

## **Mechatronics Lab 6 Report: Thermocouple Measurements Using ADS1115 and TMP36**

**Course:** CSE4355/5355/6351 Electromechanical Systems and Sensors

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### **Introduction**

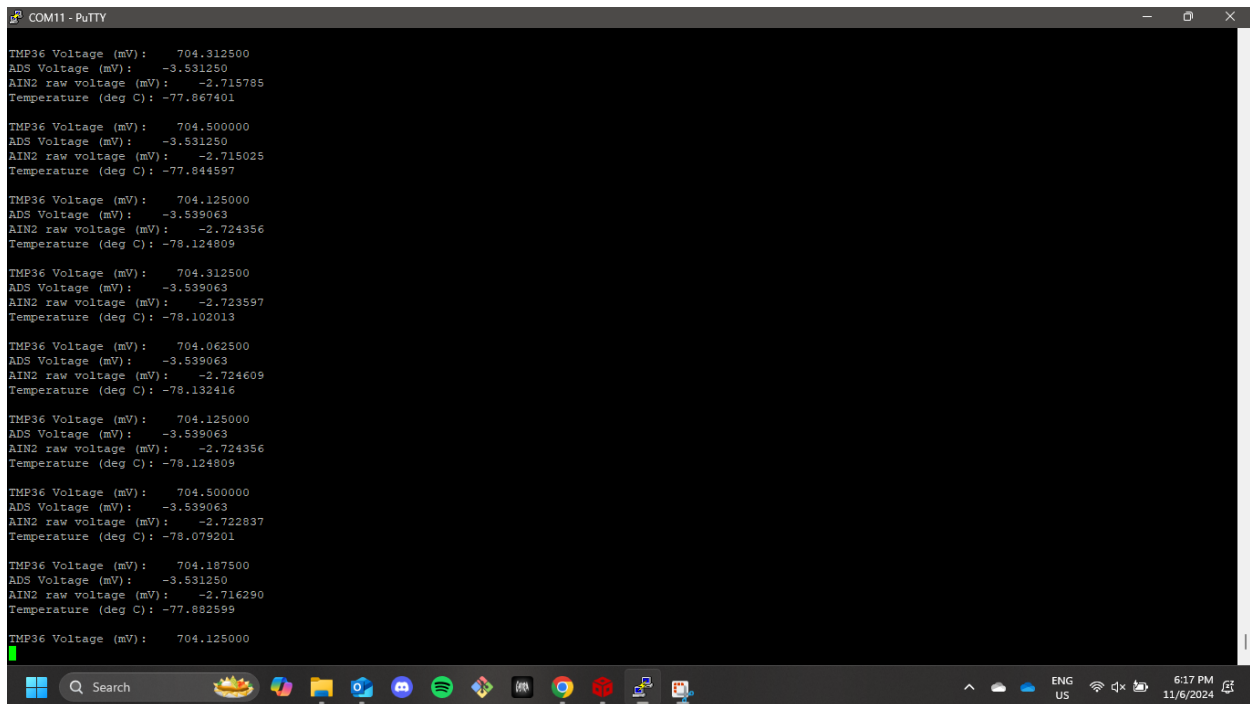
This lab demonstrates the process of measuring temperature using a type K thermocouple, an ADS1115 A/D converter, and a TMP36 temperature sensor for cold junction compensation. The objective is to accurately convert sensor readings into temperature values using lookup tables and linear interpolation 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 ( $V_{cj}$ ).
- 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 ( $V_{tc}$ ) of the thermocouple at the highest programmable gain amplifier (PGA) setting for improved resolution.
- The cold junction voltage ( $V_{cj}$ ) was added to the measured thermocouple voltage ( $V_{tc}$ ) to compensate for ambient temperature variations.

