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ABSTRACT

This individualized learning module on wave-shaping circuits 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. Three lessons are included in the modules: (1) Clippers, (2) Clampers, and (3) Integrators/Differentiators. 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)

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ED190899

Military Curricula for Vocational & Technical Education

CHIEF OF NAVAL EDUCATION AND TRAINING

1 APRIL 1977

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 24. WAVE SHAPING CIRCUITS.

STUDY BOOKLET.

CE 026 584

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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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.

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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. Office 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. Office of Education and the Department of Defense.

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

The 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?

One 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 Occupations	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 COORDINATION CENTERS

EAST CENTRAL
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Springfield, IL 62777
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NORTHWEST
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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

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The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

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 FOUR

WAVE SHAPING CIRCUITS

PREPARED BY

INDIVIDUALIZED LEARNING DEVELOPMENT GROUP

SERVICE SCHOOL COMMAND, NTC, SAN DIEGO, CA 92133

STUDY BOOKLET

1 APRIL 1977

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OVERVIEW

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY FOUR

Wave Shaping Circuits

In the last two modules, we've seen how to generate sine waves and square waves with electronic circuits. This module is designed to show you how we can modify these two basic waveforms into countless other waveforms.

You will find that the circuits used for wave shaping are not complex and that you already have all the basic theory needed to solve them.

This module has been divided into the following three lessons:

- Lesson I Clippers
- Lesson II Clampers
- Lesson III Integrators/Differentiators

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY FOUR

LESSON 1

CLIPPERS

1 APRIL 1977

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OVERVIEW
LESSON I
Clippers

This lesson will show you the functional operation of a clipper, how to recognize the schematic diagram and the actual circuit, and how you will put this theory and practical information to use by troubleshooting the clipper circuits.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

24.1.46 When the student completes this course he will be able to IDENTIFY wave shaping circuits and their affects on input waveforms by matching an output waveform to a wave shaping circuit and its input waveform given input and output waveform illustrations and wave shaping circuit schematic diagrams.

ENABLING OBJECTIVE(S):

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

24.1.46.1 IDENTIFY the function of a clipper circuit by selecting the correct statement from a list of four statements. 100% accuracy is required.

24.1.46.2 IDENTIFY the schematic diagrams for each of the five basic clipper circuits (series positive, series negative, parallel positive, parallel negative, and parallel positive and negative), given a set of five schematic diagrams, be selecting the schematic that matches the name given for each type of clipper circuit. 100% accuracy is required.

24.1.46.2.1 IDENTIFY by selecting, the schematic diagrams of series/parallel clipper configurations given a set of schematic diagrams which includes one of each of the configurations. 100% accuracy is required.

24.1.46.3 IDENTIFY by selecting, the output waveform for each of the following three clipper circuits (positive, negative, and parallel negative and positive), given input and output waveshapes and schematic diagrams. 100% accuracy is required.

OVERVIEW

24.1.46.4 IDENTIFY by selacting, output waveforms showing bias effects on series and paralled clipper circuits given a choice of five schematic diagrams and their respective output waveforms. 100% accuracy is required.

24.1.46.5 OBSERVE and INTERPRET clipper output waveforms (normal and abnormal) by varying the bias voltage on a series or parallel clipper circuit, given an oscilloscope, a job program, and a training device circuit. 100% accuracy is required.

24.1.4 .1 IDENTIFY the input section, conversion section, and the output section in each of the five basic clipper circuits (series, positive, and parallal positive and negative) by locating all of the components in each section, given a training device or circuit boards containing clipper circuits, a job program, and the applicable schematic diagrams 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 I

Clippers

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 Four-I-1 "CLIPPERS"
Job Program Twenty Four-I-2 "CLIPPERS"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Four-I "Introduction to Clippers"

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120 (EIMB)

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.

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SUMMARY
LESSON I

Introduction to Clippers

A clipper or limiter (both terms mean the same thing) is little more than a half wave rectifier. Using a diode, resistor, and sometimes a DC potential, a clipper/limiter can be used to eliminate the positive or negative alternation of an input waveform or can clip a desired amount from either alternation. In a circuit where the voltage limits are extremely critical, a clipper may be employed as a safety device. In this lesson you will be introduced to five types of clippers: (see illustration on next page) series positive; series negative, parallel positive, parallel negative; and parallel positive and negative clippers.

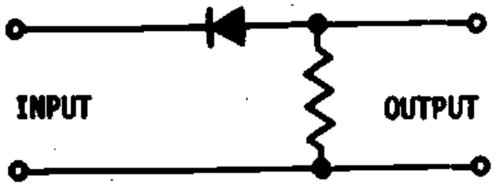
Since the diode is actually the limiting component, its location with respect to the signal flow and its polarity are the factors that determine circuit configuration. In the series clipper, the diode is in series with the input in parallel clippers, the diode is in parallel with the output.

Remembering that a diode will pass current in only one direction, and that the anode (arrow) of the diode must be less negative (more positive) with respect to the cathode (vertical line) to make the diode conduct, you can look at the waveform as applied to the diode and determine what the output will be.

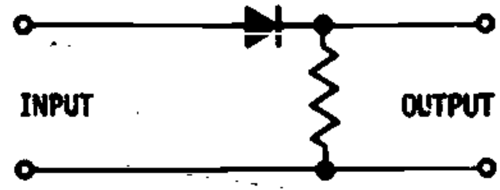
In a series clipper the diode must be forward biased in order to obtain an output. In a parallel clipper whose diode is forward biased the signal will be shorted to the reference voltage. So in order to obtain an output the diode must be reverse biased.

To clip only a portion of either alternation a DC potential is placed in parallel with the output. This potential, depending upon its polarity, will keep the diode conducting or cut-off until the input waveform exceeds the DC potential.

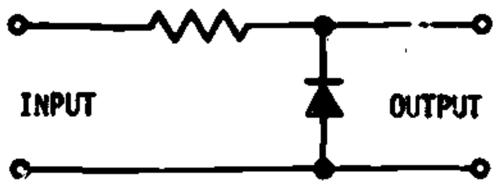
To clip both alternations, two diodes are utilized in a parallel configuration. Actually this circuit is nothing more than a combination of two parallel clippers with DC aiding reverse bias.



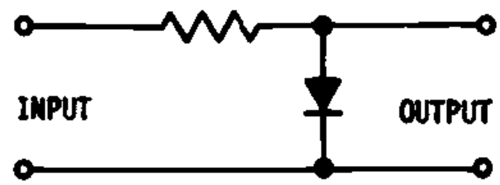
SERIES POSITIVE CLIPPER



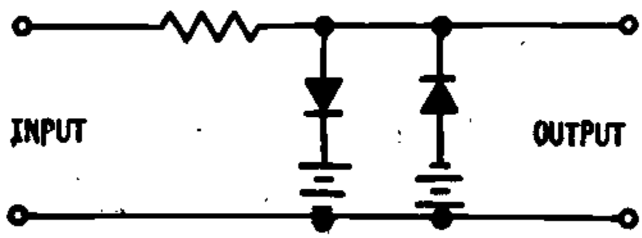
SERIES NEGATIVE CLIPPER



PARALLEL NEGATIVE CLIPPER



PARALLEL POSITIVE CLIPPER



PARALLEL POSITIVE AND NEGATIVE CLIPPER

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

Introduction to Clippers

TESTS FRAMES ARE 9, 12, 15, 17. TRY FRAME 9 FIRST AND THEN FOLLOW THE INSTRUCTIONS AT THE END OF THE FRAME.

1. Perhaps the title should read "Introduction to Halfwave Rectifiers". A clipper (or limiter) circuit is essentially a diode and a resistor, sometimes used with a DC potential. In the power supply module, you learned that a diode will pass current in only one direction. When a waveform having positive and negative alternations is applied to a diode, only the positive or negative alternation, depending upon the diode's insertion in the circuit, is passed. A simple clipper/limiter circuit eliminates either the positive or the negative alternation which is what a halfwave rectifier does. How do you tell which alternation is to be eliminated? Since the circuits contain the same components, only the direction of the diode determines which alternation (the positive or negative) is to be clipped (limited).

When a waveform is applied to a diode either the positive or the negative alternation will be passed depending on the ________________.

- -

direction of the diode as it is connected into the circuit (or words to that effect)

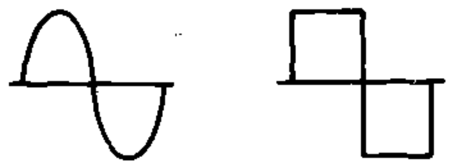
2. Since the diode is the component that controls current flow, it is essential that you understand how a diode conducts. Current always flows against the arrow, so the cathode must be more negative then the anode for conduction to take place.

Identify the anode and cathode of the diode illustrated below.

- -

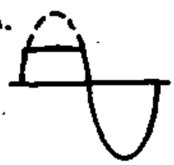
A. Cathode B. Anode

We have studied two waveforms that were generated electronically - - sine wave and square wave. These waveforms are symmetrical; that is, the positive half cycle is exactly the same shape as the negative half cycle:



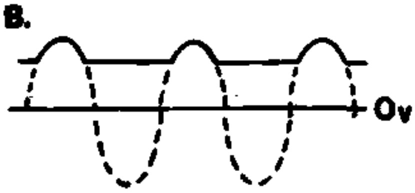
The sine wave and square wave are basic signals used in electronics but they are often not the kind of signal we need. For example, we might easily need one of the following waveforms.

A.

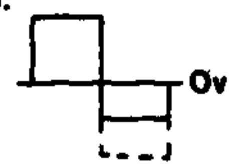


C.

B.



D.



Waveforms A through D cannot be generated by any oscillator circuit because they are not symmetrical. The addition of the dotted line to the waveforms shows that the basic waveform could be either a sine wave or square wave. The clipper circuit can change the basic two waveforms into the waveforms shown in A through D.

A clipper circuit is like a customized kit. The manufacturer sends out sine waves from its oscillator plant and square waves from its multivibrator plant. You, the customer, use a clipper to modify the standard waveforms into shapes you want.

Depending on how you want to customize a waveform, one of the following clipper circuits could be used:

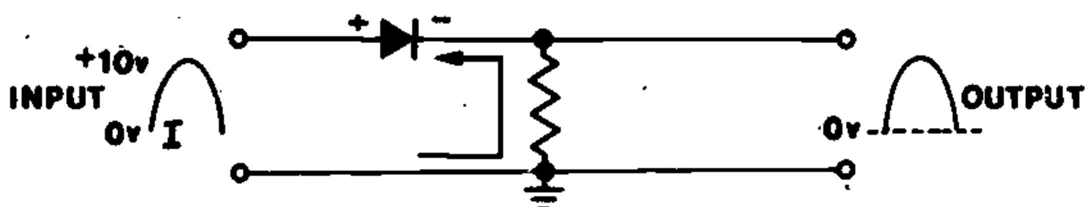
1. Series positive or negative clipper.

2. Parallel positive or negative clipper.

3. Parallel positive and negative clipper.

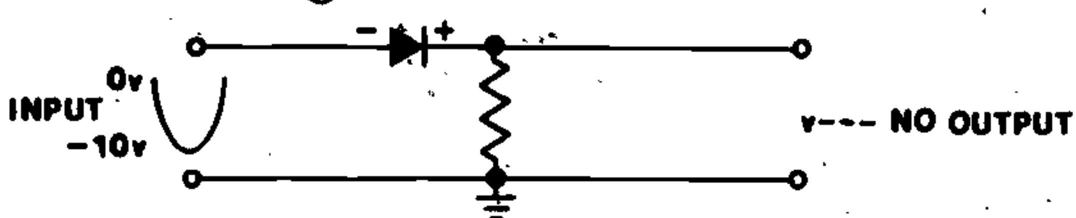
Let's take the series negative clipper:

When the input waveform (in this case from a sine wave generator) is positive, the diode in a series negative clipper will conduct, current will flow and a potential will be dropped across the resistor. Since the resistor is in parallel with the output the same voltage that is dropped across the resistor will appear at the output.



SERIES NEGATIVE CLIPPER

When the input waveform is negative, the anode is more negative than the cathode, and the diode will not conduct. No current will flow, and there will be no output.



SERIES NEGATIVE CLIPPER

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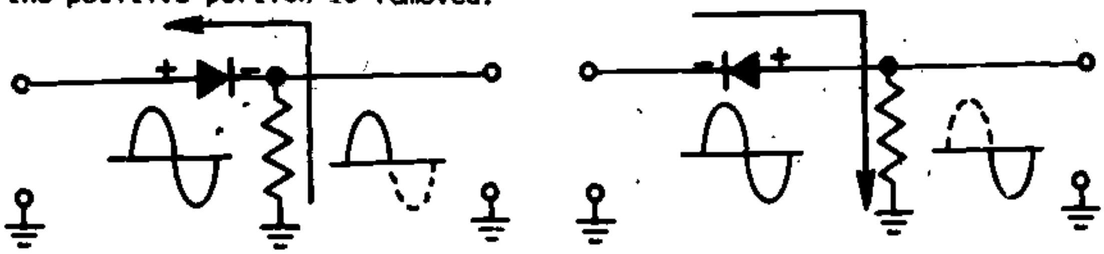
When the diode is conducting, it acts like a short circuit. When it is cut-off, it acts like an open circuit.

When the input waveform is positive the diode in a series negative clipper acts like a/an ________________ circuit and when the input waveform is negative the diode acts like a/an ________________ circuit.

- -

short, open (in that order)

4. To convert the series negative clipper to a series positive clipper, the diode is merely reversed. Current flows in the opposite direction, so the positive portion is removed.



SERIES NEGATIVE CLIPPER SERIES POSITIVE CLIPPER

When the incoming signal is positive the diode in a series positive clipper is ________________, and when the incoming signal is negative the diode is ________________.

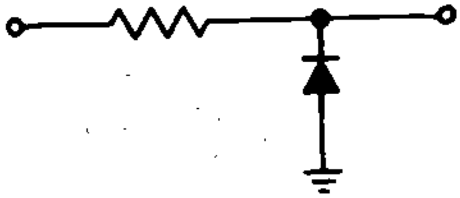
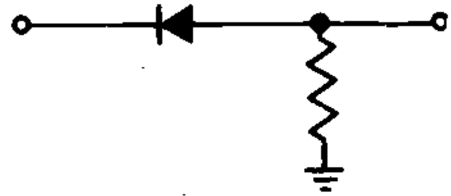
- -

cut-off, conducting (in that order)

5. Another type of clipper is the parallel clipper. In this circuit the output is taken across the diode. The resistor is in series with the input.

19

Which of the circuits illustrated below is a parallel clipper?

A.  B. 

A.

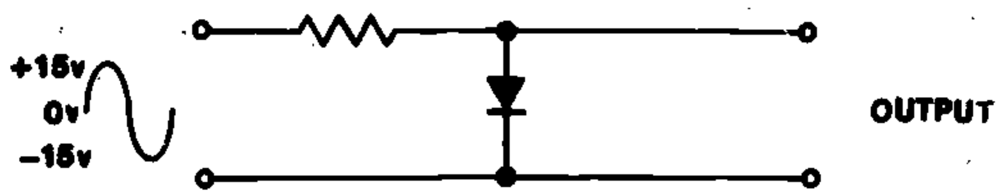
6. In a parallel positive clipper, the diode will conduct when the positive portion of the waveform is applied. When the diode conducts, there will be a voltage drop across the resistor and no voltage will appear in the output.

When the diode in a parallel positive clipper is cut off, the diode (will/will not) have a voltage drop across it.

will

7. In a parallel negative clipper, the diode will act like an open circuit (cut-off) during the positive half cycle of the input waveform and like a short circuit (conducting) during the negative half cycle of the input waveform.

Draw the output waveform of the parallel clipper illustrated below and identify the type (parallel positive clipper or parallel negative clipper).



parallel positive clipper

8. What are the relationships between series and parallel clippers? Both types of clippers are named after the alternation they eliminate. For example, a series or parallel positive clipper will remove the positive portion of the waveform. Negative series or parallel clippers remove the negative alternation of the waveform. In series clippers, the diode must conduct for an output. In the parallel clipper, the diode must be cut-off for an output.

Indicate whether the diode is conducting or cut-off for each clipper to produce an output.

A. Parallel Clipper	1. Diode Conducting
B. Series Clipper	2. Diode Cut-off

- -

A. 2; B. 1

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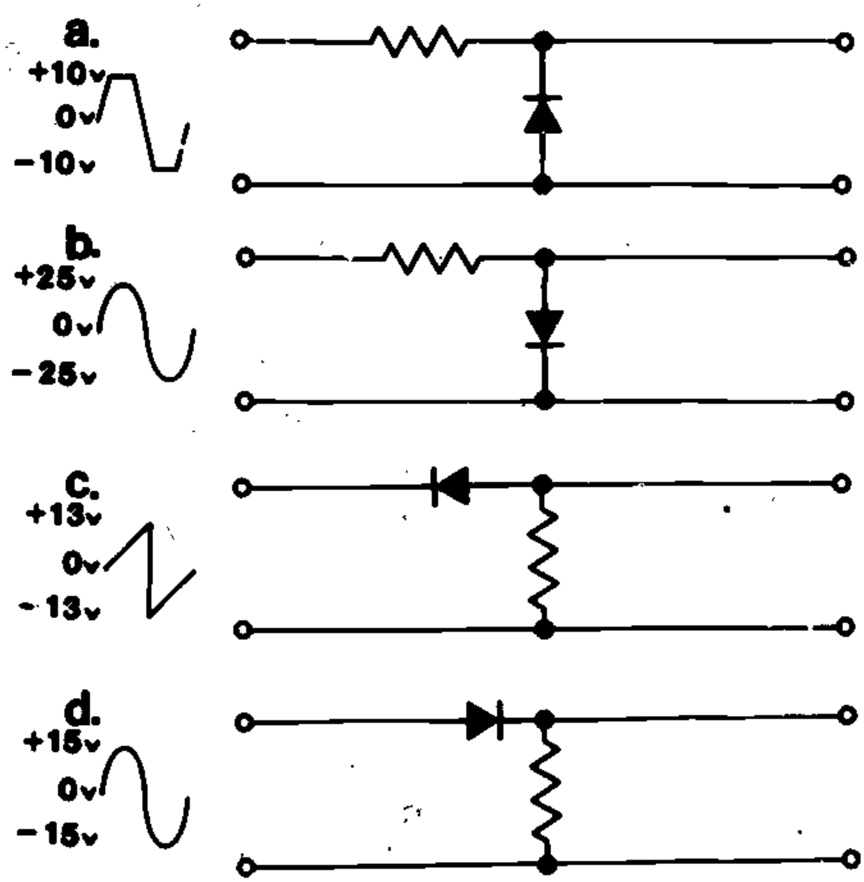
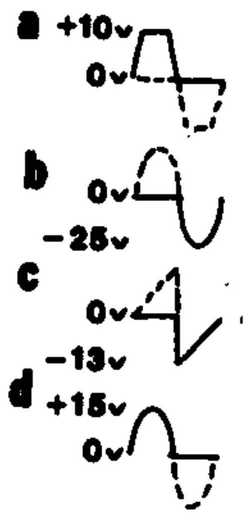
9. TEST FRAME

In each circuit below draw the output waveform.

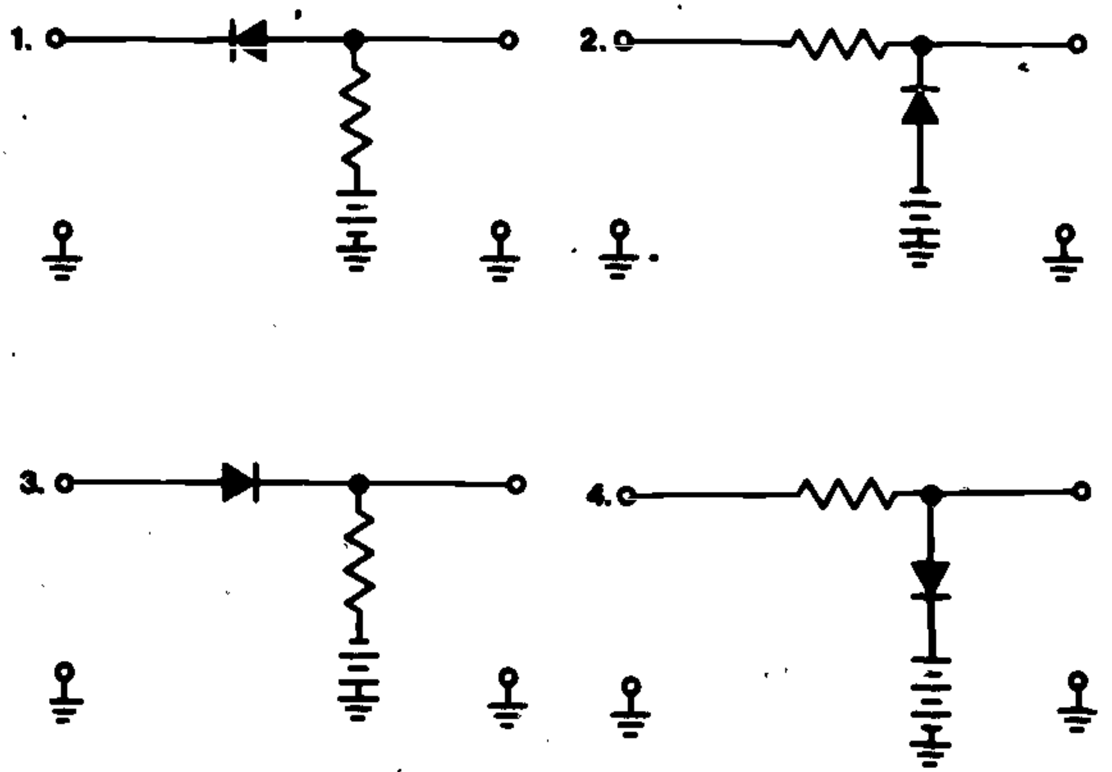


THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.



IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY NOW GO ON TO TEST FRAME 12. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 9 AGAIN.

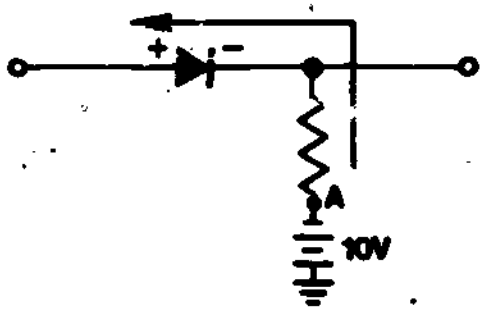
1D. If you desire to clip just a portion of either alternation in a series or parallel clipper, a DC potential can be placed in parallel with the output. This DC potential will either forward or reverse bias the diode, depending solely on how the diode and DC potential are inserted in the circuit. Indicate whether each clipper circuit illustrated below is forward biased or reverse biased.



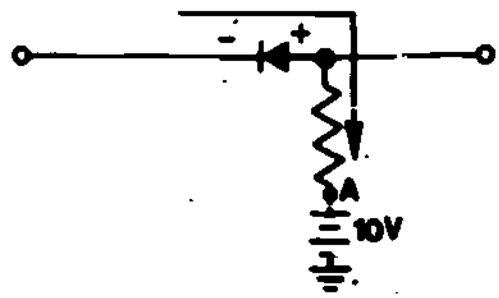
- -

Forward biased = 1 and 3
Reverse biased = 2 and 4

11. Series Clippers with Bias



Series Negative

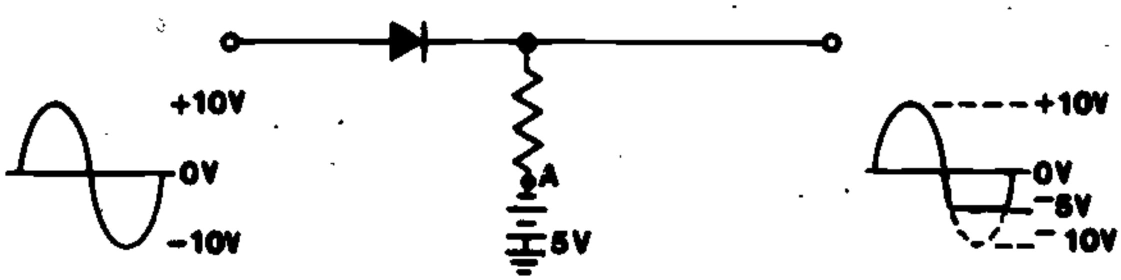


Series Positive

BIASED CLIPPERS

Both circuits have 10 volt DC supplies. Both circuits also have the DC potential forward biasing the diode when input signal is applied. Therefore, both diodes conduct. The diode may only be cut-off if the input signal is greater than -10 volts for the series negative clipper and greater than +10 volts for the series positive clipper. That means, that any waveform with a peak 10 volts or less will pass through these circuits untouched. Waveforms with peaks greater than 10 volts will be limited. The voltage level at which they are clipped is the voltage level of the battery potential at point A.

Let's check what we have just said:



As you can see, only the negative peak was removed from the input waveform. Point A is -5 volts and the negative portion of the output waveform stopped at - 5 volts.

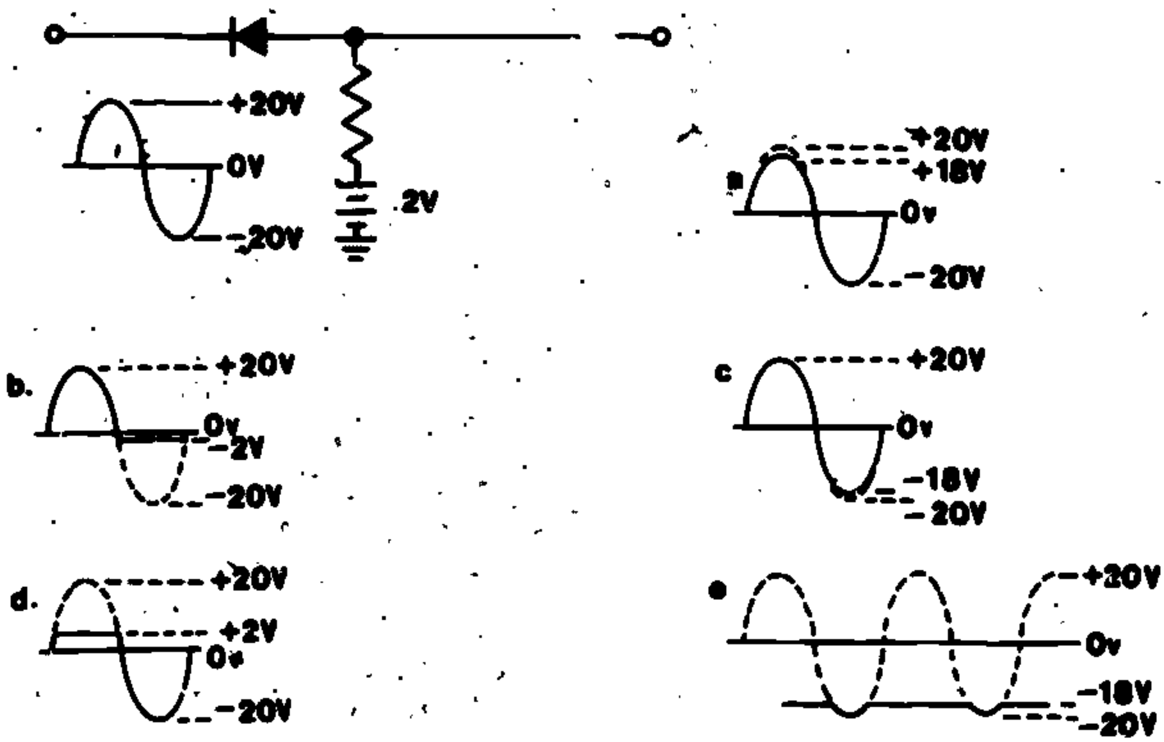
What change would you have to make in the figure on the previous page to cause it to clip the output at -7 volts?

