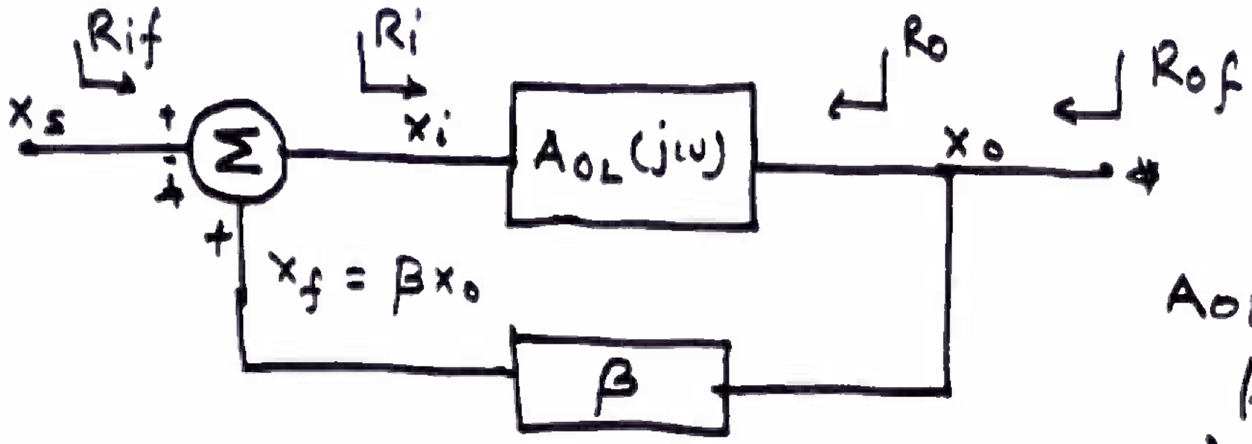
Slide No: 1

Feedback



General Feedback System

$A_{OL}(j\omega)$ = Open Loop Gain

β = Feedback Factor

$A_{CL}(j\omega)$ = Closed Loop Gain

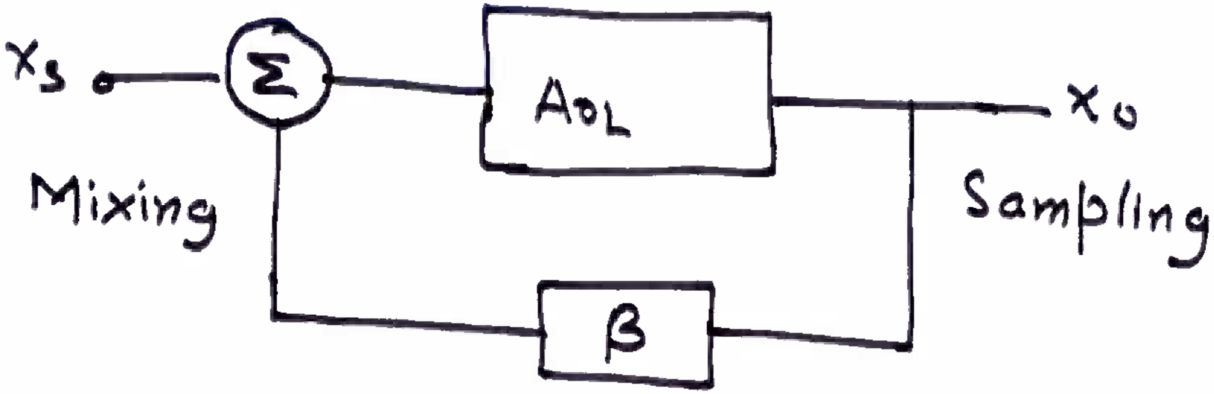
$$x_o = A_{OL}(j\omega) \cdot x_i = A_{OL}(j\omega)\,[x_s - x_f]$$

Here $x_i = x_s - x_f$ And $x_f = \beta x_o$

$\therefore\ x_o = A_{OL} x_s - A_{OL} \beta x_o \qquad \therefore\ A_{CL}(j\omega) = \dfrac{x_o}{x_s} = \dfrac{A_{OL}}{1 + A_{OL}\beta}$

CDEEP
IIT Bombay

Definitions



$A_{OL} = A_o$ = Gain without feedback

A_{CL} = Closed Loop Gain

$$\frac{A_{OL}\beta}{1 + A_o\beta} = \frac{\text{Loop Gain}}{\text{Amount of Feedback}}$$

$A_o\beta$ = Loop Gain = Return Ratio

If $A_o\beta >> 1$

Then $A_{CL} \cong \frac{A_o}{A_o\beta} = \frac{1}{\beta}$

This means that Gain of Feedback Amplifier (A_{CL}) is only decided by Passive Feedback network gain β.

