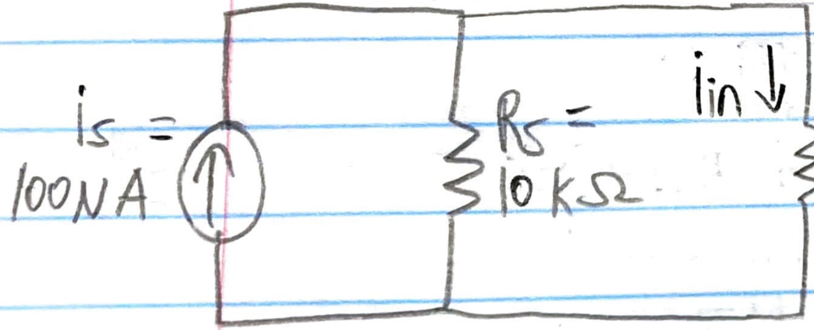
Noble Huang (Mulia Widjaja)

HW #4: Amplifiers

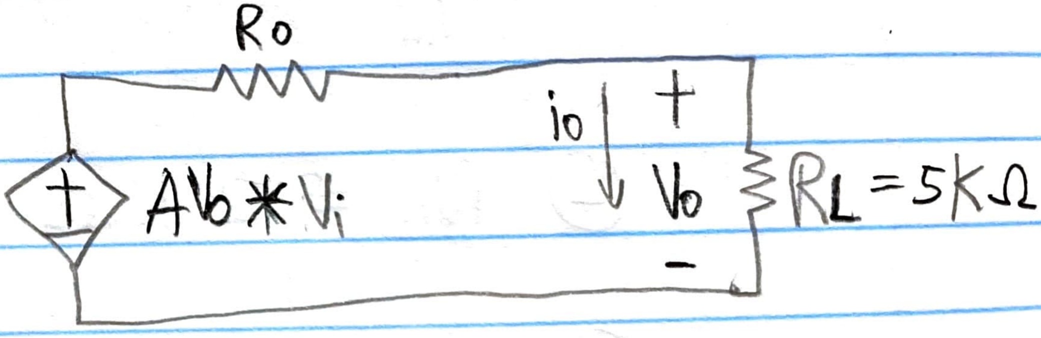
1. a. $\text{Gain} = \frac{V_o}{i_{in}} = \frac{50\text{ mV}}{1\text{ NA}} = \frac{50\cdot\cancel{10^{-3}}}{10^{\cancel{-6}-3}} = 50000\text{ V/A}$

Input current (I_{in})

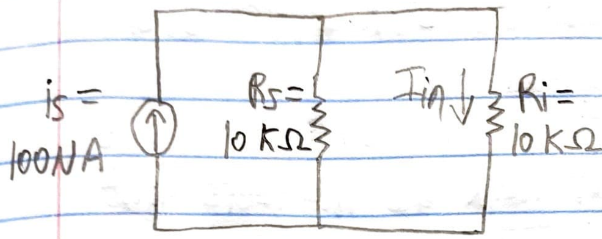


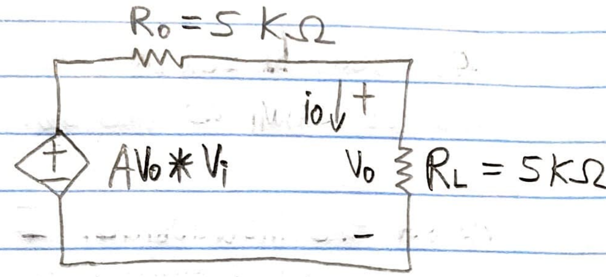
$R_i \ll R_s$

Output Voltage (V_o)

