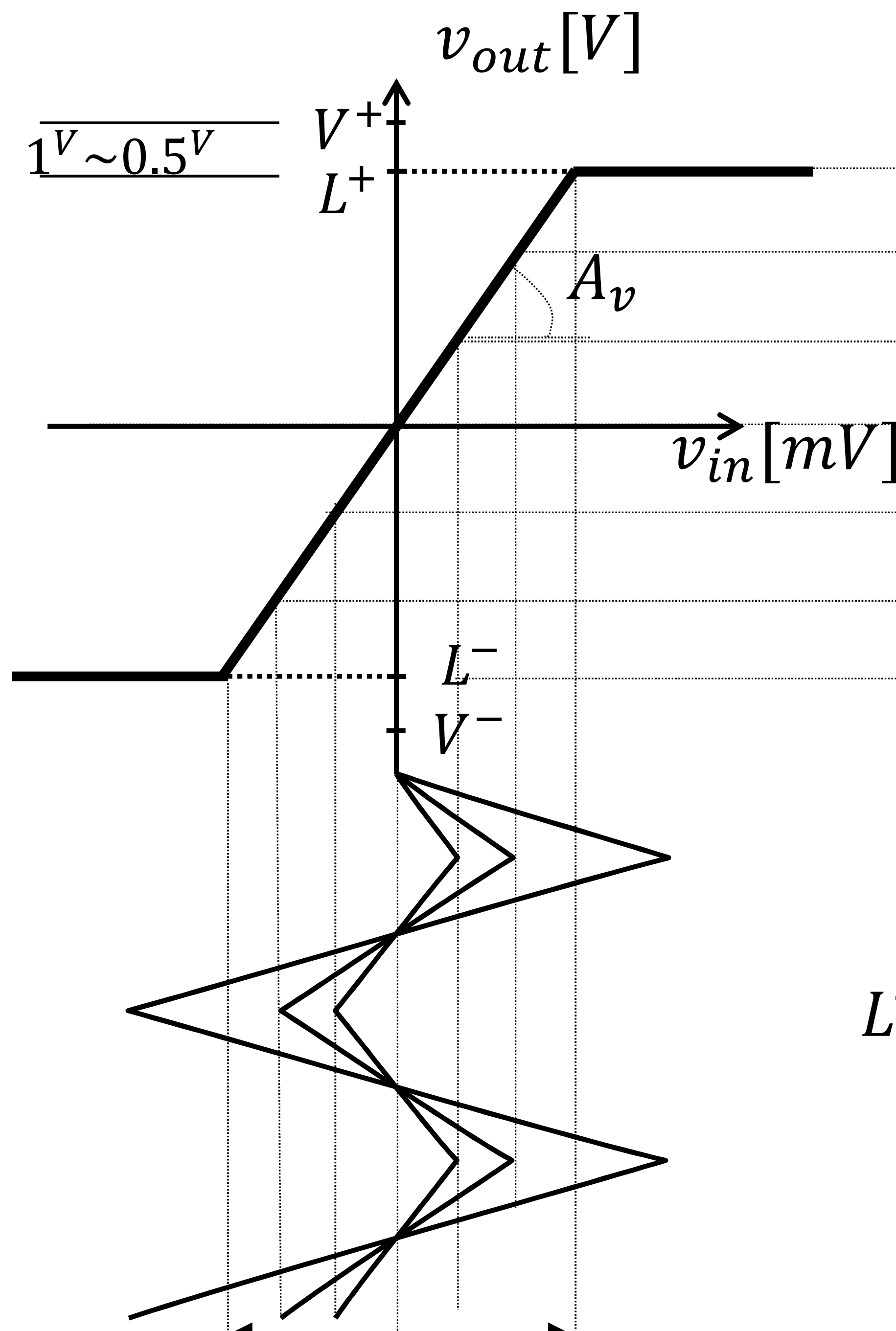
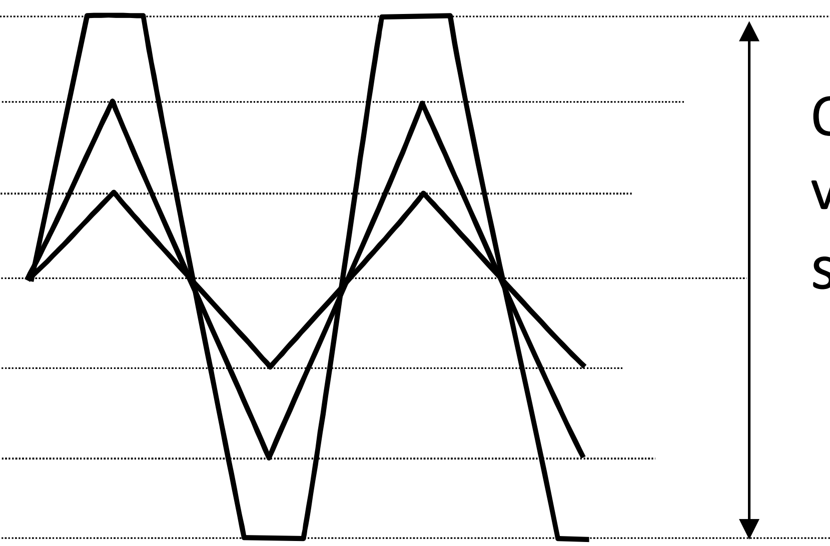
Week2 Electronics1

