APPENDIX 2. MOST USED FORMULAS

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.*

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

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

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,
$2\pi = 6.28$

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.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

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.

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*

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

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 M 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*.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

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,

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

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 resonant circuit, where equals X_C, θ equals 0°.

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

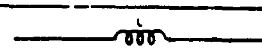
Numerical Magnitude of Impedance

of resistance alone

$$Z = R$$
$$\theta = 0°$$

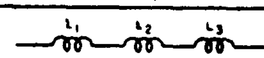
of resistance in series

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



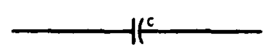
of inductance alone

$$Z = X_L$$
$$\theta = +90°$$



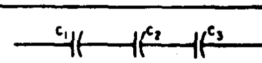
of inductance in series

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



of capacitance alone

$$Z = X_C$$
$$\theta = -90°$$



of capacitance in series

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

APPENDIX 2. MOST USED FORMULAS (CONT'D)

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

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

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

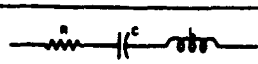
of inductance and capacitance in series

$$Z = X_L - X_C$$

$$\theta = -90^\circ \text{ when } X_L < X_C$$

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

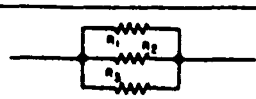
$$= +90^\circ \text{ when } X_L > X_C$$



of resistance, inductance and capacitance in series

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

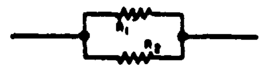
$$\theta = \text{arc tan}\ \frac{X_L - X_C}{R}$$



of resistance in parallel

$$Z = \cfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots \text{etc.}}$$

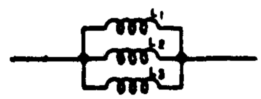
$$\theta = 0^\circ$$



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

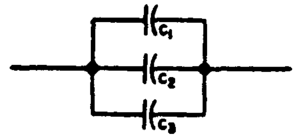
$$Z = \cfrac{1}{\frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}} \ldots \text{etc.}}$$

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

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

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

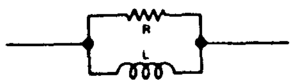
$$\theta = -90^\circ$$

or where only 2 capacitances C_1 and C_2 are involved,

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

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

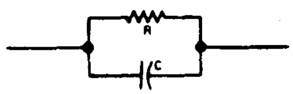
APPENDIX 2. MOST USED FORMULAS (CONT'D)



of inductance and resistance in parallel,

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

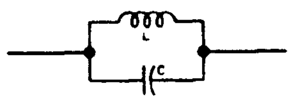
$$\theta = \text{arc tan } \frac{R}{X_L}$$



of capacitance and resistance in parallel,

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

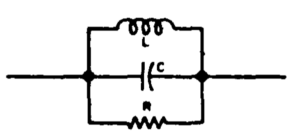
$$\theta = -\text{ arc tan } \frac{R}{X_C}$$



of inductance and capacitance in parallel,

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

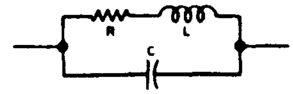
$$\theta = 0° \text{ when } X_L = X_C$$



of inductance, resistance and capacitance in parallel

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

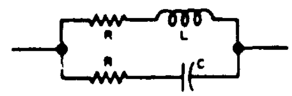
$$\theta = \text{arc tan } \frac{RX_C - RX_L}{X_L X_C}$$



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 for example, in a parallel group, by

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

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Resistance 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,
F = potential in volts,
= 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.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

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

$$\arctan \frac{X}{R}$$

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.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Ohm's Law Formulas for A-C Circuits

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

Ohm's Law Formulas for D-C Circuits

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

APPENDIX 2. MOST USED FORMULAS (CONT'D)

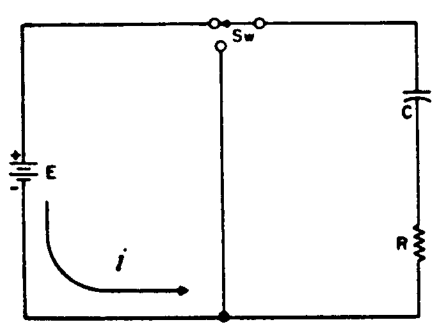
Transient *I* and *E* in *LCR* Circuits

The formulas which follow may be used to closely approximate the growth and decay of current and voltage in circuits involving L, C and R:

where i = instantaneous current in amperes at any given time (t),
E = potential in volts as designated,
R = circuit resistance in ohms,
C = capacitance in farads,
L = inductance in henrys,
V = steady state potential in volts,
V_C = reactive volts across C,
V_L = reactive volts across L,
V_R = voltage across R
RC = time constant of RC circuit in seconds,
$\frac{L}{R}$ = time constant of RL circuit in seconds,
t = any given time in seconds after switch is thrown,
ϵ = a constant, 2.718 (base of the natural system of logarithms).
Sw = switch

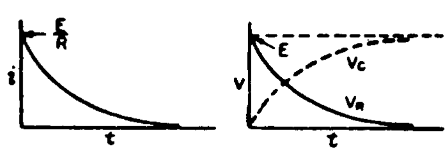
The time constant is defined as the time in seconds for current or voltage to fall to $\frac{1}{\epsilon}$ or 36.8% of its initial value or to rise to $\left(1-\frac{1}{\epsilon}\right)$ or approximately 63.2% of its final value.

Charging a De-energized Capacitive Circuit



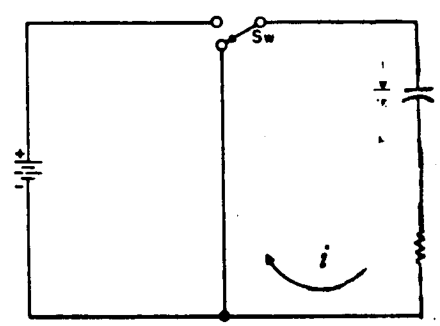
E = applied potential.

