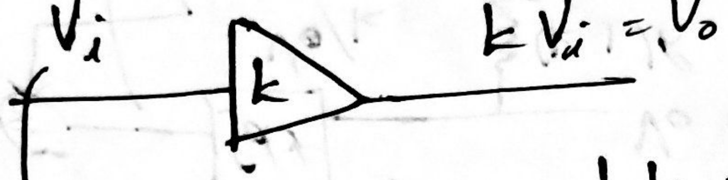
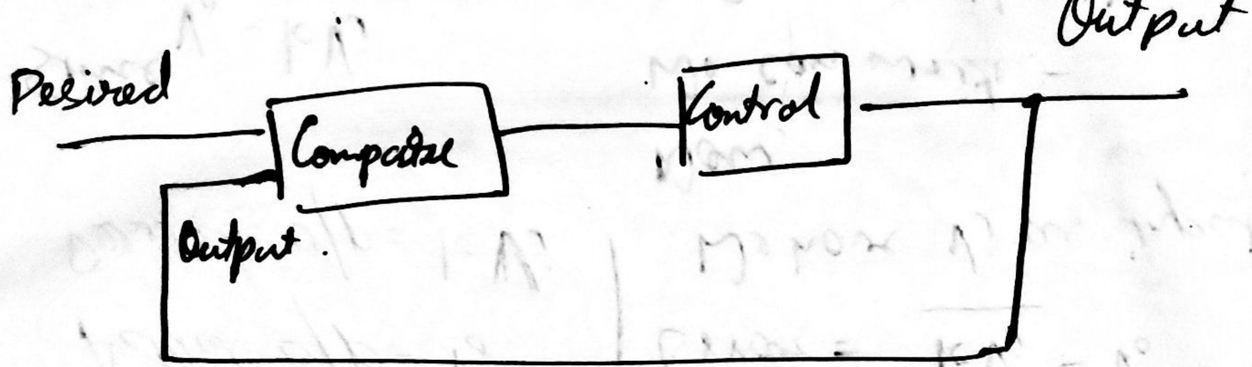
* Negative Feedback amplifier

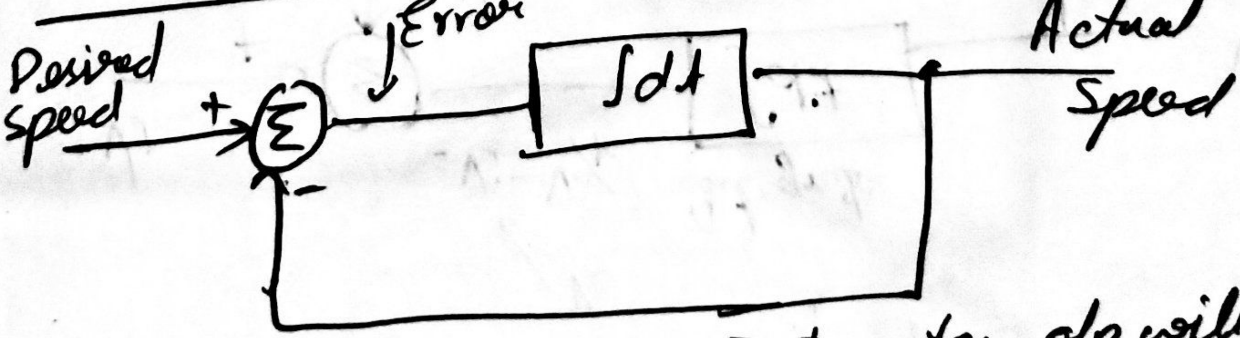


DC [Constant with time] | k → Gain

Example [Feedback system]

