Spring 2002

EEE598D: Analog Filter & Signal Processing Circuits

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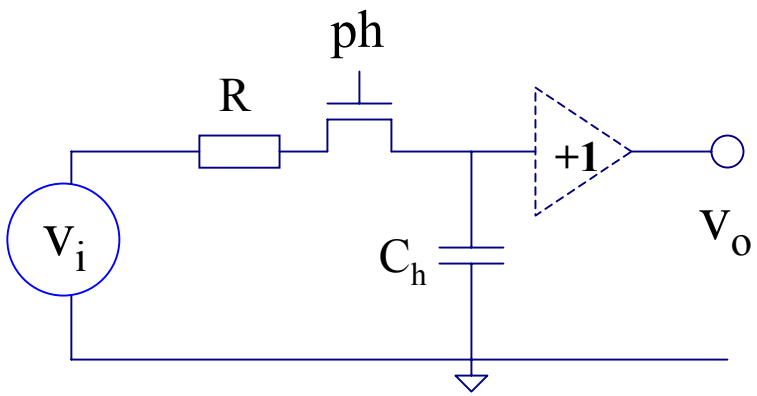
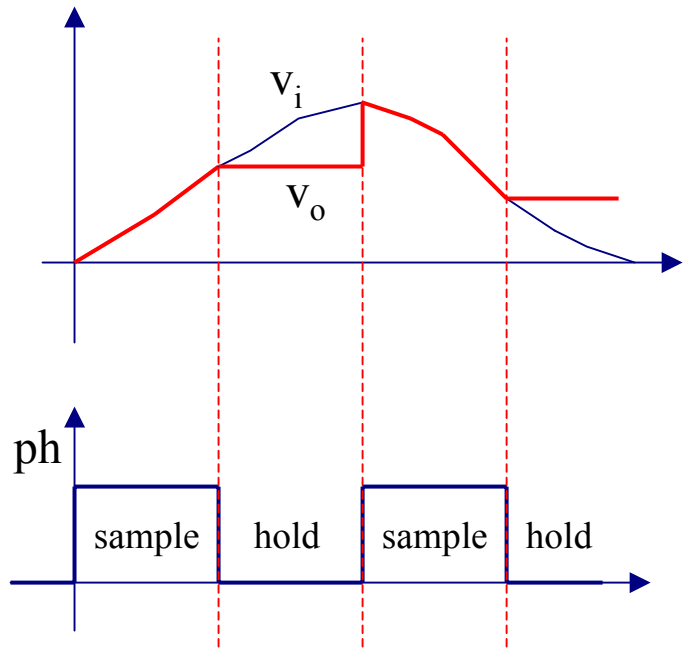
Today: Basic SC Circuit Building Blocks

- SC S/H Circuits
- SC Delay Circuits
- SC Gain Stage Circuits
- SC Integrator Circuits

Sample-and-Hold Circuits

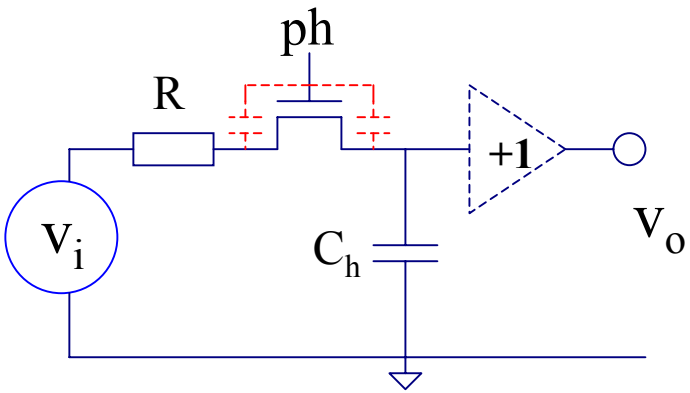
- S/H circuits are used to avoid continuous signal feed through which causes frequency response distortion.

