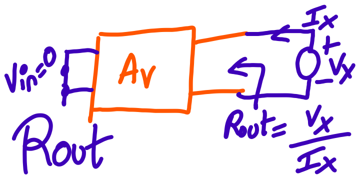
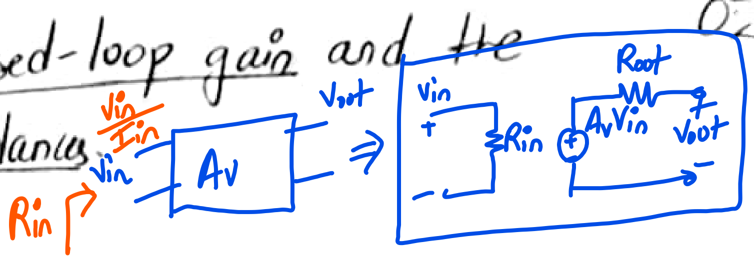
AEC 34.2 22/4/22



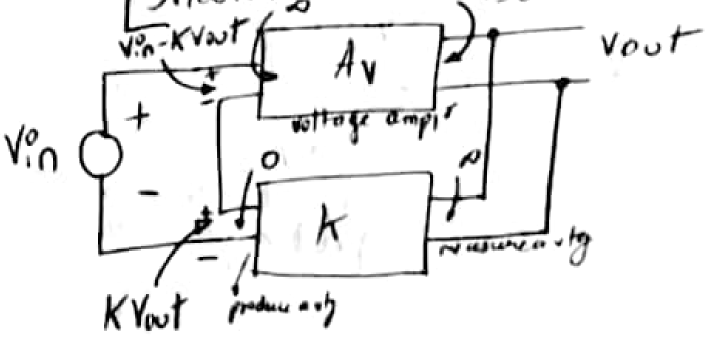
Objective:- To find the closed-loop gain and the closed-loop input & o/p impedance.

v. important



Analysis of Voltage-Voltage feedback :- (Voltage-series) topology

[Shunt series f/b]

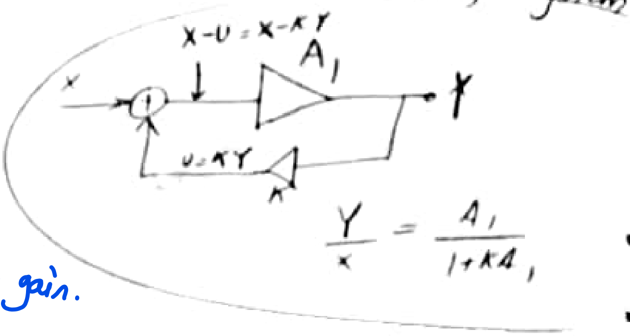


∞ & 0 ideal situation

open loop gain = A_v

closed loop gain = $\frac{V_{out}}{V_{in}}$

General f/b system



$$\rightarrow \quad V_{out} = A_v (V_{in} - K V_{out})$$

$$V_{out} + A_v K V_{out} = A_v V_{in}$$

$$V_{out}(1+KA_v) = A_v V_{in}$$

Av - open-loop gain.

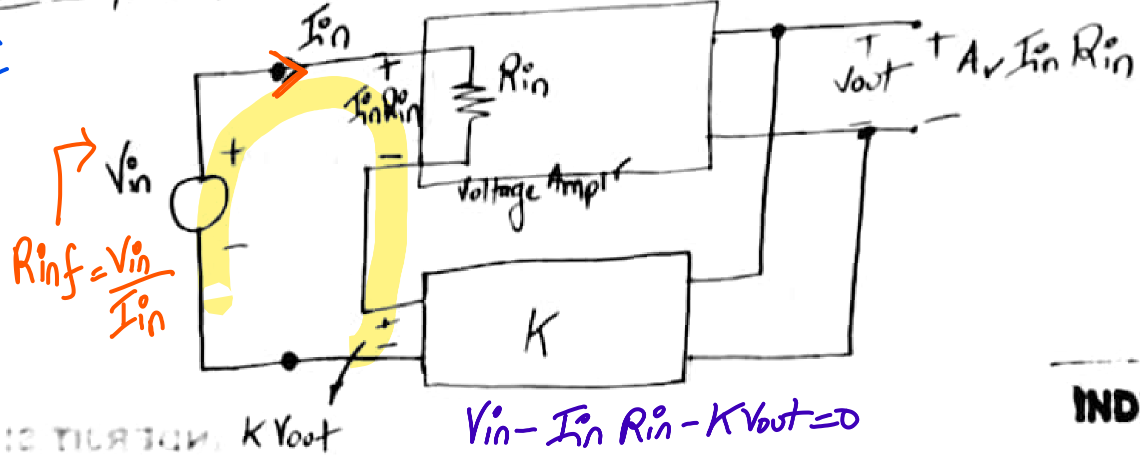
Closed loop gain

$$\boxed{A_{vf} \rightarrow \frac{V_{out}}{V_{in}} = \frac{A_v}{1+KA_v}} \rightarrow \text{closed-loop gain}$$

Closed-loop Input impedance :- R_{inf} → $\frac{V_{in}}{I_{in}}$

A_v

R_{inf}



KVout

$$V_{in} - I_{in}R_{in} - KV_{out} = 0$$

$$V_{in} = I_{in}R_{in} + KV_{out}$$

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$$\boxed{V_{out} = A_v \cdot I_{in} R_{in}}$$ ✓

→ ✓ KVL at I/P side, $\rightarrow V_{in} - I_{in}R_{in} - K V_{out} = 0$

$$V_{in} = I_{in} R_{in} + K \overset{V_{out}}{\boxed{A_v R_{in} I_{in}}}$$

$$R_{inf} \rightarrow \boxed{\frac{V_{in}}{I_{in}} = R_{in}(1+KA_v)} \dashrightarrow \text{Closed-loop I/p impedance}$$

$$\boxed{R_{inf} = R_{in}(\underline{1+KA_v})}$$

R_{in} - I/p impedance of open loop amp^r

holds for vtg feedback

→ Is this good or bad ?

