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RESEARCH ARTICLE
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IoT-based Smart Storage System Using Peltier Technology

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ABSTRACT

Cold storage is an essential component in the food industry to maintain the quality and safety of perishable goods. However, traditional cold storage systems have certain drawbacks, including high energy consumption, environmental concerns, and maintenance issues. To overcome these challenges, this paper proposes a Smart Cold Storage System with Peltier technology and IoT. The proposed system utilizes Peltier modules, DHT11 sensors, and Load cell sensors with HX711 to monitor the temperature, humidity, and weight of the stored goods. A custom-built IoT app is also developed to remotely monitor and control the storage conditions of cold storage. The proposed system provides a cost-effective and sustainable solution for cold storage needs while also addressing the challenges of traditional cold storage systems.

Keywords: *Peltier, IoT, DHT11, HX711*

INTRODUCTION

Cold storage systems are an integral part of the food industry, providing a means to preserve perishable goods for extended periods of time. Traditional cold storage systems use compressors and refrigerants to maintain a stable temperature inside the storage unit. However, these systems can be energy-intensive and have a negative impact on the environment. Moreover, traditional cold storage systems lack the ability to monitor and control the temperature and humidity levels inside the unit, which can result in spoilage and waste of food products.

The use of cold storage systems has become increasingly important in many industries, including food and pharmaceuticals, as these systems help to maintain the quality and safety of stored products.

[1] presents a GSM-based cold storage design for potato crops, while [2] discusses a Peltier-based temperature controller for MOS dosimeter characterization. [3] explores cold thermal energy storage for reliable ship cooling, and [4] provides a review of positive cold energy storage technologies for air conditioning. [5] proposes fuzzy control of Peltier-based thermal chambers for reliability tests, and [6] introduces an ETC-Cold Room for fruit preservation. [7] presents a novel design for a dual-powered automatic Peltier effect cooler, and [8] is an IoT system for monitoring aeroponic chamber temperatures. [9] is a design for thermoregulation of clothing using Peltier elements, and [10] is a portable solar-powered thermoelectric refrigerator

for insulin storage. [11] proposes an operator-based tracking controller design for a perturbed Peltier refrigeration system, while [12] introduces a smart cooling system for milk transportation in rural areas. [13] describes a weight detection system using IoT flooring, and [14] introduces an enhanced thermoelectric collaborative cooling system. [15] proposes active thermal management of high-power LED using thermoelectric coolers, and [16] presents an optimum strategy for controlling the Peltier device's cold side temperature. Finally, [17] presents an IoT-based grain storage monitoring system with an Android application.

Description of the Peltier

In this project, we use TEC 12706 which is a type of Peltier thermoelectric cooler that is commonly used for temperature control in electronic devices and scientific applications. It consists of a ceramic plate that is sandwiched between two thermoelectric modules, which are made of semiconductor materials.

When an electrical current is passed through the thermoelectric modules, a temperature difference is created across the ceramic plate, with one side becoming cooler and the other side becoming warmer. This effect is known as the Peltier effect, and it is what allows the TEC 12706 to be used as a cooler or a heater, depending on the direction of the electrical current.

