DOCUMENT RESUME

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INSTITUTION Chief of Naval Education and Training Support, Pensacola, Fla.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.

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ABSTRACT

This set of individualized learning modules on power supplies is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Two modules are included in the set: (1) Solid State Power Supplies and (2) Electron Tube Power Supplies. Each module is comprised of individual lessons. 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 026 582.) (LRA)

Military Curricula for Vocational & Technical Education

CHIEF OF NAVAL EDUCATION AND TRAINING

1 APRIL 1977

BASIC ELECTRICITY AND ELECTRONICS.

MODULES 20 SOLID STATE POWER SUPPLIES
20T ELECTRON TUBE POWER SUPPLIES.

STUDY BOOKLET.

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

MILITARY CURRICULUM MATERIALS

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

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

Military Curriculum Materials Dissemination Is . . .

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

This project, funded by the U.S. 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
Rebecca S. Douglass
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Springfield, IL 62777
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The National Center Mission Statement

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

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

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

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

OVERVIEW

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY

Solid State Power Supplies

All electronic equipment requires some type of power supply. The power supply may be as small as a miniature integrated circuit or large enough to fill an entire room. Regardless of their size, most power supplies have only one function: to convert AC voltage to a smooth, steady DC voltage.

This module has been divided into the following seven lessons:

Lesson I Power Supply Functional Analysis
Lesson II Power Supply Input Stage
Lesson III Power Supply Transformer Secondary Stage
Lesson IV Power Supply Rectifiers
Lesson V Power Supply Filters
Lesson VI Power Supply Regulators
Lesson VII Power Supply System Concept

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY

LESSON 1

POWER SUPPLY FUNCTIONAL ANALYSIS

1 APRIL 1977

OVERVIEW
LESSON 1

Power Supply Functional Analysis

In this lesson you will learn the function of the power supply input stage, the first conversion stage (transformer secondary), second conversion stage (rectifier), third conversion stage (filter) and the output stage (regulator).

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.1.40 When the student completes this course, he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair-work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.1.40.1 RECOGNIZE the overall function of an electronic power supply by selecting the correct statement from a list of possible choices, only one of which is correct. 100% accuracy is required.

20.1.40.1.1 IDENTIFY the functions of the input stage (circuit) of a basic electronic power supply by selecting the correct functions from a list of several choices. 100% accuracy is required.

20.1.40.1.2 IDENTIFY the function of the rectifier stage of a basic power supply by selecting the correct function from a list of several choices. 100% accuracy is required.

20.1.40.1.3 IDENTIFY the function of the transformer secondary of an electronic power supply by selecting the correct statement of the function of the transformer secondary in an electronic power supply from a list of four statements, only one of which is correct. 100% accuracy is required.

OVERVIEW

20.1.40.1.4 IDENTIFY the function of the filter stage of an electronic power supply by selecting the correct statement of the function of the filter stage of a basic power supply from a list of several choices, only one of which is correct. 100% accuracy is required.

20.1.40.1.5 IDENTIFY the function of the regulator stage of an electronic power supply by selecting the correct statement of the function of the regulator stage of a basic power supply from a list of several statements, only one of which is correct. 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 1

Power Supply Functional Analysis

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 ...:

Summary
Programmed Instruction
Narrative

Student's Guide:

Progress Check

Enrichment Material(s):

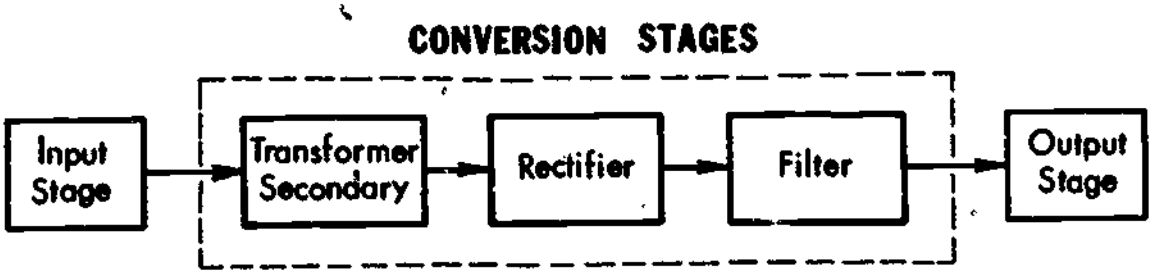
Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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

SUMMARY
LESSON I

Power Supply Functional Analysis

A Power Supply provides all voltages and currents required by a power consuming device or electronic equipment. This function of a power supply is accomplished by combining the individual functions of each of five stages as shown in the block diagram.



The input stage is a circuit accomplishing four functions:

1. Couples the AC voltage from the source to the first conversion stage.
2. Provides overload protection.
3. Indicates power on.
4. Enables the power supply to be turned on or off.

The first conversion stage consists of the secondary of a transformer which steps-up or steps-down the AC voltage from the input circuit. The AC voltage from the transformer secondary is connected to the second conversion stage which rectifies the AC into pulsating DC voltage. The pulsating DC voltage is then sent to the third conversion stage which consists of a filter circuit to suppress the pulsations in the DC voltage.

The filtered DC is then coupled to the output stage where a regulator circuit is frequently used to hold the DC output at a constant level. This DC output can now be coupled to the electronic equipment.

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

Power Supply Functional Analysis

TEST FRAMES ARE FRAMES 6, 11, 16, AND 19. GO FIRST TO TEST FRAME 6 AND SEE IF YOU CAN ANSWER THE QUESTION. FOLLOW DIRECTIONS AT THE END OF THE TEST FRAME.

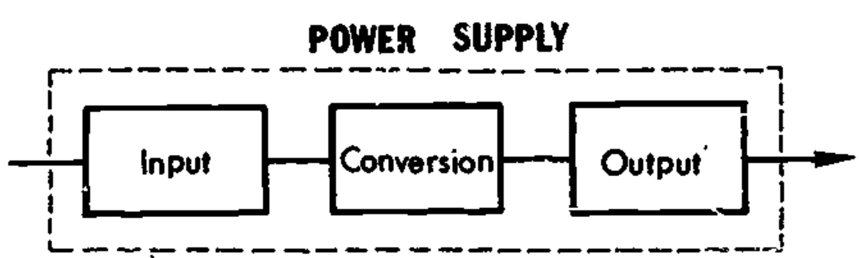
1. Sufficient power must be supplied to any electrical device. The source of this electrical energy is the steam or water driven generator at the power plant; however, the device that actually provides the correct voltages and currents to electronic equipment is referred to as a power supply. The power supply will take the power supplied by a power plant (normally AC) and change this power to the specific form required by the electronic device (normally DC voltages and currents).

If the voltage at a wall outlet is 115 volts AC, and an electrical circuit requires 50 volts DC, a _______ _______ must be used.

- -

power supply

2. A block diagram of a power supply will usually consist of three stages: the input stage, the conversion stage or stages, and the output stage.



Power supplies have an input, an output, and a _______ stage.

- -

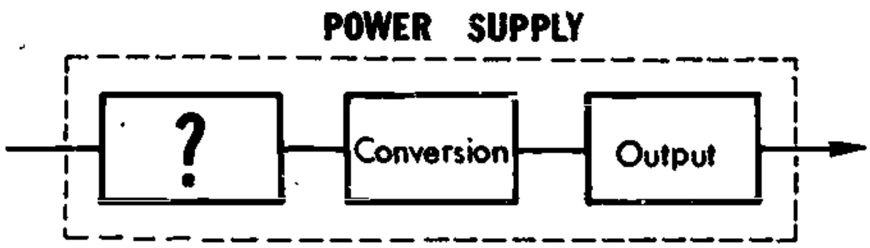
conversion

3. Correct DC currents and voltages must be supplied to electronic circuits; to do this, a ________ ________ is used.

- -

power supply

4. If a three stage block diagram of a power supply is drawn, the second stage is the conversion stage and the third stage is the output stage. What is the <u>first</u> stage?



- -

Input

5. The function of a power supply is to supply the correct ________ voltages and currents to electronic equipment.

- -

DC

6. TEST FRAME

What is the function of a power supply?

- -

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

To supply the correct DC voltages and currents to electronic equipment (or words to that effect)

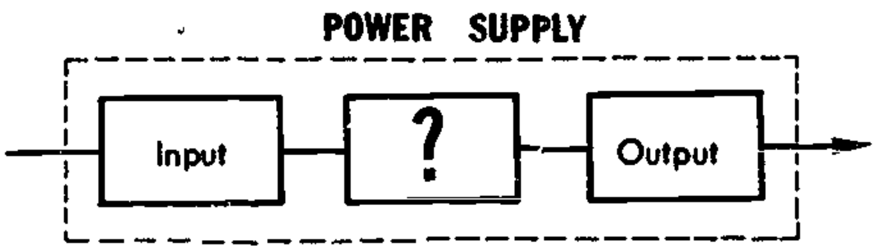
IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU MAY GO ON TO TEST FRAME 11. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 6 AGAIN.

7. The input stage of a power supply usually provides (1) overload protection, (2) a power on indicator, (3) a device to couple in the line voltage, (4) and an on-off switch. The input stage of a power supply is usually equipped with an on-off ________ and a power on ________.

---

switch, indicator

8. When drawing a power supply block diagram in three stages, the second stage is the ________ stage.



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conversion

9. The input stage of a power supply usually performs four functions. One function is to couple line voltage to the power supply; the four functions are?

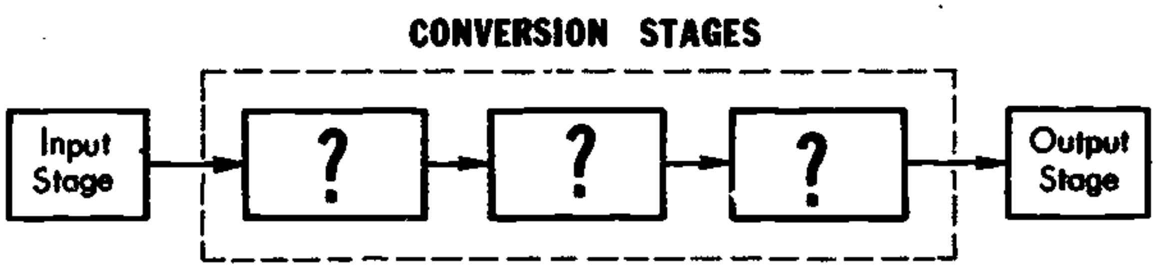
1. Provide ________ protection
2. Provide a ________ indication
3. Couple ________ to the power supply
4. Provide an on-off ________.

---

1. overload; 2. power on; 3. line voltage; 4. switch

10. In common electronic power supplies, the conversion process is often accomplished in three sub-stages. (1) The line voltage is stepped up or down by the transformer secondary; (2) AC is converted to pulsating DC by the rectifier; (3) the pulsations are smoothed out by a filter.

Write the names of the three sub-stages of the conversion stage.



- -

1. Transformer secondary winding or output
2. Rectifier
3. Filter

11. TEST FRAME

What are the four functions of the input stage of the power supply?

- -

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

C

1. Provide overload protection.
2. Provide a power on indicator.
3. Couple line voltage to the power supply.
4. Provide an on-off switch.

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO TO TEST FRAME 16. OTHERWISE, GO BACK TO FRAME 7 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

12. The transformer secondary winding usually steps voltage up or down.

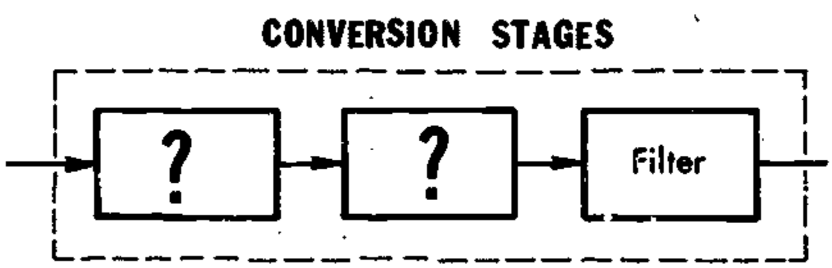
What stage is the transformer secondary a part of?

a. Input stage
b. Conversion stage
c. Output stage

- -

b. Conversion stage

13. There are three sub-stages in the conversion stage. What are the names and functions of the first two?



- -

Transformer secondary - steps voltage up or down. Rectifier - converts AC to pulsating DC.

14. Some electronic circuits require very smooth or pure DC. The removal of variations in pulsating DC is accomplished in the ______ sub-stage.

- -

Filter

15. The overall function of the conversion stage of a power supply is to supply the correct type and amount of voltage. Most electronic circuits require DC voltage in order to operate. Write the function of each sub-stage.

SUB STAGE	FUNCTIONS
1. Transformer secondary	
2. Rectifier	
3. Filter	

Functions

1. Steps voltages up or down (usually).
2. Converts AC to pulsating DC
3. Smoothes pulsations

16. TEST FRAME

State the names and functions of each of the three substages in the power supply conversion stage.

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

Transformer secondary	- steps voltage up or down (usually)
Rectifier	- converts AC to DC
Filter	- removes ripple

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO TO TEST FRAME 19 OTHERWISE, GO BACK TO FRAME 12 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 16 AGAIN.

17. The third stage of many power supplies is the voltage regulator stage. It functions to maintain a constant output voltage to couple the output voltage to the electronic equipment.

The output from an unregulated power supply will fluctuate if either the input voltage or the equipment requirements change. To eliminate or reduce these fluctuations, a voltage regulator frequently is built into the ______ stage of the power supply.

- -

output

18. The output stage regulates the output voltage and couples the power supply to the ______________.

- -

electronic equipment

19. TEST FRAME

Write the name and two functions of the output stage of the power supply.

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

The output stage is named the voltage regulator stage. It (1) maintains a constant voltage, and (2) couples the power supply to the electronic equipment.

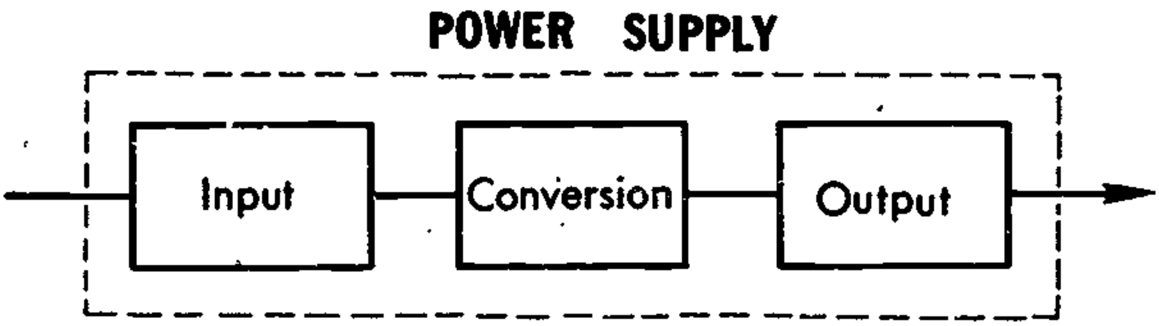
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN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

Power Supply Functional Analysis

This lesson deals with a vital part of any electronic equipment - its power supply.

The function of the power supply is what its name implies. It provides the voltages and current required by an electronic system to perform its designed function.



The power supply is made up of several stages, each of which is designed to perform a particular task

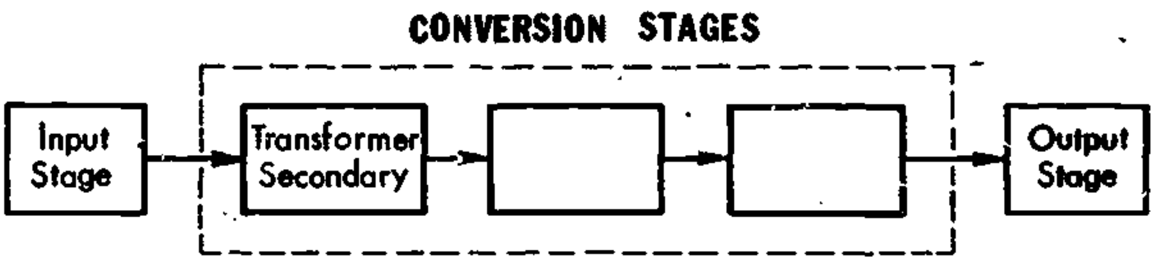
The first stage we are going to talk about is the INPUT stage.

The input stage has four primary functions:

(1) It provides a method of coupling the AC line voltage into the power supply.
(2) It provides overload protection.

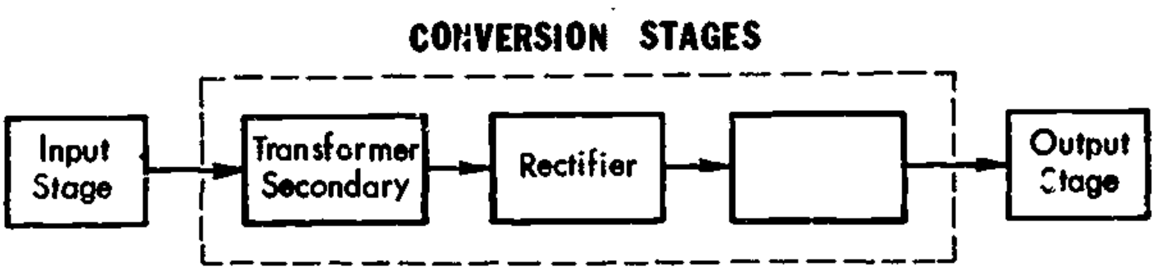
(3) It provides power-on indication.
(4) It provides a means of turning power on or off.

The second stage in the power supply is the CONVERSION stage which receives the AC line voltage from the input stage. The conversion stage is subdivided into three substages of which the first is a TRANSFORMER SECONDARY WINDING.



The function of the first sub-stage, the transformer secondary winding, is to step-up or step-down the AC line voltage to a value that is near the value of the required equipment voltage.

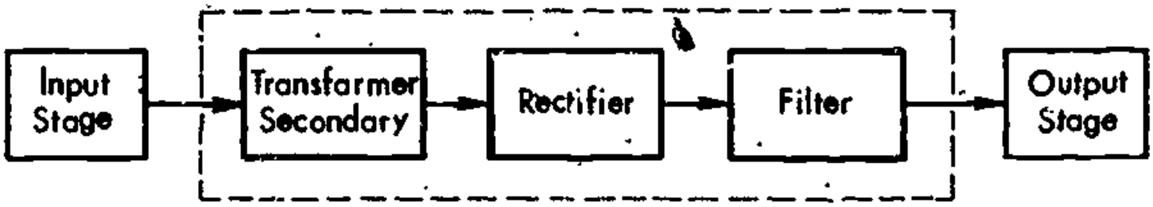
The second stage of conversion is the RECTIFIER stage.



The rectifier stage receives the voltage that the transformer secondary stage has provided and converts it to a pulsating DC. This conversion is called rectification.

This pulsating DC is then passed to the third sub-stage of conversion, the FILTER.

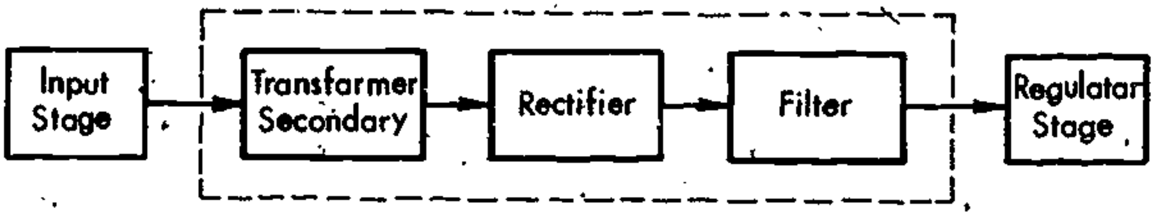
CONVERSION STAGES



The function of the filter is to remove or suppress the variations in the pulsating DC. In order to have a smooth DC these variations must be filtered. The filter smooths the pulsating DC into a smoother DC.

The output stage in our power supply is the VOLTAGE REGULATOR.

CONVERSION STAGES



The voltage regulator receives the DC voltage from the filter and maintains the DC voltage level at the required value. Its function is to maintain a steady DC output and couple this output to the equipment.

In review, the power supply's function is to provide the required voltages and currents for equipment operation. The power supply is made up of five stages. The function of each stage is:

1. Input stage - provide coupling, overload protection, power-on indication and a method for turning the power supply on or off.

2. Transformer secondary stage - steps the AC line voltage up or down.

3. Rectifier stage - converts the AC into pulsating DC.

4. Filter stage - reduces the variations of the pulsating DC.

5. Voltage regulator stage - maintains the DC at the required voltage level and couples the DC to the equipment.

Match the circuit with its function by writing letters in the proper blanks. Any letter may be used more than once.

LETTER	FUNCTION	CIRCUIT
1. ___	Smoothes DC voltage	A. Input stage
2. ___	Couples voltages to equipment	B. Rectifier
3. ___	Maintains constant DC voltage	C. Filter
4. ___	Converts AC to DC	D. Voltage regulator
5. ___	Provides circuit protection	E. Transformer secondary
6. ___	Couples power supply to source voltage	
7. ___	Indicates power on	
8. ___	Converts AC input to required AC level	

- -

1. C
2. D
3. D
4. B
5. A
6. A
7. A
8. E

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

LESSON II

POWER SUPPLY INPUT STAGE

1 APRIL 1977

OVERVIEW
LESSON II

Power Supply Input Stage

In this lesson you will study and learn about input power connectors, circuit breakers/fuses, indicator lights, switches, and the transformer primary.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.2.40 When the student completes this course, he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.2.40.2 ANALYZE the function of the input stage of an electronic power supply by observing, recording and interpreting waveforms and voltages at indicated test points on a training device. All recorded data must fall within specifications as stated in the job program.

20.2.40.2.1 IDENTIFY the function of an electronic circuit breaker by selecting the correct statement of a function of a circuit breaker from a list of several statements, only one of which is correct. 100% accuracy is required.

20.2.40.2.2 IDENTIFY the function of an indicator light connected across the primary of the power supply transformer by selecting the correct statement from a list of several statements, only one of which is correct. 100% accuracy is required.

20.2.40.2.3 MATCH physical components found in the input stage of an electronic power supply with their proper schematic symbols, given typical components and a list of symbols. 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

Power Supply Input Stage

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 - II "Input Stages"
Progress Check

Enr'chment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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.

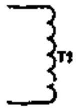
SUMMARY
LESSON II

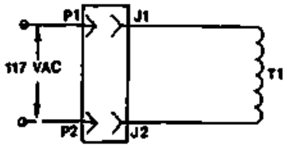
Power Supply Input Stage

The power supply input circuit is used to:

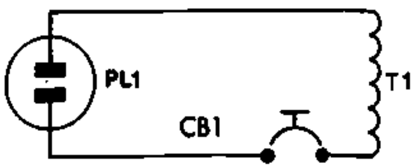
1. couple AC line voltage to the next stage;
2. protect the circuit from excessive current flow;
3. indicate when AC voltage is on;
4. provide a means of turning the power supply on or off.

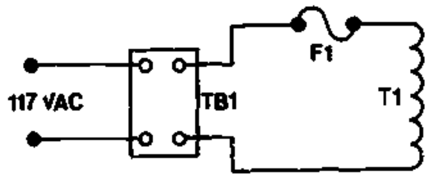
The first function (coupling) is accomplished by using a plug or power connectors

 **or**  and a transformer primary. 

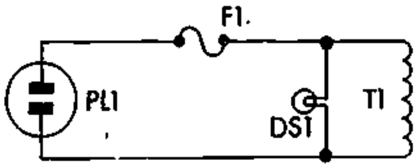


The second function (overload protection) is accomplished by using either a circuit breaker ( ) or fuse ( ). If excessive current is drawn by the equipment, the overload protection components will open and stop current flow in the input circuit.

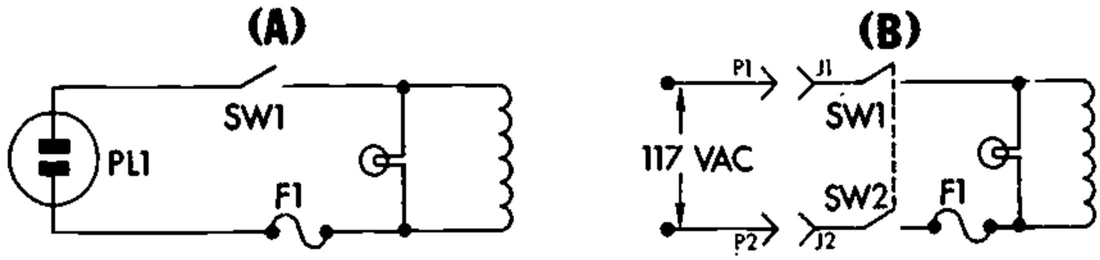




The third function (power on indication) is accomplished by a lamp or light bulb across the primary of a transformer. When current flows in the input circuit, the lamp will light.



The fourth function is to turn power on or off. This is accomplished by means of a switch.



Example (B) is a "ganged" switch. The dotted line indicates that both contacts will move together.

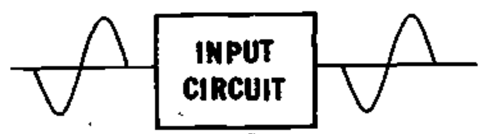
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN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

PROGRAMMED INSTRUCTION
LESSON II

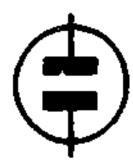
Power Supply Input Stage

TEST FRAMES ARE 3 AND 8. AS BEFORE, GO FIRST TO TEST FRAME 3 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The input circuit has four functions. The first function is to couple AC line voltage through the input circuit to the next stage of the power supply.



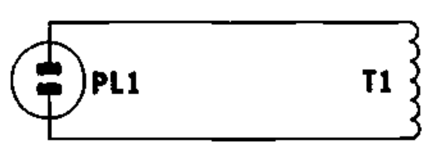
This is usually done through the use of a power connector and the primary winding of a transformer. The most often used symbol for a power connector is:



This symbolizes a plug that is normally connected to a wall outlet.

The symbol for a transformer winding is:

The first function is accomplished by combining these two components as illustrated by the following circuit:

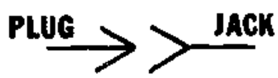


The _____ connects the wall outlet to the input circuit and the ______ ________ couples the signal out of the input circuit to the next stage.

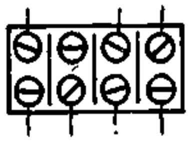
- -

Plug; transformer primary winding

2. The transformer primary winding symbol is standard but the power connector has several different symbols. The reason there are several symbols for a power connector is that there are various ways of connecting the external line voltage to the input circuit. Some common examples are:



Interconnector. Generally indicates jack and plug connections; e.g., a 6B25 PC card is put into a jack.



This indicates a terminal board and is used when a number of wires must be connected to a number of other wires. It is a good way to keep all connections in the same place.

No response required

3. TEST FRAME

(1) The purpose of the transformer primary is to ___________.
(2) The purpose of a power connector is to ___________.

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

(1) Couple line voltage out of input circuit. (or words to that effect)
(2) Couple line voltage into the input circuit. (or words to that effect)

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 8. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 3 AGAIN.

4. We know how the function of coupling the line voltage into and out of the power supply is accomplished by power connectors and a transformer primary, but now we must look at the next function of the input circuit. That function is to provide overload protection. Overload protection is accomplished by a component that will prevent the possible damage of other circuit components if excessive currents try to flow in the circuit. This protection component generally opens the circuit when current flow exceeds its rating. Fuses and circuit breakers are the most common types of overload protection components. Their symbols are:

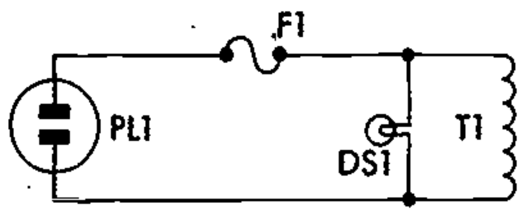
The major difference between a fuse and a circuit breaker is that the fuse wire melts when its current rating is exceeded while a circuit breaker simply opens itself. A fuse can therefore be used only once but a circuit breaker can be reset and used any number of times.

The flow of current in a circuit protected by an overload device will (be stopped/continue to flow) if the amount of current exceeds specifications.

- -

be stopped

5. Another function of the input circuit is to provide some means to indicate when power is on. The simplest way is to connect a lamp or light bulb across (in parallel with) the primary of the transformer.

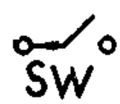


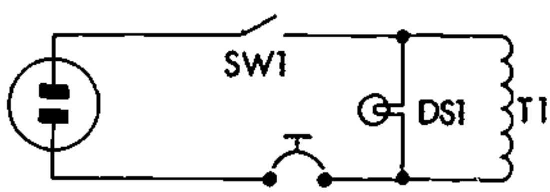
When the lamp is lit, power is (on/off).

---

on

6. The last function of the input circuit provides the capability to turn the power supply "on" or "off". This is accomplished through the use of a switch. In one position the switch opens the circuit and in the other position the switch closes the circuit. Imagine, instead, how tiresome it would be to disconnect the plug or remove a fuse everytime we wish to turn off our television set.

The symbol for a switch is: 



With the switch in the position shown in the above diagram, would DS1 be lit?

No (the switch is open)

7. Sometimes a double switch is used as a safety factor. This switch has only one lever to turn it on or off but both switches operate at the same time. A dotted line between two contacts indicates that the switches are mechanically connected or "ganged".

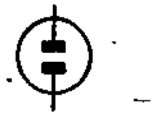
If SW1 is shorted, the power supply can still be turned off. True or false?

- -

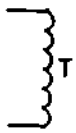
True - because SW2 will still open

8. TEST FRAME

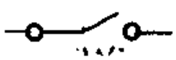
Match function of the input stage of the power supply to the schematic representation of the component.

1. 

2. 

3. 

4. 

5. 

a. Provides coupling of line voltage into the input circuit.

b. Provides indication of power on

c. Protects the circuit from excessive current.

d. Turns power on or off.

e. Provides coupling out of input circuit.

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

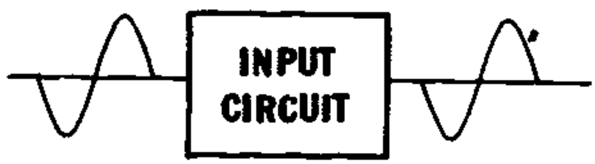
1. a; 2. c; 3. e; 4. b; 5. d

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEEO 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 OIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN HEDIUM 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

Power Supply Input Stage

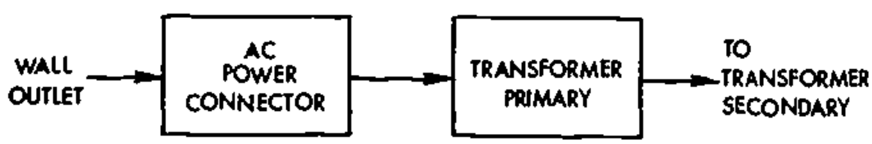
In the previous lesson, the power supply was separated into five stages. Each stage performed a distinct function. In this and later lessons, we will take each stage individually and show how the components of a stage work together to produce the stage function. The first stage is called the input circuit.



As shown in the drawing, the input circuit does not change the input waveform in any way. At first glance it would appear that the input stage does very little but this is not the case. The functions of the input stage are to:

1. Couple AC line voltage into the first conversion stage of the power supply.
2. Provide overload protection.
3. Indicate whether power is on.
4. Provide a method of turning power on or off.

How does the input stage do all of these functions? Let's take the first function and identify the components that provide a means to couple AC line voltage into the power supply and to the first conversion stage.

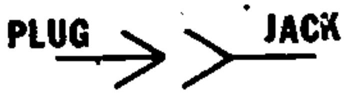


The two components that satisfy the first function are an AC power connector and a transformer primary. The AC power connector connects the external source to the input stage and the transformer primary provides a means of coupling the AC to the next stage.

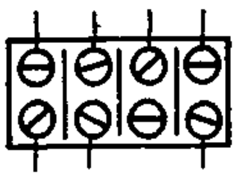
There are a number of ways to connect the line voltage to a power supply but the most common is with a standard plug. The plug is put into a wall outlet and the line voltage is connected to the power supply. The symbol for a plug is

and it looks like

In electronic equipment a number of other power connector symbols are often found. For example:

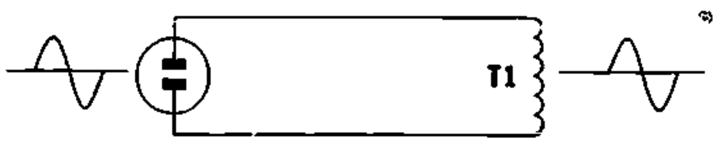


This symbol is commonly found when printed circuit cards are plugged into card jacks.