→ I/P resistance/impedance (↑se) with intro. of R_x ve feedback

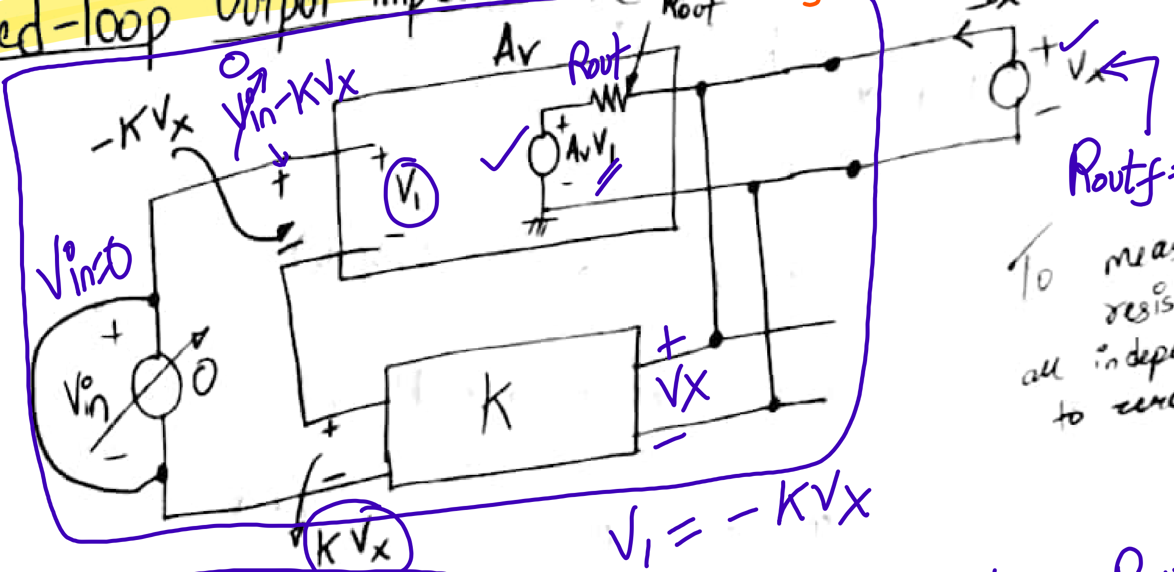
$I_x = \frac{V_1 - V_2}{R_x}$ — V_1 —R_x— V_2, → I_x

↓ Good thing for a voltage amp^r & overall system to sensing vtg

Closed-loop Output impedance : ($R_{out\,f}$) $\rightarrow \frac{V_x}{I_x}$

$R_{out\,f}$

$$I_x = \frac{V_x - A_v V_1}{R_{out}}$$



$$R_{out\,f} = \frac{V_x}{I_x}$$

To measure o/p resistance, set all independent source to zero.

$$V_1 = -KV_x$$

$$\rightarrow \boxed{A_v V_1 = -A_v K V_x}$$

$$\rightarrow I_x = \frac{V_x - \boxed{A_v V_1}}{R_{out}} = \frac{V_x + A_v K V_x}{R_{out}}$$

$$I_x = \frac{V_x(1+KA_v)}{R_{out}}$$

$$\frac{V_x}{I_x} = \frac{R_{out}}{\boxed{(1+KA_v)}} = R_{out\,f}$$

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$I_x R_{out} = V_x(1+A_vK)$

R_{out} → open-loop o/p impedance.

$$\Rightarrow \boxed{\frac{V_x}{I_x} = \frac{R_{out}}{1+A_vK}} \dashrightarrow \text{closed-loop o/p Impedance}$$

R_{out_f}

with -ve f/b, R_{out} (o/p impedance) goes down

Good or Bad ?

ckt deliver a vtg (act as a vtg source), so it shld have a low o/p resistance.

Better vtg ampl^r since R_{out} is lower.

→ As a result of negative feedback we sacrifice some voltage gain $\left(\frac{A_v}{1+KA_v}\right)$; but we gained two important benefits

1. I/p impedance went up by $(1+KA_v)$ (Good for better vtg ampl^r)
2. O/p impedance went down by $(1+KA_v)$ (-11-)
3. Bandwidth also goes up by $(1+KA_v)$

Improves performance of the system.

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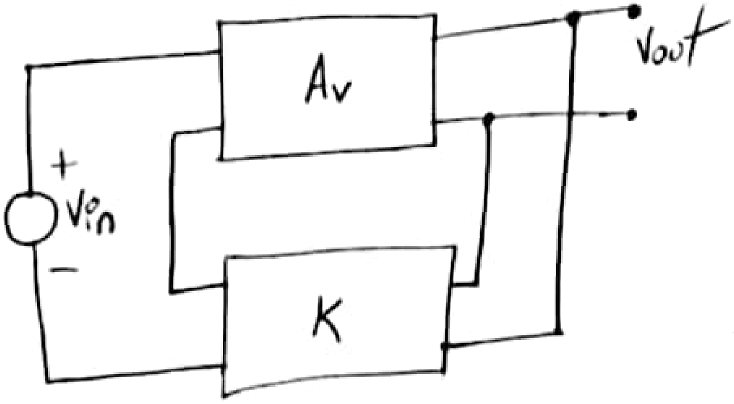
Summary:- ① Voltage-Voltage feedback

→ $A_{vf} = \frac{V_{out}}{V_{in}} = \frac{A_v}{1+A_vK}$



→ Closed loop i/p impedance = $R_{in}(1+KA_v)$

→ Closed loop o/p impedance = $\frac{R_{out}}{(1+KA_v)}$

- Sensing a vtg at the o/p
- Returning a vtg at the I/p → Better vtg ampl^r, vtg sensor since its R_{inf} is higher

→ Stable voltage gain

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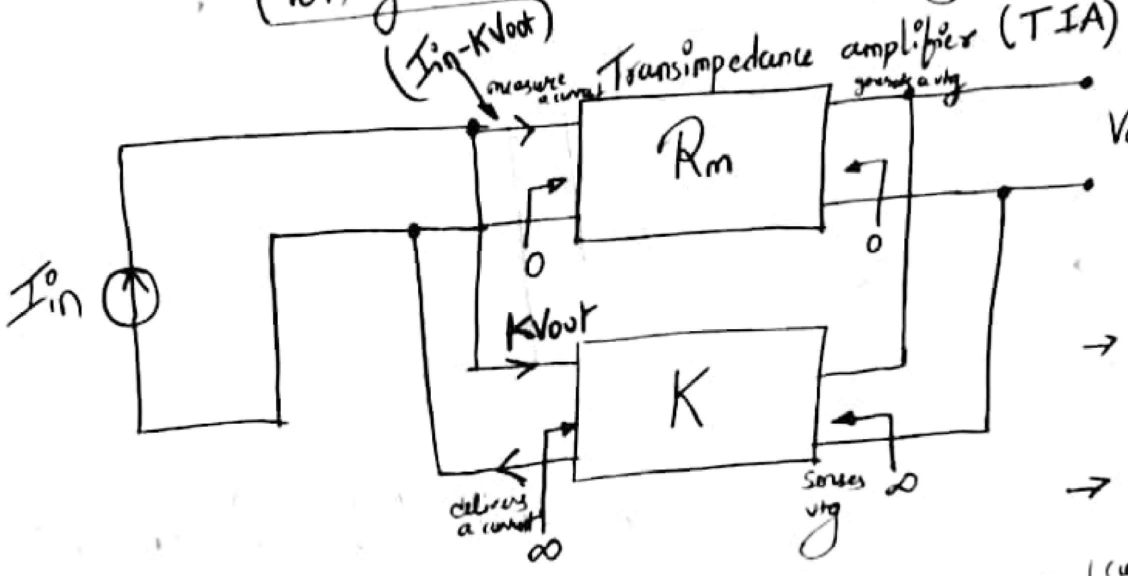
- Voltage - Current (Shunt-Shunt) Feedback
(Voltage-shunt Feedback topologies) :