- -

Change the battery from 5v to 7v.

12. TEST FRAME.

With a 40 volt p-p input waveform applied to the circuit illustrated below, which of the output waveforms is most correct?

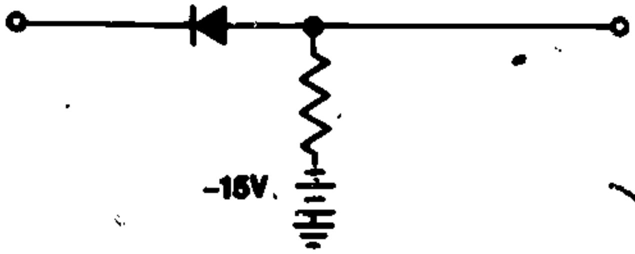


THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.

d. ____

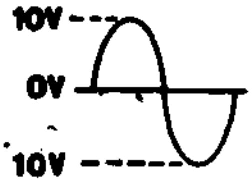
IF YOUR ANSWER MATCHES THE CORRECT MASWER, GD TO TEST FRAME 15. OTHERWISE GO BACK TO FRAME 10 AND TAKE THE PROGRAMMED SEQUENCE.

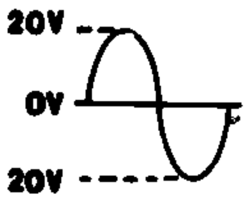
13. We have seen that if the diode's forward bias is aided by a DC potential, the result is a waveform that extends both above and below the reference line (more than one half cycle). Now, if the diode's reverse bias is aided by the DC potential, we should expect the resultent output to be less than one half cycle. This happens because the diode remains cut-off during most of the input cycle the only way we get it to conduct is to have a signal high enough to make the diode conduct.

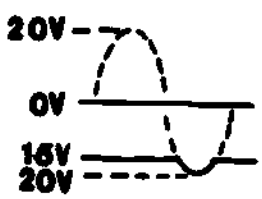


If this signal is the input:

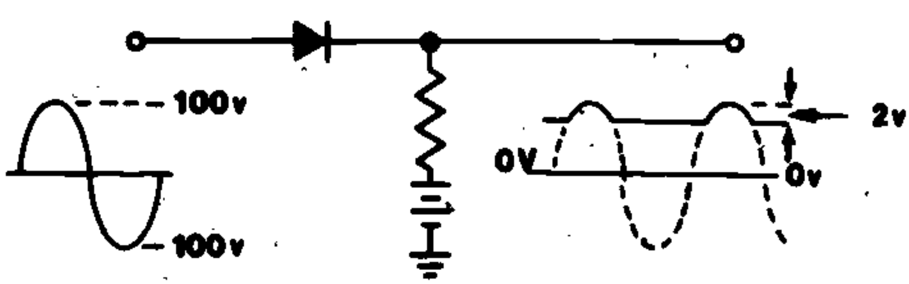
This signal will be the resultant output:







Given the following circuit, what DC potential would we have to use to get the indicated output?

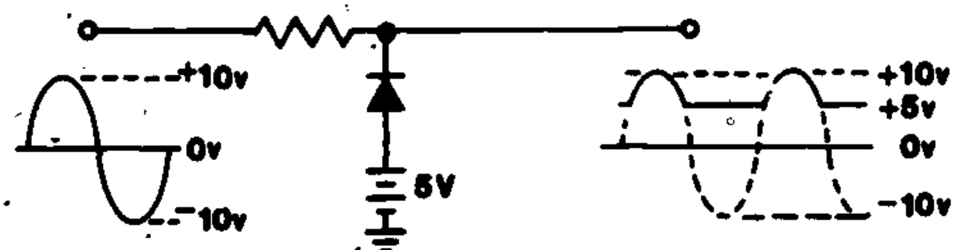


a. -2VDC
b. +102VDC
c. +98VDC
d. +2VDC

---

c. +98VDC

14. A DC potential can also be used with parallel clipper circuits. When the diode conducts the DC potential will be observed in the output. At the times when the diode is cut-off, that portion of the input waveform will be observed as the output.



In the parallel case shown, the diode is forward biased when no input signal is applied. The diode cuts-off when the voltage exceeds +5 volts battery potential. Therefore, we will see only the portion of the input signal which is greater than +5 volts.

In either the series or parallel clipper, the following general rules apply.

1. Negative clippers remove the negative alternation either totally or in part.

2. Positive clippers remove the positive alternation either totally or in part.

3. Output in series clippers occurs when the diode conducts. Output in parallel clippers occurs when the diode is cut-off.

4. When the DC potential aids the forward bias in a series clipper, the output will be greater than a half cycle. Conversely, when the DC potential aids the foward bias in a parallel clipper, the output will be less than a half cycle.

The illustration above is a waveform that has been clipped by a parallel clipper.

Is the diode cut-off or conducting when the waveform is at point A?

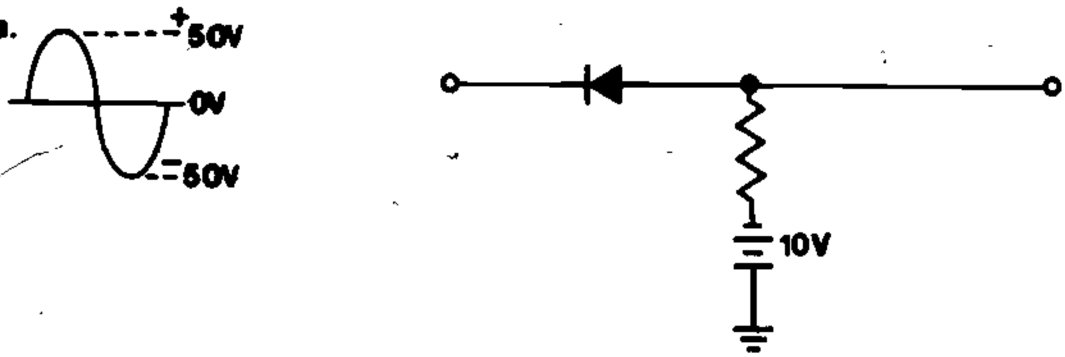
- -

cut-off

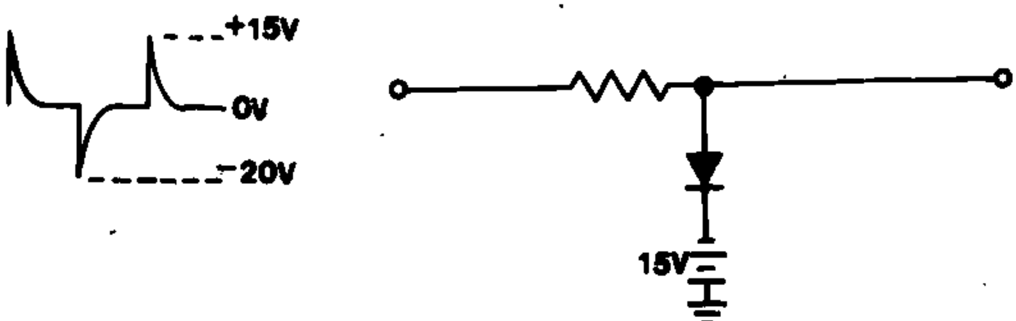
15. TEST FRAME

Draw the output for the following circuits and identify them using their proper names.

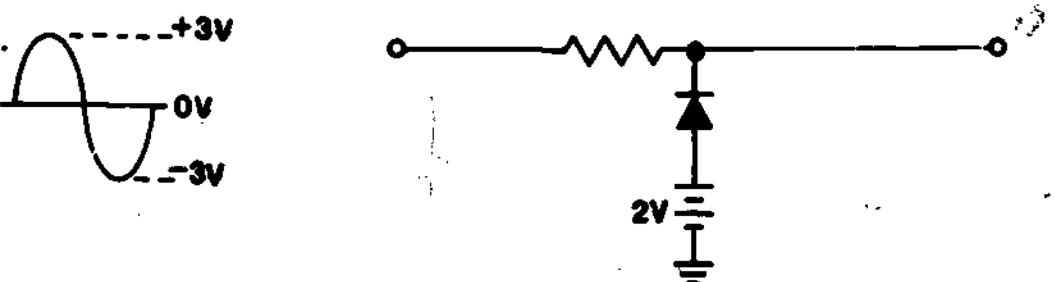
a.



b.



c.

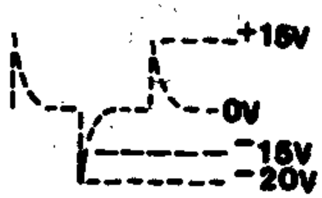


THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

a.

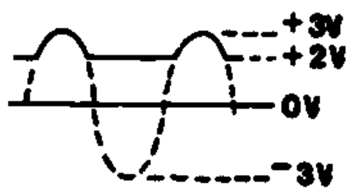
Series Positive Clipper With Bias

b.



Parallel Positive Clipper With Bias

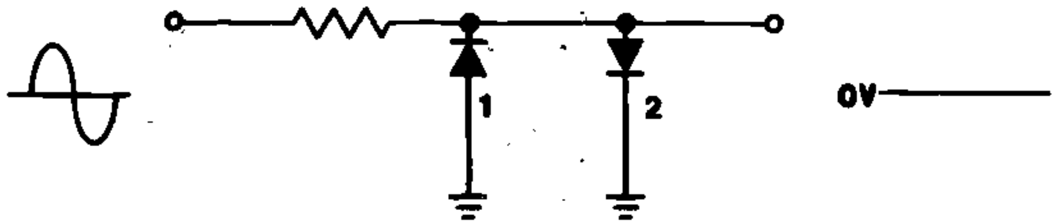
c.



Parallel Negative Clipper With Bias

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, GO ON TO TEST FRAME 17. IF NOT, GO BACK TO FRAME 13 AND DO THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

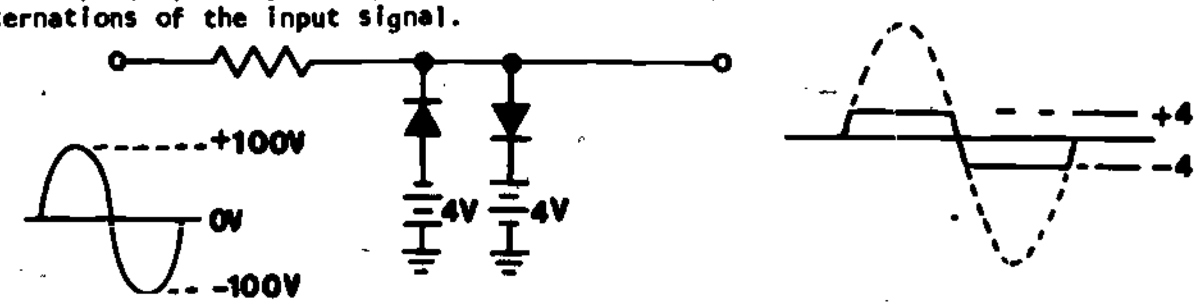
16. This next circuit is called a parallel negative and positive clipper. If there is no DC bias either diode circuit there will be no output.



The positive portion of the input signal passes through diode 2 and the negative portion passes through diode 1.

Result: No Output!

Now, if the diodes are cut-off (reverse biased) during a portion of each half cycle by using a DC potential, we will clip the peaks of both alternations of the input signal.



NOTE: If the diodes were forward biased by the DC potential, no output would occur. Each diode would conduct for more than half of each cycle.

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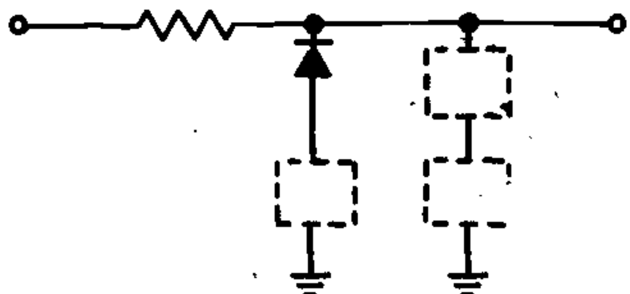
The only time a parallel positive and negative clipper will have an output is when?

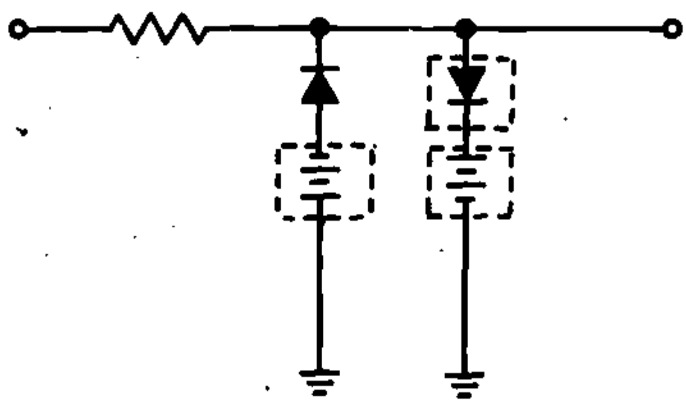
(a) Both diodes are hooked-up opposite but in parallel with each other and the output, 2nd

(b) both diodes are reverse biased.

Fill in the missing components to produce a parallel positive and negative clipper.



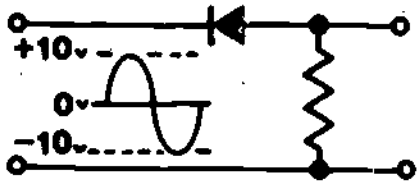
- -

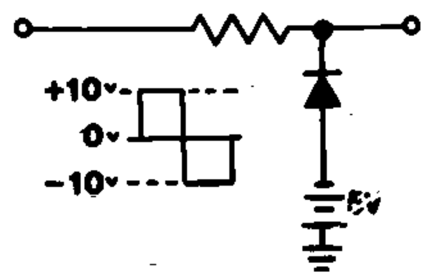


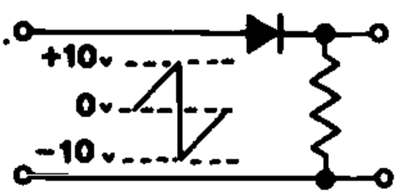
33

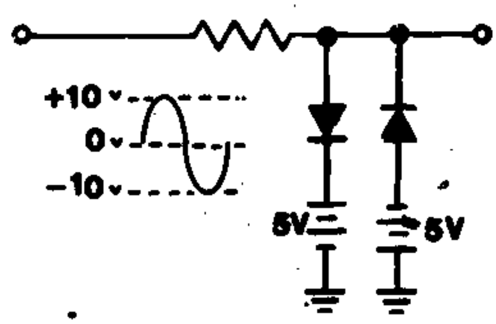
17. TEST FRAME

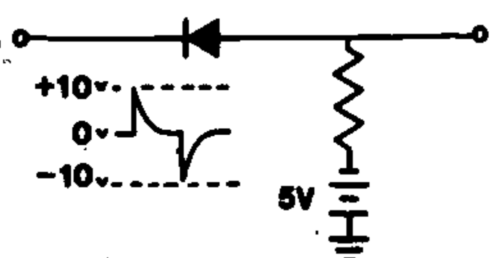
Illustrated below are various configurations of clipper circuits. Identify each with its correct name and draw the correct output signal given an input signal.

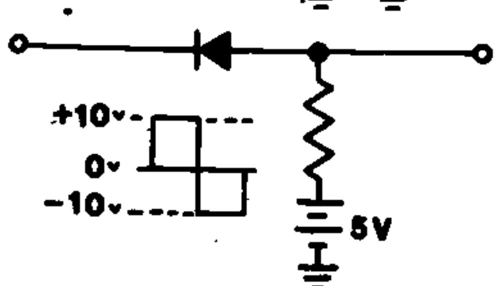
a.


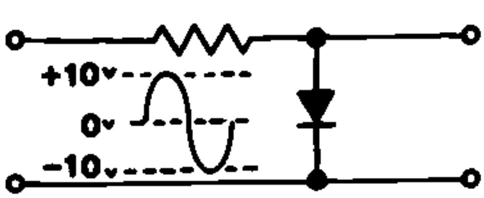
b.


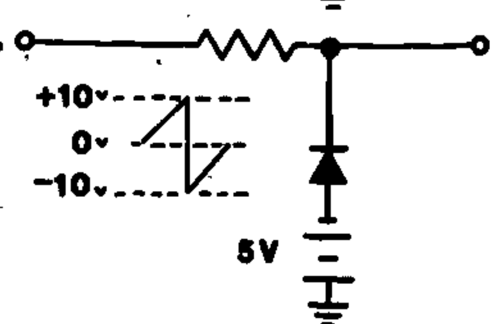
c.


d.


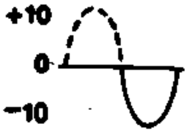
e.


f.


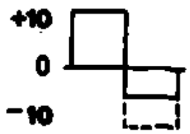
g.


h.


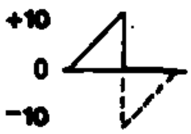
THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

a. 

Series Positive Clipper

b. 

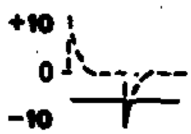
Parallel Negative Clipper With DC Aiding Reverse Bias

c. 

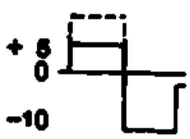
Series Negative Clipper

d. 

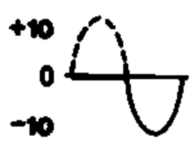
Parallel Negative And Positive Biased Clipper

e. 

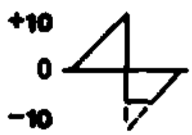
Series Positive Clipper With DC Aiding Reverse Bias

f. 

Series Positive Clipper With DC Aiding Forward Bias

g. 

Parallel Positive Clipper

h. 

Parallel Negative Clipper With DC Aiding Reverse Bias

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON I. OTHERWISE, GO BACK TO FRAME I AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 17 AGAIN.

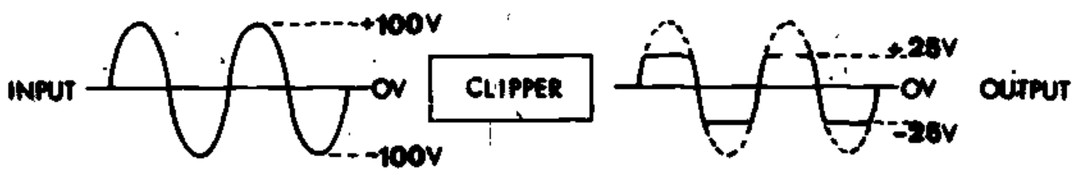
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN 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

Clippers

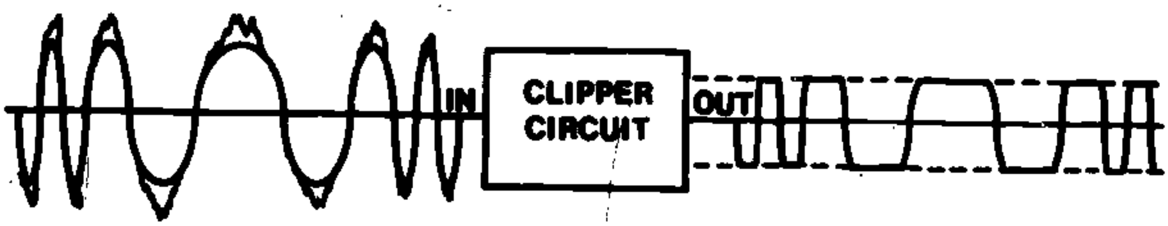
This lesson is about clippers. What do clippers do? Well, from what the name sounds like, it must clip things. What kind of things? Picture in your mind a long series of sine waves or square waves. Take a pair of imaginary hedge trimmers and level the tops off the waveform. This is what a clipper does - - - it limits the amplitude of any kind of waveform to a predetermined level. That's why clippers are sometimes called limiters; so in this lesson, limiter is just another name for a clipper.

Before we get started, let's identify what the clipper is used for in electronics. One application is to change a sine wave into a square wave:



*Dotted line shows portion of waveform removed by clipper circuit.

Another example is in FM radios and the audio portion of TV broadcasts. Have you ever noticed that when you listen to FM or TV, you do not get the noise like you do when you listen to AM stations? Even in a thunderstorm, when AM stations are drowned out with snaps and crackles and your TV picture is fading in and out, the sound on FM and TV is great. Why? Noise is very high amplitude interference that is picked up from lightening, electric mixers, X-ray machines, auto-ignitions and many other electrical/electronic devices. In AM, this noise rides on the transmitted broadcast and distorts the waveform. In FM it's also on the waveform but we can use a clipper to remove it and not ruin the broadcast.



FM
Signal With Noise

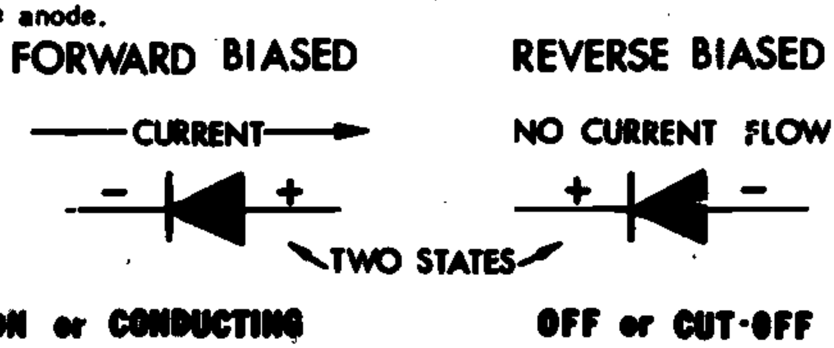
FM
Signal Without Noise

In this lesson, we'll talk about five types of clippers:

1. Series Positive
2. Series Negative
3. Parallel Positive
4. Parallel Negative
5. Parallel Negative and Positive

We'll also consider the effects of bias on these clipper circuits. Now that we've identified the scope of this lesson, let's review the basic operation of a diode because it is the key to the clipper circuit.

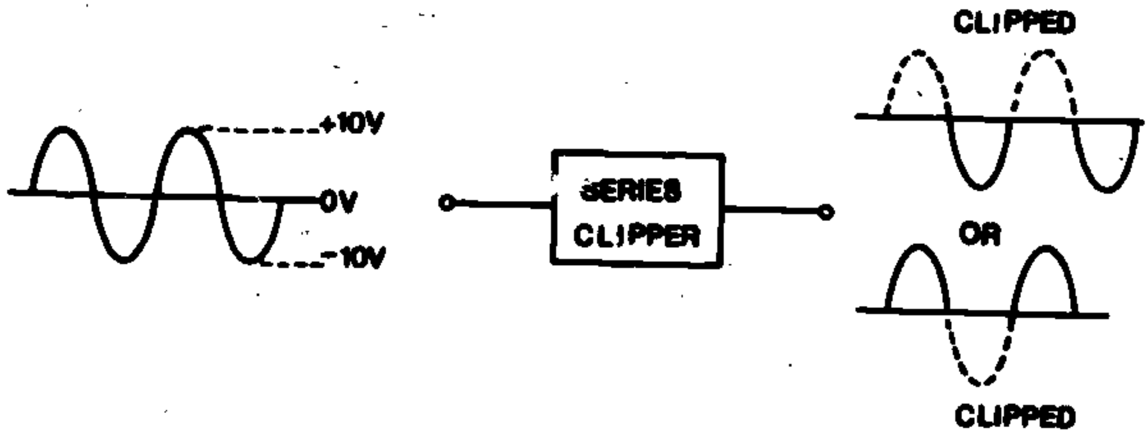
A diode has a cathode and anode. Conduction is only possible from the cathode to the anode.



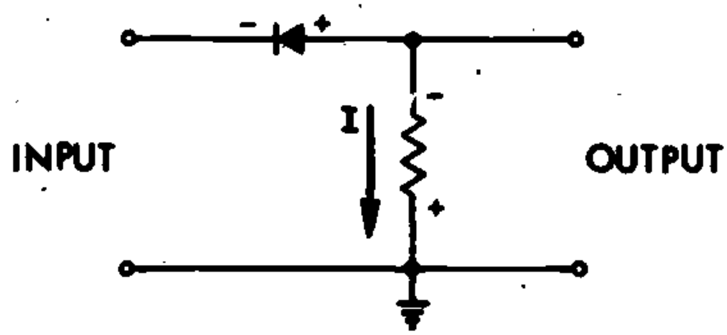
The cathode is the vertical line and the anode is the arrowhead. When the cathode is negative with respect to the anode, the diode is said to be cut off. The diode is forward biased when conducting and reverse biased when cut off.

SERIES CLIPPER CIRCUITS

Now we'll take a look at the clipper circuit. Functionally, it can clip either the positive or negative alternation.

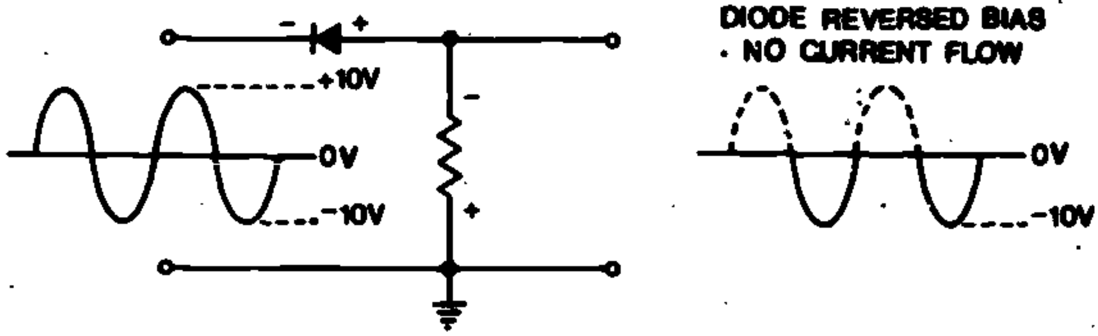


Wait a minute! This sound familiar. A halfwave rectifier does the same thing. A series clipper is exactly like a halfwave rectifier, only it is not used in a power supply. Take a look. . .



SERIES POSITIVE CLIPPER

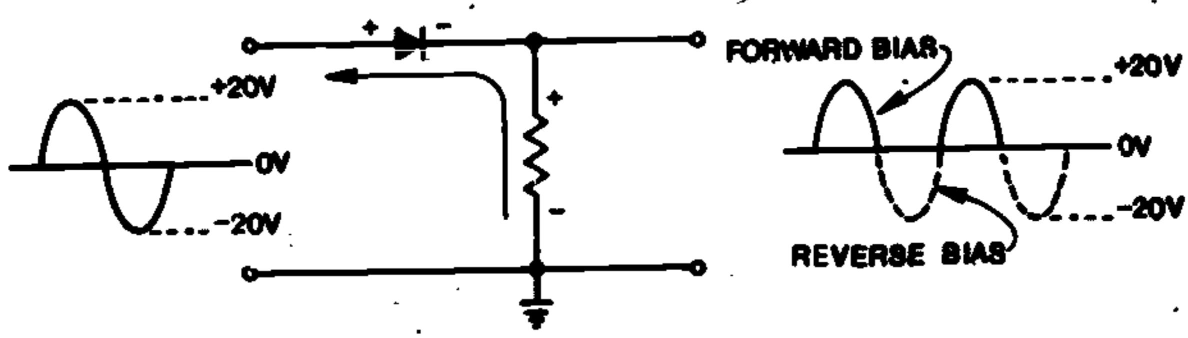
The diode is in series with the input. To make the diode conduct the input waveform must be negative with respect to anode of the diode. We'll apply a 20 volt peak-to-peak sine wave and see what happens.