This symbol indicates a terminal board. When a lot of line voltages are coupled to a lot of places the terminal board makes it easy.

Now that we have the line voltage coupled into the power supply, how do we get it out of the input circuit? In this case, the primary winding of a transformer is the means used to couple the line voltage to the first conversion stage.



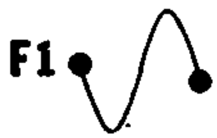
What components are used to (1) couple line voltage into the power supply and (2) line voltage out of the input stage?
(1)__________ and (2)______________

- -

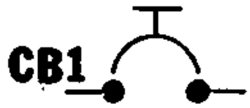
(1) power connector
(2) transformer primary winding

Another function of the input circuit is to provide overload protection. That is great, but what is overload protection? Overload protection means that there is a method used to protect the circuit from excessive current flow. The components most often used are fuses or circuit breakers.

Fuses and circuit breakers protect against a flow of current which approaches the limit of the current carrying ability of the circuit components by opening the circuit. The fuse does this by melting when overheated, and the circuit breaker does it by opening when the current is excessive. One advantage of having a circuit breaker instead of a fuse is that the circuit breaker can be reset while the fuse must be replaced.



Symbol for a fuse.



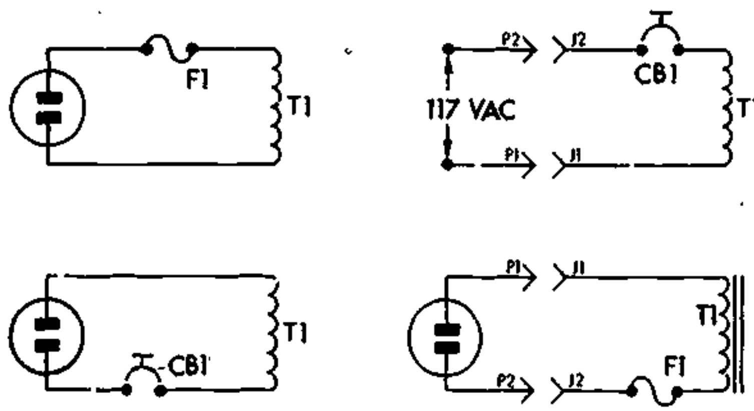
Symbol for a circuit breaker.

Overload protection is provided by a ______ or a ________.

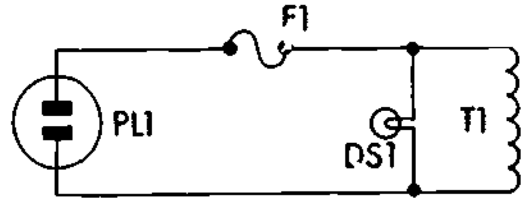
- -

fuse, circuit breaker

Our input circuit schematic at this point, may look like any of the following:

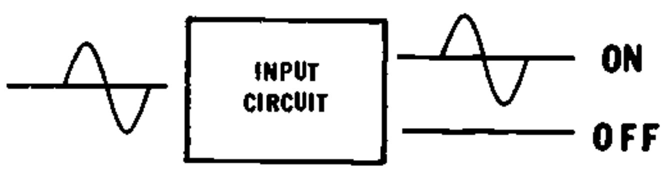


We have now covered the first two functions of the input circuit; the third function is to indicate that power is on. The best way to indicate power on is to use a light bulb or lamp. This lamp is generally connected in parallel with the primary of the transformer and is indicated by the symbol: 

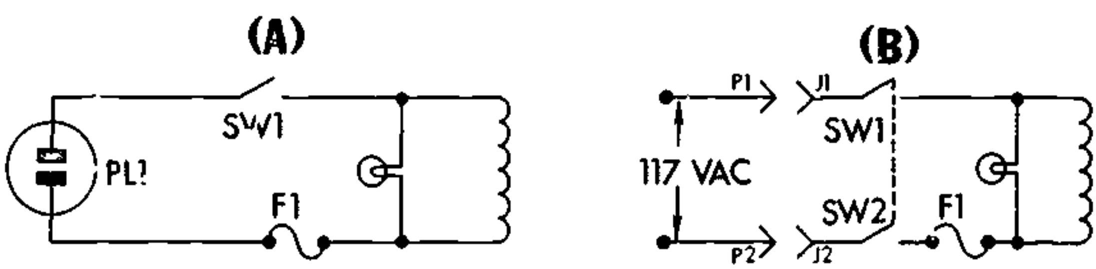


When current flows through the input circuit the lamp will light and indicate that power is available in the primary circuit.

The last function of the input circuit is to provide a safe, efficient way to turn the power supply on or off.



We have identified all components necessary to produce the "on" waveform. An additional component is needed to produce the "off", or no output. This component is a switch. The switch will open the circuit and prevent current flow.



In circuit (B), the dotted line indicates that both switches are mechanically connected. These ganged switches will open and close at the same time.

Match each component with the correct function.

1.	Switch	a.	Provides overload protection.
2.	Fuse/circuit breaker	b.	Couples line voltage.
3.	Transformer primary/ power connector	c.	Indicates power on.
4.	Indicator lamp	d.	Turns power supply off or on.

- -

1. d
2. a
3. b
4. c

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.


DON'T
GET
TURNED
ON
PLAY IT
COOL WITH
ELECTRICITY

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY

LESSON III

POWER SUPPLY TRANSFORMER SECONDARY STAGE

1 APRIL 1977

OVERVIEW
LESSON III

Power Supply Transformer Secondary Stage

In this lesson, you will study and learn about several types of power supply transformers. You will be able to identify step-up transformers, step-down transformers, single-secondary transformers, multi-secondary transformers, center-tapped transformers and their input/output voltage polarity relationships.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.3.40 When the student completes this course, he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.3.40.3 ANALYZE the function of the first conversion stage (transformer secondary) of the basic power supply by observing, measuring, and recording the normal waveforms and voltages at the transformer secondary test-points and interpreting the differences in the primary and secondary measurements, given test equipment, training device, and a job program. All measured data must fall within tolerances as stated in the job program.

20.3.40.3.1 IDENTIFY the function of a multi-secondary electronic transformer by selecting the correct statement of the function of a multi-secondary transformer from a list of several choices, only one of which is correct. 100% accuracy is required.

20.3.40.3.2 IDENTIFY the function of a center-tapped secondary of an electronic power supply transformer by selecting the correct statement of the function of a center-tapped secondary in a power supply transformer from a list of several choices, only one of which is correct. 100% accuracy is required.

OVERVIEW

20.3.40.3.3 LOCATE the three power supply transformer secondary connections in the electronic power supply using a training device and a schematic of the power supply circuit. All three connections must be correctly identified.

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

Power Supply Transformer Secondary Stage

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

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty - III "Power Supply Input and Transformer Secondary Stage"
Progress Check

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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 III

Power Supply Transformer Secondary Stage

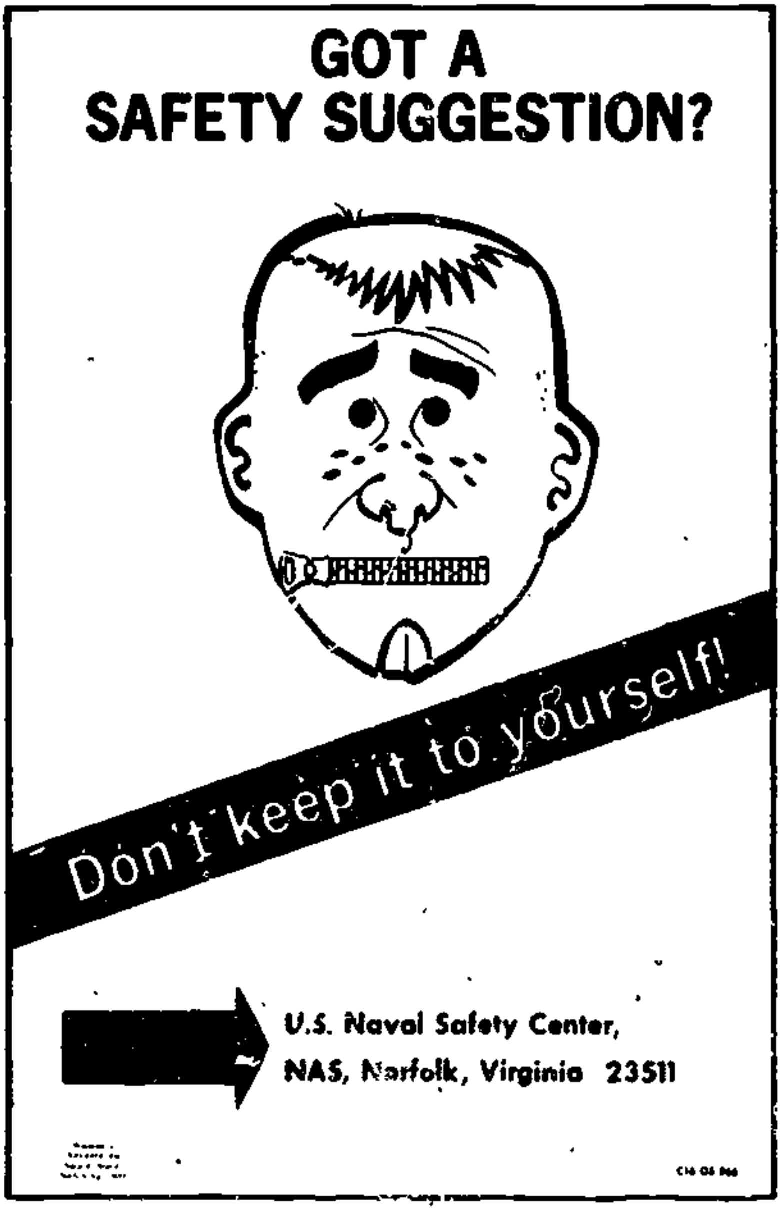
The AC voltage supplied from the wall socket is coupled through the input stage to the transformer secondary. The secondary may step-up, step-down, or leave the voltage the same, depending on the turns ratio between the primary and secondary windings. The voltage may need to be increased or decreased because the rest of the power supply requires a different level than is supplied by the external source.

The power supply often requires more than one voltage. Therefore multiple secondaries driven by a single primary may be used. Each secondary winding provides a desired voltage depending on its turns ratio as compared to the primary.

Another commonly used secondary is the center-tapped secondary. The center-tapped secondary splits the total secondary voltage into two equal voltages of opposite polarity.

No matter what amplitude or phase of AC voltage(s) is needed by the power supply, it can be provided by one of these types of secondary windings.

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.


GOT A
SAFETY SUGGESTION?
Don't keep it to yourself!
U.S. Naval Safety Center,
NAS, Norfolk, Virginia 23511

PROGRAMMED INSTRUCTION
LESSON III

Power Supply Transformer Secondary Stage

TEST FRAME IS FRAME 9. GO FIRST TO TEST FRAME 9 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS AT THE END OF THE TEST FRAME.

1. The first conversion stage in a power supply is the secondary of a transformer. The secondary matches the voltage amplitude of the external source (wall outlet) to the requirements of the rest of the power supply. One way a secondary can do this is by stepping up the voltage. This increase is accomplished by the ratio of turns from the primary to the secondary. If the number of turns in the secondary is greater than the number of turns in the primary, the voltage will be stepped up.

If the power supply requires 150VAC and the wall outlet supplies 110VAC, the number of turns will be greater in: a. the primary winding b. the secondary winding

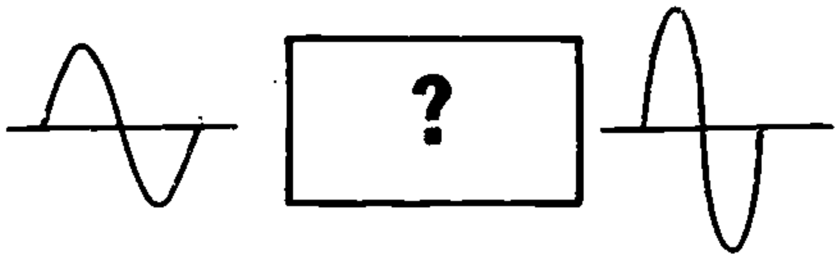
- -

b. the secondary winding

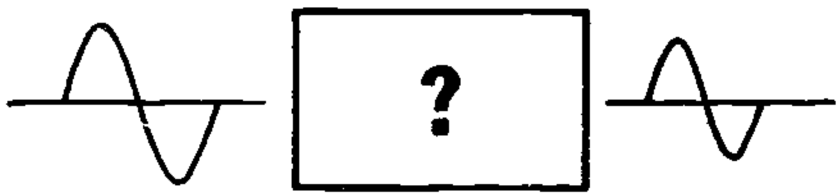
2. Sometimes the voltage supplied is far greater than the voltage required so a step-down transformer is used. The number of turns is greater in the primary than in the secondary.

Which type of transformers are used to make the indicated conversions?

a.



b.



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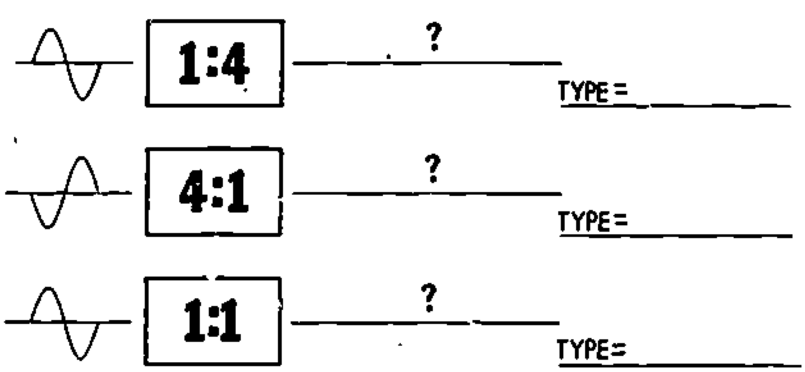
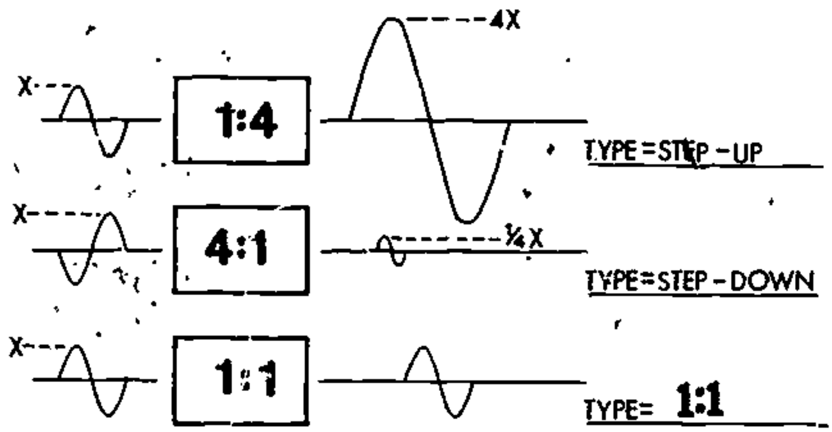
a. step-up b. step-down

3. Sometimes the voltages match exactly and neither an increase nor a decrease of the voltage is necessary. The turns in the primary and secondary are the same. A transformer with a 1:1 ratio passes an AC voltage without changing its value. When a 1:1 ratio is used, the primary function of the power transformer is to isolate the source from any undesired DC current path to ground within the power supply.

Draw the output waveforms for the transformers illustrated, and indicate the type of transformer. (Use a separate sheet of paper.)

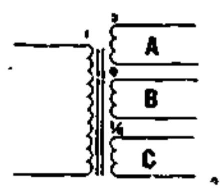




4. The power supply needs specific voltage levels to operate. The voltage conversion of the transformer secondary makes it easy to match the supply to the demand. Power supplies often require more than one transformer to supply the voltages. Engineers have simplified this by using more than one secondary with a single primary.

In the circuit shown, this single transformer with multiple secondaries provides three turns ratios.

Section A = 1:3 turns ratio
Section B = 1:6 turns ratio
Section C = 4:1 turns ratio



Which type of transformer conversion is not used in the multiple-secondary transformer illustrated?

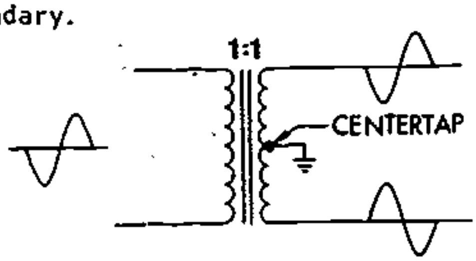
a. Step-up
b. Step-down
c. 1:1

- -

c. 1:1 is not shown

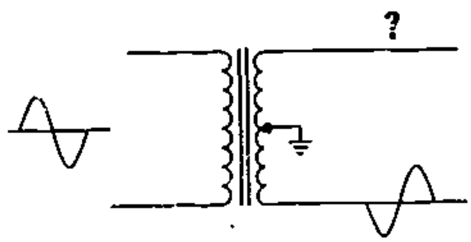
5. Power Supplies, on occasion, need two equal voltages of opposite polarity.

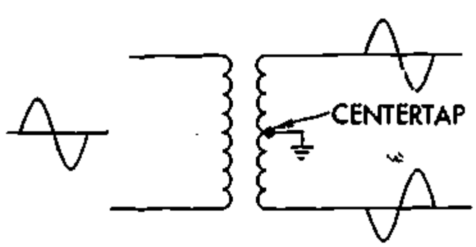
The si plest way to get those two voltages is to use a center-tapped transformer secondary.



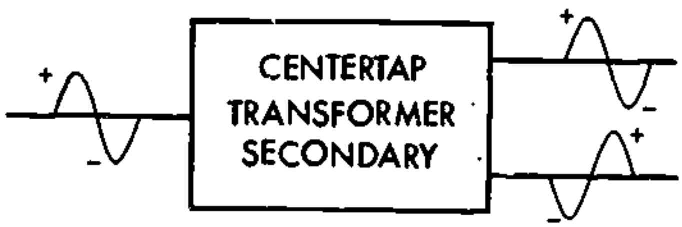
The center-tap divides the actual secondary winding into two equal secondary windings to supply the two voltages. Secondary voltage outputs will equal half of the input voltage using a 1:1 transformer.

Draw the missing waveform. (Use a separate sheet of paper.)





6. The two outputs c. a center-tapped secondary are equal, but of opposite polarity. Opposite polarity means that the voltage of one waveform is negative at the same time the voltage of the other waveform is positive.



The amplitude, frequency, and shape of each waveform are the same.

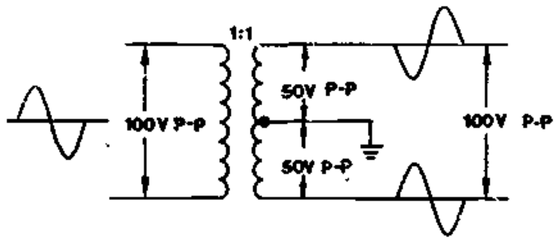
What is the only difference between the two outputs of a center-tapped transformer?

a. Frequency
b. Shape
c. Amplitude
d. Polarity

---

d. Polarity

7. The amplitude of each output of a center-tapped transformer is one half the amplitude of the total voltage induced across the secondary.



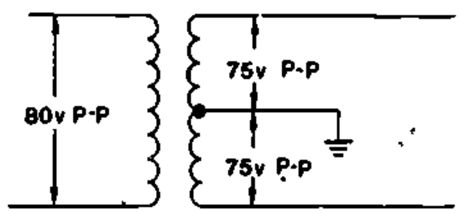
Remember, the total voltage across the secondary depends on the turns ratio between the primary and the secondary. Therefore, whatever amplitude is required can be obtained by stepping-up or stepping-down the voltage.

If the primary voltage is 50V and the total secondary voltage is 100 volts, what is the amplitude of each secondary waveform?

---

50 volts for each waveform

8. What type of transformer conversion is used in the example below?

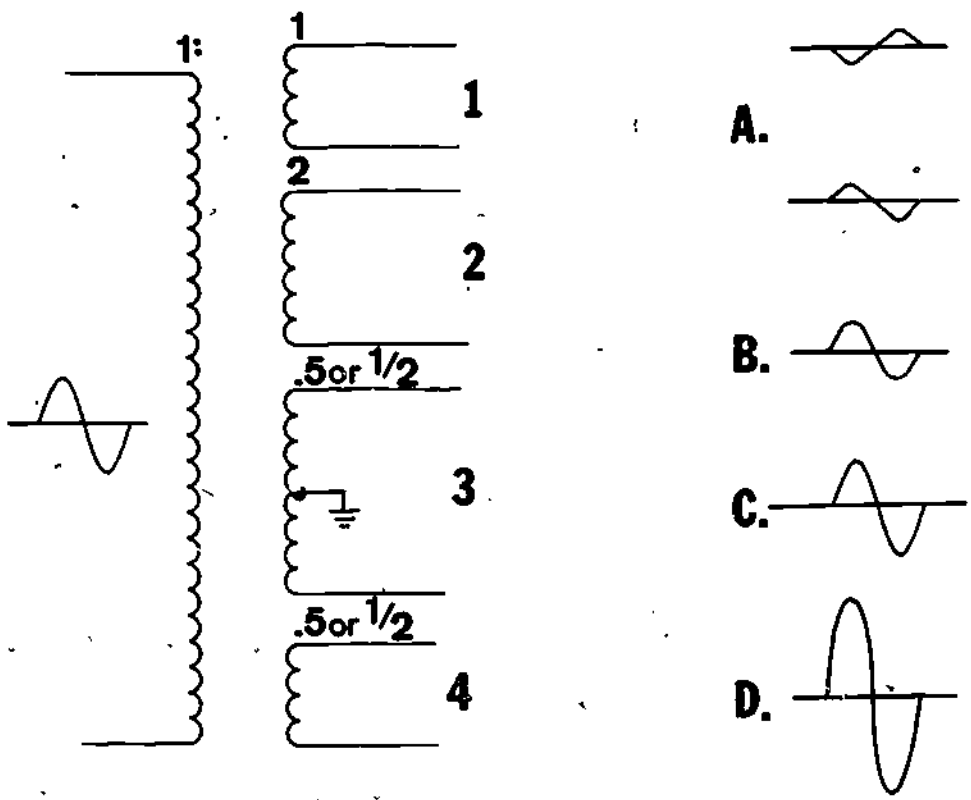


a. Step-down
b. Step-up
c. Isolation

---

b. Step-up

9. Match the waveform in column "B" to the correct winding in column "A".



- -

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

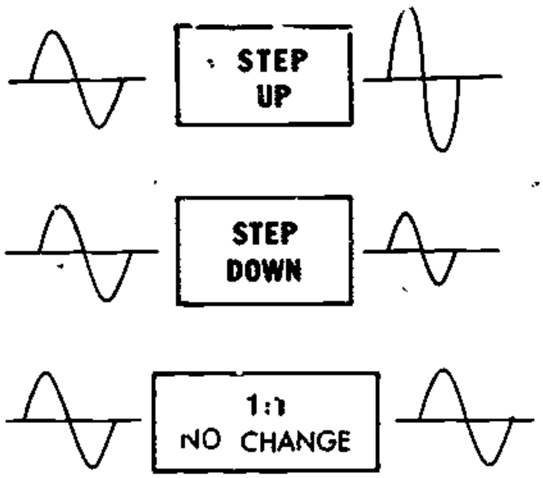
1. c
2. d
3. a
4. b

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

Power Supply Transformer Secondary Stage

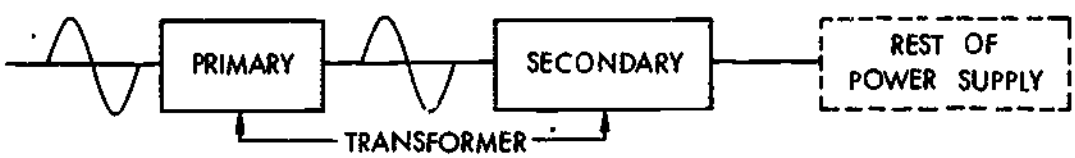
You have just finished studying the input circuit of the power supply. Now, let's take a look at the first conversion stage - the transformer secondary. As you know, the transformer secondary may provide one of three possible AC voltage outputs: Step-up, step-down, or no change as compared to the input.



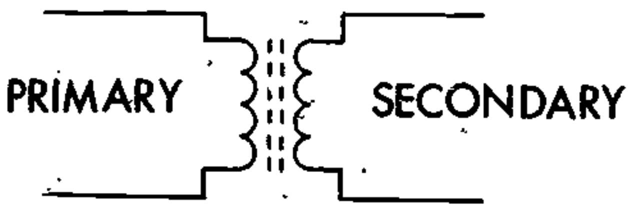
This conversion is often necessary to satisfy the voltage requirements of the stages that follow the power supply. The external source that supplies the input circuit generally does not match the voltage requirements of the rest of the power supply. The transformer secondary is designed to match these voltages. If the source voltage matches the voltage required by the rest of the power supply, a transformer with a 1:1 ratio is generally used. When this ratio is used, the primary function of the power transformer is to isolate the source from any undesired DC current path to ground within the power supply.

Most of us have had or have seen transistor radios that may either use batteries or be plugged into a wall outlet. The wall outlet is 110-120 VAC and the batteries usually provide only 9 VDC or 12 VDC. A step-down transformer may be used to decrease the AC voltage.

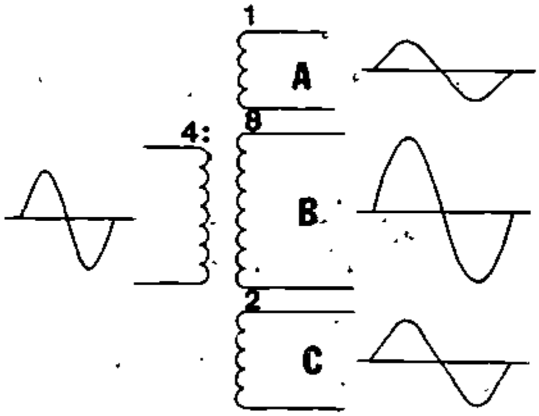
An important thing to remember is that the voltage may be changed but the shape and frequency of the waveform remain the same.



The most common type of transformer is the single-secondary transformer,

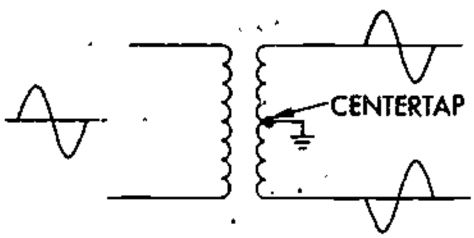


but if more than one voltage is required a multi-secondary transformer may be used.



The three secondaries, because of their different turns ratios, provide three different voltages.

The last type of transformer found in basic power supplies is called the center-tapped transformer.



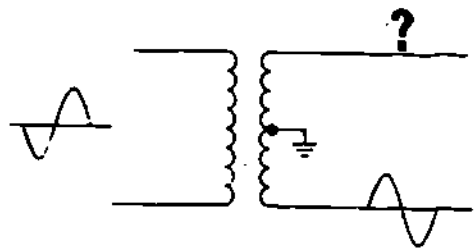
The ground connection in the center of the transformer does two things:

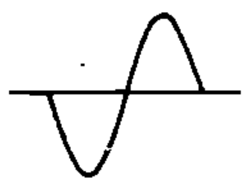
1. It effectively splits the secondary into two windings, each having 1/2 of the total number of secondary turns. The voltage amplitude across each half of the secondary is half of the total secondary voltage.

2. Each half of the secondary will have equal voltage amplitude but will have opposite polarities. When the top of the secondary winding is

positive in respect to ground, the bottom of the secondary winding will be negative in respect to ground, and vice-versa. Therefore, the AC voltages on each half of the center-tapped transformer are 180° out of phase with each other.

Draw the missing waveform.





Like any transformer, the center-tapped transformer can step-up or step-down a voltage.

In short, the type of secondary found in a particular power supply depends on what the rest of the power supply requires. It may require only one AC voltage, more than one AC voltage, or two equal voltages of opposite polarity.

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

C33-GS 567
Contributed by AMHC L J Glover VP 4

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY

LESSON IV

POWER SUPPLY RECTIFIERS

1 APRIL 1977

OVERVIEW
LESSON IV

Power Supply Rectifiers

In this lesson you will study and learn about the output waveforms and schematics of half wave, full wave and bridge rectifier circuits and the advantages and disadvantages of half wave, full wave and bridge rectifier circuits.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.4.40 When the student completes this course, he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.4.40.4 DIFFERENTIATE between the schematic drawings of half-wave, full-wave, and bridge rectifier circuits by matching each of three schematics with its correct type name. 100% accuracy is required.

20.4.40.5 MATCH illustrations to statements about the effects of applying forward bias to a diode, given four choices only one of which is correct concerning forward bias. 100% accuracy is required.

20.4.40.6 MATCH illustrations to statements about the effects of applying reverse bias to a diode, given four choices only one of which is correct concerning reverse bias. 100% accuracy is required.

OVERVIEW

20.4.40.7 MATCH the drawings of output waveforms of half-wave, full-wave, and bridge rectifier circuits with their correct names, given choices of names and drawings. Each waveform must be correctly named.

20.4.40.8 MEASURE the resistances and CALCULATE front-to-back ratios of diodes, given four different types of diodes, a job program, and a multimeter. All measurements and ratios to fall within tolerances specified on the job program.

20.4.40.9 MATCH the physical components of the second conversion stage of an electronic power supply with their respective schematic symbols, given a schematic diagram, a job program, and a training device power supply. 100% accuracy is required.

20.4.40.9.1 IDENTIFY the location of components, letter/number designations, and test points of the second conversion stage of an electronic power supply as required on the job program, given a schematic diagram and a training device power supply. 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 IV

Power Supply Rectifiers

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:

Audio/Visual Response Sheet Twenty - IV
Job Program Twenty - IV "Power Supply Rectifiers".
Progress Check

Additional Material(s):

Audio/Visual Program Twenty - IV "Basic Power Supply Rectifiers".

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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.

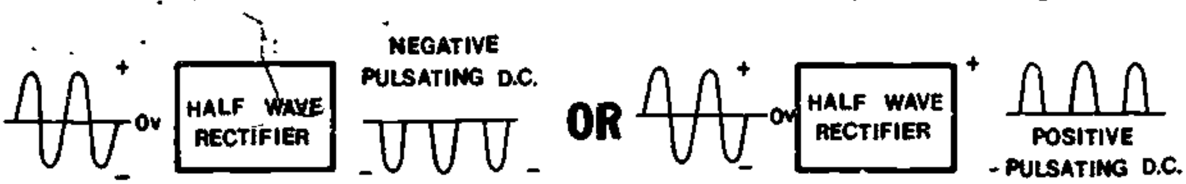
SUMMARY
LESSON IV

Power Supply Rectifiers

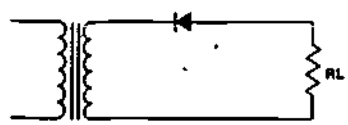
Rectifier circuits are connected to the secondary of a power supply transformer in order to convert AC voltage into DC voltage. Three types of rectifiers are: half-wave, full-wave, and bridge.

Power supply rectifiers utilize diodes for their operation. Diodes conduct when they are forward biased (cathode negative with respect to the anode) and offer tremendous resistance to current flow when they are reverse biased (cathode positive with respect to the anode).

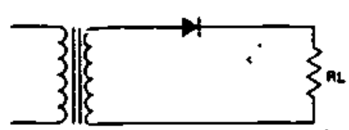
The half-wave rectifier consists of one diode which simply eliminates either the positive or negative alternations of the input AC voltage.



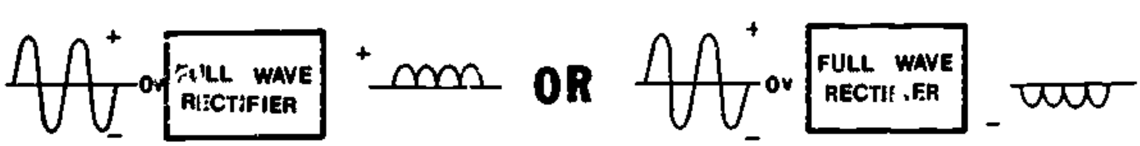
A half-wave rectifier circuit with a negative DC output will contain one diode connected as shown.



