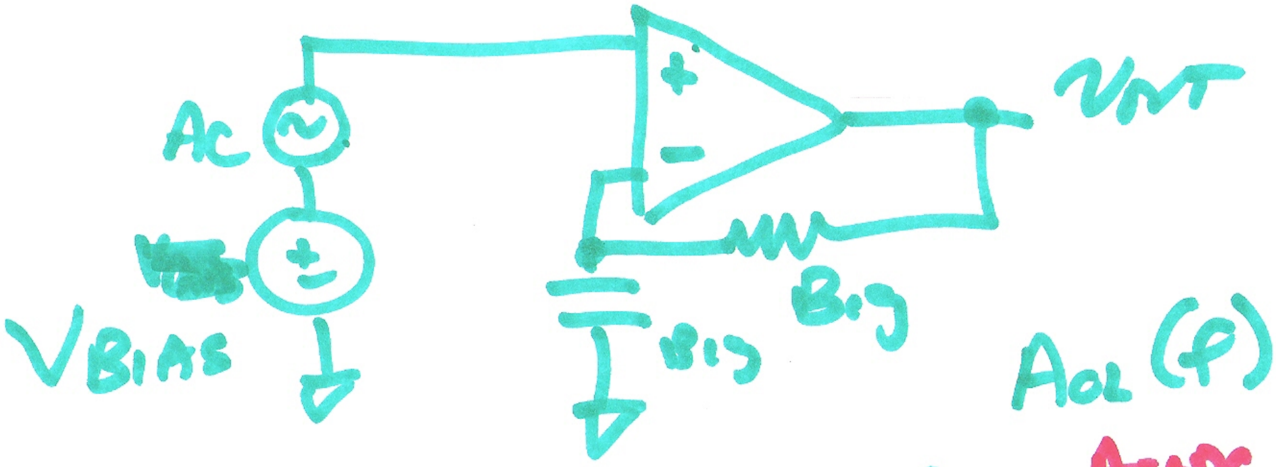
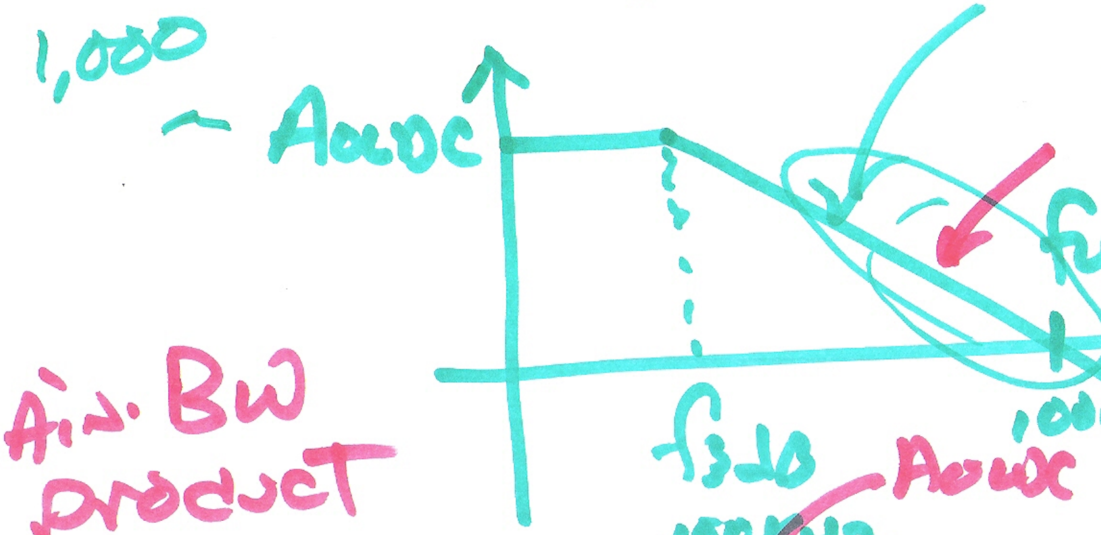
ECE 615 CMOS mixed-signal ckt design

Lecture 7 Sept. 15, 2010



$$A_{OL}(f) = \frac{A_{OLDC}}{1 + j\frac{f}{f_{3dB}}}$$

$$\frac{A_{OLDC}}{j\, f/f_{3dB}}$$



f_{un} = unity-gain freq.

