ELK346E Term Project Report

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Abstract

This project details the development and design of a real-time embedded system built to regulate and observe the humidity and temperature of a dormitory room. The system employs a DHT11 digital temperature and humidity sensor operating at 3.3 V, interfaced with an STM32F103 "Blue Pill" microcontroller programmed using STM32CubeIDE.

The sensor data is shown on a GME1 2864-43 3.3 V OLED display through I^2C communication. In order to maintain signal stability and prevent floating conditions on the data line, an 820-ohm pull-up resistor was added to the circuit.

The system conducts environmental sensing in real time and triggers a 5 V fan and a steam module depending on the sensor inputs, thus achieving rudimentary climate control. Since the control parts require 5 V while the microcontroller uses 3.3 V logic levels, a BJT transistor is used as a switching device (base to GND) to safely interface logic signals with power components. The fan and steam module operate in an on/off manner based on threshold comparisons rather than PWM or analog control.

The components were selected based on availability, cost, and ease of integration with the STM32 platform. The system architecture allows for ongoing sensing and decision-making independently of external control, with potential applications in resource-constrained environments. While the control logic is simple, the modular format allows future expansion — such as wireless data transmission, remote monitoring, or the addition of feedback control algorithms.

Experimental results show that the system runs stably in expected environmental conditions, with accurate sensor measurements and timely actuation. Overall, this project presents a low-cost, real-time embedded solution for basic environmental monitoring and control using widely available microcontroller and sensor technologies.

1 Introduction

Embedded systems lie at the core of most automation applications, enhancing both user comfort and energy efficiency. Monitoring and controlling environmental parameters such as temperature and humidity is crucial to maintaining indoor air quality and occupant health.

This project was developed as a model to understand the working principles of air conditioners and humidifiers and to offer a cost-effective solution to common thermal comfort issues experienced in dormitory settings. It includes a DHT11 digital temperature and humidity sensor, a GME1 2864-43 OLED display, a 5V fan, and a vapor module, all powered by an STM32F103 ("Blue Pill") microcontroller, which was a preset requirement for the project.

Although the system lacks wireless communication capability, it operates in real-time. Sensor data is continuously read and used to trigger either the fan or the vapor module based on preset thresholds. This creates a basic closed-loop control structure that dynamically adapts to environmental changes.

The main objective is to achieve autonomous environmental control to improve indoor comfort. While the components used are relatively simple — the fan measures just 4 cm and the vapor module operates purely for demonstration — the modular design leaves room for enhancements. Current limitations include the sensor's low precision and the small size of the actuators, making practical deployment challenging. However, improvements in sensor accuracy, actuator power, and the addition of wireless connectivity could transform the system into an affordable indoor climate control solution.

1.1 Hardware

The hardware is centered on the STM32F103C8T6 development board, also known as the "Blue Pill." It operates at 3.3V logic and serves as the main controller for acquiring sensor data and activating outputs.

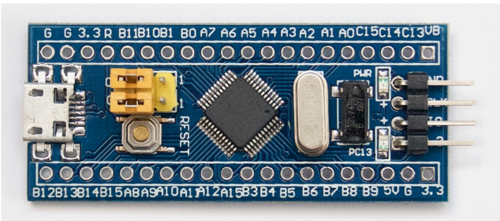

Figure 1: STM32F103C8T6

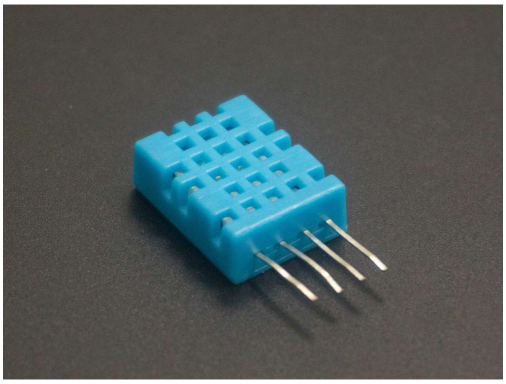

Figure 2: DHT11

Ambient humidity and temperature are measured using a DHT11 sensor, chosen for its simplicity, affordability, and ease of integration, despite its relatively low accuracy.

Figure 3: Display

Figure 4: FAN

A GME1 2864-43 OLED display (3.3V) is connected via I^{2}C to provide real-time visual feedback of temperature and humidity readings. To maintain signal integrity on the I^{2}C line, an 820-ohm pull-up resistor is included.

Two actuators simulate climate control:

- 5V DC ventilation fan controlled by an NPN BJT transistor. The fan's higher operating voltage is managed by switching its base via a GPIO pin through a current-limiting resistor.
- 5V vapor (humidifier) module controlled in the same way, operating in binary (ON/OFF) mode depending on sensor data.