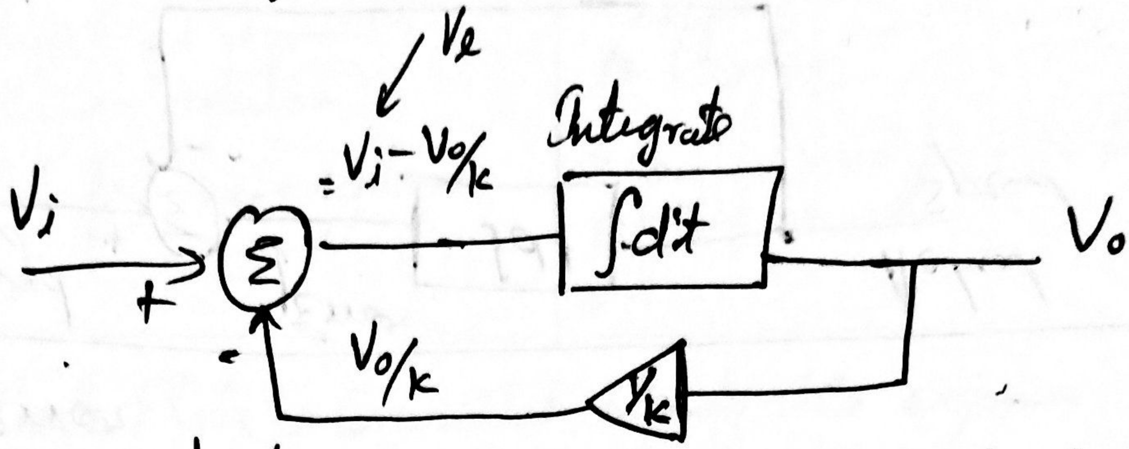


Negative Feedback :- Compare the desired & actual outputs to compute the error.
→ Control the output in a direction that reduces the error.



When error = 0 → Integrator o/p will be constant.

Amplifier using negative feedback



$V_o = kV_i$ → Gain

$V_i \to$ dc.

Compare actual o/p to the desired o/p

Actual o/p $= V_o$

Desired o/p $= kV_i$

Error $= \underline{kV_i} - V_o$

We have V_i as input.

