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ELECTRONICS

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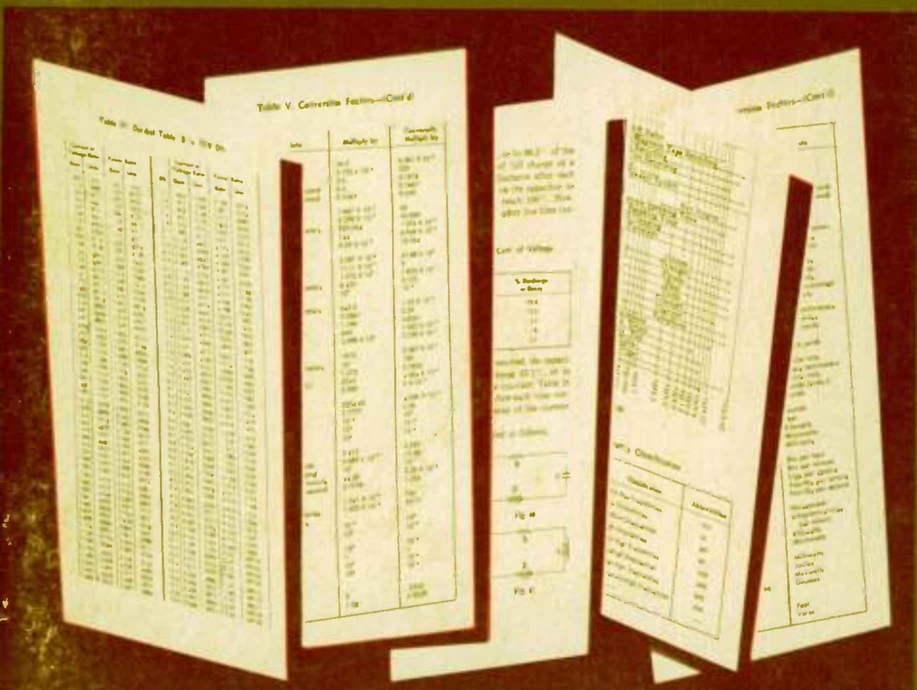

Electronics Data Book

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PREFACE

The electronics industry is constantly expanding. As more and more people become involved in electronics, a condensed book of basic data is a necessity. It is to fill this need that this book has been compiled.

Section 1 contains the basic formulas and laws that are pertinent to the different branches of electronics. These include Ohm's laws, Kirchhoff's laws, resistance and capacitance formulas, impedance formulas, handy nomographs, and other valuable information.

Section 2 is comprised of mathematics data and formulas. This section includes such items as mathematical constants, symbols, algebraic operations, and related information.

Section 3 contains data used in the communications branch of the electronics field. Information includes television standards, items concerning the ham-, commercial- and CB-radio bands, etc.

Section 4 has miscellaneous data associated or used with electronics. It encompasses a myriad of valuable information. A small sampling of the information includes dielectric constants of materials, metric prefixes, resistor and capacitor color codes, and miniature lamp data.

Every effort has been made to make this book a valuable source of information and reference for any one associated with the many branches of electronics.

RADIO SHACK

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Section 1. Electronics Formulas and Laws

Section 2. Mathematics Data and Formulas

Section 3. Communications Data

Section 4. Miscellaneous Data

SECTION 1

ELECTRONICS FORMULAS AND LAWS

OHM'S LAW FOR DIRECT CURRENT

All substances offer some resistance to the flow of current. Ohm's law states that the current in a closed circuit (Fig. 1) is directly proportional to the applied voltage and inversely proportional to the resistance. Thus:

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

$$E = IR$$

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

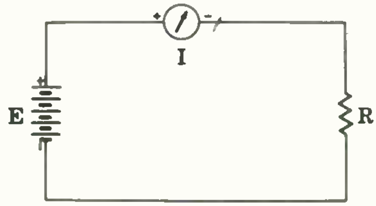


Fig. 1.

where,

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

DC POWER FORMULAS

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

Using the nomograph in Fig. 2 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.

RESISTANCE FORMULAS

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

Ohm's Law Nomograph

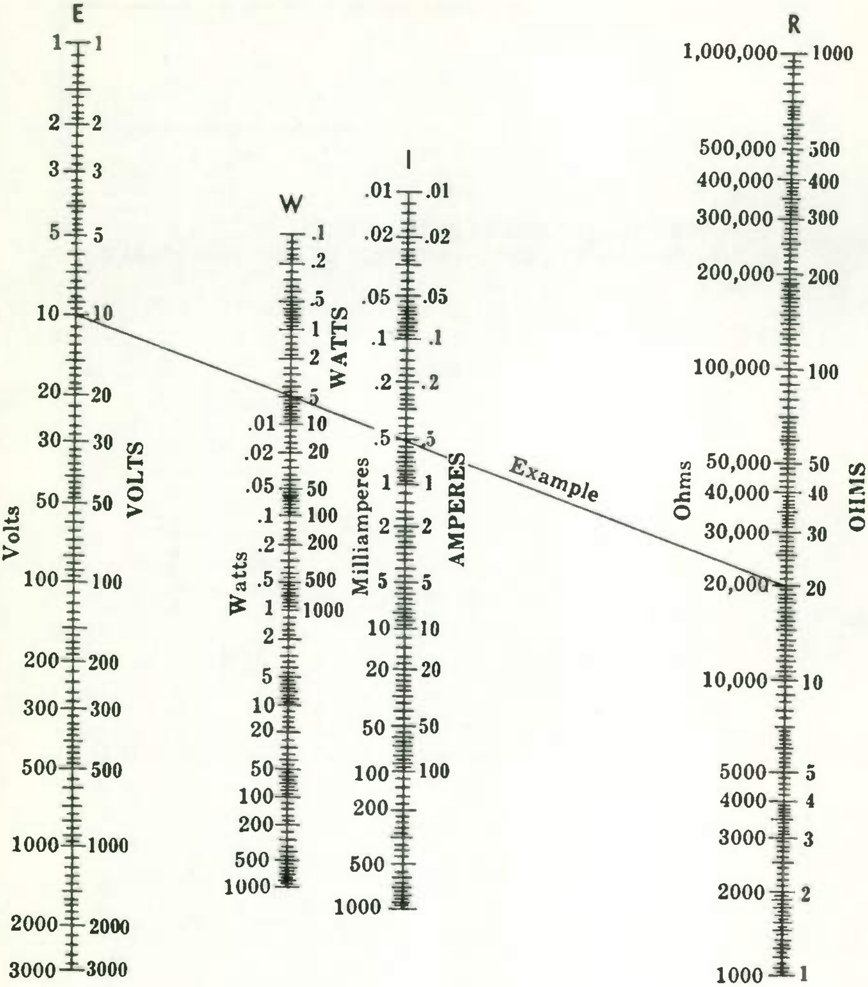


Fig. 2.

Resistors in series (Fig. 3)

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

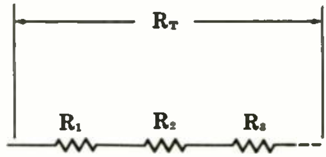


Fig. 3.

where,

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

Resistors in parallel (Fig. 4)

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

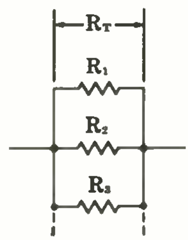


Fig. 4.

where,

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

Two resistors in parallel (Fig. 5)

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

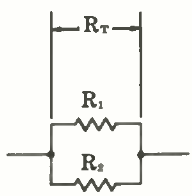


Fig. 5.

where,

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

PARALLEL RESISTANCE NOMOGRAPH

The equivalent value of resistors in parallel can be solved with the nomograph given in Fig. 6. Place a straightedge across the points on scales R_1 and R_2 corresponding to the values of the known resistors. The point at which the straightedge crosses the R_T scale will show the equivalent resistance of the two resistors in parallel. If three resistors are in parallel, first find the equivalent resistance of two of

Parallel Resistance Nomograph

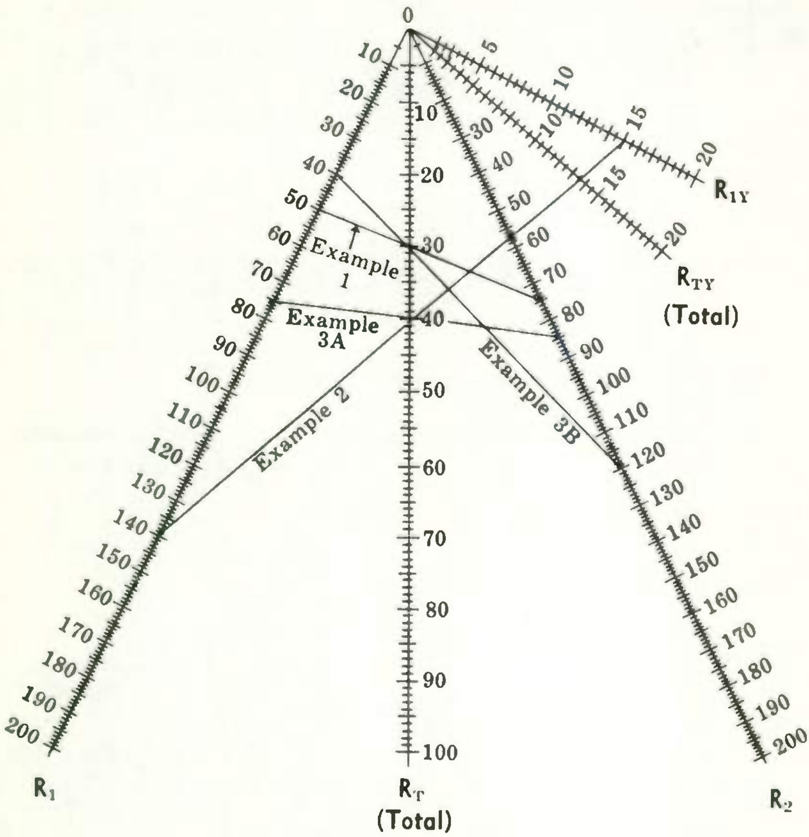


Fig. 6.

the resistors, then consider this value as being in parallel with the remaining resistor.

If the total resistance 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 known total resistance.

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, 1000, or more, as required.

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 1500-ohm and a 14,000-ohm resistor in parallel?

Answer—1355 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.)

KIRCHHOFF'S LAWS

Kirchhoff's voltage law states: "The sum of the voltage drops around a dc series circuit (Fig. 7) equals the source or applied voltage. In other words, disregarding losses due to the wire resistance:

$$E_T = E_1 + E_2 + E_3$$

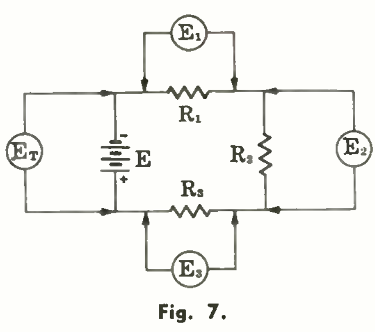


Fig. 7.

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 (Fig. 8), the sum of the currents through the individual paths must equal the current flowing to the point where the circuit branches, or:

$$I_T = I_1 + I_2 + I_3$$

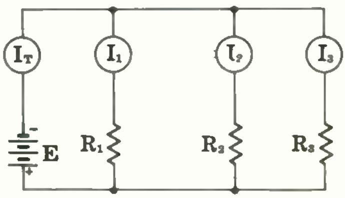


Fig. 8.

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 (Fig. 9) the relationships are as follows:

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

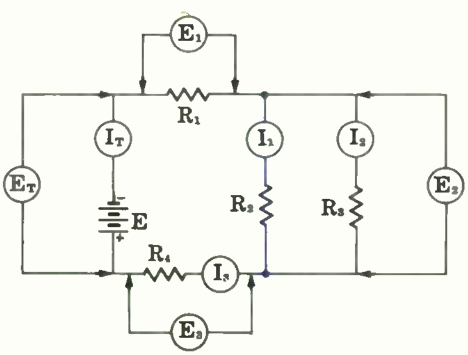


Fig. 9.

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

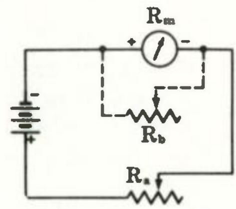


Fig. 10.

Voltage Multipliers (Fig. 11)

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

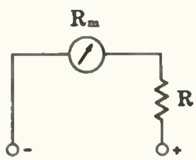


Fig. 11.

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.

Shunt-Type Ohmmeter for Low Resistance (Fig. 12)

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

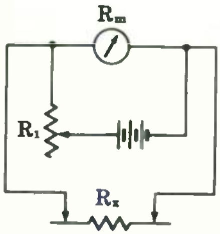


Fig. 12.

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.

Series-Type Ohmmeter for High Resistance (Fig. 13)

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

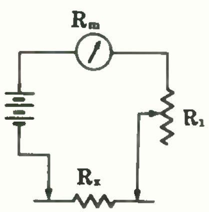


Fig. 13.

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.

Ammeter Shunts (Fig. 14)

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

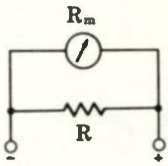


Fig. 14.

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.

Ammeter With Multirange Shunt (Fig. 15)

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

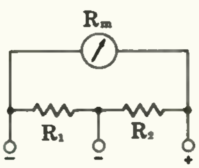


Fig. 15.

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.

CAPACITANCE FORMULAS

Total Capacitance

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

Capacitors in parallel (Fig. 16)

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

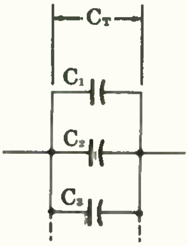


Fig. 16.

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 capacitance of a parallel-plate capacitor is determined by:

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

where,
C is the capacitance in picofarads,
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.

Capacitors in series (Fig. 17)

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

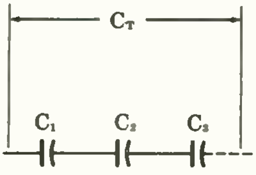


Fig. 17.

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

Two capacitors in series (Fig. 18)

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

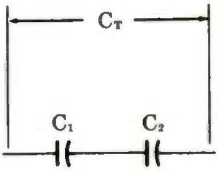


Fig. 18.

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.

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.

Voltage Across Series Capacitors

When an ac voltage is applied across a group of capacitors connected in series (Fig. 19), the voltage drop across the combination is 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:

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

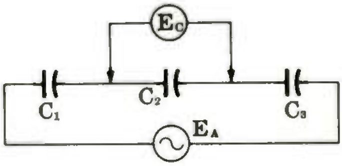


Fig. 19.

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.

INDUCTANCE FORMULAS

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

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

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

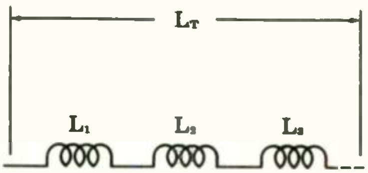


Fig. 20.

where,

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

Inductors in parallel (with no mutual inductance) (Fig. 21)

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

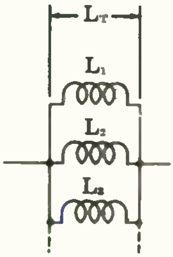


Fig. 21.

where,

L_T is the total inductance of the circuit,

L_1, L_2, and L_3 are the inductances of the individual coils.

Two inductors in parallel (with no mutual inductance) (Fig. 22)

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

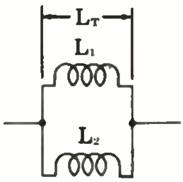


Fig. 22.

where,

L_T is the total inductance of the circuit,

L_1, L_2, and L_3 are the inductances of the individual coils.

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 the two coils with fields aiding,

L_B is the total inductance of the two coils with fields opposing.

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.

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.

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 henrys,
I is the current in amperes.

REACTANCE FORMULAS

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

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 hertz,
C is the capacitance in farads.

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 hertz,
L is the inductance in henrys.

RESONANCE FORMULA

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 hertz,
L is the inductance in henrys,
C is the capacitance in farads.

REACTANCE AND RESONANCE CHARTS

Charts for determining unknown values of reactance, inductance, capacitance, and frequency are given in Figs. 23A, 23B, and 23C.