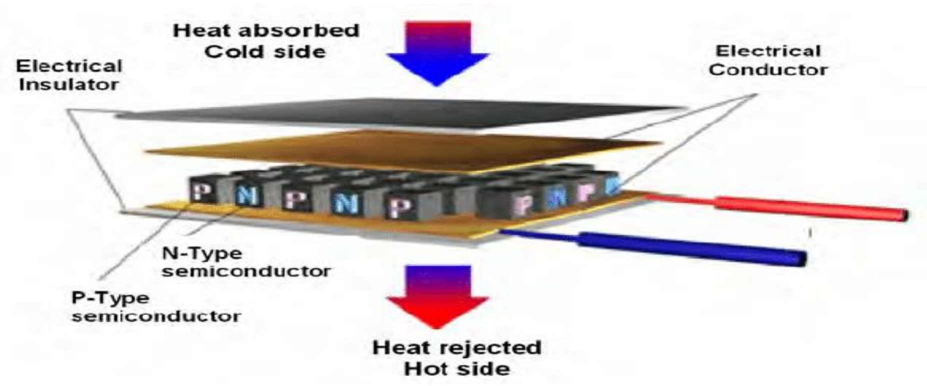

FIG 1: Peltier Module

The performance of the TEC 12706 is determined by several factors, including the size and material of the thermoelectric modules, as well as the temperature difference across the ceramic plate.

Cooling capacity: The cooling capacity of the TEC 12706 can be calculated using the following equation:

$$Qc = (\text{Peltier Coefficient}) \times I \times \Delta T$$

where Qc is the cooling capacity in watts, Peltier Coefficient is the coefficient of performance of the thermoelectric modules, I refer to the electrical current in amperes, and ΔT is the temperature difference across the TEC in Kelvin.

Heat load: The heat load on the TEC 12706 can be calculated using the following equation:

$$Qh = m \times Cp \times \Delta T$$

where Qh is the heat load in watts, m is the mass of the object being cooled in kg, Cp is the specific heat capacity of the object being cooled in J/(kg.K), and ΔT is the temperature difference between the object and the desired temperature in Kelvin.

Power consumption: The power consumption of the TEC 12706 can be calculated using the following equation:

$$P = V \times I$$

where P is the power consumption in watts, V is the voltage applied to the TEC in volts, and I is the electrical current in amperes.

The maximum temperature difference that can be achieved by the TEC 12706 is limited by the maximum current and voltage that can be applied to the thermoelectric modules, as well as the thermal resistance of the ceramic plate. Therefore, the performance of the TEC 12706 is highly dependent on the design and operating conditions of the device in which it is used.

METHODOLOGY

The Smart Cold Storage System uses a Peltier module for cooling instead of traditional refrigeration technology. The objective of this project is to design and develop a smart cold storage system that utilizes Peltier technology and IoT to maintain the optimal temperature and humidity for perishable items. The system will use a combination of the Peltier module, DHT11 sensor, and Load cell sensor with HX711 to accurately monitor and control the temperature and weight of the stored items. The project will also include a custom-built mobile application that allows users to remotely monitor the storage conditions and receive real-time alerts and notifications in case of any abnormalities.

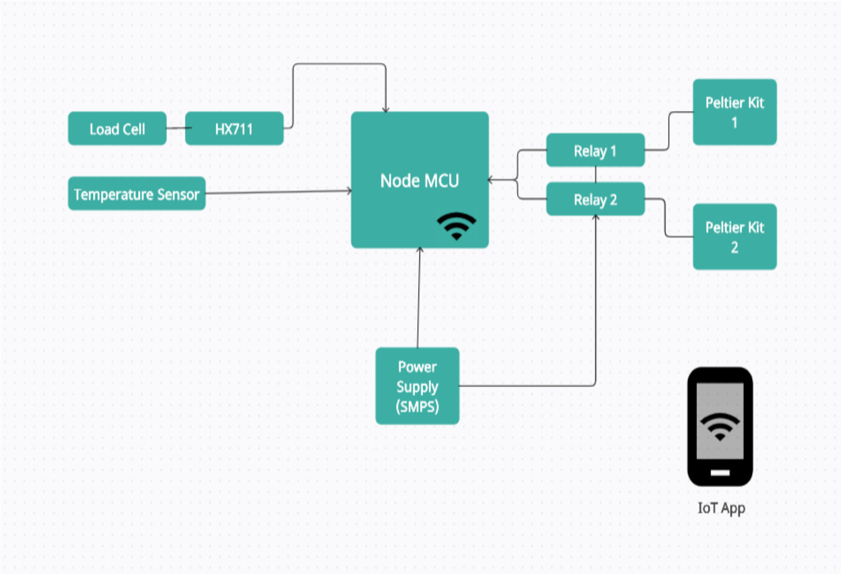

FIG 2: Block Diagram

Fig.2 shows the block diagram that explains the hardware components used in the project. The list of the modules and their configurations are detailed below.

