Lab 1.1: Analog Signals and Circuits

Upon completion of this lab exercise the student should be able to:

1. Measure DC voltage and DC current using the signal generator or a DMM
2. Source current to a circuit using a signal generator
3. Simulate a thermocouple using a signal generator
4. Calculate the voltage drop across a 250 ohm resistor based on circuit current
5. Connect an instrument circuit using a P/S, transmitter and analog input channel
6. Calibrate a transmitter to adjust the control current in a circuit
7. Simulate a transmitter in an instrument circuit using a signal generator

***This lab could be performed in the NSCC PLC Lab**.

Part 1: KCH Signal Generator

Figure 1 shows the KCH-71B signal generator that students will use in the Instrumentation course. It is important to learn how to use this device to measure, and create analog signals for calibrating the troubleshooting analog control systems. It is also important to have a digital multimeter, since we will be measuring milli-volts, milli-amps and DC voltage. The following video will help you understand how to use the signal generator: *Intro to the KCH Signal Generator 080123*: https://youtu.be/ldw1LFF9yOA

***Important**: When working with the signal generator or a digital multimeter, the COM (common) port is for the black lead and would have a negative polarity.*

Figure 1. KCH-71B Signal Generator.

1. Measure the Precision Resistor. Use an Ohmmeter to measure the resistance of the precision resistor the Instructor has provided, as shown in Figure 2A.
   What is the resistive value? _______________
2. Use the Signal Generator to source mA to a 250 ohm resistor, and use a DMM as an ammeter to measure the current, as shown in Figure 2, graphic B & C
   a. Adjust the Signal Generator to put out 8mA. Does the DMM read the same? ____
   b. Adjust the Signal Generator to put out 12mA. Is the DMM reading the same? ___

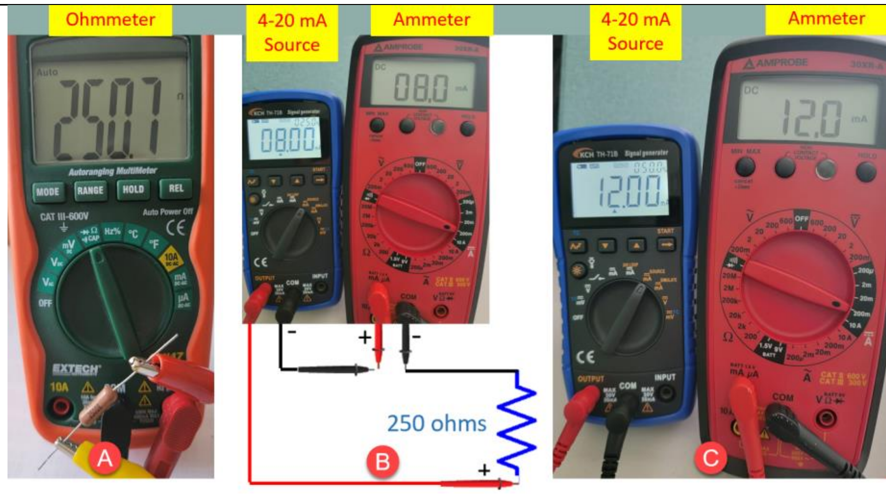

Figure 2. Sourcing and Measuring Current.

3. Use the Signal Generator to source mA (to simulate a 4 wire transmitter) to a 250 ohm resistor, as shown in Figure 3. Set the mA output to 12mA, as shown in Figure 3, graphic A. Put a voltmeter across the resistor. What does the voltage read?

