Experiment: 6

Describe the Construction and Characteristics of a Thermocouple.

EQUIPMENTS

- Temperature Transducer Trainer IT-5929
- Stopwatch (not supplied).
- Digital Multimeter.
- 2mm Connecting Leads.

THEORY

THERMOCOUPLE:

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. A thermocouple is an electrical device consisting of two different conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.

Advantages:

- Inexpensive
- Interchangeable
- supplied with standard connectors
- can measure a wide range of temperatures
- self-powered
- require no external form of excitation

The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (°C) can be difficult to achieve.

Applications:

- Thermocouples are widely used in science and industry
- Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes.
- Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats
- As flame sensors in safety devices for gas-powered major appliances

Principle of Operation:

In 1821, the German physicist Thomas Johann Seebeck discovered that when different metals are joined at the ends and there is a temperature difference between the joints a magnetic field is observed. At the time Seebeck referred to this as thermo-magnetism, the magnetic field he observed was later shown to be due to thermo-electric current. In practical use the voltage generated at a single junction of two different types of wire is what is of interest as this can be used to measure temperature at very high and low temperatures. The magnitude of the voltage depends on the types of wire used. Generally, the voltage is in the microvolt range and care must be taken to obtain a usable measurement. Although current flows very little, power can be generated by a single thermocouple junction.

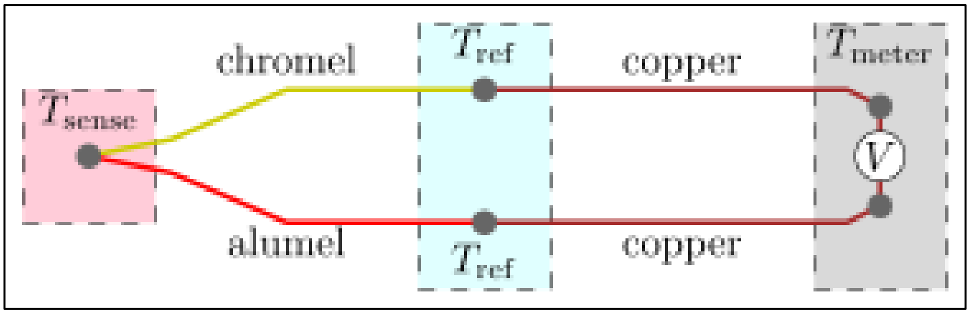


Figure 6.1 (Thermocouple Construction)

Physical principle: Seebeck Effect

The Seebeck effect refers to an electromotive force whenever there is a temperature gradient in a conductive material. Under open-circuit conditions where there is no internal current flow, the gradient of voltage **(∇V)** is directly proportional to the gradient in temperature **(∇T)**:

$$\nabla V = -S(T)\nabla T \qquad (6.1)$$

Where **S(T)** is a temperature-dependent material property known as the Seeback coefficient.

Types of Thermocouples:

Type E

Material: chromel – constantan

Sensitivity: 68 µV/°C

Range: −50 °C to +740 °C

Type J

Material: iron – constantan

Sensitivity: 50 µV/°C

Range: −40 °C to +750 °C

Type K

Material: chromel – alumel

Sensitivity: 41 µV/°C.

Range: 200 °C to +1350 °C

Type N

Material: Nicrosil – Nisil

Sensitivity: 39 µV/°C at 900 °C

Range: −270 °C and +1300 °C

Type M

Material: Ni/Mo 82%/18% – Ni/Co 99.2%/0.8% (by weight)

Range: Upper temperature is limited to 1400 °C.

Type T

Material: copper – constantan
Range: −200 to 350 °C

Sensitivity: 43 µV/°C

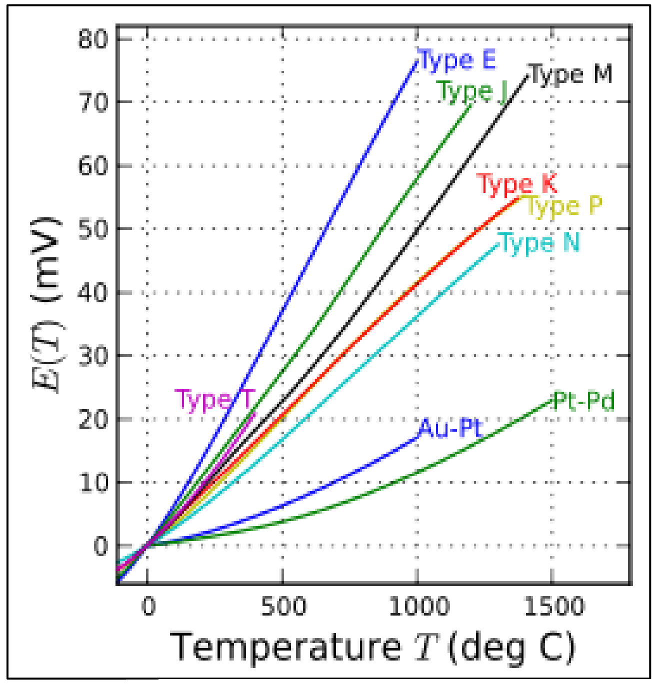


Figure 6.2 (Characteristics of Different Types

The Type "K" Thermocouple Temperature Transducer:

Figure 6.3 shows the basic construction of a thermocouple, consisting of two wires of different materials joined together at one end.

