M.S in Embedded Systems Design
Maritime Systems

Under the guidance of
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Laboratory Report
Temperature Measurement

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Introduction

This project involves the development of a temperature measurement system utilizing a PT100 platinum resistance thermometer, a Wheatstone bridge, and an instrumentation amplifier. The system is designed to measure temperatures ranging from -15°C to 110°C with high precision. The measured temperature is processed by an ATmega32 microcontroller, which outputs the data via a serial interface.

System Overview

1. **Temperature Sensor**

The PT100 is a widely used platinum resistance thermometer with a resistance of 100Ω at 0°C. The sensor's resistance increases with temperature according to the following equation:

$$R(T) = R_0 \cdot (1 + \alpha \cdot T + \beta \cdot T^2)$$

Where:

- $R_0 = 100\,\Omega$
- $\alpha = 3.9083 \times 10^{-3}\ {}^\circ\mathrm{C}^{-1}$
- $\beta = -0.5775 \times 10^{-6}\ {}^\circ\mathrm{C}^{-2}$

2. **Wheatstone Bridge**

The PT100 sensor is integrated into a Wheatstone bridge circuit, which is used for measuring small resistance changes. The bridge is balanced to provide an output voltage of approximately 0V at the minimum temperature of -15°C.

3. **Instrumentation Amplifier**

An AD623 instrumentation amplifier is used to amplify the small voltage difference from the Wheatstone bridge. The amplifier increases the signal to a level suitable for measurement by the microcontroller.

4. **Microcontroller Integration**

The ATmega32 microcontroller reads the amplified signal and converts it to a temperature value. The microcontroller is programmed to automatically calibrate the system and output the temperature data via a serial interface.

Circuit Design

The measurement circuit is composed of the following key components:

- PT100 sensor: Provides temperature-dependent resistance.
- Wheatstone bridge: Converts resistance changes into voltage changes.
- Zener diode: Stabilizes the voltage supply for the bridge.
- AD623 instrumentation amplifier: Amplifies the bridge output voltage.
- Resistors Precisely selected to match the required specifications.
- ATmega32 microcontroller: Processes the amplified signal and outputs the temperature data.

Key Calculations

- Wheatstone Bridge Calibration: Calculated to ensure the bridge output voltage is approximately 0V at -15°C.
- Amplification Resistor: Determined to provide the required gain for the instrumentation amplifier, ensuring the output voltage is within the microcontroller's input range.

Simulation

The circuit design was validated using SPICE simulations. The simulations confirmed that the output voltage of the Wheatstone bridge and the amplified signal were within the expected ranges across the entire temperature range.

Calibration and Measurement

The system was calibrated using a two-point calibration method:

1. 0°C Calibration: The PT100 was placed in an ice-water mixture, and the output was adjusted to match the expected voltage.

2. 100°C Calibration: The PT100 was placed in boiling water, and the system was calibrated accordingly.

The microcontroller was programmed to handle this calibration process automatically, guiding the user through each step.

Data Acquisition

The ATmega32 microcontroller reads the amplified voltage, calculates the corresponding temperature using a linear approximation, and sends the result as ASCII text via a serial port. The system provides a temperature resolution of 0.1°C.

Conclusion

The temperature measurement system successfully measures and outputs accurate temperature readings in the range of -15°C to 110°C. The combination of the PT100 sensor, Wheatstone bridge, instrumentation amplifier, and ATmega32 microcontroller provides a robust solution for precise temperature monitoring.

The project demonstrates the effectiveness of combining analog signal processing with digital data acquisition to achieve accurate and reliable measurements.