As $\beta < 1$ $A_{CL} > 1$

However $A_{CL} = \frac{A_o}{1 + A_o\beta}$ can change with β & value & sign of A_o

(i) Negative Feedback (ii) Positive Feedback

Properties of Negative Feedback

[1] Gain Desensitivity

We have $A_{CL} = \dfrac{A_0}{1+A_0\beta}$

$$\text{or } dA_{CL} = dA_0\left[\frac{1}{1+A_0\beta} - \frac{A_0\beta}{(1+A_0\beta)^2}\right] \qquad x_i = x_s + x_f$$

$$\text{or } dA_{CL} = \frac{dA_0}{(1+A_0\beta)^2}$$

$$\therefore \quad \frac{dA_{CL}}{A_{CL}} = \frac{dA_0}{(1+A_0\beta)^2}\cdot\frac{(1+A_0\beta)}{A_0} = \frac{1}{(1+A_0\beta)}\cdot\frac{dA_0}{A_0}$$

Clearly % change in A_{CL} is Always Less than % change in A_0

$\therefore (1+A_0\beta)$ is also called Desensitivity Factor

[2] Bandwidth Enhancement

$$A_{OL}(s) = \frac{A_{Midband}}{1+ S/\omega_0} = \frac{A_M}{1+ S/\omega_0} = A_0$$

ω_0 is Dominant Pole

Then with Negative Feedback

$$A_{CL}(s) = \frac{A_{OL}(s)}{1+ A_{OL}(s)\,\beta} = \frac{A_M / (1+S/\omega_0)}{1+ \frac{A_M}{1+S/\omega_0}\cdot\beta}$$

