UnnaTI Analog Program Reference Material

UnnaTI Analog Program

Syllabus for screening:

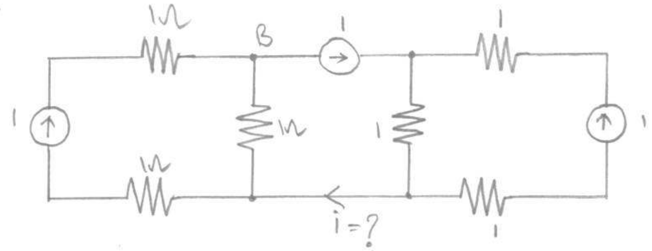
- ❑ KCL & KVL
- ❑ Thevenin & Norton theorems
- ❑ Superposition concepts
- ❑ R-C circuits time constant/ waveform
- ❑ Final conditions for R-C circuits
- ❑ Charge conservation in a capacitor
- ❑ Inductance concepts
- ❑ Controlled sources
- ❑ Periodic waveforms
- ❑ Laplace domain
- ❑ Differential equations
- ❑ Probability
- ❑ Permutation & Combination
- ❑ Data analysis and interpretation
- ❑ Digital gates - Boolean algebra

Points to note:

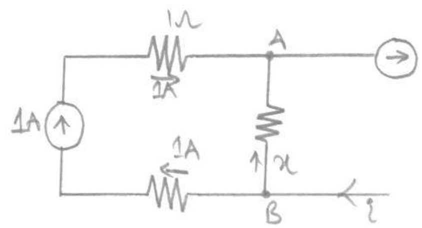
- ❑ Use the provided notes to get a feel for what the screening test will be like
- ❑ If you spot any errors in the notes, please bring it to the notice of saivarun@ti.com
- ❑ Actually screening will be multiple choice format
- ❑ You will be tested on the understanding of basic concepts

KCL, KVL

① KCL



Solution



Applying KCL at node B

$$i - 1 - x = 0$$
$$x = i - 1 \quad \text{—— (1)}$$

Applying KCL at node A

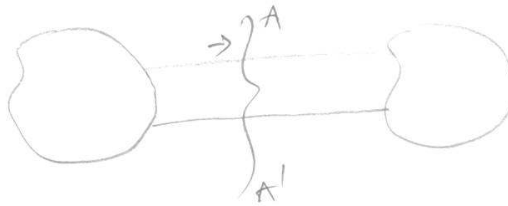
$$1 + x - 1 = 0$$
$$x = 0 \quad \text{—— (2)}$$

Equating (1) and (2)

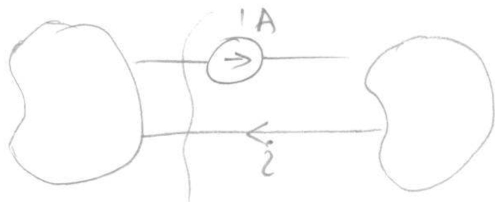
$$i - 1 = 0$$
$$\Rightarrow i = 1$$

Simple solution :

KCL States at any node that Sum of total incoming Current is equal to Sum of total Outgoing Current Applying the Same law across any plane : AA'

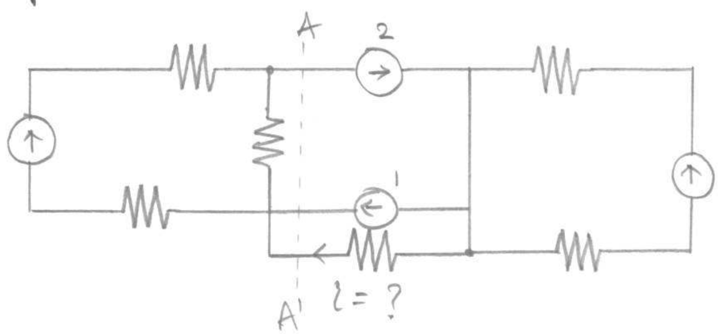


total current coming in AA' = total current going out AA'



from this principle $i = 1$

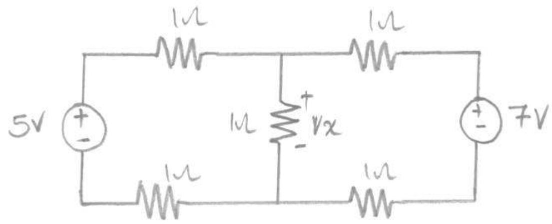
Other example



Across AA'

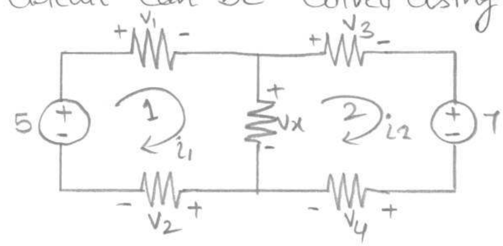
$$2 - 1 - i = 0$$
$$i = 1$$

2. find V_x in the following Circuit



Solution :

Above Circuit Can be Solved using loop analysis (KVL)



Applying KVL in loop 1 :

$$V_1 + V_x + V_2 - 5 = 0 \quad \text{—— (1)}$$

(Observe that sign is used according to + or − appearing first on an element while traversing the Loop)

Similarity for loop 2

$$V_3 + 7 + V_4 - V_x = 0 \quad \text{—— (2)}$$

Applying ohm's law :

$$V_1 = i_1 * 1 \;,\; V_2 = i_1 * 1 \;,\; V_3 = i_2 * 1 \;,\; V_4 = i_2 * 1$$

where as the Current through the resistor across which voltage drop is $V_x = (i_1 - i_2) * 1$

$$V_x = (i_1 - i_2) * 1$$

Replacing V_1 to V_4 & V_x in 1 & 2

$$i_1 + i_1 + (i_1 - i_2) - 5 = 0 \quad \text{— 1A}$$

$$i_2 + 7 + i_2 - (i_1 - i_2) = 0 \quad \text{— 2A}$$

Simplyfying 1A & 2A

$$3i_1 - i_2 = 5 \quad \text{— 1B}$$

$$-i_1 - 3i_2 = -7 \quad \text{— 2B}$$

Solving 1B & 2B

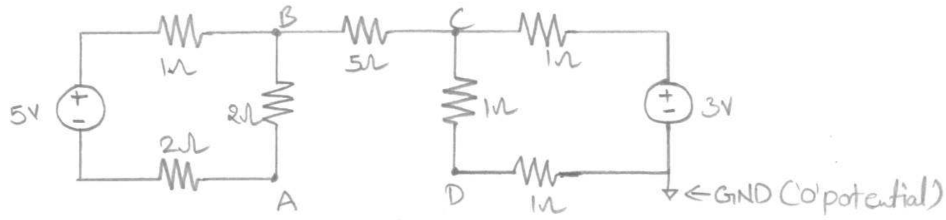
$$i_2 = -2A \,,\; i_1 = 1A$$

Negative Sign for i_2 means actual direction of current in loop2 is opposite to what is assumed

$$V_x = (i_1 - i_2) * 1 = [1 - (-2)] * 1 = 3V$$

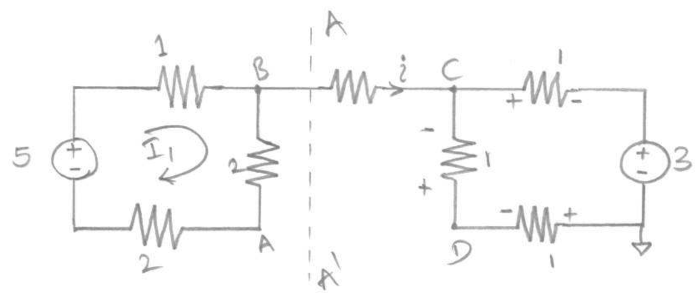
KCL + KVL

3)



Find V_A (potential at node A) in the above circuit (with respect to ground)

Solution:



According to KCL, current through 5Ω resistor (BC) i will be ZERO, as there is no path between AD for current to return

So, I_1 loop 1 and loop 2 can be solved independently

Only purpose of 5Ω resistor is that $V_B = V_C$

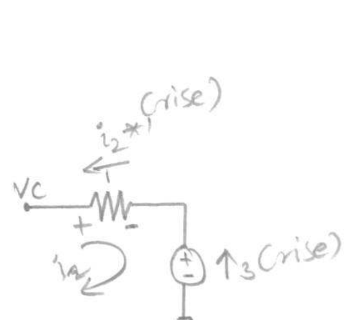
$$\text{Because } V_B - V_C = 5 * i = 5 * 0 = 0$$

$$\Rightarrow V_B = V_C$$

In loop2

$$i_2 * 1 + 3 + i_2 * 1 + i_2 * 1 = 0$$

$$i_2 = \frac{-3}{3} = -1$$



$$V_C = 0 + 3 + i_2 * 1$$

$$= 3 + (-1) * 1 = 2$$

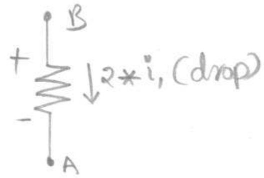
$$V_B = V_C = 2V$$

For loop 1, applying KVL

$$i_1 * 1 + i_1 * 2 + i_1 * 2 - 5 = 0$$

$$5 i_1 = 5$$

$$i_1 = 1A$$



$$V_A = V_B - 2i_1$$

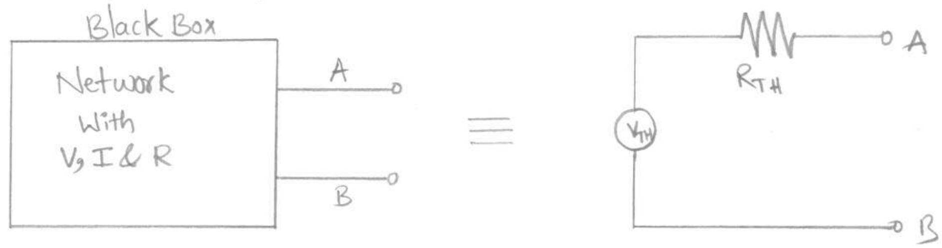
$$V_A = 2 - 2*1$$

$$= 0V$$

Thevenin, Norton & Superposition Theorems

Thevenin's theorem:

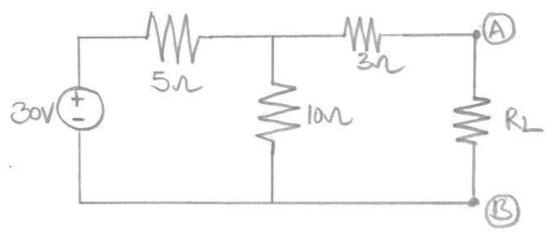
Any linear electrical network with any Combination of voltage Sources, current Sources and resistances can be replaced at terminals A-B by an equivalent voltage Source V_{TH} in Series Connection with equivalent resistance R_{TH}.



The theorem allows us to replace large network partially or Completely with equivalent voltage Source & Series resistance to Simplify the analysis

Example:

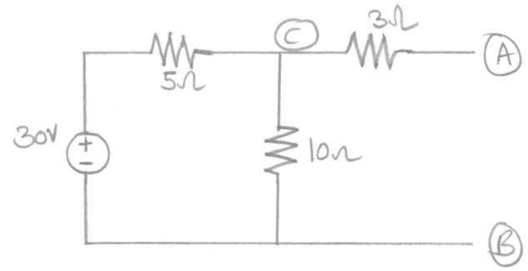
1)



find V_{TH} & R_{TH} for above Circuit

Step 1: Find V_{TH}

To find V_{TH} open R_L (Terminals A&B have infite resistance across them which means no Current flows through them (A&B)



Note that no current flows through 3Ω resistor Hence, nodes Ⓐ & Ⓒ have same potential

By voltage division,

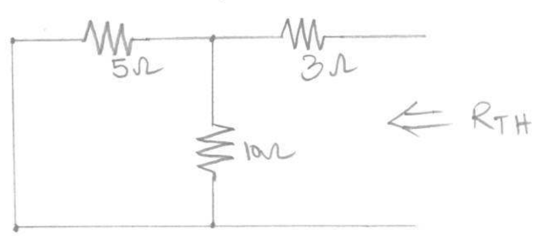
$$V_C = V_A = \frac{10}{15} \cdot 30 = 20V$$

$$\boxed{\therefore \quad V_{TH} = 20V}$$

Step 2: Find R_{TH}

To find R_{TH}, each independant source should be replaced with its internal resistance

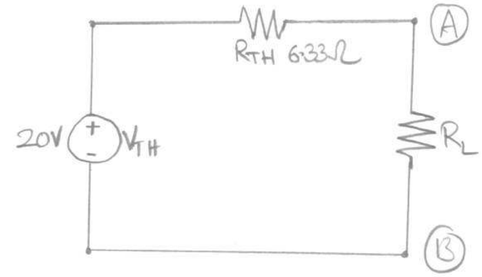
For ideal voltage source internal resistance is zero, while for ideal current source internal resistance is infinite. Hence, V source is replaced with short while current source with open circuit



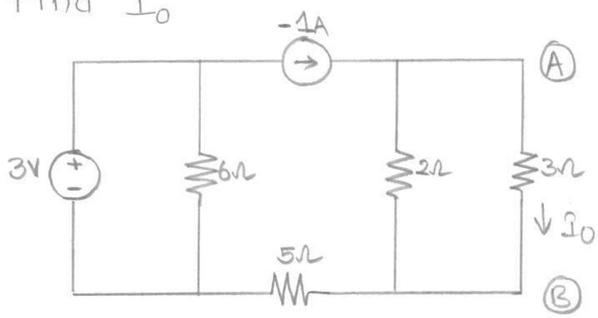
$$R_{TH} = 3 + \left(\frac{5 \times 10}{5+10}\right) = 3 + 3.33$$

$$\boxed{R_{TH} = 6.33\Omega}$$

Equivalent Circuit →



2) Find I_o



V_{oc} → open circuit Voltage

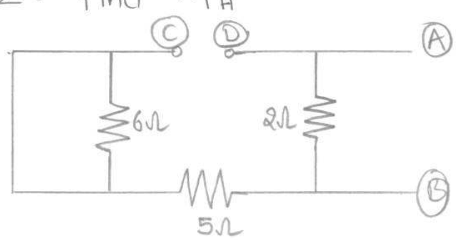
Step 1 : Find $V_{oc} = V_{AB}$

Open 3Ω resistance

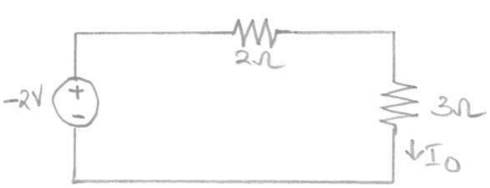
It is Clear that −1A Current flows via 2Ω. Hence $V_{oc} = -2V$

(Note that −ve Sign indicates potential at B is greater than A)

Step 2 : Find R_{TH}



Note that Circuit is open between C and D Hence $R_{TH} = 2\Omega$

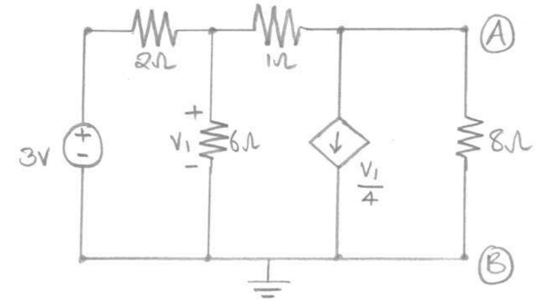


Equivalent Circuit

Hence, $I_o = \frac{-2}{5} = \underline{\underline{-0.4A}}$

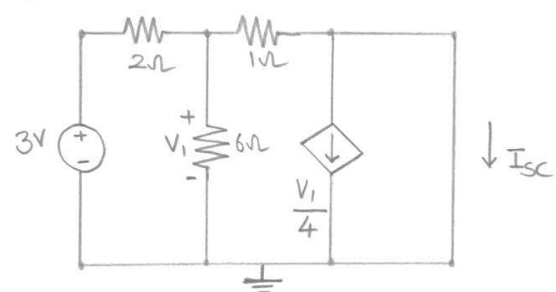
Norton's Theorem

1)



Find voltage across 8Ω resistor by Norton's theorem

Step 1: Short 8Ω resistor and find I_{SC}



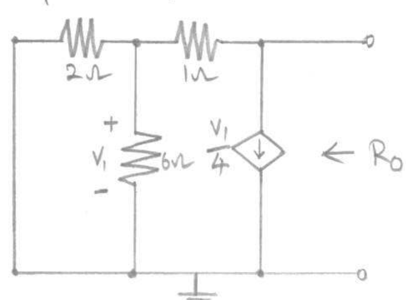
By KCL, $\frac{3 - V_1}{2} = \frac{V_1}{1} + \frac{V_1}{6}$

$\therefore \frac{3}{2} = \frac{10}{6} V_1 \Rightarrow V_1 = \frac{9}{10}$ V

$\therefore I_{SC} = \frac{V_1}{1} - \frac{V_1}{4} = \frac{3}{4} * \frac{9}{10} = \frac{27}{40}$

$= 0.675$A

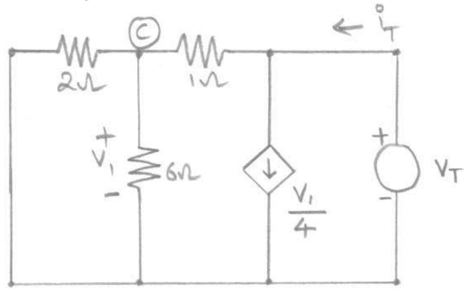
Step 2: find R_0



Note that only independant Sources are ~~replacement~~d with their internal resistance

