Experiments 51, 53, 55, 57 & 58 to be done BENG 2
Mr. P. copy.

EXPERIMENT 51

PN JUNCTION

LAB 1 DOVT

OBJECTIVES

At the completion of this experiment, you will be able to:

- Determine the forward-bias conditions of a diode.
- Determine the reverse-bias conditions of a diode.
- Develop the characteristic curve for a diode.

SUGGESTED READING

Chapter 28, *Basic Electronics,* B. Grob, Eighth Edition

INTRODUCTION

This experiment will introduce the characteristics of a silicon diode. The diode will be ohmmeter-tested and then connected to a dc power supply and its operating characteristics graphed.

Basically, a 1N4004 diode will conduct in the forward direction (forward bias) with a low value of internal forward resistance. In the reverse-bias condition, the diode will not conduct and has an almost infinite resistance. However, under extreme conditions of high voltage or current, in either direction, the diode will break down and conduct or else be destroyed.

A manufacturer's specification sheet for this diode has been included in Appendix A. Note the ratings and characteristics for these diodes. These terms should be consistent with the explanations found in most theory textbooks.

EQUIPMENT

Oscilloscope
VTVM
DC power supply, 0–10 V
DC power supply, 0–150 V
Protoboard or springboard
Test leads

COMPONENTS

(1) 1N4004

Resistors (all 0.25 W):

(1) 330 Ω	(1) 12 kΩ
(1) 680 Ω	(1) 1.0 MΩ

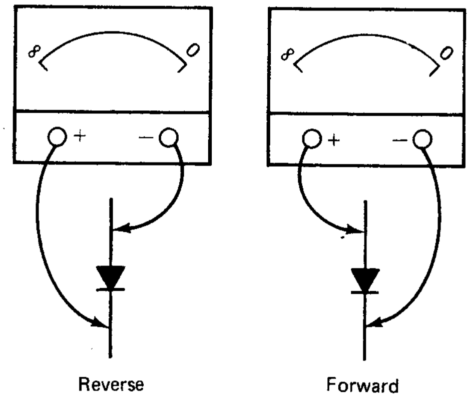


Fig. 51-1. Circuit connection for the measurement of forward and reverse resistance.

PROCEDURE

1. With the VTVM on the ohmmeter function, measure and record in Table 51-1 the forward and reverse resistance of the diode. See Fig. 51-1.

2. Connect the circuit of Fig. 51-2, with R_{L_1} equal to 12 kΩ. By use of the oscilloscope, measure and record in Table 51-1 the voltage of the power supply (V_T), the voltage across the diode (V_D), and the voltage across the load resistor (V_{R_1}). Also, with the oscilloscope across the diode, slowly increase the power supply from 0 to 4 V and note that the voltage across the diode should increase to approximately 0.65 V and remain constant regardless of any further increase in supply voltage.

3. Repeat step 2 for a load resistance of 680 Ω. Be sure to record this information in Table 51-1.

4. Reverse the power supply leads so that the polarity is reversed for the circuit of Fig. 51-2. The diode is now reversed-biased. For both values of load resistance (12 kΩ and 680 Ω), measure and record in Table 51-1 the values of V_T, V_{R_1}, and V_D.

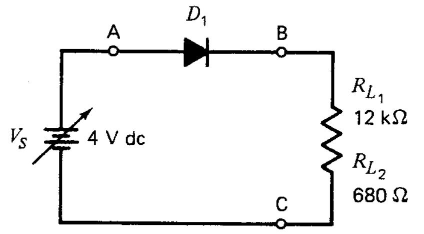


Fig. 51-2. Forward-biasing the diode.

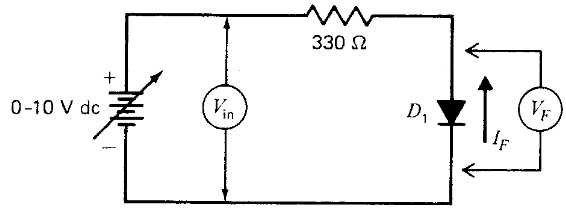


Fig. 51-3. Forward-bias condition.

5. Connect the forward-biasing circuit of Fig. 51-3.
6. Using the VTVM, measure and record in Table 51-1 the resistance value of the 330-Ω resistor.
7. Turn on the power supply and adjust the applied voltage to 0.2 V. The forward-biasing voltage measure across the diode is given the symbol V_F. Measure and record in Table 51-2 the value of V_F. Calculate and record the forward-biasing current I_F by the relationship of

$$I_F = \frac{V_F}{R}$$

8. Repeat step 7 for the V_T values of:

0.25 V	0.65 V
0.30 V	0.70 V
0.35 V	0.75 V
0.40 V	0.80 V
0.45 V	0.85 V
0.50 V	0.90 V
0.55 V	0.95 V
0.60 V	1.00 V

9. Using the data obtained in steps 7 and 8, plot the forward characteristics of this diode in Fig. 51-4 (quadrant 1).

Note: If desired, draw your own plot similar to Fig. 51-4 to hand in with your report.

10. Connect the circuit shown in Fig. 51-5.
11. Increase the power supply voltage from 0 to 150 V in 50-V steps. This voltage will reverse-bias the diode. The reverse-bias voltage measured

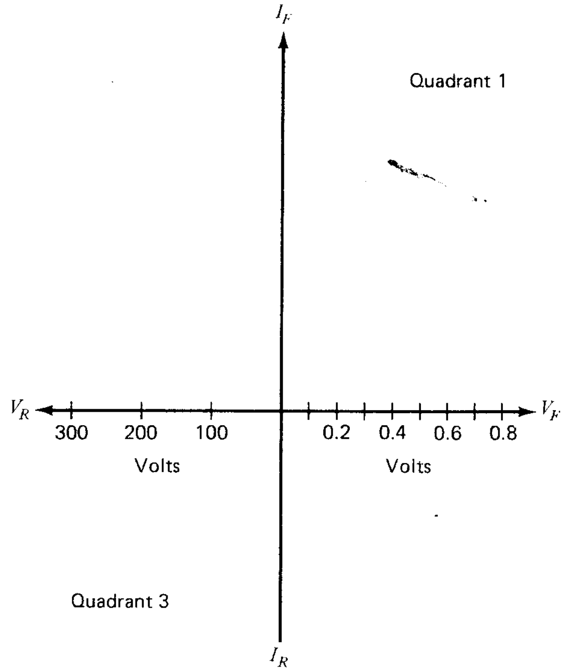


Fig. 51-4. Silicon diodes' forward and reverse characteristic curves.

across the diode is given the symbol V_R. Measure and record in Table 51-3 the corresponding voltage dropped across R_1.
12. Calculate and record the reverse current I_R for each voltage level applied in step 11.
13. Plot I_R versus V_R on Fig. 51-4 (quadrant 3).