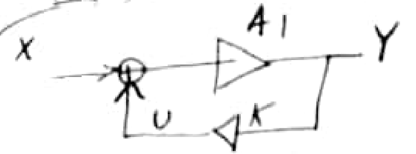


Rm - open loop gain

→ Unit of gain Rm is $\underline{\Omega}$

→ K unit is $\left(\frac{1}{\Omega}\right)$ $\left(\frac{\text{current}}{\text{vtg}}\right)$

Q. Does the unit of K always have to be $\frac{1}{\text{unit of } A_1}$? → Yes



$$\frac{Y}{X} = \frac{A_1}{1+KA_1}$$

- Closed-loop Gain :- - - → $\frac{V_{out}}{I_{in}} = ?$

$$(I_{in} - K V_{out}) R_m = V_{out}$$

$$\rightarrow I_{in} R_m = V_{out} + K V_{out} R_m$$

$$\rightarrow I_{in} R_m = V_{out}(1 + K R_m)$$

$$\rightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{R_m}{1+KR_m}} \rightarrow R_{mf} \rightarrow \text{closed-loop gain}$$

→ Gain with -ve f/b reduces by a factor of $(1 + K R_m)$

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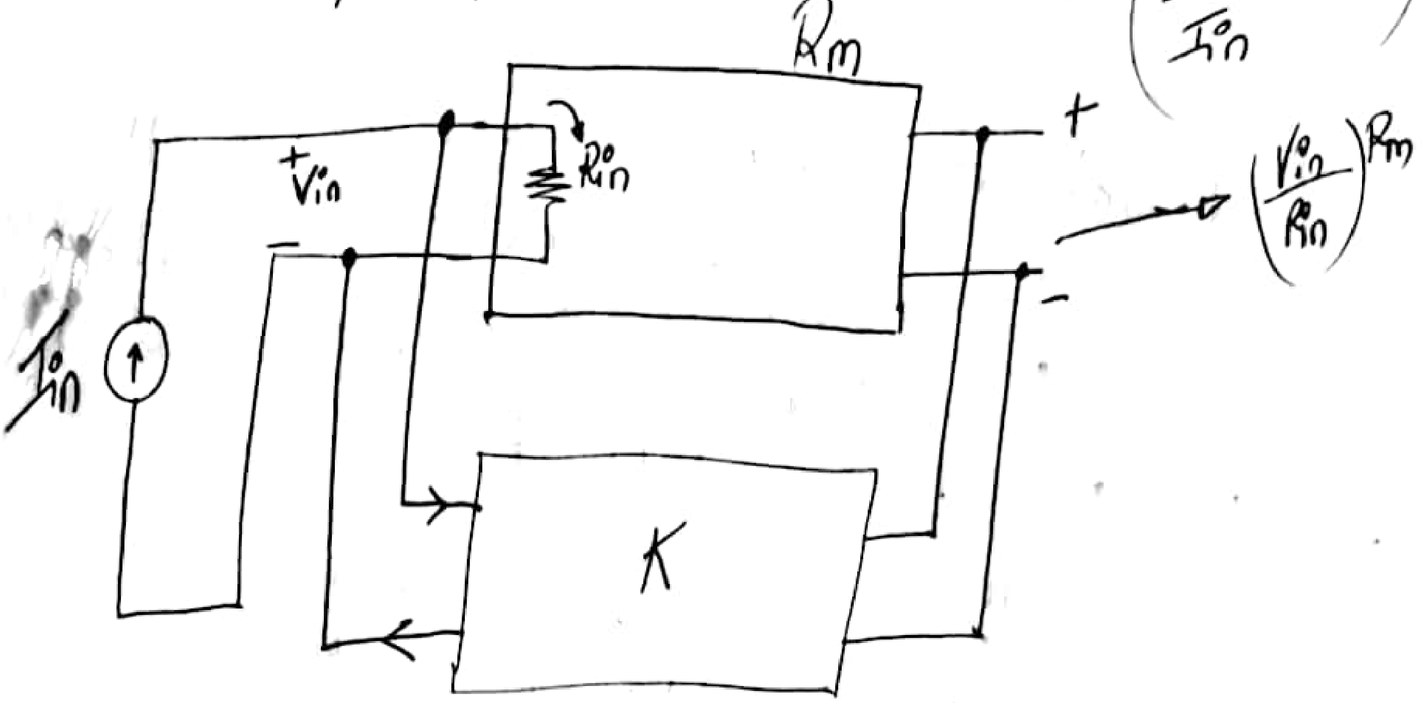
Closed-loop Input impedance :- $\rightarrow \left(\frac{V_{in}}{I_{in}} = ?\right)$



$\left[\frac{V_{in}}{R_{in}} R_m\right] K \dashrightarrow$ current that comes out of f/b n/w.

