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ABSTRACT

This individualized learning module on special devices is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Two lessons are included in the module: (1) Silicon Controlled Rectifier Theory and (2) Unijunction Transistor Theory. Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks are provided for each lesson in a separate document, CE 026 586.) (LRA)

CHIEF OF NAVAL EDUCATION AND TRAINING

1 APRIL 1977

Military Curricula for Vocational & Technical Education

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 25. SPECIAL DEVICES.

STUDY BOOKLET.

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Dffice of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Dffice pf Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matte. specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

he National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

Dne hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Dccupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM CODRDINATIDN CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
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1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
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Mississippi State, MS 39762
601/325-2510

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225 West State Street
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WESTERN
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1776 University Ave.
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The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

PREPARED FOR

BASIC ELECTRICITY AND ELECTRONICS

CANTRAC A-100-0010

MODULE TWENTY FIVE

SPECIAL DEVICES

PREPARED BY

INDIVIDUALIZED LEARNING DEVELOPMENT GROUP

SERVICE SCHOOL COMMAND, NTC, SAN DIEGO, CA. 92133

STUDY BOOKLET

1 APRIL 1977

OVERVIEW
BASIC ELECTRICITY AND ELECTRONICS
MODULE TWENTY FIVE

Special Devices

In most electronic systems there is a need for some sort of controlling or switching action. It may be necessary to modify the incoming signal so that it may be processed for the desired output. An example would be FM multiplexing in a radio. In earlier electronics the controlling/switching action was performed by mechanical relays and rheostats. In today's high speed computers, however, a mechanical relay is often too slow to meet equipment requirements, and rheostats consume too much power. Therefore, instead of relays and rheostats, special devices are used. They are actually "electronic relays/rheostats" or categorically, "electronic switches".

In this module you will study two types: Silicon Controlled Rectifiers (SCR's) and Unijunction Transistors (UJT's).

You will see as you study the two devices that, though they are both classed as controlling or switch devices, they have distinctly different operating characteristics.

This module has been divided into two lessons:

Lesson I Silicon Controlled Rectifier Theory
Lesson II Unijunction Transistor Theory

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY FIVE

LESSON 1

SILICON CONTROL RECTIFIER THEORY

1 APRIL 1977

OVERVIEW
LESSON 1

Silicon Control Rectifier Theory

In this lesson, you will study and learn about Silicon Controlled Rectifiers (SCR). You will be able to identify them schematically, as well as, learn the conditions necessary to start and stop their conduction. In addition, you will be able to identify physically, schematically and functionally SCR circuits.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

25.1.47 When the student completes this course, he will be able to TROUBLESHOOT faulty UJT/SCR circuits, given a training device, prefaulted UJT/SCR circuit cards, and proper tools. Repair to be done on a practice board with similar components. Repaired board to pass Learning Supervisor's visual and physical inspection for quality. Replaced component to be tested for damage incurred during installation.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

25.1.47.1 IDENTIFY by selecting, the names of the three leads of an SCR, given an unlabelled diagram of an SCR and a list of names. 100% accuracy is required.

25.1.47.2 IDENTIFY the conditions necessary to make an SCR start conducting by selecting the correct statement from a choice of four. 100% accuracy is required.

25.1.47.3 IDENTIFY the conditions necessary to maintain an SCR in conduction by selecting the correct answer from a choice of four. 100% accuracy is required.

25.1.47.4 IDENTIFY the conditions necessary to stop conduction of an SCR by selecting the correct answer from a choice of four. 100% accuracy is required.

OVERVIEW

25.1.47.5 OBSERVE and RECORD waveforms from an SCR AC control circuit, given a training device or circuit and the proper tools, an oscilloscope, a job program, and schematic diagrams or technical manuals. Recorded data must be within limits shown in the job program.

25.1.47.6 OBSERVE and RECORD waveforms from an SCR DC control circuit given a training device or circuit and the proper tools, an oscilloscope, a job program, and schematic diagram or technical manuals. Recorded data must be within limits shown on the job program.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON 1

Silicon Control Rectifier Theory

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Five-1-1 "Silicon Controlled Rectifier DC Control"
Job Program Twenty Five-1-2 "Silicon Controlled Rectifier AC Control"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Five-1 "Introduction to Silicon Controlled Rectifiers"

Enrichment Material(s):

Basic Electronics Vol. I, NAVPERS 10087-C
GE SCR Manual

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON I

Silicon Controlled Rectifier Theory

The Silicon Controlled Rectifier is a solid state device used in motor controllers, switching circuits and power supply circuits. Its advantages include the following:

It is quiet in operation.
Vibration and shock do not affect it.
Most important, you can control a large amount of voltage and current with a small controlling voltage.

We can see from the schematic symbol shown below that the SCR has 3 leads.

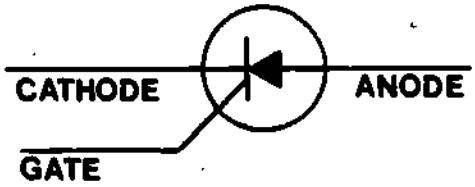


Figure 1

The anode and cathode leads are the same as the diode you have studied previously. The gate lead is added to control conduction of the SCR.

Like a diode, the SCR must be forward biased to conduct - - negative on the cathode, positive on the anode.

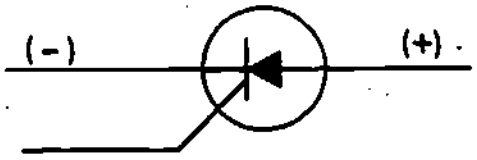


Figure 2

Unlike a diode, the SCR must have a positive signal on the gate lead (usually +.1 to +1 v) while it is forward biased or it will not conduct.

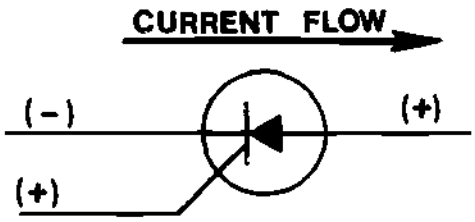
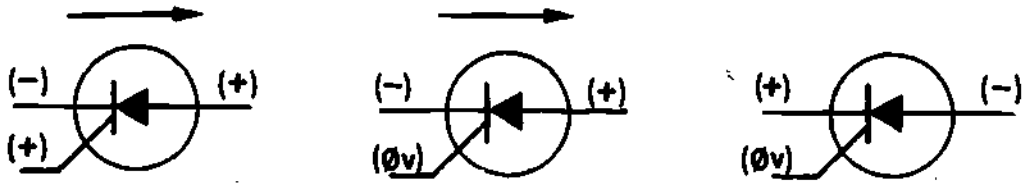


Figure 3

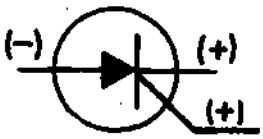
In Figure 3, the conditions for conduction are met. Current flows from cathode to anode. If we remove the gate signal, the SCR will remain in conduction; however, if we remove forward bias, the SCR will cut off. (Stop conducting.)



SCR Conducting SCR Conducting SCR Cut Off

Figure 4

If we reverse bias the SCR, then it will not conduct even if we apply a positive gate signal.



SCR Cut Off

Figure 5

Using this information let's look at an SCR with a DC voltage applied.

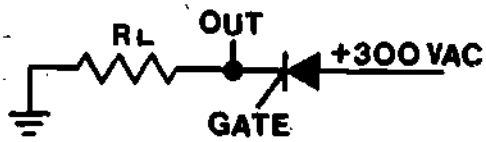


Figure 6

The output waveform will be taken across R_L.

This SCR needs +.1v on the gate to conduct.

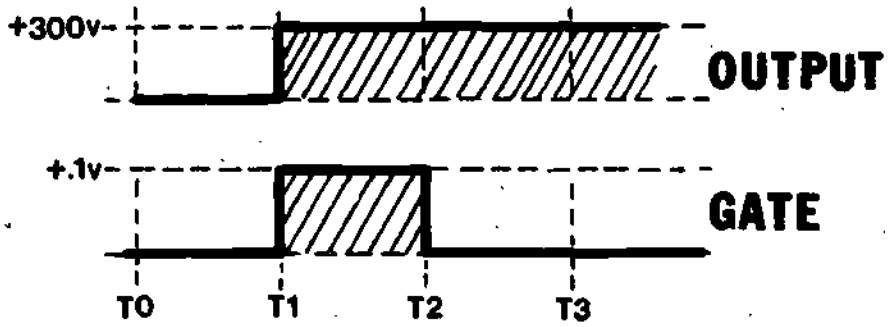
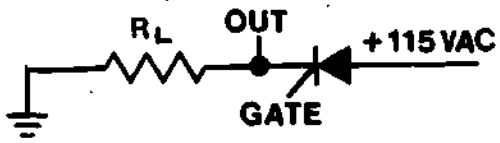


Figure 7

At T0 there is no output although forward bias is applied. When the gate voltage is applied at T1 the SCR conducts and we will see the +300v across R_L. Even though we remove the gate voltage at T2 the SCR remains in conduction as long as forward bias is applied. If we remove the forward bias then the SCR will stop conducting.

Let's examine an SCR with AC applied to the anode and a DC voltage applied to the gate.



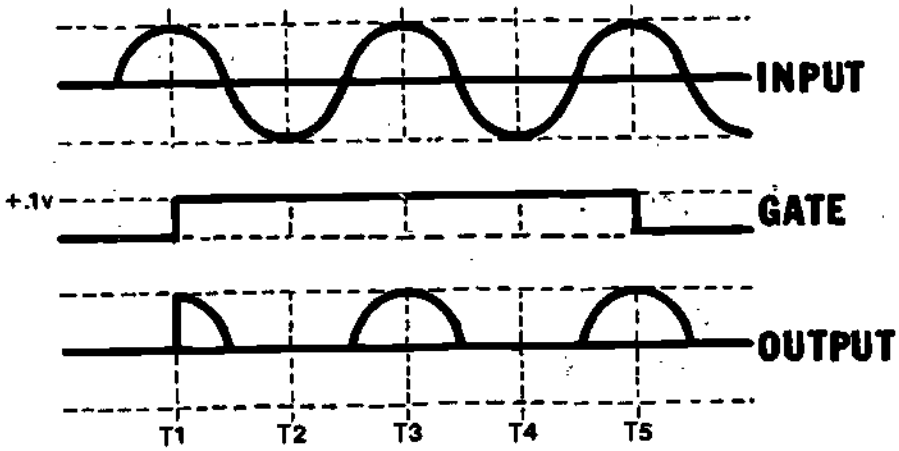
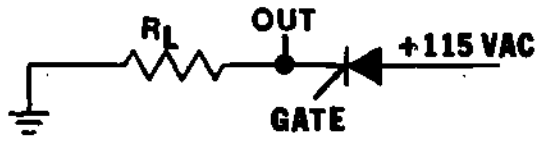


Figure 8

As you can see, the SCR will conduct only when it is forward biased and has the proper gate signal. With AC applied to the input and to the gate we can choose a variety of waveforms by varying the gate signal.



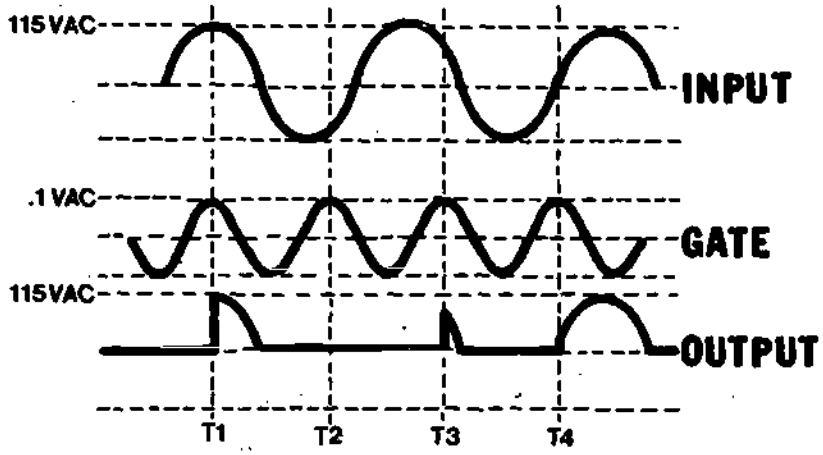


Figure 9

Notice that the SCR conducts only when the proper gate signal coincides with the proper forward bias. By timing the gate signal we can make the SCR pass the entire positive portion of the waveform or only a part of it.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON I

Silicon Controlled Rectifier Theory

TEST FRAMES ARE 4, 8, AND 13. AS BEFORE, GO TO TEST FRAME 4 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The Silicon Controlled Rectifier - more commonly called an SCR - is a compact and quiet solid state device. SCR's come in a wide range of sizes, operating characteristics and applications.

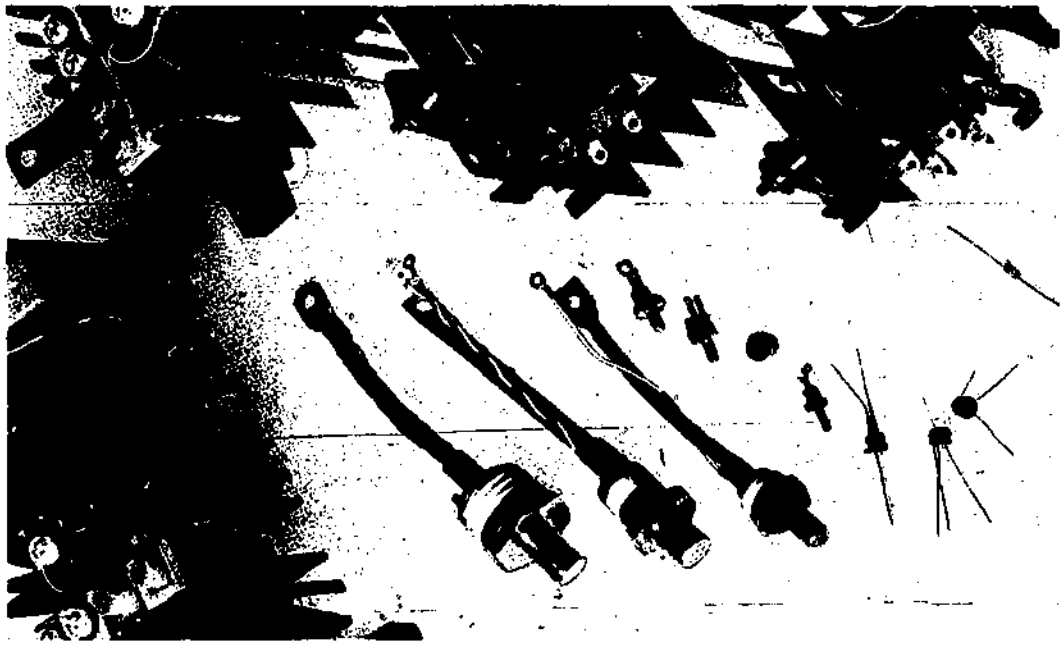
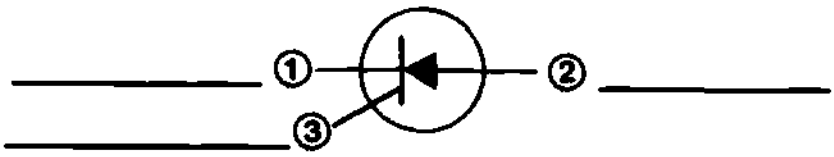


Figure I

They can be used in electronic switching circuits, power supply circuits and motor speed control circuits. When properly chosen and protected with cooling fins and heat sinks, the SCR can efficiently control a very large amount of power. The SCR, like the diode, is not effected by vibration.

The SCR is very similar to the diode rectifier we covered in previous lessons. A diode, as you recall, has an anode and cathode. The SCR has an anode and cathode with the addition of a third lead called a gate. In the SCR schematic, the gate lead is attached to the cathode of the SCR.