$$= \frac{A_M/(1+A_M\beta)}{S/(1+A_M\beta)\omega_0 + 1}$$

$$A_{CLO} = \frac{A_M}{1+A_M\beta}$$

$$= \frac{A_{CLO}}{1+ S/[(1+A_M\beta)]\omega_0}$$

Slide No: 6

Clearly Gain (OL) $= \dfrac{A_M}{1+A_M\beta}$

$\wedge$ New Pole $= \omega_o(1+A_M\beta) = \omega_f$

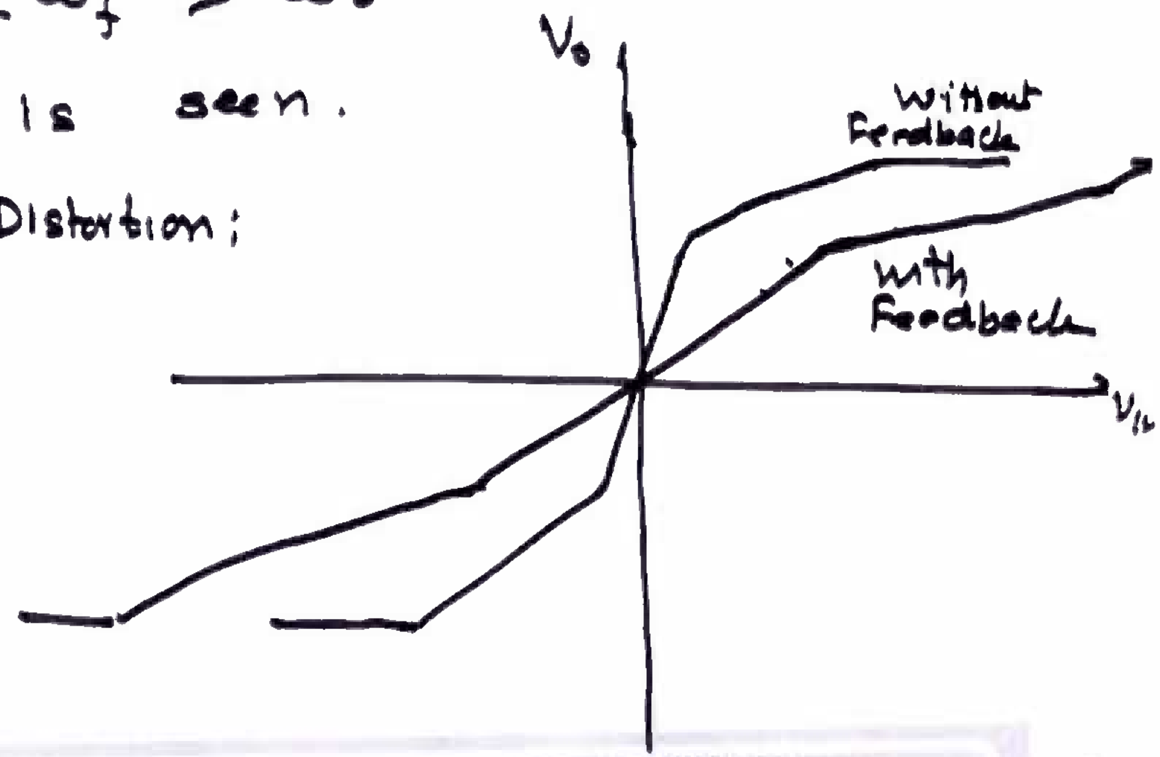
As $A_M\beta > 1$

$\therefore \omega_o(1+A_M\beta) = \omega_f > \omega_o$

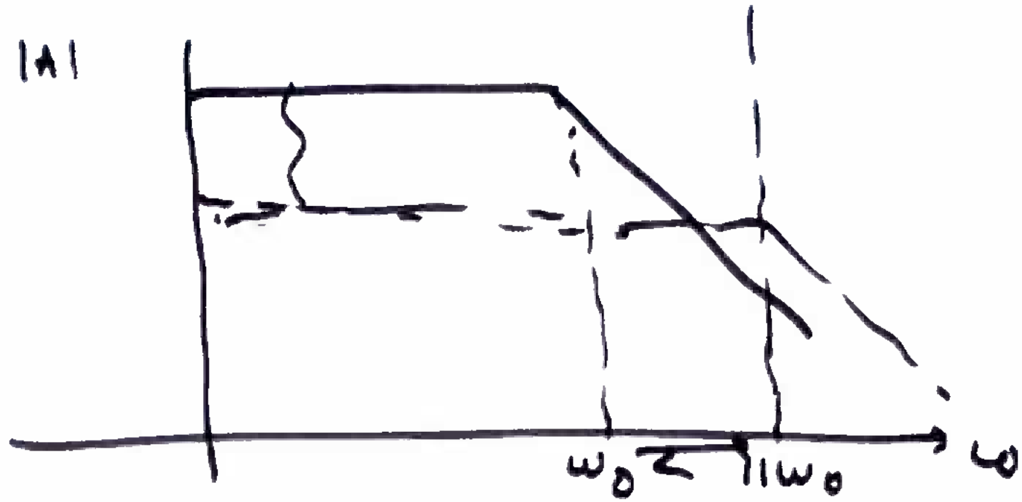
$\therefore$ Bandwidth extension is seen.

[3] Reduction in Non-Linear Distortion;

:→ <u>Linearization</u> ?