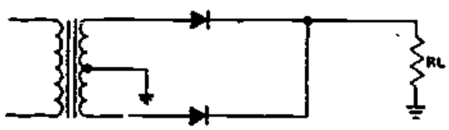
A positive DC output can be obtained with this cicruit:



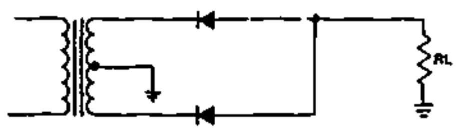
In order to convert every alternation of the input AC voltage to pulsating DC, a full-wave rectifier is used. The full-wave rectifier converts each alternation of the AC voltage to either positive or negative pulsating DC Voltage.



A full-wave rectifier uses two diodes and a center-tapped transformer secondary winding.



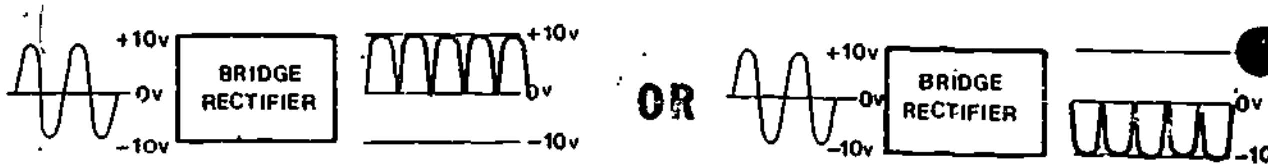
or



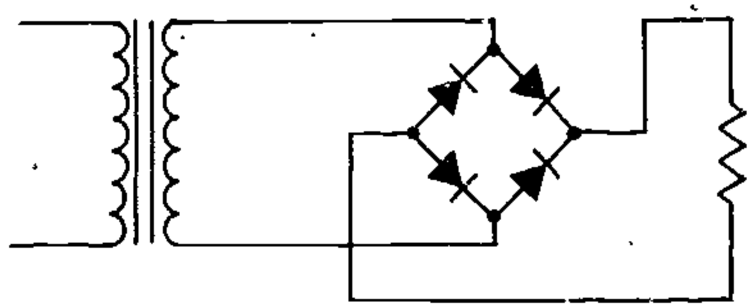
Positive DC Output Negative DC Output

The transformer center-tapped secondary divides the secondary AC voltage into two equal, out-of-phase AC voltages, each of which is half the total secondary voltage. Depending on circuit configuration, the diodes will pass either the positive or negative alternations of the AC input voltage, first from one diode, then from the other. The average output voltage of the full-wave rectifier is the same as the half-wave rectifier, but the variations in the pulsating DC output are less with the full-wave rectifier.

A bridge rectifier also converts each alternation of the input AC voltage to the same DC polarity at the output, but, with the same secondary voltages, the peak amplitude of the DC voltage is twice that of the full-wave.



The circuit for a bridge rectifier requires (4) diodes.



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

PROGRAMMED INSTRUCTION
LESSON IV

Power Supply Rectifiers

GO FIRST TO TEST FRAME (18) AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

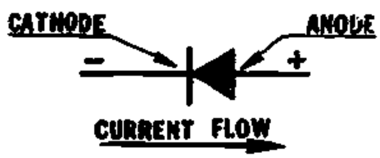
1. Rectifier circuits have one function: to convert AC voltage into DC voltage. In this lesson we will discuss three types of rectifiers: Half-Wave; Full-Wave; and Bridge.

Each of the three types of rectifiers use one or more diodes. A diode, the key to rectifier operation, is a device that allows current to flow easily in one direction but offers tremendous opposition to current flow in the other direction.

This is the schematic symbol for a diode. The short vertical line is referred to as the cathode and the solid triangular figure is called the anode. A diode will readily conduct current from the cathode to the anode or, said differently against the arr in the diode symbol.

Draw an arrow indicating the direction of current flow through, and label the parts of, the diode below. (Use a separate sheet of paper.)

- -



2. As stated in the previous frame, current will only flow from cathode to anode in a diode. Therefore, in order for current to flow, the cathode must be negative with respect to the anode. When these polarity conditions are met, the diode is said to be forward biased. If the cathode's potential is positive and the anode's potential is negative, no current flows. This condition is referred to as reverse biased.

What are the bias conditions of the diodes below?

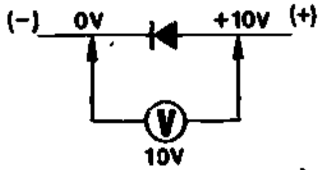
a. 

b. 

---

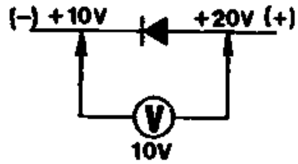
a. reverse biased
b. forward biased

3. From the definitions of diode bias, it is the relative voltage across the diode that determines whether or not the diode will conduct. For example: A diode that has 0 volts on the cathode and +10 volts on the anode is forward biased. (The cathode is negative with respect to the anode).



The meter reads a difference of 10 volts. The cathode is negative with respect to the anode.

Let's take another example: If a diode has +10 volts on the cathode and +20 volts on the anode, the difference of potential across the diode is again 10 volts. The cathode is less positive than the anode.



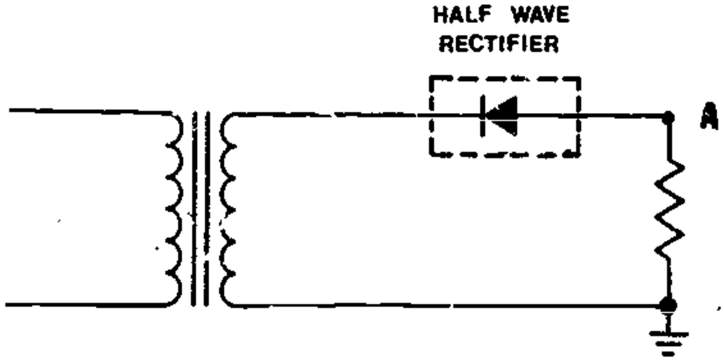
The meter reads a differnece of 10 volts. The cathode again, is negative with respect to the anode.

Which of the following diodes will conduct current (more than one choice may be correct)?)

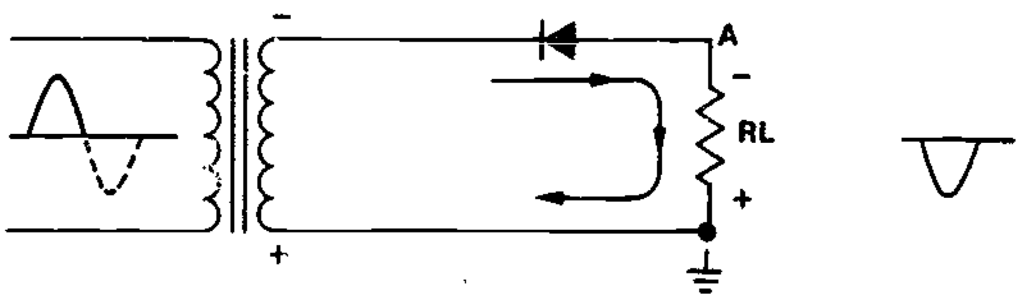
---

a, c, and d only

4. The first rectifier we will discuss is the half-wave. It uses one diode.



This rectifier will allow only negative half-cycles to pass from the transformer secondary to point A. When the top of the transformer secondary is negative and the bottom is positive, current will flow clockwise from the top of the transformer, through the diode, down through R_L, and back to the bottom of the transformer.

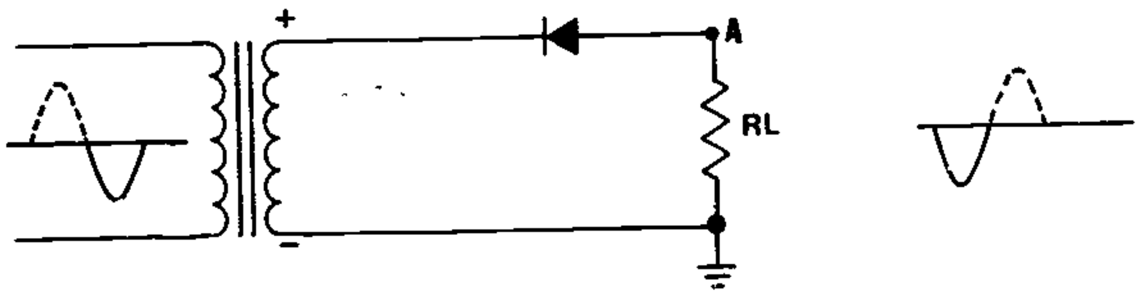


Since current flows from top to bottom through R_L, the top of R_L (point A) will be negative in respect to ground.

Would current flow counter-clockwise through the circuit?

No - the diode will block counter-clockwise current. (or words to that effect.)

5. During the negative half-cycle, when the top of the transformer secondary is positive and the bottom is negative, no current will flow through the circuit and the voltage at point A will be zero with respect to ground.

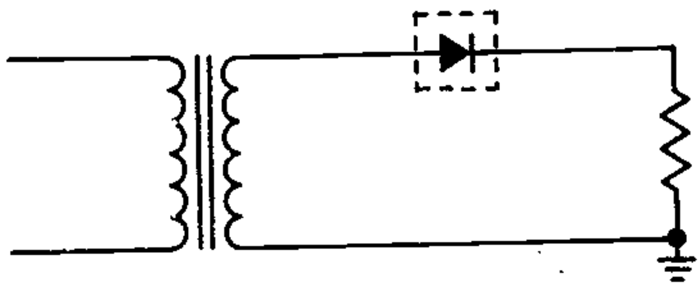


Therefore, only negative half-cycles will appear at point A and the output voltage is negative pulsating DC voltage.

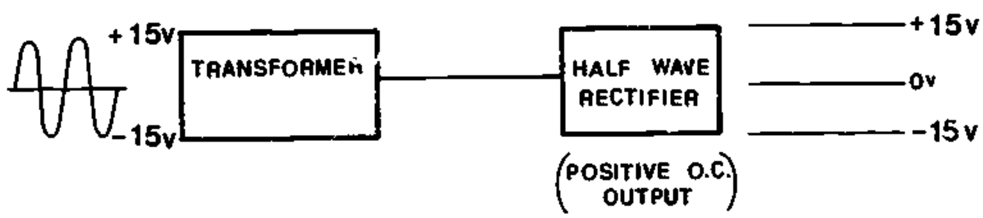
If the diode in the above circuit was physically turned around, what kind of voltage would appear at point A?

Positive pulsating DC voltage. (or words to that effect.)

6. This circuit will provide positive pulsating DC voltage.



In block diagram form, the circuit above could be shown as:



Draw, on a separate sheet of paper, the output waveform for the circuit illustrated above.

- -

76

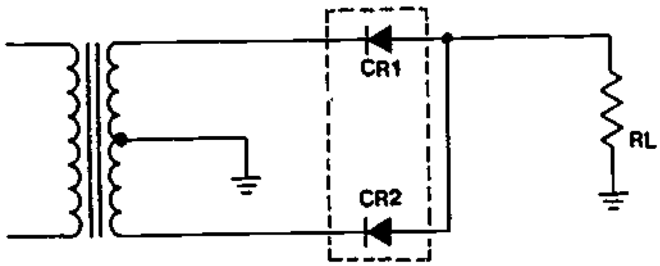
7. The voltage obtained from a half-wave rectifier is pulsating DC voltage, but only half of the AC alternations are felt at the output. A full-wave rectifier will convert every alternation of the input voltage to one polarity at the output. By rectifying every alternation the full-wave rectifier will have less variation in the output DC voltage than the output obtained from the half-wave rectifier. However, because the full-wave rectifier uses a center-tapped secondary, it will have only half the peak amplitude of the half-wave rectifier with the same input signal. Compare the below outputs.

Which rectifier has less variation in the pulsating DC output?

- -

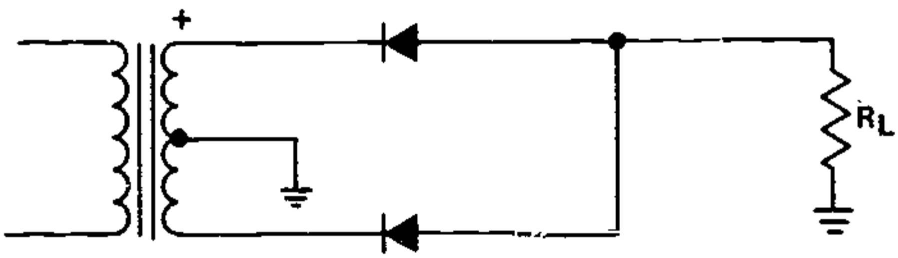
full-wave rectifier

8. A full-wave rectifier uses two diodes in order to rectify every alternation of the input AC voltage.



FULL WAVE
RECTIFIER

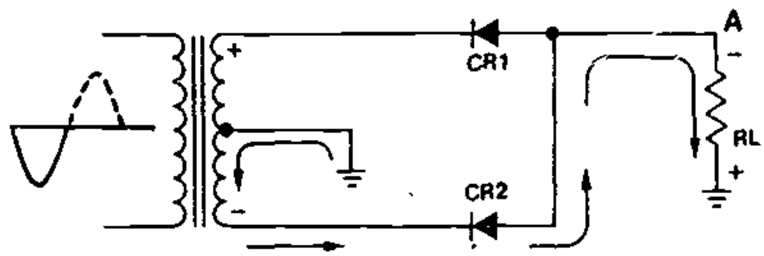
The rectifier above provides negative pulsating DC voltage, but if the diodes were physically turned around, the circuit would provide positive pulsating DC voltage. Notice that a transformer with a center-tapped secondary winding is used. You will recall that a center-tapped transformer winding provides two equal, out-of-phase voltages. For example, at one instant of time the top of the transformer secondary is positive with respect to ground.



What would the polarity at the bottom of the transformer with respect to ground be at that instant?

negative

3. Since current flows from negative to positive, diode CR2 will conduct current and diode CR1 will block current when the top of the winding is positive and the bottom of the winding is negative.

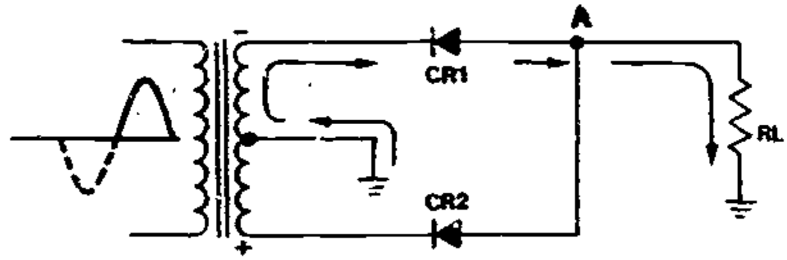


Current flows from the bottom of the transformer, through CR2, down through R_L, and back to the center-tap, via ground. The top of R_L will be negative in respect to ground, and a negative half-cycle will be felt at point A.

Draw on a separate sheet of paper, the waveform that would appear at point A.

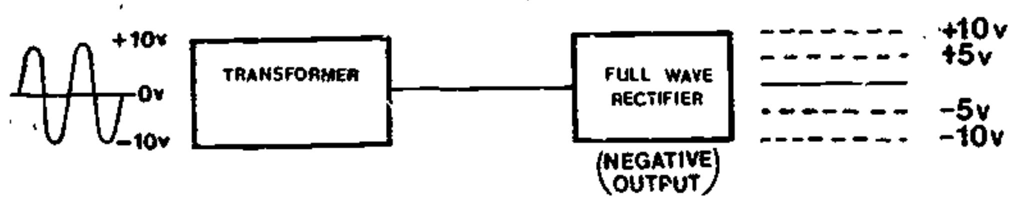
- -

10. On the next half-cycle, the top of the transformer secondary will be negative when the bottom is positive.



Current will now flow from the top of the secondary, through CR1, down through R_L, and back to the center-tap via ground. Notice that the flow through R_L is in the same direction as before, and, consequently, the voltage across R_L is the same as before. The same polarity of alternations will always reach point A -- first from one diode, then from the other diode.

Draw, on a separate sheet of paper, the negative output waveform, given the input waveform across the transformer.



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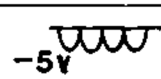
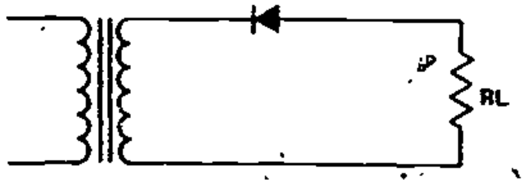
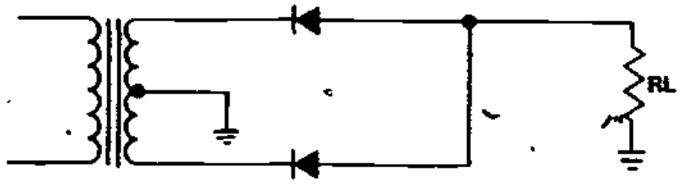
Remember that the center-tap on the transformer secondary winding halves the total AC voltage.	

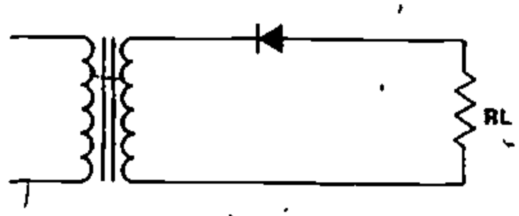
80

11. Label the circuits below as either a half-wave or full-wave rectifier. (Use a separate sheet of paper.)

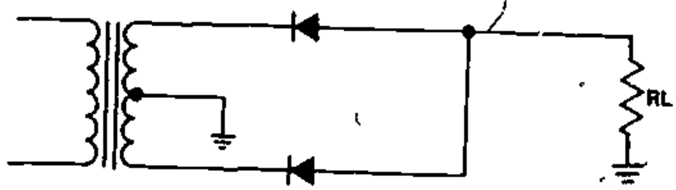




Half - Wave



Full - Wave



12. Which rectifier has the greater variation in the DC output voltage -- half-wave or full-wave?

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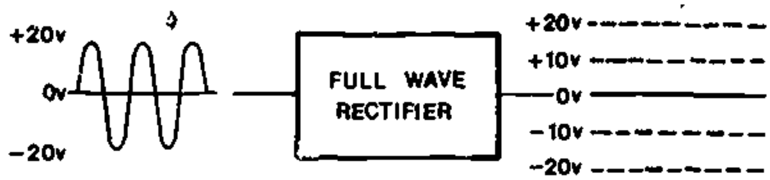
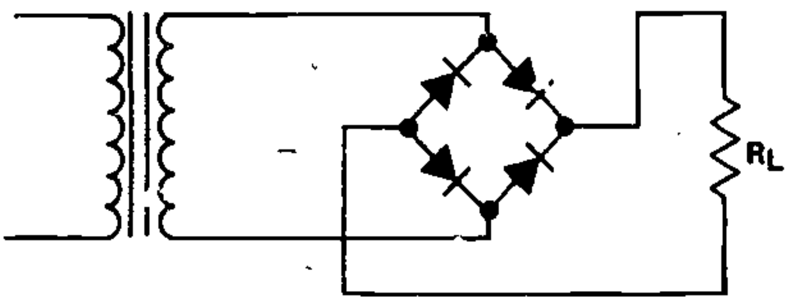
half-wave

13. Draw the output waveforms for the circuits illustrated. (Assume a positive DC output and use a separate sheet of paper.)

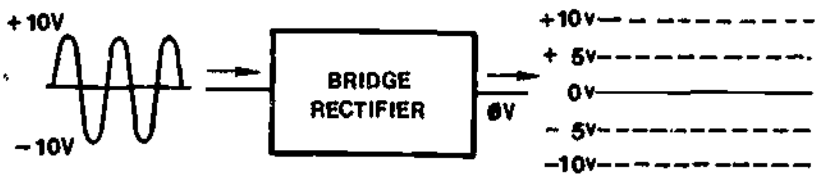


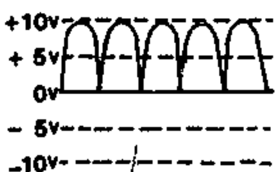
14. A third type of rectifier is called a bridge rectifier and uses four (4) diodes.



For the same input voltage, the bridge rectifier has twice the output DC voltage of a full-wave rectifier. Notice that a bridge does not use a transformer with a center-tapped secondary so the full amplitude of the secondary voltage is transmitted to the output.

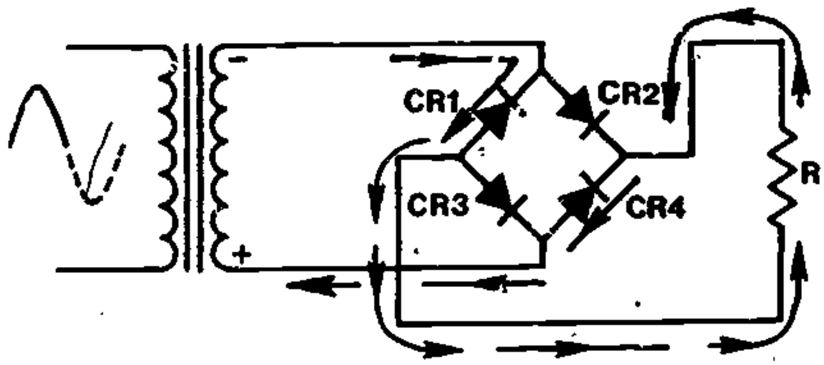
Draw, on a separate sheet of paper, the output for a bridge rectifier (assume a positive DC output).





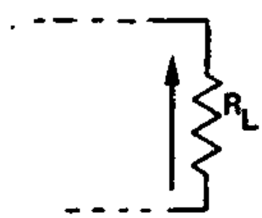
15. The bridge rectifier is normally shown on schematic diagrams in a "diamond" pattern. The configuration may look complicated at first glance, but if we trace current flow on each half cycle of AC voltage on the transformer, it should be clear how the bridge rectifier does its job.

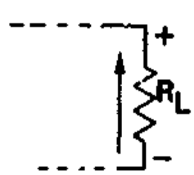
Say that at one instant of time, the top of the transformer secondary is negative and the bottom is positive.



Diodes CR1 and CR4 will conduct with the above polarity of voltage on the transformer, and diodes CR2 and CR3 will not conduct current. Trace the flow from the top of the transformer back to the bottom of the transformer. Current flows through CR1, up through R_L, and through CR4.

If current flow through R_L is as shown, mark the relative polarities on the ends of the resistor. (Use a separate sheet of paper.)





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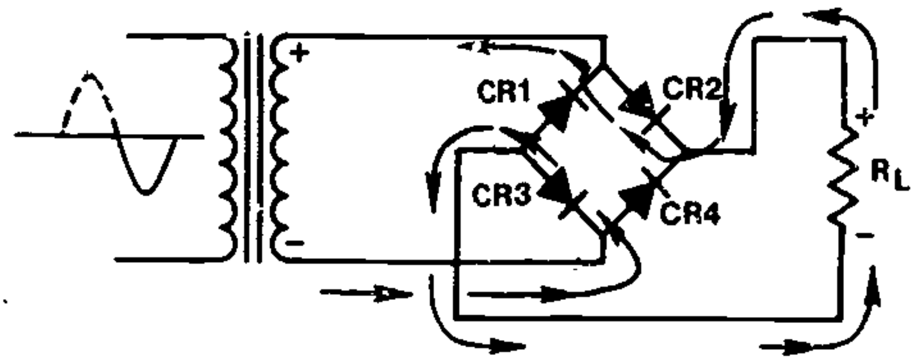
16. On the next half-cycle, the top of the secondary winding will be positive and the bottom will be negative.



Diodes CR2 and CR3 will conduct and diodes CR1 and CR4 will not conduct. Using the arrows, trace current through the circuit. Remember that there must be a complete path for current (from the negative side of the secondary back to the positive side of the secondary).

Current through R_L is in the (same/opposite) direction as before.

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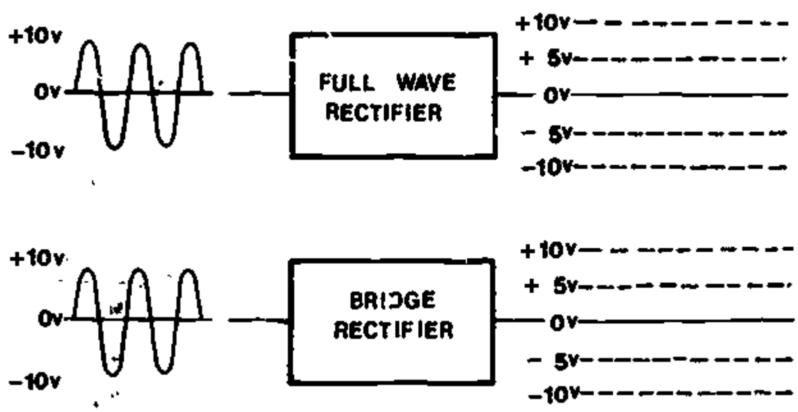
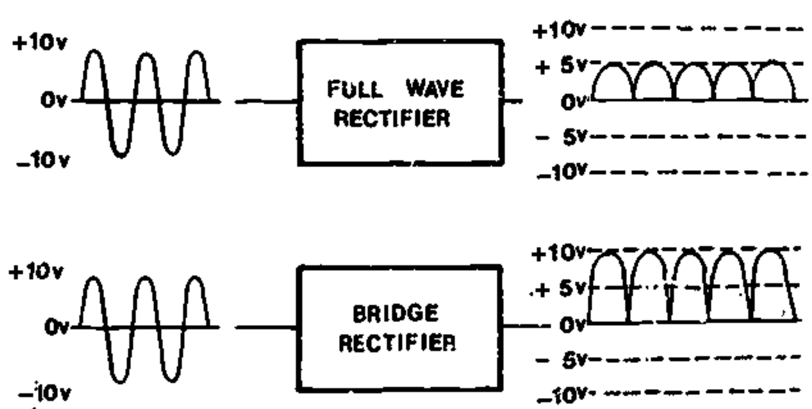
17. The current flow through R_L will always be in the same direction. Therefore, the output voltage polarity will always be the same despite the fact that the AC voltage is changing polarity many times per second. The output voltage from a bridge rectifier will vary at the same frequency but twice the peak amplitude as the output from a full-wave rectifier with the same applied voltage.

(Remember: The full-wave rectifier uses a center-tapped transformer while the bridge does not.)

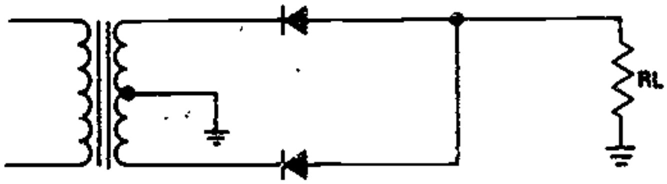
Draw the output waveforms (assume positive rectification) for the following circuits. (Use a separate sheet of paper.)



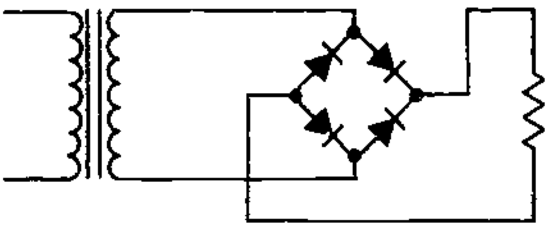


18. TEST FRAME

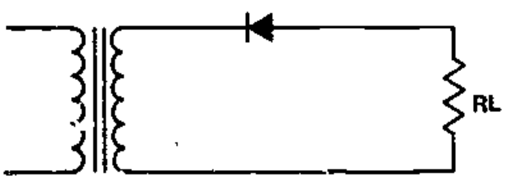
On a separate sheet of paper, label each rectifier type shown below.



a. ________



b. ________



c. ________

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

a. full-wave
b. bridge
c. half-wave

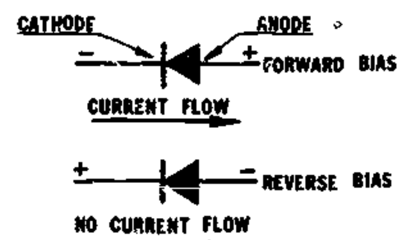
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN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

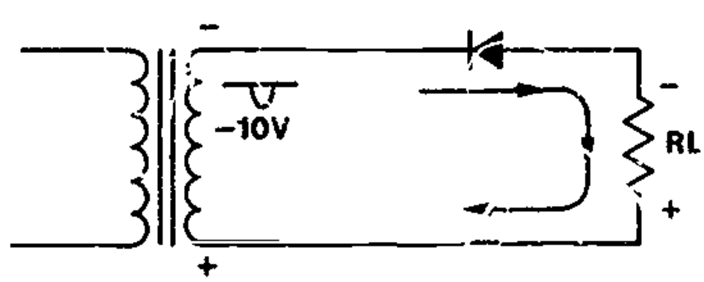
Power Supply Rectifiers

Rectifier circuits have one function: to convert AC voltage into DC voltage. This lesson will cover three basic types of rectifiers: Half-wave, full-wave, and bridge. Each of these rectifiers uses one or more diodes. A diode, the key to rectifier operation, is a device that allows current to flow easily in one direction but offers tremendous opposition to current flow in the other direction.

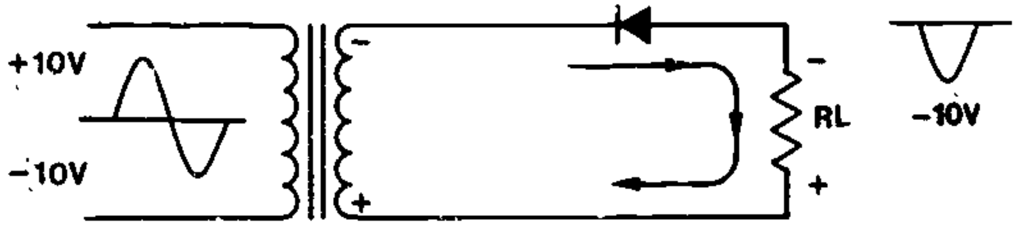
As you can see in the illustration, current will only flow from the cathode (schematically depicted as a short vertical line) to the anode (depicted as a solid triangular figure). Therefore, in order for current to flow, the cathode must be negative with respect to the anode. When these polarity conditions are met, the diode is said to be forward biased. If the cathode is more positive than the anode, no current flows. This condition is referred to as reverse bias. (See the following illustration.)



The simplest rectifier circuit is a half-wave rectifier which consists of a single diode. The diode is connected to the secondary of a transformer and it will block either the positive or negative alternation of the AC current in the secondary. Note the direction of the diode in the half-wave rectifier shown below.



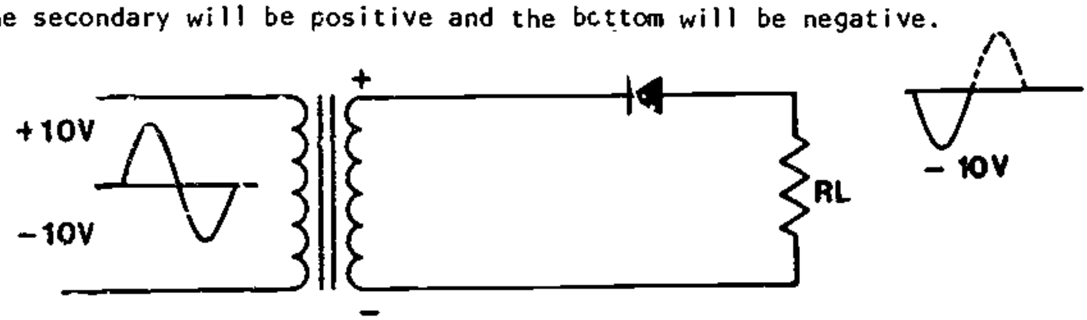
The voltage on the secondary of the transformer is AC - i.e. the voltage is changing polarity many times per second (probably 60 times per second). When the top of the secondary is negative and the bottom is positive,



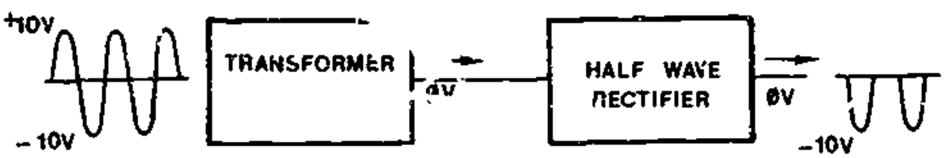
current will flow clockwise, through the diode and through R_L.

Because the diode is acting like a short; R_L will be in parallel with the transformer secondary and feel the same half-cycle of voltage.