To find R_o we will add test source V_T at output & measure i_T Then

$$R_o = \frac{V_T}{i_T}$$



$$i_T = \frac{V_1}{4} + \frac{V_T - V_1}{1} \qquad \text{--- (1)}$$

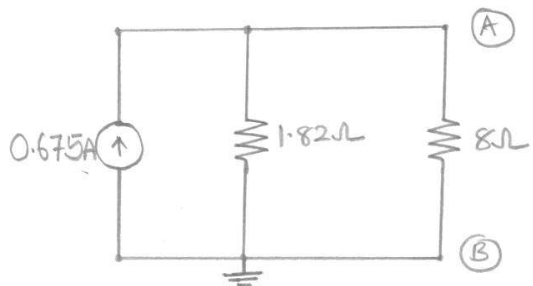
At node ©
$$\frac{V_T - V_1}{1} = \frac{V_1}{6} + \frac{V_1}{2}$$

$$\therefore V_T = \frac{10}{6} V_1 \qquad \therefore V_1 = \frac{6}{10} V_T$$

$$\therefore i_T = V_T - \frac{3}{4} V_1 = V_T - \frac{9}{20} V_T$$

$$\therefore R_o = \frac{V_T}{i_T} = \frac{20}{11}\,\Omega = 1.82\,\Omega$$

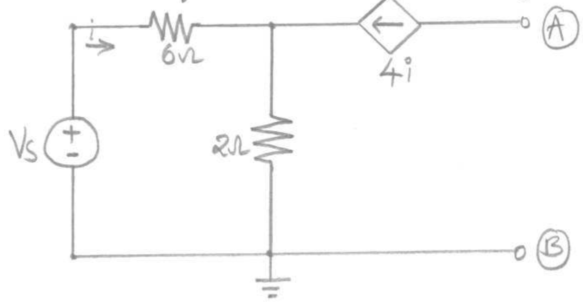
∴ Norton's equivalent ckt is -



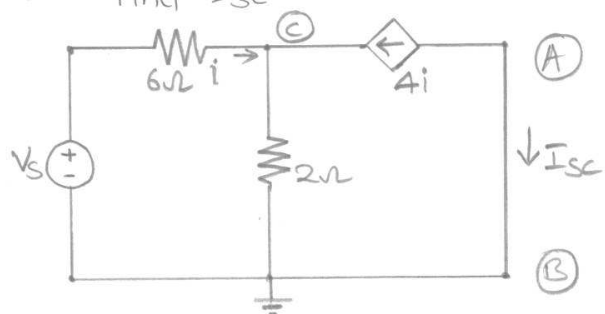
Hence, voltage across 8Ω resistor is -

$$V_{AB} = 0.675\,(1.82 \parallel 8)$$
$$\doteq 1V$$

Q) Find Norton's equivalent of following network. Comment on result



Step 1: Find I_{sc}



At node ⓒ,

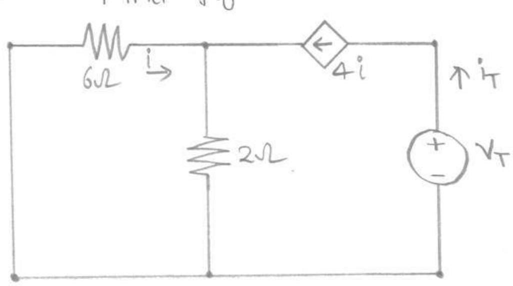
$$V_C = 2(5i) = 10i$$

But,

$$i = \frac{V_S - V_C}{6}$$

$$\therefore \quad i = \frac{V_S - 10i}{6} \qquad \therefore I_{sc} = +i = \frac{V_S}{16}$$

Step 2: Find R_0



V_T is test Voltage Source

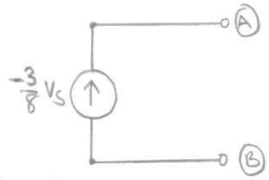
Note that current $i_T = 4i$

Hence i_T is independent of V_T

$$\therefore R_0 = \frac{\Delta V_T}{\Delta i_T} = \infty \text{ (infinite)}$$

(4)

Hence, Norton's equivalent is

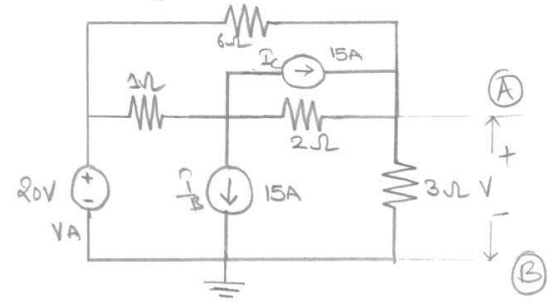


Clearly above circuit represents ideal current Source

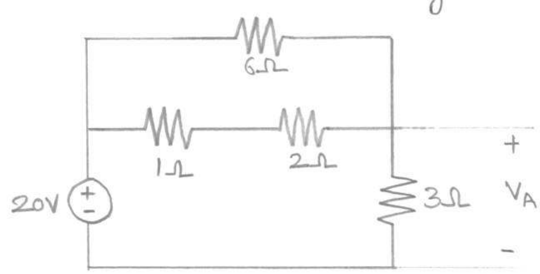
moreover, Can you observe topological similarity with equivalent circuit of Common base amplifier

Superposition Theorem:

1) Find 'v' using Superposition theorem:



Step 1: Consider effect of only V_A

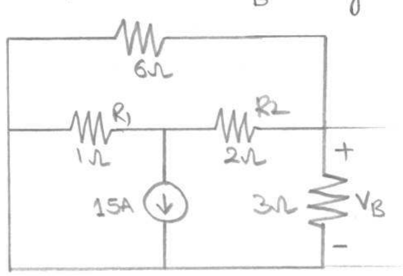


$6 \| 3\Omega = 2\Omega$

$V_A = \frac{3}{2+3} \times 20$

$V_A = 12V$

Step 2: Effect of I_B only



Note that 3Ω and 6Ω are in Parallel

$\therefore$ R_{eff} (parallel R) $= 2\Omega$

By Current distribution current through R_2

$I_{R2} = \frac{1}{1+4} \cdot (-15)$

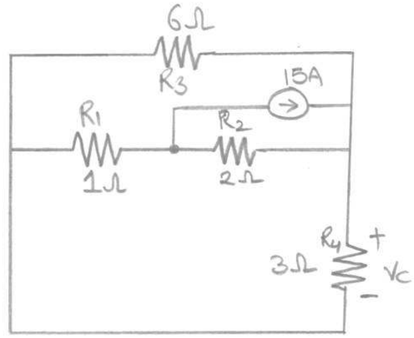
$= -3A$

This current flows through Reff creating voltage drop V_B

$\therefore V_B = (-3A)(2\Omega) = -6V$

Negative sign indicates polarity of V_B is opposite of assumed value.

Step 3: Effect of I_c Only



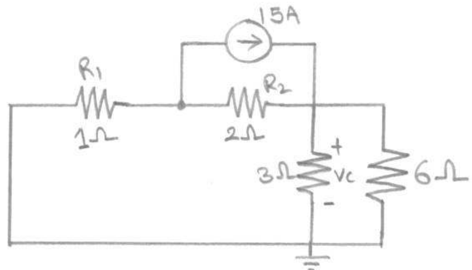
Note that R_3 and R_4 are in parallel

$R_{eff} = R_3 \| R_4 = 2\Omega$

Also, this Reff is in Series with

R_1 and $(R_1 + R_{eff})$ is Parallel to R_2

≡



By current division, Current through R_2 is

$$I_{R_1} = \frac{R_{eff} + R_1}{R_{eff} + R_1 + R_2} \cdot I_c$$

$$= \frac{3}{5} \cdot 15 = 9A$$

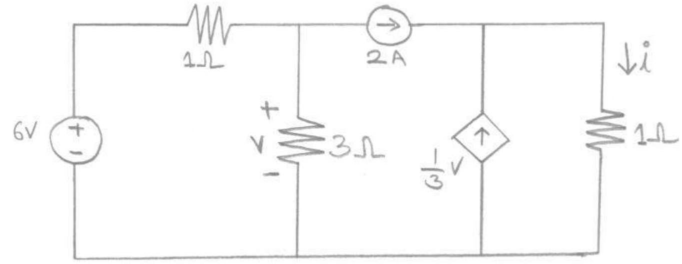
$\therefore$ Voltage $V_c = (15 - 9) \cdot 2 = 12V$

Step 4: find Voltage V_{AB} by addition of all Components

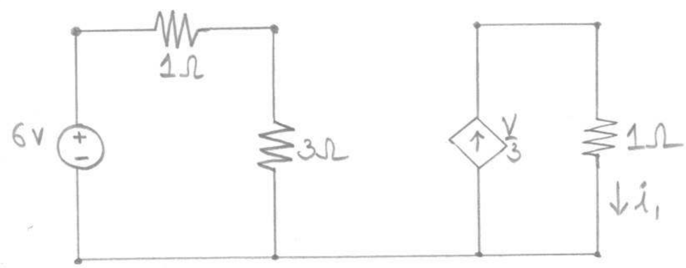
$\therefore V = V_A + V_B + V_c = 18V$

Texas Instruments

2) Find i in following circuit:



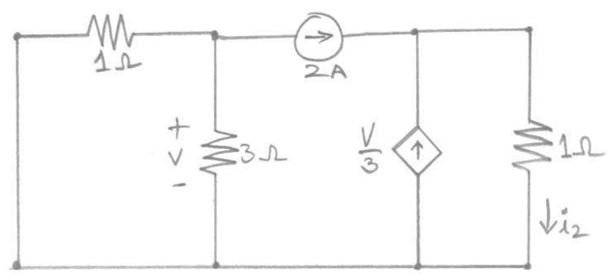
Step 1: Effect of 6V Source



$$V = \frac{3}{1+3} \cdot 6 = 4.5V$$

$$\therefore i_1 = \frac{4.5}{3} = 1.5A \quad \text{—— (1)}$$

Step 2: Effect of 2A Source



Current through 3Ω resistor $= \frac{1}{1+3}(-2) = -0.5$ A

$$\therefore V = (-0.5)(3) = -1.5V$$

$$\therefore i_2 = 2 + -\frac{1.5}{3} = 1.5A$$

Step 3:

Total Current by Super position theorem $= i_1 + i_2$

$= 3A$

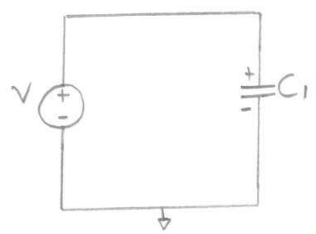
Charge conservation in a capacitor

→ Charge Conservation in a Capacitor

According to change Conservation theory:

$$\boxed{\text{Initial charge} = \text{final charge}}$$

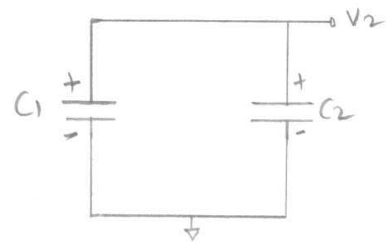
Consider a capacitor that is Connected to a voltage Source (v) as shown below



In a steady state charge stored in capacitor is given by

$$\boxed{Q_1 = C_1 V}$$

Now Suppose this charged capacitor is disconnected them voltage Source and Connected back in parallel to another Capacitor C2,



Charge stored in new Configuration is →

$$Q_F = C_1V_2 + C_2V_2$$

By charge Conservation theory →

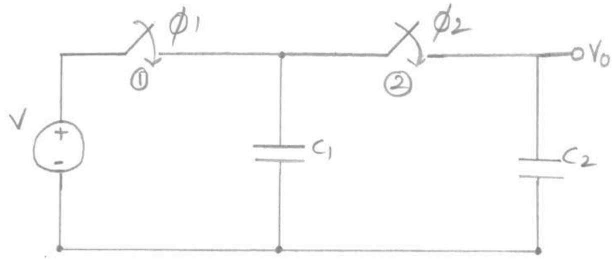
$$Q_I = Q_F$$

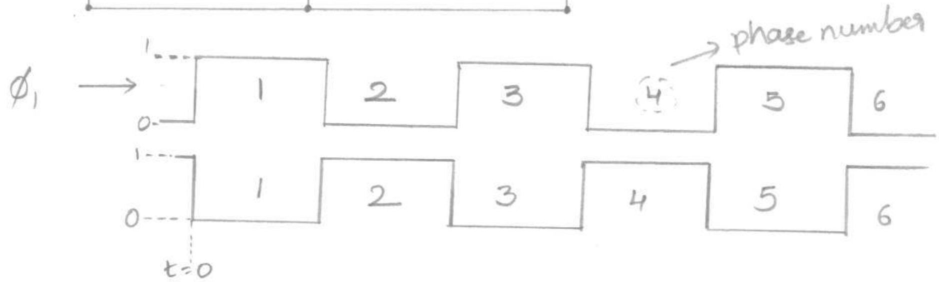
$$C_1V = C_1V_2 + C_2V_2$$

Therefore V_2 is given by →

$$\boxed{V_2 = \left(\frac{C_1}{C_1+C_2}\right)\cdot V}$$

Q1. For below circuit calculate o/p voltage $V_0 \xrightarrow{\text{with time}}$





- Assume both the capacitors are charged to 0V at t=0
- When $\phi_1 = 1$, Switch 1 will be ON
  $\phi_1 = 0$, Switch 1 will be OFF

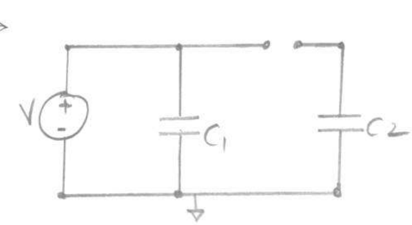
Same is true for switch 2

Sol) → At phase 1 ⟶

Charge in $C_1 \longrightarrow C_1 \cdot V$

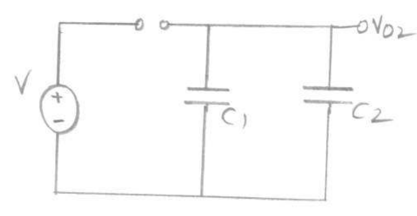
$C_2 \longrightarrow C_2 \times 0 = 0$

$\boxed{V_{01} \longrightarrow 0}$



→ At phase 2 ⟶

Total charge ⟶ $(C_1+C_2)V_{02}$



By charge conservation theory

Charge in phase 1 = Charge in phase 2

$$C_1 V + 0 = (C_1 + C_2)V_{02}$$

$$\boxed{V_{02} = \left(\frac{C_1}{C_1+C_2}\right)V}$$

(3)

At phase (3) →

Charge in $C_1 \rightarrow C_1 V$

$C_2 \rightarrow C_2 V_{02}$

In this phase o/p voltage v_0 will remain Same as that of Phase 2, as there is no discharge path

$$V_{03} = \left(\frac{C_1}{C_1+C_2}\right) V = V_{02}$$

$$\text{Total charge} = C_1 V + C_2 V_{02}$$

→ At phase (4) →

$$\text{Total charge} = (C_1+C_2)\, V_{04}$$

$$\text{Charge in phase 3} = \text{charge in phase 4}$$

$$C_1 V + C_2 V_{02} = (C_1+C_2)\, V_{04}$$

$$\therefore \quad V_{04} = \frac{C_1}{C_1+C_2} \cdot V + \frac{C_2}{C_1+C_2} \cdot \left(\frac{C_1}{C_1+C_2}\right) V$$

$$V_{04} = \frac{C_1}{C_1+C_2}\left(1 + \frac{C_2}{C_1+C_2}\right) V$$

→ At phase (5) →

Charge in $C_1 = C_1 V$

$C_2 = C_2 V_{04}$

$$\text{Total charge} = C_1 V + C_2 V_{04}$$

O/p voltage

$$\boxed{V_{05} = V_{04}}$$

→ At phase ⑥ →

Total charge $= (C_1 + C_2) V_{06}$

Charge in phase 5 = charge in phase 6

$$C_1 V + C_2 V_{04} = (C_1 + C_2) V_{06}$$

$$\therefore \; V_{06} = \frac{V C_1}{C_1 + C_2}\left(1 + \frac{C_2}{C_1} \cdot V_{04}\right)$$

$$\boxed{V_{06} = \frac{V C_1}{C_1 + C_2}\left(1 + \frac{C_2}{C_1 + C_2} + \left(\frac{C_2}{C_1 + C_2}\right)^2\right)}$$

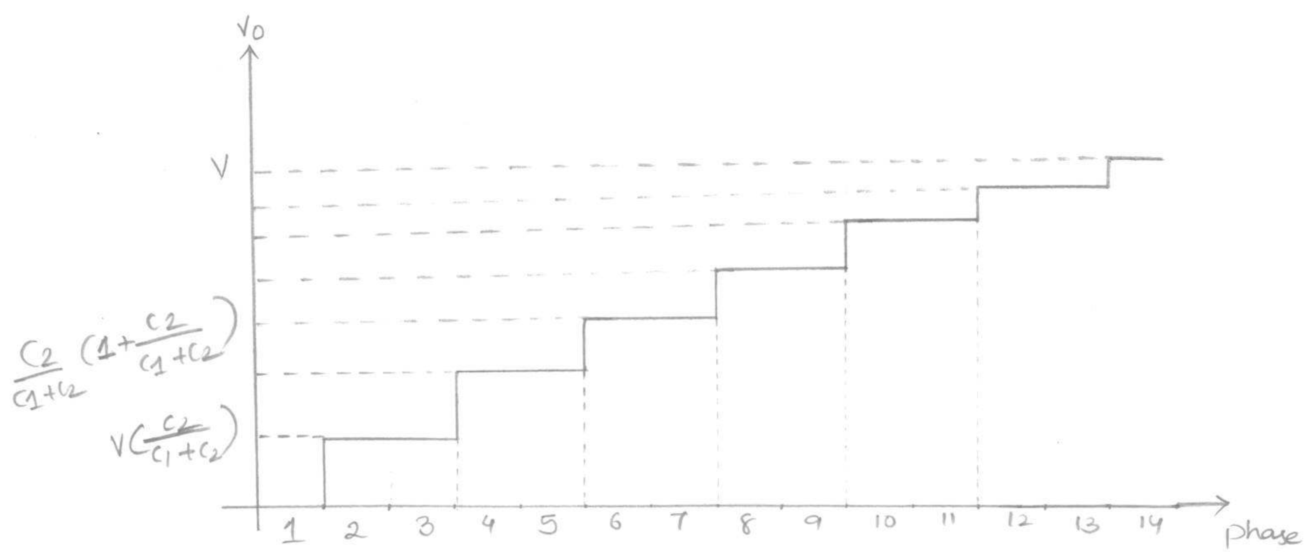
→ At infinite phase →

$$V_{0,\infty} = \frac{V C_1}{C_1 + C_2}\left(1 + \frac{C_2}{C_1 + C_2} + \left(\frac{C_2}{C_1 + C_2}\right)^2 + \left(\frac{C_2}{C_1 + C_2}\right)^3 + \cdots\cdots \infty\right)$$

