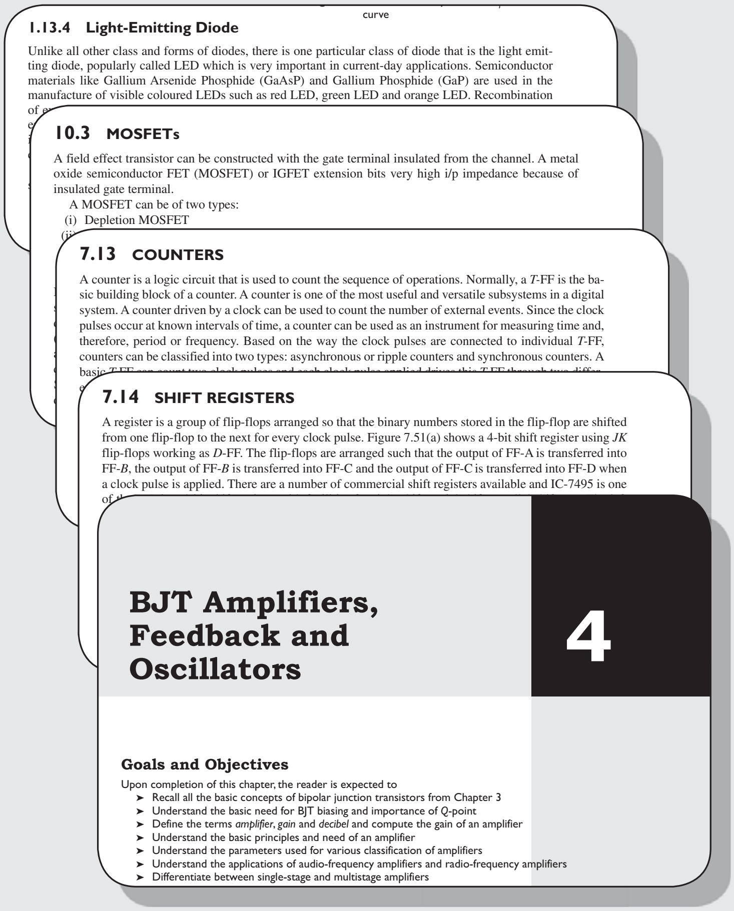
Guided Tour


curve

1.13.4 Light-Emitting Diode

Unlike all other class and forms of diodes, there is one particular class of diode that is the light emitting diode, popularly called LED which is very important in current-day applications. Semiconductor materials like Gallium Arsenide Phosphide (GaAsP) and Gallium Phosphide (GaP) are used in the manufacture of visible coloured LEDs such as red LED, green LED and orange LED. Recombination

10.3 MOSFETs

A field effect transistor can be constructed with the gate terminal insulated from the channel. A metal oxide semiconductor FET (MOSFET) or IGFET extension bits very high i/p impedance because of insulated gate terminal.

A MOSFET can be of two types:

(i) Depletion MOSFET

7.13 COUNTERS

A counter is a logic circuit that is used to count the sequence of operations. Normally, a *T*-FF is the basic building block of a counter. A counter is one of the most useful and versatile subsystems in a digital system. A counter driven by a clock can be used to count the number of external events. Since the clock pulses occur at known intervals of time, a counter can be used as an instrument for measuring time and, therefore, period or frequency. Based on the way the clock pulses are connected to individual *T*-FF, counters can be classified into two types: asynchronous or ripple counters and synchronous counters. A

7.14 SHIFT REGISTERS

A register is a group of flip-flops arranged so that the binary numbers stored in the flip-flop are shifted from one flip-flop to the next for every clock pulse. Figure 7.51(a) shows a 4-bit shift register using *JK* flip-flops working as *D*-FF. The flip-flops are arranged such that the output of FF-A is transferred into FF-*B*, the output of FF-*B* is transferred into FF-C and the output of FF-C is transferred into FF-D when a clock pulse is applied. There are a number of commercial shift registers available and IC-7495 is one

