Solutions 080109

1 a) In a linear regulator the current is equal before and after the regulator but the voltage is reduced giving an efficiency $\eta = \frac{P_{out}}{P_{in}} = \frac{U_{out} \cdot \cancel{I_{out}}}{U_{in} \cdot \underbrace{\cancel{I_{in}}}_{=I_{out}}} = \frac{U_{out}}{U_{in}}$

In a switched regulator the current is increased when the voltage is reduced.

b)

$R_{in} = \infty$

$R_{out} = 0$

$A_{V0} = \infty$

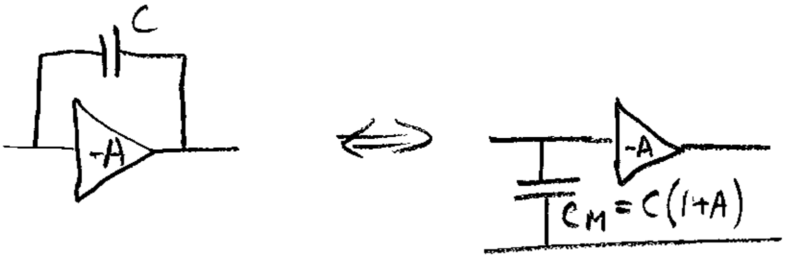
$I_{in} = 0$

$V_{in\,diff} = 0$

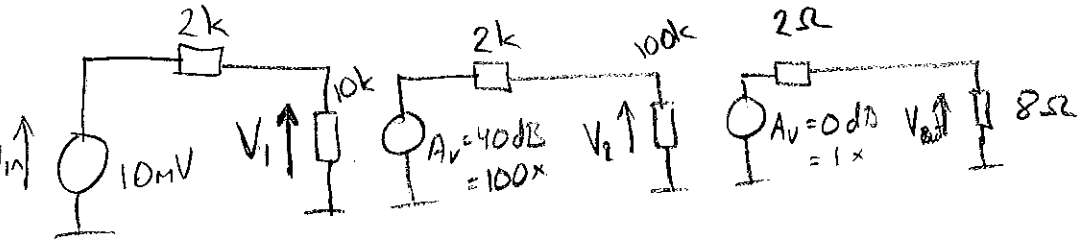
c) The noise bandwidth of an non-ideal filter is the bandwidth of an ideal filter which will pass the same noise power as the non-ideal filter.

$BW_N > BW_{-3dB}$ $(BW_N = 1{,}57 \cdot BW_{-3dB}$ for a 1_{st} order filter)

d) A capacitor connected between the input and output of an inverted amplifier behaves like an larger amplifier connected at the input.



2|



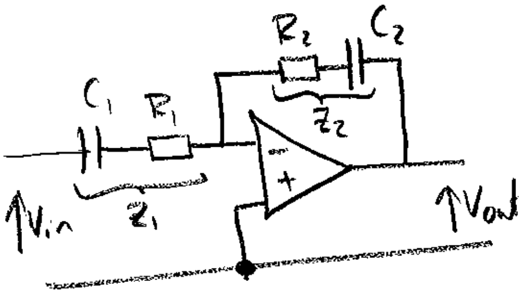
Voltage division

$$V_1 = V_{in}\frac{10}{10+2} = V_{in}\frac{10}{12}$$

$$V_2 = 100 \times V_1 \times \frac{100}{100+2} = 100 \cdot V_{in}\frac{10}{12}\frac{100}{102}$$

$$V_{out} = 1 \times V_2 \times \frac{8}{8+2} = 100\cdot V_{in}\frac{10}{12}\frac{100}{102}\frac{8}{10} = 65\cdot V_{in} = \underline{650\,mV}$$

3 a|



$$Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1+j\omega R_1 C_1}{j\omega C_1}$$

$$Z_2 = \frac{1+j\omega R_2 C_2}{j\omega C_2}$$

$$H(\omega) = A_V = -\frac{Z_2}{Z_1} = -\frac{\dfrac{1+j\omega R_2 C_2}{\cancel{j\omega} C_2}}{\dfrac{1+j\omega R_1 C_1}{\cancel{j\omega} C_1}} = -\frac{C_1}{C_2}\,\frac{1+j\omega R_2 C_2}{1+j\omega R_1 C_1}$$