$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$



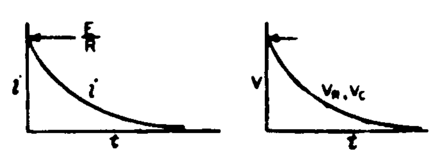
$$V_C = E\left(1 - \epsilon^{-\frac{t}{RC}}\right) \qquad V_R = E\,\epsilon^{-\frac{t}{RC}}$$

Discharging an Energized Capacitive Circuit



E = potential to which C is charged prior to closing S_w.

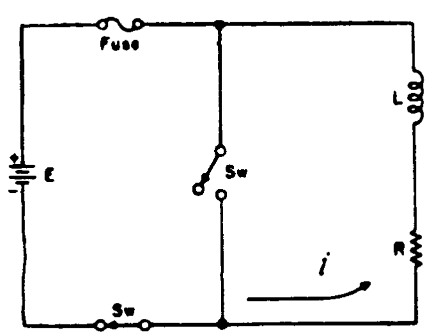
$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$



$$V_C = V_R = E\,\epsilon^{-\frac{t}{RC}}$$

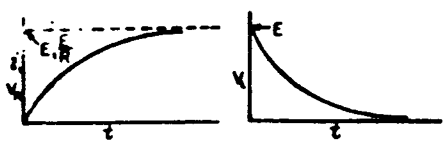
APPENDIX 2. MOST USED FORMULAS (CONT'D)

Voltage is Applied to a De-energized Inductive Circuit



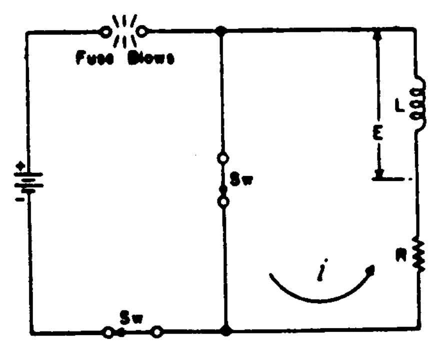
E = applied potential

$$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{Rt}{L}}\right)$$



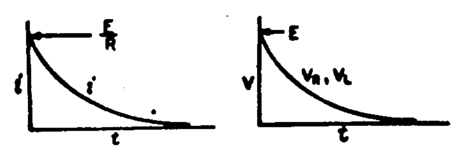
$$V_R = E\left(1 - \epsilon^{-\frac{Rt}{L}}\right) \qquad V_L = E\epsilon^{-\frac{Rt}{L}}$$

An Energized Inductive Circuit is Short Circuited



E = counter potential induced in coil when switch is closed.

$$i = \frac{E}{R}\epsilon^{-\frac{Rt}{L}}$$



$$V_L = V_R = E\epsilon^{-\frac{Rt}{L}}$$

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Steady State Current Flow

In a Capacitive Circuit

In a capacitive circuit, where resistance loss components may be considered as negligible, the flow of current at a given alternating potential of constant frequency, is expressed by

$$I = \frac{E}{X_C} = \frac{E}{\left(\frac{1}{2\pi fC}\right)} = E\,(2\pi fC)$$

where I = current in amperes,
X_C = capacitive reactance of the circuit in ohms,
E = applied potential in volts.

In an Inductive Circuit

In an inductive circuit, where inherent resistance and capacitance components may be so low as to be negligible, the flow of current at a given alternating potential of a constant frequency, is expressed by

$$I = \frac{E}{X_L} = \frac{E}{2\pi fL}$$

where I = current in amperes,
X_L = inductive reactance of the circuit in ohms,
E = applied potential in volts.

Decibels

The number of db by which two power outputs P_1 and P_2 (in watts) may differ, is expressed by

$$10 \log \frac{P_1}{P_2};$$

or in terms of volts,

$$20 \log \frac{E_1}{E_2};$$

or in current,

$$20 \log \frac{I_1}{I_2}.$$

While power ratios are independent of source and load impedance values, voltage and current ratios in these formulas hold true only when the source and load impedances Z_1 and Z_2 are equal. In circuits where these impedances differ, voltage and current ratios are expressed by,

$$db = 20 \log \frac{E_1\sqrt{Z_2}}{E_2\sqrt{Z_1}} \quad \text{or,} \quad 20 \log \frac{I_1\sqrt{Z_1}}{I_2\sqrt{Z_2}}$$

DBM Expressed in Watts & Volts

DBM	Above Zero Level		Below Zero Level	
	Watts	Volts	Watts	Volts
0	0.0010	0.775	1.00×10^{-3}	0.7746
1	0.0013	0.869	7.94×10^{-4}	0.6904
2	0.0016	0.975	6.31×10^{-4}	0.6153
3	0.0020	1.094	5.01×10^{-4}	0.5483
4	0.0025	1.227	3.98×10^{-4}	0.4888
5	0.0032	1.377	3.16×10^{-4}	0.4356
6	0.0040	1.545	2.51×10^{-4}	0.3883
7	0.0050	1.734	2.00×10^{-4}	0.3460
8	0.0063	1.946	1.59×10^{-4}	0.3084
9	0.0079	2.183	1.26×10^{-4}	0.2748
10	0.0100	2.449	1.00×10^{-4}	0.2449
11	0.0126	2.748	7.94×10^{-5}	0.2183
12	0.0159	3.084	6.31×10^{-5}	0.1946
13	0.0200	3.460	5.01×10^{-5}	0.1734
14	0.0251	3.882	3.98×10^{-5}	0.1545
15	0.0316	4.356	3.16×10^{-5}	0.1377
16	0.0398	4.888	2.51×10^{-5}	0.1228
17	0.0501	5.483	2.00×10^{-5}	0.1095
18	0.0631	6.153	1.59×10^{-5}	0.0975
19	0.0794	6.904	1.26×10^{-5}	0.0869
20	0.1	7.746	10^{-5}	7.75×10^{-2}
30	1.0	24.493	10^{-6}	2.45×10^{-2}
40	10.0	77.460	10^{-7}	7.75×10^{-3}
50	10^{2}	244.93	10^{-8}	2.45×10^{-3}
60	10^{3}	774.60	10^{-9}	7.75×10^{-4}
70	10^{4}	2,449.0	10^{-10}	2.45×10^{-4}
80	10^{5}	7,746.0	10^{-11}	7.75×10^{-5}
90	10^{6}	24,493.0	10^{-12}	2.45×10^{-5}
100	10^{7}	77,460.0	10^{-13}	7.75×10^{-6}

