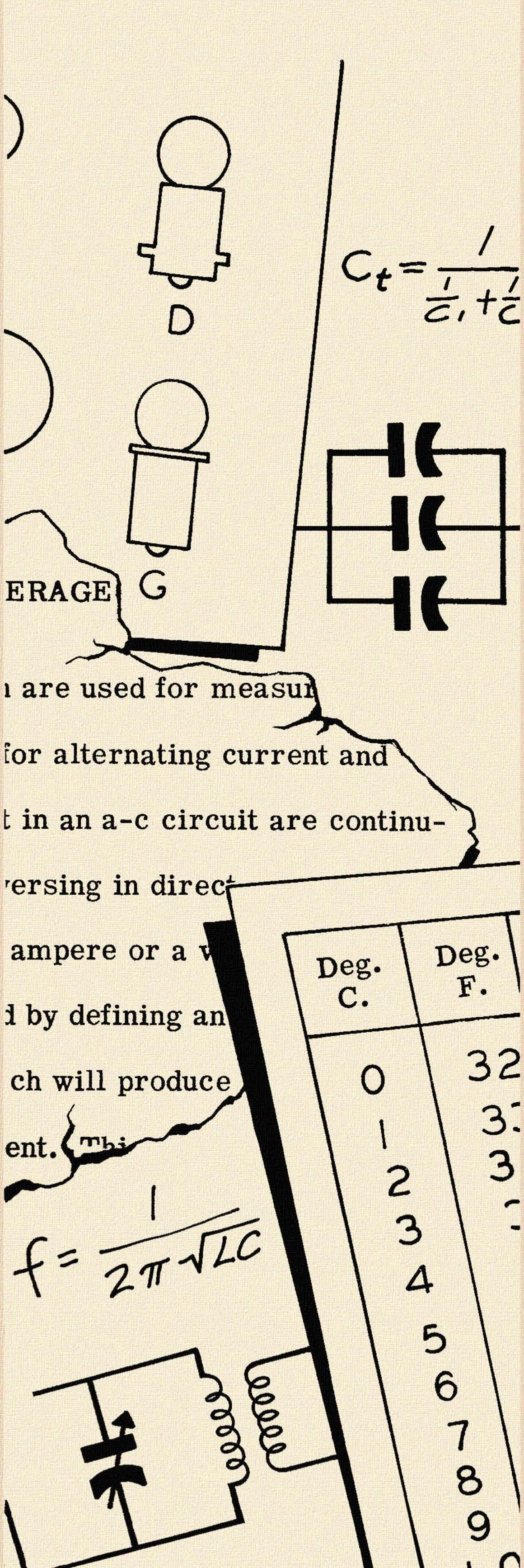
PHILCO PHILCO Factory-Supervised Service **SERVICE**

RADIO **HOME STUDY**



PHILCO

EVERYDAY ELECTRONICS REFERENCE MANUAL

- Color Codes
- Frequently Used Formulas
- Conversion Factors
- New U-H-F Channels and Frequencies
- Germanium Crystal Diodes
- Trouble-Shooting Information
- *Plus Many Other Subjects*

EVERYDAY ELECTRONICS REFERENCE MANUAL

PR-2404

TABLE OF CONTENTS

Page

COLOR CODES

Resistor Color Code 1
Capacitor Color Codes 1
  6-Dot RMA-JAN-AWS Standard Capacitor Color Code 1
  6-Dot RMA Standard Capacitor Color Code (Superseded 1948) 2
  3-Dot RMA Standard (Obsolete) Capacitor Color Code 2
  5-Dot Capacitor Color Code 2
  Ceramic Capacitor Color Codes 3
  Molded Paper Tubular Capacitor Color Code 4
Transformer-Lead Color Codes 5
  Radio Power Transformers 5
  Intermediate-Frequency Transformers 6
  Audio-Frequency and Speaker-Matching Transformers 7

FREQUENTLY USED FORMULAS

Ohm's Law for D.C. 8
Ohm's Law for A.C. 8
Resistances in Series 8
Resistances in Parallel 8
Capacitances in Parallel 9
Capacitances in Series 9
Resonant Frequency 9
Wavelength and Frequency 9
Capacitive Reactance 9
Inductive Reactance 9
Phase Angle 10
Power Factor 10
Impedance 10

FREQUENCY VS. REACTANCE OF CAPACITORS AND INDUCTORS 11

INDUCTANCE, CAPACITANCE, AND RESONANT FREQUENCY NOMOGRAPH 12

IMPEDANCE MATCHING AND TURNS RATIO 14

INDUCTANCE-CAPACITANCE (L-C) CONSTANT 14

PEAK, EFFECTIVE, AND AVERAGE VALUES OF A.C. 15

THE DECIBEL 16

PROPER USE OF DECIBEL SCALES ON COMBINATION TEST METERS 17

"Q" OR QUALITY FACTOR 18

CHARACTERISTICS OF RADIO-TYPE FUSES 19

PANEL LIGHT AND INDICATOR LAMP INFORMATION 20

COLOR CODES

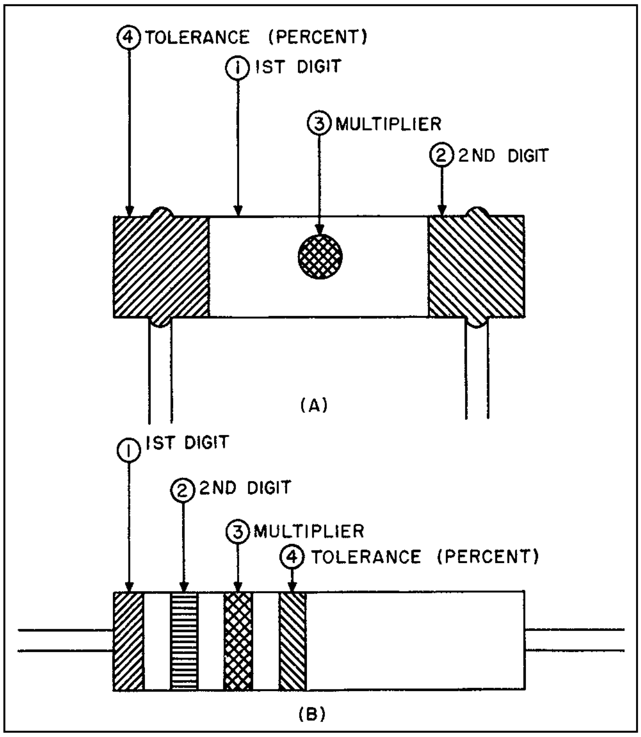
These standardized systems of color markings are used to indicate the values of small fixed resistors and capacitors, and to provide a means for identifying the various wire leads of audio and power transformers, speaker fields and voice coils, and similar types of components.

RESISTOR COLOR CODE

Resistors which have their wire leads brought out at right angles to the ends are color coded as shown in (A) of figure 1. For resistors having the wire leads brought straight out from the ends, the system of marking shown in (B) of figure 1 is used. The color values used are the same for either system of marking, and are given in Table 1. Figure 2 illustrates the method of using both systems.

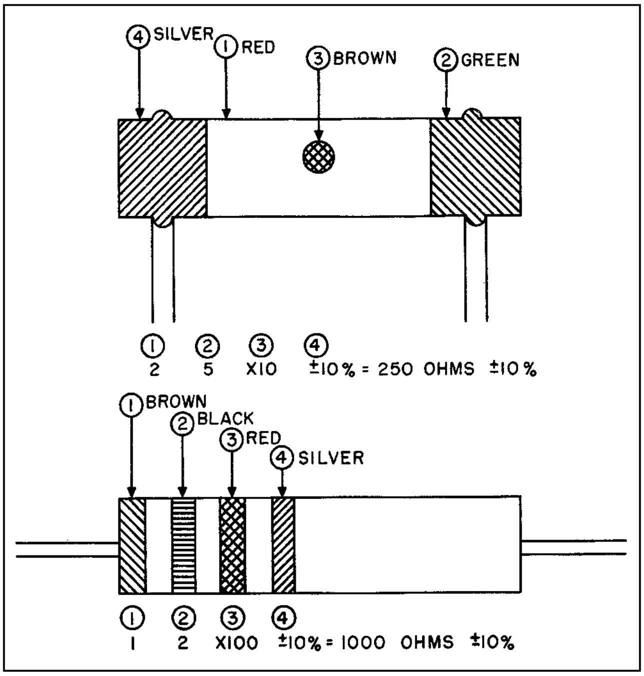
TABLE 1. RESISTOR COLOR CODE

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Gold			.1	5
Silver			.01	10
No color				20



TP2-2507

Figure 1. Marking Systems Used for Color Coding of Resistors



TP2-2508

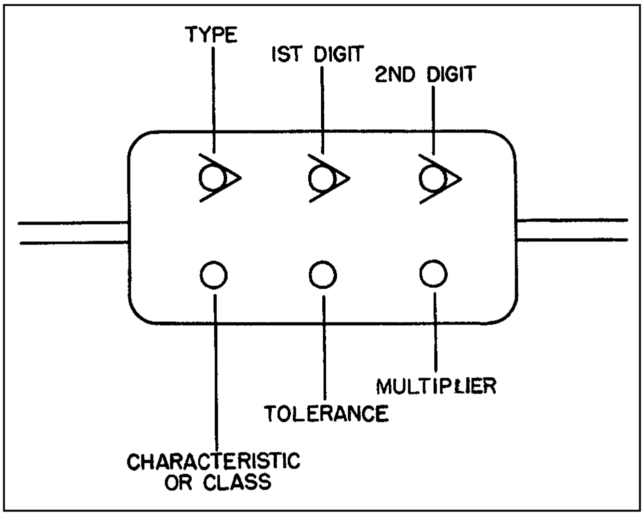
Figure 2. Examples of Resistor Color Codes

CAPACITOR COLOR CODES

Because of the many types of capacitors that are used and the various forms which they may take, a number of standardized marking systems are used.

6-Dot RMA-JAN-AWS Standard Capacitor Color Code

This marking is used with capacitors made to JAN, AWS, or the new (1948) RMA standards, and is illustrated in figure 3.



TP2-2509

Figure 3. 6-Dot RMA-JAN-AWS Standard Capacitor Color-Coding System

TABLE 2. 6-DOT RMA-JAN-AWS STANDARD CAPACITOR COLOR CODE

COLOR	TYPE	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	CHARACTERISTIC OR CLASS
Black	JAN, mica	0	0	1.0		Applies to temperature coefficients or methods of testing
Brown		1	1	10	1	
Red		2	2	100	2	
Orange		3	3	1,000	3	
Yellow		4	4	10,000	4	
Green		5	5	100,000	5	
Blue		6	6	1,000,000	6	
Violet		7	7	10,000,000	7	
Gray		8	8	100,000,000	8	
White	RMA, mica	9	9	1,000,000,000	9	
Gold				.1		
Silver	AWS, paper			.01	10	
Body					20	

6-Dot RMA Standard Capacitor Color Code (Superseded 1948)

In the old 6-dot RMA standard capacitor color code, six dots are used in two rows of three dots each, as shown in figure 4.

3-Dot RMA Standard (Obsolete) Capacitor Color Code

This system of marking, which was discontinued in 1948, was used only for capacitors having a rating of 500 volts and a tolerance of 20 percent. The three dots were used only for indicating the capacitance. This system is illustrated in figure 5.

5-Dot Capacitor Color Code

This method of color coding is shown in figure 6.

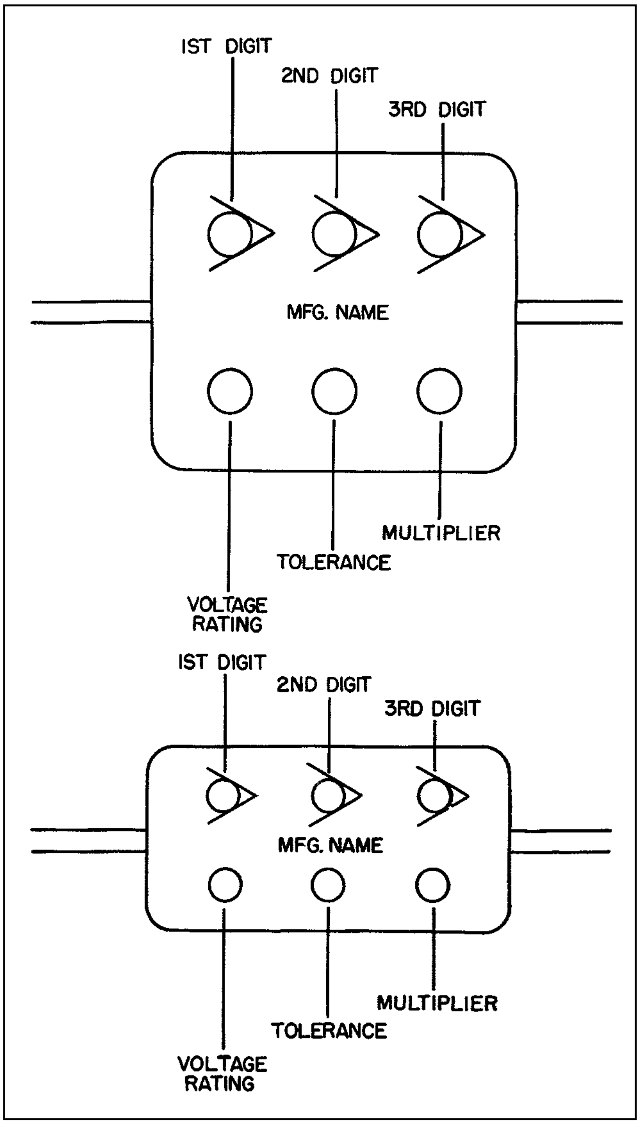
TABLE 3. 6-DOT RMA STANDARD (OBSOLETE) CAPACITOR COLOR CODE

COLOR	1ST DIGIT	2ND DIGIT	3RD DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	VOLTAGE RATING
Black	0	0	0	1.0		
Brown	1	1	1	10	1	100
Red	2	2	2	100	2	200
Orange	3	3	3	1,000	3	300
Yellow	4	4	4	10,000	4	400
Green	5	5	5	100,000	5	500
Blue	6	6	6	1,000,000	6	600
Violet	7	7	7	10,000,000	7	700
Gray	8	8	8	100,000,000	8	800
White	9	9	9	1,000,000,000	9	900
Gold				.1		1000
Silver				.01	10	2000
Body					20	500

TABLE 4. 5-DOT CAPACITOR COLOR CODE

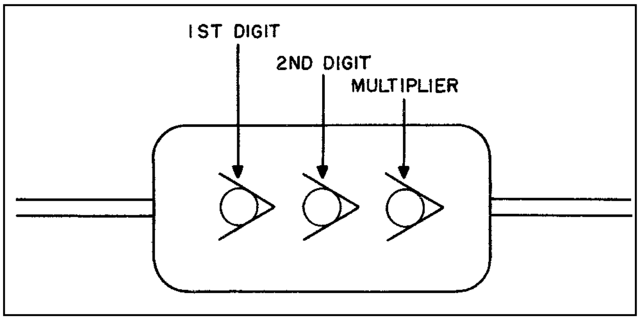
COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	VOLTAGE RATING
Black	0	0	1.0		
Brown	1	1	10	1	100
Red	2	2	100	2	200
Orange	3	3	1,000	3	300
Yellow	4	4	10,000	4	400
Green	5	5	100,000	5	500
Blue	6	6	1,000,000	6	600
Violet	7	7	10,000,000	7	700
Gray	8	8	100,000,000	8	800
White	9	9	1,000,000,000	9	900
Gold			.1		1000
Silver			.01	10	2000
Body				20	*

* Where no color is indicated, the voltage rating may be as low as 300 volts.