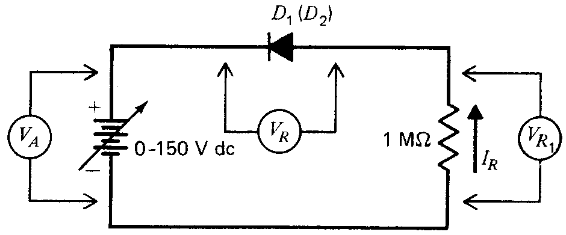


Fig. 51-5. Reverse-bias condition.

NAME ______________________________ DATE ______________

RESULTS FOR EXPERIMENT 51

QUESTIONS

1. What general statement could be made for the forward and reverse resistances of a good diode?

2. Under what conditions can the diode be forward-biased?

3. Under what conditions can the diode be reversed-biased?

4. Describe the significance of the curve found in quadrant 1 of Fig. 51-4.

5. Describe the significance of the curve found in quadrant 3 of Fig. 51-4.

REPORT

Write a complete report. Discuss the results. Discuss the three most significant aspects of the experiment and write a conclusion.

TABLE 51–1

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Fwd. bias R = ______ Ω				
	Rev. bias R = ______ Ω				
2	Fwd. bias	12 kΩ	______	______	______
3	Fwd. bias	680 Ω	______	______	______
4	Rev. bias	12 kΩ	______	______	______
		680 Ω	______	______	______
6	330 Ω R (nominal) = ______ Ω (measured)				

TABLE 51–2

Procedure Step	V_T	V_F	Calculated I_F
7	0.20 V		
8	0.25 V		
	0.30 V		
	0.35 V		
	0.40 V		
	0.45 V		
	0.50 V		
	0.55 V		
	0.60 V		
	0.65 V		
	0.70 V		
	0.75 V		
	0.80 V		
	0.85 V		
	0.90 V		
	0.95 V		
	1.00 V		

TABLE 51–3

Procedure Step	V_T	V_D	Calculated I_R
11 and	50 V		
12	100 V		
	150 V		

EXPERIMENT 53

ZENER DIODES FOR REGULATION AND PROTECTION

OBJECTIVES

At the completion of this experiment, you will:

- Understand how zener diodes operate.
- Be able to use a zener diode to protect circuits from excessive current or voltage.
- Be able to use a zener diode as a simple voltage regulator.

SUGGESTED READING

Chapter 28, *Basic Electronics,* B. Grob, Eighth Edition

INTRODUCTION

Zener diodes are similar to, but also different from, ordinary silicon PN junction diodes. Zener diodes are similar because both these types of diodes are made from P and N material. However, they differ because in the zener diode, the P and N material is "doped" so that it can be used in the reverse direction. Recall that a typical PN junction diode (silicon) allows current to flow in the forward direction when about 0.7 V is across it, causing forward bias.

Generally, a PN junction diode is found in a rectifier circuit where it passes only one direction of current flow from an ac signal. Current is blocked when the PN junction diode is reverse-biased, unless the reverse voltage reaches the breakdown level, which is usually around 5 V. However, the zener diode is designed to perform a different task. It is used in its reverse direction so that current will flow through it when a particular voltage reverse-biases the zener diode. Like the PN junction diode, the zener diode allows current to flow when about 0.7 V is across it in the forward direction. The characteristics of an 8-V zener diode are shown in Fig. 53-1.

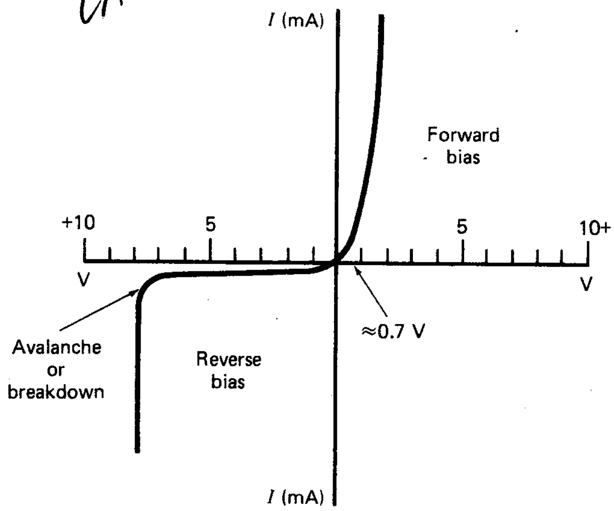


Fig. 53-1. The 8-V zener diode characteristics.

Notice that when 8 V is across the zener diode, in the reverse direction, an "avalanche" or breakdown of the PN junction occurs and the zener is then like a closed switch. Before 8 V is across the zener, only a small leakage current flows. Figure 53-2 shows the symbol for a zener diode where current will flow when 8 V is across the zener.

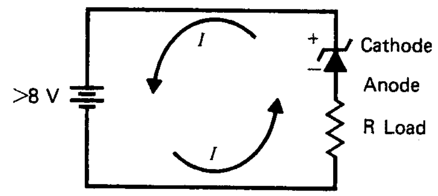


Fig. 53-2. Zener diode used as a switch.

The zener diode cathode (−) is on the positive side of the battery, and its anode (+) is on the negative side. When 8 V or more is across the diode, current will flow. Of course, the load has some resistance, which is why more than 8 V is required here.

However, zener diodes are not usually used in this configuration. They are usually put in parallel with other components requiring voltage regulation or protection. Figure 53-3 shows a zener diode used to protect a circuit which would be destroyed if too much voltage were across it.

In Fig. 53-3, the zener was selected to protect the load from too much current. The load circuit will be destroyed if the voltage across it is 15.5 V or more, resulting in too much current: $I_L = V_Z/R_L$. While V applied is less than 15 V, the zener is like an open switch and the current I_L is all flowing through the load. (See Fig. 53-3*a*.) However when V applied reaches 15 V, the zener acts as a closed switch (0 Ω) so that very little

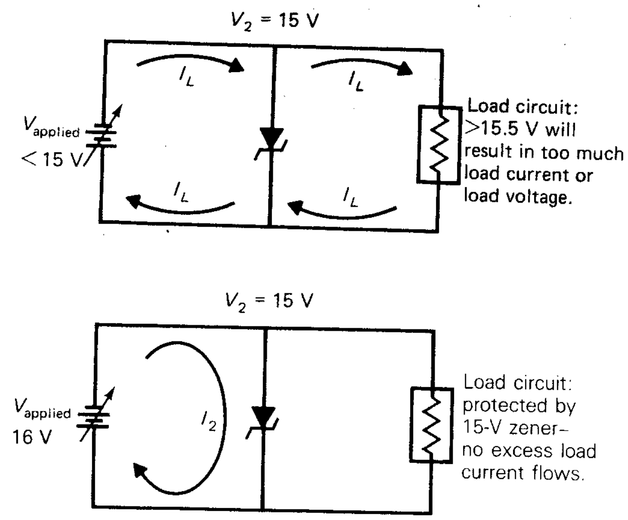


Fig. 53-3. Zener protection circuit. (*a*) Zener is like an open switch—current flows through load). (*b*) Zener is like a closed switch—minimal current flows through load.

current can flow through the load (see Fig. 53-3*b*). In this way, the zener protects the load circuit. In other words, the zener acts as a protection switch to keep the load protected in case there is a short that draws more current than the load can withstand.

