Ministry of Higher Education & Scientific Research
University of Technology
Laser & Optoelectronic Eng. Department
Branch: Laser Engineering.
Class: 3rd Year
Subject: Power Electronics

Final Examinations
Time: Three Hours
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Examiner: Lect. Wail Yas Nassir
Code: LE3305
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Attempt Five Questions Only

Q1: The single-phase half-wave rectifier with $R=10\Omega$ and $L = 100$ mH. The rectifier is supplied from a voltage source has value of 220V, 50Hz. Derive and Calculate:
a) Average and rms voltage, b) Rectification efficiency,
c) Ripple factor and form factor, [10 Marks]

Q2: Design three-stage voltage multiplier supplied from the transformer with secondary voltage equal to 1KV at 1kHz and its average output voltage 3kV and output current equal to 3mA. Then calculate voltage drop and ripple voltage [10 Marks]

Q3: The single-phase half wave rectifier has a purely resistive load and the delay angle is $\alpha = \pi/3$, derive and calculate:
a) Average and rms voltage, b) Rectification efficiency,
c) Ripple factor and form factor, [10 Marks]

Q4: A three-phase full wave rectifier has a purely resistive load of R. The rectifier output voltage of $V_{dc} = 460$V and the source frequency is 60 Hz. Determine
a. The efficiency b. The form factor c. The ripple factor
d. The peak inverse voltage of each diode [10 Marks]

Q5: (A) Derive the total power loss in the transistor. [6 Marks]
(B) What is a freewheeling diode? [4 Marks]

Q6: Design the single-phase bridge controlled rectifier has an inductive load supplied from a voltage source has value of 220V and the average output voltage varied from 160V to 180V. Calculate efficiency and ripple factor
Note: Drive any formula that used in solution [10 Marks]

Good luck

الثالث

الكترونيك القدرة ٢٦ طالب - واحد غياب

Q1: The single-phase half-wave rectifier with R=10Ω and L = 100 mH. The rectifier is supplied from a voltage source has value of 220V, 50Hz. Derive and Calculate:

a) Average and rms voltage, b) Rectification efficiency,

c) Ripple factor and form factor, [10 Marks]

Sol. $\boldsymbol{Vm = \sqrt{2} * 220 = 311V}$

$$\boldsymbol{tan\varphi = \frac{wL}{R} = \frac{2\pi fL}{R} = \frac{2 * 3.14 * 50 * 0.1}{10} = 72^o}$$

$$\boldsymbol{\beta = 180 + \varphi = 252^o}$$

$$\boldsymbol{V_{dc} = \frac{1}{2\pi}\int_0^\beta Vm \cdot sinwt \cdot dt = \frac{Vm}{2\pi}(-coswt) = \frac{Vm}{2\pi}(1 + 0.3)}$$

$$\boldsymbol{Vdc = \frac{311 * 1.3}{6.28} = 64.38V}$$

$$\boldsymbol{V_L = \sqrt{\frac{1}{2\pi}\int_0^\beta V_m^2 \cdot sin^2(wt) \cdot dt} = \sqrt{\frac{V_m^2}{4\pi}\left(\beta - \frac{sin2\beta}{2}\right)}}$$

$$\boldsymbol{V_L = \frac{Vm}{2}\sqrt{\left(\frac{2\beta - sin2\beta}{2\pi}\right)} = \frac{311}{2}\sqrt{\left(\frac{4.4 + 0.59}{6.28}\right)} = 138.58V}$$

$$\boldsymbol{FF = \frac{V_L}{V_{dc}} = \pi\sqrt{\left(\frac{2\beta - sin2\beta}{2\pi(1 - cos\beta)^2}\right)} = 2.15}$$

$$\boldsymbol{RF = \sqrt{FF^2 - 1} = 1.9}$$

Q2: Design three-stage voltage multiplier supplied from the transformer with secondary voltage equal to 1KV at 1kHz and its average output voltage 3kV and output current equal to 3mA. Then calculate voltage drop and ripple voltage

[10 Marks]

Sol. $V_o = V_{no-load} - \Delta V - \delta V$

$$V_{no-load} = 2 * n * V_{max} = 2 * 3 * 1 = 6KV$$

$$\Delta V = \frac{I}{fC}\left(\frac{2n^3}{3} + \frac{n^2}{9} - \frac{n}{6}\right) = 22\frac{I}{fC}$$

