ELEC-E8421 - Power Electronics Components
Exercise 1 - Solutions

September 13, 2020

1 Diodes to be considered

1.a Bolt Type

IR: 130 HF 120 PV (1200 V, 130 A @ $T_C = 125$ °C)

But, following parts should also be considered
85 HF 120 (1200 V, 85 A @ $T_C = 140$ °C)
88 HF 120 (1200 V, 85 A @ $T_C = 140$ °C)
Given that T_C can be cooled under 140 °C, thus increasing maximum I_{FAV}

1.b Modules

IR: T85HF120 (1200 V, 85 A @ $T_C = 85$ °C)
T85HF120 (1200 V, 85 A @ $T_C = 85$ °C)

IRKD 91/12 etc. (1200 V, 100 A @ $T_C = 100$ °C)

SEMIKRON: SKKD 100 (400 .. 1800 V, 100 A @ $T_C = 85$ °C)
(SKMD 100 same, but module has differrent internal connections)

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Datasheet constains parit of figure: Fig.1L & Fig.1R
using these two figures constant current I_D can be directly determined.
In Fig.1R there is a parameter $R_{th(c-a)}$ meaning thermal resistance from case to heatsink surface.

$$R_{th(c-a)} = R_{th(c-s)} + R_{th(s-a)}$$

This datasheet gives numeric values
$R_{th(c-s)} = 0.15$ K/W and exercise paper gives $R_{th(s-a)} = 5$ K/W.
Therefore $R_{th(c-a)} = 5.15$ K/W
Fig. 1R shows that reading around 5.15 K/W and 65 °C is difficult due to unlinear behaviour. Therefore to be sure we should read the values from C-curve when $R_{th(c-a)} = 3$, 4, 6 & 8 K/W. (C-curve corresponds to capacitive DC-filtering).

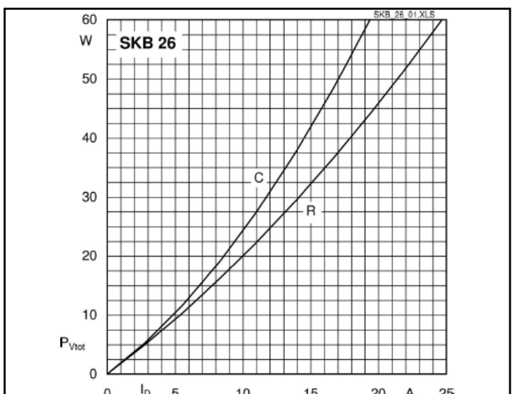

Fig. 1L Power dissipation vs. output current

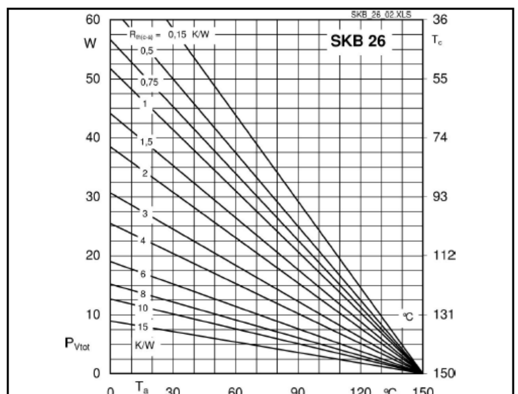

Fig. 1R Power dissipation vs. case temperature

$R_{th(c-a)}$	I_D / A
3	7.7
4	6.7
6	5.2
8	4.3

This is then plotted and interpolated. In exams direct reading from the graph is also allowed.

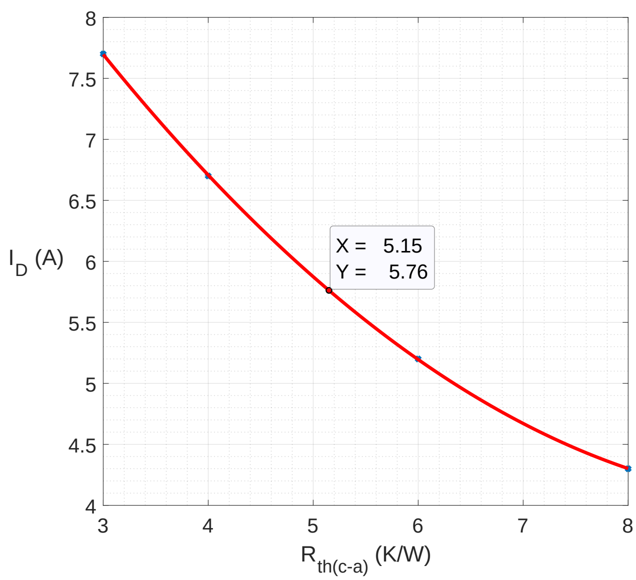

Figure 1: From the curve: $I_D \approx 5.8$ A

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3.a

Circuit differential equation:

$$E = L\frac{di}{dt}$$
$$\frac{di}{dt} = \frac{E}{L} = \frac{1500\text{ V}}{10\ \mu\text{H}} = 150\frac{A}{\mu s}$$

From datasheet figure 7 we get $I_{RRM} \approx 255$ A Figure 8 curves gives $Q_{RR} = 495\ \mu$C Book equation (3.13):

$$t_{RR} = \frac{2Q_{RR}}{I_{RRM}} = \frac{2 \cdot 495\ \mu As}{255\ A} \approx 3.88\ \mu s$$

3.b

When reverse recovery current switches off, voltage is seen over the inductor

$$U_L = L\frac{di}{dt}$$

Book equation (3.11) gives recovery delay t_A

$$t_A = \frac{I_{RRM}}{di/dt} = \frac{255\ A}{150\ A/\mu s} \approx 1.7\ \mu s$$

$t_{RR} = t_A + t_B$, so damping time

$$t_B = t_{RR} - t_A = 3.88\ \mu s - 1.7\ \mu s \approx 2.18\ \mu s$$

Book equation (3.2)

$$\frac{di}{dt} = \frac{I_{RRM}}{t_B} = \frac{255\ A}{2.18\ \mu s} \approx 117\ \text{A}/\mu s$$

Therefore the voltage over inductor during transition

$$U_L = \frac{di}{dt} \cdot L = 117\ \text{A}/\mu s \cdot 10\ \mu H = 1170\ V$$

Diode voltage stress is then

$$U_{max} = E + U_L = 1500\ V + 1170\ V = 2670\ V$$

As can be seen from the datasheet, the diode 5SDF05D2505 blocking voltage rating a measly 2500 V, so it is possible that the diode is destroyed from overvoltage.

Note, that datasheet gives $U_{DC} = 1500$ V is the voltage rating for stready state blocking voltage due to cosmic radiation caused avalanche breakdown

Not only for over voltage, but also for limiting the voltage du/dt a protection is needed. For example a GTO tyriston next to the diode might not be able to handle as high of a du/dt values as the diode. Manufacturers assumes typical protection snubber capactior to be 2 µF. Protection snubber also limits the radio interferences.