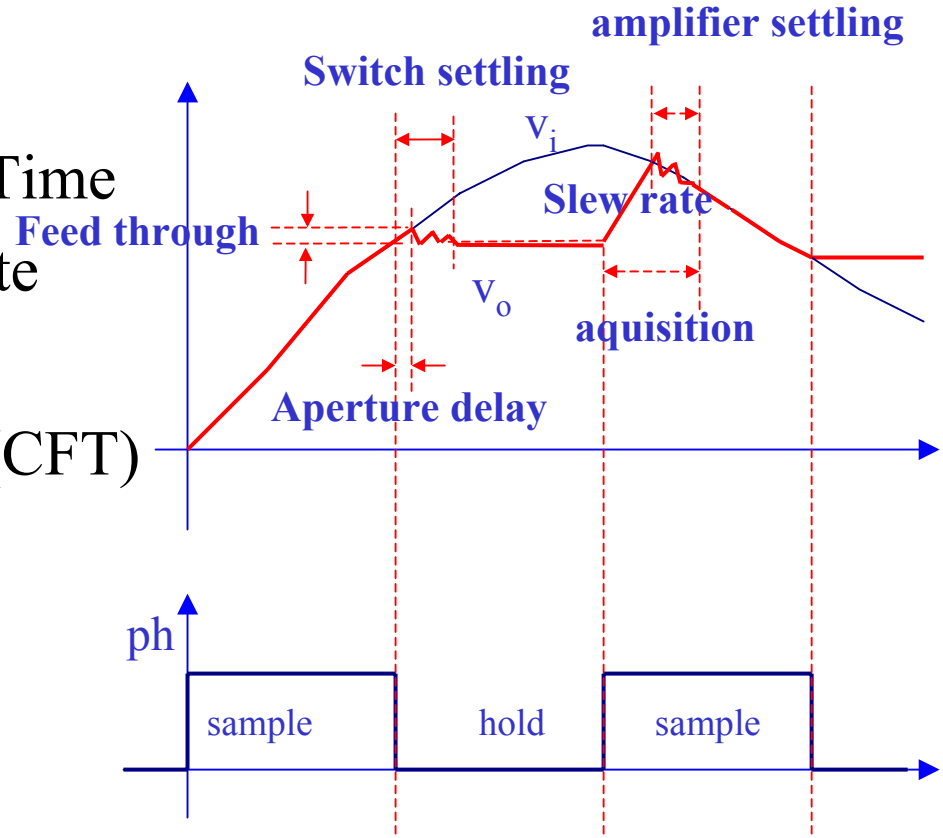




Sample-and-Hold Circuits

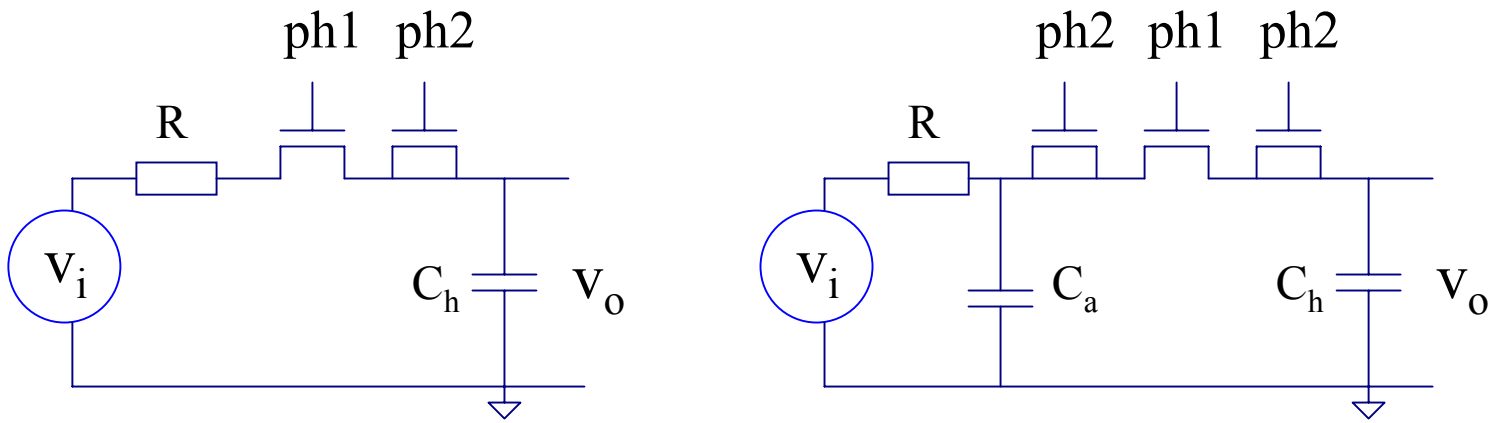
- Practical S/H Circuits
  - Acquisition Time
  - Slew Rate
  - Aperture uncertainty Time
  - Hold-mode Droop Rate
  - Offset
  - Clock Feed Through (CFT)





Sample-and-Hold Circuits

- CFT minimization technique

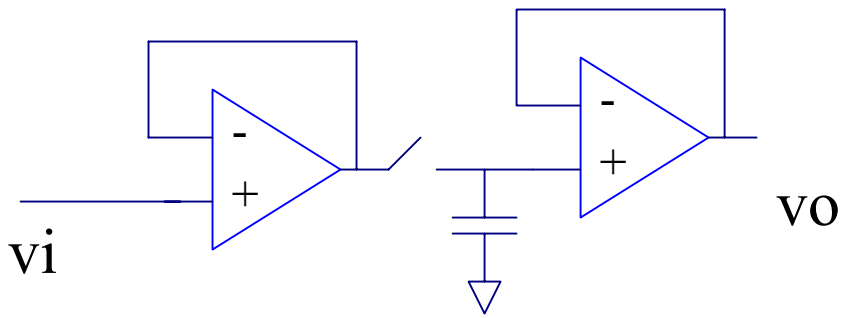


(a)
Dummy switch

(b)
Balanced dummy switch

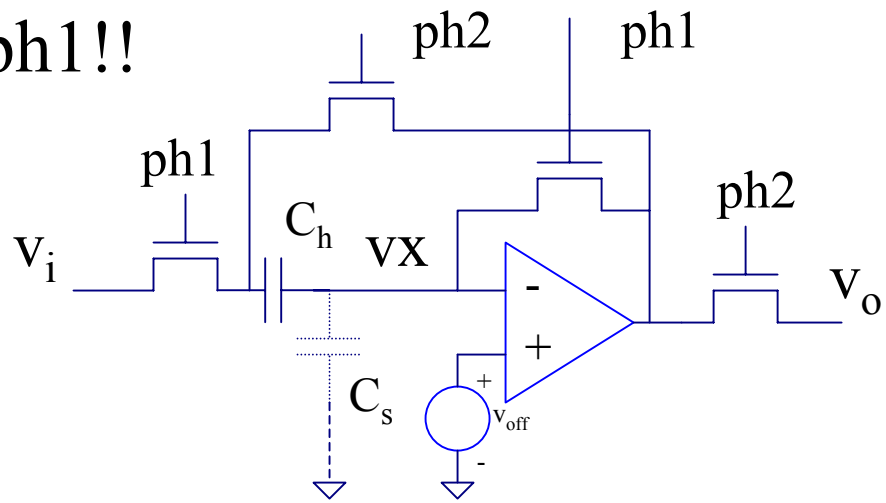
S/H Amplifier Structures

- Buffered S/H
  - Better drive capability
  - Better Isolation
  - Sensitive to offset



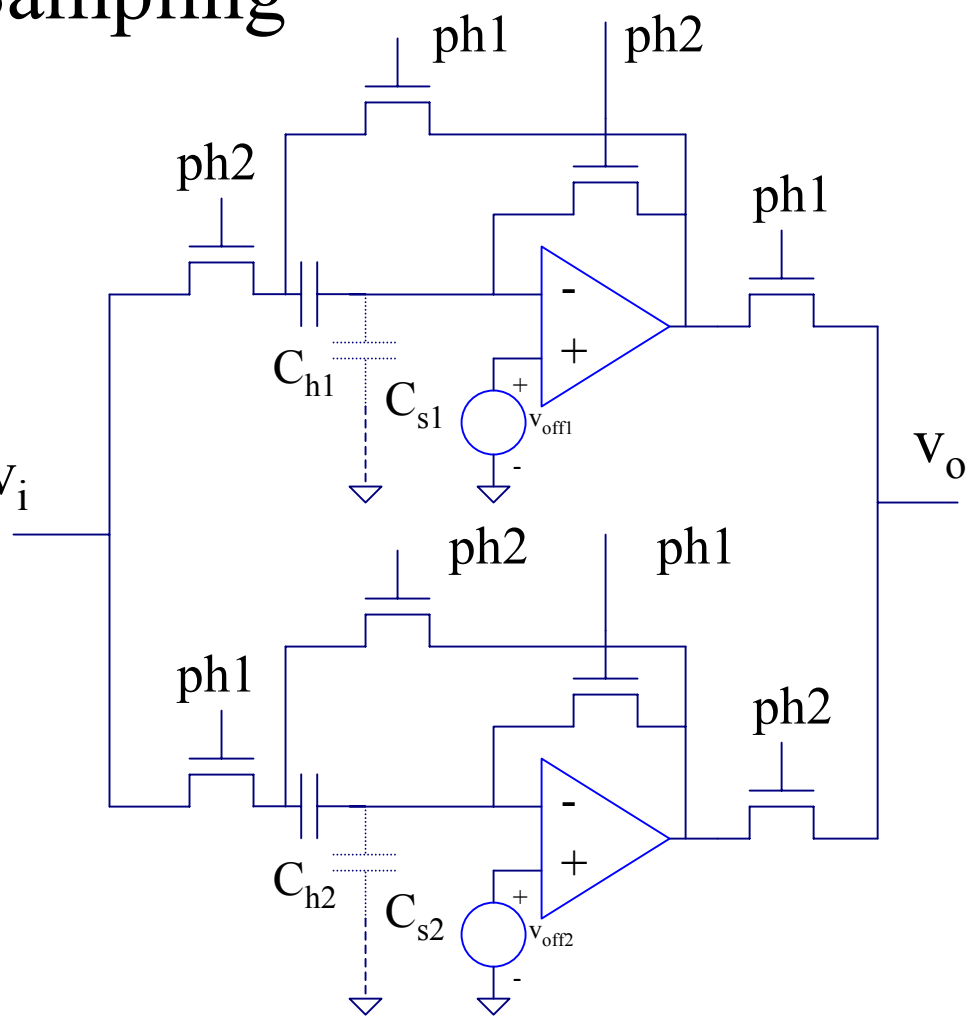
Improved S/H Circuit

- Offset minimization
- 1/f noise minimization
- PSSR improvement
- Vo unavailable at ph1!!



