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Howard W. Sams

HANDBOOK OF ELECTRONIC TABLES & FORMULAS

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HANDBOOK OF ELECTRONIC
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PREFACE

In the Preface to the first edition of this book, published in November, 1959, we asked for recommendations of additional items to consider for inclusion in a future edition. Many suggestions were received and considered; most of them are incorporated in this volume. Hence, this book contains the information which users of the first edition—engineers, technicians, students, experimenters, and hobbyists—have told us they would like to have in a comprehensive one-stop edition.

The basic formulas and laws, so important in all branches of electronics, are given in Part One. Also included are nomographs to speed up the solution of problems involving Ohm's law, power, parallel resistance, and reactance.

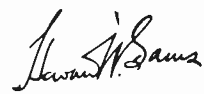
Useful, but hard to remember constants, and standards which have been established by the government or industry, are included in Part Two. The comprehensive Table of Conversion Factors is especially helpful in electronic computations.

Part Three contains symbols and codes which have been adopted over the years. The latest semiconductor information is included, to keep you abreast of this rapidly expanding field.

Items of particular interest to electronics service technicians are included in Part Four. Data most often used in circuit design work are given in Part Five. The filter and attenuator configurations and formulas are particularly useful to service technicians and design engineers.

Mathematical tables, formulas, and other information are presented in Part Six. Binary numbers and an introduction to Boolean algebra—the tools of the computer field—are also included in this section. Many items of a miscellaneous nature are included in Part Seven.

No effort has been spared to make this revised handbook of maximum value to anyone, in any branch of electronics. Once again your comments, criticisms, and recommendations for additional data you would like to see included in a future edition, will be welcomed.



January, 1962

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

Electronics Formulas and Laws

1. OHM'S LAW FOR DIRECT CURRENT

All substances offer some obstruction to the flow of current. Ohm's law states that the current which flows is directly proportional to the applied voltage and inversely proportional to the resistance. Thus:

$$I = \frac{E}{R}$$

$$E = IR$$

$$R = \frac{E}{I}$$

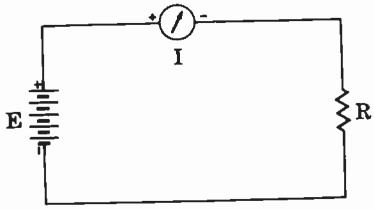


Fig. 1

where,
I is the current in amperes,
E is the voltage in volts,
R is the resistance in ohms.

2. DC POWER

The power P expended in load resistance R when current I flows under a voltage pressure E can be determined by the formulas:

$$P = EI$$

$$P = I^2R$$

$$P = \frac{E^2}{R}$$

where,
P is the power expressed in watts,
E is the voltage in volts,
I is the current in amperes,
R is the resistance in ohms.

Ohm's Law Nomograph

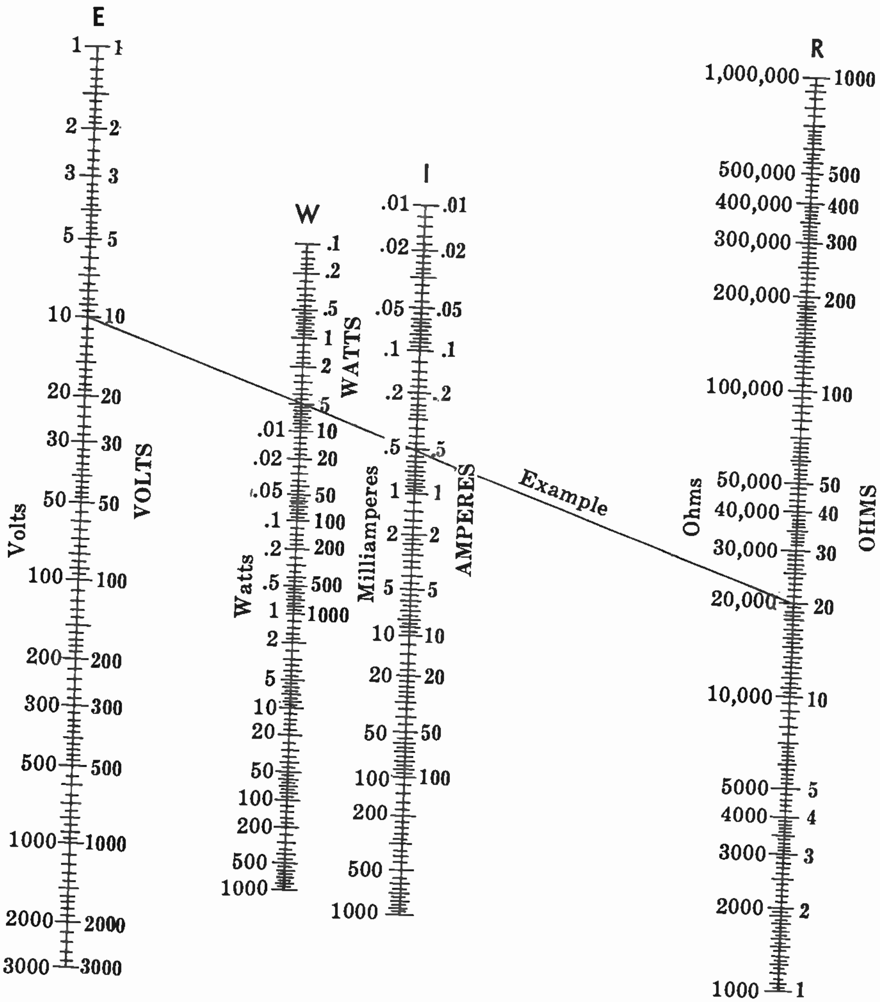


Fig. 2

3. OHM'S LAW NOMOGRAPH

The nomograph on the preceding page is a convenient way of solving most Ohm's law and DC power problems. If two values are known, the two unknown values can be determined by placing a straightedge across the two known values and reading the unknown values at the points where the straightedge crosses the appropriate scales. The figures in bold face (on the right side of all scales) cover one range of given values, and the figures in light face (on the left side) cover another range. For a given problem, all values must be read in either the bold- or light-face figures.

Example—What is the value of a resistor if a 10-volt drop is measured across it and a current of 500 milliamperes (.5 ampere) is flowing through it? What is the power dissipated by the resistor?

***ANSWER*: The value of the resistor is 20 ohms. The power dissipated in the resistor is 5 watts.**

4. KIRCHHOFF'S LAWS

Kirchhoff's voltage law states: "The sum of the voltage drops around a DC series circuit equals the source or applied voltage. In other words, disregarding losses due to the wire resistance:

$$E_T = E_1 + E_2 + E_3$$

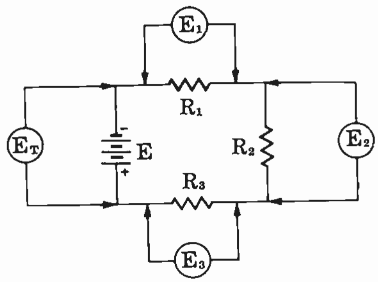


Fig. 3

where,

E_T is the source voltage,

E_1, E_2, and E_3 are the voltage drops across the individual resistors.

Kirchhoff's current law states: "The current flowing toward a point in a circuit must equal the current flowing away from that point." Hence, if a circuit is broken up into several parallel paths, the sum of the currents through the individual paths must equal the current flowing to the point where the circuit branches, or:

$$I_T = I_1 + I_2 + I_3$$

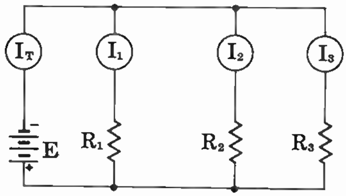


Fig. 4

where,

I_T is the total current flowing through the circuit,
I_1, I_2, and I_3 are the currents flowing through the individual branches.

In a series-parallel circuit, the relationships are as follows:

$$E_T = E_1 + E_2 + E_3$$
$$I_T = I_1 + I_2$$
$$I_T = I_3$$

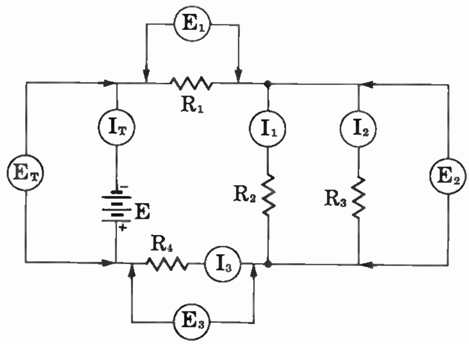


Fig. 5

5. RESISTANCE

The following formulas can be used for calculating the total resistance in a circuit.

Resistors in series (Fig. 6):

$$R_T = R_1 + R_2 + R_3 + \ . \ . \ .$$

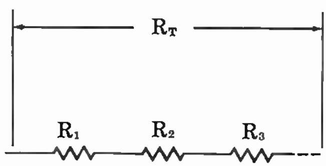


Fig. 6

Resistors in parallel (Fig. 7):

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots}$$

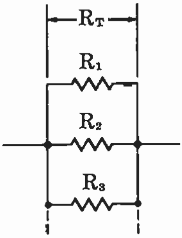


Fig. 7

Two resistors in parallel (Fig. 8):

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

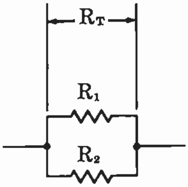


Fig. 8

where,

R_T is the total resistance of the circuit,
R_1, R_2, and R_3 are the values of the individual resistors.

The equivalent value of resistors in parallel can be solved with the nomograph given in Fig. 9. Place a straightedge across the points on scale R_1 and R_2 where the known value resistors fall. The point at which the straightedge crosses the R_T scale will show the total resistance of the two resistors in parallel. If three resistors are in parallel, first find the equivalent resistance of two of the resistors, then consider this value as being in parallel with the remaining resistor.

If the total resistance needed is known, the straightedge can be placed at this value on the R_T scale and rotated to find the various combinations of values on the R_1 and R_2 scales which will produce the needed value.

Scales R_{1Y} and R_{TY} are used with the R_1 scale when the values of the known resistors differ greatly. The range of the nomograph can be increased by multiplying the values of all scales by 10, 100, 1,000, or more, as required.

Parallel Resistance Nomograph

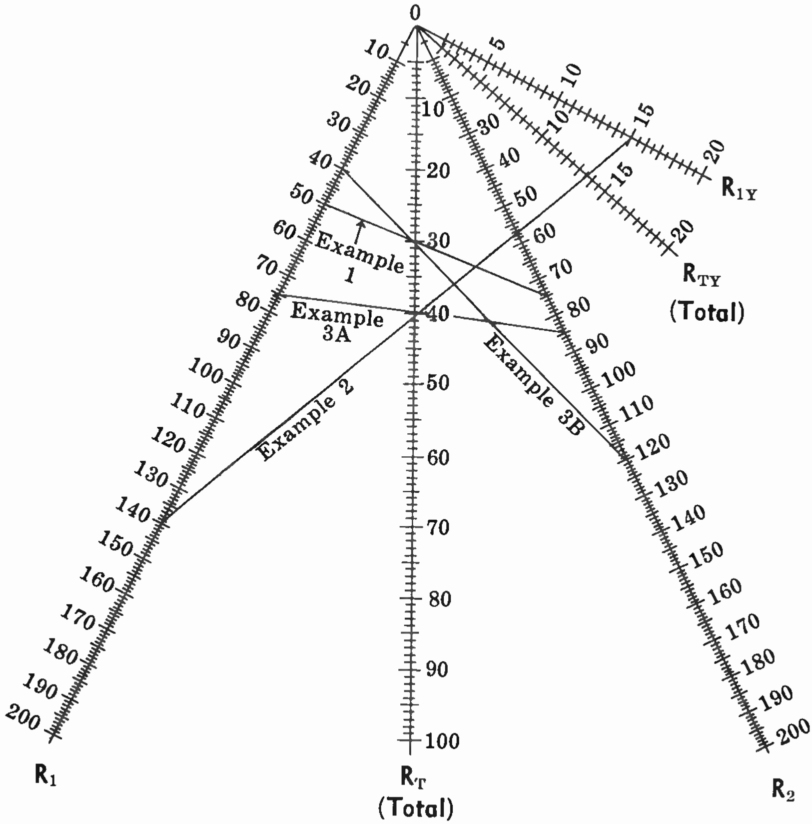


Fig. 9

Example 1—What is the total resistance of a 50-ohm and a 75-ohm resistor in parallel.

ANSWER: 30 ohms.

Example 2—What is the total resistance of a 1,500-ohm and a 14,000-ohm resistor in parallel?

ANSWER: 1,355 ohms. (Use R_1 and R_{1Y} scales; read answer on R_{TY} scale.)

Example 3—What is the total resistance of a 75-ohm, an 85-ohm, and a 120-ohm resistor in parallel?

ANSWER: 30 ohms. (First, consider the 75-ohm and 85-ohm resistors, which will give 40 ohms; then consider this 40 ohms and the 120-ohm resistor, which will give 30 ohms.)

6. CAPACITANCE

(A) Total Capacitance

The following formulas can be used for calculating the total capacitance in a circuit.

Capacitors in parallel (Fig. 10):

$$C_T = C_1 + C_2 + C_3 + \ . \ . \ .$$

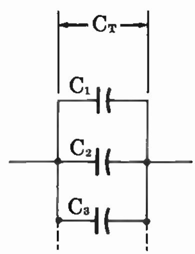


Fig. 10

Capacitors in series (Fig. 11):

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ . \ . \ .}$$

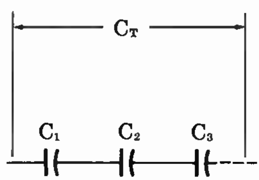


Fig. 11

Two capacitors in series (Fig. 12):

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

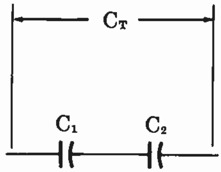


Fig. 12

where,

C_T is the total capacitance in a circuit,
C_1, C_2, and C_3 are the values of the individual capacitors.

The parallel-resistance nomograph in § 5 can also be used to determine the total capacitance of capacitors in series.

The capacitance of a parallel-plate capacitor is determined by:

$$C = 0.2235 \frac{KA}{d} (N - 1)$$

where,

C is the capacitance in micromicrofarads,
K is the dielectric constant,*
A is the area of one plate in square inches,
d is the thickness of the dielectric in inches,
N is the number of plates.

(B) Charge Stored

The charge stored in a capacitor is determined by:

$$Q = CE$$

where,

Q is the charge, in coulombs,
C is the capacitance in farads,
E is the voltage impressed across the capacitor.

(C) Energy Stored

The energy stored in a capacitor can be determined by:

$$W = \frac{CE^2}{2}$$

where,

W is the energy in joules (watt-seconds),
C is the capacitance in farads,
E is the applied voltage in volts.

* For a list of dielectric constants of materials, see § 27.

(D) Voltage Across Series Capacitors

When an AC voltage is applied across a group of capacitors connected in series (Fig. 13), the voltage drop across the combination is, of course, equal to the applied voltage. The drop across each individual capacitor is inversely proportional to its capacitance. The drop across any capacitor in a group of series capacitors is calculated by the formula:

$$E_C = \frac{E_A \times C_T}{C}$$

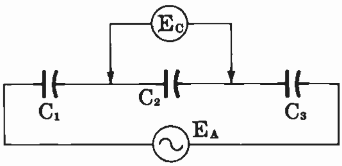


Fig. 13

where,

E_C is the voltage across the individual capacitor in the series (C_1, C_2, or C_3),
E_A is the applied voltage,
C_T is the total capacitance of the series combination,
C is the capacitance of the individual capacitor under consideration.

Note: C_T and C may be in any unit of measurement as long as the unit selected is the same for both.

7. INDUCTANCE

The following formulas can be used for calculating the total inductance in a circuit.

Inductors in series (with no mutual inductance) (Fig. 14):

$$L_T = L_1 + L_2 + L_3 + \ldots$$

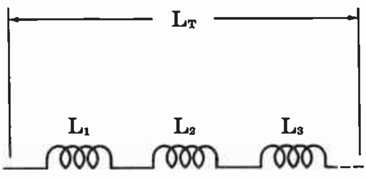


Fig. 14

Inductors in parallel (with no mutual inductance) (Fig. 15):

$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots}$$

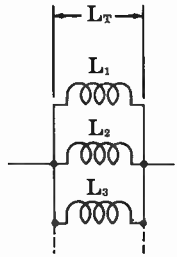


Fig. 15

Two inductors in parallel (with no mutual inductance) (Fig. 16):

$$L_T = \frac{L_1 \times L_2}{L_1 + L_2}$$

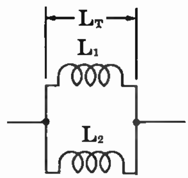


Fig. 16

where,

L_T is the total inductance of the circuit,
L_1, L_2, and L_3 are the inductances of the individual inductors (coils).

The parallel-resistance nomograph in § 5 can also be used to determine the total inductance of inductors in parallel.

(A) Mutual Inductance

The mutual inductance of two coils with fields interacting can be determined by:

$$M = \frac{L_A - L_B}{4}$$

where,

M is the mutual inductance expressed in the same unit as L_A and L_B,
L_A is the total inductance of coils L_1 and L_2 with fields aiding,
L_B is the total inductance of coils L_1 and L_2 with fields opposing.

(B) Coupled Inductance

The coupled inductance can be determined by the following formulas.

In parallel, with fields aiding:

$$L_T = \frac{1}{\frac{1}{L_1 + M} + \frac{1}{L_2 + M}}$$

In parallel, with fields opposing:

$$L_T = \frac{1}{\frac{1}{L_1 - M} + \frac{1}{L_2 - M}}$$

In series, with fields aiding:

$$L_T = L_1 + L_2 + 2M$$

In series, with fields opposing:

$$L_T = L_1 + L_2 - 2M$$

where,

L_T is the total inductance,
L_1 and L_2 are the inductances of the individual coils,
M is the mutual inductance.

(C) Coupling Coefficient

When two coils are inductively coupled to give transformer action, the coupling coefficient is determined by:

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

where,

K is the coupling coefficient,
M is the mutual inductance,
L_1 and L_2 are the inductances of the two coils.

(D) Energy Stored

The energy stored in an inductor can be determined by:

$$W = \frac{LI^2}{2}$$

where,

W is the energy in joules (watt-seconds),
L is the inductance in henries,
I is the current in amperes.

8. Q FACTOR

The ratio of reactance to resistance is known as the Q factor. It can be determined by the following formulas.

For a coil wherein R and L are in series:

$$Q = \frac{\omega L}{R}$$

For a capacitor wherein R and C are in series:

$$Q = \frac{1}{\omega RC}$$

For a capacitor wherein R and C are in parallel:

$$Q = \omega RC$$

where,

Q is a ratio expressing the factor of merit,
ω equals $2\pi f$,
L is the inductance in henries,
R is the resistance in ohms,
C is the capacitance in farads.

9. RESONANCE

The resonant frequency, or the frequency at which the reactances of the circuit add up to zero ($X_L = X_C$), is determined by the formula:

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

where,

f_R is the resonant frequency in cycles per second,
L is the inductance in henries,
C is the capacitance in farads.

The resonant frequency of various combinations of inductance and capacitance can also be obtained from the reactance charts in § 14. Simply lay a straightedge across the values of inductance and capacitance, and read the resonant frequency from the frequency scale of the chart.

10. ADMITTANCE

The measure of the ease with which alternating current flows in a circuit is the admittance of the circuit.

Admittance of a series circuit is given by:

$$Y = \frac{1}{\sqrt{R^2 + X^2}}$$

Admittance is also expressed as the reciprocal of impedance; thus:

$$Y = \frac{1}{Z}$$

where,
Y is the admittance in mhos,
R is the resistance in ohms,
X is the reactance in ohms,
Z is the impedance in ohms.

11. SUSCEPTANCE

The susceptance of a series circuit is given by:

$$B = \frac{X}{R^2 + X^2}$$

When the resistance is zero, susceptance becomes the reciprocal of reactance; thus:

$$B = \frac{1}{X}$$

where,
B is the susceptance in mhos,
X is the reactance in ohms,
R is the resistance in ohms.

12. CONDUCTANCE

Conductance is the measure of the ability of a component to conduct electricity. Conductance for DC circuits is expressed as the reciprocal of resistance; therefore:

$$G = \frac{1}{R}$$

where,
G is the conductance in mhos,
R is the resistance in ohms.

Ohm's law formulas when conductance is considered are:

$$I = EG$$

$$G = \frac{I}{E}$$

$$E = \frac{I}{G}$$

where,

I is the current in amperes,
E is the voltage in volts,
G is the conductance in mhos,
R is the resistance in ohms.

13. ENERGY UNITS

Energy is the capacity or ability to do work. The joule is a unit of energy. One joule is the amount of energy required to maintain a current of one ampere for one second through a resistance of one ohm. It is equivalent to a watt-second. The watt-hour is the practical unit of energy; 3600 watt-seconds equals one watt-hour. The number of watt-hours is calculated:

$$\text{Watt-hours} = P \times T$$

where,

P is the power in watts,
T is the time in hours the power is dissipated.

See § 6 for the energy stored in a capacitor, and § 7 for the energy stored in an inductor.

14. REACTANCE

The opposition to the flow of alternating current by the inductance or capacitance of a component or circuit is called the reactance.

(A) Capacitive Reactance

The reactance of a capacitor may be calculated by the formula:

$$X_C = \frac{1}{2\pi fC}$$

where,

X_C is the reactance in ohms,
f is the frequency in cycles per second,
C is the capacitance in farads.

(B) Inductive Reactance

The reactance of an inductor may be calculated by the formula:

$$X_L = 2\pi fL$$

where,

X_L is the reactance in ohms,
f is the frequency in cycles per second,
L is the inductance in henries.

(C) Reactance Charts

Charts for determining unknown values of reactance, inductance, capacitance, and frequency are given on the following pages. The chart in Fig. 17A covers 1 to 1,000 cycles, Fig. 17B covers 1 to 1,000 kilocycles, and Fig. 17C covers 1 to 1,000 megacycles.

To find the amount of reactance of a capacitor at a given frequency, lay the straightedge across the capacitor value and the frequency. Then read the reactance from the reactance scale. By extending the line, the value of an inductance which will give the same reactance can be obtained.

Since $X_C = X_L$ at resonance, by laying the straightedge across the capacitance and inductance values, the resonant frequency of the combination can be determined.

Example—If the frequency is 10 cycles per second and the capacitance is 50 mfd, what is the reactance of the capacitor? What value of inductance will give this same reactance?

ANSWER: The reactance is 310 ohms. The inductance needed to produce this same reactance is 5 henries. Thus, it follows that a 50-mfd capacitor and a 5-henry choke are resonant at 10 cps. [Place the straightedge, on the proper chart (Fig. 17A), across 10 cps and 50 mfd. Read the values indicated on the reactance and inductance scales.]

15. IMPEDANCE

The basic formulas for calculating the total impedance are as follows.

For parallel circuits:

$$Z = \frac{1}{\sqrt{G^2 + B^2}}$$

Reactance Chart — 1 cps to 1 kc

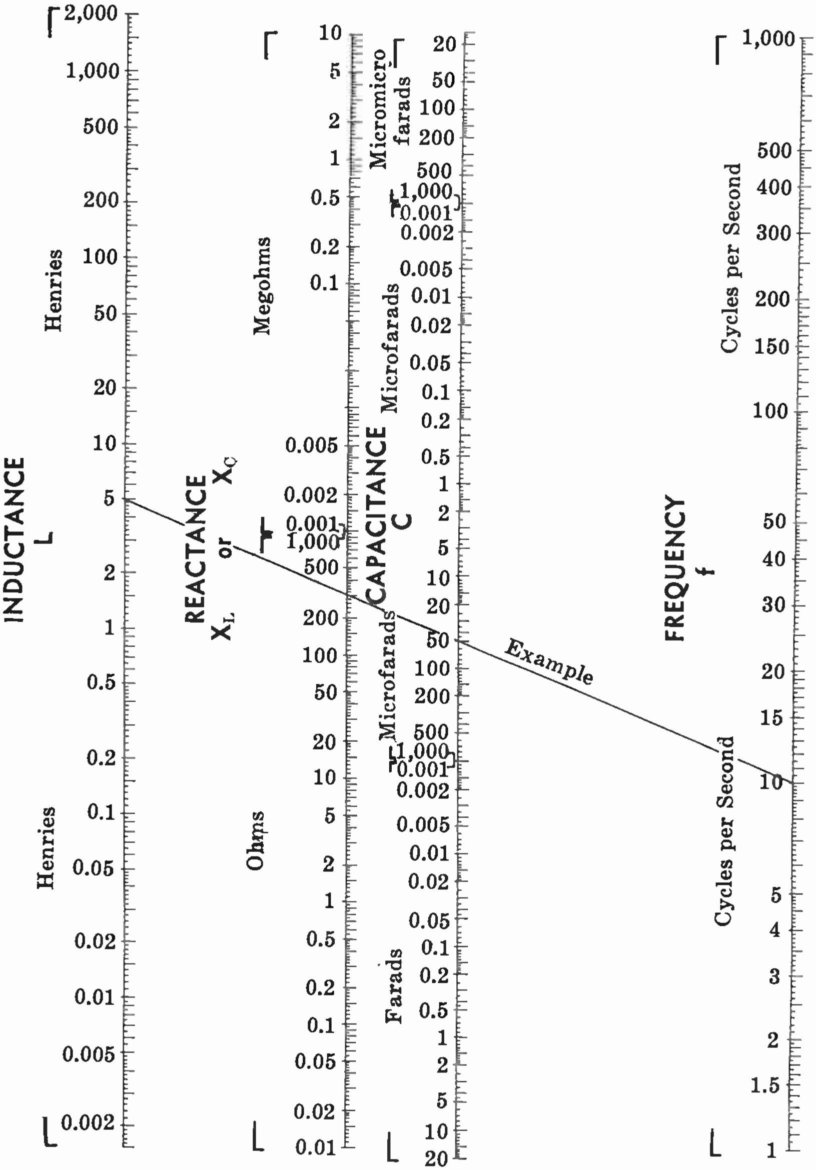


Fig. 17A

Reactance Chart — 1 kc to 1 mc

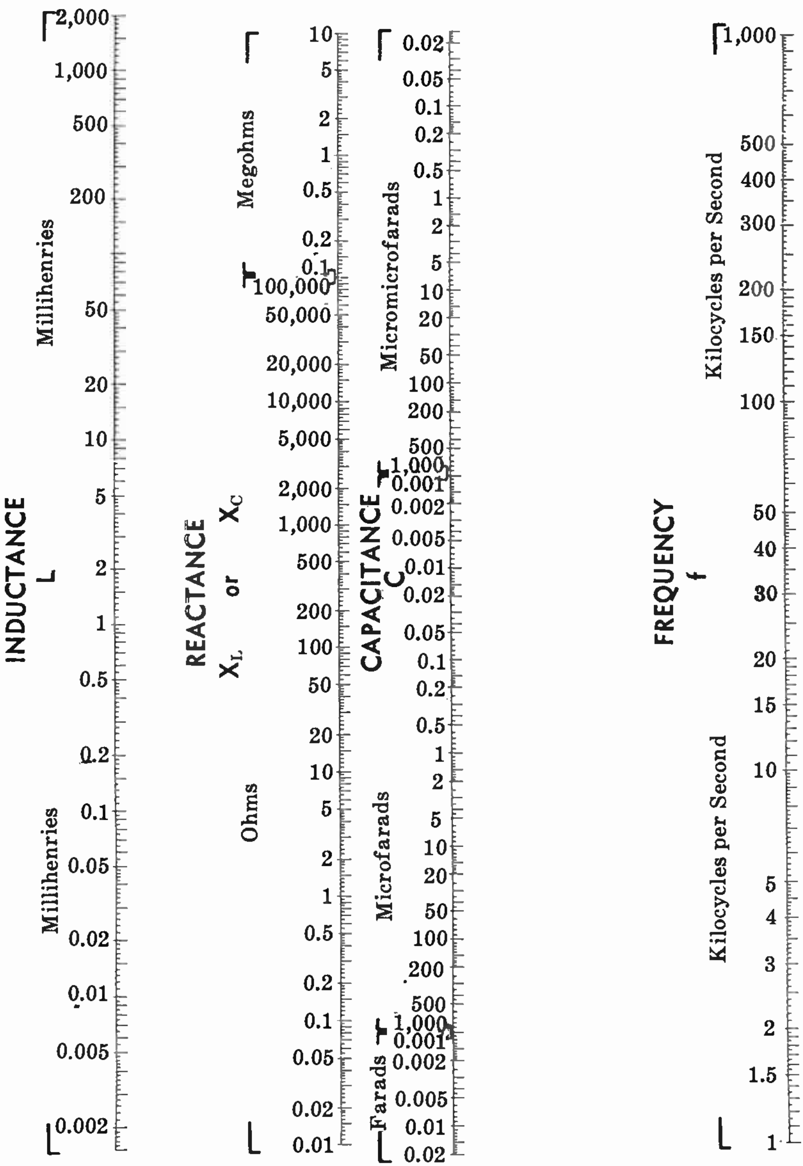


Fig. 17B

Reactance Chart — 1 mc to 1,000 mc

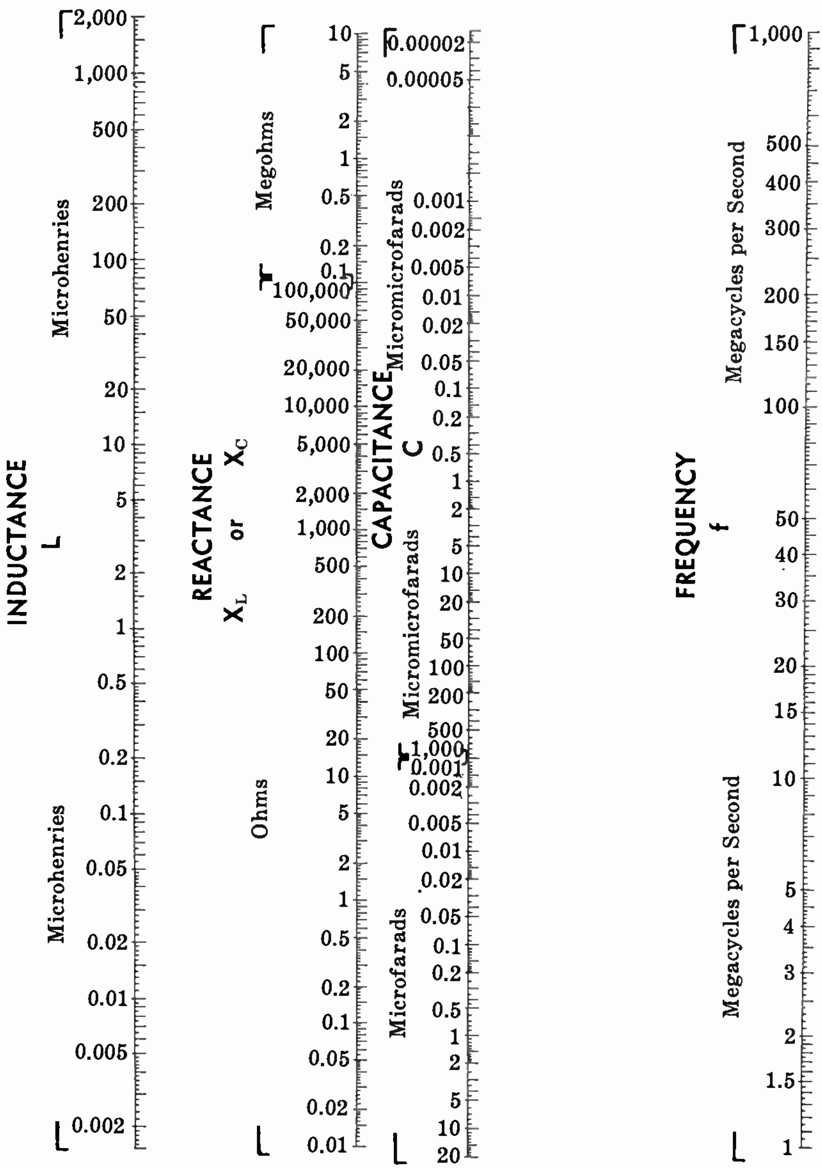


Fig. 17C

For series circuits:

$$Z = \sqrt{R^2 + X^2}$$

where,

Z is the total impedance,
G is the total conductance or the reciprocal of the total parallel resistance,
B is the total susceptance,
R is the total resistance,
X is the total reactance.

The following formulas can be used to find the impedance of the various combinations of inductance, capacitance, and resistance.

For a single resistance (Fig. 18):

$$Z = R$$
$$\theta = 0^\circ$$

Fig. 18

For resistances in series (Fig. 19):

$$Z = R_1 + R_2 + R_3 + \ldots$$
$$\theta = 0^\circ$$

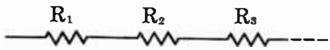


Fig. 19

For a single inductance (Fig. 20):

$$Z = X_L$$
$$\theta = 90^\circ$$

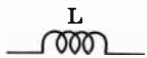


Fig. 20

For inductances in series (with no mutual inductance) (Fig. 21):

$$Z = X_{L_1} + X_{L_2} + X_{L_3} + \ldots$$
$$\theta = 90^\circ$$

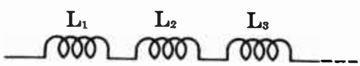


Fig. 21

For a single capacitance (Fig. 22):

$$Z = X_C$$
$$\theta = 90^\circ$$

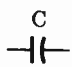


Fig. 22

For capacitances in series (Fig. 23):

$$Z = X_{C_1} + X_{C_2} + X_{C_3} + \ldots$$

$$\theta = 90^\circ$$

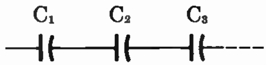


Fig. 23

For resistance and inductance in series (Fig. 24):

$$Z = \sqrt{R^2 + X_L^2}$$

$$\theta = \arctan \frac{X_L}{R}$$

Fig. 24

For resistance and capacitance in series (Fig. 25):

$$Z = \sqrt{R^2 + X_C^2}$$

$$\theta = \arctan \frac{X_C}{R}$$

Fig. 25

For inductance and capacitance in series (Fig. 26):

When X_L is larger than X_C

$$Z = X_L - X_C$$

When X_C is larger than X_L

$$Z = X_C - X_L$$

$$\theta = 0^\circ \text{ when } X_L = X_C$$

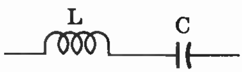


Fig. 26

For resistance, inductance, and capacitance in series (Fig. 27):

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\theta = \arctan \frac{X_L - X_C}{R}$$

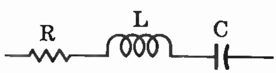


Fig. 27

For resistances in parallel (Fig. 28):

$$Z = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

$$\theta = 0^\circ$$

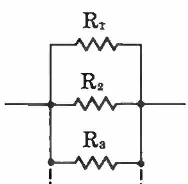


Fig. 28

For inductances in parallel (with no mutual inductance) (Fig. 29):

$$Z = \frac{1}{\frac{1}{X_{L_1}} + \frac{1}{X_{L_2}} + \frac{1}{X_{L_3}} + \ldots}$$

$$\theta = 90°$$

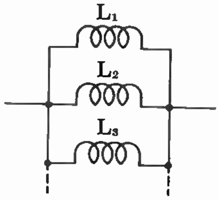


Fig. 29

For capacitances in parallel (Fig. 30):

$$Z = \frac{1}{\frac{1}{X_{C_1}} + \frac{1}{X_{C_2}} + \frac{1}{X_{C_3}} + \ldots}$$

$$\theta = 90°$$

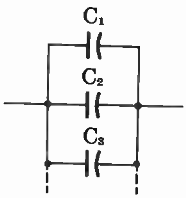


Fig. 30

For resistance and inductance in parallel (Fig. 31):

$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$$

$$\theta = \text{arc tan}\,\frac{R}{X_L}$$

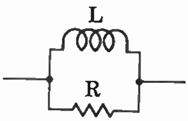


Fig. 31

For capacitance and resistance in parallel (Fig. 32):

$$Z = \frac{RX_C}{\sqrt{R^2 + X_C^2}}$$

$$\theta = \text{arc tan}\,\frac{R}{X_C}$$

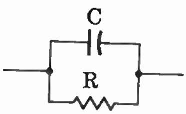


Fig. 32

For capacitance and inductance in parallel (Fig. 33):

When X_L is larger than X_C:

$$Z = \frac{X_L X_C}{X_L - X_C}$$

When X_C is larger than X_L:

$$Z = \frac{X_C X_L}{X_C - X_L}$$

$$\theta = 0° \text{ when } X_L = X_C$$

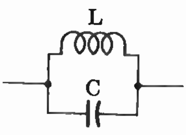


Fig. 33

For inductance, capacitance, and resistance in parallel (Fig. 34):

$$Z = \frac{RX_LX_C}{\sqrt{X_L^2\,X_C^2 + R^2(X_L - X_C)^2}}$$

$$\theta = \text{arc tan}\,\frac{R(X_L - X_C)}{X_LX_C}$$

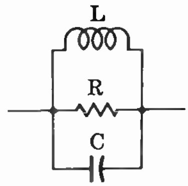


Fig. 34

For inductance and series resistance in parallel with resistance (Fig. 35):

$$Z = R_2\sqrt{\frac{R_1^2 + X_L^2}{(R_1 + R_2)^2 + X_L^2}}$$

$$\theta = \text{arc tan}\,\frac{X_LR_2}{R_1^2 + X_L^2 + R_1R_2}$$

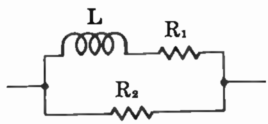


Fig. 35

For inductance and series resistance in parallel with capacitance (Fig. 36):

$$Z = X_C\sqrt{\frac{R^2 + X_L^2}{R^2 + (X_L - X_C)^2}}$$

$$\theta = \text{arc tan}\,\frac{X_L(X_C - X_L) - R^2}{RX_C}$$

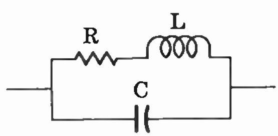


Fig. 36

For capacitance and series resistance in parallel with inductance and series resistance (Fig. 37):

$$Z = \sqrt{\frac{(R_1^2 + X_L^2)\ (R_2^2 + X_C^2)}{(R_1 + R_2)^2 + (X_L - X_C)^2}}$$

$$\theta = \text{arc tan}\,\frac{X_L\ (R_2^2 + X_C^2) - X_C\ (R_1^2 + X_L^2)}{R_1\ (R_2^2 + X_C^2) + R_2\ (R_1^2 + X_L^2)}$$

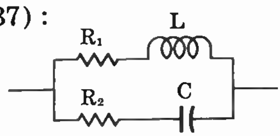


Fig. 37

where,

Z is the impedance in ohms,
R is the resistance in ohms,
L is the inductance in henries,
X_L is the inductive reactance in ohms,
X_C is the capacitive reactance in ohms,
θ is the phase angle in degrees by which the current leads the voltage in a capacitive circuit or lags the voltage in an inductive circuit. 0° indicates an in-phase condition.

16. OHM'S LAW FOR ALTERNATING CURRENT

The fundamental Ohm's law formulas for alternating current are given by:

$$E = IZ$$

$$I = \frac{E}{Z}$$

$$Z = \frac{E}{I}$$

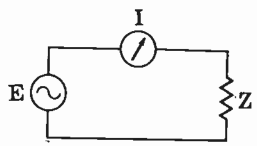


Fig. 38

where,

E is the voltage in volts,
I is the current in amperes,
Z is the impedance in ohms.

The power expended in an AC circuit is calculated by the formula:

$$P = EI \cos \theta$$

where,

P is the power in watts,
E is the voltage in volts,
I is the current in amperes,
θ is the phase angle in degrees.

The phase angle is the difference in degrees by which the current leads or lags the voltage in a reactive circuit. In a series circuit, the phase angle is determined by the formula:

$$\theta = \text{arc tan } \frac{X}{R}$$

where,

X is the inductive or capacitive reactance in ohms,
R is the nonreactive resistance in ohms.

Therefore:

For a purely resistive circuit:

$$\theta = 0^\circ$$
$$\cos\theta = 1$$
$$P = EI$$

For a resonant circuit:

$$\theta = 0^\circ$$
$$\cos\theta = 1$$
$$P = EI$$

For a purely reactive circuit:

$$\theta = 90^\circ$$
$$\cos\theta = 0$$
$$P = 0$$

17. AVERAGE, RMS, PEAK, AND PEAK-TO-PEAK VOLTAGE AND CURRENT

The following table can be used to convert sinusoidal voltage (or current) values from one method of measurement to another. To use the table, first find the given type of reading in the left-hand column, then find the desired type of reading across the top of the table. To convert the given value to the desired value, multiply the given value by the factor listed under the desired value.

Example—What factor must peak voltage be multiplied by to obtain rms voltage?

ANSWER: .707.

Table I. Average, Rms, Peak, and Peak-to-Peak Values

Given Value	Multiplying Factor To Get			
	Average	Rms	Peak	Peak-to-Peak
Average	—	1.11	1.57	3.14
Rms	0.9	—	1.414	2.828
Peak	0.637	0.707	—	2.0
Peak-to-Peak	0.32	0.3535	0.5	—

18. POWER FACTOR

Power factor is the ratio of true power to apparent power in an alternating circuit. Thus:

$$pf = \frac{P_T}{P_A} = \frac{EI \cos \theta}{EI}$$

$$= \cos \theta$$

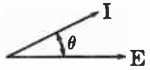


Fig. 39

where,

pf is the power factor,
P_T is the true power in watts,
P_A is the apparent power in volt-amperes,
$EI \cos \theta$ is the true power in watts,
EI is the apparent power in volt-amperes.

Therefore:

For a purely resistive circuit:

$$\theta = 0°$$
$$pf = 1$$

For a resonant circuit:

$$\theta = 0°$$
$$pf = 1$$

For a purely reactive circuit:

$$\theta = 90°$$
$$pf = 0$$

19. TIME CONSTANTS

A certain amount of time is required, after a DC voltage has been applied to an R-C or R-L circuit, before the capacitor can charge or the current can build up to a portion of the full value. This time is called the time constant of the circuit. However, the time constant is not the time required for the voltage or current to reach the full value; instead, it is the time required to reach 63.2% of full value. During the next time constant, the capacitor is charged or the current builds up to 63.2% of the remaining difference, or to 86.5% of the full value. Table II gives the per cent of full charge on a capacitor, or current buildup in an inductance after each time constant. Theoretically, the charge on the capacitor, or the current through the coil, can never reach 100%. However, it is usually considered to be 100% after five time constants.

Table II. Time Constants *versus* Per Cent of Voltage or Current

No. of Time Constants	% Charge or Buildup	% Discharge or Decay
1	63.2	36.8
2	86.5	13.5
3	95.0	5.0
4	98.2	1.8
5	99.3	0.7

Likewise, when the voltage source is removed, the capacitor will discharge or the current will decay 63.2%, or to 36.8% of full value during the first time constant. Table II also gives the per cent of full voltage after each time constant for discharge of a capacitor or decay of the current through a coil.

The time per time constant is calculated as follows.

