EECS 16A Dis 9B Notes

Tuesday, October 19, 2021 8:12 AM

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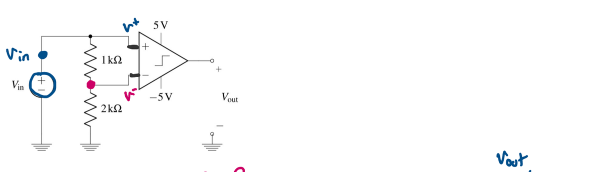
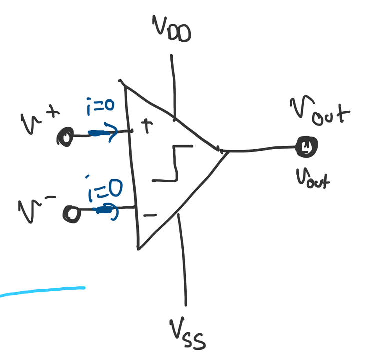
1. Comparators

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)





$$V_{out} = \begin{cases} V_{DD} & \text{if } v^+ > v^- \\ V_{SS} & \text{if } v^+ < v^- \end{cases}$$

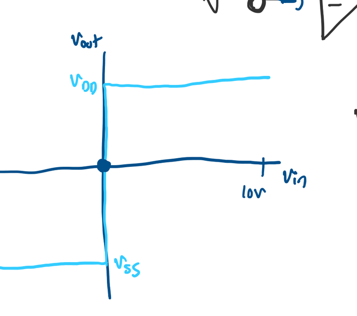
$v^+ = v_{in}$ $\quad v^- = \frac{2k\Omega}{2k\Omega + 1k\Omega} \cdot v_{in} = \frac{2}{3} v_{in}$

$v^+ > v^-$: $v_{in} > \frac{2}{3} v_{in}$

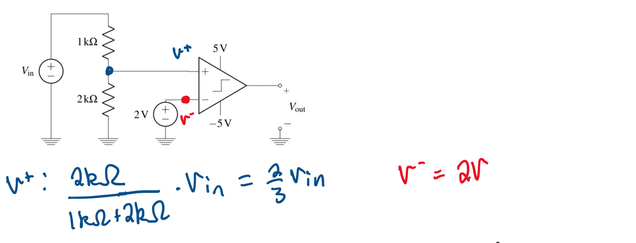
$v_{in} - \frac{2}{3} v_{in} > 0$

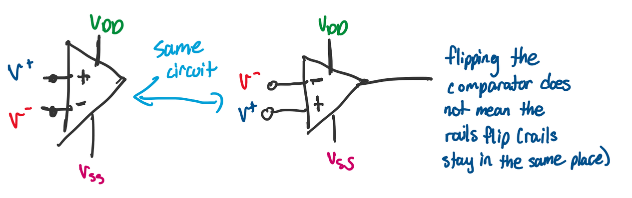
$v_{in}(1 - \frac{2}{3}) > 0$

$v_{in} > 0$ flip point



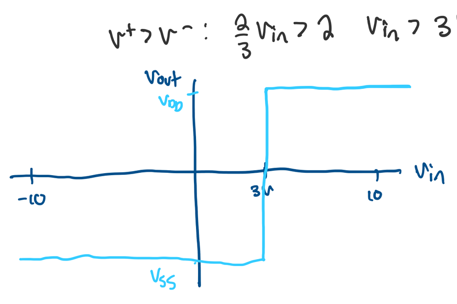
(b)





v^+: $\frac{2k\Omega}{1k\Omega + 2k\Omega} \cdot v_{in} = \frac{2}{3} v_{in}$ $\quad v^- = 2V$

$v^+ > v^-$: $\frac{2}{3} v_{in} > 2$ $\quad v_{in} > 3V$



2. Charge Sharing

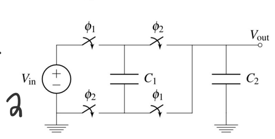
Recipe for charge sharing:

Step 1: Label the voltages across all the capacitors. Choose whichever direction (polarity) you want for each capacitor - this means you can mark any one of the plates with the "+" sign, and then you can mark the other plate with the "−" sign. Just make sure you stay consistent with this polarity across phases.
Step 2: Draw the equivalent circuit during both phases (Phase 1: ϕ_1 closed, ϕ_2 open - Phase 2: ϕ_1 open, ϕ_2 closed). Also, label all node voltages on the circuit for both phases. No need to try and maintain the same names, since certain nodes of the phase 1 circuit might be merged or split in phase 2.
Step 3: Calculate the note voltages during phase 1. This can be done by using one of the previously introduced circuit analysis techniques (most likely KVL will do the job).
Step 4: Identify all "floating" nodes in your circuit during phase 2. A floating node is a node out of or into which no charge can flow. You can identify those nodes as the nodes connected only to capacitor plates, op amp inputs or comparator inputs. These will be the nodes where we apply charge sharing.
Step 5: For steps 5-7 we will **examine each phase 2 floating node individually**. Pick a floating node from the ones you found in step 4 and identify all capacitor plates connected to that node during phase 2. Then, calculate the charge on each of these plates during phase 1.
To do so, identify all nodes in your circuit during phase 1. Label all node voltages, and write the voltages across each capacitor as functions of node voltages (step 2 and 3 should help you with that). Do this according to the polarities you have selected. Then the charge is found as $Q = CV_C$ (where V_C is the voltage *across* a capacitor).
Careful: The plate marked with the "−" sign will have $Q = -CV_C$ and the plate marked with the "+" sign will have $Q = CV_C$ stored onto them.
Step 6: Find the total charge on each of the floating nodes during phase 2 as a function of node voltages. Use the same process as in Step 5, but this time using the node voltages during phase 2 to write the voltages across each capacitor. Make sure you kept the polarity same and pay attention to the sign of each plate.
Step 7: Equate the total charge calculated in phase 1 (Step 4) to the total charge calculated in phase 2 (Step 6) (charge conservation).
Step 8: Repeat steps 5-7 for every floating node. This will give you one equation per floating node (i.e. if you have *m* floating nodes you will have *m* equations). You can then solve the system of equations to find the node voltages during phase 2 (unknowns). It should have a unique solution!

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.

ϕ_1: phase 1

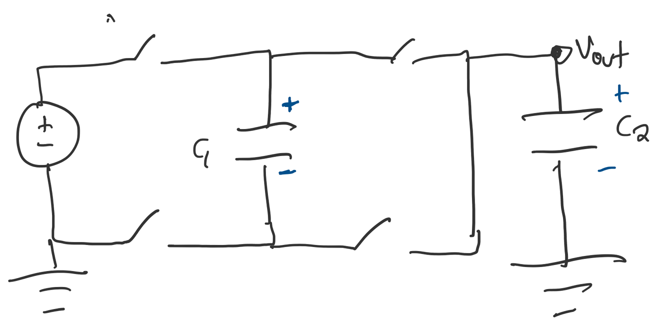
ϕ_2: phase 2



Charge Sharing Algorithm:

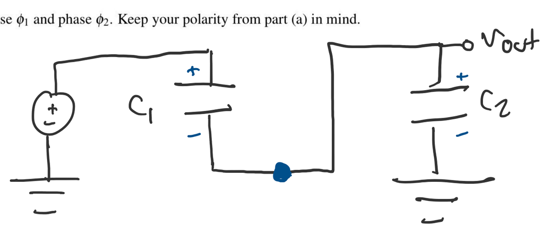
1. Label capacitor voltages and choose polarities to be used for rest of the algorithm
2. Draw circuit for each phase
3. In phase 2, label floating nodes
4. For each floating node, solve for Q^{ϕ_1}
5. Solve for Q^{ϕ_2}
6. Equate $Q^{\phi_1} = Q^{\phi_2}$ due to charge conservation
7. Repeat steps 4-6 for each floating node

(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!)

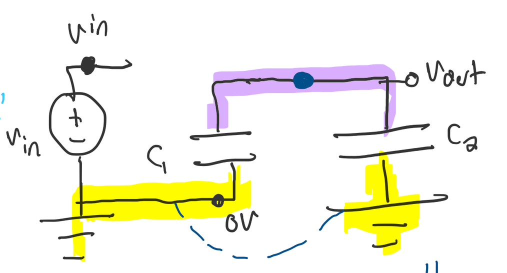


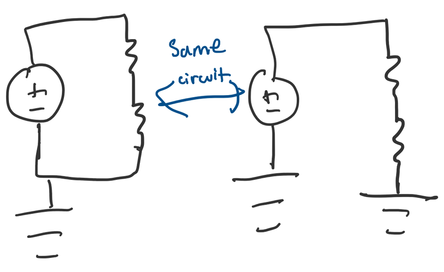
(b) Redraw the circuit in phase ϕ_1 and phase ϕ_2. Keep your polarity from part (a) in mind.

Phase 1:



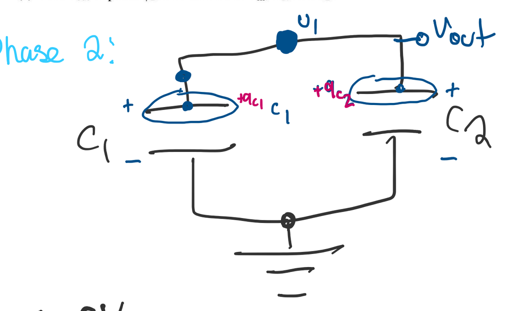
Phase 2:



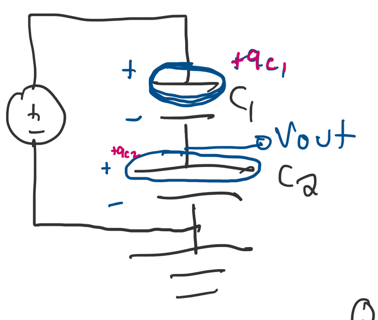


(c) Find V_{out} in phase ϕ_2 as a function of V_{in}, C_1, and C_2.