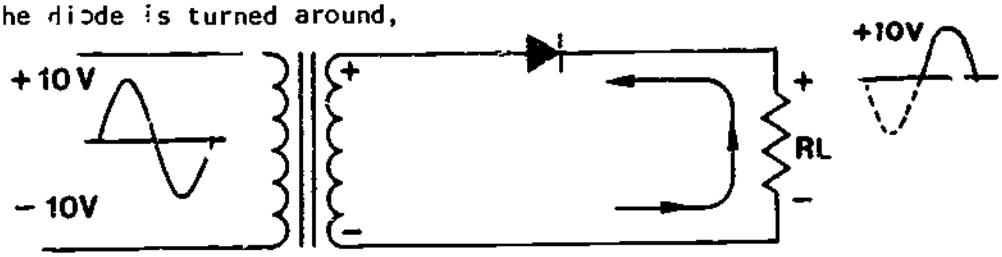
During a negative half-cycle on the transformer primary, the top of the secondary will be positive and the bottom will be negative.



Current will attempt to flow counter-clockwise in the circuit, but current cannot flow through the diode. Therefore, with no current through the secondary, no voltage can be developed. If no voltage is developed by the secondary, no voltage can be felt on R_L. Effectively, this half-wave rectifier eliminat , all positive half-cycles at the output and only the negativ ha c cles will be allowed to pass thus creating a negative pulsat C voltage.



If the diode is turned around,



the circuit is still a half-wave rectifier, but now the positive half-cycles will be allowed to pass.

Draw the output waveform if the output is positive pulsating DC from a half-wave rectifier.

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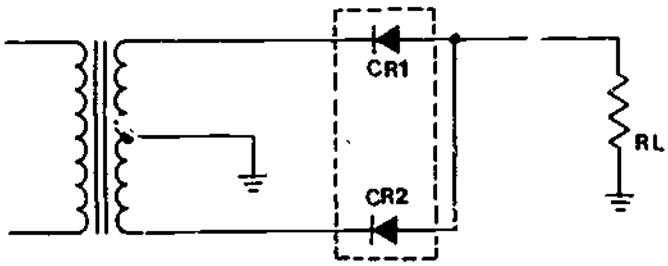
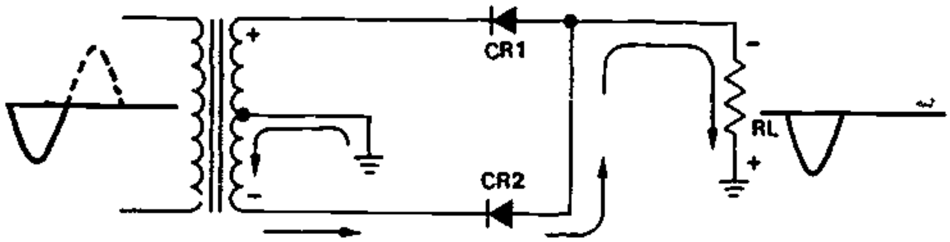
A full- wave rectifier uses two diodes to convert each negative and positive alternation of the input AC voltage to one polarity at the output. Like the half-wave rectifier, the full-wave rectifier output will be either positive or negative pulsating DC. This circuit is a full-wave rectifier with a negative DC output:



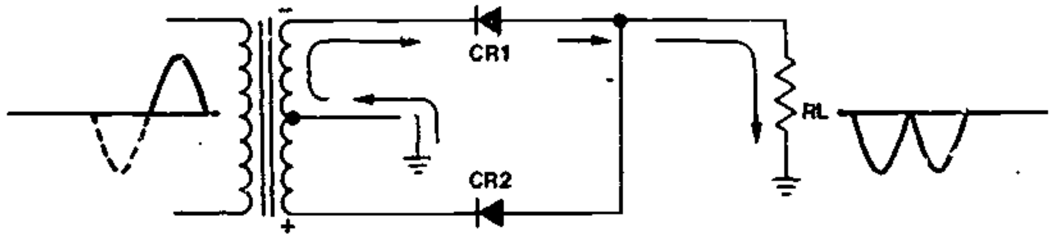
By using a center-tapped transformer, we can effectively have two half-wave rectifiers feeding the same load (R_L). Each rectifier will provide a pulse that is one-half the amplitude of the peak input voltage. In this manner we can use both half cycles of the input AC voltage. For example, say that the top of the primary is negative and the bottom is positive on one half-cycle of the input voltage.



Since current flows from negative to positive only, CR1 will not conduct current, but CR2 will conduct. Current will flow through CR2, down through

R_L, and back to the secondary center-tap via the ground. Since current flows <u>down</u> through R_L, the top of R_L will be negative with respect to ground.

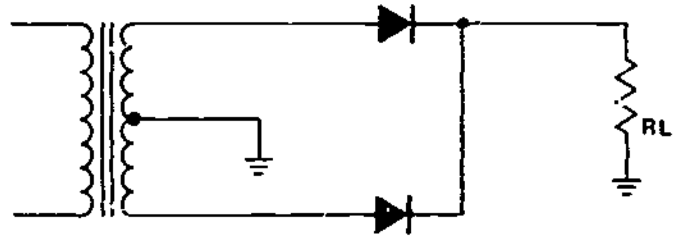
On the next half-cycle, the top of the primary will be positive and the bottom will be negative.



Current will now flow through CR1, but <u>not</u> through CR2, and the current will again flow <u>down</u> through R_L. The top of R_L will again be negative in respect to ground.

The rectifier example shown above will allow only the negative half-cycles to pass to the output--first from one diode, and then from the other. The output combines the alternations from each diode to produce pulsating DC voltages since the polarity of voltages at the output will always be the same.

The below circuit is also a full-wave rectifier.



Will the output voltage be positive or negative in respect to ground?

---

positive - note that the diodes are reversed from the full-wave rectifier with a negative output voltage, so current will flow in the opposite direction.

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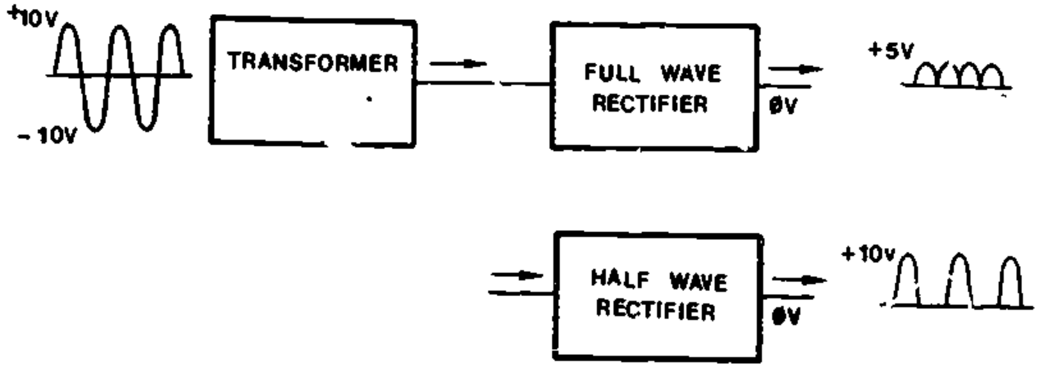
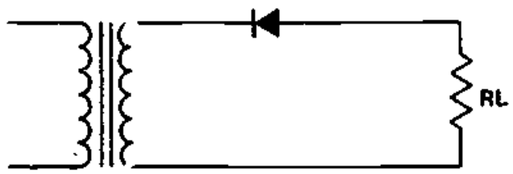
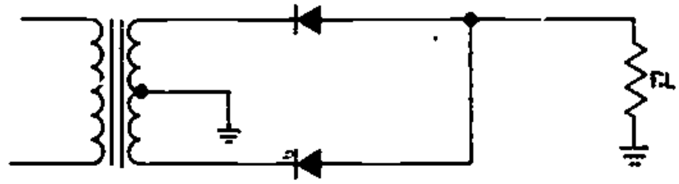
In the illustration below, both rectifiers will provide an average output of approximately +5VDC for an AC input of 10V peak. The difference is that the pulsating DC output of the full-wave rectifier will have less amplitude variation than the pulsating DC output of the half-wave rectifier. The reason for this is two-fold: First, a center-tapped transformer will provide only one-half of the available voltage (in this case 5V for 10V); second, because every half-cycle is used the output never really returns to ØV level and we are able to maintain an average voltage of approximately +5VDC.



Identify and label the half-wave and full-wave rectifier circuits illustrated below.



_______ WAVE RECTIFIER

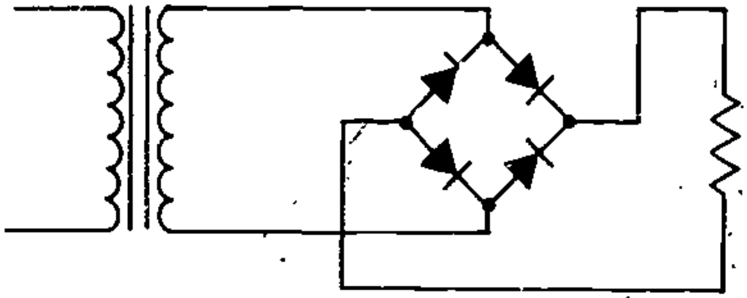


_______ WAVE RECTIFIER

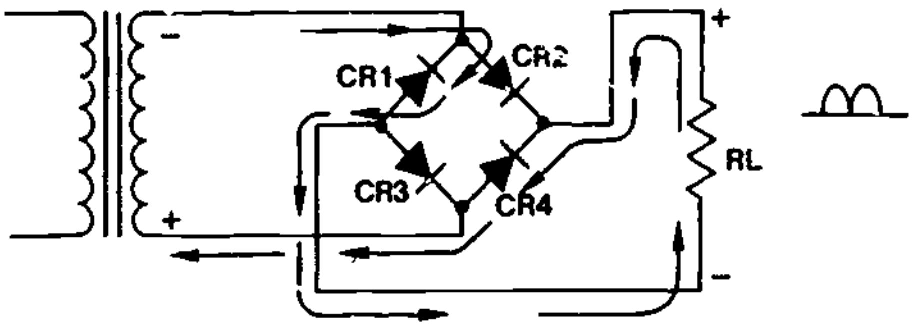
a. half-wave rectifier
b. full-wave rectifier

The last type of rectifier we will discuss is called the bridge rectifier. The bridge rectifier is the most commonly used rectifier in electronic equipment. Four (4) diodes are used to convert each alternation of the transformer secondary AC voltage into either positive or negative DC voltage at the output like a full-wave rectifier.

The circuit configuration for a bridge rectifier is normally shown on schematic diagrams with the diodes in a "diamond" pattern.



The diodes are arranged so that the output voltage will always be of the same polarity even though the input AC voltage changes polarity many times per second. The bridge circuit may look complicated at first glance, but it is fairly simple to analyze if you keep in mind that at any instant of time only two diodes are conducting current. The other two diodes will block current flow. For example, say that the top of the transformer secondary is negative and the bottom is positive.



On this half-cycle, CR1 and CR4 will conduct current, and CR2 and CR3 will block current flow. Current flows from the negative side of the secondary winding, through CR1, up through R_L, through CR4, and back

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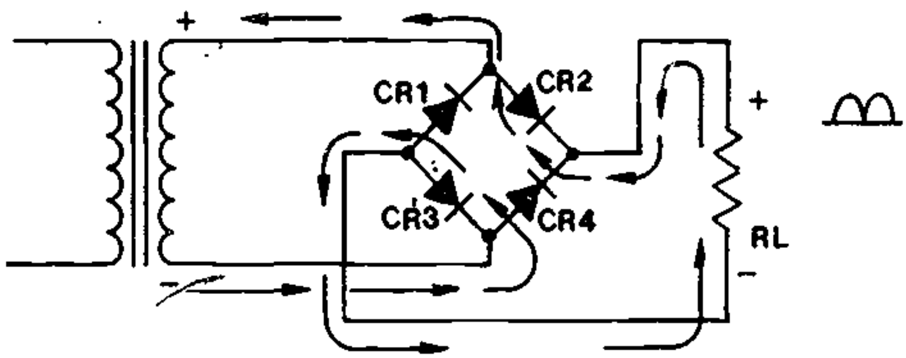
to the positive side of the secondary winding. There is no other complete path for current flow from the negative side to the positive side of the secondary winding. Try to find another complete path for current (remember that current flows from negative to positive).

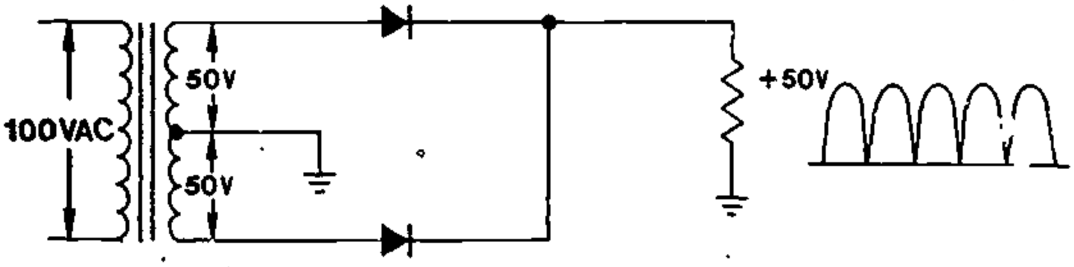
Since the current flow through R_L is from bottom to top, the top of R_L will be positive in respect to the bottom.

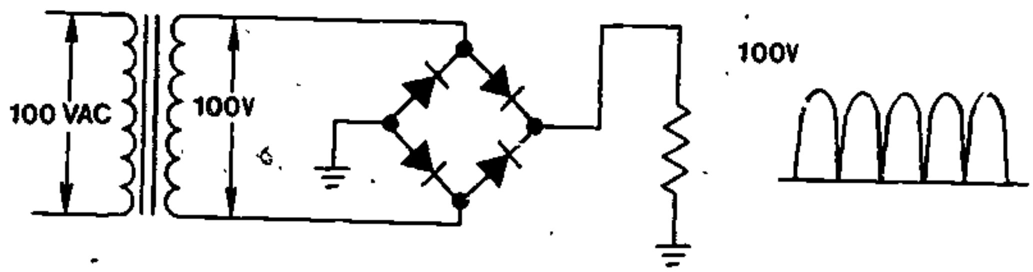
On the next half-cycle, CR2 and CR3 will conduct current and CR1 and CR4 will block current.



Let's trace the current path again. Current flows from the bottom of the secondary winding (now negative), through CR3, up through R_L, through CR2, and back to the positive side of the secondary winding. The current through R_L is in the same direction as before, so the polarity of voltage at the output is still the same.

The variations in the pulsating DC voltage will be about the same as the variations obtained with a full-wave rectifier if both circuits use the same transformer and the same primary voltage. However, the peak amplitude of the bridge is twice the amplitude of the full wave rectifier.





NOTE: Both transformers are the same except the full wave circuit transformer is center-tapped.

In the full wave circuit, at any one time, there is only one diode passing current. Each diode gets only one-half of the secondary voltage. Therefore, the output voltage is equal to one-half of the peak input voltage.

In the bridge circuit, however, the two diodes that are passing current at any one time are connected across the whole secondary of the transformer. Therefore, the output voltage is equal to the peak input voltage.

For each type of rectifier circuit, some of the advantages and disadvantages are:

	ADVANTAGES	DISADVANTAGES
HALF-WAVE	Simple circuit, few components.	High voltage variation, low output current.
FULL-WAVE	Low voltage variation in output.	More components, low output voltage.
BRIDGE	Low voltage variation in output, higher output voltage.	Complex circuitry, more components.

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.


Knob
Turning Is
A Bad
Habit
For
Every
One

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY

LESSON V

POWER SUPPLY FILTERS

1 APRIL 1977

OVERVIEW
LESSON V

Power Supply Filters

In this lesson you will study and learn about the function of the power supply filter, and the schematics and output waveforms of capacitor input, choke input, and Pi filters.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.5.40 When the student completes this course he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.5.40.10 OBSERVE, MEASURE, and INTERPRET the output waveforms and voltages from the filter stage of an electronic power supply, given an oscilloscope, and a training device. Readings must be within specified tolerances.

20.5.40.10.1 IDENTIFY schematic configurations of capacitor input, choke input, and pi type filters of electronic power supplies, given schematic configurations of each. 100% accuracy is required.

20.5.40.10.2 IDENTIFY the output waveform of an electronic power supply filter circuit, given drawings of various waveforms only one of which is correct. 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.

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LIST OF STUDY RESOURCES
LESSON V

Power Supply Filters

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:

Audio/Visual Response Sheet Twenty - V "Rectifiers and Filters"
Job Program Twenty - V "Power Supply"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty - V "Basic Power Supply Filters"

Enrichment Material(s):

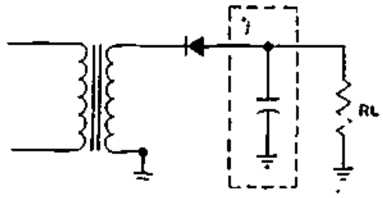
Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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.

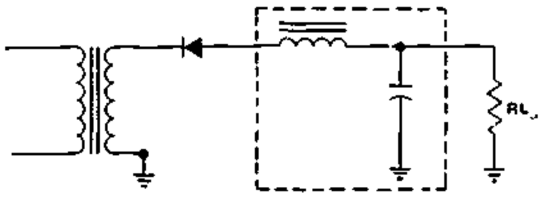
SUMMARY
LESSON V

Filter Section

Filter circuits used in power supplies are of two general types; capacitor input

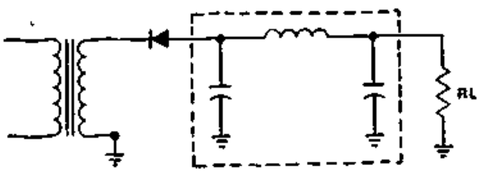


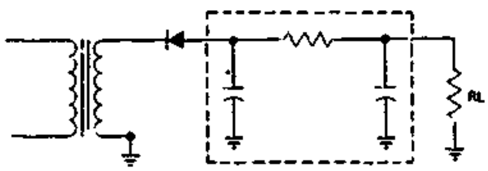
and choke input.



The filter's sole purpose is to remove the pulsations from the rectifier output to produce a smooth DC voltage.

The Capacitor Input Filter produces a smooth, steady DC voltage by opposing any change in voltage. The Choke Input Filter accomplishes the same thing by opposing any change in current. A happy median is reached by combining the two filters and creating a pi filter. The pi filter is a capacitor input filter that may have either a coil or a resistor separating a pair of capacitors in parallel.





The pi configuration using the coil is the most common one used in electronics. it can provide high voltage and high current. The pi filter gets its name from its schemaric configuration which is usually drawn to resemble the Greek letter pi (π).

102

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 V

Filter Section

GO FIRST TO TEST FRAME 8 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The output of a rectifier is a pulsating DC voltage. This pulsating DC voltage is usually of little use in electronic equipment. A steady, constant DC level is required. To get this steady voltage we use a filter to remove the pulsations. The filter will not remove all of the variations in the DC output. The variations that remain are called ripple.

Which of the illustrations below best describe what a filter does?

a.

b.

c.

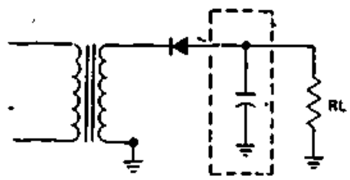
d.

- -

d.

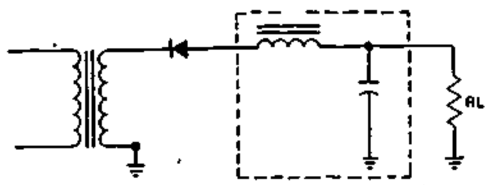
2. There are two basic electronic components used in filters; capacitors and coils (chokes). A capacitor is used because it opposes any change in voltage, and a coil is used because it opposes any change in current.

These components determine the name and basic puspose of the filter. If the closest component to the rectifier is a capacitor...



it is called a Capacitor Input Filter and will provide maximum voltage.

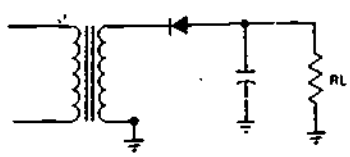
If the closest component to the rectifier is a coil (choke)...



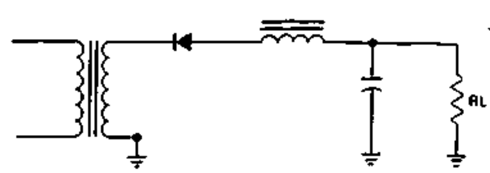
it is called a Choke Input Filter and will provide maximum current.

Match the filter schematic with its description as to the type and application.

a.



b.



1. Choke input for high voltage.
2. Capacitor input for high current.
3. Choke input for high current.
4. Capacitor input for high voltage.

---

a. 4, b. 3

3. The capacitor input filter maintains a high voltage level because the capactior charges very quickly and discharges much more slowly. This slow discharge rate means that before the capacitor can discharge very much the next pulse has arrived and boosted the voltage level back to peak value.

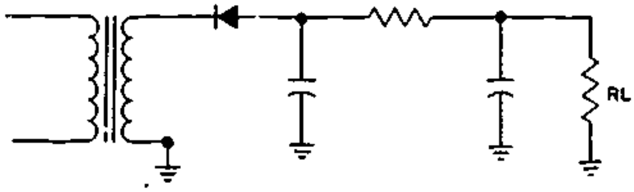
The choke input filter opposes any change in current. As the voltage pulsates, the current follows. The coil opposes the current change to obtain a relatively steady current output to the load. This constant current flow, passing through a fixed resistor, provides a steady voltage.

A capacitor input filter provides a constant high ______ level, while a ______ input filter provides a constant current.

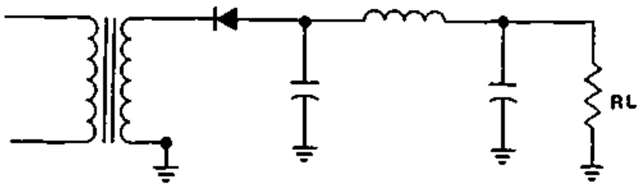
- -

voltage, choke (in that order)

4. The addition of a capacitor and a resistor to the capacitor input filter



or another capacitor to the choke input filter



provides us with configurations called PI filters. (The name is derived from the Greek letter pi (π).) The pi filter with the resistor is used mainly in low current applications.

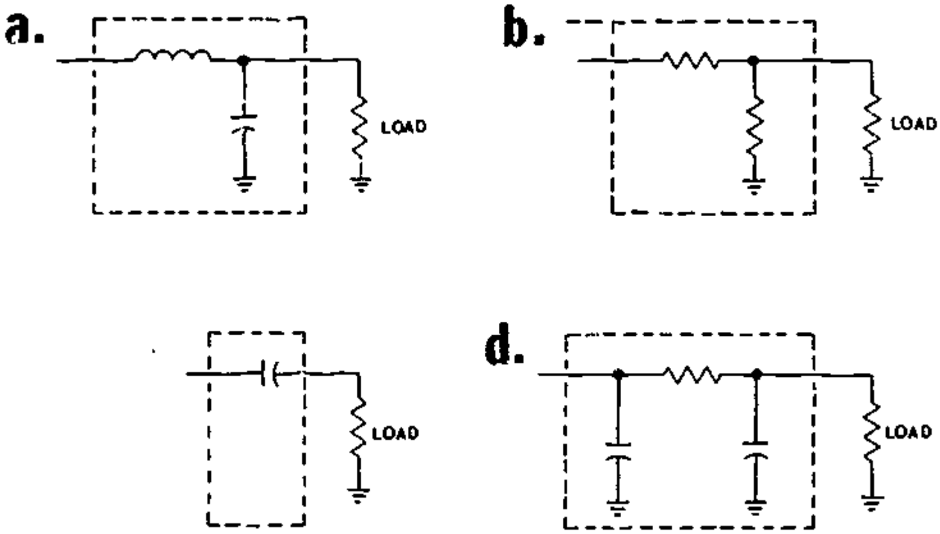
The pi filter with the coil is probably the most common configuration found in power supplies. The capacitor's ability to maintain a constant high voltage and the coil's ability to maintain a constant current gives us the best of both worlds.

The pi filter is produced by adding a _______ and a _____ to a capacitor input filter or by adding a _______ to the choke input filter.

---

capacitor, resistor, capacitor (in that order)

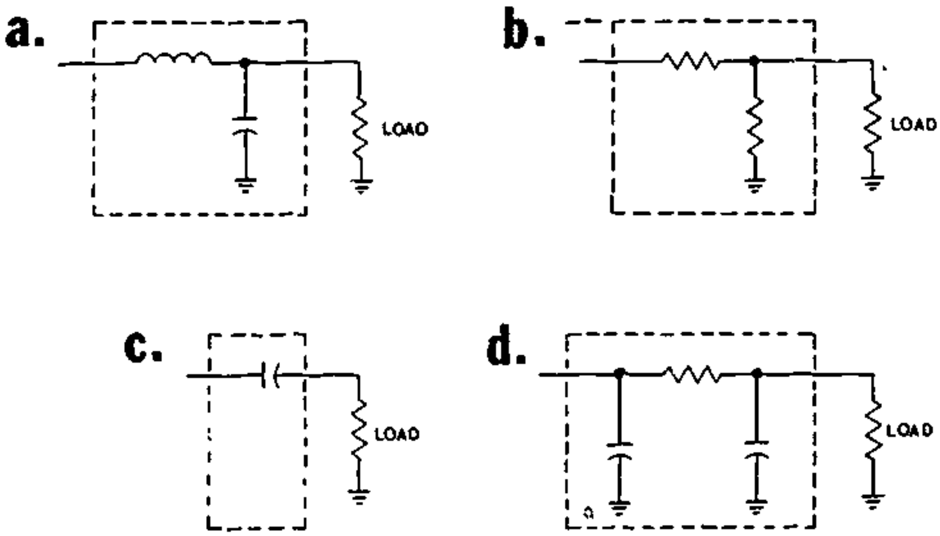
5. Which of these filters would be used for high voltage?



- -

d. (c will block all DC voltage from the load)

6. Which of these filters would be used for high current?

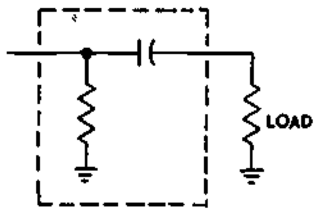


- -

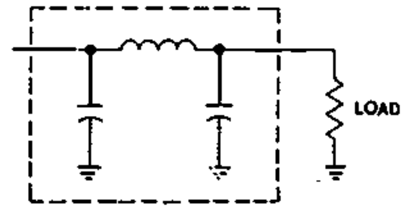
a.

7. Which filter is a pi filter?

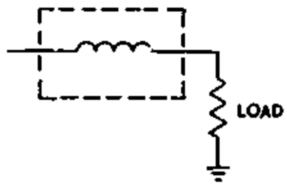
a.



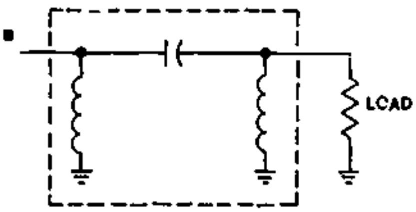
b.



c.



d.



---

b. (Choices a and d will divert the DC to ground)

8. TEST FRAME

The pi filter provides the high ______ capacity of a capacitor input filter and the high ________ capacity of a choke input filter.

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

voltage, current (in that order)

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 V

.ilter Section

The pulsating DC supplied by the rectifier is of little practical use in most electronic equipment. What is usually required is a smooth DC voltage. In order to get this voltage we use a filter to smooth out the pulsations. The filter will not get rid of all of the pulsations, just most of them. The voltage variations that are left are called ripple.

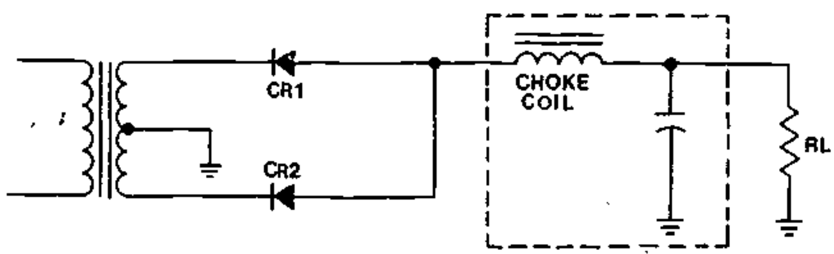
There are two basic electronic components that are used as filters; the capacitor, because it opposes any change in voltage, and the coil (choke) because it opposes any change in current.

What is the function of the filter stage of a power supply?

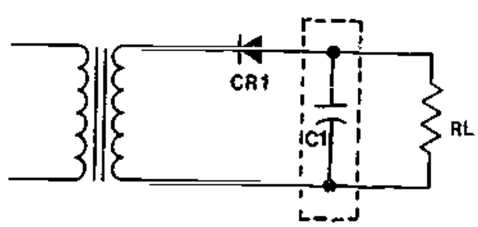
- -

To remove pulsations from the rectifier output and give a smooth DC voltage. (or words to that effect)

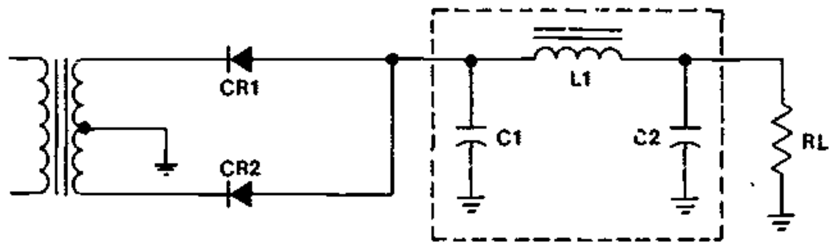
When a coil is used as the first component following the rectifier output, the filter is called a Choke Input Filter.



When a capacitor is the first component following the rectifier, the filter is called a Capacitor Input Filter.

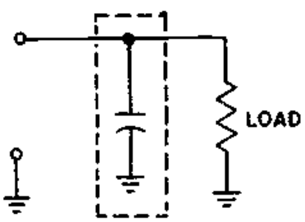


What type of input filter does the following schematic show?



Capacitor input filter.

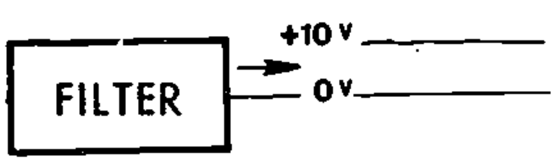
How do filters work? Well, in the capacitor input filter,



the capacitor charges very quickly up to the applied voltage and discharges very slowly.

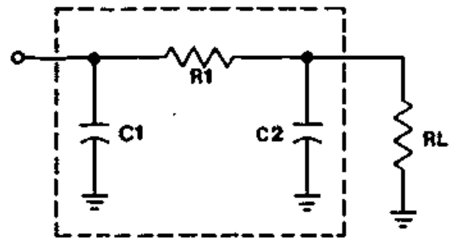
This slow discharge means that before the capacitor can discharge completely the next pulsation has arrived and boosted the voltage to its original level. This input to the filter

will give this output from the filter

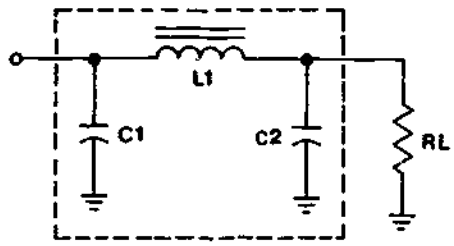


The choke (coil) filter opposes current change. It opposes current change throughout the entire alternation of the pulsed DC. This gives a relatively constant current output to the load, which results in a constant voltage.

The addition of a capacitor and a resistor to the capacitor input filter



or adding another capacitor to the choke input filter



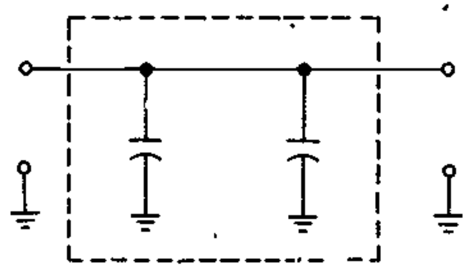
gives us a common configuration called a Pi filter. (The only reason for the name is because the schematic resembles the Greek Letter Pi [π]).

The pi filter with the resistor is used mainly in low current applications.

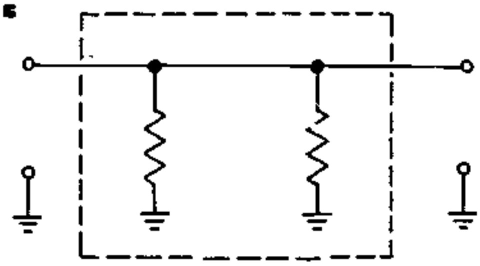
The pi filter with a coil is probably used to a greater extent than any other filter in power supplv applications. This pi filter takes advantage of the capacitor's ability to maintain a constant high voltage and the coil's ability to maintain a constant high current.

Identify the correct schematic illustration of a power supply's pi filter.

