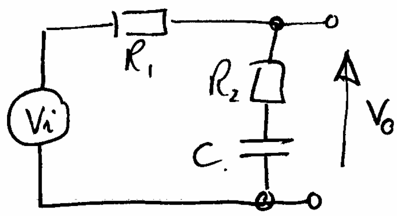
1

Q1 (a) (i) h.f. gain $= \dfrac{R_2}{R_1+R_2}$

(C looks like a short cct in comparison to R_2 ...).



l.f. gain $= 1$

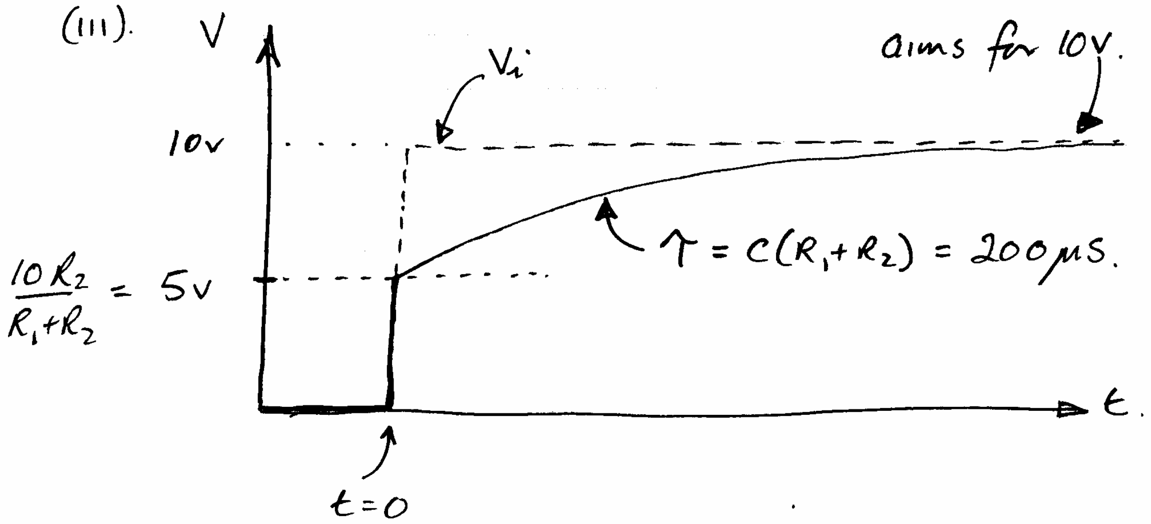
(C looks like an open cct ...)

(ii). $$\frac{V_o}{V_i} = \frac{R_2 + 1/j\omega C}{R_1 + R_2 + 1/j\omega C} = \frac{1 + j\omega C R_2}{1 + j\omega C(R_1+R_2)}.$$

$$\equiv k \cdot \frac{1 + j\,f/f_1}{1 + j\,f/f_0} \quad \text{where } k = 1,\ f_0 = \frac{1}{2\pi C(R_1+R_2)}$$

$$+\ f_1 = \frac{1}{2\pi C R_2}.$$

(iii).



(b) (i) $-3\text{dB BW} = \dfrac{GBP}{G} = \dfrac{20\times10^6}{50} = \underline{400\,\text{kHz}}$ (or $2.5\,\text{M rad s}^{-1}$)

associated $\tau = \dfrac{1}{2\pi \cdot 400\,\text{kHz}} = \underline{398\,\text{ns}}.$

(2)

Q1 (b) (ii) The amplifier is a first order system with $k = 50$ and $f_0 = 400\text{kHz}$.

$$\therefore \quad \frac{v_o}{v_i} = \frac{50}{1 + j\, f/400\text{kHz}} \,.$$ So at 1MHz ...

