SUBCOURSE
MM0311

EDITION
9

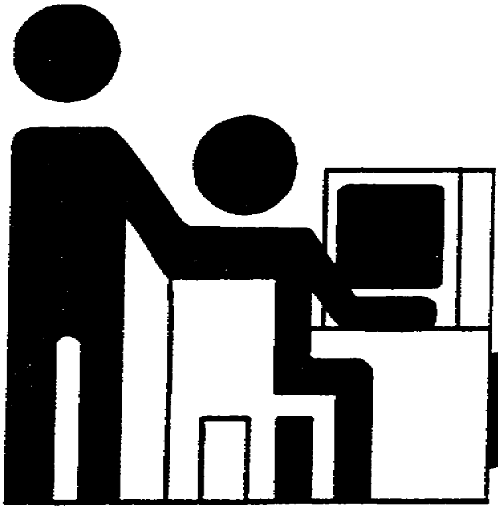
ELECTRON TUBES

AIPD

READINESS/
PROFESSIONALISM
THRU
GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM



Notice to Students

Use the Ordnance Training Division website,
http://www.cascom.army.mil/ordnance/,
to submit your questions, comments, and suggestions
regarding Ordnance and Missile & Munitions
subcourse content.

If you have access to a computer with Internet capability and can receive e-mail, we recommend that you use this means to communicate with our subject matter experts. Even if you're not able to receive e-mail, we encourage you to submit content inquiries electronically. Simply include a commercial or DSN phone number and/or address on the form provided. Also, be sure to check the Frequently Asked Questions file at the site before posting your inquiry.

NOTE

Proponency for this subcourse has changed from Signal(SS) to Missile and Munitions(MM).

SIGNAL SUBCOURSE SS0311

CREDIT HOURS: 10

CONTENTS PAGE

VALIDATION INFORMATION

This subcourse has been validated in the field by continuous use for over three years.

Whenever pronouns or other references denoting gender appear in this manual, they are written to refer to either male or female unless otherwise indicated.

SIGNAL SUBCOURSE SS0311, ELECTRON TUBES

INFORMATION TO STUDENT

This is an "unsupervised" subcourse and is designed to give you an understanding of electron tube theory. Although this is an unsupervised subcourse, you should always feel free to seek assistance from your supervisor, peers or someone knowledgeable on the subject matter whenever you encounter difficulty.

The subject of electron tubes has been divided into two signal subcourses. This subcourse, SS0311, is concerned with the general operational theory of tubes. Signal Subcourse SS0312, which you should study next, discusses the various uses and configurations of tubes; such as tube oscillators or amplifiers.

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

INTRODUCTION

In this age of advanced computer technology and probes into deep space which were made possible by the miniaturization of solid state circuitry, an invention by Thomas Edison still plays an important role in communications and our everyday lives. This invention, the electron tube, enables us to enjoy television, radio and safe air travel with pin-point navigational accuracy.

An extremely large variety of electron tubes is used to perform many varied functions. In this subcourse you will study the basic types of tubes and how they function.

***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

LEARNING STRATEGY

This subcourse is comprised of five lessons and the subcourse examination, as follows:

Lesson 1: Electron Emission

Lesson 2: Diodes

Lesson 3: Triode Fundamentals

Lesson 4: Triode Characteristics and Constants

Lesson 5: Multielectrode Tubes

Examination

Credit Hours: 10

The lesson objectives which you are to achieve will be specified at the start of each lesson. Study assignments in the technical manual are listed at the beginning of each lesson under text assignments. That portion of the TM which is relative to the lesson has been extracted from the TM and printed with the lesson.

When you have completed the lesson text assignment, answer the lesson exercises associated with each lesson to insure that you understand the subject matter. Check your answers with those provided in the lesson solutions portion of this subcourse. Then, research the question(s) you have answered incorrectly before you proceed to the next lesson.

Once you have progressed through all five lessons you should be ready to take the subcourse examination. Then, mail in the examination punch card to receive credit for this subcourse.

When you see this symbol (√) in the margin of the TM, refer to either change 1, change 2 or the DNI corrections.

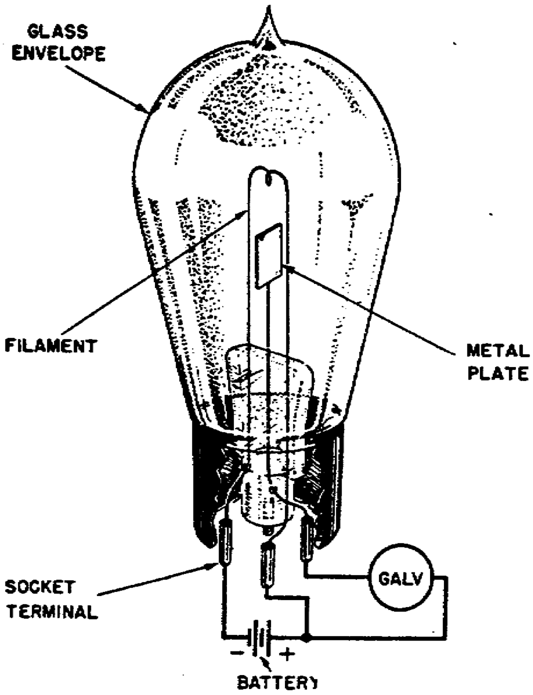
RESOURCE REQUIREMENTS

Texts and materials furnished:

--Subcourse booklet, examination

--TM 11-662, Basic theory and Application of Electron Tubes, dated Feb 1952, w/C1 dated 8 Nov 55 and C2 dated 21 Apr 58. Chapters 1 thru 5 extracted.

--DNI corrections to TM 11-662.



electron emission

lesson one

electron emission

INTRODUCTION

Electronics has been defined as the science dealing with the control of electron flow, especially by the means of electron (or vacuum) tubes. The terms electron tubes and vacuum tubes are used interchangeably to refer to a tube in which a flow of current takes place in an enclosed space. A vacuum tube is one from which the air has been removed to form a partial vacuum.

There are numerous types of electron tubes manufactured; each type differs from the other and has specific electrical characteristics. In this lesson you will study the early experiments in the development of the electron tube and the various types and functions of tubes commonly used today in commercial and military equipment.

TEXT ASSIGNMENT

TM 11-662, chapters 1 and 2, paragraphs 1 thru 12.

RESOURCE REQUIREMENTS

Signal Subcourse SSO 311

LESSON OBJECTIVES

When you complete this lesson you should be able to:

1. Explain the Edison effect.

2. Distinguish tube types.

3. Plot an amplified, rectified, squared, clipped, and generated ac signal.

PAGES 3 THRU 17

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AND ARE PROVIDED AS A SEPARATE PDF DOCUMENT

SIGNAL SUBCOURSE SS0311

LESSON 1 - ELECTRON EMISSION

LESSON 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 action of changing an alternating current into a pulsating direct current is generally referred to as

a. clipping.
b. filtering.
c. squaring.
d. rectifying.

2. An electron tube with four elements is called a

a. diode.
b. triode.
c. tetrode.
d. pentode.

3. Among the many special functions which electron tubes are capable of performing, which of the following tubes does not amplify?

a. diode
b. triode
c. tetrode
d. pentode

4. In 1907, Lee DeForest inserted an extra electrode in the form of a few turns of fine wire between the filament and the plate of Fleming's valve and made a tube called a

a. rectifier.
b. generator.
c. amplifier.
d. clipper.

5. An electron tube capable of sound reproduction from a photographic image on a film is called a

a. generator.
b. audion.
c. phototube.
d. rectifier.

6. Electron tubes are classified as diodes, triodes, tetrodes and pentodes according to

a. their circuit function.

b. amplification factors.

c. the Edison effect.

d. the number of elements.

7. In all electron tubes, the emitter of electrons is called the

a. cathode.

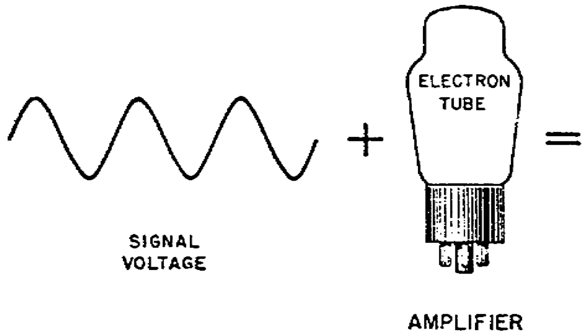
b. anode.

c. grid.

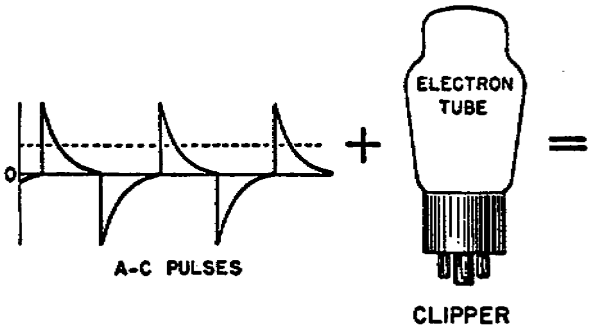
d. plate.

For questions 8-12, draw the correct output for function listed.

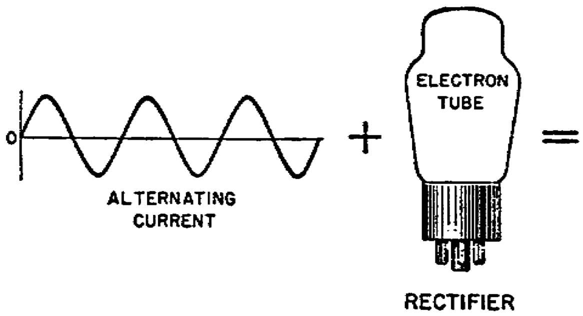
8. Amplifier.



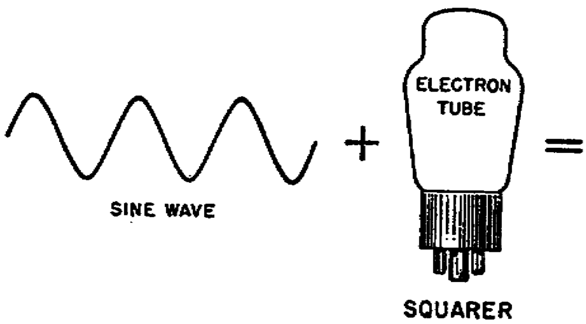
9. Clipper.



