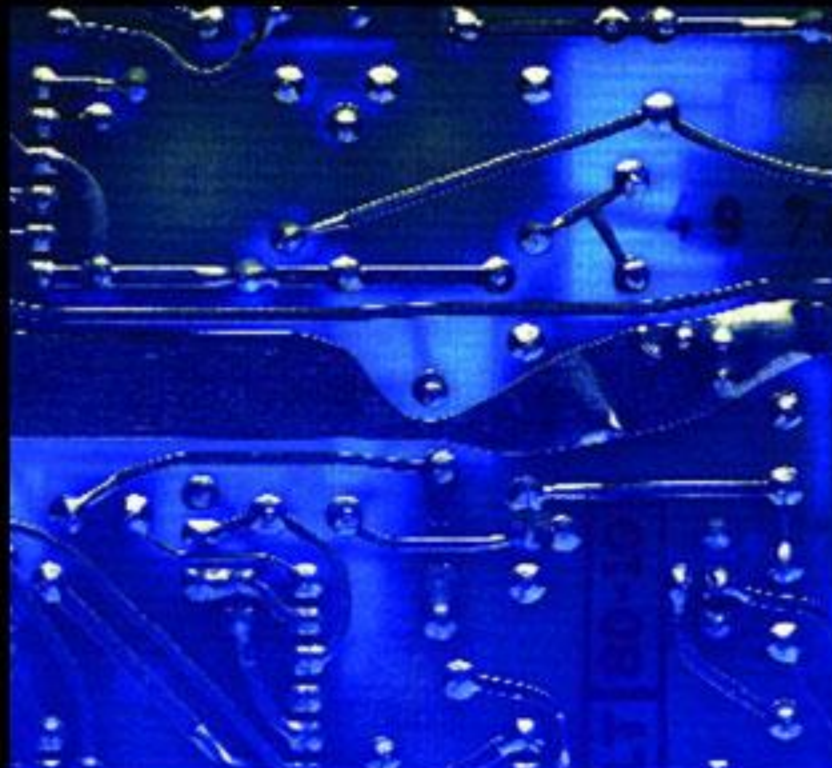
ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION

BOYLESTAD



PEARSON

PART-1 INTRODUCTION

SEMICONDUCTOR MATERIALS: Ge, Si, AND GaAs

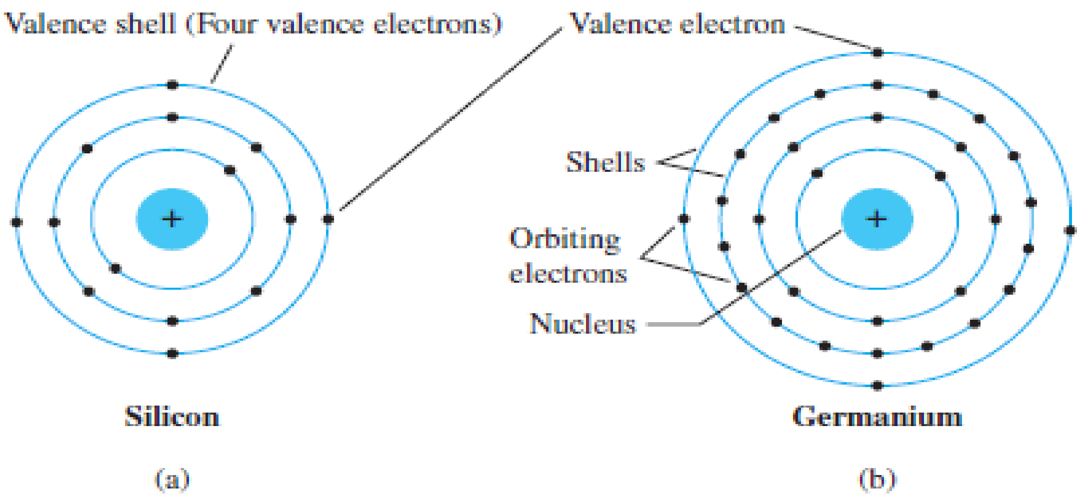
- *Semiconductors are a special class of elements having a conductivity between that of a good conductor and that of an insulator*
- two classes: *single-crystal and compound*
- Single-crystal semiconductors such as germanium (Ge) and silicon(Si) have a repetitive crystal structure.
- compound semiconductors such as gallium arsenide(GaAs), cadmium sulfide (CdS), gallium nitride (GaN), and gallium arsenide phosphide (GaAsP) are constructed of two or more semiconductor materials of different atomic structures.

The three semiconductors used most frequently in the construction of electronic devices are Ge, Si, and GaAs.

- 1947 germanium was used almost exclusively
- easy to find and was available in fairly large quantities.
- easy to refine to obtain very high levels of purity, an important aspect in the fabrication process
- suffered from low levels of reliability due primarily to its sensitivity to changes in temperature.
- 1954 the first silicon transistor was introduced, and silicon quickly became the semiconductor material of choice.
- less temperature sensitive, but it is one of the most abundant materials on earth
- Manufacturing and design technology improved steadily through the following years
- Si transistor networks for most applications were cheaper to manufacture and had the advantage of highly efficient design strategies

•first GaAs transistor in the early 1970s

- speeds of operation up to five times that of Si
- GaAs was more difficult to manufacture at high levels of purity, was more expensive and had little design support in the early years of development
- demand for increased speed -base material for new high-speed, very large scale integrated (VLSI) circuit designs.
- **COVALENT BONDING AND INTRINSIC MATERIALS**



Atomic structure of (a) silicon; (b) germanium

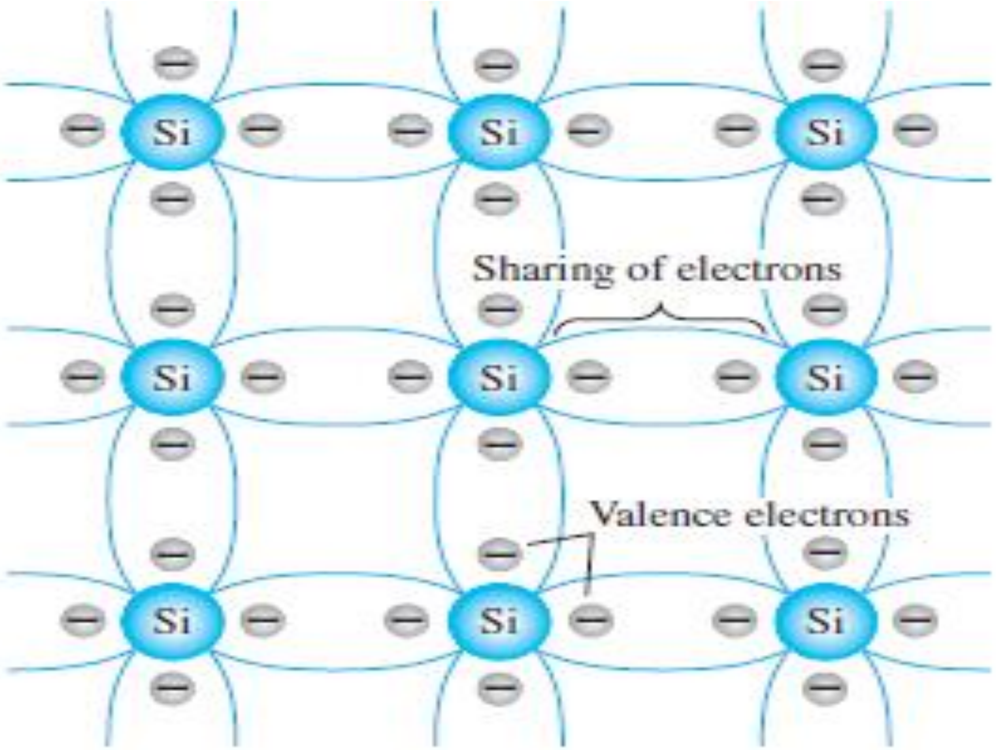


FIG. 1.4
Covalent bonding of the silicon atom.

- ***This bonding of atoms, strengthened by the sharing of electrons, is called covalent bonding.***

•The external causes include effects such as light energy in the form of photons and thermal energy (heat) from the surrounding medium.

- **At room temperature, there are approximately 1.5 x 10 ^{10} free carriers in 1 cm ^{3} of *intrinsic silicon material***
- **intrinsic *is applied to any semiconductor material that has been carefully ENERGY LEVELS refined to reduce the number of impurities to a very low level***

TABLE 1.1

Intrinsic Carriers n_i

Semiconductor	Intrinsic Carriers (per cubic centimeter)
GaAs	1.7×10^6
Si	1.5×10^{10}
Ge	2.5×10^{13}

TABLE 1.2

Relative Mobility Factor μ_n

Semiconductor	μ_n ($cm^2/V \cdot s$)
Si	1500
Ge	3900
GaAs	8500

A semiconductor material that has been subjected to the doping process is called an extrinsic material

- ***n -Type Material***
- *five valence electrons (pentavalent), such as antimony , arsenic , and phosphorus*
- ***Diffused impurities with five valence electrons are called donor atoms***

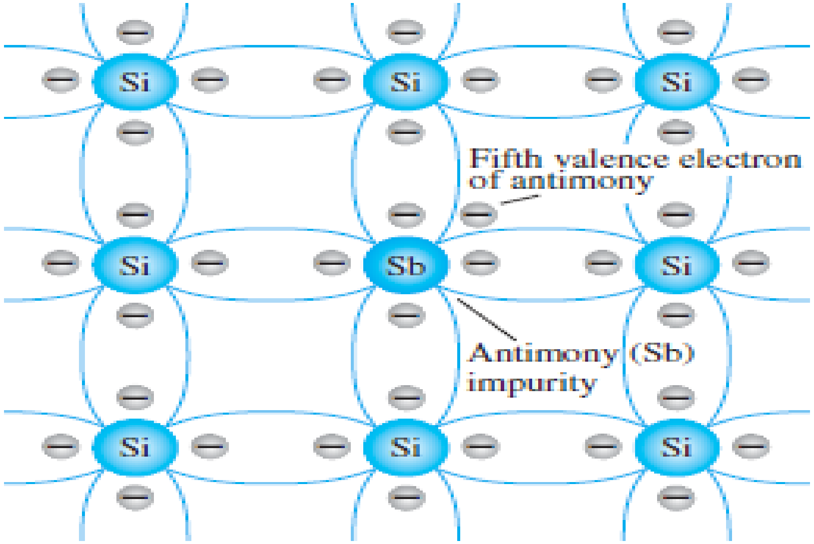


FIG. 1.7
Antimony impurity in n-type material.

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At room temperature in an intrinsic Si material there is about one free electron for every 10^{12} atoms

- If the dosage level is 1 in 10 million (10^7), the ratio $10^{12}/10^7 = 10^5$ indicates that the carrier concentration has increased by a ratio of 100,000:1.

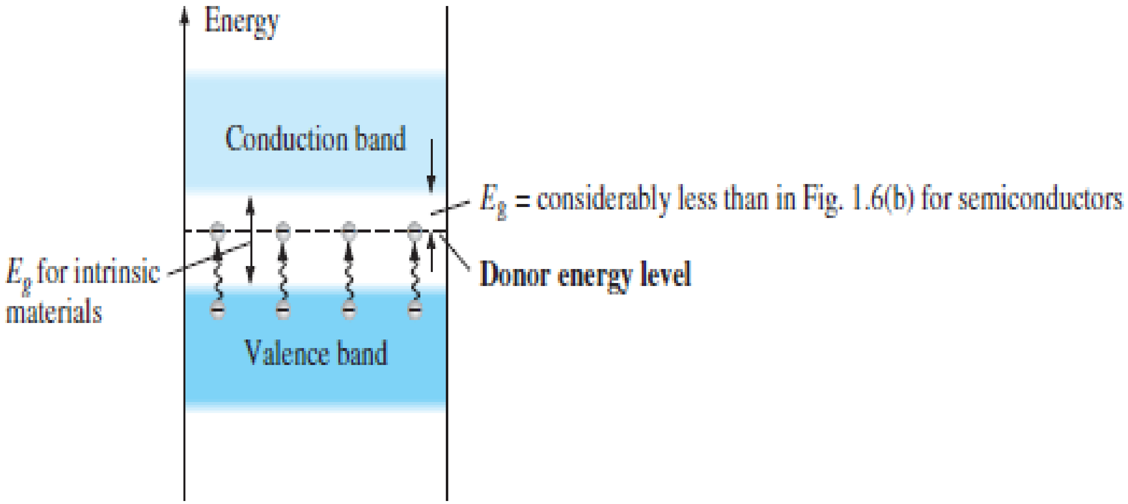

FIG. 1.8
Effect of donor impurities on the energy band structure.

p -Type Material

- *three valence electrons- boron , gallium , and indium-* ***acceptor atoms.***

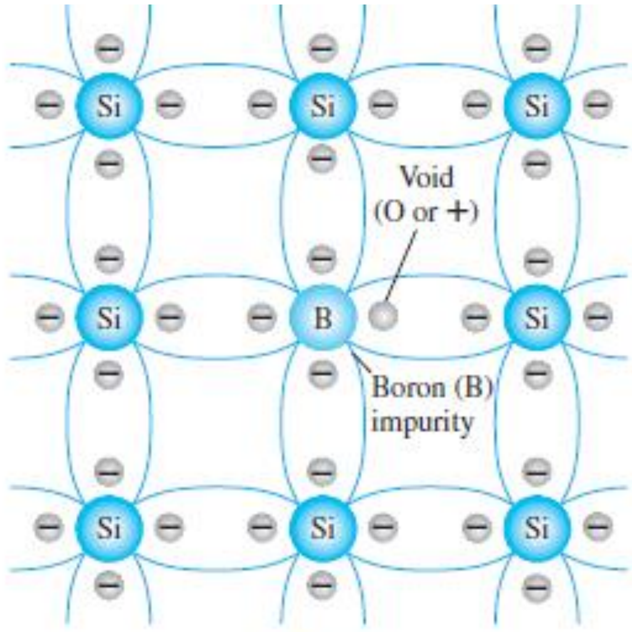

FIG. 1.9
Boron impurity in p-type material.

Electron versus Hole Flow

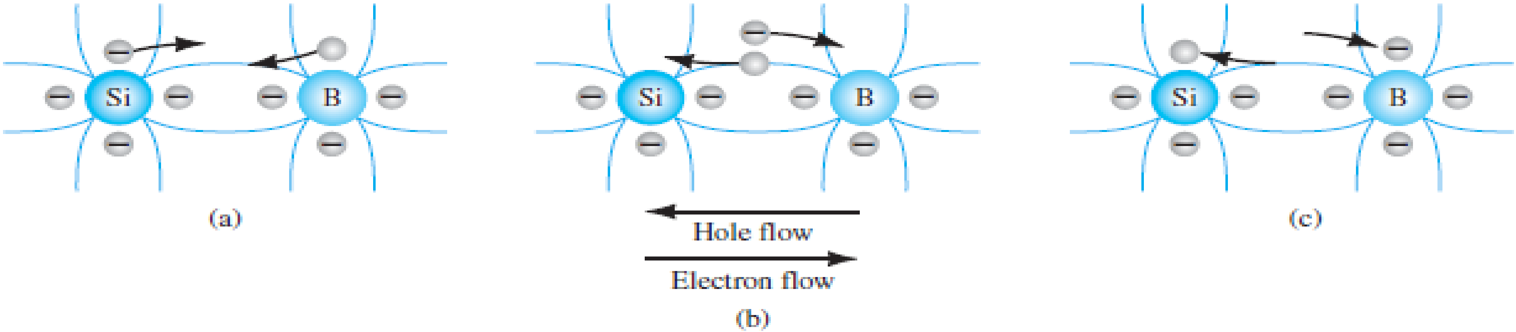

FIG. 1.10
Electron versus hole flow.

Majority and Minority Carriers

- *In an n-type material the electron is called the majority carrier and the hole the minority carrier.*
- *In a p-type material the hole is the majority carrier and the electron is the minority carrier*

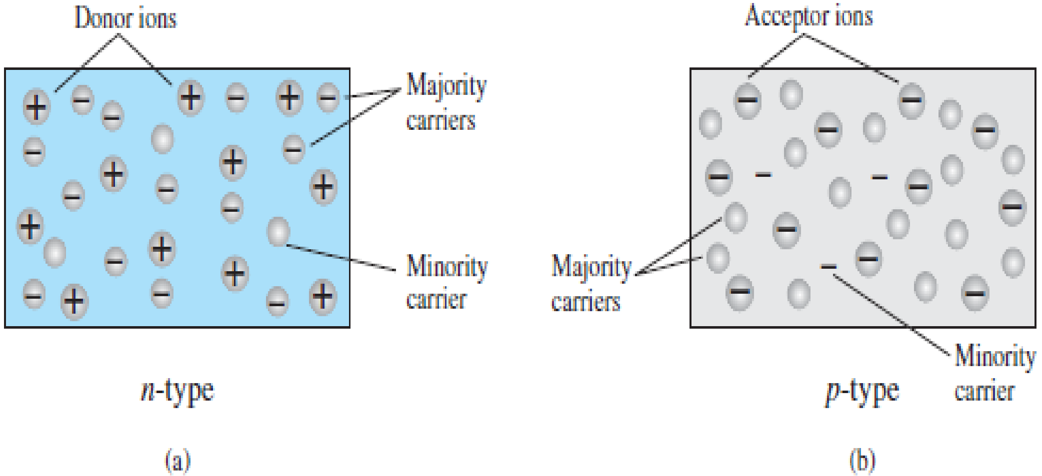

FIG. 1.11
(a) n-type material; (b) p-type material.

