1A Analysis of ccts + dev Ex #3 CRIBS

Q1 a) DC $\Rightarrow$ No C + $C_L$ $\equiv$ open cct

$\Rightarrow$ input $V_{in}$ $\Rightarrow$ pot divider $\dfrac{R_{in}}{R_S+R_{in}}$

$$\Rightarrow V' = V_{in}\frac{R_{in}}{R_S+R_{in}} = V_{in} \text{ as } R_{in} = 1M\Omega \gg 1k\Omega$$

at output $V_{out} = 100V' \dfrac{R_L}{R_{out}+R_L} = 100V_{in}\dfrac{9k}{1k+9k}$

$= 90V_{in}$

$$\Rightarrow \frac{V_{out}}{V_{in}} = 90$$

b) Include $C_L // R_L$ $= \dfrac{R_L \, {}^1/_{j\omega C_L}}{R_L + {}^1/_{j\omega C_L}} \times \dfrac{j\omega C_L}{j\omega C_L} = \dfrac{R_L}{1+j\omega C_L R_L}$

From Midband (a) $V_{out} = 100 V_{in} \dfrac{R_L}{R_{out}+R_L}$

Replace $R_L$ with $R_L // R_L$

$$\Rightarrow \frac{V_{in}}{V_{out}} = 100 \frac{R_L/_{1+j\omega C_L R_L}}{R_{out} + R_L/_{1+j\omega C_L R_L}} \times \frac{1+j\omega C_L R_L}{1+j\omega C_L R_L}$$

$$= \frac{100 R_L}{R_L + (1+j\omega C_L R_L)R_{out}} \quad \left(\frac{A+jB}{C+jD}\right) \Rightarrow C = D \text{ at 3dB.}$$

$\Rightarrow R_L + R_{out} = \omega C_L R_L R_{out}$ $\Rightarrow f = \dfrac{R_L + R_{out}}{2\pi C_L R_L R_{out}} = 980\text{kHz}$

1

c) Switch to AC & ignore $C_L$ ($\equiv$ open cct)

$$\Rightarrow \quad V_{out} = 100 v_{in} \frac{R_L}{R_{out} + 1/j\omega C + R_L} \times \frac{j\omega C}{j\omega C}$$

$$= \frac{j\omega C R_L}{1 + j\omega C (R_{out} + R_L)}$$

$\Rightarrow$ 3dB ($1/\sqrt{2}$) when $1 = \omega C (R_{out} + R_L)$

$$\Rightarrow f = \frac{1}{2\pi C (R_{out} + R_L)} = 1.6\,Hz$$

d) Power gain defined as: $\left|\frac{V_{out}}{V_{in}}\right|^2 \times \frac{R_{in}}{R_L}$

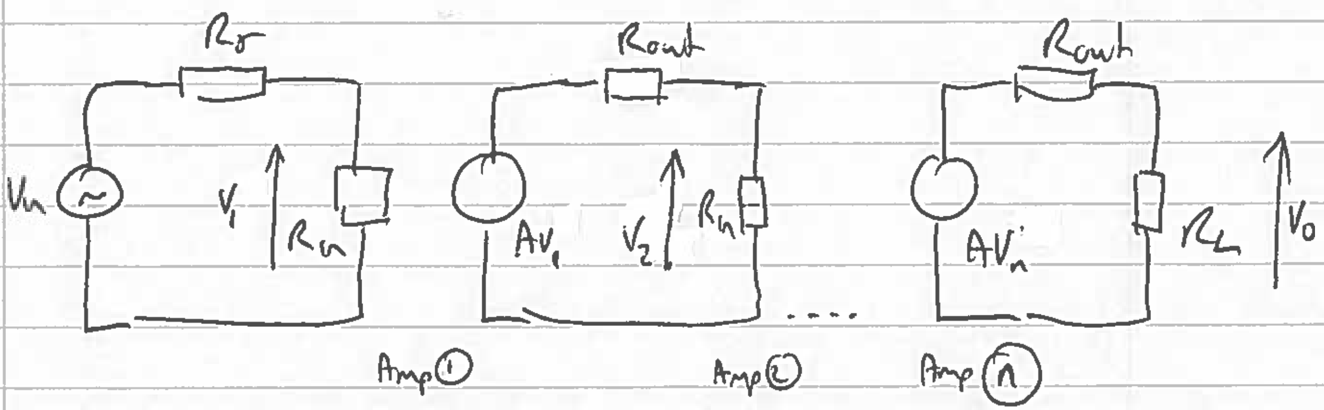
in decibels $= 10 \log_{10} \left[ \left|\frac{V_{out}}{V_{in}}\right|^2 \frac{R_{in}}{R_L} \right]$

