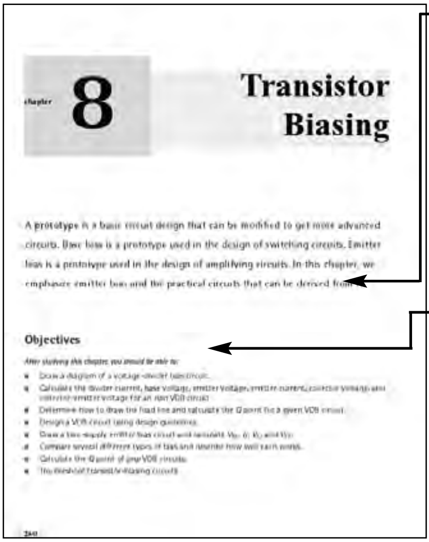
Guided Tour

Learning Features

Many new learning features have been incorporated into the seventh edition of *Electronic Principles*. These learning features, found throughout the chapters, include:



chapter 8 Transistor Biasing

A **prototype** is a basic circuit design that can be modified to get more advanced circuits. Base bias is a prototype used in the design of switching circuits. Emitter bias is a prototype used in the design of amplifying circuits. In this chapter, we emphasize emitter bias and the practical circuits that can be derived from

Objectives

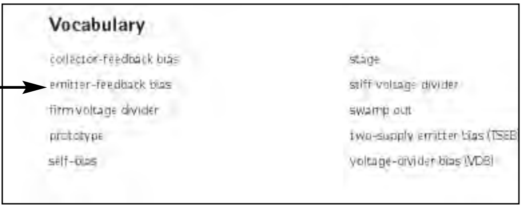
After studying this chapter, you should be able to:

CHAPTER INTRODUCTION

Each chapter begins with a brief introduction setting the stage for what the student is about to learn.

CHAPTER OBJECTIVES

Chapter Objectives provide a concise statement of expected learning outcomes.



Vocabulary

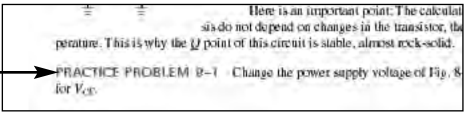
collector-feedback bias
emitter-feedback bias
firm voltage divider
prototype
self-bias
stage
stiff voltage divider
swamp out
two-supply emitter bias (TSEB)
voltage-divider bias (VDB)

VOCABULARY

A comprehensive list of new vocabulary words alerts the students to key words found in the chapter. Within the chapter, these key words are highlighted in bold print the first time used.

PRACTICE PROBLEMS

Students can obtain critical feedback by performing the Practice Problems that immediately follow most Examples. Answers to these problems are found at the end of each chapter.



Here is an important point: The calculat

sis do not depend on changes in the transistor, th

perature. This is why the Q point of this circuit is stable, almost rock-solid.

PRACTICE PROBLEM 8–1 Change the power supply voltage of Fig. 8

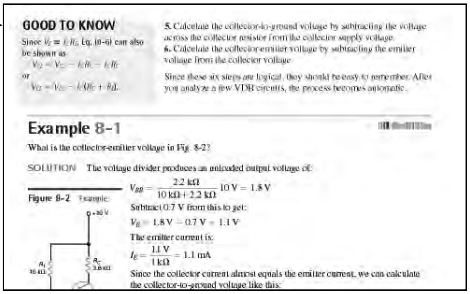
for V_{CE}.

GOOD TO KNOW

Good To Know statements, found in the margins, provide interesting added insights to topics being presented.

EXAMPLES

Each chapter contains worked-out Examples that demonstrate important concepts or circuit operation, including circuit analysis, applications, troubleshooting, and basic design.



GOOD TO KNOW

Since $V_E = I_E R_E$, Eq. (8-6) can also be shown as:

$V_{CE} = V_{CC} - I_C R_C - I_E R_E$

or

$V_{CE} = V_{CC} - I_C(R_C + R_E)$.