Now,

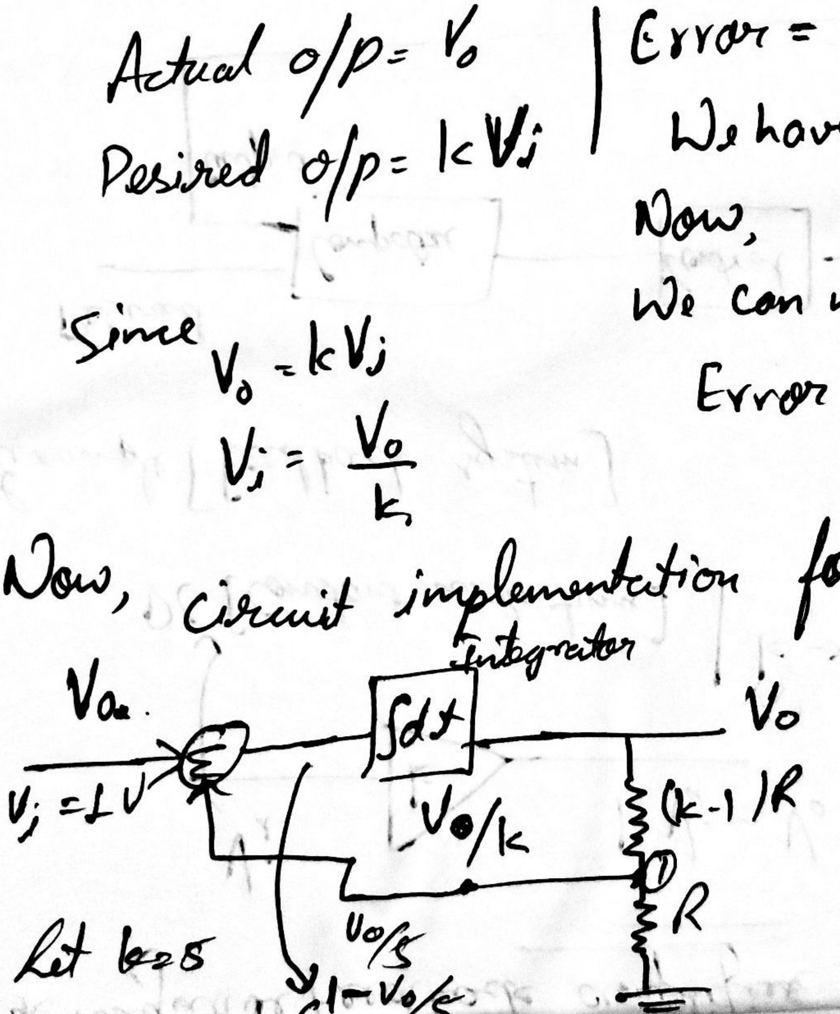
We can write :-

Error $= V_i - \frac{V_o}{k}$

Since $V_o = kV_j$

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

Now, circuit implementation for getting $\frac{V_o}{k}$ from



Let $k=5$

$$V_i = \frac{V_o \times R}{(k-1)R + R} = \frac{V_o \times R}{\cancel{kR}} = \frac{V_o}{k}$$

$\frac{V_o}{5} < 1V \to$ Error > 0.

$\frac{V_o}{5} = 1V \rightarrow$ Error $= 0$

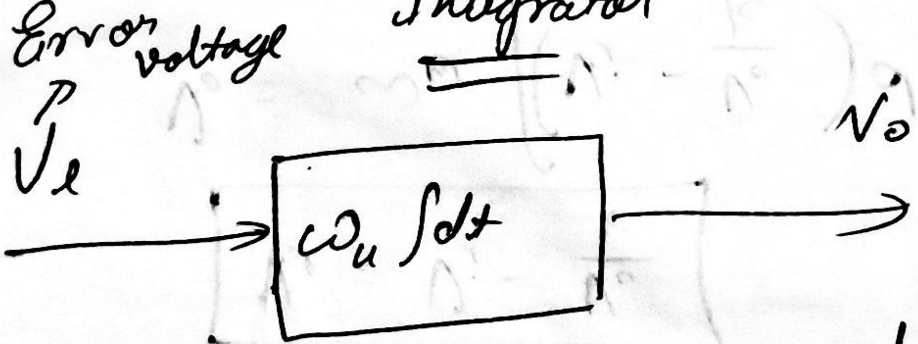
Now, output V_o is constant if error $= 0$

$$\boxed{\begin{aligned} \frac{V_o}{k} &= V_i \\ V_o &= k V_i \end{aligned}}$$

Negative feedback Amplifier:-

↳ Basic principle:- Integrate the error to drive the output.

Integrator



$\boxed{\omega_u \rightarrow \text{Constant for dimension frequency}}$

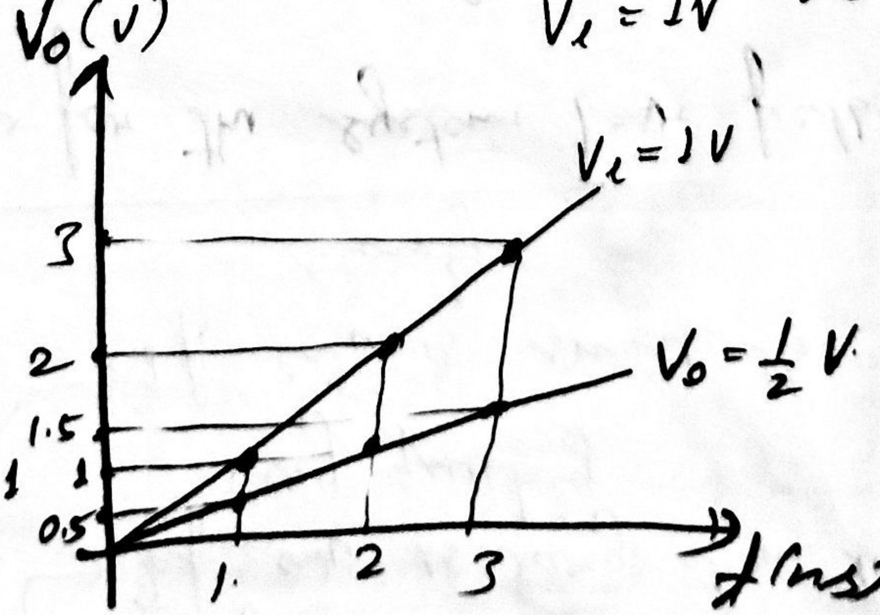
$V_o = \omega_u \int V_e \, dt$ | $\omega_u \rightarrow$ ~~freq~~ dimension of freq.

