Integrator building blocks

JAN. 21, 2016

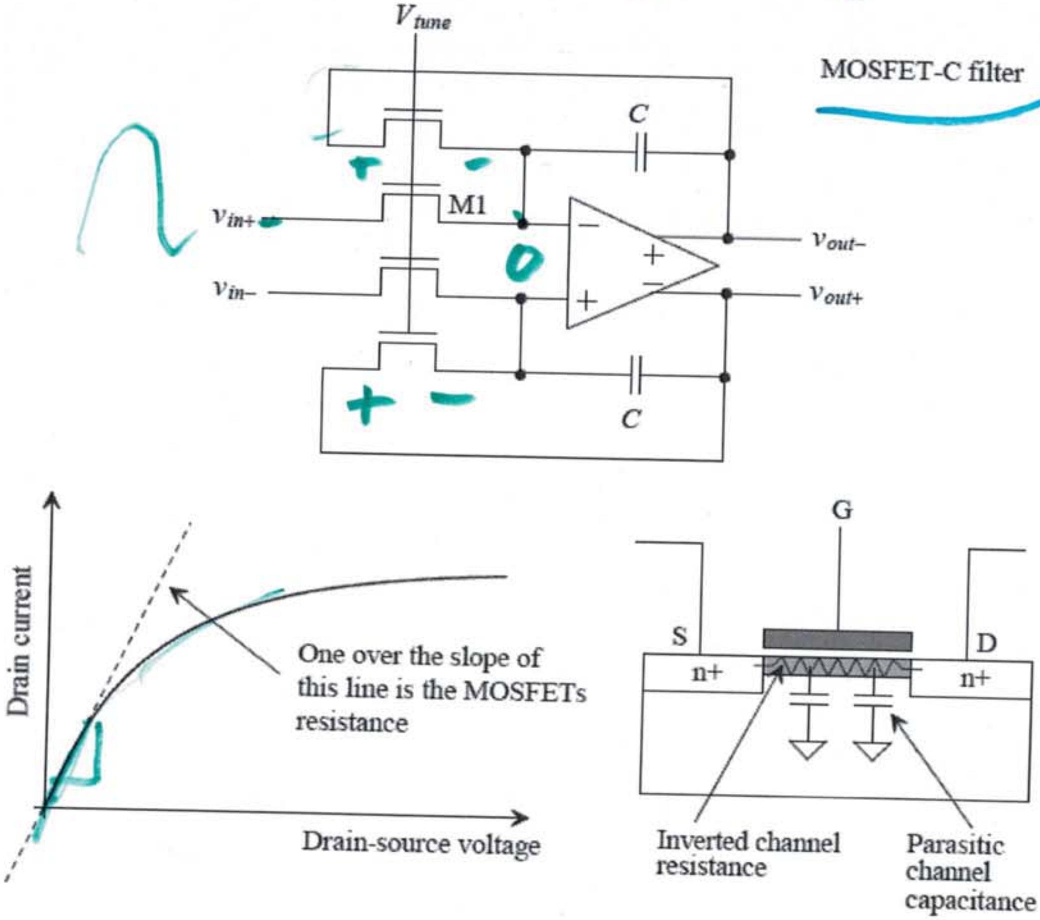
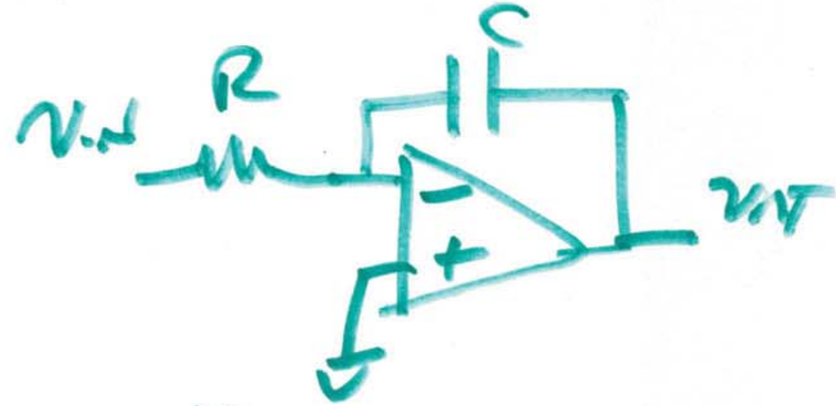
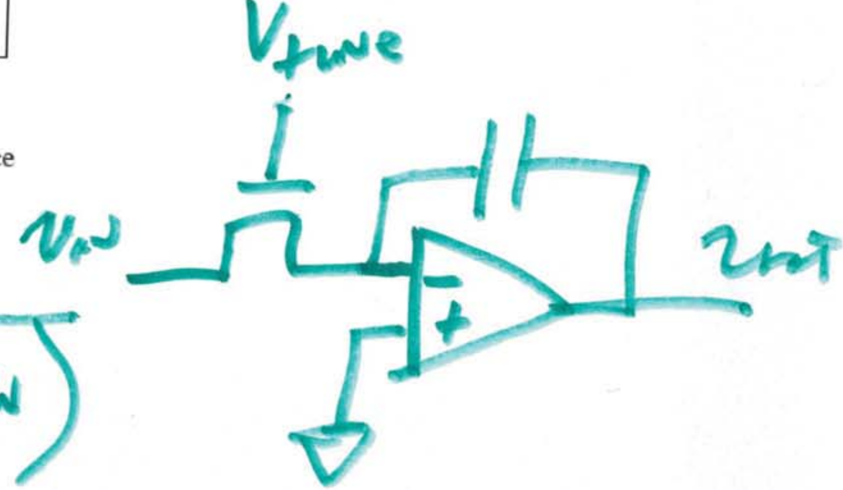


Figure 3.12 A first-order MOSFET-C filter.

