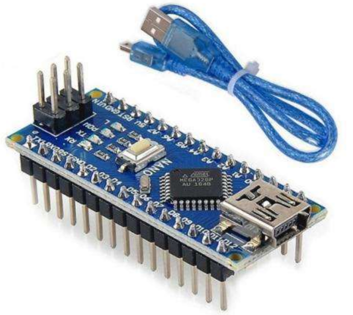

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Figure 4.11: Arduino Nano

The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone, or they can communicate with software running on a computer (e.g., Flash, Processing, MaxMSP). Arduino Nano is a surface-mount breadboard-embedded version with integrated USB. It is a small, complete, and breadboard-friendly component. It has everything that Decimal/ Duemilanove has (electrically), with more analog input pins and an onboard +5V AREF jumper. Physically, it is missing a power jack. The Nano can automatically sense and switch to the higher potential source of power.

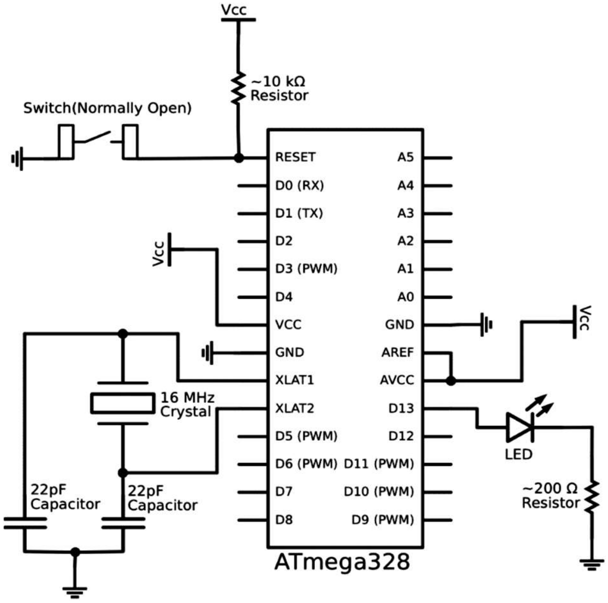


Figure 4.12: Arduino Nano Schematic Diagram

Nanos got the breadboard-ability of the Boarding and the Minibus with a smaller footprint than either, so users have more breadboard space. It's got a pin layout that works well with the Mini or the Basic Stamp (TX, RX, ATN, and GND on one top, power and ground on the other). This new version 3.0 comes with ATMEGA328, which offers more programming and data memory space. It has two layers. That makes it easier to hack and more affordable. One of the best features of Arduino Nano is that it's easy to use, compact, and small.

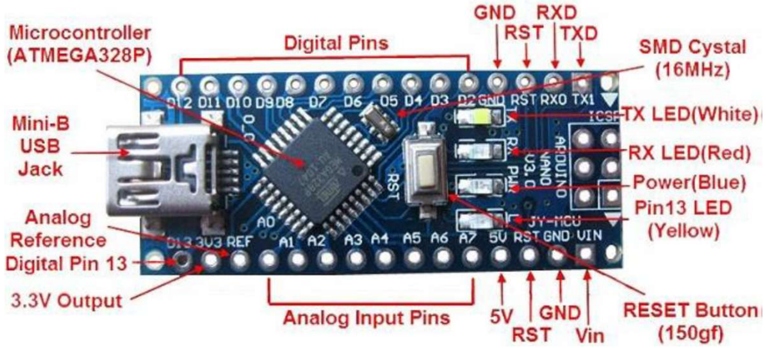


Figure 4.13: How Arduino Nano looks

Specifications

- Microcontroller: Atmel ATmega328
- Operating Voltage (logic level): 5 V
- Input Voltage (recommended): 7-12 V
- Input Voltage (limits): 6-20 V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB (of which 2KB is used by the boot loader)
- SRAM : 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz
- Dimensions: 0.70” x 1.70”

Features

- Automatic reset during program download
- Power OK blue LED
- Green (TX), red (RX), and orange (L) LED
- Auto-sensing/switching power input
- Small mini-B USB for programming and serial monitor
- ICSP header for direct program download
- Manual reset switch

4.7 Peltier Module

A Peltier cooler, heater, or Thermoelectric heat pump is a solid-state active heat pump that transfers heat from one side of the device to the other, with the consumption of electrical energy, depending on the direction of the current.

