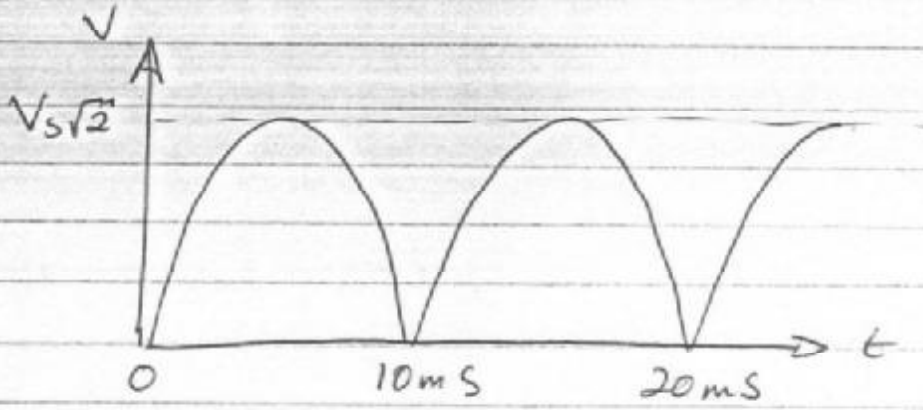
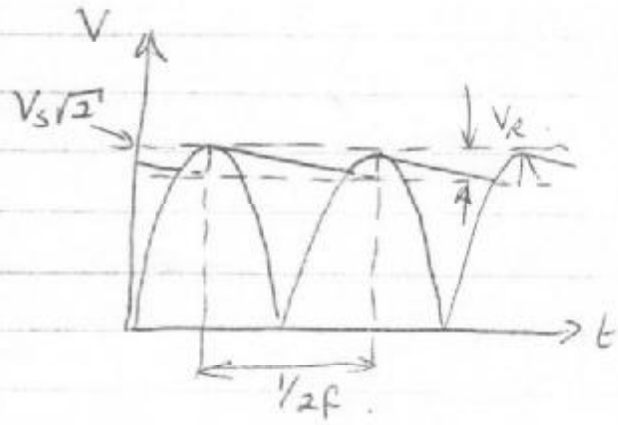
Solutions to EEE103 June 2002

Q1. (i)



(This sketch assumes diode turn on voltage = 0)

(ii) Assume that I_L is constant at 1.5A.
Assume that C discharges for a whole half cycle.
Then...



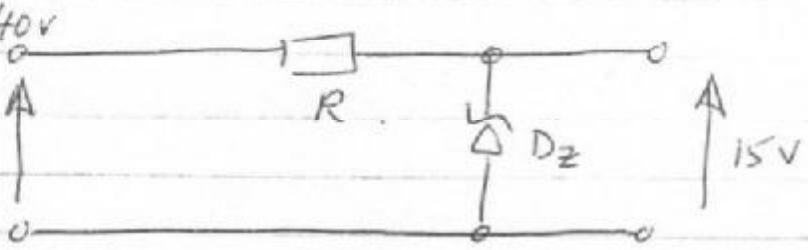
$$I = I_L = C\frac{dV}{dt} = C\frac{V_R}{1/2f}$$

$$\text{or } C = \frac{I_L}{2f V_R} = \frac{1.5}{100 \cdot 0.75} = \underline{20{,}000\,\mu F \text{ or more}}$$

(iii). For a V_o of ~40v, $V_s\sqrt{2} \approx 40$ or $\underline{V_s = 28\,V}$

Each diode must withstand a peak reverse voltage of $\underline{40\,V}$.

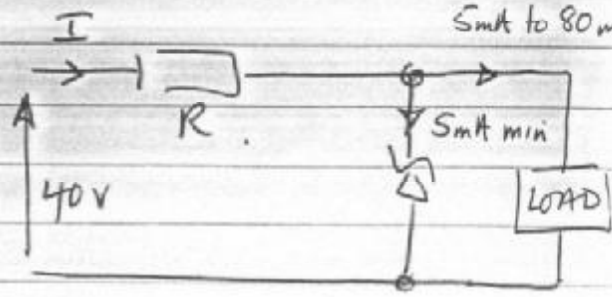
(iv).



EEE103 June '02 sols cont....