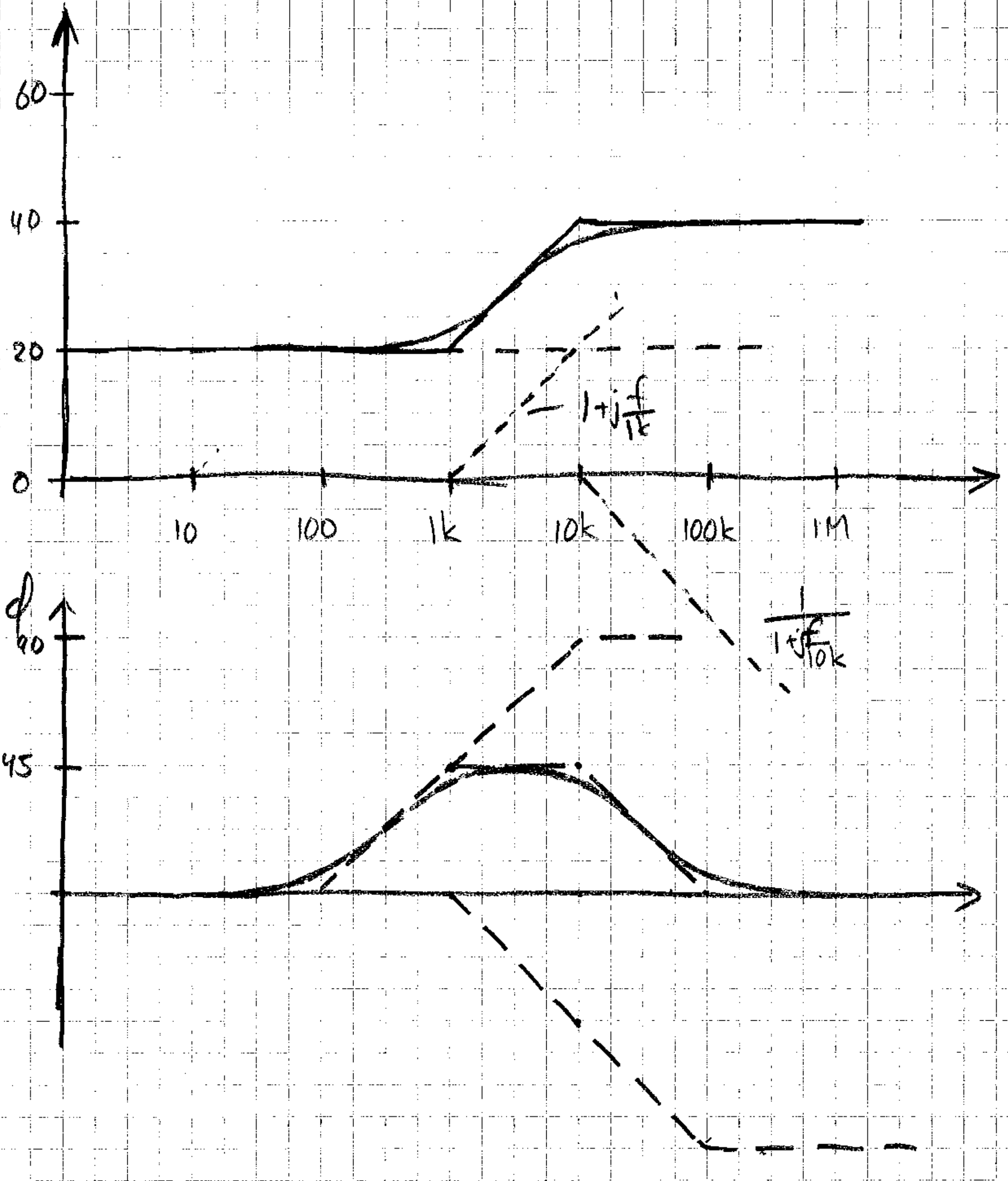
$$= -\frac{C_1}{C_2}\,\frac{1+j\frac{f}{f_1}}{1+j\frac{f}{f_2}}$$

$$f_2 = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi 40\cdot 40n} = 10\,kHz$$

