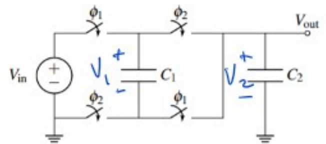
Dis 9A EECS16A

tinyurl.com/miyuki-feedback

1. Charge Sharing

Consider the circuit shown below. In phase ϕ_1, the switches labeled ϕ_1 are on while the switches labeled ϕ_2 are off. In phase ϕ_2, the switches labeled ϕ_2 are on while the switches labeled ϕ_1 are off.



Charge Sharing Algorithm — Note 17B

1. label voltages across caps, choose polarity (+ −) and stick with it
2. draw the circuit in both phases (label nodes differently)
3. identify floating nodes in phase 2 → node where charge is trapped

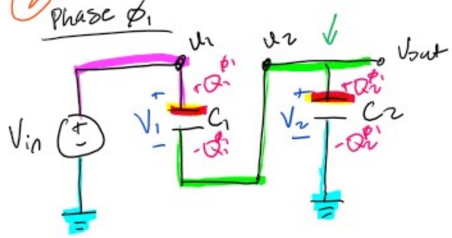
For each floating node:

4. Calculate total charge on floating node plates in phase 1 $Q^{\phi_1}_{float}$
5. Find total charge on floating node plates in phase 2 $Q^{\phi_2}_{float}$
6. charge conservation: $Q^{\phi_1}_{float} = Q^{\phi_2}_{float}$ (solve for unknowns)
7. repeat

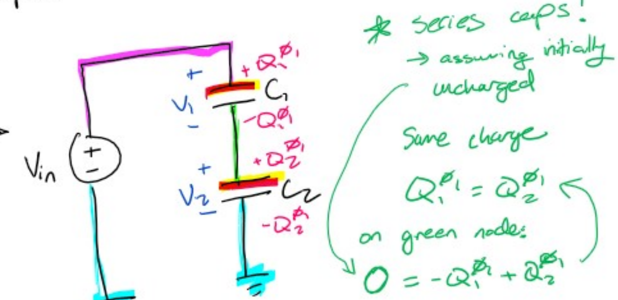
(a) Draw the polarity of the voltage (using + and − signs) across the two capacitors C_1 and C_2. (It doesn't matter which terminal you label + or −; just remember to keep these consistent through phase 1 and 2!) (1)

(b) Redraw the circuit in phase ϕ_1 and phase ϕ_2. Keep your polarity from part (a) in mind.

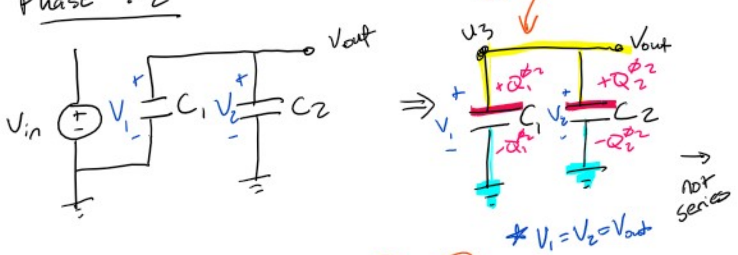
(2) Phase ϕ_1

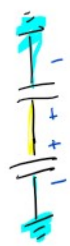


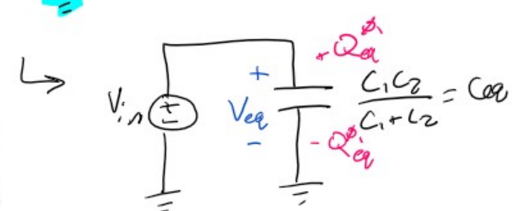
$u_2 \neq u_3$



Phase ϕ_2







$Q_{eq}^{\phi_1} = Q_1^{\phi_1} = Q_2^{\phi_1}$

$Q_{eq}^{\phi_1} = \frac{C_1C_2}{C_1+C_2} V_{in}$

(c) Find V_{out} in phase ϕ_2 as a function of V_{in}, C_1, and C_2. (4)—(7)

(4)
$$Q_{u_3}^{\phi_1} = +Q_1^{\phi_1} + Q_2^{\phi_1} = C_1V_1 + C_2V_2$$
$$= Q_{eq}^{\phi_1} + Q_{eq}^{\phi_1} = 2Q_{eq}^{\phi_1}$$
$$= 2\frac{C_1C_2}{C_1+C_2}V_{in}$$

(5)
$$Q_{u_3}^{\phi_2} = Q_1^{\phi_2} + Q_2^{\phi_2}$$
$$= C_1V_1 + C_2V_2 = C_1V_{out} + C_2V_{out}$$
$$= (C_1+C_2)V_{out}$$

(6)
$$Q_{u_3}^{\phi_1} = Q_{u_3}^{\phi_2}$$
$$2\frac{C_1C_2V_{in}}{C_1+C_2} = (C_1+C_2)V_{out} \rightarrow \boxed{V_{out} = \frac{2C_1C_2}{(C_1+C_2)^2}V_{in}}$$

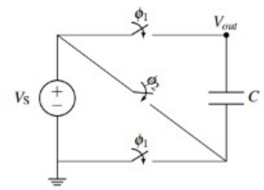
(d) How will the charges be distributed in phase ϕ_2 if we assume $C_1 \gg C_2$?

