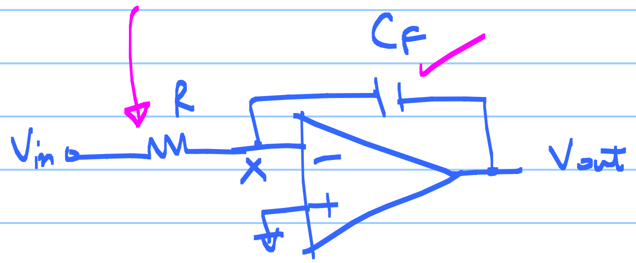
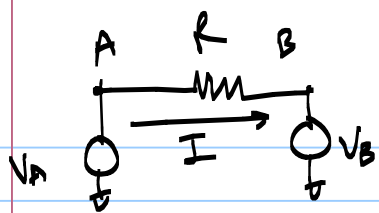
ECE 614 – Lecture 18

Note Title 11/1/2012



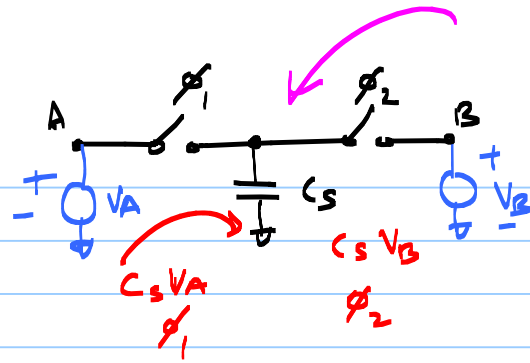
$$\frac{V_{out}}{V_{in}}(s) = -\frac{1}{sRC_F} = -\frac{\omega_I}{s}$$

CT integrator



$$I = \frac{V_A - V_B}{\boxed{R}}$$

↑ avg charge transferred from A to B



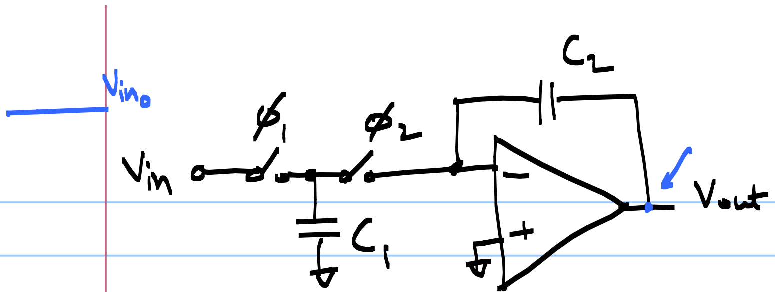
charge transferred from A to B

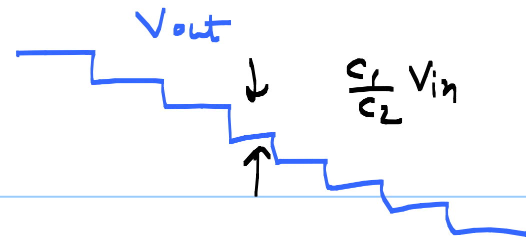
$$\Delta Q = C_s (V_A - V_B)$$

$$I_{av} = \frac{\Delta Q}{T_s} = \boxed{\frac{C_s}{T_s}} (V_A - V_B)$$

switched capacitor resistor (SCR)

$$\boxed{R = \frac{1}{f_s C}}$$





"accumulator"

$-\frac{C_1}{C_2}$

In every clock cycle

$$V_{out}[nT_s] = V_{out}[(n-1)T_s] - \frac{C_1}{C_2} \cdot V_{in}[(n-1)T_s]$$

DT equations
↓
charge conservation in the circuit

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

z-transforms
DTFT.
↓
DFT ← FFT algorithm

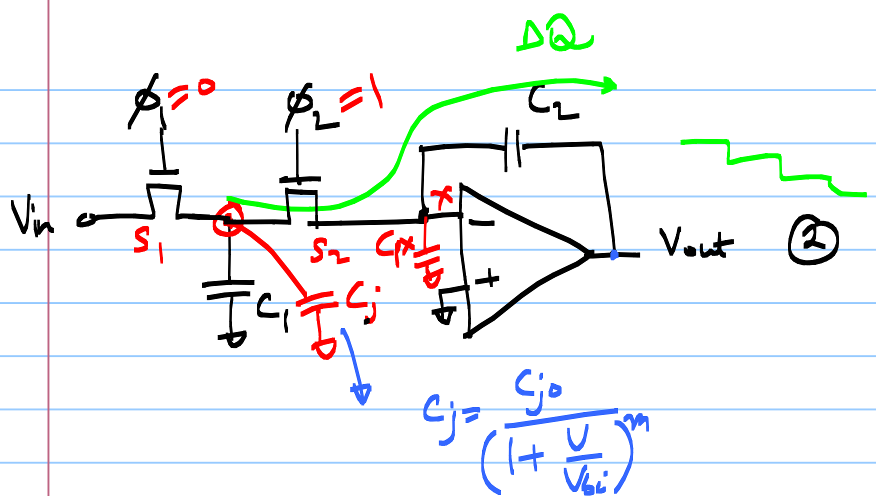
$$V_{out}(z) = z^{-1} V_{out} - \frac{C_1}{C_2} z^{-1} V_{in}(z)$$