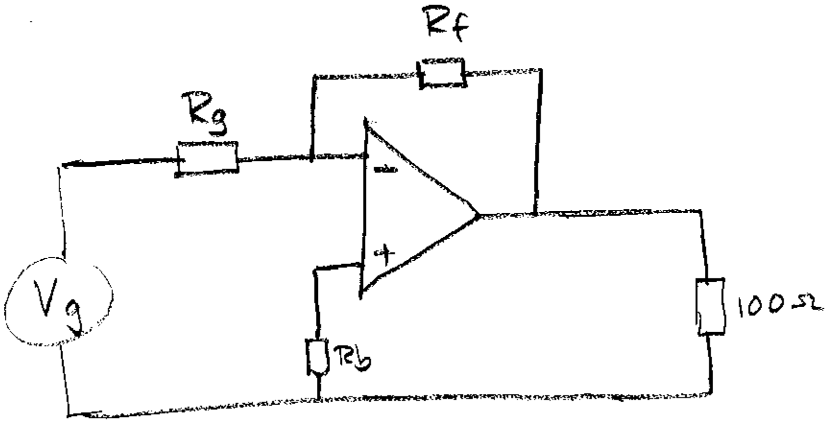
$$f_1 = \frac{1}{2\pi R_2 C_2} = \frac{1}{2\pi 40k\,4n} = 1\,kHz$$

$$\frac{C_1}{C_2} = \frac{40}{4} = 10 \quad (20dB)$$

3 b)



4



$V_g = 100\mu V$ $\quad A_v = -\frac{R_f}{R_g} = \frac{1k}{50} = 20\,\text{times}$ Fig 2, page 3 in data sheet

$\Rightarrow$ -3 dB @ 100 MHz

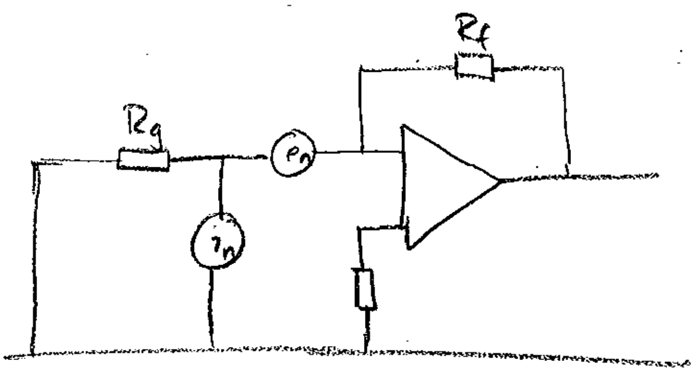
$\Rightarrow A_v = 10$ times

$V_{out} = V_g \cdot A_v = 100\mu \times 10 = .1\,mV$

a]

$P_{out} = V_{out} \cdot I_{out} = V_{out} \frac{V_{out}}{R_L} = \frac{V_{out}^2}{R_L} = \frac{.1\,mV^2}{100} = 10\,nW$

b]



$V_n = \sqrt{e_n + i_n \cdot R_g \underbrace{+4kTgR_g}_{\text{Ger inga poängavdrag}}} = \sqrt{(1,05\cdot10^{-9})^2 + (1,6\cdot10^{-12}\cdot50)^2 + 16,4\cdot10^{-21}\cdot50}$

$= 1,38\,nV/\sqrt{Hz}$

$V_{noise_{out}} = A_v \cdot V_n \cdot \sqrt{BW_N} = 20 \cdot 1,38\cdot10^{-9} \cdot \sqrt{100\,MHz \cdot 1,57}$

Fig 2, page 3 in datasheet

Bandwidth

→ Noise BW

Also in text page 6 datasheet

$= 350\,\mu V$

$P_{noise_{out}} = \frac{V_{noise_{out}}^2}{R_L} = \frac{350\cdot10^{-6^2}}{100} = 1,2\,nW$

$$SNR = \frac{P_{out}}{P_{Noise\,out}} = \frac{10nW}{1{,}2nW} = 8{,}3 \text{ times}$$

c) By filtering the amplifier to only cover the 100 MHz band with a BW of 5 MHz would not affect the signal but reduce the noise $\sqrt{\frac{100}{5}} = 4{,}5$ times