CDEEP
IIT Bombay

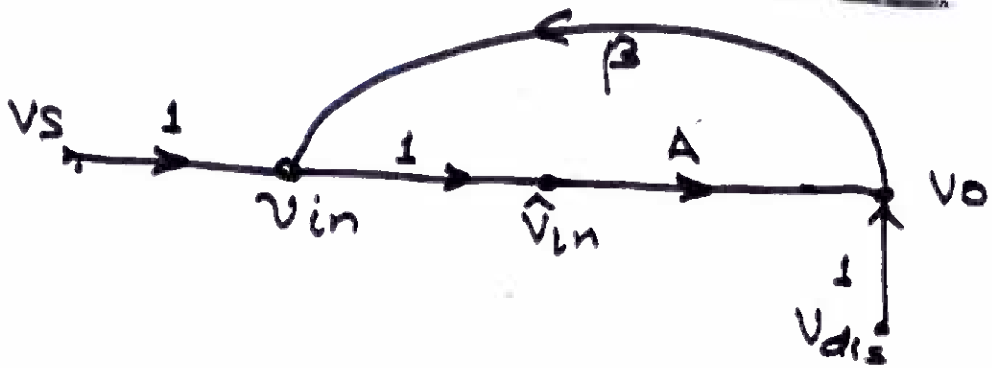


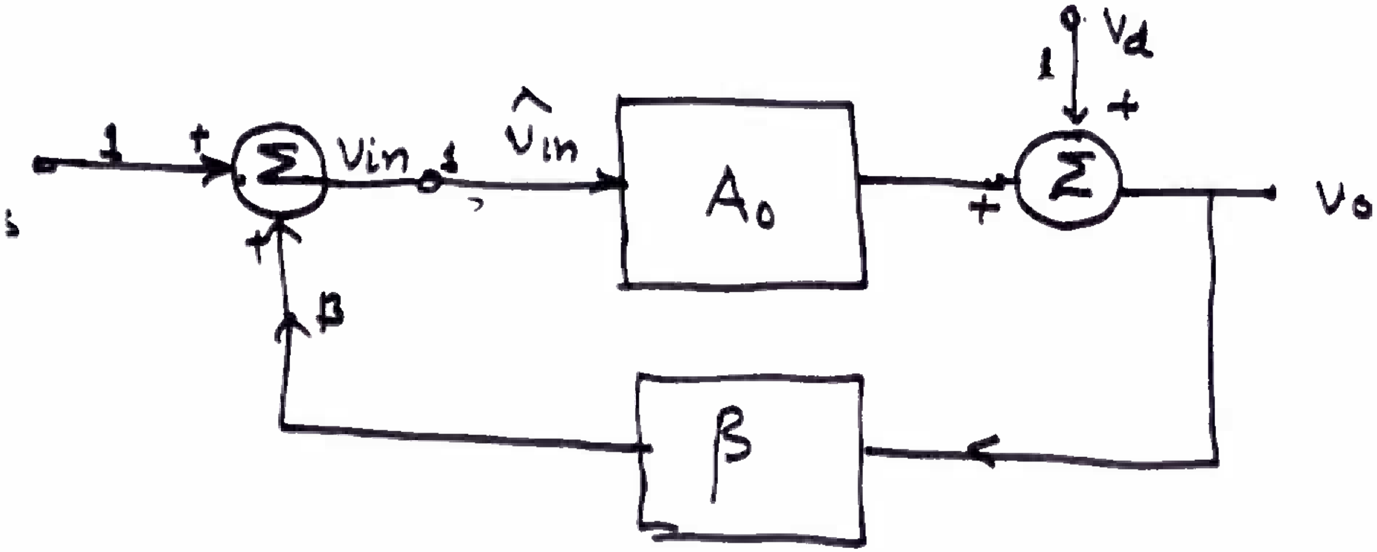
$A_0\beta = 10$

$$\frac{k'}{\left(\frac{s}{\omega}-1\right)} = \frac{1}{s-\omega} = \frac{K}{\left(\frac{s}{\omega}-1\right)\omega}$$

$$k' = \frac{K}{\omega}$$

Signal Flow Graph



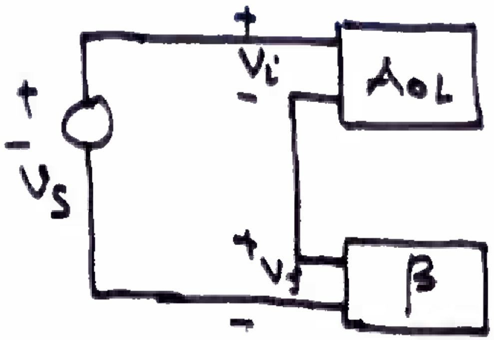


$$\therefore V_o = A_F V_s + \frac{V_d}{1 + A_o \beta}$$

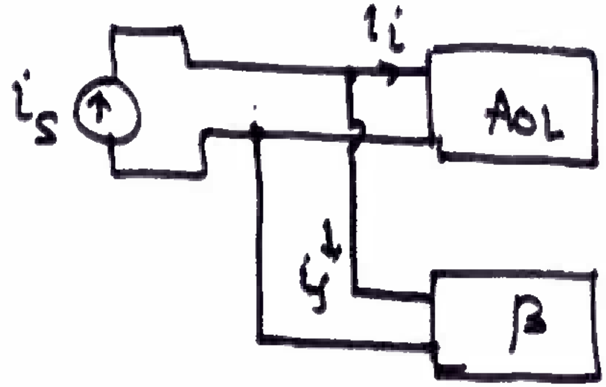
$$A_o \beta = T > 1$$

$$V_o = A_F V_s + \frac{V_d}{T}$$

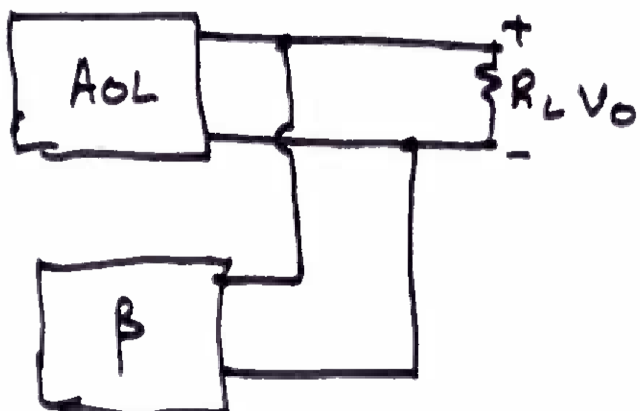
Circuit equivalent for Mixing & Sampling



