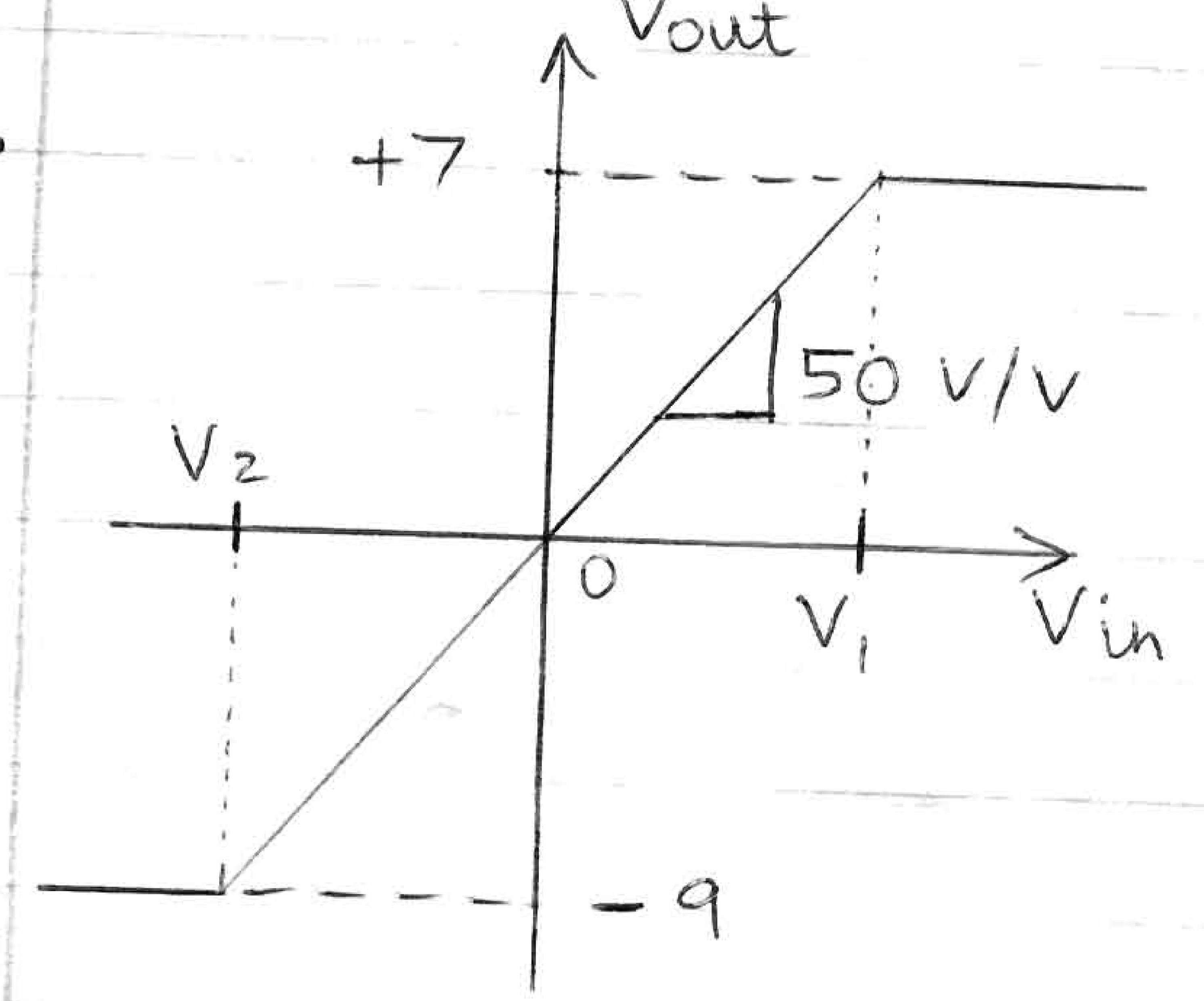
1.



$$\frac{7-0}{V_1-0} = 50 \Rightarrow V_1 = 0.14\,V$$

$$\frac{0+9}{0-V_2} = 50 \Rightarrow V_2 = -0.18\,V$$

$\therefore$ DC op. pt. to obtain the largest output signal magnitude is given by,

$$V_{in\,(dc)} = \frac{V_1+V_2}{2} = \frac{-0.04}{2} = -0.02\,V$$

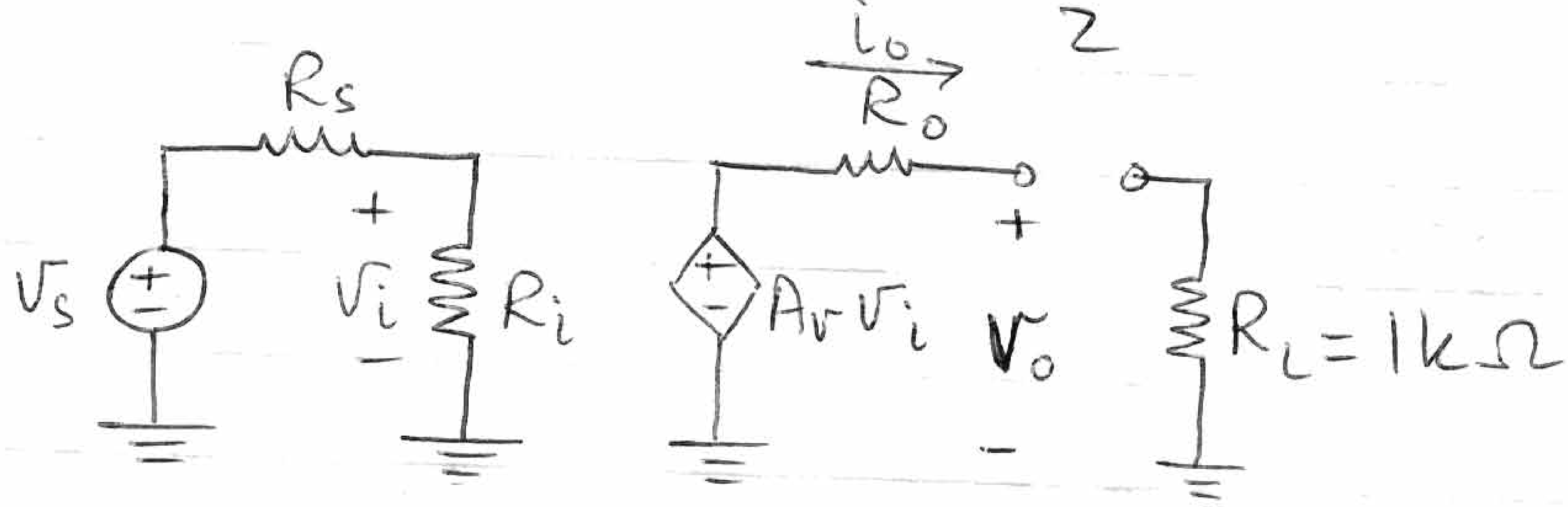
$$V_{out\,(dc)} = \frac{7-9}{2} = -1\,V$$