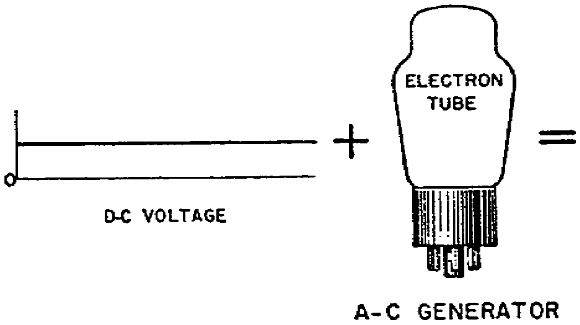
10. Rectifier.



11. Squarer.



12. A-C Generator.



13. When a filament is heated to incandescence, electrons will flow from it to the plate. This effect was first noted by British scientist Sir J. J. Thomson and is still known today as the

a. Edison effect.
c. hot cathode.
b. rectification.
d. electron theory.

14. If a signal equal to 1 volt was fed into an electron tube and the output signal was equal to 20 volts, the signal was fed into a ____________________ tube.

a. rectifier
c. squarer
b. amplifier
d. clipper

15. In 1901 the first wireless telegraph signal spanned the Atlantic ocean. The inventor-experimenter credited with this radio signal is

a. Thomas A. Edison.
c. Guglielmo Marconi.
b. Sir J. J. Thomson.
d. J. A. Fleming.

16. Thermionic emission of electrons is the release of electrons from their original material by

a. force of collision with an incoming stream of electrons.

b. cold-cathode ionization action.

c. application of heat.

d. chemical action.

17. The indirectly heated cathode has an advantage over the directly heated cathode in that it can

a. provide almost instantaneous operation.

b. operate from either an ac or a dc source.

c. use oxide-coated emitters, which are more economical.

d. provide a constant temperature despite fluctuations in heating current.

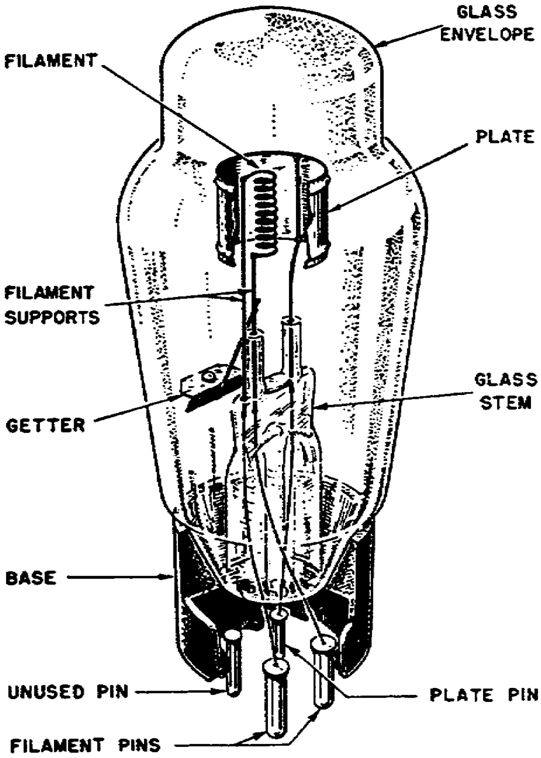
18. What filament material provides the greatest durability and can withstand overloads when used in thermionic tubes?

a. Tungsten.

b. Thoriated tungsten.

c. Oxide-coated nickel.

d. Nickel-coated platinum.


GLASS
ENVELOPE
FILAMENT
PLATE
FILAMENT
SUPPORTS
GLASS
STEM
GETTER
BASE
UNUSED PIN
PLATE PIN
FILAMENT PINS

diodes

lesson two

diodes

INTRODUCTION

The simplest form of vacuum tube contains two electrodes--a cathode and a plate. This type tube is called a diode. Thomas Edison discovered what may be called the earliest diode, his special lamp. The modern diode differs little in principle of operation from the early versions. However, today's diodes are much improved--higher vacuum, longer life and increased ruggedness.

Diodes are used mainly to change alternating current to a pulsating direct current, since it permits current flow in only one direction. In this lesson you will study the construction, operation, characteristics and uses of the diode.

TEXT ASSIGNMENT

TM 11-662, chapter 3, paragraphs 15 thru 29.

RESOURCE REQUIREMENTS

Signal Subcourse SS0311

LESSON OBJECTIVES

When you complete this lesson you should be able to:

1. Explain the construction of the diode tube.

2. Explain electrostatic fields.

3. Explain space charge.

4. Explain the relationship between plate-current and plate-voltage.

5. Explain characteristic curves.

PAGES 25 THRU 50

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LESSON 2 - DIODES

LESSON 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. In a diode with an indirectly heated cathode, the element that collects the electrons is known as the

a. plate.

b. heater.

c. getter.

d. cathode.

2. The getter is a substance used to facilitate the operation of the

a. space charge.

b. evacuation process.

c. beam-forming plates.

d. electrode within an electronic tube.

3. In addition to the heater element, a duodiode tube requires a minimum of

a. two plates and two cathodes.

b. one plate and two cathodes.

c. one cathode and two plates.

d. two plates and one anode.

4. Electron flow in a diode tube is best described as the flow of electrons from the

a. plate to the cathode when the cathode is positive in respect to the plate.

b. plate to the cathode when the plate is positive in respect to the cathode.

c. cathode to the plate when the plate is positive in respect to the cathode.

d. cathode to the plate when the cathode is positive in respect to the plate.

5. What are the four important factors that control a diode's plate current?

a. Cathode temperature, emission rate, space charge, and plate potential relative to the cathode.

b. Emission rate, magnetic field intensity, electrostatic field intensity, and cathode material.

c. Space charge, emission velocity, plate potential relative to the cathode, and filament type.

d. Filament type, cathode temperature, electrostatic field strength, and electromagnetic field strength.

6. Assume that the emission of electrons is in the direction shown in B of figure 22 (TM 11-662). When does emission saturation occur?

a. When all the electrons in the space charge are attracted to the plate.

b. When an increase in cathode temperature fails to increase electron emission.

c. When the space charge becomes so dense that electron flow to the plate is cut off.

d. When an electron is supplied back to the cathode from the space charge for each electron emitted by the cathode.

7. The space charge within a diode tube is best described as a charge that

a. is constantly varying in density.

b. maintains a positive potential with respect to the cathode.

c. builds up to a point of equilibrium at which it has neither negative nor positive characteristics.

d. remains at a negative potential, regardless of whether a positive or a negative charge is applied to the plate.

8. Figure 25 of TM 11-662 shows a characteristic curve for a diode. This curve shows the relationship between the

a. plate voltage and plate current.

b. plate current and filament voltage.

c. filament current and plate voltage.

d. space charge voltage and plate current.

SITUATION

Assume that you are analyzing the characteristic curves of a diode tube to determine if the tube is acceptable as the rectifier in a power supply. The characteristic curves for the tube are shown in figures 29 and 30 in TM 11-662.

Exercises 9 through 13 are based on the above situation.

9. Curve ABC in figure 29 is relatively flat along the portion from B to C. This flattened portion of the filament voltage-plate current curve is caused by the

a. space charge in the tube.

b. secondary emission in the tube.

c. temperature saturation of the tube.

d. dynamic characteristics of the tube.

10. Point D on curve ADE in figure 29 is known as the

a. ionization point. c. operating point.

b. saturation point. d. cutoff point.

11. In figure 30, point A on curve ABC indicates that

a. the plate current is zero when plate voltage is zero.

b. the space charge is repelling electrons back to the cathode.

c. a small amount of filament current is added to the plate current.

d. a small amount of plate current flows when plate voltage is zero.

12. To increase the curve to give it the shape shown as the extended straight dotted line in figure 30, it is necessary to

a. increase the plate voltage.

b. raise the emitter temperature.

c. reverse the polarity of battery E_{bb}.

d. change from a directly to an indirectly heated cathode.

13. Assume that curve ABC in figure 30 is being used to determine the dc plate resistance of the diode. What is the dc plate resistance if the plate voltage is 450 volts?

a. 6,800 ohms. c. 5,100 ohms.

b. 6,400 ohms. d. 1,500 ohms.

14. In the characteristic curve shown in figure 32, a saturation point is not indicated. This curve illustrates the

a. theoretical action if the effects of saturation were ignored.

b. characteristics of a tube with extremely low dc plate resistance.

c. primary difference between static and dynamic characteristics of diode tubes.

d. action of an oxide-coated cathode which, for all practical circuits, has no saturation point.

15. The ac and dc resistances of a diode tube are related directly to the tube's operating potentials. The ac and dc plate resistances are related to the plate voltage in such a way that as the

a. plate voltage increases, both the ac and dc plate resistances increase.

b. plate voltage increases, both the ac and dc plate resistances decrease.

c. plate voltage decreases, the ac plate resistance decreases, and the dc plate resistance increases.

d. plate voltage decreases, the ac plate resistance increases, and the dc plate resistance decreases.

16. The plate-current plate-voltage characteristic of a certain diode is shown in figure 33 of TM 11-662. If this diode is operated with its plate voltage varying between 12 and 14 volts, the ac plate resistance of the tube will be approximately

a. 250 ohms.

b. 300 ohms.

c. 400 ohms.

d. 500 ohms.

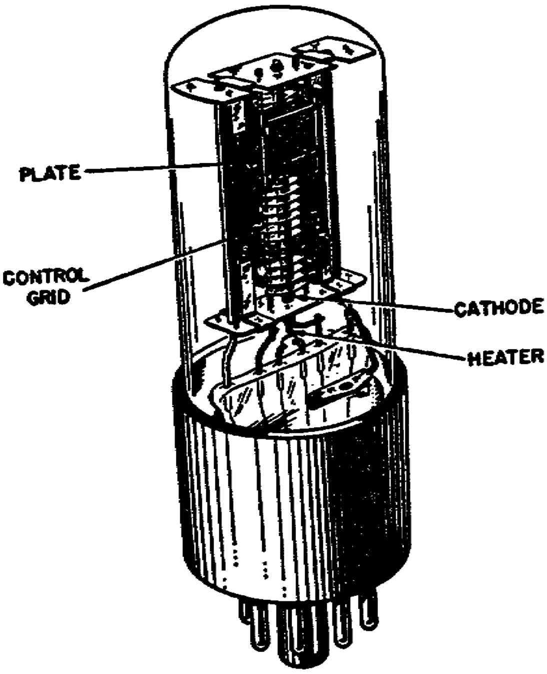
17. Both the static and the dynamic characteristic curves depict the behavior of electron tubes. The methods of obtaining the curves differ in that the dynamic curves are obtained

a. by applying ac voltages to the tubes, and the static curves are obtained by applying do voltages.

b. by applying do voltages to the tubes, and the static curves are obtained by applying ac voltages.

c. when there is NO load in the circuit, and the static curves are obtained when there is a load in the circuit.

d. when there is a load in the circuit, and the static curves are obtained when there is NO load in the circuit.



triode fundamentals

lesson three

triode fundamentals

INTRODUCTION

The remarkable achievements in the field of electrons, which includes radio, radar, television, guided missiles, etc., are a direct result of the discovery of the vacuum tube. The single greatest advance in the development of vacuum tube theory and application was the audion tube of Lee DeForest. The outstanding feature of this tube was the insertion of a third electrode in the diode that Fleming had developed. DeForest used his third electrode which was placed between the plate and the amount of electron flow. Because of the form of this control electrode in the earlier tubes, the term grid was applied to it. The grid is now defined as an electrode that contains openings through which electrons may pass. Physically, it is constructed of mesh, screen or spiral wires placed between the plate and cathode.

