ECE 614 – Lecture 19

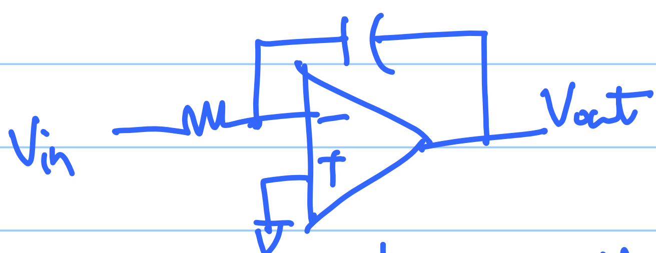
Note Title 10/28/2014

DT integrator

$$H(z) = \frac{z^{-1}}{1-z^{-1}} \quad \text{Delaying Integrator}$$

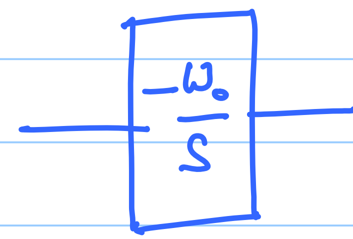
$$\frac{1}{1-z^{-1}} \quad \text{non-delaying integrator}$$

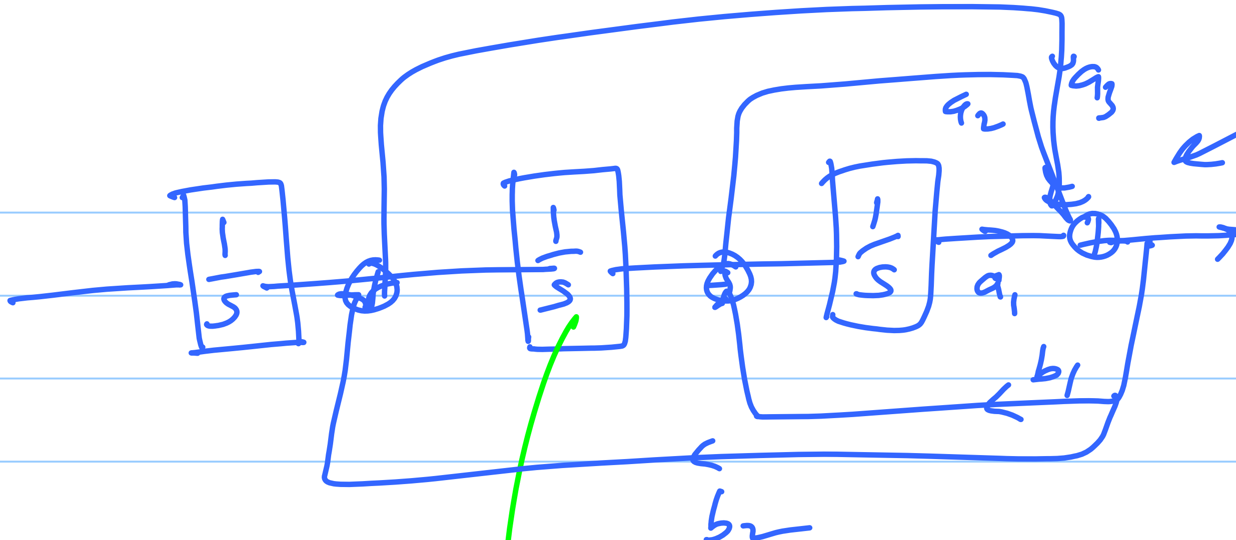
CT filters



$$-\frac{1}{sRC} = -\frac{\omega_o}{s}$$

$\Rightarrow$