NodeMCU

NodeMCU is an open-source IoT development board based on the ESP8266 WiFi module. It has Lua-based firmware and can be programmed using the Arduino IDE. Its configurations include 4MB flash memory, WiFi connectivity, and GPIO pins for interfacing with sensors and actuators. It can also be used as a standalone device or as a WiFi-enabled module to connect with other devices in a network.

Load cell with HX711

A load cell with HX711 is a type of sensor used to measure weight or force. It consists of a load cell, which converts mechanical force into electrical signals, and an HX711 module, which amplifies and digitizes the signals. The HX711 module has two input channels, allowing for dual-load cell configurations, and can communicate with microcontrollers such as Arduino through digital interfaces. The load cell with HX711 is commonly used in industrial and commercial applications such as weighing scales, process control, and automation.

DHT11

The DHT11 is a digital temperature and humidity sensor module. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and provides the data through a digital signal on a single data pin. The sensor is compact and easy to use, with a voltage range of 3-5V and a humidity range of 20-80% RH with an accuracy of +/- 5% RH. The sensor can be configured with a microcontroller such as Arduino, and the data can be read using a simple library.

Relay

A relay module is an electronic component that allows you to control high-power circuits with low-power signals. It typically includes a relay switch and a driver circuit that operates the switch. Some common configurations include single or multiple relay modules and options for controlling voltage and current levels. Relay modules are commonly used in industrial automation, robotics, and home automation applications.

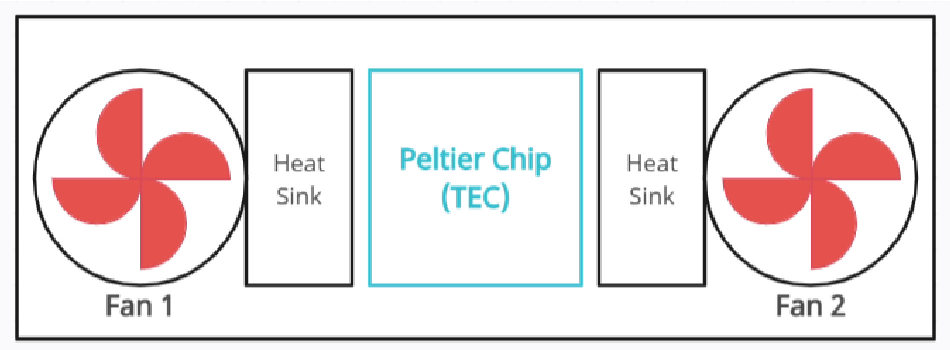

FIG 3: Peltier cooling kit

Peltier Cooling Kit

Fig.3 explains a Peltier cooling kit with TEC 12706 is a thermoelectric cooling device that uses the Peltier effect to create a temperature difference between two surfaces. The kit typically includes a TEC 12706 module, a heat sink, a fan, and a power supply. The TEC 12706 module has a maximum cooling capacity of 50 watts and operates on a voltage of 12 volts DC. The kit is commonly used in small-scale cooling applications such as electronics, PC cooling, and portable refrigeration.

Working

The Smart Storage System project involves several components working together to maintain the optimal temperature and humidity for perishable items. To achieve this, data needs to be transferred between these components.

The Peltier module is responsible for cooling the storage system and maintaining the desired temperature. It receives instructions on the required temperature from the NodeMCU microcontroller, which controls its operation.

The DHT11 sensor is used to measure the humidity and temperature levels within the storage system. It continuously sends this data to the NodeMCU microcontroller, which uses it to adjust the operation of the Peltier module as needed.

