DOCUMENT RESUME

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IDENTIFIERS	Military Curriculum Project

ABSTRACT

This military-developed text consists of four lessons on the basics of electronics. Covered in the individual lessons are the following topics: electron tubes and solid-state devices, radio transmission and reception, radio set components, and electronic diagrams. Each lesson contains objectives, coded text, review exercises, and answers to the exercises that are keyed to the text for self-evaluation. The material is designed for self-paced, individualized instruction. (MN)

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.

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:

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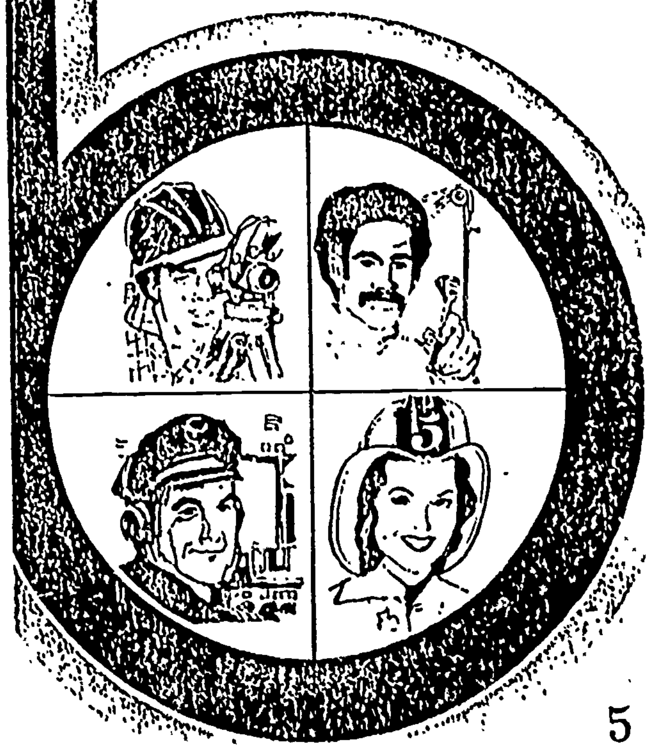
Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education



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.

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INTRODUCTION TO ELECTRONICS

Table of Contents

Developed by:

United States Army

Development and Review Dates

Reviewed January 1976

Occupational Area:

Electronics

Cost:

Print Pages:

87

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Lessons containing objectives, readings, review exercises, and answers

Type of Instruction:

Individualized, self-paced

Type of Materials:	No. of Pages:	Average Completion Time:
Introduction to Electronics		
Lesson 1 – Electron Tubes and Solid-State Devices	16	Flexible
Lesson 2 – Radio Transmission and Reception	20	Flexible
Lesson 3 – Radio Set Components	17	Flexible
Lesson 4 – Electronic Diagrams	16	Flexible

Supplementary Materials Required:

None

Expires July 1, 1978

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Course Description

This course contains one volume presenting four lessons on the basics of electronics. It is designed to present fundamental principles in an individualized format. Each lesson contains objectives, coded text, review exercises, and answers to the exercises keyed to the text for self-evaluation. The scope of each lesson is as follows:

Lesson 1 – *Electron Tubes and Solid-State Devices* discusses operation of electron tubes and solid-state devices, applications of electron tubes and solid-state devices in electronic circuits; and rectifiers, amplifiers, and oscillators.

Lesson 2 – *Radio Transmission and Reception* covers signal frequencies, principles of radiation, antennas, and transmission lines, modulation; AM, FM, and SSB transmitting and receiving systems; and frequency synthesizers, discriminators, limiters, and detectors.

Lesson 3 – *Radio Set Components* includes printed circuits; operational amplifiers, construction and application of IC's, switches, and connectors, jacks and plugs.

Lesson 4 – *Electronic Diagrams* discusses application and use of wiring, cabling, block, layout, and schematic diagrams, and the use of voltage, resistance, and trouble-shooting charts.

This material was designed for student self-study and evaluation. As basic material it can be useful as a sub-unit or it can offer remedial information in a classroom for students who want to brush up on fundamentals or need some basic information before moving on to more advanced material.

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US ARMY SIGNAL SCHOOL

FORT GORDON, GEORGIA 30905

SIGNAL SUBCOURSE 309

Edition 2

INTRODUCTION TO ELECTRONICS

7-2

SSO 309 2

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SIGNAL SUBCOURSE 309, INTRODUCTION TO ELECTRONICS

INTRODUCTION

Electronics today is a part of almost every field of endeavor. The entertainment field is a big user of electronics for radio, television, record players, and tape recorders. Electronics is used in industry to control production, maintain records, inventory stock, and guard critical areas, as well as for many other purposes. Military uses for electronics include such things as aiming guns, guiding missiles, dropping bombs, navigating ships and aircraft, and, of course, communicating.

To operate military electronic equipment, you must have some knowledge of electronic fundamentals. This subcourse will introduce you to basic electronics.

This subcourse consists of four lessons and an examination, as follows:

Lesson 1. Electron Tubes and Solid-State Devices

Lesson 2. Radio Transmission and Reception

Lesson 3. Radio Set Components

Lesson 4. Electronic Diagrams

Examination

Credit Hours: 10

You are urged to finish this subcourse without delay; however, there is no specific limitation on the time you may spend on any lesson or on the examination.

Texts and materials furnished:

Subcourse Booklet, Examination and Punch Card

You may keep the Subcourse Booklet.

REVIEWED AND REPRINTED WITH MINOR REVISIONS JAN 76.

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LESSON 1

ELECTRON TUBES AND SOLID-STATE DEVICES

SCOPE .... Operation of electron tubes and solid-state devices; applications of electron tubes and solid-state devices in electronic circuits, to include: rectifiers, amplifiers, and oscillators.

CREDIT HOURS 3

TEXT ASSIGNMENT .... Attached Memorandum, para 1-1 thru 1-3

MATERIALS REQUIRED .... None

SUGGESTIONS .... None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Be able to identify diode, triode, tetrode, and pentode tubes from the schematic symbols.

2. Be able to identify junction diodes and transistors from the schematic symbols.

3. Know the characteristics of electron tubes.

4. Know the characteristics of solid-state devices.

5. Know the applications of tubes and solid-state devices in electronic circuits.

ATTACHED MEMORANDUM

1-1. ELECTRON TUBES

a. General. An electron tube is a glass or metal envelope enclosing metal electrodes in a vacuum.

(1) Cathode. When heated, the cathode emits electrons. The directly heated cathode (A of fig. 1-1) is a single filament. The indirectly heated cathode (B of fig. 1-1) is a metal sleeve that is heated by an enclosed filament, or heater. In either case, a voltage applied to the filament causes current to flow, which generates the heat.

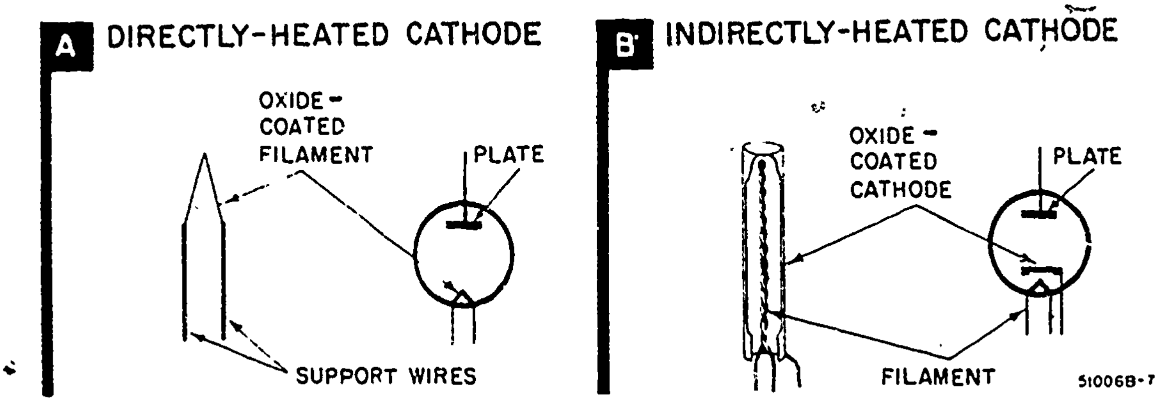

Figure 1-1. Directly and indirectly heated cathodes.

(2) Plate. The plate collects the electrons emitted from the cathode. This is caused by making the plate positive with respect to the cathode. The movement of electrons from the cathode to the plate is called the plate current.

(3) Grids. Grids are made of wire and are used to control the flow of electrons from the cathode to the plate.

b. Diode Tubes. A diode tube has only two electrodes, cathode and plate. When the plate of the diode is made positive with respect to the heated cathode, the plate attracts the electrons, causing current to flow between cathode and plate as shown in figure 1-2. The only control over this current is the difference of potential between the electrodes. If the plate is made negative with respect to the cathode, no current can flow through the tube. Since current can flow in only one direction, from cathode to plate, the current is said to be unidirectional. If E_{bb} in A of figure 1-2 is replaced by an ac source, the tube will conduct on the positive half-cycle (plate positive) but not on the negative half-cycle (plate negative). The diode tube changes the ac wave to dc.

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c. Triode Tubes. When a wire mesh, known as a control grid, is placed between the cathode and plate, the tube becomes a triode, or three-element tube. The effect is to reduce the capacitance between plate and cathode and to provide a means for controlling plate current. Electrons moving from cathode to plate must pass through the control grid. If a negative voltage, called bias, is applied between the control grid and cathode, the grid will tend to repel the electrons and reduce current flow to the plate. By making the grid sufficiently negative, current can be stopped completely, a condition known as cutoff. If a positive bias voltage is applied between the control grid and the cathode, current through the tube will increase. If the grid becomes sufficiently positive, current will increase to the point that the tube will be producing all the current that it is capable of producing. This condition is known as saturation. Cutoff and saturation are the two operating extremes of an electron tube.

d. Tetrode Tubes. Placing a second grid, known as a screen grid, between the control grid and the plate results in a tetrode tube (four elements). This grid is added specifically to accelerate electron flow in the tube. A positive voltage, approximately the same as the plate voltage, is applied to the screen grid to attract the electrons that are emitted by the cathode. The

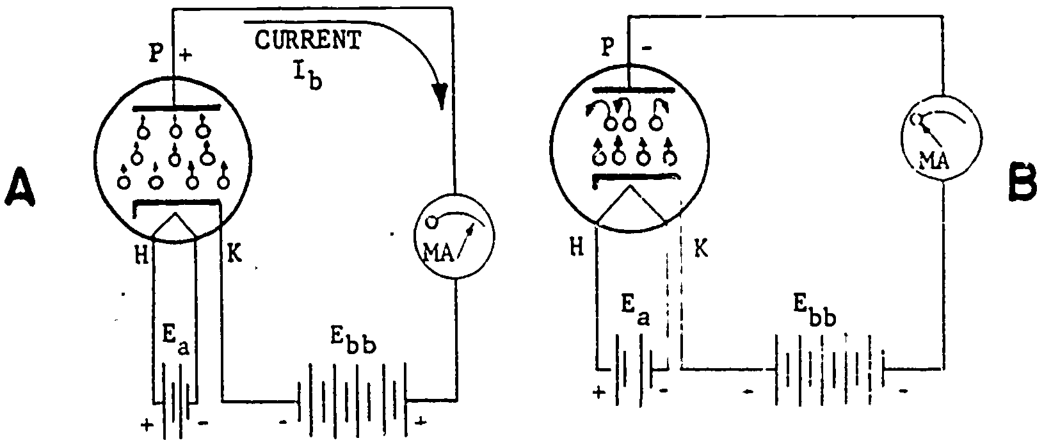

Figure 1-2. Electron flow in a diode.

screen grid, being a coil of wire, will attract only a small number of electrons. The majority of the electrons pass through the screen grid at an accelerated rate, thus increasing the amount and velocity of electron flow. The small number of electrons attracted to the screen grid form a current known as screen grid current. The insertion of the screen grid also reduces the internal capacitance of the tube, permitting operation at higher frequencies than the triode. Because of the high velocity of the electrons in a tetrode, some of them bounce off the plate and return to the screen grid. This undesirable effect is known as secondary emission, and the current is called secondary current.

e. Pentode Tubes. Adding a third grid, known as a suppressor grid, results in a pentode (five elements) and reduces secondary emission. The introduction of the suppressor grid further reduces the internal capacitance of the tube, permitting the use of higher frequencies. The function of the other elements are the same as in the tetrode. By operating the suppressor grid at the same potential as the cathode, the electrons from the plate due to secondary emission are repelled back to the plate by the suppressor grid. Since the electrons cannot return to the screen grid, screen grid current is reduced, and plate current is greater than that of a tetrode.

1-2. SOLID-STATE DEVICES

Semiconductor devices include an increasingly large family of solid-state, current-controlling devices. Two of the most widely known are junction diodes and transistors. Semiconductors require only a low operating current; consequently battery size can be reduced. The low current requirements also reduce the heat problem, and components can be mounted close together. Therefore, the use of semiconductors results in smaller and lighter electronic equipment.

a. Conductors and Insulators. The primary difference in the physical characteristics of conductors and insulators is the number of electrical charge carriers (electrons) that are free to move when electrical pressure (voltage) is applied. Conductors, having a large number of free electrons, permit current to flow easily when voltage is applied. Insulators have fewer free electrons and therefore seriously impede the flow of current.

b. Semiconductors. A semiconductor is sometimes defined as a material that has less resistance than an insulator but more resistance than a good conductor.

(1) In a true semiconductor the atoms and molecules of the crystalline material are bound together in fixed patterns. Germanium and silicon are two of the more important semiconductor materials. Other elements are often added to the semiconductor material in a process known as doping. Doping is done to change the electrical characteristics of the semiconductor material. The addition of the phosphorus, antimony, arsenic, or bismuth creates an N-type semiconductor. It contains a quantity of negative charges (electrons) that can move freely. The addition of indium, gallium, or boron has the effect of inserting positive charges; in other words, it creates an affinity for free electrons. This is known as a P-type semiconductor. A quantity of doped semiconductor material has less resistance than an equal amount of undoped semiconductor material.

(2) When a piece of semiconductor material is connected in series with a battery, current will flow through the material. If the battery leads are reversed, the same amount of current will flow in the opposite direction. Semiconductor material has a bidirectional current characteristic.

c. Junction Diodes. If a piece of P- and a piece of N-type semiconducting material are pressed together, a mechanical junction is formed and a semiconductor diode is created. At the junction, a barrier voltage is created when some of the electrons from the N-type material join with the positive charges of the P-type material.

(1) The barrier voltage can be strengthened or weakened by connecting a battery. The result will be to either increase or decrease current through the barrier, depending upon whether the battery opposes or aids the barrier voltage. When the junction barrier weakens, current flows freely through the junction diode, impeded only by the natural resistance of the semiconductor material

(saturation). When the junction barrier is strengthened, current through the diode is reduced to such a small value that it can be disregarded (cutoff).

(2) To better understand the operation of a junction diode, compare its operation to that of an electron-tube diode. Figure 1-3 shows the comparison. When battery E_{bb} is connected as in A, the positive on the plate attracts the negative electrons emitted by the cathode. Current flow is indicated by the meter.

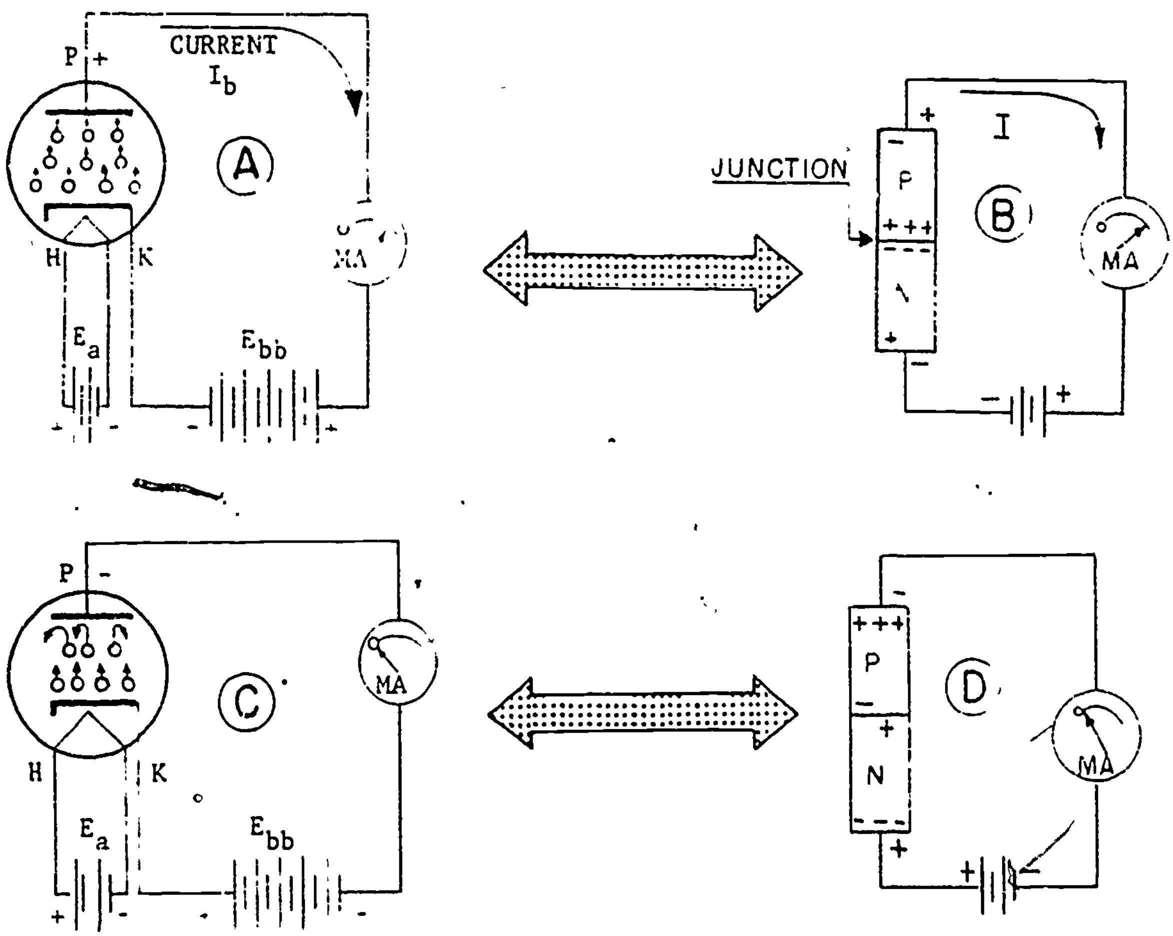

Figure 1-3. Comparison of electron-tube diode with junction diode.

(3) In B of figure 1-3, the positive charge of the battery on the P-type material repels the positive charges in the P material toward the junction. Likewise, the negative charge of the battery on the N-type material repels the negative charges in the N material toward the junction. Since unlike charges attract, the opposing charges effectively combine, weakening the opposition of the junction barrier. When the battery is connected in this manner, it aids the flow of current across the junction, and the diode is said to be forward biased.

(4) In ·' of figure 1-3, battery E_{bb} is reversed, making the plate of the tube negative. The plate repels the negative electrons, and, as the meter indicates, no current is flowing.

(5) In , of figure 1-3, the negative charge of the battery on the P-type material attracts the positive charges of the P material away from the junction. Likewise, the positive charge of the battery on the N-type material attracts the negative charges of the N material away from the junction. The concentration of unlike charges at the junction is thus reduced (strengthening the junction barrier), so the current flow across the junction is reduced. When the battery is connected in this manner, it impedes the flow of current across the junction, and we say that the diode is <u>reverse biased</u>.

(6) If the battery in B of figure 1-3 is replaced by an ac source, the charges will move <u>to</u> the junction on the positive alternation (forward voltage), and <u>from</u> the junction on the negative alternation (reverse voltage) of the ac wave. Since the junction diode has low opposition to the forward voltage and high opposition to the reverse voltage, the ac wave is changed to dc.

d. <u>Transistors</u>. Transistors are composed of semiconductor materials. Both the N- and P-type material are used in the same transistor. Two NP junctions and two barriers are created. The conductance can be varied by external control voltages and signals. The transistor can be compared with a triode tube. Instead of a cathode, control grid, and plate, the transistor has an emitter, base, and collector, respectively. The emitter and collector are made of the same type of semiconductor material, with the same electrical characteristic, both either N or P. The base must always be of the opposite electrical characteristic. The transistor is enclosed in a case, and three leads are usually brought out of the case, one lead connected to each of the three elements. Transistors are made of small bits of solid-state material. They are normally light in weight, small in size, and free from the effects of vibration. They are, however, sensitive to heat changes. There are two types of transistors.

(1) The NPN transistor is constructed with the emitter and collector made of N-type semiconductor material, while the base is made of P-type material. The schematic symbol is shown in figure 1-4.

(2) The PNP transistor is constructed with the emitter and collector made of P-type semiconductor material, while the base is made of N-type material. The schematic symbol for the PNP transistor is shown in figure 1-4.

e. <u>Transistor Operation</u>. When the signal is applied to the base of a transistor, the immediate effect is to either strengthen or weaken the junction barrier. This, in turn, will cause the current to decrease or increase with the input signal. In both cases the input signal is amplified (strengthened).

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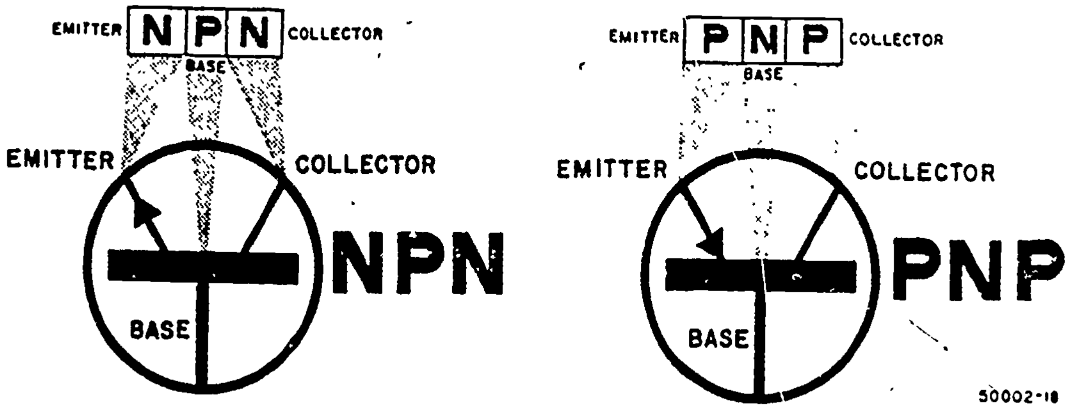


Figure 1-4. Transistor symbols.

1-3. APPLICATION OF ELECTRON TUBES AND SOLID-STATE DEVICES IN ELECTRONIC CIRCUITS

a. Rectifiers and Power Supplies.

(1) A typical diode tube half-wave rectifier circuit is shown in figure 1-5. This circuit converts the ac input voltage into a dc voltage. The unfiltered output of this circuit is shown in A of figure 1-6. The effects of adding filter capacitor C to the circuit is shown in B of figure 1-6. Additional filtering will further smooth the dc.

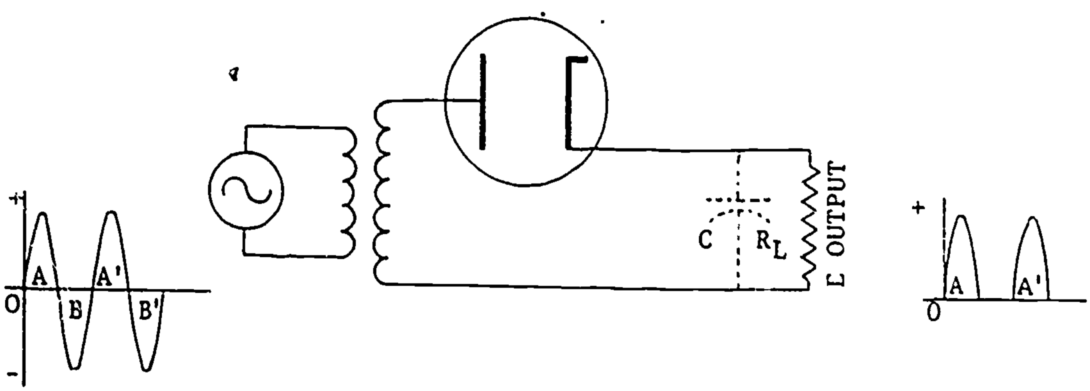


Figure 1-5. Diode used as a half-wave rectifier.

(2) Figure 1-7 shows a typical full-wave rectifier power supply. Section A of the twin diode converts one-half the input cycle to a dc pulse when plate A is positive, and section B converts the other half-cycle when plate B is positive. The result is an output frequency twice that of the output from the half-wave rectifier. The higher frequency is easier to filter to a steady dc. When the input frequency to a full-wave rectifier is 60 hertz, the output frequency is 120 hertz.

(3) The junction diode can also be used in the half-wave and full-wave rectifier circuits.

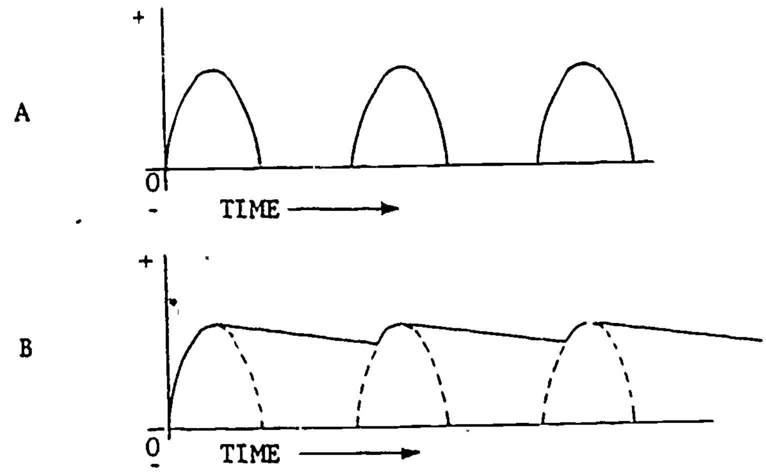


Figure 1-6. Effect of filter capacitor on waveform.