Finally, Fig. 53-4 shows a zener diode used to keep a constant voltage across a load. This is a simple regulator where R_S limits the total circuit current and, regardless of how much current is drawn by the load, the zener diode keeps the load voltage constant. However, this circuit assumes that *V* applied remains high enough that the voltage across the zener allows current I_Z to flow.

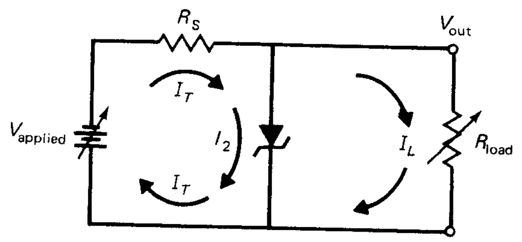


Fig. 53-4. Simple zener diode voltage regulator.

Although the zener diode protection circuit and the zener diode regulator circuit may appear similar, remember that the difference is simple. In Fig. 53-3, the protection zener is *not* biased on during normal operation—it conducts only when too much voltage is seen across it or the load. In Fig. 53-4, the zener is purposely biased on during normal operation so that it keeps a constant voltage across the load.

The following procedure will validate the basic operation of a zener diode. However, keep in mind that not all aspects of a zener diode are covered here. A zener diode, like any semiconductor device, has numerous properties and characteristics which require extensive testing to verify. This experiment will introduce you to the most widely used application of a zener diode.

EQUIPMENT

Variable dc power supply (0-30 V)
VOM, VTVM, or DVM
Ammeter

COMPONENTS

(1) 1-kΩ resistor (0.25-W)
(1) 330-Ω resistor (1-W)
(1) Zener diode, 5-V (1-W)
(1) 4.7-kΩ resistor (0.25-W)
(1) 100-Ω resistor (0.25-W)

PROCEDURE

1. Connect the circuit shown in Fig. 53-5.

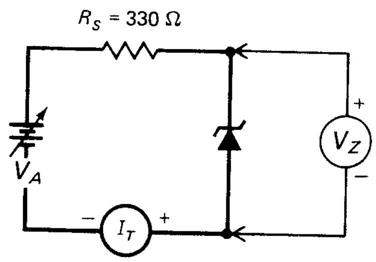


Fig. 53-5. Zener diode circuit.

2. Turn on the power supply, and slowly increase the applied voltage until 5 V appears across the zener diode. Measure and record the applied voltage at this point in Table 53-1.

3. Measure and record the current I_T in Table 53-1.

4. Measure the voltage across R_S and record the results in Table 53-1. Calculate the current through R_S and record the results next to I_T (measured) in Table 53-1.

5. Increase the applied voltage by 2 V, and repeat steps 3 and 4. Use the voltmeter to verify that *V* applied is 2 V greater. Be sure to measure and record V_Z and V_A.

6. Increase the applied voltage by 2 V more (4 V greater than step 2), and repeat steps 3 and 4. Be sure to measure and record V_Z.

7. Connect a 4.7-kΩ resistor across the zener diode, keeping the rest of the circuit the same as shown in Fig. 53-5.

8. Repeat steps 2 through 4 for the circuit with the 4.7-kΩ load connected. Turn off the power when you have finished.

9. Repeat steps 2 through 4 with a 100-Ω load resistor. Turn off the power when you have finished.

10. Remove any load resistors and connect the zener in the opposite polarity. Vary the power supply voltage between 0 and 8 V and measure the voltage across the zener at 1-V intervals. Also measure I_T and record the results in Table 53-2.

NAME ______________________________ DATE ____________

RESULTS FOR EXPERIMENT 53

QUESTIONS

1. How does a zener diode act when it is connected in the forward-bias manner?

2. How does a zener diode operate when it is connected as a voltage regulator?

3. How does a zener diode operate when it is connected as a protection device?

4. Explain the difference between a zener diode and a PN junction diode.

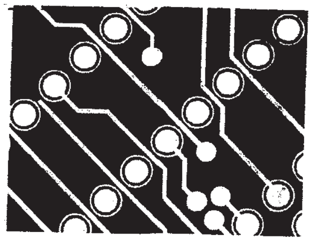
5. What was the purpose of R_S in the circuit in Fig. 53-5?

REPORT

Write a complete report. Describe how the zener diode acts both above and below its zener voltage.

TABLE 53–1

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2–4	5	______	______	______	______
5 $V_a + 2$ V	______	______	______	______	______
6 $V_a + 4$ V	______	______	______	______	______
8 $R_L = 4.7\ k\Omega$	5	______	______	______	______
9 $R_L = 100\ \Omega$	5	______	______	______	______



EXPERIMENT 55

RECTIFICATION AND FILTERS

OBJECTIVES

At the completion of this experiment, you will be able to:

- Compare the average value, also called the dc value, of the half-wave and the full-wave voltages across the load resistor.
- Observe the effects of filtering on a rectified ac voltage.

SUGGESTED READING

Chapters 27, 28, and 29, *Basic Electronics,* B. Grob, Eighth Edition

INTRODUCTION

Rectified ac voltage can be filtered to resemble the unidirectional quality of battery dc voltage, although it will always contain some small amount of the ac component, regardless of filtering. This ac voltage component is called *ripple,* and it is a measure of the quality of rectification and filtering.

This experiment investigates the use of reactive components as filters for smoothing the rectified ac voltage. Capacitive reactance, inductive reactance, *RC* time constant, and circuit configuration all affect the smoothing of the ripple.

EQUIPMENT

Oscilloscope
VTVM
AC filament power supply (12.6 V, center tap at 6.3 V)
Test leads

COMPONENTS

(4) 1N4004 diodes or equivalent
(1) 1-H inductor (choke) or larger up to 8 H
(1) 47-μF capacitor
(1) 10-μF capacitor
(1) 680-Ω 0.25-W resistor
(1) 2.2-kΩ 0.25-W resistor

PROCEDURE

1. Connect the circuit shown in Fig. 55-1 without the capacitor.
2. Using an oscilloscope, measure and record in Table 55-1 the ac output voltage across R_L.

