Exercise 4- Solution

1- At first, we have to figure out the amount of losses for each one of the switches. Calculate IGBT Energy per pulse Figure 3 upholds when V_{ge} = ±15 and R_g = 3.8 Ω, However, voltage is 560 V not 600 V. Using linear scaling for pulse energy E_{on} = 14 mJ * 560 V / 600 V = 13 mJ

E_{off} = 21 mJ * 560 V / 600 V = 20 mJ

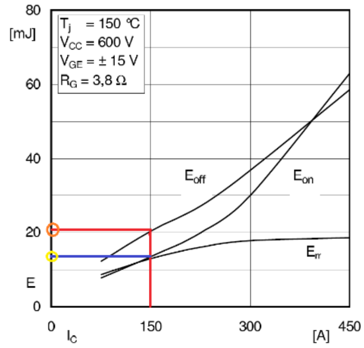


Fig. 3: Typ. turn-on /-off energy = f (I_C)

Conduction losses can be calculated using figure 1 voltage. Uce = 2.0 V, when Ic = 150 V, Vge = 15 and Tj = 150 C.

or using numerical values in the datasheet

Uce = U_{ce0} + r_{ce} * I_c = 0.98 V + 7 mΩ * 150 A = 2.03 V

Therefore, E_{cond} = U_{ce} * I_c * t_{on} = 2.0 V * 150 V * 0.6 ms = 180 mJ

Switching time < 1 us while conduction time is 0.6 ms, therefore we may disregard conducting operation during dead time. IGBT loss power is:

P_{IGBT} = f * (E_{on} + E_{off} + E_{cond})= 1000 Hz * (13 mJ + 20 mJ + 180 mJ) = 213 W

<u>Diode Losses</u>

Also diode reverse recovery causes switching losses, which are also depicted in figure 3. Again lets use linear voltage scaling E_{rr} = 13 mJ * 560 V / 600 V = 12 mJ.

Voltage for 150 A I_{rr} is given in figure 10. U_F = 1.9 V, when Tj = 150 C.

Or numerical values, U_F = U_{F0} + r_F * I_f = 1.1 V + 5.9 mΩ * 150 A= 1.99 V

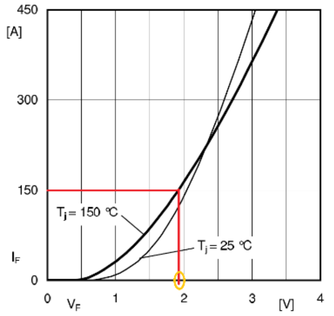
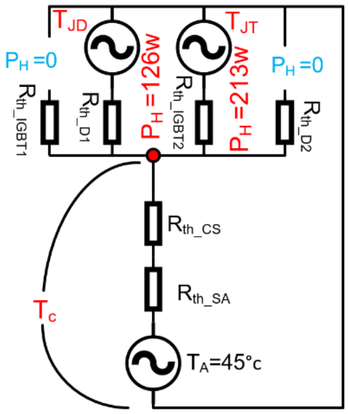


Fig. 10: Typ. CAL diode forward charact., incl. $R_{CC'+EE'}$

Therefore conduction energy is E_{cond_D} = 1.9 V * 150 A * 0.4 ms = 114 mJ

and average losses P_{HD} = f * (E_{rr} + E_{cond_D}) = 1000 Hz * (12 mJ + 114 mJ) = 126 W

Module thermal equivalent circuit when frequency is 1 kHz, as in. The thermal circuit is constant during switching action.



Maximum thermal resistances for the junction to case and case to sink are given:

R_{th_IGBT}=0.14 k/w R_{th_D}=0.23 k/w R_{th_cs}=0.04 k/w

Therefore:

$T_c=(P_{H\_IGBT2}+P_{H\_D1})x(R_{th\_cs}+R_{th\_sA})+T_A=(213+126)x(0.04+0.08)+45°c=86°c$

$T_{J\_IGBT2}=P_{H\_IGBT2}xR_{th\_IGBT2}+T_c=213x0.14+86°c=116°c$

$T_{J\_D1}=P_{H\_D1}xR_{th\_D1}+T_c=126x0.23+86°c=115°c$

2- According to the given datasheet, we are not able to find the absolute values of I_{rr} and t_{rr} at the given operating point and we need more detailed data. Nevertheless, we can define a boundary for them by considering the maximum values.

Figure 11 gives the I_{rr} of around 210 A, when Gate resistor is 3,8 Ω.

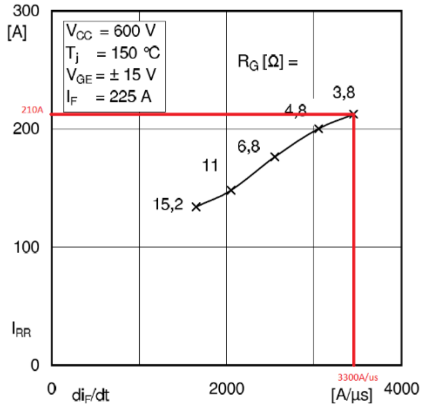


Fig. 11: Typ. CAL diode peak reverse recovery current

Figure 12 gives 3,8 Ω R_g and 150 A Ic, di/dt value of around 3300 A/us

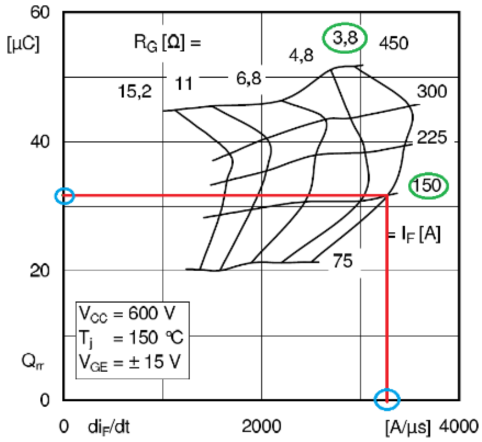


Fig. 12: Typ. CAL diode recovery charge

Reverse recovery equation is $Q_{rr} = I_{rr} * t_{rr} / 2$

then t_{rr}=2*32uc/210A=0.3us