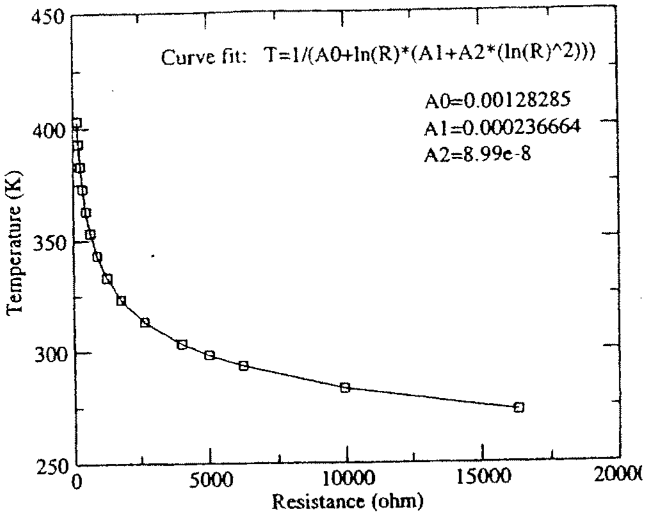
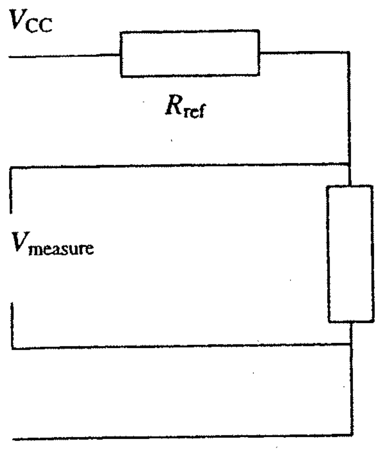
Temperature sensor:

Thermistor, Type ACC-003 (ELFA).



Temperature (°C)	Temperature (K)	Resistance (Ω)
0	273.15	16325
10	283.15	9950
20	293.15	6245
25	298.15	5000
30	303.15	4028.5
40	313.15	2663.3
50	323.15	1801.5
60	333.15	1244
70	343.15	876
80	353.15	627.5
90	363.15	457.7
100	373.15	339.2
110	383.15	255.2
120	393.15	194.7
130	403.15	150.5

4-wire temperature measurement: The exitation current is passed through separate wires to avoid voltage drop in the wires used for measuring the signal. Voltage across thermistor measured using a 16 bit DAQ card (NI 6036E) in differential mode. Excitation current provided by external voltage source ($V_{CC} \approx 5$ V) with large resistor in series ($R_{ref} = 1.5984$ MΩ).



$V_{CC} = 5.0717$ V
$R_{ref} = 1.598400$ MΩ

$$I = \frac{V_{CC} - V_{measure}}{R_{ref}}$$

$$R_{thermistor} = \frac{V_{measure}}{I}$$

$$T = \frac{1}{A0 + \ln R_{thermistor}\left(A1 + A2\left(\ln R_{thermistor}^{2}\right)\right)}$$

$(\ln R_{thermistor})^2$

CONSIDERATIONS IN SELECTING A THERMOELECTRIC HEAT PUMP

Depending on the direction and amount of current, thermoelectric heat pumps have the ability to cool, heat, or stabilize the temperature of devices. The most publicized operating condition is the cooling mode; however, heating mode and temperature stabilization capabilities should not be overlooked when considering the use of heat pumps.

By applying the correct amount of current at the desired polarity, the temperature of a device can be stabilized as the ambient temperature oscillates. "Fine tuning" temperature stability depends on the quality of the temperature controller. The more sophisticated the temperature controller the more constant the temperature. Tolerances of ± 0.1 to ± 0.3°C at a stabilized temperature are reasonable. A major feature of a thermoelectric heat pump is the ability to stabilize device temperatures when the ambient temperature is within approximately + 5°C of the desired control temperature. A conventional heater has the ability to heat a device above the ambient temperature but does not have positive action capability when the ambient exceeds the control capability. Separate heating and cooling systems are eliminated by using a thermoelectric heat pump.