To find the 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.

Reactance Chart—1 Hz to 1 kHz

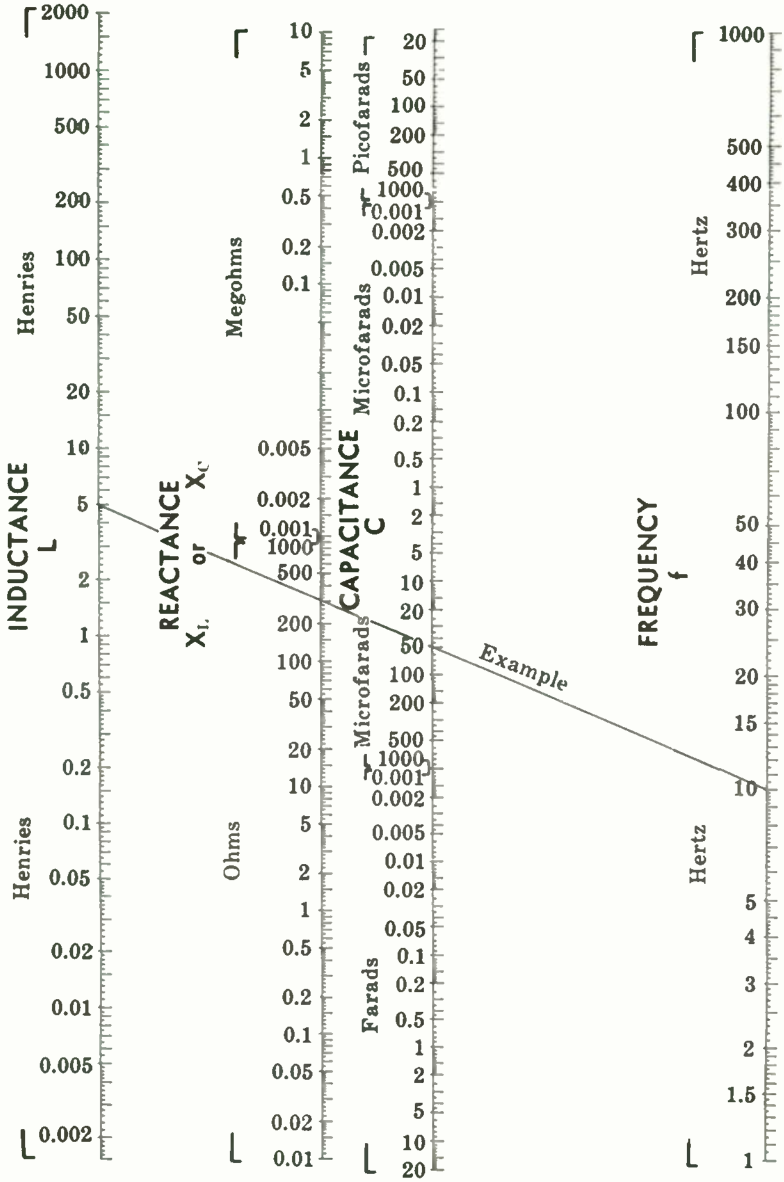


Fig. 23A.

Reactance Chart—1 kHz to 1 MHz

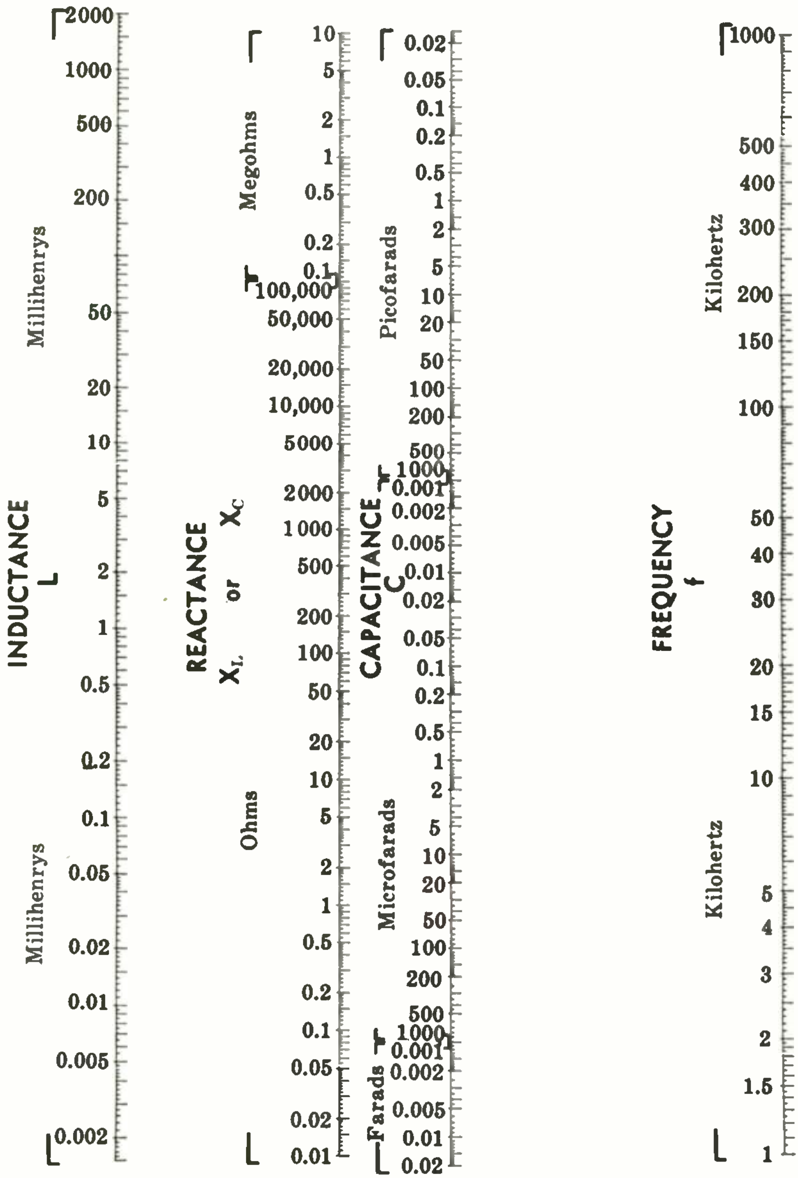


Fig. 23B.

Reactance Chart—1 MHz to 1000 MHz

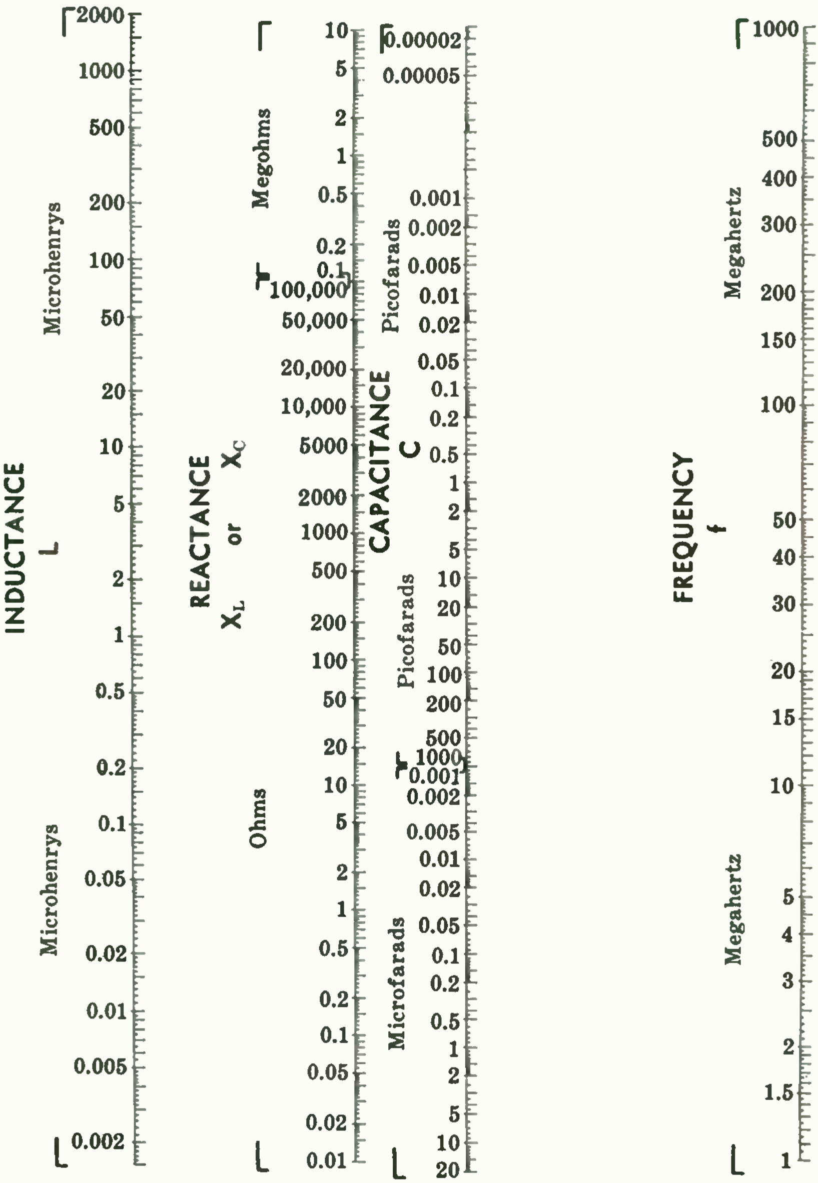


Fig. 23C.

Example—If the frequency is 10 hertz and the capacitance is 50 μF, 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 henrys. Thus, it follows that a 50-μF capacitor and a 5-henry choke are resonant at 10 hertz. [Place the straightedge, on the proper chart (Fig. 23A), across 10 hertz and 50 μF. Read the values indicated on the reactance and inductance scales.]

IMPEDANCE FORMULAS

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

Parallel circuits

$$Z = \frac{1}{\sqrt{G^2 + B^2}} \quad \text{or} \quad Z = \frac{RX}{\sqrt{R^2 + X^2}}$$

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.

A single resistance (Fig. 24)

$$Z = R$$
$$\theta = 0°$$

Fig. 24.

Resistances in series (Fig. 25)

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

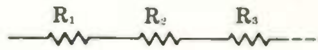


Fig. 25.

A single inductance (Fig. 26)

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

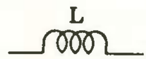


Fig. 26.

Inductances in series (with no mutual inductance) (Fig. 27)

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

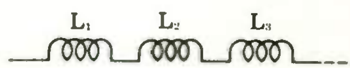


Fig. 27.

A single capacitance (Fig. 28)

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

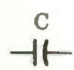


Fig. 28.

Capacitances in series (Fig. 29)

$$Z = X_{C_1} + X_{C_2} + X_{C_3} + \dots$$
$$\theta = 90^\circ$$

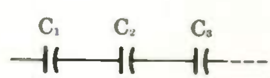


Fig. 29.

Resistance and inductance in series (Fig. 30)

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

Fig. 30.

Resistance and capacitance in series (Fig. 31)

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

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

Fig. 31.

Inductance and capacitance in series (Fig. 32)

When X_L is larger than X_C

$$Z = X_L - X_C$$

When X_C is larger than X_L

$$Z = X_C - X_L$$

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

Fig. 32.

Resistance, inductance, and capacitance in series (Fig. 33)

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

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

Fig. 33.

Resistances in parallel (Fig. 34)

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

$$\theta = 0°$$

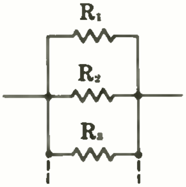


Fig. 34.

Inductances in parallel (with no mutual inductance) (Fig. 35)

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

$$\theta = 90°$$

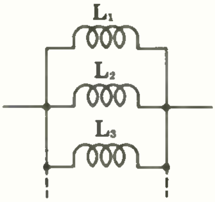


Fig. 35.

Capacitances in parallel (Fig. 36)

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

$$\theta = 90°$$

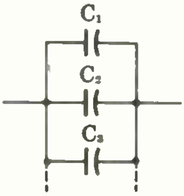


Fig. 36.

Resistance and inductance in parallel (Fig. 37)

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

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

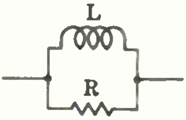


Fig. 37.

Capacitance and resistance in parallel (Fig. 38)

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

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

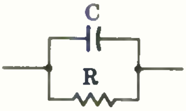


Fig. 38.

Capacitance and inductance in parallel (Fig. 39)

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:

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

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

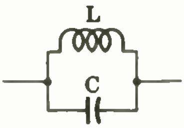


Fig. 39.

Inductance, capacitance, and resistance in parallel (Fig. 40)

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

$$\theta = \frac{R(X_L - X_C)}{X_L X_C}$$

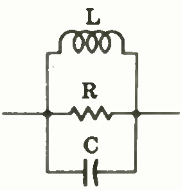


Fig. 40.

Inductance and series resistance in parallel with resistance (Fig. 41)

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

$$\theta = \text{arc tan } \frac{X_L R_2}{R_1^2 + X_L^2 + R_1 R_2}$$

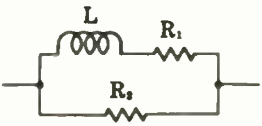


Fig. 41

Inductance and series resistance in parallel with capacitance (Fig. 42)

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

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

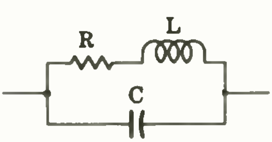


Fig. 42.

Capacitance and series resistance in parallel with inductance and series resistance (Fig. 43)

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

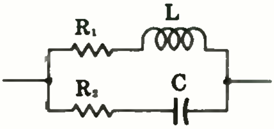


Fig. 43.

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

where,

Z is the impedance in ohms,
R is the resistance in ohms,
L is the inductance in henrys,
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.

OHM'S LAW FOR ALTERNATING CURRENT

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

$$E = IZ$$

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

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

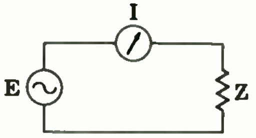


Fig. 44.

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:

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

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

Table 1 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.

Table 1. 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	—

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

Answer—.707.

VACUUM-TUBE FORMULAS

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

Amplification factor

$$\mu = \frac{\Delta E_b}{\Delta E_c} \text{(with } I_b \text{ constant)}$$

Ac (dynamic) plate resistance

$$r_p = \frac{\Delta E_b}{\Delta I_b} \text{(with } E_c \text{ constant)}$$

Mutual conductance (transconductance)

$$g_m = \frac{\Delta I_b}{\Delta E_c} \text{(with } E_b \text{ constant)}$$

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_b is the plate voltage in volts,
E_c is the grid voltage in volts,
I_b 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.

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.

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:

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

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

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

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

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

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

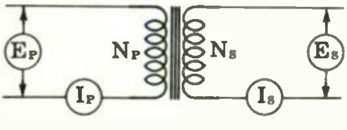


Fig. 45.

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

A step-up transformer

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

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 formulas:

A step-up transformer

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

$$Z_s = Z \times Z_p$$

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.

FREQUENCY AND WAVELENGTH FORMULAS

Since frequency is defined as the number of complete hertz (cycles per second) and since all radio waves travel at a constant 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 kilohertz,
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 kilohertz,
λ is the wavelength in feet.

The preceding formula can be used to determine the length of a single-wire antenna.

For a half-wave antenna:

$$L = \frac{492}{f}$$

For a quarter-wave antenna:

$$L = \frac{246}{f}$$

where,

L is the antenna length in feet,
f is the frequency in megahertz.

FREQUENCY-TO-WAVELENGTH CONVERSION

The wavelength of any frequency from 30 kHz to 3000 MHz can be read directly from the chart in Fig. 46. Also, 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 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-MHz signal?

Answer—75 meters. (Find 4 MHz on the third scale from the left. Opposite 4 MHz on the frequency scale we find 75 meters on the wavelength scale.)

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.

Coaxial Line

The characteristic impedance of a coaxial line (Fig. 47) is given by:

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

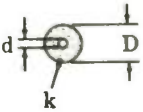


Fig. 47.

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).

