Exercise: page 573 of the refrene Book.

Lecture 4 : 65/96

Find the capacitance values needed for a first-order switched-capacitor circuit such that its 3-dB point is at 10 kHz when a clock frequency of 100 kHz is used. It is also desired that the filter have zero gain at 50 kHz and the dc gain be unity. Assume $C_A = 10$ pF.

Exercise: page 573 of the refrence Book.

Lecture 4 : 65/96

Find the capacitance values needed for a first-order switched-capacitor circuit such that its 3-dB point is at 10 kHz when a clock frequency of 100 kHz is used. It is also desired that the filter have zero gain at 50 kHz and the dc gain be unity. Assume $C_A = 10$ pF.

Specification of filter:

CT

Exercise: page 573 of the refrene Book.

Lecture 4 : 65/96

Find the capacitance values needed for a first-order switched-capacitor circuit such that its 3-dB point is at 10 kHz when a clock frequency of 100 kHz is used. It is also desired that the filter have zero gain at 50 kHz and the dc gain be unity. Assume $C_A = 10$ pF.

Specification of filter:

CT

designe:

DT

Exercise: page 573 of the refrene Book.

Lecture 4: 65/96

Find the capacitance values needed for a first-order switched-capacitor circuit such that its 3-dB point is at 10 kHz when a clock frequency of 100 kHz is used. It is also desired that the filter have zero gain at 50 kHz and the dc gain be unity. Assume $C_A = 10$ pF.

Specification of filter:

CT

$h(S)$

Laplace domain

designe:

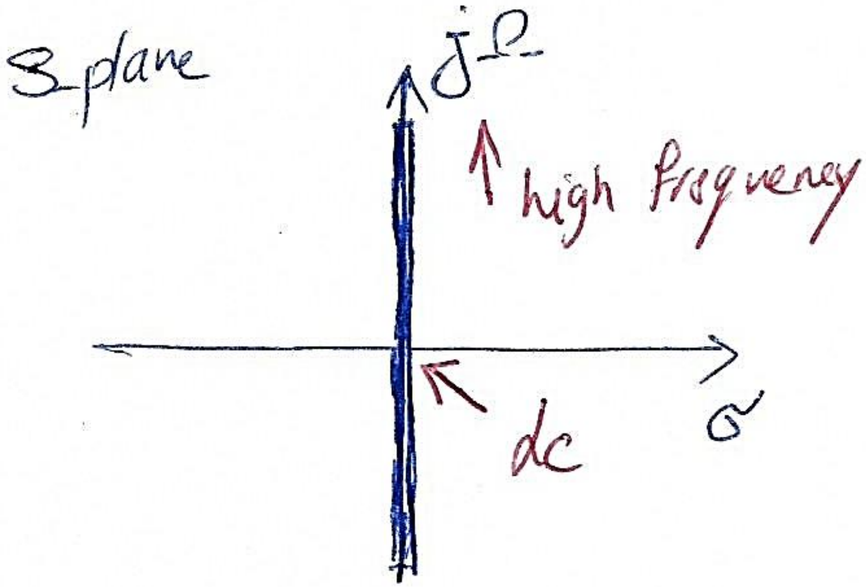
DT

$H(z)$

z-domain

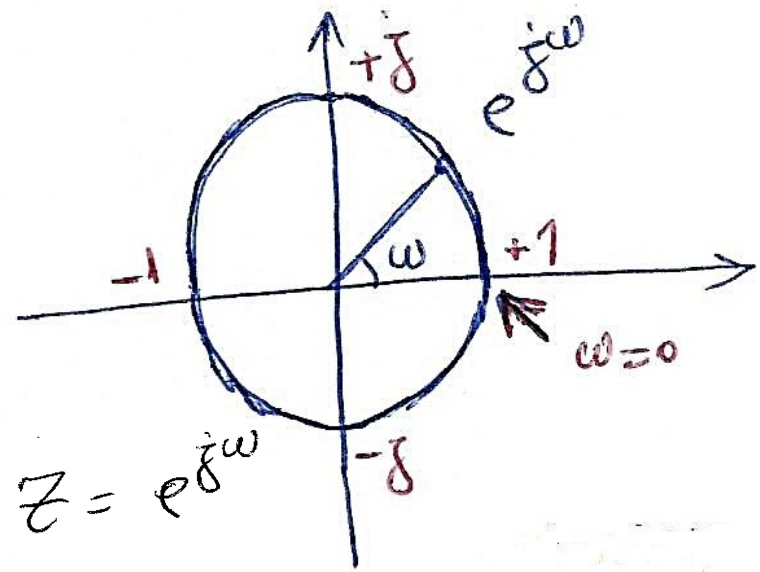
page 550 of reference book (13.5.4, bilinear transform)

s-domain



$s = j\Omega$

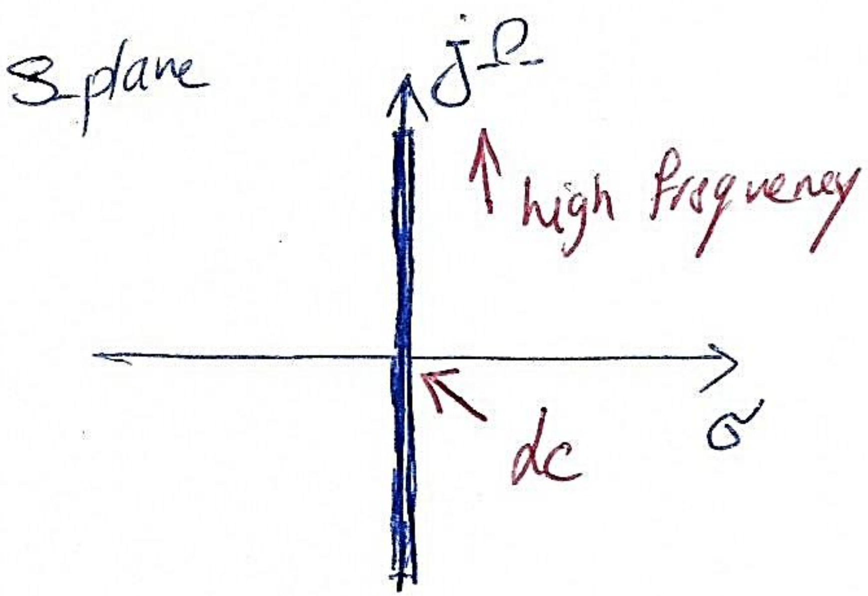
z-domain



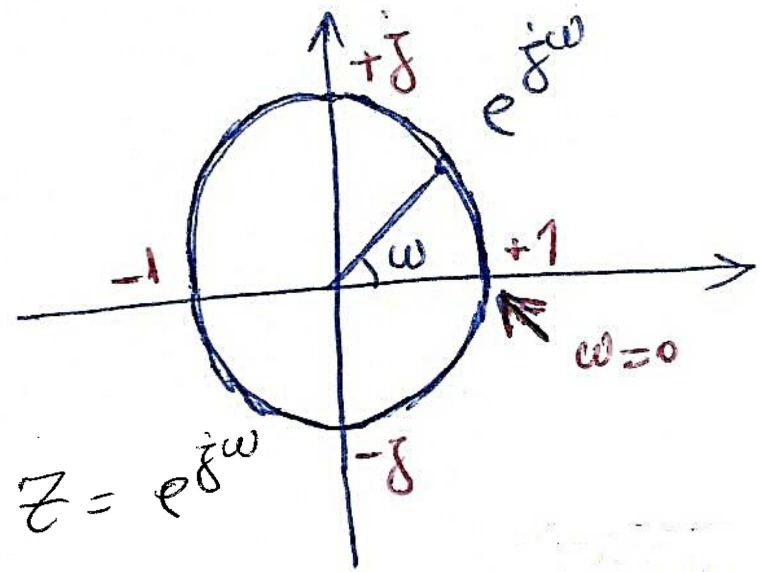
page 550 of reference book (13.5.4, bilinear transform)

s-domain

z-domain



$s = j\Omega$

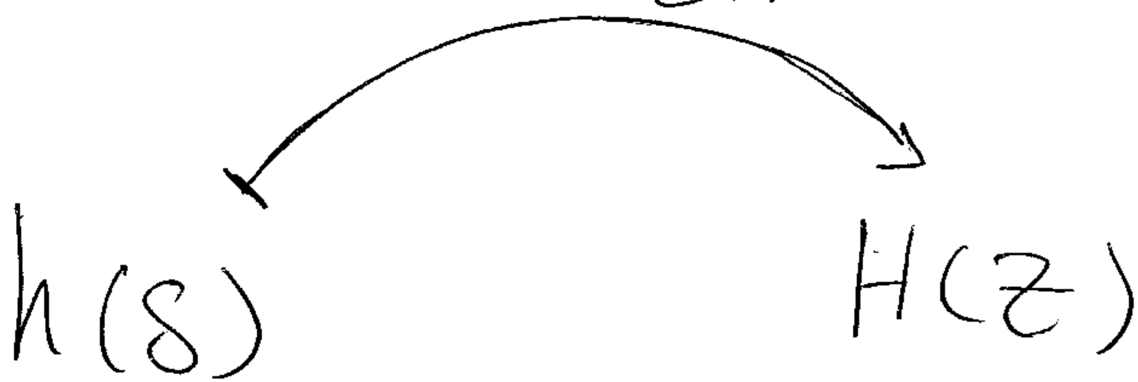


$$\Omega = \tan(\omega/2)$$

page 550 of reference book (13.5.4, bilinear transform)

