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Comprehensive Course on Analog Circuit

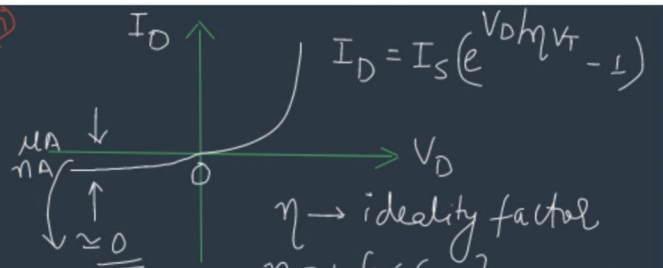
Diode Circuit - Part I

1. Diode with respect to DC source.
2. Clipper Circuit
3. DC Power Supply design
   → Rectifier + filter + Voltage Regulator
4. Clamper
5. Small signal model of diode.

→ Robert L. boylstead
→ Millman Halkias
→ Sedra Smith
} Notes + R.K. Kanodia

Lesson 1 • June 9, 2020 • Kamesh Shrivastava

Diode:



$I_D = I_S\left(e^{V_D/\eta V_T} - 1\right)$

η → ideality factor
$\eta = 1$ for Ge
$\eta = 2$ for Si
} Generally

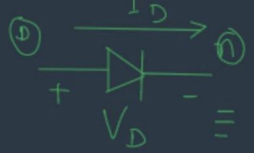
V_T → Thermal voltage
$V_T = T/11{,}600$ T → Kelvin

I_S → Reverse saturation current.

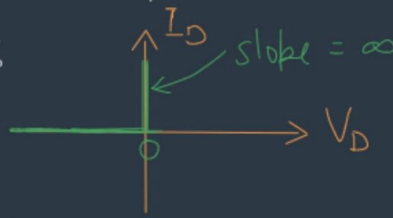
Diode Model:

Diode application → As a switch

① ideal diode:



$\equiv$

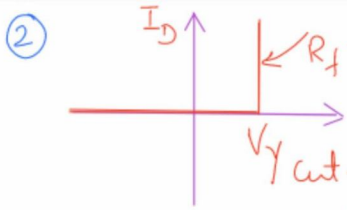


$R_f = 0\Omega$

$V_D < 0 : I_D = 0$: 0A → (R.B)

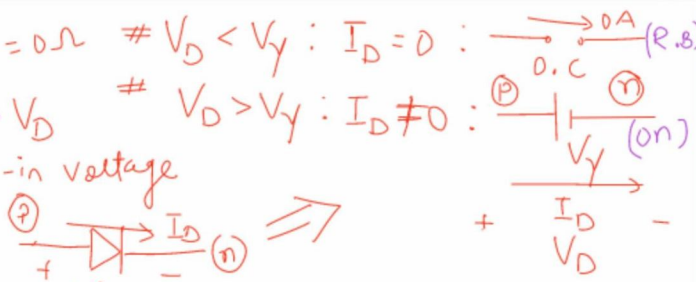
$V_D > 0 : I_D \neq 0$: P → n (f.B.) : 0.C. : S.C → I_D ✓

② $R_f = 0\Omega$

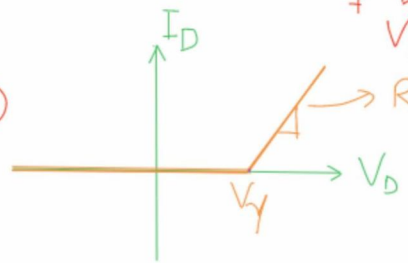


$V_D < V_\gamma : I_D = 0$: 0A → (R.B)

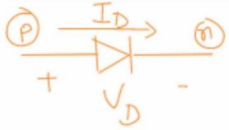
$V_D > V_\gamma : I_D \neq 0$:



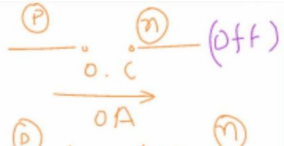
③

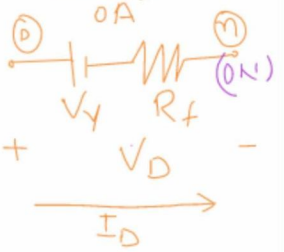


$R_f = \frac{1}{\text{slope}} = 1/\left(\frac{\Delta I_D}{\Delta V_D}\right)$

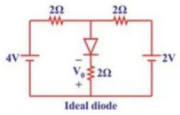


$\equiv$

$V_D < V_\gamma : I_D = 0 :$ 

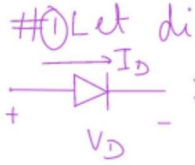
$V_D > V_\gamma : I_D \neq 0 :$ 

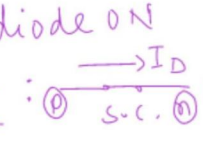
Q.1 Find Vo

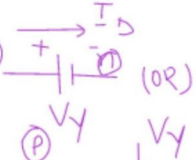


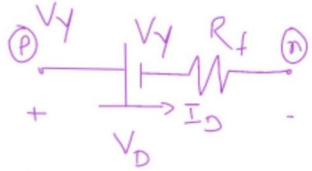
Procedure : (General)

#① Let diode ON



: 

(OR) 

(OR) 

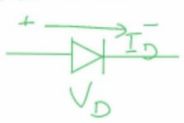
② find I_D

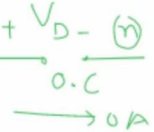
I_D (P to N) :⟶ F.B (ON)

I_D (N to P) ⟶ R.B. (off)

(OR) **2nd way :**

① Let diode off



$\equiv$ 

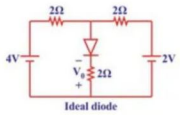
② If $V_D > 0$ (OR) $V_D > V_\gamma$ (or) $V_D > V_\gamma$

: Diode ON ✓

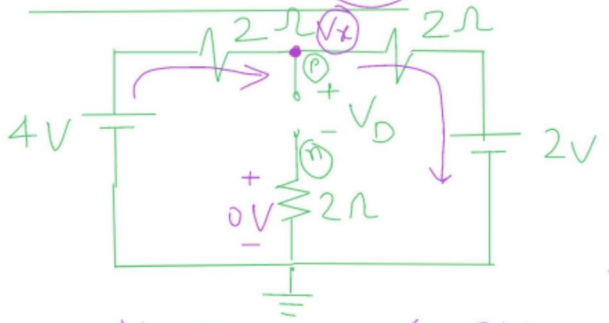
if $V_D < 0$ (OR) $V_D < V_\gamma$ (OR) $V_D < V_\gamma$

: Diode off

Q.1 Find Vo



→ Let diode is (off) :



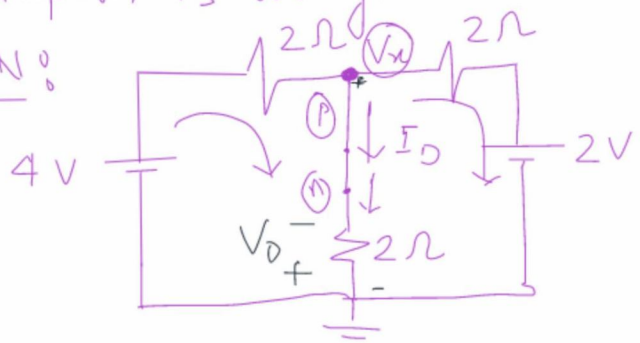
$\frac{4 - V_x}{2} = 0 + \frac{V_x - 2}{2} \Rightarrow 6 = 2V_x$

$\boxed{V_x = 3V} = V_D$

$V_D > 0$: (Diode ON)

Our Assumption is wrong.