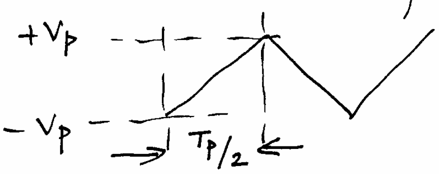
$$\frac{v_o}{v_i} = \frac{50}{1 + j\,\frac{1000\text{ kHz}}{400\text{ kHz}}} = \frac{50}{1 + j\,2.5}$$

$$\therefore \left|\frac{v_o}{v_i}\right| = \frac{50}{(1 + 6.25)^{1/2}} = \underline{\underline{18.6}}\,.$$

$$\phi\left(\frac{v_o}{v_i}\right) = -\tan^{-1}\frac{im}{re} = -\tan^{-1} 2.5 = \underline{\underline{-68^\circ}}$$

(iii) The amplifier slew rate must be equated to max rate of change in the signal ....

max rate of change.



$$= \frac{2V_p}{T_p/2} = \frac{4V_p}{T_p}$$

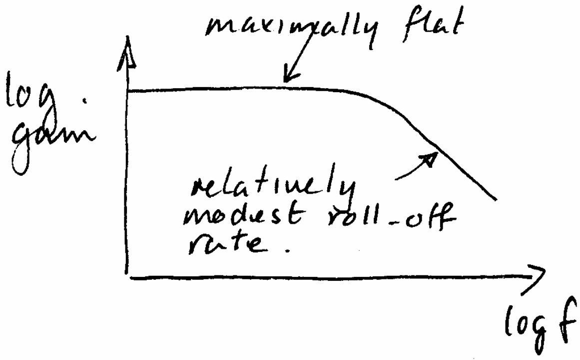
$$= 4 V_p f.$$

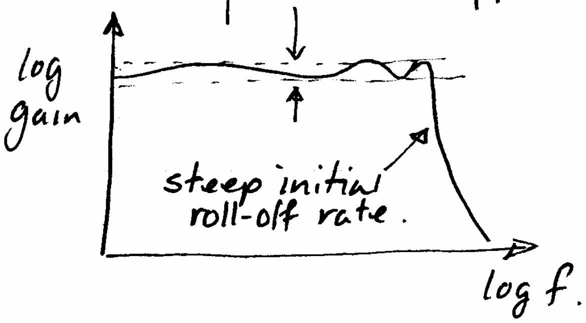
$$\therefore \quad 70 \times 10^6 = 4 \,.\, 10 \,.\, f$$

$$\text{or } f_{max} = \underline{\underline{1.75\text{ MHz}}}.$$

3

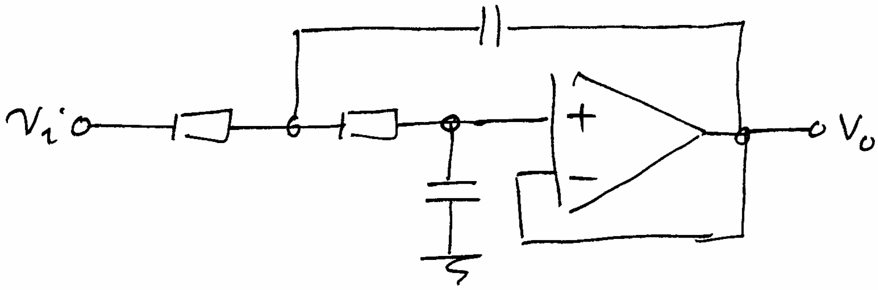
Q2 (i) Butterworth. Chebychev...





- In pass band, Butterworth is as flat as is possible but Chebychev has gain ripple.
- In cut-off region, Chebychev has much steeper initial roll-off than Butterworth although for $f \gg f_c$ the two roll-off rates converge to $n \times 20$ dB / decade where n = filter order.
- Butterworth is attractive because it is much less sensitive to component tolerance errors than Chebychev.

