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Including Tolerance in Mathcad Calculations

by Anji Seberino

Sometimes it is necessary to incorporate tolerance into calculations such that the results include maximum, minimum, and nominal values. Often, physical components and device properties do not deliver their exact, nominal values. The sections that follow provide guidance on how to set up a tolerance function in Mathcad and include the defined tolerance in subsequent calculations so that the uncertainty introduced by the component can be considered as part of the design or analysis process. This article demonstrates the concept of using tolerance within Mathcad calculations with a simple RL circuit example.

Setting Up a Tolerance Function

To create a tolerance function, use the +/- operator on the **Custom Characters** toolbar. The function has two arguments. The first argument is the nominal value, and the second argument is the tolerance. This tolerance function creates a 3-element vector, where the second element of the vector stores the nominal value, and the first and third elements store the maximum and minimum values, respectively.

first argument below is the nominal value

second argument below is the tolerance

$$\pm(x, y) := \begin{pmatrix} x + x \cdot y \\ x \\ x - x \cdot y \end{pmatrix}$$

Example: Simple First Order RL Circuit Response

Consider the case of a first order RL circuit.

This circuit has two resistors in parallel with each other, which are also in parallel with a set of parallel inductors. Using the tolerances specified for the components, calculate the equivalent inductance, equivalent resistance, and the voltage drop across the components given an initial current of 12 Amps.

First, define the nominal component values:

$$R_1 := 80\Omega$$

$$R_2 := 120\Omega$$

$$L_1 := 5H$$

$$L_2 := 20H$$

Suppose you are working with 5% resistors and 10% inductors. Redefine the components to include these tolerances so that you have a maximum, minimum, and nominal value for each component. These three values (max, min, nom) are stored in a vector where the first element represents the maximum value, the second element represents the nominal value, and the third element represents the minimum value for the given component.

$$R_1 := \pm(R_1, 5\%) = \begin{pmatrix} 84 \\ 80 \\ 76 \end{pmatrix} \Omega$$

$$R_2 := \pm(R_2, 5\%) = \begin{pmatrix} 126 \\ 120 \\ 114 \end{pmatrix} \Omega$$



$$L_1 := \pm(L_1, 10\%) = \begin{pmatrix} 5.5 \\ 5 \\ 4.5 \end{pmatrix} \text{ H}$$

$$L_2 := \pm(L_2, 10\%) = \begin{pmatrix} 22 \\ 20 \\ 18 \end{pmatrix} \text{ H}$$

Now calculate the equivalent resistance and equivalent inductance including the tolerances you imposed on the components. Just as the components are now represented by 3 element vectors, R_{eq} and L_{eq} will also be 3-element vectors.

$$R_{eq} := \frac{\overrightarrow{R_1 \cdot R_2}}{R_1 + R_2} = \begin{pmatrix} 50.4 \\ 48 \\ 45.6 \end{pmatrix} \Omega$$

$$L_{eq} := \frac{\overrightarrow{L_1 \cdot L_2}}{L_1 + L_2} = \begin{pmatrix} 4.4 \\ 4 \\ 3.6 \end{pmatrix} \text{ H}$$

Next, calculate the voltage drop across R_{eq} and L_{eq} . Because the equivalent resistance can actually assume the high value (max), the low value (min), or any value in between the high and low values, define a range variable to use in the formula for calculating the voltage drop $v(t)$. The range variable is used to define R_{eq} values spanning the tolerance range with a 1Ω step size.

$$R_{eq_min} := R_{eq2,0}$$

$$R_{eq_max} := R_{eq0,0}$$

$$r1 := R_{eq_min} \cdot R_{eq_min} + 1\Omega .. R_{eq_max}$$

Using an initial current of 12 amps, define the current through R_{eq} (and thus also through L_{eq}) as a function of time.

$$I_0 := 12 \text{ A}$$

$$i(t) := I_0 e^{-5t}$$

Multiplying the time-dependent current by the equivalent resistance gives the voltage drop across R_{eq} and L_{eq} . However, you want the voltage calculation to include the tolerances of the resistors, so create a function to do this calculation. The function is dependent on time and resistance because the current is time-dependent and the resistance can vary from the min to the max.

$$v(t, r1) := i(t) \cdot r1$$

See below for plotted results.

Write a function to calculate the maximum, minimum, and nominal voltage drops at a given time. So instead of calculating over the entire resistive range, calculate using the R_{eq} vector.

$$t1 := .005$$

$$\text{voltage_drop} := v(t1, R_{eq}) = \begin{pmatrix} 589.867 \\ 561.779 \\ 533.69 \end{pmatrix} \cdot \text{V}$$