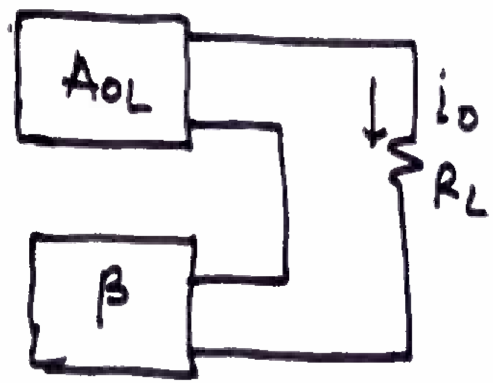
Series Mixing



Shunt Mixing

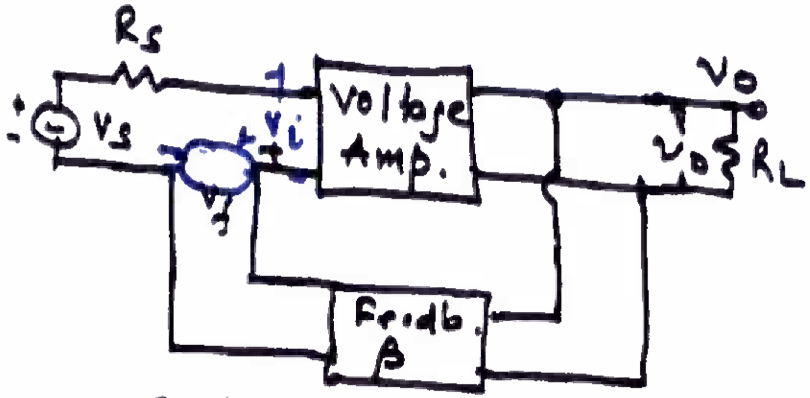


Shunt Sampling

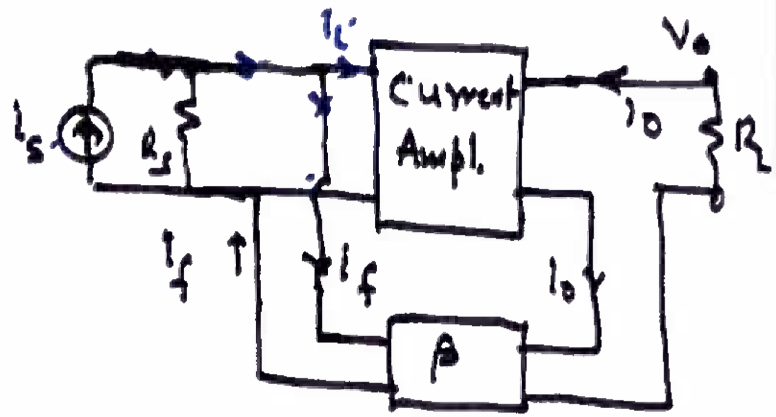


Series Sampling

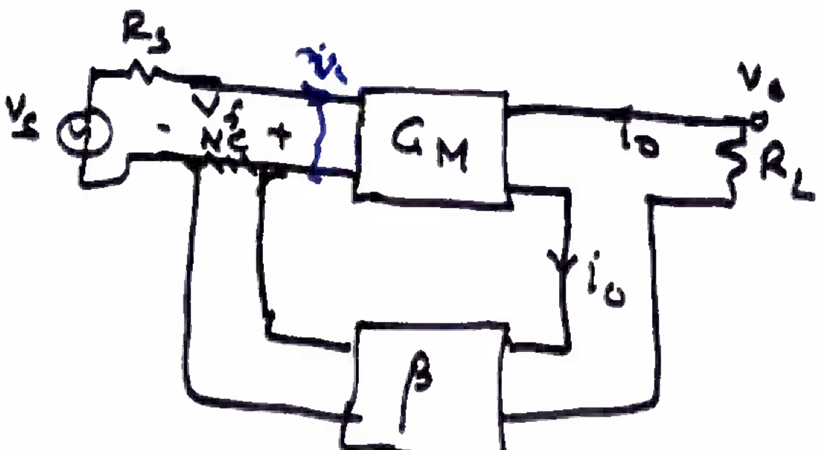
Four Topologies for Feedback Amplifiers



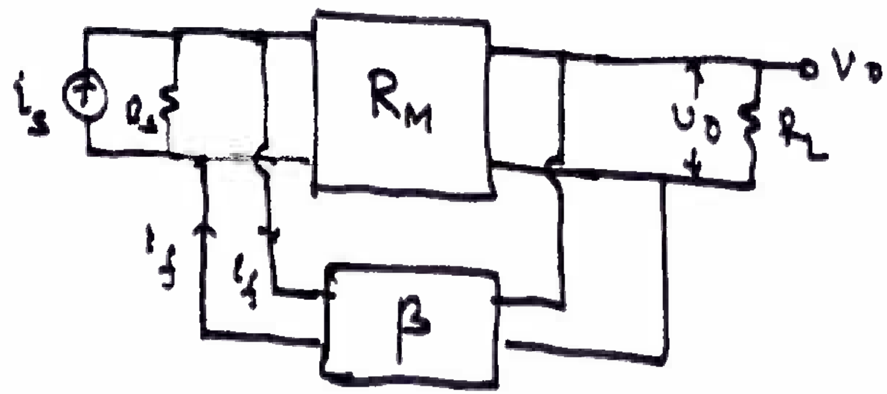
Series – Shunt



Shunt – Series



Series – Series



Shunt – Shunt

CDEEP
IIT Bombay

Types of Feedback Amplifiers

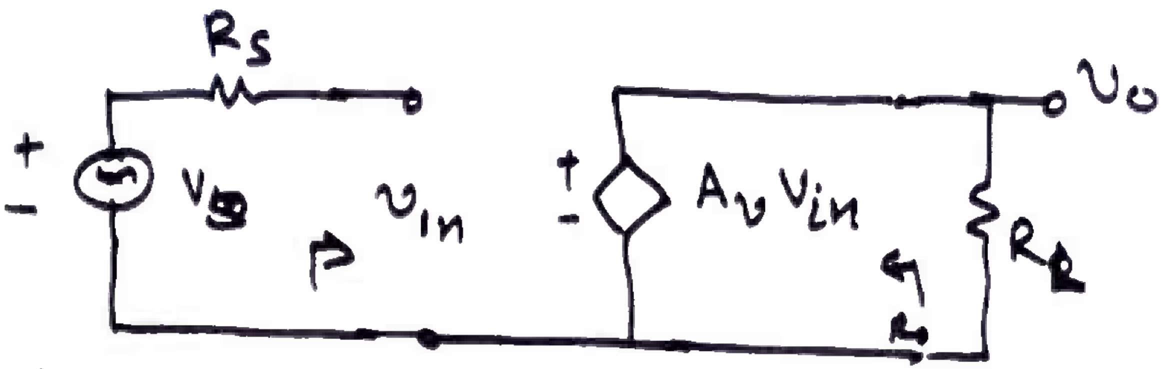
	x_s, x_i & x_f	x_o	Mixing – Sampling
①	Voltage	Voltage	Series – Shunt
②	Voltage	Current	Series – Series
③	Current	Current	Shunt – Series
④	Current	Voltage	Shunt – Shunt

