

How to Select a Thermoelectric Cooler

Thermoelectric coolers, or TECs, can be used to heat or cool components and/or systems with low power dissipation. This ability, along with their high reliability, make TECs a strong choice for providing precise thermal control over a heat-generating device

The following example presents a proven way to select a TEC for a given application.

Problem Statement:

A 30 mm x 30 mm device needs to dissipate 12.3 W of power. The surface temperature of the device must be maintained at 20°C. The ambient air temperature is 40°C. The available heat sink has a thermal resistance of 0.4°C/W. Determine an appropriate TEC to meet the sub-ambient cooling requirements of this application, and determine the operating conditions for the TEC.

In practical applications, TECs are used with heat sinks to more effectively dissipate heat from hot junctions and thus increase their efficiency.

A general mathematical model can be constructed to describe TEC performance, using the governing equations below [1], [3]:

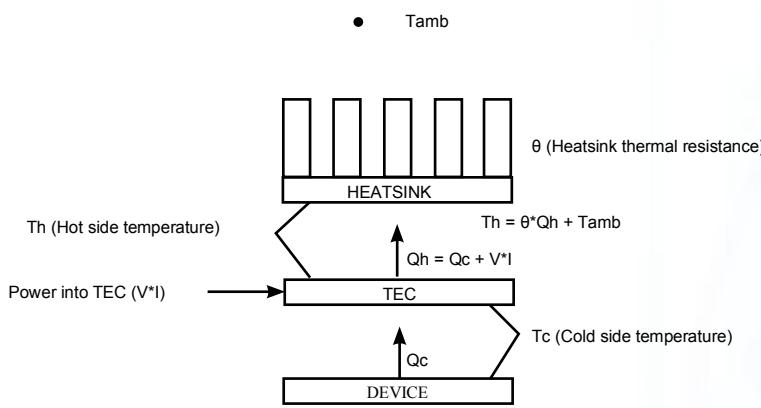


Figure 1.
Illustration of problem statement (exploded view) [1].

T_{amb} = ambient temperature

T_c = required surface temperature of the device

Q_c = required device power dissipation

Effectively, there are three equations that describe the system and can be used to solve for the unknown quantities.

The first equation is:

$$\Delta T = T_h - T_c$$

Where ΔT is the temperature difference across the TEC, T_h is the TEC's hot-side temperature (unknown) and T_c is the TEC cold side temperature.

The second equation is:

$$Q_h = Q_c + V^*I$$

Where Q_c is the heat absorbed on the cold side (common surface of the device to be cooled and the TEC), V is the TEC input voltage, I is the TEC input current, and Q_h is the output heat of the TEC, which must be dissipated by the heat sink (unknown). The product V^*I is the input power to the TEC and constitutes the Joule heating for the device (unknown).

The last equation is:

$$T_h = R_{HS} * Q_h + T_{amb}$$

Where T_h , T_{amb} , and Q_h are as previously defined, and R_{HS} is the heat sink thermal resistance.