Amplifiers 2

Non-ideal Amplifier



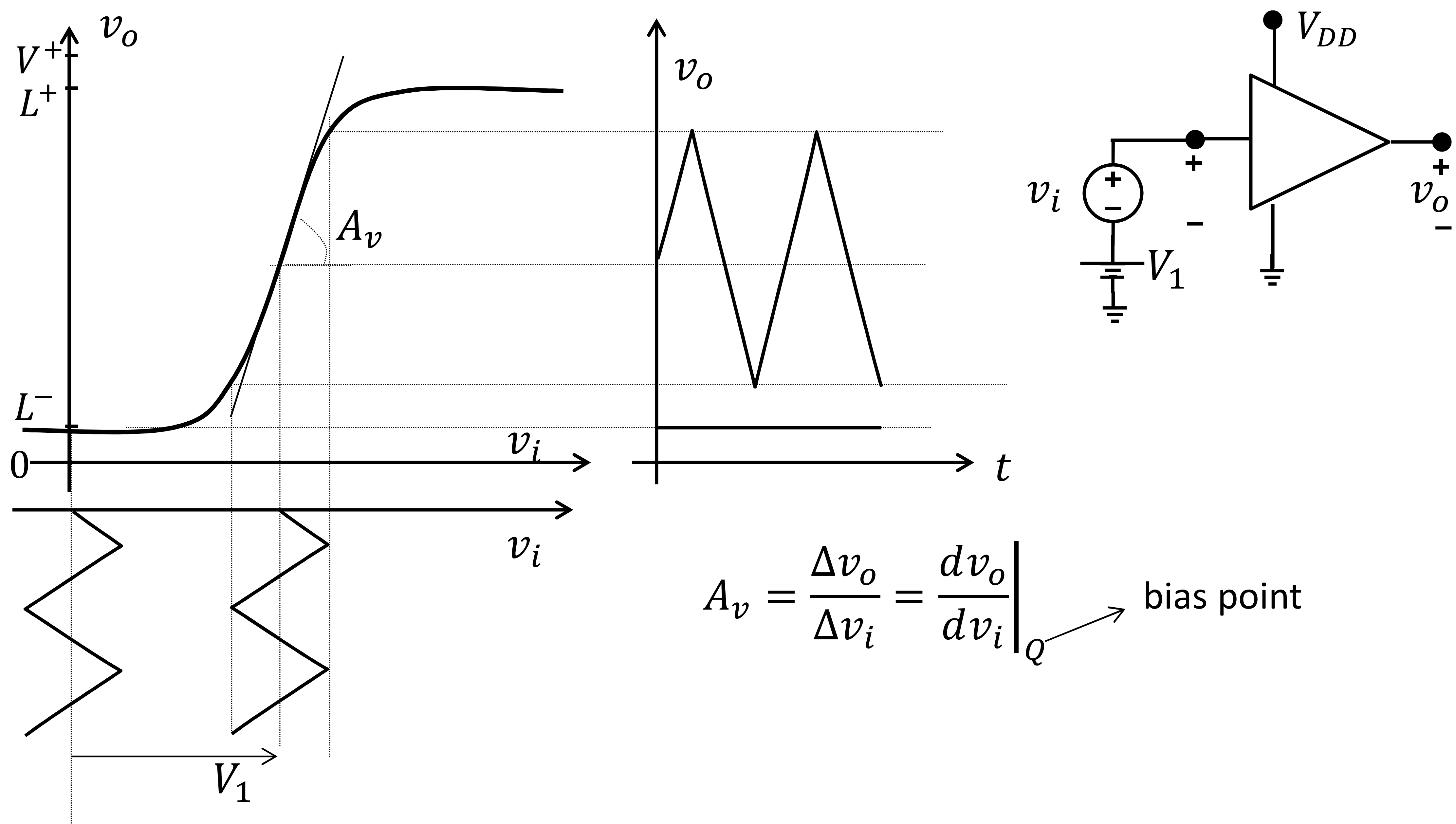
rail-to-rail OpAmp $L^{\pm} = V^{\pm}$



$$L^- < v_{out} < L^+ \xrightarrow{v_{out}=A_v v_{in}} \left(\frac{L^-}{A_v} < v_{in} < \frac{L^+}{A_v}\right)$$

You have heard distortion in Audio amplifier!

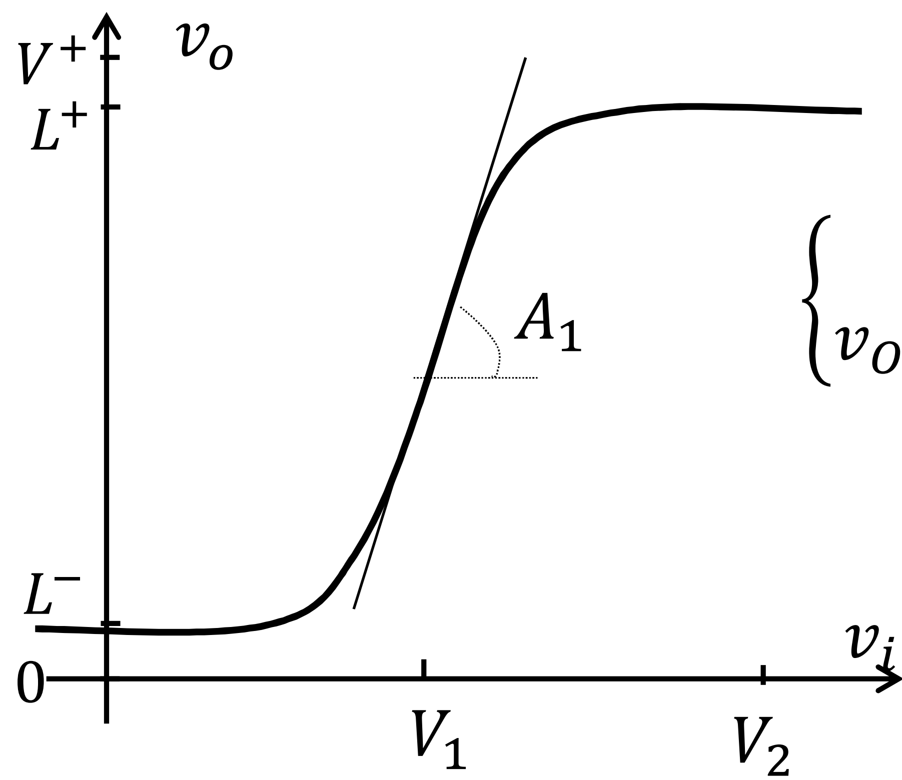
Nonlinear Transfer Function
Biasing



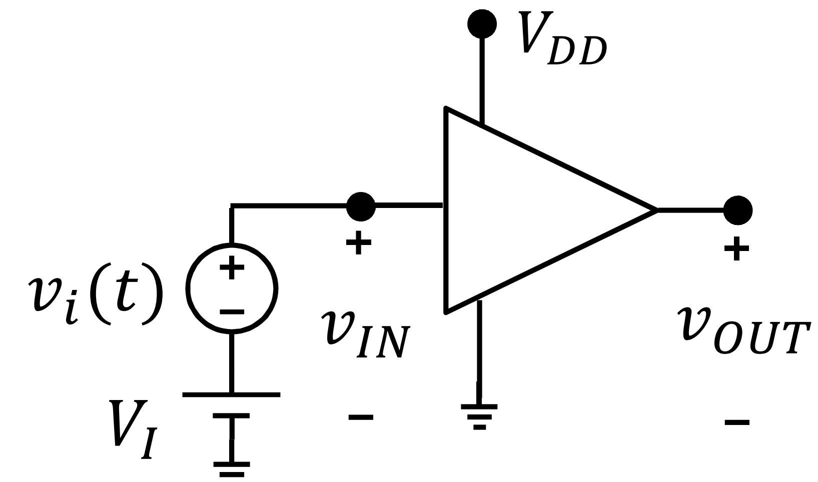
$$A_v = \frac{\Delta v_o}{\Delta v_i} = \left.\frac{dv_o}{dv_i}\right|_Q$$

→ bias point

Nonlinear Transfer Function
Biasing



$$\begin{cases} v_{IN} = V_I + v_i(t) \\ v_{OUT} = V_O + A_v v_i(t) \end{cases}$$

