Introduction

Brief Overview: You may notice that there are numerous pages of instruction devoted to the use of this module selector program. At first glance, this may make the program appear much more complex than it really is. In actuality, the module selection is simple. All you need to do is to enter the DTmax for the module, a hot-side temperature, a cold side temperature, and how much heat you want to remove.

The output of the program is simple, too. After you click the "calculate button", the program will calculate two ratios based on the design inputs you entered. The first ratio is "**Q/Qmax for lowest power consumption**." This number is the ratio of the heat you are trying to remove to the total Qmax of the module when the system has been optimized to consume as little input power as possible. The second ratio is "**Q/Qmax for smallest size**." This number is the ratio of the heat you are trying to remove to the total Qmax of the module when the system has been optimized to have the smallest Qmax and consequently the physically smallest module possible.

Because these ratios by themselves will not tell you what module to use, we simply divide the heat you are trying to remove (Q) by each ratio to tell you the Qmax for the systems with the lowest power consumption and the smallest size.

These values for Qmax are the main parameter of interest. While the program goes on to recommend modules based on which goal you are trying to achieve (lowest power consumption or smallest size), you have much more flexibility than just what is listed by the program. For example, let us say the Qmax for lowest power consumption is 60W, the Qmax for smallest size is 20W, and you want to optimize for lowest power. You can use one 60W module, or two 30W modules. You could use a center hole module with a Qmax of 59 or 56 W. They won't be exactly optimum, but they will be close. Those options may not all be listed, but they are all acceptable alternatives. If you are trying to achieve a Qmax that is too large for a single module, then you can simply use more than one module and divide the heat load evenly among each. The key is to select a module or group of modules that has the correct Qmax for the goal you are trying to achieve.

You also have flexibility in obtaining the operating voltage and current you desire. By varying the number of couples you can vary the operating voltage for the module. For example, suppose your first module selection was to run a 30 Watt, 63 couple module at 5 amps and about 6.5 volts. However, this is not a desirable voltage because you want your product to operate from an automobile which has 12-13VDC available. In this case, you can select a 30W module with about two times the number of couples. A 30 W, 127 couple module will operate at about 2.5A and 13V in your application. Finally, when using multiple modules, you can wire them in series, parallel, or series/parallel to have even more options for voltage and current.

TE▲▲▲▲▲▲®
TECHNOLOGY, INC.

1590 Keane Dr.
Traverse City, MI 49696-8257
http://www.tetech.com

PH: (231) 929-3966
FAX: (231) 929-4163
e-mail: cool@tetech.com

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Introduction

If module selection is so simple, how come there are so many pages of instructions?
Selecting a module based on your input parameters is relatively simple. So, the bulk of these instructions is dedicated to the process of verifying that your initial design parameters are actually attainable when the module is incorporated into a cooling assembly. This process requires a bit of effort, but it is not excessively difficult if you have a basic understanding of heat transfer.

There are three steps to verifying whether a module will work in your cooling assembly: **Initial Calculation**, **Analysis**, and **Iteration**. You must first enter the operating parameters as described in the previous page; remember some of these parameters are initially estimated. First, using the program, you make an **initial calculation** to determine which modules would work best for these operating parameters. Once you have this initial suggestion for a module, you **analyze** how it will perform in a cooling system. Based on the physical characteristics of the selected module and the corresponding system design, the analysis may show that the initial estimates of the operating parameters need refinement. So, you enter new operating parameters and then recalculate to determine a new suggested module. This process is **iterated** until the suggested module does not change. At this point all of the operating parameters are in agreement with what can realistically be achieved in a cooling assembly, and the module selection is complete. The flow chart on the next page shows this process.

The calculations and analysis are based on modeling with a single module. If the heat load is too large for any one single module, the program will tell you that you need to use more than one module for the application. If this is the case, simply divide your total heat load by a whole number (2, 3, 4, etc.), and recalculate until the program says that this fractional heat load can be removed by a single module. Then, use that multiple of modules when making the cooling assembly.

