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Development of the measuring part of a device for automatic temperature regulation

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***Abstract* — This article explores the development of the measuring part of a device for automatic temperature regulation. Advancements in this field have revolutionized the way we manage temperature control systems. These innovative devices have the potential to enhance energy efficiency, reduce human intervention, and create more comfortable and productive living and working spaces. Throughout the article, we delve into the design and functionality of this device, highlighting its critical components and their contributions to improving temperature regulation and sustainability.**

***Keywords* — Cooling, heating, regulation, relay, thermostat**

I. Introduction

In today's rapidly advancing world, temperature regulation plays a crucial role in maintaining comfort and optimal functionality in various environments. From homes to offices, and industries to healthcare facilities, the ability to achieve and maintain desired temperatures has become an essential aspect of modern living. However, achieving this balance can often be challenging, especially in large-scale settings where manual temperature control systems may be impractical.

The development of devices for automatic temperature regulation has revolutionized the way we manage our living and working spaces. These innovative devices have the potential to enhance energy efficiency, reduce the need for human intervention, and create more comfortable and productive environments.

Case studies underscore the significance of temperature regulation. Consistent room temperatures have been shown to reduce anxiety and enhance recovery, highlighting the importance of these systems in creating optimal conditions for well-being and productivity.

II. Hardware Design of the Measuring Part of the Thermostat

The measuring part is critical for the functioning of a thermostat. Without accurate temperature readings from the room, the thermostat cannot regulate the temperature effectively. To ensure optimal performance, the measuring part must provide precise temperature readings to allow the thermostat to make accurate adjustments.

Responsiveness is also essential; the measuring part should quickly react to changes in room temperature to maintain the desired level of comfort. Stability is another key function, as the sensor should provide consistent readings over time without drifting or becoming inaccurate.

Additionally, the measuring part should be capable of measuring a wide range of temperatures to accommodate different environmental conditions. Durability is crucial as well, ensuring that the measuring part is robust and reliable, capable of functioning well in various conditions without frequent need for replacement.

A. External timer TPL5111

The TPL5111 is a highly efficient timer circuit produced by Texas Instruments, designed to enhance power management and reduce overall energy consumption in low-power microcontroller (MCU) applications. Its minimal power consumption and compact size make it ideal for battery-powered devices, Internet of Things (IoT) applications, and other energy-sensitive projects.

The TPL5111 operates in two modes: one-shot and periodic. In one-shot mode, the timer can power down the system for a specified duration before reactivating it, thereby conserving energy during periods of inactivity. In periodic mode, the TPL5111 can be programmed to power up the system at regular intervals, allowing for precise control over power cycles.

One of the notable features of the TPL5111 is its ultra-low quiescent current consumption, which can be as low as 35 nA, contributing to its exceptional power efficiency. Additionally, the device offers flexibility in voltage and time settings, allowing users to customize the power management of their applications according to specific needs.[1]

B. Charging circuit TP4056

The TP4056 is a popular, highly integrated linear battery charger IC designed specifically for single-cell lithium-ion or lithium-polymer batteries. This chip provides a simple and cost-effective solution for charging rechargeable batteries.

The TP4056 offers several key features that make it suitable for a wide range of applications. It has an adjustable charging current, typically up to 1A, allowing users to optimize the charging process based on their battery requirements. The chip also includes built-in over-temperature protection, ensuring safe charging without risking damage to the battery or the surrounding circuitry.

One of the notable features of the TP4056 is its integrated precision voltage reference and charge termination circuitry. This ensures accurate and consistent charging, automatically transitioning to a low current trickle charge mode when the battery is full. Additionally, the chip incorporates various safety measures such as battery temperature monitoring and over-discharge protection, helping to prolong battery lifespan and prevent potential hazards.[2]

C. Sensing temperature and humidity

The DHT22, also known as the AM2302, is a digital temperature and humidity sensor that provides accurate and reliable measurements. This sensor is widely used in various applications due to its high precision and stability in measuring both temperature and humidity levels. The DHT22 is particularly favored in environmental monitoring, HVAC systems, and weather stations, where consistent and accurate data is crucial. Its digital output makes it easy to interface with microcontrollers and other digital systems, simplifying integration into various projects.