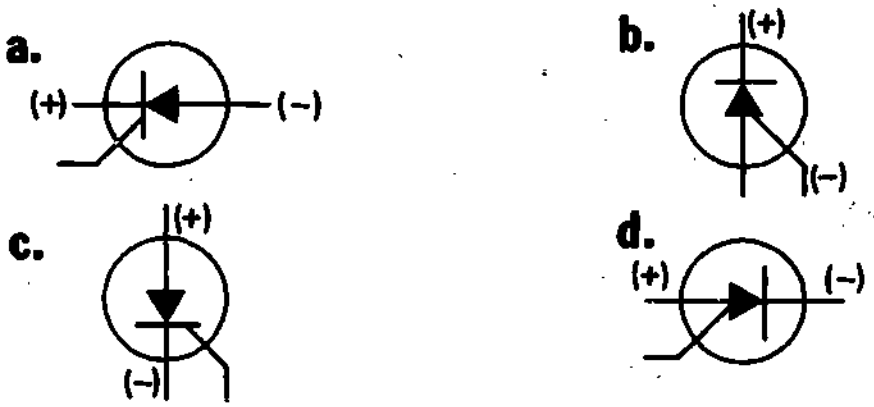
The schematic symbol for an SCR is illustrated below. Label the leads of the SCR.



1. Cathode, 2. Anode, 3. Gate

2. Another similarity that exists between the diode and the SCR is that they both must be forward biased in order to conduct. Also current flows against the arrow in both devices.

Which of the following shows the correct schematic symbol for a forward biased SCR?



c.

3. Now that we've looked at the similarities between the diode and the SCR, let's take a look at what makes them operate. The key to understanding the SCR is in knowing how the gate controls the operation of the SCR.

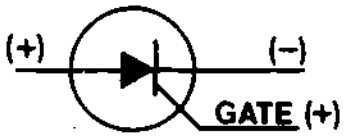


Figure 2

Unlike the diode, an SCR will not conduct with just forward bias across it. The SCR must have a positive voltage applied to the gate at the time it is forward biased in order for it to conduct. With no voltage on the gate lead the SCR is essentially an open circuit and will not pass any current.

Figure 3 shows essentially what occurs electronically to a forward biased SCR with:

(1) no voltage applied to the gate, and
(2) a positive voltage applied to the gate.

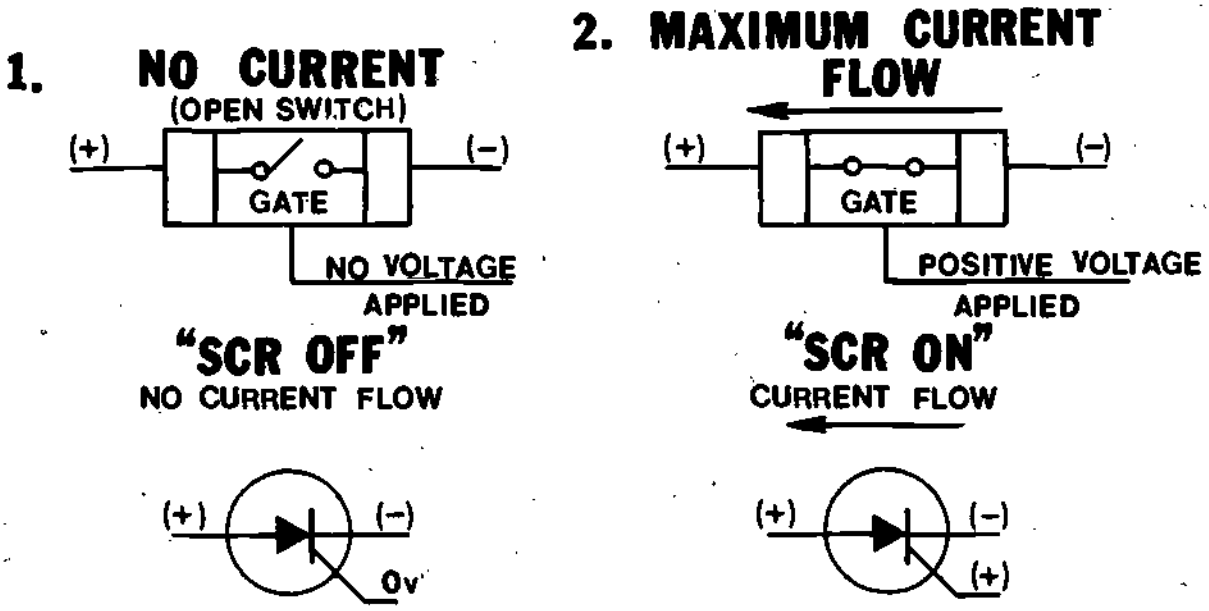
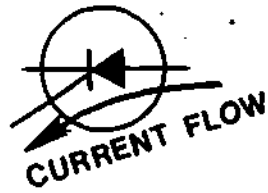


Figure 3

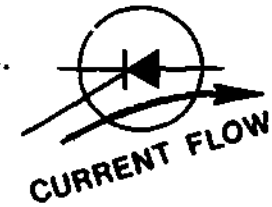
Notice that with no voltage applied to the gate of the SCR, it acts like an open switch even though it is forward biased. When we apply the positive voltage to the forward biased SCR, there is current flow against the arrow and the SCR acts like a closed switch.

Current flow in an SCR is:

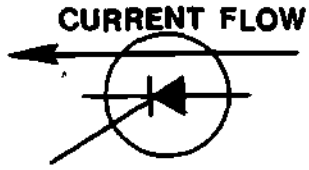
A.



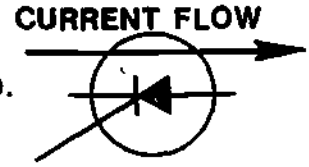
B.



C.



D.

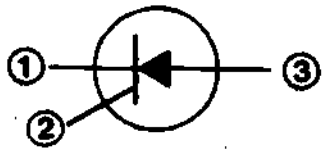


d.

4. TEST FRAME

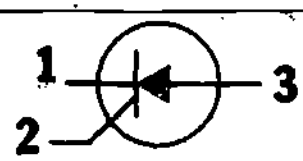
a. Label the leads of the SCR in the blanks provided.
b. Determine the polarity (with respect to lead 1) of the voltage that must be applied to each lead to cause the SCR to conduct.
c. Show the direction of current flow.

A.	B.	C.
(1) _____	( )	→
(2) _____	( )	or
(3) _____	( )	←



(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

A. (1) Cathode B. (-)
(2) Gate (+) C.
(3) Anode (+)



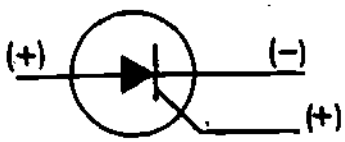
IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 8. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 4 AGAIN.

5. The gate works like a "turn on" switch during the time that the SCR is forward biased. Once the SCR is in conduction, the gate no longer has any control. In other words the gate can't turn the SCR "off". The only ways to stop the SCR conduction are to:

1. Remove the forward bias or
2. Reverse bias the SCR.

Therefore, as long as a conducting SCR is forward biased, it will remain in conduction. We can remove the gate signal completely without affecting current flow through the SCR.

In the following schematic, the SCR is conducting. Which of the following is required to cause the SCR to stop conducting?



a. Remove the gate signal.
b. Reverse bias the SCR.
c. Remove the forward bias from the SCR.
d. Either b or c.

---

d. Either b or c.

6. Depending on the circuit application we can apply either a DC level or an AC signal to the gate of an SCR. In Figure 4, a DC level of +.4 volts is required for the gate to turn the SCR on. Other types of SCRs may require different voltage levels on the gate to turn them "on". Most of the SCRs you will see will have from +.1 volts to +1 volts applied to the gate for a turn on voltage.

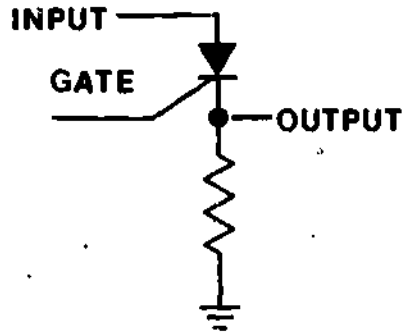


Figure 4

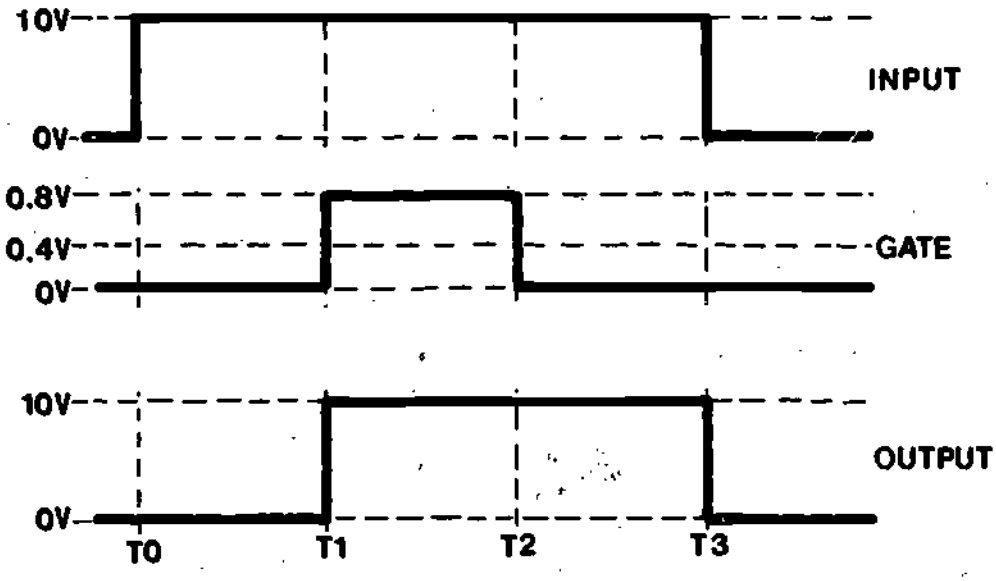


Figure 5

Figure 5 illustrates the waveforms of an SCR with DC applied to the gate and with a DC input voltage. Notice that at T0 the SCR is forward biased but there is no output at T0. Which of the following explains why the SCR is not in conduction?

a. Insufficient forward bias.
b. Insufficient DC on the gate.
c. The SCR is Reverse Biased.
d. Too much DC on the gate.

b. Insufficient DC on the gate.

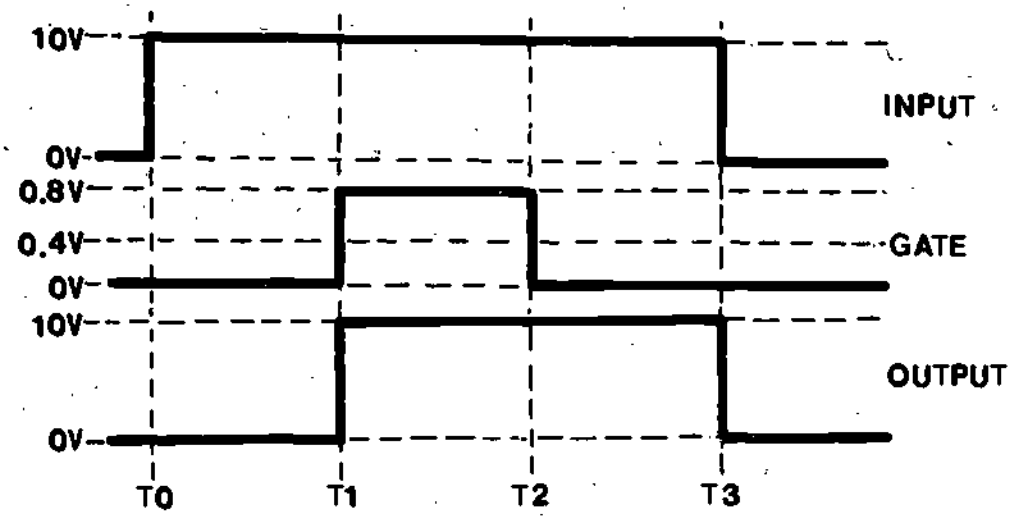


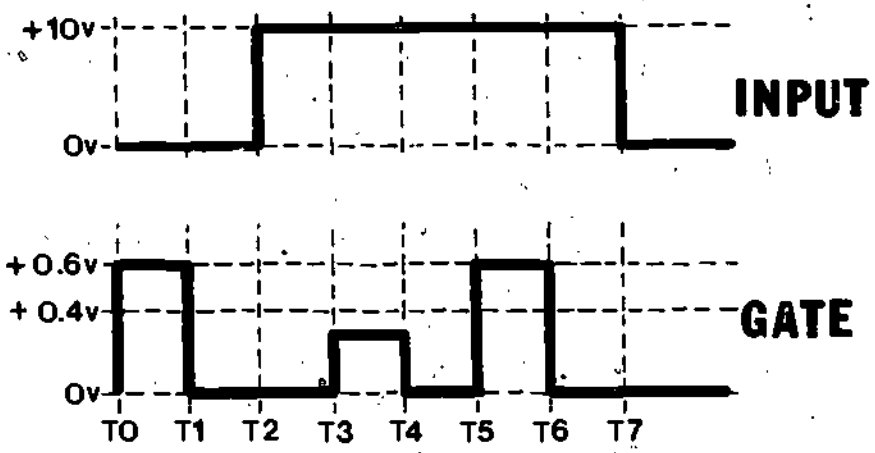
Figure 6

7. Refer to Figure 6. At time T1 a DC signal in excess of +.4 volts is applied to the gate. The SCR now conducts and we get an output. At time T2 we remove the DC on the gate. Why does the SCR remain in conduction?

The gate cannot turn off the SCR.

8. TEST FRAME

If the SCR in the following illustration requires +.4v on the gate to turn it on, at which time will the SCR (1.) turn "on"? (2.) turn "off"?



a. 1. Turn "on" at T0 2. Turn "off" at T1
b. 1. Turn "on" at T3 2. Turn "off" at T7
c. 1. Turn "on" at T5 2. Turn "off" at T7
d. 1. Turn "on" at T5 2. Turn "off" at T6

(THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.)

c. 1. Turn "on" at T5 2. Turn "off" at T7

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 13. OTHERWISE GO BACK TO FRAME 5 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 8 AGAIN.

9. Now, let's apply a DC signal to the gate as an AC signal is applied across the anode to cathode of the SCR. The waveforms are illustrated in Figure 7.

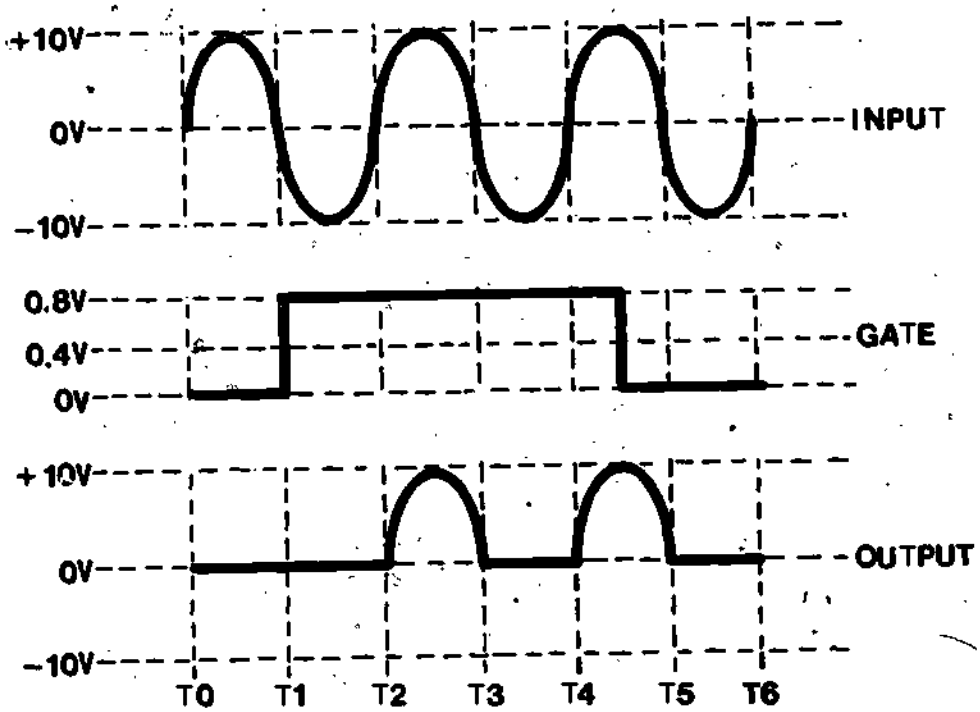


Figure 7

Figure 7 shows that, even though the SCR has been forward biased by the AC signal from T0 to T1, there is no conduction. This is due to the fact that there is no positive signal applied to the gate. At T1 the gate voltage is applied at a sufficient level to cause conduction.