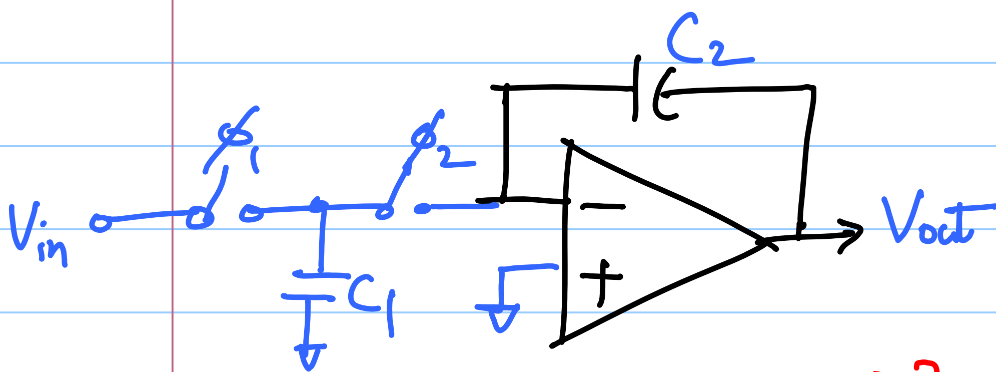


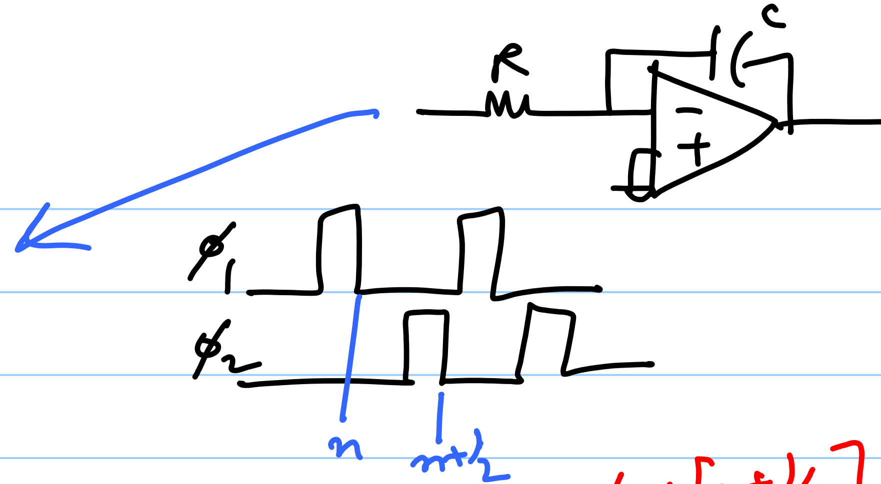


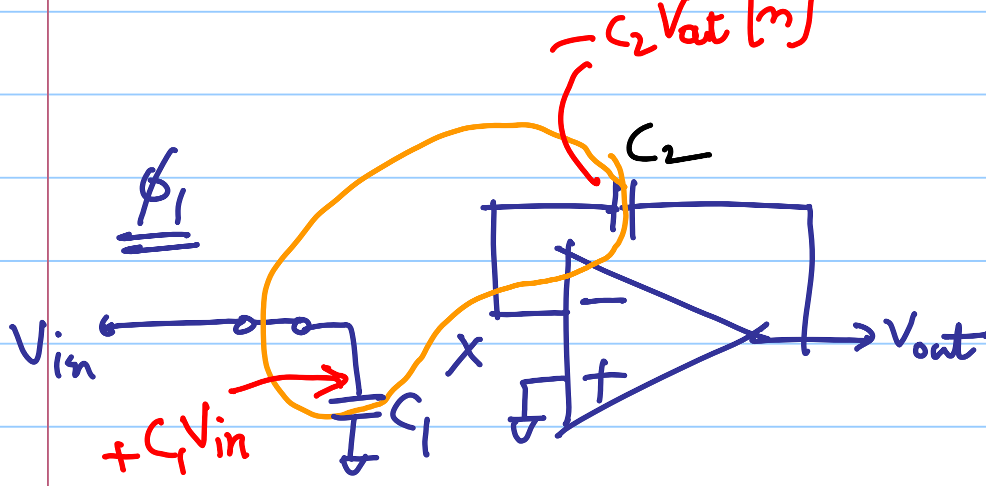
generic
CT
filter

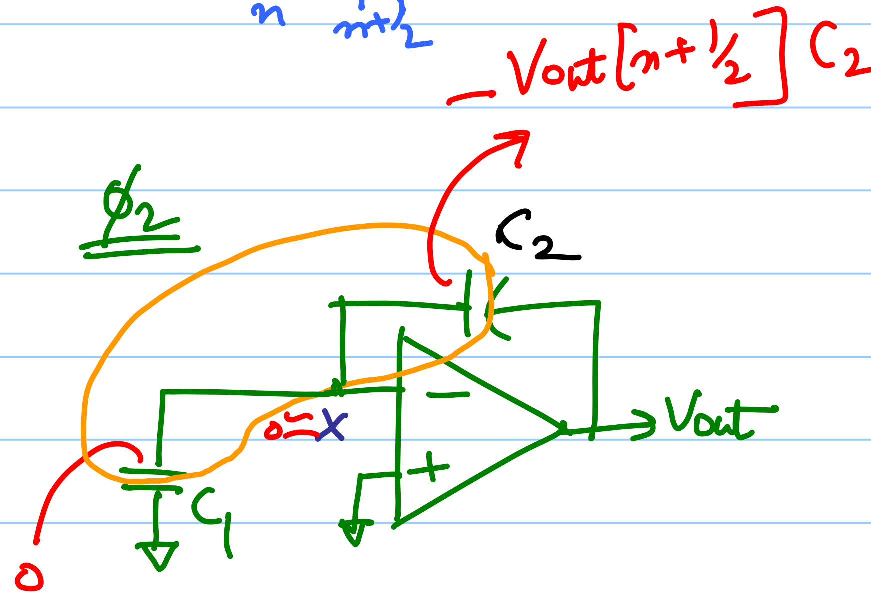
$$\frac{z^{-1}}{1-z^{-1}} \quad \text{or} \quad \frac{1}{1-z^{-1}}$$

integrator is a building block for filters
$\Delta\Sigma$ Modulator
Control loops









$$-C_2 V_{out}[n+\tfrac{1}{2}] = -C_2 V_{out}[n] + C_1 V_{in}[n]$$