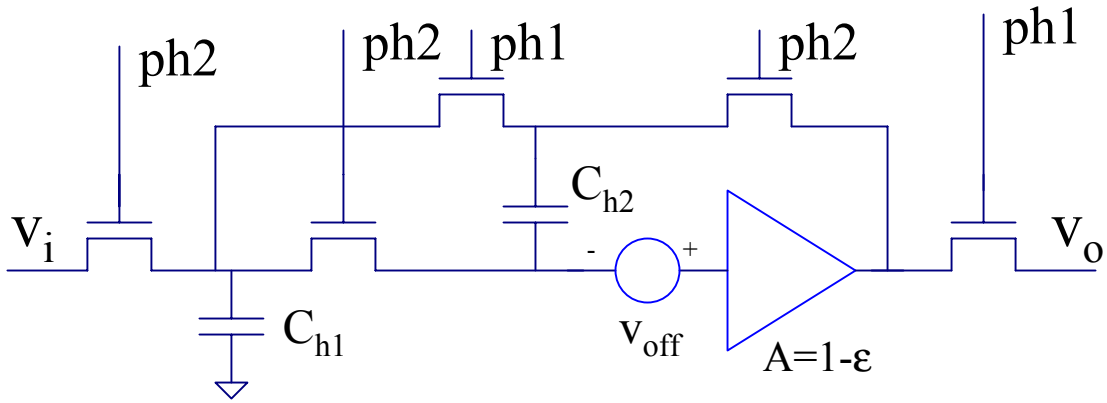
CDS S/H Circuit

- Correlated Double Sampling
- CDS Minimizes:
  - Offset
  - 1/f Noise
  - Power supply noise



Offset & Parasitic Free S/H Circuit

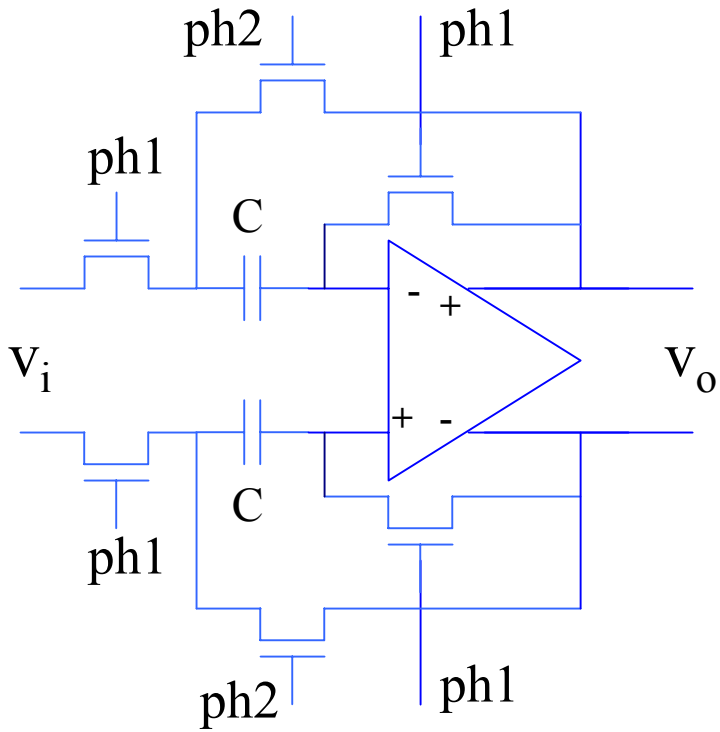
- Alternative Approach



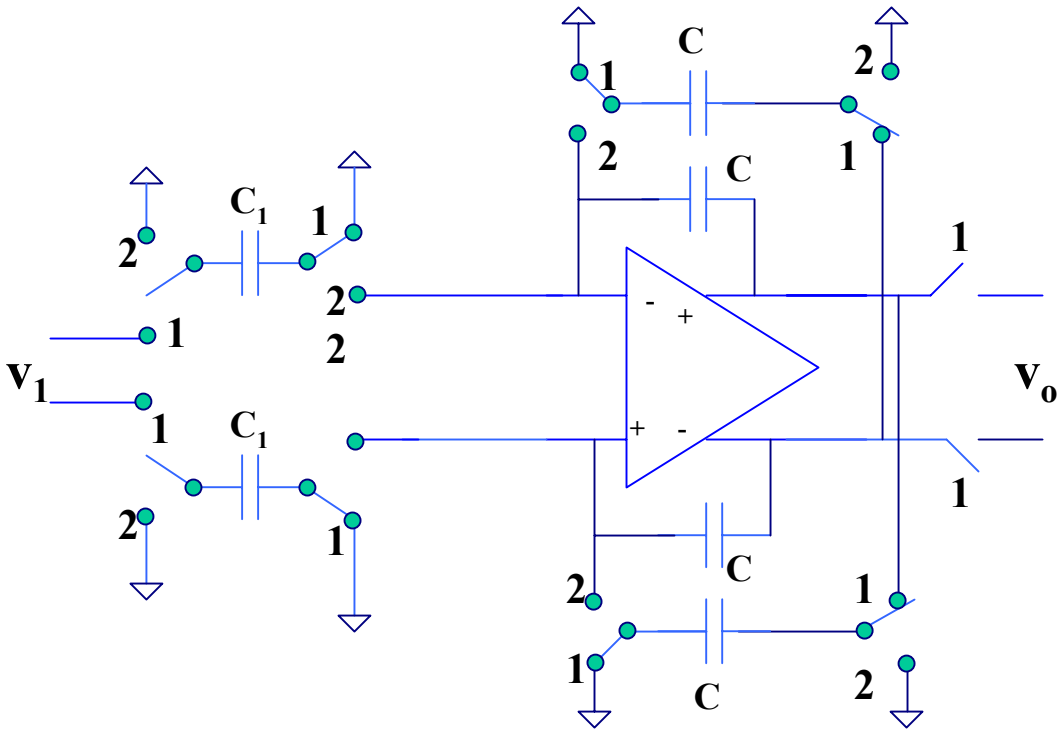
$$v_o = (1-\varepsilon^2)v_i + \varepsilon(1-\varepsilon)v_{off}$$

Fully Differential S/H Circuit

- Cancellation of
  - Charge injection
  - Power supply noise
  - Common Mode Signal