During the positive half cycle the cathode is more positive than the anode. The diode is cut-off and will not conduct. No current will flow through the resistor. As a result, the entire series of positive alternations will be missing from the output of this circuit.

During the negative half of the waveform the cathode is negative with respect to the anode. Current flows through the resistor. The negative alternations pass through the circuit without any changes.

What if we wanted to limit the negative alternations? The situation, in this case, would call for turning the diode around. Makes sense, huh?

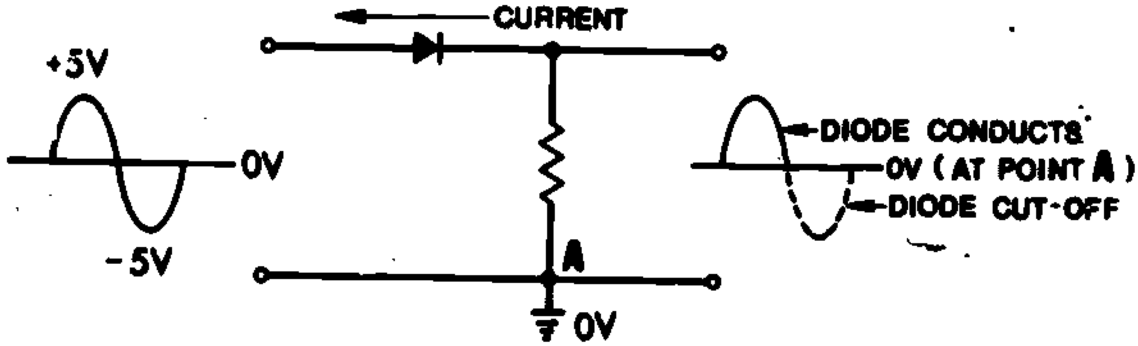


SERIES NEGATIVE CLIPPER

The series negative clipper can remove either the positive or negative portion of a waveform. The easiest way to determine which type of series clipper you have is to first try to decide which way current flows through the diode and then which way it flows through the resistor.

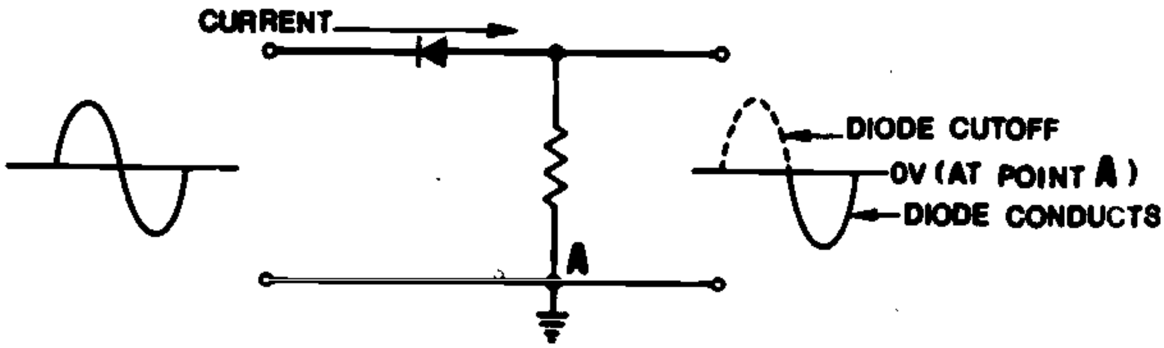
Remember, in a series clipper, the only part of the input waveform that will show up in the output is that part that forward biases the diode. Once the diode is cut-off, the output will remain at the reference level set at the bottom of the resistor (ground in this case).

Negative clippers remove the negative part.



SERIES NEGATIVE CLIPPER

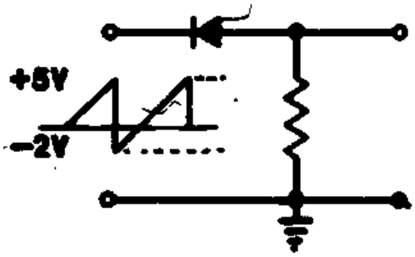
Positive clippers remove the positive part.

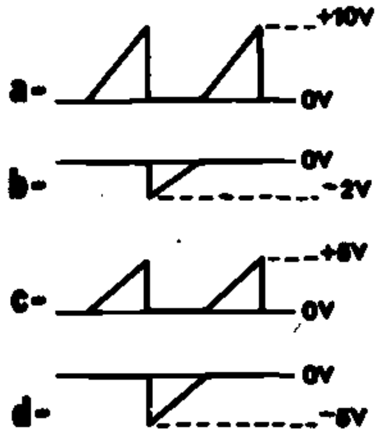


SERIES POSITIVE CLIPPER

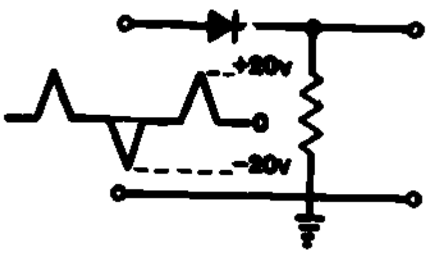
In each of the below circuits select the correct output.

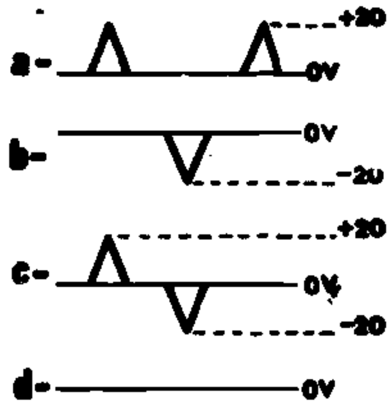
1-





2-





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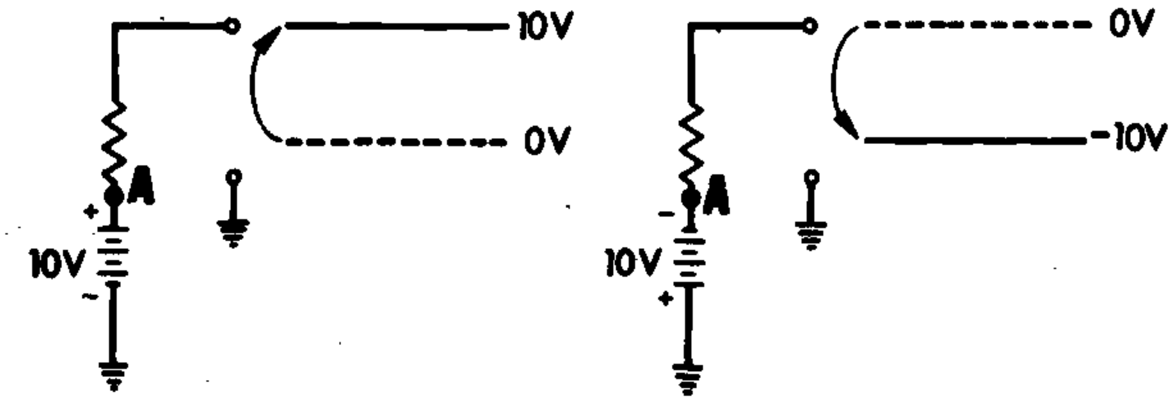
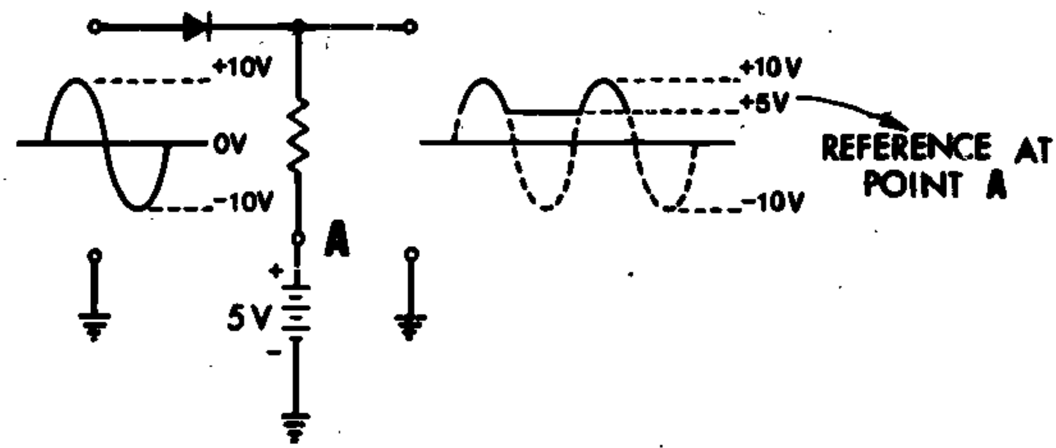
1. b, 2. a

Up to now, the reference point at the bottom of the resistor (point A) was zero volts. What happens if a DC potential is placed at point A? The battery will raise or lower the potential at point A. So when the diode is cut-off, the output goes to the battery potential.



DC POTENTIAL SHIFTS REFERENCE LEVEL



Earlier we saw that there are only two ways to connect a diode in the series clipper and now we have only two ways to connect the bias potential. There are then a total of four combinations of diodes and batteries. The batteries will either <u>aid or oppose</u> the flow of current in the clipper circuit.

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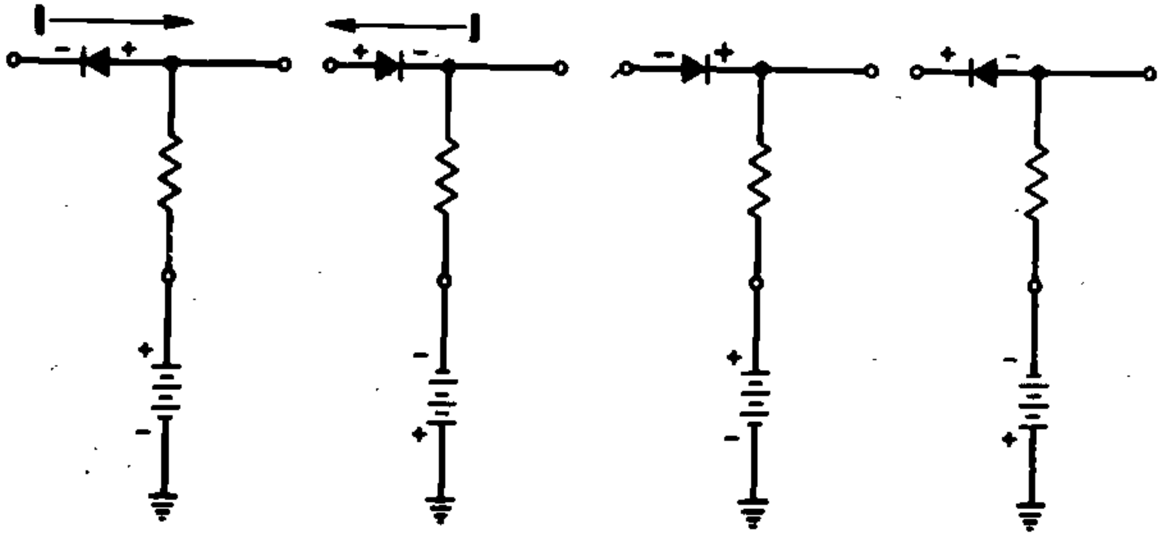
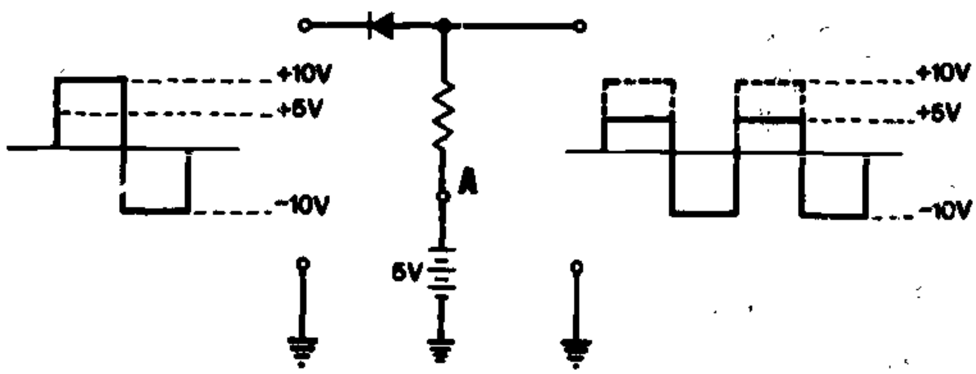
WITH NO SIGNAL INPUT. . . .



FOUR POSSIBLE COMBINATIONS

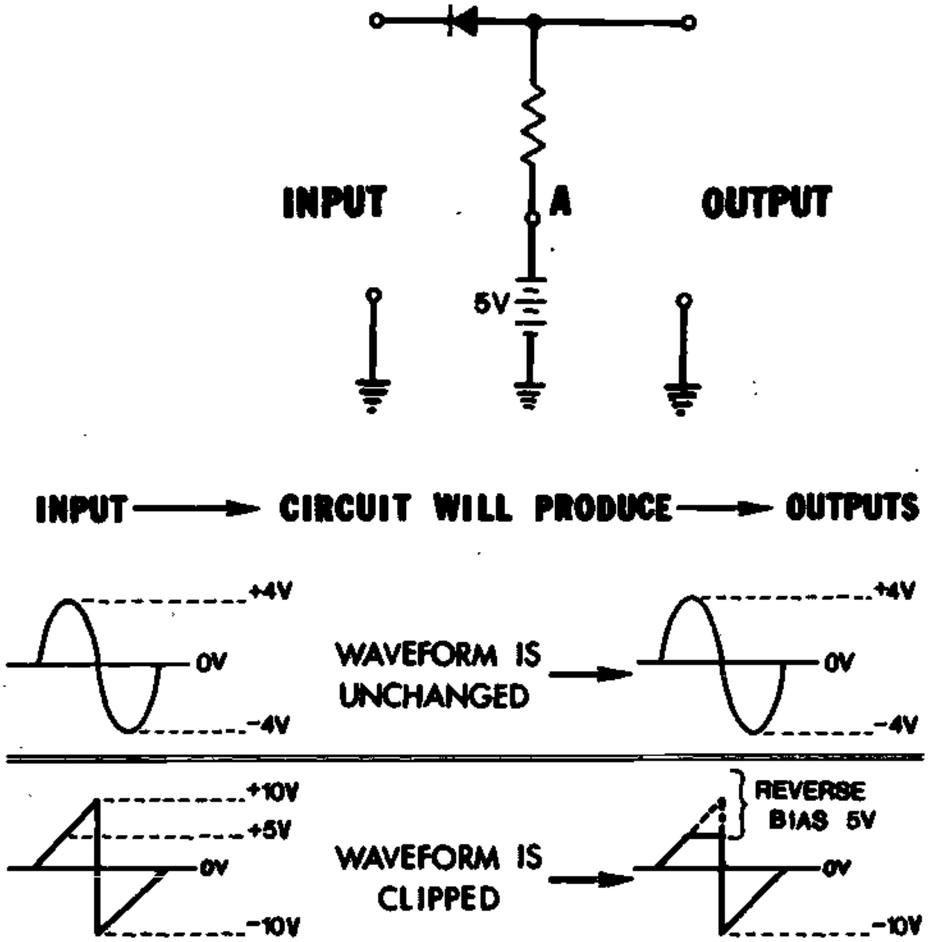
When the DC aids forward bias the diode conducts with no signal applied. In fact, the only way to reverse bias and cut-off the diode is to have the input signal get large enough to over balance the DC source. Look at the following circuit.



SERIES POSITIVE CLIPPER

The negative portion passes through the diode. The positive alternation must exceed +5 volts to cut the diode off because the battery aids the forward bias.

In the preceeding illustration, only those input signals over positive 5 volts will be affected. The negative portion of the input signal will be unaffected. Take a look at the following input and output waveforms.



In the last combination, the diode remains forward biased until the positive bias on the anode is exceeded by the positive going input signal. When the input signal exceeds the battery voltage, the diode cuts-off. When the diode cuts-off only the 5 volt reference remains in the output.

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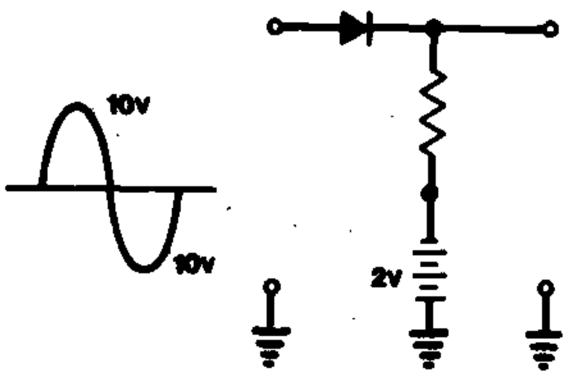
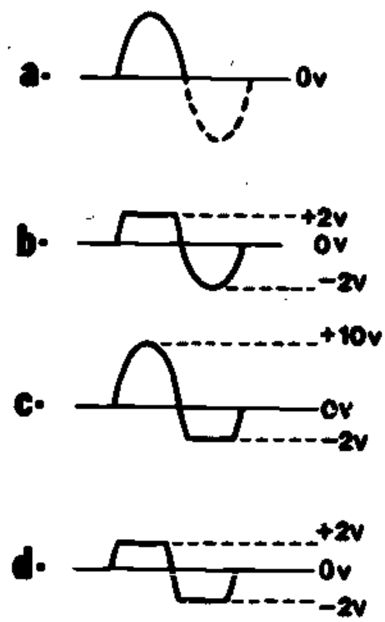
What is the correct output waveform from the following circuit?





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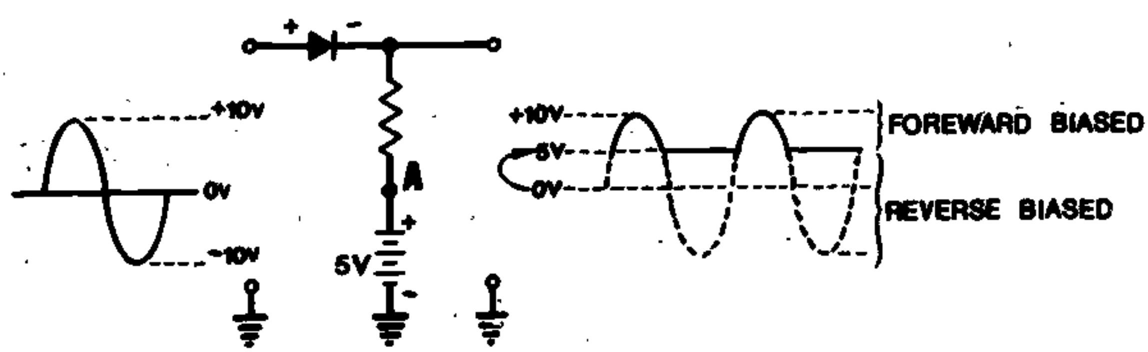
c.

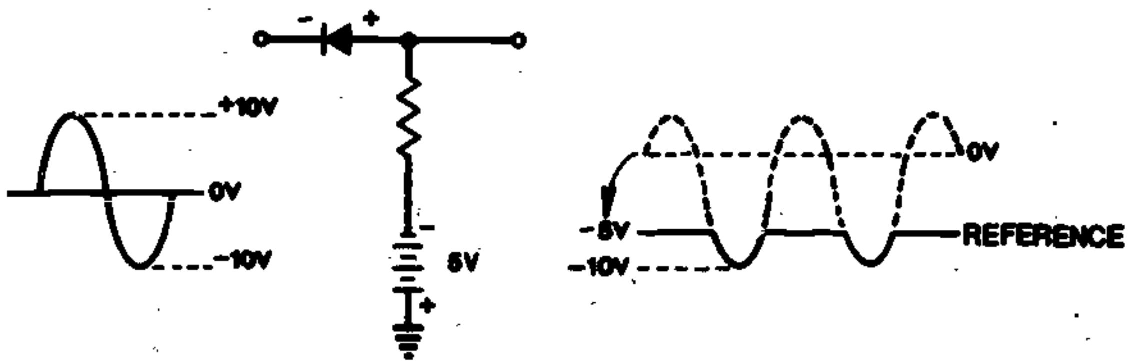
We've just completed half the picture for series clippers with DC bias. Now, we'll discuss the positive and negative series clipper using the DC <u>aiding</u> the reverse bias. In this case, we will remove all of the negative alternation and part of the positive alternation.



SERIES NEGATIVE CLIPPER WITH BIAS

In the preceeding illustration, the only time the diode will conduct is when it is forward biased. The only time it is forward biased is when the positive portion of the input signal exceeds the +5 volt battery potential on the cathode. So by having the battery aid the reverse bias, the final result is an output waveform that is less than a half cycle.

The series positive clipper with the DC aiding the reverse bias would naturally produce a waveform identical to the series negative clipper but the polarity would be opposite.

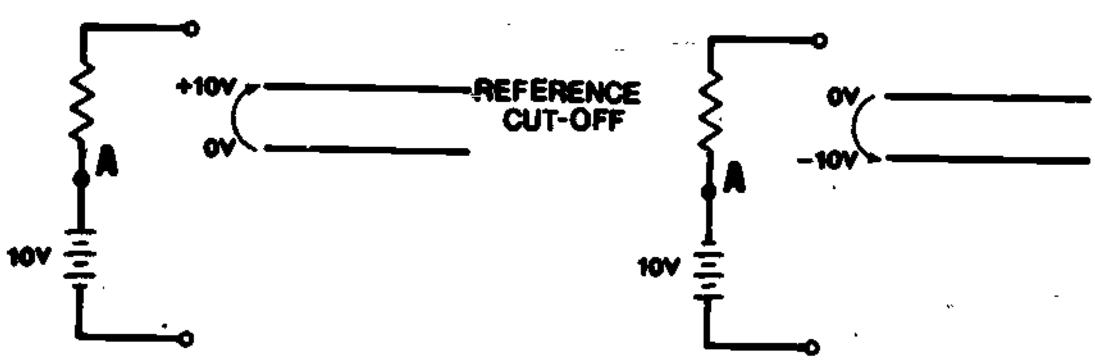


SERIES POSITIVE CLIPPER WITH BIAS

The following series may be used to determine the ouput waveform of a biased series clipper.

1. Determine if the series is a positive or a negative clipper. To do this, you must determine which direction current will flow through the resistor. This is most easily done by determining the only possible direction of current through the diode and then follow that direction through the resistor.

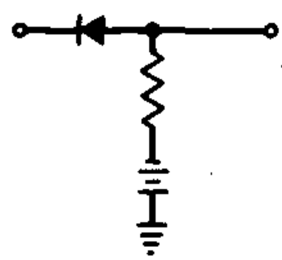
2. If the series circuit is biased, set the new reference level at the battery potential. This reference determines what the level will be when the diode is cut off.



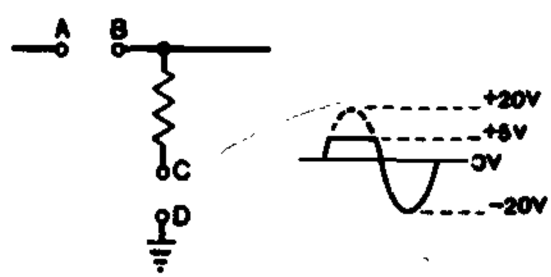
3. Determine whether the battery aids forward or reverse bias. If it aids forward bias, you should expect to see more than half of the waveform in the output. Conversely, if the battery aids the reverse bias, expect the output waveform to be less than a half cycle. Remember, when the diode cuts off, the output goes to the battery level at point A.

One last self-check before proceeding.

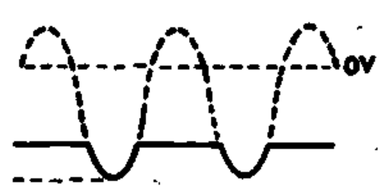
1. The circuit below is a ______________________________.



2. Complete the circuit below to produce the indicated output waveform.



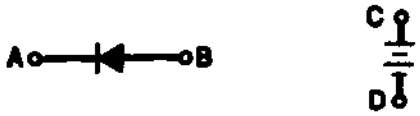
3. The name of the circuit which will produce the output waveform illustrated below is a series (positive/negative) clipper with bias.



4. In the circuit in question 3, (forward/reverse) bias is aided by the battery.

- -

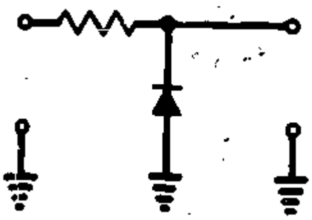
1. Positive Series Clipper with battery aiding reverse bias.
2. Positive Series Clipper with battery aiding forward bias.



3. Positive
4. Reverse.

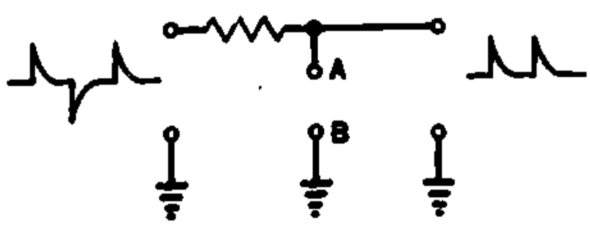
PARALLEL CLIPPER

You know we would have not stressed the word "series" unless a parallel clipper also existed.

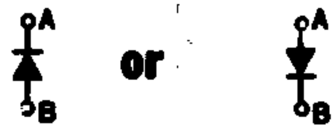


PARALLEL CLIPPER

Looking at the illustration, we see that the output is taken across the diode. The only time we'll read anything is when the diode is reverse biased or cut-off. When it is forward biased, the diode is a short circuit; no voltage can be developed across a short.

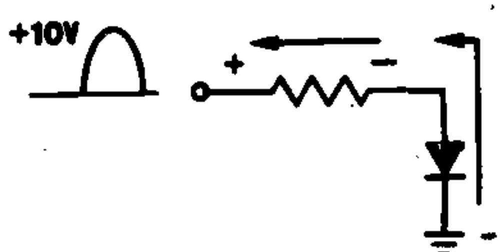


In the preceding circuit, which way would the diode have to be inserted to produce the waveform shown?

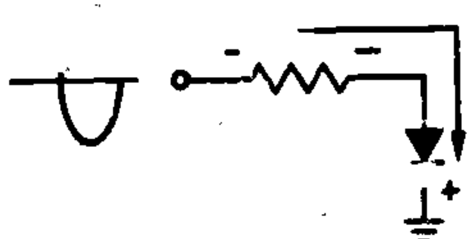


This is called a parallel negative clipper.

You may have noticed that the operation of the parallel clipper is just opposite that of the series clipper. In the series clipper, the output occurs when the diode conducts. In the parallel clipper, the output occurs when the diode is cut-off. There is no way of trying to memorize all these circuits. What is important is that you be able to figure them out.



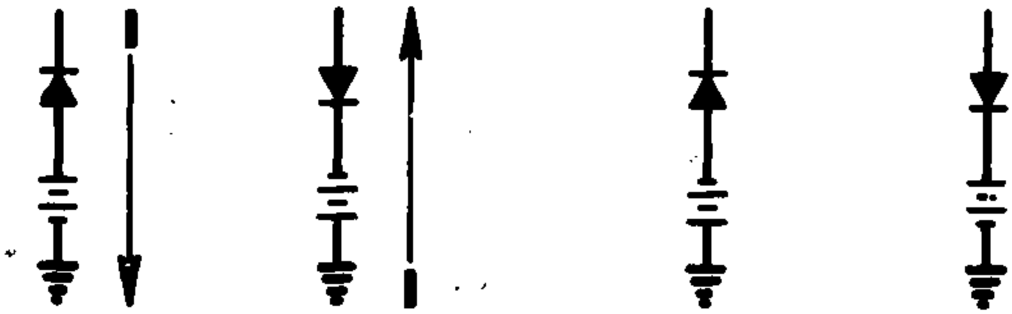
Diode forward
Biased no output



Diode reversed
Biased output

PARALLEL POSITIVE CLIPPER

We added DC bias to the series clipper circuit; now let's add it to the parallel clipper.



