EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL

SUBCOURSE 106, TRANSISTORS

INTRODUCTION

The introduction of the first transistor in 1948 was accompanied by a forecast that it would, because of its small size, its durability, and its low power requirements, completely alter many of the existing electronics practices. Since that time, the forecast has been substantiated in large part, and an increasing variety of transistors with improvements in quality, dependability, and adaptability has become available. There is no doubt that transistors will have an even greater effect on the design of all types of electronic equipment in the next decade.

Although they serve substantially as replacements of the vacuum tube, it is not enough to think of transistors in such limited terms. Because they are solid-state semiconductors, they have patterns of electron flow quite different from tubes. It is important for anyone interested in electronics to understand these patterns and to know the general advantages and limitations of transistors.

Transistors can serve as amplifiers, oscillators, detectors, multivibrators, or in countless other applications. These applications, both in the types of circuit functions and the different equipments in which they are used, are described in the text material accompanying this subcourse. The subcourse first treats the physical and chemical fundamentals of transistor operation. The fundamentals and characteristics of transistor amplifier circuits are then covered extensively, and other types of transistor circuits and applications are discussed.

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

Lesson 1. Fundamental Theory of Transistors

Lesson 2. Transistor Amplifier Fundamentals

Lesson 3. Audio Amplifiers

Lesson 4. Tuned RF Amplifiers

Lesson 5. Oscillators

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Lesson 6. Pulse and Switching Circuits

Lesson 7. Modulation, Mixing, and Demodulation

Lesson 8. Servicing Transistor Circuits

Lesson 9. Transistor Circuit Applications

Examination

Credit Hours: 21

There is no limit to the time you may spend on any lesson or the examination. For statistical purposes, however, you are required to enter on each answer sheet the total number of hours spent on the solution.

Text and materials furnished:

TM 11-690, Basic Theory and Application of Transistors, 17 March 59 W/Changes C1 and DN1 Errata

Attached Memorandum

All textual material, other than the Attached Memorandum, will be returned to the school upon completion of the subcourse. Please do not deface the text as it is to be used by other students.

LESSON 1 . . . . Fundamental Theory of Transistors

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 1-35, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To introduce you to the subject of transistors and to show how the electron and crystalline structure of semiconductors is used in transistor operation

SUGGESTIONS . . . . None

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 answer sheet by filling in with pencil the appropriate lettered block.

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

1. An elemental charge is the smallest electrical charge yet discovered. The polarity of this charge is

   a. negative when it refers to either an electron or a proton.

   b. positive when it refers to either an electron or a proton.

   c. negative when it refers to an electron and positive when it refers to a proton.

   d. positive when it refers to an electron and negative when it refers to a proton.

2. Some of the fundamental building blocks of nature are electrons, protons, and neutrons. If the nucleus of an atom contains 73 of these sub-atomic particles, 41 of which are neutrons, how many electrons are needed for electrical balance?

   a. 16

   b. 32

   c. 41

   d. 73

3. A semiconductor is a material whose resistivity is in the range between conductors and insulators. As the temperature rises, the value of this resistivity

   a. increases rapidly.

   b. increases slowly.

c. decreases rapidly.

d. decreases slowly.

4. Most metals, such as copper, are characterized by the formation of extremely small crystals into one mass. Germanium, as prepared for use in transistors, however, is characterized by

a. a uniform cubical structure.

b. an irregular cubical structure.

c. a uniform polycrystalline structure.

d. an irregular polycrystalline structure.

5. The arrangement of germanium cores and electron-pair bonds is referred to as a lattice. Each germanium core is equidistant from four adjacent germanium cores. How many valance electrons are required per core to form and complete adjacent electron-pair bonds?

a. Two

b. Four

c. Eight

d. Sixteen

6. When an impurity such as arsenic is added to a pure germanium crystal, which electrons are current carriers under normal conditions?

a. Valence electrons of the impurity that form electron-pair bonds

b. Valence electrons of the impurity that do not form electron-pair bonds

c. Valence electrons of the germanium atoms that form electron-pair bonds

d. Valence electrons of the germanium atoms that do not form electron-pair bonds

7. Adding atoms with either three or five valence electrons to germanium results in the formation of an impure crystal. Atoms with three valence electrons are called

a. donors and produce a P-type crystal.

b. donors and produce an N-type crystal.

c. acceptors and produce a P-type crystal.

d. acceptors and produce an N-type crystal.

8. The hole in a germanium crystal results from the substitution of an acceptor impurity for a germanium atom within the crystal lattice. Two specific characteristics of a hole are that it is

a. negatively charged and independent of the crystalline structure.

b. positively charged and independent of the crystalline structure.

c. negatively charged and dependent upon crystalline electron-pair bonds for existence.

d. positively charged and dependent upon crystalline electron-pair bonds for existence.

9. When a battery is connected across a P-type germanium slab, the current carriers within the slab are

a. holes which flow from the negative to the positive side of the slab.

b. holes which flow from the positive to the negative side of the slab.

c. electrons which flow from the negative to the positive side of the slab.

d. electrons which flow from the positive to the negative side of the slab.

10. When P-type germanium and N-type germanium are joined to form a PN junction, combinations of holes and excess electrons result. After a short time a barrier is formed, restraining further combination. The electric field that exists between the acceptor and donor ions is a restraining force because of its

a. width.

b. density.

c. polarity.

d. intensity.

11. When a reverse bias is placed across the terminals of a PN junction, the holes are attracted toward the negative terminal and the excess electrons are attracted toward the positive terminal. After a short time the barrier height becomes

a. considerably less than the potential of the external battery, and current flow is excessive.

b. approximately equal to the potential of the external battery, and current flow is excessive.

c. considerably less than the potential of the external battery, and current flow is insignificant.

d. approximately equal to the potential of the external battery, and current flow is insignificant.

12. When a forward bias is placed across the terminals of a PN junction, some of the holes and the excess electrons penetrate the depletion region and combine. Under this condition, the current flow through the junction is high, and the barrier height with respect to the potential of the external battery is

a. less.

b. greater.

c. the same.

d. eliminated.

13. A junction transistor is a sandwich of P-, N-, and P-type germanium, or N-, P-, and N-type germanium. For correct transistor action, the junctions of a PNP transistor must be biased so that the collector-to-base voltage and the emitter-to-base voltage are, respectively

a. negative and negative.

b. positive and positive.

c. negative and positive.

d. positive and negative.

14. The collector, base, and emitter of a junction transistor are comparable respectively to which elements of a vacuum tube?

a. Cathode, grid, and plate

b. Grid, cathode, and plate

c. Plate, cathode, and grid

d. Plate, grid, and cathode

15. The collector current of a junction transistor is relatively constant in the region between X and Y in A of figure 38 (TM 11-690) because of the high collector resistance. This high collector resistance is due primarily to the

a. internal resistance of the base region.

b. internal resistance of the collector region.

c. limited supply of carriers through the emitter-base barrier.

d. profuse supply of carriers through the emitter-base barrier.

LESSON 2 . . . . Transistor Amplifier Fundamentals

CREDIT HOURS 2

TEST ASSIGNMENT . . . . TM 11-690, par. 36-44, incl, par. 74-106, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE To familiarize you with the basic amplifier circuit configurations, and the problems involved in stabilizing the operation of transistor circuits

SUGGESTIONS . . . . None

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 answer sheet by filling in with pencil the appropriate lettered block.

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

16. The emitter arrow of a PNP or an NPN transistor symbol points in the direction

a. identical to that of the electron flow in the external circuit.

b. identical to that of the majority carriers within the transistor.

c. opposite to that of the electron flow in the external circuit.

d. opposite to that of the majority carriers within the transistor.

17. When the base element of a transistor amplifier is common to the input circuit and the output circuit, the configuration is referred to as a common-base amplifier. Such an amplifier is characterized by the fact that the input impedance is

a. high and the output impedance high.

b. low and the output impedance high.

c. high and the output impedance low.

d. low and the output impedance low.

18. A common-emitter amplifier may be properly biased with a single battery. Internally, the two PN junctions act as a voltage divider and develop the

a. forward base-emitter bias.

b. reverse base-emitter bias.

c. forward collector-emitter bias.

d. reverse collector-emitter bias.

19. There is no voltage phase reversal of a signal amplified by a common-base amplifier. In a common-emitter circuit using an NPN transistor, when the input signal goes positive, it

a. aids the base-emitter bias, and the output signal goes positive.

b. aids the base-emitter bias, and the output signal goes negative.

c. opposes the base-emitter bias, and the output signal goes positive.

d. opposes the base-emitter bias, and the output signal goes negative.

20. If an NPN common-base amplifier has a current gain (α_{fb}) of 0.95, a total emitter current (I_e) of 2 ma, and a reverse-bias current (I_{CBO}) of 0.02 ma, what is the magnitude of the base lead current, and in what direction is it flowing?

a. 0.02 ma toward the base

b. 0.02 ma away from the base

c. 0.08 ma toward the base

d. 0.08 ma away from the base

21. The effect of the negative temperature coefficient of the emitter-base junction resistance in a junction transistor may be minimized by

a. decreasing the external emitter resistance.

b. increasing the external emitter resistance.

c. decreasing the forward bias as the temperature decreases.

d. increasing the forward bias as the temperature increases.

22. If a good current stability factor is required in a common-collector transistor amplifier, the emitter resistance and the base resistance, respectively, must be

a. low and low.

b. low and high.

c. high and low.

d. high and high.

23. The thermistor shown in figure 77 (TM 11-690) is used to lessen the change in collector current due to changes in temperature. If the temperature increases, the thermistor resistance and the emitter-base forward bias

a. both increase.

b. both decrease.

c. decrease and increase, respectively.

d. increase and decrease, respectively.

24. Double-diode stabilization compensates for variations of both emitter-base junction resistance and saturation current with temperature. To accomplish double-diode stabilization, one diode is

a. forward-biased to track the emitter-base junction resistance, and the other diode is reverse-biased to track the saturation current.

b. reverse-biased to track the emitter-base junction resistance, and the other diode is forward-biased to track the saturation current.

c. forward-biased to stabilize the emitter-base junction current, and the other diode is reverse-biased to track the collector current.

d. reverse-biased to stabilize the emitter-base junction current, and the other diode is forward-biased to track the collector current.

25. The emitter-collector current of transistor Q1 in figure 85 (TM 11-690) can be used in conjunction with the emitter-collector current of transistor Q2 for temperature-stabilized operation. The emitter-collector current is common to both Q1 and Q2 and is stabilized by a

a. common emitter-base voltage developed at Q1.

b. common emitter-base voltage developed at Q2.

c. swamping resistor in the emitter lead of Q1.

d. swamping resistor in the emitter lead of Q2.

26. Assume that diode CR1 in figure 89 (TM 11-690) is rated at a maximum current of 2 ma and a breakdown voltage of 12 volts. If battery V_c supplies 24 volts, what value of R2 is necessary to maintain maximum current through CR1 when the collector current I_c is zero?

a. 3,000 ohms

b. 6,000 ohms

c. 12,000 ohms

d. 24,000 ohms

27. Assume that the operating point of the common-emitter transistor circuit shown in A of figure 91 (TM 11-690) is 20 μa, the peak-to-peak input current (I_B) is 10 μa, the emitter-base resistance (r_i) is 500 ohms, and the load resistance (R2) is 2,000 ohms. Using the characteristic curves shown in figure 1 and a collector-supply voltage of 12 volts, determine the approximate power gain of the circuit.

a. 18,000

b. 33,000

c. 65,000

d. 144,000

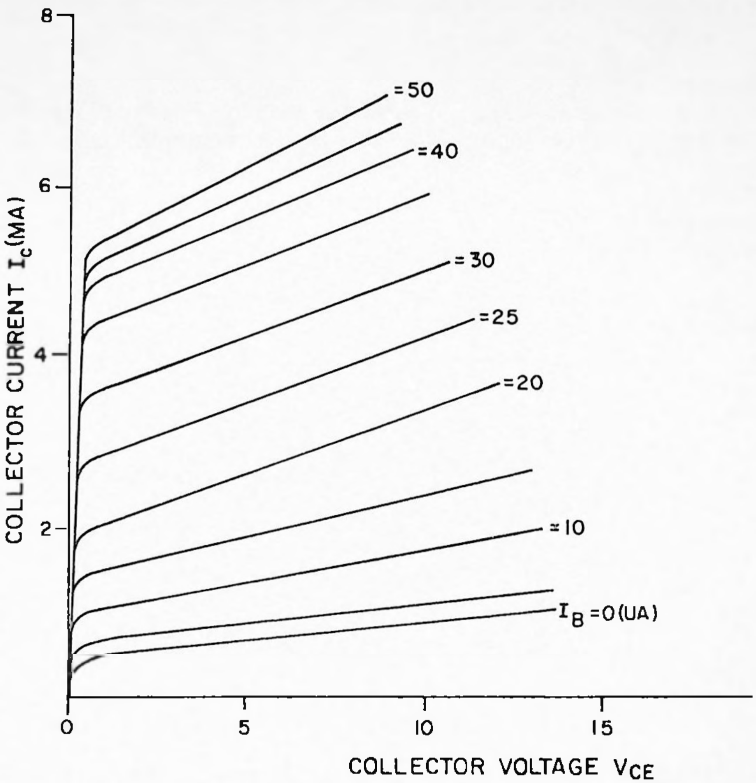

Figure 1. Output characteristic curves of CE amplifier.

28. A dynamic transfer characteristic curve shows the operating conditions of a transistor amplifier using a given value of load impedance. One of the important amplifier characteristics that may be determined from a transfer curve is the amount of change in the value of

a. base current produced by a given change in emitter current.

b. base current produced by a given change in collector voltage.

c. collector current produced by a given change in base current.

d. collector current produced by a given change in collector voltage.

29. In a high-frequency transistor amplifier, an increase in collector current may result in oscillation because the

a. emitter-base capacitance is increased.

b. emitter-base capacitance is decreased.

c. collector-base capacitance is increased.

d. collector-base capacitance is decreased.

