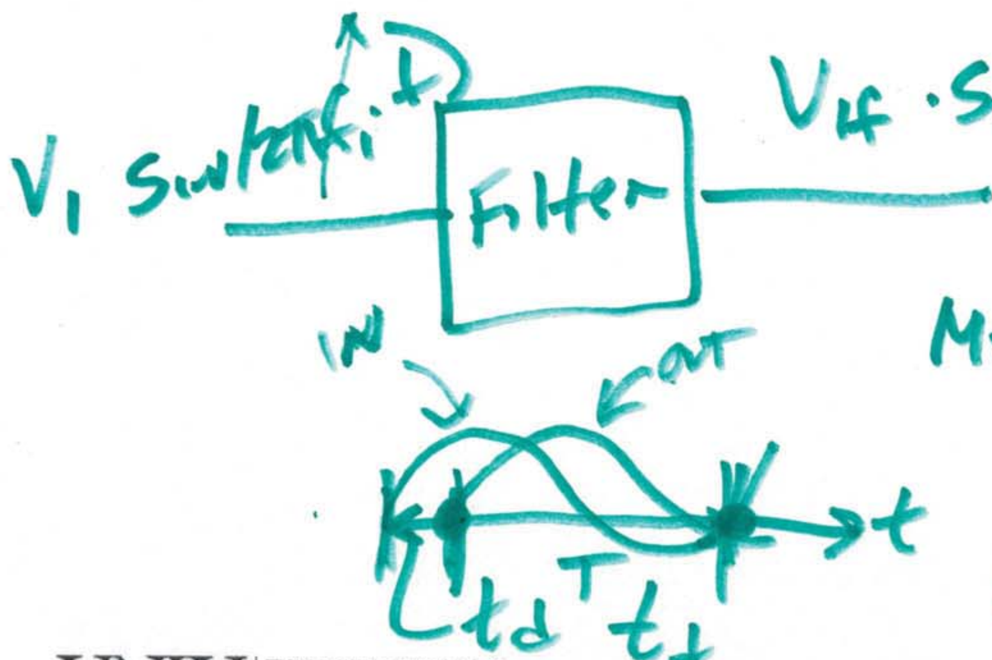
Ch. 3 Integrator building blocks

CMOS mixed-signal circuit Design

$V_{rf} \cdot \sin(2\pi f_1 \cdot t)$



Magnitude $\left|\frac{V_{rf}}{V_1}\right|$

$$\angle \frac{V_{rf}}{V_1} = \theta = \frac{t_d}{T} \cdot 360 \quad (2\pi)$$

$$V_{out} = \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + R} \cdot V_{in}$$