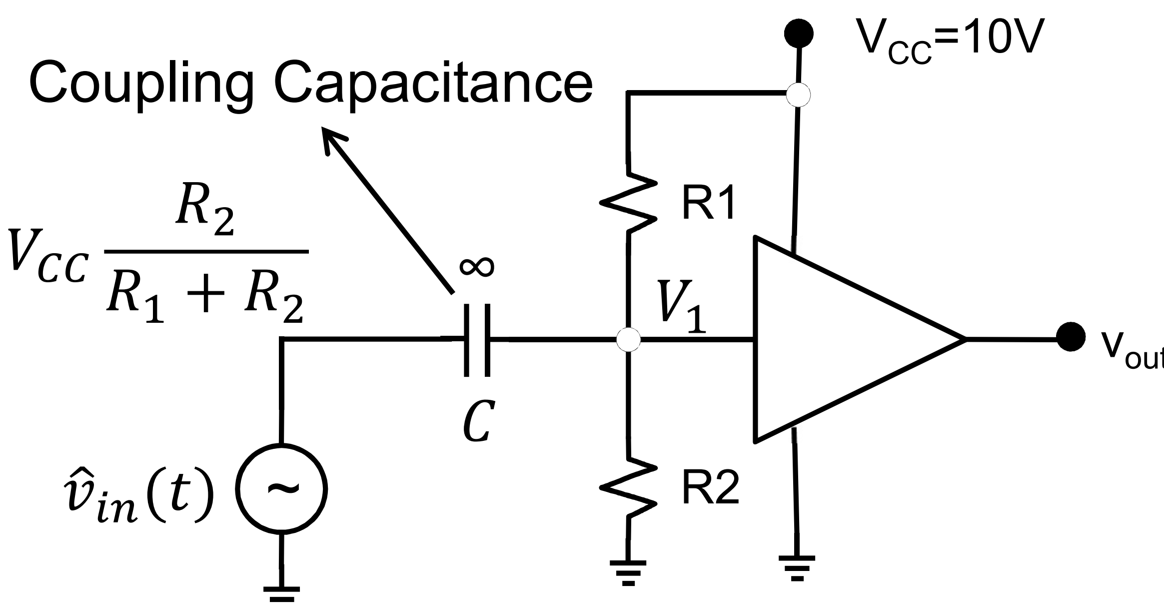


$$V_I = 0 \rightarrow A_v = 0$$

$$V_I = V_1 \rightarrow A_v = A_1$$

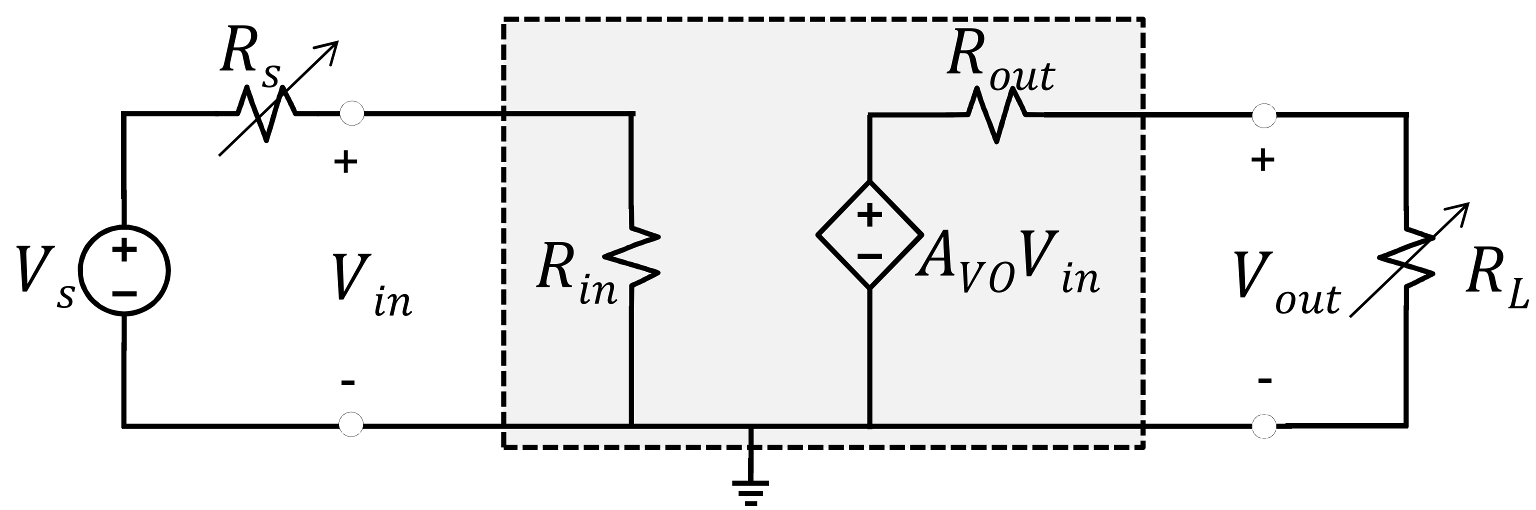
$$V_I = V_2 \rightarrow A_v = 0$$

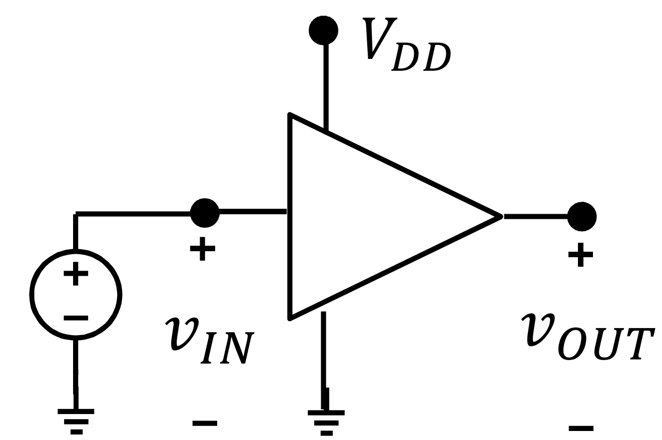
$$V_1 = V_{CC}\frac{R_2}{R_1 + R_2}$$



$$v_{out}(t) = V_{out} + A_v \hat{v}_{in}(t)$$

Voltage Amplifier





Open circuit: $R_L = \infty \rightarrow \frac{V_{out}}{V_{in}} = A_{VO} \quad \left[\frac{V}{V}\right]$ open circuit voltage gain

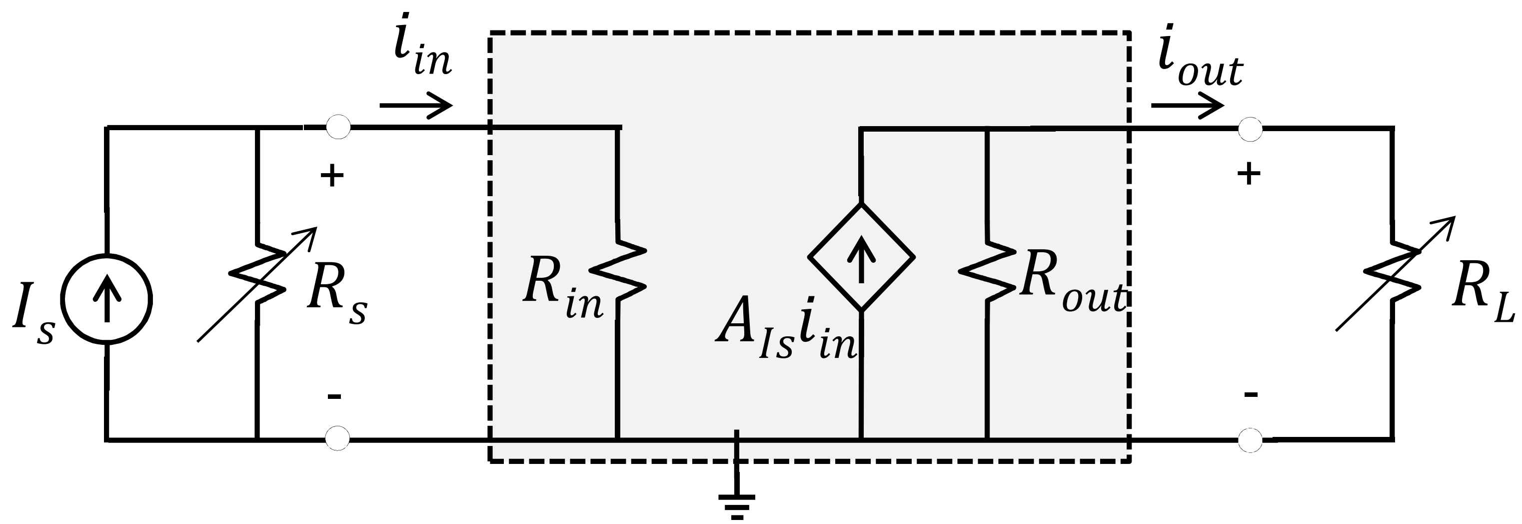
$V_{in} = \frac{R_{in}}{R_{in} + R_s} . V_s$ $\qquad V_{in} = V_s \quad \forall R_s$ $\qquad$ if $R_{in} = \infty$ Ideal case