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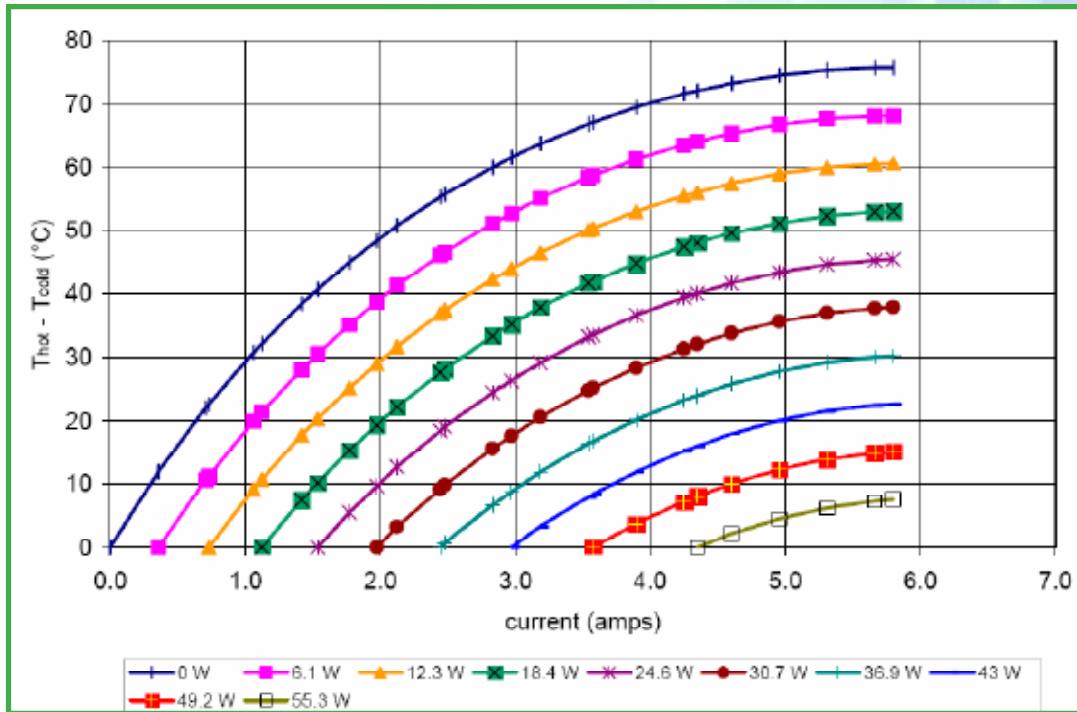


Figure 2. ΔT vs. Current (amps) [1].

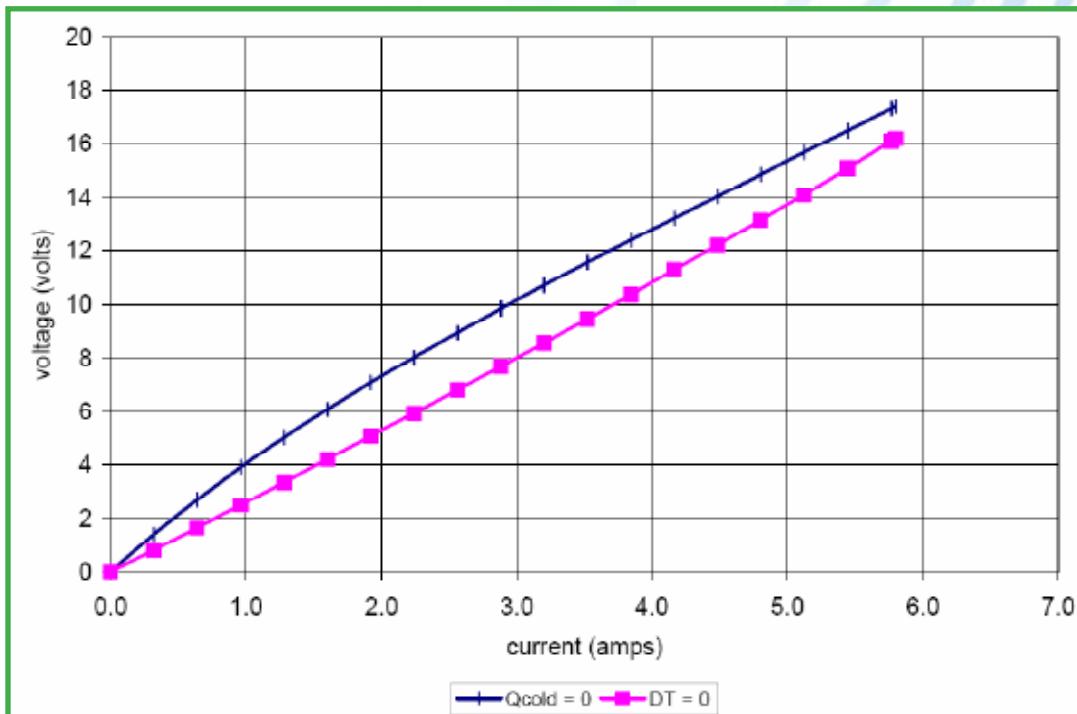


Figure 3. Voltage (volts) vs. Current (amps) [1].