$$= 10 \log_{10}(900{,}000) = 59.5\,dB$$

e) In dB, add power gain

$$\Rightarrow G = 40 - 4 + 59.5 = 95.5\,dB$$

Q2) Multi-stage cascaded amplifier



At input $V' = \frac{R_{in}}{R_S + R_{in}} V_{in}$

1st amp output to 2nd amp input

$$V_2 = A V_1 \frac{R_{in}}{R_{in} + R_{out}}$$

This then repeats n-1 times till the last ($n^{th}$) stage out-put

$$V_o = \frac{R_L}{R_{out} + R_L} A V_n$$

$\Rightarrow$ Total gain of the cascade

$$G = \frac{V_o}{V_{in}} = \left(\frac{R_{in}}{R_S + R_{in}}\right) \times \left(\frac{A R_{in}}{R_{in} + R_{out}}\right)^{n-1} \times \frac{A R_L}{R_{out} + R_L}$$

~~Fa~~ Input voltage $V_{in} = 1\,mV_{p-p} = 0.5\,mV_p$

$V_o$ required $= 1\,V_p$ $\quad$ 22dB $\rightarrow A = 12.59$ per stage

$$\Rightarrow \text{Gain} = 1/0.5\times10^{-3} = 2000$$

$$\Rightarrow 2000 = \left(\frac{100K}{10K + 100K}\right)\left(\frac{100k \times 12.59}{100k + 1k}\right)^{n-1}\left(\frac{12.59 \times 100k}{1k + 100k}\right)$$

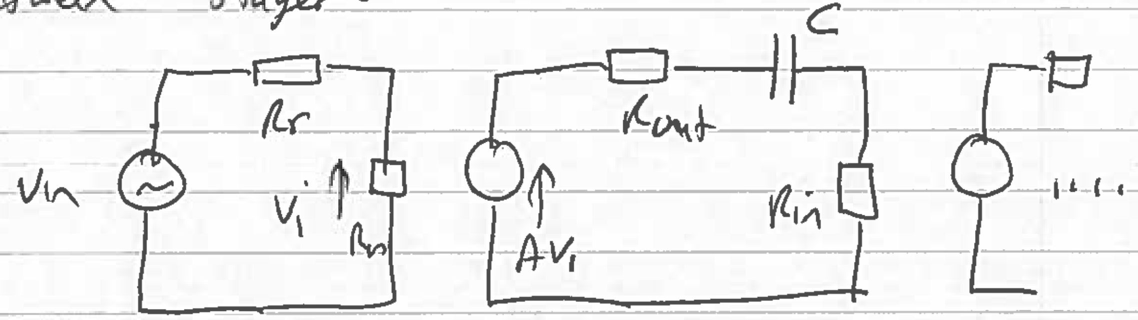
$$= 0.91 \times (12.47)^{n} \cancel{(12.47)}$$

$$(12.47)^n = \frac{2000}{0.91} = 2198 \quad \Rightarrow n = 3.05$$

3 stages will be ok as can add a bit of extra gain to 1 stage.