*Zero dbm - 1 milliwatt into a 600 ohm load. Power ratios hold for any impedance, but voltages must be referred to an impedance load of 600 ohms.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

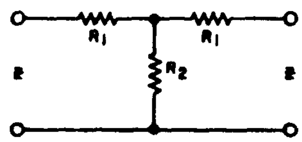
db	Voltage or Current Ratio	B	C	D	E	db	Voltage or Current Ratio	B	C	D	E
.1	0.98855	0.011447	86.340	0.005756	86.857	27.0	0.044668	0.95533	0.046757	0.91448	0.089515
.2	0.97724	0.022763	42.931	0.011512	43.426	27.5	0.042170	0.95783	0.044026	0.91907	0.084490
.25	0.97163	0.028372	34.247	0.014390	34.739	28.0	0.039811	0.96019	0.041461	0.92343	0.079748
.3	0.96605	0.034046	28.456	0.017268	28.947	30.0	0.031623	0.96838	0.032655	0.93869	0.063309
.4	0.95499	0.045006	21.219	0.023022	21.707	32.0	0.025119	0.97438	0.025766	0.95099	0.060269
.5	0.94406	0.055939	16.876	0.028774	17.362	32.5	0.023714	0.97629	0.024290	0.95367	0.047454
.6	0.93325	0.066745	13.982	0.034525	14.428	33.0	0.022387	0.97761	0.022900	0.95621	0.044797
.7	0.92257	0.077429	11.915	0.040274	12.395	34.0	0.019953	0.98005	0.020359	0.96088	0.039921
.75	0.91728	0.082724	11.088	0.043147	11.567	35.0	0.017783	0.98222	0.018105	0.96506	0.035577
.8	0.91201	0.087989	10.365	0.046019	10.842	36.0	0.015849	0.98415	0.016104	0.96880	0.031706
.9	0.90157	0.098429	9.1596	0.051762	9.6337	37.5	0.013335	0.98666	0.013515	0.97368	0.026675
1.0	0.89125	0.10875	8.1955	0.057501	8.6667	38.0	0.012589	0.98741	0.012750	0.97513	0.025183
1.5	0.84140	0.15860	5.3050	0.086133	5.7619	39.0	0.011220	0.98878	0.011348	0.97781	0.022443
2.0	0.79433	0.20567	3.8621	0.11462	4.3048	40.0	0.010000	0.99000	0.010101	0.98020	0.020002
2.5	0.74989	0.25011	2.9983	0.14293	3.4268	42.0	0.0079433	0.99206	0.0080069	0.98424	0.015888
3.0	0.70795	0.29205	2.4240	0.17100	2.8385	42.5	0.0074989	0.99250	0.0075556	0.98511	0.015999
3.5	0.66834	0.33166	2.0152	0.19879	2.4158	44.0	0.0063096	0.99369	0.0063496	0.98746	0.012620
4.0	0.63096	0.36904	1.7097	0.22627	2.0966	45.0	0.0056234	0.99438	0.0056552	0.98882	0.011247
4.5	0.59566	0.40434	1.4732	0.25340	1.8465	47.5	0.0042170	0.99578	0.0042348	0.99160	0.0084341
5.0	0.56234	0.43766	1.2849	0.28013	1.6448	48.0	0.0039811	0.99602	0.0039970	0.99207	0.0079623
6.0	0.50119	0.49881	1.0048	0.33228	1.3386	50 0	0.0031623	0.99684	0.0031723	0.99370	0.0063246
7.0	0.44668	0.55332	0.80728	0.38247	1.1160	51.0	0.0028184	0.99718	0.0028264	0.99438	0.0056368
7.5	0.42170	0.57830	0.72920	0.40677	1.0258	52.0	0.0025119	0.99749	0 0015182	0.99499	0.0050238
8.0	0.39611	0.60189	0.66143	0.43051	0.94617	54.0	0.0019953	0.99800	0.0019993	0.99602	0.0039905
9.0	0.35481	0.64519	0.54994	0.47622	0.81183	55.0	0.0017783	0.99822	0.0017815	0.99645	0.0035566
10.0	0.31623	0.68377	0.46248	0.51949	0.70273	56.0	0.0015849	0.99842	0.0015874	0.99685	0.0031698
11.0	0.28184	0.71816	0.39244	0.56026	0.61231	57.0	0.0014125	0.99859	0.0014145	0.99718	0.0028251
12.0	0.25119	0.74881	0.33545	0.59848	0.53621	60.0	0.0010000	0.99900	0.00100100	0.99800	0.0020000
12.5	0.23714	0.76286	0.31085	0 61664	0.50253	64.0	0.00063096	0.99937	0.00063136	0.99874	0.0012619
13.0	0.22387	0.77613	0.28845	0.63416	0.47137	65.0	0.00056234	0.99944	0.00056266	0.99888	0.0011247
14.0	0.19953	0.80047	0.24926	0 66732	0.41560	66.0	0.00050119	0.99950	0.00050144	0.99900	0.0010024
15.0	0.17783	0.82217	0.21629	0.69804	0.36727	68.0	0.00039811	0.99960	0.00039827	0.99920	0.0007962
16.0	0.15849	0.84151	0.18834	0.72639	0.32515	70.0	0.00031623	0.99968	0.00031633	0.99937	0.0006325
17.0	0.14125	0.85875	0.16449	0.75246	0.28826	72.0	0.00025119	0.99975	0.00025125	0.99950	0.0005024
17.5	0.13335	0.86665	0.15387	0.76468	0.27153	75.0	0.00017783	0.99982	0 00017786	0.99964	0.0003557
18.0	0.12589	0.87411	0.14402	0.77637	0.25584	76.0	0.00015849	0.99984	0 00015851	0.99968	0.0003170
19.0	0.11220	0.88780	0.12638	0.79823	0.22726	78.0	0.00012589	0.99987	0.00012591	0.99975	0.0002518
20.0	0.100000	0.90000	0.111111	0.81818	0.20202	80.0	0.00010000	0.99990	0.00010000	0.99980	0.0002000
21.0	0.089125	0.91087	0.097846	0.83634	0.17968	84.0	0.00006310	0.99994	0.00006310	0.99987	0.0001262
22.0	0.079433	0.92057	0.086287	0.85282	0.15987	85.0	0.00005623	0.99995	0.00005624	0.99989	0.0001125
22.5	0.074989	0.92501	0.081069	0.86048	0.15083	90.0	0.00003162	0.99996	0.00003162	0.99994	0.00006325
24.0	0.063096	0.93690	0.067345	0.88130	0.12670	96.0	0.00001778	0.99997	0.00001778	0.99996	0.00003557
25.0	0.056234	0.94377	0.059585	0.89352	0.11283	98.0	0.00001585	0.99998	0.00001585	0.99997	0.00003170
26.0	0.050119	0.94988	0.052763	0.90455	0.10049	100.0	0.00001000	0.99999	0.00001000	0.99998	0.00002000