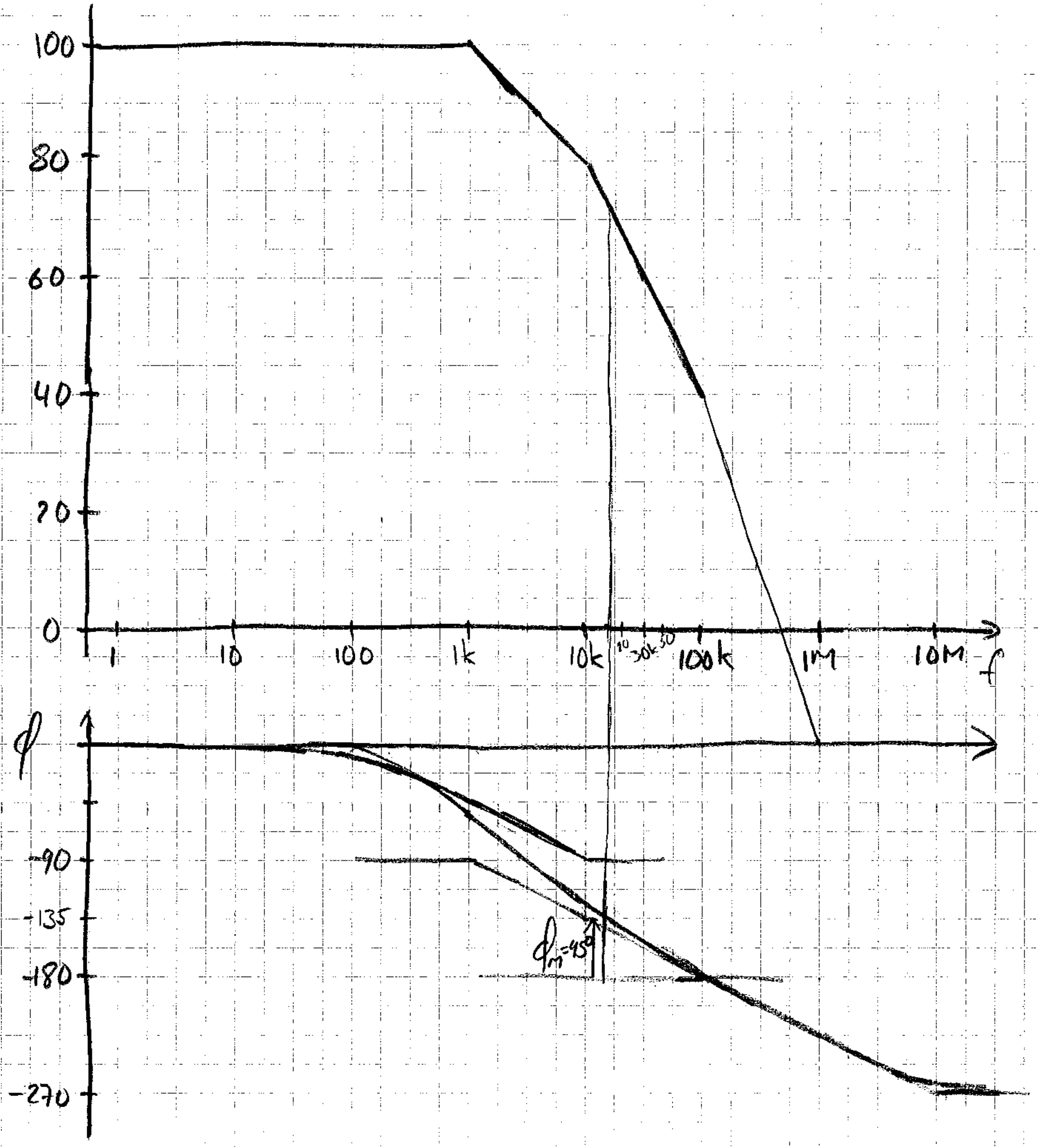
$$\Rightarrow SNR \simeq 8{,}3 \times 4{,}5 = 37 \text{ times}$$

(A low pass filter would be enough as the amplifier itself have a upper bandwidth of 100 MHz.