   ____

   Reverse the leads of the voltmeter. What does the voltmeter read? ____________

   Change the Signal Generator to 8mA output. What does the voltmeter read? __________

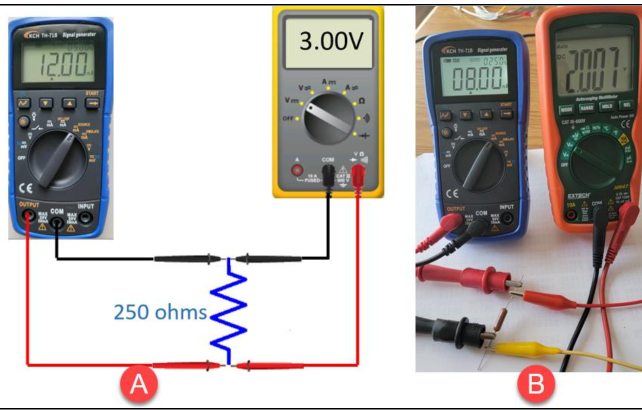

Figure 3. Measuring the Voltage across a Resistor.

4. Connect the signal generator leads to the same color leads of a DMM that is setup to read DC mV as shown in Figure 4.
    a. Make sure the red lead on the signal generator is plugged into the OUTPUT jack.
    b. Set the signal generator dial to the DCmV TC setting.
    c. Toggle the TC button to choose the J type of thermocouple.
    d. Use the START and UP/DN buttons to set the temperature to 300 degrees.
    e. What does the DMM display in mV? ________________
    f. Notice the number of 21.5 just above the 300 setting. This is the ambient temperature in the room at the time.

Figure 4. Signal Generator simulating a Thermocouple.

5. In module 1 within Sakai, there should be a link to the chart for the mV output at a specific temperature for a J-type of thermocouple (for both F & C). Open this link to view the document.

6. What is the mV output supposed to be for 300 degrees C? ___________

7. Subtract the 21.5 degrees from 300 degrees, which should be approximately 279 degrees. What should be the mV output for 279 degrees? ____________

8. This information is shown in Figure 5.

300 279

°C	0	1	2	3	4	5	6	7	8	9	10	°C
						Thermoelectric Voltage in Millivolts						
250	13.555	13.611	13.666	13.722	13.777	13.833	13.888	13.944	13.999	14.055	14.110	250
260	14.110	14.166	14.221	14.277	14.332	14.388	14.443	14.499	14.554	14.60[illegible]	14.665	260
270	14.665	14.720	14.776	14.831	14.887	14.942	14.998	15.053	15.109	15.164	15.219	270
280	15.219	15.275	15.330	15.386	15.441	15.496	15.552	15.607	15.663	15.718	15.773	280
290	15.773	15.829	15.884	15.940	15.995	16.050	16.106	16.161	16.216	16.272	16.327	290
300	16.327	16.383	16.438	16.493	16.549	16.604	16.659	16.715	16.770	16.825	16.881	300
310	16.881	16.936	16.991	17.046	17.102	17.157	17.212	17.268	17.323	17.378	17.434	310
320	17.434	17.489	17.544	17.599	17.655	17.710	17.765	17.820	17.876	17.931	17.986	320

Figure 5. Information from mV output chart for J-type of T/C in Celcius.

Part 2: Using the Signal Generator to simulate a Transmitter

1. Connect the circuit in Figure 6, using the signal generator to replace and simulate a 2-wire transmitter. Observe the polarity shown on the diagram.

The following video will explain this circuit: M1 Simulating a Transmitter 081723
https://youtu.be/VtKusAcpIbc

2. Set the DMM to measuring current on the milli-amp range (check your probe connection for a separate connector for current).
3. Set the signal generator dial to the mA Simulate setting.
4. Set the signal generator to 4 mA output.
   a. What does the circuit ammeter read? _________
   b. What is the voltage dropped across the resistor? _______
5. Set the signal generator to 8 mA output.
   a. What does the circuit ammeter read? _________
   b. What is the voltage dropped across the resistor? _______
6. Set the signal generator to 12 mA output.

a. What does the circuit ammeter read? ________
b. What is the voltage dropped across the resistor? _______