30. For all transistor amplifier configurations (common-base, common-emitter, or common-collector), the voltage gain (A_V) increases with increasing

a. load resistance (R_L).

b. input resistance (r_i).

c. output resistance (r_o).

d. generator resistance (R_g).

LESSON 3 . . . . Audio Amplifiers

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 107-144, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To familiarize you with coupling methods and associated circuits used with transistorized audio frequency amplifiers

SUGGESTIONS . . . . None

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 answer sheet by filling in with pencil the appropriate lettered block.

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

31. If the collector current in a transistor amplifier circuit is cut off except during the entire time when the input signal voltage is aiding the forward bias, the amplifier is said to be operated class

a. A.

b. AB.

c. B.

d. C.

32. Assume that a typical transistor preamplifier has a zero-signal emitter current of 0.25 ma, a collector-supply voltage of 1.0 volt, and is fed from a signal source having a resistance of 3000 ohms. A lower noise factor (F_O) may be obtained by changing the

a. emitter current to 1.0 ma.

b. collector supply voltage to 3.0 v.

c. signal source resistance to 100 ohms.

d. signal source resistance to 800 ohms.

33. When a crystal pickup head is to be used as a signal source for a transistor preamplifier, the preamplifier circuit must provide a voltage gain greater than unity and must have good bias stabilization. What circuit configuration must be used under these conditions to obtain a high input resistance without using a transformer?

a. Common-base

b. Common-collector

c. Common-emitter with a series base resistance

d. Common-emitter with an unbypassed emitter resistance

34. In order to compensate for the reduced low-frequency output of many transducers, transistor preamplifier circuits often contain low-pass filter networks. These networks, which are usually series RC circuits, compensate for the poor low-frequency transducer output by

a. increasing the amplifier's input impedance at low frequencies.

b. decreasing the amplifier's input impedance at high frequencies.

c. decreasing the amplifier's output impedance at low frequencies.

d. increasing the amplifier's output impedance at high frequencies.

35. Which circuit shown in figure 112 (TM 11-690) would give an ideal transistor current stability factor if a swamping resistor were used in the emitter lead?

a. A

b. B

c. C

d. D

36. When the volume controls in the circuits shown in figure 114 (TM 11-690) are varied, the low-frequency response will vary in circuits

a. A, B, and C.

b. A, B, and D.

c. A, C, and D.

d. B, C, and D.

37. Volume control circuits in transistor amplifiers usually are considered to be current dividers due to the large amount of current flow normally present in the transistors' input circuit. The general requirements for satisfactory operation of all volume controls used in transistor amplifiers are

a. minimum noise, maximum current flow, and an ideal frequency response.

b. maximum current flow, minimum noise, and maximum range of variation.

c. an ideal frequency response, maximum range of variation, and minimum noise.

d. maximum range of variation, an ideal frequency response, and maximum current flow.

38. To prevent unequal frequency attenuation, volume controls used in transformer-coupled transistor amplifier circuits must be designed to avoid large changes in the reflected primary impedance. If a 4:1 stepdown transformer is used for output coupling, an impedance

change of 2000 ohms in the secondary will cause a change in the primary of approximately

a. 125 ohms.

b. 500 ohms.

c. 8000 ohms.

d. 32,000 ohms.

39. Tone control circuits may be used to permit manual adjustment of the frequency response of transistor audio amplifiers. In the circuit shown in figure 110 (TM 11-690) a low-frequency boost tone control may be obtained by replacing

a. R1 with a variable resistor.

b. R3 with a variable resistor.

c. R4 with a variable resistor.

d. R5 with a variable resistor.

40. In the one-stage phase inverter shown in figure 118 (TM 11-690), the addition of resistor R4 results in equal signal source impedances for transistors Q2 and Q3. The loss of signal voltage, caused by this equalizing resistor, may be compensated for by decreasing the value of

a. resistor R1.

b. resistor R2.

c. resistor R3.

d. capacitor C2.

41. Either one-stage or two-stage transistor phase inverters may be used to obtain the two signals of equal amplitudes, but 180 degrees out of phase, that are required to drive push-pull amplifiers. An advantage of using a two-stage phase inverter instead of a one-stage phase inverter is that it

a. has a high input resistance.

b. eliminates negative feedback.

c. requires only one power supply.

d. operates with less input power.

42. The primary function of resistor R6 in the amplifier shown in A of figure 125 (TM 11-690) is to

a. minimize distortion at the crossover points.

b. prevent distortion introduced by reverse bias.

c. limit the discharge current of capacitors C1 and C2.

d. ensure equal signal source impedances for Q1 and Q2.

43. Crystal diodes CR1 and CR2 are used in the class B, push-pull, audio power amplifier shown in B, figure 125 (TM 11-690), in place of resistors R3 and R4 shown in A, figure 125 (TM 11-690). In this application diodes are preferable to resistors because they

a. minimize distortion of the audio signal.

b. facilitate rapid charging of capacitors C1 and C2.

c. prevent reverse bias from being developed across R6.

d. prevent C1 and C2 from discharging through R1 and R2, respectively.

44. Complementary symmetry circuits may be used to obtain all of the advantages resulting from push-pull operation in audio power amplifiers. An additional advantage derived from using complementary symmetry circuits in place of conventional push-pull audio power amplifiers is that these circuits

a. require only one audio input signal.

b. can use either RC or transformer coupling.

c. may be operated either class A or class B.

d. use discharge diodes to eliminate reverse bias.

45. Assume that two transistors having short circuit forward current amplification factors (α_{fb}) of 0.96 (Q1) and 0.98 (Q2) are to be compound connected. The combined α_{fb} of the two compound-connected transistors will be equal to approximately

a. 0.970.

b. 0.975.

c. 0.995.

d. 0.999.

LESSON 4 . . . . Tuned RF Amplifiers

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 145-169, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To familiarize you with the characteristics of radio-frequency, wide-band, and video amplifiers

SUGGESTIONS . . . . None

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 answer sheet by filling in with pencil the appropriate lettered block.

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

46. Assume that the resonant frequency of the tuned coupling circuit (C_T and the primary of T1) shown in A of figure 141 (TM 11-690) is 2020 kc. If the inductive reactance (X_L) of the primary winding of T1 is 1200 ohms, and the total resistance of the tuned circuit is 8 ohms, the band pass of the tuned transistor amplifier is approximately

a. 1.7 kc.

b. 7.8 kc.

c. 13.5 kc.

d. 25.2 kc.

47. The band pass of the transistor amplifier shown in figure 148 (TM 11-690) may be determined by dividing the resonant frequency of the tuned tank circuit, consisting of C2 and the primary winding of T2, by the ratio of the

a. tank impedance to the capacitive reactance of C2.

b. capacitive reactance of C2 to the tank impedance.

c. tank resistance to the capacitive reactance of C2.

d. inductive reactance of T2 (primary) to the tank impedance.

48. Assume that the output impedance of the common-emitter transistor amplifier shown in figure 148 (TM 11-690) is four times greater than the input impedance of the following stage. If maximum power transfer is desired, the turns ratio (primary to secondary) of the coupling transformer T2 should be

a. 2:1.

b. 4:1.

c. 8:1.

d. 16:1.

49. There are several methods used for coupling transistor stages in tuned amplifier circuits. What type of coupling results in maximum attenuation of the unwanted frequencies and minimum frequency distortion within the band pass?

a. Transformer coupling with a tuned primary

b. Capacitive coupling with a tuned LC circuit

c. Autotransformer coupling with a tuned primary

d. Transformer coupling with a tuned primary and secondary

50. The current amplification factor of a transistor decreases as the signal frequency increases, which results in reduced gain at high frequencies. To maintain equal gain in a two-stage transistor amplifier over a wide band of frequencies, additional circuitry must be added to attenuate the lower frequencies. A circuit which will accomplish this is a

a. series RC circuit in series with the coupling network.

b. series RC circuit in parallel with the coupling network.

c. parallel RC circuit in series with the coupling network.

d. parallel RC circuit in parallel with the coupling network.

51. In a transformer-coupled, tuned, transistor amplifier circuit using a common-base configuration, unwanted oscillations may occur as a result of regenerative feedback. To prevent oscillations, a neutralizing circuit is connected as shown in C of figure 147 (TM 11-690). This RC circuit develops a degenerative feedback voltage which opposes the positive feedback voltage resulting from the

a. emitter-base current flow.

b. total emitter current flow.

c. collector-base current flow.

d. total collector current flow.

52. In the common-emitter transistor amplifier shown in figure 148 (TM 11-690), partial emitter degeneration is used to unilateralize the circuit. The voltage developed across resistor R_{N1} is equal and opposite to the voltage that

a. aids forward bias and appears across the collector-base barrier.

b. opposes forward bias and appears across the collector-base barrier.

c. aids forward bias and appears across the resistance of the base material.

d. opposes forward bias and appears across the resistance of the base material.

53. What is the effect on the amplifier circuit shown in A of figure 149 (TM 11-690) if capacitor C_N opens?

a. Oscillations occur in the circuit.

b. The circuit is neutralized, but not unilateralized.

c. The circuit is unilateralized, but not neutralized.

d. Oscillations are eliminated due to the effect of R_N.

54. Assume that the strength of a received rf signal decreases, causing the input to a tuned, common-emitter, PNP transistor amplifier to decrease. To maintain the original output power level of the amplifier, the positive agc voltage and emitter current must

a. decrease and increase, respectively.

b. increase and decrease, respectively.

c. both increase.

d. both decrease.

55. Assume that the common-emitter transistor amplifier shown in B of figure 151 (TM 11-690) is being used in a receiver. If the strength of the received rf signals suddenly increases, the resulting automatic gain control voltage decreases the

a. base bias voltage.

b. collector voltage.

c. collector current.

d. emitter current.

56. Assume that the i. f. transistor amplifier shown in figure 152 (TM 11-690) is being used in a superheterodyne receiver. A check with an oscilloscope indicates that the amplifier is oscillating at its resonant frequency. The probable cause of trouble is

a. an open resistor R1.

b. an open resistor R4.

c. a shorted capacitor C2.

d. a disconnected capacitor C5.

57. The upper and lower bandwidth limits of a transistor amplifier circuit designed to amplify pulses having recurrence times varying from 5 μsec to 150 μsec should be approximately

a. 50 cps and 15 mc.

b. 670 cps and 2 mc.

c. 6.7 kc and 200 kc.

d. 500 cps and 1.5 mc.

58. The high- and low-frequency response of the RC-coupled transistor amplifier shown in figure 155 (TM 11-690) may be improved by using frequency compensation networks. In some instances it is possible to improve the low-frequency response of the circuit without adding compensation networks by

a. increasing the value of C_c.

b. decreasing the value of R_g.

c. increasing the value of R_L.

d. decreasing the value of R_L.

59. When a square wave is applied to a wide-band transistor amplifier, phase distortion at low frequencies is usually more noticeable than distortion caused by variations in gain. To minimize the distortion resulting from a 4-degree phase shift in the output fundamental frequency, the phase shift of the output third harmonic frequency should be

a. 1.3 degrees.

b. 4 degrees.

c. 8 degrees.

d. 12 degrees.

60. Assume that the wide-band transistor amplifier shown in figure 160 (TM 11-690) is being used in a radar receiver to amplify the reflected radar energy. If low-frequency attenuation is noticeable in the amplifier output, the probable cause of the trouble is

a. an open resistor R_F.

b. a shorted capacitor C_c.

c. a shorted capacitor C_F.

d. a shorted turn in inductor L1.

LESSON 5 . . . . Oscillators

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 170-184, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To familiarize you with the basic feedback, resonant oscillator circuits, including free-running, nonsinusoidal multivibrators and blocking oscillators

SUGGESTIONS . . . . None

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 answer sheet by filling in the appropriate lettered block.

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

61. Either common-base, common-emitter, or common collector configurations may be used in transistor oscillator circuits. However, the common-emitter configuration normally is preferred because of its

a. high voltage gain and high input impedance.

b. high voltage gain and high output impedance.

c. high power gain and low input and output impedances.

d. high power gain and easily matched input and output impedances.

62. Assume that the amplifier used in a transistor oscillator circuit has a power gain of 29. 5. If the amplifier input power level is 4. 5 mw and the power loss incurred in the feedback network is 44. 5 mw, what is the level of the power delivered to the load?

a. 49 mw

b. 84 mw

c. 88 mw

d. 133 mw

63. Since transistor parameters have considerable effect on the oscillating frequency of transistor oscillators, these parameters must be kept constant to ensure maximum frequency stability of the oscillator's output signal. What should be done to minimize variations in the transistor parameters?

a. A variable bias supply voltage should be used.

b. A constant bias supply voltage should be used.

c. Individual bias supplies should be used for the emitter and base electrodes.

d. Individual bias supplies should be used for the collector and emitter electrodes.

64. The four requirements for oscillation in any circuit are (1) a frequency determining network, (2) an amplifier, (3) a feedback voltage, and (4) a source of power. Eight transistor circuits, each fulfilling all requirements, are shown in figure 164 (TM 11-690). Which of the circuits do not require a phase inversion of the feedback voltage?

a. A, C, and E

b. B, D, and F

c. C, E, and G

d. D, F, and H

65. When oscillations take place in a transistor oscillator circuit, the transistor is continuously being driven from saturation to cutoff and back to saturation. At the instant when the transistor is cut off, the emitter-base bias is

a. reversed.

b. unaffected.

c. increased slightly.

d. decreased slightly.

SITUATION

Assume that a transistor oscillator has a tuned collector circuit consisting of two series capacitors (C1 and C2) in parallel with the primary winding (L1) of a transformer. The junction of C1 and L1 is connected to the collector, and the junction of C2 and L1 is connected to ground.

Exercises 66 and 67 are based on the above situation.

66. Loss in the oscillator's feedback network can be minimized if the ratio of output impedance to input impedance of the transistor equals the reactance ratio of

a. C1 to C2.

b. C2 to C1.

c. C1 to L1.

d. C2 to L1.

67. The frequency stability of the oscillator can be increased by adding a capacitor in series with L1 and parallel to C1 and C2. This capacitor is added primarily to reduce the effect of the transistor

a. input resistance.

b. output resistance.

c. emitter-to-base capacitance.

d. collector-to-emitter capacitance.

