Q₁: The single-phase half-wave rectifier has an R-L load with R= 5Ω and L=100 mH. The rectifier is supplied from a voltage source has rms value of 120V and at 50Hz. Calculate:

a) Average and rms value of output voltage, (4 marks)
b) Rectification efficiency, (3 marks)
c) Ripple factor and form factor, (2 marks)
d) Peak inverse voltage. (1 Mark)

a) $$V_{dc} = \frac{\sqrt{2} V_i}{\pi} \left(\frac{1 - \cos\beta}{2} \right)$$

$$\beta = \phi + \pi$$

$$\phi = \tan^{-1} \frac{\omega L}{R} = \tan^{-1} \frac{2\pi \times 50 \times 100 \times 10^{-3}}{5}$$

$$= \tan^{-1}(6.38) = 1.41$$

$$\beta = \pi + 1.41 = 4.55 \text{ rad}$$

$$V_{dc} = \frac{\sqrt{2} \times 120}{\pi} \left(\frac{1 - \cos(4.55)}{2} \right) = 53.84V$$

$$V_L = \frac{V_i}{\sqrt{2}} \sqrt{\frac{2\beta - \sin 2\beta}{2\pi}} = \frac{120}{\sqrt{2}} \cdot \sqrt{\frac{2 \times 3.265 - \sin 2(4.55)}{2\pi}}$$

$$= 84.89V$$

b) $$\eta = \frac{P_{dc}}{P_L} = \frac{V_{dc} I_{dc}}{V_L I_L}$$

$$P_{dc} = V_{dc} \times \frac{V_{dc}}{R} = 53.84 \times \frac{53.84}{5} = 579.75W$$

$$P_L = V_L \times \frac{V_L}{R} = (84.89)^2 \cdot \frac{1}{5} = 1441.26$$

$$\eta = \frac{579.75}{1441.26} = 40.22\%$$

c) $F.F = \frac{V_L}{V_{dc}} = \frac{84.89}{53.84} = 1.577$

$R.F = \sqrt{F.F^2 - 1} = \sqrt{(1.577)^2 - 1} = 1.219$

d) Peak inverse Voltag "PIV" $= V_m$

$PIV = \sqrt{2} \times V_s = \sqrt{2} \times 120 = 169.7\,V$

Q₂: Two diodes are connected in series to share a total voltage of 12 kV. The reverse leakage currents of the two diodes are I_{s1}=1mA, *1mA* I_{s2}=1.5mA *1.5mA* and the total leakage current I_s = 2mA. Find the voltage sharing resistance R_1 and R_2 when diodes voltages are equal. *a*

(10 marks)

b) The diodes voltages (V_{D1}, V_{D2}) if $R_1 = 8M$, $R_2 = 10M$

a) $V_{D1} = V_{D2} = \frac{1}{2} V_s$

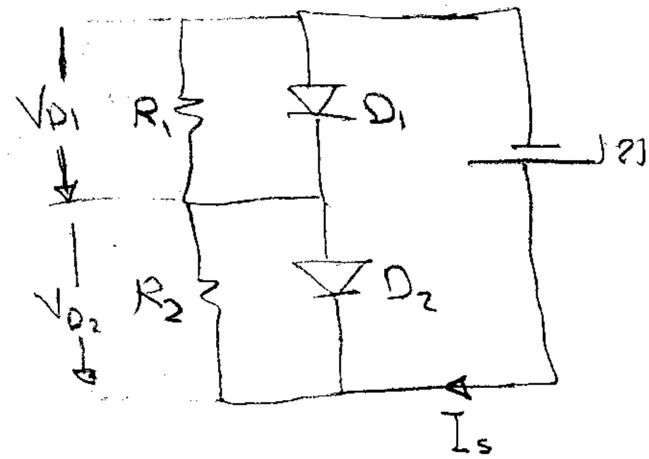
$V_{D1} = V_{D2} = \frac{1}{2} \times 12K = 6KV$

$I_s = I_{s1} + I_{R_1}$

$2 \times 10^{-3} = 1 \times 10^{-3} + I_{R_1}$

$I_s = I_{s2} + I_{R_2}$

$2 \times 10^{-3} = 1 \times 10^{-3} + I_{R_2}$



$I_{R_1} = \frac{V_{D1}}{R_1}$, $I_{R_2} = \frac{V_{D2}}{R_2}$

$2 \times 10^{-3} = 1 \times 10^{-3} + \frac{6 \times 10^3}{R_1} \Rightarrow R_1 = \frac{6 \times 10^3}{1 \times 10^{-3}} = 6 \times 10^6 = 6M\Omega$

