Mechatronics Lab 6 Report: Thermocouple Measurements Using ADS1115 and TMP36

Course: CSE4355/5355/6351 Electromechanical Systems and Sensors
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Authors: Anaf Mahbub & Yasasvi Vanapalli

Introduction

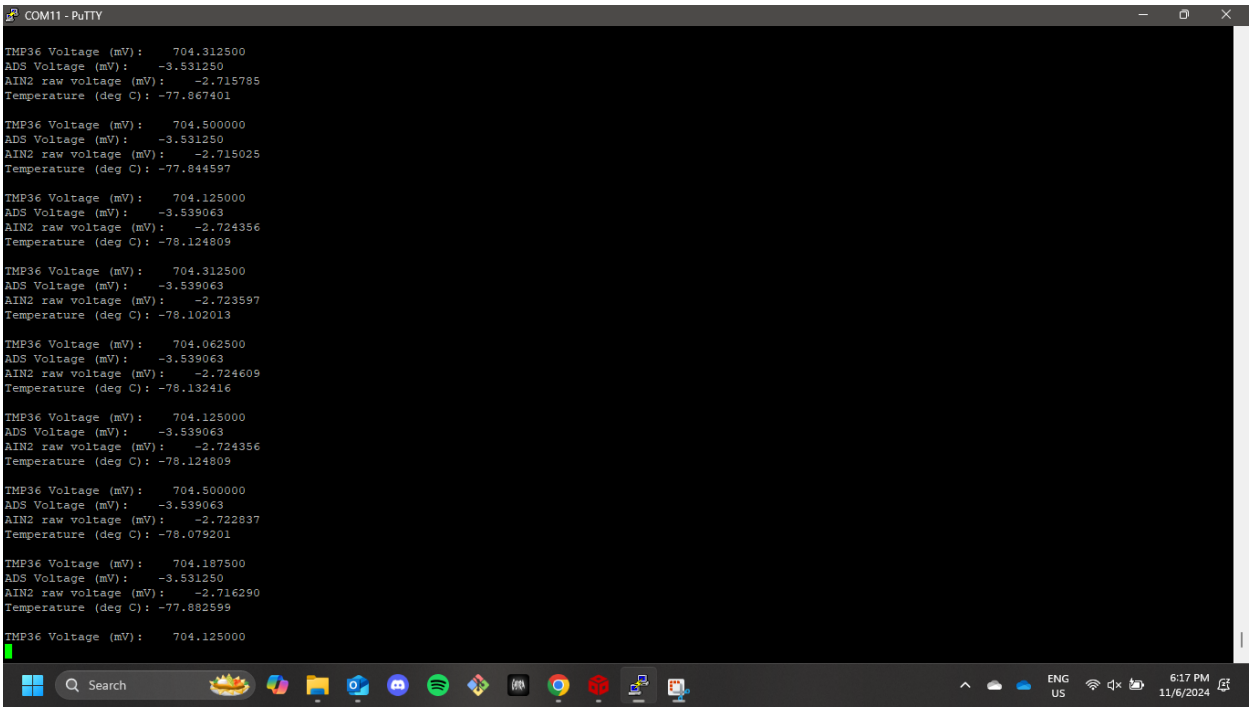
This lab demonstrates the process of measuring temperature using a type K thermocouple, an ADS1115 A/D converter, and a TMP36 temperature sensor for cold junction compensation. The objective is to accurately convert sensor readings into temperature values using lookup tables and linear interpolation and to verify the system's performance through practical temperature tests.

