1 MEASUREMENT

To measure the temperature sensor, we connected LM35 with analog signal processing, transmitter, receiver, ADC circuits and Arduino. Here is the diagram of this measurement as below:

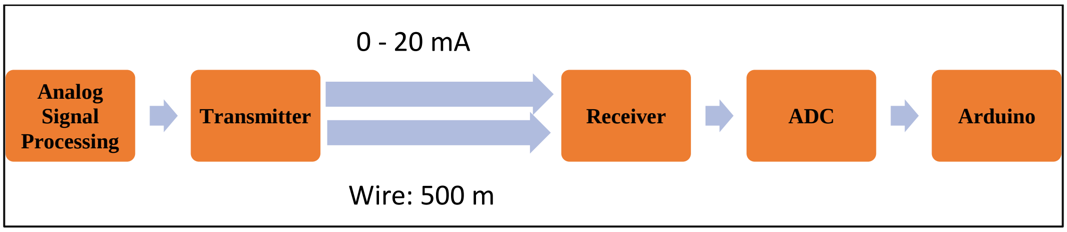

Figure 1. Measurement's proccess

1.1 Analog Signal Processing

The analog signal processing circuit was used to amplify, filter and condition of the analog signal from the LM35 sensor. LM35 provided a linear output with a 10mV/°C scale factor so within the range of temperature from -30 to +30 °C, the voltage output was converted into from -300mV to +300mV, respectively.

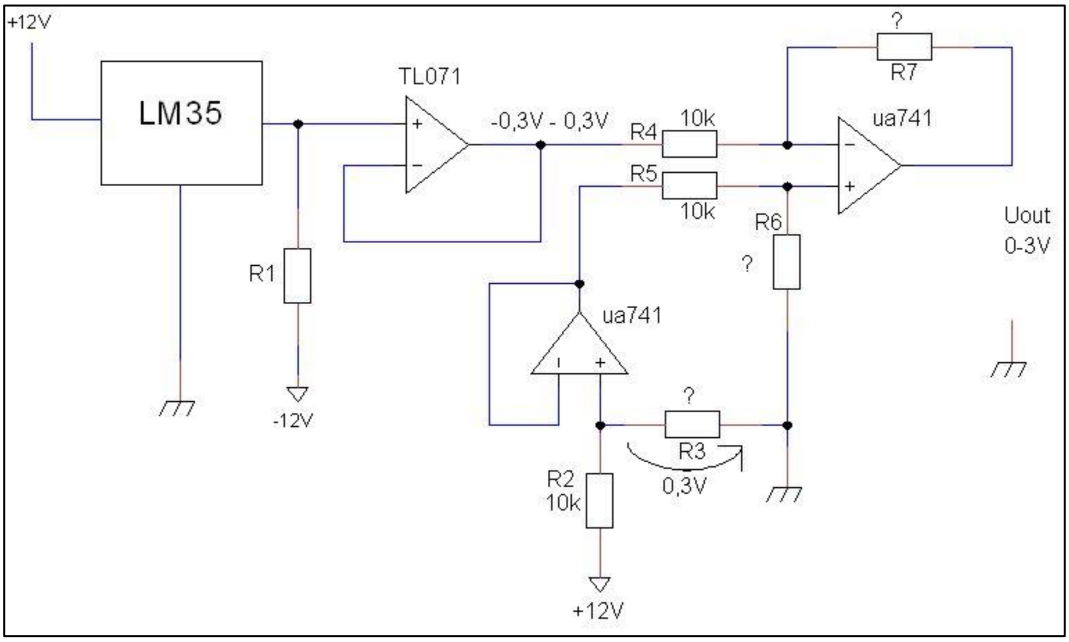

Figure 2. Analog signal processing circuit

1.1.1 Simulation

In the next step, we designed and simulated the analog signal processing circuit in LTspice. However, due to LM35 could not be found from LTspice libraries, the voltage source with the range of -0.3V - +0.3V was considered to the input temperature sensor.