$V_{out} = A_{Vo} V_{in} \frac{R_L}{R_L + R_{out}}$ $\qquad V_{out} = A_{Vo} V_{in} \quad \forall R_L$ $\qquad$ if $R_{out} = 0$ Ideal case

Generally: $\frac{V_{out}}{V_s} = A_{Vo} \left(\frac{R_L}{R_L + R_{out}}\right)\left(\frac{R_{in}}{R_{in} + R_s}\right)$

Ideal case: $\frac{V_{out}}{V_s} = A_{Vo}$

Current Amplifier



Short circuit: $R_L = 0 \quad \rightarrow \dfrac{i_{out}}{i_{in}} = A_{Is} \quad \left[\dfrac{A}{A}\right]$ short circuit current gain

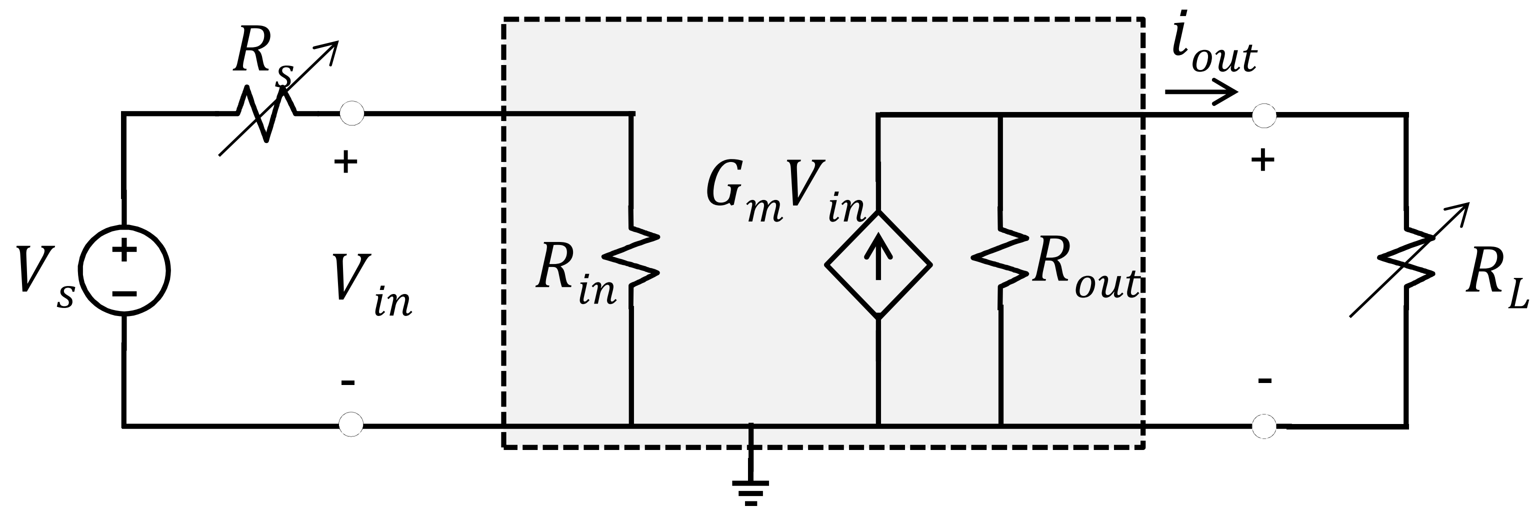
$i_{in} = \dfrac{R_S}{R_{in} + R_s}.I_s \qquad i_{in} = I_s \quad \forall R_s$ if $R_{in} = 0$ Ideal case

$i_{out} = A_{Is} i_{in} \dfrac{R_{out}}{R_L + R_{out}} \qquad i_{out} = A_{Is} i_{in} \quad \forall R_L$ if $R_{out} = \infty$ Ideal case

Generally: $$\frac{i_{out}}{I_s} = A_{Is}\left(\frac{R_{out}}{R_L + R_{out}}\right)\left(\frac{R_S}{R_{in} + R_s}\right)$$

Ideal case: $$\frac{i_{out}}{I_s} = A_{Is}$$

TransConductance Amplifier



Short circuit: $R_L = 0 \rightarrow \frac{i_{out}}{V_{in}} = G_m \quad \left[\frac{A}{V} = \Omega^{-1}\right]$ short circuit Trans-conductance

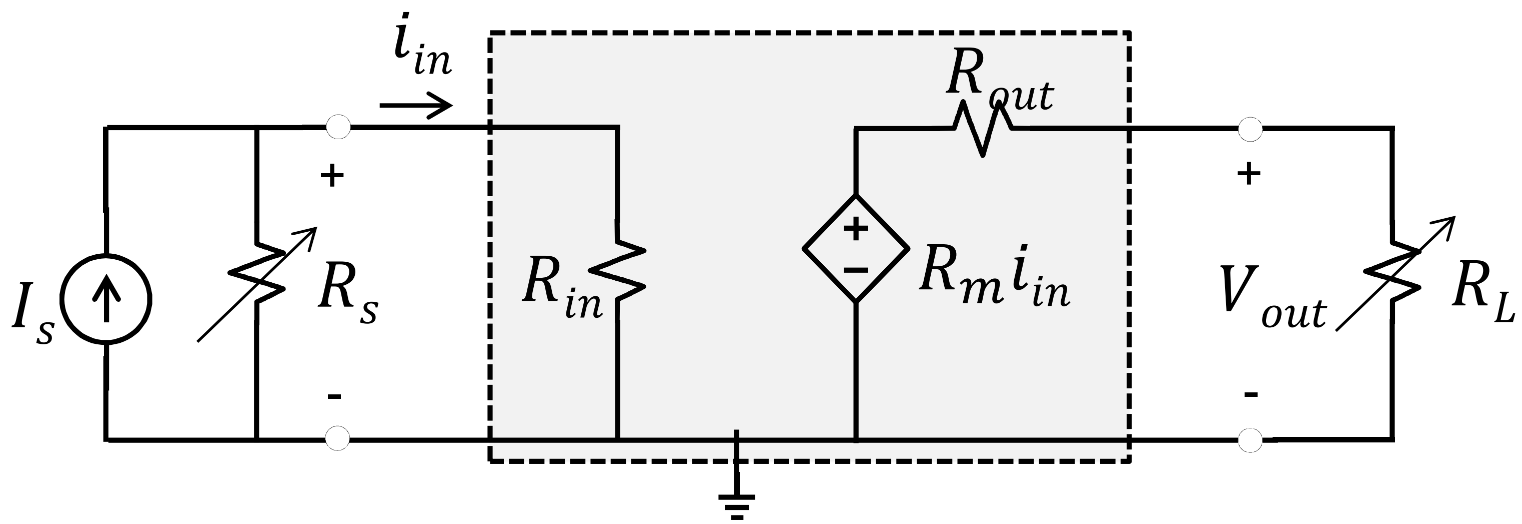
$V_{in} = \frac{R_{in}}{R_{in} + R_s} . V_s$ $\quad V_{in} = V_s \quad \forall R_s$ $\quad$ if $R_{in} = \infty$ Ideal case