The Load cell sensor with HX711 is used to monitor the weight of the stored items. It continuously sends the weight data to the NodeMCU microcontroller.

All of the data collected from the sensors is transmitted to the NodeMCU microcontroller or IoT device, which processes the data and uses it to determine the appropriate action to take. For example, if the temperature is too high, the microcontroller will send a signal to the Peltier module to increase cooling. If the weight of the stored items changes significantly, the microcontroller will send an alert to the user via the mobile application.

The custom-built mobile application allows users to remotely monitor the storage conditions and receive real-time alerts and notifications in case of any abnormalities. The mobile application communicates with the IoT device, which sends the necessary data to the mobile application. Users can view real-time temperature and humidity data, as well as receive alerts and notifications about any abnormal conditions detected by the system.

Flow Chart

Here is the flow chart of the hardware and it explains clearly how the IoT device and the IoT Android application communicate with each other in both normal and abnormal conditions.

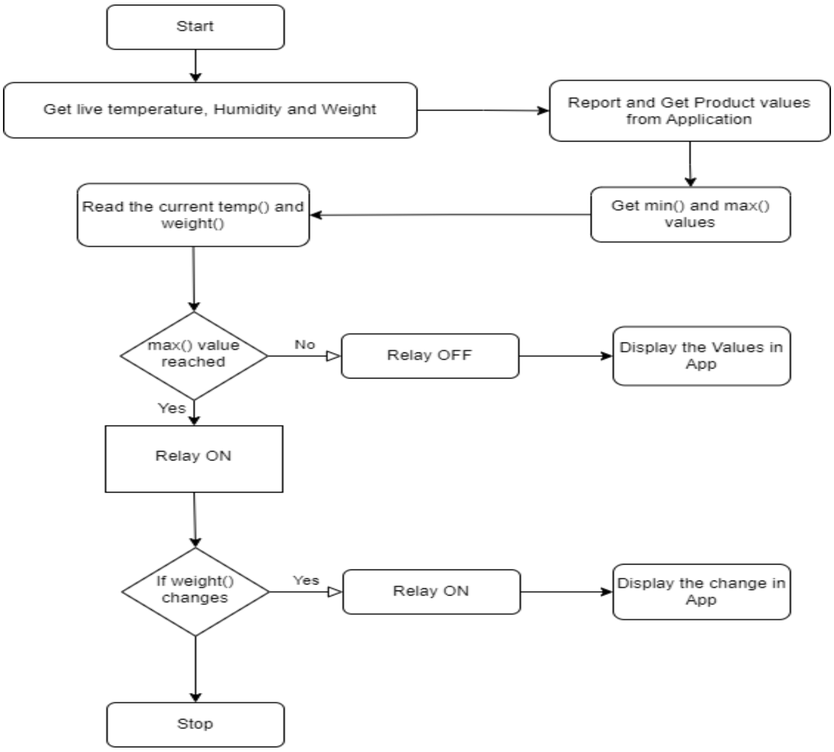

FIG. 4: Flow chart

Fig.4 explains about the flow chart that explains the process of the storage unit with the help of the IoT application as follows:

Step 1: Start the process.
Step 2: Get the live temperature, humidity, and weight from the sensors.
Step 3: Report the values and display them in the app.
Step 4: Get the input load values based on the product to be stored.
Step 5: Get the min() and max() values of the stored product.
Step 6: When the max() value is reached, The relay module will be OFF and the values are displayed.
Step 7: If the max() value is not reached, the relay module will be ON.
Step 8: If the weight of the product gets increases, the Relay will be ON and the updated values will be changed.
Step 9: Stop the process.

Simulation

To give a detailed explanation of the hardware setup, we have created a small simulation of how the hardware is connected to the NodeMCU microcontroller and how the input and output controls are operated.