KCL at I/P loop,

$$\left[I_{in} - \frac{V_{in}}{R_{in}} R_m K\right] R_{in} = V_{in}$$

$$I_{in} R_{in} - V_{in} R_m K = V_{in}$$

$$I_{in} R_{in} = V_{in} \quad [1 + K R_m]$$

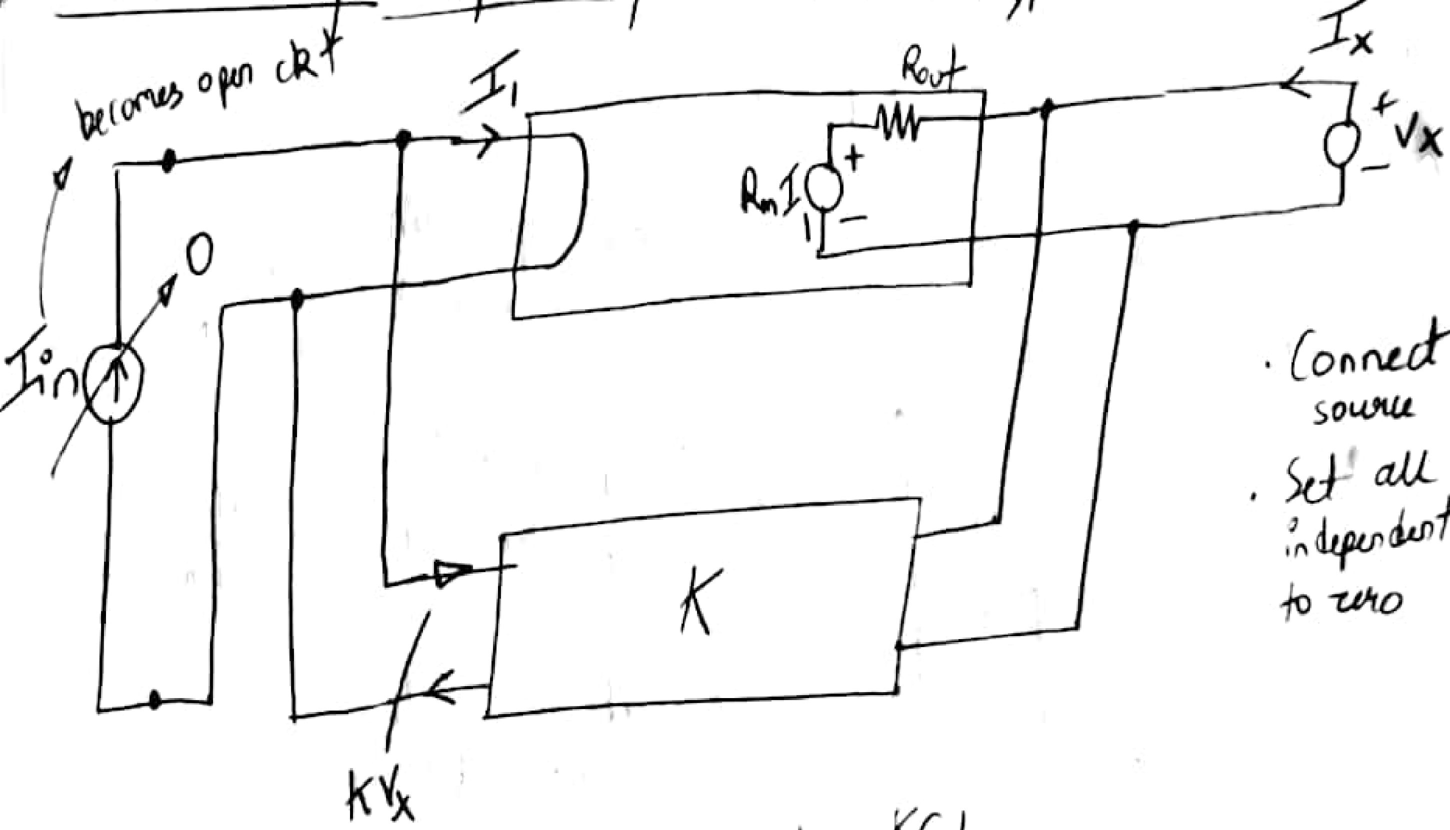
$$\rightarrow \boxed{\frac{V_{in}}{I_{in}} = \frac{R_{in}}{1 + K R_m}} \rightarrow R_{in_f}$$

As a result of returning a current to the I/P, R_{in} ↓ses.

Ckt is Good current sensor

→ Closed-loop i/p impd has gone down by a factor of $(1+KR_m)$

Closed-loop Output Impedance :- → V_x/I_x = ?



- Connect a test source V_x
- Set all independent source to zero

$I_1 = -KV_x$ ---- by KCL

ie $-KV_x R_m \approx R_m I_1$

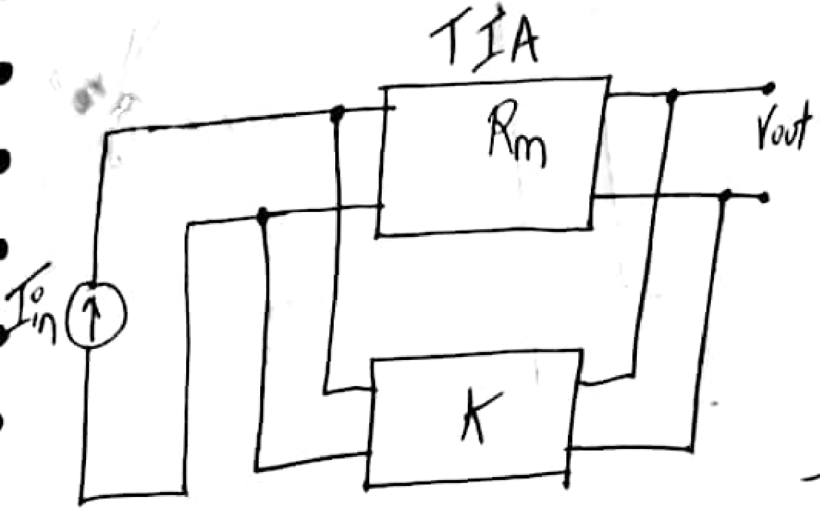
→ $I_x = \frac{V_x - R_m I_1}{R_{out}} = \frac{V_x + KV_x R_m}{R_{out}}$

→ $I_x R_{out} = V_x(1+KR_m)$

$\boxed{\frac{V_x}{I_x} = \frac{R_{out}}{1+KR_m}}$ ----→ R_{outF}

↳ closed-loop o/p impedance

Summary.- Voltage-current feedback (shunt)