$i_{out} = G_m V_{in} \frac{R_{out}}{R_L + R_{out}}$ $\quad i_{out} = G_m V_{in} \quad \forall R_L$ $\quad$ if $R_{out} = \infty$ Ideal case

Generally: $\frac{i_{out}}{V_s} = G_m \left(\frac{R_{out}}{R_L + R_{out}}\right)\left(\frac{R_{in}}{R_{in} + R_s}\right)$

Ideal case: $\frac{i_{out}}{V_s} = G_m$

TransResistance Amplifier



Short circuit: $R_L = \infty \rightarrow \frac{V_{out}}{i_{in}} = R_m \quad \left[\frac{V}{A} = \Omega\right]$ open circuit Trans-resistance

$i_{in} = \frac{R_S}{R_{in} + R_s} . I_s$ $\quad i_{in} = I_s \quad \forall R_s$ $\quad$ if $R_{in} = 0$ Ideal case

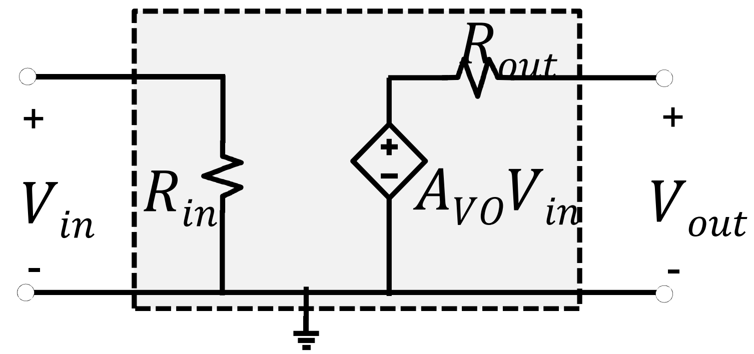
$V_{out} = R_m i_{in} \frac{R_L}{R_L + R_{out}}$ $\quad V_{out} = R_m i_{in} \quad \forall R_L$ $\quad$ if $R_{out} = 0$ Ideal case

Generally: $$\frac{V_{out}}{I_s} = R_m \left(\frac{R_L}{R_L + R_{out}}\right)\left(\frac{R_S}{R_{in} + R_s}\right)$$

Ideal case: $$\frac{V_{out}}{I_s} = R_m$$

Amplifiers

Voltage Amplifier



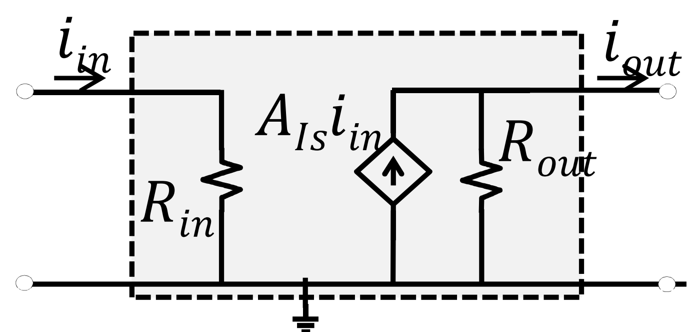
$$A_{Vo} = \left.\frac{V_{out}}{V_{in}}\right|_{i_{out}=0}$$

open circuit voltage gain

Ideal:

$R_{in} = \infty$
$R_{out} = 0$

Current Amplifier

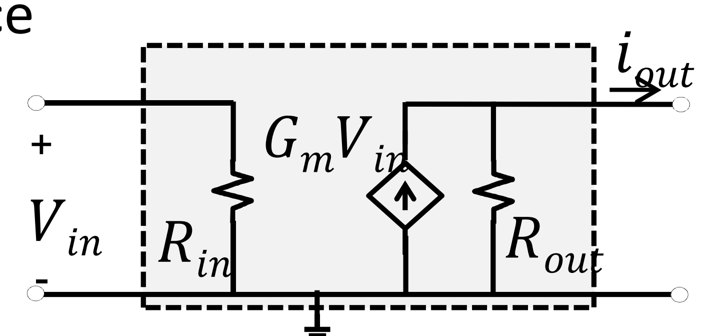


$$A_{Is} = \left.\frac{i_{out}}{i_{in}}\right|_{V_{out}=0}$$

short circuit current gain

$R_{in} = 0$
$R_{out} = \infty$

Trans-Conductance Amplifier

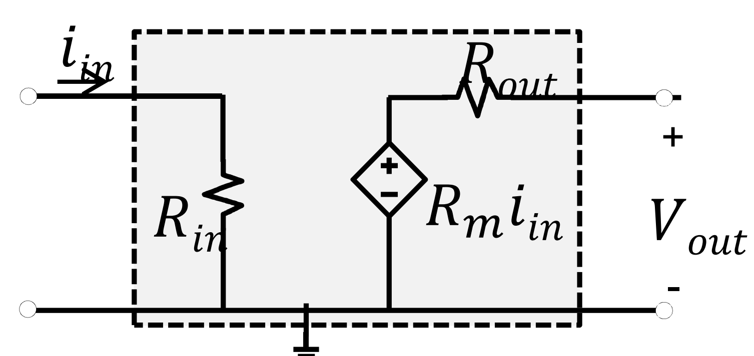


$$G_m = \left.\frac{i_{out}}{V_{in}}\right|_{V_{out}=0}$$

short circuit Trans-conductance

$R_{in} = \infty$
$R_{out} = \infty$

Trans-Resistance Amplifier



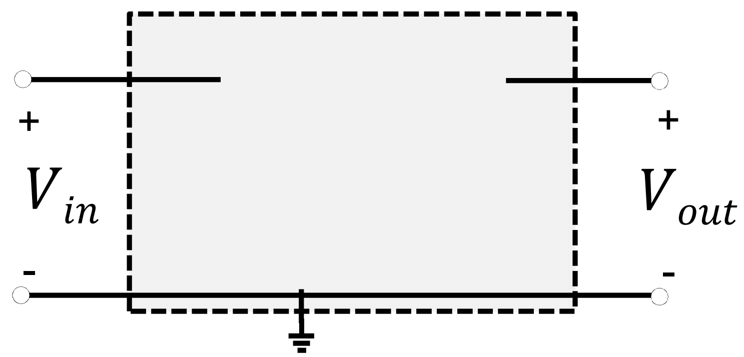
$$R_m = \left.\frac{V_{out}}{i_{in}}\right|_{i_{out}=0}$$