PN JUNCTION-DIODE
NO BIAS

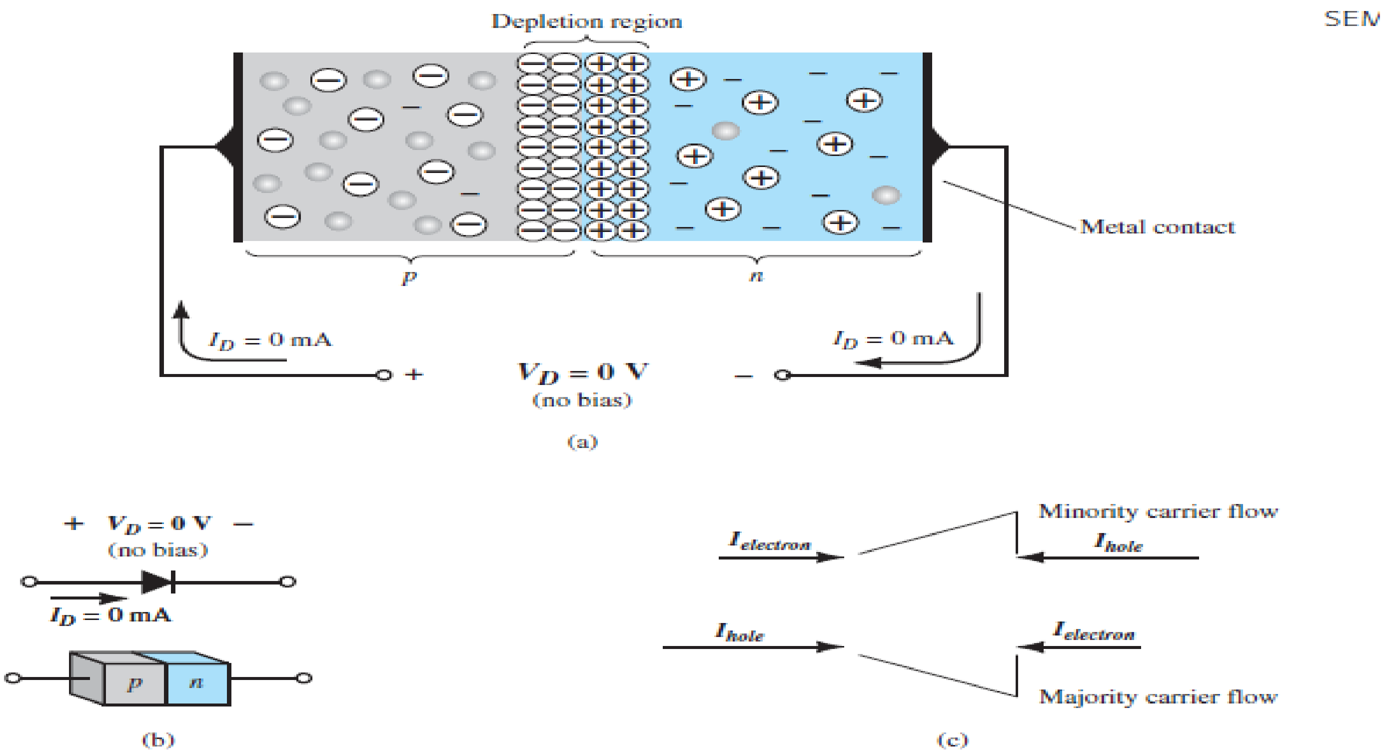

FIG. 1.12
A p–n junction with no external bias: (a) an internal distribution of charge; (b) a diode symbol, with the defined polarity and the current direction; (c) demonstration that the net carrier flow is zero at the external terminal of the device when $V_D = 0$ V.

In the absence of an applied bias across a semiconductor diode, the net flow of charge in one direction is zero

REVERSE BIAS

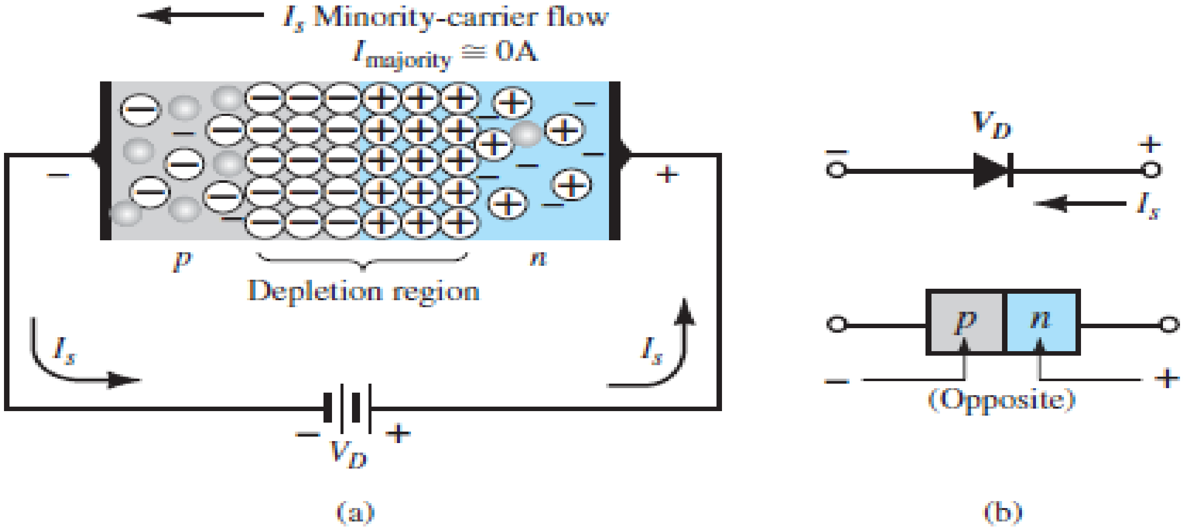

FIG. 1.13

Reverse-biased p–n junction: (a) internal distribution of charge under reverse-bias conditions; (b) reverse-bias polarity and direction of reverse saturation current.

The current that exists under reverse-bias conditions is called the reverse saturation current and is represented by I s .

FORWARD BIAS

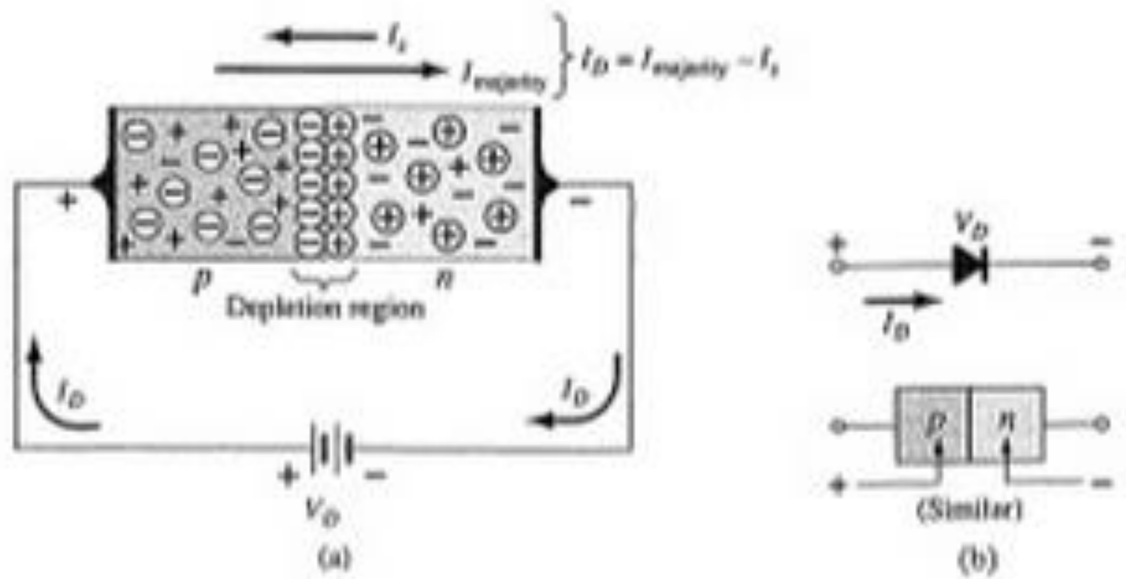

FIG. 1.14

Forward-biased p–n junction. (a) Internal distribution of charge under forward-bias conditions; (b) forward-bias polarity and direction of resulting current.

Shockleys Equation

Shockley's equation, for the forward- and reverse-bias regions:

$$I_D = I_s(e^{V_D/nV_T} - 1) \quad \text{(A)} \tag{1.2}$$

where I_s is the reverse saturation current
V_D is the applied forward-bias voltage across the diode
n is an ideality factor, which is a function of the operating conditions and physical construction; it has a range between 1 and 2 depending on a wide variety of factors ($n = 1$ will be assumed throughout this text unless otherwise noted).

The voltage V_T in Eq. (1.1) is called the *thermal voltage* and is determined by

$$V_T = \frac{kT_K}{q} \quad \text{(V)} \tag{1.3}$$

where k is Boltzmann's constant $= 1.38 \times 10^{-23}$ J/K
T_K is the absolute temperature in kelvins $= 273 +$ the temperature in °C
q is the magnitude of electronic charge $= 1.6 \times 10^{-19}$ C

Ge,Si,GaAS

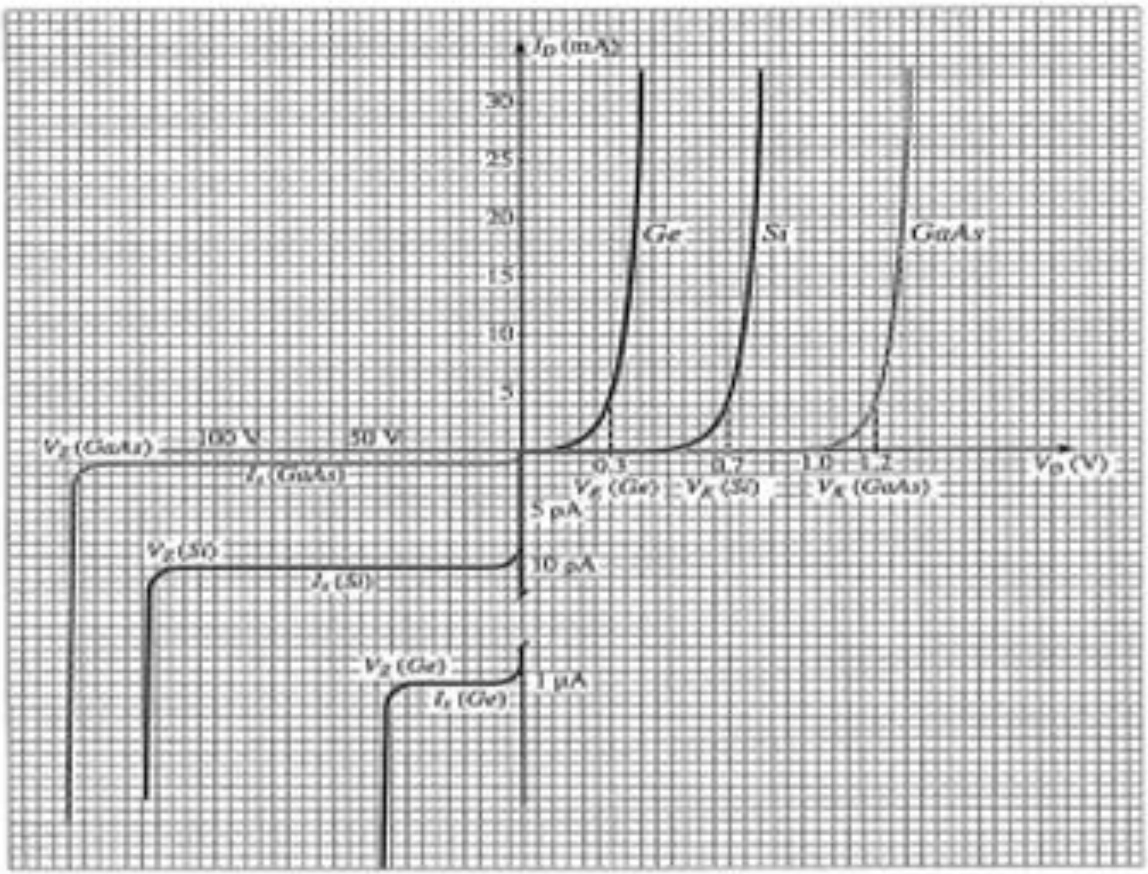

FIG. 1.18
Comparison of Ge, Si, and GaAs diodes.

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Breakdown Region

- The reverse-bias potential that results in this dramatic change in characteristics is called the *breakdown potential and is given the label* V_{BV} .

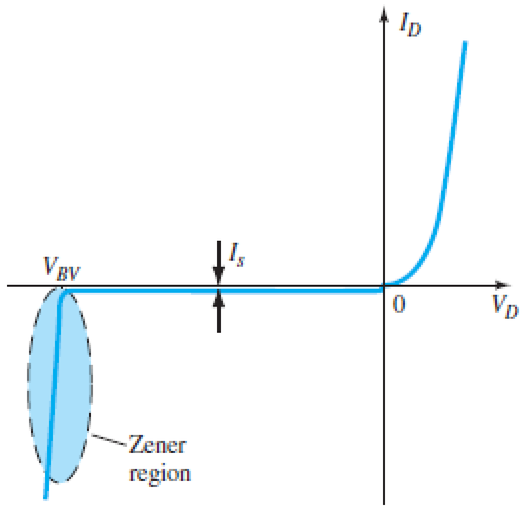


FIG. 1.17
Breakdown region.

•As the voltage across the diode increases in the reverse-bias region

- velocity and associated kinetic energy (*WK = 12 mv2) will be sufficient to release* additional carriers through collisions with otherwise stable atomic structures
- *ionization process will result-* valence electrons absorb sufficient energy to leave the parent atom----- *avalanche breakdown.*
- V_{BV} *can be brought closer to the vertical axis by increasing the* doping levels in the *p - and n -type materials.*
- *V BV decreases to very low levels,* such as 5 V, another mechanism, called *Zener breakdown*
- strong electric field in the region of the junction that can disrupt the bonding forces within the atom and "generate" carriers
- Zener breakdown mechanism---------- contributor only at lower levels of V_{BV}
- *Zener region*---------- characteristic of a *p – n junction are called Zener*
- *diodes .*

The maximum reverse-bias potential that can be applied before entering the breakdown region is called the peak inverse voltage (referred to simply as the PIV rating) or the peak reverse voltage (denoted the PRV rating

TABLE 1.3

Knee Voltages V_K

Semiconductor	V_K(V)
Ge	0.3
Si	0.7
GaAs	1.2

Temperature effects

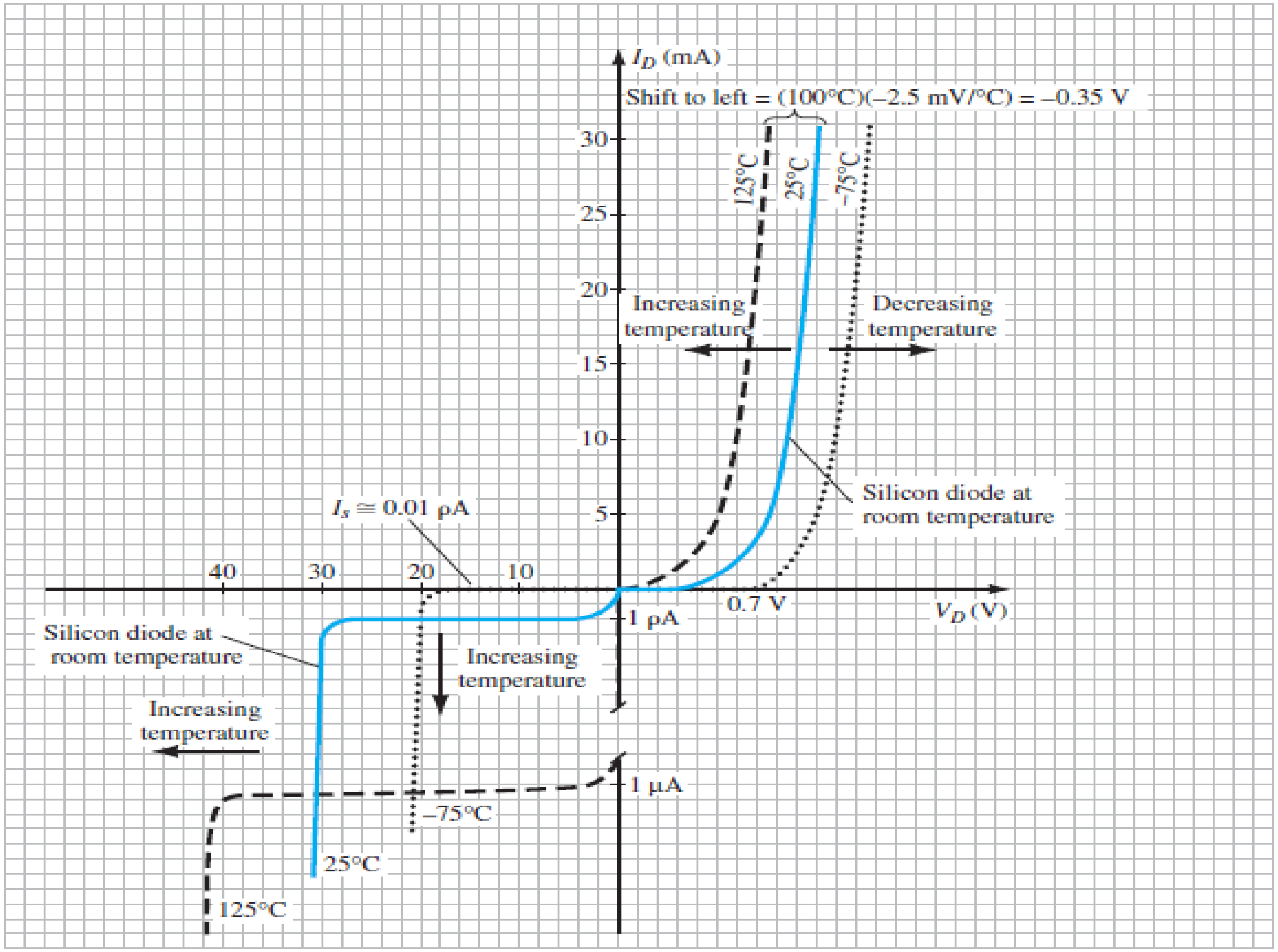


FIG. 1.19

Variation in Si diode characteristics with temperature change.

•***In the forward-bias region the characteristics of a silicon diode shift to the left at a rate of 2.5 mV per centigrade degree increase in temperature***

- An increase from room temperature (20°C) to 100°C (the boiling point of water) results in a drop of 80(2.5 mV) 200 mV, or 0.2 V, which is significant on a graph scaled in tenths of volt.
- ***In the reverse-bias region the reverse current of a silicon diode doubles for every 10°C rise in temperature.***
- For a change from 20°C to 100°C, the level of I_s *increases from 10 nA to a value of* 2.56 mA, which is a significant, 256-fold increase. Continuing to 200°C would result in a monstrous reverse saturation current of 2.62 mA.
- ***The reverse breakdown voltage of a semiconductor diode will increase or decrease with temperature***

Ideal v/s practical diode

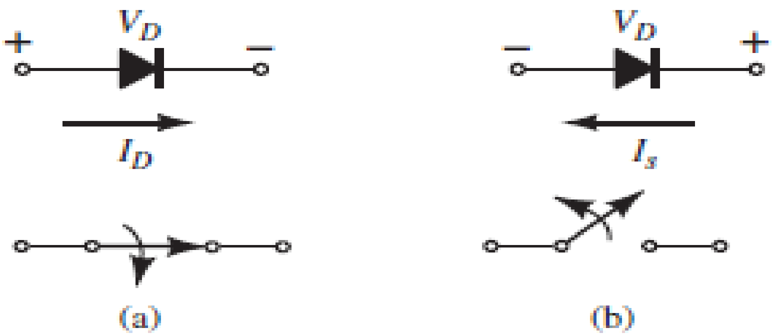


FIG. 1.21
Ideal semiconductor diode: (a) forward-biased; (b) reverse-biased.

if the semiconductor diode is to behave like a closed switch in the forward-bias region, the resistance of the diode should be 0 . In the reverse-bias region its resistance $\infty\Omega$, should be to represent the open-circuit equivalent

$$R_F = \frac{V_D}{I_D} = \frac{0\text{ V}}{5\text{ mA}} = 0\ \Omega \qquad \text{(short-circuit equivalent)}$$

In fact:

At any current level on the vertical line, the voltage across the ideal diode is 0 V and the resistance is 0 Ω.

