RESISTORS
FIXED COMPOSITION
RETMA STANDARD REC-116
MILITARY STANDARD MIL-R-11A

Color	*Digits of Resistance (ohms)*	*Multiplier*	*Tolerance (%)*
Black	0	1	—
Brown	1	10	—
Red	2	100	—
Orange	3	1000	—
Yellow	4	10,000	—
Green	5	100,000	—
Blue	6	1,000,000	—
Violet	7	10,000,000	—
Gray	8	100,000,000	—
White	9	—	—
Gold	—	0.1	±5
Silver	—	0.01	±10
No color	—	—	±20

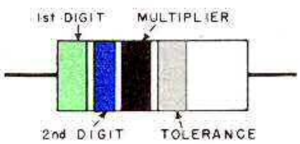
INSULATION CODING

RETMA: Insulated fixed composition resistors with axial leads are designated by a background of any color except black. The usual color is natural tan. Noninsulated fixed composition resistors with axial leads are designated by a black background color.

MILITARY (MIL): Insulated resistors are designated by a background of any color except black. The usual color is natural tan. Noninsulated resistors with axial leads are designated by a black background color. Noninsulated resistors with radial leads are designated by a black background color or by a background the same color as the first significant figure of the resistance value.

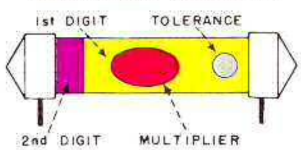
EXAMPLES

AXIAL LEADS



56 ohms ±10%

RADIAL LEADS (OBSOLETE)



4700 ohms ±10%

CAPACITORS
MICA DIELECTRIC

RETMA STANDARD REC-115A

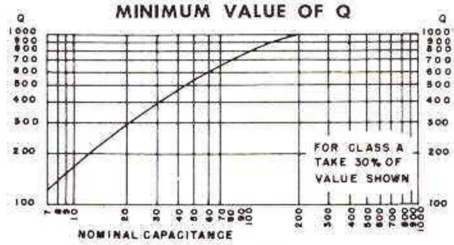
(See example under MIL-C-5A)

Color	*Digits of Capacitance (μμf)*	*Class*	*Multiplier*	*Tolerance (%)*
Black	0	A	1	±20
Brown	1	B	10	—
Red	2	C	100	±2
Orange	3	D	1000	±3
Yellow	4	E	10,000	—
Green	5	—	—	±5
Blue	6	—	—	—
Violet	7	—	—	—
Gray	8	I	—	—
White	9	J	—	—
Gold	—	—	0.1	—
Silver	—	—	0.01	±10

DESCRIPTION OF CLASS

Class	*Temperature Coefficient (parts per million per °C)*	*Maximum Capacitance Drift*	*Minimum Insulation Resistance (megohms)*
A	±1000	±(5% +1 μμf)	3000
B	±500	±(3% +1 μμf)	6000
C	±200	±(0.5% +0.5 μμf)	6000
D	±100	±(0.3% +0.1 μμf)	6000
E	+100 −20	±(0.1% +0.1 μμf)	6000
I	+150 −50	±(0.3% +0.2 μμf)	6000
J	+100 −50	±(0.2% +0.2 μμf)	6000

MINIMUM VALUE OF Q



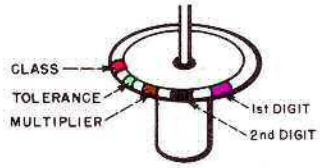
VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Dimensions (inches)			*Style*	*Capacitance (μμf)*	*Voltage Rating (v d-c)*
Length	*Width*	*Thickness*			
51/64	15/32	7/32	20	5–510 560–1000	500 300
1 7/64	15/32	7/32	25	5–1000 1100–1500	500 300
53/64	53/64	9/32	30	470–6200 Over 6200	500 300
53/64	53/64	3/8	35	3300–6200 Over 6200	500 300
1 1/32	41/64	11/32	40	100–2400 2700–7500 Over 7500	1000 500 300

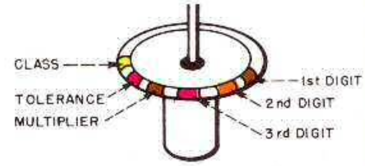
EXAMPLES

SILVER MICA BUTTON CAPACITORS (5-DOT)



700 μμf ± 5%, Class C

SILVER MICA BUTTON CAPACITORS (6-DOT)



1320 μμf ± 2%, Class E

CAPACITOR AND RESISTOR COLOR CODE CHART

CAPACITORS
MICA DIELECTRIC

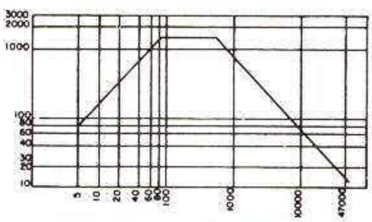
MILITARY STANDARD MIL-C-5A

Color	*Digits of Capacitance (μμf)*	*Characteristic*	*Multiplier*	*Tolerance (%)*
Black	0	A	1	±20
Brown	1	B	10	—
Red	2	C	100	±2
Orange	3	D	1000	—
Yellow	4	E	—	—
Green	5	F	—	—
Blue	6	G	—	—
Violet	7	—	—	—
Gray	8	—	—	—
White	9	—	—	—
Gold	—	—	0.1	±5
Silver	—	—	0.01	±10

DESCRIPTION OF CHARACTERISTIC

Characteristic	*Temperature Coefficient (parts per million per °C)*	*Maximum Capacitance Drift*	*Minimum Insulation Resistance (megohms)*
B	Not specified	Not specified	7500
C	±200	±0.5%	7500
D	±100	±0.3%	7500
E	+100 −20	±(0.1% +0.1 μμf)	7500
F	+70	±(0.05% +0.1 μμf)	7500

MINIMUM VALUE OF Q



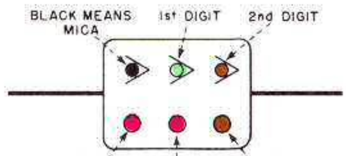
NOMINAL CAPACITY, μμfd, AT 1 MEGACYCLE

VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Dimensions (inches)			*Style CM*	*Capacitance (μμf)*	*Voltage Rating (v d-c)*
Length	*Width*	*Thickness*			
35/64	5/16	7/32	15	5–510	300
51/64	15/32	7/32	20	5–510 560–1000	500 300
1 7/64	15/32	7/32	25	51–1000	500
53/64	53/64	9/32	30	560–3300	500
53/64	53/64	11/32	35	3600–6200 6800–10,000	500 300
1 1/32	41/64	11/32	40	3300–8200 9100–10,000	500 300

EXAMPLE
6-DOT CODE



510 μμf ± 2%, Characteristic C, 500 v (Style 20)

The arrangement of dots under RETMA Standard REC-115A is the same as in the example above. The only difference is that the *first* dot is *white* instead of *black*.

CAPACITORS
MICA DIELECTRIC

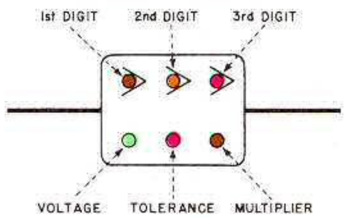
OBSOLETE STYLES

Color	*Digits of Capacitance (μμf)*	*Multiplier*	*Tolerance (%)*	*Voltage Rating (v d-c)*
Black	0	1	±20	—
Brown	1	10	±1	100
Red	2	100	±2	200
Orange	3	1000	±3	300
Yellow	4	10,000	±4	400
Green	5	—	±5	500
Blue	6	—	±6	600
Violet	7	—	±7	700
Gray	8	—	±8	800
White	9	—	±9	900
Gold	—	0.1	±5*	1000
Silver	—	0.01	±10	2000
No color	—	—	±20*	500*

*Old 3-dot only.

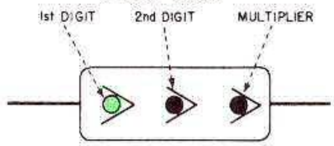
EXAMPLES

6-DOT CODE



1320 μμf ± 2%, 500 v

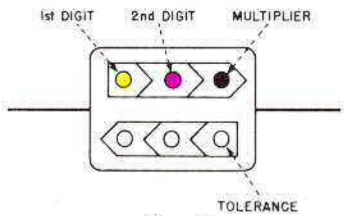
3-DOT CODE



50 μμf

(Voltage rating is always 500 v; tolerance is always 20%.)

3-DOT CODE (OLD RMA)



47 μμf

(Voltage rating is always 500 v; tolerance is always 20%.)

GENERAL ELECTRIC

SCHENECTADY, NEW YORK

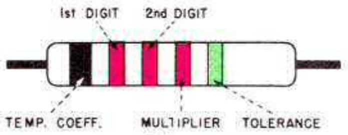
CAPACITORS
CERAMIC DIELECTRIC
RETMA STANDARD REC-107A
MILITARY STANDARD MIL-C-20A

Color	Digits of Capacitance (μμf)	Multiplier	Tolerance: 10 μμf or Less (μμf)	Tolerance: Over 10 μμf (%)	Temperature Coefficient (parts per million per °C): RETMA	Temperature Coefficient (parts per million per °C): MIL
Black	0	1	±2.0	±20	0	0
Brown	1	10	±0.1†	±1	−33	−30
Red	2	100	—	±2	−75	−80
Orange	3	1000	—	±2.5†	−150	−150
Yellow	4	10,000†	—	—	−220	−220
Green	5	—	±0.5	±5	−330	−330
Blue	6	—	—	—	−470	−470
Violet	7	—	—	—	−750	−750
Gray	8	0.01	±0.25	—	+150 to −1500	+30
White	9	0.1	±1.0	±10	+100 to −750	−330
Gold	—	—	—	—	—	+100

†RETMA only.

EXAMPLES

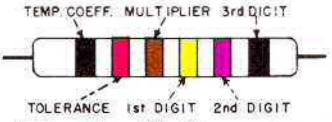
TUBULAR CAPACITORS



2200 μμf ± 5%, 0 temperature coefficient

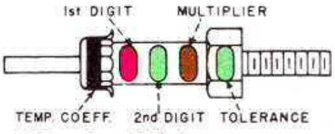
(Voltage rating is always 500 v.)

TUBULAR CAPACITORS (OLD RMA)



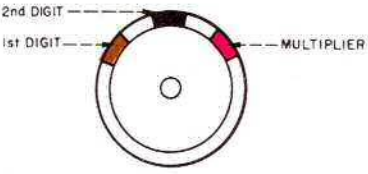
4700 μμf ± 2%, 0 temperature coefficient

STAND-OFF CAPACITORS (RETMA ONLY)



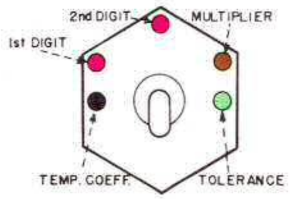
250 μμf ± 5%, 0 temperature coefficient

3-DOT BUTTON CAPACITORS (RETMA ONLY)



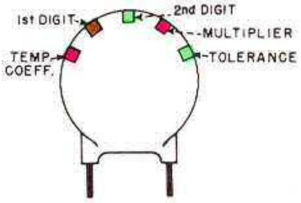
1000 μμf

FEED-THROUGH CAPACITORS (RETMA ONLY)



220 μμf ± 5%, 0 temperature coefficient

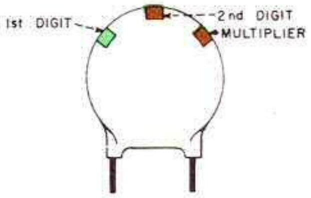
5-DOT DISC CAPACITORS (RETMA ONLY)



1500 μμf ± 5%, −75 temperature coefficient

(Voltage rating is always 500 v.)

3-DOT DISC CAPACITORS (RETMA ONLY)



510 μμf

(Voltage rating is always 500 v; tolerance is always −0.)

CAPACITORS
PAPER DIELECTRIC

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)

Color	*Digits of Capacitance (μμf)*	*Multiplier*	*Tolerance (%)*	*Voltage Rating* (v d-c)*	*Characteristic*	*Temperature Rating (°C)*
Black	0	1	±20	—	A	85
Brown	1	10	—	100	E	85
Red	2	100	—	200	—	—
Orange	3	1000	±30	300	—	—
Yellow	4	10,000	—	400	—	—
Green	5	—	—	500	—	—
Blue	6	—	—	600	—	—
Violet	7	—	—	700	—	—
Gray	8	—	—	800	—	—
White	9	—	—	900	—	—
Gold	—	—	—	1000	—	—
Silver	—	—	±10	—	—	—

*Tubular capacitors only; for rectangular capacitors see table below.