$$\Rightarrow \quad V_{out}[n+\tfrac{1}{2}] = V_{out}[n] - \frac{C_1}{C_2} V_{in}[n]$$

$$V_{out}[n+1] \triangleq V_{out}[n+\tfrac{1}{2}] = V_{out}[n] - \frac{C_1}{C_2} V_{in}[n]$$

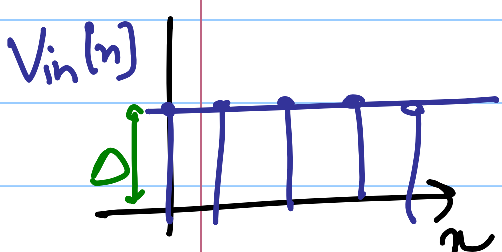
$n+1 \Rightarrow n$

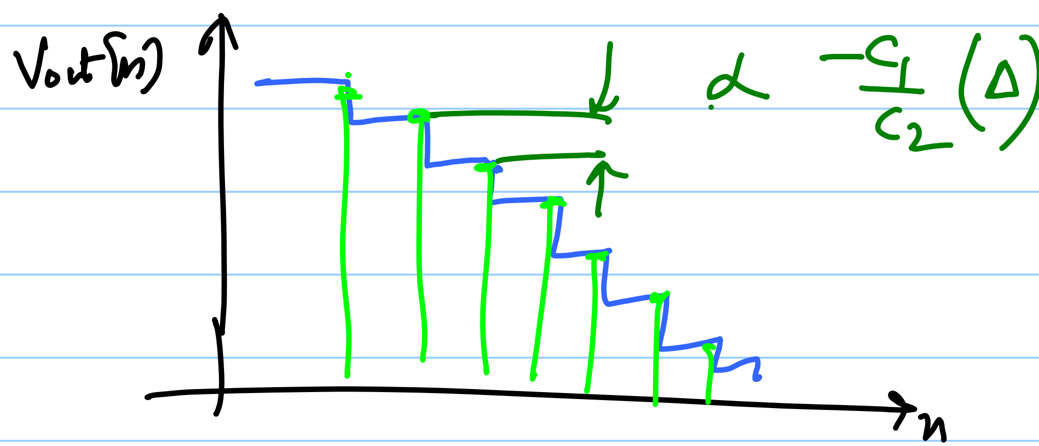
$$\Rightarrow V_{out}[n] = V_{out}[n-1] - \frac{C_1}{C_2} V_{in}[n-1]$$

