EE4001 Quiz 2: Power Electronics

Name: **Student Number:**

1. What are the *disadvantages* of switch-mode power electronics amplifiers compared to linear amplifiers?

Harmonics → noise → EMI

Lower bandwidth

2. Express the Pole A duty ratio, d_A, in terms of the control voltage, $v_{c,A}$ and the peak of the triangular voltage, $\hat{V}_{tri}$.

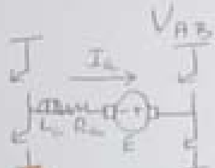
$$d_A = \frac{1}{2} + \frac{1}{2} \cdot \frac{v_{c,A}}{\hat{V}_{tri}}$$

3. In a two-quadrant single-pole converter of dc bus voltage V_d=100V, fed by a **generator** of back emf E_a=45V and armature resistance R_a=0.25 Ω, calculate the output pole voltage V_{AN} and the duty ratio d_A when pulling an armature current I_a=20A.

$$V_{AN} = E - I_a R_a = (45 - 5)\,V = 40\,V$$

$$d = \frac{40}{100} = 0.4$$

4. In a four-quadrant two-pole converter of dc bus voltage V_d=100V, supplied by a **generator** of back emf E_a=-75V (spinning in reverse) and armature resistance R_a=0.5 Ω, calculate the output pole voltage V_{AB} and the duty ratio d when pulling an armature current I_a=10A.



$$V_{AB} = E - I_a R_a = -75V - (-10A)(5\Omega) = -70V$$

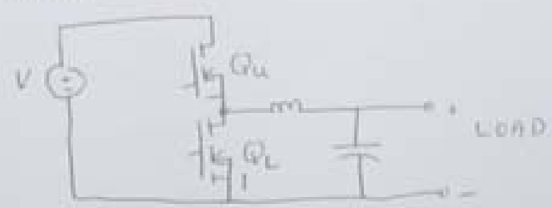
$$d = \left| \frac{70}{100} \right| = -0.7$$

5. Calculate the peak-peak armature current ripple in the above generating question when armature inductance L_a=1mH and the triangular frequency f_s=10 kHz?

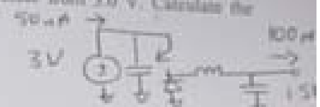
$$\Delta I_{p\text{-}p} = \frac{V_d - (\overset{-V_{AB}}{\cancel{E}})}{L}\, d\, \frac{T_s}{2}$$

$$= \frac{(100 - 75)\,V}{1\,mH}\; 0.7 \cdot \frac{1\times10^{-4}\,s}{2} = 1.05\ A_{p\text{-}p}$$

6. Sketch a synchronous buck converter.



7. A buck converter, switching at 1 MHz, powers a 1.5 V, 100 mA microprocessor from 3.0 V. Calculate the inductance required to limit the current ripple to +/- 10 %.



$$d = \frac{V_o}{V_{IN}} = 0.5$$

$$V_L = L \frac{\Delta I_L}{\Delta t}$$

$$L = \frac{V_L \, \Delta t}{\Delta I_L} = \frac{(3-1.5) \cdot 0.5 \cdot 1\times10^{-6}}{0.2 \cdot 100\times10^{-3}} = 37.5\,\mu H$$

8. Calculate the capacitance required in the above converter to reduce the output voltage ripple to +/- 20 mV.

$$C = \frac{1}{2} \cdot \frac{T_s}{2} \cdot \frac{\Delta I}{2} \cdot \frac{1}{\Delta V}$$

$$= \frac{1}{2} \cdot \frac{1\times10^{-6}}{2} \cdot \frac{0.2\times100\times10^{-3}}{2} \cdot \frac{1}{40\times10^{-3}} = 62.5\ nF$$

9. What are the peak and rms currents in the above inductor?

$$\Delta I_{p\text{-}p} = \cancel{0.2} \; 20\,mA$$

$$I_{pk} = I_o + \frac{\Delta I_{p\text{-}p}}{2} = 110\,mA \ (pk)$$

$$I_{L,rms} = \sqrt{I_o^2 + \left(\frac{\Delta I_{p\text{-}p}}{\sqrt{12}}\right)^2} = \sqrt{0.1^2 + \left(\frac{0.02}{\sqrt{12}}\right)^2} \simeq 100\ mA\ (rms)$$

10. What are the rms currents in the controlled switched and the input capacitor on the 3V dc bus?

$$I_{Q_{U},rms} = \sqrt{d}\; I_{L,rms} = \sqrt{0.5}\; 100\,mA = 70.7\ mA\ (rms)$$

$$I_{C_I} = \sqrt{I_{Q_U,rms}^2 - (I_{I,DC})^2} = \sqrt{(70.7\,mA)^2 - (50\,mA)^2} = 50\ mA\ (rms)$$

11. A three-phase sinusoidal PWM inverter is required to output 400 V line-line. What is the minimum dc bus voltage required?

$$V_{LL} = 400\ V_{RMS}$$

$$V_{ph} = \frac{V_{LL}}{\sqrt{3}} = 231\ V_{rms}$$

$$V_{dc} = \sqrt{2} \times V_{ph} \times 2 = 653\ V_{dc}$$

12. A sinusoidal PWM full bridge inverter is required to output single phase 100 V in Japan. What is the minimum dc bus voltage required?

$$V_{ph} = 100\ V_{rms}$$

$$V_{dc} = \sqrt{2} \cdot V_{ph} = 141\ V_{dc}$$