

**Graph Definitions:**

**Temperature Difference (DT):** hot side temperature of the module minus the cold side temperature of the module. Temperatures are referenced at the ceramic substrates of the module.

**Heat Removed:** total rate of heat being removed from the cold side of the module.

**Waste Heat:** this is the rate of heat that the heat sink attached to the hot side of the module must dissipate. It is the sum of the heat removed from the cold side of the module plus the power input to the module.

**Input Current:** the current the module will draw at a particular input voltage.

**Input Voltage:** the voltage applied to the module. Generally, the straight lines in the graphs represent constant input voltages.

**Coefficient of Performance (COP):** ratio of heat removed to power input.

## **Thermoelectric (Peltier) Module / Material Definitions:**

**Qmax:** The amount of heat that a TE cooler can remove at a zero degree temperature difference when the hot-side of the elements within the thermoelectric module are at 300 K.

**I<sub>max</sub>:** The current that produces DT<sub>max</sub> when the hot-side of the elements within the thermoelectric module are held at 300 K.

**V<sub>max</sub>:** The voltage that is produced at DT<sub>max</sub> when I<sub>max</sub> is applied and the hot-side temperature of the elements within the thermoelectric module are at 300 K.

**DT<sub>max</sub>:** The maximum obtainable temperature difference between the cold and hot side of the thermoelectric elements within the module when I<sub>max</sub> is applied and there is no heat load applied to the module. This parameter is based on the hot side of the elements within the thermoelectric module being at 300 K. In reality, it is virtually impossible to remove all sources of heat in order to achieve the true DT<sub>max</sub>. Therefore, the number only serves as a standardized indicator of the cooling capability of a thermoelectric module.