(ii)



(iii)

$$\frac{V_o}{V_i} = \frac{1}{1 + s\,2C_2R + s^2C_1C_2R_2^2}$$

$$\therefore\ \omega_n = \frac{1}{R\sqrt{C_1C_2}}$$

$$\frac{1}{\omega_n q} = 2C_2R \quad \underline{\text{or}} \quad \frac{1}{q} = \omega_n 2C_2R$$

Q2 (iii) cont...

$$= \frac{2C_2R}{R\sqrt{C_1C_2}} = 2\sqrt{\frac{C_2}{C_1}}$$

$$\therefore \quad q = \frac{1}{2}\sqrt{\frac{C_1}{C_2}}$$

(iv) – 2nd order factor is $\dfrac{1}{s^2 + 0.299s + 0.839}$

$$= \frac{1}{0.839\left(1 + \frac{0.299}{0.839}s + \frac{s^2}{0.839}\right)}.$$

[the multiplying term can be discarded].

$$\therefore \quad \frac{\omega_n}{\omega_c} = (0.839)^{1/2} = 0.916.$$

and $\dfrac{1}{\frac{\omega_n}{\omega_c}q} = \dfrac{0.299}{0.839}$ or $\dfrac{1}{q} = \dfrac{0.299 \times 0.916}{0.839}$

$= 0.326.$

$$\therefore \quad q = 3.06.$$

so for cut off of 20kHz, $f_n = 0.916 \times 20\text{kHz}$

$= 18.3\text{kHz}$

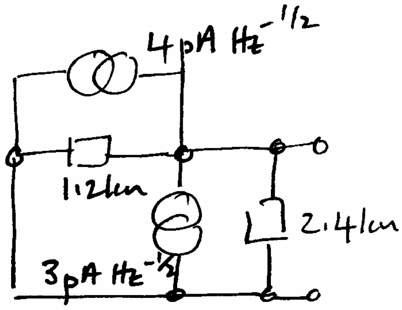
– first order factor $\dfrac{1}{s + 0.299} = \dfrac{1}{0.299(1 + s/0.299)}$

$$\therefore f_0 = 0.299 \times 20\text{kHz} = 5.98\text{ kHz}$$

and $\tau = \dfrac{1}{2\pi f_0} = 26.6\,\mu s.$

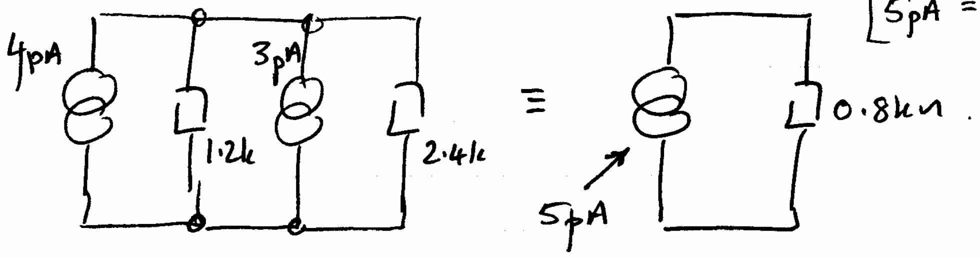
(v) $3.06 = \dfrac{1}{2}\sqrt{\dfrac{C_1}{C_2}}$ or $\dfrac{C_1}{C_2} = 4 \times 3.06^2 = 37.5.$

Q3 (a) (i) By inspection...
R_{Th} = 0.8 kΩ



There are several ways of approaching the next bit...
Both the current sources and the resistors could be combined to produce a single parallel combination.... I'll do it this way....