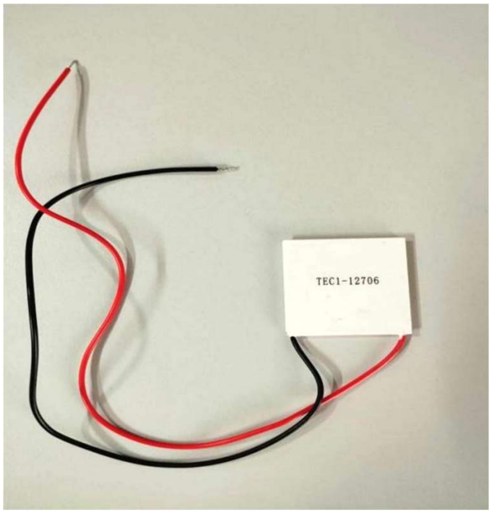


Figure 4.14: Peltier Module

The TEC1-12706 40x40mm Thermoelectric Cooler 0~6A Peltier Module is the simple application of the Peltier Thermoelectric Effect. Thermoelectric coolers, also known as TEC or Peltier modules, create a temperature differential on each side. One side gets hot, and the other side gets cool. Therefore, they can be used to either warm something up or cool something down, depending on which side you use. You can also take advantage of a temperature differential to generate electricity.

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series, and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors, there is a flow of DC across the junction of the semiconductors, causing a temperature difference. The side with the cooling plate absorbs heat, which is then moved to the other side of the device, where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs, are typically connected side by side and sandwiched between two ceramic plates.