BJT Amplifiers, Feedback and Oscillators

4

Goals and Objectives

Upon completion of this chapter, the reader is expected to

- Recall all the basic concepts of bipolar junction transistors from Chapter 3
- Understand the basic need for BJT biasing and importance of Q-point
- Define the terms *amplifier*, *gain* and *decibel* and compute the gain of an amplifier
- Understand the basic principles and need of an amplifier
- Understand the parameters used for various classification of amplifiers
- Understand the applications of audio-frequency amplifiers and radio-frequency amplifiers
- Differentiate between single-stage and multistage amplifiers

Important topics like LED Characteristics, MOSFET, Power Semiconductor Devices, Feedback Amplifiers and Oscillators, Shift Registers and Counters discussed in detail

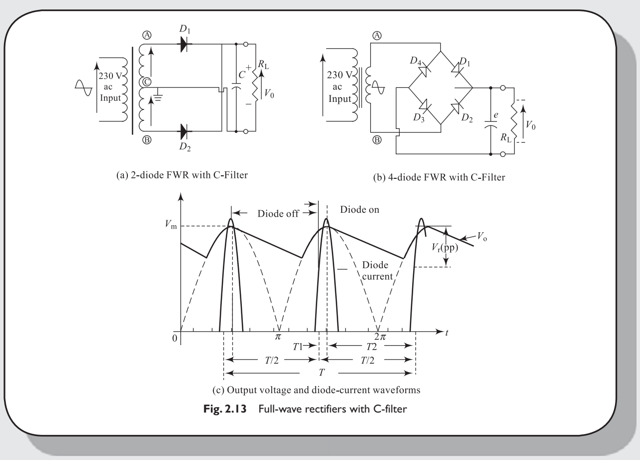


Fig. 2.13 Full-wave rectifiers with C-filter

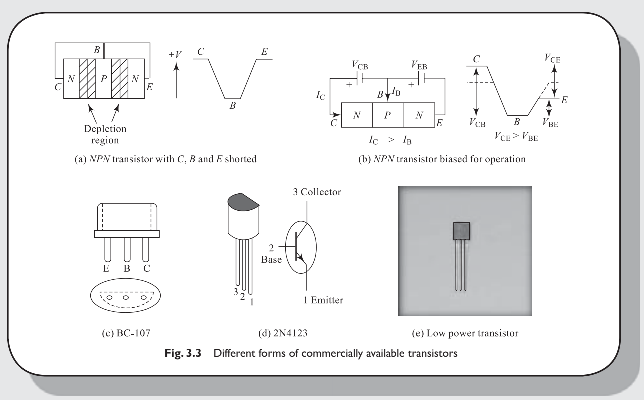


Fig. 3.3 Different forms of commercially available transistors

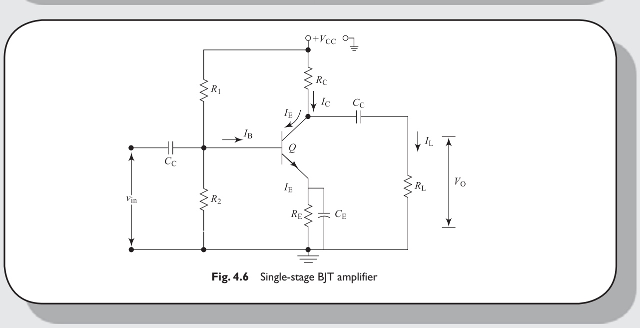


Fig. 4.6 Single-stage BJT amplifier

300 block diagrams and circuit diagrams to enhance understanding

1 Semiconductor Physics and *PN* Junction

Goals and Objectives

Upon completion of this chapter, the reader of the book is expected to

- Understand the importance of electronics in everyday life
- Review the basics of atomic structure and energy levels of different materials
- Understand the general characteristics of important semiconductor materials like silicon, germanium, gallium arsenide, etc
- Understand the principle of electron and hole conduction
- Differentiate between *N*-type and *P*-type semiconductor materials
- Understand the characteristics of a *PN* junction under unbiased, forward-biased and reverse-biased conditions
- Understand the importance and draw an equivalent circuit of a *PN* junction
- Understand the use of diode as a switch in electronic applications
- Understand the importance of diode capacitances: diffusion capacitance and transition capacitance
- Understand the use of diode capacitances in applications such as FM generation
- Understand the effect of reverse recovery time on performance of diode circuits
- Understand the working principle and characteristics of other semiconductor diodes
- Understand the concepts of Zener regulator, FM generation, LED display, etc.
- Understand the reading and interpretation of diode-specification sheets
- Do physical interpretation of concepts with a good number of examples provided
- Feel confident in moving to the next chapter on **diode applications**

Goals and Objectives at the beginning of each chapter to introduce the topics

Example 1.5

Find the current flowing through a *PN* junction when a potential of 0.2 V is applied across the junction at room temperature, given the junction current of 5×10^{-7} A when a large reverse bias applied across the junction.