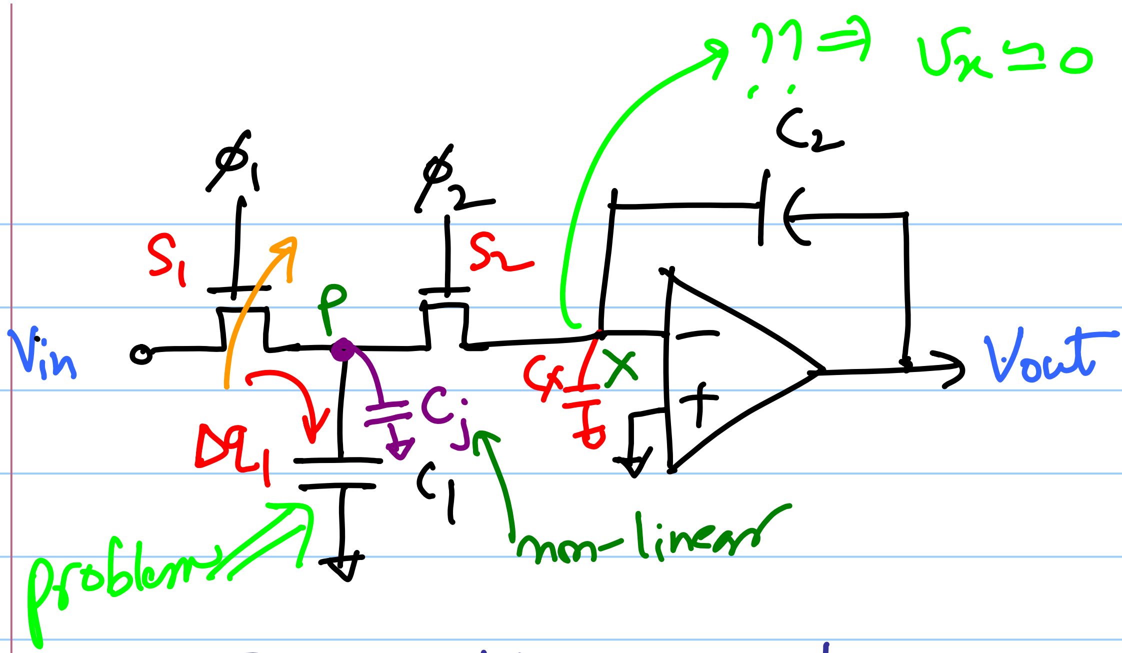
$$\Rightarrow V_{out}(z) = z^{-1} V_{out}(z) - \frac{C_1}{C_2} z^{-1} V_{in}(z)$$

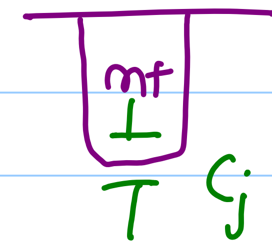
$$\Rightarrow \frac{V_{out}(z)}{V_{in}(z)} = -\frac{C_1}{C_2} \cdot \left(\frac{z^{-1}}{1-z^{-1}}\right)$$

$=$ Effective gain of the integrator









$$C_j = \frac{C_{j0}}{\left(1 + \frac{V_D}{V_{bi}}\right)^m}$$

* Input-dependent charge injection of S_1 when ϕ_1 goes low

⇒ non-linearity

C_j gets charge to V_{in} during ϕ_1

* ϕ_2 ⇒ C_j does charge sharing with C_x

charge stored in the j^{th} cap C_j:

$$\Delta q_{c_j} = C_j(v) \cdot dV \Rightarrow \qquad q_{c_j} = \int_0^{V_{in_0}} C_j(V) \cdot dV$$