Frequency-Wavelength Conversion Chart

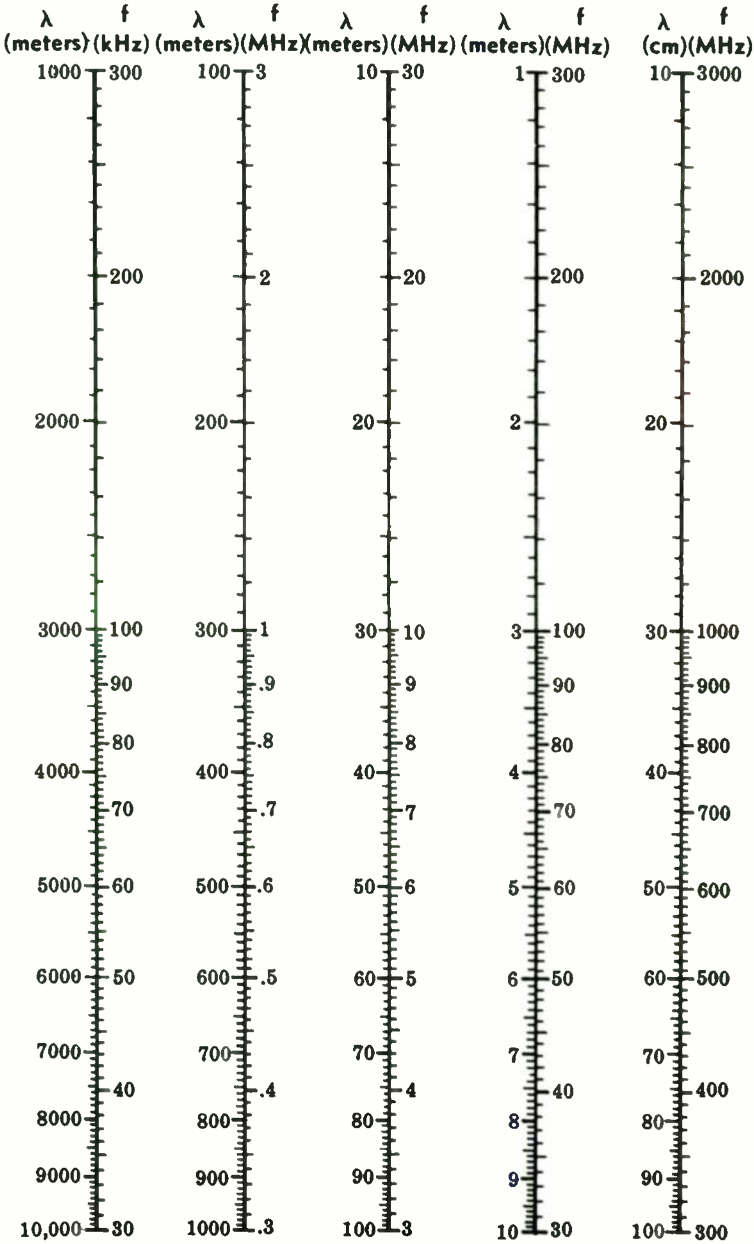


Fig. 46.

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 megahertz,
D is the inside diameter of the outer conductor in inches,
d is the outside diameter of the inner conductor in inches.

Parallel-Conductor Line

The characteristic impedance of parallel-conductor line (Fig. 48) (twin-lead) is determined by the formula:

$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{2D}{d}$$

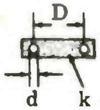


Fig. 48.

where,

Z_0 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).

COIL-WINDING FORMULAS

The following formulas can be used to calculate the inductance of coil windings.

Single-Layer Coils

The inductance of single-layer coils (Fig. 49) can be calculated to an accuracy of approximately 1% with the formula:

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

Fig. 49.

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 microhenrys,
N is the number of turns,
A is the mean radius in inches,
B is the length of the coil in inches.

Multilayer Coils

The inductance of a multilayer coil (Fig. 50) of rectangular cross section can be computed from the formula:

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

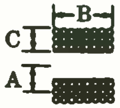


Fig. 50.

where,

L is the inductance in microhenrys,
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.

SINGLE-LAYER COIL CHART

The chart in Fig. 51 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 microhenrys) of the coil. The number of turns can be determined by reversing the procedure.

Single-Layer Coil Chart

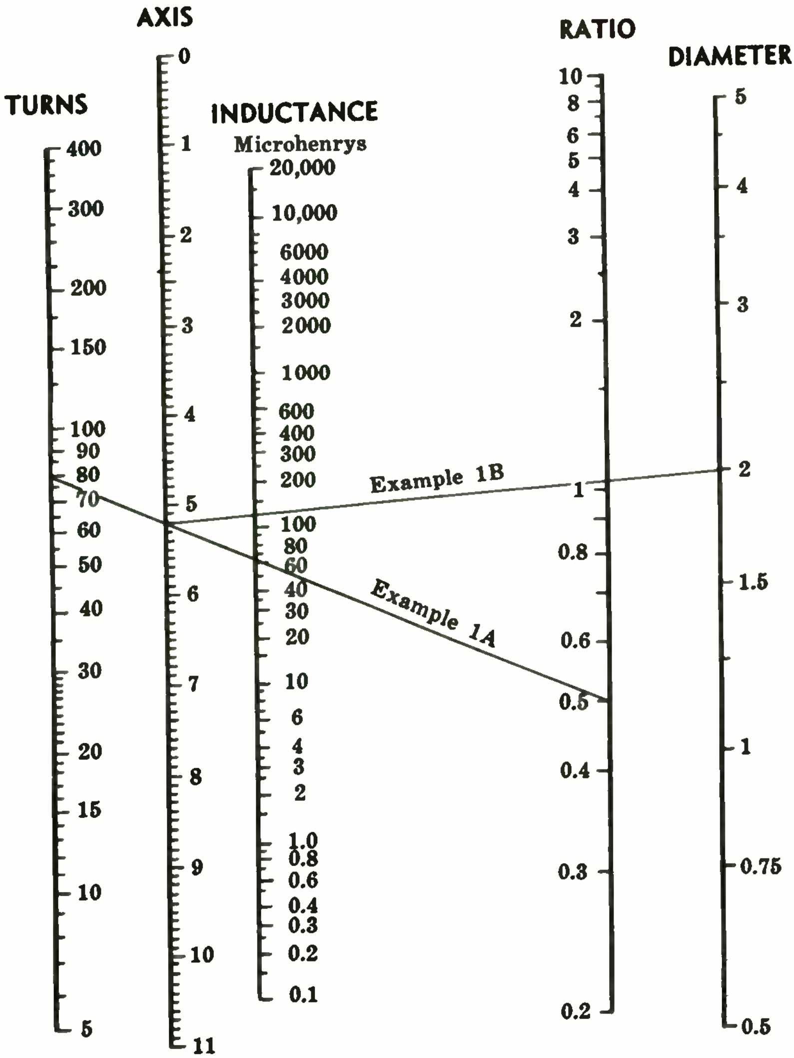


Fig. 51.

After finding the number of turns, consult a wire table 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 microhenrys. (First lay the straightedge as indicated by the line labeled "Example 1A." Then lay the straightedge as indicated by the line labeled "Example 1B.")

TIME-CONSTANT FORMULAS

A certain amount of time is required, after a dc voltage has been applied to an rc or rl 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 2 gives the percent 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.

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 2 also gives the percent of full voltage after each time constant for discharge of a capacitor or decay of the current through a coil.

Table 2. Time Constants Versus Percent 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

The time per time constant is calculated as follows.

For an RC circuit (Fig. 52):

T = RC

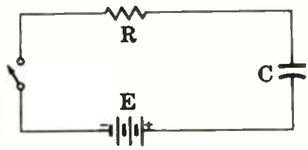


Fig. 52.

For an RL circuit (Fig. 53):

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

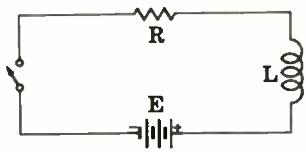


Fig. 53.

where,

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

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

T	*R*	*C or L*
seconds	megohms	microfarads
seconds	megohms	microhenrys
microseconds	ohms	microfarads
microseconds	megohms	picofarads
microseconds	ohms	microhenrys

DECIBEL FORMULAS

The number of decibels (dB) 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 decibles 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:

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

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

DECIBEL 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 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} watt
VU—1 milliwatt, 600 ohms (complex waveforms varying in both amplitude and frequency).

DECIBEL TABLE

The decibel table shown in Table 3 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

Table 3. Decibel Table (0 to 10.9 db)

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

Table 3. Decibel Table—cont (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 3. Decibel Table—cont (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}

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.]

SECTION 2

MATHEMATICS DATA AND FORMULAS

MATHEMATICAL CONSTANTS

$\pi = 3.1416$	$(2\pi)^2 = 39.4786$
$\pi^2 = 9.8696$	$4\pi = 12.5664$
$\pi^3 = 31.0063$	$\frac{\pi}{2} = 1.5708$
$\frac{1}{\pi} = 0.3183$	$\sqrt{\frac{\pi}{2}} = 1.2533$
$\frac{1}{\pi^2} = 0.1013$	$\sqrt{2} = 1.4142$
$\frac{1}{\pi^3} = 0.0323$	$\sqrt{3} = 1.7321$
$\sqrt{\pi} = 1.7725$	$\frac{1}{\sqrt{2}} = 0.7271$
$\frac{1}{\sqrt{\pi}} = 0.5642$	$\frac{1}{\sqrt{3}} = 0.5773$
$\frac{1}{2\pi} = 0.1592$	$\log \pi = 0.4971$
$\left(\frac{1}{2\pi}\right)^2 = 0.0253$	$\log \pi^2 = 0.9943$
$2\pi = 6.2832$	$\log \sqrt{\pi} = 0.2486$
	$\log \frac{\pi}{2} = 0.1961$

MATHEMATICAL SYMBOLS

$\times$ or $\cdot$	Multiplied by.	$+$	Positive, add, and plus.
$\div$	Divided by.	$-$	Negative, subtract, and minus.
$=$	Equals.	$>$	Is greater than.
$\neq$	Does not equal.	$\geqq$	Equal to or greater than.
$<$	Is less than.	$\leqq$	Equal to or less than.
$\pm$	Plus or minus.	$\perp$	Perpendicular to.
$\equiv$	Identical with.	$\vert n \vert$	Absolute value of n.
$\therefore$	Therefore.	$\cong$	Is approximately equal to.
$\vert\vert$	Parallel to.	$\sqrt{\ }$	Square root.
$\angle$	Angle.		
$\ll$	Is much less than.		
$\gg$	Is much greater than.		

FRACTIONAL INCH, DECIMAL, AND MILLIMETER EQUIVALENTS

Table 4 gives the decimal inch and millimeter equivalents of fractional parts of an inch by 64ths, to four significant figures.

Table 4. Fractional Inch, Decimal, and Millimeter Equivalents

Fractional Inch	Decimal Inch	Millimeter Equivalent	Fractional Inch	Decimal Inch	Millimeter Equivalent
1/64	0.0156	0.397	19/64	0.2969	7.541
1/32	0.0313	0.794	5/16	0.3125	7.938
3/64	0.0469	1.191	21/64	0.3281	8.334
1/16	0.0625	1.588	11/32	0.3438	8.731
5/64	0.0781	1.984	23/64	0.3594	9.128
3/32	0.0938	2.381	3/8	0.3750	9.525
7/64	0.1094	2.778	25/64	0.3906	9.922
1/8	0.1250	3.175	13/32	0.4063	10.319
9/64	0.1406	3.572	27/64	0.4219	10.716
5/32	0.1563	3.969	29/64	0.4375	11.113
11/64	0.1719	4.366	7/16	0.4531	11.509
3/16	0.1875	4.763	15/32	0.4688	11.906
13/64	0.2031	5.159	31/64	0.4844	12.303
7/32	0.2188	5.556	1/2	0.5000	12.700
15/64	0.2344	5.953	33/64	0.5156	13.097
1/4	0.2500	6.350	17/32	0.5313	13.494
17/64	0.2656	6.747	35/64	0.5469	13.891
9/32	0.2813	7.144	9/16	0.5625	14.288

Table 4. Fractional Inch, Decimal, and Millimeter Equivalents—cont

Fractional Inch	Decimal Inch	Millimeter Equivalent	Fractional Inch	Decimal Inch	Millimeter Equivalent
37/64	0.5781	14.684	51/64	0.7969	20.241
19/32	0.5938	15.081	13/16	0.8125	20.638
39/64	0.6094	15.478	53/64	0.8281	21.034
5/8	0.6250	15.875	27/32	0.8438	21.431
41/64	0.6406	16.272	55/64	0.8594	21.828
21/32	0.6563	16.669	7/8	0.8750	22.225
43/64	0.6719	17.066	57/64	0.8906	22.622
11/16	0.6875	17.463	29/32	0.9063	23.019
45/64	0.7031	17.859	59/64	0.9219	23.416
23/32	0.7188	18.256	15/16	0.9375	23.813
47/64	0.7344	18.653	61/64	0.9531	24.209
3/4	0.7500	19.050	31/32	0.9688	24.606
49/64	0.7656	19.447	63/64	0.9844	25.003
25/32	0.7813	19.844	1	1.000	25.400

POWERS OF TEN

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:

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

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:

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

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

Multiplication

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

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

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

Division

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

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

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

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:

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

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:

$$\text{Reciprocal of } 400 = \frac{1}{400}$$
$$\frac{1}{400} = \frac{1}{.4 \times 10^3}$$
$$= 2.5 \times 10^{-3}$$
$$= .0025$$
$$\text{Reciprocal of } .0025 = \frac{1}{.0025}$$
$$\frac{1}{.0025} = \frac{1}{.25 \times 10^{-2}}$$
$$= 4 \times 10^2$$
$$= 400$$

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:

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

ALGEBRAIC OPERATIONS

Transposition of Terms

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

Quadratic Equation

The general quadratic equation:

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

may be solved by:

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

GEOMETRIC FORMULAS

Triangle

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

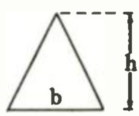


Fig. 54.

Square

area (A) $= b^2$

Fig. 55

Rectangle

area (A) $= ab$

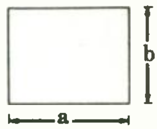


Fig. 56.

Parallelogram

area (A) $= ah$

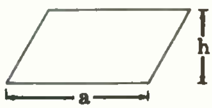


Fig. 57.

Trapezoid

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

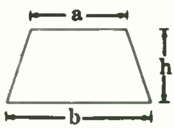


Fig. 58.

Trapezium

area (A) $= \frac{1}{2}[b(H + h) + ah + cH]$

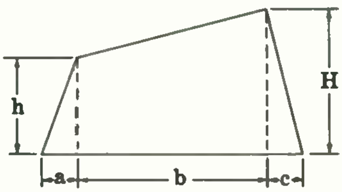


Fig. 59.

Regular Pentagon

area (A) = $1.720\ a^2$

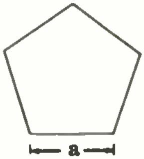


Fig. 60.

Regular Hexagon

area (A = $2.598\ a^2$

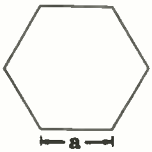


Fig. 61.

Regular Octagon

area (A) = $4.828\ a^2$

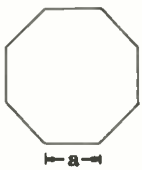


Fig. 62.

Circle

circumference (C) $= 2\pi R$

$= \pi D$

area (A) $= \pi R^2$

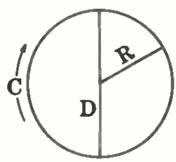


Fig. 63.

Segment

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

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

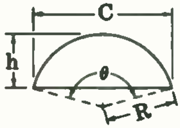


Fig. 64.

Sector

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

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

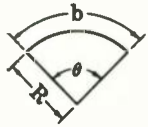


Fig. 65.

Circular Ring

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

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

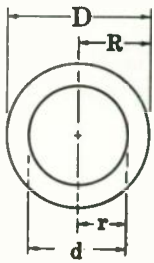


Fig. 66.

Ellipse

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

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

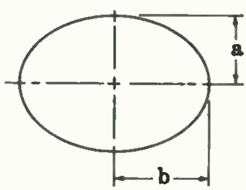


Fig. 67.

