DEVELOPMENT OF TEMPERATURE MONITORING SYSTEM FOR ART CONSERVATION

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THE ART WALTERS MUSEUM

Introduction

Temperature is an important measured physical quantity in a wide range of applications requiring building ventilation control, such as the conservation of artworks in museums. Many materials, such as acrylic, copper, and natural dyes, used in artworks are susceptible to deterioration. The most common deterioration observed at the Walters Art Museum in Baltimore includes dimensional changes, chemical reactions, and biodeterioration.

In this work, we present the design and fabrication of a compact wireless nickel RTD temperature detecting system to monitor temperature in museums. The fabricated system is designed to be cost-effective compact and discreet, while enabling precise wireless monitoring of temperature.

Objective

Design and fabricate a low power, wireless resistance temperature detector (RTD) system to monitor temperature in museums.

Instrumentation

Hardware:

- Arduino Uno Wifi
- Texas Instruments CC2650
- INA114 Operational Amplifier
- LM10CLN Operational Amplifier
- TLE2426 Virtual Ground
- Resistors

Software:

- Arduino IDE
- Smart RF Studio
- Code Composer Studio
- TI-RTOS

Analog to Digital Converter (ADC)

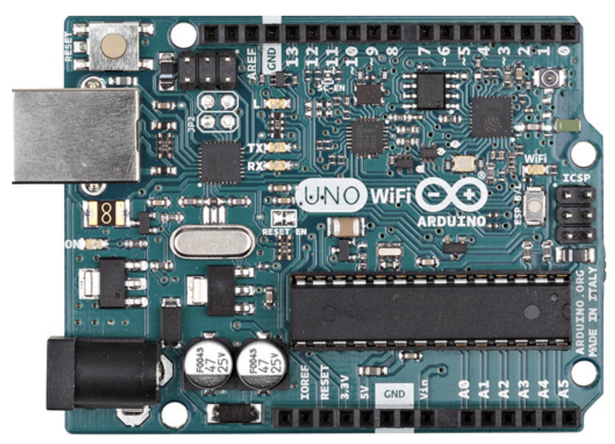
• Responsible for converting an analog voltage to the nearest digital value (expressed in binary).
• ADC resolution is directly correlated to number of bits (0's or 1's) in a digital value.
• Reference voltage found on microcontrollers is negatively correlated to ADC resolution.
• Oversampling technique (found on Arduinos) simulates increased ADC resolution (21-bit vs. 10-bit) at the cost of longer sampling time.
• To determine input voltage (indirectly used to ultimately map temperature), we use the equation:

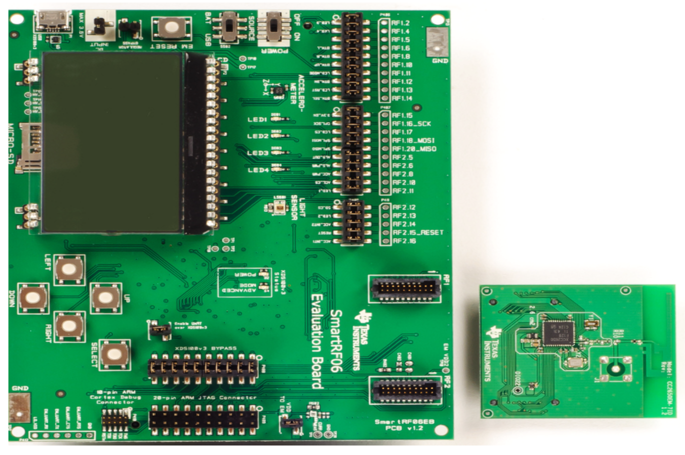
$$V_{IN} = \frac{O_{ADC}}{2^N} \bullet V_{REF}$$

where, V_{IN} – Analog input voltage,
O_{ADC} – Digital ADC output,
N – number of bits of the ADC,
V_{REF} – ADC reference voltage.