Diode ON?



$$\frac{4-V_x}{2} = \frac{V_x-0}{2} + \frac{V_x-2}{2} \Rightarrow 3V_x = 6$$

$$\boxed{V_x = 2V}$$

$$I_D = \frac{V_x-0}{2} = 1A \ (D \to ON)$$

Really diode is ON.

$$V_0 = -V_x = -2V \quad \text{Ans.}$$

Question

Rahul Gupta

sir V_γ and threshold voltage same hai kya?

yes

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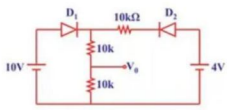
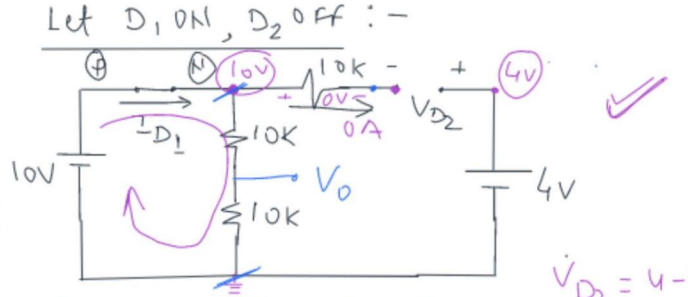
Q2

D1,D2: Ideal. Find Vo



Let D_1 ON, D_2 OFF :-



$$I_{D_1} = \frac{10}{20k} = 0.5mA > 0 \quad \therefore (D_1 \text{ ON})$$

$$V_{D_2} = 4-10$$

$$V_{D_2} = -6V$$

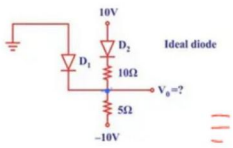
($D_2 \to$ OFF)

Our Assumption is correct.

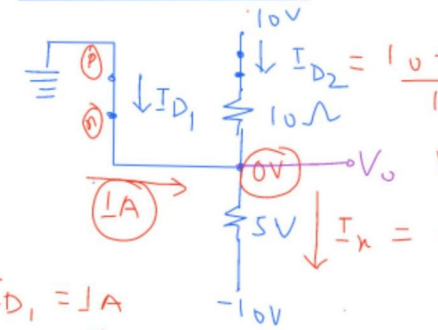
$$V_0 = \frac{10 \times 10}{10+10} = 5V \quad \text{Ans.}$$

(or) $V_0 = I_{D_1} \times 10K = 5V$

Q.3



Let D_1 ON, D_2 ON :



$I_{D_2} = \frac{10-0}{10} = 1A > 0$ ptoN

(D_2 ON)

$I_x = \frac{0+10}{5} = 2A$

$I_{D_1} = 1A$ ptoN

(D_1 ON)

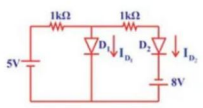
$\therefore$ $V_o = 0V$ Ans

Q.4

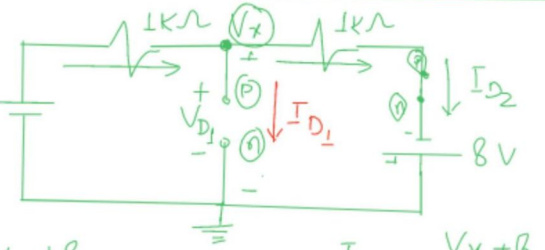
Diode ideal.

I_{D_1}, I_{D_2} = ?

Let D_1 OFF, D_2 ON



≡



$\frac{5-V_x}{1K} = 0 + \frac{V_x+8}{1K}$

$2V_x = -3$

$V_x = -1.5V = V_{D_1} < 0$

($D_1 \rightarrow$ OFF)

$I_{D_1} = 0A$

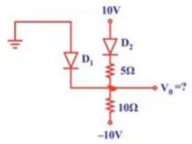
$I_{D_2} = \frac{V_x+8}{1K} = \frac{-1.5+8}{1K}$

$= \frac{6.5}{1K}$

$I_{D_2} = 6.5mA > 0$ ptoN

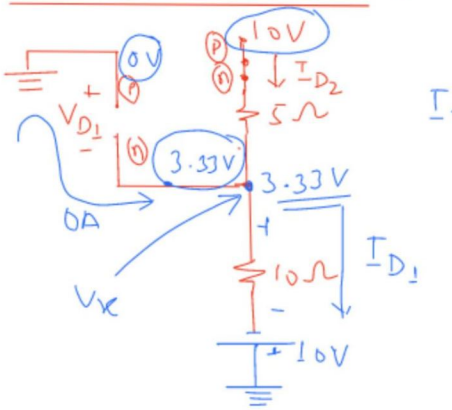
(D_2 ON)