$\therefore$ Magnitude of maximum output signal,

$$V_{out_{max}}(pk\text{-}pk) = 7-(-9) = 16\ V\ pk\text{-}pk$$

$$\therefore V_{out_{max}} = \frac{7-(-9)}{2} = 8\,V$$

2.



without load: $i_o = 0 \Rightarrow V_{R_o} = 0$

$$\therefore v_o = A_v v_i = A_v\left(v_s \times \frac{R_i}{R_i+R_s}\right)$$

$$\frac{v_o}{v_s} = A_v \times \frac{R_i}{R_iR_s} = 100\,V/V$$

(given)

$$\therefore v_o = A_v v_i = 100\, v_s \quad \text{— ①}$$

with load: $V_o = \dfrac{1k}{R_o + 1k} \times A_v V_i$

$\therefore$ From ①,

$$V_o = \frac{1k}{R_o + 1k} \times (100\, V_s)$$

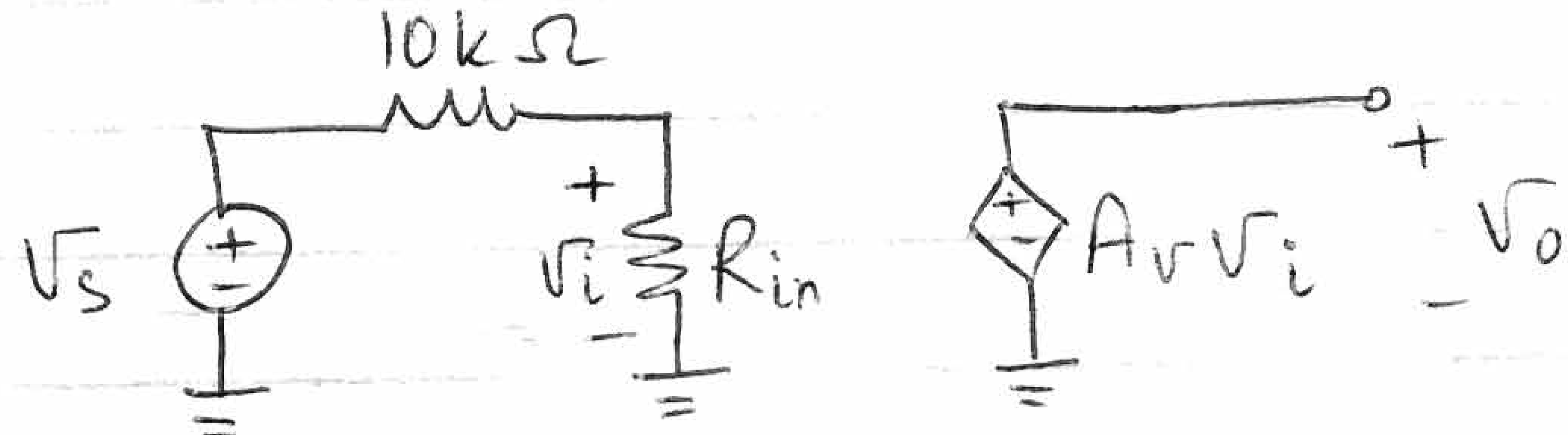
$$\frac{V_o}{V_s} = \frac{1k}{R_o + 1k} \times 100 = 70 \text{ V/V}$$

(given)

$$\therefore \quad \frac{1k}{R_o + 1k} = 0.7$$

$$\Rightarrow \quad R_o = 429\ \Omega$$

3.

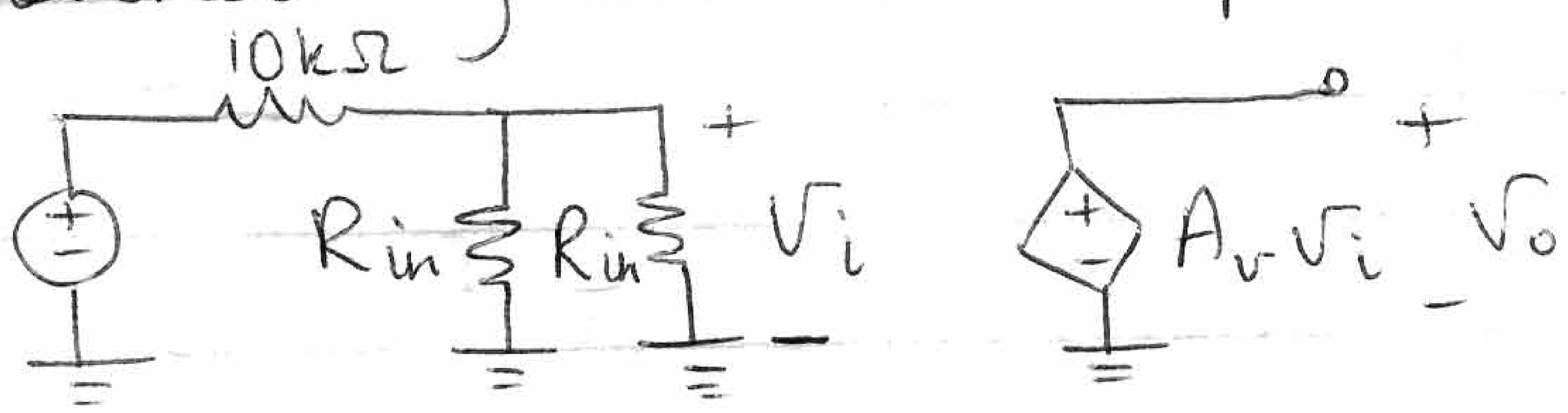


$$V_o = A_v V_i \quad \Rightarrow \quad \frac{V_o}{V_i} = A_v$$

$$V_i = \frac{R_{in}}{10k + R_{in}} \times V_s \Rightarrow \frac{V_i}{V_s} = \frac{R_{in}}{10k + R_{in}}$$

$$\therefore \quad \frac{V_o}{V_s} = \frac{V_o}{V_i} \times \frac{V_i}{V_s} = A_v \cdot \frac{R_{in}}{10k + R_{in}} = 1667 \text{ V/V} \quad \text{— ①}$$