$2 \times 10^{-3} = 1.5 \times 10^{-3} + \frac{6 \times 10^3}{R_2}$

$R_2 = \frac{6 \times 10^3}{0.5 \times 10^{-3}} = 12 \times 10^6 = 12M\Omega$

b) $I_{s1} + I_{R_1} = I_{s2} + I_{R_2}$

$1 \times 10^{-3} + \frac{V_{D1}}{8 \times 10^6} = 1.5 \times 10^{-3} + \frac{V_{D2}}{10 \times 10^6}$

$V_{D1} = 12 \times 10^3 - V_{D2}$

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$$1\times10^{-3} + \frac{12\times10^{3} - V_{D2}}{8\times10^{-6}} = 1.5\times10^{-3} + \frac{V_{D2}}{10\times10^{6}}$$

$$1\times10^{3} + 1.5\times10^{3} - \frac{V_{D2}}{8} = 1.5\times10^{3} + \frac{V_{D2}}{10}$$

$$1\times10^{3} = \frac{V_{D2}}{10} + \frac{V_{D2}}{8}$$

$$1\times10^{3} = \frac{4V_{D2}+5V_{D2}}{40}$$

$$\therefore V_{D2} = \frac{40\times10^{3}}{9} = 4.44\,kV$$

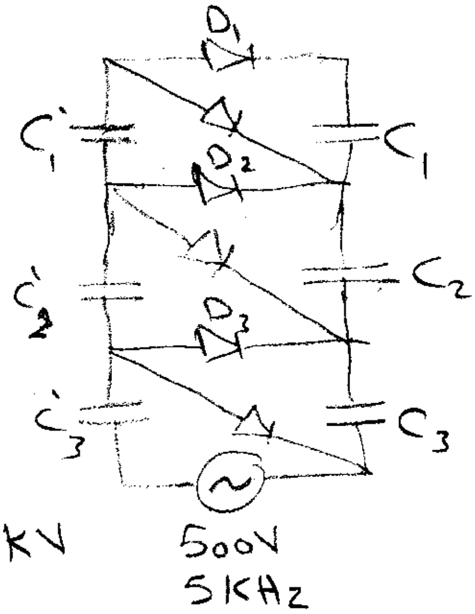
$$\therefore V_{D1} = 12 - 4.44 = 7.56\,kV$$

Q_3: Three-stage voltage multiplier supplied from the transformer with secondary voltage equal to 500V at 5 kHz. The capacitors used in voltage doubler are identical and equal to 3.3 nF. Find the average output voltage when the output current equal to 1[redacted] mA. 1mA

(10 marks)

Sol

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



$$V_{no-load} = 2nV_{max}$$

$$V_{max} = \sqrt{2}\, V_s$$

$$= \sqrt{2} \times 500 = 707 \text{ V}$$

$$V_{no-load} = 707 \times 2 \times 3 = 4.242 \text{kV}$$

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

$$= \frac{1 \times 10^{-3}}{5 \times 10^3 \times 3.3 nf}\left(\frac{2 \times 27}{3} + \frac{9}{2} - \frac{3}{6}\right)$$