Thermoelectric heat pumps have a fast thermal response. The single- or multi-stage heat pumps will achieve the maximum cold side temperature within 60 seconds after power is applied. This response time occurs when there is no added mass on the cold side and the hot side is attached to a good heat sink. As the mass of a device is added to the cold surface the time to reach maximum temperature will be increased. The amount of increase will depend on the mass of the device.

For heating, less current is required to achieve a given temperature differential than when cooling. Due to the fast response time, care should be taken not to reverse current to the heat pumps until the amount of current necessary to achieve a specified temperature differential in the heating mode is defined. When the required amount of current has been defined, the current can be switched from cooling to heating as desired.

The basic operating characteristics of a thermoelectric heat pump include the cold and hot side temperature, heat pumping capacity at the cold side, heat dissipated at the hot side, input current, and voltage. The acceptable range of each of these characteristics are usually known before selecting a specific heat pump. Generally there are several heat pumps that have characteristics in the desired range. The best suited heat pump will depend on the application. Considerations in the final selection are cost, reliability, maximum heat pumping or maximum COP.

The first consideration is to determine the number of stages required to obtain the desired temperature differential. A single-stage heat pump is defined as a group of n- and p-type semiconductor materials connected electrically in series and thermally in parallel as shown in Figure 2a. The heat load generally determines the lowest cold side temperature that a heat pump will attain. However, even with zero heat load regardless of the amount of power applied, every heat pump has a theoretical maximum cold temperature. For example, the coldest temperature that can be reached from a hot side temperature of 27°C (300°K) is approximately −47°C (226°K) for a single-stage heat pump. This is determined by the basic parameters of the thermoelectric material. For colder temperatures multi-stage heat pumps must be used. A multi-stage heat pump as shown in Figure 2b is essentially several single-stage heat pumps stacked in a vertical array. Typically a multi-stage heat pump is pyramid shaped because the lower stage must pump the heat dissipated by the upper stages in addition to the active heat load. Therefore there are usually more thermoelements in the lower stage than the upper stage.

(a) Single-Stage

(b) Multi-Stage

FIGURE 2 Single- and Multi-Stage Heat Pumps

1.2.3 Peltier oven

A peltier element is an electric device that consists of p- and n-type semiconductors connected electrically in series and thermally in parallel as shown in Figure 1. If a dc current passes from the n- to the p-type semiconductor the electrons, which travels the opposite way from p- to n-side, will absorb energy, or heat, from the interconnect to reach the higher energy level they need to be inside the n-type semiconductor. The energy is then conducted via the electrons through the semiconductor to the opposite side. Here the electrons pass through another interconnect where the energy is released has heat, because the electrons can be in a lower energy state in the next p-type semiconductor. These steps continue in every pair of n- and p-type semiconductors in the peltier element, so that one of the sides becomes cold and the opposite hot. In this way the device is functioning as a heat pump. By reversing the current the heat transfer is reversed.

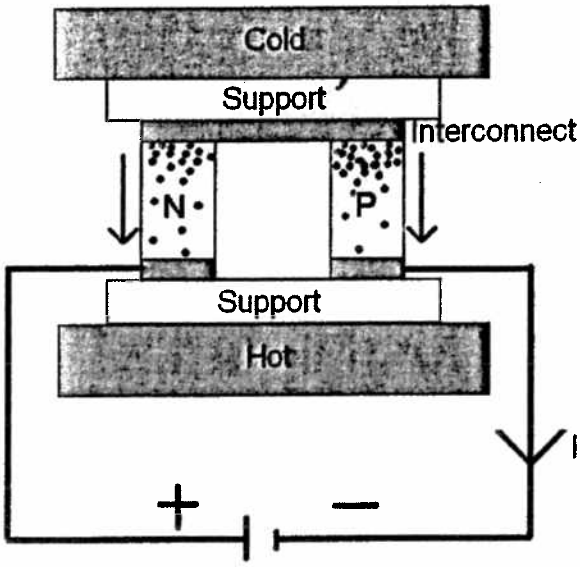


Figure 1: Schematic view of a peltier element.