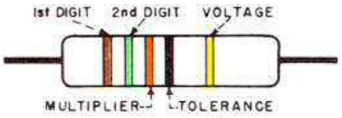
VOLTAGE RATING FOR RECTANGULAR CAPACITORS

(Indicated by dimensions rather than color coding)

Maximum Dimensions (inches)			*Style CM*	*Capacitance (μμf)*	*Voltage Rating (v d-c)*
Length	*Width*	*Thickness*			
51/64	15/32	7/32	20	1000 2000–6000 10,000	400 200 120
57/64	37/64	17/64	22	2000–3000 6000–10,000 20,000	400 300 120
53/64	53/64	9/32	30	1000–2000 3000 6000–10,000 20,000	800 600 400 120
53/64	53/64	11/32	35	3000 6000–10,000 20,000	800 600 300
1¼	41/64	9/32	41	3000–6000 10,000 20,000 30,000	600 400 300 120
1 15/32	49/64	11/32	42	1000–6000 10,000–20,000 30,000 50,000 100,000	1000 600 400 300 120
1 15/32	49/64	13/32	43	10,000 20,000–30,000 50,000–100,000 200,000	1000 600 400 120

EXAMPLES

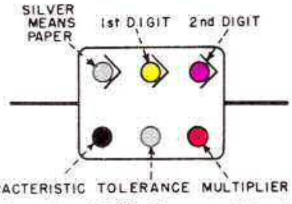
TUBULAR CAPACITORS
(COMMERCIAL ONLY)



15,000 μμf ± 20%, 400 v

(No characteristic or temperature rating)

RECTANGULAR CAPACITORS



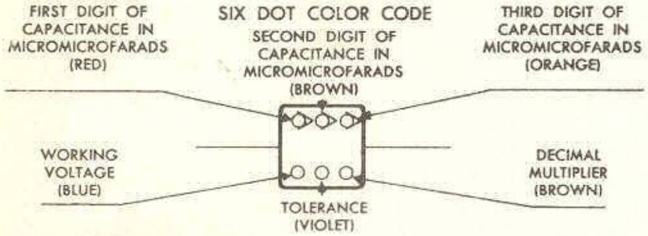
4700 μμf ± 10%, Characteristic A

PRINTED IN U.S.A.

RTMA CAPACITOR, RESISTOR, AND TRANSFORMER COLOR CODES

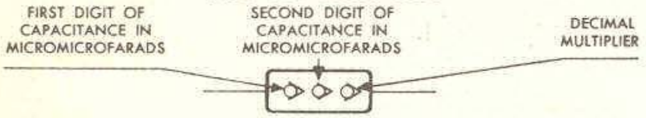
CAPACITOR COLOR CODE

SIX DOT COLOR CODE



EXAMPLE: 2130 $\mu\mu$f. ±7%, 600 W.V. (Values for color shown in the above parenthesis)

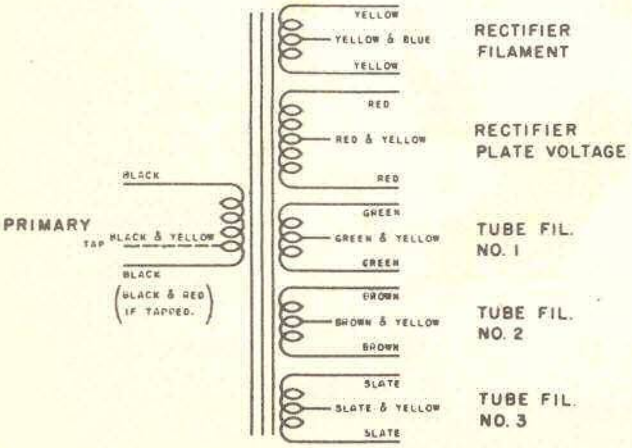
THREE DOT COLOR CODE



COLOR	DIGIT NUMERAL	DECIMAL MULTIPLIER	TOLERANCE	WORKING VOLTAGE
BLACK	0	1	20%	—
BROWN	1	10	1%	100
RED	2	100	2%	200
ORANGE	3	1000	3%	300
YELLOW	4	10000	4%	400
GREEN	5	—	5%	500
BLUE	6	—	6%	600
VIOLET	7	—	7%	700
GRAY	8	—	8%	800
WHITE	9	—	9%	900
GOLD	–	0.1	–	1000
SILVER	–	0.01	10%	—

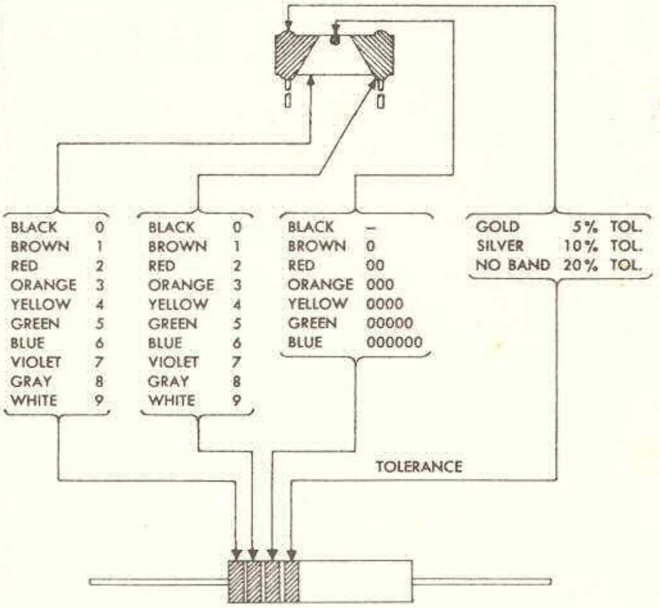
POWER TRANSFORMER LEAD COLOR CODE

Power transformer leads in radio receivers may be identified by the following colors (or color patterns) on the lead coverings.



Courtesy TUNG-SOL Lamp Works, Inc.

RESISTOR COLOR CODE



RESISTANCE VALUE: The nominal resistance valuu in ohms is identified by a three digit symbol. The first two digits are the first two figures of the resistance value in ohms. The third digit specifies the number of zeros which follow the first two figures.

I-F TRANSFORMER LEAD COLOR CODE

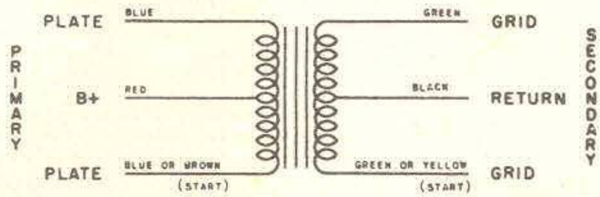
I-F transformer leads in radio receivers may be identified by the following colors on the lead coverings.

PLATE LEAD	BLUE	GRID (or diode lead)	GREEN
B+ LEAD	RED	GRID RETURN	BLACK

FOR "FULL-WAVE" TRANSFORMER SECOND DIODE LEAD WILL BE GREEN-BLACK.

AUDIO TRANSFORMER LEAD COLOR CODE

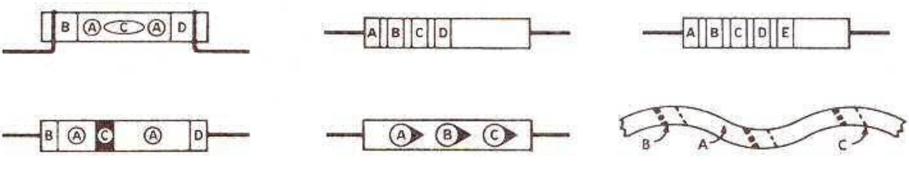
Interstage and Output Audio Transformer leads in radio receivers may be identified by the colors on the lead coverings as shown.



In cases where use is made of a single primary and/or a single secondary, the upper half of the diagram indicates the color coding. The brown and yellow leads indicate the start of the primary and secondary windings respectively and will be used in place of the blue and green (as shown) where polarity indications are required.

Resistor Color Code

EIA STANDARD RS-172 MILITARY STANDARD MIL-R-11E



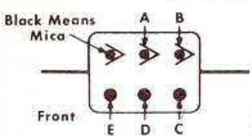
Color	1st Digit A	2nd Digit B	Multiplier C	Tolerance D	Failure Rate* E
Black	0	0	1	—	—
Brown	1	1	10	± 1%	1.0
Red	2	2	100	± 2%	0.1
Orange	3	3	1,000	± 3%	0.01
Yellow	4	4	10,000	± 4%	0.001
Green	5	5	100,000	—	—
Blue	6	6	1,000,000	—	—
Violet	7	7	10,000,000	—	—
Gray	8	8	100,000,000	—	—
White	9	9	—	—	Solderable*
Gold	—	—	0.1	± 5%	—
Silver	—	—	0.01	±10%	—
No Color	—	—	—	±20%	—

* **Band E,** when used on composition resistors, indicates percent failure per 1,000 hours. On film resistors, a white band E indicates solderable terminal.

INSULATION CODING

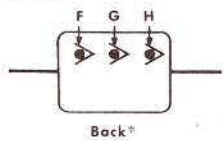
EIA: Insulated resistors with axial leads are designated by a background of any color except black. The usual color is natural tan. Noninsulated resistors with axial leads are designated by a black background color.

MILITARY (MIL): Same as EIA with the addition of: Noninsulated resistors with radial leads designated by a black background color or by a background the same color as the first significant figure of the resistance value.



Mica Capacitor Color Code

MILITARY STANDARD MIL-C-5C



Color	Digits of Capacitance ($\mu\mu$f) A	Digits of Capacitance ($\mu\mu$f) B	Multiplier C	Tolerance % D	Characteristic. See table below E	Working Volts DC F	Operating Temperature G	Vibration Grade(cps) H
Black	0	0	1	±20	—	—	−55 to +70°C	10-55
Brown	1	1	10	± 1	B	—	—	—
Red	2	2	100	± 2	C	—	−55 to +85°C	—
Orange	3	3	1,000	—	D	300	—	—
Yellow	4	4	—	—	E	—	−55 to +125°C	10-2,000
Green	5	5	—	± 5	F	500	—	—
Blue	6	6	—	—	—	—	−55 to +150°C	—
Violet	7	7	—	—	—	—	—	—
Gray	8	8	—	—	—	—	—	—
White	9	9	—	—	—	—	—	—
Gold	—	—	0.1	± 5	—	—	—	—
Silver	—	—	—	±10	—	—	—	—

*Earlier MIL-C-5 capacitors are not color coded on back. In such cases ignore F, G, H and use Voltage Rating Table below.

DESCRIPTION OF CHARACTERISTIC

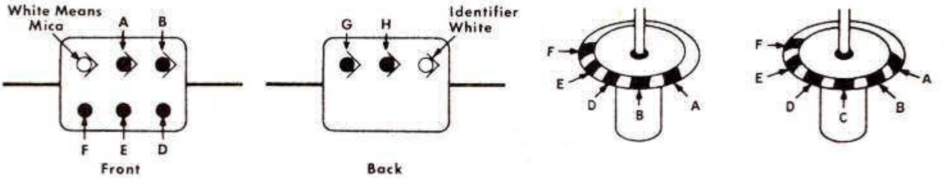
Characteristic	*Temperature Coefficient (parts per million per °C)*	*Maximum Capacitance Drift*	*Minimum Insulation Resistance (megohms)*
B	Not specified	Not specified	7500
C	±200	±0.5%	7500
D	±100	±0.3%	7500
E	−20 to +100	±(0.1% +0.1 $\mu\mu$f)	7500
F	0 to +70	±(0.05% +0.1 $\mu\mu$f)	7500

VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Inches Long	*Wide*	*Thick*	*Style CM*	*Capacitance ($\mu\mu$f)*	*Rating (v d-c)*
35/64	5/16	7/32	15	5-510	300
51/64	15/32	7/32	20	5-510 560-1000	500 300
17/64	15/32	7/32	25	51-1000	500
53/64	53/64	9/32	30	560-3300	500
53/64	53/64	11/32	35	3600-6200 6800-10,000	500 300
1 1/32	41/64	11/32	40	3300-8200 9100-10,000	500 300

Mica Capacitor Color Code
EIA STANDARD RS-153 A



Color	Digits of Capacitance (μμf) A	B	C	Multiplier D	Tolerance % E*	Characteristic—See table below F	Working Voltage G	Operating Temperature H
Black	0	0	0	1	±20	A	—	—
Brown	1	1	1	10	± 1	B	100 V. DC	—
Red	2	2	2	100	± 2	C	—	−55 to +85°C
Orange	3	3	3	1,000	± 3	D	300 V. DC	—
Yellow	4	4	4	10,000	—	E	—	−55 to +125°C
Green	5	5	5	—	± 5	—	500 V. DC	—
Blue	6	6	6	—	—	—	—	—
Violet	7	7	7	—	—	—	—	—
Gray	8	8	8	—	—	—	—	—
White	9	9	9	—	—	—	—	—
Gold	—	—	—	0.1	—	—	1,000 V. DC	—
Silver	—	—	—	0.01	±10	—	—	—

*or ± 1 μμf, whichever is greater.