For an R-C circuit (Fig. 40):

$$T = RC$$

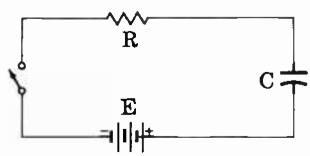


Fig. 40

For an R-L circuit (Fig. 41):

$$T = \frac{L}{R}$$

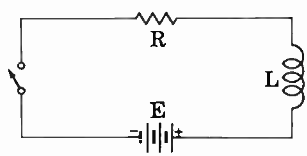


Fig. 41

where,

T is the time in seconds,
R is the resistance in ohms,
C is the capacitance in farads,
L is the inductance in henries.

In addition, the values can also be expressed by the following relationships:

T	R	C or L
seconds	megohms	microfarads
seconds	megohms	microhenries
microseconds	ohms	microfarads
microseconds	megohms	micromicrofarads
microseconds	ohms	microhenries

20. TRANSFORMER FORMULAS

In a transformer, the relationships between the number of turns in the primary and secondary, the voltage across each winding, and the current through the windings are expressed by the equations:

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \quad \text{and} \quad \frac{E_p}{E_s} = \frac{I_s}{I_p}$$

By rearranging these equations, any unknown can be determined from the following formulas:

$$E_p = \frac{E_s N_p}{N_s} = \frac{E_s I_s}{I_p}$$

$$E_s = \frac{E_p N_s}{N_p} = \frac{E_p I_p}{I_s}$$

$$N_p = \frac{E_p N_s}{E_s} = \frac{N_s I_s}{I_p}$$

$$N_s = \frac{E_s N_p}{E_p} = \frac{N_p I_p}{I_s}$$

$$I_p = \frac{E_s I_s}{E_p} = \frac{N_s I_s}{N_p}$$

$$I_s = \frac{E_p I_p}{E_s} = \frac{N_p I_p}{N_s}$$

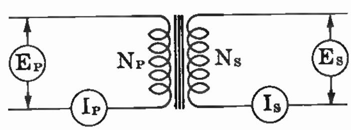


Fig. 42

The turns ratio of a transformer is determined by the following formulas:

For a step-up transformer:

$$T = \frac{N_s}{N_p}$$

For a step-down transformer:

$$T = \frac{N_p}{N_s}$$

The impedance ratio of a transformer is determined by:

$$Z = T^2$$

The impedance of an unknown winding is determined by the following:

For a step-up transformer:

$$Z_p = \frac{Z_s}{Z}$$

$$Z_s = Z \times Z_p$$

For a step-down transformer:

$$Z_p = Z \times Z_s$$

$$Z_s = \frac{Z_p}{Z}$$

where,

E_p is the voltage across the primary winding,
E_s is the voltage across the secondary winding,
N_p is the number of turns in the primary winding,
N_s is the number of turns in the secondary winding,
I_p is the current through the primary winding,
I_s is the current through the secondary winding,
T is the turns ratio,
Z is the impedance ratio,
Z_p is the impedance of the primary winding,
Z_s is the impedance of the secondary winding.

21. VOLTAGE REGULATION

When a load is connected to a power supply, the output voltage drops because more current flows through the resistive elements of the power supply. Voltage regulation is a measure of how much the voltage drops and is usually expressed as a percentage. It is determined by the following formula:

$$\%R = \frac{E_1 - E_2}{E_2} \times 100$$

where,

%R is the voltage regulation in per cent,
E_1 is the no-load voltage,
E_2 is the voltage under load.

22. DC METER FORMULAS

The basic instrument for testing current and voltage is the moving-coil meter. The meter can be either a DC milliammeter or a DC microammeter. A series resistor converts the meter to a DC voltmeter, and a parallel resistor converts the meter to a DC ammeter. The resistance of the meter movement is determined first, as follows. Connect a suitable variable resistor R_a and a battery as shown in Fig. 43. Adjust resistor R_a until full-scale deflection is obtained. Then connect a variable resistor R_b in parallel with the meter, and adjust R_b until half-scale deflection is obtained. Disconnect

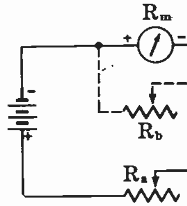


Fig. 43

R_b and measure its resistance. The measured value is the resistance of the meter movement.

(A) Voltage Multipliers

$$R = \frac{E_s}{I_s} - R_m$$

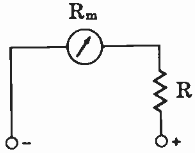


Fig. 44

where,

R is the multiplier resistance in ohms,
E_s is the full-scale reading in volts,
I_s is the full-scale reading in amperes,
R_m is the meter resistance in ohms.

(B) Shunt-type Ohmmeter for Low Resistance

$$R_X = R_m \frac{I_2}{I_1 - I_2}$$

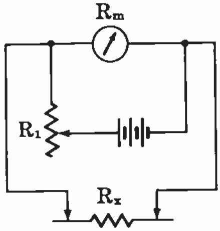


Fig. 45

where,

R_X is the unknown resistance,
R_m is the meter resistance in ohms,
I_1 is the current reading with probes open,
I_2 is the current reading with probes connected across unknown resistor,
R_1 is a variable resistance for current limiting to keep meter adjusted for full-scale reading with probes open.

(C) Series-type Ohmmeter for High Resistance

$$R_X = (R_1 + R_m)\,\frac{I_1 - I_2}{I_2}$$

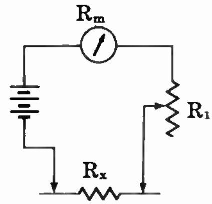


Fig. 46

where,

R_X is the unknown resistance,
R_1 is a variable resistance adjusted for full-scale reading with probes shorted together,
R_m is the meter resistance in ohms,
I_1 is the current reading with probes shorted,
I_2 is the current reading with unknown resistor connected.

(D) Ammeter Shunts

$$R = \frac{R_m}{N - 1} = \frac{I_m\,R_m}{I_s}$$

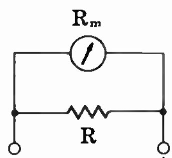


Fig. 47

where,

R is the resistance of the shunt,
R_m is the meter resistance in ohms,
N is the scale multiplication factor,
I_m is the meter current,
I_s is the shunt current.

(E) Ammeter With Multirange Shunt

$$R_2 = \frac{(R_1 + R_2) + R_m}{N}$$

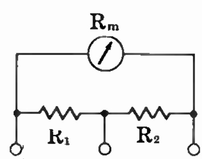


Fig. 48

where,
R_2 is the intermediate value in ohms,
$R_1 + R_2$ is the total shunt resistance for lowest full-scale reading,
R_m is the meter resistance in ohms,
N is the scale multiplication factor.

23. FREQUENCY AND WAVELENGTH

(A) Formulas

Since the frequency is the number of complete cycles per second and since radio waves travel at a fixed speed, it follows that a complete cycle occupies a given distance in space. The distance between two corresponding parts of two waves (the two positive or negative crests or the points where the two waves cross the zero axis in a given direction) constitutes the wavelength. If either the frequency or the wavelength is known, the other can be computed as follows:

$$f = \frac{300{,}000}{\lambda}$$

$$\lambda = \frac{300{,}000}{f}$$

where,
f is the frequency in kilocycles,
λ is the wavelength in meters.

If it is desired to calculate the wavelength in feet, the following formulas should be used:

$$f = \frac{984{,}000}{\lambda}$$

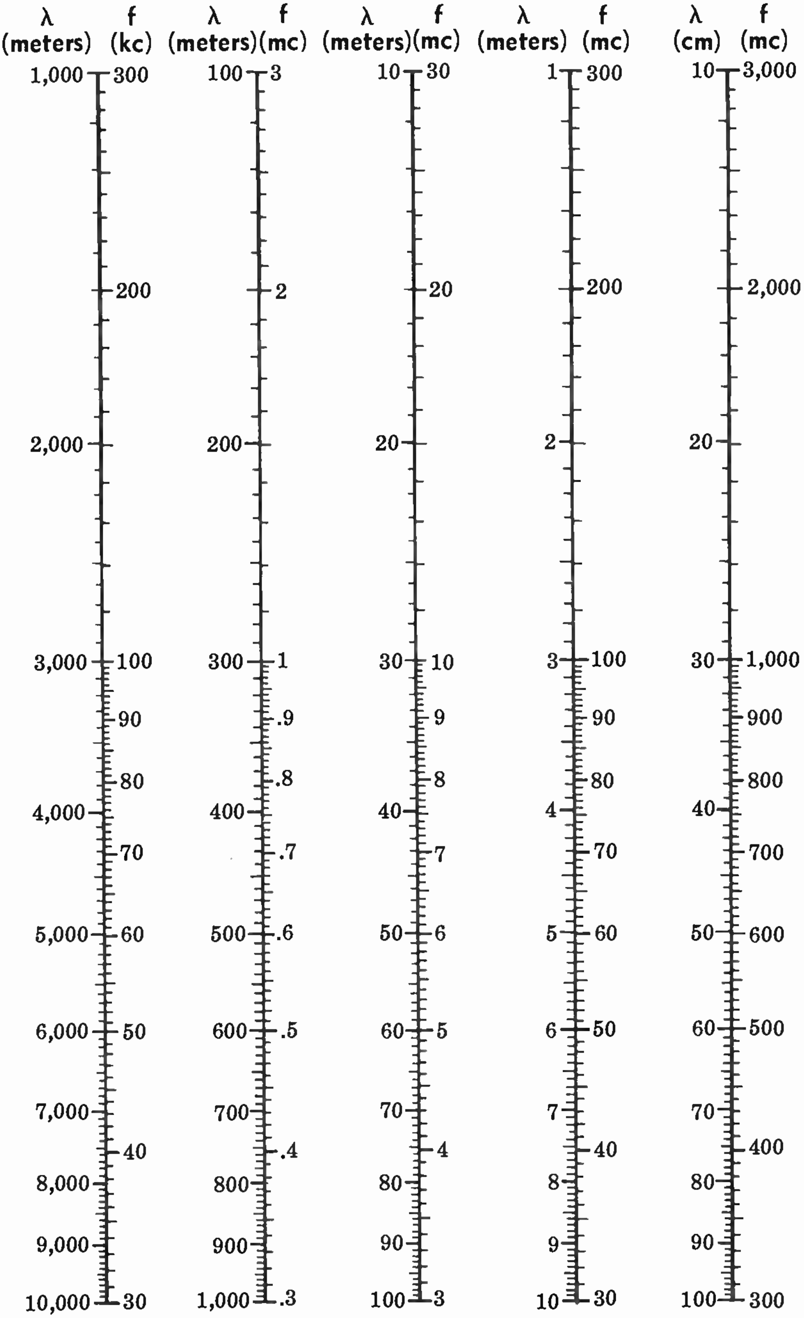
$$\lambda = \frac{984{,}000}{f}$$

where,
f is the frequency in kilocycles,
λ is the wavelength in feet.

(B) Conversion Chart

The wavelength of any frequency from 30 kc to 3000 mc can be read directly from the chart in Fig. 49. Likewise, if the wavelength is known, the corresponding frequency can be obtained from the chart for wavelengths from 10 centimeters to 1000 meters. To use the chart, merely find the

Frequency-Wavelength Conversion Chart



known value (either frequency or wavelength) on one of the scales, and then read the corresponding value from the opposite side of the scale.

Example—What is the wavelength of a 4-mc signal?

ANSWER: 75 meters. (Find 4 mc on the third scale from the left. Opposite 4 mc on the frequency scale we find 75 meters on the wavelength scale.)

24. TRANSMISSION-LINE FORMULAS

The characteristic impedance of a transmission line is defined as the input impedance of a line of the same configuration and dimensions but of infinite length. When a line of finite length is terminated with an impedance equal to its own characteristic impedance, the line is said to be matched.

(A) Coaxial Line

The characteristic impedance of a coaxial line is given by:

$$Z_o = \frac{138}{\sqrt{k}} \log \frac{D}{d}$$

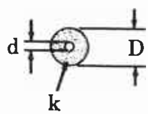


Fig. 50

where,

Z_o is the characteristic impedance,
D is the inside diameter of the outer conductor,
d is the outside diameter of the inner conductor expressed in the same units as D,
k is the dielectric constant of the insulating material* (k equals 1 for dry air).

The attenuation of coaxial line in decibels per foot can be determined by the formula:

$$a = \frac{4.6\sqrt{f}\,(D + d)}{D \times d\left(\log \frac{D}{d}\right)} \times 10^{-6}$$

where,

a is the attenuation in decibels per foot of line,
f is the frequency in megacycles,
D is the inside diameter of the outer conductor in inches,
d is the outside diameter of the inner conductor in inches.

* For a list of dielectric constants of materials, see § 27.

(B) Parallel-Conductor Line

The characteristic impedance of parallel-conductor line (twin-lead) is determined by the formula:

$$Z_o = \frac{276}{\sqrt{k}} \log \frac{2D}{d}$$

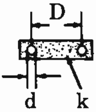


Fig. 51

where,

Z_o is the characteristic impedance,
D is the center-to-center distance between conductors,
d is the diameter of the conductors in the same units as D,
k is the dielectric constant of the insulating material between conductors* (k equals 1 for dry air).

25. MODULATION FORMULAS

(A) Amplitude Modulation

The amount of modulation of an amplitude-modulated carrier is referred to as the percentage of modulation. It can be determined by the following formulas:

$$\%M = \frac{E_C - E_T}{2E_{AV}} \times 100$$

or,

$$\%M = \frac{E_C - E_T}{E_C + E_T} \times 100$$

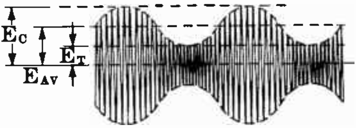


Fig. 52

where,

%M is the percentage of modulation,
E_C is the amplitude of the crest of the modulated carrier,
E_T is the amplitude of the trough of the modulated carrier,
E_{AV} is the average amplitude of the modulated carrier.

Also, the percentage of modulation can be determined by applying the modulated carrier wave to the vertical plates and the modulating voltage wave to the horizontal plates of an oscilloscope. This produces a trapezoidal wave, as shown in Fig. 53. The dimensions A and B are proportional to the crest and trough amplitudes, respectively. The percentage

* For a list of dielectric constants of materials, see § 27.

of modulation can be determined by measuring the height of A and B, and using the formula:

$$\%M = \frac{A - B}{A + B} \times 100$$

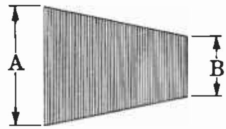


Fig. 53

where,

$\%M$ is the percentage of modulation,
A and B are the dimensions measured in Fig. 53.

The sideband power of an AM carrier is determined by:

$$P_{SB} = \frac{\%M^2}{2} \times P_C$$

The total radiated power is the sum of the carrier and the radiated powers:

$$P_T = P_{SB} + P_C$$

where,

P_{SB} is the sideband power (includes both sidebands),
$\%M$ is the percentage of modulation,
P_C is the carrier power,
P_T is the total radiated power.

Note: The carrier power does not change with modulation.

(B) Frequency Modulation

In a frequency-modulated carrier, the amount the carrier frequency changes is determined by the amplitude of the modulating signal, and the number of times the changes occur per second is determined by the frequency of the modulating signal.

The percentage of modulation of an FM carrier can be computed from:

$$\%M = \frac{\Delta f}{\Delta f \text{ for } 100\%M} \times 100$$

where,

$\%M$ is the percentage of modulation,
Δf is the change in frequency, or the deviation,
Δf for $100\%M$ is the change in frequency for a 100% modulated carrier. (For commercial FM, 75 kc; for television sound, 25 kc; and for two-way radio, 15 kc.)

The modulation index of an FM carrier is determined by:

$$M = \frac{f_d}{f_a}$$

where,

M is the modulation index,
f_d is the deviation in frequency,
f_a is the modulating audio frequency in the same units as f_d.

26. DECIBELS AND VOLUME UNITS

(A) Equations

The number of decibels corresponding to a given power ratio is 10 times the common logarithm of the ratio. Thus:

$$db = 10 \log \frac{P_2}{P_1}$$

The number of decibels corresponding to a given voltage or current ratio is 20 times the common logarithm of the ratio. Thus, when the impedances across which the signals are being measured are equal, the equations are:

$$db = 20 \log \frac{E_2}{E_1}$$

$$db = 20 \log \frac{I_2}{I_1}$$

If the impedances across which the signals are measured are not equal, the equations become:

$$db = 20 \log \frac{E_2\sqrt{Z_1}}{E_1\sqrt{Z_2}}$$

$$db = 20 \log \frac{I_2\sqrt{Z_2}}{I_1\sqrt{Z_1}}$$

(B) Reference Levels

The decibel is not an absolute value; it is a means of stating the ratio of a level to a certain reference level. Usually, when no reference level is given, it is 6 millivolts across a 500-ohm impedance. However, the reference level should be stated whenever a value in db's is given. Other units, which do have specific reference levels, have been established. Some of the more common are:

dbk —1 kilowatt
dbm —1 milliwatt, 600 ohms
dbv —1 volt
dbw —1 watt
dbvg —voltage gain
dbrap—decibels above a reference acoustical power of 10^{-16} watts
VU —1 milliwatt, 600 ohms (complex waveforms varying in both amplitude and frequency).

(C) Decibel Table

The decibel table on the following pages lists most of the current, voltage, and power ratios encountered, with their decibel values. If a db value is not listed and it is desired to find the corresponding ratio, first subtract one of the given values from the unlisted value (select a value so the remainder will also be listed). Then multiply the ratios given in the chart for each value. To convert a ratio which is not given in the table to a db value, first factor the ratio so that each factor will be a listed value; then find the db equivalents for each factor and add them.

Example 1—Find the db equivalent of a power ratio of .631.

ANSWER: 2-db loss.

Example 2—Find the current ratio corresponding to a gain of 43 db.

ANSWER: 141. [First find the current ratio for 40 db (100); then find the current ratio for 3 db (1.41). Multiplying, $100 \times 1.41 = 141$.]

Example 3—Find the db value corresponding to a voltage ratio of 150.

ANSWER: 43.5. [First factor 150 into 1.5×100. The db value for a voltage ratio of 100 is 40; the db value for a voltage ratio of 1.5 is 3.5 (approximately). Therefore, the db value for a voltage ratio is $40 + 3.5$ or 43.5 db.]

Table III. Decibel Table (0 to 10.9 Db)

Db	Current or Voltage Ratio		Power Ratio	
	Gain	Loss	Gain	Loss
0	1.000	1.0000	1.000	1.0000
.1	1.012	.9886	1.023	.9772
.2	1.023	.9772	1.047	.9550
.3	1.035	.9661	1.072	.9333
.4	1.047	.9550	1.096	.9120
.5	1.059	.9441	1.122	.8913
.6	1.072	.9333	1.148	.8710
.7	1.084	.9226	1.175	.8511
.8	1.096	.9120	1.202	.8318
.9	1.109	.9016	1.230	.8128
1.0	1.122	.8913	1.259	.7943
1.1	1.135	.8810	1.288	.7762
1.2	1.148	.8710	1.318	.7586
1.3	1.161	.8610	1.349	.7413
1.4	1.175	.8511	1.380	.7244
1.5	1.189	.8414	1.413	.7079
1.6	1.202	.8318	1.445	.6918
1.7	1.216	.8222	1.479	.6761
1.8	1.230	.8128	1.514	.6607
1.9	1.245	.8035	1.549	.6457
2.0	1.259	.7943	1.585	.6310
2.1	1.274	.7852	1.622	.6166
2.2	1.288	.7762	1.660	.6026
2.3	1.303	.7674	1.698	.5888
2.4	1.318	.7586	1.738	.5754
2.5	1.334	.7499	1.778	.5623
2.6	1.349	.7413	1.820	.5495
2.7	1.365	.7328	1.862	.5370
2.8	1.380	.7244	1.905	.5248
2.9	1.396	.7161	1.950	.5129
3.0	1.413	.7079	1.995	.5012
3.1	1.429	.6998	2.042	.4898
3.2	1.445	.6918	2.089	.4786
3.3	1.462	.6839	2.138	.4677
3.4	1.479	.6761	2.188	.4571
3.5	1.496	.6683	2.239	.4467
3.6	1.514	.6607	2.291	.4365
3.7	1.531	.6531	2.344	.4266
3.8	1.549	.6457	2.399	.4169
3.9	1.567	.6383	2.455	.4074
4.0	1.585	.6310	2.512	.3981
4.1	1.603	.6237	2.570	.3890
4.2	1.622	.6166	2.630	.3802
4.3	1.641	.6095	2.692	.3715
4.4	1.660	.6026	2.754	.3631
4.5	1.679	.5957	2.818	.3548
4.6	1.698	.5888	2.884	.3467
4.7	1.718	.5821	2.951	.3388
4.8	1.738	.5754	3.020	.3311
4.9	1.758	.5689	3.090	.3236
5.0	1.778	.5623	3.162	.3162
5.1	1.799	.5559	3.236	.3090
5.2	1.820	.5495	3.311	.3020
5.3	1.841	.5433	3.388	.2951
5.4	1.862	.5370	3.467	.2884
5.5	1.884	.5309	3.548	.2818
5.6	1.905	.5248	3.631	.2754
5.7	1.928	.5188	3.715	.2692
5.8	1.950	.5129	3.802	.2630
5.9	1.972	.5070	3.890	.2570
6.0	1.995	.5012	3.981	.2512
6.1	2.018	.4955	4.074	.2455
6.2	2.042	.4898	4.169	.2399
6.3	2.065	.4842	4.266	.2344
6.4	2.089	.4786	4.365	.2291
6.5	2.113	.4732	4.467	.2239
6.6	2.138	.4677	4.571	.2188
6.7	2.163	.4624	4.677	.2138
6.8	2.188	.4571	4.786	.2089
6.9	2.213	.4519	4.898	.2042
7.0	2.239	.4467	5.012	.1995
7.1	2.265	.4416	5.129	.1950
7.2	2.291	.4365	5.248	.1905
7.3	2.317	.4315	5.370	.1862
7.4	2.344	.4266	5.495	.1820
7.5	2.371	.4217	5.623	.1778
7.6	2.399	.4169	5.754	.1738
7.7	2.427	.4121	5.888	.1698
7.8	2.455	.4074	6.026	.1660
7.9	2.483	.4027	6.166	.1622
8.0	2.512	.3981	6.310	.1585
8.1	2.541	.3936	6.457	.1549
8.2	2.570	.3890	6.607	.1514
8.3	2.600	.3846	6.761	.1479
8.4	2.630	.3802	6.918	.1445
8.5	2.661	.3758	7.079	.1413
8.6	2.692	.3715	7.244	.1380
8.7	2.723	.3673	7.413	.1349
8.8	2.754	.3631	7.586	.1318
8.9	2.786	.3589	7.762	.1288
9.0	2.818	.3548	7.943	.1259
9.1	2.851	.3508	8.128	.1230
9.2	2.884	.3467	8.318	.1202
9.3	2.917	.3428	8.511	.1175
9.4	2.951	.3388	8.710	.1148
9.5	2.985	.3350	8.913	.1122
9.6	3.020	.3311	9.120	.1096
9.7	3.055	.3273	9.333	.1072
9.8	3.090	.3236	9.550	.1047
9.9	3.126	.3199	9.772	.1023
10.0	3.162	.3162	10.000	.1000
10.1	3.199	.3126	10.23	.09772
10.2	3.236	.3090	10.47	.09550
10.3	3.273	.3055	10.72	.09333
10.4	3.311	.3020	10.96	.09120
10.5	3.350	.2985	11.22	.08913
10.6	3.388	.2951	11.48	.08710
10.7	3.428	.2917	11.75	.08511
10.8	3.467	.2884	12.02	.08318
10.9	3.508	.2851	12.30	.08128

Table III. Decibel Table—(Cont'd) (11.0 to 19.9 Db)

Db	Current or Voltage Ratio		Power Ratio		Db	Current or Voltage Ratio		Power Ratio	
	Gain	Loss	Gain	Loss		Gain	Loss	Gain	Loss
11.0	3.548	.2818	12.59	.07943	15.5	5.957	.1679	35.48	.02818
11.1	3.589	.2786	12.88	.07762	15.6	6.026	.1660	36.31	.02754
11.2	3.631	.2754	13.18	.07586	15.7	6.095	.1641	37.15	.02692
11.3	3.673	.2723	13.49	.07413	15.8	6.166	.1622	38.02	.02630
11.4	3.715	.2692	13.80	.07244	15.9	6.237	.1603	38.90	.02570
11.5	3.758	.2661	14.13	.07079	16.0	6.310	.1585	39.81	.02512
11.6	3.802	.2630	14.45	.06918	16.1	6.383	.1567	40.74	.02455
11.7	3.846	.2600	14.79	.06761	16.2	6.457	.1549	41.69	.02399
11.8	3.890	.2570	15.14	.06607	16.3	6.531	.1531	42.66	.02344
11.9	3.936	.2541	15.49	.06457	16.4	6.607	.1514	43.65	.02291
12.0	3.981	.2512	15.85	.06310	16.5	6.683	.1496	44.67	.02239
12.1	4.027	.2483	16.22	.06166	16.6	6.761	.1479	45.71	.02188
12.2	4.074	.2455	16.60	.06026	16.7	6.839	.1462	46.77	.02138
12.3	4.121	.2427	16.98	.05888	16.8	6.918	.1445	47.86	.02089
12.4	4.169	.2399	17.38	.05754	16.9	6.998	.1429	48.98	.02042
12.5	4.217	.2371	17.78	.05623	17.0	7.079	.1413	50.12	.01995
12.6	4.266	.2344	18.20	.05495	17.1	7.161	.1396	51.29	.01950
12.7	4.315	.2317	18.62	.05370	17.2	7.244	.1380	52.48	.01905
12.8	4.365	.2291	19.05	.05248	17.3	7.328	.1365	53.70	.01862
12.9	4.416	.2265	19.50	.05129	17.4	7.413	.1349	54.95	.01820
13.0	4.467	.2239	19.95	.05012	17.5	7.499	.1334	56.23	.01778
13.1	4.519	.2213	20.42	.04898	17.6	7.586	.1318	57.54	.01738
13.2	4.571	.2188	20.89	.04786	17.7	7.674	.1303	58.88	.01698
13.3	4.624	.2163	21.38	.04677	17.8	7.762	.1288	60.26	.01660
13.4	4.677	.2138	21.88	.04571	17.9	7.852	.1274	61.66	.01622
13.5	4.732	.2113	22.39	.04467	18.0	7.943	.1259	63.10	.01585
13.6	4.786	.2089	22.91	.04365	18.1	8.035	.1245	64.57	.01549
13.7	4.842	.2065	23.44	.04266	18.2	8.128	.1230	66.07	.01514
13.8	4.898	.2042	23.99	.04169	18.3	8.222	.1216	67.61	.01479
13.9	4.955	.2018	24.55	.04074	18.4	8.318	.1202	69.18	.01445
14.0	5.012	.1995	25.12	.03981	18.5	8.414	.1189	70.79	.01413
14.1	5.070	.1972	25.70	.03890	18.6	8.511	.1175	72.44	.01380
14.2	5.129	.1950	26.30	.03802	18.7	8.610	.1161	74.13	.01349
14.3	5.188	.1928	26.92	.03715	18.8	8.710	.1148	75.86	.01318
14.4	5.248	.1905	27.54	.03631	18.9	8.811	.1135	77.62	.01288
14.5	5.309	.1884	28.18	.03548	19.0	8.913	.1122	79.43	.01259
14.6	5.370	.1862	28.84	.03467	19.1	9.016	.1109	81.28	.01230
14.7	5.433	.1841	29.51	.03388	19.2	9.120	.1096	83.18	.01202
14.8	5.495	.1820	30.20	.03311	19.3	9.226	.1084	85.11	.01175
14.9	5.559	.1799	30.90	.03236	19.4	9.333	.1072	87.10	.01148
15.0	5.623	.1778	31.62	.03162	19.5	9.441	.1059	89.13	.01122
15.1	5.689	.1758	32.36	.03090	19.6	9.550	.1047	91.20	.01096
15.2	5.754	.1738	33.11	.03020	19.7	9.661	.1035	93.33	.01072
15.3	5.821	.1718	33.88	.02951	19.8	9.772	.1023	95.50	.01047
15.4	5.888	.1698	34.67	.02884	19.9	9.886	.1012	97.72	.01023

Note: For values from 20 to 180 db, see next page.

Table III. Decibel Table—(Cont'd) (20 to 180 Db)

Db	Current or Voltage Ratio		Power Ratio	
	Gain	Loss	Gain	Loss
20.0	10.00	0.1000	100.00	0.01000
25.0	17.78	0.0562	3.162×10^{2}	3.162×10^{-3}
30.0	31.62	0.0316	10^{3}	10^{-3}
35.0	56.23	0.0178	3.162×10^{3}	3.162×10^{-4}
40.0	100.00	0.0100	10^{4}	10^{-4}
45.0	177.8	0.0056	3.162×10^{4}	3.162×10^{-5}
50.0	316.2	0.0032	10^{5}	10^{-5}
55.0	562.3	0.0018	3.162×10^{5}	3.162×10^{-6}
60.0	10^{3}	10^{-3}	10^{6}	10^{-6}
65.0	1.778×10^{3}	5.623×10^{-4}	3.162×10^{6}	3.162×10^{-7}
70.0	3.162×10^{3}	3.162×10^{-4}	10^{7}	10^{-7}
75.0	5.623×10^{3}	1.78×10^{-4}	3.162×10^{7}	3.162×10^{-8}
80.0	10^{4}	10^{-4}	10^{8}	10^{-8}
85.0	1.778×10^{4}	5.623×10^{-5}	3.162×10^{8}	3.162×10^{-9}
90.0	3.162×10^{4}	3.162×10^{-5}	10^{9}	10^{-9}
95.0	5.632×10^{4}	1.78×10^{-5}	3.162×10^{9}	3.162×10^{-10}
100.0	10^{5}	10^{-5}	10^{10}	10^{-10}
110.0	3.162×10^{5}	3.162×10^{-6}	10^{11}	10^{-11}
120.0	10^{6}	10^{-6}	10^{12}	10^{-12}
130.0	3.162×10^{6}	3.162×10^{-7}	10^{13}	10^{-13}
140.0	10^{7}	10^{-7}	10^{14}	10^{-14}
150.0	3.162×10^{7}	3.162×10^{-8}	10^{15}	10^{-15}
160.0	10^{8}	10^{-8}	10^{16}	10^{-16}
170.0	3.162×10^{8}	3.162×10^{-9}	10^{17}	10^{-17}
180.0	10^{9}	10^{-9}	10^{18}	10^{-18}

Constants and Standards

27. DIELECTRIC CONSTANTS OF MATERIALS

The dielectric constants of most materials vary for different temperatures and frequencies. Likewise, small differences in the composition of materials will cause differences in the dielectric constants. A list of materials, and the approximate range (where available) of their dielectric constants, are given in Table IV. The values shown are accurate enough for most applications. The dielectric constants of some materials (such as quartz, *Styrofoam*, and *Teflon*) do not change appreciably with frequency.

Table IV. Dielectric Constants of Materials

Material	Dielectric Constant (Approx.)	Material	Dielectric Constant (Approx.)
Air	1.0	Nylon	3.4-22.4
Amber	2.6-2.7	Paper (dry)	1.5-3.0
Bakelite (asbestos base)	5.0-22	Paper (paraffin coated)	2.5-4.0
Bakelite (mica filled)	4.5-4.8	Paraffin (solid)	2.0-3.0
Beeswax	2.4-2.8	Plexiglass	2.6-3.5
Cambric (varnished)	4.0	Polyethylene	2.3
Celluloid	4.0	Polystyrene	2.4-3.0
Cellulose Acetate	3.1-4.5	Porcelain (dry process)	5.0-5.5
Durite	4.7-5.1	Porcelain (wet process)	5.8-6.5
Ebonite	2.7	Quartz	5.0
Fiber	5.0	Quartz (fused)	3.78
Formica	3.6-6.0	Rubber (hard)	2.0-4.0
Glass (electrical)	3.8-14.5	Ruby Mica	5.4
Glass (photographic)	7.5	Shellac (natural)	2.9-3.9
Glass (Pyrex)	4.6-5.0	Silicone (glass) (molding)	3.2-4.7
Glass (window)	7.6	Silicone (glass) (laminate)	3.7-4.3
Gutta Percha	2.4-2.6	Slate	7.0
Isolantite	6.1	Steatite (ceramic)	5.2-6.3
Lucite	2.5	Steatite (low loss)	4.4
Mica (electrical)	4.0-9.0	Styrofoam	1.03
Mica (clear India)	7.5	Teflon	2.1
Mica (filled phenolic)	4.2-5.2	Vaseline	2.16
Micarta	3.2-5.5	Vinylite	2.7-7.5
Mycalex	7.3-9.3	Water (distilled)	34-78
Neoprene	4.0-6.7	Wood (dry)	1.4-2.9

28. CONVERSION FACTORS

The following table lists the multiplying factors necessary to convert from one unit of measure to another, and vice versa. To use the table, locate the unit of measure you are converting from or the one you are converting to in the first column. Opposite this listing are the multiplying factors for converting either unit of measure to the other unit of measure.

Table V. Conversion Factors

To Convert	Into	Multiply by	Conversely, Multiply by
Acres	Square feet	4.356×10^{4}	2.296×10^{-5}
Acres	Square meters	4047	2.471×10^{-4}
Acres	Square miles	1.5625×10^{-3}	640
Amperes	Microamperes	10^{6}	10^{-6}
Amperes	Micromicroamperes	10^{12}	10^{-12}
Amperes	Milliamperes	10^{3}	10^{-3}
Ampere-hours	Coulombs	3600	2.778×10^{-4}
Ampere-turns	Gilberts	1.257	0.7958
Ampere-turns per cm.	Ampere-turns per in.	2.54	0.3937
Angstrom units	Inches	3.937×10^{-9}	2.54×10^{8}
Angstrom units	Meters	10^{-10}	10^{10}
Bars	Atmospheres	9.870×10^{-7}	1.0133
Bars	Dynes per sq. cm.	10^{6}	10^{-6}
Bars	Pounds per sq. in.	14.504	6.8947×10^{-2}
Btu	Ergs	1.0548×10^{10}	9.486×10^{-11}
Btu	Foot-pounds	778.3	1.285×10^{-3}
Btu	Joules	1054.8	9.480×10^{-4}
Btu	Kilogram-calories	0.252	3.969
Btu per hour	Horsepower-hours	3.929×10^{-4}	2545
Bushels	Cubic feet	1.2445	0.8036
Calories, gram	Joules	4.185	0.2389
Centigrade	Celsius	1	1
Centigrade	Fahrenheit	$(°C \times 9/5) + 32 = °F$	$(°F - 32) \times 5/9 = °C$
Centigrade	Kelvin	$°C + 273.1 = °K$	$°K - 273.1 = °C$
Chains (surveyor's)	Feet	66	1.515×10^{-2}
Circular mils	Square centimeters	5.067×10^{-6}	1.973×10^{5}
Circular mils	Square mils	0.7854	1.273
Cubic feet	Gallons (liq. U.S.)	7.481	0.1337
Cubic feet	Liters	28.32	3.531×10^{-2}
Cubic inches	Cubic centimeters	16.39	6.102×10^{-2}
Cubic inches	Cubic feet	5.787×10^{-4}	1728
Cubic inches	Cubic meters	1.639×10^{-5}	6.102×10^{4}
Cubic inches	Gallons (liq. U.S.)	4.329×10^{-3}	231
Cubic meters	Cubic feet	35.31	2.832×10^{-2}
Cubic meters	Cubic yards	1.308	0.7646
Cycles	Kilocycles	10^{-3}	10^{3}
Cycles	Megacycles	10^{-6}	10^{6}

Table V. Conversion Factors—(Cont'd)

To Convert	Into	Multiply by	Conversely, Multiply by
Degrees (angle)	Mils	17.45	5.73×10^{-2}
Degrees (angle)	Radians	1.745×10^{-2}	57.3
Dynes	Pounds	2.248×10^{-6}	4.448×10^{5}
Ergs	Foot-pounds	7.376×10^{-8}	1.356×10^{7}
Fahrenheit	Rankine	°F+459.58=°R	°R−459.58=°F
Faradays	Ampere-hours	26.8	3.731×10^{-2}
Farads	Microfarads	10^{6}	10^{-6}
Farads	Micromicrofarads	10^{12}	10^{-12}
Farads	Millifarads	10^{3}	10^{-3}
Fathoms	Feet	6	0.16667
Feet	Centimeters	30.48	3.281×10^{-2}
Feet	Meters	0.3048	3.281
Feet	Mils	1.2×10^{4}	8.333×10^{-5}
Foot-pounds	Gram-centimeters	1.383×10^{4}	1.235×10^{-5}
Foot-pounds	Horsepower-hours	5.05×10^{-7}	1.98×10^{6}
Foot-pounds	Kilogram-meters	0.1383	7.233
Foot-pounds	Kilowatt-hours	3.766×10^{-7}	2.655×10^{6}
Foot-pounds	Ounce-inches	192	5.208×10^{-3}
Gallons (liq. U.S.)	Cubic meters	3.785×10^{-3}	264.2
Gallons (liq. U.S.)	Gallons (liq. Br. Imp.)	0.8327	1.201
Gausses	Lines per sq. cm.	1.0	1.0
Gausses	Lines per sq. in.	6.452	0.155
Gausses	Webers per sq. in.	6.452×10^{-8}	1.55×10^{7}
Grams	Dynes	980.7	1.02×10^{-3}
Grams	Grains	15.43	6.481×10^{-2}
Grams	Ounces (avdp.)	3.527×10^{-2}	28.35
Grams	Poundals	7.093×10^{-2}	14.1
Grams per cm.	Pounds per in.	5.6×10^{-3}	178.6
Grams per cu. cm.	Pounds per cu. in.	3.613×10^{-2}	27.68
Henries	Microhenries	10^{6}	10^{-6}
Henries	Millihenries	10^{3}	10^{-3}
Horsepower	Btu per minute	42.418	2.357×10^{-2}
Horsepower	Foot-lbs. per minute	3.3×10^{4}	3.03×10^{-5}
Horsepower	Foot-lbs. per second	550	1.182×10^{-3}
Horsepower	Horsepower (metric)	1.014	0.9863
Horsepower	Kilowatts	0.746	1.341
Inches	Centimeters	2.54	0.3937
Inches	Feet	8.333×10^{-2}	12
Inches	Meters	2.54×10^{-2}	39.37
Inches	Miles	1.578×10^{-5}	6.336×10^{4}
Inches	Mils	10^{3}	10^{-3}
Inches	Yards	2.778×10^{-2}	36
Joules	Foot-pounds	0.7376	1.356
Joules	Ergs	10^{7}	10^{-7}
Joules	Watt-hours	2.778×10^{-4}	3600
Kilograms	Tonnes	10^{3}	10^{-3}
Kilograms	Tons (long)	9.842×10^{-4}	1016
Kilograms	Tons (short)	1.102×10^{-3}	907.2
Kilograms	Pounds (avdp.)	2.205	0.4536
Kilograms per sq. meter	Pounds per sq. feet	0.2048	4.882

Table V. Conversion Factors—(Cont'd)

To Convert	Into	Multiply by	Conversely, Multiply by
Kilometers	Feet	3281	3.408×10^{-4}
Kilometers	Inches	3.937×10^{4}	2.54×10^{-5}
Kilometers	Light years	1.0567×10^{-13}	9.4637×10^{12}
Kilometers per hr.	Feet per minute	54.68	1.829×10^{-2}
Kilometers per hr.	Knots	0.5396	1.8532
Kilowatt-hours	Btu	3413	2.93×10^{-4}
Kilowatt-hours	Foot-pounds	2.655×10^{6}	3.766×10^{-7}
Kilowatt-hours	Joules	3.6×10^{6}	2.778×10^{-7}
Kilowatt-hours	Horsepower-hours	1.341	0.7457
Kilowatt-hours	Pounds water evaporated from and at 212°F.	3.53	0.284
Kilowatt-hours	Watt-hours	10^{3}	10^{-3}
Knots	Feet per second	1.688	0.5925
Knots	Meters per minute	30.87	0.0324
Knots	Miles per hour	1.1508	0.869
Lamberts	Candles per sq. cm.	0.3183	3.142
Lamberts	Candles per sq. in.	2.054	0.4869
Leagues	Miles	3	0.33
Links	Chains	0.01	100
Links (surveyor's)	Inches	7.92	0.1263
Liters	Bushels (dry U.S.)	2.838×10^{-2}	35.24
Liters	Cubic centimeters	10^{3}	10^{-3}
Liters	Cubic meters	10^{-3}	10^{3}
Liters	Cubic inches	61.02	1.639×10^{-2}
Liters	Gallons (liq. U.S.)	0.2642	3.785
Liters	Pints (liq. U.S.)	2.113	0.4732
$\log_\epsilon N$	$\log_{10} N$	0.4343	2.303
Lumens per sq. ft.	Foot-candles	1	1
Lux	Foot-candles	0.0929	10.764
Maxwells	Kilolines	10^{-3}	10^{3}
Maxwells	Megalines	10^{-6}	10^{6}
Maxwells	Webers	10^{-8}	10^{8}
Meters	Centimeters	10^{2}	10^{-2}
Meters	Feet	3.28	30.48×10^{-2}
Meters	Inches	39.37	2.54×10^{-2}
Meters	Kilometers	10^{-3}	10^{3}
Meters	Miles	6.214×10^{-4}	1609.35
Meters	Yards	1.094	0.9144
Meters per minute	Feet per minute	3.281	0.3048
Meters per minute	Kilometers per hour	0.06	16.67
Mhos	Micromhos	10^{6}	10^{-6}
Mhos	Millimhos	10^{3}	10^{-3}
Microfarads	Micromicrofarads	10^{6}	10^{-6}
Miles (nautical)	Feet	6076.1	1.646×10^{-4}
Miles (nautical)	Meters	1852	5.4×10^{-4}
Miles (statute)	Feet	5280	1.894×10^{-4}
Miles (statute)	Kilometers	1.609	0.6214
Miles (statute)	Light years	1.691×10^{-13}	5.88×10^{12}
Miles (statute)	Miles (nautical)	0.869	1.1508

Table V. Conversion Factors—(Cont'd)

To Convert	Into	Multiply by	Conversely, Multiply by
Miles (statute)	Yards	1760	5.6818×10^{-4}
Miles per hour	Feet per minute	88	1.136×10^{-2}
Miles per hour	Feet per second	1.467	0.6818
Miles per hour	Kilometers per hour	1.609	0.6214
Miles per hour	Knots	0.8684	1.152
Milliamperes	Microamperes	10^3	10^{-3}
Millihenries	Microhenries	10^3	10^{-3}
Millimeters	Centimeters	0.1	10
Millimeters	Inches	3.937×10^{-2}	25.4
Millimeters	Microns	10^3	10^{-3}
Millivolts	Microvolts	10^3	10^{-3}
Mils	Minutes	3.438	0.2909
Minutes (angle)	Degrees	1.666×10^{-2}	60
Nepers	Decibels	8.686	0.1151
Newtons	Dynes	10^5	10^{-5}
Newtons	Pounds (avdp.)	0.2248	4.448
Ohms	Milliohms	10^3	10^{-3}
Ohms	Micro-ohms	10^6	10^{-6}
Ohms	Micromicro-ohms	10^{12}	10^{-12}
Ohms	Megohms	10^{-6}	10^6
Ohms	Ohms (International)	0.99948	1.00052
Ohms per foot	Ohms per meter	0.3048	3.281
Ounces (fluid)	Quarts	3.125×10^{-2}	32
Ounces (avdp.)	Pounds	6.25×10^{-2}	16
Picofarad	Micromicrofarad	1	1
Pints	Quarts (liq. U.S.)	0.50	2
Pounds (force)	Newtons	4.4482	0.2288
Pounds carbon oxidized	Btu	14,544	6.88×10^{-5}
Pounds carbon oxidized	Horsepower-hours	5.705	0.175
Pounds carbon oxidized	Kilowatt-hours	4.254	0.235
Pounds of water (dist.)	Cubic feet	1.603×10^{-2}	62.38
Pounds of water (dist.)	Gallons	0.1198	8.347
Pounds per sq. in.	Dynes per sq. cm.	6.8946×10^4	1.450×10^{-5}
Poundals	Dynes	1.383×10^4	7.233×10^{-5}
Poundals	Pounds (avdp.)	3.108×10^{-2}	32.17
Quadrants	Degrees	90	11.111×10^{-2}
Quadrants	Radians	1.5708	0.637
Radians	Mils	10^3	10^{-3}
Radians	Minutes	3.438×10^3	2.909×10^{-4}
Radians	Seconds	2.06265×10^5	4.848×10^{-6}
Rods	Feet	16.5	6.061×10^{-2}
Rods	Miles	3.125×10^{-3}	320
Rods	Yards	5.5	0.1818
Rpm	Degrees per second	6.0	0.1667
Rpm	Radians per second	0.1047	9.549

Table V. Conversion Factors—(Cont'd)

To Convert	Into	Multiply by	Conversely, Multiply by
Rpm	Rps	1.667×10^{-2}	60
Square feet	Acres	2.296×10^{-5}	43,560
Square feet	Square centimeters	929.034	1.076×10^{-3}
Square feet	Square inches	144	6.944×10^{-3}
Square feet	Square meters	9.29×10^{-2}	10.764
Square feet	Square miles	3.587×10^{-8}	27.88×10^{6}
Square feet	Square yards	11.11×10^{-2}	9
Square inches	Circular mils	1.273×10^{6}	7.854×10^{-7}
Square inches	Square centimeters	6.452	0.155
Square inches	Square mils	10^{6}	10^{-6}
Square inches	Square millimeters	645.2	1.55×10^{-3}
Square kilometers	Square miles	0.3861	2.59
Square meters	Square yards	1.196	0.8361
Square miles	Acres	640	1.562×10^{-3}
Square miles	Square yards	3.098×10^{6}	3.228×10^{-7}
Square millimeters	Circular mils	1973	5.067×10^{-4}
Square millimeters	Square centimeters	.01	100
Square mils	Circular mils	1.273	0.7854
Tons (long)	Pounds (avdp.)	2240	4.464×10^{-4}
Tons (short)	Pounds	2,000	5×10^{-4}
Tonnes	Pounds	2204.63	4.536×10^{-4}
Varas	Feet	2.7777	0.36
Volts	Kilovolts	10^{-3}	10^{3}
Volts	Microvolts	10^{6}	10^{-6}
Volts	Millivolts	10^{3}	10^{-3}
Watts	Btu per hour	3.413	0.293
Watts	Btu per minute	5.689×10^{-2}	17.58
Watts	Ergs per second	10^{7}	10^{-7}
Watts	Foot-lbs per minute	44.26	2.26×10^{-2}
Watts	Foot-lbs per second	0.7378	1.356
Watts	Horsepower	1.341×10^{-3}	746
Watts	Kilogram-calories per minute	1.433×10^{-2}	69.77
Watts	Kilowatts	10^{-3}	10^{3}
Watts	Microwatts	10^{6}	10^{-6}
Watts	Milliwatts	10^{3}	10^{-3}
Watt-seconds	Joules	1	1
Webers	Maxwells	10^{8}	10^{-8}
Webers per sq. meter	Gausses	10^{4}	10^{-4}
Yards	Feet	3	.3333
Yards	Varas	1.08	0.9259

29. METRIC PREFIXES

(A) Unit Prefixes

The metric system, whereby a different prefix is assigned for each order of magnitude, is particularly suited for electronic values. In 1958 the International Committee on Weights and Measures assigned prefixes for the ninth and twelfth orders of magnitude (both positive and negative). (See Table VI.) This system eliminates the cumbersome double prefixes (micromicro-," "kilomega-," etc. In 1959 the National Bureau of Standards began using these terms; however, acceptance by industry in the United States has been slow, particularly in using the newer term "picofarad" instead of "micromicrofarad."