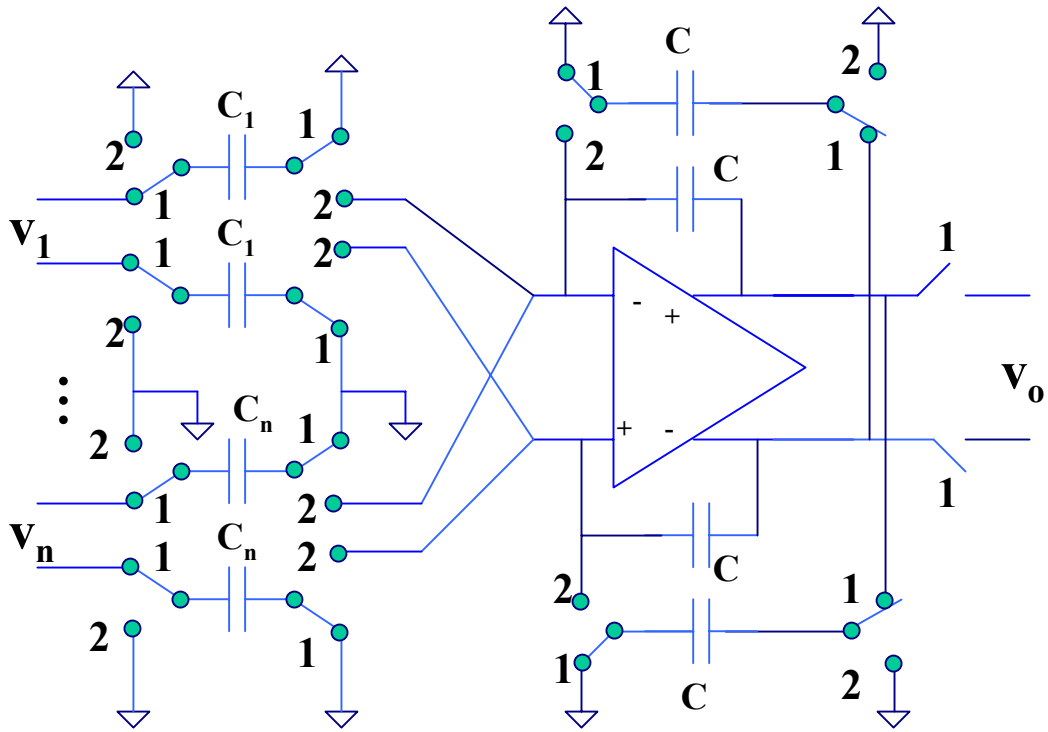
SC Delay Stage



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1}{C} z^{-1}$$

1 = ph1
2 = ph2

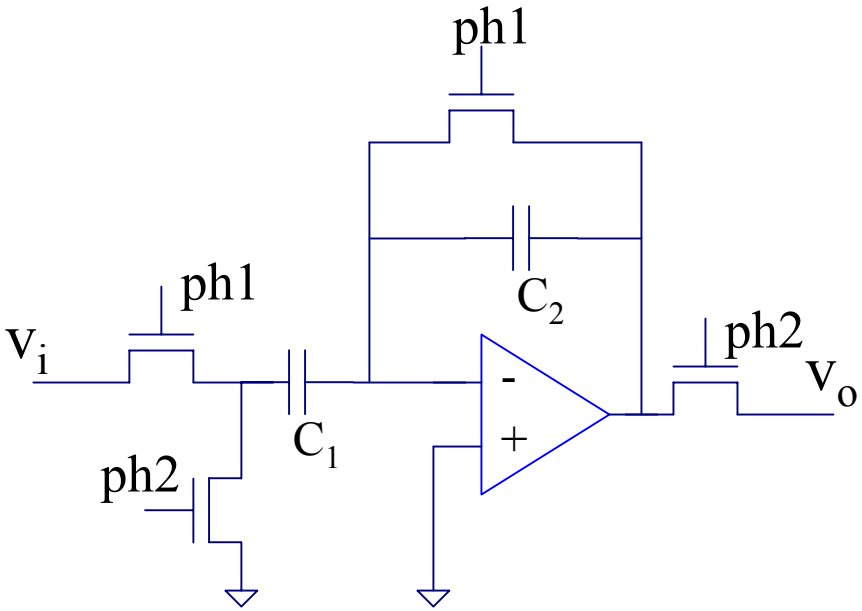
Delay Stage with Weighted Addition



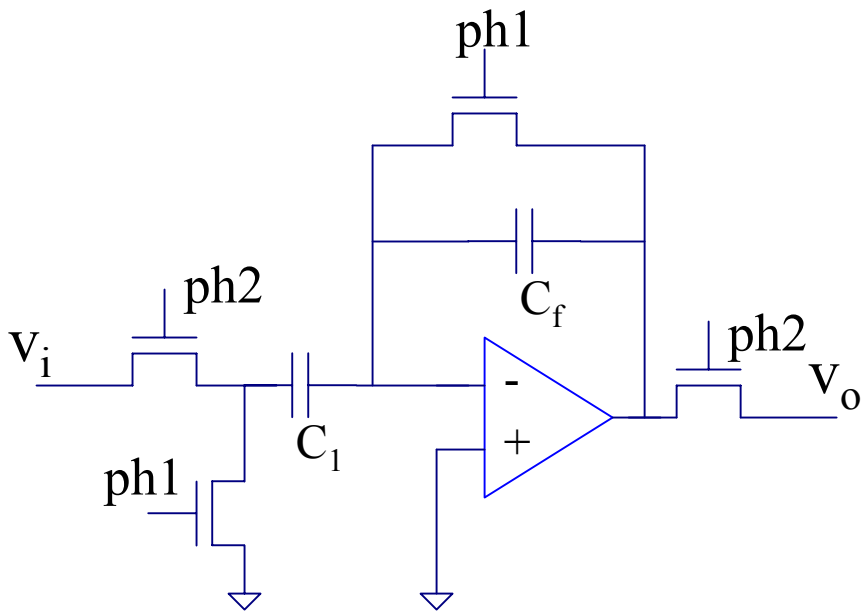
$$v_o(z) = \frac{z^{-1}}{C} \sum_{k=1}^{n} C_k v_k(z)$$