5]

a]

$$A_{v_0} = \frac{100\ 000}{\left(1+j\frac{f}{1k}\right)\left(1+j\frac{f}{10k}\right)\left(1+j\frac{f}{1\,MHz}\right)}$$



b| $\phi_M = 45°$ ($\phi = -135°$) @ approx 15 kHz

This is the highest frequency the amplifier can be used as an amplifier.

c|

B	Av	
$0-2{,}5 \cdot 10^{-4}$	100-72 dB	Stable
$2{,}5 \cdot 10^{-4} - 0{,}01$	72 - 40 dB	Nearly stable
$0{,}01 - 1$	40 - 0 dB	Unstable

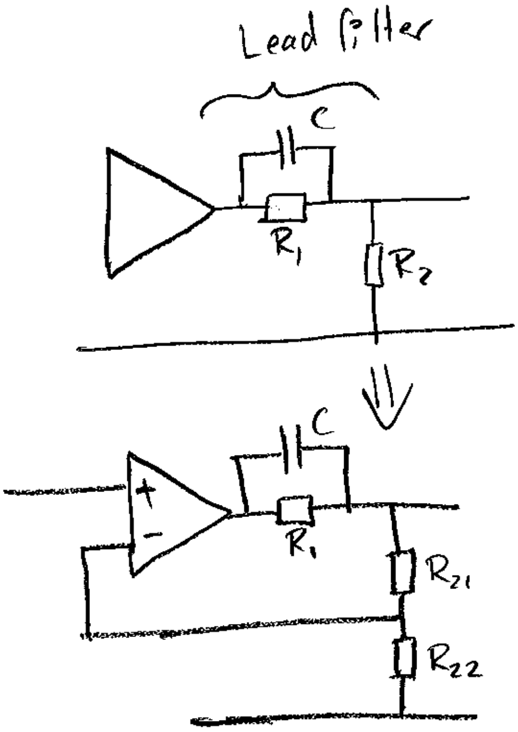
See separate bode diagrams

d| $f_1 = 10$ kHz (2nd pole)

$f_2 = 1$ MHz (10×3rd pole)

e| Se separate bode diagram

f|



$A_{v0} \cdot$ Filter

$\frac{R_2}{R_1+R_2} = 0{,}01$ $R_1 = 100 \cdot R_2$

Let $R_1 = 100k$, $R_2 = 1k$

$f_1 = \frac{1}{2\pi R_1 C}$ $C = \frac{1}{2\pi f_1 \cdot R_1} = 160pF$

20 dB amp (100 times)

$B = 0{,}01$ $(= \frac{1}{A_v})$

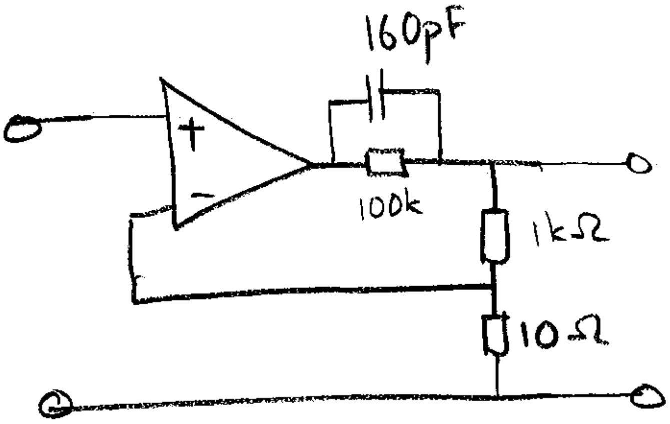
Feed-back factor

Voltage division

$$B = \frac{R_{22}}{R_{21}+R_{22}} = 0,01 \quad \Longrightarrow \quad R_{21} = 100 \cdot R_{22}$$