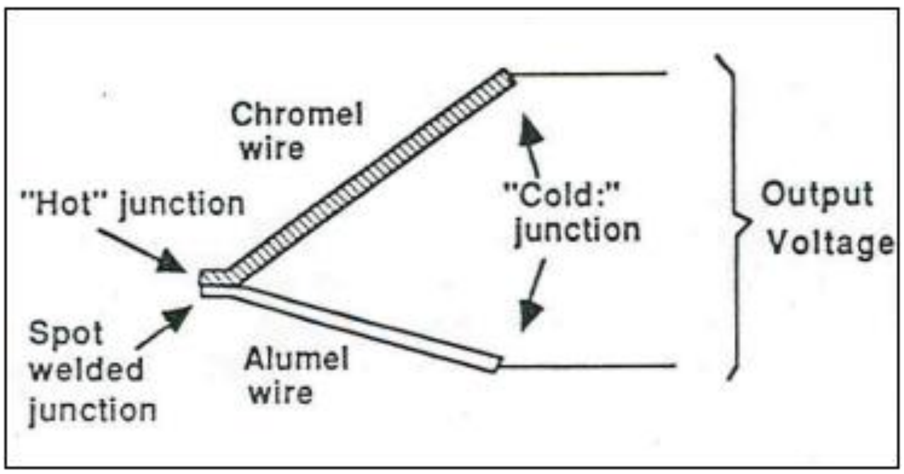


Figure 6.3 (Thermocouple internal structure)

For the type "K" thermocouple the two materials are alumel and chromel. With this arrangement, when the ends that are joined together are heated, an output voltage is obtained between the other two ends. The ends that are joined together are referred to as the "hot" junction and the other ends are referred to as the "cold" junction. The magnitude of the output voltage depends on the temperature difference between the "hot" and "cold" junctions and on the materials used. For the type "K" thermocouple the output voltage is linear over the temperature range 0-100°C, and of magnitude 40.28 µV/°C, difference between the "hot" and "cold" junctions. Two thermocouples are provided with the DIGIAC 1750 unit, one being mounted within the heated enclosure, this being the active unit which will have its "hot" and "cold" junctions at different temperatures in operation.

The other unit is mounted outside the heated enclosure and is incorporated in a heat sink with an LM 335 I.C. temperature transducer so that the temperature of the "cold" junction of the active thermocouple can be measured. This second thermocouple is connected in series with the first with the wires of the same material connected. This ensures that the connections to the output circuit are made from the same material and thus eliminates the possibility of an e.m.f. being introduced into the circuit by connections between different materials. The second thermocouple does not contribute to the output voltage because its “hot” and “cold” junctions are maintained at the same temperature.

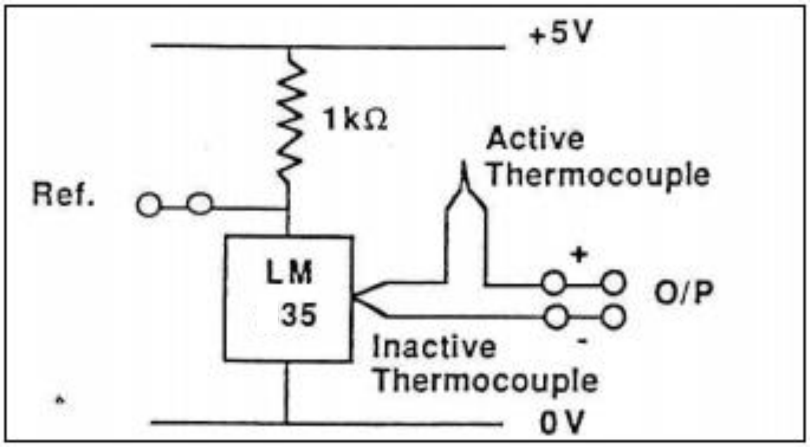


Figure 6.4 (Circuit Diagram)

Due to low voltage output, the output requires amplification; an amplification factor of 200 will give reading within one range of digital multimeter. During operation, the temperature of the “cold” junction varies, due mainly to heat conduction from the heater along the baseboard and the junction is in effect “floating”.