The SCR still does not conduct because it is reverse biased. T2 arrives and we have the right combination for conduction:

1. A gate signal of sufficient level.
2. Forward bias from anode to cathode.

Which of the following statements describes what occurs at T3?

a. The output decreases due to lack of forward bias.
b. The output decreases due to loss of gate signal.
c. The output increases due to the signal on the gate.
d. The output increases due to loss of signal on the gate.

---

a. The output decreases due to lack of forward bias.

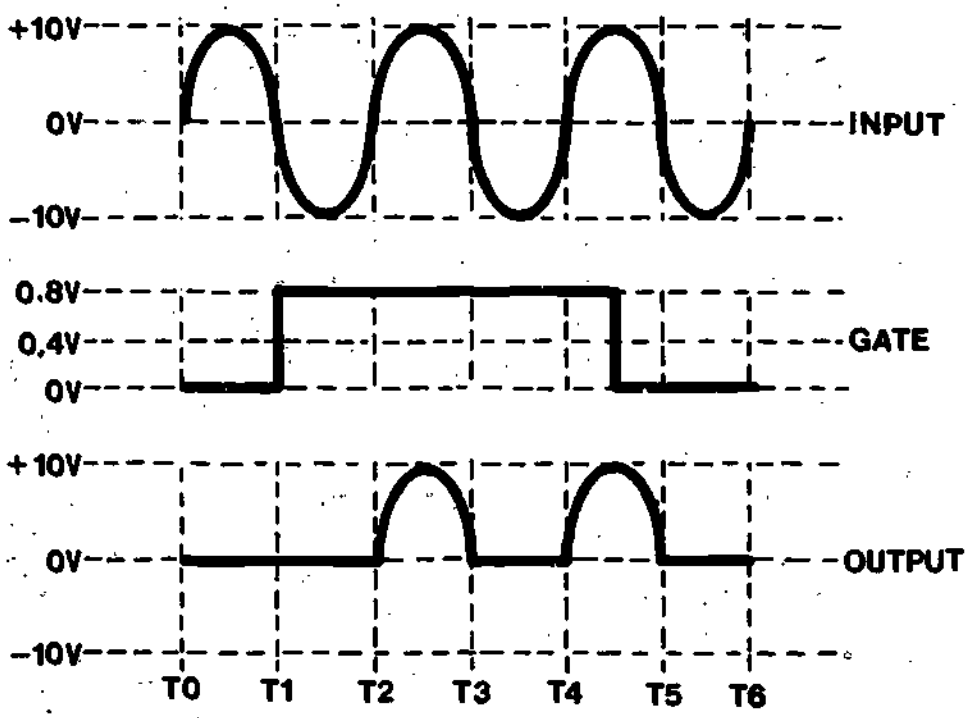


Figure 8

10. At T4 in Figure 8, the SCR starts conducting and removal of the gate signal between T4 and T5 has no effect on its operation. Select the statement which:

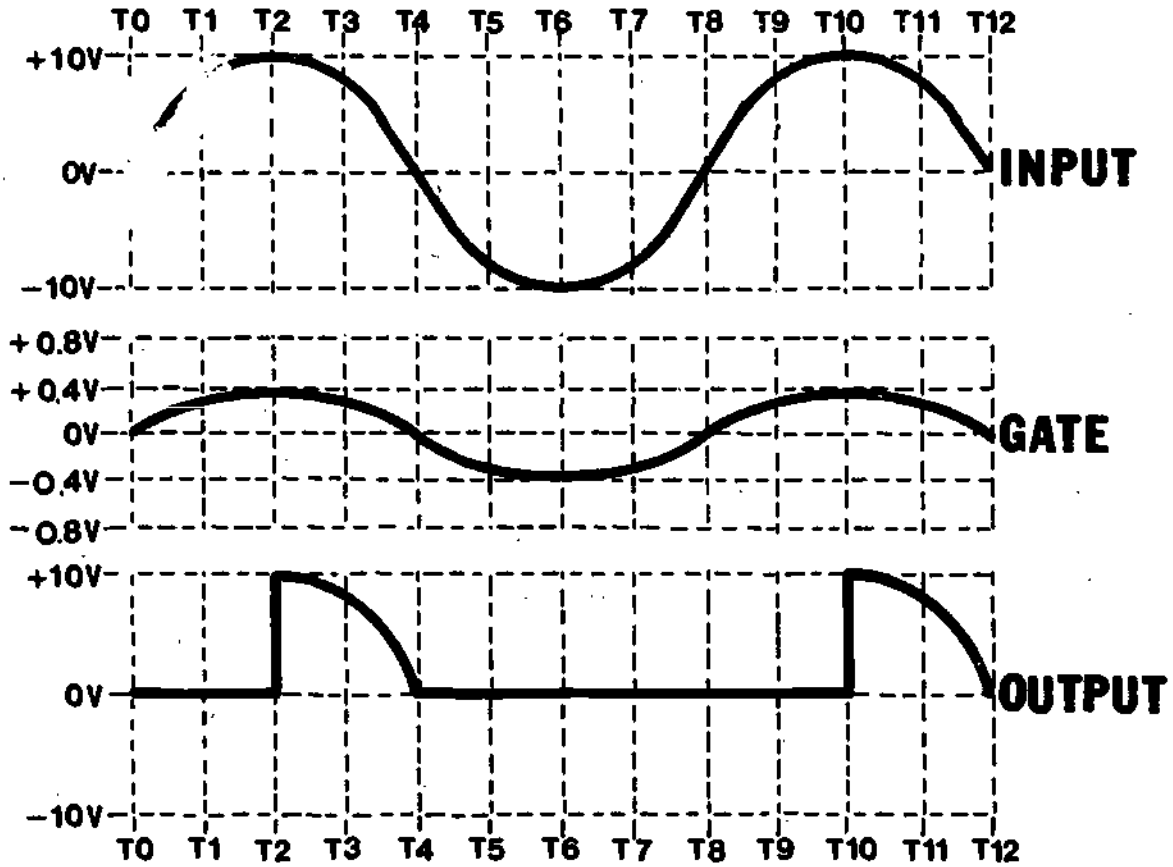
1. Describes the conditions necessary to turn the SCR "on".
2. Describes the conditions necessary to turn the SCR "off".

a. (1) Forward bias and sufficient negative signal on the gate.
(2) Reverse bias/or remove forward bias.
b. (1) Forward bias and sufficient positive signal on the gate.
(2) Remove the gate signal.
c. (1) Forward bias and sufficient negative signal on the gate.
(2) Reverse bias/or remove forward bias.
d. (1) Forward bias and a sufficient positive signal on the gate.
(2) Reverse bias/or remove forward bias.

- -

d. (1) Forward bias and a sufficent positive signal on the gate.
(2) Reverse bias/or remove forward bias.

11. So far in our study of SCR's we have used a DC signal on the gate. In these circuits the output waveform has stayed the same as the input signal when the SCR was conducting, and the input signal has been blocked when the SCR was not conducting. Now, we'll see that by using an AC signal as gate and also as input signals, control of the SCR becomes smoother. We can pass as little or as much of the positive portion of the AC cycle as we want.



Note: The gate waveform is expanded in amplitude with respect to the input and output waveforms.

Figure 9

Looking at Figure 9, let's assume that the SCR used for these waveforms requires a +.4 volt signal on the gate to enable the forward biased SCR to conduct. Notice that the SCR still operates in the same manner but our output waveform is different.

Although the SCR is forward biased at T0, the AC gate signal does not reach +.4v until T2. At this time the gate signal is of sufficient amplitude to cause the forward biased SCR to conduct. Even though the gate voltage immediately drops below .4 volts, the SCR continues to conduct until the forward bias is removed at T4. This action is repeated again at T10.

How does the power output of the SCR device in Figure 9 compare with the power output of the same device with a continuous +.4 volt DC signal applied to the gate?

a. The power is the same in both cases.
b. The power output in Figure 9 is less.
c. The power output in Figure 9 is greater.

- -

b. The power output in Figure 9 is less.
Note: The device with the +.4 volt DC signal applied to the gate will pass the entire positive portion of the input cycle whereas the device in Figure 9 passes only about half of the positive input alternation.

12. Now let's take the same SCR and apply a +0.6 volt AC signal to the gate.

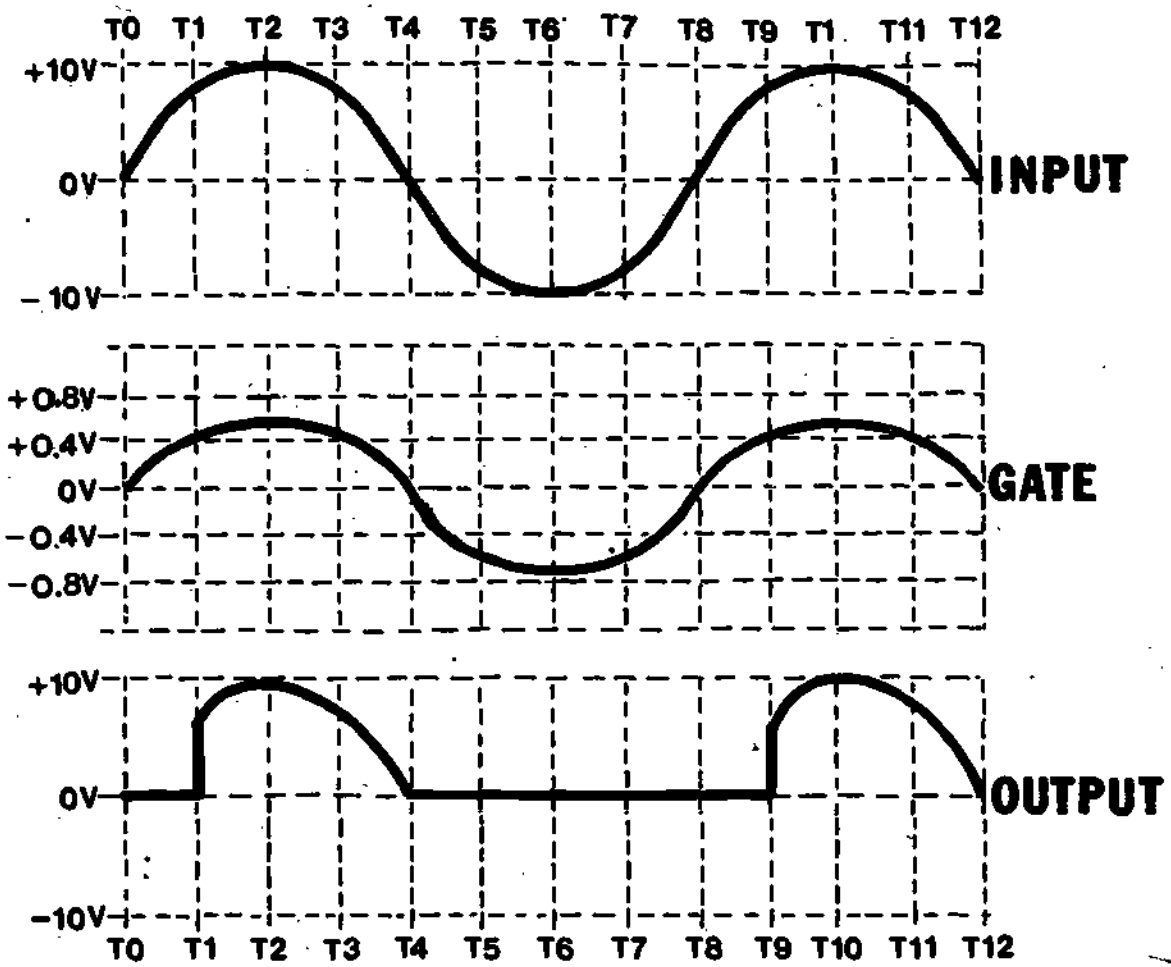


Figure 10

Note: The gate waveform is expanded in amplitude with respect to the input and output waveforms.

It can be seen that the gate signal now rises to the +.4 volt level at time T1. This allows more of the positive portion of the input cycle to be passed through the device which, in turn, increases the power output.

If we increased the AC gate signal to an even greater amplitude -- say one volt for example -- the SCR would conduct almost as soon as it was forward biased and all of the positive portion of the AC cycle would be passed. We have developed a method of controlling the exact amount of power we allow through the SCR device.

What is the minimum AC gate voltage in Figure 10 that will cause the SCR to conduct?

a. +0.6v
b. -0.4v
c. +0.4v
d. -0.6v

- -

c. +0.4v

13. TEST FRAME

How do we vary the amount of positive AC signal passed by a forward biased SCR?

a. Vary the signal on the cathode.
b. Vary the signal on the gate.
c. Vary the signal on the anode.
d. Vary the forward bias.

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.)

b. Vary the signal on the gate.

IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON I, MODULE TWENTY FIVE. OTHERWISE GO BACK TO FRAME 9 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 13 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON I

Silicon Controlled Rectifier Theory

The silicon controlled rectifier, commonly called an SCR, is a compact and quiet solid state device. Its operation is unaffected by vibration and shock. When properly chosen and protected with heat sinks and cooling fins, the SCR can efficiently control a very large amount of power.

SCR's come in a wide range of sizes, operating characteristics and circuit applications. When used properly they should have virtually unlimited operating life.

Figure 1

An SCR can be compared to a diode rectifier. Recall that a diode has two leads; an anode and a cathode. It must be forward biased in order to conduct or reverse biased to be cut-off.

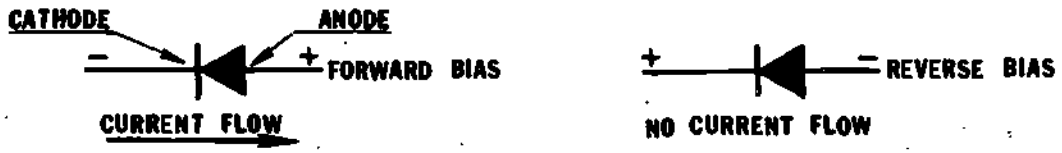


Figure 2

An SCR has the same two leads, anode and cathode, with an additional lead called a gate. Figure 3, shows the schematic symbol of an SCR device.

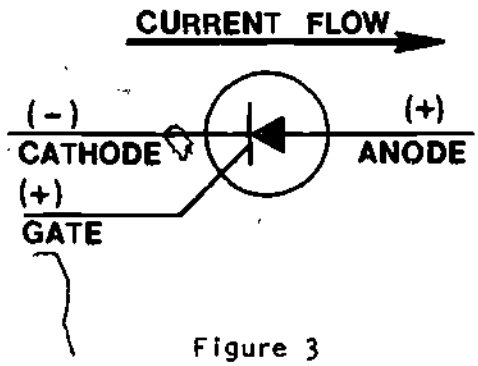


Figure 3

The operation of an SCR is similar to that of a diode. The SCR must be forward biased in order to allow current flow through the device. But the SCR differs from a diode rectifier in that the SCR not only requires forward bias but also requires a positive signal on its gate for conduction (as shown in Figure 4). Like the diode, once the device is forward biased and conducting the only way to cut it off is to remove or reverse the cathode to anode bias.