RC - integrator





$$R_{CH} = \frac{1}{KP_n \frac{W}{L}\left(V_{TUNE} - V_{THN} - v_{IN}\right)}$$

$$R_{CH} = \frac{1}{KP \cdot \frac{W}{L}\left(V_{TUNE} - V_{THN} - v_{in}\right)}$$

$.6\ V_{TUNE+}$

$.1 \quad \frac{1}{2}$

$-.1 \quad .4$

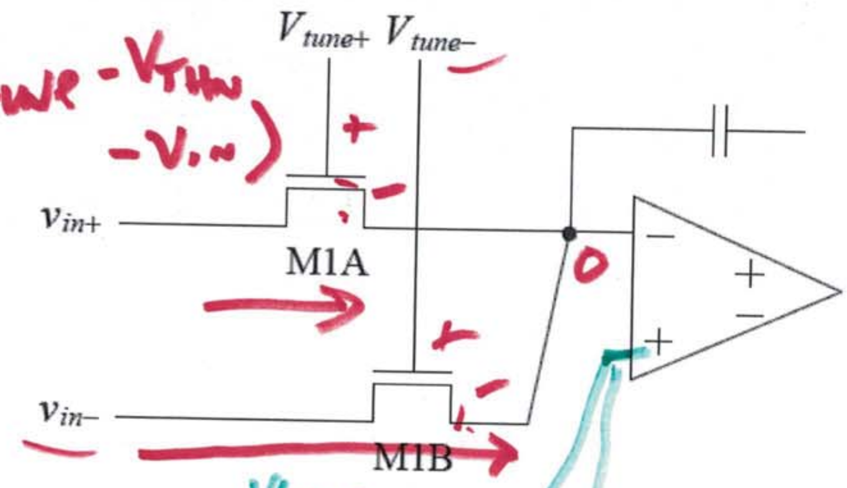


Figure 3.13 Linearizing MOSFET resistors.

$$v_{in+} = -v_{in-}$$

$$V_{TUNE+} = V_{TUNE-}$$

$$\frac{v_{in+}}{R_{N1}} = KP \cdot \frac{W}{L} \cdot V_{TUNE}$$

$$= \frac{v_{in+}}{R_{CH}} + \frac{v_{in-}}{R_{CH}} = v_{in+}\left(KP \cdot \frac{W}{L}\left(V_{TUNE+} - V_{THN} - v_{in+}\right)\right)$$

$$+ v_{in-}\left(KP \cdot \frac{W}{L}\left(V_{tune-} + V_{THN} + v_{in-}\right)\right)$$

2)

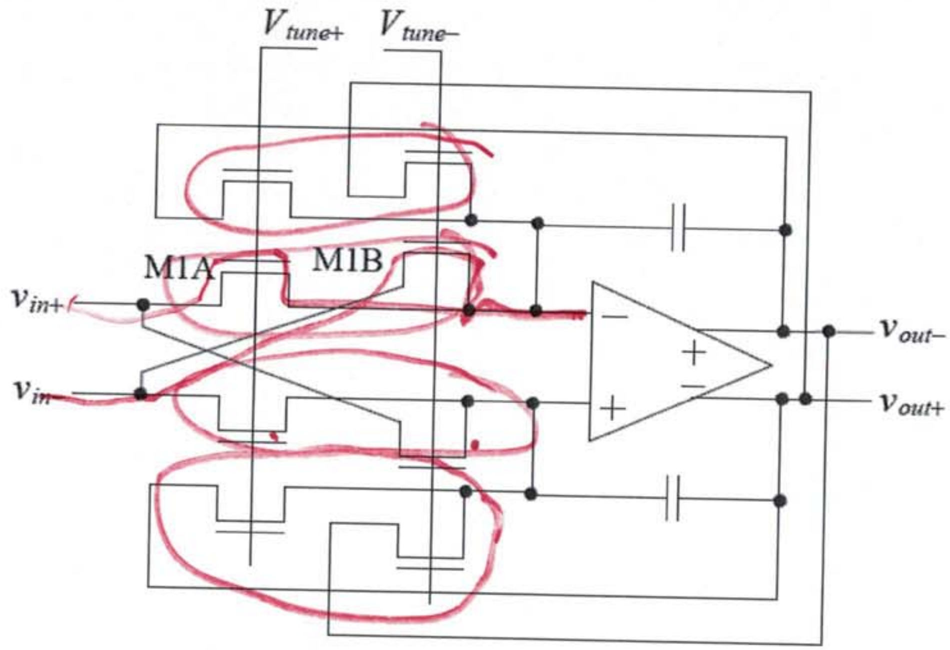
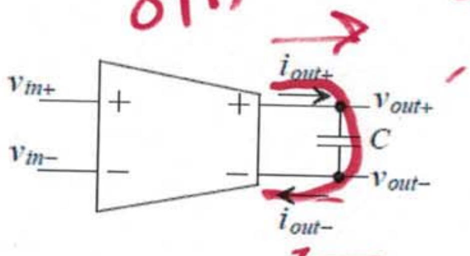


Figure 3.14 First-order MOSFET-C filter using linearized MOSFET resistors.