For the horizontal section, if we again apply Ohm's law, we find

$$R_R = \frac{V_D}{I_D} = \frac{20\text{ V}}{0\text{ mA}} \cong \infty\ \Omega \qquad \text{(open-circuit equivalent)}$$

Again:

Because the current is 0 mA anywhere on the horizontal line, the resistance is considered to be infinite ohms (an open-circuit) at any point on the axis.

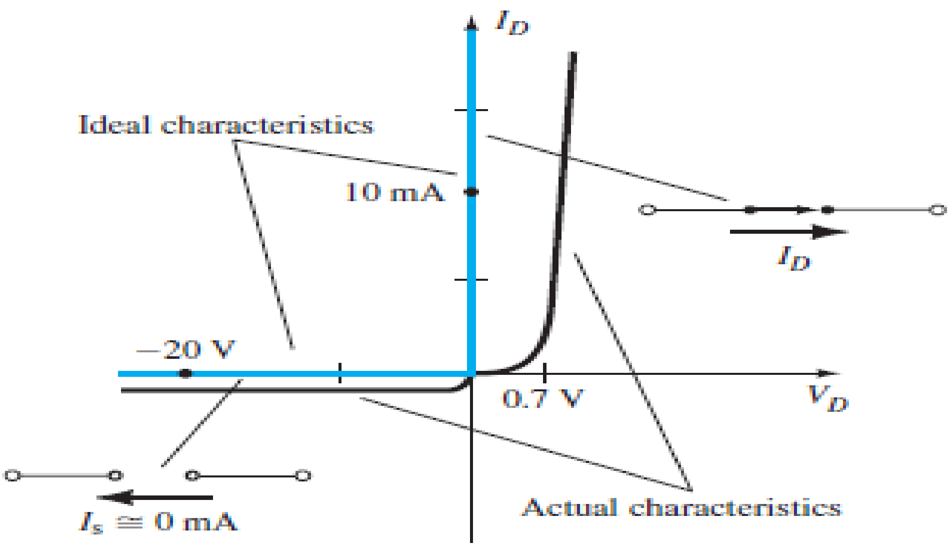


FIG. 1.22
Ideal versus actual semiconductor characteristics.

RESISTANCE LEVELS

- **DC or Static Resistance**

$$R_D = \frac{V_D}{I_D}$$

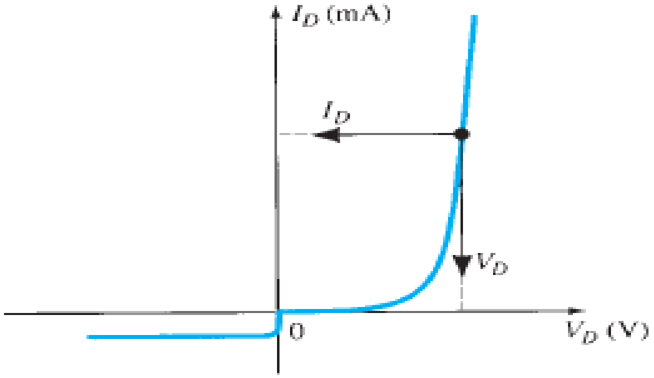


FIG. 1.23
Determining the dc resistance of a diode at a particular operating point.

The dc resistance levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section of the characteristics. The resistance levels in the reverse-bias region will naturally be quite high

In general, therefore, the higher the current through a diode, the lower is the dc resistance level. Typically, the dc resistance of a diode in the active (most utilized) will range from about10 to 80Ω .

AC or Dynamic Resistance

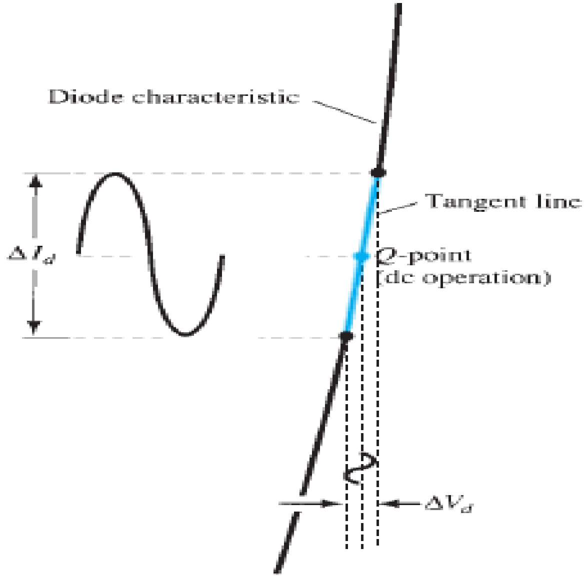


FIG. 1.25
Defining the dynamic or ac resistance.

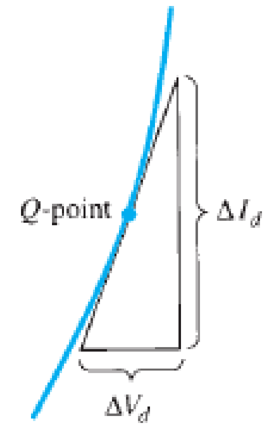


FIG. 1.26
Determining the ac resistance at a Q-point.

With no applied varying signal, the point of operation would be the *Q - point*

$$r_d = \frac{\Delta V_d}{\Delta I_d}$$

In general, therefore, the lower the Q-point of operation (smaller current or lower voltage), the higher is the ac resistance.

the dynamic resistance can be found simply by substituting the quiescent value of the diode current into the equation

$$r_d = \frac{26\ \text{mV}}{I_D}$$

$$r'_d = \frac{26\ \text{mV}}{I_D} + r_B \quad \text{ohms}$$

Average AC Resistance

$$r_{av} = \left.\frac{\Delta V_d}{\Delta I_d}\right|_{\text{pt. to pt.}}$$

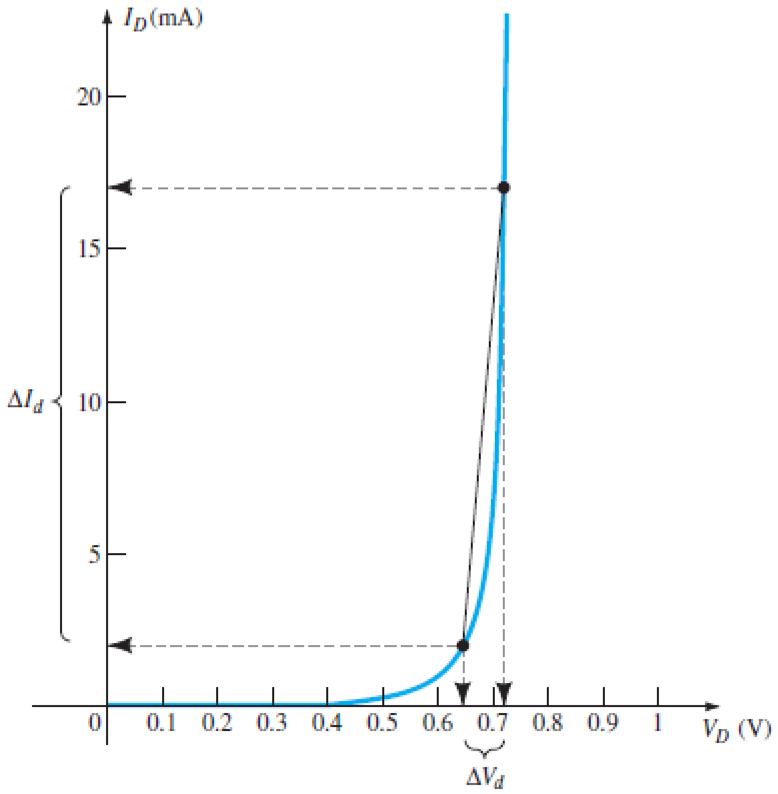
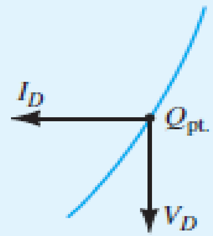
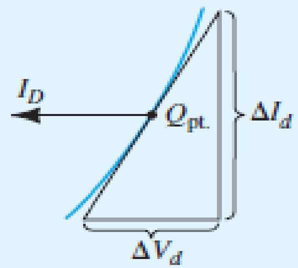
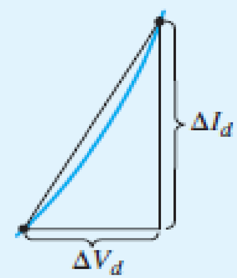


FIG. 1.28
Determining the average ac resistance between indicated limits.

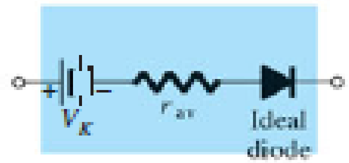
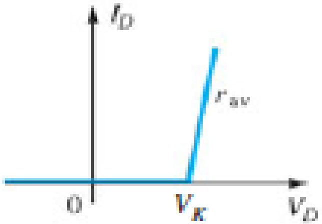
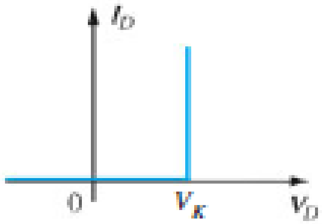
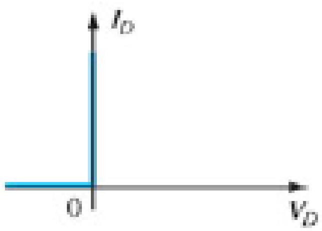
Resistance levels

Resistance Levels

Type	Equation	Special Characteristics	Graphical Determination
DC or static	$R_D = \frac{V_D}{I_D}$	Defined as a point on the characteristics	
AC or dynamic	$r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{26\text{ mV}}{I_D}$	Defined by a tangent line at the Q-point	
Average ac	$r_{av} = \frac{\Delta V_d}{\Delta I_d}\Big\vert_{\text{pt. to pt.}}$	Defined by a straight line between limits of operation	

Diode equivalent circuits

Diode Equivalent Circuits (Models)

Type	Conditions	Model	Characteristics
Piecewise-linear model			
Simplified model	$R_{network} \gg r_{av}$		
Ideal device	$R_{network} \gg r_{av}$ $E_{network} \gg V_K$		

TRANSITION AND DIFFUSION CAPACITANCE

- ***Every electronic or electrical device is frequency sensitive.***
- *For diode stray capacitance is a problem,* $X_C = 1/2\pi fC$,
- ***the transition capacitance is the predominant capacitive effect in the reverse-bias region whereas the diffusion capacitance is the predominant capacitive effect in the forward-bias region.***
- ***Transition capacitance*** $C = \epsilon A/d$,

This capacitance, called the transition (C_T), barriers, or depletion region capacitance, is determined by

$$C_T = \frac{C(0)}{(1 + |V_R/V_K|)^n} \qquad (1.9)$$

Diffusion capacitance

- capacitance effect directly dependent on the rate at which charge is injected into the regions just outside the depletion region

$$C_D = \left(\frac{\tau_T}{V_K}\right) I_D$$

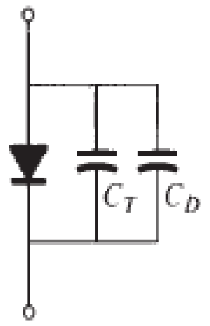


FIG. 1.34
Including the effect of the transition or diffusion capacitance on the semiconductor diode.

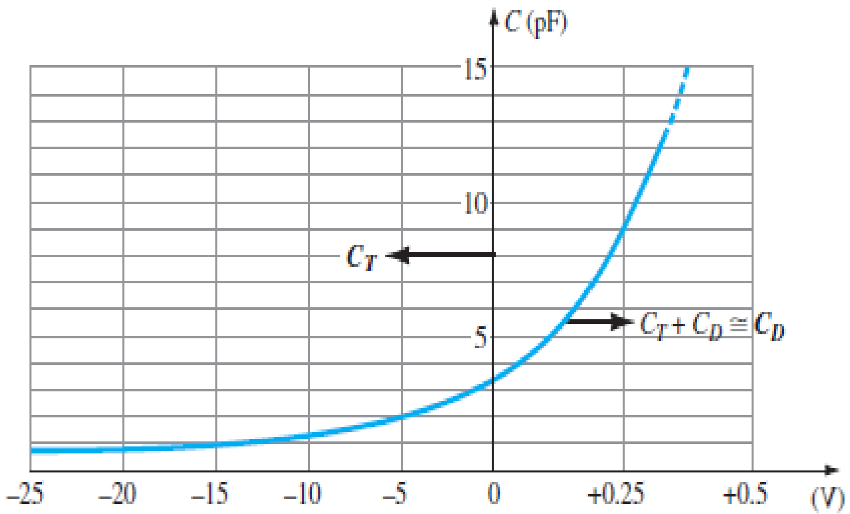


FIG. 1.33
Transition and diffusion capacitance versus applied bias for a silicon diode.

REVERSE RECOVERY TIME

- data that are normally provided on diode specification sheets provided by manufacturers
- reverse recovery time, denoted by t_{rr}

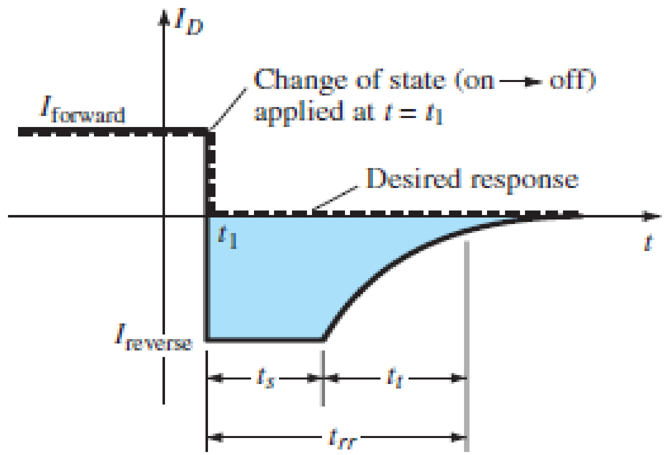


FIG. 1.35
Defining the reverse recovery time.

$$t_{rr} = t_s + t_t.$$

t_s (storage time)

t_t (transition interval).

t_{rr} in the range of a few nanoseconds to 1 μs.

Important - high-speed switching applications

DIODE SPECIFICATION SHEETS

Data on specific semiconductor devices are normally provided by the manufacturer in one of two forms. Most frequently, they give a very brief description limited to perhaps one page. At other times, they give a thorough examination of the characteristics using graphs, artwork, tables, and so on. In either case, there are specific pieces of data that must be included for proper use of the device. They include:

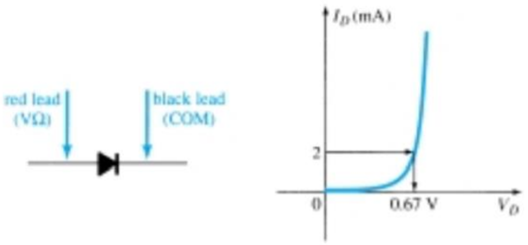
1. The forward voltage V_F (at a specified current and temperature)
2. The maximum forward current I_F (at a specified temperature)
3. The reverse saturation current I_R (at a specified voltage and temperature)
4. The reverse-voltage rating [PIV or PRV or V(BR), where BR comes from the term "breakdown" (at a specified temperature)]
5. The maximum power dissipation level at a particular temperature
6. Capacitance levels
7. Reverse recovery time t_{rr}
8. Operating temperature range

ELECTRICAL CHARACTERISTICS (25°C Ambient Temperature unless otherwise noted)

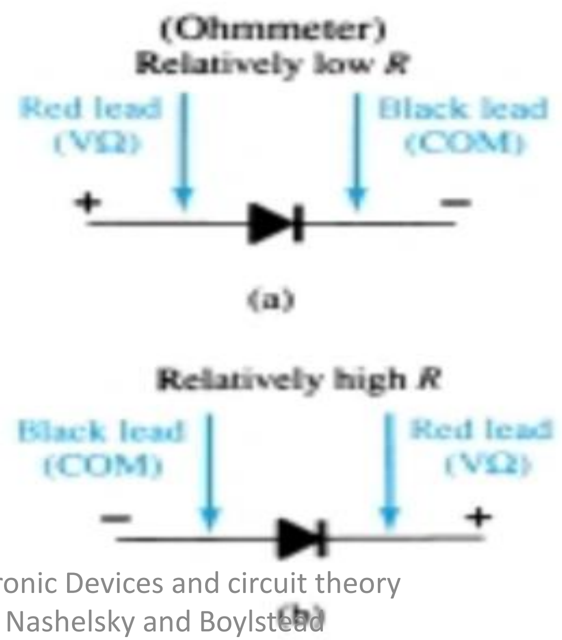
SYMBOL	CHARACTERISTIC	BAY73		UNITS	TEST CONDITIONS
		MIN	MAX		
V_F	Forward Voltage	0.85	1.00	V	$I_F = 200$ mA
		0.81	0.94	V	$I_F = 100$ mA
		0.78	0.88	V	$I_F = 50$ mA
		0.69	0.80	V	$I_F = 10$ mA
		0.67	0.75	V	$I_F = 5.0$ mA
		0.60	0.68	V	$I_F = 1.0$ mA
I_R	Reverse Current		500	nA	$V_R = 20$ V, $T_A = 125°C$
			1.0	μA	$V_R = 100$ V, $T_A = 125°C$
			0.2	nA	$V_R = 20$ V, $T_A = 25°C$
			0.5	nA	$V_R = 100$ V, $T_A = 25°C$
BV	Breakdown Voltage	125		V	$I_R = 100$ μA
C	Capacitance		5.0	pF	$V_R = 0$, $f = 1.0$ MHz
t_{rr}	Reverse Recovery Time		3.0	μs	$I_F = 10$ mA, $V_R = 35$ V $R_L = 1.0$ to 100 kΩ $C_L = 10$ pF, JAN 256