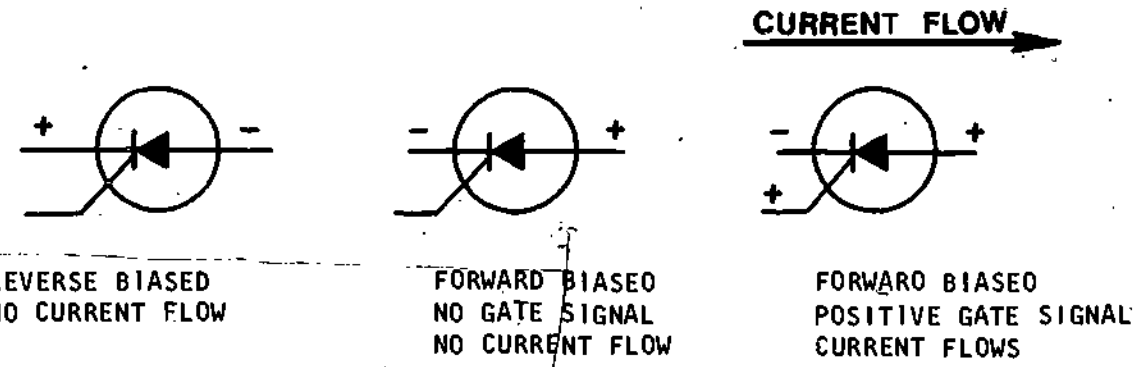


Figure 4

The gate works like a "turn on" switch during the time that the SCR is forward biased. Once the SCR starts conducting, the gate no longer has any control. In other words the gate can not turn the SCR "off". The only ways to stop conduction of the SCR (turn it off) are to:

(1) remove the forward bias, or
(2) reverse bias the SCR.

Therefore, the SCR will remain in conduction even after the gate signal is removed, but only as long as forward bias is applied. This action is shown in Figure 5.

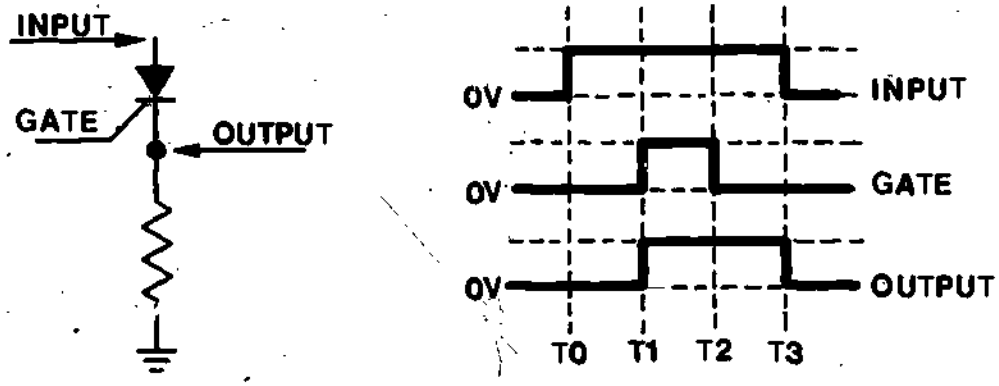


Figure 5

An SCR requires (forward/reverse) bias and a (positive/negative) gate signal to enable it to conduct.

- -

forward; positive

Which of the following is required to cause an SCR to stop conducting:

a. simultaneous removal of the gate signal and continued forward bias application.
b. removal of the gate signal.
c. reverse bias the SCR.
d. either b or c

- -

c. reverse bias the SCR (removing the forward bias is also sufficient to cause the SCR to stop conducting).

We can apply either a DC level or an AC signal to the gate of an SCR. If we apply a DC level to the gate the waveforms will look like those illustrated in Figure 5. You will notice that Figure 6 is identical to Figure 5 except that voltage levels are indicated. This particular SCR requires a +.4 volt level on the gate to turn the SCR on. Other types of SCR's may require different voltage levels on their gates, but the voltage is usually fixed somewhere between +.1V and +1V.

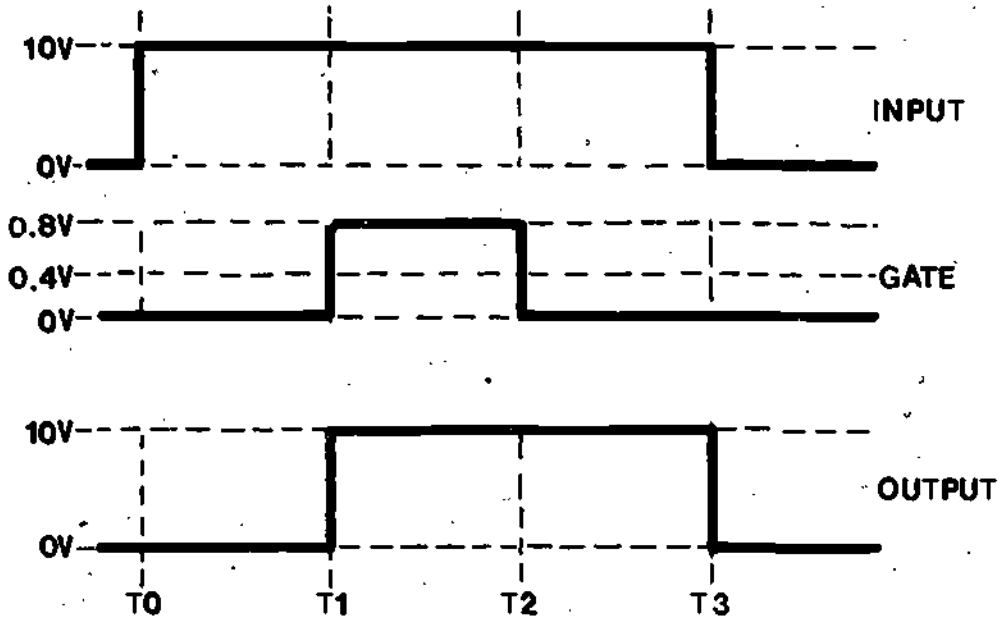


Figure 6

Notice that the SCR is forward biased from time T0 until T1, but with no signal on its gate, it won't conduct. At time T1 a DC signal in excess of +.4 volts is applied to the gate. The SCR now conducts and we get an output. At time T2 we remove the DC level on the gate. The SCR remains in conduction! This illustrates that once the SCR is turned on, the gate no longer has any control over conduction of the SCR. The gate signal can't turn it off! We turned it off at time T3 by removing the forward bias.

Now let's use an AC signal.

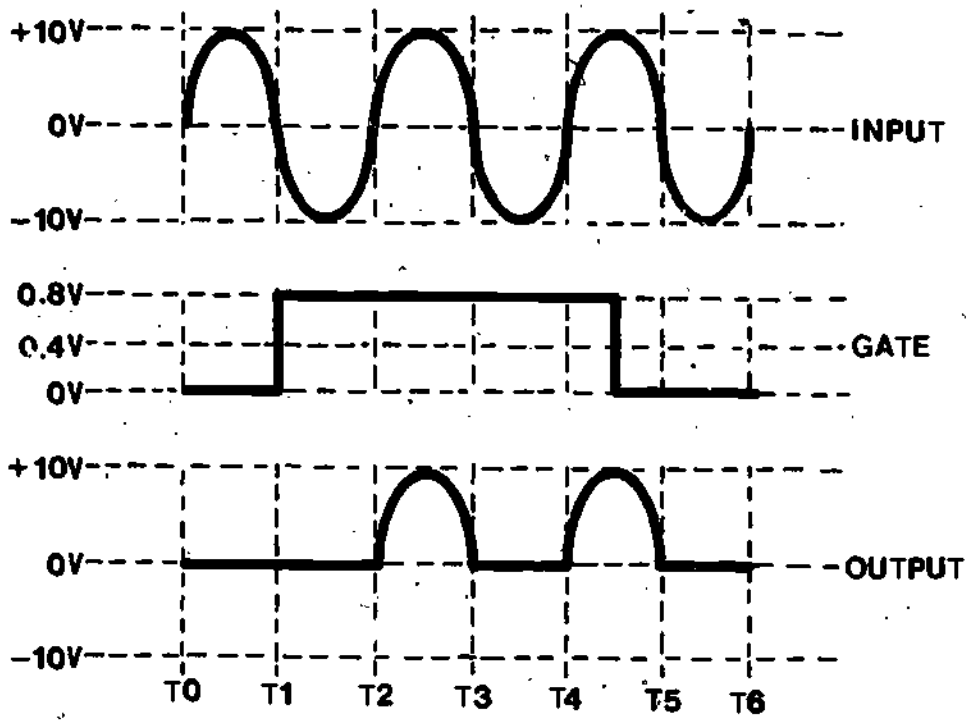


Figure 7

Referring to Figure 7; although the SCR has been forward biased from T0 to T1, it did not conduct. This is because no gate signal was applied. Now, at T1 a gate signal of sufficient level is applied but at the same time the SCR has no forward bias. So - it still doesn't conduct. But wait -- T2 arrives and we have both a gate and signal of sufficient level and forward bias. The SCR now conducts! T3 rolls around and what happens? The SCR cuts off and there is no output. Why?

- -

Although the gate signal is still applied the forward bias is removed (or words to that effect).

Now, at T4 the SCR becomes forward biased once again - and the gate signal is still present. The SCR conducts. But look - between T4 and T5 the gate signal is removed. Do we still have an output? We certainly do! Why?

- -

Once the SCR starts conducting removal of the gate signal is not sufficient cause to cut it off. Only removal of forward bias - or application of reverse bias - can turn it off. (or words to that effect.)

Now, that wasn't so difficult, was it? So far we've seen a DC level as both the gate signal and the input signal - and we've just looked at a situation where the gate signal was DC and the input was AC. Let's now see what happens when we use AC as both gate and input signal. For this example let's also assume we're using an SCR which requires a minimum +.4 volts on the gate to enable the SCR to conduct. (Remember - it must also be forward biased.)

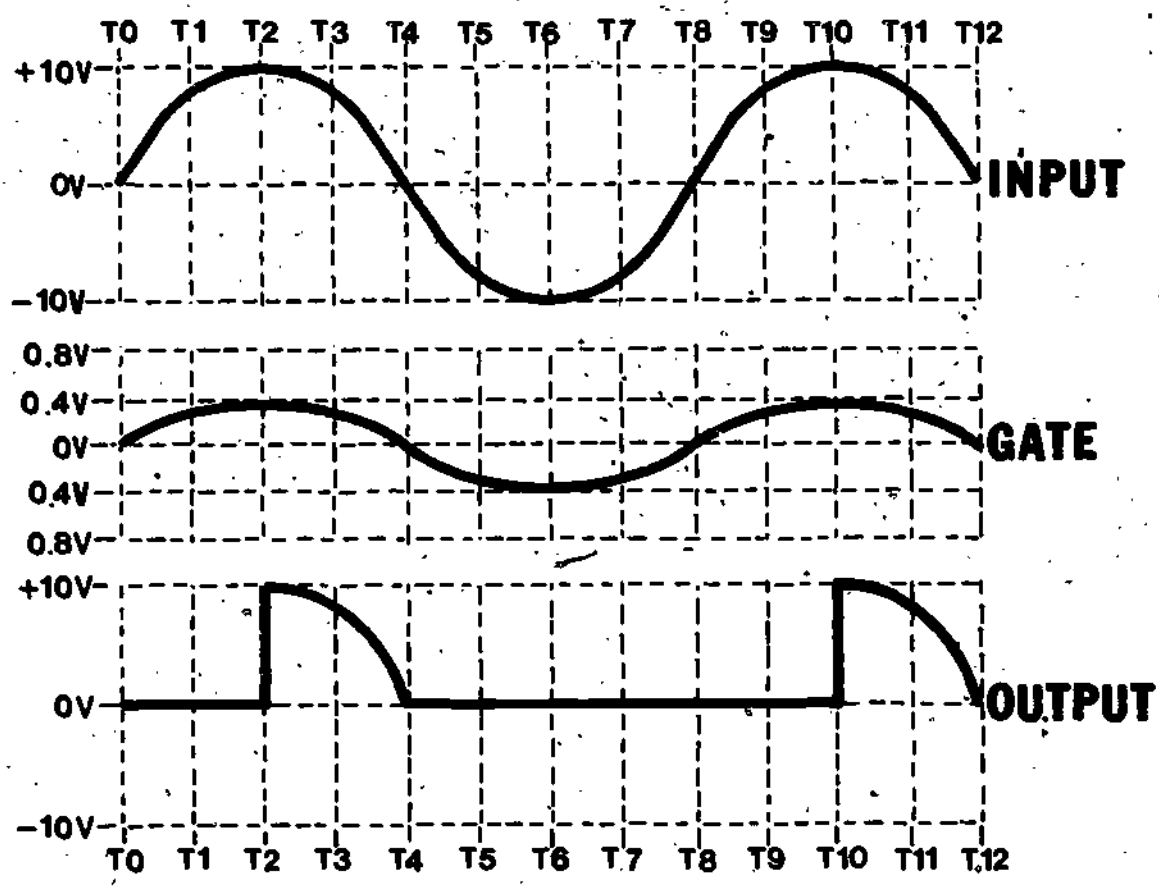


Figure 8

Looking at Figure 8 we see an output signal of yet another wave shape. The same basic SCR concept applies. It must be forward biased and the gate signal must be of sufficient level to enable the SCR to conduct. In this case, as the gate signal peaks at T2 and again at T10 it is of a sufficient level, +.4 volt, to cause the forward biased SCR to conduct.

Now let's take the same SCR and apply an AC gate signal with a peak amplitude of +.6 volts. First we will expand our time chart and examine what is happening on the gate.

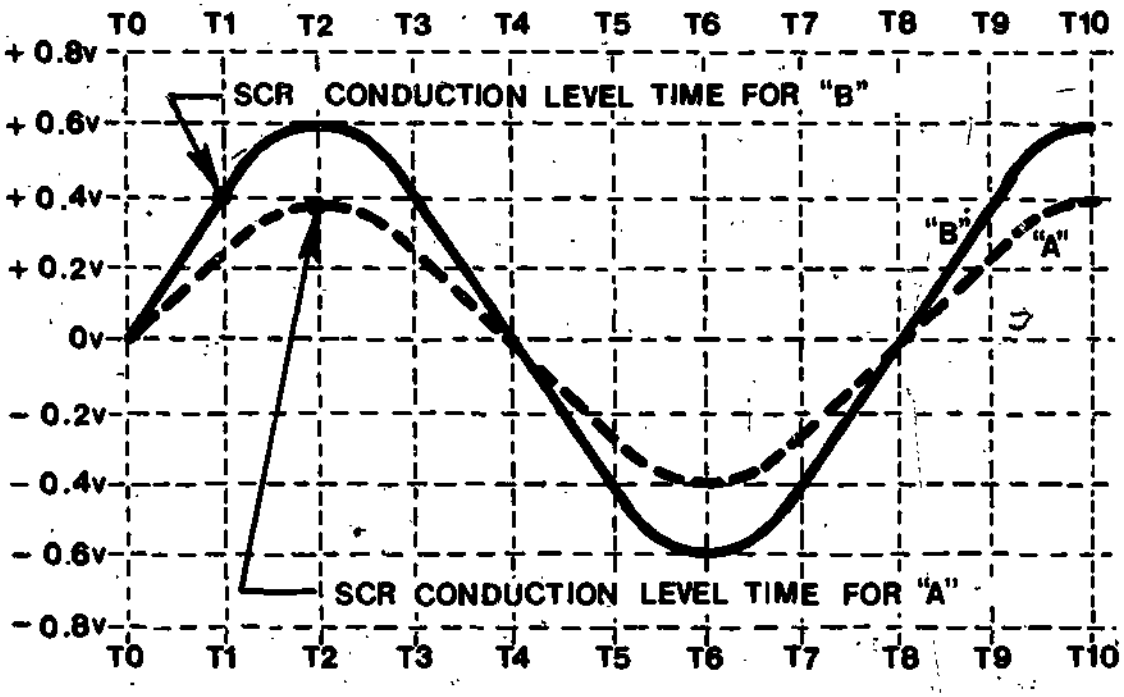


Figure 9

Look at waveform "A" first. It is the same waveform we applied to the gate of the SCR in Figure 8. It's of low amplitude peaking at +.4 volts, the level sufficient to cause the forward biased SCR to conduct. It reaches this level at T2. Now, look at waveform "B", our new input signal on the gate. It's of a much greater amplitude. It also peaks at T2 - but - it reaches +.4 volts at T1, much earlier than did waveform "A". Therefore, the forward biased SCR is able to conduct much earlier, allowing more of the input to pass through the device to the output as shown in Figure 10.