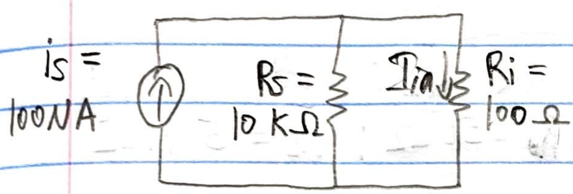


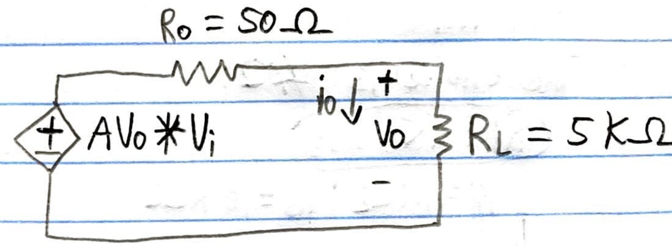
① $R_i = 10\ K\Omega$; $R_o = 5\ K\Omega$



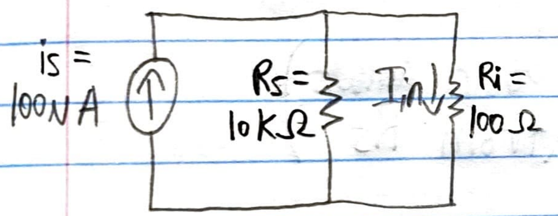


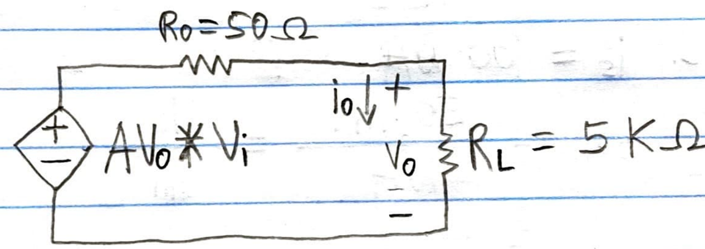
② $R_i = 100\ \Omega$; $R_o = 50\ \Omega$



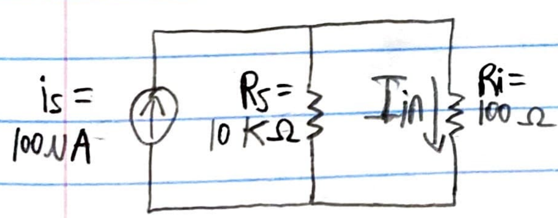


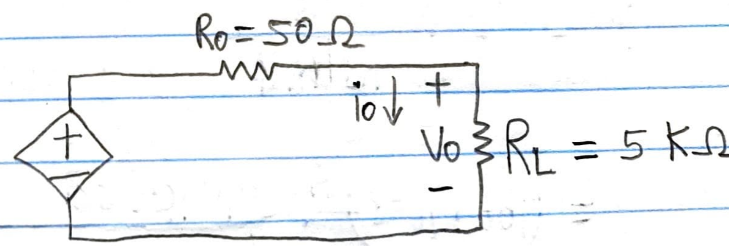
③ $R_i = 10\ K\Omega$; $R_o = 50\ \Omega$





④ $R_i = 100\ \Omega$; $R_o = 5K\Omega$





b. $R_i \ll R_s$

$\downarrow R_s = 10\ K\Omega$

$R_i \ll 10\ K\Omega$

$R_o \ll R_L$

$\downarrow R_L = 5\ K\Omega$

$R_o \ll 5\ K\Omega$

We need R_i and R_o below $10\ k\Omega$ and $5\ k\Omega$, respectively, and as small as possible.

As per the instructions, I do NOT work the numbers out for each choice, as it is already apparent what option the designer should choose.

The choice is #2:

$R_i \ll R_S$

$R_i = 100\ \Omega$; $R_S = 10\ k\Omega$

$\downarrow$

$100 \ll 10\ K$

$R_o \ll R_L$

$R_o = 50\ \Omega$; $R_L = 5\ k\Omega$

$\downarrow$

$50 \ll 5K$

C. $i_s = 100\ \mu A$

$$\text{Gain} = \frac{50\ mV}{\mu A} = \frac{V_o}{i_{in}}$$

(other values from R_S)