Q.5V



≡

Let D_1 : OFF & D_2 : ON ⇒



$I_{D_2} = \frac{10+10}{5+10}$

$= \frac{20}{15} = \frac{4}{3}A > 0$

(D_2 ON)

$V_x = -10 + 10(I_{D_1}) = -10 + 10 \times 4/3 = \frac{-30+40}{3} = 10/3$ Volt

$= 3.33V$

$V_{D_1} = 0 - 3.33 = -3.33V < 0$ (D_1 OFF)

$\therefore$ $V_o = 3.33$ Volt

Next class : 9 PM

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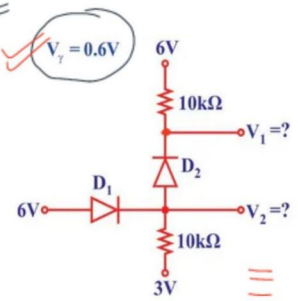
Comprehensive Course on Analog Circuit

Diode Circuit - Part II

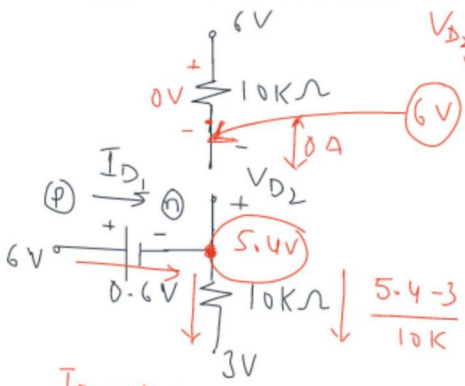
Lesson 2 • June 9, 2020 • Kamesh Shrivastava

Q.6



≡

Let D_1 ON, D_2 OFF :



$V_{D_2} = 5.4 - 6$

$V_{D_2} = -0.6 < 0$

$V_{D_2} < V_\gamma$

(D_2 OFF)

$\frac{5.4-3}{10K} = \frac{2.4}{10K}$

$= 0.24mA$

$I_{D_1} = 0.24mA > 0$

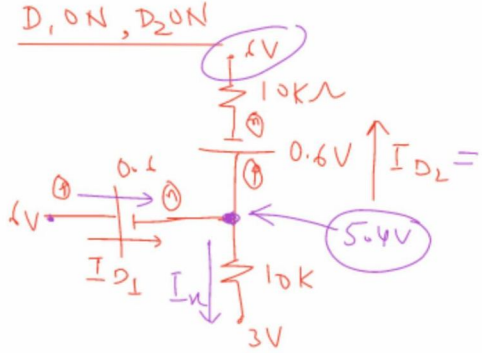
P to N

(D_1 ON)

$V_1 = 6V$

$V_2 = 5.4V$

(OR) D_1 ON, D_2 ON



$I_{D_2} = \frac{5.4-6-0.6}{10k} = \frac{5.4-6.6}{10K}$

$= \frac{-1.2}{10k} = -0.12$ mA

0.12mA : N to P

(D_2 OFF)

$I_x = \frac{5.4-3}{10K} = \frac{2.4}{10K} = 0.24mA$

$I_{D_1} = I_x + I_{D_2} \Rightarrow I_{D_1} = 0.24 + (-0.12mA)$

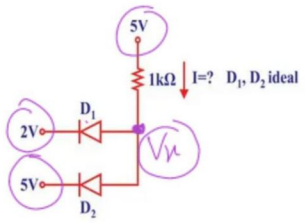
$= 0.12mA > 0$ (D_1 ON)

Our Assumption is wrong.

→ D_1 ON, D_2 OFF → check & find Ans.

