EEE 313 Project Report (Part 3)
Emir Arda Bayer

Introduction

For the term project of EEE313, the students designed and implemented a thermocouple-based instrumentation amplifier for controlling a heater, on simulation and hardware. The system is designed to maintain the heater at a specified temperature above the room temperature. The system uses a type-K thermocouple for temperature sensing, with an ON/OFF controller to regulate the heater operation and provide visual feedback through an LED. Key specifications that are as in Figure 1 were met, and the design was verified through simulations and lab experiments.

Specifications:

1. The output voltage at 2V±0.5V when the thermocouple is at room temperature (thermocouple output voltage is zero).
2. The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is $39.2 \times T_S$ μV)
3. LED turns ON when the heater resistance is being heated. It should turn OFF when the heater is OFF.

Figure 1: Specifications on the Manual

Methodology and Design

The project involved the following steps:

1. **Simulation and Design**: The system was designed and simulated in LTSpice to ensure the specifications were met. An instrumentation amplifier was implemented to amplify the thermocouple signal, and a comparator with hysteresis controlled the heater and LED.
2. **PCB Design**: Using Diptrace, a PCB layout was created for a compact and error-free implementation.
3. **Testing and Experimentation**: The design was tested on a breadboard and later soldered onto a PCB to finalize the design and decide the values for circuit elements.

The system operates by sensing temperature through a type-K thermocouple, which generates a voltage proportional to the temperature. This small voltage is amplified by an instrumentation amplifier to a measurable range. A comparator with hysteresis processes this signal and determines whether the heater should be ON or OFF based on the target temperature. When the heater is activated, an LED provides visual feedback. The system functions accurately by leveraging the precision of the instrumentation amplifier, the stability of the comparator, and the control capability of a BJT switch to regulate the heater. The combination of these components ensures the desired output is achieved by maintaining the heater's temperature within the specified range. The design on Diptrace is as in Figure 2. The physical implementation is as in Figures 3-4.