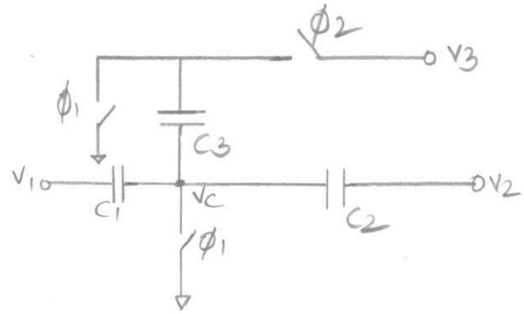
$$= V \cdot \frac{C_1}{C_1 + C_2} \cdot \frac{1}{1 - \frac{C_2}{C_1 + C_2}} = V$$

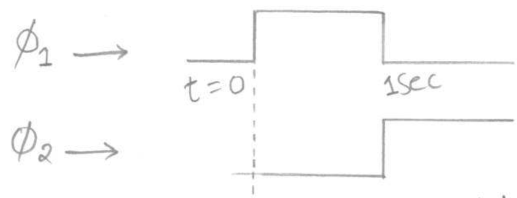
$$\therefore \; \boxed{V_{0\infty} = V}$$

→ Below plot shows V_0 V/s phase →



Q_2.





For the above circuit calculate voltage V_C at $t = 1$ sec

Sol^n,

When ϕ_1 is high $\rightarrow$

Total charge $= C_1(V_1 - 0) + C_2(V_2 - 0) + C_3(0 - 0)$

$= C_1 V_1 + C_2 V_2$

When ϕ_2 is high $\rightarrow$

Total Charge $= C_1(V_1 - V_c) + C_2(V_2 - V_c) + C_3(V_3 - V_c)$

Charge in ϕ_1 = Charge in ϕ_2 phase

$$C_1 V_1 + C_2 V_2 = C_1(V_1 - V_c) + C_2(V_2 - V_c) + C_3(V_3 - V_c)$$

$$\cancel{C_1 V_1} + \cancel{C_2 V_2} = \cancel{C_1 V_1} + \cancel{C_2 V_2} + C_3 V_3 - V_C(C_1 + C_2 + C_3)$$

$$\boxed{V_C = \frac{C_3 V_3}{C_1 + C_2 + C_3}}$$

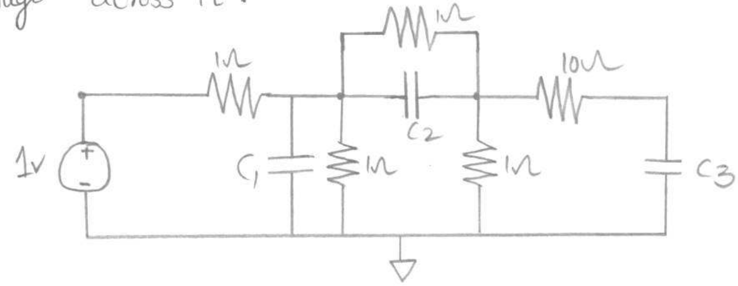
Transients in circuits with R,C and switches

→ final Condition in RC Circuits →

Points to remember →

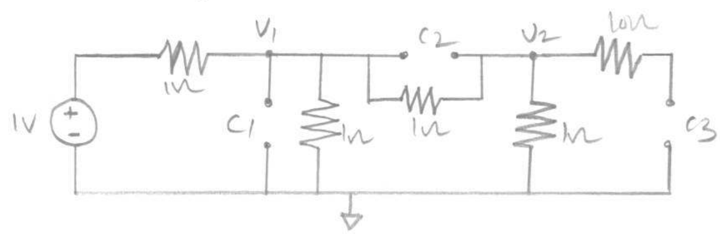
1) In steady State, Capacitor behaves as an open Circuit for DC Input
2) To change voltage across capacitor instantaneously, it requires infinite Current via it
3) In steady State inductor behaves as a short circuit for DC Input
4) To Change Current via inductor instantaneously it requires infinite voltage across it.

Q1.



for above Circuit calculate voltage that each Capacitor gets charged to in a steady state

Soln. In steady state above Circuit will look like



Apply KCL at node 1

$$\frac{(V_1 - 1)}{1} + \frac{V_1}{1} + \frac{V_1 - V_2}{1} = 0$$

KCL at node 2 →

$$\frac{V_2 - V_1}{1} + \frac{V_2}{1} = 0$$

$$V_2 = \frac{1}{2} V_1$$

$$3V_1 = 1 + V_2$$

$$3V_1 - V_2 = 1$$

$$3V_1 - \frac{1}{2} V_1 = 1 \Rightarrow V_1 = \frac{2}{5} V$$

&

$$V_2 = \frac{1}{5} V$$

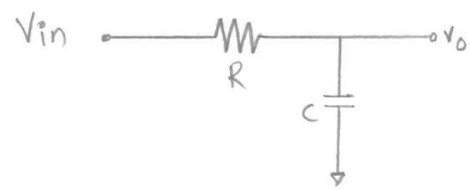
So, C_1 will get charged

$$\boxed{V_1 = 2/5}$$

$$C_2 \rightarrow \boxed{V_1 - V_2 = \frac{2}{5} - \frac{1}{5} = 1/5 \ V}$$

$$C_3 \rightarrow \boxed{V_2 = 1/5 \ V}$$

Q2.



In RC Circuit, Square wave as shown above, is applied. plot output waveform for:

Case I $\rightarrow$ $RC << T$

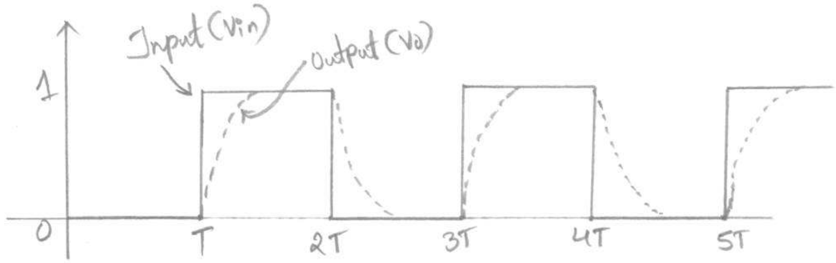
Case II $\rightarrow$ $RC >> T$

under steady state Condition

Sol:

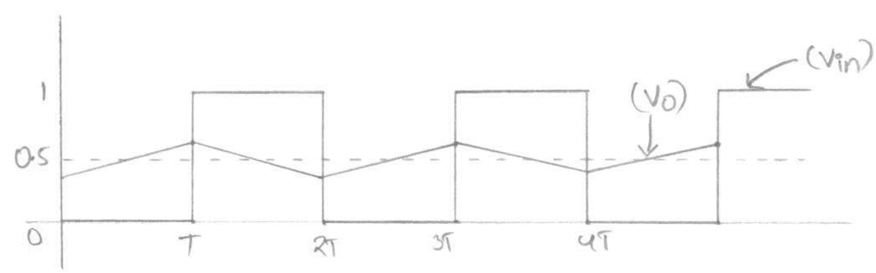
Case 1) → RC << T

→ RC is a time Constant of a Circuit. If RC time Constant is less than Square wave time period, output waveform will Settle down to input level & will look like.