Phase 2:



Phase 1:



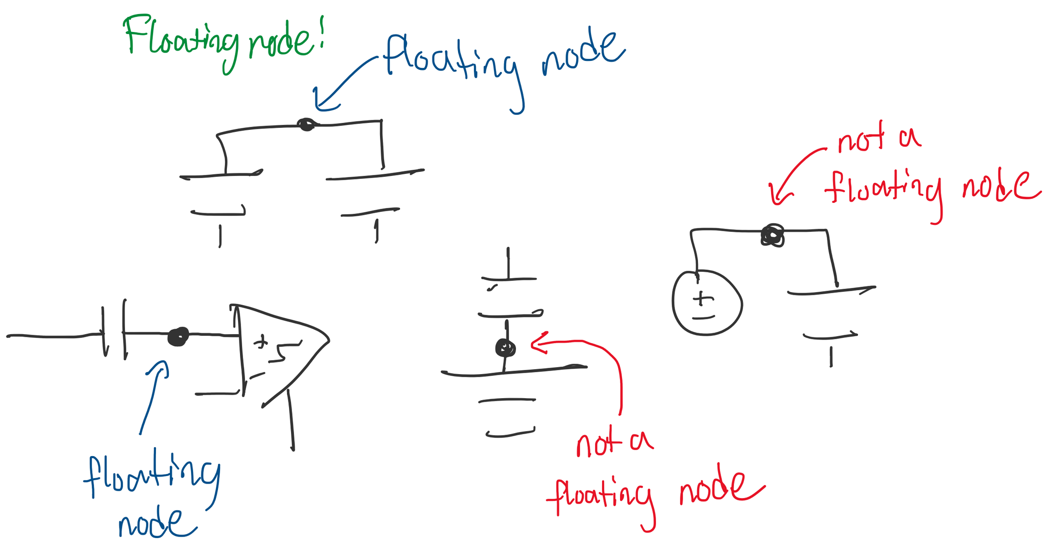
Series capacitors:

$Q_T = Q_1 = Q_2 = \dots = Q_n$

$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$

$Q = CV$ $\quad Q_T = \frac{C_1 C_2}{C_1 + C_2} \cdot V_{in} = Q_1$

Floating node!



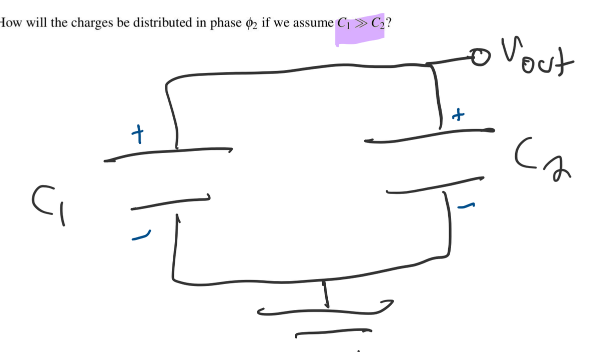
$Q = CV$

$@ v_1: +Q_{C_1}^{\phi_2} + Q_{C_2}^{\phi_2} = Q_{C_1}^{\phi_1} + Q_{C_2}^{\phi_1}$

$Q=CV$ $\quad C_1 V_{out} + C_2 V_{out} = \frac{C_1 C_2}{C_1 + C_2} \cdot V_{in} + \frac{C_1 C_2}{C_1 + C_2} V_{in}$

$$V_{out} = \frac{2 \cdot C_1 C_2 V_{in}}{(C_1 + C_2)^2}$$

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



$Q = CV$

$Q_1 = C_1 V_{out}$ $\quad Q_2 = C_2 \cdot V_{out}$

$$Q_1 \gg Q_2$$

Since $C_1 \gg C_2$ and $v_{C_1} = v_{C_2} = V_{out}$

Redo problem 2 w/ C_2 polarity flipped

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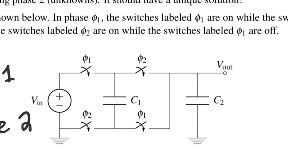
ϕ_2: phase 2