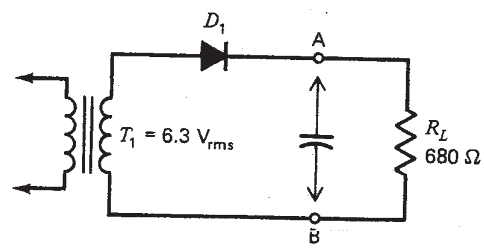


Fig. 55-1. Half-wave rectifier.

3. Using a VTVM, measure and record the dc value of the voltage across R_L.
4. Connect a 47-μF filtering capacitor across points A and B in the Fig. 55-1 circuit. Repeat steps 2 and 3 for measuring the output voltage.
5. Determine and record in Table 55-1 the percent of ripple for the filtered circuits only, using the following formula.

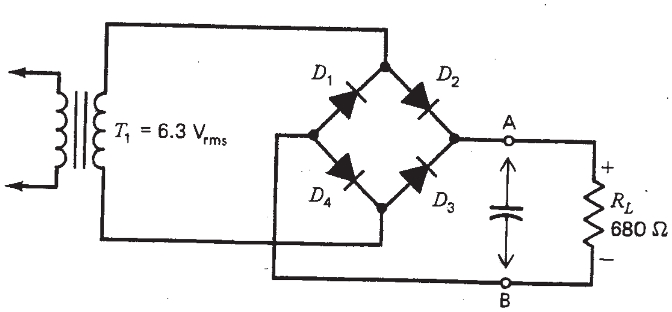


Fig. 55-2. Full-wave bridge circuit.

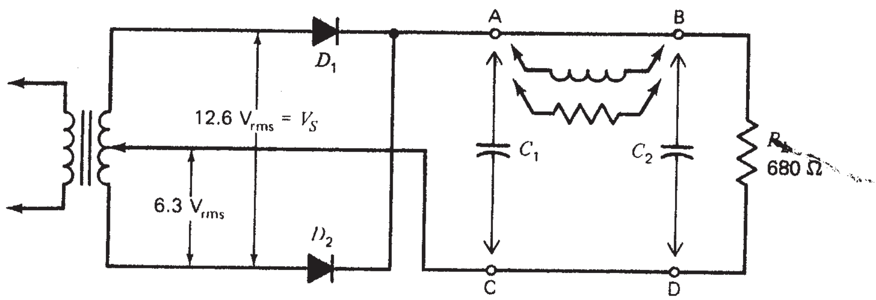


Fig. 55-3. Full-wave center-tap circuit.

$$\% \text{ ripple} = \frac{\text{rms value of ripple voltage across } R_L}{\text{dc component across } R_L} \times 100$$

6. Connect the full-wave rectification bridge circuit of Fig. 55-2.

7. Repeat steps 2 to 5 for the full-wave rectifier bridge of Fig. 55-2.

8. Connect the full-wave center-tap circuit shown in Fig. 55-3 with the load resistor only (omit the "arrowed" components).

Note: Procedures 9 to 14 refer to Fig. 55-3 as altered for each specific filter configuration. Do not remove a filter component unless you are instructed to do so. The inductor is also called a "choke."

9. Using the oscilloscope, measure and record the ac output voltage across R_L.

10. Using the oscilloscope, measure the dc value of the voltage across R_L and, only if filtered, compute the percent of ripple.

11. Connect a 47-μF capacitor (C_1) across points A and C and repeat steps 9 and 10.

12. Remove the jumper between points A and B, and in its place (in series with the load), connect the choke. Repeat steps 9 and 10.

13. Connect a 10-μF capacitor (C_2) across R_L (points B and D) and repeat steps 9 and 10.

14. Replace the choke with a 2.2-kΩ resistor, leaving the capacitors in place, and repeat steps 9 and 10.

NAME

DATE

RESULTS FOR EXPERIMENT 55

QUESTIONS

1. How does a full-wave bridge rectifier compare with a center-tap circuit in this experiment?

2. Concerning each of the circuits studied in this experiment, how do each of the displayed oscilloscope waveforms compare?

3. How does the oscilloscope input coupling affect the displayed waveform?

4. Does the resistance of the PN junction diodes affect the operation of the rectified circuits studied?

5. With respect to this experiment, what would be a definition of filtration?

REPORT

Write a complete report. Discuss the results. Discuss the three most significant aspects of the experiment and write a conclusion.

TABLE 55–1

Procedure Step	Measurement	Value	Ripple Calculation
2	V_{R_L} (oscill.)	_____ Vp-p	
3	V_{R_L} (VTVM)	_____ V	
4	V_{R_L} (oscill.)	_____ Vp-p	
	V_{R_L} (VTVM)	_____ V	
5	% ripple		_____ %
7	V_{R_L} (oscill.)	_____ Vp-p	
	V_{R_L} (VTVM)	_____ V	
	V_{R_L} (oscill.)	_____ Vp-p	
	V_{R_L} (VTVM)	_____ V	
	% ripple		_____ %
9	V_{R_L} (ac)	_____ Vp-p	
10	V_{R_L} (dc)	_____ V	
11	V_{R_L} (ac)	_____ Vp-p	
	V_{R_L} (dc)	_____ V	_____ %
12	V_{R_L} (ac)	_____ Vp-p	
	V_{R_L} (dc)	_____ V	_____ %
13	V_{R_L} (ac)	_____ Vp-p	
	V_{R_L} (dc)	_____ V	_____ %
14	V_{R_L} (ac)	_____ Vp-p	
	V_{R_L} (dc)	_____ V	_____ %

EXPERIMENT 57

FET AMPLIFIER

OBJECTIVES

At the completion of this experiment, you will be able to:

- Identify the polarity of a JFET.
- Study the circuit components and power supply polarity necessary to permit a JFET to function as an amplifier.
- Evaluate the performance of a JFET amplifier.

SUGGESTED READING

Chapters 28 and 29, *Basic Electronics,* B. Grob, Eighth Edition

INTRODUCTION

A junction field-effect transistor (JFET) is a semiconductor device that is controlled like a vacuum tube. In its simplest form, the JFET is a layer or channel of N-type material that acts like a resistor between its two end terminals called the *source* and the *drain*. On both sides of the channel, P-type material forms a gate through which electrons flow (drain current) from source to drain. With current flowing through the N channel, the JFET is considered to be a *normally on* device, which is also referred to as in an *enhancement mode*. However, when a control voltage is applied to the gate which is a reverse-bias gate-to-source condition, the channel is depleted and the current through the channel decreases. Once the channel has been depleted enough, the JFET is said to be *pinched off*; that is, no further drain current will flow. It is important to note, however, that current can still flow while the channel is pinched off. The point is that no further amount of current will flow. See the family of curves in Fig. 57-1. It is also important to note that a JFET amplifier (common source) will have a Q point of operation well into the pinch-off region, allowing for a symmetrical (positive to negative) output voltage swing.