→ Closed-loop Gain $(R_{mf}) = \frac{R_m}{1+KR_m}$

→ Closed-loop Input impedance $(R_{if}) = \frac{R_{in}}{1+KR_m}$

→ Closed-loop output impedance $(R_{outf}) = \frac{R_{out}}{1+KR_m}$

- senses a voltage at the o/p
- returns a current at the I/p

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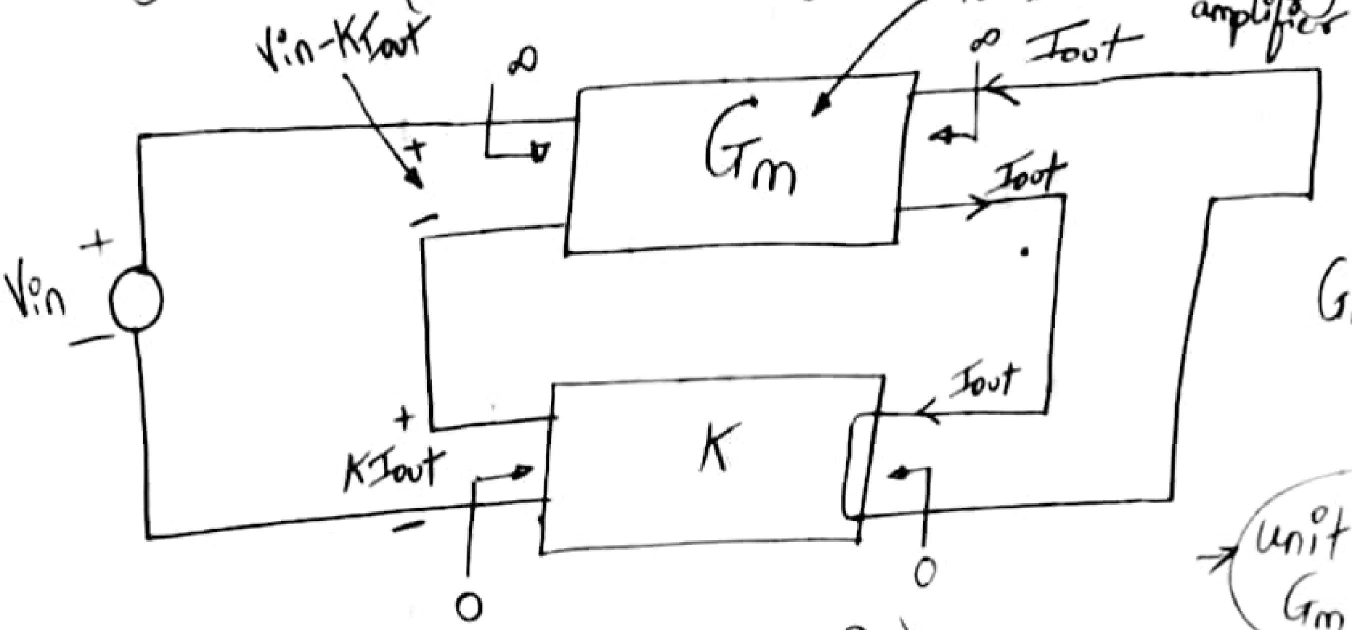
Analysis of Current-Voltage feedback topology:-

(current-series)

11/3/



Gm → open-loop gain

unit of Gm is $\frac{1}{\Omega}$

unit of K is Ω

- Closed-loop gain: $\left(\frac{I_{out}}{V_{in}} = ?\right)$

$$(V_{in} - K I_{out}) G_m = I_{out}$$

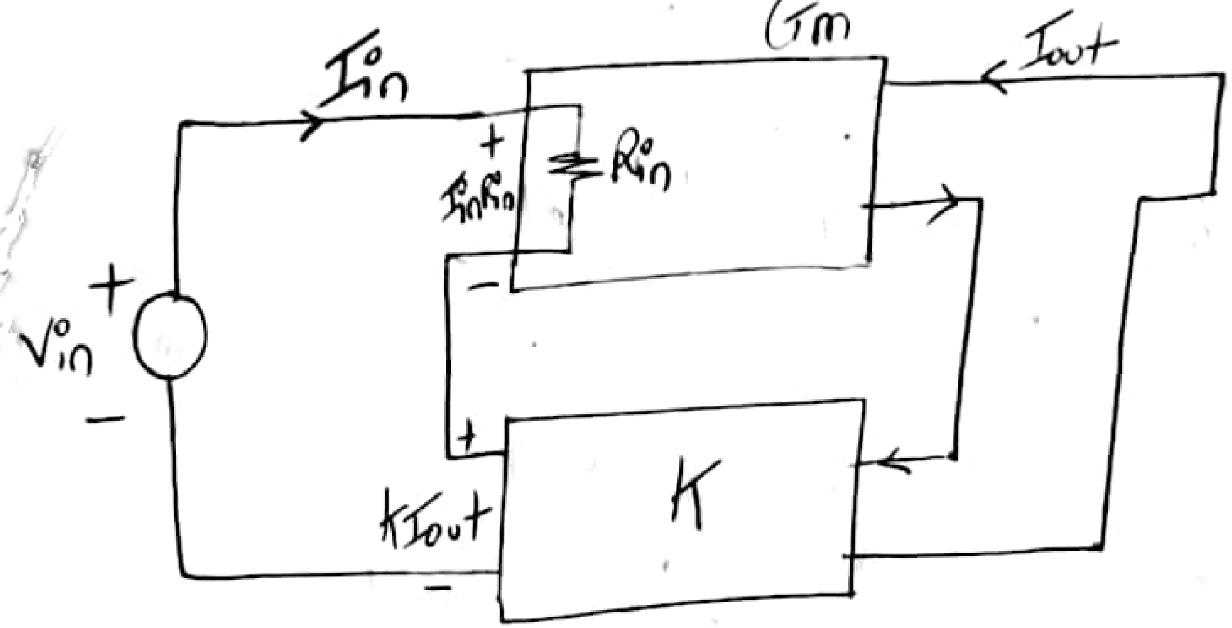
$$V_{in} G_m = K G_m I_{out} + I_{out}$$

$$V_{in} G_m = I_{out} (1 + K G_m)$$

$$\Rightarrow \boxed{\frac{I_{out}}{V_{in}} = \frac{G_m}{1 + K G_m}} = G_{mf} \longrightarrow \text{closed-loop gain}$$

→ Gain with f/b reduces by a factor of $(1+KG_m)$

Closed-loop Input impedance :- $\left(\frac{V_{in}}{I_{in}} = ? \right)$



$(I_{in} R_{in}) G_m K \Rightarrow$ voltage at o/p of f/b n/w.