Caution: Proper module selection is an iterative process! If this process is too time intensive for you, if you are uncertain of the process, or if a mistake would destroy your project's timeline and budget, then we suggest that you purchase a standard or custom cooling assembly.
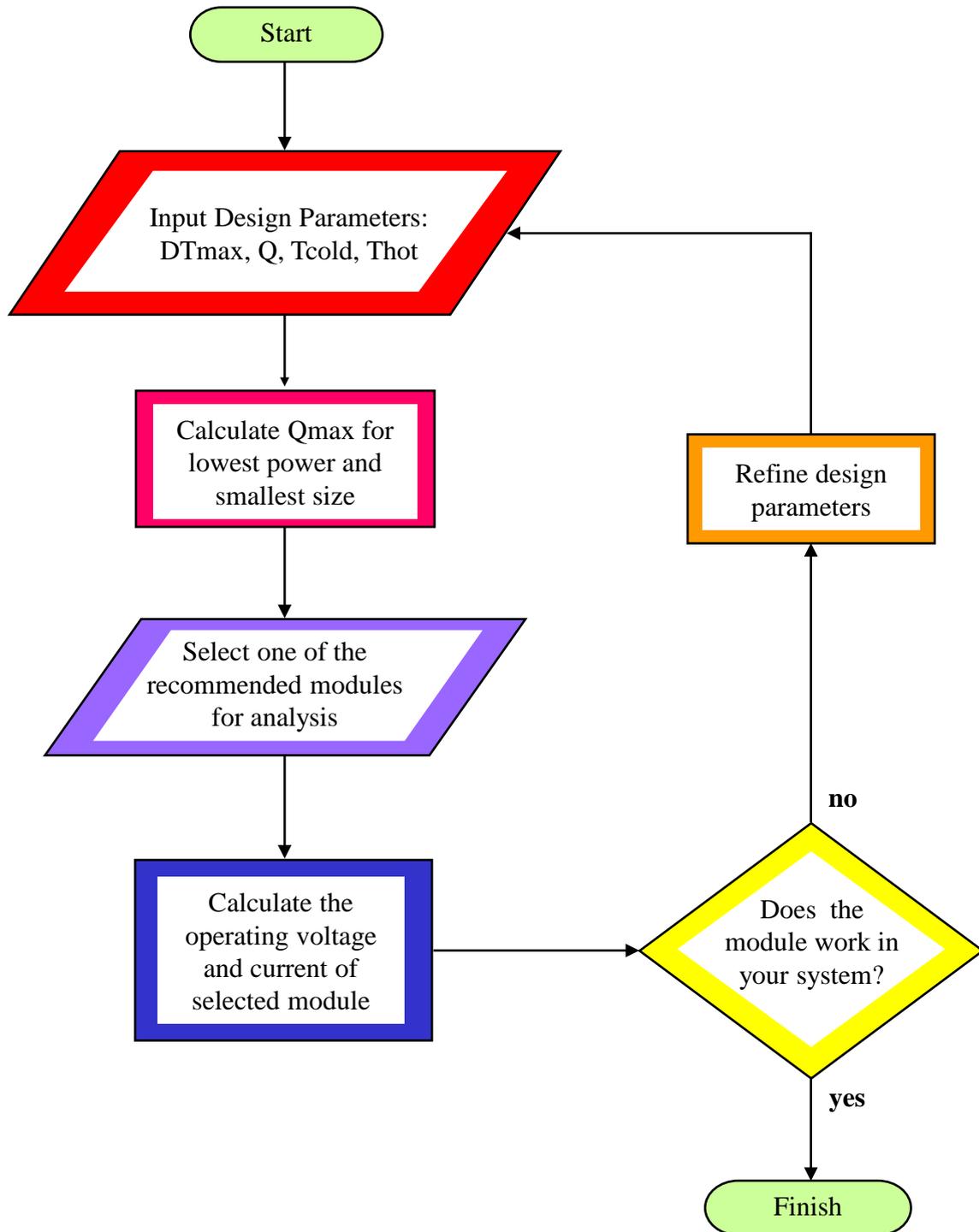
TE Technology's standard cooling assemblies take the guesswork out of system design. They provide a cooler that has defined performance, is sealed against moisture, has a proper heat sink, and is ready to install and run. If a standard product is not exactly what you need, and you expect that you will need a total of 10 or more cooling units, then a custom unit (either a modified standard product or a completely custom product) can often be optimized to provide lower cost and power consumption. To see our standard coolers or some examples of custom coolers, follow the links on a menu bar at the left of any of our web pages or visit the home page at www.tetech.com.