DIODE TESTING

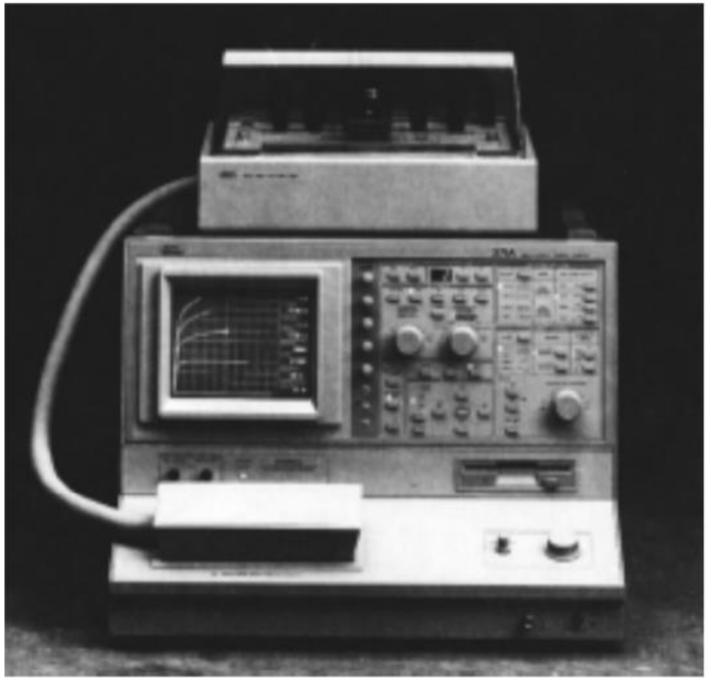
Diode Checking Function

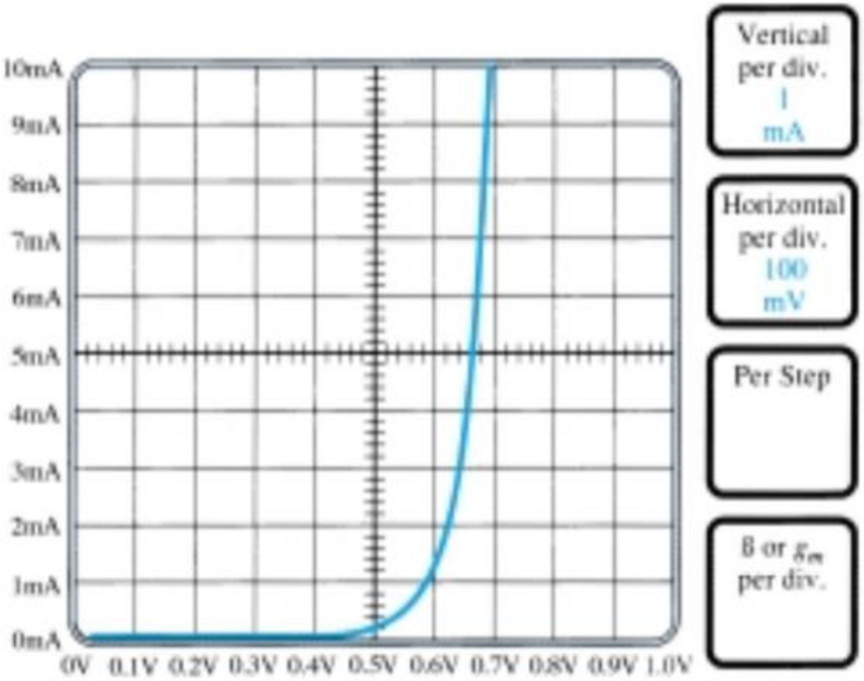


Ohmmeter Testing



Curve Tracer





LIGHT-EMITTING DIODES

As the name implies, the light-emitting diode is a diode that gives off visible or invisible (infrared) light when energized. In any forward-biased *p–n* junction there is, within the structure and primarily close to the junction, a recombination of holes and electrons. This recombination requires that the energy possessed by the unbound free electrons be transferred to another state. In all semiconductor *p–n* junctions some of this energy is given off in the form of heat and some in the form of photons.

In Si and Ge diodes the greater percentage of the energy converted during recombination at the junction is dissipated in the form of heat within the structure, and the emitted light is insignificant.

For this reason, silicon and germanium are not used in the construction of LED devices. On the other hand:

Diodes constructed of GaAs emit light in the infrared (invisible) zone during the recombination process at the p–n junction.

Light-Emitting Diodes

Color	Construction	Typical Forward Voltage (V)
Amber	AlInGaP	2.1
Blue	GaN	5.0
Green	GaP	2.2
Orange	GaAsP	2.0
Red	GaAsP	1.8
White	GaN	4.1
Yellow	AlInGaP	2.1

LOAD-LINE ANALYSIS

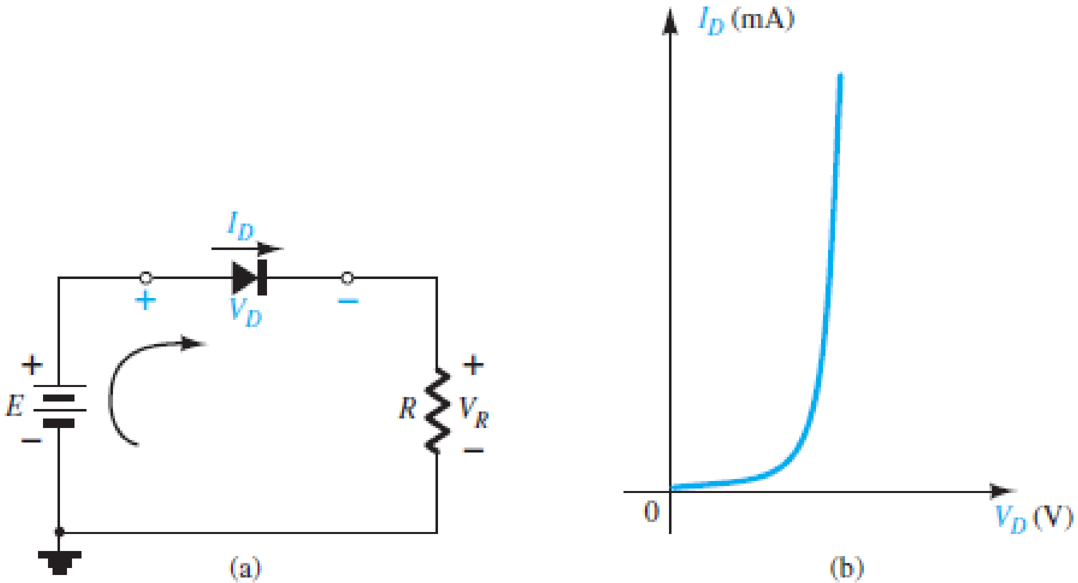


FIG. 2.1
Series diode configuration: (a) circuit; (b) characteristics.

first applying Kirchhoff's voltage law in the clockwise direction, which results in

$$+E - V_D - V_R = 0$$

or

$$E = V_D + I_D R$$

If we *set* $V_D = 0$ V in Eq. (2.1) and solve for I_D, we have the magnitude of I_D *on* the vertical axis. Therefore, with $V_D = 0$ V, Eq. (2.1) becomes

$$E = V_D + I_D R$$
$$= 0\text{ V} + I_D R$$

and

$$I_D = \frac{E}{R}\bigg|_{V_D = 0\text{ V}} \qquad (2.2)$$

Therefore, with $I_D = 0$ A, Eq. (2.1) becomes

$$E = V_D + I_D R$$
$$= V_D + (0\ \text{A})R$$

$$\boxed{V_D = E|_{I_D = 0\ \text{A}}}$$

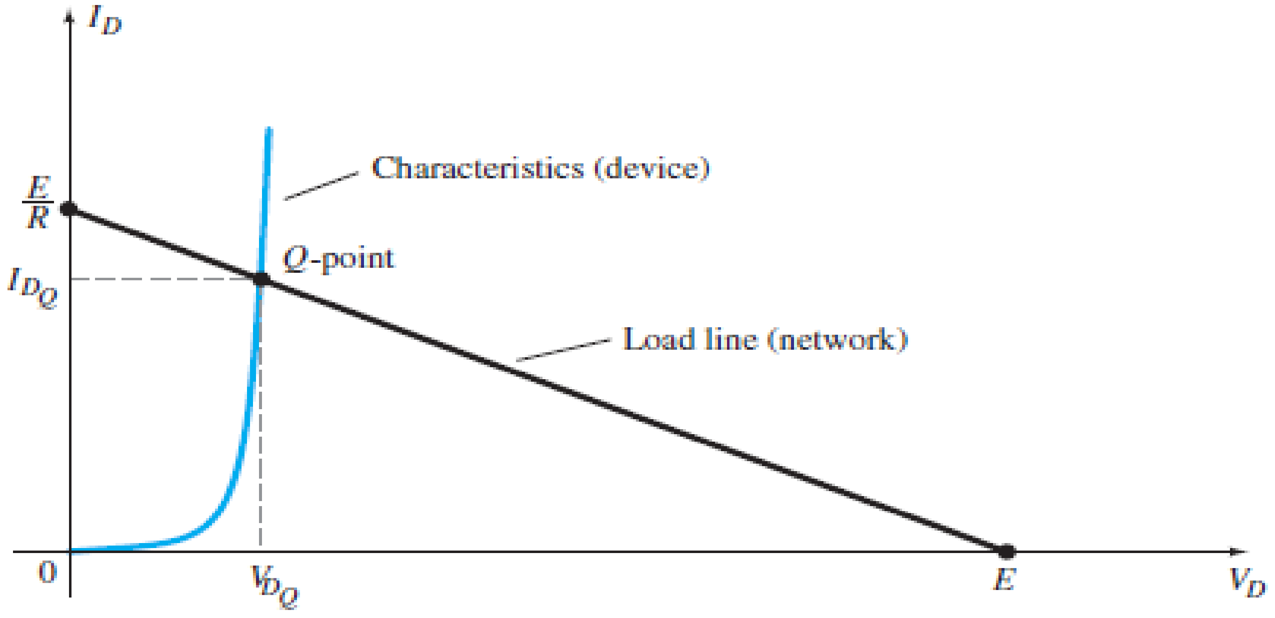
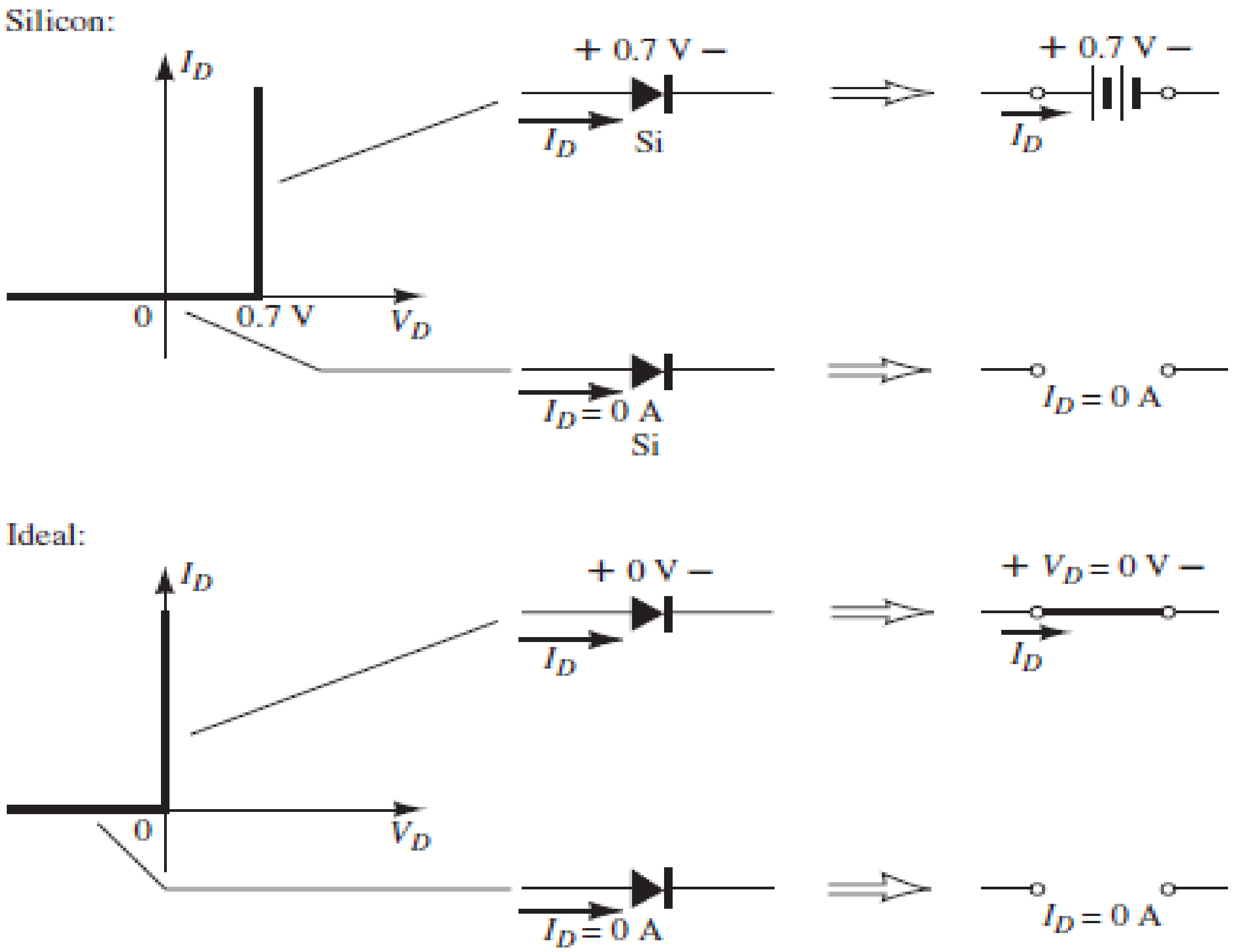


FIG. 2.2
Drawing the load line and finding the point of operation.

Approximate and Ideal Semiconductor Diode Models.



Series diode configuration

$$V_D = V_T$$

$$V_R = E - V_T$$

$$I_D = I_R = \frac{V_R}{R}$$

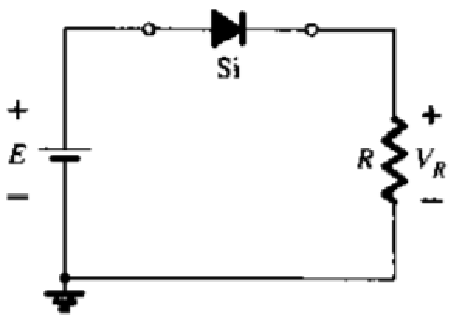


Figure 2.10 Series diode configuration.

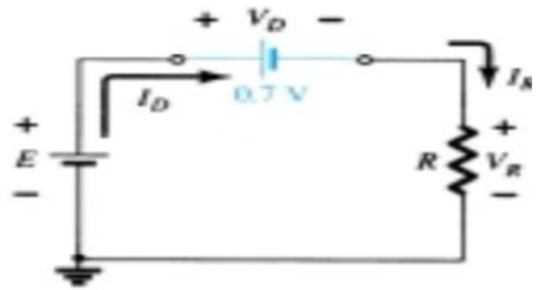


Figure 2.12 Substituting the equivalent model for the "on" diode of Fig. 2.10.

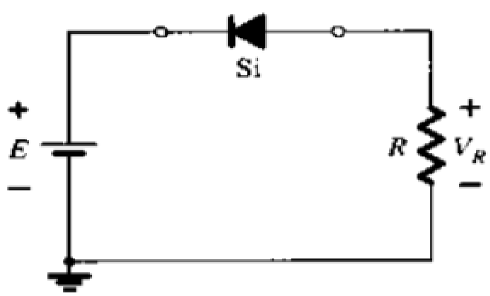


Figure 2.13 Reversing the diode of Fig. 2.10.

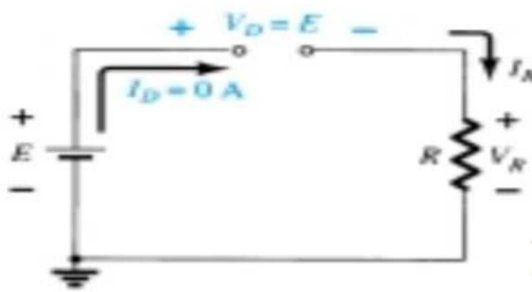
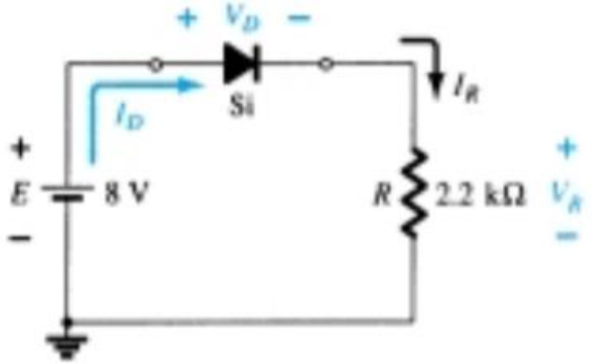


Figure 2.15 Substituting the equivalent model for the "off" diode of Figure 2.13.

$$V_R = I_R R = I_D R = (0\text{ A})R = \mathbf{0\ V}$$

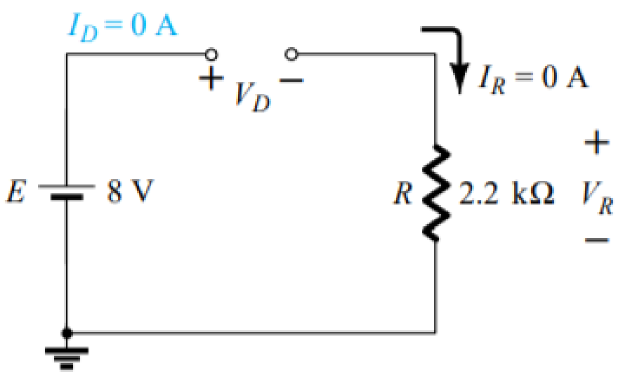
For the series diode configuration shown, determine V_D, V_R, and I_D.



$$V_D = \mathbf{0.7\ V}$$

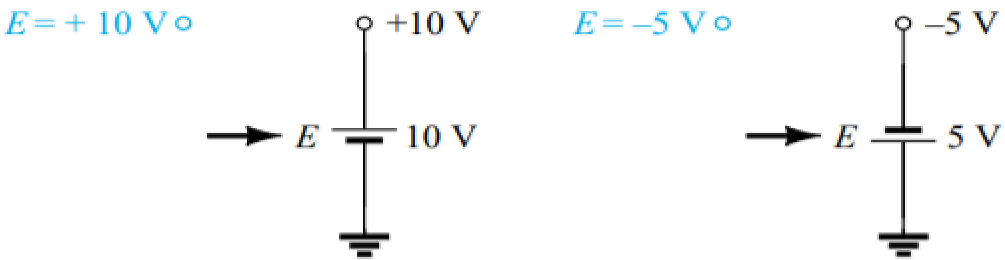
$$V_R = E - V_D = 8\text{ V} - 0.7\text{ V} = \mathbf{7.3\ V}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\text{ V}}{2.2\text{ k}\Omega} \cong \mathbf{3.32\ mA}$$



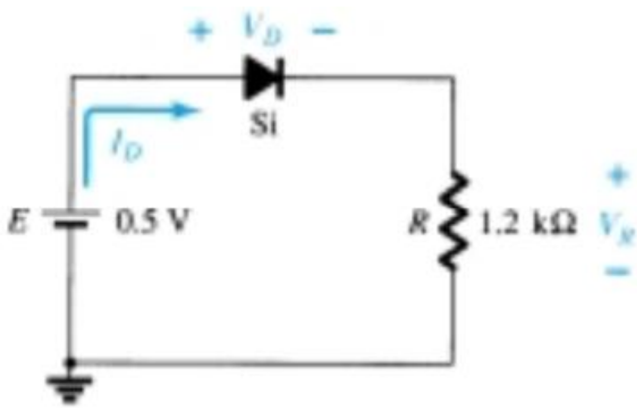
$$E - V_D - V_R = 0$$

$$V_D = E - V_R = E - 0 = E = \mathbf{8\ V}$$



Source notation.