$f_{un} \gg f_{3dB}$

$$\frac{1}{j\, f/(f_{3dB}\cdot f_{un})}$$

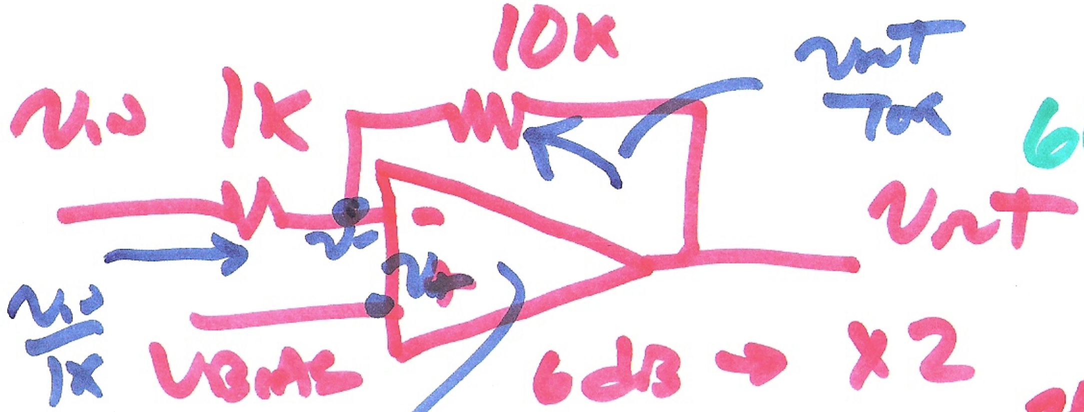
A_{OLDC}

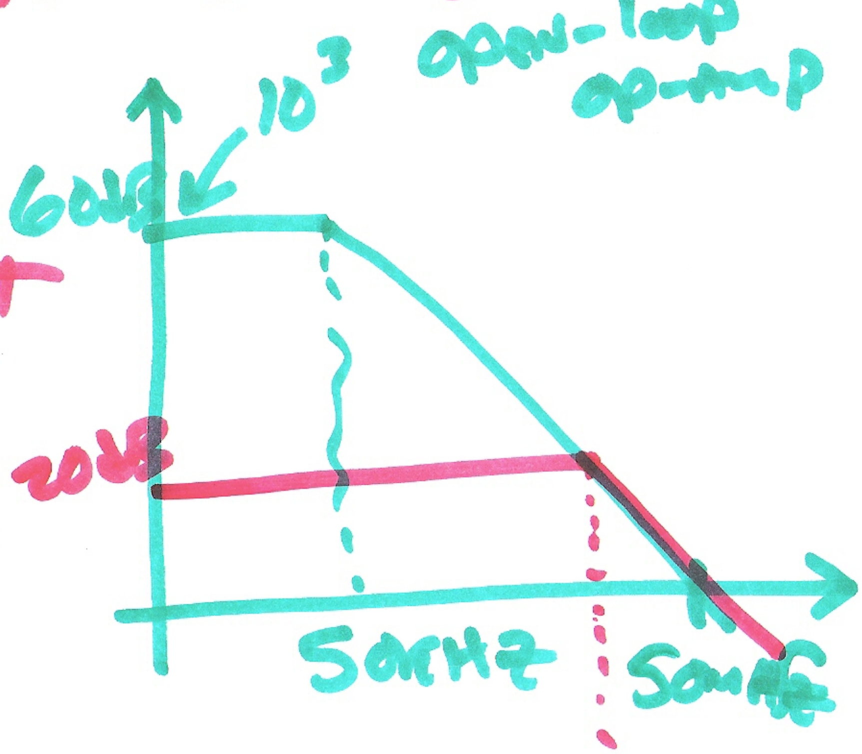
GAIN·BW product

A_{OLDC} 100kHz

$= f_{3dB}\cdot A_{OLDC} = f_{un}$

$A_{OLDC} = 10^3$, $f_{un} = 50MHz$





6dB → ×2

20dB → ×10

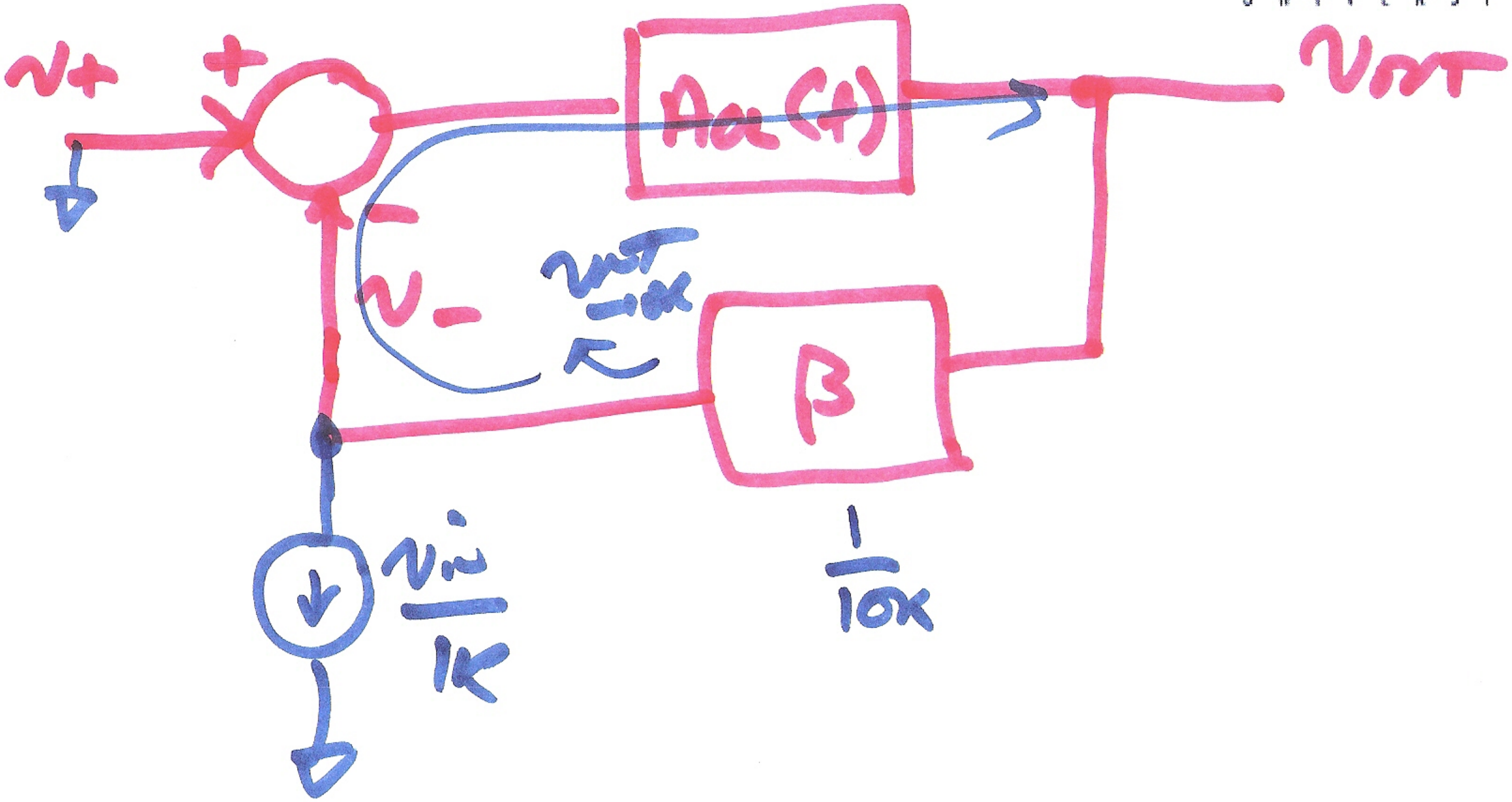
14dB → ×5

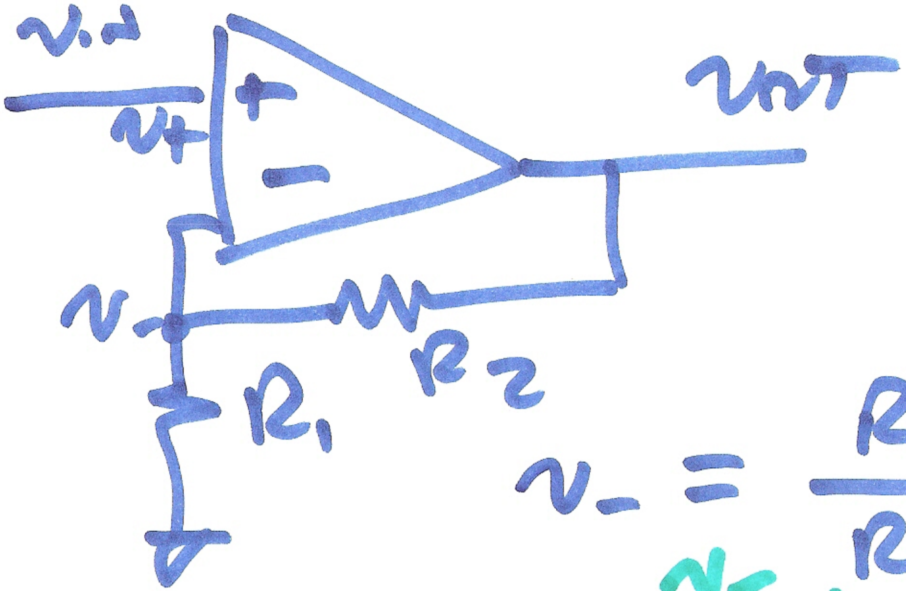
−6dB → ÷2

Closed Amp

$$A_{OL}(f) = \frac{v_{out}}{v_+ - v_-} = \frac{A_{OLDC}}{1 + j\frac{f}{f_{3dB}}} = 5MHz$$

2)


v+
+
−
$A_{OL}(f)$
v_{OUT}
v_-
$\frac{v_{OUT}}{10k}$
β
$\frac{1}{10k}$
$\frac{v_{in}}{1k}$



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

$$v_- = \underbrace{\frac{R_1}{R_1+R_2}}_{\beta} \cdot v_{OUT}$$

$$= A_{OL} \cdot (v_{IN+} - v_{IN-})$$