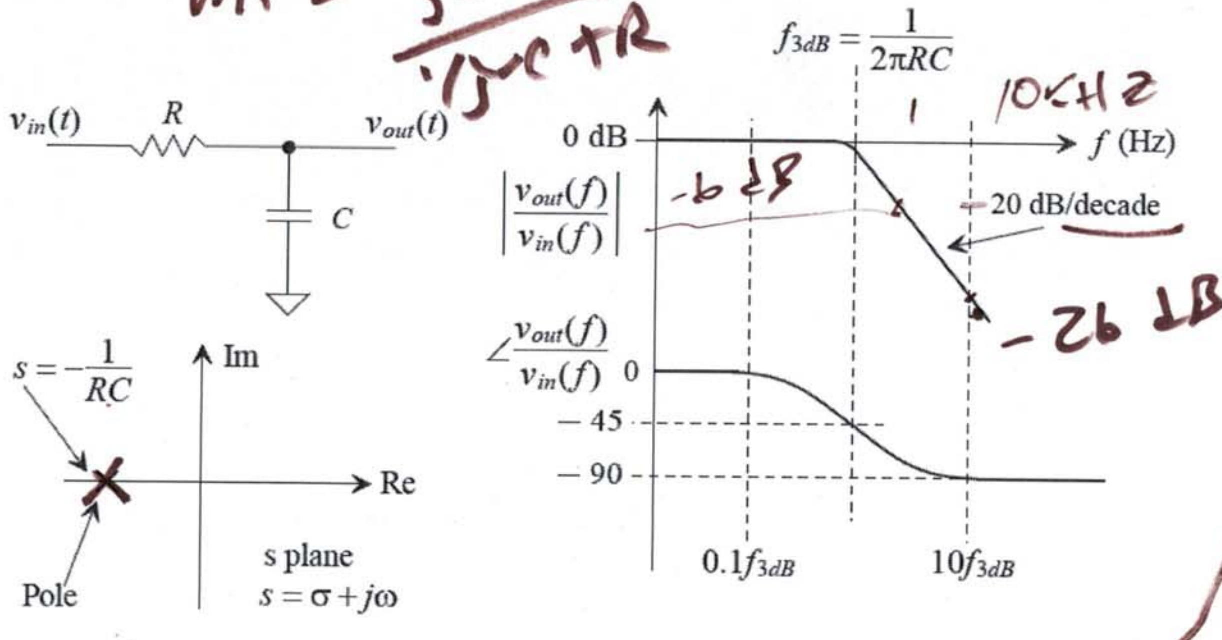


Figure 3.1 First-order lowpass filter.

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 + j\omega RC}$$

$$s = j\omega = -\frac{1}{RC}$$

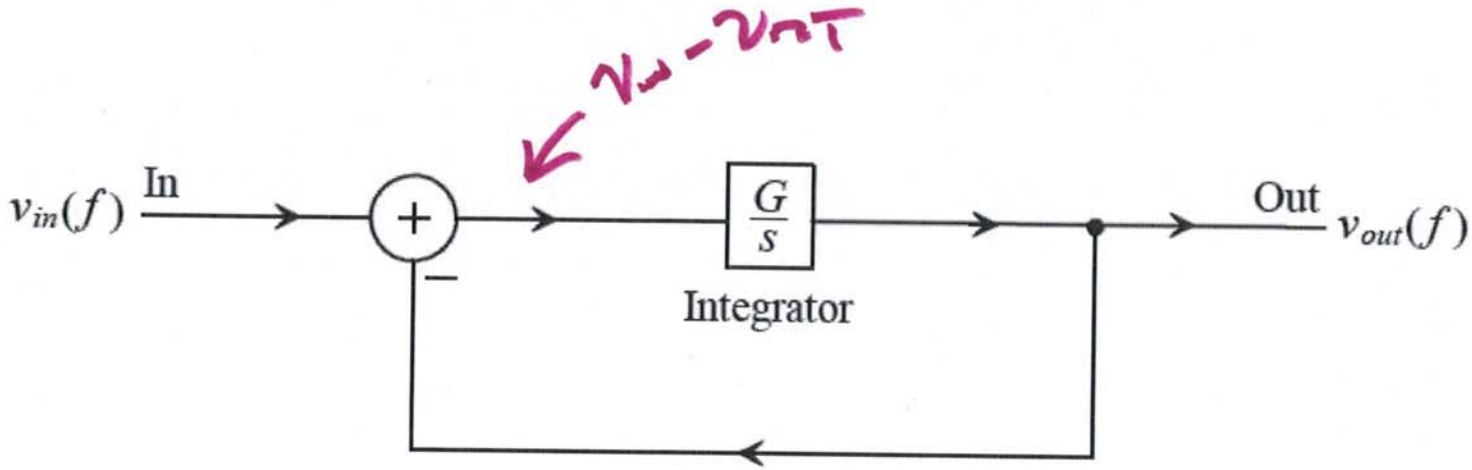


Figure 3.2 Block diagram of an integrator-based lowpass filter.