7. Set the signal generator to 16 mA output.
   a. What does the circuit ammeter read? ________
   b. What is the voltage dropped across the resistor? _______
8. Set the signal generator to 20 mA output.
   a. What does the circuit ammeter read? ________
   b. What is the voltage dropped across the resistor? _______

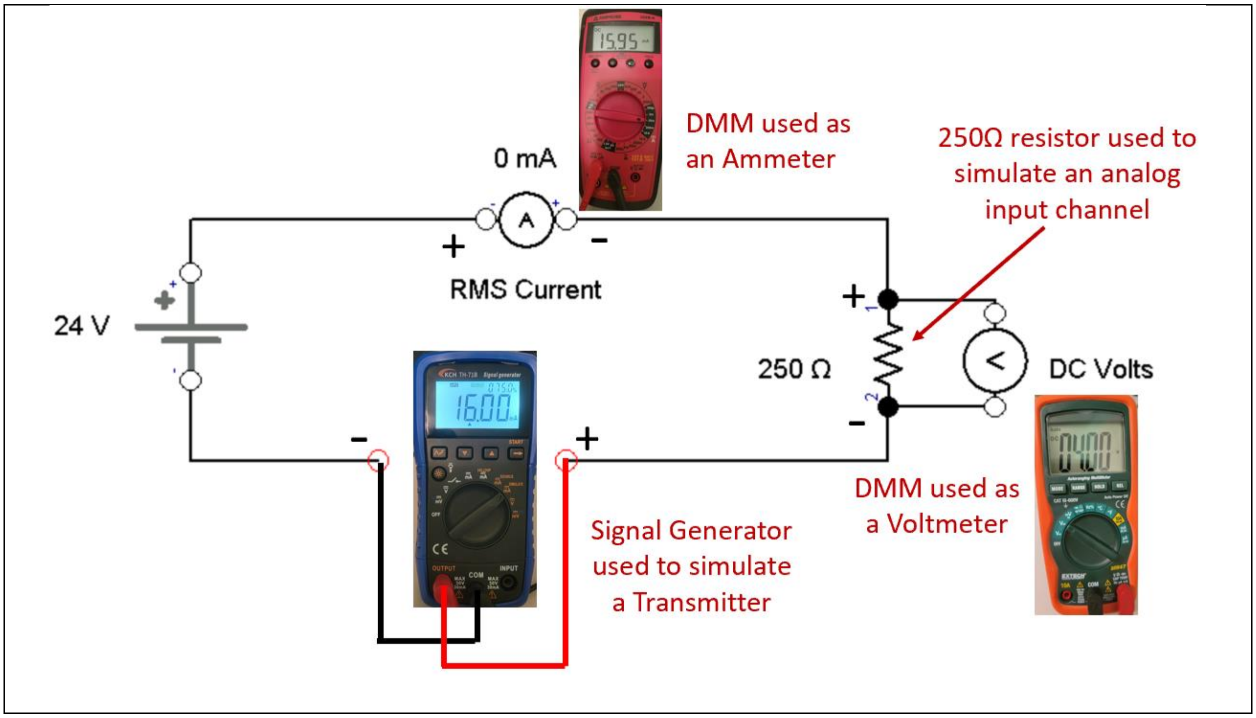

Figure 6. Using the Signal Generator to simulate a Transmitter.

Part 3: Calibrating the Acromag 250T Thermocouple Transmitter:

1. Connect the circuit in Figure 7 to calibrate the temperature transmitter. Make sure to connect the signal generator to the input side of the transmitter and set it up for a J-type of thermocouple.

The following video will explain this circuit and process: M1 Calibrating the Acromag TC Transmitter 081723: https://youtu.be/jHzNtl9M8_M

2. Turn the Zero and Span potentiometers counterclockwise for 5-6 turns, to loose the current calibration settings.

3. Calibrate the transmitter for a temperature range of 100 to 200 degrees Celsius. Important to view the video prior to performing this task.