DESCRIPTION OF CHARACTERISTIC

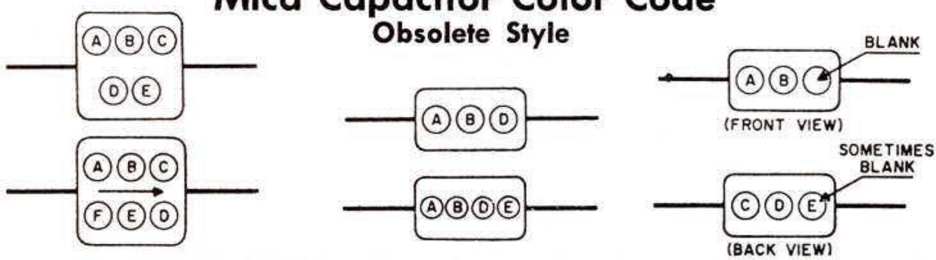
Characteristic	*Temperature Coefficient (parts per million per °C)*	*Maximum Capacitance Drift*	*Minimum Insulation Resistance (megohms)*
A	±1000	±(5% +1 μμf)	3000
B	±500	±(3% +1 μμf)	6000
C	±200	±(0.5% +0.5 μμf)	6000
D	±100	±(0.3% +0.1 μμf)	6000
E	−20 to +100	±(0.1% +0.1 μμf)	6000
—	—	—	—
—	—	—	—

VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Inches *Long*	*Wide*	*Thick*	*Style*	*Capacitance (μμf)*	*Rating (v d-c)*
51/64	15/32	7/32	20	5-510 560-1000	500 300
1 7/64	15/32	7/32	25	5-1000 1100-1500	500 300
53/64	53/64	9/32	30	470-6200 Over 6200	500 300
53/64	53/64	3/8	35	3300-6200 Over 6200	500 300
1 1/32	41/64	11/32	40	100-2400 2700-7500 Over 7500	1000 500 300

Mica Capacitor Color Code
Obsolete Style

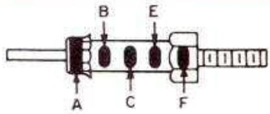


Dot Color	Digits of Capacitance (μμf) A	B	C	Multiplier D	Tolerance % E	Voltage Rating (v d-c) F
Black	0	0	0	1	±20	—
Brown	1	1	1	10	± 1	100
Red	2	2	2	100	± 2	200
Orange	3	3	3	1,000	± 3	300
Yellow	4	4	4	10,000	± 4	400
Green	5	5	5	100,000	± 5	500
Blue	6	6	6	1,000,000	± 6	600
Violet	7	7	7	10,000,000	± 7	700
Gray	8	8	8	100,000,000	± 8	800
White	9	9	9	1,000,000,000	± 9	900
Gold	—	—	—	0.1	± 5	1,000
Silver	—	—	—	0.01	±10	2,000
No Color	—	—	—	—	±20	500

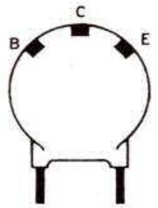
Ceramic Capacitor Color Code

EIA STANDARD RS-198

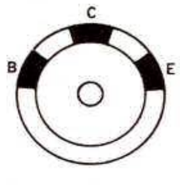
MILITARY STANDARD MIL-C-20D



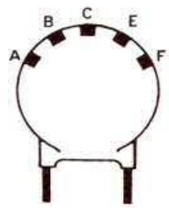
Stand-Off Capacitors (EIA ONLY)



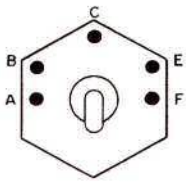
3-Dot Disc Capacitors (RETMA ONLY) (Voltage rating is always 500 v., tolerance is always —0.)



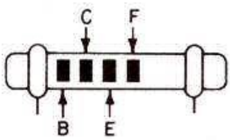
3-Dot Button Capacitors (EIA ONLY)



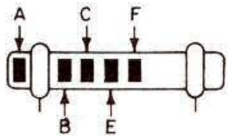
5-Dot Disc Capacitors (EIA ONLY) (Voltage rating is always 500 v.)



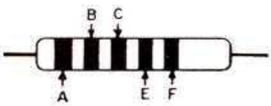
Feed Through Capacitors (EIA ONLY)



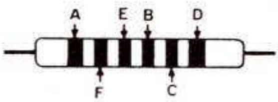
High Capacity Tubulars (Insulated or Non-Insulated)



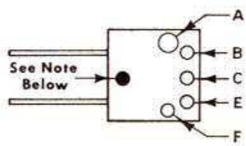
Temperature Compensating Tubulars



Tubular Capacitors (Voltage rating is always 500 v.)



Tubular Capacitors (Old RMA)



MIL Style CC Rectangular

Note: Styles CC-60 through CC-71 will be color coded here with Green = 500 and Brown = 150, working volts DC.

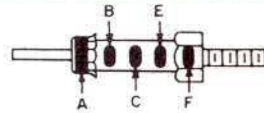
Color	Digits of Capacitance (μμf)			Multiplier E	Tolerance F		Temp. Coef. A (Parts per million per °C.)	
	B	C	D		10 μμf or less (μμf)	Over 10 μμf (%)	EIA	MILITARY†
Black	0	0	0	1	±2.0	±20*	±0	±0
Brown	1	1	1	10	±0.1*	±1	− 33	− 30
Red	2	2	2	100	±0.25	±2	− 75	− 80
Orange	3	3	3	1,000	—	±2.5*	−150	−150
Yellow	4	4	4	10,000*	—	—	−220	−220
Green	5	5	5	—	±0.5	±5	−330	−330
Blue	6	6	6	—	—	—	−470	−470
Violet	7	7	7	—	—	—	−750	−750
Gray	8	8	8	0.01	±0.25*	—	+150 to −1500	—
White	9	9	9	0.1	± 1.0	±10	+100 to −750	—
Gold	—	—	—	—	—	—	—	+100

*EIA only †Per charts in MIL-C-20D

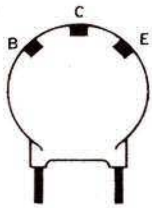
Ceramic Capacitor Color Code

EIA STANDARD RS-198

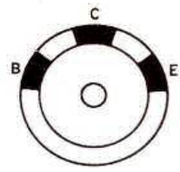
MILITARY STANDARD MIL-C-20D



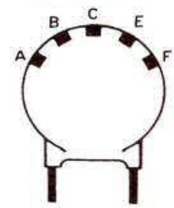
Stand-Off Capacitors
(EIA ONLY)



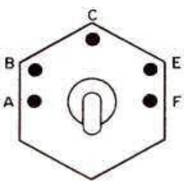
3-Dot Disc Capacitors
(RETMA ONLY)
(Voltage rating is always 500 v., tolerance is always —0.)



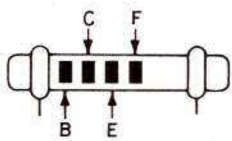
3-Dot Button Capacitors
(EIA ONLY)



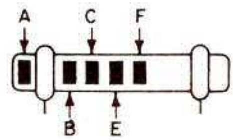
5-Dot Disc Capacitors
(EIA ONLY)
(Voltage rating is always 500 v.)



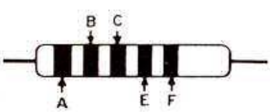
Feed Through Capacitors
(EIA ONLY)



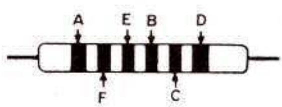
High Capacity Tubulars
(Insulated or Non-Insulated)



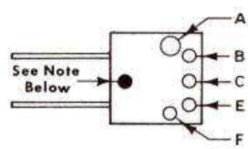
Temperature Compensating Tubulars



Tubular Capacitors
(Voltage rating is always 500 v.)



Tubular Capacitors
(Old RMA)



MIL Style CC
Rectangular

Note: Styles CC-60 through CC-71 will be color coded here with Green = 500 and Brown = 150, working volts DC.

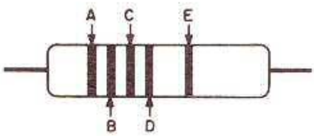
Color	Digits of Capacitance (μμf) B	C	D	Multiplier E	Tolerance F: 10 μμf or less (μμf)	Tolerance F: Over 10 μμf (%)	Temp. Coef. A (Parts per million per °C.): EIA	MILITARY†
Black	0	0	0	1	±2.0	±20*	±0	±0
Brown	1	1	1	10	±0.1*	±1	− 33	− 30
Red	2	2	2	100	±0.25	±2	− 75	− 80
Orange	3	3	3	1,000	—	±2.5*	−150	−150
Yellow	4	4	4	10,000*	—	—	−220	−220
Green	5	5	5	—	±0.5	±5	−330	−330
Blue	6	6	6	—	—	—	−470	−470
Violet	7	7	7	—	—	—	−750	−750
Gray	8	8	8	0.01	±0.25*	—	+150 to −1500	—
White	9	9	9	0.1	± 1.0	±10	+100 to −750	—
Gold	—	—	—	—	—	—	—	+100

*EIA only †Per charts in MIL-C-20D

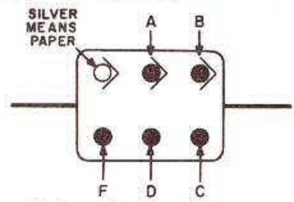
Paper Capacitor Color Code

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)



Tubular Capacitors (Commercial Only)



Rectangular Capacitors

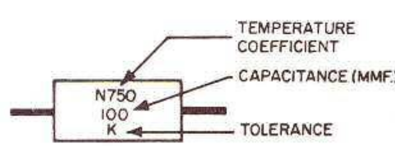
Color	Digits of Capacitance (μμf) A	Digits of Capacitance (μμf) B	Multiplier C	Tolerance % D	Tubular Voltage Rating (v d-c) E	Temp. Rating °C and Characteristic F
Black	0	0	1	± 20	—	85-A
Brown	1	1	10	—	100	85-E
Red	2	2	100	—	200	—
Orange	3	3	1,000	± 30	300	—
Yellow	4	4	10,000	—	400	—
Green	5	5	—	—	500	—
Blue	6	6	—	—	600	—
Violet	7	7	—	—	700	—
Gray	8	8	—	—	800	—
White	9	9	—	—	900	—
Gold	—	—	—	—	1,000	—
Silver	—	—	—	± 10	—	—

VOLTAGE RATING FOR RECTANGULAR CAPACITORS

(Indicated by dimensions rather than color coding)

Maximum Dimensions (inches) Length	Width	Thickness	*Style CN*	*Capacitance (μμf)*	*Voltage Rating (v d-c)*
51/64	15/32	7/32	20	1000 2000–6000 10,000	400 200 120
57/64	37/64	17/64	22	2000–3000 6000–10,000 20,000	400 300 120
53/64	53/64	9/32	30	1000–2000 3000 6000–10,000 20,000	800 600 400 120
53/64	53/64	11/32	35	3000 6000–10,000 20,000	800 600 300
1¼	41/64	9/32	41	3000–6000 10,000 20,000 30,000	600 400 300 120
1 15/32	49/64	11/32	42	1000–6000 10,000–20,000 30,000 50,000 100,000	1000 600 400 300 120
1 15/32	49/64	13/32	43	10,000 20,000–30,000 50,000–100,000 200,000	1000 600 400 120

TYPOGRAPHICALLY MARKED TUBULAR CERAMICS



JAN LETTER	*TOLERANCE* 10 μμf or Less	*TOLERANCE* Over 10 μμf
C	± 0.25 μμf	....
D	± 0.5 μμf	....
F	± 1.0 μμf	± 1%
G	± 2.0 μμf	± 2%
J	....	± 5%
K	....	± 10%
M	....	± 20%

Military Capacitor Letter-Number Codes

The long used color-code method of identifying fixed capacitors is rapidly being replaced under the currently effective Military Standards System, where type, capacitance, tolerance, voltage, temperature range and all required specifications are designated by letter and number symbols stamped on the capacitor case in place of the color-code system previously used.