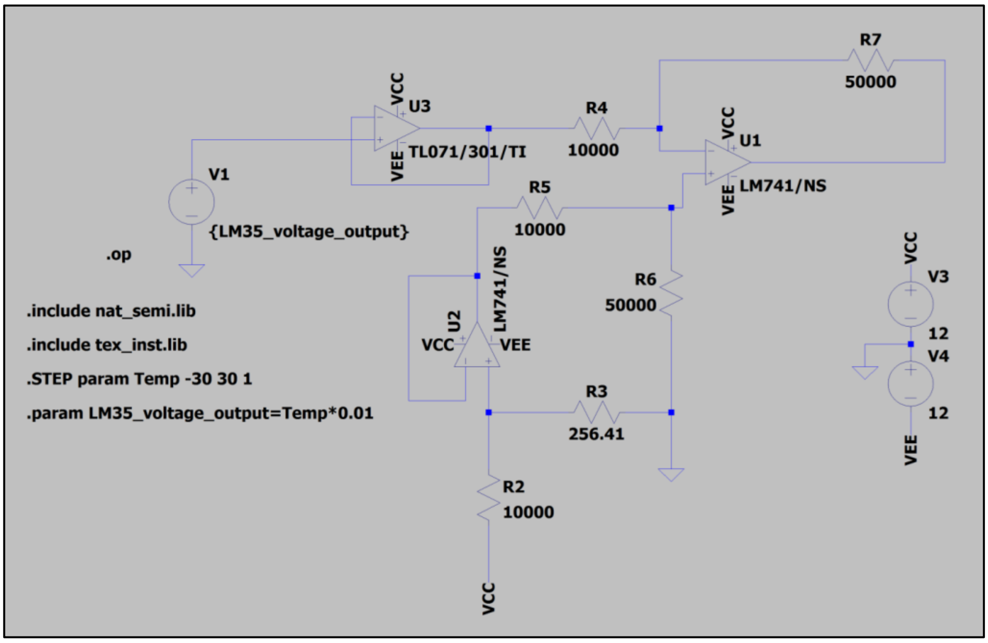

Figure 3. Analog signal processing circuit drawn in LTspice.

After that, we simulated this circuit as the picture below. The results showed that when the LM35 output voltage was -0.3V, the circuit's output voltage was generated at 3V. In contrast, when the LM35 output voltage was +0.3V, the circuit's output voltage was created at 0V.

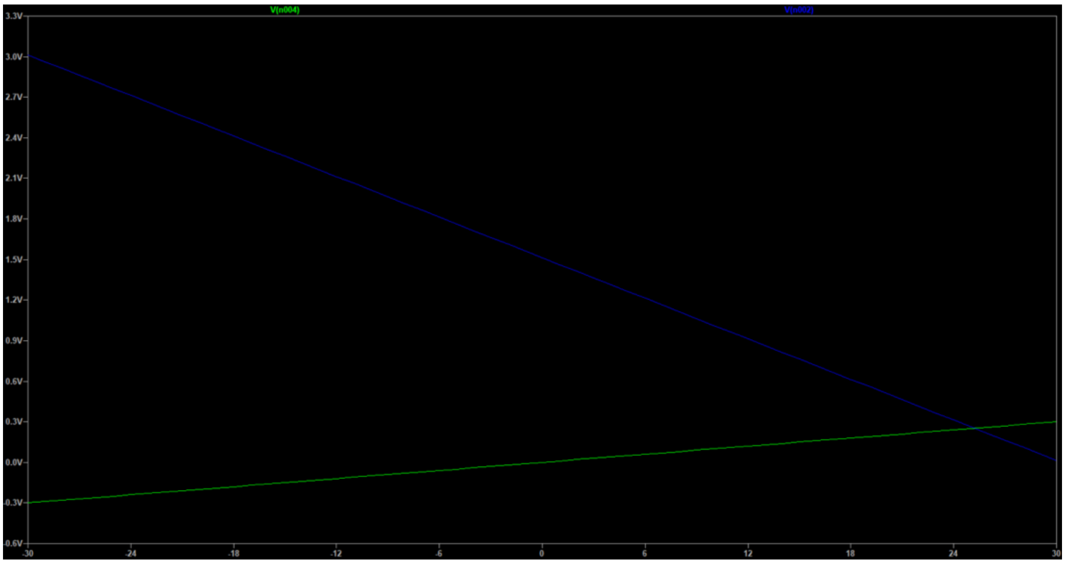

Figure 4. Simulation of the LM35 and the analog signal processing's output voltage.