5. Calculate the collector-to-ground voltage by subtracting the voltage across the collector resistor from the collector supply voltage.
6. Calculate the collector-emitter voltage by subtracting the emitter voltage from the collector voltage.

Since these six steps are logical, they should be easy to remember. After you analyze a few VDB circuits, the process becomes automatic.

Example 8-1

What is the collector-emitter voltage in Fig. 8-2?

SOLUTION The voltage divider produces an unloaded output voltage of:

Figure 8-2 Example.

$$V_{BB} = \frac{2.2\ \text{k}\Omega}{10\ \text{k}\Omega + 2.2\ \text{k}\Omega} 10\ \text{V} = 1.8\ \text{V}$$

Subtract 0.7 V from this to get:

$$V_E = 1.8\ \text{V} - 0.7\ \text{V} = 1.1\ \text{V}$$

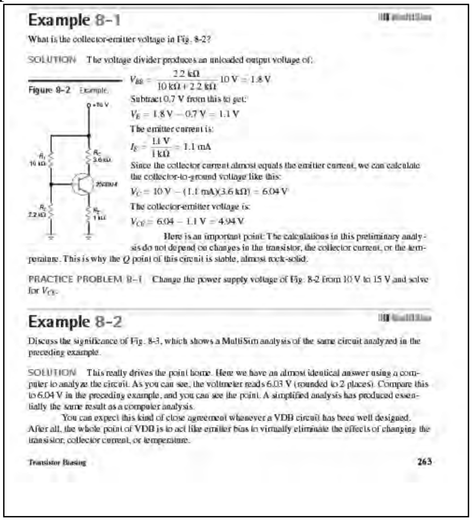
The emitter current is:

$$I_E = \frac{1.1\ \text{V}}{1\ \text{k}\Omega} = 1.1\ \text{mA}$$

Since the collector current almost equals the emitter current, we can calculate the collector-to-ground voltage like this:

MULTISIM

Students can "bring to life" many of the circuits found in each chapter. A CD containing MultiSim files is included with the textbook; with these files students can change the value of circuit components and instantly see the effects, using realistic Tektronix and Agilent simulation instruments. Troubleshooting skills can be developed by inserting circuit faults and making circuit measurements. Students new to computer simulation software will find a MultiSim Primer in the appendix.



Example 8-1

What is the collector-emitter voltage in Fig. 8-2?

SOLUTION The voltage divider produces an unloaded output voltage of:

Figure 8-2 Example.

$$V_{BB} = \frac{2.2\ \text{k}\Omega}{10\ \text{k}\Omega + 2.2\ \text{k}\Omega} 10\ \text{V} = 1.8\ \text{V}$$

Subtract 0.7 V from this to get:

$$V_E = 1.8\ \text{V} - 0.7\ \text{V} = 1.1\ \text{V}$$

The emitter current is:

$$I_E = \frac{1.1\ \text{V}}{1\ \text{k}\Omega} = 1.1\ \text{mA}$$

Since the collector current almost equals the emitter current, we can calculate the collector-to-ground voltage like this:

$$V_C = 10\ \text{V} - (1.1\ \text{mA})(3.6\ \text{k}\Omega) = 6.04\ \text{V}$$

The collector-emitter voltage is:

$$V_{CE} = 6.04 - 1.1\ \text{V} = 4.94\ \text{V}$$

Here is an important point: The calculations in this preliminary analysis do not depend on changes in the transistor, the collector current, or the temperature. This is why the Q point of this circuit is stable, almost rock-solid.

PRACTICE PROBLEM 8–1 Change the power supply voltage of Fig. 8-2 from 10 V to 15 V and solve for V_{CE}.

Example 8-2

Discuss the significance of Fig. 8-3, which shows a MultiSim analysis of the same circuit analyzed in the preceding example.

SOLUTION This really drives the point home. Here we have an almost identical answer using a computer to analyze the circuit. As you can see, the voltmeter reads 6.03 V (rounded to 2 places). Compare this to 6.04 V in the preceding example, and you can see the point. A simplified analysis has produced essentially the same result as a computer analysis.