- The total compensated voltage ( $V_{cj} + V_{tc}$ ) was converted to temperature using the lookup table function to get the thermocouple temperature ( $T_{tc}$ ).
- The setup was tested with dry ice ( $-78.5^{\circ}\text{C}$ ), an ice water bath ( $0^{\circ}\text{C}$ ), 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  $-78.5^{\circ}\text{C}$ .



```

COM11 - PuTTY

TMP36 Voltage (mV): 704.312500
ADS Voltage (mV): -3.531250
AIN2 raw voltage (mV): -2.715785
Temperature (deg C): -77.867401

TMP36 Voltage (mV): 704.500000
ADS Voltage (mV): -3.531250
AIN2 raw voltage (mV): -2.715025
Temperature (deg C): -77.844597

TMP36 Voltage (mV): 704.125000
ADS Voltage (mV): -3.539063
AIN2 raw voltage (mV): -2.724356
Temperature (deg C): -78.124809

TMP36 Voltage (mV): 704.312500
ADS Voltage (mV): -3.539063
AIN2 raw voltage (mV): -2.723597
Temperature (deg C): -78.102013

TMP36 Voltage (mV): 704.062500
ADS Voltage (mV): -3.539063
AIN2 raw voltage (mV): -2.724609
Temperature (deg C): -78.132416

TMP36 Voltage (mV): 704.125000
ADS Voltage (mV): -3.539063
AIN2 raw voltage (mV): -2.724356
Temperature (deg C): -78.124809

TMP36 Voltage (mV): 704.500000
ADS Voltage (mV): -3.539063
AIN2 raw voltage (mV): -2.722837
Temperature (deg C): -78.079201

TMP36 Voltage (mV): 704.187500
ADS Voltage (mV): -3.531250
AIN2 raw voltage (mV): -2.716290
Temperature (deg C): -77.882599

TMP36 Voltage (mV): 704.125000

```

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

```
COM11 - PuTTY

TMP36 Voltage (mV): 705.187500
ADS Voltage (mV): -0.679688
AIN2 raw voltage (mV): 0.139322
Temperature (deg C): -0.490635

TMP36 Voltage (mV): 705.187500
ADS Voltage (mV): -0.679688
AIN2 raw voltage (mV): 0.139322
Temperature (deg C): -0.490635

TMP36 Voltage (mV): 705.500000
ADS Voltage (mV): -0.687500
AIN2 raw voltage (mV): 0.132775
Temperature (deg C): -0.655543

TMP36 Voltage (mV): 705.625000
ADS Voltage (mV): -0.687500
AIN2 raw voltage (mV): 0.133281
Temperature (deg C): -0.642790

TMP36 Voltage (mV): 705.625000
ADS Voltage (mV): -0.687500
AIN2 raw voltage (mV): 0.133281
Temperature (deg C): -0.642790

TMP36 Voltage (mV): 705.750000
ADS Voltage (mV): -0.687500
AIN2 raw voltage (mV): 0.133788
Temperature (deg C): -0.630038

TMP36 Voltage (mV): 705.750000
ADS Voltage (mV): -0.695313
AIN2 raw voltage (mV): 0.125975
Temperature (deg C): -0.826826

TMP36 Voltage (mV): 704.500000
ADS Voltage (mV): -0.687500
AIN2 raw voltage (mV): 0.128725
Temperature (deg C): -0.757557

TMP36 Voltage (mV): 705.875000
```

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

```
COM11 - PuTTY

Temperature (deg C): 96.481453

TMP36 Voltage (mV): 705.187500
ADS Voltage (mV): 3.328125
AIN2 raw voltage (mV): 4.147134
Temperature (deg C): 97.238113

TMP36 Voltage (mV): 705.312500
ADS Voltage (mV): 3.546875
AIN2 raw voltage (mV): 4.366391
Temperature (deg C): 102.546989

TMP36 Voltage (mV): 705.625000
ADS Voltage (mV): 3.687500
AIN2 raw voltage (mV): 4.508281
Temperature (deg C): 105.982597

TMP36 Voltage (mV): 705.750000
ADS Voltage (mV): 3.757813
AIN2 raw voltage (mV): 4.579100
Temperature (deg C): 107.705605

TMP36 Voltage (mV): 705.625000
ADS Voltage (mV): 3.812500
AIN2 raw voltage (mV): 4.633281
Temperature (deg C): 109.023880

TMP36 Voltage (mV): 705.687500
ADS Voltage (mV): 3.812500
AIN2 raw voltage (mV): 4.633534
Temperature (deg C): 109.030037

TMP36 Voltage (mV): 705.687500
ADS Voltage (mV): 3.875000
AIN2 raw voltage (mV): 4.696034
Temperature (deg C): 110.550720

TMP36 Voltage (mV): 705.125000
ADS Voltage (mV): 3.906250
AIN2 raw voltage (mV): 4.725006
Temperature (deg C): 111.255623
```

```
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
```



## 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.