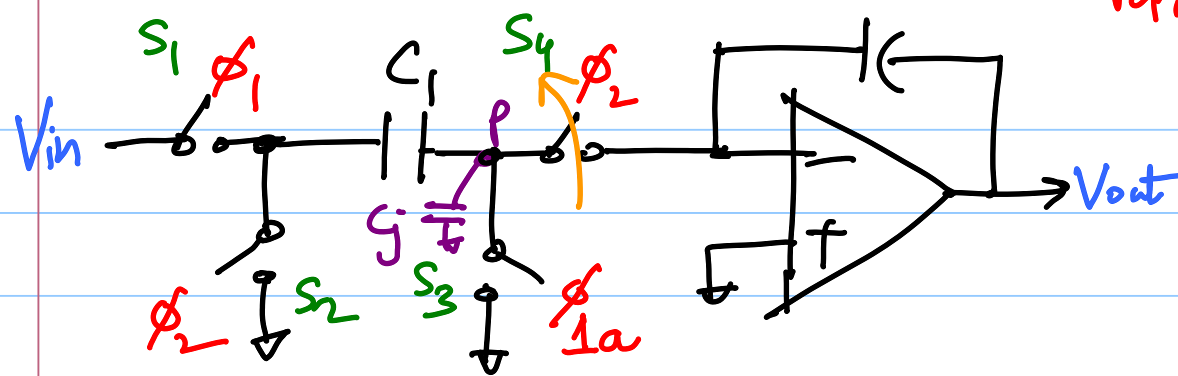
$$\neq C_j V_{in_0}$$ but a non-linear function of V_{in}

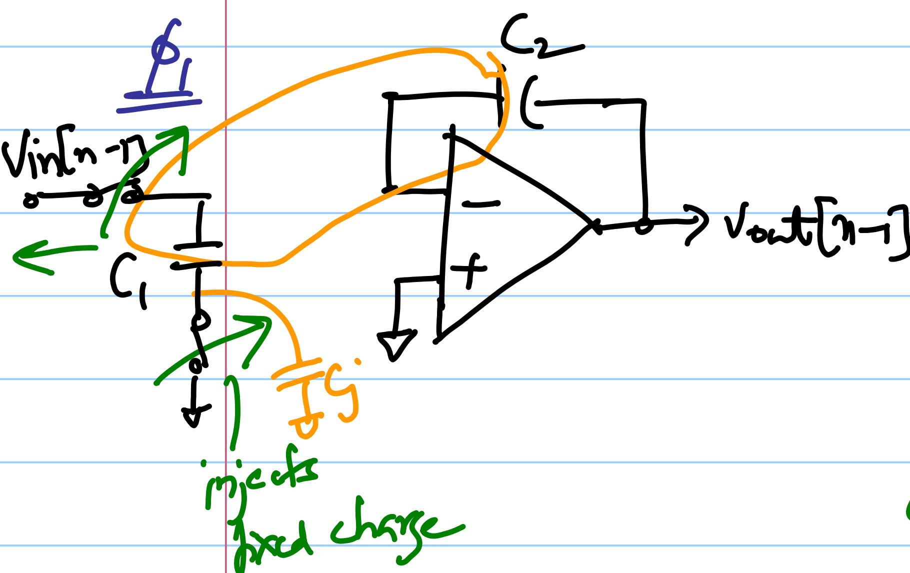
$$\frac{V_o}{V_i}(z) = -\frac{C_1 + C_j}{C_2} \cdot \frac{z^{-1}}{1-z^{-1}}$$

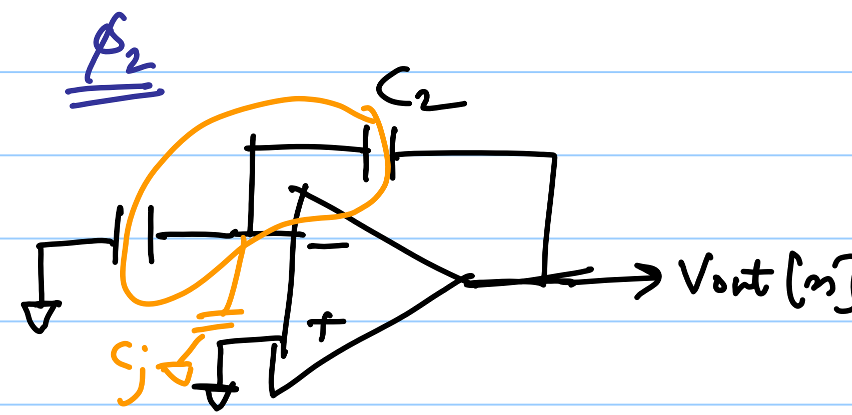
non linear

"parasitic - sensitive integrator"