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Attenuator Networks

For Insertion Between Equal Impedances

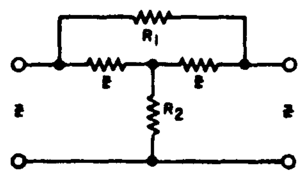
See table on page for values of A, B, C, D, E used in the following attenuator network formulas.



T

$R_1 = ZD$

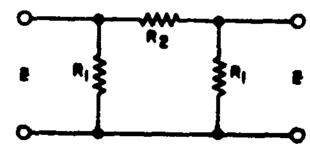
$R_2 = ZE$



Bridged T

$R_1 = \frac{Z}{C}$

$R_2 = ZC$

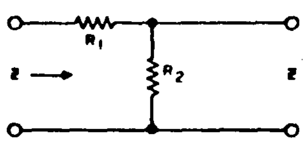


π

$R_1 = \frac{Z}{D}$

$R_2 = \frac{Z}{E}$

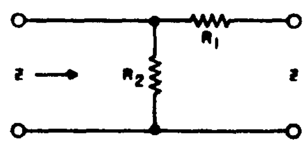
In the case of L and U networks where only the input or output can be matched, as required, the matched side is indicated by an arrow pointing toward the pad. On all other networks, both the input and output circuits are matched.



L

$R_1 = ZB$

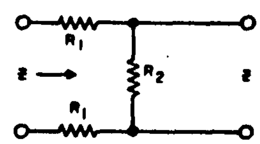
$R_2 = ZC$



L

$R_1 = \frac{Z}{C}$

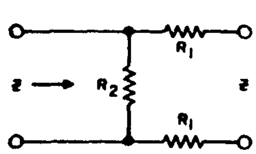
$R_2 = \frac{Z}{B}$



U

$R_1 = \frac{ZB}{2}$

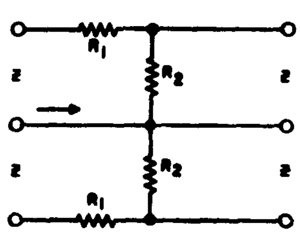
$R_2 = ZC$



U

$R_1 = \frac{Z}{2C}$

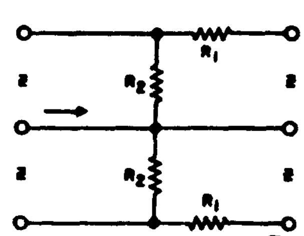
$R_2 = \frac{Z}{B}$



Balanced U

$R_1 = \frac{ZB}{2}$

$R_2 = \frac{ZC}{2}$



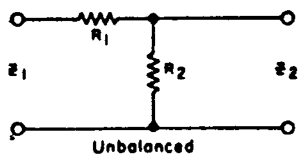
Balanced U

$R_1 = \frac{Z}{2C}$

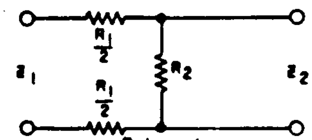
$R_2 = \frac{Z}{2B}$

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Minimum Loss Pads



Unbalanced



Balanced

For Matching Two Impedances where $Z_1 > Z_2$

$$R_1 = \sqrt{Z_1(Z_1 - Z_2)}$$

$$R_2 = \frac{Z_1 Z_2}{R_1}$$

$$db \text{ loss} = 20 \log_{10}\left(\sqrt{\frac{Z_1}{Z_2}} + \sqrt{\frac{Z_1}{Z_2} - 1}\right)$$

Where Only One Impedance is to be Matched

If the larger impedance only is to be matched, use a resistor R_L in series with the smaller impedance such that

$$R_L = Z_1 - Z_2$$

$$db \text{ loss} = 20 \log_{10}\sqrt{\frac{Z_1}{Z_2}}$$

If the smaller impedance only is to be matched, use a resistor R_S in shunt across the larger impedance such that

$$R_S = \frac{Z_1 Z_2}{Z_1 - Z_2}$$

Here also db loss $= 20 \log_{10}\sqrt{\frac{Z_1}{Z_2}}$

Tables of R_1 and R_2 Values

When Z_1 is 600 ohms
and Z_2 is less than 600 ohms.

Z_2	500	400	300	250	200	150	100	75	50	40	30	25
R_1	245	346	424	458	490	520	548	561	575	580	585	587
R_2	1,225	694	425	328	245	173	110	80.2	52.2	41.4	30.8	25.6
db Loss	3.8	5.7	7.6	8.7	10.0	11.4	13.4	14.8	16.6	17.6	18.9	19.7

When Z_2 is less than 25 ohms,

$$\text{let } R_1 = 600 - \frac{Z_1}{Z_2}$$
$$\text{and } R_2 = Z_2$$

Where Z_2 is 600 ohms,
and Z_1 is greater than 600 ohms.