$$v_{out} = (v_{in} - v_{out})\frac{G}{s}$$

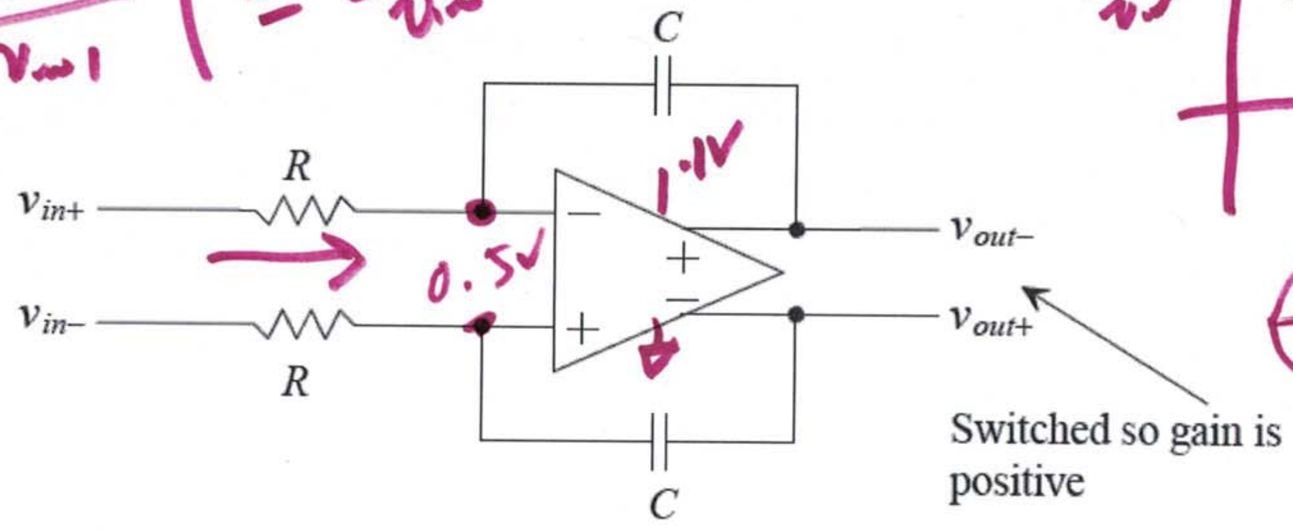
$$v_{out}\left(1 + \frac{G}{s}\right) = v_{in} \cdot \frac{G}{s}$$

$$\frac{v_{out}}{v_{in}} = \frac{1}{1 + \frac{s}{G}}$$

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

3)

$$\left|\frac{v_{OUT+} - v_{OUT-}}{v_{in+} - v_{in-}}\right| = \frac{v_{OUT}}{v_{IN}}$$



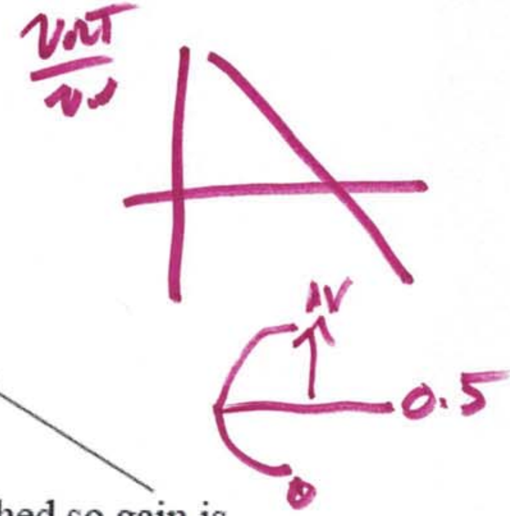
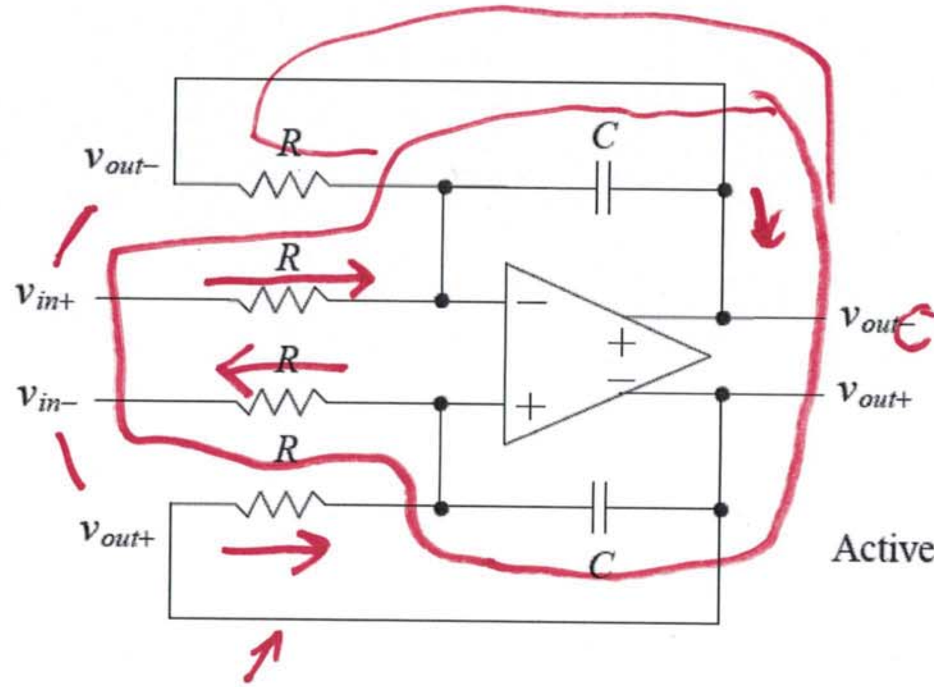