1 = ph1
2 = ph2

Basic SC Amplifier Structures

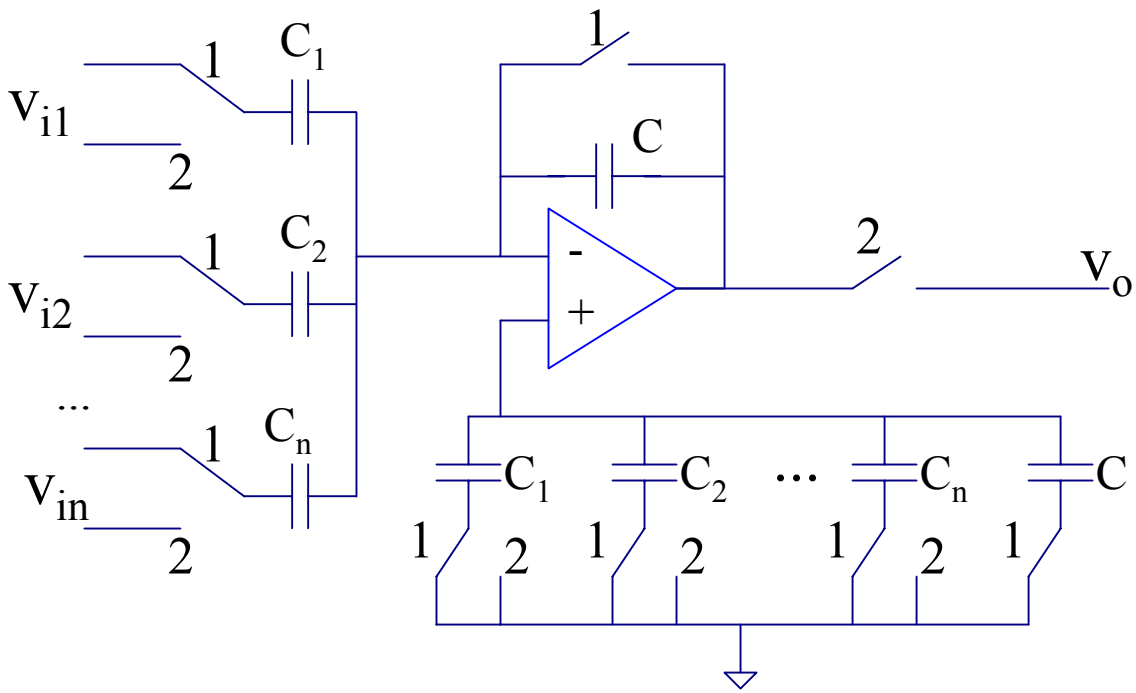


$$V_o = \frac{C_1}{C_2} V_i$$



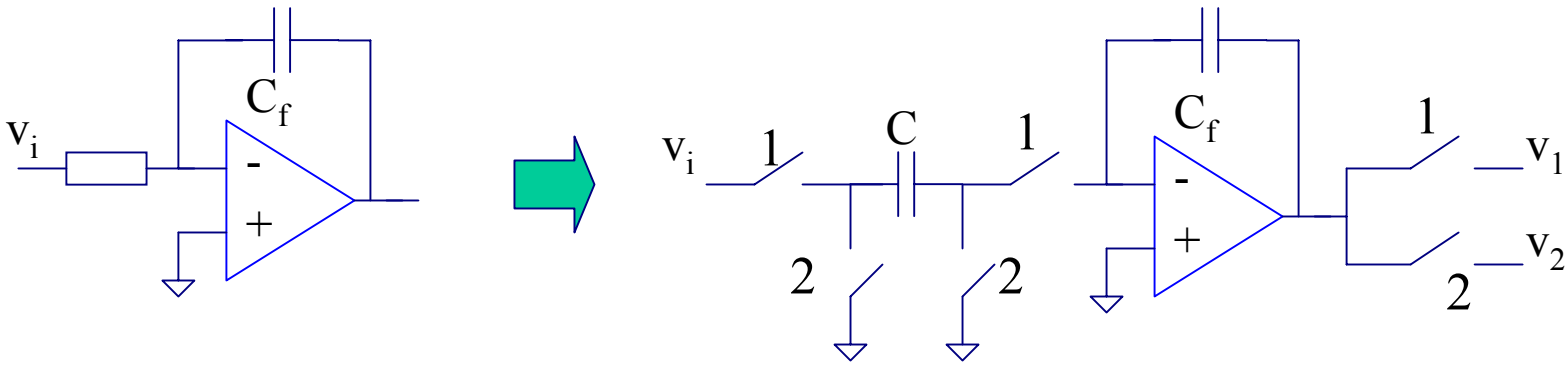
$$V_o = -\frac{C_1}{C_2} V_i$$

CFT Reduced Technique



$$V_o(z) = \frac{z^{-1}}{C} \sum_{k=1}^{n} C_k V_k(z)$$

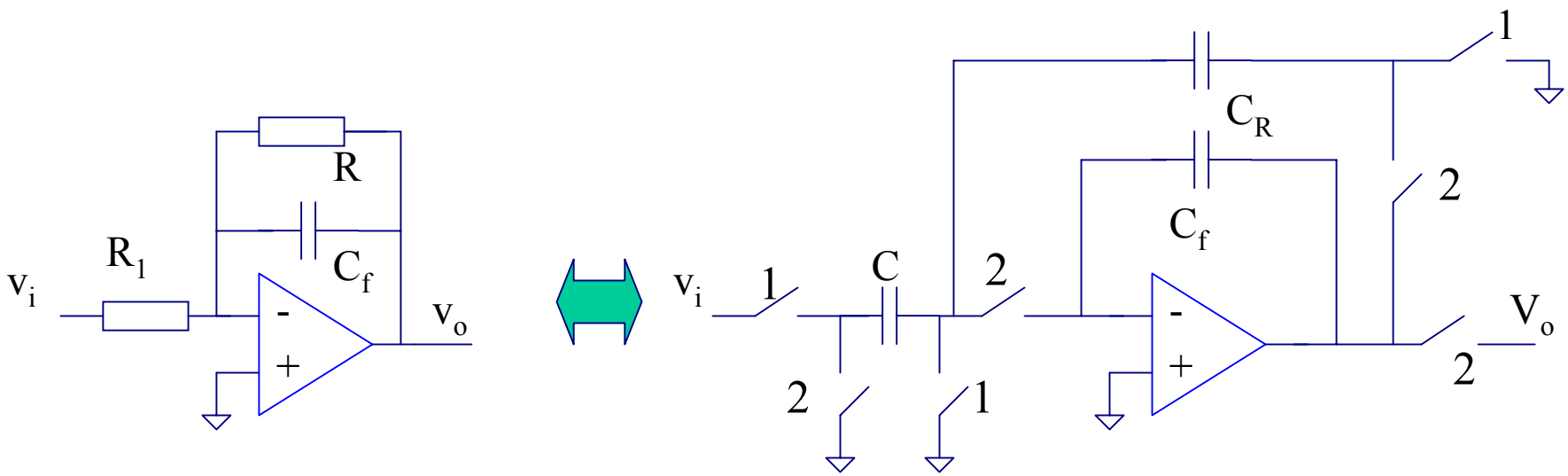
SC Integrator Structure



$$\frac{V_1(z)}{V_i(z)} = -\frac{C_1}{C_f}\frac{1}{1-z^{-1}}$$

$$\frac{V_2(z)}{V_i(z)} = -\frac{C_1}{C_f}\frac{z^{-1/2}}{1-z^{-1}}$$

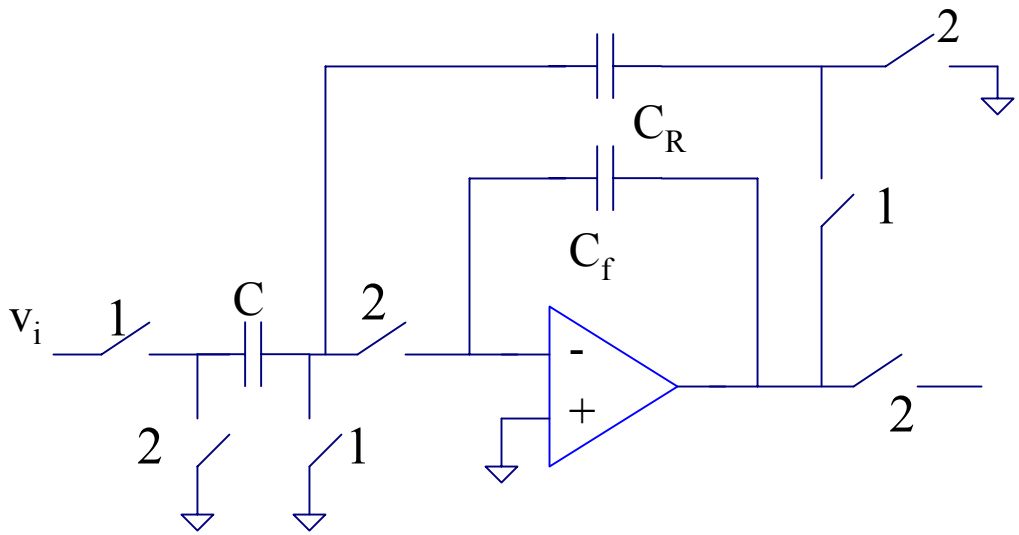
Lossy (Damped) SC Integrator Structure



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1}{(C_f + C_R)} \frac{z^{-1/2}}{(1 - z^{-1}\frac{C_f}{C_R + C_f})}$$

Lossy (Damped) SC Integrator Structure

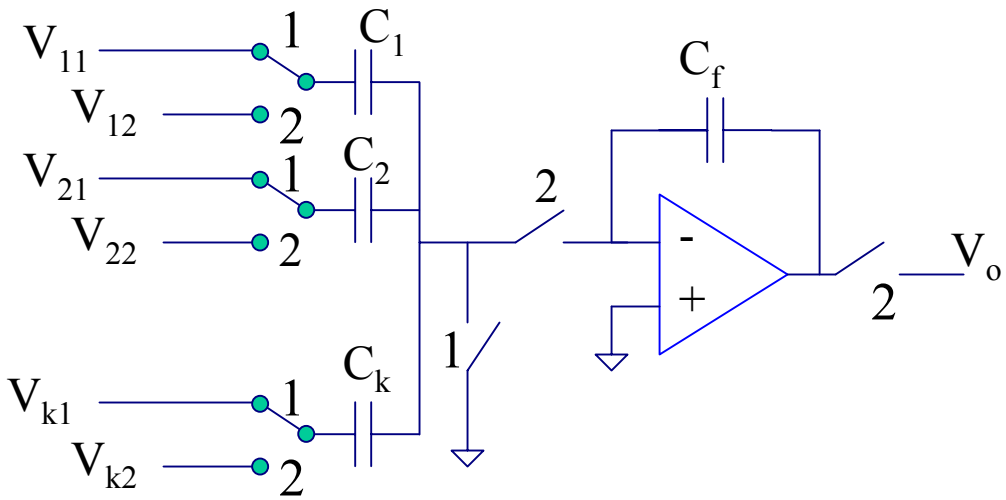
- Alternative (Positive Damped)