Connecting the two amplifiers in parallel,



Similarly, $\dfrac{V_o}{V_s} = A_v \cdot \dfrac{(R_{in} \| R_{in})}{10k\Omega + (R_{in} \| R_{in})}$

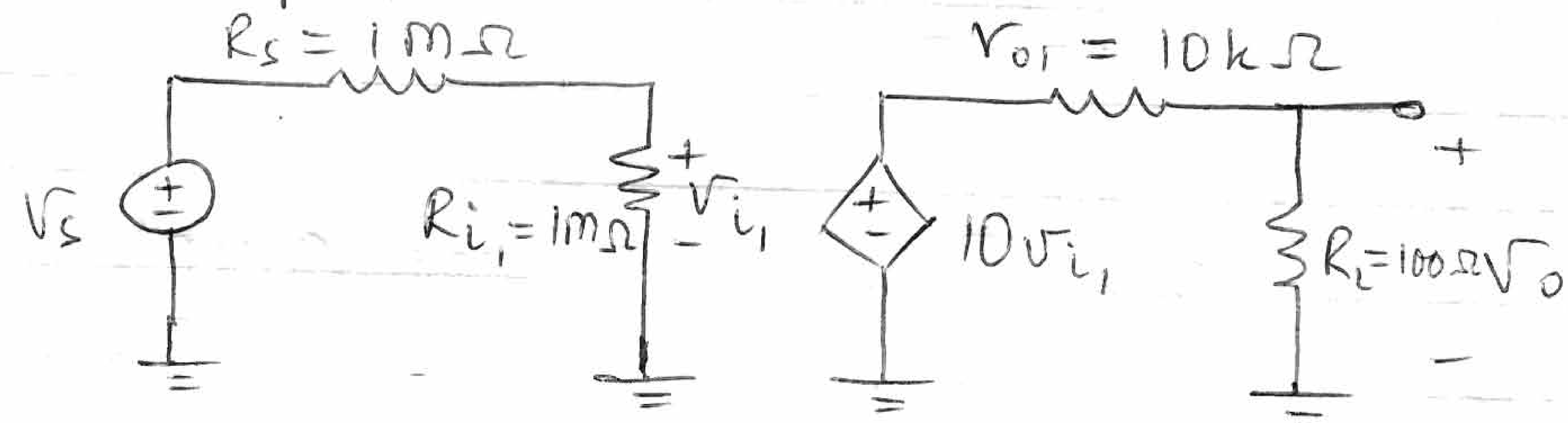
$$= A_v \cdot \frac{(R_{in}/2)}{10k + (R_{in}/2)}$$

$$\frac{V_o}{V_s} = A_v \cdot \frac{R_{in}}{R_{in}+20k} = 909\,V/V \quad -(2)$$

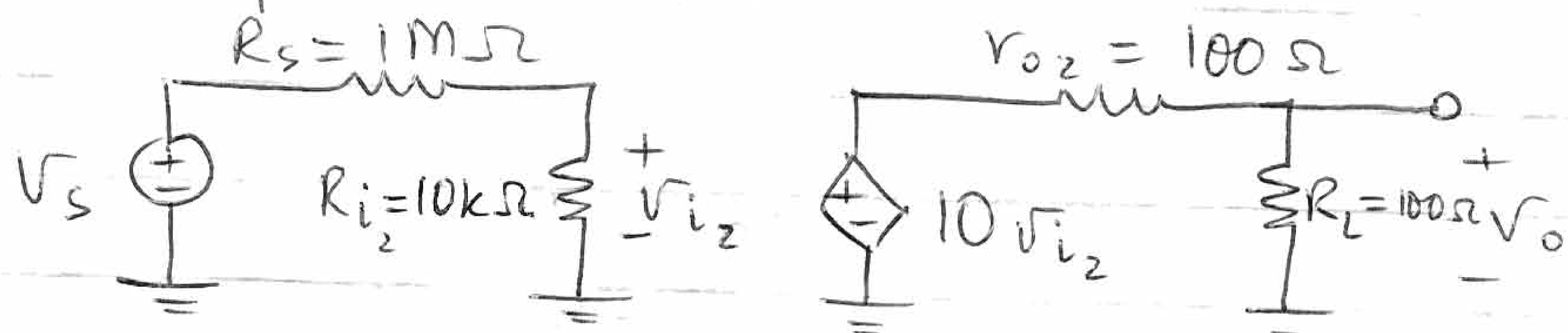
$$(1) \div (2) \Rightarrow \frac{1667}{909} = \frac{R_{in}+20k}{R_{in}+10k}$$

$$\therefore R_{in} = 1.99\,k\Omega$$

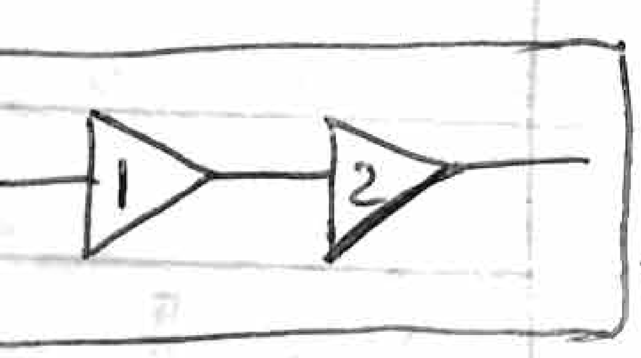
4. Amplifier 1:

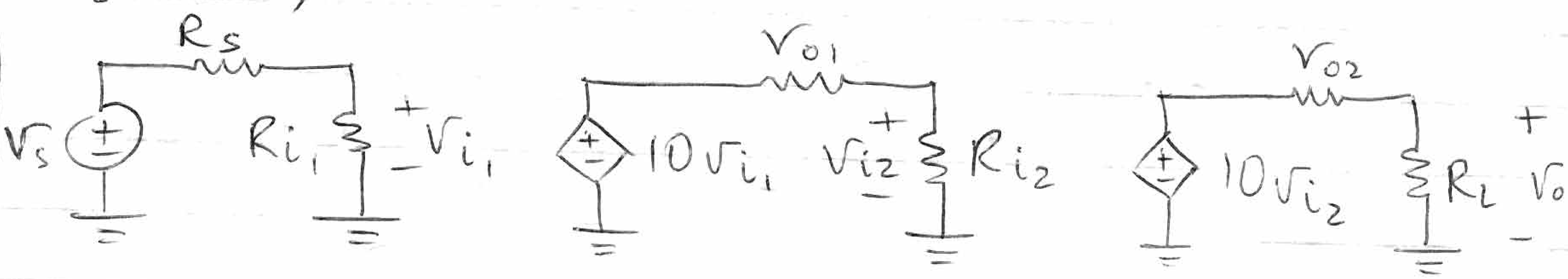


Amplifier 2:



Connecting amplifier 1 and amplifier 2 in series,





$$\frac{V_o}{V_{i2}} = 10 \cdot \frac{R_L}{r_{o2}+R_L}$$

$$\frac{V_{i2}}{V_{i1}} = 10 \cdot \frac{R_{i2}}{r_{o1}+R_{i2}}$$

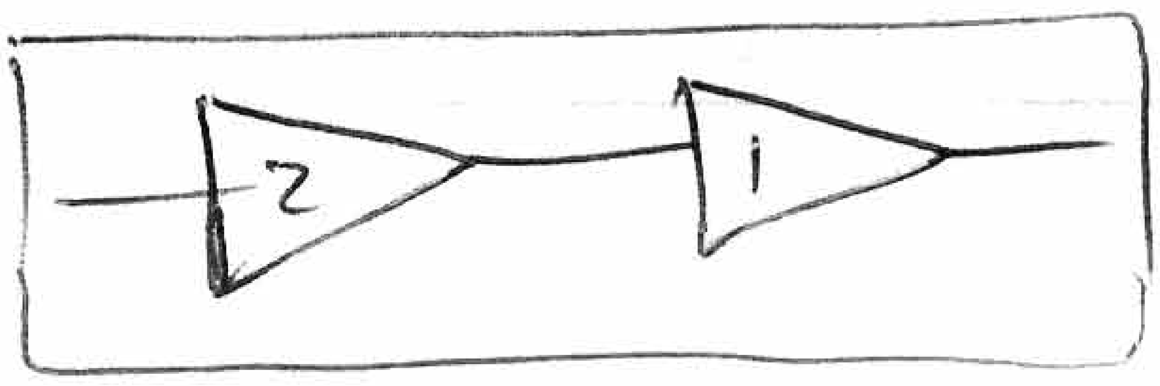
$$\frac{V_{i1}}{V_s} = \frac{R_{i1}}{R_s+R_{i1}}$$

$$\therefore \frac{V_o}{V_s} = \frac{V_o}{V_{i2}} \times \frac{V_{i2}}{V_{i1}} \times \frac{V_{i1}}{V_s}$$

$$= \frac{R_{i1}}{R_s + R_{i1}} \times \frac{R_{i2}}{R_{i2} + r_{o1}} \times \frac{R_L}{R_L + r_{o2}} \times 100$$

$$\therefore \frac{V_o}{V_s} = \frac{1M}{1M + 1M} \times \frac{10k}{10k + 10k} \times \frac{100}{100 + 100} \times 100$$

$$= 12.5 \text{ V/V} \quad \text{— (1)}$$



Connecting amplifier 2 and amplifier 1 in series,

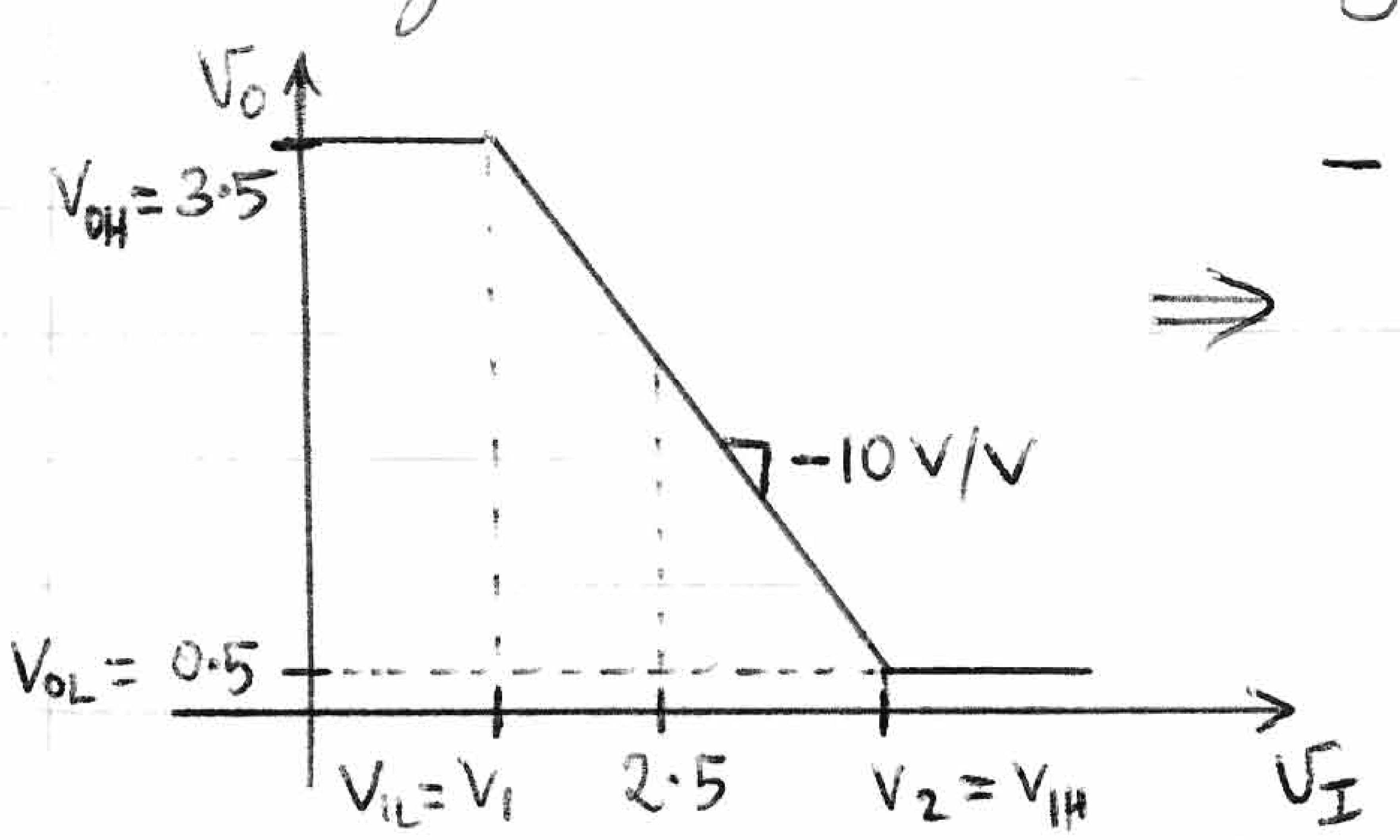
Similarly, $$\frac{V_o}{V_s} = \frac{R_{i2}}{R_s + R_{i2}} \times \frac{R_{i1}}{R_{i1} + r_{o2}} \times \frac{R_L}{R_L + r_{o1}} \times 100$$

$$= \frac{10k}{1M + 10k} \times \frac{1M}{1M + 100} \times \frac{100}{100 + 10k} \times 100$$

$$= 9.802 \text{ mV/V} \quad \text{— (2)}$$

$\therefore$ Comparing (1) & (2), the configuration in which amplifier 1 and amplifier 2 are connected in series with amplifier 1 preceding amplifier 2 results in the highest overall gain of 12.5 V/V.