Figure 3.3 A continuous-time analog integrator (CAI).

$$\frac{v_{IN} - 0}{R} = \frac{v_{OUT} - 0}{1/j\omega C} \Rightarrow \frac{v_{OUT}}{v_{IN}} = \frac{-\frac{1}{j\omega C}}{R}$$

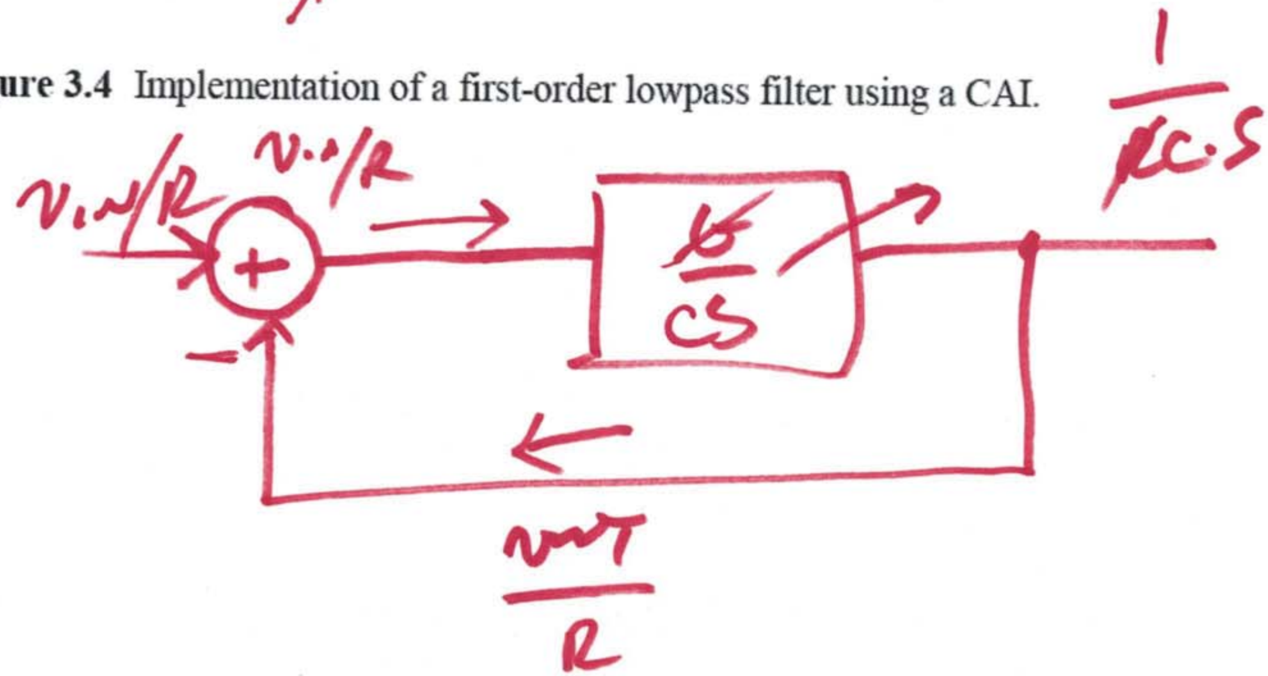
$$= \frac{-1}{j\omega RC}$$

Swapping the outputs $\frac{1}{j\omega RC}$



Active-RC filter.

Figure 3.4 Implementation of a first-order lowpass filter using a CAI.