Module Selection Flow Chart

Start

Input Design Parameters:
DTmax, Q, Tcold, Thot

Calculate Qmax for lowest power and smallest size

Refine design parameters

Select one of the recommended modules for analysis

Calculate the operating voltage and current of selected module

no

Does the module work in your system?

yes

Finish

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Definitions

Module Specifications:

DTmax for module—the maximum temperature difference that can be achieved across the thermoelectric elements within a module with zero watts of heat load and at Thot = 27 °C. The DTmax you enter should be greater than the temperature difference (DT) you are trying to achieve.

Qmax—the amount of heat that a module removes at zero degrees DT, at Thot = 27 °C, and while operating at Imax.

Imax—the current which produces the DTmax.

Vmax—the voltage that occurs when DTmax is produced.

Design Parameters:

Heat Load (Q)—the total amount of heat the module needs to remove.

Note: for this software program, Q must be greater than zero.

Cold-side Temperature (Tcold)—the temperature at the cold side of the element within the module.

Hot-side Temperature (Thot)—the temperature at the hot side of the element within module.

Note: for this software program, Tcold must be less than Thot.

Calculation Results:

DT—the temperature difference, Thot - Tcold.

I/Imax for lowest power—the ratio of the module's suggested operating current to the Imax of the module.

Qmax for lowest power—the Qmax of a module that has been optimized for minimum power consumption.

Q/Qmax for lowest power—the ratio of Q to Qmax of a module that has been optimized for minimum power consumption.

Qmax for smallest size—the minimum Qmax of a module that will meet the cooling requirement. *This generally translates to a module that is as physically small as possible.*

Q/Qmax for smallest size—the ratio of Q to the minimum Qmax capable of meeting the cooling requirements.

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Initial Calculation

Refer to the diagram labeled "Typical Cooling Assembly Thermal Diagram" (page 10)

Step 1: Enter a DTmax in the Module Selector program (entry #1). Many single-stage, *unsealed* modules have a DTmax of 70 °C; single-stage, *sealed* modules have a typical DTmax of 68 °C. You can use these as starting points. If you need a higher DTmax, review the multi-stage module or high-performance module specifications and enter a DTmax from one of those products.

Step 2: Enter the total heat load (Q) the module must remove in the Module Selector program (entry #2). The total heat load is Q = Qactive + Qpassive + Qloss. The active heat (Qactive) is generated from electrical components, chemical reactions, etcetera. The passive heat (Qpassive) is that which is transferred through enclosure walls from air convection, solar radiation, etcetera. Lastly, Qloss is the heat that gets transferred from the hot side of the assembly right back into the cold side of the assembly. This heat load might be transferred through assembly bolts, the insulation between the heat sink and cold plate, radiation from the heat sink back to the cold plate, etcetera. Qloss must be estimated for the first iteration because you will not know the number of assembly bolts, amount of insulation, etcetera until you get a rough idea of the module required after the first iteration.

Hint: Qpassive from air convection can be determined by using TE Technology's Product Selector program at http://www.tetech.com/Cooling-Assembly-and-Heat-Load-Calculator/index.php.

Step 3: Enter the Thot value into the Module Selector program (entry #3). Thot = Tambient + Qhsr * HSR. Thot is derived from the total thermal resistance of the heat sink (HSR), the amount of heat the heat sink is dissipating (Qhsr), and the warmest ambient temperature the heat sink must operate in (Tambient). Thot can be estimated for the first iteration as follows: for a liquid-cooled heat sink, Thot is 10 °C above the warmest liquid temperature; for a bonded-fin, forced-air heat sink, Thot is 15 °C above the warmest air temperature; for an extruded-fin, forced-air heat sink, Thot is 20 °C above the warmest air temperature.

Step 4: Enter the Tcold value into the Module Selector program (entry #4). Tcold = Tobject - Qcsr * CSR. Tcold is derived from the total thermal resistance of the cold sink (CSR), the amount of heat the heat sink is removing (Qcsr), and the coldest temperature the object must reach (Tobject). Tcold is determined from your thermal model of your cooling system and the heat loads from Step 2.

Caution: This software program requires that Tcold be less than Thot, and that your heat load be greater than zero.

Step 5: Click the "calculate" button and then select a module to analyze by clicking on the corresponding "graph" button.

The modules are grouped into two sections: "Qmax for lowest power" and "Qmax for smallest size." You can also analyze a module based on combination of these two design goals. The Qmax for any particular module must be greater than "Qmax for smallest size."