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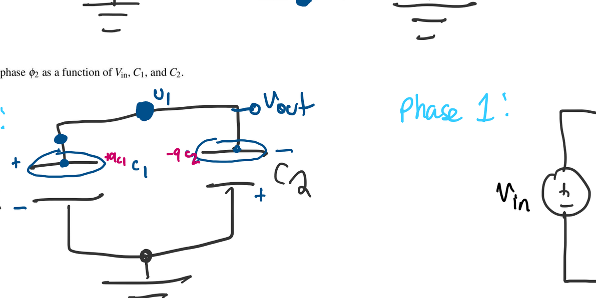

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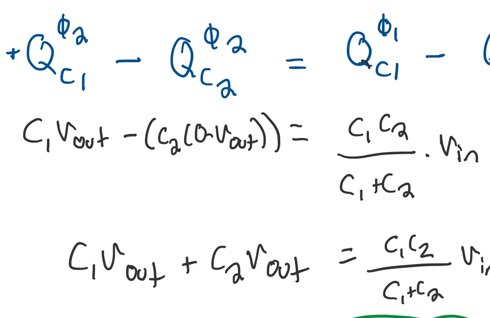
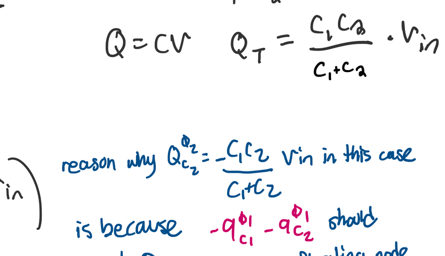


Phase 2:



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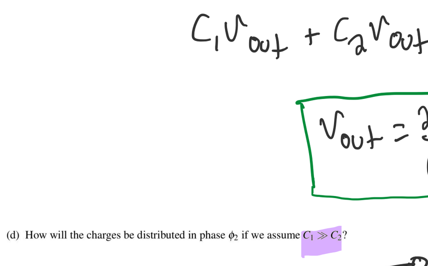

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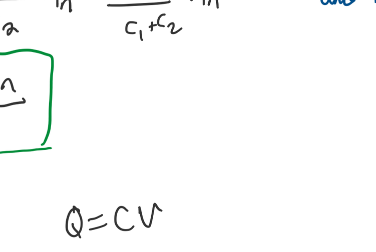

Series capacitors:

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$Q = CV$

$@ v_1: +Q_{C_1}^{\phi_2} - Q_{C_2}^{\phi_2} = Q_{C_1}^{\phi_1} - Q_{C_2}^{\phi_1}$

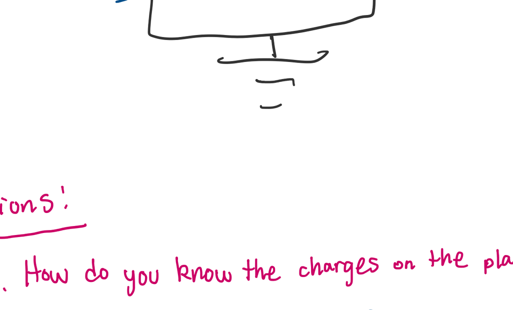
$Q=CV$ $\quad C_1 V_{out} - (C_2(0 - V_{out})) = \frac{C_1 C_2}{C_1 + C_2} \cdot V_{in} - \left(-\frac{C_1 C_2}{C_1 + C_2} V_{in}\right)$

reason why $Q_{c_2}^{\phi_2} = -\frac{C_1 C_2}{C_1 + C_2} V_{in}$ in this case is because $-q_{c_1}^{\phi_1} - q_{c_2}^{\phi_1}$ should equal 0 since v_2 is a floating node and the capacitors are initially uncharged

$C_1 V_{out} + C_2 V_{out} = \frac{C_1 C_2}{C_1 + C_2} V_{in} + \frac{C_1 C_2}{C_1 + C_2} V_{in}$

$$V_{out} = \frac{2 \cdot C_1 C_2 V_{in}}{(C_1 + C_2)^2}$$

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



$Q = CV$

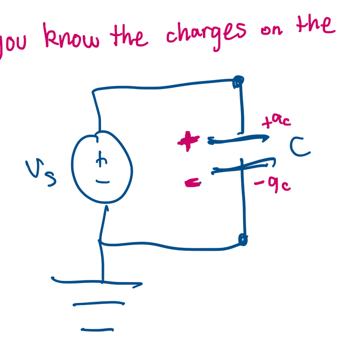
$Q_1 = C_1 V_{out}$ $\quad +Q_2 = C_2 \cdot V_{out}$

$$Q_1 \gg Q_2$$

Since $C_1 \gg C_2$ and $v_{C_1} = v_{C_2} = V_{out}$

Questions:

1. How do you know the charges on the plates of the capacitors when it is hooked up to a capacitor?



$Q = CV$ ← V_s

$Q_c = C \cdot V_s$

↑ charge on capacitor ($+q_c$ on positive plate and $-q_c$ on negative plate)