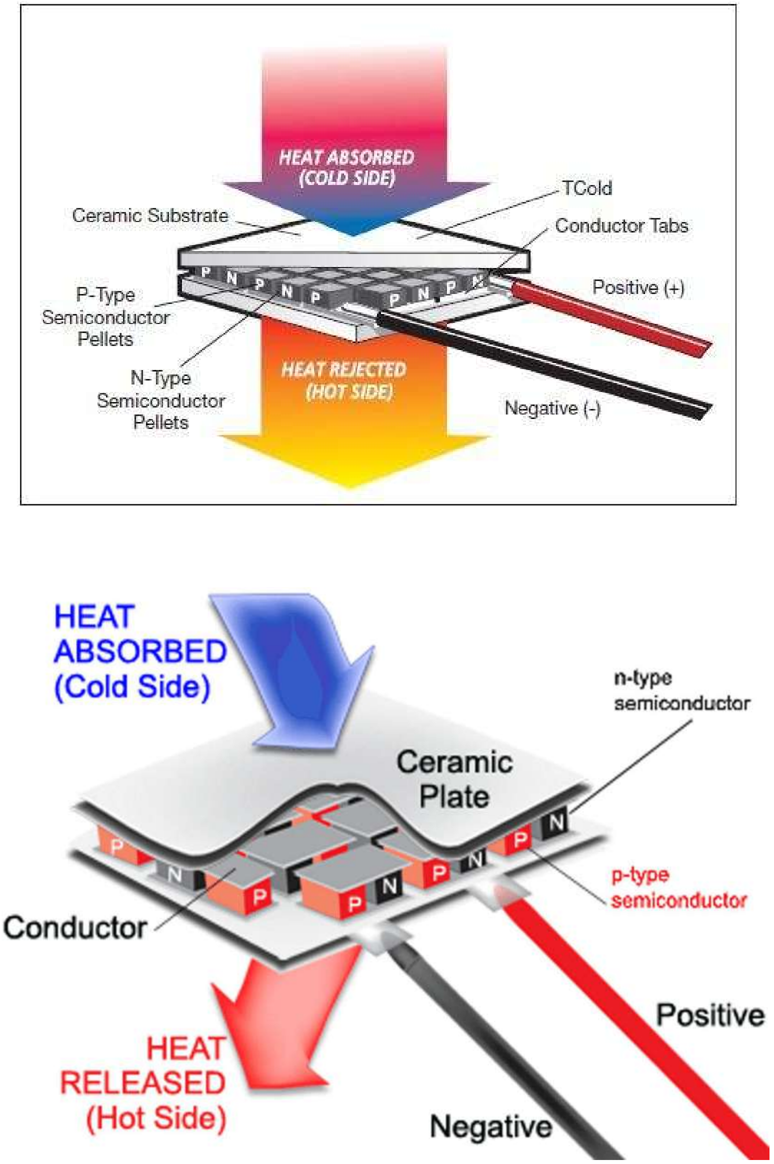


Figure 4.15: Construction of Peltier

The cooling ability of the total unit is then proportional to the number of TECs in it. This Peltier works very well as long as you remove the heat from the hot side. After turning on the device, the hot side will heat quickly, and the cold side will cool quickly. If you do not remove the heat from the hot side (with a heat sink or other device), the Peltier will quickly reach stasis and do nothing. We recommend using an old computer CPU heatsink or another block of metal to pull heat from the hot side. We were able to use a computer power supply and CPU heat sink to make the cold side so uncomfortable that we could not hold our finger to it. A Thermoelectric cooling (TEC) module is a semiconductor-based electronic component that functions as a small heat pump. By applying the DC power source to a TEC, heat will be transferred from one side of the module to the other. It creates a cold and a hot side. They are widely used in industrial areas, for example, computer CPUs, CCDs, portable refrigerators, medical instruments, and so on. Also known as Thermoelectric cooling modules, Thermoelectric modules, Peltier modules, Thermoelectric cooling module.

Features

- Small module.
- Easy transition between the hot side and the cool side and vice versa, just by reversing the polarity of the supply.
- Quality-tested cooling cells.
- Solid state, vibration-free, noise-free.
- Simple to install and operate.
- Should be used with a heat sink.

4.8 Water Cooling Heat Sink

A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light-emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.

Figure 4.16: Water Cooling Heat Sink

Features

- Aluminum Water Cooling Block for CPU Heat sink Cooler Peltier Plate 80x40x12mm
- Internal flow channel extrusion forming
- Brazing parts into a whole
- Leak rate of less than 5X10-6 mbar.l/s parts
- Internal fin thickness 0.5MM
- Connection: 9 mm ID tubes
- Processing: vacuum aluminum brazing
- Surface treatment: silver oxidation
- Applicable to computer CPU water, industrial inverter driver, laser head cooling, industrial control cabinet cooling, and Thermoelectric Cooler
- Size:80 (D) x 40 (W) x 12 (H) MM

4.9 Pump Motor

This is a low-cost, small-sized Submersible Pump Motor which can be operated from a 2.5 ~ 6V power supply. It can take up to 120 liters per hour with very low current consumption of 220mA. Just connect the tube pipe to the motor outlet, submerge it in water, and power it. Make sure that the water level is always higher than the motor. A dry run may damage the motor due to heating, and it will also produce noise.

Figure 4.17: Pump Motor

Features

- Operating Current: 130 ~ 220mA
- Flow Rate: 80 ~ 120 L/H
- Maximum Lift: 40 ~ 110 mm
- Continuous Working Life: 500 hours
- Driving Mode: DC, Magnetic Driving
- Material: Engineering Plastic
- Outlet Outside Diameter: 7.5 mm
- Outlet Inside Diameter: 5 mm

4.10 Heating Plate

The aluminum heating plates are commonly used for small-scale heating applications. Each plate features a flat metal surface designed to distribute heat evenly when powered. The plates are equipped with insulated wire terminals with ring connectors, allowing easy electrical connections to an AC power source, typically 220V. A mounting hole is provided on each plate for secure placement within a system, such as inside a heating chamber. These plates are ideal for projects like the Bottle Heating and Cooling System, where direct surface contact is needed to efficiently transfer heat to a container, such as an aluminum bottle. Their compact design, durability, and stable heat output make them suitable for domestic, DIY, and low-power industrial heating solutions.

Figure 4.18: Heating Plate

Features

- **Material:** Made of high-quality aluminum for fast and even heat conduction.
- **Voltage Rating:** Operates typically at AC 220V, suitable for standard power sources.
- **Flat Surface:** Ensures uniform heat distribution across the contact area.
- **Compact Design:** Small and lightweight, ideal for compact heating systems.
- **Mounting Hole:** Built-in hole for easy installation and secure mounting.
- **Wire Connectors:** Comes with insulated wires and ring terminals for safe electrical connections.
- **Quick Heating:** Heats up quickly, making it efficient for small-scale applications.
- **Durable Build:** Resistant to corrosion and high temperatures.
- **Low Maintenance:** Simple structure with minimal upkeep requirements.

