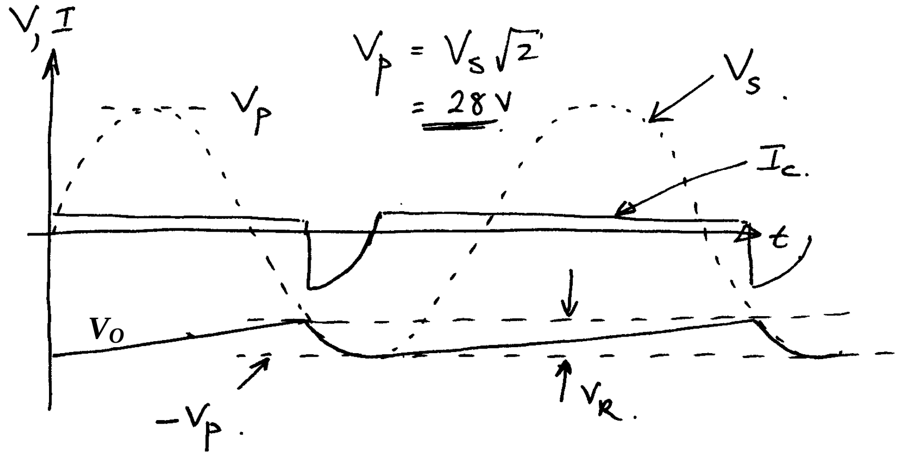
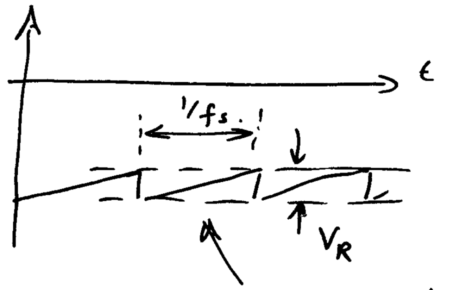
Q1 (i)




Unattractive because the peaky nature of IC adds many harmonics to the supply current.

(ii) Suitable model is

$$I = C\frac{dv}{dt} = C\frac{V_R}{1/f_s}$$




assume inst. charging and constant current discharge.

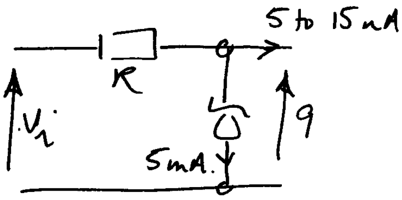
$I_{pk} = \dfrac{V_p}{R_L}$ and is more or less constant at this value

$$\therefore \frac{V_p}{R_L} = C\frac{V_R}{1/f_s}$$

$$\text{or } C = \frac{V_p}{R_L V_R f_s} = \underline{2.8\,mF}.$$

[0.7v diode drop has been neglected]

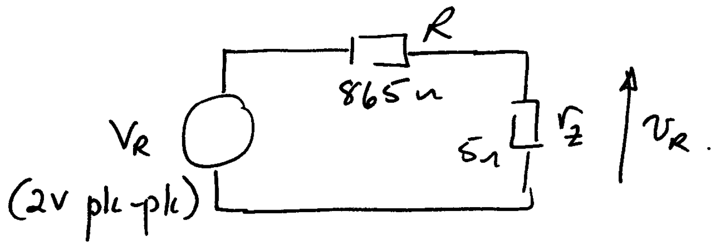
(iii) Worst case condition is minimum $V_i$ $(V_s\sqrt{2} - V_R)$ and maximum $I_L$




$$\therefore R_{max} = \frac{V_s\sqrt{2} - V_R - 9}{15mA + 5mA} = \frac{28.3 - 2 - 9}{20\,mA} = \underline{865\Omega}.$$

The 0.7 v diode drop has been neglected.

(iv) ripple equivalent circuit.....