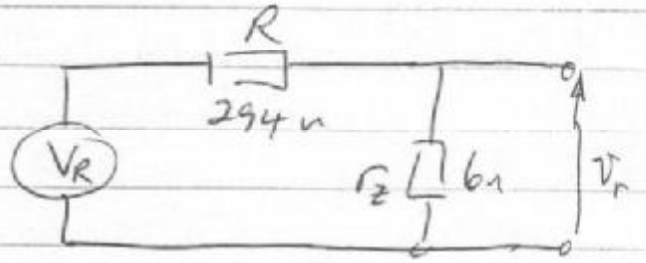
Q1 cont...

(V) I must be 85mA in order to keep 5mA through D_Z when $I_L = 80mA$.



Thus, $R = \frac{V_i - V_o}{I} = \frac{40 - 15}{85mA} = \underline{294\Omega}$

(VI) $V_R = 0.75V$ pk-pk.



$$V_r = \frac{V_R r_z}{R + r_z}$$

$$= \frac{0.75 \times 6}{294 + 6}$$

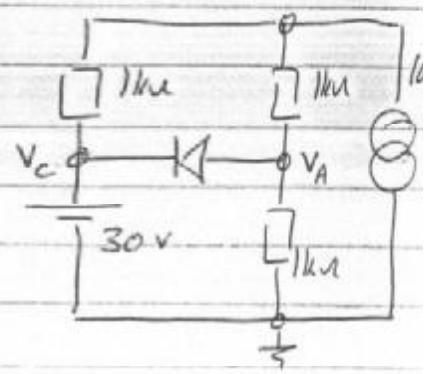
$$= \frac{0.75 \times 6}{300} = \frac{0.75 \times 2}{100} = \underline{15mV.\ \text{pk-pk}}$$

(VII) The worst case situation for the zener diode is when I_L is 5mA. Under these conditions, 80mA flows through D_Z and power dissipation in D_Z is

$$P_{D_Z} = V_Z \times I = 15 \times 0.08 = \underline{1.2W}$$

EEE103 June '02 sols

Q2. (a) Assume the diode is not conducting and work out V_A + V_c with diode open cct....



due to 30V...

$V_c = 30V$

$V_A = 30 \times \frac{1}{1+1+1} = 10V.$

due to 100mA....

$V_c = 0V.$

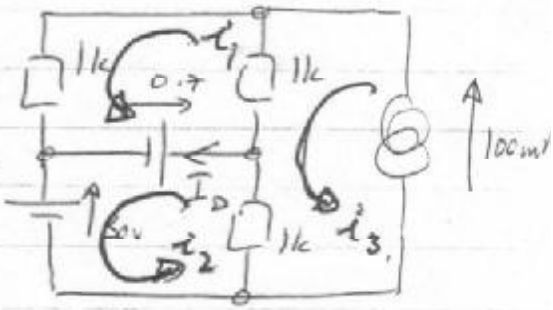
$V_A = \frac{1}{2} \cdot 100mA \cdot 2k\Omega // 1k\Omega = \frac{0.1}{2} \times \frac{2000}{3} = 33.3V.$

$V_{c\,TOT} = 30V + 0V. = 30V$

$V_{A\,TOT} = 10V + 33.3V = 43.3V$

$V_A - V_c = +13.3V$ ∴ diode must be conducting

Replace diode with 0.7V source and work out forward current...



$0.7 = i_1 1k - i_3 1k + i_1 1k$ — ①

$30 + 0.7 + i_2 1k - i_3 1k = 0$ — ②

Since $i_3 = 0.1A$

① gives $0.7 = 2k\Omega\, i_1 - 100$ or $i_1 = \frac{100.7}{2000} = 50.35mA$

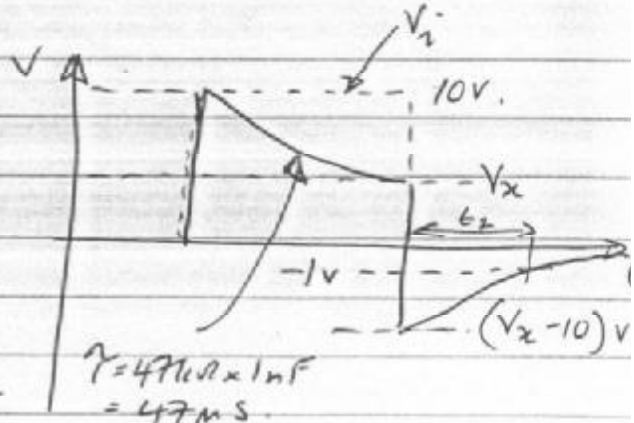
② gives $30.7 - 100 + 1k\Omega\, i_2 = 0$ or $i_2 = \frac{69.3}{1000} = 69.3mA$

$I_D = i_2 - i_1 = (69.3 - 50.35)mA = \underline{\underline{18.95mA}}$

(b) (i)



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To find peak values, it is necessary to find V_x .....