Many modern tubes contain more than one grid; so to describe its function as well as to differentiate it from other grids, this third electrode is called a "control grid." A tube which contains three active elements--a cathode, a control grid, and a plate--is called a "triode." In this lesson you will study the construction, operation and characteristics of the triode.

TEXT ASSIGNMENT

TM 11-662, chapter 4, paragraphs 32-44.

RESOURCE REQUIREMENTS

Signal Subcourse SS0311

LESSON OBJECTIVES

When you complete this lesson you will be able to:

1. Recognize the major elements of the triode electron tube.

2. Characterize and explain the function of the control grid.

3. Know the function of the bias voltage and potentials used.

4. Know the importance of the cutoff voltage and the effect it has on the operation of the triode.

PAGES 60 THRU 81

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LESSON 3 - TRIODE FUNDAMENTALS

LESSON 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. In addition to the two elements contained in a diode, the triode tube contains a third element that enables it to amplify signals. This third element is called a

a. grid.

b. plate.

c. cathode.

d. filament.

2. A common check on the operation of a glass electron tube is to see if the emitter is incandescent. This is often difficult in a triode because the

a. emitter is often indirectly heated.

b. plate will usually envelop the emitter surface.

c. brilliance of the getter flash hides the emitter incandescence.

d. inside of the tube envelope is covered with a deposit from the getter.

3. When a vacuum tube is being made, a getter is used to eliminate unwanted gases. The material usually used for the getter in a triode tube is

a. molybdenum.

b. magnesium.

c. nichrome.

d. tungsten.

4. To operate properly, a triode requires three different supply voltages: an A-supply, a B-supply, and a C-supply. The functions of the A-, B-, and C-voltages are to supply, respectively, the

a. filament, grid, and plate voltages.

b. plate, grid, and filament voltages.

c. grid, filament, and plate voltages.

d. filament, plate, and grid voltages.

5. The basic triode amplifier circuit shown in figure 50 (TM 11-662) can be divided into three basic systems: the input circuit, the cathode circuit, and the output circuit. The output circuit includes circuit elements between the

a. plate and ground.

b. grid and cathode.

c. grid and ground.

d. plate and grid.

6. The control grid in a triode tube normally governs the flow of plate current by

a. preventing a space charge from being established.

b. changing the distance between the wires of the helix.

c. producing an electrostatic field which controls the effect of the plate's electrostatic field.

d. attracting a definite portion of the emitted electrons to control the number of electrons reaching the plate.

7. A very small voltage on the control grid can overcome the effect of a large plate voltage. This effect, which enables the control grid to control plate current, arises from the fact that the

a. distance between the grid and cathode is much smaller than the distance between the plate and cathode.

b. plate's electrostatic field is perpendicular to the control grid's electrostatic field.

c. control grid can completely eliminate the space charge.

d. majority of grids are wound into a helix-like shape.

8. When applied to the grid, the voltage that reduces the plate current to zero is known as the

a. bias voltage.
c. cutoff voltage.

b. zero voltage.
d. saturation voltage.

9. Figure 51 of TM 11-662 shows a triode circuit and a characteristic curve for the triode. If the grid voltage on this triode is changed from -2.5 volts to +0.5 volt, the plate current (as indicated by the ammeter) will change from 15 mA to approximately

a. 0 mA.
c. 40 mA.

b. 32 mA.
d. 54 mA.

10. A dc voltage usually is applied to the control grid of a triode tube to prevent the grid from becoming positive and drawing current. This voltage is termed

a. bias voltage.
c. limiter voltage.

b. cutoff voltage.
d. saturation voltage.

11. To maintain a continuously negative potential on the control grid of a triode when the signal voltage is 14 volts peak to peak, the minimum grid bias that can be used is

a. -8 volts.

b. -11 volts.

c. -15 volts.

d. -29 volts.

NOTE: A 14-volt peak-to-peak signal is one that varies between the limits of +7 volts and -7 volts.

12. The conventional symbol used to indicate the value of dc grid-bias voltage is

a. e_b.

b. e_c.

c. E_{bb}.

d. E_{cc}.

13. In a grid family of static characteristic curves, the individual curves indicate a constant value of

a. grid voltage.

b. plate voltage.

c. grid current.

d. plate current.

14. Figure 51 of TM 11-662 illustrates a static plate-current grid-voltage characteristic. The word "static" indicates that the data for the curve was obtained

a. by using a constant grid voltage.

b. under "interference-free" conditions.

c. without a load resistor in the plate circuit.

d. without changing any of the circuit parameters.

15. Plate-current saturation is the point at which all electrons emitted by the cathode are attracted to the plate and the grid. Further positive increases in grid voltage will not increase the plate current. This condition can be avoided if the tube's emitter is

a. oxide-coated.

b. directly heated.

c. made of tungsten.

d. indirectly heated.

16. As grid voltage is made increasingly positive; plate current will increase to a certain point. This point occurs when the

a. grid current exceeds the plate current.

b. positive potential on the grid can no longer be increased.

c. emitted electrons are divided between the plate and the grid.

d. grid's electrostatic field opposes the plate's electrostatic field.

17. A grid family of characteristic curves for a 6J5 is shown in figure 53 of TM 11-662. If a 6J5 has plate voltage of 200 volts, what is the minimum voltage that can be applied to the grid of this triode so that no plate current will flow?

a. -12.6 volts

b. -13.5 volts

c. -15.5 volts

d. -18.0 volts

18. When the bias voltage applied to a 6J5 triode tube is maintained at -8 volts and the plate voltage is increased from 200 to 250 volts, the plate current will increase approximately

a. 3.4 mA.

b. 5.5 mA.

c. 6.7 mA.

d. 8.9 mA.

19. Point B on the 200-volt plate-voltage curve (fig. 53) corresponds to a current of 2.1 mA with a negative grid voltage of 9 volts. If the plate voltage is increased to 250 volts, the grid voltage needed to keep the plate current constant at 2.1 mA is approximately

a. -9.5 volts.

b. -11.6 volts.

c. -12.6 volts.

d. -15.5 volts.

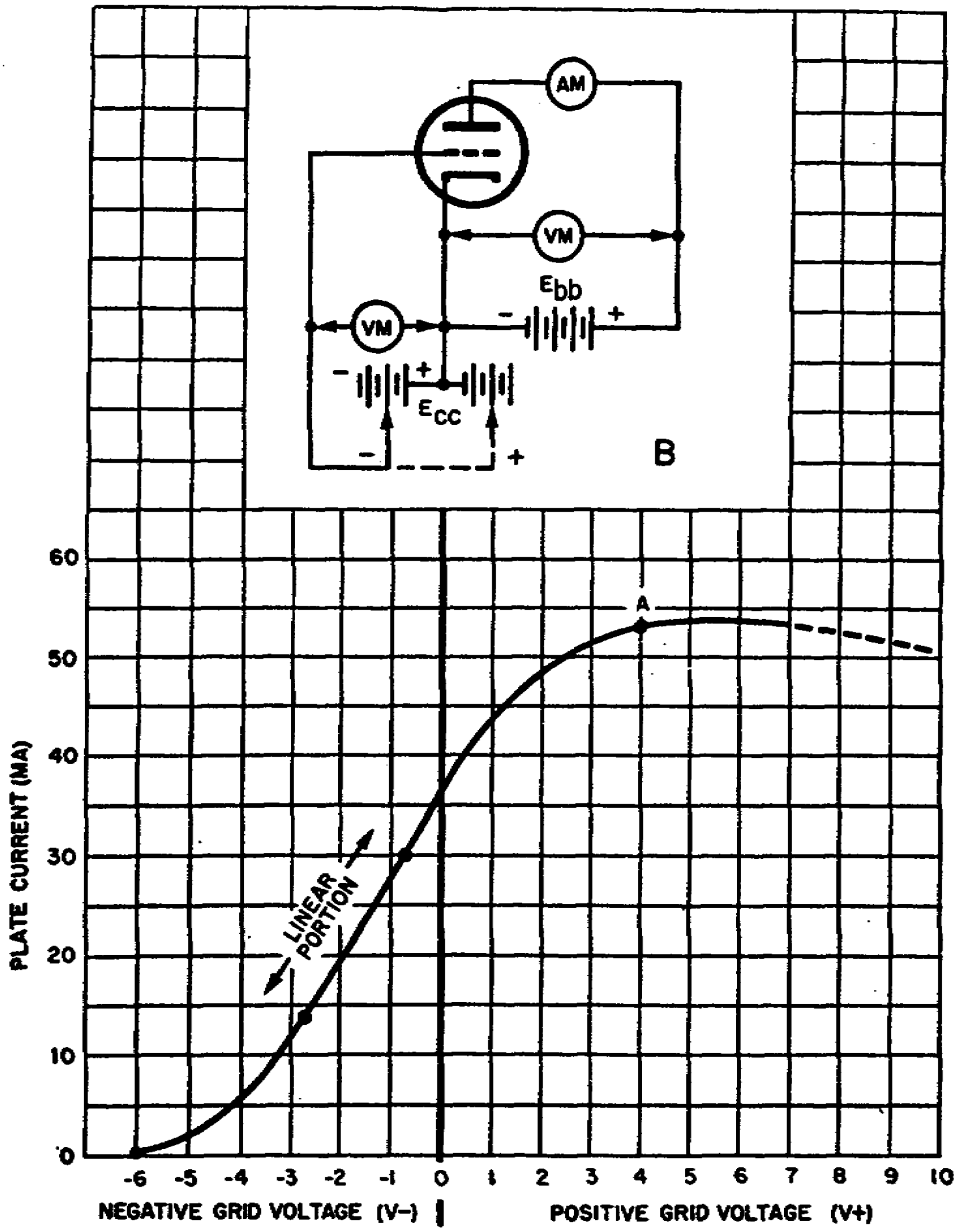
20. The operating potentials of a tube must be adjusted so that conduction takes place in the proper operating regions of the characteristic curves. Selecting an operating point for a triode on the straight portion of the characteristic curves will provide

a. a change in grid current that is inversely proportional to a change in plate current.

b. the correct cathode temperature for proper thermionic emission.

c. a change in plate current that is proportional to a change in grid potential.

d. the smallest change in plate current with a given change in grid potential.



triode characteristics

lesson four

triode characteristics

INTRODUCTION

The behavior of the plate current in a triode (or in any vacuum tube that contains three or more elements), under the influence of different control-grid and plate voltages, does not occur at random. It is a function of the tube design--specifically, the geometric organization of the tube electrodes. Examples of these are the separation between the electrodes, shape and dimensions of the electrodes and other physical details. It is these factors that determine the maximum voltages that can be applied to the electrodes, the maximum plate current permissible through the tube, the conditions for plate cutoff, and other similar facts. All of these are expressed by a group of numbers referred to as tube "constants."