Because of the increasing use of military styles of fixed capacitors throughout the electronics industry and the resulting confusion for those not familiar with this system, we publish on the following pages, basic outlines of the designating letter-number symbols covering MIL-C-91, MIL-C-20 and MIL-C-5 specifications now used in place of the color codes shown on the three preceding pages.

MIL-C-91A TYPE CN

Capacitors • Fixed • Paper Dielectric • Nonmetallic Cases

CN 22 A E 202 N

(1) 22 (2) A (3) E (4) 202 (5) N

① STYLE

Rectangular molded case styles, 20, 22, 41, 42, 43. Square molded case styles, 30, 35.

② CHARACTERISTIC

A = −55 to +85°C
E = −55 to +85°C
as per tables and charts in MIL-C-91

③ VOLTAGE

DC working at 40°C.

Y = 120	F = 600
C = 200	Z = 800
X = 300	G = 1,000
E = 400	

④ CAPACITANCE

Expressed in picofarads. First two digits represent significant figures. Last digit indicates the number of zeros to follow.

⑤ CAPACITANCE TOLERANCE

K = ±10%
M = ±20%
N = ±30%

Military Capacitor Letter-Number Codes

MIL-C-20D TYPE CC

Capacitors • Fixed • Ceramic Dielectric • Temperature Compensating

CC 20 A K OR5 C
① ② ③ ④ ⑤

① STYLE

Radial lead tubular case, 500 DC working volts, styles, 20, 22, 25, 27, 30, 31, 32, 33, 35, 37, 45, 47. Axial lead tubular case, 500 DC working volts, styles, 21, 26, 36. Disc case, 500 DC working volts, styles, 50, 51, 52, 53. Rectangular case styles, 60, 62, 64, 66, 68, 70, all 150 DC working volts; and 61, 63, 65, 67, 69, 71, all 500 DC working volts.

② TEMPERATURE COEFFICIENT

A = P100 = +100
C = NPO = ±0
H = N30 = −30
L = N80 = −80
P = N150 = −150
R = N220 = −220
S = N330 = −330
T = N470 = −470
U = N750 = −750

all as per charts in MIL-C-20D

③ T-C TOLERANCE BAND ENVELOPE

F, G, H, J, K, all as per curves in MIL-C-20D

④ CAPACITANCE

Expressed in picofarads. First two digits represent significant figures. Last digit indicates the number of zeros to follow. When fractional values are required, the letter "R" indicates the placing of the decimal point, and the following digits represent significant figures.

⑤ CAPACITANCE TOLERANCE

C = ±0.25 picofarads

D = ±0.5 picofarads

F = ±1% (±1.0 pf @ ≦ 10 pf)

G = ±2% (±2.0 pf @ ≦ 10 pf)

J = ±5%

K = ±10%

Military Capacitor Letter-Number Codes

MIL-C-5C TYPE CM

Capacitors • Fixed • Mica Dielectric

CM	15	C	D	100	K	N	3
	①	②	③	④	⑤	⑥	⑦

① STYLE

Dipped rectangular case styles, 05, 06, 07, 08. Lead mounting molded case styles, 15, 20, 30, 35, 40. Ear mounting molded case styles, 45, 50. Semi-hexagonal molded case, tapped mounting holes styles, 55, 60. Molded case, potted styles, 65, 70. Stack mounting ceramic case, potted eliptical base styles, 75, 80, 85, 90. Stack mounting ceramic case, potted, circular base style, 95.

② CHARACTERISTIC

Symbol	Temperature Coefficient Parts/Million/°C	Capacitance Drift
B	Not Specified	
C	−200 to +200	±(0.5% +0.1 pf)
D	−100 to +100	±(0.3% +0.1 pf)
E	−20 to +100	±(0.1% +0.1 pf)
F	0 to + 70	±(0.05% +0.1 pf)

③ VOLTAGE RATING

This rating not shown on earlier production.

Symbol	Volts	Symbol	Volts	Symbol	Volts
B	250	J	2,000	R	10,000
C	300	K	2,500	S	12,000
D	500	L	3,000	T	15,000
E	600	M	4,000	U	20,000
F	1,000	N	5,000	V	25,000
G	1,200	P	6,000	W	30,000
H	1,500	Q	8,000	X	35,000

④ CAPACITANCE

Expressed in picofarads. First two digits represent significant figures. Last digit indicates the number of zeros to follow.

⑤ CAPACITANCE TOLERANCE

F = ±1% or 0.5 pf, whichever is greater.
G = ± 2%
J = ± 5%
K = ±10%

⑥ OPERATING TEMPERATURE RANGE

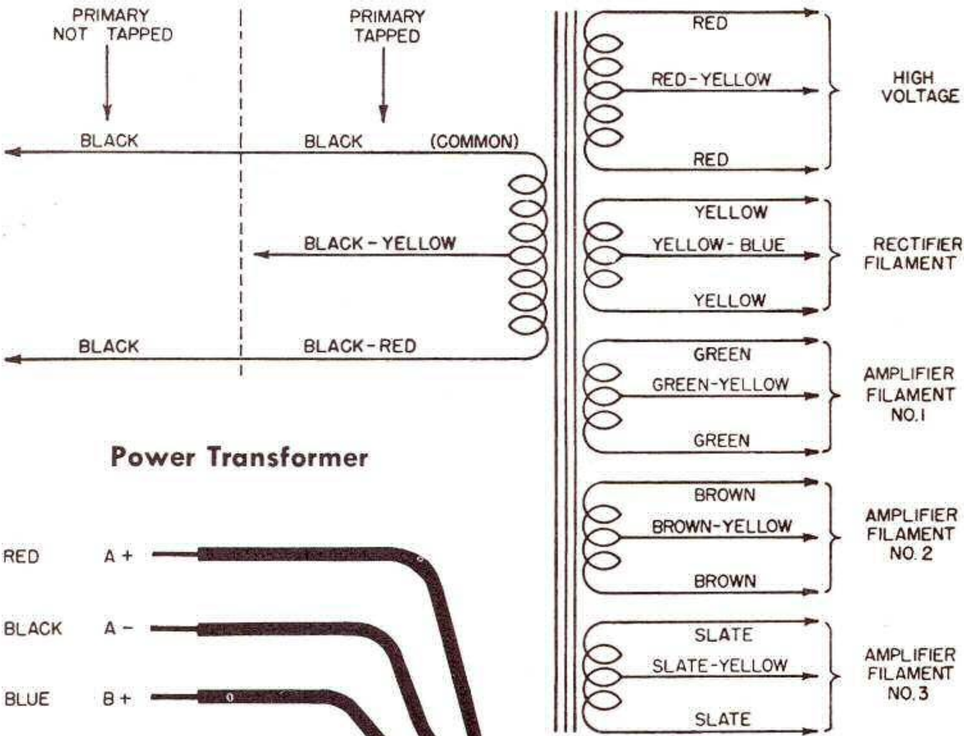
M = −55°C to + 70°C
N = −55°C to + 85°C
O = −55°C to +125°C
P = −55°C to +150°C

⑦ VIBRATION GRADE

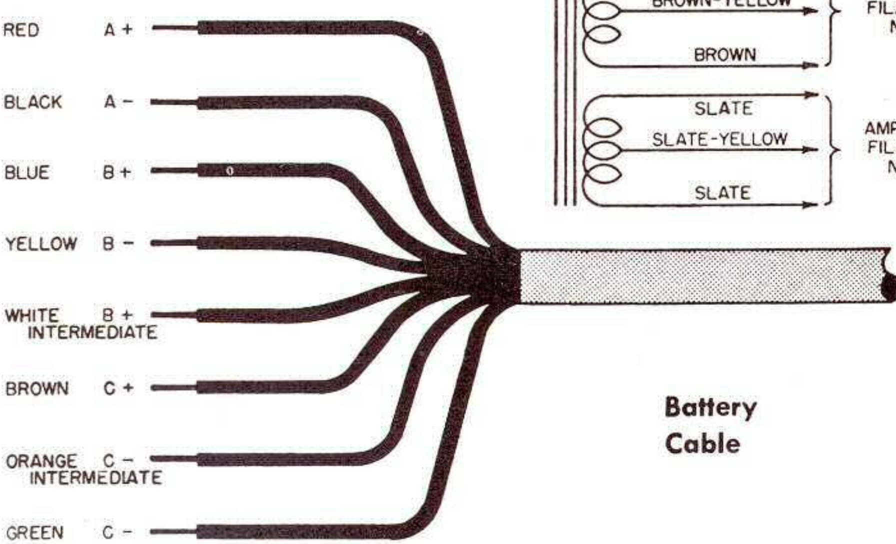
1 = 10 to 55 cps
3 = 10 to 2,000 cps

EIA Color Codes

The color codes on the preceding and two following pages are used by most radio and instrument manufacturers in the wiring of their products, and by parts manufacturers for identifying lead placement or resistor and capacitor values, ratings, and tolerances. These have been included for whatever help they may provide in identifying parts and leads when trouble-shooting. Since all manufacturers do not use these codes, however, due caution must be observed to determine whether or not the set, instrument, or part under examination does or does not follow the code colors given here. A quick check with a voltmeter, ohmmeter, or continuity meter is usually all that is needed to establish this fact.