After leading edge of input pulse, V(t) is $V(t) = 10e^{-t/\tau}$ and at end of pulse:

$V_x = 10e^{-50\mu s/47\mu s} = \underline{3.45V}$.

So peak values are $\underline{10V}$ and $\underline{-6.55V}$.

After trailing edge, $V(t) = -6.55e^{-t/\tau}$ assuming a time origin now at the trailing edge. This falls back to -1V in a time t_2 given by

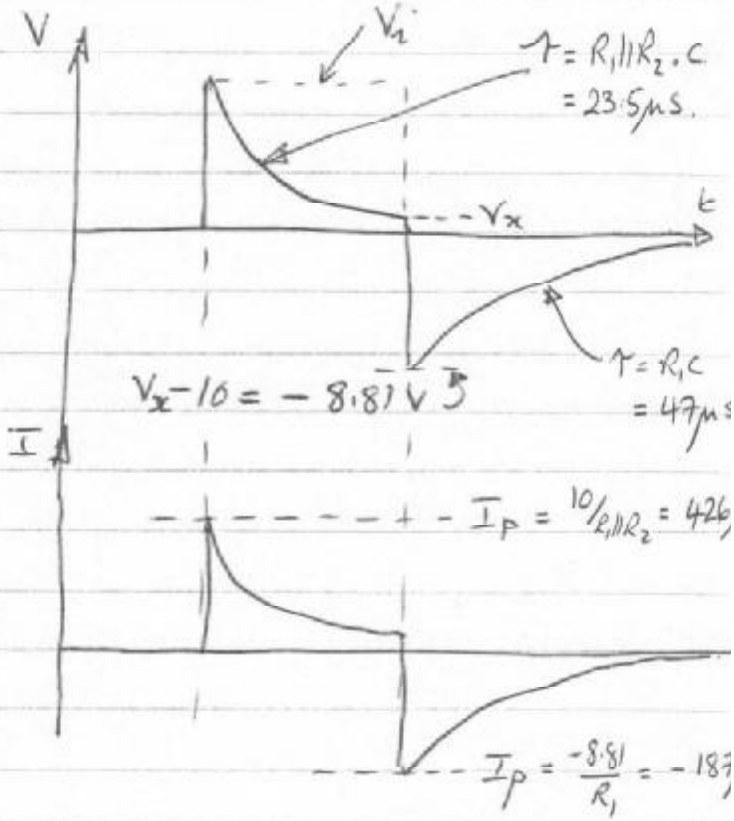
$-1 = -6.55e^{-t_2/47\mu s}$. or $t_2 = 47\mu s \ln 6.55$

so time $< -1V$ ... $= \underline{88.3\mu s}$.

b)(ii) $V_x = 10e^{-\frac{50\mu s}{23.5\mu s}} = 1.19V$

After leading edge, V_o is +ve so D conducts and $\tau = R_1 \| R_2 . C$

After trailing edge V_o is -ve so D is reverse biassed and $\tau = R_1 C$



EEE103 June '02 sols...

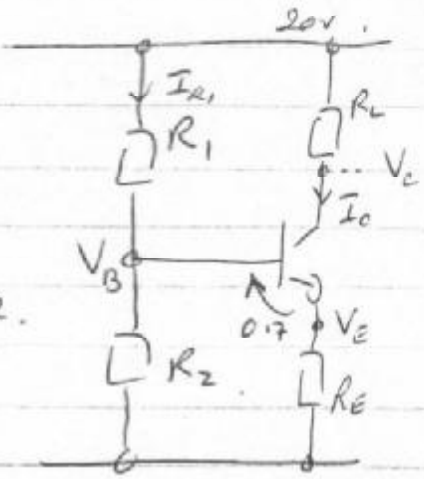
Q3. (i) h_{FE} is a static ratio I_C/I_B.