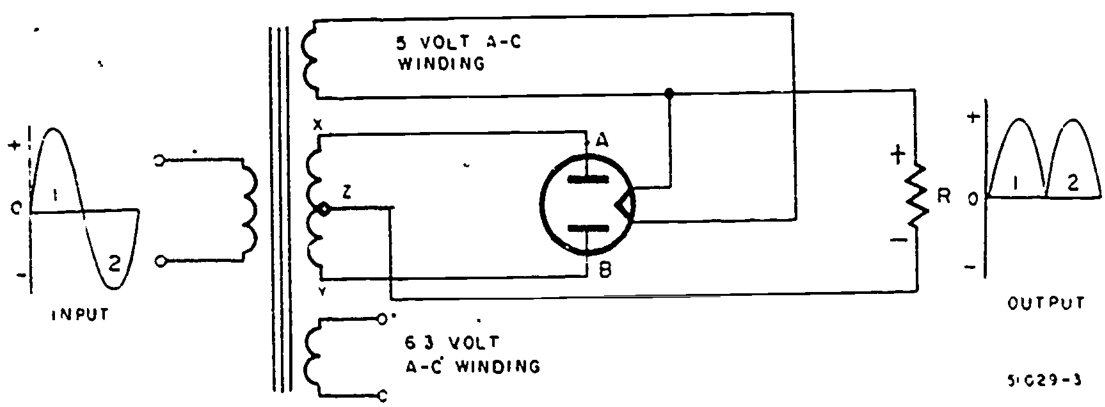


Figure 1-7. The full-wave rectifier.

(a) In A of figure 1-8, a junction diode is used as a half-wave rectifier. The output is identical with that of a diode tube rectifier. Again, filtering will result in a near-steady dc output.

(b) In B of figure 1-8, two junction diodes are used as a full-wave rectifier, each rectifying one-half the input signal. The resulting output voltage can be filtered into a steady dc voltage.

b. Detectors.

(1) A simple electron-tube diode detector circuit is shown in A of figure 1-9. The ac signal from the intermediate frequency (IF) amplifier is rectified by the diode. The remaining IF carrier is filtered out of the circuit by capacitor C1. The final audio-frequency (AF) wave form is developed across the volume control and sent to the AF amplifier.

(2) The circuit in B of figure 1-9 is similar to the circuit in A. The junction diode passes only the forward voltage (rectifies), and this portion of the IF carrier is again filtered out by C1 leaving the AF to be amplified for listening.

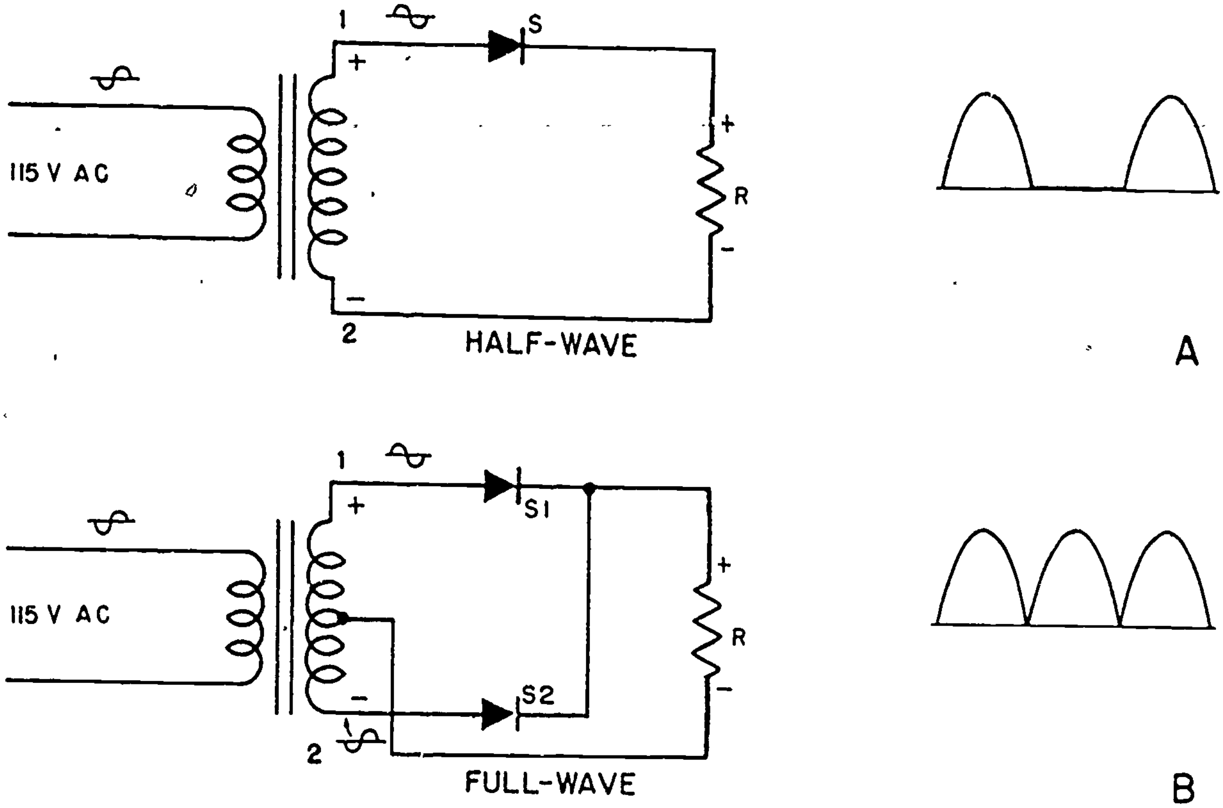


Figure 1-8. Half-wave and full-wave solid-state rectifiers.

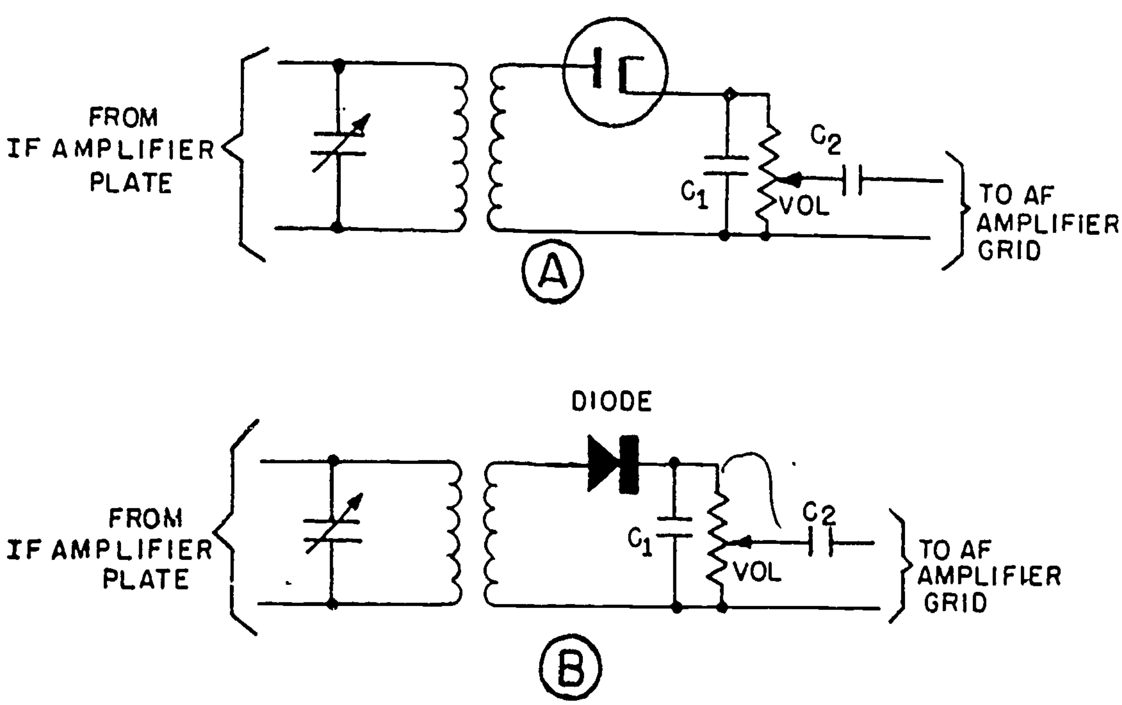


Figure 1-9. Simple diode detector circuits.

c. Junction Diode Voltage Regulator. There are silicon diodes designed for a specific breakdown voltage with reverse bias. This diode is known as a zener diode. When the breakdown voltage is exceeded, current through the diode increases very rapidly, while the voltage across the diode remains relatively constant. This characteristic makes the diode useful as a voltage regulator.

d. Varactor. The barrier voltage created at the junction of a semiconductor diode allows it to serve as a capacitance because of the separated charges. The amount of junction capacitance can be controlled by the reverse voltage. Diodes designed for this effect of a voltage-sensitive capacitance are known as varactors.

e. Amplifiers.

(1). In electron tubes such as the triode, tetrode, and pentode, the plate current is varied when the input signal is varied. When a load resistance is placed in the plate current path, the varying current will cause a varying voltage across the load resistor as shown in figure 1-10. The amplitude of the varying input signal is small compared with the amplitude of the varying voltage

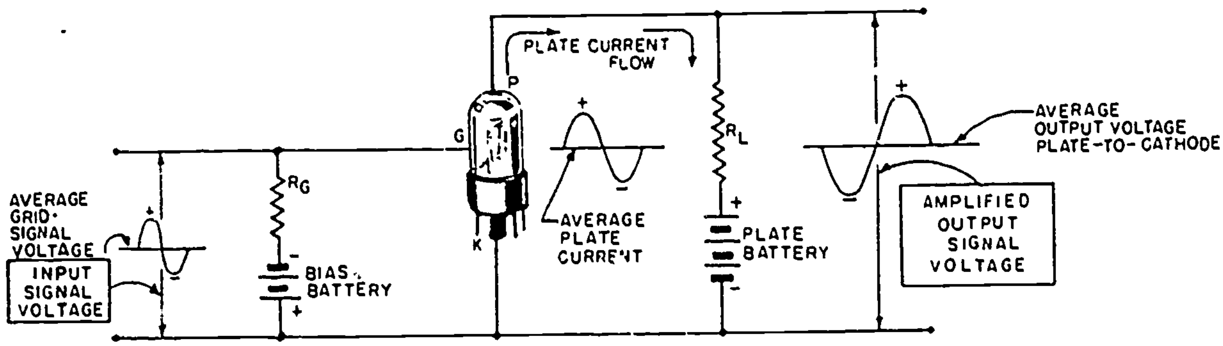


Figure 1-10. Comparison of input and output waveforms.

across the load resistor. The increase in amplitude between input and output signals is known as the gain of the amplifier. An electron-tube amplifier stage is shown in A of figure 1-11.

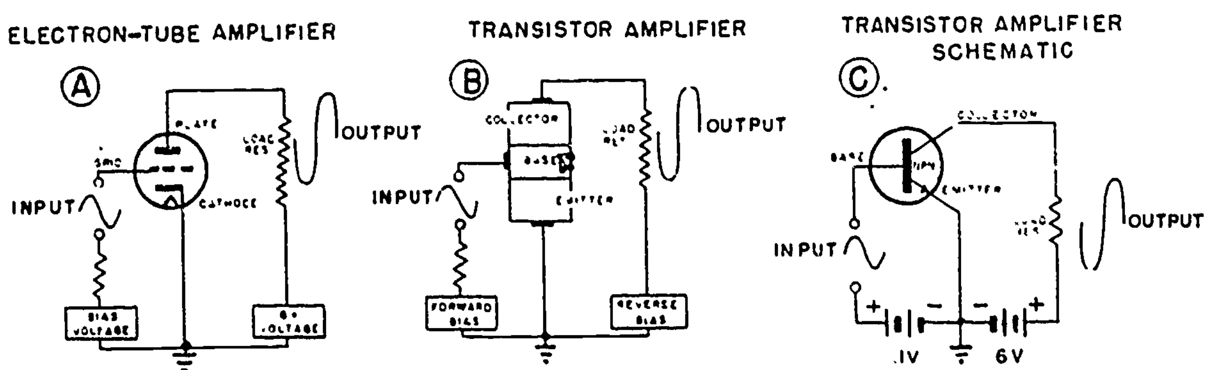


Figure 1-11. Electron-tube and transistor amplifier.

(2) A transistor amplifier comparable to an electron-tube amplifier is shown in B of figure 1-11. The schematic of the same amplifier is shown in C of that figure. The varying input signal results in a varying output voltage across the load resistor. The amplitude of the output signal is greater than that of the input signal; therefore, amplification has been accomplished.

f. Oscillators. Assume that an amplifier is designed to amplify a given frequency, or band of frequencies, as shown in A of figure 1-12. If the output signal is fed back to the input circuit, in phase with the input signal (B of fig. 1-12), the amplifier will oscillate as long as the in-phase feedback continues. In this circuit, the oscillating frequency is determined by the values

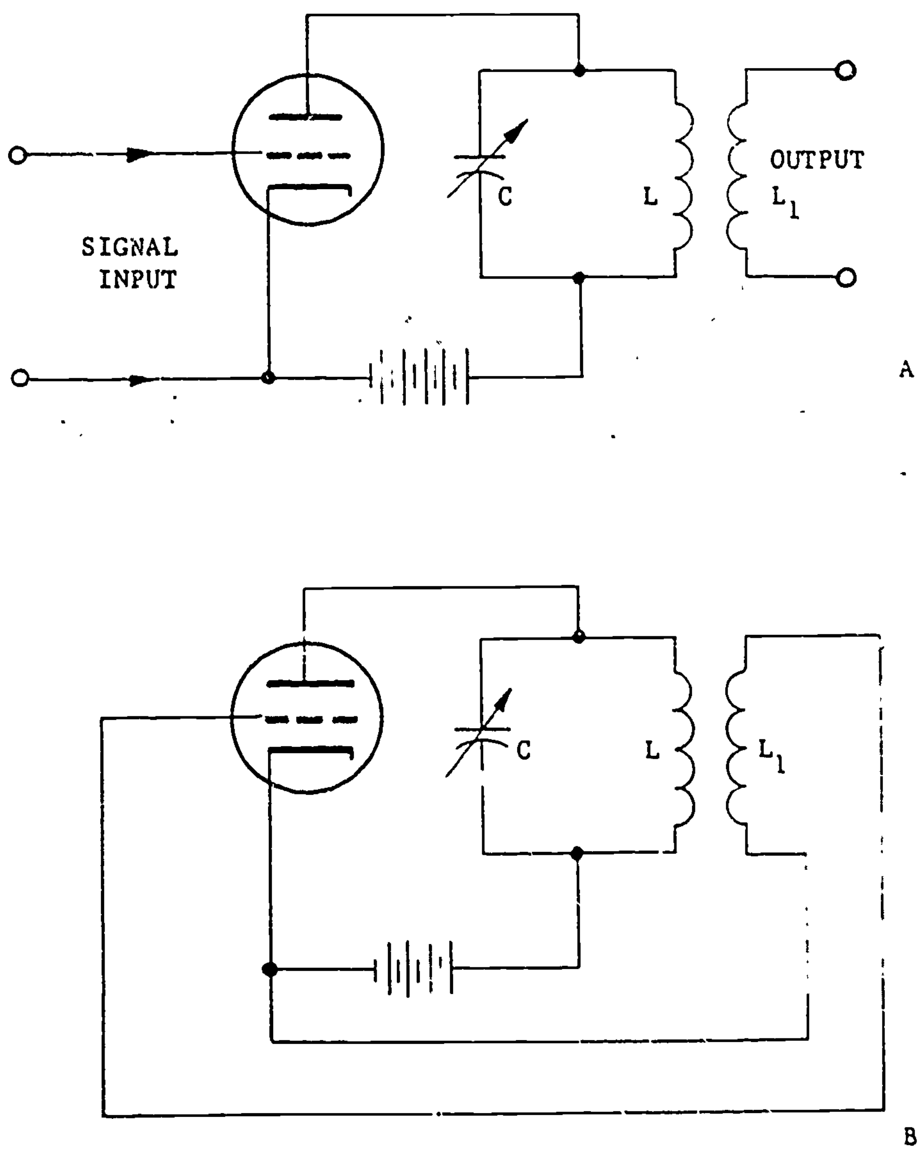


Figure 1-12. Development of an RF oscillator circuit.

of inductor L and capacitor C. In another circuit it may be determined by a resistor and capacitor, or by a crystal. The requirements for any oscillator are that there must be a method of determining frequency, there must be in-phase feedback, and amplification must occur. These requirements must be met whether the frequency is low or high, and whether the amplifier is a tube or a transistor. The principle of operation of the transistor oscillator is the same as that of the electron-tube oscillator.

STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. The cathode of an electron tube emits electrons when a

   a. voltage is applied to the filament.

   b. voltage is applied to the screen grid.

   c. positive voltage is applied to the plate.

   d. positive voltage is applied to the control grid.

2. The element in an electron tube that is designed to collect electrons is the

   a. control grid.
   c. cathode.

   b. filament.
   d. plate.

3. The current flow through a diode tube is controlled by the voltage between the

   a. plate and cathode.
   c. filament and ground.

   b. cathode and ground.
   d. filament and cathode.

4. A comparison of the characteristics of electron-tube current and semiconductor current shows that

   a. both are bidirectional.

   b. both are unidirectional.

   c. tube current is unidirectional, semiconductor current is bidirectional.

   d. tube current is bidirectional, semiconductor current is unidirectional.

5. The three elements of a triode electron tube are

   a. plate, cathode, and screen grid.

   b. control grid, cathode, and plate.

   c. cathode, control grid, and screen grid.

   d. screen grid, control grid, and plate.

6. Where is bias voltage applied to an electron tube?

   a. To the cathode

   b. To the screen grid

   c. Between the control grid and the plate

   d. Between the cathode and the control grid

7. The purpose of operating a screen grid at or near plate potential is to

   a. decrease screen grid current.

   b. repel the secondary electrons back to the plate.

   c. accelerate the movement of electrons to the plate.

   d. give the screen grid absolute control over plate current.

8. In addition to the cathode and plate, the elements of a tetrode tube are the

   a. control grid and suppressor grid.

   b. control grid and screen grid.

   c. screen grid and repeller grid.

   d. repeller grid and suppressor grid.

9. The suppressor grid reduces the internal capacitance of the tube and permits

   a. operation at lower frequencies.

   b. operation at higher frequencies.

   c. more plate current and screen grid current.

   d. more screen grid current and less plate current.

10. The accelerating element in a pentode electron tube is the

a. suppressor grid.

b. control grid.

c. screen grid.

d. plate.

11. The use of semiconductors in equipment design resul[illegible] and lighter electronic equipment. This is made possible beca[illegible] have

a. large size and low current.

b. large size and low resistance.

c. low current and low heat emission.

d. low resistance and low heat emission.

12. A process known as doping is used in making semiconductor material to

a. change the electrical characteristics of the material.

b. fuse together N- and P-type materials.

c. change the material into an insulator.

d. crystallize the material.

13. One element that is added to semiconductor material to create an N-type material is

a. oxygen.

b. indium.

c. nitrogen.

d. phosphorus.

14. When a piece of N- and a piece of P-type semiconductor material are pressed together, a diode is formed. The joining also creates a voltage that is best descrioed as a

a. bias voltage.

b. barrier voltage.

c. negative voltage.

d. positive voltage.

15. The three elements of a transistor are known as the

a. collector, base, and emitter.

b. emitter, grid, and collector.

c. collector, cathode, and grid.

d. base, collector, and cathode.

16. The transistor type is determined by its construction. An NPN transistor is made with the

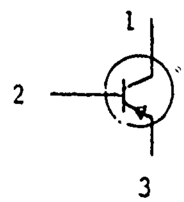
a. emitter and collector of N-type material, and the base of P-type material.

b. emitter and base of N-type material, and the collector of P-type material.

c. collector and base of P-type material, and the emitter of N-type material.

d. base and emitter of P-type material, and the collector of N-type material.

17. For the transistor symbol shown below, identify the type of transistor and the element at each pin number.



a. NPN - 1 collector, 2 base, 3 emitter

b. NPN - 1 base, 2 collector, 3 emitter

c. PNP - 1 collector, 2 base, 3 emitter

d. PNP - 1 emitter, 2 base, 3 collector

18. If there are 30 dc pulses per second in the output of an unfiltered half-wave rectifier, an unfiltered full-wave rectifier with the same input frequency would produce

a. 15 pulses per second.

b. 30 pulses per second.

c. 60 pulses per second.

d. 120 pulses per second.

19. The circuit shown in B of figure 1-9 develops the audio frequency (AF) from the intermediate frequency (IF) carrier by

a. rectification only.

b. rectification and filtering.

c. filtering only.

d. amplification and filtering.

20. What happens when the breakdown voltage is exceeded in a zener diode?

a. The diode current rapidly increases, while the voltage remains constant.

b. The diode separates the audio signal from the RF carrier.

c. The diode operates as a variable capacitance.

d. The current stops flowing through the diode.

CHECK YOUR ANSWERS WITH LESSON SOLUTION SHEET (Page 73).

LESSON 2

RADIO TRANSMISSION AND RECEPTION

SCOPE .... Signal frequencies; principles of radiation, antennas, and transmission lines; modulation; AM, FM, and SSB transmitting and receiving systems; frequency synthesizers, discriminators, limiters, and detectors.

CREDIT HOURS 2

TEXT ASSIGNMENT .... Attached Memorandum, para 2-1 thru 2-6

MATERIALS REQUIRED .... None

SUGGESTIONS .... None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know the extent of the AF and RF ranges.

2. Know the various types of modulation.

3. Know the purposes of detectors, limiters, discriminators, and frequency synthesizers.

4. Know how RF waves are radiated.

5. Know the radiating characteristics of half- and quarter-wave antennas.

6. Know the uses for the four most common types of transmission lines.

SIG 4 FRONT 2 1

ATTACHED MEMORANDUM

Section I. RADIO WAVE PROPAGATION

2-1. SIGNAL FREQUENCIES

The entire frequency range of alternating voltage or current, from 1 hertz (Hz) to many megahertz (MHz), can be considered in two broad groups: AF and RF.

a. Audio Frequencies. The AF range includes frequencies that can be heard by the human ear. The range of audible frequencies is approximately 16 to 16,000 Hz. The higher the frequency, the higher the pitch of the sound. Audio frequencies are used in electronic equipments that produce sound for the human ear, such as radios, tape recorders, record players, television, and public address systems. Audio frequencies cannot be efficiently radiated from an antenna. The power requirements are too great and the antenna needed would be much too long to be practical. For example, efficient transmission of a 20-Hz audio signal would require an antenna 4,500 miles long.

b. Radio Frequencies. The RF range includes all frequencies above the AF range. Although these frequencies are not audible, they are useful as carriers for those frequencies that are audible. Radio waves travel near the earth's surface and are also radiated skyward at various angles to the earth's surface, as illustrated in figure 2-1.

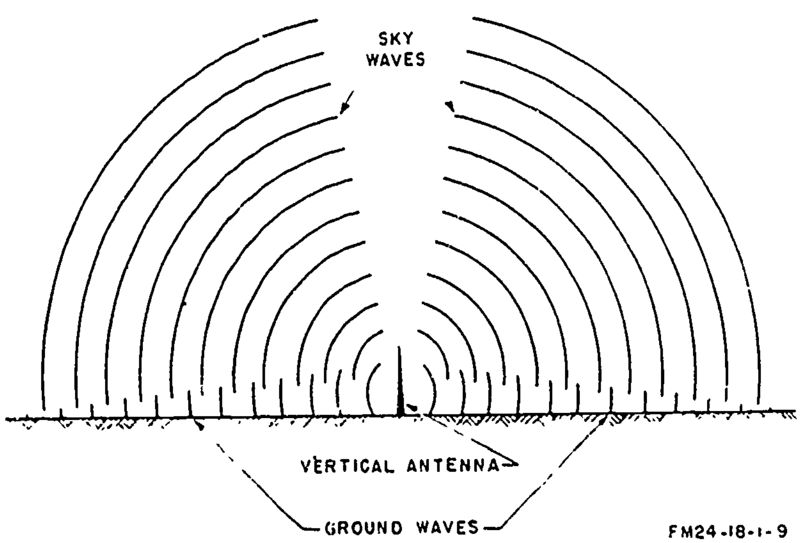


Figure 2-1. Radiation of radio waves from a vertical antenna.

(1) The electromagnetic waves travel through space at the speed of light, approximately 186,000 miles (300,000,000 meters) per second.

(2) The length of a radio wave is the distance traveled by the wave during the time interval of one complete cycle. Each complete cycle of two alternations of the wave is one wavelength. Wavelength is normally expressed in meters. The wavelength may be measured from the start of one wave to the start of the next, as shown in figure 2-2, or from the crest of one wave to the crest of the next. It is computed by dividing the velocity by the frequency.

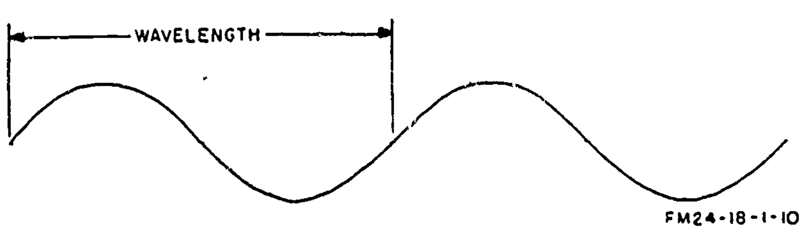


Figure 2-2. Wavelength of a radio wave.

(3) The frequency of a radio wave is the number of complete cycles that occur in 1 second. Figure 2-3 compares the wavelength of radio waves of two different frequencies. Since the frequency of a radio wave is very great, it is expressed in kilohertz (kHz) or MHz. One kHz equals 1,000 Hz, and one MHz equals 1,000,000 Hz.

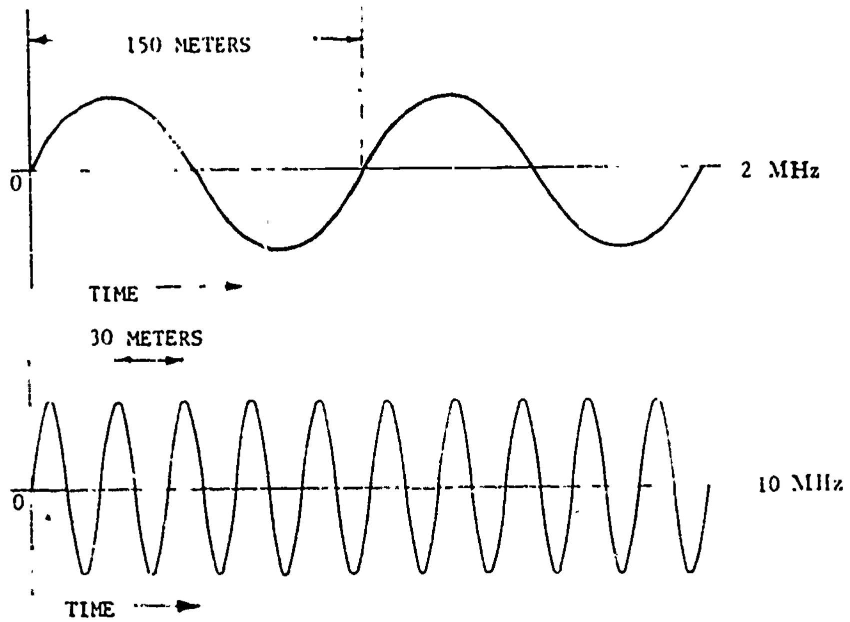


Figure 2-3. Comparison of two waves of different frequencies.

(4) Most tactical radio sets operate within the 1.5-MHz to 400-MHz portion of the frequency spectrum. Radio frequencies are divided into bands of frequencies for convenience of reference. The frequency bands for most tactical radios are shown in the following chart.