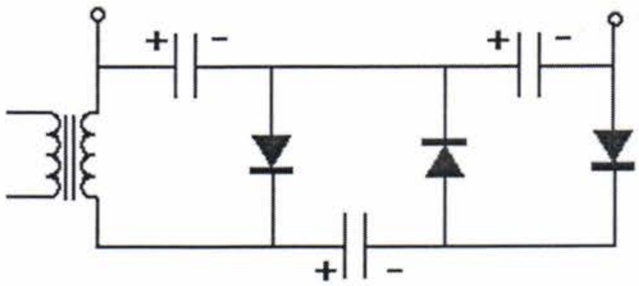
$$\delta V = \frac{I}{fC} \cdot \frac{n(n+1)}{4} = 3\frac{I}{fC}$$

$$V_o = 6 - \frac{3 * I}{fC} - \frac{22 * I}{fC} \quad => \quad 3 = 6 - \frac{25 * I}{fC}$$

$$C = \frac{25 * I}{3 * f} = 25\mu F$$

$$\Delta V = 22\frac{I}{fC} = \frac{66}{25} = 2.64KV$$

$$\delta V = 3\frac{I}{fC} = \frac{9}{25} = 360V$$



Q3: The single-phase half wave rectifier has a purely resistive load and the delay angle is $\alpha = \pi/3$, derive and calculate:

a) Average and rms voltage,

b) Rectification efficiency,

c) Ripple factor and form factor,

[10 Marks]

Sol.

$$V_{dc} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \cdot sinwt \cdot dt = \frac{V_m}{2\pi}(1 + cos\alpha) = \frac{V_m}{2\pi}(1 + 0.5)$$

$$Vdc = \frac{1.5}{6.28} = 0.239V_m$$

$$V_L = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi} V_m^2 \cdot sin^2(wt) \cdot dt} = \frac{Vm}{\sqrt{2\pi}}\sqrt{\left(\frac{\pi - \alpha}{2} - \frac{sin2(\pi - \alpha)}{4}\right)}$$

$$\eta = \frac{V_{dc}^2}{V_L^2} = \frac{(1 + cos\alpha)^2}{2\pi\left(\frac{\pi - \alpha}{2} - \frac{sin2(\pi - \alpha)}{4}\right)}$$

$$FF = \frac{V_L}{V_{dc}} = \frac{\sqrt{2\pi}\sqrt{\left(\frac{\pi - \alpha}{2} - \frac{sin2(\pi - \alpha)}{4}\right)}}{(1 + cos\alpha)}$$

$$RF = \sqrt{FF^2 - 1}$$

Q4: A three-phase full wave rectifier has a purely resistive load of R. The rectifier output voltage of Vdc = 460V and the source frequency is 60 Hz. Determine

a. The efficiency b. The form factor c. The ripple factor

d. The peak inverse voltage of each diode [10 Marks]

Sol.

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi} = 1.654V_m$$

$$V_m = 278V$$

$$V_L = V_m\sqrt{\left(\frac{3}{2} - \frac{9\sqrt{3}}{4\pi}\right)} = 1.655V_m$$

$$\eta = \frac{V_{dc}^2}{V_L^2} = \left(\frac{1.654V_m}{1.655V_m}\right)^2 = 99.85\%$$