4.11 Waterproof Temperature Sensor

This product is the waterproof version of the DS18B20 temperature sensor, specifically designed for temperature measurements in distant or humid environments. This temperature & humidity sensor has a wide temperature range of -55°C to 125°C, but we recommend keeping the included PVC jacketed cable below 100°C to ensure optimal performance and durability.

The DS18B20 waterproof temperature sensor is a digital sensor that maintains signal integrity even over long distances. It utilizes a 1-Wire interface, connecting to a central microprocessor through a single wire (along with a ground wire). This design simplifies installation and connection, making it particularly suitable for systems operating within the 3V~5.5V range. Each DS18B20 temperature sensor has a unique silicon serial number, useful for verifying its authenticity and enabling the connection of multiple sensors on a single 1-Wire bus. This feature facilitates the installation of temperature sensors in various locations for applications like indoor temperature monitoring, smart home integration, object temperature detection, greenhouse farming, and more.

Figure 4.19: Waterproof Temperature Sensor

Features

- The probe is based on the DS18B20 chip.
- High-quality stainless steel tube encapsulation waterproof moisture proof prevent rust.
- Stainless steel shell 6*50mm.
- Power supply range: 3.0V to 5.5V.
- Operating temperature range: -55°C to +125°C (-67°F to +257°F).
- Storage temperature range: -55°C to +125°C (-67°F to +257°F).
- Accuracy over the range of -10°C to +85°C: ±0.5°C.
- No other components required, working directly with the One Wire data protocol.
- Output lead: red (VCC), yellow(DATA), black(GND).
- Cable length: 50 cm.

4.12 Software

- Arduino Software IDE
- Easy EDA

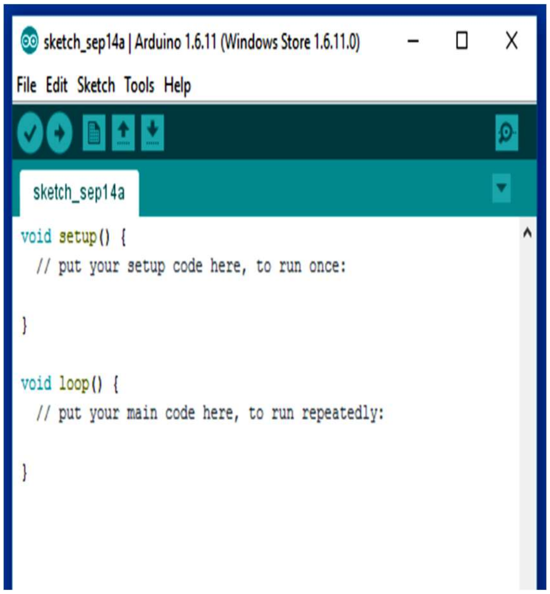
4.13 Arduino Software IDE

The digital microcontroller unit named Arduino Nano can be programmed with the Arduino software IDE. There is no requirement to install any other software other than Arduino. Firstly, select "Arduino Nano from the Tools, Board menu (according to the microcontroller on our board). The IC used, named ATmega328 on the Arduino Nano, comes pre-burned with a boot loader that allows us to upload new code to it without the use of an external hardware programmer.

Communication is using the original STK500 protocol (reference, C header files). We can also bypass the boot loader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header. The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. On Rev2 or later boards, there is a resistor that pulls the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode. The Arduino Nano is one of the latest digital microcontroller units and has several facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL at (5V) with serial communication, which is available on digital pins 0 (RX) for receiving data and pin no.1 (TX) for transmitting data. An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual COM port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .in file is required. The Arduino software includes a serial monitor, which allows simple textual data to be sent to and from the Arduino board.