$$A_{CL} = \frac{v_{OUT}}{v_{IN}} = \frac{A_{OL}}{1+\beta A_{OL}}$$

4)

$$A_{CL} = \frac{A_{OL}}{1+\beta A_{OL}} \qquad \text{if } A_{OL} \to \infty \qquad A_{CL} = \frac{1}{\beta}$$

$$A_{CL} = \frac{\dfrac{A_{OLDC}}{1+j\,f/f_{3dB}}}{1+\beta \cdot \dfrac{A_{OLDC}}{1+j\dfrac{f}{f_{3dB}}}}$$

$$= \frac{A_{OLDC}}{1+j\dfrac{f}{f_{3dB}}+\beta A_{OLDC}}$$

5)

$$A_{CL}(f) = \frac{1}{\frac{1}{A_{OLDC}} + j\frac{f}{f_{3dB}\cdot A_{OLDC}} + \beta}$$

$$\frac{1}{\beta} = A_{CLDC}$$

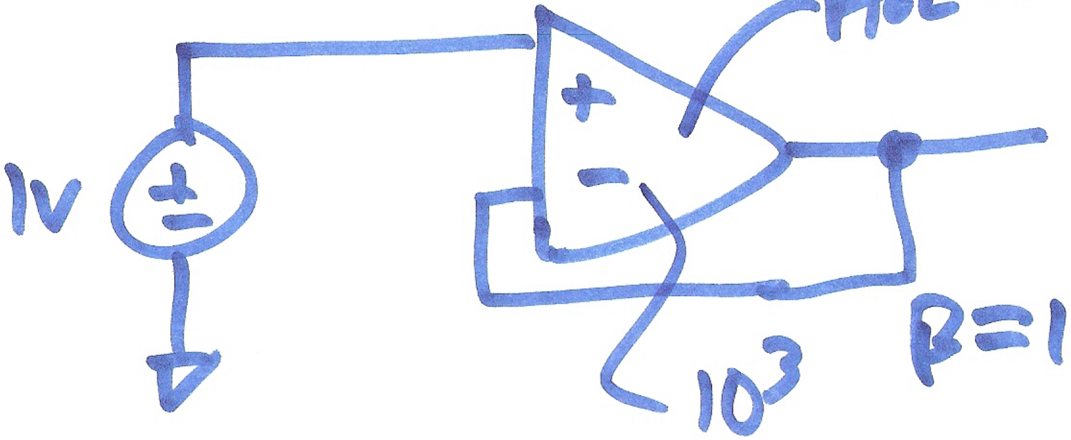
$$= \frac{\frac{1}{\beta}}{\underset{\approx 0}{\cancel{\frac{1}{A_{OLDC}\cdot\beta}}} + 1 + j\frac{f}{f_{un}\cdot\beta}}$$

$$f_{3dBCL} = \frac{f_{un}}{A_{CLDC}}$$

$$= \frac{\frac{1}{\beta}}{1 + j\frac{f}{f_{un}/1/\beta}}$$

$$A_{CLDC}\, f_{3dBCL} =$$
$$f_{un}$$

v)