① Voltage Amplifier ② Transconductance Amplifier

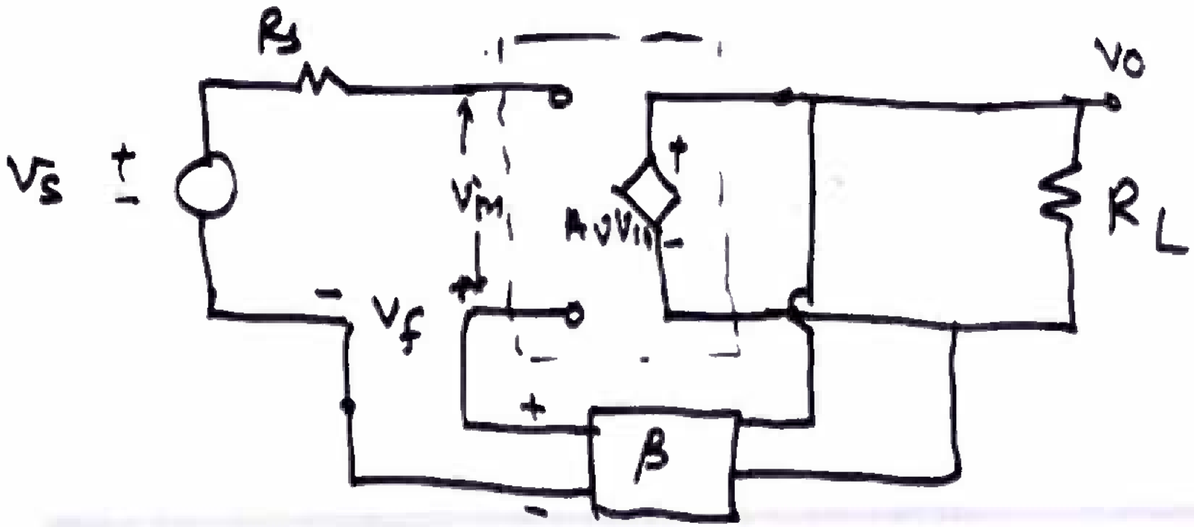
③ Current Amplifier ④ Trans Resistance Amplifier

CDEEP
IIT Bombay

Ideal Amplifier



Assumption $R_{in} = \infty$ $R_o = 0$. Now we apply Negative Feedback



Here Sampling is Shunt (Volt)