Band	Frequency (MHz)
Medium frequency (MF)	0.3 to 3.0
High frequency (HF)	3.0 to 30
Very high frequency (VHF)	30 to 300
Ultrahigh frequency (UHF)	300 to 3,000

(5) Unlike audio frequencies, radio frequencies can be radiated efficiently; therefore, radio frequencies are used as carrier waves.

2-2. PRINCIPLES OF RADIATION

a. Radio Wave Components. Energy is radiated by a transmitting antenna in the form of an electromagnetic wave which consists essentially of two parts, groundwave and skywave.

(1) The groundwave travels close to the surface of the earth and has a relatively short range. The distance range of the groundwave is affected by the transmitting frequency; the higher the frequency, the shorter the range.

(2) The skywave travels upward from the antenna at all angles, and is usually bent back to the earth's surface by the ionosphere, an electrically charged (ionized) region of the atmosphere. Because of the bending effect of the ionosphere, the skywave returns to the earth at some distance from the transmitting antenna. In this way, the skywave makes long-distance communication possible.

(3) The approximate ranges of groundwaves and skywaves at tactical radio frequencies are shown in the following chart.

Band	Groundwave		Skywave	
	Km	Miles	Km	Miles
MF	0 - 161	0 - 100	161 - 2,415	100 - 1,500
HF	0 - 83	0 - 50	161 - 12,872	100 - 8,000
VHF	0 - 48	0 - 30	83.5 - 241	50 - 150
UHF	line-of-sight		none	

b. Antennas. During transmission, an RF current in the conductor (transmitting antenna) produces an electromagnetic field which is radiated. During receiving periods, when a conductor (receiving antenna) is cut by an electromagnetic field, a current will flow in the conductor. If the wavelength of the conductor is equal to half the wavelength of the electromagnetic wave, the result is a half-wave antenna.

(1) The half-wave is the physical length of the basic antenna element. The dipole shown in figure 2-4 is a typical half-wave antenna. Ideally, the radiation is at right angles to the plane of the antenna, and completely encircles the conductor. The resulting radiation pattern, therefore, can be compared with a doughnut, with the radiator passing through its center, as shown in figure 2-4.

(2) The quarter-wave vertical antenna is a variation of the basic half-wave antenna. The mast represents a quarter wavelength of the radio signal, and the other quarter wavelength is supplied by a ground image to make up the required half-wave antenna. The ground image may be an artificial ground (called a counterpoise), the earth itself, or the metal body of a vehicle on which the antenna is mounted.

(1) The open-wire line shown in A of figure 2-5 is used mainly with transmitters. The spacing between lines may be varied by changing the insulators between wires. Such lines require much time and work to install. This type of line is not often used with receivers because of the possibility of noise pickup along the line.

(2) The insulated parallel-wire line (B of fig. 2-5) is widely used for television reception. The plastic ribbon maintains the spacing between the conductors. This type of transmission line is flexible and easy to handle and install, but is subject to noise pickup from external sources.

(3) The shielded parallel-wire line (C of fig. 2-5) is often used in radio reception because of reduced noise pickup from external sources along the line.

(4) The type of transmission line shown in D of figure 2-5 is used for both transmission and reception. Receiving-type coaxial cable is usually small in diameter and very flexible. The copper-braid shield greatly reduces noise pickup from external sources. The transmitting-type coaxial cable is larger in diameter because a larger center wire is used to keep resistance losses to a minimum, and a thicker dielectric material is used to insulate the center conductor from the copper-braid shield.

Section II. RADIO SYSTEMS

2-3. MODULATION

The function of a radio transmitter is to supply power to an antenna at a definite frequency, and to convey intelligence by means of the radiated wave. Radio transmitters generate waves which may be either of two types: one is the continuous wave, the other is the modulated wave.

a. Continuous Wave (CW). The waveform of the CW or unmodulated wave resembles the RF current in the tank circuit of an oscillator. This signal is called the carrier and conveys no information within itself. The carrier is a sine wave of alternating current as illustrated in figure 2-3. At the higher frequencies, each cycle is so close to the other that the peaks may appear sharp or pointed, although they are actually rounded.

b. Modulated Wave. The modulated wave is produced when the information signal varies the carrier's amplitude or frequency.

2-4. TRANSMITTING SYSTEMS

a. Radiotelegraph Transmitter.

(1) The simplest radiotelegraph, or CW, transmitter is shown in figure 2-6. A key to turn the carrier on and off is connected to the oscillator. A power supply to furnish power to the oscillator, and an antenna to radiate the carrier complete the transmitter.

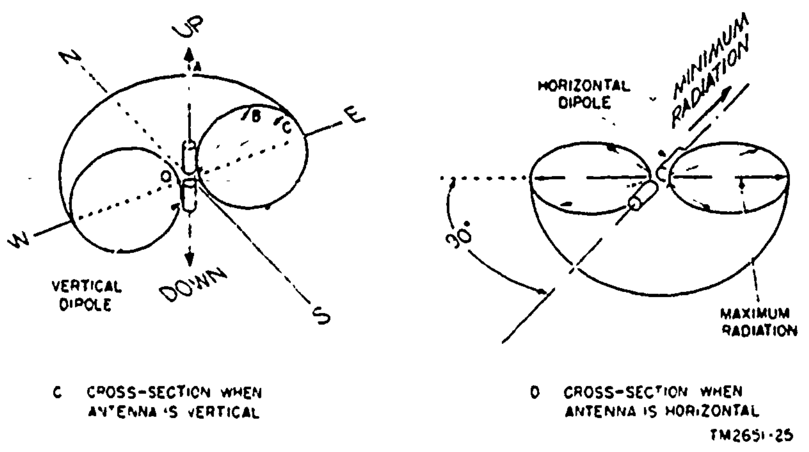


Figure 2-4. Radiation pattern of a half-wave antenna.

c. Transmission Lines. RF energy developed by a radio transmitter must be conveyed to a transmitting antenna to be radiated. RF energy intercepted by a receiving antenna must be conveyed to a receiver so that the receiver can develop a usable audio signal. The link between the antenna and the transmitter or receiver is called a transmission line. There are four types of commonly used RF transmission lines. These are shown in figure 2-5.

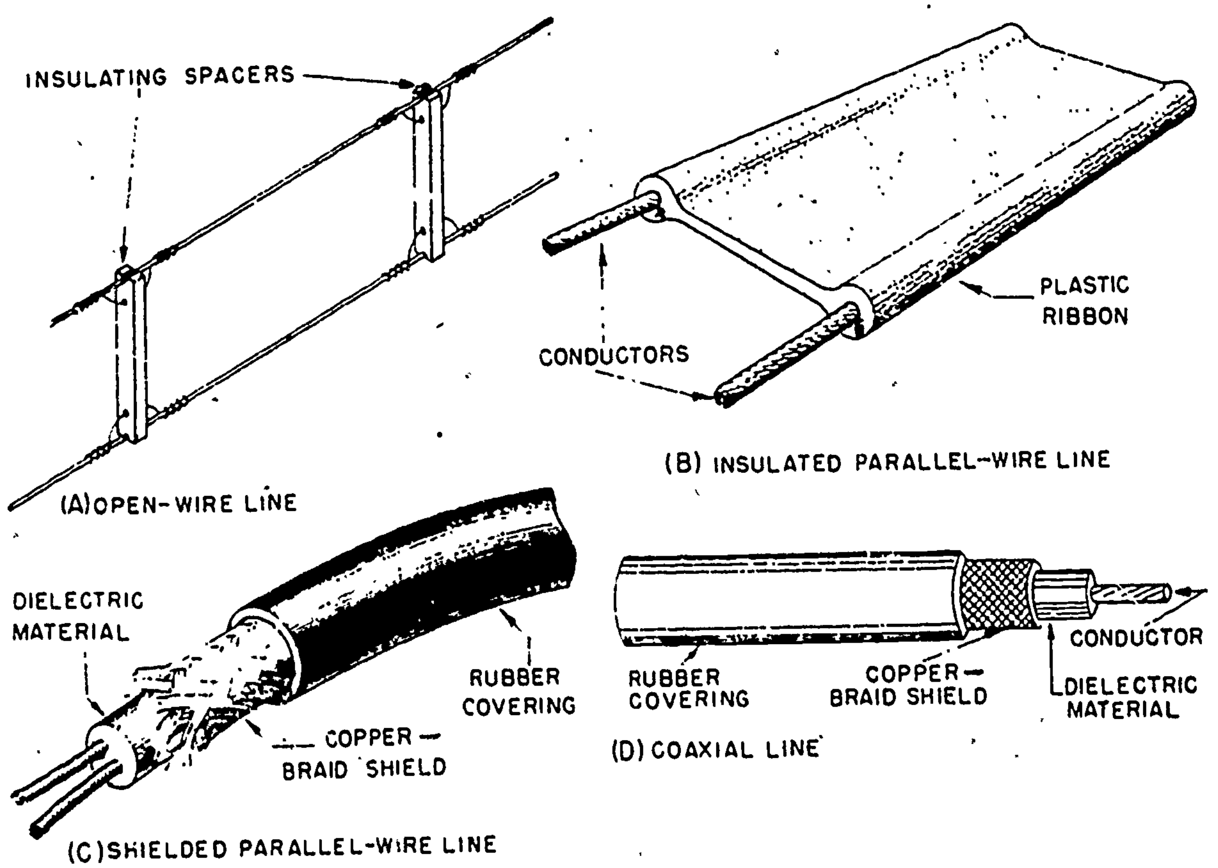


Figure 2-5. Types of RF transmission lines.

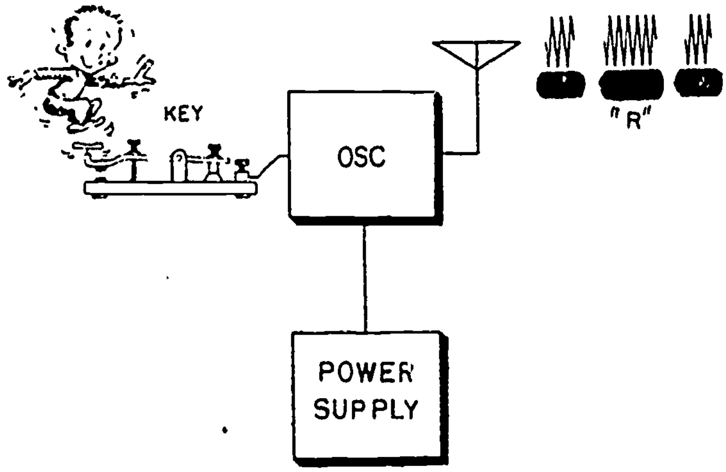


Figure 2-6. A simple CW transmitter.

(a) The continuous wave is used for the transmission of telegraph signals. Information is given to the carrier by starting and stopping the carrier with a switch or key. Keying is done in code, such as the international Morse code.

(b) The switch is closed for a short period of time, representing a dot. Closing the key for a longer period of time represents a dash. The Morse code is composed of dots and dashes representing the various letters and numbers of the alphabet and numeric system.

(2) A more powerful transmitter can be seen in figure 2-7. This transmitter has a more stable frequency. The frequency is stabilized by keying the amplifier instead of the oscillator.

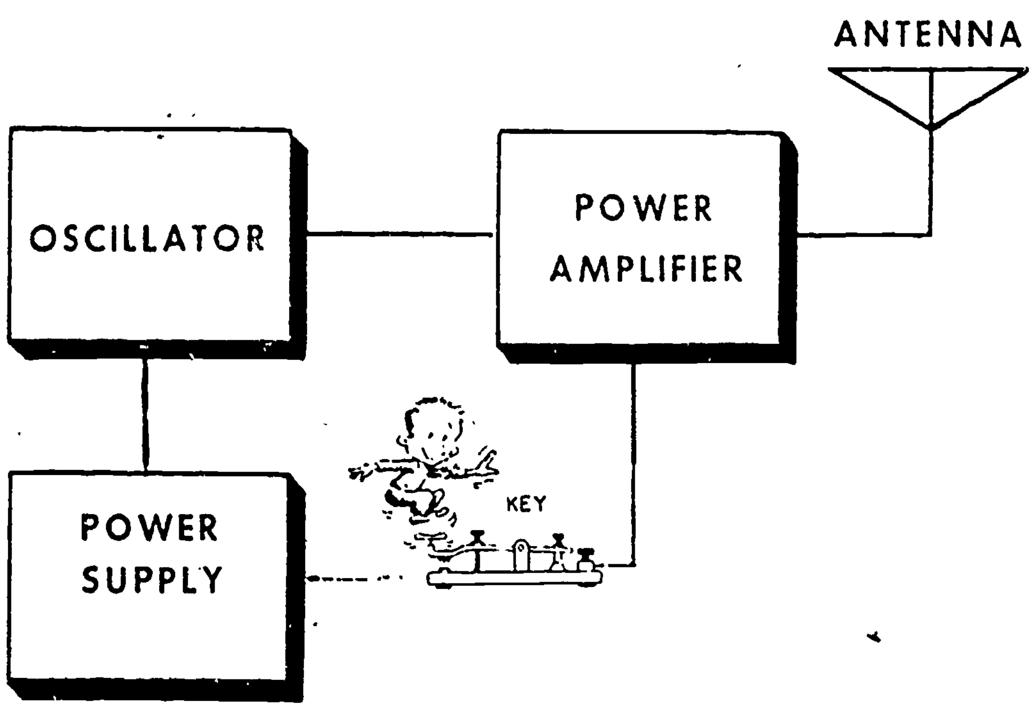


Figure 2-7. An improved CW transmitter.

b. Radiotelephone Transmitter. Radiotelephone and CW transmitters are similar in many respects. They differ mainly in the method of adding information to the carrier. The CW transmitter adds information to the carrier with code by means of a key, while a radiotelephone transmitter modulates the carrier with sound energy by means of a modulator.

(1) Figure 2-8 illustrates a simple radiotelephone transmitter. A modulator is added to the improved CW transmitter, and a microphone replaces the key. The functions of the power supply, oscillator, power amplifier, and antenna are the same in both transmitters. The modulator uses the voice energy (audio signal) from the microphone to vary the power to the power amplifier at an audio rate.

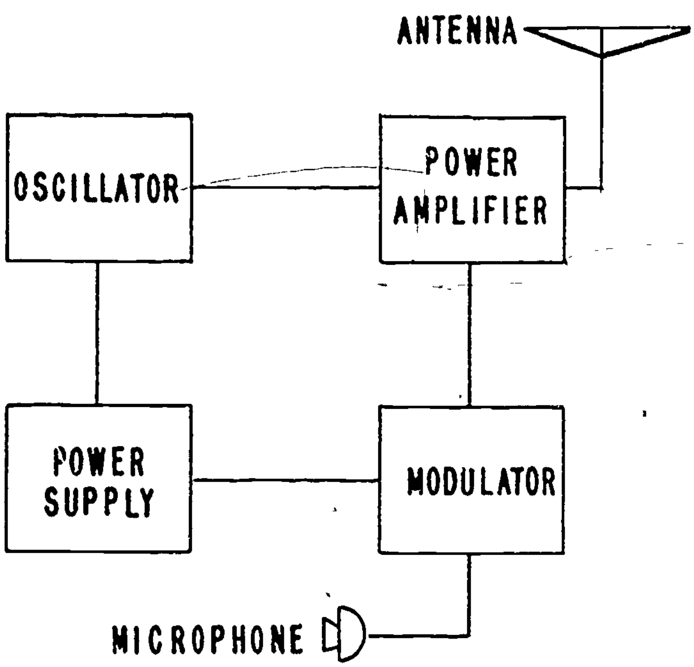


Figure 2-8. A simple radiotelephone transmitter.

(2) The addition of a buffer amplifier and a speech amplifier (fig. 2-9) improves the performance of the transmitter. The speech amplifier strengthens the voice signal to drive the modulator. The buffer amplifier isolates the oscillator from the final RF amplifier, thus stabilizing the oscillator frequency.

c. Amplitude Modulation. Amplitude modulation is one method of adding information to the RF carrier. This is done by varying the amplitude of the carrier with the audio signal from the microphone. Figure 2-9 shows the stages required and the waveforms produced by the process.

(1) The carrier is generated by the oscillator and amplified by the buffer amplifier.

(2) The microphone transforms voice (audio) signals into voltages. The audio signal voltage is amplified by the speech amplifiers

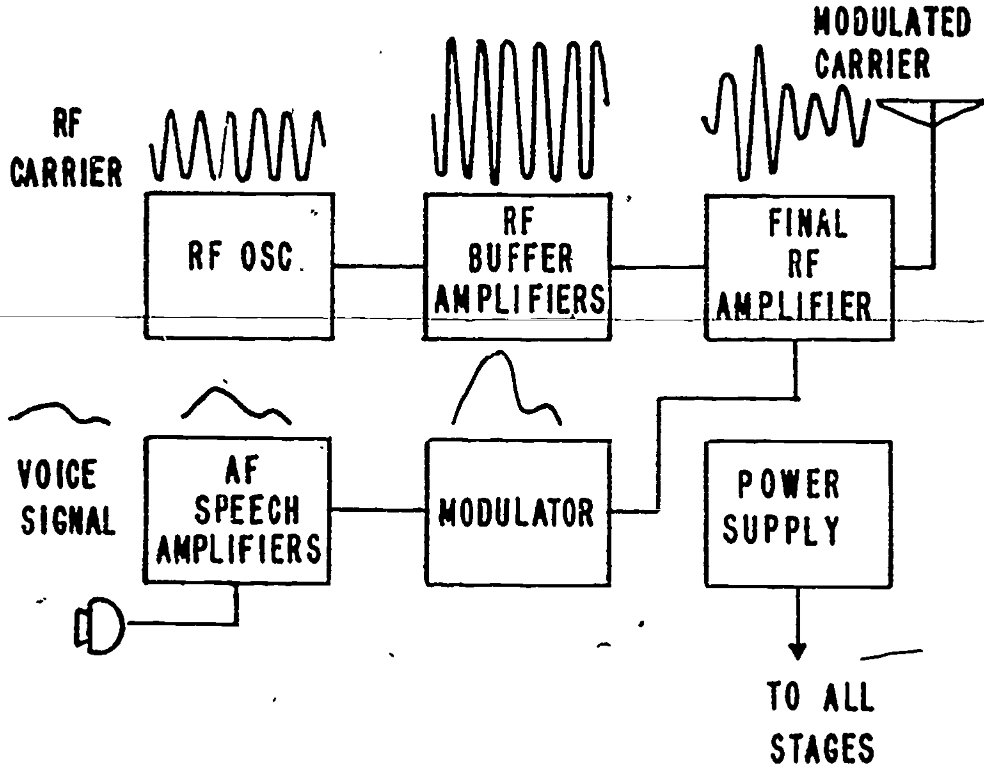


Figure 2-9. Amplitude-modulated radiotelephone transmitter.

and the modulator, and is used to vary the plate power of the power amplifier. If the plate power is varied at an audio rate, the output power varies at the same rate. The modulating signal determines the amount of output power that the final RF amplifier will furnish to the antenna.

(3) The final RF amplifier produces the composite of the carrier and the audio signals. Notice in the figure that the amplitude of the carrier frequency is varying at the audio rate.

(4) A of figure 2-10 illustrates one method of introducing the modulating AF voltage into the power amplifier. This method of modulating the carrier is known as plate modulation. The waveforms in B, C, D, and E show the effects of modulation.

(5) The modulation occurring in the power amplifier generates sideband frequencies. Assume that the carrier frequency in B of figure 2-10 is 100 kHz, and the constant-frequency modulating signal shown in C is 1 kHz. The frequencies appearing in the plate circuit of the power amplifier are:

100 kHz
100 kHz plus 1 kHz = 101 kHz
100 kHz minus 1 kHz = 99 kHz
1 kHz

The sideband frequencies are 101 and 99 kHz, and the center frequency is 100 kHz. The carrier wave and sidebands are illustrated in figure 2-11.

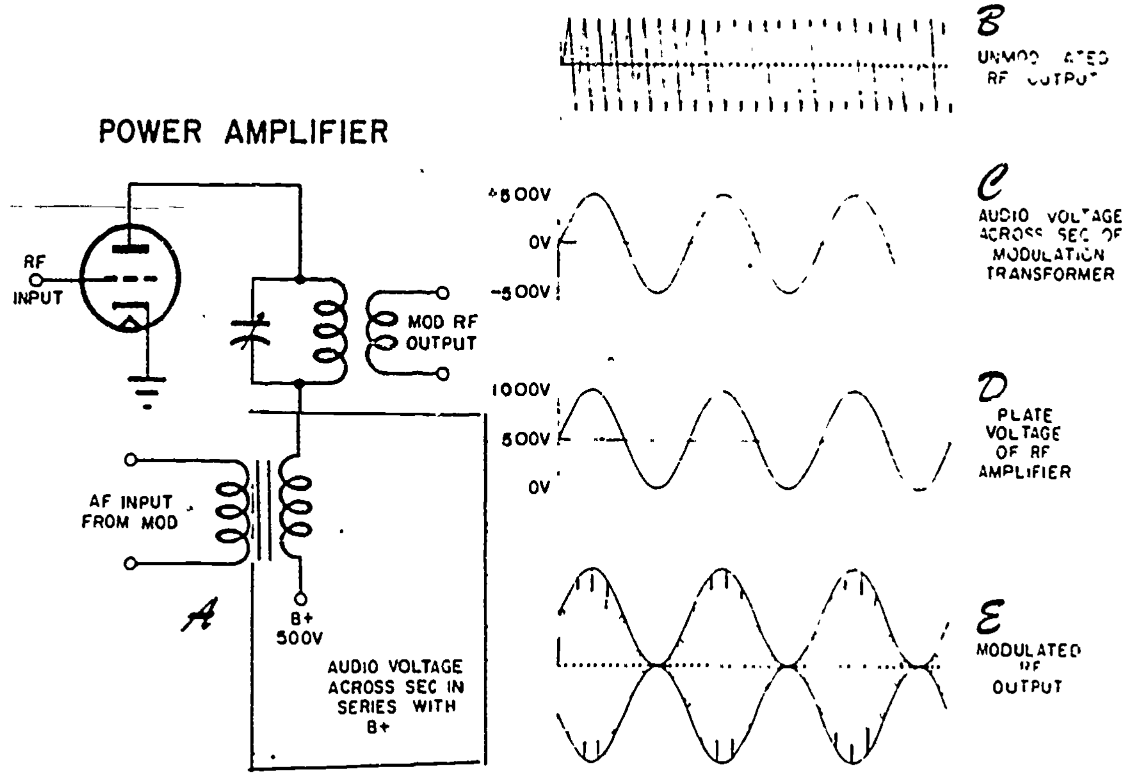


Figure 2-10. Carrier modulated at an audio rate.

(6) The double-sideband system is used by most broadcast radio stations. The carrier is transmitted together with the upper sideband (USB) and lower sideband (LSB) frequencies. All three are received in the radio receiver at the same time. A demodulator extracts the audio signal. The signal is amplified by an amplifier and reproduced by the speaker.

(7) If the receiver can locally produce the same frequency as the carrier to beat with the sidebands, there is no need to transmit the carrier. Also, since both the USB and LSB carry the same information, it is not necessary to transmit both. A single-sideband (SSB) transmitter filters one sideband (either upper or lower), suppresses the carrier, and makes available the power that normally is used to transmit the carrier and both sidebands, to transmit only one sideband frequency. This is illustrated in figure 2-11. To produce at the SSB receiver a signal whose power is equivalent to the power of the signal received by the DSB receiver, the SSB transmitter requires only one-sixth of the output power required by the DSB transmitter. Since the SSB transmitter does not have to produce as much power as the DSB transmitter, the SSB transmitter can be lighter and more compact. In addition, SSB transmission also saves space in the transmitting frequency spectrum, and is less subject to interference from adjacent frequency channels.

d. Frequency Modulation. Frequency modulation (FM) is a second method of adding information to an RF carrier. This is accomplished by varying the frequency of the carrier using the audio signal developed by the microphone.

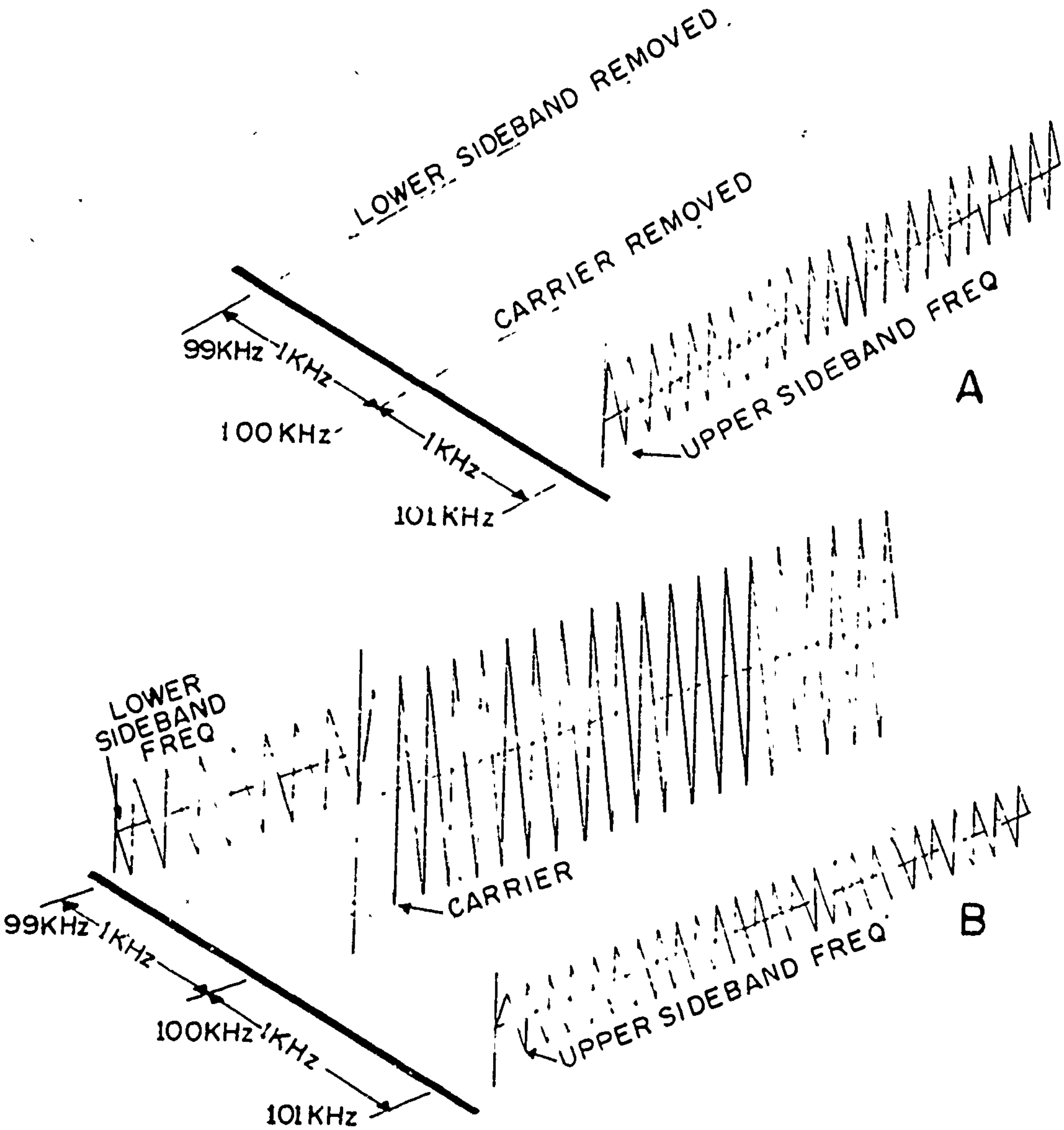


Figure 2-11. Comparison of AM and SSB.