$\left[5\,pA = \sqrt{4pA^2 + 3pA^2}\right]$



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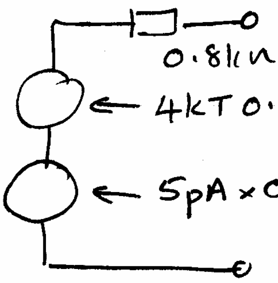


← $4kT\,0.8k\Omega = 13.25\times10^{-18}\ V^2\,Hz^{-1}$

← $5pA \times 0.8k\Omega = 4\,nV\,Hz^{-1/2}$

$$\therefore\ \overline{v_{nTh}^2}\Big|_{tot} = 13.25\times10^{-18} + 16\times10^{-18} = 29.25\times10^{-18}$$

$$\therefore\ v_{nTh} = \underline{\underline{5.4\ nV\ Hz^{-1/2}}}.$$

(ii) If all the noise came from R_{Th}...

$$4kT_e R_{Th} = 29.25\times10^{-18}$$

$$\text{or}\quad T_e = \frac{29.25\times10^{-18}}{4.k.0.8k\Omega} = \underline{\underline{662\ K}}.$$

(b) By definition $F = \dfrac{S_i/N_i}{S_o/N_o} = \dfrac{S_i}{S_o}\cdot\dfrac{N_o}{N_i}$

Q3(b) cont...

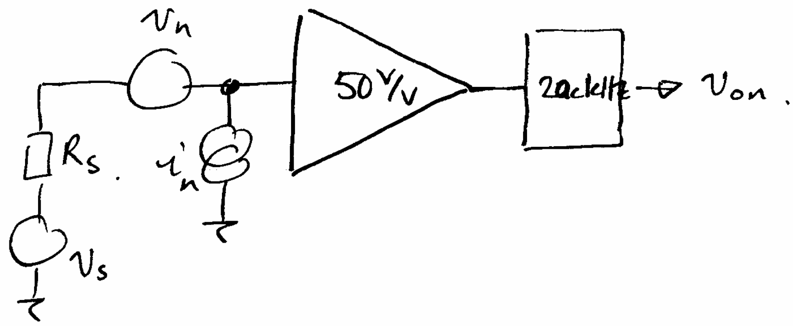
but $\frac{S_i}{S_o} = \frac{1}{A_p}$

and $N_o = A_p N_i + N_A$

amplified input noise — amplifier "added" noise.

$$\therefore\ F = \frac{N_o}{A_p N_i} = \frac{A_p N_i + N_A}{A_p N_i} = \underline{\underline{1 + \frac{N_A}{A_p N_i}}}.$$

(c)



$$\overline{v_{on}^2} = 50^2\left[v_n^2 + i_n^2 R_s^2 + 4kTR_s\right] \times 20\,\text{kHz}$$

$$= 2500\left[144\times10^{-18} + 400\times10^{-18} + 166\times10^{-18}\right]\times 20\,\text{kHz}$$

$$= 2500\left[710\times10^{-18}\right]\times 20\,\text{kHz} = \underline{\underline{35.5\times10^{-9}\ V^2}}.$$

$$\overline{v_{o\,sig}^2} = (30\,\mu V)^2(50)^2 = \underline{\underline{2.25\times10^{-6}\ V^2}}.$$

$$\therefore\ S/N = \frac{2.25\times10^{-6}}{35.5\times10^{-9}} = \underline{\underline{63.4}}\ [= 18\,\text{dB}.]$$

Q4 (a)

(i) T_1, R_1 and R_2 form a floating voltage source with a value of approximately 1.4V. It is included in order to bias out the missing 1.4V due to the transistor base-emitter voltage drops that would otherwise give rise to serious crossover distortion.

(ii) Because transistor characteristics are not perfect and because they drift slightly with temperature, designers aim to ensure a smooth transition from conduction in one to conduction in the other by designing in a small conduction overlap.

(iii)
- $R_3 + R_4$ together with the voltage across T_1 allow the output quiescent current to be defined
- They also give the circuit a defence against the destructive process of "thermal runaway".