A_{OL} is finite

$v_{OUT} < 1V$
(neglect offset)

$$(1 - v_{OUT}) \cdot 10^3 = v_{OUT}$$

$$10^3 = v_{OUT}(1 + 10^3)$$

$$v_{OUT} = \frac{10^3}{1 + 10^3}$$

$$= .999$$

Resolution

1 LSB $\frac{\overset{1}{V_{REF+}} - \overset{0}{V_{REF-}}}{2^N}$

$N = 10$-bits

$$\frac{1}{2^{10}} \approx 1mV$$

7)

$$\frac{VDD - Resolution}{VDD} < \frac{A_{OLDC}}{1 + A_{OLDC}}$$

$\nwarrow$ $\beta = 1$

$\uparrow$

S/H this is true.

$$A_{OLDC} > \frac{VDD}{Resolution}$$

$$f_{un} = \overset{1}{\cancel{A}}_{CL} \cdot f_{3dB} > \frac{1V}{1ns}$$

$$A_{OLDC} > 10^7$$

$$\beta = 1 \ , \ f_{CL3dB} = \underline{\underline{f_{un}}}$$

8)

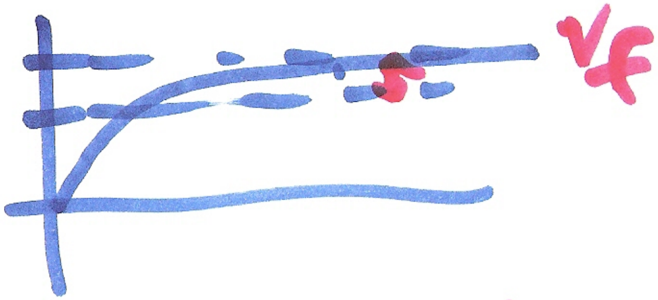
$$S/H \rightarrow \frac{1}{1+j\frac{f}{f_{cw}}} \xrightarrow[RC]{f_{cw}} \frac{1}{1+j\frac{f}{f_{3dB}}}$$

$$\rightarrow \left(1-e^{-t/RC}\right)$$

$$f_{3dB} = \frac{1}{2\pi \underbrace{RC}}$$

~~$RC = \frac{f_{cw}}{2\pi}$~~

$$RC = \frac{1}{2\pi f_{cw}}$$



$$.999\,\cancel{V_f} = \cancel{V_f}\left(1-e^{-t/RC}\right)$$

$$-RC \ln .001 = t_{settling}$$

$$v_{out} = v_{in}\left(1 - e^{-t 2\pi f_{un}}\right)$$

$$\text{Resolution} = 1 - \frac{v_{out}}{v_{in}} = e^{-t 2\pi f_{un}} \qquad \underbrace{\begin{matrix}2\\ 2^{N}\end{matrix}}$$

$$t_{settling} < \frac{1}{2f_s} = \frac{T_s}{2}$$

$$1 - \frac{1}{\underset{.999}{[illegible]}}$$

$$f_{un} = A_{OLDC} \cdot f_{3dB} > \frac{-f_s \ln(\text{Res})}{\pi}$$

$$\frac{-10^{8} \cdot \ln .0015001}{\pi}$$

$$\boxed{f_{un} > 2.205\ \text{MHz}}$$

10)

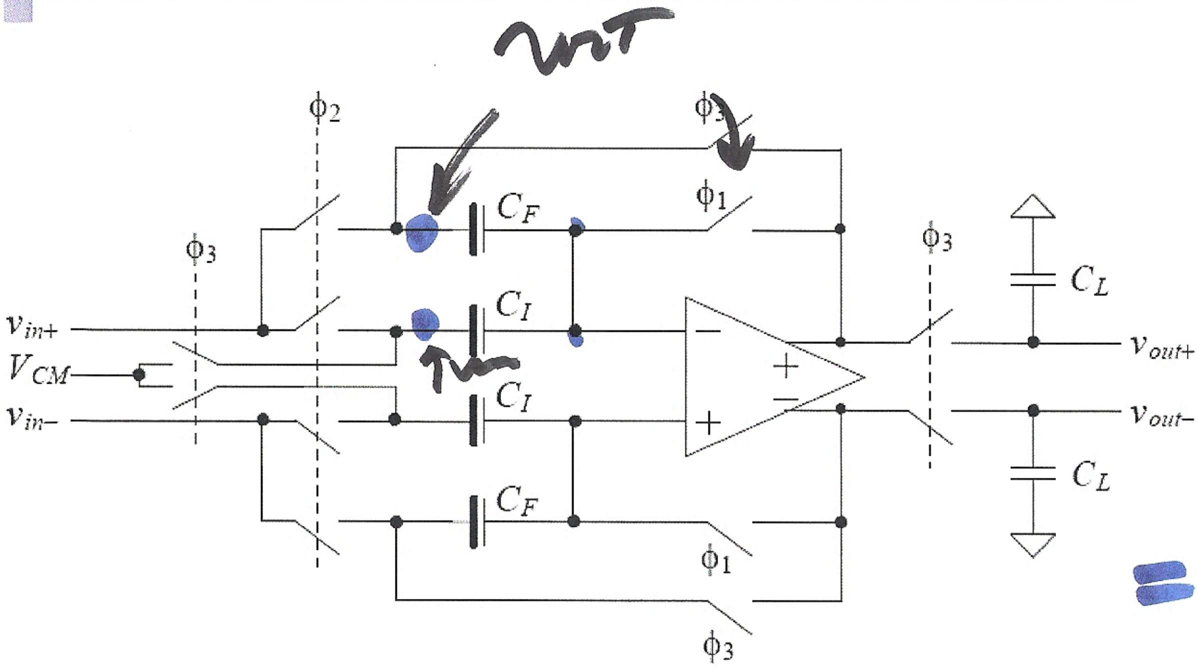


Figure 2.46 A S/H with gain.