Z_1	800	1,000	1,200	1,500	2,000	2,500	3,000	3,500	4,000	5,000	6,000	8,000	10,000
R_1	400	632	849	1,162	1,673	2,180	2,683	3,186	3,688	4,690	5,692	7,694	9,695
R_2	1,200	949	849	775	717	688	671	659	651	638	633	624	619
db Loss	4.8	6.5	7.6	9.0	10.5	11.6	12.5	13.3	13.9	15.0	15.8	17.1	18.1

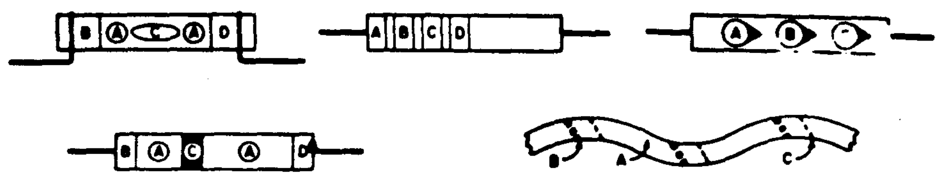
When Z_1 is greater than 10,000 ohms,

$$\text{let } R_1 = Z_1 - 300$$
$$\text{and } R_2 = 600$$

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Resistor Color Code

EIA STANDARD RS-172 **MILITARY STANDARD MIL-R-[illegible]**



Color	1st Digit A	2nd Digit B	Multiplier C	Tolerance D
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	—	—
Gold	—	—	0.1	± 5%
Silver	—	—	0.01*	± 10%
No Color	—	—	*EIA ONLY –	± 20%

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.

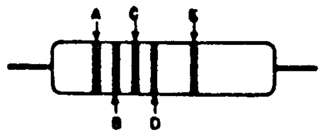
MILITARY (MIL): Same as EIA with the addition of Noninsulated resistors with radial leads designated by a black background color or by a background the same color as the first significant figure of the [illegible] value.

APPENDIX 2. MOST USED FORMULAS (CONT'D)

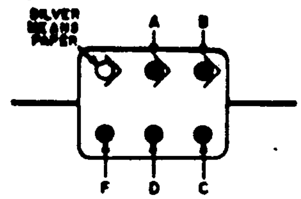
Paper Capacitor Color Code

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)



Tubular Capacitors
(Commercial Only)



Rectangular Capacitors

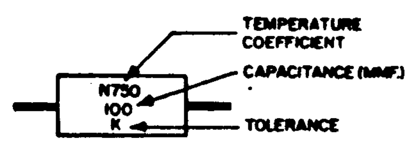
Color	Digits of Capacitance ($\mu\mu f$) A	Digits of Capacitance ($\mu\mu f$) B	Multiplier C	Tolerance % D	Tubular Voltage Rating (v d-c) E	Temp. Rating °C and Characteristic F
Black	0	0	1	± 20	—	85-A
Brown	1	1	10	—	100	85-E
Red	2	2	100	—	200	—
Orange	3	3	1,000	± 30	300	—
Yellow	4	4	10,000	—	400	—
Green	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 ($\mu\mu f$)	Voltage Rating (v d-c)
[illegible]	[illegible]	[illegible]	20	1000 2000–6000 10,000	400 200 120
[illegible]	[illegible]	[illegible]	22	2000–3000 6000–10,000 20,000	400 300 120
[illegible]	[illegible]	[illegible]	30	1000–2000 3000 6000–10,000 20,000	800 600 400 120
[illegible]	[illegible]	[illegible]	35	3000 6000–10,000 20,000	800 600 300
[illegible]	[illegible]	[illegible]	41	3000–6000 10,000 20,000 30,000	600 400 300 120
[illegible]	[illegible]	[illegible]	42	1000–6000 10,000–20,000 30,000 50,000 100,000	1000 600 400 300 120
[illegible]	[illegible]	[illegible]	43	10,000 20,000–30,000 50,000–100,000 200,000	1000 600 400 120

TYPOGRAPHICALLY MARKED TUBULAR CERAMICS

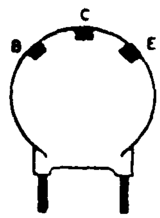


JAN LETTER	TOLERANCE 10 $\mu\mu f$ or Less	TOLERANCE Over 10 $\mu\mu f$
C	± 0.25 $\mu\mu f$	....
D	± 0.5 $\mu\mu f$	....
F	± 1.0 $\mu\mu f$	± 1%
G	± 2.0 $\mu\mu f$	± 2%
J	....	± 5%
K	....	± 10%
M	....	± 20%

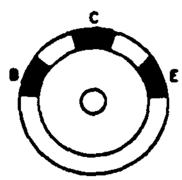
3/3/89

APPENDIX 2. MOST USED FORMULAS (CONT'D)

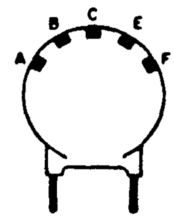
Ceramic Capacitor Color Code
EIA STANDARD RS-198
MILITARY STANDARD JAN-C-20A
Proposed Mil-C-20C



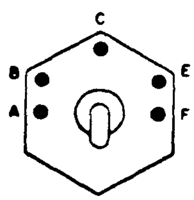
3-Dot Disc Capacitors
(RETMA ONLY)
(Voltage rating is always 500 v., tolerance is always —0.)



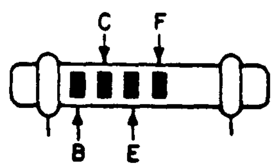
3-Dot Button Capacitors
(EIA ONLY)



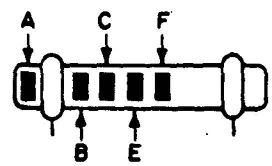
5-Dot Disc Capacitors
(EIA ONLY)
(Voltage rating is always 500 v.)