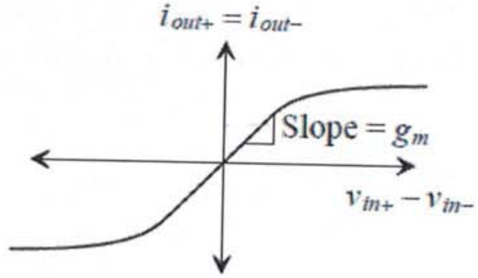
3)

OTA

G



(a) Schematic symbol of an OTA or transconductor.



(b) Transfer curves for an OTA.

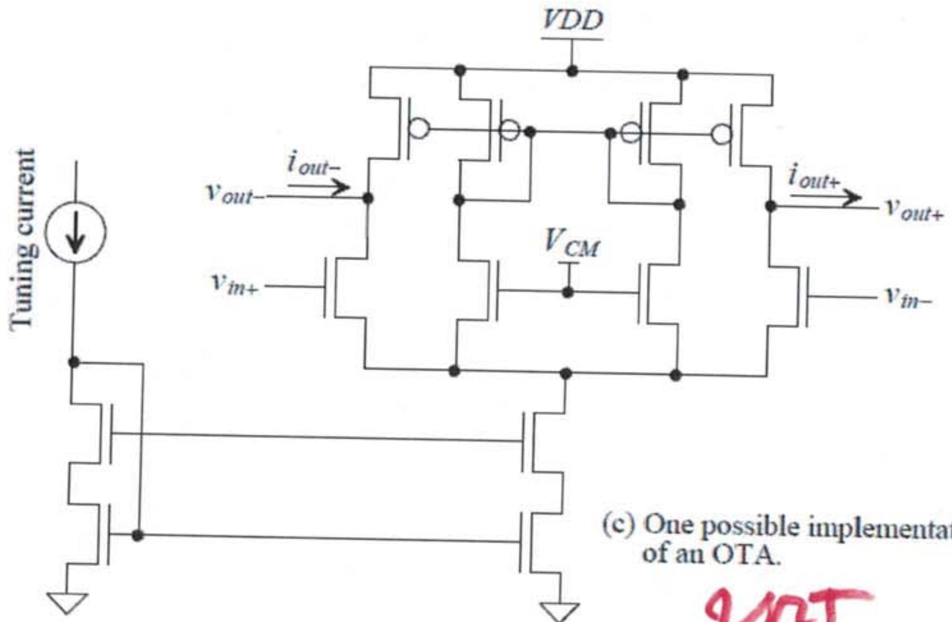
$g_m - C$

$OTA - C$

$$v_{out+} = i_{out+} \cdot \frac{1}{j\omega C} + v_{out-}$$

$$v_{out+} - v_{out-} = \frac{i_{out+}}{j\omega C}$$

$$i_{out+} = g_m \cdot (v_{in+} - v_{in-})$$



(c) One possible implementation of an OTA.

$$\frac{v_{out}}{v_{in}} = \frac{v_{out+} - v_{out-}}{v_{in+} - v_{in-}} = \frac{g_m}{j\omega C}$$

$$= \frac{1}{\frac{1}{g_m} \cdot C \cdot j\omega}$$

$$G = \frac{1}{RC}$$

Figure 3.15 Showing an implementation of an OTA and transfer curves.

4)