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5)

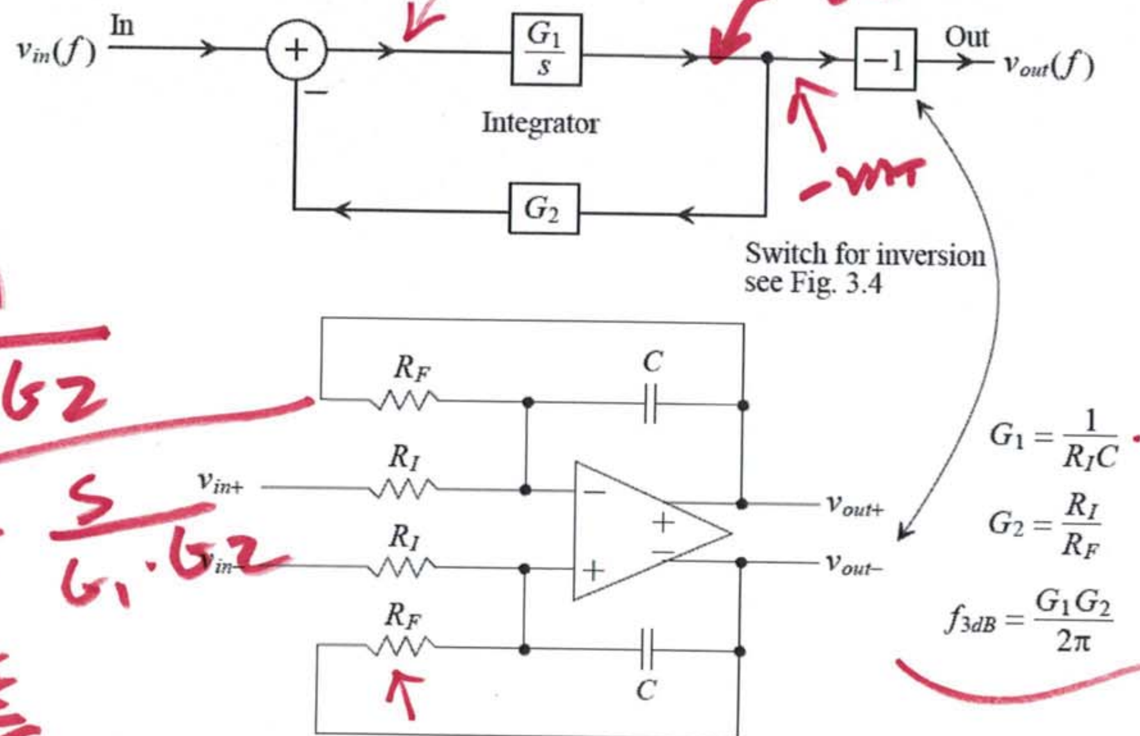


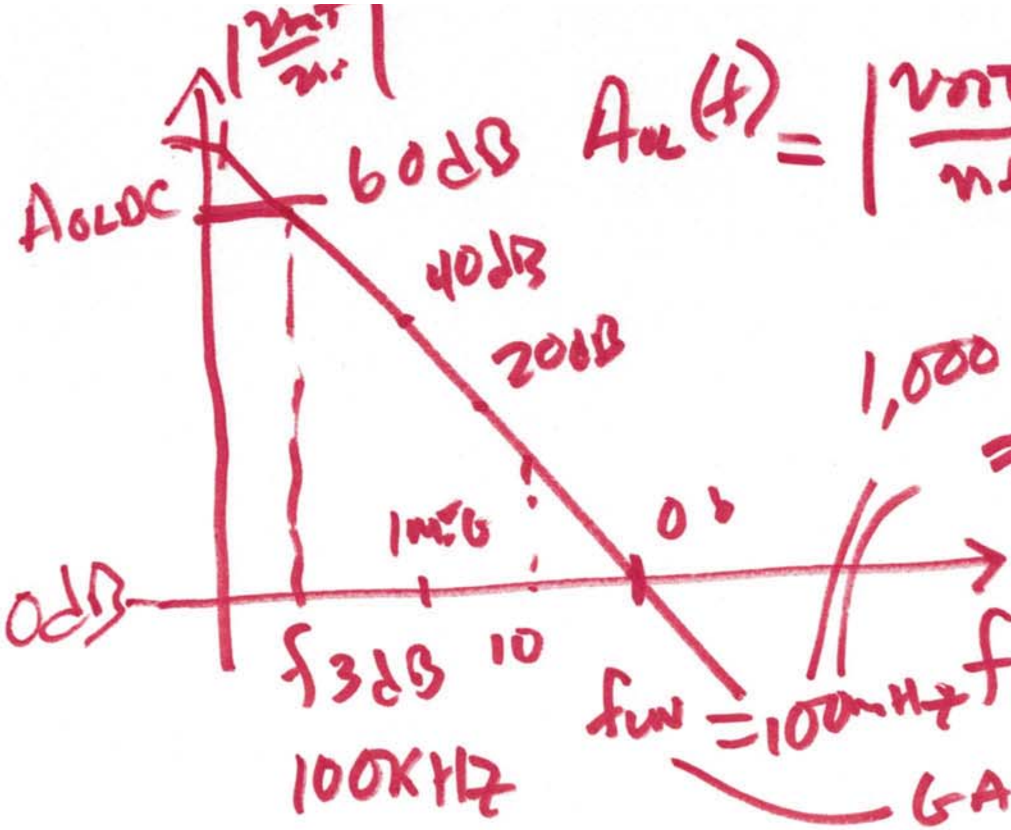
Figure 3.6 Integrator-based first-order filter.