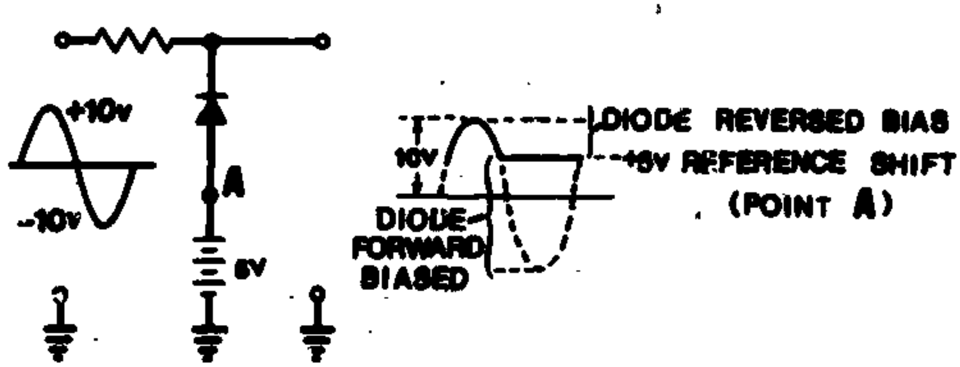
CONDUCTS

Battery Aids Forward Bias

CUT-OFF

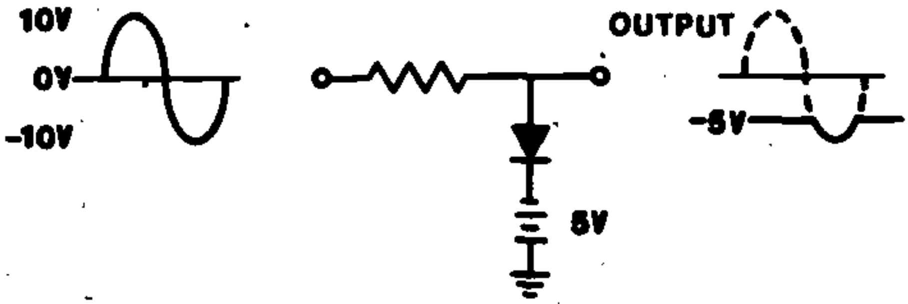
Battery Aids Reverse Bias

Let's take the cases where the diode is initially forward biased by the DC potential.

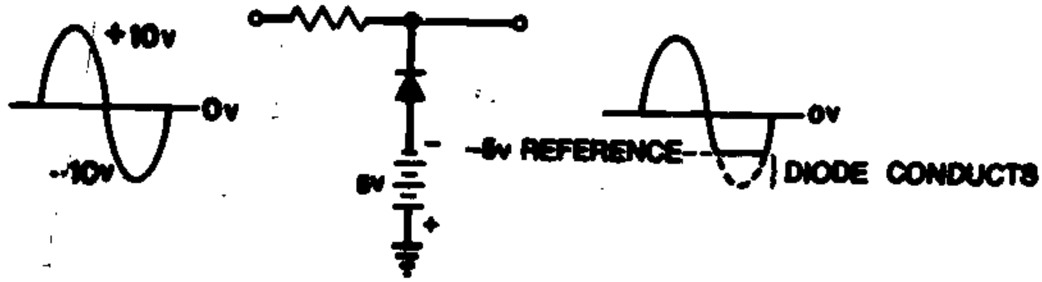


PARALLEL NEGATIVE CLIPPER WITH BIAS

The only time the diode in this circuit is cut-off is when the input waveform goes positive enough to overcome the forward bias of the DC potential. Had the diode and battery been reversed, the negative peak would appear in the output.

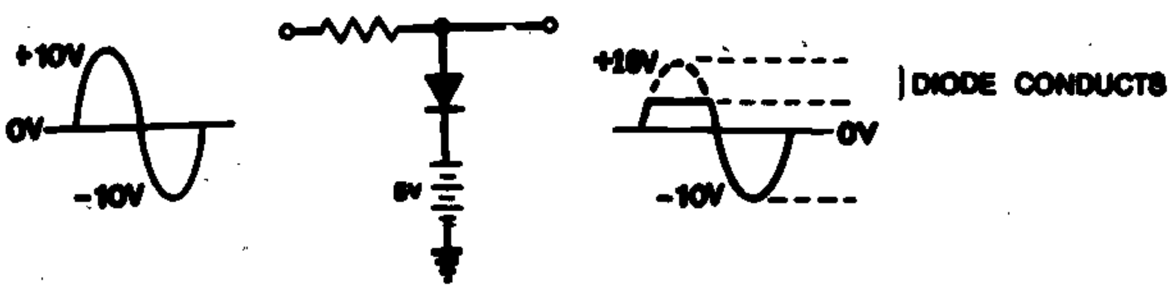


OK, so now we'll look at the case where the diode is initially reverse biased by the DC potential.

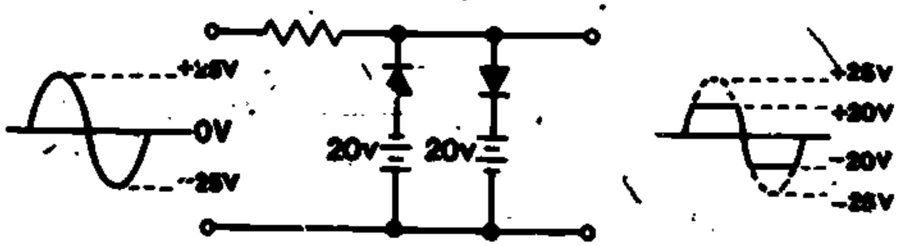


PARALLEL NEGATIVE CLIPPER WITH BIAS

The only time the diode conducts in this circuit (shown above) is when the input waveform goes negative enough to overcome the DC potential. Had the diode and battery connections been reversed, as shown below, the positive peak would have been cut off.



The last type of clipper to be discussed combines the biased positive and negative parallel clippers. It will remove parts of both the positive and the negative alternations. Each battery must be aiding the reverse bias of the diode in its circuit. If it didn't there would be no output.



PARALLEL POSITIVE AND NEGATIVE BIASED CLIPPER

What is interesting to note in this circuit is that it is the only combination of diodes and DC sources that will produce the desired output. So what are the characteristics?

1. Each DC potential aids the reverse bias of the diode in its circuit.

2. One branch is a negative parallel clipper and the other is a positive parallel clipper. Therefore, the diodes must face in opposite directions.

3. In the static state (no input signal), the reference level will equal zero. Each battery opposes the other and since they are equal but opposite in amplitude, a voltmeter connected across the output will read zero volts.

About the only thing we can do to this combination clipper is to use different values of biasing potential to get different amounts clipped off the waveform.

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 FOUR

LESSON II

CLAMPERS

1 APRIL 1977

ERIC

OVERVIEW
LESSON II

Clampers

In this lesson you will learn about the function of clampers, theory of operation of clampers, how to discriminate between different types of clampers and how to troubleshoot clamper circuits.

The learning objectives for this lesson are as follows:

TERMINAL OBJECTIVE(S):

24.1.46 When the student completes this course he will be able to IDENTIFY wave shaping circuits and their effects on input waveforms by matching an output waveform to a wave shaping circuit and its input waveform given input and output waveform illustrations and wave shaping circuit schematic diagrams.

ENABLING OBJECTIVE(S):

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

24.2.46.6 IDENTIFY the type of clamper output waveforms, given four/five schematic diagrams of clamper types and output waveforms. 100% accuracy is required.

24.2.46.6.1 IDENTIFY by matching, the function of the resistor, the capacitor, the diode, and the source (battery) in a basic clamper circuit, given a schematic diagram, a list of functions, and a list of components. 100% accuracy is required.

24.2.46.7 OBSERVE and INTERPRET clamper output waveforms (normal and abnormal), given a training device/circuit, an oscilloscope, a job program, a variable bias supply, and a positive and/or negative clamper circuit. Interpret waveforms by answering applicable questions on the job program. 100% accuracy is required.

OVERVIEW

24.2.46.7.1 LOCATE all of the components in each input section, output section, and conversion section of the two basic types of clamper circuits (positive and negative), given a training device or circuit boards containing clamper circuits, a job program, and the applicable schematic diagrams or technical manuals. 100% accuracy is required.

24.2.46.7.2 IDENTIFY the type of clamper and the amount and polarity of bias, given a training device, a job program, an oscilloscope and the applicable schematic diagram. Either the oscilloscope waveform or schematic diagram, or both, may be used in analyzing for type and/or biasing. 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

Clampers

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 Four-II "Clampers"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Four-II "Introduction to Clampers"

Enrichment Material(s):

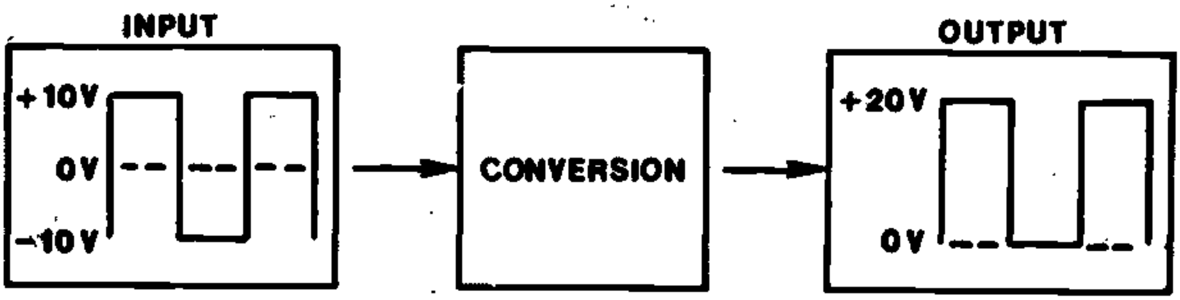
Markus, J., Electronic & Nucleonics Dictionary New York, McGraw Hill Book Co., 1960
Basic Electronics, Vol. 2, NAVPERS 10087-C
Fundamentals of Electronics, Vol. 5, NAVPERS 93400A-5

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.

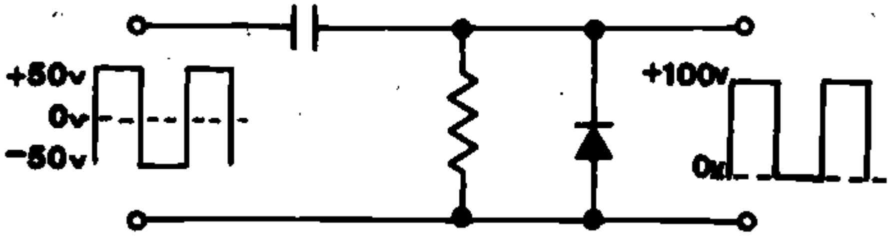
SUMMARY
LESSON II

Clampers

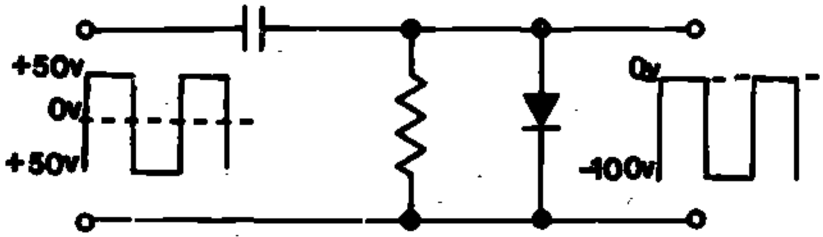
Clampers, sometimes called DC restorers, are used to raise or lower a reference voltage. They are used in test equipment, radar systems, electronic countermeasures systems, and sonar systems. Depending upon your equipment, you could find negative or positive clampers, with or without bias. In this lesson, you will learn the function of the different types, and the circuitry that constitutes each type. Let's look at an ICO diagram of a clamper.



Since you clipped a sine wave and made a square wave in the last lesson, let's use a square wave input. This waveform will vary its amplitude from +50V to -50V with its reference at zero volts. When you apply this input to a positive clamper, the output amplitude will now range from 0V to almost +100 volts. If you apply the same input to a negative clamper, the output amplitude will range from 0V to almost -100V. Let's look at the schematic diagram.

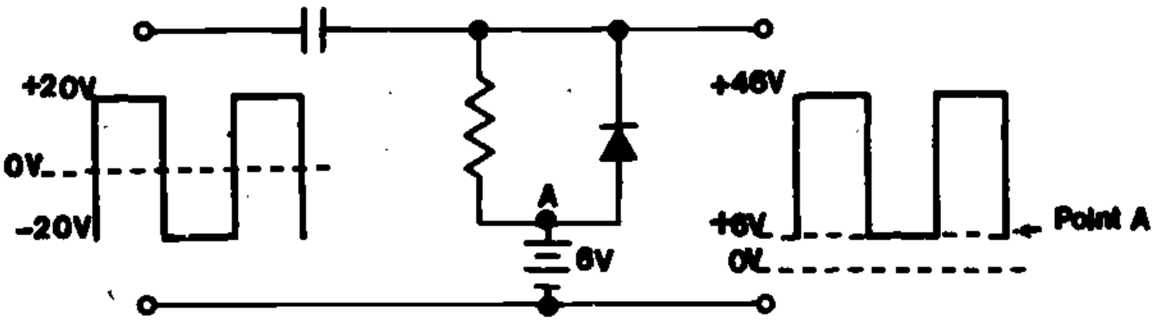


Positive Clamper

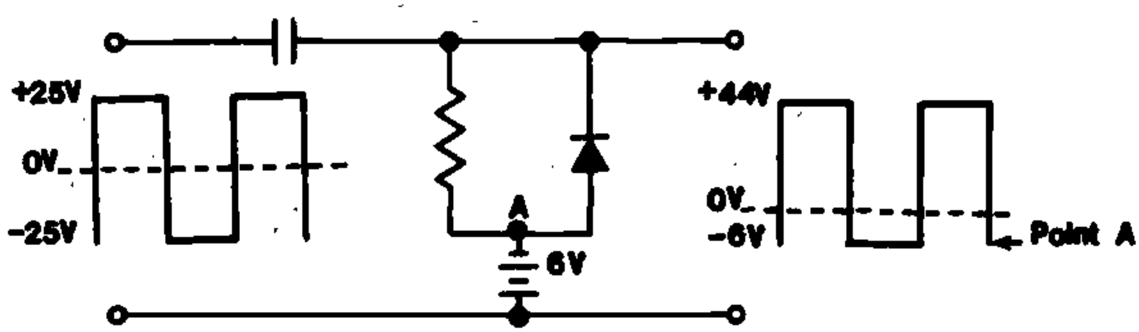


Negative Clamper

Remember when you inserted a DC potential into the clipper circuit? It established the output reference level for the circuit. Well, a DC potential does the same thing in a clamper circuit. Below are some examples of biased clampers.



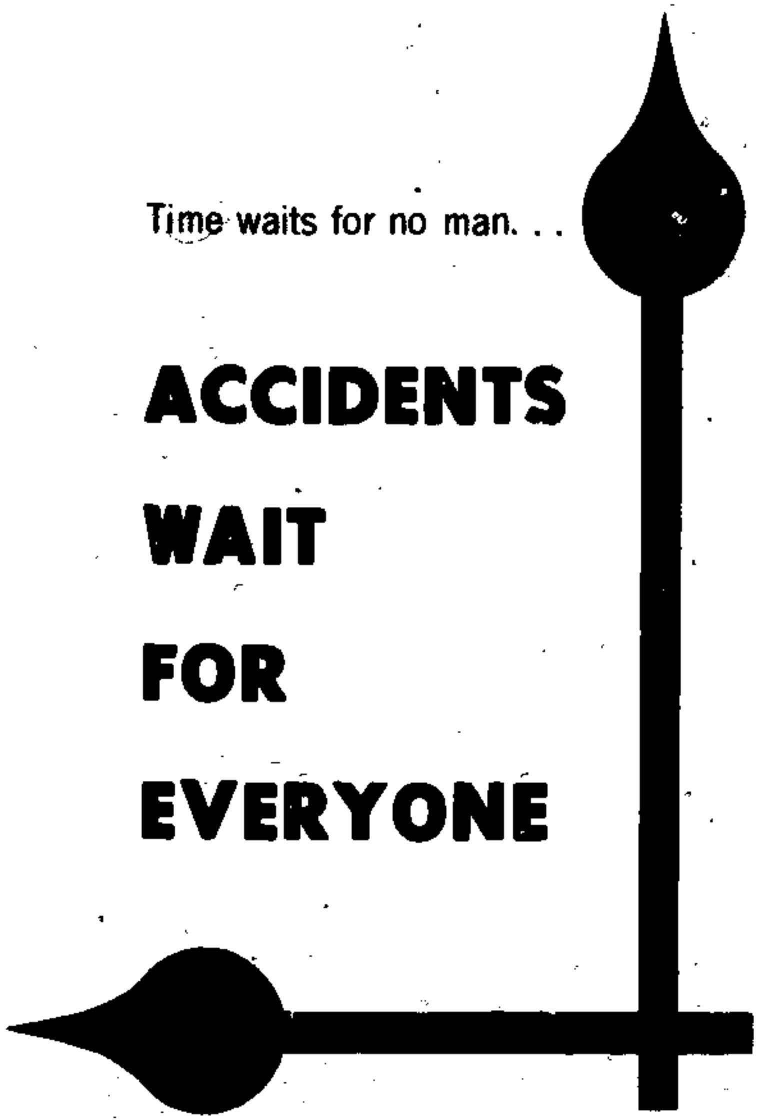
Positive Clamper with Positive Bias



Positive Clamper with Negative Bias

At this time you may be asking yourself "How do these circuits work?" It's all in the time constants. The diode (forward biased) and capacitor produce a very short time constant. When the diode is reverse biased the resistor and capacitor produce a very long time constant. This action of short and long time constants keeps the voltage across the capacitor constant. Keeping the voltage level almost constant across the capacitor raises or lowers the output voltage reference level. This can be proven by the application of Kirchoff's voltage law.

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.


Time waits for no man. . .
ACCIDENTS
WAIT
FOR
EVERYONE
COMPLACENCY KILLS!

61

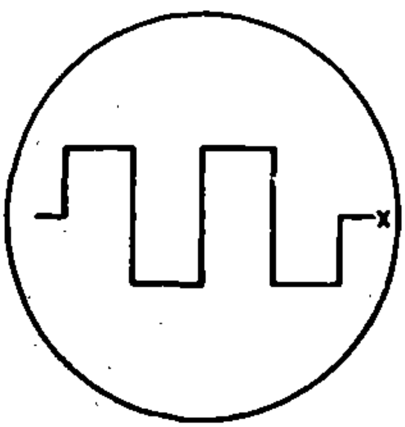
PROGRAMMED INSTRUCTION
LESSON II

Clampers

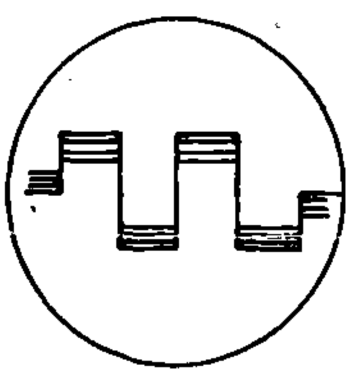
TEST FRAMES ARE 11 AND 14. AS BEFORE, GO FIRST TO TEST FRAME 11 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. Now that you have mastered clippers, the next step is to understand clampers. Although you generally hear the two names, clippers and clampers, in the same context, their functions are miles apart. A clamper's function is to raise or lower the reference level of a given signal. Clampers are capable of changing the reference level of almost any type of waveform - - - sine wave, square wave, triangular wave or spikes.

Clampers have many applications in electronics. One example is found in an oscilloscope. A clamper circuit is used to prevent the start of the line trace from shifting up and down.

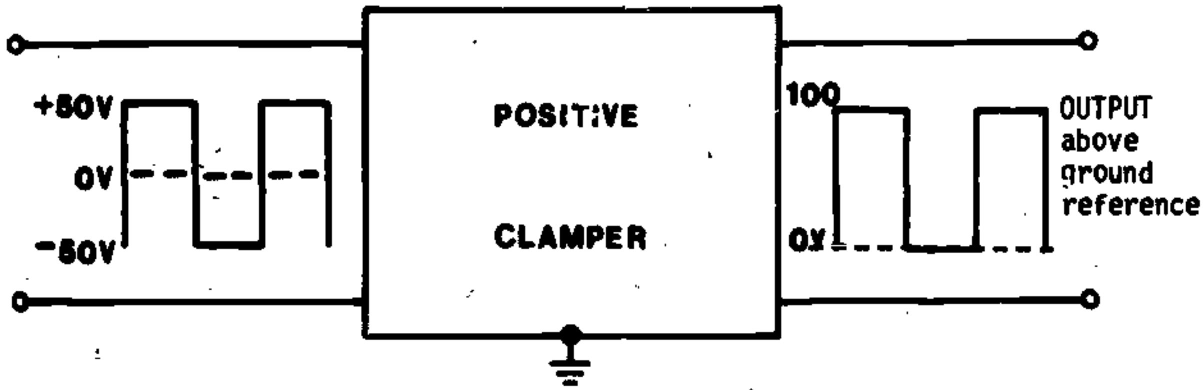


WITH CLAMPER--CLEAR WAVEFORM



WITHOUT CLAMPER--WAVEFORM MOVES UP AND DOWN, MAKING ACCURATE READINGS DIFFICULT OR IMPOSSIBLE.

Basically, there are two types of clampers, positive and negative. Let's look at a functional block diagram of a basic clamper.



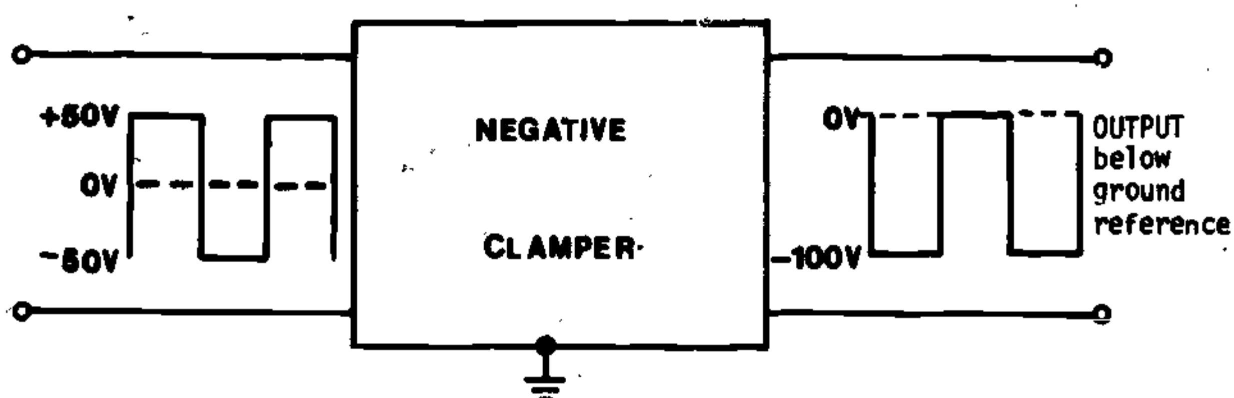
Using the ICO concept, look at the positive clamper's input. The input swings from +50 volts to -50 volts. In the output, the same voltage waveform swings from 0 volts to +100 volts.

A positive clamper takes an input voltage with some given reference level and clamps that reference level to a ______________ level.

- -

more positive

2. A functional block diagram of a negative clamper would look like this:



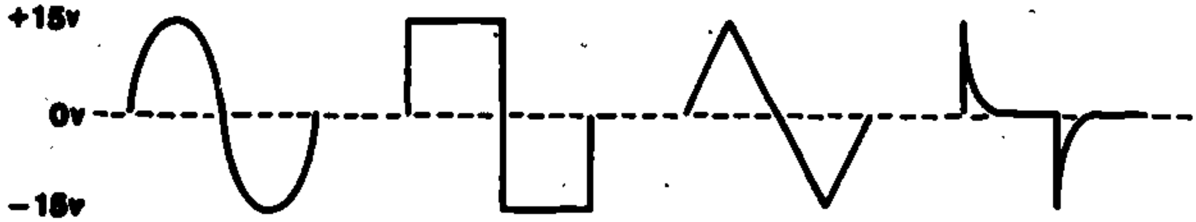
Both clampers bear a striking resemblence - - except for the output. Notice that the output of this clamper swings from 0V to -100V.

A negative clamper takes an input voltage with some given reference level and clamps that reference level to a ______________ level.

- -

more negative

3. A clamper is sometimes referred to as a DC restorer. What this title means is that the circuit adds a fixed reference level to a signal which has a varying reference level or none at all. In the figure below, we have a signal that swings from a positive voltage to a negative voltage and has 0V for an exact midpoint.



But some electronics circuits, for one reason or another, need an input reference other than zero. In a clamping circuit, the output appears to be "riding" on some DC level.

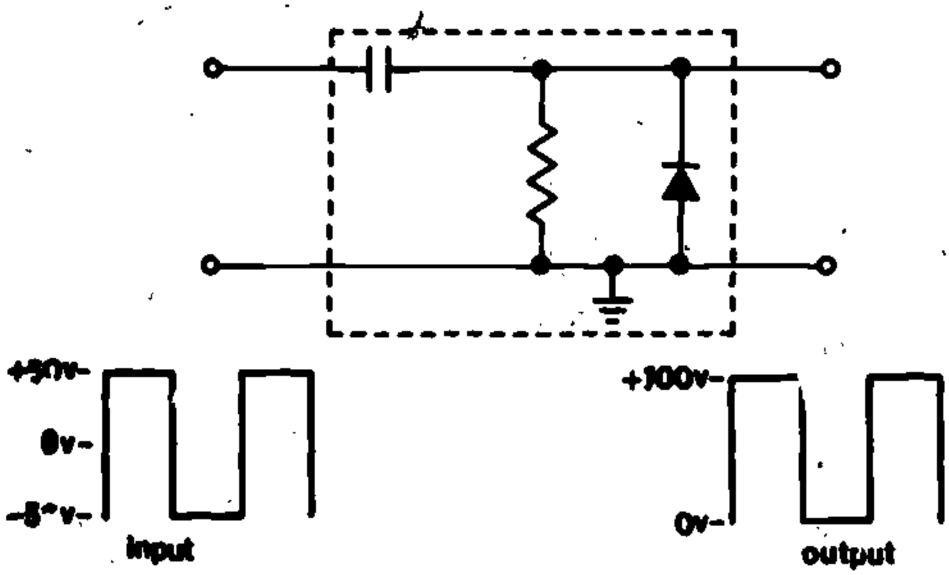
A DC restorer will:

a. change an AC signal to DC.
b. add a DC level to an AC signal.
c. cause DC to ride on an AC level.

- -

b. add a DC level to an AC signal.

4. OK, you have seen the input and the output. Now, let's open up the "black box".



All there is in there is a capacitor, a diode, and a resistor. How can these three components do all this clamping?