Solution Given $I_O = 5 \times 10^{-7}$ A, $V = 0.2$ V and $T = 27°C$

We have Eq. (1.4); $V_T = T/11600 = 26$ mV

We have diode current equation given by Eq. (1.2):

$$I_D = I_O (e^{V/\eta} V_T - 1) \text{ A}; \ \eta = 1 \text{ for germanium}$$
$$= 5 \times 10^{-7}(e^{0.2/1\times 26 \text{ mV}} - 1) \text{ A} = 5 \times 10^{-7}(2191.426 - 1) \text{ A}$$
$$\boxed{I_D = 1.095 \text{ mA}}$$

In summary, the most important characteristic of a *PN* junction diode is its ability to offer very little resistance for the current flow in the forward direction and maximum resistance to current flow in the reverse direction. This property can be exploited in using the diode as an electronic switch.

320 Solved Examples spread across the text to help students solve numerical problems related to the topics

Example 4.2

A single-stage amplifier with an input of 250 mV produces an output of 1.5 V. What is the gain?

Solution Given $v_{in} = 250$ mV and $v_o = 1.5$ V

From Eq. 4.2(a), the voltage gain is

$$A_v = \frac{v_o}{v_{in}}$$
$$= \frac{1.5}{250 \times 10^{-3}} = 6$$

Example 4.3

A single-stage amplifier offering a stage gain of 7.5 dB produces an output of 0.5 V. What is the input voltage needed?

Solution Given $A_V = 7.5$ dB and $v_o = 500$ mV

From Eq. (4.5) $A_V = 20 \log\left(\frac{v_o}{v_{in}}\right)$ dB

Summary

After a detailed study of the complete concepts in this chapter, the following important inferences may be drawn:

- The conductivity of a semiconductor material lies in between that of a good conductor and an insulator.
- A covalent bond is a formed by the process of bonding of atoms through the electrons sharing between the neighbouring atoms.
- Atomic number of a semiconductor decides the number of valence electrons in its outermost orbit.
- The number of free electrons in a semiconductor material and its conductivity can be significantly increased by increasing the temperature.
- For a majority of semiconductor materials, the resistance decreases with an increase in temperature (negative temperature coefficient -α).
- An intrinsic material is a pure form of a semiconductor with zero or very low level of impurity.
- An extrinsic material is an impure form of a semiconductor with an impurity added by a process called doping.
- An *N*-type material is formed by adding a pentavalent impurity (donor atoms). In an *N*-type material, electrons are the majority carriers and holes are the minority carriers.
- A *P*-type material is formed by adding a trivalent impurity (acceptor atoms). In a *P*-type material, holes are the majority carriers and electrons are the minority carriers.
- The region near the *PN* junction that has very few carriers is called the depletion region.
- In the forward-bias region, the diode current exponentially increases with increase in the bias voltage.