Bilinear Transform:

$$s = \frac{z-1}{z+1}$$



Bilinear Transform:

$$s = \frac{z-1}{z+1}$$

$h(s)$ $\quad\quad$ $H(z)$

$$z = \frac{1+s}{1-s}$$

Golden relations

Golden relations

$$\begin{cases} \omega = 2\pi f / f_S & ; \quad f_S\text{: clock freq} \\ \Omega = \tan(\omega/2) \end{cases}$$

$$z = e^{j\omega}$$

page 550 of reference book (13.5.4, bilinear transform)

Golden relations

for first order filters:

$$\delta p = -\Omega_{3dB}$$

page 550 of reference book (13.5.4, bilinear transform)

Golden relations

for first order filters:

$$s_p = -\Omega_{3dB}$$

$$z_p = \frac{1+s_p}{1-s_p}$$

Golden relations

for first order filters:

$$s_p = -\Omega_{3dB}$$

$$z_p = \frac{1+s_p}{1-s_p}$$

Crazy but true!

Exercise: page 573 of the refrene Book.

Lecture 4 : 65/96

Find the capacitance values needed for a first-order switched-capacitor circuit such that its 3-dB point is at 10 kHz when a clock frequency of 100 kHz is used. It is also desired that the filter have zero gain at 50 kHz and the dc gain be unity. Assume $C_A = 10$ pF.

$f_{3-dB} = 10$ KHZ

$f_S = 100$ KHZ

zero @ 50 KHZ

$H(1) = 1$

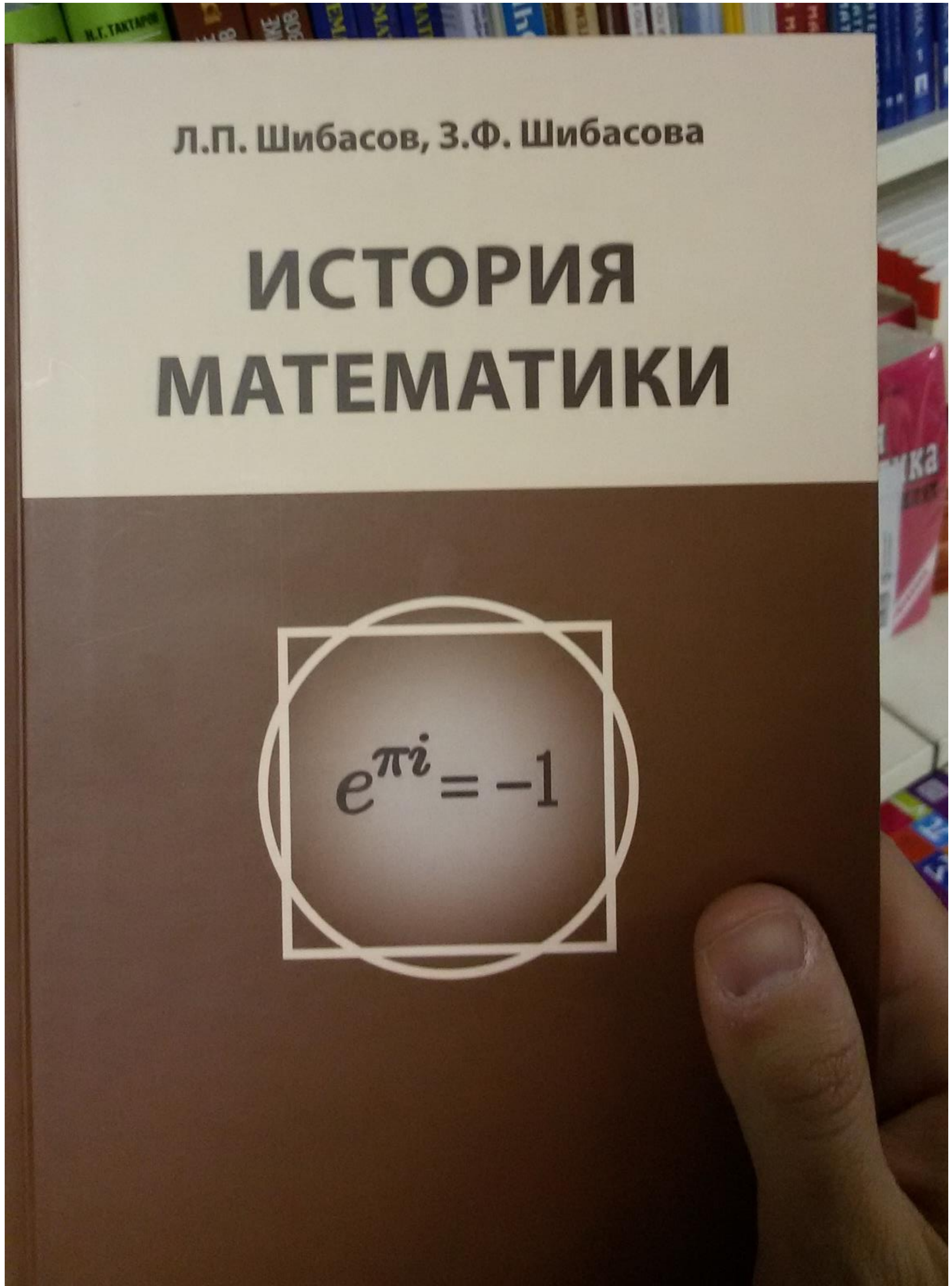
$C_A = 10$ PF

Exercise: page 573 of the refrene Book.

$$\begin{cases} z = e^{j\omega} \\ \omega = f/f_s \cdot 2\pi \end{cases}$$

Exercise: page 573 of the refrene Book.

$$\begin{cases} z = e^{j\omega} \\ \omega = f/f_s \cdot 2\pi \end{cases} \Rightarrow z_{zero} = e^{j \cdot 2\pi \cdot 50/100} = e^{j\pi}$$


Л.П. Шибасов, З.Ф. Шибасова
ИСТОРИЯ
МАТЕМАТИКИ
$e^{\pi i} = -1$

Exercise: page 573 of the refrence Book.

$$\begin{cases} z = e^{j\omega} \\ \omega = f/f_s \cdot 2\pi \end{cases} \Rightarrow z_{zero} = e^{j \cdot 2\pi \cdot 50/100} = e^{j\pi} =$$

Exercise: page 573 of the reference Book.

$$\begin{cases} z = e^{j\omega} \\ \omega = f/f_s \cdot 2\pi \end{cases} \Rightarrow z_{zero} = e^{j \cdot 2\pi \cdot 50/100} = e^{j\pi} = -1$$

Exercise: page 573 of the refrene Book.

$$\begin{cases} z = e^{j\omega} \\ \omega = f/f_s \cdot 2\pi \end{cases} \Rightarrow z_{zero} = e^{j \cdot 2\pi \cdot 50/100} = e^{j\pi} = -1$$

$$\Rightarrow \boxed{z_{zero} = -1}$$

Exercise: page 573 of the refrene Book.

$$\omega_{3\text{-dB}} = 2\pi \cdot {f_{3\text{-dB}}}/{f_S} = 2\pi \cdot {10}/{100} = 0.2\pi$$

Exercise: page 573 of the refrence Book.

$$\omega_{3\text{-}dB} = 2\pi \cdot f_{3\text{-}dB}/f_s = 2\pi \cdot 10/100 = 0.2\pi$$

$$\Omega_{3dB} = \tan\left(\frac{\omega_{3dB}}{2}\right) = \tan\left(0.2\pi/2\right) = 0.3249$$

Exercise: page 573 of the refrene Book.

$$\omega_{3\text{-}dB} = 2\pi \cdot f_{3\text{-}dB} / f_s = 2\pi \cdot 10/100 = 0.2\pi$$

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$$s_p = -\Omega_{3dB} \Rightarrow s_p = -0.3249$$

Exercise: page 573 of the refrene Book.