TP2-2510

Figure 4. 6-Dot RMA Standard (Obsolete) Capacitor Color-Coding System

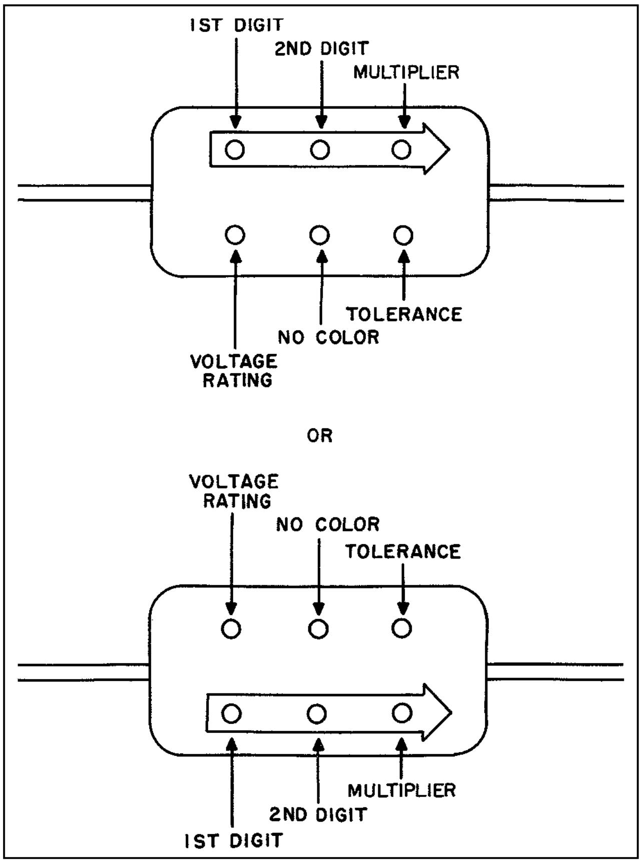


TP2-2511

Figure 5. 3-Dot RMA Standard (Obsolete) Capacitor Color-Coding System

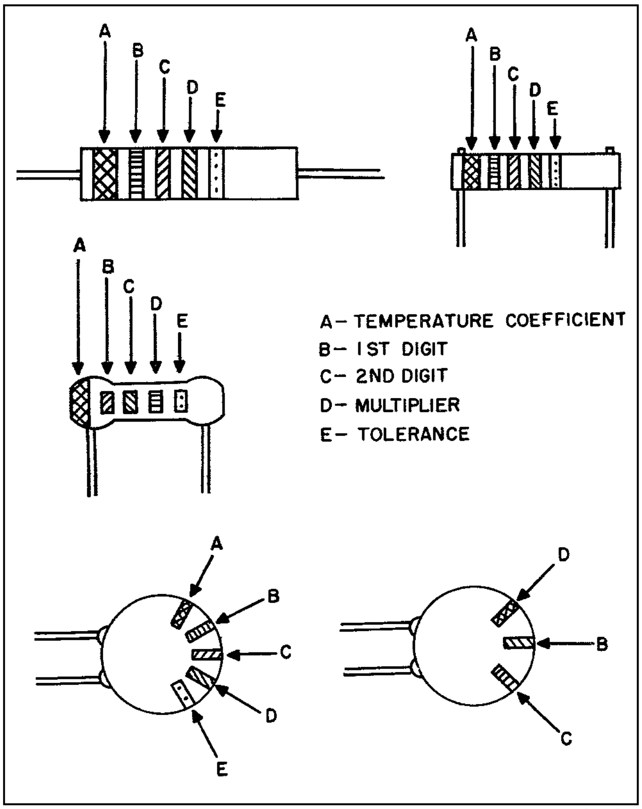
Ceramic Capacitor Color Codes

The methods used for marking ceramic-type capacitors are shown in figure 7. Either dots or bands may be used, depending upon the manufacturer.



TP2-2512

Figure 6. 5-Dot Capacitor Color-Coding System



TP2-2513

Figure 7. Ceramic Capacitor Color-Coding Systems

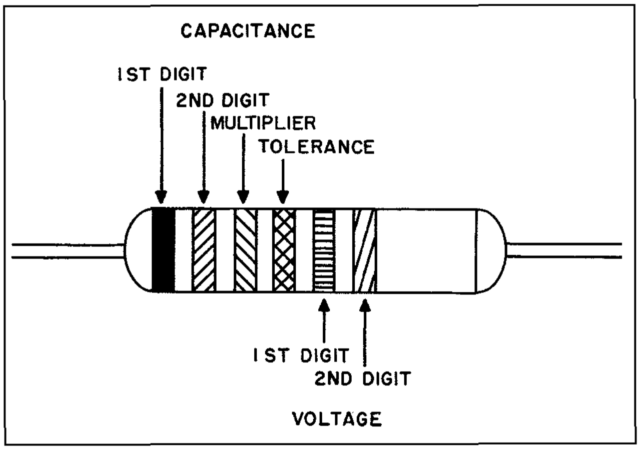
TABLE 5. CERAMIC CAPACITOR COLOR CODE

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE		TEMPERATURE COEFFICIENT*
				MORE THAN 10 µµf. (in percent)	LESS THAN 10 µµf. (in µµf.)	
Black	0	0	1.0	±20	2.0	0
Brown	1	1	10	±1		-30
Red	2	2	100	±2		-80
Orange	3	3	1,000			-150
Yellow	4	4	10,000			-220
Green	5	5		±5	0.5	-330
Blue	6	6				-470
Violet	7	7				-750
Gray	8	8	.01		0.25	+30
White	9	9	.1	±10	1.0	+120 to -75 (RMA)
						+500 to -330 (JAN)
						+100
						By-pass or coupling

* Parts per million per degree Centigrade.

Molded Paper Tubular Capacitor Color Code

Molded paper tubular capacitors are color coded in accordance with the system shown in figure 8. Capacitors having a voltage rating of less than 900 volts have only five bands, while capacitors having a voltage rating of greater than 900 volts have six bands; in either case two zeros are understood to follow the digit or digits of the voltage rating.



TP2-2514

Figure 8. Molded Paper Tubular Capacitor Color-Coding System

TABLE 6. MOLDED PAPER TUBULAR CAPACITOR COLOR CODE

COLOR	CAPACITANCE			TOLERANCE (PERCENT)	VOLTAGE RATING	
	1ST DIGIT	2ND DIGIT	MULTIPLIER		1ST DIGIT	2ND DIGIT
Black	0	0	1	±20	0	0
Brown	1	1	10		1	1
Red	2	2	100		2	2
Orange	3	3	1,000	±30	3	3
Yellow	4	4	10,000	±40	4	4
Green	5	5	100,000	±5	5	5
Blue	6	6	1,000,000		6	6
Violet	7	7			7	7
Gray	8	8			8	8
White	9	9		±10	9	9

TRANSFORMER-LEAD COLOR CODES

The following systems of markings are in common use for the identification of connecting leads from transformers and coils employed in electronic equipment.

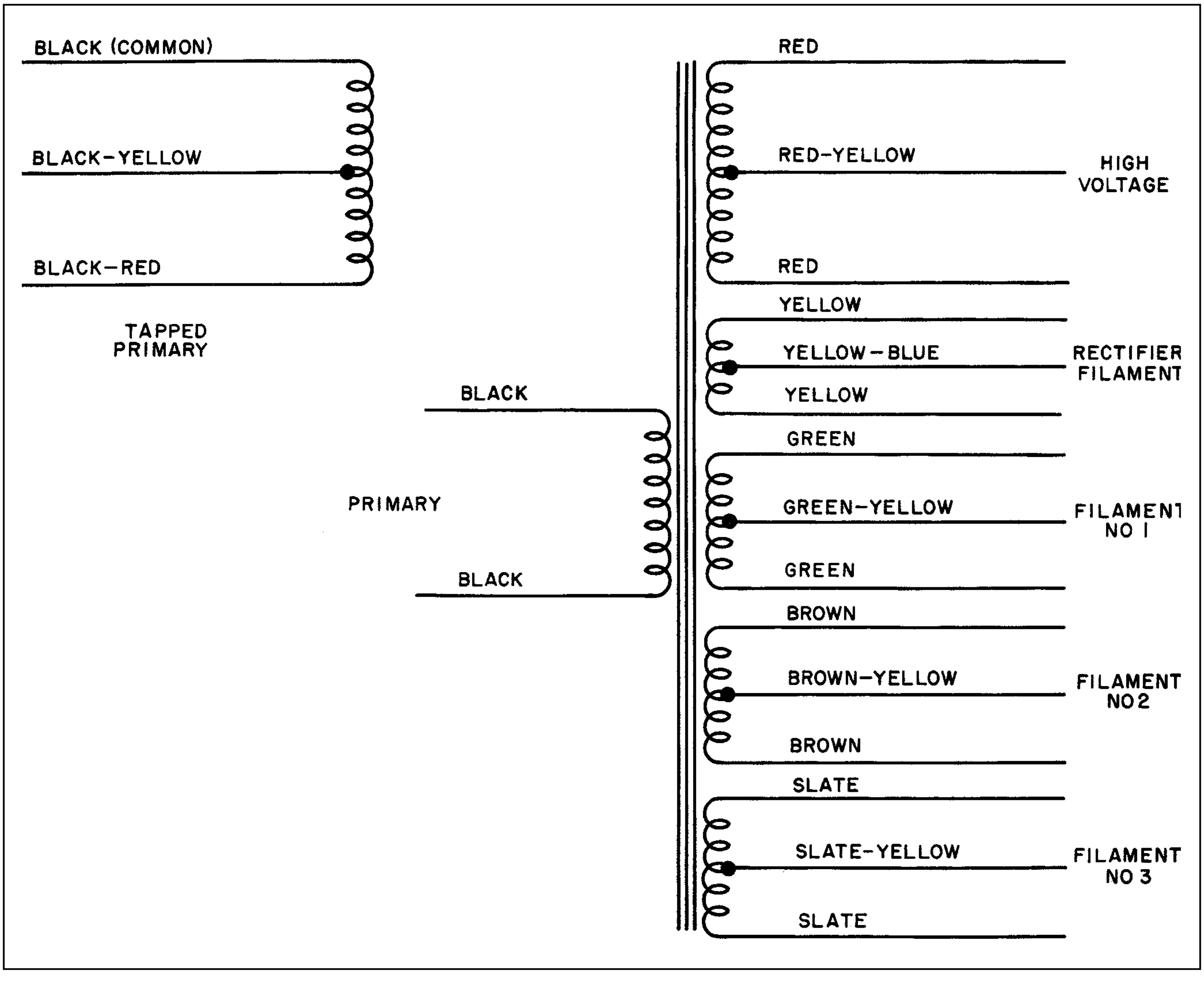
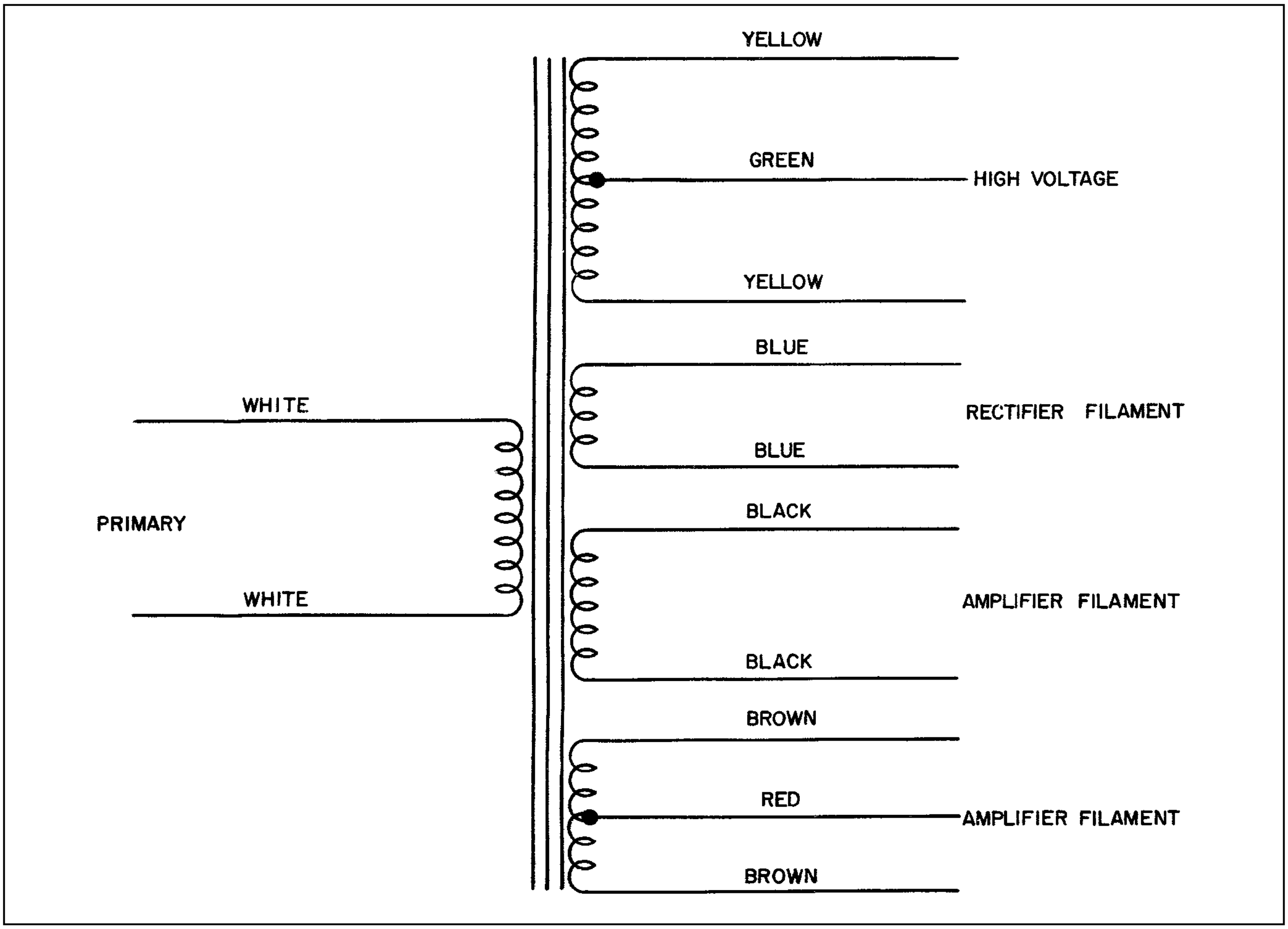
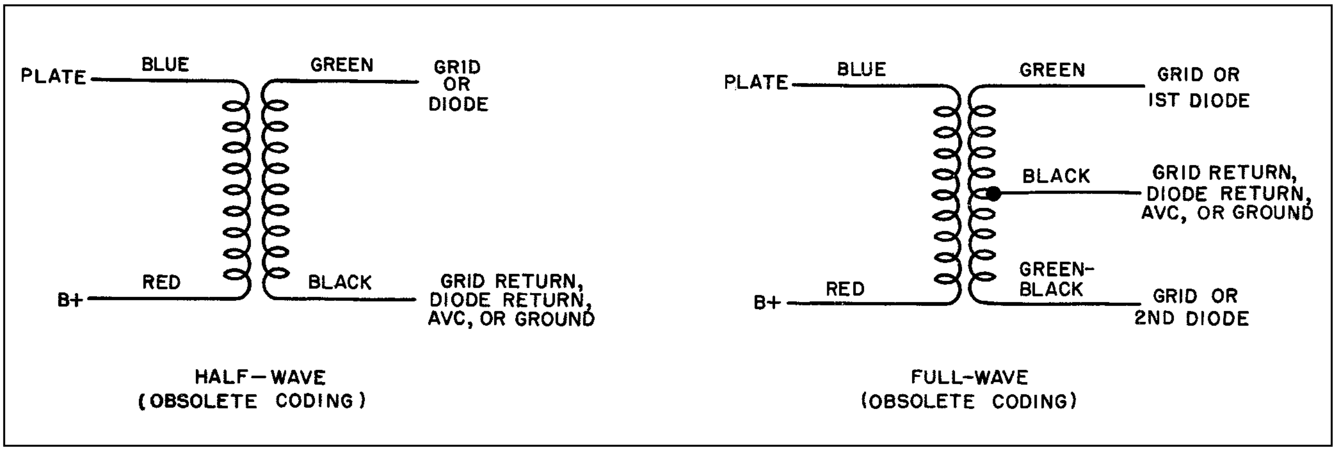