Current divider:

$$i_{in} = i_s \cdot \frac{R_S}{R_S + R_i}$$

$$= (100 \cdot 10^{-6}) \cdot \frac{10000}{10000 + 100}$$

$$= (100 \cdot 10^{-6}) \cdot \frac{10000}{10100}$$

$$= 9.901 \cdot 10^{-5}\ A$$

$V_o = Gain \cdot I_{in}$

$$= \frac{50 \cdot 10^{-3}}{\cancel{10^{-6}}} \cdot (9.901 \cdot 10^{\cancel{-8}})$$

$= 4.9505$ V

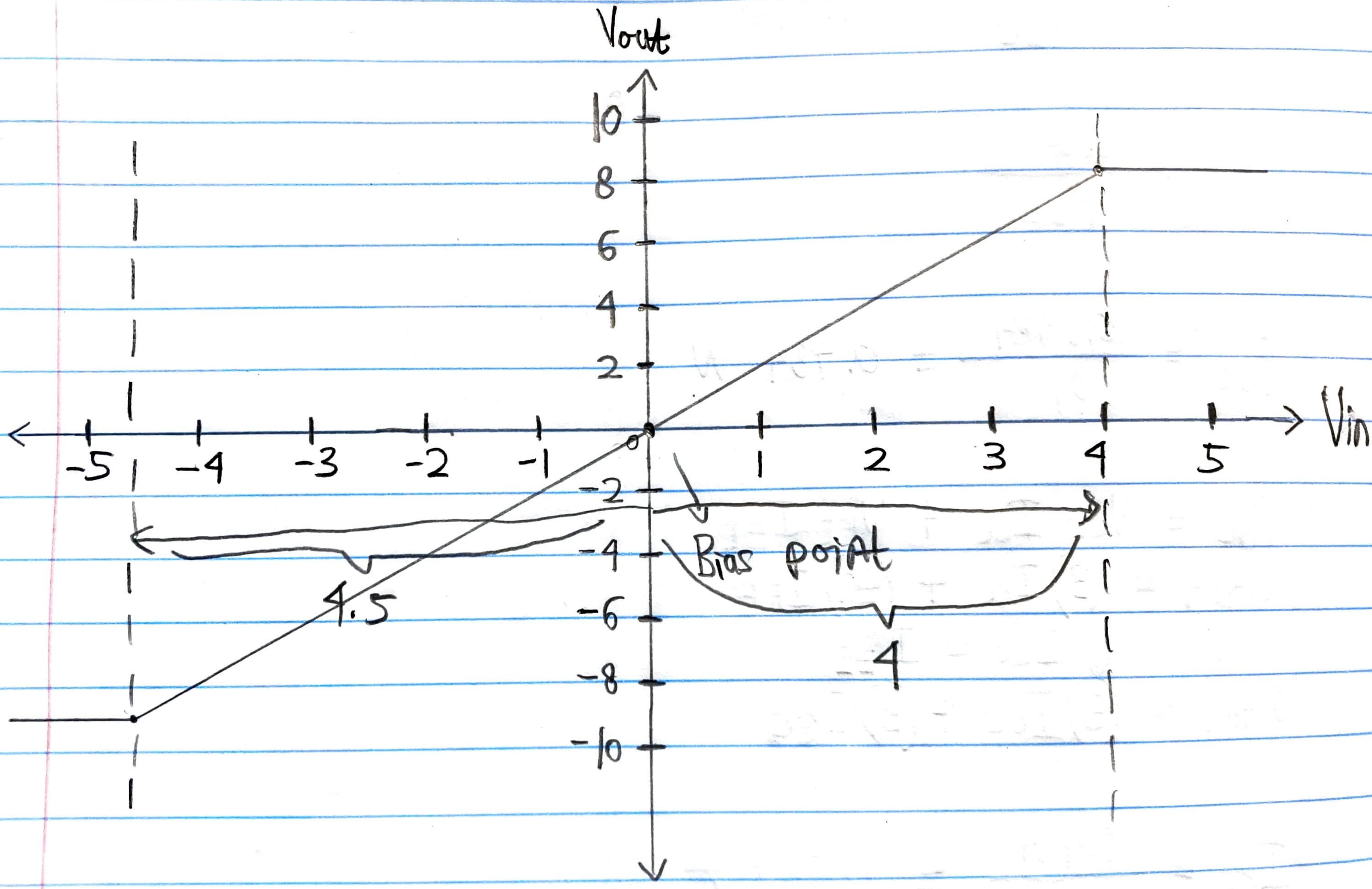
$$P = \frac{V_o^2}{R_L} = \frac{(4.9505)^2}{5000} = 4.901 \cdot 10^{-3} \text{ W}$$