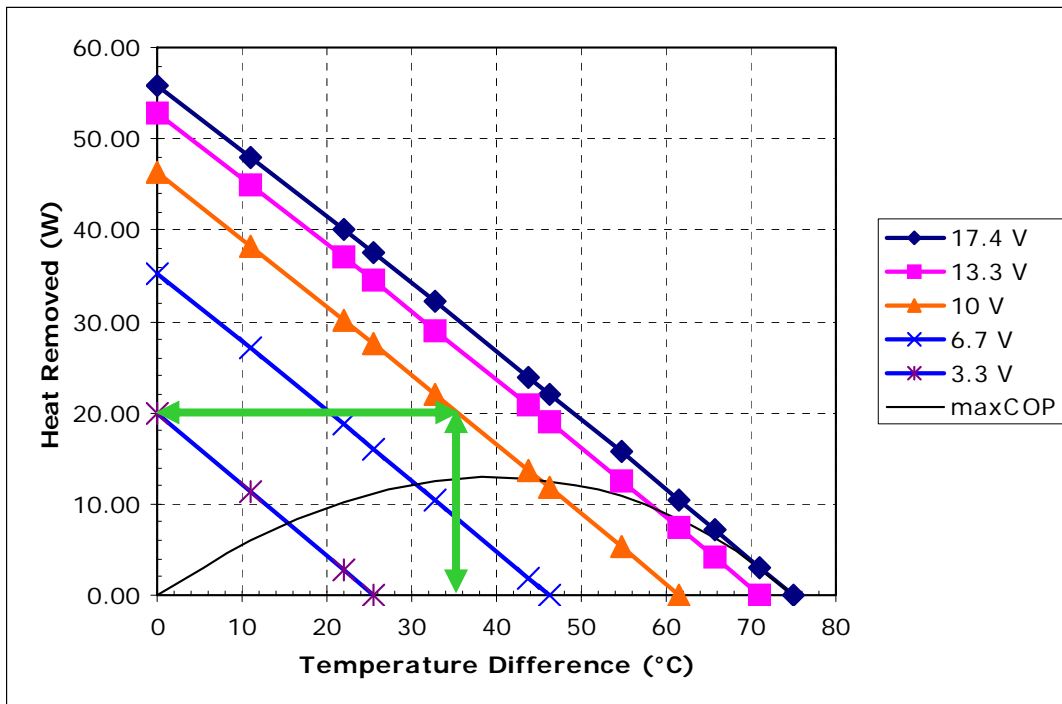


Please note that a thermoelectric (Peltier) module does not by itself pump heat. It must be used with a heat sink with a sufficiently low thermal resistance in order for the module to be able to effectively remove heat. Usually, the heat sink will require moving fluid, either air provided by a fan or by moving water, for example. If a proper heat sink is not used, the module can over-heat and catastrophically fail.

Each set of graphs is based on one particular hot-side temperature. You will need to verify that the hot-side temperature calculated from the amount of heat the heat sink must dissipate in conjunction with the thermal resistance of the heat sink and the local ambient temperature corresponds with (or is at least less than) the temperature that the graphs are based on.

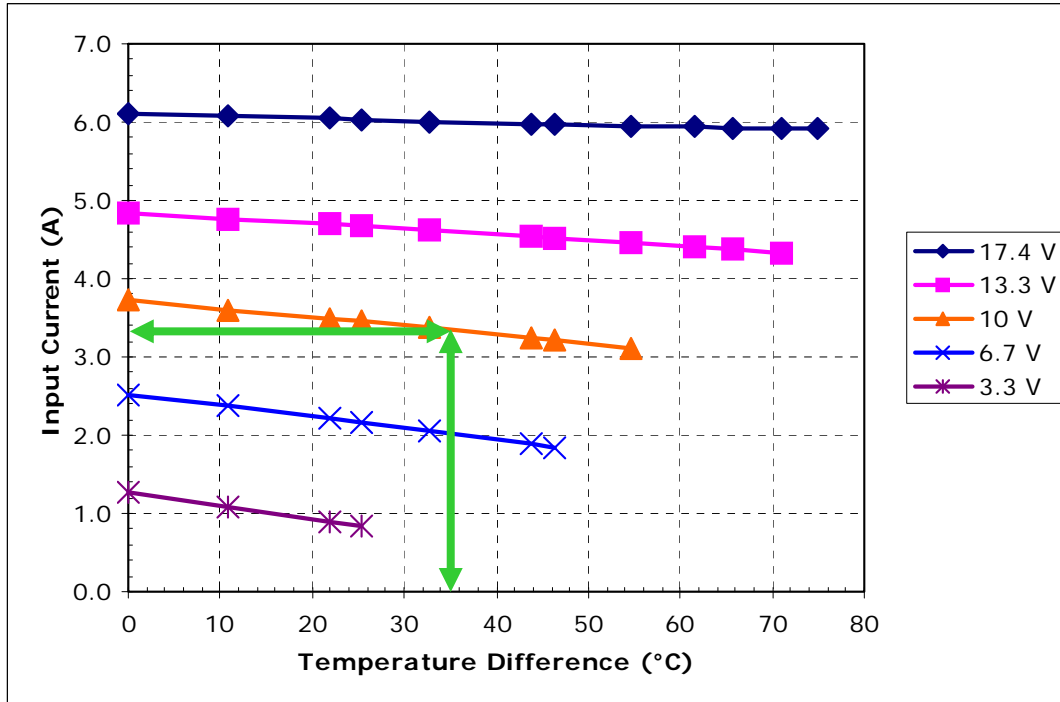
**Method/General Principles**

There are several sets of graphs provided in the specification corresponding to the hot-side temperature of the module and whether or not the module is potted. Be sure that you are using the correct set of graphs for your application. Initially, you might have to estimate the hot-side temperature of the module. If this is the case, and the ambient temperature is approximately 25 °C, then using the 50 °C hot-side graphs is a good starting place.