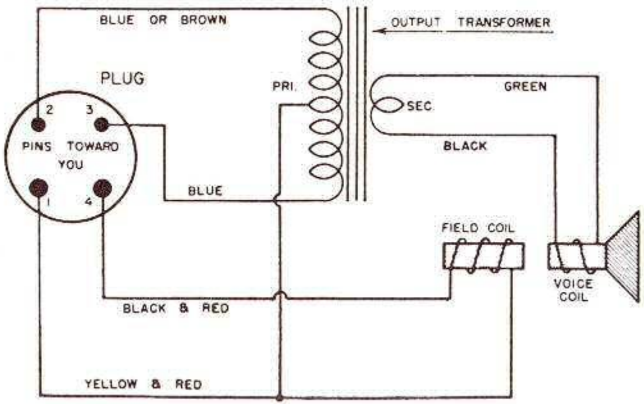


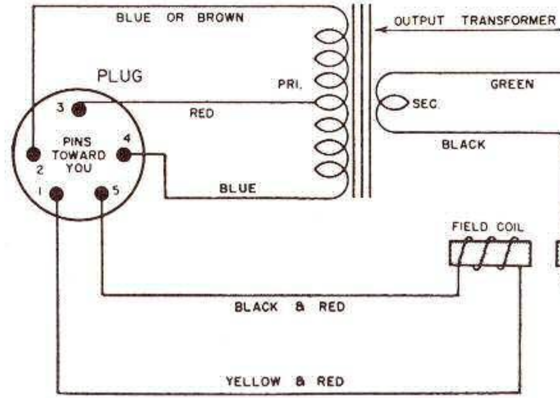
Power Transformer



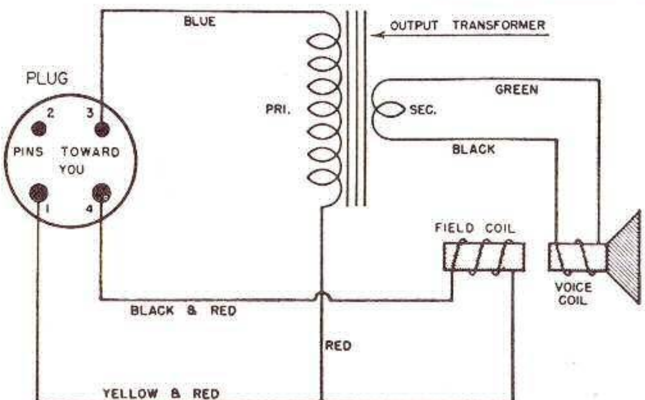
Battery Cable

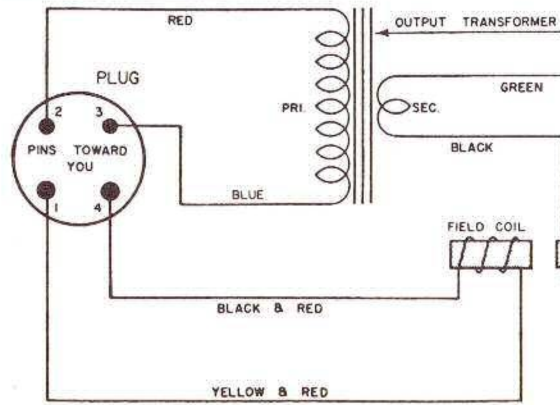
Speaker Leads and Plug Connections



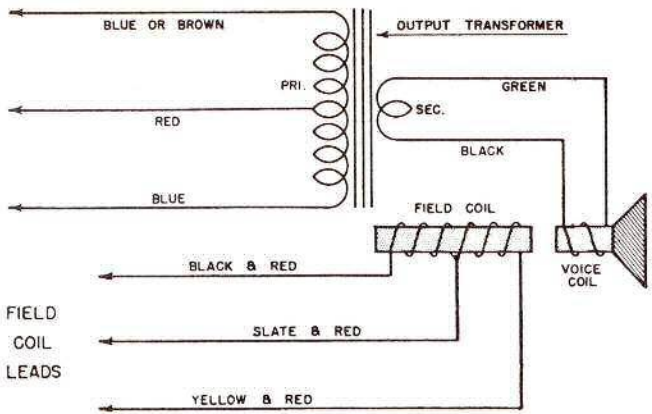


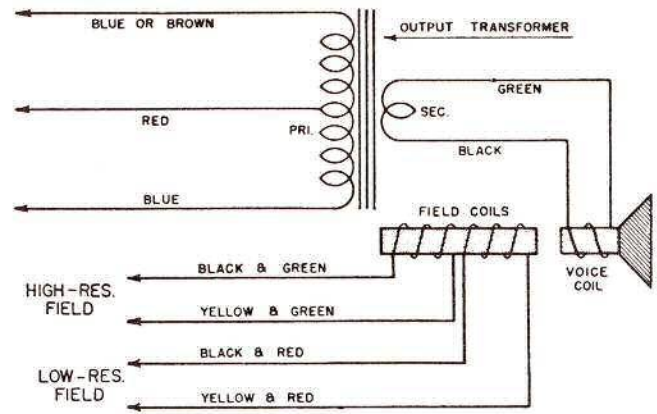
Speaker Leads and Plug Connections



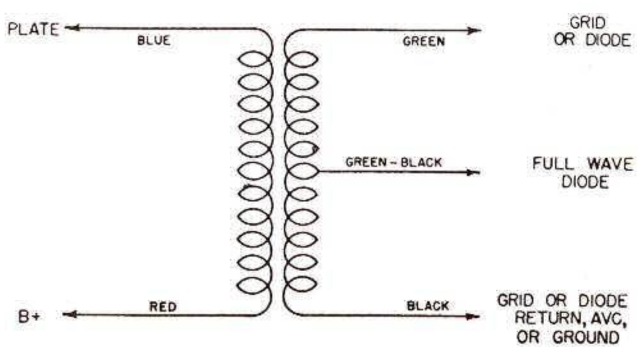


Speaker Lead Color Codes—(Continued)

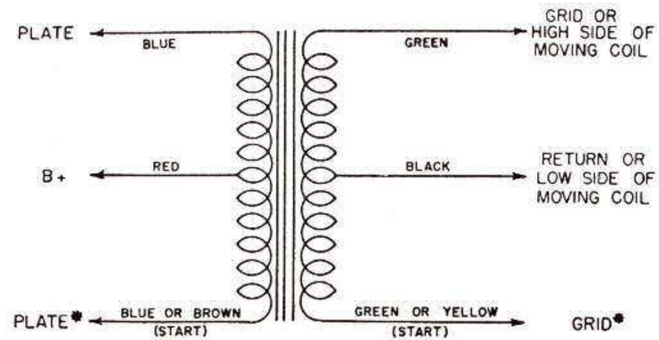




I-F Transformers

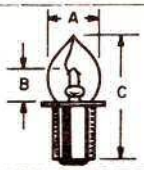
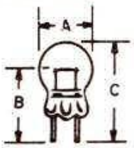
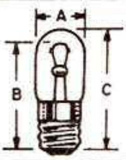
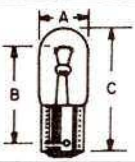
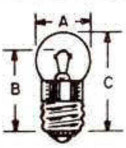
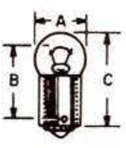
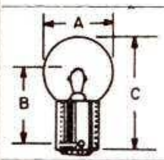
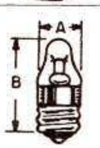


Audio & Output Transformers



* FOUND ONLY ON PUSH-PULL PRIMARY OR SECONDARY WINDINGS

Pilot Lamp Data

Bulb Silhouette	Maximum Size (See Chart Below)			Bulb No.	Base	Bulb Type	Lamp Numbers
	A	B	C				
	7/16"	1/4"	1 1/4"	B-3½	S.C. Flange (Miniature)	Small Round	PR2 PR3 PR4 PR6 PR12
	7/16"	5/8"	11/16"	G-3½	2-Pin (Miniature)	Small Round	12
	13/32"	15/16"	1 3/16"	T-3¼	Screw (Miniature)	Tubular	40 41 42 46 48 1892
	13/32"	3/4"	1 3/16"	T-3¼	Bayonet (Miniature)	Tubular	43 44 45 47 49 1490 1891
	7/16"	23/32"	15/16"	G-3½	Screw (Miniature)	Small Round	50
	7/16"	1/2"	15/16"	G-3½	Bayonet (Miniature)	Small Round	51
	9/16"	1/2"	1 1/16"	G-4½	Bayonet (Miniature)	Large Round	55 57
	5/8"	5/8"	1 3/16"	G-5	Bayonet (Miniature)	Large Round	1458
	3/8"	—	15/16"	TL-3	Screw (Miniature)	Pinched Round	112 222

Pilot Lamp Data (Cont'd)

Lamp No.	Bead Color	Base (Miniature)	Bulb Type	Rating		Used For
				Volts	Amps.	
PR-2	Blue	Flange	B-3½	2.4	0.50	Flashlights
PR-3	Green	Flange	B-3½	3.6	0.50	Flashlights
PR-4	Yellow	Flange	B-3½	2.3	0.27	Flashlights
PR-6	Brown	Flange	B-3½	2.5	0.30	Flashlights
PR-12	White	Flange	B-3½	5.95	0.50	Flashlights
12	....	2-Pin	G-3½	6.3	0.15	Dials
40	Brown	Screw	T-3¼	6-8	0.15	Dials
41	White	Screw	T-3¼	2.5	0.5	Dials
42	Green	Screw	T-3¼	3.2	‡	Dials
43	White	Bayonet	T-3¼	2.5	0.5	Dials and Tuning Meters
44	Blue	Bayonet	T-3¼	6-8	0.25	Dials and Tuning Meters
45	*	Bayonet	T-3¼	3.2	‡	Dials
46▲	Blue	Screw	T-3¼	6-8	0.25	Dials and Tuning Meters
47	Brown	Bayonet	T-3¼	6-9	0.15	Dials
48	Pink	Screw	T-3¼	2.0	0.06	Battery Set Dials
49	Pink	Bayonet	T-3¼	2.0	0.06	Battery Set Dials
50	White	Screw	G-3½	6-8	0.2	Auto-Radio Dials; Flashlights
51▲	White	Bayonet	G-3½	6-8	0.2	Auto-Radio Dials; Panel Boards
55	White	Bayonet	G-4½	6-8	0.4	Auto-Radio Dials; Parking Lights
57	White	Bayonet	G-4½	14	0.24	Auto Radio Dials
112	Pink	Screw	TL-3	1.1	0.22	Flashlights
222	White	Screw	TL-3	2.2	0.25	Flashlights; Soldering Guns
1458	.....	Bayonet	G-5	20.0	0.25	Dials
1490	White	Bayonet	T-3¼	3.2	0.15	Dials
1891	Pink	Bayonet	T-3½	14	0.23	Auto Radio Dials
1892	White	Screw	T-3½	14	0.12	Auto Panel Lights

*White in G.E. and Sylvania; Green in National Union Raytheon and Tung-Sol.
‡0.35 in G.E. and Sylvania; 0.5 in National Union Raytheon and Tung-Sol.
▲Have frosted bulb.

Neon Glow Lamps

High Brightness

Lamp Number	Hours of Average Useful Life*	Maximum Overall Length	Base	Nominal Current in Ma.	Circuit Volts, AC or DC	Nominal Watts 110-125 V.
NE-2H	25,000	¾"	2" Wire Term.	1.7	110-125	1/5
NE-2J	25,000	15/16"	S.C. Mid. Flange	1.7	110-125	1/5
NE-2P	25,000	¾"	1" Wire Term.	1.7	110-125	1/5
NE-51H	25,000	1 3/16"	Min. Bay.	1.2	110-125	1/7

Standard Brightness

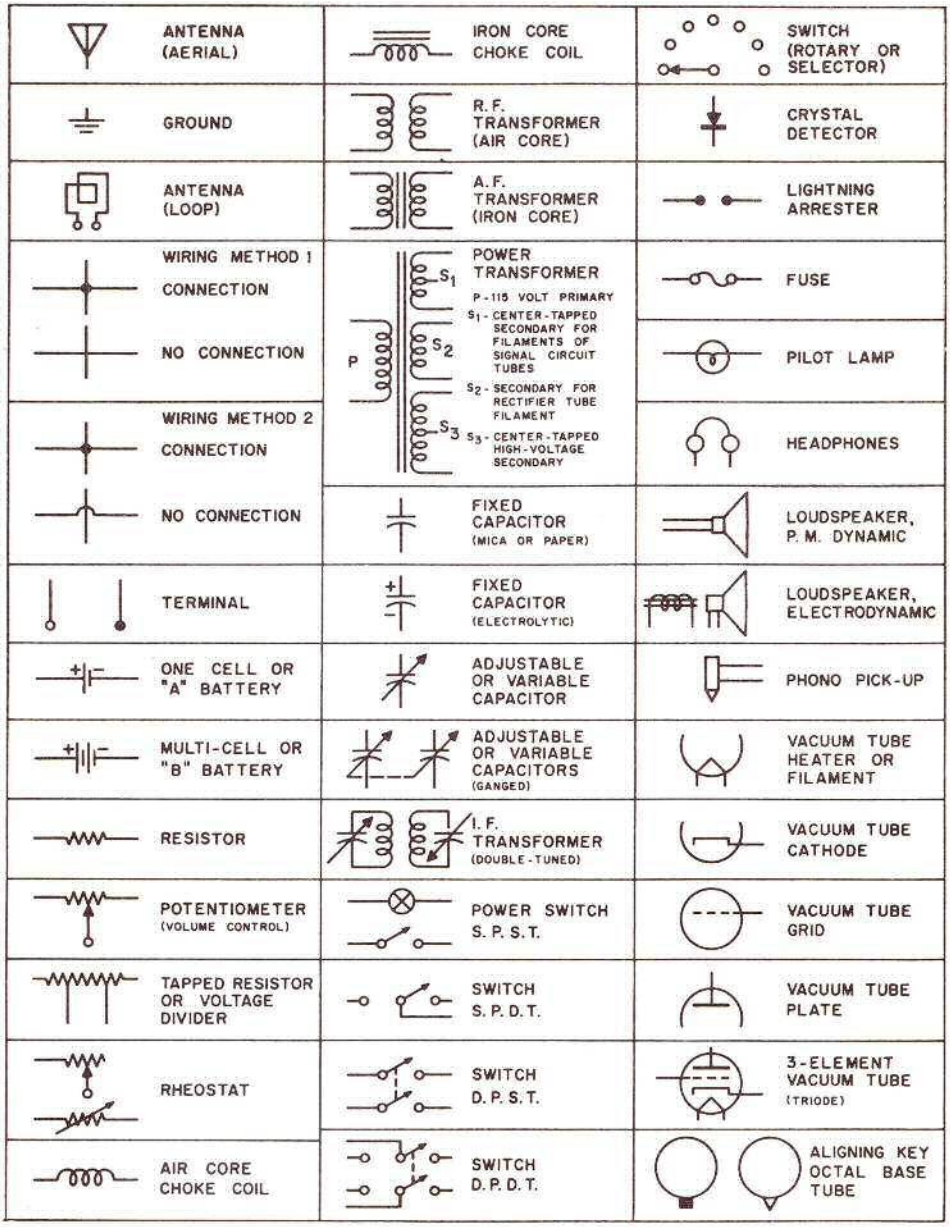
NE-2	25,000	1 1/16"	1" Wire Term.	0.5	110-125	1/17
NE-2D	25,000	15/16"	S.C. Mid. Flange	0.6	110-125	1/15
NE-2E	25,000	¾"	2" Wire Term.	0.6	110-125	1/15
NE-2M	25,000	¾"	1" Wire Term.	0.5	110-125	1/17
NE-7	7,500	1¼"	1⅛" Wire Term.	2.0	110-125	¼
NE-17	7,500	1½"	D.C. Bay	2.0	110-125	¼
NE-21	7,500	1½"	S.C. Bay	2.0	110-125	¼
NE-30	10,000	2¼"	Med. Screw	12.0	110-125	1
NE-34	10,000	3½"	Med. Screw	18.0	110-125	2
NE-42	10,000	3 15/16"	D.C. Bay	30.0	110-125	3
NE-45	7,500	1 17/32"	Cand. Screw	2.0	110-125	¼
NE-48	7,500	1½"	D.C. Bay	2.0	110-125	¼
NE-51	15,000	1 3/16"	Min. Bay	0.3	110-125	1/25
NE-56	10,000	2¼"	Med. Screw	5.0	220-250	1
NE-57	7,500	1 17/32"	Cand. Screw	2.0	110-125	¼
NE-58	7,500	1 17/32"	Cand. Screw	2.0	220-250	½
NE-79	10,000	2"	D.C. Bay	12.0	110-125	1