68. In the shunt-fed transistor Hartley oscillator shown in figure 171 (TM 11-690), the dc transistor current does not flow through the circuit's frequency determining network. The components that prevent dc tank current and provide an alternate path are

a. C2 and R_C.

b. C_C and R_B.

c. C_E and R_E.

d. C_C and R_F.

69. In the tickler-coil feedback transistor oscillator shown in figure 176 (TM 11-690), the required feedback path is provided by crystal Y1. The signal output frequency of the oscillator is determined primarily by

a. Y1 and winding 3-4 of T1.

b. C_{02} and winding 1-2 of T1.

c. crystal Y1 in the feedback loop.

d. C1 and winding 1-2 of T1 in the collector circuit.

70. The common-base Colpitts-type crystal oscillator shown in figure 177 (TM 11-690) uses the parallel mode of resonance of the crystal. In this circuit the feedback voltage is developed across

a. Y1

b. C1.

c. C_E.

d. R_E.

71. The feedback required to sustain oscillations in a transistor RC phase-shift oscillator is obtained by a series of RC phase-shifting networks. The power output of this type of oscillator may be increased by

a. reducing the number of phase-shifting networks.

b. reducing the amount of phase shift introduced by each network.

c. increasing the amount of phase shift introduced by each phase-shifting network.

d. decreasing the time constant of each phase-shifting network.

72. In a transistor oscillator circuit, a change in feedback voltage is usually associated with a change in gain. However, this is not true in the Wien-bridge oscillator shown in figure 180 (TM 11-690). In this circuit, an increase in the feedback voltage results in

a. a decrease in the circuit's degenerative action.

b. an increase in the circuit's degenerative action.

c. a decrease in the circuit's oscillating frequency.

d. an increase in the circuit's oscillating frequency.

73. In the transistor multivibrator circuit shown in figure 181 (TM 11-690), the base-emitter bias of transistor Q1 becomes more positive as the current flow through transistor Q2 increases. This more positive bias causes an increase in the

a. collector voltage of Q1.

b. emitter current of Q1.

c. base voltage of Q1.

d. base current of Q1.

74. In the saturable-core square wave oscillator shown in figure 184 (TM 11-690), current flows through only one transistor at a time. When transistor Q2 is conducting heavily, transistor Q1 is maintained at cutoff by the positive voltage developed across

a. winding 1-2 of T1.

b. winding 3-4 of T1.

c. source voltage supply V_{CC}.

d. voltage divider network R_B and R_F.

75. The output of the transistor blocking oscillator shown in figure 185 (TM 11-690) consists of a series of evenly spaced pulses. The pulse repetition frequency of this output may be decreased by

a. decreasing the value of R_F.

b. increasing the value of C_F.

c. increasing the inductance of winding 3-4 (T1).

d. decreasing the inductance of winding 1-2 (T1).

LESSON 6 . . . . Pulse and Switching Circuits

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 185-203, incl

MATERIALS REQUIRED. . . . . None

LESSON OBJECTIVE . . . . To familiarize you with the switching characteristics employed in basic trigger and gating circuits

SUGGESTIONS . . . . None

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 answer sheet by filling in the appropriate lettered block.

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

76. Transistor configurations used in switching circuits are (1) preferred as a result of power gain, (2) rejected as a result of a loss in input and output impedance properties at saturation, or (3) acceptable as a result of providing a high speed transient response. To which respective configurations do these characteristics apply?

a. Common-emitter, common-collector, and common-base

b. Common-collector, common-base, and common-emitter

c. Common-base, common-collector, and common-emitter

d. Common emitter, common-base, and common-collector

77. Assume that the input switching network in the transistor switching circuit shown in A of figure 188 (TM 11-690) is removed and a negative pulse is applied to the base of the transistor. During what portion of the resulting output pulse will the junctions of the transistor be forward biased, and in what region will the transistor operate at this time?

a. Rise time and cutoff region

b. Storage time and transient region

c. Pulse time and saturation region

d. Decay time and transient region

78. Assume that a squarewave is applied to a transistor circuit. Nonlinear characteristics of the transistor, the external circuit, and energy storage effects contribute to the time required for the leading or trailing edge of the output pulse to rise or decay 80 percent of the maximum amount attainable. The saturation delay time represents the time during which the

a. majority carriers are inactive but not cut off.

b. majority carriers are active but not saturated.

c. minority carriers are stored in the base.

d. minority carriers are in storage in the collector.

79. For ideal operation in a switching circuit the output current of a transistor should equal zero when the transistor is cut off. In practice this ideal condition cannot be achieved, since there is always a certain amount of leakage current. This is especially true in the CE configuration where the collector to emitter leakage current is equal to the CE forward current amplification factor multiplied by the

a. base to emitter current.

b. emitter to base current.

c. collector to base current.

d. base to collector current.

80. The output pulse width of the NOR gate shown in figure 206B (TM 11-690) may be greater than the width of the input pulse applied to R1 due to the effect of the

a. rise time.

b. pulse time.

c. decay time.

d. storage time.

81. Assume that a switching circuit is composed of an NPN, common-emitter transistor with two clamping diode networks in parallel with the load resistor and collector bias battery. One clamping network (CR1) prevents the transistor from reaching cutoff while the other (CR2) prevents the transistor from reaching saturation. What is the bias arrangement for these clamping diode networks?

a. Both are forward biased.

b. Both are reverse biased.

c. CR1 is forward biased while CR2 is reverse biased.

d. CR1 is reverse biased while CR2 is forward biased.

82. Assume that the monostable transistor multivibrator circuit shown in figure 194 (TM 11-690) is in a quiescent state. What effect will a positive trigger, applied to the input, have on the circuit's operation?

a. Feedback from Q1 increases.

b. The forward bias of Q2 decreases.

c. The reverse bias of Q1 increases.

d. The collector potential of Q2 decreases.

83. When an input pulse of the correct polarity and sufficient amplitude is applied to the monostable multivibrator shown in figure 194 (TM 11-690), a flip-flip action takes place, producing a negative output pulse. The width of this pulse may be increased by

a. decreasing the value of R_{F2}.

b. increasing the value of R_{F1}.

c. decreasing the value of C_{F1}.

d. increasing the value of C_C.

84. Assume that in the conventional bistable multivibrator circuit shown in figure 198 (TM 11-690), transistor Q1 is conducting and transistor Q2 is cut off. It is possible to switch the conducting state of this circuit by applying a

a. negative pulse to the base of Q2.

b. positive pulse to the base of Q2.

c. positive pulse to the collector of Q1.

d. negative pulse to the collector of Q2.

85. Although the trigger pulses from a single source can be applied simultaneously to both transistors of a bistable multivibrator, switching time is increased. How can pulses from a single source be applied to the multivibrator circuit shown in figure 198 (TM 11-690) without increasing the switching time? (Assume that Q1 is cut off, and Q2 is conducting.)

a. Use a negative pulse-steering circuit to apply a negative trigger pulse to Q2.

b. Use a positive pulse-steering circuit to apply a negative trigger pulse to Q1.

c. Use a negative pulse-steering circuit to apply a positive trigger pulse to Q1.

d. Use a positive pulse-steering circuit to apply a positive trigger pulse to Q2.

86. Diodes CR1, CR2, CR3, and CR4 provide saturation and cutoff clamping for transistors Q1 and Q2 in the nonsaturating bistable multivibrator shown in figure 203 (TM 11-690). If transistor Q1 is cut off, which two clamping diodes will conduct after a positive trigger has been applied to the input?

a. CR1 and CR3

b. CR1 and CR4

c. CR2 and CR3

d. CR2 and CR4

87. In the bistable multivibrator shown in figure 204 (TM 11-690), transistor Q3 functions as a negative-pulse steering device. Another function of transistor Q3 in this circuit is to

a. decrease the circuit's switching time.

b. maintain the "off" transistor at cutoff.

c. prevent saturation of transistors Q1 and Q2.

d. provide regeneration for the conducting transistor.

88. A single CB configuration transistor, having two isolated input circuits, is being used as an OR gating circuit. How will the output pulse obtained when input pulses are applied simultaneously to both input circuits differ from the output pulse obtained when only one input pulse is applied?

a. Its width will be decreased.

b. Its width will be increased.

c. Its amplitude will be decreased.

d. Its amplitude will be increased.

89. When a positive pulse of sufficient amplitude to overcome the forward bias established by V_{BB} is applied to input A of the emitter follower AND gating circuit shown in A of figure 209 (TM 11-690), transistor Q1 is cut off. What happens to the output voltage across R_L at this time?

a. It becomes more negative.

b. It becomes less negative.

c. It becomes more positive.

d. It remains constant.

90. Either series gating or shunt gating transistor circuits will operate as switches, and may be used as limiters, clippers, or clamping circuits. One advantage of using a series gate transistor circuit instead of a shunt gate transistor circuit is that the series gate offers

a. signal amplification.

b. minimum storage delay time.

c. minimum transient distortion.

d. a choice of forward or reverse bias operation.

LESSON 7 . . . . Modulation, Mixing, and Demodulation

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 204-220, incl; review par. 101

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To familiarize you with the basic principles of transistorized modulation, demodulation, mixer and converter circuits

SUGGESTIONS . . . . None

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 answer by filling in the appropriate lettered block.

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

91. Either low-level or high-level modulation may be used in transistorized am transmitters. When modulation is accomplished by base injection, low-level modulation is always used in order to

a. produce an rf carrier with maximum amplitude variations.

b. produce an am carrier output with minimum distortion.

c. increase the strength of the rf carrier.

d. decrease the strength of the rf carrier.

92. When amplitude modulating an amplifier, the modulating signal may be injected into either the base, emitter, or collector circuit. An advantage of using collector injection instead of emitter injection is that

a. a smaller modulating signal is required.

b. a higher percentage of modulation is possible.

c. both low- and high-level modulation may be used.

d. the amplitude of the modulating signal may be varied.

93. In figure 219 (TM 11-690) what is the function of inductor L1 and capacitor C1?

a. To determine the frequency of the modulating signal

b. To offer a high impedance to the oscillating frequency

c. To offer maximum impedance to the modulating frequency

d. To offer minimum impedance to the modulating frequency

94. In a transistorized a. m. transmitter, modulation may take place in either the oscillator or one of the amplifiers. A disadvantage of modulating the oscillator instead of an amplifier is that

a. the rf carrier frequency requires multiplication.

b. a larger modulating signal is required to obtain the same percentage of modulation.

c. the oscillator must operate at the same frequency as the transmitting frequency.

d. a center-tapped transformer winding is required for proper injection of the modulating signal.

95. Assume that the frequency of the oscillator shown in figure 223 (TM 11-690) does not vary when a signal is applied to the modulator input. If the oscillator is operating at a higher-than-normal frequency, a possible source of trouble is

a. an open T1.

b. an open T2.

c. a shorted Q1.

d. a shorted Q2.

96. Assume that the oscillator and reactance modulator circuits shown in figure 223 (TM 11-690) are being used in an fm transmitter. The instantaneous frequency of the fm carrier signal output will vary directly with the instantaneous value of the

a. collector voltage of Q1.

b. collector voltage of Q2.

c. output capacitance, C1, of Q1.

d. output capacitance, C_{ce}, of Q2.

97. If amplitude variations are present in the output of the final power amplifier of a transistorized fm transmitter, a possible cause of trouble is in the

a. limiter stage.

b. power amplifier.

c. modulating circuits.

d. frequency multipliers.

98. Transistorized superheterodyne radio receivers use either a semiconductor diode or a transistor in the mixer stage. When a transistor is used, the mixer should be operated on the portion of the dynamic characteristic curve as shown in TM 11-690, figure

a. 92.

b. 93.

c. 95.

d. 96.

99. Assume that the mixer stage shown in figure 227 (TM 11-690) is being used in an a.m. superheterodyne receiver. If the frequency of the rf signal input is 1130 kc, and the oscillator signal input frequency is 1590 kc, what frequencies are probably present in the output of Q1?

a. 460 kc, 1360 kc, and 2720 kc

b. 1130 kc, 1360 kc, and 1590 kc

c. 460 kc, 1130 kc, 1590 kc, and 2720 kc

d. 1130 kc, 1590 kc, 2260 kc, and 3180 kc

100. In a transistorized superheterodyne receiver containing no rf amplifier stages, the rf signal induced in the antenna circuit is coupled to the

a. base of the mixer stage.

b. emitter of the mixer stage.

c. emitter of the converter stage.

d. collector of the converter stage.

101. In the mixer stage shown in figure 227 (TM 11-690) the collector tank circuit, consisting of capacitor C5 and the primary winding of transformer T3, is tuned to resonate at a frequency equal to the

a. oscillator input signal.

b. radio frequency input signal.

c. sum of the rf and the oscillator frequency.

d. difference between the rf and the oscillator frequency.

102. Frequency converter stages use a single transistor which functions both as an oscillator and as a mixer. In the converter shown in figure 228 (TM 11-690), oscillations are sustained by the action of

a. capacitor C5.

b. capacitor C1.

c. transformer T1.

d. transformer T2.

103. Assume that the common-emitter transistor detector shown in figure 231 (TM 11-690) is being used in a superheterodyne receiver. Waveform checks have indicated that the i. f. variations have not been completely removed from the output signal. The probable cause of trouble is

a. an open resistor R1.

b. a shorted capacitor C4.

c. a shorted capacitor C5.

d. disconnected capacitor C2.

104. The discriminator circuit in figure 233 (TM 11-690) converts a frequency-modulated i. f. signal to the desired audio frequency. The parallel circuit formed by capacitor C2 and the primary winding of transformer T1 should resonate at

a. the unmodulated intermediate frequency.

b. a frequency slightly above the unmodulated i. f.

c. a frequency slightly below the unmodulated i. f.

d. the average frequency deviation of the unmodulated i. f.

105. Capacitor C1 and the primary winding of T1 as well as capacitor C2 and inductor L1 form parallel tuned circuits in the slope detector shown in figure 234 (TM 11-690). How does the resonant frequency of C1 and the primary of T1 compare to the resonant frequency of C2 and L1?

a. It is slightly lower.

b. The frequencies are the same.

c. It is slightly less than double.

d. It is slightly more than double.