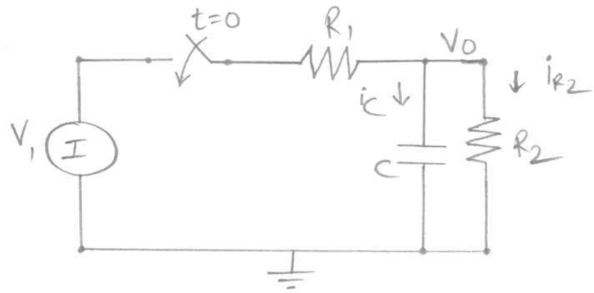


Case II) → RC >> T

→ If RC time Constant is ~~less~~ larger than T, then Circuit will not respond much to the input but under steady State, this Circuit will Settle to equivalent DC level of an Input



Q.1 Plot v_o, i_c, i_{R_2} for the circuit shown below, if the switch is closed at $t=0$



For $t>0$, writing KCL for the output node,

$$\frac{V_o}{R_2} + C\cdot\frac{dV_o}{dt} + \frac{V_o}{R_1} = \frac{V_1}{R_1}$$

$$\frac{dv_o}{dt} + \frac{V_o}{C}\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{V_1}{R_1C} \quad \text{—— (1)}$$

The solution to the above equation is found by solving the characteristic equation ($V_1 = V_1 = 0$)

$$\frac{dv_o}{dt} + \frac{V_o}{C}\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = 0 \quad \text{—— (2)}$$

The solution to eq^n (2) can be of the form

$V_o = Ke^{-t/\tau} + C_1$ where K & C_1 are constants

At $t=0^+$ $V_o = 0$ $\qquad \tau = C\left(\frac{R_1R_2}{R_1+R_2}\right) = C(R_1 \| R_2)$

$0 = K + C_1$

$K = -C_1$

At $t=\infty$ $\quad V_o = \frac{V_1R_2}{R_1+R_2}$

$$\frac{V_1 \cdot R_2}{R_1 + R_2} = C_1 \quad \Rightarrow K = \frac{-V_1 \, R_2}{R_1 + R_2}$$

Therefore,

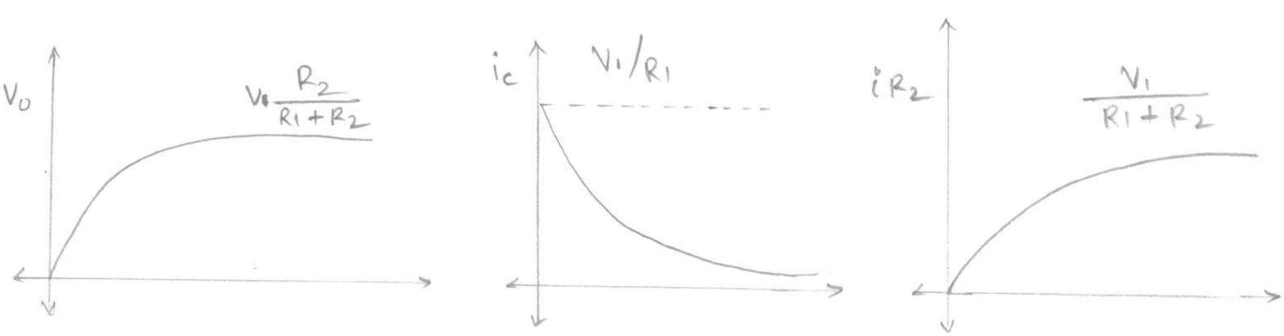
$$V_0 = \frac{V_1 \, R_2}{R_1 + R_2} \left(1 - e^{-t/\tau}\right)$$

$$i_C = \frac{C \cdot dv_0}{dt} = C \cdot \frac{V_1 \cdot R_2}{R_1 + R_2} \cdot \frac{1}{\tau} \cdot e^{-t/\tau}$$

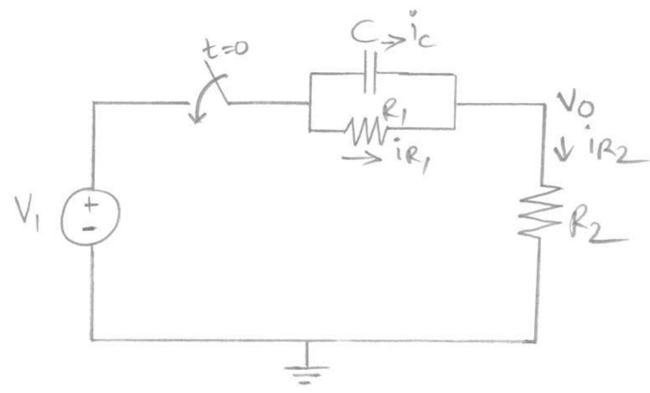
$$i_C = \frac{V_1}{R_1} e^{-t/\tau}$$

$$i_{R_2} = \frac{V_0}{R_2} = \frac{1}{R_2} \cdot V_1 \cdot \frac{R_2}{R_1 + R_2} \cdot \left(1 - e^{-t/\tau}\right)$$

$$= \frac{V_1}{R_1 + R_2} \left(1 - e^{-t/\tau}\right)$$



Q.2 If the Switch is closed at $t=0$, plot $V_0, i_C, i_{R_2}, i_{R_2}$ 3



For $t>0$, Writing KCL for Output node,

$$\frac{V_0}{R_2} + \frac{V_0}{R_1} + \frac{C\,dv_0}{dt} = \frac{V_1}{R_1} + C.\frac{dv_1}{dt}$$

$$\frac{dv_0}{dt} + \frac{V_0}{C}\cdot\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{V_1}{R_1 C} + \frac{dv_1}{dt}$$

$\frac{dv_1}{dt}=0$, $V_1=0$ gives us the Characteristic equation

$$\frac{dv_0}{dt} + \frac{V_0}{C}\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = 0$$

$\therefore\ V_0 = k\,e^{-t/\tau} + C_1$ where k, C_1 are Constants

$$\tau = C.\frac{R_1 R_2}{R_1+R_2} = C(R_1 \parallel R_2)$$

At $t=0$, C appears like a Short ckt

$V_0 = V_1$

$V_1 = k + C_1$

At $t=\infty$, C appears like open ckt

$$V_0 = V_1 \cdot \frac{R_2}{R_1+R_2} = 0 + C_1$$

$$C_1 = V_1 \cdot \frac{R_2}{R_1+R_2}$$

$$K = V_1 \frac{R_1}{R_1 + R_2}$$

$$\therefore \quad V_o = \frac{V_1 \cdot R_1}{R_1 + R_2} \cdot e^{-t/\tau} + V_1 \cdot \frac{R_2}{R_1 + R_2}$$

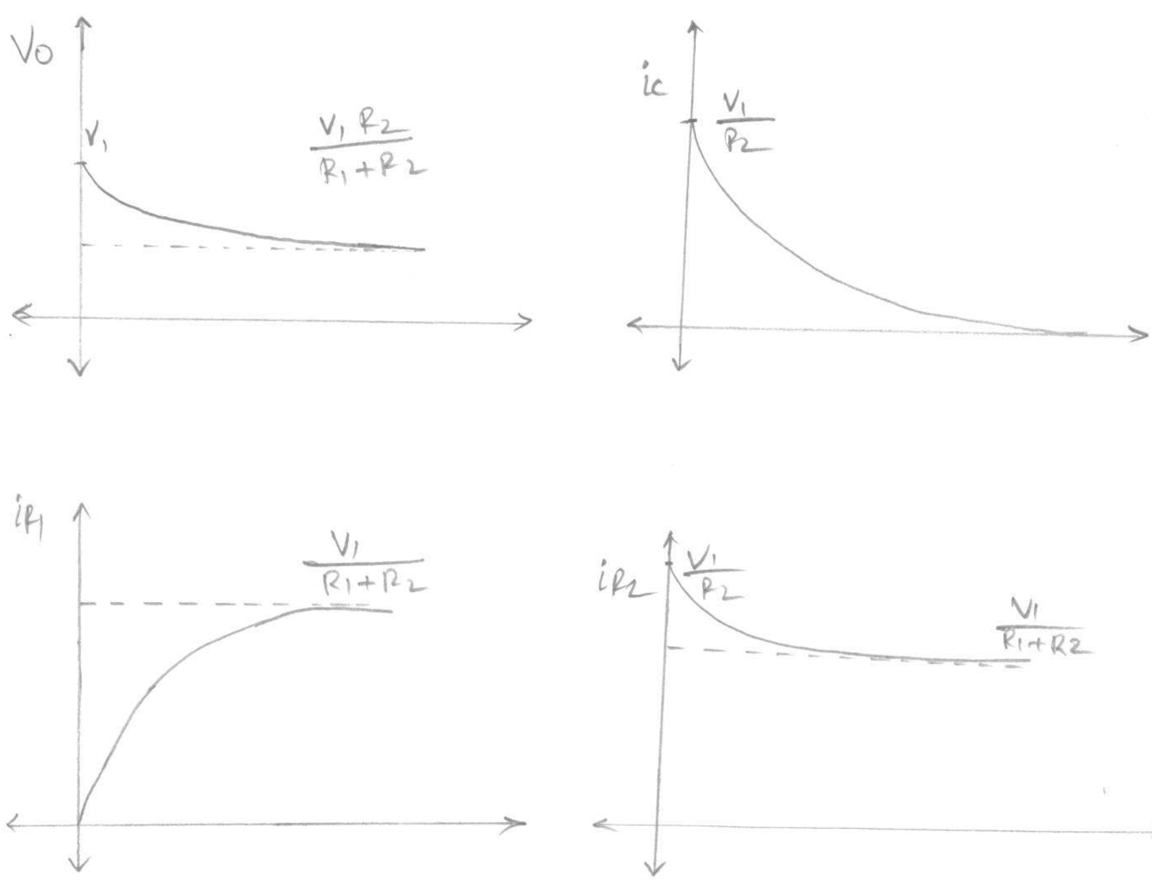
$$V_o = \frac{V_1}{R_1 + R_2} \left(R_1 e^{-t/\tau} + R_2 \right)$$

$$i_C = C \cdot \frac{d}{dt} (V_1 - V_0) = C \cdot \frac{V_1}{R_1 + R_2} \cdot R_1 \frac{1}{\tau} \cdot e^{-t/\tau}$$