The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial Communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Nano's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. Arduino programs are written in C or C++, and the program code written for Arduino is called a sketch. The Arduino IDE uses the GNU tool chain and AVR Lab to compile programs, and for uploading the programs it uses argued. As the Arduino platform uses Atmel micro-controllers, Atmel's development environment, AVR Studio or the newer Atmel Studio, may also be used to develop software for the Arduino.



```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Figure 4.20: Arduino Software Interface IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

Writing Sketches

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ion. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting, and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

Upload Using Programmer

This will overwrite the boot loader on the board; you will need to use Tools > Burn Boot Loader to restore it and be able to upload to the USB serial port again. However, it allows you to use the full capacity of the Flash memory for your sketch. Please note that this command will NOT burn the fuses. To do so, a Tools -> Burn Boot Loader command must be executed.

Sketchbook

The Arduino Software (IDE) uses the concept of a sketchbook: a standard place to store your programs (or sketches). The sketches in your sketchbook can be opened from the File > Sketchbook menu or from the Open button on the toolbar. The first time you run the Arduino software, it will automatically create a directory for your sketchbook. You can view or change the location of the sketchbook from within the Preferences dialog. Beginning with version 1.0, files are saved with a .ino file extension. Previous versions use the .pde extension. You may still open .pde named files in version 1.0 and later, the software will automatically rename the extension to .ino.

Tabs, Multiple Files, and Compilation

Allows you to manage sketches with more than one file (each of which appears in its own tab). These can be normal Arduino code files (no visible extension), C files (.c extension), C++ files (.cpp), or header files (.h).

Uploading

Before uploading your sketch, you need to select the correct items from the Tools > Board and Tools > Port menus. The boards are described below. On the Mac, the serial port is probably something like /dev/tty.usbmodem241 (for an Uno or Mega2560 or Leonardo) or /dev/tty.usbserial-1B1 (for a Duemilanove or earlier USB board), or /dev/tty.USA19QW1b1P1.1 (for a serial board connected with a Key span USB-to-Serial adapter). On Windows, it's probably COM1 or COM2 (for a serial board) or COM4, COM5, COM7, or higher (for a USB board) - to find out, you look for a USB serial device in the ports section of the Windows Device Manager. On Linux, it should be /dev/ttyACMx, /dev/ttyUSBx, or similar. Once you've selected the correct serial port and board, press the upload button in the toolbar or select the Upload item from the Sketch menu. Current Arduino boards will reset automatically and begin the upload. With older boards (pre-Decimal) that lack auto-reset, you'll need to press the reset button on the board just before starting the upload. On most boards, you'll see the RX and TX LEDs blink as the sketch is uploaded. The Arduino Software (IDE) will display a message when the upload is complete or show an error.

When you upload a sketch, you're using the Arduino boot loader, a small program that has been loaded onto the microcontroller on your board. It allows you to upload code without using any additional hardware. The boot loader is active for a few seconds when the board resets; then it starts whichever sketch was most recently uploaded to the microcontroller. The boot loader will blink the on-board (pin 13) LED when it starts (i.e., when the board resets).

Libraries

Libraries provide extra functionality for use in sketches, e.g., working with hardware or manipulating data. To use a library in a sketch, select it from the Sketch > Import Library menu. This will insert one or more #include statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its #include statements from the top of your code.

There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library Manager. Starting with version 1.0.5 of the IDE, you can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library.

Third-Party Hardware

Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions (which appear in the board menu), core libraries, boot loaders, and programmer definitions. To install, create the hardware directory, then unzip the third-party platform into its own subdirectory. (Don't use "Arduino" as the sub-directory name, or you'll override the built-in Arduino platform.) To uninstall, simply delete its directory.

For details on creating packages for third-party hardware, see the Arduino IDE 1.5 3rd party Hardware specification.

Serial Monitor

This displays serial sent from the Arduino or Genuino board over USB or serial connector. To send data to the board, enter text and click on the "send" button or press enter. Choose the baud rate from the drop-down menu that matches the rate passed to Serial. Begin in your sketch. Note that on Windows, Mac, or Linux, the board will reset (it will rerun your sketch) when you connect with the serial monitor. Please note that the Serial Monitor does not process control characters; if your sketch needs complete management of the serial communication with control characters, you can use an external terminal program and connect it to the COM port assigned to your Arduino board. You can also talk to the board from Processing, Flash, MaxMSP, etc (see the interfacing page for details).

4.14 Easy EDA Software

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share publicly and privately, and discuss schematics, simulations, and printed circuit boards. Other features include the creation of a bill of materials, Gerber files, pick and place files, and documentary outputs in PDF, PNG, and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits, and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

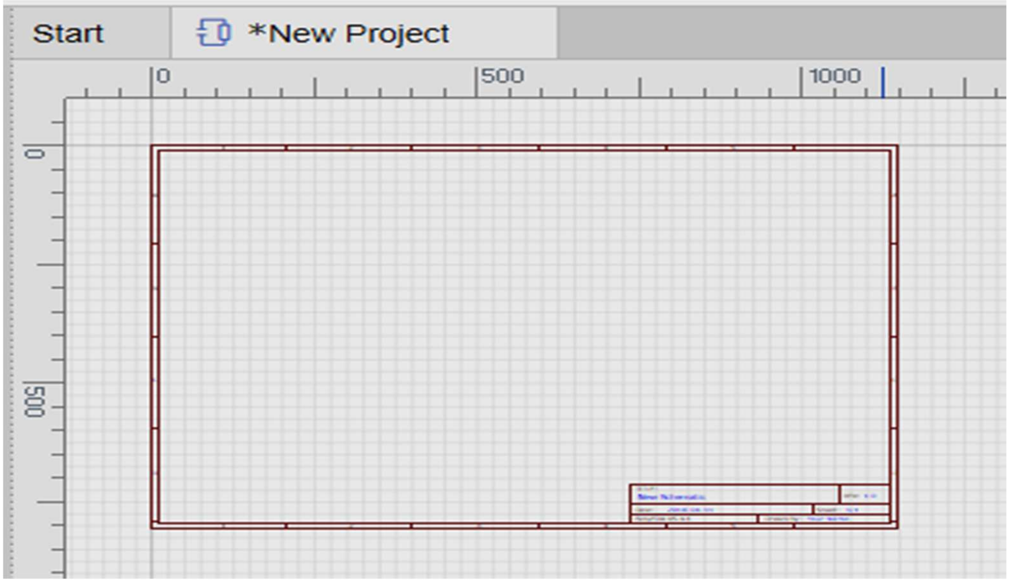


Figure 4.21: Easy EDA Software Interface

Subscription-free membership is offered to the public, plus a limited number of private projects. The number of private projects can be increased by contributing high-quality public projects, schematic symbols, and PCB footprints, and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge, but for a fee, EasyEDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third-party tools.

CHAPTER 5

RESULT AND DISCUSSION

5.1 Data Analysis

Peltair Key Specifications:

Model	TEC1-12706
Dimensions	40x40x4 mm
Operating Voltage	12V DC
Maximum Current	6A
Power	~60W
Weight	0.027 kg
Specific Heat(J/Kg-K)	154.4

[11]

Reading	
Time(Second)	**Temperature(Celcious)**
0	39.7
30	36.2
60	34.1

Temperature Difference (Δt)= (39.7-34.1) ℃ = 5.6 K
Total time, t = 60 Second.
Steel plate dimension= 17.8 cm ×17.5 cm ×0.4 cm

Volume of steel plate = (0.178×0.175×0.004) m^3
= 0.0001246 m^3

Density of steel, ρ = 7850 kg/m^3
Mass of steel plate, m = v×ρ
= 0.0001246 × 7850 kg
= 0.97811 kg

Specific Heat of steel, C_P = 500 J/kg-K
= 0.5 kJ/kg-K

Amount of Heat Energy Transferred $Q = m \times C_P \times \Delta t$
= 0.97811 × 0.5 × 5.6 kJ
= 2.7387 kJ

Rate of Heat Energy Transferred $= 2.7387 \div 60$ kW (Q/t)
$= 0.0456$ kW

Power consumption (Peltair), p_p $= V \times I$
$= 12 \times 6$ W
$= 72$ W
$= 72 \times 2$ W (number of peltair 02)
$= 144$ W
$= 0.144$ kW

Power consumption (pump-motor), p_{pm} $= V \times I$
$= 6 \times 1.5$ W
$= 9$ W
$= 0.009$ kW

Total Power consumption , p_t $= p_p + p_{pm}$
$= 0.144 + 0.009$ kW
$= 0.153$ kW

The Coefficient of Performance $(COP)_{peltair} = \frac{Q}{P}$
$= \frac{0.0456}{0.144}$
$= 0.316$

Peltair (model:TEC1-12706) cop range= 0.3 to 0.7 [12]

The Coefficient of Performance $(COP)_{total} = \frac{Q}{P}$
$= \frac{0.0456}{0.153}$
$= 0.298$

Project Outcome

Our project is a Three-Phase Transmission Line Fault Detection System. In our project making we used PVC boards for the total hardware making. After finally completing this project, we ran it & we observed the output of this project. We can see that it is working well as expected. After making our project, we observe it very carefully. It works as we desire. Our project gives output perfectly, and all the equipment works perfectly.

- The system successfully reduced CPU temperature compared to
- normal conditions, showing effective cooling performance.

- The Peltier module provided rapid cooling on the CPU surface, maintaining a stable temperature during operation.
- The water-cooling heat sink efficiently removed heat from the hot side of the Peltier, improving overall system efficiency.
- The system operated without any cooling fan, resulting in silent operation and reduced noise.