$$= 1333.3 \text{V}$$

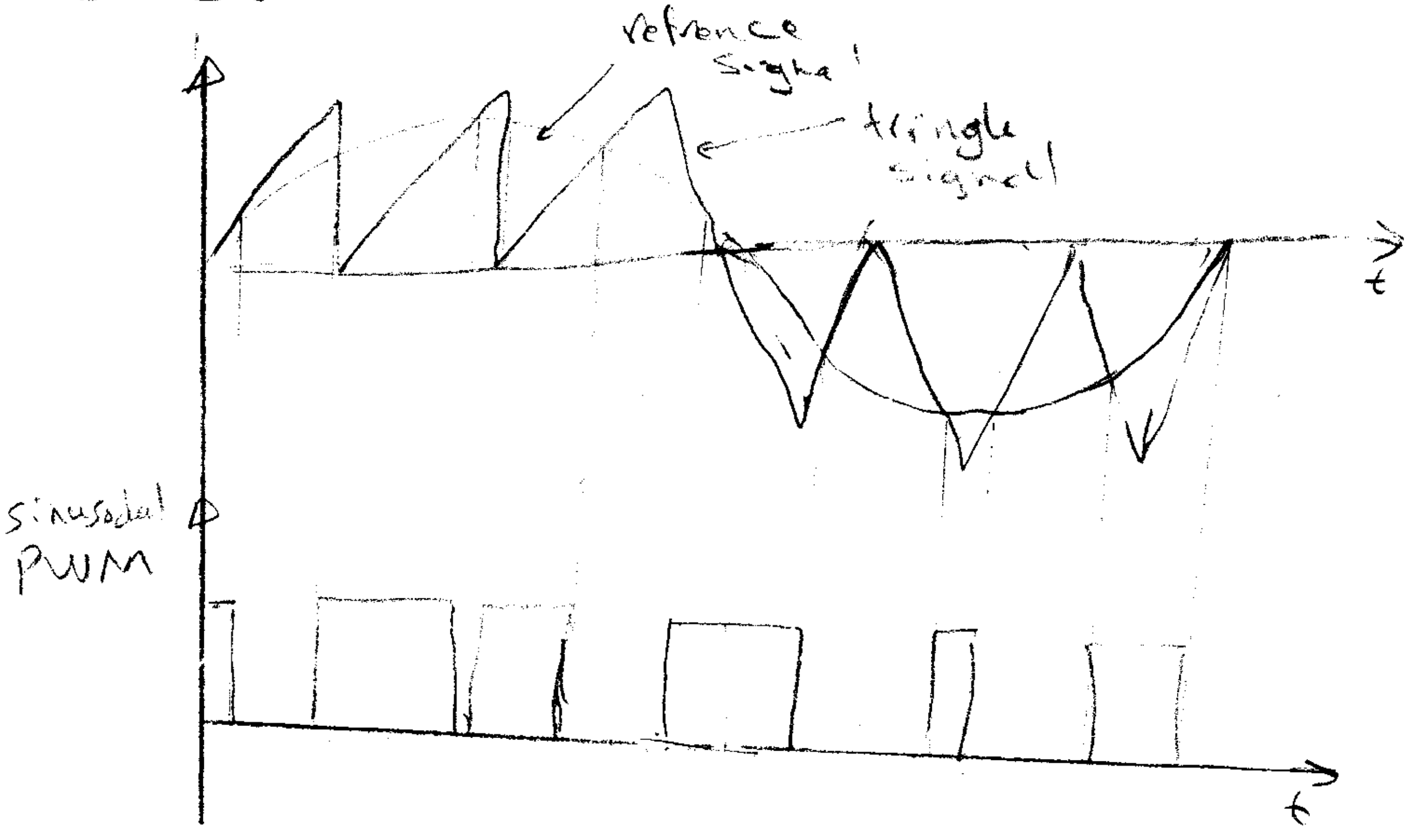
$$\delta V = \frac{I}{f \cdot C} \times \frac{n(n+1)}{4}$$

$$= \frac{1 \times 10^{-3}}{5 \times 10^3 \times 3.3 \times 10^{-9}} \times \frac{3 \times 4}{4} = 182 \text{ V}$$

$$\therefore V_o = 4242 - 1333.3 - 182 = 2726.7 \text{ V}$$

b) sinusoidal pulse width modulation

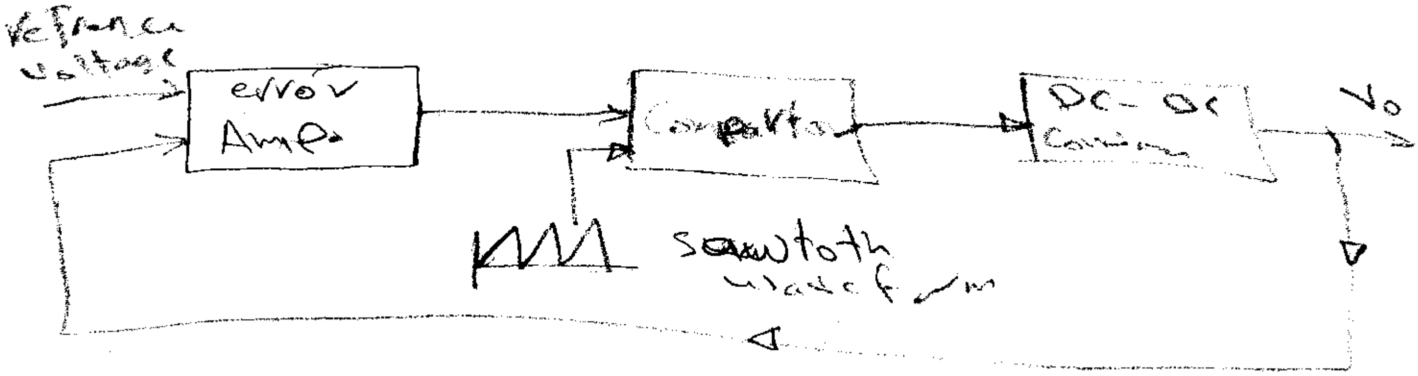
Instead of mainting the width of all pulses the same as in the case of uniform pulse width mdulation, the width of each pulse is vary in proportion to the amplitude of sine wave evaluated at the center of the same pulse. The sinusoidal signal is generated by comparing an sine wave refrence signal with a triangular carrier signal of frequency f_c as shown in figure below.