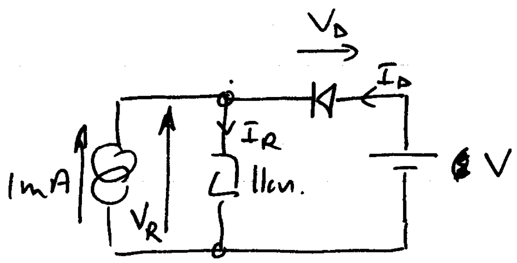



$$v_R = 2 \times \frac{5}{865+5} = \frac{10}{870} = \underline{\underline{11.5\,mV}}.$$

(v) If output is short circuited to ground, all of $V_{in}$ appears across R.
Assuming that $V_{in} = V_{pk}$ (a worst case assumption from a power point of view

$$P_R = \frac{V_p^2}{R} = \frac{(20\sqrt{2})^2}{865} = \frac{800}{865} = \underline{\underline{0.92\,W}}.$$

Q2 (a) (i) On point of conduction, $I_D = 0$, $V_D = 0.7$




If $I_D = 0$, all of 1mA goes through 1kΩ so $V_R = 1mA \times 1k\Omega = 1V$. Since $V_R$ is on the diode cathode, diode anode will be $V_R + 0.7 = V \underline{\underline{= 1.7\,V}}$.

(ii) If V = +5v, diode will conduct and $V_R = V - 0.7 = 5 - 0.7 = 4.3$.

So $I_R = 4.3\,mA$. 1mA of this comes from the current source, the rest comes from $I_D$ since

$$I_D + 1mA = I_R$$

so $I_D = 4.3\,mA - 1\,mA = \underline{\underline{3.3\,mA}}$.

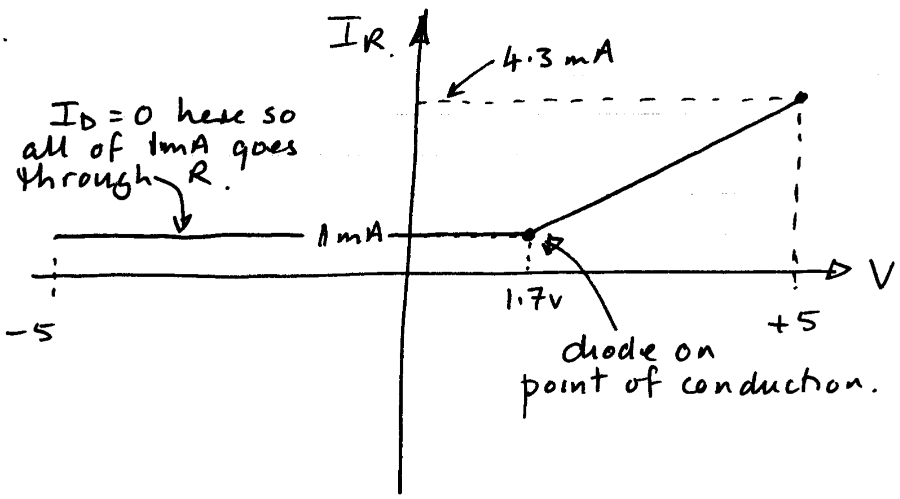
$V_D = \underline{\underline{0.7\,v}}$.

When $V = -5V$, diode cathode is at $V_R$ volts which is $1mA \times 1k\Omega = 1V$. So diode is reverse biassed and the reverse bias is

$V_{D(RB)} = 1 - (-5) = \underline{\underline{6V}}$.

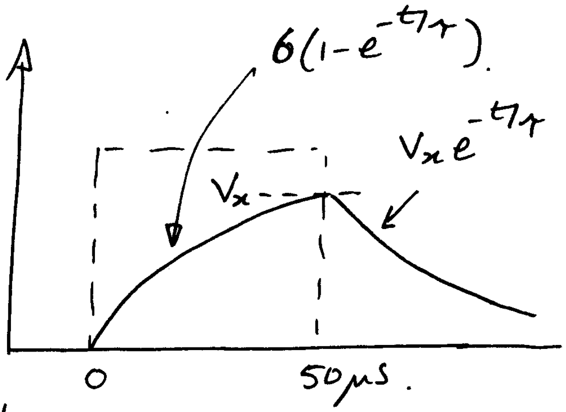
and $I_D = \underline{\underline{0\,mA}}$.

(iii).




(b) (i) lead edge ...