All hardware was assembled on a breadboard for prototyping. Power regulation and grounding were carefully managed to prevent signal integrity issues or logic level mismatches. The system is low-power and prioritizes simplicity over advanced scalability.

1.2 Software

The software reads data from the DHT11 sensor and displays it on the SSD1306 OLED screen. It begins communication with a start signal, receives five bytes (humidity, temperature, and checksum), and verifies data accuracy.

Once validated, the system calculates Celsius and Fahrenheit values and displays them alongside relative humidity. Based on thresholds, the system controls a fan and steam generator: the fan activates above 25°C, and the steam generator turns on below 45Precise timing for sensor communication is handled using a hardware timer. GPIO pins are used both for reading sensor data and controlling output devices, enabling automatic environmental regulation.

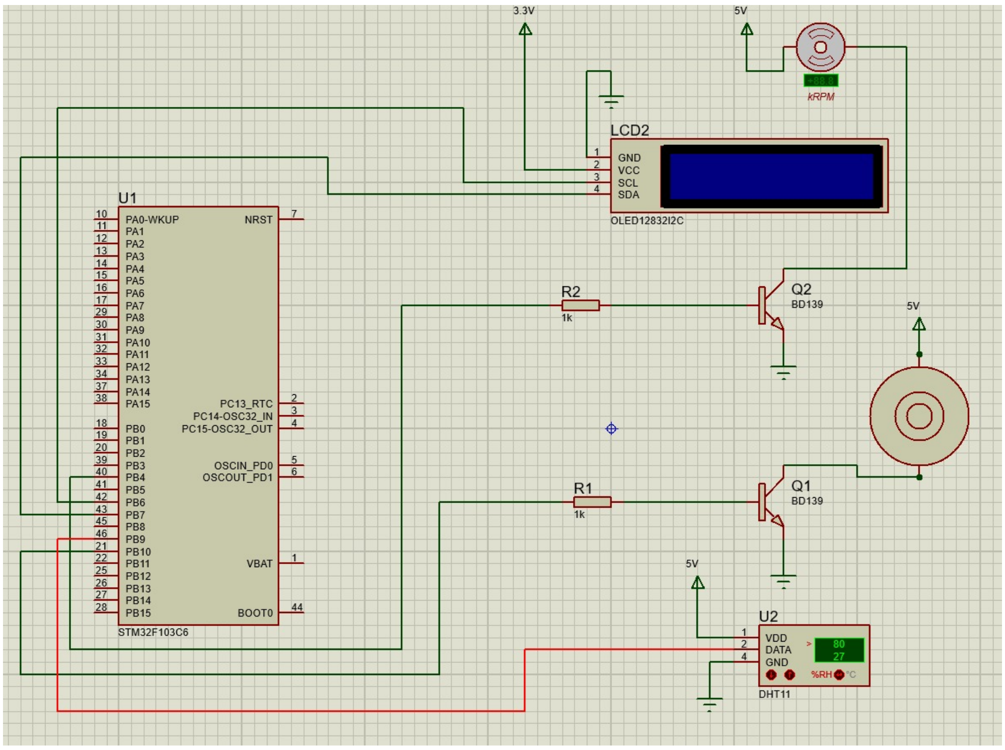

Figure 5: Circuit Scheme

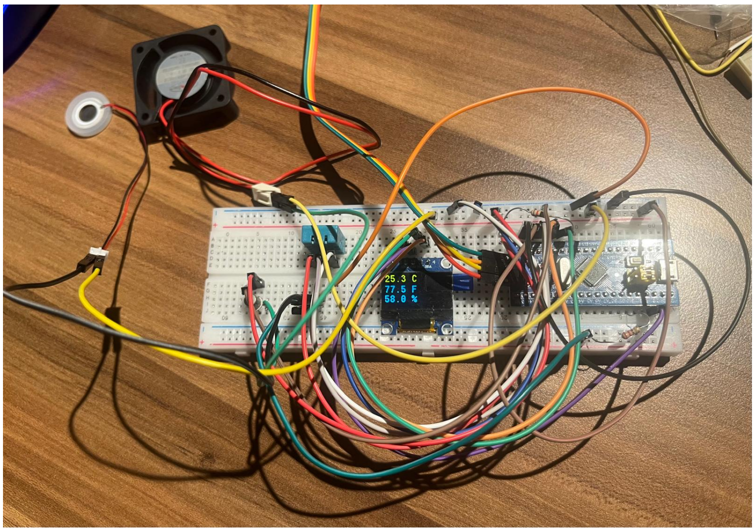

Figure 6: Circuit View

Key Code Snippets:

```
// Start communication with the DHT11 sensor
uint8_t DHT11_Start(void)
{
  GPIO_InitTypeDef GPIO_InitStructPrivate = {0};
  GPIO_InitStructPrivate.Pin = DHT11_PIN;
  GPIO_InitStructPrivate.Mode = GPIO_MODE_OUTPUT_PP;
  HAL_GPIO_Init(DHT11_PORT, &GPIO_InitStructPrivate);

  HAL_GPIO_WritePin(DHT11_PORT, DHT11_PIN, 0);
  HAL_Delay(20); // Pull pin low for 20 ms
  HAL_GPIO_WritePin(DHT11_PORT, DHT11_PIN, 1);
  microDelay(30); // Wait for 30 us

  GPIO_InitStructPrivate.Mode = GPIO_MODE_INPUT;
  GPIO_InitStructPrivate.Pull = GPIO_PULLUP;
  HAL_GPIO_Init(DHT11_PORT, &GPIO_InitStructPrivate);

  // Wait for sensor response and verify it
  // ...
  return Response;
}

// Reading one byte from DHT11 sensor
uint8_t DHT11_Read(void)
{
  uint8_t value = 0;
```

```
  for (uint8_t i = 0; i < 8; i++)
  {
    // Wait for pin to go high
    // Wait precise timing for bit value
    // Read bit and construct byte
  }
  return value;
}

// Main loop reading sensor and controlling devices
while (1)
{
  if (DHT11_Start())
  {
    RHI = DHT11_Read();
    RHD = DHT11_Read();
    TCI = DHT11_Read();
    TCD = DHT11_Read();
    SUM = DHT11_Read();

    if (RHI + RHD + TCI + TCD == SUM)
    {
      // Calculate temperature and humidity
      // Display values on OLED
      // Control fan and steam devices based on thresholds
    }
  }
  HAL_Delay(1000);
}
```

2 Results

We successfully achieved our prototype goals. During testing, the system responded correctly to changing conditions. However, we encountered issues with the steam module, which did not always respond to input despite being connected properly.

Overall, the output was close to what was expected. This project demonstrates that many seemingly complex electronic systems rely on simple principles. Our prototype serves as a functional simulation of these fundamentals.

3 Discussion

While the current system is adequate for basic environmental control, it has limitations. The DHT11 sensor's slow response and low precision impact measurement accuracy. Replacing it with higher-end sensors like the BME280, SHT31, or DHT22 would enhance performance. This system has various potential applications in both industrial and domestic scenarios:

- **Electronics Storage Warehouses**: Many electronic components are sensitive to humidity and temperature fluctuations. Our system can help maintain stable environmental conditions to reduce oxidation, corrosion, and product degradation.
- **Greenhouse Agriculture**: The system can control humidity and temperature in small-scale greenhouses, promoting optimal growth conditions for fruits, vegetables, and flowers.
- **Food Storage Facilities**: Certain food items are prone to spoilage under poor environmental conditions. This system can help reduce moisture and temperature-induced degradation in warehouses or refrigerators.
- **Smart Home Environment Monitoring**: Integrated into a smart home setup, the system can ensure a comfortable living environment by regulating indoor air conditions automatically.
- **Medical Storage Rooms**: Many medical materials, such as vaccines and biological samples, require stable environmental conditions. This system could serve as a basic environmental regulator for small labs or storage units.

The current binary control logic causes sudden environmental changes and energy waste. Implementing PWM or stepless digital control would provide smoother operation and improved comfort. The absence of wireless communication restricts remote control and monitoring — especially useful in dorm or office settings. Adding modules like HC-05 (Bluetooth) or ESP8266 (Wi-Fi) would allow real-time data access and remote management.

Hardware limitations include small actuators that reduce practicality. Moving to larger, more capable components is necessary for real-world deployment. Moreover, the lack of protective elements (voltage regulators, flyback diodes, TVS) affects circuit stability and safety. Including such components is critical for long-term use.

Breadboarding is also not viable for permanent setups due to mechanical instability and short circuit risks. Designing a PCB would significantly improve durability and reliability.

Lastly, the system lacks power-saving features such as sleep modes or wake-on-environmental-event functionalities, which would optimize battery usage. In summary, while this project presents a functional prototype, improvements in sensor precision, control methods, wireless connectivity, and hardware robustness are necessary for real-world application.

4 Conclusion

In this project, a climate control prototype utilizing the STM32 Bluepill microcontroller was developed to regulate temperature and humidity. Based on data acquired from the DHT11 sensor, the system controlled a fan and a humidifier module by switching them on or off to respond to environmental conditions in real time. The design successfully demonstrated basic functionality and real-time control; however, limitations were observed in sensor accuracy and hardware scale for practical applications. This prototype serves as a valuable learning tool for embedded system design and can be further enhanced with more precise sensors and advanced control techniques to broaden its applicability.

References

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STM32F103C8T6 Datasheet – AllDatasheet
STM32 CubeIDE Tutorial – Phipps Electronics