



Technical Note #2, v. 1.00

"Using The TEC Array Calculation Spreadsheet"

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1. These instructions describe the operation of the TEC Array Calculation Spreadsheet, used for calculating the TEC current and voltage for a user-defined array of thermoelectric coolers in a real world application that includes the thermal resistances of the elements required to get heat to and from the TEC. Please follow the discussion in the Spin One Technical Note #1 for the derivation of the equations used in this spreadsheet. Please go to www.spin1.com/support and look under the section on Technical Notes. The spreadsheet itself may be downloaded from our website. As of this writing, the spreadsheet is at www.spin1.com/TECArrayCalc.xls.

While the spreadsheet takes the various thermal resistances into consideration, it assumes uniform temperature distributions across the TEC surfaces. This can lead to overly optimistic predictions of performance, so the calculated results should be considered a best-case design and the user should build additional "headroom" into the actual apparatus (for example, by anticipating the need for a lower thermal resistance heat sink or by assuming that additional TEC current will be needed).

2. First, be sure you are comfortable with running a spreadsheet. However, if you corrupt the spreadsheet cells, you can always download it again and start over.

3. The top row of the spreadsheet has the names of the various variables that are calculated as per Spin One Technical Note #1. The remaining rows of the spreadsheet are either variable input cells or cells whose contents are the results of calculations. Since the material parameters are temperature-dependent (average between the hot and cold sides) and the TEC hot side temperature depends on these same variables, the calculations are run iteratively and monitored to see that the results converge after about 10 steps. The definition of the column variables are

- A. Number of couples N_C .
- B. Geometry factor λ .
- C. Number of TECs N .
- D. Cold Side Input Heat Q_C .
- E. Load temperature T_{load} .
- F. Ambient temperature T_{amb} .
- G. Thermal resistance of the heat spreader θ_{load} .
- H. Thermal resistance of the heat sink θ_{HS} .
- I. Material Resistivity ρ .
- J. Resistivity at T_C minimum.
- K. TEC Resistance R .
- L. Material Seebeck Coefficient S_m .
- M. TEC Seebeck Coefficient S .
- N. Material Seebeck Coefficient for T_C minimum.
- O. Material Thermal Conductivity K_m .
- P. Material Thermal Conductivity for T_C minimum.
- Q. Minimum Cold Side Temperature T_C minimum.
- R. Average of the minimum cold side temperature and the hot side temperature.
- S. Thermal Resistance θ_{TEC} of the TEC.
- T. Q_{max} (see Tech Note #1 for definition)

- U. I_{\max} (see Tech Note #1 for definition)
- V. TEC Cold Side Temperature T_C
- W. TEC Hot Side Temperature T_H
- X. Average of the TEC Hot and Cold Side Temperatures
- Y. Delta T (Difference in Hot Side and Cold Side Temperatures)
- Z. 'a' coefficient in solution for I
- AA. 'b' coefficient in solution for I
- AB. 'c' coefficient in solution for I
- AC. TEC Array Current I
- AD. TEC Array Voltage V
- AE. Total TEC Array Heat Output

4. All the user needs to do is to input various basic TEC and environment variables into the appropriate input cells, and let the spreadsheet crank (virtually instantaneously). The *input* cells, highlighted in orange, are

- A2. Number of couples N_C in the individual TEC you've chosen for the array.
- B2. Geometry factor λ of the TEC in 1/cm (remember that some manufacturers use λ and some use $G = 1/\lambda$).
- C2. Number of TECs N in the array.
- D2. Heat Q_C to be pumped into the TEC cold side in Watts.
- E2. The desired load temperature T_{load} in Celsius.
- F2. The ambient temperature T_{amb} in Celsius.
- G2. The thermal resistance of the heat spreader θ_{load} (including everything from the TEC cold side surface to the heat load) in K/W.
- H2. The thermal resistance of the entire heat sink θ_{HS} (including everything from the TEC hot side surface to the ambient environment) in K/W.

5. The principal *output* cells, highlighted in blue, are the TEC Array Current I, the TEC Array Voltage V, the Total TEC Array Heat Output, and the hot and cold side TEC temperatures. Also calculated are the values of I_{\max} and $T_{C\min}$ for the resultant TEC hot side temperature. Various starting values have already been placed into the spreadsheet. As a comment on the calculation, the first actual row of calculation (row #2) has been primed with coefficients at $T = 298$ K to get the iteration started with something that makes approximate sense. Subsequent rows are calculated with numbers from the previous row and the process is repeated. The complexity of the spreadsheet is driven by the temperature dependence of the material coefficients; convergence of the variables should occur in less than 10 rows. Simpler calculations can be performed by assuming that all material coefficients are calculated at 298 K, but a noticeable difference in the final results will result.

We advise running the spreadsheet for a range of variables that might be encountered in a practical application. For example, designing a system for a maximum specified ambient temperature of 35 °C that goes unstable at 36 °C is not going to be a practical design.

If the spreadsheet calculation seems to crash by generating error outputs to the cells, it is because the values that have been selected for input values are driving the

system into thermal runaway. For a given TEC array selection (geometry factor, number of couples, and number of TECs), this can happen if the heat to be pumped is too high, the thermal resistances (heat sink or load side) are too high, the ambient temperature is too high, or the desired load temperature is too low. In fact, it is good to try to crash the calculation by starting with a configuration that works and then, for example, increasing the thermal resistance at the TEC hot side. In this way, the designer can find out how robust the thermal design is.

Disclaimer

The spreadsheet and all Spin One Technical Notes are provided free of charge and Spin One and the author exclude any and all implied warranties, including warranties of merchantability and fitness for a particular purpose. Further, Spin One assumes no responsibility for results you may obtain in using the spreadsheet or by following the suggestions in said technical notes.