(1) The waveforms shown in B and E of figure 2-12 represent stable carrier frequencies. Parts A and D show audio signals of different frequencies that are used to modulate the carrier. Parts C and F show the effects of the modulating signals on the RF carriers. Notice in both C and F that a positive voltage peak of the modulating signal results in an increase of frequency, while a negative voltage peak results in a decrease of frequency. Also, the higher modulating frequency (D) causes the carrier to be varied more often than the lower modulating frequency (A).

(2) The waveforms shown in B and E of figure 2-13 show a stable carrier frequency. Parts A and D show audio signals of the same frequency but different amplitudes, used to modulate the carrier. In C and F you can see the effect of the modulating

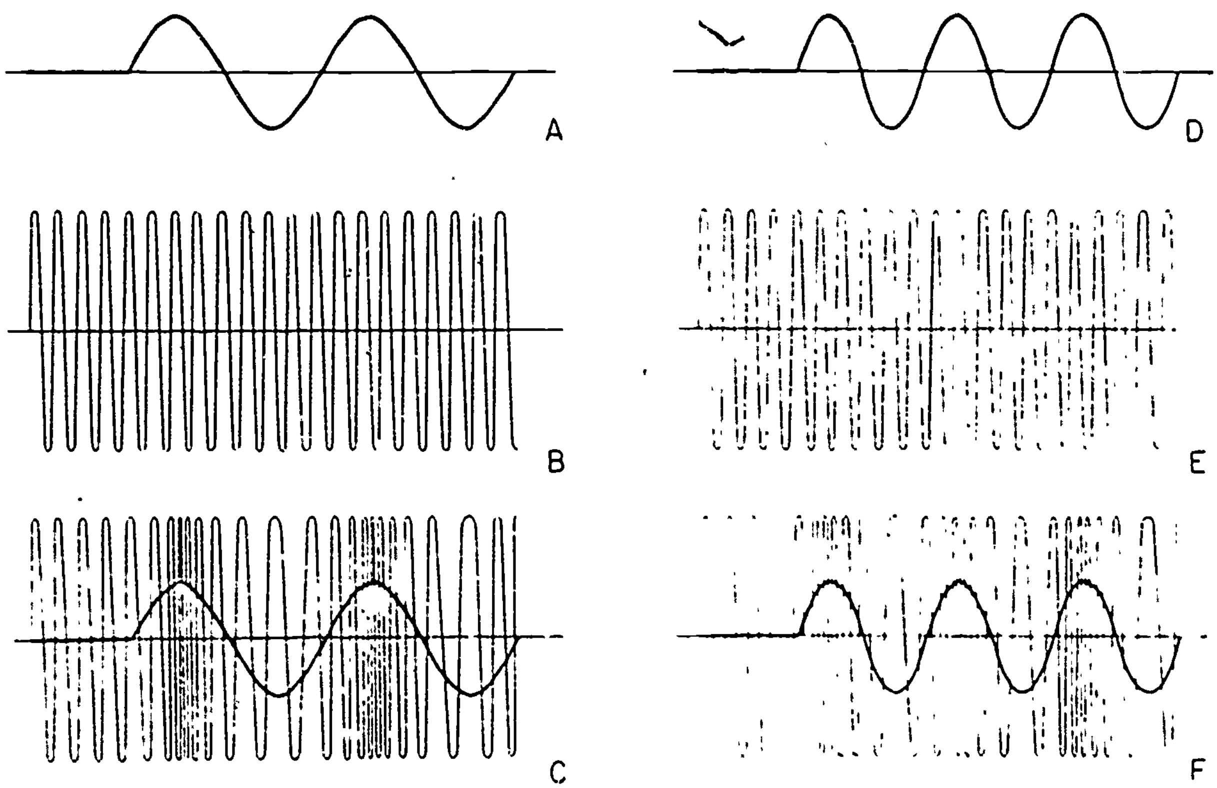


Figure 2-12. Effect of signal frequency variations on the FM wave.

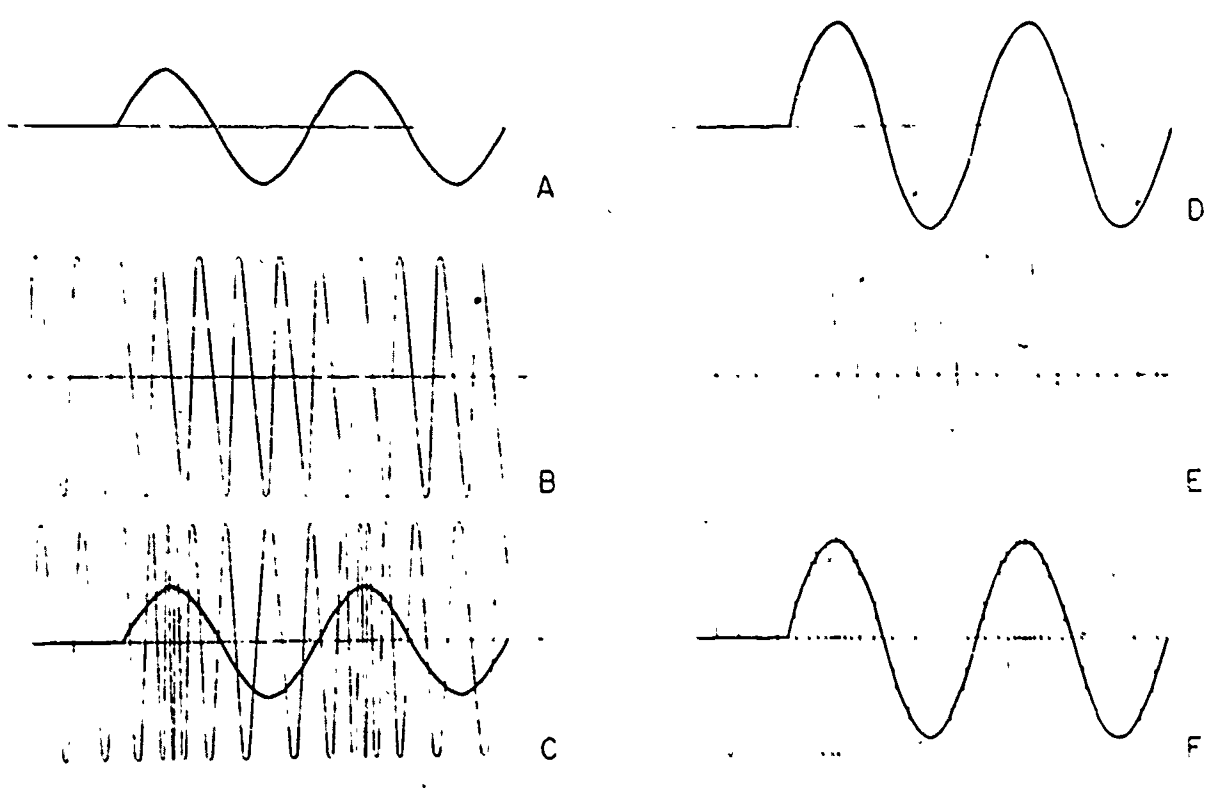


Figure 2-13. Effect of signal amplitude variations on the FM wave.

signals on the carrier. Notice that the modulating signal with the greater amplitude causes a greater amount of variation to the carrier frequency. Notice also that the amplitude of the carrier remains constant. Only the frequency is varied.

(3) A study of figures 2-12 and 2-13 shows that both the frequency and amplitude of the modulating signal have an effect on the FM carrier.

(4) FM communication channels are located in the VHF range or higher. This is because the bandwidth requirement is 50 kHz per channel as compared with the 6 kHz for DSB and the 3 kHz for SSB. There is more room in the VHF and higher ranges to accommodate FM.

(5) One characteristic of VHF and higher ranges is line-of-sight transmission. Consequently, it is possible to use large numbers of FM radio sets operating on the same frequency, provided they are physically separated a sufficient distance to prevent interference.

(6) Another feature of FM radios is that lightning storms, diathermy machines, automobile ignition systems, and interfering radio stations have little effect on FM reception. These noises cause an amplitude variation of a radio wave. An FM receiver can eliminate most of the amplitude variations, so most of the noise is eliminated.

e. FM Transmitters. There are two types of modulation that are used most often in Army FM transmitters. In direct modulation, the RF wave is modulated at its source (the oscillator). In indirect modulation, the RF wave is modulated in a stage following the oscillator. The FM wave created by either system can be received by the same receiver. The block diagram of a typical direct-modulation transmitter is shown in A of figure 2-14. In B of figure 2-14, a typical indirect-modulation transmitter is shown.

2-5. RECEIVING SYSTEMS

a. Principles of Radio Reception. The receiving antenna intercepts a small portion of all radio waves passing by. These waves are of many different frequencies, each carrying its own information. The ideal receiver will select the desired signal from among the many intercepted by the antenna, and will reproduce a signal identical with the one originally modulated and transmitted.

b. Basic Radio Receiver. A radio receiver must be able to select the signals from the various radio stations, extract the information, and produce the sound for the listener. Block diagrams of basic radio receivers are shown in figure 2-15. In A, the antenna, detector, and headset provide a very weak signal and only one or two stations can be heard. In B, there is an improvement in volume because an AF amplifier has been added, but the ability to select stations is not much better. In the block diagram in C, the signals from the antenna are amplified before detection. Some of the weaker stations can now be heard, and overall volume has been improved.

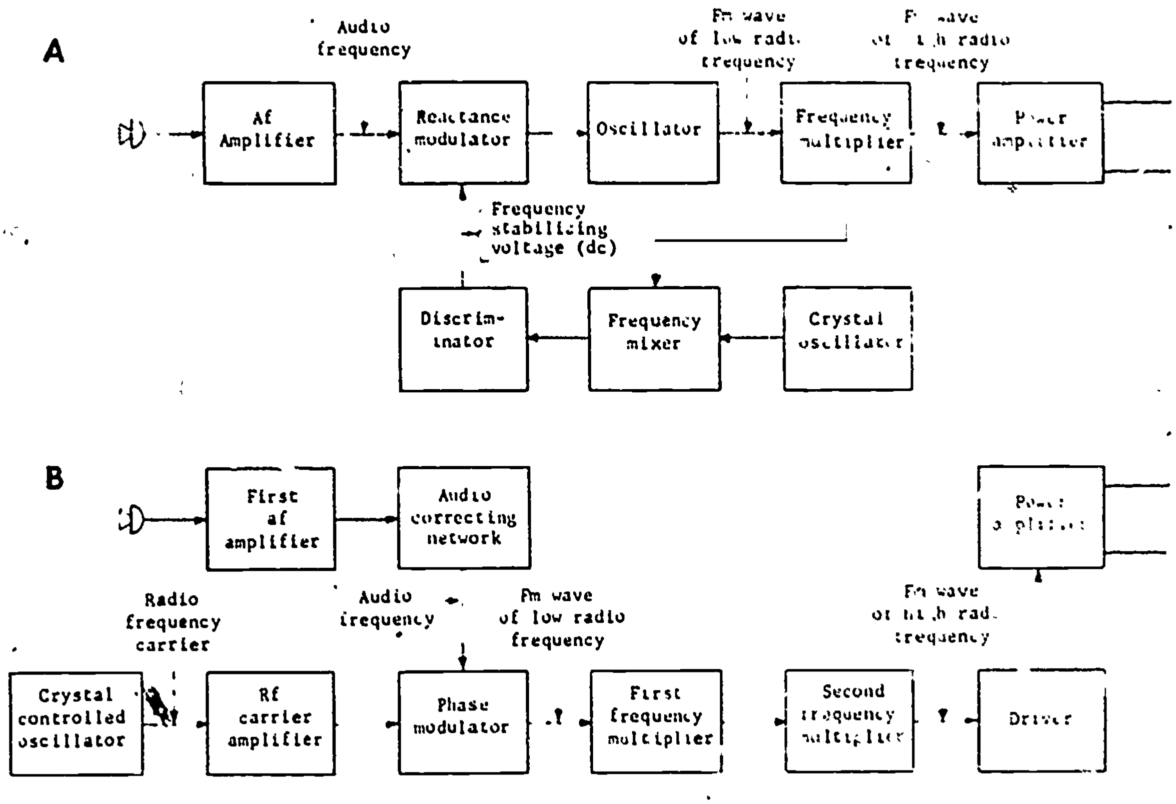


Figure 2-14. Block diagrams of FM transmitters.

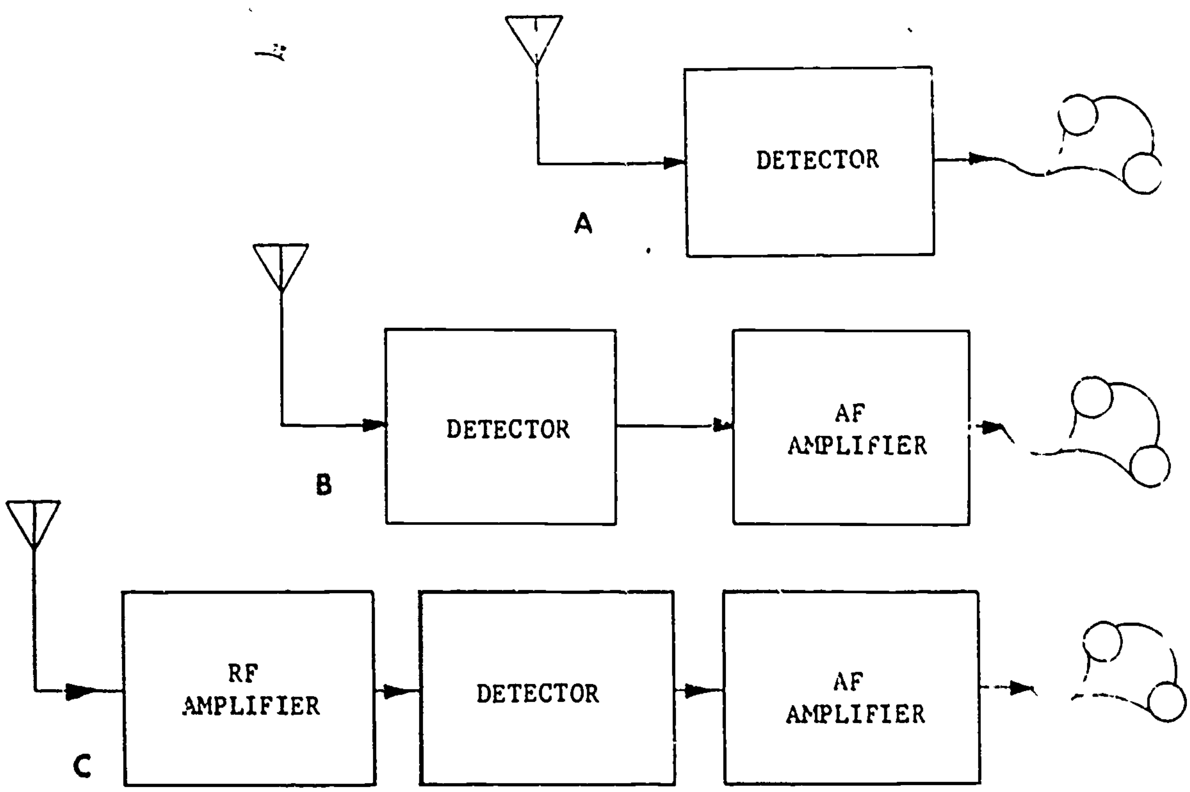


Figure 2-15. Basic radio receivers.

c. AM Receiving System. In figure 2-16, the block diagram of a typical AM receiver is illustrated. The RF amplifier selects one of the many signals on the antenna, amplifies it, and sends the amplified signal to the mixer. Here, a second signal is applied from the local oscillator. The two signals are mixed in this stage, producing four predominant frequencies: the two inputs, the sum of the two, and the difference between the two. For example, if the frequency at the antenna is 1,500 kHz and the local oscillator frequency is 1,045 kHz, the frequencies at the output of the mixer are:

Antenna	- 1,500 kHz
Local oscillator	- 1,045 kHz
Sum	- 2,545 kHz
Difference	- 455 kHz

The difference frequency is usually selected as the output and is known as the IF signal. It carries the information of the received RF signal. The IF amplifier stage amplifies this frequency and sends it to the detector. Here, the information (AF voltage) and the carrier are separated. The carrier is filtered out, leaving only the audio. The audio is amplified by the audio amplifier stages and reproduced by the speaker.

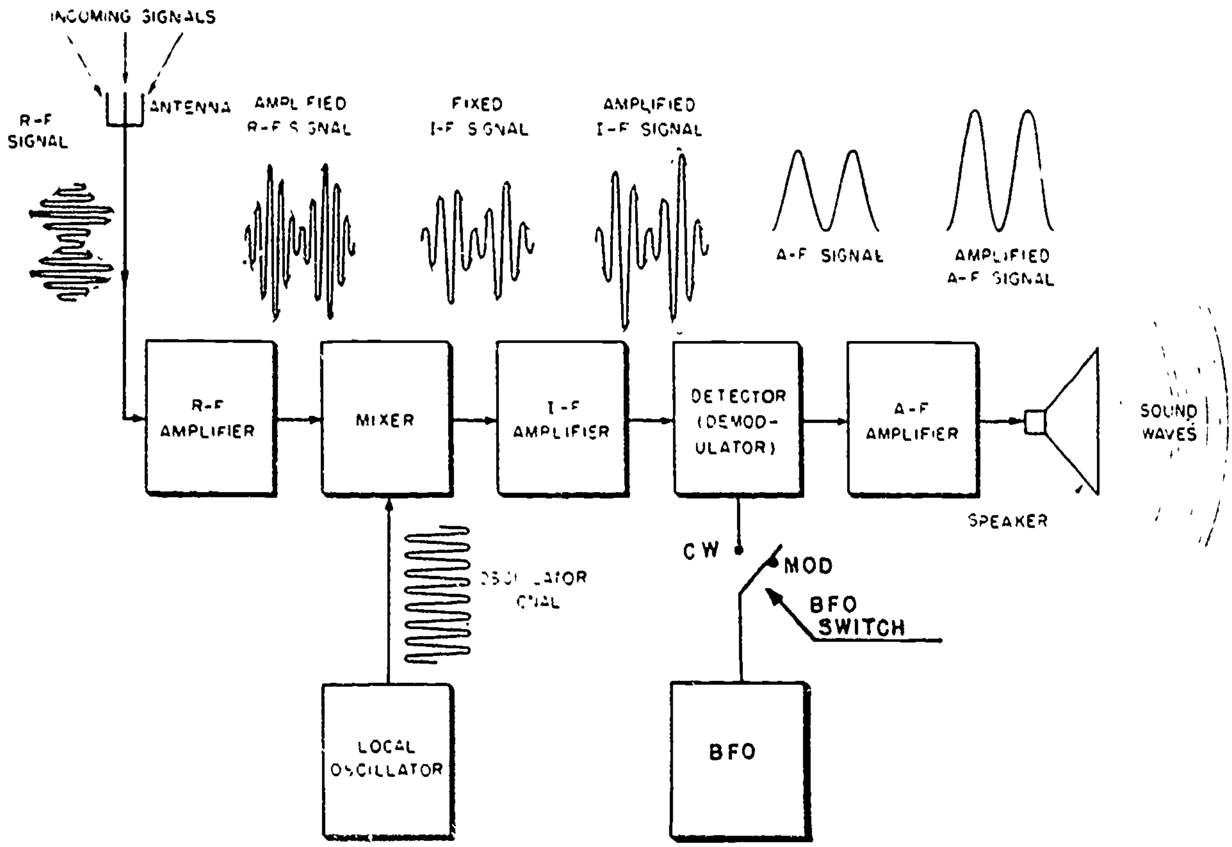


Figure 2-16. Block diagram of an AM receiver.

d. CW Reception. The receiver in figure 2-16 can be used to receive CW signals. All stages of the receiver operate the same except the detector. In this stage the IF is mixed with a signal from the beat-frequency oscillator

(BFO). This is a constant-amplitude signal whose frequency is set slightly higher or lower than the IF. The output of the detector is the difference between the two frequencies (a low audio frequency) in the form of the dots and dashes of code. CW can only be heard if the BFO switch is in the BFO position.

e. FM Receiving System. Figure 2-17 compares the block diagrams of AM and FM receivers. In each receiver there is a stage of RF amplification, a local oscillator, and a mixer stage, followed by one or more IF amplifiers. The stages of both sets are similar in purpose up to this point. In the next two stages are found the two main differences between the receivers. The limiter of the FM set may be considered as a special type of IF amplifier, while the discriminator is a special type of detector.

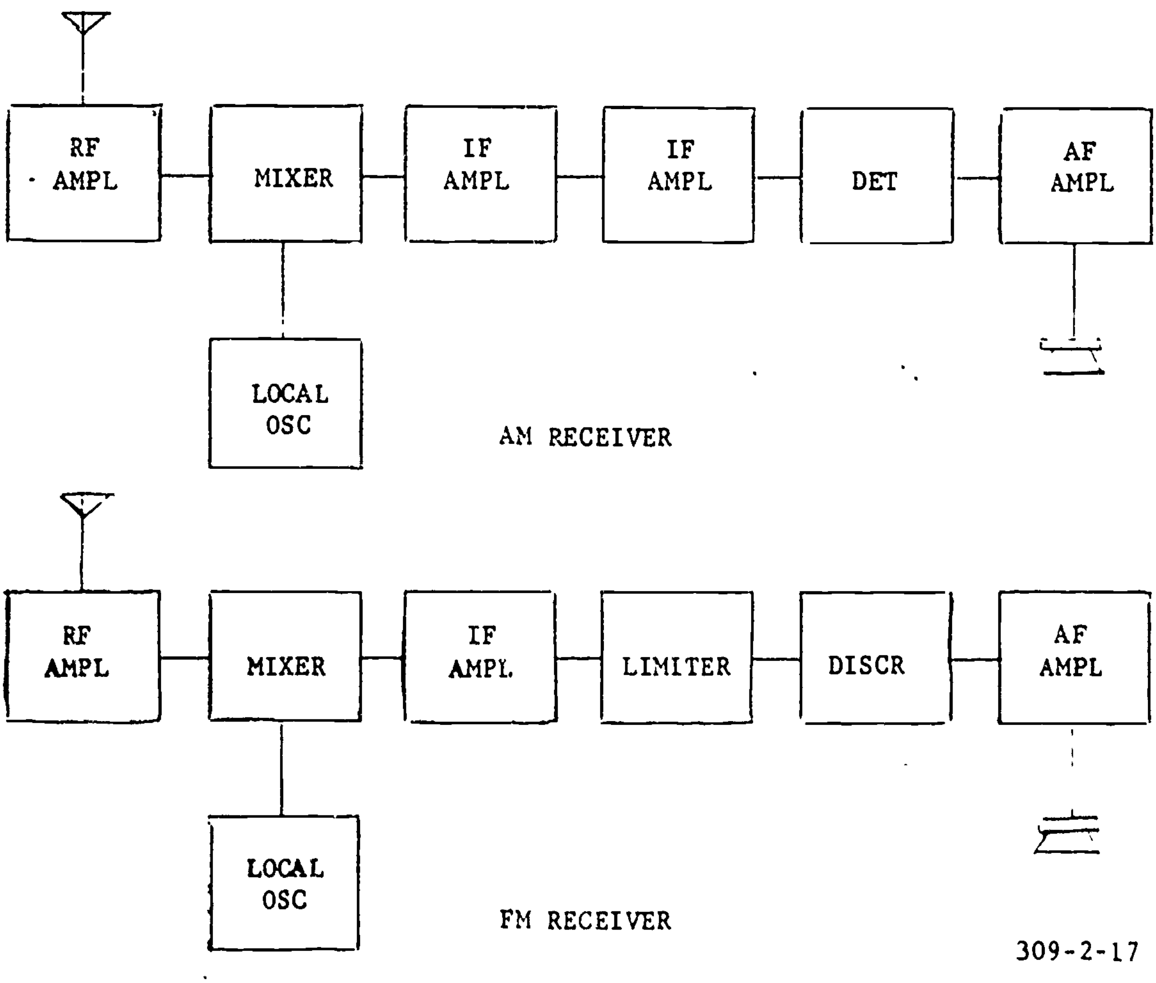


Figure 2-17. Comparison of AM and FM receivers.

(1) The IF signal applied to the limiter contains undesired amplitude variations. The limiter clips these amplitude variations from the carrier, leaving only the carrier with the frequency variations from the modulating signal. The output from the limiter is sent to the discriminator.

(2) The discriminator is a frequency detector. The center frequency of the discriminator is the same as the IF. Any deviation from this frequency (above or below) will be detected, and the discriminator will produce a voltage proportional to the amount of deviation. This voltage is filtered to eliminate the IF carrier, leaving only the dc voltage variation to be amplified by the audio stages. The output of the discriminator is considered to be the AF component of the dc voltage.

2-6. FREQUENCY SYNTHESIZERS

In modern communication, it is common practice to simultaneously transmit several hundred telephone messages over one radio channel. To prevent interference, each telephone message must have its own carrier signal. Each signal requires a different frequency which must be extremely stable. The most practical means of producing these signals is by a method known as frequency synthesis. The circuit that produces these stable frequencies is known as a frequency synthesizer.

a. Frequency Synthesis Methods. The basic principle of frequency synthesis is shown in figure 2-18. Each of the several methods or combinations of methods used to synthesize signals follows this principle. Some of the various methods used to synthesize frequencies are circuits designed to add, subtract, multiply, and divide a stable basic frequency.

b. Uses For Synthetic Frequencies. The signals that are produced by frequency synthesizers may be used in a variety of ways. They may be used as carrier frequencies, testing signals, synchronizing signals, or as alarm or ringing signals. The intended use of the signal will in many cases determine which of several methods will be used to synthesize the signals.