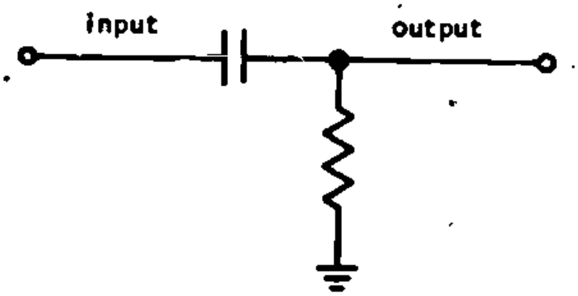
It's all in the time constant. The capacitor and the resistor together must produce a long time constant. The capacitor and the diode produce a short time constant. These two time constants allow the capacitor to maintain an almost constant voltage.

In the positive clamper the diode-capacitor combination has a very __________ time constant and the resistor-capacitor combination has a very ____________________ time constant.

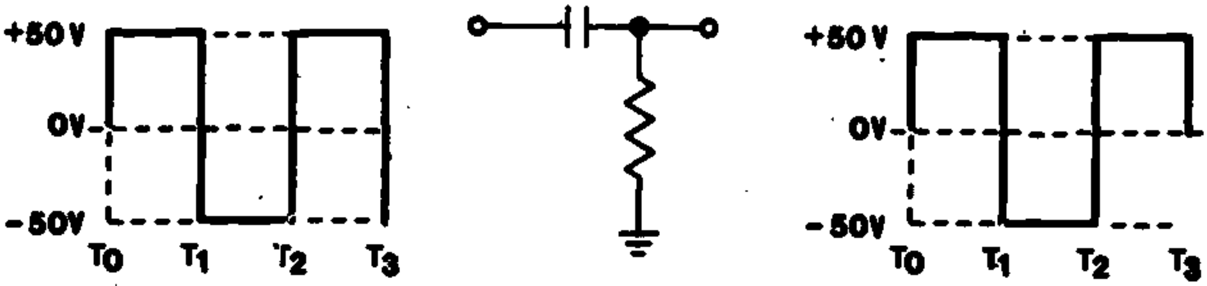
---

short, long (in that order)

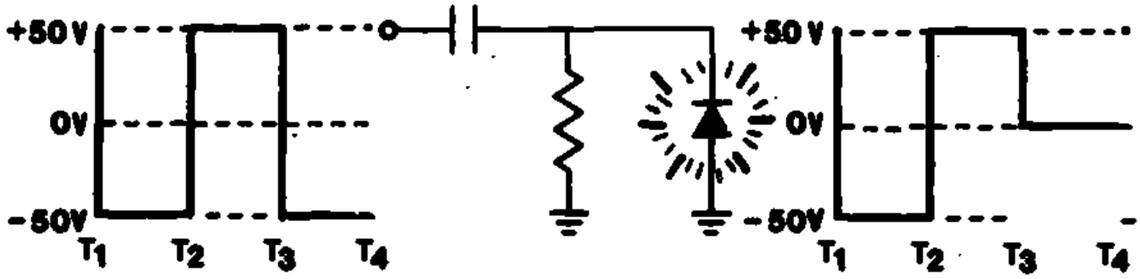
5. Let's start with an RC network.



Any input that is applied to this network will be divided across the capacitor and the resistor. If the RC time of the network is long compared to the period of the input waveform the majority of the waveform will be dropped across the resistor and very little across the capacitor. The signal will be passed to the output with very little change.



At T3 let's insert a diode into the circuit.



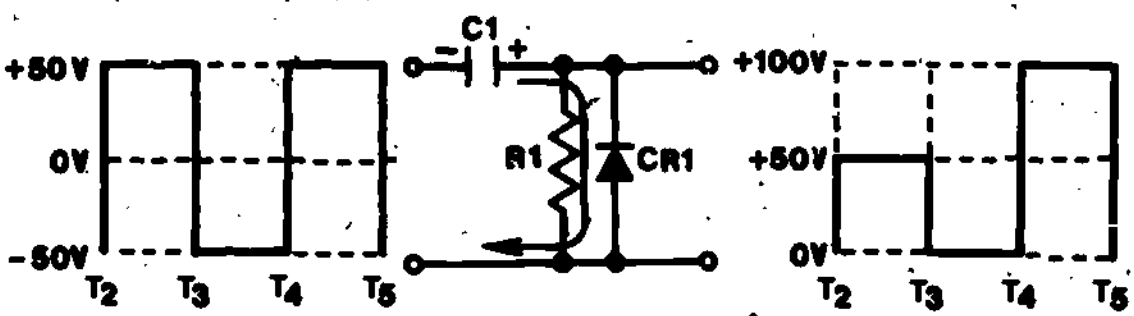
As soon as the input signal goes below zero volts the diode will be forward biased allowing the capacitor to quickly change its charge. Now, at T4, there will be -50 volts on the left side of the capacitor and zero volts on its right side.

What will the charge on the capacitor be at T4?

- -

50V

6. During the negative half cycle of the input signal (T3 to T4) the capacitor was charged to 50 volts. At time T4 the input changes to +50V. The diode becomes reverse biased giving us a long RC time constant again. The capacitor keeps its 50 volt charge.

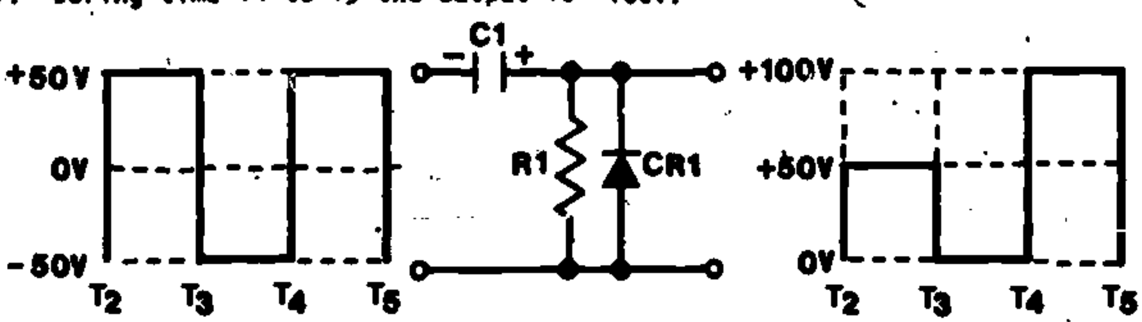


With +50 volts at the input in series with +50V across the capacitor what will the output voltage be after time T4?

- -

+100V

7. During time T4 to T5 the output is +100V.



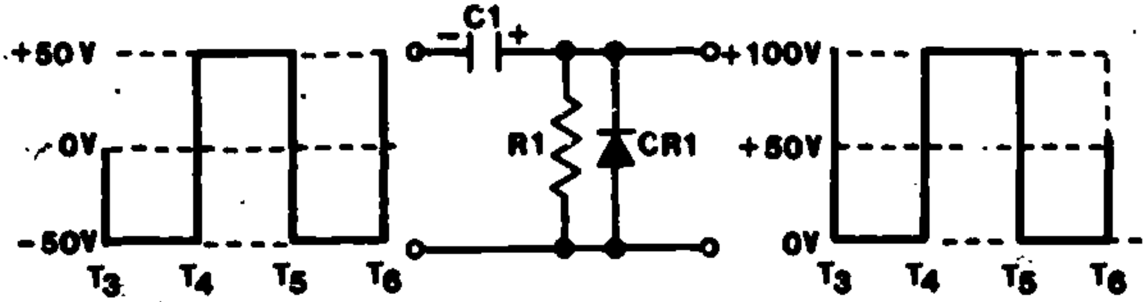
The capacitor tries to discharge but because the diode is now reverse biased and will not conduct the discharge path is through the resistor. We now have a long RC time constant and the capacitor does not lose much of its charge. What is the charge on the capacitor at time T5?

- -

67

The charge on the capacitor is still close to 50V.

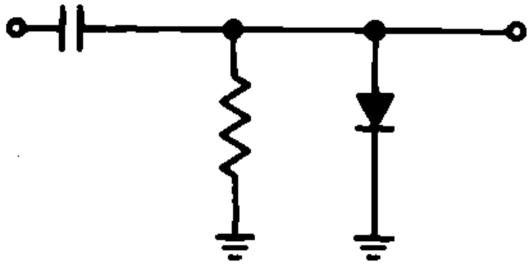
8. During the negative half cycle of the input signal (time T5 to T6) the diode will be forward biased long enough to allow the capacitor to charge back to 50 volts and make up for any losses that occured during the rest of the cycle.



If the input to the circuit shown above is a sine wave what is the most negative voltage that could be found in the output?

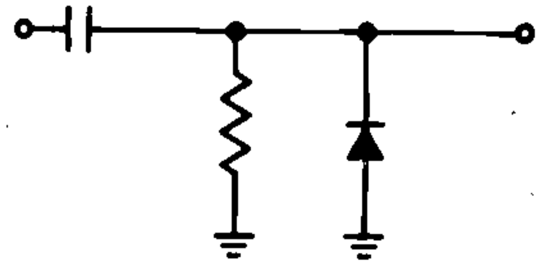
-100 volts

10. There is a quick way to determine if your circuit is a positive clamper or a negative clamper. If the diode symbol points down...it is a negative clamper. If the diode symbol points up...it's a positive clamper.



DIODE POINTS TOWARD REFERENCE

NEGATIVE CLAMPER



DIODE POINTS AWAY FROM REFERENCE

POSITIVE CLAMPER

In a positive diode clamper the diode will ____________ during the negative half cycle and will ____________ during the positive half cycle.

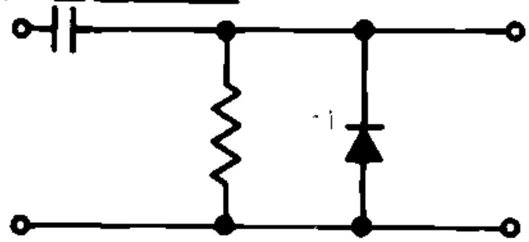
- -

conduct; cutoff (in that order)

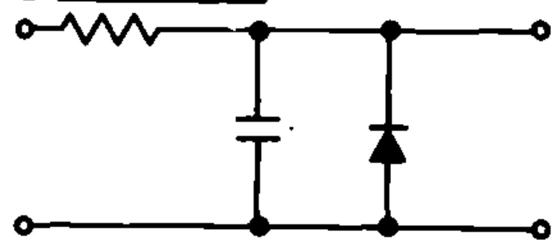
II. TEST FRAME

Indicate which of the circuits illustrated below are clampers and whether they are positive or negative.

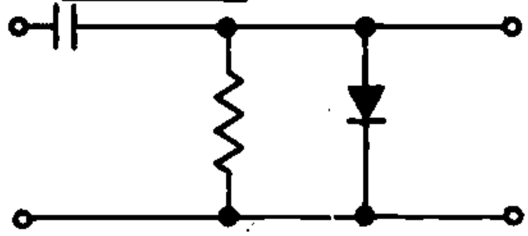
A. ____________



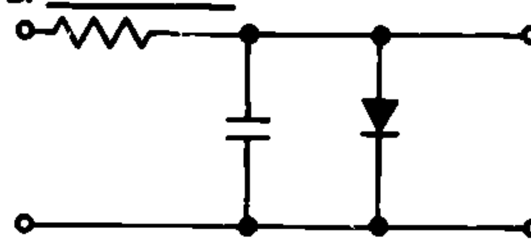
B. ____________



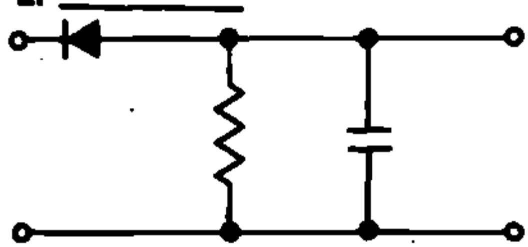
C. ____________



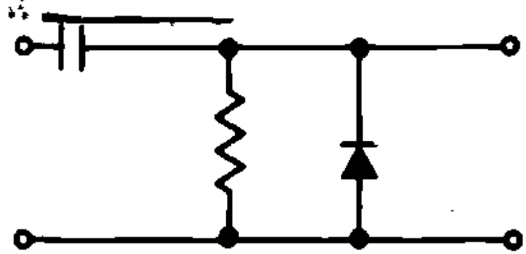
D. ____________



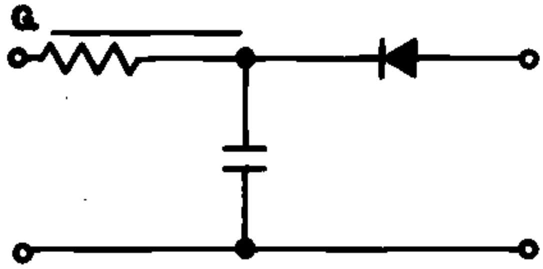
E. ____________



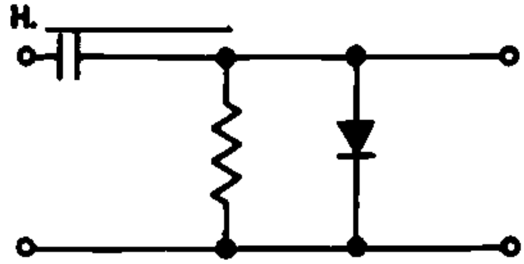
F. ____________



G. ____________



H. ____________



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

A. Positive.
C. Negative
F. Positive
H. Negative

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 14. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

12. Remember what happened when you placed a DC potential in a clipper circuit? You can do the same thing in a clamper. These clampers are called biased clampers. The amount of DC potential will always be the output reference level, just like the clipper circuits.

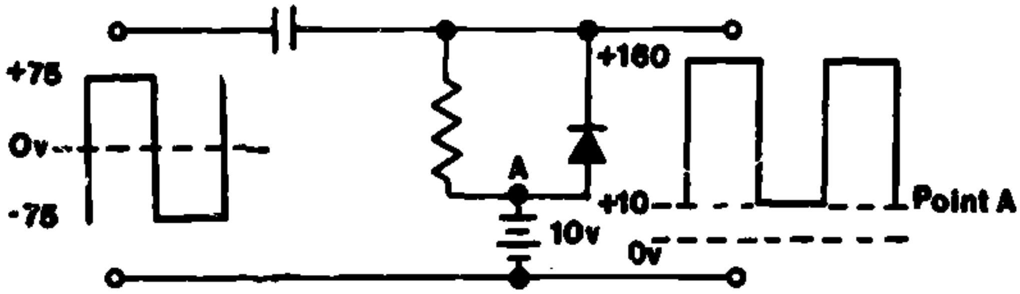
Each type of clamper (negative and positive) can be biased with either a positive or a negative potential.

What would be the output reference level of a negative clamper with a bias potential of -5 volts and an input voltage swing from +50V to -50V.

- -

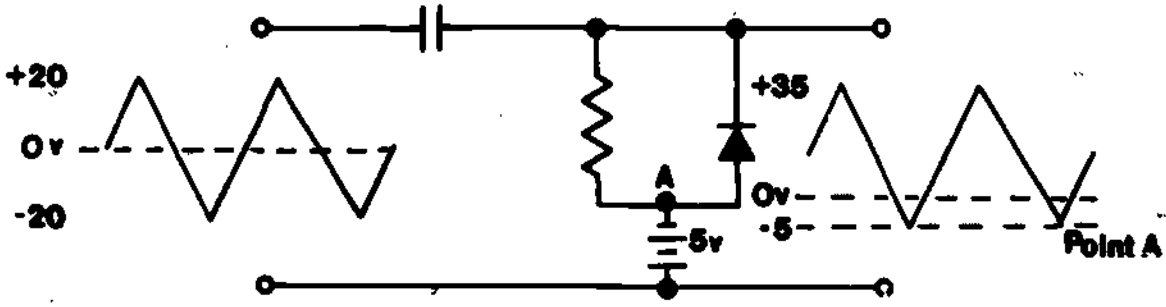
-5 volts

13. Some examples of biased positive or negative clampers can be found in oscilloscopes, electronic countermeasures, radar, and sonar systems. Illustrated below are the various types of clampers.

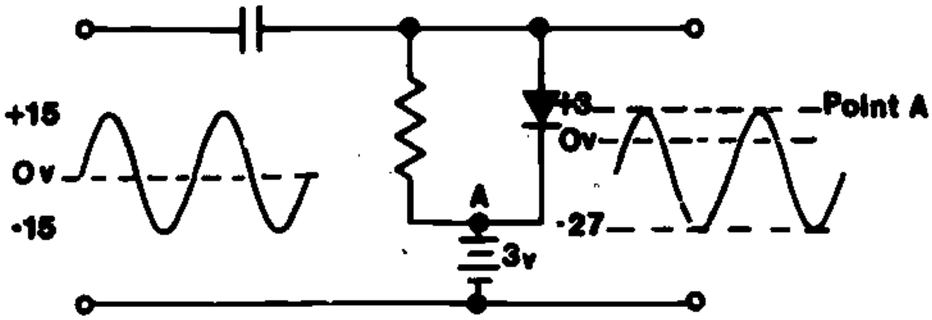


Positive Diode Clamper with Positive Bias

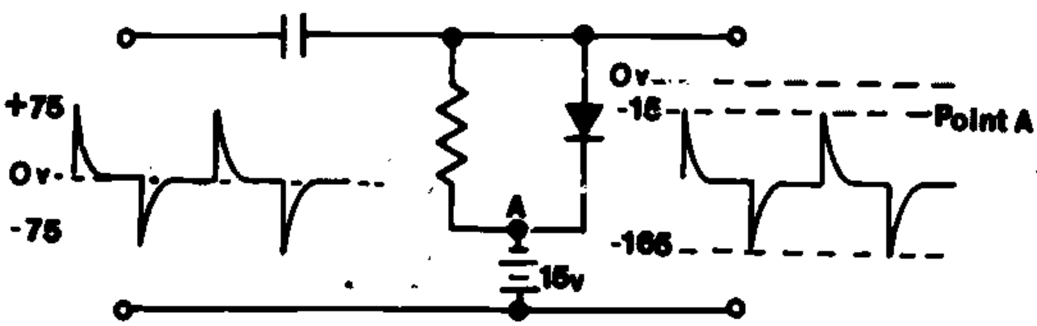
71



Positive Diode Clamper with Negative Bias

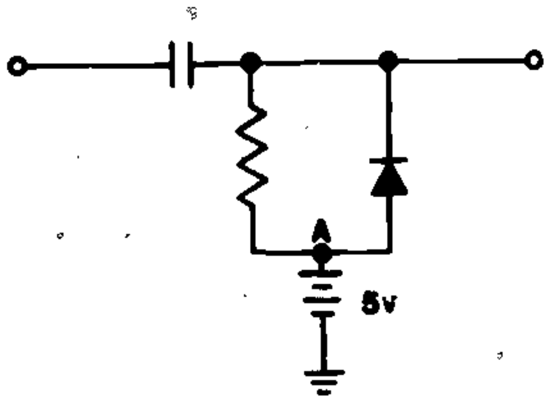


Negative Diode Clamper with Positive Bias



Negative Diode Clamper with Negative Bias

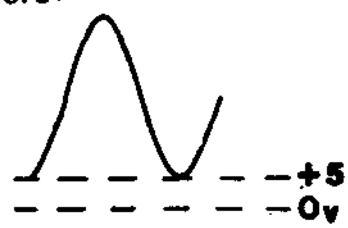
Clampers with positive and negative bias may sound pretty confusing. We have a rule to save you time:

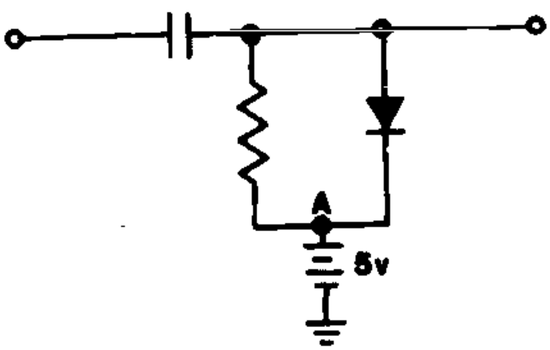


(1) Since the diode points away from reference; it is a positive clamper.

(2) Point A = +5V.

(3) Therefore:

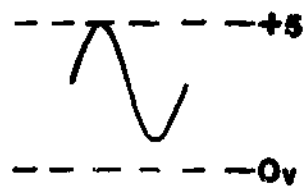


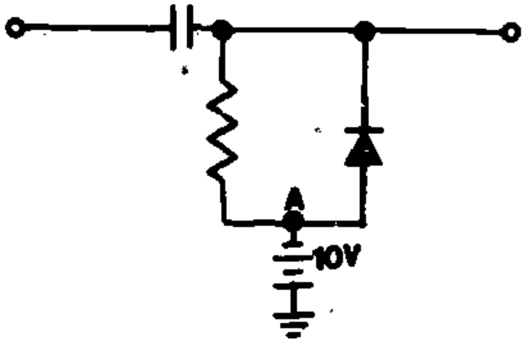


(1) Now the diode points toward the reference; it is a negative clamper.

(2) Point A is still = +5V.

(3) Therefore:

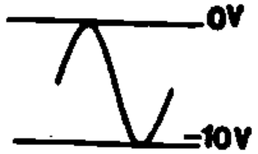


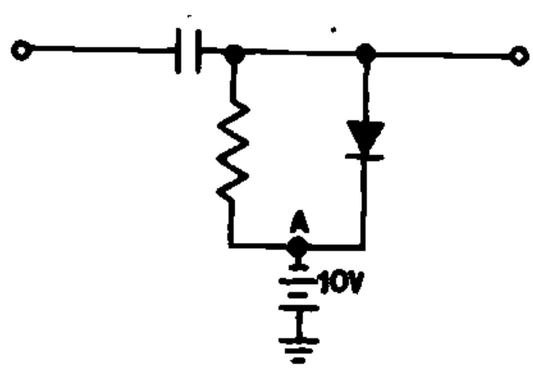


(1) Diode points away from reference; it is a positive clamper.

(2) Point A = -10V.

(3) Therefore:

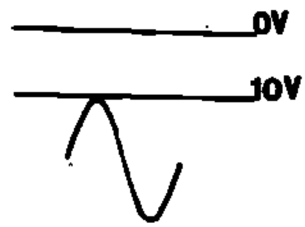




(1) Diode points toward reference; it is a negative clamper.

(2) Point A = -10V.

(3) Therefore:



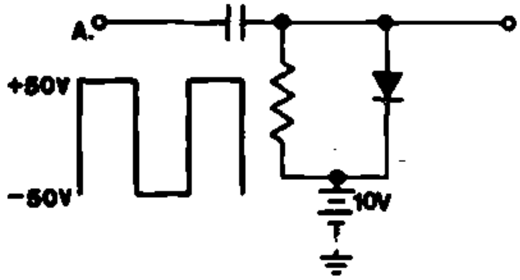
Negative clampers place the entire waveform (above/below) the reference voltage. Positive clampers place the entire waveform (above/below) the reference voltage.

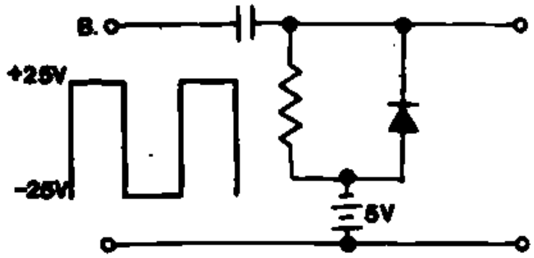
- -

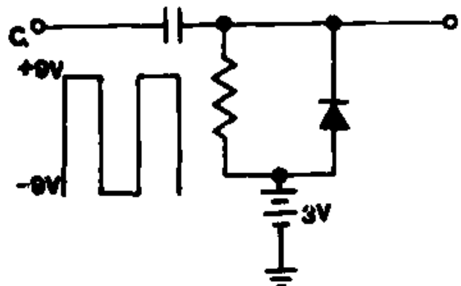
below, above (in that order)

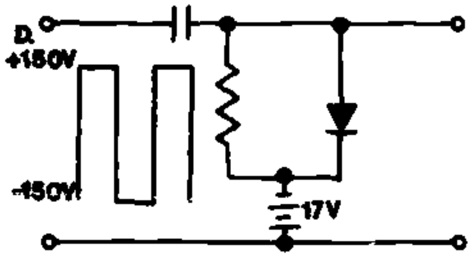
14. TEST FRAME

Identify by name each of the circuits illustrated below and draw the proper output waveform of each.





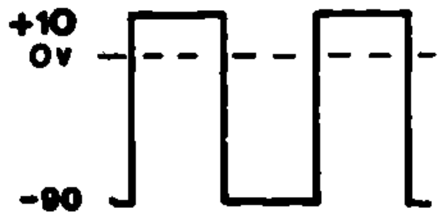




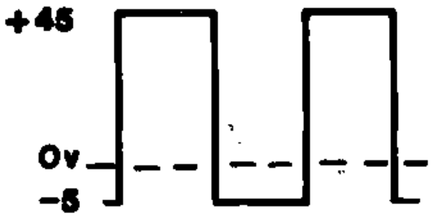
- -

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

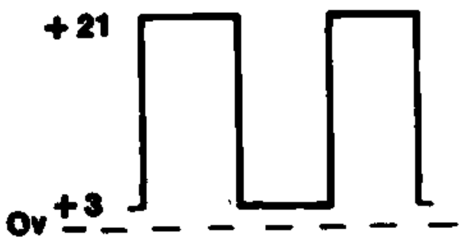
A. Negative clamper with positive bias.



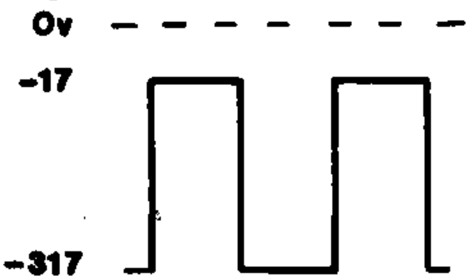
B. Positive clamper with negative bias.



C. Positive clamper with positive bias.



D. Negative clamper with negative bias.



IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON II, MODULE TWENTY FOUR. OTHERWISE GO BACK TO FRAME 12 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 14 AGAIN.

THIS COMPLETES THE PROGRAMMED INSTRUCTION FOR LESSON II, MODULE TWENTY FOUR.

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.

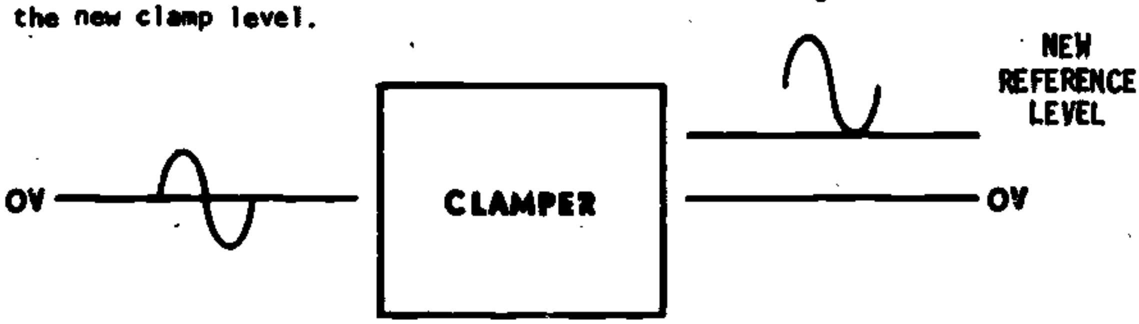
NARRATIVE
LESSON II

Clampers

This lesson deals with:

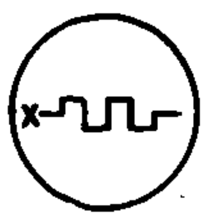
1. DC Restorer Circuits
2. Baseline Stabilizer Circuits
3. Clamper Circuits

Sounds like a lot of sophisticated circuits? Fortunately all three names describe the same circuit, so from here on out we simply will call them clamper circuits. Clamper is a name that better describes what the circuit will actually do for us. The clamper merely raises or lowers the reference level of the waveform and holds the signal above or below the new clamp level.