$$\frac{v_{out}}{v_{in}} = \frac{\frac{1}{G_2}}{1 + \frac{s}{G_1 \cdot G_2}} = \frac{\frac{R_F}{R_I}}{1 + sR_F C}$$

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

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

6)



$$A_{OL}(f) = \left|\frac{v_{OUT}}{v_{in}}\right| = \frac{A_{OL} \Rightarrow 1{,}000}{1 + j\frac{f}{f_{3dB}}}$$

$\rightarrow 100\times$

$1{,}000 \cdot 100KHZ = 100MHZ$

$$\frac{1}{1 + sRC} = \frac{1}{1 + j2\pi f \cdot RC} = \frac{1}{1 + j\frac{f}{f_{3dB}}}$$

GAIN · BW = f_{unity}

$$A_{OL}(f) \approx \frac{A_{OLDC}}{j \cdot \frac{f}{f_{3dB}}}, \quad f \gg f_{3dB}$$

$$\approx \frac{A_{OLDC} f_{3dB}}{j \cdot f} = \frac{f_{un}}{j \cdot f}$$

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

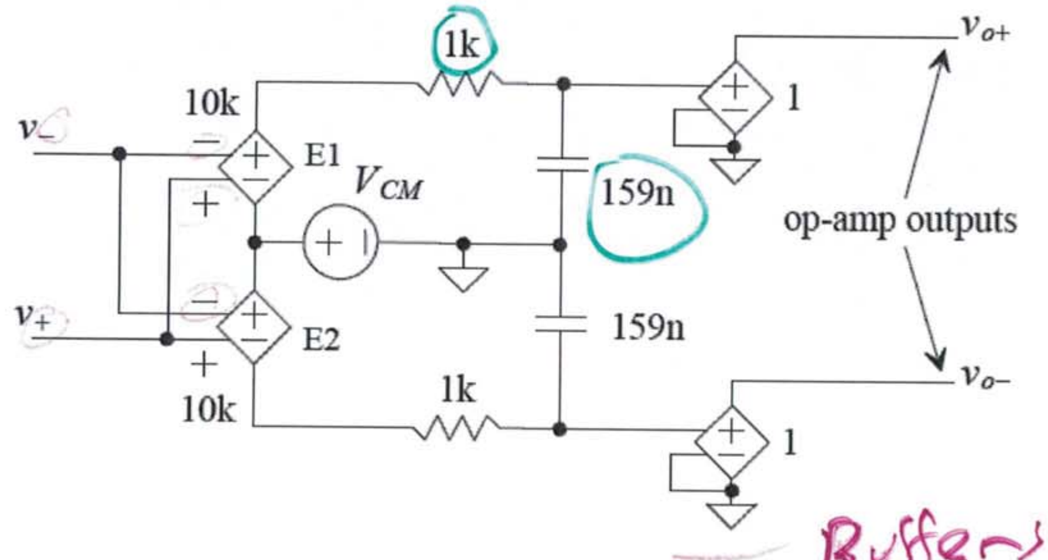


Figure 3.8 SPICE modeling of a differential input/output op-amp with finite bandwidth.