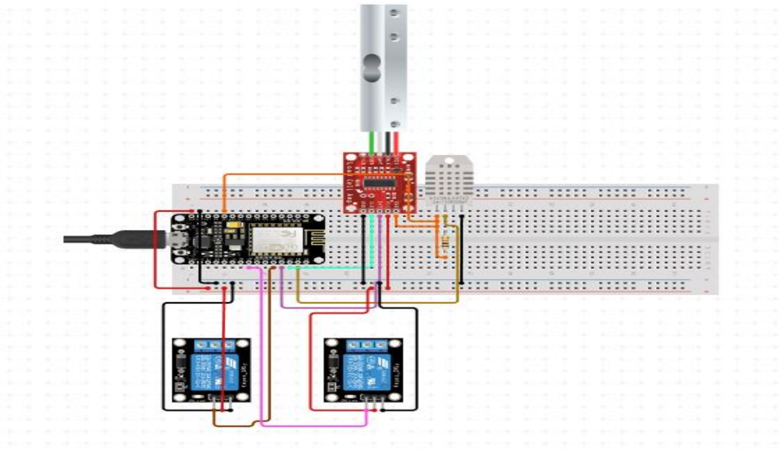

FIG 5: Simulation diagram

Fig.5 shows the simulation diagram of the project is connected as follows:

S.No	Components	NodeMCU
1	DHT11 (Data)	GPIO 0 (D3)
2	HX711(Data)	GPIO 12 (D6)
3	HX711(Clock)	GPIO 13 (D7)
4	Relay 1	GPIO 5 (D1)
5	Relay 2	GPIO 4 (D2)
6	Vcc	3v3
7	GND	GND

FIG 6 Connection Table

The Arduino IDE is used to program the NodeMCU microcontroller and the output is verified through the serial monitor. When the values of temperature, humidity, and weight will be displayed in the serial monitor.

The Output of the hardware will be sent to the IoT Android application through Google Firebase. It is a cloud-based platform that provides a set of tools and services for building web and mobile applications. Firebase is commonly used for developing IoT applications, as it provides a robust backend infrastructure that can handle data storage, user authentication, and real-time communication.

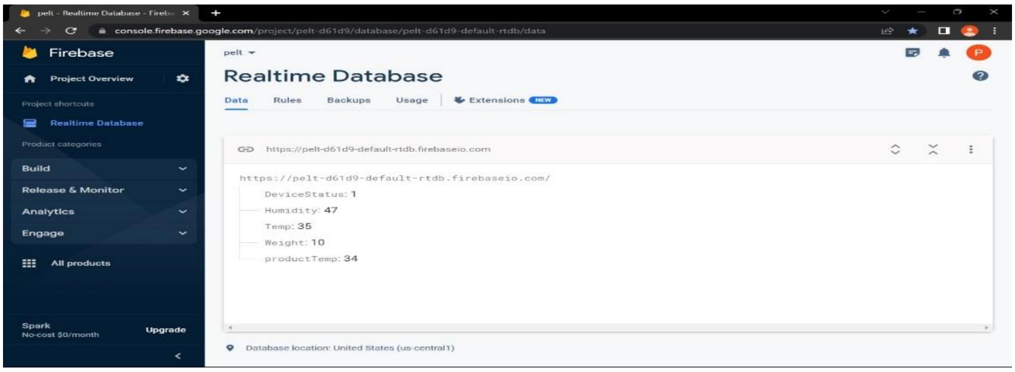

FIG 7: Google Firebase

Firebase includes a real-time database that can be used to store and sync data in real time across multiple devices. This makes it easy for IoT devices to communicate with each other and share data with the cloud. Firebase also includes a hosting service, which can be used to deploy and serve web applications.

The IoT android application is developed through Android Studio. It is an IDE platform particularly created for developing Android applications. It includes a suite of tools to help developers create, test, and deploy Android apps.