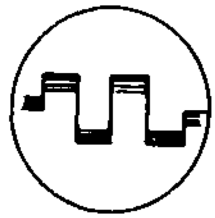
The lesson on clippers shows how we can modify any waveform by limiting the amplitude to a predetermined level. Another way of manipulating a waveform is by using a clamper. By the time we've finished wave shaping circuits you will see that we can do just about anything we want to a waveform.

Why are clampers important? To give you an idea, consider the line trace across the display of an oscilloscope. It always starts at the same point on the left side of the screen and travels across to the right side.



OSCILLOSCOPE DISPLAY WITH CLAMPER CIRCUIT

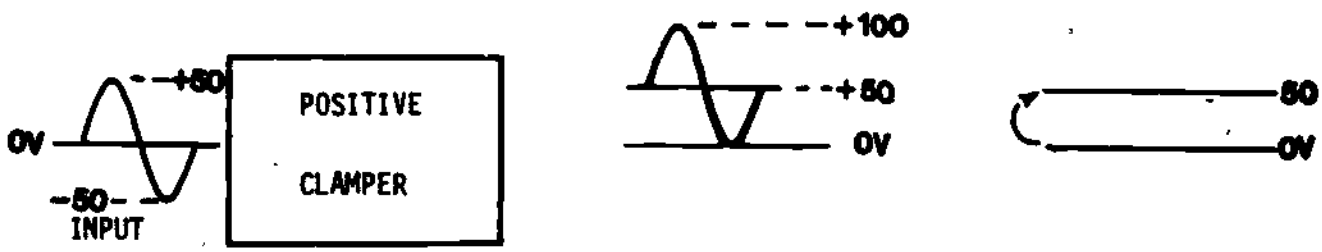
Clamper circuits ensure that the line trace always starts at the same point (X, this is our reference point). If we did not have a clamper circuit for holding the line trace, we could have had the following problem:



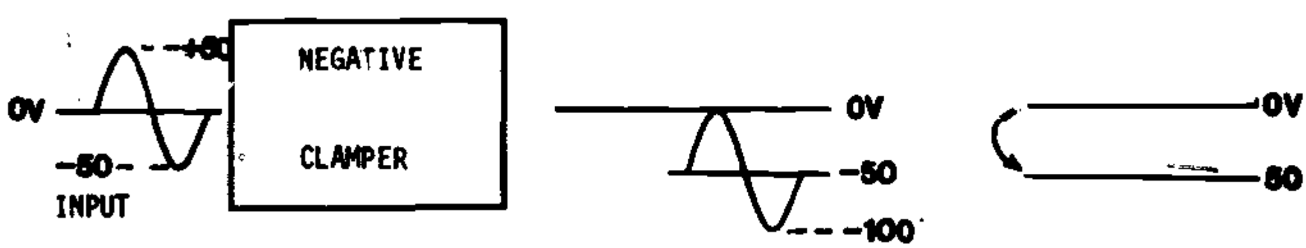
OSCILLOSCOPE DISPLAY WITHOUT A CLAMPER CIRCUIT

Without the clamper circuit, there is no guarantee that the line trace will start at the same point. So we could have many horizontal lines shifting up and down. This makes waveform analysis extremely difficult.

Basically, there are only two types of clampers, positive and negative.



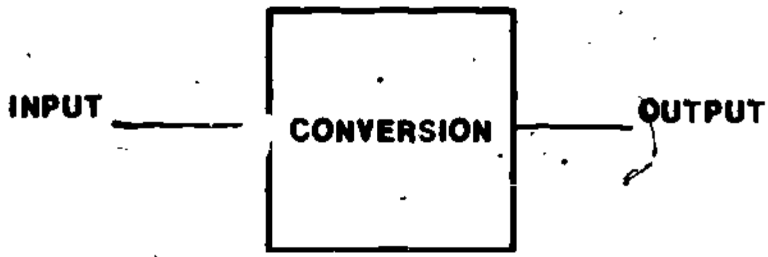
CONVERSION OUTPUT CLAMPER SHIFTED REFERENCE



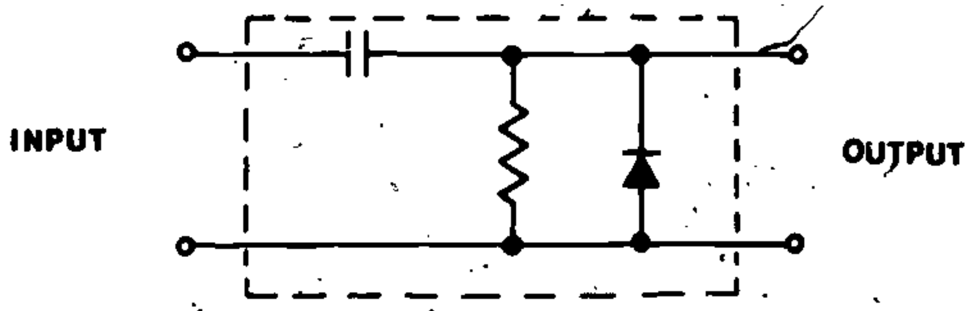
CONVERSION OUTPUT CLAMPER SHIFTED REFERENCE

Looking at the illustrations, you can readily see that a positive clamper converts a waveform ranging from -50V to +50V to a waveform which varies from 0V to +100V. The same input into a negative clamper changes the signal which varies from -50V to +50V into a signal that varies from 0V to -100V. Both positive and negative clampers do not change the shape or amplitude of the waveform, they simply put the waveform either above (positive) or below (negative) 0 volts. A clamper's input could be almost anything - - - square wave, sine wave, triangular wave or pulsed input - - - only the output reference will be shifted. Some students confuse clippers and clampers, but you won't, as long as you remember that clampers only shift reference levels while clippers change the waveform.

We've talked about input and output; this only leaves the conversion stage. Look at the illustration again.



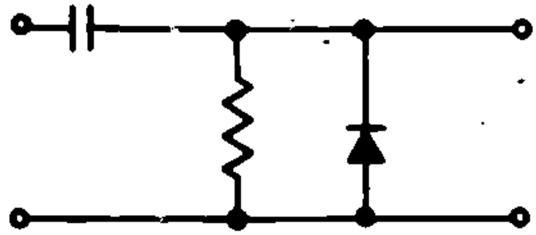
Assume the input amplitude varies from +1V to -1V. If you want a voltage amplitude of 0V to +2V, you'd use a positive clamper. Let's open up the conversion stage and gaze at the electronic circuitry that accomplishes this feat.



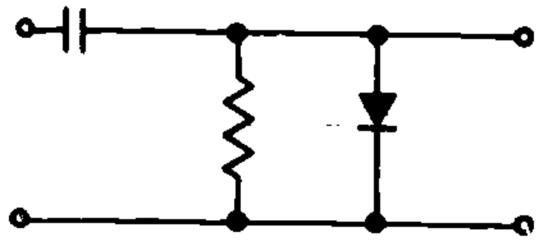
POSITIVE CLAMPER

This little marvel of electronic sophistication will not only convert sine wave inputs, but many other types of waveforms as well..

We have looked at a positive clamper. The negative clamper has the diode connected the other way. Take a look and compare the positive and negative clampers.



POSITIVE CLAMPER

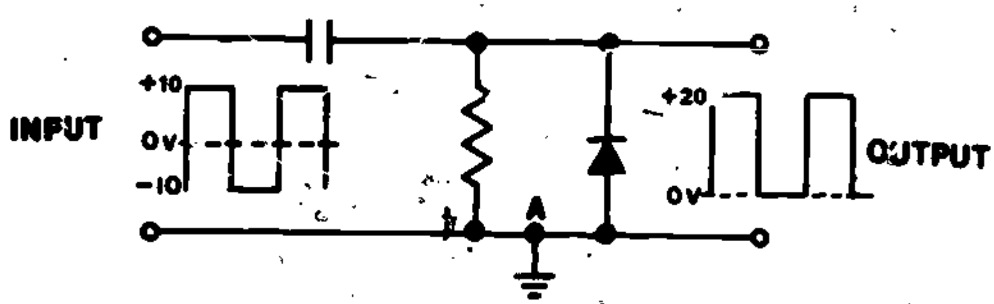


NEGATIVE CLAMPER

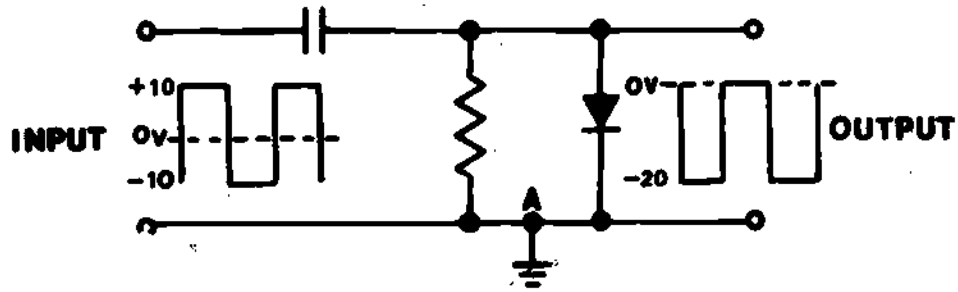
What makes this circuit "tick"? Well, it's all in time constants. The capacitor will charge quickly through the diode (short RC time constant), but it will discharge very slowly through the resistor when the diode is cut-off. In the positive clamper shown above, the diode will conduct and the capacitor will charge to the input signal's peak voltage whenever the top of the diode tends to go negative. When the input signal changes polarity the diode will cut-off and the sum of the signal voltage and capacitor charge will appear at the circuit output. The long RC time constant will hold the capacitor charge nearly constant, and the output signal will be entirely positive.

During the first cycle or two, the capacitor charges up to the reference voltage. After that, everything settles down to a nice clamped output. Since you are concerned mainly with how to recognize a malfunction and to repair that malfunction, you needn't worry at this stage of the game about why it works the way it does. If you are really concerned, you can refer to the P.I. for a more detailed explanation.

Now let's look at the difference between basic positive and negative clampers again. Here is a positive clamper - -

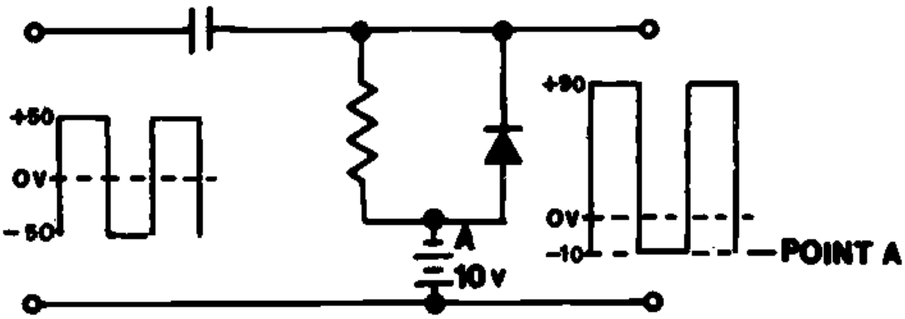


and here is a negative clamper - -

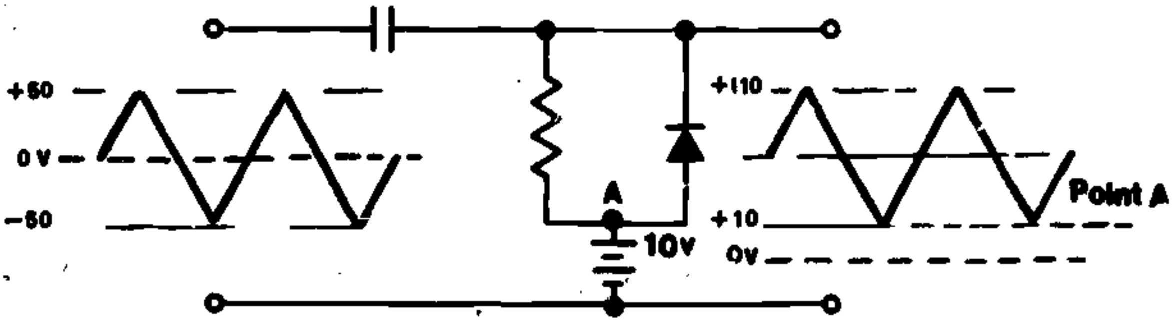


As you can see, the only difference is that the diode is turned around. Both circuits work the same way, using the RC time constants to clamp the waveform above or below the reference level. In this case, the reference is point A or ground. It works like another circuit you've had.

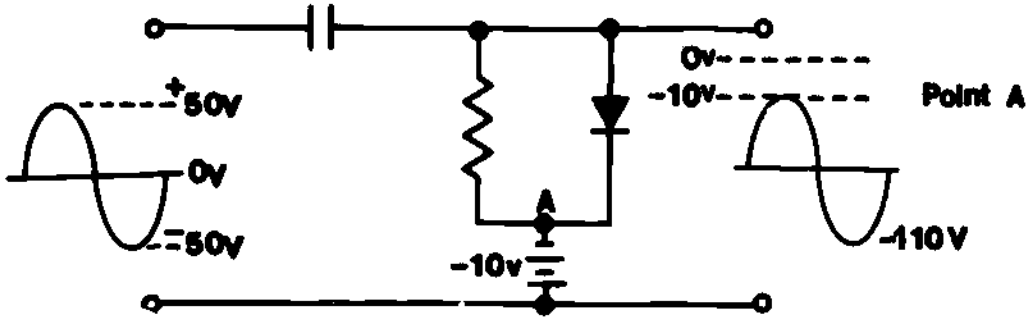
Remember when you placed a potential in the clipper-circuit? You can do the same thing in clampers. This is called a biased clamper. The amount of DC potential will always be the new reference level.



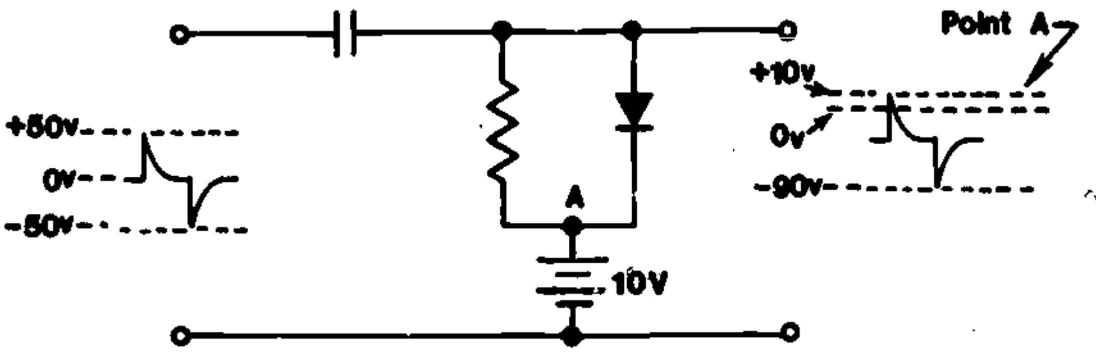
Each clamper (negative, positive) can have either negative or positive bias.



Positive Clamper With Positive Bias



Negative Clamper with Negative Bias



Negative Clamper with Positive Bias

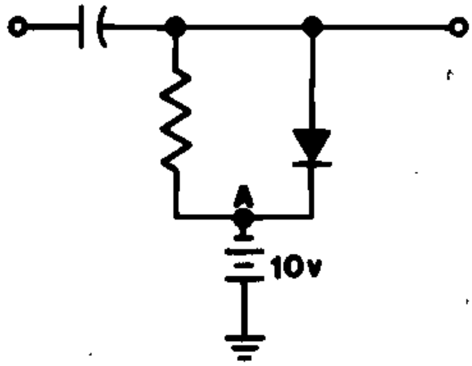
Want an easy way to tell which side of the reference line the waveform will be located? Look at the diode!

Points away from the reference (Point A) - Positive clamper waveform located above voltage at point A.

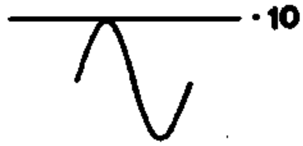
Points toward the reference - Negative clamper, waveform located below voltage at point A.

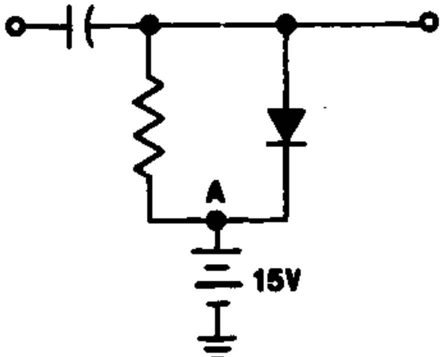
See how it works? If the symbol points up, the diode is a positive clamper and the total input waveform is located above point A's voltage. Point A's voltage can be positive, negative, or zero volts.

Let's analyze the following circuits:

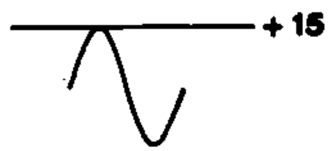


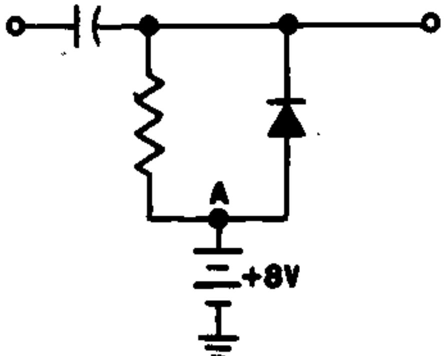
1) Diode points toward the reference negative clamper.
2) Point A = -10 volts.





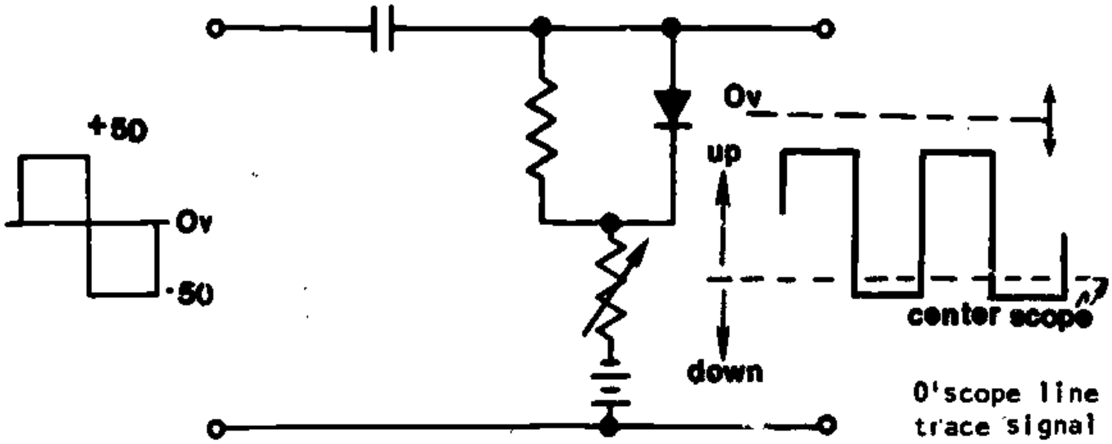
1) Diode points toward the reference - negative clamper.
2) Point A = +15 volts.





1) Diode points away from the reference - positive clamper.
2) Point A = +8 volts.

The clamper circuit with DC bias is simple. With one additional component, we'll understand how an oscilloscope can move the line trace up or down.

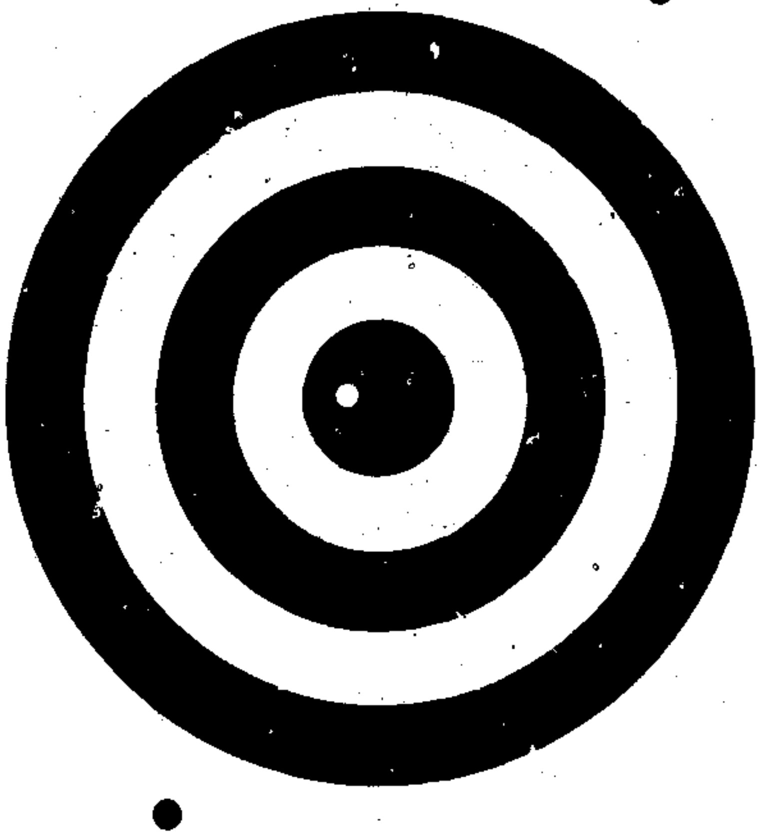


The output can be changed over a range from 0V to 100V to move the clamped signal anywhere we want to. The oscilloscope's line trace could, therefore, be moved up or down.

Circuits of this nature are used in radar systems, test equipments, electronic countermeasures systems, and sonar systems. In your role as a technician, you may encounter clamper circuits quite frequently, depending upon your equipment. In any event, the recognition of the clamper circuit, and knowing what output comes from what types of clamper, is extremely helpful in the ICO concepts of the interconnecting circuits. This working knowledge of basic circuits will make your job easier, and liberty call could come more often.

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.

SCORE WITH SAFETY!



ACCIDENTS COST MORE MORE THAN MONEY

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY FOUR

LESSON III

INTEGRATORS/DIFFERENTIATORS

1 APRIL 1977

ERIC

OVERVIEW
LESSON III

Integrators/Differentiators

This lesson deals with square wave shaping circuits. Although integrators and differentiators only contain two components, the relatively short or long time constant of these components produce completely different output waveforms. These new waveforms add to our growing list of possible "creations" from our basic sine wave and square wave.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

24.3.46 When the student completes this course, he will be able to IDENTIFY wave shaping circuits and their effects on input waveforms by matching an output waveform to a wave shaping circuit and its input waveform given input and output waveform illustrations and wave shaping circuit schematic diagrams.

ENABLING OBJECTIVE(S):

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

24.3.46.8 IDENTIFY by selecting, the schematics for RL and RC integrator and differentiator circuits, given a set of schematic diagrams. 100% accuracy is required.

24.3.46.9 ANALYZE the conversion action in RL and RC differentiator/integrator circuits, by matching given input and output waveforms to the correct schematic diagram, with 100% accuracy.

24.3.46.10 DIFFERENTIATE "long" and "short" time constants of RL and RC circuits used as integrators differentiators, given five time statements, an RC circuit and an RL circuit, and selecting the best statement of relative time constant length. 100% accuracy is required.

OVERVIEW

24.3.46.11 OBSERVE, INTERPRET, and RECORD the effects of varying the time constant or an RC differentiator circuit, given a training device/circuit, an oscilloscope, and a job program. Recorded observations to fall within tolerances stated in the job program.

24.3.46.11.1 LOCATE and IDENTIFY integrator and differentiator components installed in equipment, given a training device or circuit boards containing integrator/differentiator circuits and circuit schematic diagrams or technical manuals and a job program. 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 III

Integrators/Differentiators

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 Four-III-1 "Introduction to Integrators"
Job Program Twenty Four-III-2 "Introduction to Differentiators"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Four-III "Introduction to Integrators and Differentiators"

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVPERS 0967-000-0120

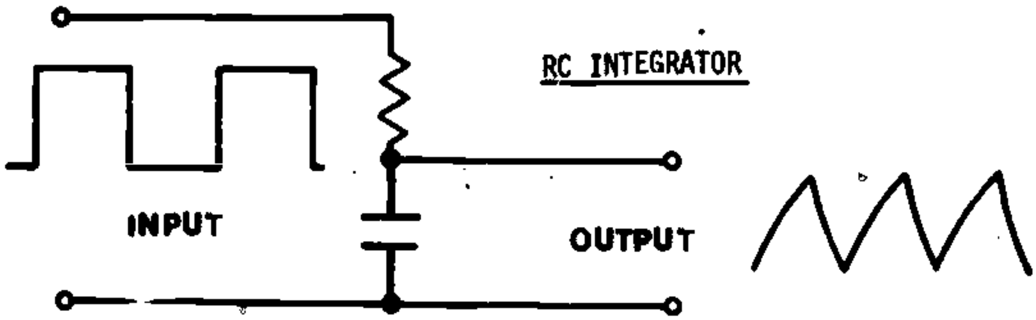
YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

ERIC

SUMMARY
LESSON III

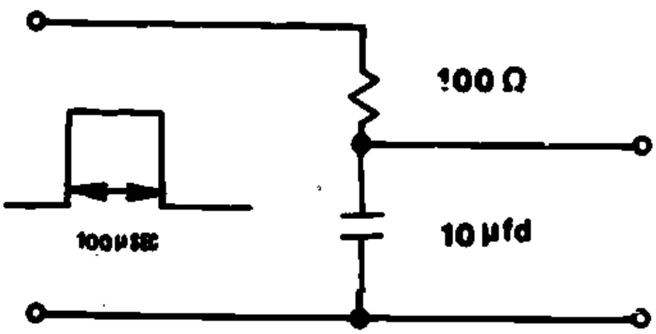
Integrators and Differentiators

In this lesson we will discuss integrators and differentiators. These circuits are used for waveshaping; both have square wave inputs. Integrators have triangular waveforms for outputs.



RC INTEGRATOR

The output is taken across the capacitor. The time constant of the RC network is long with respect to the time of the input pulse width. The time constant will usually be 10 times or more longer than the input pulse width.



RC Integrator

$T = RC$

$= 100 \times 10 \times 10^{-6}$

$= 1000$ µsec

$= 1$ msec

RC INTEGRATOR

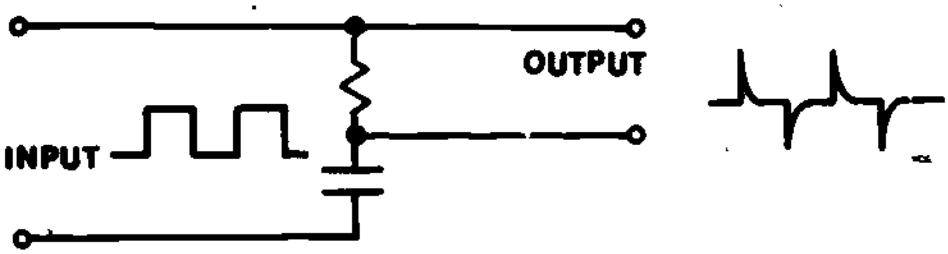
In short, RC integrators have the following characteristics:

1. Square wave input - triangular output.

2. The output is taken across the capacitor.

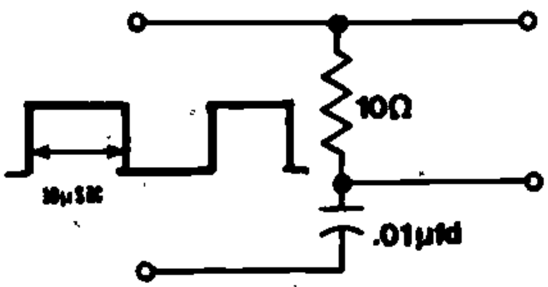
3. RC time constant is long with respect to the input width; usually 10 times or more longer.