$$FF = \frac{V_L}{V_{dc}} = \frac{1.655V_m}{1.654V_m} = 1.0008$$

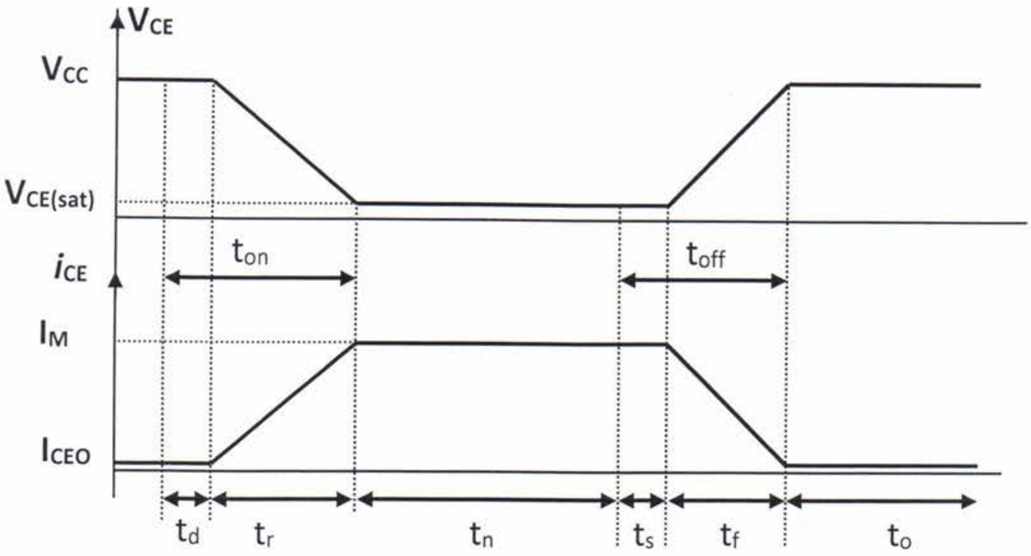
$$RF = \sqrt{FF^2 - 1} = 4\%$$

$$PIV = \sqrt{3}V_m = 480V$$

Q5: (A) Derive the total power loss in the transistor. [6 Marks]

(B) What is a freewheeling diode? [4 Marks]

Sol. A:



During delay time, *iC(t) = ICEO* *VCE(t) = VCC*

$$P_d = \frac{1}{T}\int_0^{t_d} Pd(t)dt = I_{CEO}V_{CC}t_d f_s$$

During rise time

$$i_C(t) = \frac{I_M}{t_r}t \qquad V_{CE}(t) = V_{CC} + \left(V_{CE(sat)} - V_{CC}\right)\frac{t}{t_r}$$

$$P_r = \frac{1}{T}\int_0^{t_r} I_M \frac{t}{t_r}\left[V_{CC} + \left(V_{CE(sat)} - V_{CC}\right)\frac{t}{t_r}\right]$$

During Conduction period, *iC(t) = IM* *VCE(t) = VCE(sat)*

$$P_n = \frac{1}{T}\int_0^{t_n} P_n(t)dt = I_M V_{CE(sat)} t_n f_s$$

During storage period, *iC(t) = IM* *VCE(t) = VCE(sat)*

$$P_s = \frac{1}{T}\int_0^{t_s} P_s(t)dt = I_M V_{CE(sat)} t_s f_s$$

During fall period,

$$i_C(t) = I_M\left(1 - \frac{t}{t_f}\right) \quad V_{CE}(t) = V_{CC}\frac{t}{t_f}$$