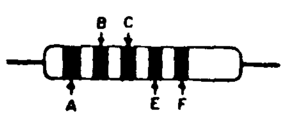
Feed Through Capacitors
(EIA ONLY)



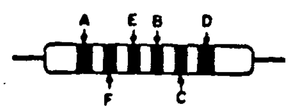
High Capacity Tubulars
(Insulated or Non-Insulated)



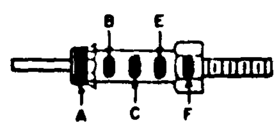
Temperature Compensating Tubulars



Tubular Capacitors
(Voltage rating is always 500 v.)



Tubular Capacitors
(Old RMA)



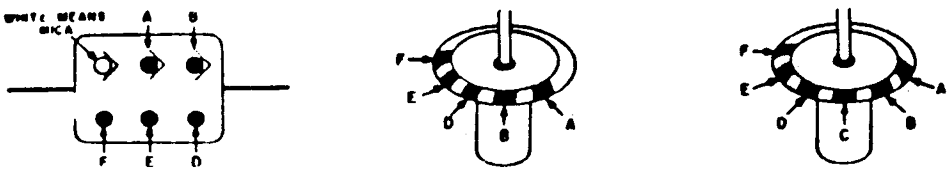
Stand-Off Capacitors
(EIA ONLY)

Color	Digits of Capacitance ($\mu\mu f$) B	C	D	Multiplier E	Tolerance F: 10 $\mu\mu f$ or less ($\mu\mu f$)	Tolerance F: Over 10 $\mu\mu f$ (%)	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	—	±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	+ 30
White	9	9	9	0.1	± 1.0	±10	+100 to —750	+330*
Gold	—	—	—	—	—	—	—	+100

*EIA only

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Mica Capacitor Color Code
EIA STANDARD RS-153



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

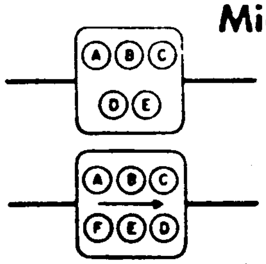
*or ± 1 μμf, whichever is greater.

DESCRIPTION OF CHARACTERISTIC

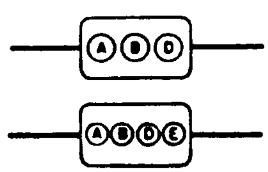
Characteristic	Temperature Coefficient (parts per million per °C)	Maximum Capacitance Drift	Minimum Insulation Resistance (megohms)
A	±1000	±(5% +1 μμf)	3000
B	±500	±(3% +1 μμf)	6000
C	±200	±(0.5% +0.5 μμf)	6000
D	±100	±(0.3% +0.1 μμf)	6000
E	+100 −20	±(0.1% +0.1 μμf)	6000
—	—	—	—
—	—	—	—

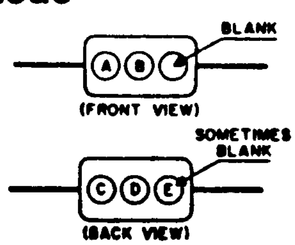
VOLTAGE RATING
(Indicated by dimensions rather than color coding)

Maximum Inches Long	Wide	Thick	Style	Capacitance (μμf)	Rating (v d-c)
[illegible]	[illegible]	[illegible]	20	5–510 560–1000	500 300
[illegible]	[illegible]	[illegible]	25	5–1000 1100–1500	500 300
[illegible]	[illegible]	[illegible]	30	470–6200 Over 6200	500 300
[illegible]	[illegible]	3/8	35	3300–6200 Over 6200	500 300
[illegible]	[illegible]	[illegible]	40	100–2400 2700–7500 Over 7500	1000 500 300



Mica Capacitor Color Code
Obsolete Style





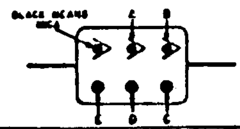
Dot Color	Digits of Capacitance (μμf) A	B	C	Multiplier D	Tolerance % E	Voltage Rating (v d-c) F
Black	0	0	0	1	± 20	—
Brown	1	1	1	10	± 1	100
Red	2	2	2	100	± 2	200
Orange	3	3	3	1,000	± 3	300
Yellow	4	4	4	10,000	± 4	400
Green	5	5	5	100,000	± 5	500
Blue	6	6	6	1,000,000	± 6	600
Violet	7	7	7	10,000,000	± 7	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

APPENDIX 2. MOST USED FORMULAS (CONT'D)

Mica Capacitor Color Code

MILITARY STANDARD

MIL-C-5B



Color	Digits of Capacitance (μμf) A	Digits of Capacitance (μμf) B	Multiplier C	Tolerance % D	Characteristic. See table below E
Black	0	0	1	± 20	—
Brown	1	1	10	—	B
Red	2	2	100	± 2	C
Orange	3	3	1,000	—	D
Yellow	4	4	—	—	E
Green	5	5	—	—	F
Blue	6	6	—	—	—
Violet	7	7	—	—	—
Gray	8	8	—	—	—
White	9	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

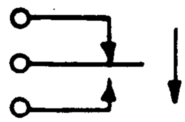
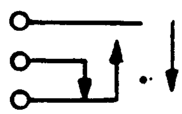
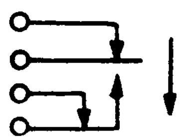
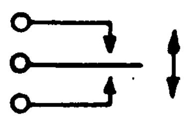
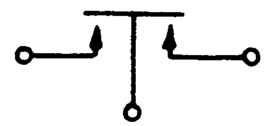
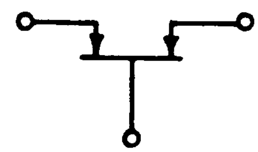
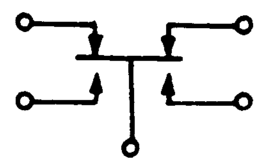
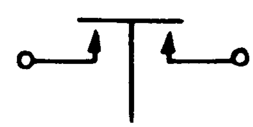
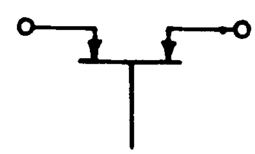
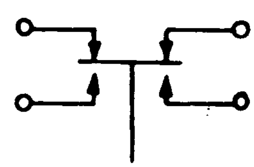
VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Inches Long	Maximum Inches Wide	Maximum Inches Thick	Style CM	Capacitance (μμf)	Rating (v d-c)
33/64	5/16	7/32	15	5–510	300
51/64	13/32	7/32	20	5–510 560–1000	500 300
1 7/64	13/32	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	49/64	11/32	40	3300–8200 9100–10,000	500 300