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TECHNOLOGY, INC.

1590 Keane Dr.
Traverse City, MI 49696-8257
http://www.tetech.com

PH: (231) 929-3966
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Analysis

The Module Selector Program graphically analyzes how the selected module compares with two "extremes." The graph below is an example analysis.

The first extreme is represented by the blue line, the "**Q/Qmax for Lowest Power**" line. This is the case where the module provides the necessary heat pumping with the smallest input power. The other extreme is represented by the black line, the "**Q/Qmax for Smallest Module**" line. It represents a module that will provide the necessary heat pumping in the smallest space possible. The red line, "**Q/Qmax for Selected Module**", is the module you are analyzing. If the selected module is below the black line, it will not have enough capacity to meet requirements, and you will need to reselect another module. If the selected module is above the blue line, then a smaller and more efficient module most likely can be selected.

Depending on where the selected module line falls between the two extremes will indicate the trade offs between efficiency and size. The closer to the blue line, the more efficient it will be. The closer to the black line, the smaller it can be. The graph below shows an example of a module that has been selected more for small size than for efficiency.

A more efficient system could mean that a more expensive module is required, but it would allow you to use a smaller power supply and heat sink. A smaller system could mean that a less expensive module is required, but you might have to use a larger power supply and heat sink.
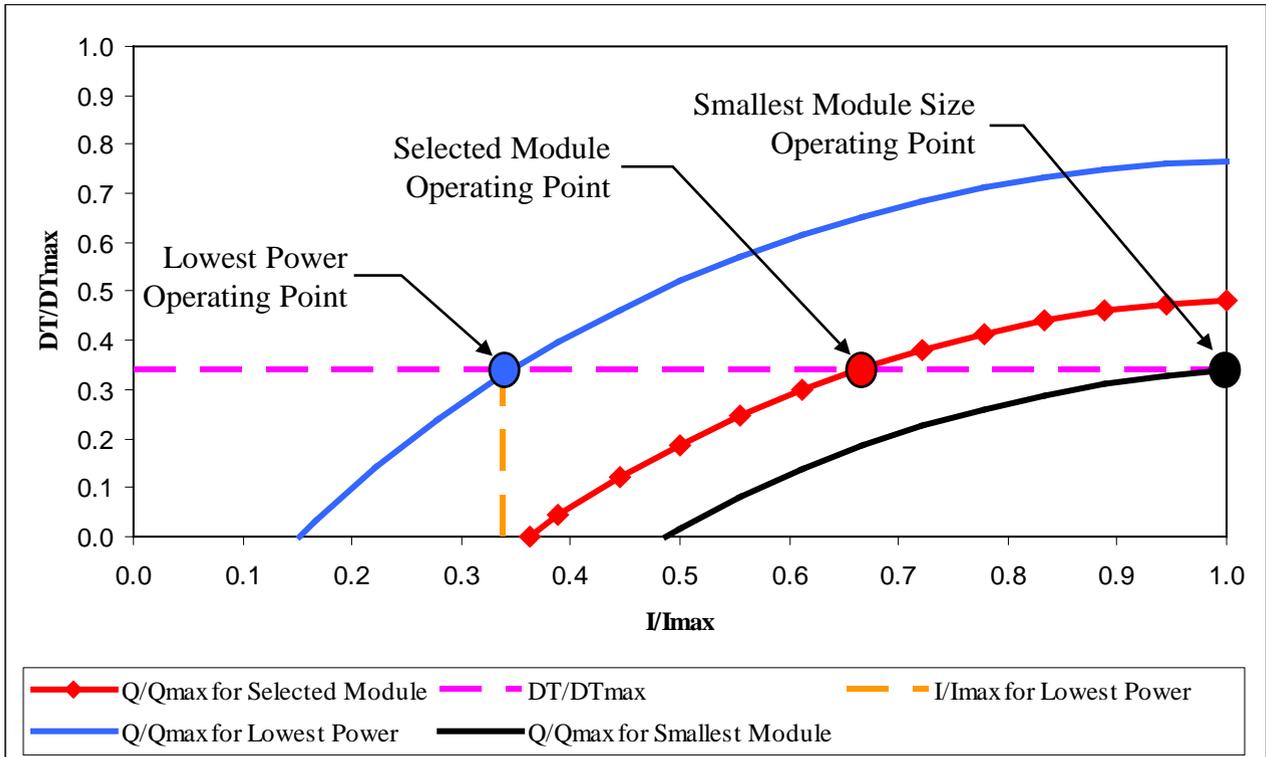
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Analysis

At this stage you should have selected a module that you would like to use in your system. The next steps will allow you to determine the operating voltage and current of that module. Once you have these numbers, you can use your thermal model to make sure the temperatures and heat load used to select the module were correct. The diagram labeled "Typical Cooling Assembly Thermal Diagram" (on page 10) may offer you a starting point in making your thermal model.