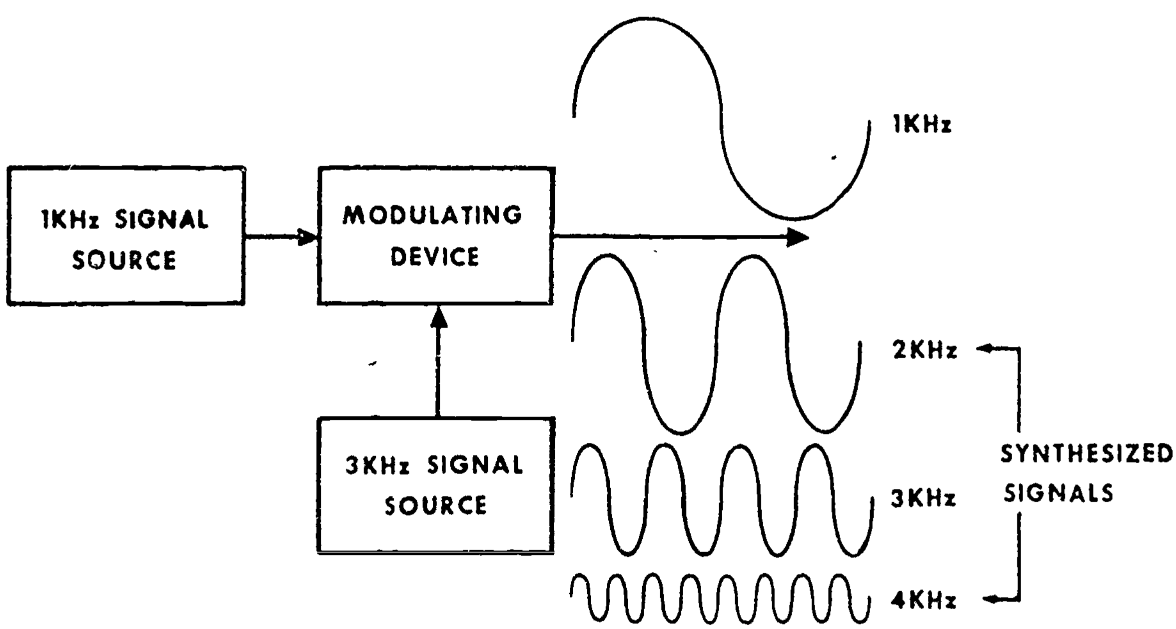


Figure 2-18. Basic frequency synthesis principle.

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STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. The speed at which a radio wave travels through space is approximately

   a. 186,000 miles per second.

   b. 300,000 miles per second.

   c. 186,000,000 miles per minute.

   d. 300,000,000 miles per minute.

2. What is the wavelength of a radio wave when the output frequency of of the radio is 3MHz?

   a. 100 meters

   b. 1,000 meters

   c. 3,00 meters

   d. 3,000,000 meters

3. Most tactical radios operate in a frequency range from approximately

   a. 16 Hz to 16 kHz.

   b. 16 kHz to 400 MHz.

   c. 1.5 MHz to 400 MHz.

   d. 300 MHz to 3,000 MHz.

4. A vertical antenna that uses the earth as one-half of its length is known as a

   a. dipole.

   b. full-wave antenna.

   c. half-wave antenna.

   d. quarter-wave antenna.

5. What method should you use to stabilize the frequency of the CW transmitter shown in figure 2-7?

   a. Key the oscillator.

   b. Use a large antenna.

   c. Key the power amplifier.

   d. Operate in a high-frequency band.

6. Frequency stabilization in the AM radiotelephone transmitter in figure 2-9 is accomplished by

45

a. modulating the final amplifier.

b. using a very stable power supply.

c. using an oscillator with a very stable frequency.

d. isolating the oscillator from the final amplifier.

7. The purpose of the AF modulator in the transmitter shown in figure 2-9 is to vary the amount of plate power of the

a. AF speech amplifier. c. final RF amplifier.

b. RF buffer amplifier. d. RF oscillator.

8. In figure 2-9, voice signals are changed into voltages by the action of the

a. modulator. c. speech amplifier.

b. microphone. d. final RF amplifier.

9. In the double-sideband transmitting system, the carrier, USB, and LSB are transmitted together. The receiver receives all three, and the audio is extracted by the

a. PF amplifier. c. demodulator.

b. IF amplifier. d. modulator.

10. To develop a given amount of signal power at the receiver, an SSB transmitter is better than a DSB transmitter because it

a. provides more carrier power and is smaller.

b. is smaller and uses less of the frequency spectrum.

c. eliminates the modulator and provides more carrier power.

d. uses less of the frequency spectrum and eliminates the modulator.

11. The information signal is used to vary either the amplitude or frequency of the transmitted carrier in a process known as

a. modulation. c. amplification.

b. demodulation. d. rectification.

12. FM communication channels are located in the VHF or higher frequency ranges because

a. outside interference does not introduce noise at higher frequencies.

b. line-of-sight transmission permits a longer operating range.

c. all of the lower ranges are already full.

d. FM channels need a broader bandwidth.

13. One of the advantages of FM radio over AM is that FM

a. is a long-range system.

b. has a narrow bandwidth.

c. can be operated as SSB or DSB.

d. can eliminate amplitude noises.

14. The two methods of modulation most often used in Army FM transmitters are indirect and direct. In the direct modulation method, the carrier is modulated in

a. the oscillator.

b. the final amplifier.

c. the frequency multiplier.

d. a stage following the oscillator.

15. The IF signal is produced in the receiver stage known as the

a. mixer.

b. detector.

c. RF amplifier.

d. IF amplifier.

16. When the input signal to a receiver is a 1,200-kHz signal and the IF is 455 kHz, the local oscillator must be tuned to a frequency of

a. 1,645 kHz.

b. 1,200 kHz.

c. 745 kHz.

d. 455 kHz.

17. In the AM and FM receivers shown in figure 2-17 there are two circuits in the FM receiver not found in the AM receiver. What are these two circuits?

a. IF amplifier and limiter

b. Discriminator and limiter

c. RF amplifier and detector

d. Detector and discriminator

18. The function of the limiter circuit in an FM receiver is to

a. control the amplitude of the local oscillator output.

b. limit the frequency variations of the local oscillator.

c. remove the unwanted amplitude variations from the carrier.

d. remove the unwanted frequency variations from the carrier.

19. A receiver circuit whose output voltage is proportional to the amount of frequency deviation that results from modulation is known as a

a. frequency synthesizer.

b. discriminator.

c. detector.

d. limiter.

20. The most practical means of simultaneously producing many stable carrier frequencies is to use

a. a signal generator.

b. a frequency synthesizer.

c. an oscillator and frequency dividers.

d. an oscillator and frequency multipliers.

CHECK YOUR ANSWERS WITH LESSON SOLUTION SHEET (Pages 74-75).

LESSON 3

RADIO SET COMPONENTS

SCOPE .... Printed circuits; operational amplifiers; construction and application of IC's; switches; connectors, jacks, and plugs.

CREDIT HOURS 1

TEXT ASSIGNMENT .... Attached Memorandum, para 3-1 thru 3-5

MATERIALS REQUIRED .... None

SUGGESTIONS .... None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know how printed circuits are made.

2. Know the characteristics of the operational amplifier.

3. Know the three types of IC.

4. Know the applications of IC's.

5. Know the symbols and uses of various common switches.

6. Be able to identify the symbols of various connectors, jacks, and plugs.

ATTACHED MEMORANDUM

3-1. PRINTED CIRCUITS

Printed circuit boards, such as those shown in figure 3-1, are assemblies of small-sized components and their associated wiring mounted on a nonconducting board. Because of its compactness and light weight, the printed circuit is used in all types of electronic equipment, from pocket radios to computers and radar systems.

a. Mounting Board. Mounting boards vary in length, width, and thickness. All mounting boards are made of nonconducting materials, such as:

(1) Paper laminations impregnated with phenolic resin.

(2) Fiber glass--glass cloth impregnated with epoxy resin.

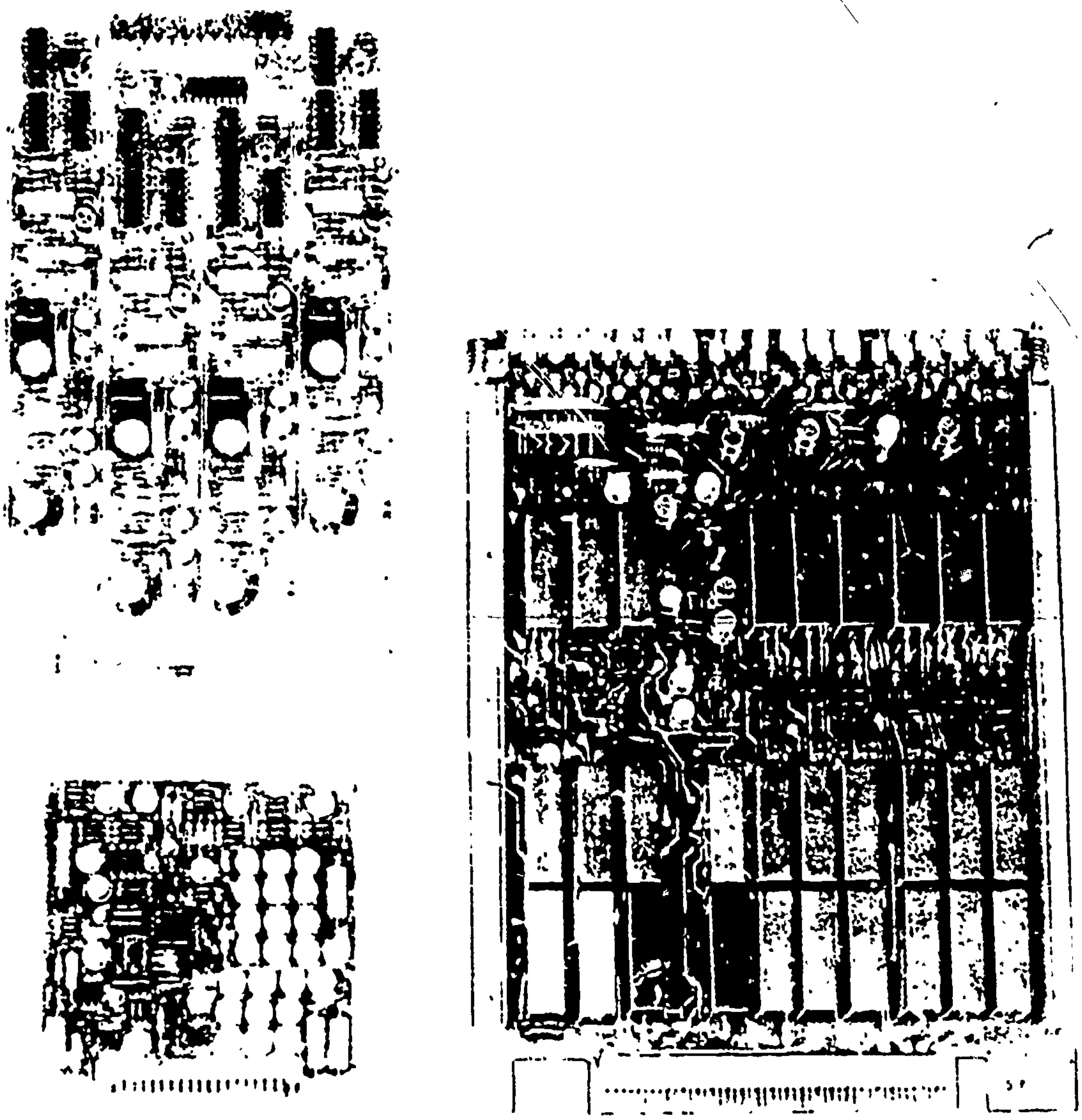


Figure 3-1. Typical circuit boards.

(3) Ceramic material.

(4) Glass.

(5) Mylar.

b. Circuit Patterns.

(1) Most circuit patterns are made by the "etched-foil" process. Copper foil bonded to a mounting board with epoxy resin is coated with a light-sensitive material. A photographic negative of the circuit pattern is placed on top, and the assembly exposed to light. Next, washing in an acid bath removes all the foil except the desired circuit pattern. The assembly is then baked to set the bond between the copper and the mounting board.

(2) Circuit boards can also be made by electroplating. After punching holes in the mounting board for all leads, the board is sprayed with silver. Ink is then stamped on the areas of silver that are to be removed. Next, the board is copper plated. Not only is the circuit pattern plated, but also the walls of the punched holes. (This provides an electrical connection from one side of the board to the other.) The last step is to remove the unplated areas by brushing off the ink and silver.

(3) A newer method of board construction is the multilayered board--a sandwich of several layers of circuit patterns and the ceramic board. Circuit pattern films are deposited on the board by using a vacuum process or the silk screen process.

(4) Circuit patterns are sometimes covered with a coating of solder, tin plating, or gold plating, to prevent corrosion and to aid soldering.

c. Termination. Standoff terminals, pads, and eyelets are used as terminals. Wires and leads may be either insulated or uninsulated copper wire.

d. Coating. After the circuit board is completed, it is coated with any of a variety of protective materials, or it may be encapsulated (enclosed in a container).

e. Connection. The printed circuit is connected into the equipment by a plug and receptacle. These may be of the edge type, the pin and socket type, or the forked type.

3-2. OPERATIONAL AMPLIFIERS

An operational amplifier (op ampl) can be considered a three-terminal device with a common, or ground, return. Two inputs are applied; the minus input (inverting input) and the plus input (noninverting input). The basic op ampl shown in figure 3-2 is a difference amplifier in that it amplifies only the difference between the two inputs and tries to reject any signal that is common to both inputs.

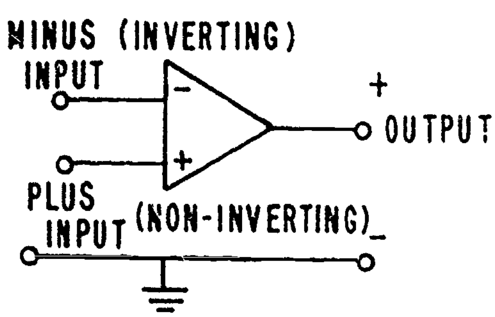


Figure 3-2. Basic operational amplifier symbol.

a. Characteristics. Operational amplifiers are characterized by high dc gain, high input impedance, and a gain that decreases with increasing frequency. Op ampls used without feedback would be operating open loop, a rare situation; but with feedback, the operation is closed loop. The use of properly applied negative feedback stabilizes the operation of the composite circuit against changes in the amplifier, and makes the circuit very versatile.

b. Applications. Operational amplifiers have many practical uses. Figure 3-3 shows the op ampl used as an inverting amplifier. Other uses include noninverting amplifiers, integrators, differentiators, oscillators, filters, and digital circuits such as schmitt triggers, gates, and flip-flops.

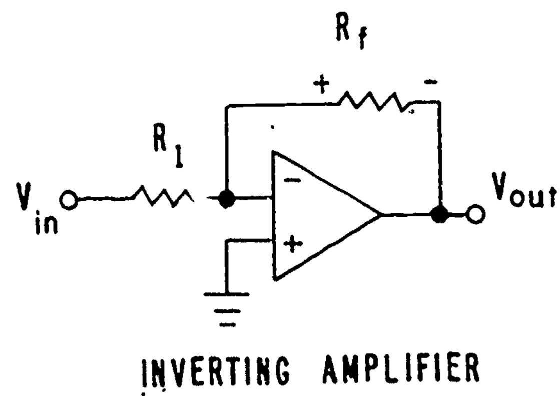


Figure 3-3. Typical operational amplifier.

3-3. INTEGRATED CIRCUITS

An integrated circuit (IC) is a circuit made on a tiny chip of glasslike material. It may be a logic gate or an amplifier, or a combination of circuits that replaces several transistors, resistors, and capacitors. The IC chip is sealed in an airtight package and is normally mounted on a printed circuit card. IC's are used in electronic equipment because they reduce size, weight, and cost, improve performance, and are more reliable than the circuitry that they replace. To reduce cost and size, transistors, resistors, and capacitors are built into the IC. However, inductors, transformers, and large-value capacitors must be mounted outside the package.

a. The Monolithic IC. The monolithic IC is the most widely used of all the various types. It is called monolithic because the circuit is formed within a single semiconductor crystal. The circuit components are isolated by reverse-bias PN junctions or by other methods. Monolithic IC's have good-quality diodes and transistors, but poor- to average-quality resistors and capacitors.

(1) Epitaxial growth. The monolithic IC begins as a very thin silicon wafer known as a substrate. A second crystal layer is formed on the substrate by a process known as epitaxial growth. The crystal structure of the growth layer must be the same as the structure of the substrate. Part A of figure 3-4 shows the process used to form the epitaxial layer. The substrate containing P-type impurities is heated in the presence of a gas containing hydrogen, and a silicon compound containing N-type impurities. The silicon atoms released by the heat form a second layer in the substrate. The completed layer is shown in B of figure 3-4. The substrate layer has positive properties and the epitaxial layer has negative properties. A PN junction has been formed by the layers.

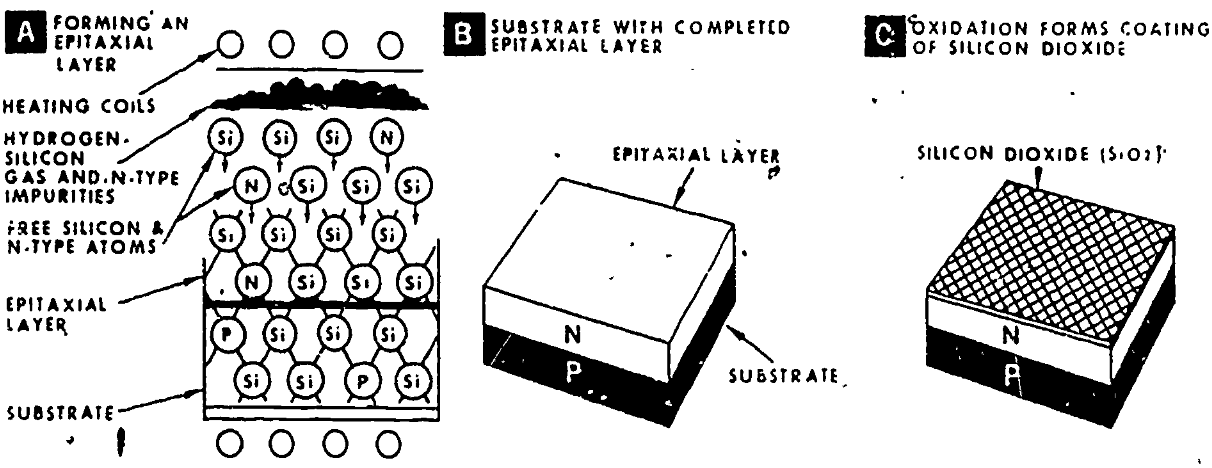


Figure 3-4. Epitaxial growth and oxidation.

(2) Completed layer. After the epitaxial growth is completed, the chip is heated and exposed to wet oxygen gas, which causes a protective silicon dioxide (SiO_2) coating to form on the chip. The crystal with a layer of SiO_2 is shown in C of figure 3-4.

(3) Photomasking. The chip is now coated with a solution of photoresist as shown in A of figure 3-5. Photoresist leaves a coating that will not dissolve in photo developing fluid after it has been exposed to ultraviolet light. A glass slide called a photomask is aligned on the chip as shown in B of figure 3-5. The photomask contains light and dark areas similar to a photo negative. The chip is exposed to ultraviolet light and then washed with photo developing fluid to dissolve the photoresist under the dark areas of the photomask. The results of the photofluid bath are shown in C. Notice that the only areas of photoresist that remain are those not protected by the photomask.

(4) Etching. The uncovered SiO_2 is removed by etching. An acid bath removes the bare SiO_2 without affecting the epitaxial layer or the SiO_2 in the two areas where the photoresist remains. This step is shown in D of figure 3-5. After the etching, the remaining photoresist is stripped from the chip as shown in E.

(5) Diffusion. The chip is placed in a furnace with a precise number of impurity atoms (dopant). At about 1,200° C, the impurity atoms diffuse into the epitaxial layer. Figure 3-6 shows the chip in the various stages of diffusion. The diffusion is rigidly controlled so that it can be stopped when impurity atoms reach the substrate. Notice in C of figure 3-6 that the diffusion does not affect the silicon directly below the protective SiO_2, which isolates these areas from diffusion. This process is known as isolation diffusion.

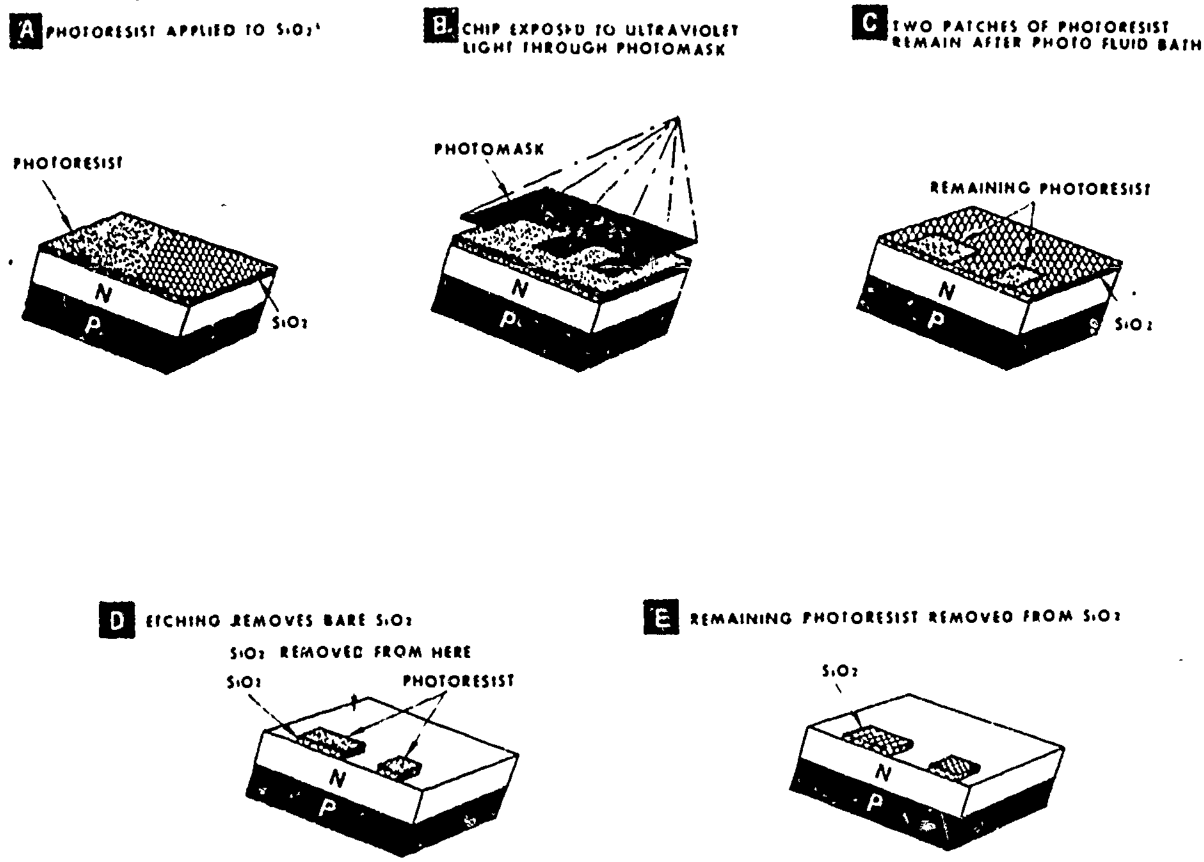


Figure 3-5. Photomasking and etching.

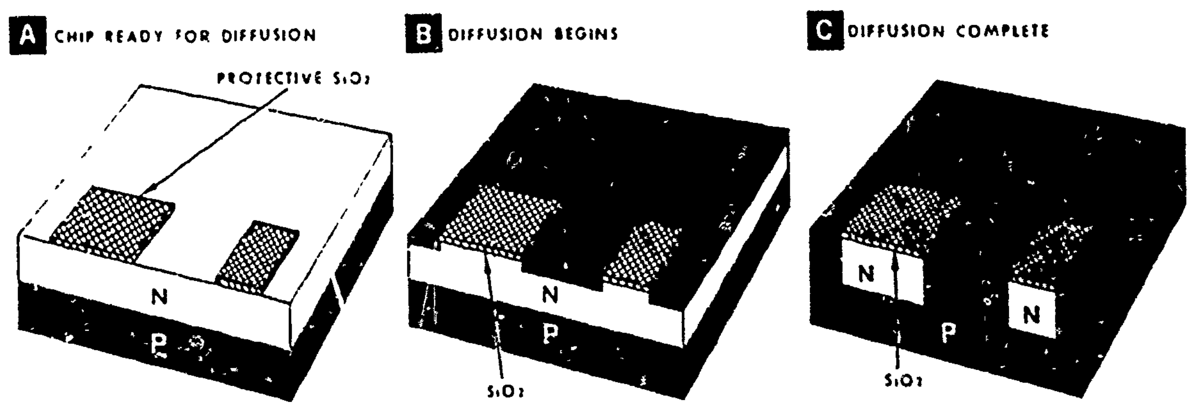
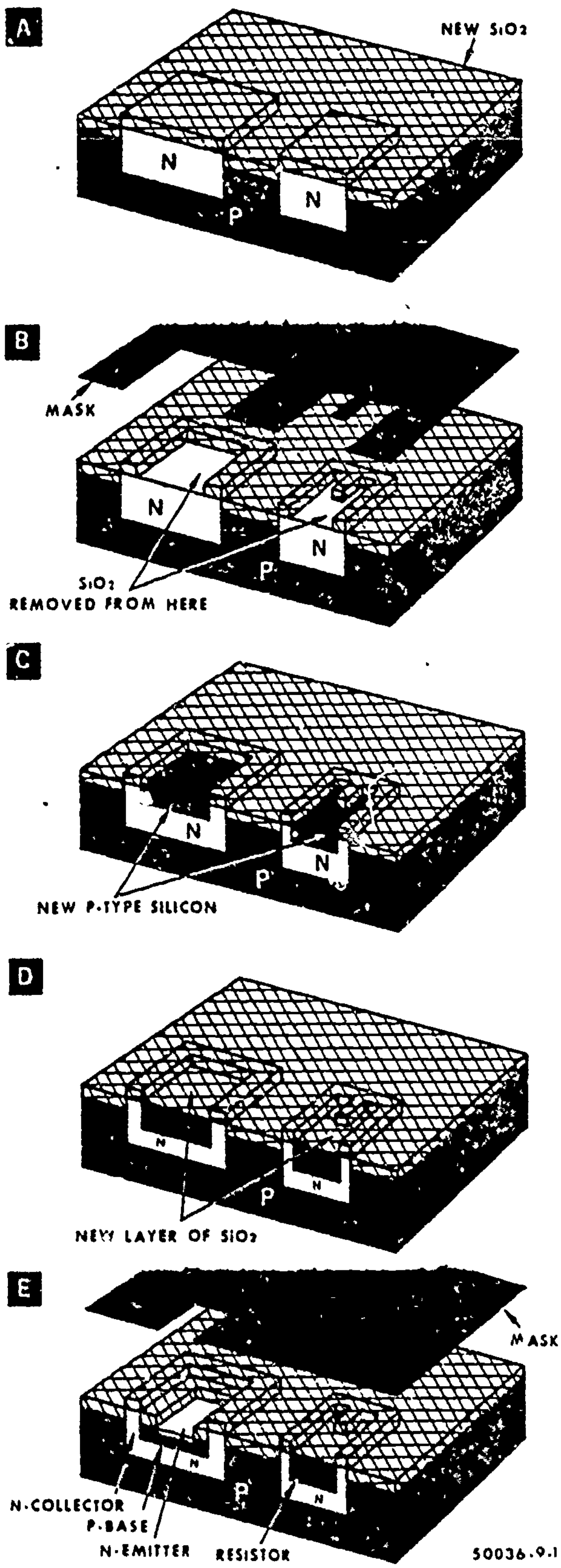


Figure 3-6. Isolation diffusion.