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$$s_p = -\Omega_{3dB} \Rightarrow s_p = -0.3249$$

$$z_p = \frac{1+s_p}{1-s_p} = 0.5095$$

Exercise: page 573 of the refrene Book.

$$H(z) = \frac{k(z+1)}{z-0.5095}$$

Exercise: page 573 of the refrene Book.

$$H(z) = \frac{k(z+1)}{z - 0.5095}$$

from $H(1) = 1 \longrightarrow k = 0.24525$

Exercise: page 573 of the refrene Book.

$$H(z) = \frac{k(z+1)}{z - 0.5095}$$

from $H(1) = 1 \longrightarrow k = 0.24525$

$$H(z) = \frac{0.24525\,(z+1)}{z - 0.5095}$$

Exercise: page 573 of the reference Book.

$$H(z) = \frac{k(z+1)}{z - 0.5095}$$

from $H(1) = 1 \longrightarrow k = 0.24525$

$$H(z) = \frac{0.24525\,(z+1)}{z - 0.5095}$$

or equivalently,

$$H(z) = \frac{0.4814z + 0.4814}{1.9627z - 1}$$

Exercise: page 573 of the refrene Book.

from the Course (lecture 4: 63/96)

$$H(z) = -\frac{\left(\frac{C_1 + C_2}{C_A}\right)z - C_1/C_2}{\left(1 + C_3/C_A\right)z - 1}$$

Exercise: page 573 of the refrene Book.

from the Course (lecture 4: 63/96)

$$H(z) = -\frac{\left(\frac{C_1+C_2}{C_A}\right)z - C_1/C_2}{\left(1+C_3/C_A\right)z - 1}$$

$C_1 = 4.814$ pF

$C_2 = -9.628$ pF

$C_3 = 9.628$

Exercise: page 573 of the refrene Book.

from the Course (lecture 4: 63/96)

$$H(z) = -\frac{\left(\frac{C_1 + C_2}{C_A}\right)z - C_1/C_2}{\left(1 + C_3/C_A\right)z - 1}$$

$C_1 = 4.814$ pF

$C_2 = -9.628$ pF → ((differential input can realize the negative Capacitance)) page 573

$C_3 = 9.628$

Exercise 1

first order filter

$$H(z) = \frac{-\left(\frac{C_1+C_2}{C_A}\right) z + C_1/C_A}{\left(1 + C_3/C_A\right) z - 1} = \frac{kz + A}{z - z_p}$$

$f_{3\text{-}dB} = 10\ kHz$

$f_S = 100\ kHz$

zero @ $z = 0$

Exercise 1

first order filter

$$H(z) = \frac{-\left(\frac{C_1+C_2}{C_A}\right) z + C_1/C_A}{\left(1 + C_3/C_A\right) z - 1} = \frac{kz + A}{z - z_p}$$

$f_{3\text{-dB}} = 10\ \text{kHz}$

$f_S = 100\ \text{kHz}$

zero @ $z = 0 \Rightarrow A = 0$

Exercise 1

first order filter

$$H(z) = \frac{-\left(\frac{C_1+C_2}{C_A}\right) z + C_1/C_A}{\left(1 + C_3/C_A\right) z - 1} = \frac{kz + A}{z - z_p}$$

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Exercise 1

first order filter

$$H(z) = \frac{-\left(\frac{C_1+C_2}{C_A}\right) z + C_1/C_A}{\left(1 + C_3/C_A\right) z - 1} = \frac{kz + A}{z - z_p}$$

$$f_{3\text{-}dB} = 10\ kHz$$

$$f_S = 100\ kHz$$

zero @ $z = 0 \Rightarrow A = 0$

$$H(1) = 1 \Rightarrow \frac{k}{1 - z_p} = 1 \Rightarrow k = 1 - z_p$$

Exercise 1

$$\omega_{3-dB} = 2\pi \times f_{3-dB}/f_S$$

Exercise 1

$$\omega_{3-dB} = 2\pi \times f_{3-dB}/f_S = 2\pi \times 10/100 = 0.2\pi$$

Exercise 1

$$\omega_{3\text{-dB}} = 2\pi \times f_{3\text{-dB}} / f_S = 2\pi \times 10/100 = 0.2\pi$$

$$\Omega_{3\text{-dB}} = \tan\left(\omega_{3\text{-dB}}/2\right)$$

Exercise 1

$$\omega_{3-dB} = 2\pi \times f_{3-dB}/f_S = 2\pi \times 10/100 = 0.2\pi$$

$$\Omega_{3-dB} = \tan(\omega_{3-dB}/2) = \tan(0.2\pi) = 0.3049 \ rad/sample$$

Exercise 1

$$\omega_{3-dB} = 2\pi \times f_{3-dB}/f_s = 2\pi \times 10/100 = 0.2\pi$$

$$\Omega_{3-dB} = \tan(\omega_{3-dB}/2) = \tan(0.2\pi) = 0.3044 \ \frac{rad}{sample}$$

$$\delta_p = -\Omega_{3-dB} = -0.3044$$

Exercise 1

$$\omega_{3\text{-}dB} = 2\pi \times f_{3\text{-}dB}/f_s = 2\pi \times 10/100 = 0.2\pi$$

$$\Omega_{3\text{-}dB} = \tan\left(\omega_{3\text{-}dB}/2\right) = \tan(0.2\pi) = 0.3044 \ \frac{rad}{sample}$$

$$\delta_p = -\Omega_{3\text{-}dB} = -0.3044$$

$$z_p = \frac{1+\delta_p}{1-\delta_p} = 0.53327$$

Exercise 1

$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

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$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

$$\begin{cases} A = 0 \rightarrow C_1 = 0\,\text{PF} \\ C_A = 10\,\text{PF} \end{cases}$$

Exercise 1

$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

$$\begin{cases} A = 0 \rightarrow C_1 = 0 \text{ PF} \\ C_A = 10 \text{ PF} \end{cases}$$

$$z_p = \frac{C_A}{C_A + C_3}$$

Exercise 1

$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

$$\begin{cases} A = 0 \rightarrow C_1 = 0\ pF \\ C_A = 10\ pF \end{cases}$$

$$z_p = \frac{C_A}{C_A + C_3} \Rightarrow C_3 = \frac{C_A(1 - z_p)}{z_p} = 8{,}752\ pF$$

Exercise 1

$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

$$\begin{cases} A = 0 \rightarrow C_1 = 0\ PF \\ C_A = 10\ PF \end{cases}$$

$$z_p = \frac{C_A}{C_A + C_3} \Rightarrow C_3 = \frac{C_A(1 - z_p)}{z_p} = 8{,}752\ PF$$

$$k = 1 - z_p.$$

Exercise 1

$$H(z) = \frac{0.46673}{1 - 0.53327 z^{-1}}$$

$$\begin{cases} A = 0 \rightarrow C_1 = 0\ pF \\ C_A = 10\ pF \end{cases}$$

$$z_p = \frac{C_A}{C_A + C_3} \Rightarrow C_3 = \frac{C_A (1 - z_p)}{z_p} = 8{,}752\ pF$$

$$k = 1 - z_p = \frac{-C_2/C_A}{1 + C_3/C_A} = -\frac{C_2}{C_A + C_3}$$

$$\Rightarrow C_2 = -k(C_A + C_3) = -8.752\ pF$$

Exercise 1

gain @ $f = 50$ kHz

Exercise 1

gain @ $f = 50$ kHz

$$\Rightarrow z = e^{j\omega} = e^{j 2\pi f/f_s} = e^{j\pi} = -1$$

Exercise 1

gain @ $f = 50$ kHz

$$\Rightarrow z = e^{j\omega} = e^{j 2\pi f/f_s} = e^{j\pi} = -1$$

$$\Rightarrow H(-1) = \frac{0.46673}{1 + 0.53327} = 0.304$$

Exercise 1

gain @ $f = 50$ kHz

$$\Rightarrow z = e^{j\omega} = e^{j 2\pi f/f_s} = e^{j\pi} = -1$$

$$\Rightarrow H(-1) = \frac{0.46673}{1 + 0.53327} = 0.304 \xrightarrow{20\log(\cdot)} -10.33\ \text{dB}$$

Exercise 2: How to draw Signal flow graph:

Circuit:

Non-Switched Capacitor

C1

Flow Graph:

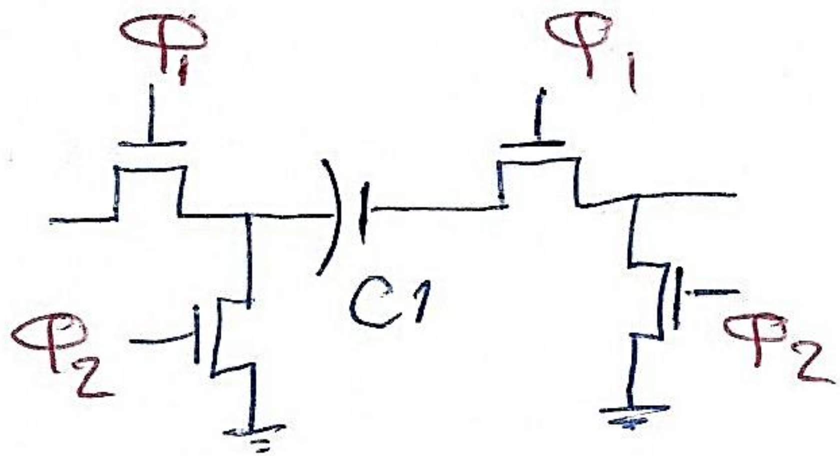
$-C1(1-z^{-1})$

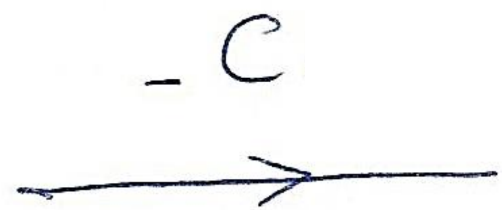
Exercise 2: How to draw Signal flow graph:

Circuit :

Flow Graph :

Non-delaying Switched Capa



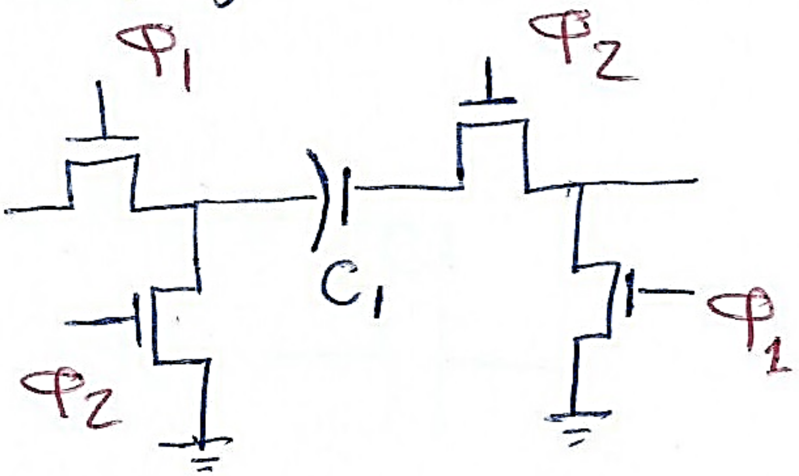


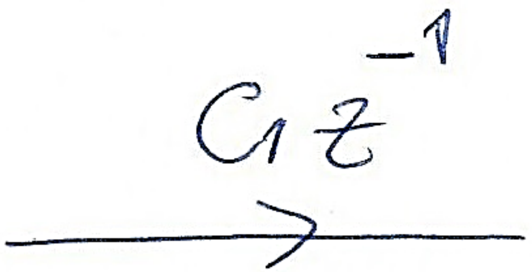
Exercise 2: How to draw Signal flow graph

Circuit :

Flow Graph :

delaying Switched Capa

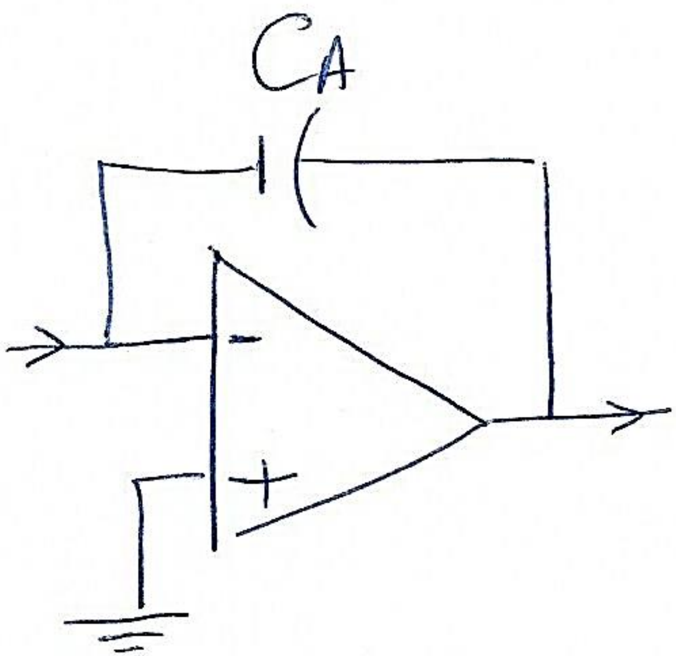




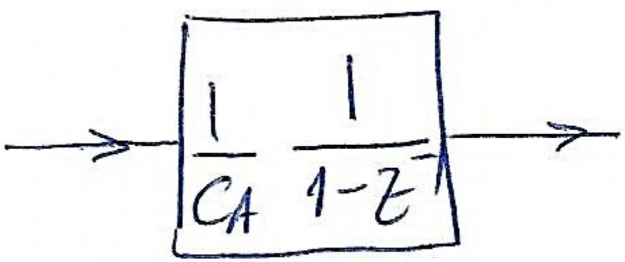
Exercise 2: How to draw Signal flow graph:

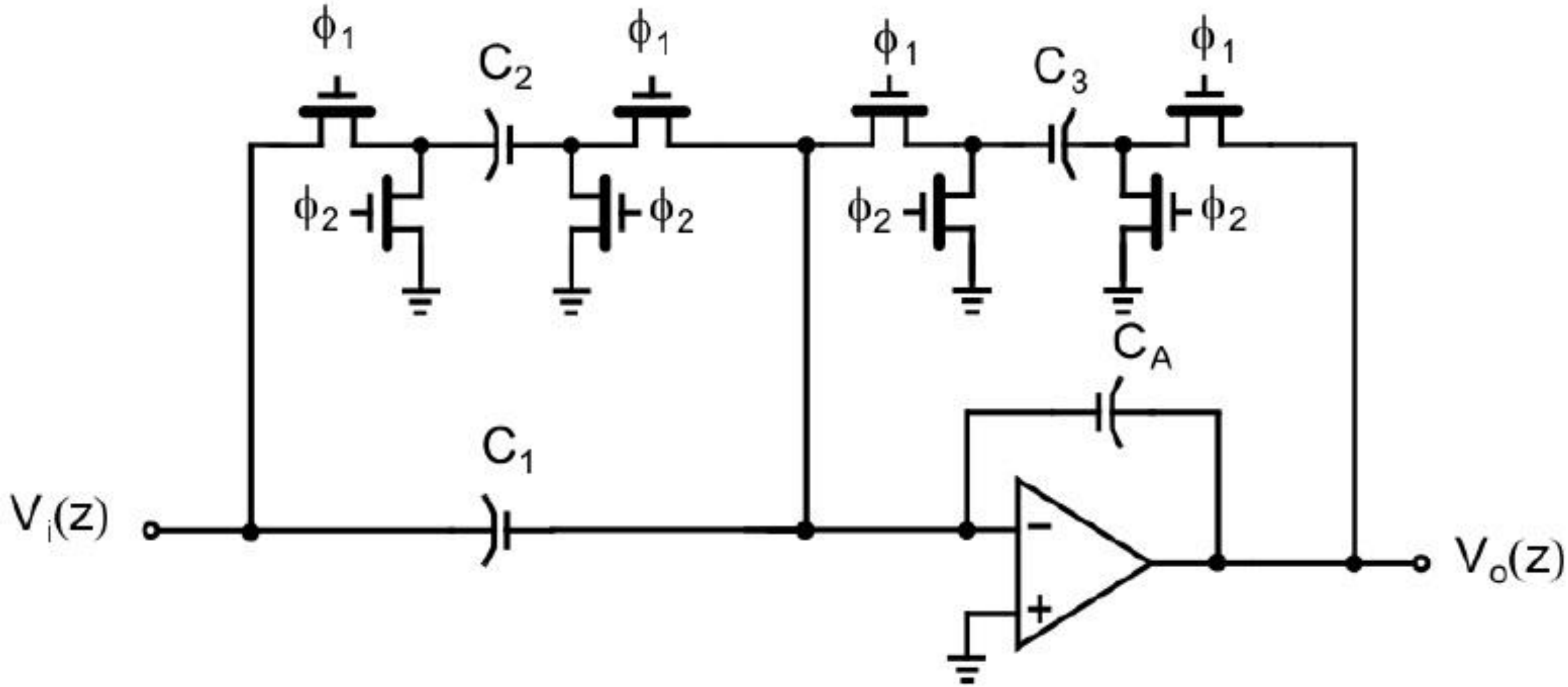
Circuit:

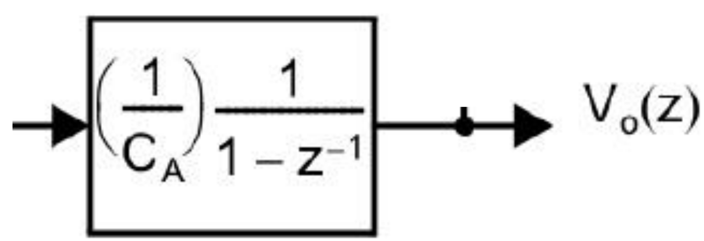
op-amp

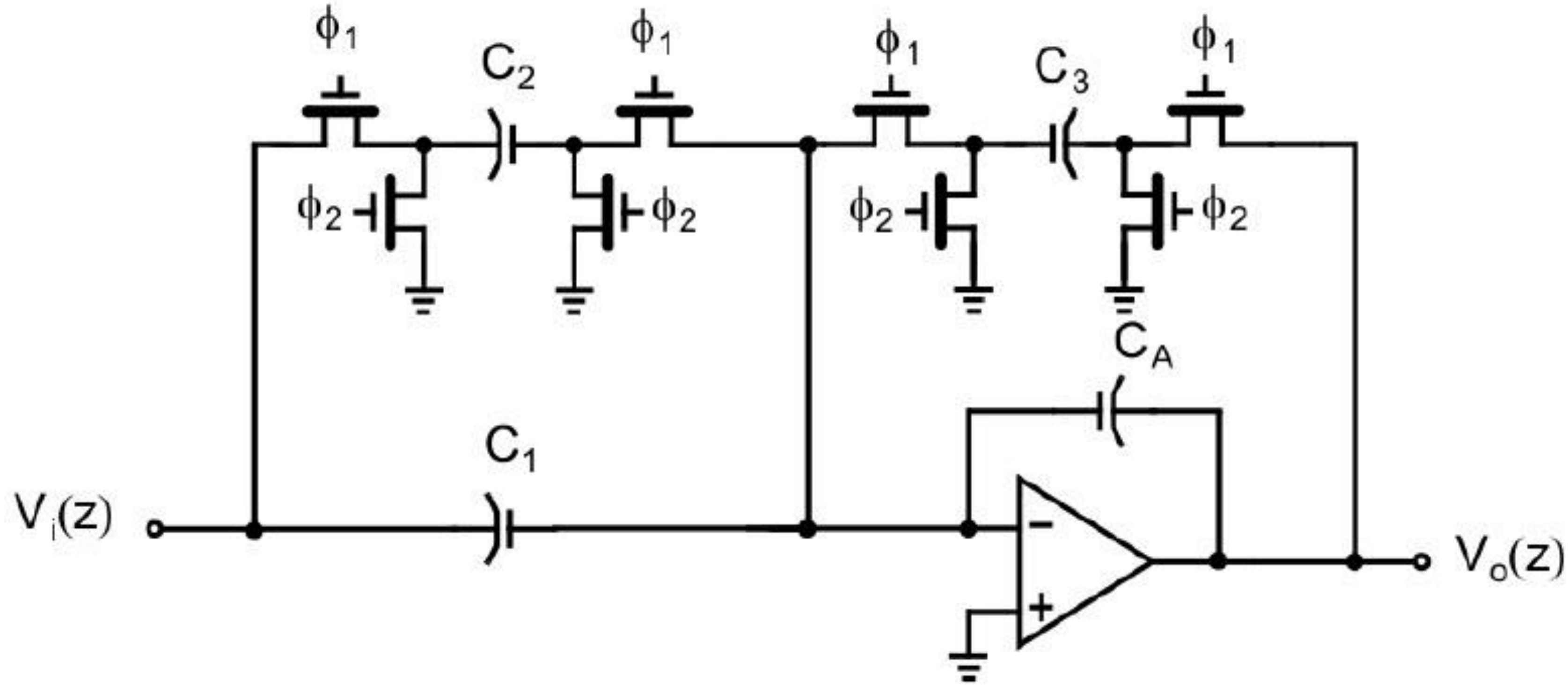


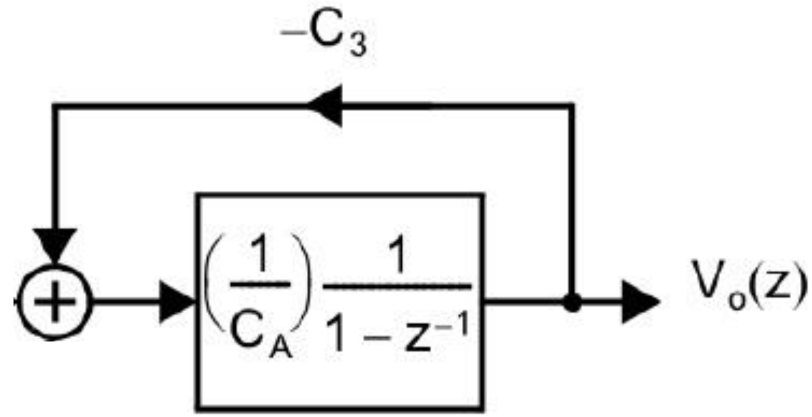
Flow Graph:

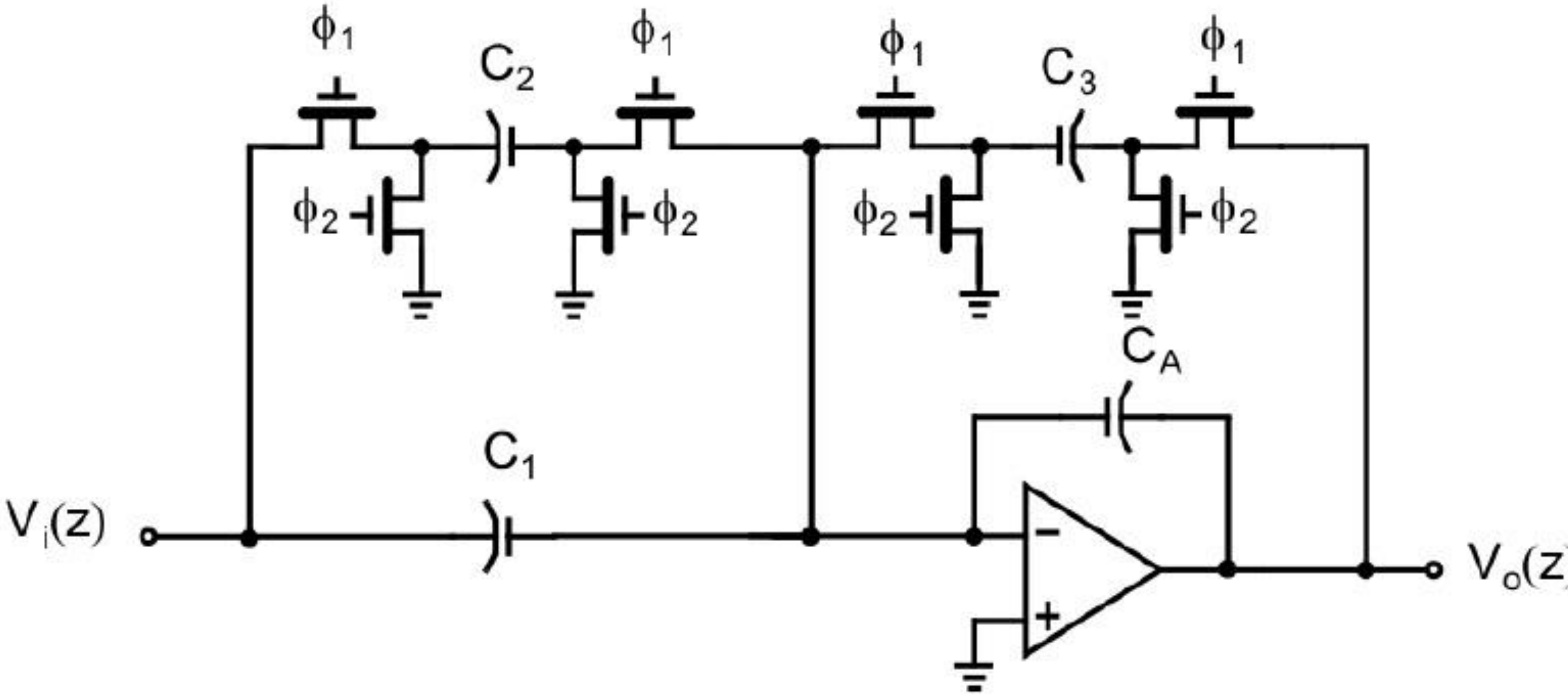



φ1
C2
φ1
φ1
C3
φ1
φ2
φ2
φ2
φ2
CA
C1
Vi(z)
Vo(z)