Sphere

$$\text{area (A)} = 4\pi R^2 = \pi D^2$$

$$\text{volume (V)} = \frac{4}{3}\pi R^3 = 1/6\pi D^3$$

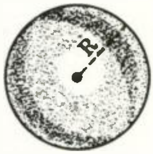


Fig. 68.

Cube

$$\text{area (A)} = 6b^2$$
$$\text{volume (V)} = b^3$$

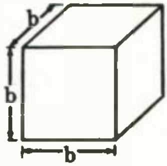


Fig. 69.

Rectangular Solid

$$\text{area (A)} = 2\,(ab + bc + ac)$$
$$\text{volume (V)} = abc$$

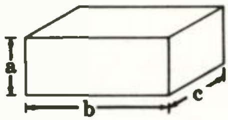


Fig. 70.

Cone

$$\text{area (A)} = \pi RS = \pi R\sqrt{R^2 + h^2}$$

$$\text{volume (V)} = \frac{\pi R^2 h}{3} = 1.047R^2h = 0.2618D^2h$$

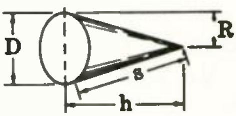


Fig. 71.

Cylinder

$$\text{cylindrical surface} = \pi Dh$$
$$\text{total surface} = 2\pi R\,(R + h)$$
$$\text{volume (V)} = \pi R^2 h = \frac{c^2 h}{4\pi}$$

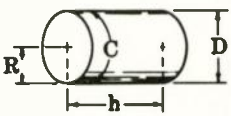


Fig. 72.

Ring of Rectangular Cross Section

$$\text{volume (V)} = \frac{\pi c}{4}(D^2 - d^2)$$
$$= \left(\frac{D + d}{2}\right)\pi bc$$

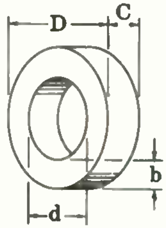


Fig. 73.

Torus (Ring of Circular Cross Section)

$$\text{total surface} = 4\pi^2 Rr$$
$$= \pi^2 Dd$$
$$\text{volume (V)} = 2\pi^2 R \times r^2$$
$$= 2.463D \times d^2$$

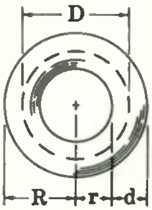


Fig. 74.

SECTION 3

COMMUNICATIONS DATA

TELEVISION SIGNAL STANDARDS

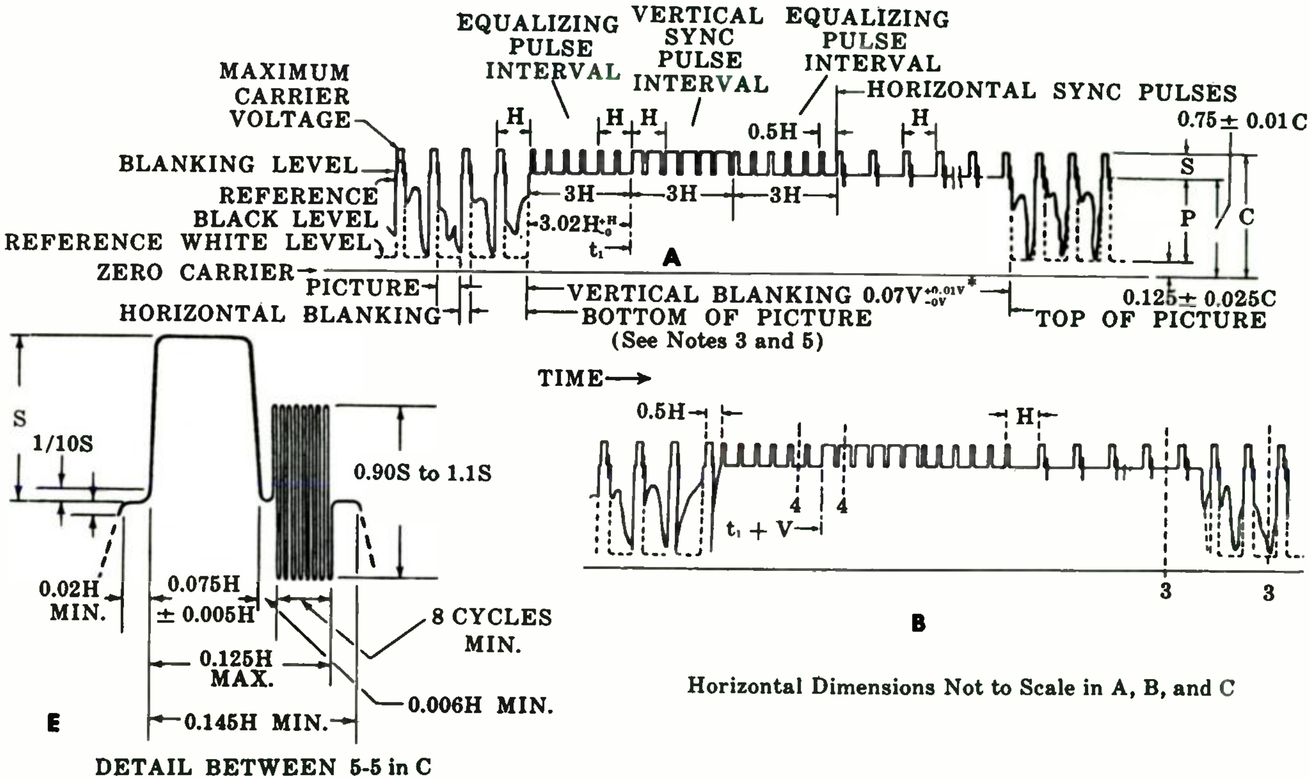
The signal standards for television broadcasting are given in Figs. 75A and B. Note: The standards given here are for color transmission. For monochrome transmission, the standards are the same except the color burst signal is omitted. Also, for color the vertical and horizontal scanning frequencies are 59.94 and 15,734.264 Hz, respectively; for monochrome they are 60 and 15,750 Hz.

TELEVISION CHANNEL FREQUENCIES

The chart in Fig. 76 lists the frequency limits of all television channels and the frequency of the picture and sound carriers of each channel.

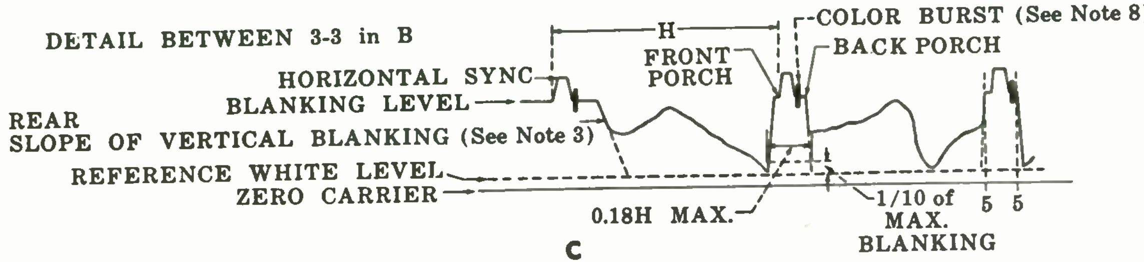
CITIZENS BAND RADIO

Most Citizens band radio stations are covered by a Class-D license. Class-D stations may operate on any of the 23 channels listed in Table 5.



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

Fig. 75A.



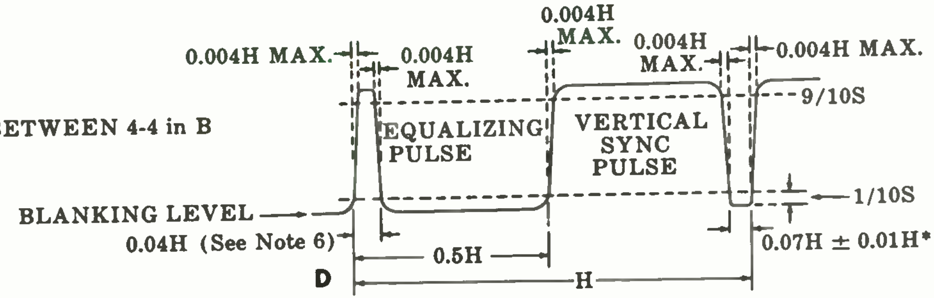


Fig. 75B.

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 MHz. The tolerance on the frequency shall be ±0.0003% with a maximum rate of change of frequency not to exceed 1/10 Hz 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.

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 MHz.

Fig. 76.

Table 5. Class-D CB Radio Channels

Channel Number	Frequency (MHz)	Channel Number	Frequency (MHz)
1	26.965	13*	27.115
2	26.975	14*	27.125
3	26.985	15*	27.135
4	27.005	16	27.155
5	27.015	17	27.165
6	27.025	18	27.175
7	27.035	19	27.185
8	27.055	20	27.205
9**	27.065	21	27.215
10*	27.075	22	27.225
11*	27.085	23*	27.255
12*	27.105		

*May be used for interstation communications.
**Emergency only.

COMMERCIAL OPERATOR LICENSES

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

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.

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.

AMATEUR OPERATOR PRIVILEGES

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 Law.* Rules and regulations essential to beginners' operation, including sufficient elementary radio theory to understand these rules.

Element 3: *General Regulations.* Amateur radio operation and apparatus, including radiotelephone and radiotelegraph. Provisions of treaties, statutes, and rules and regulations affecting all amateur stations and operators.

Element 4(A): *Intermediate Amateur Practice.* Involving intermediate level for general amateur practice in radio theory and operation as applicable to modern amateur techniques, including—but not limited to—radiotelephony and radiotelegraphy.

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.

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). Two years experience in amateur radio not including Novice Class or Technician Class.
2. *Advanced Class.* Elements 1(B), 3, and 4(A).
3. *General Class.* Elements 1(B) and 3.
4. *Conditional Class.* Elements 1(B) and 3.
5. *Technician Class.* Elements 1(A) and 3.
6. *Novice Class.* Elements 1(A) and 2.

NOTE: Examinations for licenses (1), (2), and (3) above must be given by an FCC examiner. The examinations for licenses (4), (5), and (6) are taken by mail, under the supervision of a volunteer examiner.

AMATEUR ("HAM") BAND

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 6. (Note: Frequencies between 220 and 225

Table 6. "Ham" Bands

Band	Frequency (MHz)
160 Meters	1.8–2.0
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

MHz are sometimes referred to as 1¼ meters, and between 420 and 450 MHz as ¾ meter.)

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 com-

Table 7. Q Signals

Signal	Question	Answer or Advice
QRG	Will you tell me my exact frequency?	Your exact frequency is . . . . kHz (or MHz).
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 . . . . kHz (or MHz)].
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 . . kHz(or MHz)].
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTH	What is your location?	My location is . . . . .

munications 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 7.

"10" SIGNALS

The abbreviations based on the number *10* plus a suffix were originally used for communication between police

Table 8. Official National CB 10-code

Signal	Meaning	Signal	Meaning
10-1	Receiving poorly	10-39	Your message delivered
10-2	Receiving well	10-41	Please tune to channel . . .
10-3	Stop transmitting	10-42	Traffic accident at . . .
10-4	OK, message received	10-43	Traffic tieup at . . .
10-5	Relay message	10-44	I have a message for you (or . . .)
10-6	Busy, stand by		
10-7	Out of service, leaving air	10-45	All units within range please report
10-8	In service, subject to call		
10-9	Repeat message	10-50	Break channel . . .
10-10	Transmission completed, standing by	10-60	What is next message number?
10-11	Talking too rapidly	10-62	Unable to copy, use phone
10-12	Visitors present	10-63	Net directed to . . .
10-13	Advise weather/road conditions	10-64	Net clear
		10-65	Awaiting your next message/assignment
10-16	Make pickup at . . .		
10-17	Urgent business	10-67	All units comply
10-18	Anything for us?	10-70	Fire at . . .
10-19	Nothing for you, return to base	10-71	Proceed with transmission in sequence
10-20	My location is . . .	10-73	Speed trap at . . .
10-21	Call by telephone	10-75	You are causing interference
10-22	Report in person to . . .	10-77	Negative contact
10-23	Stand by	10-81	Reserve hotel room for . . .
10-24	Completed last assignment	10-82	Reserve room for . . .
10-25	Can you contact . . . ?	10-84	My telephone number is . . .
10-26	Disregard last information	10-85	My address is . . .
10-27	I am moving to channel . . .	10-89	Radio repairman needed at . . .
10-28	Identify your station		
10-29	Time is up for contact	10-90	I have TVI
10-30	Does not conform to FCC rules	10-91	Talk closer to mike
		10-92	Your transmitter is out of adjustment
10-32	I will give you a radio check		
10-33	Emergency traffic at this station	10-93	Check my frequency on this channel
10-34	Trouble at this station, help needed	10-94	Please give me a long count
		10-95	Transmit dead carrier for 5 seconds
10-35	Confidential information		
10-36	Correct time is . . .	10-99	Mission completed, all units secure
10-37	Wrecker needed at . . .		
10-38	Ambulance needed at . . .	10-200	Police needed at . . .

Table 9. Revised Official 10-Code of Associated Police Communication Officers, Inc.

Signal	Meaning	Signal	Meaning
10-1	Unable to copy—change location	10-47	Emergency road repairs needed
10-2	Signals good	10-48	Traffic standard needs repairs
10-3	Stop transmitting	10-49	Traffic light out
10-4	Acknowledgment	10-50	Accident—F, PI, PD
10-5	Relay	10-51	Wrecker needed
10-6	Busy—stand by unless urgent	10-52	Ambulance needed
10-7	Out of service (Give location and or telephone number)	10-53	Road blocked
		10-54	Livestock on highway
10-8	In service	10-55	Intoxicated driver
10-9	Repeat	10-56	Intoxicated pedestrian
10-10	Fight in progress	10-57	Hit and run—F, PI, PD
10-11	Dog case	10-58	Direct traffic
10-12	Stand by	10-59	Convoy or escort
10-13	Weather and road report	10-60	Squad in vicinity
10-14	Report of prowler	10-61	Personnel in area
10-15	Civil disturbance	10-62	Reply to message
10-16	Domestic trouble	10-63	Prepare to make written copy
10-17	Meet complainant	10-64	Message for local delivery
10-18	Complete assignment quickly	10-65	Net message assignment
10-19	Return to . . .	10-66	Message cancellation
10-20	Location	10-67	Clear to read net message
10-21	Call . . . by telephone	10-68	Dispatch information
10-22	Disregard	10-69	Message received
10-23	Arrived at scene	10-70	Fire alarm
10-24	Assignment completed	10-71	Advise nature of fire (size, type, and contents of building)
10-25	Report in person to . . .		
10-26	Detaining subject, expedite		
10-27	Drivers license information	10-72	Report progress on fire
10-28	Vehicle registration information	10-73	Smoke report
		10-74	Negative
10-29	Check records for wanted	10-75	In contact with
10-30	Illegal use of radio	10-76	En route
10-31	Crime in progress	10-77	ETA (Estimated Time of Arrival)
10-32	Man with gun		
10-33	EMERGENCY	10-78	Need assistance
10-34	Riot	10-79	Notify coroner
10-35	Major crime alert	10-82	Reserve lodging
10-36	Correct time	10-84	Are you going to meet . . ., if so, advise ETA.
10-37	Investigate suspicious vehicle		
		10-85	Will be late
10-38	Stopping suspicious vehicle (give station complete description before stopping)	10-87	Pick up checks for distribution
		10-88	Advise telephone No. to contact
10-39	Urgent—use light and siren		
10-40	Silent run—no light or siren	10-90	Bank alarm
10-41	Beginning tour of duty	10-91	Unnecessary use of radio
10-42	Ending tour of duty	10-93	Blockade
10-43	Information	10-94	Drag racing
10-44	Request permission to leave patrol for . . .	10-96	Mental subject
		10-98	Prison or jail break
10-45	Animal carcass in . . . lane at . . .	10-99	Records indicated wanted or stolen
10-46	Assist motorist		

units. Now they are often used in other forms of two-way communications. The most common signals are given in Table 8. The police signals are given in Table 9.