- For the series diode configuration shown, determine V_D, V_R, and I_D.

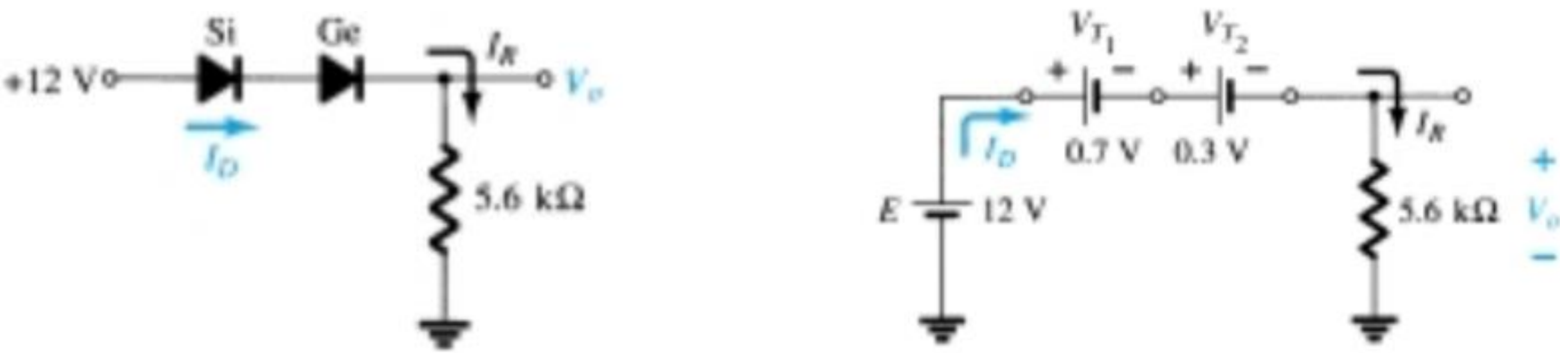


$$I_D = \mathbf{0\ A}$$

$$V_R = I_R R = I_D R = (0\ \text{A})1.2\ \text{k}\Omega = \mathbf{0\ V}$$

$$V_D = E = \mathbf{0.5\ V}$$

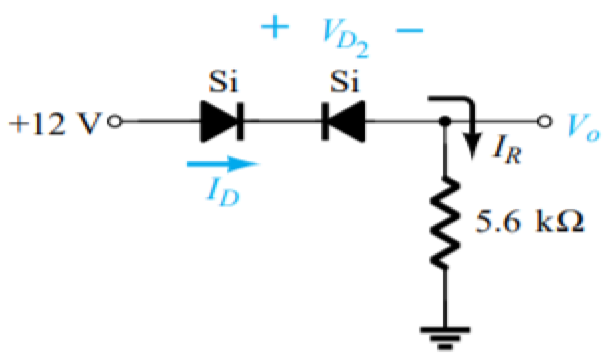
Determine V_o and I_D for the series circuit of Fig.

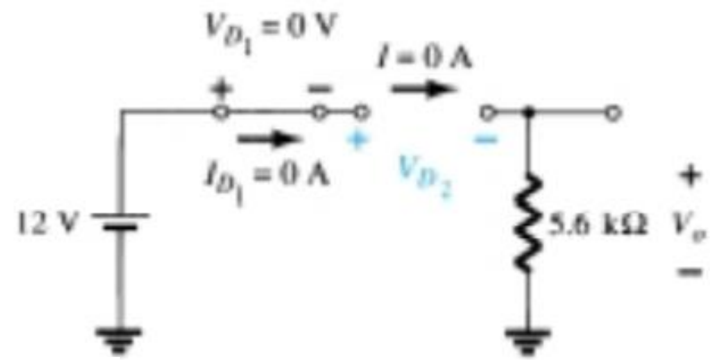


$$V_o = E - V_{T_1} - V_{T_2} = 12\text{ V} - 0.7\text{ V} - 0.3\text{ V} = \mathbf{11\text{ V}}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{V_o}{R} = \frac{11\text{ V}}{5.6\text{ k}\Omega} \cong \mathbf{1.96\text{ mA}}$$

Determine I_D, V_{D_2}, and V_o for the circuit of Fig.





$$V_o = I_R R = I_D R = (0\text{ A})R = 0\text{ V}$$

$$V_{D_2} = V_{\text{open circuit}} = E = \mathbf{12\ V}$$

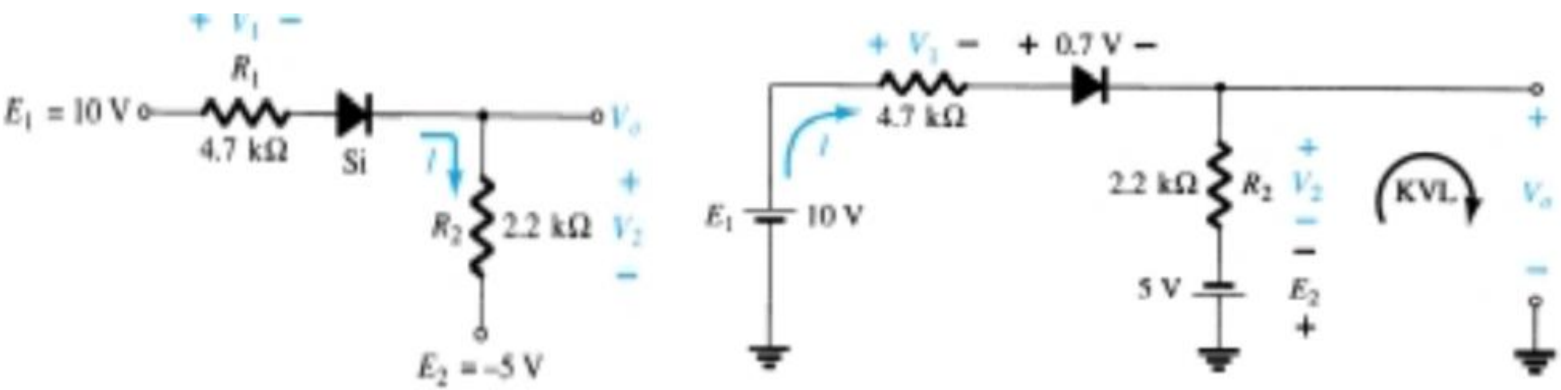
Applying Kirchhoff's voltage law :

$$E - V_{D_1} - V_{D_2} - V_o = 0$$

$$V_{D_2} = E - V_{D_1} - V_o = 12\text{ V} - 0 - 0$$
$$= \mathbf{12\ V}$$

$$V_o = \mathbf{0\ V}$$

Determine I, V_1, V_2, and V_o for the series dc configuration of Fig.



$$I = \frac{E_1 + E_2 - V_D}{R_1 + R_2} = \frac{10\text{ V} + 5\text{ V} - 0.7\text{ V}}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = \frac{14.3\text{ V}}{6.9\text{ k}\Omega}$$

$$\cong \mathbf{2.072\ mA}$$

$$V_1 = IR_1 = (2.072\text{ mA})(4.7\text{ k}\Omega) = \mathbf{9.74\ V}$$

$$V_2 = IR_2 = (2.072\text{ mA})(2.2\text{ k}\Omega) = \mathbf{4.56\ V}$$

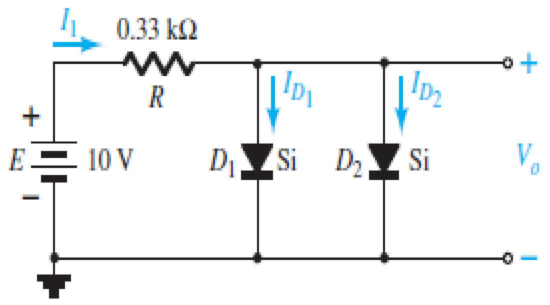
Applying Kirchhoff's voltage law to the output section

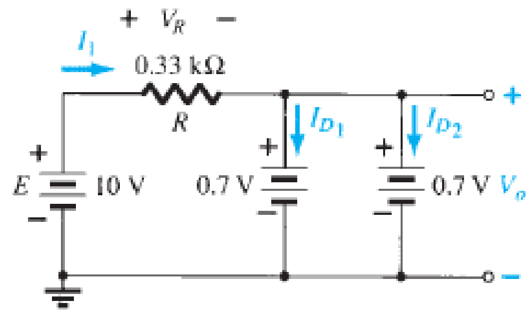
$$-E_2 + V_2 - V_o = 0$$

$$V_o = V_2 - E_2 = 4.56\text{ V} - 5\text{ V} = \mathbf{-0.44\ V}$$

PARALLEL AND SERIES–PARALLEL CONFIGURATIONS

Determine V_O, I_1, I_{D_1}, and I_{D_2} for the parallel diode configuration of Fig





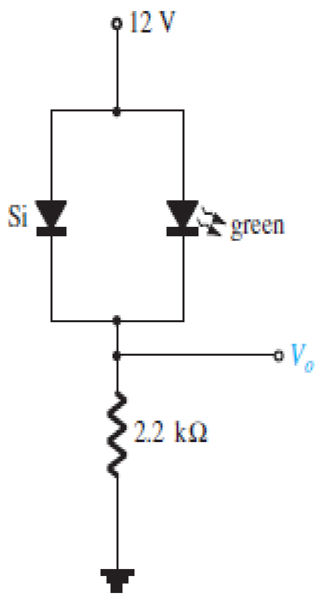
$$V_o = \mathbf{0.7\ V}$$

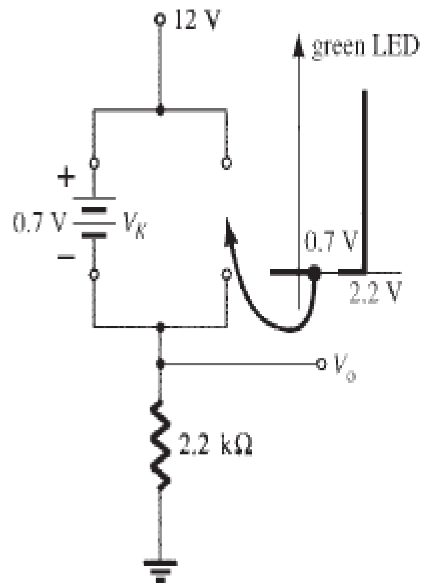
$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\text{ V} - 0.7\text{ V}}{0.33\text{ k}\Omega} = \mathbf{28.18\ mA}$$

Assuming diodes of similar characteristics, we have

$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\text{ mA}}{2} = \mathbf{14.09\ mA}$$

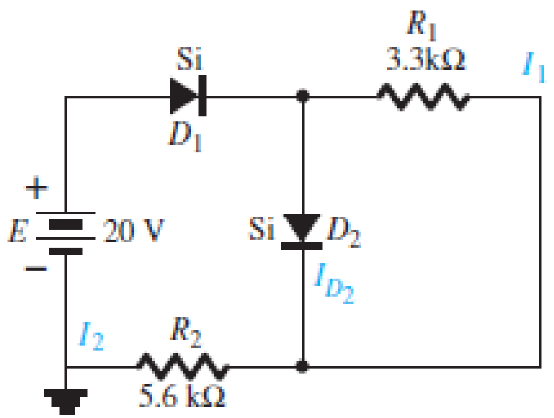
Determine the voltage V_o for the network of Fig.

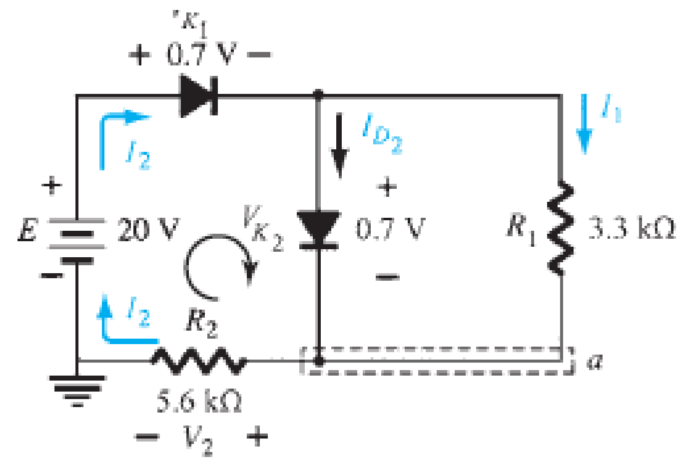




$$V_o = 12\text{ V} - 0.7\text{ V} = 11.3\text{ V}$$

Determine the currents I_1, I_2, and I_{D_2} for the network of Fig.





$$I_1 = \frac{V_{K_2}}{R_1} = \frac{0.7\text{ V}}{3.3\text{ k}\Omega} = \mathbf{0.212\text{ mA}}$$

$$-V_2 + E - V_{K_1} - V_{K_2} = 0$$

$$V_2 = E - V_{K_1} - V_{K_2} = 20\text{ V} - 0.7\text{ V} - 0.7\text{ V} = \mathbf{18.6\text{ V}}$$

$$I_2 = \frac{V_2}{R_2} = \frac{18.6\text{ V}}{5.6\text{ k}\Omega} = \mathbf{3.32\text{ mA}}$$

$$I_{D_2} + I_1 = I_2$$

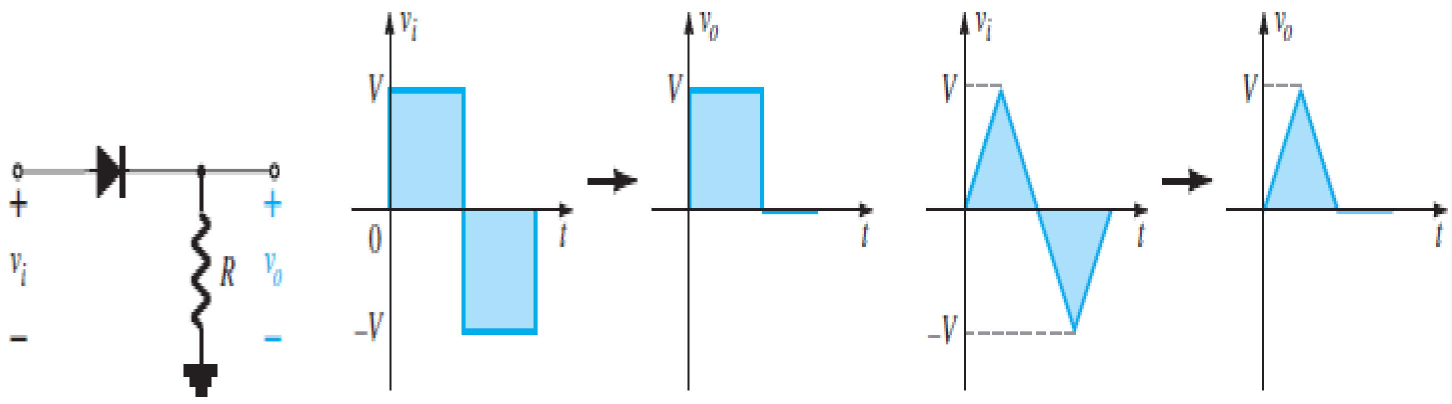
$$I_{D_2} = I_2 - I_1 = 3.32\text{ mA} - 0.212\text{ mA} \cong \mathbf{3.11\text{ mA}}$$

CLIPPERS

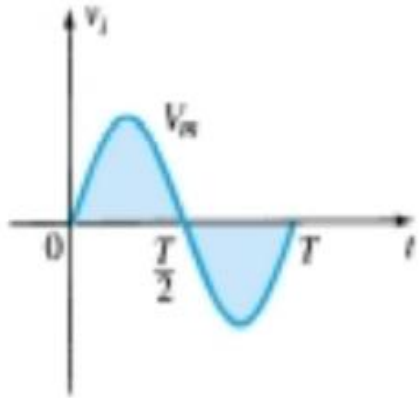
Clippers are networks that employ diodes to "clip" away a portion of an input signal without distorting the remaining part of the applied waveform.

There are two general categories of clippers: *series* and *parallel*. The series configuration is defined as one where the diode is in series with the load, whereas the parallel variety has the diode in a branch parallel to the load.

Series



(a) (b)



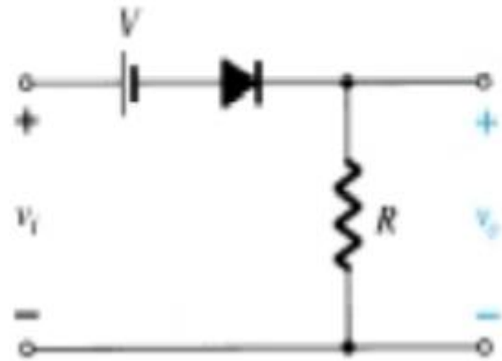


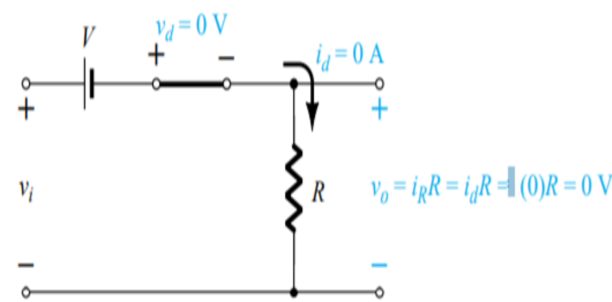
Figure 2.68 Series clipper with a dc supply.