Q2 cont

Each stage has its own DC biasing and we do not want DC currents between stages, hence we add a capacitor between each stage to block ~~the~~ DC and allow AC signals to pass between stages



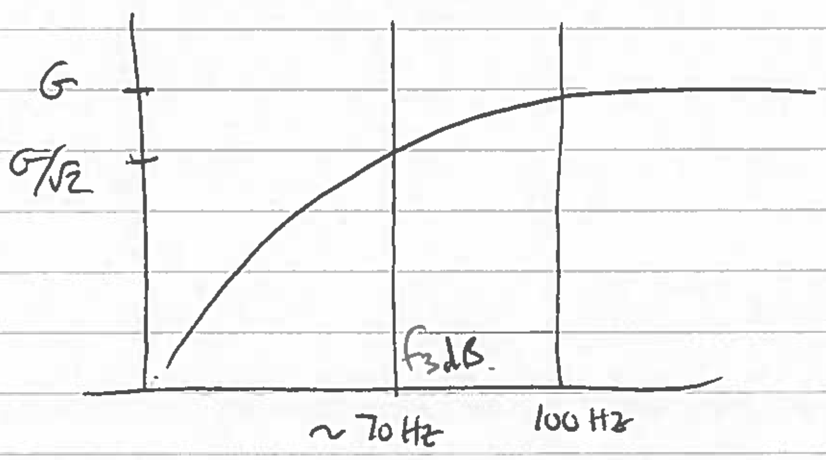

This is in fact the same situation as in Q1 part (c) where C is acting as a decoupling capacitor between each stage, but $R_L = R_{in}$

From Q1 (c) $\Rightarrow$ $$f = \frac{1}{2\pi C(R_{out} + R_{in})}$$

$$f = 100\,Hz \Rightarrow C = \frac{1}{2\pi \times 100 \times (100\times10^3 + 1\times10^3)}$$

$$= 1.58 \times 10^{-8}\,F$$
$$(15.8\,nF)$$

In reality we would probably choose a 3dB frequency less than 100Hz to reduce the effect of the $1/\sqrt{2}$ attenuation at the 3dB freq.



3. Use $R = \frac{\rho l}{A}$, $= R = \frac{\rho \times 100 \times 10^{-6}}{10 \times 10^{-6} \times 1 \times 10^{-6}}$ $= 10^7 \rho$

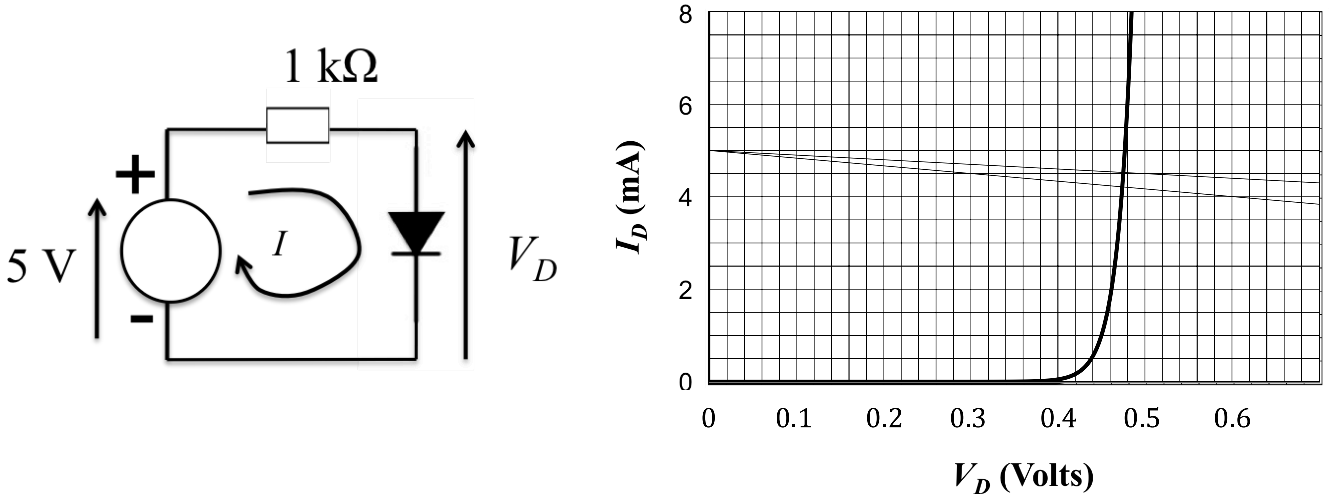
Copper, $\rho$= 1.7x10$^{-8}$ Ωm => R = 0.17 Ω