Tube constants differ from tube characteristics. Whereas the characteristic is a graphical representation of tube behavior under the particular set of conditions shown, the tube constants are individual numerical ratings predicated upon the geometry of the tube. Tubes possessing similar relationships, although the specific values of grid voltage, plate voltage, and plate current necessary to make the tube perform properly may be different for the various tubes. The three primary tube constants are amplification factor, ac plate resistance and transconductance which will be discussed in this lesson.

TEXT ASSIGNMENTS

1. Attached Memorandum, paragraphs 3-1 thru 3-9.

2. TM 11-662, chapter 4, paragraphs 45-57

   NOTE: Study the attached memorandum before studying the TM references.

RESOURCE REQUIREMENTS

Signal Subcourse SS0311

LESSON OBJECTIVES

When you complete this lesson, you should be able to:

1. Define tube constants and know how tube constants affect the electron-tube circuit.

2. Calculate the amplification factor, ac plate resistance, and transconductance of an electron-tube circuit.

3. State the purpose and use of the load line and how the load line affects the electron-tube circuit.

4. State the purpose and use of a tube tester, and know how to make and interpret tube measurements.

ATTACHED MEMORANDUM

Section I. PEAK-TO-PEAK VOLTAGE

3-1. SINE WAVE SIGNAL VOLTAGES

The magnitude of a sine wave signal voltage can be specified by giving its peak-to-peak value. This method of describing the magnitude of a sine wave voltage specifies the difference in potential between the signal's positive and negative voltage peaks. For example, the sine wave voltage shown in figure 3-1 of this lesson booklet swings 3 volts in a positive direction and 3 volts in a negative direction. There is a 6-volt difference in magnitude between the positive and negative peaks. The alternating voltage in figure 3-1 is therefore referred to as being a 6-volt peak-to-peak signal.

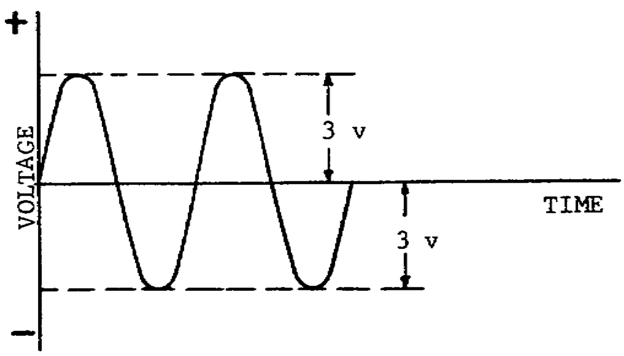


Figure 3-1. A 6-volt peak-to-peak sine wave voltage.

3-2. DISTORTED SINE WAVES

If a sine wave voltage is distorted, i.e., if it does not swing to an equal peak in both the positive and negative direction, then a single peak reference, such as 6 volts peak to peak, does not fully describe the signal. To avoid this limitation in the use of the peak-to-peak designation, this definition is made: any peak-to-peak voltage mentioned in this subcourse is assumed to be an undistorted sine wave swinging to an equal peak magnitude in both the positive and negative directions.

Section II. TUBE TESTERS

3-3. GENERAL OPERATION

Tube testers, in general, provide a means of applying typical operating voltages to the tube that is being tested. By providing a number of sockets or by adjusting several switches and potentiometers, a typical filament voltage, grid voltage, or plate voltage is applied to the tube. The tube can then be given various tests in this "typical" environment. Obviously, if the tube is to be used in an application where it is not being operated with these "typical" operating voltages, the tube tester will not be likely to give an accurate indication of the tube's condition.

3-4. GASSY TUBES

If a tube is gassy (that is, if the tube's vacuum is low or absent because of insufficient evacuation or the release of gasses imbedded in the electrode metals), grid current will flow in spite of negative grid bias. Thus, a milliammeter or microammeter in the grid circuit can be used to determine whether a tube is gassy. If a current is detected when a tube's grid is negatively biased, then that tube is gassy.

3-5. TRANSCONDUCTANCE TEST

Figure 3-2 illustrates a typical circuit used in making a transconductance test. Recommended operating voltages (E_g, E_f, E_{bb} etc.) are applied to the tube and a 1-volt rms signal is applied to the grid. The ac component of the resulting plate current is indicated by the ac milliammeter. The transformer in the plate circuit isolates the milliammeter so that it is not deflected by the dc component of plate current. The transconductance is then equal to the milliammeter reading (an rms reading) multiplied by 1000 $\left(g_m = \frac{i_b}{e_g}\right)$.

For example, if the plate milliammeter reads 3-mA rms, the tube's transconductance is 3 x 1000 = 3000 micromhos. The complete calculation is:

$$g_m = \frac{i_b}{e_g} = \frac{3 \text{ mA}}{1 \text{ volt}} = \frac{3 \times 10^{-3} \text{ amp}}{1 \text{ volt}} = 3 \times 10^{-3} \text{ mhos}$$

$$= 3{,}000 \times 10^{-6} \text{ mhos}$$

$$= 3{,}000 \text{ micromhos.}$$

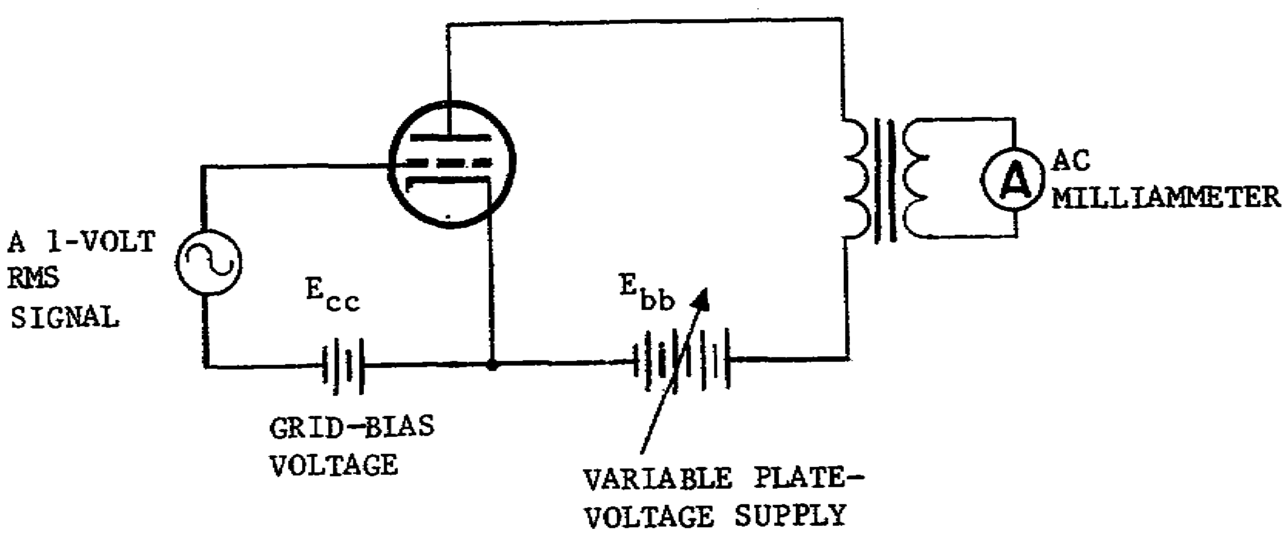


Figure 3-2. A circuit for a transconductance test.

3-6. EMISSION TEST

An emission test is generally made by a circuit of the form shown in figure 3-3 below. Rated filament voltage is utilized and a reasonable value of voltage is applied to the plate electrode. The milliammeter indicates whether the cathode is emitting properly. The various remaining electrodes (control grid, screen grid, etc.) are, by means of switches, attached to the plate, one at a time. Failure of the current to increase when a given electrode is connected is an indication that that particular electrode is open-circuited.

3-7. SHORT TESTS

Occasionally a short circuit develops between electrodes in a tube. A test for this condition consists merely in applying a voltage across the two suspected electrodes. A device to

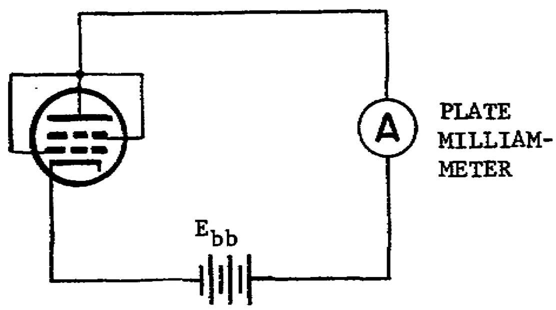


Figure 3-3. A circuit for an emission test.

detect current flow (a meter or neon lamp) in series with the voltage source will then indicate whether a short exists. Switches on the tube tester allow connection of the voltage source across any two suspected electrodes.

3-8. FILAMENT CONTINUITY TEST

Frequently a tube's filament burns out, leaving an open circuit between the filament electrodes. A filament continuity test is performed in the same manner as a short test. A voltage source is connected across the filament electrode, and current flow indicates the filament is "good," that is, not open-circuited.

3-9. USING A TUBE TESTER

Most tube testers will perform a variation of some or all of the tests discussed. The transconductance (g_m) and emission tests are the basic tests performed on most tube testers. It should be remembered, however, that a tube tester only provides an estimate of the condition of a tube. Many tubes will pass all tube tester tests and yet not operate properly in a certain circuit. The ultimate check on a tube's operation is to ascertain whether is does its job in the circuit in which it is said to be used.

PAGES 95 THRU 121

ARE EXTRACTS FROM TM 11-662/TO 16-1-255

AND ARE PROVIDED AS A SEPARATE PDF DOCUMENT

LESSON 4 - TRIODE CHARACTERISTICS

LESSON 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. Assume that a 0.2-volt change in the grid voltage on a certain triode causes exactly the same change in plate current as does a 4.0-volt change in plate voltage. The amplification factor (μ) of this triode is

a. 2.

b. 4.

c. 20.

d. 40.

