Design and Implementation of a Microcontroller-based Automatic Temperature-sensing Relay

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Abstract: ***A temperature-based relay is designed using a microcontroller, which can be programmed easily for changed settings. The system is built around an Arduino Uno microcontroller that is connected to relays, an LED, and an LM35 temperature sensor. The temperature sensor provides an electrical output corresponding to the temperature in °C and can be used to measure temperature. To determine the temperature of a given room, the Arduino Uno microcontroller decodes the temperature reading from the temperature sensor and compares it to a temperature value that has been set through the program. The microprocessor then automatically switches the relay ON or OFF depending on the comparison algorithm, which is indicated by an LED turning ON or OFF. The primary goal of this work was to design and build an automatic temperature-controlled relay, based on a microcontroller. It has been accomplished with high accuracy. The relay tested for different temperature conditions shows a wide variability in the range of operation. This experimental work serves as an example of how embedded systems are used in electrical device design.***

Keywords: LM35; Arduino UNO; LED; temperature relay.

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1. Introduction

Every day, billions of people utilize technology, which has grown significantly more complex over time. This indicates that the operational safety of those gadgets is now extremely crucial. Thankfully, by triggering a function to cool down, heat up, or modify the functionality of their system in some way based on the surrounding temperature, designers may avoid thermal disasters like batteries setting on fire or damaged components. Every electrical system needs temperature sensors since they are fundamental components that ensure user safety while maximizing performance. There are many kinds of temperature sensors, each with advantages and disadvantages, such as integrated circuit temperature sensors, thermistors, thermocouples, and resistance temperature detectors.

A microcomputer-controlled relay referred to as a digital protective relay is very convenient to measure and act against a high build-up of temperature. In such relays, the information from the transducers is gathered by the data collection system, which then transforms it into the format required by the microcomputer. In analog form, the data from CT, PT, and other sensor systems are amplified and sampled. With an A/D converter, the sampled signals are converted to digital form and sent to registers in the microprocessor system. When comparing the data with predefined limits for overcurrent, over/undervoltage, etc., the microprocessor may utilize some sort of counting approach or the Discrete Fourier Transform (DFT), and then transmit commands through a D/A converter to warn or trip signals to the circuit breakers. Based on current and/or voltage magnitude and, in some applications angle, the digital relay can determine whether it should trip or refrain from tripping [1].

Temperature sensors are used to ensure that a process is either staying within a defined range, providing safe usage of that application, or meeting a statutory need while dealing with extreme heat, dangers, or inaccessible locations. To maintain thermal comfort, it is crucial to keep an eye on the temperature in a variety of locations, including mortuaries, hospitals, airplanes, and living rooms. According to ISO 1984, thermal comfort is typically understood to be the mental or physiological state that reflects happiness with the thermal environment. Unhappiness can be brought on by the body or equipment being excessively warm or cold overall, or by the unintentional heating or cooling of a specific body region [2].

Several temperature sensors that can be used for sensing and reporting temperature values to a microcontroller, with a fair degree of accuracy, can lead to effective temperature monitoring and control. Thermistors, thermocouples, integrated circuit temperature sensors, and resistance temperature detectors are all temperature sensors, each having specific advantages and disadvantages, that can be used for the purpose.

Creating a temperature-sensing relay system that reduces operating expenses for manufacturing in homes and businesses is the primary motivation for the current work. Additionally, it helps to prevent risks brought on by unintentional disregard for heating and cooling equipment in homes and workplaces, even when they are not required. We encounter numerous equipment whose temperatures must be controlled in our daily lives. If the equipment exceeds the specified temperature, several issues arise. Devices have been created to sense temperature and trip the relay if it exceeds a pre-set setting to avoid these issues. The temperature can be managed using this type of relay.

2. Related Works

As mentioned in many works of literature and technical manuals, the output voltage of the LM35 series precision integrated-circuit temperature sensor is linearly proportional to the temperature in degrees Celsius [6-7]. In comparison to linear temperature sensors calibrated in Kelvin, the LM35 device has an advantage because it does not require the user to deduct a significant constant voltage from the output to gain convenient Centigrade scaling. The LM35 device can deliver typical accuracies of 14°C at room temperature and 34°C, over the entire temperature range of -55°C to 150°C without the need for any external calibration or trimming [5]. As mentioned in [6], trimming and calibration at the wafer level ensures lower costs. The low-output impedance, linear output, and precise inherent calibration of the LM35 device make interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. The LM35 device draws only 60 µA from the supply, so it has very low self-heating of less than 0.1°C in still air [6].

Figure 1 shows the functional block diagram of the LM35 series device. The amplifier has a simple class-A output stage with a typical 0.5 Ω output impedance as shown in the functional block diagram. Therefore, the LM35 can only source current, and its sinking capability is limited to 1 µA [6].

