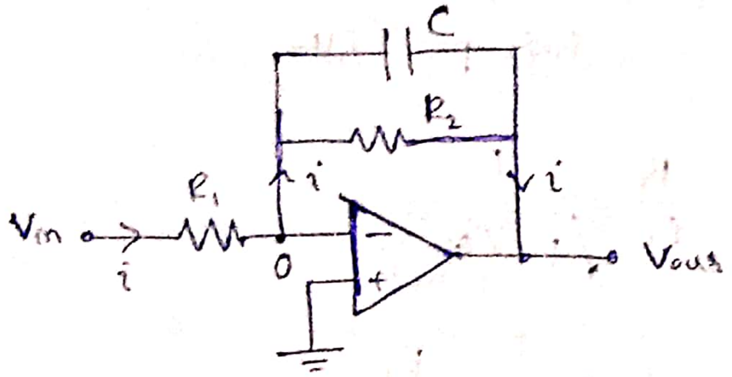
2016 Electronics III

Question 1

a) * Load resistance changes the filter's transfer function

* Cannot supply a high current to the output

b)



I)
$$V_{in}(s) = iR_1 \quad -①$$

$$-V_{out}(s) = i\left(\frac{R_2/Cs}{R_2 + 1/Cs}\right) \quad -②$$

$$②/① \Rightarrow \quad \frac{-V_{out}(s)}{V_{in}(s)} = \frac{R_2}{R_1(1+R_2Cs)}$$

$$\therefore H(s) = -\frac{R_2}{R_1}\left(\frac{1}{1+R_2Cs}\right)$$

II) The current going into the inverting input of the op amp is negligible.

III) Active filter

IV)

$$\therefore H(j\omega) = -\frac{R_2}{R_1}\left(\frac{1}{1+j\omega R_2C}\right)$$

$$|H(j\omega)| = \frac{R_2}{R_1} \frac{1}{\sqrt{1+\omega^2 R_2^2 C^2}}$$

$\omega \to 0, \quad |H(j\omega)| \to \frac{R_2}{R_1}$

$\omega \to \infty, \quad |H(j\omega)| \to 0$

$\therefore$ This is a high pass filter.

$$\therefore |H(j\omega)| = \frac{R_2}{R_1} \frac{1}{\sqrt{1+\left(\omega/\omega_c\right)^2}}$$

$$\text{Passband gain} = \frac{R_2}{R_1}$$

$$\omega_c = \frac{1}{R_2 C} \Rightarrow f_c = \frac{1}{2\pi R_2 C}$$

Question 2

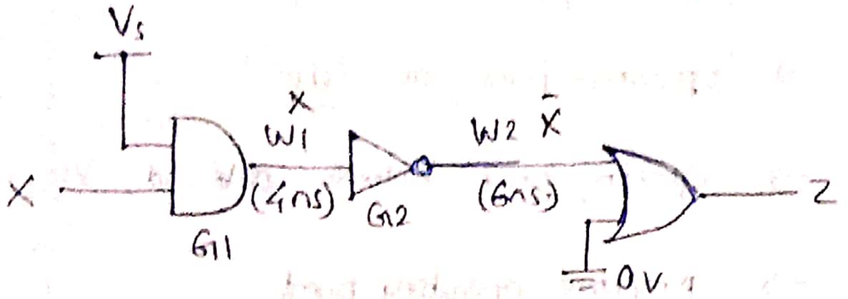
a) When the input to a logic gate is changed, the time taken to produce the corresponding output by ~~too~~ the logic gate is called it's propagation delay.

b) * Changing the output logic values ~~of~~ from 0-to-1 and 1-to-0 corresponds to switching off a ~~t~~ CMOS transistor and switching ON an CMOS transistor.

* To switch ON a CMOS (NMOS), we need to place positive charges on the gate which is equivalent to charging a capacitor.
* To turn it off we must remove that charge which is equivalent to discharging a capacitor.

* These two processes take different amounts of time
* Thus t_{PHL} and t_{PLH} differs

c)



i) Input = X , Output = Z

X	Z
0	1
1	0

$Z = \bar{X}$

ii) Consider the transition of 0-to-1 (low-to-high)

Gate	Previous output	Current output	Delay (ns)
G3	0	1	~~12~~ 13
G2	0	1	10
G1	1	0	15

$\therefore t_{PLH} = 13 + 10 + 15 + 6 + 4 = \underline{\underline{48\ ns}}$.