Table VI. Metric Prefixes

Multiple	Prefix	Abbreviation	Multiple	Prefix	Abbreviation
10^{12}	tera-	T	10^{-1}	deci-	d
10^{9}	giga-	G	10^{-2}	centi-	c
10^{6}	mega-	M	10^{-3}	milli-	m
10^{4}	myria-	My	10^{-6}	micro-	μ
10^{3}	kilo-	K	10^{-9}	nano-	n
10^{2}	hecto-	H	10^{-12}	pico-	p
10	deka-	D			

(B) Conversion Table

Table VII gives the number of places, and the direction, the decimal point must be moved to convert from one metric notation to another. The value labeled "units" is the basic unit of measurement—e.g., ohms, farads, etc. To use the chart, find the desired value in the left-hand column; then follow the horizontal line across to the column with the prefix in which the original value is stated. The number and arrow at this point indicate the number of places and the direction the decimal point must be moved to change the original value to the desired value.

Table VII. Metric Conversion Table

Desired Value	Original Value													
	Tera-	Giga-	Mega-	Myria-	Kilo-	Hecto-	Deka-	Units	Deci-	Centi-	Milli-	Micro-	Nano-	Pico-
Tera-		← 3	← 6	← 8	← 9	←10	←11	←12	←13	←14	←15	←18	←21	←24
Giga-	3→		← 3	← 5	← 6	← 7	← 8	← 9	←10	←11	←12	←15	←18	←21
Mega-	6→	3→		← 2	← 3	← 4	← 5	← 6	← 7	← 8	← 9	←12	←15	←18
Myria-	8→	5→	2→		← 1	← 2	← 3	← 4	← 5	← 6	← 7	←10	←13	←16
Kilo-	9→	6→	3→	1→		← 1	← 2	← 3	← 4	← 5	← 6	← 9	←12	←15
Hecto-	10→	7→	4→	2→	1→		← 1	← 2	← 3	← 4	← 5	← 8	←11	←14
Deka-	11→	8→	5→	3→	2→	1→		← 1	← 2	← 3	← 4	← 7	←10	←13
Units	12→	9→	6→	4→	3→	2→	1→		← 1	← 2	← 3	← 6	← 9	←12
Deci-	13→	10→	7→	5→	4→	3→	2→	1→		← 1	← 2	← 5	← 8	←11
Centi-	14→	11→	8→	6→	5→	4→	3→	2→	1→		← 1	← 4	← 7	←10
Milli-	15→	12→	9→	7→	6→	5→	4→	3→	2→	1→		← 3	← 6	← 9
Micro-	18→	15→	12→	10→	9→	8→	7→	6→	5→	4→	3→		← 3	← 6
Nano-	21→	18→	15→	13→	12→	11→	10→	9→	8→	7→	6→	3→		← 3
Pico-	24→	21→	18→	16→	15→	14→	13→	12→	11→	10→	9→	6→	3→	

30. STANDARD FREQUENCIES AND TIME SIGNALS

(A) WWV and WWVH

Time signals, audio frequencies, and a 36-digit binary timing code are broadcast continuously day and night from WWV, operated by the National Bureau of Standards near Washington, D.C. The WWV broadcast frequencies are 2.5, 5, 10, 15, 20, and 25 megacycles; and its modulation consists of 1-cps pulses and 440- and 600-cps tones. A similar station, WWVH, is located at Maui, Hawaii. It broadcasts on frequencies of 5, 10, and 15 megacycles.

Signals from WWV and WWVH are coordinated with Stations GBR and MSF at Rugby, England, and Station NBA in the Canal Zone. This coordination provides a more uniform system of time and frequency transmissions throughout the world. It also aids in the solution of many scientific and technical problems such as radiocommunications, geodesy, and tracking of artificial satellites.

WWV is silent for a four-minute period beginning approximately 45 minutes after each hour. The WWVH transmissions are silent for a four-minute period beginning approximately 15 minutes after the hour, and for 34 minutes beginning at 1900 Universal Time.

The frequencies transmitted from WWV and WWVH are accurate to within 1 part in 10 billion.

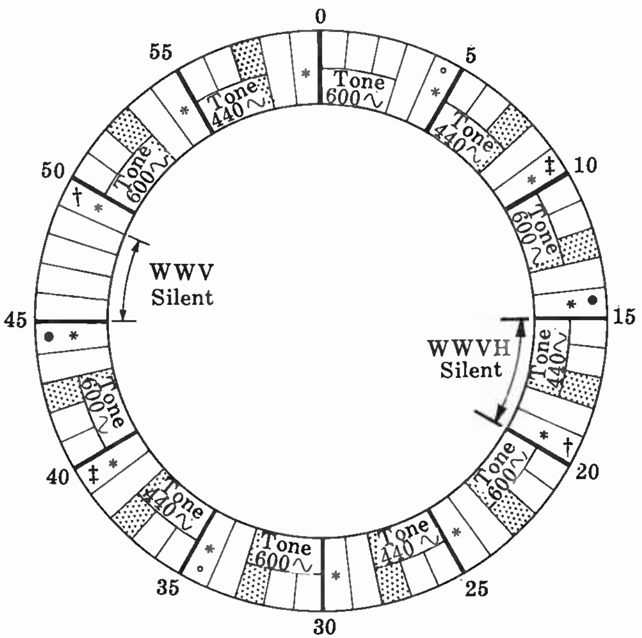
The drawing in Fig. 54 shows a breakdown of the transmissions during each hour. Each small division represents 1 minute; each large division, 5 minutes.

The audio-frequency signals are transmitted from WWV for precisely two minutes at the beginning of each five-minute period except at the beginning of each hour, when the transmission is for three minutes, and at 45 minutes after the hour when WWV is silent. The audio-frequency signal from WWVH is for precisely three minutes during the periods indicated in Fig. 54.

The timing code (a 36-bit, 100-pulses-per-second code carried on 1,000-cps modulation) is broadcast for one-minute intervals, 10 times per hour. This timing code is indicated by the shaded area in Fig. 54, and immediately follows the 440- and 600-cps modulation except at the beginning of each hour. The 440- and 600-cps modulations are alternated as shown in Fig. 54.

The code is binary-coded decimal (BCD), as shown in Fig. 55, and contains the time-of-year information (in Universal Time) in seconds, minutes, hours, and days. The code consists of nine binary groups each second, as shown in Fig. 55A. The groups appear in the following order: two groups for seconds, two for minutes, two for hours, and three for day of year. The expanded drawing at the bottom of Fig. 55A shows the make-up of the pulse code. A "0" pulse is 2 milliseconds long (or 2 cycles at 1,000 cps), and the "1" pulse is 6 milliseconds (6 cycles at 1,000 cps). The code is locked in phase with the frequency and time signals.

A complete time frame is 1 second. Fig. 55B shows the make-up of a typical time code. The time code is amplitude-



* One Minute Announcement interval (See Fig. 56).
† North Atlantic Propagation Notice—WWV.
‡ North Pacific Propagation Notice—WWVH.
° IWDS Warning—WWV.
• IWDS Warning—WWVH.

WWVH Silent Between 1900 and 1934 Universal Time

Fig. 54

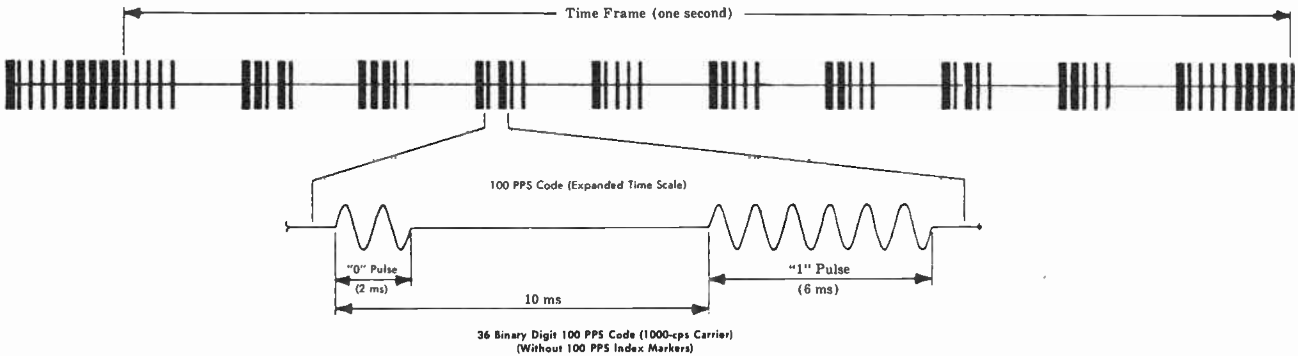


Fig. 55A

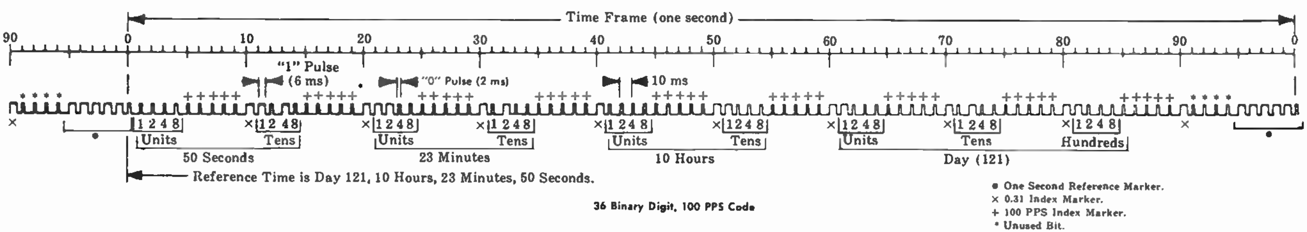


Fig. 55B

modulated on 1,000 cps. The leading edge of the time-code pulses coincide with the zero axis of the positive-going 1,000-cps signal. The least significant binary group and least significant binary digit in each group occur first. The binary groups follow the 1-second reference marker. The start time occurs at the leading edge of all pulses.

The BCD contains a 100-per-second clocking rate, 10-per-second index markers, and 1-per-second reference markers. The 1,000-cps signal is locked to the code pulses so that millisecond resolution can be obtained easily.

The 10-per-second index markers consist of "1" pulses preceding each code group except at the beginning of the second, where there is a "0" pulse.

Each second begins at the leading edge of the "0" pulse, as shown in Fig. 55.

The 1-second reference marker is made up of five "1" pulses followed by a "0" pulse.

The code is spaced so that it follows each of the 10-per-second index markers. The last index marker is followed by an unused four-bit group of "0" pulses immediately preceding the 1-second reference marker.

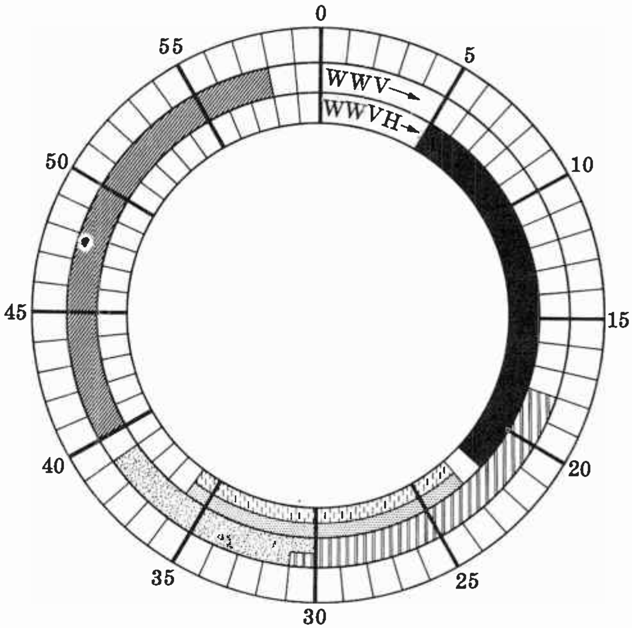
A five-millisecond pulse spaced at intervals of one second is also transmitted. The pulse transmitted by WWV consists of five cycles of a 1,000-cycle tone. The pulse transmitted by WWVH consists of six cycles of a 1,200-cycle tone. The 440- and 600-cps tone signal is interrupted for .04 second for each seconds pulse. The pulse starts .01 second after commencement of the interruption, and resumes .025 second after the pulse. For identification, the fifty-ninth second pulse is omitted, and the zero-second pulse is followed by another pulse 100 milliseconds later.

A voice announcement of Eastern Standard Time and call letters is given each five minutes from station WWV. This is followed by a telegraph-code announcement of Universal Time and another voice announcement of Eastern Standard Time. WWVH broadcasts call letters and Universal Time (UT) in telegraphic code only. The time given is the time at the resumption of the tone.

The drawing in Fig. 56 shows a breakdown of the transmissions during the one-minute announcement intervals marked with an asterisk (*) in Fig. 54. Each division on this drawing represents one second.

During announcement intervals at 19½ and 49½ minutes past every hour, propagation notices applying to transmission paths over the North Atlantic are transmitted from WWV. Similar forecasts for the North Pacific are transmitted from WWVH, during announcement intervals, at 9.4 and 39.4 minutes after the hour.

These notices, in telegraphic code, consist of a letter followed by a number. The letter signifies the propagation conditions at the time of the broadcast. The following designations are used:



Universal Time and Call Letters (Code).

IWDS Warning (Code) — WWV. (4.3 and 34.3 Minutes After Hour Only.)

North Pacific Propagation Forecast. (Approx. 9.4 and 39.4 Minutes After Hour Only.)

IWDS Warning (Code) — WWVH. (Approx. 14.4 and 44.4 Minutes After Hour Only.)

North Atlantic Propagation Forecast. (19.5 and 49.5 Minutes After Hour Only.)

Call Letters and EST (Voice) — UT (Code) — EST (Voice).

Fig. 56

N—Normal	U—Unsettled	W—Disturbance

The number following the letter applies to expected propagation conditions during the subsequent 6 or more hours. The following designations are used:

1—Useless	4—Poor to Fair	7—Good
2—Very Poor	5—Fair	8—Very good
3—Poor	6—Fair to Good	9—Excellent

At 4.3 and 34.3 minutes past the hour on WWV, and at approximately 14.4 and 44.4 minutes past the hour on WWVH, the IWDS (International World Day Service) warning is broadcast. This message reveals to experimenters in radio, geophysical, and solar sciences the content of the warning message issued at 1600 UT by the world warning agency on days when an outstanding geophysical event has occurred during the preceding 24 hours. This message is first broadcast at 1604.3 UT on WWV and at 1714.4 UT on WWVH.

If the IWDS warning declares an alert, the letters AGI AAAA are broadcast very slowly in code. This means that a significant magnetic storm has started or that an outstanding auroral display or increase in cosmic-ray flux has been reported or observed.

If a special world interval is in progress, the code letters AGI are followed by three extra-long dashes. This again indicates that an alert has been declared and that the geophysical activity is of sufficient interest to warrant special attention and intensified observations. Special world intervals usually last two or three days.

When there is no "state of alert" or "special world interval" in progress, the letters AGI EEEEE are broadcast.

(B) CHU

The Dominion Observatory at Ottawa, Canada, broadcasts time signals which can be heard throughout the North American continent and many other parts of the world. The frequencies are 3,330, 7,335, and 14,670 kc, and the transmission is continuous on all frequencies. The 3,330-kc transmitter has a power of 0.75 kw and the other two, 3 kw.

The frequencies are synthesized from a 100-kc crystal oscillator which is maintained accurate to within a few parts in one billion. The "seconds" pips are also derived from this same oscillator and consist of 200 cycles of a 1,000-cps tone.

The "seconds" pips are broadcast continuously except for the 29th and the 51st through 59th pips, which are omitted each minute. In addition, the 1st to 29th pips are omitted during the first minute of the hour. The beginning of the pip marks the exact second. The zero pip has a duration of 0.5 second instead of the 0.2 second of the other pips.

During the first half-minute of each hour, CHU CANADA CHU is transmitted in code.

A voice announcement of the time is given each minute during the 10-second interval between the 50th and 60th second when the pips are omitted. The announcement is as follows: "CHU, Dominion Observatory Canada, Eastern Standard Time, ______ hours, ______ minutes." The time given refers to the beginning of the minute pip which follows, and is on the 24-hour system.

(C) Other Standards Stations

Throughout the world, there are many other stations which broadcast similar data. Table VIII lists some of them, and other data about stations operating on the standards frequencies. Table IX lists some other stations in the LF and VLF bands which broadcast similar data, but not on the frequencies assigned for standard-frequency operation.

31. FREQUENCY AND OPERATING POWER TOLERANCES

(A) AM Broadcast

The operating frequency tolerance of each station shall be maintained within ±20 cycles of the assigned frequency.

The operating power of each AM broadcast station shall be maintained as near as practicable to the licensed power and shall not exceed the limits of 5 per cent above and 10 per cent below the licensed power except in emergencies.

(B) FM Broadcast

Operating frequency tolerance of each station shall be maintained within ±2,000 cycles of the assigned center frequency.

Table VIII. Other Standards Stations

Call Sign	Location	Carrier Freq. (mc)	Modulation (cps)	Power (kw)
ATA	New Delhi, India	10	1; 1000	1.0
FFH	Paris, France	2.5; 5; 10	1; 440; 1000	0.3
HBN	Neuchatel, Switzerland	2.5; 5	1; 500	0.5
IAM	Rome, Italy	5	1; 440; 600; 1000	1.0
IBF	Turin, Italy	5	1; 440; 1000	0.3
JJY	Tokyo, Japan	2.5; 5; 10; 15	1; 440; 1000	2.0
LOL	Buenos Aires, Argentina	2.5; 5; 10; 15; 20; 25	1; 440; 1000	2.0
MSF	Rugby, England	2.5; 5; 10	1; 1000	0.5
OMA	Prague, Czechoslovakia	2.5	1; 1000	1.0
ZLFS	Lower Hutt, New Zealand	2.5	— — — — — —	0.03
ZUO	Olifantsfontein, South Africa	5	1	4.0
WWVL	Fort Collins, Colorado	20 kc	— — — — — —	1.0

Table IX. LF and VLF Stations

Call Sign	Location	Carrier Freq. (kc)	Modulation (cps)	Power (kw)
WWVB	Fort Collins, Colorado	60	— — — — — —	5
DCF77	Federal German Republic	77.5	1; 200; 440	12
OMA	Czechoslovakia	50	— — — — — —	5
GBR	Rugby, England	16	— — — — — —	300
MSF	Rugby, England	60	1; 1000	10
NBA	Canal Zone (U. S. Navy)	18	1	100

The operating power of each station shall be maintained as near as practicable to the authorized operating power and shall not exceed the limits of 5 per cent above and 10 per cent below the authorized power except in emergencies.

(C) TV Broadcast

The carrier frequency of the visual transmitter shall be maintained within ±1,000 cycles of the authorized carrier frequency.

The center frequency of the aural transmitter shall be maintained 4.5 megacycles ±1,000 cycles above the visual carrier frequency.

The peak power shall be monitored by a peak-reading device which reads proportionally to voltages, current, or power in the radio-frequency line. The operating power as so monitored shall be maintained as near as practicable to the authorized operating power and shall not exceed the limits of 10 per cent above and 20 per cent below the authorized power except in emergencies.

The operating power of the aural transmitter shall be maintained as near as practicable to the authorized operating power, and shall not exceed the limits of 10 per cent above and 20 per cent below the authorized power except in emergencies.

(D) Industrial Radio Service

The carrier frequency of stations operating below 220 megacycles in the Industrial Radio Service shall be maintained within ±.01% of the authorized power for stations of 3 watts or less, and ±.005% for stations with an authorized power of more than 3 watts. The frequency tolerance of Industrial Radio Service stations operating between 220 and 1,000 megacycles is specified in the station authorization.

(E) Citizens-Band Radio

The maximum plate power input to the anode (plate) circuit of the electron tube or tubes which supply energy to the radiating system of a station in this service shall not exceed the values given in Table X.

Table X. Power Limits of Citizens-Band Stations

Class of Station	Maximum Plate Power Input (Watts)
A	60
B	5
C	5*
D	5

* A maximum plate power input of 30 watts is permitted on 27.255 mc only.

The carrier frequency of a station in this service shall be maintained within the percentages of authorized frequency given in Table XI.

Table XI. Frequency Tolerances of Citizens-Band Stations

Class	Maximum Authorized Plate Power Input (Watts)	Frequency Tolerance %	
		Fixed and Base	Mobile
A	3 or less	.001	.005
A	Over 3	.001	.001
B	3 or less	— — —	.5
B	Over 3	— — —	.3
C	5 or less*	— — —	.005
C	Over 5 (27.255 mc only)	— — —	.005
D	5 or less	— — —	.005

* Class-C stations which have a plate power input of 3 watts or less and are used solely for remote control of objects or devices by radio (other than devices used solely as a means of attracting attention) are permitted a frequency tolerance of 0.01%.

32. COMMERCIAL OPERATOR LICENSES

The classes of commercial radio operator licenses issued by the Federal Communications Commission are classified basically as radiotelegraph and radiotelephone licenses.

(A) Examination Elements

Written examinations are composed of questions from various categories called elements. These elements, and the types of questions in each, are:

Element 1. *Basic Law.* Provisions of laws, treaties, and regulations with which every operator should be familiar.

Element 2. *Basic Operating Practice.* Radio operating procedures and practices generally followed or required in communicating by means of radiotelephone stations.

Element 3. *Basic Radiotelephone.* Technical, legal, and other matters applicable to the operation of radiotelephone stations other than broadcast.

Element 4. *Advanced Radiotelephone.* Advanced technical, legal, and other matters particularly applicable to the operation of the various classes of broadcast stations.

Element 5. *Radiotelegraph Operating Practice.* Radio operating procedure and practices generally followed or required in communicating by means of radiotelegraph stations primarily other than in the maritime mobile services of public correspondences.

Element 6. *Advanced Radiotelegraph.* Technical, legal, and other matters applicable to the operation of all classes of radiotelegraph stations, including operating procedures and practices in the maritime mobile services of public correspondences, and associated matters such as radionavigational aids, message traffic routing and accounting, etc.

Element 7. *Aircraft Radiotelegraph.* Basic theory and practice in the operation of radiocommunications and radionavigational systems aboard aircraft.

Element 8. *Ship Radar Techniques.* Specialized theory and practice applicable to the proper installation, servicing, and maintenance of ship radar equipment in general use for marine navigational purposes.

(B) Examination Requirements

Applicants for licenses must be able to transmit and receive spoken messages in English, and be able to pass the examination elements required for the license. The requirements for the various licenses are:

1. *Radiotelephone second-class operator licenses.* Written examination elements 1, 2, and 3.
2. *Radiotelephone first-class operator licenses.* Written examination elements 1, 2, 3, and 4.
3. *Radiotelegraph second-class operator license.* Transmitting and receiving code test of 16 code groups per minute. Written examination elements 1, 2, 5, and 6.
4. *Radiotelegraph first-class operator license.* Transmitting and receiving code test of 25 words per minute in conversational language and 20 groups per minute in code. Written examination elements 1, 2, 5, and 6.
5. *Radiotelephone third-class operator permit.* Written examination elements 1 and 2.
6. *Radiotelegraph third-class operator permit.* Transmitting and receiving code test of 16 code groups per minute. Written examination elements 1, 2, and 5.

33. AMATEUR OPERATOR PRIVILEGES

(A) Examination Elements

Examinations for amateur operator privileges are composed of questions from various categories, called elements. The various elements and their requirements are:

Element 1(A): *Beginner's Code Test.* Code test at 5 words per minute.

Element 1(B): *General Code Test.* Code test at 13 words per minute.

Element 1(C): *Expert's Code Test.* Code test at 20 words per minute.

Element 2: *Basic Amateur Practice.* Amateur radio operation and apparatus, including radiotelephone and radiotelegraph.

Element 3(A): *Basic Law.* Rules and regulations essential to beginners' operation, including sufficient elementary radio theory to understand these rules.

Element 3(B): *General Regulations.* Provisions of treaties, statutes, and rules and regulations affecting all amateur stations and operators.

Element 4(B): *Advanced Amateur Practice.* Advanced radio theory and operation applicable to modern amateur techniques, including—but not limited to—radiotelephony, radiotelegraphy, and transmission of energy for (1) measurements and observations applied to propagation, (2) radio control of remote objects, and (3) similar experimental purposes.

(B) Examination Requirements

Applicants for original licenses will be required to pass examinations as follows:

1. *Amateur Extra Class.* Elements 1(C), 2, 3(B), and 4(B).
2. *General Class.* Elements 1(B), 2, and 3(B).
3. *Conditional Class.* Elements 1(B), 2, and 3(B).
4. *Technician Class.* Elements 1(A), 2, and 3(B).
5. *Novice Class.* Elements 1(A) and 3(A).

Note: Examinations for licenses (1) and (2) above must be given by an FCC examiner. The examinations for licenses (3), (4), and (5) are taken by mail, under the supervision of a volunteer examiner.

34. AMATEUR ("HAM") BANDS

The various bands of frequencies used by amateur radio operators ("hams") are usually referred to in meters instead of the actual frequencies. The number of meters approximates the wavelength at the band of frequencies being designated. The meter bands and their frequency limits are given in Table XII. (Note: Frequencies between 220 and 225 mc are sometimes referred to as 1¼ meters, and between 420 and 450 meters as ¾ meter.)

Table XII. "Ham" Bands

Band	Frequency (mc)
80 Meters	3.5—4.0
40 Meters	7.0—7.3
20 Meters	14.0—14.35
15 Meters	21.0—21.45
10 Meters	28.0—29.7
6 Meters	50—54
2 Meters	144—148

Table XIII. Types of Emission

Type of Modulation	Type of Transmission	Supplementary Characteristics	Symbol
1. Amplitude	Absence of any modulation	- - - - - - - - - - - - - - - -	A0
	Telegraphy without the use of modulating audio frequency (on-off keying)	- - - - - - - - - - - - - - - -	A1
	Telegraphy by the keying of a modulating audio frequency or frequencies or by the keying of the modulated emission (special case: an unkeyed modulated emission)	- - - - - - - - - - - - - - - -	A2
	Telephony	Double sideband, full carrier	A3
		Single sideband, reduced carrier	A3a
		Two independent sidebands, reduced carrier	A3b
	Facsimile	- - - - - - - - - - - - - - - -	A4
	Television	- - - - - - - - - - - - - - - -	A5
	Composite transmissions, and cases not covered by the above	- - - - - - - - - - - - - - - -	A9
	Composite transmissions	Reduced carrier	A9c
2. Frequency (or phase) modulated	Absence of any modulation	- - - - - - - - - - - - - - - -	F0
	Telegraphy without the use of modulating audio frequency (frequency shift keying)	- - - - - - - - - - - - - - - -	F1

	Telegraphy by the keying of a modulating audio frequency or audio frequencies or by the keying of the modulated emission (special case: an unkeyed emission modulated by audio frequency)	------------------------	F2
	Telephony	------------------------	F3
	Facsimile	------------------------	F4
	Television	------------------------	F5
	Composite transmissions and cases not covered by the above	------------------------	F9
3. Pulsed emissions	Absence of any modulation carrying information	------------------------	P0
	Telegraphy without the use of modulating audio frequency	------------------------	P1
	Telegraphy by the keying of a modulating audio frequency or of the modulated pulse (special case: an unkeyed modulated pulse)	Audio frequency or frequencies modulating the pulse in amplitude	P2d
		Audio frequency or frequencies modulating the width of the pulse	P2c
		Audio frequency or frequencies modulating the phase (or position) of the pulse	P2f
	Telephony	Amplitude-modulated pulse	P3d
		Width-modulated pulse	P3e
		Phase-(or position-) modulated pulse	P3f
	Composite transmissions and cases not covered by the above	------------------------	P9

35. TYPES OF EMISSIONS

Emissions are classified according to their modulation, type of transmission, and supplementary characteristics. These classifications are given in Table XIII on pages 72 and 73. When a full designation of the emissions—including bandwidth—is necessary, the symbols in Table XIII are prefixed by a number indicating the bandwidth in kilocycles. Below 10 kc, this number is given to two significant figures.

36. TELEVISION CHANNEL FREQUENCIES

The chart in Fig. 57 (page 75) lists the frequency limits of all television channels and the frequency of the picture and sound carriers of each channel.

37. TELEVISION SIGNAL STANDARDS

The signal standards for television broadcasting are given in Figs. 58A and B (pages 76 and 77). Note: The standards given here are for color transmission. For monochrome transmission, the standards are the same except the color burst signal is omitted. Also, for color the vertical and horizontal scanning frequencies are 59.94 and 15,734.264 cps, respectively; for monochrome they are 60 and 15,750 cps.

38. AUDIO-FREQUENCY SPECTRUM

The audio-frequency spectrum is generally accepted as extending from 15 cps to 20,000 cps. Fig. 60 (page 79) gives the frequencies for each tone of the standard keyboard, based on the current musical pitch of A = 440 cps. Fig. 59 (page 78) shows the frequency range of various musical instruments and of other sounds. The frequency range shown for each sound is the range needed for faithful reproduction, and includes the fundamental frequency and the necessary harmonic frequencies. The frequency range of the human ear, and the various broadcasting and recording media, are also included in Fig. 59.

39. RADIO-FREQUENCY SPECTRUM

(A) Frequency Classification

The radio-frequency spectrum from 3 kc to 3,000,000 mc is divided into the various bands (shown in Table XIV on page 78) for easier identification.

Television Channel Frequencies

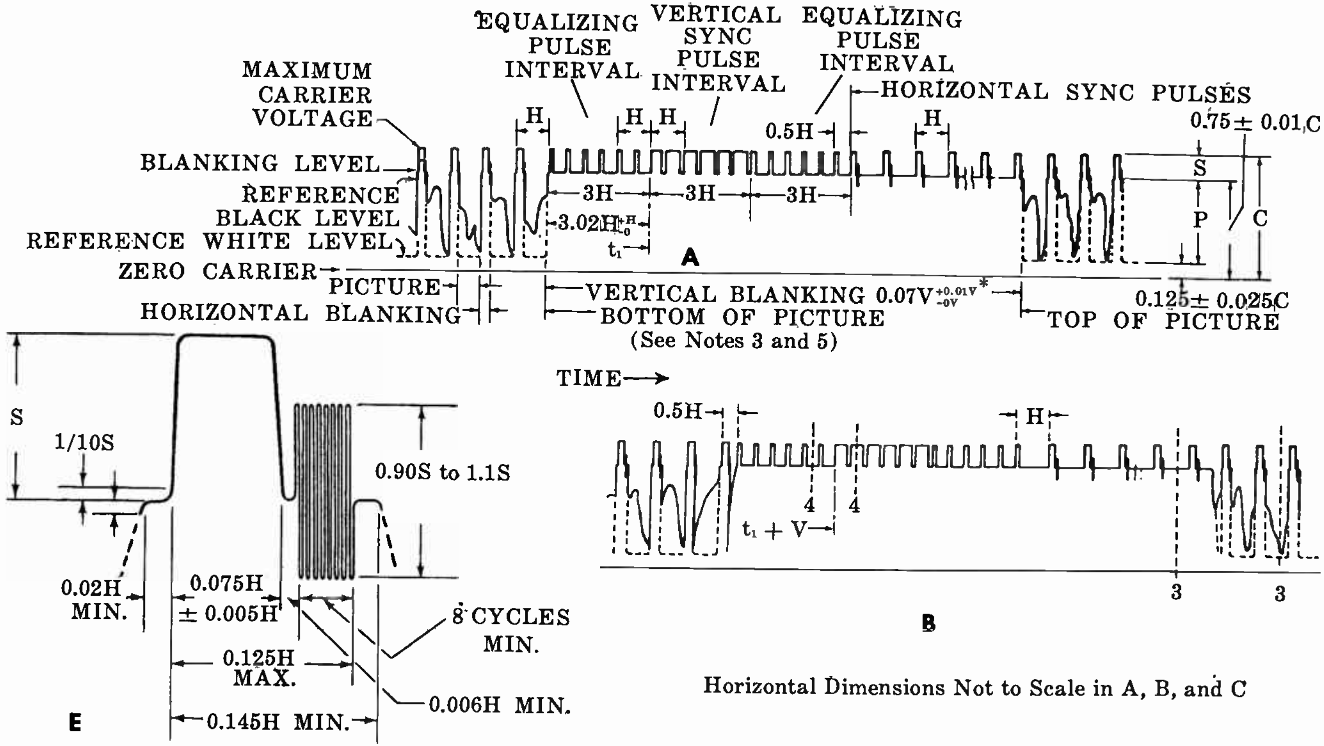
Channel No.	P	S	Freq. Limits
2	55.25	59.75	54–60
3	61.25	65.75	60–66
4	67.25	71.75	66–72
5	77.25	81.75	76–82
6	83.25	87.75	82–88
7	175.25	179.75	174–180
8	181.25	185.75	180–186
9	187.25	191.75	186–192
10	193.25	197.75	192–198
11	199.25	203.75	198–204
12	205.25	209.75	204–210
13	211.25	215.75	210–216
14	471.25	475.75	470–476
15	477.25	481.75	476–482
16	483.25	487.75	482–488
17	489.25	493.75	488–494
18	495.25	499.75	494–500
19	501.25	505.75	500–506
20	507.25	511.75	506–512
21	513.25	517.75	512–518
22	519.25	523.75	518–524
23	525.25	529.75	524–530
24	531.25	535.75	530–536
25	537.25	541.75	536–542
26	543.25	547.75	542–548
27	549.25	553.75	548–554
28	555.25	559.75	554–560
29	561.25	565.75	560–566
30	567.25	571.75	566–572
31	573.25	577.75	572–578
32	579.25	583.75	578–584
33	585.25	589.75	584–590
34	591.25	595.75	590–596
35	597.25	601.75	596–602
36	603.25	607.75	602–608
37	609.25	613.75	608–614
38	615.25	619.75	614–620
39	621.25	625.75	620–626
40	627.25	631.75	626–632
41	633.25	637.75	632–638
42	639.25	643.75	638–644
43	645.25	649.75	644–650
44	651.25	655.75	650–656
45	657.25	661.75	656–662
46	663.25	667.75	662–668
47	669.25	673.75	668–674
48	675.25	679.75	674–680
49	681.25	685.75	680–686
50	687.25	691.75	686–692
51	693.25	697.75	692–698
52	699.25	703.75	698–704
53	705.25	709.75	704–710
54	711.25	715.75	710–716
55	717.25	721.75	716–722
56	723.25	727.75	722–728
57	729.25	733.75	728–734
58	735.25	739.75	734–740
59	741.25	745.75	740–746
60	747.25	751.75	746–752
61	753.25	757.75	752–758
62	759.25	763.75	758–764
63	765.25	769.75	764–770
64	771.25	775.75	770–776
65	777.25	781.75	776–782
66	783.25	787.75	782–788
67	789.25	793.75	788–794
68	795.25	799.75	794–800
69	801.25	805.75	800–806
70	807.25	811.75	806–812
71	813.25	817.75	812–818
72	819.25	823.75	818–824
73	825.25	829.75	824–830
74	831.25	835.75	830–836
75	837.25	841.75	836–842
76	843.25	847.75	842–848
77	849.25	853.75	848–854
78	855.25	859.75	854–860
79	861.25	865.75	860–866
80	867.25	871.75	866–872
81	873.25	877.75	872–878
82	879.25	883.75	878–884
83	885.25	889.75	884–890

P = Picture Carrier Freq. S = Sound Carrier Freq. All frequencies in mc.

Fig. 57

Television Signal Standards

Fig. 58A



Horizontal Dimensions Not to Scale in A, B, and C

DETAIL BETWEEN 5-5 in C

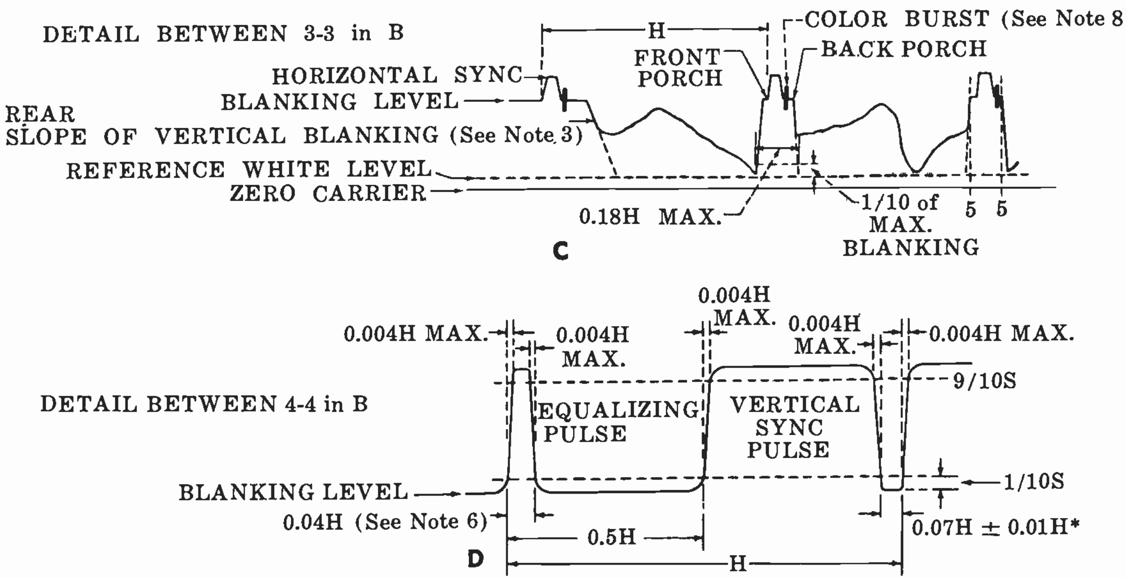


Fig. 58B

NOTES

1. H = Time from start of one line to start of next line.
2. V = Time from start of one field to start of next field.
3. Leading and trailing edges of vertical blanking should be complete in less than 0.1H.
4. Leading and trailing slopes of horizontal blanking must be steep enough to preserve minimum and maximum values of (x + y) and (z) under all conditions of picture content.
5. Dimensions marked with asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.
6. Equalizing pulse area shall be between 0.45 and 0.5 of area of a horizontal sync pulse.
7. Color burst follows each horizontal pulse, but is omitted following the equalizing pulses and during the broad vertical pulses.
8. Color burst to be omitted during monochrome transmissions.
9. The burst frequency shall be 3.579545 mc. The tolerance on the frequency shall be ±0.0003% with a maximum rate of change of frequency not to exceed 1/10 cycle per second per second.
10. The horizontal scanning frequency shall be 2/455 times the burst frequency.
11. The dimensions specified for the burst determine the times of starting and stopping the burst but not its phase. The color burst consists of amplitude modulation of a continuous sine wave.
12. Dimension "P" represents the peak excursion of the luminance signal at blanking level but does not include the chrominance signal. Dimension "S" is the sync amplitude above blanking level. Dimension "C" is the peak carrier amplitude.