ϕ_1

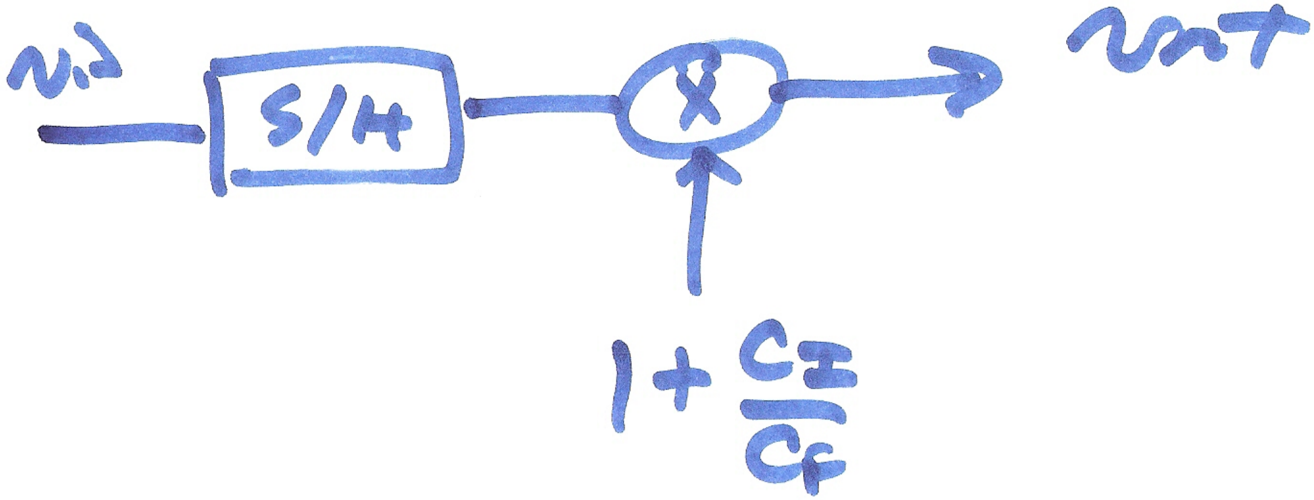
$$Q_{I,F} = C_I(v_{in} - V_{cm} \pm V_{os})$$

$$= C_F(v_{in} - V_{cm} \pm V_{os})$$

$$\underbrace{(C_I + C_F)\cdot(v_{in} - V_{cm} \pm V_{os})}_{\phi_1\ \text{close}} = C_F(v_{out} - \cancel{V_{cm} \pm V_{os}}) + \underbrace{C_I(\cancelto{0}{V_{cm} - V_{cm}} \pm V_{os})}_{\phi_3\ \text{closed}}$$

$$v_{out} = \left(1 + \frac{C_I}{C_F}\right)\cdot v_{in} - \frac{C_I}{C_F}\cdot V_{cm}$$

$$v_{OUT+} - v_{OUT-} = \left(1 + \frac{C_I}{C_F}\right)\left(v_{IN+} - v_{IN-}\right)$$



VDD = 1

VCI+ = 1

VCI- = 0

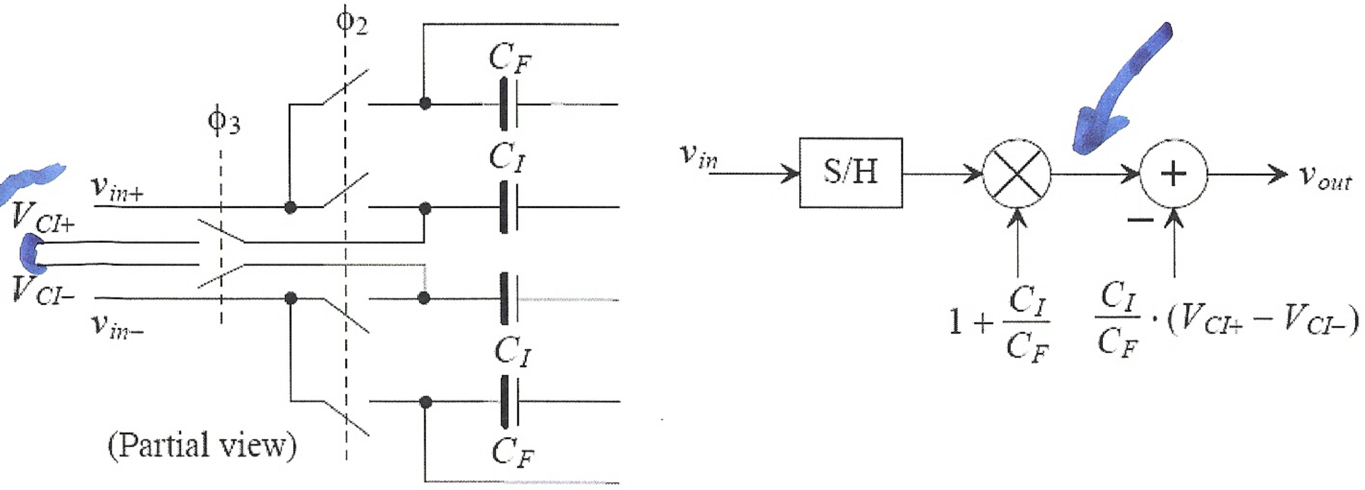


Figure 2.49 Implementing subtraction in the S/H.