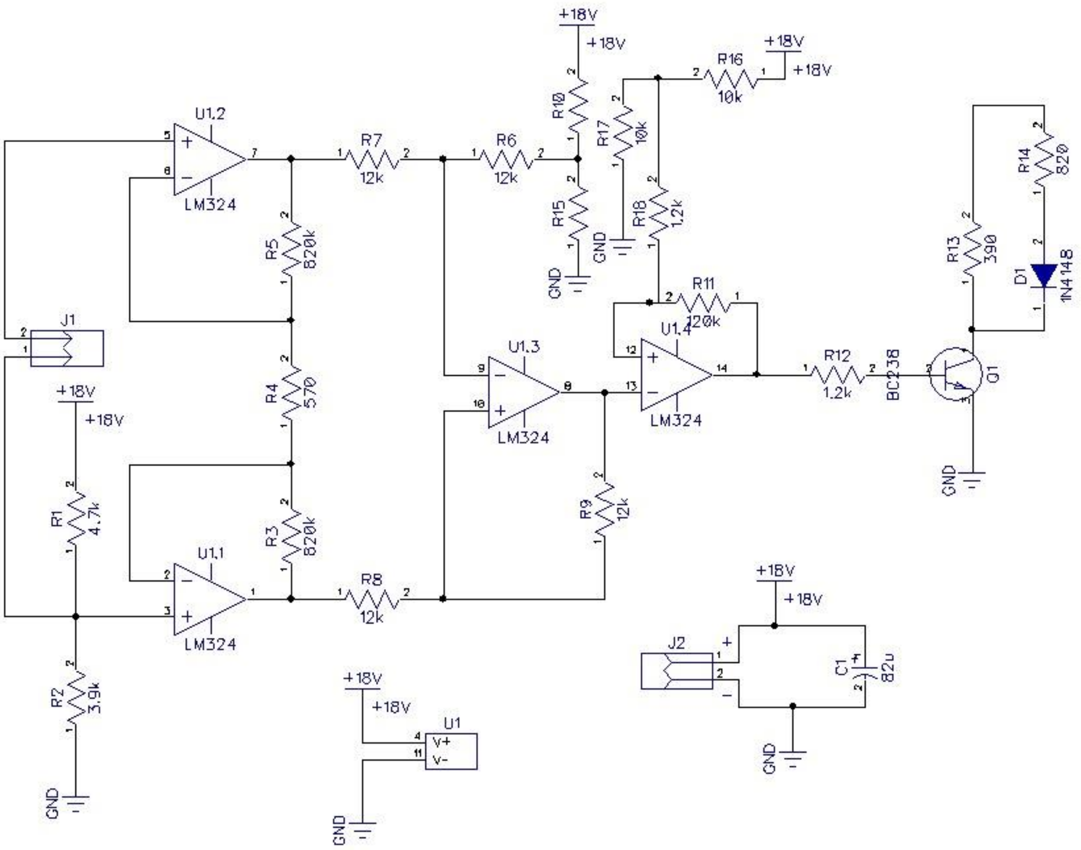

Figure 2: Design on Diptrace

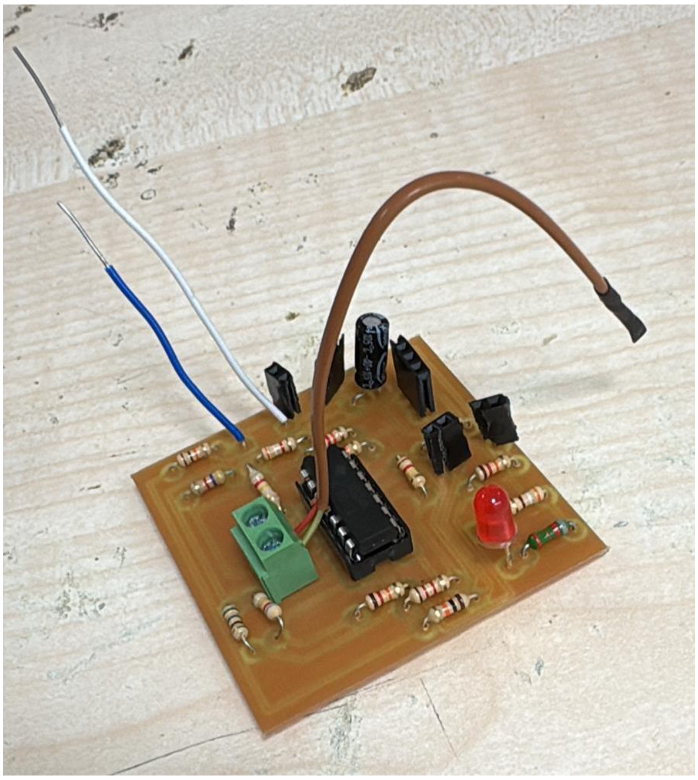

Figure 3: Physical Implementation

Sockets were soldered for certain circuit elements to improve potential troubleshooting. The appearance of the PCB after placing the remaining the resistor and BJT is as in Figure 4.

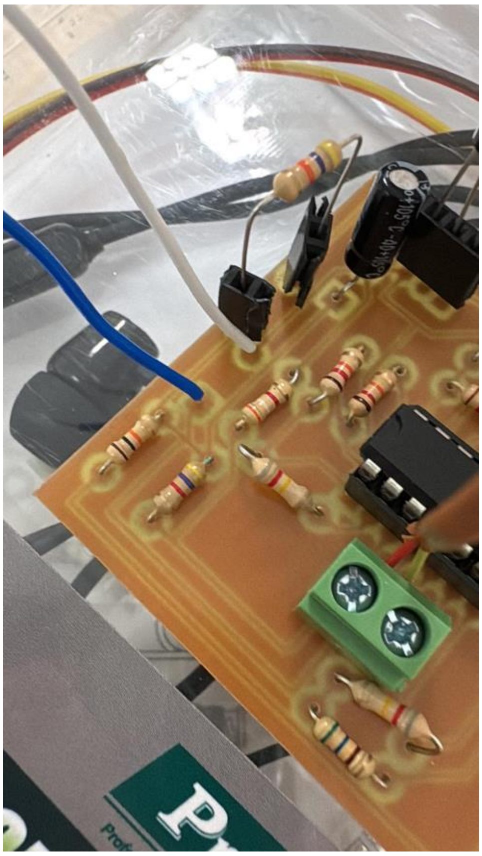

Figure 4: Use of Sockets

Specifications

Figure 5 below demonstrates the behavior of the circuit as temperature increases.