(6) Completed IC. The preceding steps have changed a silicon chip into an IC. During the process, diodes, transistors, resistors, and capacitors may be formed in the same IC. To complete the IC, further oxidation, masking, etching, and diffusion connect the components. This is shown in figure 3-7.

b. Thin Film IC. Another type of integrated circuit is the thin film IC. It is made by depositing extremely thin films of metals and insulators on a glass or ceramic substrate. The substrate in this case merely serves as a platform for the circuit as opposed to the monolithic IC, in which the substrate is a part of the circuit.



A. Oxidation forms a coating of SiO_2 over the entire chip. A transistor will be formed in the N-type area on the left and a resistor in the N-type area on the right.

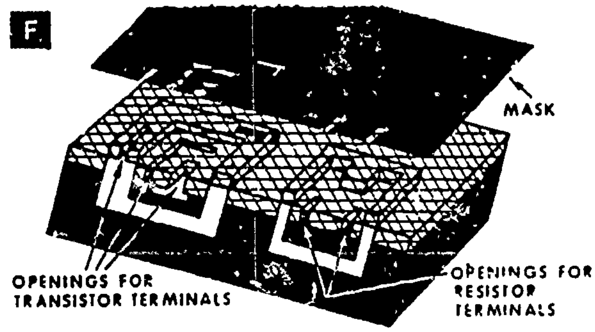
B. Masking and etching make openings in the SiO_2.

C. Diffusion changes the top half of the N-type silicon to P-type.

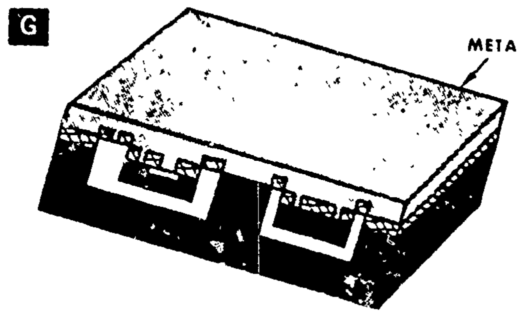
D. Oxidation covers the new P-type areas.

E. Masking, etching, and a final diffusion form a small area of N-type silicon for transistor emitter. The transistor and resistor are now complete.

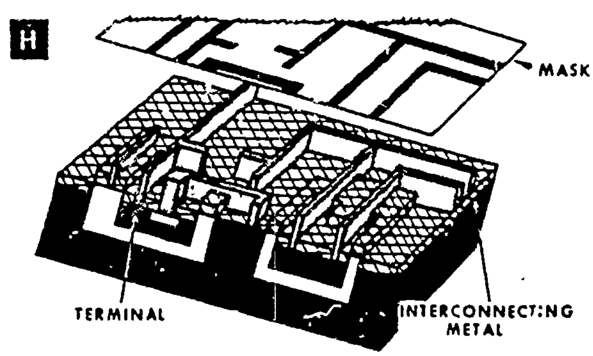
Figure 3-7(1). Completing the IC.
(Part 1 of 2)



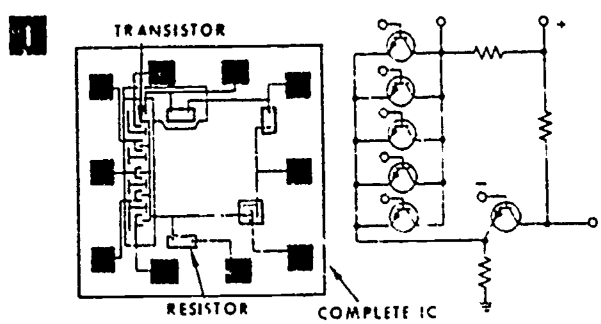
F. SiO_2 is formed on the emitter surface. Masking and etching make holes for transistor and resistor contacts.



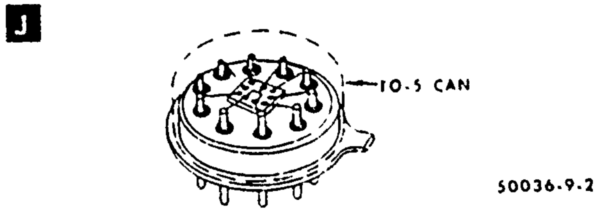
G. Metal is deposited over the entire chip.



H. Final masking and etching of the metal surface forms terminals and connections between circuit components.



I. The completed IC and schematic show other components that were formed simultaneously.



J. The completed IC is tested and packaged.

Figure 3-7(2). Completing the IC.
(Part 2 of 2)

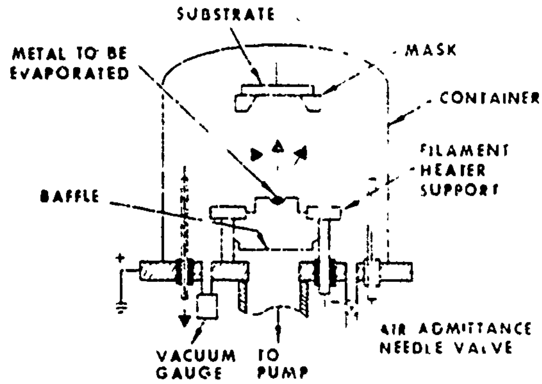


Figure 3-8. Vacuum evaporation forming a thin film IC.

(1) A process known as vacuum evaporation is often used to form a thin film IC. This method is shown in figure 3-8. Here you see a small piece of metal inside a container. Directly above the metal is the substrate with a mask attached. The mask, similar to the ones used with monolithic IC's, determines the pattern of the deposited film. A high vacuum is created in the container and the metal is heated to its boiling point. As the metal boils, its vapor condenses on the substrate through the openings in the mask. This process is repeated with different materials and masks until all the required resistors, capacitors, and conductors are formed. Unlike the monolithic IC, in which transistors are formed as part of the epitaxial layer, the thin film IC has miniature diodes or transistors attached to the circuit. Figure 3-9 is an exploded view of a thin film IC. If capacitors are needed in this circuit, they are deposited as a separate film.

(2) In the thin film process it is possible to make resistors and capacitors with higher values and closer tolerances than those in monolithic IC's. For this reason, thin film IC's are preferred for high-frequency circuits that require precision components.

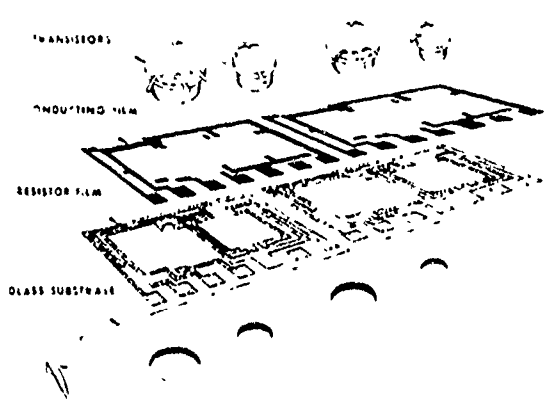


Figure 3-9. Exploded view of a thin film IC.

c. The Hybrid IC. The monolithic and thin film processes are sometimes combined to make a hybrid IC. The resulting hybrid can have the high-quality diodes and transistors formed in the monolithic IC and the high-quality resistors and capacitors formed in the thin film process. Hybrid IC's are also made by mounting individual chips, connected by fine wires, in the same package. This method, called the chip and wire method, is shown in figure 3-10. It allows more complicated circuitry and improves isolation between components.

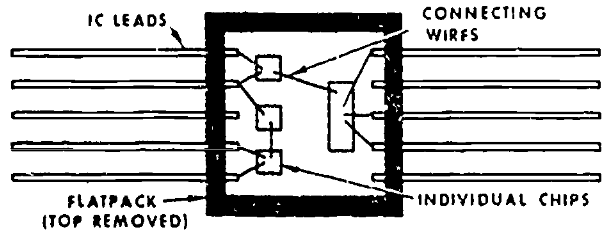


Figure 3-10. A chip and wire hybrid IC.

d. Applications. Originally conceived for military equipment, IC's are now also being used in commercial products ranging from automobiles to hearing aids. Basically, IC's are divided into two categories--linear and digital.

(1) Linear. Linear, or analog, IC's produce outputs directly proportional to their inputs. They are used for transmitter and receiver circuits, such as amplifiers (audio, video, AF, and IF), squelch switches, mixers, oscillators, and other linear circuit functions. Most linear IC's must be custom-made because the requirements of each circuit are usually different. Figure 3-11 shows a partial schematic of a radio receiver that uses linear IC's. The IC's are represented by triangles, and the lines extending from them represent the leads to the IC package. In the blown-up portion of the figure, you see the detailed schematic of the IF amplifier. Although the IF amplifier contains 13 different components, it requires no more space than a conventional transistor. Because of this and the fact that IC's need so little power to operate, some of the larger communication systems of today will be reduced to manpack size in the future.

(2) Digital. Digital IC's perform switching functions in logic circuits. Because digital IC's operate with low power, are used thousands of times in the same form, and can operate effectively despite loose tolerances, they have proved ideal for integration. Digital IC's include logic gates, flip-flops, counters, and shift registers. The entire circuit is contained in a single monolithic chip, and is used in high-speed computers. One big advantage of digital IC's over conventional digital circuits is that they operate faster. Some digital IC's can operate in 400 trillionths of a second.

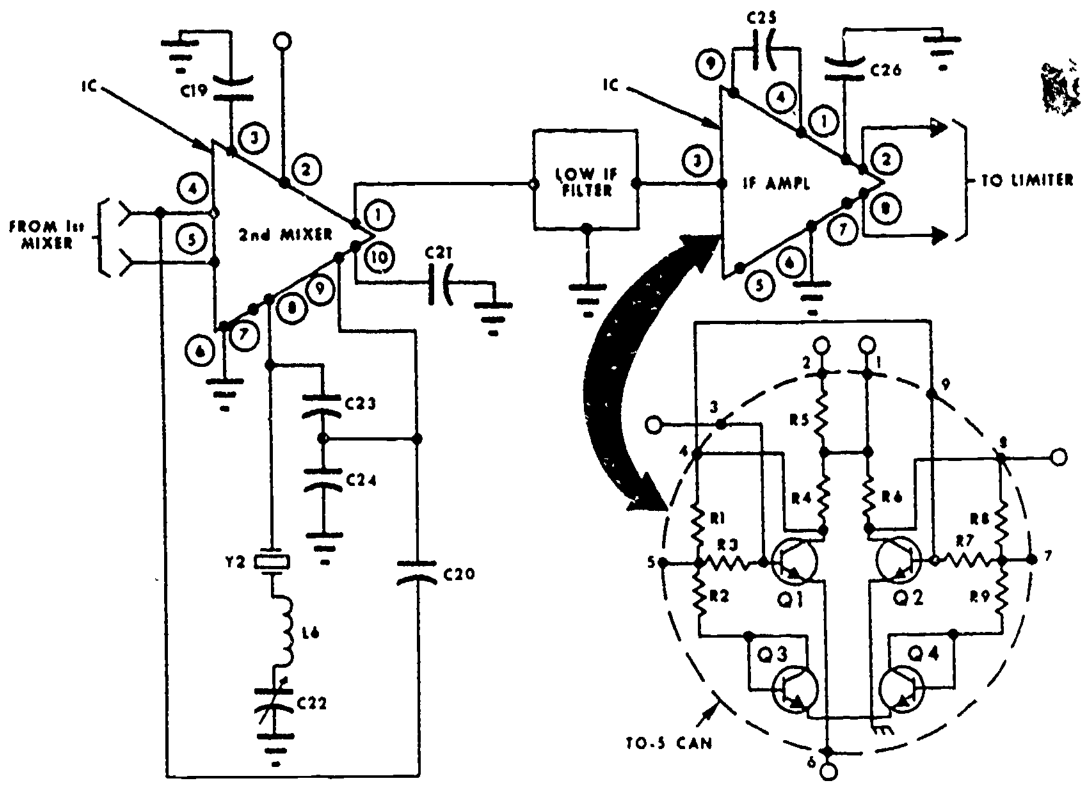


Figure 3-11. Linear IC's in a schematic diagram.

3-4. SWITCHES

Switches are usually classified by two methods: the number of circuits they control, and the type of physical construction. Some of the many switch symbols used in electronics are shown in figure 3-12.

a. Common Switches.

(1) The single-pole, single-throw (SPST) switch can open or close one circuit. The symbol for the SPST switch is shown in A of figure 3-12.

(2) The symbol for the single-pole, double-throw (SPDT) switch is shown in B. Two connections can be made separately. Either of two circuits is closed while the other is open.

(3) A double-pole, single-throw (DPST) switch symbol is shown in C. This switch controls two circuits; both are either open or closed.

(4) The symbol for a double-pole, double-throw (DPDT) switch is shown in D. With this switch, it is possible to have two circuits closed while two other circuits are open.

(5) The symbols in E represent toggle switches, those in F represent pushbutton switches, and those in G represent safety interlocks. These switches are shown in their normal positions. Operating the switch causes the action shown in the switch label.

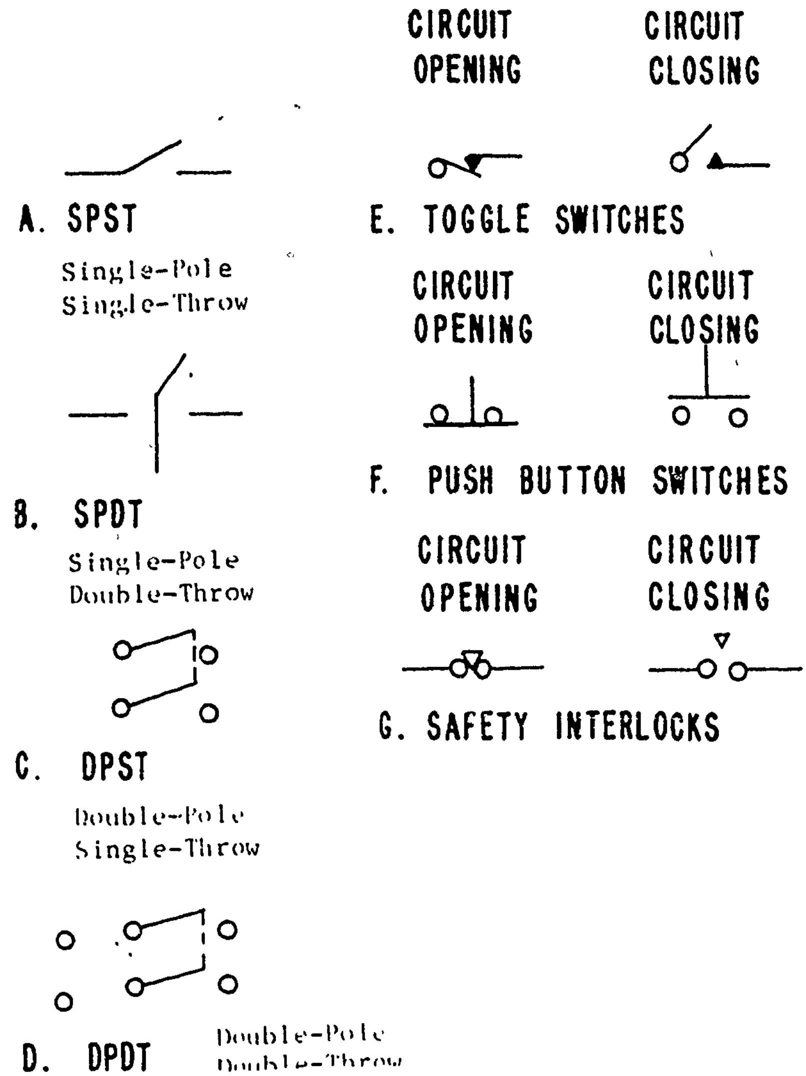


Figure 3-12. Frequently used switch symbols.

b. Wafer Switch. The wafer switch is used to control several circuits simultaneously, with a single control. The individual sections (wafers) can be added as needed, and all are connected to the same shaft. Two sections (decks) are shown in A of figure 3-13. By turning the control knob, the circuits wired to each wafer are either activated or deactivated. A typical individual section is shown in B. In this section, the rotor lug (the contact lug at the right of the mounting hole) is longer than the other lugs. At all times it is in contact with the metal center ring. Notice that an extension at the outer edge of the center ring is contacting lug 2. Thus, lug 2 is connected to the rotor lug through the center ring. As the shaft is rotated, the center ring will connect other contacts, in turn, to the rotor lug. By varying the number and length of contacts on the ring, any number of connections can be made. The ring can be constructed in two or three sections so that each section will make connection to a different circuit. The schematic symbol for a three-section wafer switch is shown in C of figure 3-13.

3-5. CONNECTORS, JACKS, AND PLUGS

a. Connectors. When connecting certain circuits, it is sometimes necessary to provide for disconnecting and reconnecting. In electronics, connectors

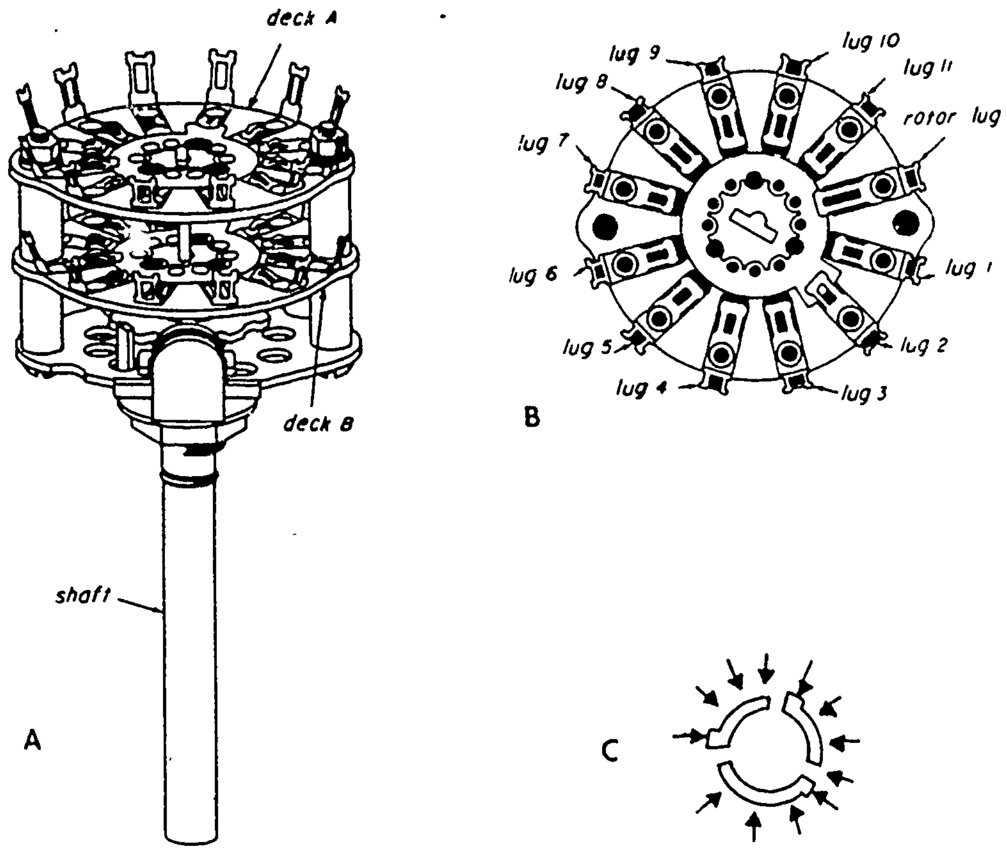
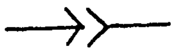


Figure 3-13. Wafer switch.

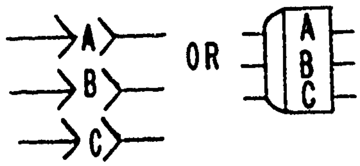
are used between chassis where it would be impractical to solder each wire between chassis. In each case, a socket and plug are used. Some connectors may be used to connect only one lead, others to connect over a hundred leads. The type of connector used depends on the application. There are thousands of connectors available. Figure 3-14 shows the schematic symbols for some of the various connectors.

(1) The schematic symbol for a basic connector is shown in A of figure 3-14. The portion on the right is the socket or hole section (female section). The portion on the left is the plug or protruding section (male section). Several of these symbols may be shown together, as in B. This indicates a multiconductor connection. In connectors where more than one connection is made, the symbols for individual connections may be located at convenient points on the schematic, and labeled. In this case, there is usually a drawing somewhere on the schematic to show the physical layout of the connector.

(2) The schematic symbol for a coaxial cable is shown in C of figure 3-14. A coaxial connector combines the basic connector symbol with the symbol for coaxial cable. A coaxial connector is shown in D.

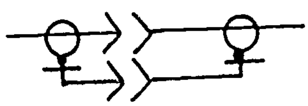


A. SINGLE CONNECTOR

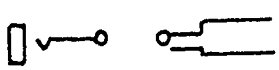


B. MULTICONDUCTOR CONNECTOR

C. COAXIAL CABLE

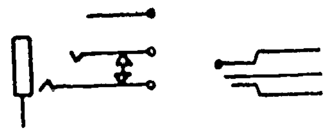


D. COAXIAL CONNECTOR



JACK PLUG

E. TWO-CONDUCTOR JACK AND PLUG

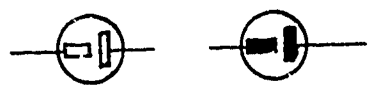


JACK PLUG

F. THREE-CONDUCTOR JACK AND PLUG

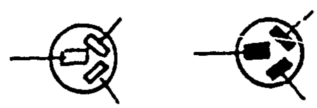
FEMALE MALE

G. TWO-CONDUCTOR NONPOLARIZED CONNECTOR



FEMALE MALE

H. TWO-CONDUCTOR POLARIZED CONNECTOR



FEMALE MALE

I. THREE-CONDUCTOR POLARIZED CONNECTOR

Figure 3-14. Connector symbols.

b. Jacks and Plugs. A jack and plug are special types of female and male connectors used to connect two circuits. The symbols for several types of jack and plug connectors are shown in F through I of figure 3-14.

STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. The one thing in common among all boards on which printed circuits are formed is that they are

a. encapsulated.

b. silver plated.

c. the same size.

d. made of nonconducting material.

2. In the etched-foil method of producing a printed circuit, an acid bath is used to

a. remove all the copper foil except the circuit pattern.

b. set the bond between the copper and the board.

c. etch the circuit pattern into the copper.

d. remove the excess epoxy resin.

3. In addition to a gain that decreases with an increasing frequency, the characteristics of operational amplifiers include a

a. low dc gain and a low input impedance.

b. low dc gain and a high input impedance.

c. high dc gain and a low input impedance.

d. high dc gain and a high input impedance.

4. When a monolithic IC is created, a PN junction is formed during the process known as

a. diffusion.

b. oxidation.

c. photomasking.

d. epitaxial growth.

5. During the forming of a monolithic IC, after the epitaxial growth is completed the epitaxial layer is given a protective coating. This coating is applied by a process known as

a. etching.
b. oxidation.
c. diffusion.
d. photomasking.

6. The desired circuit design is applied to a monolithic IC by using a photomask and exposing the chip to

a. ultraviolet light.
b. infrared rays.
c. sunlight.
d. X-rays.

7. One step in making a monolithic IC is to wash the chip with a photo developing fluid. The purpose of washing the chip is to

a. prepare the chip for exposure to the ultraviolet light.

b. develop the picture of the circuit on the epitaxial layer.

c. dissolve the photoresist that was protected by the photomask.

d. dissolve the photoresist that was not protected by the photomask.

8. In the forming of a monolithic IC, the diffusion process must be rigidly controlled so that it can be stopped when the impurity atoms reach the

a. epitaxial layer.
b. photoresist.
c. substrate.
d. dopant.

9. One difference between the thin film IC and the monolithic IC is that

a. transistors are not formed as part of the thin film IC.

b. the monolithic IC has components with closer tolerances.

c. the thin film IC is preferred for low-frequency circuits.

d. the substrate serves only as a platform for the monolithic IC.

10. A comparison of digital and linear IC's shows that both

a. are custom made.

b. have low power requirements.

c. operate with very loose tolerances.

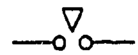
d. perform switching functions in digital circuits.

11. The symbol for a SPST switch is

a. 

c. 

b. 

d. 

12. A DPST switch is used when it is necessary to

a. close two circuits while opening two others.

b. open or close two circuits simultaneously.

c. close one circuit while opening another.

d. open or close a circuit.

13. The rotor lug in a wafer switch can be distinguished from the other lugs because it

a. is divided into sections.

b. is shorter than the other lugs.

c. always touches the center ring.

d. rotates as the shaft is rotated.

14. What type of connector is represented by the symbol shown below?

a. A coaxial connector

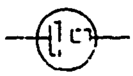
b. A multiconductor connector

c. A two-conductor jack and plug

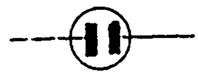
d. A two conductor polarized connector

15. The symbol for a two-conductor nonpolarized male connector is shown in

a.

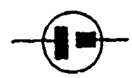


c.



b.

d.



CHECK YOUR ANSWERS WITH LESSON SOLUTION SHEET (Page 76).

LESSON 4

ELECTRONIC DIAGRAMS

SCOPE .... Application and use of wiring, cabling, block, layout, and schematic diagrams; use of voltage, resistance, and trouble-shooting charts.

CREDIT HOURS 2

TEXT ASSIGNMENT .... Attached Memorandum, para 4-1, 4-2

MATERIALS REQUIRED .... None

SUGGESTIONS .... None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know the purpose of each type of electronic diagram and chart.

2. Know how and when to use the various charts and diagrams as aids in trouble-shooting.

ATTACHED MEMORANDUM

4-1. ELECTRONIC DIAGRAMS

Much of the electronic equipment in use today is very complicated. Radio, computers, radar, and television use many of the most intricate circuits presently used in electronics. The technician is not expected to remember all of the circuits present in these equipments. Diagrams and charts are available to help him in maintaining and repairing the equipment. These diagrams and charts present pertinent information about the equipment in a manner that is understandable to the technician. The information includes voltage, resistance, and capacitance values, and connections between components.

a. Wiring Diagrams. Military communication equipment is made as compact and as light as its purpose will allow. However, items of electronic equipment such as radio receivers have many components making up their various circuits and stages. Tubes, transistors, resistors, capacitors, coils, and relays are connected by wires to form the circuits. Some or all of the components may be mounted on component boards with either conventional or printed wiring used to connect them. The component boards may be permanently mounted or they may plug into a receptacle. The stages are connected by wires to form the complete unit.