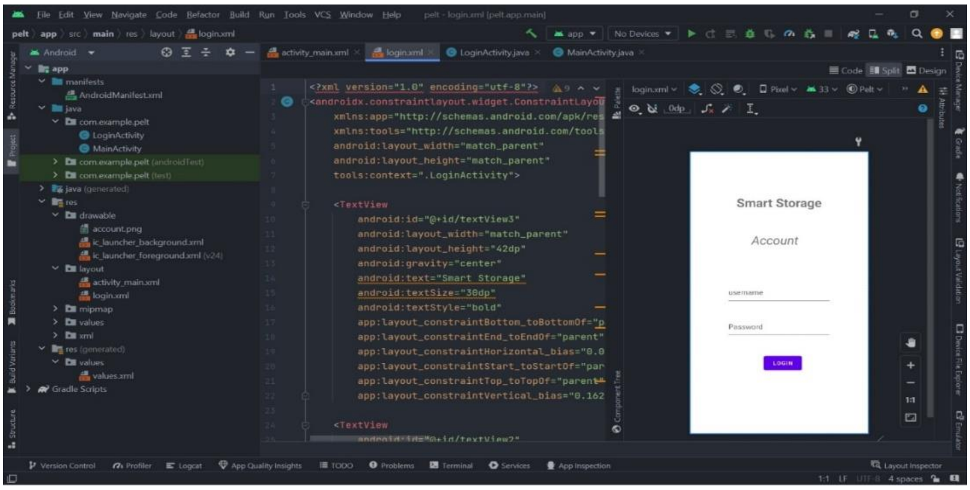

FIG 8: Android Studio

Android Studio can be used to develop mobile applications that communicate with IoT devices over Wi-Fi, Bluetooth, or other wireless protocols. This can be done by integrating third-party libraries and SDKs for IoT protocols and communication.

RESULTS

As the output is observed in the IoT android application, users can monitor them anywhere by using the internet. In this, we have verified the output on the user-end side.

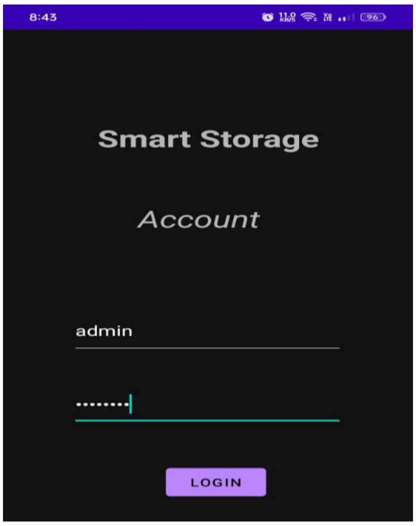

FIG 7: Login Interface

Fig.1 shows the IoT android application's user login. Using this, the user can log in to the IoT android application by entering their User ID and password. Only by providing the correct credentials will allow them to use your account. Each consumer will have login credentials so that they can access the data from their storage unit.

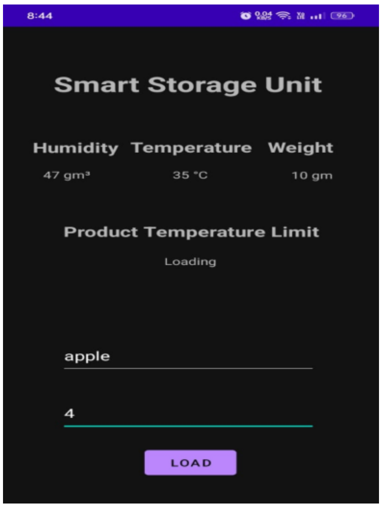

FIG 8: Dashboard

Fig.2 shows the dashboard of your IoT android application. Users can view the humidity, temperature, and weight stored in the storage unit using the dashboard. After logging in, the app will show the current values of Humidity, Temperature, and weight from the storage unit.