EQUIPMENT

Audio signal generator
Oscilloscope
DC power supply, 0–15 V
VTVM
Test leads

COMPONENTS

(1) 2N3823 FET, or equivalent

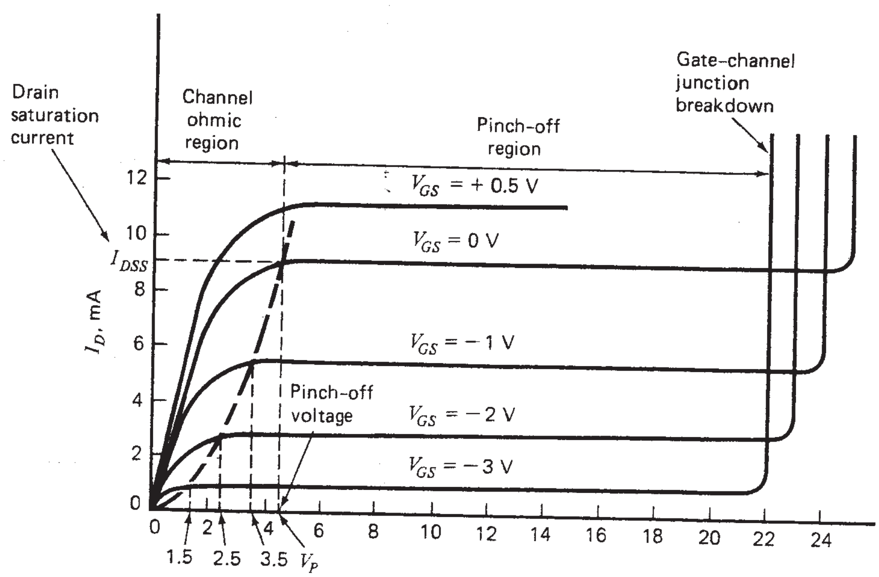


Fig. 57-1. N-channel JFET drain curves.

Resistors (all 0.25 W):

(1) 1 kΩ	(1) 5.6 kΩ
(1) 2.2 kΩ	(1) 8.2 kΩ
(1) 4.7 kΩ	(1) 470 kΩ

(2) 0.01-μF capacitors
(1) 100-μF capacitor

PROCEDURE

1. Use an ohmmeter on the R × 1000 range and measure $S - G$, $G - D$, and $S - D$ in both directions of lead polarity. Record results in Table 57-1. A diode junction should be indicated when measuring $S - G$ and $G - D$. The polarity of the JFET should be indicated by the forward-bias indication of the ohmmeter. A P channel will require a positive-ground, negative-drain potential. An N-channel JFET will require a negative-ground, positive-drain potential. See Fig. 57-2 for the correct lead orientation for N- and P-channel FETs.

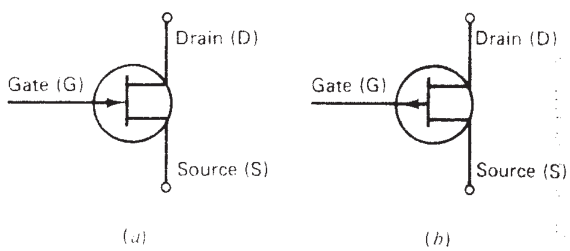
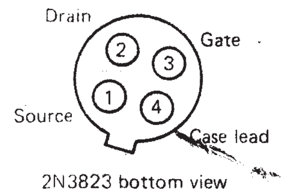


Fig. 57-2. (*a*) N-channel FET. (*b*) P-channel FET.

2. Connect the circuit shown in Fig. 57-3, being sure to observe proper V_{DD} polarity and also electrolytic capacitor polarity. Apply 1 kHz at 100 mV p-p. Use a 2.2-kΩ resistor as the load (drain) resistance. Measure and record in Table 57-2 all dc and peak-to-peak voltages. Determine the voltage gain (A_V).



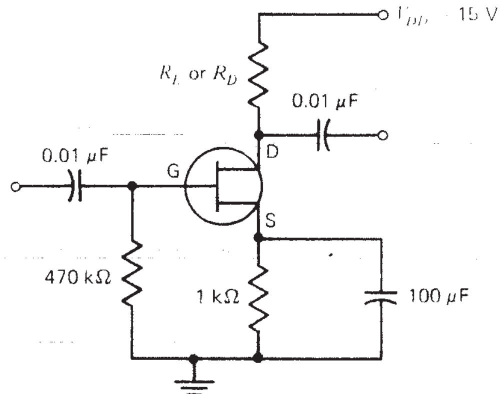


Fig. 57-3. N-channel FET amplifier using a 2N3823 FET.

3. Replace the load resistor with 4.7-kΩ, 5.6-kΩ, and 8.2-kΩ resistances and record all dc and ac peak-to-peak values around the circuit. Determine A_V. Record in Table 57-2.

4. Using the 8.2-kΩ resistor as a drain load, increase the power supply voltage to 30 V dc, and note any effects (in Table 57-3) upon the amplifier.

5. Remove the source bypass capacitor and note the effect (in Table 57-3) upon gain and dc parameters.

Note: Use V_{DD} = 15 V and R_L = 5.6 kΩ.

6. While the source bypass capacitor is removed, make a frequency check of this amplifier, determine the low-frequency cutoff value, and calculate the input resistance based on that value and the value of the coupling capacitor.

Note: Use semilog graph paper in Appendix E.

NAME DATE

RESULTS FOR EXPERIMENT 57

QUESTIONS

1. What was the polarity of the JFET used in this experiment?

2. What is the function of the bypass capacitor? What happens when it is removed from the amplifier circuit?

3. What factors influence the input resistance of the amplifier?

4. What is the overall effect that is created by increasing the value of load resistance?

5. What effects to the amplifier are created by increasing the value of the power supply voltage?

REPORT

Write a complete report. Discuss the results. Discuss the three most significant aspects of the experiment and write a conclusion.

TABLE 57–1

Procedure Step	Measurement	R, Ω
1	*S* to *G*	
	G to *D*	
	S to *D*	
Leads reversed	*S* to *G*	
	G to *D*	
	S to *D*	

TABLE 57–2

Procedure Step	R_D, kΩ	V_G(dc)	V_D(dc)	V_S(dc)	V_G(ac)	V_D(ac)	V_S(ac)	A_V
2	2.2							
3	4.7							
	5.6							
	8.2							

TABLE 57–3

Procedure Step	V_{DD}	Noted Effects
4	30 Vdc	
5	15 Vdc	Capacitor removed:

EXPERIMENT 58

TRANSISTOR AMPLIFIER

OBJECTIVES

At the completion of this experiment, you will be able to:

- Study the phase relationship of the input signal versus the output signal of a common-emitter amplifier.
- Investigate the purpose of biasing in a common-emitter amplifier.
- Determine the polarity of a transistor emitter-base junction.
- Study the concept of biasing a transistor.
- Plot a load line on the characteristic curves of a transistor.
- Compare the actual operation of a transistor amplifier to the operation indicated by the load-line graph.