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	· – · – ·

SECTION 4

MISCELLANEOUS DATA

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 10. 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.

METRIC 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 11.) 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 10. 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	Plexiglas	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

Table 11. 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	10^{-15}	femto-	f
			10^{-18}	atto-	a

Table 12. Metric Conversion Table

Desired Value	Original Value															
	Tera-	Giga-	Mega-	Myria-	Kilo-	Hecto-	Deka-	Units	Deci-	Centi-	Milli-	Micro-	Nano-	Pico-	Femto-	Atto-
Tera-		← 3	← 6	← 8	← 9	←10	←11	←12	←13	←14	←15	←18	←21	←24	←27	←30
Giga-	3→		← 3	← 5	← 6	← 7	← 8	← 9	←10	←11	←12	←15	←18	←21	←24	←27
Mega-	6→	3→		← 2	← 3	← 4	← 5	← 6	← 7	← 8	← 9	←12	←15	←18	←21	←24
Myria-	8→	5→	2→		← 1	← 2	← 3	← 4	← 5	← 6	← 7	←10	←13	←16	←19	←22
Kilo-	9→	6→	3→	1→		← 1	← 2	← 3	← 4	← 5	← 6	← 9	←12	←15	←18	←21
Hecto-	10→	7→	4→	2→	1→		← 1	← 2	← 3	← 4	← 5	← 8	←11	←14	←17	←20
Deka-	11→	8→	5→	3→	2→	1→		← 1	← 2	← 3	← 4	← 7	←10	←13	←16	←19
Units	12→	9→	6→	4→	3→	2→	1→		← 1	← 2	← 3	← 6	← 9	←12	←15	←18
Deci-	13→	10→	7→	5→	4→	3→	2→	1→		← 1	← 2	← 5	← 8	←11	←14	←17
Centi-	14→	11→	8→	6→	5→	4→	3→	2→	1→		← 1	← 4	← 7	←10	←13	←16
Milli-	15→	12→	9→	7→	6→	5→	4→	3→	2→	1→		← 3	← 6	← 9	←12	←15
Micro-	18→	15→	12→	10→	9→	8→	7→	6→	5→	4→	3→		← 3	← 6	← 9	←12
Nano-	21→	18→	15→	13→	12→	11→	10→	9→	8→	7→	6→	3→		← 3	← 6	← 9
Pico-	24→	21→	18→	16→	15→	14→	13→	12→	11→	10→	9→	6→	3→		← 3	← 6
Femto-	27→	24→	21→	19→	18→	17→	16→	15→	14→	13→	12→	9→	6→	3→		← 3
Atto-	30→	27→	24→	22→	21→	20→	19→	18→	17→	16→	15→	12→	9→	6→	3→	

METRIC CONVERSION TABLE

Table 12 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.

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 13. 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	Picoamperes	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}
Atmospheres	Feet of water	33.90	0.02950
Atmospheres	Pounds per sq. in.	14.70	0.06804
Barns	Square centimeters	10^{-24}	10^{24}
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}

Table 13. Conversion Factors—cont

To Convert	Into	Multiply by	Conversely, Multiply by
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 per second	Hertz	1	1
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	Picofarads	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

Table 13. Conversion Factors—cont

To Convert	Into	Multiply by	Conversely, Multiply by
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}
Hertz	Kilohertz	10^{-3}	10^{3}
Hertz	Megahertz	10^{-6}	10^{6}
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. Foot	0.2048	4.882
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}

Table 13. Conversion Factors—cont

To Convert	Into	Multiply by	Conversely, Multiply by
Liters	Gallons (liq. U.S.)	0.2642	3.785
Liters	Pints (liq. U.S.)	2.113	0.4732
$\log_e N$	$\log_{10} N$	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	Picofarads	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
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	Pico-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

Table 13. Conversion Factors—cont

To Convert	Into	Multiply by	Conversely, Multiply by
Pints	Quarts (liq. U.S.)	0.50	2
Pounds	Grams	453.6	2.205×10^{-3}
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^{-3}
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
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}

Table 13. Conversion Factors—cont

To Convert	Into	Multiply by	Conversely, Multiply by
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

COAXIAL CABLE CHARACTERISTICS

Table 14 lists the most frequently used coaxial cables. The electrical specifications include the impedance in ohms, capacitance in picofarads per foot, attenuation in dB per 100 feet, and the outside diameter.

Table 14. Coaxial Cable Characteristics

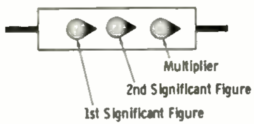
Type RG... /U	Imp. (ohms)	Cap. (pF per ft.)	Diam. (inches)	Attenuation—dB per 100 ft. 1 MHz	10 MHz	100 MHz	400 MHz	1000 MHz	REMARKS
5	52.5	28.5	.332	.21	.77	2.9	6.5	11.5	Small, double braid
5A	50	29	.328	.16	.66	2.4	5.25	8.8	Small, low loss
6	76	20	.332	.21	.78	2.9	6.5	11.2	IF & video
8	52	29.5	.405	.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)

Table 14. Coaxial Cable Characteristics—cont

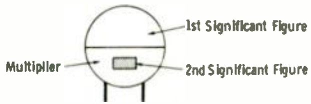
Type RG.../U	Imp. (ohms)	Cap. (pF per ft.)	Diam. (inches)	Attenuation—dB per 100 ft. 1 MHz	10 MHz	100 MHz	400 MHz	1000 MHz	REMARKS
25	48	50	.565	—	—	—	—	—	Pulse
26	48	50	.525	—	—	—	—	—	Pulse
27	48	50	.675	—	—	—	—	—	Pulse
28	48	50	.805	—	—	—	—	—	Pulse
33	51	30	.470	—	—	—	—	—	Pulse
34	71	21.5	.625	.065	.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
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

RESISTOR COLOR CODES

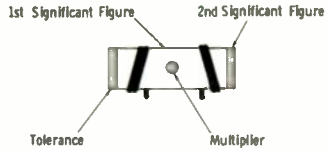
BODY-DOT SYSTEM



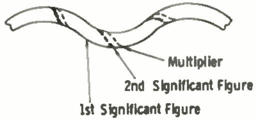
MINIATURE RESISTOR CODE



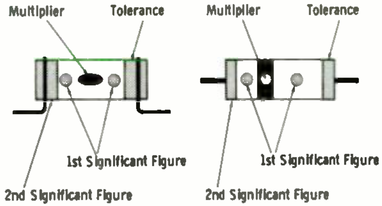
BODY-END-DOT SYSTEM



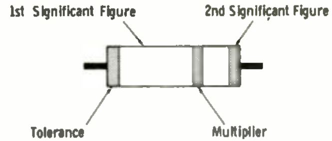
DASH-BAND SYSTEM



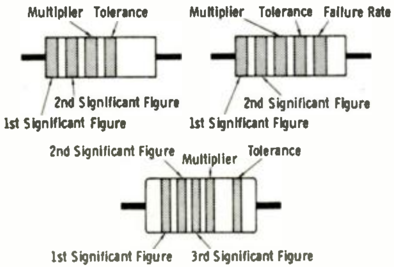
DOT-BAND SYSTEM



BODY-END BAND SYSTEM



COLOR BAND SYSTEM



Resistors With Black Body Color Are Composition, Noninsulated.
Resistors With Colored Bodies Are Composition Insulated.
Wirewound Resistors Have The 1st Digit Color Band Double Width.

RESISTOR COLOR CODE

COLOR	SIGNIFICANT FIGURES	MULTIPLIER	TOLERANCE	FAILURE RATE*
Black	0	1	-	-
Brown	1	10	±1%	1.0
Red	2	100	±2%	0.1
Orange	3	1000	±3%	0.01
Yellow	4	10,000	±4%	0.001
Green	5	100,000	-	-
Blue	6	1,000,000	-	-
Violet	7	10,000,000	-	-
Gray	8	100,000,000	-	-
White	9	-	-	Solderable*
Gold	-	0.1	±5%	-
Silver	-	0.01	±10%	-
No Color	-		±20%	-

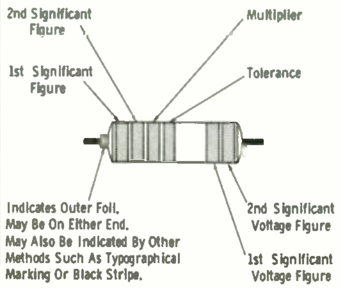
*When used on composition resistors, indicates percent failure per 1000 hours. On film resistors, a white fifth band indicates solderable terminal.

CAPACITOR COLOR CODES

MOLDED PAPER CAPACITOR COLOR CODE (CAPACITANCE GIVEN IN PF)

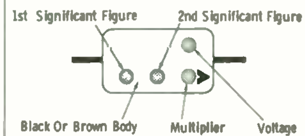
COLOR	DIGIT	MULTI-PLIER	TOLER-ANCE
BLACK	0	1	20%
BROWN	1	10	
RED	2	100	
ORANGE	3	1000	
YELLOW	4	10,000	
GREEN	5	100,000	5%
BLUE	6	1,000,000	
VIOLET	7		
GRAY	8		
WHITE	9		10%
GOLD			5%
SILVER			10%
NO COLOR			20%

MOLDED PAPER TUBULAR

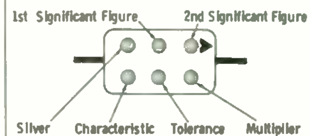


Add Two Zeros To Significant Voltage Figures.
One Band Indicates Voltage Ratings Under 1000 Volts.

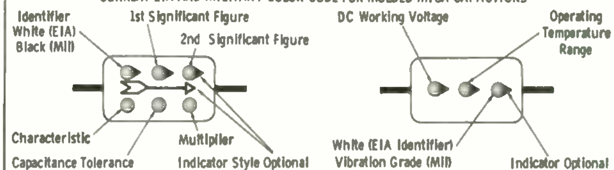
MOLDED FLAT PAPER CAPACITORS (COMMERCIAL CODE)



MOLDED FLAT PAPER CAPACITORS (MILITARY CODE)



CURRENT EIA AND MILITARY COLOR CODE FOR MOLDED MICA CAPACITORS



A (FRONT) B (REAR)

MICA CAPACITOR COLOR CODE

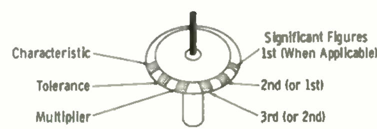
COLOR	CHARAC-TERISTIC*	CAPACITANCE: 1ST AND 2ND SIGNIFICANT FIGURES	CAPACITANCE: MULTIPLIER	CAPACITANCE TOLERANCE	DC WORKING VOLTAGE	OPERATING TEMPERATURE RANGE	VIBRATION GRADE (MIL)
Black	A (EIA)	0	1	±20% (EIA)		- 55°C to + 70°C (MIL)	10-55 Hz
Brown	B	1	10	±1%	100 (EIA)		
Red	C	2	100	±2%		- 55° to + 85°C	
Orange	D	3	1000		300		
Yellow	E	4	10,000 (EIA)			- 55° to + 125°C	10-2000 Hz
Green	F	5		±5%	500		
Blue		6				- 55° to + 150°C (MIL)	
Purple (violet)		7					
Gray		8					
White		9					
Gold			0.1	± 1/2% (EIA)†	1000 (EIA)		
Silver			0.01 (EIA)	±10%			

* Denotes specifications of design involving Q factors, temperature coefficients, and production test requirements.
† Or ±0.5 pf, whichever is greater. All others are specified tolerance or ±1.0 pf, whichever is greater.

NOTES:

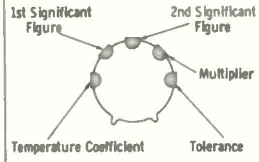
1. The multiplier is the factor by which the two significant figures are multiplied to yield the nominal capacitance.
2. "A" illustrates standard six-dot system used for "N" temperature range capacitors manufactured according to EIA Standard RS-153-A.
3. Drawings "A" and "B" combined illustrate standard nine-dot system used for "O" temperature range capacitors manufactured according to EIA Standard RS-153-A, and for all units manufactured according to Military Specification MIL-C-5C.

SILVERED MICA BUTTON CAPACITORS

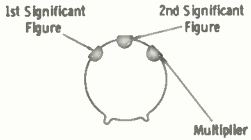


CAPACITOR COLOR CODES

DISC CERAMICS (5-DOT SYSTEM)



DISC CERAMICS (3-DOT SYSTEM)



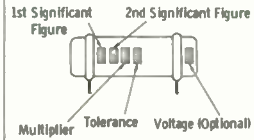
CERAMIC CAPACITOR CODES (CAPACITANCE GIVEN IN PF)

In reference to RS-198-A of the EIA, ceramic dielectric capacitors have three major classifications:
Class 1, temperature compensating ceramics requiring high Q and capacitance stability.
Class 2, where Q and stability of capacitance are not required
Class 3, low voltage ceramics, where dielectric losses, high insulation resistance, and capacitance stability are not of major importance.

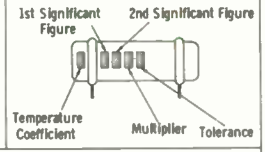
COLOR	DIGIT	MULTIPLIER	CLASS 1 TOLERANCE* 10 PF OR LESS	CLASS 1 TOLERANCE* OVER 10 PF	CLASS 1 TEMPERATURE COEFFICIENT PPM °C	CLASS 1 TEMP. SIGNIFICANT FIGURE	CLASS 1 COEFF. MULTIPLIER	CLASS 2 TOLERANCE*
BLACK	0	1	± 2.0 pF	± 20%	0	0.0	-1	±20%
BROWN	1	10	± 0.1 pF	±1%	-33		-10	
RED	2	100		±2%	-75	1.0	-100	
ORANGE	3	1000		± 3%	-150	1.5	-1000	
YELLOW	4	10,000			-220	2.2	-10,000	+100%, -0%
GREEN	5		± 0.5 pF	± 5%	-330	3.3	+1	±5%
BLUE	6				-470	4.7	+10	
VIOLET	7				-750	7.5	+100	
GRAY	8	.01	± 0.25 pF		+150 To -1500		+1000	+80%, -20%
WHITE	9	.1	± 1.0 pF	± 10%	+100 To -750		+10,000	± 10%
SILVER								
GOLD								

*Tolerance on Class 3 Ceramic Capacitors is indicated by its code, either ± 20% (Code M) or +80, -20% (Code Z).

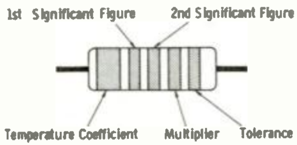
HIGH-CAPACITANCE TUBULAR CERAMICS INSULATED OR NONINSULATED



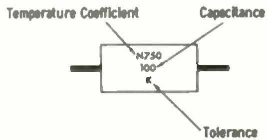
TEMPERATURE COMPENSATING TUBULAR CERAMICS



MOLDED-INSULATED AXIAL LEAD CERAMICS

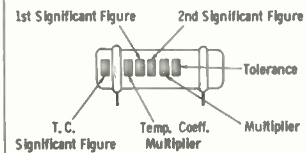


TYPOGRAPHICALLY MARKED CERAMICS

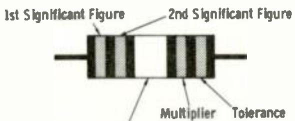


LETTER	TOLERANCE 10PF OR LESS	TOLERANCE OVER 10PF
B	± 0.1 pF	
C	± 0.25 pF	
D	± 0.5 pF	
F	± 1.0 pF	± 1%
G	± 2.0 pF	± 2%
J		± 5%
K		±10%
M		±20%

EXTENDED RANGE T.C. TUBULAR CERAMICS

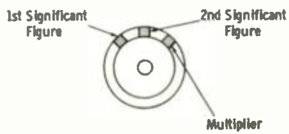


MOLDED CERAMICS
Using Standard Resistor Color Code



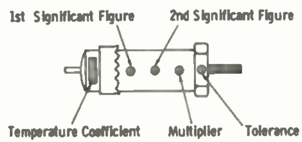
White Band Distinguishes Capacitor From Resistor

BUTTON CERAMICS

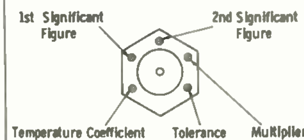


Viewed From Soldered Surface

STANDOFF CERAMICS



FEEDTHROUGH CERAMICS



EIA TRANSFORMER COLOR CODE

The diagrams in Figs. 77, 78, and 79 illustrate the color code for transformers recommended by the EIA.