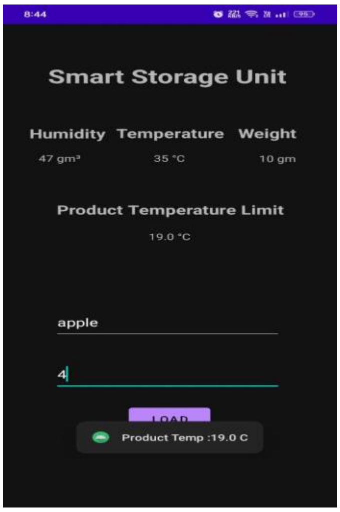

FIG 9: Product temperature

The user will provide the app about the product to be stored in the storage unit. Then the app will calculate the max() and min() values of the temperature in the application and sends it to the hardware.

We have taken sample min() and max() values for several items to verify the working of the storage unit. When the user enters the details of the stored product and their count, the app will calculate the required temperature limit of the product.

For example, if eggplants are stored, the min() and max() values are 10°C and 13°C. The humidity range should be around 90-95%. The system will take the input values and calculate the average temperature and report it as ProductTemp() as shown in Fig.9.

This shows the optimum temperature of the given product according to its weight within the limit of 5000 grams. The storage unit can hold up to five kilograms of storage space.

CONCLUSION

In conclusion, the "IoT-based Smart Storage System Using Peltier Technology" project successfully demonstrated the implementation of an innovative and efficient solution for cold storage management. The use of Peltier technology, DHT11 sensor, and Load cell sensor with HX711 has allowed for accurate temperature and weight monitoring, which is crucial for maintaining the quality and freshness of stored products.

The project also featured a custom-built app that provides users with real-time data monitoring and control, making it convenient and accessible for them to manage their cold storage from anywhere. Additionally, the integration of the two relay modules has provided an automatic control mechanism that helps to maintain the desired temperature range.

The calibration procedure ensured accurate readings of the Load cell sensor and the use of a 10kg load cell allows for the storage of various products of different weights. The successful implementation of this project could potentially be extended to larger-scale cold storage facilities.

Overall, the project has demonstrated the potential of using IoT technology in cold storage management, and its success can lead to improvements in food safety and waste reduction is achieved.

REFERENCES

1. Priya B.K, Musalareddygari Sucharitha, Nagaraju Sri Sai Lohith Varma, Divya Kalluru, "Design and Implementation of Automotive Cold Storage Unit for Potato Crop Using GSM", IEEE International Conference on Computational Intelligence and Computing Research, 2017
2. Toncho Papanchev, "A Fuzzy Control of Peltier-Based Thermal Chamber for Reliability Tests", IEEE Transactions on Instrumentation and Measurement, December 2018
3. Rafael García Cozzi, Sebastián Carbonetto, Adrián Faigón, "Peltier based Temperature Controller for MOS Dosimeter Characterization", Argentine Conference on Electronics, IEEE Latin America Transactions, May 2019
4. Shuang-Fei Li, Zhen-Hua Liu, Xue-Jiao Wang: “A comprehensive review on positive cold energy storage technologies and applications in air conditioning with phase change materials”, Renewable and Sustainable Energy Reviews, Vol. 123, May 2020
5. Sam Yang, Juan Ordonez, "Cold Thermal Energy Storage for Reliable Ship Cooling Under Thermal Cycling and Cooling Loss", Journal of Marine Science and Engineering, June 2020
6. Ahmad Arabkoohsar, Meisam Sadi, "ETC-Cold Room with Hot Storage Tank, a Reliable Solution for Prevention of Fruit Degradation", The 8th International Conference on Smart Energy Grid Engineering, 2020
7. Nazmul Islam, Rakibul Islam, Juwel Rana, Hasan U. Zaman, "A Novel Design of a Dual-Powered Automatic Peltier Effect Cooler", IEEE Region 10 Symposium (TENSYMP), 5-7 June 2020
8. Charisma Aulia Jamhari, Wahyu Kunto Wibowo, Aulia Rahma Annisa, Teuku Muhammad Roffi, "Design and Implementation of IoT System for Aeroponic Chamber Temperature Monitoring", Third International Conference on Vocational Education and Electrical Engineering, 2020
9. Mikhail F. Mitsik, Marina V. Byrdina, "Thermoregulation of Smart Clothing based on Peltier Elements", Proceedings of the International Conference on Industrial Engineering, Applications, and Manufacturing, November 2018
10. Julian Albert D. Nohay, John Karl H. De Belen, John Vernon B. Claros, Ron Benjo P. Lupo, Amiel Benedict Barrato, Jennifer C. Dela Cruz, Timothy M. Amado, Mark Christian E. Manuel, "Design and Fabrication of a Portable Solar Powered Thermoelectric Refrigerator for Insulin Storage", 11th IEEE Control and System Graduate Research Colloquium (ICSGRC 2020), 8 August 2020
11. Shengjun Wen, Ping Liu, Jun Yu, "Development of Operator-Based Tracking Controller Design for a Perturbed Peltier Refrigeration System", International Conference on Advanced