Figure 9 RMA Standard Color Coding for Radio Power Transformers



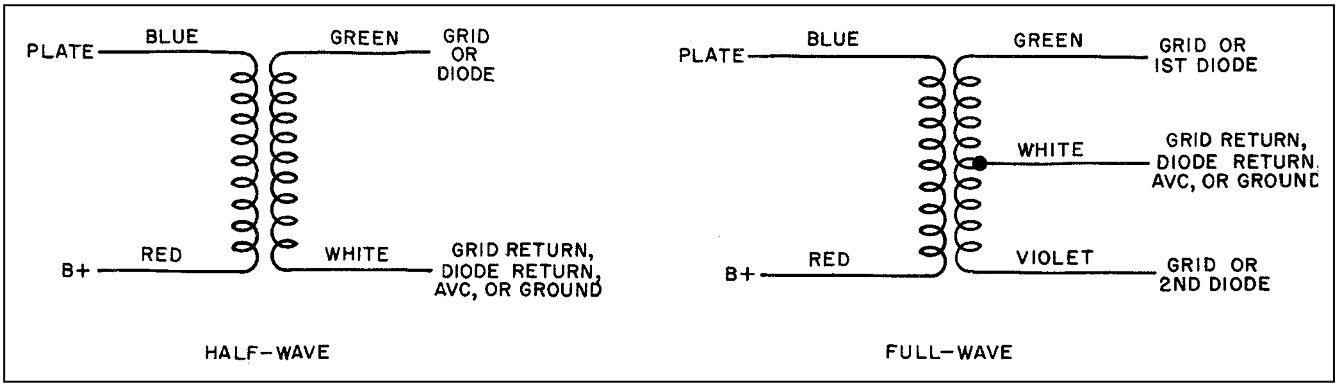
TP2-2516

Figure 10. Philco Color Coding for Radio Power Transformers



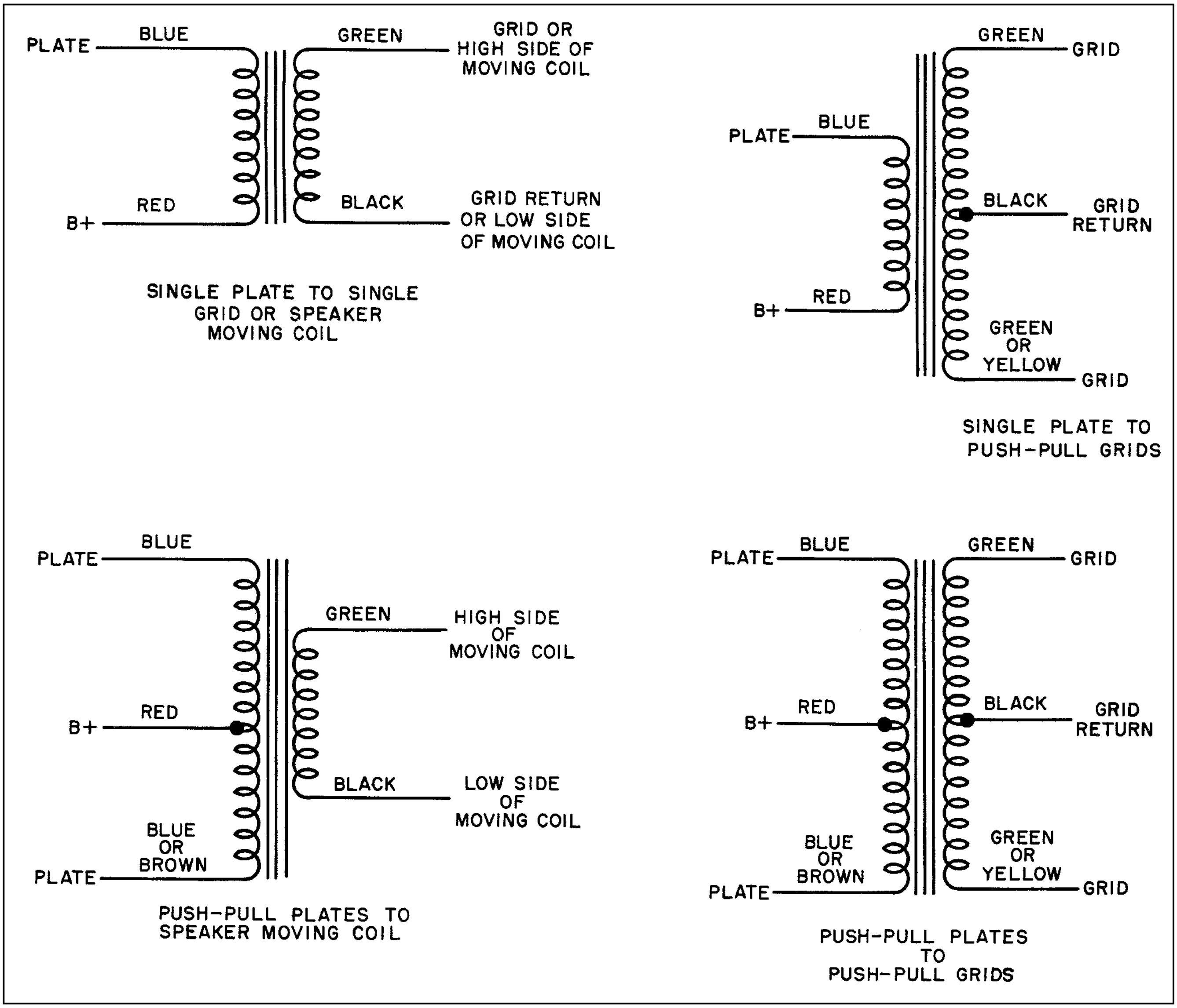
TP2-2517A

Figure 11A. RMA Standard Color Coding for I-F Transformers (Superseded)



TP2-2517B

Figure 11B. RMA Standard Color Coding for I-F Transformers



TP2-2518

Figure 12. RMA Standard Color Coding for A-F Transformers

FREQUENTLY USED FORMULAS

OHM'S LAW FOR D.C.

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

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

$$E = IR = \frac{P}{I} = \sqrt{PR}$$

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

Where

I = current in amperes

R = resistance in ohms

E = e.m.f. in volts

P = power in watts

OHM'S LAW FOR A.C.

$$I = \frac{E}{Z} = \sqrt{\frac{P}{Z\cos\theta}} = \frac{P}{E\cos\theta}$$

$$Z = \frac{E}{I} = \frac{P}{I^2\cos\theta} = \frac{E^2\cos\theta}{P}$$

$$E = IZ = \frac{P}{I\cos\theta} = \sqrt{\frac{PZ}{\cos\theta}}$$

$$P = EI\cos\theta = I^2Z\cos\theta = \frac{E^2\cos\theta}{Z}$$

Where

I = current in amperes

Z = impedance in ohms (see page 10)

E = e.m.f. in volts

P = power in watts

θ = phase angle in degrees (angle by which current, I, leads or lags voltage, E. See page 10)

RESISTANCES IN SERIES

Resistances connected in series will have a total resistance value equal to the *sum* of their individual resistance. Thus, for example

$$R_{total} = R_1 + R_2 + R_3 = 1000 + 2000 + 3000 = 6000 \text{ ohms}$$

RESISTANCES IN PARALLEL

When resistances are connected in parallel, the resultant value of resistance will always be *less* than that of the individual resistance having the *lowest* value.

When only two resistances are connected in parallel

$$R_{total} = \frac{R_1 \times R_2}{R_1 + R_2}$$

Where three or more resistances are connected in parallel

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

An alternate method using Ohm's law to determine the total resistance of a parallel combination may sometimes be found easier to employ than the above formulas. Briefly, the method consists of using an arbitrarily assumed voltage to find the current through each resistance $\left(\frac{E_{assumed}}{R} = I\right)$, and then dividing the *sum* of the current into the assumed voltage to obtain the total resistance $\left(\frac{E_{assumed}}{I_{total}} = R_{total}\right)$ For example, suppose:

$R_1 = 100$ ohms

$R_2 = 200$ ohms

$R_3 = 300$ ohms

$E_{assumed} = 600$ volts

Then

$$\frac{E_{assumed}}{R_1} = \frac{600}{100} = 6$$

$$\frac{E_{assumed}}{R_2} = \frac{600}{200} = 3$$

$$\frac{E_{assumed}}{R_3} = \frac{600}{300} = 2$$

$$I_{total} = 6 + 3 + 2 = 11 \text{ amperes}$$

$$R_{total} = \frac{E_{assumed}}{I_{total}} = \frac{600}{11} = 54.5 \text{ ohms}$$

CAPACITANCES IN PARALLEL

Capacitances connected in *parallel* will have a total capacitance equal to the *sum* of their individual capacitances. Thus, for example

$$C_{total} = C_1 + C_2 + C_3 = 100\ \mu\mu f. + 200\ \mu\mu f. + 300\ \mu\mu f. = 600\ \mu\mu f.$$

All capacitances must be expressed either in μf. or μμf. Both units cannot be used in the formula at the same time.

CAPACITANCES IN SERIES

When capacitors are connected in *series*, the total capacitance will always be less than that of the individual capacitor having the lowest value.

When only two capacitors are connected in series

$$C_{total} = \frac{C_1 \times C_2}{C_1 + C_2}$$

When three or more capacitors are connected in series

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \cdots}$$

RESONANT FREQUENCY

The basic formula for resonant frequency is as follows:

$$f(\text{cycles}) = \frac{1}{6.28 \times \sqrt{L(\text{henrys}) \times C(\text{farads})}}$$

Since the fundamental units (cycles, henrys, and farads) are inconveniently large for most computations, the following variations of the basic formula will be found more suitable for practical applications.

$$f(\text{kilocycles}) = \frac{159.2}{\sqrt{L(\mu h.) \times C(\mu f.)}}$$

$$f(\text{kilocycles}) = \frac{159200}{\sqrt{L(\mu h.) \times C(\mu\mu f.)}}$$

$$f(\text{megacycles}) = \frac{159.2}{\sqrt{L(\mu h.) \times C(\mu\mu f.)}}$$

$$f(\text{megacycles}) = \frac{159200}{\sqrt{L(\mu\mu h.) \times C(\mu\mu f.)}}$$

WAVELENGTH AND FREQUENCY

The relationship between wavelength and frequency is given by the formula

$$\text{Wavelength (meters)} = \frac{300{,}000{,}000}{\text{frequency (cycles/sec.)}}$$

$$\text{Wavelength (meters)} = \frac{300{,}000}{\text{frequency (megacycles/sec.)}}$$

or

$$\text{Wavelength (meters)} = \frac{300}{\text{frequency (megacycles/sec.)}}$$

Conversely,

$$\text{Frequency (cycles/sec.)} = \frac{300{,}000{,}000}{\text{wavelength (meters)}}$$

$$\text{Frequency (kilocycles/sec.)} = \frac{300{,}000}{\text{wavelength (meters)}}$$

or

$$\text{Frequency (megacycles/sec.)} = \frac{300}{\text{wavelength (meters)}}$$

CAPACITIVE REACTANCE

Capacitive reactance is the opposition which is offered to the flow of alternating current by the capacitance in a circuit. Its value is given in ohms, and may be calculated from the formula

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

Where

X_c = capacitive reactance in *ohms*
f = frequency in *cycles per second*
C = capacitance in *farads*
π = 3.14 (approx.)

The fundamental units, *cycles per second* and *farads*, are too large for practical use. However, the reactance value in *ohms* will also be obtained if capacitance is stated in *microfarads* and *frequency* in *megacycles.*

INDUCTIVE REACTANCE

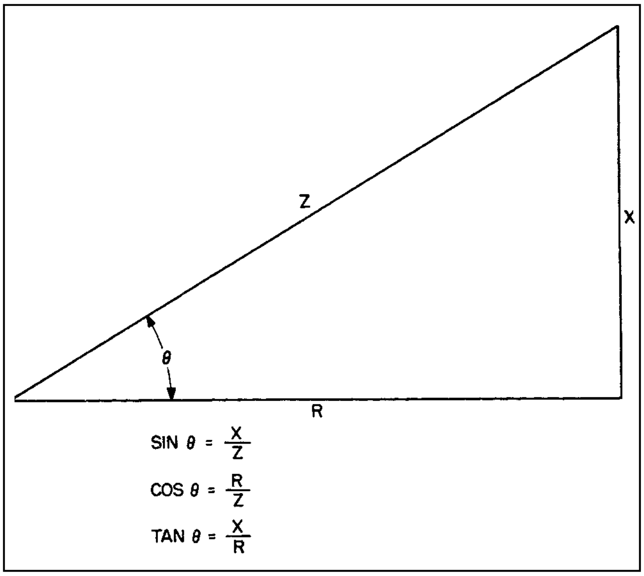
Inductive reactance is the opposition which is offered to the flow of alternating current by the inductance in a circuit. Its value is also given in ohms, and may be calculated from the formula

$$X_L = 2\pi fL$$

Where

X_L = inductive reactance in ohms
f = frequency in cycles per second
L = inductance in henrys
π = 3.14 (approx.)