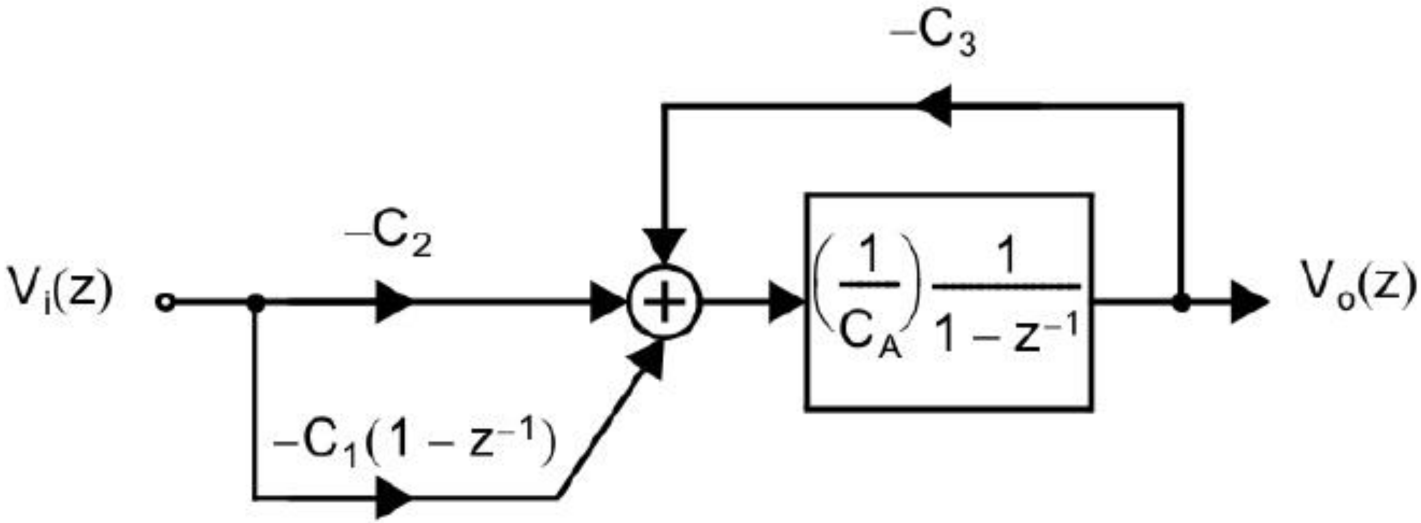

(1/CA) 1/(1 − z^−1)
Vo(z)


φ1
C2
φ1
φ1
C3
φ1
φ2
φ2
φ2
φ2
CA
C1
Vi(z)
Vo(z)


–C3
(1/CA) 1/(1 – z⁻¹)
Vo(z)

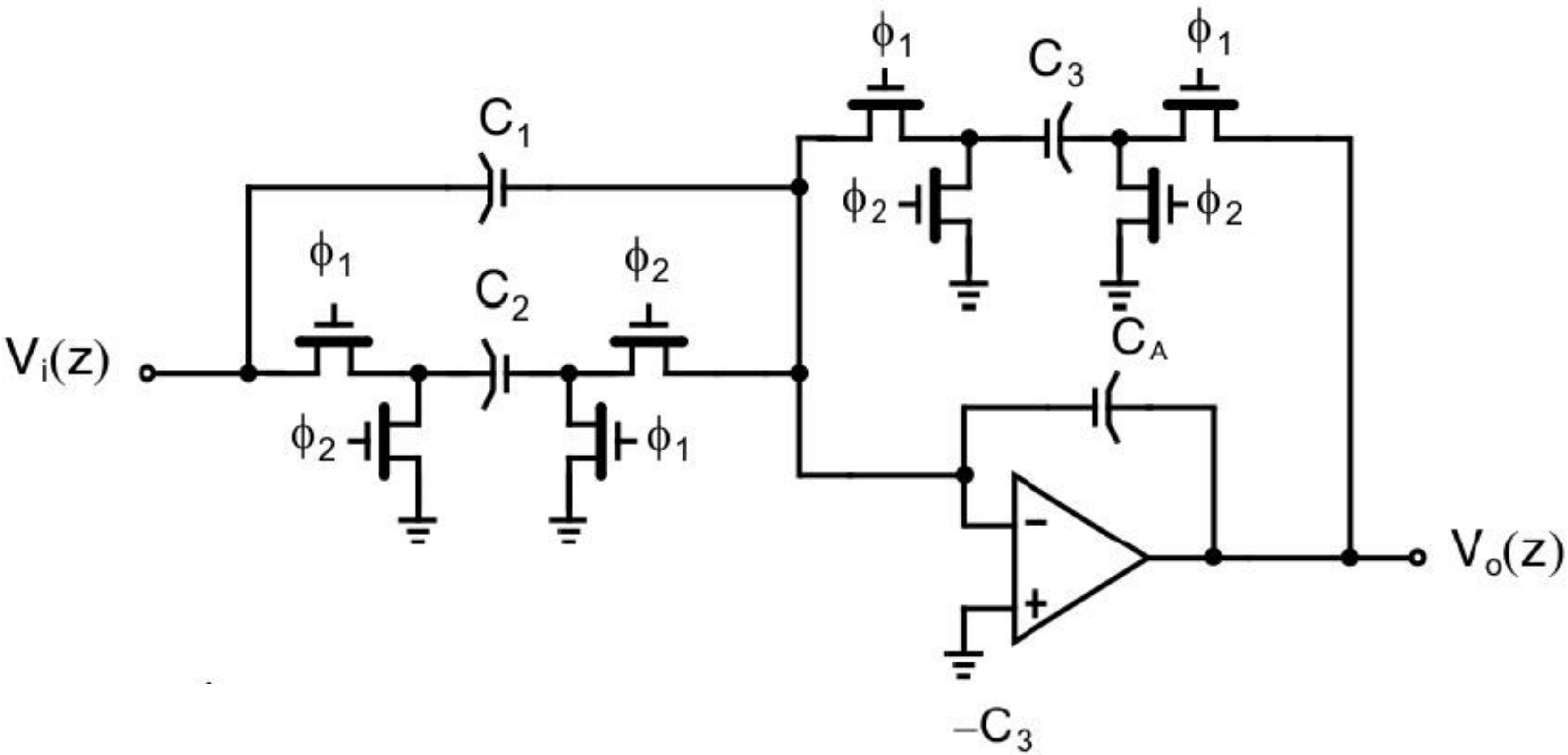


φ1
C2
φ1
φ1
C3
φ1
φ2
φ2
φ2
φ2
CA
C1
Vi(z)
Vo(z)

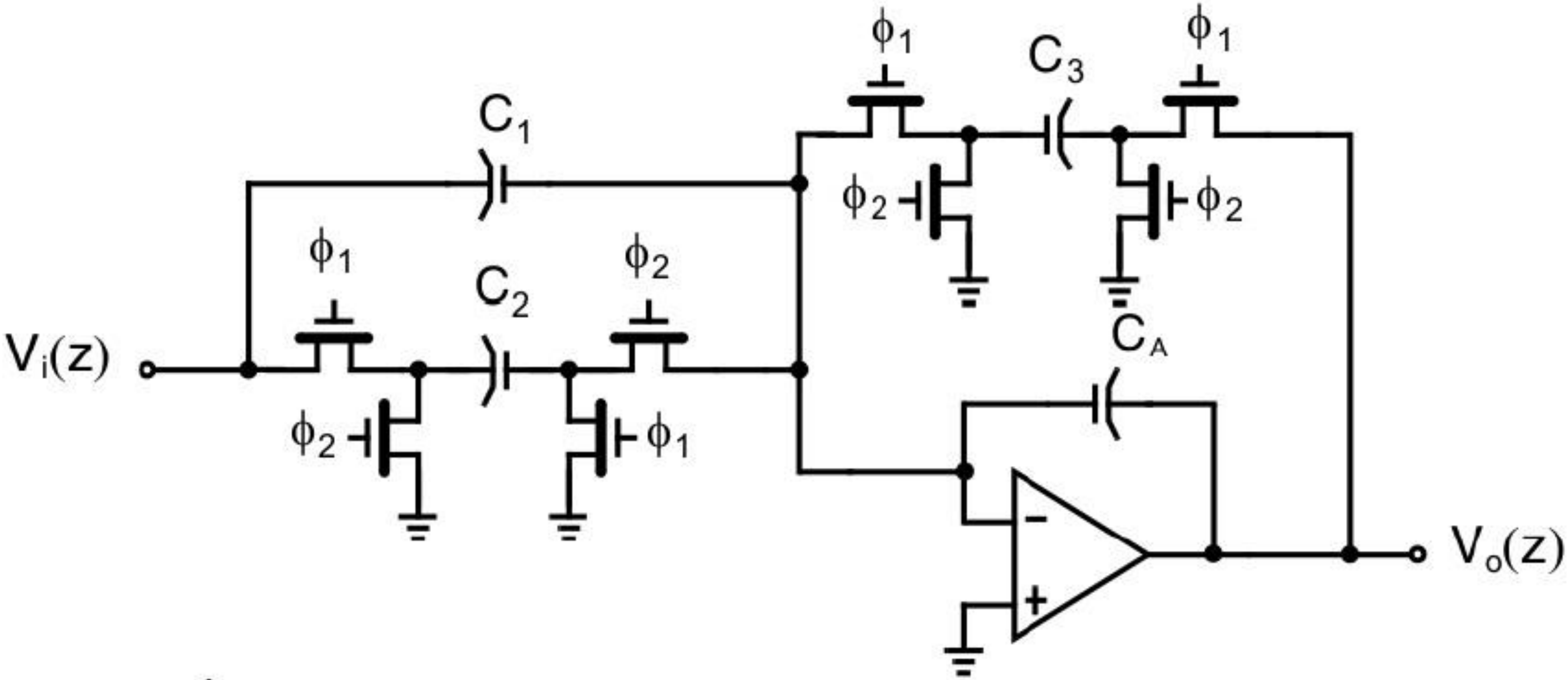


–C3
–C2
Vi(z)
(1/CA) 1/(1 – z⁻¹)
Vo(z)
–C1(1 – z⁻¹)