4. Turn the Zero and Span potentiometers counterclockwise for 5-6 turns, to loose the current calibration settings.

5. Calibrate the transmitter for a temperature range of 150 to 200 degrees Celsius. Important to view the video prior to performing this task.
6.

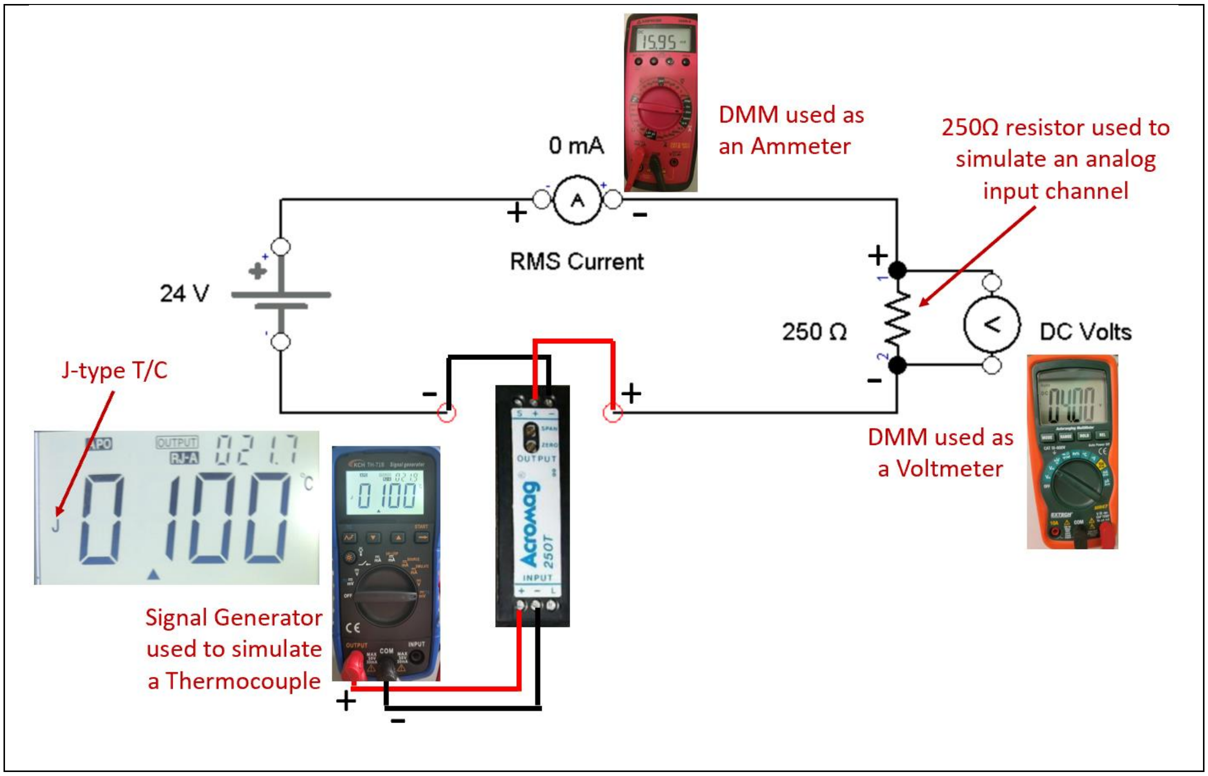

Figure 7. Calibrating a Transmitter in a Current Loop.

Some important things to know about this lab:
1. The KCH-71B Signal Generator is an extremely versatile piece of test equipment that can be used to source a 4-20mA signal (simulating a 4 wire transmitter), simulate a 2-wire transmitter, simulate any type of thermocouple, and measure any electrical analog signal.
2. It is critical to know how to convert the analog signal to a voltage signal. Simple Ohm's law is that voltage=current * resistance, so a 12mA signal flowing through a 250 ohm resistor will create a 3 Vdc drop across the resistor.

