ELEC-E8421 Components of Power Electronics **Exam 8.12.2020**

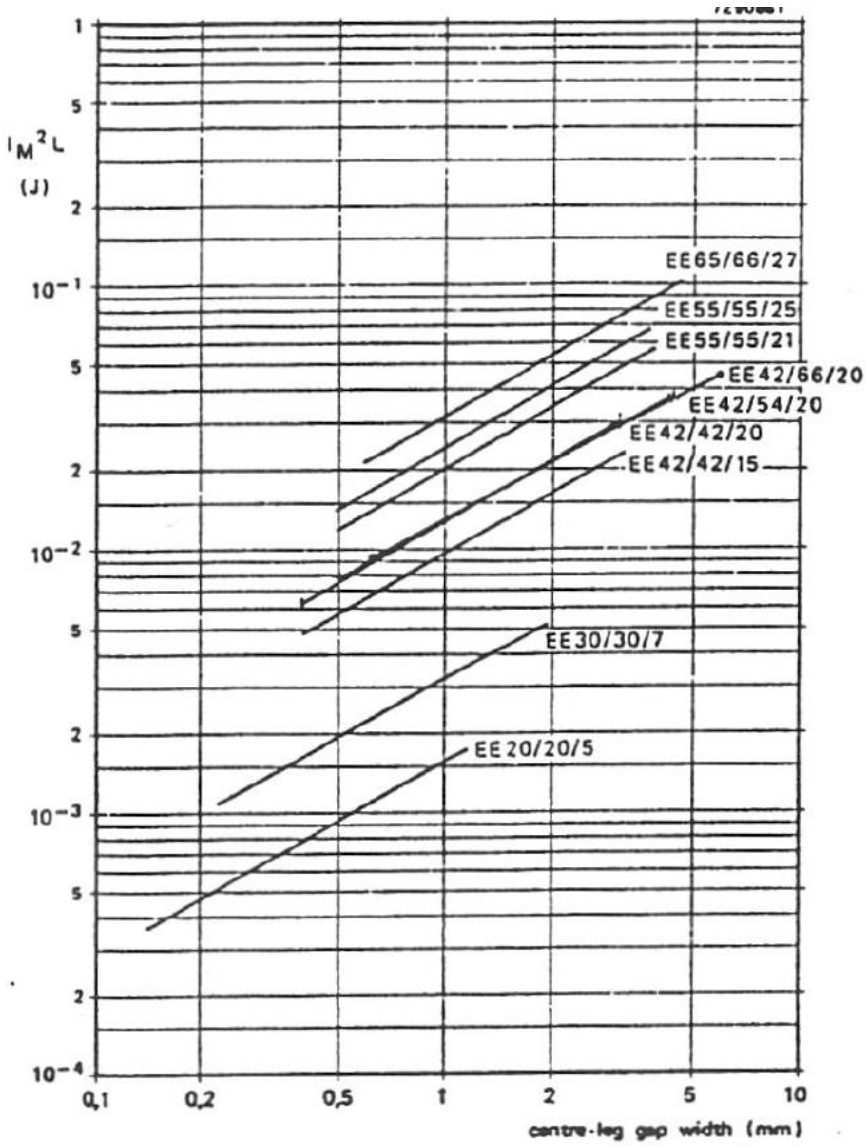
1. Explain shortly (2...4 sentences + possible drawing), what the following terms mean
   - Miller effect
   - Reverse recovery charge
   - SOA
   - Prospective short-circuit current
   - ESR.

2. Describe the construction, functioning principle and properties of IGBT.

3. Discuss filters used for the filtering of EMC, their operating principles and components used.

4. A dc-dc converter has a Mosfet dissipating 40 W and a freewheeling diode dissipating 24 W. Both devices and mounted on a common heatsink. The Mosfet junction-to-case thermal resistance is 0,7 K/W and case-to-heatsink resistance 0,5 K/W. For the diode the same values are 0,8 K/W and 0,6 K/W respectively. Calculate the maximum heatsink thermal resistance so that for both devices junction temperatures are below 90ºC when ambient temperature is 30 ºC.