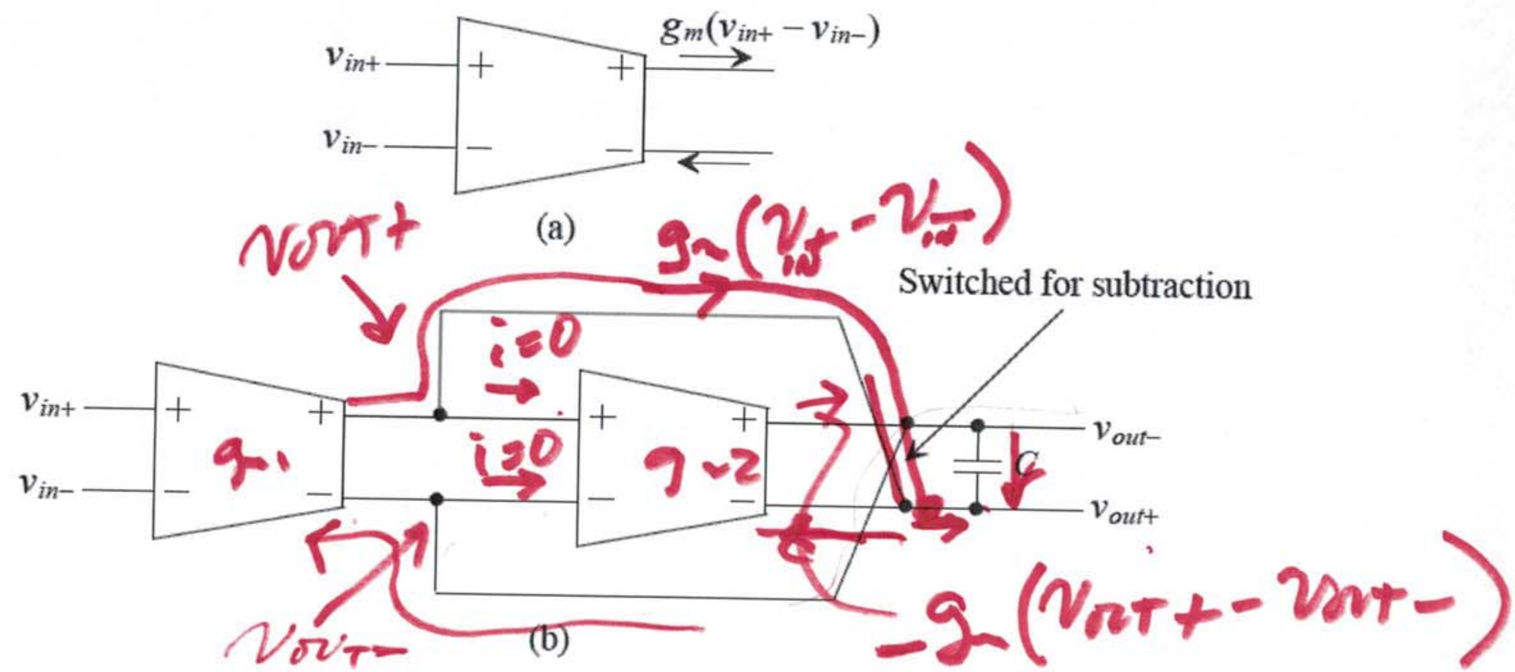
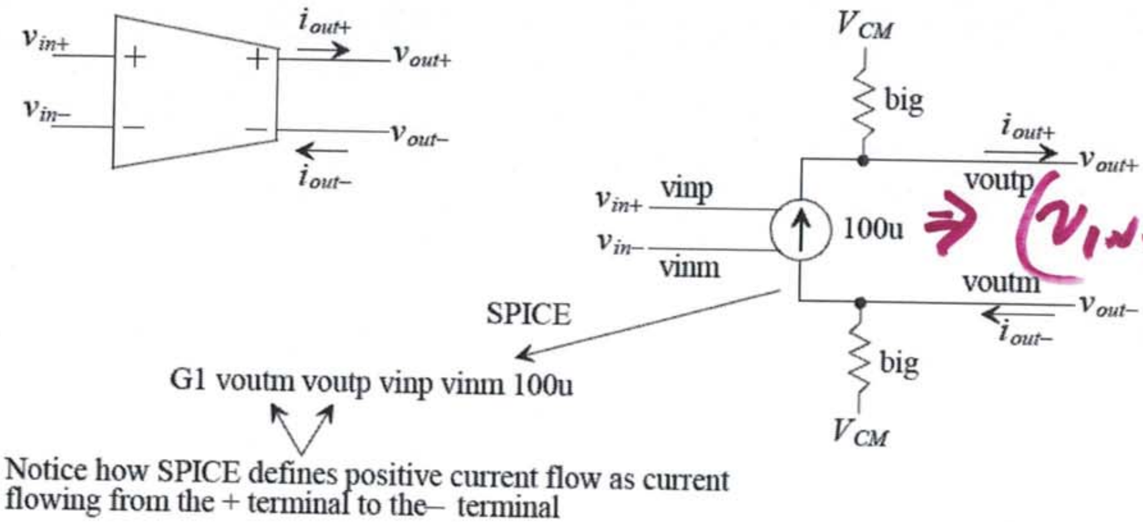


Figure 3.16 Implementing a first-order filter using transconductors.

$$0 = g_m(v_{in+} - v_{in-}) - g_m(v_{out+} - v_{out-}) + \frac{v_{out-} - v_{out+}}{1/j\omega C}$$

$$= g_m(v_{in+} - v_{in-}) - (v_{out+} - v_{out-})(g_m + j\omega C)$$

$$\frac{v_{out+} - v_{out-}}{v_{in+} - v_{in-}} = \frac{g_m}{g_m + j\omega C} = \frac{1}{1 + j\omega C \cdot \frac{1}{g_m}}$$



$\Rightarrow (v_{IN+} - v_{IN-})\, 100\mu$

g_m

$\frac{1}{g_m} = 10K$

Figure 3.17 Modeling an ideal transconductor in SPICE using a voltage-controlled current source.