Power transformers

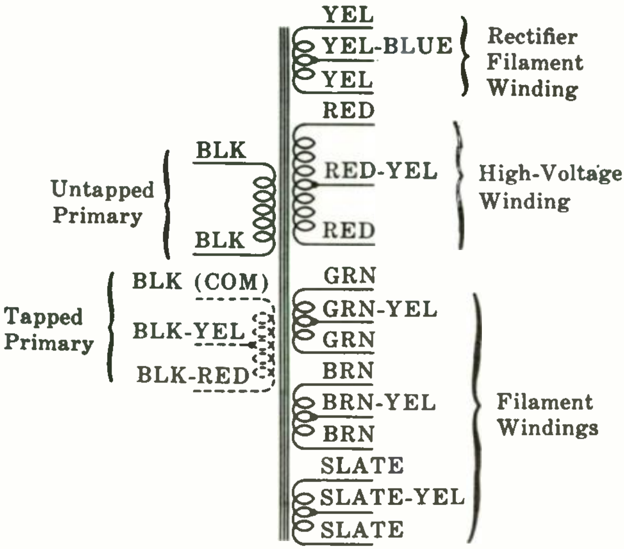


Fig. 77.

I-F transformers

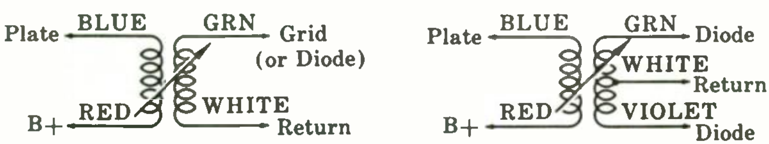


Fig. 78.

Audio output and interstage transformers

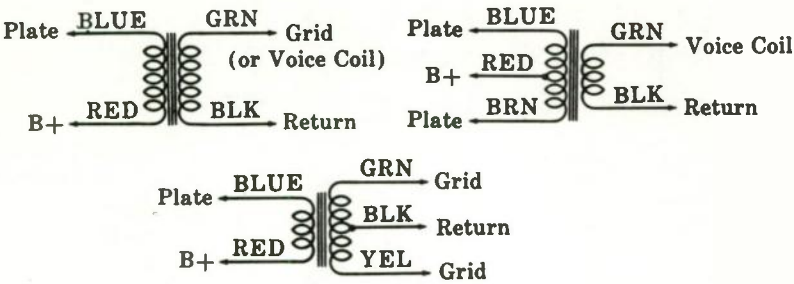


Fig. 79.

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
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., f-m—Frequency modulation
G—Conductance
G_m, gm, g_m—Mutual conductance
GCT—Greenwich Civil Time
GMT—Greenwich Mean Time
gnd—Ground
H, h—Henry
HF, h.f., h-f, hf—High frequency
hp—Horsepower
hy—Henry
Hz—Hertz
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
kHz—Kilohertz
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
MC, Mc, mc—Megacycle
mf, mfd—Microfarad
MHz—Megahertz
mcw—Modulated continuous wave
meg—Megohm
MF, m.f., m-f, mf—Medium frequency
mf, mfd—Microfarad

mh—Millihenry
mm—Millimeter
mmf, mmfd—Micromicrofarad (picofarad)
mv—Millivolt (sometimes microvolt)
mw—Milliwatt (sometimes microwatt)
NC—No connection
OD—Outside diameter
P—Power
pf—Power factor; picofarad
p-p—Peak-to-peak
Q—Merit of a coil or capacitor; quantity of electricity
R—Resistance; resistor
RC, R-C—Product of resistance and 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
μa—Microampere
μf—Microfarad
μh—Microhenry
μv—Microvolt
μμf—Micromicrofarads (picofarad)
∿—Hertz

SEMICONDUCTOR SYMBOLS AND ABBREVIATIONS

The following letter symbols and abbreviations are recommended by the Joint Electron Device Engineering Council (JEDTC) of the Electronic Industries Association (EIA) and the National Electrical Manufacturers Association (NEMA).

A, a—Anode
B, b—Base
b_{fs}—Common-source small-signal forward transfer susceptance
b_{is}—Common-source small-signal input susceptance
b_{os}—Common-source small-signal output susceptance
b_{rs}—Common-source small-signal reverse transfer susceptance
C, c—Collector
C_{cb}—Collector-base interterminal capacitance
C_{ce}—Collector-emitter interterminal capacitance
C_{ds}—Drain-source capacitance
C_{du}—Drain-substrate capacitance
C_{eb}—Emitter-base interterminal capacitance
C_{ibo}—Common-base open-circuit input capacitance
C_{ibs}—Common-base short-circuit input capacitance
C_{ieo}—Common-emitter open-circuit input capacitance
C_{ies}—Common-emitter short-circuit input capacitance
C_{iss}—Common-source short-circuit input capacitance

C_{obo}—Common-base open-circuit output capacitance

C_{obs}—Common-base short-circuit output capacitance

C_{oeo}—Common-emitter open-circuit output capacitance

C_{oes}—Common-emitter short-circuit output capacitance

C_{oss}—Common-source short-circuit output capacitance

C_{rbs}—Common-base short-circuit reverse transfer capacitance

C_{rcs}—Common-collector short-circuit reverse transfer capacitance

C_{res}—Common-emitter short-circuit reverse transfer capacitance

C_{rss}—Common-source short-circuit reverse transfer capacitance

C_{tc}—Collector depletion-layer capacitance

C_{te}—Emitter depletion-layer capacitance

D, d—Drain

E, e—Emitter

η—Intrinsic standoff ratio

f_{hfb}—Common-base small-signal short-circuit forward current transfer ratio cutoff frequency

f_{hfc}—Common-collector small-signal short-circuit forward current transfer ratio cutoff frequency

f_{hfe}—Common-emitter small-signal short-circuit forward current transfer ratio cutoff frequency

f_{max}—Maximum frequency of oscillation

f_T—Transition frequency (frequency at which common-emitter small-signal forward current transfer ratio extrapolates to unity)

G, g—Gate

g_{fs}—Common-source small-signal forward transfer conductance

g_{is}—Common-source small-signal input conductance

g_{MB}—Common-base static transconductance

g_{MC}—Common-collector static transconductance

g_{ME}—Common-emitter static transconductance

g_{os}—Common-source small-signal output conductance

G_{PB}—Common-base large-signal insertion power gain

G_{pb}—Common-base small-signal insertion power gain

G_{PC}—Common-collector large-signal insertion power gain

G_{pc}—Common-collector small-signal insertion power gain

G_{PE}—Common-emitter large-signal insertion power gain

G_{pe}—Common-emitter small-signal insertion power gain

G_{pg}—Common-gate small-signal insertion power gain

G_{ps}—Common-source small-signal insertion power gain

g_{rs}—Common-source small-signal reverse transfer conductance

G_{TB}—Common-base large-signal transducer power gain

G_{tb}—Common-base small-signal transducer power gain

G_{TC}—Common-collector large-signal transducer power gain

G_{tc}—Common-collector small signal transducer power gain

G_{TE}—Common-emitter large-signal transducer power gain

G_{te}—Common-emitter small signal transducer power gain

G_{tg}—Common-gate small-signal transducer power gain

G_{ts}—Common-source small-signal transducer power gain

h_{FB}—Common-base static forward current transfer ratio

h_{fb}—Common-base small-signal short-circuit forward current transfer ratio

h_{FC}—Common-collector static forward current transfer ratio

h_{fc}—Common-collector small-signal short-circuit forward current transfer ratio

h_{FE}—Common-emitter static forward current transfer ratio

h_{fe}—Common-emitter small-signal short-circuit forward current transfer ratio

h_{FEL}—Inherent large-signal forward current transfer ratio

h_{IB}—Common-base static input resistance

h_{ib}—Common-base small-signal short-circuit input impedance

h_{IC}—Common-collector static input resistance

h_{ic}—Common-collector small-signal short-circuit input impedance

h_{IE}—Common-emitter static input resistance

h_{ie}—Common-emitter small-signal short-circuit input impedance

$h_{ie(imag)}$—Imaginary part of common-emitter small-signal short-circuit input impedance

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

h_{ob}—Common-base small-signal open-circuit output admittance

h_{oc}—Common-collector small-signal open-circuit output admittance

h_{oe}—Common-emitter small-signal open-circuit output admittance

$h_{oe(imag)}$—Imaginary part of common-emitter small-signal open-circuit output admittance

$h_{oe(real)}$—Real part of common-emitter small-signal open-circuit output admittance

h_{rb}—Common-base small-signal open-circuit reverse voltage transfer ratio

h_{rc}—Common-collector small-signal open-circuit reverse voltage transfer ratio

h_{re}—Common-emitter small-signal open-circuit reverse voltage transfer ratio

I_B—Base-terminal dc current

I_b—Alternating component (rms value) of base-terminal current

i_B—Instantaneous total value of base-terminal current

I_{BEV}—Base cutoff current, dc

$I_{B2(mod)}$—Interbase modulated current

I_C—Collector-terminal dc current

I_c—Alternating component (rms value) of collector-terminal current

i_C—Instantaneous total value of collector-terminal current

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

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

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

I_{CES}—Collector cutoff current (dc), base shorted to emitter

I_{CEV}—Collector cutoff current (dc), specified voltage between base and emitter

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

I_D—Drain current, dc

$I_{D(off)}$—Drain cutoff current

$I_{D(on)}$—On-state drain current

I_{DSS}—Zero-gate-voltage drain current

I_E—Emitter-terminal dc current

I_e—Alternating component (rms value) of emitter-terminal current

i_E—Instantaneous total value of emitter-terminal current

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

I_{EB2O}—Emitter reverse current

$I_{EC(ofs)}$—Emitter-collector offset current

I_{ECS}—Emitter cutoff current (dc), base short-circuited to collector

$I_{E1E2(off)}$—Emitter cutoff current

I_F—For voltage-regulator and voltage-reference diodes: dc forward current. For signal diodes and rectifier diodes: dc forward current (no alternating component)

I_f—Alternating component of forward current (rms value)

i_F—Instantaneous total forward current

$I_{F(AV)}$—Forward current, dc (with alternating component)

I_{FM}—Maximum (peak) total forward current

$I_{F(OV)}$—Forward current, overload

I_{FRM}—Maximum (peak) forward current, repetitive

$I_{F(RMS)}$—Total rms forward current

I_{FSM}—Maximum (peak) forward current, surge

I_G—Gate current, dc

I_{GF}—Forward gate current

I_{GR}—Reverse gate current

I_{GSS}—Reverse gate current, drain short-circuited to source

I_{GSSF}—Forward gate current, drain short-circuited to source

I_{GSSR}—Reverse gate current, drain short-circuited to source

I_I—Inflection-point current

$Im(h_{ie})$—Imaginary part of common-emitter small-signal short-circuit input impedance

$Im(h_{oe})$—Imaginary part of common-emitter small-signal open-circuit output admittance

I_O—Average forward current, 180° conduction angle, 60-Hz half sine wave

I_P—Peak-point current

I_R—For voltage-regulator and voltage-reference diodes: dc reverse current. For signal diodes and rectifier diodes: dc reverse current (no alternating component)

I_r—Alternating component of reverse current (rms value)

i_R—Instantaneous total reverse current

$I_{R(AV)}$—Reverse current, dc (with alternating component)

I_{RM}—Maximum (peak) total reverse current

I_{RRM}—Maximum (peak) reverse current, repetitive

$I_{R(RMS)}$—Total rms reverse current

I_{RSM}—Maximum (peak) surge reverse current

I_S—Source current, dc

I_{SDS}—Zero-gate-voltage source current

$I_{S(off)}$—Source cutoff current

I_V—Valley-point current

I_Z—Regulator current, reference current (dc)

I_{ZK}Regulator current, reference current dc near breakdown knee)

I_{ZM}—Regulator current, reference current (dc maximum rated current)

K, k—Cathode

L_c—Conversion loss

M—Figure of merit

NF_o—Overall noise figure

NR_o—Output noise ratio

P_{BE}—Power input (dc) to base, common emitter

p_{BE}—Instantaneous total power input to base, common emitter

P_{CB}—Power input (dc) to collector, common base

P_{CB}—Instantaneous total power input to collector, common base

P_{CE}—Power input (dc) to collector, common emitter

p_{CE}—Instantaneous total power input to collector, common emitter

P_{EB}—Power input (dc) to emitter, common base

p_{EB}—Instantaneous total power input to emitter, common base

P_F—Forward power dissipation, dc (no alternating component)

p_F—Instantaneous total forward power dissipation

$P_{F(AV)}$—Forward power dissipation, dc (with alternating component)

P_{FM}—Maximum (peak) total forward power dissipation

P_{IB}—Common-base large-signal input power

P_{ib}—Common-base small-signal input power

P_{IC}—Common-collector large-signal input power

P_{ic}—Common-collector small-signal input power

P_{IE}—Common-emitter large-signal input power

P_{ie}—Common-emitter small-signal input power

P_{OB}—Common-base large-signal output power

P_{ob}—Common-base small-signal output power

P_{OC}—Common-collector large-signal output power

P_{oc}—Common-collector small-signal output power

P_{OE}—Common-emitter large-signal output power

p_{oe}—Common-emitter small-signal output power

P_R—Reverse power dissipation, dc (no alternating component)

p_R—Instantaneous total reverse power dissipation

$P_{R(AV)}$—Reverse power dissipation, dc (with alternating component)

P_{RM}—Maximum (peak) total reverse power dissipation

P_T—Total nonreactive power input to all terminals

p_T—Nonreactive power input, instantaneous total, to all terminals

Q_S—Stored charge

r_{BB}—Interbase resistance

$r_b'C_c$—Collector-base time constant

$r_{CE(sat)}$—Saturation resistance, collector-to-emitter

$r_{DS(on)}$—Static drain-source on-state resistance

$r_{ds(on)}$—Small-signal drain-source on-state resistance

$Re(h_{ie})$—Real part of common-emitter small-signal short-circuit input impedance

$Re(h_{oe})$—Real part of common-emitter small-signal open-circuit output admittance

$r_{e1e2(on)}$—Small-signal emitter-emitter on-state resistance

r_i—Dynamic resistance at inflection point

R_θ—Thermal resistance

$R_{\theta CA}$—Thermal resistance, case to ambient

$R_{\theta JA}$—Thermal resistance, junction to ambient

$R_{\theta JC}$—Thermal resistance, junction to case

S, s—Source

T_A—Ambient temperature or free-air temperature

T_C—Case temperature

t_d—Delay time

$t_{d(off)}$—Turn-off delay time

$t_{d(on)}$—Turn-on delay time

t_f—Fall time

t_{fr}—Forward recovery time

T_j—Junction temperature

t_{off}—Turn-off time

t_{on}—Turn-on time

t_p—Pulse time

t_r—Rise time

t_{rr}—Reverse recovery time

t_s—Storage time

TSS—Tangential signal sensitivity

T_{stg}—Storage temperature

t_w—Pulse average time

U, u—Bulk (substrate)

V_{BB}—Base supply voltage (dc)

V_{BC}—Average or dc voltage, base to collector

v_{bc}—Instantaneous value of alternating component of base-collector voltage

V_{BE}—Average or dc voltage, base to emitter

v_{be}—Instantaneous value of alternating component of base-emitter voltage

$V_{(BR)}$—Breakdown voltage (dc)

$v_{(BR)}$—Breakdown voltage (instantaneous total)

$V_{(BR)CBO}$—Collector-base breakdown voltage, emitter open

$V_{(BR)CEO}$—Collector-emitter breakdown voltage, base open

$V_{(BR)CER}$—Collector-emitter breakdown voltage, resistance between base and emitter

$V_{(BR)CES}$—Collector-emitter breakdown voltage, base shorted to emitter

$V_{(BR)CEV}$—Collector-emitter breakdown voltage, specified voltage between base and emitter