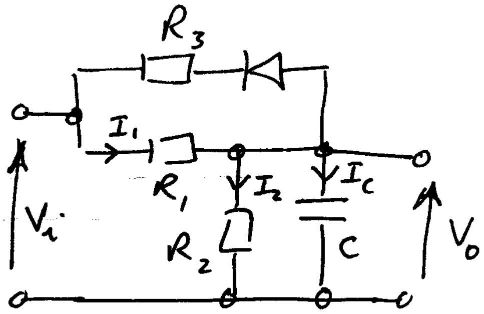
- initial voltage is zero
- aiming voltage $10 \times \frac{R_2}{R_1 + R_2}$ $= 6V$.




$$V_x = 6(1 - e^{-t/\tau})$$

where $\tau = 33nF \times 3k\Omega // 2k\Omega$
$= 33nF \times 1.2k\Omega = 39.6\mu s$.

$$V_x = 6\left(1 - e^{-50/39.6}\right) = \underline{\underline{4.3\text{ V}}}.$$

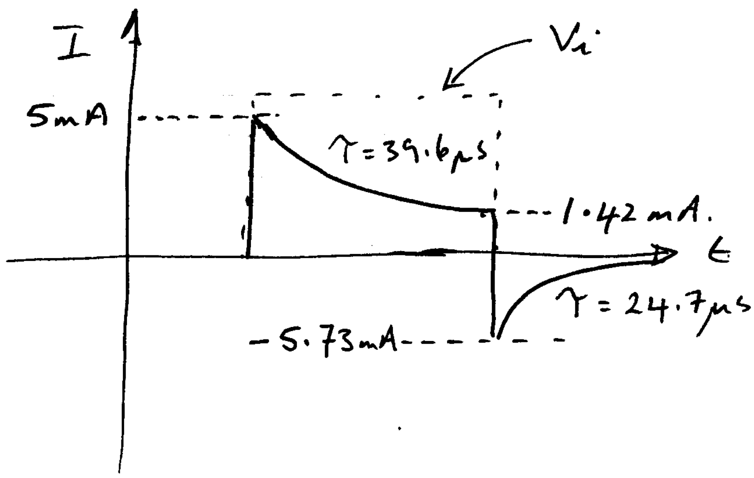



(ii) On leading edge, C initially discharged so initial $I_c = 10/R_1$
$= 5\text{mA}$.

Since diode does not conduct in response to leading edge, $V_x$ is the same as in part (i), ie 4.3V. and $\tau = 39.6\mu s$ as before

On trailing edge, $V_i$ goes to zero, but C is charged up to $V_x$. D conducts and sees the three resistors in parallel as a discharge path so $I_p = -\dfrac{4.3}{R_1 \| R_2 \| R_3} = \underline{\underline{-5.73\text{mA}}}$.

and $\tau = 33\text{nF} \times R_1 \| R_2 \| R_3 = 33\text{nF} \times 750\Omega$
$= \underline{\underline{24.75\mu s}}$.




At end of pulse $I_c = I_1 - I_2$

$$= \frac{10-4.3}{2k\Omega} - \frac{4.3}{3k\Omega}.$$

$$= (2.85 - 1.43)\text{mA} = \underline{\underline{1.42\text{mA}}}.$$

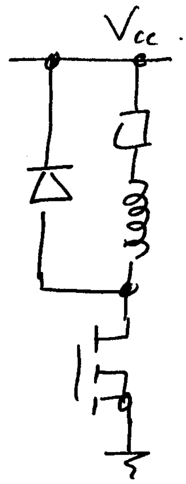
Q3 (a) (i) on state $I_D = \frac{V_{cc}}{R_L}$, neglecting $r_{DSon}$

$$= \frac{42}{5} = \underline{\underline{8.4\,A}}.$$

(ii) on state $P_D \approx (8.4)^2 r_{DSon}$

$$= \underline{\underline{7.1\,W}}.$$

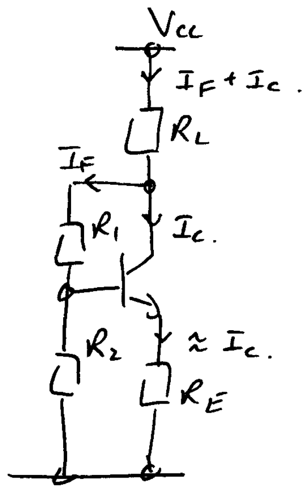
(iii) An inductive load would store energy. This would not cause a problem on turn on but would give rise to a large transient voltage when the FET tried to switch off. Can be controlled by an idling diode as shown....




The diode provides a path for the inductor current when the switch turns off.

[Note that answers to pt (i) + (ii) will be slightly different from those given if $r_{DSon}$ not neglected in part (i).]