The fundamental units, cycles per second and henrys, are cumbersome to use in most applications. The reactance value in ohms can also be obtained, however, if inductance is expressed in millihenrys and frequency in kilocycles. Likewise, inductance may be stated in microhenrys if frequency is given in megacycles.



TP2-3077

Figure 13. Relationships between X, Z, R, and θ

PHASE ANGLE

The phase angle, θ, is the angle in degrees by which the current *leads* the voltage in a capacitive circuit, or *lags* the voltage in an inductive circuit. This is illustrated in figure 14, where an inductive impedance, Z, with a lagging current, I, is shown. The value θ can easily be determined from the simple trigonometric formulas relating the angle θ to any two sides. See figure 13.

In a purely resistive circuit, θ is equal to 0 degrees.

In a purely reactive circuit, θ is equal to 90 degrees.

In a resonant circuit, θ is equal to 0 degrees.

POWER FACTOR

The power factor of a circuit is the ratio of the true power to the apparent power. For d-c circuits it is equal to 1. For a-c circuits it may be calculated from the formula

$$\text{p.f.} = \frac{\text{true power}}{\text{apparent power}}, \text{ or p.f.} = \frac{EI\cos\theta}{EI} = \cos\theta = \frac{R}{Z}$$

Where

p.f. = circuit load power factor

EI cos θ = true power in watts

EI = apparent power in volt-amperes

E = applied e.m.f. in volts

I = load current in amperes

θ = phase angle

R = circuit resistance

Z = circuit impedance

For a purely resistive circuit, θ is equal to 0 degrees and p.f. equals 1.
For a purely reactive circuit, θ is equal to 90 degrees and p.f. equals 0.
For a resonant circuit, θ is equal to 0 degrees and p.f. equals 1.

IMPEDANCE

Impedance is the total of the opposition which is offered to the flow of an alternating current at a given frequency by the combined effects of the reactance and resistance in the circuit. Its value is given in ohms, and may be calculated from the formula

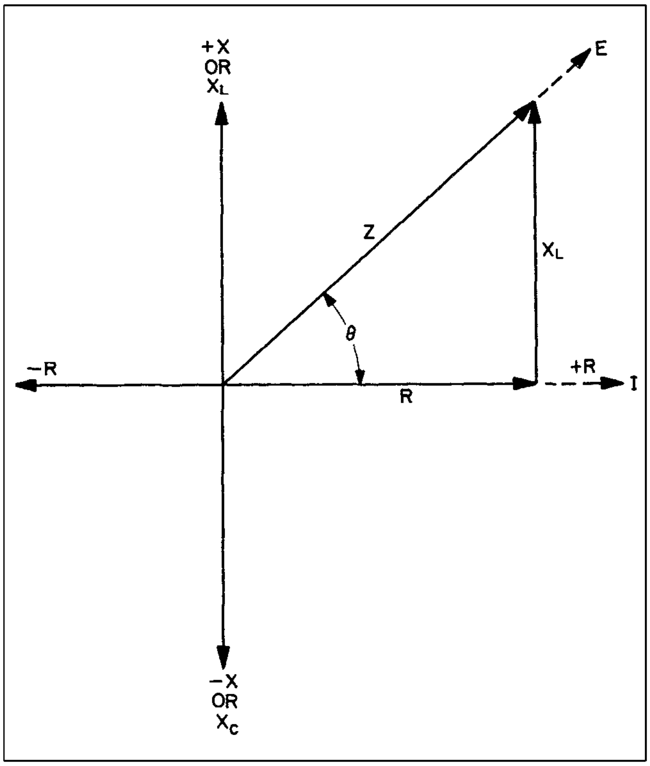
$$Z = \sqrt{R^2 + X^2}$$

Where

Z = impedance of the circuit

R = resistance of the circuit

X = reactance (X_L—X_c). See figure 14.

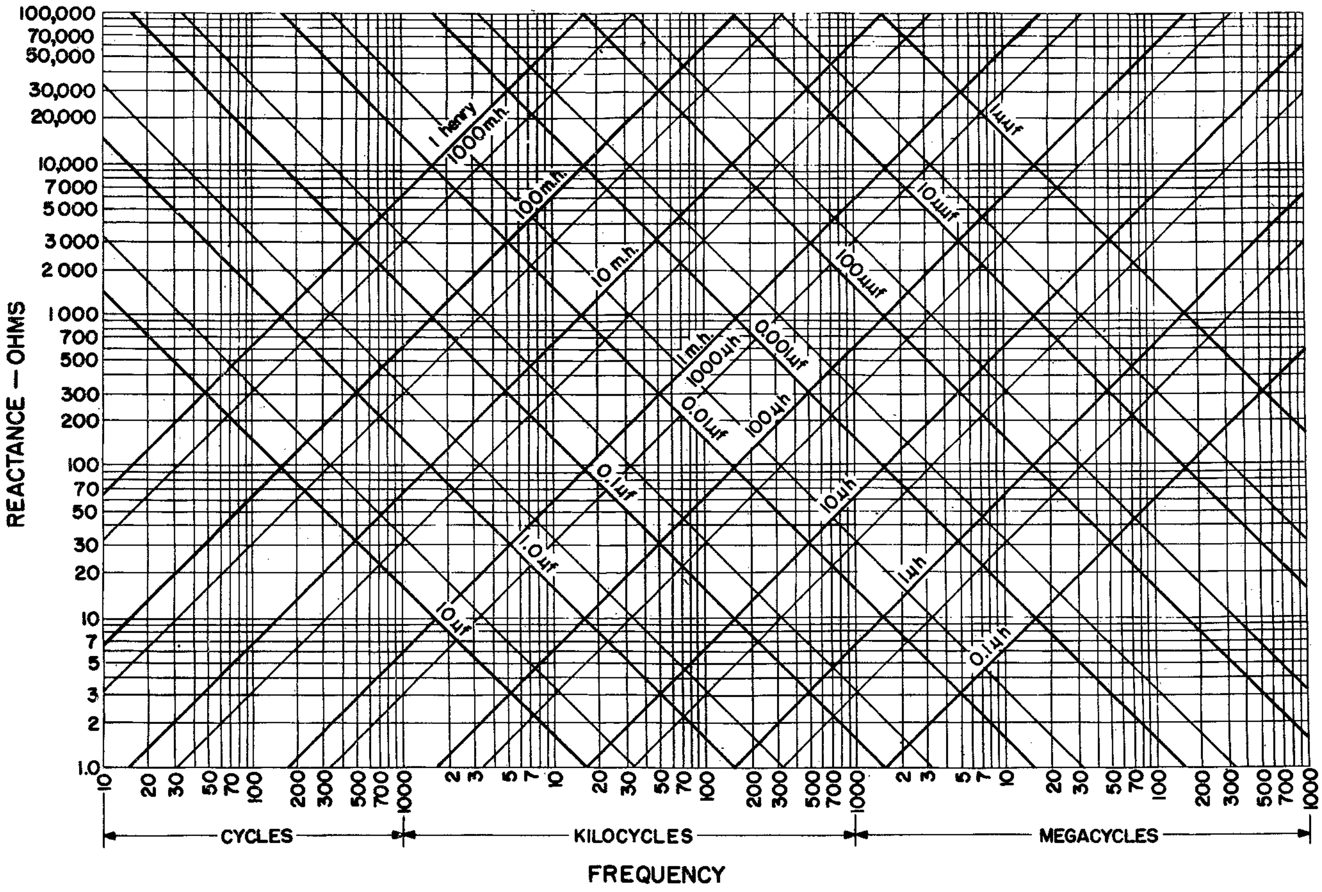


TP2-3077

Figure 14. Relationships between Impedance, Resistance, and Reactance

FREQUENCY vs. REACTANCE OF CAPACITORS AND INDUCTORS

The chart shown in figure 15 can be used to quickly determine the approximate reactance of capacitors and inductors at any frequency from the low audio frequencies up to the ultra high radio frequencies. Values intermediate between those shown on the chart are easily estimated, although it must be remembered that the rate of change is logarithmic, and this fact should be taken into consideration when interpolating between values.



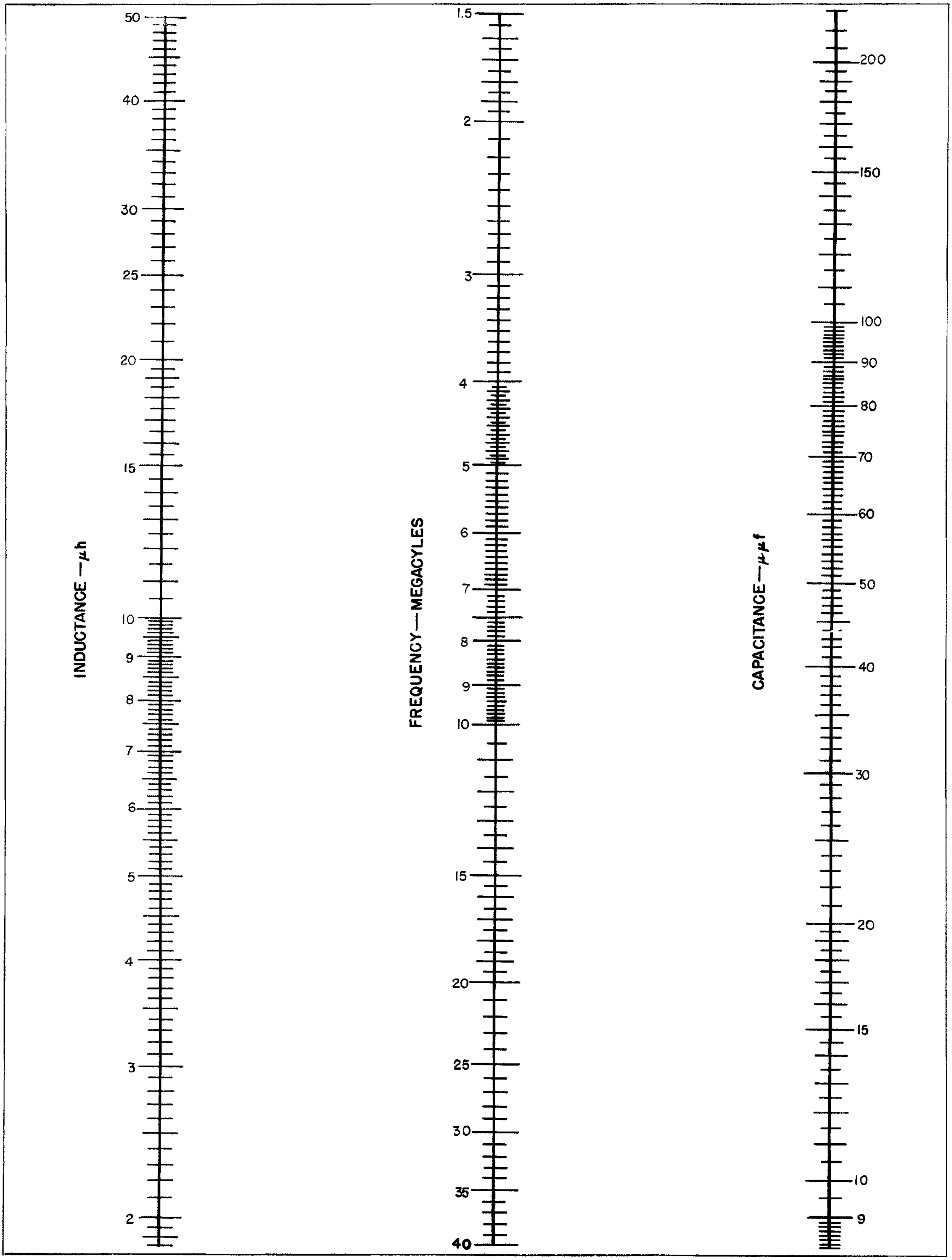
TP2-2519

Figure 15. Frequency vs. Reactance of Capacitors and Inductors

INDUCTANCE, CAPACITANCE, AND RESONANT FREQUENCY NOMOGRAPH

By means of the nomograph shown in figure 16, the value of inductance and capacitance required for resonance at a particular frequency is quickly determined. A straightedge, used to connect any two values on the chart will also pass through a third, thereby permitting any one of the three values to be easily found if the other two are known. For example, suppose it is desired to know what capacitance is required to resonate an inductance of 4 microhenrys at a frequency of 15.5 megacycles. A ruler, or other straightedge, laid on the chart and crossing these two values will also intersect the value of 27 micromicrofarads on the capacitance scale. The required value is, therefore, 27 micromicrofarads.

It is a very simple procedure to extend the range of values given on the chart in either direction. To extend to the lower frequencies, the values in the inductance and capacitance scales are multiplied by 10 and the frequency scale is multiplied by 0.1; to extend the scales higher, the values in the inductance and capacitance scales are multiplied by .1 and the frequency scale values are multiplied by 10.



TP2-2520

Figure 16. Inductance, Capacitance, and Resonant Frequency Nomograph

IMPEDANCE MATCHING AND TURNS RATIO

A great many electronic devices, vacuum tubes for example, require a specific value of load impedance to work into if optimum results are to be obtained. But this value will, more likely than not, be considerably different from the impedance value of the load. Some intermediate device is, therefore, required to change, or "match", the impedance of the actual load to the value required by the device. In the majority of cases, a transformer is used for this purpose.

With a well-designed transformer, the source of power (vacuum tube or other device) will look into, or "see", a value of impedance which is equal to the impedance of the load connected across the transformer secondary, multiplied by the square of the transformer primary-to-secondary turns ratio. Or,

$$Z\text{ primary} = Z\text{ secondary} \times \left(\frac{\text{Turns primary}}{\text{Turns secondary}}\right)^2$$

Thus, a load of any given impedance, when connected across the secondary of the transformer, will have a different value when seen from the power source looking into the transformer primary. This change in value, or impedance transformation, is directly proportional to the square of the primary-to-secondary turns ratio. Therefore, by proper choice of turns ratio, the impedance of a particular load can be transformed to the optimum load required by an amplifier or other type of equipment.

The method of determining the proper primary-to-secondary turns ratio to provide correct matching is relatively simple. Suppose, for example, that the required plate load impedance of the output tube in a certain amplifier is 5000 ohms. The amplifier, however, is to be connected to a 500-ohm line. Since

$$Z\text{ primary} = Z\text{ secondary} \times \left(\frac{\text{Turns primary}}{\text{Turns secondary}}\right)^2$$

Then

$$\sqrt{\frac{Z\text{ primary}}{Z\text{ secondary}}} = \frac{\text{Turns primary}}{\text{Turns secondary}}$$

or,

$$\sqrt{\frac{5000}{500}} = \sqrt{\frac{10}{1}} = \frac{3.16}{1}$$

The primary of the transformer should, therefore, have 3.16 times as many turns as the secondary. In some instances it may not be possible to obtain a transformer having the exact ratio required for a particular application. In such cases it is best to select one with a ratio as close as possible to the desired value, but of *higher* rather than lower ratio.