Step 7: The voltage and current must now be determined. This will be done graphically using the Performance Chart for the selected module. Clicking on the module name will bring up a Performance Chart for that module based on the hot-side temperature you entered and based on the DTmax for that module. If you want to analyze a potted module, and the DTmax(potted) column is zero, you will need to contact us for further information. Generally, the DTmax(potted) is zero for multi-stage modules. For most, multi-stage modules, potting is not recommended because the potting will considerably degrade the cooling performance.

The next page shows a sample chart. Here is how to use it:

Step A: Sketch in the curve corresponding to your Q, and draw in the horizontal DT – line corresponding to the calculation results. (In the example, DT =40 °C and Q = 18 W.)

Step B: Draw in the vertical I - line in the upper and lower graphs. The position along the x-axis of both graphs corresponds to the intersection of the DT – line and Q – line graphed in Step A. This defines the operating current.

Step C: The upper graph example shows three points labeled A, B, and C and three points in the lower graph defined by E, F and G.

Point A is always defined by the intersection of the I – line with the Q = 0 line. Point B is the intersection of the DT – line and the Q – line. Point C is the intersection of the I – line with the DT = 0 line.

Point E is the intersection of the I – line with the "Qcold =0" line in the lower graph. Point G is the intersection of the I – line with the "DT = 0" line in the lower graph. Point F is defined such that the ratio of line segments AB/BC = EF/FG, as illustrated in the sample chart.

Draw in the horizontal V – line in the lower graph so that it intersects Point F. This defines the operating voltage.

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Potted TE-127-1.4-1.5 at a hot-side temperature of 27 °C

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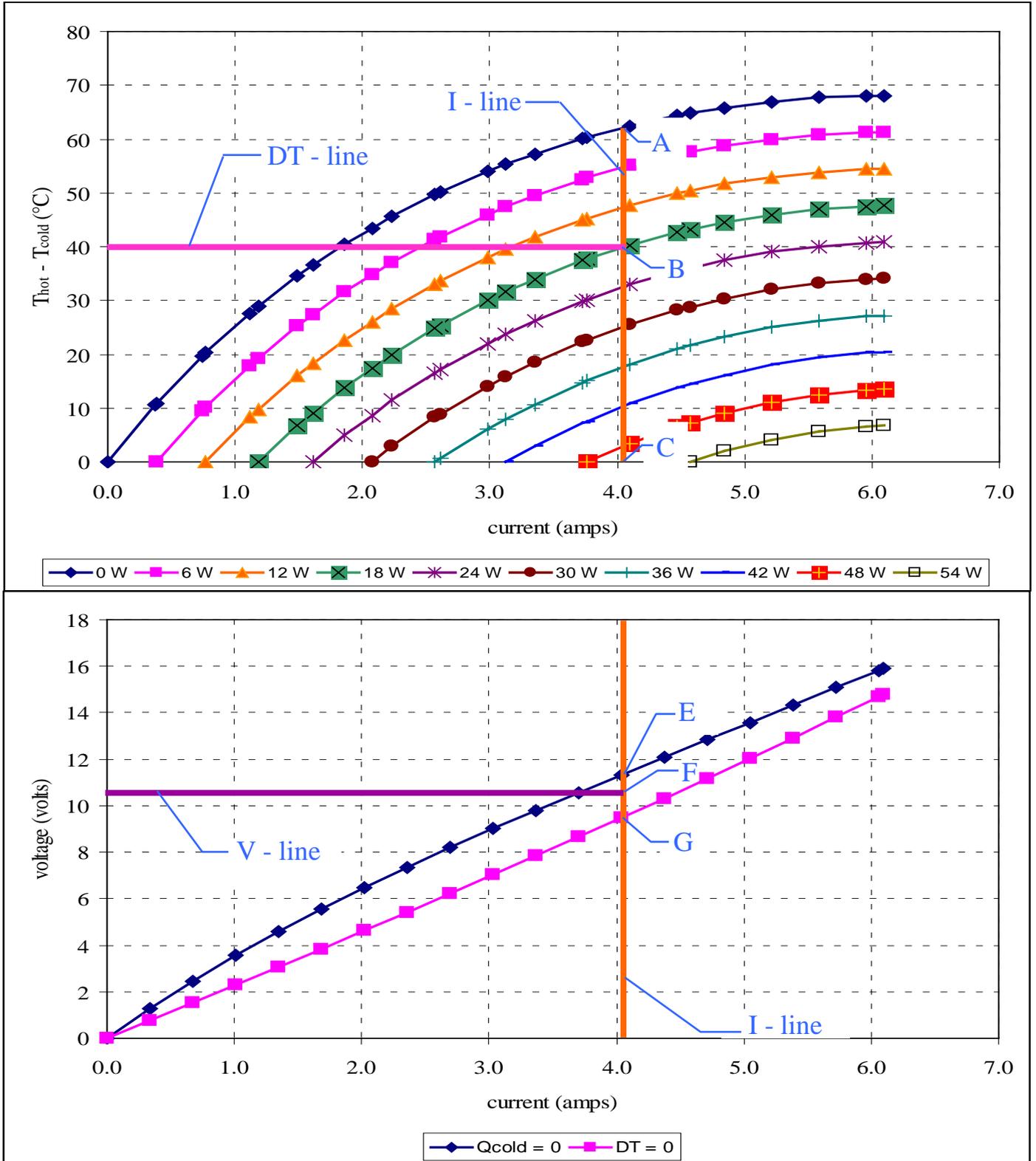
Iteration