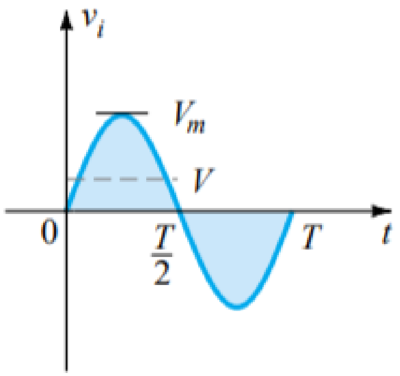
Make a mental sketch of the response of the network based on the direction of the diode and the applied voltage levels.

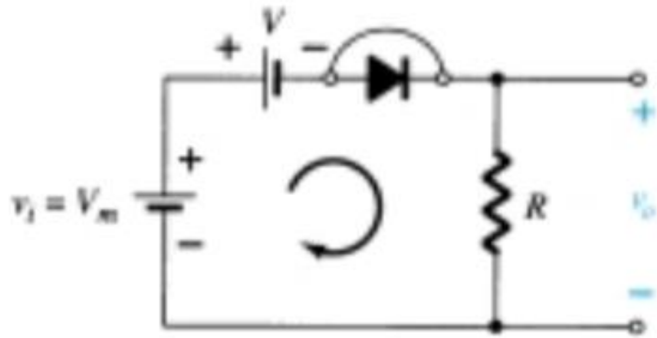
Determine the applied voltage (transition voltage) that will cause a change in state for the diode.

Vi-Vt=0

Vi=Vt

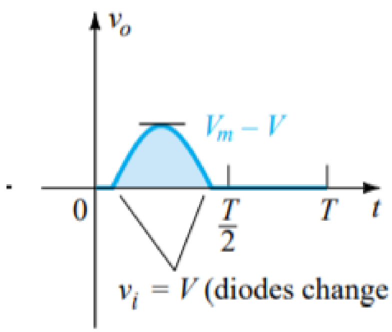






$$v_i - V - v_o = 0 \text{ (CW direction)}$$

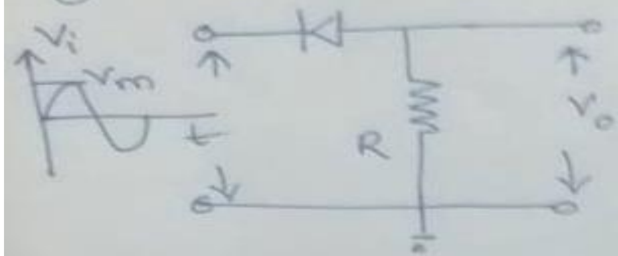
$$v_o = v_i - V$$



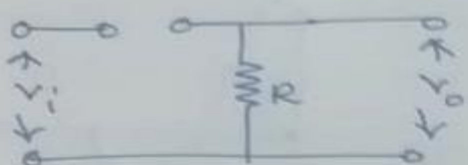
Simple series Clipper

① Ideal diodes

Positive Clipper

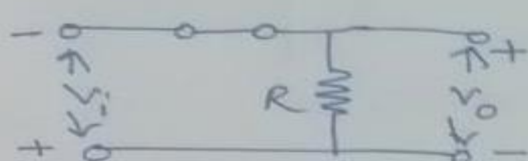


During +ve half of applied i/p



$V_o = 0$.

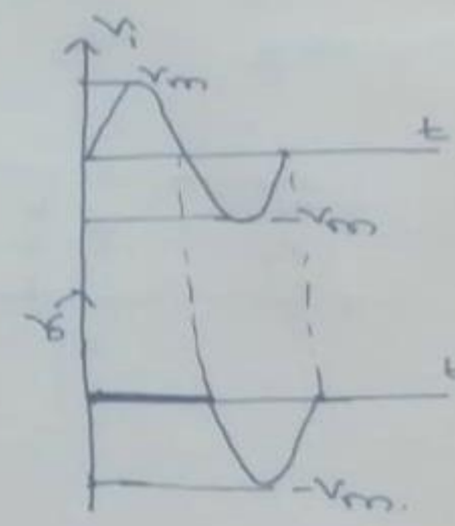
During −ve half of applied i/p.



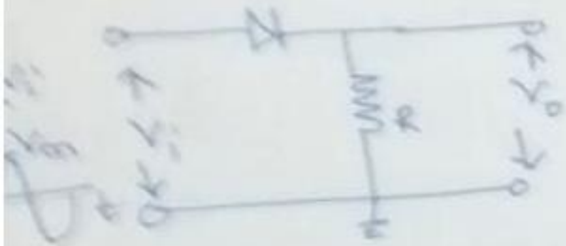
apply KVL

$-V_i - V_o = 0$

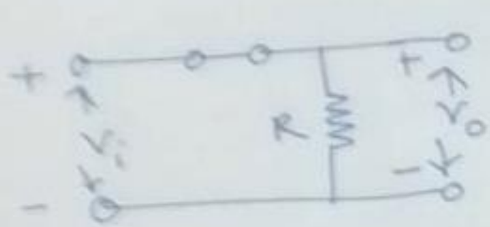
$-V_i = V_o$



Negative Clipper



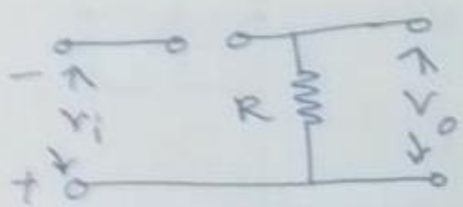
During +ve half of applied i/p,



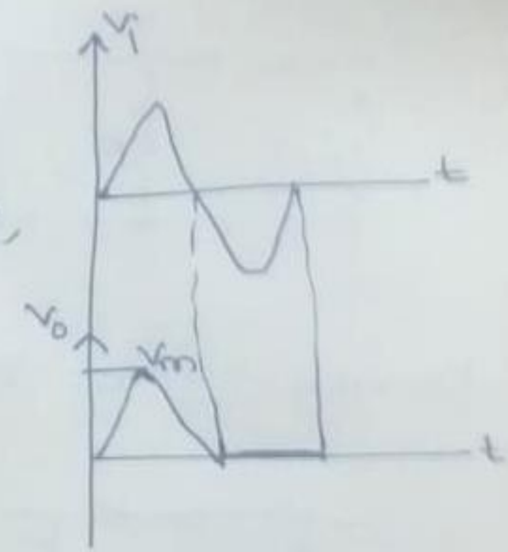
$V_i - V_o = 0$

$V = V_o$

During −ve half of applied i/p,

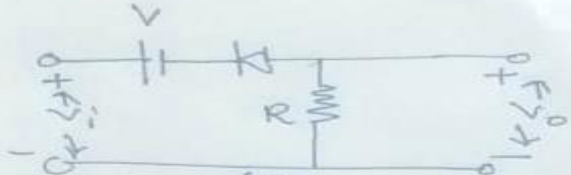


$V_o = 0$



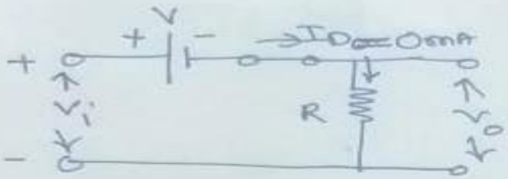
Biased series Clipper

(1)

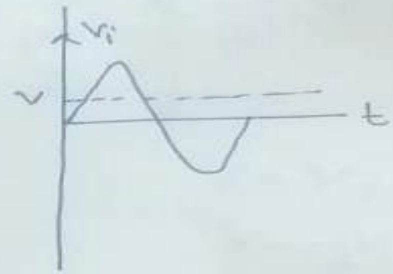


(a)

To determine V_t → transition voltage



$\because I_D = 0mA, V_R = V_o = 0.$



apply KVL,

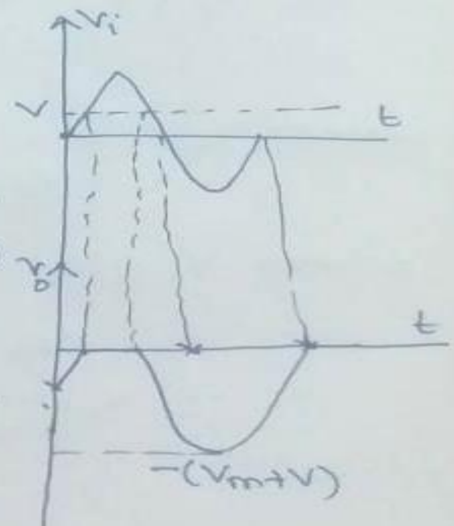
$V_i - V_t = 0.$

$\therefore V_i = V_t$

apply KVL to circuit in (a)

$V_i - V - V_o = 0$

$V_o = V_i - V.$



when $V_i < V_t$, Diode is F.B, $\therefore V_o = V_i - V.$

$V_o = -V_m - V$
$= -(V_m + V)$

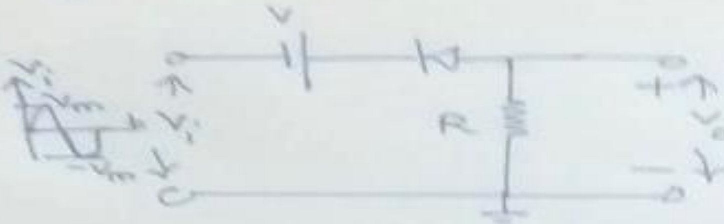
when $V_i = V_t$, $V_o = V_i - V_t (= V_i) = 0.$

when $V_i > V_t$, Diode is R.B, $\therefore V_o = 0.$

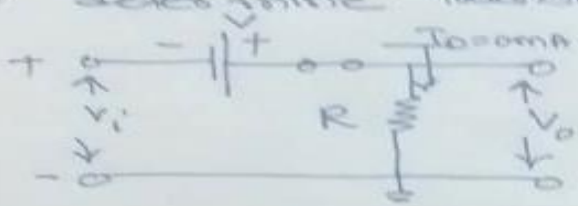
Notice :- If $V_i = 0$, $V_o =$

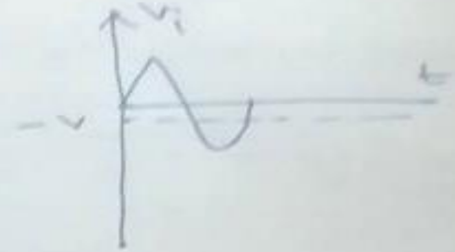
Electronic Devices and circuit theory
Nashelsky and Boylstead

(2)



To determine transition Voltage





$V_i + V = 0$

$V_i = V_t = -V$

apply KVL to the ckt,

$V_i + V - V_o = 0$

$V_o = V_i + V.$

when $V_i > V_t$, Diode is R.B → open ckted,

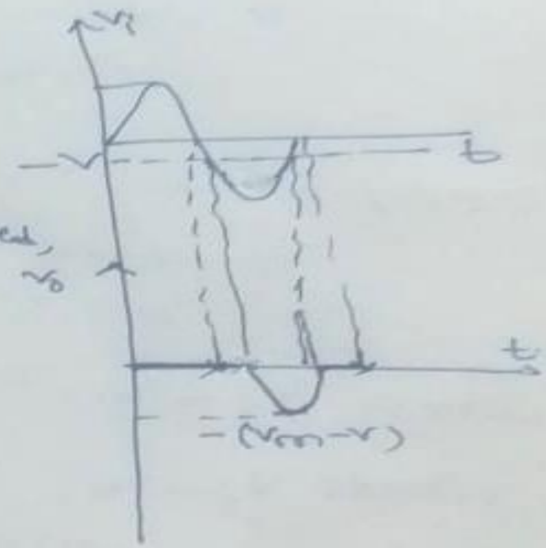
$\therefore V_o = 0.$

when $V_i \leq V_t$, Diode is F.B.

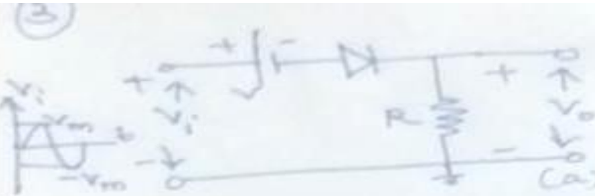
$\therefore V_o = V_i + V$

$\because V_i = -V_m$

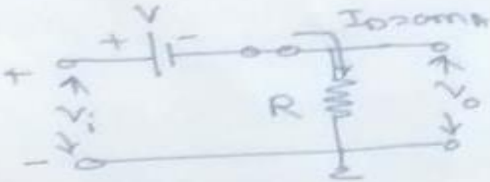
$\therefore V_o = -V_m + V = -(V_m - V)$

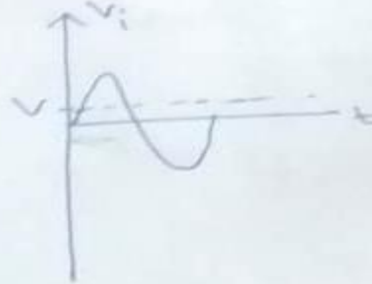


(3)



To find transition voltage,

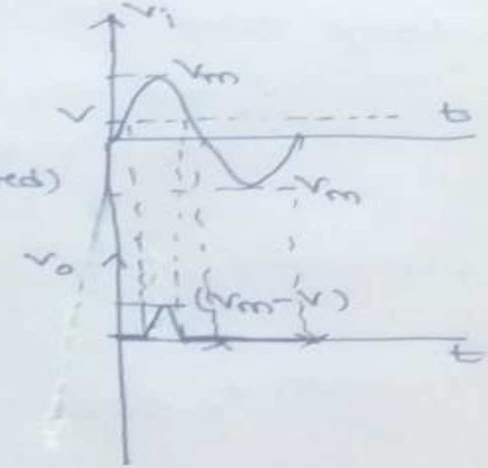




$$V_i - V = 0$$
$$V_i = V_t = V$$

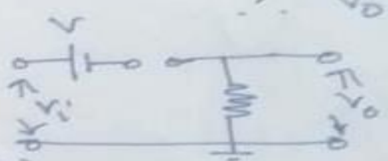
apply KVL to ckt a,

$$V_i - V - V_o = 0$$
$$V_o = V_i - V$$



when $V_i < V_t$, Diode is R.B (open ckted)

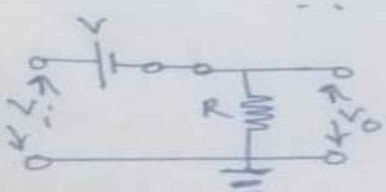
$$\therefore V_o = 0$$



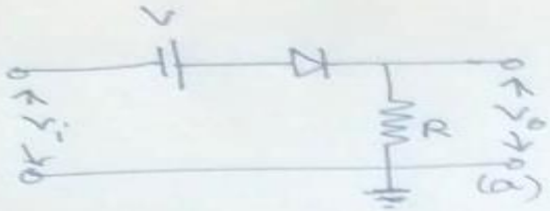
$(V_i < V_t)$

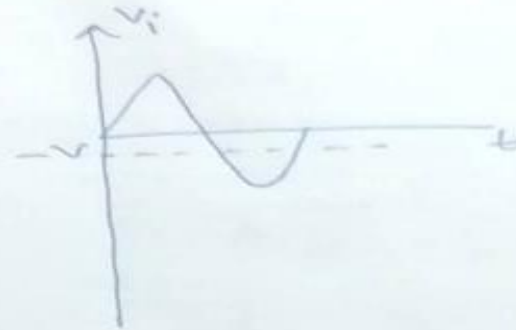
when $V_i \geq V_t$, Diode is F.B,

$$\therefore V_o = V_i - V$$
$$V_o = V_m - V$$

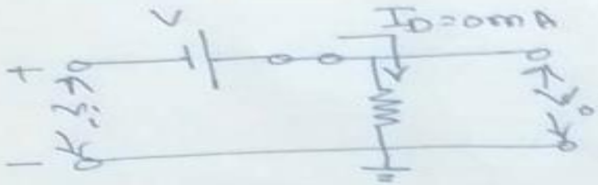


(4)





to find transition voltage,



$$v_i + V = 0$$

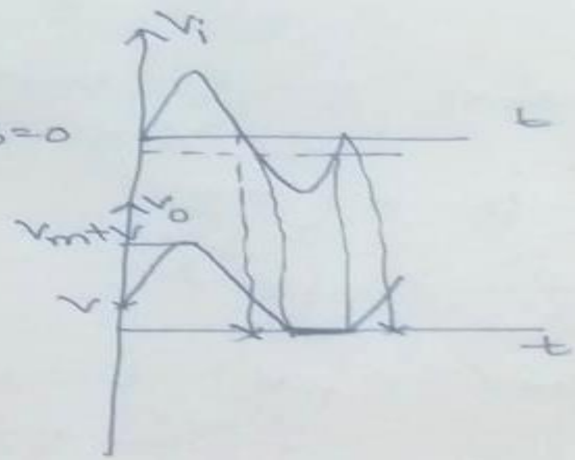
$$v_i = V_t = -V$$

apply KVL to ckt (a)

$$v_i + V - v_o = 0.$$

$$v_o = v_i + V$$

when $v_i < V_t$, Diode is R.B (open ckted), $\therefore v_o = 0$



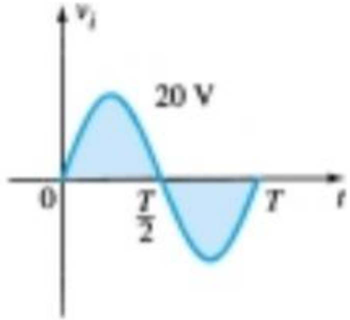
when $v_i \geq V_t$, Diode is F.B,

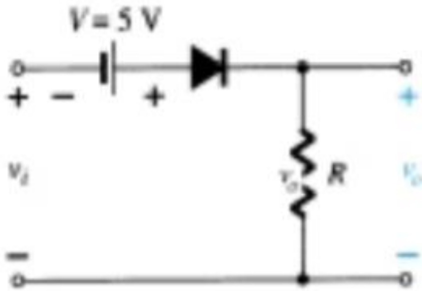
$$\therefore v_o = v_i + V$$

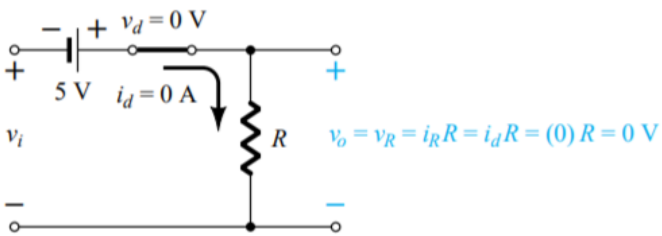
$$= V_m + V.$$

Note: if $v_i = 0$, $v_o = V$.