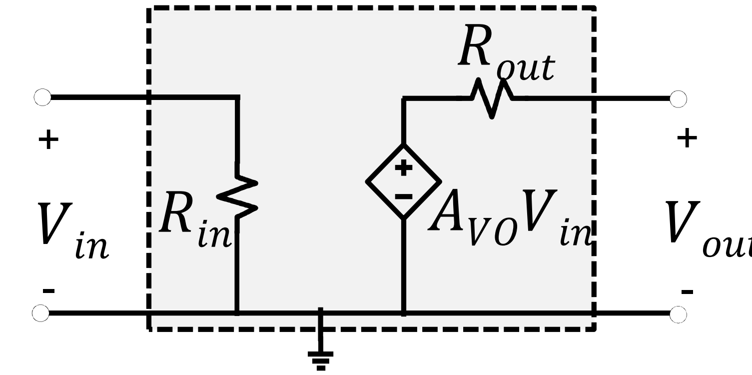
open circuit Trans-resistance

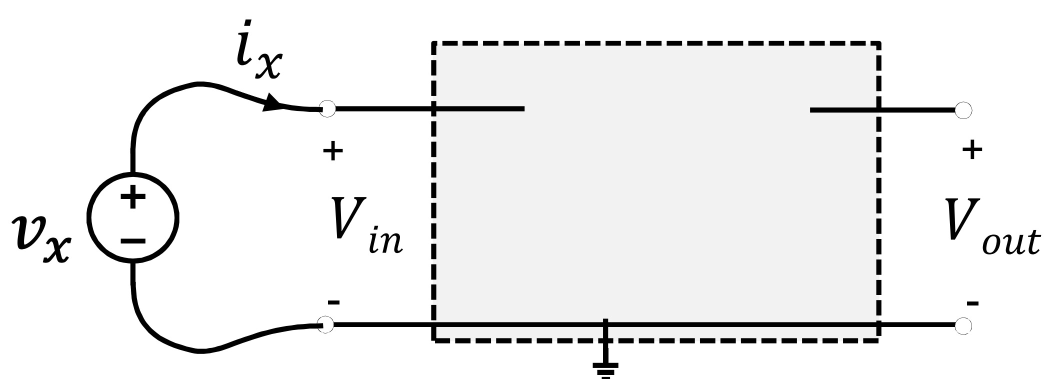
$R_{in} = 0$
$R_{out} = 0$

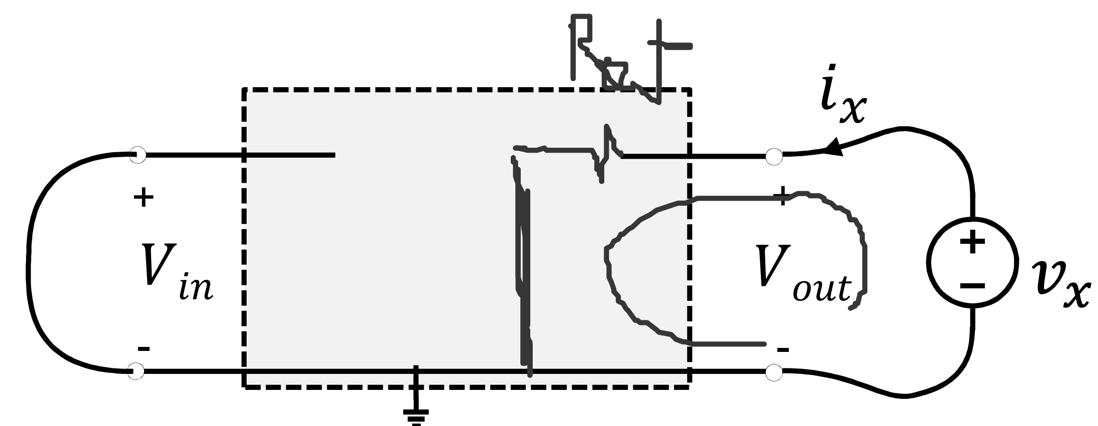
Amplifiers

Voltage Amplifier









$$R_{in} = \frac{v_x}{i_x}$$

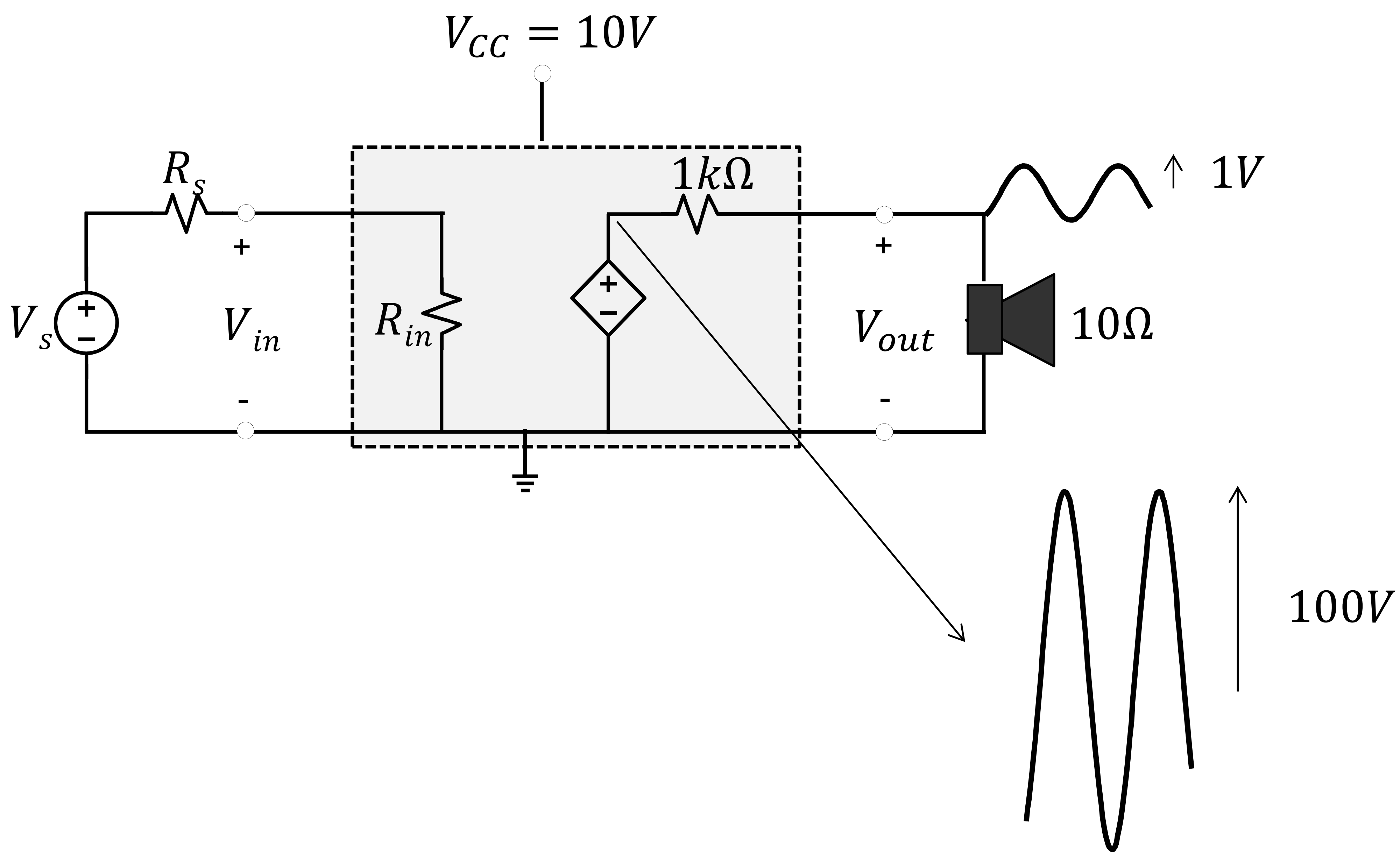
$$V_{in} = v_x$$

$$A_{VO} = \left.\frac{V_{out}}{v_x}\right|_{I_{out}=0}$$

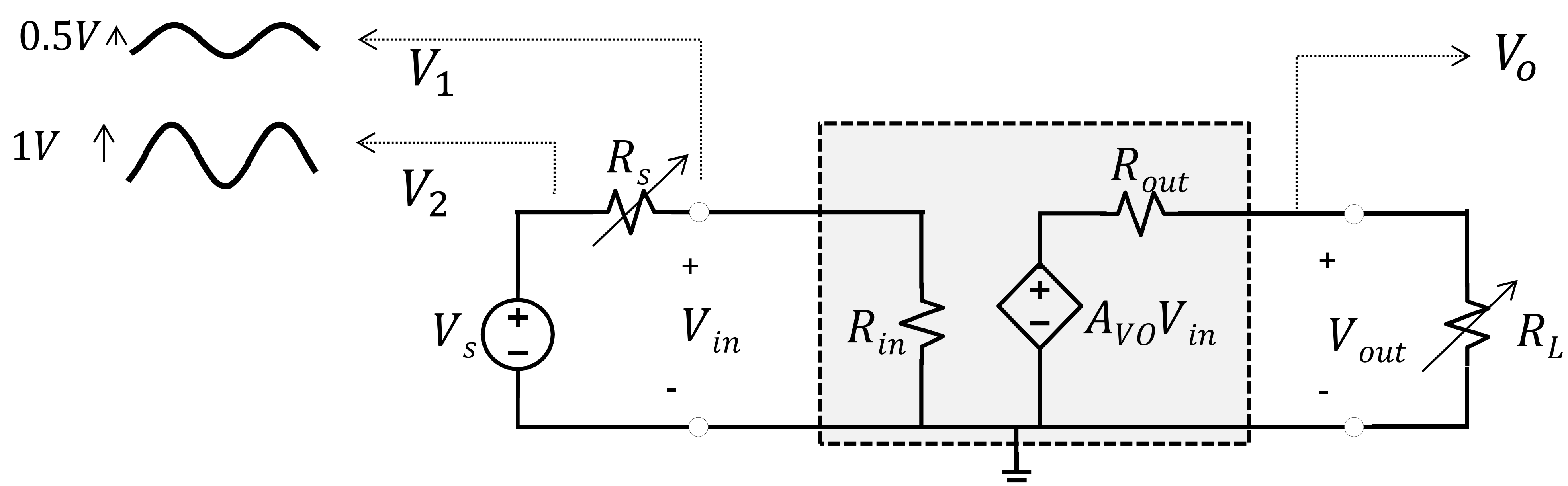