This lesson also concerns itself with differentiators. Differentiators are the opposite of integrators. Differentiators also have a square wave input but produce spiked or peaked waveform outputs.



RC DIFFERENTIATOR

The output is taken across the resistor. The time constant is short with respect to the input pulse width. The time constant will usually be 10 times or more less than the input pulse width.



$TC = RC$

$= 10 \times .01 \times 10^{-6}$

$= .1$ µsec

RC DIFFERENTIATOR

The characteristics of an RC differentiators are:

1. Square wave input; spiked or peaked waveform out.
2. The output is taken across the resistor.
3. The RC time constant is short (usually $\frac{1}{10}$ or less) with respect to the input pulse width.

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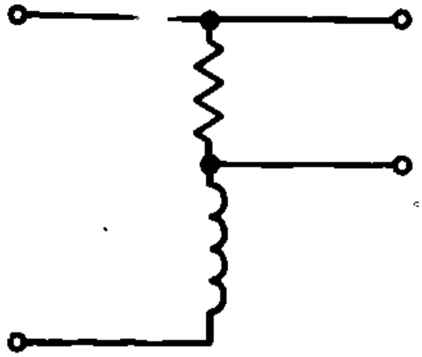
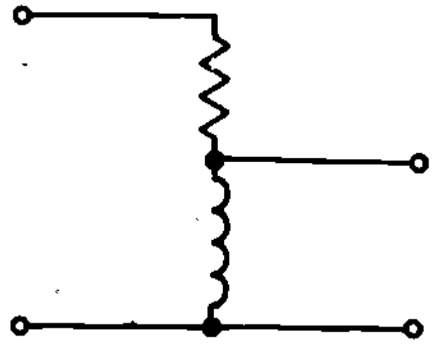
There are also L/R differentiators and integrators, because at low frequencies capacitors must be very large and this is not practical.



L/R INTEGRATOR



L/R DIFFERENTIATOR

The characteristics of the L/R integrator and differentiator are the same as the RC circuits, except inductors are used instead of capacitors and the outputs are taken from different points. The L/R integrator output is taken across the resistor and the differentiator's output is taken across the coil.

Another difference is the method in which time constant is figured.

The inductance is divided by the resistance, $Tc = \frac{L}{R}$, instead of multiplied like the RC.

The following jingle may help you remember the type of outputs integrators and differentiators produce.

I saw D spikes.

I = integrator = sawtooth waveform.

D = differentiator = spikes (peaked waveform)

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.

...The Only Thing Between You and The Deep Six!

ERIC
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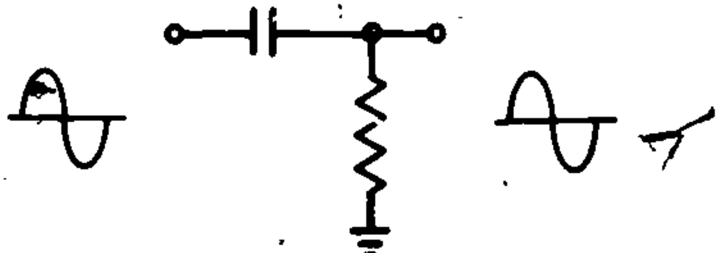
PROGRAMMED INSTRUCTION
LESSON III

Integrators and Differentiators

TEST FRAMES ARE 8 AND 11. GO TO FRAME 8 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS AT THE END OF FRAME 8.

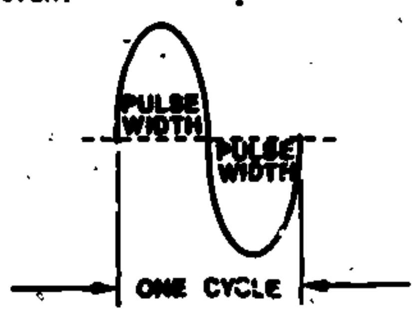
1. Integrators and differentiators are complex names for very simple circuits. You already have all the theory you need to understand how they work. It is only the application of this theory that will be new. For example, you are familiar with RC coupling used to transfer signals into and out of an amplifier. You also know about time constants. Integrators and differentiators are nothing more than a resistor and capacitor with different time constants.

Let's take something you've already learned first - - - RC coupling.



RC COUPLING

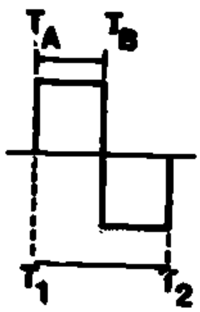
The waveform is not changed because of the relationship between the time constant and pulse width. The time constant must be long compared with the pulse width. That statement may not be very clear so let's look at the following illustration:



The pulse width is the time it takes to complete a half cycle. The time it takes to complete one cycle is called the period.

$\frac{1}{PERIOD}$ = Frequency

$\frac{PERIOD}{2}$ = Pulse Width



1. T_A to T_B = Pulse Width
2. T_1 to T_2 = Period
3. Number of Cycles = Frequency

If the period is .5 seconds, the pulse width is ____________ and the frequency is ____________.

- -

.25 seconds; 2Hz (in that order)

2. Let's find the RC time constant of a 500KΩ resistor and a 10μf capacitor.

The time constant of an RC circuit is equal to:

The resistance times the capacitance
(R) (C) = One Time Constant

Tc = 500 K X 10 μfds

$= .5 \times 10^{+6} + 10 \times 10^{-6}$

$Tc = 5 \times 10^{0}$ or 5 seconds

In our example, we see it takes 5 seconds for the capacitor to charge to 63.2% of source amplitude. We know that five time constants equals the time it takes for the capacitor to fully charge. So if one times constant is 5 seconds, the capacitor will take 25 seconds (5 X 5) to fully charge.

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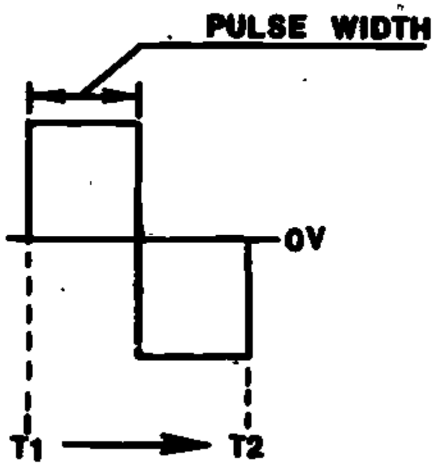
If our resistance equals 5 M Ω and capacitance equals 1 μfd, what is the time constant?

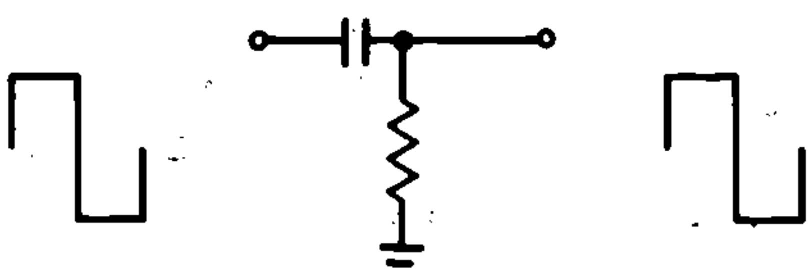
- -

$TC = 5 \times 10^{6} + 1 \times 10^{-6}$ $= 5 \times 10^{0}$ or 5 seconds	Same result with different values.

3. If we have a waveform whose pulse is .5 seconds, our RC time constant of 5 seconds will allow the waveform to pass without changes.



1. T1 to T2 = 1 second = period
2. Pulse Width = .5 seconds
3. RC time constant must be long compared with pulse width; in this case 10 times.



The ____________ must be at least 10 times greater than the ____________ for the square wave to pass unchanged.

- -

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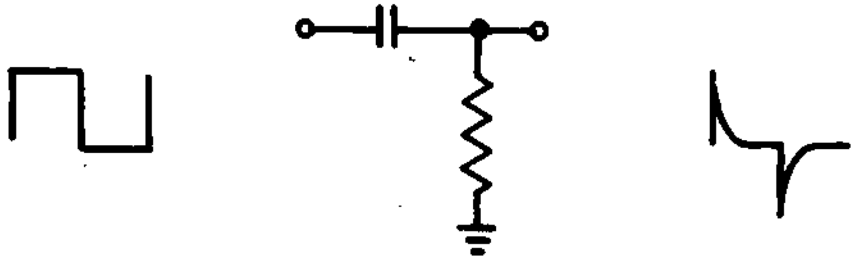
4. Now, if the RC time constant is reduced by a hundredth or equals .05 seconds, what will happen to the square wave?



The output will be spikes. The capacitor charges and discharges very quickly compared to the pulse width. So when we have a time constant that is 1/10th or less the input pulse width, the circuit is called a differentiator.

Match the following columns:

1. RC coupling — A. Short time constant
2. Differentiator — B. Long time constant

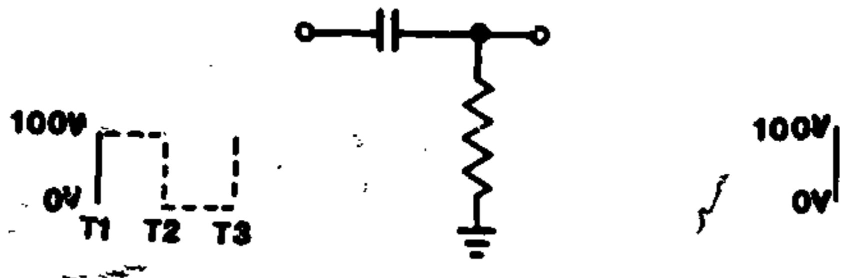
- -

1. B; 2. A

5. Let's break the input waveform into parts and see how it works.

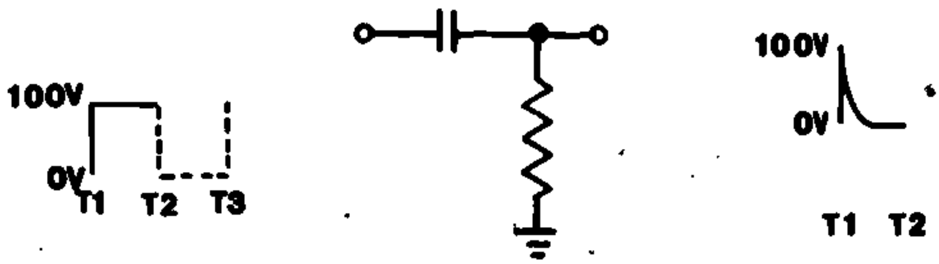
Look at T1 in the figure below.

The input voltage changes very rapidly from 0 to 100V at T1. This rapid change "sees" the capacitor as a short circuit. All voltage is dropped across the resistor.



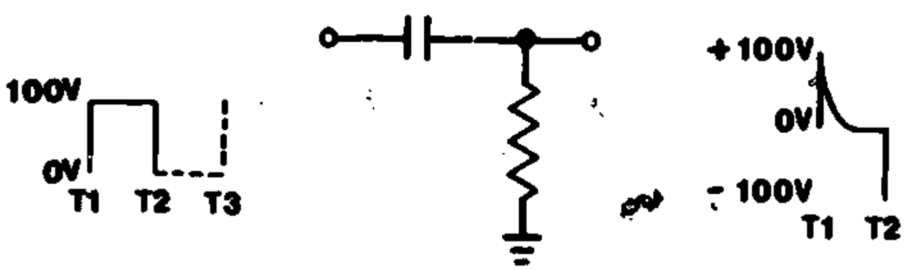
Now look at T1 to T2.

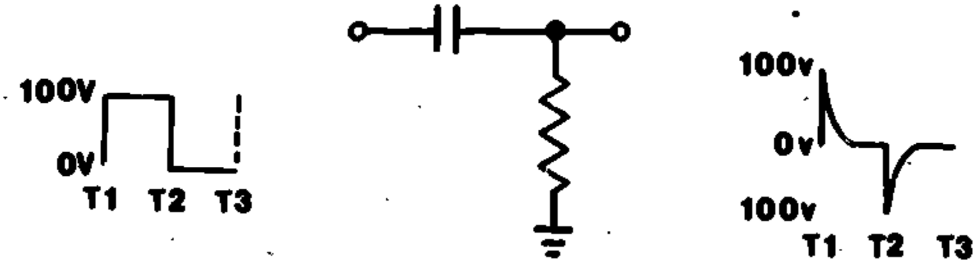
The short time constant allows the capacitor to charge quickly to +100 volts. The voltage across the resistor drops to zero.



Now look at T2.

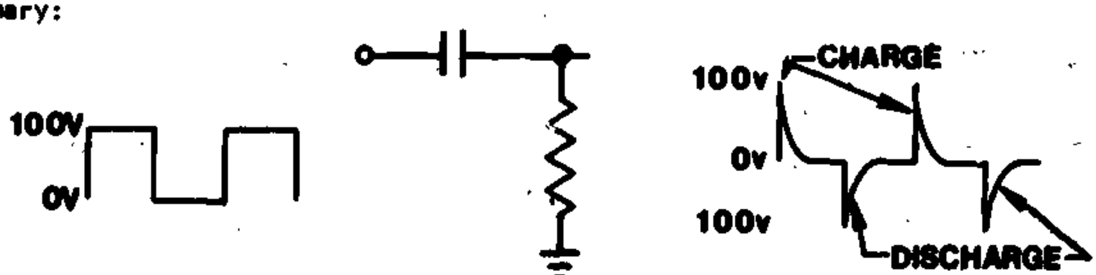
The input waveform drops from +100V to 0V at T2. This is a negative-going change. The output goes from 0 volts to -100 volts. The output momentarily feels the charge on the capacitor.





During T2 to T3 the capacitor quickly discharges back of 0V.

In summary:



If the input never goes more negative than 0 volts, why does the output go to -100 volts?

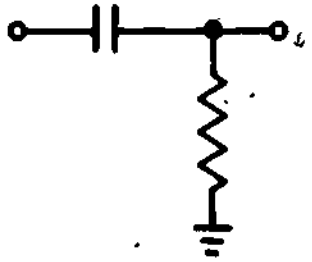
When the input goes negative it changes by 100 volts. The entire change will be felt across the output so the output must also change by 100 volts. Since the output starts its change at 0V it ends up at -100V. (or words to that effect)

---

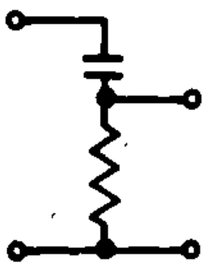
6. We have discovered that a differentiator is like an RC coupling circuit with a time constant that is one-tenth of the pulse width of the input waveform. The output of the circuit is taken across the resistor. Sometimes the circuit is drawn slightly different but the function will not change.

Select the circuits that are <u>NOT</u> differentiators.

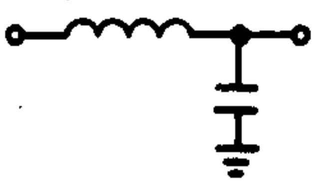
A.



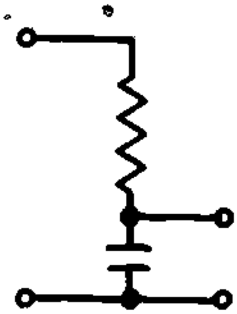
B.



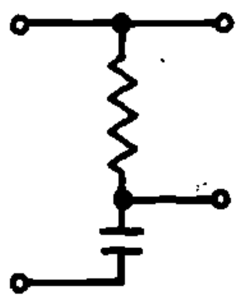
C.



D.

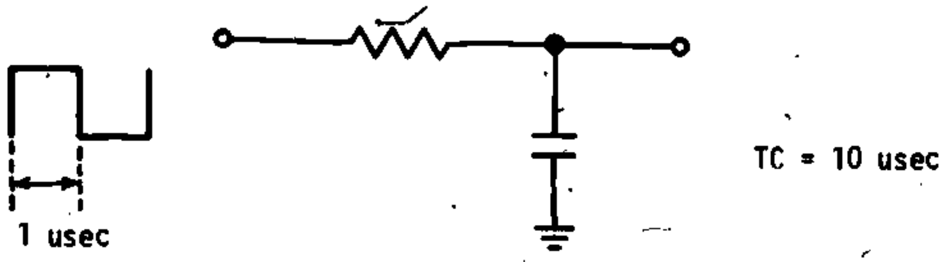


E.



C, D

7. So far, we've talked about RC circuits with the output taken across the resistor. Now let's talk about RC circuits with the output taken across the capacitor. This circuit is called an integrator and the RC time is usually long (at least 10 times the input pulse width).



The figure above shows a (long/short) time constant.

---

long

8. TEST FRAME

From the two lists below select one statement from each that best identifies:

an integrator ______________; a Differentiator ______________

1. RCT = 1/10 Pulse Width
2. RCT = Pulse Width
3. RCT = 10 X Pulse Width

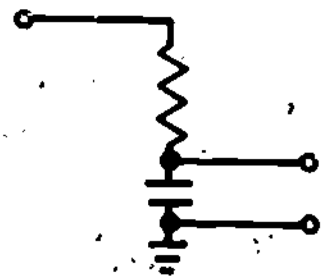
a. Output taken across the resistor.
b. Output taken across the capacitor.

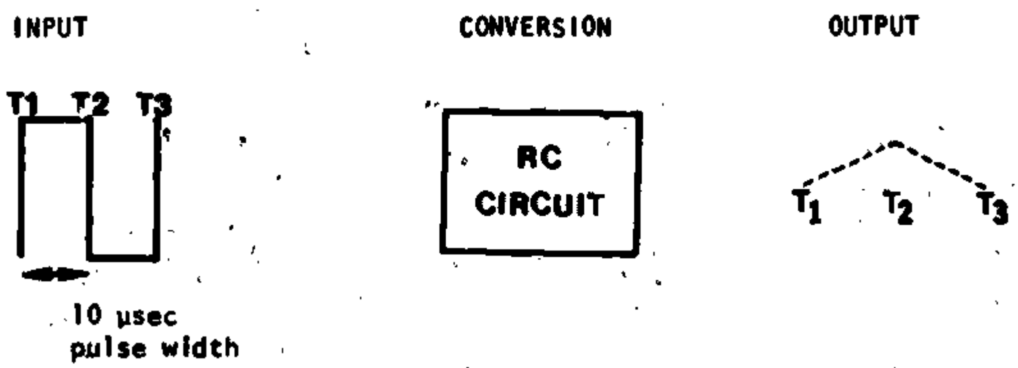
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

an Integrator __3B__ ; a Differentiator __1A__

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, GO ON TO TEST FRAME 11. IF NOT, GO BACK TO FRAME I AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 8 AGAIN.

9. The integrator circuit's time constant is far longer than that of the input pulse width. Look at the following illustration:





Pulse width = 10 µsec

COMBINING INPUT AND OUTPUT

Solid Line = Input waveform

Dotted Line = Output waveform

The same type of thinking applies to integrators that applies to differentiators. The integrator's longer time constant means it takes longer to charge and discharge. The resultant waveform is called a triangular waveform.

TRIANGULAR WAVEFORM

If the pulse width is 1.23 µseconds, what must the TC be if you want an integrator? ____________ differentiator? ____________

12.3 µsec = integrator; .123 µsec = differentiator

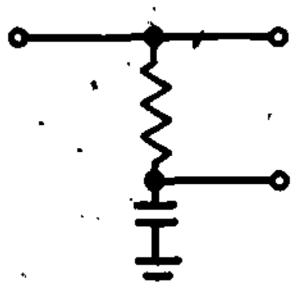
10. It would make sense that if we can use the RC circuit's time constant to change a square wave, we should also be able to use the L/R circuit. RC circuits are used about 80% of the time because they are cheap and easy to use. L/R circuits cost more and take up a lot more space. However, at very low frequencies the capacitor size gets very large, so we use L/R circuits.

LOW FREQUENCY USES L/R CIRCUITS

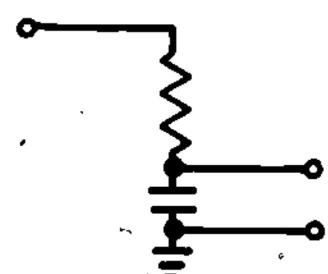
Another place to use L/R integrators and differentiators is with tuned or transformer coupled circuits. We simply insert a resistor with the inductor or transformer to get the waveform we need.

The major difference between the L/R and RC circuits is where you take the output from.

In RC circuits:

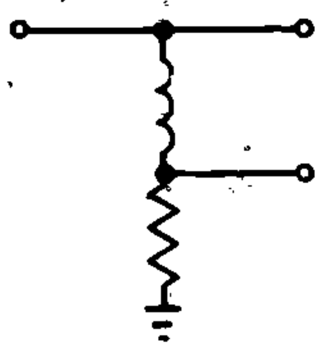


DIFFERENTIATOR
(Across the resistor)

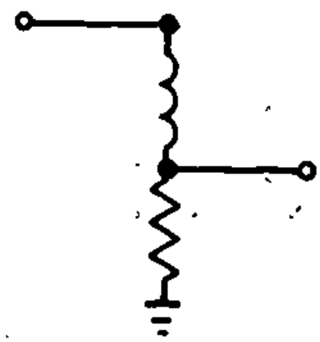


INTEGRATOR
(Across the capacitor)

In L/R circuits:



DIFFERENTIATOR
(Across the coil)



INTEGRATOR
(Across the resistor)

RC Differentiators have a (long/short) time constant. L/R Differentiators have a (long/short) time constant.

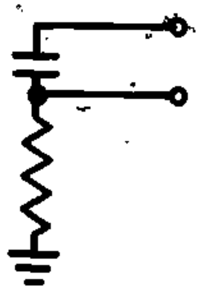
- -

short; short (in that order)

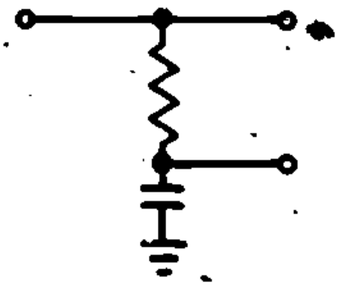
II. TEST FRAME

Identify the circuits illustrated below by name:

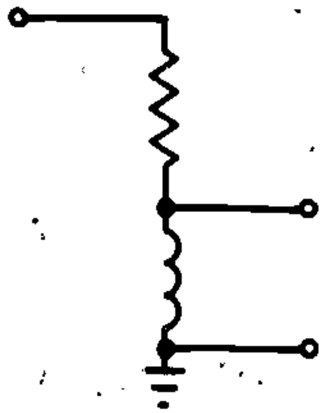
1.



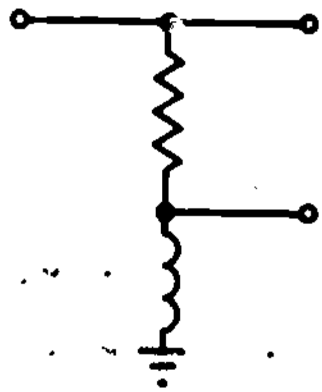
3.



2.



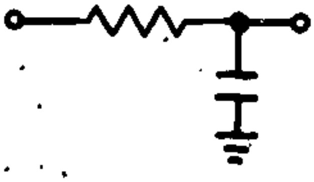
4.



Correctly match the waveform to the circuit which will produce it:

A.  B.  C. 

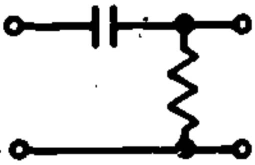
All waveform pulse widths = 2 seconds.

5. 

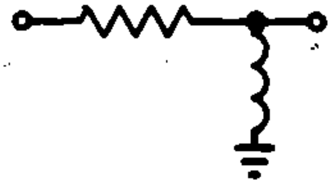
TC = 20 sec

7. 

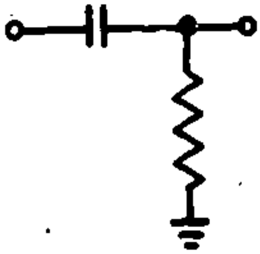
TC = 20 sec

6. 

TC = 0.2 sec

8. 

TC = 0.2 sec

9. 

TC = 20 sec

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

1. Integrator
2. Differentiator
3. Differentiator
4. Integrator
5. C
6. B
7. C
8. B
9. A

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON III. MODULE TWENTY FOUR. OTHERWISE GO BACK TO FRAME 9 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

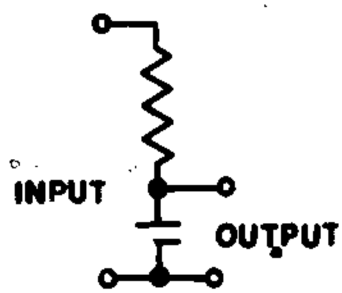
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN 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 III

Integrators and Differentiators

Let's look at a couple of very simple circuits. Both circuits have the same components - - - - - resistors and capacitors.

The first circuit we will look at is an integrator.



RC Integrator
Figure 1

As you can see, this is a series RC circuit, and the output is taken across the capacitor. The input to an integrator will be a square wave and the output is a sawtooth wave.

Figure 2

We put in a square wave and get out a sawtooth wave. What would we ever want with a sawtooth wave? The signal that causes the horizontal sweep in an oscilloscope is a sawtooth waveform. The amplitude of the sawtooth waveform determines how wide the CRT's display will be.

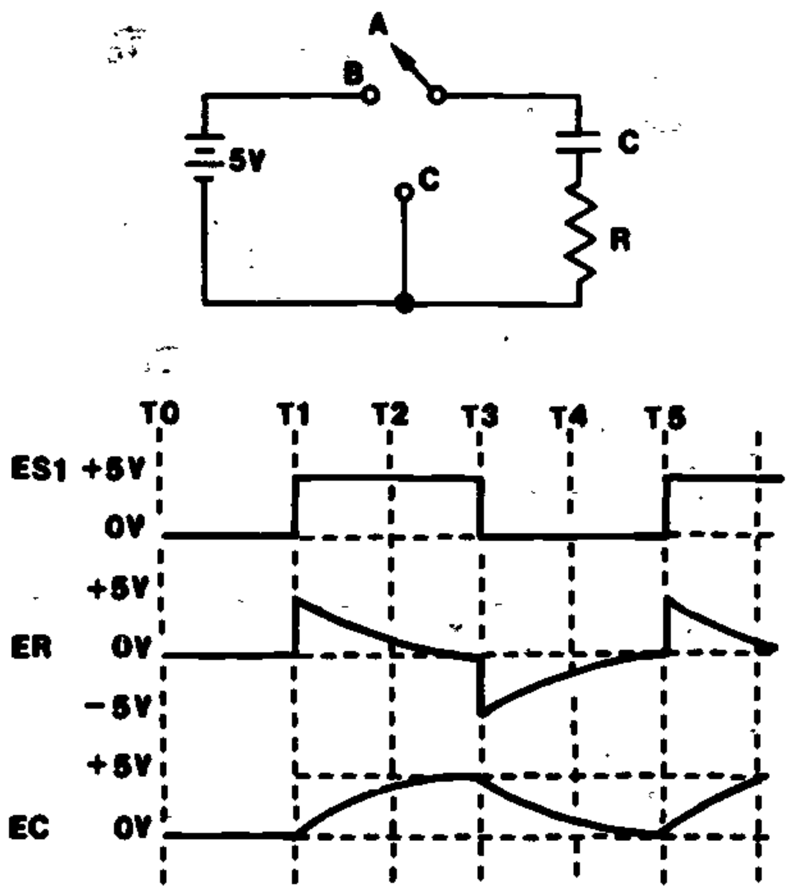


Figure 3

Let's review how time constants affect the voltage across each component in a series RC network. Look at the waveforms and schematic in Figure 3. At time (T_0) the switch (S1), is opened and there is no voltage on its moveable arm. Also, with (S1) open there is no current flow in the RC network. With no current flow we will not have any voltage dropped across the resistor (R) or the capacitor (C).