& Mixing is Series

$V_f = \beta V_o$

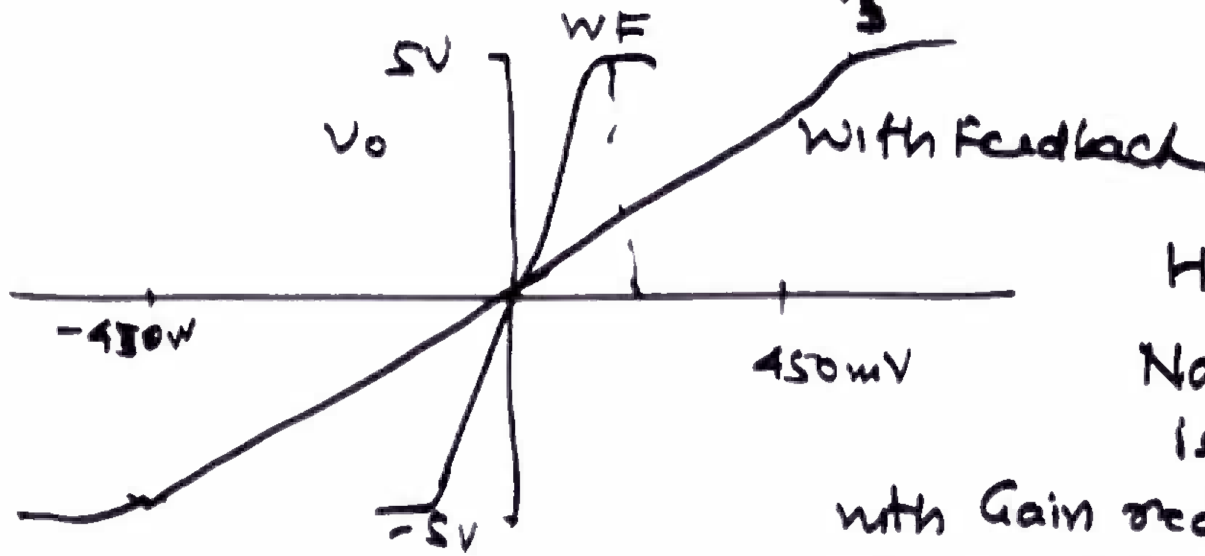
Then $V_s = v_{in} + v_f$

$= v_{in} + 0.09\, V_o$ Here $\beta = 0.09$

If $V_o = 5V$ then $0.09 \times 5 = 0.45\ V$

$= 450\ mV$

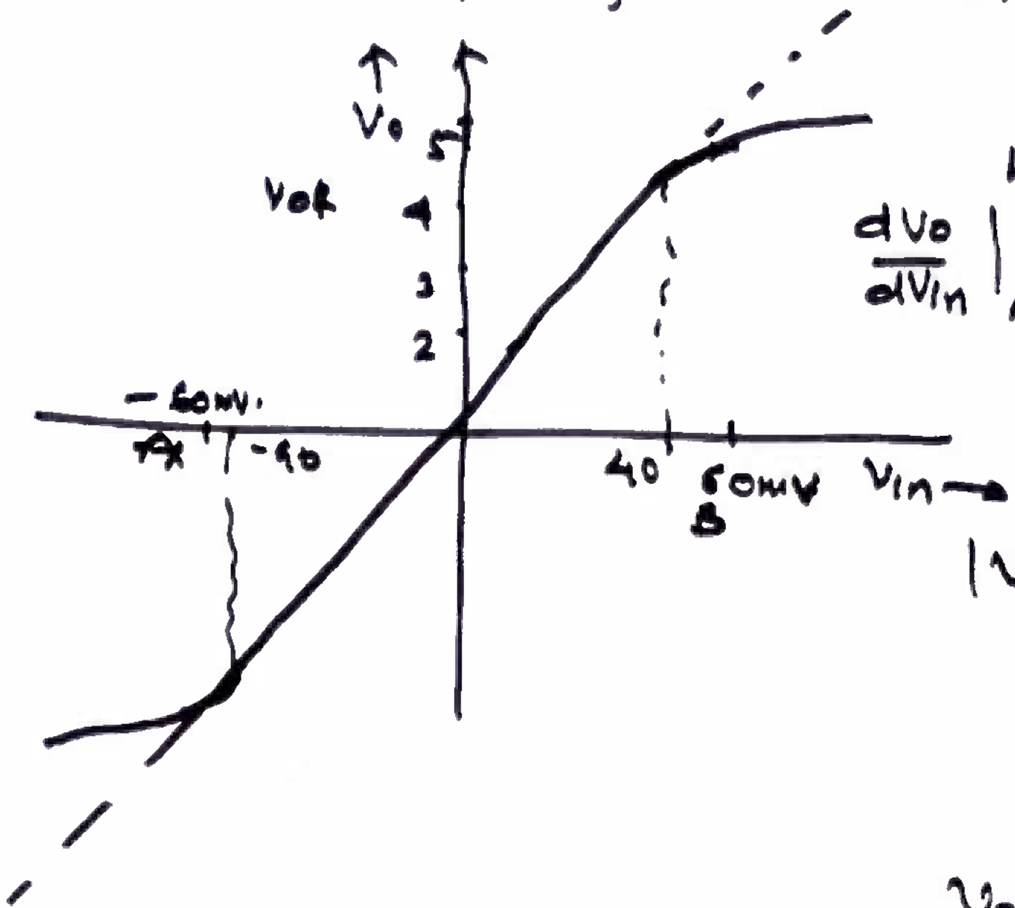
clearly for $V_s \leq 500\ mV$ $\frac{V_o}{V_s}$ = constant $= A_F \simeq 10$



Hence we say Nonlinear Distortion is reduced.

with Gain reducing

Concept of Non Linear Distortion



Let

$$\left.\frac{dV_o}{dV_{in}}\right|_{A \to B} = 100 = \text{Gain}$$

$|v_o| = 100\, v_{in} \quad -40 \leq v_{in} \leq 40mV$

$|v_o| = 100[v_i - 40mV]$

$- 2500[v_{in} - 0.04]^2 + \ldots$

$40 \leq v_{in} \leq 60mV$

$v_o = 5V \qquad v_{in} > 60mV$

$f(x) = a_0 x + a_1 x^2$

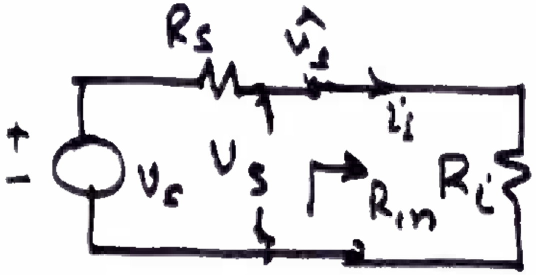
$v_1 = A \sin \omega t$

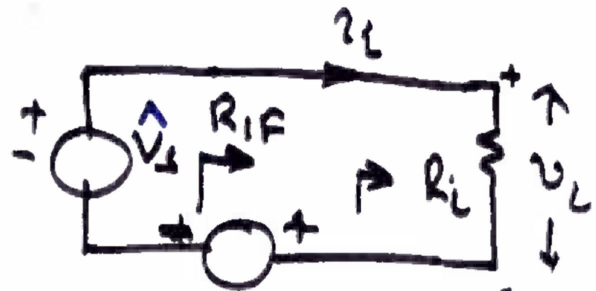
Slide No: 15

Impedance in feedback Amplifiers

[A] Input Resistance

ⓐ Series Mixing & (Shunt Sampling)