INDUCTANCE-CAPACITANCE (L-C) CONSTANT

When it becomes necessary to make a number of computations which involve the determination of different values of inductance and capacitance (L-C ratios) for resonance at the same frequency, a considerable simplification can be achieved by using the numerical value of the L-C constant. For any frequency, the L-C constant is given by the following equation:

$$\text{L-C constant} = \frac{25332}{f^2}$$

Where

L = inductance in microhenrys

C = capacitance in micromicrofarads

f = frequency in megacycles

Table 7 provides a means of ready reference for L-C constants covering the range of frequencies from .16 megacycles to 150 megacycles. For the range from .16 to 1.5 megacycles, the figures given are to be multiplied by 10,000. For the range from 1.6 to 15 megacycles, the figures are to be multiplied by 100. The L-C constant for the range from 16 to 150 megacycles can be read directly.

For a particular frequency and a given value of inductance, the capacitance required is determined from the formula

$$C = \frac{\text{L-C constant}}{L(\mu\text{h.})}$$

For a particular frequency and a given value of capacitance, the inductance required is determined from the formula

$$L = \frac{\text{L-C constant}}{C(\mu\mu\text{f.})}$$

TABLE 7. INDUCTANCE-CAPACITANCE (L-C) CONSTANTS

mc.	L-C	mc.	L-C	mc.	L-C	mc.	L-C	mc.	L-C
16	98.945	43	13.699	70	5.1492	97	2.6920	124	1.6475
17	87.646	44	13.084	71	5.0247	98	2.6372	125	1.6212
18	78.197	45	12.509	72	4.8912	99	2.5842	126	1.5957
19	70.167	46	11.970	73	4.7532	100	2.5332	127	1.5706
20	63.325	47	11.466	74	4.6257	101	2.4833	128	1.5461
21	57.637	48	10.994	75	4.5032	102	2.4348	129	1.5223
22	52.335	49	10.549	76	4.3855	103	2.3878	130	1.4988
23	47.880	50	10.136	77	4.2722	104	2.3421	131	1.4761
24	43.975	51	9.7380	78	4.1635	105	2.2977	132	1.4538
25	40.545	52	9.3675	79	4.0585	106	2.2545	133	1.4321
26	37.470	53	9.0170	80	3.9577	107	2.2126	134	1.4108
27	34.747	54	8.6867	81	3.8605	108	2.1718	135	1.3900
28	32.307	55	8.3735	82	3.7670	109	2.1322	136	1.3696
29	30.120	56	8.0767	83	3.6767	110	2.0935	137	1.3497
30	28.145	57	7.7962	84	3.6022	111	2.0560	138	1.3302
31	26.360	58	7.5296	85	3.5062	112	2.0195	139	1.3111
32	24.736	59	7.2767	86	3.4242	113	1.9839	140	1.2923
33	23.260	60	7.0362	87	3.3465	114	1.9492	141	1.2742
34	21.911	61	6.8072	88	3.2710	115	1.9155	142	1.2563
35	20.677	62	6.5900	89	3.1970	116	1.8826	143	1.2388
36	19.565	63	6.3820	90	3.1272	117	1.8854	144	1.2216
37	18.503	64	6.1840	91	3.0595	118	1.8193	145	1.2049
38	17.542	65	5.9952	92	2.9995	119	1.7887	146	1.1884
39	16.654	66	5.8150	93	2.9287	120	1.7590	147	1.1723
40	15.831	67	5.6425	94	2.8665	121	1.7302	148	1.1565
41	15.068	68	5.4777	95	2.8067	122	1.7020	149	1.1410
42	14.409	69	5.3202	96	2.7485	123	1.6744	150	1.1256

PEAK, EFFECTIVE, AND AVERAGE VALUES OF A.C.

The same units, the volt and the ampere, that are used for measuring and expressing direct voltage and current are also used for alternating current and voltage. However, because the voltage and current in an a-c circuit are continually rising and falling in value and periodically reversing in direction, the question may arise as to how one can speak of an ampere or a volt of alternating current. Simplification of this problem is achieved by defining an ampere of alternating current as *that rate of current flow which will produce heat at exactly the same rate as one ampere of steady direct current.* This value is known as the *effective* value of the alternating current. For a sine-wave voltage, the effective value is equal to that value attained by the current at the peak of its swing, in either direction, multiplied by .707. Because it is the square root of the average, or mean, of several squares of current values taken during one cycle, the effective value is also known as the *root-mean-square,* or *r.m.s.* value.

Unless otherwise stated, the voltage and current values in an a-c circuit are always considered to be effective values. Therefore, all a-c meters, unless marked to the contrary, read effective values of current and voltage.

Because the r.m.s., or effective, value of a sine-wave voltage or current is equal to .707 times the maximum value, it is evident that the maximum or *peak* value of the voltage or current must equal $\frac{1}{.707}$, or 1.414 times as much as the effective value. The *peak* value is an important consideration in many a-c applications, particularly where insulation breakdown voltages may be involved.

Another very important value involving a. c., particularly where a. c. is rectified to d. c., is the *average* value. This is simply the average of all the instantaneous values in one alternation, and is equal to .636 of the peak value of the current or voltage.

The three terms, maximum or peak, effective or r. m. s., and average, are related to each other as follows:

$$E_{max} = E_{eff} \times 1.414 = E_{av} \times 1.57$$

$$E_{eff} = E_{max} \times .707 = E_{av} \times 1.11$$

$$E_{av} = E_{max} \times .636 = E_{eff} \times .9$$

THE DECIBEL

The decibel, or db, is the unit which has been widely adopted in radio, sound amplification, and other branches of electronics to express logarithmically the ratio between two power or voltage levels. It is less commonly used for expressing the ratio between current levels.

Although power, voltage, or current amplification, or the magnitude of a particular power, voltage, or current, relative to a given reference value, can be expressed as an ordinary ratio, the db has been adopted because of its much greater convenience.

Because the response of the human ear to sound waves is approximately proportional to the logarithm of the energy of the sound wave and is not proportional to the energy itself, the use of a logarithmic unit permits a closer approach to the reaction of the human ear. In other words, the impression gained by the human ear as to the magnitude of sound is roughly proportional to the logarithm of the actual energy contained in the sound, hence the logarithmic unit provides a convenient method for comparison. Thus, for example, a change in the gain of an amplifier, expressed in decibels, provides a much better index of the effect of the sound upon the ear than it does if expressed as a power or voltage ratio.

The small numbers which may be used to indicate in decibels the gain or loss which correspond to large power, voltage or current ratios, and the ease with which the db gains or losses may be added or subtracted are two additional important advantages to the use of the decibel.

The ratio, expressed in decibels, of two amounts of power, P_2 and P_1, is given by the following

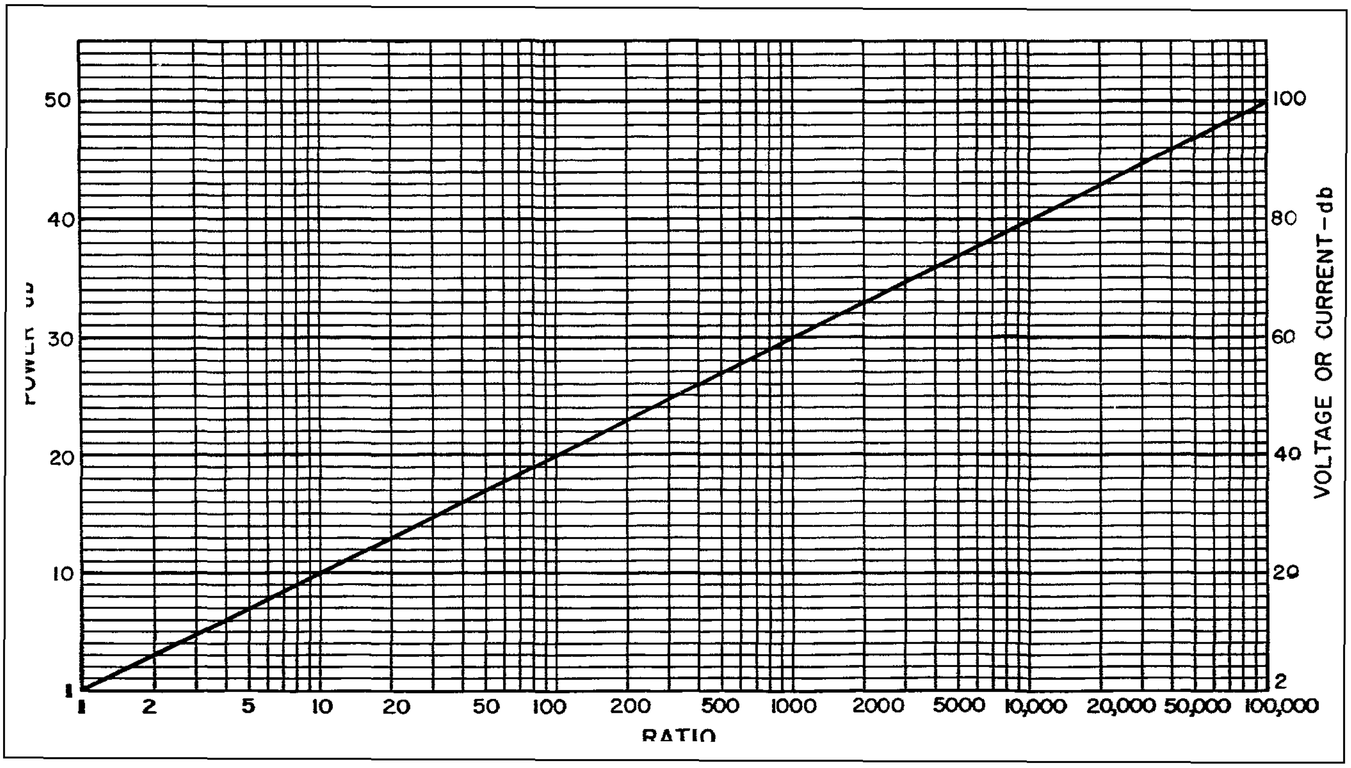
$$\text{db} = 10 \log_{10} \frac{P_2}{P_1}$$

The ratio, expressed in decibels, of two voltages, E_2 and E_1, or two currents, I_2 and I_1, is given by

$$\text{db} = 20 \log_{10} \frac{E_2}{E_1} \text{ or } \text{db} = 20 \log_{10} \frac{I_2}{I_1}$$

Figure 17 gives the values, expressed in decibels, which correspond to power, voltage, and current ratios from 1 up to 100,000 and will be found of considerable assistance in quickly determining the db equivalent for a given ratio.

The decibel is based upon *power* ratios, hence the preceding formula for deriving decibel equivalents from voltage or current ratios is true *only if the impedance is the same for both values of voltage or current.* For example, if the above information were used, it would not be possible to obtain correct information on the gain of a given amplifier if the input impedance differed from that of the output. Hence, in circuits where the impedances differ, the expres-



TP2-2521

Figure 17. Decibels and Power, Voltage, or Current Ratios

sions for decibel equivalents of voltage and current ratios become

$$db = 20 \log_{10} \frac{E_2\sqrt{R_1}}{E_1\sqrt{R_2}} \quad \text{or} \quad db = 20 \log_{10} \frac{I_2\sqrt{R_2}}{I_1\sqrt{R_1}}$$

It has been stressed that the decibel always refers to the *ratio* of two levels of power, voltage, or current. It is very often desirable, however, to express a single level or quantity of power, voltage or current in decibels, as for example in transmission-line work, or in connection with the input to or output from amplifiers. The decibel may be used as such an absolute unit by agreeing to specify the ratio always with respect to a fixed reference value, called the "zero level," and to indicate the absolute unit by its number of decibels above or below the fixed reference value. As an example, assume that it is desired to specify the value in decibels of the output from a 20-watt amplifier. Further assume that .001 watt is the reference level. This is equivalent to a power ratio of $\frac{20}{.001}$ or 20,000, which, from the accompanying table, is found to be approximately 43 db. Similarly

$$db = 10 \log_{10} \frac{20}{.001} = 10 \times 4.3 = 43 \text{ db}$$

A "zero level" of 6 milliwatts has gained considerable acceptance as the reference value, although the more convenient 1 milliwatt, and other values are also widely used. It is therefore very important, when the decibel is being used as an absolute unit in this way, that the reference value employed be clearly understood.

PROPER USE OF DECIBEL SCALES ON COMBINATION TEST METERS

Many combination test instruments, particularly volt-ohm-milliammeters of the better type, are equipped with scales calibrated in decibels. Such meters are of great value in making many types of measurements where direct indication in decibels is desirable. When improperly used, however, the indication obtained may be so inaccurate as to be utterly meaningless. In most cases the calibration of these instruments is based upon an impedance of 500 ohms and a zero level of 6 milliwatts. Therefore, *when the meter is connected across an impedance having a value of something other than 500 ohms, the calibration will no longer be correct.* The correction factor which must be applied is determined as follows:

$$\text{Correction factor (db)} = 10 \log_{10} \frac{500}{Z}$$

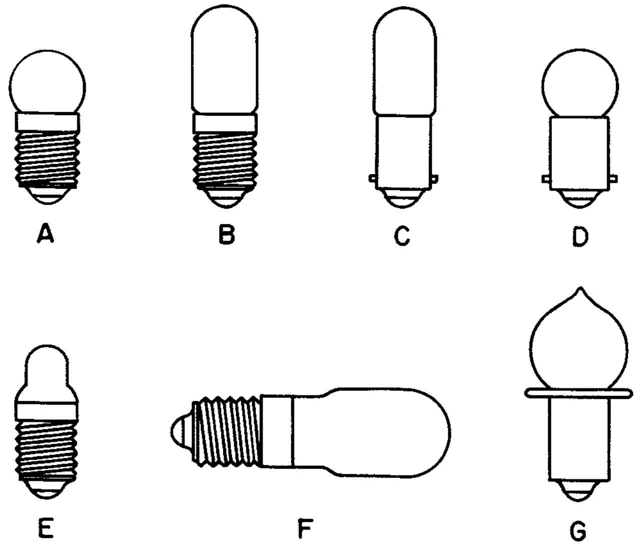
where Z is the impedance of the circuit across which the meter is connected. When the impedance of the circuit under measurement is *greater* than 500 ohms, the correction factor is *subtracted* from the meter indication; when the value of the impedance is *less* than 500 ohms, the correction factor is *added* to the meter indication. Correction factors for most of the impedance values commonly met with in electronics work are given below.