Semiconductor Physics and PN Junction **41**

Chapter-end Summary provided for each chapter for quick recap of the concepts

Guided Tour

225 Review Questions to enhance theoretical grasp of the concepts

Review Questions

1. Sketch the output waveform for the circuit of Fig. P6.1 for a sinusoidal input of $2V_{(peak)}$.
2. Sketch the output waveform for the circuit of Fig. P6.1 for a sinusoidal input of $2V_{(peak)}$ when R_{in} is increased tenfold.
3. Sketch the output waveform for the circuit of Fig. P6.1 for a sinusoidal input of $2V_{(peak)}$ when R_f is decreased tenfold.
4. For the circuit of Fig. P6.1, what is the maximum input signal that results in an undistorted output?
5. What is the role of level shifter in an op-amp? Explain.
6. What is the meaning of virtual ground? On what assumption do we arrive at this concept?
7. Sketch the output waveform for the circuit of Fig. P6.7 for a sinusoidal input of $2V_{(peak)}$.
8. Sketch the output waveform for the circuit Fig. P6.7 for a sinusoidal input of $2V_{(peak)}$ when R_{in} is increased tenfold.
9. Sketch the output waveform for the circuit of Fig. P6.7 for a sinusoidal input of $2V_{(peak)}$ when R_f is decreased tenfold.
10. For the circuit of Fig. P6.7, what is the maximum input signal that results in an undistorted output?
11. List the major functions of each block in an op-amp.
12. Obtain the operating point for a dual input, balanced output DA.
13. What is the significance of off sets in an op-amp?
14. What is the significance of input impedance in an op-amp?
15. What is the significance of output impedance in an op-amp?
16. What is the significance of slew rate in an op-amp?
17. What is the significance of CMRR in an op-amp?
18. What is the significance of PSRR an op-amp?
19. What is the significance of unity gain bandwidth 'f_U' in an op-amp?
20. What is the significance of full power bandwidth 'f_P' in an op-amp?
21. Draw the transfer characteristics for an op-amp and comment on region of uncertainty.
22. What is the role of a buffer in system design using op-amps?
23. Explain how a buffer is different from a non-inverter.
24. An even number of buffers are cascaded together. What is the output expected for a sine-wave input?
25. An integrator with a square-wave input is driving a differentiator. What is the expected output of this cascaded combination?
26. Comment whether designing an Inverting type Op-Amp Summer is complex or a Non-Inverting type Op-Amp Summer?

Exercise Problems

1. Calculate the amount of energy required to move a charge of 5 coulombs through a field set by a potential difference of 5 V.
2. A total energy of 36 eV is spent in moving a charge of *x* coulombs through a field set by a potential difference of 10 V. Determine the value of charge *x*.
3. Calculate the amount of the diode current at 10°C for a silicon diode with I_o of 200 nA and an applied forward-bias voltage of 0.6 V.
4. Repeat Problem 3 for temperatures of (i) 27°C (room temperature), and (ii) 100°C (boiling point of water).
5. Repeat Problem 3 for a temperature of 100°C assuming that Io has increased to 500 nA.
6. (a) Calculate the amount of the diode current at 20°C for a silicon diode with I_o = 200 nA and a reverse-bias potential of 10 V.
   (b) Comment on the result critically.
7. (a) In the reverse-bias region, the saturation current of a silicon diode is about 0.1 mA at a temperature of 20°C. Determine its approximate value if the temperature is doubled.
   (b) Check whether the theory 'current doubles for every 10°C rise in temperature' holds good in the answer to part (a).
8. If the reverse-bias potential for a diode changes from 10 V to 100 V, what will be the percentage change in the reverse saturation current of the diode?
9. Determine the forward voltage drop across a diode at temperatures of 27°C, 100°C and 125°C given a diode current of 10 mA.
10. Determine the static or dc resistance of a diode whose *VI* characteristics is given in Table P10 below at a forward current of 2 mA.