$Q_1^{\phi_2} = C_1V_{out}$ if $C_1 >> C_2 \rightarrow Q_1^{\phi_2} >> Q_2^{\phi_2}$

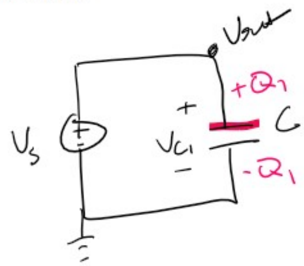
$Q_2^{\phi_2} = C_2V_{out}$

2. **Voltage Booster**

We have made extensive use of resistive voltage dividers to reduce voltage. What about a circuit that boosts voltage to a value greater than the supply $V_S = 5V$? We can do this with capacitors!



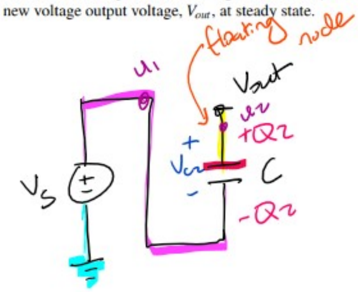
(a) In the circuit above switches ϕ_1 are initially closed and switch ϕ_2 is initially open. Calculate the value of the output voltage, V_{out} with respect to ground, and the amount of charge stored on capacitor, C, at that state (phase 1).



$$Q_1 = C V_{C_1} = C V_{out} = C V_S$$

$$V_{out} = V_S$$

(b) Now, after the capacitors are charged, switches ϕ_1 are opened and switch ϕ_2 is closed. Calculate the new voltage output voltage, V_{out}, at steady state.



by charge conservation: $Q_{u_2}^{\phi_1} = Q_{u_2}^{\phi_2}$

$$Q_{u_2}^{\phi_1} = +Q_1 = CV_S$$

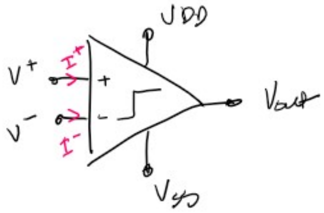
$$Q_{u_2}^{\phi_2} = +Q_2 = CV_{C_2} = C(u_2 - u_1) = C(V_{out} - V_S)$$

$$CV_S = C(V_{out} - V_S)$$

$$\rightarrow V_{out} = 2V_S$$

* by observation:
open circuit at V_{out}
in phase ϕ_2
means $Q_1 = Q_2$
$\rightarrow V_{C_1} = V_{C_2} = V_S \rightarrow V_{C_2} = V_{out} - V_S = V_S$
$V_{out} = 2V$

Comparators



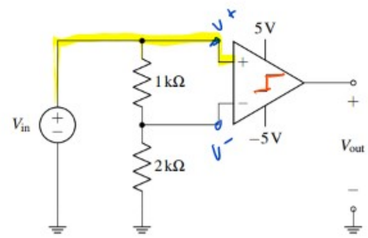
$I^+ = I^- = 0$

$$V_{out} = \begin{cases} V_{DD} & \text{if } V^+ > V^- \\ V_{SS} & \text{otherwise } (V^+ \leq V^-) \end{cases}$$

3. Comparators

For each of the circuits shown below, plot V_{out} for V_{in} ranging from −10 V to 10 V for part (a) and from 0 V to 10 V for part (b).

(a)



$V^+ = V_{in}$

$V^- = \frac{2k\Omega}{1k\Omega + 2k\Omega} V_{in}$

$= \frac{2}{3} V_{in}$

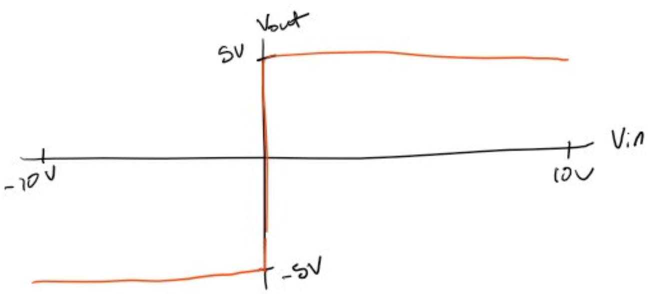
* flip point (from V_{SS} to V_{DD} or other way)

$V^+ = V^-$

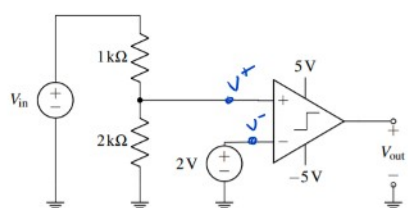
$V_{in} = 0$

if $V_{in} > 0$ $V^+ > V^-$ $V_{out} = 5V$

$V_{in} < 0$ $V^+ < V^-$ $V_{out} = -5V$



(b)



$V^+ = \frac{2}{3} V_{in}$

$V^- = 2V$

* flip point: $V^+ = V^-$

$V_{in} = 3V$

if $V_{in} > 3V$ $V^+ > V^-$ $V_{out} = 5V$

$V_{in} < 3V$ $V^+ < V^-$ $V_{out} = -5V$