- The type K thermocouple was connected to the ADS1115 A/D converter to enable differential measurement.
- A bias network was implemented by tying the positive input of the ADS1115 to Vdd with a 1 MΩ resistor and the negative input to GND with another 1 MΩ resistor.
- The TMP36 sensor was connected to one of the remaining ADS1115 inputs and placed in contact with the thermocouple jack to measure the cold junction temperature, which ensures accurate temperature compensation.
- The ADS1115 A/D converter was connected to the TM4C123GXL microcontroller, ensuring that the SDA and SCL lines had 2 kΩ pull-up resistors for reliable I2C communication.
- The I2C bus was tested using an I2C tool to confirm that the ADS1115 was correctly recognized by the microcontroller.
- A lookup table based on NIST ITS-90 tables, normalized for 0°C, was developed to cover the temperature range from -80°C to 300°C. This table provides corresponding voltage values for given temperatures.
- Functions for converting temperature to voltage and voltage to temperature using linear interpolation were written. Polynomial-based solutions were avoided due to high floating-point precision requirements.
- The TMP36 sensor was read through the ADS1115, and the resulting temperature was converted to voltage using the interpolation function created in step 3. This voltage represents the cold junction voltage (Vcj).
- The process included reading the TMP36 output, converting the analog reading into millivolts, and then adjusting it using a scaling factor.
- The ADS1115 was configured to measure the differential voltage (Vtc) of the thermocouple at the highest programmable gain amplifier (PGA) setting for improved resolution.
- The cold junction voltage (Vcj) was added to the measured thermocouple voltage (Vtc) to compensate for ambient temperature variations.

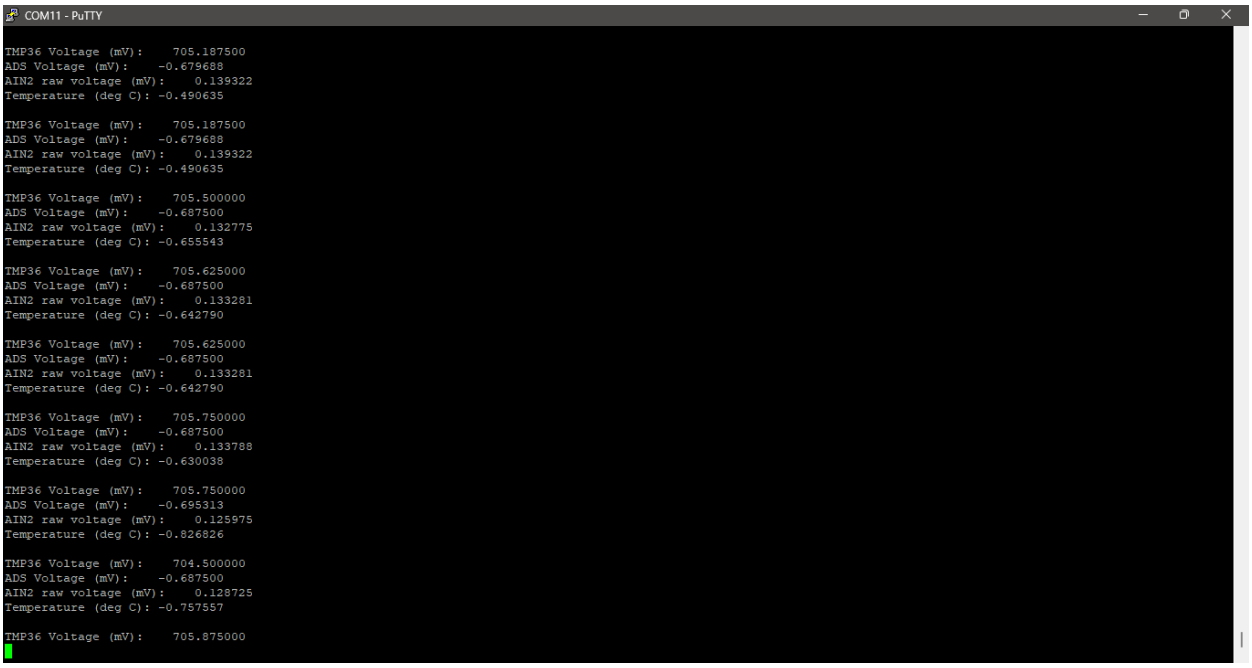
- The total compensated voltage (Vcj + Vtc) was converted to temperature using the lookup table function to get the thermocouple temperature (Ttc).
- The setup was tested with dry ice (-78.5°C), an ice water bath (0°C), and a soldering iron (varied high temperatures). The accuracy of the readings was checked to ensure they aligned with expected values.
- A function was added to detect if the thermocouple was disconnected or broken by checking if the reading was 0x7FFF, indicating an open circuit.