LESSON 8	Servicing Transistor Circuits
CREDIT HOURS	2
TEXT ASSIGNMENT	Attached Memorandum, par. 1-12, incl
MATERIALS REQUIRED	None
LESSON OBJECTIVE	To introduce you to some of the problems encountered in servicing equipment with transistor circuits
SUGGESTIONS	None

ATTACHED MEMORANDUM

(This attached memorandum is approved for resident and extension course instruction only. It reflects the current thought of the U. S. Army Signal School and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.)

1. GENERAL CIRCUIT CHARACTERISTICS

The servicing of transistor circuits differs from the servicing of vacuum-tube circuits in two important respects. First, the transistor itself is seldom the defective component, and second, transistor circuitry, consistent with the low power drain and small size of the transistors used in the circuit, is extremely compact, and introduces special problems in the replacement of parts.

2. COMPARISON WITH VACUUM TUBES

When troubleshooting electronic circuits built around vacuum tubes, it is a normal practice to make tube testing one of the first steps in the procedure. In four cases out of five, defective tubes are the cause of the malfunction. In circuits containing transistors, the reverse is more apt to be the case; the difficulty usually will be found in other components. As solid-state devices having no parts that can be easily broken or damaged, transistors are much more rugged than vacuum tubes and far less susceptible to damage by shock or vibration.

3. TYPES OF FAILURES

a. General. Transistors can be expected to give many thousands of hours of service. Normally, when deterioration does set in after long service, it occurs gradually and can be detected by one of several measurable indications. Sudden failures, although infrequent, do occur and are caused primarily by overheating as a result of overloading or improper bias control of the transistor. Overheating can cause an open circuit by melting the leads inside the transistor case, or cause the emitter and collector leads to become unsoldered from the transistor or mounting base.

b. Short Circuit. When a sudden transistor failure occurs, it often results in a short circuit. For example, when the power rating of a junction transistor is exceeded (overloading), the crystal structure may be destroyed at the junctions by the resulting excessive heat. This causes the impurities in the collector region to diffuse into the base region.

c. Reduced Performance. One indication of transistor deterioration is an undesirable increase in saturation current (collector current in excess of the transistor's rating). In an amplifier circuit, this appears as an increase in distortion, or a decrease in gain. Transistor deterioration also is indicated by a decrease in output resistance. In a circuit requiring critical impedance matching, a loss in interstage gain results from the impedance mismatch.

4. OPERATING PRECAUTIONS

Transistor damage or deterioration can be minimized by routine precautions. Some of these are described below.

5. TEMPERATURE CONTROL

a. Temperature Sensitivity. Transistors are limited inherently in their resistance to high temperature by their crystalline structure. Moderate increases in temperature can cause unwanted variations in circuit parameters because of the effects on carrier mobility. If temperatures rise above the transistor's tolerance, the unit breaks down and a short circuit results. Preventing a temperature rise is a problem because of the small size of the transistor and its resulting low heat dissipation. Thus, close control of ambient temperature (temperature of the environment surrounding the transistor) and a close limit on transistor power handling are necessary.

b. Heat Dissipation. When practicable, transistors should be mounted adjacent to metal panels or chassis members into which heat can be dissipated. To aid heat dissipation in some installations, the heat sink method of mounting is used. This consists of encasing the transistor body in metal and placing the metal in contact with a chassis or some other good heat conductor which dissipates the heat. Transistors never should be mounted close to heat-producing components, such as motors or large power transformers.

c. Power Control. The maximum rated power of transistors is usually based on an ambient temperature of 25 degrees C (77 degrees F). If the ambient temperature cannot be maintained at or below this figure, the power input to the circuit must be reduced accordingly. A rule-of-thumb useful in changing power to offset temperature increases when both the maximum allowable junction temperature and the power dissipation are in danger of being exceeded, is to cut power by 10 percent for each temperature increase of 5 degrees C (9 degrees F).

6. BIAS CONTROL

a. Bias Voltages and Currents. Transistor bias voltages and currents must be carefully controlled to prevent exceeding the ratings of the particular transistors being used.

(1) Maximum Collector Voltage. If the maximum collector voltage rating is exceeded, even for an instant, internal breakdown of the transistor, and degradation of its characteristics below acceptable limits, may result. In large-signal circuits employing resistors as collector loads, the collector supply voltage should not exceed the maximum collector voltage rating, since under conditions of collector current cut-off there is no voltage drop across the collector load resistor. In circuits employing inductors, transformers, or tuned circuits as collector loads, the restrictions are even greater. In these circuits, the amplifier output voltage is superimposed on the collector supply voltage, and the instantaneous collector voltage may reach a value of twice the supply voltage. Therefore, in circuits of this nature, it is good practice to use a collector supply voltage of one-half or less of the maximum collector voltage rating of the particular transistor used. In switching circuits employing relays or other inductive devices in the collector circuit, diodes should be connected across the

devices to absorb the high peak voltages generated due to switching transients.

(2) Maximum Collector Current. Exceeding the maximum collector current rating may cause either deterioration or complete failure of the transistor. When making adjustments to transistorized circuits, it is good practice to ensure that there is sufficient dc resistance between the collector and emitter through the collector supply voltage (including the resistance of the collector load and emitter swamping resistor) to drop the full supply voltage under conditions of excessive input bias.

(3) Maximum Collector Dissipation. Collector dissipation is found by multiplying the collector voltage by the collector current. This power is converted to heat within the semiconductor crystal. The greater the power dissipation, the higher the temperature created. The maximum dissipation rating is the maximum amount of power which can be dissipated without the temperature rising high enough to damage the crystal. The effect of ambient temperature is discussed in paragraph 5c. Dissipation in the emitter junction is so small compared to that in the collector junction that it is not ordinarily considered. Since the emitter junction is forward biased and, therefore, exhibits very low resistance, care must be exercised to see that this bias is supplied through a sufficiently high series resistance to limit the current to a safe value.

b. Polarity. The polarity of voltages applied to transistor circuits must be checked carefully to prevent transistor damage. For example, transistor circuits such as amplifiers and oscillators require negative collector voltages and positive emitter voltages with respect to the base. In switching and gating circuits, negative emitter voltages are normal. The reverse is true for NPN transistors.

c. Replacing Transistors. Transistors should never be inserted into an energized circuit, or the initial surge of current may damage the transistor. If the effect of a bias voltage on the transistor circuit is questionable, an ammeter should be connected in series with the collector circuit and the bias voltage should be applied gradually through a potentiometer arrangement.

7. TESTING

When a transistor has been identified as the probable source of trouble in a defective circuit, it can be checked by several tests. Some of these, like simple ohmmeter tests for shorts and open circuits, are relatively straightforward. Others, involving voltage and current readings under various signal conditions, must be undertaken with care.

8. USE OF A SIGNAL GENERATOR

When checking transistor performance with a signal generator, precautions are necessary so as not to overload the transistor circuit. The signal generator should be set first to a low output level, and then the amplitude should be increased slowly until satisfactory test indications are obtained. If there is any reason to doubt the effectiveness of the attenuator of the signal generator employed, a suitable external attenuator should be used. If the signal generator is to be connected to a point in the transistor circuit where dc voltage is present, a capacitor should be inserted in series with the test lead of the signal generator in order to prevent added attenuation.

9. TRANSISTOR TEST CIRCUITS

The simplest way to test a transistor's performance is to substitute another transistor, known to be good, in the defective circuit. When this is inconvenient, the suspected transistor must be checked in a test circuit.

a. Voltage Gain Measurement. Figure 2 shows a simplified low frequency test arrangement for an NPN transistor in a grounded emitter circuit. An audio oscillator may be used as the signal source with the input being applied between the base and emitter, and the output being taken between the collector and ground. The input and output amplitudes are measured with an ac, vacuum-tube voltmeter (vtvm) and compared to determine the voltage gain of the transistor. The computed gain is compared with the rated gain of the transistor, or with the gain of similar transistors known to be good. The voltage gain of transistors at high frequencies can best be checked by measuring the input and output amplitudes under actual operating conditions.

b. Current Gain Measurement. The current gain of a transistor circuit is defined as the change in collector current caused by a change in the base current. Figure 3 shows a simple circuit used to measure the current gain of PNP-type transistor in a grounded-emitter circuit. (Like the voltage gain test described above, this test is only effective at low frequencies.) First, the meter in the collector circuit is read with no current applied to the base (pushbutton switch open). Then, the pushbutton switch is depressed (applying a small current to the base) and another reading is taken of the meter in the collector circuit. The difference between the two readings divided by 0. 03 will give the approximate CE current gain of the transistor under test. A comparison of the actual current gain with the rated current gain of the transistor indicates whether or not there is a satisfactory amplification level. The meter reading with the pushbutton switch open should also provide an indication of the leakage current (reverse bias current flow between the base and collector) of the transistor. The test circuit battery should be checked periodically; the meter should read about 3 ma when a 2000-ohm resistor is inserted between the collector and emitter.

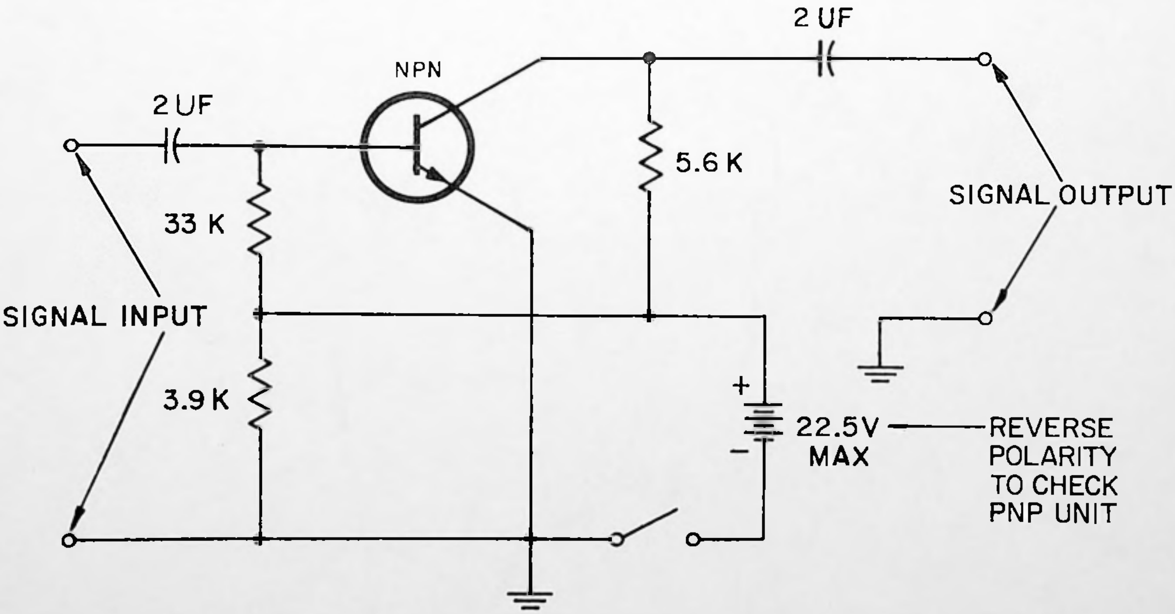

Figure 2. Voltage gain test circuit.

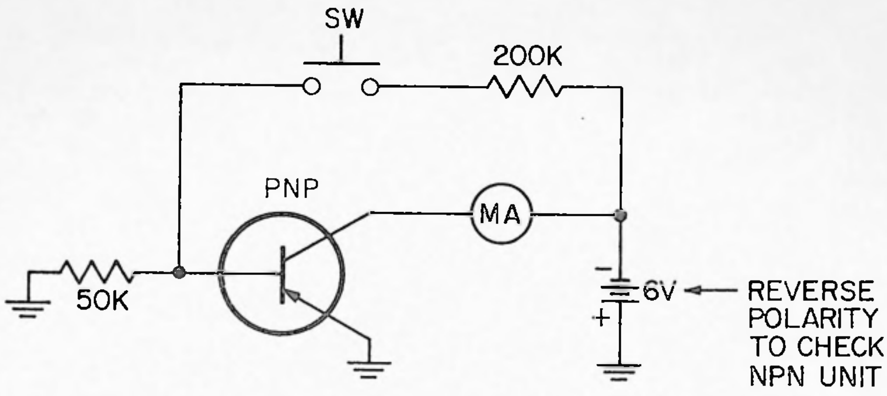

Figure 3. Current gain test circuit.

10. TRANSISTOR SOLDERING PRECAUTIONS

When a defective transistor is replaced in a circuit, care must be taken not to damage the new unit by excessive heat from the soldering iron. Longnose pliers should be clamped on the lead between the body of the transistor and the end of the lead to be soldered. The pliers act as a heat sink to prevent the heat from reaching the transistor. Transistors with short leads should not be soldered directly into a circuit, but connected through a transistor socket. A typical socket for transistors is shown in figure 4.

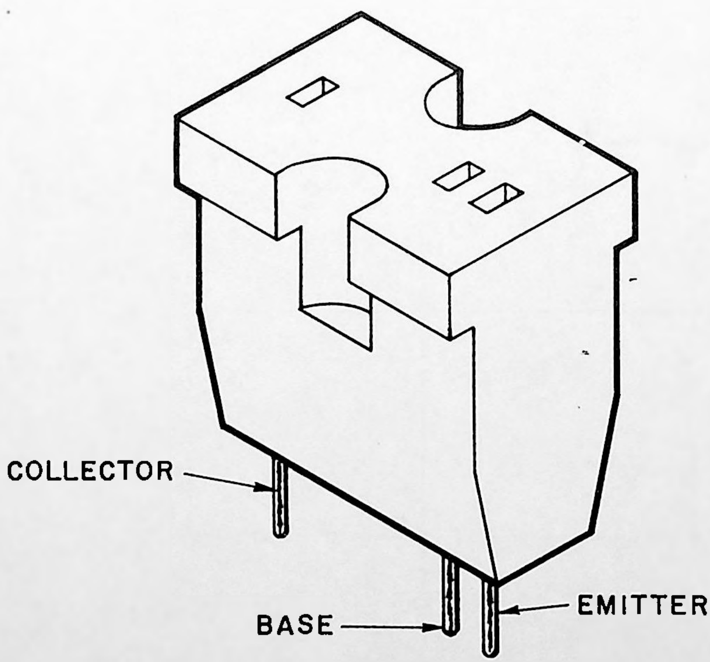

Figure 4. Typical transistor socket.