This is a common occurrence with thermocouple installations where the thermocouple leads are short. To overcome the problem, extra leads of the same material or different materials having the same thermoelectric properties are used to extend the “cold” junction to a point where a steady temperature can be maintained. These cables are referred to as “Compensating cables”.

EXPERIMENT

- Connect the circuit as shown in Figure 6.5, set the voltmeter to its 200mV or 2 V range and set amplifier #1 GAIN to 10 and fine gain controls to 0.25 respectively.
- Switch the power supply ON and then set the offset control of amplifier #1 as follows:
- Short circuit the input connections to the instrumentation amplifier and adjust the offset control for zero indication on the voltmeter.
- Re-connect the thermocouple output to the instrumentation amplifier as shown in Figure above. The output voltage should still be zero with the “hot” and “cold” junctions at the same temperature.
- Note the temperatures of the inside and outside of the enclosure (cold junction) by setting the voltmeter to its 20 V range and then measuring the voltage output from the “INT” socket of the I.C. temperature transducer and then from the “Ref” output socket of the LM 335 provided on the type “K” thermocouple unit.
- Enter the values in Table 6.1.
- Connect the 12 V supply to the heater ant at 1-minute intervals, note the values of the thermocouple output voltage and the voltages representing the temperatures of the “hot” and “cold” junctions of the thermocouple.

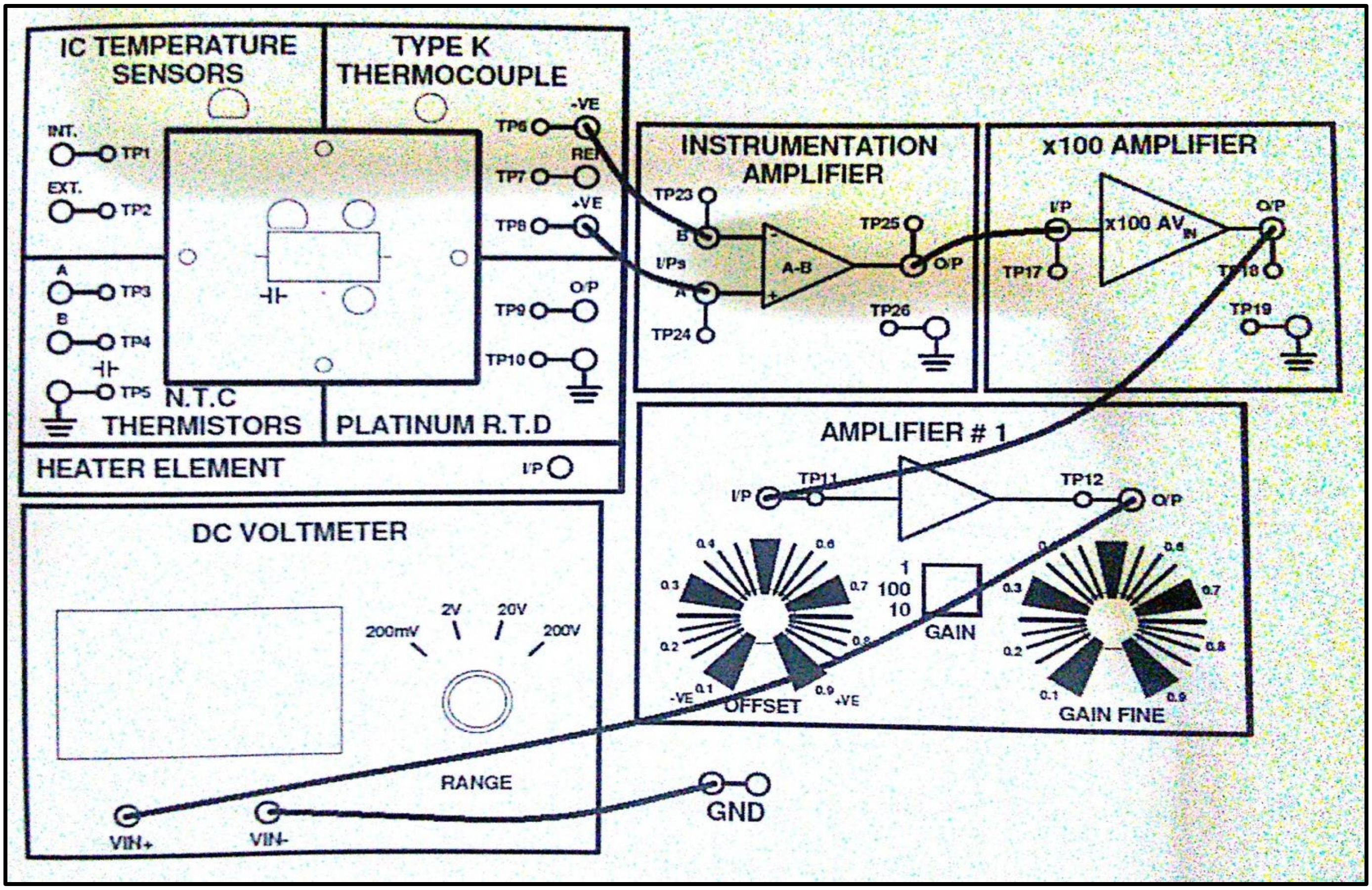


Figure 6.5 (Experimental Setup)