Microcontroller Features

Arduino Uno WiFi[2]	TI CC2650[3]
• 2.4 GHz RF	• Bluetooth + 2.4 GHz RF
• Low power modes	• Low power modes
• 10-bit ADC	• 12-bit ADC
• Separate WiFi chip	• Built-in WiFi
• Simple Development	• Complex Development
• 35 x 5 mm size	• 7x7 mm size





ADC

± 0.5 mV Accuracy | ± 3 mV Accuracy

Wireless

Wireless libraries were imported, but no data has been successfully transmitted and captured.

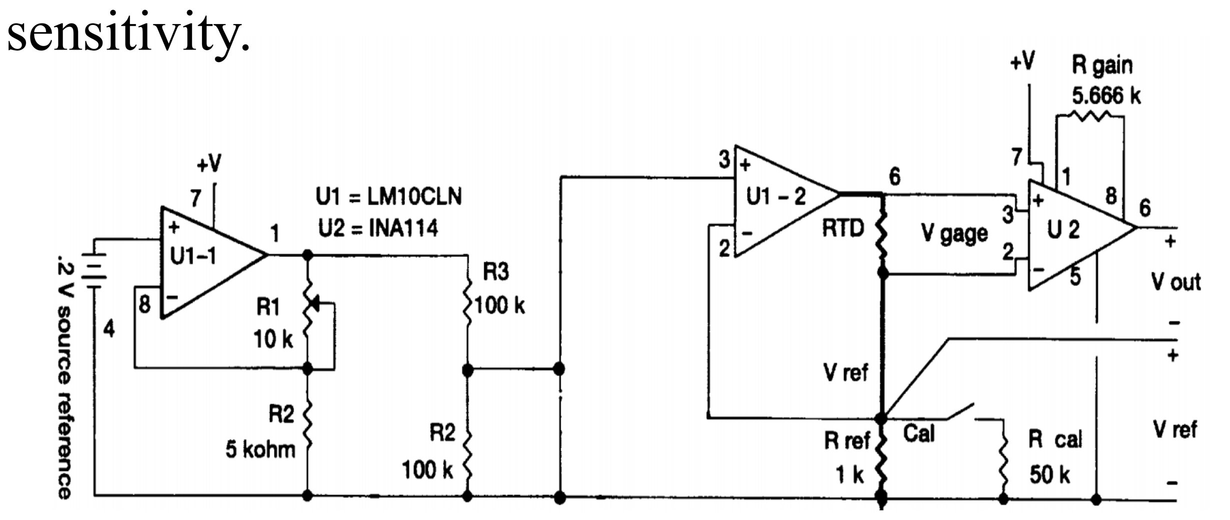
Relevant data was successfully sent from one transmitter to one receiver.

Temperature Conversion

Temperature was mapped using a linear function with slope 1 mV/°C.

Anderson Loop Signal Conditioning[1]

• Provides constant current source to RTD.
• Subtraction of bias voltage allows for higher ADC resolution.
• Op-amps induce voltage gain → amplify voltage sensitivity.

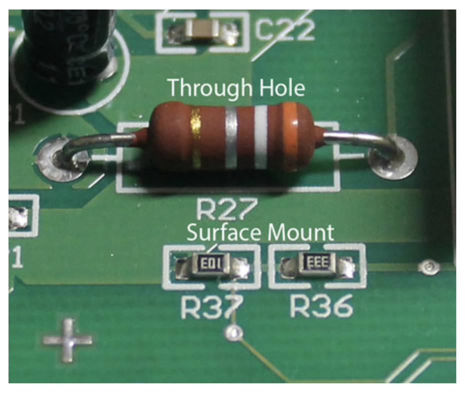


Experimental Results

• Accurate voltage (± 0.2mV) was measured when powering the RTD.
• Current was confirmed to be stable (± 0.00mA).
• Output was interfaced to microcontrollers' ADC.

Next Steps

• Condense the system by removing the need for a development board.
• Reduce overall power consumption by incorporating low power modes.
• Program a central hub for wireless data capture.
•Miniaturize PCB layouts.
•Add capability for additional sensors (i.e. humidity, pollution, etc.).



References

[1] NASA's "High Accuracy Temperature Measurements Using RTD's With Current Loop Conditioning"
[2] ATmega328P Datasheet
[3] TI CC2650 Datasheet

Acknowledgements

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