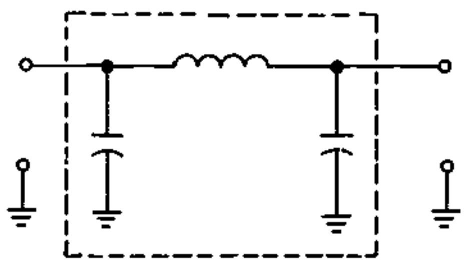
a.



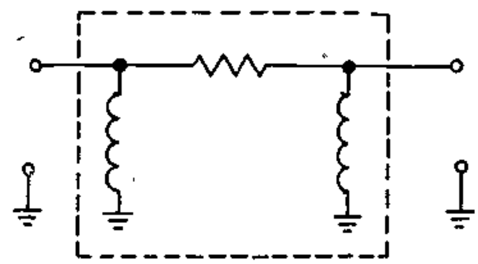
b.



c.



d.



---

c.

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

LESSON VI

POWER SUPPLY REGULATORS

1 APRIL 1977

OVERVIEW
LESSON VI

Power Supply Regulators

In this lesson you will study and learn about the function of a voltage regulator, the operation of a simple series regulator, the operation of a simple shunt regulator, and the purpose of a zener diode in a shunt voltage regulators.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.6.40 When the student completes this course he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.6.40.11 OBSERVE, MEASURE and INTERPRET the voltage at the power supply regulator output when (1) input voltages change and (2) when loads are added, given a VOM, schematic diagram, a job program, and a training device with provisions for varying line voltage and load conditions. Readings to be within tolerances specified in the job program.

20.6.40.11.1 IDENTIFY the function of a series regulator by selecting the statement best describing the function of an electronic series regulator, given an illustration and a set of statements. 100% accuracy is required.

20.6.40.11.2 IDENTIFY the function of a shunt regulator by selecting the statement best describing the function of an electronic shunt regulator, given an illustration and a set of statements. 100% accuracy is required.

20.6.40.11.3 IDENTIFY the function of a Zener diode acting as a voltage regulator in a power supply by selecting the most correct statement from a list of statements, one of which correctly describes the functions of a Zener diode, given an illustration and a set of statements. 100% accuracy is required.

OVERVIEW

20.6.40.11.4 MATCH the physical components of the output stage of an electronic power supply with their respective schematic symbols given a schematic diagram, a job program, and a training device power supply. 100% accuracy is required.

20.6.40.11.4.1 IDENTIFY the location of components, letter number designations and test points of the output stage of an electronic power supply as required on the job program given a schematic diagram and a training device power supply. 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 VI

Power Supply Regulators

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:

Progress Check

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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.

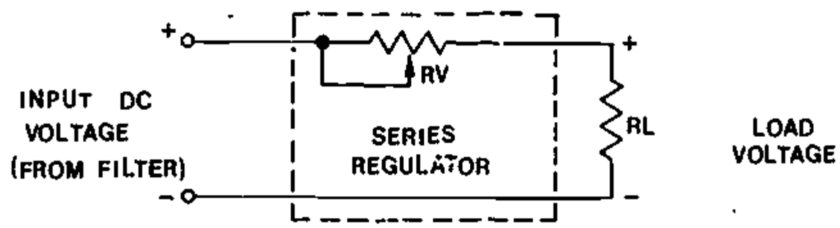
SUMMARY
LESSON VI

Power Supply Regulator Theory

A voltage regulator is the final stage in many power supplies. A voltage regulator will maintain a constant DC output voltage in spite of input AC line voltage fluctuations or output load changes.

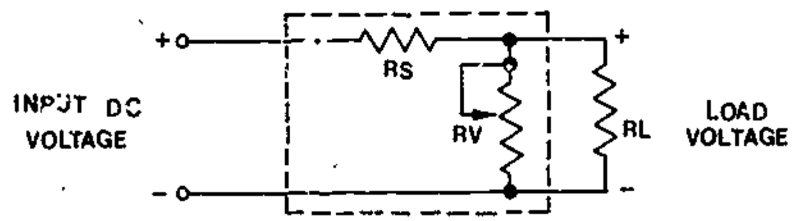
There are two classifications of voltage regulators: series regulators and shunt regulators. Regulators are classified according to the way the regulating device is connected with the load: in series or in parallel (shunt).

The simplest type of regulator is a series regulator.



In this schematic, the regulating device is represented by a variable resistor (Rv). If the input DC voltage from the filter increases, the resistance of Rv may be increased in order to maintain a constant voltage across R_L. By the same token, Rv may be decreased if input voltage decreases.

A shunt regulator has the regulating device in parallel with the load:

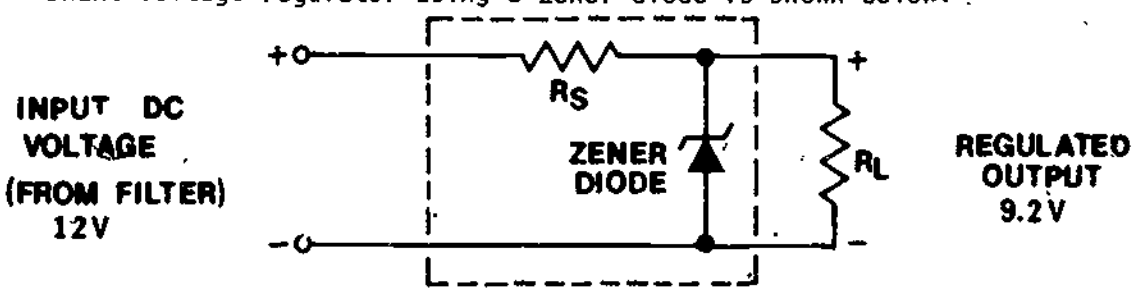


Rs is a resistor in series with the load and Rv again represents a regulating device. If the input voltage increases, it is necessary to increase the voltage drop on Rs in order to maintain a constant voltage across R_L. By decreasing the resistance of Rv, the current flow through Rv and Rs will increase and the voltage drop across Rs will increase.

If the input voltage decreases, the resistance of Rv must be increased to decrease the voltage drop across Rs to maintain a constant voltage across R_L.

Most regulators do not use variable resistors because the input voltage will fluctuate too rapidly to be controlled manually. One type of automatic regulating device is the Zener diode. A Zener diode is a special kind of diode that will maintain a constant voltage (known as Zener voltage) when biased to conduct in the reverse direction even through its current may vary over a wide range.

A shunt voltage regulator using a Zener diode is shown below:



Since the Zener diode maintains a constant load voltage, all increases and decreases in input DC voltage or variations of the load will be absorbed by the series resistor Rs.

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PROGRAMMED INSTRUCTION
LESSON VI

Power Supply Regulators

TEST FRAMES ARE 4, 10, AND 18. AS BEFORE, GO FIRST TO TEST FRAME 4 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The final stage in many power supplies is a voltage regulator circuit. A voltage regulator will maintain a constant DC output voltage in spite of input AC line voltage fluctuations or output load changes. Precision electronic equipment requires a constant DC voltage for proper operation, but there are several reasons why the DC output voltage might tend to vary:

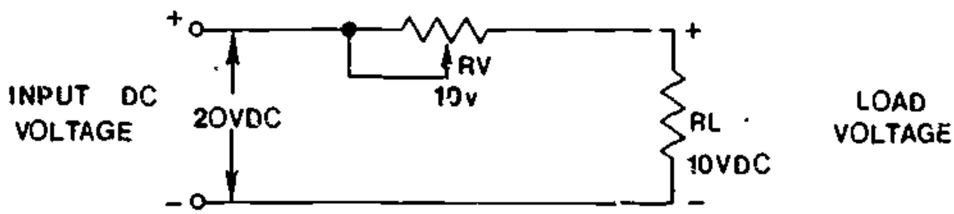
a. The input AC line voltage may vary.
b. The load on the power supply might change; for instance, part of the circuit must be removed during testing.
c. Aging of components; the characteristics of resistors, transistors, and some other components will change as they get older.

Therefore, to offset factors that affect voltage, a voltage regulator must mainain a __________ DC output voltage.

- -

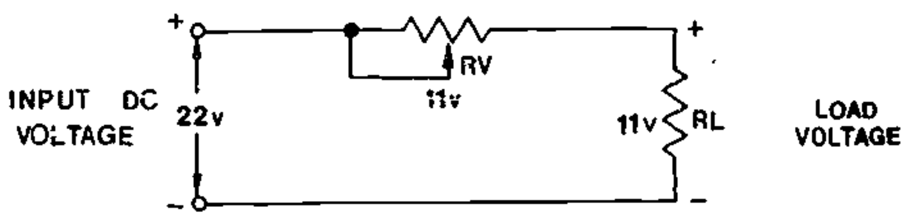
constant

2. A voltage regulator will always have some sort of regulating device to adjust voltage and/or current in case AC line voltage fluctuates or the load changes. The simplest type of regulating device is a variable resistor. A variable resistor can be placed in series with a load resistance. (Note: the load will be represented as a resistor (R_L) in this lesson, but the load may actually be an entire electronic circuit.)



In the example above, Rv is a variable resistor, R_L represents the load, and 20v DC will be supplied from the filter circuit of a power supply. Rv and R_L each have a voltage drop of 10v.

If the voltage from the filter increases to 22v, the voltages across Rv and R_L will also increase - to 11v each - since the total voltage drop must equal the applied voltage.



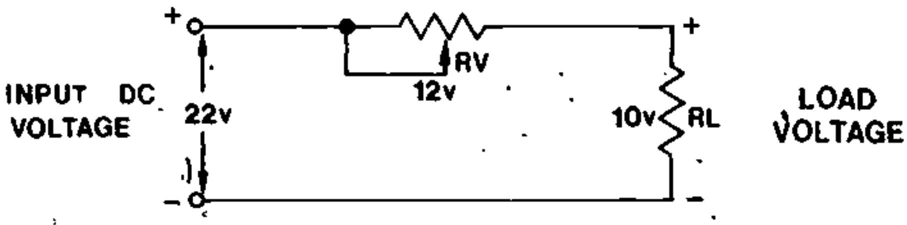
But the voltage across R_L <u>must</u> remain 10v in order to make the circuit operate properly.

What component in the circuit can be adjusted to reduce the current flow through resistor R_L? ____________

- -

Rv can be adjusted

3. Let's say that we increase the resistance of Rv until Rv drops 12v and R_L drops 10v:



Now the load voltage has been "regulated" or adjusted to maintain a constant 10v.

If the voltage from the filter dropped to 18v, what must be done within this circuit to maintain a constant 10v across R_L? ____________

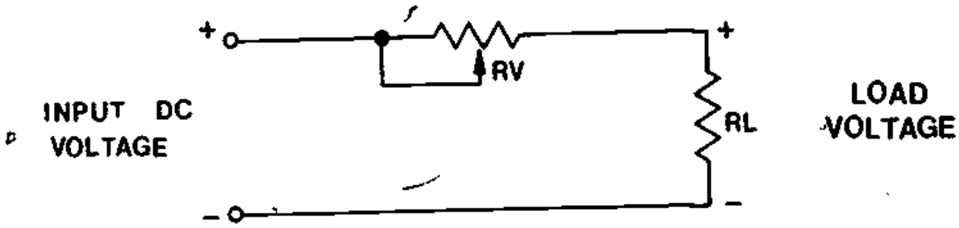
- -

The voltage across Rv must be adjusted to 8v. (or words to that effect)

123

4. TEST FRAME

The type of regulator discussed so far is called a Series Regulator since the regulating device is in series with the load resistance. In order to maintain a constant voltage across R_L in a series regulator



the resistance of Rv must be __________ if the input DC voltage increases.

- -

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

increased

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 10. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 4 AGAIN.

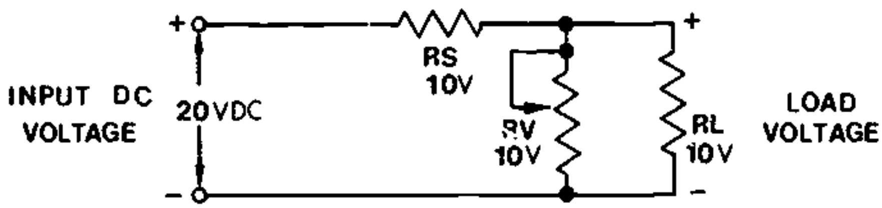
5. A voltage regulator will maintain a constant ________ in spite of input voltage __________ or output load ____________.

- -

DC output voltage, fluctuations, changes

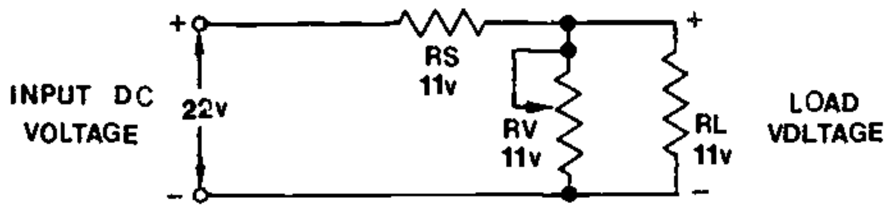
6. Another type of regulator circuit is the shunt regulator in which the regulating device is in parallel with the load.

For example, again say that the DC voltage from the filter is 20v DC:



The voltage required across R_L is 10v. Note that the voltage across R_L plus the voltage across Rs must be equal to the total DC voltage from the filter.

If the DC voltage from the filter increases to 22v DC because of an increase in AC line voltage, all voltages will tend to increase proportionally:



The voltage across R_L is now 11v. But we require 10v across R_L.

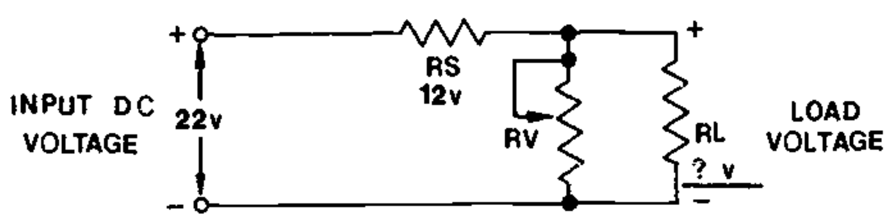
In order to obtain 10v across R_L with an input DC voltage of 22v DC, what voltage must exist across Rs?

12V

---

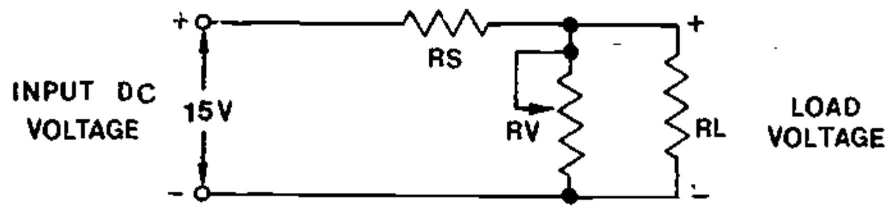
7. The only adjustment available in the circuit is Rv. By decreasing the resistance of Rv, we increase current flow through Rv. Note that Rv and Rs are in series, so increasing the current through Rv also increases the current through Rs.

Let's increase the current flow through Rs until the voltage drop across Rs increases to 12v. What is the voltage across R_L now:



10V

8. We have now adjusted the load voltage back to 10v when the input DC voltage increased. Assume that the input voltage decreased to 15v:

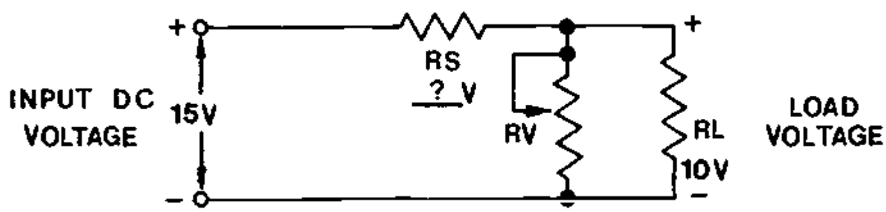


Do we increase or decrease the resistance of Rv to obtain 10v at R_L?

- -

Increase the resistance of Rv in order to reduce the current through Rs.

9. Now what is the voltage across Rs?

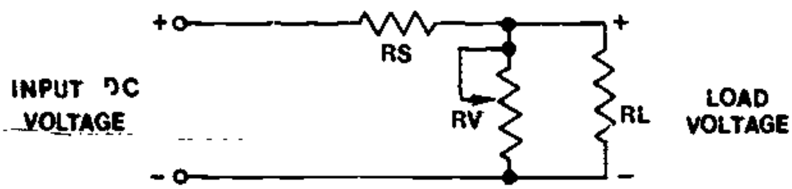


- -

5V

10. TEST FRAME

In general, if the input DC voltage increases in a shunt voltage regulator:



we should (increase/decrease) the resistance of Rv in order to maintain a constant voltage across R_L.

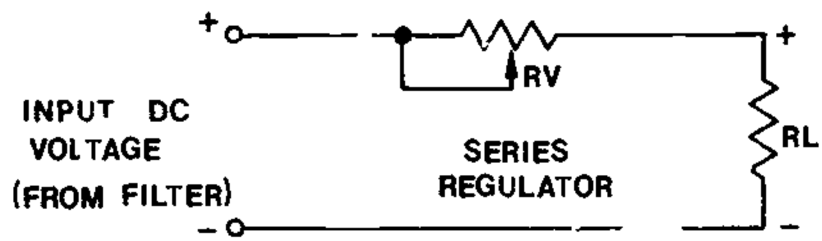
- -

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

decrease

IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU MAY GO ON TO TEST FRAME 18. OTHERWISE, GO BACK TO FRAME 5 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 10 AGAIN.

11. As seen, the output DC voltage may be maintained at a constant level if the input DC voltage changes. But we can also compensate for changes in load. Refer to the series regulator below:



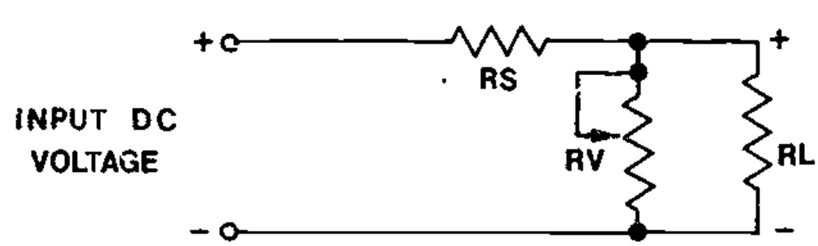
Resistances Rv and R_L form a voltage divider network to divide the total input DC voltage proportionately. If R_L decreases in value, Rv must also be decreased in value in order to maintain the same resistance proportion. The variable resistor is always adjusted to maintain the same proportion of voltages across Rv and R_L.

If R_L increases, should we increase or decrease Rv in order to maintain a constant load voltage?

---

increase Rv

12. A shunt voltage regulator can also compensate for changes in the load resistance. The load resistance and the variable resistance are in parallel:



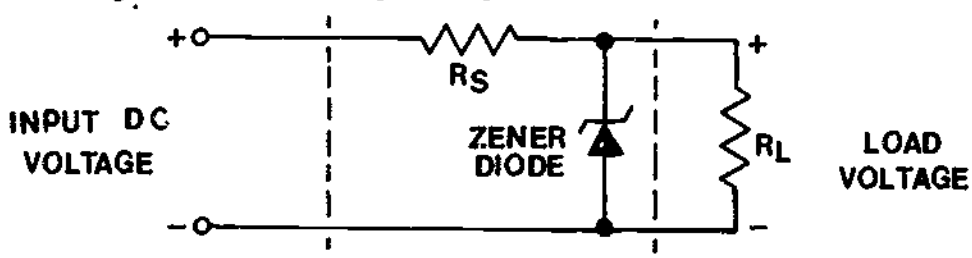
129

The parallel combination of Rv and R_L must be maintained at a constant resistance in order to maintain a constant load voltage. Therefore, if R_L increases Rv must be decreased. What should be done if the load resistance decreases?

- -

increase Rv

13. So far, you have seen the voltage regulating device represented as a variable resistor. Normally, a variable resistor cannot be used since the voltage fluctuations occur too rapidly to be corrected manually. Most voltage regulators operate automatically and will continuously regulate the output voltage without any external manipulation. One such automatic regulator uses a regulating device called a Zener diode:

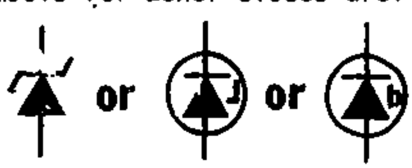


Would the above Zener diode regulator be classified as a shunt regulator or a series regulator?

- -

Shunt regulator - since the regulating device, the Zener diode, is in parallel (shunt) with the load.

14. A Zener diode is a special type of diode that blocks current like a normal diode until the applied voltage reaches a value known as the <u>breakdown voltage</u> or <u>Zener voltage</u>. When this happens the Zener diode conducts from its anode to its cathode (with the arrow!!!). The Zener diode will maintain this constant voltage (Zener voltage) as long as the Zener continues to conduct. The Zener current can vary over a range. Zener diodes are available with various Zener voltages. Some of the common schematic symbols for Zener diodes are:



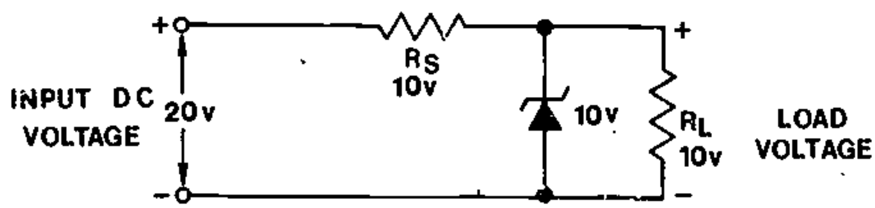
A Zener diode is conducting from anode to cathode. It will

a. Maintain a constant voltage drop.
b. Burn out.
c. Increase voltage as current increases.

- -

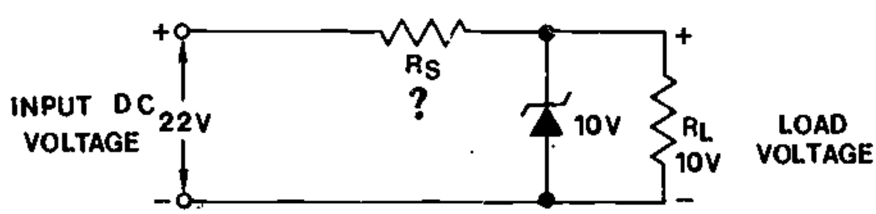
a. Maintain a constant voltage drop.

15. A shunt voltage regulator using a Zener diode has the Zener diode in parallel with the load resistor:



For example, say that the input DC voltage from the filter is 20v and the Zener voltage is 10v. Since the Zener is in parallel with the load, the load voltage will also be 10v.

If input voltage increases to 22v, the Zener diode voltage will not increase. However, the Zener diode current will increase which increases the current through Rs. The voltage drop across Rs increases because of the increased current:



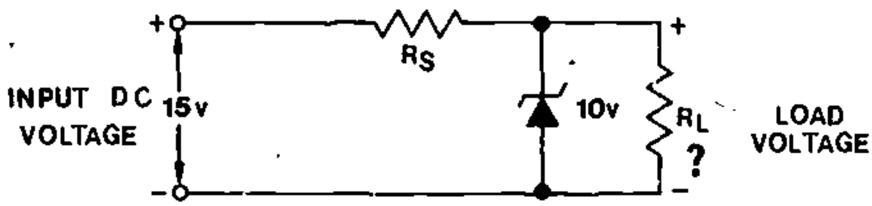
Now what is the voltage drop across Rs?

- -

12V

16. The series resistor, Rs, absorbs the entire increase or decrease of input voltage. If the input DC voltage decreases, the current through Rs and the Zener diode will also decrease, but again, the voltage drop across the Zener will not change.

What is the voltage across R_L if the input voltage changes to 15v DC?

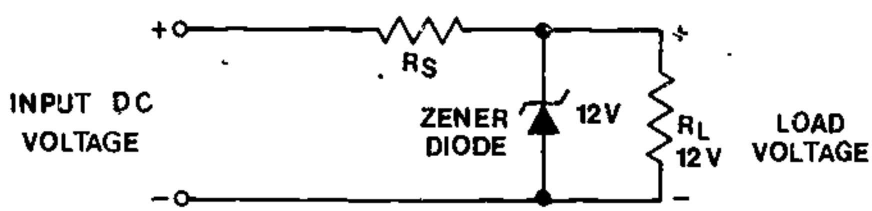


- -

10V

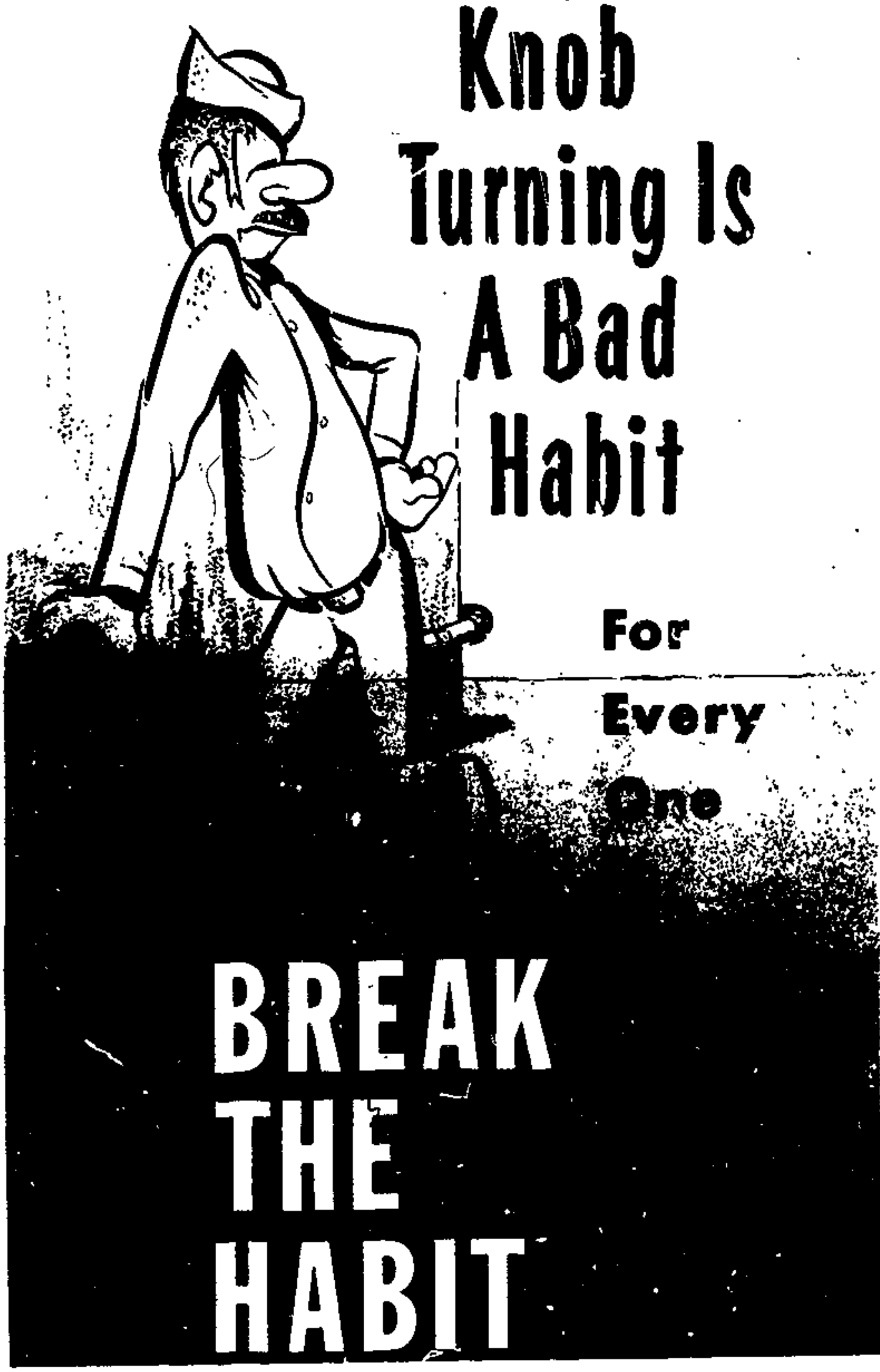
17. If the input voltage drops below the Zener voltage, the Zener diode will stop conducting and there will be no regulating effect. Therefore, because of the presence of resistance Rs in the regulator circuit, the input voltage must always be higher than the Zener voltage.

If 12v is required across the load resistance in the circuit below, what can be said about the requirement of the input DC voltage from the filter?



- -

It must be higher than 12V.


Knob Turning Is A Bad Habit
For Every One
BREAK THE HABIT

18. TEST FRAME

1. A Zener diode can be used as part of a voltage regulator because
____.

2. State the purpose of a voltage regulator.

- -

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

1. It maintains a constant DC voltage drop. (or words to that effect)
2. A voltage regulator will maintain a constant DC output voltage in spite of input AC line voltage fluctuations or output load changes. (or words to that effect)

IF YOUR ANSWERS MATCH THE CORRECT ANSWER, YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON VI MODULE TWENTY. OTHERWISE GO BACK TO FRAME 11 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 18 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 VI

Power Supply Regulators

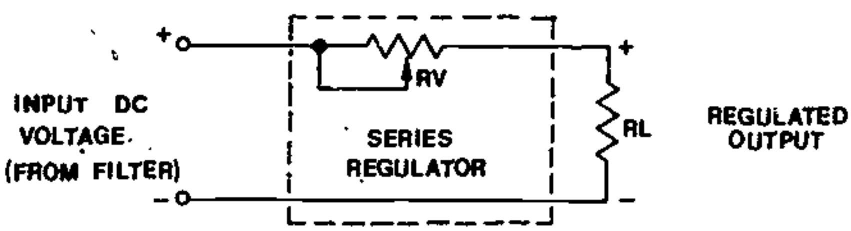
The final stage in many power supplies is a voltage regulator circuit. A voltage regulator will maintain a constant DC output voltage in spite of input AC line voltage fluctuations or output load changes. Precision electronic equipment requires a constant DC voltage for proper operation. There are several reasons why the voltage might te' ' to vary:

a. The input AC line voltage may vary.
b. The load on the power supply might change.
c. Components will age; the characteristics of resistors, transistors, and some other components will change as they get older.

Despite these various factors that affect voltage, a voltage regulator will maintain a constant DC output.

A voltage regulator will always have some sort of regulating device to adjust voltage and/or current. Regulators are classified as shunt regulators or series regulators depending on whether the regulating device is in parallel (shunt) or in series with the load. (In this lesson, the load will be represented by a resistor (R_L) although the load may actually be an entire electronic circuit.)

A simple series regulator is shown below:

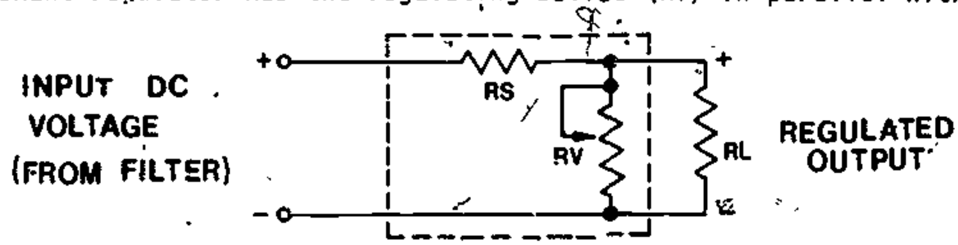


The regulating device is represented by a variable resistor (Rv). If the DC voltage from the filter increases, the resistance of Rv will be manually increased in order to maintain a constant voltage across R_L. If the input voltage decreases, would you increase or decrease Rv in order to maintain a constant voltage across R_L?

- -

decrease the resistance of Rv

A shunt regulator has the regulating device (Rv) in parallel with the load:



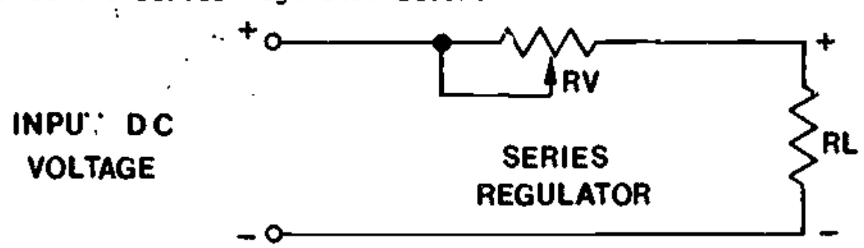
Rs is a resistor in series with the load, and Rv again represents a regulating device. Note that the voltage across Rv plus the voltage across Rs must be equal to the total DC voltage from the filter since they are in series. The voltage across Rv and R_L will be the same because they are in parallel. Therefore, if the input voltage increases, it is necessary to increase the voltage drop of Rs in order to maintain the original voltage across R_L and Rv. The only adjustment is Rv. By decreasing the resistance of Rv, the current flow through Rv and Rs will increase because the circuit has less total resistance. With an increase in current flow through Rs the voltage drop across Rs will increase. Therefore, if the input voltage increases, Rv must be decreased to maintain a constant voltage across the load.