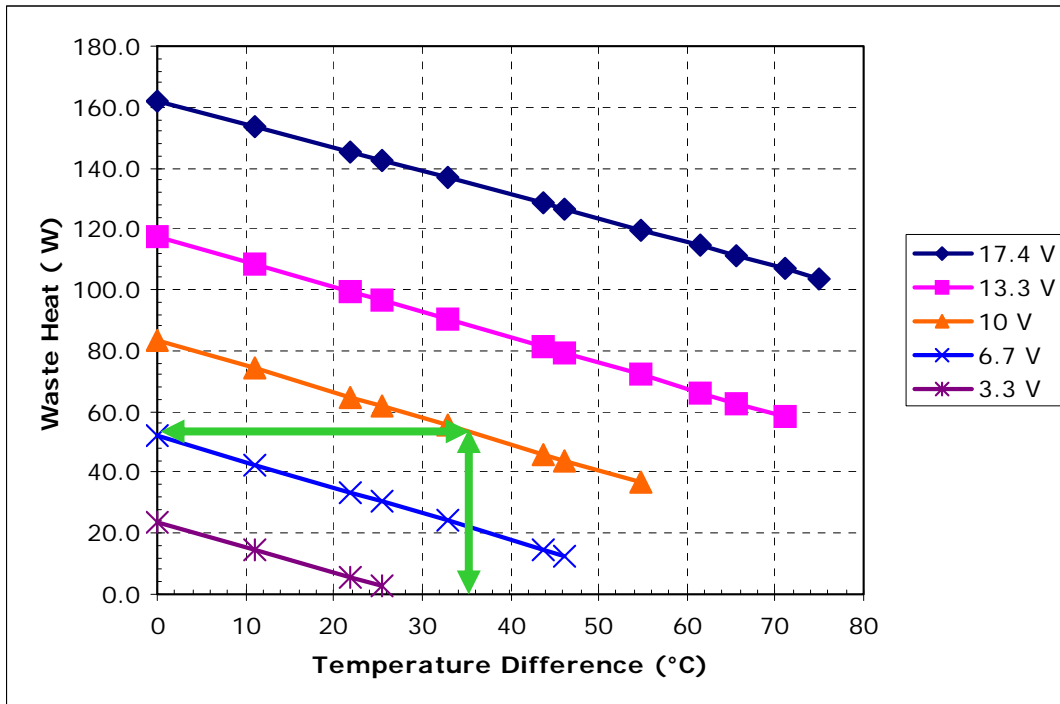
If you know the amount of heat load you need to remove and the desired cold-side temperature, you can determine what input voltage is required. Suppose you need to remove 20 W of heat at 15 °C and assume for now that the hot side of the module is at 50 °C. The temperature difference is then 50 - 15 = 35 °C. Therefore, the module would need a 10 V input.

The “maxCOP” line represents heat removal points at which the module is operating at the maximum coefficient of performance for a given temperature difference. If the operating point is on this line then the module will provide the desired amount of heat pumping for the least power input. If the operating point is above the line, then the module will tend to require more power input but its size may be smaller and/or it will tend to be less expensive than a module selected for maximum COP. If your operating point is below this line, then you may be able to select a module with a lower Qmax that yields better performance.



Once you know the input voltage, you can then determine what the steady-state current draw the module will have. In the example, a vertical line is drawn from the “Temperature Difference” axis until it intersects the graphed line representing the input voltage. Then draw a horizontal line from the intersection to “Input Current” axis to determine the current draw.

For our example, the module would be drawing approximately 3.3 A. Please note that this is an operating current at steady state. The start-up current would generally be approximately 20% greater. The start-up current can be determined by looking up the input current (corresponding to the operating voltage) at a zero-degree temperature difference using the Input Current vs. Temperature Difference graph for the hot-side temperature corresponding to the ambient temperature.