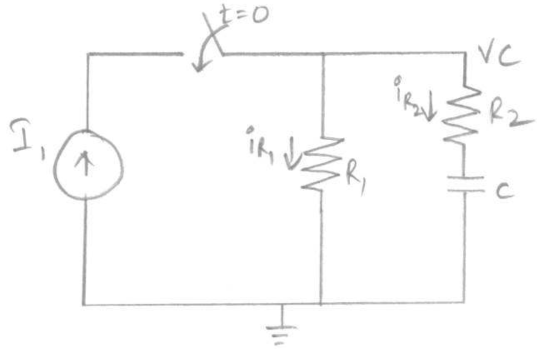
$$i_C = \frac{V_1}{R_2} \cdot e^{-t/\tau}$$

$$i_{R_1} = \frac{V_1 - V_o}{R_1} = \frac{V_1}{R_1 + R_2} \left(1 - e^{-t/\tau} \right)$$

$$i_{R_2} = \frac{V_o}{R_2} = \frac{V_1}{R_1 + R_2} \left(\frac{R_1}{R_2} \cdot e^{t/\tau} + 1 \right)$$



Q_3. For the ckt shown below, if the switch is closed at $t=0$, plot v_c, i_{R2}, i_{R1} ⑤

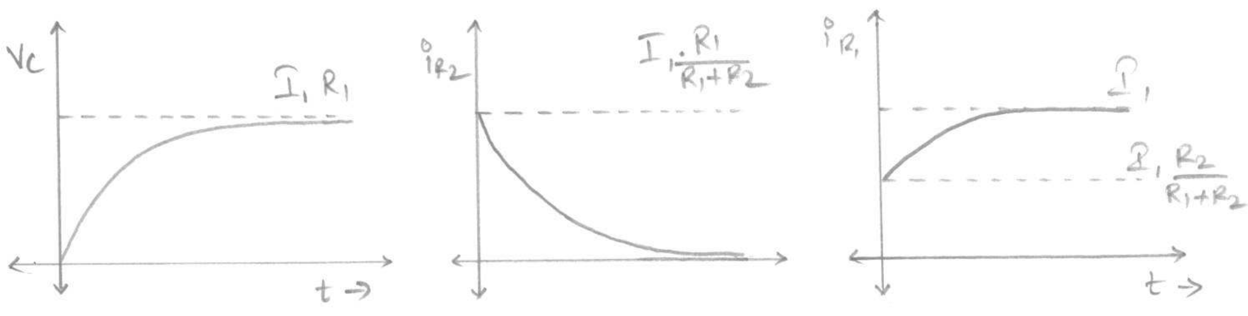


Sol^n

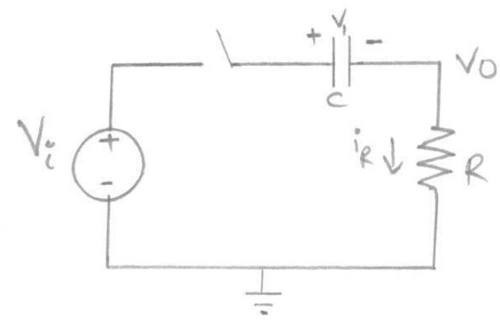
$$V_C = I_1 R_1 (1-e^{-t/\tau}) \quad \text{where} \quad \tau = (R_1+R_2)\cdot C$$

$$i_{R_2} = I_1 \cdot \frac{R_1}{R_1+R_2} \cdot e^{-t/\tau}$$

$$i_{R_1} = I_1\left(1 - \frac{R_1}{R_1+R_2} \cdot e^{-t/\tau}\right)$$

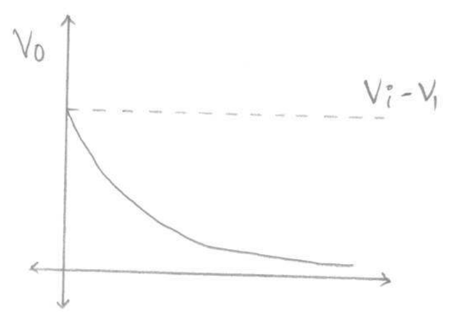


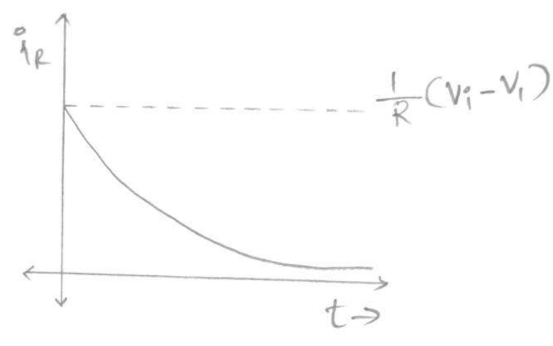
Q4. For the Circuit shown below, if the Voltage across the capacitor is V_1 at $t=0^-$ and the Switch is closed at $t=0$, plot V_0, i_R for $t>0$



$$V_0 = (V_i - V_1)e^{-t/\tau} \qquad \text{where } \tau = RC$$

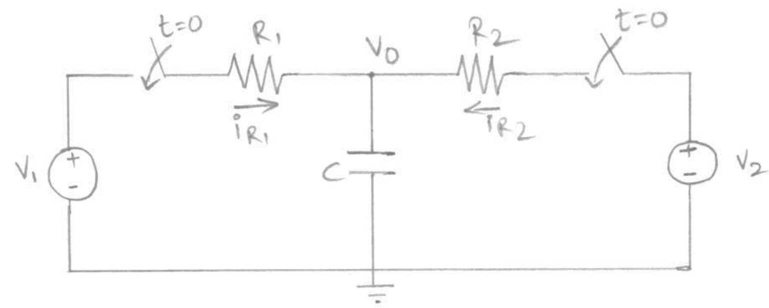
$$i_R = \frac{1}{R}(V_i - V_1)e^{-t/\tau}$$





(7)

Q_5. For the circuit shown below, if both the switches are closed at $t=0$, plot V_0, i_{R_1}, i_{R_2}



Sol^n

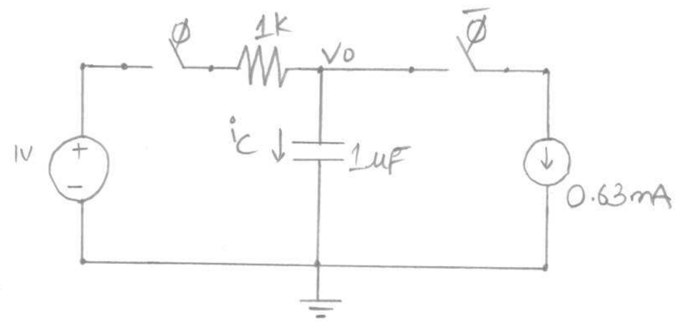
$$V_0 = V_{SS}\left(1 - e^{-t/\tau}\right) \quad \text{where } \tau = C(R_1 \| R_2)$$

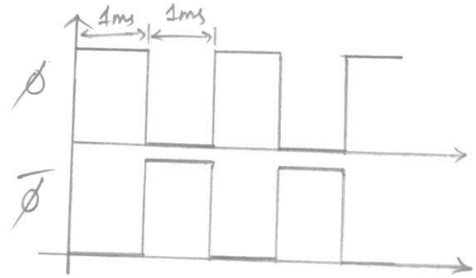
$$V_{SS} = V_1 \cdot \frac{R_2}{R_1+R_2} + V_2 \frac{R_1}{R_1+R_2}$$

$$i_{R_1} = \frac{V_1 - V_2}{R_1 + R_2} + \frac{V_{SS}}{R_1} \cdot e^{-t/\tau}$$

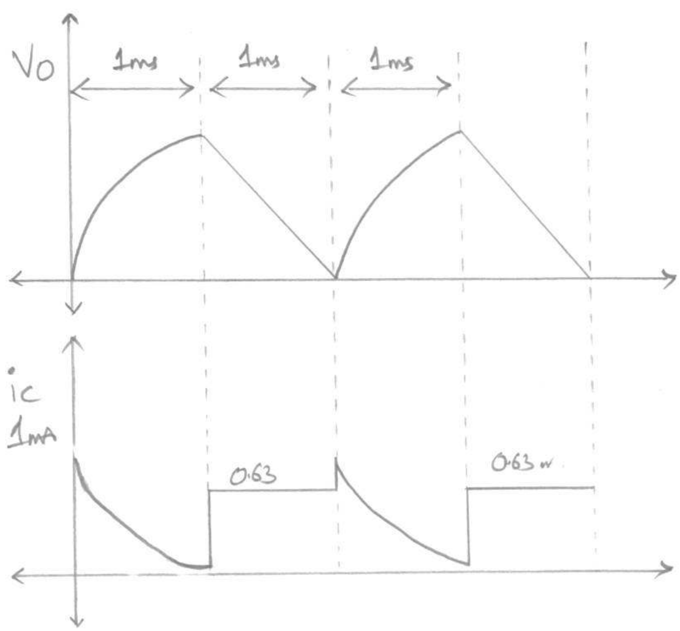
$$i_{R_2} = \frac{V_2 - V_1}{R_1 + R_2} + \frac{V_{SS}}{R_2} \cdot e^{-t/\tau}$$

Q6. For the circuit shown below, if the switches are operated using complementary clocks ϕ and $\bar{\phi}$ as shown plot V_O and i_C

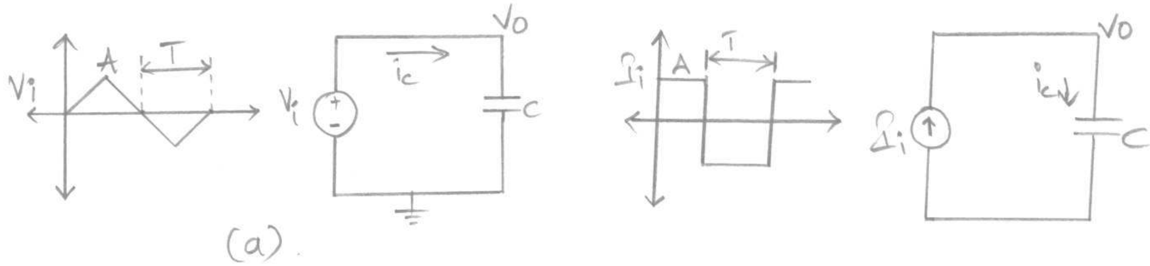




Sol^n.