$$v_{out+} - v_{out-} = \frac{1}{j\omega C} \cdot i_{out+}$$

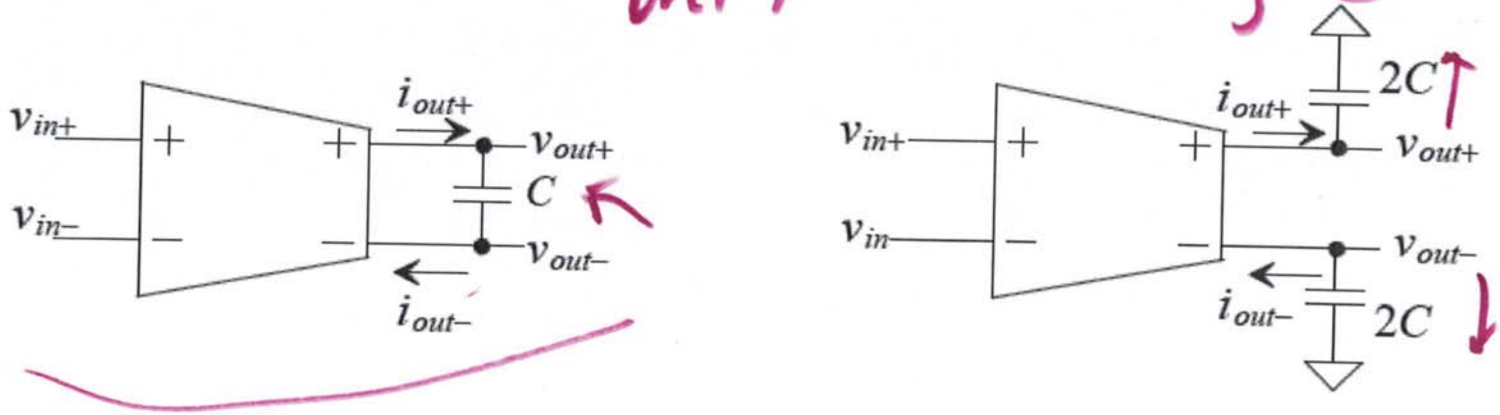


Figure 3.19 Showing how we break the capacitor up to provide a load for the CMFB circuit.

$$i_{out+} = (v_{out+} - v_{out-}) \cdot \frac{\cancel{\;}}{j\omega C} \Rightarrow v_{out+} - v_{out-} = j\omega C \cdot i_{out+}$$

$$i_{out+} = \frac{v_{out+}}{1/j\omega 2C} \qquad i_{out-} = \frac{v_{out-}}{1/j\omega C 2} = i_{out+}$$

$$v_{out+} - v_{out-} = \frac{2\,\cancel{i_{out+}}\; i_{out+}}{j\omega \cancel{2}C} \qquad -v_{out-} = \frac{i_{out+}}{j\omega 2C}$$

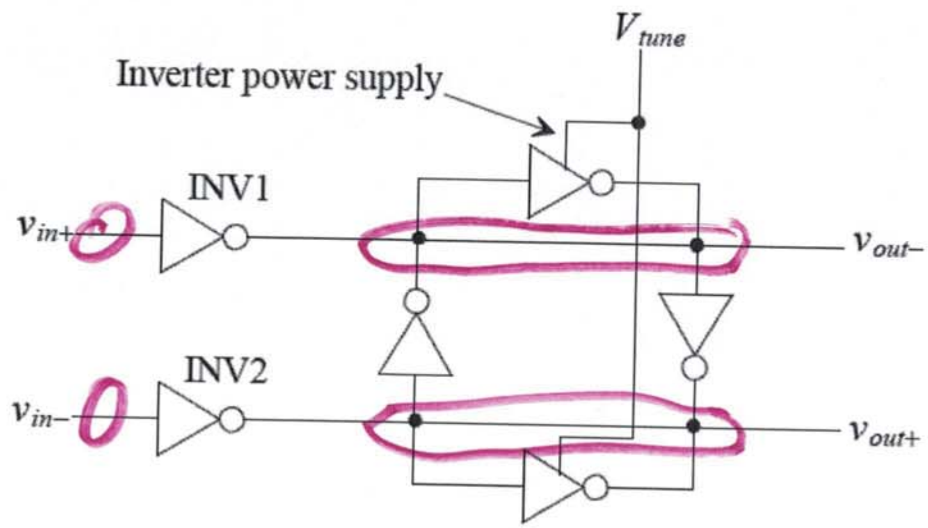


Figure 3.20 High-frequency transconductor.

8)

$$\frac{C_I}{C_F} \frac{z^{-1}}{1-z^{-1}} = \frac{C_I}{C_F}\frac{1}{z-1} = \frac{C_I}{C_F}\frac{1}{s}\cdot T_{CLK} = \frac{C_I}{C_F}\cdot f_{clk}\cdot\frac{1}{s}$$