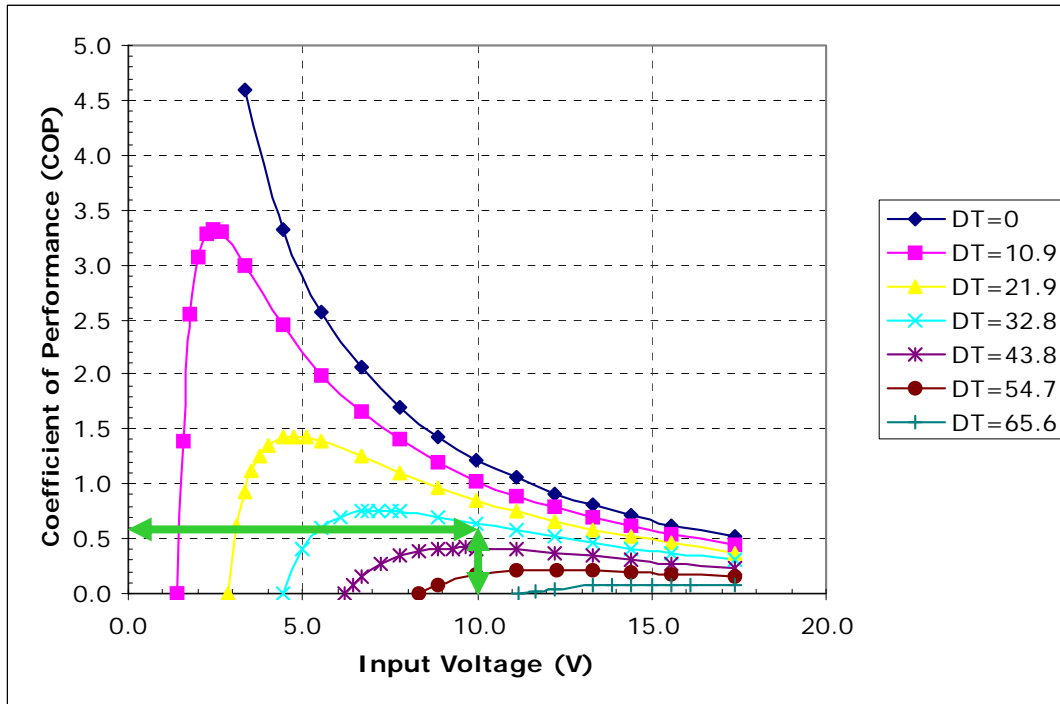


With our current example, we have actually already determined that the waste heat is 53 W (20 W of cooling plus 10 V x 3.3 A power input = 53 W). However, if you already knew the thermal resistance of your heat sink but did not know how much heat you could remove from the cold side, you could use this graph as your starting point.

In any case, this graph can be used to determine whether the thermal resistance of the heat sink you already have selected is sufficiently low enough to provide the performance you need, or it can tell you what the maximum thermal resistance can be.

Suppose the inlet fluid (air, water, etc.) to the heat sink is 20 °C. With our assumed hot-side temperature of 50 °C, the maximum allowable thermal resistance of the heat sink is then  $(50\text{ °C} - 20\text{ °C})/53\text{ W} = 0.57\text{ °C/W}$ . This is the total allowable thermal resistance which includes the basic thermal resistance of the heat sink, spreading resistance, and interface resistance.

If the total actual thermal resistance is equal to the maximum allowable thermal resistance, then the module can provide the necessary amount of cooling at the desired cold-side temperature, but there would be no safety factor. If the total actual thermal resistance is less than the maximum allowable thermal resistance, then the module would be able to pump more heat than actually required.