Assume that the input voltage decreases. Do we increase or decrease Rv to maintain a constant load voltage?

Increase the resistance of Rv

As seen, the output DC voltage may be maintained at a constant level if the input DC voltages changes. Also, both the series and the shunt regulator can compensate for changes in the load.

Refer to the series regulator below:



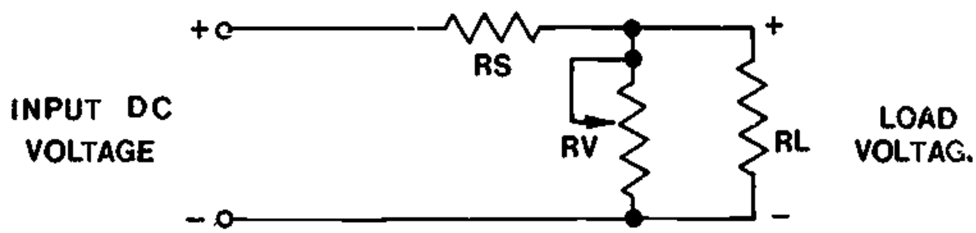
Resistance Rv and R_L form a voltage divider network which divide the total input DC voltage proportionately. If R_L decreases in value, Rv must also be decreased in value to maintain the same proportion.

Assume that the input DC voltage is 20v and the voltage required across R_L is 10v. If the load is 20 ohms, Rv must also be 20 ohms. If the load resistance decreases to 15 ohms, Rv will need to be decreased to 15 ohms also. The variable resistor is adjusted to maintain the same proportion of voltages across Rv and R_L.

If R_L increases, should we increase or decrease Rv in order to maintain a constant load voltage?

Increase Rv

A shunt voltage regulator can also compensate for changes in the load resistance. The load resistance and the variable resistance are in parallel:

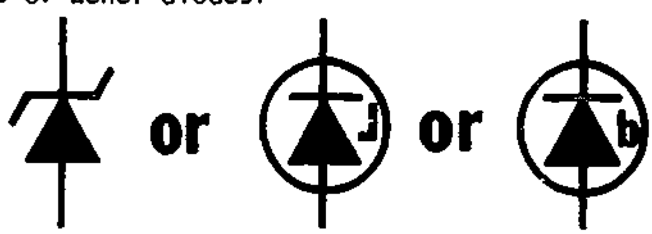


The parallel combination of Rv and R_L must be maintained at a constant resistance in order to maintain a constant load voltage. Therefore, if R_L increases, Rv must be decreased.

What should be done if the load resistance decreases?

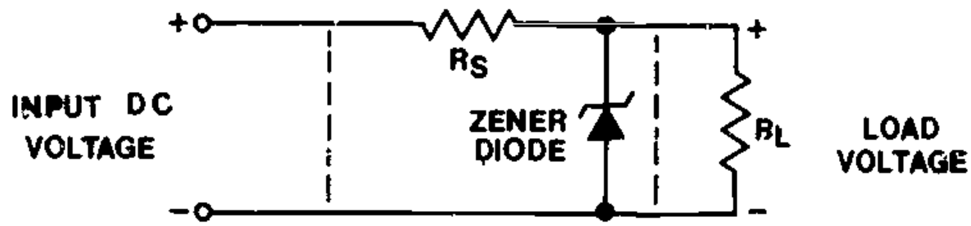
Increase Rv

So far, you have seen the voltage regulating device represented as a variable resistor. Normally, a variable resistor cannot be used since the voltage fluctuations occur too rapidly to be corrected manually. Most voltage regulators operate automatically and will continuously regulate the output voltage without any external manipulation. One such automatic regulator uses a device called a <u>Zener diode</u>: below are some schematic symbols of Zener diodes.



Zener diodes, like other diodes you have studied, will pass current (against the arrow) when forward biased and block current when reverse biased. However, should you increase the reverse bias to higher and higher levels, it will reach a point at which the diode conducts in the reverse direction (with the arrow). This point is known as the peak inverse voltage (PIV). If this point is reached in a normal diode, it will destroy the diode, but a ZENER diode is constructed in such a manner that it will conduct in the reverse direction without burning up. The reverse bias point at which a Zener diode will conduct is called BREAKDOWN VOLTAGE or ZENER VOLTAGE. Zener diodes are normally biased to operate (conduct) in the reverse direction. When the Zener diode does conduct in the reverse direction, it will maintain a constant voltage drop over a specific range of current. The Zener accomplishes this by decreasing its internal resistance as the reverse bias voltage tends to increase and increasing its internal resistance as the reverse bias voltage tends to decrease. The point at which the Zener will conduct in the reverse direction (breakdown or Zener voltage) and the range over which it will maintain a regulated voltage (Avalanche region) is predetermined by the way it is manufactured, and it varies from one zener type to another, according to need. Zener diodes are therefore classified according to Zener breakdown voltage and current handling capability.

Now that we know how the Zener basically works let's plug it into a shunt regulator circuit.



In the illustration, notice that the Zener replaces the variable resistor (Rv). The following voltages have been assigned for ease of explanation. The Zener has been reverse-biased into conduction and thus will maintain a 9.2 VDC voltage drop. Because the Zener is in parallel with the load (R_L) it will regulate the load voltage to 9.2 VDC.

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

LESSON VII

POWER SUPPLY SYSTEM CONCEPT

1 APRIL 1977

OVERVIEW
LESSON VII

Power Supply System Concept

In this lesson you will study and learn about the cause and effect of loading and interloading. As you proceed through this lesson, observe and follow directions carefully.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

20.7.40 When the student completes this course he will be able to TROUBLESHOOT two (one at a time) faulty solid state power supplies to the component level, given a training device, multimeter, oscilloscope, and schematic diagrams. Repair work will be done with similar components on a practice card. Fault diagnosis to be 100% correct with repair work passing a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

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

20.7.40.12 OBSERVE, MEASURE, RECORD and INTERPRET the normal waveforms at the output from each stage of an electronic power supply when each stage is in a loaded condition, given a training device, schematic diagrams, a job program, and an oscilloscope. Readings to fall within specified tolerances.

20.7.40.13 IDENTIFY how changes in current requirements are compensated for in an electronic power supply by selecting the correct statement from a list, given a list of choices only one of which is correct. 100% accuracy is required.

20.7.40.14 IDENTIFY the stage of an electronic power supply showing the most noticeable output waveform change as a result of interstage loading by selecting the correct statement concerning such change, given a list of statements only one of which is correct. 100% accuracy is required.

OVERVIEW

20.7.40.14.1 DEFINE the cause of "loading" by selecting the correct statement of the cause of loading of an electronic system, given a list of statements only one of which is correct. 100% accuracy is required.

20.7.40.14.2 STATE the effect(s) of "loading" of an electronic system by selecting the correct statement of the effect(s) of loading given a list of statements only one of which is correct. 100% accuracy is required.

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

LIST OF STUDY RESOURCES
LESSON VII

Power Supply System Concept

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 - VII "Power Supply Filtering, Regulation and Loading Effects"
Progress Check

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 2

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.

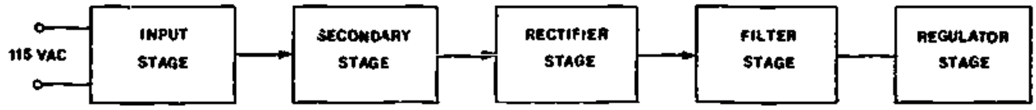
SUMMARY
LESSON VII

Power Supply System Concept

The previous six lessons dealt with the functional stages of the power supply. This lesson is designed to present a system concept of the power supply. This lesson covers the following areas:

1. The effects of loading and the importance of matching the power supply specifications to the load.

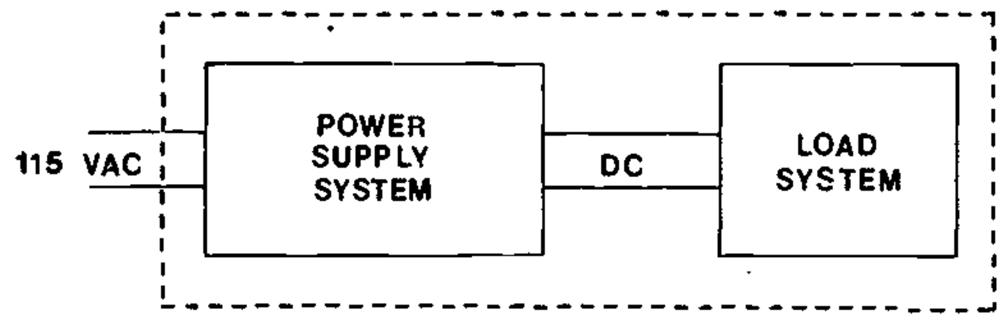
2. The effects of interstage loading in the power supply system.



POWER SUPPLY SYSTEM

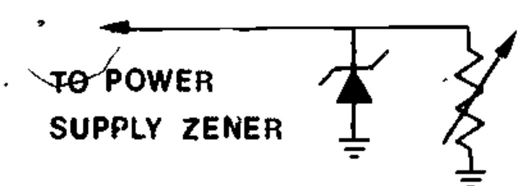
The five stages of the power supply make up a system. This system is designed to perform a specific overall function. That function is to provide the voltage and current requirements of the load. Any device or circuit connected to the power supply is called the load. As long as the power supply is matched to the load, the power supply will perform with no difficulty. If a mismatch occurs between the power supply and load, the power supply will operate much like a track star trying to run with a 200 pound weight. Not only will the power supply encounter serious problems with performance; it may also fail to hold up under the strain of the mismatch.

When a load is added to the power supply, the total impedance offered to the 115VAC changes. If the load is primarily the addition of parallel impedance the total impedance of both circuits will decrease. (Adding resistance in parallel will decrease the total resistance of all the branches). Adding a load that is mainly in series between the power supply and the original load will increase the total impedance of the network. If the load impedance increases or decreases, the amount of current drawn from the 115VAC souce will change.

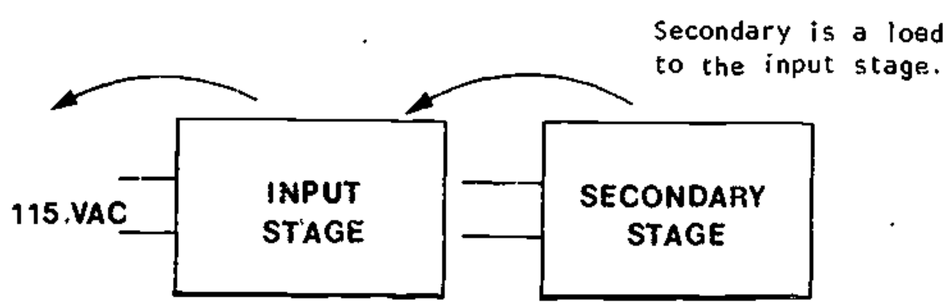


EQUIPMENT SYSTEM

If the load attached to the power supply is fixed, it is simple to design a power supply to provide a constant voltage. The situation changes when the load is variable. Without regulation, everytime the variable load's impedance changes, the current through the entire system changes. The voltage output of the power supply will also change. By using an oscilloscope, the voltage output can be seen to change with changes in the variable load. Automatic voltage regulators correct this varying output voltage. For example, the Zener diode will pass more or less current depending on how much current is demanded by the variable load. Since current in each parallel branch is additive, total current is the sum of the current in each branch. When the variable load is reduced, more current will try to flow in the load. The Zener will adjust its internal resistance and allow less current to flow through it. The increase in current through the load is exactly offset by the decrease of current through the Zener. Therefore, total system current remains unchanged.

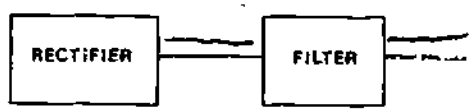


The Zener is capable of operating only within a specific range of current changes. If the load calls for more regulation than the Zener can provide, total current will start to rise; total voltage start to decrease. When this happens the power supply is said to be over-loaded.



When stages are added in sequence to the 115 VAC source, total impedance changes with each addition. For instance, the input stage offers a specific amount of impedance to the 115 VAC. When the secondary stage is then added, the secondary will act like a load to the input stage. In other words, each stage added acts like a load to the previous stage or stages. When the loading effect of each stage within the power supply system is considered, it is referred to as interstage loading. The most visible interstage loading occurs when the filter is added to the rectifier. The "bumps" coming out of the rectifier are immediately changed to a ripple. The loading effect of the filter causes this change.

Without A Load



With A Filter Load

When the regulator is added to the filter, the amount of ripple in the filter increases. Without the regulator, the filter does a great job of smoothing out the "bumps" from the rectifier. The regulator load draws current through the filter and makes the filter work harder. The final result--the ripple becomes more pronounced.

So remember, each stage of the power supply has a specific function. Each separate function combines to produce the system function. One system interacts with another system (power supply + radio circuits) to provide another combined system function (receive radio broadcasts). These interlocking functions have endless combinations.

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 VII

Power Supply System Concept

TEST FRAMES ARE 4, 10, 13, 19 AND 22. GO FIRST TO TEST FRAME #4 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS AT THE END OF THE TEST FRAME.

1. In this lesson we will discuss the power supply in a system. You will see how each stage of the power supply is connected to the other stages and how they interact with each other. Voltage, current, and impedance relationships are important for the proper operation of the system. Remembering Ohm's Law; $I = E/Z$, we see that a change in resistance or impedance will result in a change in current, as long as the voltage is held constant. The greater the impedance; the smaller the current.

With a decrease in the impedance in the system, which statement is the most probable result?

a. current decreases
b. current increases
c. voltage decreases
d. voltage increases

---

b. current increases

---

2. These changes in impedance can be thought of as the "loading effect". A load effect is caused by any circuit added to a system which causes the impedance of the system to change and thereby the amount of current to change. Adding circuits in parallel to the power supply system causes the total impedance of the power supply and load to drop. On the other hand, if the load is added in series with the existing load, the overall impedance will increase.

a. Loading a system with mainly parallel impedances will do what to the total current drawn or demanded from the 115 VAC source?
b. If the load impedance is added in series, what will happen to the current?

---

a. increases current in parallel.
b. falls for series load.

3. In working with our system we must match our load to the power supply design capabilities. Just as you wouldn't try to light your house with a flashlight battery, you wouldn't use 115 VAC in your flashlight. The loading effects mainly result in channe of current requirements in electronic circuits. As circuits are added or removed, the current required from the power supply will increase or decrease. Therefore, it is important to match the power supply to the load.

No response required

4. TEST FRAME

If the load requires 100 Volts, any 100 Volt power supply will work. (True/False).

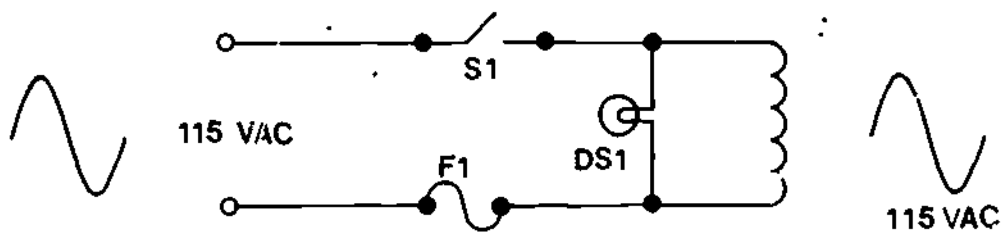
- -

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

False. Current requirements must also be met before the load and power supply may be considered matched.

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 10. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 4 AGAIN.

5. By taking the power supply stages you've learned about and connecting them together, we can make a power supply system. The first stage of our system is the input.



INPUT STAGE

As soon as we turn the switch on, 115 VAC will be applied to DS1 and the primary of the transformer. The input stage now acts as a load to the 115V source. The current required will be the sum of the currents through DS1 and the primary of the transformer.

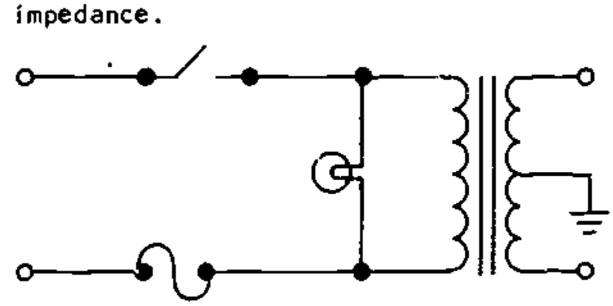
Would the load on the 115 VAC source increase or decrease if DS1 were to burn out?

- -

decrease

6. As soon as we add the secondary of the transformer to the system the impedance of the input will change because the secondary impedance will be reflected back into the primary of the transformer.

Now any change in secondary impedance (z) will cause a corresponding change in input impedance.

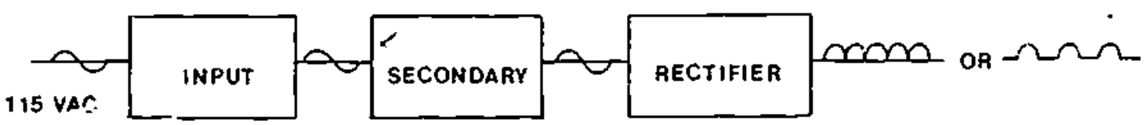


If current goes up in the secondary what happens to current supplied by the 115 VAC source?

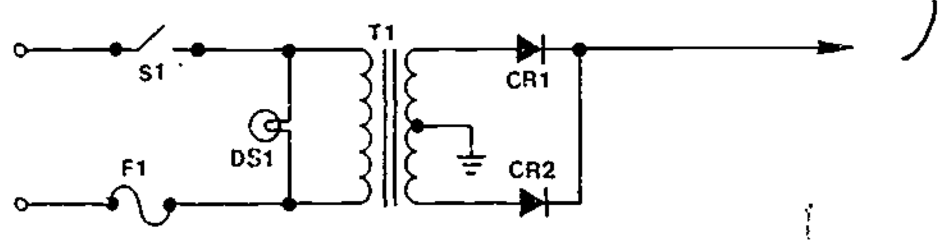
- -

Current will increase.

7. The next stage that we add to our system is the rectifier. The rectifier is a "load" to the first two stages of the power supply. Total impedance of the system will be changed by current flow in the rectifier circuit. Any time the addition of one stage of a system loads other stages in the system we call that interstage loading. In other words interstage loading is caused by a change of impedance in one stage which affects the impedance of other stages in the same system.



The output from the rectifier will be pulsating DC. Dependent upon the type of rectifier (full or half wave) you have, the output may look different, but it will still be pulsating DC.

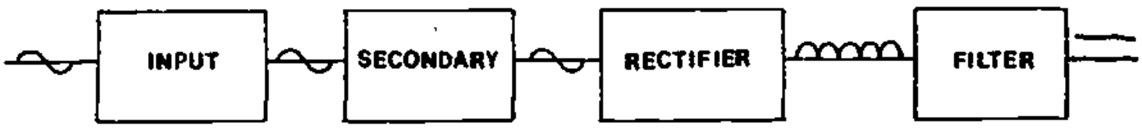


Will the addition of the rectifier stage cause interstage loading on the transformer secondary?

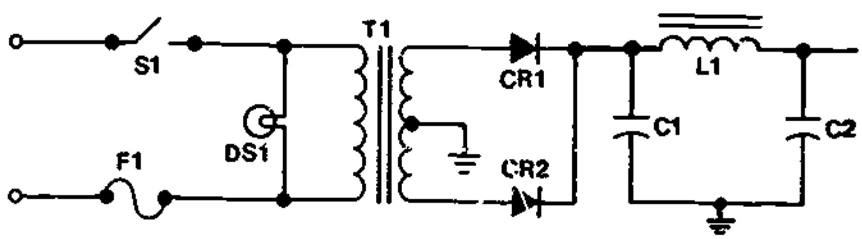
- -

Yes

8. As we construct our power supply system further, we add a filter. The filter is used to smooth out the "bumps" from the rectifier.



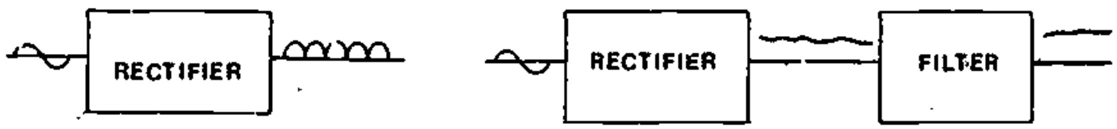
The filter is used to give a smoother DC. By adding the filter, we again "load" the previous stages and the total impedance of our system changes. The filter is a parallel impedance, which causes the total impedance of our power supply to change, therefore total circuit current changes interstage loading again!



The output voltage from the filter will be much more than the peak output of the rectifier. (True/False)

False

9. When the filter is added to the rectifier in our system we may see the most visible effect of interstage loading.



Without the Filter

With the Filter "Loading" the Rectifier

As soon as the filter is added to the rectifier in our power supply system, the "bumps" coming out of the rectifier change to a ripple. There is an immediate change in the total impedance of our system. It is not just felt at the filter. The filter is a "load" to the rectifier.

No response required.

10. TEST FRAME

If, after the filter has been added to the system, we see pulsating DC coming out of the rectifier, the filter is probably good. (True/False)

- -

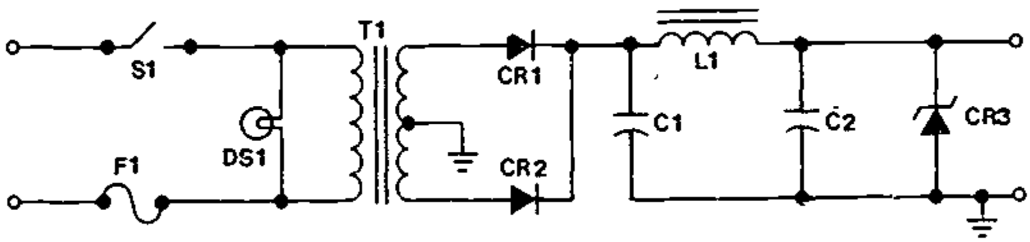
(THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.)

False

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 13. OTHERWISE GO BACK TO FRAME 5 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 10 AGAIN.

11. Following the filter in our power supply, we add a regulator. For this regulator we use a Zener diode:

The regulator is used to give us a constant output voltage. The regulator is added in parallel in our system, therefore, it causes total impedance to decrease.



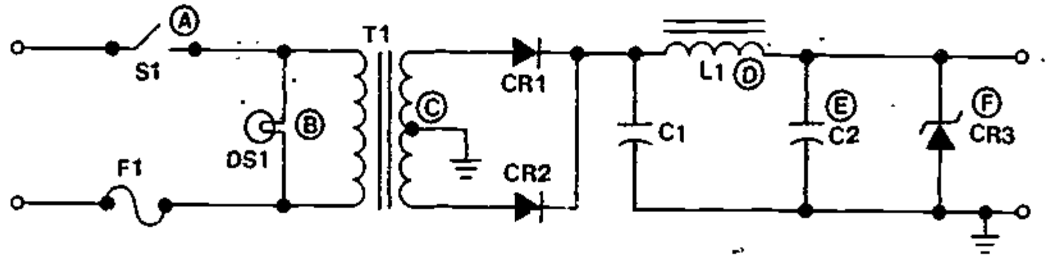
The power supply we have constructed, now has a specific value of impedance, therefore, we will have a certain voltage output.

When the regulator is added to the system, however, total current in our system will increase.
(True/False)

- -

True

12. Any changes in the output of our system are compensated for by the Zener changing its internal impedance. If there is more current drawn from the power supply the Zener will increase in impedance to maintain the same voltage at the output. Remembering Ohm's Law, E = IZ, we can see why this is.



We have now constructed a Power Supply System.

No response required.

13. TEST FRAME

In the circuit shown in Frame 12, where would you expect to read total current?

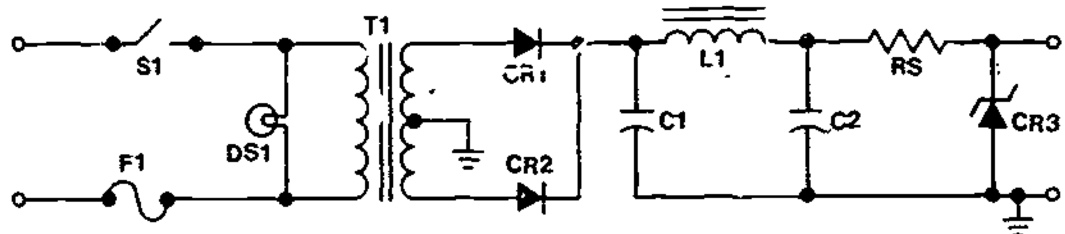
1. Point A
2. Point B
3. Point C
4. Point D
5. Point E
6. Point F

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

1. Point A.

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 19. OTHERWISE GO BACK TO FRAME 11 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 13 AGAIN.

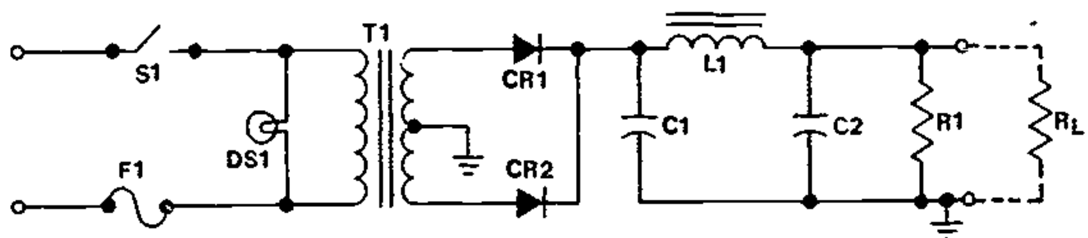
14. Let's see what would happen if we change or add components in our system. Let's place a dropping resistor (Rs) after the filter.



What would we expect to happen in this power supply?

Current goes down.

15. We now have a Power Supply System but it doesn't do us any good unless we use it to supply power to something. Let's connect a constant or fixed "load" to our power supply and see what happens.



We'll represent the "load" with a resistor. R1 offers a specific amount of impedance to the power supply. When we connect RL to the output terminals our effective impedance will change throughout the power supply. For example, if we add a load that is mainly parallel impedance, the total impedance will decrease and total current will increase. If the load is added in series with existing loads, impedance goes up and current goes down.

Adding a "load" to the power supply will cause total impedance to

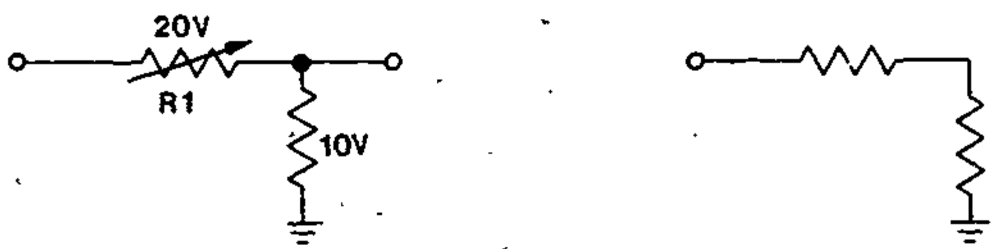
____

a. increase
b. decrease
c. either a or b
d. remain constant

- -

c. either a or b

16. With a constant load, the impedance does not change. If the 115 VAC at the input remains constant, there is no need for voltage or current regulation. But component values change with age and our input may also vary, so we must have some way to compensate for these changes. Most of the time these changes are gradual so we'll use a variable resistor to give us a constant DC output.



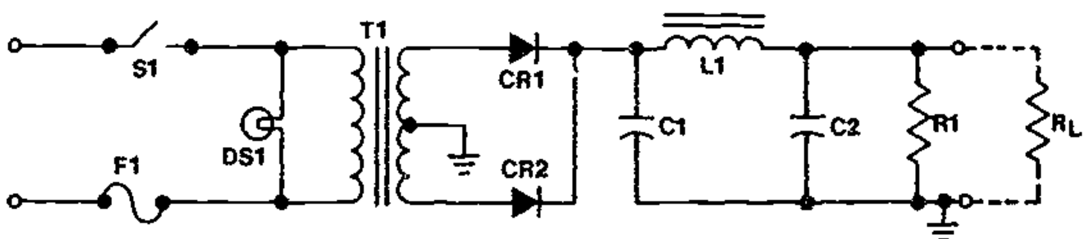
R1 may be adjusted to drop 20 volts. If our load requires a constant 10 volts and input voltage changes we may adjust R1 to drop more or less voltage and gives us a constant 10 volts across our load.

If current increased what would have to be done with R1?

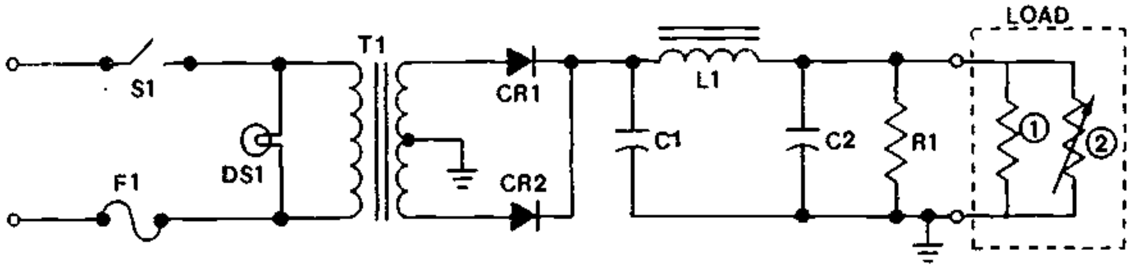
- -

Increase R1 to maintain a constant output voltage.

17. We added a constant load to our system, now let's see what happens if a variable load is added.



we can see that if R_L is changed, current will change and cause voltage to change throughout our system. This loading effect is undesirable. In circuits which have more than one branch in the load any change in the variable branch will affect the voltages across the other branches.



If branch 2 is changed, a voltage change will also appear on branch 1 and cause it to function improperly. For example, let's say that branch 2 is 50Ω and 50 volts is dropped across it. We have 1 amp of current flow through Branch 2. Branch 1 is 100Ω. It has .5 amp through it for a total current of 1.5 amps. If Branch 2 is increased to 100Ω, current drops to .5 amp. This in turn decreases <u>total current</u> to 1 amp. With decreased current the voltage losses in the earlier stages will be less, so the voltage across branch 1 will increase. The point is, without a regulator in the circuit, current changes in one branch will cause voltage changes in the other branches.

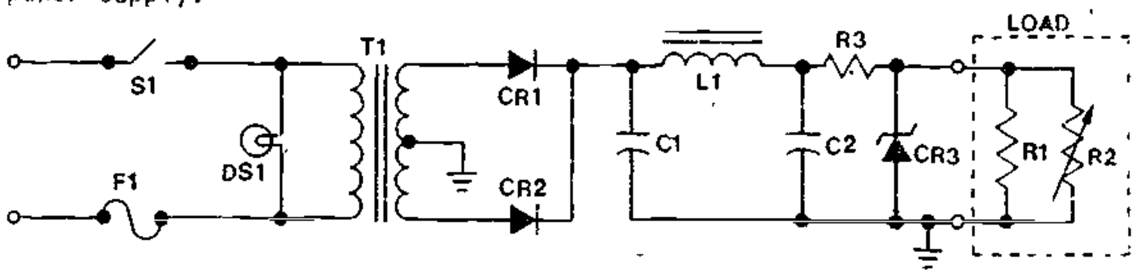
What would be the effect on Branch 1 of decreasing the resistance of Branch 2?

a. increased current
b. decreased current
c. increased voltage
d. no effect

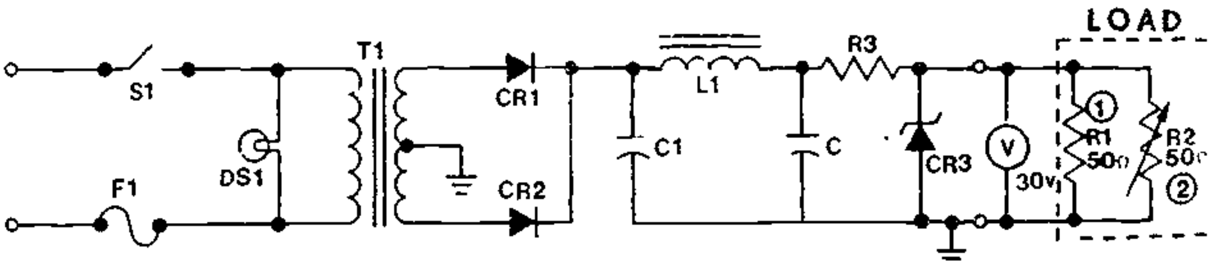
---

b. decreased current.