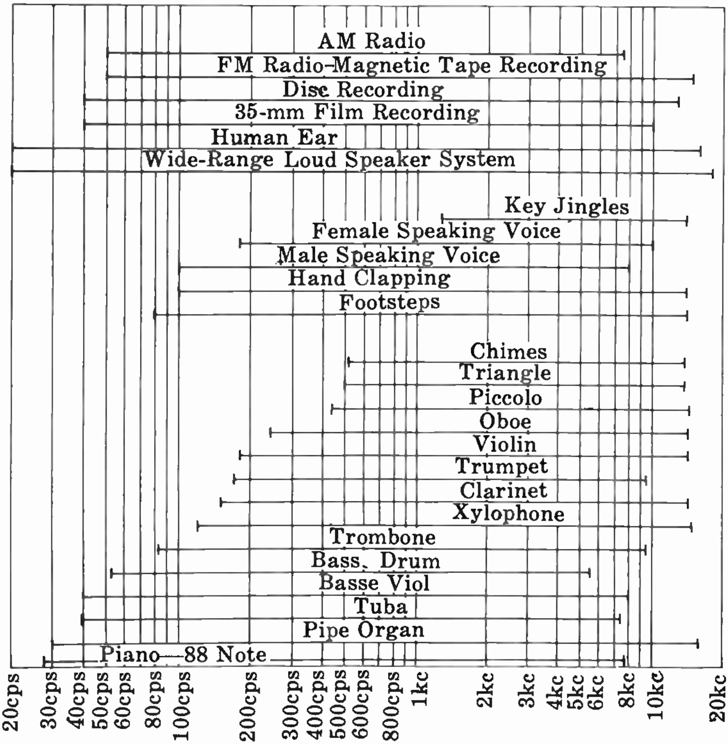


Fig. 59

Table XIV. Frequency Classification

Frequency	Band No.	Classification	Abbreviation
3–30 kc	4	Very low frequencies	VLF
30–300 kc	5	Low frequencies	LF
300–3000 kc	6	Medium frequencies	MF
3–30 mc	7	High frequencies	HF
30–300 mc	8	Very high frequencies	VHF
300–3000 mc	9	Ultrahigh frequencies	UHF
3000–30,000 mc	10	Super-high frequencies	SHF
30,000–300,000 mc	11	Extremely high frequencies	EHF
300,000–3,000,000 mc	12	———	—

(B) FCC Allocations

The FCC allocations for the various services between 10 kc and 100,000 mc are given in Fig. 61A and B (located on the fold-out page between pages 180 and 181.

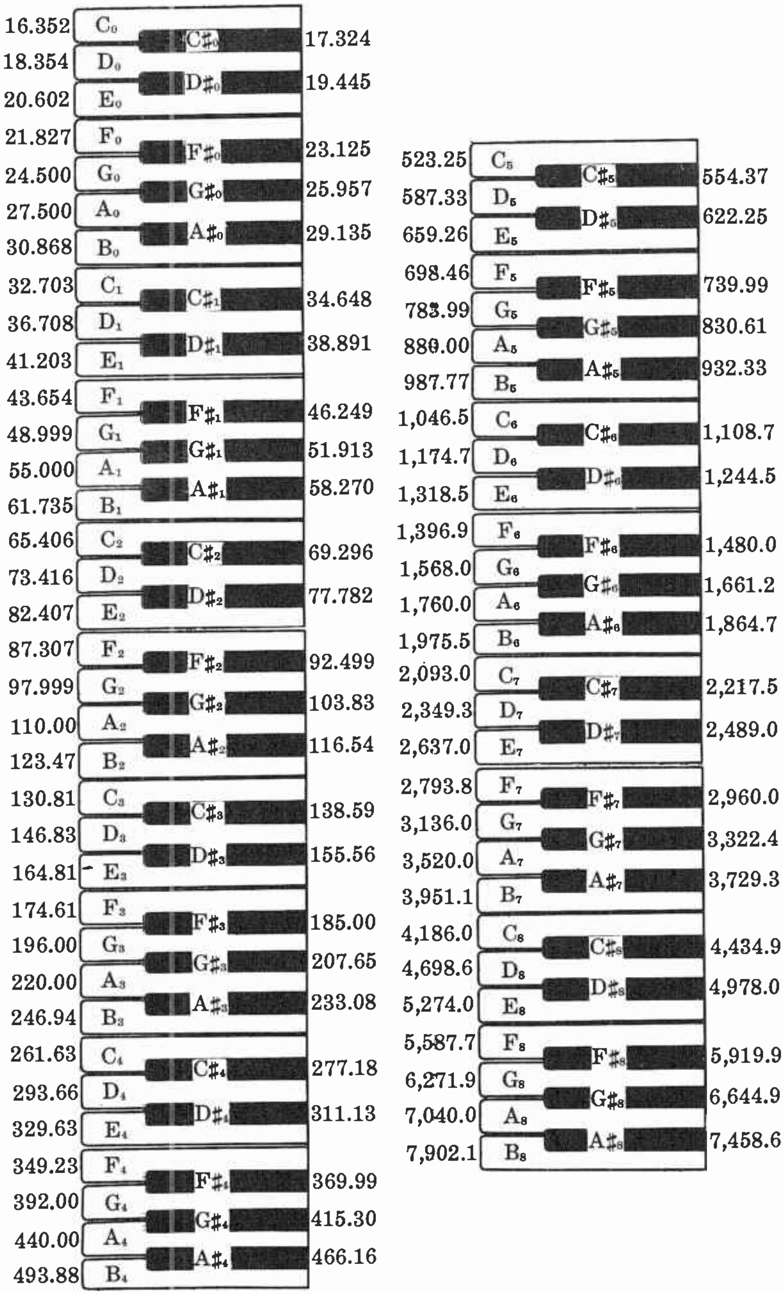

16.352 C_0
$C\sharp_0$ 17.324
18.354 D_0
$D\sharp_0$ 19.445
20.602 E_0
21.827 F_0
$F\sharp_0$ 23.125
24.500 G_0
$G\sharp_0$ 25.957
27.500 A_0
$A\sharp_0$ 29.135
30.868 B_0
32.703 C_1
$C\sharp_1$ 34.648
36.708 D_1
$D\sharp_1$ 38.891
41.203 E_1
43.654 F_1
$F\sharp_1$ 46.249
48.999 G_1
$G\sharp_1$ 51.913
55.000 A_1
$A\sharp_1$ 58.270
61.735 B_1
65.406 C_2
$C\sharp_2$ 69.296
73.416 D_2
$D\sharp_2$ 77.782
82.407 E_2
87.307 F_2
$F\sharp_2$ 92.499
97.999 G_2
$G\sharp_2$ 103.83
110.00 A_2
$A\sharp_2$ 116.54
123.47 B_2
130.81 C_3
$C\sharp_3$ 138.59
146.83 D_3
$D\sharp_3$ 155.56
164.81 E_3
174.61 F_3
$F\sharp_3$ 185.00
196.00 G_3
$G\sharp_3$ 207.65
220.00 A_3
$A\sharp_3$ 233.08
246.94 B_3
261.63 C_4
$C\sharp_4$ 277.18
293.66 D_4
$D\sharp_4$ 311.13
329.63 E_4
349.23 F_4
$F\sharp_4$ 369.99
392.00 G_4
$G\sharp_4$ 415.30
440.00 A_4
$A\sharp_4$ 466.16
493.88 B_4
523.25 C_5
$C\sharp_5$ 554.37
587.33 D_5
$D\sharp_5$ 622.25
659.26 E_5
698.46 F_5
$F\sharp_5$ 739.99
783.99 G_5
$G\sharp_5$ 830.61
880.00 A_5
$A\sharp_5$ 932.33
987.77 B_5
1,046.5 C_6
$C\sharp_6$ 1,108.7
1,174.7 D_6
$D\sharp_6$ 1,244.5
1,318.5 E_6
1,396.9 F_6
$F\sharp_6$ 1,480.0
1,568.0 G_6
$G\sharp_6$ 1,661.2
1,760.0 A_6
$A\sharp_6$ 1,864.7
1,975.5 B_6
2,093.0 C_7
$C\sharp_7$ 2,217.5
2,349.3 D_7
$D\sharp_7$ 2,489.0
2,637.0 E_7
2,793.8 F_7
$F\sharp_7$ 2,960.0
3,136.0 G_7
$G\sharp_7$ 3,322.4
3,520.0 A_7
$A\sharp_7$ 3,729.3
3,951.1 B_7
4,186.0 C_8
$C\sharp_8$ 4,434.9
4,698.6 D_8
$D\sharp_8$ 4,978.0
5,274.0 E_8
5,587.7 F_8
$F\sharp_8$ 5,919.9
6,271.9 G_8
$G\sharp_8$ 6,644.9
7,040.0 A_8
$A\sharp_8$ 7,458.6
7,902.1 B_8

Fig. 60

Symbols and Codes

40. INTERNATIONAL Q SIGNALS

The international *Q* signals were first adopted to enable ships at sea to communicate with each other or to foreign shores without experiencing language difficulties. The signals consist of a series of three-letter groups starting with *Q* and having the same meaning in all languages. Today, *Q* signals serve as a convenient means of abbreviation in communications between amateurs. Each *Q* signal has both an affirmative and an interrogative meaning. The question is designated by the addition of the question mark after the *Q* signal. The most common *Q* signals are listed in Table XV.

Table XV. Q Signals

Signal	Question	Answer or Advice
QRG	Will you tell me my exact frequency?	Your exact frequency is . . . kc (or mc).
QRH	Does my frequency vary?	Your frequency varies.
QRK	What is the readability of my signals?	The readability of your signals is . . . .
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by static?	I am troubled by static.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send more slowly?	Send more slowly (. . . . words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRX	When will you call again?	I will call you again at . . . . hours [on . . . . kc (or mc)].
QSA	What is the strength of my signals?	The strength of your signals is . . . .
QSB	Are my signals fading?	Your signals are fading.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last message I sent you?	Repeat the last message you have sent me.
QSO	Can you communicate with . . . . direct or by relay?	I can communicate with . . . . direct (or by relay through . . . .).
QSV	Shall I send a series of V's?	Send a series of V's.
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency [or on . . . . kc (or mc)].
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTH	What is your location?	My location is . . . . .

41. "10" SIGNALS

The abbreviations based on the number *10* plus a suffix was originally used for communication between police units. Now they are often used in other forms of two-way communications. The most common signals are given in Table XVI.

Table XVI. "10" Signals

Signal	Meaning	Signal	Meaning
10-1	Unable to copy	10-27	Operator on duty
10-2	Signal good	10-30	Does not conform to rules
10-3	Affirmative—granted—will do	10-33	Emergency traffic this station
10-5	Relay	10-36	Confidential information
10-6	Busy	10-41	Beginning tour of duty
10-7	Off the air	10-42	Ending tour of duty
10-8	On the air	10-44	Message received by all concerned
10-9	Repeat		
10-10	On detail, but subject to call	10-60	What is next number?
10-11	Remain in service	10-61	CW traffic
10-12	Visitors or officials present	10-62	Teletype traffic
10-13	Weather and road conditions	10-63	Any answer our number . . .
10-14	Correct time	10-64	Message for local delivery
10-16	Pick up (. . .)	10-65	Net message assignment
10-17	Urgent—rush present detail	10-66	Cancellation
10-18	Anything for us?	10-67	Clear for net message
10-19	Nothing for you	10-68	Dispatch information
10-20	Location	10-88	Advise present phone number of . . .
10-21	Call . . . by telephone		
10-22	Reporting in person to . . .	10-91	Too weak; talk closer to mike
10-23	Arrived at scene	10-92	Too loud; talk farther from mike
10-24	Finished with last assignment	10-93	Frequency check
10-25	Disregard last information	10-94	Give a test

42. THE INTERNATIONAL CODE

A	. -	M	- -	Y	- . - -
B	- . . .	N	- .	Z	- - . .
C	- . - .	O	- - -	1	. - - - -
D	- . .	P	. - - .	2	. . - - -
E	.	Q	- - . -	3	. . . - -
F	. . - .	R	. - .	4	. . . . -
G	- - .	S	. . .	5	. . . . .
H	. . . .	T	-	6	- . . . .
I	. .	U	. . -	7	- - . . .
J	. - - -	V	. . . -	8	- - - . .
K	- . -	W	. - -	9	- - - - .
L	. - . .	X	- . . -	0	- - - - -

Question Mark	. . - - . .	Period	. - . - . -
Error	. . . .	Comma	- - . . - -
Wait	. - . . .	End of Message	. - . - .

43. GREEK ALPHABET

The Greek alphabet is given in Table XVII. The items for which each letter is a symbol are also listed. The small Greek letter is the symbol for all the items listed unless a capital letter is indicated (cap).

Table XVII. Greek Alphabet

Letter		Name	Designates
Small	Capital		
α	A	Alpha	Angles, coefficients, attenuation constant, absorption factor, area.
β	B	Beta	Angles, coefficients, phase constant.
γ	Γ	Gamma	Specific quantity, angles, electrical conductivity, propagation constant, complex propagation constant (cap).
δ	Δ	Delta	Density, angles, increment or decrement (cap or small), determinant (cap), permittivity (cap).
ε	E	Epsilon	Dielectric constant, permittivity, base of natural (Napierian) logarithms, electric intensity.
ζ	Z	Zeta	Co-ordinate, coefficients.
η	H	Eta	Intrinsic impedance, efficiency, surface charge density, hysteresis, co-ordinates.
θ	Θ	Theta	Angular phase displacement, time constant, reluctance, angles.
ι	I	Iota	Unit vector.
κ	K	Kappa	Susceptibility, coupling coefficient.
λ	Λ	Lambda	Wavelength, attenuation constant, permeance (cap).
μ	M	Mu	Prefix *micro-*, permeability, amplification factor.
ν	N	Nu	Reluctivity, frequency.
ξ	Ξ	Xi	Co-ordinates.
ο	O	Omicron	——
π	Π	Pi	3.1416 (circumference divided by diameter).
ρ	P	Rho	Resistivity, volume charge density, co-ordinates.
σ	Σ	Sigma	Surface charge density, complex propagation constant, electrical conductivity, leakage coefficient, sign of summation (cap).
τ	T	Tau	Time constant, volume resistivity, time-phase displacement, transmission factor, density.
υ	Υ	Upsilon	——

Table XVII. Greek Alphabet—(Cont'd)

Letter		Name	Designates
Small	Capital		
φ	Φ	Phi	Magnetic flux, angles, scalar potential (cap).
χ	X	Chi	Electric susceptibility, angles.
ψ	Ψ	Psi	Dielectric flux, phase difference, coordinates, angles.
ω	Ω	Omega	Angular velocity ($2\pi f$), resistance in ohms (cap), solid angles (cap).

44. ELECTRONIC SYMBOLS AND ABBREVIATIONS*

A—Ammeter; ampere; area
a—Ampere
AC, a.c., a-c, ac—Alternating current
AF, a.f., a-f, af—Audio frequency
AFC, afc—Automatic frequency control
AGC, agc—Automatic gain control
AM, am—Amplitude modulation
Amp, amp., Amps, amps.—Ampere; amperes
Ant, ant.—Antenna
AVC, a.v.c., avc—Automatic volume control
B—Susceptance
b—Magnetic flux density
BC, bc—Broadcast
BFO, bfo—Beat-frequency oscillator
C—Capacitance; capacitor
°C—Degrees Celsius or centigrade
cm—Centimeter
cps—Cycles per second
CW, cw—Continuous wave
db—Decibels
DC, d.c., d-c, dc—Direct current
d.c.c., dcc—Double cotton-covered
DPDT, d.p.d.t., dpdt—Double-pole, double-throw
DPST, d.p.s.t., dpst—Double-pole, single-throw
d.s.c., dsc—Double silk-covered
E, e—Voltage
e.c., ec—Enamel-covered
EMF, emf—Electromotive force
ERP—Effective radiated power
F, f—Farad
f—Frequency
°F—Degrees Fahrenheit
FM, f.m., fm—Frequency modulation
G—Conductance
G_m, gm, g_m—Mutual conductance
GCT—Greenwich Civil Time
gnd—Ground
H, h—Henry
HF, h.f., h-f, hf—High frequency
hp—Horsepower
hy.—Henry
I—Current
IF, i.f., i-f, if—Intermediate frequency
ips—Inches per second
j—Joule; an imaginary number; an operator to rotate a vector quantity 90° counterclockwise
K—× 1000; dielectric constant; a numerical value that does not change during a given period
k—Dielectric constant
KC, kc—Kilocycle
kv—Kilovolt
kva—Kilovolt ampere
KW, kw—Kilowatt
KWH, kwh—Kilowatt hour
L—Inductance; inductor
l—Length
LF, l.f., l-f, lf—Low frequency
M—Mutual inductance; × 1000
m—Meter
ma—Milliampere

* For Greek letters used as symbols (such as Ω, ω, and ψ), see the Greek alphabet in § 43.

MC, Mc, mc—Megacycle
mcw—Modulated continuous wave
meg—Megohm
MF, m.f., m-f, mf—Medium frequency
mf, mfd—Microfarad
mh—Millihenry
mm—Millimeter
mmf, mmfd—Micromicrofarad
mv—Millivolt (sometimes microvolt)
mw—Milliwatt (sometimes microwatt)
NC—No connection
OD—Outside diameter
P—Power
pf—Power factor
p-p—Peak-to-peak
Q—Merit of a coil or capacitor; quantity of electricity
R—Resistance; resistor
RC, R-C—Product of resistance time capacitance; resistor-capacitor
RF, r.f., r-f, rf—Radio frequency
RFC—Radio-frequency choke coil
rms—Root mean square
rpm—Revolutions per minute
s.c.c., scc—Single cotton-covered
s.c.e., sce—Single cotton enamel
sec—Second; secondary
s.s.c., ssc—Single silk-covered
SHF; s.h.f., shf—Super-high frequencies
SW, sw—Short wave
t—Time
T—Temperature
trf—Tuned radio frequency
UHF, uhf—Ultrahigh frequencies
V, v—Volt; voltmeter
VHF, vhf—Very high frequencies
VOM, vom—Volt-ohm-milliammeter
VTVM, vtvm—Vacuum-tube voltmeter
VU—Volume unit
W—Watt; work
w—Watt
wh, whr—Watt-hour
X—Reactance
X_C—Capacitive reactance
X_L—Inductive reactance
Y—Admittance
Z—Impedance
μ**a**—Microampere
μ**f**—Microfarad
μ**h**—Microhenry
$\mu\mu$**f**—Micromicrofarad
∿—Cycles per second

45. SEMICONDUCTOR ABBREVIATIONS

The following symbols and abbreviations have been adopted as standard by the Electronic Industries Association (EIA) and the National Electrical Manufacturers Association (NEMA).

B, b—Base electrode for units employing a single base
b_1, b_2, **etc.**—Base electrodes for more than one base
BV_{CBO}—Breakdown voltage, collector to base, emitter open
BV_{CEO}—Breakdown voltage, collector to emitter, base open
BV_{CER}—Breakdown voltage, collector to emitter, with specified resistance between base and emitter
BV_{CES}—Breakdown voltage, collector to emitter, with base short-circuited to emitter
BV_{EBO}—Breakdown voltage, emitter to base, collector open
BV_R—Breakdown voltage, reverse
C, c—Collector electrode
C_{ib}—Input capacitance (common base)
C_{ic}—Input capacitance (common collector)
C_{ie}—Input capacitance (common emitter)
C_{ob}—Output capacitance (common base)
C_{oc}—Output capacitance (common collector)
C_{oe}—Output capacitance (common emitter)
E, e—Emitter electrode

f_{hfb}—Small-signal, short-circuit, forward-current, transfer-ratio cutoff frequency (common base)

f_{hfc}—Small-signal, short-circuit, forward-current, transfer-ratio cutoff frequency (common collector)

f_{hfe}—Small-signal, short-circuit, forward-current, transfer-ratio cutoff frequency (common emitter)

f_{max}—Maximum frequency of oscillation

G_{PB}—Large-signal average power gain (common base)

G_{pb}—Small-signal average power gain (common base)

G_{PC}—Large-signal average power gain (common collector)

G_{pc}—Small-signal average power gain (common collector)

G_{PE}—Large-signal average power gain (common emitter)

G_{pe}—Small-signal average power gain (common emitter)

h_{FB}—Static value of the forward-current transfer ratio (common base)

h_{fb}—Small-signal, short-circuit, forward-current transfer ratio (common base)

h_{FC}—Static value of the forward-current transfer ratio (common collector)

h_{fc}—Small-signal, short-circuit, forward-current transfer ratio (common collector)

h_{FE}—Static value of the forward-current transfer ratio (common emitter)

h_{fe}—Small-signal, short-circuit, forward-current transfer ratio (common emitter)

h_{IB}—Static value of the input resistance (common base)

h_{ib}—Small-signal value of short-circuit input impedance (common base)

h_{IC}—Static value of the input resistance (common collector)

h_{ic}—Small-signal value of short-circuit input impedance (common emitter)

h_{IE}—Static value of the input resistance (common emitter)

h_{ie}—Small-signal value of short-circuit input impedance (common emitter)

h_{ie} **(real)**—Real part of small-signal value of short-circuit input impedance (common emitter)

h_{OB}—Static value of open-circuit output conductance (common base)

h_{ob}—Small-signal value of open-circuit output admittance (common base)

h_{OC}—Static value of open-circuit output conductance (common collector)

h_{oc}—Small-signal value of open-circuit output admittance (common collector)

h_{OE}—Static value of open-circuit output conductance (common emitter)

h_{oe}—Small-signal value of open-circuit output admittance (common emitter)

h_{rb}—Small-signal value of open-circuit, reverse-voltage transfer ratio (common base)

h_{rc}—Small-signal value of open-circuit, reverse-voltage transfer ratio (common collector)

h_{re}—Small-signal value of open-circuit, reverse-voltage transfer ratio (common emitter)

I, i—Intrinsic region of a device (where neither holes nor electrons predominate)

I_B—Base current (DC)

I_b—Base current (rms)

i_b—Base current (instantaneous)

I_C—Collector current (DC)

I_c—Collector current (rms)

i_c—Collector current (instantaneous)

I_{CBO}—Collector cutoff current (DC), emitter open

I_{CEO}—Collector cutoff current (DC), base open

I_{CER}—Collector cutoff current (DC), with specified resistance between base and emitter

I_{CEX}—Collector current (DC), with specified circuit between base and emitter

I_{CES}—Collector cutoff current (DC), with base short-circuited to emitter

I_E—Emitter current (DC)

I_e—Emitter current (rms)

i_e—Emitter current (instantaneous)

I_{EBO}—Emitter cutoff current (DC), collector open

I_F—Forward current (DC)

i_F—Forward current (instantaneous)

I_O—Average output (rectified) current

I_R—Reverse current (DC)

i_R—Reverse current (instantaneous)

K_θ—Thermal derating factor

L_c—Conversion loss

N, n—Region of a device where electrons are the majority carriers

NF—Noise figure

P, p—Region of a device where holes are the majority carriers

P_{BE}—Total power input (DC or average) to the base electrode with respect to the emitter electrode

p_{BE}—Total power input (instantaneous) to the base electrode with respect to the emitter electrode

P_{CB}—Total power input (DC or average) to the collector electrode with respect to the base electrode

p_{CB}—Total power input (instantaneous) to to the collector electrode with respect to the base electrode

P_{CE}—Total power input (DC or average) to the collector electrode with respect to the emitter electrode

p_{CE}—Total power input (instantaneous) to the collector electrode with respect to the emitter electrode

P_{EB}—Total power input (DC or average) to the emitter electrode with respect to the base electrode

p_{EB}—Total power input (instantaneous) to the emitter electrode with respect to the base electrode

P_{IB}—Large-signal input power (common base)

P_{ib}—Small-signal input power (common base)

P_{IC}—Large-signal input power (common collector)

P_{ic}—Small-signal input power (common collector)

P_{IE}—Large-signal input power (common emitter)

P_{ie}—Small-signal input power (common emitter)

P_{OB}—Large-signal output power (common base)

P_{ob}—Small-signal output power (common base)

P_{OC}—Large-signal output power (common collector)

P_{oc}—Small-signal output power (common collector)

P_{OE}—Large-signal output power (common emitter)

P_{oe}—Small-signal output power (common emitter)

P_T—Total power input (DC or average) to all electrodes

p_T—Total power input (instantaneous) to all electrodes

R_B—External base resistance

R_C—External collector resistance

r_{CE} (sat)—Collector-to-emitter saturation resistance

R_E—External emitter resistance

R_L—Load resistance

T—Temperature

T_A—Ambient temperature

T_C—Case temperature

t_d—Delay time

t_f—Fall time

t_{fr}—Forward recovery time

T_J—Junction temperature

T_{opr}—Operating temperature

t_p—Pulse time

t_r—Rise time

t_{rr}—Reverse recovery time

t_s—Storage time

T_{stg}—Storage temperature

t_w—Pulse average time

θ—Thermal resistance

θ_{J-A}—Thermal resistance, junction-to-ambient

θ_{J-C}—Thermal resistance, junction-to-case

V_{BB}—Base supply voltage (DC)

V_{BC}—Base-to-collector voltage (DC)

V_{bc}—Base-to-collector voltage (rms)

v_{bc}—Base-to-collector voltage (instantaneous)

V_{BE}—Base-to-emitter voltage (DC)

V_{be}—Base-to-emitter voltage (rms)

v_{be}—Base-to-emitter voltage (instantaneous)

V_{CB}—Collector-to-base voltage (DC)

V_{cb}—Collector-to-base voltage (rms)

v_{cb}—collector-to-base voltage (instantaneous)

V_{CC}—Collector supply voltage (DC)

V_{CE}—Collector-to-emitter voltage (DC)

V_{ce}—Collector-to-emitter voltage (rms)

v_{ce}—Collector-to-emitter voltage (instantaneous)
V_{CE} (sat)—Collector-to-emitter saturation voltage
V_{EB}—Emitter-to-base voltage (DC)
V_{eb}—Emitter-to-base voltage (rms)
v_{eb}—Emitter-to-base voltage (instantaneous)
V_{EC}—Emitter-to-collector voltage (DC)
V_{ec}—Emitter-to-collector voltage (rms)
v_{ec}—Emitter-to-collector voltage (instantaneous)
V_{EE}—Emitter supply voltage (DC)
V_F—Forward voltage (DC)
v_F—Forward voltage (instantaneous)
V_{CBF}—DC open-circuit voltage (floating potential) between collector and base, with emitter biased in reverse direction with respect to base
V_{ECF}—DC open-circuit voltage (floating potential) between emitter and collector, with base biased in reverse direction with respect to collector
V_{RT}—Reach-through voltage
V_R—Reverse voltage (DC)
v_R—Reverse voltage (instantaneous)

46. EIA TRANSFORMER COLOR CODE

The following diagrams illustrate the color code for transformers recommended by the EIA.

(A) Power Transformers

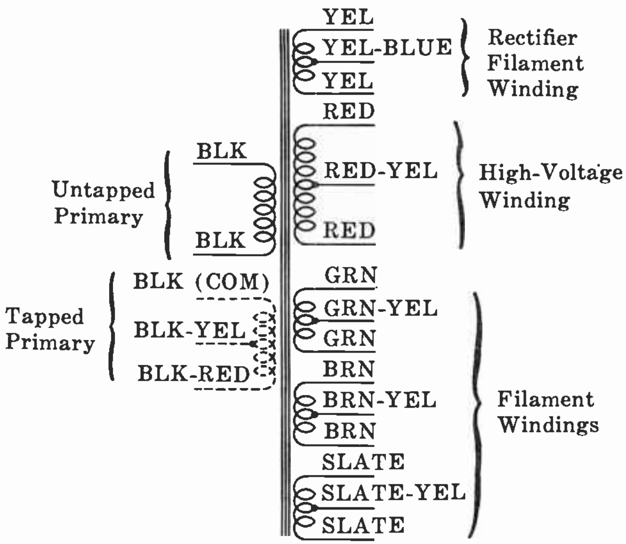


Fig. 62

(B) IF Transformers

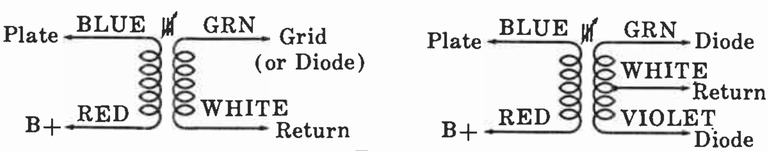


Fig. 63

(C) Audio Output and Interstage Transformers

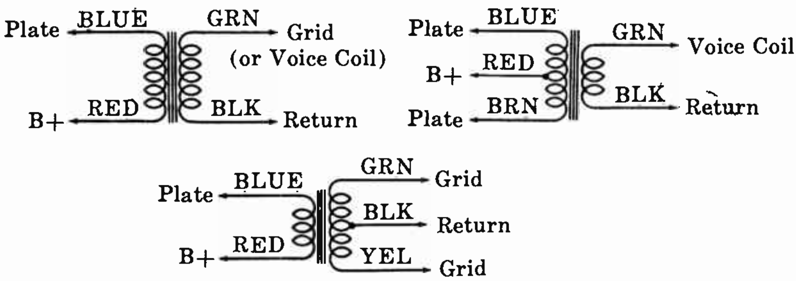


Fig. 64

47. RESISTOR AND CAPACITOR COLOR CODES

The present method and some of the older methods of color-coding resistors and capacitors are given in Figs. 65A and B (pages 89 and 90).

48. ELECTRONIC SCHEMATIC SYMBOLS

The most common schematic symbols are illustrated in Figs. 66A, B, C, and D (pages 91, 92, 93, and 94).

Resistor and Capacitor Color Codes

Fig. 65A

MOLDED MICA CAPACITOR CODES
(Capacity Given In MMF)

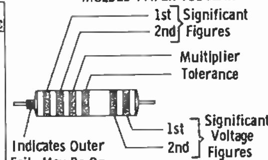
COLOR	DIGIT	MULTIPLIER	TOLERANCE	CLASS OR CHARACTERISTIC
BLACK	0	1	20%	A
BROWN	1	10	1%	B
RED	2	100	2%	C
ORANGE	3	1000	3%	D
YELLOW	4	10000		E
GREEN	5		5%(EIA)	F(JAN)
BLUE	6			G(JAN)
VIOLET	7			
GRAY	8			I(EIA)
WHITE	9			J(EIA)
GOLD		.1	5%(JAN)	
SILVER		.01	10%	

Class or characteristic denotes specifications of design involving Q factors, temperature coefficients, and production test requirements.
All axial lead mica capacitors have a voltage rating of 300, 500, or 1000 volts.
*or ±1.0 MMF whichever is greater.

MOLDED PAPER CAPACITOR CODES
(Capacity Given In MMF)

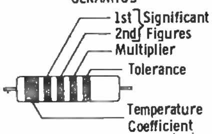
COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	20%
BROWN	1	10	
RED	2	100	
ORANGE	3	1000	
YELLOW	4	10000	
GREEN	5	100000	5%
BLUE	6	1000000	
VIOLET	7		
GRAY	8		
WHITE	9		10%
GOLD			5%
SILVER			10%
NO COLOR			20%

MOLDED PAPER TUBULAR

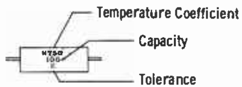


Add Two Zeros To Significant Voltage Figures. One Band Indicates Voltage Ratings Under 1000 Volts.

MOLDED-INSULATED AXIAL LEAD CERAMICS

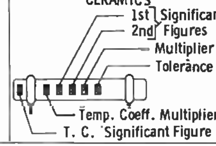


TYPOGRAPHICALLY MARKED CERAMICS

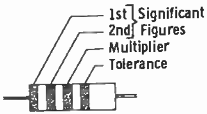


JAN LETTER	TOLERANCE 10MMF or LESS	TOLERANCE OVER 10MMF
C	±0.25MMF	
D	±0.5MMF	
F	±1.0MMF	±1%
G	±2.0MMF	±2%
J		±5%
K		±10%
M		±20%

EXTENDED RANGE T.C. TUBULAR CERAMICS



COLOR BAND SYSTEM



Resistors With Black Body Color Are Composition, Non-Insulated.
Resistors With Colored Bodies Are Composition, Insulated.
Wire-Wound Resistors Have The 1st Digit Color Band Double Width.

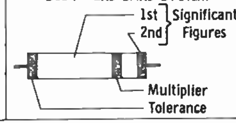
RESISTOR CODES (RESISTANCE GIVEN IN OHMS)

COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	±20%
BROWN	1	10	±1%
RED	2	100	±2%
ORANGE	3	1000	±3% *
YELLOW	4	10000	GMV*
GREEN	5	100000	±5% (EIA Alternate)
BLUE	6	1000000	±6%*
VIOLET	7	10000000	±12 1/2%*
GRAY	8	.01 (EIA Alternate)	±30% *
WHITE	9	.1 (EIA Alternate)	±10% (EIA Alternate)
GOLD		.1 (JAN and EIA Preferred)	±5% (JAN and (EIA Preferred)
SILVER		.01 (JAN and EIA Preferred)	±10% (JAN and EIA Preferred)
NO COLOR			±20%

*GMV = guaranteed minimum value, or -0 + 100% tolerance.
±3, 6, 12 1/2, and 30% are ASA 40, 20, 10, and 5 step tolerances.

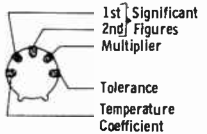
BODY-END-DOT SYSTEM

BODY-END BAND SYSTEM

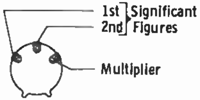


Resistor and Capacitor Color Codes—(Cont'd)

DISC CERAMICS (5-DOT SYSTEM)



DISC CERAMICS (3-DOT SYSTEM)

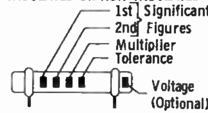


CERAMIC CAPACITOR CODES (CAPACITY GIVEN IN MMF)

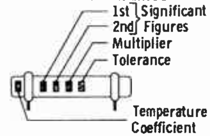
COLOR	DIGIT	MULTI-PLIER	TOLERANCE 10MMF or LESS	TOLERANCE OVER 10MMF	TEMPERATURE COEFFICIENT PPM/°C	EXTENDED RANGE TEMP. COEFF. SIGNIFICANT FIGURE	EXTENDED RANGE TEMP. COEFF. MULTIPLIER
BLACK	0	1	±2.0MMF	±20%	0(NPO)	0.0	-1
BROWN	1	10	±0.1MMF	±1%	-33(N033)		-10
RED	2	100		±2%	-75(N075)	1.0	-100
ORANGE	3	1000		±2.5%	-150(N150)	1.5	-1000
YELLOW	4	10000			-220(N220)	2.2	-10000
GREEN	5		±0.5MMF	±5%	-330(N330)	3.3	+1
BLUE	6				-470(N470)	4.7	+10
VIOLET	7				-750(N750)	7.5	+100
GRAY	8	.01	±0.25MMF		+30(P030)		+1000
WHITE	9	.1	±1.0MMF	±10%	General		
					Purpose		+10000
SILVER					Bypass & Coupling		
GOLD					+100(P100) (Jan)		

Ceramic capacitor voltage ratings are standard 500 volts, for some manufacturers, 1000 volts for other manufacturers, unless otherwise specified.

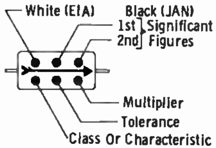
HIGH CAPACITY TUBULAR CERMICS INSULATED OR NON-INSULATED



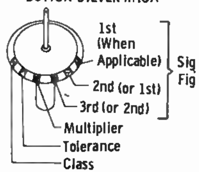
TEMPERATURE COMPENSATING TUBULAR CERAMICS



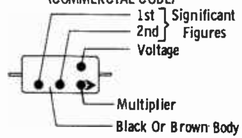
CURRENT STANDARD JAN AND EIA CODE



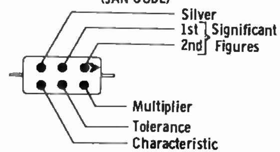
BUTTON SILVER MICA



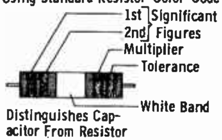
MOLDED FLAT PAPER CAPACITORS (COMMERCIAL CODE)



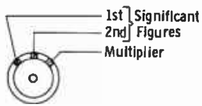
MOLDED FLAT PAPER CAPACITORS (JAN CODE)



MOLDED CERAMICS
Using Standard Resistor Color-Code

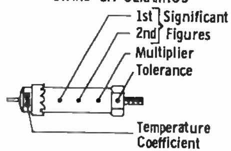


BUTTON CERAMICS



Viewed From Soldered Surface

STAND-OFF CERAMICS



FEED-THRU CERAMICS

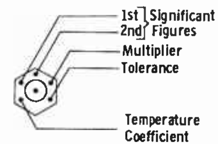


Fig. 65B

Electronic Schematic Symbols

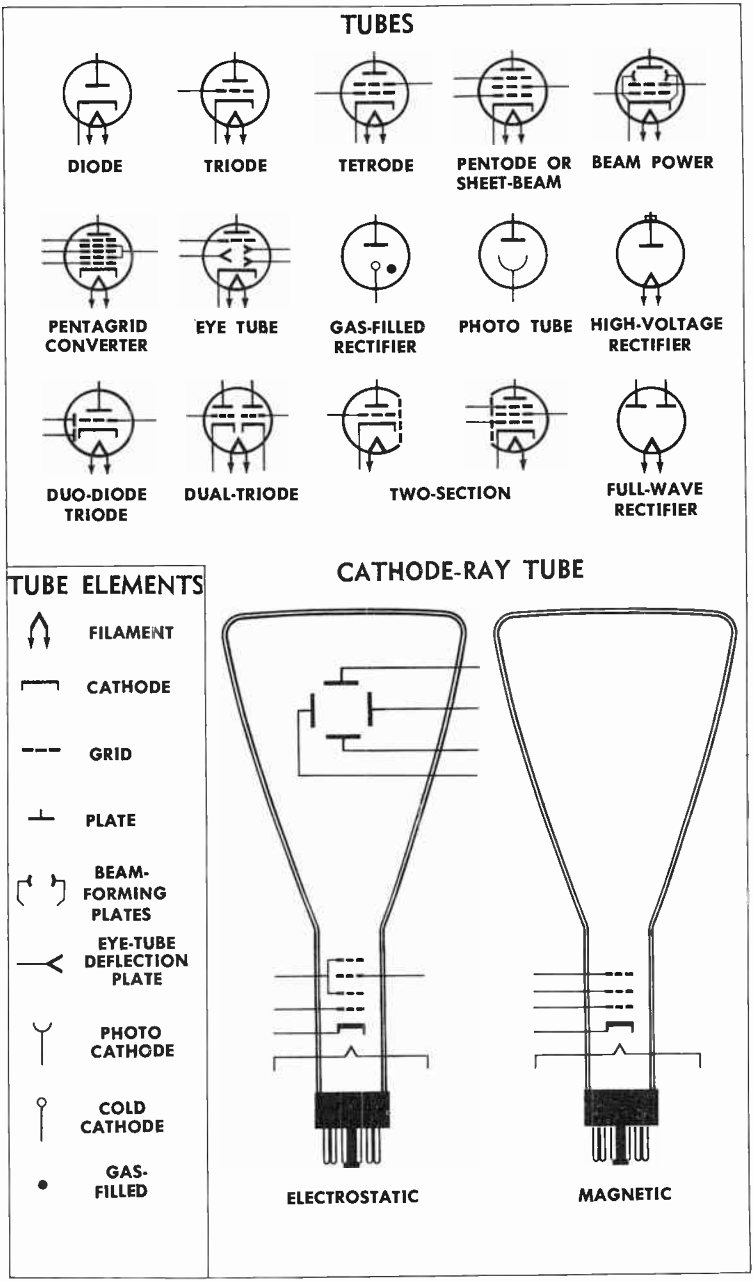


Fig. 66A

Electronic Schematic Symbols—(Cont'd)

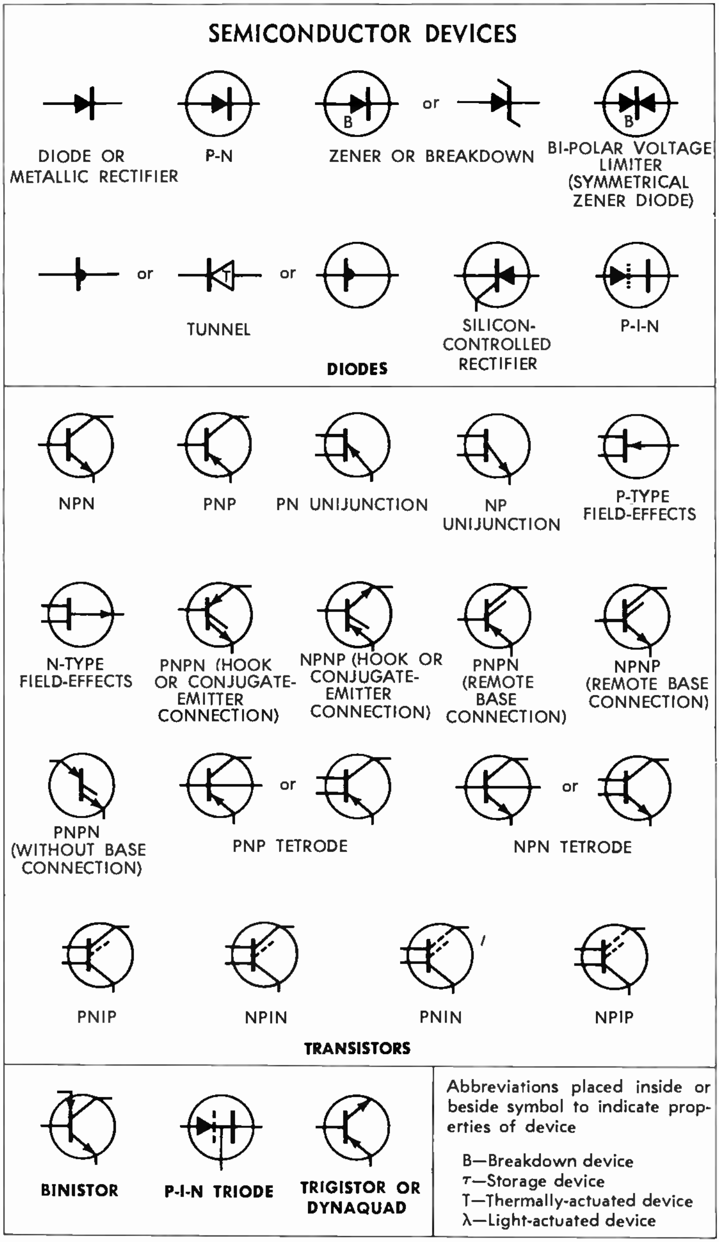


Fig. 66B

Electronic Schematic Symbols—(Cont'd)

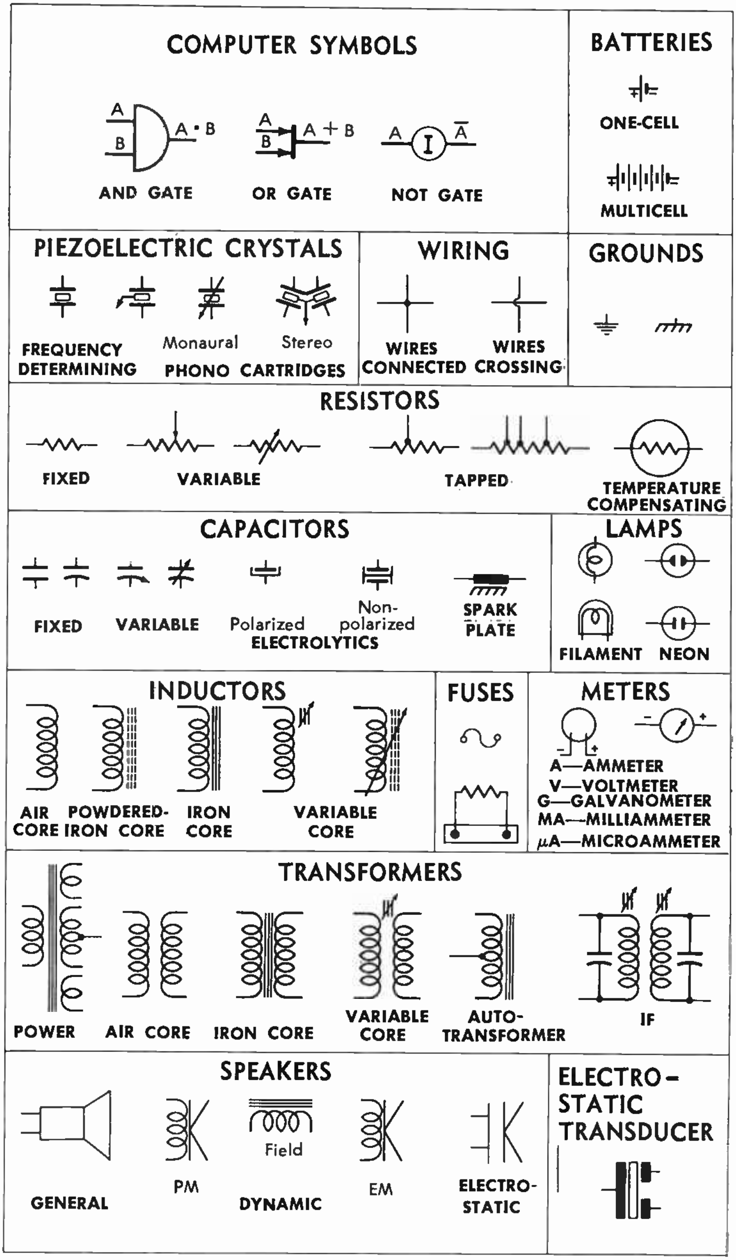


Fig. 66C

Electronic Schematic Symbols—(Cont'd)

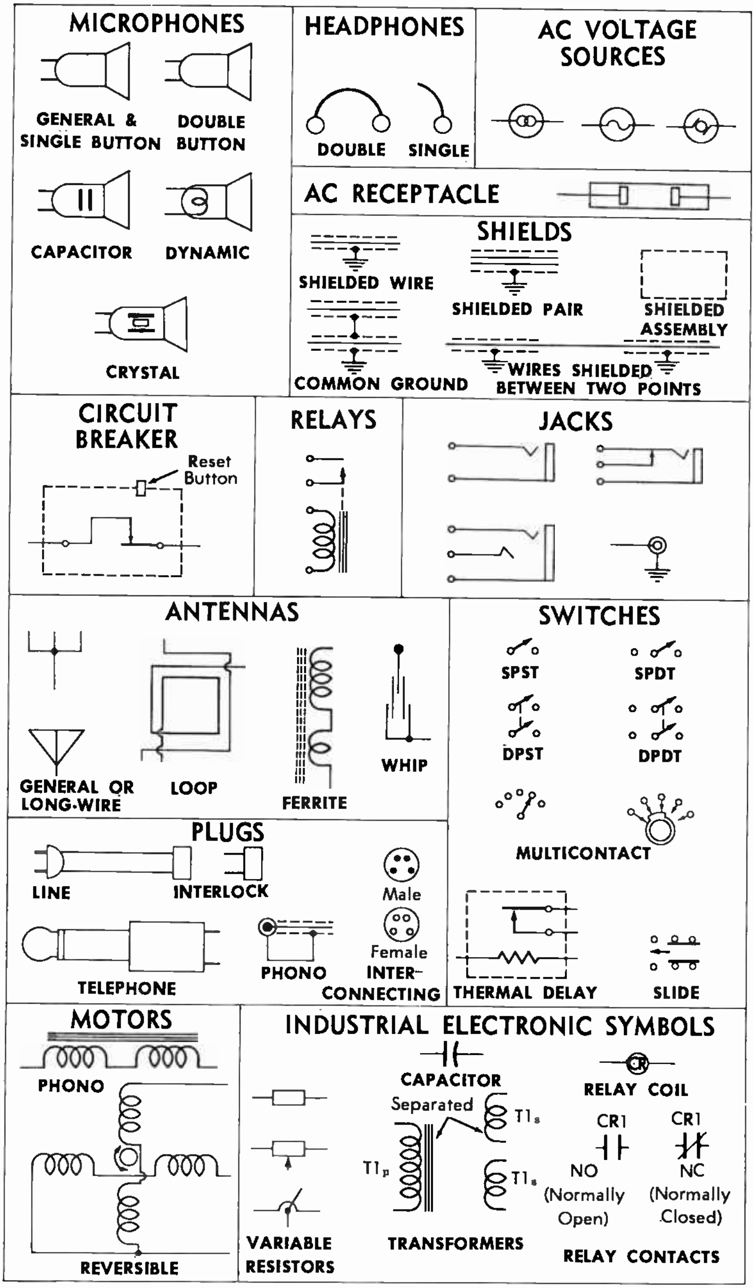


Fig. 66D

Service and Installation Data

49. COAXIAL CABLE CHARACTERISTICS

Table XVIII lists the most frequently-used coaxial cables. The electrical specifications include the impedance in ohms, capacitance in micromicrofarads per foot, attenuation in db per 100 feet, and the outside diameter. (See page 43 for formulas.)