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The values in these graphs represent information that is typically available from TEC manufacturers and can be used to determine if a TEC will work for an application.

To determine the operating point of the TEC and whether it will fall within the full operating range, we will perform the following calculations.

The first step is to assume a value for T_h . As a starting point, we'll calculate the temperature rise above ambient that we would expect if the heat sink were applied directly to the device:

$$T_{h\text{-guess } 1} = (0.4^\circ\text{C/W}) * (12.3 \text{ W}) + 40^\circ\text{C} = 44.9 \sim 45.0^\circ\text{C}$$

Next, we calculate the required ΔT across the TEC:

$$\Delta T = T_h - T_c = 45 - 20 = 25^\circ\text{C}$$

We substitute this value into the graph in Figure 3 and solve for the TEC operating voltage and current (see red lines/some interpolation is required).

With this information we can solve for the value of Q_h as follows:

$$Q_h = Q_c + V * I = 12.3 \text{ W} + (5.2 \text{ V}) * (1.75 \text{ A}) = 21.4 \text{ W}$$

Substituting and solving for T_h , we get:

$$T_h = (0.4^\circ\text{C/W}) * (21.4 \text{ W}) + 40^\circ\text{C} = 48.6^\circ\text{C} > 45^\circ\text{C}$$

As expected, our initial guess was somewhat low because we have not accounted for the internal heating of the TEC. Let's try a new guess for T_h of 50°C and run through the same set of calculations (see green lines). The details of the calculations are shown below:

$$T_{h\text{-guess } 2} = 50^\circ\text{C}$$

$$\Delta T = T_h - T_c = 50 - 20 = 30^\circ\text{C}$$

$$Q_h = Q_c + V * I = 12.3 \text{ W} + (6.2 \text{ V}) * (2.0 \text{ A}) = 24.7 \text{ W}$$

$$T_h = (0.4^\circ\text{C/W}) * (24.7 \text{ W}) + 40^\circ\text{C} = 49.9^\circ\text{C} < 50^\circ\text{C}$$

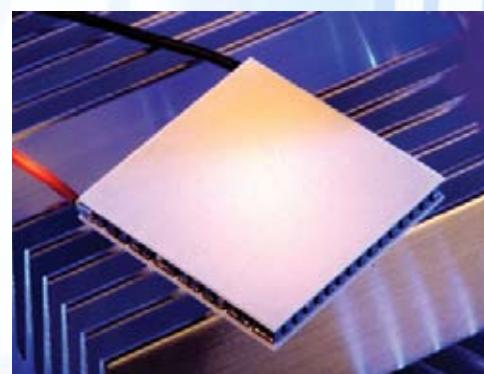
The new calculated value for T_h is less than the guess value. So, we can conclude that the operating point for the TEC will lie between our two guess values. An exact

value for this operating point could be determined with further iterations if required, but at least we know the TEC will work for our application.

As a practical matter, there are a number of issues that will affect the "true" operating point for the TEC. These include, but are not limited to, the following:

1. Radiation heat transfer between the assembly (device, TEC and heat sink) and its surroundings.
2. Conduction heat transfer between the assembly components (e.g., nuts and bolts used to clamp the assembly together and in place). Clamping the TEC between a heat sink and the component to be cooled or heated is the preferred method of attachment. However, TECs can also be soldered or epoxied in place, if care is taken to consider thermal expansion and contraction of the materials involved.
3. Spreading resistance due to non-uniform heat sources.
4. Interfacial resistances between the assembly components. The use of high performance thermal interface materials is recommended to minimize interfacial resistances and maximize TEC efficiency [1], [2].

Finally, because this is a sub-ambient cooling application, special care is required to minimize or eliminate the effects of condensation on the TEC and surrounding components.



References:

1. TE-127-1.0-0.8 TEC Specifications, TE Technology, Inc.
2. Thermoelectric Technical Reference, FerroTec Corporation, 2001-2006.
3. Godfrey, S., Melcor Corporation, An Introduction to Thermoelectric Coolers, Electronics Cooling, September 1996.