CaYPT
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Thermocouple Reader

Author: Jim Chen
Editor: Jim Chen

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Abstract

In this SOP, the principle of operation thermocouples are documented. The thermocouple readers available in the lab are listed.

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[1] *Footnote 1 etc.*

[2] *Footnote 2 etc.*

1 Thermocouple Principle of Operation

1.1 Construction of a thermocouple junction

A thermocouple junction can be made by electrically connecting two metallic or semiconducting materials together at a junction. This can be achieved by welding (common for high temperature uses) or soldering (for low temperature uses). Welding is more common for its compatibility with a range of materials and its superior mechanical strength.

1.2 Peltier and Seebeck Effect

The ability for a thermocouple to measure temperature arises from the thermoelectric effect. There are two opposite and related effects, the Peltier effect and Seebeck Effect. When an electric current flows through a thermocouple circuit a temperature difference is created between the two materials of the thermocouple. This is known as the Peltier effect. When the temperature of a thermocouple changes, the voltage across the two materials of a thermocouple changes. This is known as the Seebeck effect.

For a detailed explanation of the Peltier and Seebeck effect, see [?] [?]

2 Electronics of Thermocouple Reader

2.1 Circuit Topology and Cold junction

The most common topology to construct a thermocouple probe can be seen in Fig. 1. Two dissimilar metals are joint at point a. This forms the hot junction. Points b to c form the thermocouple probe. The probe is connected to the sensing circuit using regular copper wires. Points b and c together are known as the cold junction and are maintained at the same temperature. One option is to use an ice-water mixture bath as a cold junction. This will ensure that the cold junction is always at precisely 0 deg celsius. However, using an ice-water mixture is not always practical. So in commercial thermocouple readers a separate temperature reference is used to measure the room temperature as the cold junction temperature. This measurement can be achieved with other types of temperature sensor like a thermistor (heat sensitive resistor) with either positive or negative temperature coefficient.

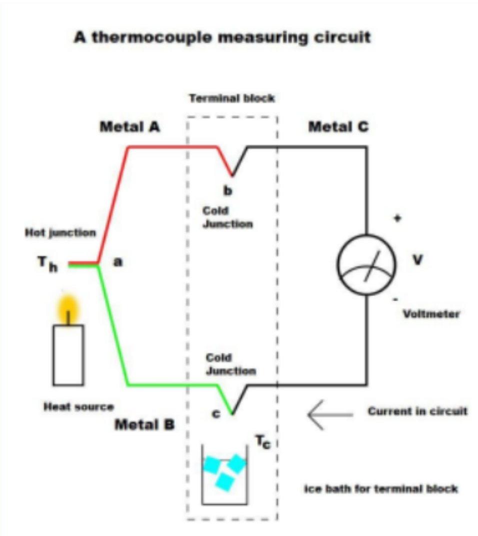

Figure 1: Thermocouple Circuit[?]

2.2 Seebeck Coefficient of Common Metals and Voltage Measurement Circuit Fig 2.

Shows a table of the Seebeck coefficient of common metals, alloys and semiconductors. It's evident from the table that the order of magnitude of seebeck coefficients are in uV/K for metals and mV/K for certain semiconductors. Accurate measurement of small voltage differences are required. Commonly the electronics inside a thermocouple reader consists of operational amplifier circuits (op-amps). The thermocouple is directly connected to op-amps in the voltage follower configuration. This could ensure that the input impedance of the measurement circuit is high enough so almost no circuit can flow into the measurement circuit. Next a differential amplifier circuit can be used to amplify the voltage difference between the two terminals. A simple single op-amp in differential amplifier configuration can be used or 3 op-amp can be set up in an instrumentation amplifier configuration to enhance stability. Finally an analog to digital converter of some type can be used to convert the differential amplifier signal into a digital signal. After some processing by a microcontroller, the data can be displayed on a screen or be stored for later use

Metals	Seebeck Coefficient
	µV/K
Antimony	47
Nichrome	25
Molybdenum	10
Cadmium	7.5
Tungsten	7.5
Gold	6.5
Silver	6.5
Copper	6.5
Rhodium	6.0
Tantalum	4.5
Lead	4.0
Aluminum	3.5
Carbon	3.0
Mercury	0.6
Platinum	0
Sodium	-2.0
Potassium	-9.0
Nickel	-15
Constantan	-35
Bismuth	-72

Semiconductors	Seebeck Coefficient
	µV/K
Se	900
Te	500
Si	440
Ge	300
n-type Bi_2Te_3	-230
p-type $Bi_{2-x}Sb_xTe_3$	300
p-type Sb_2Te_3	185
PbTe	-180
$Pb_{03}Ge_{39}Se_{58}$	1670
$Pb_{06}Ge_{36}Se_{58}$	1410
$Pb_{09}Ge_{33}Se_{58}$	-1360
$Pb_{13}Ge_{29}Se_{58}$	-1710
$Pb_{15}Ge_{37}Se_{58}$	-1990
$SnSb_4Te_7$	25
$SnBi_4Te_7$	120
$SnBi_3Sb_1Te_7$	151
$SnBi_{2.5}Sb_{1.5}Te_7$	110
$SnBi_2Sb_2Te_7$	90
$PbBi_4Te_7$	-53

Figure 2: Seebeck Coefficient of some metals, alloys and semiconductors[?]

2.3 Common Types of Thermocouples and Their Properties

See [?] for details For each type, the thermocouple probe may come in different constructions. Some are bare wires, some have breaded wires to improve resistance to bending, some have a metal casing to protect it from liquids. The most important consideration when choosing a probe construction is the compatibility between the probe and the target of measurement. The secondary consideration is the thermal mass and heat conduction properties of the probe. Choosing a probe with a thermal mass greater than the target of measurement may significantly misrepresent the temperature of target.

3 Thermocouple and Reader in CaYPT Lab

3.1 Thermocouples

1. UNI-T K-type thermocouple
   - green insulated wire
   - Compatible with UNI-T multimeter and other thermocouple readers
2. UNI-T K-type thermocouple probe

  - approximately 30 cm long, green handle, coiled cable
  - Compatible with UNI-T multimeter and other thermocouple readers

3. Generic K-type thermocouple
   - White braided wire
   - Compatible with UNI-T multimeter and other thermocouple readers

4. Generic K-type thermocouple with banana connector
   - included with generic multimeter
   - only compatible with generic multimeter

5. Heavy duty thermocouple probe
   - full steel enclosure with spring coil cable guard
   - Compatible with UNI-T multimeter and other thermocouple readers

3.2 Thermocouple readers

- UNI-T multimeter thermocouple functionality
- Generic multimeter thermocouple functionality
- Orange 2 channel thermocouple reader[**?**]
- Data logging 4 channel thermocouple reader[**?**]

4 General Procedure of Operation

1. Connect thermocouple to thermocouple reader. Be aware of the polarity.
2. Turn on the thermocouple reader and choose the appropriate unit and mode of operation. Consult the instruction manual if necessary.
3. Be aware of the accuracy of the thermocouple. The last digit displayed may not tell you anything about the precision or accuracy of the device. Check the specifications for uncertainty information.
4. If the thermocouple reader is not turning on, check and replace the battery 5. If the thermocouple is damaged, do not try to cut the junction and repair it. Ask your team leader for assistance.

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