Table XVIII. Coaxial Cable Characteristics

Type RG... /U	Imp. (ohms)	Cap. (mmf per ft.)	Diam. (inches)	Attenuation—db per 100 ft. 1 mc	10 mc	100 mc	400 mc	1000 mc	REMARKS
5	52.5	28.5	.332	.21	.77	2.9	6.5	11.5	Small, double braid
5A	50	29	.328	.16	.66	2.4	5.25	8.8	Small, low loss
6	76	20	.332	.21	.78	2.9	6.5	11.2	IF & video
8	52	29.5	.405	.16	.55	2.0	4.5	8.5	General purpose
9	51	30	.420	.12	.47	1.9	4.4	8.5	General purpose
9A	51	30	.420	.16	.59	2.3	5.2	8.6	Stable attenuation
11	75	20.5	.405	.18	.62	2.2	4.7	8.2	Community TV
13	74	20.5	.420	.18	.62	2.2	4.7	8.2	IF
14	52	29.5	.545	.10	.38	1.5	3.5	6.0	RF power
16	52	29.5	.630	—	—	—	—	—	RF power
17	52	29.5	.870	.06	.24	.95	2.4	4.4	RF power
19	52	29.5	1.120	.04	.17	.68	1.28	3.5	Low-loss RF
21	53	29	.332	1.4	4.4	14.0	29.0	46.0	Attenuating cable
22	95	16	.405	.41	1.3	4.3	8.8	—	Twin conductors
23	125	12	.65 X .945	—	.4	1.7	—	—	Twin conductors (balanced)
25	48	50	.565	—	—	—	—	—	Pulse
26	48	50	.525	—	—	—	—	—	Pulse
27	48	50	.675	—	—	—	—	—	Pulse
28	48	50	.805	—	—	—	—	—	Pulse
33	51	30	.470	—	—	—	—	—	Pulse
34	71	21.5	.625	.065	.29	1.3	3.3	6.0	Flexible, medium
35	71	21.5	.945	.064	.22	.85	2.3	4.2	Low-loss video
36	69	22	1.180	—	—	—	—	—	———
41	67.5	27	.425	—	—	—	—	—	Special twist
54A	58	26.5	.250	.18	.74	3.1	6.7	11.5	Flexible, small

Table XVIII. Coaxial Cable Characteristics—(Cont'd)

Type RG.../U	Imp. (ohms)	Cap. (mmf per ft.)	Diam. (inches)	Attenuation—db per 100 ft. 1 mc	10 mc	100 mc	400 mc	1000 mc	REMARKS
55	53.5	28.5	.206	.36	1.3	4.8	10.4	17.0	Flexible, small
56	—	—	.535	—	—	—	—	—	Pulse
57	95	17	.625	.18	.71	3.0	7.3	13.0	Twin conductors
58	53.5	30	.195	.38	1.4	5.2	11.2	20.0	General purpose
58A	50	30	.195	.42	1.6	6.2	14.0	24.0	Test leads
59	73	21	.242	.30	1.1	3.8	8.5	14.0	TV lead-in
60	50	—	.425	—	—	—	—	—	Pulse cable
61	500	—	—	—	—	—	—	—	Special 500-ohm twin-lead
62	93	13.5	.242	.25	.83	2.7	5.6	9.0	Low capacity, small
63	125	10	.405	.19	.61	2.0	4.0	6.3	Low capacity
64	48	50	.495	—	—	—	—	—	Pulse
65	950	44	.405	—	—	—	—	—	Coaxial delay line
71	93	13.5	.250	.25	.83	2.7	5.6	9.0	Low capacity, small
77	48	50	.415	—	—	—	—	—	Pulse
78	48	50	.385	—	—	—	—	—	Pulse
87A	50	29.5	.425	.13	.52	2.0	4.4	7.6	Teflon dielectric
88	48	50	.490	—	—	—	—	—	Pulse
101	75	—	.588	—	—	—	—	—	———
102	140	—	1.088	—	—	—	—	—	———
108	76	25	.245	—	—	—	—	—	Twin conductors
114	185	6.5	.405	—	—	—	—	—	Extra flexible
117	50	29	.730	.05	.20	.85	2.0	3.6	Teflon & Fiberglas
119	50	29	.470	—	—	—	—	—	Teflon & Fiberglas
122	50	29.3	.160	.40	1.70	7.0	16.5	29.0	———
126	50	29	.290	3.20	9.0	25.0	47.0	72.0	Teflon & Fiberglas
140	73	21	.242	.33	1.03	3.3	6.9	11.7	Teflon & Fiberglas
141	50	29	.195	.35	1.12	3.8	8.0	13.8	Teflon & Fiberglas
142	50	29	.206	.35	1.12	3.8	8.0	13.8	Teflon & Fiberglas
143	50	29	.325	.24	.77	2.5	5.3	9.0	Teflon & Fiberglas
144	72	21	.395	.16	.53	1.8	3.9	7.0	Teflon & Fiberglas
174	50	30	.10	—	—	—	19.0	—	Miniature coaxial

50. TEST-PATTERN INTERPRETATION

The Indian Head test pattern in Fig. 67 is transmitted by many TV stations and is also used in the flying-spot scanner type of video pattern generators. In addition, many of the features of this pattern are incorporated in the individual test patterns of TV stations. The test pattern is a quick and accurate way of checking receiver adjustments and operating conditions.

In the following explanation, the significance of each point indicated by an arrow and letter on the test pattern is

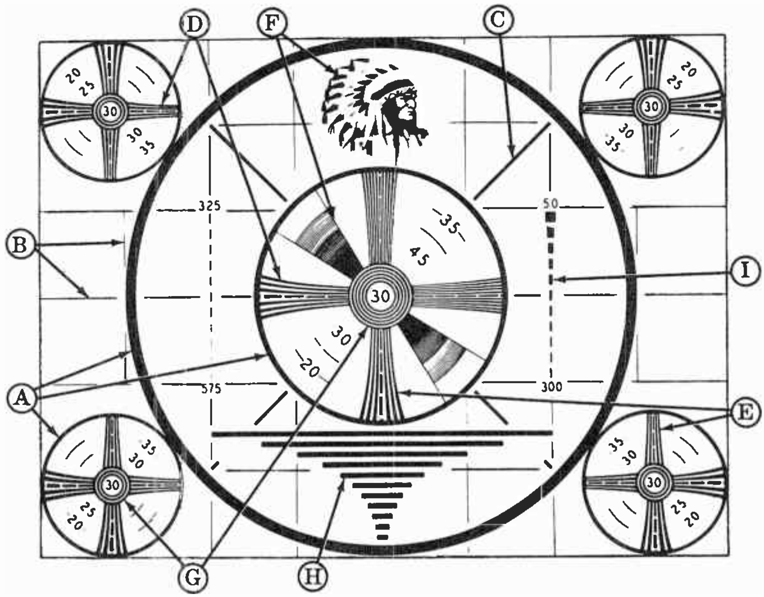


Fig. 67

explained. For example, the letter A indicates the circles at each corner and the two circles in the center of the pattern.

A. The six circles serve as a check for the adjustment of the Height, Width, Vertical Linearity, Horizontal Linearity, and Horizontal Drive controls and the ion-trap magnets, as well as the over-all operation of the vertical, horizontal, and power-supply circuits. All circles should be round and should not overlap the sides of the picture tube by more than three-fourths of an inch.

B. The eight squares along the horizontal axis and the six squares along the vertical axis indicate the standard aspect ratio of 4:3. These squares serve as a check for rectangular distortion caused by misadjusted or missing anti-pincushion magnets or by defects in the deflection yoke.

C. The four diagonal lines are used to check interlace. Poor interlace due to improper operation of the vertical-oscillator circuit will make the lines appear jagged.

D. The horizontal wedges located at each corner and in the center of the pattern serve as a check of the vertical resolution and interlace. Note the point where the horizontal lines are no longer clear and straight. The breaks in the center line indicate 50-line intervals. That is, starting from the left (on the center and left-hand wedges), the first break indicates vertical resolution of 150 lines; the others, 200, 250, 300, and 350. The first break to the right of the center circles indicates 500 lines, then 450, 400, 350, and 300. The wedges at the top and bottom of the right side of the pattern give the same information except that the wedge is reversed. The numbers (20, 30, 35, and 45) between the vertical and horizontal wedges in each circle indicate these vertical resolution check points, with the last zero omitted.

E. The vertical wedges at each corner and at the center of the pattern indicate the horizontal resolution. Hence, they serve as a check on all video-amplifying circuits and alignment. Note the point where the vertical lines are no longer clear. Each break in the center line of the vertical wedge indicates 50 lines, as explained for D. The horizontal resolution can be converted to bandwidth by dividing the number of lines by 80. For example, if the lines are no longer clear at the 300-line point, the bandwidth equals 300 divided by 80, or 3.75 mc.

F. The two diagonal wedges and the Indian head indicate the contrast ratio. Therefore, they can be used to check the adjustment of the Contrast, Brightness, and AGC controls, as well as the video-amplifying and picture-tube circuits. When video-amplifier and picture-tube circuits are operating properly and the controls are properly adjusted, four degrees of shading should be observed, ranging from black at the center to light gray at the outermost point on the wedge.

G. The bull's-eyes at each corner and at the center of the pattern indicate receiver focus. Hence, they serve to check the adjustment of the focusing device or, if electromagnetic focusing is employed, of the low-voltage power supply.

H. The eleven horizontal bars represent half cycles of square-wave signals, and are used to check the low-frequency response or phase shift of the receiver. The bars, from top to bottom, represent the following video signals: 19 kc, 28 kc, 38 kc, 56 kc, 75 kc, 113 kc, 150 kc, 225 kc, 300 kc, 450 kc, and 600 kc. If the low-frequency response is satisfactory, the bars will be sharply defined. However, if the receiver has poor low-frequency response due to a defect in the video-amplifier circuit or misadjustment of the Fine

Tuning, Contrast, or AGC controls, the bars will have trailing black or white edges.

I. The single resolution lines at each side of the center circle represent the width of a single line ranging from 50 to 575 lines, in steps of 25. These lines are used to check for ringing in the video amplifier at frequencies from approximately 600 kc to 7 mc. When ringing occurs at any frequency, the resolution line corresponding to that frequency will be repeated several times at evenly spaced intervals. To convert the resolution lines to the frequency, divide the number of lines by 80, as explained in the foregoing for E.

51. CLASSES OF VACUUM-TUBE OPERATION

Class-A amplifiers are biased so that the AC input signal is on the linear portion of their characteristic curve, as shown in Fig. 68.

The output signal is a faithful reproduction of the input signal. The only difference is in the amplification. Plate current flows at all times in a Class-A amplifier. Class-A amplifiers are used in audio or other applications where distortion cannot be tolerated. Their efficiency is around 20 to 25%.

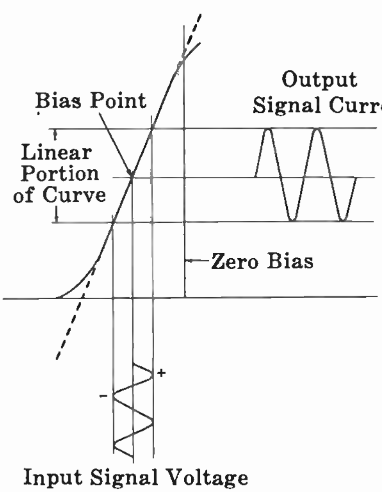


Fig. 68

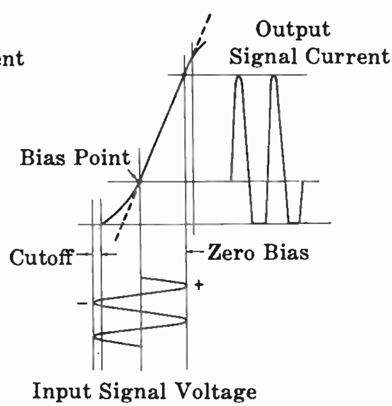


Fig. 69

Class-AB amplifiers are biased as shown in Fig. 69. Here, plate current will flow more than one half but less than a full cycle. Higher plate voltages and currents can be employed than for Class-A amplifiers because the increased negative grid bias will hold the plate current within the plate-dissipation rating. For this reason, more power output can be obtained from Class-AB operation. Class-AB amplifiers may be operated either single-ended or in push-pull.

Class-AB amplifiers are subdivided into two classes, AB_1 and AB_2. In a Class-AB_1 amplifier, no grid current will flow.

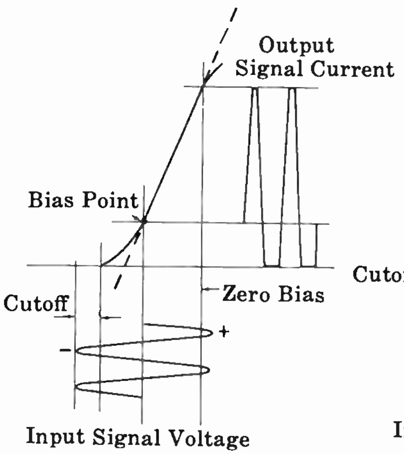


Fig. 70

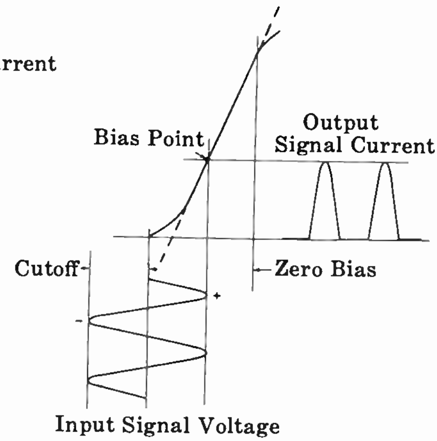


Fig. 71

That is, the peak signal voltage applied to each grid is never greater than the negative grid bias; therefore, the grid is never driven positive. In a Class-AB_2 amplifier, grid current will flow because the peak signal is greater than the negative grid bias and the grid is driven positive during a portion of the cycle, as shown in Fig. 70. The efficiency of Class-AB amplifiers varies from 40 to 75%, depending on the bias voltage.

Class-B amplifiers are biased at or near cutoff, as shown in Fig. 71. When on exciting grid voltage is applied, plate current is near zero; therefore, it will flow only during approximately half of a cycle. Because plate current flows for only one half the cycle, Class-B amplifiers must be operated in push-pull. More power can be obtained from Class-B amplifiers than from Class-A or Class-AB amplifiers without

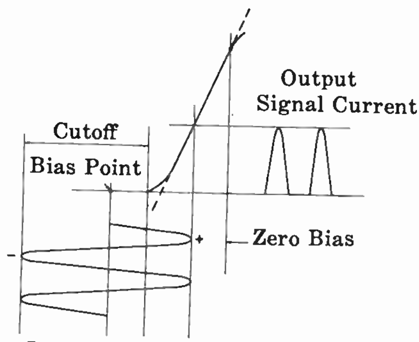


Fig. 72

excessive plate dissipation. The efficiency of Class-B amplifiers is around 40 to 60%.

Class-C amplifiers are biased below cutoff, as shown in Fig. 72. Therefore, plate current flows for less than half of a cycle. More power can be obtained from Class-C than Class-B amplifiers. Usually, Class-C amplifiers are used in a selective-tuned circuit, such as those employed in RF amplifiers. The high distortion, characteristic of Class-C amplifiers, is overcome by the flywheel effect of the tuned circuits. The efficiency of Class-C amplifiers is around 50 to 80%.

52. MINIATURE LAMP DATA

Table XIX (page 102) lists the most common miniature lamps and their characteristics. The outline drawings for each lamp are given in Fig. 73 below.

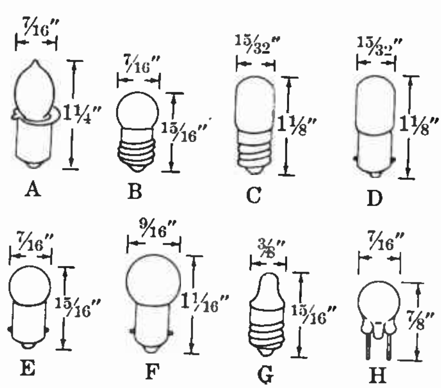


Fig. 73

Table XIX. Miniature Lamp Data

Lamp No.	Volts	Amps	Bead Color	Base	Bulb Type	Fig. No.
PR2	2.4	0.50	Blue	Flange	B-3½	A
PR3	3.6	0.50	Green	Flange	B-3½	A
PR4	2.3	0.27	Yellow	Flange	B-3½	A
PR6	2.5	0.30	Brown	Flange	B-3½	A
PR12	5.95	0.50	White	Flange	B-3½	A
12	6.3	0.15	— — —	2-Pin	G-3½	H
13	3.8	0.30	Green	Screw	G-3½	B
14	2.5	0.30	Blue	Screw	G-3½	B
40	6.3	0.15	Brown	Screw	T-3¼	C
41	2.5	0.50	White	Screw	T-3¼	C
42	3.2	0.35*	Green	Screw	T-3¼	C
43	2.5	0.50	White	Bayonet	T-3¼	D
44	6.3	0.25	Blue	Bayonet	T-3¼	D
45	3.2	0.35†	Green†	Bayonet	T-3¼	D
46	6.3	0.25	Blue	Screw	T-3¼‡	C
47	6.3	0.15	Brown	Bayonet	T-3¼	D
48	2.0	0.06	Pink	Screw	T-3¼	C
49	2.0	0.06	Pink	Bayonet	T-3¼	D
50	6.3	0.20	White	Screw	G-3½	B
51	6.3	0.20	White	Bayonet	G-3½	E
55	6.3	0.40	White	Bayonet	G-4½	F
57	14.0	0.24	White	Bayonet	G-4½	F
112	1.1	0.22	Pink	Screw	TL-3	G
222	2.2	0.25	White	Screw	TL-3	G
233	2.3	0.27	Purple	Screw	G-3½	B
291	2.9	0.17	White	Screw	T-3¼	C
292	2.9	0.17	White	Screw	T-3¼	C
1490	3.2	0.16	White	Bayonet	T-3¼	D
1891	14.0	0.23	Pink	Bayonet	T-3¼	D
1892	14.0	0.12	White	Screw	T-3¼	C

* Some brands are .50 amp.
† Some brands are .50 amp and white bead.
‡ Frosted.

53. GAS-FILLED LAMP DATA

The characteristics of the more common gas-filled lamps are given in Table XX. The value of external resistance needed for operation with circuit voltages from 110 to 600 volts is given in Table XXI.

Table XX. Gas-Filled Lamps

Number	Hours of Average Useful Life*	Type Gas	Max. Length In inches	Base	Amps	Volts	Watts†
AR-1	3,000	Argon	3 1/2	Medium Screw	0.018	110-125	2
AR-3	1,000	Argon	1 5/8	Cand. Screw	0.0035	110-125	1/4
AR-4	1,000	Argon	1 1/2	Double-Contact Bayonet	0.0035	110-125	1/4
NE-2	Over 25,000	Neon	1 1/16‡	Unbased	0.003	110-125	1/25
NE-2A	Over 25,000	Neon	27/32‡	Unbased	0.003	110-125	1/25
NE-17	5,000	Neon	1 1/2	Double-Contact Bayonet§	0.002	110-125	1/4
NE-30	10,000	Neon	2 1/4	Medium Screw§	0.012	110-125	1
NE-32	10,000	Neon	2 1/16	Double-Contact Bayonet§	0.012	110-125	1
NE-34	8,000	Neon	3 1/2	Medium Screw	0.018	110-125	2
NE-40	8,000	Neon	3 1/2	Medium Screw§	0.030	110-125	3
NE-45	Over 7,500	Neon	1 5/8	Cand. Screw	0.002	110-125	1/4
NE-48	Over 7,500	Neon	1 1/2	Double-Contact Bayonet	0.002	110-125	1/4
NE-51	Over 15,000	Neon	1 3/16	Miniature Bayonet	0.0003	110-125	1/25
NE-56	10,000	Neon	2 1/4	Medium Screw§	0.005	220-250	1
NE-57	5,000	Neon	1 5/8	Cand. Screw§	0.002	110-125	1/4
NE-58	Over 7,500	Neon	1 5/8	Cand. Screw	0.002	220-250	1/2

* Life on DC is approximately 60% of AC values.
† For 110-125V operation.
‡ The dimension is for glass only.
§ On DC circuits the base should be negative.

Table XXI. External Resistances Needed For Gas-Filled Lamps

Type	110-125V	220-300V	300-375V	375-450V	450-600V
AR-1	Included in Base	10,000	18,000	24,000	30,000
AR-3	Included in Base	68,000	91,000	150,000	160,000
AR-4	15,000	82,000	100,000	160,000	180,000
NE-2	200,000	750,000	1,000,000	1,200,000	1,600,000
NE-2A	200,000	750,000	1,000,000	1,200,000	1,600,000
NE-17	30,000	110,000	150,000	180,000	240,000
NE-30	Included in Base	10,000	20,000	24,000	36,000
NE-32	7,500	18,000	27,000	33,000	43,000
NE-34	Included in Base	9,100	13,000	16,000	22,000
NE-40	Included in Base	6,200	8,200	11,000	16,000
NE-45	Included in Base	82,000	120,000	150,000	200,000
NE-48	30,000	110,000	150,000	180,000	240,000
NE-51	200,000	750,000	1,000,000	1,200,000	1,600,000
NE-56	Included in Base	———	———	———	———
NE-57	Included in Base	82,000	120,000	150,000	200,000
NE-58	Included in Base	———	———	———	———

54. LIGHT PROPERTIES OF COLOR TV

When we speak of light, we usually think of light coming from the sun or the light emitted from some artificial lighting source, such as electrical lighting. This light is referred to as direct light. Another type of light is indirect or reflected light, which is given off by an object when direct light strikes it. The difference between these two types of light is that the indirect light depends upon the direct light. When light is not shining upon an object, no light will be given off unless the object contains self-luminating properties.

White light is made up of different colors. This composition can be shown by passing light through a prism. The light spectrum is broken up into its constituent wavelengths, each representing a different color. The ability to disperse the light by a prism stems from the fact that light of shorter wavelengths travels slower through glass than does light of longer wavelengths. The spectrum ranges from violet on the lower end to red on the upper end. In between fall blue, green, yellow, and orange. A total of six distinct colors are visible when white light passes through a prism. Since the colors of the spectrum pass gradually from one to the other, the theoretical number of colors becomes infinite.

There are three color attributes used to describe any one color or to differentiate between several colors. These are (1) hue, (2) saturation, and (3) brightness. Hue is the quality used to identify any color under consideration, such as red, blue, or yellow. Saturation is a measure of the absence of dilution by white light, and can be expressed with such terms as rich, deep, vivid, or pure. Brightness defines the amount of light energy contained within a given color.

Color may be produced by either of two processes. When working with paint pigments, the subtractive process is employed. The other process of mixing colors is called the additive process. This process is used in color television. The colors in the additive process do not depend upon an incident light source. Self-luminous properties are characteristic of the additive colors. Phosphorescent signs which glow in the dark are good examples of this process. Cathode-ray tubes contain self-luminance properties; so it is only logical that the additive process would be employed in color television.

The three primaries for the additive process of color mixing are red, green, and blue. Two requirements for the primary colors are that each primary must be different and that the combination of any two primaries must not be capable of producing the third. Red, green, and blue were chosen for the additive primaries because they fulfilled these requirements and because it was determined that the greatest number of colors could be produced by the combination of these three colors.

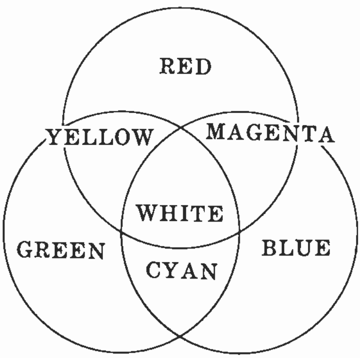


Fig. 74

The three additive primaries used in color television are shown in Fig. 74. From the illustration we can see that by mixing colors in certain proportions, we can obtain the following:

Red + Green = Yellow
Red + Blue = Magenta
Blue + Green = Cyan
Yellow + Blue = White
Cyan + Red = White
Magenta + Green = White
Red + Blue + Green = White
Cyan + Magenta + Yellow = White

It is not necessary to overlap the primary colors in the additive process to produce a different color. They may be placed close to each other, and at a certain viewing distance the two colors will blend and produce the new color.

To be compatible, the composite color signal must contain a complete black-and-white signal to which an additional signal is added to convey the color information. The black-and-white signal (also called the luminance signal) carries all the information pertaining to the brightness of the scene being televised, by means of amplitude modulation of the carrier envelope. The other color attributes—hue and saturation—are carried by the color signal.

To keep the color signal from interfering with black-and-white reception of the composite color signal, the color information is included within the 4.25-mc video band by an interleaving process. This process is possible because the energy of the luminance signal concentrates at specific intervals in the frequency spectrum. The spaces between these intervals are relatively void of energy, and the energy of the chrominance signal can be caused to concentrate in these spaces.

The color or chrominance signal is conveyed by means of a subcarrier at 3.579 megacycles. This frequency was chosen so that the interleaving process could be accomplished. This chrominance signal is modulated in both phase and amplitude. A change in the phase of this signal represents a change in the hue of the scene, and a change in amplitude represents a change of color saturation. A color sync signal which keeps the receiver circuits synchronized to the color information is included in the composite signal. This signal is placed on the "back porch" of the horizontal blanking pedestal and is transmitted at a fixed or reference phase. This signal is known as the "color burst" signal.

55. RELAY REWINDING DATA

The following nomograph can be used if it is desired to rewind a relay for operation on a different voltage. To calculate the wire size needed for operation on the desired voltage, first lay a straightedge across the points where the present voltage and the desired voltage appear on the first

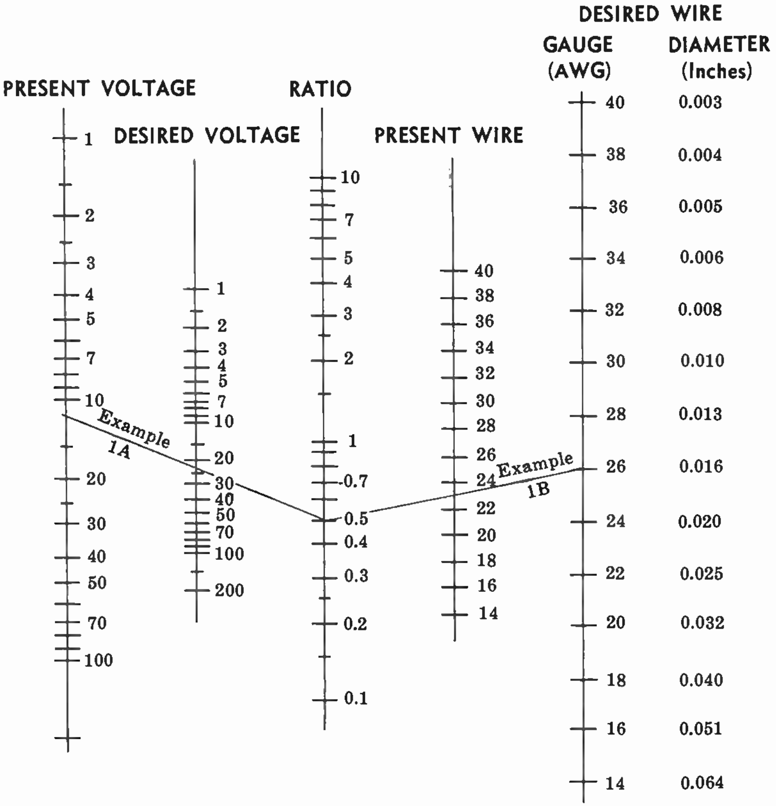


Fig. 75

two columns, and note the point where the straightedge intersects the ratio column. Then lay the straightedge across this point on the ratio column and the present wire gauge column. Read the wire gauge needed for the desired voltage from the fifth column. Directly opposite this point, the wire diameter (in inches) is also given.

Example—What size wire is needed to rewind a relay wound with No. 23 wire and designed for 12-volt operation, for operation on 24 volts?

ANSWER: No. 26 (0.0159 inch diameter). [First lay the straightedge across 12 in the first column and 24 in the second column. Note the point where the straightedge crosses the third column (.5), and lay the straightedge across this point and across 23 on the fourth column. Read the desired size from the fifth and sixth columns.]

56. SPEAKER CONNECTIONS

The following diagrams show the proper connection methods for single- or multiple-speaker operation.

(A) Single Speaker

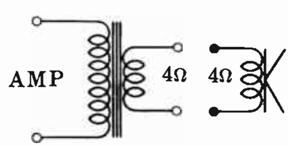


Fig. 76

(B) Two Speakers in Series

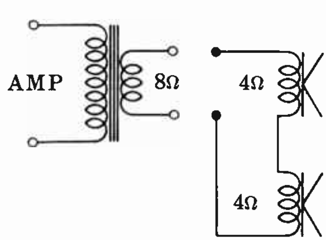


Fig. 77

(C) Speakers in Parallel

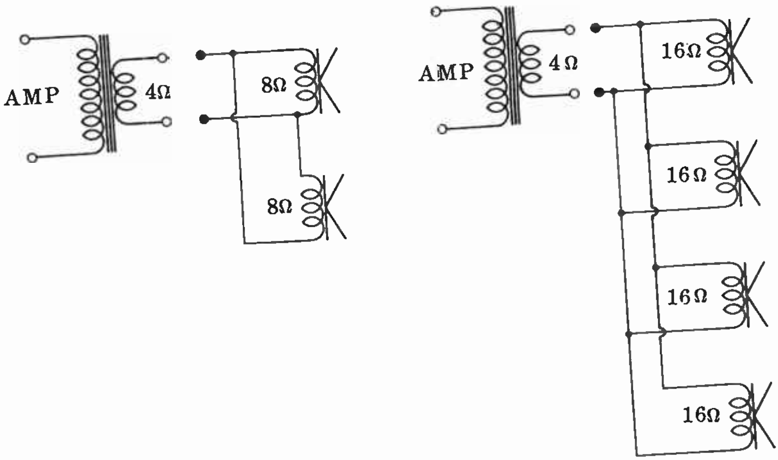


Fig. 78

(D) 70.7-Volt Hook-up Using Matching Transformers

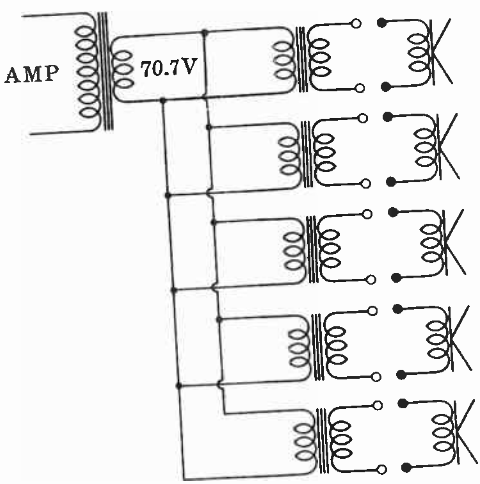


Fig. 79

57. MACHINE SCREW AND DRILL SIZES

The most common screw sizes and threads, together with the tap and clearance drill sizes, are given in Table XXII. The number listed under the "Type" column is actually a combination of the screw size and the number of threads per inch. For example, a No. 6-32 screw denotes a size No. 6 screw with 32 threads per inch.

Table XXII. Machine Screw and Drill Sizes

Type	Tap Drill	Clearance Drill	Type	Tap Drill	Clearance Drill
1-64	53	47	10-24	25	13/64
1-72	53	47	10-32	21	13/64
2-56	50	42	12-24	16	7/32
2-64	50	42	12-28	14	7/32
3-48	47	36	1/4-20	7	17/64
3-56	45	36	1/4-28	3	17/64
4-40	43	31	5/16-18	F	21/64
4-48	42	31	5/16-24	I	21/64
5-40	38	29	3/8-16	5/16	25/64
5-44	37	29	3/8-24	Q	25/64
6-32	36	25	7/16-14	U	29/64
6-40	33	25	7/16-20	25/64	29/64
8-32	29	16	1/2-13	27/64	33/64
8-36	29	16	1/2-20	29/64	33/64

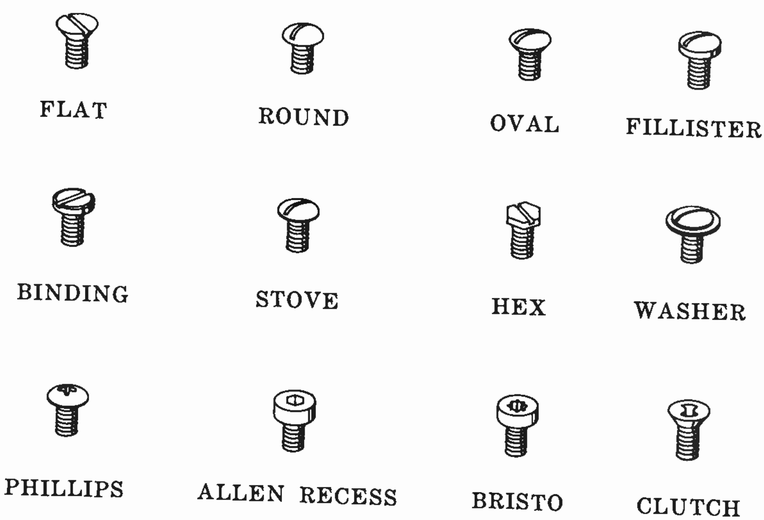


Fig. 80

58. TYPES OF SCREW HEADS

The most common types of screw heads are listed and illustrated in Fig. 80 on the preceeding page.

59. RESISTANCE OF METALS AND ALLOYS

The resistance for a given length of wire is determined by:

$$R = \frac{KL}{d^2}$$

where,

R is the resistance, in ohms, of the length of wire.
K is the resistance, in ohms per circular mil foot, of the material,
L is the length of the wire in feet,
d is the diameter of the wire in mils.

The resistance, in ohms per circular mil foot, of many of the materials used for conductors or heating elements is given in Table XXIII. The resistance shown is for 20°C (68°F).

Table XXIII. Resistance of Metals and Alloys

Material	Symbol	Resistance (ohms per cir. mil foot)
Nichrome	Ni-Fe-Cr	675
Nichrome V	Ni-Cr	650
Manganese Nickel	Ni-Mu	85
Pure Nickel	Ni	60
High Brass	Cu-Zn	50
Commercial Bronze	Cu-Zn	25
Platinum	Pt	63.8
Iron	Fe	60.14
Zinc	Zn	35.58
Molybdenum	Mo	34.27
Tungsten	W	33.22
Aluminum	Al	16.06
Gold	Au	14.55
Copper	Cu	10.37
Silver	Ag	9.796

60. COPPER WIRE TABLE

Copper wire sizes ranging from American wire gauge (B & S) 0000 to 40 are listed in Table XXIV (pages 112 and 113). The turns per linear inch, diameter, area in circular mils, current-carrying capacity, feet per pound, and resistance per 1000 feet are included in the table.

Table XXIV. Copper Wire Table

AWG B & S Gauge	Turns Per Linear Inch				Diameter (Inches)	Circular Mils	Current Carrying Capacity @700 CM Per Amp	Feet Per Lb. (Bare)	Ohms Per 1,000 Ft. @ 20°C
	Enamel	D.C.C.	S.C.C.	Nylon					
0000	—	—	—	—	.4600	211,600	302.3	1.561	0.04901
000	—	—	—	—	.4096	167,800	239.7	1.968	0.06180
00	—	—	—	—	.3648	133,100	190.1	2.482	0.07793
0	—	—	—	—	.3249	105,500	150.7	3.130	0.09827
1	—	3.3	3.3	—	.2893	83,690	119.6	3.947	0.1239
2	—	3.6	3.8	—	.2576	66,370	94.8	4.977	0.1563
3	—	4.0	4.2	—	.2294	52,640	75.2	6.276	0.1970
4	—	4.5	4.7	—	.2043	41,740	59.6	7.914	0.2485
5	—	5.0	5.2	—	.1819	33,100	47.3	9.980	0.3133
6	—	5.6	5.9	—	.1620	26,250	37.5	12.58	0.3951
7	—	6.2	6.5	—	.1443	20,820	29.7	15.87	0.4982
8	7.6	7.1	7.4	—	.1285	16,510	23.6	20.01	0.6282
9	8.6	7.8	8.2	—	.1144	13,090	18.7	25.23	0.7921
10	9.6	8.9	9.3	—	.1019	10,380	14.8	31.82	0.9989
11	10.7	9.8	10.3	—	.09074	8,234	11.8	40.12	1.260
12	12.0	10.9	11.5	—	.08081	6,530	9.33	50.59	1.588
13	13.5	12.0	12.8	—	.07196	5,178	7.40	63.80	2.003
14	15.0	13.8	14.2	14.9	.06408	4,107	5.87	80.44	2.525
15	16.8	14.7	15.8	—	.05707	3,257	4.65	101.4	3.184

16	18.9	16.4	17.9	18.6	.05082	2,583	3.69	127.9	4.016
17	21.2	18.1	19.9	—	.04526	2,048	2.93	161.3	5.064
18	23.6	19.8	22.0	23.2	.04030	1,624	2.32	203.4	6.385
19	26.4	21.8	24.4	—	.03589	1,288	1.84	256.5	8.051
20	29.4	23.8	27.0	28.9	.03196	1,022	1.46	323.4	10.15
21	33.1	26.0	29.8	—	.02846	810.1	1.16	407.8	12.80
22	37.0	30.0	34.1	36.0	.02535	642.4	.918	514.2	16.14
23	41.3	31.6	37.6	—	.02257	509.5	.728	648.4	20.36
24	46.3	35.6	41.5	44.7	.02010	404.0	.577	817.7	25.67
25	51.7	38.6	45.6	—	.01790	320.4	.458	1,031	32.37
26	58.0	41.8	50.2	55.7	.01594	254.1	.363	1,300	40.81
27	64.9	45.0	55.0	—	.01420	201.5	.288	1,639	51.47
28	72.7	48.5	60.2	69.4	.01264	159.8	.228	2,067	64.90
29	81.6	51.8	65.4	—	.01126	126.7	.181	2,607	81.83
30	90.5	55.5	71.5	86.2	.01003	100.5	.144	3,287	103.2
31	101.0	59.2	77.5	—	.008928	79.70	.114	4,145	130.1
32	113.0	62.6	83.6	106.0	.007950	63.21	.090	5,227	164.1
33	127.0	66.3	90.3	—	.007080	50.13	.072	6,591	206.9
34	143.0	70.0	97.0	133.0	.006305	39.75	.057	8,310	260.9
35	158.0	73.5	104.0	—	.005615	31.52	.045	10,480	329.0
36	175.0	77.0	111.0	167.0	.005000	25.00	.036	13,210	414.8
37	198.0	80.3	118.0	—	.004453	19.83	.028	16,660	523.1
38	224.0	83.6	126.0	206.0	.003965	15.72	.022	21,010	659.6
39	248.0	86.6	133.0	—	.003531	12.47	.018	26,500	831.8
40	282.0	89.7	140.0	263.0	.003145	9.89	.014	33,410	1,049.0

Design Data

61. VACUUM-TUBE FORMULAS

The following formulas can be used to calculate the vacuum-tube properties listed.