1.2 Communication

The communication circuit was designed to include transmitter and receiver circuits.

1.2.1 Transmitter

The transmitter was used to convert the input voltage into the output current. The transmitter circuit was designed as Figure 5.

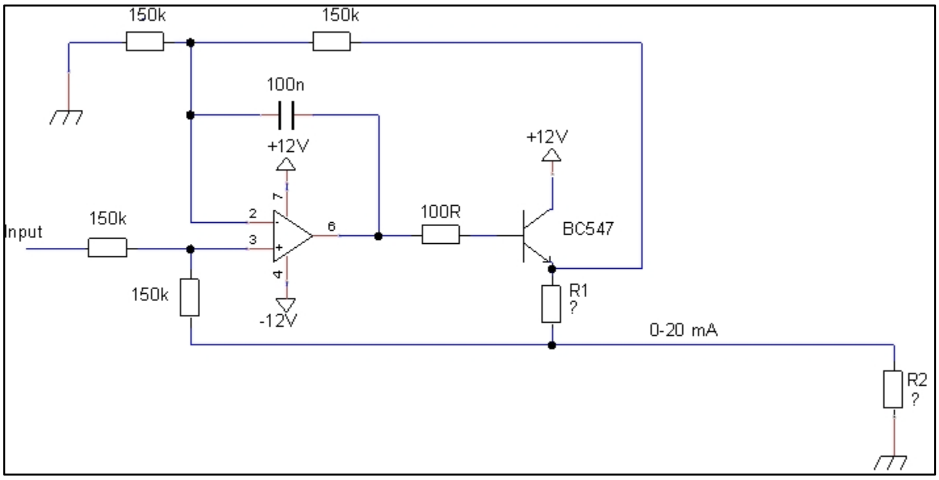

Figure 5. Transmitter's circuit

The value of R1 and R2 was calculated as below:

$$R1 = \frac{Uin}{I} = \frac{3V}{20mA} = 150\ \Omega$$

$$R2 = \frac{U2}{I} = \frac{5V}{20mA} = 250\ \Omega$$

1.2.2 Receiver

The receiver was used to receive the transmitted current signal and convert it back into its original form. The receiver circuit was shown in Figure 9.

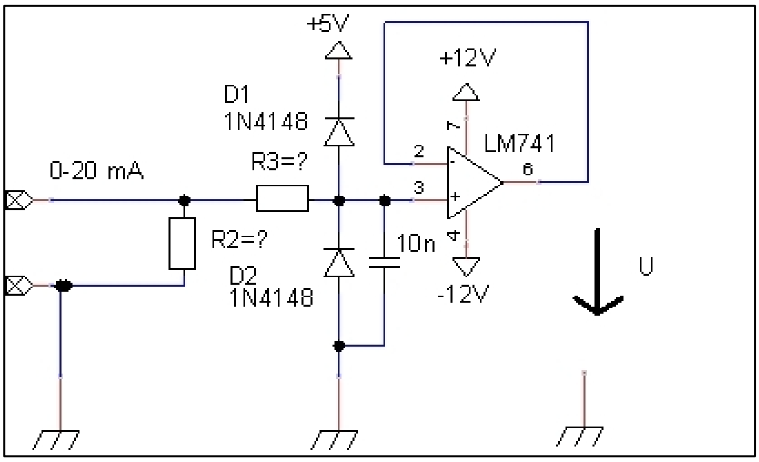

Figure 6. Receiver's circuit

The previous transmitter resistor R2 is the same resistor as input resistor in receiver circuit. Therefore, R2 = 250 Ω.