Z (ohms)	db
4000	-9
2000	-6
600	-1
500	0
250	+ 3
24	+13
15	+15
10	+17
8	+18
6	+19
5	+20
4	+21
2.5	+23
2	+24

PANEL LIGHT AND INDICATOR LAMP INFORMATION

NUMBER	BEAD COLOR	RATING			TYPE
		VOLTS	MILLIAMPERES	WATTS	
13		3.8	300		A***
14		2.5	300		A**
40	Brown	6-8.	150 @ 6.3v		B
41	White	2.5	500		B
43	White	2.5	500		C
44	Blue	6-8.	250 @ 6.3v		C
46	Blue	6-8.	250 @ 6.3v		B
47	Brown	6-8.	150 @ 6.3v		C
48	Pink	2.	60		B
49	Pink	2.	60		C
51	White	6-8.	200 @ 7.5v		D
53	White	12-16.	100 @ 15v		C
55	White	6-8.	400 @ 6.5v		D
123	Pink	1.25	300		D
222		2.2	250		E
NE45		105-125.		¼	F*
NE14		75.		¼	F*
PR2		2.4	500		G**
PR3		3.6	500		G***

* Neon
** 2-cell flashlight type
*** 3-cell flashlight type



TP2-2524

CONVERSION FACTORS

TO CONVERT	MULTIPLY BY
ELECTRICAL	
Amperes to micromicroamperes	1,000,000,000,000.
Amperes to microamperes	1,000,000.
Amperes to milliamperes	1,000.
Cycles to kilocycles	0.001
Cycles to megacycles	0.000,001
Farads to micromicrofarads	1,000,000,000,000.
Farads to microfarads	1,000,000.
Henrys to microhenrys	1,000,000.
Henrys to millihenrys	1,000.
Kilocycles to cycles	1,000.
Kilovolts to volts	1,000.
Kilowatts to watts	1,000.
Megacycles to cycles	1,000,000.
Mhos to micromhos	1,000,000.
Microamperes to amperes	0.000,001
Microfarads to farads	0.000,001
Microhenrys to henrys	0.000,001
Micromhos to mhos	0.000,001
Microvolts to volts	0.000,001
Microwatts to watts	0.000,001
Micromicrofarads to farads	0.000,000,000,001
Milliamperes to amperes	0.001
Millihenrys to henrys	0.001
Millivolts to volts	0.001
Milliwatts to watts	0.001
Megohms to ohms	1,000,000.
Volts to microvolts	1,000,000.
Volts to millivolts	1,000.
Watts to microwatts	1,000,000.
Watts to milliwatts	1,000.
Watts to kilowatts	.001
Watts to horsepower	.001,341
Watts to foot-pounds per minute	45.25
ENERGY	
B.T.U. to foot-pounds	778.
B.T.U. to joules	1,055.
Foot-pounds to B.T.U.	0.001,285
Joules to B.T.U.	.009,470
Joules to ergs	10,000,000.
Watt-hours to B.T.U.	3.4126
LENGTH	
Centimeters to inches	0.3937
Inches to centimeters	2.54
Inches to mils	1,000.
Meters to feet	3.2808
Meters to inches	39.3701
Miles to kilometers	1.6093
AREA	
Circular mils to square inches	0.000,000,7854
Circular mils to square mils	0.7854
Square centimeters to square inches	0.155
Square inches to square centimeters	6.4516
POWER	
Foot-pounds per minute to horsepower	.000,0303
Foot-pounds per minute to watts	.0226
Horsepower to foot-pounds per minute	33,000.
Horsepower to watts	746.

TEMPERATURE CONVERSIONS

DEGREES CENTIGRADE TO DEGREES FAHRENHEIT

Deg. C.	Deg. F.	Deg. C.	Deg. F.
0	32.0	51	123.8
1	33.8	52	125.6
2	35.6	53	127.4
3	37.4	54	129.2
4	39.2	55	131.0
5	41.0	56	132.8
6	42.8	57	134.6
7	44.6	58	136.4
8	46.4	59	138.2
9	48.2	60	140.0
10	50.0	61	141.8
11	51.8	62	143.6
12	53.6	63	145.4
13	55.4	64	147.2
14	57.2	65	149.0
15	59.0	66	150.8
16	60.8	67	152.6
17	62.6	68	154.4
18	64.4	69	156.2
19	66.2	70	158.0
20	68.0	71	159.8
21	69.8	72	161.6
22	71.6	73	163.4
23	73.4	74	165.2
24	75.2	75	167.0
25	77.0	76	168.8
26	78.8	77	170.6
27	80.6	78	172.4
28	82.4	79	174.2
29	84.2	80	176.0
30	86.0	81	177.8
31	87.8	82	179.6
32	89.6	83	181.4
33	91.4	84	183.2
34	93.2	85	185.0
35	95.0	86	186.8
36	95.8	87	188.6
37	98.6	88	190.4
38	100.4	89	192.2
39	102.2	90	194.0
40	104.0	91	195.8
41	105.8	92	197.6
42	107.6	93	199.4
43	109.4	94	201.2
44	111.2	95	203.0
45	113.0	96	204.8
46	114.8	97	206.6
47	116.6	98	208.4
48	118.4	99	210.2
49	120.2	100	212.0
50	122.0		

Degrees centigrade = (degrees Fahrenheit — 32) × .5556
Degrees Fahrenheit = (degrees centigrade × 1.8) + 32

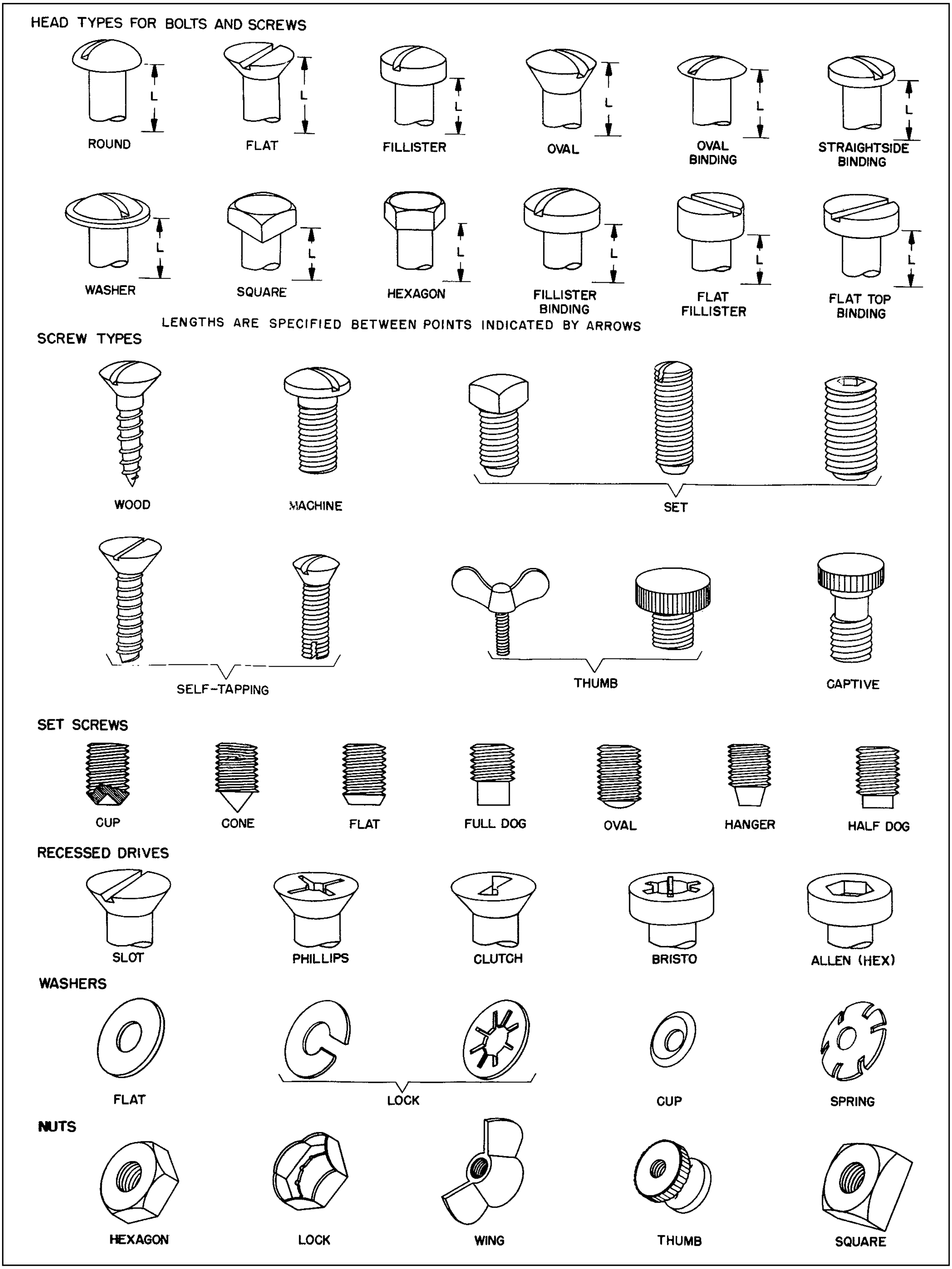
DECIMAL EQUIVALENTS OF PARTS OF AN INCH

1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
1/32	.0312	9/32	.2812	17/32	.5312	25/32	.7812
3/64	.0468	19/64	.2968	35/64	.5468	51/64	.7968
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0937	11/32	.3437	19/32	.5937	27/32	.8437
7/64	.1093	23/64	.3593	39/64	.6093	55/64	.8593
⅛	.125	⅜	.375	⅝	.625	⅞	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1562	13/32	.4062	21/32	.6562	29/32	.9062
11/64	.1718	27/64	.4218	43/64	.6718	59/64	.9218
3/16	.1975	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2187	15/32	.4687	23/32	.7187	31/32	.9687
15/64	.2343	31/64	.4843	47/64	.7343	63/64	.9843
¼	.25	½	.5	¾	.75	1	1.0

MACHINE SCREW, DRILL, AND TAP DATA

SCREW		THREADS PER INCH		CLEARANCE DRILL		TAP DRILL*	
No.	Dia.	Coarse	Fine	No.	Dia.	No.	Dia.
0	0.060		80	52	0.063	56	0.046
1	0.073	64	72	47	0.078	53	0.059
2	0.086	56	65	42	0.093	50	0.070
3	0.099	48		37	0.104	47	0.079
			56			45	0.082
4	0.112	40		31	0.120	43	0.088
			48			42	0.092
5	0.125	40		29	0.136	38	0.101
			44			37	0.103
6	0.138	32		27	0.144	36	0.108
			40			33	0.114
8	0.164	32		18	0.169	29	0.134
			36			29	0.137
10	0.190	24		9	0.196	25	0.149
			32			21	0.160
12	0.216	24		1	0.228	16	0.175
			28			14	0.181
¼	0.250	20			17/64	7	0.201
			28			3	0.213

* Size for use in hand-tapping brass or soft steel; for copper, aluminum, bakelite or similar material, use one size larger.



TP2-2522

Figure 18. Hardware Commonly Used in Electronic Equipment

COPPER WIRE TABLE

AWG Wire Size	Dia. (mils)	Area (cir. mils)	Ohms per 1000 Feet (25 deg. C.)	Feet per Lb.	Pounds per 1000 Ft.
10	101.900	10380.00	1.018	31.82	31.5000
12	80.810	6530.00	1.619	50.59	19.8000
14	64.080	4107.00	2.575	80.44	12.4000
16	50.820	2583.00	4.094	127.90	7.8100
18	40.300	1624.00	6.510	203.40	4.9100
20	31.960	1022.00	10.350	323.40	3.1000
22	25.350	642.00	16.460	514.20	1.9400
24	20.100	404.00	26.170	817.70	1.2200
26	15.940	254.10	41.620	1300.00	0.7650
28	12.640	159.80	66.170	2067.00	0.4810
30	10.030	100.50	105.200	3287.00	0.3030
32	7.950	63.21	167.300	5227.00	0.1940
34	6.305	39.75	266.000	8310.00	0.1200
36	5.000	25.00	423.000	13210.00	0.0757
38	3.965	15.72	672.600	21010.00	0.0484
40	3.145	9.88	1069.000	33410.00	0.0291

V-H-F TELEVISION CHANNELS AND FREQUENCIES

CHANNEL	BAND WIDTH (MC.)	VIDEO CARRIER FREQUENCY (MC.)	SOUND CARRIER FREQUENCY (MC.)
2	54—60	55.25	59.75
3	60—66	61.25	65.75
4	66—72	67.25	71.75
5	76—82	77.25	81.75
6	82—88	83.25	87.75
7	174—180	175.25	179.75
8	180—186	181.25	185.75
9	186—192	187.25	191.75
10	192—198	193.25	197.75
11	198—204	199.25	203.75
12	204—210	205.25	209.75
13	210—216	211.25	215.75

NEW U-H-F TELEVISION CHANNELS AND FREQUENCIES

The new band of frequencies in the ultra-high-frequency range that has been recently assigned to television covers the 470 to 890 megacycle portion of the frequency spectrum. The new band will include Channels 14 through 83, a total of 70 new channels.

The numbers of the new u-h-f channels and the frequencies assigned to each are given in the following table. In each case, as with the channels in the v-h-f range, the video carrier frequency is 1.25 megacycles higher than the lower frequency limit of the channel, and the sound carrier frequency is .25 megacycle lower than the higher frequency end of each channel. For example, Channel 14 is assigned the band of frequencies from 470 to 476 megacycles. The video carrier frequency is, therefore, 470+1.25, or 471.25 megacycles; the sound carrier frequency is 476—.25, or 475.75 megacycles.

TABLE 8. U-H-F TELEVISION CHANNELS AND FREQUENCIES

CHANNEL	BAND LIMITS (MC.)	CHANNEL	BAND LIMITS (MC.)
14	470—476	49	680—686
15	476—482	50	686—692
16	482—488	51	692—698
17	488—494	52	698—704
18	494—500	53	704—710
19	500—506	54	710—716
20	506—512	55	716—722
21	512—518	56	722—728
22	518—524	57	728—734
23	524—530	58	734—740
24	530—536	59	740—746
25	536—542	60	746—752
26	542—548	61	752—758
27	548—554	62	758—764
28	554—560	63	764—770
29	560—566	64	770—776
30	566—572	65	776—782
31	572—578	66	782—788
32	578—584	67	788—794
33	584—590	68	794—800
34	590—596	69	800—806
35	596—602	70	806—812
36	602—608	71	812—818
37	608—614	72	818—824
38	614—620	73	824—830
39	620—626	74	830—836
40	626—632	75	836—842
41	632—638	76	842—848
42	638—644	77	848—854
43	644—650	78	854—860
44	650—656	79	860—866
45	656—662	80	866—872
46	662—668	81	872—878
47	668—674	82	878—884
48	674—680	83	884—890

STANDARD-FREQUENCY TRANSMISSIONS FROM NATIONAL BUREAU OF STANDARDS STATIONS WWV AND WWVH

A continuous service of technical broadcasts is provided by the National Bureau of Standards over Stations WWV, near Washington, D. C., and WWVH, in the Territory of Hawaii.

The services from these stations include: (1) standard radio frequencies of 2.5, 5, 10, 15, 25, 30, and 35 megacycles; (2) standard time intervals of 1 second, and 1, 4, and 5 minutes; (3) time announcements at 5-minute intervals by voice and International Morse code, (4) standard audio frequencies of 440 cycles (standard musical pitch, A above middle C) and 600 cycles; (5) radio propagation conditions and forecasts.

The two standard audio frequencies, 440 c.p.s. and 600 c.p.s., are broadcast on all radio carrier frequencies except 30 and 35 megacycles. These audio tones are broadcast alternately, starting on the hour with 600 c.p.s. for four minutes, interrupted one minute, followed by 440 c.p.s. for four minutes and again interrupted one minute. The sequence then repeats and continues to repeat at 10-minute intervals.

The one-minute intervals which interrupt the transmission of the audio tones are used to provide time announcements based upon GCT in International Morse code and time announcements of EST in voice. The resumption of the tones precisely mark the hour and the successive 5-minute periods. Each carrier is modulated by a seconds pulse, which is heard as a faint tick when listening to the broadcasts.