Results and Discussion

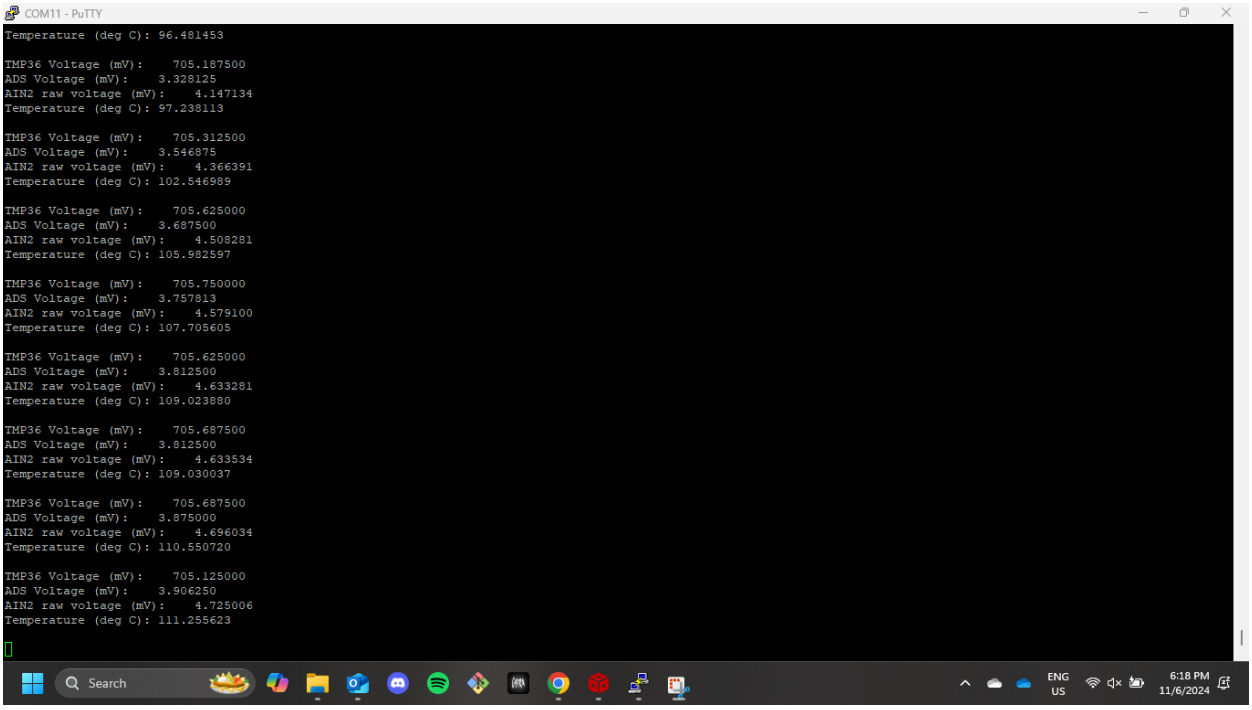
- **Dry Ice Test**: The measured temperature was around -77, which aligned with the expected -78.5°C.



- **Ice Water Test**: The output was -0.7, validating the 0°C baseline.