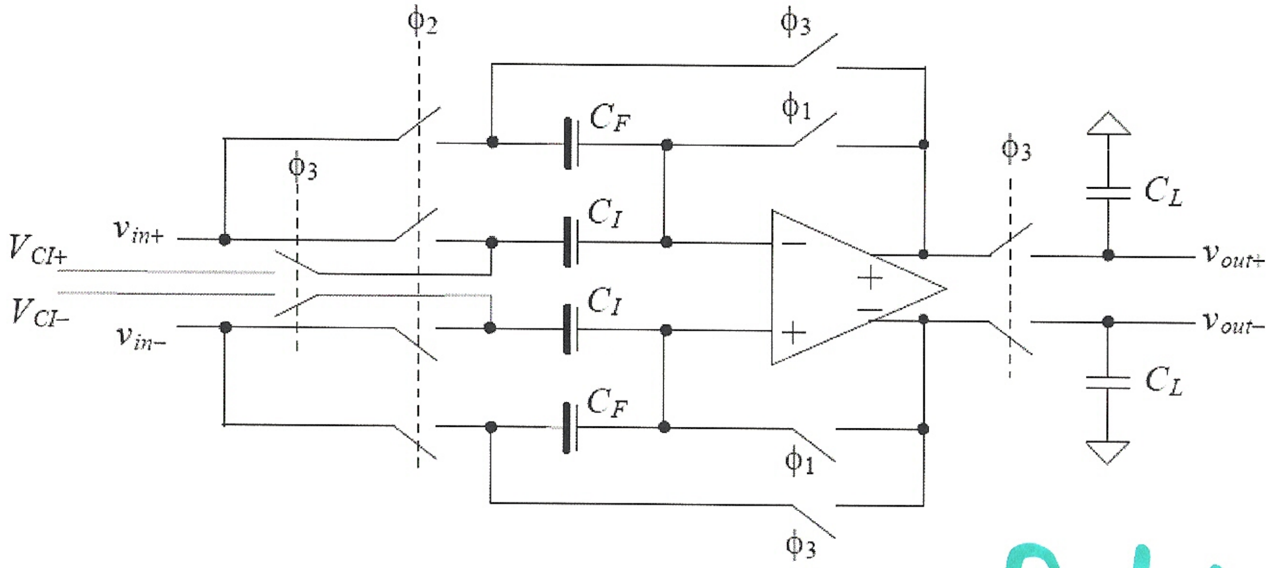


Figure 2.51 S/H used in Ex. 2.5.

fully-differential

Does this S/H use CDs?

14)

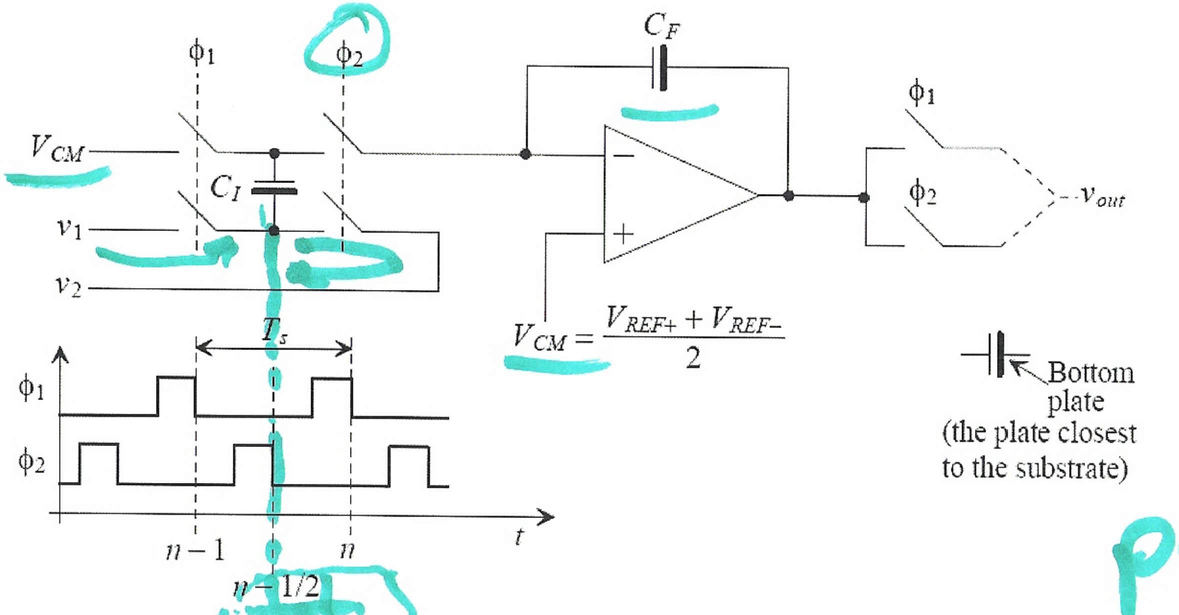
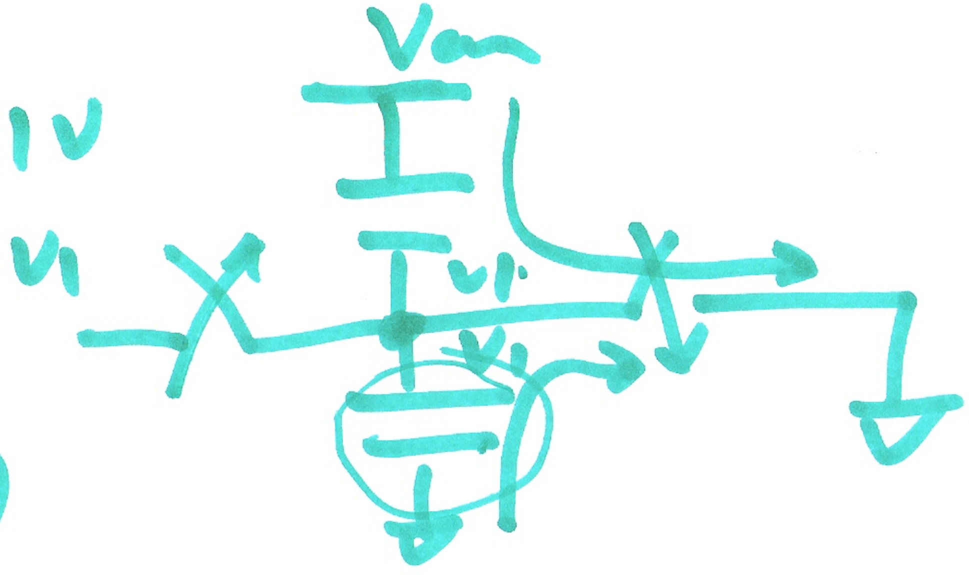
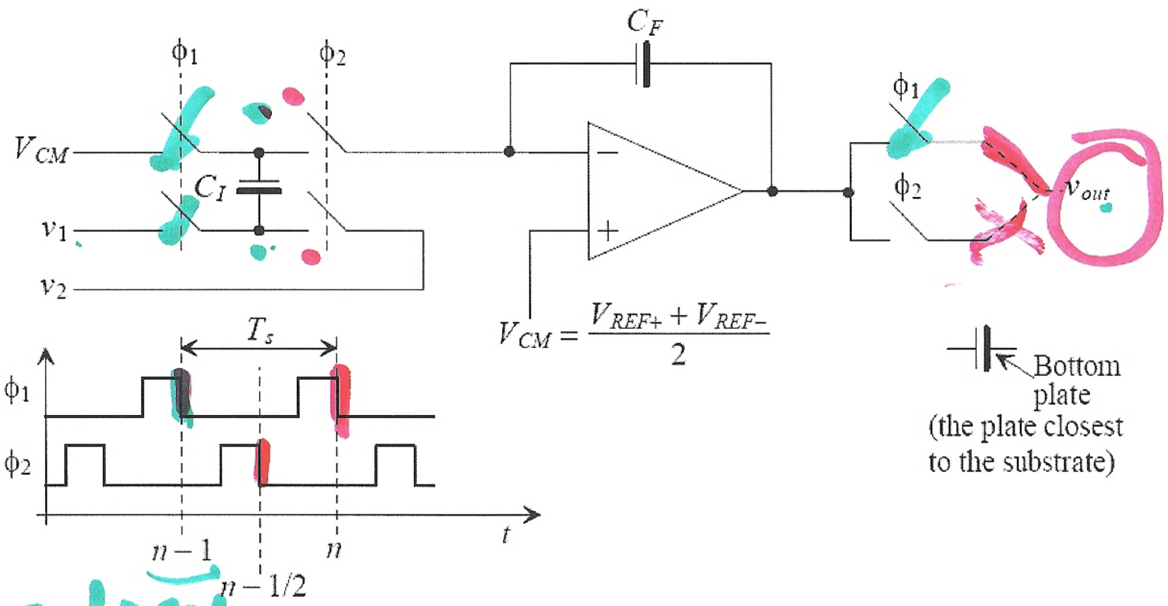