KVL at i/p side,

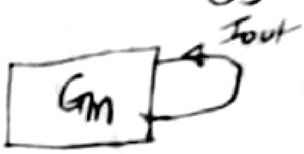
$$V_{in} - I_{in} R_{in} G_m K = I_{in} R_{in}$$

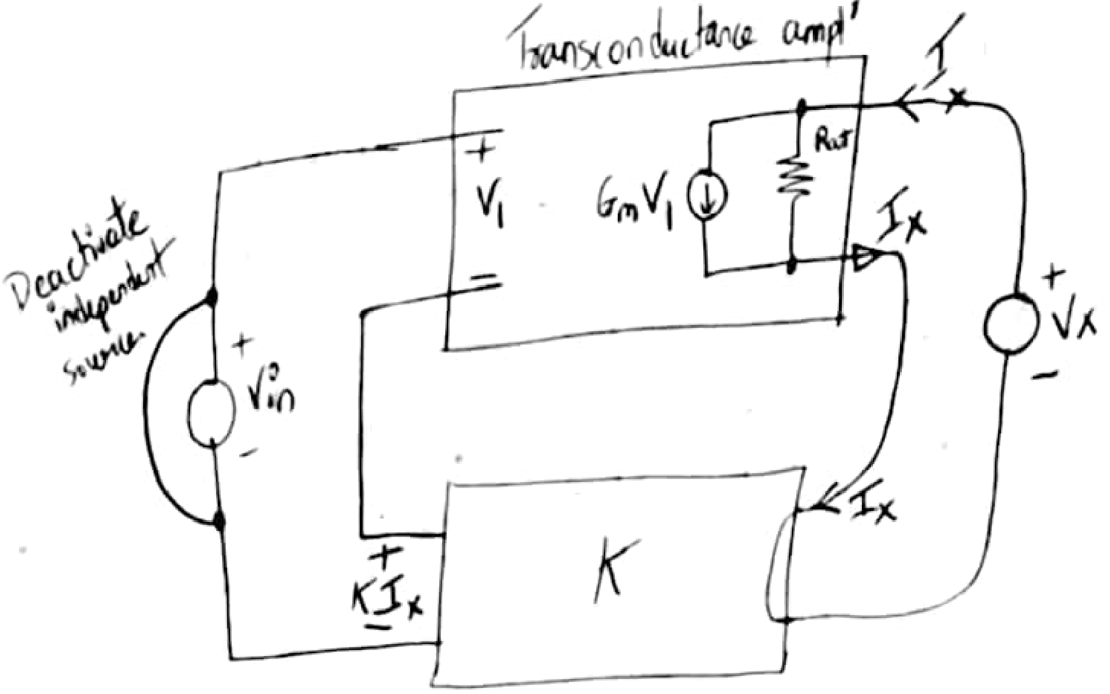
$$V_{in} = I_{in} R_{in} (1 + G_m K)$$

$$\Rightarrow \boxed{\frac{V_{in}}{I_{in}} = R_{in}(1 + G_m K)} \dashrightarrow R_{inf} \dashrightarrow \text{closed-loop i/p impedance}$$

closed-loop i/p impd has gone up by a factor of $(1 + KG_m)$

Closed-loop O/P impedance :





- How to measure o/p impedance when there a current at the o/p?
- Cut the o/p loop, place a vtg source &

- $V_1 = -KI_x$

→ KCL at o/p loop,

$$KI_x G_m + \frac{V_x}{R_{out}} = I_x$$

$$\frac{V_x}{R_{out}} = I_x(1+KG_m)$$

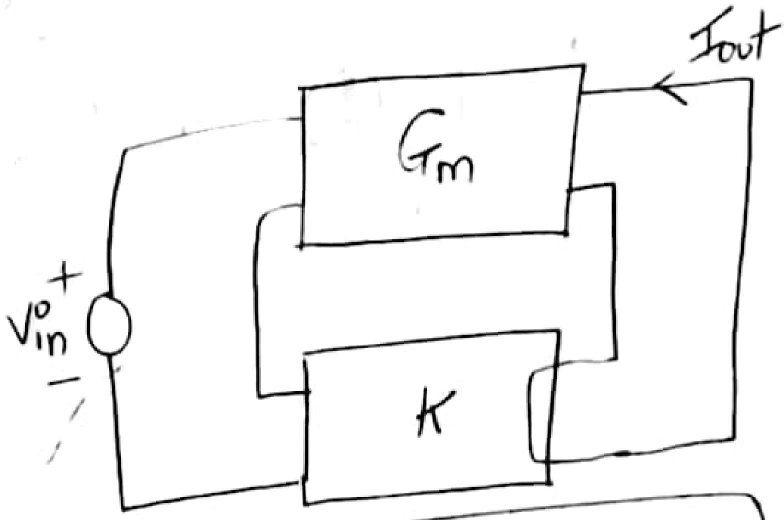
$$\Rightarrow \boxed{\frac{V_x}{I_x} = R_{out}(1+KG_m)} \rightarrow R_{outf} \rightarrow \text{Closed-loop o/p impedance}$$

→ The above ckt wants to deliver a current (i.e wants to become a good current source, so Routf ↑)

means the above ckt has become a good current source.

Summary:-

Current - Voltage feedback topology:-



→ Closed loop gain $G_{mf} = \frac{G_m}{1+KG_m}$

→ Closed loop I/P impedance $R_{inf} = R_{in}(1+KG_m)$

- senses a current at o/p
- returns a voltage at I/p

→ Closed-loop O/P impedance $R_{outf} = R_{out}(1+KG_m)$

Analysis of Current-current feedback topology :-

(Current - shunt)

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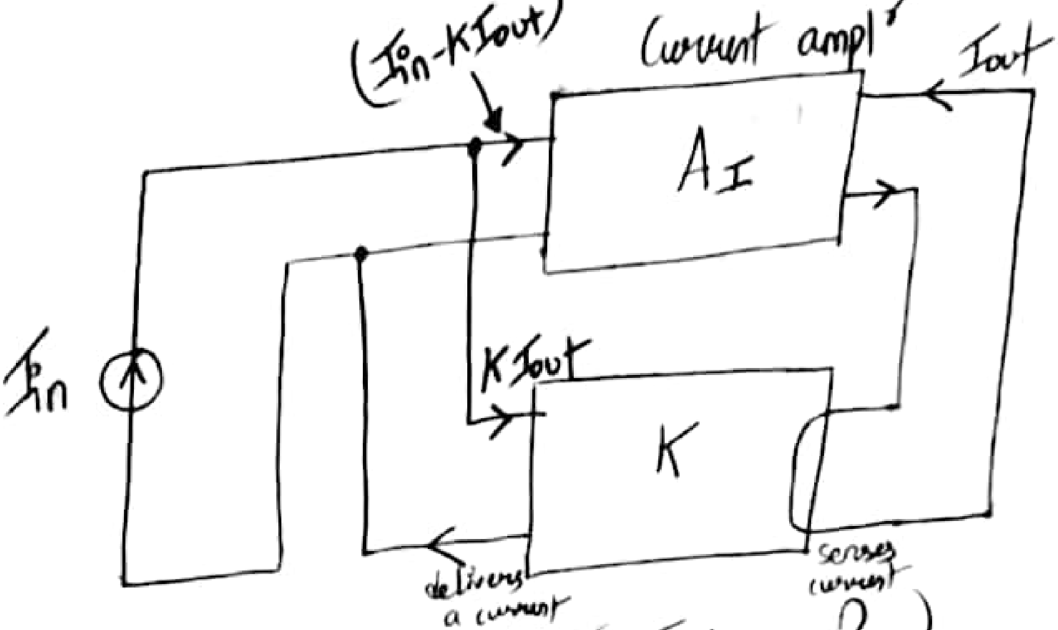