You can expect this kind of close agreement whenever a VDB circuit has been well designed. After all, the whole point of VDB is to act like emitter bias to virtually eliminate the effects of changing the transistor, collector current, or temperature.

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DATA SHEETS

Full and partial component data sheets are provided for many semiconductor devices; key specifications are examined and explained. Complete data sheets of these devices can be found on the Internet.

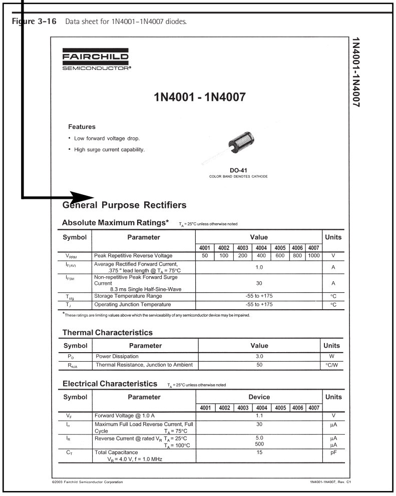

Figure 3–16 Data sheet for 1N4001–1N4007 diodes.

FAIRCHILD
SEMICONDUCTOR®

1N4001-1N4007

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings* T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

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1N4001-1N4007, Rev. C1

COMPONENT PHOTOS

Photos of actual electronic devices bring students closer to the device being studied.

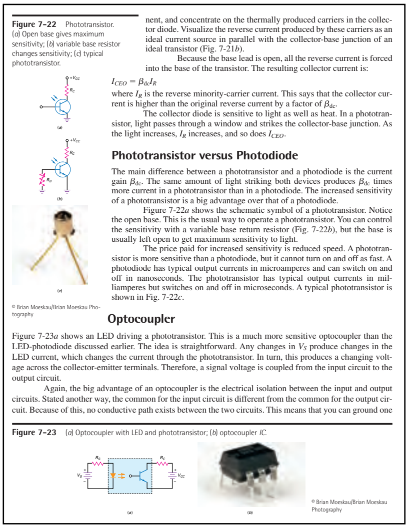

Figure 7-22 Phototransistor. (*a*) Open base gives maximum sensitivity; (*b*) variable base resistor changes sensitivity; (*c*) typical phototransistor.

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nent, and concentrate on the thermally produced carriers in the collector diode. Visualize the reverse current produced by these carriers as an ideal current source in parallel with the collector-base junction of an ideal transistor (Fig. 7-21*b*).

Because the base lead is open, all the reverse current is forced into the base of the transistor. The resulting collector current is:

$$I_{CEO} = \beta_{dc} I_R$$

where I_R is the reverse minority-carrier current. This says that the collector current is higher than the original reverse current by a factor of β_{dc}.

The collector diode is sensitive to light as well as heat. In a phototransistor, light passes through a window and strikes the collector-base junction. As the light increases, I_R increases, and so does I_{CEO}.

Phototransistor versus Photodiode

The main difference between a phototransistor and a photodiode is the current gain β_{dc}. The same amount of light striking both devices produces β_{dc} times more current in a phototransistor than in a photodiode. The increased sensitivity of a phototransistor is a big advantage over that of a photodiode.

Figure 7-22*a* shows the schematic symbol of a phototransistor. Notice the open base. This is the usual way to operate a phototransistor. You can control the sensitivity with a variable base return resistor (Fig. 7-22*b*), but the base is usually left open to get maximum sensitivity to light.

The price paid for increased sensitivity is reduced speed. A phototransistor is more sensitive than a photodiode, but it cannot turn on and off as fast. A photodiode has typical output currents in microamperes and can switch on and off in nanoseconds. The phototransistor has typical output currents in milliamperes but switches on and off in microseconds. A typical phototransistor is shown in Fig. 7-22*c*.