11. MINIATURIZATION

a. General. The development of the transistor has affected nearly every phase of the electronics industry. The compactness and low current and voltage requirements of the transistor have had a compelling influence on equipment designs. These changes in design of components have introduced new problems in circuit operation, maintenance, and repair.

b. Transformers. Miniaturized transformers develop more heat because the current flows through a smaller wire with a higher resistance. Thus, the ambient temperature is higher and the transformer material must be able to perform under this higher temperature. New insulating materials have been developed, improved insulating methods have been introduced, and flat-shaped, high-permeability materials have been adopted for core construction.

c. Capacitors. Miniaturized capacitors are generally made with plastic, impregnated paper, or ceramic dielectrics, which have the characteristics of high insulation resistance, operation over a wide range of temperatures, and a high dielectric constant. Testing by substitution is impractical with the miniaturized circuits commonly used in transistorized equipment due to the difficulty of working with printed circuits. The most satisfactory method is to disconnect one lead of the capacitor from its circuit and check the capacitor resistance with the ohmmeter of a vacuum-tube voltmeter. If the polarities are correct, and if the capacitor is good, the meter needle will deflect fully and then gradually return to a finite resistance level which is produced by the small leakage current which maintains the dielectric (approximately 100,000 ohms). If the capacitor is open, the needle will not deflect. If the capacitor is leaking, the meter needle will indicate a definite resistance value which is below the level produced by the normal leakage current.

d. Inductors and Resistors. The problems associated with the miniaturization of inductors are similar to those for transformers. The coils use very fine wires and heat dissipation is a problem. The reduction of the size of resistors, on the other hand, is simplified by the lower voltage and current requirements of transistor circuits. In one new technique for constructing very small resistors, resistive coatings are deposited on glass and ceramic bases, and then the coated bases are encased in a plastic jacket for moisture protection and insulation. Coils and resistors can be checked in the conventional manner with ohmmeters. However, because of the small size of the components and the reduced working space, extra care must be exercised when placing test leads in the circuits to prevent shorting or grounding of other components.

12. PRINTED CIRCUITS

a. Construction. Printed circuit boards were developed both to simplify the assembly of all electronic circuits, and to furnish a practical means of packaging the newer, miniaturized components. The basic step in printed board manufacture is the bonding of metal foil, usually copper, to one or both sides of an insulating material, such as laminated plastic. Circuit patterns are drawn on this foil with an acid-resistant ink. The board is then dipped in an acid etching solution, which removes all of the foil not protected by the ink. The board is then punched or drilled at appropriate points for the insertion of component leads. The components are inserted, and the leads and all parts of the circuit to be soldered are fluxed. All parts which must remain free of solder are masked or coated with lacquer. The board is then dipped in a solder bath. After soldering, the printed circuit is varnished with a silicon resin to protect the circuit from shorts caused by dust or moisture. A properly fabricated board has a uniform printed circuit which is compact and free of errors and poor solder connections.

b. Replacement of Parts. Two methods of replacing defective components in a printed circuit are in common use.

(1) If the leads on the new component are long enough, the defective component can

be completely removed. To do this, first heat the leads of the defective component where they are soldered to the printed side of the board. When the solder joint is broken, straighten the leads and remove the component from the other side of the board. Insert the leads of the new component through the same holes in the board, bend them back against the points of the old connections, and resolder the connections.

(2) If the leads on the new component are too short to pass through the board to the proper points on the printed side, the old leads must be used. As shown in A of figure 5, cut the leads as closely as possible to the faulty component (at "X"). With longnose pliers, form loops in the old leads and attach the new component leads to these loops (B of fig. 5). Then solder the connections, as shown in C of figure 5. If necessary, more lead length can be gained by cutting or breaking the faulty component, and stripping its excess composition from the leads. Any part of the lead formerly inside the component must be cleaned thoroughly before any new connections are made.

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 answer sheet by filling in with pencil the appropriate lettered block.

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

106. In what way does excessive heating damage a transistor crystal?

a. The number of current carriers decreases.

b. An open circuit occurs between collector and base.

c. Impurities can no longer diffuse into the base region.

d. The junction breaks down as impurity atoms are displaced.

107. Although transistors normally fail gradually, they also can fail abruptly. Abrupt failure of a transistor may be caused by

a. migration of impurities across the BE junction.

b. migration of impurities across the CB junction.

c. decrease in saturation current.

d. decrease in gain.

108. The gradual deterioration of a transistor is indicated by

a. an increase in saturation current.

b. a decrease in saturation current.

c. an increase in output resistance.

d. a sudden increase in gain.

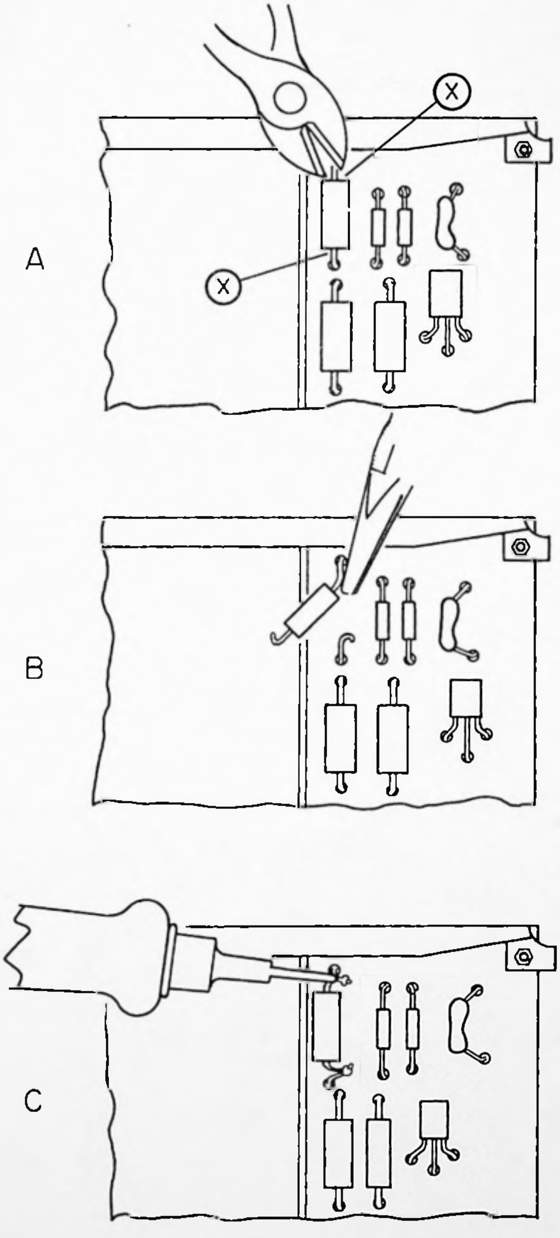

Figure 5. Changing components on a printed-circuit board.

109. Transistors should not be located near transformers or power tubes in a circuit because of the

a. induced signal from the electric fields.

b. increased intercomponent capacitance.

c. induced signal from the magnetic fields.

d. possible damage from high ambient temperatures.

110. Ambient temperature can affect the operation of transistor circuits, and must be controlled. The average operating temperature for which transistors are rated is

a. 5 degrees C.

b. 10 degrees C.

c. 25 degrees C.

d. 40 degrees C.

111. When checking an NPN transistor circuit, always ensure that the polarities of the collector and emitter bias, with respect to the base, are

a. negative and positive respectively.

b. positive and negative respectively.

c. both positive.

d. both negative.

112. Assume that the maximum collector voltage rating of a transistor in a common-emitter, transformer-coupled amplifier is 50 volts. The maximum recommended collector supply voltage that should be used is

a. 50 volts.

b. 33 volts.

c. 25 volts.

d. 17 volts.

113. Signal generators are often employed to provide input signals for testing transistor circuits. If these test signals are to be inserted in a circuit containing dc voltages, they should be coupled

a. directly.

b. inductively.

c. resistively.

d. capacitively.

114. The current gain of a transistor can be checked by inserting the transistor in a test circuit in which the collector current is measured both with and without a potential on the base. However, this type of check is unreliable when testing

a. a PNP junction transistor.

b. a transistor having low input impedance.

c. a transistor used for high-frequency operation.

d. a transistor having a grounded-emitter configuration.

115. The results obtained with most transistor test circuits are used primarily to check the transistor's performance against its rated

a. power output.

b. input impedance.

c. output impedance.

d. current gain.

116. The best method of checking the performance of a transistor used in a high-frequency amplifier circuit, where it is inconvenient to substitute another transistor, is to

a. measure the collector current both with and without current applied to the base.

b. measure the signal input and output amplitudes under actual operating conditions.

c. use an audio oscillator as a signal source and measure the input and output amplitudes.

d. measure the collector current both with and without a 2000-ohm resistor inserted between the collector and emitter.

117. What circuit parameter may be checked by the measurement of a change in the collector current of a transistor when the base current is changed a given amount?

a. Output resistance

b. input resistance

c. Voltage gain

d. Current gain

118. When replacing transistors, longnose pliers are used primarily to prevent

a. cold (improper) solder joints.

b. excessive bending of the lead.

c. accidental damage to other components.

d. heat damage to the transistor caused by soldering.

119. The difficulty in checking out miniature capacitors used in transistor circuits is caused by their

a. proximity to other components.

b. lower capacitor voltage ratings.

c. higher capacitor power ratings.

d. low insulation resistance.

120. The final step that must be taken when fabricating a printed-circuit board is to

a. apply a silicon resin coating.

b. dip the board in a solder bath.

c. apply flux to all solder connections.

d. dip the board in an acid etching solution.

LESSON 9 . . . . Transistor Circuit Applications

CREDIT HOURS 2

TEXT ASSIGNMENT . . . . TM 11-690, par. 221-228, incl; Attached Memorandum, par. 13-21, incl

MATERIALS REQUIRED . . . . None

LESSON OBJECTIVE . . . . To familiarize you with the practical applications of transistor circuits in electronic equipments

SUGGESTIONS . . . . Read the text assignment in TM 11-690 before reading the Attached Memorandum

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ATTACHED MEMORANDUM

13. GENERAL

Previous chapters of this text have discussed the use of transistors in a wide variety of electronic circuitry. Wherever amplification, modulation, detection, or oscillation is required, transistors may be used. They match, and frequently surpass, the performance of vacuum tubes in many applications. This chapter will describe some of the ways in which transistors are employed.

14. ELECTRONIC COMPUTERS

a. Today's complex electronic computer is an integration of numerous circuits which store information. The computer can be used to perform intricate and lengthy calculations at lightning-like speed if the information inserted in the machine is carefully programmed. This involves a breakdown of problem components into parts the computer can handle. Answers are obtained by the selective extraction of information from the numerous modules. In vacuum-tube models of the computer, each of the modules normally contains one or two tubes and their associated circuit components. The greater the versatility of the machine and the greater the number of functions it can perform, the greater the number of modules required. A computer similar to that used in many military and commercial establishments would fill three or more rooms in a house of average size. When transistors are used, however, the overall size of computer equipment can be greatly reduced.

b. A typical transistor module of a computer is shown in figure 6. It is about one-fourth the size of the comparable vacuum-tube type. When this saving in space is multiplied several thousand times (the number of modules in a typical computer), a vacuum-tube model requiring four rooms, when transistorized, can be reduced to a size requiring only one room. Furthermore, the transistorized computer is less expensive and more reliable, its power and cooling requirements are greatly reduced, and its maintenance is greatly simplified.

15. BROADCAST RECEIVERS

Obviously, transistors can be effectively employed in small as well as in large-scale electronic equipment. One of the first replacements of vacuum tubes by transistors took place in the simple, portable broadcast receiver.

a. Portable A. M. Receivers. A typical transistor portable receiver is shown in figure 7. It is very light, weighing about 1-1/2 pounds, and measures only 3-1/2 by 7-1/2

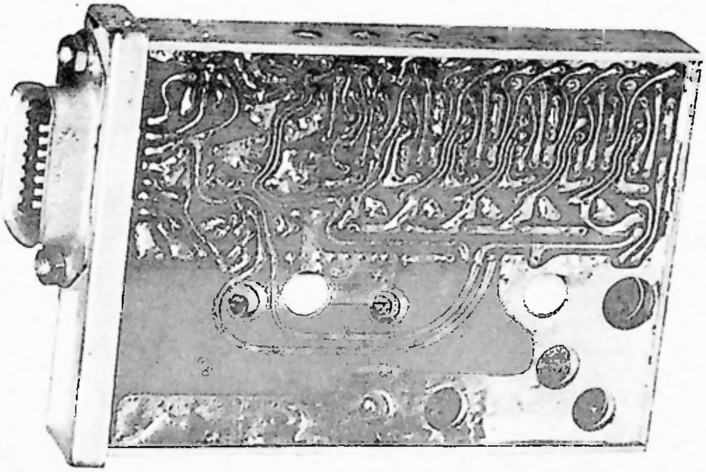


Figure 6. Typical transistor module.

by 1-3/4 inches. The superheterodyne circuit employs six transistors and two crystal diodes, all mounted on a printed-circuit board. This particular receiver employs a nickel-cadmium battery for power; an accessory device permits recharging of the battery from a conventional 110-volt ac line. The radio may also be operated with standard B-type batteries which supply 9 to 22.5 volts. Comparable circuitry may also be applied to more versatile instruments. One receiver, employing a 9-transistor circuit, can receive the standard broadcast band, two domestic shortwave bands, and four international shortwave bands.

b. Portable FM Receivers. One experimental model of an fm receiver bypasses the problem of rf amplification in the 100-mc region by eliminating the rf stage. The input from the antenna is applied directly to the mixer stage. The mixer, which operates the same as an a.m. diode detector, consists of a pair of germanium diodes in a balanced circuit. The local oscillator circuit is similar to a shunt-fed Hartley circuit and uses an rf junction transistor. It operates below the carrier frequency to give sufficient excitation, since the oscillator output diminishes with frequency. The oscillator is not affected by small changes in battery voltage, and there is no noticeable frequency shift due to temperature changes. The mixer feeds the intermediate frequency signal to the first intermediate transformer with only a small conversion loss. The intermediate-frequency amplifiers consist of six PNP-junction transistors connected in common-base circuits. A conventional discriminator circuit, using a pair of germanium diodes, serves as the fm detector. The audio driver consists of a two-stage, common-collector amplifier using two junction transistors. In all, a total of 11 transistors and 4 germanium diodes are used. Power is supplied by two batteries: a 22.5-volt battery that supplies each collector through an individual LC decoupling filter, and a 1.5-volt battery that supplies each emitter through an individual LC decoupling circuit. The receiver performs well over the vhf fm band in strong signal areas, using a dipole antenna.