(1) Wiring methods. In equipments with many stages, terminal boards with numbered terminals are used as common connecting points between stages. If there are sufficient terminals on the terminal board, several stages can be connected to the same board without interference between stages. This method of wiring provides easily accessible test points and less confusion in the wiring. Since the output signal from one circuit may be used as the input signal to several other circuits, a terminal board is a convenient place to make these connections, rather than at the pins of a transistor or tube.

(2) Identification of wires. Before a technician can use a wiring diagram, he must know how to read one. A wiring diagram such as the one shown in figure 4-1 uses either a color code or a numbering system, or a combination of both to identify the wires. You will find that in most wiring diagrams the system of parts identification is standardized, as shown in the following chart.

Part	Designator	Example
Plug	P	P301
Jack	J	J[illegible]02
Terminal strip	E or TB	E601 or TB403
Motor	B	B1
Relay	K	K2
Switch	S	S4
Heater element	HR	HR3

The terminals may be either numbered or lettered. To illustrate how a wiring diagram is read, we will start with the plug labeled P4101 (fig. 4-1). From terminal E, a wire labeled P4204-Q leads to terminal Q on P4204. Notice that at terminal Q the same wire is labeled P4101-E. This enables you to quickly identify the connections from either terminal. Notice also that on P4204, terminal Q is connected to terminal T. The wire at terminal T is labeled P4001-17. This wire leads to terminal 17 of P4001. Therefore, terminal E of P4101, terminals Q and T of P4204, and terminal 17 of P4001 are all connected together. Since each plug on this chassis connects to a jack on another chassis, it permits a physical ground on either chassis to serve as electrical ground for both chassis.

(3) Use of wiring diagrams. Wiring diagrams are useful when making continuity checks. A continuity check is a test to determine if a wire in an electronic circuit is open (broken). To perform this test, all power must be removed from the equipment to prevent damage to the ohmmeter. To illustrate a continuity check,

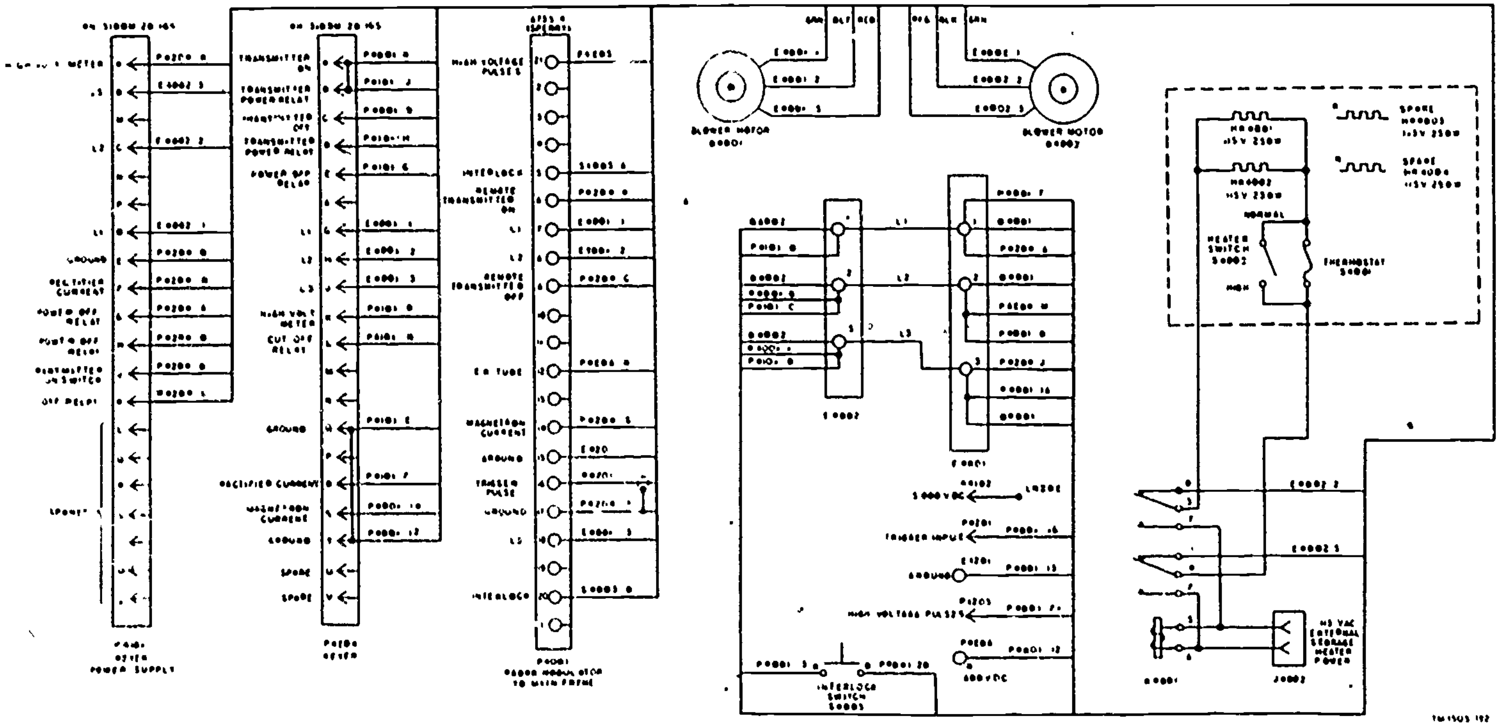


Figure 4-1. Typical wiring diagram.

Let us use figure 4-1 and assume that the technician wants to check the circuit labeled L3. One end of the circuit is at terminal B of P4101. The technician places one probe of the ohmmeter on terminal B and the other probe on pin 3 of terminal strip E4002. He then reads the ohmmeter. If the circuit is open (incomplete), the meter will indicate an extremely high resistance (maximum deflection). If the circuit is complete, the meter will indicate the resistance of the circuit under test. If there are no components in the circuit, the reading will be at or near zero ohm (the resistance of the wire). If there are any components in the circuit, the meter indication will include the resistance of the components in the circuit. There are four wires connected at terminal 3 of E4002: one from B of P4101, one from terminal 1 of relay K4001, one from terminal 3 of blower motor B4002 (the red wire is identified as E4002-3), and the fourth, labeled L3, from terminal 3 of E4001. Since we have already checked the continuity between E4002-3 and P4101-B, we now move the probe from P4101-B to B4002 (the red wire), then to K4001-1 (and when K4001 is closed, to heater switch S4002), checking the continuity at each point. To check the switch, place probes across S4002 and set the switch to ON. Assuming that these circuits are good, we check between E4002-3 and E4001-3. The final checks are made from E4001-3 to P4204-J, to P4001-18, and to B4001, in turn. This entire circuit has been checked for continuity. The same procedures are used to make continuity checks of other circuits. The wiring diagram may be used with other types of diagrams to help the technician select the proper points for making other tests and measurements.

b. Cabling Diagrams. Many communication and electronics sets used by the military are composed of several units connected by multicolored cables to form an operating unit. These cables carry signal, power, and control voltages between the various units that form the complete installation. The several units may be in close proximity or may be separated by many feet or yards.

(1) The technician must often install the communication equipment himself. When making the installation, he follows the cabling diagrams to assure that each cable is properly connected. A cabling diagram shows the cables required to connect the various units of the installation. Differing in length, diameter, and number of conductors, the construction of the cable is determined by the purpose for which it is to be used. For example the output signal from a radio transmitter is usually carried to the antenna by a coaxial cable. This minimizes loss and reduces noise pickup. On the other hand, power cables carry operating current to the transmitter. The power cables may contain one or many pairs of wires, depending on the voltage requirements of the transmitter. A typical cabling diagram illustrating interunit connections is shown in figure 4-2.

(2) In some vehicular installations, cables are difficult to inspect or test. The cabling diagram indicates the location of the various test points that give access to these cables for testing purposes.

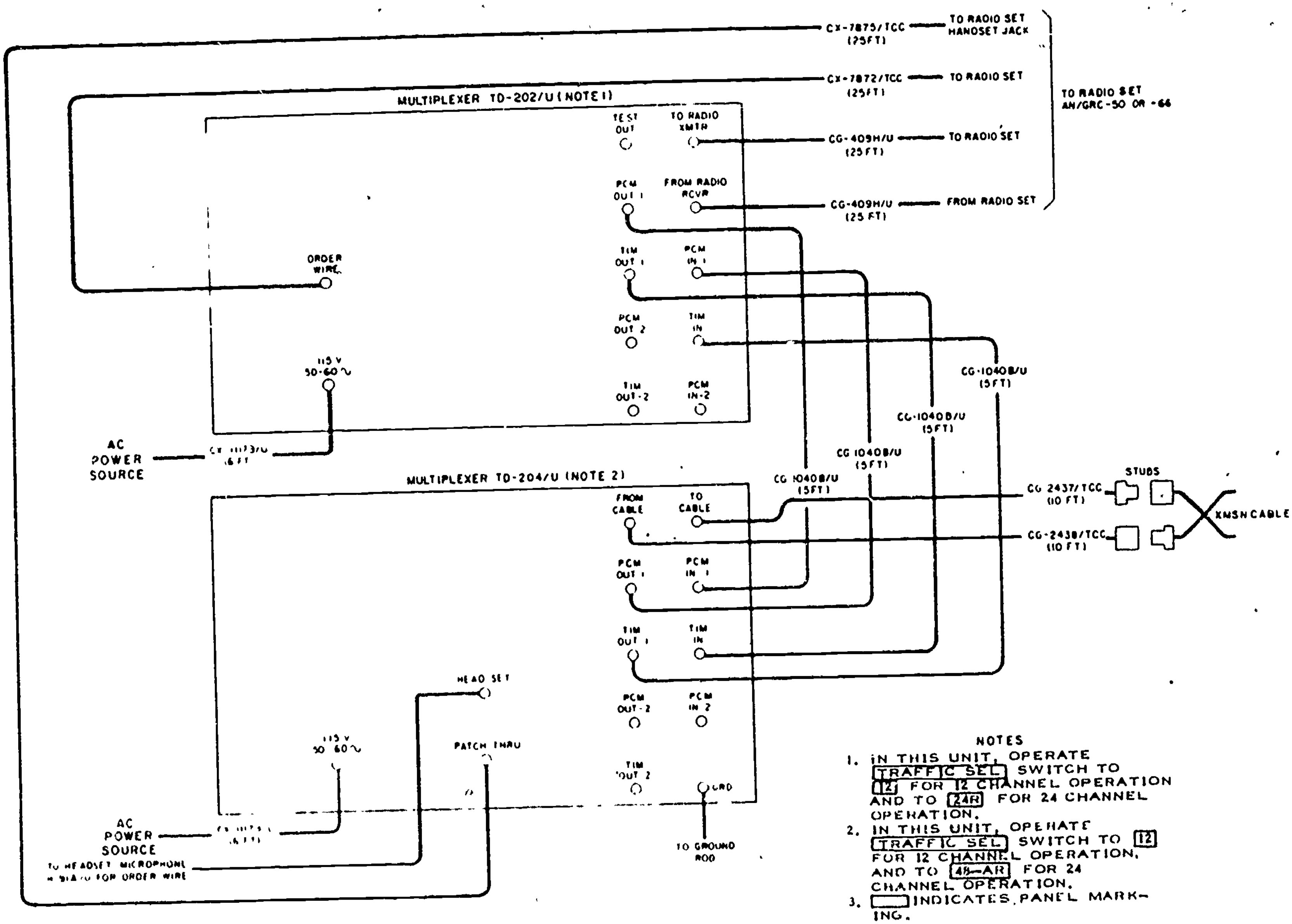


Figure 5-2. Cabling diagram (interunit connection).

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c. Block Diagrams. Of all the diagrams used in electronics, the block diagram is probably the simplest to understand. Figure 4-3 shows that the block diagram is a series of "boxes," each representing a stage, or stages, in a radio receiver. An example of a multiple-stage block is the IF, which may include several amplifier circuits. As in this figure, waveforms are often included as part of the block diagram. Some block diagrams even show numbered test points. The box is labeled with the function performed by the stage, the lines between the boxes show the connections between stages, and the arrows indicate the direction of signal flow. The block diagram presents the general idea of what is happening in the unit, and is often used by the technician to localize trouble to a stage. A block diagram can also be used to show an entire electronic installation. In this case, each block represents a unit in the equipment, such as a transmitter, receiver, power supply, etc. The block diagram would then be used to sectionalize a trouble (determine which unit is defective). Since each of these units contains many stages, there may be separate block diagrams representing each unit.

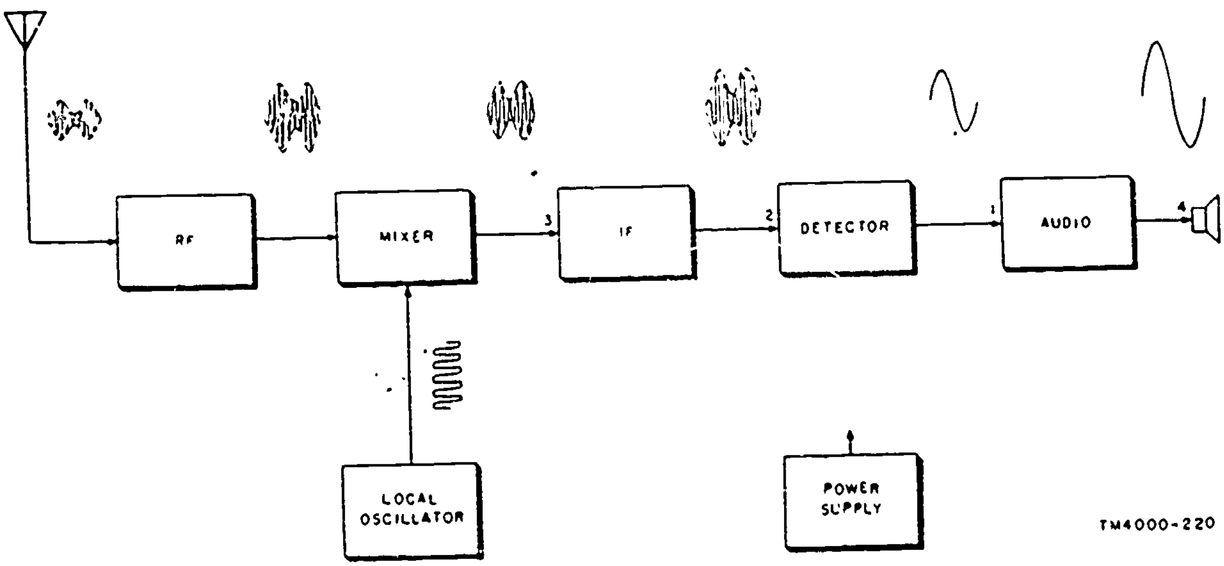


Figure 4-3. Radio receiver block diagram.

d. Schematic Diagrams. A schematic diagram can be compared with a road-map. A map uses symbols to show the highways, interconnecting roads, cities and towns, structures, rivers and lakes, and other landmarks. A schematic is a diagram that uses symbols to represent the tubes, transistors, resistors, capacitors, coils, relays, and other components. Some of the symbols that are commonly used in schematics are shown in figure 4-4. The schematic shows how these components are connected to make up the various circuits, and how these circuits are connected into stages. Each component is numbered, and its nominal value is either shown with the component or listed in a table on the schematic.

(1) If the schematic is of a unit, such as a reciever, the stages of the unit are usually labeled according to their functions (mixer, oscillator, IF amplifier, etc). Although the schematic is often all the technician needs to locate a trouble in the equipment, it is more often used in conjuction with voltage, resistance, and, when appropriate, the troubleshooting chart to isolate a defective component.

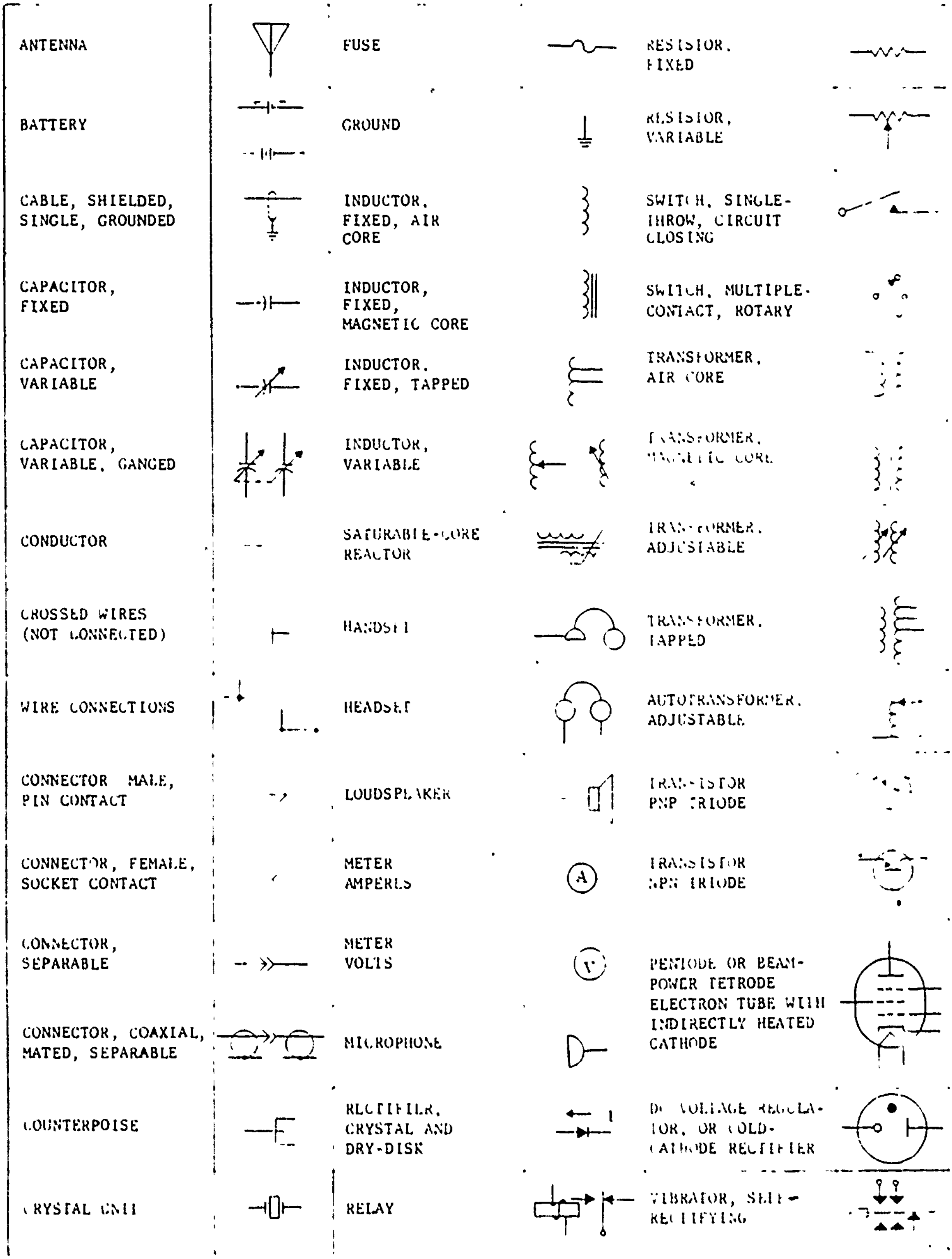


Figure 4-4. Circuit symbols commonly used in military electronic equipment.

(2) A schematic diagram showing all the components of a low-frequency oscillator circuit is shown in figure 4-5. All components are identified by a number, and the value of each component is listed. The components are connected into three stages to form the oscillator circuit. Resistors R31 through R34, and capacitor C12, are connected with transistor Q8 to form an emitter follower. Crystal Y1 provides the input signal to this stage. Resistors R26 through R30, and capacitors C9 through C11, are connected with Q7 to form a voltage amplifier stage. A second emitter follower is used as the oscillator output stage. This consists of Q6, R21 through R25, and C6 and C8. A feedback link is connected from R23 to Y1. The procedure of numbering the components and labeling the stages makes it easy for the technician to locate the various components when he is making voltage and resistance measurements. By seeing where and how a component is connected in a circuit, he can determine the function of the component. In many cases, the technician can look at the schematic and determine whether a specific component could, or could not, produce the trouble symptoms that the equipment is producing.

e. Layout Diagrams. A layout diagram is a drawing or photograph of the chassis of an electronic unit, showing the positioning of the parts on the chassis. Such a diagram is shown in figure 4-6. With this type of diagram, the technician can physically locate and identify the various parts and observe their relative positions. Some layout diagrams also show and identify the test points that are located on the chassis.

4-2. CHARTS

There are several types of charts available to help the technician when he is troubleshooting the equipment. He uses these charts to localize a trouble to a stage and isolate a specific part.

a. Voltage Charts.

(1) General. A voltage chart lists the ac and dc voltages at specific points in the equipment. The technician uses the voltage chart as a guide to measure voltages when localizing a trouble to a stage. Voltage charts provide all the special instructions that are required to obtain accurate measurements. In figure 4-7, these instructions are included as Notes. The equipment publication usually gives tolerances for voltage measurements; as an example, voltage readings ±10%. Any readings that are not within tolerance are considered abnormal.

(2) Ac voltages. The voltages shown on the voltage chart are the voltages required for normal operation. In figure 4-7, Note 1 specifies that the voltage and resistance measurements should be made with a vacuum tube voltmeter (VTVM). The 6.3v ac shown for each tube is the required filament voltage, and the VTVM must be set to read ac volts. Note 3 explains where to place the meter probes to read this voltage.

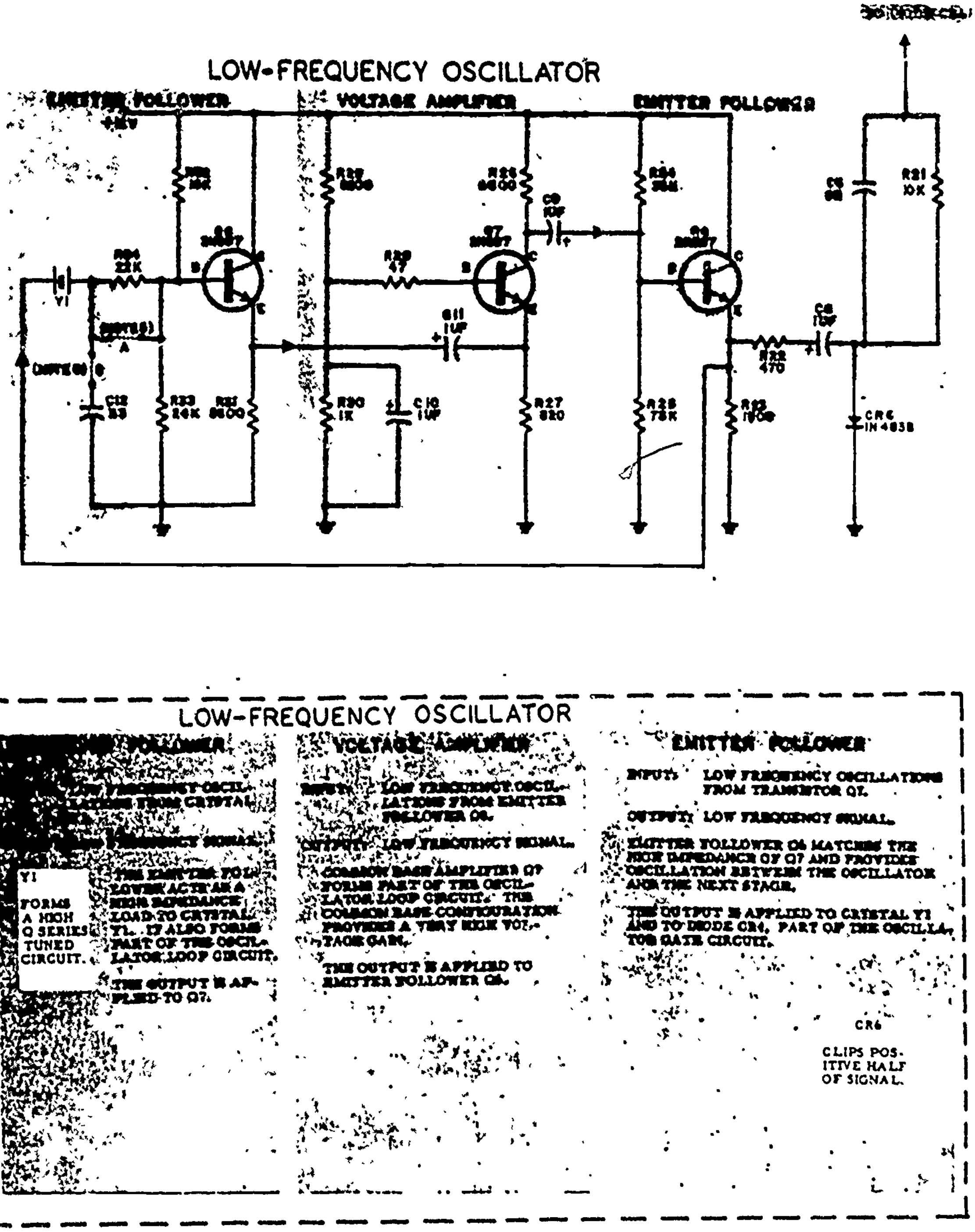
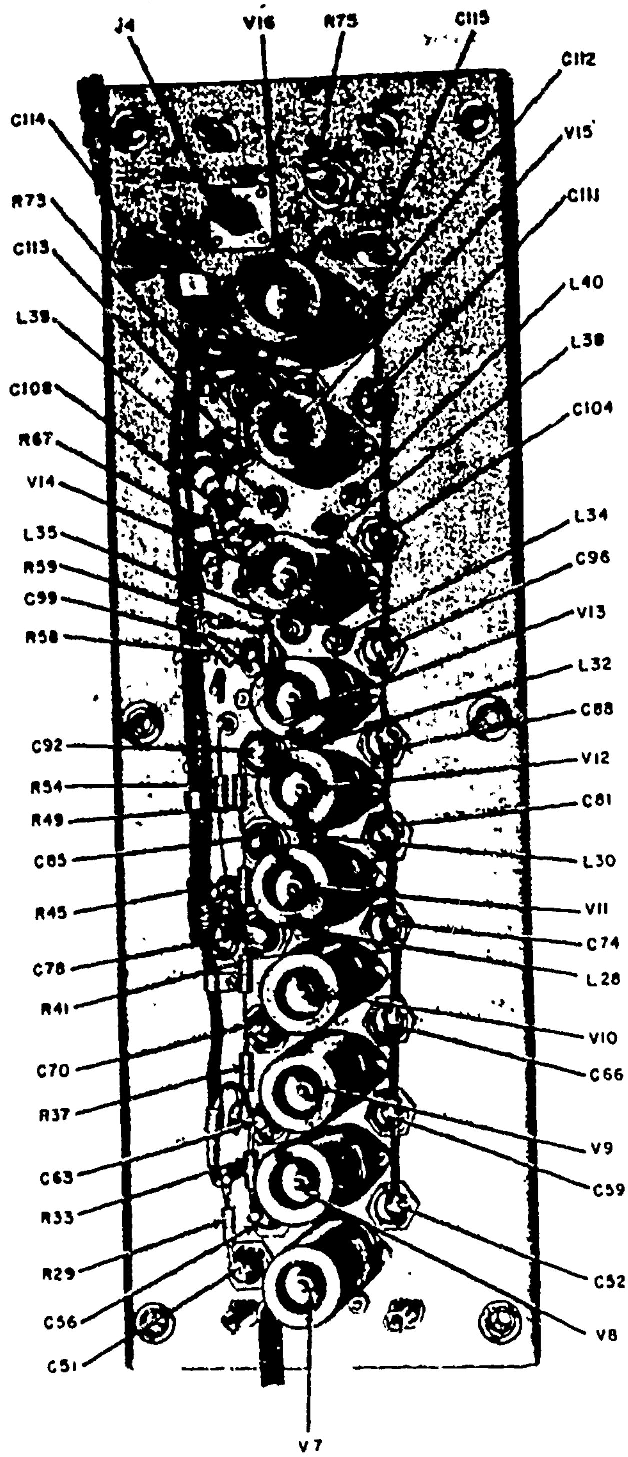


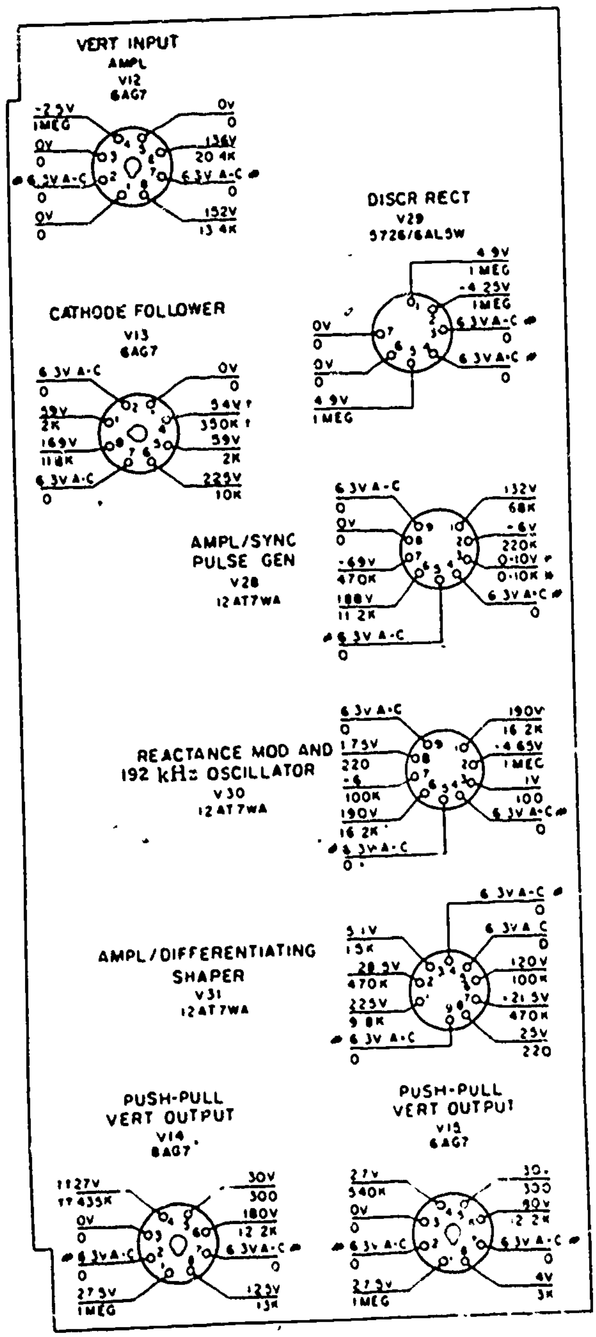
Figure 4-5. Schematic diagram with block text.