Parasitic-Insensitive







No input-dependent charge-injection

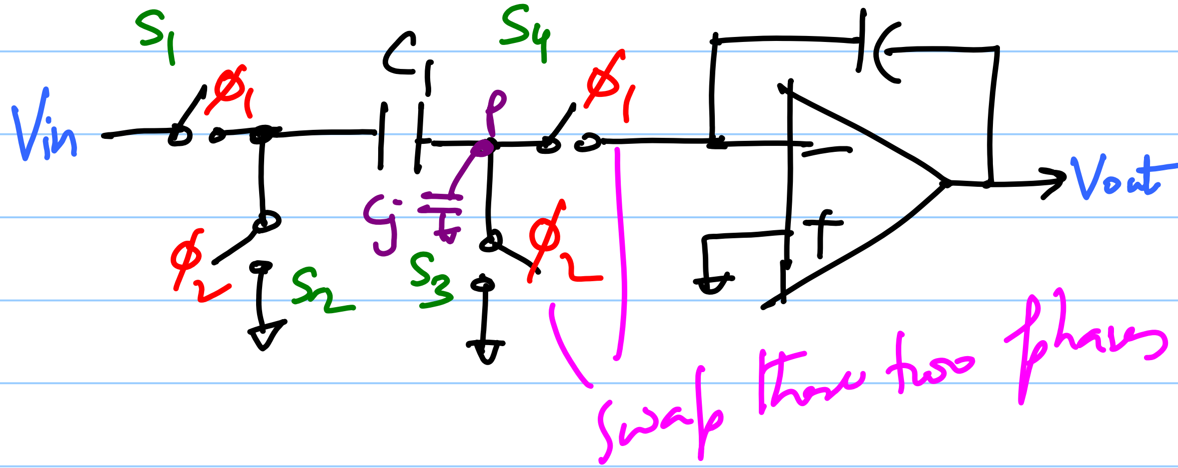
$C_j \Rightarrow 0$ to $V_x \approx 0$

C_j mostly sees potential ≈ 0

$\Rightarrow$ this nonlinear charge is negligible

Delay-free Integrator

$$-\frac{C_1}{C_2}\frac{1}{1-z^{-1}}$$

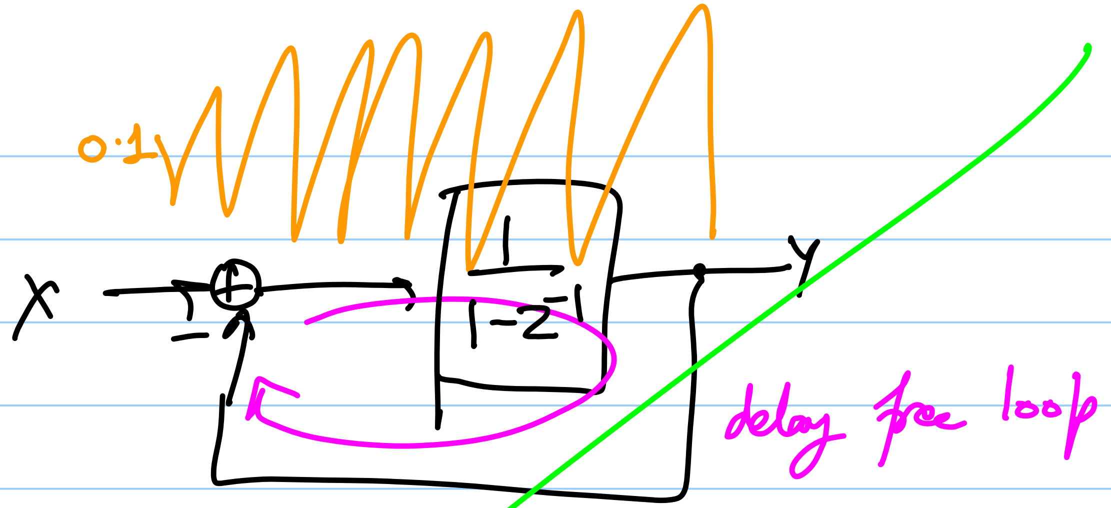


$z^{-1/2}$

↑ half cycle delay

opamp will take $T_s/2$ to settle

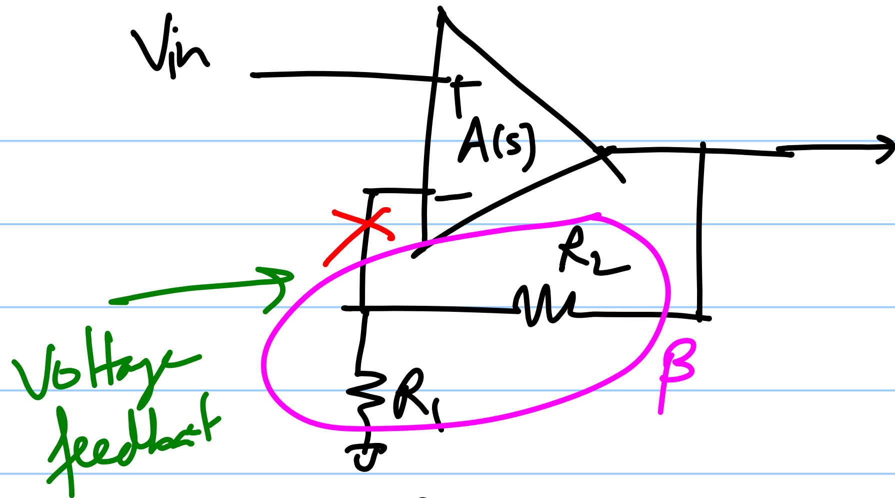
Aside