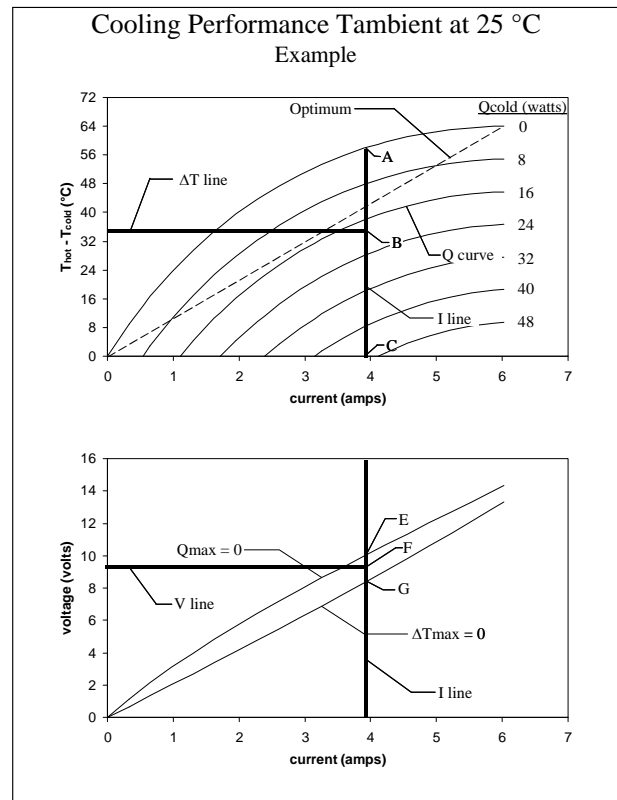
As with the heat removed in our current example, we have also already determined that the coefficient of performance (COP) is 0.6 [20 W of cooling divided by (10 V x 3.3 A) power input, 20/33 = 0.6]. However, this graph provides a visual indication of how far off of the maximum COP that the operating point is.

The graph can also be used as a starting point if you know how much heat you need to remove but you only have a limited amount of power available. You could then calculate your required COP and determine from the graph what input voltage would be required to obtain the desired temperature difference.

Note: some module performance graphs will be in the format shown in the example below, and the instructions below describe its use.

There are four engineering parameters which define the cooling performance of a thermoelectric (TE) module.

1.  $\Delta T$ : The hot-side temperature ( $T_{hot}$ ) minus the cold-side temperature ( $T_{cold}$ ) of the TE module.  
 $\Delta T = T_{hot} - T_{cold}$
2.  $Q_c$ : Total heat pumped by the TE module at the surface defined by  $T_{cold}$ .
3.  $I$ : Current drawn by the TE module.
4.  $V$ : Voltage applied to the TE module.



**Method Description / General Principles:**

The performance chart can be used to define all four engineering parameters provided that two are known or defined by a given cooling requirement. Generally,  $T_{hot}$ ,  $T_{cold}$ , and  $Q_c$  are known and the  $I$  and  $V$  needed to produce this cooling is of interest. In other cases, you may use this to analyze a test result when  $V$ ,  $I$ ,  $T_{hot}$ , and  $T_{cold}$  were measured, and you want to know  $Q_c$ . If the latter is the case, try to measure  $I$ , and use this in the analysis rather than  $V$ .  $V$  can be misleading since it can include effects of wiring and other external resistances. In contrast,  $I$  is truly flowing through the TE module.

Start with the known parameters and graph them as shown in the example. The parameters  $V$  and  $\Delta T$  are graphed by simple horizontal lines. The parameter  $I$  is graphed by a simple vertical line. The parameter  $Q_c$  is graphed as a curve and must be sketched in if not already present. The intersection of the lines that you can sketch in will determine the placement of the lines for the parameters you do not know.

**Example 1:** If you know the required  $\Delta T$  and the required  $Q_c$ , the required current can be determined by drawing a vertical line downward from the intersection of the  $\Delta T$  line and the  $Q_c$  curve on the upper graph. Then, on the lower graph, the placement of the  $V$  line can be determined by making the ratio of  $AB/BC = EF/FG$  as shown on the graphs above.

**Example 2:** If you know the current that is flowing through the module and one additional parameter such as  $\Delta T$  or  $Q_c$ , you can draw in these two lines/curves on the upper graph. The intersection of these two lines/curves will determine the intersection point for the third, unknown parameter.