$V_{(BR)CEX}$—Collector-emitter breakdown voltage, specified circuit between base and emitter

$V_{(BR)EBO}$—Emitter-base breakdown voltage, collector open

$V_{(BR)ECO}$—Emitter-collector breakdown voltage, base open

$V_{(BR)E1E2}$—Emitter-emitter breakdown voltage

$V_{(BR)GSS}$—Gate-source breakdown voltage

$V_{(BR)GSSF}$—Forward gate-source breakdown voltage

$V_{(BR)GSSR}$—Reverse gate-source breakdown voltage

V_{B2B1}—Interbase voltage

V_{CB}—Average or dc voltage, collector to base

v_{cb}—Instantaneous value of alternating component of collector-base voltage

$V_{CB(fl)}$—Collector-base dc open-circuit voltage (floating potential)

V_{CBO}—Collector-base voltage, dc, emitter open

V_{CC}—Collector supply voltage (dc)

V_{CE}—Average or dc voltage, collector to emitter

v_{ce}—Instantaneous value of alternating component of collector-emitter voltage

$V_{CE(fl)}$—Collector-emitter dc open-circuit voltage (floating potential)

V_{CEO}—Collector-emitter voltage (dc), base open

$V_{CE(ofs)}$—Collector-emitter offset voltage

V_{CER}—Collector-emitter voltage (dc), resistance between base and emitter

V_{CES}—Collector-emitter voltage (dc), base shorted to emitter

$V_{CE(sat)}$—Collector-emitter dc saturation voltage

V_{CEV}—Collector-emitter voltage (dc), specified voltage between base and emitter

V_{CEX}—Collector-emitter voltage (dc), specified circuit between base and emitter

V_{DD}—Drain supply voltage (dc)

V_{DG}—Drain-gate voltage

V_{DS}—Drain-source voltage

$V_{DS(on)}$—Drain-source on-state voltage

V_{DU}—Drain-substrate voltage

V_{EB}—Average or dc voltage, emitter to base

v_{eb}—Instantaneous value of alternating component of emitter-base voltage

$V_{EB(fl)}$—Emitter-base dc open-circuit voltage (floating potential)

V_{EBO}—Emitter-base voltage (dc), collector open

$V_{EB1(sat)}$—Emitter saturation voltage

V_{EC}—Average or dc voltage, emitter to collector

v_{ec}—Instantaneous value of alternating

$V_{EC(fl)}$—Emitter-collector dc open-circuit voltage (floating potential)

$V_{EC(ofs)}$—Emitter-collector offset voltage

V_{EE}—Emitter supply voltage (dc)

V_F—For voltage-regulator and voltage-reference diodes: dc forward voltage. For signal diodes and rectifier diodes: dc forward voltage (no alternating component)

V_f—Alternating component of forward voltage (rms value)

v_F—Instantaneous total forward voltage

$V_{F(AV)}$—Forward voltage, dc (with alternating component)

V_{FM}—Maximum (peak) total forward voltage

$V_{F(RMS)}$—Total rms forward voltage

V_{GG}—Gate supply voltage (dc)

V_{GS}—Gate-source voltage

V_{GSF}—Forward gate-source voltage

$V_{GS(off)}$—Gate-source cutoff voltage

V_{GSR}—Reverse gate-source voltage

$V_{GS(th)}$—Gate-source threshold voltage

V_{GU}—Gate-substrate voltage

V_I—Inflection-point voltage

V_{OB1}—Base-1 peak voltage

V_P—Peak-point voltage

V_{PP}—Projected peak-point voltage

V_R—For voltage-regulator and voltage-reference diodes: dc reverse voltage. For signal diodes and rectifier diodes: dc reverse voltage (no alternating component)

V_r—Alternating component of reverse voltage (rms value)

v_R—Instantaneous total reverse voltage

$V_{R(AV)}$—Reverse voltage, dc (with alternating component)

V_{RM}—Maximum (peak) total reverse voltage

V_{RRM}—Repetitive peak reverse voltage

$V_{R(RMS)}$—Total rms reverse voltage

V_{RSM}—Nonrepetitive peak reverse voltage

V_{RT}—Reach-through voltage

V_{RWM}—Working peak reverse voltage

V_{SS}—Source supply voltage (dc)

V_{SU}—Source-substrate voltage

$V_{(TO)}$—Threshold voltage

V_v—Valley-point voltage

V_Z—Regulator voltage, reference voltage (dc)

V_{ZM}—Regulator voltage, reference voltage (dc at maximum rated current)

y_{fb}—Common-base small-signal short-circuit forward transfer admittance

y_{fc}—Common-collector small-signal short-circuit forward transfer admittance

y_{fe}—Common-emitter small-signal short-circuit forward transfer admittance

y_{fs}—Common-source small-signal short-circuit forward transfer admittance

$y_{fs(imag)}$—Common-source small-signal forward transfer susceptance

$y_{fs(real)}$—Common-source small-signal forward transfer conductance

y_{ib}—Common-base small-signal short-circuit input admittance

y_{ic}—Common-collector small-signal short-circuit input admittance

y_{ie}—Common-emitter small-signal short-circuit input admittance

$y_{ie(imag)}$—Imaginary part of small-signal short-circuit input admittance (common-emitter)

$y_{ie(real)}$—Real part of small-signal short-circuit input admittance (common-emitter)

y_{is}—Common-source small-signal short-circuit input admittance

$y_{is(imag)}$—Common-source small-signal input susceptance

$y_{is(real)}$—Common-source small-signal input conductance

y_{ob}—Common-base small-signal short-circuit output admittance

y_{oc}—Common-collector small-signal short-circuit output admittance

y_{oe}—Common-emitter small-signal short-circuit output admittance

$y_{oe(imag)}$—Imaginary part of small-signal short-circuit output admittance (common-emitter)

$y_{oe(real)}$—Real part of small-signal short-circuit output admittance (common-emitter)

y_{os}—Common-source small-signal short-circuit output admittance

$y_{os(imag)}$—Common-source small-signal output susceptance

$y_{os(real)}$—Common-source small-signal output conductance

y_{rb}—Common-base small-signal short-circuit reverse transfer admittance

y_{rc}—Common-collector small-signal short-circuit reverse transfer admittance

y_{re}—Common-emitter small-signal short-circuit reverse transfer admittance

y_{rs}—Common-source small-signal short-circuit reverse transfer admittance

$y_{rs(imag)}$—Common-source small-signal reverse transfer susceptance

$y_{rs(real)}$—Common-source small-signal reverse transfer conductance

z_{if}—Intermediate-frequency impedance

z_m—Modulator-frequency load impedance

z_{rf}—Radio-frequency impedance

$Z_{\theta JA(t)}$—Junction-to-ambient transient thermal impedance

$Z_{\theta JC(t)}$—Junction-to-case transient thermal impedance

$Z_{\theta(t)}$—Transient thermal impedance

z_v—Video impedance

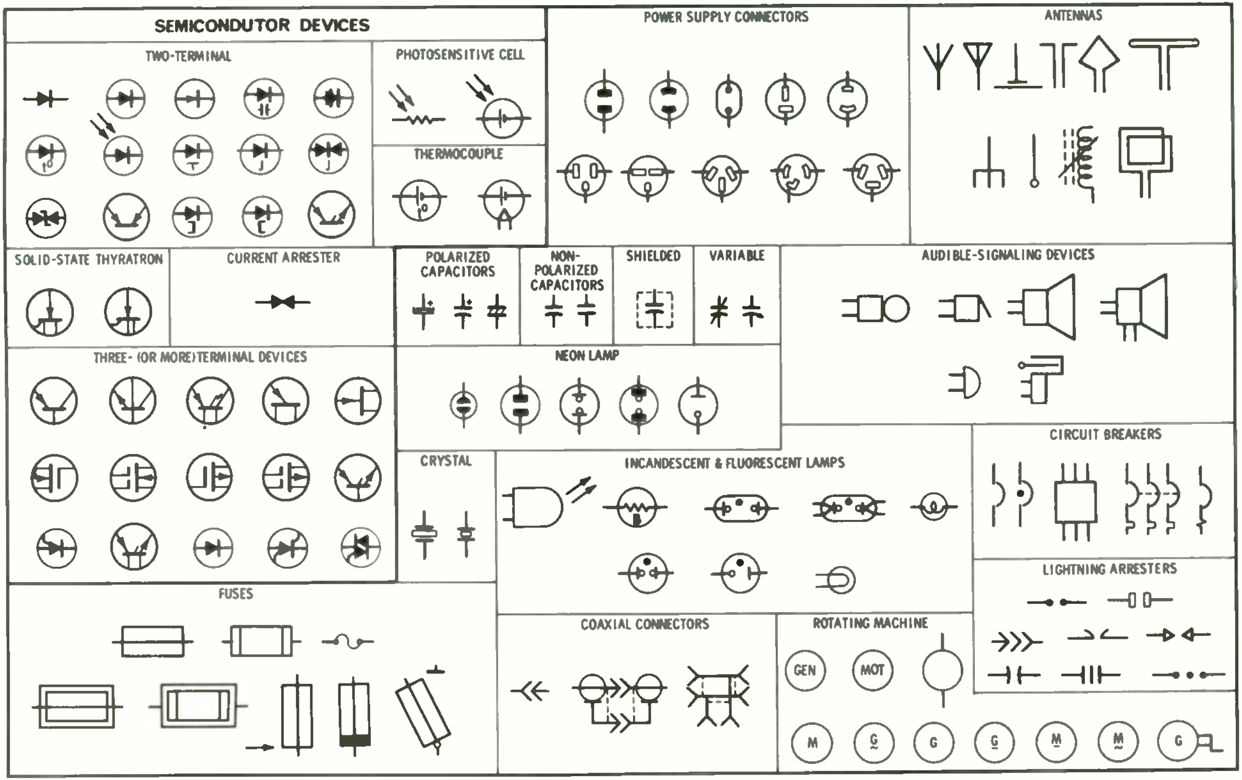
z_z—Regulator impedance, reference impedance (small-signal at I_Z)

z_{zk}—Regulator impedance, reference impedance (small-signal at I_{ZK})

z_{zm}—Regulator impedance, reference impedance (small-signal at I_{ZM})

ELECTRONIC SCHEMATIC SYMBOLS

The most commonly used schematic symbols are given in Figs. 80, 81, and 82.


SEMICONDUTOR DEVICES
TWO-TERMINAL
PHOTOSENSITIVE CELL
THERMOCOUPLE
POWER SUPPLY CONNECTORS
ANTENNAS
SOLID-STATE THYRATRON
CURRENT ARRESTER
POLARIZED CAPACITORS
NON-POLARIZED CAPACITORS
SHIELDED
VARIABLE
AUDIBLE-SIGNALING DEVICES
THREE- (OR MORE) TERMINAL DEVICES
NEON LAMP
CIRCUIT BREAKERS
CRYSTAL
INCANDESCENT & FLUORESCENT LAMPS
LIGHTNING ARRESTERS
FUSES
COAXIAL CONNECTORS
ROTATING MACHINE
GEN
MOT
M
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M
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Fig. 80.

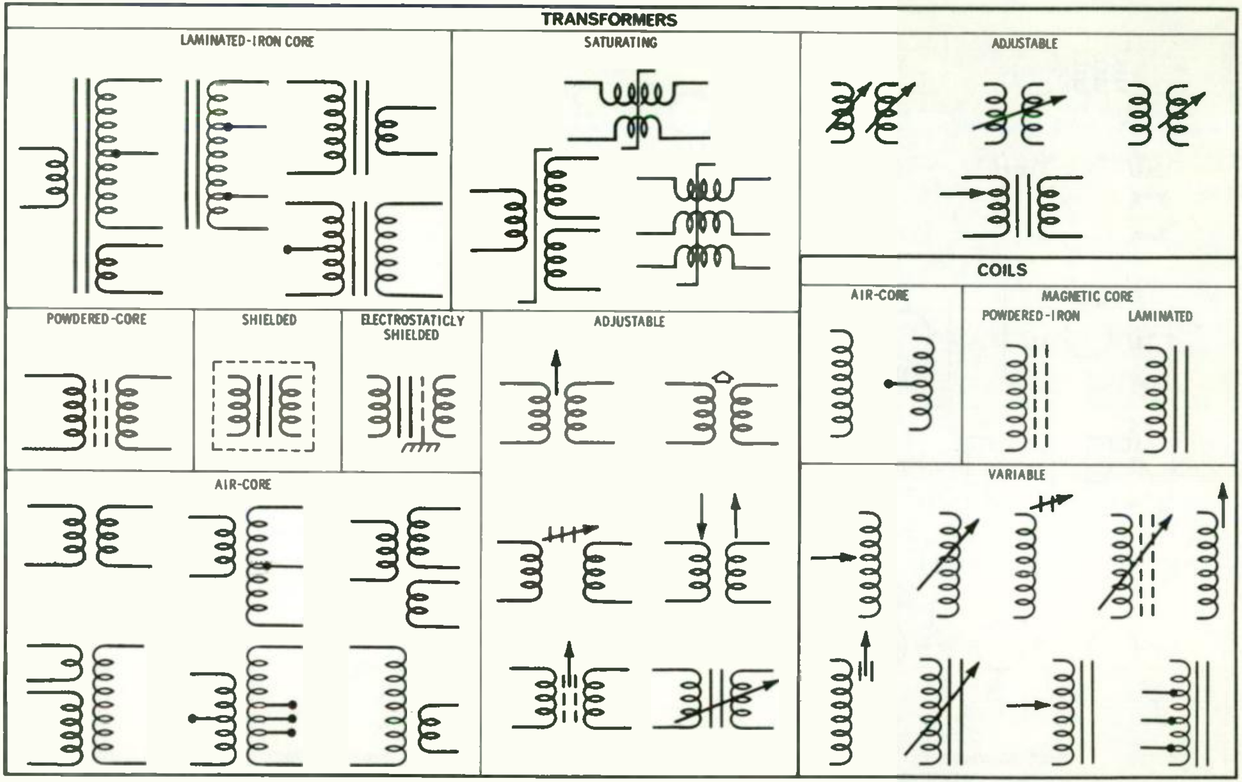
TRANSFORMERS
LAMINATED-IRON CORE
SATURATING
ADJUSTABLE
POWDERED-CORE
SHIELDED
ELECTROSTATICLY SHIELDED
ADJUSTABLE
AIR-CORE
COILS
AIR-CORE
MAGNETIC CORE
POWDERED-IRON
LAMINATED
VARIABLE

Fig. 81.

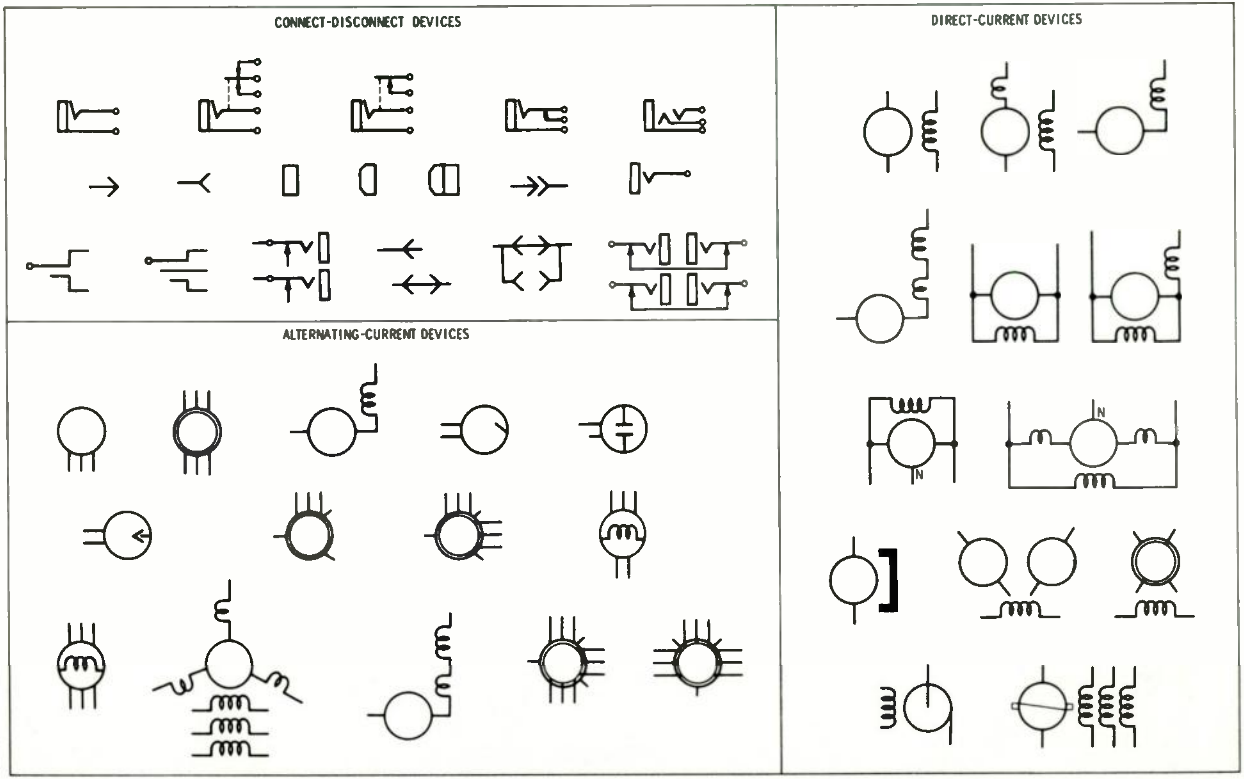
CONNECT-DISCONNECT DEVICES
DIRECT-CURRENT DEVICES
ALTERNATING-CURRENT DEVICES
N
N

Fig. 82.