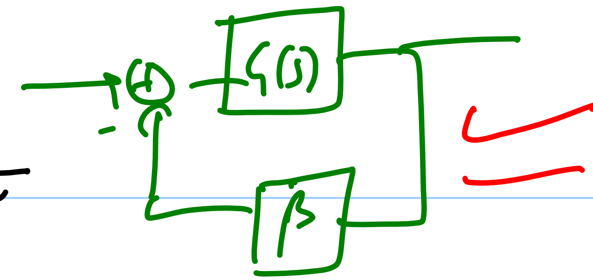


$$\frac{(X-Y)}{1-z^{-1}} = Y$$

$$\Rightarrow \quad \frac{X}{1-z^{-1}} = Y\left(1 + \frac{1}{1-z^{-1}}\right) = Y\left(\frac{1+1-z^{-1}}{1-z^{-1}}\right)$$

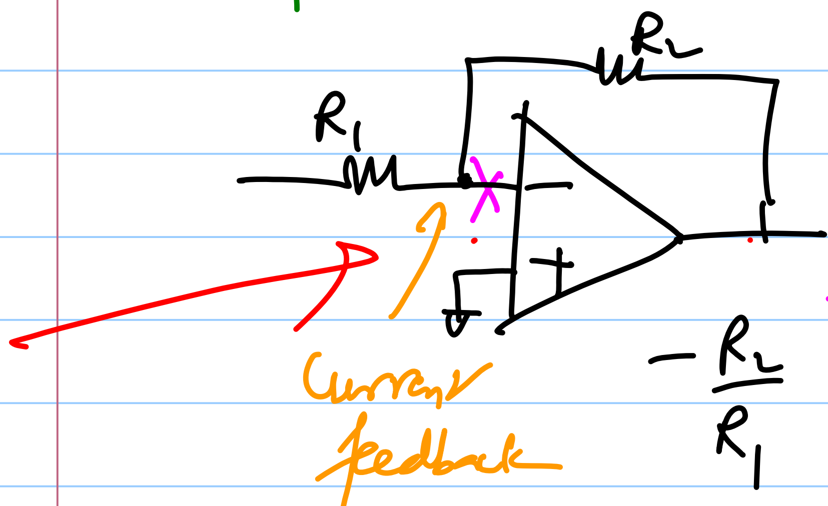
$$\Rightarrow \quad \frac{Y}{X} = \frac{1}{2-z^{-1}} = \frac{z}{2z-1}$$





$$A_{CL} = \frac{1}{\beta} = \frac{1}{\frac{R_1}{R_1+R_2}}$$

$$= 1 + \frac{R_2}{R_1}$$



$$-\frac{R_2}{R_1}$$

Razavi feedback chapter