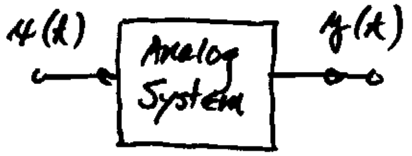
CHAPTER 11 – ANALOG SYSTEMS → AMPLIFIERS

1.) Linearity vs. nonlinearity



A system is linear iff

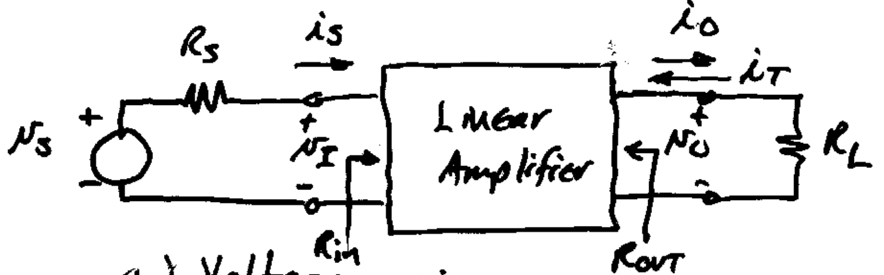
$x_1(t) \rightarrow y_1(t)$

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

and $x_1(t)+x_2(t) \rightarrow y_1(t)+y_2(t)$ for all $x(t)$.

"A system is linear if the relationship between $y(t)$ and $x(t)$ is constant for all value $x(t)$."

2.) Linear Amplifier



a.) Voltage gain

$\frac{R_{IN}}{R_S+R_{IN}}$ A_v

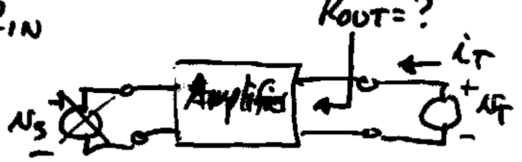
$$A_v = \frac{v_O}{v_I}\ (R_S=0) \quad \text{or} \quad A_V = \frac{v_O}{v_S} = \frac{v_O}{v_I} \times \frac{v_I}{v_S}$$

$$A_V = A_v \frac{R_{IN}}{R_S+R_{IN}}$$

b.) Current gain

$$A_I = \frac{i_O}{i_S} = \frac{v_O/R_L}{\frac{v_S}{R_S+R_{IN}}} = \frac{v_O}{v_S}\,\frac{R_S+R_{IN}}{R_L} = A_V\,\frac{R_S+R_{IN}}{R_L}$$

c.) Power gain



$$A_P = A_V A_I$$

d.) $R_{IN} = \frac{v_I}{i_I}$ and $R_{OUT} = -\frac{v_O}{i_O}\Big|_{v_S=0} = \frac{v_O}{i_T}\Big|_{v_S=0}$

3.) Decibels

$A_p(dB) \equiv 10\log_{10}(A_p)$ If $A_p = 10$, then $\log_{10} 10 = 1$

∴ $A_p = 10dB$

$A_p(dB) = 10\log_{10}[A_V A_I]$

Suppose that $R_S = 0$ and $R_L = R_{IN}$ from the previous page $A_I = \frac{R_S + R_{IN}}{R_L} A_V = A_V \rightarrow A_I = A_V$

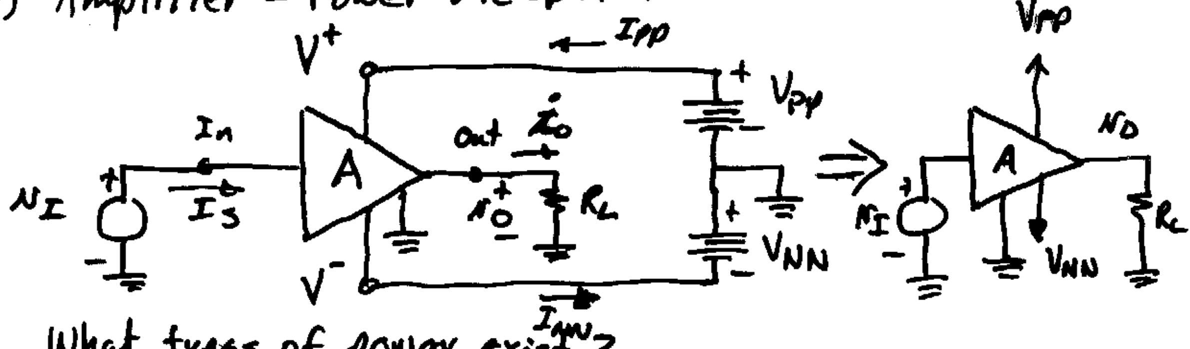
$$A_V(dB) = 10\log_{10}(A_I A_V) = 10\log_{10}(A_V^2) = 20\log_{10}(A_V)$$

If $R_S = 0$ and $R_{IN} = R_L$, then

$$\underline{\underline{A_V(dB) = 20\log_{10}(A_V)}}$$ If $A_V = 10$, then $A_V(dB) = 20dB$

Av V/V	10	100	1000	...	30	20	40
Av(dB)	20	40	60	--	30	26	32

4.) Amplifier – Power Viewpoint



What types of power exist?

1.) DC power delivered to the amplifier, $P_{DC} = V_{PP}I_{PP} + V_{NN}I_{NN}$

2.) Power in: $P_{IN} = v_I i_S$

3.) Power out: $P_{out} = i_o v_o$ (Power to the load)

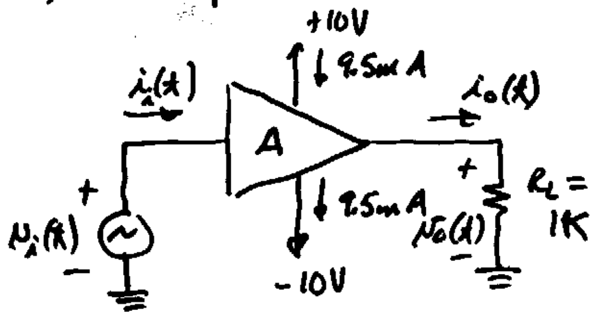
4.) Power lost P_{diss}

Power conservation:

$$P_{DC} + P_{IN} = P_{OUT} + P_{diss} = P_L + P_{diss}$$

$$\text{Efficiency} \equiv \frac{P_L}{P_{DC}} \times 100\%$$

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.

$$\text{Efficiency} = \eta = \frac{P_L}{P_{DC}}$$

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

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

$$i_o(t) = 9\sin\omega_0 t\ (mA) \rightarrow A_i = \frac{9mA}{0.1mA} = 90 \rightarrow A_i(dB) = 39.1dB$$

$$\left.\begin{aligned} P_L &= \left(\frac{9}{\sqrt{2}}\right)\left(\frac{9mA}{\sqrt{2}}\right) = \frac{81mW}{2} = \underline{\underline{40.5mW}} \\ P_I &= \left(\frac{1V}{\sqrt{2}}\right)\left(\frac{0.1mA}{\sqrt{2}}\right) = \frac{0.1mW}{2} = \underline{\underline{0.05mW}} \end{aligned}\right\} A_p = \frac{40.5}{0.05} = 810\ W/W = 29.1dB$$

$$P_{DC} = (10\cdot 9.5mA)\times 2 = 190mW$$

$$\eta = \frac{P_L}{P_{DC}} = \frac{40.5mW}{190mW}\times 100\% = 21.3\%$$

$$P_{diss} = P_{DC} + P_I - P_L = 149.65mW$$