Figure 2.54 Schematic diagram of a discrete analog integrator (DAI).

parasitic
insensitive
integrator



15)



ϕ_1 - closed

Figure 2.54 Schematic diagram of a discrete analog integrator (DAI).

$$Q_1 = C_I(V_{cm} - v_1((N-1)T_s))$$

$$v_{out}[(N-1)\cdot T_s] \leftarrow$$

ϕ_2 - closed

$$Q_2 = C_I \cdot (V_{cm} - v_2[(N-\tfrac{1}{2})T_s]$$

16)

$$C_F\left(V_{OUT}[nT_S] - v_{OUT}[(n-1)T_S]\right) =$$

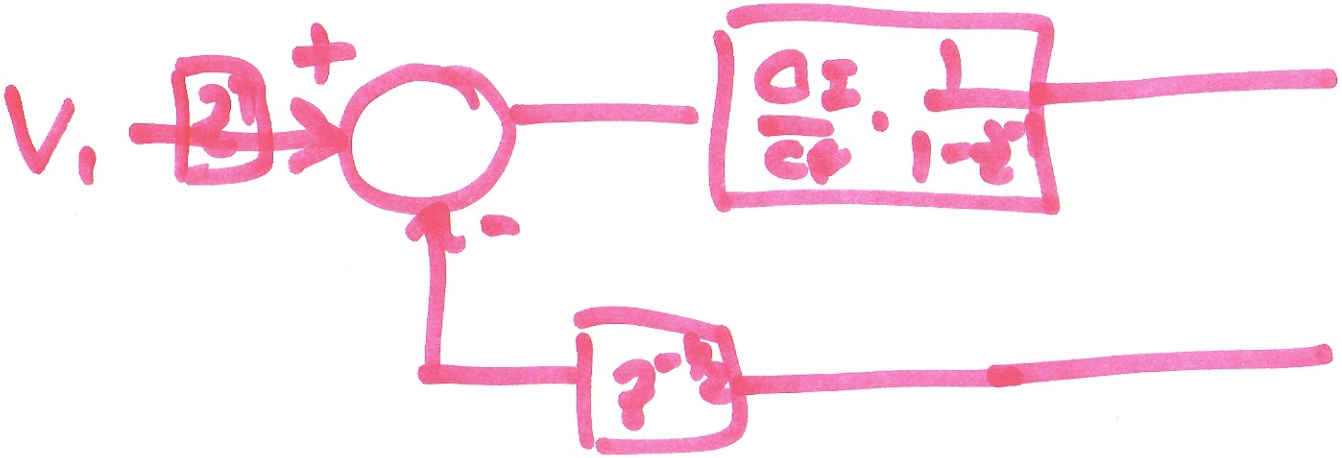
$$= C_I\left(v_1[(n-1)T_S - v_2(n-1/2)T_S\right)$$

z-transform

$$C_F\left(V_{OUT}(z) - V_{OUT}(z)\cdot z^{-1}\right)$$

$$= C_I\left(V_1(z)\cdot z^{-1} - V_2(z)\, z^{-1/2}\right)$$

$$V_{OUT} = \frac{C_I}{C_F}\cdot\frac{V_1(z)z^{-1} - V_2(z)z^{-1/2}}{1 - z^{-1}}$$



18)