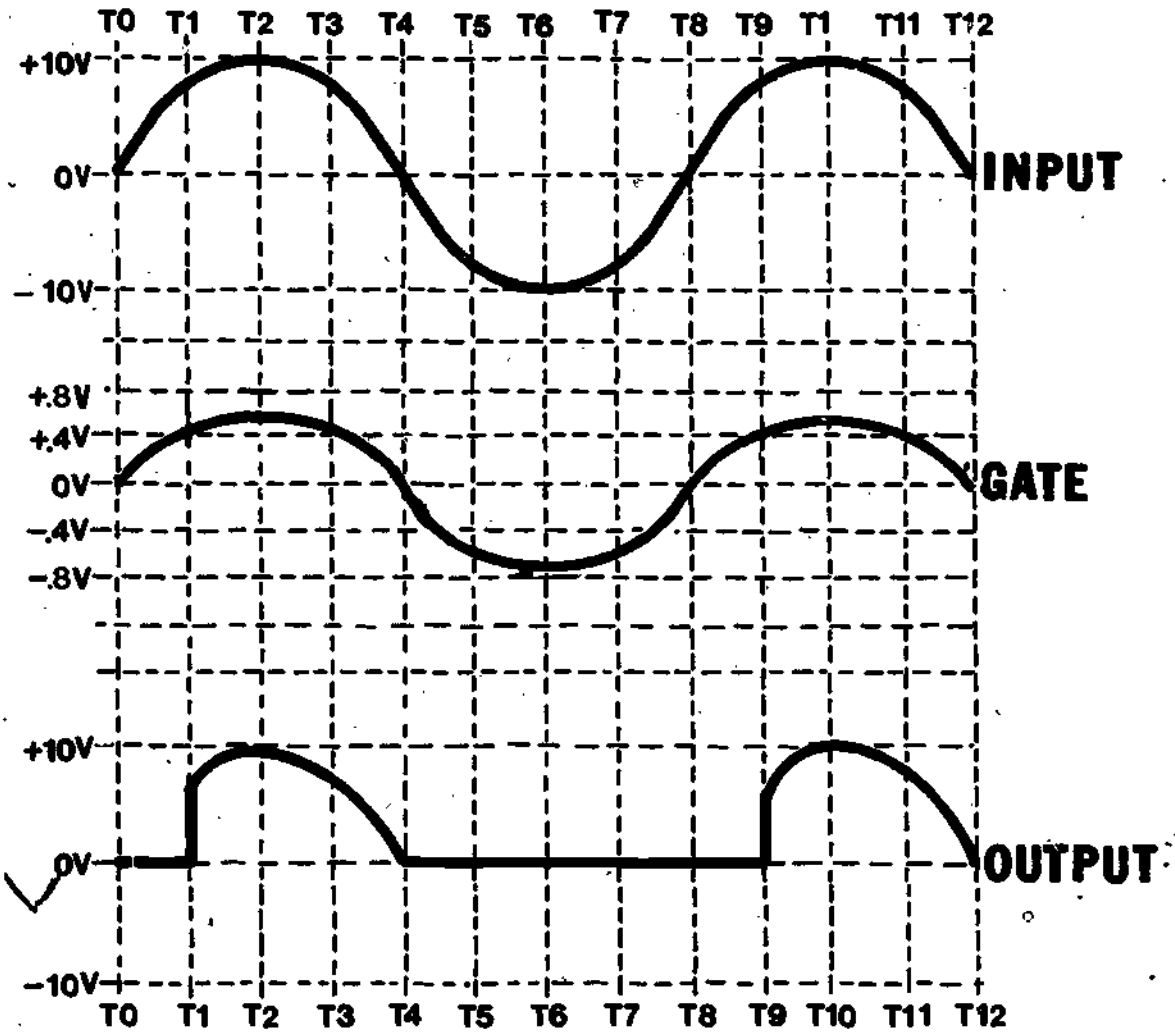


Figure 10

This increase in output power can readily be seen by comparing the output waveform in Figure 10 to the output waveform in Figure 8.

Silicon Controlled Rectifiers have many applications. Depending on your rating you will see certain of these applications. They are used in motor speed control circuits, electronic switching circuits and power supply rectifiers, among others.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY FIVE

LESSON II

UNIJUNCTION TRANSISTOR THEORY

1 APRIL 1977

OVERVIEW
LESSON 11

Unijunction Transistor Theory

In this lesson, you will study and learn about Unijunction Transistors (UJT). You will be able to identify them physically and schematically. You will also be able to identify the necessary voltage, current and resistance relationships present in a Unijunction Transistor.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

25.2.47 When the student completes this course, he will be able to TROUBLESHOOT faulty UJT/SCR circuits, given a training device, prefaulted UJT/SCR circuit cards, and proper tools. Repair to be done on a practice board with similar components. Repaired board to pass Learning Supervisor's visual and physical inspection for quality. Replaced component to be tested for damage incurred during installation.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

25.2.47.7 IDENTIFY by matching, the names of the three leads of a UJT given an unlabelled diagram of a UJT and a list of names. 100% accuracy is required.

25.2.47.8 IDENTIFY the conditions necessary to make a UJT conduct by selecting the correct statement of conditions from a choice of four. 100% accuracy is required.

25.2.47.9 DEFINE the term "voltage gradient" as it applies to a UJT by selecting the correct answer from a choice of four. 100% accuracy is required.

25.2.47.10 IDENTIFY the conditions necessary to maintain conduction of a UJT by selecting the correct answer from a choice of four. 100% accuracy is required.

25.2.47.11 IDENTIFY the conditions necessary to stop conduction of a UJT by selecting the correct answer from a choice of four. 100% accuracy is required.

OVERVIEW

25.2.47.12 OBSERVE and RECORD normal waveforms from a UJT sawtooth generator circuit given a training device, a job program, proper tools, an oscilloscope, a signal generator, and applicable schematic diagrams or technical manuals. Recorded data must be within limits stated in job program.

25.2.47.13 OBSERVE and RECORD waveforms from a UJT multivibrator circuit given a training device, proper tools, an oscilloscope, a signal generator, a job program, and schematic diagrams or technical manuals. Recorded data must be within limits stated on the job program.

25.2.47.14 OBSERVE and RECORD normal waveforms from a UJT trigger circuit given an applicable training device or circuit and the proper tools, an oscilloscope, a signal generator, a job program, and schematic diagrams or technical manuals. 100% accuracy is required.

25.2.47.15 LOCATE a faulty component in a SCR control circuit/UJT ramp generator circuit by discriminating between normal and abnormal waveforms from a prefaulted training device or circuit, and using the proper tools, an oscilloscope, a signal generator and given a job program and schematics or technical manuals. 100% accuracy is required.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON II

Unijunction Transistor Theory

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Five-II-1 "Unijunction Transistor Sawtooth/Trigger Generator"
Job Program Twenty Five-II-2 "Unijunction Transistor Multivibrator"
Job Program Twenty Five II-3 "UJT Ramp Generator and SCR Control Circuit"

Progress Check

Additional Material(s):

Audio/Visual Program Twenty Five-II "Introduction to UJT's"

Enrichment Material(s):

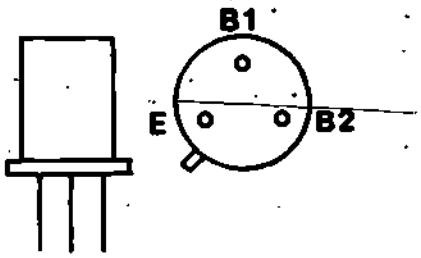
Basic Electronics, Vol. I, NAVPERS 10087-C

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT any TIME.

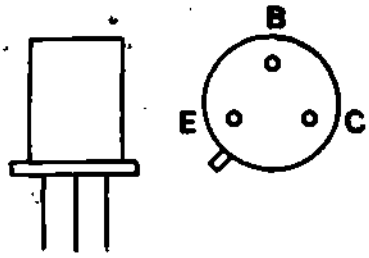
SUMMARY
LESSON II

Unijunction Transistor Theory

The Unijunction Transistor is a solid state device used in switching and timing circuits. Its physical appearance is identical to a common transistor.

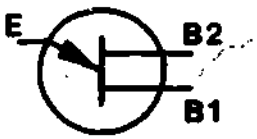


UJT



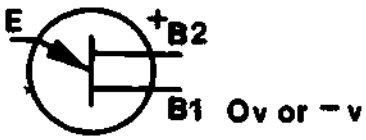
TRANSISTOR

A second base lead instead of a collector is the major difference between a UJT and a transistor. The schematic symbol for a UJT looks like this:

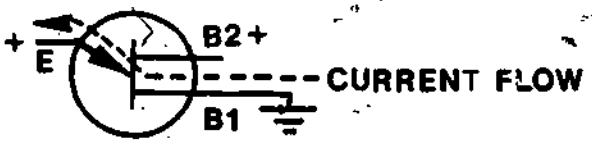


The lead with the arrow is the emitter; Base 1 (B1) is the lead to which the emitter arrow points; the Base 2 (B2) is the other lead. Base 2 can be compared to the collector of a common transistor in that Base 2 is usually where Vcc is applied.

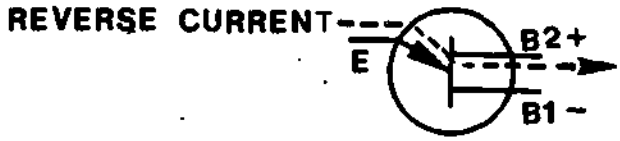
Proper operation of a UJT depends upon proper bias. The UJT must have a positive voltage level on Base 2 and a less positive voltage level on Base 1.



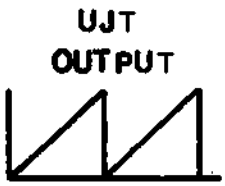
This type of voltage arrangement prepares the UJT for conduction. When a positive voltage level large enough to forward bias the E-B1 junction appears on the emitter the UJT conducts. Current flow is from B1 to the emitter -- against the arrow.

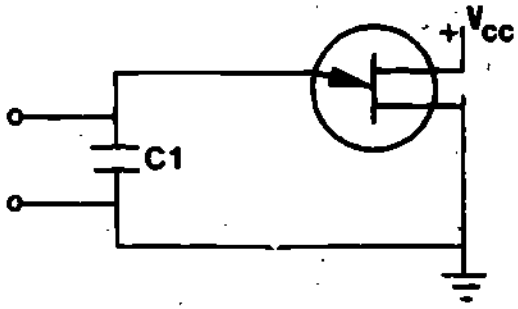


If there is no voltage on the emitter or if the voltage level is too low then the E-B1 junction is reverse biased and no current flows through the E-B1 junction. However; a small reverse current flows from the emitter to B2 due to imperfections in the material.

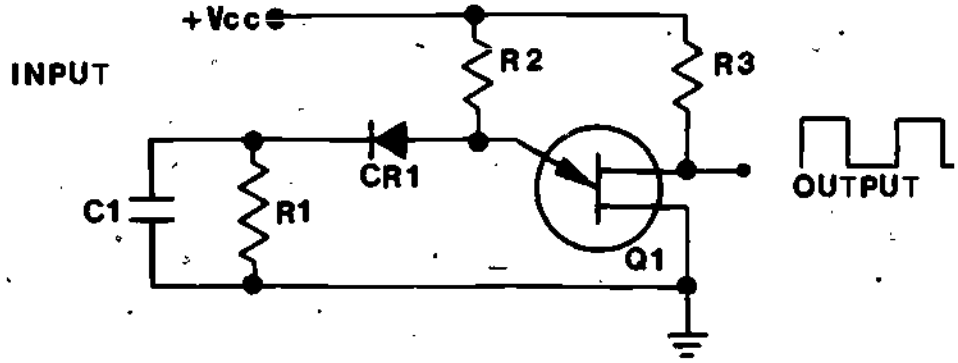


A UJT sawtooth generator produces a sawtooth waveform output due to the charge and discharge of C1 and the switching action of the UJT.

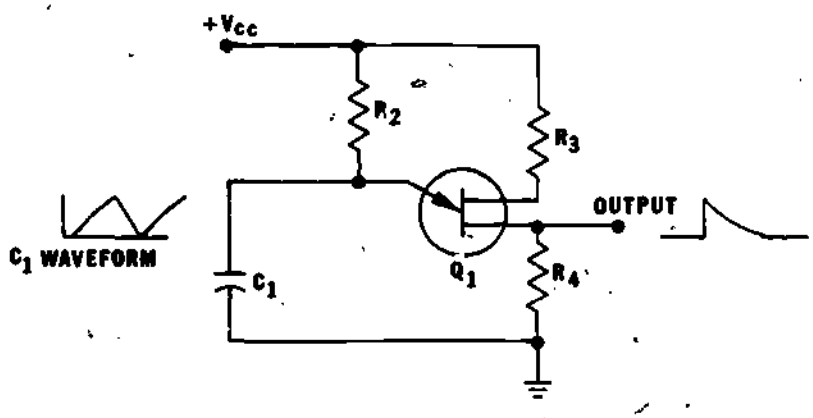




In the UJT multivibrator the combined switching action of CR1 and the UJT controls the charge and discharge of C1 and develops a square wave output at B2 of Q1.



A trigger circuit may be constructed by removing CR1 and R1 from the multivibrator circuit and placing a resistor between B1 and ground. The output is taken from B1 of the UJT. The schematic diagram of a typical UJT trigger circuit is:



AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

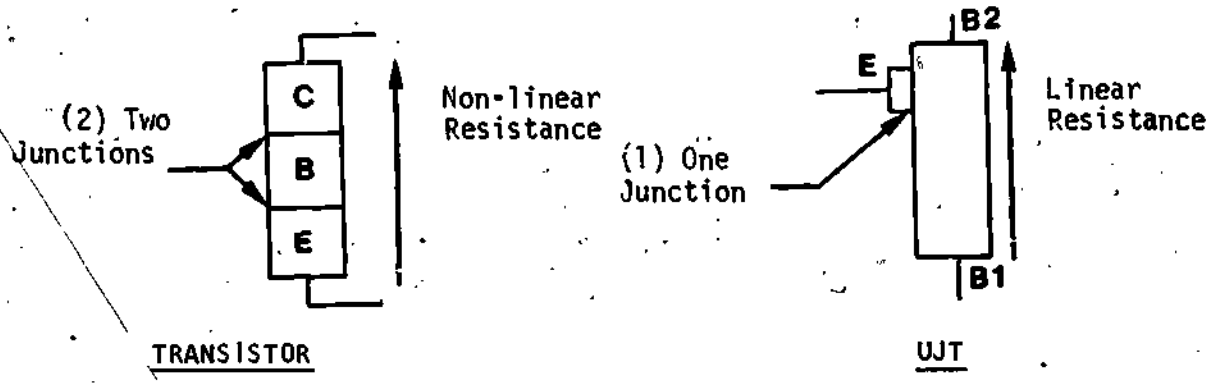
PROGRAMMED INSTRUCTION
LESSON II

Unijunction Transistor Theory

TEST FRAMES ARE 6 AND 13. AS BEFORE, GO TO TEST FRAME 6 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The Unijunction Transistor is a solid state device used in switching, pulse triggering, and multivibrator circuits. It has several advantages over conventional transistors. It is very stable over a wide temperature range and it reduces the number of circuit components needed when used in place of conventional transistors.

Let's compare a transistor and a UJT.

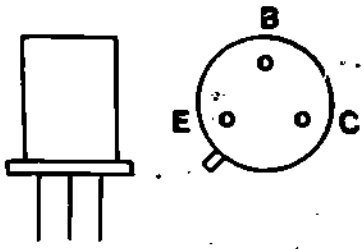


Notice that in a block diagram configuration the difference between a transistor and a UJT are very apparent:

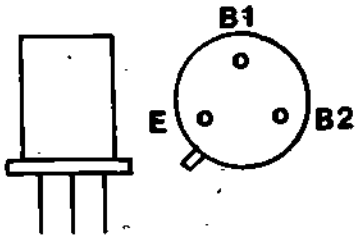
1. Two junctions for the transistor; one for the UJT.

2. The material between Base 1 and Base 2 of the UJT acts as a resistor. The materials separating the emitter and collector of the transistor do not.

In physical appearance however, the transistor and the UJT are identical.



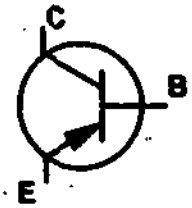
TRANSISTOR



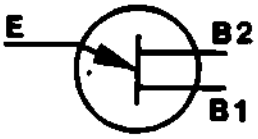
UJT

You can see that the tab on the case of both devices denotes the emitter. The lead configuration is the same. If we move in a clockwise direction from the emitter on the UJT, the first lead we encounter is Base 1; the second lead is Base 2. This is another difference between a transistor and a UJT.