Table P10

Sl. No.	V_D in volts	I_D in mA
1	0	0
2	0.1	0.01
3	0.2	0.02
4	0.3	0.04
5	0.4	0.5
6	0.5	1.0
7	0.6	10.0
8	0.7	28
9	0.75	59
10	0.78	99

11. Determine the dynamic or ac resistance of a diode whose *VI* characteristics is given in Table P10 above around a forward current of 2 mA.
12. Draw the piecewise linear equivalent circuit for the diode in Problem 10.
13. Determine the dynamic (ac) resistance of the diode of Fig. P1.13 at a forward current of 10 mA using the equation $r_{ac} = (\Delta V_D/\Delta I_D)\Omega$.

44 *Basic Electronics*

185 Exercise Problems to help students have practice in solving numerical problems

450 Multiple-Choice Questions to practice for competitive examinations

Multiple-Choice Questions

1. All electronic circuits for their working and operation require
   (a) ac source (b) dc source (c) both (a) and (b) (d) no source
2. The electronic circuit that generates dc power from an available ac source is
   (a) power supply (b) amplifier (c) oscillator (d) all the above
3. A power-supply unit consists of
   (a) a rectifier (b) a filter (c) a regulator (d) all the above
4. The output of which unit of a power supply contains maximum dc components?
   (a) A rectifier (b) A transformer (c) A filter (d) None
5. A transformer in a power-supply unit necessarily
   (a) isolates high-tension unit from low-tension units
   (b) steps down i/p
   (c) amplifies i/p
   (d) both (a) and (b)
6. The turns ratio in a transformer is related to primary and secondary parameters through
   (a) $N_1/N_2 = I_1/I_2 = V_1/V_2$ (b) $N_1/N_2 = I_2/I_1 = V_2/V_1$
   (c) $N_1/N_2 = I_2/I_1 = V_1/V_2$ (d) none
7. The rectifier of a power-supply unit is also called
   (a) a converter (b) a transformer (c) an inverter (d) none
8. The output of a rectifier in a power-supply unit is
   (a) a pure ac (b) a pure dc (c) a pulsating dc (d) none
9. The unit in a power supply that minimises the ripples is
   (a) a rectifier (b) a transformer (c) a regulator (d) a filter
10. The ripple factor in a rectifier output is the signal ratio of
    (a) output ac to output dc (b) output dc to output ac
    (c) output ac to input ac (d) none
11. The unit in a power supply that provides constant dc against certain variations is
    (a) a rectifier (b) a transformer (c) a filter (d) a regulator
12. The conversion efficiency of a full-wave rectifier output is ideally
    (a) 0.48 (b) 1.21 (c) 0.812 (d) 0.406
13. The TUF in a half-wave rectifier is ideally
    (a) 0.48 (b) 1.21 (c) 0.286 (d) 0.693

Quiz Questions (Short-answer Questions)

Chapter 1: Semiconductor Physics and *PN* Junction

1.1 **Classify solid materials based on electrical properties**

Ans Solid materials may be classified into the following three types: (i) Insulators, (ii) Conductors, and (iii) Semiconductors.

1.2 **What do you mean by atomic number?**

Ans The number of protons or electrons in an atom is called the "atomic number".

1.3 **Give the atomic number for silicon, carbon and aluminium.**

Ans The atomic number for silicon is 14, for carbon it is 5, and for aluminium it is 13.

1.4 **What do you mean by forbidden energy gap?**

Ans The energy gap between the conduction band and the valence band is called 'forbidden energy gap'. In conductors this gap is zero; in insulators, it is too high; and in semiconductors, it is reasonably small.

1.5 **Give the forbidden-energy-gap value for silicon and germanium**

250 Short-Answer Questions for easy recap of definitions and terms