$$R3 = \frac{\text{Input signal Voltage}}{I} = \frac{8kV}{0.8A} = 10\ k\Omega$$

The low pass filter cut-off frequency:

$$f = \frac{1}{2\pi RC} = \frac{1}{2\pi * 10k\Omega * 10nF} = 1591\ Hz\ \approx 1.6\ kHz$$

1.2.3 Simulation

By using LTspice, we designed and simulated the communication circuit to measure the output current of transmitter and the output voltage of receiver.

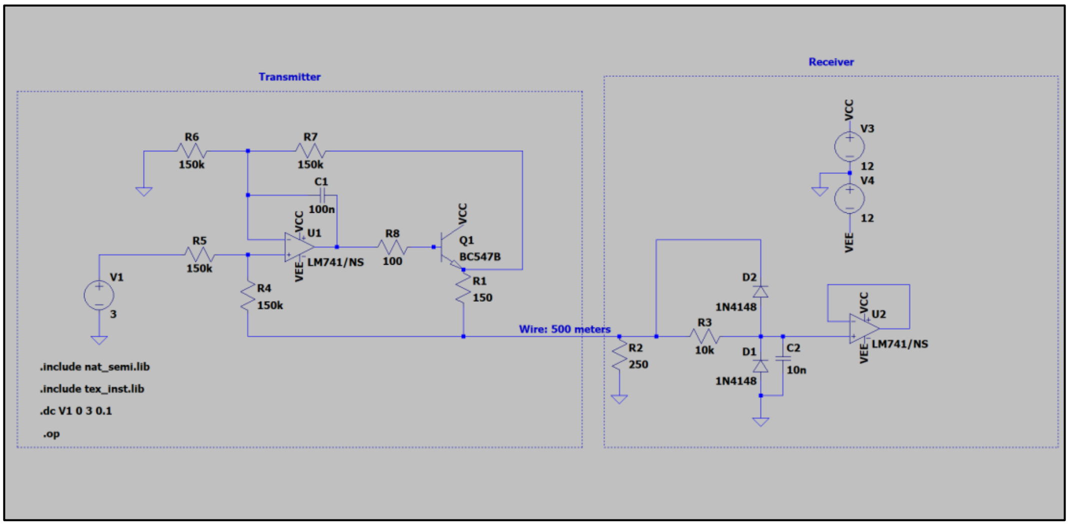

Figure 7. Communication's circuit in LTspice

After simulating, within the input voltage range of 0-3V, the transmitter output current was from 0 mA to 20 mA and the receiver output voltage was from 0 V to 5 V. These results were shown in Figure 11 below.