MINIATURE LAMP DATA

Table 15 lists the most common miniature lamps and their characteristics. The outline drawings for each lamp are given in Fig. 83.

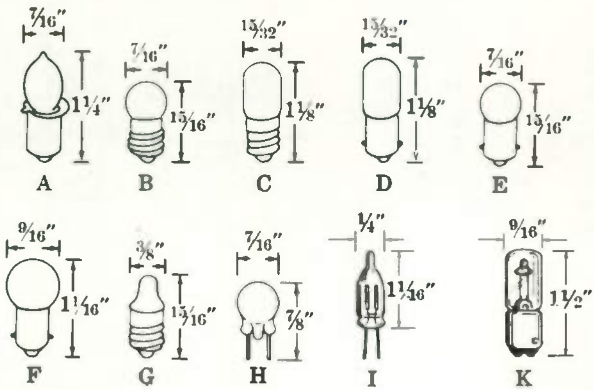

Fig. 83.

POWER CONSUMPTION OF HOME ELECTRICAL EQUIPMENT

The power consumption for many items of home electrical equipment used by an average family is given in Table 16. The approximate usage of each item is also listed where applicable.

GAS-FILLED LAMP DATA

The characteristics of the most common gas-filled lamps are given in Table 17. The value of external resistance needed for operation with circuit voltages from 110 to 600 volts is given in Table 18.

COPPER WIRE TABLE

Copper wire sizes ranging from American wire gauge (B & S) 0000 to 60 are listed in Table 19. 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 15. 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
PR5	2.35	0.35		Flange	B-3½	A
PR6	2.5	0.30	Brown	Flange	B-3½	A
PR7	3.8	0.30		Flange	B-3½	A
PR8	1.90	0.60		Flange	B-3½	A
PR9	2.70	0.15		Flange	B-3½	A
PR12	5.95	0.50	White	Flange	B-3½	A
PR13	4.75	0.50		Flange	B-3½	A
PR15	4.8	0.50		Flange	B-3½	A
PR16	12.5	0.25		Flange	B-3½	A
PR17	4.9	0.30		Flange	B-3½	A
PR18	7.2	0.55		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
39	6.8	0.36	White	Bayonet	T-3¼	D
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
123	1.25	0.30	Pink	Screw	G-3½	B
201	1.2	0.22	White	Screw	G-3½	B
222	2.2	0.25	White	Screw	TL-3	G
233	2.3	0.27	Purple	Screw	G-3½	B
239	6.3	0.36	White	Bayonet	T-3¼	D
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
1819	28.0	0.40	White	Bayonet	T-3¼	D
1847	6.3	0.15	White	Bayonet	T-3¼	D
1888	6.3	0.46	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.

Table 16. 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 kwh 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		
black-and-white	14	90 hr. per mo.
color	27	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)

Table 17. Gas-Filled Lamp Data

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-2D	25,000	Neon	15/16	Flanged	0.0007	110-125	1/12
NE-2E	25,000	Neon	3/4	Unbased	0.0007	110-125	1/12
NE-2H	25,000	Neon	3/4	Unbased	0.0019	110-125	1/4
NE-2J	25,000	Neon	15/16	Flanged	0.0019	110-125	1/4
NE-7	7,500	Neon	1 1/4	Unbased	0.002	105-125	1/4
NE-16	1,000	Neon	1 1/2	Bayonet	0.0015	67-87	
NE-17	5,000	Neon	1 1/2	Double-Contact Bayonet§	0.002	110-125	1/4
NE-21	7,500	Neon	1 1/2	Bayonet	0.002	105-125	1/4
NE-23	6,000	Neon	1	Unbased	0.0003	60-90	
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-51H	25,000	Neon	1 3/16	Bayonet	0.0012	110-125	1/7
NE-54	7,500	Neon	1 1/4	Unbased	0.002	105-125	1/4
NE-56	10,000	Neon	2 1/4	Medium Screw§	0.005	220-225	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
NE-66	25	Neon	1 17/32	Cand. Screw	0.001	105-125	
NE-76	2,000	Neon	1	Unbased	0.0004	68-76	
NE-79	10,000	Neon	2	Bayonet	0.012	105-125	1
NE-83	5,000	Neon	1 1/2	Unbased	0.005	60-100	
NE-86	5,000	Neon	1 13/16	Unbased	0.0015	55-90	
NE-97	6,000	Neon	1	Unbased	0.005	110-140	

* Life on DC is approximately 60% of AC values.
† For 110-125V operation.

‡ The dimension is for glass only.
§ In DC circuits the base should be negative.

Table 18. 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-2D	100,000	———	———	———	———
NE-2E	100,000	———	———	———	———
NE-2H	30,000	———	———	———	———
NE-2J	30,000	———	———	———	———
NE-7	30,000	———	———	———	———
NE-17	30,000	110,000	150,000	180,000	240,000
NE-21	30,000	———	———	———	———
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-51H	47,000	———	———	———	———
NE-54	30,000	———	———	———	———
NE-56	Included in Base	———	———	———	———
NE-57	Included in base	82,000	120,000	150,000	200,000
NE-58	Included in Base	———	———	———	———
NE-66	3,600	———	———	———	———
NE-79	7,500	———	———	———	———

MACHINE SCREW AND DRILL SIZES

The decimal equivalents of No. 80 to 1-inch drills are given in Table 20.

METRIC EQUIVALENTS

Length

1 centimeter	= 0.3937 inch	1 inch	= 2.5400 centimeters (cm)
1 meter	= 3.2808 feet	1 foot	= 0.3048 meter
1 meter	= 1.0936 yards	1 yard	= 0.9144 meter
1 kilometer	= 0.6214 mile	1 mile (statute)	= 1.6093 kilometers (km)

Area

1 sq cm	= 0.1550 sq inch	1 sq inch	= 6.4516 sq cm
1 sq meter	= 10.7639 sq feet	1 sq foot	= 0.0929 sq meter
1 sq meter	= 1.1960 sq yards	1 sq yard	= 0.8361 sq meter
1 hectare	= 2.4710 acres	1 acre	= 0.4047 hectare
1 sq km	= 0.3861 sq mile	1 sq mile	= 2.5900 sq km

Volume

1 cu cm	= 0.0610 cu inch	1 cu inch	= 16.3872 cu cm
1 cu meter	= 35.3145 cu feet	1 cu foot	= 0.0283 cu meter
1 cu meter	= 1.3079 cu yards	1 cu yard	= 0.7646 cu meter

Capacity

1 liter	= 61.0250 cu inches	1 liter	= 0.9081 quart (dry)
1 liter	= 0.0353 cu feet	1 liter	= 2.2046 pounds of water @ 4° C
1 liter	= 0.2642 gallon (U.S.)	1 cu inch	= 0.0164 liter
1 liter	= 0.0284 bushel (U.S.)	1 cu foot	= 28.3162 liters
1 liter	= 1000.027 cu cm	1 gallon	= 3.7853 liters
1 liter	= 1.056 quarts (liquid)	1 bushel	= 35.2383 liters

Weight

1 gram	= 15.4324 grains	1 grain	= 0.0648 gram
1 gram	= 0.0353 ounce (avdp)	1 ounce (avdp)	= 28.3495 grams
1 kg	= 2.2046 pounds (avdp)	1 pound (avdp)	= 0.4536 kg
1 kg	= 0.0011 ton (short)	1 ton (short)	= 907.1848 kg
1 ton (metric)	= 1.1023 tons (short)	1 ton (short)	= 0.9072 ton (metric)
1 ton (metric)	= 0.9842 ton (long)	1 ton (long)	= 1.0160 ton (metric)

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

Table 19. Copper Wire Table

AWG	Nom. Bare Diameter (Inches)	Nom. Circular Mils	Nom. Feet Per Lb. (Bare)	Nom. Ohms Per 1000 Ft. @20°C	Current Carrying Capacity @700 CM/Amp	Turns Per Linear Inch	
						Single Film Coated	Heavy Film Coated
0000	.4600	211600	1.561	.04901	302.3		
000	.4096	167800	1.969	.06182	239.7		
00	.3648	133100	2.482	.07793	190.1		
0	.3249	105600	3.130	.09825	150.9		
1	.2893	83690	3.947	.1239	119.6		
2	.2576	66360	4.978	.1563	94.8		
3	.2294	52620	6.278	.1971	75.2		
4	.2043	41740	7.915	.2485	59.6		4.80
5	.1819	33090	9.984	.3134	47.3		5.38
6	.1620	26240	12.59	.3952	37.5		6.03
7	.1443	20820	15.87	.4981	29.7		6.75
8	.1285	16510	20.01	.6281	23.6		7.57
9	.1144	13090	25.24	.7925	18.7		8.48
10	.1019	10380	31.82	.9988	14.8		9.50
11	.0907	8230	40.2	1.26	11.8		10.6
12	.0808	6530	50.6	1.59	9.33		11.9
13	.0720	5180	63.7	2.00	7.40		13.3
14	.0641	4110	80.4	2.52	5.87	15.2	14.8
15	.0571	3260	101	3.18	4.66	17.0	16.6
16	.0508	2580	128	4.02	3.69	19.0	18.5
17	.0453	2050	161	5.05	2.93	21.3	20.7
18	.0403	1620	203	6.39	2.31	23.9	23.1
19	.0359	1290	256	8.05	1.84	26.7	25.9
20	.0320	1020	323	10.1	1.46	29.9	28.9
21	.0285	812	407	12.8	1.16	33.4	32.3
22	.0253	640	516	16.2	.914	37.5	36.1
23	.0226	511	647	20.3	.730	41.8	40.2
24	.0201	404	818	25.7	.577	46.8	44.8
25	.0179	320	1030	32.4	.457	52.5	50.1

26	.0159	253	1310	41.0	.361	58.8	56.0
27	.0142	202	1640	51.4	.289	65.6	62.3
28	.0126	159	2080	65.3	.227	73.3	69.4
29	.0113	128	2590	81.2	.183	81.6	76.9
30	.0100	100	3300	104.0	.143	91.7	86.2
31	.0089	79.2	4170	131	.113	103	96
32	.0080	64.0	5160	162	.091	114	106
33	.0071	50.4	6550	206	.072	128	118
34	.0063	39.7	8320	261	.057	145	133
35	.0056	31.4	10500	331	.045	163	149
36	.0050	25.0	13200	415	.036	182	167
37	.0045	20.2	16300	512	.029	202	183
38	.0040	16.0	20600	648	.023	225	206
39	.0035	12.2	27000	847	.017	260	235
40	.0031	9.61	34400	1080	.014	290	263
41	.0028	7.84	42100	1320	.011	323	294
42	.0025	6.25	52900	1660	.0089	357	328
43	.0022	4.84	68300	2140	.0069	408	370
44	.0020	4.00	82600	2590	.0057	444	400
45	.00176	3.10	107000	3350	.0044	520	465
46	.00157	2.46	134000	4210	.0035	580	510
47	.00140	1.96	169000	5290	.0028	630	560
48	.00124	1.54	215000	6750	.0022	710	645
49	.00111	1.23	268000	8420	.0018	800	720
50	.00099	.980	337000	10600	.0014	880	780
51	.00088	.774	427000	13400	.0011	970	855
52	.00078	.608	543000	17000	.00087	1080	935
53	.00070	.490	674000	21200	.00070	1270	1110
54	.00062	.384	859000	27000	.00055	1430	1220
55	.00055	.302	1090000	34300	.00043	1560	1330
56	.00049	.240	1380000	43200	.00034	1690	1450
57	.000438	.192	1722000	54100	.00027	1960	
58	.000390	.152	2166000	68000	.00022	2160	
59	.000347	.121	2737000	85900	.00017	2450	
60	.000309	.090	3453000	108400	.00014	2740	

Table 20. Drill Sizes and Decimal Equivalents

Drill Size	Decimal	Drill Size	Decimal	Drill Size	Decimal
80	.0135	1/8	.1250	P	.3230
79	.0145	30	.1285	21/64	.3281
1/64	.0156	29	.1360	Q	.3320
78	.0160	28	.1405	R	.3390
77	.0180	9/64	.1406	11/32	.3438
76	.0200	27	.1440	S	.3480
75	.0210	26	.1470	T	.3580
74	.0225	25	.1495	23/64	.3594
73	.0240	24	.1520	U	.3680
72	.0250	23	.1540	3/8	.3750
71	.0260	5/32	.1562	V	.3770
70	.0280	22	.1570	W	.3860
69	.0292	21	.1590	25/64	.3906
68	.0310	20	.1610	X	.3970
1/32	.0313	19	.1660	Y	.4040
67	.0320	18	.1695	13/32	.4062
66	.0330	11/64	.1709	Z	.4130
65	.0350	17	.1730	27/64	.4219
64	.0360	16	.1770	7/16	.4375
63	.0370	15	.1800	29/64	.4531
62	.0380	14	.1820	15/32	.4688
61	.0390	13	.1850	31/64	.4844
60	.0400	3/61	.1875	1/2	.5000
59	.0410	12	.1890	33/64	.5156
58	.0420	11	.1910	17/32	.5313
57	.0430	10	.1935	35/64	.5469
56	.0465	9	.1960	9/16	.5625
3/64	.0469	8	.1990	37/64	.5781
55	.0520	7	.2010	19/32	.5938
54	.0550	13/64	.2031	39/64	.6094
53	.0595	6	.2040	5/8	.6250
1/16	.0625	5	.2055	41/64	.6406
52	.0635	4	.2090	21/32	.6562
51	.0670	3	.2130	43/64	.6719
50	.0700	7/32	.2188	11/16	.6875
49	.0730	2	.2210	45/64	.7031
48	.0760	1	.2280	23/32	.7188
5/64	.0781	A	.2340	47/64	.7344
47	.0785	15/64	.2344	3/4	.7500
46	.0810	B	.2380	49/64	.7656
45	.0820	C	.2420	25/32	.7812
44	.0860	D	.2460	51/64	.7969
43	.0890	1/4	.2500	13/16	.8125
42	.0935	F	.2570	53/64	.8281
3/32	.0938	G	.2610	27/32	.8438
41	.0960	17/64	.2656	55/64	.8594
40	.0980	H	.2660	7/8	.8750
39	.0995	I	.2720	57/64	.8906
38	.1015	J	.2770	29/32	.9062
37	.1040	K	.2810	59/64	.9219
36	.1065	9/32	.2812	15/16	.9375
7/64	.1094	L	.2900	61/64	.9531
35	.1100	M	.2950	31/32	.9688
34	.1110	19/64	.2969	63/64	.9844
33	.1130	N	.3020	1"	1.000
32	.1160	5/16	.3125		
31	.1200	O	.3160		

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