Now consider 1-to-0 transition

Gate	Previous output	Current output	Delay (ns)
G3	1	0	14
G2	1	0	9
G1	0	1	12

$\therefore t_{PHL} = 14 + 9 + 12 + 6 + 4 = \underline{\underline{45\ ns}}$

Question 3

a)

- Class A → Operating point at $V_{cc}/2$
- Class B → Operating point at 0V
- Class AB → Operating point between 0V and $V_{cc}/2$
- Class C → Negative operating point

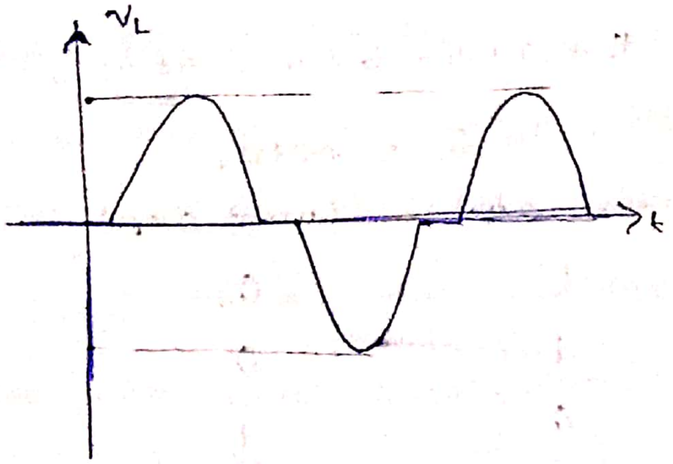
- Conduction angle is the time during which the transistor conducts when a sinusoidal signal is applied.

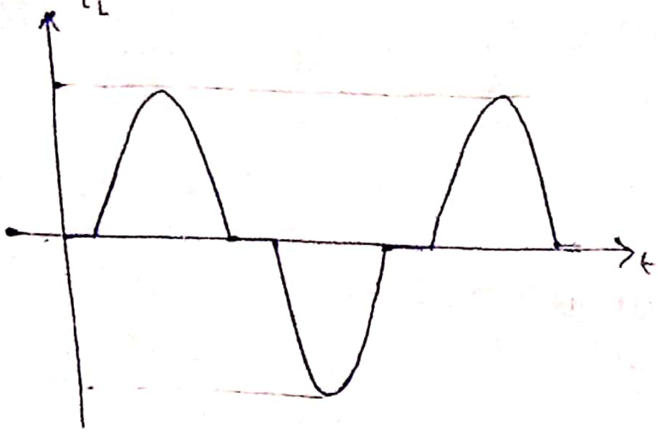
Class	conduction angle
A	360° (Conducts during the whole cycle)
B	180° (half a cycle)
AB	Slightly higher than 180°
C	Slightly lower than 180°

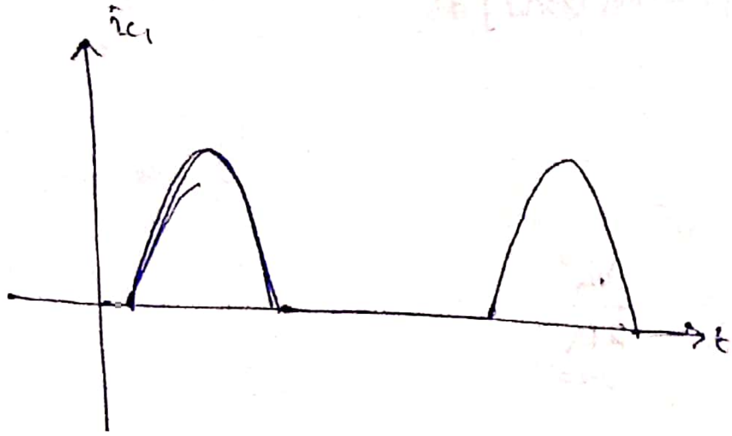
b). I)

