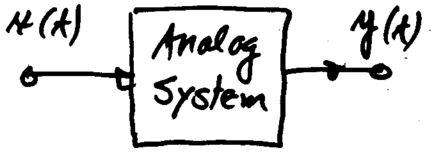
Topics:
- Linearity
- Linear Amplifier
- Decibels
- Amplifiers (power viewpoint)
- Example

CHAPTER 10 - ANALOG SYSTEMS

AMPLIFER – System Viewpoint

1.) Linearity



A system is linear iff

$x_1(t) \rightarrow y_1(t)$

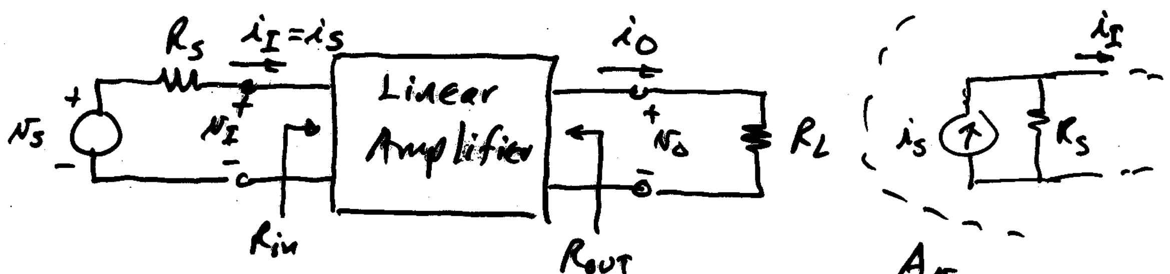
$x_2(t) \rightarrow y_2(t)$

and

$x_1(t)+x_2(t) \rightarrow y_1(t)+y_2(t)$

for all $x(t)$.

2.) Linear Amplifier



a.) Voltage gain

$$A_v = \frac{v_O}{v_I}(R_S=0) \rightarrow A_V = \frac{v_O}{v_S} = \overset{A_v}{\overset{\downarrow}{\frac{v_O}{v_I}}} \times \underset{\frac{R_{in}}{R_S+R_{in}}}{\underset{\uparrow}{\frac{v_I}{v_S}}}$$

$$\therefore A_V = A_v \frac{R_{in}}{R_S+R_{in}} \quad \left(\text{loaded amplifier}\right)$$

b.) Current gain

$$A_I = \frac{i_O}{i_I} = \frac{i_O}{i_S} = \frac{v_O/R_L}{v_S/R_{in}+R_S} = \left(\frac{R_{in}+R_S}{R_L}\right)A_V$$

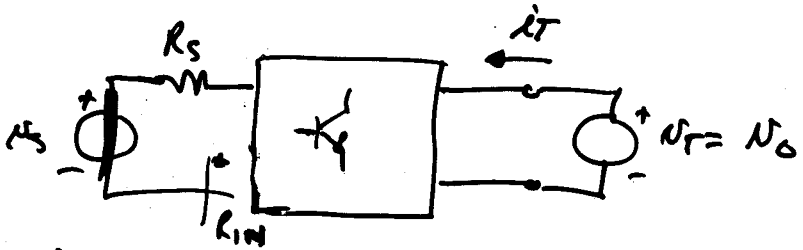
Comment on Rout:

When calculating Rout, be sure to set $v_S = 0$

c.) Power gain –

$$A_p = A_V A_I$$

d.) $R_{in} = \frac{v_I}{i_I} = \frac{v_I}{i_S}$ and $R_{out} = -\frac{v_o}{i_o}\Big|_{v_S=0} = \frac{v_o}{i_T}\Big|_{v_S=0}$



3.) Decibels

Definition: $A_p(dB) \equiv 10 \log_{10}(A_p)$

If $A_p = 10$, then $A_p(dB) = 10\,dB$

Suppose that $R_S = 0$, and $R_L = R_{IN}$

$A_I = \frac{R_S + R_{IN}}{R_L} A_v \longrightarrow A_I = A_v$

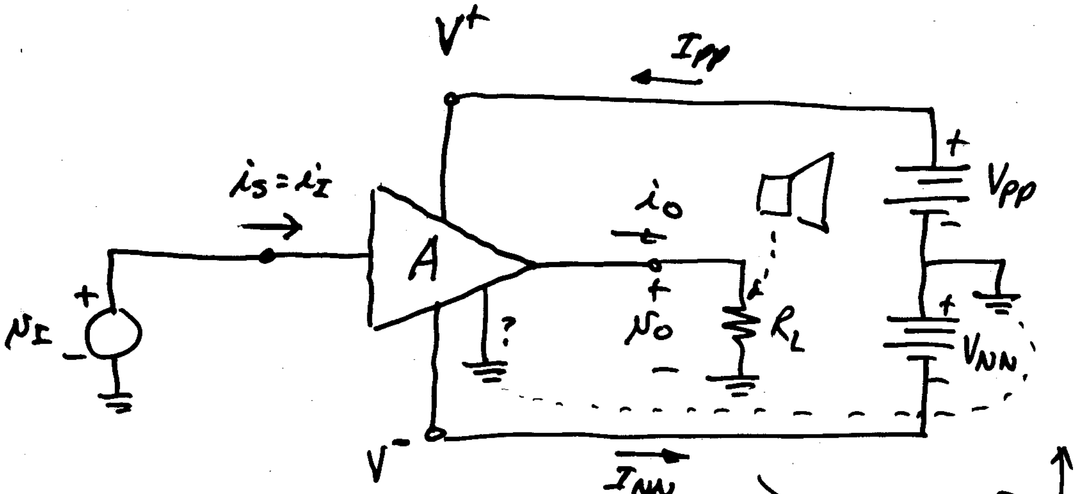
$A_v(dB) = 10 \log_{10}(A_I A_v) = 10 \log_{10}(A_v)^2 = 20 \log_{10} A_v$