Amplification factor:

$$\mu = \frac{\Delta E_p}{\Delta E_g} \text{ (with } I_p \text{ constant)}$$

AC (dynamic) plate resistance:

$$r_p = \frac{\Delta E_p}{\Delta I_p} \text{ (with } E_g \text{ constant)}$$

Mutual conductance (transconductance):

$$g_m = \frac{\Delta I_p}{\Delta E_g} \text{ (with } E_p \text{ constant)}$$

Gain of an amplifier stage:

$$\text{Gain} = \mu \frac{R_L}{R_L + r_p}$$

where,

μ is the amplification factor,
Δ is the variation or change in value,
E_p is the plate voltage in volts,
E_g is the grid voltage in volts,
I_p is the plate current in amperes,
R_L is the plate-load resistance in ohms,
r_p is the AC plate resistance in ohms,
g_m is the mutual conductance in mhos.

62. TRANSISTOR FORMULAS

The following formulas can be used to calculate the transistor properties listed.

Input Resistance:

$$R_i = \frac{\Delta V_i}{\Delta I_i}$$

Current Gain:

$$A_i = \frac{\Delta I_c}{\Delta I_b} \text{ (with } V_c \text{ constant)}$$

Voltage Gain:

$$A_v = \frac{\Delta V_c}{\Delta V_b} \text{ (with } I_c \text{ constant)}$$

Output Resistance:

$$R_o = \frac{\Delta V_o}{\Delta I_o}$$

Power Gain:

$$A_p = \frac{\Delta P_o}{\Delta P_i}$$

The current gain of the common-base configuration is *alpha:*

$$\alpha = \frac{\Delta I_c}{\Delta I_e} \text{ (with } V_c \text{ constant)}$$

The current gain of the common emitter is *beta:*

$$\beta = \frac{\Delta I_c}{\Delta I_b} \text{ (with } V_c \text{ constant)}$$

A direct relationship exists between the *alpha* and *beta* of a transistor:

$$\alpha = \frac{\beta}{1 + \beta} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

where,

α is the current gain of a common-base configuration,
A_v is the voltage gain,
A_i is the current gain,
A_p is the power gain,
β is the current gain in a common-emitter configuration,
I_b is the base current,
I_c is the collector current,

I_e is the emitter current,
I_i is the input current,
I_o is the output current,
P_i is the input power,
P_o is the output power,
R_i is the input resistance,
R_o is the output resistance,
V_b is the base voltage,
V_c is the collector voltage,
V_i is the input voltage,
V_o is the output voltage.

63. THREE-PHASE POWER FORMULAS

In a three-phase system, there are three voltages, each separated by a phase difference of 120°: The power-supply input transformers may be connected in either a delta or a Y (star). Fig. 81 shows how the terminals are placed in relationship to the coils. In the delta connection, there is one coil between each pair of terminals; and in the Y connection, there are two. The voltage between two terminals of the Y-connected coil is equal to $\sqrt{3}$ times the voltage across one winding.

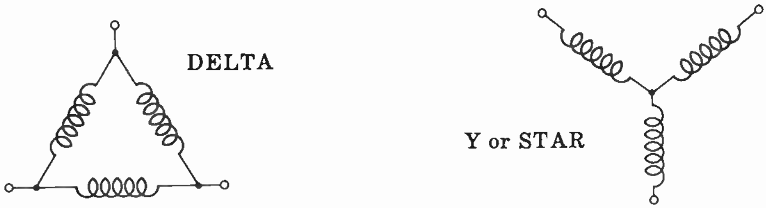


Fig. 81

The formulas for determining the voltage across the secondary winding for each of the four possible connections are as follows:

Δ to Y:

$$E_s = E_p \times N \times \sqrt{3}$$

Y to Δ:

$$E_s = \frac{E_p \times N}{\sqrt{3}}$$

Δ to Δ:

$$E_s = E_p \times N$$

Y to Y:

$$E_s = E_p \times N$$

where,
E_s is the secondary voltage,
E_p is the primary voltage,
N is the turns ratio.

64. COIL WINDINGS

(A) Single-Layer Coils

The inductance of single-layer coils can be calculated to an accuracy of approximately 1% with the formula:

$$L = \frac{(N \times A)^2}{9A + 10B}$$

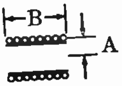


Fig. 82

To find the number of turns required for a single-layer coil with a given inductance, the foregoing formula is rearranged as follows:

$$N = \frac{\sqrt{L(9A + 10B)}}{A}$$

where,
L is the inductance in microhenries,
N is the number of turns,
A is the mean radius in inches,
B is the length of the coil in inches.

(B) Multilayer Coils

The inductance of a multilayer coil of rectangular cross section can be computed from the formula:

$$L = \frac{0.8(N \times A)^2}{6A + 9B + 10C}$$

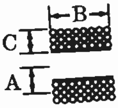


Fig. 83

where,

L is the inductance in microhenries,
N is the number of turns,
A is the mean radius in inches,
B is the length of the coil in inches,
C is the depth of the coil in inches.

(C) Single-Layer Coil Chart

The chart on the following page provides an easy method for determining either the inductance or the number of turns for single-layer coils. When the length of the winding, the diameter, and the number of turns of the coil are known, the inductance can be found by placing a straightedge from the "Turns" scale to the "Ratio" (diameter ÷ length) scale and noting the point where the straightedge intersects the "Axis" scale. Then lay the straightedge from the point of intersection of the "Axis" scale to the "Diameter" scale. The point at which this line intersects the "Inductance" scale indicates the inductance (in microhenries) of the coil. The number of turns can be determined by reversing the procedure.

After finding the number of turns, consult the wire table in § 60 to determine the size of wire to be used.

Example—What is the inductance of a single-layer coil having 80 turns wound to 4 inches in length on a coil form 2 inches in diameter?

ANSWER: 130 microhenries. (First lay the straightedge as indicated by the line labeled "Example 1A." Then lay the straightedge as indicated by the line labeled "Example 1B.")

65. FILTER FORMULAS

(A) Constant-k Filters

A constant-k filter presents an impedance match to the line at only one frequency, and a mismatch at all others. The three basic configurations are the T, L (half-section), and pi.

A constant-k low-pass filter will pass frequencies below and attenuate those above a set frequency. Fig. 85 gives the circuit configurations, attenuation characteristics, and impedance characteristics of the three types of constant-k low-pass filters.

The attenuation of the L section is equal to half that of the T or pi sections. The impedance of the filter is equal to

Single-Layer Coil Chart

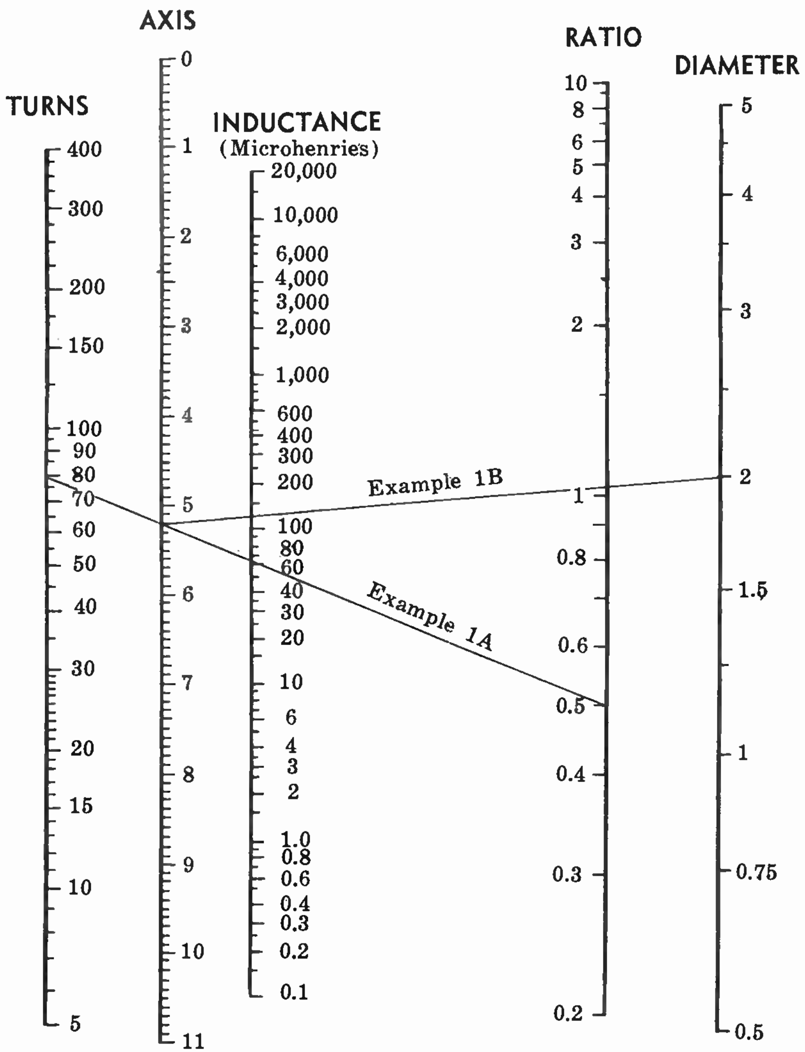


Fig. 84

the characteristic impedance of the line (Z_o) at zero frequency only. For all other frequencies, the input and output impedance of the filter are equal to Z_I or Z_I', as shown in Fig. 85.

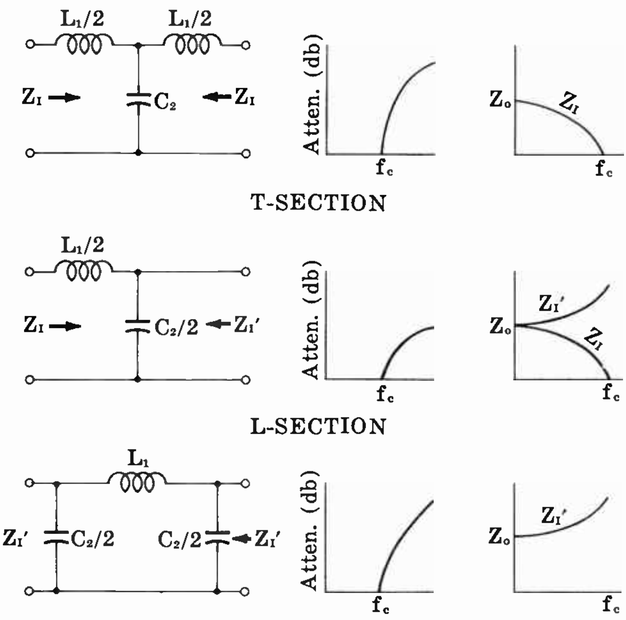


Fig. 85

The values for L_1, C_2, Z_o, and f_c can be computed from the following formulas:

$$L_1 = \frac{Z_o}{\pi f_c}$$

$$C_2 = \frac{1}{\pi f_c Z_o}$$

$$Z_o = \sqrt{\frac{L_1}{C_2}}$$

$$f_c = \frac{1}{\pi\sqrt{L_1 C_2}}$$

The values computed for L_1 and C_2 must be divided in half, where specified in Fig. 85. That is, the coils in the T

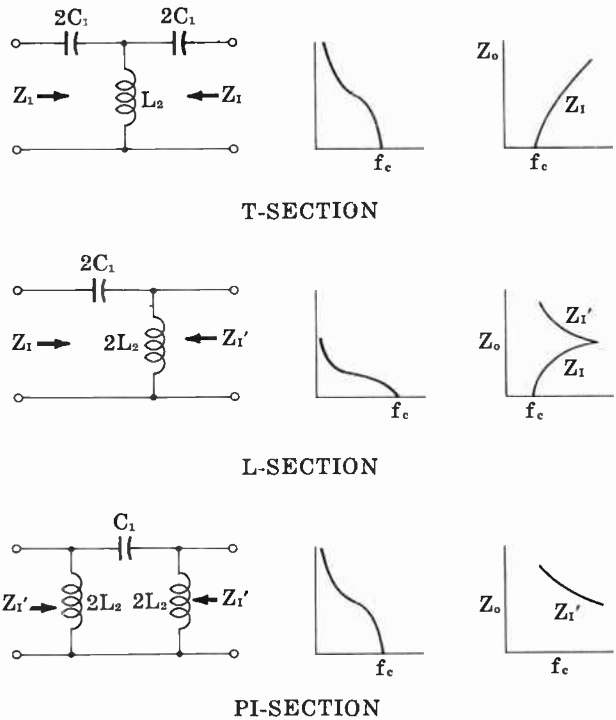


Fig. 86

and L sections, and the capacitors in the L and pi sections, are equal to one-half the computed value.

A high-pass filter will pass all frequencies above and attenuate all those below a set frequency.

The circuit configurations, attenuation characteristics, and impedance characteristics of constant-k high-pass filters are given in Fig. 86. The formulas for computing L_2, C_1, Z_o, and f_c are as follows:

$$L_2 = \frac{Z_o}{4\pi f_c}$$

$$C_1 = \frac{1}{4\pi f_c Z_o}$$

$$Z_o = \sqrt{\frac{L_2}{C_1}}$$

$$f_c = \frac{1}{4\pi\sqrt{L_2 C_1}}$$

Notice that the values computed for C in the foregoing formulas must be doubled in the T and L sections. Likewise, the value computed for L must be doubled in the L and pi sections.

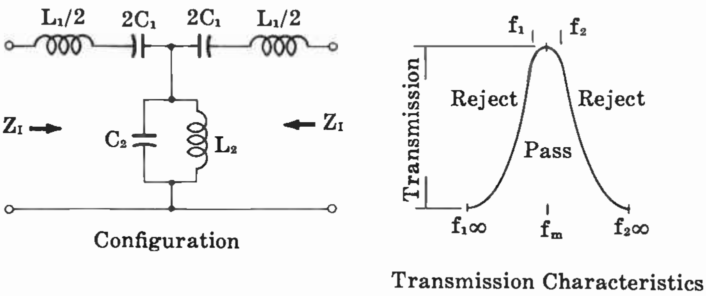


Fig. 87

Bandpass filters will pass frequencies of a certain band and reject all others. The configuration and the transmission characteristics for a constant-k bandpass filter are given in Fig. 87. The formulas for computing the various values are:

$$L_1 = \frac{Z_o}{\pi(f_2 - f_1)}$$

$$L_2 = \frac{(f_2 - f_1) Z_0}{4\pi f_1 f_2}$$

$$C_1 = \frac{(f_2 - f_1)}{4\pi f_1 f_2 Z_o}$$

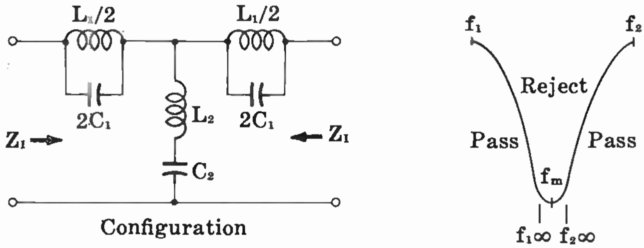
$$C_2 = \frac{1}{\pi(f_2 - f_1) Z_o}$$

$$f_m = \sqrt{f_1 f_2} = \frac{1}{2\pi\sqrt{L_1 C_1}} = \frac{1}{2\pi\sqrt{L_2 C_2}}$$

$$Z_o = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}}$$

As before, some values must be doubled or halved, as shown in Fig. 87.

A band-rejection filter will reject a certain band of frequencies and pass all others. The configuration and the transmission characteristics of a constant-k band-rejection filter



Configuration

Transmission Characteristics

Fig. 88

are given in Fig. 88. The formulas for computing the component values, frequencies, and line impedance are:

$$L_1 = \frac{(f_2 - f_1)\, Z_o}{\pi f_1 f_2}$$

$$L_2 = \frac{Z_o}{4\pi (f_2 - f_1)}$$

$$C_1 = \frac{1}{4\pi\ (f_2 - f_1)\ Z_o}$$

$$C_2 = \frac{(f_2 - f_1)}{\pi\, f_1\, f_2\, Z_o}$$

$$f_m = \sqrt{f_1\, f_2} = \frac{1}{2\pi\sqrt{L_1C_1}} = \frac{1}{2\pi\sqrt{L_2C_2}}$$

$$Z_o = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}}$$

where,

L_1 and L_2 are the inductances of the coils in henries,
C_1 and C_2 are the capacitances of the capacitors in farads,
f_1 and f_2 are the frequencies at the edge of the passband, in cycles per second,
f_m is the frequency at the center of the passband, in cycles per second,
$f_{1\infty}$ and $f_{2\infty}$ are the frequencies of infinite attenuation, in cycles per second,
Z_o is the line impedance in ohms.

(B) M-Derived Filters

In an *m*-derived filter, the designer can control either the impedance or the attenuation characteristics. The values are first computed as for a constant-k filter and then modified by an algebraic expression containing the constant *m*. The

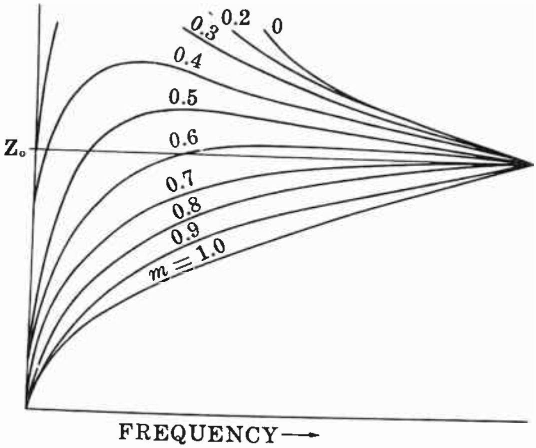


Fig. 89

term m will be a positive number between zero and one, and its value governs the characteristics of the filter.

Two frequencies—the cutoff and the frequency of infinite attenuation—are involved in the design of m-derived filters. By selecting the proper value for m, it is possible to control the spacing between the two frequencies. Fig. 89 shows the effect which different values of m have on the impedance

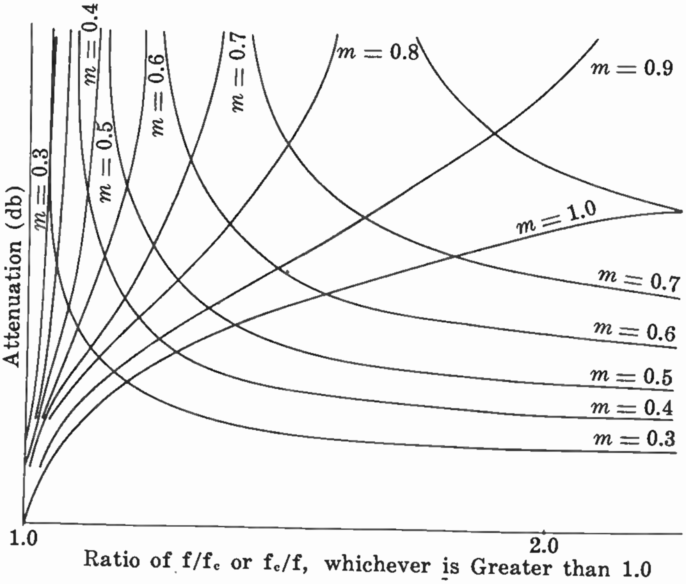


Fig. 90

characteristics. Note that the best impedance match is obtained when m is equal to 0.6; hence this value is usually employed.

The attenuation characteristics for the various values of m are given in Fig. 90. The attenuation rises to maximum and then drops on all curves. This graph applies to both low- and high-pass filters.

The value of m is determined from the formulas:

$$m = \sqrt{1-\left(\frac{f_c}{f_\infty}\right)^2}$$

or,

$$m = \sqrt{1-\left(\frac{f_\infty}{f_c}\right)^2}$$

Select the formula which will give a positive number.

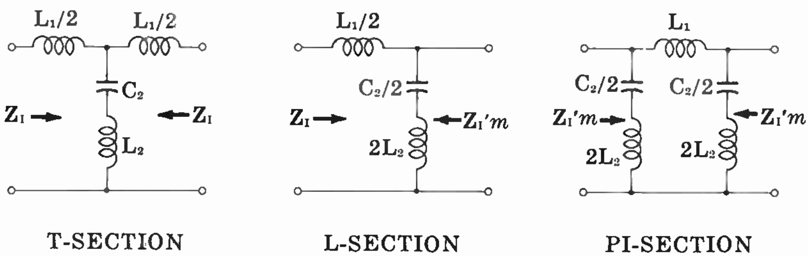


Fig. 91

The configurations for m-derived filters are classified as either series or shunt. Those for the series m-derived low-pass filters are given in Fig. 91. The formulas are as follows:

$$L_1 = m\left(\frac{Z_0}{2\pi f_c}\right)$$

$$L_2 = \left(\frac{1-m^2}{4m}\right)\left(\frac{Z_0}{2\pi f_c}\right)$$

$$C_2 = m\left(\frac{1}{\pi f_c Z_0}\right)$$

For a series m-derived high-pass filter (Fig. 92), the formulas are:

$$L_2 = \frac{\left(\frac{Z_0}{4\pi f_c}\right)}{m}$$

$$C_1 = \frac{\left(\frac{1}{4\pi f_c Z_o}\right)}{m}.$$

$$C_2 = \left(\frac{4m}{1 - m^2}\right)\left(\frac{1}{4\pi f_c Z_o}\right)$$

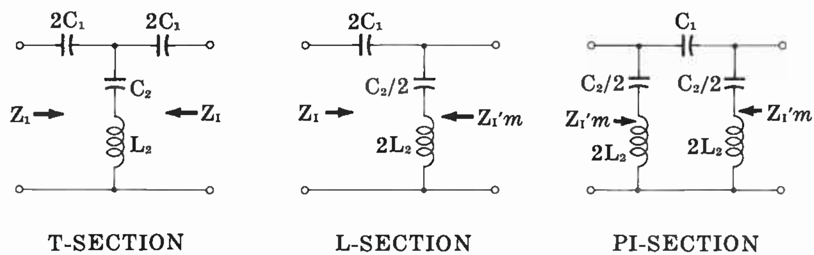


Fig. 92

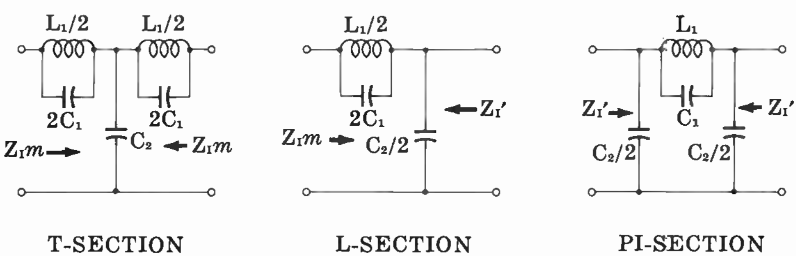


Fig. 93

The configurations for shunt m-derived low-pass filters are given in Fig. 93. The formulas for computing the component values are:

$$L_1 = m\left(\frac{Z_o}{\pi f_c}\right)$$

$$C_1 = \left(\frac{1 - m^2}{4m}\right)\left(\frac{1}{\pi f_c Z_o}\right)$$

$$C_2 = m\left(\frac{1}{\pi f_c Z_o}\right)$$

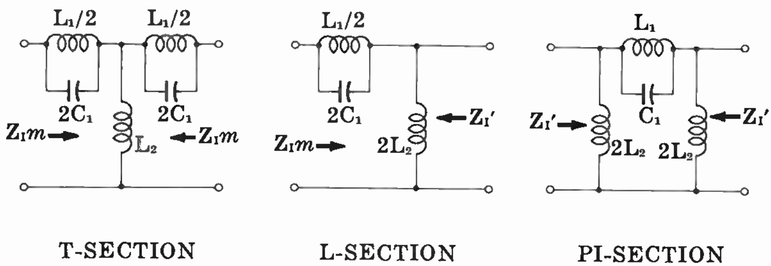


Fig. 94

For shunt *m*-derived high-pass filters (Fig. 94), the formulas are:

$$L_1 = \left(\frac{4m}{1 - m^2}\right)\left(\frac{Z_o}{4\pi f_c}\right)$$

$$L_2 = \frac{\left(\frac{Z_o}{4\pi f_c}\right)}{m}$$

$$C_1 = \frac{\left(\frac{1}{4\pi f_c Z_o}\right)}{m}$$

where,

L_1 and L_2 are the inductances of the coils in henries,
C_1 and C_2 are the capacitances of the capacitors in farads,
m is a constant between 0 and 1,
Z_o is the line impedance in ohms,
f_c is the cutoff frequency in cycles per second.

66. ATTENUATOR FORMULAS

(A) General

An attenuator is an arrangement of noninductive resistors used in an electrical circuit to reduce the audio- or radio-signal strength without introducing distortion. The resistors may be fixed or variable. Attenuators can be designed to work between equal or unequal impedances; hence, they are often used as impedance-matching networks.

Any attenuator working between unequal impedances must introduce a certain minimum loss. These values are given in the graph of Fig. 95. The impedance ratio is the input impedance divided by the output impedance, or vice versa—whichever gives a value of more than one.

A factor is used in the calculation of resistor values in attenuator networks. Called K, it is the ratio of current, voltage, or power corresponding to a given value of attenuation in decibels. Table XXV gives the value of "K" for the more common loss values.

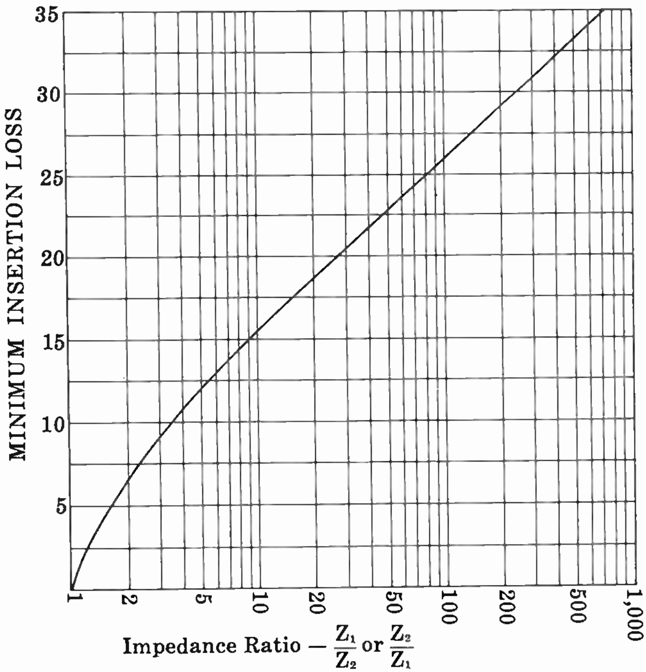


Fig. 95

The four steps in the design of a pad are: (1) Determine the type of network required. (2) If impedances are unequal, calculate the ratio of input to output impedance (or output to input impedance) and refer to Fig. 95 for the minimum loss value. (3) From Table XXV find the value of K for the desired loss. (4) Calculate the resistor values, using the following formulas.

Table XXV. K Factors for Calculating Attenuator Loss

db	K	db	K	db	K	db	K
.05	1.0058	9.5	2.9854	29.0	28.184	49.0	281.84
.1	1.0116	10.0	3.1623	30.0	31.623	50.0	316.23
.5	1.0593	11.0	3.5481	31.0	35.481	51.0	354.81
1.0	1.1220	12.0	3.9811	32.0	39.811	52.0	398.11
1.5	1.1885	13.0	4.4668	33.0	44.668	54.0	501.19
2.0	1.2589	14.0	5.0119	34.0	50.119	55.0	562.34
2.5	1.3335	15.0	5.6234	35.0	56.234	56.0	630.96
3.0	1.4125	16.0	6.3096	36.0	63.096	57.0	707.95
3.5	1.4962	17.0	7.0795	37.0	70.795	58.0	794.33
4.0	1.5849	18.0	7.9433	38.0	79.433	60.0	1000.0
4.5	1.6788	19.0	8.9125	39.0	89.125	65.0	1778.3
5.0	1.7783	20.0	10.0000	40.0	100.000	70.0	3162.3
5.5	1.8837	21.0	11.2202	41.0	112.202	75.0	5623.4
6.0	1.9953	22.0	12.589	42.0	125.89	80.0	10,000
6.5	2.1135	23.0	14.125	43.0	141.25	85.0	17,783
7.0	2.2387	24.0	15.849	44.0	158.49	90.0	31,623
7.5	2.3714	25.0	17.783	45.0	177.83	95.0	56,234
8.0	2.5119	26.0	19.953	46.0	199.53	100.0	10^5
8.5	2.6607	27.0	22.387	47.0	223.87		
9.0	2.8184	28.0	25.119	48.0	251.19		

(B) Combining or Dividing Network

$$R_B = \left(\frac{N-1}{N+1}\right) Z$$

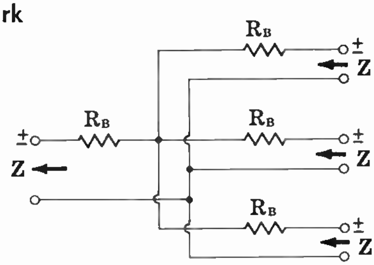


Fig. 96

where,

R_B is the resistance of the building-out resistors in ohms,
N is the number of circuits fed by the source impedance,
Z is the source impedance in ohms.

(C) T-Type Attenuator (Between Equal Impedances)

$$R_1 \text{ and } R_2 = \left(\frac{K-1}{K+1}\right) Z$$

$$R_3 = \left(\frac{K}{K^2-1}\right) 2Z$$

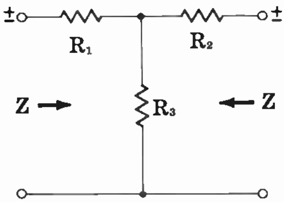


Fig. 97

(D) H-Type Attenuator (Balanced-T Attenuator)

Calculate the values for R_1, R_2, and R_3 as for an unbalanced T-attenuator (Fig. 97). Then halve the values of R_1 and R_2, as shown in Fig. 98. The tap on R_3 is exactly in the center.

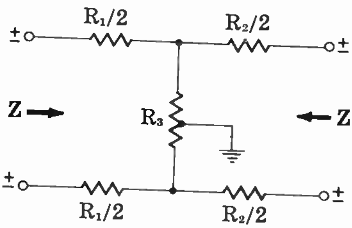


Fig. 98

(E) Taper Pad (T-Type Attenuator Between Unequal Impedances)

$$R_1 = Z_1\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{Z_1Z_2}\left(\frac{K}{K^2-1}\right)$$

$$R_2 = Z_2\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{Z_1Z_2}\left(\frac{K}{K^2-1}\right)$$

$$R_3 = 2\sqrt{Z_1Z_2}\left(\frac{K}{K^2-1}\right)$$

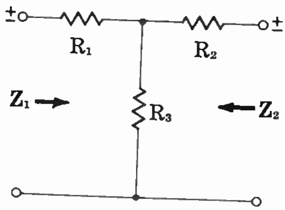


Fig. 99

where,

Z_1 is the larger impedance.

(F) Bridged-T Attenuator (Unbalanced)

$$R_1 = Z$$

$$R_5 = (K-1)Z$$

$$R_6 = \left(\frac{1}{K-1}\right)Z$$

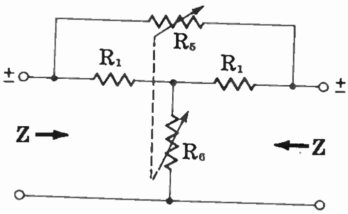


Fig. 100

R_5 and R_6 are connected to a common shaft, and each varies inversely in value with respect to the other.

(G) Balanced Bridged-T Attenuator

Calculate the values for R_1, R_5, and R_6 as for an unbalanced bridged-T attenuator (Fig. 100). Then halve the values as shown in Fig. 101.

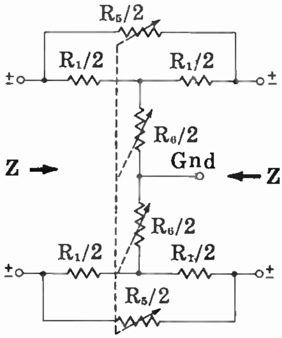


Fig. 101

(H) L-Type Attenuators

An L-type attenuator can supply an impedance match in only one direction. If the impedances it works out of and into are unequal, it can be made to match either—but not both—impedances. The arrows in the following illustrations indicate the direction of impedance match.

Between equal impedances and with the impedance match in the direction of the series arm:

$$R_1 = Z\left(\frac{K-1}{K}\right)$$

$$R_2 = Z\left(\frac{1}{K-1}\right)$$

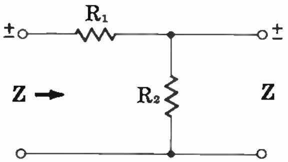


Fig. 102

Between equal impedances and with the impedance match in the direction of the shunt arm:

$$R_1 = Z\ (K-1)$$

$$R_2 = Z\left(\frac{K}{K-1}\right)$$

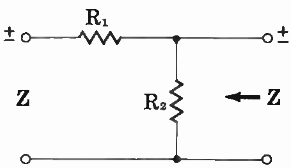


Fig. 103

Between unequal impedances and with the impedance match toward the larger value:

$$R_1 = \left(\frac{Z_1}{S}\right)\left(\frac{KS - 1}{K}\right)$$

$$R_2 = \left(\frac{Z_1}{S}\right)\left(\frac{1}{K - S}\right)$$

where,

$$S = \sqrt{\frac{Z_1}{Z_2}}$$

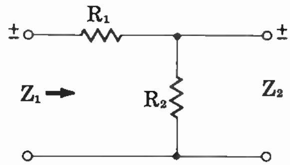


Fig. 104

Between unequal impedances and with the impedance match toward the smaller value:

$$R_1 = \left(\frac{Z_1}{S}\right)(K - S)$$

$$R_2 = \left(\frac{Z_1}{S}\right)\left(\frac{K}{KS - 1}\right)$$

where,

S equals $\sqrt{\frac{Z_1}{Z_2}}$

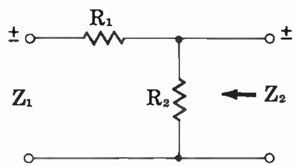


Fig. 105

(I) Pi-Type Attenuator (Between Equal Impedances)

$$R_1 = Z\left(\frac{K + 1}{K - 1}\right)$$

$$R_2 = \left(\frac{Z}{2}\right)\left(\frac{K^2 - 1}{K}\right)$$

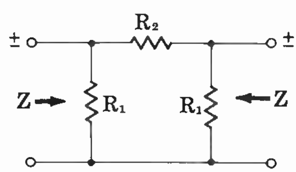


Fig. 106

(J) Pi-Type Attenuator (Between Unequal Impedances)

$$R_1 = Z_1\left(\frac{K^2 - 1}{K^2 - 2KS + 1}\right)$$

$$R_2 = \left(\frac{\sqrt{Z_1 Z_2}}{2}\right)\left(\frac{K^2 - 1}{K}\right)$$

$$R_3 = Z_2\left(\frac{K^2 - 1}{K_2 - 2\frac{K}{S} + 1}\right)$$

where,

S equals $\sqrt{\frac{Z_1}{Z_2}}$

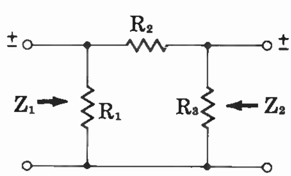


Fig. 107

(K) O-Type Attenuators

Calculate the values for a pi-type attenuator (Figs. 106 and 107), then halve the values for the series resistors as shown in Figs. 108 (balanced) and 109 (unbalanced).

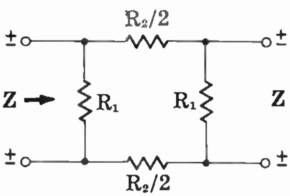


Fig. 108

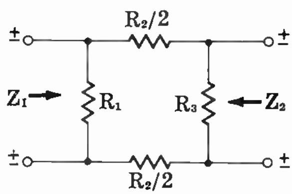


Fig. 109

(L) U-Type Attenuator

For impedance match in the direction of the series arms:

$$R_1 = \left(\frac{Z_1}{2S}\right)\left(\frac{KS-1}{K}\right)$$

$$R_2 = \left(\frac{Z_1}{S}\right)\left(\frac{1}{K-S}\right)$$

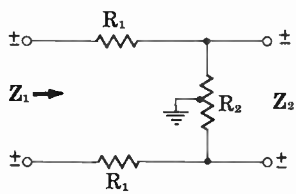


Fig. 110

For impedance match in the direction of the shunt arm:

$$R_1 = \left(\frac{Z_1}{2S}\right)(K-S)$$

$$R_2 = \left(\frac{Z_1}{S}\right)\left(\frac{K}{KS-1}\right)$$

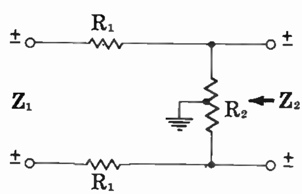


Fig. 111

where,

The arrows indicate the direction of the impedance match,

S equals $\sqrt{\frac{Z_1}{Z_2}}$

(M) Lattice-Type Attenuator

$$R_1 = \left(\frac{K-1}{K+1}\right) Z$$

$$R_2 = \left(\frac{K+1}{K-1}\right) Z$$

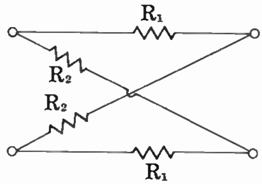


Fig. 112

(N) Ladder-Type Attenuator

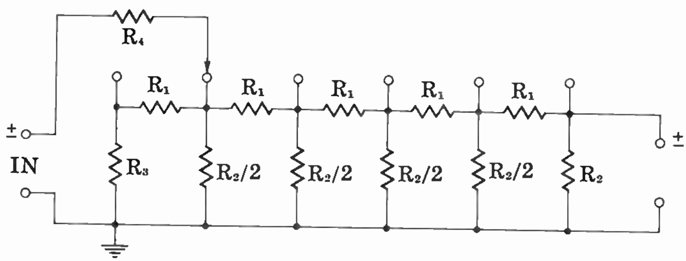


Fig. 113

$$R_1 = \left(\frac{K^2-1}{2K}\right) Z$$

$$R_2 = \left(\frac{K+1}{K-1}\right) Z$$

$$R_3 = \frac{R_2 \times Z}{R_2 + Z}$$

$$R_4 = \frac{Z}{2}$$

$$Z_{in} = Z_{out}$$

where,

K depends on the loss per step—not on the total loss.

Mathematical Tables and Formulas

67. MATHEMATICAL CONSTANTS

$\pi =$	3.1416	$(2\pi)^2 =$	39.4786
$\pi^2 =$	9.8696	$4\pi =$	12.5664
$\pi^3 =$	31.0063	$\frac{\pi}{2} =$	1.5708
$\frac{1}{\pi} =$	0.3183	$\frac{\sqrt{\pi}}{2} =$	1.2533
$\frac{1}{\pi^2} =$	0.1013	$\sqrt{2} =$	1.4142
$\frac{1}{\pi^3} =$	0.0323	$\sqrt{3} =$	1.7321
$\sqrt{\pi} =$	1.7725	$\frac{1}{\sqrt{2}} =$	0.7071
$\frac{1}{\sqrt{\pi}} =$	0.5642	$\frac{1}{\sqrt{3}} =$	0.5773
$\frac{1}{2\pi} =$	0.1592	$\log \pi =$	0.4971
		$\log \pi^2 =$	0.9943
$\left(\frac{1}{2\pi}\right)^2 =$	0.0253	$\log \sqrt{\pi} =$	0.2486
$2\pi =$	6.2832	$\log \frac{\pi}{2} =$	0.1961

68. MATHEMATICAL SYMBOLS

$\times$ or $\cdot$	Multiplied by.	$+$	Positive, add, and plus.
$\div$	Divided by.	$-$	Negative, subtract, and minus.
$=$	Equals.		
$\neq$	Does not equal.	$>$	Is greater than.

$<$	Is less than.
$\pm$	Plus or minus.
$\equiv$	Identical with.
$\therefore$	Therefore.
$\parallel$	Parallel to.
$\angle$	Angle.
$\ll$	Is much less than.
$\gg$	Is much greater than.
$\geqq$	Equal to or greater than.
$\leqq$	Equal to or less than.
$\perp$	Perpendicular to.
$\lvert n \rvert$	Absolute value of *n*.
$\cong$	Is approximately equal to.
$\sqrt{\ }$	Square root.

69. DECIMAL EQUIVALENTS OF FRACTIONS

The decimal equivalents to four places of fractions by 64ths are given in Table XXVI.

Table XXVI. Decimal Equivalents of Fractions

Fraction				Decimal	Fraction				Decimal
1/64				0.0156	33/64				0.5156
	1/32			0.0313		17/32			0.5313
3/64				0.0469	35/64				0.5469
		1/16		0.0625			9/16		0.5625
5/64				0.0781	37/64				0.5781
	3/32			0.0938		19/32			0.5938
7/64				0.1094	39/64				0.6094
			1/8	0.1250				5/8	0.6250
9/64				0.1406	41/64				0.6406
	5/32			0.1563		21/32			0.6563
11/64				0.1719	43/64				0.6719
		3/16		0.1875			11/16		0.6875
13/64				0.2031	45/64				0.7031
	7/32			0.2188		23/32			0.7188
15/64				0.2344	47/64				0.7344
			1/4	0.2500				3/4	0.7500
17/64				0.2656	49/64				0.7656
	9/32			0.2813		25/32			0.7813
19/64				0.2969	51/64				0.7969
		5/16		0.3125			13/16		0.8125
21/64				0.3281	53/64				0.8281
	11/32			0.3438		27/32			0.8438
23/64				0.3594	55/64				0.8594
			3/8	0.3750				7/8	0.8750
25/64				0.3906	57/64				0.8906
	13/32			0.4063		29/32			0.9063
27/64				0.4219	59/64				0.9219
		7/16		0.4375			15/16		0.9375
29/64				0.4531	61/64				0.9531
	15/32			0.4688		31/32			0.9688
31/64				0.4844	63/64				0.9844
			1/2	0.5000				1	1.0000

70. POWERS OF TEN

(A) Exponent Determination

Large numbers can be simplified by using powers of ten. For example, some of the multiples of ten from 1 to 1,000,000, with their equivalents in powers of ten are:

$$1 = 10^{0}*$$
$$10 = 10^{1}$$
$$100 = 10^{2}$$
$$1000 = 10^{3}$$
$$10{,}000 = 10^{4}$$
$$100{,}000 = 10^{5}$$
$$1{,}000{,}000 = 10^{6}$$

Likewise, powers of ten can be used to simplify decimal expressions. Some of the submultiples of ten from 0.1 to 0.000001, with their equivalents in powers of ten are:

$$0.1 = 10^{-1}$$
$$0.01 = 10^{-2}$$
$$0.001 = 10^{-3}$$
$$0.0001 = 10^{-4}$$
$$0.00001 = 10^{-5}$$
$$0.000001 = 10^{-6}$$

Any whole number can be expressed as a smaller whole number, and any decimal can be expressed as a whole number, by moving the decimal point to the left or right and expressing the number as a power of ten. If the decimal point is moved to the left, the power is positive and is equal to the number of places the decimal point was moved. If the decimal point is moved to the right, the power is negative and is equal to the number of places the decimal point was moved.