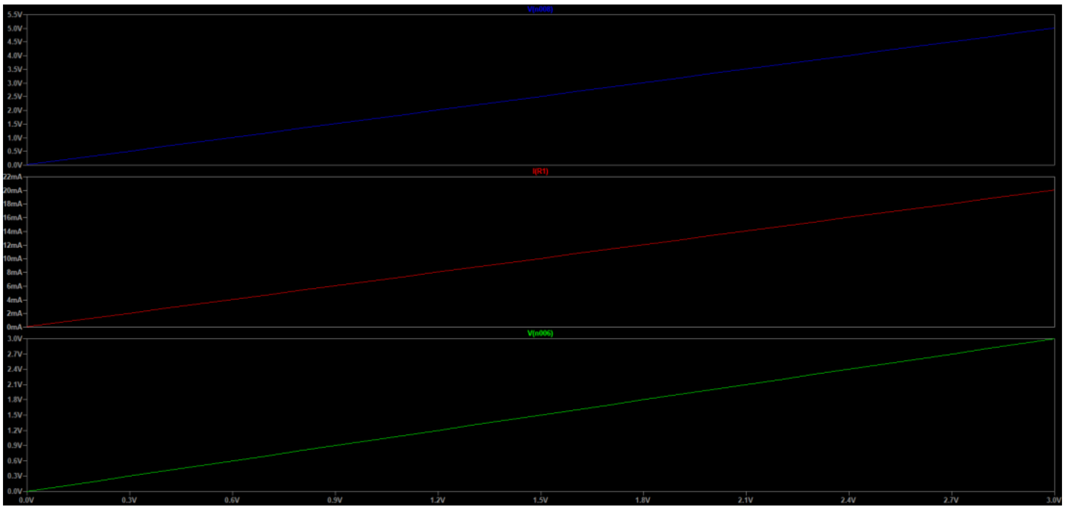

Figure 8. Simulation of the transmitter output current and the receiver output voltage.

1.2.4 Testing Circuit on Breadboard

We also tested the communication circuit on breadboard.

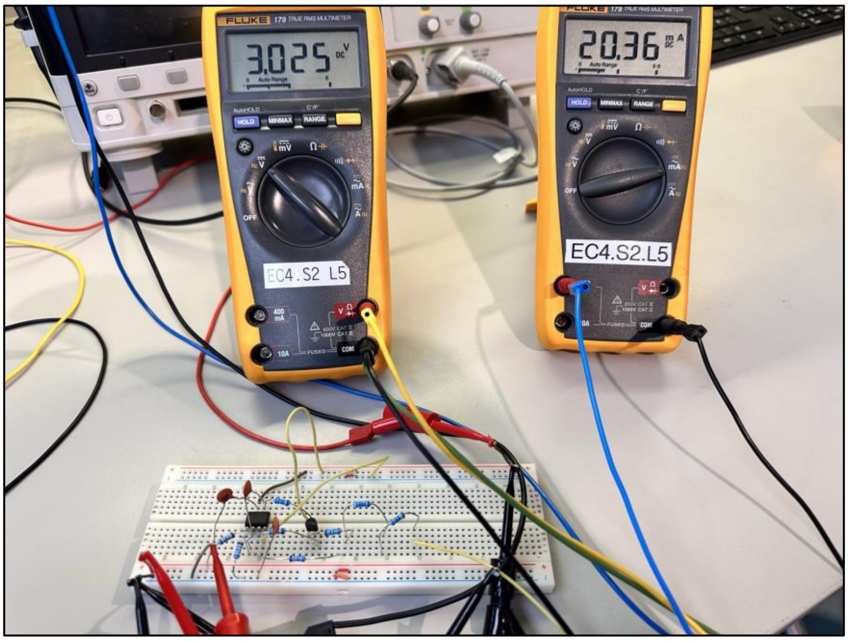

Figure 9. Results of the transmitter output current on breadboard.

We got 20 mA of the transmitter output current when the input voltage was at about 3 V, matching with the simulation's result.

Next, we continued to connected analog signal processing, transmitter and receiver circuit with each other on breadboard.