$V_f = \beta V_o$

We have

$$\frac{V_o}{V_i} = A$$

$$A_F = \frac{V_o}{V_s} = \frac{A_{OL}}{1 + A_{OL}\beta} = \frac{A_o}{1 + A_o\beta} = \frac{A}{1 + A\beta}$$

$$R_i = \frac{\hat{V}_s}{i_i} = R_i \qquad R_{iF} = \frac{V_s}{I_i} = \frac{\hat{V}_s}{v_i / R_i} = R_i \frac{V_s}{V_i} = (1 + A\beta) R_i$$

$$V_i + V_f = V_s = V_i + \beta V_o = (1 + A\beta) V_i$$

$$\therefore\ i_x = \frac{V_x + A\beta V_x}{R_o}$$

or $$\frac{V_x}{i_x} = \frac{R_o}{1+A\beta} = \frac{R_o}{T} = R_{OF}$$

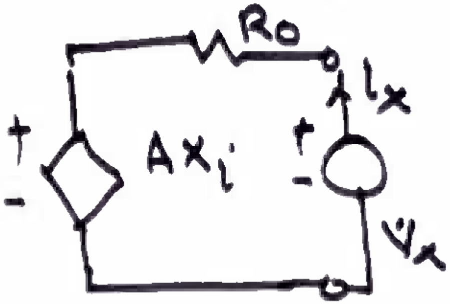
$$\therefore\ R_{OF} < R_o$$

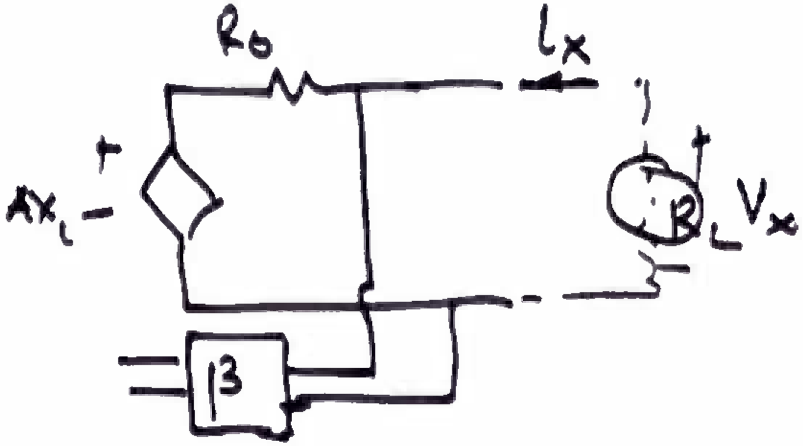
(b) Similarly we can show that series sampling

$$R_{OF} = (1+A\beta)R_o \quad \text{\&} \quad R_{OF} > R_o$$

[B] Output Resistance

(a) Shunt Sampling





With $x_1 = 0$

$R_{o_{OL}} = R_o$

With feedback $\quad R_{oF} = \dfrac{V_x}{i_x}$

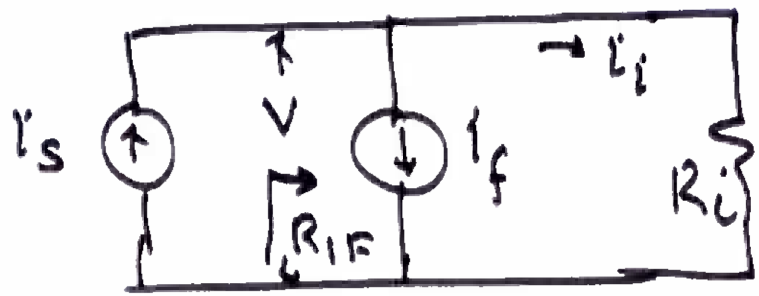
$x_s = x_i + x_f \quad$ with $x_s = 0$

$-x_i = x_f = \beta V_o =$

$x_i = -\beta V_x$

CDEEP
IIT Bombay

[B] Shunt Mixing



x_0 (V_0 or I_0

$$i_f = \beta x_0$$

$$x_0 = A i_i$$

$$i_i = i_s - i_f = i_s - \beta x_0 = i_s - A\beta i_i$$

or $$(1+A\beta) i_i = i_s$$

$$R_{IF} = \frac{V}{i_s} = \frac{V/i_i}{(1+A\beta)} = \frac{R_i}{1+A\beta}$$