2. Assume that a certain tube's plate current increases from 4 mA to 5 mA when the grid voltage, E_{CC} , changes by 0.5 volt. If plate voltage must be decreased 30 volts to return the plate current to 4 mA, the tube's amplification factor (μ) is approximately

a. 4.

b. 15.

c. 30.

d. 60.

SITUATION

Figure 3-4 below shows a triode circuit and a graph of the plate characteristics of the triode. The operating point of the triode is indicated on the characteristics by point Q. At point Q, the plate current is 7.0 mA and plate voltage is 210 volts.

Exercises 3 through 7 are based on the above situation.

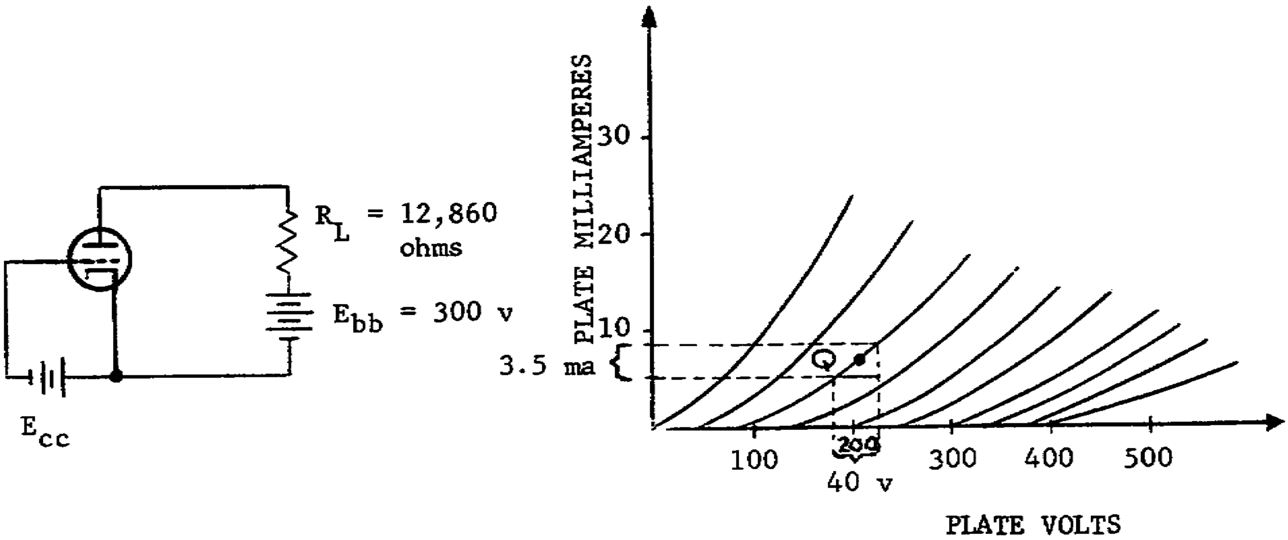


Figure 3-4. A basic triode circuit and plate characteristics.

3. At the quiescent conditions indicated by point Q, the do resistance of the triode R_p is

a. 10K.

b. 15K.

c. 21K.

d. 30K.

4. The ac resistance, r_p , of the tube describes the opposition the tube presents to small changes in plate current. The resistance offered by this tube to small changes around point Q is approximately

a. 3.5K.

b. 7.0K.

c. 11.4K.

d. 14.0K

NOTE: Use the changes shown in figure 3-4.

5. If the tube is operating at point Q, (fig. 3-4) and no signal is applied to the grid, what is the voltage drop across the load resistor?

a. 40 volts

b. 90 volts

c. 140 volts

d. 210 volts

6. If the grid-bias voltage, E_{CC} increases to a value so that the tube is cut off, the voltage drop across R_L will be equal to

a. zero.

b. -20 volts.

c. 150 volts.

d. 300 volts.

7. If you draw the circuit load line on the plate characteristics graph, at what point will it intersect the plate voltage axis?

a. 90 volts

b. 150 volts

c. 210 volts

d. 300 volts

8. Assume that you do not have the characteristic curves for a certain tube but you know that is has an r_p of 9,000 ohms and a g_m of 3,000 micromhos. You can calculate that this tube's amplification factor is

a. 27.

b. 30.

c. 270.

d. 300.

Exercises 9 through 13 are based on figure 3-5 below.

9. The point on the load line that corresponds to the quiescent conditions in the circuit of part A in figure 3-5 is point

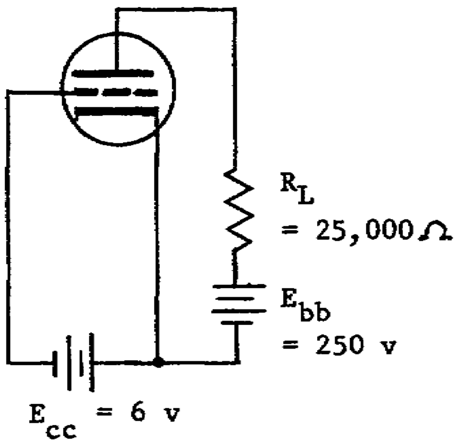
a. B. c. D.

b. C. d. E.

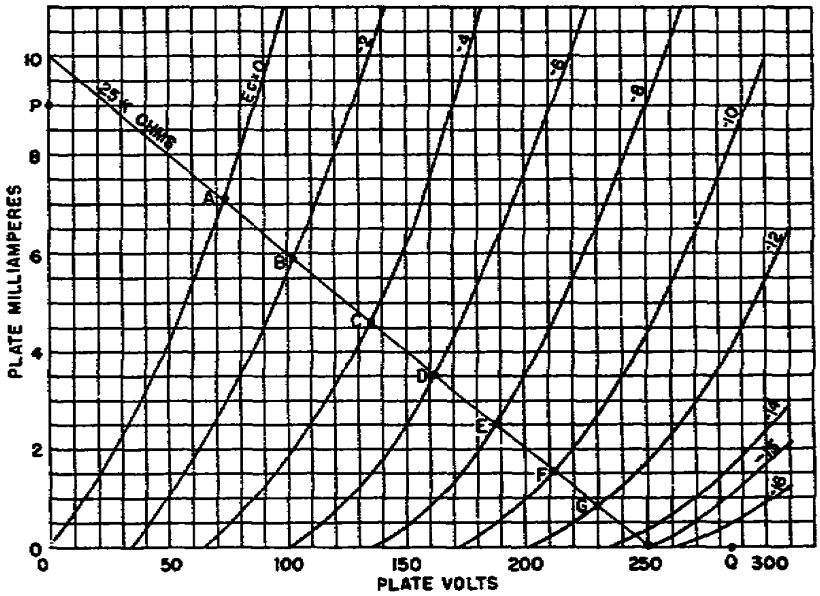
10. If the grid-bias voltage is momentarily changed to –4 volts, the current flowing in the plate circuit will momentarily increase to

a. 3.5 mA. c. 4.6 mA.

b. 4.1 mA. d. 5.8 mA.



PART A. THE TRIODE CIRCUIT



PART B. THE TRIODE'S PLATE CHARACTERISTICS WITH LOAD LINE

Figure 3-5. Analyzing the basic triode circuit.

11. Assume that an 8-volt peak-to-peak signal is applied to the grid circuit in the manner shown in figure 64 (TM 11-662). The point of operation on the load line will then vary between points

a. A and C.
b. A and G.
c. B and E.
d. B and F.

12. Assume that a 12-volt peak-to-peak voltage is applied to the grid circuit in the manner illustrated in figure 64 of TM 11-662. The load line shows that when the signal voltage swings 6 volts positive the plate current increases by 3.6 mA, and when the signal voltage swings 6 volts negative the plate current decreases by 2.7 mA. The fact that equal changes in grid voltage cause different changes in plate current shows that the

a. tube is defective.

b. output will be slightly distorted.

c. control-grid bias is not functioning properly.

d. interelectrode capacitances will be abnormally high.

13. If the load resistor is changed to 50K, the orientation of the load line will change. However, the load line still intersects the plate voltage axis at 250 volts, but will intersect the plate current axis at

a. 2 mA.
b. 5 mA.
c. 10 mA.
d. 15 mA.

14. As a circuit's load resistance is changed, there is a significant effect upon the linearity of the dynamic transfer characteristic and, therefore, upon the distortion. What effect will an increase in the load resistance have on the transfer characteristic and the distortion?

a. The transfer characteristic becomes straighter and, therefore, the distortion decreases.

b. The transfer characteristic becomes straighter and, therefore, the distortion increases.

c. The transfer characteristic becomes more curved and, therefore, the distortion decreases.

d. The transfer characteristic becomes more curved and, therefore, the distortion increases.

15. Figure 3-6 below illustrates the dynamic transfer characteristic for a certain triode circuit. If, in this circuit, E_{CC} = -3 volts, then the operating point (point of quiescent conditions) on the transfer characteristic will be point

a. A.

b. B.

c. C.

d. D.

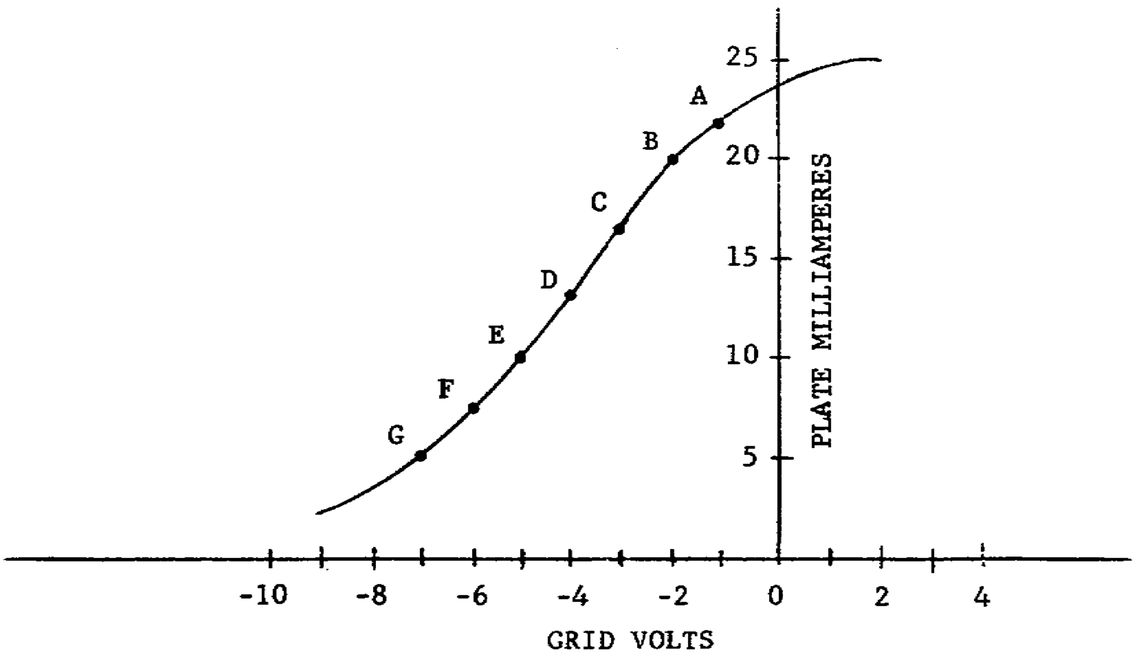


Figure 3-6. A dynamic transfer characteristic curve.