(b) Two equations ...




$$V_{cc} = (I_F + I_c)R_L + I_F(R_1 + R_2) \quad \text{——(1)}$$

and $I_c R_E + 0.7 = I_F R_2$. ——(2)

$I_B$ is assumed to be negligible.

developing (1) ....

$$V_{cc} = I_c R_L + I_F(R_1 + R_2 + R_L) \quad \text{——(3)}$$

developing (2)

$$I_F = \frac{I_c R_E + 0.7}{R_2} \quad \text{——(4)}$$

putting 4 into 3 ...

$$V_{cc} = I_c R_L + \frac{I_c R_E + 0.7}{R_2}(R_1 + R_2 + R_L).$$

$$V_{cc} - \frac{0.7(R_1+R_2+R_L)}{R_2} = I_c\left(R_L + \frac{R_E(R_1+R_2+R_L)}{R_2}\right).$$

$$18 - 2.24 = I_c(4.7k + 6.4k).$$

$$\frac{15.76}{11.1\,k\Omega} = I_c = \underline{1.42\,mA}.$$

$$V_c = \quad \text{So} \quad I_F = \frac{1.42mA \times 2k\Omega + 0.7}{33k\Omega} = 107\mu A.$$

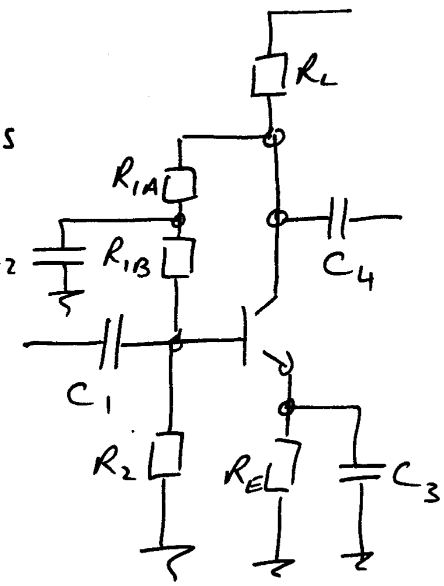
$$V_c = 18 - (1.42mA + 107\mu A)\,4.7k\Omega$$
$$= 18 - 7.18 = \underline{10.8V}.$$

$$V_B = 1.42 \times 2k\Omega + 0.7 = \underline{3.54V}.$$

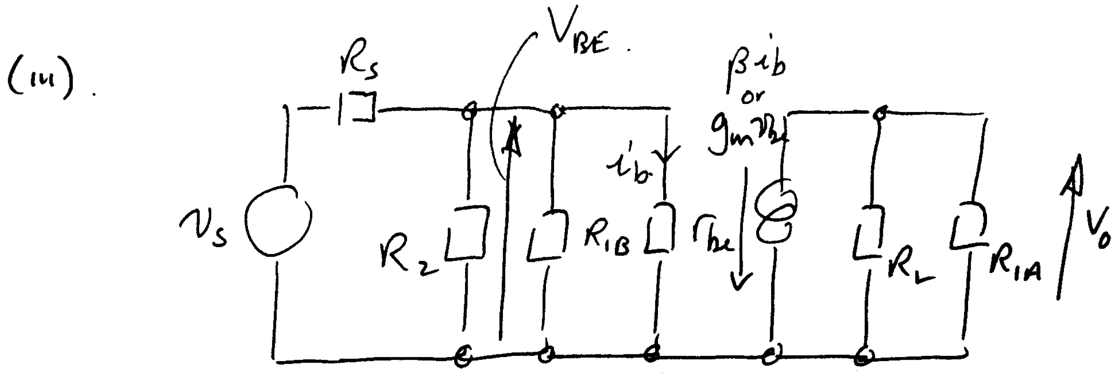
(ii)

$C_1$ + $C_4$ are coupling capacitors

$C_2$ + $C_3$ are decoupling capacitors.



(iii).

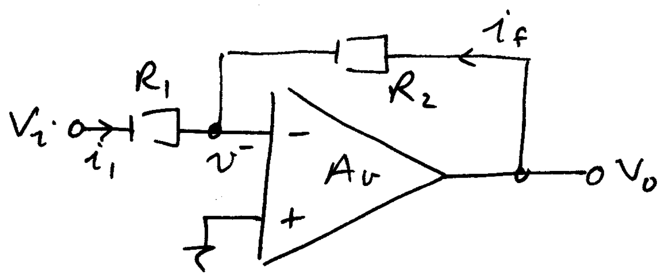



minus 1 mark per error.