Mechatronic Systems, Hanoi, Vietnam, December 10 - 13, 2020

12. Tankiso A. Komako Ashleigh K. Townsend, Immanuel N. Jiya, Rupert Gouws, "Smart Cooling System for Milk Transportation in Rural Areas", IEEE Transactions on Sustainable Energy, June 2020
13. Rusyaizila binti Ramli, Nur Dini Afrina binti Nazri, Omar Ismael Al-Sanjary, Nabilah Rozzani, "The Development of Weight Detection System using IOT Flooring", IEEE 11th IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE), 2021
14. Ning Wang, Jian-Nan Zhang, Zhi-Yuan Liu, Can Ding, Guo-Rong Sui, Hong-Zhi Jia, Xiu-Min Gao, "An Enhanced Thermoelectric Collaborative Cooling System with Thermoelectric Generator Serving as a Supplementary Power Source", IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 68, NO. 4, APRIL 2021
15. Shuang Li, Jinglong Liu, Lu Ding, Jiaxin Liu, Jian Xu, Yang Peng, Mingxiang Chen, "Active Thermal Management of High-Power LED Through Chip on Thermoelectric Cooler", Ieee Transactions On Electron Devices, Vol. 68, NO. 4, APRIL 2021
16. T.H. Indiketiya, "An Optimum Strategy to Control Peltier Device Cold Side Temperature", 2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC), 2021
17. Mir Sajjad Hussain Talpur, Soofia Khan, Ammar Oad, Raheel Sarwar, Akhtar Hussain Soomro, Hina Rehman, Fauzia Talpur, Abida Luhrani, Shakir Hussain Talpur, Erum Saba Chan, "IoT Based Grain Storage Monitoring with Android Application", International Journal of Advanced Trends in Computer Science and Engineering, Volume 10, No.2, March - April 2021
18. Dr.R.S.Sabeenian, "Design of Control Electronics for Microwave Photonics Based carrier Generation", Design of Control Electronics for Microwave Photonics Based Carrier Generation - IEEE Conference Publication, July 2019
19. Dr.R.S.Sabeenian, .Yuvaraja, "Dual Tree Complex Wavelet Transform-based Image Security Using Steganography" Applied Mathematics & Information Sciences, An International Journal, Appl. Math. Inf. Sci. 13, No. 2, 215-222 (2019).
20. Vijayashaarathi, S., Agalya, T., Sp, T., “Automized Gesture Controlled Switch”, 3rd International Conference on Electronics and Sustainable Communication Systems, ICESC 2022 - Proceedings, 2022.
21. Saranya.K, Vijayashaarathi.S, Amutha.M, “Automatic detection of vehicle entry into a restricted area using IoT”, International Journal of Recent Technology and Engineering, 2019.
22. Suganya.E, Vijayashaarathi.S, “Smart vehicle monitoring system for air pollution detection using WSN”, International Conference on Communication and Signal Processing, ICCSP 2016, 2016.