A_I → open loop gain

unit of A_I : unitless

Closed-loop gain: $\left(\frac{I_{out}}{I_{in}} = ?\right)$

$$(I_{in} - KI_{out})A_I = I_{out}$$

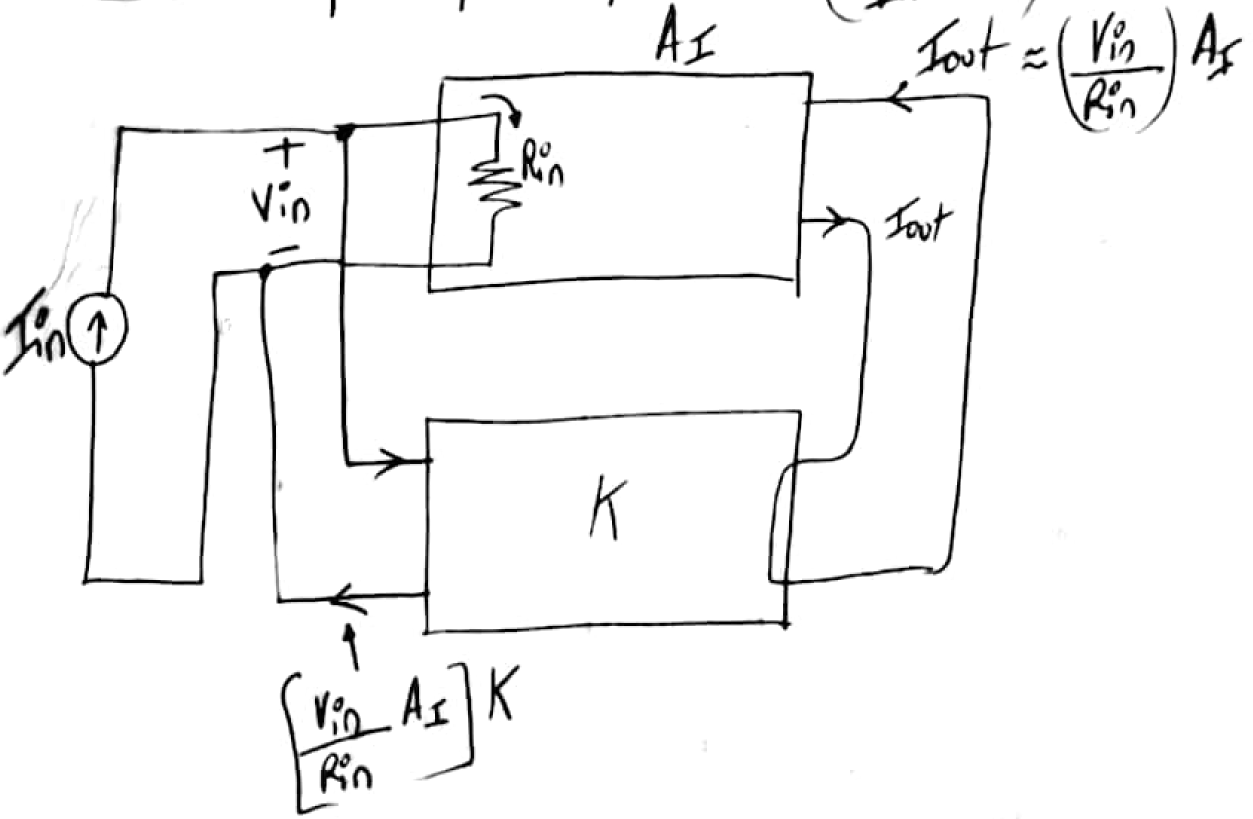
ie $I_{in}A_I = A_I K I_{out} + I_{out}$

ie $I_{in} A_I = I_{out}(1 + KA_I)$

$$\Rightarrow \boxed{\frac{I_{out}}{I_{in}} = \frac{A_I}{1 + KA_I}} \longrightarrow A_{I_f} \rightarrow \text{Closed-loop gain}$$

→ Gain with -ve f/b reduces by a factor of (1+KA_I)

Closed-loop Input impedance:- $\left(\frac{V_{in}}{I_{in}} = ?\right)$



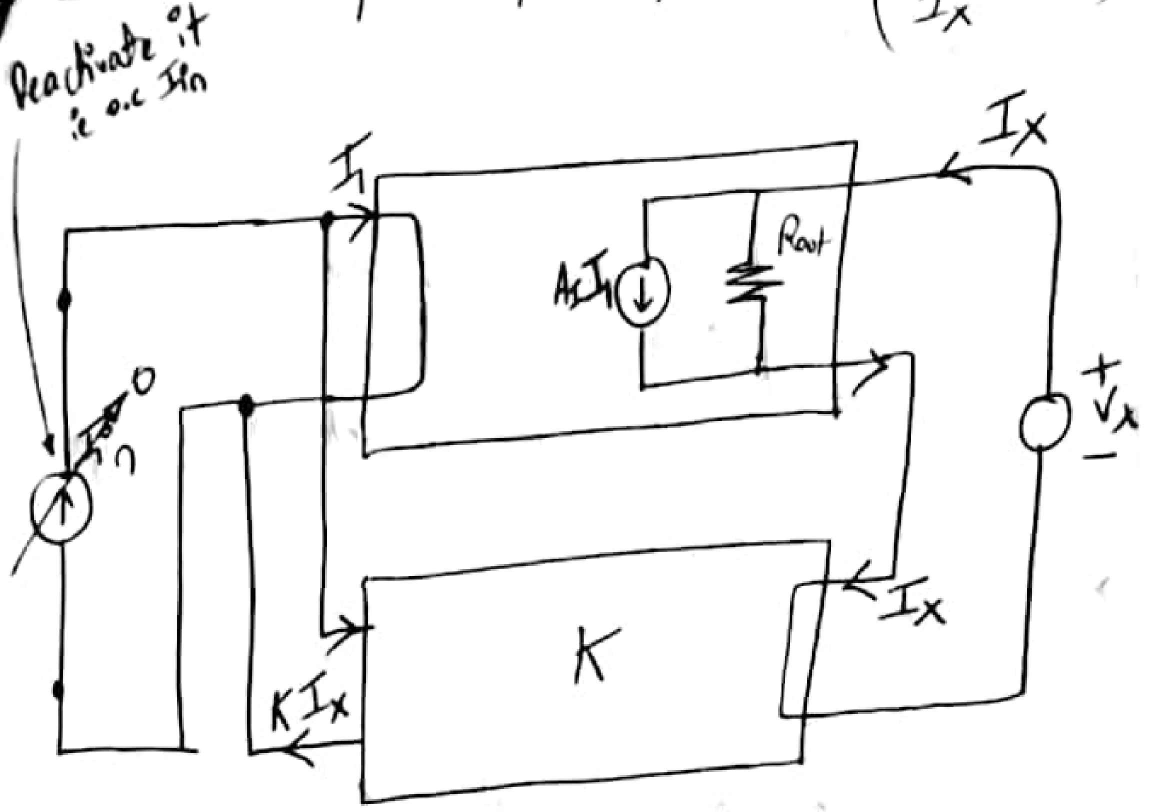
$$\rightarrow \left[I_{in} - \left(\frac{V_{in}}{R_{in}} A_I K\right)\right] R_{in} = V_{in}$$