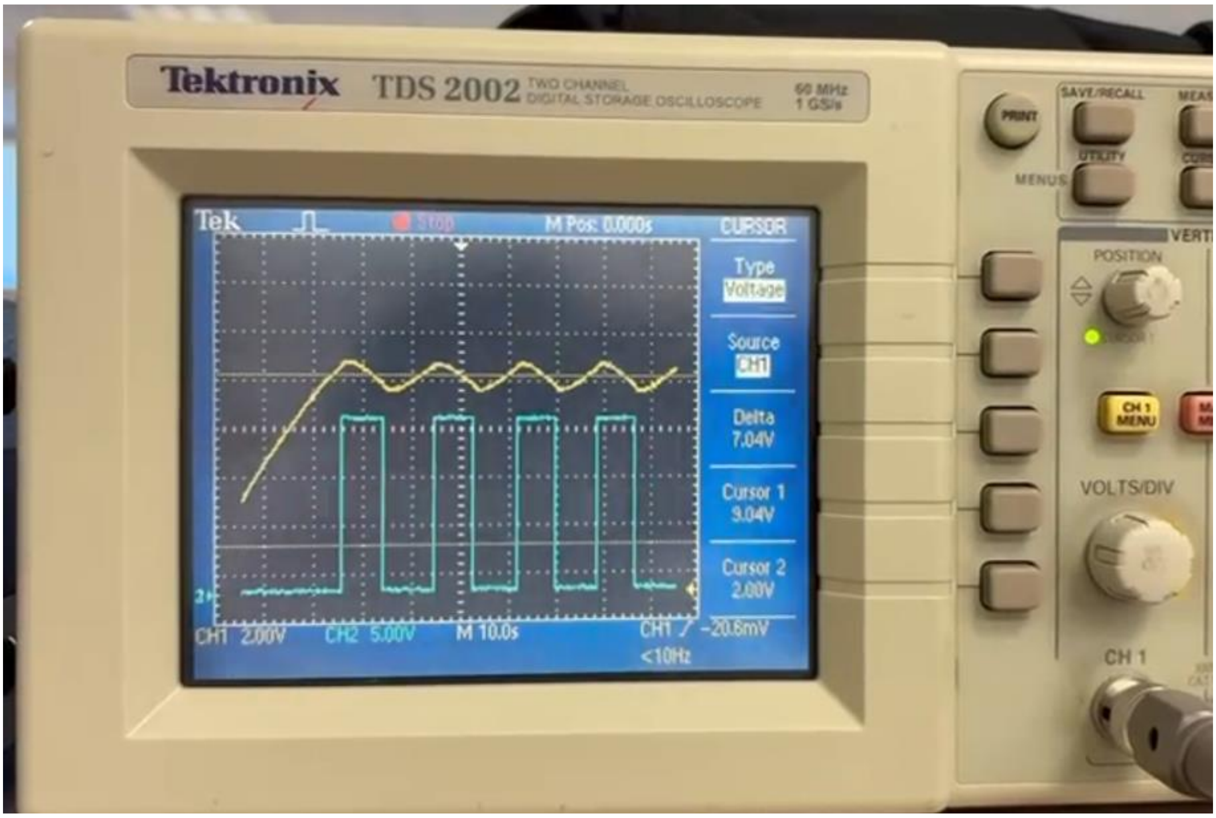

Figure 5: Oscilloscope Outputs

REQUIREMENT 1

The output voltage at 2V±0.5V when the thermocouple is at room temperature (thermocouple output voltage is zero).

The LED is on at room temperature and the output voltage is at 1.995V, satisfying the requirement. This can be observed on both multimeter and oscilloscope readings, as in Figure 5 where the output begins increasing from 2V, and where the multimeter displays the desired voltage level when the circuit is turned on after being off for a long time (when the circuit is not heated and at room temperature).

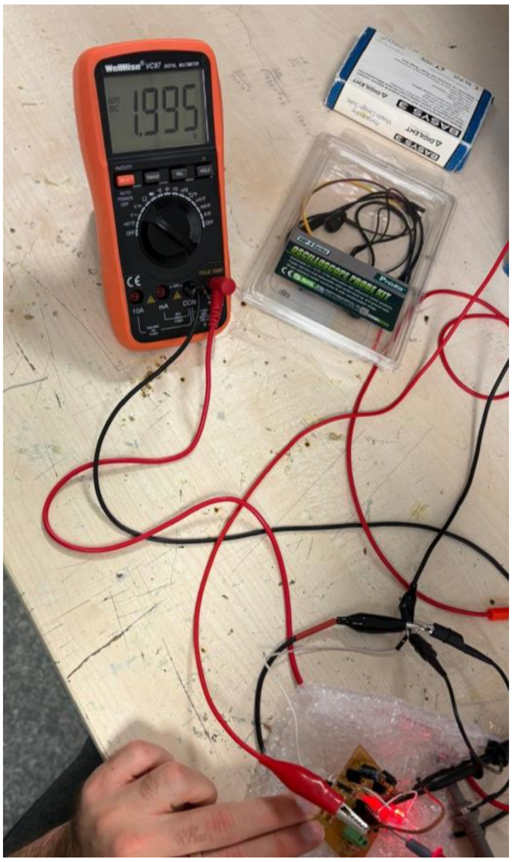

Figure 6: Circuit at Room Temperature

REQUIREMENT 2

The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is $39.2 \times T_S$ μV)

It can be observed that the output voltage oscillates near 9V from Figure 5, satisfying the given requirement.

REQUIREMENT 3

LED turns ON when the heater resistance is being heated. It should turn OFF when the heater is OFF.

Figures 5 (blue) displays the behavior of the LED with increasing temperature, it turns OFF and back ON as circuit output oscillates.

Conclusion

The project successfully implemented a thermocouple instrumentation amplifier-controlled heater. All specifications were met through careful design, simulation, and testing. The project enhanced my understanding of instrumentation amplifiers, comparator circuits, and PCB design.