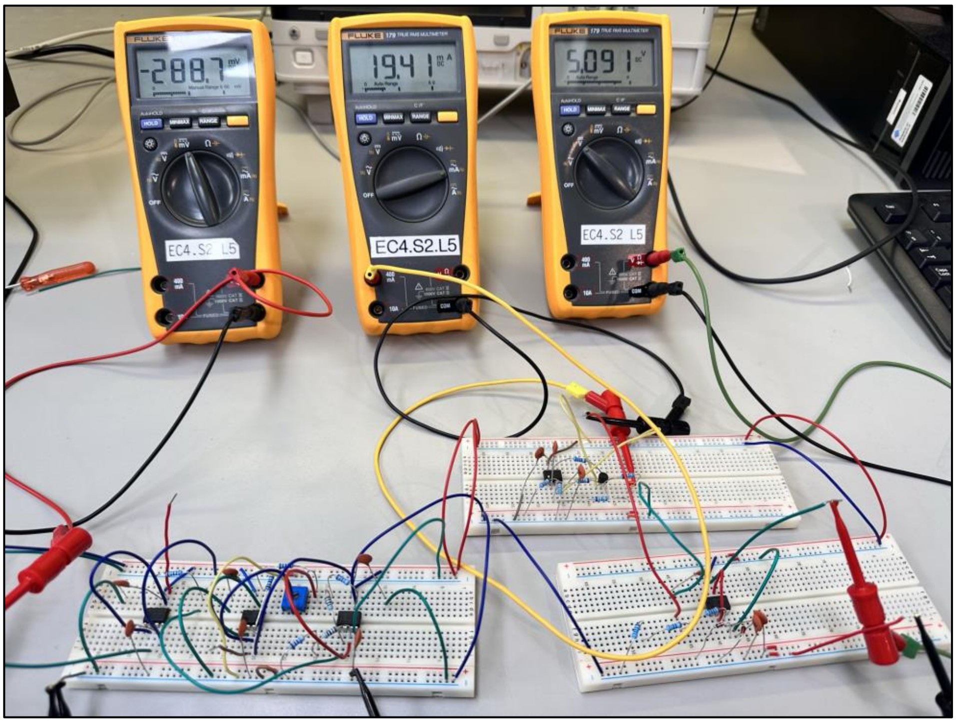

Figure 10. Testing results of the receiver output voltage on breadboard.

After integrating these circuits together, the output voltage of the receiver circuit was approximate 5 V when LM35's output voltage was near -300 mV and the transmitter output current was about 20 mA. These results matched with the simulation's result above.

1.2.5 Testing Circuit on Arduino

After checking these individual circuits correctly, we integrated these circuits together and then connected with Arduino to measure the temperature sensor. In addition, we also tested the current loop at the same time by using 500 meters of wire to connect with between transmitter and receiver. The results showed that it was matching and corresponding with the target of the output voltage. As a result, at -30℃, the output voltage of receiver was around 5 V and ADC value was 1023.