This is the part where you modify your previous design estimates based on the resulting calculations and analysis. On page 10, a generic Typical Cooling Assembly Thermal Diagram is shown. This can be used to assist you with keeping track of all the relevant heat transfers that are occurring. If the diagram does not exactly match your system, it should be modified so that it does.

Note: The exact nature of the calculations of these thermal resistance is beyond the scope of the engineering assistance we can provide for thermoelectric modules. However, the following Iteration steps provide some insight as to their nature.

Step 8:

   Step A: Enter the DTmax of the module you just analyzed (entry #1).

   Step B: Enter the new Thot (entry #3). This is done by calculating Qhsr = Qactive + Qpassive + (V * I) where V and I are the voltage and current, respectively, that you determined in the Analysis section. Now calculate Thot = Tambient + Qhsr * HSR. The total HSR = R3 + R4 + R5 (refer to the Thermal Resistance Network). It should be remembered that the analysis is based on modeling a single module, so the R3, R4, and R5 values you calculate and use with this program need to be adjusted accordingly.

   Step C: Enter the new Q (entry #2). This is calculated from Q = Qactive + Qpassive + Qloss. Qloss is determined from Q = (Thot – Tcold)/Rsystem. Rsystem = 1/(1/R6 + 1/R7 + 1/R8 + 1/R9). Again, it should be remembered that the analysis is based on modeling with a single module. So, if you actually need to use multiple modules, the corresponding Rsystem needs to be adjusted accordingly.

   Step D: Presumably, your Tcold has not changed for the analysis. Be sure this value is properly entered.

Step 9: Click the "Calculate" button. If the Module Selector program suggests the same module that you have previously analyzed then you are finished! If the module is not suggested, you will need to select another module and then repeat steps 6 through 9.

Typical Cooling Assembly Thermal Diagram

Temperature of object to be cooled

Qactive + Qpassive

R1

Qloss

R2

Qactive + Qpassive + Qloss

Heat Load (Q)

Tcold

R3

TE cooler →

Thot

R3

Qactive + Qpassive + Qloss + V * I

R4

Qloss

R5

Qactive + Qpassive + V * I

Temperature of cooling gas or liquid

R6

Qloss (bolts)

R7

Qloss (gasket)

R8

Qloss (air)

R9

Qloss (radiation)

R1 = cold sink thermal resistance

R2 = cold sink spreading resistance

R3 = module's substrate and interface thermal resistance

R4 = heat sink spreading resistance

R5 = heat sink thermal resistance

R6 = thermal resistance through assembly bolts

R7 = thermal resistance through gasket material

R8 = thermal resistance through internal air volume

R9 = thermal radiation resistance from heat sink to cold sink

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