The accuracy of all frequencies transmitted is better than 1 part in 50,000,000, and the accuracy of the 1-minute, 4-minute and 5-minute intervals is of the same high order.

At 19½ and 49½ minutes past the hour, WWV broadcasts, in International Morse code, announcements of existing propagation conditions affecting radio transmission over the North Atlantic path to Europe. If a warning is in effect, the letter "W" is broadcast; if unstable conditions exist, the letter "U" is sent; if conditions are normal the letter "N" is broadcast. The letter which indicates the existing condition is followed by a digit, on the scale from 1 (impossible) through 9 (excellent), which provides a forecast of expected conditions. These forecasts are prepared four times daily, beginning at 0500, and cover a period of approximately six hours in advance.

GERMANIUM CRYSTAL DIODES

The widespread applications of the germanium crystal diode in such fields as television, FM radio, communications equipment, test and measurement instruments, and many others, has brought about the development of a considerable number of types, in order to provide electrical characteristics suitable for the varied applications.

A listing of the most common types, together with their more important technical characteristics and the general form of application for which they are intended, is given in Table 9.

The maximum continuous working voltage, shown in column 2, indicates the amount of d.c. which can be applied across each diode for an indefinite time without damage to the crystal.

The reverse voltage for zero dynamic resistance, shown in column 3, is the maximum voltage which may be applied to the diode in a reverse direction without voltage breakdown.

The average rectified (anode) current, column 4, is the maximum continuous safe operating current for the diode. Operation upon an intermittent basis will permit somewhat greater current to be handled.

The maximum recurrent peak anode current, column 5, indicates the maximum allowable value to which the rectified current may be permitted to rise on peaks when the wave shape and duty cycle are such that the r.m.s. value of the current does not exceed the average current rating for the diode and the frequency is not less than 25 cycles.

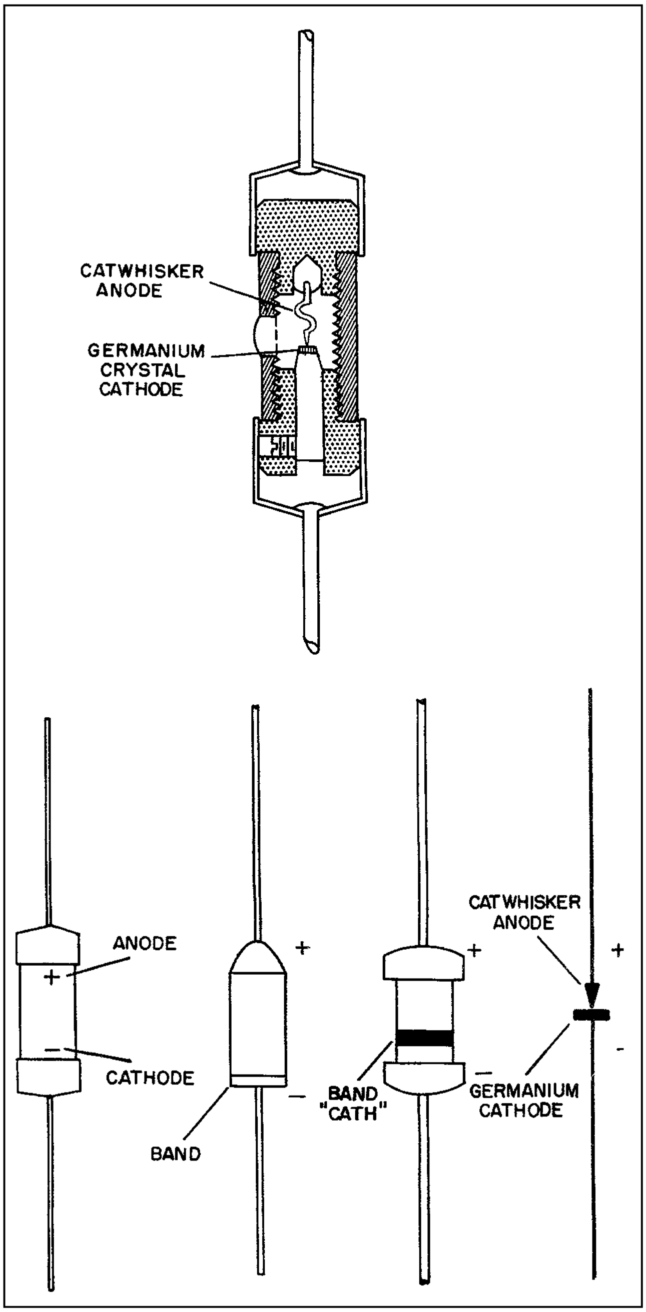
The maximum forward surge current, column 6, is the maximum value of current that can flow for one second without damage to the crystal.

The maximum reverse current, column 7, is the maximum current that will flow through the diode with the anode connected to the negative lead. The value of back resistance of a particular diode can be determined by dividing the applied voltage by this current value.

The internal construction and physical characteristics of a typical germanium diode are illustrated in figure 19. In commercially manufactured germanium diodes the catwhisker is the anode and the germanium crystal is the cathode. Methods of indicating polarity for several types of diodes are also shown in figure 19.

TABLE 9. ELECTRICAL CHARACTERISTICS AND GENERAL APPLICATIONS OF GERMANIUM CRYSTAL DIODES

RTMA Type No.	Maximum Continuous Reverse Working Volts	Minimum Reverse Voltage for Zero Dynamic Resistance	Average Rectified Current in Milliamperes	Maximum Recurrent Peak Anode Current in Milliamperes	Maximum Forward Surge Current in Milliamperes	Maximum Reverse Current in Milliamperes	General Application
1	2	3	4	5	6	7	8
1N34	60	75	50	150	500	.05 at –10v .8 at –50v	General-purpose diode.
1N34A	60	75	50	150	500	.03 at –10v .5 at –50v	General-purpose diode. (Sealed in glass.)
1N35	50	75	22.5	60	100	.01 at –10v	Matched duodiode. (Ratings are for each diode.)
1N38	100	120	50	150	500	.006 at –3v .625 at –100v	100-volt diode.
1N38A	100	120	50	150	500	.005 at –3v .5 at –100v	100-volt diode. (Sealed in glass.)
1N39	200	225	50	150	500	.2 at –100v .8 at –200v	200-volt diode.
1N43		60	40	125	50	.9 at –50v	General-purpose diode.
1N44		115	35	100	400	1.0 at –50v	General-purpose diode.
1N45		75	35	100	400	.4 at –50v	General-purpose diode.
1N46		60	40	125	500	1.5 at –50v	General-purpose diode.
1N47		115	30	90	350	.004 at –3v	General-purpose diode.
1N48		86	50	150	400	.83 at –50v	General-purpose diode.
1N51	40	50	25	100	300	1.6 at –50v	General-purpose diode.
1N52	70	85	50	150	400	.25 at –50v	General-purpose diode.
1N54	35	75	50	150	500	.01 at –10v	High back-resistance diode.
1N54A	50	75	50	150	500	.007 at –10v .1 at –50v	High back-resistance diode. (Sealed in glass.)
1N55	150	170	50	150	500	.3 at –100v .8 at –150v	150-volt diode.
1N55A	150	170	50	150	500	.5 at –150v	150-volt diode. (Sealed in glass.)
1N56	40	50	60	200	1000	.3 at –30v	High-conduction diode.
1N56A	40	50	60	200	1000	.3 at –30v	High-conduction diode. (Sealed in glass.)
1N58	100	120	50	150	500	.8 at –100v	100-volt diode.
1N58A	100	120	50	150	500	.6 at –100v	100-volt diode. (Sealed in glass.)
1N60	25	30	50	150	500	.03 at –1.5v	Video detector diode.
1N63	100	125	50	150	400	.05 at –50v	General-purpose diode.
1N64		25					Video detector diode.
1N65		85	50	150	400	.2 at –50v	
1N69	60	75	40	125	400	.05 at –10v .85 at –50v	General-purpose diode.
1N70	100	125	30	90	350	.01 at –10v	General-purpose diode.
1N72		5	25	75			U-H-F diode.



TP2-2594

Figure 19. Internal Structure and Physical Characteristics of Typical Germanium Diodes

IDENTIFYING RECTIFIER SOCKETS AND "B" SUPPLY TERMINALS

Since the rectifier tube is the next link to the transformer in the a-c power supply, it is important to know the makeup of the rectifier and the connections of socket terminals and rectifier tube elements.

The rectifier tube socket may be located visually by observing where the power transformer is located, since the leads from the high-voltage winding will connect to the rectifier socket. The socket terminals to which they connect will be the plate connections of the rectifier tube. In tracing the transformer leads, bear in mind that the filament leads as well as the high-voltage leads will connect to the same socket. Also, the rectifier may be either a half-wave or a full-wave type. If it is of the half-wave type, only one high-voltage lead from the transformer will connect to the socket. The power supply might also be of the full-wave type using two separate half-wave rectifier tubes, such as is done in heavy-duty high-voltage power supplies for Public Address and similar equipment. Only one high-voltage lead from the transformer will connect to each tube plate, which in some cases will be the plate cap on top of the tube.

Normally, a rectifier socket will not be found in equipment designed to receive plate-supply voltage directly from a dynamotor, batteries, or from the power supply of another piece of equipment. A piece of equipment so designed will generally have at least four power input terminals, two for the low-voltage filament power, and two for the high-voltage plate supply.

After the rectifier socket has been located, the various terminals may be identified by a combined visual inspection and voltage check. By removing the rectifier tube from its socket, and using a high range a-c voltmeter (0—1000 volts), the plate terminal or terminals can be located by measuring from B minus or chassis to the various terminals. The terminal at which the highest reading is obtained with respect to the chassis or B minus is a plate terminal. If a full-wave rectifier tube is used as such, there will be two such terminals. It should be noted that the voltage reading from plate to plate will be the total voltage across the high-voltage secondary winding, while the reading from either plate to B minus will be one half of the plate-to-plate reading. This is true because, in measuring from either one of the plates to B minus, the meter is actually connected across only one half of the high-voltage secondary. When the high-voltage terminals have been found, a lower range on the voltmeter can be used to determine the filament terminals. If the tube is a directly heated cathode type, the filament terminals can be readily identified, since there will be only these two additional connections. With the indirectly heated type cathode, there will be the two filament terminal connections and the cathode connection to the filter circuit.

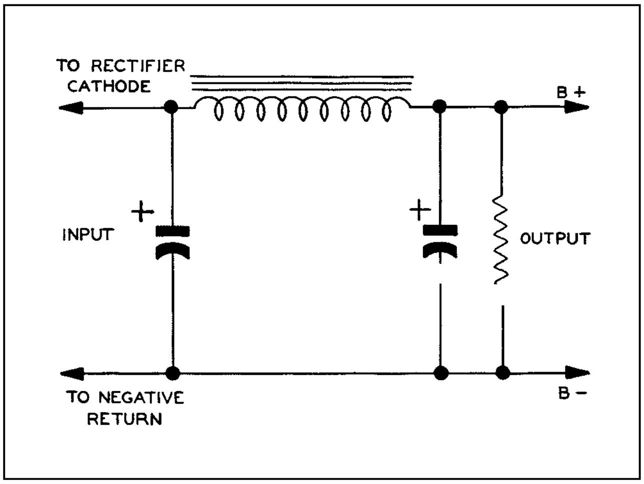
Important reference test points in any receiver are the B plus (+) and B minus (–) terminals of the plate supply. To quickly identify these points, certain simple relationships can be used. An examination of the schematic diagram of the receiver will reveal the circuit arrangement of the parts of the power supply. If the schematic shows that the filter choke is connected to one side of the rectifier filament, one can expect that in the power supply one lead from the choke will connect to a filament terminal of the rectifier socket. The other side of the choke, as shown on the schematic, connects to the B plus terminal of the power-supply output. Therefore, locating this lead in the chassis and tracing it from the choke to a terminal will locate the B plus point in the chassis.

In the usual type of receiver power supply, checking with the schematic will usually indicate that one filter capacitor is connected from each side of the choke to B minus. By locating the filter capacitor and identifying the leads connecting to the choke, the remaining capacitor leads can be traced to B minus. Electrolytic capacitor leads or terminals are usually color-coded, although a standard code does not apply to all circuits. In general, it can be said that the black lead from the electrolytic capacitor will connect to B minus.

The visual check outlined above can be supplemented by a continuity check with an ohmmeter. In many cases the actual circuit wiring is such that some of the leads are buried in cabling or hidden from sight. For such conditions, the use of a low-range ohmmeter will be of considerable assistance in tracing the leads.

TESTING "B" SUPPLY FILTER CIRCUITS

One method of testing filter circuits for defective parts is by resistance analysis of the input and output circuits. By comparing the readings taken with those which are normal, and using a practical application of Ohm's law for series-parallel circuits, the defective part may be determined. An advantage of this type of testing is that the power supply is inoperative during test; therefore, no damage can result to any part due to excessive current flow, should a short-circuit exist. By referring to figure 20 it may be seen that the input of the filter is actually the output of the rectifier, and the output of the filter is the final output of the whole power supply.



TP1-2255

Figure 20. Typical Radio Power-Supply Filter Circuit

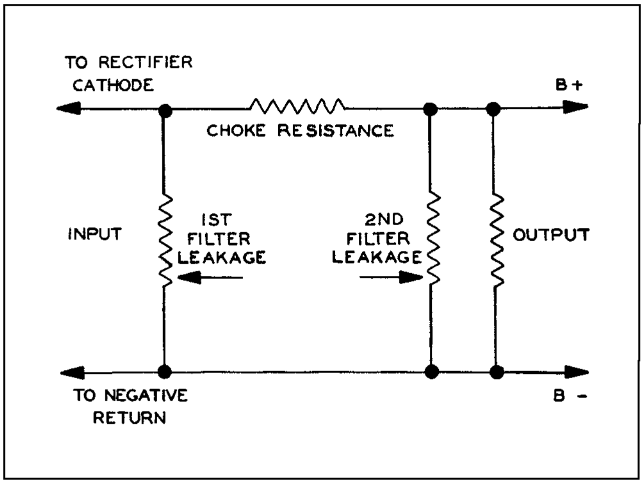
If the ohmmeter test prods are connected (observing proper polarity) across the input terminals of the filter circuit, a reading will be made of the equivalent resistance of a complex network, composed of the resistance of the first-capacitor leakage, paralleled by the resistance of the choke in series with the parallel resistance of the second-capacitor leakage and the bleeder resistor, as shown in figure 21. Since the leakage resistance of normal electrolytic capacitors is relatively very high, it will not greatly affect the resistance indications; for all practical purposes, the ohmmeter indication would be equal to the sum of the resistance of the filter choke and the resistance of the bleeder resistor.

If the ohmeter prods are connected across the output terminals of the filter circuit, a reading will be made of the equivalent resistance of the bleeder resistor, shunted by the leakage resistance of the second capacitor, and also shunted by the resistance of the choke in series with the leakage resistance of the first capacitor. In this case the ohmmeter would read, for practical purposes, the resistance of the bleeder resistor only. Thus the resistance of the input circuit is higher than that of the output circuit by the value of the choke.