Current, $I = V/R = \frac{1\text{ V}}{0.17\ \Omega}$ = 5.88 A

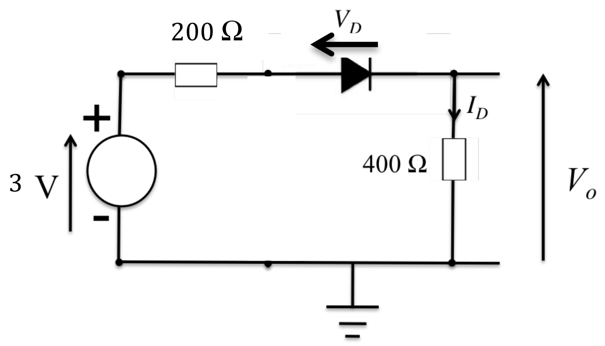
Power, $P = VI$ = 5.88 W.

4. Draw the load-line, using the relationship $V_D = 5\text{-}1000I_D$. => $I_D = 5\text{x}10^{-3} - V_D/1000$, or $I_D$ (mA) = 5-$V_D$ (mV) [this is the upper line shown below]. This intercepts the diode curve at $I_D$ = 4.5 mA, $V_D$ = 0.475 V.

(a) (b)



5. Replace the battery and the 600 Ω and 300 Ω resistors with their Thevenin equivalent to simplify the circuit:




$V_0 = 400I_D$

Applying Kirchoff's voltage law around the loop, we obtain:

$3 - 200I_D - V_D - 400I_D = 0$ …………there will be a voltage *drop* across the diode.

$$=> I_D = \frac{3}{600} - \frac{V_D}{600}$$

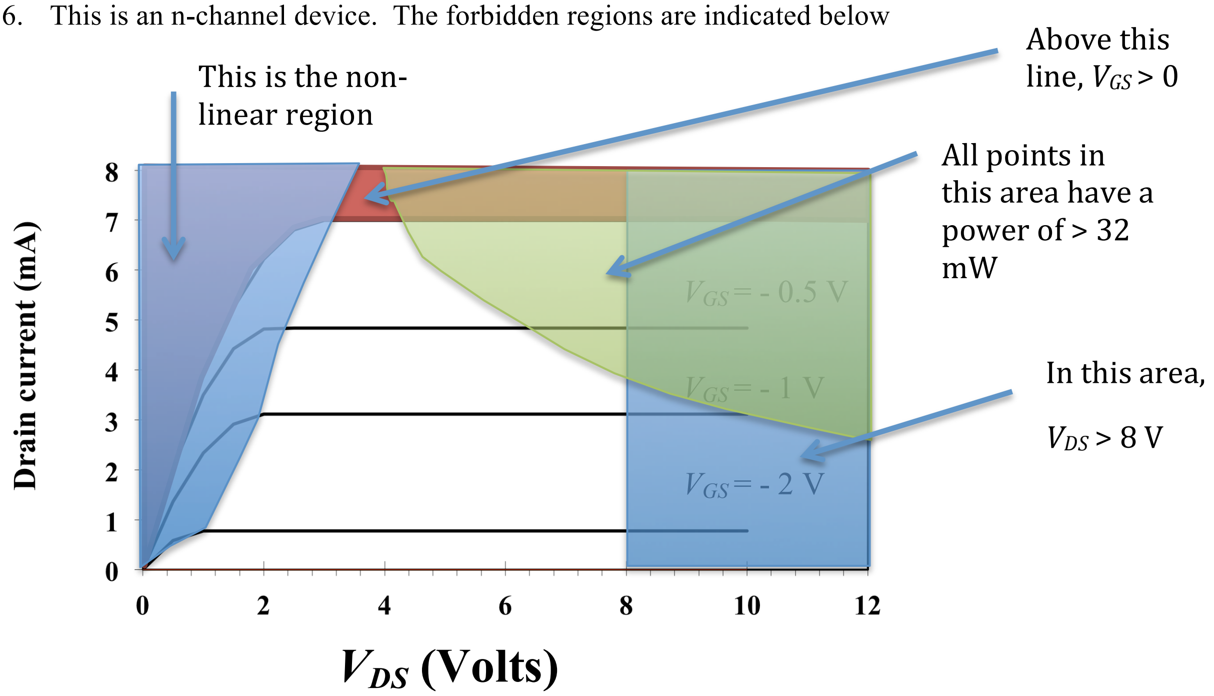
From which we find that $I_D$ (mA) = $5 - 1.66V_D$ (mV)

This is the lower line on the diode curve, from which we find that at $I_D = 4.25$ mA, $V_D = 0.4$ V.