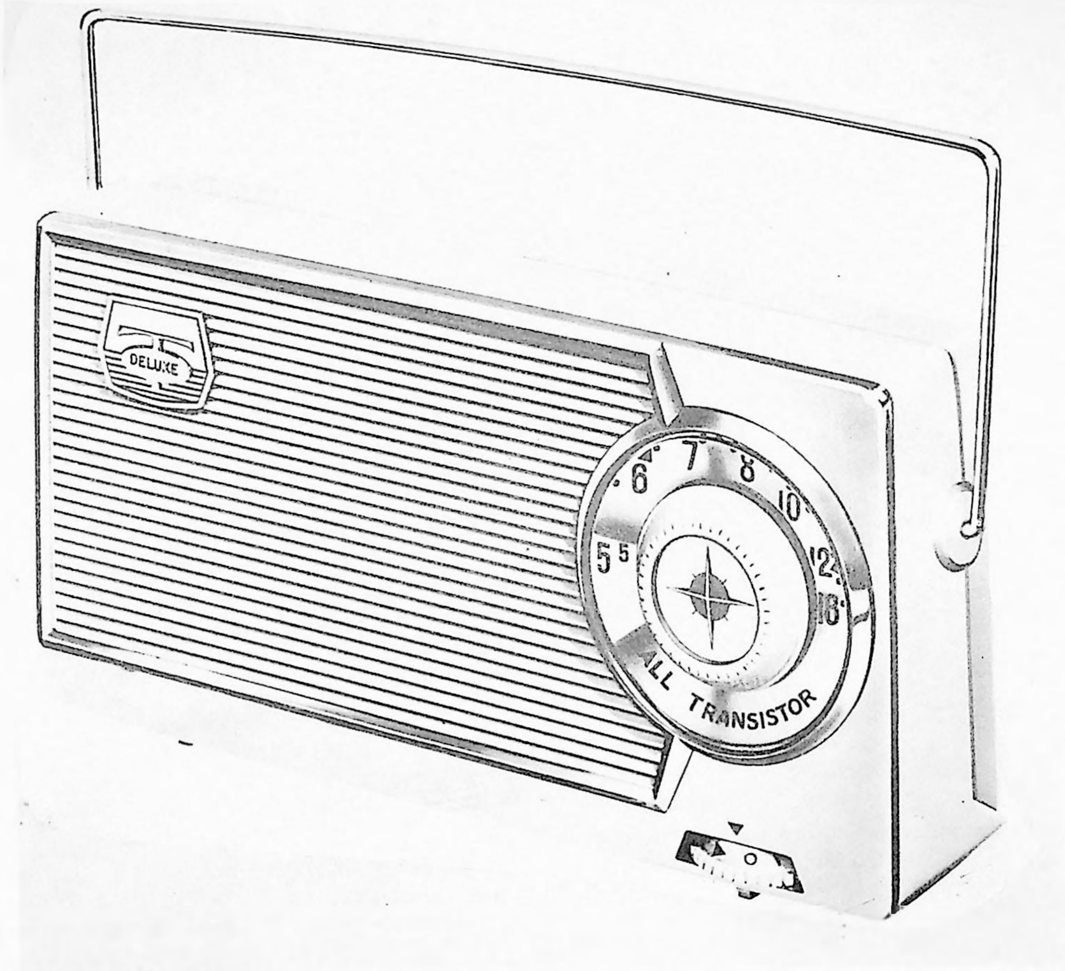


Figure 7. Typical transistor portable radio.

c. Automobile Receivers. Because of their lower power requirements, transistor circuits operate very well in car radios, operating off the 6- or 12-volt automobile battery. The vibrator, power transformer, and rectifier necessary for a vacuum-tube circuit are eliminated. This results in lower initial cost, lower servicing cost, and more compact construction. A typical receiver contains an rf stage, a converter, two i. f. amplifiers, a transistor detector, and an audio amplifier with a push-pull output.

16. PORTABLE VHF TRANSMITTER-RECEIVER COMBINATION

a. A recent development in commercial communication equipment is a combination portable vhf transmitter and receiver. The transmitter usually has seven subminiature vacuum tubes; the receiver is fully transistorized. Both units may be carried by clipping them to a belt, as shown in figure 8. There are two models, one for voice operation with a

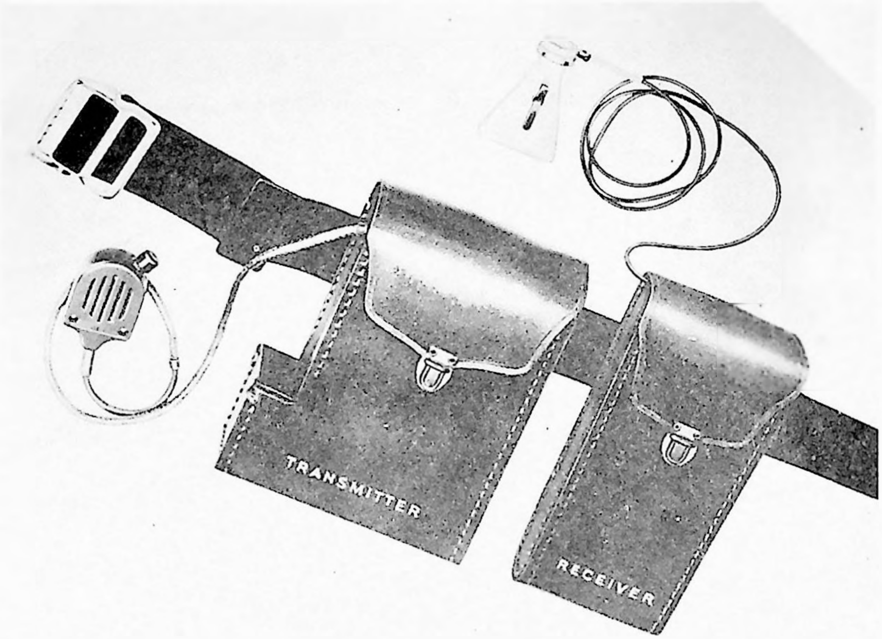


Figure 8. Belt-pack transmitter-receiver.

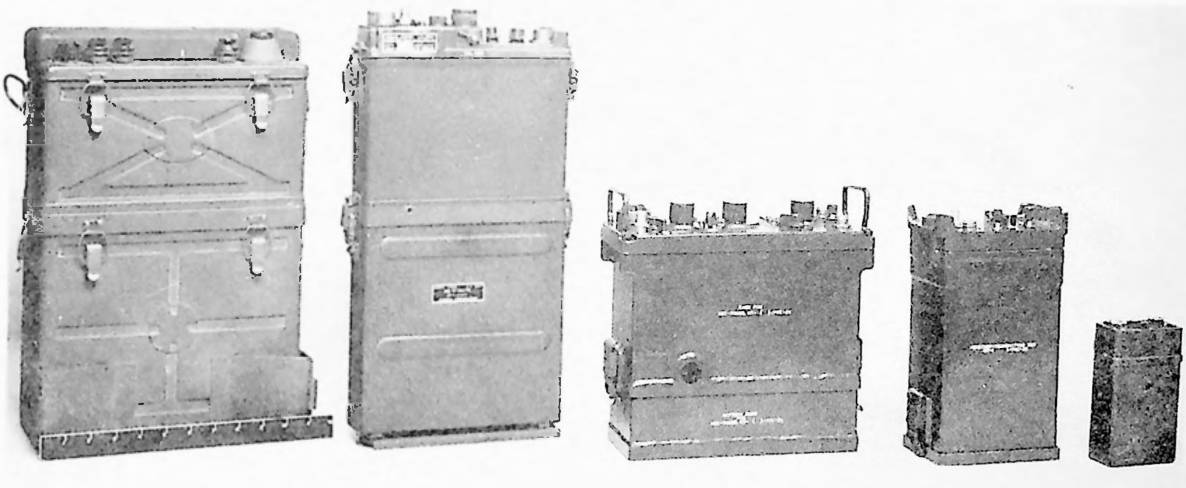
noise-operated squelch circuit and the other with provisions for selective calling (use of coded signals to call the receiver of one desired user station from among numerous user stations). The latter contains a decoder (device which decodes a coded series of signals) with 66 separate combinations, and a buzzer which notifies the user when the properly coded call has been received. A recording device makes a visual record to notify the user if the receiver has been called during his absence.

b. The receiver uses two crystal-controlled oscillators. The output from one oscillator is injected into the first mixer, and the output from the other oscillator is injected into the second mixer. This receiver, since it uses two mixers, is called a double-conversion superheterodyne. Fifteen transistors are included in the receiver circuit to achieve a high order of performance and to assure equipment quality. The circuitry of the unit is of modular construction. Each primary circuit function has been incorporated in an individual module. There are 10 modules in the receiver, with each module connected to a common base module.

c. Battery life in the vhf transmitting and receiving units can be prolonged by an accessory circuit which keeps the receiver circuits deenergized when no signal is available. The battery-saver circuit consists of a 2-transistor multivibrator circuit in a switching circuit which acts in conjunction with the squelch switch. The cycle period of this circuit is about 2 seconds. During each period it energizes the receiver for a fraction of a second to sample the channel. If a signal is present in the channel, the noise squelch circuit energizes and, in turn, energizes the multivibrator circuit. The receiver remains energized as long as the multivibrator circuit is energized. When the signal is removed from the channel, the squelch circuit deenergizes the multivibrator circuit, and the sampling cycle resumes.

17. MILITARY COMMUNICATION EQUIPMENT

a. Reduction in Size. Military man-pack communication equipment has been developed to the point where it is comparable in performance to heavy stationary equipment. Accompanying this improvement in performance has been a constant reduction in size as use has been made of the latest electronic developments, such as miniature and subminiature vacuum tubes, semiconductors, printed circuits, and associated miniaturized components. Figure 9 illustrates the reduction in size achieved with pack equipments having the same general communication function.



b. Radio Set SCR-300. Radio Set SCR-300 was one of the first man-pack equipments, widely used during World War II. It used miniature tubes and weighed about 40 pounds. Forty channels were available, the rf power was 0.3 watt, and the operating range was about 3 miles. The SCR-300 is shown at the extreme left in figure 9. It stands 17 inches high.

c. Radio Set AN/PRC-10. Radio Set AN/PRC-10 makes use of subminiature tubes, and weighs about 10 pounds. It has 170 channels, the rf power is 1 watt, and the range is about 5 miles.

d. Radio Set AN/PRC-25. Radio Set AN/PRC-25 is one of the first man-pack equipments to make extensive use of transistors and printed circuits. In a package weighing only 15 pounds, it provides 920 crystal-controlled channels, and has a range of about 6 miles.

e. Radio Sets AN/PRC-35 and -36. Further refinement of transistor circuits has been incorporated in Radio Set AN/PRC-35 and Radio Set AN/PRC-36. The AN/PRC-35 weighs about 5 pounds, due in large part to a reduction in battery size to about one-sixteenth the weight and volume of the SCR-300 battery. The rf power is 0.35 watt, the range is about 1 mile, and 800 channels are available. In the AN/PRC-36, the performance level is also sacrificed to attain extremely small size. The AN/PRC-36 is less than 6 inches long and weighs only 26 ounces; it can be carried on a belt.

f. Transceiver AN/PRC-34. The AN/PRC-34 is a microminiaturized fm transceiver, small enough to be mounted in a battle helmet for short-range field communications (fig. 10). It weighs 17 ounces and measures 4 by 3 by 3/4 inches. With the antenna down, the range is about 300 yards; with the antenna extended, the range is increased to about 500 yards.

Figure 10. Transceiver AN/PRC-34.

18. FIELD TELEVISION EQUIPMENT

a. Back-Pack Vidicon Camera. The back-pack vidicon camera, shown in figure 11, is a complete television transmitting system for use in the field. All operating controls are provided on the camera. The camera itself weighs 8 pounds and the complete back-pack weighs less than 50 pounds. The transmitter has a peak power output of 2 watts, a 10-mc bandwidth, and an operating frequency of 360 mc. The camera has 525-line, 30-frame, interlaced scanning. The power supply consists of rechargeable, silver-zinc batteries and a small dynamotor.

b. JTV-1 Hand Camera. The JTV-1 camera is an ultraminiature, hand-held television camera which is used for remote field operation (fig. 12). It weighs about 2 pounds and measures 2-3/8 by 1-7/8 by 4-1/2 inches. The resolution of the received picture is equal to that of a standard home television receiver.