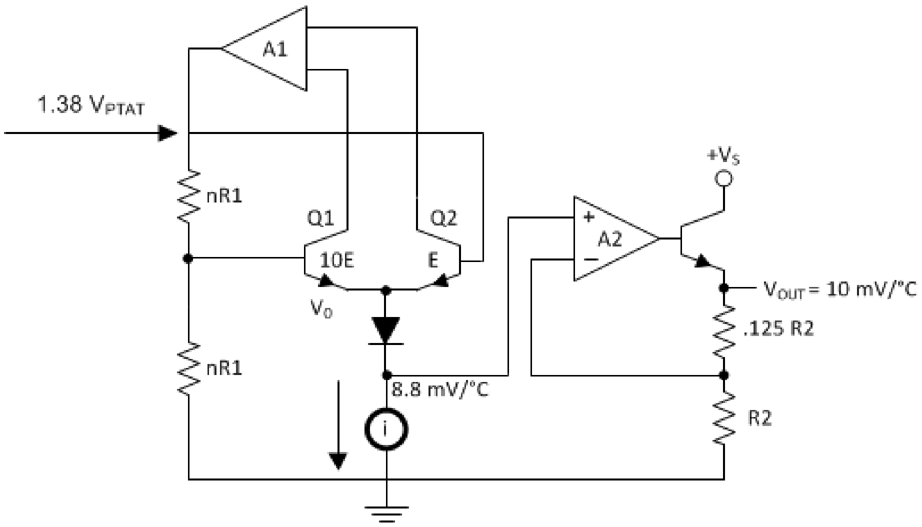

Figure 1: Functional block diagram of LM35 series device [6]

In another work [3], LEDs were controlled based on the ambient temperature. The red LED will automatically turn on if the temperature rises beyond a certain threshold (in this circuit, 50 degrees), while the yellow LED will stay lit if the temperature is lower. By altering the variable resistor in the circuit to the requirements, the threshold temperature value can be set.

In [4], a DC fan control system based on room temperature was designed and simulated utilizing pulse width modulation technology, temperature sensor LM35, along an Arduino Uno Microcontroller. A fan was used to lower the room's temperature.

3. Circuit Model and Components

We come across numerous devices in daily life that need to have their temperatures controlled. If the equipment exceeds the specified temperature, several issues arise. A device to sense temperature and trip the relay has been created to prevent these issues if it exceeds the specified value. The temperature can be managed using this. This circuit is made up of a breadboard, LED, relay, and a temperature sensor.

Creating a temperature sensing relay system that reduces operating expenses for manufacturing in homes and businesses. Additionally, it helps to prevent risks brought on by unintentional disregard for heating and cooling equipment in homes and workplaces, even when they are not required.

In the LM35 circuit shown in Figure 2, the LM35 V_{CC} is powered with +5V operating voltage (V_s). Then the V_{OUT} is connected to an ADC input (Analog-to-Digital Converter). After which the reading from ADC output voltage (V_{OUT}) is processed. Finally, the output voltage is converted to the corresponding temperature. As mentioned in [7], the following equations are used to convert the voltage reading into temperature-

Centigrade temperature

$$= \frac{\textbf{Voltage read by ADC}}{\textbf{10 mV}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Also,

$$\mathbf{V_{OUT} = 10\ mV/°C \times T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where,

V_{OUT} = LM35 output voltage
T = Temperature in centigrade
10 mV represents the linear scale factor of LM35.

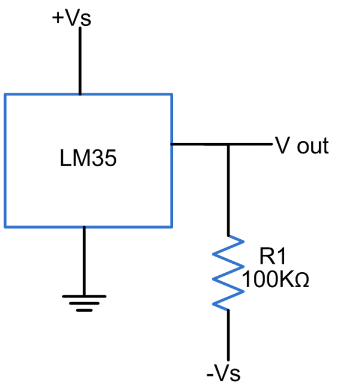

Figure 2: Operation of LM35 circuit [6]

Figure 3 shows the wiring diagram of the working model. In this work, the system is built around an Arduino Uno microcontroller that is connected to relays, an LED, and an LM35 temperature sensor. The hardware and software components of the system design are separated. The temperature sensor provides an electrical output corresponding to the temperature in °C and can be used to measure temperature. To determine the temperature of a given room, the Arduino Uno microcontroller decodes the temperature reading from the temperature sensor and compares it to a temperature value that has been set through the program. The microprocessor then automatically switches the relay ON or OFF depending on the comparison algorithm, which is indicated by an LED turning ON or OFF. The measured room temperature is displayed correctly on the serial monitor. The relay cuts off the circuit when the temperature exceeds the setting value.

