

Normalized Transient Thermal Impedance (Z_{th}) Using T_C Reference Point Under Chip For 600V and 1200V A, NF, NFH and S-Series IGBT Modules

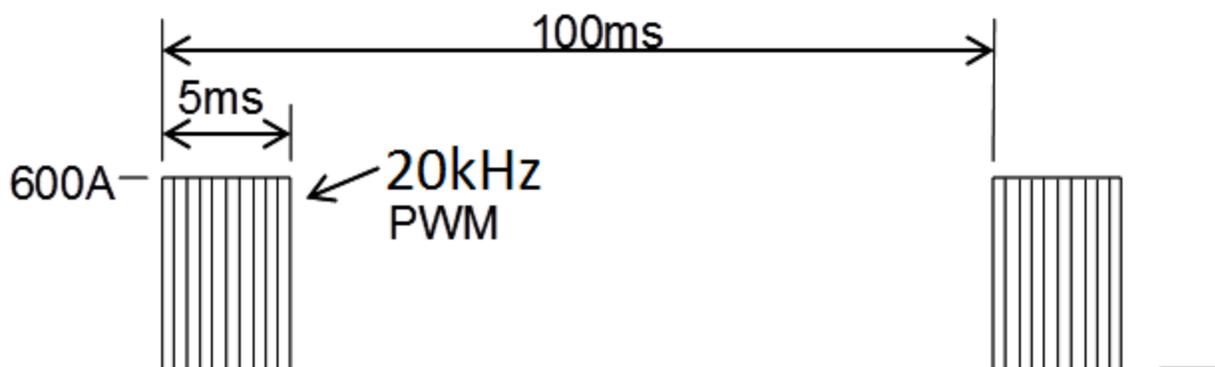
Introduction:

One of the ways to determine if a certain power semiconductor device can be used for a given application is to verify that the device's maximum allowable junction temperature is not exceeded. The MELCO Average Loss Simulation Software provides a means of estimating the average junction temperature. This kind of calculation is useful for most applications where the run time is long (seconds or more) and the switching frequency remains high.

However, in pulse power applications the MELCO simulator's average junction temperature calculation is really overestimated because it assumes a constant condition. In order to adequately estimate the junction temperature in such applications the transient thermal impedance curve or the accompanying equation must be used. Please note that this curve is normalized to a unit value. The curves shown in the appendix apply to most A, NF and NFH series IGBT modules. The following example shows how the transient thermal impedance (Z_{th}) curve and equation can be used. Please check your datasheet against the curves in the appendix to ensure that you use the right coefficients.

Example:

A Laser power source needs to produce tightly regulated 600A, 5ms pulses at a 10Hz rate. 20 kHz switching is needed to regulate the current. The maximum PWM duty is limited to 50%. Circuit topology is a