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1}{C_f} \frac{z^{-1/2}}{(1 - z^{-1} \frac{C_R}{C_f})}$$

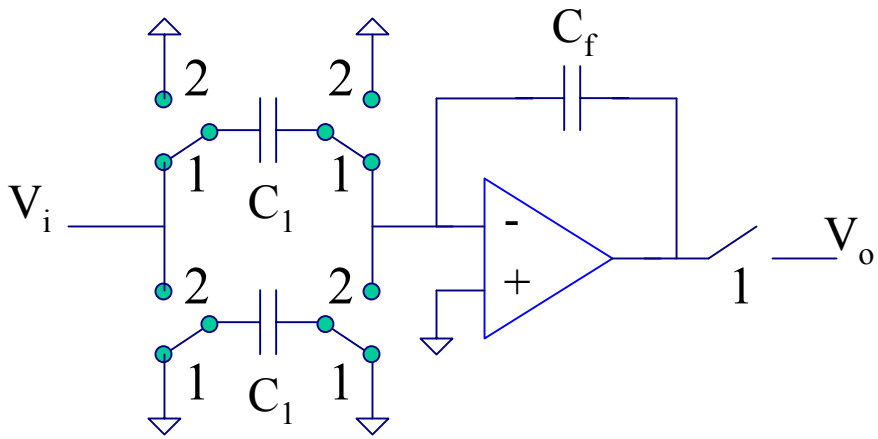
Multiple Inputs SC Integrator Structure

- Ideal Case



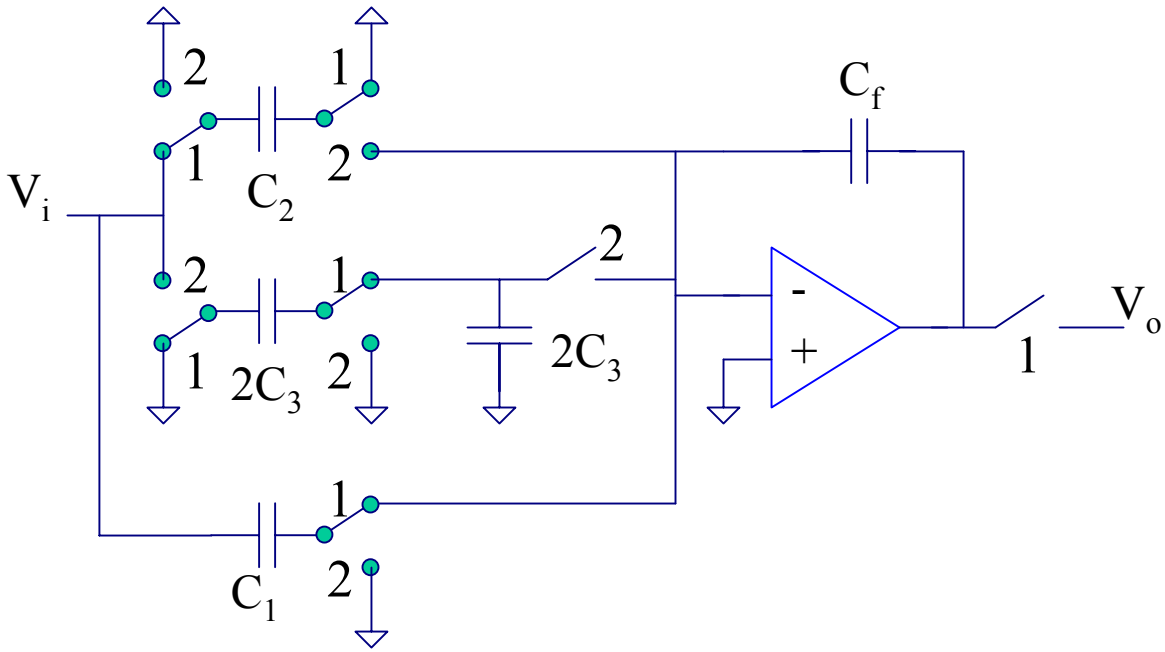
$$\frac{V_o(z)}{V_i(z)} = \sum_{i=1}^{k} \frac{C_i}{C_f} \frac{z^{-1/2} V_{i1}(z) - V_{i2}(z)}{(1 - z^{-1})}$$

Bilinear SC Integrator Structure



$$\frac{V_o(z)}{V_i(z)} = -\frac{C_1(1+z^{-1})}{C_f(1-z^{-1})}$$

2-Step SC Integrator Structure



$$\frac{V_o(z)}{V_i(z)} = \left(\frac{C_1}{C_f} z^{-1/2}\right) \frac{1 + \frac{C_2}{C_1} z^{-1/2} + \frac{C_3}{C_1} z^{-1}}{(1 - z^{-1})}$$

2-Step SC Integrator Structure

$$\frac{V_o(z)}{V_i(z)} = \left(\frac{C_1}{C_f} z^{-1/2}\right) \frac{1 + \frac{C_2}{C_1} z^{-1/2} + \frac{C_3}{C_1} z^{-1}}{(1 - z^{-1})}$$

$C_2 / C_1 = 4 \quad C_3 / C_1 = 1 \quad \Rightarrow \quad Simpson \quad Integrator$

$C_2 / C_1 = 8/5 \quad C_3 / C_1 = 1 \quad \Rightarrow \quad Gauss \quad Integrator$

$C_1 / C_f = C_3 / C_f = 0.3584 \quad C_2 / C_f = 1.2832 \quad \Rightarrow \quad Tick's \quad Integrator$

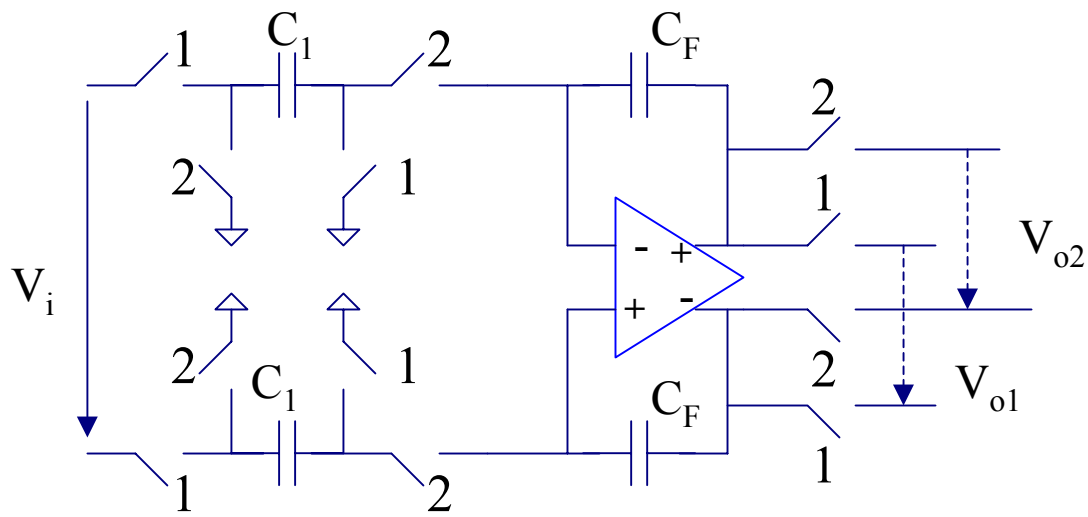
$C_2 / C_1 = 2 \quad C_3 / C_1 = 1 \quad \Rightarrow \quad Bilinear \quad Integrator$

...