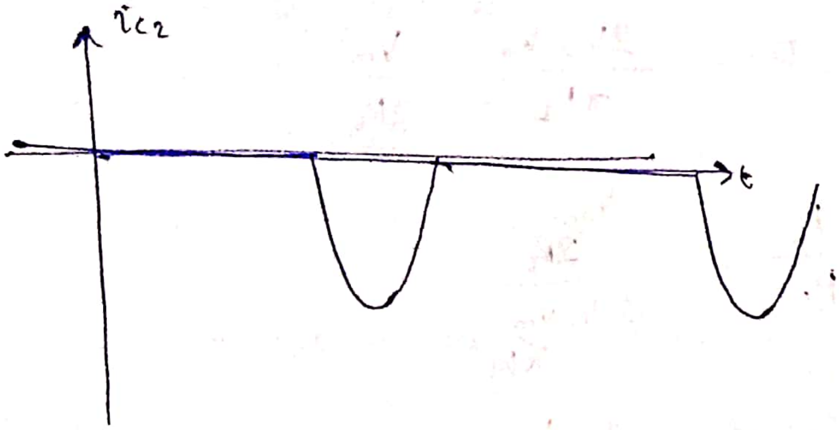
- Higher efficiency
- Possible ripples in the power supply is balanced out.

II)

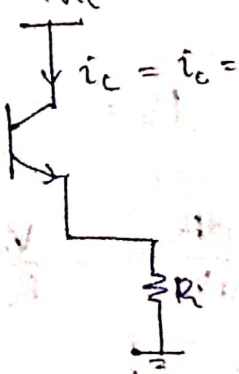








III) Considering the positive cycle,



$i_c = i_c = I_p \sin(\omega t)$

$I_p = \dfrac{V_m}{R_L}$

$$P_{in} = \frac{2}{T}\int_0^{T/2} i_c V_{cc}\, dt$$

$$= \frac{2V_{cc}}{T}\int_0^{T/2} \frac{V_m}{R_L} \sin(\omega t)\, dt$$

$$= \frac{2V_{cc}V_m}{TR_L} \cdot \left[\frac{-\cos(\omega t)}{\omega} \right]_0^{T/2}$$

$$P_{in} = \frac{4V_{cc}V_m}{\omega T R_L} = \frac{2V_{cc}V_m}{\pi R_L}$$

$$P_L = \frac{2}{T}\int_0^{T/2} i_c^2 R_L \, dt$$

$$= \frac{2R_L}{T}\int_0^{T/2} I_p^2 \sin^2 \omega t \, dt$$

$$= \frac{\cancel{2} I_p^2 R_L}{T}\int_0^{T/2} [1 - \cos(2\omega t)] \, dt$$

$$= \frac{I_p^2 R_L}{T} \cdot \frac{T}{2}$$

$$P_L = \frac{\left(V_m/R_L\right)^2 R_L}{2} = \frac{V_m^2}{2R_L}$$

$$P_D = P_{in} - P_L = \frac{2V_{cc}V_m}{\pi R_L} - \frac{V_m^2}{2R_L}$$

$$\eta = \frac{P_L}{P_{in}} = \frac{V_m^2/2R_L}{2V_{cc}V_m/\pi R_L}$$

$$\therefore \eta = \frac{\pi}{4} \cdot \frac{V_m}{V_{cc}}$$

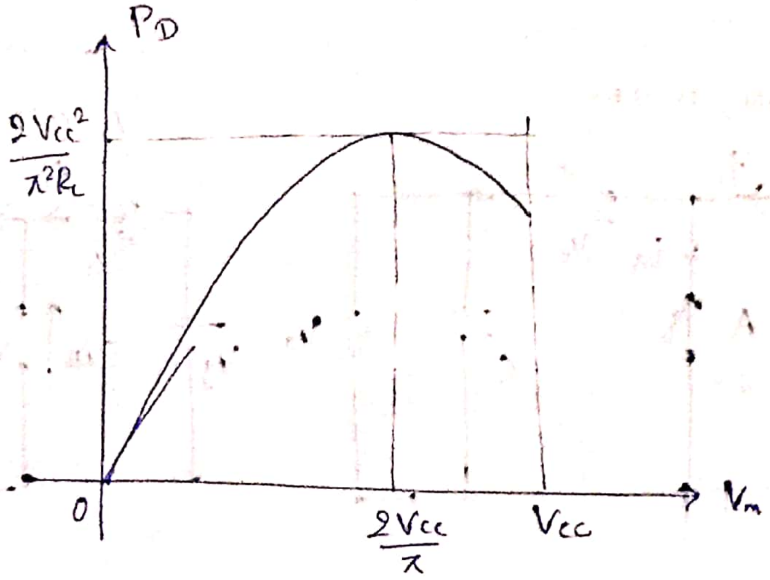
IV) $$P_D = -\frac{V_m^2}{2R_L} + \frac{2V_{cc}V_m}{\pi R_L}$$