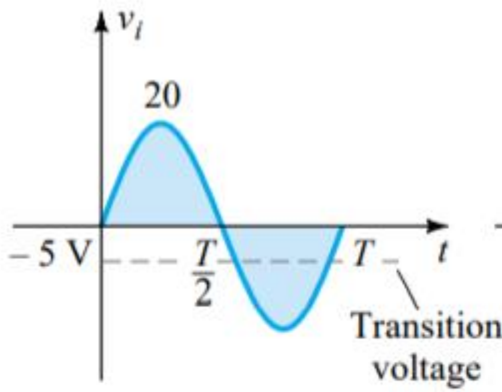
Determine the output waveform for the network of Fig.

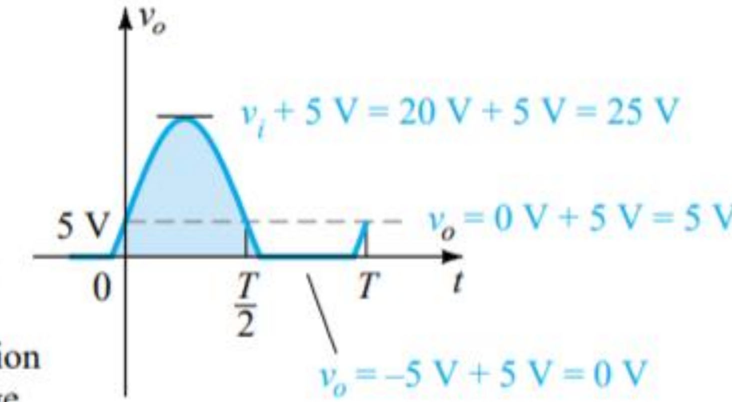




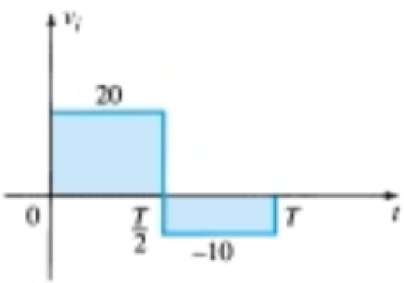


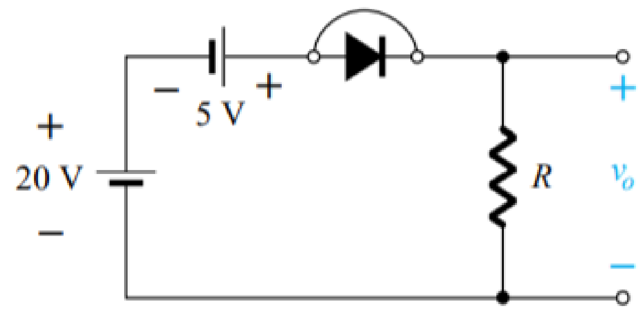
For v_i more negative than -5 V the diode will enter its open-circuit state, while for voltages more positive than -5 V the diode is in the short-circuit state. The input and output voltages appear in Fig.



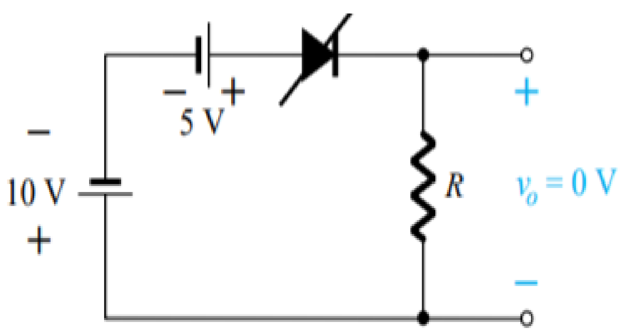


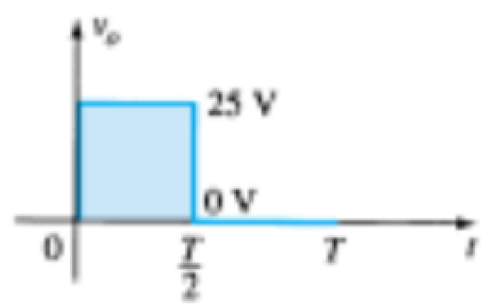
for the square-wave input





v_o at $v_i = +20$ V.





v_o at $v_i = -10$ V.

Parallel

The network of Fig. 2.82 is the simplest of parallel diode configurations with the output for the same inputs of Fig. 2.67. The analysis of parallel configurations is very similar to that applied to series configurations, as demonstrated in the next example.

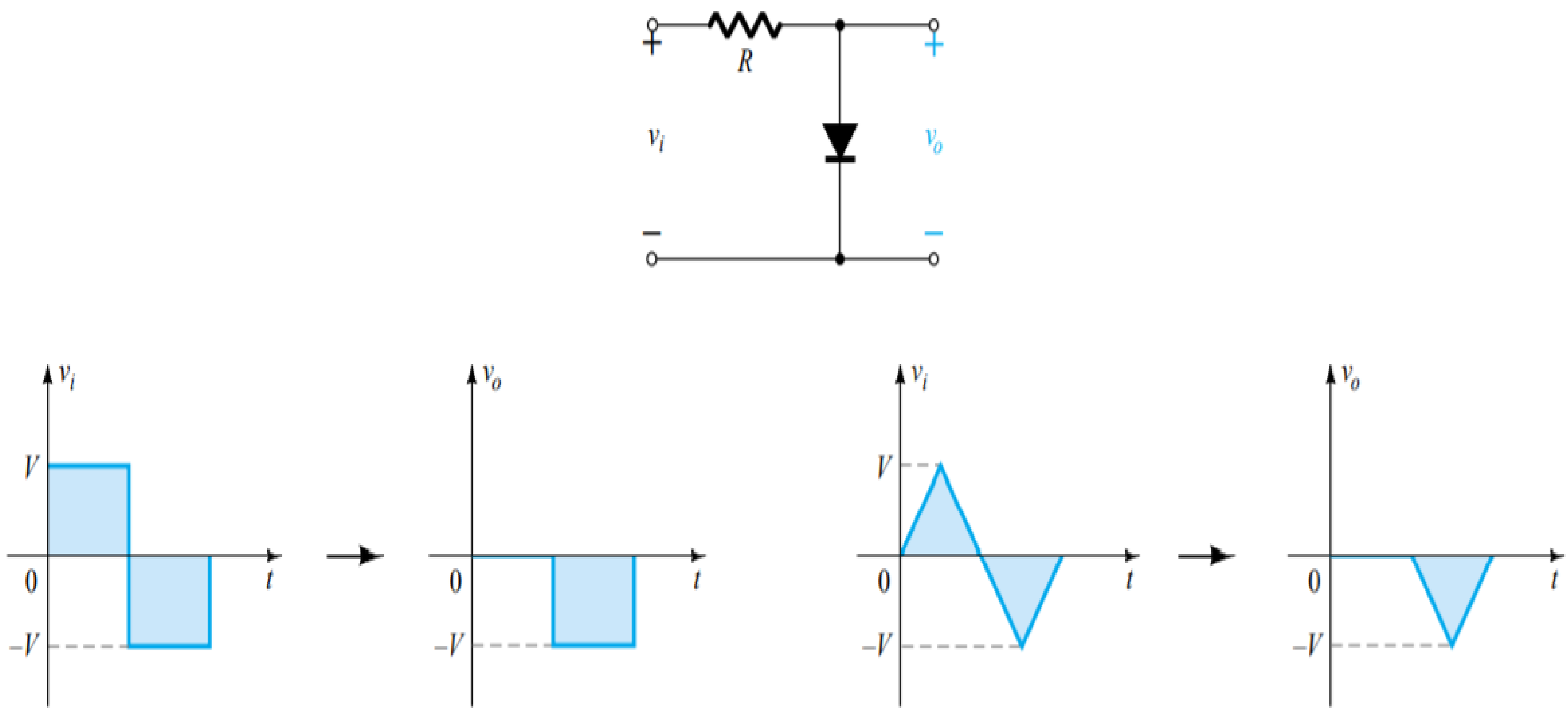


Figure 2.82 Response to a parallel clipper.

Parallel

The network of Fig. 2.81 is the simplest of parallel diode configurations with the output for the same inputs of Fig. 2.68. The analysis of parallel configurations is very similar to that applied to series configurations, as demonstrated in the next example.

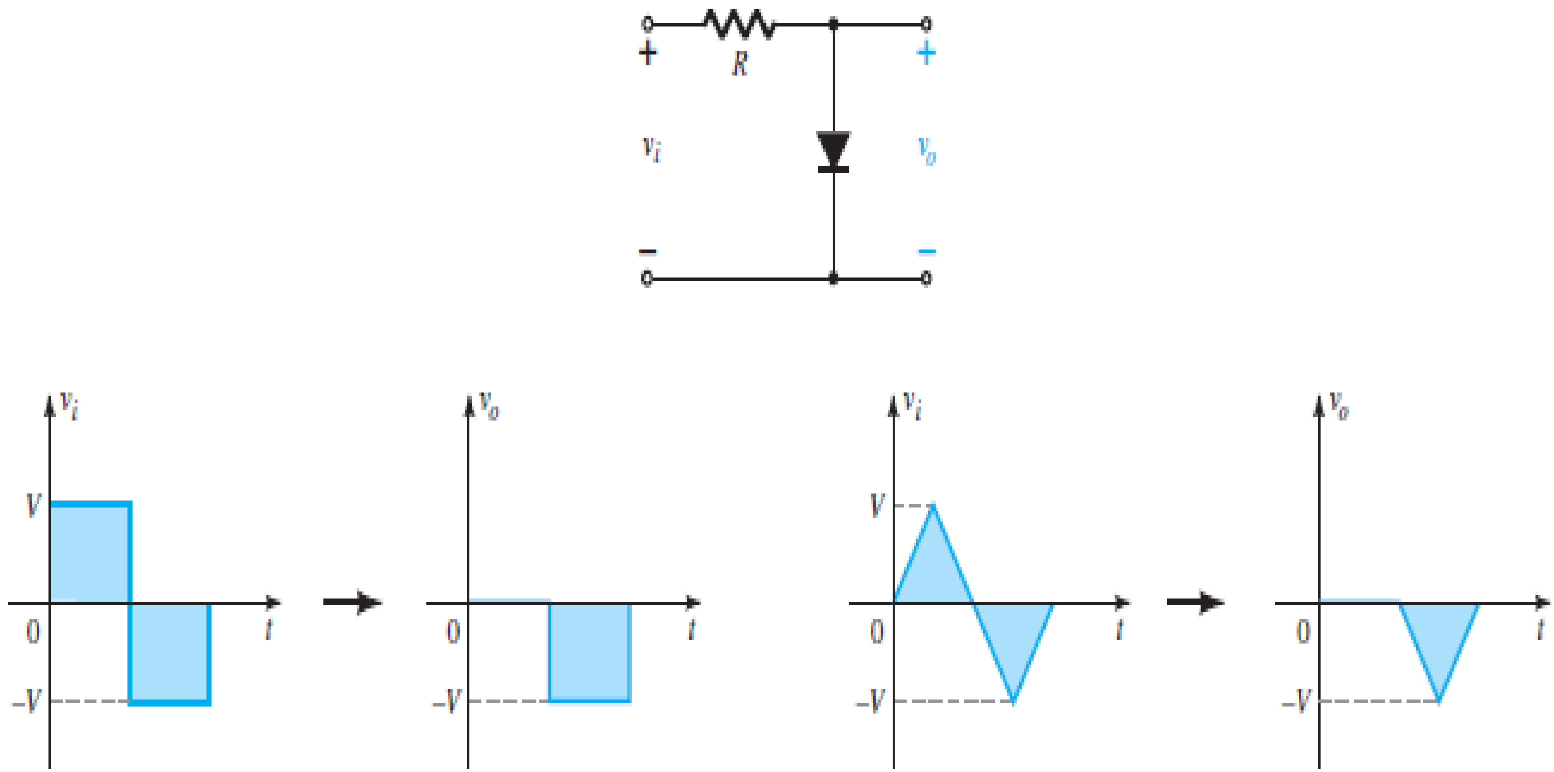
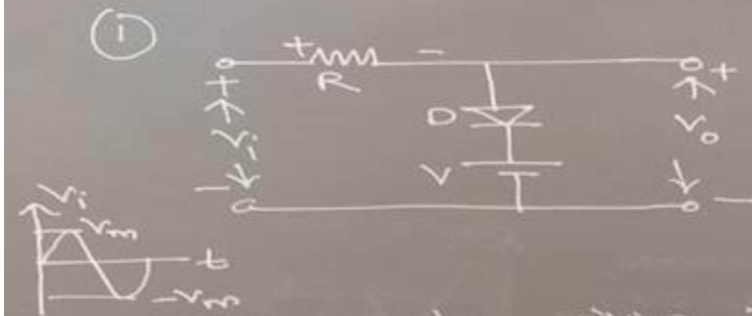


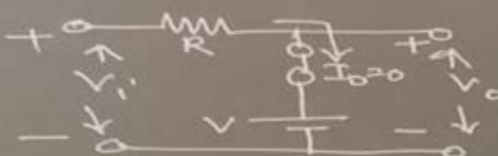
FIG. 2.81
Response to a parallel clipper.

Biased Parallel Clipper

(1)



to find transition voltage



$\because I_D = 0,\ V_R = 0V$

$\therefore V_i - V = 0$

$V_i = V_t = V$

when $V_i < V_t$, Diode is R.B (O.C), $\therefore V_o = V_i$

when $V_i \geq V_t$, Diode is f.B (S.C), $\therefore V - V_o = 0$, $V_o = V$

transfer characteristic

Electronic Devices and circuit theory
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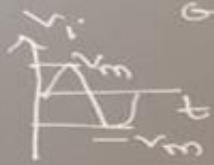
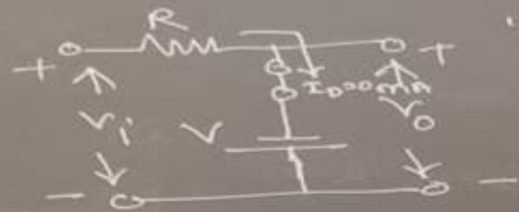
(2)



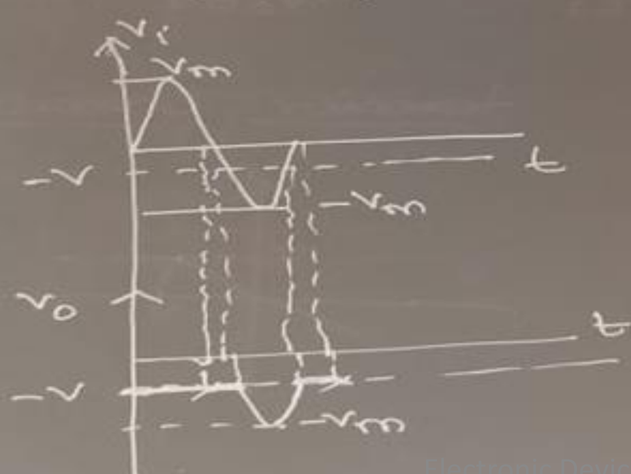
to find V_t,



$\because I_D = 0mA,$
$V_R = 0V$

$v_i + v = 0$
$v_i = v_t = -v.$

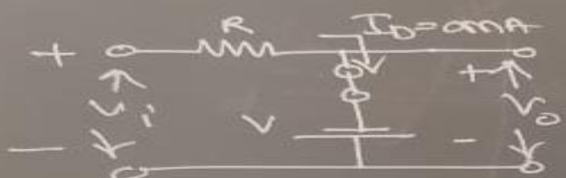
when $v_i < v_t$, Diode is R.B (o.c), $v_o = v_i$
when $v_i > v_t$, Diode is F.B (S.C), $-v - v_o = 0$
$v_o = -v.$



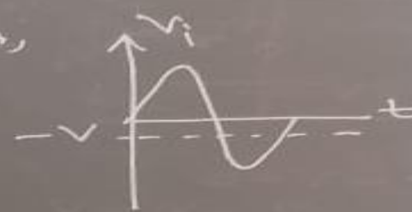
transfer characteristics

③

to find V_t :-



∵ $I_D = 0mA$,
$V_R = 0V$.



∴ $V_i + V = 0$,
$V_t = V_i = -V$.

when $V_i < V_t$, Diode is F.B (S.C), $-V - V_o = 0$
$V_o = -V$

when $V_i \geq V_t$, Diode is (O.C) R.B, $V_o = V_i$

transfer characteristics

Electronic Devices and circuit theory
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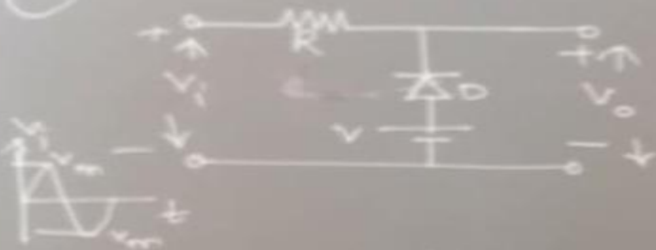
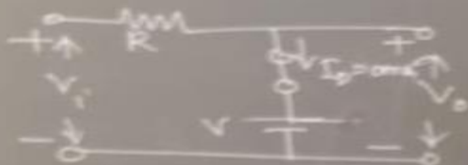
(4)

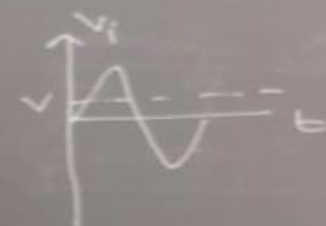


to find V_t:-



$\because I_D = 0\,mA$

$V_R = 0V$.