As soon as we move the switch (S1) to position B at time T1, we instantaneously feel +5V across the resistor. The capacitor acts like a short circuit and drops 0V. As time passes, the capacitor begins to charge, and drops more and more voltage and the resistor drops less and less. At time T3 the capacitor is fully charged and we feel 0 volts across the

Now, if we put S1 to position C, the capacitor is charged to 5V. The resistor instantaneously feels the entire charge (T3). As the capacitor starts to discharge (T3 to T5) less and less voltage is felt across the resistor. At (T5), the capacitor is fully discharged and we have 0 volts across both the capacitor and the resistor. Moving the switch back to position B (T5) will start the cycle over again.

To take on a full charge, 5 time constant are required. To discharge completely it also takes 5 time constants. The longer the time constants, the more time it takes the capacitor to fully charge and discharge. In an integrator the output is taken across the capacitor. If the capacitor is allowed to charge for five time constants the output will look like waveform EC (Figure 3). A good sawtooth wave on the other hand should not be curved. What we do in an integrator is to make the RC time constant long (10 times) compared to the pulse width of the input signal.

An RC integrator is illustrated below. Right away you can see the circuit has a resistor and a capacitor, and that the output is taken across the capacitor.

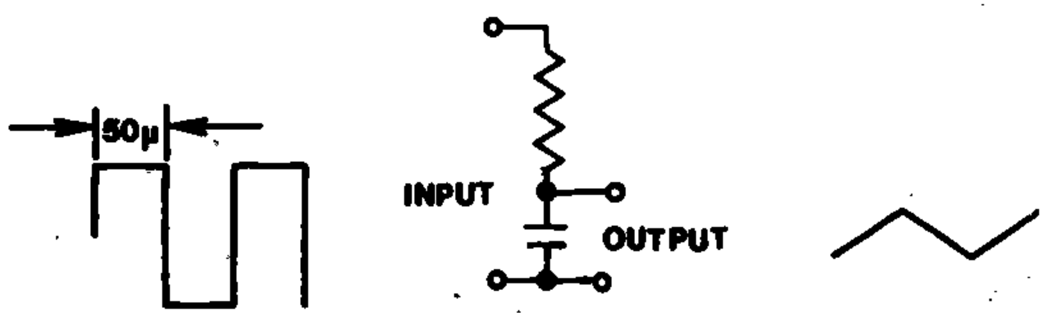


Figure 4

A pulse is the time the signal takes to complete one half cycle. In the above illustration the pulse width is 50 μsec. If this input pulse width is one tenth or less of the RC network time constant, then you can say you have a long time constant. What this means is that we allow the capacitor to charge for only 1/10 of the RC time constant. This will give us a better sawtooth.

Now, let's give the network some values - - -

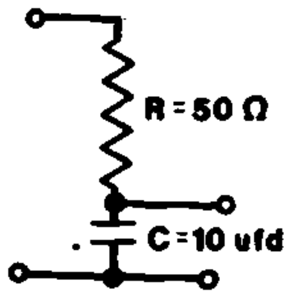


Figure 5

With a little mathematics it can be seen that the RC network has a long time constant with respect to the input pulse width.

$Tc = RC$
$Tc = 50 \times 10 \times 10^{-6}$
$Tc = 500\ \mu sec$
Input Pulse Width - $50\ \mu sec$ =
RC time constant = $10 \times$ Pulsewidth

Now that we have established that this is an integrator, let's apply an input and see what happens.

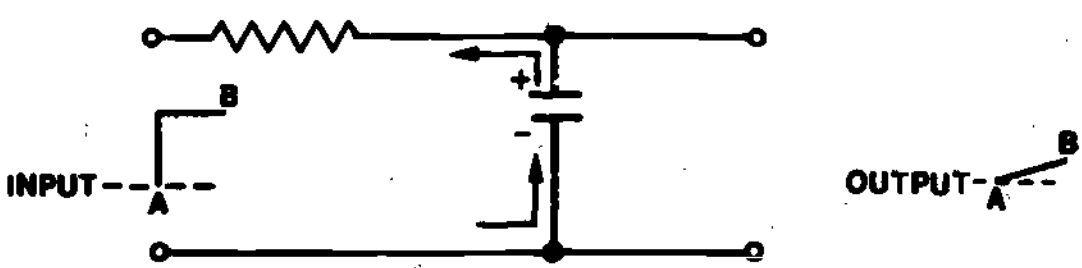


Figure 6

When the input pulse starts going positive (A to B) the capacitor starts to charge - - very slowly (A to B). We get the start of a sawtooth wave in our output.

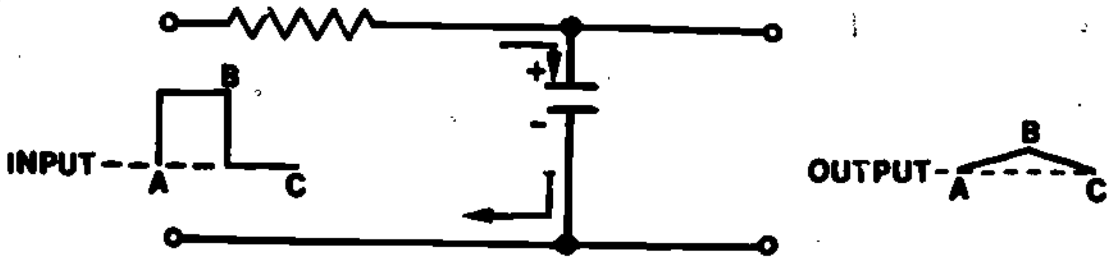


Figure 7

As soon as the input pulse stops going positive (B to C) the capacitor stops charging and starts to discharge - - - very slowly (B to C). A triangular wave appears at the output. Some other circuit components must be used if the fast retrace of a sawtooth wave is to be generated.

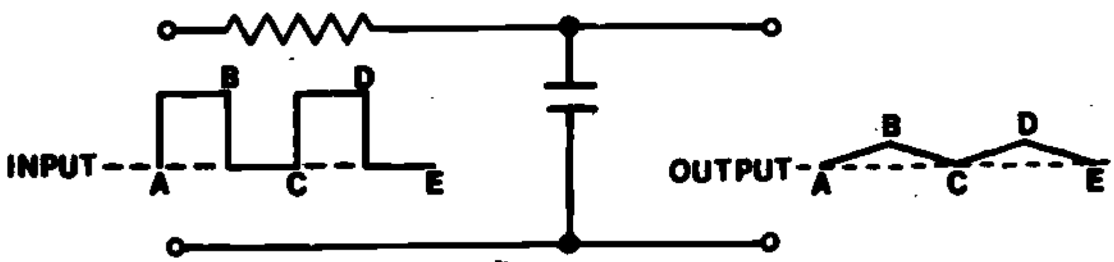


Figure 8

During the next half cycle, the charging and discharging process repeats itself.

We may see different shapes of output waveforms, dependent upon the length of the RC time constant. Below are some examples of integrated waveforms you may see.

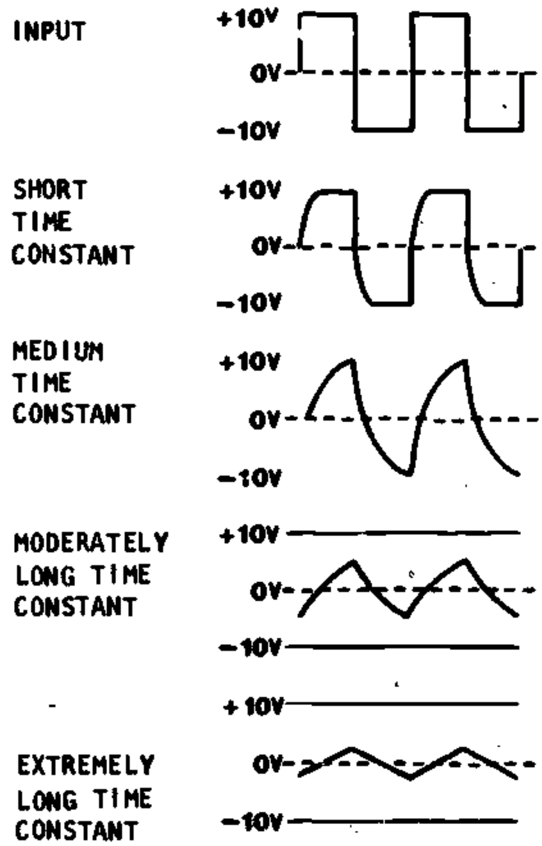


Figure 9

Now let's review what we know about integrators.

1.) The output is taken across the capacitor.

2.) The RC time constant is long with respect to the input pulse; usually 10 times or more.

3.) We put a square wave in and get a triangular wave out.

As you can see, wonders can be done to the output waveform by just varying the length of the time constant. Integrators are used in timing circuits, test equipment, communication systems, navigation systems and radar systems.

Okay, now that we've taken an input signal and integrated it,

Figure 10

let's take an input signal and differentiate it. Integrating a signal is like taking it and stretching it out. A differentiator output can be like a Volkswagen caught between two Mack trucks - squashed.

We use differentiators to provide a spike or peaked waveform for timing or synchronizing purposes.

Figure 11

If you think about it a minute you can see that differentiation is the direct opposite of integration. RC integrators have long time constants and the output is taken across the capacitor. RC differentiators have short time constants and the output is taken across the resistor.

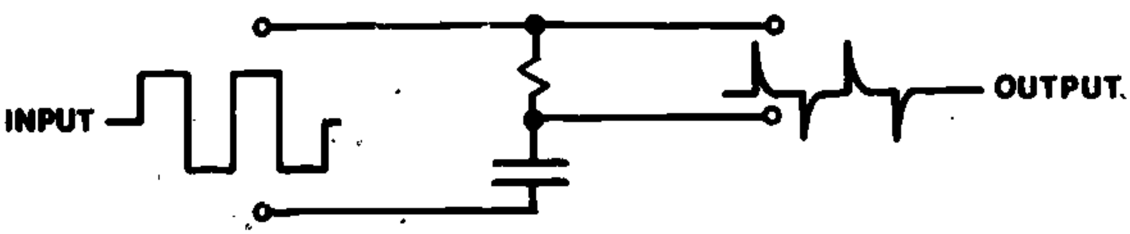
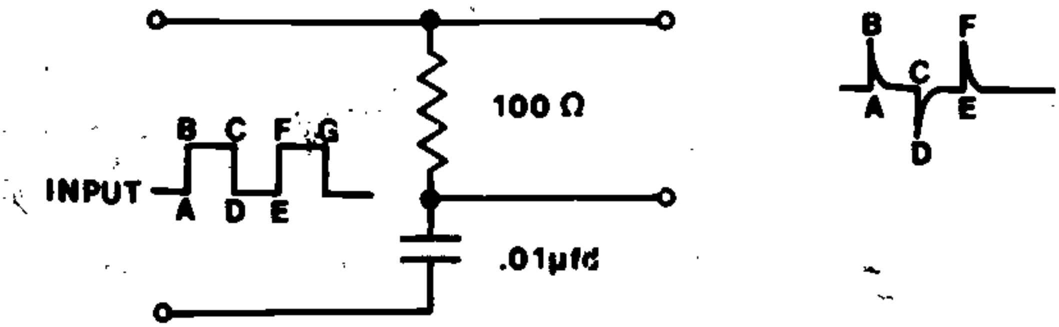


Figure 12

The time constant of a differentiator will be 1/10 or less than the time of the input pulse width.

Let's take our differentiator, give the components some values, and see what happens. Differentiators have very short time constants, so the capacitor will charge to the source voltage almost instantaneously when the input signal is first applied.



$$TC = RC$$
$$= 100 \times .01 \times 10^{-6}$$
$$= 1 \text{ usec}$$

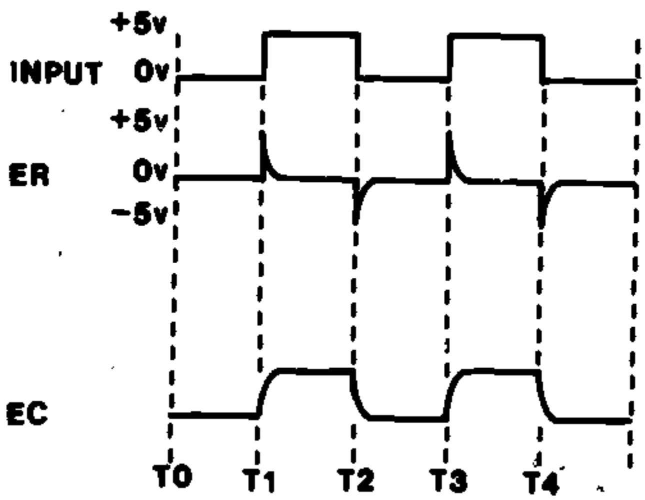


Figure 13

With an RC time constant of 1 µsec and an input pulse width of 10 µsec we can see that the RC time is 1/10 of the input pulse width. This tells us we have a differentiator.

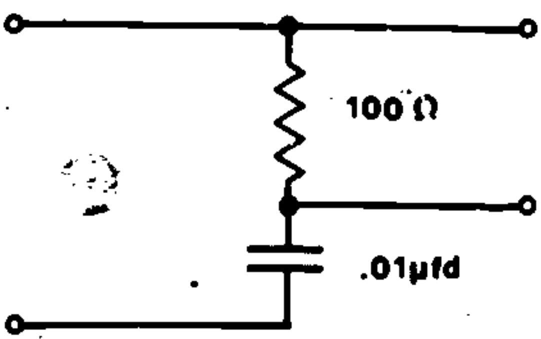


Figure 14

At time T1 as the input goes positive (A to B) the capacitor acts like a short circuit and all the voltage is dropped across the resistor (A to B in the output).

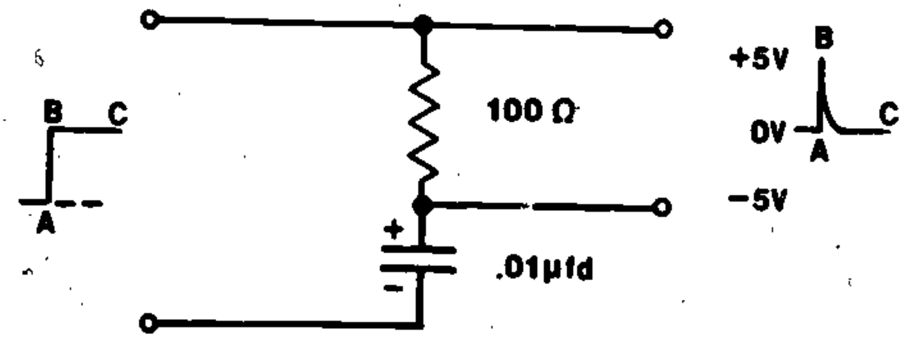


Figure 15

You can see that the circuit has a short time constant with respect to the input pulse width. It will charge very quickly to the value of source voltage and there will be no output (B to C).

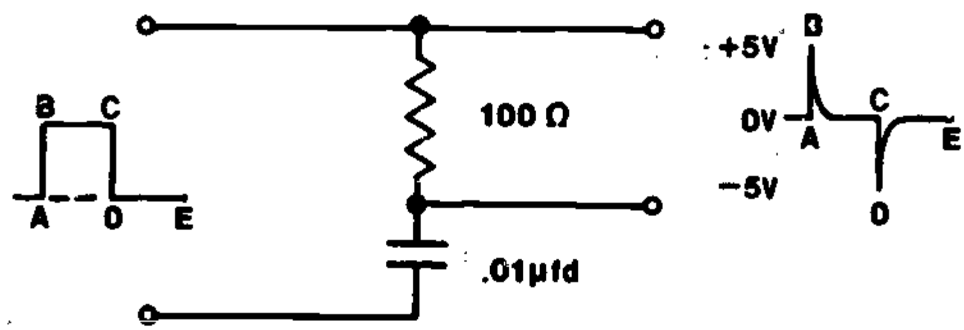


Figure 16

At time T2 when the input goes to zero (C to D in the input) the voltage change across the capacitor is felt instantaneously across the resistor. The capacitor then discharges very quickly (D to E in the output). Now we'll look at a complete cycle of the input and see what our output looks like.

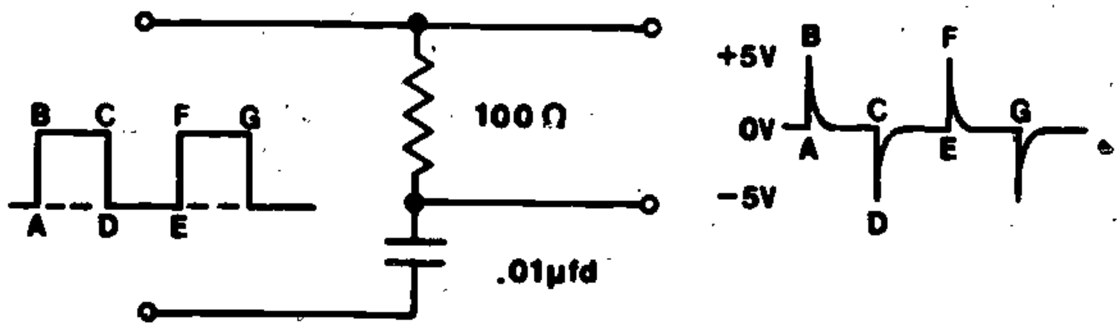


Figure 17

Remembering Kirchoff's voltage law, we know that "The Algebraic sum around any closed loop is equal to zero." We see that the output ranges from +5V to -5V. The reason for this is that after the capacitor is charged, it acts like e source when it discharges. If we calculate the voltage drops across each component during each portion of the cycle we will find that the algebraic sum is still equal to zero.

We should know now that, like in integrators, various wave shapes can be obtained by varying the time constant of our differentiator. Some of the wave shapes we may see are represented below:

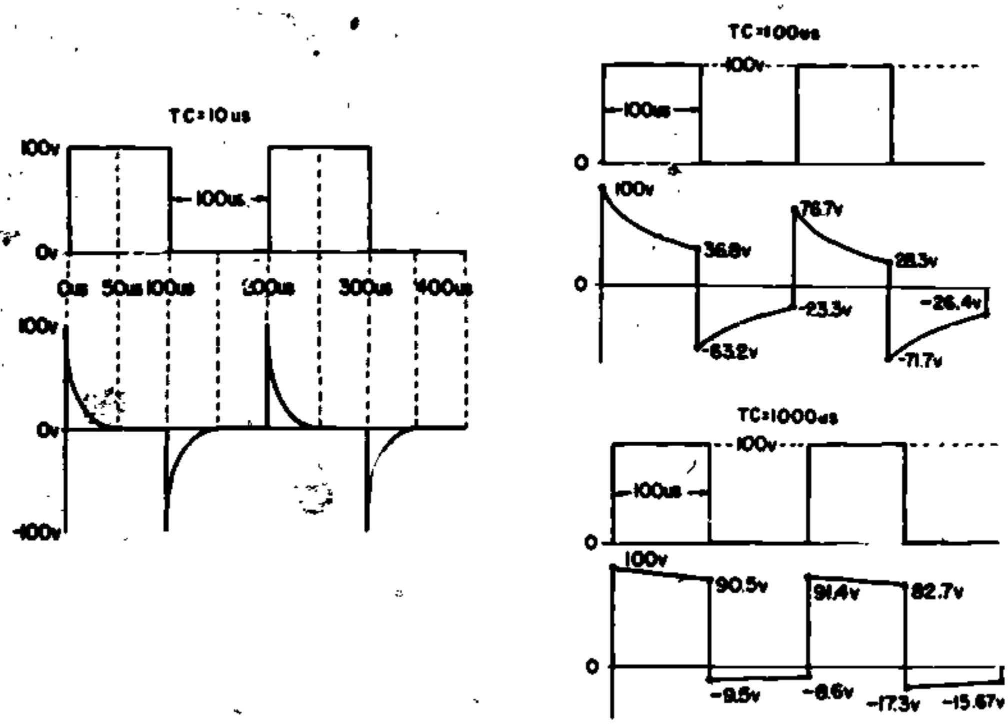


Figure 18

A few things to remember about a differentiator are:

1. The output is taken across the resistor.

2. The RC time constant is short with respect to the input pulse width; usually 1/10 or less.

3. We put a square wave in and get a spike or peaked waveform out.

We have seen how RC integrators and differentiators operate. There are also integrators and differentiators that use active devices such as tubes and transistors to do the job for us.

L/R circuits may also be seen. An L/R circuit is often used as an integrator. L/R integrators have the same function as the RC integrators; they both produce triangular waveforms. The output of an L/R integrator is taken across the resistor.

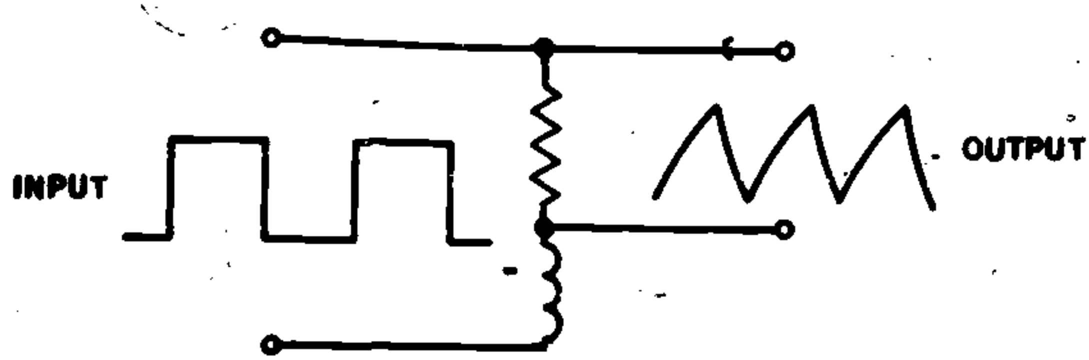


Figure 19

The reason we use an L/R configuration is because at low frequencies in an RC network, we would need to use such a large capacitor that it wouldn't be practical. We could also put a resistor in series with a coupling transformer. We would then have either an integrator or a differentiator, depending upon the size of the resistor. Let's see how these L/R circuits operate.

Remember how a coil (inductor) reacts the instant a voltage is applied? Of course, it acts like an open circuit. It allows very little current to pass through it and consequently, almost all of the input voltage is dropped across it. As time passes, the coil allows more current to flow in the circuit and the voltage across the coil decreases. According to Kirchoff, when one voltage in a series circuit decreases, another must increase. If the voltage across the coil decreases, the voltage across the resistor must increase. This action, coupled with a long time constant, will give us an integrated output.

To summarize, let's restate a few points. Integrators have long time constants. Ten (10) times or more than the input pulse width. There are two types - - RC and L/R. In the RC integrator, the output is taken across the capacitor. In the L/R integrator, the output is taken across the resistor. Integrators are wave shaping networks used in switching circuits, test equipments, and other electronic circuits.

We also have L/R differentiators. An L/R differentiator gives us the same output as the RC differentiator; a spike or peaked waveform.

In an L/R differentiator, as shown below,

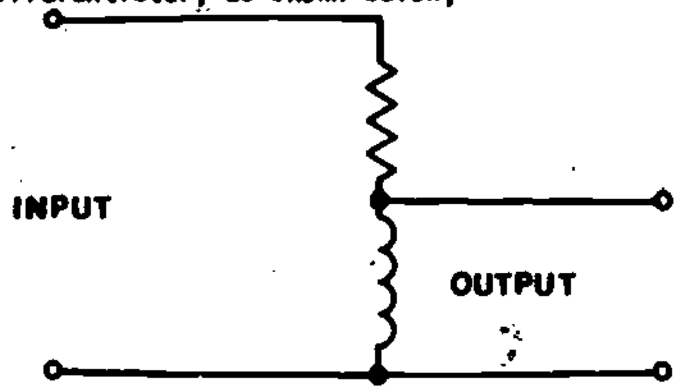


Figure 20

the output is taken across the coil and has a short time constant.

The coil's action will allow the maximum input voltage to appear in the output. When the input stops going positive (B to C).

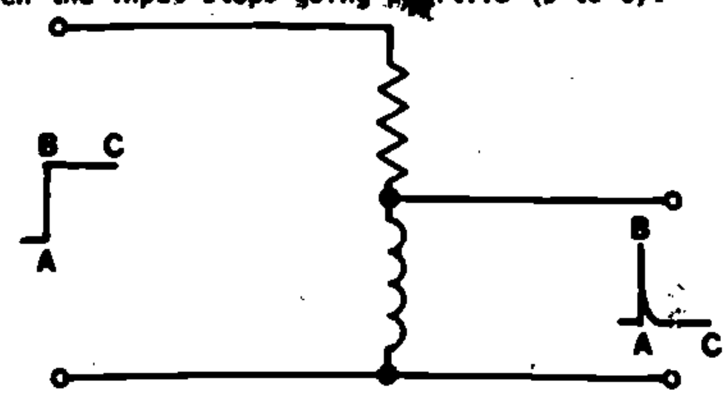


Figure 21

the voltage across the coil starts to decrease very rapidly due to the short time constant; and you have a spiked output.

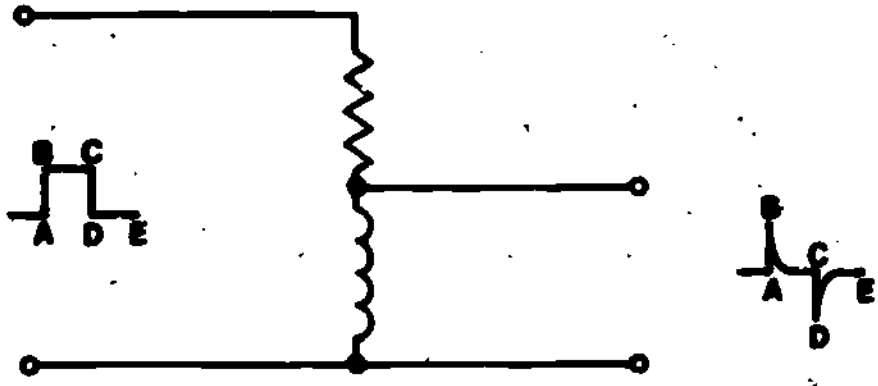


Figure 22

When the voltage across the coil goes in a negative direction, a negative spike will be observed at the output (C to D). When the input stops going negative (D to E), the voltage across the coil again decreases very rapidly to zero; and we get a spiked output.

Another difference between RC and L/R integrators and differentiators is the way in which we figure the time constant. When we figure the time constant for an L/R circuit we divide the inductance by the resistance, Tc = L/R instead of multiplying like we did in the RC circuits.

A few things to remember now about L/R integrator and differentiators are

1. The L/R integrator gives us a sawtooth waveform output and the output is taken across the resistor.

2. The L/R differentiator gives us a spike or peaked output and its output is taken across the inductor.

3. Integrators have long time constants with respect to the input pulse width; 10 times or more longer.

4. Differrntiators have short time constants with respect to the input pulse width; 1/10 or less shorter.

5. When figuring L/R time constants we divide the inductance by the resistance.

We have talked about RC and L/R integrators and differentiators. Something that may help you remember the type of output we get from these circuits is this little ditty.

I saw D spikes.

I = integrator = sawtooth waveform

D = differentiator = spikes (peaked waveform)

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.