ie $I_{in} R_{in} - V_{in} A_I K = V_{in}$

ie $I_{in} R_{in} = V_{in}(1 + K A_I)$

$$\Rightarrow \boxed{\frac{V_{in}}{I_{in}} = \frac{R_{in}}{1 + K A_I}} \dashrightarrow R_{inf} \dashrightarrow \text{Closed-loop I/P impedance}$$

Closed-loop Output Impedance :- $\left(\frac{V_x}{I_x} = ?\right)$



- Cut the o/p wire & insert a test source
- Deactivate all independent source ie $I_{in} = 0$
- Find $\frac{V_x}{I_x} = ?$

$$I_1 = -KI_x \quad \text{---} \; (KCL)$$

ie $A_I I_1 = -KI_x A_I$

KCL at o/p loop,

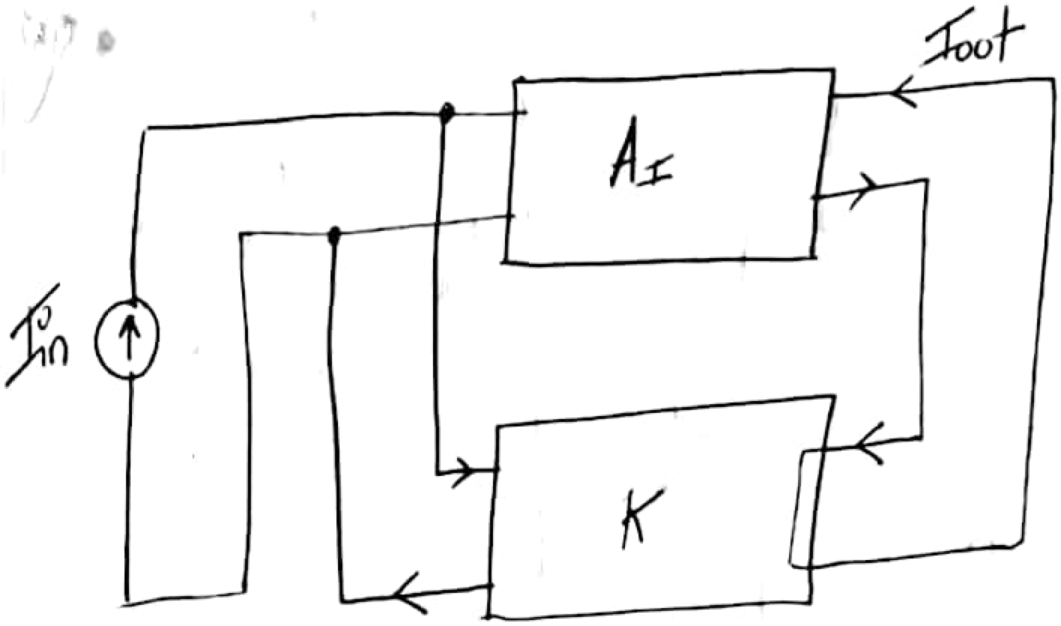
$$-KI_x A_I + \frac{V_x}{R_{out}} = I_x$$

ie $\frac{V_x}{R_{out}} = I_x(1+KA_I)$

ie $\boxed{\frac{V_x}{I_x} = R_{out}(1+KA_I)}$ ---→ R_{out_f} → Closed-loop o/p impedance.

Summary:-

Current-Current feedback topology:-



→ senses current at o/p

→ returns a current at I/P

→ Closed-loop gain: $A_{If} = \frac{A_I}{1+KA_I}$

→ Closed-loop i/p impedance: $R_{inf} = \frac{R_{in}}{1+KA_I}$

→ Closed-loop o/p impedance; $R_{out_f} = R_{out}\,(1+KA_I)$

Feedback Topologies	Sense (Sampling) mechanism	Return (Mixing) mechanism	Amplifier used	Closed loop gain	Closed loop I/p impedance R_{inf}	Closed loop o/p impedance R_{out_f}
1. Voltage-voltage (shunt-series) (Voltage-series)	sensing a voltage at the o/p in parallel	returning a voltage at the o/p in series	Voltage amplifier	$A_{vf} = \frac{A_v}{1+KA_v}$	$R_{in}(1+KA_v)$	$\frac{R_{out}}{(1+KA_v)}$
2. Voltage-current (shunt-shunt) (Voltage-shunt)	Sensing a voltage at the o/p in parallel	returning a current at the o/p in parallel	Trans-impedance amplifier	$R_{mf} = \frac{R_m}{1+KR_m}$	$\frac{R_{in}}{1+KR_m}$	$\frac{R_{out}}{1+KR_m}$
3. Current-voltage (series-series) (Current-series)	Sensing a current at the o/p in series	returing a voltage at the I/p in series	Trans-conductance amplifier	$G_{mf} = \frac{G_m}{1+KG_m}$	$R_{in}(1+KG_m)$	$R_{out}(1+KG_m)$
4. Current-current (series-shunt) (current-shunt)	Sensing a current at the o/p in series	returning a current at the I/p in parallel	Current amplifier	$A_{If} = \frac{A_I}{1+KA_I}$	$\frac{R_{in}}{(1+KA_I)}$	$R_{oot}(1+KA_v)$