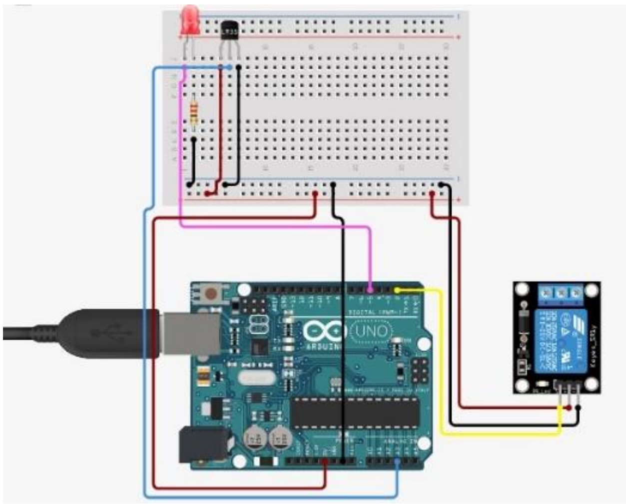

Figure 3: Wiring diagram

As shown in Figure 3, the Arduino is programmed to read the temperature values from the LM35 which are displayed in the serial monitor, and to turn on the relay when a certain event occurs. Almost any sensor can be used to trigger the relay to turn on or off. The trigger doesn't even need to be from a sensor. It can occur at set time intervals, it can be triggered from the press of a button, or even when you get an email. The components used in the circuit of Fig. 3 are listed in Table 1.

Table 1: Components used with ratings

Components used	Rating
Arduino Uno	5V
LM35	-55ºC to 150ºC
Relay	5V DC
Light emitting diode	3V DC
Jumper wires	-

4. Results and Analysis

When a specific event of temperature rise occurs, such that the LM35 sensor temperature goes beyond a certain level, the Arduino is programmed to read the temperature values from LM35 displayed in the serial monitor and switch on the relay. The temperature sensor triggers the activation or deactivation of the relay. In this case, the relay will remain ON as shown in Fig. 4, and the LED will be OFF (as shown in Fig. 5) until LM35 reaches the threshold level of temperature. The relay operates when the temperature value goes above a certain value.

The relay can send a signal through the LED or any other alarm-generating device when the measured temperature by the sensor crosses the threshold value. The relay is also able to cut off the circuit that is producing the heat and increasing the temperature. This way the relay can protect the circuit from overheating.

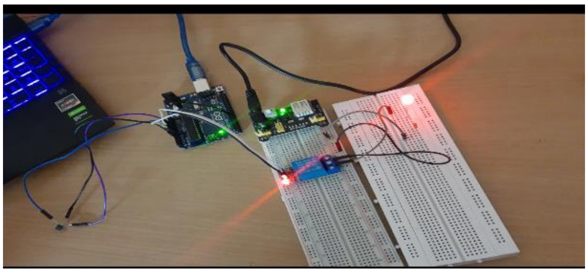

Figure 4: During normal conditions (LED ON)

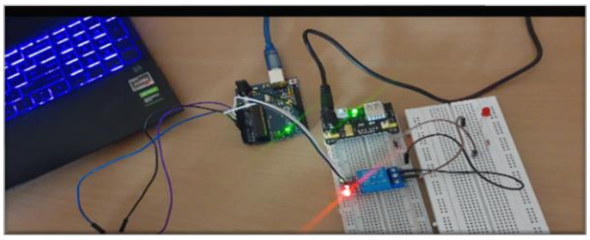

Figure 5: During faulty condition (LED OFF)

The observations made as shown in Figure 4 and Figure 5 are listed in Table 2.

Table 2: Observation Table

Input Data	Expected output	Received output
Relay and LM35	It shows the working model where the relay is activated at the desired room temperature, and it will trip if it exceeds the desired temperature level indicated by the lighting of the LED.	Same as expected.

4.1 Limitations and Future Scope

The LM35 may not respond to rapid changes in temperature as quickly as some other sensors. Consequently, it might not be the best choice for applications requiring real-time temperature monitoring because of its somewhat poor response time. We might need to take more accurate sensors into account for more accurate temperature data.

By incorporating features like wireless communication, remote monitoring, automatic calibration, and other functions, temperature sensors have developed into smart sensors. The market is paying increasing attention to wearables, which are small, integrated sensors that are worn as clothing or accessories. The market for temperature sensors is currently expanding because of these gadgets.

5. Conclusion

The primary goal of this work was to design and build an automatic temperature-controlled relay, based on a microcontroller. It has been accomplished with high accuracy. The relay tested for different temperature conditions shows a wide variability in the range of operation. This experimental work serves as an example of how embedded systems are used in electrical device design. The results of this work demonstrate the use of microcontrollers in designing relays with simple techniques. The relays made with microcontroller circuits like this are flexible, programmable, and adaptive. The relaying technique used in this work can be extended to any other relays using different kinds of sensors.

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Author's Profiles

Winnie Dkhar is currently an M.Tech. student at Assam Don Bosco University, India. She is interested in research work related to Load Forecasting, Energy Management, Grid Optimization, Cybersecurity, and Renewable Energy Integration.