18. We've seen a power supply with a constant load, and with a variable load. What can be done to maintain voltage constant in a load that has variable and fixed branches? We use a Zener diode as a regulator in our power supply.



Now if R2 is changed, the Zener diode will adjust its internal impedance instantaneously to allow more or less current flow to give us a constant output across our load. Look at the following power supply with a fixed and a variable load:



As branch 2 is changed, the total impedance of the load will change. Total impedance of the power supply will tend to change, but the Zener adjusts its internal impedance instantaneously to compensate for any changes in external impedance. If branch 2 were increased to 100Ω, the total impedance of our load would increase and the current through the load would decrease. The current supplied by the power supply does not change, because the Zener doesn't allow it to.

If load impedance increases the Zener will decrease its impedance to allow more current to flow and maintain a constant output voltage to the load.

No response required.

---

19. TEST FRAME

The impedance of the Zener is inversely proportional to the variable load impedance. (True/False)

- -

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

True

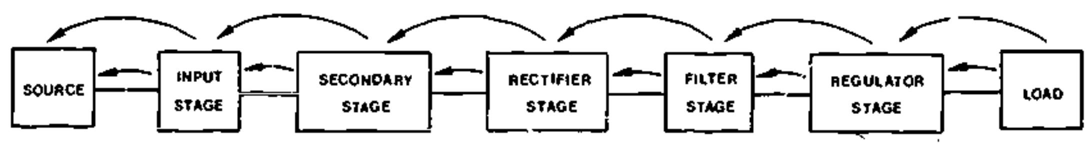
IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 22. OTHERWISE GO BACK TO FRAME 14 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 19 AGAIN.

20. Even though the Zener is a good device it will only do so much. It will operate over a range of current values. If the power supply is "overloaded" (something is drawing too much current and is about to burn up), the impedance of the Zener will approach infinity and since it will no longer draw current it can not regulate the voltage. This is why a fuse is used in the input stage. The fuse is rated at a certain current and if more current is drawn than the fuse is designed for, it will blow. The fuse protects the power supply and the load. The fuse will usually be of a lower current rating than the rated current handling capabilities of the power supply and the load. (True/False)

- -

True.

21. Something to remember is that any time a circuit is added in our system or a "load" is placed on the power supply, the impedance is reflected back into the previous stages and then into the source.



Thus, any changes will be felt by each of the stages and by the source, and must be compensated for. A change in load impedance would change the amount of current drawn from the source. (True/False)

- -

True.

22. TEST FRAME

Match the answers in Column B with the proper statement in Column A.

Column A	Column B
1. The addition of circuits which causes total impedance to change.	a. Zener Diode
2. Compensates for changes in variable load.	b. Interstage loading
3. Loading within the Power Supply System.	c. Filter
4. Change in voltage due to change in current.	d. Loading
	e. Loading Effect

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

1.d; 2.a; 3.b; 4.e

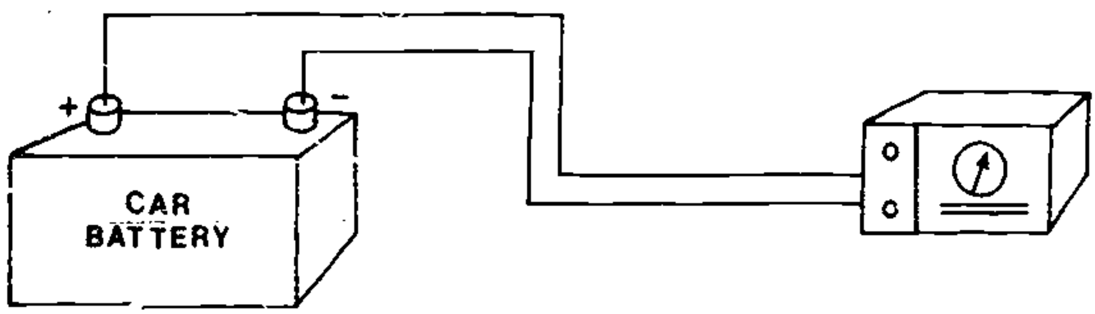
IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON VII MODULE TWENTY. OTHERWISE GO BACK TO FRAME 20 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 22 AGAIN.

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.

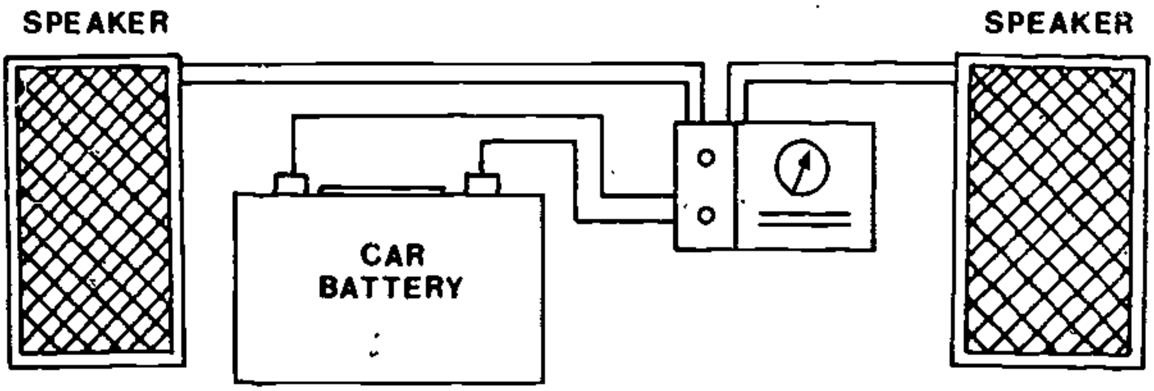
NARRATIVE
LESSON VII

Power Supply System Concept

A student just beginning studies of DC theory in a Navy technical school has a small problem. The battery of his transistor radio went dead and he didn't have a spare. So he thought he'd apply some of the knowledge he had gained from his technical training. He reasoned that since the battery used in his transistor radio was only 12 volts and voltage determines the amount of current in the circuit; he would use a car battery to operate his radio. In addition, he figured the car battery would last a lot longer than the tiny 12 volt battery. He, therefore, made the following connections.



The radio played fine! His buddies were impressed by his ingenuity. So, favorably encouraged, he decided to further improve the performance of his radio. He knew that the small size of his radio's speaker was a prime factor that made the sound quality inferior when compared to larger radios. If he hooked up larger speakers to the radio, he was sure the sound quality would improve. However, when he had tried it in the past, his tiny radio did not put out enough power to drive the large speakers above a whisper. Ah! but his time would be different. With a bigger power source...volume should be no problem. After all, the volume depends on the amount of current and the car battery should certainly be capable of supplying more than enough current to drive the larger speakers. He then made the following connections:



The transistor radio was turned on. It went off like a flashbulb! Puff and smoke. When our friend opened the radio, he found the whole inside was solid state. The circuit board, transistors, wires, and other components had all melted into a chunk of material that no one would have ever guessed was once a radio.

What went wrong? Our student was not stupid. He did not have any problems working Ohm's law in school but when he tried to apply it, the radio burned up. Why?

All circuits use current, voltage, and impedance. Most electronic circuits hold voltage constant. With voltage constant, the only way to change current is to vary impedance. If the voltage is 10 volts and the impedance is 1 ohm, the current is equal to 10 amps ($I = E/R$). If the impedance is then increased to 100 ohms, the current demand falls to .1 amp. When the student added the two speakers in parallel, the total impedance of the radio was decreased (adding impedance in parallel, lowers the total impedance). The current demanded by the radio circuit increased. The components in the radio were not designed for handling the increased current. When the normal 12 volt battery was used, it could not supply this increased current demand. But using a car battery that is capable of supplying up to 200 amps for short periods of time, the increased current was supplied. All the circuit components responded by burning up.

If the speakers had been added in series, the total circuit impedance would have increased. Current demand would have decreased. Nothing would have happened to the radio. But with less current to the big speakers, you would not have been able to hear them.

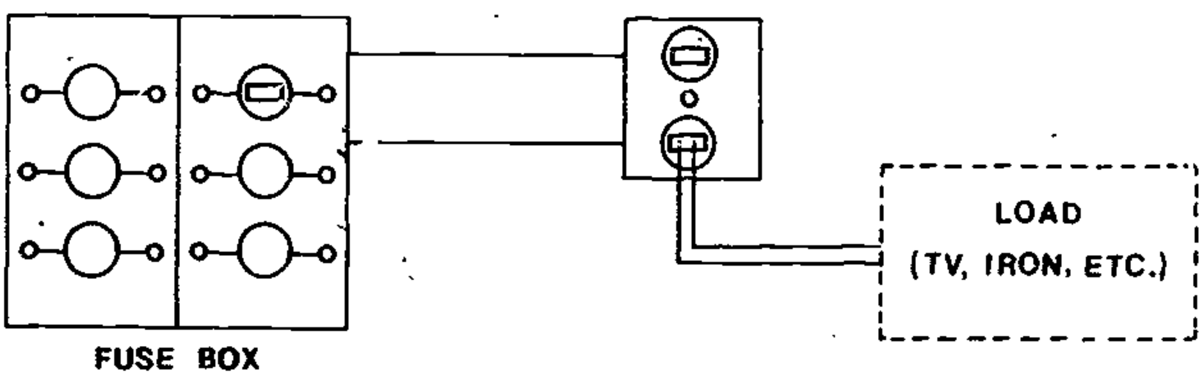
The moral of the story is: be sure to match the power supply to the circuit load. The correct matching of the power supply to the load depends on both current demand (by the amount of impedance) and the voltage demand. Current capacity must be matched to current demand.

CURRENT X VOLTAGE = POWER

That is why they are called power supplies rather than current or voltage supplies.

The disaster could have been prevented if a fuse had been used. The fuse should have been connected in series with the battery so all of the current would flow through it. Naturally the current rating or the capacity of the fuse to pass current would have to be lower than the current rating of the radio circuit. Then, if the load demanded more current than was considered safe, the fuse would melt and the radio would be unharmed. It is far more economical to replace a couple of pennies worth of fuse than the whole radio. Radios make lousy fuses.

If a 15 amp fuse in a house fails and you replace the 15 amp fuse with a 30 amp fuse...will the appliance connected to the wall outlet burn-up?



Not necessarily. The only time you will have problems is when the current demand exceeds the current capacity of the appliance.

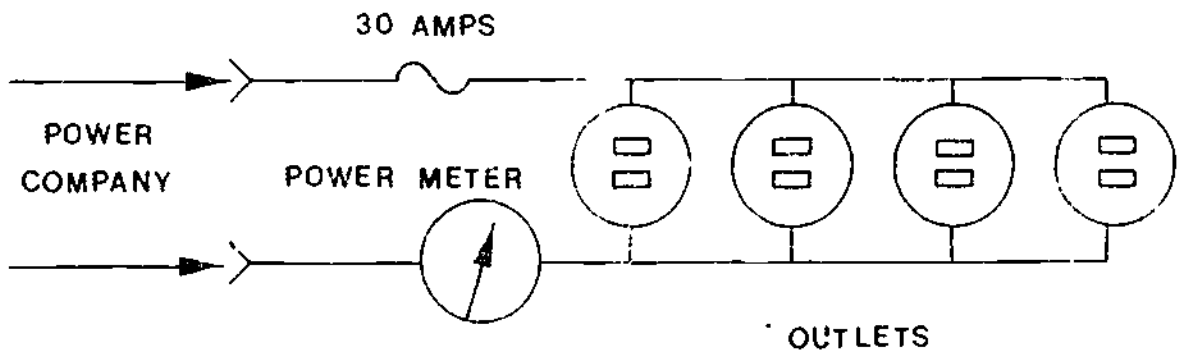
Referring to the previous question, if a short circuit in the appliance connected to the wall outlet caused the 15 amp fuse to fail, what would happen if the appliance were turned on with the 30 amp fuse in the circuit?

a. Nothing, the resistance of the short is so low, no current will flow.
b. The house wiring, without adequate overload protection, could heat up and cause a fire because current demand exceeds current capacity of the wiring.
c. The wall outlet could burn up.
d. Appliances at the other outlets would be destroyed because of the excessive current flow in the wiring.
e. b or c are possible, the others are not.

- -

e. is the correct answer. Answer d is wrong because current in parallel depends on the resistance of each branch. Since house outlets are connected in parallel, each branch's current flow is independent of the next.

The 115 VAC supplied to a house is comparable to the car battery. It is a constant voltage that is capable of supplying a range of current values depending on the appliances connected to the wall outlets. Since household wiring is in parallel, it is fused at a point where the total current of each branch is combined.



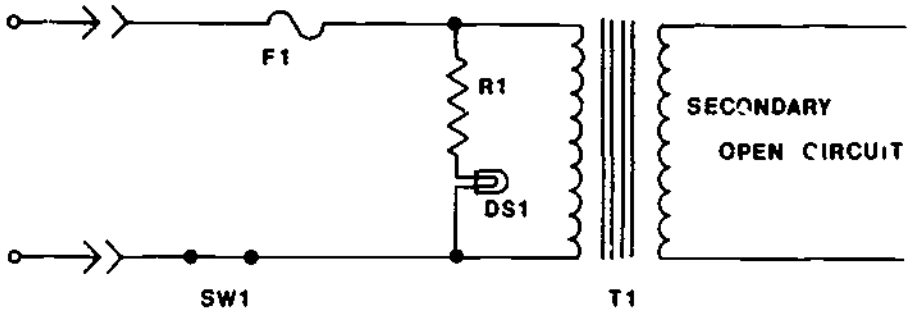
PARALLEL CONNECTION

Appliances (based on their impedance) have different demands for current. In the above circuit, when total current tries to exceed 30 amps, the fuse will melt. So each parallel branch current, when added, must not exceed 30 amps or the fuse opens. If one branch requires 15 amps (say an air conditioner), the other branches have only 15 amps left to use. The point is, the load current demand at a particular voltage must be equal to or less than the current capacity of the fuse.

It is now time for us to look at the systems operation of a typical electronic power supply. An electronic power supply is provided voltage from a 115 VAC voltage source. The electronic power supply is a load (current demand) for the 115 VAC.

OPERATING CHARACTERISTICS OF ELECTRONIC POWER SUPPLIES:

When just the input stage is added to the 115 VAC, current will flow. The input stage of the electronic power supply is a complete circuit and has a certain amount of impedance that will allow a certain amount of current. Let's see what happens when just the input stage is connected to the 115 VAC source.



The fuse and the switch, when closed, do not have very much resistance. The first parallel branch has a resistor (R-1) and the indicator lamp (DS-1). The impedance of this branch is very high for two reasons:

1. The lamp requires less than 115 VAC to light. R-1, the series resistor, then drops the difference between 115 VAC and the smaller voltage required by the lamp. For instance, if the lamp needs only 10 volts, the resistor must drop 105 volts.

2. The lamp doesn't need very much current. R-1 again comes to the rescue by limiting the amount of current allowed in this parallel branch.

Now the second parallel branch in the input stage is simply the primary of the transformer. We know that a coil offers large impedance to AC, so we would expect that the primary will allow little current. This is the case only if the secondary has no current flow. The primary will reflect the impedance of the secondary because of mutual inductance between primary and secondary. The impedance of the primary then mirrors the secondary impedance. As a result, total impedance of the input state is very high when the secondary is open. Total current demand is very low.

Now when we hook-up an oscilloscope across the secondary, we see a voltage. If the secondary is an open circuit, how is this possible? The impedance of the oscilloscope is high but with the oscilloscope connected across the secondary, it does make a complete path for current flow. This impedance is reflected back to the primary and lowers the total impedance of the input stage. Lower impedance, more current demanded from the 115 VAC. In short, the oscilloscope completes the secondary circuit which then changes the overall impedance in the input stage.

If the secondary is shorted...you guessed it...zero resistance is reflected back to the primary. The primary demands maximum current. Before the current can rise high enough to harm the circuit components, the fuse will fail.

Current flow in the input stage depends on the impedance of:

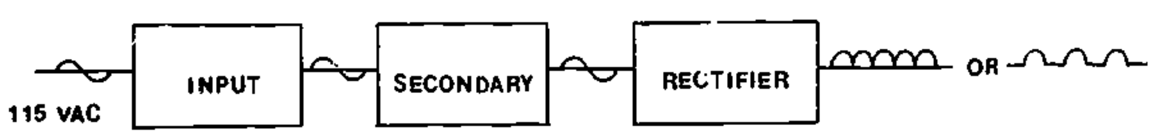
a. the secondary circuit.
b. the input stage components.
c. the source.
d. all of the above.

- -

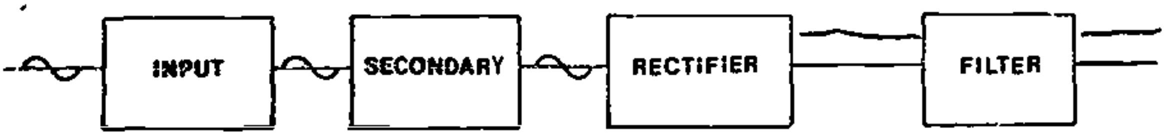
d. all of the above.

We've seen three examples of how the input stage's impedance and current flow will change with changes in the secondary impedance. The input stage acts like a source to the secondary. The input stage then supplies the current and voltage required by the secondary. The secondary, in turn, acts like a load to the input circuit. When one stage loads another stage within the same system, we call it interstage loading. When one system is connected to another system, the second system is a load to the first system to produce the 115 VAC source for our electronic power supply. Our power supply acts as a load to the power company's system.

Now when we add the rectifier to the open secondary, current flows in the secondary. More current is required in the input stage. The rectifier stage output will look like bumps. We could look at the rectifier stage as a load to the input and secondary stages, or all three stages combined as the total load to the 115 VAC source.



When the filter stage is added to the system, the most visible change due to interstage loading occurs. The output of the rectifier goes from pulsating DC to DC with ripple. Because of the filter capacitor's action the rectifier output no longer appears to be pulsating DC. This happens because as soon as the filter is added, there is an <u>instantaneous</u> change in the total impedance within the entire system. Impedance is not only changed at the point where the filter is added, but also throughout the entire system.



Now when the last stage is added, what loading effects will it have on the system? The regulator adjusts for changes in current demand from the load or changes in the 115 VAC source power. With the addition of the regulator stage the power supply must now provide the current required by the Zener diode as well as the current required by the load. Once again the total impedance of the system is changed.

Another interstage loading effect caused by the regulator is it makes the filter work harder. The level of ripple increases as we draw more current out of the filter.

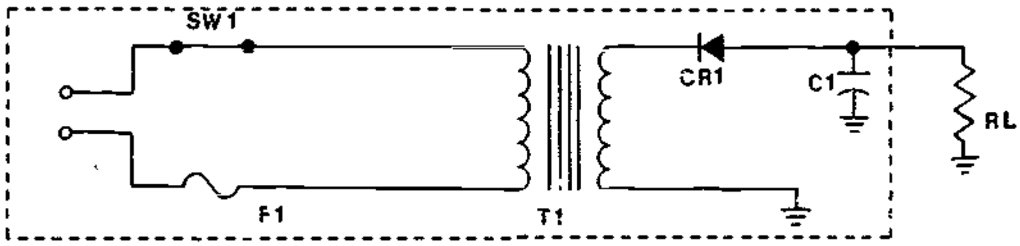
1. When one stage has an effect on the operation of another stage, we call it _______________ effects. When one system has effects on another system, we call it _______________ effects.

2. The output of which stage is changed the most as we add stages to the power supply?

- -

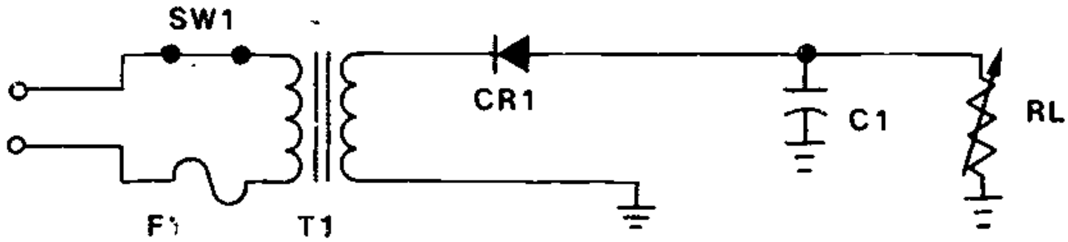
1. Interstage loading; systems loading, or simply loading
2. rectifier stage

We've shown how interstage loading effects the function of each stage. Now let's look at the effects of loading. First we'll take a simple power supply and connect a constant or fixed load.



In the schematic, we see the voltage developed across filter capacitor C1 is the same voltage that is across the load R_L. The resistance of R_L is 25 ohms, so with 50 volts across it -- 2 amps will flow. As long as the impedance and voltage stay the same, R_L will pass 2 amps.

If, a variable load is connected to our simple power supply, things change:

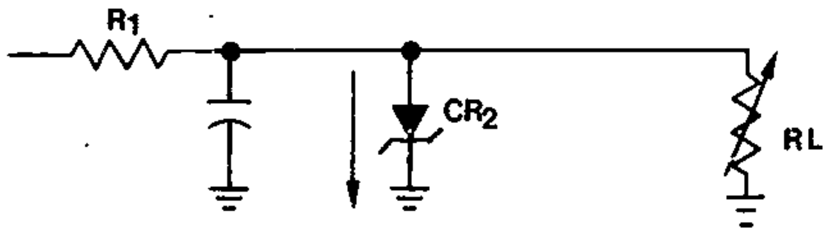


When R_L changes, total impedance felt by the 115 VAC source changes. If we increase R_L, total impedance increases and total current drops. With less current there will be less voltage loss in the input and transformer. Voltage across R_L increases. This voltage increase is a loading effect.

Anytime a change in the amount of current demanded causes a change in the output voltage of a power supply we say a loading effect is causing the voltage change.

What can we add to our simple power supply that will combat loading effects?

A voltage regulator.



With the addition of a voltage regulator, as current tends to increase through R_L, the Zener branch current decreases. The zener's internal impedance changes in the opposite direction with the changes in impedance of R_L. If R_L impedance is increased, the zener's internal impedance is decreased.

There is a trade off of current in these parallel branches so the net result is that total current remains unchanged and voltage stays constant.

If R_L's resistance is decreased, more current is demanded by the load. CR2 senses the change, and increases its internal impedance to exactly offset the decrease caused by R_L. Less current is demanded by the zener.

The zener has effectively transferred some of its current to the load. Why is it necessary to keep voltage constant? Most loads in electronics consist of several series-parallel branches. Each branch has a different current demand because each branch has a difference impedance. One or more may be a variable impedance. If voltage is held constant by the voltage regulator all branches can use whatever current they need and not effect the other branches.

If one of the loads shorts out (zero resistance), will the voltage output stay the same?

- -

no

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.

PREPARED FOR

BASIC ELECTRICITY AND ELECTRONICS

CANTRAC A-100-0010

MODULE TWENTY-T

ELECTRON TUBE POWER SUPPLIES

PREPARED BY

INDIVIDUALIZED LEARNING DEVELOPMENT GROUP

SERVICE SCHOOL COMMAND, NTC, SAN DIEGO, CA 92133

STUDY BOOKLET

1 APRIL 1977

OVERVIEW

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY-T

Electron Tube Power Supplies

In this module you will learn about the similarity between power supplies using electron tubes and power supplies that use solid state components. You will study the tube counterpart of a solid state diode, and find that the conversion sections of both kinds of power supplies do the same things with very few differences in components.

This module contains the following:

Lesson I Electron Tube Power Supplies

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY-T

LESSON I

ELECTRON TUBE POWER SUPPLIES

1 APRIL 1977

OVERVIEW
LESSON 1

Electron Tube Power Supplies

In this lesson you will study and learn about the principles of operation of vacuum tube diodes, the principles of operation of gas filled diode tubes and tube type power supplies. As you proceed through this lesson, observe and follow directions carefully.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

Supported by this lesson topic:

20T.1.41 When the student completes this course, he will be able to DESCRIBE the functional and voltage similarities of differences between tube and solid state power supplies by selecting the correct statement(s) concerning these similarities and/or differences from a given list of statements. 100% accuracy is required.

ENABLING OBJECTIVE(S):

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

20T.1.41.1 DIFFERENTIATE between tube and solid state power supply input circuits by choosing the correct statement(s) concerning similarities/differences, given a set of statements. 100% accuracy is required.

20T.1.41.2 STATE the general similarities and/or differences in tube type and solid state power supply transformer secondaries by selecting the best statement of similarities and/or differences, given a choice of four statements. 100% accuracy is required.

20T.1.41.3 COMPARE the functional circuit differences and/or similarities in the tube type and solid state rectifier circuits by selecting the most correct statement, given a set of four choices. 100% accuracy is required.

20T.1.41.4 COMPARE the schematic symbols and direction of current flow of a tube type diode to a solid state diode by selecting the correct illustration from a given set of illustrations showing directions of current flow through tube type and solid state diodes. 100% accuracy is required.

OVERVIEW

20T.1.41.5 COMPARE and CONTRAST the function/size/configuration of solid state and tube type power supply filter networks by selecting the correct statement(s) concerning the above differences/similarities from a set of given statements. 100% accuracy is required.

20T.1.41.6 COMPARE and CONTRAST the functions and/or circuit configurations of tube type and Zener diode regulators by selecting the correct statement(s) concerning the above differences/similarities from a set of given statements. 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

ELECTRON TUBE POWER SUPPLIES

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:

Progress Check

Additional Material(s):

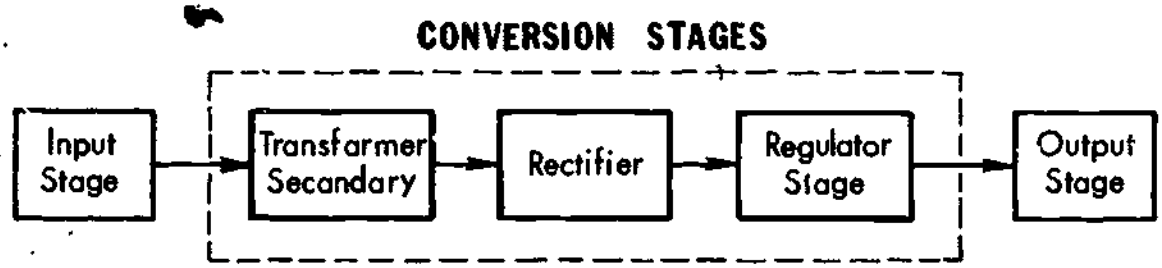
Audio/Visual Program Twenty-T-I "Vacuum Tube Power Supplies"

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 1

Electron Tube Power Supplies

Transistors are rapidly replacing tubes. The big reason transistors are taking over is that transistorized circuits reduce the size and the voltage requirements of equipments. We will be discussing vacuum tubes because they still take a very active part within the Navy's electronic inventory.

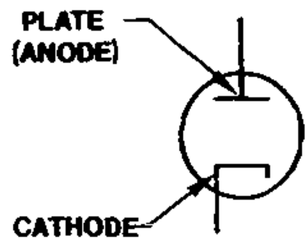


The block diagram shown above should be familiar. It is a block diagram of a basic power supply and could be either solid state or tube. The schematics are also very similar except, naturally, there will be tube symbols instead of transistor symbols. NOTE: Solid state means transistors are used.

The input circuits will be schematically identical and perform the same function. The components in a vacuum tube power supply will generally be physically larger because of higher power requirements.

The transformer secondaries in a vacuum tube power supply are usually multi-winding: step-up and step-down. The step-up winding supplies the high voltage required by the equipments while the step-down winding supplies the low voltage required by the filament or heater.

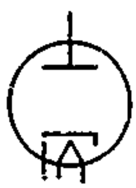
Vacuum tube rectifier circuits also use diodes. Vacuum tube diodes have two elements: a plate and a cathode.



The plate is the positive element and the cathode is the negative element. Vacuum tube diodes function the same as solid state diodes. They allow current to flow in only one direction: from cathode to plate. In order to have current flow in the vacuum tube diode the cathode must be heated to "boil off" free electrons. Heating is accomplished in one of two ways: directly or indirectly.

DIRECTLY HEATED CATHODE

In a directly heated cathode, the heating current flows directly through the cathode. In this case, the cathode is called a filament.

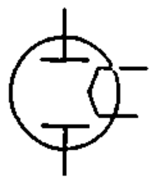


INDIRECTLY HEATED CATHODE

In an indirectly heated cathode, the heating current flows through a heater placed in close proximity to the cathode.

NOTE: Schematically the filament or heater circuits are rarely shown. When they are, you'll see the filament or heater wires chopped off with two symbols (such as X's) at the end. The X's means that somewhere on the schematic you will find two other X's that show where (usually by the transformer step-down secondary) the heater voltage originates.

Vacuum tube power supply rectifier circuits (the half-wave, the full-wave and the bridge) have output waveshapes which will be exactly identical to solid state rectifier circuit output waveforms; only the amplitude will be much higher. Of the three rectifiers, the full-wave rectifier is the most commonly used rectifier for vacuum tube circuits. The full-wave rectifier may consist of two vacuum tube diodes or one duo-diode which contains two plates and a common cathode enclosed within a single tube envelope.

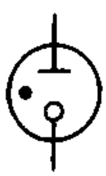


Duo-diode Schematic

The bridge rectifier, although common in solid state power supplies, is seldom used in vacuum tube power supplies because of its large size and high cost.

Filters used in vacuum tube power supplies are of the same type as used in transistor power supplies: choke input, capacitor input, and pi. Here again, the actual components in the filter circuits will be larger in size and higher in current rating because of the higher voltages they are required to handle.

The final stage of the power supply is the regulator. The solid state power supply used a Zener diode. The tube equivalent of a zener is the VR tube (<u>V</u>oltage <u>R</u>egulator).

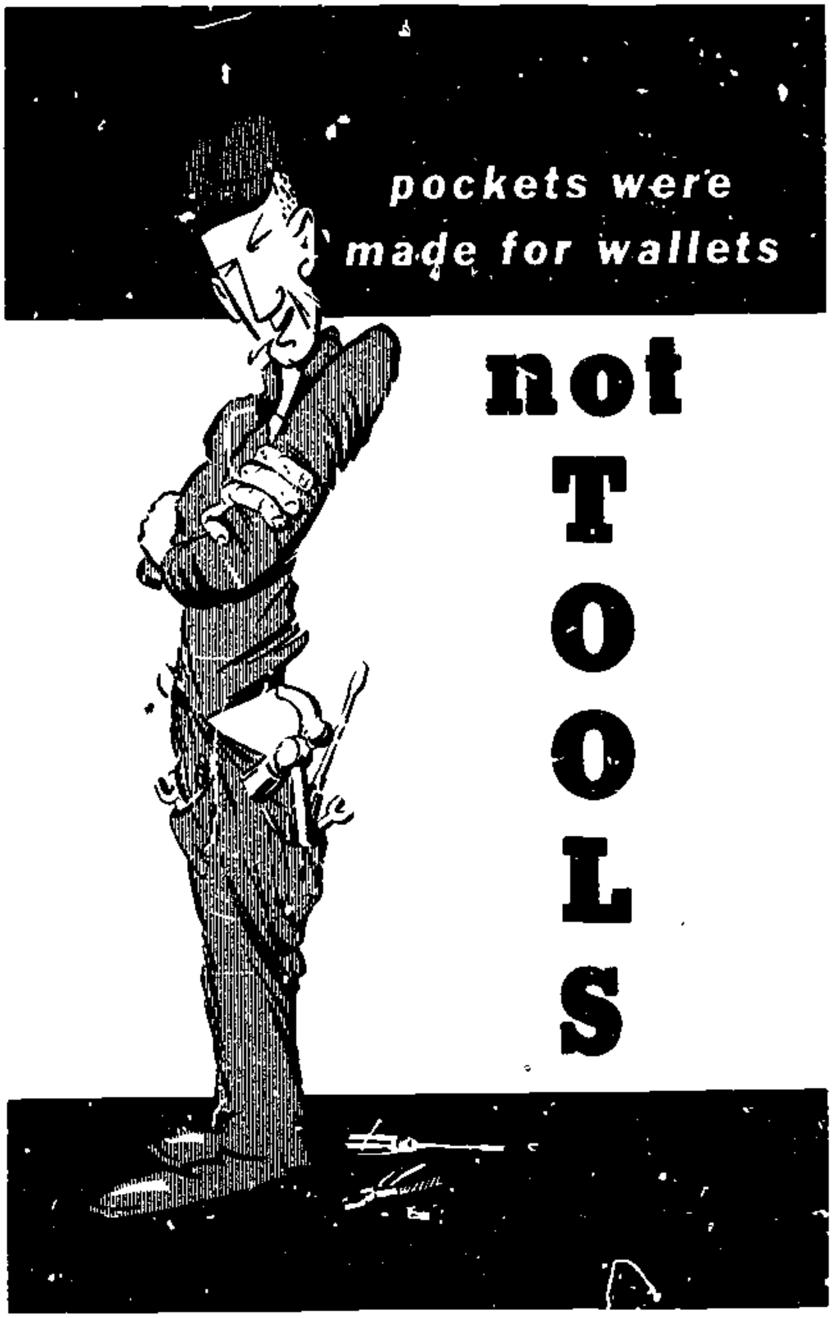


Note: Dot indicates gas filled

VR Tube Schematic

The VR tube, like the Zener, is connected in parallel with the load. The function of both is identical: to regulate the output.