2. Clipped peaks: $V_o > 8$ V
$V_o < -9$ V

Dual supply: ± 10 V $\rightarrow V_{in}$

$$Gain = \frac{V_o}{V_{in}} = 2 \text{ V/V}$$

2.



i. Highest $\longrightarrow$ $V_{in} = 4$

Lowest $\longrightarrow$ $V_{in} = 1.5$

Expression: $0\text{ V} + 4.5 \sin wt$ $\rightarrow$ 4.5 $\rightarrow$ 4.5

a. 4.5 V

b. 4 V

ii. $\frac{4-(-4.5)}{2} = 4.25$

$4.25 + (-4.5) = -0.5$

$V_{in} = 4.25 - 0.5 \sin wt$

Bias point (Max possible undistorted sine wave ouput):
4.25 V

3. $V_s = \pm 3\,V \longrightarrow V_{CC} = 3\,V\ ;\ V_{EE} = -3\,V$

$V_o = 2.2\,V$ (Peak sine wave)

$R_L = 100\,\Omega$ (100-Ω load)

$V_i = 0.2\,V$ (0.2-V peak input)

$i_I = 1\,mA \longrightarrow$

a. Unknown:

1. Voltage gain
2. Current gain
3. Power gain

1. Voltage gain = Av

$$= \frac{V_o}{V_i} = \frac{2.2}{0.2} = 11$$

$$A_V(dB) = 20 \log |A_V|$$
$$= 20 \log |11|$$
$$= 20.83\ dB$$

2. Current gain = A_i

$$i_o = \frac{V_o}{R_L} = \frac{2.2}{100} = 0.022$$

$$A_i = \frac{i_o}{i_I} = \frac{0.022}{10^{-3}} = 22$$

$$A_i(dB) = 20 \log |A_i|$$
$$= 20 \log |22|$$
$$= 26.85\ dB$$

3. Power gain $= A_P$

$$= A_V \cdot A_i$$

$$= (11)(22)$$

$$= 242$$

$$A_{P(dB)} = 23.84 \text{ dB}$$

b. $$P_L = \frac{V_o^2}{R_L} = \frac{(2.2)^2}{100} = 0.0484 \text{ W}$$

$$\eta = \frac{P_L}{P_{dc}} \cdot 100\%$$

$$10\% = \frac{0.0484}{P_{dc}} \cdot 100\%$$

$$0.1 = \frac{0.0484}{P_{dc}}$$

$$P_{dc} = \frac{0.0484}{0.1} = 0.484 \text{ W}$$

$$P_{dc} = V_{CC} I_{CC} + V_{EE} I_{EE}$$

$$0.484 = (3) I_{CC} + (3) I_{EE}$$

$$I_{CC} = I_{EE}$$

$$0.484 = (3) I_{CC} + (3) I_{CC}$$

$$I_{CC} = \frac{0.484}{6} = 0.0807 \text{ A}$$

P_I : very small $\rightarrow$ can be ignored $\rightarrow$ $P_I = 0$

$$P_{dc} + P_I = P_L + P_{dissipated}$$

$$\downarrow P_I = 0$$

$$P_{dc} = P_L + P_{dissipated}$$

$$0.484 = 0.0484 + P_{dissipated}$$

$$P_{dissipated} = 0.4356 \text{ W}$$

Answers: ① $P_L = 0.0484$ W

② $P_{dc} = 0.484$ W

③ $P_{dissipated} = 0.4356$ W