Open Output

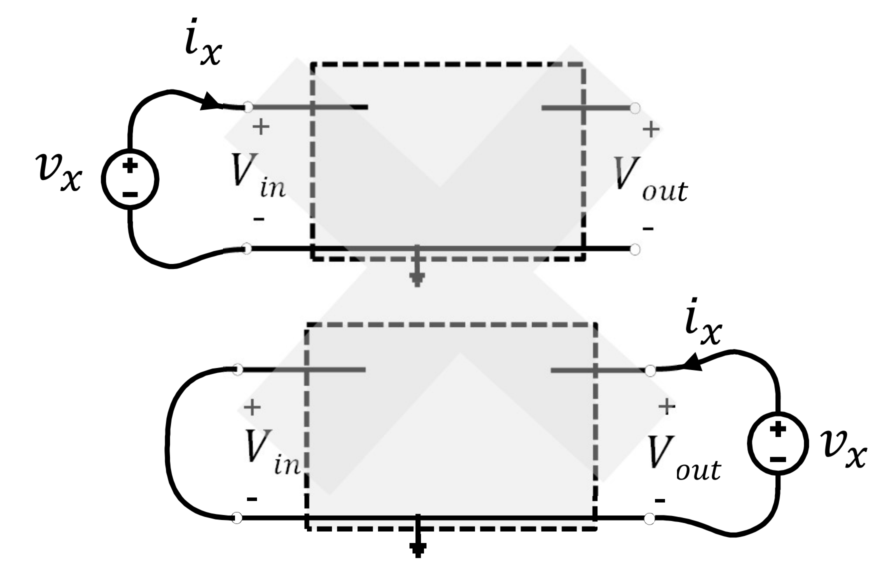
$$R_{out} = \left.\frac{v_x}{i_x}\right|_{V_{in}=0}$$

Practical Consideration



Practical Consideration: Input / Output Resistance

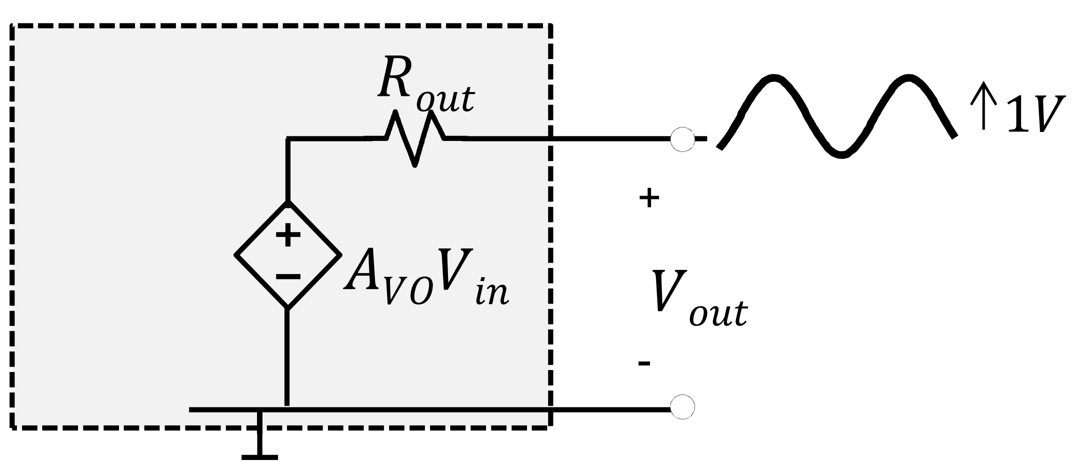




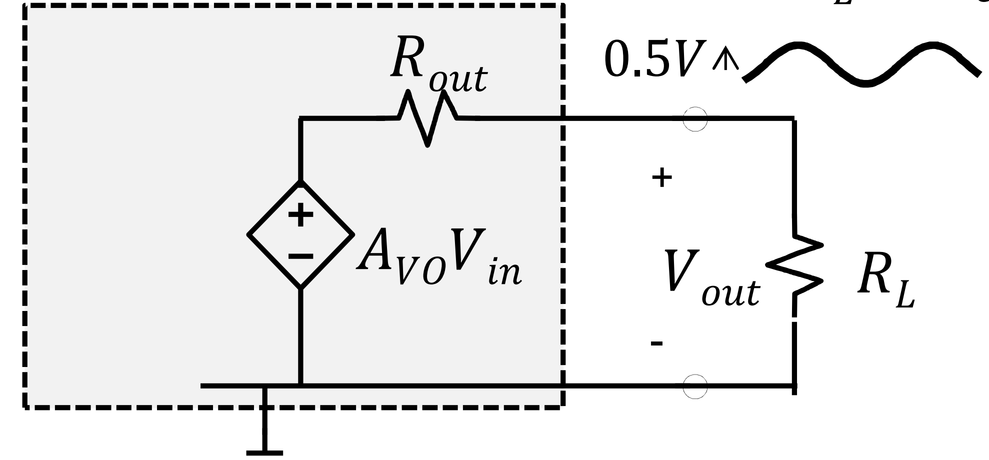
$$R_S = 1k\Omega \;\rightarrow\; \frac{V_1}{V_2} = \frac{R_{in}}{R_{in} + 1k} \qquad R_{in} = 1k \times \frac{1}{\frac{V_2}{V_1} - 1}$$