- The temperature sensor and LCD provided accurate real-time temperature monitoring.
- The Arduino Nano with relay control ensured automatic switching, improving system control and safety.
- Continuous water circulation using a pump motor maintained uniform cooling and prevented overheating.
- The system demonstrated compact design and suitability for small-scale CPU cooling applications.
- However, the higher power consumption of the Peltier module was observed as a limitation.

Overall, the project proved that a Peltier-based water-cooling system is an effective alternative to conventional air-cooling methods.

5.2 Advantages

There are certainly many advantages of our project, and some of the major ones have been given below:

- Provides efficient and fast cooling of the CPU
- Silent operation (no cooling fan used)
- Compact and lightweight design
- Better heat dissipation using water cooling heat sink
- Automatic temperature control with Arduino
- Real-time temperature monitoring using LCD
- Reduces the risk of CPU overheating and damage
- Less maintenance compared to air cooling (no dust issue)y

5.3 Applications

Our project has many application areas. Some of the application areas of the project have been pointed out below:

- High-performance desktop computers, laptops, and gaming PCs
- Industrial control systems and automation panels
- Electronics testing and research laboratories
- Medical and precision electronic equipment

5.4 Limitations

Though this project has many advantages, it has some limitations as well, and they are listed below

- High power consumption of the Peltier module
- Risk of water leakage in the system
- The initial setup cost can be higher
- Not suitable for large-scale or heavy-duty cooling without optimization
- It cannot detect gas leaks

5.5 Discussion

While working on our project, we did face some difficulties as it is a very complex system, but the results we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involve improvement in system design and wiring, and adding features for more efficiency.

This project demonstrates an alternative approach to CPU cooling by integrating a Peltier module with a water-cooling heat sink system. The results show that effective temperature reduction can be achieved without using a conventional cooling fan, ensuring silent operation. The use of water circulation improves heat dissipation from the hot side of the Peltier, enhancing overall efficiency. However, the system also highlights challenges such as high-power consumption and the need for proper insulation to prevent condensation. Careful design of the heat sink and water flow system is essential. Overall, the project proves that thermoelectric cooling is a viable solution for compact and controlled cooling applications.

CHAPTER 6

CONCLUSION

6.1 Conclusion

This project successfully develops a smart and reliable three-phase line fault detection system with Fire Safety and GSM Notification. It is capable of detecting various faults such as line-to-line, earth fault, under-voltage, and open/short circuit conditions in real-time. The integration of a flame sensor enhances safety by automatically tripping the system during fire hazards, preventing serious damage.

The use of a box-based method helps in identifying the fault location and reducing troubleshooting time. Additionally, the GSM module ensures instant communication by sending SMS alerts with fault details and location, enabling quick response from maintenance personnel.

Although the system has some limitations in large-scale applications, it proves to be a cost-effective and efficient solution for small to medium-level power systems. Overall, the project improves system safety, reduces downtime, and enhances reliability, making it highly useful for modern electrical protection systems.

6.2 Future Scope

We are thinking about adding many features to our project in the future to get more desirable outcomes. Some of the steps that we are thinking about taking are given below:

- In the future, develop an extra power system (including renewable energy).
- In future development, this project can be developed with more sensors (Temperature & Gas Sensor).
- In the future, develop wireless communication for remote monitoring and control.
- In the future, develop an Android Phone IoT System
- In the future, I will try to apply it in the real field.

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