5.



$$-10(V_2 - V_1) = 0.5 - 3.5$$

$$\Rightarrow \quad V_2 - V_1 = 0.3$$

$$\frac{V_2 + V_1}{2} = 2.5 \quad \text{(given)}$$

$$\therefore \quad V_{IL} = V_1 = 2.35\text{V}$$

$$V_{IH} = V_2 = 2.65\text{V}$$

$\therefore NM_H = V_{OH} - V_{IH} = 3.5 - 2.65 = 0.85V$
$NM_L = V_{IL} - V_{OL} = 2.35 - 0.5 = 1.85V$

Width of transition region $= V_{IH} - V_{IL}$
$= 2.65 - 2.35$
$= 0.3\ V$

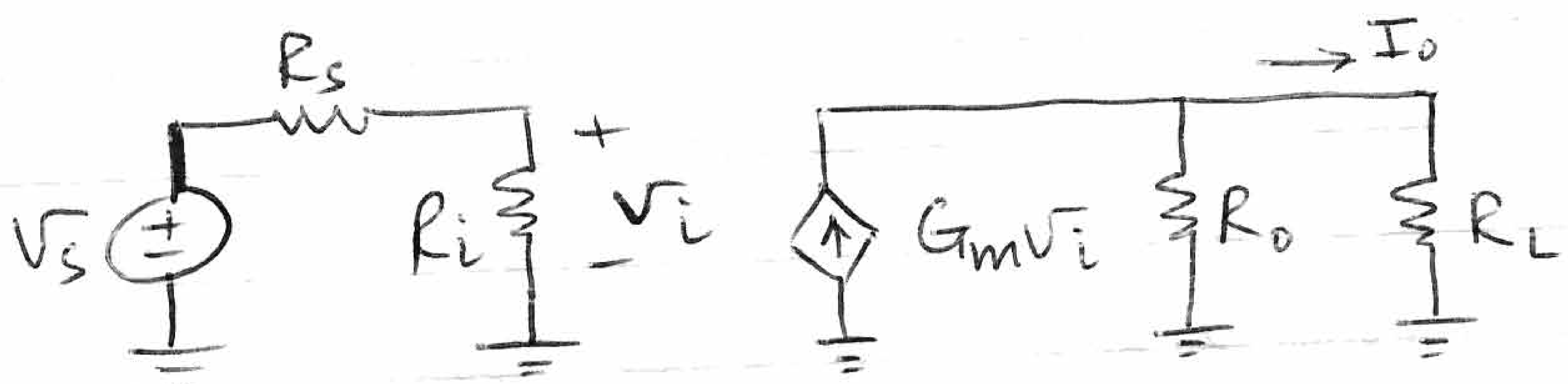
Doubling the width of the transition region
$\Rightarrow V_{IH} - V_{IL} = 0.6\ V$
$\therefore$ slope (constant gain) $= -5\ V/V$

$$V_2 - V_1 = 0.6$$
$$\frac{V_2 + V_1}{2} = 2.5$$

$\therefore V_{IL} = V_1 = 2.2\ V$
$V_{IH} = V_2 = 2.8\ V$

$NM_H = V_{OH} - V_{IH} = 3.5 - 2.8 = 0.7V$
$NM_L = V_{IL} - V_{OL} = 2.2 - 0.5 = 1.7\ V$

6.

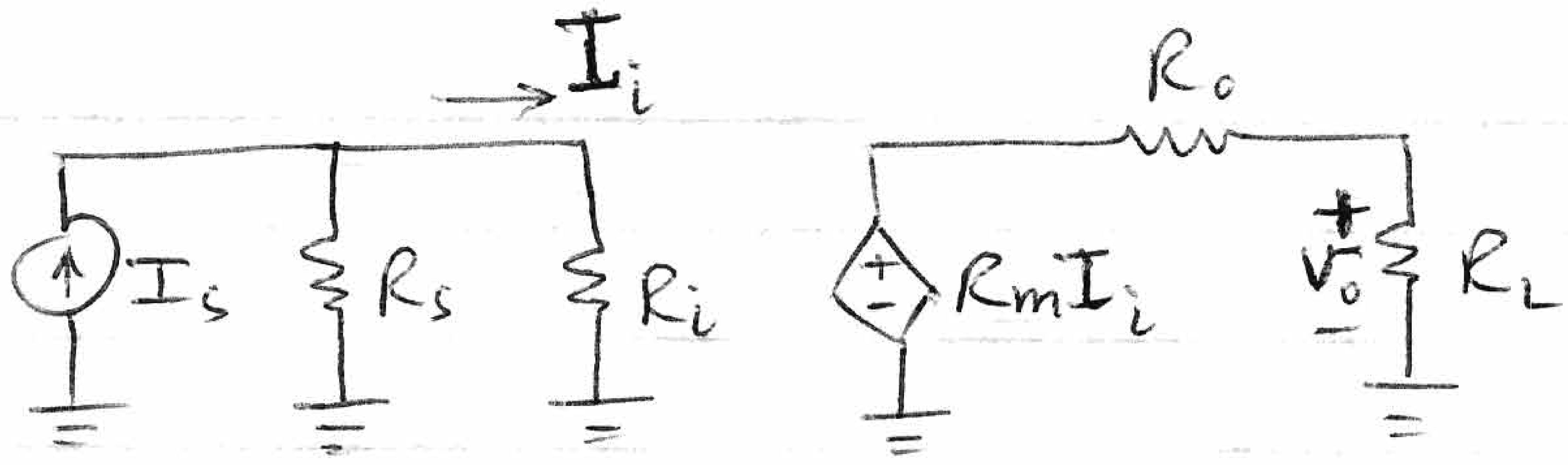


Transconductance amplifier

$$\frac{V_i}{V_s} = \frac{R_i}{R_i + R_s} \qquad I_o = \frac{R_o}{R_o + R_L} G_m V_i$$

$$\therefore G = \frac{I_o}{V_s} = \frac{R_i}{R_i + R_s} \times \frac{R_o}{R_o + R_L} \times G_m$$