If the choke were short-circuited, the readings at both the input and output would be identical. If the circuit to the choke were open at the input side, the input reading would be very high (leakage resistance of first capacitor), and the output reading would remain practically the same. If either capacitor were open-circuited, both readings would remain about the same. However, if the first capacitor were short-circuited, the input resistance would be low, and the output reading would be the value of the bleeder resistor in parallel with the choke. If the second condenser were short-circuited, the input reading would be the value of the choke, and the output resistance would be very low. Other possible troubles may be found by similar analysis.

The choke performs a very important function in the operation of a filter circuit. To understand its action it will be necessary to review some fundamental ideas.

At the instant that a direct current starts to flow through an inductance it encounters a form of opposition that is different from the coil resistance. This opposition, which is in the form of a voltage of opposite polarity to that of the input voltage (counter e.m.f.), is set up in the inductance when the coil current, increasing from zero to maximum, changes the magnetic field. The magnetic field was nonexistent, or zero, until current started to flow.



TP1-2254

Figure 21. Equivalent Leakages of Radio Power-Supply Filter

Since a change in the magnetic field of a coil will produce an e.m.f., any variation in the magnetic field due to a current change will, in turn, produce an e.m.f., or voltage, that acts to retard the change in current. Because of this effect, the current does not immediately reach the value determined by the resistance and the applied voltage according to Ohm's law. The time required for the current to reach the maximum value depends upon the inductance of the coil. The larger the inductance, the longer the time required for the current to reach its final value. Hence, if the applied voltage is suddenly decreased or removed, the current in the coil will begin to decrease. This will produce an inductive voltage, but it will have a polarity that will tend to sustain the current for some time after the applied voltage has decreased to zero. This characteristic of choke coils accounts for the opposition they offer to changes in current. When alternating current is applied to a choke coil, the current encounters the opposition caused by the inductance as well as the opposition due to the resistance The opposition that inductance offers to the change in current, or to alternating current, because of self-induced voltage, is called *inductive reactance.* Inductive reactance becomes greater as either the inductance of the coil or the frequency of the applied voltage is increased. The limiting or opposing action to the flow of current, therefore, becomes greater when either the inductance of the coil or the frequency of the current is increased.

The ability of inductance to store electric energy as a magnetic field and then later to return this energy to the circuit, together with the opposition it offers to changes in current, is put to good use in filter circuits. The current from a rectifier is a series of pulses. During the first part of the rectified pulse the current increases from zero to some maximum value, thereby charging the input filter capacitor to a potential which is approximately equal to the maximum value of the rectified pulse. Because of the considerable opposition it offers to these pulses, the action of the choke is such that only a portion of this pulse current reaches the output capacitor of the filter. Again, when the pulse decreases toward zero, the charge on the input filter capacitor causes a current to flow that adds to the current produced by the e.m.f. of the choke. Thus, the capacitors and the choke tend to keep the current constant, thereby eliminating hum and making the rectified current flowing through the load a steady current rather than a series of pulses.

The inductance for a filter may be obtained from either a specially constructed iron-core coil or by making use of the inductance of the loudspeaker field coil. It is economical to use the speaker field coil as the filter choke, because the current demanded by the equipment will produce a magnetic field sufficient to operate the speaker. The inductance of the field coil will be sufficient for filter action; hence, one less part will be required. When the filter inductance is connected in the negative lead of the power supply, the d-c voltage drop across the coil due to its resistance is sometimes used to supply bias voltages.

Common troubles in filter chokes are: open coils, internal shorts across the terminals of the coils, leaks to the frame of the inductance, and shorted turns.

An open choke coil will result in loss of voltage output from the power supply. High hum or ripple in the output voltage will result if the coil develops a short across its terminals. Occasionally, an electrolytic-type capacitor having several sections will develop an internal short from one positive lead to another, and will effectively short out the choke, thereby causing a hum. Capacitors that are used to resonate the choke should also be suspected when this type of trouble is encountered. (Capacitors that are used for this purpose are of a low value of capacitance, and are shunted directly across the choke.) Likewise, if a large percentage of the choke-coil turns should short out because of insulation breakdown between turns, similar trouble may be expected. Leaks or shorts to the choke-coil frame, or to the iron core, will cause low or no voltage output; the effect is similar to that of shorted or leaky filter capacitors.

Each time the pulse voltage from the rectifier rises, the input filter capacitor charges to a potential approaching the highest value of this pulse. When the value of the input pulse decreases, the energy stored in the input capacitor discharges into the load and thereby helps to keep the flow of current constant. The output capacitor acts in somewhat the same manner. In addition, its low reactance at the ripple frequency serves to practically eliminate any ripple voltage which may reach the output of the filter.

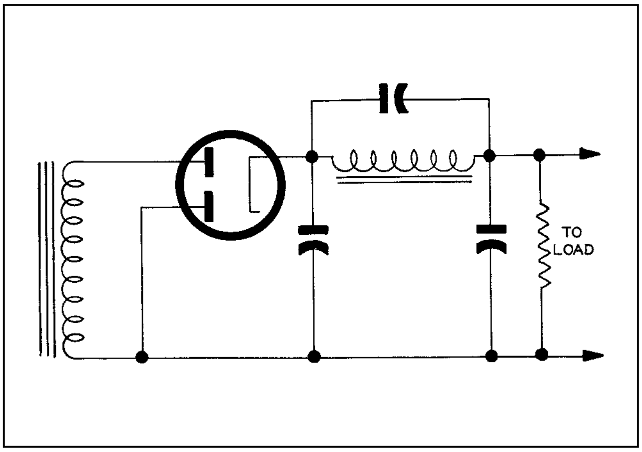
It is evident that if the capacitance of the input capacitor is low, the output voltage of the filter will be lower than normal, and will have considerable ripple voltage in it. This will cause the radio equipment to work inefficiently and to hum.

Lack of sufficient capacitance in the output filter capacitor will cause the filter circuit to act in a similar manner as to hum or ripple voltage, but the d-c output voltage will be only slightly affected. Sometimes insufficient capacitance in the output capacitor will cause motorboating or even i-f or r-f oscillation, because of the common impedance path that the filter presents to the signal currents. If the output capacitor is large enough, and in good condition, there will be practically no common impedance in the filter circuit, as the capacitor will act as a short circuit across the impedance. Therefore, there will be no common coupling impedance to cause either regeneration or degeneration. Regeneration may cause distortion if some frequencies are amplified more than others. Degeneration results in lower amplification.

Summing up, low amplification, instability, and high hum level result when an output capacitor of too small a value is used, or when a normally adequate electrolytic capacitor loses considerable capacitance. When electrolytic capacitors lose capacitance, through decomposition, or through evaporation of the electrolyte, the very common troubles described above will result.

Leaky dielectric in filter capacitors will generally cause the voltage to be lower than normal, and the hum level to be high. The resistance of the dielectric used in non-electrolytic filter capacitors is usually several megohms when the units are new. Values of 20 to 100 megohms are not uncommon for these types. As the units age, they may often be considered satisfactory if the leakage resistance is as low as one-half megohm; the permissible tolerance depends to a large extent upon the voltage to which the capacitors are subjected. For electrolytic filter capacitors to be considered good, the dielectric resistance should be higher than 500,000 ohms; however, they often work satisfactorily with leakage resistances of 100,000 ohms. As a general rule, if the leakage resistance of an electrolytic filter capacitor is less than 100,000 ohms, it should be replaced. This rule does not apply to cathode-by-pass capacitors or other low-voltage bypass capacitors of the electrolytic type, as leakage values of less than 100,000 ohms in these applications are often not troublesome. These figures are arbitrary, being dependent upon the satisfactory operation of the equipment. The voltage applied and the capacitance of the capacitor are factors that influence the leakage resistance. Increasing either the applied voltage or the capacitance increases the leakage. Another way of stating the condition of an electrolytic capacitor is to express the leakage current in terms of milliamperes per microfarad. Usually 0.5 milliampere per microfarad is an acceptable leakage current. Thus, an 8-μf. capacitor with a leakage current of 4 milliamperes would be acceptable, but if the leakage current is appreciably higher than this value, the capacitor should be replaced.

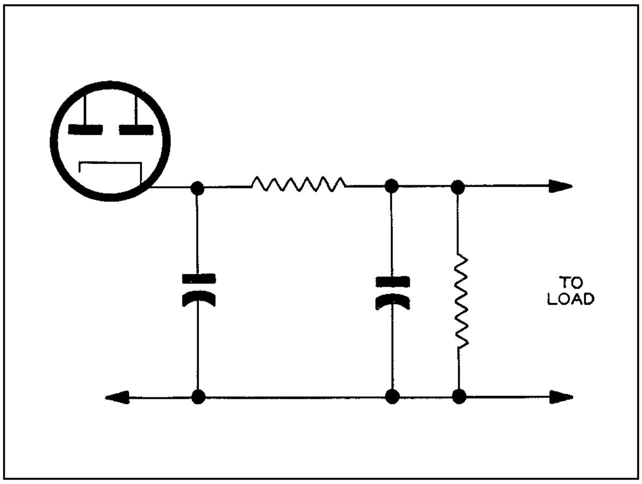
Some filter circuits use a capacitor across the filter choke to resonate it to the frequency of the hum voltage. (See figure 22.) Since a parallel-resonant circuit offers very high impedance at its resonant frequency, very little hum voltage will be apparent at the output of the filter. If it should become necessary at any time to replace this capacitor the replacement should have the same value; otherwise, the choke-capacitor combination will no longer be resonant at the ripple frequency, and the filtering action is likely to be very poor.



TP1-2252

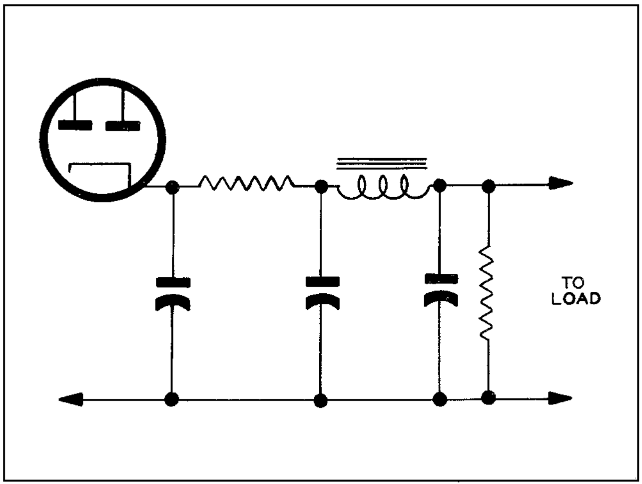
Figure 22. Use of Resonant Filter Choke in Power-Supply Filter

When the value of current taken from the power supply is low, the choke can be dispensed with, if efficiency is not of paramount importance. Instead of the choke coil, a resistor can be used, as shown in figure 23, to offer opposition to the hum frequencies. However, since the resistor will offer practically the same resistance to the d-c flowing through it that it does to the hum frequencies, this type of filter is not as efficient as the choke-coil type. The resistance-capacitor type filter is frequently used in small a-c/d-c type radios because of its compactness and lower cost. Because the resistor offers nearly the same opposition as a choke-coil to a wide range of frequencies, it is used to good advantage in many low-current filter circuits. Circuits making use of this idea sometimes add a resistor of a few hundred ohms before the filter choke, as shown in figure 24. Capacitors are connected from the terminals of the resistor to B minus in the same way as when the choke alone is used. This circuit is effective in eliminating a wide band of disturbance frequencies.



TP1-2250

Figure 23. Use of Resistor to Replace Filter Choke in Power-Supply Filter



TP1-2251

Figure 24. Use of Resistor and Filter Choke in Power-Supply Filter

COMMONLY USED ABBREVIATIONS FOR ELECTRONIC TERMS

In compiling the following list of abbreviations, the original thought was to provide a list which would be both simple and consistent. A survey of many technical publications in the electronics field, however, indicates numerous deviations from consistency in the abbreviations employed. Because due weight should be given to the common usage, it appears impossible, at present, to compile such a list without some sacrifice in consistency. The most sensible policy seems to be a compromise between consistency and established usage, and the accompanying list is based upon this policy.

alternating current	**a.c.**
alternating current/direct current	**a.c./d.c.**
ampere(s)	**amp.**
amplifier	**ampl.**
amplitude modulation	**AM**
antenna	**ant.**
assembly	**ass'y**
audio frequency	**a.f.**
sound intermediate frequency	**s.i.f.**
automatic gain control	**a.g.c.**
automatic volume control	**a.v.c.**
beat-frequency oscillator	**b.f.o.**
cathode-ray tube	**c.r.t.**
centimeter(s)	**cm.**
coaxial	**coax**
continuous wave	**CW**
crystal	**xtal**
cycles per second	**c.p.s.**
decibel(s)	**db**
detector	**det.**
direct current	**d.c.**
double pole	**d.p.**
double pole, double throw	**d.p.d.t.**
electron-coupled oscillator	**e.c.o.**
electromotive force	**e.m.f.**
extremely high frequency	**e.h.f.**
Federal Communications Commission	**FCC**
frequency	**freq.**
frequency modulation	**FM**
ground	**gnd.**
henry(s)	**hy.**
high frequency	**h.f.**
high voltage	**h.v.**
horizontal	**hor.**
horsepower	**hp**
intermediate frequency	**i.f.**
interrupted continuous wave	**ICW**
kilocycle(s)	**kc.**
kilovolt(s)	**kv**
kilowatt(s)	**kw.**
long play(ing)	**l.p.**
low frequency	**l.f.**
manual	**man.**
maximum	**max.**
megacycle(s)	**mc.**
megohm(s)	**meg.**
microampere(s)	**μa.**
microfarad(s)	**μf.**
microhenry(s)	**μh.**
micromicrofarad(s)	**μμf.**
microsecond(s)	**μsec.**
microvolt(s)	**μv**
milliampere(s)	**ma.**
millihenry(s)	**mh.**
millimeter(s)	**mm.**
millivolt(s)	**mv.**
minimum	**min.**
modulated continuous wave	**MCW**
oscillator	**osc.**
pair	**pr.**
permanent magnet	**p.m.**
phonograph	**phono**
power	**pwr.**
public address	**PA**
radio frequency	**r.f.**
revolutions per minute	**r.p.m.**
revolutions per second	**r.p.s.**
root-mean-square	**r.m.s.**
short wave	**s.w.**
signal generator	**sig. gen**
single pole	**s.p.**
single pole, double throw	**s.p.d.t.**
single pole, single throw	**s.p.s.t.**
super-high frequency	**s.h.f.**
switch	**sw.**
synchronizer or synchronizing	**sync**
television	**TV**
temperature	**temp.**
tuned radio frequency	**t.r.f.**
ultra-high frequency	**u.h.f.**
vacuum-tube voltmeter	**v.t.v.m.**
vertical	**vert.**
very-high frequency	**v.h.f.**
very-low frequency	**v.l.f.**
vibrator	**vib.**
voice coil	**v.c.**
volt(s)	**v**
voltmeter	**vm.**
watt(s)	**w.**