The output voltage, $V_0 = 400I_D = 1.7$ V.

**FET Amplifiers**

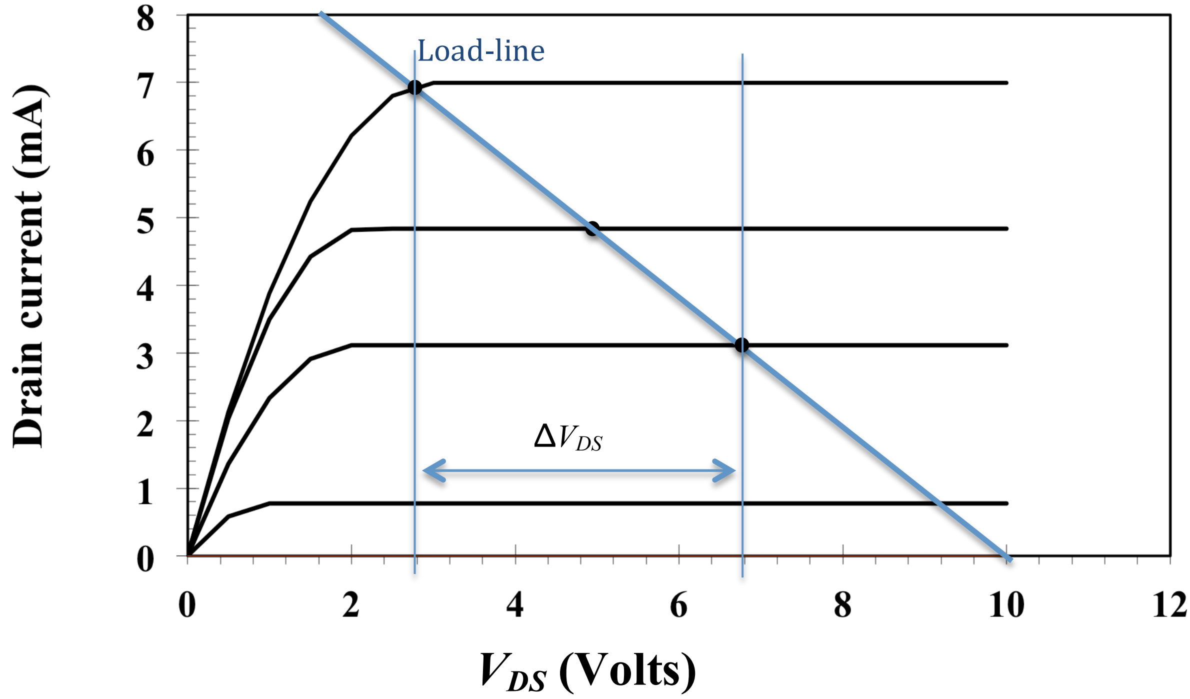
6. This is an n-channel device. The forbidden regions are indicated below



6 7. The operating point is P, where VDS = 5 V, $V_{GS}$ = - 0.5 V, $I_D$ = 4.8 mA.

(i) The voltage across $R$ = 10 V – $V_{DS}$ = 5 V.

=> $R$ = 5V/4.8 mA = 1.042 kΩ.




(ii) From the load-line, when $V_{GS}$ changes between 0 & - 1 V, the load-line intercepts move to $V_{DS}$ = ~ 2.8 V and 6.8 V. Therefore, the change in $V_{DS}$ is 4 V. The gain is (change in $V_{DS}$)/(change in $V_{GS}$) = - 4.

7 8. The operating point is the same as before, so the voltage across $R_2$ is 0.5 V ($V_{GS}$).

⇨ $R_2$ = 0.5 V/4.8 mA = 104.2 Ω.

The voltage across $R_1$ is 10 V – 5 V – 0.5 V = 4.5 V, => $R_1$ = 4.5 V/4.8 mA = 937.5 Ω.