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

$$G_I = -\frac{C_1}{C_2}$$

DSP

delaying integrator/accumulator



① input-dependent charge injection due to S_1

↳ nonlinearity in the output

②

"Parasitic-Sensitive Integrator"

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

* charge stored in cap C_j

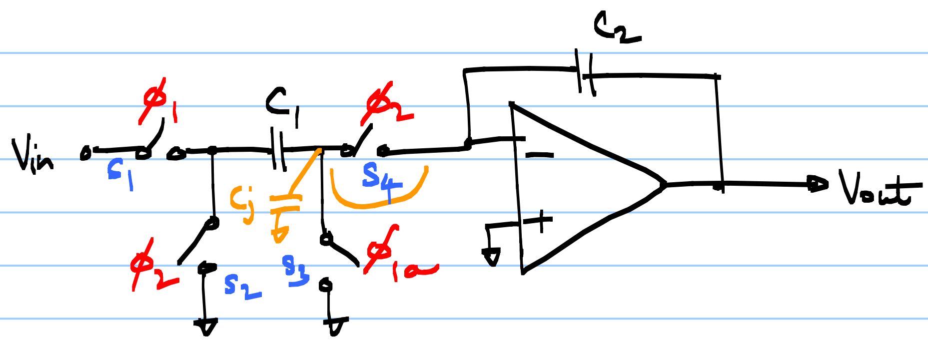
$$q_{C_j} = \int_0^{V_{in}} C_j \cdot dV = \int_0^{V_{in}} \frac{C_{j0}}{\left(1 + \frac{V}{V_{bi}}\right)^m} dV$$

↳ $q_{C_j} \neq C_j V_{in} = f_{NL}(V_{in})$

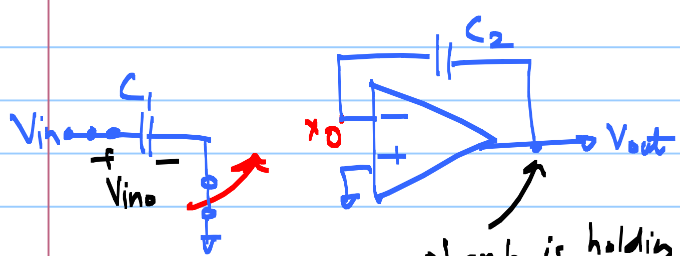
↳ transferred to C_2

⇒ nonlinearity in the output

Parasitic Insensitive Integrator :

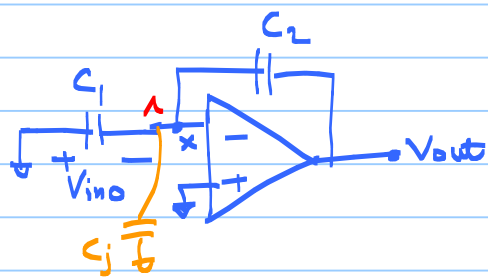


ϕ_1 (sampling phase)



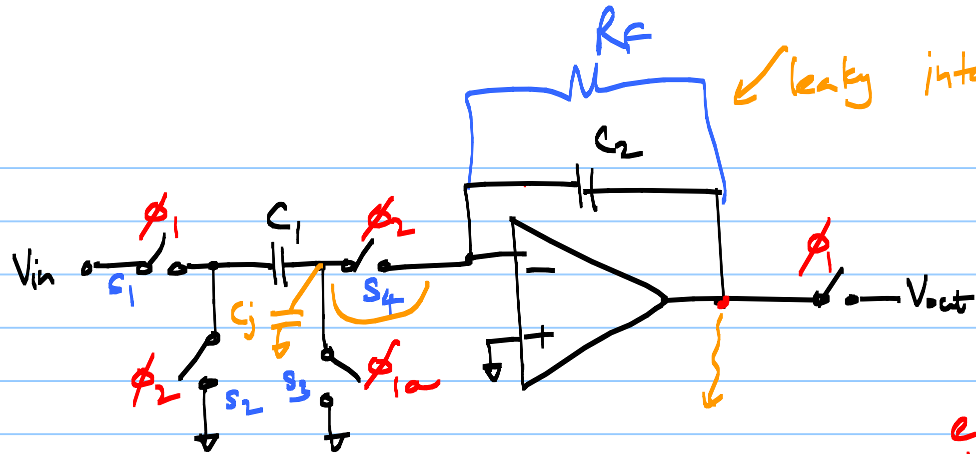
opamp is holding the previous "state"