$$P_f = \frac{1}{T}\int_0^{t_f} P_f(t)dt = \frac{V_{CC} I_M t_f f_s}{6}$$

During off-period, *iC(t) = ICEO* *VCE(t) = VCC*

$$P_o = \frac{1}{T}\int_0^{t_o} P_o(t)dt = I_{CEO}V_{CC}t_o f_s$$

∴ *The total power loss in the transistor due to collector current is:*

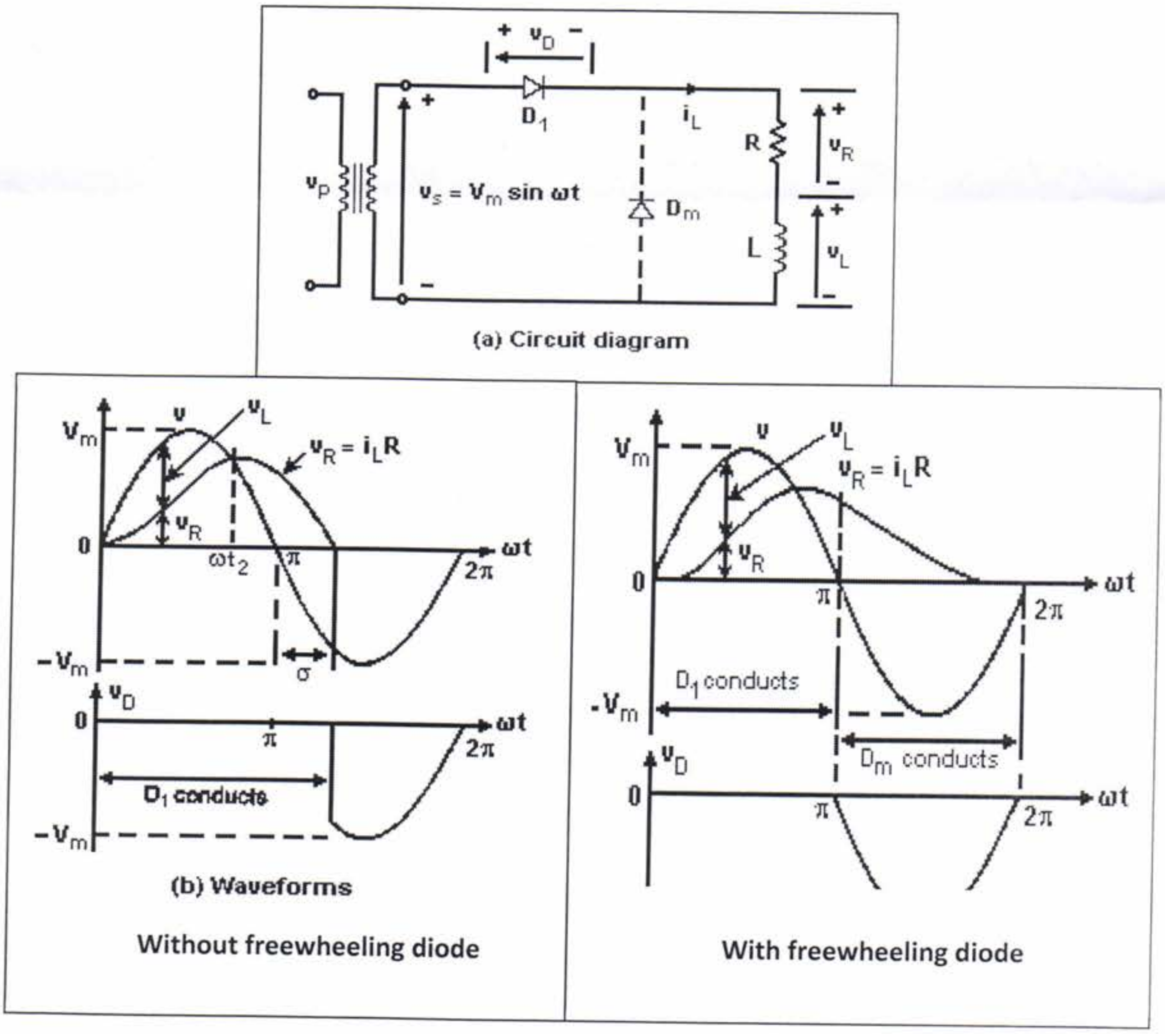
PT = Pd + Pr + Pn + Ps + Pf + Po

Sol. B:

The average dc voltage varies proportionately to [1 - cos(β)]. This can be made to be a maximum, thereby increasing the average dc voltage, by making cos(β) a maximum. The maximum value that this can take is given by cos($\pi + \sigma$) = 1, which can be obtained if σ = 0. We can make σ = 0 with the addition of a freewheeling diode given by D_m as shown with the dotted line.

When the supply voltage goes to zero, the current from D_1 is transferred across to diode D_m. This is called commutation of diodes. The result is the charge in the inductor will be used to keep diode D_m on, instead of previously forcing D_1 to remain in its forward state. This would reduce the value of the extended angle of conduction of the diode D_1, σ to zero. We can see that if the value of the inductance is high, it will store more charge and therefore be able to keep diode D_m on for a longer time.

Then the inductor would be able to keep diode D_m on for the entire duration of the negative half cycle, and by so doing, maintain a continuous load current.



(a) Circuit diagram

(b) Waveforms

Without freewheeling diode

With freewheeling diode

Q6: Design the single-phase bridge controlled rectifier has an inductive load supplied from a voltage source has value of 220V and the average output voltage varied from 160V to 180V. Calculate efficiency and ripple factor

Note: Drive any formula that used in solution [10 Marks]

Sol. $V_m = \sqrt{2} * 220 = 311$

$$V_{dc} = \frac{1}{2\pi}\int_{\alpha}^{\beta} 2V_m \cdot sinwt \cdot dt = \frac{V_m}{\pi}(cos\alpha - cos\beta)$$

$$180 = \frac{311}{\pi}(1 - cos\beta) \quad => \quad cos\beta = -0.8$$

$$\beta = 217^o$$

$$160 = \frac{311}{\pi}(cos\alpha + 0.8) \quad => \quad cos\alpha = 0.8$$

$$\alpha = 37^o$$

$$V_L = V_m\sqrt{\left(\frac{\beta - \alpha}{2\pi} - \frac{sin2\alpha - sin2\beta}{4\pi}\right)} = 219.6V$$

$$\eta = \frac{V_{dc}^2}{V_L^2} = \frac{160^2}{219.6^2} = 53\%$$

$$FF = \frac{V_L}{V_{dc}} = \frac{219.6}{160} = 1.3725$$

$$RF = \sqrt{FF^2 - 1} = 94\%$$