Q7. Plot V_o, i_c for the circuits shown below



(a)

a) For a Capacitor, $i_c = C \cdot \frac{dv_c}{dt}$

$$V_C = V_i \Rightarrow i_C = C \cdot \frac{dv_i}{dt} \quad \text{- - - - (1)}$$

Equation (1) indicates a useful property of a capacitor, the capacitor current is a derivative of the voltage across it. This property is utilised in many circuits for waveform generation

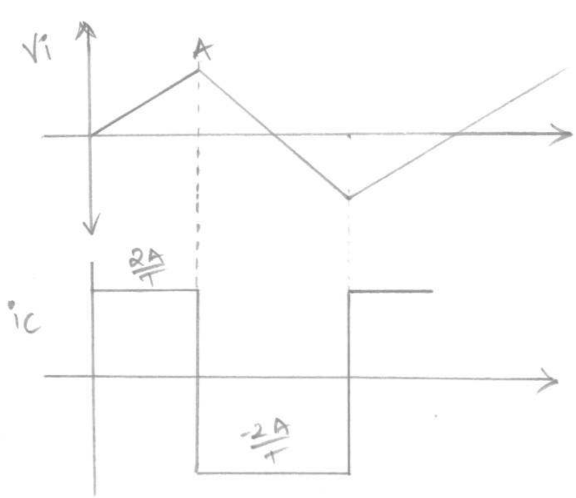
For (a), $V_i = \frac{2A}{T} t$ for $0 < t < \frac{T}{2}$

$= 2A - \frac{2A}{T} \cdot t$ for $\frac{T}{2} < t < \frac{3T}{2}$

Using eq^n (1)

$i_c = \frac{2A}{T}$ for $0 < t < \frac{T}{2}$

$= -\frac{2A}{T}$ for $\frac{T}{2} < t < \frac{3T}{2}$



$V_C = V_i$

for a capacitor, $V_C = \frac{1}{C}\int_0^t I_i \cdot dt + V_C^{0^-}$ — (2)

Where $V_C^{0^-}$ is the initial voltage on capacitor

Equation(2) shows that the current flowing into a capacitor is intigrated to develop the voltage across it. This is a very useful property utilised in many circuits

$$I_i = I_1 \quad \text{for} \quad 0 < t < \frac{T}{2}$$

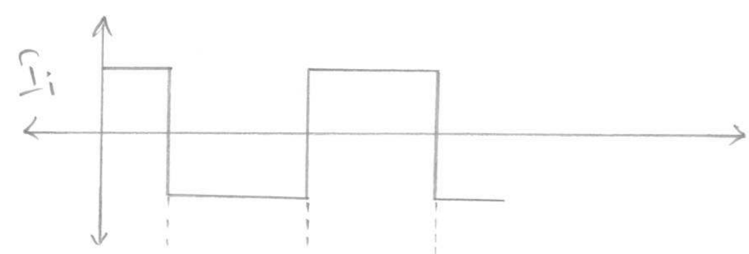
$$= -I_1 \quad \text{for} \quad \frac{T}{2} < t < \frac{3T}{2}$$

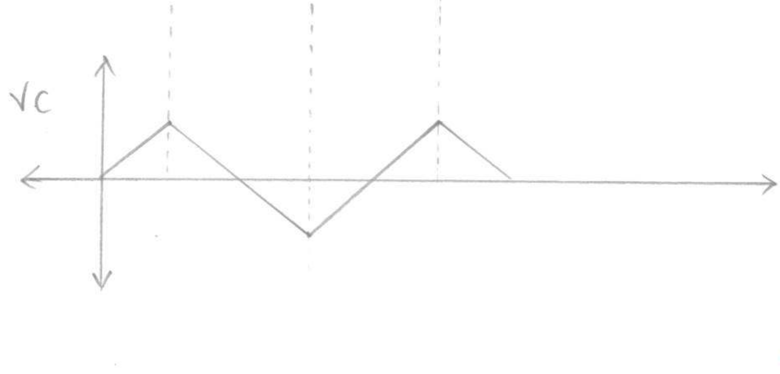
Using eq^n(2) and assuming that initial voltage $V_C^{0^-}$ on the capacitor is zero.

$$V_C = \frac{1}{C}\int_0^t I_1\,dt = \frac{I_1}{C}\cdot t \quad \text{for} \quad 0 < t < \frac{T}{2}$$

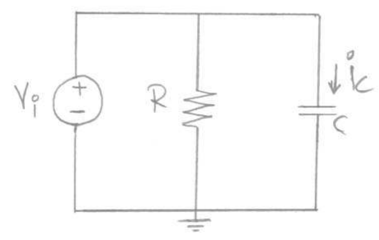
$$= \frac{1}{C}\int_{T/2}^t (-I_1)\cdot dt = \frac{-I_1}{C}\cdot t + \frac{I_1}{C}\cdot\frac{T}{2} \qquad \frac{T}{2} < t < \frac{3T}{2}$$

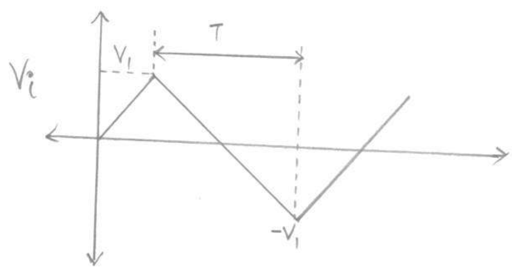
$$i_c = I_i$$





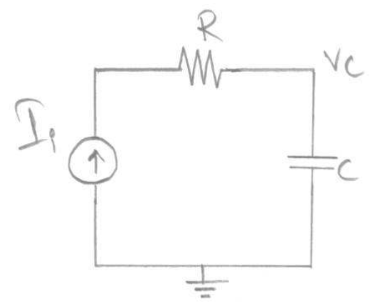
Q8. Plot i_c for the circuit shown below

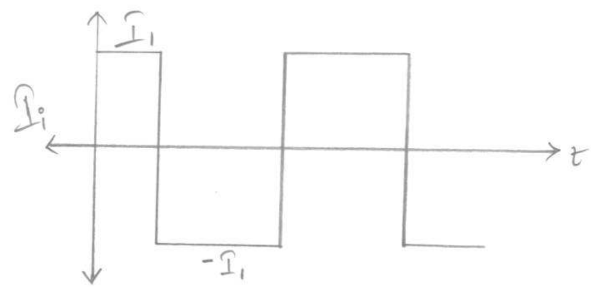




Sol^n → Same as Q.7(a)

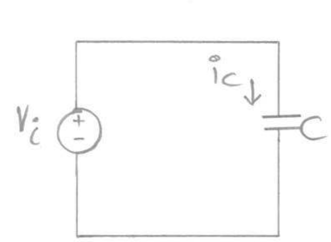
Q.9 Plot V_C for the circuit shown below

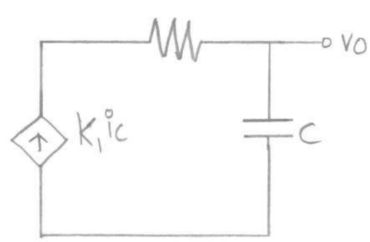


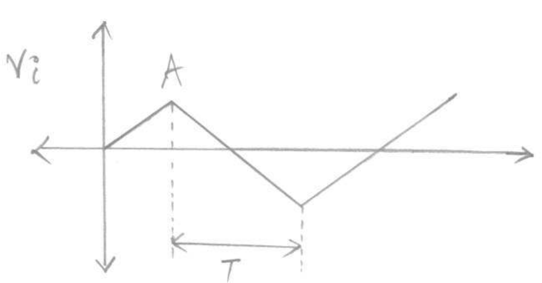


Sol^n → Same as Q.7(b)

Q.10 Plot V_0 for the circuit shown below







t→