ϕ_2 (integration phase)

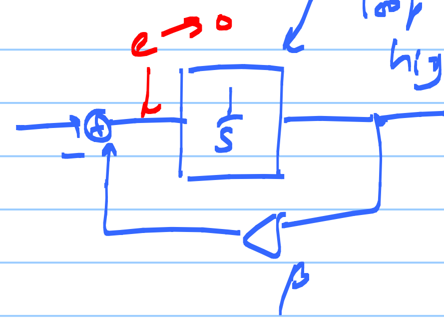


* Node x is a virtual ground
q_{c_j} is negligible
⇒ negligible nonlinearity in the output

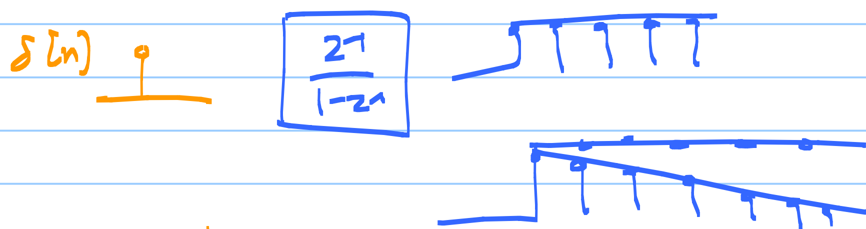
* Charge injected by S_4 is indep
of V_{in}



leaky integrator



loop filter
high gain at
low frequencies

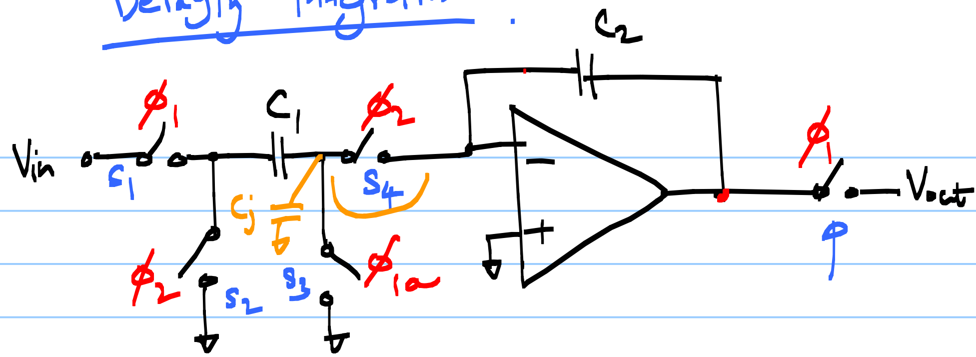


$e^{-\alpha t}$

$\frac{1}{s}$ $\qquad$ $\frac{1}{s-\alpha}$

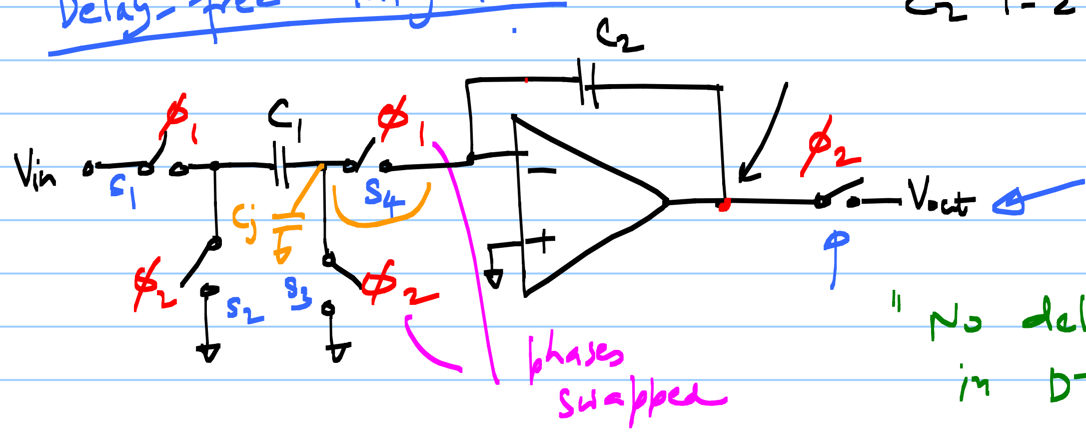
Delaying integrator

z^{-1}



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

Delay-free integrator



$$-\frac{C_1}{C_2}\,\frac{z^{-1/2}}{1-z^{-1}}$$

"No delay-free loops in DT system"