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.


pockets were made for wallets
not
TOOLS

PROGRAMMED INSTRUCTION
LESSON I

Electron Tube Power Supplies

TEST FRAMES ARE 7 AND 12. GO FIRST TO TEST FRAME 7 AND SEE IF YOU CAN ANSWER THE QUESTION. FOLLOW THE DIRECTIONS AT THE END OF THE TEST FRAME.

1. Vacuum tubes work fine and usually last a long time but not quite as good or as long as the transistor. Vacuum tube equipment is still used and is a definite part of the Naval electronics inventory. This means that you, as a technician, will have to know how to troubleshoot and repair vacuum tube equipment.

Probably the easiest way to explain how vacuum tube circuits function is to relate them to transistor circuits. The biggest difference between the two is that vacuum tube equipment will be much <u>larger</u> and will require a much <u>higher voltage</u> to operate. A power supply is a power supply, transistor or tube, and will accomplish the same function--supply power to the equipment. Vacuum tube and solid state power supplies have the same stages and function basically the same. NOTE: In electronics the term solid state is used to describe circuits and components that use transistors instead of vacuum tubes.

What are the basic differences between tube and solid state equipment?

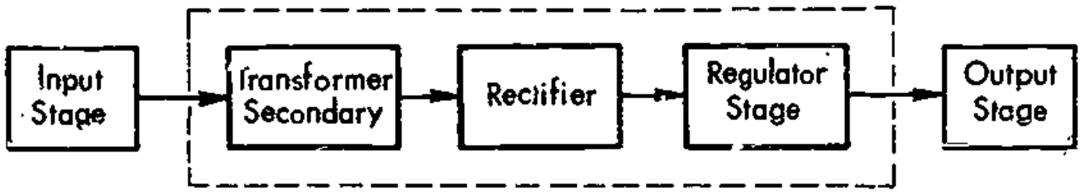
a. Function and power outputs.
b. Size and voltage requirements.
c. Availability and size.
d. Usage and voltage requirements.

- -

b. Size and voltage requirements.

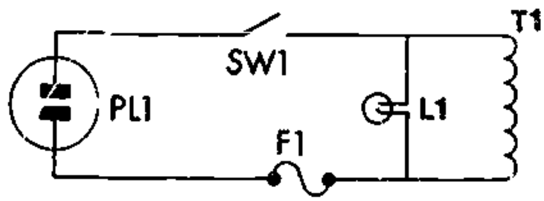
2.

CONVERSION STAGES



The block diagram shown above should be very familiar. It is a block diagram of a basic power supply. This time it's for a vacuum tube power supply. As you can see, there is no difference between vacuum tube and solid state power supplies as far as the block diagram is concerned.

Now let's get into the schematic for the input stage of a vacuum tube power supply.



The schematic diagram again shows no difference between a vacuum tube and a solid state power supply. It contains a plug, a switch (on-off), a fuse, an indicator light, and a transformer primary. In the actual equipment, the differences lie in the size of the components because of the higner power requirements. The fuse in the vacuum tube power supply may have a higher current rating. Functionally, both types of power supply input stages are the same.

What is the difference between a vacuum tube power supply input section and solid state power supply input section?

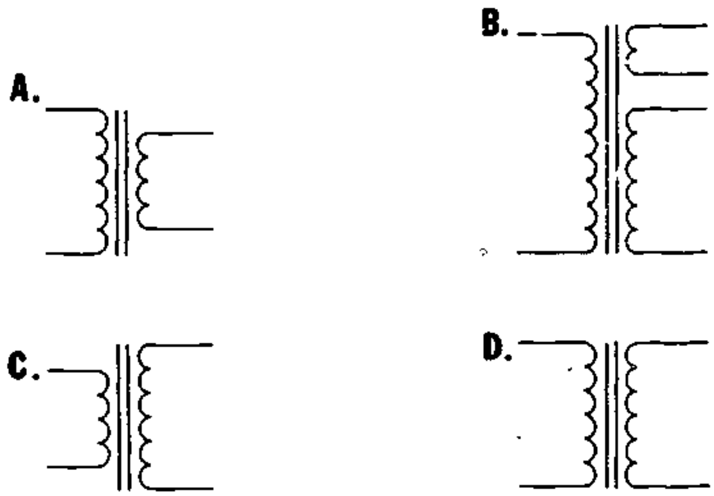
a. Tubes are used instead of transistors.
b. The input voltage is higher.
c. The components are larger because of the higher power requirements.
d. Provides greater overload protection.

---

c. The components are larger because of the high power requirements.

3. Transformer secondaries in vacuum tube power supplies are usually multi-winding step-up and step-down. The step-down windings are used to supply the low voltage required by the filaments of vacuum tubes while the step-up winding supplies the high voltage required by the equipment.

Which of the transformers below will normally be used with a vacuum tube power supply.



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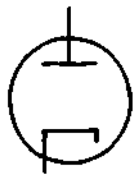
b.

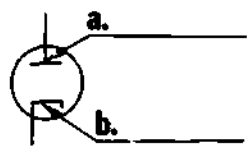
4. The functions of the input circuits and transformer secondaries are the same in both vacuum tube and solid state power supplies. In the rectifier section of a vacuum tube power supply a vacuum tube diode is used instead of a solid state diode but both types of rectifiers are still functionally the same. They change AC to pulsating DC.

As you know, the schematic symbol at the left is a solid state diode. It consists of two parts: the cathode (schematically shown as a short vertical line) and the anode (schematically shown as solid triangular figure).



The vacuum tube diode also has two elements: a cathode and a plate. The cathode is schematically shown as a backward 7 and the plate is schematically shown as an inverted T. The two elements are enclosed in a glass envelope which is shown as a circle surrounding the two elements. The whole assembly is called a vacuum tube because all the air is drawn out of the glass envelope at the time of the tube's manufacture leaving a vacuum in its place.

What are the proper names for the elements of a vacuum tube diode?



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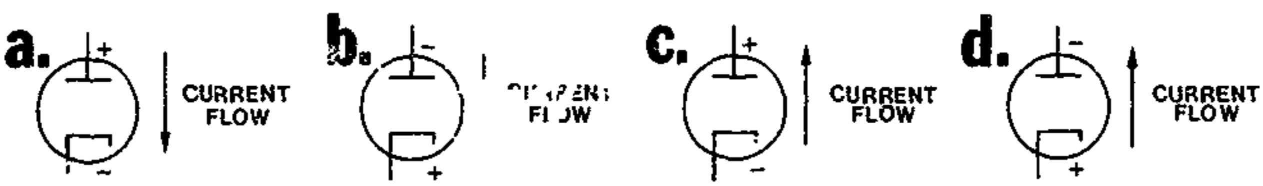
a. plate; b. cathode (in that order)

5. In vacuum tube diodes, as in solid state diodes, current will flow in only <u>one</u> direction. In the solid state diode current flows against the arrow: from cathode to anode. In the vacuum tube diode current flows from cathode to plate. This means that the tube will operate only when the plate is positive with respect to the cathode.

Which of the following illustrations is most correct?

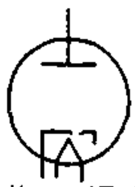


---

c.

6. In addition to having the plate positive in relation to the cathode, one more condition must be met before current will flow through the vacuum tube diode: the availability of free electrons for conduction. By heating the cathode, free electrons are "boiled off" the cathode material. These electrons are then "sucked up" by the plate whenever its potential is more positive than the cathode's. Cathodes are heated in one of two ways: directly and indirectly.

DIRECTLY HEATED CATHODE



INDIRECTLY HEATED CATHODE

A directly heated cathode is so named because the heating current flows directly through the cathode. It is schematically displayed as a triangular figure connected to the cathode or just as a triangular figure. In this case the cathode is called a "filament."

An indirectly heated cathode is one in which the heating current does not flow through the cathode but rather through a "heater" which is placed in close proximity to the cathode. It is schematically displayed as a triangular figure separate from and directly under the cathode. The heater is not considered an element of the tube.

Which of the following statements is most correct?

a. An indirectly heated cathode is called a filament.
b. A directly heated cathode has a filament that is connected directly to the plate.
c. Heater current flows through an indirectly heated cathode.
d. Indirectly heated cathodes have a heater that is not connected to the cathode.

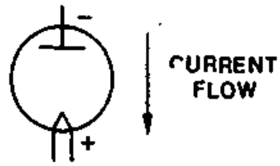
- -

d. Indirectly heated cathodes have a heater that is not connected to the cathode.

7. TEST FRAME

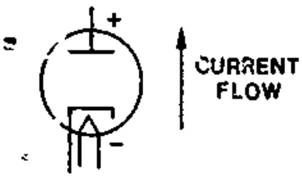
Which of the following illustrations is most correct?

a.



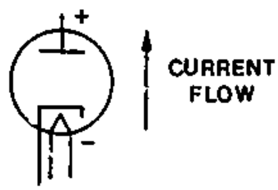
DIRECTLY HEATED

b.



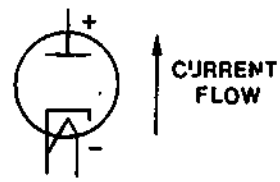
INDIRECTLY HEATED

c.



DIRECTLY HEATED

d.



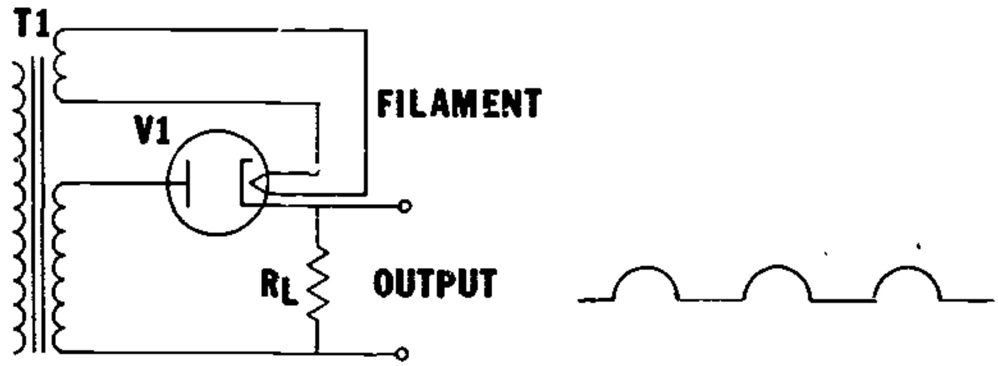
INDIRECTLY HEATED

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

b. ______________________________

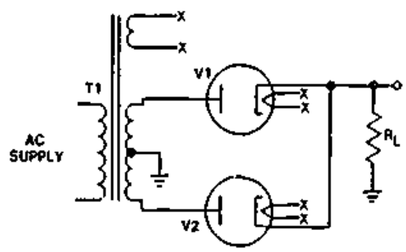
IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 12. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 7 AGAIN.

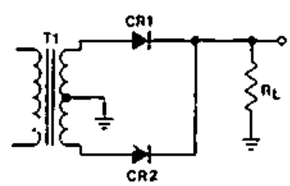
8.



The schematic shown above is a simple half-wave rectifier. As you can see, the only real differences between a vacuum tube diode half-wave rectifier and solid state diode half-wave rectifier is the transformer step-down secondary winding that supplies the filament or heater voltage (usually 6.3v), the filament or heater circuit, and the tube itself. The voltage level will also be different but the basic circuit and the output wave shapes are the same.

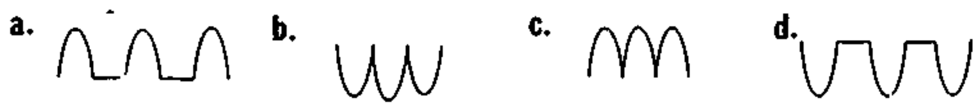
NOTE: As in the vacuum tube rectifier circuit below, the whole filament or heater circuit is often not shown in actual schematics. Instead, X's (or Y's or Z's) are placed at the triangular figure that denotes a filament or heater and again from where the filament or heater voltage is coming (usually the transformer secondary).





Does the above solid state rectifier look familiar? It should! Both circuits are rectifiers and will have the same type of output waveform.

What will the output waveform look like?



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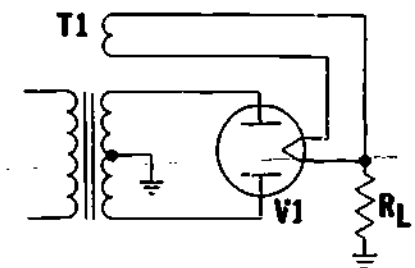
c.

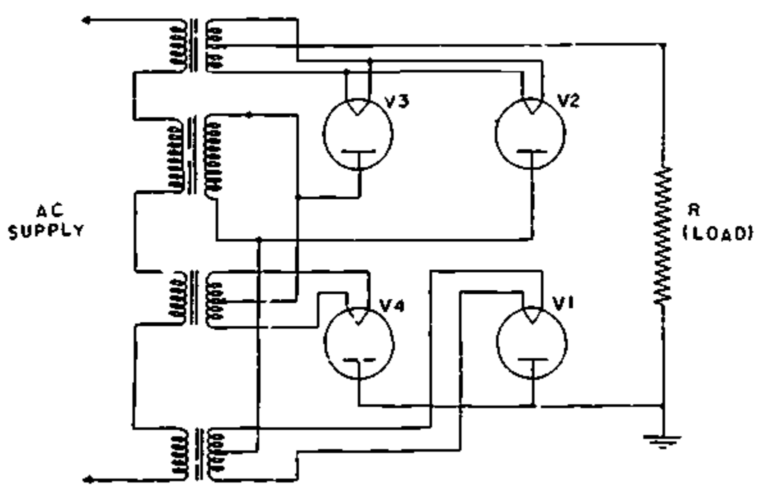
9. The previous schematic was a full-wave rectifier. In vacuum tube power supplies, full-wave rectifiers are the most common type of rectifier used.



The circuit shown above is also a full-wave rectifier. The vacuum tube is a directly heated duo-diode (which means that the two diodes with one common directly heated cathode are enclosed in the same envelope) and it works just like any other full-wave rectifier. It puts out pulsating DC!

The bridge rectifier, although common in solid state power supplies, is rarely found in tube-type equipment because it takes up too much space and is very expensive.

The following schematic is a bridge rectifier using tubes.



This configuration of tubes and filament transformers does exactly the same thing a transistorized bridge rectifier does. Because of the component size, most modern power supplies use solid-state devices rather than tubes for bridge rectifiers.

Which of the following statements is most correct?

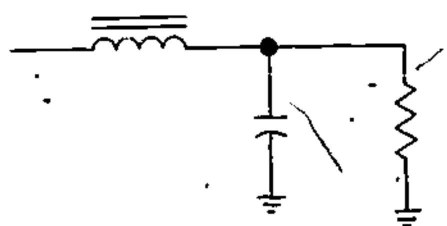
a. Bridge vacuum tube rectifiers are not used because the voltages requirements are too high.
b. The duo-diode produces the same waveform as a regular half-wave rectifier.
c. The duo-diode doesn't use heaters or filaments.
d. The bridge rectifier is rarely found in tube equipment.

---

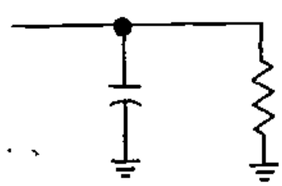
d. The bridge rectifier is rarely found in tube equipment.

10. After the voltage has been rectified, it has to be filtered. Vacuum tube power supplies use the same type filters as solid state power supplies:

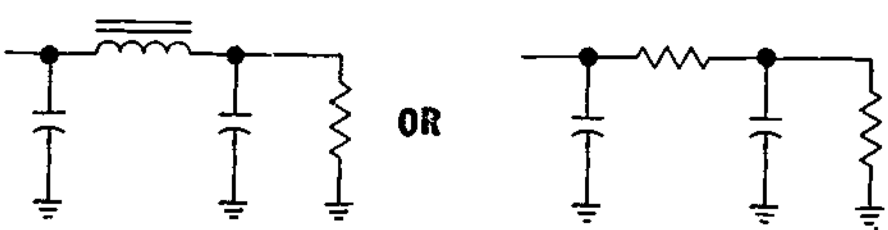
the choke input filter,



the capacitor input filter,



and the pi filter,



The components may be somewhat larger than those found in transistorized equipment but they function in exactly the same way.

Why would the filter components be larger in a vacuum tube power supply as compared to a transistor power supply?

a. To change the RC time constant.
b. Because of higher current and voltage levels.
c. For stabilization.
d. To prolong the life of the tube.

- -

b. Because of higher current and voltage levels.

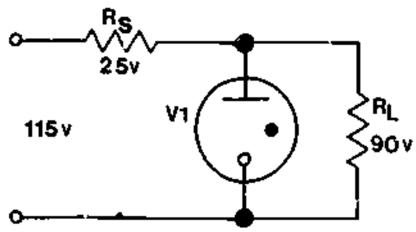
11. The final stage of a power supply is the regulator. The solid state device was a Zener diode. The tube equivalent of a Zener diode is the VR tube. (VR stands for Voltage Regulator).

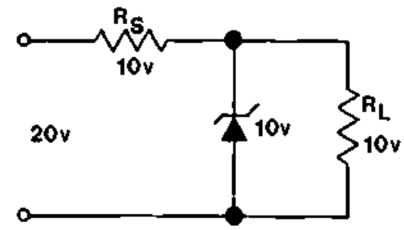
Schematically the VR tube is somewhat different from the diode vacuum tube.

The element called the plate in a vacuum tube diode is referred to as the anode in the VR tube. The cathode is displayed as a small circle and the black dot inside the envelope (circle) indicates that the tube is gas filled.

NOTE: Gas filled regulator will "fire" (the gas ionizes) when a large enough voltage is applied across the tube. Once the tube fires, the voltage drop across it will remain constant as long as the tube current is within the design range.

The VR tube, like the Zener diode, is connected in parallel with the load.





If the voltage increased to 150v, the VR tube would continue to drop 90v and maintain a constant voltage across the load regardless of the current increase. The remaining 60v would be absorbed by Rs. The only real difference between VR's and Zeners is the higher voltages that the VR's regulate. They both do the same thing: regulate voltage.

What is the main difference, if any, between Zener diode regulators and VR tube regulators?

a. Zeners are always connected in parallel with the load and VR tubes are always connected in series with the load.
b. There is no real functional difference.
c. VR tubes have a longer life than Zener diodes.
d. VR tubes are only used in low voltage applications.

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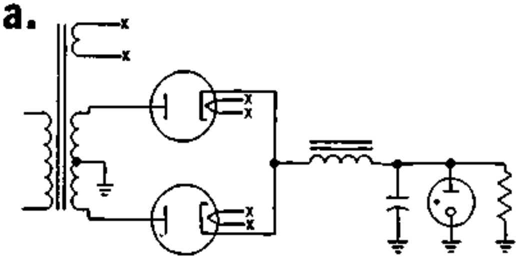
b. There is no real functional difference.

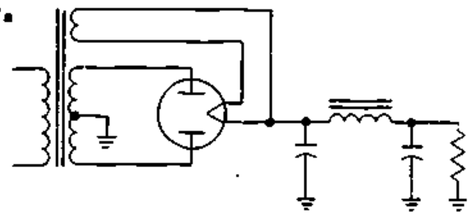
12. TEST FRAME

Which of the below circuits is a regulated, indirectly heated duo-diode vacuum tube power supply with a choke input filter?

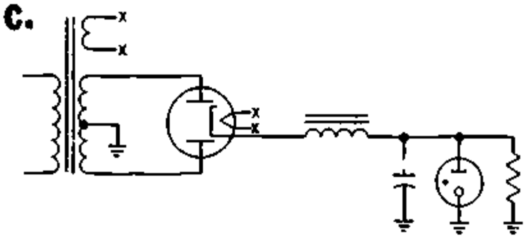
a.



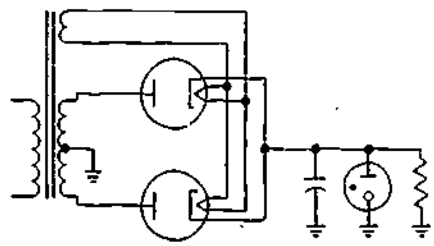
b.



c.



d.



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

C.

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

Electron Tube Power Supplies

Electron (vacuum) tubes are not as efficient as transistors in most applications, but there are some jobs that vacuum tubes can do better than transistors. For this reason they are still used in many circuits, and you as a technician will have to troubleshoot circuits using them.

The primary difference between a circuit using electron tubes and one using solid state devices (transistors and similar devices other than tubes) is the size and voltage rating of their components. Electron tube supplies usually provide higher voltages; consequently, they are constructed with larger components. Both units still do the same thing; that is, they provide required voltages at the current levels needed to enable an electronic system to operate.

Since you have just finished learning about solid state power supplies, this lesson will explain electron tube supplies by comparing them to the solid state units. Remember the input section of the solid state power supply? The input section of an electron tube power supply is identical in schematic and in function. It couples the AC line voltage from the outlet to the conversion stage; it provides overload protection; it indicates when power is on; and it gives a means for turning the equipment on or off. The only difference you are likely to see between the electron tube power supply circuit and the solid state power supply input circuits is that the tube circuits may have larger components so they can deliver higher current to the conversion section.

The transformer secondaries (conversion sections) of a vacuum tube supply almost always have multiple windings. One reason for this is that the power supply output is usually a high voltage (requires a step-up winding) and almost all tubes must also have a relatively low voltage (requires a step-down winding) to operate. In fact, the power supply frequently must provide two or more different low AC voltages to the equipment. The most efficient way to do this is to place a separate secondary winding on the transformer for each different voltage requirement.

Tube-type power supplies use diodes to rectify AC voltages just as do solid state power supplies, but the diodes are very different. Actually, this is the thing that really decides whether the power supply is solid state or tube. A solid state power supply has a solid state rectifier; an electron tube power supply has a tube rectifier.

The tube diode, like the solid state diode has two elements: a cathode and a plate. As in the solid state diode, electrons flow through the tube in one direction only: from cathode to plate. Figure 1 shows the schematic diagrams, direction of current flow, and names of the elements for both kinds of diodes.

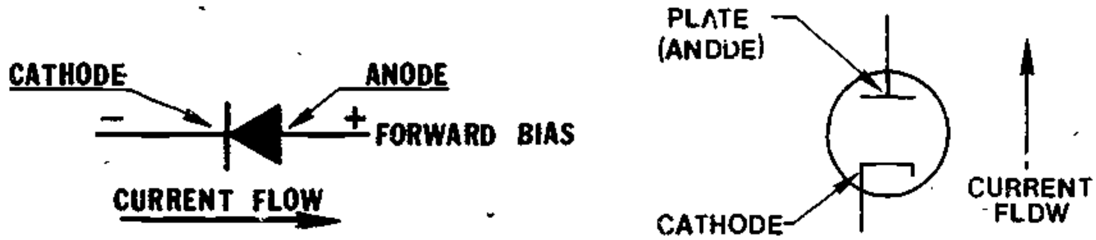


Figure 1

The circle around the elements of the electron tube indicates the metal or glass envelope that seals air out of the tube. (This is the reason electron tubes are sometimes called vacuum tubes, the elements must operate in a vacuum.) Besides the vacuum, another difference between solid state and tube diodes is that the tubes have filaments. The filaments are not always shown on schematic diagrams (Figure 1 doesn't show them), but Figure 2 shows electron tubes complete with two different kinds of filaments. The directly heated cathode tube is designed so that the filament itself acts as the cathode.

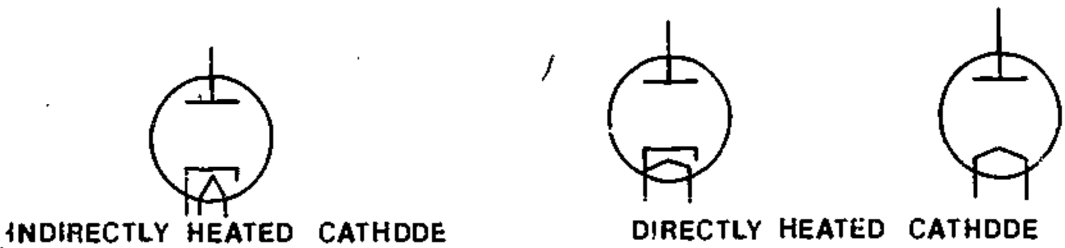


Figure 2

The function of the filament is to heat the cathode so that electrons will "boil off" its surface. When the cathode is hot, electrons will form a cloud around the cathode. A positive potential on the plate will attract electrons from that cloud to the plate and current will flow through the tube circuit. On the other hand, a negative potential on the plate will repel electrons and no current will flow.

Now let's look at a schematic for a simple half-wave rectifier using a diode tube rectifier. As you can see, the most noticable difference

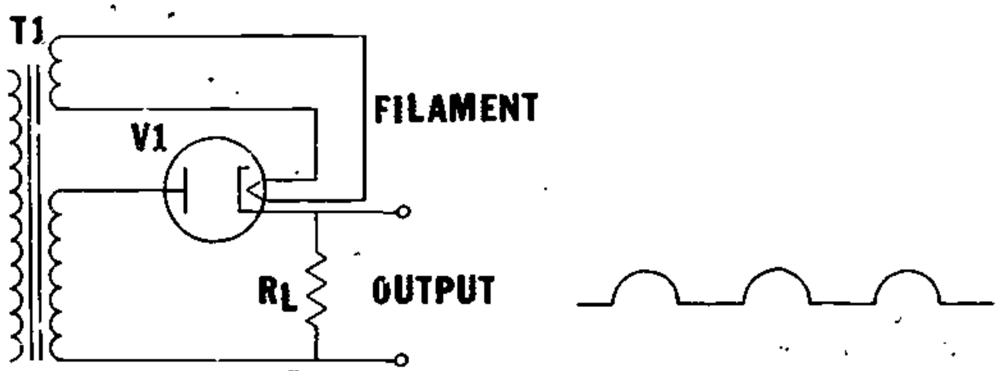


Figure 3

from the similar solid state circuit is the circuitry required for the tube's filament. The additional transformer winding supplies the heater voltage (usually between 2.5 and 12.6 VAC) for the filament.

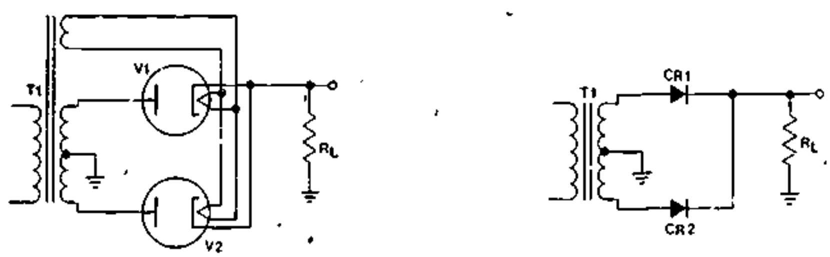


Figure 4

Figure 4 shows two circuits that should be familiar to you. They are both full wave rectifiers and they will provide identical output waveshapes. In schematic diagrams of circuits using tubes it is common practice to indicate filament connections by writing letters (W, X, Y, etc.) by the filament leads and transformer leads that connect together (see Figure 5).

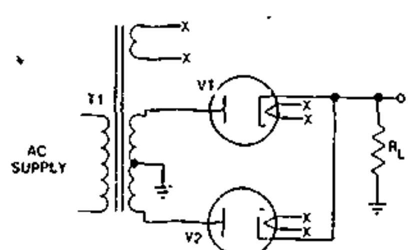


Figure 5

The most common electron tube rectifier circuit is probably the full-wave rectifier. Because it is so common a circuit, special duo-diode tubes are manufactured. Here is a schematic for a fullwave rectifier using a directly heated duo-diode; a tube with two plates and a common cathode all within the same envelope. It works just like all the other fullwave rectifiers you have seen.

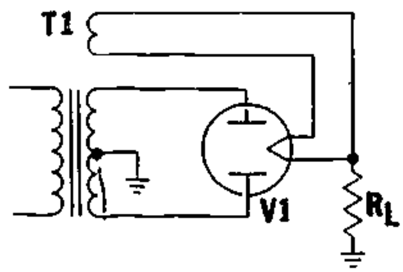


Figure 6

Although the bridge rectifier circuit is very commonly used with solid state rectifiers, it is not often found with electron tube rectifiers. Figure 7 may indicate why these circuits are not very common -- they involve a mess of wires and components and filament supply transformer windings.

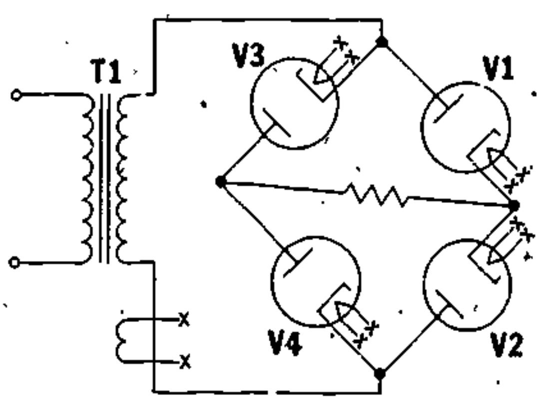


Figure 7

After the AC input voltage has been rectified it must be filtered just as solid state rectifier outputs must be filtered. It shouldn't be a great surprise to find that tube power supplies use exactly the same kinds of filters -- choke input, capacitor input, or pi -- that solid state supplies use. The components are often larger in tube units than in solid state because of the higher voltage usualy involved.

In the solid state power supplies a Zener diode acted as a voltage regulator at the power supply output. In electron tube power supplies a voltage regulator (VR) tube does the same job. The VR tube is a gas-filled diode that maintains a constant voltage drop within its current operating range. The amount of voltage drop involved depends on factors that are set when the tube is built. VR's are commonly built for 75 VDC, 90 VDC, 150 VDC, etc. Figure 8 is the schematic diagram for a VR tube. The anode (plate) of this tube is just like the plate in any electron tube schematic, and the circle represents the cathode. The black dot just sitting inside the envelope without any connecting leads indicates that the tube is filled with gas. When a VR tube is operating you can see a glow (usually blue or orange depending on the kind of gas used) from the ionized gas. Once the tube "fires" the voltage drop across it will remain constant.

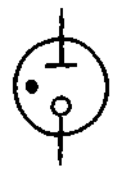


Figure 8

The VR tube is connected in parallel with the load just like the Zener diode connects.

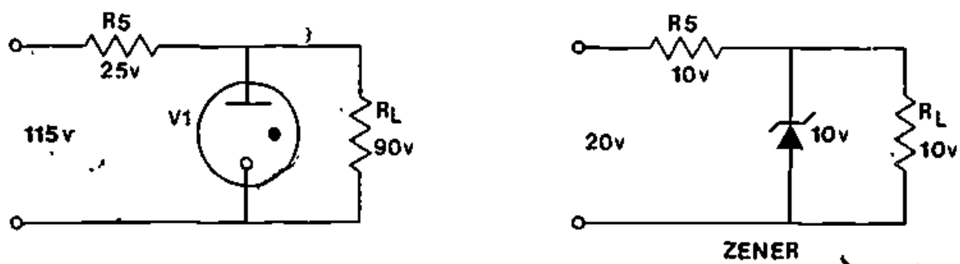


Figure 9

In fact the VR tube works exactly like the Zener diode except for the voltage values involved. In the circuit shown in Figure 9, if the supply voltage increased to 150 V the VR tube would still drop 90 V and the circuit current would increase enough to cause a 60 volt drop across R5. So long as the VR tube current remains within its design range its voltage drop will be constant.

200

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.