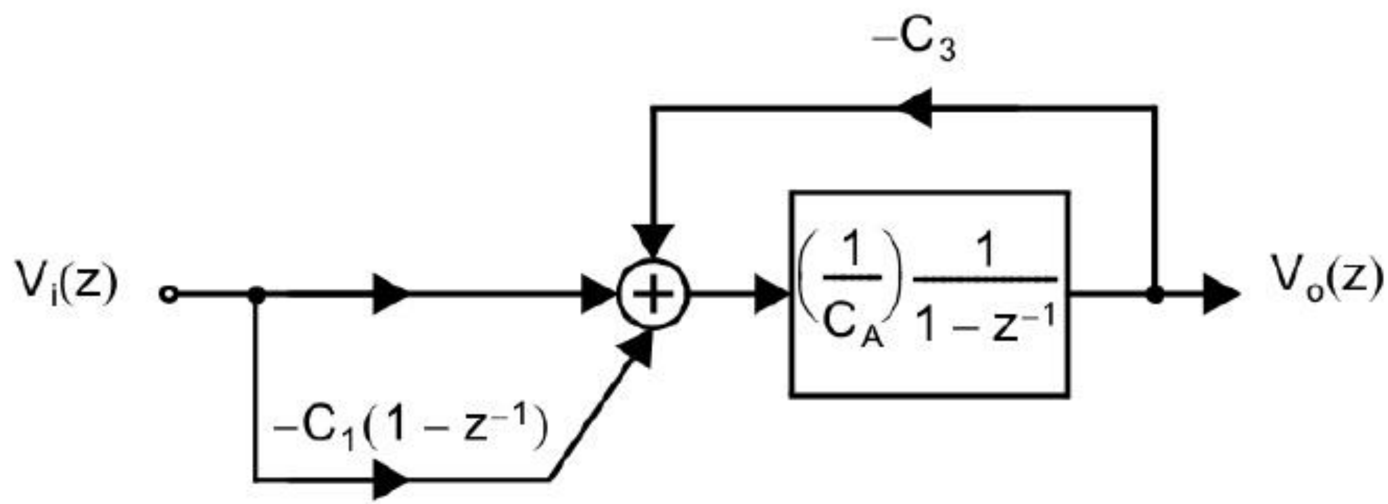
Exercise 5



Exercise 5

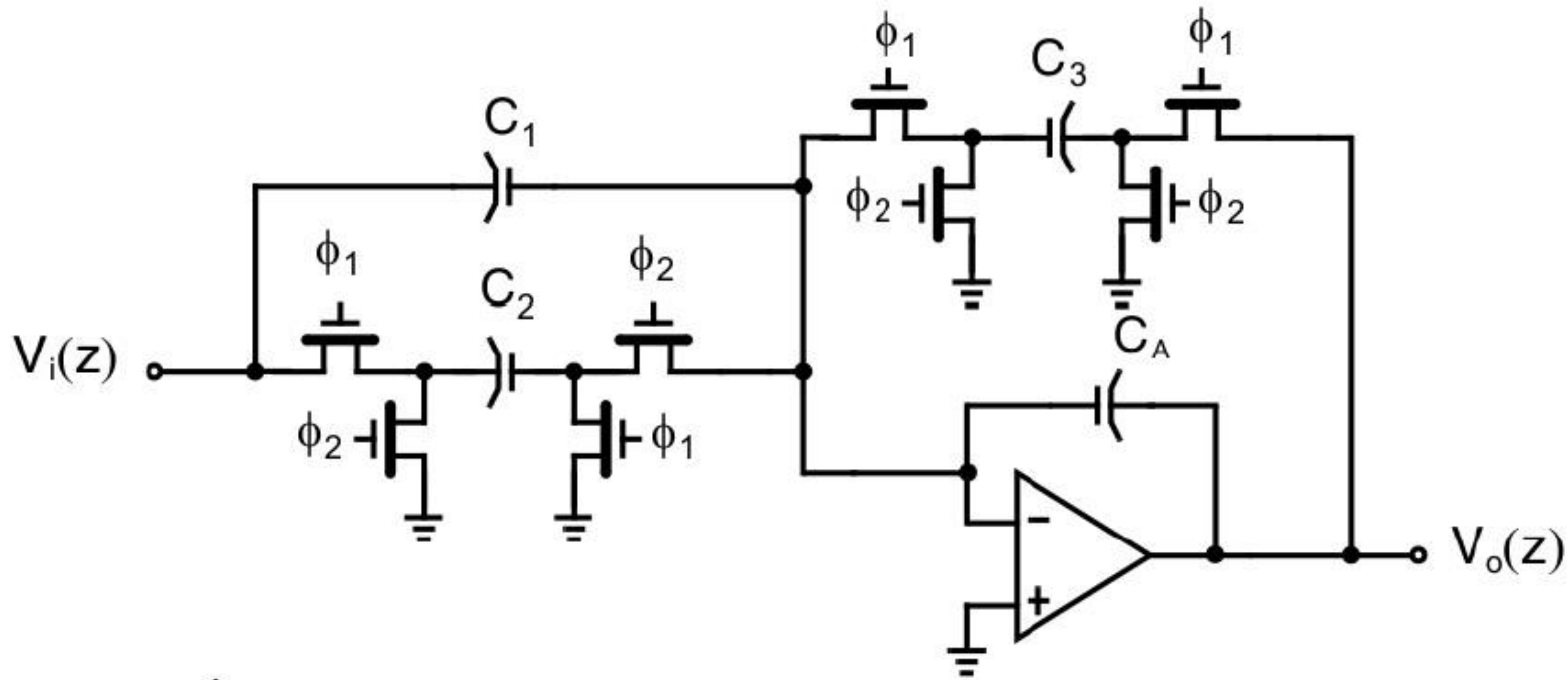


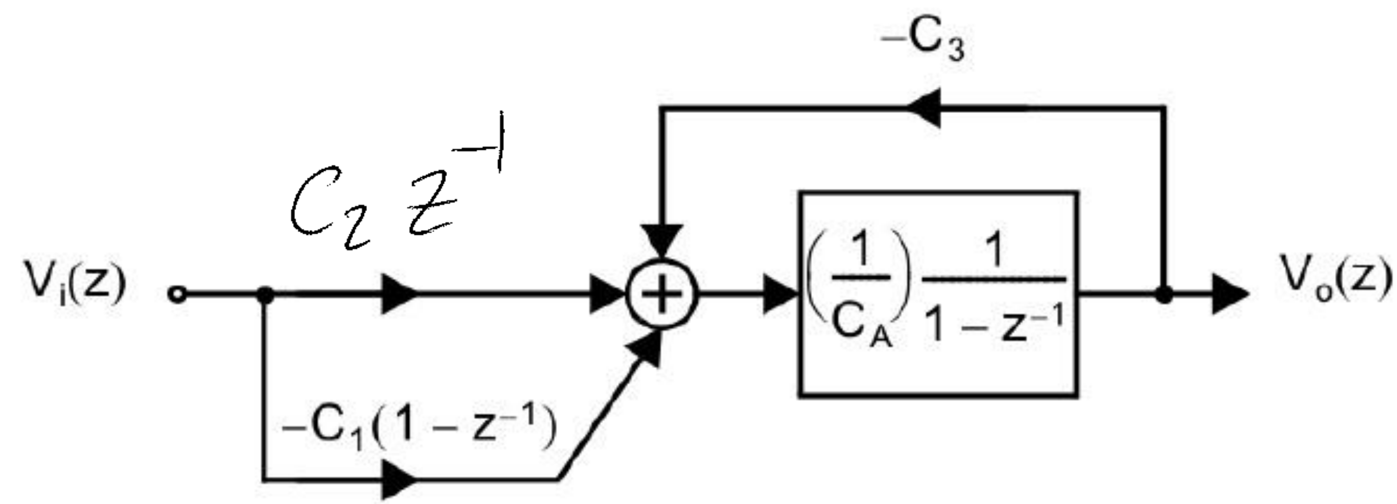
C1
ϕ1
C2
ϕ2
Vi(z)
ϕ2
ϕ1
ϕ1
C3
ϕ1
ϕ2
ϕ2
CA
Vo(z)