16. Assume that point D is the operating point on the transfer characteristic in figure 3-6, and a 6-volt peak-to-peak signal is applied to the grid. The plate current will then vary between the limits of

a. 5 and 22 mA.

b. 7 and 13 mA.

c. 7 and 20 mA.

d. 13 and 22 mA.

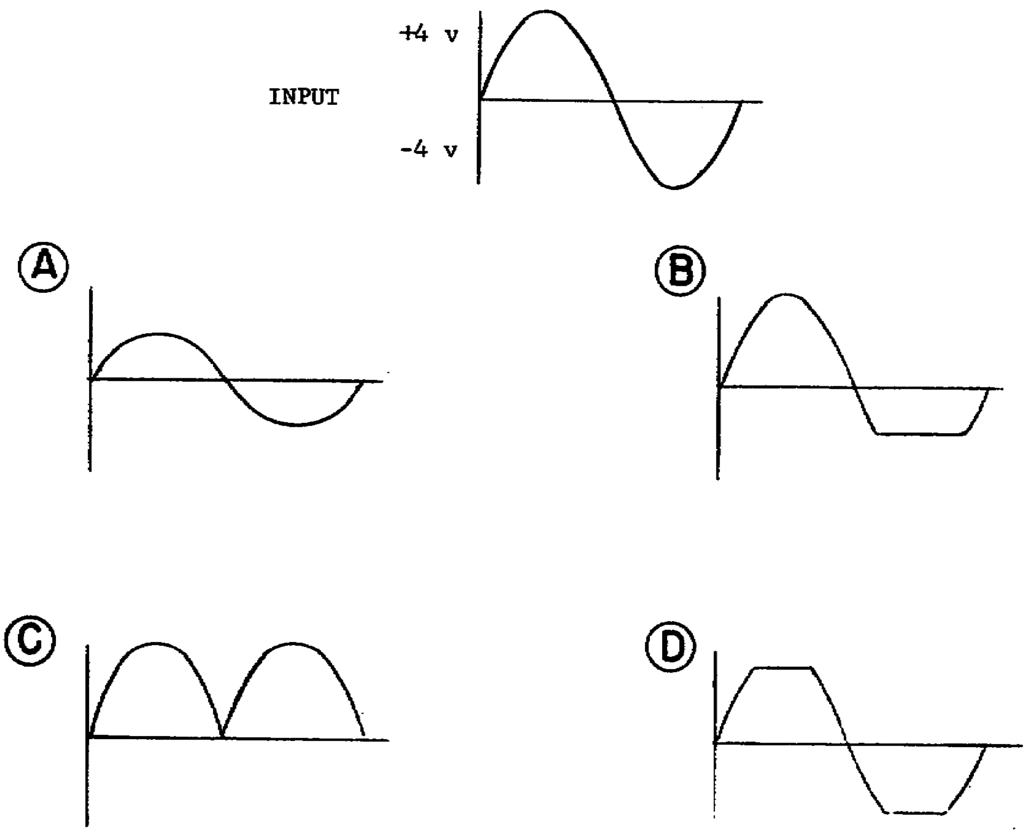
17. Assume that you are using the dynamic transfer characteristic in figure 3-6 to determine the plate-current waveform for a triode circuit biased at -7 volts (point G). If the input signal shown in figure 3-7 is applied to the grid, the plate-current waveform will be most like the waveform shown in figure 3-7 in the sketch labeled.

a. A.

b. B.

c. C.

d. D.



18. The interelectrode capacitance existing between a tube's control grid and its cathode is designated by the symbol

a. C_{pk}.

b. C_{gk}.

c. C_{gp}.

d. C_{cgc}.

19. Interelectrode capacitance in an electron tube should be kept as low as possible. A high grid-to-plate capacitance is undesirable in a triode because it

a. neutralizes the feedback action.

b. minimizes the possibility of oscillation.

c. results in harmful interaction between the control grid circuit and the plate circuit.

d. causes distortion by introducing serious curvature in the circuit's dynamic transfer characteristic.

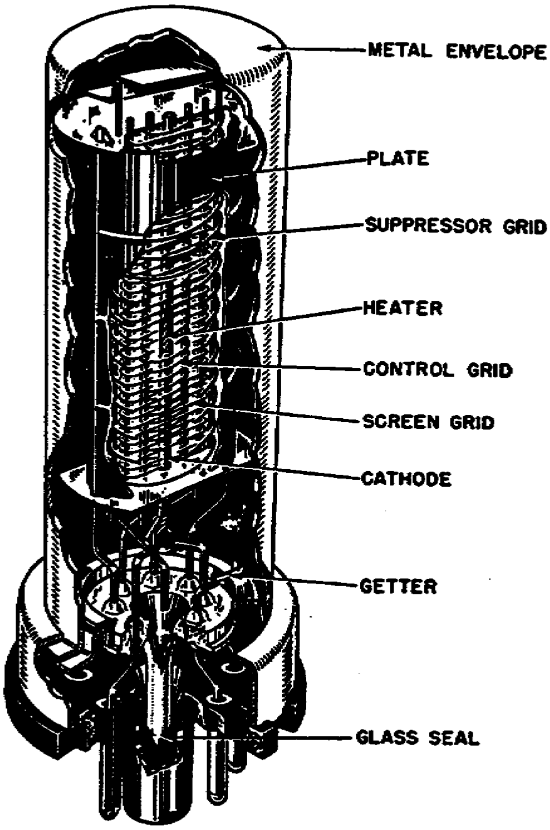
20. Assume that the proper adjustments for a transconductance measurement have been made in the circuit shown in figure 3-2 of this lesson booklet. If the plate milliammeter indicates a 4.5-mA (rms) plate current, the tube's transconductance is

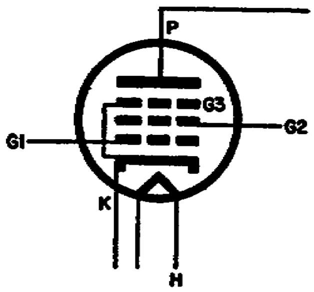
a. 3,500 micromhos.

b. 4,000 micromhos.

c. 4,500 micromhos.

d. 5,000 micromhos.





multielement tubes

lesson five

multielement tubes

INTRODUCTION

Early in the history of tube development and application, tubes were designed for general service. That is, one type of tube, the triode, was used for many varied applications. Obviously, this one tube could not meet every possible requirement and do it effectively.

Present trends in tube design are the development of "specialty" type tubes. These tubes are designed either to give optimum performance in a particular application; or to combine in one vacuum envelope functions which required two or more tubes.

The construction and theory of operation of these multi-electrode tubes will be discussed in this lesson.

TEXT ASSIGNMENT

TM 11-662, chapter 5, paragraphs 60-74

RESOURCE REQUIREMENTS

Signal Subcourse SS0311

LESSON OBJECTIVES

When you have completed this lesson you should:

1. Know the function of the screen grids and the effects they have on the tetrode and pentode tubes.

2. Be able to explain the function of the suppressor grid and the effects of its secondary emission in pentode tubes.

3. Know the theory and application of beam power tubes.

4. Know the function of the different types of multigrid tubes.

PAGES 132 THRU 157

ARE EXTRACTS FROM TM 11-662/TO 16-1-255

AND ARE PROVIDED AS A SEPARATE PDF DOCUMENT

LESSON 5 - MULTIELEMENT TUBES

LESSON 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 tetrode and pentode tube types often are used in place of the triode at frequencies between the audio and microwave ranges. In general, the triode requires neutralizing circuits at high frequencies because the

a. interelectrode capacitance couples an undesirable feedback from the output circuit back to the input circuit.

b. secondary emission creates a negative resistance region in the tube's transfer characteristic.

c. single control grid cannot withstand the high frequency plate current.

d. amplification factor is often too large for high-frequency applications.

2. A fourth electrode, called the screen grid, exists in a tetrode, which is not found in a triode. The purpose of the screen grid is to

a. act as an electrostatic shield between the control grid and the plate, thus reducing Cgp .

b. shield the control grid from the effects of secondary emission.

c. supplement the controlling action of the control grid.

d. collect electrons that do not reach the plate.

3. The control grid or plate electrode is sometimes connected to a cap on the top of an electron tube. The reason for this practice is to

a. allow visual examination of the electrode.

b. allow that particular electrode to dissipate its heat.

c. provide an electrode that will collect the spurious electrons rising to the top of the tube.

d. provide physical separation of the control grid and plate electrodes in order to minimize grid-to-plate capacitance.

SITUATION

Figure 4-1 shows a tetrode circuit and the plate characteristic for the tetrode.

Exercises 4 through 8 are based on this situation.

4. Note the four points: A, B, C and D, in part A of figure 4-1. The input of the tube in this circuit is between points

a. A and C. c. B and D.

b. B and C. d. C and D.

5. What is the value of the screen grid voltage, E_{C2}?

a. 100 volts. c. 200 volts.

b. 150 volts. d. 250 volts.