3. A 2-wire transmitter only needs 2 wires ran to the output side (4-20mA side) which will both power the transmitter and regulate the analog signal on the same two wires. It is important to understand that the Acromag 250T transmitter requires at least 12 volts dropped across it in order to work correctly (power the electronic circuit internally to convert the sensor to an analog signal, and regulate the loop current at the correct level.
4. The signal generator can be used to simulate a thermocouple. It is important to understand that the mV output charts for specific type of thermocouples are based on the reference junction of the thermocouple being at the freezing point (32 degrees F, or 0 degrees C). So the signal generator give us the reference temperature (ambient temp of the room the signal generator is measuring). The difference of the temp output setting and the ambient temperature is the temperature that the signal generator will send the mV output for. This is the reason for the discrepancy between the mV output charts and the output temperature setting on the signal generator.
5. The signal generator can be used to simulate a 2-wire transmitter, and can be put into a circuit to perform this function. The purpose in doing this is to make sure all the components in a current control loop is working correctly by testing at the specific signal levels.
6. A temperature transmitter can be calibrated for a specific temperature range. The same type of transmitter could be used on 2 different machines, and could be calibrated for different temperature ranges. One transmitter could be calibrated for a 100-150 degree range, and another calibrated for a 100-300 degree range. It is important to understand the process of calibration. By using the Zero and Span (Range) adjustments, the user would set the loop current to be 4mA for the lower temperature, and 20mA for the higher temperature of the range. The Acromag 250T is a passive transmitter that has interactive zero and span adjustments, which means that when the span is adjusted, it changes the zero setting and vice versa.
7. Ammeters connect in series to measure current in a circuit. Voltmeters connect in parallel to the device they are measuring voltage across. Ohmmeters should only be used to measure component resistance when the component is removed from a circuit, and should never be used in a live circuit.

Questions:

1. Based on the chart in Figure 5, what will be the mV output for a J-type thermocouple at 255 degrees C?

2. What adjustment on a transmitter will be used to set 4mA in the circuit during calibration?
   a. Span
   b. Zero
   c. Range
   d. The transmitter automatically senses the 4mA setting

3. What would be the voltage dropped across the resistor in Figure 3 if the signal generator is sourcing 20mA?

4. Voltmeter always connect in:
   a. Series
   b. Parallel

5. T F An ohmmeter should never be used to measure resistance in a live circuit.

Figure 8. Dial setting on the Signal Generator

6. What would be the dial setting on the signal generator (in Figure 8) if it were used to simulate a 4-wire transmitter?
   a. 1
   b. 2
   c. 3
   d. 4

7. What would be the current in a 4-20mA control loop of a transmitter at 75 degrees if the transmitter is calibrated for 50-100 degrees?

Figure 9. Display on the Signal Generator

8. What would be the ambient temperature in Fahrenheit based on the signal generator display in Figure 9?

9. What would be the thermocouple simulation temperature in Fahrenheit based on the signal generator display in Figure 9?

10. What is the minimum voltage that will be dropped across the transmitter in Figure 7?

Answers to the Questions Asked in this Lab:

This section will be important for the student to verify that the answers they had written down in the lab, are correct. If you have any questions, please contact your instructor. It is important to perform this lab exercise in its entirety, since questions will be asked about it in both the KAA and the performance assessments.

Part 1:

1. Approximately 250 ohms
2a. yes
2b. yes
3. 3 Vdc, -3Vdc, 2 Vdc
4e. 15.2 mV
6.16.327
7.15.164

Part 2:

4a. 4mA, 4b. 1 Vdc
5a. 8mA, 5b. 2 Vdc
6a. 12mA, 6b. 3 Vdc
7a. 16mA, 7b. 4 Vdc
8a. 20mA, 8b. 5 Vdc

Answers to the Review Questions:

1. 13.833 mV
2. b
3. 5 Vdc
4. b
5. T
6. c
7. 12 mA
8. 71 degrees, F=C*9/5+32
9. 212 degrees
10. 19 Vdc

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