Optocoupler

Figure 7-23*a* shows an LED driving a phototransistor. This is a much more sensitive optocoupler than the LED-photodiode discussed earlier. The idea is straightforward. Any changes in V_S produce changes in the LED current, which changes the current through the phototransistor. In turn, this produces a changing voltage across the collector-emitter terminals. Therefore, a signal voltage is coupled from the input circuit to the output circuit.

Again, the big advantage of an optocoupler is the electrical isolation between the input and output circuits. Stated another way, the common for the input circuit is different from the common for the output circuit. Because of this, no conductive path exists between the two circuits. This means that you can ground one

Figure 7-23 (*a*) Optocoupler with LED and phototransistor; (*b*) optocoupler *IC*.

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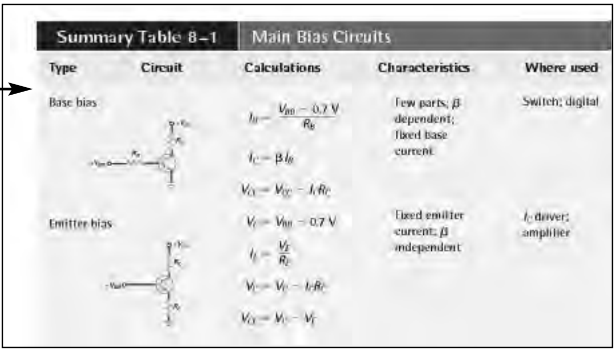
SUMMARY TABLES

Summary Tables have been included at important points within many chapters. Students use these tables as an excellent review of important topics, and as a convenient information resource.



Summary Table 8-1 Main Bias Circuits

Type	Circuit	Calculations	Characteristics	Where used
Base bias		$I_B = \frac{V_{BB} - 0.7\text{ V}}{R_B}$ $I_C = \beta I_B$ $V_{CE} = V_{CC} - I_C R_C$	Few parts; β dependent; fixed base current	Switch; digital
Emitter bias		$V_E = V_{BB} - 0.7\text{ V}$ $I_E = \frac{V_E}{R_E}$ $V_C = V_{CC} - I_C R_C$ $V_{CE} = V_C - V_E$	Fixed emitter current; β independent	I_C driver; amplifier

COMPONENT TESTING

Students will find clear descriptions of how to test individual electronic components using common equipment such as digital multimeters (DMMs).

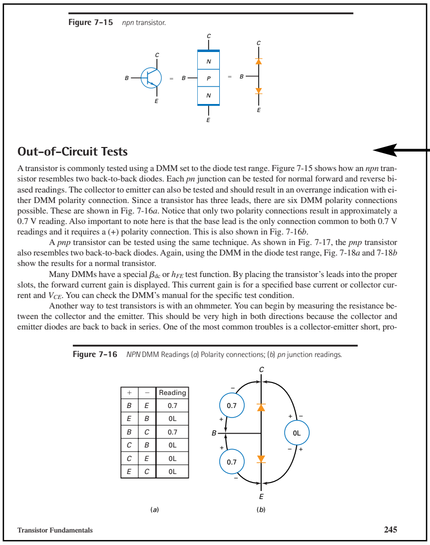


Figure 7-15 *npn* transistor.

Out-of-Circuit Tests

A transistor is commonly tested using a DMM set to the diode test range. Figure 7-15 shows how an *npn* transistor resembles two back-to-back diodes. Each *pn* junction can be tested for normal forward and reverse biased readings. The collector to emitter can also be tested and should result in an overrange indication with either DMM polarity connection. Since a transistor has three leads, there are six DMM polarity connections possible. These are shown in Fig. 7-16*a*. Notice that only two polarity connections result in approximately a 0.7 V reading. Also important to note here is that the base lead is the only connection common to both 0.7 V readings and it requires a (+) polarity connection. This is also shown in Fig. 7-16*b*.