SUGGESTED READING

Chapter 30, *Basic Electronics*, B. Grob, Eighth Edition

INTRODUCTION

This experiment uses a bipolar junction transistor (BJT) to amplify a small value of audio-range signal. The transistor polarity will be verified (PNP or NPN), and the bias supply will be adjusted to allow a maximum value of undistorted output voltage for the sine-wave input. The concept of gain (A_V) will be examined by varying the value of the collector resistor. The fundamental aspects of the common-emitter configuration can be determined from an analysis of the data obtained in the experiment.

Bias is defined as electrical force applied to a semiconductor transistor for the purpose of establishing a reference level for the operation of the device. In this experiment, a common-emitter PNP transistor amplifier is biased for operation under different levels of reference. The reference levels are established with respect to the load line and the Q point of operation. Consistent with the principles discussed in theory textbooks, amplification of a sine wave will have varying output results depending upon the biasing of the transistor. The results obtained in this experiment should provide sufficient data for analysis of the concept of transistor bias.

EQUIPMENT

Audio signal generator
Oscilloscope
Low-voltage power supply
Microammeter
Test leads
VTVM

COMPONENTS

(1) 100-kΩ potentiometer
(2) 10-μF at 25-V capacitors
(1) 2N3638 transistor or equivalent

Resistors (all 0.25 W):

(1) 470 Ω	(1) 10 kΩ
(1) 1 kΩ	(1) 4.7 kΩ

PROCEDURE

1. Using a VTVM (range = R × 1000), test the transistor to determine the emitter-to-base and base-to-collector junctions. This is a test of the diode action of the transistor. Forward bias is positive potential to the P material and negative potential to the N material, indicated by a low-resistance reading with the ohmmeter. Emitter-to-collector junctions will have a high resistance reading.

2. Connect the circuit shown in Fig. 58-1.

3. With the power supply (V_{CC}) adjusted at −10 V, obtain −5 V at the collector by adjusting the poten-

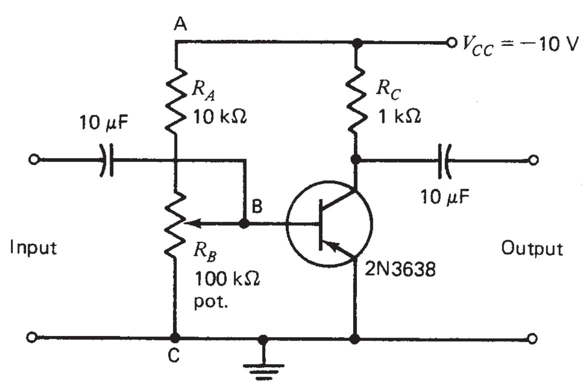


Fig. 58-1. PNP common-emitter amplifier.

tiometer (R_B). This means that one-half the voltage (V_{CC}) of the supply is developed both across the collector to ground and across the collector resistor itself.

Note: The wiper of the potentiometer divides the potentiometer so that part of its resistance is added to the value of R_A. The remaining resistance is equal to R_B. This is called *voltage divider bias.*

4. Apply a 30-mV p-p input signal to the amplifier.

Note: It may be necessary to attenuate the output of the signal generator. This can be done by creating a voltage divider network across the terminals of the signal generator. For example, a 10-kΩ resistor in series with a 1-kΩ resistor will divide the voltage into 11 equal parts, 1 part across 1 kΩ and 10 parts across 10 kΩ. The frequency of the input signal should be set at 1 kHz.

5. Measure and record in Table 58-1 the output voltage from the amplifier.
6. Measure and record in Table 58-1 the dc voltage from the base to the emitter.
7. Calculate the gain of the amplifier (A_V):

$$A_V = \frac{V_{out}}{V_{in}}$$

Record the results in Table 58-1.

8. Disconnect the power supply from the circuit (V_{CC} and ground). Carefully remove the potentiometer wiper lead (point B) from the circuit and measure the resistance of R_A (points A and B) and R_B (points B and C). Record the results in Table 58-1.
9. Change the value of R_C to 470 Ω and repeat steps 2 to 8. Record the results in Table 58-2.

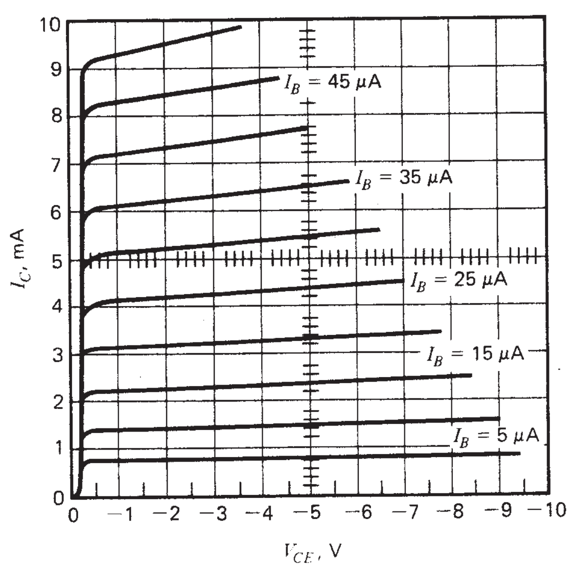


Fig. 58-2. 2N3638 family of curves (approximate).

10. Change the value of R_C to 4.7 kΩ and repeat steps 2 to 8. Record the results in Table 58-3.
11. Determine the phase relationship of the input and output signals by obtaining a second oscilloscope lead and using the dual-trace capabilities of the oscilloscope. Note the results in your report.
12. Draw a dc load line on the family of characteristic curves for a 2N3638 shown in Fig. 58-2, where R_C = 1 kΩ and V_{CC} = 10 V.

Note: The circuit for which this load line is drawn appears in Fig. 58-3.

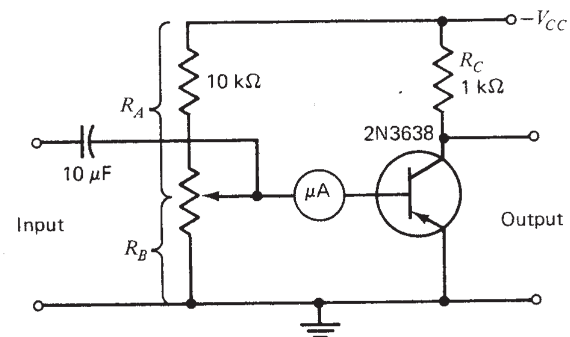


Fig. 58-3. Common-emitter amplifier.