Argon Glow Lamps

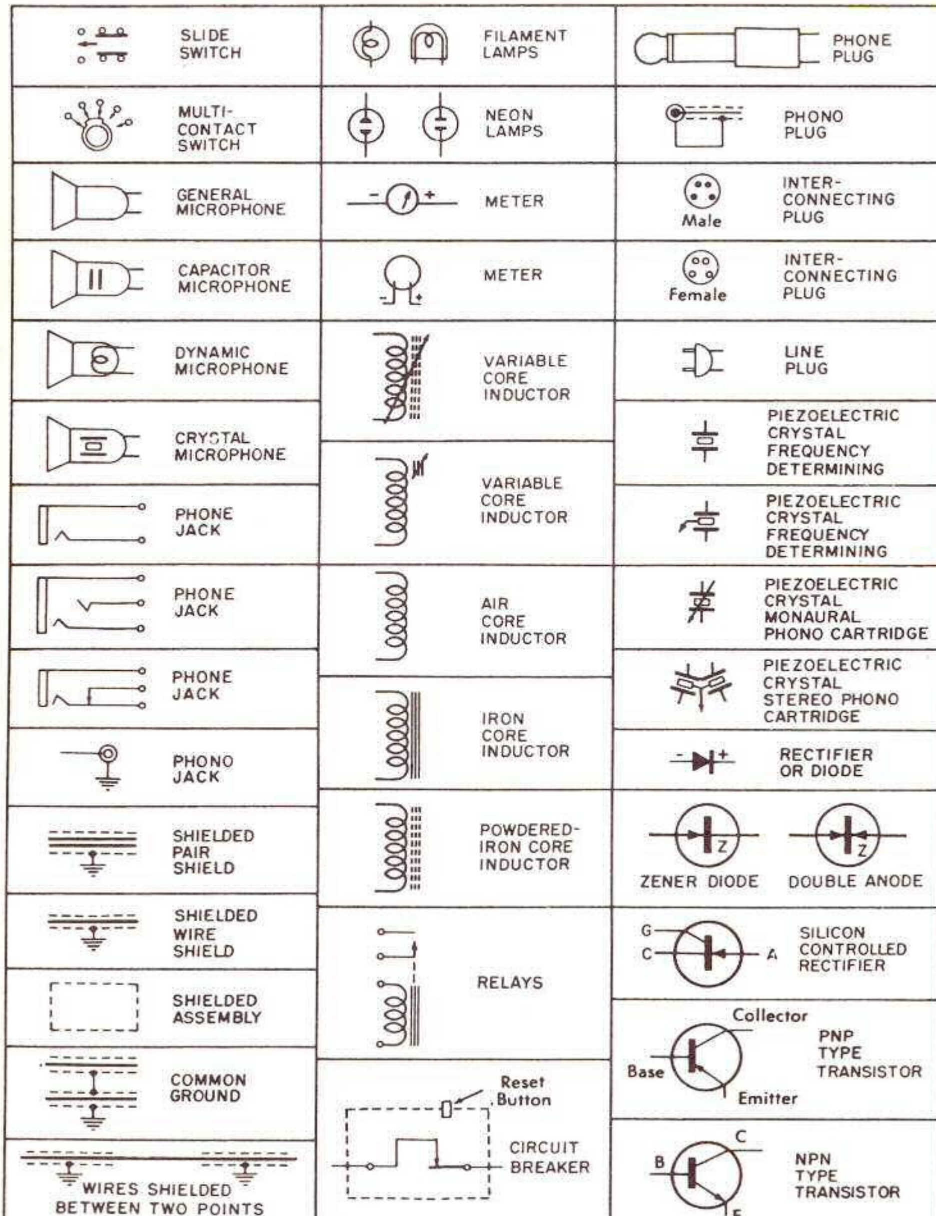
AR-1	1,000	3½"	Med. Screw	18.0	110-125	2
AR-3	150	1 17/32"	Cand. Screw	3.5	110-125	¼
AR-4	150	1½"	D.C. Bay	3.5	110-125	¼
AR-9	50	1 1/16"	1" Wire Term.	0.3	110-125	1/25

*On A.C. unless otherwise noted. D-C life is approximately 60% of A-C values.

Schematic Symbols
Used in Radio Diagrams



Schematic Symbols
Used in Radio Diagrams



Metric Unit Prefixes

Prefix	Symbol	Power of 10	Numerical Value	
tera	T	10^{12}	trillion	1,000,000,000,000
		10^{11}	hundred-billion	100,000,000,000
		10^{10}	ten-billion	10,000,000,000
giga	G	10^{9}	billion	1,000,000,000
		10^{8}	hundred-million	100,000,000
		10^{7}	ten-million	10,000,000
mega	M	10^{6}	million	1,000,000
		10^{5}	hundred-thousand	100,000
myria	my	10^{4}	ten-thousand	10,000
kilo	k	10^{3}	thousand	1,000
hecto	h	10^{2}	hundred	100
deka	da	10^{1}	ten	10
		10^{0}	one	1
deci	d	10^{-1}	tenth	.1
centi	c	10^{-2}	hundredth	.01
milli	m	10^{-3}	thousandth	.001
		10^{-4}	ten-thousandth	.000 1
		10^{-5}	hundred-thousandth	.000 01
micro	μ	10^{-6}	millionth	.000 001
		10^{-7}	ten-millionth	.000 000 1
		10^{-8}	hundred-millionth	.000 000 01
nano	n	10^{-9}	billionth	.000 000 001
		10^{-10}	ten-billionth	.000 000 000 1
		10^{-11}	hundred-billionth	.000 000 000 01
pico	p	10^{-12}	trillionth	.000 000 000 001
		10^{-13}	ten-trillionth	.000 000 000 000 1
		10^{-14}	hundred-trillionth	.000 000 000 000 01
femto	f	10^{-15}	quadrillionth	.000 000 000 000 001
		10^{-16}	ten-quadrillionth	.000 000 000 000 000 1
		10^{-17}	hundred-quadrillionth	.000 000 000 000 000 01
atto	a	10^{-18}	quintillionth	.000 000 000 000 000 001

Ohm's Law for A-C Circuits

The fundamental Ohm's law formulas for a-c circuits are given by

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

$$E = IZ, \qquad P = EI \cos\theta$$

where I = current in amperes,
Z = impedance in Ohms,
E = volts across Z,
P = power in watts,
θ = phase angle in degrees.

Phase Angle

The phase angle is defined as the difference in degrees by which current leads voltage in a capacitive circuit, or lags voltage in an inductive circuit, and in series circuits is equal to the angle whose tangent is given by the

ratio $\frac{X}{R}$ and is expressed by

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

where X = the inductive or capacitive reactance in ohms,
R = the non-reactive resistance in ohms,

of the combined resistive and reactive components of the circuit under consideration.

Therefore

in a purely resistive circuit, $\theta = 0°$
in a purely reactive circuit, $\theta = 90°$
and in a resonant circuit, $\theta = 0°$

also when

$\theta = 0°$, $\cos\theta = 1$ and $P = EI$,
$\theta = 90°$, $\cos\theta = 0$ and $P = 0$.

Degrees $\times$ 0.0175 = radians.
1 radian = 57.3°.

Power Factor

The power-factor of any a-c circuit is equal to the true power in watts divided by the apparent power in volt-amperes which is equal to the cosine of the phase angle, and is expressed by

$$p.f. = \frac{EI \cos\theta}{EI} = \cos\theta$$

where

$p.f.$ = the circuit load power factor,
$EI \cos\theta$ = the true power in watts,
EI = the apparent power in volt-amperes,
E = the applied potential in volts
I = load current in amperes.

Therefore

in a purely resistive circuit.

$\theta = 0°$ and $p.f. = 1$

and in a reactive circuit,

$\theta = 90°$ and $p.f. = 0$

and in a resonant circuit,

$\theta = 0°$ and $p.f. = 1$

Ohm's Law for D-C Circuits

The fundamental Ohm's law formulas for d-c circuits are given by,

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

$$E = IR, \qquad P = EI.$$

where I = current in amperes,
R = resistance in ohms,
E = potential across R in volts,
P = power in watts.

Ohm's Law Formulas for D-C Circuits

Known Values	Formulas for Determining Unknown Values of . . .			
	I	R	E	P
I & R			IR	I^2R
I & E		$\frac{E}{I}$		EI
I & P		$\frac{P}{I^2}$	$\frac{P}{I}$	
R & E	$\frac{E}{R}$			$\frac{E^2}{R}$
R & P	$\sqrt{\frac{P}{R}}$		$\sqrt{PR}$	
E & P	$\frac{P}{E}$	$\frac{E^2}{P}$		

Ohm's Law Formulas for A-C Circuits

Known Values	Formulas for Determining Unknown Values of . . .			
	I	Z	E	P
I & Z			IZ	$I^2Z \cos \theta$
I & E		$\frac{E}{I}$		$IE \cos \theta$
I & P		$\frac{P}{I^2 \cos \theta}$	$\frac{P}{I \cos \theta}$	
Z & E	$\frac{E}{Z}$			$\frac{E^2 \cos \theta}{Z}$
Z & P	$\sqrt{\frac{P}{Z \cos \theta}}$		$\sqrt{\frac{PZ}{\cos \theta}}$	
E & P	$\frac{P}{E \cos \theta}$	$\frac{E^2 \cos \theta}{P}$		

Coil Winding Data

Turns Per Inch

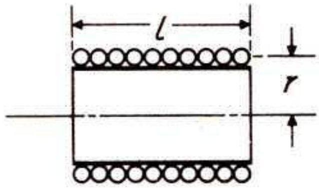
Gauge (AWG) or (B&S)	Number of Turns per Linear Inch			
	Enamel	S.S.C.	D.S.C. and S.C.C.	D.C.C.
1	—	—	3.3	3.3
2	—	—	3.8	3.6
3	—	—	4.2	4.0
4	—	—	4.7	4.5
5	—	—	5.2	5.0
6	—	—	5.9	5.6
7	—	—	6.5	6.2
8	7.6	—	7.4	7.1
9	8.6	—	8.2	7.8
10	9.6	—	9.3	8.9
11	10.7	—	10.3	9.8
12	12.0	—	11.5	10.9
13	13.5	—	12.8	12.0
14	15.0	—	14.2	13.8
15	16.8	—	15.8	14.7
16	18.9	18.9	17.9	16.4
17	21.2	21.2	19.9	18.1
18	23.6	23.6	22.0	19.8
19	26.4	26.4	24.4	21.8
20	29.4	29.4	27.0	23.8
21	33.1	32.7	29.8	26.0
22	37.0	36.5	34.1	30.0
23	41.3	40.6	37.6	31.6
24	46.3	45.3	41.5	35.6
25	51.7	50.4	45.6	38.6
26	58.0	55.6	50.2	41.8
27	64.9	61.5	55.0	45.0
28	72.7	68.6	60.2	48.5
29	81.6	74.8	65.4	51.8
30	90.5	83.3	71.5	55.5
31	101.	92.0	77.5	59.2
32	113.	101.	83.6	62.6
33	127.	110.	90.3	66.3
34	143.	120.	97.0	70.0
35	158.	132.	104.	73.5
36	175.	143.	111.	77.0
37	198.	154.	118.	80.3
38	224.	166.	126.	83.6
39	248.	181.	133.	86.6
40	282.	194.	140.	89.7

Coil Winding Formulas

The following approximations for winding *r-f* coils are accurate to within approx. 1% for nearly all small air-core coils, where

L = self inductance in microhenrys,
N = total number of turns,
r = mean radius in inches,
l = length of coil in inches,
b = depth of coil in inches.