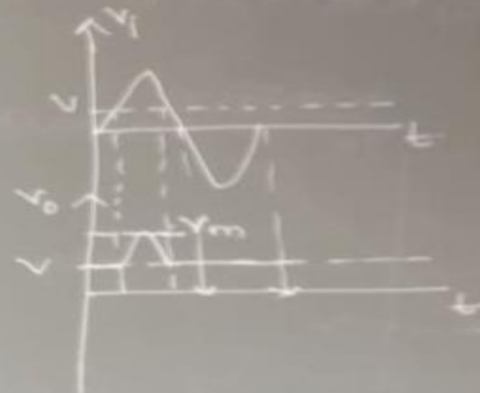


$\therefore V_i - V = 0$

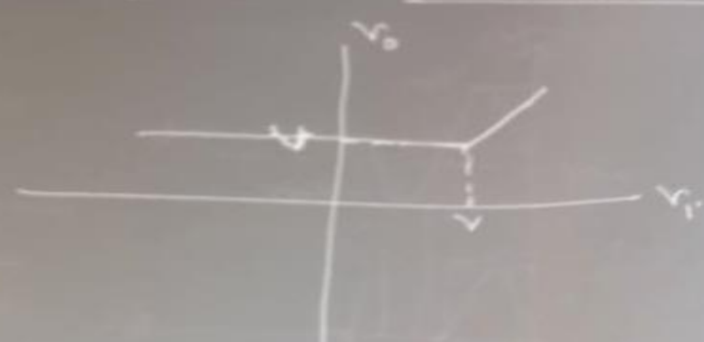
$V_i = V_t = V$

when $V_i < V_t$, Diode is F.B (S.C), $V - V_o = 0$, $V_o = V$

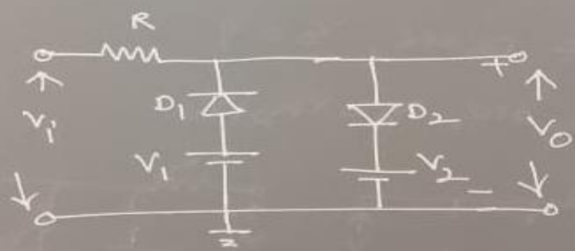
when $V_i \geq V_t$, Diode is R.B (O.C), $V_o = V_i$.

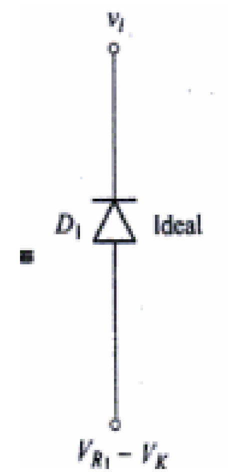


transfer characteristics



Double Ended Clipper (Clipping at two Independent levels).





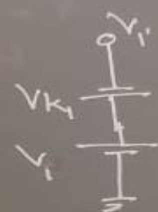
To find V_t :-

for D_1 :- (Diode is ideal)

$V_i - V_1 = 0$

$V_i = V_t = V_1$

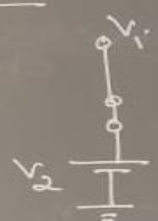
(Diode is practical)



$V_i + V_{K_1} - V_1 = 0$

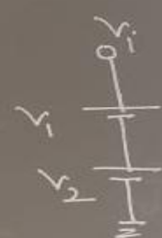
$V_i = V_t = V_1 - V_{K_1}$

for D_2 :-



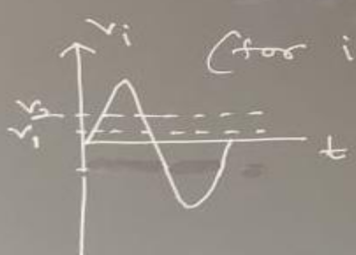
$V_i - V_2 = 0$

$V_i = V_t = V_2.$

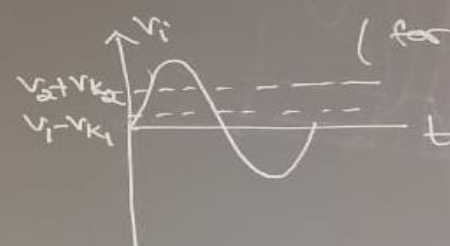


$V_i - V_{K_2} - V_2 = 0$

$V_i = V_t = V_{K_2} + V_2.$



(for ideal case)



(for practical case)

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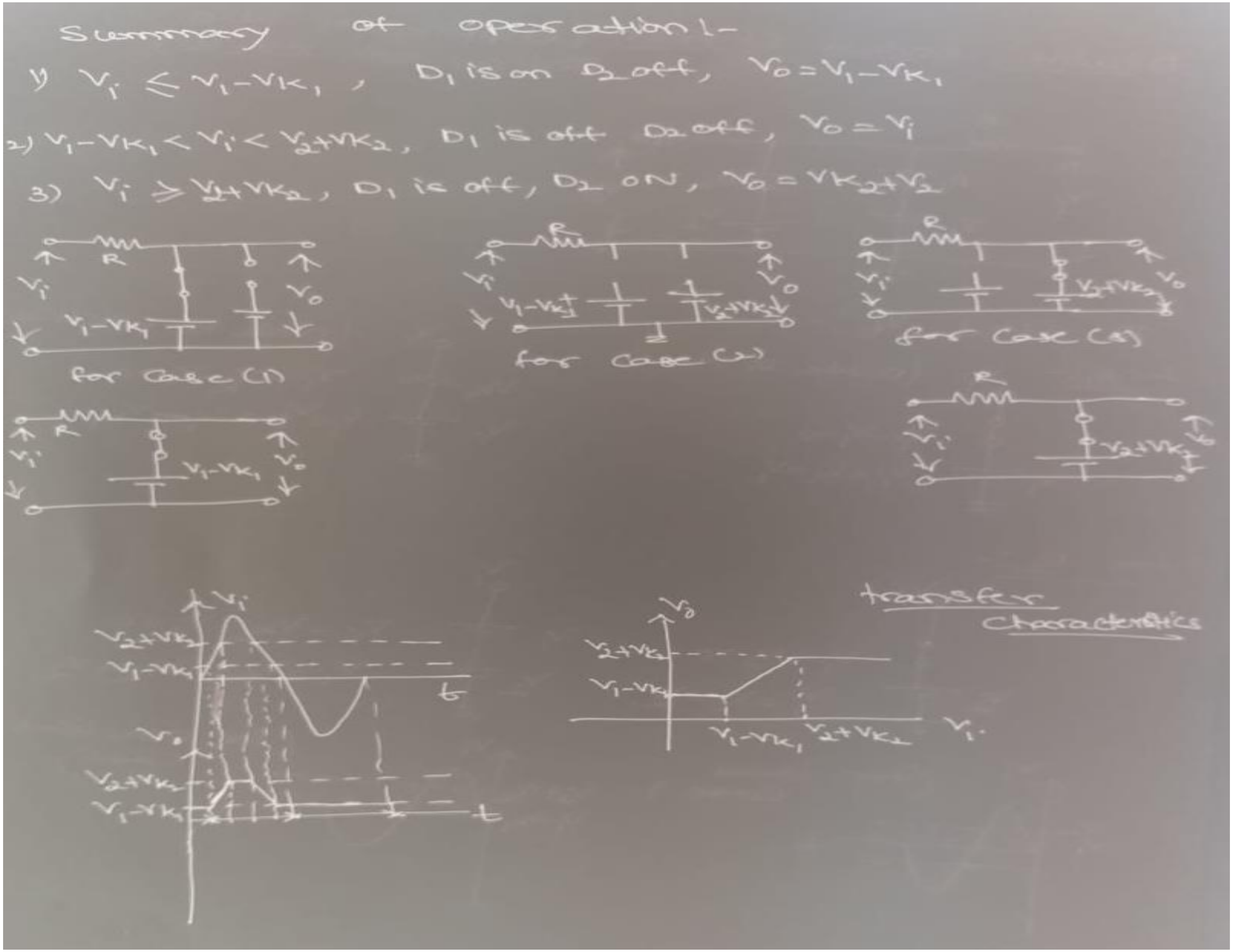

Electronic Devices and circuit theory
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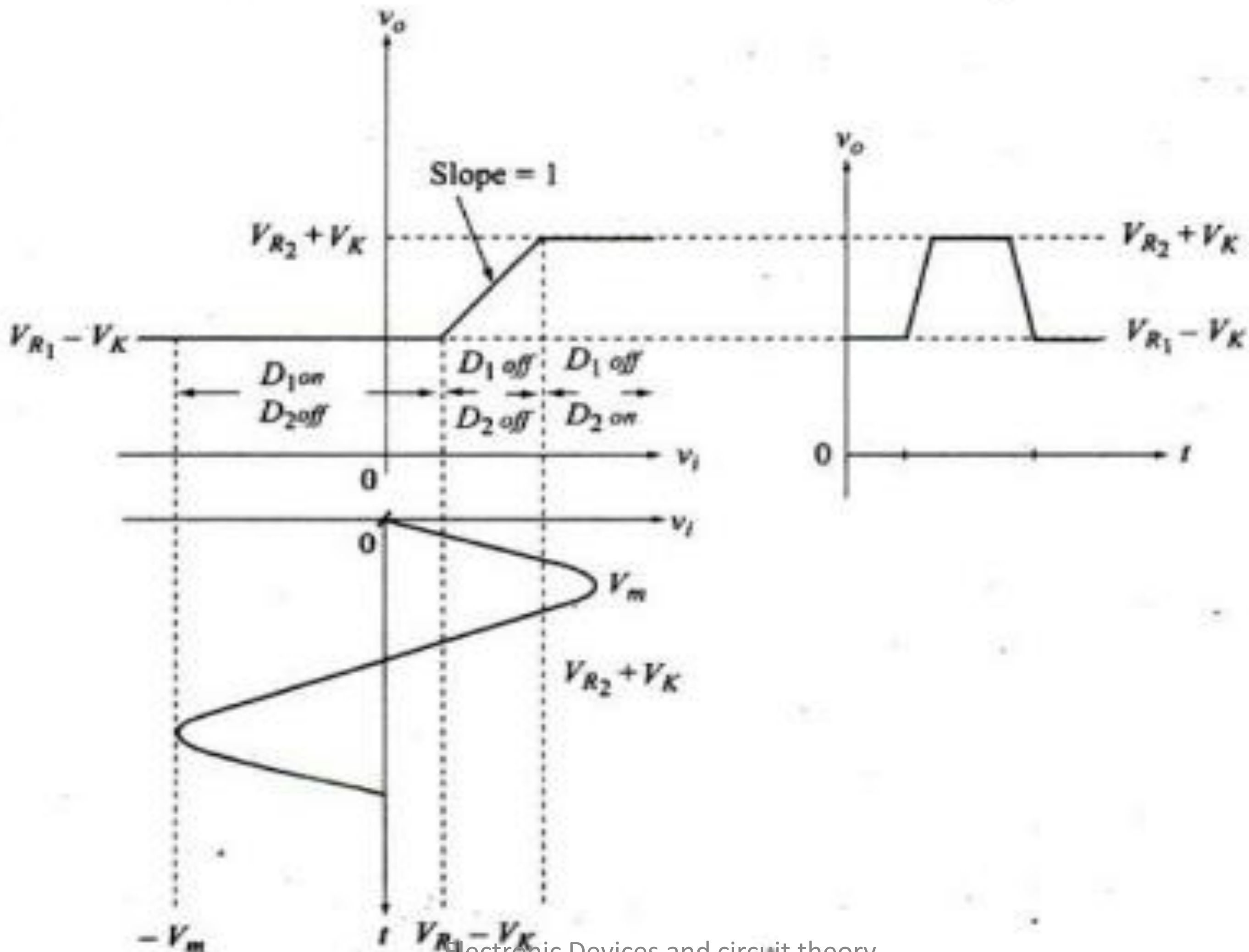
Transfer characteristics

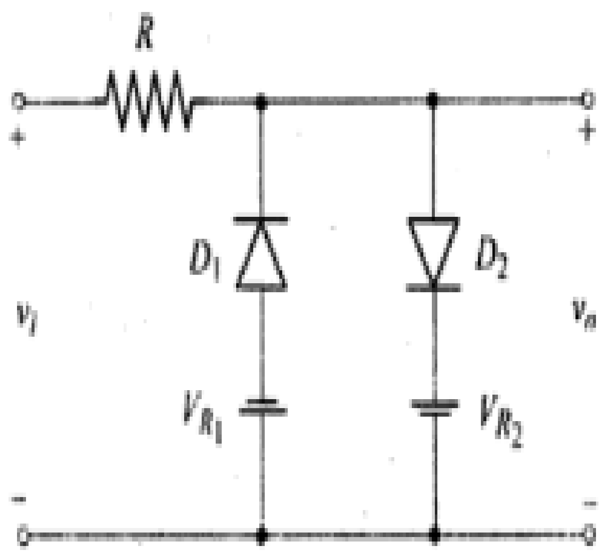


Another Double ended clipper

The variation in the double ended clipper results as shown in Fig. when the polarity of V_{R_1} is reversed in the circuit of Fig. ...

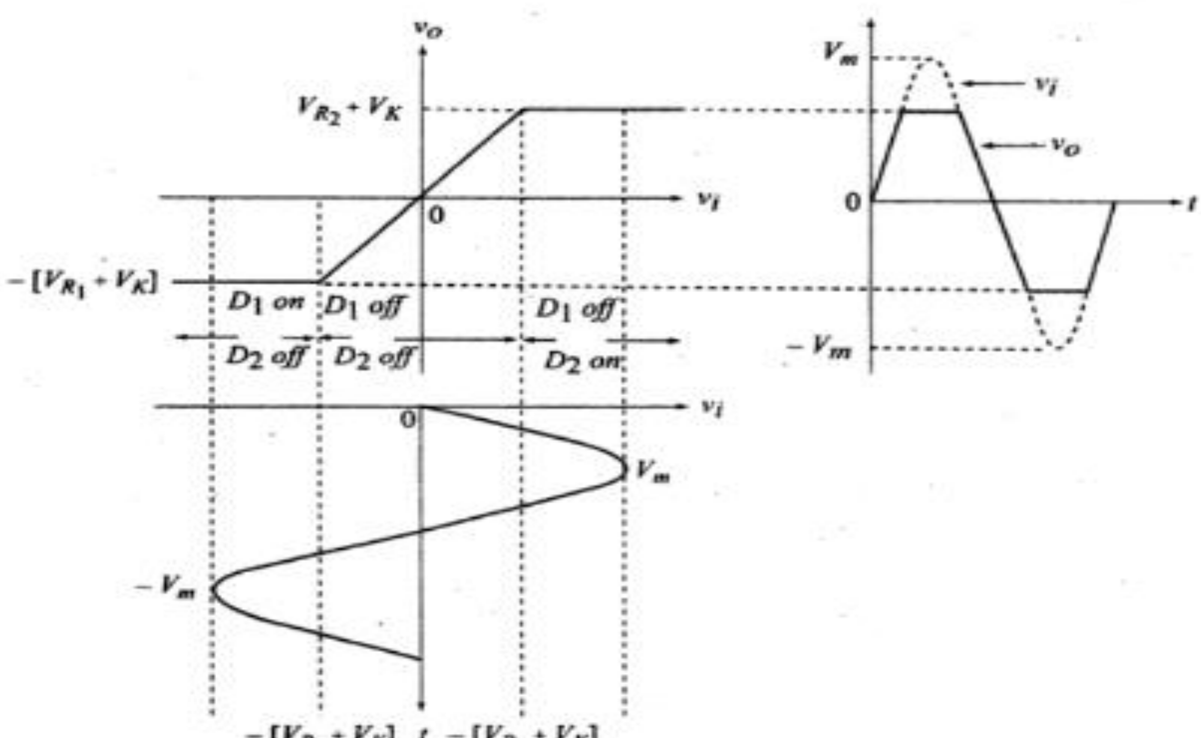
Since V_{R_1} is negative, the condition for D_1 to conduct becomes

$$v_i \le -[V_{R_1} + V_K]$$



Input voltage	Diode status	Output voltage	Slope
$v_i \leq -[V_{R_1} + V_K]$	D_1 on D_2 off	$v_o = -[V_{R_1} + V_K]$	0
$-[V_{R_1} + V_K] < v_i < [V_{R_2} + V_K]$	D_1 off D_2 off	$v_o = v_i$	1
$v_i \geq V_{R_2} + V_K$	D_1 off D_2 on	$v_o = [V_{R_2} + V_K]$	0

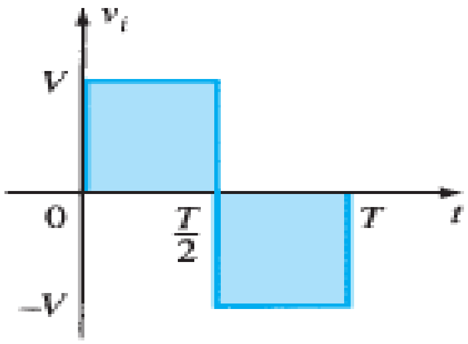
The transfer characteristic along with output for sinusoidal input is shown in Fig.

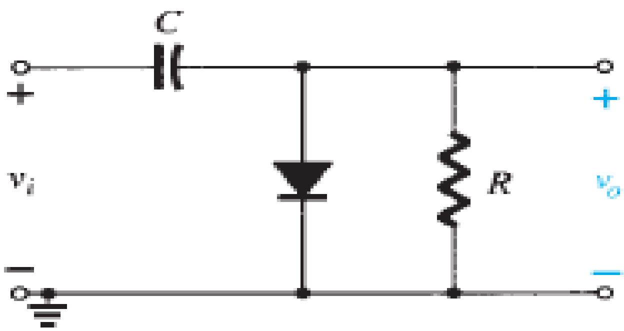


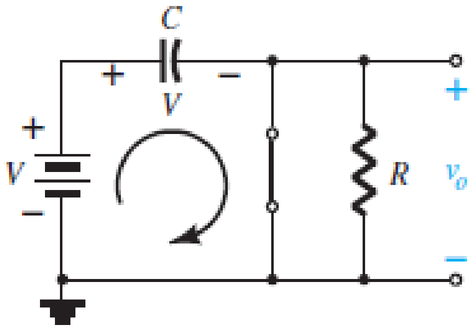
CLAMPERS

A clamper is a network constructed of a diode, a resistor, and a capacitor that shifts a waveform to a different dc level without changing the appearance of the applied signal.

Clamping networks have a capacitor connected directly from input to output with a resistive element in parallel with the output signal. The diode is also in parallel with the output signal but may or may not have a series dc supply as an added element.







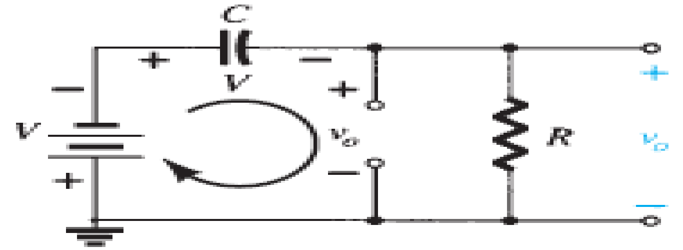


FIG. 2.91
Determining v_o with the diode "off."