5. DC current is filtered with an inductor made from two E55/28/21 half creating E55/55/21. Average current is 44 A and peak-to-peak variation 2,5 A. The needed inductance is at least 15 µH. Calculate the turns number and length of air gap by using the attached graph and datasheet. Also, calculate the maximum flux density.



$I_M{}^2L$ (J)
1
5
2
10^{-1}
5
2
10^{-2}
5
2
10^{-3}
5
2
10^{-4}
0,1
0,2
0,5
1
2
5
10
centre-leg gap width (mm)
EE65/66/27
EE55/55/25
EE55/55/21
EE42/66/20
EE42/54/20
EE42/42/20
EE42/42/15
EE30/30/7
EE20/20/5

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Proposed answers

Q1 and Q2, see textbook and slides

Q3, see slides and the extra material

Q4

Thesolution from Page 120 of the textbook is adapted here and calculated with the numerical values of the question.

When the diode losses are replaced from 20 W to 24 W the first temperatures are 33,6 ºC and 48 ºC. As Mosfet losses and temperature are higher, the same heat sink surface temperature as below, i.e. 42 ºC. The diode junction temperature will be 42 ºC + 28 ºC = 70 ºC . The heatsink thermal resistance should be then 12 ºC / (40+24)W = 0,19 K/W

Solution

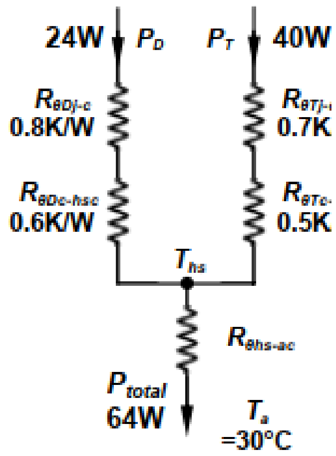
i. Applying Kirchhoff's voltage law to each loop of the equivalent thermal circuit shown gives:

$$T_{Dj} - T_{hs} = 20\text{W} \times (0.8\text{K/W} + 0.6\text{K/W}) = 28°\text{C}$$

$$T_{Tj} - T_{hs} = 40\text{W} \times (0.7\text{K/W} + 0.5\text{K/W}) = 48°\text{C}$$

Since both semiconductor devices are mounted on the same heatsink, T_{hs} is the same in each case, the MOSFET virtual junction will operate 20°C hotter than the diode junction. Therefore the MOSFET junction temperature should not exceed 90°C, that is

$$90°\text{C} - T_{hs} = 40\text{W} \times (0.7\text{K/W} + 0.5\text{K/W}) = 48°\text{C}$$



giving a heat sink surface temperature of 90°C - 48°C = 42°C and a diode juncti temperature of 42°C + 28°C = 70°C. The heatsink thermal resistance requirement is

$$T_{hs} - T_a = 42°\text{C} - 30°\text{C} = R_{\theta hs-a} \times (40\text{W} + 24\text{W})$$

$$R_{\theta hs-a} = {}^{42°\text{C} - 30°\text{C}}\!/_{40\text{W} + 24\text{W}} = {}^{12°\text{C}}\!/_{64\text{W}} = 0.19\text{K/W}$$

Q5

The peak value of the inductor current is 44 A + 0,5 *2,5 A = 45,25 A

The needed I^2L value is 45,25 A*45,25 A*15 µH = 0,0307 VAs and from the graph of the core we get appromaxtely for the airgap 1,75 mm. It is not a standard value and the next suitable is 2 mm. For that A_L = 292 nH and using

$$L \approx \frac{\mu_0 N^2}{\frac{l_g}{A_g} + \frac{C_1}{\mu}} = \frac{\mu_0 \mu_e N^2 A_e}{l_e} = A_L N^2$$

we achieve the number of turns 7,1673 => 8. With this value the inductance is $L = A_L N^2$ = 18,69 nH. Maximum flux density is calculated from

$B = \Phi/A_e = LI/(NA_e)$ = 18,69 nH*45,25 A/8/0,000354 m^2 = 298,6 mT

This is well below the maximum flux density 320 mT of the core and therefore it should not saturate.