$$\frac{dP_D}{dV_m} = -\frac{V_m}{R_L} + \frac{2V_{cc}}{\pi R_L}$$

When P_D is maximum, $\frac{dP_D}{dV_m} = 0$

$$\Rightarrow -\frac{V_m}{R_L} + \frac{2V_{cc}}{\pi R_L} = 0 \Rightarrow V_m = \frac{2V_{cc}}{\pi}$$

$$\therefore (P_D)_{max} = -\frac{1}{\cancel{2}R_L}\frac{\cancel{4}^{2}V_{cc}^2}{\pi^2} + \frac{2V_{cc}}{\pi R_L}\cdot\frac{2V_{cc}}{\pi} = \frac{2V_{cc}^2}{\pi^2 R_L}$$



V)

$$P_L = 20\ W$$

$$\therefore 20 = \frac{V_m^2}{2\times 8}$$

$$V_m = 17.889\ V$$

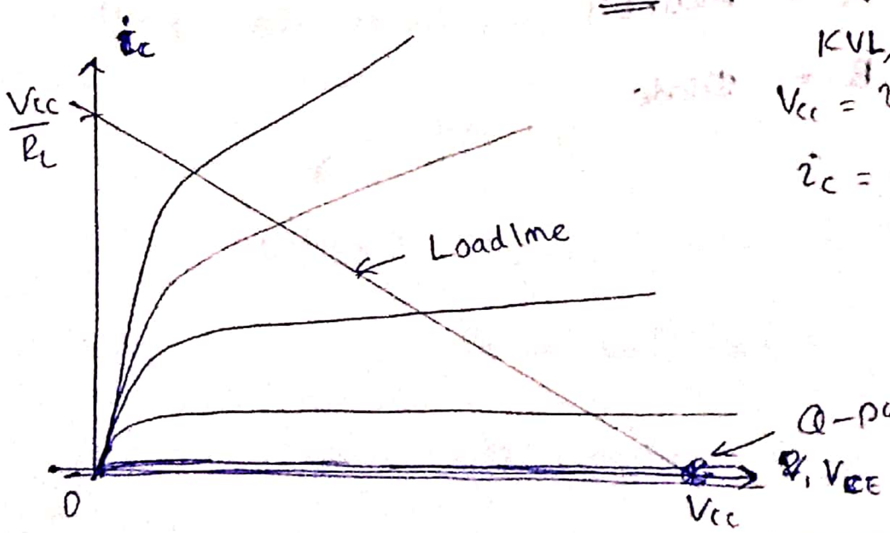
To get the maximum efficiency, $V_m = V_{cc}$

$$\Rightarrow V_{cc} = 17.89\,V$$

$$I_p = \frac{V_m}{R_L} = \frac{17.89}{8}$$

$$I_p = 2.236\ A$$

VI)