$\Rightarrow$ $R_i \rightarrow$ Large , ideal characteristics
$R_o \rightarrow$ Large

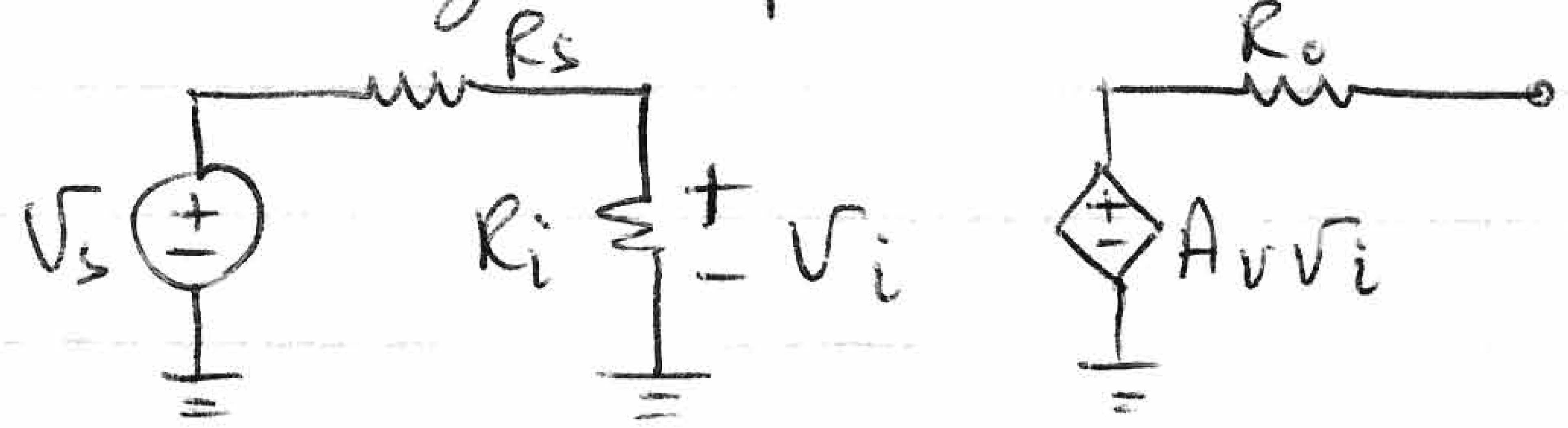


$$I_i = \frac{R_s}{R_s + R_i} \cdot I_s \qquad V_o = \frac{R_L}{R_L + R_o} \times R_m I_i$$

$$\therefore R = \frac{V_o}{I_s} = \frac{R_s}{R_s + R_i} \times \frac{R_L}{R_L + R_o} \times R_m$$

$\Rightarrow$ $R_i \to$ small , ideal characteristics
$R_o \to$ small

(7) Voltage amplifier :

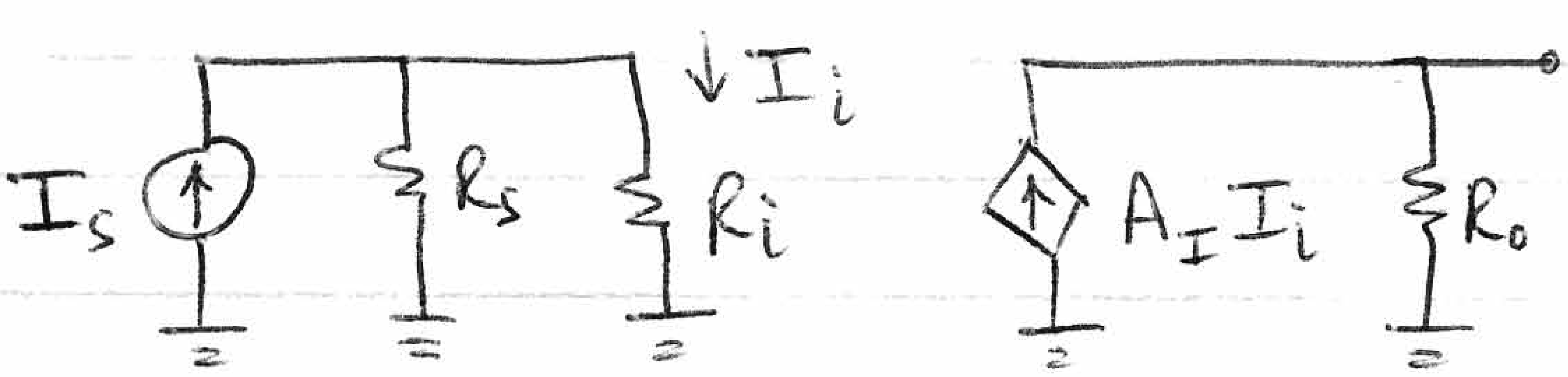


$$V_{oc} = A_V V_i = V_s \frac{R_i}{R_i + R_s} A_V$$

$$I_{sc} = \frac{A_V V_i}{R_o} = \frac{A_V}{R_o} \frac{R_i}{R_i + R_s} V_s$$

$$\therefore \frac{V_{oc}}{I_{sc}} = R_o$$

Current amplifier :