(b)

(i)
$$\underbrace{P_{supplied}}_{2V_{cc} I_{S\,AVE}} = \underbrace{P_{DISS}}_{?} + \underbrace{P_{LOAD}}_{\frac{V_p^2}{2R_L}}$$

or
$$P_{DISS} = 2V_{cc}\frac{V_p}{\pi R_L} - \frac{V_p^2}{2R_L} \qquad \text{——— (1)}$$

to find max P_{DISS}, equate $\frac{dP_{DISS}}{dV_p}$ to zero...

$$\frac{dP_{DISS}}{dV_p} = \frac{2V_{cc}}{\pi R_L} - \frac{2V_p}{2R_L} = 0$$

or
$$V_p = \frac{2V_{cc}}{\pi} \qquad \text{——— (2)}$$

substituting condition (2) back into (1) gives

$$P_{DISS} = \frac{2V_{cc}\left(\frac{2V_{cc}}{\pi}\right)}{\pi R_L} - \frac{\left(\frac{2V_{cc}}{\pi}\right)^2}{2R_L}$$

Q4 (b) (i) cont...

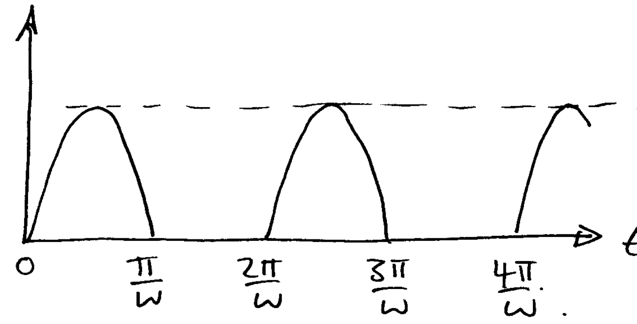
$$\text{so } P_{DISS} = \frac{4V_{cc}^2}{\pi^2 R_L} - \frac{4V_{cc}^2}{2\pi^2 R_L} = \frac{2V_{cc}^2}{\pi^2 R_L}.$$

but this is the total power dissipated, ie, the dissipation in both devices. The dissipation in one device will be half of this..., ie,

$$P_{DISS}/_{device} = \underline{\underline{\frac{V_{cc}^2}{\pi^2 R_L}}}.$$

(ii) $\max P_L = \dfrac{V_{cc}^2}{2R_L} = \dfrac{1600}{8} = \underline{\underline{200\,W}}.$

(iii)



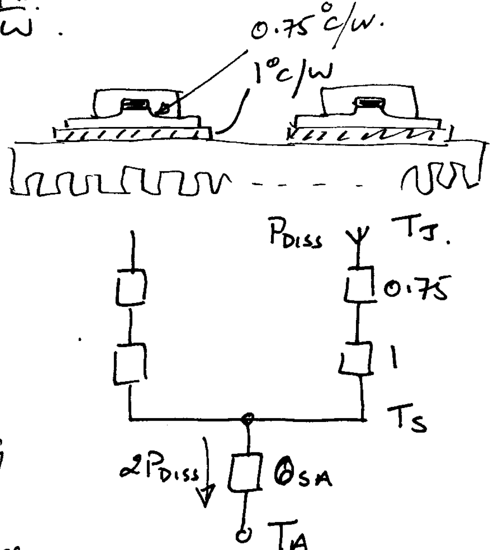
$I_{LPM} = \dfrac{40}{4} = \underline{\underline{10\,A}}.$

(iv). $P_{DISS} = 40.5\,W/\text{device}$

Assume T_j is the limiting factor...

$T_S = T_j - (0.75+1)\times 40.5$
$= 150 - 70.1 = 79.9$

which is lower than max T_S allowed $\rightarrow$ T_j is limiting factor



$\therefore T_S - T_A = 2P_{DISS}\theta_{SA} = 81\,\theta_{SA}$

$$\text{or } \theta_{SA} = \frac{T_S - T_A}{81} = \frac{79.9-35}{81} = \underline{\underline{0.55\,°C/W}}.$$