TM689-111

Figure 4-6. Typical layout diagram.

(3) Dc voltages. All other equipment voltages are either positive or negative dc voltages. The VTVM must be adjusted to read dc voltages (positive or negative as required), and Note 1 explains that the voltage is to be measured between the tube pin and ground. A voltage reading outside the tolerance set by the



NOTES

1. UNLESS OTHERWISE SHOWN VOLTAGES AND RESISTANCES ARE MEASURED TO GROUND WITH A VACUUM TUBE VOLTMETER
2. NC INDICATES NO CONNECTION
3. # INDICATES FILAMENT READING BETWEEN FILAMENT PINS
   * INDICATES READING DEPENDS ON SETTING OF R150 VOLTAGE ALSO DEPENDS ON SYNC INPUT WITHOUT SYNC VOLTAGE 0-4V WITH SYNC, VOLTAGE 0-10V
   † INDICATES READING DEPENDS ON SETTING OF R59
   †† INDICATES READING DEPENDS ON SETTING OF R71

TM509-158

Figure 4-7. Combined voltage and resistance chart.

equipment publication is considered an abnormal reading, and is often a symptom of the trouble in the equipment. The technician then uses the resistance chart and ohmmeter to isolate the trouble to a component.

Item No.	Symptom	Probable trouble	Correction
	Warning: **Up to 1100 volts are developed by panel 6A1. Before making dc resistance measurements, insure that primary power is removed.** *Note:* Prior to troubleshooting the panel, it is assumed that fuse replacement has been tried, with no corrective results.		
1	Incorrect voltage at +10V jack J2; F1 keeps blowing.	Q1, Q2, Q3, or R1 defective	Check voltage at E3 (−18 ±1.8 volts dc). If voltage is incorrect, proceed to item 2. If voltage correct, check Q1, Q2, Q3, and R1.
2	Incorrect voltage at E3	L1C defective	Check voltage at E7 (−18 ±1.8 volts dc). If voltage is incorrect, proceed to item 3. If voltage correct, check L1C for resistance (*b* below).
3	Incorrect voltage at E7	CR1 or CR2 defective	Check voltage at E5 and E8 (12 ±1.2 volts ac). If voltage is incorrect, proceed to item 4. If voltage correct, check CR1 and CR2.
4	Incorrect voltage at E5 and E8	Secondary of T1 defective	Check terminals 12, 13, and 14 of T1 for correct resistance (*b* below).
5	Incorrect voltage at all power supply outputs with all fuses intact.	Primary of T1 defective	Check terminals 1 and 2 of T1 for correct resistance (*b* below).
6	F1 fails to blow when terminals 13 and 19 are shorted together.	F1 or fuse holder defective	Check F1 for continuity and exact value, check its fuseholder for foreign material lodged on its contacts.
7	Improper voltage regulation at +10V jack J2 when input voltage varies from 109 to 121 volts ac	VR1 defective	Check VR1 for breakdown voltage of 6.2 volts. If defective, replace; if not defective, proceed to item 8.
8	Improper voltage regulation at +10V jack J2 when input voltage varies from 109 to 121 volts ac. VR1 not defective.	Q2 or Q3 defective	Check base of Q1 for correct voltage (*c* below). If voltage incorrect, proceed to item 9. If voltage correct, check voltage at bases of Q2 and Q3. If voltage unequal, troubleshoot Q2 and Q3. If voltages equal (R1 adjusted), proceed to item 9.
9	Incorrect voltage at base of Q1, equal voltages at bases of Q2 and Q3 (R1 adjusted	Q1 or R1 defective	Check Q1 and R1.
10	High output ripple at 10V jack J2	C1, C2, L1C, CR1, CR2, C4 or C5 defective	Check C1, C2, L1C, CR1, CR2, C4, and C5.
11	Incorrect voltage at −10V jack J3, F2 keeps blowing	Q4, Q5, Q6, or R7 defective	Check voltage at E14 (−17.5 ±1.8 volts dc) If voltage is incorrect, proceed to item 12. If voltage correct, check Q4, Q5, Q6, and R7.
12	Incorrect voltage at E14	L1B defective	Check voltage at E17 (−17.5 ±1.8 volts dc) If voltage is incorrect, proceed to item 13. If voltage correct, check resistance of L1B (*b* below).

Figure 4-8. Typical troubleshooting chart.

b. Resistance Charts. Resistance charts list the resistance values and the points at which these values can be measured. When the technician gets an incorrect resistance measurement, he consults the schematic diagram, then makes measurements of the individual components to isolate the faulty one. The resistances shown on the resistance chart represent the normal resistance measured from the tube (or transistor) pin to ground. In figure 4-7, this is indicated in Note 1. The ohmmeter portion of the VTVM is used, and the multiplier set to the range that will give a center-scale reading. (The ohmmeter scale is not linear, and the most accurate measurement is obtained at the center of the scale.) Remove all power from the equipment and place one probe on chassis ground and the other on the proper tube (or transistor) pin. Any reading that is not within the tolerance (usually ±20%) is considered abnormal. For example, if the chart gives the resistance as 470K (470,000) ohms, the measurement should fall between 376K and 564K ohms. A zero reading obtained where there should be some resistance indicates that there is a short circuit between the points contacted by the meter probes. A reading at the upper extreme of the scale indicates that the circuit is open. The circuit that presents an abnormal reading must be checked further, even down to individual resistors, to determine the faulty resistor or to locate the short circuit. This is done by using the VTVM and the schematic diagram. Locate the proper tube and pin on both the schematic and chassis, and, working from that point toward ground, measure each resistance in the circuit individually by placing the probes directly across the resistor. It may be necessary to temporarily disconnect one end of certain resistors to obtain accurate measurements. Any defective component must be replaced.

c. Troubleshooting Charts. The troubleshooting chart is designed to save the technician much valuable time. This chart consists of a series of troubleshooting shortcuts relating to the particular equipment. The list is confined to those troubles which experience has shown are most likely to occur. Figure 4-8 shows a portion of a troubleshooting chart. This chart refers to a plug-in panel which is part of a larger electronic unit. Notice that the chart has a list of abnormal indications (symptoms), and that for each symptom listed there is at least one probable cause. If more than one trouble can produce the same symptoms, more than one trouble is listed. The probable trouble guides the technician to the component or circuit that is most likely to cause the listed symptoms. The technician then takes the action shown in the Correction column of the chart. The action may further require that he also make use of the voltage and resistance charts and schematic diagrams. Obviously, not all of the possible problems can be listed in a troubleshooting chart. However, the technician is supplied with a list of potential or recurring problems and suggestions on how to correct them.

STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution on the multiple-lesson answer sheet by a cross with a lead pencil in the appropriate lettered block.

All exercises of this lesson are of equal weight. The total weight is 100.

1. Terminal boards are used in electronic equipment when

   a. there are only a few stages.

   b. the many stages complicate the wiring.

   c. tubes are used rather than transistors.

   d. transistor are used rather than tubes.

2. The type of diagram that uses a numbering system or color code to aid the technician is known as a

   a. block diagram.
   b. wiring diagram.
   c. layout diagram.
   d. schematic diagram.

3. In the wiring diagram in figure 4-1, the identification numbers for the relay and the interlock switch, respectively, are

   a. K4001 and S4003.
   b. K4001 and B4002.
   c. E4001 and S4003.
   d. B4001 and P4101.

4. Power must be removed from the equipment when you make a continuity check so that you can

   a. prevent damage to the ohmmeter.

   b. conserve power not needed for the test.

   c. insure against the transmission of test signals.

   d. obtain an accurate measurement of the charge on the capacitors.

5. Assume that you suspect interlock switch S4003 in figure 4-1 to be defective. One way to check the switch is to remove the power from the equipment and operate the switch while the probes of the ohmmeter are connected to P4001, contacts

   a. 5 and 17.
   b. 5 and 20.
   c. 15 and 17.
   d. 15 and 20.

6. To assure that the various components of a radio terminal set are properly interconnected, the technician consults a

   a. block diagram.
   b. wiring diagram.
   c. cabling diagram.
   d. schematic diagram.

7. The construction of any particular type of cable is determined by the

   a. distance between the units it connects.

   b. purpose for which it is to be used.

c. type of connectors to be used.

d. location of the installation.

8. To reduce noise pickup and minimize power losses, the output signal from the transmitter is carried to the antenna by a

a. power cable.

b. coaxial cable.

c. shielded parallel-wire line.

d. insulated parallel-wire line.

9. When the functions of several stages in electronic equipment are identical, a block diagram will usually show all these stages

a. as a single block.

b. with numbered test points.

c. with waveforms at each stage.

d. with the arrows indicating the signal flow.

10. A technician consults the block diagram of an electronic unit to

a. study the circuit-by-circuit operation.

b. determine the identity of unit components.

c. determine component values and circuit connections.

d. get a general idea of the unit and localize a trouble.

11. The electronic diagram that symbolically shows all the circuits and components of a unit is the

a. block diagram.

b. wiring diagram.

c. cabling diagram.

d. schematic diagram.

12. In the schematic shown in figure 4-5, the resistor whose value is 6,800 ohms is identified as

a. R23.

b. R26.

c. R29.

d. R34.

13. When a technician wants to know the nominal value of a specific resistor, he checks the

a. layout diagram.

b. resistance chart.

c. schematic diagram.

d. troubleshooting chart.

14. Assume that you are troubleshooting a radio receiver. When you have localized the trouble, your next step is to isolate the defective component. To do this, you will use the schematic diagram and the

a. voltage and resistance charts.

b. block diagram and voltage chart.

c. wiring diagram and resistance chart.

d. cabling diagram and troubleshooting chart.

15. Assume that you must make a continuity check of the windings in transformer T4, but you cannot differentiate between T2 and T4. To assure that you check the correct transformer, you should first consult the

a. schematic diagram.

b. layout diagram.

c. wiring diagram.

d. block diagram.

16. Special instructions for obtaining voltage measurements are usually found in the

a. wiring diagram.

b. troubleshooting chart.

c. inside cover of the meter.

d. notes of the voltage chart.

17. Assume that you are repairing a defective radio transmitter, and you obtain an abnormal voltage measurement. Your next step is to

a. test the tubes in the transmitter.

b. test the tubes in the power supply.

c. measure the voltage with another meter.

d. check resistances of the components in the circuit.

18. One characteristic of a short circuit in electronic equipment is

a. an extremely high resistance reading.

b. a near-zero resistance reading.

c. a center-scale ohmmeter reading.

d. a nonlinear ohmmeter reading.

19. The repairman can find shortcuts to the repair of electronic equipment in the

a. block diagram.

b. voltage chart.

c. schematic diagram.

d. troubleshooting chart.

20. The troubles listed in an equipment troubleshooting chart are those troubles that are most

a. easily repaired.

b. likely to occur.

c. unlikely to occur.

d. difficult to repair.

HOLD ALL TEXTS AND MATERIALS FOR USE WITH EXAMINATION.

LESSON SOLUTIONS

SIGNAL SUBCOURSE 309 .... Introduction to Electronics

LESSON 1 .... Electron Tubes and Solid State Devices

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to the Attached Memorandum.

1. a--para 1-1a(1)
2. d--para 1-1a(2)
3. a--para 1-1b
4. c--para 1-1b, 1-2b(2)
5. b--para 1-1c
6. d--para 1-1c
7. c--para 1-1d
8. b--para 1-1d
9. b--para 1-1e
10. c--para 1-1d, e
11. c--para 1-2
12. a--para 1-2b(1)
13. d--para 1-2b(1)
14. b--para 1-2c
15. a--para 1-2d
16. a--para 1-2d(1)
17. c--para 1-2d(2), fig. 1-4
18. c--para 1-3a(2)
19. b--para 1-3b(2)
20. a--para 1-3c

SIG . FRONT - 1

All concerned will be careful that neither this solution nor information concerning it comes into the possession of students or prospective students who have not completed the work to which it pertains.

SOLUTIONS

SIGNAL SUBCOURSE 309 .... Introduction to Electronics

LESSON 2 .... Radio Transmission and Reception

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All exercises of this lesson are of equal weight. The total weight is 100.

All references are to the Attached Memorandum.

1. a--para 2-1b(1)
2. d--para 2-1b(1)-(3)
3. c--para 2-1b(4)
4. d--para 2-2b(2)
5. c--para 2-4a(2)
6. d--para 2-4b(2)
7. c--para 2-4c(2)
8. b--para 2-4c(2)
9. c--para 2-4c(6)
10. b--para 2-4c(7)
11. a--para 2-4c, d
12. d--para 2-4d(4)
13. d--para 2-4d(6)
14. a--para 2-4e
15. a--para 2-5c
16. c--para 2-5c

The IF is usually the difference between the signal frequency and the local oscillator frequency. The signal frequency = 1,200 kHz; the IF = 455 kHz:

L.O. = signal - IF

= 1,200 - 455

= 745 kHz

All concerned will be careful that neither this solution nor information concerning it comes into the possession of students or prospective students who have not completed the work to which it pertains.

17. b--para 2-5e

18. c--para 2-5e(1)

19. b--para 2-5e(2)

20. b--para 2-6

SOLUTIONS

SIGNAL SUBCOURSE 309 .... Introduction to Electronics

LESSON 3 .... Radio Set Components

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to the Attached Memorandum.

1. d--para 3-1a
2. a--para 3-1b(1)
3. d--para 3-2a
4. d--para 3-3a(1)
5. b--para 3-3a(2)
6. a--para 3-3a(3)
7. c--para 3-3a(3)
8. c--para 3-3a(5)
9. a--para 3-3b(1)
10. b--para 3-3d(1)(2)
11. a--para 3-4a(1)
12. b--para 3-4a(3)
13. c--para 3-4b
14. a--para 3-5a(2)
15. c--para 3-5b

All concerned will be careful that neither this solution nor information concerning it comes into the possession of students or prospective students who have not completed the work to which it pertains.

SOLUTIONS

SIGNAL SUBCOURSE 309 .... Introduction to Electronics

LESSON 4 .... Electronic Diagrams

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to the Attached Memorandum.

1. b--para 4-1a(1)
2. b--para 4-1a(2)
3. a--para 4-1a(2), fig. 4-1
4. a--para 4-1a(3)
5. b--para 4-1a(3), fig. 4-1
6. c--para 4-1b(1)
7. b--para 4-1b(1)
8. b--para 4-1b(1)
9. a--para 4-1c
10. d--para 4-1c
11. d--para 4-1d
12. b--para 4-1d
13. c--para 4-1d
14. a--para 4-1d(1)
15. b--para 4-1e
16. d--para 4-2a(1)
17. d--para 4-2a(3)
18. b--para 4-1a(3), 4-2b
19. d--para 4-2c
20. b--para 4-2c

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EXTENSION COURSE OF THE US ARMY SIGNAL SCHOOL

EXAMINATION

SIGNAL SUBCOURSE 309 .... Introduction to Electronics

CREDIT HOURS 2

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution on the examination answer card by punching out the correct letter.

1. In an electron tube that has a directly-headed cathode, the element that emits electrons is called the

    a. grid.

    b. plate.

    c. filament.

    d. suppressor.

2. The diode tube has only two elements. These elements are the

    a. plate and grid.

    b. cathode and grid.

    c. plate and screen.

    d. cathode and plate.

3. The requirements for causing plate current to flow in a diode tube are a heated

    a. cathode and a positive voltage applied to the plate.

    b. cathode and a negative voltage applied to the plate.

    c. plate and a positive voltage applied to the cathode,

    d. plate and a negative voltage applied to the cathode.

4. The element in a pentode tube that has the greatest effect on plate current is the

a. plate.
b. cathode.
c. control grid.
d. suppressor grid.

5. The element of an electron tube that is designed to accelerate the flow of electrons to the plate is the

a. control grid.
b. screen grid.
c. cathode.
d. plate.

6. The high velocity of the electrons in certain types of electron tubes may cause secondary emission. Which tube incorporates an element to reduce the effects of secondary emission?

a. Diode tube
b. Triode tube
c. Tetrode tube
d. Pentode tube

7. When reverse bias is applied to a junction diode, it results in a

a. weaker junction barrier and reduced current.

b. weaker junction barrier and increased current.

c. stronger junction barrier and reduced current.

d. stronger junction barrier and increased current.

8. A transistor of the PNP type is one that is made with N-type material for the

a. base, and P-type material for the emitter and collector.

b. emitter and collector, and P-type material for the base.

c. emitter, and P-type material for the collector and base.

d. collector, and P-type material for the emitter and base.

9. The semiconductor device that is capable of amplification is a

a. varactor.
b. rectifier.
c. transistor.
d. zener diode.

10. When either a diode tube or junction diode is used as a half-wave rectifier, its purpose is to

a. change a dc voltage to an ac voltage.

b. change an ac voltage to a dc voltage.

c. amplify the input to the power supply.

d. filter the output of the power supply.

11. The number of dc pulses in the output of a full-wave rectifier whose input frequency is 50 Hz is

a. 25 pulses.
b. 50 pulses.
c. 100 pulses.
d. 200 pulses.

12. A zener diode is a semiconductor device used as a

a. rectifier.
b. demodulator.
c. voltage regulator.
d. variable capacitor.

13. The semiconductor diode that can serve as a capacitance by controlling the reverse voltage is known as a

a. detector.
b. varactor.
c. rectifier.
d. zener diode.

14. An amplifier circuit that is designed to amplify a given frequency can be converted to an oscillator circuit by

a. providing in-phase feedback.

b. increasing the plate voltage.

c. increasing the input frequency.

d. reducing the gain of the amplifier.

15. The entire frequency range of alternating voltage and current can be considered in the two groups known as

a. radio and audio frequencies.

b. video and audio frequencies.

c. radio and intermediate frequencies.

d. video and intermediate frequencies.

16. What is the distance that a radio wave travels through space in 1 second?

a. 300.000 meters
b. 3.000.000 meters
c. 30.000,000 meters
d. 300.000.000 meters

17. When you say that the antenna is receiving a signal of 100 kHz, you are referring to the

12 FRONT - 1

a. type of modulation.

b. frequency of the signal.

c. length of the radio wave.

d. velocity of the radio wave.

18. The electromagnetic wave radiated from a transmitting antenna consists of a

a. groundwave and skywave.

b. skywave and radiated wave.

c. skywave and reflected wave.

d. groundwave and radiated wave.

19. The transmission of radio waves over long distances is made possible by employing

a. groundwave propagation.

b. ultrahigh-frequency transmission.

c. stratospheric penetration.

d. ionospheric refraction.

20. The physical length of the basic antenna element is equal to

a. twice the electromagnetic wavelength.

b. half of the electromagnetic wavelength.

c. one quarter of the electromagnetic wavelength.

d. three quarters of the electromagnetic wavelength.

21. The link between the antenna and a vehicular mounted radio receiver or transmitter is the

a. counterpoise.

b. vehicle body.

c. power amplifier.

d. transmission line.

22. Because it is so flexible and easy to handle, the transmission line most often used for television installation is the

a. coaxial cable.

b. open-wire line.

c. shielded parallel-wire line.

d. insulated parallel-wire line.

23. Shielded parallel-wire line is often used to carry the received signals from the antenna to the receiver because it

a. is easily tuned.

b. is very flexible.

c. has little noise pickup.

d. has easily adjustable conductor spacing.

24. The main difference between coaxial cables used with receivers and transmitters is that the cable used with transmitters has a

a. smaller center wire and thicker dielectric insulation.

b. smaller center wire and thinner dielectric insulation.

c. larger center wire and thicker dielectric insulation.

d. larger center wire and thinner dielectric insulation.

25. The process of transmitting information by varying either the amplitude or frequency of a carrier is known as

a. detection.

b. modulation.

c. amplification.

d. rectification.

12 BACK - 2

26. Assume that the frequencies appearing in the plate circuit of the power amplifier in figure 2-10 are 2 kHz, 73 kHz, 75 kHz, and 77 kHz. The 75-kHz frequency is known as the

a. LSB frequency.

b. USB frequency.

c. carrier frequency.

d. modulating frequency.

27. Line-of-sight transmission is common to transmitters operating in the

a. MF and HF ranges.

b. MF and VHF ranges.

c. HF and UHF ranges.

d. VHF and UHF ranges.

28. In a radio receiver, the intermediate frequency first appears in the stage known as the

a. mixer.

b. oscillator.

c. IF amplifier.

d. RF amplifier.

29. The function of a beat-frequency oscillator is to generate a signal to be mixed with the IF carrier. This produces

a. an RF carrier.

b. an audio signal for the speaker.

c. an audio signal to be radiated.

d. a coded signal to be radiated.

30. The function of the limiter stage in an FM receiver is to eliminate

a. unwanted amplitude variations.

b. unwanted frequency variations.

c. the carrier, leaving only the audio voltage.

d. the audio voltage, leaving only the carrier.

31. An FM radio receiver contains a circuit whose output voltage is proportional to the amount of deviation from the IF. This circuit is known as the

a. mixer.
b. limiter.
c. IF amplifier.
d. discriminator.

32. A practical means of producing many stable frequencies for use as carriers in radiotelephone communication is to use a circuit known as a

a. frequency synthesizer.
b. frequency stabilizer.
c. frequency detector.
d. RF generator.

33. In the process of contructing the monolithic IC, two layers develop to form a PN juncti `. The materials in the two layers are identified as

	Substrate	Epitaxial
a.	Silicon	Hydrogen
b.	Hydrogen	Silicon
c.	Silicon (P-type impurity)	Silicon (N-type impurity)
d.	Silicon (N-type impurity)	Silicon (P-type impurity)

34. When a monolithic IC is being made, the chip must be washed in photo developing fluid to remove the

a. silicon dioxide that was exposed by etching.

b. photomask after the exposure to the ultraviolet light.

c. photoresist from the areas exposed to the ultraviolet light.

d. photoresist from the areas not exposed to the ultraviolet light.

35. The process used to make a thin film IC is known as

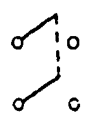
a. vacuum evaporation.

b. epitaxial growth.

c. hybrid formation.

d. chip and wire.

36. The type of switch represented by the symbol shown below is known as



a. DPDT.

b. DPST.

c. SPDT.

d. SPST.

37. Before a technician performs a continuity check, he must make sure that

a. the VTVM is set on the lowest dc range.

b. the VTVM is set on the highest ac range.

c. all power is removed from the equipment.

d. filament voltage is applied to the equipment.

38. To obtain a general idea of the operation of a radio receiver, the technician should consult a

a. block diagram.

b. voltage chart.

c. cabling diagram.

d. troubleshooting chart.

39. Which electronic diagram helps the technician to identify the various parts and observe their relative positions?

a. Schematic diagram

b. Wiring diagram

c. Layout diagram

d. Block diagram

40. Assume that the resistance chart for a radio receiver gives the resistance between two points as 5.0 megohms (5,000,000 ohms). The ohmmeter reading will be normal if it is any value between

a. 5.0 and 7.0 megohms.

b. 4.0 and 6.0 megohms.

c. 3.0 and 5.0 megohms.

d. 1.0 and 3.0 megohms.

COMPLETE YOUR EXAMINATION AND RETURN THE PUNCH CARD TO THE SCHOOL FOR GRADING.