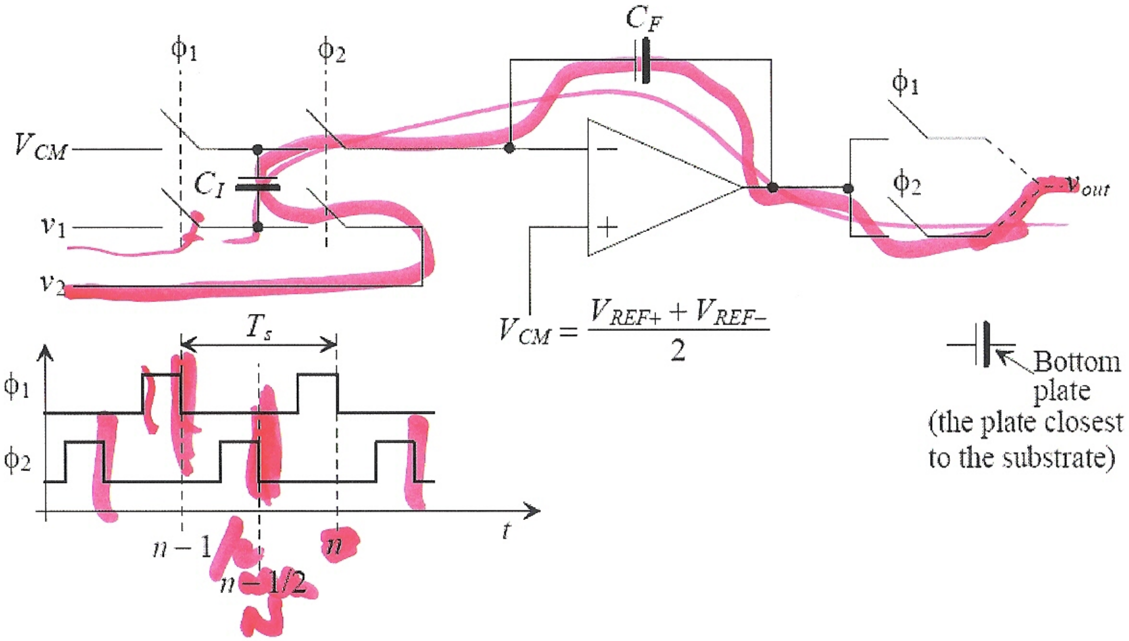


Figure 2.54 Schematic diagram of a discrete analog integrator (DAI).

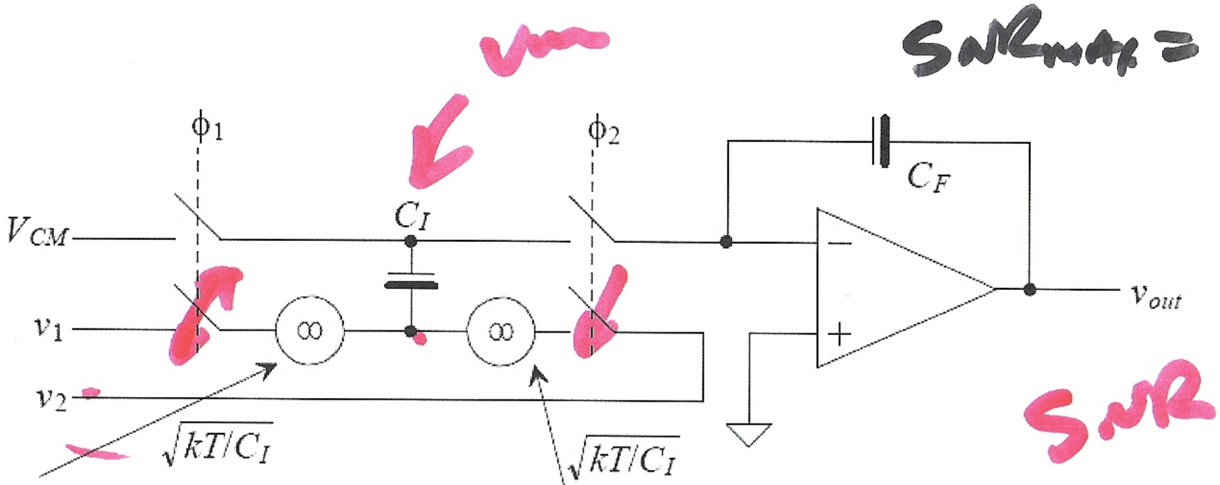
$$\left\{ \frac{V_1 z^{-1/2} - V_2}{1 - z^{-1}} \right.$$

$$C_F \left[v_{OUT}(NT_s) - v_{OUT}[(N-1)T_s] \right] =$$

$$C_I \left(v_1 (N - 1/2) T_s - v_2 (NT_s) \right]$$

19)

$$SNR_{max} = 20 \log \frac{VDD/\sqrt{2} \cdot 2}{\sqrt{\frac{2kT}{C_I}}}$$

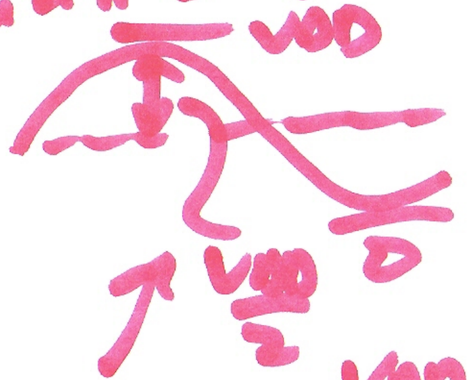


Sampled onto C_I when φ1 switches close.

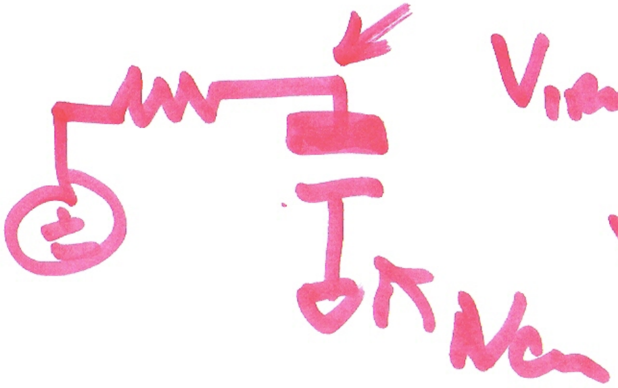
Sampled onto C_I when φ2 switches close

Figure 2.58 Noise performance of the DAI.

SNR_{max} = ?



$$V_{rms} = \frac{VDD}{2\sqrt{2}}$$



$$V_{1rms} = \sqrt{\frac{kT}{C_I}}$$

$$V_{2rms} = \sqrt{\frac{kT}{C_I}}$$

$$V_{EFF} = \sqrt{\frac{2kT}{C_I}}$$

20)