Let $\omega_u = 1$ Grad/s

$= 10^9$ rad/s

$V_o = 10^9 \int_0^t 1 \, dt$

$= 10^9 t$.



$\boxed{\omega_u \rightarrow \text{proportionality constant}}$

→ The speed of integration defines by ω_u.

Proportanility ~~con~~ condition :-

→ If ω_u is large then integrator integrates very quickly

→ If ω_u is small then integrator integrates slowly.

Now for the system [-ve feedback amp.]

$$V_o = \omega_u \int V_e \, dt$$

$$\boxed{V_e = V_i - \frac{V_o}{k}}$$

$$V_o = \omega_u \int \left(V_i - \frac{V_o}{k}\right) dt$$

diff. both sides [this will be easy]

$$\frac{dV_o}{dt} = \omega_u \left[V_i - \frac{V_o}{k}\right]$$

<u>1st order diff. eqⁿ</u>

$$\frac{dV_o}{\left(V_i - \frac{V_o}{k}\right)} = \omega_u \, dt \quad \Big\} \text{ ~~Integrate.~~ Rearrange}$$

$$\frac{dV_o}{kV_i - V_o} = \frac{\omega_u \, dt}{k}$$

Integrating

$$-\ln\left(kV_i - V_o\right)\Big|_{V_o(0)}^{V_o(t)} = \frac{\omega_u}{k} t\,\Big|_0^t$$

$$\ln\left[\frac{kV_i - V_o(0)}{kV_i - V_o(t)}\right] = \frac{\omega_u}{k}.t$$

or

$$\ln\left[\frac{kV_i - V_o(t)}{kV_i - V_o(0)}\right] = -\frac{\omega_u}{k}.t$$

Now, $\cancel{V_o(t) = V_o(0)\exp\left[-\frac{\omega_u}{k}.t\right]}$

→ Solution to the 1st order differential equation

$$\boxed{V_o(t) = V_o(0).\exp\left(-\frac{\omega_u}{k}.t\right) + kV_i\left[1-\exp\left(-\frac{\omega_u}{k}t\right)\right]}$$

$\cancel{V_o(t) = k}$ $V_o = kV_i$ → when $t = \infty$

Let say intial condion of output is 0, ie $V_o(0)=0$

So, $\boxed{V_o(t) = kV_i\left[1-\exp\left(-\frac{\omega_u t}{k}\right)\right]}$

$= 0.99 \cdot \underbrace{kV_i}_{\text{Ideal value}} \rightarrow$ 99% of the ideal value

So,

$$1-\exp\left(\frac{-\omega_u t}{k}\right) = 0.99$$

$\frac{k}{\omega_u}$ } time Constant

$$\exp\left(-\frac{\omega_u t}{k}\right) = 0.01 \rightarrow 1\%$$

So, $\boxed{t = 2\ln(10) \cdot \frac{k}{\omega_u}}$ $\omega_u \rightarrow$ dim(freq)

So, $\frac{k}{\omega_u}$ } dim(time)

~~So, $t \approx 46$ for $k=5$~~ $V_i = 1V$

Q) $\omega_u = 1$ G rad/s.

$k = 5$

So, $\exp\left(-\frac{\omega_u}{k}t\right) = 0.01$

$t = 2 \cdot \ln(10) \cdot k/\omega_u$

$\frac{k}{\omega_u} = \frac{5}{10^9} = 5\times10^{-9}$ s $= 5$ ns

So, $t = 2 \times \ln(10) \times 5$ ns

$= 23$ ns.

$= \underline{\underline{23\ ns.}}$

this time o/p will take to reach 99% of the steady state value $[k V_i]$ } for zero initial condition.

(b)

$\omega_u = 5\ G\ rad/s \rightarrow$ faster integrator

$k = 5$

So, $\exp\left(-\frac{\omega_u}{k} t\right) = 0.01$

$\frac{k}{\omega_u} = \frac{5}{5 \times 10^9} = 1\ ns$

So, $t = 2 \ln(10) \cdot \frac{k}{\omega_u} = 2 \times \ln(10) \cdot 1\ ns$

$= \underline{\underline{4.6\ ns.}}$

→ For high speed amp. you need high speed integrator also