KVL,

$$V_{cc} = v_{CE} + i_C R_L$$

$$i_C = -\frac{v_{CE}}{R_L} + \frac{V_{cc}}{R_L}$$

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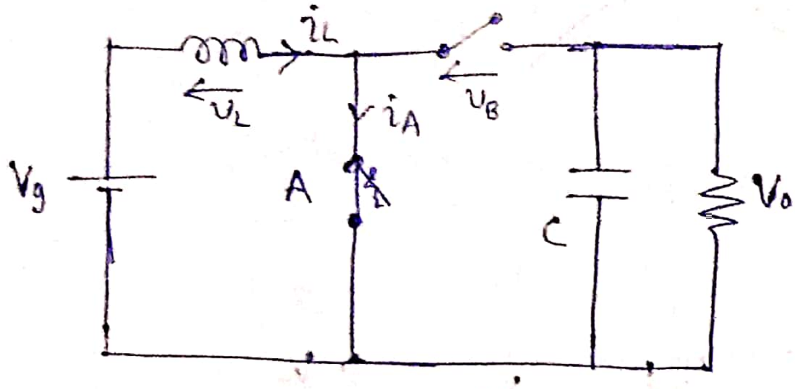
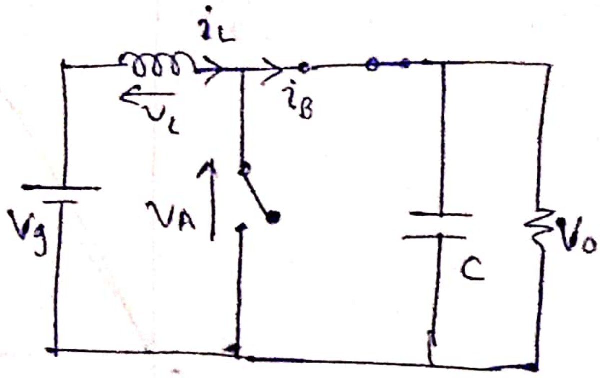
Question 4

c) I) A ON, B OFF A OFF, B ON





A : ON → $i_A = i_L > 0$ ~~∴ positive~~

OFF → $v_A = V_o > 0$ (Assuming V_o is positive)

∴ A conducts positive currents and blocks positive voltages

B : ON → $i_B = i_L > 0$

OFF → $v_B = V_g - V_o < 0$ (∵ $V_o > V_g$ because this is a boost converter)

∴ B conducts positive currents and blocks negative voltages

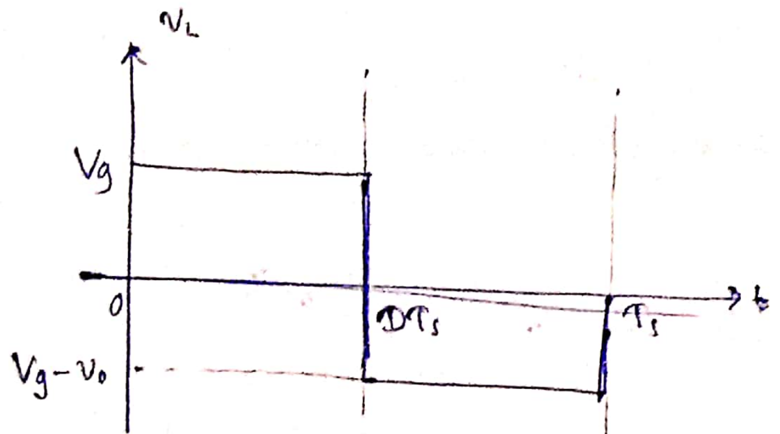
II) A = MOSFET

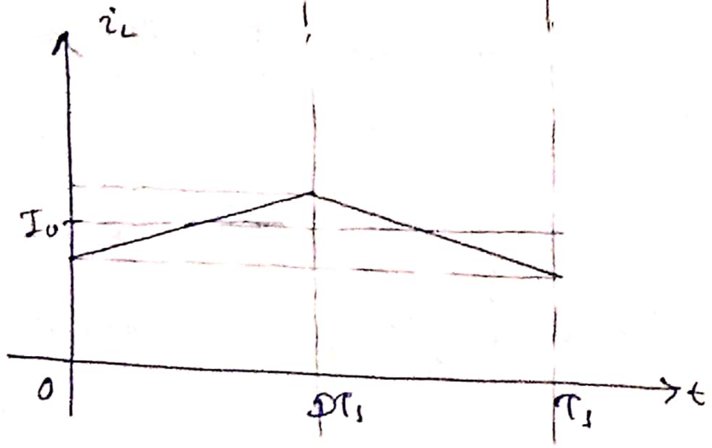
B = Diode

III) Assuming steady state operation.

$0 \le t \le DT_s$; $v_L = V_g > 0$

$DT_s \le t \le T_s$; $v_L = V_g - V_o < 0$





V) Using small ripple approximation,

$$v_o \approx V_o$$

$$\therefore \; v_L|_{DT_s} = V_g$$

$$v_L|_{D'T_s} \approx V_g - V_o$$

Using volt-second balance,

$$\int_0^T v_L(t)\, dt = 0$$

$$\therefore \; V_g.(D\cancel{T_s}) + (V_g - V_o)(1-D)\cancel{T_s} = 0$$

$$V_g = V_o(1-D)$$

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