Q4 (a) (i). $\frac{V_o}{V_i} = -\frac{R_2}{R_1}$

suitable values would have a ratio of 10 with both resistors > 200 Ω and < 1MΩ.

(ii)




$$i_1 + i_f = 0$$

$$\frac{V_i - v^-}{R_1} + \frac{v_o - v^-}{R_2} = 0.$$

$$\frac{v_i}{R_1} + \frac{v_o}{R_2} = v^-\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

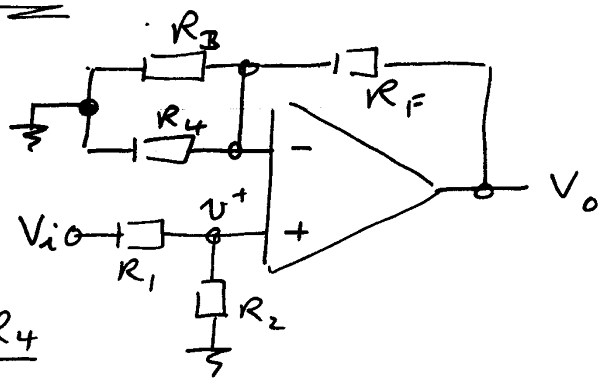
$$\text{or} \quad v^- = \frac{v_i R_2}{R_1 + R_2} + \frac{v_o R_1}{R_1 + R_2}.$$

$$\text{Also,} \quad v_o = A_v(v^+ - v^-)$$
$$= A_v\left(0 - \frac{v_i R_2}{R_1 + R_2} - \frac{v_o R_1}{R_1 + R_2}\right)$$

$$\text{so} \quad v_o\left[\frac{1}{A_v} + \frac{R_1}{R_1 + R_2}\right] = -\frac{V_i R_2}{R_1 + R_2}$$

$$\text{so} \quad \frac{V_o}{V_i} = -\frac{R_2/(R_1+R_2)}{\left[\frac{1}{A_v} + \frac{R_1}{(R_1+R_2)}\right]}.$$

(b) (i)




$$v^+ = V_i \frac{R_2}{R_1+R_2}$$

$$V_o = v^+ \frac{R_F + R_3 \| R_4}{R_3 \| R_4}.$$

$$\therefore \frac{V_o}{V_i} = \frac{R_2}{R_1+R_2} \cdot \frac{R_F + R_3\|R_4}{R_3\|R_4} = 0.4 \cdot \frac{11}{1} = \underline{\underline{4.4}}.$$

(ii) the same except that $R_1$ becomes $R_2$ and vice versa

$$\frac{V_o}{V_i} = \frac{R_1}{R_1+R_2} \cdot 11 = 0.6 \cdot \frac{11}{1} = \underline{\underline{6.6}}.$$

(iii) when $V_1 + V_2 = 0$, $v^+ = 0$

$$\frac{V_o}{V_i} = -\frac{R_F}{R_3} = -\frac{10k}{1.5k} = \underline{\underline{-6.66}}.$$

(iv) the same as (iii) except $R_3$ becomes $R_4$ + vice versa.

$$\frac{V_o}{V_i} = -\frac{R_F}{R_4} = -\frac{10k}{3k} = \underline{\underline{-3.33}}$$

[note that in cases (iii) + (iv), there is no voltage across the resistor connected to 0V so it doesn't affect gain].

(v) $V_1 = 3V$, $V_2 = 2\sin\omega t$, $V_3 = a + b\sin\omega t$
and $V_4 = 5 - 3\sin\omega t$

$$\frac{V_o}{V_1} \times V_1 + \frac{V_o}{V_2} \times V_2 + \frac{V_o}{V_3} \times V_3 + \frac{V_o}{V_4} \times V_4 = 0.$$

$$13.2 + 13.2\sin\omega t + (-6.67a - 6.67b\sin\omega t)$$
$$+ (-3.33.5 + 3.33.3.\sin\omega t) = 0.$$

dc terms $13.2 - 6.67a - 16.65 = 0.$

$$\text{or } -a = \frac{16.65 - 13.2}{6.67} = 517\,mV.$$

$$\therefore \quad a = \underline{\underline{-517\,mV}}.$$

ac terms $13.2 - 6.67b + 9.99 = 0.$

$$\text{or } b = \frac{13.2 + 9.99}{6.67} = \underline{\underline{3.48}}.$$