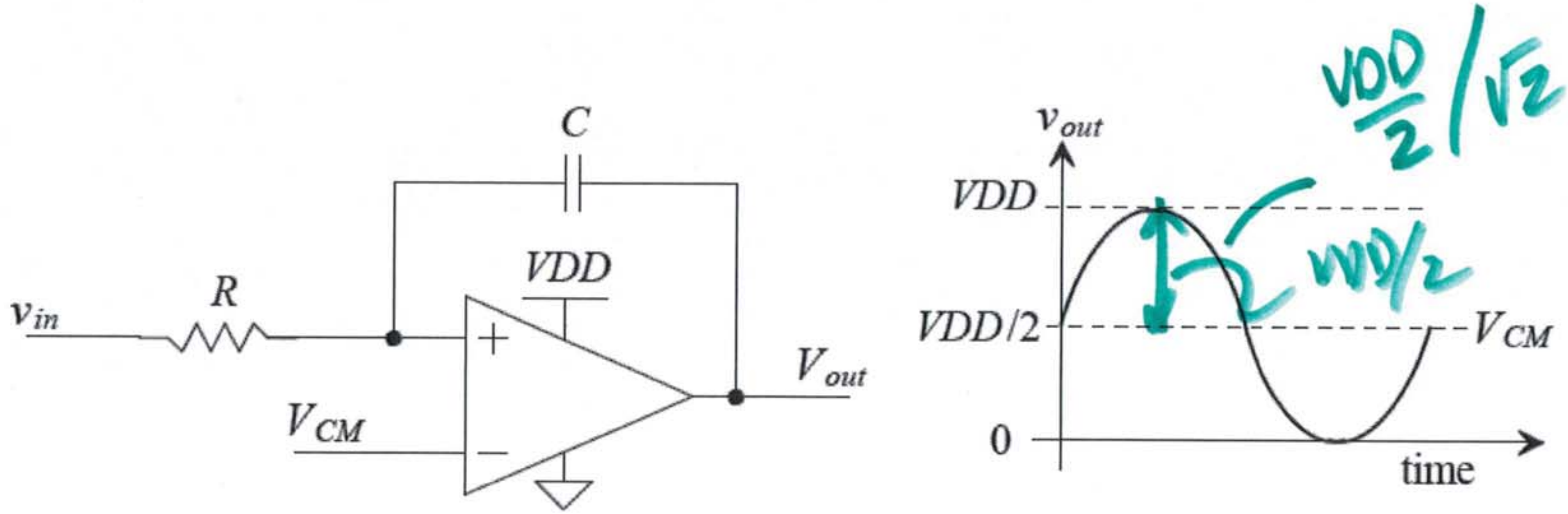
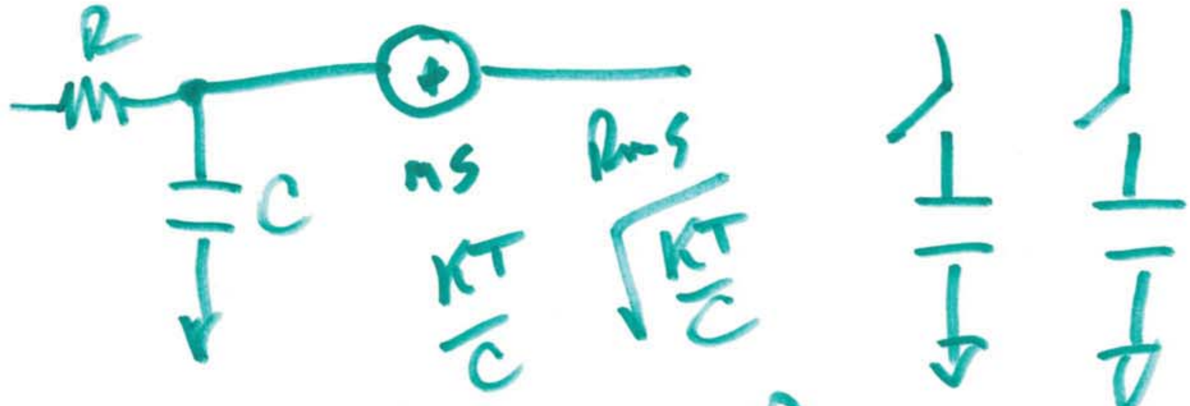


Figure 3.11 Estimating maximum possible SNR of an active-RC filter.



1000 : 1
60dB
N = 10

$$60\text{dB} = SNR = 20 \log \frac{\frac{VDD}{2\sqrt{2}}}{\sqrt{\frac{KT}{C}}}$$

Dynamic Range

6 · N ← # of bits