19. METERS

a. Microammeter. Figure 13 shows the circuit for a two-range microammeter which employs a transistor as a current amplifier. With unamplified input currents, readings between 0 and 1 milliampere can be obtained on the 0-1 milliampere meter shown in the circuit. When the input is shunted through the transistor amplifier, measurements between 0 and 100 microamperes can be obtained on the same meter. This provides the circuit with its dual-range capabilities. The amplifier stage has an overall gain of 10, being slightly less than 10 near the bottom of the scale and slightly more than 10 near full scale. To compensate for this difference, the variable 10K resistor is adjusted for an exact indication when a reading of 0. 8 is registered on the meter scale. This adjustment permits accurate meter readings over almost the entire range. For microammeter readings, "A" is the positive input

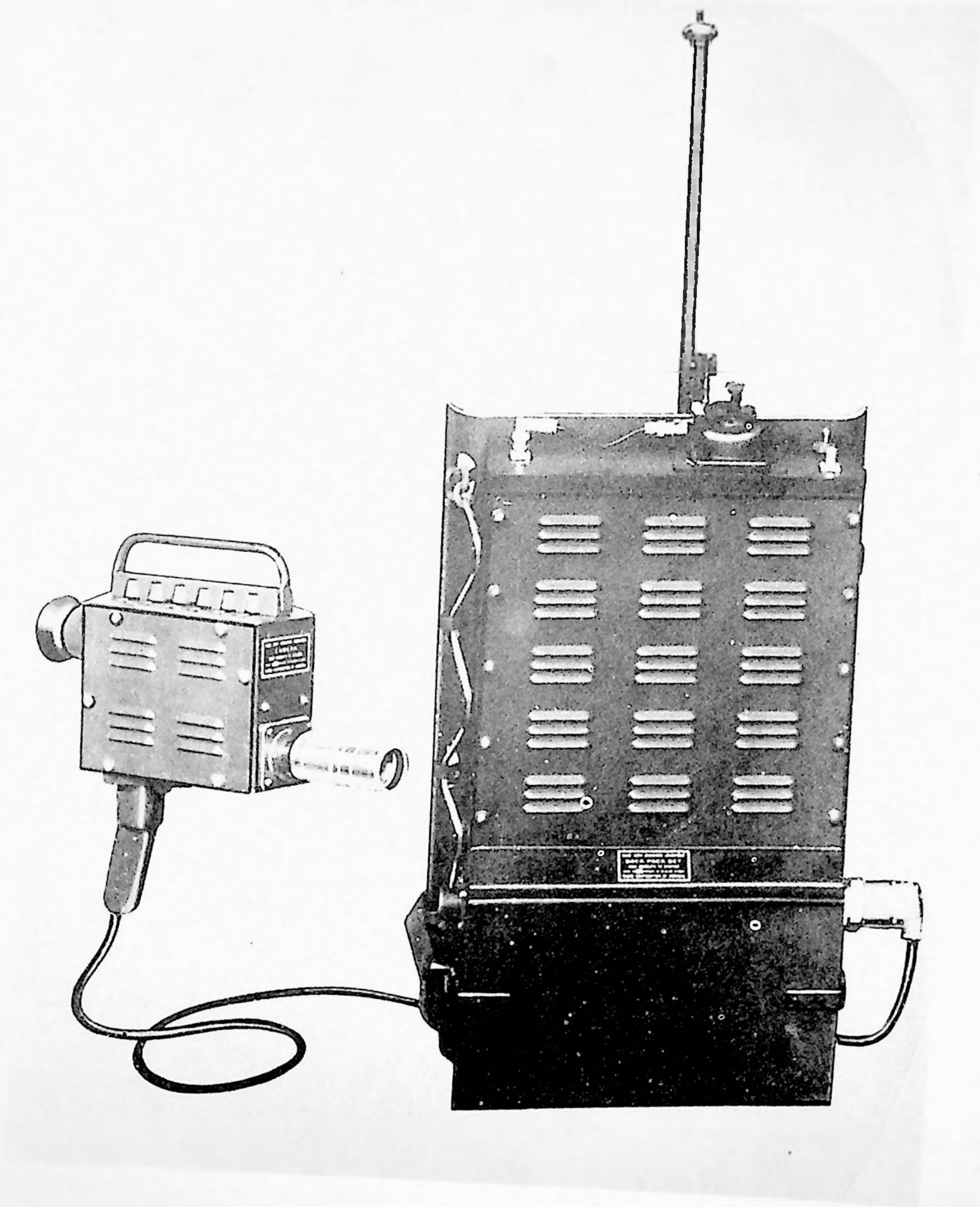


Figure 11. Back-pack vidicon camera.

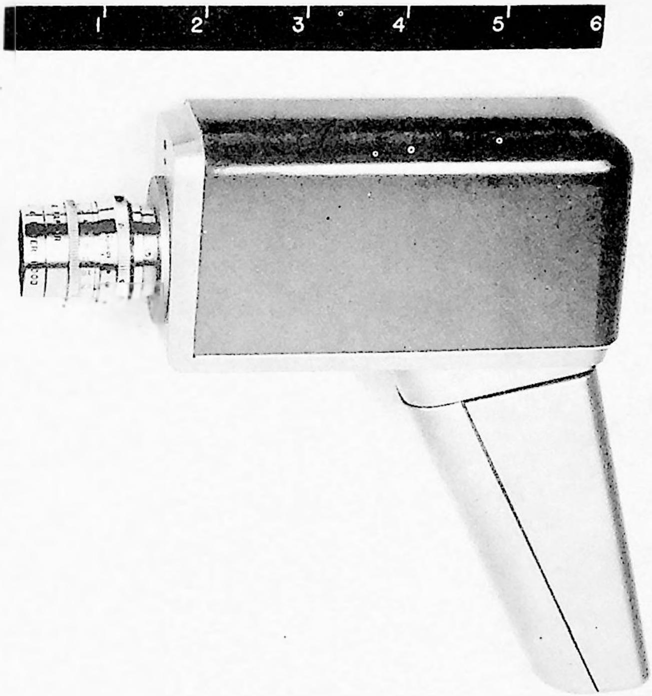


Figure 12. JTV-1 hand television camera.

terminal; when the switch is placed in the milliampere position, "B" becomes the positive input terminal.

b. Megohmmeter. Figure 14 shows the circuit of a two-range megohmmeter employing a transistor as a high-voltage generating circuit. The two ranges of operation are 3-1500 megohms and 35-22,000 megohms. Rx represents the resistor being checked. High voltage is supplied by the battery-driven transistor oscillator with a step-up autotransformer which feeds a selenium rectifier voltage-doubling system. The transistor functions as an automatic switch which connects the tuned circuit to the battery supply during each negative alternation. The peak-to-peak voltage developed across the tuned circuit then becomes equal to twice the battery voltage. In accomplishing switching, the operation of the transistor is very similar to that of an astable (free-running) multivibrator. This mode of operation provides the advantage of low collector dissipation during both cutoff and conduction. Since a transistor has no gain at zero bias, oscillations may be delayed in starting during periods of low ambient temperatures. Consequently, a fixed 39K resistor is connected between the collector and base, which reduces the time required for starting oscillations. A switch allows the insertion of this resistor when starting; it is opened after oscillations have begun to avoid overloading the tuned circuit. The megohmmeter has a high internal resistance which minimizes the hazard of electrical shock to personnel handling the test leads. The high-voltage generator can also be used to supply operational voltage for Geiger-Mueller radiation counters, image-converter tubes, stroboscopic photo flash tubes, or small cathode-ray tubes.

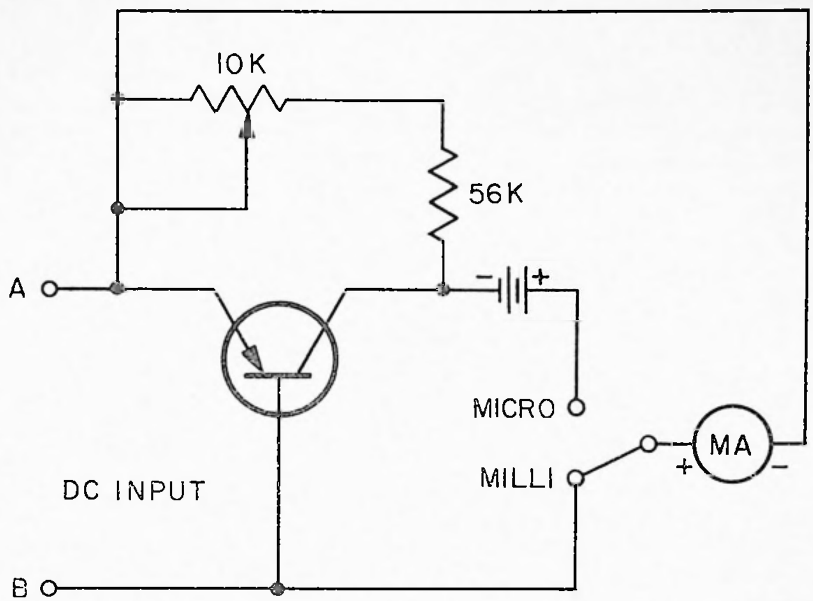


Figure 13. Two-range microammeter circuit.

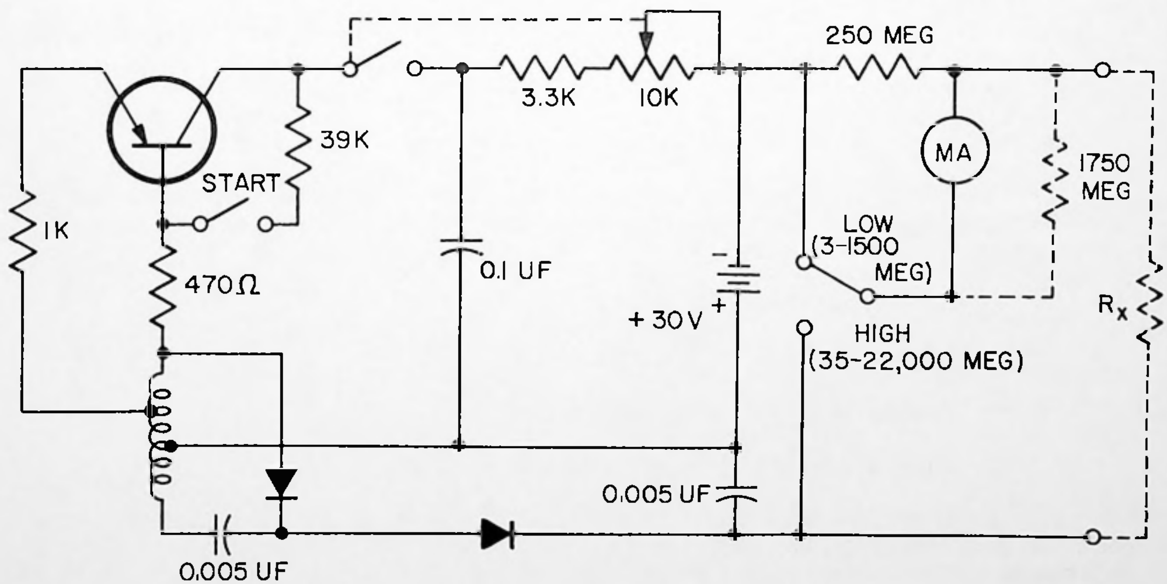


Figure 14. Two-range megohmmeter circuit.

20. MICROPHONES

A transistorized microphone has been developed in which the output of a magnetic reluctance transducer is fed into a transistor amplifier. The reluctance element ensures undistorted speech, while the single-transistor amplifier provides the audio amplification necessary to drive the modulating circuits of a transmitter. This transistorized microphone is interchangeable with the conventional carbon microphones used in communications services and significantly improves voice reproduction. When used with the built-in transistor amplifier, the reluctance mechanism is as sensitive as the carbon microphone. A balanced feedback circuit compensates for variations in load impedances, transistor performance, and microphone elements. The circuit is powered by the voltage normally supplied to a carbon microphone. Available transistorized microphones include the reluctance and velocity types for both mobile and desk use.

21. DIRECTION FINDERS

A compact, economical marine direction finder using transistors is shown in figure 15. Like its vacuum-tube counterpart, it enables the operator to take bearings on marine radio beacons, broadcast stations, and signals from radio-telephone-equipped boats and shore stations. Bearings are established by rotating the antenna which, in this model, is a compact, shielded, ferrite rod extending only 2 inches above the cabinet. Unlike visual bearings taken on prominent landmarks or other known objects, radio bearings can be taken over great distances even when visibility is poor. The direction finder contains a sensitive 8-transistor superheterodyne receiver with a built-in loudspeaker, a headphone jack, and a terminal for connecting an external antenna. It is powered by three 4.5-volt, self-contained batteries.

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 answer sheet by filling in with pencil the appropriate lettered block.

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

121. The tetrode transistor has improved high-frequency response when compared to a three-terminal NPN- or PNP-type junction transistor. This improvement is due primarily to the fact that the tetrode transistor has

a. less semiconductor material.

b. more semiconductor material.

c. reduced input and output capacitances.

d. increased input and output capacitances.

122. Spacistors, because of their rapid transit time, can be used in vhf amplifier circuits. In such an application, variations in current flow to the collector are controlled by impressing the input signal across the terminals of the

a. injector and the base.

b. base and the collector.

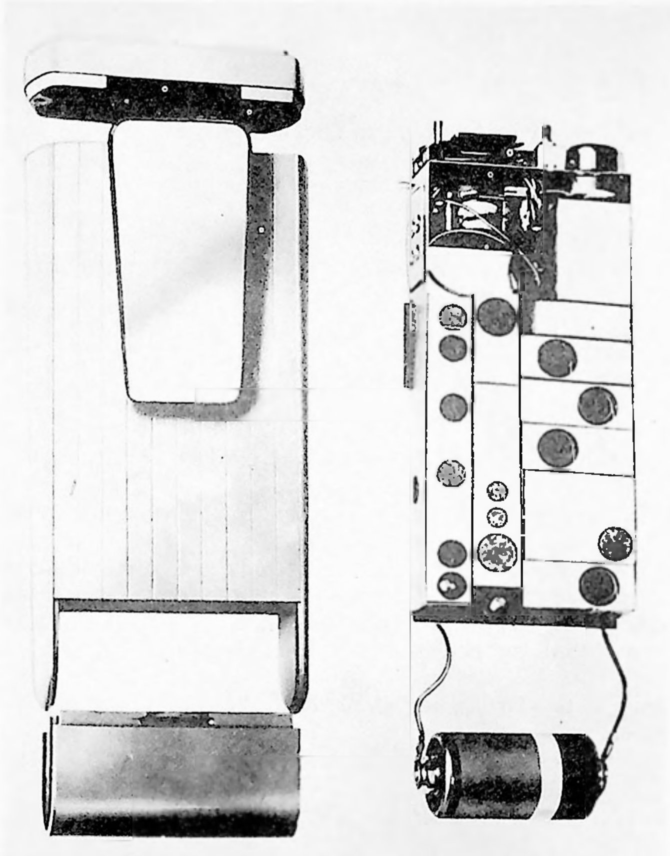


Figure 15. Portable direction finder.

c. modulator and the injector.

d. collector and the modulator.