Now, let's look at the schematic symbol of a UJT as compared to that of a transistor.



TRANSISTOR

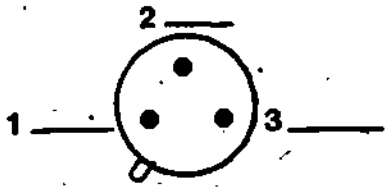


UJT

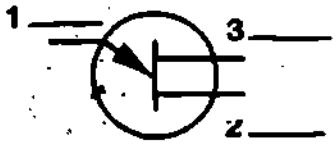
Quite a bit of difference here, isn't there?

You have already learned which lead is which in the transistor symbol so it will be easy to identify the UJT leads. The lead with the arrow is the emitter. The lead to which the arrow points is Base 1. That leaves one other lead - Base 2.

Label the leads of the UJT in each of the below illustrations:



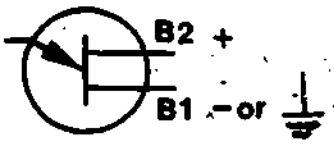
A



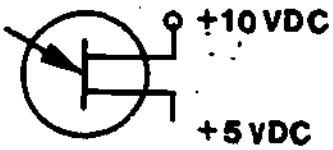
B

A. 1. Emitter 2. Base 1 3. Base 2
B. 1. Emitter 2. Base 1 3. Base 2

2. All types of transistors or diodes need a certain bias level to operate. The UJT is no different. Base 2 of a UJT must be connected to some positive value. Base 1 must be at ground potential (or some value of voltage less than that on Base 2).

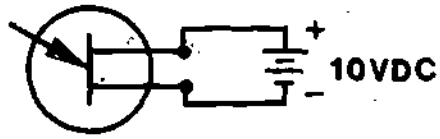


Is the UJT in the illustration below properly biased for correct operation?

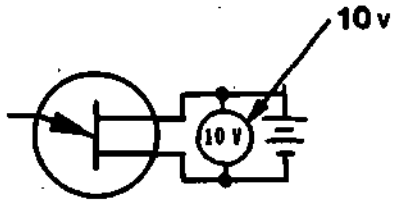


yes

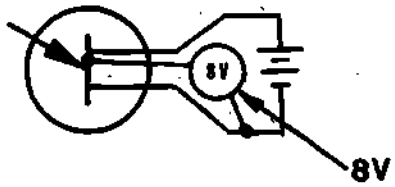
3. Let's connect a known voltage to the UJT.



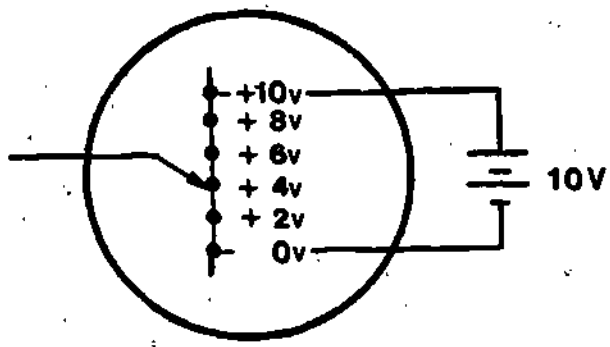
If we connect a voltmeter between the Base 1 and Base 2 leads we will read the full ten volts.



However, if we could take a reading at some point between the two base leads we would read a value less than ten volts.



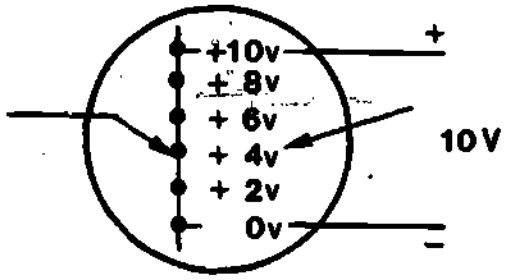
The area between the base leads is acting like a resistor. At different points we read different voltage levels. This sequential rise in potential is called a Voltage Gradient.



The material between Base 1 and Base 2 of a UJT acts like a/an _____ and the difference in potential is called a/an _____.

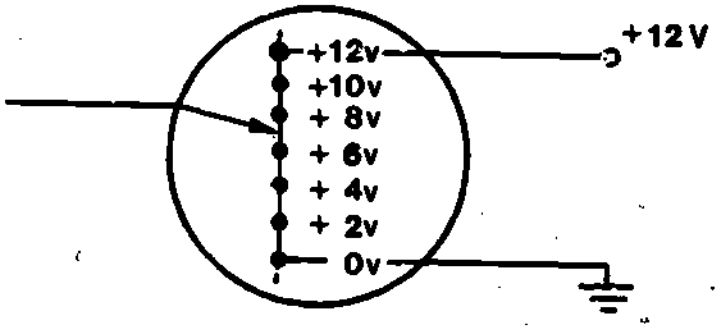
resistor, voltage gradient (in that order)

4. The emitter of the UJT acts like the wiper arm of a variable resistor. Although it does not physically move, it does feel the potential of the voltage gradient opposite it.



In this case the emitter feels a positive 4 volts. The voltage level the emitter feels is the conduction point voltage needed to turn on the UJT. This turn on voltage is determined by the type of UJT and is established at the time of construction.

What is the conduction point of the UJT illustrated below?

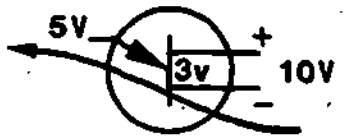


- -

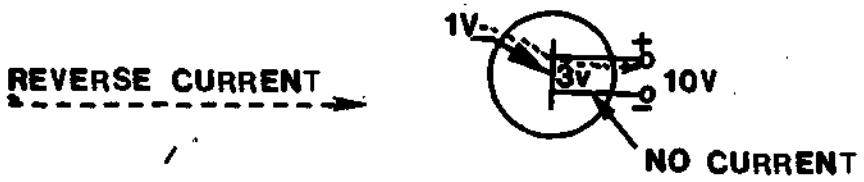
7 volts (6 1/2 - 7 1/2 acceptable)

5. You have seen how the bias voltage is developed between Base 1 and Base 2. Now let's see what happens when we apply a voltage to the emitter.

If we apply a voltage level to the emitter that is greater than the difference of potential opposite the emitter-Base 1 junction, then the UJT will conduct heavily through the emitter-Base 1 junction.



If the voltage level on the emitter drops below the level of the potential difference opposite the emitter, then the emitter-Base 1 junction acts like an open circuit and no current flows.



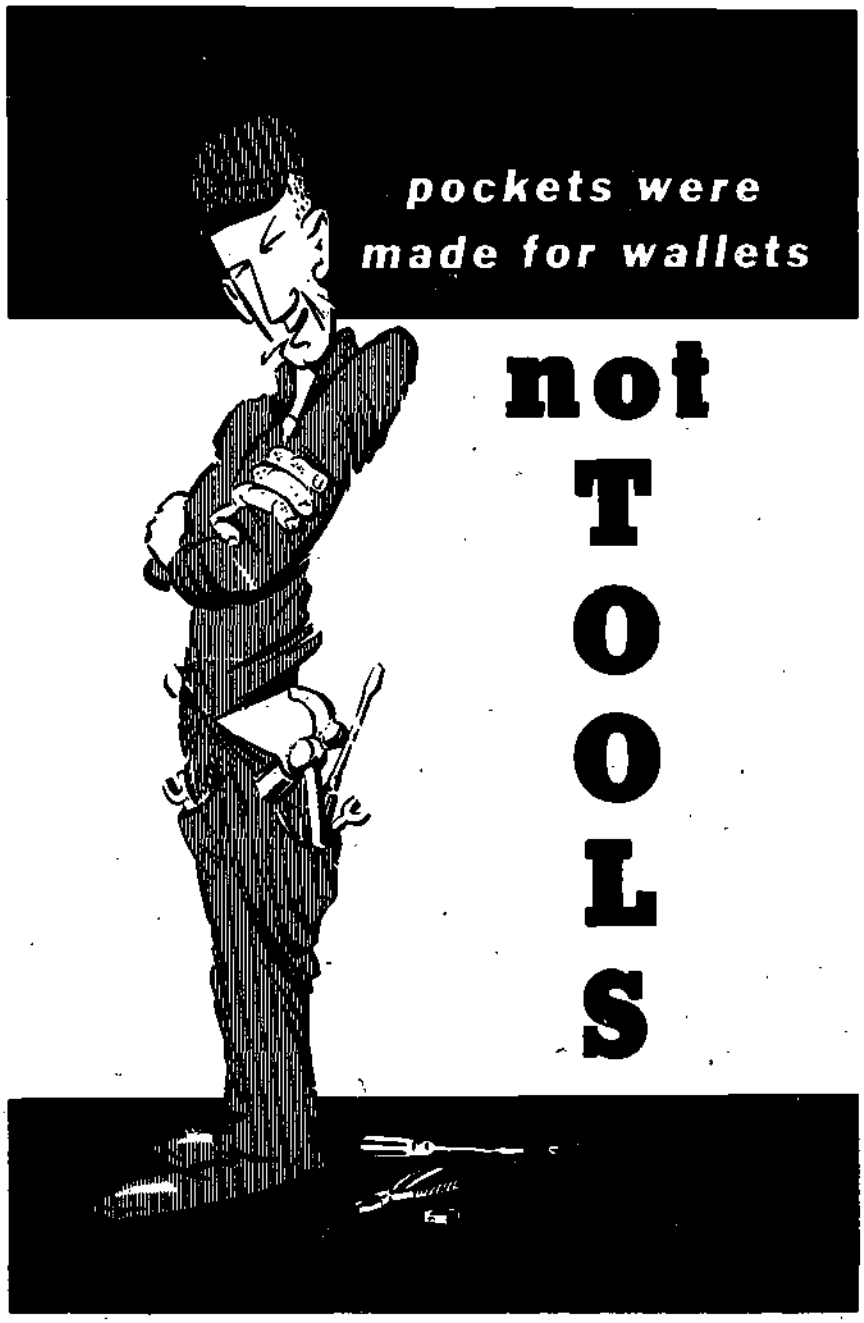
However, a small current will flow between the emitter-Base 2 junction. This small amount of current is called reverse current. It is due to imperfections in the material used in construction of the UJT.

In order for the UJT to conduct through the E-B1 junction the voltage level on the emitter must be _____ the voltage gradient at the E-B1 junction.

a. less than
b. the same as
c. in phase with
d. greater than

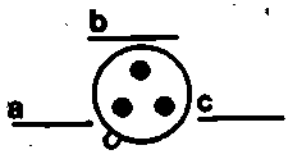
- -

d. greater than

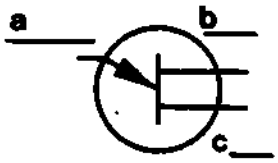

pockets were
made for wallets
not
TOOLS

6. TEST FRAME

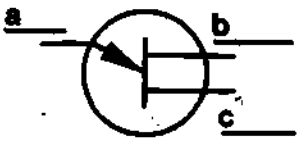
1. Correctly label the leads of the UJT shown in the illustration below.



2. Correctly label the leads of the UJT shown in the schematic diagram below.



3. Indicate the proper forward biasing voltages on the UJT shown below by placing a (+) or (-) or (0) on the appropriate leads.



4. Define voltage gradient.

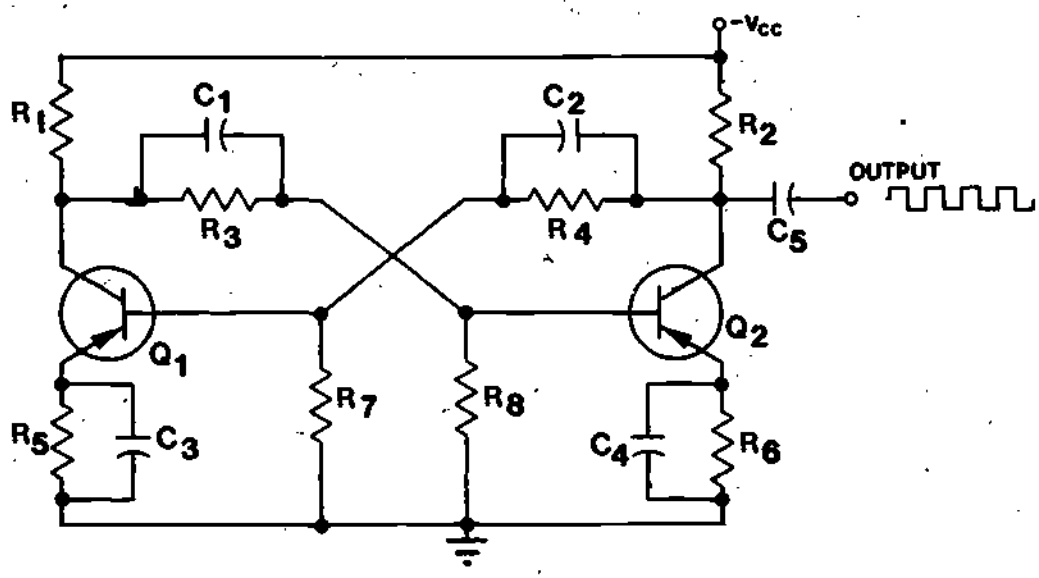
- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

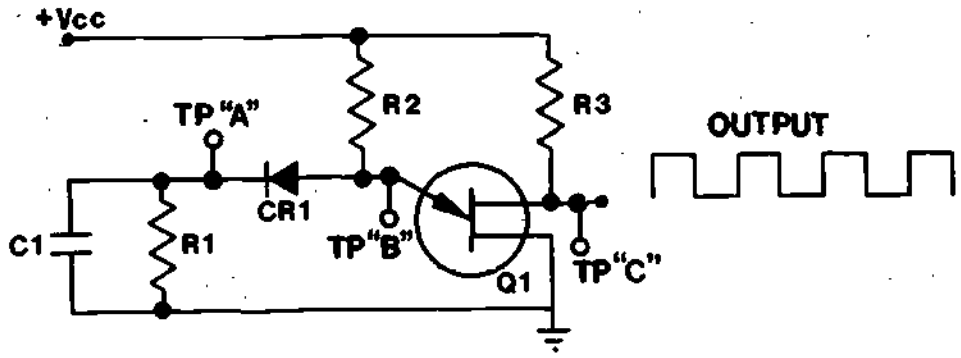
1. a. emitter, b. Base 1, c. Base 2
2. a. emitter, b. Base 2, c. Base 1
3. a. 0V, b. +v c. -v
4. a voltage gradient is the sequential rise in voltage from Base 1 to Base 2 (or words to that effect).

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 13. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 6 AGAIN.

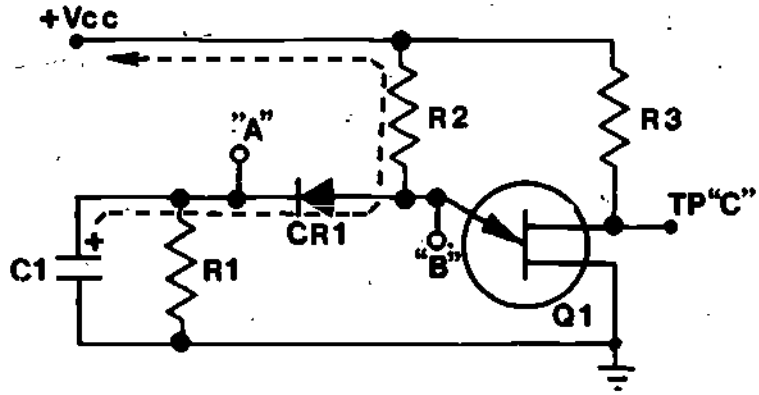
7. Let's look at a UJT multivibrator. The normal solid state multivibrator looks something like this.



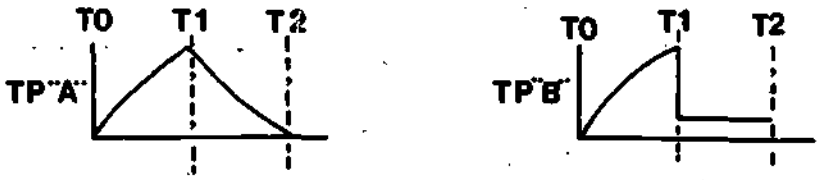
A UJT multivibrator looks like this, notice the decrease in component requirements.