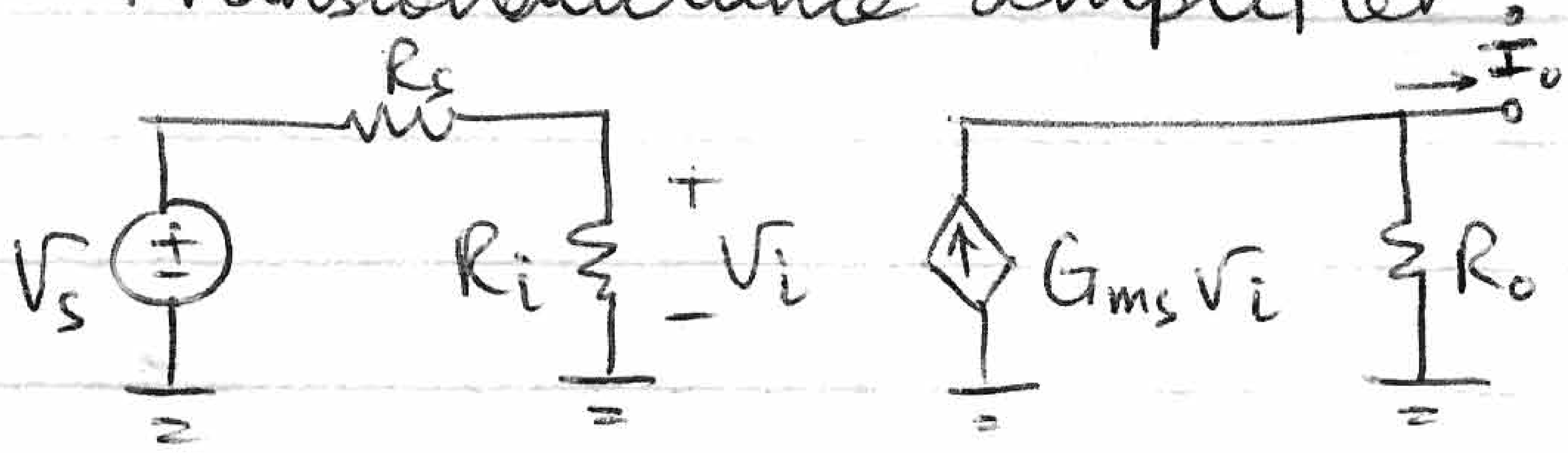


$$V_{oc} = A_I I_i R_o$$
$$= A_i \frac{R_s}{R_s + I_i} I_s R_o$$

$$I_{sc} = A_I I_i$$

$$\therefore \frac{V_{oc}}{I_{sc}} = R_o$$

Transconductance amplifier :

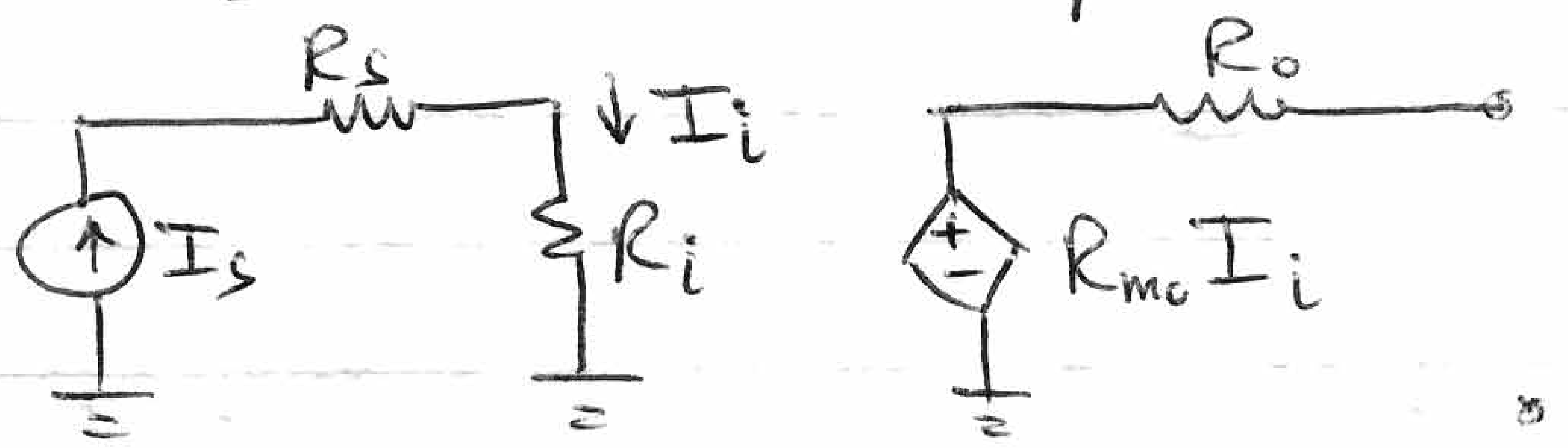


$$V_{oc} = G_{ms} V_i R_o$$

$$I_{sc} = G_{ms} V_i$$

$$\therefore \frac{V_{oc}}{I_{sc}} = R_o$$

Transresistance amplifier:

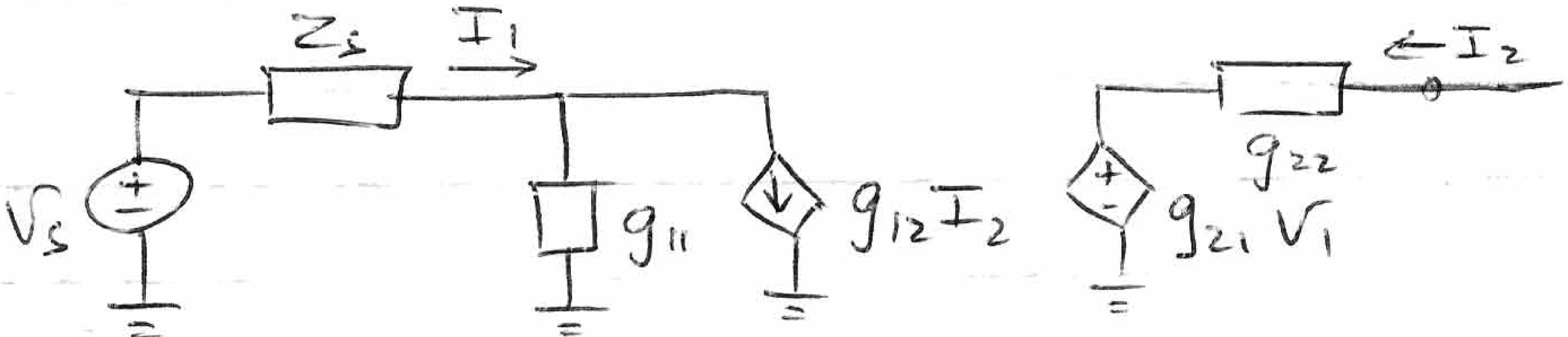


$$V_{oc} = R_{mo} I_i$$

$$I_{sc} = \frac{R_{mo} I_i}{R_o}$$

$$\therefore \frac{V_{oc}}{I_{sc}} = R_o$$

8.



$$V_{oc} = g_{21} V_1 = g_{21} \frac{\frac{1}{g_{11}}}{\frac{1}{g_{11}} + Z_s} V_s = \frac{g_{21}}{g_{11} Z_s + 1} V_s$$

$$I_{sc} = g_{22}\, g_{21} V_1$$

$$\frac{V_s - V_1}{Z_s} = V_1 g_{11} + g_{12} I_2$$

$$I_2 = - I_{sc}$$

$$\therefore V_1 \left(g_{11} + \frac{1}{Z_s} \right) = \frac{V_s}{Z_s} + g_{12} I_{sc}$$

$$\therefore I_{sc} = \frac{g_{21} g_{22}}{g_{11} + \frac{1}{Z_s}} \left(\frac{V_s}{Z_s} + g_{12} I_{sc} \right)$$

$$I_{sc} \left(1 - \frac{g_{12} g_{21} g_{22}}{g_{11} + \frac{1}{Z_s}} \right) = \frac{g_{21} g_{22}}{g_{11} Z_s + 1} \cdot V_s$$