$$\underline{A_v(dB) = 20 \log_{10}(A_v)}$$

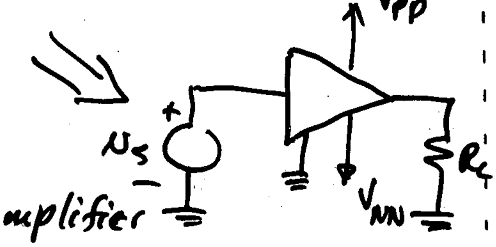
$A_v(V/V)$	10	100	1000	$\frac{1}{10}$	...	2	30	20	40
$A_v(dB)$	20	40	60	-20	...	6	30	26	32

Doubling in ratio → 6dB increase
Halving " " → -6dB decrease

4.) Amplifier from a power flow viewpoint



What types of power exist?



1.) DC power delivered to the amplifier from the batteries.

$$P_{DC} = V_{PP} I_{PP} + V_{NN} I_{NN}$$

2.) Input power from v_I or the source.

$$P_{IN} = v_I i_S = v_I i_I \quad \text{(typically small)}$$

3.) Power out - the power in R_L.

$$P_{OUT} = i_O v_O = \frac{v_O^2}{R_L} = i_O^2 R_L$$

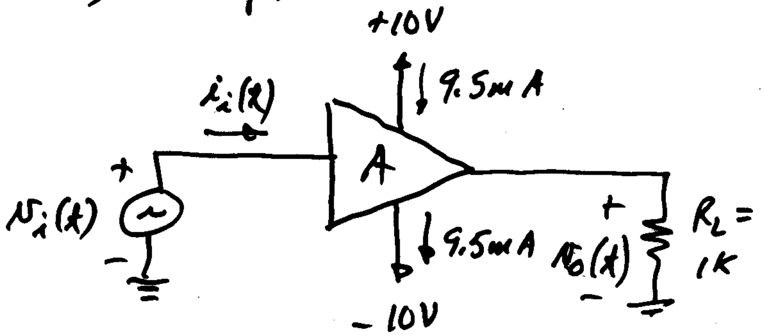
4.) Power loss - The losses in the amplifier.
P_{DISS}

Power conservation:

$$P_{DC} + P_{IN} = P_{OUT} + P_{DISS}$$

Efficiency: $$\eta = \frac{P_{OUT}}{P_{DC} + P_{IN}} \approx \underset{\nearrow\ 25\%}{\frac{P_{OUT}}{P_{DC}}} \quad \text{where } P_{IN} \approx 0$$

5.) Example -



If $v_i(t) = 1 \sin \omega_0 t$, then $v_o(t) = 9 \sin \omega_0 t$ and $i_i(t) = 0.1 \sin \omega_0 t$ (mA). Find the efficiency of this amplifier.

Solution

$$\underline{\eta = \frac{P_L}{P_{DC}+P_{IN}}}$$

$$A_v = 9 \text{ V/V} \longrightarrow A_v(dB) = 20\log_{10}(9) = 19.1 dB$$

$$i_o(peak) = \frac{v_o(peak)}{R_L} = \frac{9V}{1K} = 9mA \text{ (peak)}$$

$\therefore$ $i_o(t) = 9 \sin \omega_0 t$ (mA)

$$A_i = \frac{i_o(peak)}{i_i(peak)} = \frac{9mA}{0.1mA} = 90 \frac{A}{A} \rightarrow A_i(dB) = 39.1dB$$

$$P_L = \left(\frac{v_o(peak)}{\sqrt{2}}\right)^2 \frac{1}{R_L} = \frac{81 V^2}{2 \cdot K} = \underline{40.5 mW}$$

$$P_{IN} = P_I = \frac{v_i(peak)}{\sqrt{2}} \frac{i_i(peak)}{\sqrt{2}} = \left(\frac{1}{\sqrt{2}}\right)\left(\frac{0.1mA}{\sqrt{2}}\right) = \underline{0.05mW}$$

$$A_p = \frac{40.5mW}{0.05mW} = 810 \rightarrow A_p(dB) = 29.1dB$$

$$P_{DC} = 10(9.5mA) + 10(9.5mA) = 190mW$$

$$\eta \approx \frac{P_L}{P_{DC}} = \frac{40.5mW}{190mW} = 0.21 \rightarrow \underline{21\%}$$

$$P_{DISS} = P_{DC} + P_I - P_L = \underline{149.65mW}$$

Next:

Review 2-port parameter

Bode plots