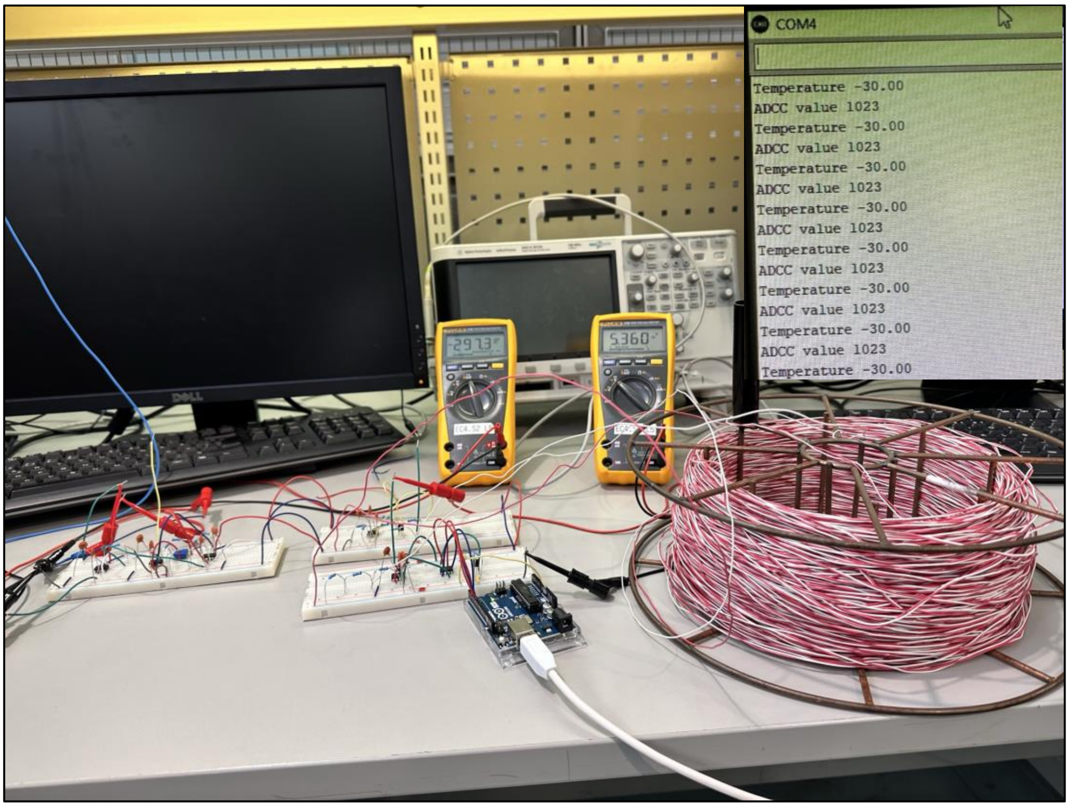

Figure 11. Testing results of the system's circuit with Arduino at −30°C

On the other hand, at +30°C, the output voltage of receiver was near 0 V and ADC value was 0. This means the current loop worked effectively because with the long distances at 500 meters, the outputs were matching with the experiments' result above.

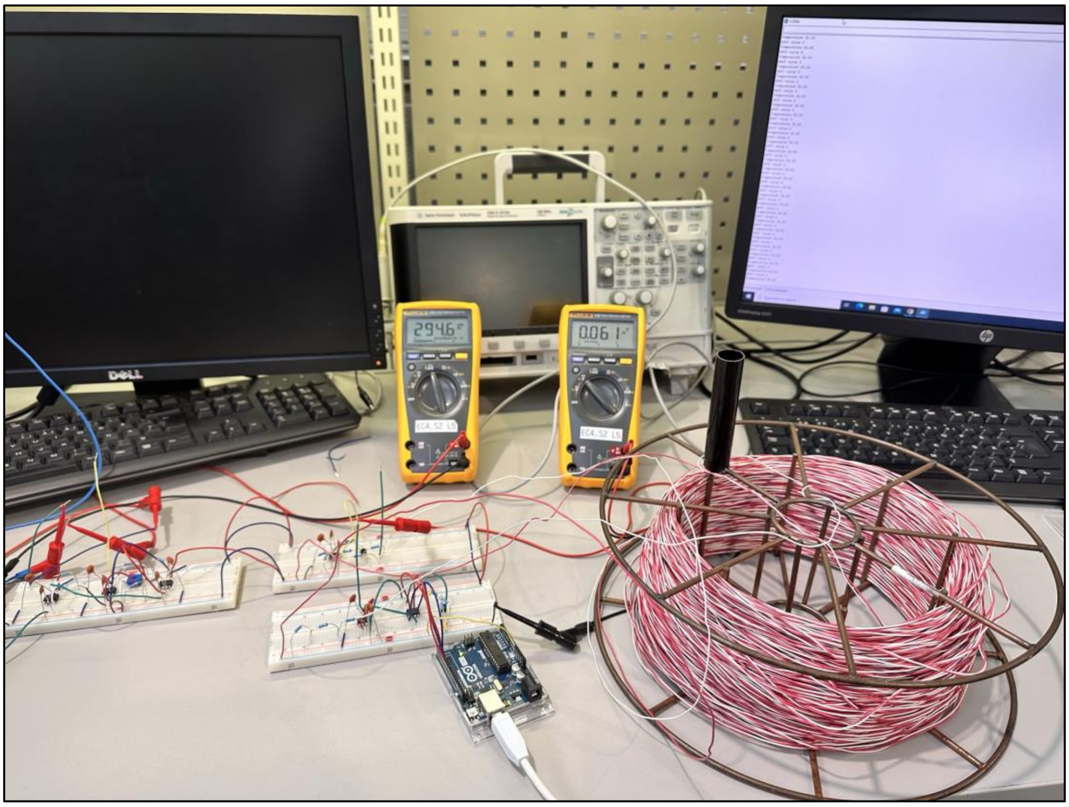

Figure 12. Testing results of the system's circuit with Arduino +30°C