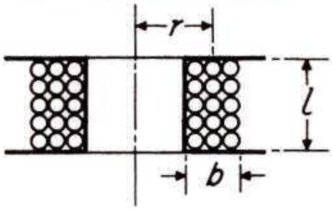
Single-Layer Wound Coils



$$L = \frac{(rN)^2}{9r + 10l}$$

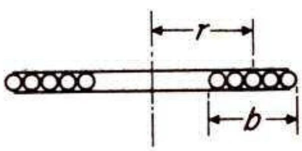
$$N = \frac{\sqrt{L(9r + 10l)}}{r}$$

Multi-Layer Wound Coils



$$L = \frac{0.8(rN)^2}{6r + 9l + 10b}$$

Single-Layer Spiral Wound Coils



$$L = \frac{(rN)^2}{8r + 11b}$$

Vacuum Tube Formulas and Symbols

Vacuum Tube Constants

Amplification factor (Mu or μ) is given by

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

Dynamic plate resistance in ohms, is given by

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

Mutual conductance in mhos, is given by

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

Vacuum Tube Formulas

Gain per stage is given by

$$\mu\left(\frac{R_L}{R_L + r_p}\right)$$

Voltage output appearing in R_L is given by

$$\mu\left(\frac{E_s R_L}{r_p + R_L}\right)$$

Power output in R_L, is given by

$$R_L\left(\frac{\mu E_s}{r_p + R_L}\right)^2$$

Maximum power output in R_L which results when $R_L = r_p$, is given by

$$\frac{(\mu E_s)^2}{4r_p}$$

Maximum undistorted power output in R_L, which results when $R_L = 2r_p$, is given by

$$\frac{2(\mu E_s)^2}{9r_p}$$

Required cathode biasing resistor in ohms, for a single tube is given by

$$\frac{E_g}{I_k}$$

Vacuum Tube Symbols

Mu or μ = Amplification factor,
r_p = Dynamic plate resistance in ohms,
g_m = Mutual conductance in mhos,
E_p = Plate voltage in volts,
E_g = Grid voltage in volts,
I_p = Plate current in amperes,
R_L = Plate load resistance in ohms,
I_k = Total cathode current in amperes,
E_s = Signal voltage in volts,
Δ = change or variation in value, which may be either an increment (increase), or a decrement (decrease).

Peak, R.M.S., and Average A-C Values of *E* & *I*

Given Value	To get . . . Peak	R.M.S.	Av.
Peak		0.707 × Peak	0.637 × Peak
R.M.S.	1.41 × R.M.S.		0.9 × R.M.S.
Av.	1.57 × Av.	1.11 × Av.	

Most Used Formulas

Resistance Formulas

In series $R_t = R_1 + R_2 + R_3 \ldots$ etc.

In parallel $$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots \text{etc.}}$$

Two resistors in parallel $$R_t = \frac{R_1 R_2}{R_1 + R_2}$$

Capacitance

In parallel $C_t = C_1 + C_2 + C_3 \ldots$ etc.

In series $$C_t = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots \text{etc.}}$$

Two capacitors in series $$C_t = \frac{C_1 C_2}{C_1 + C_2}$$

The Quantity of Electricity Stored Within a Capacitor is Given by

$$Q = CE$$

where Q = the quantity stored, in coulombs,
E = the potential impressed across the **capacitor** in volts,
C = capacitance in farads.

The Capacitance of a Parallel Plate Capacitor is Given by

$$C = 0.0885 \frac{KS\,(N-1)}{d}$$

where C = capacitance in mmfd.,
K = dielectric constant,
*S = area of one plate in square centimeters,
N = number of plates,
*d = thickness of the dielectric in centimeters (same as the distance between plates).

* When S and d are given in inches, change constant 0.0885 to 0.224. Answer will still be in micromicrofarads.

DIELECTRIC CONSTANTS

Kind of Dielectric	*Approximate* K Value*
Air (at atmospheric pressure)	1.0
Bakelite	5.0
Beeswax	3.0
Cambric (varnished)	4.0
Fibre (Red)	5.0
Glass (window or flint)	8.0
Gutta Percha	4.0
Mica	6.0
Paraffin (solid)	2.5
Paraffin Coated Paper	3.5
Porcelain	6.0
Pyrex	4.5
Quartz	5.0
Rubber	3.0
Slate	7.0
Wood (very dry)	5.0

* These values are approximate, since true values depend upon quality or grade of material used, as well as moisture content, temperature and frequency characteristics of each.

Self-Inductance

In series $L_t = L_1 + L_2 + L_3 \ldots$ etc.

In parallel $$L_t = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \ldots \text{etc.}}$$

Two inductors in parallel $$L_t = \frac{L_1\, L_2}{L_1 + L_2}$$

Coupled Inductance

In series with fields *aiding*

$$L_t = L_1 + L_2 + 2M$$

In series with fields *opposing*

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

In parallel with fields *aiding*

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

In parallel with fields *opposing*

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

where L_t = the total inductance,
M = the mutual inductance,
L_1 and L_2 = the self inductance of the individual coils.

Mutual Inductance

The mutual inductance of two r-f coils with fields interacting, is given by

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

where M = mutual inductance, expressed in same units as L_A and L_O,
L_A = Total inductance of coils L_1 and L_2 with fields *aiding*,
L_O = Total inductance of coils L_1 and L_2 with fields *opposing*.

Coupling Coefficient

When two r-f coils are inductively coupled so as to give transformer action, the coupling coefficient is expressed by

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

where K = the coupling coefficient; ($K \times 10^2$ = coupling coefficient in %),
M = the mutual inductance value,
L_1 and L_2 = the self-inductance of the two coils respectively, both being expressed in the same units.

Resonance

The resonant frequency, or frequency at which inductive reactance X_L equals capacitive reactance X_C, is expressed by

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

also $$L = \frac{1}{4\pi^2 f_r^2 C}$$

and $$C = \frac{1}{4\pi^2 f_r^2 L}$$

where f_r = resonant frequency in cycles per second,
L = inductance in henrys,
C = capacitance in farads,
$2\pi = 6.28$
$4\pi^2 = 39.5$

Reactance

of an inductance is expressed by

$$X_L = 2\pi fL$$

of a capacitance is expressed by

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

where X_L = inductive reactance in ohms, (known as positive reactance),
X_C = capacitive rectance in ohms, (known as negative reactance),
f = frequency in cycles per second,
L = inductance in henrys,
C = capacitance in farads,
$2\pi = 6.28$

Frequency from Wavelength

$$f = \frac{3 \times 10^5}{\lambda} \text{ (kilocycles)}$$

where λ = wavelength in *meters*.

$$f = \frac{3 \times 10^4}{\lambda} \text{ (megacycles)}$$

where λ = wavelength in *centimeters*.

Wavelength from Frequency

$$\lambda = \frac{3 \times 10^5}{f} \text{ (meters)}$$

where f = frequency in *kilocycles*.

$$\lambda = \frac{3 \times 10^4}{f} \text{ (centimeters)}$$

where f = frequency in *megacycles*.

Q or Figure of Merit

of a simple reactor

$$Q = \frac{X_L}{R_L}$$

of a single capacitor

$$Q = \frac{X_C}{R_C}$$

where Q = a ratio expressing the figure of merit,

X_L = inductive reactance in ohms,

X_C = capacitive reactance in ohms,

R_L = resistance in ohms acting in series with inductance,

R_C = resistance in ohms acting in series with capacitance,

Impedance

In any a-c circuit where resistance and reactance values of the R, L and C components are given, the absolute or numerical magnitude of impedance and phase angle can be computed from the formulas which follow.

In general the basic formulas expressing total impedance are:

for series circuits,

$$Z_t = \sqrt{R_t^2 + X_t^2},$$

for parallel circuits,

$$Z_t = \frac{1}{\sqrt{G_t^2 + B_t^2}}.$$

See page 17 for formulas involving impedance, conductance, susceptance and admittance.

In series circuits where phase angle and any two of the Z, R and X components are known, the unknown component may be determined from the expressions:

$$Z = \frac{R}{\cos\theta} \qquad Z = \frac{X}{\sin\theta}$$

$$R = Z\cos\theta \qquad X = Z\sin\theta$$

where Z = magnitude of impedance in ohms,

R = resistance in ohms,

X = reactance (inductive or capacitive) in ohms.

Nomenclature

Z = absolute or numerical value of impedance magnitude in ohms

R = resistance in ohms,

X_L = inductive reactance in ohms,

X_C = capacitive reactance in ohms,

L = inductance in henrys,

C = capacitance in farads,

R_L = resistance in ohms acting in series with inductance,

R_C = resistance in ohms acting in series with capacitance,

θ = phase angle in degrees by which current leads voltage in a capacitive circuit, or lags voltage in an inductive circuit. In a resonant circuit, where X_L equals X_C, θ equals 0°.

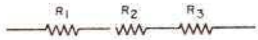
Degrees × 0.0175 = radians.
1 radian = 57.3°.

Numerical Magnitude of Impedance . . .

of resistance alone

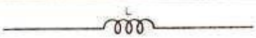
$$Z = R$$

$$\theta = 0°$$



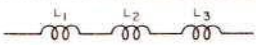
of resistance in series

$$Z = R_1 + R_2 + R_3 \ldots \text{etc.}$$
$$\theta = 0^\circ$$



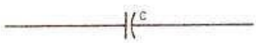
of inductance alone

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



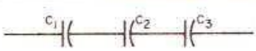
of inductance in series

$$Z = X_{L1} + X_{L2} + X_{L3} \ldots \text{etc.}$$
$$\theta = +90^\circ$$



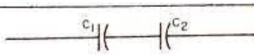
of capacitance alone

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



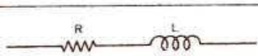
of capacitance in series

$$Z = X_{C1} + X_{C2} + X_{C3} \ldots \text{etc.}$$
$$\theta = -90^\circ$$



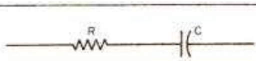
or where only 2 capacitances C_1 and C_2 are involved,

$$Z = \frac{1}{2\pi f}\left(\frac{C_1 + C_2}{C_1\, C_2}\right)$$
$$\theta = -90^\circ$$



of resistance and inductance in series

$$Z = \sqrt{R^2 + X_L^2}$$
$$\theta = \text{arc tan}\,\frac{X_L}{R}$$

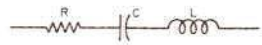


of resistance and capacitance in series

$$Z = \sqrt{R^2 + X_C^2}$$
$$\theta = \text{arc tan}\,\frac{X_C}{R}$$

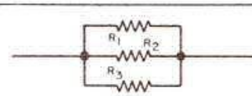
of inductance and capacitance in series

$$Z = X_L - X_C$$
$$\theta = -90^\circ \text{ when } X_L < X_C$$
$$= 0^\circ \text{ when } X_L = X_C$$
$$= +90^\circ \text{ when } X_L > X_C$$



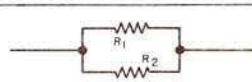
of resistance, inductance and capacitance in series

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



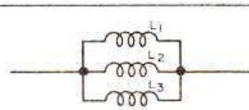
of resistance in parallel

$$Z = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots \text{etc.}}$$
$$\theta = 0^\circ$$



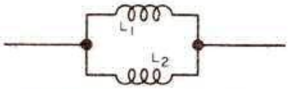
or where only 2 resistances R_1 and R_2 are involved,

$$Z = \frac{R_1\, R_2}{R_1 + R_2}$$
$$\theta = 0^\circ$$



of inductance in parallel

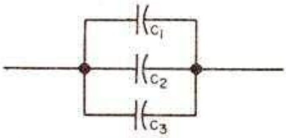
$$Z = \frac{1}{\frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}} \ldots \text{etc.}}$$
$$\theta = +90^\circ$$



or where only 2 inductances L_1 and L_2 are involved,

$$Z = 2\pi f \left(\frac{L_1 L_2}{L_1 + L_2} \right)$$

$$\theta = +90^\circ$$



of capacitance in parallel

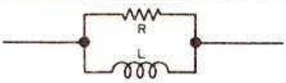
$$Z = \frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}} + \frac{1}{X_{C3}} \ldots \text{etc.}}$$

$$\theta = -90^\circ$$

or where only 2 capacitances C_1 and C_2 are involved,

$$Z = \frac{1}{2\pi f\,(C_1 + C_2)}$$

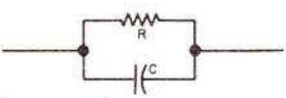
$$\theta = -90^\circ$$



of inductance and resistance in parallel,

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

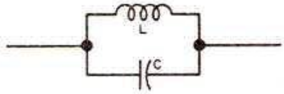
$$\theta = \text{arc tan}\,\frac{R}{X_L}$$



of capacitance and resistance in parallel,

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

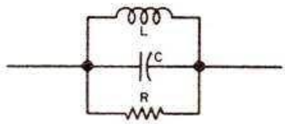
$$\theta = -\,\text{arc tan}\,\frac{R}{X_C}$$



of inductance and capacitance in parallel,

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

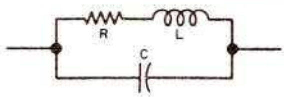
$$\theta = 0^\circ \text{ when } X_L = X_C$$



of inductance, resistance and capacitance in parallel

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

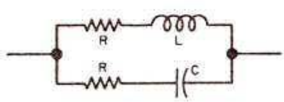
$$\theta = \text{arc tan}\,\frac{RX_C - RX_L}{X_L X_C}$$



of inductance and series resistance in parallel with capacitance

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

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



of capacitance and series resistance in parallel with inductance and series resistance

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

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

Conductance

In direct current circuits, conductance is expressed by

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

where G = conductance in mhos,
R = resistance in ohms.