For example:

$$123 = 1.23 \times 10^{2}$$
$$456.7 = 4.567 \times 10^{2}$$
$$78{,}900 = 78.9 \times 10^{3}$$
$$0.00012 = 1.2 \times 10^{-4}$$
$$0.0345 = 34.5 \times 10^{-3}$$
$$.678 = 67.8 \times 10^{-2}$$

* Any number to the zero power is 1.

(B) Addition and Subtraction

To add or subtract using powers of ten, first convert all numbers to the same power of ten. The numbers can then be added or subtracted, and the answer will be in the same power of ten. For example:

$$9.32 \times 10^2 + 17.63 \times 10^3 + 297 = ?$$

$$\begin{aligned} 9.32 \times 10^2 &= 0.932 \times 10^3 \\ 17.63 \times 10^3 &= 17.630 \times 10^3 \\ 297 &= 0.297 \times 10^3 \\ \hline & 18.859 \times 10^3 = 18{,}859 \end{aligned}$$

$$18.47 \times 10^2 - 1.59 \times 10^3 = ?$$

$$\begin{aligned} 18.47 \times 10^2 &= 1.847 \times 10^3 \\ 1.59 \times 10^3 &= 1.590 \times 10^3 \\ \hline & .257 \times 10^3 = 257 \end{aligned}$$

(C) Multiplication

To multiply using powers of ten, add the exponents. Thus:

$$\begin{aligned} 1000 \times 3721 &= 10^3 \times 37.21 \times 10^2 \\ &= 37.21 \times 10^{3+2} \\ &= 37.21 \times 10^5 \\ &= 3{,}721{,}000 \end{aligned}$$

$$\begin{aligned} 225 \times .00723 &= 2.25 \times 10^2 \times 7.23 \times 10^{-3} \\ &= 2.25 \times 7.23 \times 10^{2+(-3)} \\ &= 2.25 \times 7.23 \times 10^{-1} \\ &= 16.2675 \times 10^{-1} \\ &= 1.62675 \end{aligned}$$

(D) Division

To divide using powers of ten, subtract the exponent of the denominator from the exponent of the numerator. Thus:

$$\begin{aligned} \frac{10^5}{10^3} &= 10^{5-3} \\ &= 10^2 \\ &= 100 \end{aligned}$$

$$\frac{72{,}600}{.002} = \frac{72.6 \times 10^3}{2 \times 10^{-3}}$$
$$= \frac{72.6 \times 10^{3+3}}{2}$$
$$= 36.3 \times 10^6$$
$$= 36{,}300{,}000.$$

(E) Combination Multiplication and Division

Problems involving a combination of multiplication and division can be solved using powers of ten by multiplying and dividing, as called for, until the problem is completed. For example:

$$\frac{3900 \times .007 \times 420}{142{,}000 \times .00005} = \frac{3.9 \times 10^3 \times 7 \times 10^{-3} \times 4.2 \times 10^2}{1.42 \times 10^5 \times 5 \times 10^{-5}}$$
$$= \frac{3.9 \times 7 \times 4.2 \times 10^2}{1.42 \times 5}$$
$$= \frac{114.66 \times 10^2}{7.1}$$
$$= 16.1493 \times 10^2$$
$$= 1614.93$$

(F) Reciprocal

To take the reciprocal of a number using powers of ten, first (if necessary) state the number so the decimal point precedes the first significant figure of the number. Then divide this number into 1. The power of 10 in the answer will be the same value as in the original number, but will have the opposite sign. For example:

$$\text{Reciprocal of } 400 = \frac{1}{400}$$
$$\frac{1}{400} = \frac{1}{.4 \times 10^3}$$
$$= 2.5 \times 10^{-3}$$
$$= .0025$$

$$\text{Reciprocal of } .0025 = \frac{1}{.0025}$$
$$\frac{1}{.0025} = \frac{1}{.25 \times 10^{-2}}$$
$$= 4 \times 10^2$$
$$= 400$$

(G) Square and Square Root

To square a number using powers of ten, multiply the number by itself, and double the exponent. Thus:

$$(7 \times 10^3)^2 = 49 \times 10^6$$
$$= 49{,}000{,}000$$
$$(9.2 \times 10^{-4})^2 = 84.64 \times 10^{-8}$$
$$= .0000008464$$

To extract the square root of a number using powers of ten, do the opposite. (If the number is an odd power of 10, first convert it to an even power of ten.) Extract the square root of the number, and divide the power of ten by 2. Thus:

$$\sqrt{36 \times 10^{10}} = 6 \times 10^5$$
$$= 600{,}000$$
$$\sqrt{5.72 \times 10^3} = \sqrt{57.2 \times 10^2}$$
$$= 7.56 \times 10$$
$$= 75.6$$

71. OPERATION OF THE SLIDE RULE

The slide rule (Fig. 114) is an instrument designed to perform mathematical calculations with a high degree of accuracy. For example, the common 10-inch slide rule has an accuracy of one-tenth of one per cent. Operations such as multiplication, division, extraction of square and cube roots, and finding trigonometric functions such as sine, cosine, and tangent can all be performed on the slide rule.

There are six scales on the front of the slide rule. The letter *A*, in the upper left-hand corner of the body, denotes the *A* scale. On the left side of the slide, the letters *B*, *CI*, and *C* denote their respective scales. The letters *D* and *K*, at the lower left corner of the body, indicate these scales.

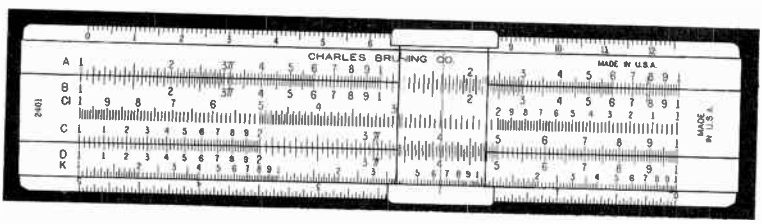


Fig. 114

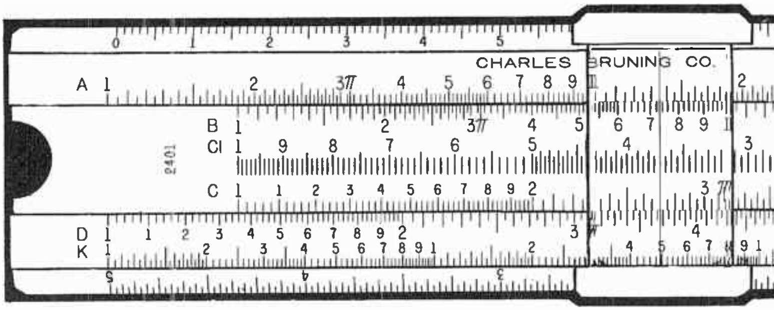


Fig. 115

The number *1* on the left end of the slide is called the left index, and the number *1* on the right end is the right index.

The *C* and *D* scales, which are identical, are used for multiplication and division. As a sample problem in multiplication, let us multiply 136 by 27. First place the left index of the slide on *136* on the *D* scale. Then slide the runner to *27* on the *C* scale, and read your answer (3672) on the *D* scale, as shown in Fig. 115.

Notice that the slide rule is accurate to three places, as illustrated by the sample problem. The fourth number can be estimated close enough for practical purposes.

As a sample problem in division, let us divide 390 by 0.7. Place the runner on *390* on the *D* scale; then push the slide to the left until *7* on the *C* scale is over the *390*, as shown in Fig. 116. Finally, place the runner at the right index, and read the answer (557) on the *D* scale.

The *CI*, or reciprocal, scale is the same as the *C* scale except its numbers increase from right to left. Hence, any number on the *CI* scale is the reciprocal of the number directly below it on the *C* scale. The *CI* scale can be used with

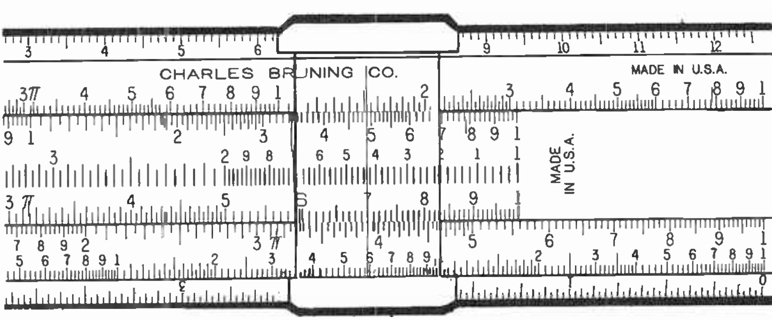


Fig. 116

the *C* and *D* scales for multiplication and division, including problems involving several multiplication and division operations in sequence.

As a sample problem in multiplication, take 26 × 32 × 6. Place the left index of the slide on *26* of the *D* scale. Then slide the runner to *32* on the *C* scale, as shown in Fig. 117. Multiplying by *6* is the same as dividing by the reciprocal of *6*. To do this, place the *6* on the *CI* scale under the hairline of the runner (Fig. 118), and read the answer (4992) under the left index.

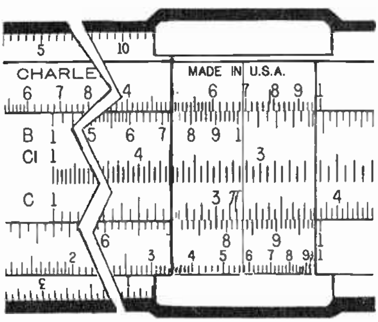


Fig. 117

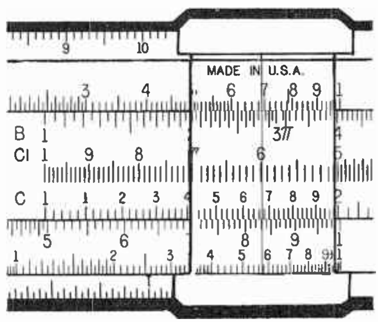


Fig. 118

The *A* and *B* scales, which are identical, are located on the upper portion of the body and slide. The *A* and/or *B* scales are used with the *C* and/or *D* scales for finding the square or square root of a number.

Example problem: Find the square root of 625. First place the runner at *625* on the *A* scale. Then read the answer (25) on the *D* scale (Fig. 119).

The slide rule can be used for finding the square root of the sum of two squares, as you might wish to do if you were

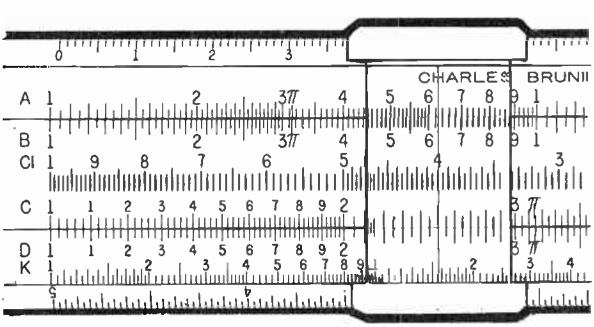


Fig. 119

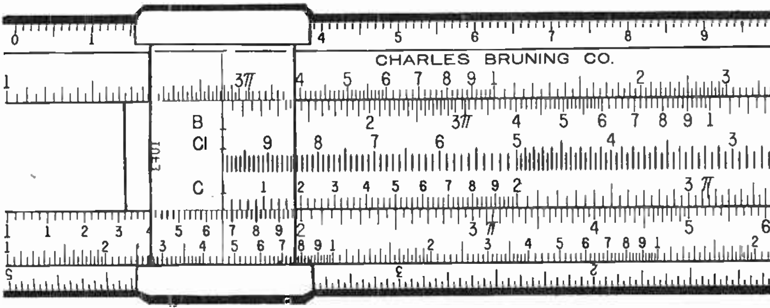


Fig. 120

solving a right triangle. For example, if the two sides of a right triangle are 3 and 5, find the hypotenuse in the following manner:

Divide the *5* by the *3*, by placing *3* on the *C* scale opposite *5* on the *D* scale. Square the quotient by reading *2.78* on the *A* scale opposite the left index of the *B* scale (Fig. 120). Mentally add *1* to get *3.78*, and set the left index of the *B* scale to *3.78* on the *A* scale. Extract the square root by going to the *D* scale and reading *1.945* opposite the *C* index mark. Without changing the slide, multiply by *3* (the number by which you originally divided) to obtain the answer (5.83) on the *D* scale (Fig. 121).

The *K* scale is used with the *D* scale for finding the cube and cube root. Each number on the *K* scale is equal to the cube of the number above it on the *D* scale. Conversely, to extract the cube root of a number, set the runner to this number on the *K* scale, and read the cube root on the *D* scale.

The back of the slide is shown in Fig. 122. On it are the sine, log, and tangent scales. The sine scale is at the top and is designated by the letter *S* on the right side of the

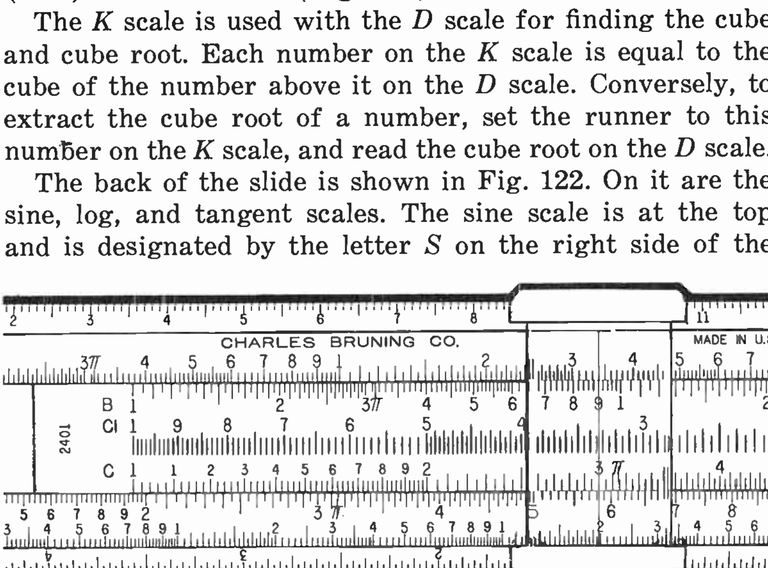


Fig. 121

slide. The log scale, designated by the letter *L*, is in the middle; and the tangent scale, designated by the letter *T*, is at the bottom.

The "inch" and "centimeter" scales on the rule are only a convenience—they are not used in any slide-rule operations.

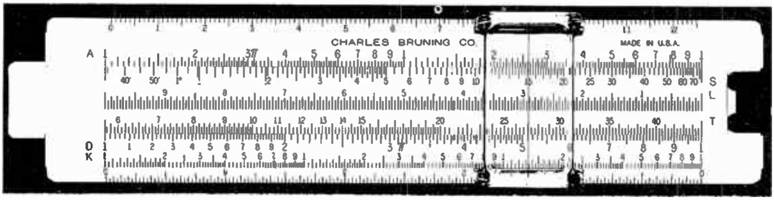


Fig. 122

72. ALGEBRAIC OPERATIONS

(A) Transposition of Terms

The following rules apply to the transposition of terms in algebraic equations:

$$\text{If } A = \frac{B}{C}\text{, then:}$$

$$B = AC$$

$$C = \frac{B}{A}$$

$$\text{If } \frac{A}{B} = \frac{C}{D}\text{, then:}$$

$$A = \frac{BC}{D}$$

$$B = \frac{AD}{C}$$

$$C = \frac{AD}{B}$$

$$D = \frac{BC}{A}$$

$$\text{If } A = \frac{1}{D\sqrt{BC}}\text{, then:}$$

$$A^2 = \frac{1}{D^2\,BC}$$

$$B = \frac{1}{D^2\,A^2\,C}$$

$$C = \frac{1}{D^2\,A^2\,B}$$

$$D = \frac{1}{A\sqrt{BC}}$$

$$\text{If } A = \sqrt{B^2 + C^2}\text{, then:}$$

$$A^2 = B^2 + C^2$$

$$B = \sqrt{A^2 - C^2}$$

$$C = \sqrt{A^2 - B^2}$$

(B) Laws of Exponents

A power of a fraction is equal to that power of the numerator divided by the same power of the denominator.

$$\left(\frac{a}{b}\right)^x = \frac{a^x}{b^x}$$

The product of two powers of the same base is also a power of that base; the exponent of the product is equal to the sum of the exponents of the two factors.

$$a^x \cdot a^y = a^{x+y}$$

The quotient of two powers of the same base is also a power of that base; the exponent of the quotient is equal to the numerator exponent minus the denominator exponent.

$$\frac{a^x}{a^z} = a^{x-z}$$

The power of a power of a base is also a power of that base; the exponent of the product is equal to the product of the exponents.

$$(a^x)^y = a^{xy}$$

A negative exponent of a base is equal to the reciprocal of that base, with a positive exponent numerically equal to the original exponent.

$$a^{-x} = \frac{1}{a^x}$$

A fractional exponent indicates that the base should be raised to the power indicated by the numerator of the fraction; the root indicated by the denominator should then be extracted.

$$a^{\frac{x}{y}} = \sqrt[y]{a^x}$$

A root of a fraction is equal to the identical root of the numerator divided by the identical root of the denominator.

$$\sqrt[x]{\frac{a}{b}} = \frac{\sqrt[x]{a}}{\sqrt[x]{b}}$$

A root of a product is equal to the product of the roots of the individual factors.

$$\sqrt[x]{ab} = \sqrt[x]{a} \times \sqrt[x]{b}$$

(C) Quadratic Equation

The general quadratic equation:

$$ax^2 + bx + c = 0$$

may be solved by:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

73. GEOMETRIC FORMULAS

(A) Triangle

$$\text{area (A)} = \frac{bh}{2}$$

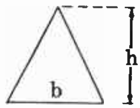


Fig. 123

(B) Square

$$\text{area (A)} = b^2$$

Fig. 124

(C) Rectangle

$$\text{area (A)} = ab$$

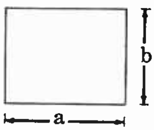


Fig. 125

(D) Parallelogram

area (A) = ah

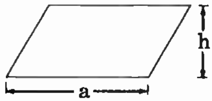


Fig. 126

(E) Trapezoid

$$\text{area (A)} = \frac{h}{2}(a + b)$$

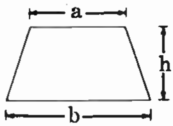


Fig. 127

(F) Trapezium

area (A) = ½ [b(H+h) + ah + cH]

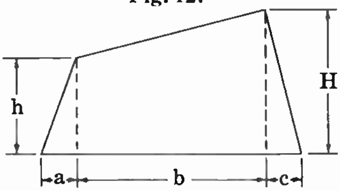


Fig. 128

(G) Regular Pentagon

area (A) = 1.720 a^2

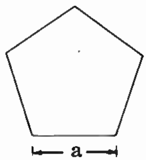


Fig. 129

(H) Regular Hexagon

area (A) = 2.598 a^2

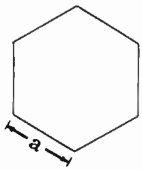


Fig. 130

(I) Regular Octagon

area (A) = 4.828 a^2

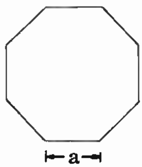


Fig. 131

(J) Circle

circumference (C) = $2\pi R$

= πD

area (A) = πR^2

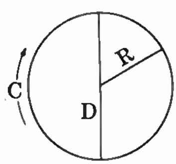


Fig. 132

(K) Segment

$$\text{chord (c)} = \sqrt{4(2hR-h^2)}$$

$$\text{area (A)} = \pi R^2\left(\frac{\theta}{360}\right)-\left(\frac{c(R-h)}{2}\right)$$

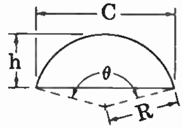


Fig. 133

(L) Sector

$$\text{area (A)} = \frac{bR}{2}$$

$$= \pi R^2\left(\frac{\theta}{360}\right)$$

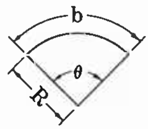


Fig. 134

(M) Circular Ring

$$\text{area (A)} = \pi(R^2-r^2)$$

$$= 7854\ (D^2-d^2)$$

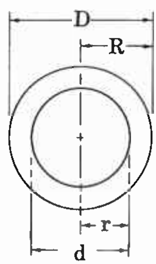


Fig. 135

(N) Ellipse

$$\text{circumference (C)} = \pi(a+b)\left[\frac{64-3\left(\frac{b-a}{b+a}\right)^4}{64-16\left(\frac{b-a}{b+a}\right)^2}\right]$$

$$\text{area (A)} = \pi ab$$

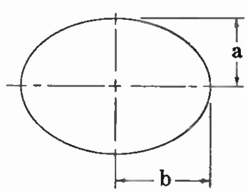


Fig. 136

(O) Sphere

$$\text{area (A)} = 4\pi R^2$$
$$= \pi D^2$$
$$\text{volume (V)} = \frac{4}{3}\pi R^3$$
$$= 1/6\pi D^3$$

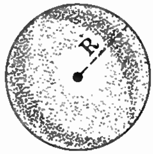


Fig. 137

(P) Cube

$$\text{area (A)} = 6b^2$$
$$\text{volume (V)} = b^3$$

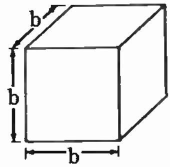


Fig. 138

(Q) Rectangular Solid

$$\text{area (A)} = 2\,(ab + bc + ac)$$
$$\text{volume (V)} = abc$$

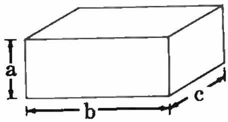


Fig. 139

(R) Cone

$$\text{area (A)} = \pi RS$$
$$= \pi R\sqrt{R^2 + h^2}$$
$$\text{volume (V)} = \frac{\pi R^2 h}{3}$$
$$= 1.047R^2h$$
$$= 0.2618D^2h$$

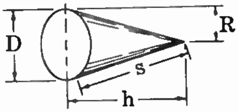


Fig. 140

(S) Cylinder

$$\text{cylindrical surface} = \pi Dh$$
$$\text{total surface} = 2\pi R(R+h)$$
$$\text{volume (V)} = \pi R^2 h$$
$$= \frac{c^2 h}{4\pi}$$

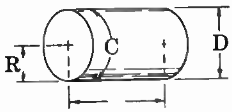


Fig. 141

(T) Ring of Rectangular Cross Section

$$\text{volume (V)} = \frac{\pi c}{4}(D^2 - d^2)$$

$$= \left(\frac{D+d}{2}\right)\pi bc$$

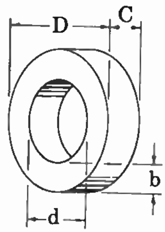


Fig. 142

(U) Torus (Ring of Circular Cross Section)

$$\text{total surface} = 4\pi^2 Rr$$

$$= \pi^2 Dd$$

$$\text{volume (V)} = 2\pi^2 R \times r^2$$

$$= 2.463 D \times d^2$$

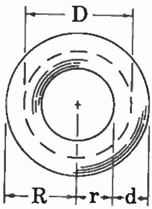


Fig. 143

74. TRIGONOMETRIC FUNCTIONS

(A) Plane Trigonometry

In any right triangle, the values in Table XXVII are valid if we let:

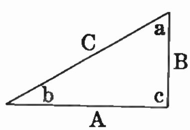


Fig. 144

a equal the acute angle formed by the hypotenuse and the altitude leg,

b equal the acute angle formed by the hypotenuse and the base leg,

A equal the side adjacent to $\angle$b and opposite $\angle$a,

B equal the side opposite $\angle$b and adjacent to $\angle$a,

C equal the hypotenuse.

Table XXVII. Trigonometric Formulas

Known Values	Formulas for Unknown Values of				
	A	B	C	∠b	∠a
A & B	—	—	$\sqrt{A^2 + B^2}$	arc tan $\frac{B}{A}$	arc tan $\frac{A}{B}$
A & C	—	$\sqrt{C^2 - A^2}$	—	arc cos $\frac{A}{C}$	arc sin $\frac{A}{C}$
A & ∠b	—	A tan ∠b	$\frac{A}{\cos \angle b}$	—	90° — ∠b
A & ∠a	—	$\frac{A}{\tan \angle a}$	$\frac{A}{\sin \angle a}$	90° — ∠a	—
B & C	$\sqrt{C^2 - B^2}$	—	—	arc sin $\frac{B}{C}$	arc cos $\frac{B}{C}$
B & ∠b	$\frac{B}{B \tan \angle b}$	—	$\frac{B}{\sin \angle b}$	—	90° — ∠b
B & ∠a	B tan ∠a	—	$\frac{B}{\cos \angle a}$	90° — ∠a	—
C & ∠b	C cos ∠b	C sin ∠b	—	—	90° — ∠b
C & ∠a	C sin ∠a	C cos ∠a	—	90° — ∠a	—

The expression "arc sin" or "sin′ " indicates an angle whose sine is. . . . Similarly, "arc tan" or "tan′" indicates the angle whose tangent is . . . , etc.

(B) Table of Trigonometric Functions

Table XXVIII gives the natural sines, cosines, tangents, and cotangents of angles. To find these values for angles from 0° to 45°, use the headings at the top of the table and the degree listings in the left-hand column. For angles from 45° to 90°, use the headings at the bottom of the table and the degree listings in the right-hand column. Note: Read the degree listings in the right-hand column from bottom to top; thus, the 10′ listing directly above 89° signifies 89° 10′.

Table XXVIII. Natural Trigonometric Functions

Degrees	Sin	Cos	Tan	Cot	
0° 00′	0.0000	1.0000	0.0000	∞	90° 00′
10	.0029	1.0000	.0029	343.77	50
20	.0058	1.0000	.0058	171.89	40
30	.0087	1.0000	.0087	114.59	30
40	.0116	.9999	.0116	85.940	20
50	.0145	.9999	.0145	68.750	10
1° 00′	0.0175	0.9998	0.0175	57.290	89° 00′
10	.0204	.9998	.0204	49.104	50
20	.0233	.9997	.0233	42.964	40
30	.0262	.9997	.0262	38.188	30
40	.0291	.9996	.0291	34.368	20
50	.0320	.9995	.0320	31.242	10
2° 00′	0.0349	0.9994	0.0349	28.636	88° 00′
10	.0378	.9993	.0378	26.432	50
20	.0407	.9992	.0407	24.542	40
30	.0436	.9990	.0437	22.904	30
40	.0465	.9989	.0466	21.470	20
50	.0494	.9988	.0495	20.206	10
3° 00′	0.0523	0.9986	0.0524	19.081	87° 00′
10	.0552	.9985	.0553	18.075	50
20	.0581	.9983	.0582	17.169	40
30	.0610	.9981	.0612	16.350	30
40	.0640	.9980	.0641	15.605	20
50	.0669	.9978	.0670	14.924	10
4° 00′	0.0698	0.9976	0.0699	14.301	86° 00′
10	.0727	.9974	.0729	13.727	50
20	.0756	.9971	.0758	13.197	40
30	.0785	.9969	.0787	12.706	30
40	.0814	.9967	.0816	12.251	20
50	.0843	.9964	.0846	11.826	10
5° 00′	0.0872	0.9962	0.0875	11.430	85° 00′
10	.0901	.9959	.0904	11.059	50
20	.0929	.9957	.0934	10.712	40
30	.0958	.9954	.0963	10.385	30
40	.0987	.9951	.0992	10.078	20
50	.1016	.9948	.1022	9.7882	10
6° 00′	0.1045	0.9945	0.1051	9.5144	84° 00′
10	.1074	.9942	.1080	9.2553	50
20	.1103	.9939	.1110	9.0098	40
30	.1132	.9936	.1139	8.7769	30
40	.1161	.9932	.1169	8.5555	20
50	.1190	.9929	.1198	8.3450	10
7° 00′	0.1219	0.9925	0.1228	8.1443	83° 00′
10	.1248	.9922	.1257	7.9530	50
20	.1276	.9918	.1287	7.7704	40
30	.1305	.9914	.1317	7.5958	30
40	.1334	.9911	.1346	7.4287	20
50	.1363	.9907	.1376	7.2687	10
	Cos	Sin	Cot	Tan	Degrees

Table XXVIII. Natural Trigonometric Functions—(Cont'd)

Degrees	Sin	Cos	Tan	Cot	
8° 00'	0.1392	0.9903	0.1405	7.1154	82° 00'
10	.1421	.9899	.1435	6.9682	50
20	.1449	.9894	.1465	6.8269	40
30	.1478	.9890	.1495	6.6912	30
40	.1507	.9886	.1524	6.5606	20
50	.1536	.9881	.1554	6.4348	10
9° 00'	0.1564	0.9877	0.1584	6.3138	81° 00'
10	.1593	.9872	.1614	6.1970	50
20	.1622	.9868	.1644	6.0844	40
30	.1650	.9863	.1673	5.9758	30
40	.1679	.9858	.1703	5.8708	20
50	.1708	.9853	.1733	5.7694	10
10° 00'	0.1736	0.9848	0.1763	5.6713	80° 00'
10	.1765	.9843	.1793	5.5764	50
20	.1794	.9838	.1823	5.4845	40
30	.1822	.9833	.1853	5.3955	30
40	.1851	.9827	.1883	5.3093	20
50	.1880	.9822	.1914	5.2257	10
11° 00'	0.1908	0.9816	0.1944	5.1446	79° 00'
10	.1937	.9811	.1974	5.0658	50
20	.1965	.9805	.2004	4.9894	40
30	.1994	.9799	.2035	4.9152	30
40	.2022	.9793	.2065	4.8430	20
50	.2051	.9787	.2095	4.7729	10
12° 00'	0.2079	0.9781	0.2126	4.7046	78° 00'
10	.2108	.9775	.2156	4.6382	50
20	.2136	.9769	.2186	4.5736	40
30	.2164	.9763	.2217	4.5107	30
40	.2193	.9757	.2247	4.4494	20
50	.2221	.9750	.2278	4.3897	10
13° 00'	0.2250	0.9744	0.2309	4.3315	77° 00'
10	.2278	.9737	.2339	4.2747	50
20	.2306	.9730	.2370	4.2193	40
30	.2334	.9724	.2401	4.1653	30
40	.2363	.9717	.2432	4.1126	20
50	.2391	.9710	.2462	4.0611	10
14° 00'	0.2419	0.9703	0.2493	4.0108	76° 00'
10	.2447	.9696	.2524	3.9617	50
20	.2476	.9689	.2555	3.9136	40
30	.2504	.9681	.2586	3.8667	30
40	.2532	.9674	.2617	3.8208	20
50	.2560	.9667	.2648	3.7760	10
15° 00'	0.2588	0.9659	0.2679	3.7321	75° 00'
10	.2616	.9652	.2711	3.6891	50
20	.2644	.9644	.2742	3.6470	40
30	.2672	.9636	.2773	3.6059	30
40	.2700	.9628	.2805	3.5656	20
50	.2728	.9621	.2836	3.5261	10
	Cos	Sin	Cot	Tan	Degrees

Table XXVIII. Natural Trigonometric Functions—(Cont'd)

Degrees	Sin	Cos	Tan	Cot	
16° 00'	0.2756	0.9613	0.2867	3.4874	74° 00'
10	.2784	.9605	.2899	3.4495	50
20	.2812	.9596	.2931	3.4124	40
30	.2840	.9588	.2962	3.3759	30
40	.2868	.9580	.2994	3.3402	20
50	.2896	.9572	.3026	3.3052	10
17° 00'	0.2924	0.9563	0.3057	3.2709	73° 00'
10	.2952	.9555	.3089	3.2371	50
20	.2979	.9546	.3121	3.2041	40
30	.3007	.9537	.3153	3.1716	30
40	.3035	.9528	.3185	3.1397	20
50	.3062	.9520	.3217	3.1084	10
18° 00'	0.3090	0.9511	0.3249	3.0777	72° 00'
10	.3118	.9502	.3281	3.0475	50
20	.3145	.9492	.3314	3.0178	40
30	.3173	.9483	.3346	2.9887	30
40	.3201	.9474	.3378	2.9600	20
50	.3228	.9465	.3411	2.9319	10
19° 00'	0.3256	0.9455	0.3443	2.9042	71° 00'
10	.3283	.9446	.3476	2.8770	50
20	.3311	.9436	.3508	2.8502	40
30	.3338	.9426	.3541	2.8239	30
40	.3365	.9417	.3574	2.7980	20
50	.3393	.9407	.3607	2.7725	10
20° 00'	0.3420	0.9397	0.3640	2.7475	70° 00'
10	.3448	.9387	.3673	2.7228	50
20	.3475	.9377	.3706	2.6985	40
30	.3502	.9367	.3739	2.6746	30
40	.3529	.9356	.3772	2.6511	20
50	.3557	.9346	.3805	2.6279	10
21° 00'	0.3584	0.9336	0.3839	2.6051	69° 00'
10	.3611	.9325	.3872	2.5826	50
20	.3638	.9315	.3906	2.5605	40
30	.3665	.9304	.3939	2.5386	30
40	.3692	.9293	.3973	2.5172	20
50	.3719	.9283	.4006	2.4960	10
22° 00'	0.3746	0.9272	0.4040	2.4751	68° 00'
10	.3773	.9261	.4074	2.4545	50
20	.3800	.9250	.4108	2.4342	40
30	.3827	.9239	.4142	2.4142	30
40	.3854	.9228	.4176	2.3945	20
50	.3881	.9216	.4210	2.3750	10
23° 00'	0.3907	0.9205	0.4245	2.3559	67° 00'
10	.3934	.9194	.4279	2.3369	50
20	.3961	.9182	.4314	2.3183	40
30	.3987	.9171	.4348	2.2998	30
40	.4014	.9159	.4383	2.2817	20
50	.4041	.9147	.4417	2.2637	10
	Cos	Sin	Cot	Tan	Degrees

Table XXVIII. Natural Trigonometric Functions—(Cont'd)

Degrees	Sin	Cos	Tan	Cot	
24° 00'	0.4067	0.9135	0.4452	2.2460	66° 00'
10	.4094	.9124	.4487	2.2286	50
20	.4120	.9112	.4522	2.2113	40
30	.4147	.9100	.4557	2.1943	30
40	.4173	.9088	.4592	2.1775	20
50	.4200	.9075	.4628	2.1609	10
25° 00'	0.4226	0.9063	0.4663	2.1445	65° 00'
10	.4253	.9051	.4699	2.1283	50
20	.4279	.9038	.4734	2.1123	40
30	.4305	.9026	.4770	2.0965	30
40	.4331	.9013	.4806	2.0809	20
50	.4358	.9001	.4841	2.0655	10
26° 00'	0.4384	0.8988	0.4877	2.0503	64° 00'
10	.4410	.8975	.4913	2.0353	50
20	.4436	.8962	.4950	2.0204	40
30	.4462	.8949	.4986	2.0057	30
40	.4488	.8936	.5022	1.9912	20
50	.4514	.8923	.5059	1.9768	10
27° 00'	0.4540	0.8910	0.5095	1.9626	63° 00'
10	.4566	.8897	.5132	1.9486	50
20	.4592	.8884	.5169	1.9347	40
30	.4617	.8870	.5206	1.9210	30
40	.4643	.8857	.5243	1.9074	20
50	.4669	.8843	.5280	1.8940	10
28° 00'	0.4695	0.8829	0.5317	1.8807	62° 00'
10	.4720	.8816	.5354	1.8676	50
20	.4746	.8802	.5392	1.8546	40
30	.4772	.8788	.5430	1.8418	30
40	.4797	.8774	.5467	1.8291	20
50	.4823	.8760	.5505	1.8165	10
29° 00'	0.4848	0.8746	0.5543	1.8040	61° 00'
10	.4874	.8732	.5581	1.7917	50
20	.4899	.8718	.5619	1.7796	40
30	.4924	.8704	.5658	1.7675	30
40	.4950	.8689	.5696	1.7556	20
50	.4975	.8675	.5735	1.7437	10
30° 00'	0.5000	0.8660	0.5774	1.7321	60° 00'
10	.5025	.8646	.5812	1.7205	50
20	.5050	.8631	.5851	1.7090	40
30	.5075	.8616	.5890	1.6977	30
40	.5100	.8601	.5930	1.6864	20
50	.5125	.8587	.5969	1.6753	10
31° 00'	0.5150	0.8572	0.6009	1.6643	59° 00'
10	.5175	.8557	.6048	1.6534	50
20	.5200	.8542	.6088	1.6426	40
30	.5225	.8526	.6128	1.6319	30
40	.5250	.8511	.6168	1.6212	20
50	.5275	.8496	.6208	1.6107	10
	Cos	Sin	Cot	Tan	Degrees

Table XXVIII. Natural Trigonometric Functions—(Cont'd)

Degrees	Sin	Cos	Tan	Cot	
32° 00′	0.5299	0.8480	0.6249	1.6003	58° 00′
10	.5324	.8465	.6289	1.5900	50
20	.5348	.8450	.6330	1.5798	40
30	.5373	.8434	.6371	1.5697	30
40	.5398	.8418	.6412	1.5597	20
50	.5422	.8403	.6453	1.5497	10
33° 00′	0.5446	0.8387	0.6494	1.5399	57° 00′
10	.5471	.8371	.6536	1.5301	50
20	.5495	.8355	.6577	1.5204	40
30	.5519	.8339	.6619	1.5108	30
40	.5544	.8323	.6661	1.5013	20
50	.5568	.8307	.6703	1.4919	10
34° 00′	0.5592	0.8290	0.6745	1.4826	56° 00′
10	.5616	.8274	.6787	1.4733	50
20	.5640	.8258	.6830	1.4641	40
30	.5664	.8241	.6873	1.4550	30
40	.5688	.8225	.6916	1.4460	20
50	.5712	.8208	.6959	1.4370	10
35° 00′	0.5736	0.8192	0.7002	1.4281	55° 00′
10	.5760	.8175	.7046	1.4193	50
20	.5783	.8158	.7089	1.4106	40
30	.5807	.8141	.7133	1.4019	30
40	.5831	.8124	.7177	1.3934	20
50	.5854	.8107	.7221	1.3848	10
36° 00′	0.5878	0.8090	0.7265	1.3764	54° 00′
10	.5901	.8073	.7310	1.3680	50
20	.5925	.8056	.7355	1.3597	40
30	.5948	.8039	.7400	1.3514	30
40	.5972	.8021	.7445	1.3432	20
50	.5995	.8004	.7490	1.3351	10
37° 00′	.6018	.7986	.7536	1.3270	53° 00′
10	.6041	.7969	.7581	1.3190	50
20	.6065	.7951	.7627	1.3111	40
30	.6088	.7934	.7673	1.3032	30
40	.6111	.7916	.7720	1.2954	20
50	.6134	.7898	.7766	1.2876	10
38° 00′	0.6157	0.7880	0.7813	1.2799	52° 00′
10	.6180	.7862	.7860	1.2723	50
20	.6202	.7844	.7907	1.2647	40
30	.6225	.7826	.7954	1.2572	30
40	.6248	.7808	.8002	1.2497	20
50	.6271	.7790	.8050	1.2423	10
39° 00′	0.6293	0.7771	0.8098	1.2349	51° 00′
10	.6316	.7753	.8146	1.2276	50
20	.6338	.7735	.8195	1.2203	40
30	.6361	.7716	.8243	1.2131	30
40	.6383	.7698	.8292	1.2059	20
50	.6406	.7679	.8342	1.1988	10
	Cos	Sin	Cot	Tan	Degrees

Table XXVIII. Natural Trigonometric Functions—(Cont'd)

Degrees	Sin	Cos	Tan	Cot	
40° 00′	0.6428	0.7660	0.8391	1.1918	50° 00′
10	.6450	.7642	.8441	1.1847	50
20	.6472	.7623	.8491	1.1778	40
30	.6494	.7604	.8541	1.1708	30
40	.6517	.7585	.8591	1.1640	20
50	.6539	.7566	.8642	1.1571	10
41° 00′	0.6561	0.7547	0.8693	1.1504	49° 00′
10	.6583	.7528	.8744	1.1436	50
20	.6604	.7509	.8796	1.1369	40
30	.6626	.7490	.8847	1.1303	30
40	.6648	.7470	.8899	1.1237	20
50	.6670	.7451	.8952	1.1171	10
42° 00′	0.6691	0.7431	0.9004	1.1106	48° 00′
10	.6713	.7412	.9057	1.1041	50
20	.6734	.7392	.9110	1.0977	40
30	.6756	.7373	.9163	1.0913	30
40	.6777	.7353	.9217	1.0850	20
50	.6799	.7333	.9271	1.0786	10
43° 00′	0.6820	0.7314	0.9325	1.0724	47° 00′
10	.6841	.7294	.9380	1.0661	50
20	.6862	.7274	.9435	1.0599	40
30	.6884	.7254	.9490	1.0538	30
40	.6905	.7234	.9545	1.0477	20
50	.6926	.7214	.9601	1.0416	10
44° 00′	0.6947	0.7193	0.9657	1.0355	46° 00′
10	.6967	.7173	.9713	1.0295	50
20	.6988	.7163	.9770	1.0235	40
30	.7009	.7133	.9827	1.0176	30
40	.7030	.7112	.9884	1.0117	20
50	.7050	.7092	.9942	1.0058	10
45° 00′	0.7071	0.7071	1.0000	1.0000	45° 00′
	Cos	Sin	Cot	Tan	Degrees

75. BINARY NUMBERS

(A) Binary Digits

In the binary system of numbers, there are only two digits—0 and 1. All numbers are written as successive powers of 2. Actually, in the decimal system, all numbers are written as successive powers of 10, although we don't normally think of them in this way. For example, decimal *3487* is actually:

$$\begin{aligned} 3\times10^3 &= 3000 \\ 4\times10^2 &= 400 \\ 8\times10^1 &= 80 \\ 7\times10^0 &= \underline{7} \\ & \ 3487 \end{aligned}$$

With binary numbers, a like system is used except the base (radix) is 2 instead of 10. For example, the binary numbers corresponding to decimal numbers 0 through 10 are 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010. Each number is written as a succession of powers of 2. For example, binary 1010 actually means:

$$\begin{array}{rr} 1 \times 2^3 = & 8 \\ +1 \times 2^1 = & \underline{2} \\ & 10 \end{array}$$

The powers of 2, from 0 to 20, are given in Table XXIX. Thus, to write a number above decimal 1,048,056 using binary numbers requires a minimum of *21* digits!

