Thermoelectric Cooling - The Basics
Revision 12/05/2000

What is Thermoelectric Cooling?

French watchmaker, Jean Charles Athanase Peltier, discovered thermoelectric cooling effect, also known as Peltier cooling effect, in 1834. Peltier discovered that the passage of a current through a junction formed by two dissimilar conductors caused a temperature change. However, Peltier failed to understand this physics phenomenon, and his explanation was that the weak current doesn't obey Ohm's law. Peltier effect was made clear in 1838 by Emil Lenz, a member of the St. Petersburg Academy. Lenz demonstrated that water could be frozen when placed on a bismuth-antimony junction by passage of an electric current through the junction. He also observed that if the current was reversed the ice could be melted.

In 1909 and 1911 another scientist Altenkirch derived the basic theory of thermoelectrics. His work pointed out that thermoelectric cooling materials needed to have high Seebeck coefficients, good electrical conductivity to minimize Joule heating, and low thermal conductivity to reduce heat transfer from junctions to junctions. Shortly after the development of practical semiconductors in 1950's, bismuth telluride began to be the primary material used in the thermoelectric cooling.

What is Thermoelectric Cooler?

Thermoelectric cooler (TEC), or Peltier Cooler is a solid-state heat pump that uses the Peltier effect to move heat. The modern commercial TEC consists of a number of p- and n- type semiconductor couples connected electrically in series and thermally in parallel. These couples are sandwiched between two thermally conductive and electrically insulated substrates. The heat pumping direction can be altered by altering the polarity of the charging DC current. TEC schematic is illustrated in Figure 1. The typical materials used for constructing TEC are:

1. Substrate: aluminum oxide (Al_2O_3), aluminum nitride (AlN), or barium oxide (BaO)
2. Conductor: Copper
3. Thermoelectric semiconductor
    i. n-type: bismuth-telluride-selenium (BiTeSe) compound
    ii. p-type: bismuth-telluride-antimony (BiTeSb) compound
4. Assembled and joined by solder.

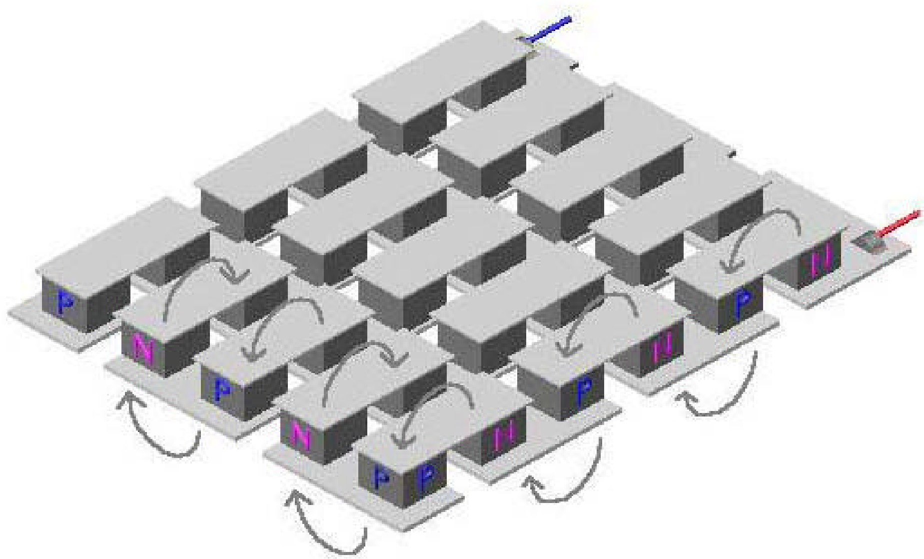

Figure 1. Thermoelectric Cooler Schematic

The TEC can be made in different shapes and sizes, but most common shape is a square or a rectangular substrate device. The practical size of a single stage TEC ranges from 3 mm x 3 mm up to 60 mm x 60 mm. The size limitation of 60 mm x 60 mm is due to the thermal stress. This stress comes from thermal expansion deformations between the cold and the hot junctions of the TEC. To obtain a larger temperature difference, a multistage TEC can be build. The multistage TEC is usually in cascade shape and 6 stages are the maximum practical limit. Figure 2. depicts various sizes of TEC.

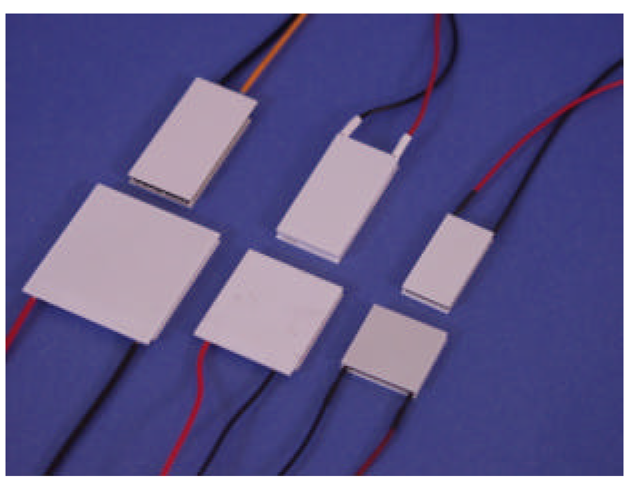

Figure 2. Various Sizes of TEC

When to consider TEC?

TEC can be used in different application where cooling or temperature control of an object is required. In general, TEC is most often used when an object:

1. Needs to be cooled below the ambient temperature, or
2. Requires to be maintained at a consist temperature under a fluctuating ambient temperature.

TEC is perfect for cooling a small, low heat load object. Due to the low COP (Coefficient of Performance) compared with compressor cooling, TEC looses its advantage if the cooling load is higher than 200 watts. But, because TECs have no moving parts, they are lightweight and reliable, they create no electrical noise, and can be operated at any orientation or environment, in some instances TECs are used to cool kilowatts of heat.

TEC is exceptionally suitable for a precision temperature control of an object such as a laser diode, CCD or other small objects. Paired with a DC power supply and an electronics proportional/integral (PI) controller packaged in a single chip device, TEC is able to control an object to +/- 0.1^{o}C accuracy. Today, no other cooling method yet can provide such precise, simple and convenient temperature control.