Here are some key features and information about the DHT22 sensor:

1) Measurement Range

The DHT22 can measure temperature within a range of -40°C to 80°C with an accuracy of ±0.5°C. It can also measure relative humidity within a range of 0% to 100% with an accuracy of ±2%. [3]

2) Digital Output

The DHT22 utilizes a digital communication protocol to output temperature and humidity data. It uses a single-wire digital signal, making it easy to interface with microcontrollers and other digital systems. The sensor sends response in 40 bits. 1st and 2nd byte contain relative humidity data. 3rd and 4th byte contain temperature data. 5th byte contains checksum of previous bytes. Each bit starts with 50us LOW signal, the sensor send signal 26us HIGH signal for “0” and 70us for “1”.[5]

3) Calibration

The DHT22 sensor is factory-calibrated, meaning it does not require additional calibration by the user. This simplifies the integration process and ensures accurate measurements right out of the box.[3]

4) Communication Protocol

The DHT22 uses a proprietary communication protocol with a timing-based signal exchange. To read measurements from the sensor, the microcontroller sends a start signal, waits for the sensor's response, and then receives the data. Libraries or code examples are readily available for popular microcontrollers, making it easy to interface and extract temperature and humidity data.[3]

5) Power Supply

The DHT22 operates on a voltage supply of 3.3V to 5V and consumes a low amount of current during operation (around 1.5mA). It is compatible with most microcontroller systems and can be powered directly from the MCU's supply.[3]

6) Response Time

The DHT22 has a reasonably fast response time. It provides temperature and humidity readings at around 2 second interval.[3]

D. Power supply of the measuring part

The measuring part is powered by a Li-Pol battery using the MIC5205-3.3 voltage regulator. This 3.3V regulator is controlled via its EN pin, which is connected to the DRV pin of the timer. This configuration ensures that the regulator is activated at the desired time intervals, allowing for efficient power management and precise timing control.

E. Measuring voltage off battery

This data is quite important as it informs the user about the state of the battery. When the battery reaches a certain limit, it becomes necessary to charge it to ensure accurate temperature measurements. The battery voltage is measured by an AD converter using a voltage divider with resistor values of 68K and 10K.

To prevent battery discharge between measurements, the voltage divider is switched using a PC817 optocoupler. Without the use of an optocoupler, the voltage divider would have a current consumption of several tens of microamperes (μA). While this may not seem like much, it can quickly reduce battery life.

A 10-bit converter is used for this measurement. The reference value of the AD converter is set to 1.1V, stabilized with an external capacitor of 100nF on the AREF pin.

F. Other functions

For the possibility of changing the bootloader of the microcontroller, the ICSP connector was added, with which it is possible to load another bootloader. A different processor frequency can be set by changing the bootloader. For the possibility of reprogramming, an FTDI connector was added, through which a new program can be loaded.

G. Design of printed circuit board

With these functions we design the PCB. Fig. 1 represent top side of designed PCB. Fig. 2 represents bottom side of PCB.

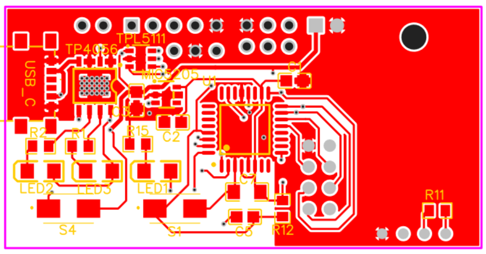

Fig. 1. Top side.