gain

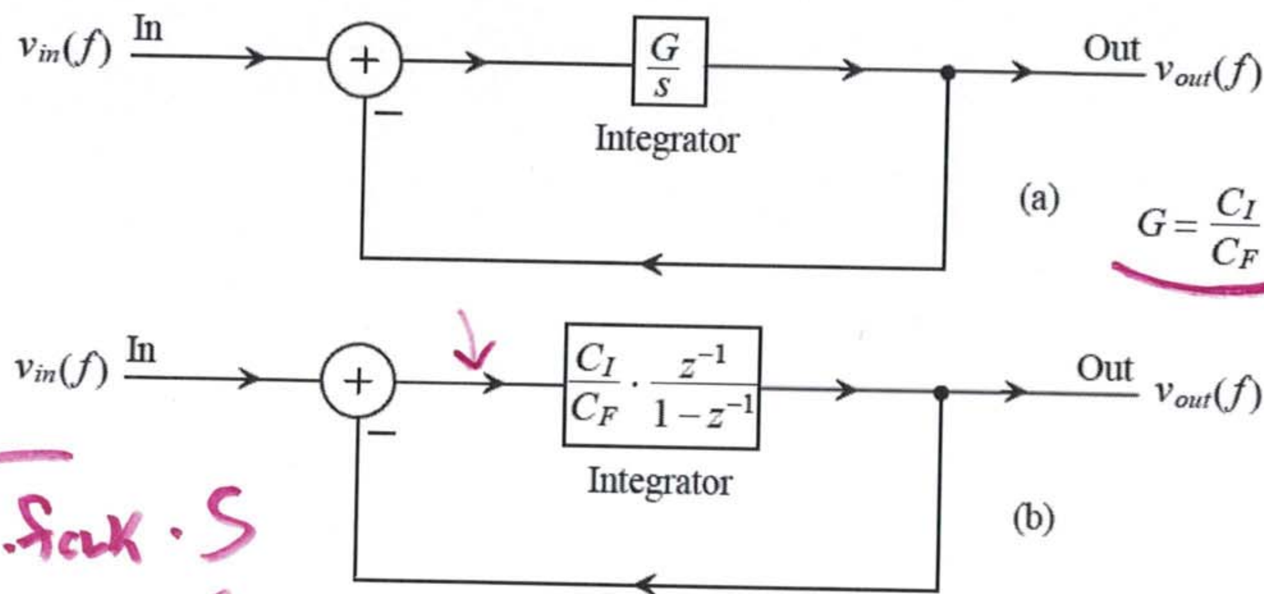
$$z = e^{j2\pi f\cdot T_{CLK}}$$

$$= 1 + \underbrace{j2\pi f\cdot T_{CLK}}_{s} + \frac{(j2\pi f\cdot T_{CLK})^2}{2!} + \cdots$$

$$f \ll \frac{1}{T_{CLK}}$$

$$z \simeq 1 + s\cdot T_{CLK}$$

$$f \ll f_{CLK}$$



$$G = \frac{C_I}{C_F} \cdot f_s$$

$$\frac{1}{1 + \frac{C_F}{C_I} \cdot f_{clk} \cdot s}$$

Figure 3.21 Block diagram of an integrator-based lowpass filter. (a) Continuous-time and (b) the discrete-time equivalent.

$$(v_{IN} - v_{OUT}) \cdot \frac{C_I}{C_F} \cdot \frac{z^{-1}}{1-z^{-1}} = v_{OUT}$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{1}{1 + \frac{C_F(1-z^{-1})}{C_I \cdot z^{-1}}}$$

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

$$\frac{1}{1 + \frac{C_F}{C_I} \cdot \left(\frac{1-z}{1}\right)}$$

10)

$$z \approx 1 + s \cdot f_{clk}$$

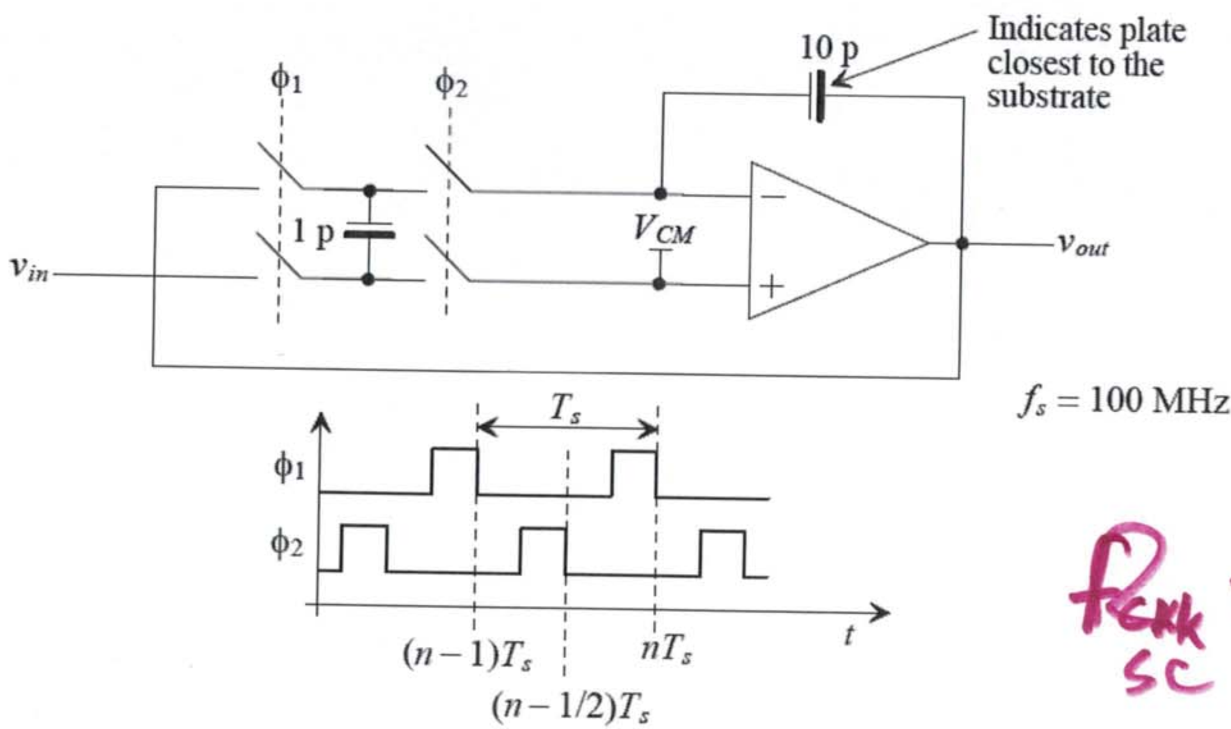


Figure 3.22 A switched capacitor, first-order filter similar to the one described in Ex. 3.1.