Sampling ← $T_s/2$ ← RC time constant of switch

Integration phase ← $T_s/2$ ← opamp has to settle

$\downarrow$

A_{DC}, f_u, SR

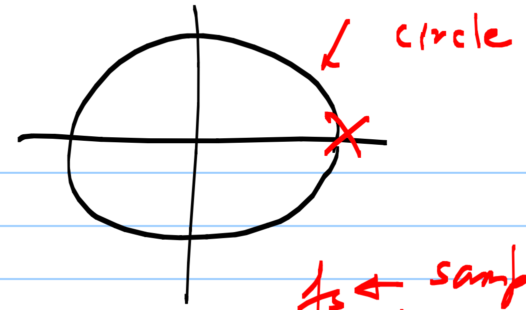
eg → Slewing allowed only for 25% of settling time

$T_s/8$

* $H(z) = G_I \cdot \frac{z^{-1}}{1-z^{-1}}$

$G_I \to -\frac{C_1}{C_2}$

$\frac{z^{-1}}{1-z^{-1}} \to \frac{1}{z-1}$



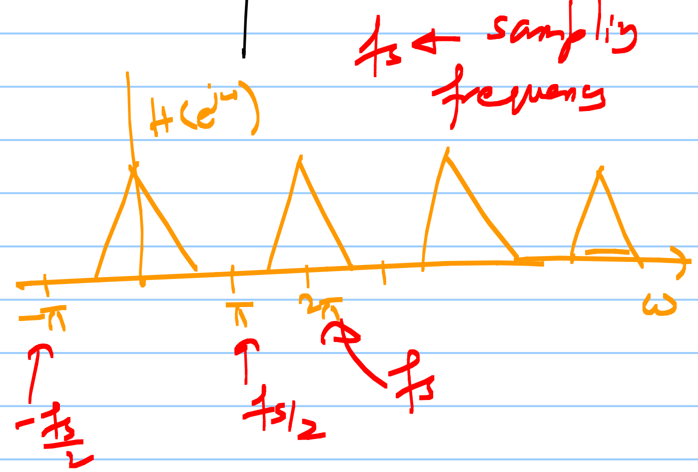
* $z \to e^{j\omega}$

DTFT $\longrightarrow H(e^{j\omega}) = G_I \cdot \frac{e^{-j\omega}}{1-e^{-j\omega}}$

periodic with period 2π

$\Rightarrow G_I \cdot \frac{e^{-j\omega}}{e^{-j\omega/2}\left(e^{+j\frac{\omega}{2}} - e^{-j\omega/2}\right)}$

$= e$



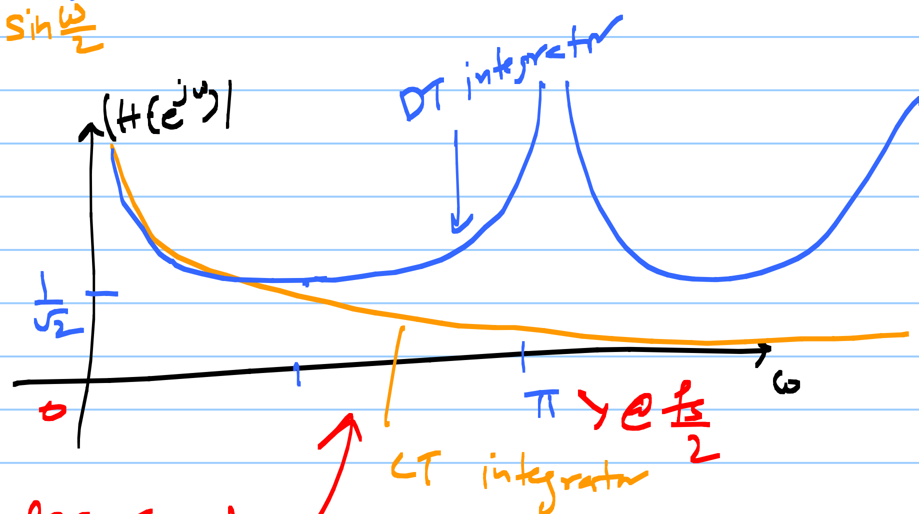
$$= \frac{e^{-j\omega/2}}{\underbrace{e^{+j\omega/2} - e^{-j\omega/2}}_{2\sin\frac{\omega}{2}}} = \frac{e^{-j\omega/2}}{2\sin(\omega/2)}$$

$$\frac{e^{j\theta} - e^{-j\theta}}{2} = \sin\theta$$

$$|H(e^{j\omega})| = \frac{1}{2\sin(\omega/2)}$$

@ $\omega = \pi/2$

$$\frac{1}{2 \cdot \frac{1}{\sqrt{2}}} = \frac{1}{\sqrt{2}}$$



x frequency response → PSS ← f_s
→ BAR