Full Differential SC Integrator

- Charge Injection
- Power Supply Rejection
- High Speed
- Common Mode Rejection

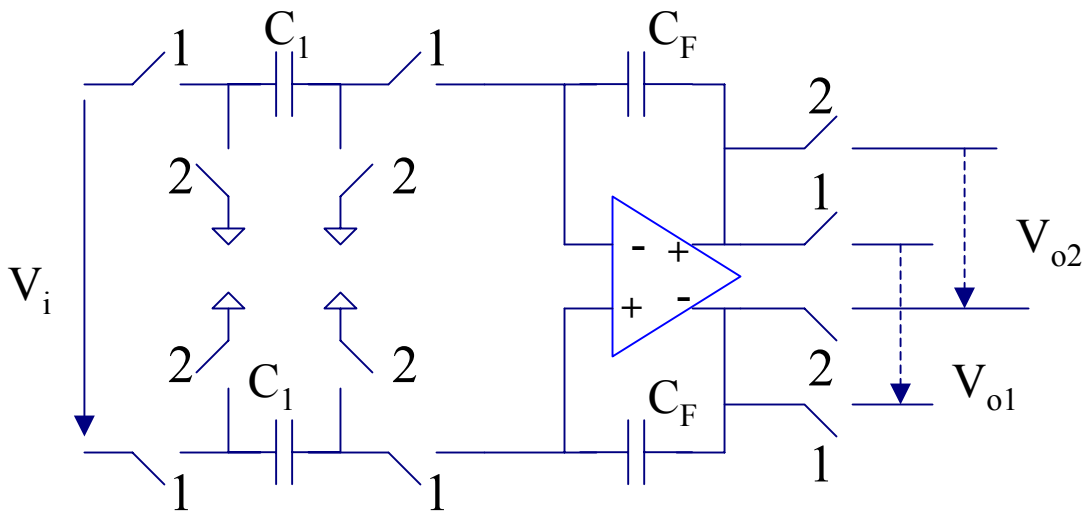
Full Differential SC Integrator Structure(I)



$$\frac{V_{o1}(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{z^{-1/2}}{1-z^{-1}}$$

$$\frac{V_{o2}(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{1}{1-z^{-1}}$$

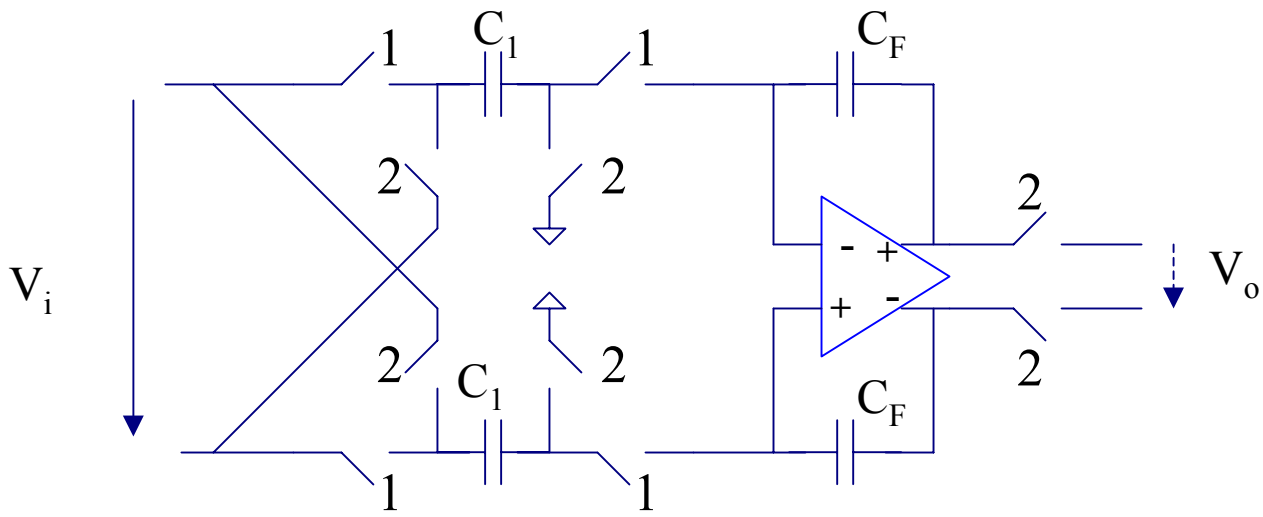
Full Differential SC Integrator Structure (II)



$$\frac{V_{o1}(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{1}{1-z^{-1}}$$

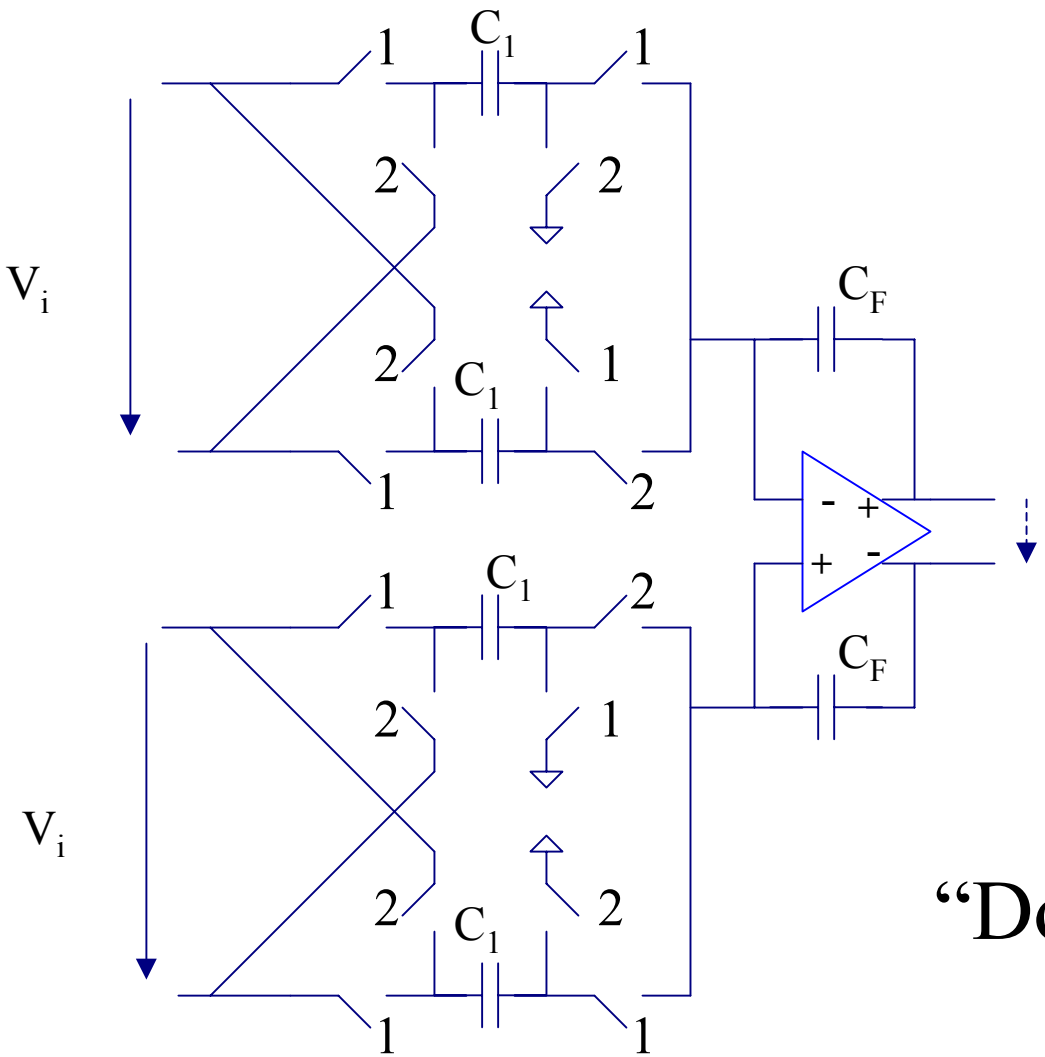
$$\frac{V_{o2}(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{z^{-1/2}}{1-z^{-1}}$$