$$R_{SC} = \frac{1}{10^8 \cdot 10^{-12}}$$

$R_{SC} = 10K$

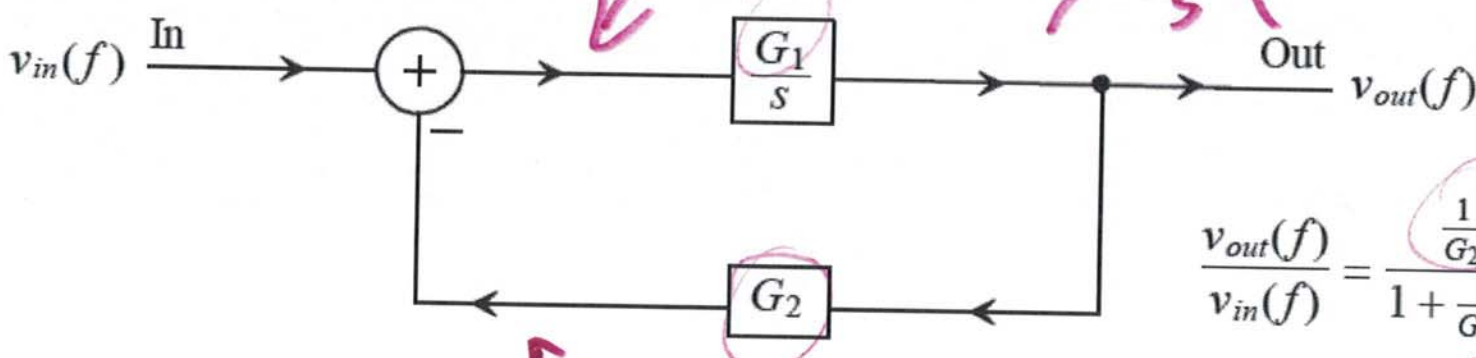
$f_{CLK} = 1.59$ MHz

is 100 MHz $\gg$ 1.59 MHz

11)

$-G_2 v_{out} + v_{in}$

$\frac{G_1}{s}(G_2 v_{out} + v_{in}) = v_{out}$



$$\frac{v_{out}(f)}{v_{in}(f)} = \frac{\frac{1}{G_2}}{1 + \frac{s}{G_1 G_2}}$$

$G_2 \cdot v_{out}$

Figure 3.24 General implementation of a lowpass first-order filter.

$$v_{out}\left(1 + \frac{G_1 G_2}{s}\right) = v_{in} \cdot \frac{G_1}{s}$$

$$\frac{v_{out}}{v_{in}} = \frac{\frac{G_1}{s}}{1 + \frac{G_1 G_2}{s}} \cdot \frac{\frac{s}{G_1 G_2}}{\frac{s}{G_1 G_2}} = \frac{\frac{1}{G_2}}{1 + \frac{s}{G_1 G_2}}$$

12)

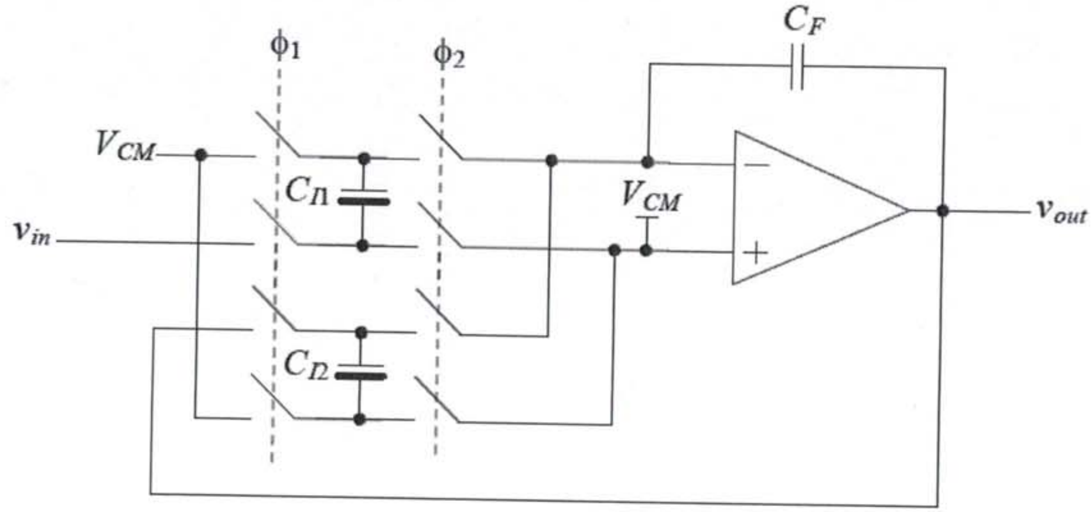


Figure 3.25 Implementation of the block diagram shown in Fig. 3.24.

$$G_1 = \frac{C_{I1}}{C_F} \cdot f_s$$

$$G_2 = \frac{C_{I2}}{C_F} \cdot f_s \cdot \frac{1}{G_1} = \underline{\underline{\frac{C_{I2}}{C_{I1}}}}$$