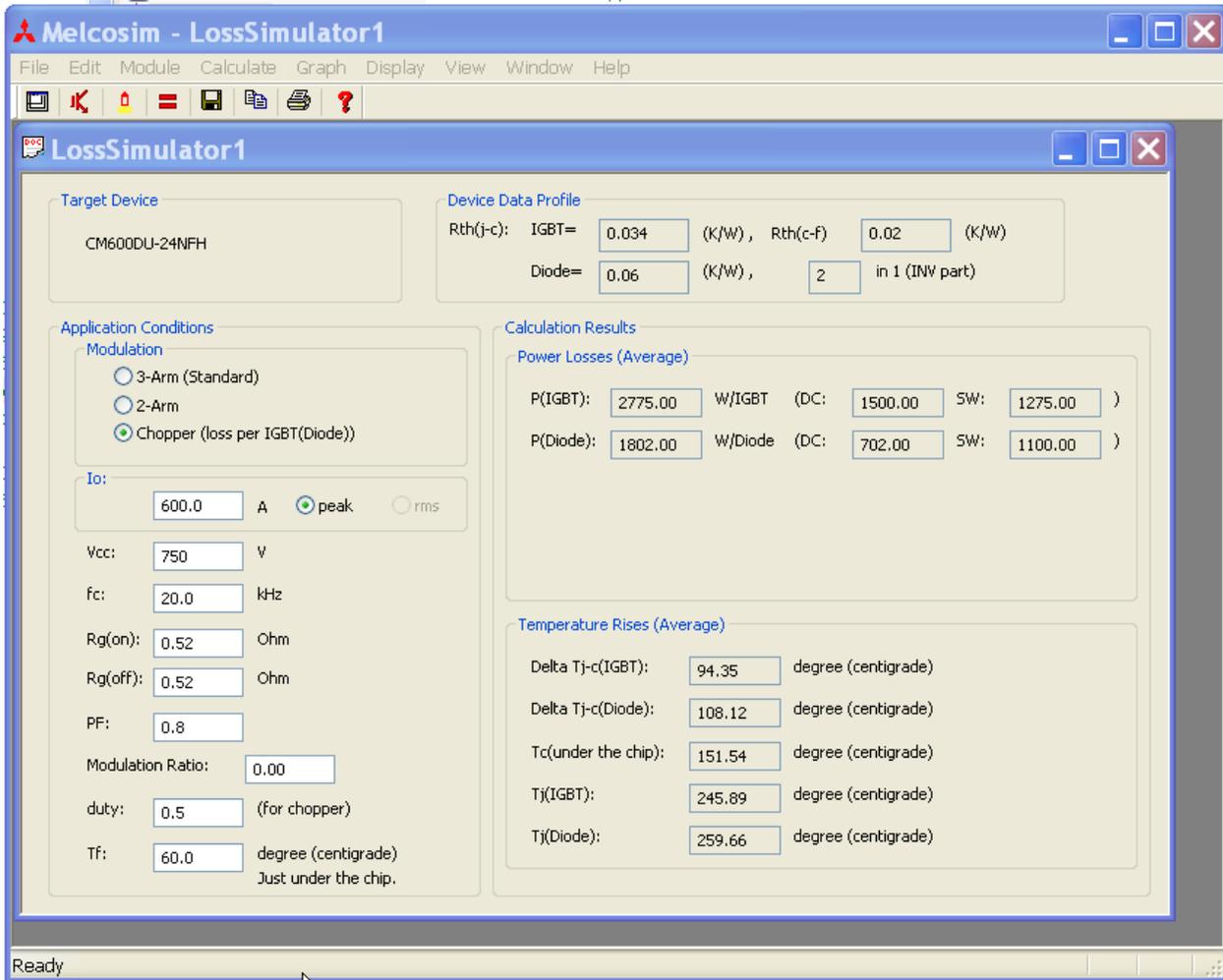
$$Z_{th} = R_1 \left(1 - e^{-\frac{t}{T_1}}\right) + R_2 \left(1 - e^{-\frac{t}{T_2}}\right) + R_3 \left(1 - e^{-\frac{t}{T_3}}\right) + R_4 \left(1 - e^{-\frac{t}{T_4}}\right)$$

$$Z_{th(j-c)}' = R_{th(j-c)}' \times Z_{th}$$

$R_{th(j-c)}'$ is the IGBT module's under-chip thermal resistance value.

basic low side chopper. Source Voltage is 750VDC.

It seems like a good choice for this kind of operation would be a 600A, 1200V high frequency IGBT module, the CM600DU-24NFH. When we run the MELCO simulator for this mode of operation it tells us that the power loss per IGBT is 2275W which is correct for the period $t_0 < t_1$.



It also tells us that the change in temperature from junction to case will be 94°C and that for a 60°C heatsink temperature the junction of the IGBT chip will be 246°C which is well beyond the maximum rating. However the Delta Tj-c(IGBT) from the MELCO simulator is for a steady state condition. From looking at the transient thermal impedance curve it can be seen that in a 5ms period the thermal impedance of the baseplate has not reached a steady state value (This occurs sometime between 0.1 and 0.2s). In order to determine the peak junction temperature after a 5ms pulse we must determine the thermal impedance at this time by either picking this point from the Zth curve or calculating it using the Zth equation.