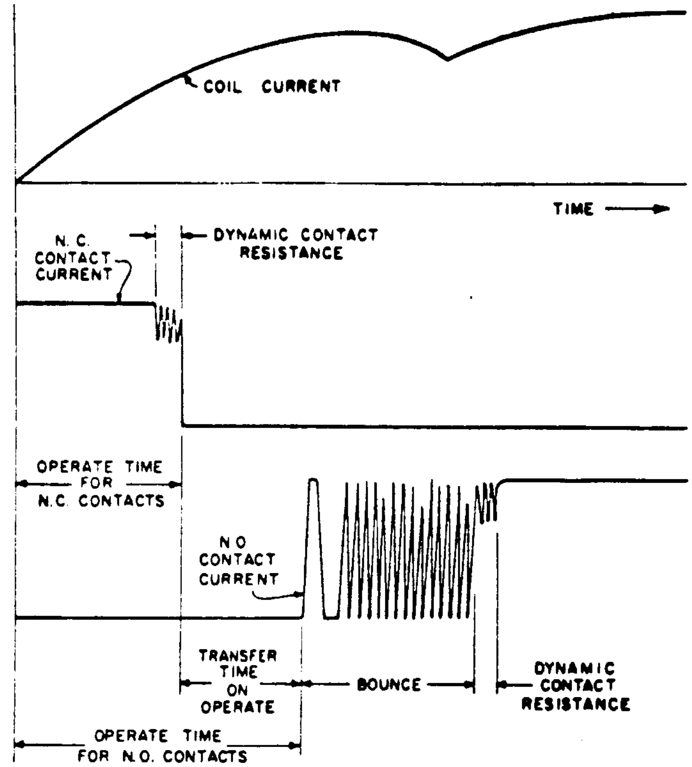
APPENDIX 2. MOST USED FORMULAS (CONT'D)

NOMENCLATURE FOR BASIC RELAY CONTACT FORMS

A	Make SPSTNO	
B	Break SPSTNO	
C	Break, make (transfer) SPDT	
D	Make before break (Mechanical continuity transfer -see definition, page 3)	
E	Break, make, break	
K	Single pole, double throw, center off. SPDTNO	
U	Double make, contact on arm	
V	Double break, contact on arm	
W	Double make double break contact on arm	
X	Double make SPSTNODB	
Y	Double break SPSTNCDB	
Z	Double make double break SPDTDB	

APPENDIX 2. MOST USED FORMULAS (CONT'D)

A typical oscillographic picture of contact performance on energization of a relay.



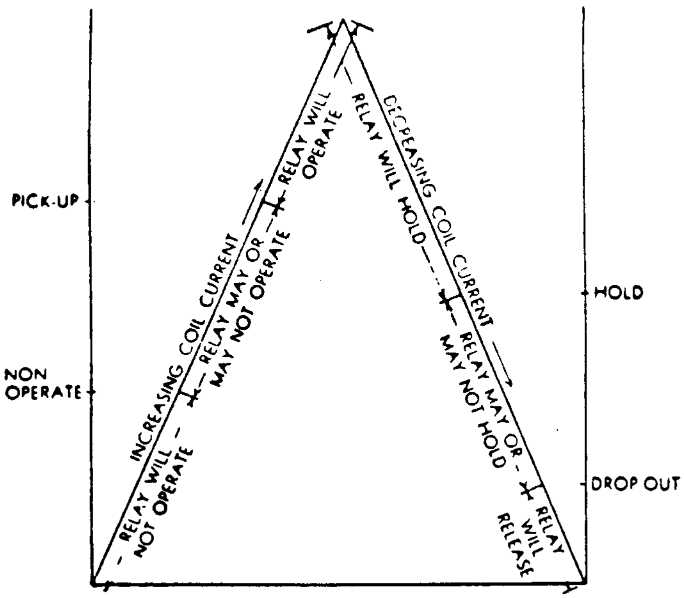
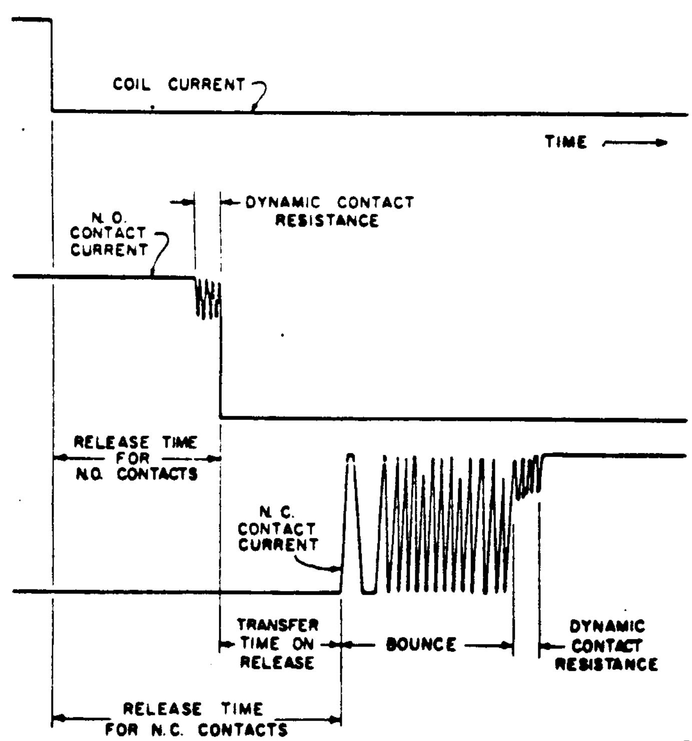