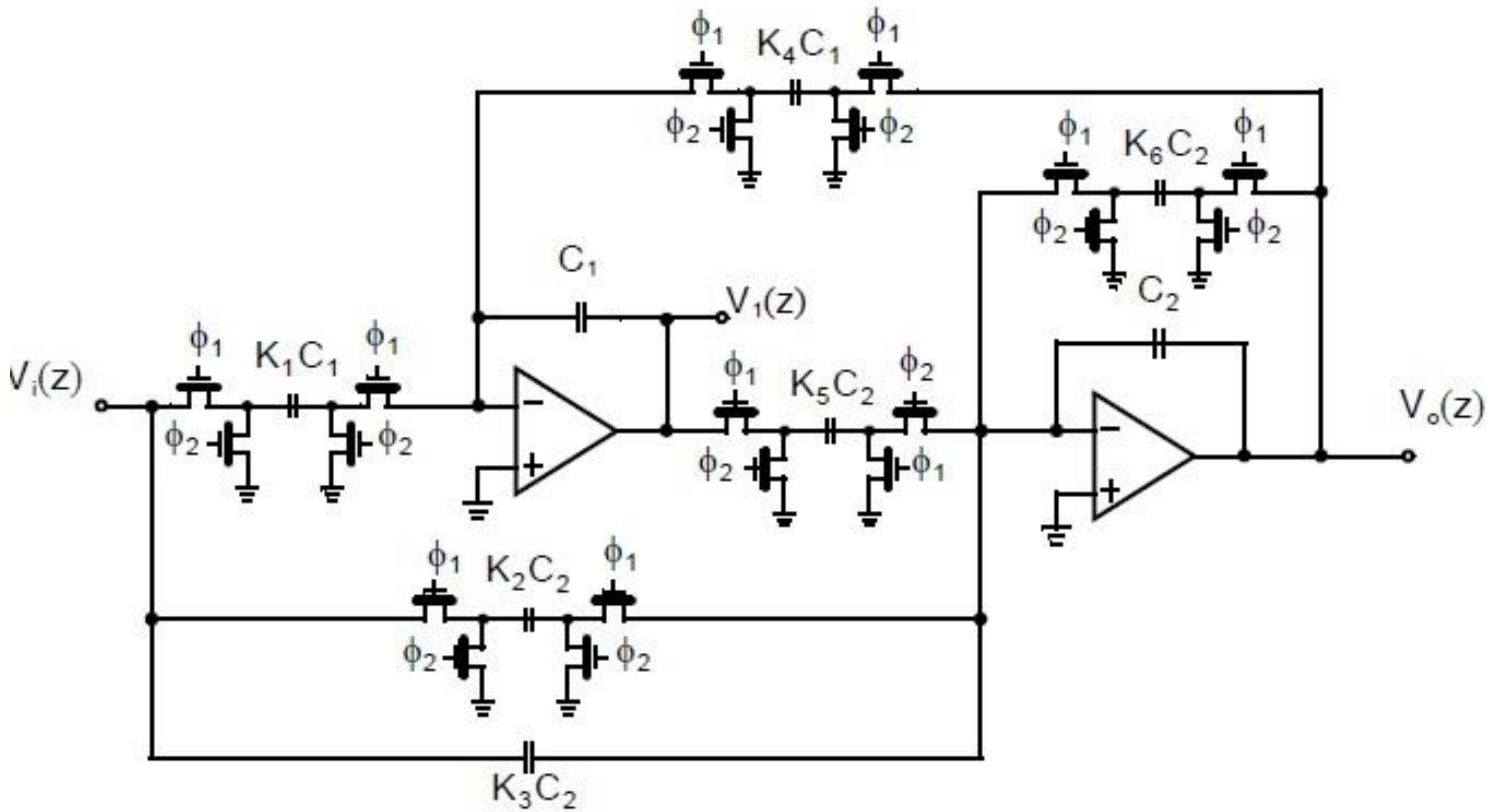
–C3
Vi(z)
(1/CA) 1/(1 – z⁻¹)
Vo(z)
–C1(1 – z⁻¹)

Exercise 5



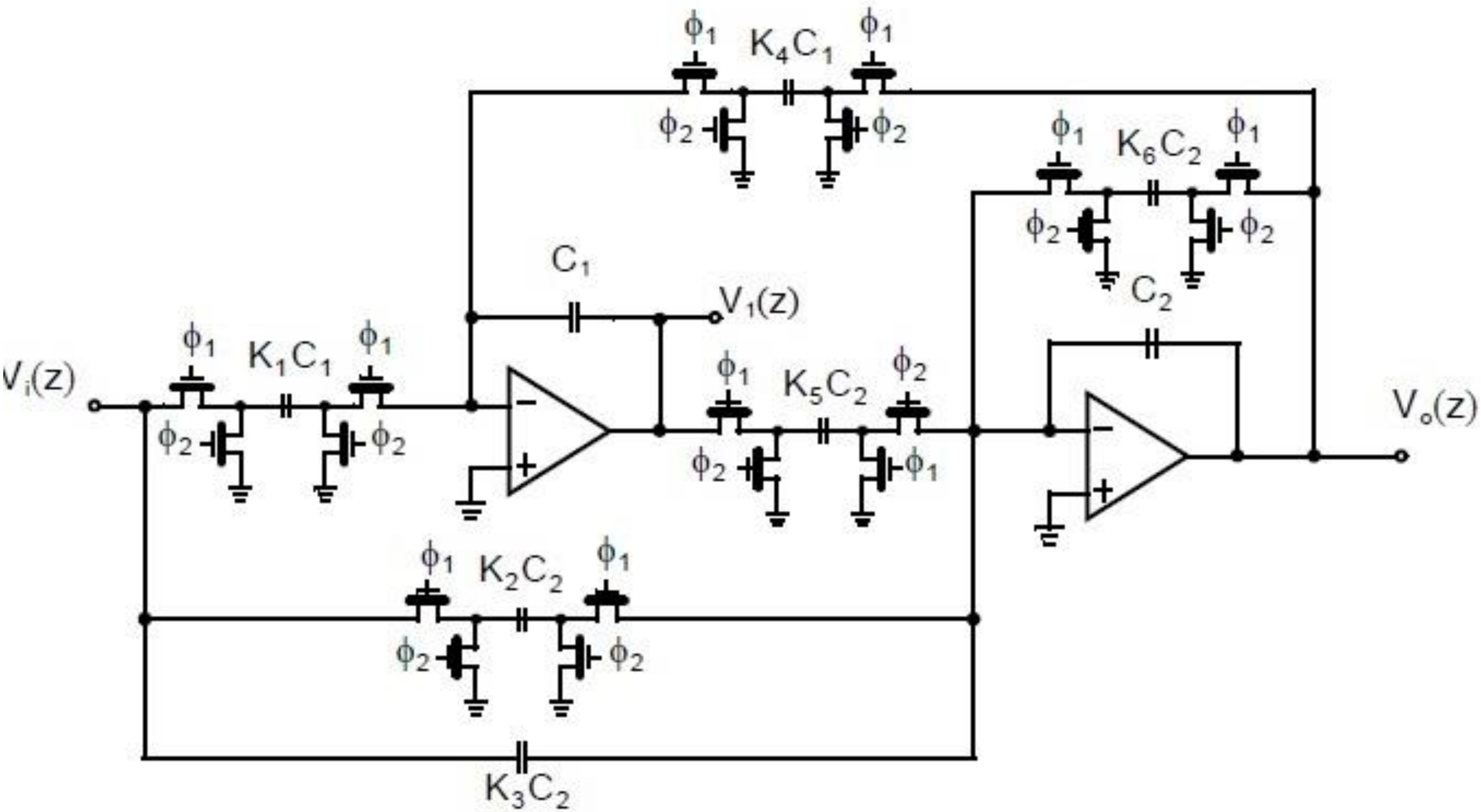


Exercise



ϕ_1
K_4C_1
ϕ_1
ϕ_2
ϕ_2
ϕ_1
K_6C_2
ϕ_1
ϕ_2
ϕ_2
C_1
$V_1(z)$
C_2
$V_i(z)$
ϕ_1
K_1C_1
ϕ_1
ϕ_2
ϕ_2
ϕ_1
K_5C_2
ϕ_2
ϕ_2
ϕ_1
$V_o(z)$
ϕ_1
K_2C_2
ϕ_1
ϕ_2
ϕ_2
K_3C_2

Exercise



ϕ_1
K_4C_1
ϕ_1
ϕ_2
ϕ_2
ϕ_1
K_6C_2
ϕ_1
ϕ_2
ϕ_2
C_1
$V_1(z)$
C_2
ϕ_1
K_1C_1
ϕ_1
$V_i(z)$
ϕ_2
ϕ_2
ϕ_1
K_5C_2
ϕ_2
ϕ_2
ϕ_1
$V_o(z)$
ϕ_1
K_2C_2
ϕ_1
ϕ_2
ϕ_2
K_3C_2

Exercise