Temperature Sensor using ATmega328P

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1. Introduction

Temperature sensors are crucial in various applications, including industrial, scientific, and consumer electronics. In this project, we design a reliable temperature sensing system based on the **ATmega328P microcontroller**, which interfaces with a **PT100 temperature sensor**. This system is powered by a **18650 Li-ion battery**, ensuring portability and long-lasting operation. The temperature reading is displayed on a **16x2 I2C LCD**, which simplifies the wiring and provides clear visual output.

This design is optimized for industrial use, focusing on durability, accuracy, and low power consumption. The **temperature range** for this system is tailored to cover a wide span, making it suitable for many industrial and commercial applications.

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2. System Overview

- **Microcontroller**: ATmega328P
- **Temperature Sensor**: PT100
- **Power Supply**: 18650 Li-ion Battery (3.7V)
- **Display**: 16x2 LCD Screen (I2C interface)
- **Communication Protocol**: I2C for LCD, analog/digital interface for the PT100
- **Calibration**: User can calibrate the temperature.
- **Temperature Range**: 0°C to 80°C

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3. Components and Materials

1. **ATmega328P Microcontroller**
    - Widely used microcontroller for low-power and low-cost applications.
    - Operates at 5V and can be easily interfaced with various sensors and displays.
    - Can be programmed using the Arduino IDE for ease of development.
2. **PT100 Temperature Sensor**
    - A resistance temperature detector (RTD) that provides accurate and stable measurements.
    - The PT100 sensor has a resistance of 100 ohms at 0°C and changes with temperature.
    - Requires signal conditioning, such as an amplifier or a precision analog-to-digital converter (ADC).

    - **Temperature Range**: -200°C to 850°C (PT100 sensors can be used in this range depending on the specific model and the conditions).
3. **18650 Li-ion Battery**
    - Provides a compact power source with a nominal voltage of 3.7V.
    - High energy density ensures long-term operation without frequent recharging.
    - Must be coupled with a charging circuit (e.g., TP4056) and a voltage regulator to step up to 5V for the ATmega328P.
4. **16x2 LCD Display (I2C Interface)**
    - The I2C interface simplifies wiring and reduces the number of required pins on the microcontroller.
    - Displays the temperature data in a clear and readable format.
    - Low power consumption suitable for battery-powered systems.
5. **Voltage Boost**
    - Steps up the voltage from 3.7V (Li-ion) to 5V to power the ATmega328P and LCD.
6. **Optional: Battery Management System**
    - Ensures safe charging and discharging of the 18650 Li-ion battery.
    - Protects against over-voltage, over-current, and short circuits.

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4. Circuit Design

4.1 ATmega328P Microcontroller

- The ATmega328P operates at 5V and is programmed via the Arduino IDE. It interfaces with the PT100 sensor through an external signal conditioning circuit and reads the temperature value.
- The I2C communication protocol is used to send data to the 16x2 LCD screen.

4.2 PT100 Signal Conditioning

- **PT100 sensors** require a **current excitation** to produce a measurable voltage that can be interpreted by the microcontroller.
- Use a **precision operational amplifier** and **analog-to-digital converter (ADC)** to convert the PT100's resistance change into a corresponding voltage.
- The circuit typically includes a **Wheatstone bridge** for temperature measurement.
- The output is fed to the ATmega328P, which uses the **ADC** to convert the voltage to a digital value, which is then processed and displayed.

4.3 Power Supply Circuit

- The **18650 Li-ion battery** provides a 3.7V nominal output, which is not directly compatible with the 5V requirements of the ATmega328P and LCD.
- A **DC-DC boost converter** (e.g., MT3608) is used to step up the 3.7V from the battery to a stable 5V for the microcontroller and peripherals.

- A **charging module** like the **TP4056** is used for safe charging of the 18650 Li-ion battery.

4.4 LCD Display (I2C Interface)

- The **16x2 LCD** has an I2C module attached, reducing the number of GPIO pins required on the ATmega328P. The **SCL (Clock)** and **SDA (Data)** lines of the I2C bus are connected to the microcontroller.

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5. Software Design

The system is programmed using the **Arduino IDE**, which allows for quick and easy development. The main tasks of the software include:

1. **Reading Temperature Data**:
    - Read the output from the PT100 sensor through the signal conditioning circuit.
    - Convert the voltage to temperature using the appropriate calibration curve for PT100.
2. **Displaying Data on LCD**:
    - Initialize the LCD display using the I2C protocol.
    - Continuously update the temperature value on the LCD screen.
3. **Power Management**:
    - Put the ATmega328P into a low-power mode when idle to maximize battery life.
    - Continuously monitor the battery level and display it (optional).
4. **Error Handling**:
    - Detect sensor or power failures and display error messages if necessary.

6. Power Consumption

- The ATmega328P operates at low power, making it suitable for battery-powered applications.
- The **I2C LCD** and **signal conditioning circuits** should be optimized for low power as well.
- The **18650 Li-ion battery** has a typical capacity of **2200mAh** to **3500mAh**, which provides long-lasting power for the system. The battery is rechargeable, and the power consumption can be minimized by using low-power modes in the microcontroller.

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7. Calibration and Accuracy

- **PT100 sensors** provide high accuracy, typically within **±0.1°C**, but the system must be calibrated using standard temperature reference points.

- The calibration process involves adjusting the reading from the sensor in the software to match the actual temperature measured by a known thermometer.
- Regular calibration is recommended to maintain accuracy.

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9. Temperature Range

- The **PT100 sensor** used in this design has a temperature range of **-200°C to 850°C**. This broad range makes the system suitable for various industrial applications, including temperature monitoring in manufacturing processes, HVAC systems, and research environments.
- The sensor's high accuracy ensures that even within this wide range, the temperature readings will be reliable and precise.
- Ensure the system is calibrated correctly for the desired temperature range, as certain factors like wiring length, power supply stability, and sensor placement can influence the accuracy.