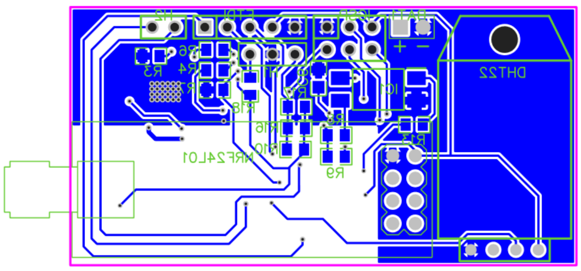

Fig. 2. Bottom side.

The manufactured PCB can look like on Fig. 3 and Fig. 4.

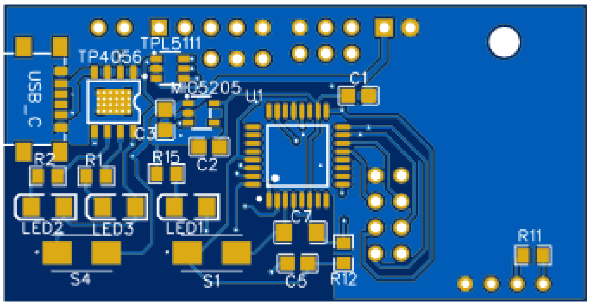

Fig. 3. Top side of PCB.

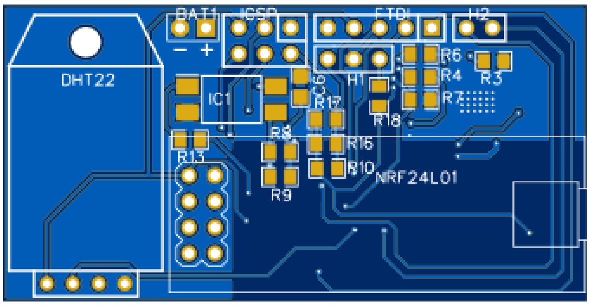

Fig. 4. Bottom side of PCB.

III. CONCLUSION

The hardware design of the measuring part includes components such as the TPL5111 timer, the TP4056 charging circuit, the DHT22 sensor for temperature and humidity sensing, and the MIC5205-3.3 voltage regulator for power supply. Additionally, the design includes the measurement of the battery voltage using an AD converter and the use of a voltage divider with a PC817 optocoupler to prevent battery discharge between measurements. The reference value of the AD converter is stabilized with an external capacitor on the AREF pin.

The printed circuit board (PCB) design, as shown in Fig. 1 (top side) and Fig. 2 (bottom side), integrates all these components to create a compact and efficient system. These advancements in temperature regulation devices have the potential to significantly enhance our everyday lives by providing more precise and reliable temperature control while contributing to a more sustainable future.

REFERENCES

[1] TPL5111 Nano-Power System Timer for Power Gating. [online]. Available on the Internet: <https://cdn-shop.adafruit.com/product-files/3573/3573_datasheet.pdf>
[2] TP4056 1A Standalone Linear Li-lon Battery Charger with Thermal Regulation in SOP-8 [online]. Available on the Internet: <https://4.bp.blogspot.com/-T3ZB0kgfjJI/XOOksKAptI/AAAAAAAAAMc/EtHz2c8qrewcJ3U1iRvJmp6_px_obNhgCLcBGAs/s1600/Untitled.png>
[3] Digital-output relative humidity & temperature sensor/module DHT22 (DHT22 also named as AM2302) [online]. Available on the Internet:
[4] <https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf>
[5] From Manual to Smart: Tracing the Evolution of Thermostats and Their Impact on Energy Efficiency. [online]. Available on the Internet: <https://energy5.com/the-evolution-of-thermostat-technology-a-journey-through-time>
[6] Basics of Interfacing DHT11/DHT22 Humidity and Temperature Sensor with MCU. [online]. Available on internet: <http://www.ocfreaks.com/basics-interfacing-dht11-dht22-humidity-temperature-sensor-mcu/>
[7] Temperature regulator: Primary Regulator: Maintaining Ideal Temperatures. [online]. Available on the Internet: <https://fastercapital.com/content/Temperature-regulator--Primary-Regulator--Maintaining-Ideal-Temperatures.html>