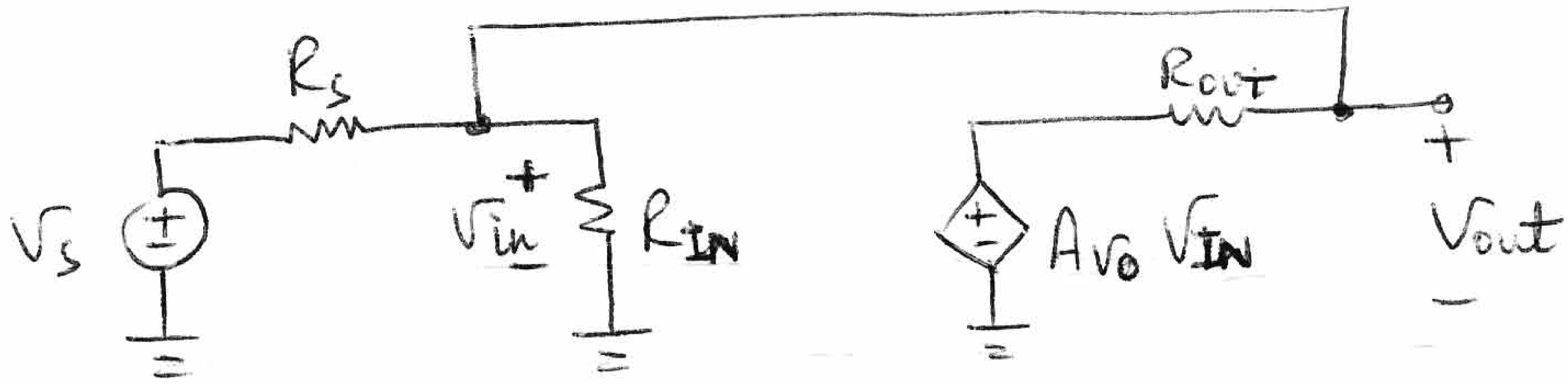
$$\therefore I_{sc} = \frac{1}{1 - \frac{g_{12} g_{21} g_{22}}{g_{11} + \frac{1}{Z_s}}} \cdot \frac{g_{21} g_{22}}{g_{11} Z_s + 1} \cdot V_s$$

Setting reverse current gain (g_{12}) to zero

$$\therefore I_{sc} = \frac{g_{21} g_{22}}{g_{11} Z_s + 1} \cdot V_s$$

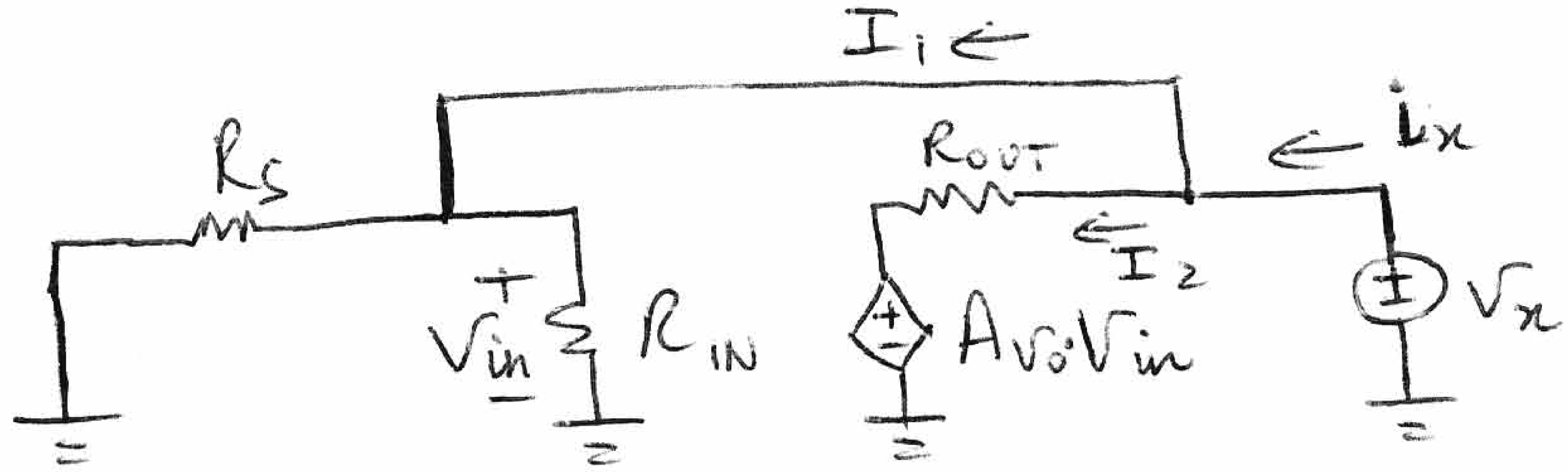
$$\therefore \frac{V_{oc}}{I_{sc}} = \frac{1}{g_{22}} = \text{output impedance}$$

9.



In order to determine R_{OUT}' set V_s to zero and apply a test voltage signal V_x to the output node. Determine the current i_x it supplies to the circuit.

$$R_{OUT}' = \frac{V_x}{i_x}$$



$$V_{in} = V_x$$

$$V_x = A_{Vo} \cdot V_{in} + I_2 R_{OUT}$$

$$I_2 = i_x - I_1 = i_x - \frac{V_x}{R_s \| R_{IN}}$$

$$\therefore V_x = A_{Vo} \cdot V_x + i_x R_{OUT} - \frac{V_x R_{OUT}}{R_{OUT} \| R_{IN}}$$

$$\frac{V_x}{i_x} = R_{OUT}' = \frac{R_{OUT}}{1 - A_{Vo} + \frac{R_{OUT}}{R_s \| R_{in}}} \quad \text{— } ①$$

Since for a near-ideal amplifier,

$$\frac{R_{OUT}}{R_s \| R_{in}} \approx \frac{R_{OUT}}{R_s} < 1 \quad \text{and} \quad A_{Vo} \gg 1$$

$\therefore$ (1) becomes,

$$\frac{v_x}{i_x} = R_{OUT}' \; x \; - \; \frac{R_{OUT}}{A_{v_0}}$$