In d-c circuits involving resistances R_1, R_2, R_3, etc., in parallel,

the total conductance is expressed by

$$G_{total} = G_1 + G_2 + G_3 \ldots \text{ etc.}$$

and the total current by

$$I_{total} = E\, G_{total}$$

and the amount of current in any single resistor, R_2 for example, in a parallel group, by

$$I_2 = \frac{I_{total}\, G_2}{G_1 + G_2 + G_3 \ldots \text{etc.}},$$

R, E and I in Ohm's law formulas for d-c circuits may be expressed in terms of conductance as follows:

$$R = \frac{1}{G}, \qquad E = \frac{I}{G}, \qquad I = EG,$$

where G = conductance in mhos,
R = resistance in ohms,
E = potential in volts,
I = current in amperes.

Susceptance

In an alternating current circuit, the susceptance of a series circuit is expressed by

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

or, when the resistance is 0, susceptance becomes the reciprocal of reactance, or

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

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

Admittance

In an alternating current circuit, the admittance of a series circuit is expressed by

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

Admittance is also expressed as the reciprocal of impedance, or

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

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

R and X in Terms of G and B

Resistance and reactance may be expressed in terms of conductance and susceptance as follows:

$$R = \frac{G}{G^2 + B^2}, \qquad X = \frac{B}{G^2 + B^2}.$$

G, B, Y and Z in Parallel Circuits

In any given a-c circuit containing a number of smaller parallel circuits only,

the effective conductance G_t is expressed by

$$G_t = G_1 + G_2 + G_3 \ldots \text{etc.},$$

and the effective susceptance B_t by

$$B_t = B_1 + B_2 + B_3 \ldots \text{etc.}$$

and the effective admittance Y_t by

$$Y_t = \sqrt{G_t^2 + B_t^2}$$

and the effective impedance Z_t by

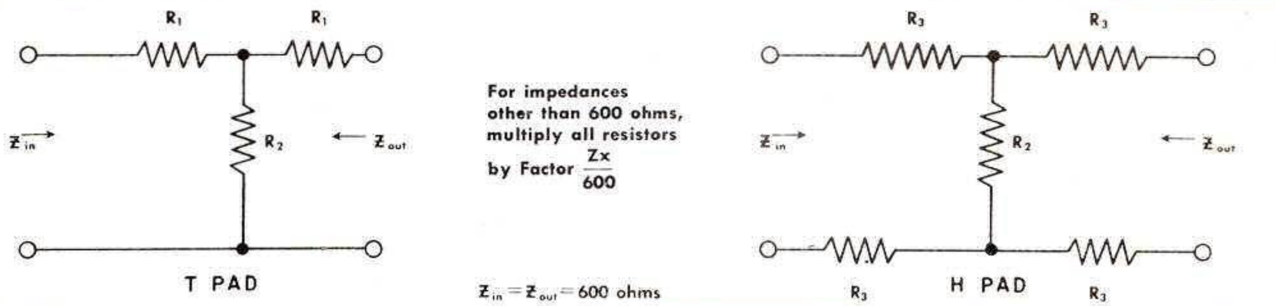
$$Z_t = \frac{1}{\sqrt{G_t^2 + B_t^2}} \text{ or } \frac{1}{Y_t}$$

where R = resistance in ohms,
X = reactance (capacitive or inductive) in ohms,
G = conductance in mhos,
B = susceptance in mhos,
Y = admittance in mhos,
Z = impedance in ohms.

VOLUME LEVEL TO POWER AND VOLTAGE CONVERSION TABLE

Reference Level
0 dbm = 1 milliwatt, 600 ohms

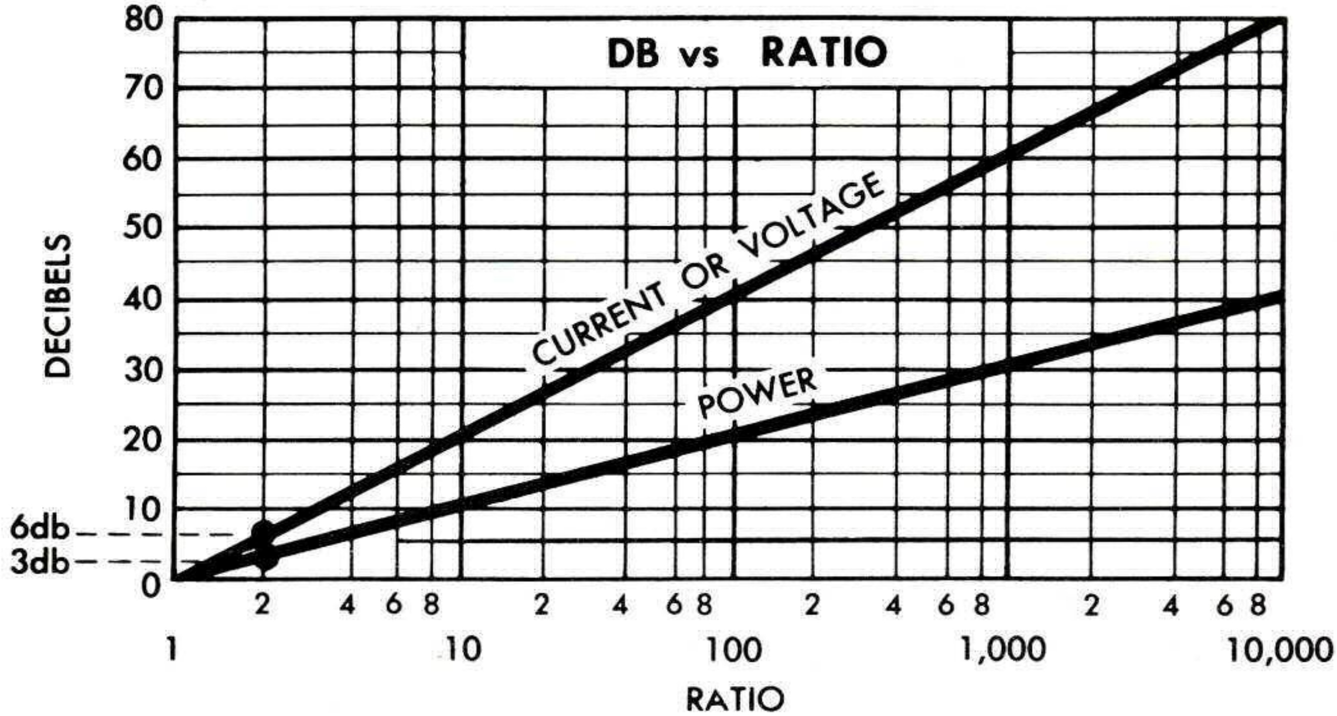
Milliwatts	Volts	DBM
.000001	.0007746	−60
.000010	.002449	−50
.000100	.007746	−40
.001	.02449	−30
.010	.07746	−20
0.100	.2449	−10
1.000	.7746	0
Watts	**Volts**	**DBM**
.001000	.7746	0
.002512	1.228	+ 4
.006310	1.946	+ 8
.01000	2.449	+10
.1000	7.746	+20
1.000	24.49	+30
10.00	77.46	+40

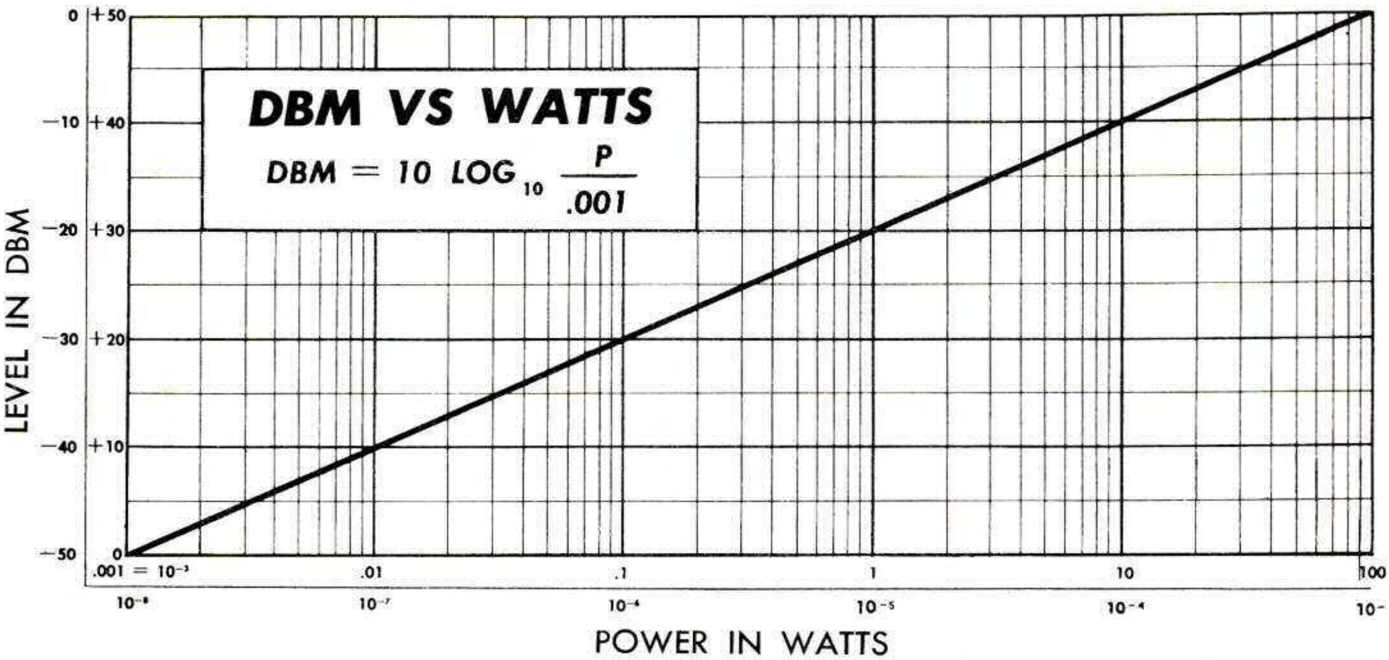


Loss in DB	EIA Resistor Values*			Loss in DB	EIA Resistor Values*		
	R_1	R_2	R_3		R_1	R_2	R_3
½	18	10,000	8.2	16	430	200	220
1	36	5,100	18	17	470	180	220
2	68	2,700	36	18	470	150	240
3	100	1,800	51	19	470	130	240
4	130	1,200	68	20	510	120	240
5	160	1,000	82	22	510	100	270
6	200	820	100	24	510	75	270
7	220	680	110	26	560	62	270
8	270	560	130	28	560	47	270
9	300	470	150	30	560	39	270
10	300	430	160	32	560	30	300
11	330	360	160	34	560	24	300
12	360	330	180	36	560	18	300
13	390	270	200	38	560	15	300
14	390	240	200	40	560	12	300
15	430	220	200				

** EIA resistor values nearest to the exact values are given*

RESISTIVE PADS


DB vs RATIO
CURRENT OR VOLTAGE
POWER
DECIBELS
80
70
60
50
40
30
20
10
6db
3db
0
2 4 6 8 2 4 6 8 2 4 6 8 2 4 6 8
1
10
100
1,000
10,000
RATIO


DBM VS WATTS
DBM = 10 LOG10 P/.001
LEVEL IN DBM
0 +50
−10 +40
−20 +30
−30 +20
−40 +10
−50 0
.001
.01
.1
1
10
100
POWER IN WATTS