β is an incremental ratio $\frac{\Delta I_C}{\Delta I_B}$.

(ii) C_1 is a signal coupling capacitor. It allows signals from the source to the transistor base without disturbing the d.c. bias conditions. R_E provides the negative feedback that stabilises the d.c. conditions of the circuit.

C_2 acts as a short circuit around R_E as far as signals are concerned. Without C_2 in the circuit, R_E would act to try and stabilise out the signal variations — not what's wanted in an amplifier. C_2 often called a "decoupling" or "bypass" capacitor.

(iii) Assume that if the current through R_1 + R_2 is ten times I_B, I_B may be regarded as negligible....



If $I_C \approx 2mA$ and $h_{FE} = 100$

$I_B \approx \frac{2}{100} mA = 20\mu A$.

$\therefore I_{R_1} = 10 \times I_B = 200\mu A$

$R_1 + R_2 = \frac{V_{CC}}{I_{R_1}} = \frac{20}{200\mu A} = \underline{100k\Omega}$.

V_B must be 0.7V higher than V_E so for $V_E \approx 4V$, $V_B \approx 4.7V$. and

$V_B = \frac{V_{CC} R_2}{R_1 + R_2}$ or $4.7 = \frac{20R_2}{100k}$ or $R_2 = \underline{23.5k\Omega}$.

$\therefore R_1 = 100k\Omega - 23.5k\Omega = \underline{76.5k\Omega}$

EEE103 June '02 soln...

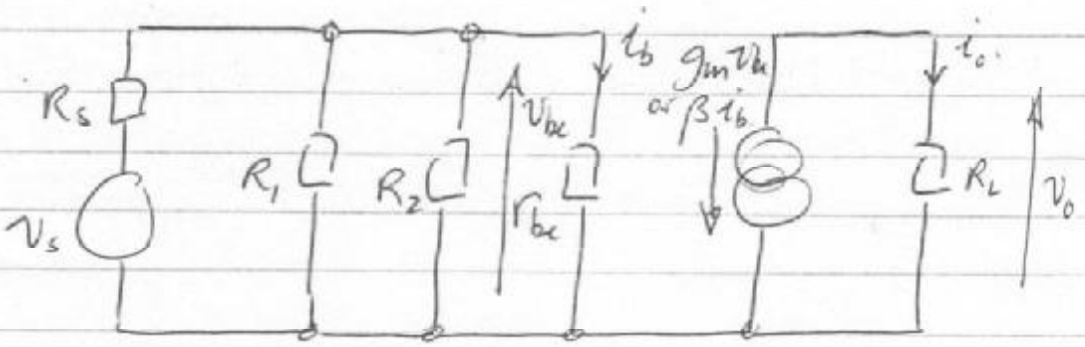
Q3 cont... $R_E = \frac{V_E}{I_E}$ (since $I_C \approx I_E$).

$= \frac{4}{2mA} = \underline{2k\Omega}$

and for V_C of 12V., $V_C = V_{CC} - I_C R_L$

or $R_L = \frac{V_{CC} - V_C}{I_C} = \frac{20-12}{2mA} = \underline{4k\Omega}$.

(iv)



(v) $v_o = i_o R_L = -g_m v_{be} R_L$ since $i_o = -g_m v_{be}$

$v_{be} = v_s \cdot \frac{R_1 \| R_2 \| r_{be}}{R_S + R_1 \| R_2 \| r_{be}}$ by potential division

$\therefore \frac{v_o}{v_s} = -g_m R_L \frac{R_1 \| R_2 \| r_{be}}{R_S + R_1 \| R_2 \| r_{be}}$

$g_m = e\frac{I_C}{kT} = \underline{77mA/V}$. $r_{be} = \beta/g_m = \frac{400}{.077} \approx \underline{5.2k\Omega}$

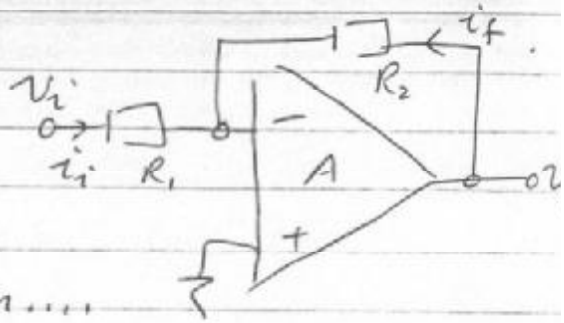
$\therefore \frac{v_o}{v_s} = -.077 \cdot 4k\Omega \cdot \frac{23.5k\Omega \| 76.5k\Omega \| 5.2k\Omega}{2.2k\Omega + 23.5k\Omega \| 76.5k\Omega \| 5.2k\Omega}$

$= -308 \cdot \frac{4.033k\Omega}{2.2k\Omega + 4.033k\Omega} = \underline{-199}$

EEE103 June '02 sols...