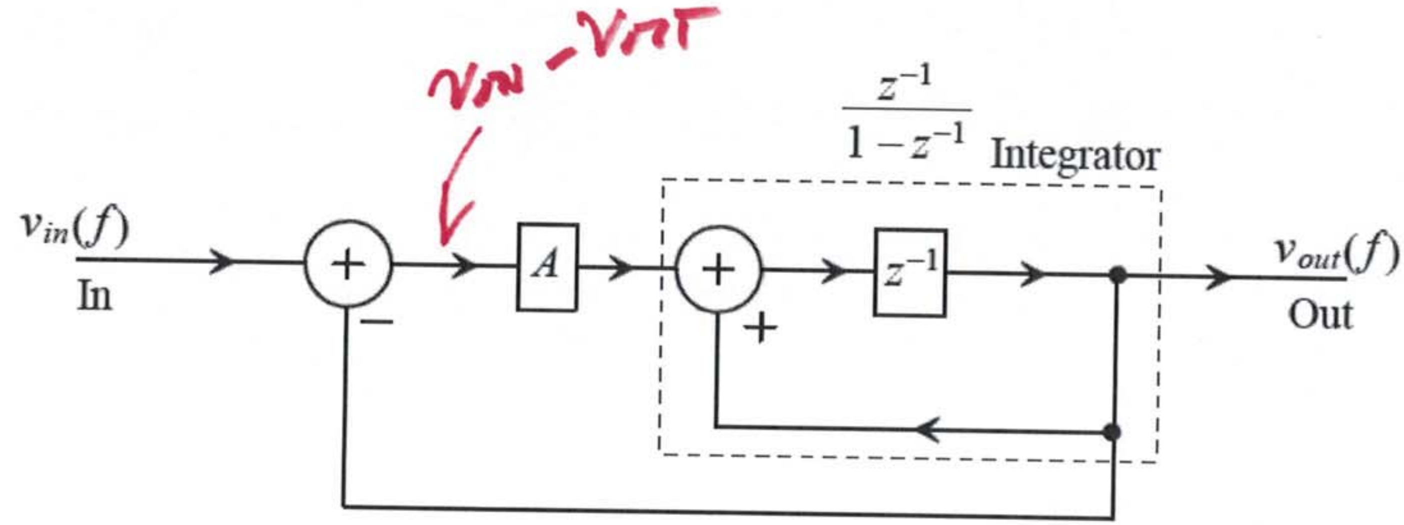


Figure 3.26 Digital block diagram of an integrator-based discrete-time lowpass filter.

$$v_{out} = (v_{in} - v_{out})A \cdot \frac{z^{-1}}{1-z^{-1}}$$

$$\frac{v_{out}}{v_{in}} = \frac{A}{z-(1-A)}$$

14)

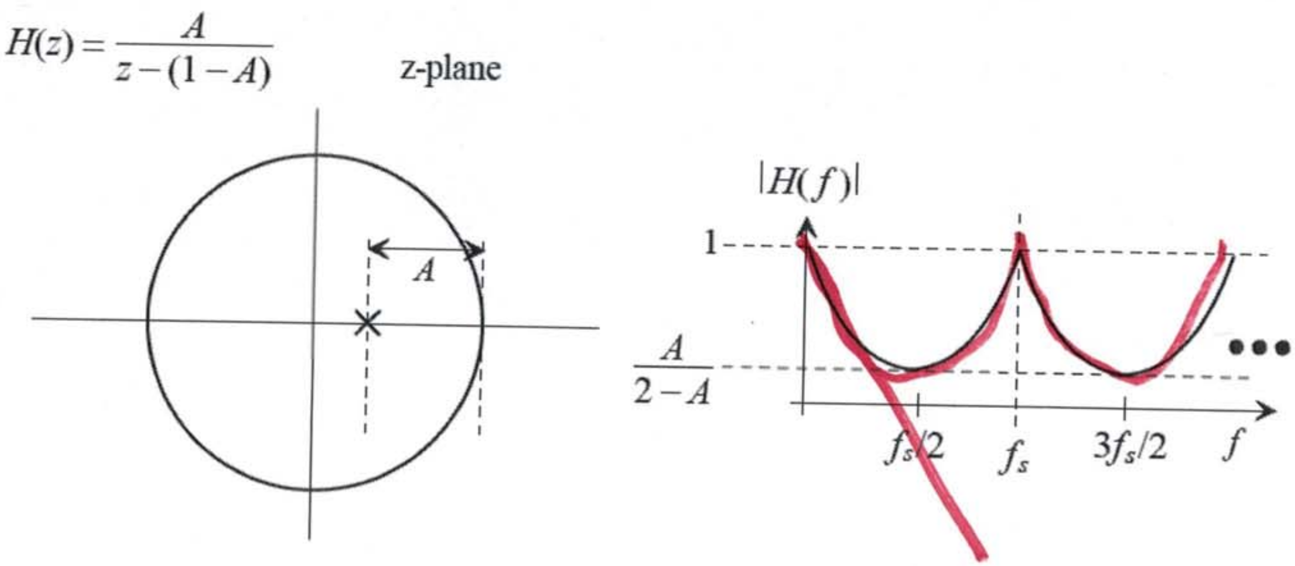


Figure 3.27 The z-plane representation and magnitude response of a first-order discrete-time filter.