123. The ratio between the rise and fall times of the output waveform produced by the circuit shown in C of figure 239 (TM 11-690) is determined principally by the relationship between the impedance of the PN junction at forward-bias and the

a. variations of V_{BB} potential supplied to the double base.

b. impedance of the PN junction at reverse-bias.

c. capacitive reactance of C_1.

d. capacitance of C_1.

124. Large electronic equipments, such as computers, must have adequate cooling or ventilation systems to maintain reliable operation. In a transistorized computer the cooling requirements are greatly reduced, compared with a vacuum-tube computer, because the

a. transistors are self-cooling.

b. power dissipation is decreased.

c. required number of modules is decreased.

d. transistor replaces several vacuum tubes.

125. Since high-frequency applications of transistors are presently in the experimental stage, what modification has been employed to handle the rf amplification in a transistorized fm portable receiver?

a. The rf input is applied directly to the mixer stage.

b. A vacuum tube is used for decreasing the rf frequency.

c. The rf input is mixed with the Hartley oscillator output.

d. The local oscillator operates slightly above carrier frequency.

126. Because the voltages of an automobile battery may be used directly to power a transistorized receiver, the power supply of a transistor automobile radio can be greatly simplified. The conventional power-supply circuits, normally required in an all-vacuum tube receiver, that are eliminated in a transistorized receiver, include the

a. vibrator, rf amplifier, and detector.

b. oscillator, rectifier, and audio amplifier.

c. rectifier, vibrator, and power transformer.

d. power transformer, vibrator, and power amplifier.

127. The weight of Radio Set AN/PRC-35 has been reduced considerably below that of the AN/PRC-10 by the use of transistors. This reduction in weight has been accompanied by

a. a decrease in the number of channels available.

b. a decrease in communication range.

c. an increase in the power output.

d. an increase in battery size.

128. There was a major improvement in military man-pack communication equipment from the early SCR-300 to the AN/PRC-34. It is marked chiefly by

a. a reduction in size and weight.

b. an increase in operating range.

c. an increase in frequency range.

d. an improvement in antenna systems.

129. An advantage of the JTV-1 hand camera, when compared to the back-pack vidicon camera shown in figure 11 of the Attached Memorandum, is that it

a. is lighter in weight.

b. uses interlaced scanning.

c. operates on rechargeable batteries.

d. contains all the necessary operating controls.

130. In the ammeter circuit shown in figure 13 of the Attached Memorandum, the negative input terminal for the MICRO and MILLI switch positions, respectively, is

a. A and A.

b. A and B.

c. B and A.

d. B and B.

131. When using the megohmmeter shown in figure 14 of the Attached Memorandum, operating personnel are protected from electrical shock by the

a. switching action of the transistor circuit.

b. low internal resistance of the meter movement.

c. high internal resistance of the megohmmeter.

d. operation of the two selenium rectifiers.

132. The transistor oscillator circuit in the megohmmeter shown in figure 14 (Attached Memorandum) functions as a high-voltage generator. It can be used to supply a high dc voltage in a number of practical applications, including

a. radiation counters, large cathode-ray tubes, and image-converter tubes.

b. large cathode-ray tubes, image-converter tubes, and photo flash tubes.

c. photo flash tubes, radiation counters, and large cathode-ray tubes.

d. image-converter tubes, photo flash tubes, and radiation counters.

133. A two-stage transistor multivibrator circuit is used in the belt-pack transmitter-receiver (fig. 8 of the Attached Memorandum) for the purpose of providing

a. prolonged battery life.

b. a high order of performance.

c. automatic channel selection.

d. double conversion in the receiver.

134. An advantage of a double junction photosensitive semiconductor circuit (C, fig. 236 of TM 11-690) over a single junction photosensitive semiconductor (B, fig. 236 of TM 11-690) is that the double junction circuit

a. is capable of receiving a larger amount of light energy input.

b. has an output that is proportional to the intensity of the light source.

c. provides a larger output signal with the same amount of light energy input.

d. can have the photosensitive area located in either the P-type or the N-type material.

135. In a transistorized reluctance element microphone, the built-in transistor amplifier ensures that the microphone output is

a. relatively free from distortion.

b. free from variations in load impedance.

c. not affected by variations in the microphone elements.

d. strong enough to facilitate proper transmitter modulation.

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RESERVE..........
RES. EAD..........

NG..........
NG EAD..........
AF..........
CIVILIAN..........

I hereby certify that in the preparation of this solution I have received no unauthorized assistance of any kind.

SIGNATURE

(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D		A	B	C	D
121	☐	☐	☐	☐	131	☐	☐	☐	☐
122	☐	☐	☐	☐	132	☐	☐	☐	☐
123	☐	☐	☐	☐	133	☐	☐	☐	☐
124	☐	☐	☐	☐	134	☐	☐	☐	☐
125	☐	☐	☐	☐	135	☐	☐	☐	☐
126	☐	☐	☐	☐					
127	☐	☐	☐	☐					
128	☐	☐	☐	☐					
129	☐	☐	☐	☐					
130	☐	☐	☐	☐					

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COMPONENT—CHECK ONE	ARM OR SERVICE

RA..........
AUS..........
RESERVE..........
RES. EAD..........

NG..........
NG EAD..........
AF..........
CIVILIAN..........

I hereby certify that in the preparation of this solution I have received no unauthorized assistance of any kind.

SIGNATURE

(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D
106	☐	☐	☐	☐
107	☐	☐	☐	☐
108	☐	☐	☐	☐
109	☐	☐	☐	☐
110	☐	☐	☐	☐
111	☐	☐	☐	☐
112	☐	☐	☐	☐
113	☐	☐	☐	☐
114	☐	☐	☐	☐
115	☐	☐	☐	☐
116	☐	☐	☐	☐
117	☐	☐	☐	☐
118	☐	☐	☐	☐
119	☐	☐	☐	☐
120	☐	☐	☐	☐

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FIRST NAME – MIDDLE INITIAL – LAST NAME

TIME SPENT ON LESSON	DATE MAILED
ARMY SERVICE NO.	GRADE
COMPONENT—CHECK ONE	ARM OR SERVICE

RA........ NG..........
AUS........... NG EAD...........
RESERVE........... AF...........
RES. EAD........... CIVILIAN...........

I hereby certify that in the preparation of this solution I have received no unauthorized assistance of any kind.

SIGNATURE

(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D		A	B	C	D
91	☐	☐	☐	☐	101	☐	☐	☐	☐
92	☐	☐	☐	☐	102	☐	☐	☐	☐
93	☐	☐	☐	☐	103	☐	☐	☐	☐
94	☐	☐	☐	☐	104	☐	☐	☐	☐
95	☐	☐	☐	☐	105	☐	☐	☐	☐
96	☐	☐	☐	☐					
97	☐	☐	☐	☐					
98	☐	☐	☐	☐					
99	☐	☐	☐	☐					
100	☐	☐	☐	☐					

Detach and Mail

106 A7

WD AGO Form 153
1 Apr 46

PREVIOUS EDITIONS ARE OBSOLETE

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL

ANSWER SHEET

FILL OUT HEADING.

LESSON NUMBER	SUBCOURSE NUMBER	TITLE OF SUBCOURSE	DATE OF LESSON
6	106	Transistors	14 July 1960 (Rep 27 May 63)

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TIME SPENT ON LESSON	DATE MAILED
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RA..........
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NG..........
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AF..........
CIVILIAN..........

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(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D
76	☐	☐	☐	☐
77	☐	☐	☐	☐
78	☐	☐	☐	☐
79	☐	☐	☐	☐
80	☐	☐	☐	☐
81	☐	☐	☐	☐
82	☐	☐	☐	☐
83	☐	☐	☐	☐
84	☐	☐	☐	☐
85	☐	☐	☐	☐
86	☐	☐	☐	☐
87	☐	☐	☐	☐
88	☐	☐	☐	☐
89	☐	☐	☐	☐
90	☐	☐	☐	☐

106 A6

WD AGO Form 158
1 Apr 46

PREVIOUS EDITIONS ARE OBSOLETE

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Detach and Mail

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL

ANSWER SHEET

FILL OUT HEADING.

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5	106	Transistors	14 July 1960 (Rep 27 May 63)

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TIME SPENT ON LESSON	DATE MAILED
ARMY SERVICE NO.	GRADE
COMPONENT—CHECK ONE	ARM OR SERVICE

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NG.........
NG EAD.........
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(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

61 ☐A ☐B ☐C ☐D
62 ☐A ☐B ☐C ☐D
63 ☐A ☐B ☐C ☐D
64 ☐A ☐B ☐C ☐D
65 ☐A ☐B ☐C ☐D
66 ☐A ☐B ☐C ☐D
67 ☐A ☐B ☐C ☐D
68 ☐A ☐B ☐C ☐D
69 ☐A ☐B ☐C ☐D
70 ☐A ☐B ☐C ☐D
71 ☐A ☐B ☐C ☐D
72 ☐A ☐B ☐C ☐D
73 ☐A ☐B ☐C ☐D
74 ☐A ☐B ☐C ☐D
75 ☐A ☐B ☐C ☐D

106 A5

WD AGO Form 153
1 Apr 46

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Detach and Mail

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL
ANSWER SHEET

FILL OUT HEADING.

LESSON NUMBER	SUBCOURSE NUMBER	TITLE OF SUBCOURSE	DATE OF LESSON
4	106	Transistors	14 July 1960 (Rep 27 May 63)

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TIME SPENT ON LESSON	DATE MAILED
ARMY SERVICE NO.	GRADE
COMPONENT—CHECK ONE	ARM OR SERVICE

RA..........
AUS..........
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NG..........
NG EAD..........
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CIVILIAN..........

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(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D
46	☐	☐	☐	☐
47	☐	☐	☐	☐
48	☐	☐	☐	☐
49	☐	☐	☐	☐
50	☐	☐	☐	☐
51	☐	☐	☐	☐
52	☐	☐	☐	☐
53	☐	☐	☐	☐
54	☐	☐	☐	☐
55	☐	☐	☐	☐
56	☐	☐	☐	☐
57	☐	☐	☐	☐
58	☐	☐	☐	☐
59	☐	☐	☐	☐
60	☐	☐	☐	☐

106 A4

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WD AGO Form 153
1 Apr 48

PREVIOUS EDITIONS ARE OBSOLETE

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL

ANSWER SHEET

FILL OUT HEADING.

LESSON NUMBER	SUBCOURSE NUMBER	TITLE OF SUBCOURSE	DATE OF LESSON
3	106	Transistors	14 July 1960 (Rep 27 May 63)

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TIME SPENT ON LESSON	DATE MAILED
ARMY SERVICE NO.	GRADE
COMPONENT—CHECK ONE	ARM OR SERVICE

RA..........
AUS..........
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RES. EAD..........

NG..........
NG EAD..........
AF..........
CIVILIAN..........

Detach and Mail

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SIGNATURE

(This space for instructor)

Your grade is:

☐ SUPERIOR

☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D
31	☐	☐	☐	☐
32	☐	☐	☐	☐
33	☐	☐	☐	☐
34	☐	☐	☐	☐
35	☐	☐	☐	☐
36	☐	☐	☐	☐
37	☐	☐	☐	☐
38	☐	☐	☐	☐
39	☐	☐	☐	☐
40	☐	☐	☐	☐
41	☐	☐	☐	☐
42	☐	☐	☐	☐
43	☐	☐	☐	☐
44	☐	☐	☐	☐
45	☐	☐	☐	☐

Detach and Mail

106 A3

WD AGO Form 153
1 Apr 48

PREVIOUS EDITIONS ARE OBSOLETE

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL

ANSWER SHEET

FILL OUT HEADING.

LESSON NUMBER	SUBCOURSE NUMBER	TITLE OF SUBCOURSE	DATE OF LESSON
2	106	Transistors	14 July 1960 (Rep 27 May 63)

Detach and Mail

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ARMY SERVICE NO.	GRADE
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☐ EXCELLENT

☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D
16	☐	☐	☐	☐
17	☐	☐	☐	☐
18	☐	☐	☐	☐
19	☐	☐	☐	☐
20	☐	☐	☐	☐
21	☐	☐	☐	☐
22	☐	☐	☐	☐
23	☐	☐	☐	☐
24	☐	☐	☐	☐
25	☐	☐	☐	☐
26	☐	☐	☐	☐
27	☐	☐	☐	☐
28	☐	☐	☐	☐
29	☐	☐	☐	☐
30	☐	☐	☐	☐

Detach and Mail

106 A2

WD AGO Form 153
1 Apr 48

Detach and Mail

EXTENSION COURSE OF THE U. S. ARMY SIGNAL SCHOOL
ANSWER SHEET

FILL OUT HEADING.

LESSON NUMBER	SUBCOURSE NUMBER	TITLE OF SUBCOURSE	DATE OF LESSON
1	106	Transistors	14 Jul 1960 (Rep 27 May 63)

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☐ SUPERIOR

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☐ SATISFACTORY

☐ UNSATISFACTORY

	A	B	C	D		A	B	C	D
1	☐	☐	☐	☐	11	☐	☐	☐	☐
2	☐	☐	☐	☐	12	☐	☐	☐	☐
3	☐	☐	☐	☐	13	☐	☐	☐	☐
4	☐	☐	☐	☐	14	☐	☐	☐	☐
5	☐	☐	☐	☐	15	☐	☐	☐	☐
6	☐	☐	☐	☐					
7	☐	☐	☐	☐					
8	☐	☐	☐	☐					
9	☐	☐	☐	☐					
10	☐	☐	☐	☐					

Detach and Mail

106 A1

WD AGO Form 153
1 Apr 48