13. Connect the circuit of Fig. 58-3.

Note: Voltages are negative for the PNP transistor, and for convenience, the following abbreviations will be used:

Q = quiescent, the point or conditions under which the currents and voltages in a transistor exist when no signal is applied = dc bias conditions
I_B = base current
I_C = collector current
V_{CC} = power supply voltage
V_{CE} = collector-to-emitter voltage
V_C = collector-to-ground voltage
V_{BE} = base-to-emitter voltage

DC Characteristics

14. Check all connections and polarity. Apply −10 V, which is equal to V_{CC}.
15. Adjust the bias potentiometer to obtain −5.0 V, which is equal to $V_{CEQ} = {}^1/_2\, V_{CC}$.
16. Measure and record I_{BQ} and I_{CQ} on the characteristic curve sheet shown in Fig. 58-4.

Note: I_{CQ} cannot be measured directly. Use Ohm's law to determine the current through R_C.

17. Measure and record V_{BEQ} in Table 58-4.
18. Disconnect V_{CC} and carefully disconnect the microammeter from the circuit in order to measure the values of R_A and R_B. Measure and record these values in Table 58-4.
19. Reconnect the circuit and repeat steps 16 to

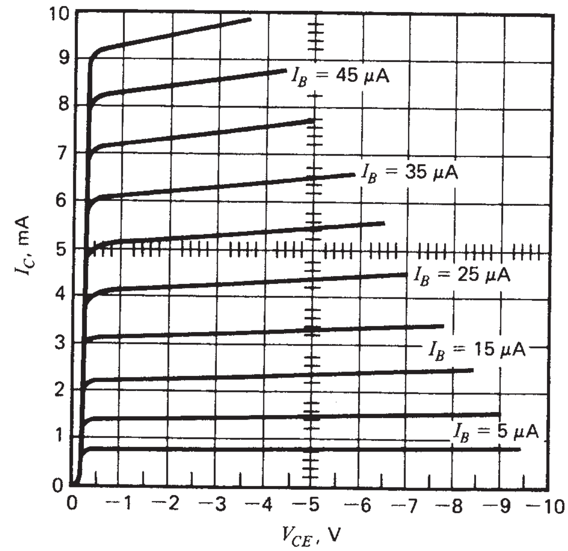


Fig. 58-4. 2N3638 family of curves (approximate).

18, with the bias potentiometer set at $V_{CEQ} = -8.5$ V and -1.5 V. (Record results in Tables 58-5 and 58-6, respectively.)

AC Characteristics

20. Disconnect or short-circuit the microammeter. Reconnect the power supply and adjust the bias potentiometer to obtain $V_{CEQ} = 5.0$ V.

21. Apply an input signal at 1 kHz and adjust the signal amplitude until the output voltage is equal to 6.0 V p-p. Measure and record the input signal (V_{in}) and use this same value for the following procedures (Table 58-7).

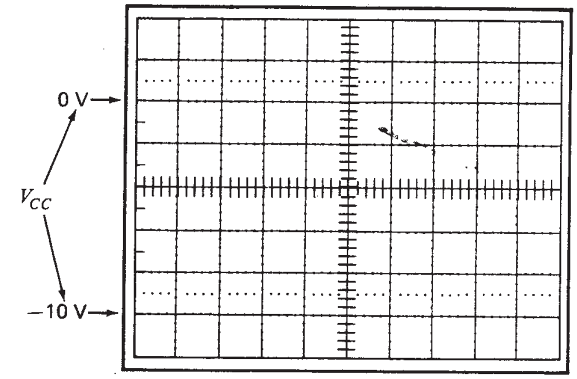


Fig. 58-5. Oscilloscope graticule.

22. Record the output waveform of the amplifier with the oscilloscope set at dc coupling. When drawing the output waveforms, indicate the parameters of the transistor bias as shown on the graticule in Fig. 58-5.

23. Repeat steps 21 and 22 with the bias potentiometer adjusted to obtain $V_{CEQ} =$ 8.5 V and 1.5 V. Be sure to use the previous value of input signal. The output signal will change. Use Table 58-7 and Fig. 58-6 for these data.

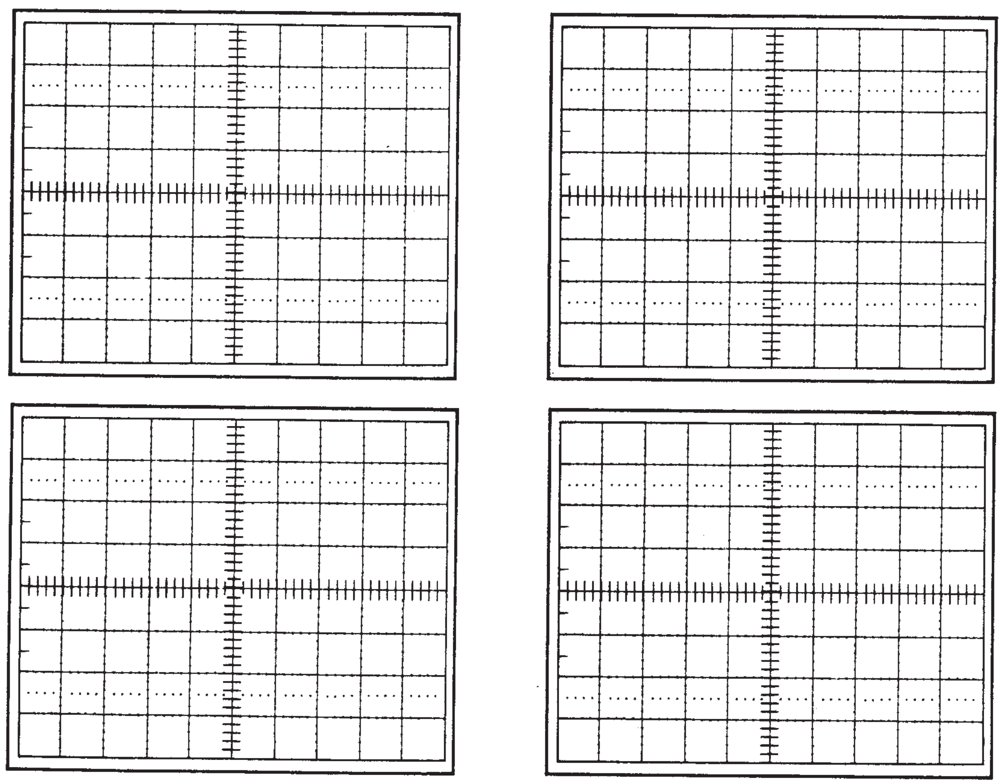


Fig. 58-6. Additional oscilloscope graticules.