Illustration of the effect of Changing Coil Current

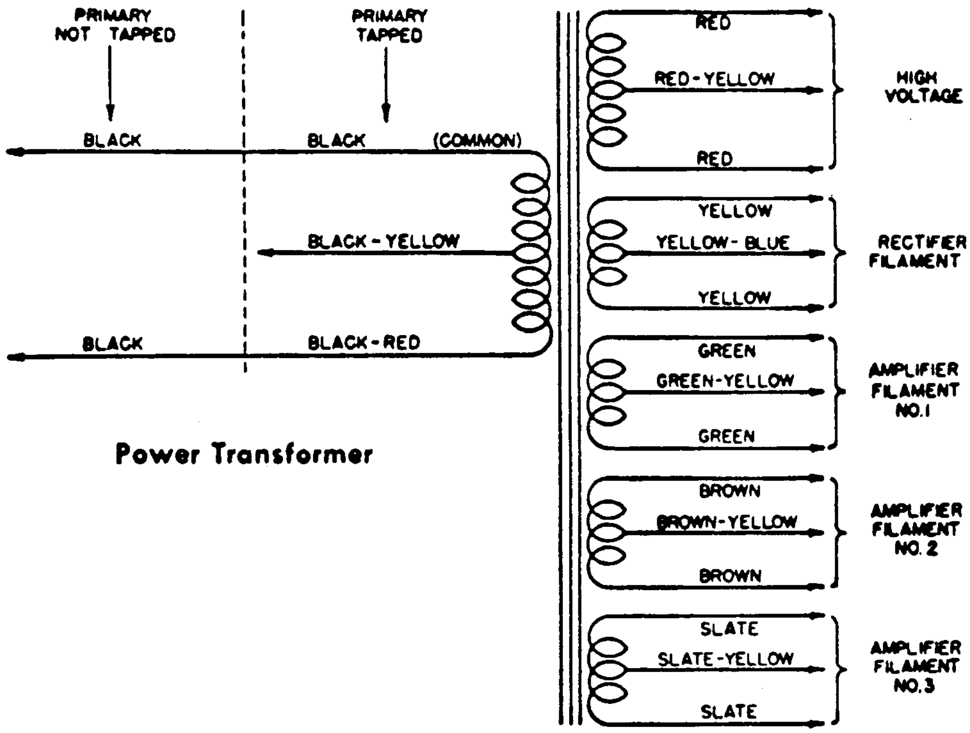


A typical oscillographic picture of contact performance on de-energization of a relay (zero coil current release).

APPENDIX 2. MOST USED FORMULAS (CONT'D)

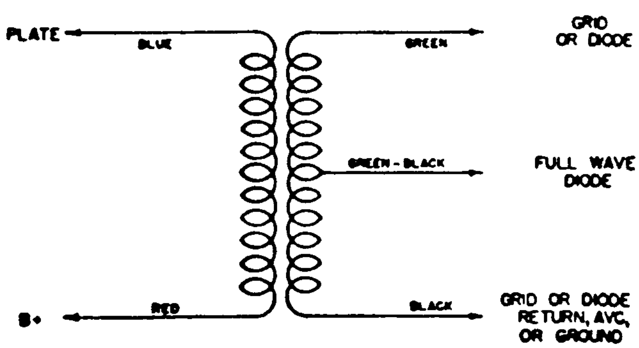
EIA COLOR CODES

The color codes shown here are used by most radio and instrument manufacturers in the wiring of their products, and by parts manufacturers for identifying lead placement. 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.

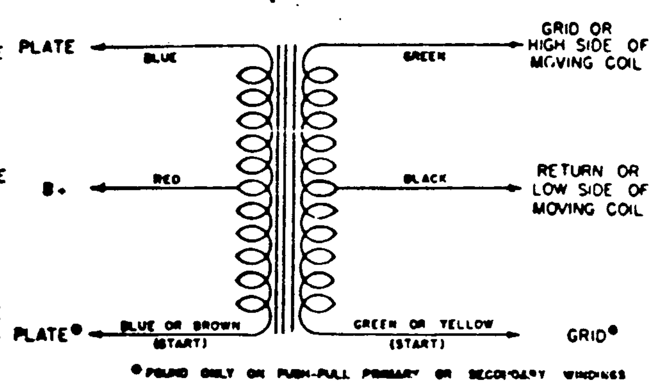


Power Transformer

I-F Transformers



Audio & Output Transformers



APPENDIX 2. MOST USED FORMULAS (CONT'D)

Crystal Frequencies for Transmitters and Receivers

TRANSMITTERS:

VHF TRANSMITTER (TYPE T1108):

$$\text{Crystal Frequency} = \frac{\text{Carrier Frequency}}{10}$$

Crystal Type = CRI8AU

UHF TRANSMITTER (TYPE T1109):

$$\text{Crystal Frequency} = \frac{\text{Carrier Frequency}}{20}$$

Crystal Type = CRI8AU

VHF RECEIVER (TYPE AN/GRR-23):

Crystal Frequency = Carrier Frequency + 20.6 MHz
10

Crystal Type = CRI8AU

UHF RECEIVER (TYPE AN/GRR-24):

FOR FREQUENCY RANGE 225 MHz TO 312 MHz:

$$\text{Crystal Frequency} = \frac{\text{Carrier Frequency} + 20.6\ \text{MHz}}{20}$$

FOR FREQUENCY RANGE 312 MHz TO 399 MHz:

$$\text{Crystal Frequency} = \frac{\text{Carrier Frequency} - 20.6\ \text{MHz}}{20}$$

Crystal Type = CRI8AU