— x — y — x —

Q.7



Possibility:

① D_1 ON, D_2 ON : ✗ not possible
Violation of KVL

② D_1 OFF, D_2 OFF : $V_x = 5V$
✗ not possible

③ D_1 OFF, D_2 ON : (✗ not possible)
if D_2 ON $\rightarrow V_x = 5V \rightarrow$ it makes (D_1 ON)

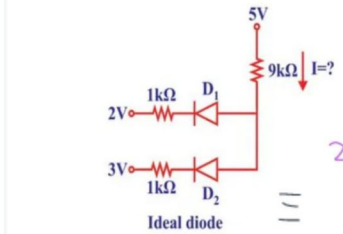
~~①~~ D_1 ON, D_2 OFF : $V_x = 2V \rightarrow D_2$ OFF

$I = 5-2/1K = 3mA$ //

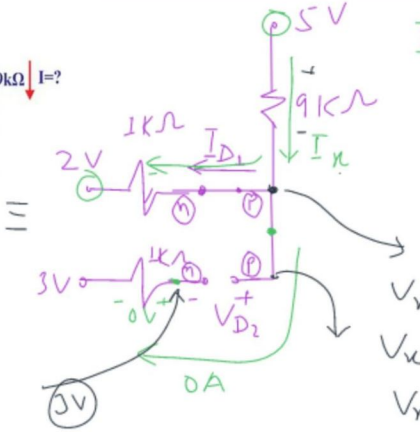
$V_x = \min(2,5,5)$

Q.8

Let D_1 ON, D_2 OFF :



$I = 0.3mA$



$I_x = I_{D_1} = \frac{5-2}{9+1} = \frac{3}{10K}$

$I_{D_1} = 0.3mA > 0$

(D_1 ON)

$V_x = 5 - 9k(I_x)$

$V_x = 5 - 9 \times 0.3$

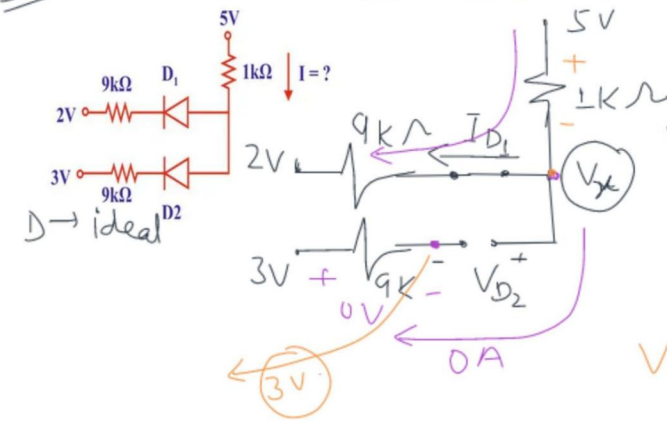
$V_x = 5 - 2.7 = 2.3V$

$V_{D_2} = V_x - 3 = 2.3 - 3 = -0.7 < 0$

(D_2 OFF)

Q.9

Let D_1 ON, D_2 OFF :



$I_x = I_{D_1} = \frac{5-2}{9+1} = \frac{0.3mA}{>0}$

(✗ D_1 ON)

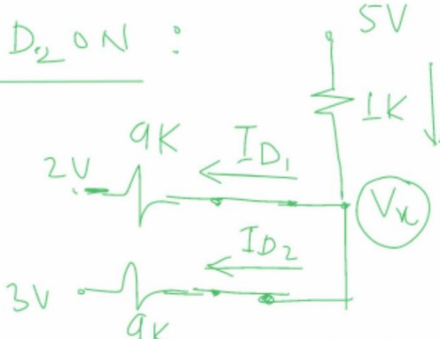
$V_x = 5 - 1k(I_x)$

$= 5 - 0.3 = 4.7V$

$V_{D_2} = V_x - 3V = 4.7 - 3 = 1.7$ volt //

$V_{D_2} = 1.7V > 0$ ($D_2 \rightarrow$ ON)

$\Rightarrow$ D_1 ON, D_2 ON :



$I_x = \frac{5-V_x}{1K}$

$I_x = \frac{5-4.5}{1K}$

$I_x = 0.5mA$

$\frac{5-V_x}{1K} = \frac{V_x-2}{9K} + \frac{V_x-3}{9K} \Rightarrow$ $V_x = 4.5$ Volt