RESULTS:

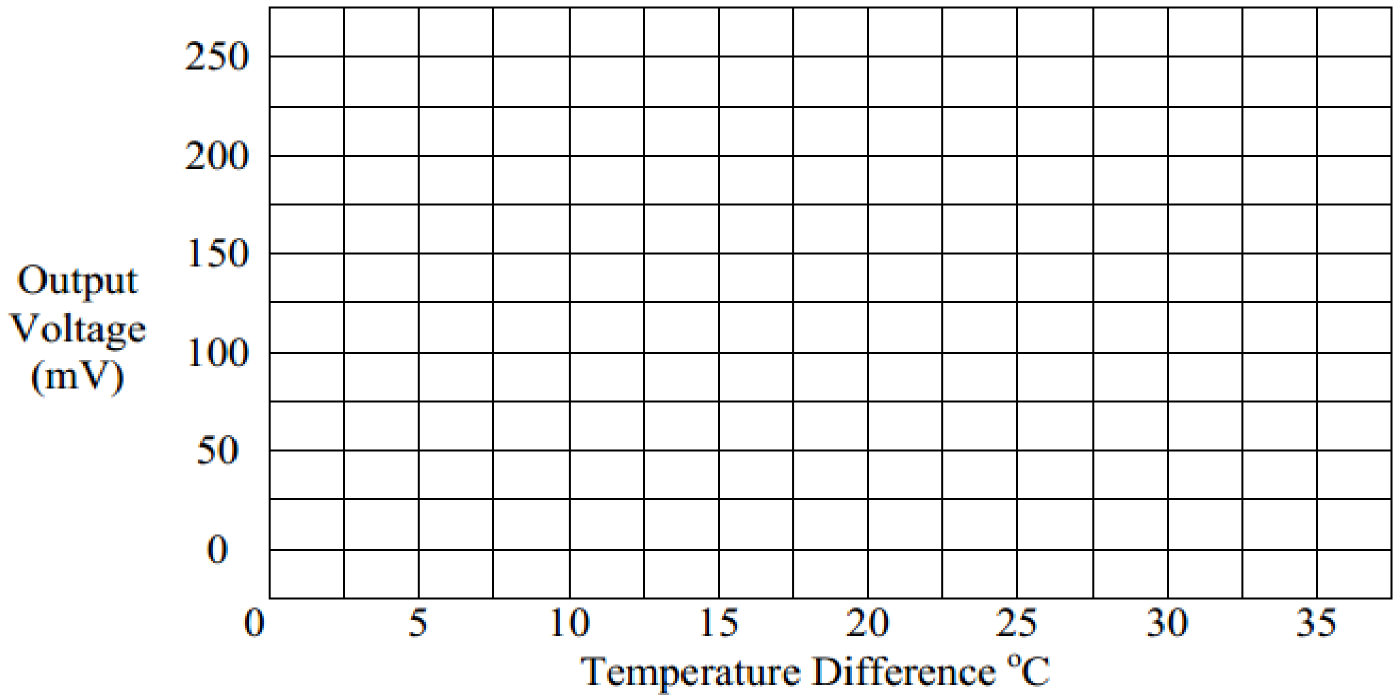
Observation Table:

Record values in the table 6.1:

Time (Minutes)	Temperature (℃)			Thermocouple O/P (mV)
	Hot Junction	Cold Junction	Difference	
0				
1				
2				
3				
4				
5				

Table 6.1 (Observation of Thermocouple)

Construct the graph of thermocouple output voltage against temperature difference between the "hot" and "cold" junctions on the axes provided.



Graph 6.1 (Voltage Vs Temperature Difference)

DISCUSSION:

A thermocouple gives an output of 40 µV for each°C, difference in temperature between the "hot" and "cold" junctions. State the output voltages expected for the junction temperatures given below:

Cold	**Hot**	**Output Voltage**
0°C	50°C	
20°C	70°C	
50°C	50°C	
-20°C	60°C	

Table 6.2

CONCLUSION:

Instructor Signature: ________________________________ **Date:** ________________