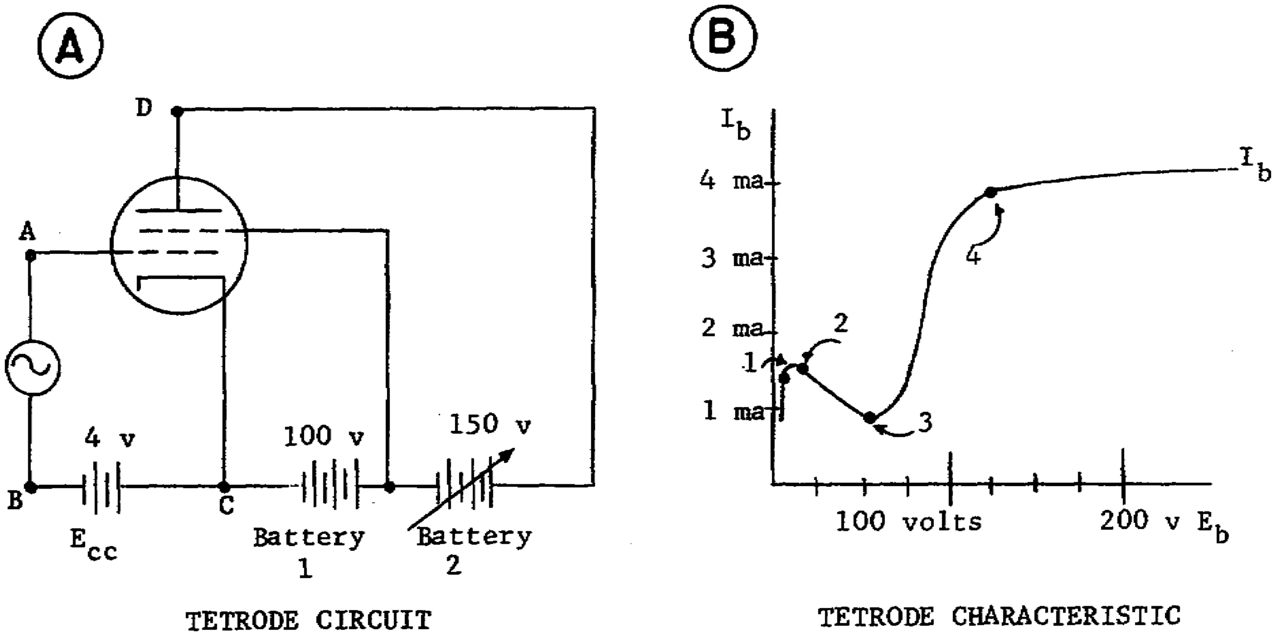


Figure 4-1. A tetrode circuit and characteristic.

6. If the plate voltage in a tetrode circuit is kept greater than a certain minimum value, large variations in plate voltage will have little effect on the value of plate current. In this circuit, this minimum value of plate voltage is approximately

a. 5 volts.

b. 50 volts.

c. 100 volts.

d. 125 volts.

7. The plate characteristic curve shown in part B of figure 4-1 illustrates how plate current varies with plate voltage. In the region between points 3 and 4, both plate current and screen current are changed by a change in plate voltage; that is, an increase in plate voltage will cause

a. a decrease in plate current and a decrease in screen current.

b. a decrease in plate current and an increase in screen current.

c. an increase in plate current and a decrease in screen current.

d. an increase in plate current and an increase in screen current.

8. The plate characteristics of a tetrode are said to have a region of negative resistance or a region in which a decrease in plate voltage will cause an <u>increase</u> in plate current or vice versa. This region is noted on the characteristic of part B (fig. 4-1) between points

a. 1 and 2.

b. 2 and 3.

c. 2 and 4.

d. 3 and 4.

9. Negative resistance effects are greatly reduced in modern tetrode tubes. This has been accomplished by

a. improvements in plate material.

b. use of isolating top cap connections.

c. nonuniform design of the control grid.

d. overlapping design of the grids within the tube.

10. The purpose of the suppressor grid in a pentode is to suppress the effects of

a. secondary emission.

b. high plate resistance.

c. plate-current saturation.

d. cathode-to-plate capacitance.

11. When a pentode is used with a high load resistance, the transfer characteristic develops a sharp "knee." This can be a disadvantage, because when such curvature in the transfer characteristic is near the operating point, it indicates the presence of

a. abnormally high transconductance.

b. high grid-to-plate capacitance.

c. secondary emission effects.

d. distortion.

12. A comparison of the two methods of aligning the screen and control grids (fig. 82 of TM 11-662) shows that method B allows more electrons to reach the plate. Another advantage gained by aligning the grids by using method B is

a. an increase in screen current.

b. a reduction in plate resistance.

c. an increase in the amplification factor.

d. a reduction in the effects of secondary emission.

13. Consider the effect of the plate voltage, the screen voltage, the control grid bias, and the plate load resistance on a pentode's transconductance rating. Which of these four can be changed without affecting the transconductance?

a. The plate voltage

b. The screen voltage

c. The control grid bias

d. The plate load resistance

14. The beam-forming plates in a beam power tube create an electric plane called the <u>virtual</u> <u>cathode</u>. The purpose of this virtual cathode is to

a. repel the secondary electrons emitted from the plate.

b. repel the electrons emitted from the actual cathode.

c. increase the plate resistance of the tube.

d. increase the screen current.

15. If a pentode's screen and suppressor grid leads are connected to the plate lead, the pentode's characteristics will more closely resemble those of a

a. diode.

b. triode.

c. tetrode.

d. beam power tube.

16. Assume that, as an experiment, you rewind the wires of the control grid of a pentode so as to make it a variable-μ pentode. How will this "new" tube differ in its operation from one with a conventional control grid?

a. The plate current will become independent of plate voltage at lower plate potentials.

b. The plate resistance will increase at low values of grid bias.

c. The grid-bias cutoff voltage will be greater.

d. The grid current will increase.

17. The suppressor grid in a pentode is located between the

a. control grid and the screen grid.

b. cathode and the control grid.

c. screen grid and the plate.

d. screen and the cathode.

18. The pentode tube element that performs approximately the same function as the beam-forming plates in a beam power tube is called a

a. plate. c. screen grid.

b. cathode. d. suppressor grid.

19. The pentagrid converter tube shown in figure 90 of TM 11-662 is a heptode that can be considered to be made up of two smaller tubes. These two tubes are a

a. pentode and a diode.

b. pentode and a hexode.

c. triode and tetrode.

d. triode and a beam power tube.

20. A multiunit tube houses the electrodes for two or more tubes inside one envelope. Of the four multiunit tube symbols shown in figure 4-2, which is the symbol for a triode-pentode tube?

a. A c. C

b. B d. D

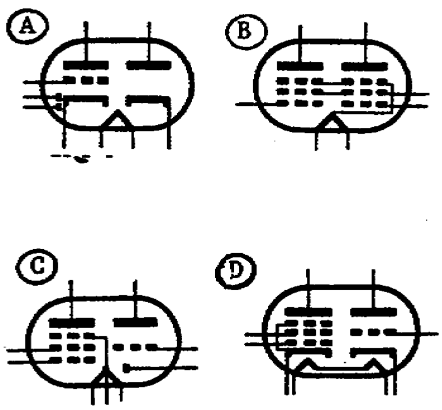


Figure 4-2. Four multiunit tube symbols.

HOLD ALL TEXTS AND MATERIALS FOR USE WITH EXAMINATION AND SS0312.

