The junction temperature for a module can be calculated by:

$$T_J = P * R_{JC} + T_A \tag{1}$$

T_A and R_{JC} are known variables. Must Calculate P to find T_J.

$$P = P_{Conduction} + P_{Switching} \tag{2}$$

For simplification, $P_{Switching}$ is assumed to be temperature independent and purely a function of bus voltage, current, and switching Frequency. For a given bus voltage and switching frequency, we can assume it's purely a function of current (I) and can be represented as a polynomial:

$$P_{Switching} = F_s(A_s I^2 + B_s I + C_s) \tag{3}$$

This can be scaled by the bus voltage since it is approximately linear such that:

$$P_{Switching}(V) = \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \tag{4}$$

Where V_0 is the bus voltage where the test data was generated.

$$P_{Switching}(V) = \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \tag{5}$$

The polynomial terms A_S, B_S, and C_S contain MOSFET and diode switching components. They should be broken out and scaled based on the type of converter.

$$\begin{aligned} A_S &= D_S A_M + (1 - D_S) A_D \\ B_S &= D_S B_M + (1 - D_S) B_D \\ A_S &= D_S C_M + (1 - D_S) C_D \end{aligned} \tag{6}$$

Where D_S is a scalar that changes based on the type of converter (D_S = 1 for active switch and D_S = 0 in synchronous switch for DC-DC converters and D_S = 0.5 for inverters)

Conduction loss is more difficult to calculate because the on-resistance is a function of temperature (we assume an independent characteristic of on-resistance vs. current level to simplify). The temperature dependent on-resistance can be represented as a polynomial

$$R_{DS-o} \quad = R_{DS-} \quad (25°C)\left(A_R T_J^2 + B_R T_J + C_R\right) \tag{7}$$

The polynomial components can be extracted from the datasheet in a per unit basis, so they must be multiplied by the on-resistance at 25°C. Conduction loss can be then calculated as:

$$P_{Conduction} = I^2 R_{DS-on}(25°C)\left(A_R T_J^2 + B_R T_J + C_R\right) \tag{8}$$

Combining equations (1), (2), (5), and (8) yields

$$T_J = \left\{ I^2 R_{DS-on}(25°C)\left(A_R T_J^2 + B_R T_J + C_R\right) + \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \right\} R_{JC} + T_A$$

Rearrangement of terms:

$$0 = \left\{ I^2 R_{DS-on}(25°C)\left(A_R T_J^2 + B_R T_J + C_R\right) + \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \right\} R_{JC} + T_A - T_J$$

$$0 = \{I^2 R_{DS-on}(25°) A_R R_{JC}\} T_J^2 + \{I^2 R_{DS-on}(25°) B_R R_{JC} - 1\} T_J$$
$$+ \left\{ I^2 R_{DS-o} \ (25°) C_R + \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \right\} R_{JC} + T_A$$

We can now see this lines up with the quadratic formula so we assign variables

$$A_J = \{I^2 R_{DS-on}(25°) A_R R_{JC}\}$$
$$B_J = \{I^2 R_{DS-} \ (25°) B_R R_{JC} - 1\}$$
$$C_J = \left\{ I^2 R_{DS-on}(25°) C_R + \frac{V}{V_o} F_s(A_s I^2 + B_s I + C_s) \right\} R_{JC} + T_A$$

Solve for Tj using quadratic formula

$$T_J = \frac{-B_J \pm \sqrt{B_J^2 - 4 A_J C_J}}{2 A_J}$$

This will calculate the direct junction temperature for a given Current.