Full Differential SC Integrator Structure (III)



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{1+z^{-1}}{1-z^{-1}}$$

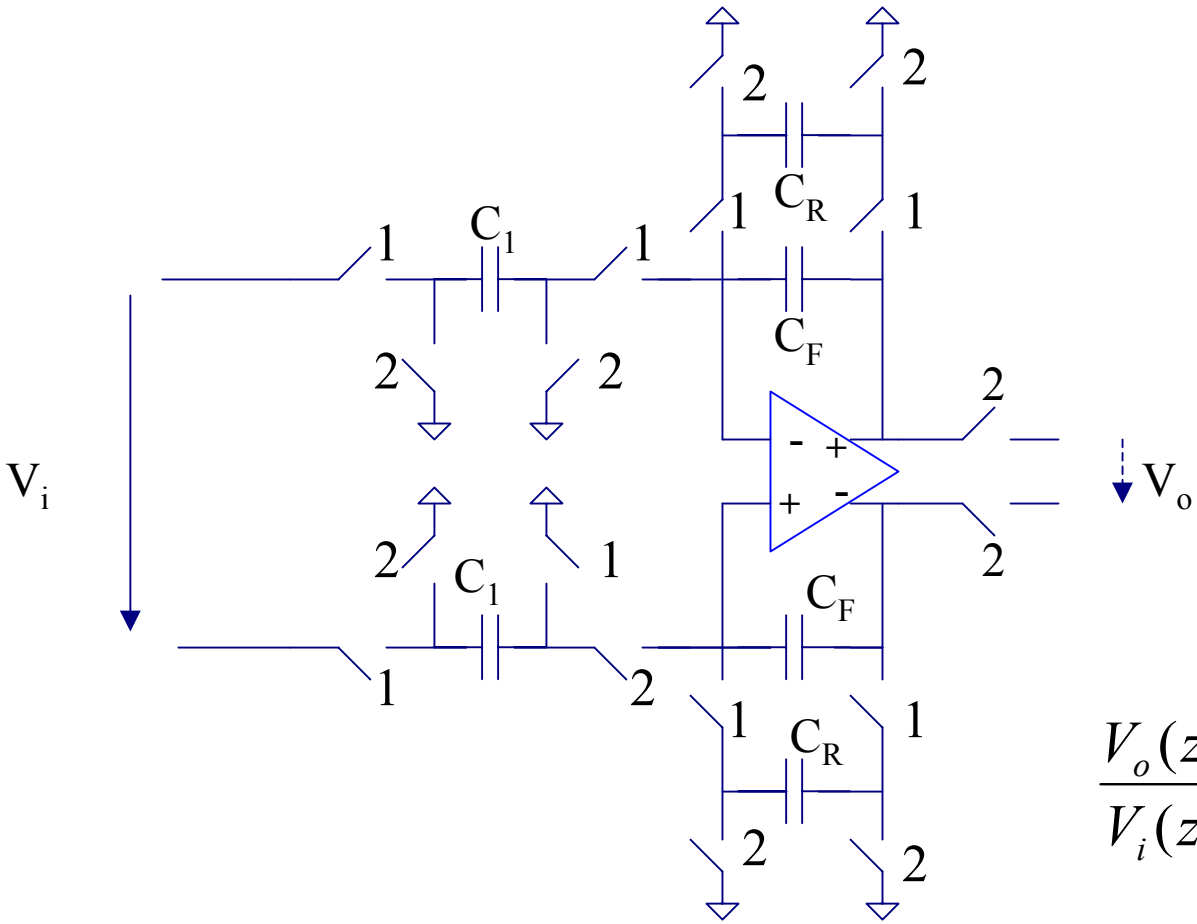
Full Differential SC Integrator Structure (IV)



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1}{C_F}\frac{1+z^{-1/2}}{1-z^{-1/2}}$$

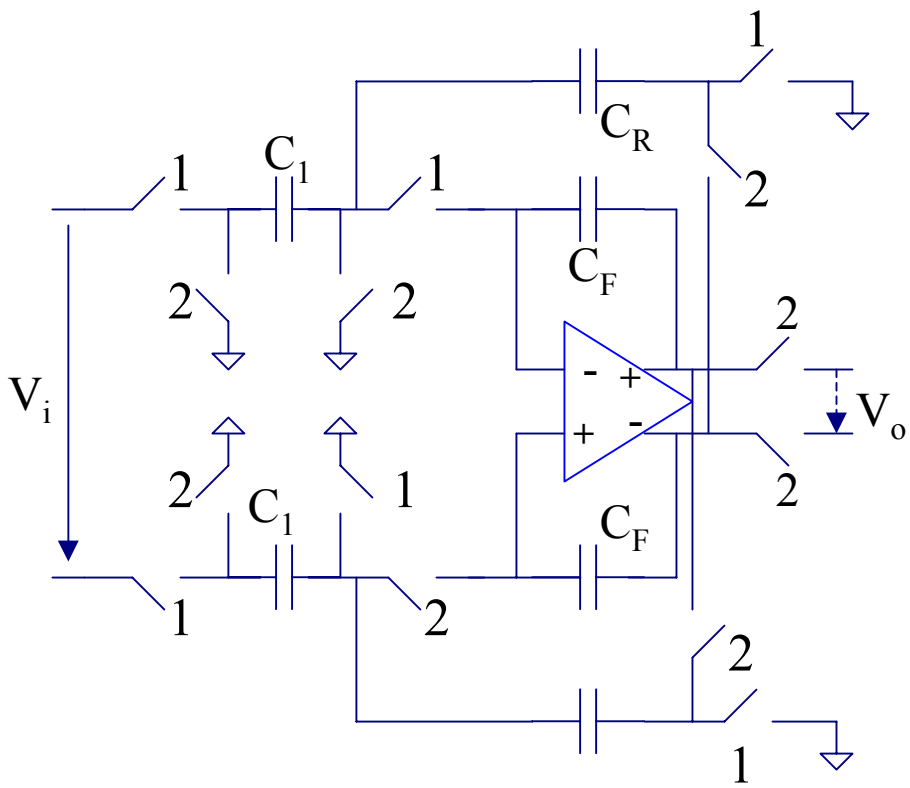
"Double-Pump"

Full Differential SC Integrator Structure (V)



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1 z^{-1/2}}{C_F(1-z^{-1}) + C_R}$$

Full Differential SC Integrator Structure (VI)



$$\frac{V_o(z)}{V_i(z)} = \frac{C_1 z^{-1/2}}{C_F(1-z^{-1}) + C_R z^{-1}}$$