Table XXIX. Powers of 2

Power	Decimal	Power	Decimal	Power	Decimal
2^0	1	2^7	128	2^{14}	16,384
2^1	2	2^8	256	2^{15}	32,768
2^2	4	2^9	512	2^{16}	65,536
2^3	8	2^{10}	1,024	2^{17}	131,072
2^4	16	2^{11}	2,048	2^{18}	262,144
2^5	32	2^{12}	4,096	2^{19}	524,288
2^6	64	2^{13}	8,192	2^{20}	1,048,576

(B) Conversion

To convert from binary to decimal or from decimal to binary, you could use Table XXIX and compute the equivalent in the other numbering system as was done in the previous section. However, there are simpler methods. To convert from decimal to binary, successively divide the decimal number by *2*. Write down a 1 if there is a remainder and a *0* if not, until the division gives a *0*. For example, to convert decimal *22* to binary:

$$\begin{array}{rl} 2\overline{)22} & \\ 2\overline{)11} & R = 0 \\ 2\overline{)\ 5} & R = 1 \\ 2\overline{)\ 2} & R = 1 \\ 2\overline{)\ 1} & R = 0 \\ \overline{\ \ 0} & R = 1 \end{array}$$

The least significant figure is at the top; thus, the binary number corresponding to decimal *22* is 10110.

To convert from binary to decimal, take the first binary digit, double it, and add your answer to the second digit. Write this sum under the second digit. Then double this number, add it to the third digit, and write the sum under the third digit. Continue this process up to and including the last digit, as follows:

1	0	1	1	0	1
	2	5	11	22	45

The number under the last digit (45) is the decimal equivalent of binary 101101.

(C) Addition

Binary addition has only four rules:

$$\begin{array}{cccc} 0 & 0 & 1 & 1 \\ \underline{0} & \underline{1} & \underline{0} & \underline{1} \\ 0 & 1 & 1 & 10 \end{array}$$

Following these rules, any binary number can be added. Thus:

$$\begin{array}{r} 1011 \\ \underline{110} \\ 10001 \end{array}$$

To simplify the carry when 1 + 1 = 10, place the carry under the next digit. Then add the partial total and the carries, as follows:

$$\begin{array}{r} 111101 \\ \underline{10110} \\ 101011 \\ \underline{1\ 1} \\ 1010011 \end{array}$$

(D) Subtraction

Binary numbers can be subtracted directly, as follows:

$$\begin{array}{r} 1111 \\ \underline{-\ 111} \\ 1000 \end{array}$$

However, a simpler method is to complement the subtracted number and add. In the binary system, a number is complemented by merely changing all *0*'s to *1*'s and all *1*'s to *0*'s and adding *1* to the final digit. Thus:

$$\begin{array}{r} 1111 \\ -0111 \\ \hline \end{array} \qquad \text{complemented} \qquad \begin{array}{r} 1111 \\ +1001 \\ \hline 11000 \end{array}$$

The first digit in the answer is disregarded. Hence, the answer is 1000 (decimal *8*), the same as before.

(E) Multiplication

Binary multiplication is similar to decimal multiplication. All products are the same as in decimal multiplication. That is:

$$0 \times 0 = 0$$
$$1 \times 0 = 0$$
$$1 \times 1 = 1$$

To multiply 1011 by 101:

$$\begin{array}{r} 1011 \\ 0101 \\ \hline 1011 \\ 0000 \\ 1011 \\ \hline 110111 \end{array}$$

(F) Division

Binary division is similar to decimal division. Thus, to divide 1101001 by 101:

```
         10101
    101)1101001
        101
        ---
          110
          101
          ---
            101
            101
            ---
```

76. FUNDAMENTALS OF BOOLEAN ALGEBRA

Boolean algebra is based on symbolic logic, which states that an idea must be either true or false—it can be nothing else. The symbols A, B, and C are used to designate the various conditions (or computer inputs). Two connectives—AND and OR—express the relationship between two statements.

OR is the logical equivalent of a parallel switch circuit. That is, a statement is true if any switch is closed, or if they are all closed. OR is symbolized by a + sign. Thus, "A OR B" is written "A + B."

AND is the logical equivalent of a series switch circuit—all switches must be closed to satisfy the condition. AND is symbolized by a multiplication sign ($A \cdot B$) or no sign at all. For example, $A \cdot B$ and AB both mean A AND B. The various symbols are given in Table XXX. Table XXXI summarizes the various logical statements, explains their meanings, and shows the equivalent switch circuit for the statement.

Table XXX. Basic Rules of Symbolic Logic

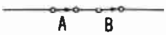
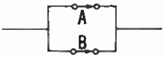
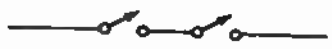
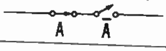
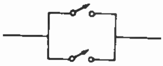
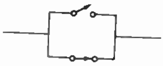
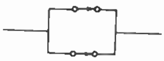
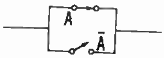
Symbol	Logic	Switch	Meaning	Circuit
1	True	Closed	The statement is true, the circuit is closed.	
0	False	Open	The statement is false, the circuit is open.	
•	Series	A and B	A is in series with B.	
+	Parallel	A or B	A is in parallel with B.	
$\overline{A}$ or A′	Not A		Opposite of A (If A = 0, $\overline{A}$ = 1; if A = 1, $\overline{A}$ = 0).	

Table XXXI. Summary of Logical Statements

Logic	Meaning	Circuit
$0 \cdot 0 = 0$	An open in series with an open is open.	
$0 \cdot 1 = 0$	An open in series with a closed is open.	
$1 \cdot 1 = 1$	A closed in series with a closed is closed.	
$A \cdot \bar{A} = 0$	A switch in series with its negation is open.	
$0 + 0 = 0$	An open in parallel with an open is open.	
$0 + 1 = 1$	An open in parallel with a closed is closed.	
$1 + 1 = 1$	A closed in parallel with a closed is closed.	
$A + \bar{A} = 1$	A switch in parallel with its negation is closed.	

77. COMMON LOGARITHMS

The logarithm of a quantity is the power to which a given number (base) must be raised in order to equal that quantity. Thus, any number may be used as the base. The most common system is the base *10*. Logarithms with the base *10* are known as common, or Briggs, logarithms; they are written $\log_{10}$, or simply log. When the base is omitted, the base *10* is understood.

A common logarithm of a given number is the number which, when applied to the number *10* as an exponent, will produce the given number. Thus, 2 is the common logarithm of 100, since 10^2 equals 100; 3 is the logarithm of 1000, since 10^3 equals 1000, etc. From this we can see that the logarithm of any number except a whole number power of 10 consists of a whole number and a decimal fraction.

(A) Characteristic of a Logarithm

The whole-number portion of a logarithm is called the *characteristic*. The characteristic of a whole number, or of a whole number and a fraction, has a positive value equal to one less than the number of digits preceding the decimal point. The characteristic of a decimal fraction has a negative value equal to one more than the number of zeros immediately following the decimal point. The characteristics of numbers between .0001 and 99,999 are:

Numbers	Characteristic
.0001 to .0009	−4
.001 to .009	−3
.01 to .09	−2
.1 to .9	−1
1 to 9	0
10 to 99	1
100 to 999	2
1,000 to 9,999	3
10,000 to 99,999	4

(B) Use of Logarithm Table

The *mantissa,* or decimal-fraction portion, of a logarithm is obtained from Table XXXII. To find the mantissa for the logarithm of any number, locate the first two figures of the number in the left-hand column (N); then, in the column under the third figure of the number, the mantissa for that number will be found.

For example, to find the logarithm of 6673, first locate 66 in the left-hand column (N); then follow across to the column numbered *7*. The mantissa for 667 (.8241) is located at this point. The characteristic for the logarithm of 6673 is 3. Therefore, the logarithm of 6670 is 3.8241. For most computations, greater accuracy will not be required.

If accuracy to four places is desired, the columns labeled *Proportional Parts* may be used. These columns list the numbers to be added to the logarithm to obtain four-place accuracy. In the foregoing, we obtained the logarithm for 6670 (3.8241), but we wanted the logarithm for 6673; therefore, we use the *proportional parts* column to find the proportional part for 3. This is 2. Therefore, the logarithm for 6673 is 3.8241 plus .0002, or 3.8243.

The *mantissa* of a logarithm is usually *positive,* whereas a *characteristic* may be either *positive* or *negative.* The total logarithm is the sum of the mantissa and the characteristic.

Thus, the mantissa of .0234 is .3692, and the characteristic is −2. The total logarithm is $-2 + .3692$, or -1.6308. A negative logarithm is difficult to use; therefore, it is more convenient to convert the logarithm to a positive number. This is possible by adding 10, or a multiple thereof, to the characteristic when it is negative, and compensating for this by indicating the subtraction of 10 from the entire logarithm. Thus, the logarithm of .0234 would be written $8.3692 - 10$, since $-2 + .3692$ equals $8 + .3692 - 10$. This logarithm may now be used like any other positive logarithm, except that the *−10* must be considered in determining the characteristic of the answer.

(C) Antilogarithms

An antilogarithm (abbreviated *antilog or* log^{-1}) is a number corresponding to a given logarithm. To find an antilog, locate in the logarithm table the mantissa closest to that of the given logarithm. Record the number in the *N* column directly opposite the mantissa located, and annex to this the number on the top line immediately above the mantissa. Next determine where the decimal point is located, by counting off the number of places indicated by the characteristic. Starting between the first and second digits, count to the right if the characteristic is positive, and to the left if it is negative. If greater accuracy is desired, the *proportional parts* columns of the logarithm table can be used, in the same manner described in the foregoing for finding the mantissa.

To find the antilog of 3.4548, locate 4548 in the table. Then read the first two figures of the antilog from the *N* column (28) and the third figure directly above the mantissa (5). Thus, the three figures of the antilog are 285. Locate the decimal point by counting off three places to the right, from the point between the *2* and the *8*, to obtain 2850.0—the antilog of 3.4548.

In the foregoing example, if the logarithm had been $-2 + .4548$, the procedure would have been the same except for the location of the decimal point. The decimal point in this example would be located by starting at the point between the *2* and the *8*, and counting two places to the left to obtain 0.0285—the antilog of $-2 + .4548$.

(D) Multiplication

Numbers are multiplied by adding their logarithms and finding the antilog of the sum. For example, to multiply 682 × 497, proceed as follows:

$$\log N = \log 682 + \log 497$$

$$\begin{aligned} \log 682 &= 2.8338 \\ + \log 497 &= \underline{2.6964} \\ \log N &= 5.5302 \end{aligned}$$

$$\text{antilog } 5.5302 = 339{,}000.$$

To multiply .02 × .03 × .5, proceed as follows:

$$\log N = \log .02 + \log .03 + \log .5$$

$$\begin{aligned} \log .02 &= -2 + .3010 = 8.3010 - 10 \\ + \log .03 &= -2 + .4771 = 8.4771 - 10 \\ + \log .5 &= -1 + .6990 = \underline{9.6990 - 10} \\ \log N &= 26.4771 - 30 \\ &= -4 + .4771 \end{aligned}$$

$$\text{antilog } -4 + .4771 = .0003$$

(E) Division

Numbers are divided by subtracting the logarithm of the divisor from the logarithm of the dividend, and finding the antilog of the difference. For example, to divide 39,200 by 27.2, proceed as follows:

$$\log N = \log 39{,}200 - \log 27.2$$

$$\begin{aligned} \log 39{,}200 &= 4.5933 \\ - \log 27.2 &= \underline{1.4346} \\ \log N &= 3.1587 \end{aligned}$$

$$\text{antilog } 3.1587 = 1441$$

To divide .3 by .007, proceed as follows:

$$\log N = \log .3 - \log .007$$
$$\log .3 = -1 + .4771 = 9.4771 - 10$$
$$-\log .007 = -3 + .8451 = \underline{7.8451 - 10}$$
$$\log N = 1.6320 - 0$$
$$\text{antilog } 1.6320 = 42.86$$

(F) Raising to Powers

A given number can be raised to any power by multiplying the logarithm of the given number by the power to which the number is to be raised, and finding the antilog of the product. For example, to raise 39.7 to the third power, proceed as follows:

$$\log N = \log 39.7 \times 3$$
$$\log 39.7 = 1.5988$$
$$\log N = 1.5988 \times 3$$
$$= 4.7964$$
$$\text{antilog } 4.7964 = 62{,}570$$

(G) Extracting Roots

Any root can be extracted from a given number by dividing the logarithm of the given number by the index of the root, and finding the antilog of the quotient. For example, to extract the cube root of 149, proceed as follows:

$$\log N = \log 149 \div 3$$
$$\log 149 = 2.1732$$
$$\log N = 2.1732 \div 3$$
$$= 0.7244$$
$$\text{antilog } 0.7244 = 5.301$$

Table XXXII. Common Logarithms

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
N	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1** Proportional Parts	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Table XXXII. Common Logarithms—(Cont'd)

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
											Proportional Parts								

Table XXXII. Common Logarithms—(Cont'd)

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
											1	2	3	4	5	6	7	8	9
N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								

Table XXXII. Common Logarithms—(Cont'd)

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
											Proportional Parts								

Miscellaneous

78. POWER CONSUMPTION OF HOME ELECTRICAL EQUIPMENT

The power consumption for many items of home electrical equipment by an average family is given in Table XXXIII. The approximate usage of each item is also listed where applicable.

Table XXXIII. Power Consumption of Home Electrical Equipment

Item	Approx. Kwh per Month	Remarks
Blanket (automatic)	15	8 hr. per day (used 7 mo.)
Clock	1½	
Coffee Maker	15	25 hr. per mo.
Dishwasher	25	1½ washings per day
Dryer (clothes)	50	10 hr. per mo. (family of 4)
Fan (10-inch)	1	25 hr. per mo.
Food Freezer	40	8 cu. ft.
Garbage Disposal Unit	¾	4 min. per day
Iron	6	12 hr. per mo.
Ironer	10	10 hr. per mo. (family of 4)
Lighting	65	
Mixer	¾	5 hr. per mo.
Oil Furnace (not including circulator fan)	30	(200-500 KW-hours per year)
Radio	10	130 hr. per mo.
Range	90	(Family of 4)
Refrigerator	22	8 cu. ft.
Roaster	12	16 hr. per mo.
Sandwich Grill	4	5 hr. per mo.
Sewing Machine	1	
Television	18	90 hr. per mo.
Toaster	3	3 hr. per mo.
Vacuum Cleaner (upright)	2¼	6 hr. per mo.
Vacuum Cleaner (tank)	3¼	6 hr. per mo.
Washer (wringer-type)	2	12 hr. per mo. (family of 4)
Washer (automatic)	3	12 hr. per mo. (family of 4)
Water Heater	350	(Family of 4)

79. TEMPERATURE CONVERSION

The nomograph in Fig. 145 can be used to convert from degrees Fahrenheit to degrees Celsius (or vice versa) for any temperature between absolute zero and 540°F. (281°C). The term Celsius was officially adopted, in place of centigrade, by international agreement in 1948; however, acceptance of the new term has been slow in Europe, and still slower in the United States. Actually, Celsius and centigrade scales differ slightly—the Celsius scale is based on 0° at the triple point of water (.01°C), and centigrade has 0° at the freezing point of water. For all practical purposes, though, the two terms are interchangeable.

Two absolute temperature scales are also in use. The Fahrenheit absolute scale is called the Rankine—0° Rankine equals −459.67° Fahrenheit. The Celsius absolute scale is the Kelvin—0° Kelvin equals −273.16° Celsius (or centigrade).

The following formulas can be used to convert from any temperature to the other:

$$°F. = (°C. \times 9/5) + 32$$

$$°F. = °R. - 459.67$$

$$°F. = 9/5\ (°K. - 273.16) + 32$$

$$°C. = 5/9\ (°F. - 32)$$

$$°C. = °K. - 273.16$$

$$°C. = 5/9\ (°R. - 491.67)$$

$$°R. = °F. + 459.67$$

$$°R. = (°C. \times 9/5) + 491.67$$

$$°R. = 9/5\ (°K. - 273.16) + 491.67$$

$$°K. = °C. + 273.16$$

$$°K. = 5/9\ (°F - 32) + 273.16$$

$$°K. = 5/9\ (°R. - 491.67) + 273.16$$

Temperature Nomograph

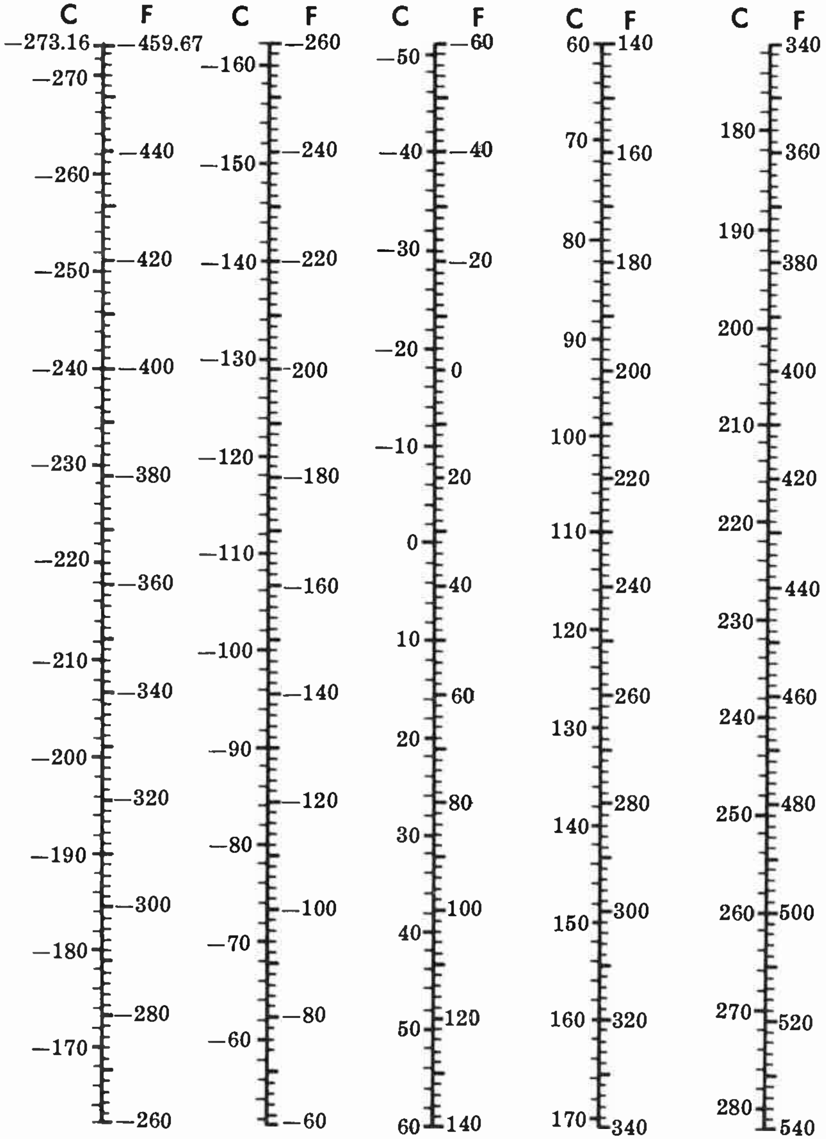


Fig. 145

80. CHARACTERISTICS OF THE ELEMENTS

A list of all the known elements (103) is given in Table XXXIV. The symbol, atomic number, and atomic weight are included for each element. Where known, the melting and boiling point of each element is also given. A value shown in parentheses indicates the value is approximated; the asterisk (*) indicates the mass number of the longest-lived of the known available forms of the element, usually synthetic; < indicates the value may be lower; > indicates the value may be higher.

Table XXXIV. Characteristics of the Elements

Element	Symbol	Atomic Number	Atomic Weight	Melting Point °C	Boiling Point °C
Actinium	Ac	89	*227	——	——
Aluminum	Al	13	26.97	660.1	1800
Americium	Am	95	*243	——	——
Antimony	Sb	51	121.76	630.5	1380
Argon	A	18	39.944	−189.2	−185.7
Arsenic	As	33	74.91	(820)	615
Astatine	At	85	*210	——	——
Barium	Ba	56	137.36	850	1140
Berkelium	Bk	97	*249	——	——
Beryllium	Be	4	9.013	1350	(1500)
Bismuth	Bi	83	209.00	271.3	1450
Boron	B	5	10.82	2300	2550
Bromine	Br	35	79.916	−7.2	58.8
Cadmium	Cd	48	112.41	320.9	766
Calcium	Ca	20	40.08	810	1170
Californium	Cf	98	*249	——	——
Carbon	C	6	12.01	>3500	(4200)
Cerium	Ce	58	140.13	640	1400
Cesium	Cs	55	132.91	28	670
Chlorine	Cl	17	35.457	−101.6	−34.7
Chromium	Cr	24	52.01	1615	2200
Cobalt	Co	27	58.94	1492	3000
Copper	Cu	29	63.54	1083	2300
Curium	Cm	96	247	——	——
Dysprosium	Dy	66	162.46	——	——
Einsteinium	E	99	*254	——	——
Erbium	Er	68	167.2	——	——
Europium	Eu	63	152.0	——	——
Fermium	Fm	100	*255	——	——
Fluorine	F	9	19.00	−223	−187
Francium	Fr	87	*223	——	——
Gadolinium	Gd	64	156.9	——	——
Gallium	Ga	31	69.72	29.7	>1600
Germanium	Ge	32	72.60	958.5	(2700)
Gold	Au	79	197.0	1063	2600

Table XXXIV. Characteristics of the Elements—(Cont'd)

Element	Symbol	Atomic Number	Atomic Weight	Melting Point °C	Boiling Point °C
Halfnium	Hf	72	178.6	1500	(>3200)
Helium	He	2	4.003	<—271.4	—268.94
Holmium	Ho	67	164.94	——	——
Hydrogen	H	1	1.0080	—259.14	—252.8
Indium	In	49	114.76	155	>1450
Iodine	I	53	126.91	113.5	184.35
Iridium	Ir	77	192.2	2443	(>4800)
Iron	Fe	26	55.85	1533	3000
Krypton	Kr	36	83.8	—169	—151.8
Lanthanum	La	57	138.92	826	1800
Lawrencium	Lw	103	——	——	——
Lead	Pb	82	207.21	327.4	1620
Lithium	Li	3	6.940	186	>1200
Lutetium	Lu	71	174.99	——	——
Magnesium	Mg	12	24.32	651	1100
Manganese	Mn	25	54.94	1260	1800
Mendelevium	Mv	101	*256	——	——
Mercury	Hg	80	200.61	—38.87	356.9
Molybdenum	Mo	42	95.95	2620	3700
Neodymium	Nd	60	144.27	840	——
Neon	Ne	10	20.183	—248.67	—245.9
Neptunium	Np	93	*237	639	——
Nickel	Ni	28	58.69	1453	2900
Niobium	Nb	41	92.91	2500	3200
Nitrogen	N	7	14.008	—209.86	—195.81
Nobelium	No	102	251	——	——
Osmium	Os	76	190.2	2700	(>5300)
Oxygen	O	8	16.000	—218.4	—183
Palladium	Pd	46	106.7	1552	2200
Phosphorus	P	15	30.975	44.1	280
Platinum	Pt	78	195.23	1769	4300
Plutonium	Pu	94	242	——	——
Polonium	Po	84	210	——	——
Potassium	K	19	39.100	62.3	760
Praseodymium	Pr	59	140.92	940	——
Promethium	Pm	61	*145	——	——
Protactinium	Pa	91	*231	——	——
Radium	Ra	88	226.05	960	1140
Radon	Rn	86	222	—110	——
Rhenium	Re	75	186.31	(3000)	——
Rhodium	Rh	45	102.91	1960	>2500
Rubidium	Rb	37	85.48	38.5	700
Ruthenium	Ru	44	101.1	2500	>2700
Samarium	Sm	62	150.43	>1300	——
Scandium	Sc	21	44.96	1200	(2400)
Selenium	Se	34	78.96	220	688
Silicon	Si	14	28.09	1420	2600
Silver	Ag	47	107.880	960.8	1950
Sodium	Na	11	22.997	97.5	880
Strontium	Sr	38	87.63	800	1150

Table XXXIV. Characteristics of the Elements—(Cont'd)

Element	Symbol	Atomic Number	Atomic Weight	Melting Point °C	Boiling Point °C
Sulfur	S	16	32.066	113-119	444.6
Tantalum	Ta	73	180.95	3005	(>4100)
Technetium	Tc	43	*99	——	——
Tellurium	Te	52	127.61	452	1390
Terbium	Tb	65	158.93	327	——
Thallium	Tl	81	204.39	303.5	1650
Thorium	Th	90	232.12	1845	>3000
Thulium	Tm	69	168.94	——	3500
Tin	Sn	50	118.70	231.9	2260
Titanium	Ti	22	47.90	1820	(>3000)
Tungsten	W	74	183.92	3380	5900
Uranium	U	92	238.07	1133	——
Vanadium	V	23	50.95	1735	(3000)
Xenon	Xe	54	131.3	−140	−109.1
Ytterbium	Yb	70	173.04	——	——
Yttrium	Y	39	88.92	1490	(2500)
Zinc	Zn	30	65.38	419.47	907
Zirconium	Zr	40	91.22	1750	>2900

81. MEASURES AND WEIGHTS

(A) Linear Measure

1 inch = 1000 mils
1 hand = 4 inches
1 foot = 12 inches
1 yard = 3 feet
1 fathom = 6 feet
1 rod = 5½ yards

1 furlong = 40 rods
1 statute mile = 8 furlongs
1 statute mile = 5,280 feet
1 nautical mile = 6076.1 feet
1 nautical mile = 1.1508 statute miles
1 league = 3 miles

(B) Square Measure

1 sq. foot = 144 sq. inches
1 sq. yard = 9 sq. feet
1 sq. rod = 30¼ sq. yards
1 section (of land) = 1 sq. mile

1 township = 6 miles sq. (36 sq. miles)
1 acre = 160 sq. rods
1 acre = 43,560 sq. feet
1 sq. mile = 640 acres

(C) Volume Measure

1 cu. foot = 1,728 cu. inches

1 cu. yard = 27 cu. feet

1 U.S. gallon = 231 cu. inches

(D) Liquid Measure

1 pint = 4 gills
1 quart = 2 pints
1 gallon = 4 quarts
1 barrel (petroleum) = 42 gallons

1 barrel = 31½ gallons
1 hogshead = 2 barrels (63 gallons)
1 tun = 252 gallons

(E) Dry Measure

1 quart = 2 pints = 67.2006 cu. in.
1 peck = 8 quarts = 537.605 cu. in.
1 bushel = 4 pecks = 2150.419 cu. in.
1 barrel = 2.381 bushels = 7056 cu. in.

(F) Avoirdupois Weight

(For other than drugs, gold, silver, etc.)

1 dram (dr.) = 27.3437 grains*
1 ounce (oz.) = 16 drams
1 pound (lb.) = 16 ounces
1 quarter = 25 pounds
1 hundredweight (cwt.) = 4 quarters
1 ton (tn.) = 20 cwts.
1 short ton = 2000 pounds
1 long ton = 2240 pounds

1 pound avdp. = 7000 grains = 453.59 grams = 1.2153 pounds troy

(G) Troy Weight

(For gold, silver, etc.)

1 pennyweight (dwt.) = 24 grains*
1 ounce troy (oz.t.) = 20 pennyweights

1 pound troy (lb.t.) = 12 ounces troy = 240 pennyweights = 5760 grains

(H) Apothecaries' Weight

(For drugs)

1 scruple (s. ap.) = 20 grains*
1 dram apoth. (dr. ap.) = 3 scruples

1 ounce apoth. (oz. ap.) = 8 drams apoth.

1 pound apoth. (lb. ap.) = 12 ounces apoth.
= 96 drams apoth.
= 288 scruples
= 5760 drams

82. METRIC EQUIVALENTS

(A) Length

1 centimeter = 0.3937 inch
1 meter = 3.2808 feet
1 meter = 1.0936 yards
1 kilometer = 0.6214 miles
1 inch = 2.5400 centimeters (cm.)
1 foot = 0.3048 meter
1 yard = 0.9144 meter
1 mile (statute) = 1.6093 kilometers (km.)

(B) Area

1 sq. cm. = 0.1550 sq. inch
1 sq. meter = 10.7639 sq. feet
1 sq. meter = 1.1960 sq. yards
1 hectare = 2.4710 acres
1 sq. km. = 0.3861 sq. mile
1 sq. inch = 6.4516 sq. cm.
1 sq. foot = 0.0929 sq. meter
1 sq. yard = 0.8361 sq. meter
1 acre = 0.4047 hectare
1 sq. mile = 2.5900 sq. km.

* The grain is the same in avoirdupois, troy, and apothecaries' weights.

(C) Volume

1 cu. cm. = 0.0610 cu. inch
1 cu. meter = 35.3145 cu. feet
1 cu. meter = 1.3079 cu. yards

1 cu. inch = 16.3872 cu. cm.
1 cu. foot = 0.0283 cu. meter
1 cu. yard = 0.7646 cu. meter

(D) Capacity

1 liter = 61.0250 cu. inches
1 liter = 0.0353 cu. feet
1 liter = 0.2642 gallon (U.S.)
1 liter = 0.0284 bushel (U.S.)
1 liter = 1000.027 cu. cm.
1 liter = 1.056 quarts (liquid)

1 liter = 0.9081 quart (dry)
1 liter = 2.2046 pounds of water @ 4° C
1 cu. inch = 0.0164 liter
1 cu. foot = 28.3162 liters
1 gallon = 3.7853 liters
1 bushel = 35.2383 liters

(E) Weight

1 gram = 15.4324 grains
1 gram = 0.0353 ounce avdp.
1 kg. = 2.2046 pounds avdp.
1 kg. = 0.0011 ton (short)
1 ton (metric) = 1.1023 tons (short)
1 ton (metric) = 0.9842 ton (long)

1 grain = 0.0648 gram
1 ounce (avdp.) = 28.3495 grams
1 pound (avdp.) = 0.4536 kg.
1 ton (short) = 907.1848 kg.
1 ton (short) = 0.9072 ton (metric)
1 ton (long) = 1.0160 ton (metric)

(F) Pressure

1 kg. per sq. cm. = 14.223 lbs. per sq. inch
1 lb. per sq. inch = 0.0703 kg. per sq. cm.
1 kg. per sq. meter = 0.2048 lb. per sq. foot
1 lb. per sq. foot = 4.8824 kg. per sq. meter
1 kg. per sq. cm. = 0.9678 normal atmosphere
1 normal atmosphere = 1.0332 kg. per sq. cm.
1 normal atmosphere = 1.01325 bars
1 normal atmosphere = 14.696 lbs. per sq. inch

83. WINDS

Table XXXV. Wind Designations

Designation	Miles per hour	Designation	Miles per hour
Calm	Less than 1	Moderate gale	32 to 38
Light air	1 to 3	Fresh gale	39 to 46
Light breeze	4 to 7	Strong gale	47 to 54
Gentle breeze	8 to 12	Whole gale	55 to 63
Moderate breeze	13 to 18	Storm	64 to 72
Fresh breeze	19 to 24	Hurricane	Above 72
Strong breeze	25 to 31		

84. WEIGHT OF WATER

1 cubic inch	= .0360 pound	1 imperial gallon	= 10.0 pounds
12 cubic inches	= .433 pound	11.2 imperial gallons	= 112.0 pounds
1 cubic foot	= 62.4 pounds	224 imperial gallons	= 2240.0 pounds
1 cubic foot	= 7.48052 U.S. gallons	1 U.S. gallon	= 8.33 pounds
1.8 cubic feet	= 112.0 pounds	13.45 U.S. gallons	= 112.0 pounds
35.96 cubic feet	= 2240.0 pounds	269.0 U.S. gallons	= 2240.0 pounds

85. HYDRAULIC EQUATIONS

Lbs. per sq. in. = 0.434 × head of water in feet

Head in feet = 2.31 × lbs. per sq. inch

Approximate loss of head due to friction in clean iron pipes is:

$$\frac{0.02 \times L \times V^2}{64.4D} \text{ ft.}$$

where,
L is the length of pipe in feet,
V is the velocity of flow in foot-pounds per second,
D is the diameter in feet.

In calculating the total head to be pumped against, it is common to consider this value as being equal to the sum of the friction head and the actual head.

$$\text{Horsepower of waterfall} = \frac{62 \times A \times V \times H}{33{,}000}$$

where,
A is the cross section of water in square feet,
V is the velocity of flow in foot-pounds per minute,
H is the head of fall in feet.

86. MISCELLANEOUS

(A) Falling Object

The speed acquired by a falling object is determined by the formula:

$$V = 32t$$

where,
V is the velocity in feet per second,
t is the time in seconds.

The distance traveled by a falling object is determined by the formula:

$$d = 16t^2$$

where,
d is the distance traveled in feet,
t is the time in seconds.

(B) Speed of Sound

The speed of sound through air at 0°C. is usually considered to be 1087.42 feet per second, and at normal temperature, 1130 feet per second. The speed of sound through any given temperature of air is determined by the formula:

$$V = \frac{1087\sqrt{(273 + t)}}{16.52}$$

where,
V is the speed in feet per second,
t is the temperature in degrees Celsius.

(C) Cost of Operation

The cost per hour of operation of an electrical device is determined by the formula:

$$C = \frac{Wtc}{1000}$$

where,
C is the cost per hour of operation,
W is the wattage of the device,
t is the time in hours,
c is the cost per kilowatt hour of electricity.

(D) Conversion of Matter Into Energy

The conversion of matter into energy (Einstein's theorem) is expressed by:

$$E = mc^2$$

where,
E is the energy in ergs,
m is the mass of the matter in grams,
c is the speed of light in centimeters per second ($c^2 = 9.10^{20}$).

FCC ALLOCATION CHART

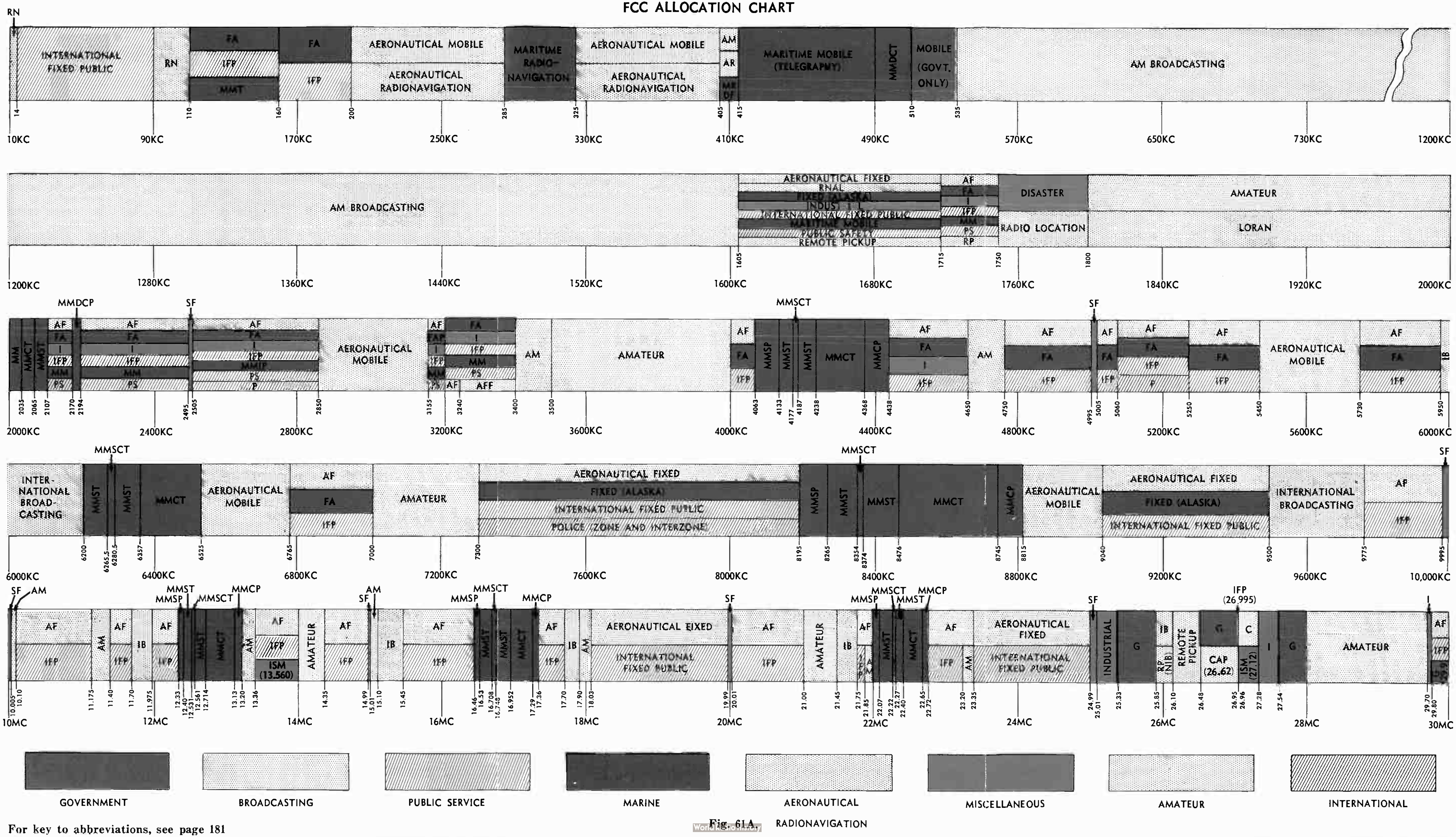


Fig. 61A.

For key to abbreviations, see page 181

FCC ALLOCATION CHART—(Cont'd)

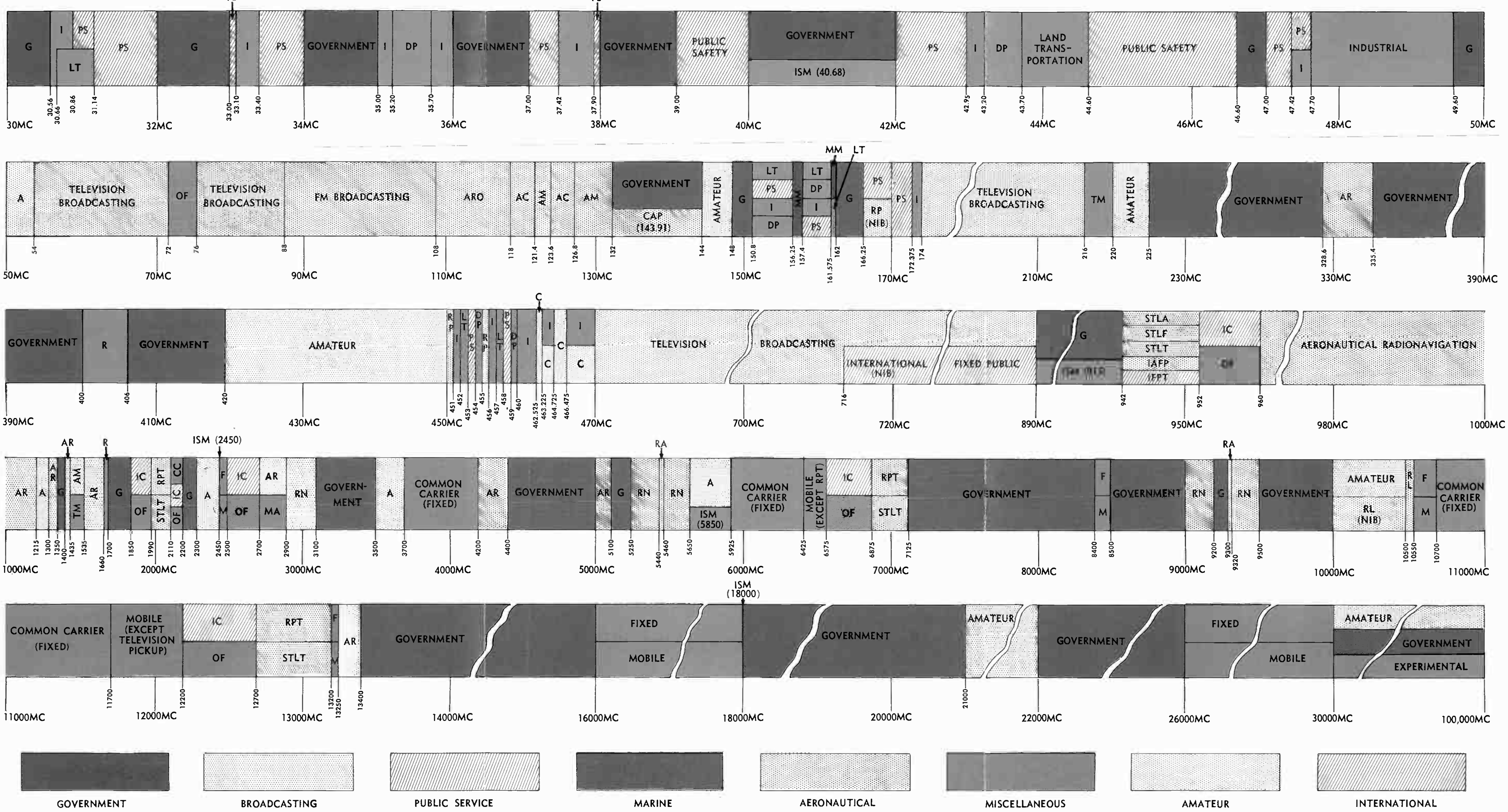


Fig. 61B

For key to abbreviations, see page 181

Key to Abbreviations for FCC Allocation Chart

A—Amateur

AC—Airdrome Control

AF—Aeronautical Fixed

AFF—Aviation (Flight Test and Aeronautical Fixed Only)

AM—Aeronautical Mobile

AR—Aeronautical Radionavigation

ARO—Aeronautical Radionavigation (Omnidirectional Radio Range)

C—Citizens Radio

CC—Common Carrier

CAP—Civil Air Patrol (Land and Mobile)

DP—Domestic Public

F—Fixed

FA—Fixed (Alaska)

FAP—Fixed (Alaska and Puerto Rico)

G—Government

I—Industrial

IAF—International Aeronautical Fixed

IAFP—International Aeronautical Fixed (Alaska, Hawaii, and U.S. Possessions)

IB—International Broadcasting

IC—International Control

IFP—International Fixed Public

IFPT—International Fixed Public (Puerto Rico and Virgin Islands)

ISM—Industrial, Scientific, and Medical Equipment

LT—Land Transportation

M—Mobile

MA—Meteorological Aids

MM—Maritime Mobile

MMCP—Maritime Mobile Coastal Telephony

MMCT—Maritime Mobile Coastal Telegraphy

MMDCP—Maritime Mobile Distress and Calling (Telephony)

MMDCT—Maritime Mobile Distress and Calling (Telegraphy)

MMIP—Maritime Mobile (Intership Telephony)

MMSCP—Maritime Mobile Ship Calling (Telephony)

MMSCT—Maritime Mobile Ship Calling (Telegraphy)

MMSP—Maritime Mobile Ship (Telephony)

MMST—Maritime Mobile Ship (Telegraphy)

MMT—Maritime Mobile (Telegraphy)

MRDF—Maritime Radionavigation (Radio Direction Finding)

(NIB)—Noninterference Basis

OF—Operational Fixed

P—Police

PS—Public Safety

R—Radiosonde

RA—Racon

RL—Radiolocation

RN—Radionavigation

RNAL—Radionavigation (Aeronautical and Land)

RP—Remote Pickup

RPT—Remote Pickup (Television)

SF—Standard Frequency

STLA—Studio Transmitter Link (AM Broadcast)

STLF—Studio Transmitter Link (FM Broadcast)

STLT—Studio Transmitter Link (Television)

TM—Telemetering

Allocations Shown Are Current Through November, 1961.

INDEX

C

G

H

I

J

K

L

T

U

V

W

X

Y

Z