Let's examine it's operation. You will see that it is much simpler than transistor multivibrators.



UJT MULTIVIBRATOR



WAVEFORMS

While Q1 is cut off, C1 charges through CR1 and R2. C1 tries to charge to the value of Vcc and a rising positive voltage appears at the anode of CR1. The anode of CR1 is the same electrical point as the emitter of Q1.

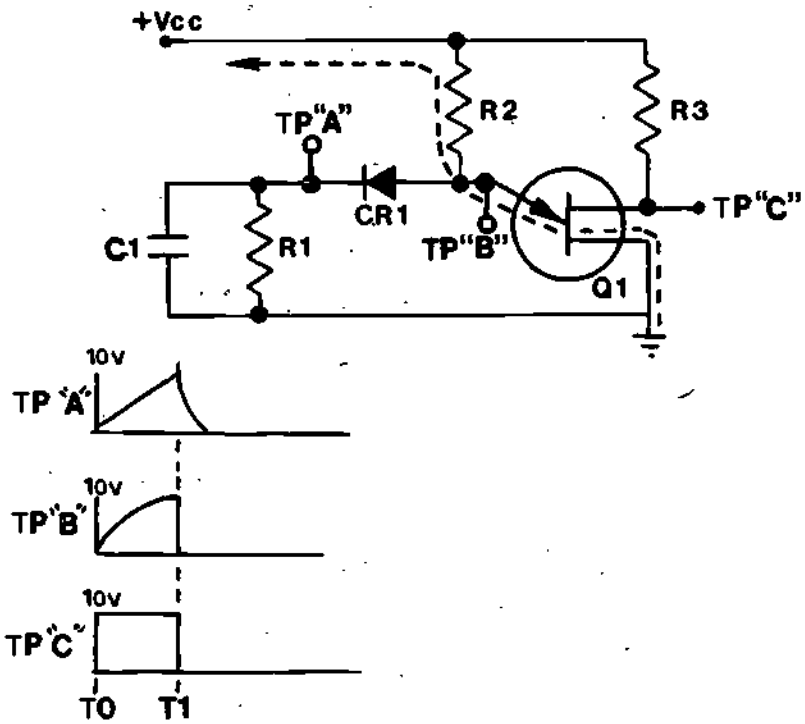
The action of C1 charging to Vcc produces a _____ voltage at the emitter of Q1.

a. more negative
b. more positive
c. zero
d. +Vcc

- -

b. more positive

8. Let's say that Q1 is rated at + 10V.



At time T1, C1 is charged to + 10V. The voltage level on Q1's emitter (also + 10V) is sufficient to cause Q1 to conduct from ground, through the E-B1 junction, through R2 to + Vcc.

While Q1 was cut off (prior to T1) the voltage level at test point "C" was approximately Vcc. At T1, the voltage at test point "C" and test point "B" dropped to near ground potential, almost instantaneously. This sudden drop in voltage is caused by the conduction of Q1. The signal at test point "A" gradually drops to zero volts; capacitor C1 is discharging through resistor R1 since CR1 is reverse biased.

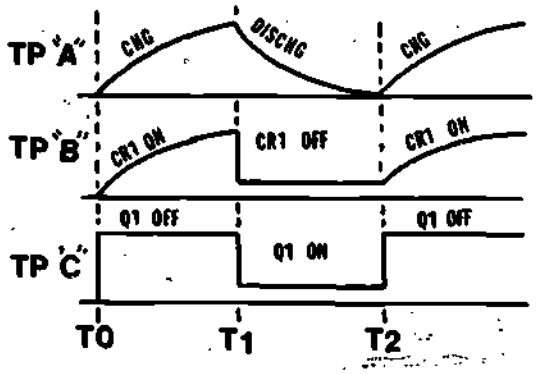
The voltage level at test point "C" is controlled by the

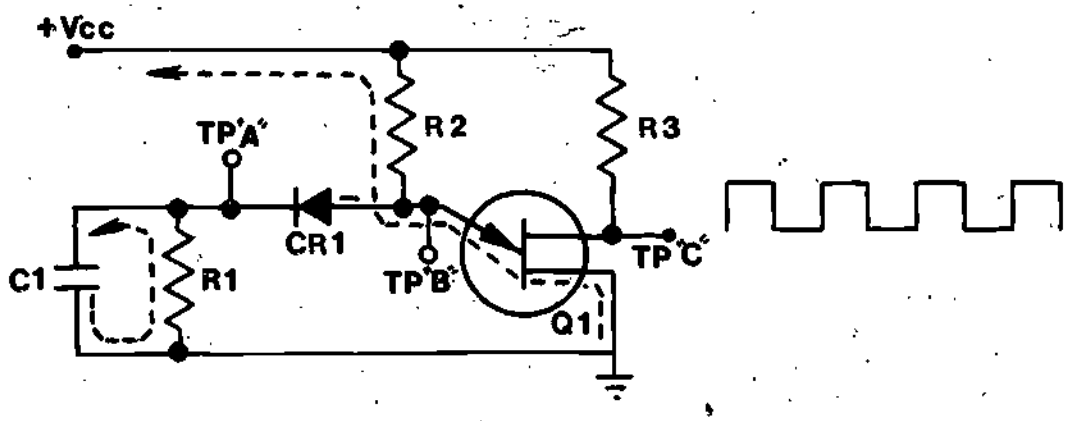
a. on/off state of Q1.
b. on/off state of CR1.
c. time constant of C1-R1.
d. time constant of Q1-R3.

- -

a. on/off state of Q1.

9.





The sudden drop in voltage at test point "B" caused by the conduction of Q1 is felt by the anode of CR1. The near ground potential at test point "B" causes CR1 to become reverse biased cutting it off. CR1 opens the circuit effectively isolating C1 from Vcc. C1 then discharges through R1. This happens in the time span between T1 and T2. (See waveforms for test points "A" and "B".)

At time T2 the voltage level at test point "A" reaches a point low enough to forward bias CR1. CR1 then conducts turning off Q1. C1 stops discharging and starts charging through CR1 and R2 once again.

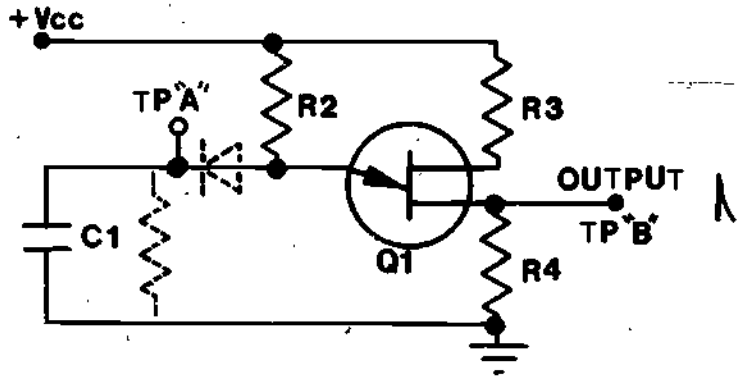
Which component(s) control(s) the duration of Q1's conduction?

a. R3
b. CR1
c. C1, R1
d. R2, Q1

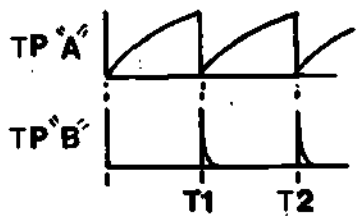
---

c. C1, R1

10. If we change some components in the UJT multivibrator we can build a trigger circuit. It's really quite simple and the UJT functions exactly the same way.



CR1 and R1 have been removed. R4 has been added between C1 and Q1's Base 1. C1 charges slowly through R2 to Q1's conduction point. When Q1 conducts, C1 discharges quickly through R4 creating a spike or trigger pulse on the output of Q1.



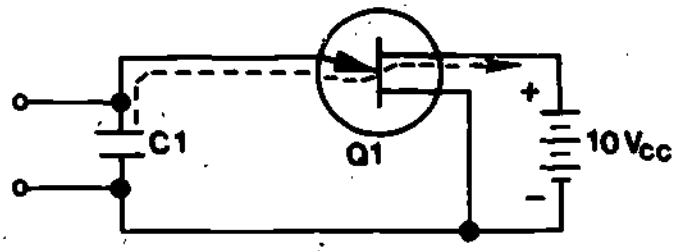
Which of the following determine(s) the frequency of the output spike?

a. R3
b. R4, R3
c. Q1, R3
d. R2, C1

- -

d. R2, C1

11. Another circuit that uses a UJT is a sawtooth generator. An example of a simple sawtooth generator is illustrated by the following schematic.



C1 charges slowly through the high resistance of Q1's E-B2 junction causing a positive voltage to develop on the emitter of Q1.

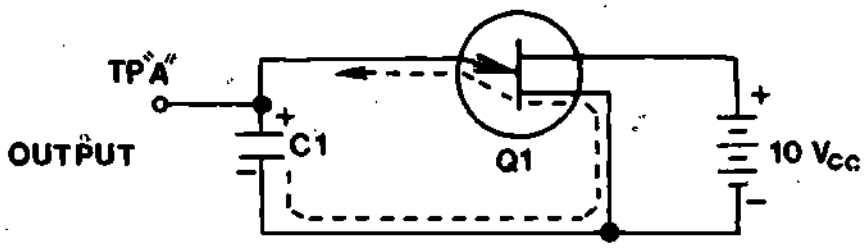
The current flowing through the E-B2 junction is called

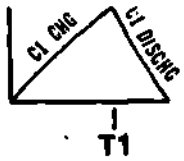
a. forward current.
b. holding current.
c. peak current.
d. reverse current.

---

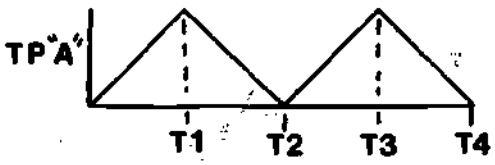
d. reverse current.

12. When the rising positive voltage reaches Q1's conduction point the E-B1 junction becomes forward biased placing a short circuit across C1. C1 then discharges quickly through Q1's E-B1 junction.





When C1 discharges to a point low enough to reverse bias Q1, Q1 turns off and C1 again starts to charge to Vcc. The cycle will repeat itself producing this waveform at the emitter of Q1.



SAWTOOTH WAVEFORM

The charge and discharge time of C1 is controlled by

a. the resistance of the E-B2 junction and the E-B1 junction.
b. the value of Vcc.
c. the mismatch of components.
d. both b and c.

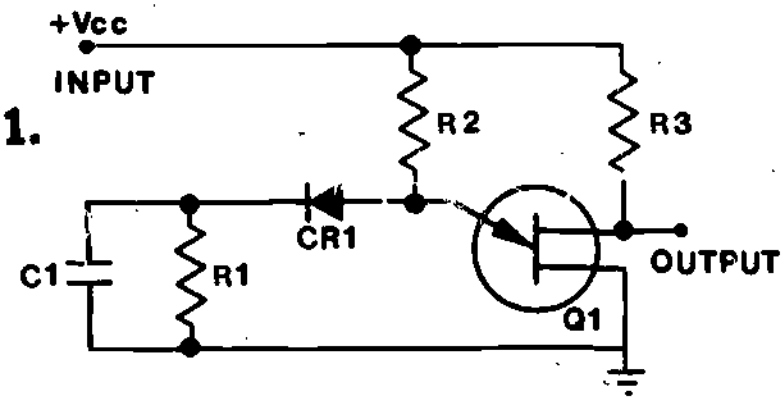
---

a. the resistance of the E-B2 junction and the E-B1 junction.

13. TEST FRAME

Match the output waveform and the circuit name to the three UJT schematic diagrams illustrated below.

1.

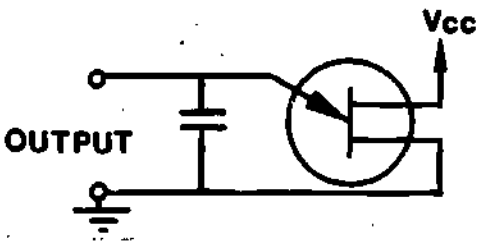


Circuit Names

a. Sawtooth Generator
b. Square Wave Generator
c. Trigger Generator

Waveforms

2.

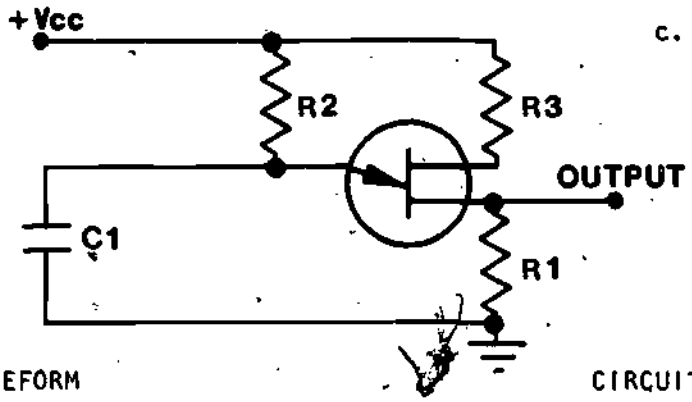


a.

b.

c.

3.



	WAVEFORM	CIRCUIT NAME
1.	_____	_____
2.	_____	_____
3.	_____	_____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

1. c, b
2. b, a
3. a, c

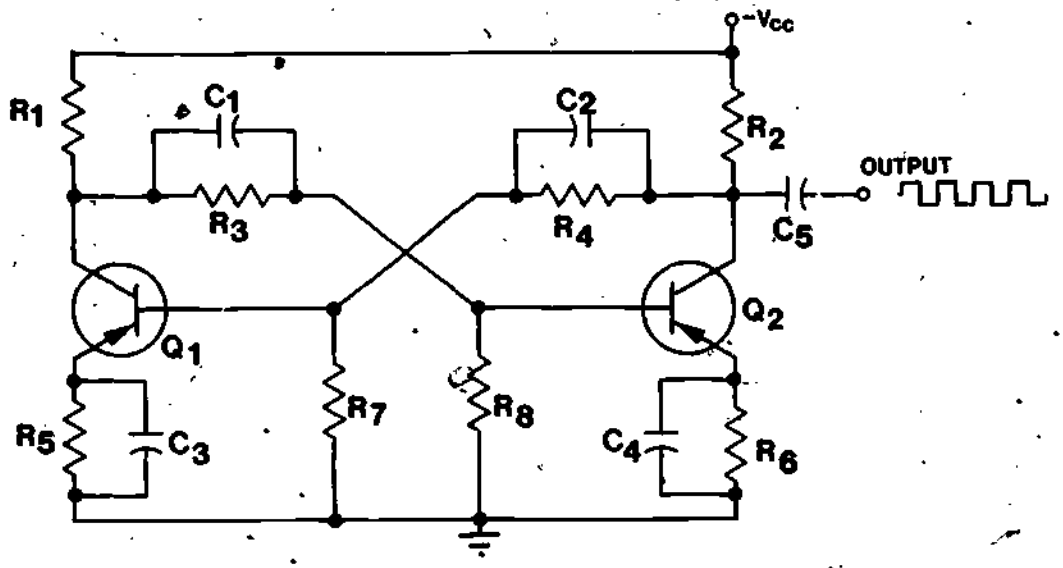
IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON II, MODULE TWENTY FIVE. OTHERWISE GO BACK TO FRAME 7 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 13 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON II

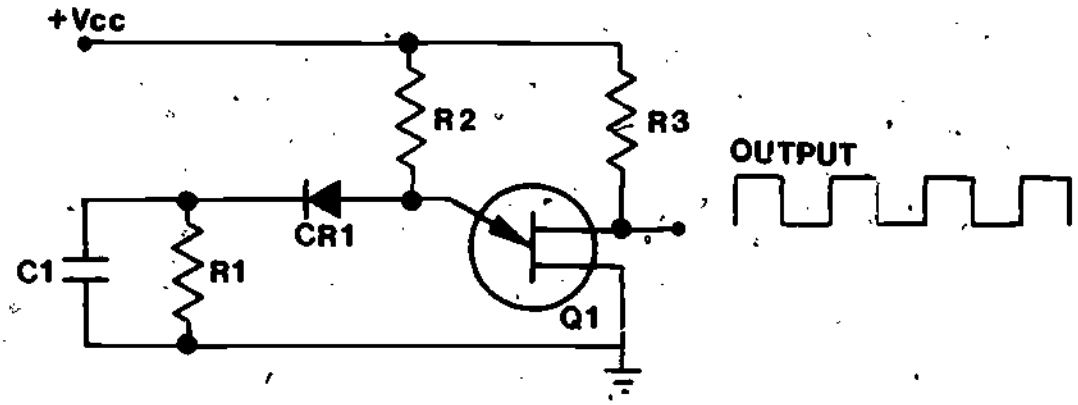
Unijunction Transistor Theory

The Unijunction Transistor (UJT) is a solid state device used in switching, pulse triggering and multivibrator circuits. It has several advantages over conventional transistors. It is very stable over a wide temperature range and allows a reduction of circuit components when used in place of conventional transistors. Let's look at this example of a multivibrator:



TRANSISTOR MULTIVIBRATOR

Now look at the same circuit using a UJT.