Point: You need to make sure circuit is in its linear operation regime (desired bias point)

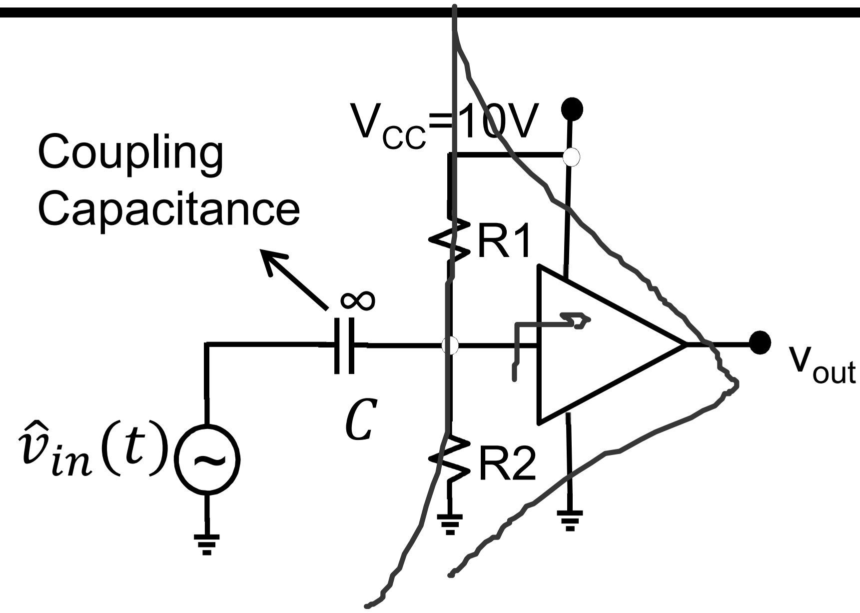
How about R_{out}?

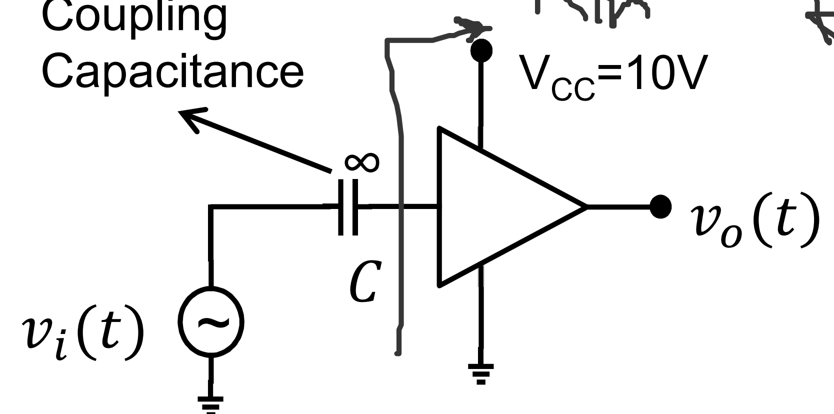


$R_L = R_{out}$



Amplifier Frequency Response





$R_{in} = R_1 \| R_3$

$\omega = \frac{1}{R_{in} C}$

$v_i(t) = V_i \sin \omega t$

$v_o(t) = V_o \sin(\omega t + \varphi)$

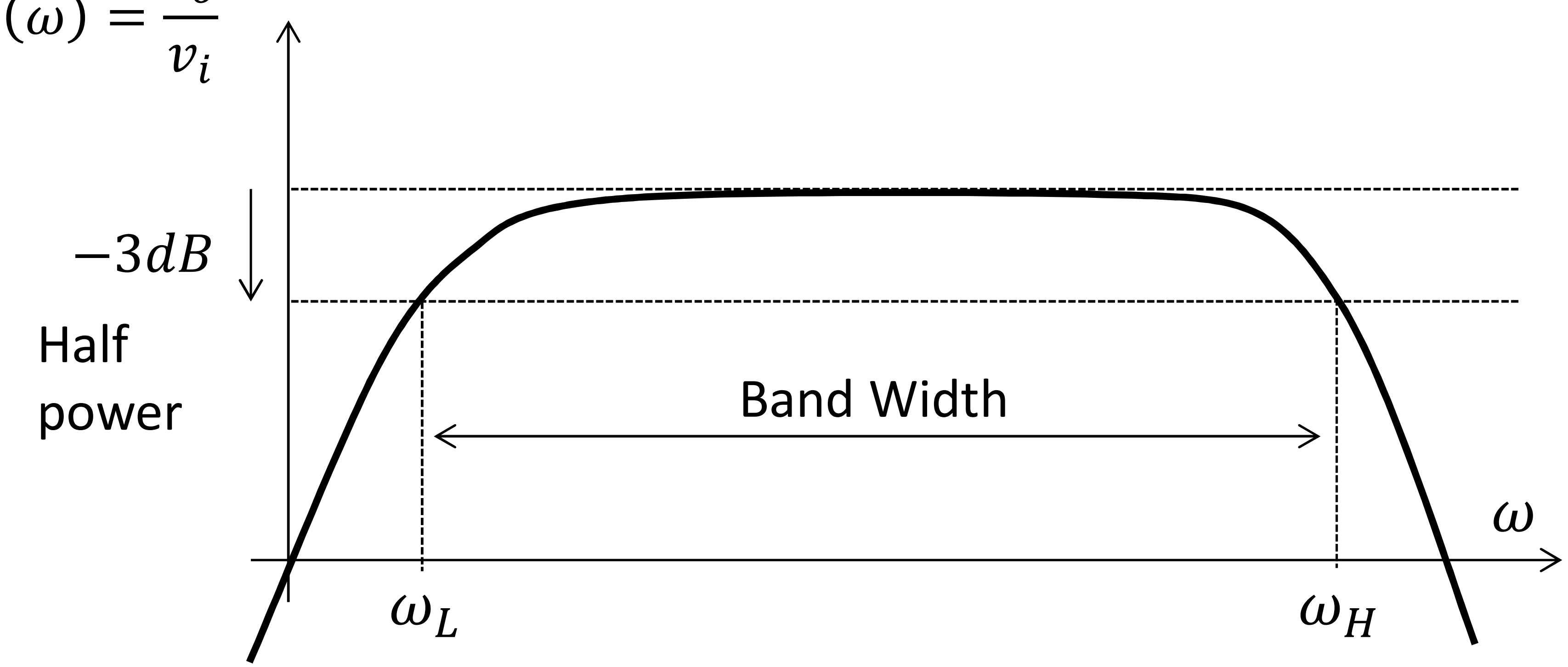
Transfer Function: $T(\omega) = \frac{v_o}{v_i}$

$|T(\omega)| = \frac{V_o}{V_i}$

Amplitude in dB

$\measuredangle T(\omega) = \varphi$

Phase



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