A *pnp* transistor can be tested using the same technique. As shown in Fig. 7-17, the *pnp* transistor also resembles two back-to-back diodes. Again, using the DMM in the diode test range, Fig. 7-18*a* and 7-18*b* show the results for a normal transistor.

Many DMMs have a special β_{dc} or h_{FE} test function. By placing the transistor's leads into the proper slots, the forward current gain is displayed. This current gain is for a specified base current or collector current and V_{CE}. You can check the DMM's manual for the specific test condition.

Another way to test transistors is with an ohmmeter. You can begin by measuring the resistance between the collector and the emitter. This should be very high in both directions because the collector and emitter diodes are back to back in series. One of the most common troubles is a collector-emitter short, pro-

Figure 7-16 *NPN* DMM Readings (*a*) Polarity connections; (*b*) *pn* junction readings.

+	−	Reading
B	*E*	0.7
E	*B*	0L
B	*C*	0.7
C	*B*	0L
C	*E*	0L
E	*C*	0L

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Summary

SEC. 8-1 VOLTAGE-DIVIDER BIAS

The most famous circuit based on the emitter-bias prototype is called voltage-divider bias. You can recognize it by the voltage divider in the base circuit.

SEC. 8-2 ACCURATE VDB ANALYSIS

The key idea is for the base current to be much smaller than the current through the voltage divider. When this condition is satisfied, the voltage divider holds the base voltage almost constant and equal to the unloaded voltage out of the voltage divider. This

on the load line with the exact location determined by the biasing. Large variations in current gain have almost no effect on the *Q* point because this type of bias sets up a constant value of emitter current.

SEC. 8-4 TWO-SUPPLY EMITTER BIAS

This design uses two power supplies: one positive and the other negative. The idea is to set up a constant value of emitter current. The circuit is a variation of the emitter-bias prototype discussed earlier.

SEC. 8-5 OTHER TYPES OF BIAS

This section introduced negative

led to voltage-div
types of bias cann
negative feedback
the performance
divider bias.

SEC. 8-6 TRO

Troubleshooting
this, it cannot be
rules. You learn tr
from experience.

SEC. 8-7 *PNP*

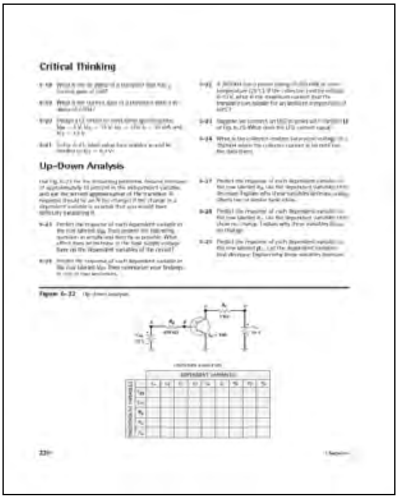
These *pnp* devices
voltages reversed
counterparts. The
negative power s
commonly, they a

CHAPTER SUMMARIES

Students can use the summaries when reviewing for examinations, or just to make sure they haven't missed any key concepts. Important circuit derivations and definitions are listed to help solidify learning outcomes.

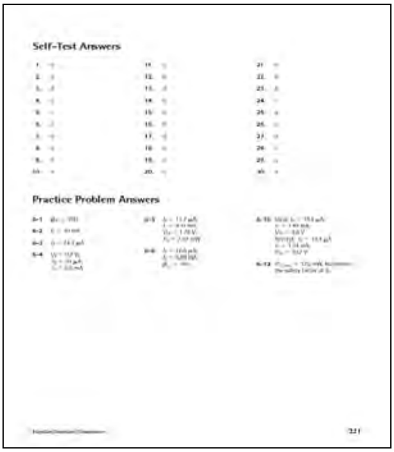
END OF CHAPTER PROBLEMS

A wide variety of questions and problems are found at the end of each chapter; over 30% are new or revised in this edition. These include circuit analysis and critical thinking questions.



Critical Thinking

Up-Down Analysis



Self-Test Answers

Practice Problem Answers