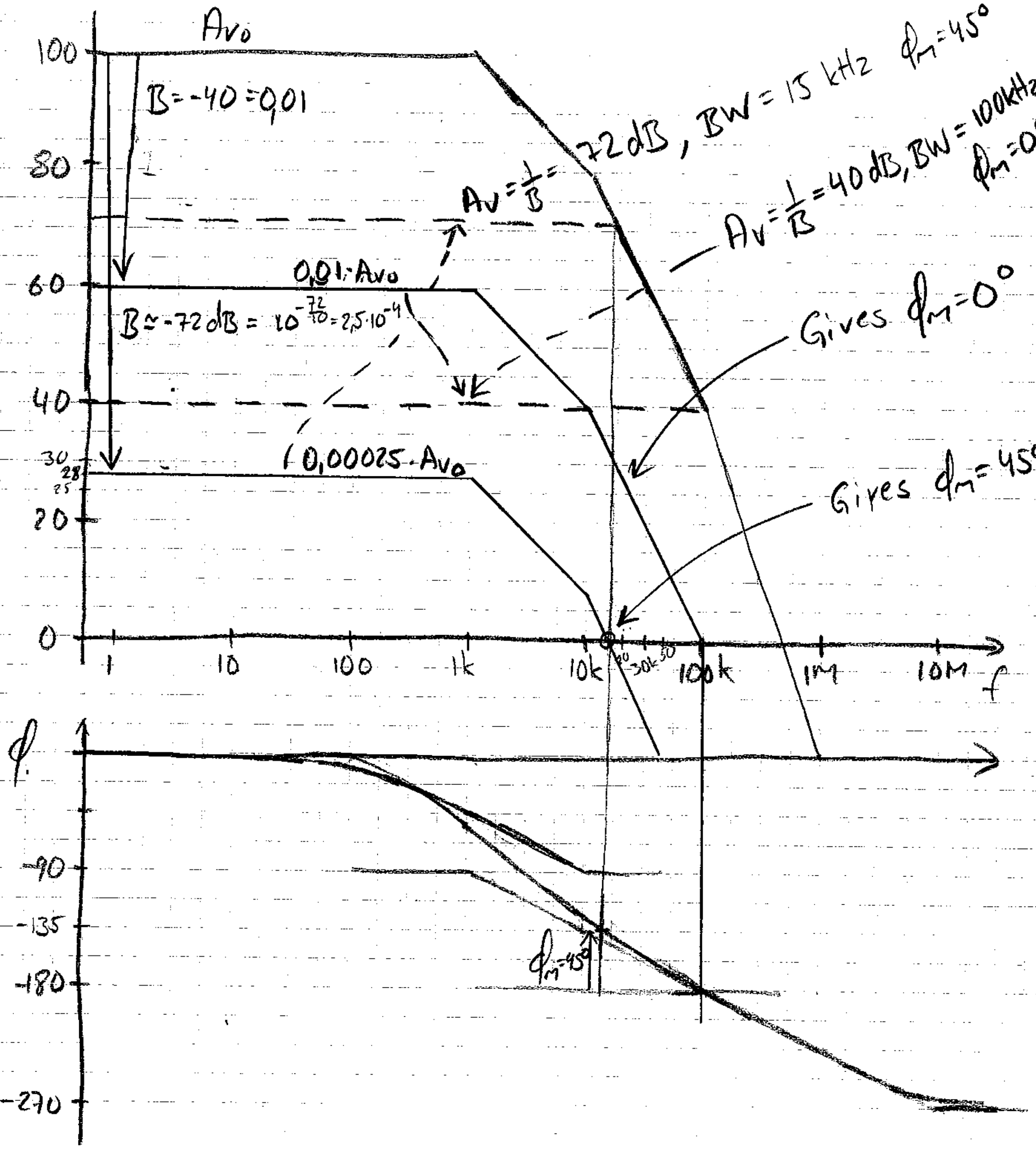
But $R_{21}+R_{22} = R_2 = 1k\Omega$

$$\Rightarrow R_{21} = 1k\Omega \; , \; R_{22} = 10\,\Omega$$



5) c)

$$A_{vo} = \frac{100\ 000}{\left(1+j\frac{f}{1k}\right)\left(1+j\frac{f}{10k}\right)\left(1+j\frac{f}{1MHz}\right)}$$



5] e]

$$A_{vo} = \frac{100\ 000}{\left(1+j\frac{f}{1k}\right)\left(1+j\frac{f}{10k}\right)\left(1+j\frac{f}{1MHz}\right)}$$