Q4. (a) (i) gain = $-R_2/R_1$.

(ii). if A finite, sum currents at v^- node...



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

From the op-amps equn....

$v_o = A(v^+ - v^-) = -Av^-$ since $v^+ = 0$

$\therefore \quad v^- = -v_o/A$

$$\therefore \frac{v_i + v_o/A}{R_1} + \frac{v_o + v_o/A}{R_2} = 0$$

$$-\frac{v_i}{R_1} = \frac{v_o}{AR_1} + \frac{v_o}{R_2} + \frac{v_o}{AR_2} = v_o\left[\frac{R_1+R_2}{AR_1R_2} + \frac{1}{R_2}\right]$$

$$\text{or } \frac{v_o}{v_i} = \frac{-1/R_1}{\frac{R_1+R_2}{AR_1R_2} + \frac{1}{R_2}} = \frac{-R_2/R_1}{\left[1 + \frac{R_1+R_2}{AR_1}\right]}$$

or any correct variant with collected terms.

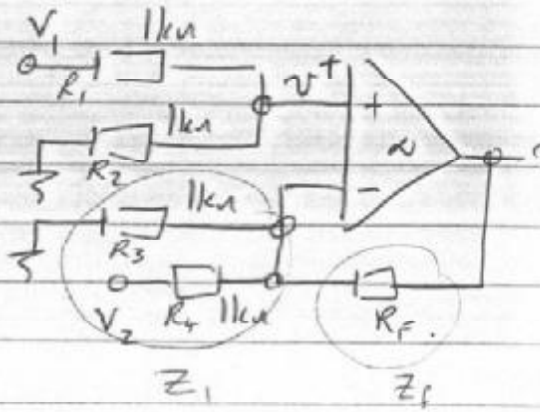
(iii) If $A \Rightarrow \infty$ $r_i = \frac{v_i}{i_i} = R_1$ since v^- = virtual ground

If A reduces, v^- has a signal on it which is in phase with v_i. Thus the voltag across R_1 is smaller than v_i (ie $(v_i - kv_i) < v$ and the apparent input resistance increase

EEE 103 June '02 sols...

Q4 cont....

(b) (i) $v^+ = \frac{V_1}{2}$ by pot div.



$$\frac{V_o}{v^+} = \frac{Z_F + Z_1}{Z_F} = \frac{0.5\text{k}\Omega + R_F}{0.5\text{k}\Omega}.$$

$$\therefore \frac{V_o}{V_1} = \frac{V_o}{v^+} \times \frac{v^+}{V_1} = \frac{1}{2} \cdot \frac{0.5 + R_F}{0.5}$$ where R_F is in kΩ.

considering a.c. part, $V_1 = 4$ and V_o required to be 10. so

$$\frac{10}{4} = \frac{1}{2}\frac{0.5 + R_F}{0.5} \quad \text{or} \quad 5 \times 0.5 = 0.5 + R_F$$

$$\text{or } \underline{R_F = 2\text{k}\Omega}$$

(ii) The gain $\frac{10}{4}$ will also operate on the d.c. component of V_1, ie 5V.

so V_o dc due to $V_1 = 5 \times \frac{10}{4} = \frac{50}{4} = 12.5\text{V}$

Now V_2 is operated on by a gain

$$\frac{V_o}{V_2} = -\frac{R_F}{1\text{k}\Omega}$$ (because R_3 plays no part)

and the output due to V_2 must be equal + opposite to that due to V_1 for the d.c. terms to cancel.

ie $\frac{-12.5}{V_2} = -\frac{R_F}{1\text{k}\Omega} = -2$

required V_o for cancellation

or $\underline{V_2 = 6.25\text{V}}$ to give $V_{o\,dc} = 0$