- **Soldering Iron Test**: Higher temperatures recorded were consistent with the calibration and lookup table data.



```
TMP36 Voltage (mV):    703.812500
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.805634
Temperature (deg C): 6306.237793

TMP36 Voltage (mV):    705.437500
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.812195
Temperature (deg C): 6306.398926

TMP36 Voltage (mV):    705.750000
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.813477
Temperature (deg C): 6306.430664

TMP36 Voltage (mV):    705.937500
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.814240
Temperature (deg C): 6306.449219

TMP36 Voltage (mV):    705.937500
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.814240
Temperature (deg C): 6306.449219

TMP36 Voltage (mV):    705.562500
Thermocoupler disconnected
ADS Voltage (mV):    255.992188
AIN2 raw voltage (mV):    256.812714
Temperature (deg C): 6306.412109
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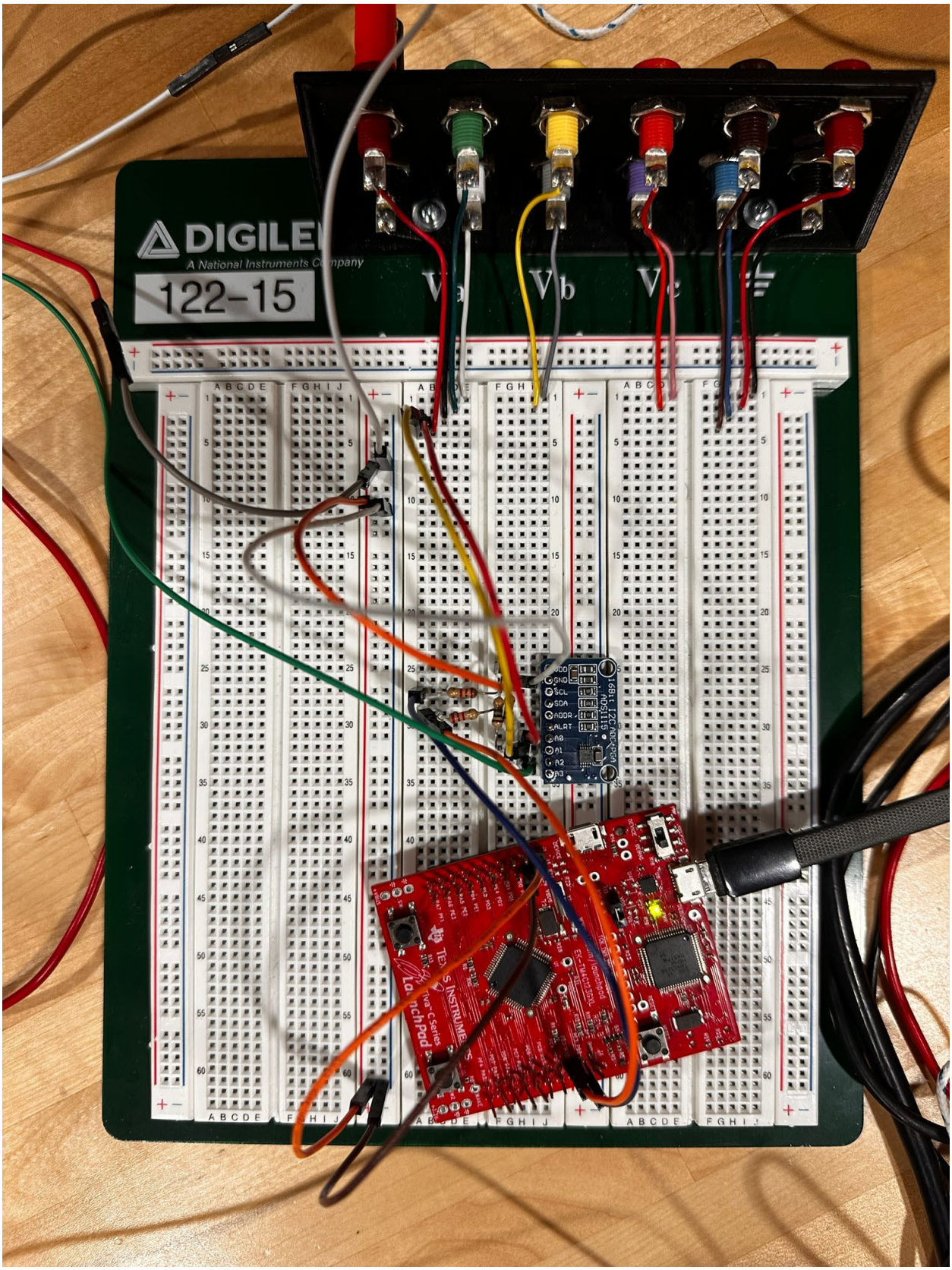
Conclusion

The lab successfully demonstrated how to interface a thermocouple and TMP36 sensor with an ADS1115 A/D converter and process the readings through a TM4C123GXL microcontroller. The interpolation functions provided accurate voltage-to-temperature and temperature-to-voltage conversions, validated through various tests.


DIGILE
A National Instruments Company
122-15
Va
Vb
Vc
ABCDE
FGHIJ
VDD
GND
SCL
SDA
ADDR
ALRT
A0
A1
A2
A3
ADS1115
16-Bit I2C ADC 4-CH
TEXAS INSTRUMENTS
Tiva C Series
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