NAME

DATE

RESULTS FOR EXPERIMENT 58

QUESTIONS

1. What is the purpose of biasing the transistor?

2. What were the values of biasing resistors used?

3. What is the difference between using NPN versus PNP transistors with respect to bias supply voltage?

4. What is the phase relationship of the input voltage versus the output voltage?

5. Explain the differences between dc and ac characteristics.

REPORT

Write a complete report. Discuss the results. Discuss the three most significant aspects of the experiment and write a conclusion.

TABLE 58–1. $V_{in} = 30$ **mVp-p**

Procedure Step	Measurement	Value
5	V_{out}	______V
6	V_{BE}	______V
7	A_V	______
8	R_A	______Ω
	R_B	______Ω

TABLE 58–2. $R_C = 470\ \Omega$

Procedure Step	Measurement	Value
9	V_{out}	______V
	V_{BE}	______V
	A_V	______
	R_A	______Ω
	R_B	______Ω

TABLE 58–3. $R_C = 4.7\ k\Omega$

Procedure Step	Measurement	Value
10	V_{out}	______V
	V_{BE}	______V
	A_V	______
	R_A	______Ω
	R_B	______Ω

TABLE 58–4. $V_{CEQ} = -5$ **V**

Procedure Step	Measurement	Value
17	V_{BEQ}	______V
18	R_A	______Ω
	R_B	______Ω

TABLE 58–5. $V_{CEQ} = -8.5$ **V**

Procedure Step	Measurement	Value
19	V_{BEQ}	______V
	R_A	______Ω
	R_B	______Ω

TABLE 58–6. $V_{CEQ} = -1.5$ **V**

Procedure Step	Measurement	Value
19	V_{BEQ}	______V
	R_A	______Ω
	R_B	______Ω

TABLE 58–7

Procedure Step	Measurement	Value
21	V_{in}	______V
23	$V_{CEQ} = 8.5$ V	V_{out} = ______V
	$V_{CEQ} = 1.5$ V	V_{out} = ______V

EXPERIMENT 59

TRANSISTOR AS A SWITCH

OBJECTIVES

At the completion of this experiment, you will be able to:

- Understand the importance of cutoff and saturation to the operation of a transistor switch.
- Define the purpose of a transistor inverter.
- Identify the function of a transistor switch.

SUGGESTED READING

Chapters 29 and 30, *Basic Electronics*, B. Grob, Eighth Edition

INTRODUCTION

The computers of today do not process numbers in the base 10 (that is, 0, 1, 2, 3, . . . , 9). Computers instead use binary logic of base 2 (0 and 1) to perform their functions. One fundamental circuit is the transistor switch, also known as an *inverter*. Here, a transistor connected in a common-emitter fashion inverts a signal. That is, if a high input signal is applied, a low output signal is created. If a low input signal is applied, then a high output signal is created. The circuit of Fig. 59-1 is an example of a transistor inverter design.

The circuit of Fig. 59-1 is also a transistor switch. In a transistor switch circuit, a voltage level applied to the base terminal will control the potential at the collector. In this fashion the transistor can be used to turn on or off circuitry connected to the collector. This common-emitter circuit is being switched from cutoff and saturation, as shown in the load line of Fig. 59-2.

In this experiment, a transistor will be connected to demonstrate this switching ability.

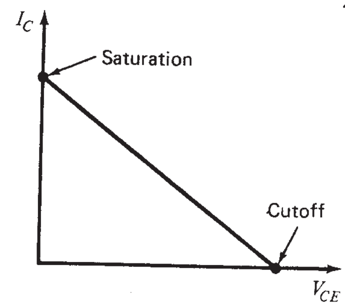


Fig. 59-2. Cutoff and saturation plotted on a load line.

EQUIPMENT

DC power supply, 0–10 V
VTVM
Protoboard or springboard
Test leads

COMPONENTS

(1) NPN transistor
(1) PNP transistor

Resistors (all 0.25 W):

(1) 1 kΩ (1) 10 kΩ

PROCEDURE

1. Connect the circuit in Fig. 59-3. Apply the correct polarity of voltage to V_{CC}.
2. Connect point A to ground. Measure and record in Table 59-1 the voltage from point B to ground.
3. Connect point A to +5 V. Measure and record in Table 59-1 the voltage from point B to ground.

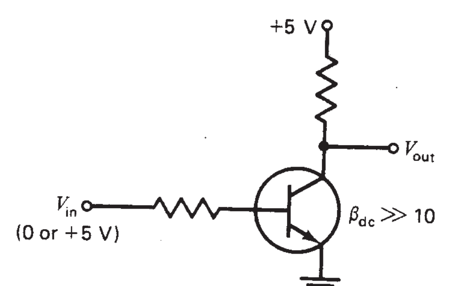


Fig. 59-1. Transistor inverter design.

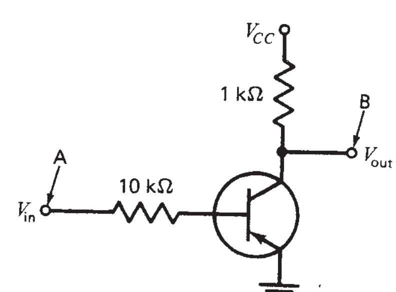


Fig. 59-3. Transistor switch.

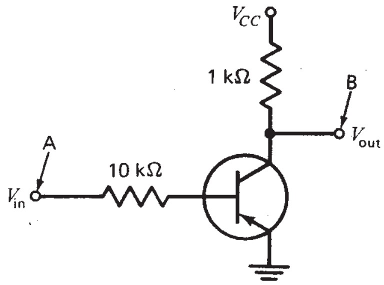


Fig. 59-4. Transistor switch.

4. Connect the circuit of Fig. 59-4. Apply the correct polarity of voltage to V_{CC}.
5. Connect point A to ground. Measure and record in Table 59-1 the voltage from point B to ground.
6. Connect point A to −5 V. Measure and record in Table 59-1 the voltage from point B to ground.
7. Construct a table of your results that will contrast the two circuits.

NAME

DATE

RESULTS FOR EXPERIMENT 59

QUESTIONS

1. In the above circuits, what voltage level would a binary 1 represent? A binary 0? Are the answers the same for both the circuits shown in Figs. 59-3 and 59-4?

2. What is saturation? How is it demonstrated in this experiment?

3. What is cutoff? How is it demonstrated in this experiment?

4. Are the saturation and cutoff points the same for both the circuits shown in Figs. 59-3 and 59-4?

5. What are the fundamental differences between the two circuits shown in Figs. 59-3 and 59-4? Do the differences significantly affect overall outcomes? Explain.

REPORT

Write a complete report. Discuss the results. Discuss the three most significant aspects of the experiment and write a conclusion.

TABLE 59–1

2	Point B to ground	______V
3	Point B to ground	______V
5	Point B to ground	______V
6	Point B to ground	______V