Q$_4$: a) Explain the operation of the voltage-mode control loop in the DC-DC converters. **(5 marks)**

b) Explain the sinusoidal pulse width modulation technique. **(5 marks)**

a) The Voltage mod Control loop is shown in figure below. It consist from the error amplifior which amplify the difference between the output Voltage and refrence Voltage. The output of error amplifier is applied to the Comparator as d.c level. The compartor is compar the Sawtoth waveform with output of error amplifier. The output of compartor become pulse width modulation waveforme. It is applied to the switching transistor of dc-dc convertor.



Voltage-mode Control

$$I_1 = I_s - \frac{1}{2}\Delta I$$

$$I_2 = I_s + \frac{1}{2}\Delta I$$

$$I_s = \frac{I_o}{1-D} = \frac{3.6}{\frac{2}{3}} = 5.4A$$

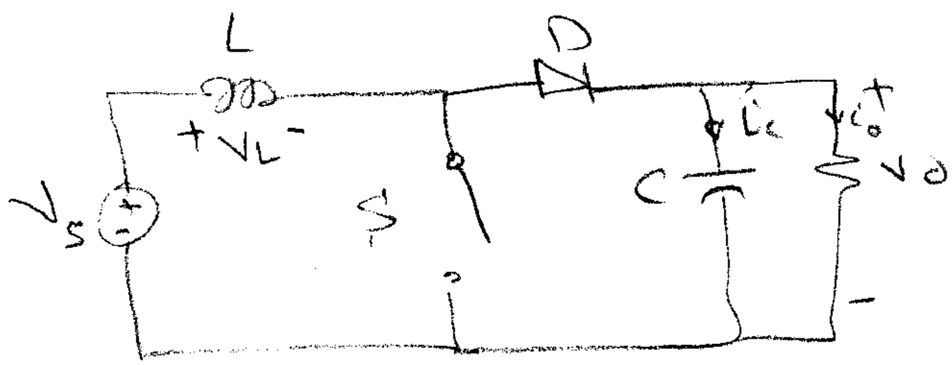
$$I_1 = 5.4 - \frac{1}{2}\times 1.2 = 4.8 A$$

$$I_2 = 5.4 - \frac{1.2}{2} = 6 A$$

$$P_s = V_s I_s = 24 \times 5.4 = 129.6 W$$

Q$_5$: Design a Step-up DC-DC converter has the following parameters: Vs = 24V, Vo = 36V, R = 10Ω, f = 25 kHz. The inductor current ripple is 1.2A and ripple of output voltage is 60 mV. **(10 marks)**

Sol



$$V_o = \frac{V_s}{1-D}$$

$$36 = \frac{24}{1-D}$$

$$1 - D = \frac{24}{36} \Rightarrow D = 1 - \frac{24}{36} = 1 - \frac{2}{3} = \frac{1}{3}$$

$$L = \frac{V_s(V_o - V_s)}{\Delta I \, V_o f}$$

$$= \frac{24(36-24)}{1.2 \times 36 \times 25 \times 10^3} = 266.7 \mu H$$

$$C = \frac{D I_o}{\Delta V_c \times f}$$

$$I_o = \frac{V_o}{R} = \frac{36}{10} = 3.6 A$$

$$\therefore C = \frac{\frac{1}{3} \times 3.6}{60 \times 10^{-3} \times 25 \times 10^3} = 800 \mu F$$

So $DF_3 = \frac{36}{7 \times 108} = 3.7\%$

Q$_6$: The single-phase half-bridge has a resistive load of R= 5Ω supplied from dc input voltage V_{dc}= 240V with switching frequency of 60Hz. Determine the following:

a) The rms value of fundamental component, (2 marks)
b) The output power, (2 marks)
c) The average and peak current of each transistor, (2 marks)
d) The total harmonic distortion, (2 marks)
e) The distortion factor of lowest harmonic. (2 marks)

a) $$V_1 = \frac{2 V_{dc}}{\pi \sqrt{2}} = \frac{2 \times 240}{\pi \sqrt{2}}$$

$$= 108\ V$$

b) $$V_o = V_{dc}/2 = \frac{240}{2} = 120$$

$$P_o = \frac{V_o^2}{R} = \frac{(120)^2}{5} = 2.88\ kW$$

c) $$I_{peak} = \frac{V_{dc}}{2R} = \frac{240}{2 \times 5} = 24\ A$$

$$I_{average} = 0\ I_{peak}$$

$$= 0.5 \times 24 = 12\ A$$

d) $$THD = \frac{(V_o^2 - V_1^2)^{\frac{1}{2}}}{V_1}$$

$$= \frac{((120)^2 - (108)^2)^{\frac{1}{2}}}{108} = 48.4\%$$

e) lowest harmonic is Third harmonic

$$DF_3 = \frac{V_3}{(3)^2 V_1}$$

$$V_3 = \frac{2 V_{dc}}{n \pi \sqrt{2}} = \frac{2 \times 240}{3 \pi \sqrt{2}} = 36$$