UJT MULTIVIBRATOR

As you can see, the output of both multivibrators are the same; however, the UJT circuit has fewer components than the transistor circuit. By reducing the number of components we may reduce cost, size, and probability of circuit failures. This also means less troubleshooting for the technician.

Let's examine a UJT.

The UJT's physical appearance is identical to that of the common transistor.

TRANSISTOR UJT

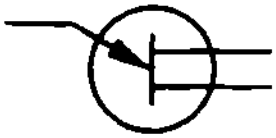
Both have three leads and the same basic shape. The tab on the case denotes the emitter on both devices. However, moving clockwise from the emitter of the UJT (bottom view) we find that Base 1 is the first lead, and, instead of a collector, Base 2 is the second lead.

In block diagram form the differences in lead arrangement are even more pronounced.

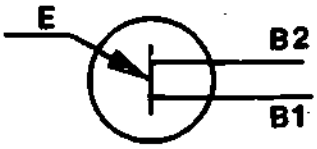
TRANSISTOR UJT

Unlike the transistor which has two junctions, the UJT has only one. The area between Base 1 and Base 2 acts like a resistor.

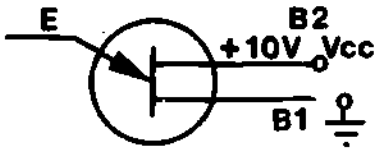
Looking at the schematic symbol below, how do we know which base is number 1 and which is number 2?



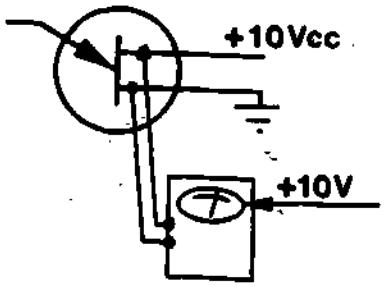
We know from transistor theory that the lead with the arrow is the emitter. In a UJT the base lead to which the emitter arrow points is Base 1. That leaves one other lead which is Base 2.



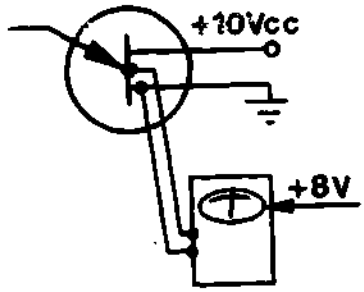
Now that we know how the base leads are connected within the device, let's see how it works. A conventional transistor needs a certain bias level (voltage level) between the Emitter, Base and Collector before it conducts. The same holds true for a UJT. It needs a certain bias level between the emitter and Base 1 and also between Base 1 and Base 2 for proper conduction. Let's look at the normal bias arrangement.



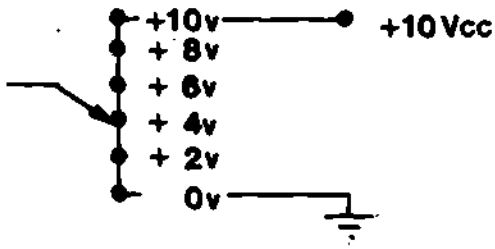
In the above illustration we have placed a positive 10 volts on Base 2 and a ground on Base 1. The area between Base 1 and Base 2 acts as a resistor. If we were to take a reading between Base 1 and Base 2 we would see the full 10 volts.



Theoretically, if we could connect one meter lead to Base 1 and the other lead to some point between Base 1 and Base 2 we would read some voltage less than 10 volts.

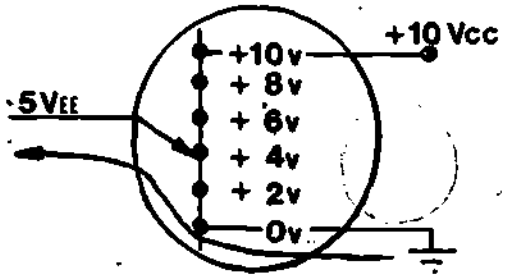


The voltage measurements would look like this depending on where the meter is connected.



The sequential rise in voltage is called a Voltage Gradient.

The emitter of the UJT can be viewed as the wiper arm of a variable resistor. If the voltage level on the emitter is more positive than the voltage gradient level at the emitter/base material contact point, then the UJT is said to be forward biased. The UJT will conduct heavily (almost a short circuit) from Base 1 to the emitter. Remember . . . current flows against the arrow!

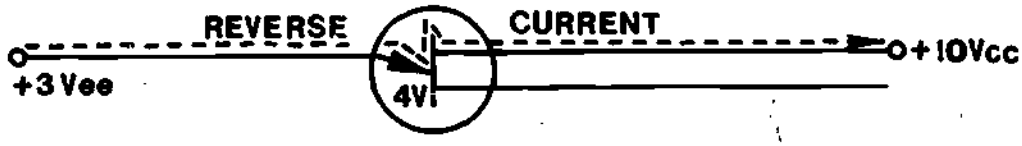


The emitter is, of course, fixed. The level of the voltage gradient therefore depends upon:

1. the amount of Vcc, and
2. where the emitter is physically placed between Base 1 and Base 2. (The manufacturer decides where the emitter is placed on the base material.)

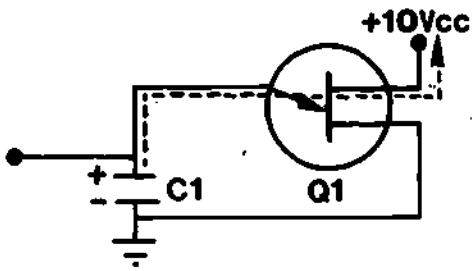
At present there are more than forty distinct types of UJTs.

Assume the voltage level on the emitter is less positive than the voltage gradient opposite the emitter. The UJT is then said to be reverse biased. No current will flow from Base 1 to the emitter. However, a small current will flow from the emitter to Base 2. This is called reverse current and is due to imperfections in the material used in the construction of the UJT.



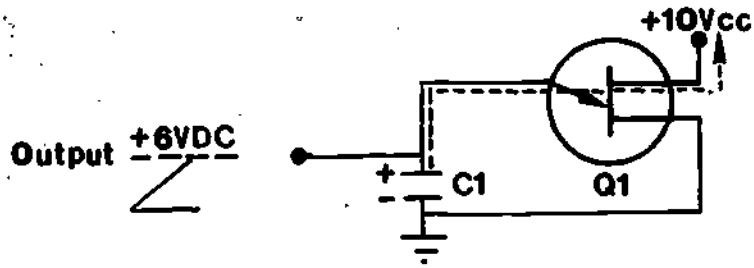
CURRENT FLOW IN A REVERSE BIASED UJT

Now, let's discuss a sawtooth generator circuit using a UJT.

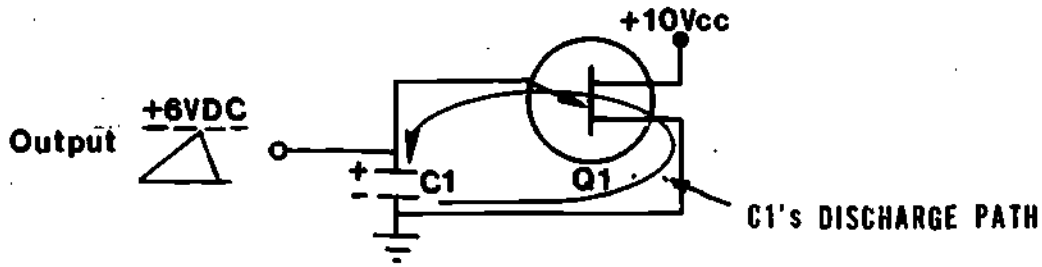


UJT SAWTOOTH GENERATOR

In this circuit assume that the conduction point of the UJT with a Vcc of + 10 VDC will be + 6 VDC. Capacitor C1 is charged slowly by the small amount of reverse current leaking through the reverse biased E - B2 junction.



As the charge on C1 rises slowly through the high resistance of the E-B2 junction it eventually reaches the level needed to forward bias the E-B1 junction (+ 6 VDC).

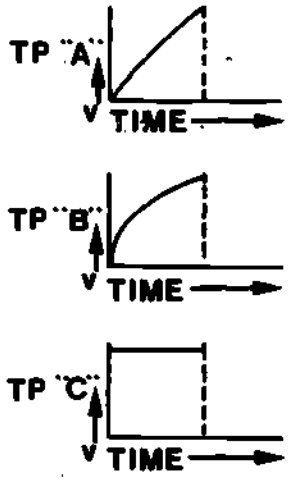


When the charge on C1 reaches the + 6 VDC conduction point of the UJT, the UJT "turns on" creating a low resistance discharge path for C1 through the now forward biased E - B1 junction. As C1 discharges, the voltage level on the emitter drops to 0V causing the UJT to again become reverse biased and turn off. The cycle then starts all over.

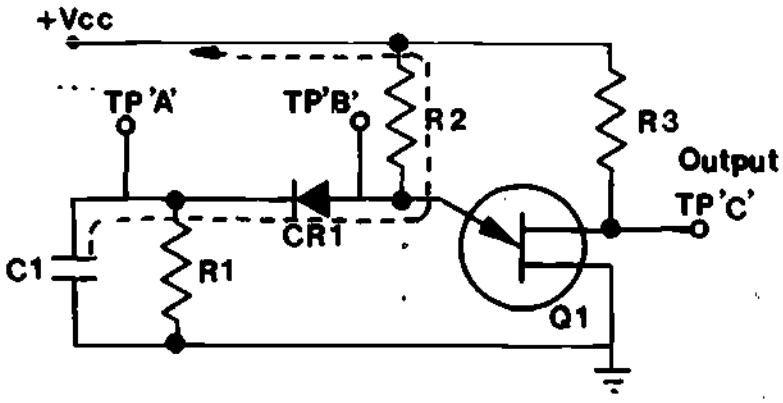
The period of the waveform is determined by the resistance of the E-B2 junction and the capacitance of C1. (The junction resistance can be measured with a VOM.) The waveform produced looks like a sawtooth--hence, the name sawtooth generator.

SAWTOOTH GENERATOR OUTPUT

We saw earlier in this lesson that the UJT can be used in several types of circuits. Obviously, to explain them all would take too much time. The two most commonly used UJT circuits are the sawtooth generator (which has been discussed) and the multivibrator. Let's discuss the multivibrator.

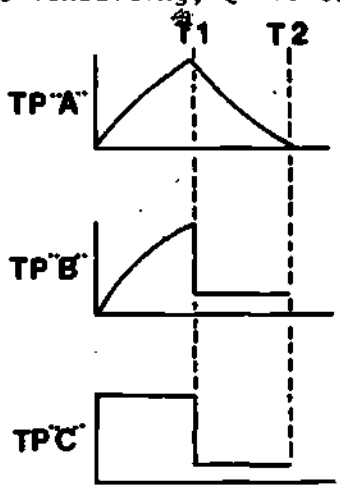


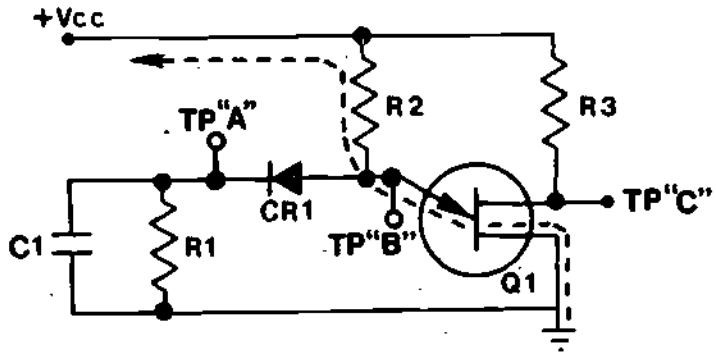
WAVEFORMS SHOWING WHAT IS HAPPENING DURING THE TIME C1 IS CHARGING.



UJT MULTIVIBRATOR

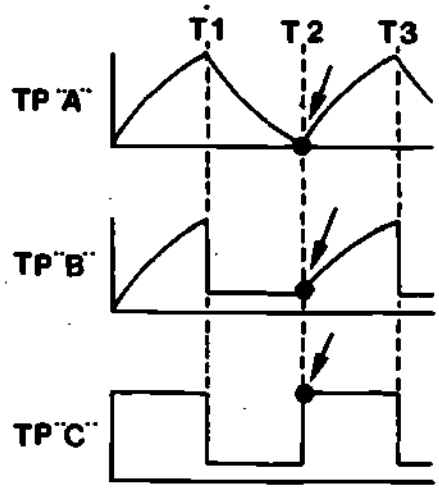
In the circuit shown, capacitor C1 charges through CR1 and R2. While CR1 is conducting, Q1 is cut off due to the low voltage level on the emitter.



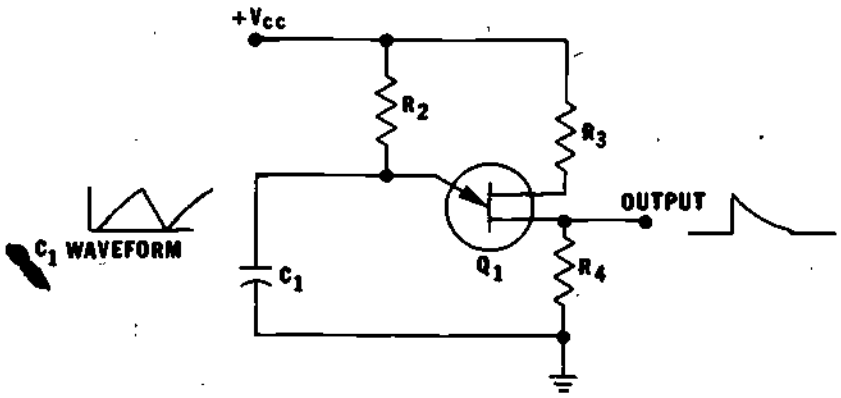


At time T1, C1's charge (TP"A") becomes equal to the voltage level required to forward bias Q1. Q1 then turns on causing the voltage level at TP"B" to drop to near ground potential -- zero volts. TP"C" (the output of the multivibrator) drops to near ground also.

This action places a negative potential (in respect to C1) on the anode of CR1 and turns it off, opening the circuit. C1 is now isolated from Vcc by the open circuit caused by CR1's reverse biased state. C1 discharges through R1 (between T1 and T2 on the illustration). When C1's charge (TP"A") reaches the same voltage level as the anode of CR1 (TP"B") turns on again removing the forward bias from the emitter of Q1 and cutting it off. The output of the multivibrator (TP"C") rises to approximately the level of +Vcc. The cycle begins again. The alternate "on-off" state of Q1 produces a square wave signal on Base 2 of Q1 TP"C".



We can change the multivibrator to a trigger ciruit by removing CR1 and R1 and adding a resistor in series with C1 and Base 1 of Q1.



The output is taken from Base 1 of the U.J.T. C1 charges slowly through R2 until the voltage level on the emitter reaches Q1's conduction point. Q1 then conducts and C1 discharges quickly through R4 and Q1 producing a spike or trigger pulse. When C1 discharges to a level below Q1's conduction point Q1 turns off and the charge cycle starts again.

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