LESSON SOLUTIONS

SIGNAL SUBCOURSE SS0311 ....ELECTRON TUBES

Lesson 1 ....Electron Emission

All references are to TM 11-662

1. d - para 5a

2. c - para 4c

3. a - para 6f

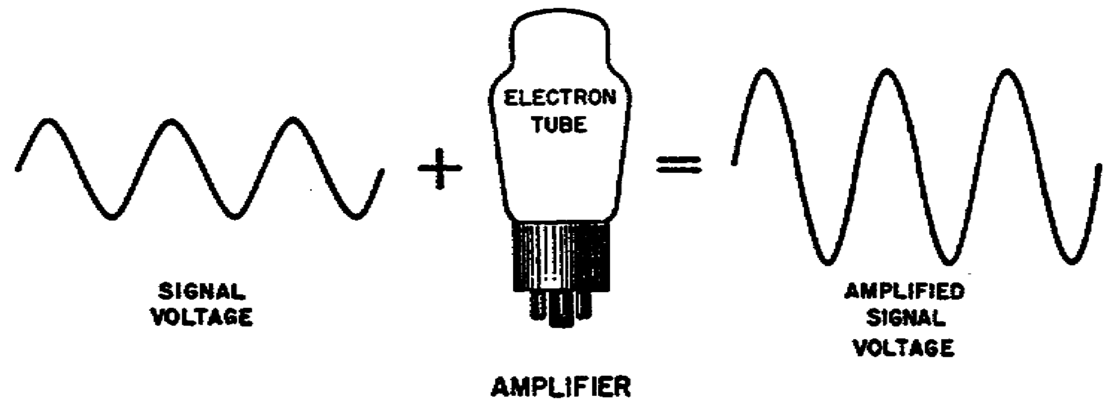
4. c - para 3g

5. c - para 5e

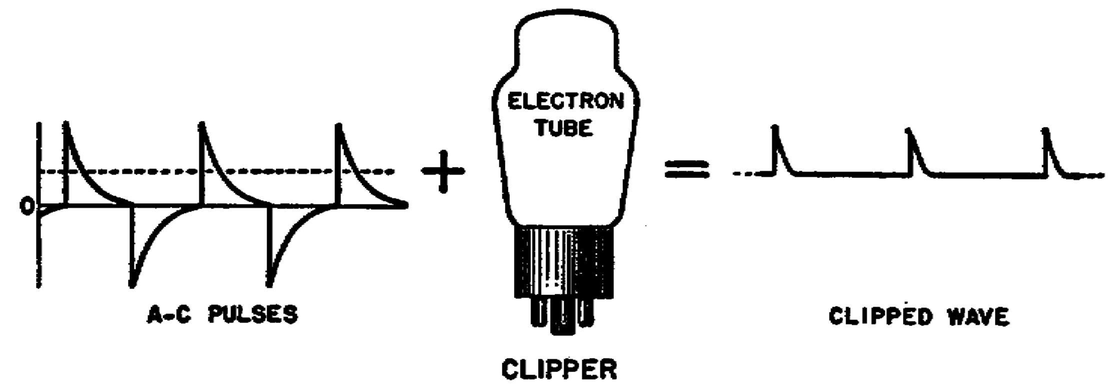
6. d - para 6e

7. a - para 4b

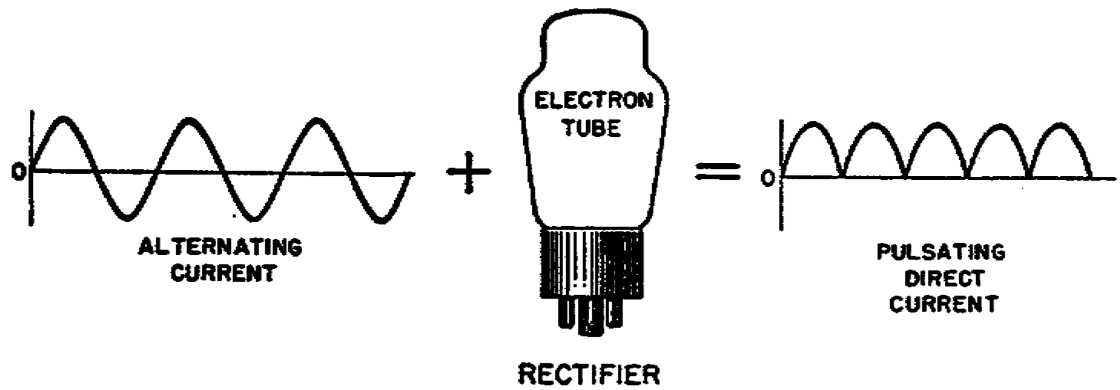
8. para 5b



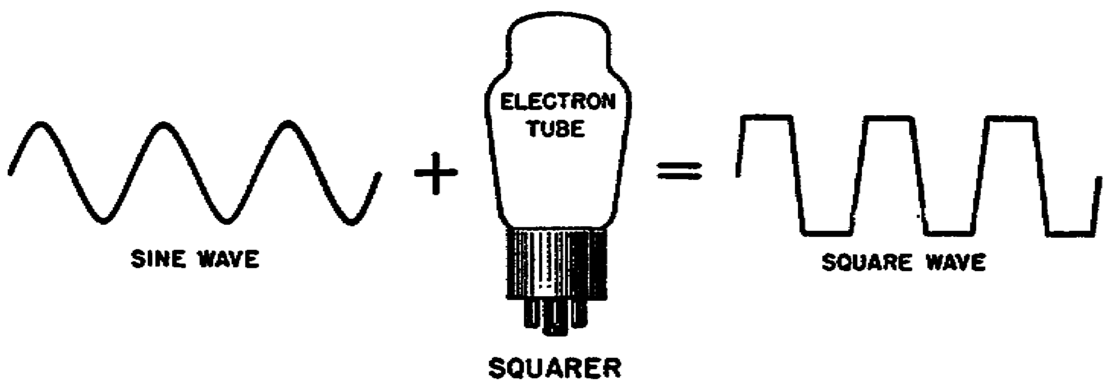
9. para 5d



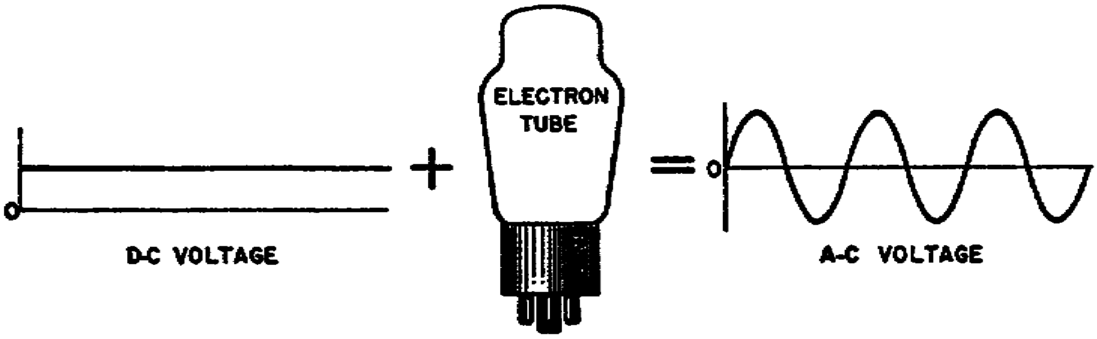
10. para 5a



11. para 5b



12. para 5c



A-C GENERATOR

13. d -- para 3c, d

14. b -- para 5b

15. c -- para 3e

16. c -- para 8a, 9b

17. d -- para 11, 11b

18. a -- para 12a

Lesson 2 ....Diodes

All references are to TM 11-662.

1. a -- para 15b

2. b -- para 15j

3. c -- para 15i; fig. 19

4. c -- para 16m

5. a -- para 17b

6. d -- para 17h

7. d -- para 17k

8. a -- para 18h; fig. 25

9. a -- para 22c

10. b -- para 22_d_

11. d -- para 23_c_

12. b -- para 23_d_

13. b -- para 24_d_

In figure 30, a plate voltage of 450 volts causes a plate current of 70 milliamperes. Therefore, the dc plate resistance is

$R_p = E_b/I_b$ = 450 volts/70 mA = 450/0.07 = 6,400 ohms.

14. d -- para 24_h_

15. b -- para 24_f_, 25_f_

16. c -- para 25_d_

$$\text{ac plate resistance} = \frac{\text{change in } e_p}{\text{change in } i_p} = \frac{14 - 12}{23 - 18} = \frac{2 \text{ volts}}{5 \text{ mA}}$$

ac plate resistance = 400 ohms.

17. d -- para 26_a_

Lesson 3 ....Triode Fundamentals

All references are to TM 11-662.

1. a -- para 32_a_, _e_(7)

2. d -- para 32_b_(3)

3. b -- para 32_b_(3)

4. d -- para 32_f_; fig. 41

5. a -- para 33_b_(l); fig. 42

6. c -- para 35_b_, _d_; fig. 45

7. a -- para 35_e_(1)

8. c -- para 35_e_(3)

9. c -- para 42d(2)

10. a -- para 39b; fig. 48

11. a -- para 39c

With a 14-volt peak-to-peak signal, the maximum positive swing of signal voltage will be 7 volts. Therefore, a fixed bias of minus 8 volts will maintain the grid at a negative value.

12. d -- para 41b(4)

13. b -- para 42b, 43a

14. c -- para 42c(2)

15. a -- para 42g(1)

16. c -- para 42f(1)

17. a - para 43d(1); fig. 53

18. b -- para 43d(2), (3); fig. 53

On the 200-volt plate voltage curve, a current of 3.4 mA is seen to correspond to a grid voltage of -8 volts. When the plate voltage is increased to 250 volts, the 250-volt curve shows a plate current of 8.9 mA corresponding to a grid voltage of -8 volts. Thus the increase in plate current is:

8.9 - 3.4 = 5.5 mA.

19. b -- para 43d(3)

20. c -- para 43e

Lesson 4 .... Triode Characteristics and Constants

All references are to TM 11-662, unless otherwise indicated.

1. c -- para 46a

$$\textbf{Amplification Factor} = \frac{\text{small change in plate voltage}}{\text{small change in grid voltage}} = \frac{4.0}{0.2} = 20$$

2. d -- para 46a

A change of 30 volts in plate voltage results in the same change in plate current as a 0.5-volt change in grid voltage. The ratio of these small changes in voltage is

$$\textbf{amplification factor, ( ) } = \frac{e_b}{e_g} = \frac{30}{0.5} = 60$$

3. d -- para 48b

The dc resistance is determined by applying Ohm's Law, where the numerator is the steady voltage at the plate, e_b 210 volts, and the denominator is the corresponding steady plate current, I_b = 7.0 mA.

$$R_p = \frac{210V}{7.0\ mA} = \frac{210}{.007} = 30K$$

4. c -- para 48c; Attached Memorandum, fig. 3-4

The construction on the plate characteristics of figure 3-4 shows that near point Q a 3.5-mA change in plate current is associated with a 40 volt total change in plate voltage:

$$r_p = \frac{e_b}{i_b} = \frac{40V}{3.5\ mA} = \frac{40}{.0035} = 11.4K$$

5. b -- para 52c(2)

This problem can be solved in two different ways.

(1) The sum of the voltage drops around the circuit must be equal E_{bb}:

$E_{bb} = e_b + I_bR_L$

Therefore: $I_bR_L = E_{bb} - e_b = 300 - 210 = 90$ volts.

(2) It is known that the steady value of plate current, I_b, is 7.0 mA. Thus the voltage drop across the resistor, I_bR_L can be calculated directly:

I_bR_L = (7.0 mA)(12,860 ohms) = 90 volts.

6. a -- para 51e(2)

7. d -- para 52c(1)

At the point where the load line intersects the plate voltage axis, the plate current is zero and there is no voltage drop across the load resistor, R_L . Therefore, the voltage drop across the tube must equal to the supply voltage, E_bb: 300 volts.

8. a -- para 50d(2)

$$= r_p \times g_m = 9{,}000 \text{ ohms} \times 3{,}000 \text{ micromhos}$$

$$= 9{,}000 \text{ ohms} \times .003 \text{ mhos}$$

$$= 27$$

9. c -- para 52a, 52c(2), 56a

10. c -- para 52c, d; Attached Memorandum, fig. 3-5

In figure 3-5 a horizontal line drawn from point C (E_{cc} = -4V) to the plate current axis shows the plate current to be 4.6 mA.

11. d -- para 52c, d

When the signal voltage swings 4 volts positive, the grid voltage will be -2 volts ($E_{cc} + e_s = e_g$, or -6 + 4 -2) and the corresponding point of operation will be point B. When the signal voltage swings 4 volts negative, the grid voltage will be -10 volts and the point of operation will be point F.

12. b -- para 52d(2), 56d(1); fig. 65

13. b -- para 52c(1)

When the load line intersects the plate current axis, the voltage across the tube is zero (e_b = 0). Thus, at this point the current in the plate circuit is limited only by R_L and is found to be:

$I_b \quad E_{bb}/R_L = 250/50K = 5$ mA.

14. a -- para 53g, 54b

15. c -- para 56a; fig. 65

16. a -- para 56c; fig. 65

When the signal voltage swings 3 volts negative, the grid voltage will be -7 volts (operating point G), and the plate current will be approximately 5 mA. When the signal voltage swings 3 volts positive, the grid voltage will be -1 volt (operating point A) and the plate current will be approximately 22 mA.

17. b -- para 56b(2); fig. 66

18. b -- para 57b; fig. 67

19. c -- para 57d

20. c -- Attached Memorandum, para 3-5

g_m = ac plate milliameter reading x 1,000

= 4.5 x 1,000 = 4,500 micromhos

Lesson 5 ....Multielectrode Tubes

All references are to TM 11-662.

1. a -- para 60a

2. a -- para 61e(1)

3. d -- para 61b(2)

4. a -- para 61d(1)

5. a -- para 61d(2); fig. 70

6. d -- para 62f; fig. 71

7. c -- para 62e; fig. 71

8. b -- para 62i

9. a -- para 62j

10. a -- para 66d

11. d -- para 69

12. b -- para 70f

13. d -- para 68c(2); fig. 77

Changes in screen grid voltage, plate voltage, and grid bias all affect the transconductance, as shown in figure 77.

14. a -- para 70h

15. b -- para 71; fig. 86

16. c -- para 72f; fig. 87

17. c -- para 66d; fig. 75

18. d -- para 70g, h

The beam-forming plates are connected to the cathode and are used to eliminate the effects of secondary emission. They perform, therefore, the function of the suppressor grid.

19. c -- para 73d(2)

20. d -- para 74, fig. 92J

a. Symbol A represents a triple-diode-triode.

b. Symbol B represents a duo-pentode tube.

c. Symbol C represents a diode-triode-pentode tube.

d. Symbol D represents a triode-pentode tube.

PAGES 186 THRU 189

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