The equation that describes the temperature rise during time $t_0 < t_1$ is:

$$\Delta T_j = P \times Z_{th}(t) \times R_{th}(j - c)'$$

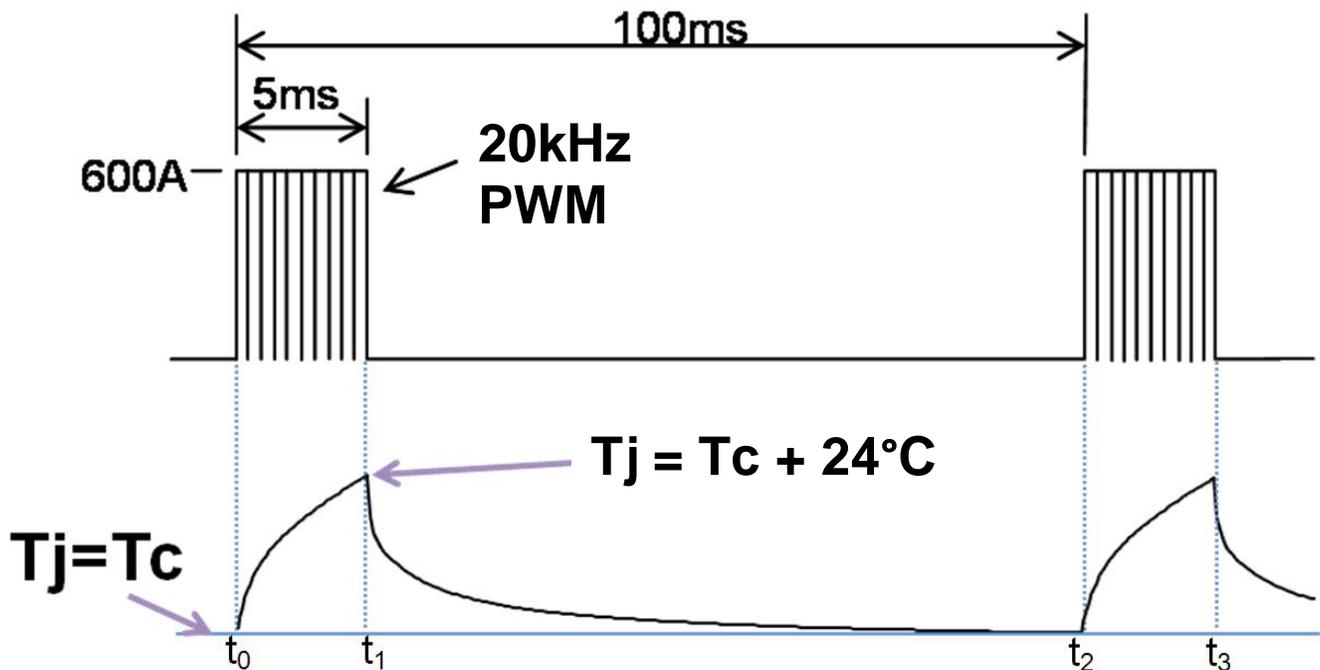
In this equation P is the power loss, Zth(t) is the transient thermal impedance at time t and Rth(j-c)' is the IGBT module's under chip thermal resistance and can be found on the device datasheet. Using the equation we come up with Zth(5ms) = 0.31. Rth(j-c)' for the IGBT is 0.034°C/W so the Zth(j-c)' for the module at 5ms is 0.01054°C/W.

Now when we multiply the 2275W power loss by 0.01054°C/W we see that the junction temperature rise after 5ms is (2275*0.01054)°C or 24°C.

At the end of the 100ms period the junction temperature has cooled back down to the device's case temperature. This can be verified by considering the equation that describes the transient cooling during time $t_1 < t_2$:

$$\Delta T_j = P \times [Z_{th}(t) - Z_{th}(t - t_1)]$$

If we now plug $t = 100\text{ms}$, $t_1 = 5\text{ms}$ and $P = 2275\text{W}$ into the above equation we can see that ΔT_j effectively becomes zero and so the chip junction temperature has returned to the case temperature of the device as represented in the complete heating cycle shown below.



As a good design practice we want to limit the junction temperature to 125°C. In this situation the case temperature should be limited to, $T_c = 125 - \Delta T_j$ or about 100°C.

For any questions on applying these equations or for other power dissipation profiles please contact Powerex application engineering at (724)-925-7272.

Appendix

Transient thermal curve #1:

