ALLIED
ELECTRONICS DATA HANDBOOK

Written and Compiled by the
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ALLIED RADIO CORPORATION
Under the Direction of
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FOREWORD

Allied Radio Corporation has long recognized the need for a comprehensive and condensed handbook of formulas and data most commonly used in the field of radio and electronics. It was felt also that such a book should serve entirely as a convenient source of information and reference and that all attempts to teach or explain the basic principles involved should be left to classroom instruction and to the many already existing publications written for this distinct purpose.

The *Electronics Data Handbook*, therefore, consists of formulas, tables, charts and data. Every effort has been made to present this information clearly and to arrange it in a convenient manner for instant reference. All material was carefully selected and prepared by *Allied's* technical staff to serve the requirements of many specific groups in the radio and electronics field. It is hoped that our objectives have been successfully attained and that this *Handbook* will serve as: (1) A valuable adjunct to classroom study and laboratory work for the student and instructor; (2) A dependable source of information for the beginner, experimenter and set builder; (3) A reliable guide for the service engineer and maintenance man in his everyday work; (4) A time-saving and practical reference for the radio amateur, technician and engineer, both in the laboratory and in the field of operations.

The publishers are indebted to the McGraw-Hill Book Company, Inc., for their permission to use material selected from "*Basic Mathematics for Electronics*" by Nelson M. Cooke. *Allied* also takes this opportunity to thank those manufacturers who so generously permitted our use of current data prepared by their engineering personnel. Special recognition and our sincere appreciation are extended to Commander Cooke for his helpful suggestions and generous contribution of his time and specialized knowledge in editing the material contained in this book.

ALLIED RADIO CORPORATION

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Mathematical Symbols

$\times$ or $\cdot$	Multiplied by
$\div$ or :	Divided by
$+$	Positive. Plus. Add
$-$	Negative. Minus. Subtract
$\pm$	Positive or negative. Plus or minus
$\mp$	Negative or positive. Minus or plus
$=$ or ::	Equals
$\equiv$	Identity
$\cong$	Is approximately equal to
$\neq$	Does not equal
$>$	Is greater than
$\gg$	Is much greater than
$<$	Is less than
$\ll$	Is much less than
$\geqq$	Greater than or equal to
$\leqq$	Less than or equal to
$\therefore$	Therefore
$\angle$	Angle
Δ	Increment or Decrement
$\perp$	Perpendicular to
$\parallel$	Parallel to
$\lvert n \rvert$	Absolute value of n

Mathematical Constants

$\pi = 3.14$ $\quad\sqrt{\pi} = 1.77$

$2\pi = 6.28$ $\quad\sqrt{\frac{\pi}{2}} = 1.25$

$(2\pi)^2 = 39.5$ $\quad\sqrt{2} = 1.41$

$4\pi = 12.6$ $\quad\sqrt{3} = 1.73$

$\pi^2 = 9.87$ $\quad\frac{1}{\sqrt{2}} = 0.707$

$\frac{\pi}{2} = 1.57$ $\quad\frac{1}{\sqrt{3}} = 0.577$

$\frac{1}{\pi} = 0.318$ $\quad\log \pi = 0.497$

$\frac{1}{2\pi} = 0.159$ $\quad\log \frac{\pi}{2} = 0.196$

$\frac{1}{\pi^2} = 0.101$ $\quad\log \pi^2 = 0.994$

$\frac{1}{\sqrt{\pi}} = 0.564$ $\quad\log \sqrt{\pi} = 0.248$

Decimal Inches

Inches $\times$ 2.540 = Centimeters

Inches $\times 1.578 \times 10^{-5}$ = Miles

Inches $\times 10^3$ = Mils

Inches			Decimal Equivalent	Millimeter Equivalent
1/64			.0156	0.397
	1/32		.0313	0.794
3/64			.0469	1.191
		1/16	.0625	1.588
5/64			.0781	1.985
	3/32		.0938	2.381
7/64			.1094	2.778
		1/8	.1250	3.175
9/64			.1406	3.572
	5/32		.1563	3.969
11/64			.1719	4.366
		3/16	.1875	4.762
13/64			.2031	5.159
	7/32		.2188	5.556
15/64			.2344	5.953
		1/4	.2500	6.350
17/64			.2656	6.747
	9/32		.2813	7.144
19/64			.2969	7.541
		5/16	.3125	7.937
21/64			.3281	8.334
	11/32		.3438	8.731
23/64			.3594	9.128
		3/8	.3750	9.525
25/64			.3906	9.922
	13/32		.4063	10.319
27/64			.4219	10.716
		7/16	.4375	11.112
29/64			.4531	11.509
	15/32		.4688	11.906
31/64			.4844	12.303
		1/2	.5000	12.700
33/64			.5156	13.097
	17/32		.5313	13.494
35/64			.5469	13.891
		9/16	.5625	14.287
37/64			.5781	14.684
	19/32		.5938	15.081
39/64			.6094	15.478
		5/8	.6250	15.875
41/64			.6406	16.272
	21/32		.6563	16.669
43/64			.6719	17.067
		11/16	.6875	17.463
45/64			.7031	17.860
	23/32		.7188	18.238
47/64			.7344	18.635
		3/4	.7500	19.049
49/64			.7656	19.446
	25/32		.7813	19.842
51/64			.7969	20.239
		13/16	.8125	20.636
53/64			.8281	21.033
	27/32		.8438	21.430
55/64			.8594	21.827
		7/8	.8750	22.224
57/64			.8906	22.621
	29/32		.9063	23.018
59/64			.9219	23.415
		15/16	.9375	23.812
61/64			.9531	24.209
	31/32		.9688	24.606
63/64			.9844	25.004
		1.0	1.0000	25.400

Algebra

Exponents and Radicals

$$a^x \times a^y = a^{(x+y)}. \qquad \frac{a^x}{a^y} = a^{(x-y)}.$$

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

$$\sqrt[x]{\frac{a}{b}} = \frac{\sqrt[x]{a}}{\sqrt[x]{b}}. \qquad a^{-x} = \frac{1}{a^x}.$$

$$(a^x)^y = a^{xy}. \qquad \sqrt[x]{\sqrt[y]{a}} = \sqrt[xy]{a}.$$

$$\sqrt[x]{ab} = \sqrt[x]{a}\sqrt[x]{b}. \qquad a^{\frac{x}{y}} = \sqrt[y]{a^x}.$$

$$a^{\frac{1}{x}} = \sqrt[x]{a}. \qquad a^0 = 1.$$

Solution of a Quadratic

Quadratic equations in the form

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

may be solved by the following:

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

Transposition of Terms

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

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

$$B = \frac{AD}{C}, \quad C = \frac{AD}{B}, \quad D = \frac{BC}{A}$$

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

$$B = \frac{1}{D^2A^2C}, \quad C = \frac{1}{D^2A^2B}, \quad D = \frac{1}{A\sqrt{BC}}.$$

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

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

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,

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

DB Expressed in Watts & Volts

DB*	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 db = 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.

Decibel—Voltage, Current and Power Ratio Table

−			+		−			+	
Voltage or Current Ratio	Power Ratio	DB	Voltage or Current Ratio	Power Ratio	Voltage or Current Ratio	Power Ratio	DB	Voltage or Current Ratio	Power Ratio
1.0000	1.0000	**0**	1.000	1.000	.4898	.2399	**6.2**	2.042	4.169
.9886	.9772	**.1**	1.012	1.023	.4842	.2344	**6.3**	2.065	4.266
.9772	.9550	**.2**	1.023	1.047	.4786	.2291	**6.4**	2.089	4.365
.9661	.9333	**.3**	1.035	1.072	.4732	.2239	**6.5**	2.113	4.467
.9550	.9120	**.4**	1.047	1.096	.4677	.2188	**6.6**	2.138	4.571
.9441	.8913	**.5**	1.059	1.122	.4624	.2138	**6.7**	2.163	4.677
.9333	.8710	**.6**	1.072	1.148	.4571	.2089	**6.8**	2.188	4.786
.9226	.8511	**.7**	1.084	1.175	.4519	.2042	**6.9**	2.213	4.898
.9120	.8318	**.8**	1.096	1.202	.4467	.1995	**7.0**	2.239	5.012
.9016	.8128	**.9**	1.109	1.230	.4416	.1950	**7.1**	2.265	5.129
.8913	.7943	**1.0**	1.122	1.259	.4365	.1905	**7.2**	2.291	5.248
.8810	.7762	**1.1**	1.135	1.288	.4315	.1862	**7.3**	2.317	5.370
.8710	.7586	**1.2**	1.148	1.318	.4266	.1820	**7.4**	2.344	5.495
.8610	.7413	**1.3**	1.161	1.349	.4217	.1778	**7.5**	2.371	5.623
.8511	.7244	**1.4**	1.175	1.380	.4169	.1738	**7.6**	2.399	5,754
.8414	.7079	**1.5**	1.189	1.413	.4121	.1698	**7.7**	2.427	5.888
.8318	.6918	**1.6**	1.202	1.445	.4074	.1660	**7.8**	2.455	6.026
.8222	.6761	**1.7**	1.216	1.479	.4027	.1622	**7.9**	2.483	6.166
.8128	.6607	**1.8**	1.230	1.514	.3981	.1585	**8.0**	2.512	6.310
.8035	.6457	**1.9**	1.245	1.549	.3936	.1549	**8.1**	2.541	6.457
.7943	.6310	**2.0**	1.259	1.585	.3890	.1514	**8.2**	2.570	6.607
.7852	.6166	**2.1**	1.274	1.622	.3846	.1479	**8.3**	2.600	6.761
.7762	.6026	**2.2**	1.288	1.660	.3802	.1445	**8.4**	2.630	6.918
.7674	.5888	**2.3**	1.303	1.698	.3758	.1413	**8.5**	2.661	7.079
.7586	.5754	**2.4**	1.318	1.738	.3715	.1380	**8.6**	2.692	7.244
.7499	.5623	**2.5**	1.334	1.778	.3673	.1349	**8.7**	2.723	7.413
.7413	.5495	**2.6**	1.349	1.820	.3631	.1318	**8.8**	2.754	7.586
.7328	.5370	**2.7**	1.365	1.862	.3589	.1288	**8.9**	2.786	7.762
.7244	.5248	**2.8**	1.380	1.905	.3548	.1259	**9.0**	2.818	7.943
.7161	.5129	**2.9**	1.396	1.950	.3508	.1230	**9.1**	2.851	8.128
.7079	.5012	**3.0**	1.413	1.995	.3467	.1202	**9.2**	2.884	8.318
.6998	.4898	**3.1**	1.429	2.042	.3428	.1175	**9.3**	2.917	8.511
.6918	.4786	**3.2**	1.445	2.089	.3388	.1148	**9.4**	2.951	8.710
.6839	.4677	**3.3**	1.462	2.138	.3350	.1122	**9.5**	2.985	8.913
.6761	.4571	**3.4**	1.479	2.188	.3311	.1096	**9.6**	3.020	9.120
.6683	.4467	**3.5**	1.496	2.239	.3273	.1072	**9.7**	3.055	9.333
.6607	.4365	**3.6**	1.514	2.291	.3236	.1047	**9.8**	3.090	9.550
.6531	.4266	**3.7**	1.531	2.344	.3199	.1023	**9.9**	3.126	9.772
.6457	.4169	**3.8**	1.549	2.399	.3162	.1000	**10.0**	3.162	10.000
.6383	.4074	**3.9**	1.567	2.455	.2985	.08913	**10.5**	3.350	11.22
.6310	.3981	**4.0**	1.585	2.512	.2818	.07943	**11.0**	3.548	12.59
.6237	.3890	**4.1**	1.603	2.570	.2661	.07079	**11.5**	3.758	14.13
.6166	.3802	**4.2**	1.622	2.630	.2512	.06310	**12.0**	3.981	15.85
.6095	.3715	**4.3**	1.641	2.692	.2371	.05623	**12.5**	4.217	17.78
.6026	.3631	**4.4**	1.660	2.754	.2239	.05012	**13.0**	4.467	19.95
.5957	.3548	**4.5**	1.679	2.818	.2113	.04467	**13.5**	4.732	22.39
.5888	.3467	**4.6**	1.698	2.884	.1995	.03981	**14.0**	5.012	25.12
.5821	.3388	**4.7**	1.718	2.951	.1884	.03548	**14.5**	5.309	28.18
.5754	.3311	**4.8**	1.738	3.020	.1778	.03162	**15.0**	5.623	31.62
.5689	.3236	**4.9**	1.758	3.090	.1585	.02512	**16.0**	6.310	39.81
.5623	.3162	**5.0**	1.778	3.162	.1413	.01995	**17.0**	7.079	50.12
.5559	.3090	**5.1**	1.799	3.236	.1259	.01585	**18.0**	7.943	63.10
.5495	.3020	**5.2**	1.820	3.311	.1122	.01259	**19.0**	8.913	79.43
.5433	.2951	**5.3**	1.841	3.388	.1000	.01000	**20.0**	10.000	100.00
.5370	.2884	**5.4**	1.862	3.467	.03162	.00100	**30.0**	31.620	1,000.00
.5309	.2818	**5.5**	1.884	3.548	.01	.00010	**40.0**	100.00	10,000.00
.5248	.2754	**5.6**	1.905	3.631	.003162	.00001	**50.0**	316.20	10^5
.5188	.2692	**5.7**	1.928	3.715	.001	10^{-6}	**60.0**	1,000.00	10^6
.5129	.2630	**5.8**	1.950	3.802	.0003162	10^{-7}	**70.0**	3,162.00	10^7
.5070	.2570	**5.9**	1.972	3.890	.0001	10^{-8}	**80.0**	10,000.00	10^8
.5012	.2512	**6.0**	1.995	3.931	.00003162	10^{-9}	**90.0**	31,620.00	10^9
.4955	.2455	**6.1**	2.018	4.074	10^{-5}	10^{-10}	**100.0**	10^5	10^{10}

Table of Values for Attenuator Network Formulas

db	Voltage or Current Ratio	B	C	D	E	db	Voltage or Current Ratio	B	C	D	E
.1	.98855	.011447	86.360	.005756	86.857	**27.0**	.044668	.95533	.046757	.91448	.089515
.2	.97724	.022763	42.931	.011512	43.426	**27.5**	.042170	.95783	.044026	.91907	.084490
.25	.97163	.028372	34.247	.014390	34.739	**28.0**	.039811	.96019	.041461	.92343	.079748
.3	.96605	.034046	28.456	.017268	28.947	**30.0**	.031623	.96838	.032655	.93869	.063309
.4	.95499	.045008	21.219	.023022	21.707	**32.0**	.025119	.97488	.025766	.95099	.050269
.5	.94406	.055939	16.876	.028774	17.362	**32.5**	.023714	.97629	.024290	.95367	.047454
.6	.93325	.066745	13.982	.034525	14.428	**33.0**	.022387	.97761	.022900	.95621	.044797
.7	.92257	.077429	11.915	.040274	12.395	**34.0**	.019953	.98005	.020359	.96088	.039921
.75	.91728	.082724	11.088	.043147	11.567	**35.0**	.017783	.98222	.018105	.96506	.035577
.8	.91201	.087989	10.365	.046019	10.842	**36.0**	.015849	.98415	.016104	.96880	.031706
.9	.90157	.098429	9.1596	.051762	9.6337	**37.5**	.013335	.98666	.013515	.97368	.026675
1.0	.89125	.10875	8.1955	.057501	8.6667	**38.0**	.012589	.98741	.012750	.97513	.025183
1.5	.84140	.15860	5.3050	.086133	5.7619	**39.0**	.011220	.98878	.011348	.97781	.022443
2.0	.79433	.20567	3.8621	.11462	4.3048	**40.0**	.010000	.99000	.010101	.98020	.020002
2.5	.74989	.25011	2.9983	.14293	3.4268	**42.0**	.0079433	.99206	.0080069	.98424	.015888
3.0	.70795	.29205	2.4240	.17100	2.8385	**42.5**	.0074989	.99250	.0075556	.98511	.014999
3.5	.66834	.33166	2.0152	.19879	2.4158	**44.0**	.0063096	.99369	.0063496	.98746	.012620
4.0	.63096	.36904	1.7097	.22627	2.0966	**45.0**	.0056234	.99438	.0056552	.98882	.011247
4.5	.59566	.40434	1.4732	.25340	1.8465	**47.5**	.0042170	.99578	.0042348	.99160	.0084341
5.0	.56234	.43766	1.2849	.28013	1.6448	**48.0**	.0039811	.99602	.0039970	.99207	.0079623
6.0	.50119	.49881	1.0048	.33228	1.3386	**50.0**	.0031623	.99684	.0031723	.99370	.0063246
7.0	.44668	.55332	.80728	.38247	1.1160	**51.0**	.0028184	.99718	.0028264	.99438	.0056368
7.5	.42170	.57830	.72920	.40677	1.0258	**52.0**	.0025119	.99749	.0025182	.99499	.0050238
8.0	.39811	.60189	.66143	.43051	.94617	**54.0**	.0019953	.99800	.0019993	.99602	.0039905
9.0	.35481	.64519	.54994	.47622	.81183	**55.0**	.0017783	.99822	.0017815	.99645	.0035566
10.0	.31623	.68377	.46248	.51949	.70273	**56.0**	.0015849	.99842	.0015874	.99684	.0031698
11.0	.28184	.71816	.39244	.56026	.61231	**57.0**	.0014125	.99859	.0014145	.99718	.0028251
12.0	.25119	.74881	.33545	.59848	.53621	**60.0**	.0010000	.99900	.00100100	.99800	.0020000
12.5	.23714	.76286	.31085	.61664	.50253	**64.0**	.00063096	.99937	.00063136	.99874	.0012619
13.0	.22387	.77613	.28845	.63416	.47137	**65.0**	.00056234	.99944	.00056266	.99888	.0011247
14.0	.19953	.80047	.24926	.66732	.41560	**66.0**	.00050119	.99950	.00050144	.99900	.0010024
15.0	.17783	.82217	.21629	.69804	.36727	**68.0**	.00039811	.99960	.00039827	.99920	.0007962
16.0	.15849	.84151	.18834	.72639	.32515	**70.0**	.00031623	.99968	.00031633	.99937	.0006325
17.0	.14125	.85875	.16449	.75246	.28826	**72.0**	.00025119	.99975	.00025125	.99950	.0005024
17.5	.13335	.86665	.15387	.76468	.27153	**75.0**	.00017783	.99982	.00017786	.99964	.0003557
18.0	.12589	.87411	.14402	.77637	.25584	**76.0**	.00015849	.99984	.00015851	.99968	.0003170
19.0	.11220	.88780	.12638	.79823	.22726	**78.0**	.00012589	.99987	.00012591	.99975	.0002518
20.0	.100000	.90000	.111111	.81818	.20202	**80.0**	.00010000	.99990	.00010000	.99980	.0002000
21.0	.089125	.91087	.097846	.83634	.17968	**84.0**	.00006310	.99994	.00006310	.99987	.0001262
22.0	.079433	.92057	.086287	.85282	.15987	**85.0**	.00005623	.99994	.00005624	.99989	.0001125
22.5	.074989	.92501	.081069	.86048	.15083	**90.0**	.00003162	.99997	.00003162	.99994	.00006325
24.0	.063096	.93690	.067345	.88130	.12670	**95.0**	.00001778	.99998	.00001778	.99996	.00003557
25.0	.056234	.94377	.059585	.89352	.11283	**96.0**	.00001585	.99998	.00001585	.99997	.00003170
26.0	.050119	.94988	.052763	.90455	.10049	**100.0**	.00001000	.99999	.00001000	.99998	.00002000

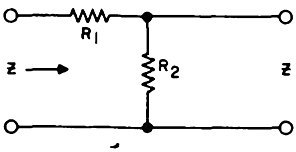
Attenuator Networks

For Insertion Between Equal Impedances

For data covering networks between unequal impedances, see Minimum Loss Pads on page 10. See also Decibel—Voltage Current and Power Ratio Table on page 6.

See table on page 7 for values of A, B, C, D, E used in the following attenuator network formulas.

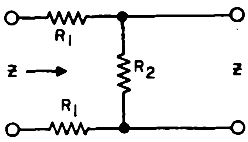
In the case of L and U networks where only the input or output can be matched, as required, the matched side is indicated by an arrow pointing toward the pad. On all other networks, both the input and output circuits are matched.



$$R_1 = ZB$$

$$R_2 = ZC$$

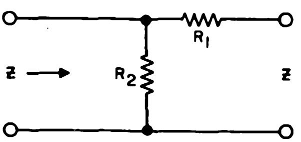
L



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

$$R_2 = ZC$$

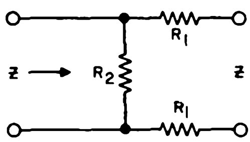
U



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

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

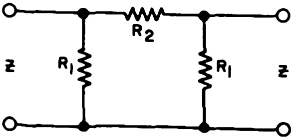
L



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

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

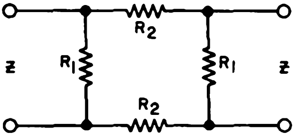
U



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

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

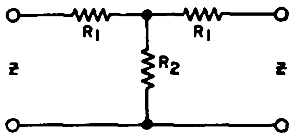
π



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

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

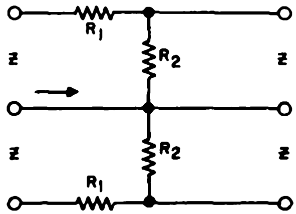
O



T

$R_1 = ZD$

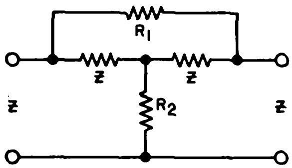
$R_2 = ZE$



Balanced U

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

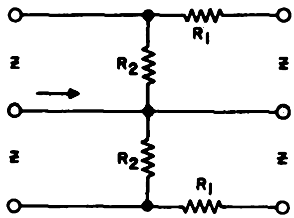
$$R_2 = \frac{ZC}{2}$$



Bridged T

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

$$R_2 = ZC$$



Balanced U

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

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

Constant Impedance Attenuators in Parallel

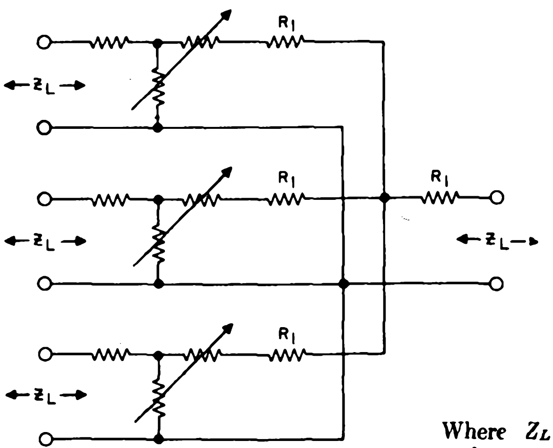


Table of R_1 Values in Ohms

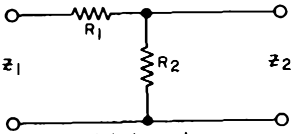
Z	Number of Channels				
	2	3	4	5	6
30	10	15	18	20	21.5
50	16.6	25	30	33.3	35.7
150	50	75	90	100	107
200	66.6	100	120	133	143
250	83.3	125	150	166	179
500	166	250	300	333	357
600	200	300	360	400	428
Network db Loss	6	9.5	12	14	15.5

$$R_1 = Z_L\left(\frac{N-1}{N+1}\right)$$

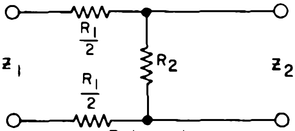
Insertion loss in $db = 20 \log_{10} N$

Where Z_L = identical line and load impedances;
and N = number of channels in parallel.

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,

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

70-Volt Loud-Speaker Matching Systems

The EIA 70.7 volt constant voltage system of power distribution provides the engineer and technician with a simple means of matching a number of loudspeakers to an amplifier. To use this method:

1. Determine the power required at each loudspeaker.
2. Add the powers required for the individual speakers and select an amplifier with a rated power output equal to or greater than this total.
3. Select 70.7-volt transformers having primary wattage taps as determined in step 1.*
4. Wire the selected primaries in parallel across the 70.7-volt line.
5. Connect each secondary to its speaker; selecting the tap which matches the voice coil impedance.

For transformers rated in impedance, the following formulas may be used to determine the proper taps in step 3.

$$\text{Primary Impedance} = \frac{(\text{Amplifier output voltage})^2}{\text{Desired speaker power}}$$

or

$$Z = \frac{E^2}{P} \qquad (1)$$

*These transformers have the primary taps marked in watts and the secondaries marked in ohms.

Since the voltage at rated amplifier power is 70.7, this reduces to:

$$Z = \frac{70.7^2}{P} = \frac{5000}{P} \qquad (2)$$

From formula (2) these relationships are:

1 watt requires 5000 ohm primary
2 watts requires 2500 ohm primary
5 watts requires 1000 ohm primary
10 watts requires 500 ohm primary

Once the primary taps have been determined, continue on through step 4 and 5 as outlined above. When selecting transformer primary taps, use the next highest available value above the computed value. A mismatch of 25% is generally considered permissible.

Example: Required

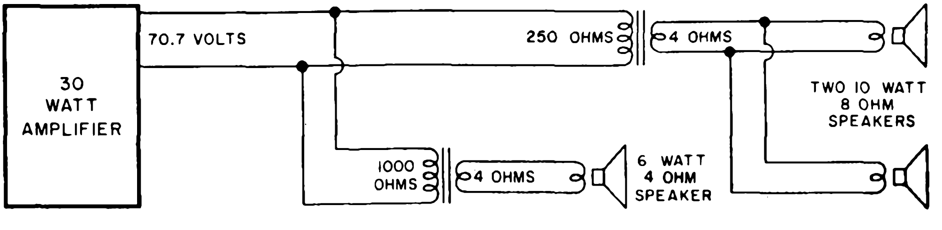
One 6 watt speaker with 4 ohm voice coil.
Two 10 watt speakers with 8 ohm voice coils (use one transformer at this location).

(1-2) Total power = 6 + 10 + 10 = 26 watts (use a 30-watt amplifier or other amplifier capable of handling at least 26 watts)

(3) $Z_{6\ \text{watts}} = \frac{5000}{6} = 833$ ohms (use 1000 ohm transformer)

$Z_{20\ \text{watts}} = \frac{5000}{20} = 250$ ohms

(4-5) See sketch below.



Most Used Formulas

Resistance Formulas

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

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

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

Capacitance

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

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

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

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 $L_t = \dfrac{1}{\dfrac{1}{L_1} + \dfrac{1}{L_2} + \dfrac{1}{L_3} \ldots \text{etc.}}$

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

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*

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

In parallel with fields *opposing*

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

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,
2π = 6.28
$4\pi^2$ = 39.5

Reactance

of an inductance is expressed by

$$X_L = 2\pi f L$$

of a capacitance is expressed by

$$X_C = \frac{1}{2\pi f C}$$

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,
2π = 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 . . .

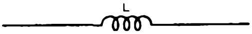
of resistance alone

$$Z = R$$

$$\theta = 0°$$

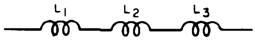
of resistance in series

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



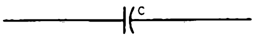
of inductance alone

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



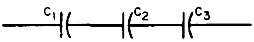
of inductance in series

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



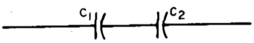
of capacitance alone

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



of capacitance in series

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

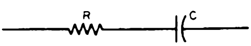


or where only 2 capacitances C_1 and C_2 are involved,

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

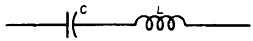
of resistance and inductance in series

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



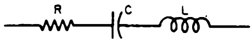
of resistance and capacitance in series

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



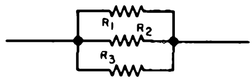
of inductance and capacitance in series

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



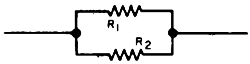
of resistance, inductance and capacitance in series

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



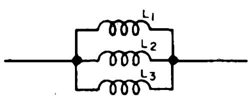
of resistance in parallel

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



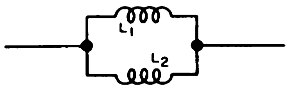
or where only 2 resistances R_1 and R_2 are involved,

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



of inductance in parallel

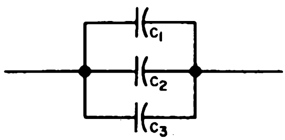
$$Z = \cfrac{1}{\cfrac{1}{X_{L1}} + \cfrac{1}{X_{L2}} + \cfrac{1}{X_{L3}} \ldots \text{etc.}}$$
$$\theta = +90^\circ$$



or where only 2 inductances L_1 and L_2 are involved,

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

$$\theta = +90°$$



of capacitance in parallel

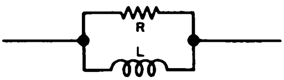
$$Z = \cfrac{1}{\cfrac{1}{X_{C1}} + \cfrac{1}{X_{C2}} + \cfrac{1}{X_{C3}} \ldots \text{etc.}}$$

$$\theta = -90°$$

or where only 2 capacitances C_1 and C_2 are involved,

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

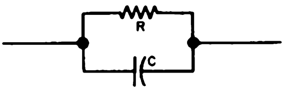
$$\theta = -90°$$



of inductance and resistance in parallel,

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

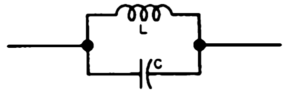
$$\theta = \text{arc tan}\,\frac{R}{X_L}$$



of capacitance and resistance in parallel,

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

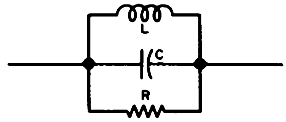
$$\theta = -\,\text{arc tan}\,\frac{R}{X_C}$$



of inductance and capacitance in parallel,

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

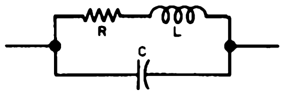
$$\theta = 0° \text{ when } X_L = X_C$$



of inductance, resistance and capacitance in parallel

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

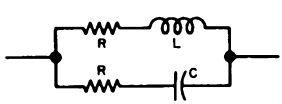
$$\theta = \text{arc tan}\,\frac{RX_C - RX_L}{X_L X_C}$$



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.

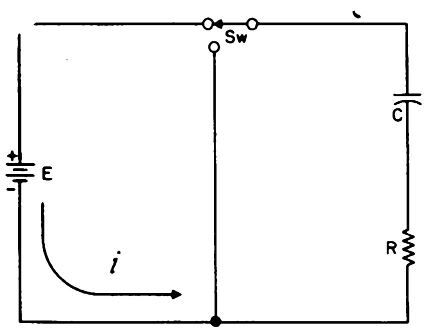
Transient *I* and *E* in *LCR* Circuits

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

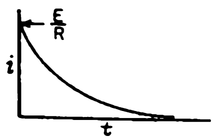
The time constant is defined as the time in seconds for current or voltage to fall to $\frac{1}{\epsilon}$ or 36.8% of its initial value or to rise to $\left(1-\frac{1}{\epsilon}\right)$ or approximately 63.2% of its final value.

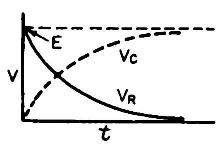
Charging a De-energized Capacitive Circuit



E = applied potential.

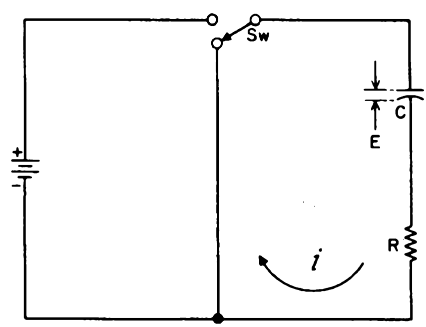
$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$





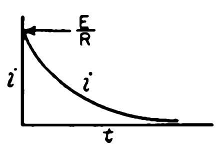
$$V_C = E\left(1 - \epsilon^{-\frac{t}{RC}}\right) \qquad V_R = E\,\epsilon^{-\frac{t}{RC}}$$

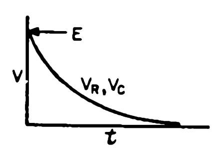
Discharging an Energized Capacitive Circuit



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

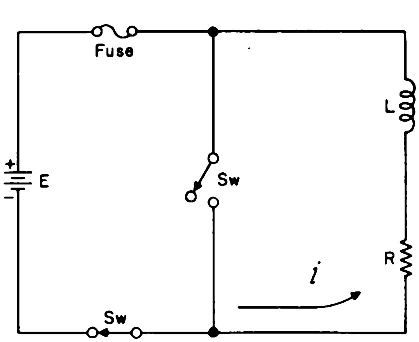
$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$





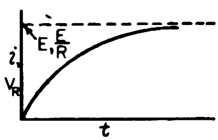
$$V_C = V_R = E\,\epsilon^{-\frac{t}{RC}}$$

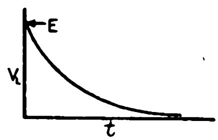
Voltage is Applied to a De-energized Inductive Circuit



E = applied potential

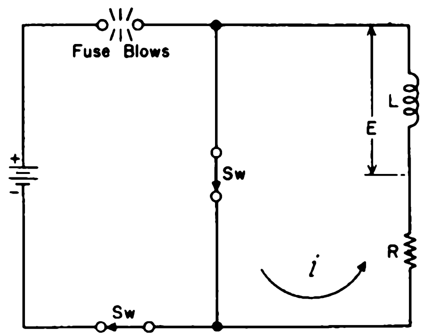
$$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{Rt}{L}}\right)$$





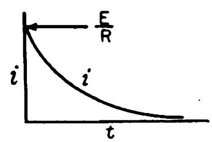
$$V_R = E\left(1 - \epsilon^{-\frac{Rt}{L}}\right) \qquad V_L = E\epsilon^{-\frac{Rt}{L}}$$

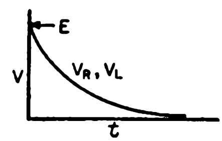
An Energized Inductive Circuit is Short Circuited



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

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





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

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.

Transmission Line Formulas

Concentric Transmission Lines

Characteristic impedance in ohms is given by

$$Z = 138 \log \frac{d_1}{d_2}$$

R-f resistance in ohms per foot of copper line, is given by

$$r = \sqrt{f}\left(\frac{1}{d_1} + \frac{1}{d_2}\right) \times 10^{-3}$$

Attenuation in decibels per foot of line, is given by

$$a = \frac{4.6\sqrt{f}\,(d_1 + d_2)}{d_1 d_2\left(\log \frac{d_1}{d_2}\right)} \times 10^{-6}$$

where Z = characteristic impedance in ohms,

r = radio frequency resistance in ohms per foot of *copper line,*

a = attenuation in decibels per foot of *line,*

d_1 = the *inside* diameter of the *outer conductor,* expressed in inches,

d_2 = the *outside* diameter of the *inner conductor,* expressed in inches,

f = frequency in megacycles.

Two-Wire Open Air Transmission Lines

Characteristic impedance in ohms is given by

$$Z = 276\left(\log \frac{2D}{d}\right)$$

Inductance in microhenrys per foot of *line* is given by

$$L = 0.281\left(\log \frac{2D}{d}\right)$$

Capacitance in micromicrofarads per foot of *line* is given by

$$C = \frac{3.68}{\log \frac{2D}{d}}$$

Attenuation in decibels per foot of *wire* is given by

$$db = \frac{0.0157\ R_f}{\log \frac{2D}{d}}$$

R-f resistance in Ohms per loop-foot of *wire,* is given by

$$R_f = \frac{2 \times 10^{-3}\sqrt{f}}{d}$$

where Z = characteristic impedance in ohms,

D = spacing between wire centers in inches,

d = the diameter of the conductors in inches,

L = inductance in microhenrys per foot of *line,*

C = capacitance in micromicrofarads per foot of *line,*

db = attenuation in decibels per foot of *wire,*

R_f = *r-f* resistance in ohms per loop-foot of *wire,*

f = frequency in megacycles.

Vertical Antenna

The capacitance of a vertical antenna, shorter than one-quarter wave length at its operating frequency, is given by

$$C_a = \frac{17l}{\left[\left(\log_\epsilon \frac{24l}{d}\right) - 1\right]\left[1 - \left(\frac{fl}{246}\right)^2\right]}$$

where C_a = capacitance of the antenna in micromicrofarads,

l = height of antenna in feet,

d = diameter of antenna conductor in inches,

f = operating frequency in megacycles,

ϵ = 2.718 (the base of the natural system of logarithms).

Trigonometric Relationships

In any right triangle, if we let

θ = the acute angle formed by the hypotenuse and the base leg,
ϕ = the acute angle formed by the hypotenuse and the altitude leg,
H = the hypotenuse,
A = the side adjacent θ and opposite ϕ,
O = the side opposite θ and adjacent ϕ,

then

$$\text{sine of } \theta = \sin\theta = \frac{O}{H}$$

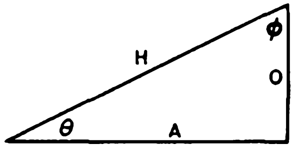
$$\text{cosine of } \theta = \cos\theta = \frac{A}{H}$$

$$\text{tangent of } \theta = \tan\theta = \frac{O}{A}$$

$$\text{cosecant of } \theta = \csc\theta = \frac{H}{O}$$

$$\text{secant of } \theta = \sec\theta = \frac{H}{A}$$

$$\text{cotangent of } \theta = \cot\theta = \frac{A}{O}$$



also

$$\sin\theta = \cos\phi \qquad \csc\theta = \sec\phi$$
$$\cos\theta = \sin\phi \qquad \sec\theta = \csc\phi$$
$$\tan\theta = \cot\phi \qquad \cot\theta = \tan\phi$$

and

$$\frac{1}{\sin\theta} = \csc\theta \qquad \frac{1}{\csc\theta} = \sin\theta$$
$$\frac{1}{\cos\theta} = \sec\theta \qquad \frac{1}{\sec\theta} = \cos\theta$$
$$\frac{1}{\tan\theta} = \cot\theta \qquad \frac{1}{\cot\theta} = \tan\theta$$

The expression "arc sin" indicates, "the angle whose sine is" . . .; likewise arc tan indicates, "the angle whose tangent is" . . . etc. See formulas in table below.

Known Values	Formulas for Determining Unknown Values of . . .				
	A	O	H	θ	ϕ
A & O			$\sqrt{A^2 + O^2}$	arc tan $\frac{O}{A}$	arc tan $\frac{A}{O}$
A & H		$\sqrt{H^2 - A^2}$		arc cos $\frac{A}{H}$	arc sin $\frac{A}{H}$
A & θ		$A \tan\theta$	$\frac{A}{\cos\theta}$		$90° - \theta$
A & ϕ		$\frac{A}{\tan\phi}$	$\frac{A}{\sin\phi}$	$90° - \phi$	
O & H	$\sqrt{H^2 - O^2}$			arc sin $\frac{O}{H}$	arc cos $\frac{O}{H}$
O & θ	$\frac{O}{\tan\theta}$		$\frac{O}{\sin\theta}$		$90° - \theta$
O & ϕ	$O \tan\phi$		$\frac{O}{\cos\phi}$	$90° - \phi$	
H & θ	$H \cos\theta$	$H \sin\theta$			$90° - \theta$
H & ϕ	$H \sin\phi$	$H \cos\phi$		$90° - \phi$	

Vacuum Tube Formulas and Symbols

Vacuum Tube Constants

Amplication 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).

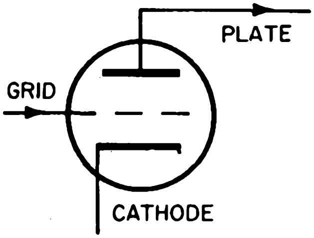
Peak, R.M.S., and Average A-C Values of *E* & *I*

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.	

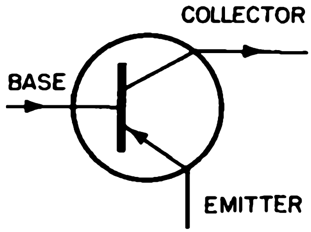
Transistor Formulas and Symbols

Common Emitter Configuration

Transistors can be made to amplify, detect, or to oscillate in much the same manner as vacuum tubes. Shown in the drawings below is a comparison between a triode vacuum-tube and a PNP transistor; where the transistor



Triode Vacuum Tube



PNP Transistor

base is comparable to the tube grid, the transistor emitter is comparable to the tube cathode, and the transistor collector is comparable to the tube plate.

Transistor Formulas

Input Resistance,

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

Current Gain,

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

Voltage Gain,

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

Output Resistance,

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

Power Gain,

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

The current gain of the common base configuration is alpha, where

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

The current gain of the common emitter is beta, where

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

Transistor Symbols

α = Current gain common base
A_e (A_v) = Voltage gain
A_i = Current gain
A = Power gain
B = Current gain common emitter
I_b = Base current
I_c = Collector current
I_e = Emitter current
I_i = Input current
P_i = Input power
P_o = Output power
R_i = Input resistance
R_o = Output resistance
V_b = Base voltage
V_c = Collector voltage
V_i = Input voltage

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

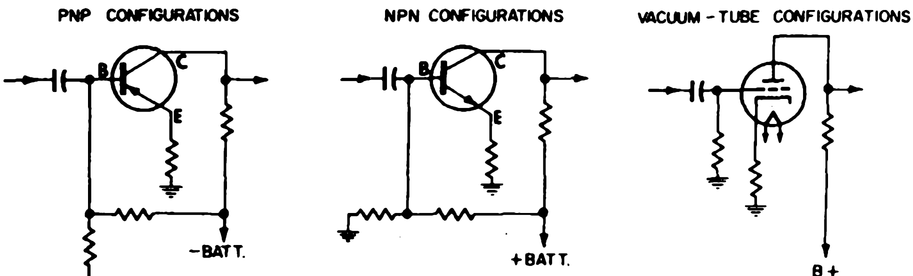
$$\alpha = \frac{B}{1 + B} \qquad B = \frac{\alpha}{1 - \alpha}$$

Courtesy Howard W. Sam's Photofact Publication: "ABC's of Transistors."

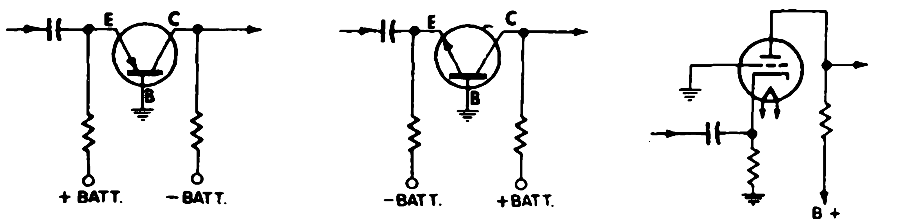
Transistor Amplifier Circuit Configurations

With Vacuum & Tube Counterparts

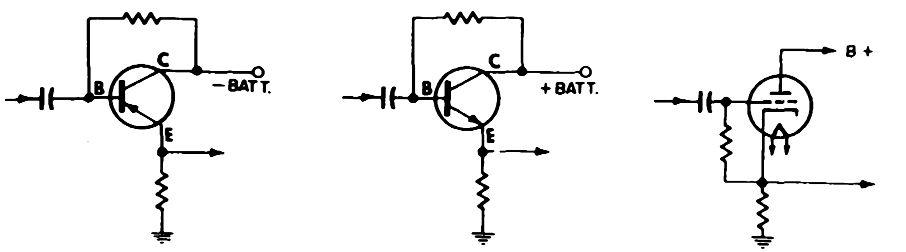
The transistors of primary interest to the radio engineer and service technician are the PNP and NPN junction types, whose transistor actions are identically alike, except that symbolically, the emitter arrow points towards the base in the PNP and away from the base in the NPN. The common-emitter circuits are used almost exclusively for most amplification purposes as are the common or grounded-cathode vacuum tube circuits. The common-base and common-grid as well as common-collector common-plate circuits are used more for special applications such as impedance matching to and from audio transmission lines, etc.



Common emitter–Common cathode.



Common base–Common grid.



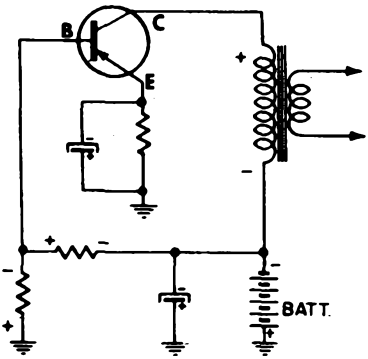
Common collector–Common plate.

Common-Emitter Amplifier Circuits

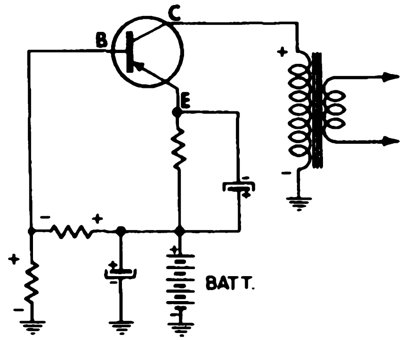
Using Transistors Only

In comparing the PNP and NPN circuits shown here, note that the current flow in the components of one is completely reversed in the other. With the vacuum tube, this complete interchange of current and voltage polarities does not exist. Because of this interchange in the transistor, circuits which have no parallel in vacuum-tube circuitry can be produced. Nevertheless, the circuits of transistorized equipment are still quite similar in many respects to those of equipment employing vacuum tubes.

Using PNP Transistors

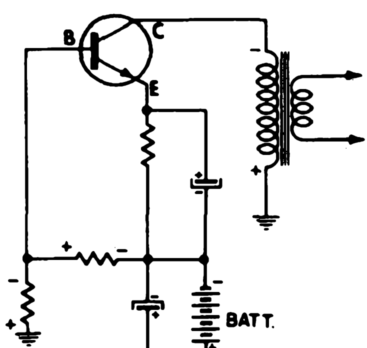


With Positive
Battery Terminal Grounded

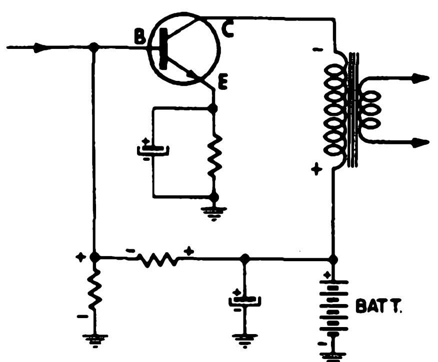


With Negative
Battery Terminal Grounded

Using NPN Transistors



With Positive
Battery Terminal Grounded

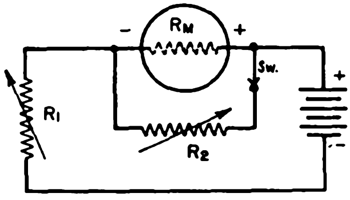


With Negative
Battery Terminal Grounded

D-C Meter Formulas

Meter Resistance

The d-c resistance of a milliammeter or voltmeter movement may be determined as follows:



1. Connect the meter in series with a suitable battery and variable resistance R_1 as shown in the diagram above.

2. Vary R_1 until a full scale reading is obtained.

3. Connect another variable resistor R_2 across the meter and vary its value until a half scale reading is obtained.

4. Disconnect R_2 from the circuit and measure its d-c resistance.

The meter resistance R_m is equal to the measured resistance of R_2.

Caution: Be sure that R_1 has sufficient resistance to prevent an off scale reading of the meter. The correct value depends upon the sensitivity of meter, and voltage of the battery. The following formula can be used if the full scale current of the meter is known:

$$R_1 = \frac{\text{voltage of the battery used}}{\text{full scale current of meter in amperes}}$$

For safe results, use twice the value computed. Also, never attempt to measure the resistance of a meter with an ohmmeter. To do so would in all probability result in a burned-out or severely damaged meter, since the current required for the operation of some ohmmeters and bridges is far in excess of the full scale current required by the movement of the average meter you may be checking.

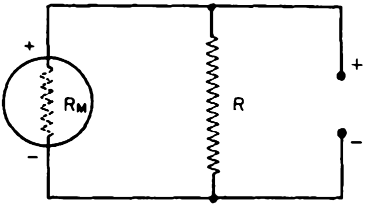
Ohms per Volt Rating of a Voltmeter

$$\Omega/V = \frac{1}{I_{fs}}$$

where Ω/V = ohms per volt,

I_{fs} = full scale current in amperes.

Fixed Current Shunts



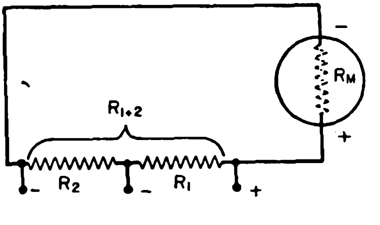
$$R = \frac{R_m}{N - 1}$$

R = shunt value in ohms,

N = the new full scale reading divided by the original full scale reading, both being stated in the same units,

R_m = meter resistance in ohms.

Multi-Range Shunts



$$R_1 = \frac{R_{1+2} + R_m}{N}$$

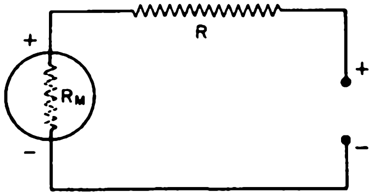
R_1 = intermediate or tapped shunt value in ohms,

R_{1+2} = total resistance required for the lowest scale reading wanted,

R_m = meter resistance in ohms,

N = the new full scale reading divided by the original full scale reading, both being stated in the same units.

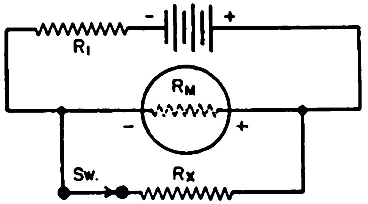
Voltage Multipliers



$$R = \frac{E_{fs}}{I_{fs}} - R_m$$

R = multiplier resistance in ohms,
E_{fs} = full scale reading required in volts,
I_{fs} = full scale current of meter in amperes,
R_m = meter resistance in ohms.

Measuring Resistance



with Milliammeter and Battery*

$$R_x = R_m \left(\frac{I_2}{I_1 - I_2}\right)$$

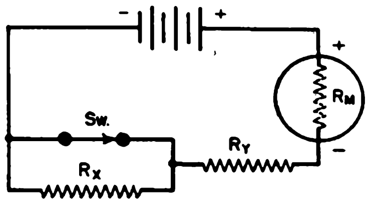
R_x = unknown resistance in ohms,
R_m = meter resistance in ohms, or effective meter resistance if a shunted range is used,
I_1 = current reading with switch open,
I_2 = current reading with switch closed,
R_1 = current limiting resistor of sufficient value to keep meter reading on scale when switch is open.

* Approximately true only when current limiting resistor is large as compared to meter resistance.

Shunt Values for 27-Ohm 0-1 Milliammeter

FULL SCALE CURRENT	SHUNT RESISTANCE
0-10 ma	3.0 ohms
0-50 ma	0.551 ohms
0-100 ma	0.272 ohms
0-500 ma	0.0541 ohms

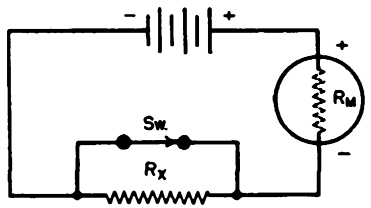
Measuring Resistance—(Continued)



with Milliammeter, Battery and Known Resistor

$$R_x = \left(R_y + R_m\right)\left(\frac{I_1 - I_2}{I_2}\right)$$

R_x = unknown resistance in ohms,
R_y = known resistance in ohms,
R_m = meter resistance in ohms,
I_1 = current reading with switch closed,
I_2 = current reading with switch open.



with Voltmeter and Battery

$$R_x = R_m \left(\frac{E_1}{E_2} - 1\right)$$

R_x = unknown resistance in ohms,
R_m = meter resistance in ohms, including multiplier resistance if a multiplied range is used,
E_1 = voltmeter reading with switch closed,
E_2 = voltmeter reading with switch open.

Multiplier Values for 27-Ohm 0-1 Milliammeter

FULL SCALE VOLTAGE	MULTIPLIER RESISTANCE
0-10 volts	10,000 ohms
0-50 volts	50,000 ohms
0-100 volts	100,000 ohms
0-250 volts	250,000 ohms
0-500 volts	500,000 ohms
0-1,000 volts	1,000,000 ohms

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

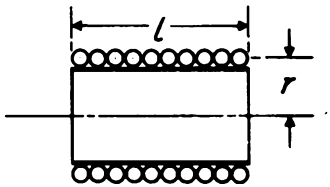
Gauge (AWG) or (B&S)	Number of Turns per Linear Inch			
	Enamel	S.S.C.	D.S.C. and S.C.C.	D.C.C.
1	—	—	3.3	3.3
2	—	—	3.8	3.6
3	—	—	4.2	4.0
4	—	—	4.7	4.5
5	—	—	5.2	5.0
6	—	—	5.9	5.6
7	—	—	6.5	6.2
8	7.6	—	7.4	7.1
9	8.6	—	8.2	7.8
10	9.6	—	9.3	8.9
11	10.7	—	10.3	9.8
12	12.0	—	11.5	10.9
13	13.5	—	12.8	12.0
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.

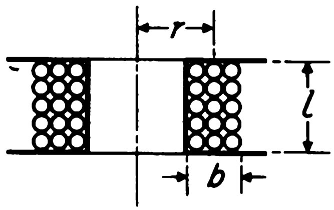
Single-Layer Wound Coils



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

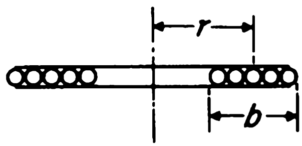
$$N = \frac{\sqrt{L(9r + 10l)}}{r}$$

Multi-Layer Wound Coils



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

Single-Layer Spiral Wound Coils



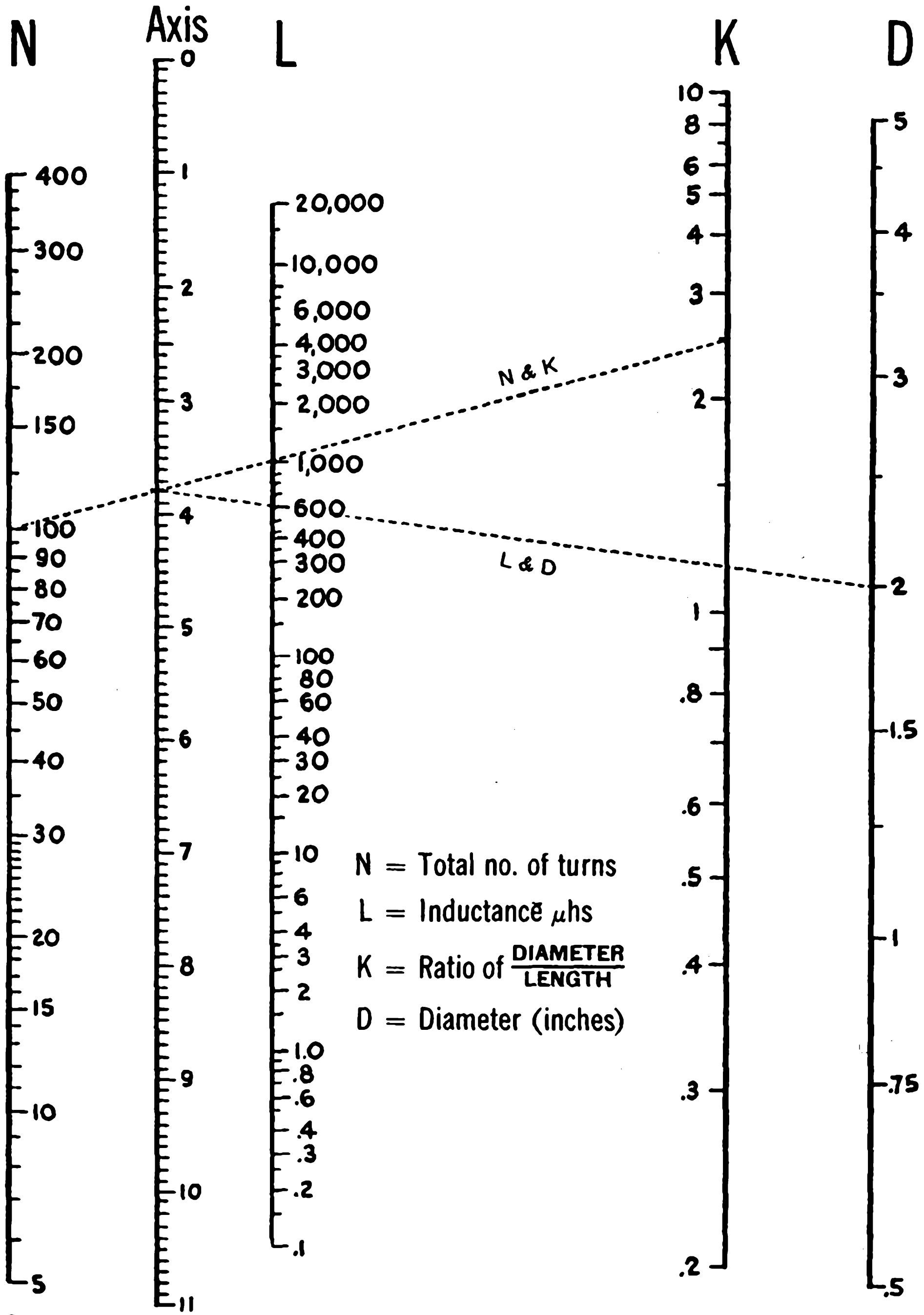
$$L = \frac{(rN)^2}{8r + 11b}$$

Table of Standard Annealed Bare Copper Wire Using American Wire Gauge (B&S)

Gauge (AWG) or (B & S)	DIAMETER INCHES			AREA	WEIGHT	LENGTH	RESISTANCE AT 68° F			Current* Capacity (Amps)— Rubber Insulated
	Min.	Nom.	Max.	Circular Mils	Pounds per M'	Feet per Lb.	Ohms per M'	Feet per Ohm	Ohms per Lb.	
0000	.4554	.4600	.4646	211600.	640.5	1.561	.04901	20400.	.00007652	225
000	.4055	.4096	.4137	167800.	507.9	1.968	.06180	16180.	.0001217	175
00	.3612	.3648	.3684	133100.	402.8	2.482	.07793	12830.	.0001935	150
0	.3217	.3249	.3281	105500.	319.5	3.130	.09827	10180.	.0003076	125
1	.2864	.2893	.2922	83690.	253.3	3.947	.1239	8070.	.0004891	100
2	.2550	.2576	.2602	66370.	200.9	4.977	.1563	6400.	.0007778	90
3	.2271	.2294	.2317	52640.	159.3	6.276	.1970	5075.	.001237	80
4	.2023	.2043	.2063	41740.	126.4	7.914	.2485	4025.	.001966	70
5	.1801	.1819	.1837	33100.	100.2	9.980	.3133	3192.	.003127	55
6	.1604	.1620	.1636	26250.	79.46	12.58	.3951	2531.	.004972	50
7	.1429	.1443	.1457	20820.	63.02	15.87	.4982	2007.	.007905	
8	.1272	.1285	.1298	16510.	49.98	20.01	.6282	1592.	.01257	35
9	.1133	.1144	.1155	13090.	39.63	25.23	.7921	1262.	.01999	
10	.1009	.1019	.1029	10380.	31.43	31.82	.9989	1001.	.03178	25
11	.08983	.09074	.09165	8234.	24.92	40.12	1.260	794.	.05053	
12	.08000	.08081	.08162	6530.	19.77	50.59	1.588	629.6	.08035	20
13	.07124	.07196	.07268	5178.	15.68	63.80	2.003	499.3	.1278	
14	.06344	.06408	.06472	4107.	12.43	80.44	2.525	396.0	.2032	15
15	.05650	.05707	.05764	3257.	9.858	101.4	3.184	314.0	.3230	
16	.05031	.05082	.05133	2583.	7.818	127.9	4.016	249.0	.5136	6
17	.04481	.04526	.04571	2048.	6.200	161.3	5.064	197.5	.8167	
18	.03990	.04030	.04070	1624.	4.917	203.4	6.385	156.5	1.299	3
19	.03553	.03589	.03625	1288.	3.899	256.5	8.051	124.2	2.065	
20	.03164	.03196	.03228	1022.	3.092	323.4	10.15	98.5	3.283	
21	.02818	.02846	.02874	810.1	2.452	407.8	12.80	78.11	5.221	
22	.02510	.02535	.02560	642.4	1.945	514.2	16.14	61.95	8.301	
23	.02234	.02257	.02280	509.5	1.542	648.4	20.36	49.13	13.20	
24	.01990	.02010	.02030	404.0	1.223	817.7	25.67	38.96	20.99	
25	.01770	.01790	.01810	320.4	.9699	1031.	32.37	30.90	33.37	
26	.01578	.01594	.01610	254.1	.7692	1300.	40.81	24.50	53.06	
27	.01406	.01420	.01434	201.5	.6100	1639.	51.47	19.43	84.37	
28	.01251	.01264	.01277	159.8	.4837	2067.	64.90	15.41	134.2	
29	.01115	.01126	.01137	126.7	.3836	2607.	81.83	12.22	213.3	
30	.00993	.01003	.01013	100.5	.3042	3287.	103.2	9.691	339.2	
31	.008828	.008928	.009028	79.7	.2413	4145.	130.1	7.685	539.3	
32	.007850	.007950	.008050	63.21	.1913	5227.	164.1	6.095	857.6	
33	.006980	.007080	.007180	50.13	.1517	6591.	206.9	4.833	1364.	
34	.006205	.006305	.006405	39.75	.1203	8310.	260.9	3.833	2168.	
35	.005515	.005615	.005715	31.52	.09542	10480.	329.0	3.040	3448.	
36	.004900	.005000	.005100	25.00	.07568	13210.	414.8	2.411	5482.	
37	.004353	.004453	.004553	19.83	.06001	16660.	523.1	1.912	8717.	
38	.003865	.003965	.004065	15.72	.04759	21010.	659.6	1.516	13860.	
39	.003431	.003531	.003631	12.47	.03774	26500.	831.8	1.202	22040.	
40	.003045	.003145	.003245	9.888	.02993	33410.	1049.	0.9534	35040.	
41	.00270	.00280	.00290	7.8400	.02373	42140.	1323.	.7559	55750.	
42	.00239	.00249	.00259	6.2001	.01877	53270.	1673.	.5977	89120.	
43	.00212	.00222	.00232	4.9284	.01492	67020.	2104.	.4753	141000.	
44	.00187	.00197	.00207	3.8809	.01175	85100.	2672.	.3743	227380.	
45	.00166	.00176	.00186	3.0976	.00938	106600.	3348.	.2987	356890.	
46	.00147	.00157	.00167	2.4649	.00746	134040.	4207.	.2377	563900.	

*Note: Values from National Electrical Code.

Single-Layer Wound Coil Chart



Courtesy, P. R. Mallory & Co., Inc.

Single-Layer Wound Coil Chart

The chart on the opposite page provides a convenient means of determining the unknown factors of small sized single-layer wound r-f coils. Values thus found so closely approximate those determined by measurement or mathematical calculation as to be entirely satisfactory for all practical purposes of experimentation, design, and repair work. Since in all coils of this type, the difference between the mean and inner diameter of the winding is so slight as to be negligible, **D** in all instances may be either the mean or inner diameter as desired.

Example: Given the total number of turns, winding length and diameter of a coil,— to find the inductance;

1. Place a straightedge on the chart so as to form a line intersecting the number of turns **N**, and the ratio of diameter to length **K**, and note the point intersected on the linear **axis** column.
2. Now move the straightedge so as to form a second line which will intersect this same point on the **axis** column, and the diameter **D**.
3. The point where this line intersects the **L** column indicates the inductance of the coil in microhenries.

Example: Given the diameter, winding length and inductance in microhenries,— to find the number of turns;

1. Simply reverse the process outlined above for determining inductance.
2. After finding the number of turns, consult the wire table on page 26 and determine the size of wire to be used.

The dotted lines appearing on the chart illustrate the correct plotting of a 600-microhenry coil consisting of 100 turns of wire, wound to 51/64" on a form 2" in diameter.

Inductance, Capacitance, Reactance Charts

The direct-reading charts appearing on the following three pages are designed for determining unknown values of frequency, inductance, capacitance and reactance components operating in a-f and r-f circuits.

The simplifications embodied in these charts make them extremely useful. The frequency range covered comprises the frequency spectrum from 1 cycle per second up to 1000 megacycles per second. All of the scales involved are plotted in actual magnitudes so that no computations are required to determine the location of the decimal point in the final result.

To make these conditions possible the frequency spectrum has been divided into three parts:

Chart I (page 30)—Covers the range from 1 cycle to 1000 cycles.

Chart II (page 31)—From 1 kilocycle to 1000 kilocycles.

Chart III (page 32)—From 1 megacycle to 1000 megacycles.

Inductance, capacitance, reactance and frequency have been plotted so that the reactance offered by an inductance or capacitance at any frequency may be readily determined by placing a straight-edge across the chart connecting the known quantities.

Since $X_L = X_C$ at resonance in most radio circuits, the charts may also be used to find the resonant frequency of any combination of L and C.

To illustrate with a simple example, suppose the reactance of a 0.01 μf. capacitor is desired at a frequency of 400 cycles. Place a straight-edge across the proper chart so as to connect the points 0.01 μf. and 400 cycles per sec. The quantity desired is the point of intersection with the reactance scale which is 40,000 ohms. The straight-edge also intersects the inductance scale at 15.8 henrys indicating that this value of inductance likewise has a reactance of 40,000 ohms at 400 cycles per sec. and furthermore, that these values of L and C produce resonance at this frequency.

There are many practical uses for these charts. The radio experimentor, maintenance man and engineer will find them helpful in the rapid solution of many reactance problems. Unusual care was exercised in laying out the various scales in order to secure a high degree of accuracy for the charts. Results should be obtainable which are at least as accurate as might be secured with a ten-inch slide rule.

Inductance, Capacitance, Reactance—(Continued)

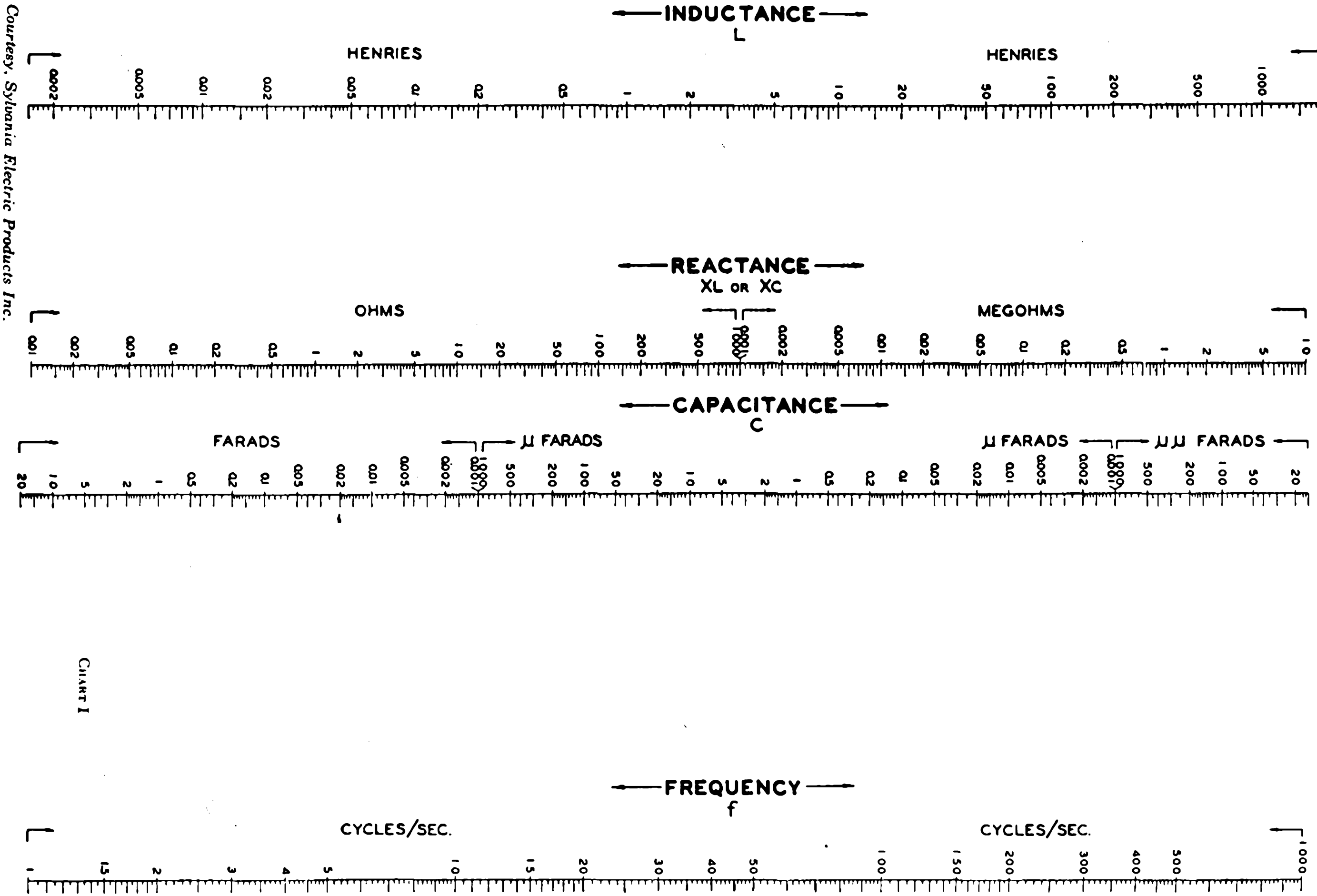


CHART I

Courtesy, Sylvania Electric Products Inc.

Inductance, Capacitance, Reactance—(Continued)

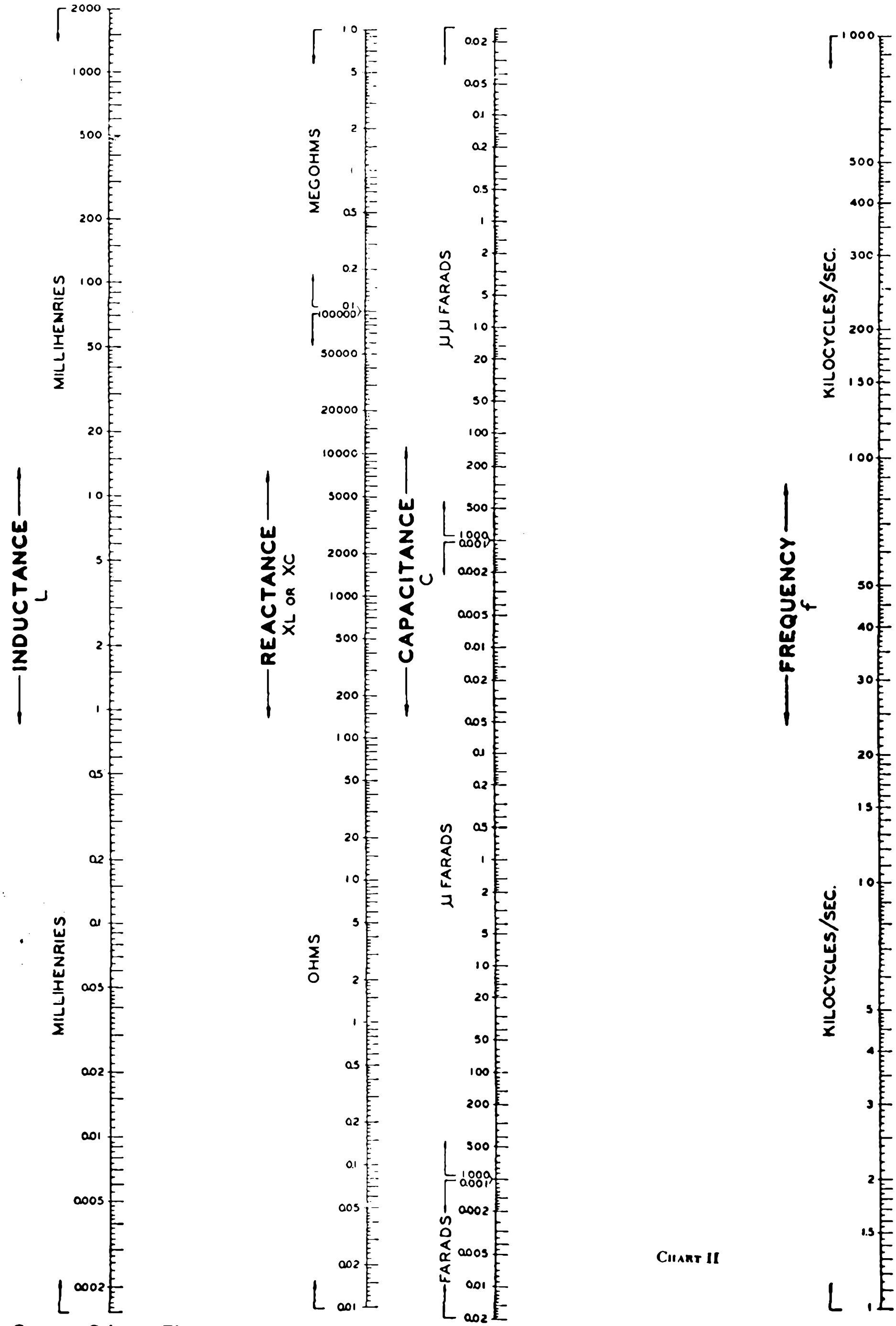
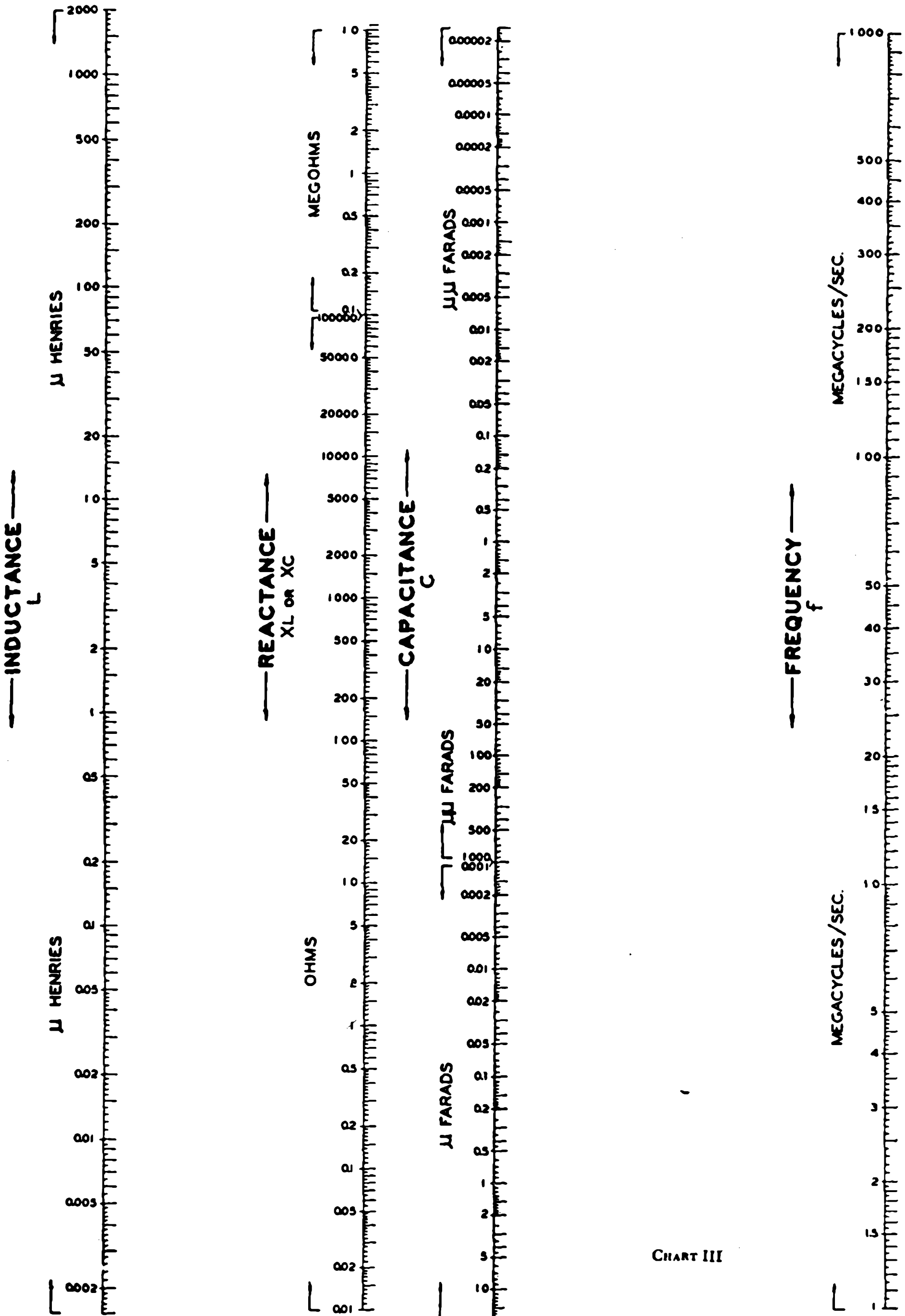


CHART II

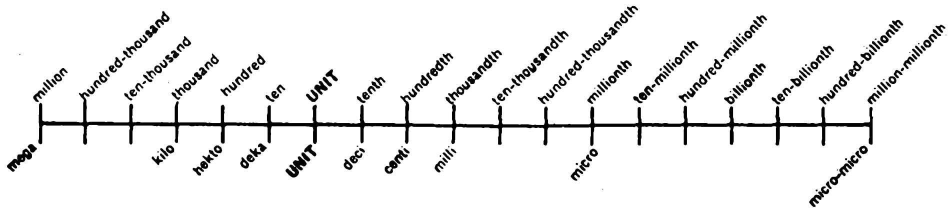
Courtesy, Sylvania Electric Products Inc.

Inductance, Capacitance, Reactance—(Continued)



Courtesy, Sylvania Electric Products Inc.

Metric Relationships



The above chart shows the relation between the American and the metric systems of notation.

This chart also serves to quickly locate the decimal point in the conversion from one metric expression to another.

Example: Convert 5.0 milliwatts to watts. Place the finger on milli and count the number of steps from there to units (since the term watt is a basic unit). The number of steps so counted is three, and the direction was to the left. Therefore, 5.0 milliwatts is the equivalent of .005 watts.

Example: Convert 0.00035 microfarads to micromicrofarads. Here the number of steps counted will be six to the right. Therefore 0.00035 microfarads is the equivalent of 350 micromicrofarads.

Metric Conversion Table

ORIGINAL VALUE	*DESIRED VALUE*							
	Mega	Kilo	Units	Deci	Centi	Milli	Micro	Micromicro
Mega		3 →	6 →	7 →	8 →	9 →	12 →	18 →
Kilo	← 3		3 →	4 →	5 →	6 →	9 →	15 →
Units	← 6	← 3		1 →	2 →	3 →	6 →	12 →
Deci	← 7	← 4	← 1		1 →	2 →	5 →	11 →
Centi	← 8	← 5	← 2	← 1		1 →	4 →	10 →
Milli	← 9	← 6	← 3	← 2	← 1		3 →	9 →
Micro	← 12	← 9	← 6	← 5	← 4	← 3		6 →
Micromicro	← 18	← 15	← 12	← 11	← 10	← 9	← 6	

The above metric conversion table provides a fast and automatic means of conversion from one metric notation to another. The notation "Unit" represents the basic units of measurement, such as amperes, volts, ohms, watts, cycles, meters, grams, etc. To use the table, first locate the original or given value in the left-hand column. Now follow this line horizontally to the vertical column headed by the prefix of the desired value. The figure and arrow at this point indicates number of places and direction decimal point is to be moved.

Example: Convert 0.15 ampere to milliamperes. Starting at the "Units" box in the left-hand column (since ampere is a basic unit of measurement), move horizontally to the column headed by the prefix "Milli", and read 3 →. Thus 0.15 ampere is the equivalent of 150 milliamperes.

Example: Convert 50,000 kilocycles to megacycles. Read in the box horizontal to "Kilo" and under "Mega", the notation ← 3, which means a shift of the decimal three places to the left. Thus 50,000 kilocycles is the equivalent of 50 megacycles.

How to Use Logarithms

Logarithms are used to simplify numerical computations involving multiplications, division, powers and roots. With logarithms, multiplication is reduced to simple addition, and division is reduced to simple subtraction. Raising to a power is reduced to a single multiplication, and extracting a root is reduced to a single division.

The common logarithm of any number is the power to which 10 must be raised in order to equal that number.

Therefore, since

$$1000 = 10^3$$
$$100 = 10^2$$
$$10 = 10^1$$
$$1 = 10^0$$
$$0.1 = 10^{-1}$$
$$0.01 = 10^{-2}$$
$$0.001 = 10^{-3}$$
$$0.0001 = 10^{-4}$$

it is true that

$$\log 1000 = 3$$
$$\log 100 = 2$$
$$\log 10 = 1$$
$$\log 1 = 0$$
$$\log 0.1 = -1$$
$$\log 0.01 = -2$$
$$\log 0.001 = -3$$
$$\log 0.0001 = -4$$

The common system of logarithms has for its base the number 10, and is written $\log_{10}$ or more commonly log, since the base 10 is always implied unless some other base is specifically indicated. There are formulas however which use the natural system of logarithms. This system has for its base the number 2.718 . . . which is represented by the Greek letter ϵ and is always written $\log \epsilon$.

A table of natural logarithms has not been included in this handbook however, since the common log of a number is approximately equal to 0.4343 times the natural log of the same number. Conversely, the natural log of a number is approximately equal to 2.3026 times the common log of the same number.

In observing the following exponential and logarithmic relationships,

Exponential Form	Logarithmic Form
$100 = 10^2$	$\log 100 = 2.000$
$15 = 10^{1.176}$	$\log 15 = 1.176$
$10 = 10^1$	$\log 10 = 1.000$
$7 = 10^{.845}$	$\log 7 = 0.845$
$1 = 10^0$	$\log 1 = 0.000$
$0.1 = 10^{-1}$	$\log 0.1 = -1.000$
$0.7 = 10^{-1.845}$	$\log 0.7 = -1.845$
$0.015 = 10^{-2.176}$	$\log 0.015 = -2.176$
$0.001 = 10^{-3}$	$\log 0.001 = -3.000$

it will be seen that only the direct powers of 10 have whole numbers for logarithms; also that the logarithms of all numbers lying between a power of 10, consist of a whole number and a decimal. The whole number is called the characteristic, and the decimal, the mantissa. Since the characteristic serves only to fix the location of the decimal point in the expression indicated by the log, it can be found by inspection and is not included in the log table. The following will be helpful:

1. The characteristic of any number greater than 1 is always positive and is equal to one less than the number of digits to the left of the decimal.
2. The characteristic of any number less than 1 is always negative and is equal to one plus the number of zeros to the decimal.
3. The characteristic of any number may be determined by expressing the number as a power of 10 and using this power as the characteristic of the logarithm for that number.

Since only the characteristic of a logarithm is ever negative, the mantissa always being a positive number, it is customary to write a log containing a negative characteristic as follows:

$$\log 0.7 = \bar{1}.845,$$

or, by adding +10 to the characteristic and, in order to maintain equality, −10 at the right of the characteristic,

$$\log 0.7 = 9.845 - 10$$

Examples:

150	1.5×10^2	2
15	1.5×10^1	1
1.5	1.5×10^0	0
0.15	1.5×10^{-1}	-1 or $9 - 10$
0.015	1.5×10^{-2}	-2 or $8 - 10$
0.0015	1.5×10^{-3}	-3 or $7 - 10$

Therefore, to find the logarithm of any number:

1. Write the number as a power of 10, and put down the resulting exponent of 10 as the characteristic.
2. Determine the mantissa from the log tables on page 56, and write this as a decimal figure following the characteristic.
3. If the resulting logarithm has a negative characteristic, change this to the positive form.

Example: Find the logarithm of .00623:
Since $.00623 = 6.23 \times 10^{-3}$, the characteristic is -3. The mantissa as shown by the log table is 7945. The resultant logarithm = $\bar{3}.7945$ or when written in its positive form, $7.7945 - 10$.

To find the log of any number having more than three significant figures (by interpolation):

1. Determine the characteristic.
2. Find the mantissa corresponding to the first three significant figures.
3. Find the next higher mantissa and take the tabular difference.
4. Find the product of the tabular difference and the digit following the first three significant figures of the given number written as a decimal.
5. Add this product to the lesser mantissa.

Example: Find the logarithm of 54.65.
Since $54.65 = 5.465 \times 10^1$, the characteristic is 1.

Next higher mantissa =	.7380
Next lower mantissa =	.7372
Tabular difference =	.0008
	× .5
Product	.00040
Plus lesser mantissa	.7372
Mantissa of 5.465	.7376

$\therefore$ log 54.65 = 1.7376

Although a four-place log table is used here, for purposes where accuracy to 3 significant figures is required, generally, a three place table is sufficiently accurate for all practical purposes. Since the mantissa of a logarithm represents only the significant figures of any number, the same mantissa is used for .04, 4, 400, etc., the decimal point being fixed later by the characteristic. Therefore any number consisting of 1 or 2 significant figures may be found in the column marked **N**, and its mantissa will be found on the same line in this column headed by **0**. For any number containing 3 significant figures, locate the first two figures in the **N** column, and the third figure in the column headed by the corresponding digit. The mantissa will be found in this column, on a line even with the first two digits.

Example:

log 21 = 1.3222
log 2.1 = 0.3222
log 210 = 2.3222
log .0021 = 7.3222 − 10
log 213 = 2.3284
log .0213 = 8.3284 − 10
log 3 = 0.4771
log 300 = 2.4771
log .003 = 7.4771 − 10

The number corresponding to a given logarithm is called the antilogarithm, and is written "antilog". Example: Since log of 692 = 2.8401, the antilog of 2.8401 = 692.

Finding the antilog of a number is the reverse of finding the logarithm. First locate the mantissa in the log table, and determine its corresponding number. Now, place the decimal as indicated by the characteristic.

Example: To find the antilog of 3.9138, look up 9138 in the log table. Its corresponding number is 82, or expressed as a power of 10, equals 8.2. A characteristic of 3 means that 8.2 must be multiplied by 10^3. Therefore, antilog $3.9138 = 8.2 \times 10^3 = 8200$.

Similarly

Antilog $5.9138 = 8.2 \times 10^5 = 82{,}0000$
Antilog $0.9138 = 8.2 \times 10^0 = 8.2$
Antilog $7.9138 - 10 = 8.2 \times 10^{-3} = 0.0082$
Antilog $9.9138 - 10 = 8.2 \times 10^{-1} = 0.82$

To find the antilogarithm of a logarithm whose mantissa is not exactly given in the table,

1. Find the tabular difference between the next highest and next lowest mantissas.
2. Divide this by the difference between the given mantissa and the next lowest mantissa.
3. Add the resulting quotient to the significant figures expressed by the next lower mantissa.
4. Place the decimal as indicated by the given characteristic.

Example: Find the antilog of 1.7376

Next higher mantissa	.7380
Next lower mantissa	.7372
Tabular difference	.0008
Given mantissa	.7376
Next lower mantissa	.7372
Tabular difference	.0004

$$\text{Quotient of } \frac{.0004}{.0008} = .5$$

The resultant figure therefore is .5 larger than the significant figures expressed by the lesser mantissa .7372 or 546. The sequence of figures therefore is 546.5

∴ the antilog of 1.7376 = 54.65

NOTE: When interpolating as shown above, do not exceed four significant figures in your answer since interpolated results from a four-place table are not accurate beyond this point.

Logarithms are added or subtracted like arithmetical numbers, provided they are written with positive characteristics. If the characteristic in the total is greater than 9, and the notation −10, −20, −30, etc., appears after the mantissa, subtract a multiple of 10 from the positive part and add the same multiple of 10 to the negative part, so as to make the resultant characteristic less than 10.

EXAMPLES:

Addition of logarithms

2.764	6.326 − 10	6.328 − 10
4.304	6.284	7.764 − 10
7.068	12.610 − 10	9.104 − 10
	or	23.196 − 30
	2.610	or
		3.196 − 10

Subtraction of logarithms

$$\left.\begin{matrix}4.107\\6.986\end{matrix}\right\} = \begin{matrix}14.107 - 10\\6.986\\\hline 7.121 - 10\end{matrix}$$

$$\begin{matrix}11.672 - 10\\5.785 - 10\\\hline 5.887\end{matrix}$$

The relationships of logarithmic operations are expressed by the following formulas:

$$\log (a \times b) = \log a + \log b$$

$$\log \left(\frac{a}{b}\right) = \log a - \log b$$

$$\log (a)^b = b \log a$$

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

EXAMPLES

To Multiply 1.24 by 246

log of 1.24 = 0.0934
log of 246 = 2.3909
Total 2.4843

The antilog of 2.4843 = 305, which is as accurate as can be determined with a four-place table. The full answer to this problem is 305.04.

To Divide 961 by 224

log of 961 = 2.9827
log of 224 = 2.3502
Difference 0.6325

The antilog of 0.6325 = 4.29 which is as accurate as can be determined with a four-place table. The product of 224 and 4.29 is 960.96.

Powers: Find 12^2 by logarithms:

log of 12 = 1.0792
× 2
2.1584

The antilog of 2.1584 = 144.

Roots Find $\sqrt[3]{343}$

log of 343 = 2.5353 ÷ 3 = .8451
The antilog of .8451 = 7.

Logarithms of Negative Numbers. Because the logarithms of negative numbers are imaginary in character, they cannot be used in computation as with positive numbers. However, since the numerical results of multiplying, dividing, etc., are not affected by the signs, you can determine the numerical results by logarithms and later affix the final + or − signs by inspection.

Directly Interchangeable Tubes

NOTE: **Tubes in the "Tube Number" column are directly replaceable with tubes in the "Replace With" column. The reverse, however, *will not* be a correct replacement on many tube types.**

Replacements shown for many older tube types are the newer more reliable industrial equivalents. Many of these will be listed only in the catalog of Allied Radio's industrial subsidiary, Allied Electronics Corp., but may be purchased from Allied Radio. Prices on request.

Tube Number	Replace with
01A	40
0A2	6073 6626
0A3	VR75
0A4	1267
0B2	OB2WA 6074 6627
0B3	VR90
0C3	VR105
0D3	VR150
0Y4	OY4G
0Z4	1003 OZ4A
1A4	1A4P 1A4T 1B4 1B4P 1B4T 32 34 951
1A5	1T5
1AC5	1V5
1AD5	1W5
1AF4	1AJ4 1AM4 1T4SF
1AF5	1AH5 1AR5
1AH5	1AF5 1AR5
1AJ4	1AF4 1AM4 1T4SF
1AM4	1AF4 1AJ4 1T4SF
1AR5	1AF5 1AH5
1AQ5	1R5SF
1AS5	1U5SF
1AU3	1N2 1N2A

Tube Number	Replace with
1AX2	1H2 1S2A
1B3GT	1AU3 1G3GT 1G3GT/1B3GT 1J3GT 1K3GT 1N2 1N2A
1B4	1A4 1A4P 1A4T 1B4P 1B4T 32 34 951
1C5	1Q5
1C8	1E8
1D5	1E5
1D8	1B8
1DN5	1U5
1E4	1G4
1E5	1D5
1E8	1C8
1G3GT	1AU3 1B3GT 1G3GT/1B3GT 1J3GT 1K3GT 1N2 1N2A
1G4	1E4
1G5	1J5
1J3GT	1AU3 1B3GT 1G3GT/1B3GT 1K3GT 1N2 1N2A
1J5	1G5
1K3GT	1AU3 1B3GT 1G3GT 1G3GT/1B3GT 1J3GT 1N2 1N2A

Tube Number	Replace with
1LA4	1LA4E
1LA6	1LC6
1LC5	1LN5
1LC6	1LA6
1LE3	1LF3
1LF3	1LE3
1LN5	1LC5
1M3	1N3
1N2	1N2A 1AU3 1J3A
1N2A	1N2 1AU3 1J3A
1N5	1P5
1P5	1N5
1Q5	1C5
1R5SF	1AQ5
1S2	1S2A 1H2
1S6	1T6
1T4SF	1AF4 1AJ4 1AM4
1T5	1A5
1T6	1S6
1U4	5910
1U5	1DN5
1U5SF	1AS5
1V	6Z3
1V5	1AC5
1W5	1AD5
1X2	1X2A 1X2B
2A3	2A3H 5930
2A7	2A7S
2AF4	2AF4A 2AF4B
2B7S	2B7
2CY5	2EA5 2EV5
2EA5	2EV5
2ER5	2FQ5 2FQ5A 2FY5

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
2EV5	2EA5
2E30	5812
2E31	2E32
2E32	2E31
2E35	2E36
2E36	2E35
2E41	2E42
2E42	2E41
2FH5	2ES5, 2FQ5, 2FQ5A, 2GK5
2FQ5	2ES5, 2FQ5A, 2GK5
2FS5	2GU5
2FY5	2ER5, 2FQ5, 2FQ5A, 2GK5
2GK5	2FQ5, 2FQ5A
2GU5	2FS5
2G21	2G22
2G22	2G21
3A3	3AW3, 3B2
3AF4A	3AF4B
3AU6	3BA6
3AW3	3A3
3B2	3A3, 3AW3
3B7	1291
3BA6	3AU6
3BC5	3CE5
3BE6	3BY6, 3CS6
3BU8	3BU8A, 3GS8, 3HS8
3BX6	3BY7
3BY6	3BE6, 3CS6
3BY7	3BX6
3BZ6	3CB6, 3CF6, 3DK6
3C5	3Q5
3CB6	3BZ6, 3CF6, 3DK6
3CE5	3BC5
3CF6	3BZ6, 3CB6, 3DK6
3CS6	3BE6, 3BY6
3CY5	3EA5, 3EV5
3DK6	3BZ6, 3CB6, 3CF6
3EA5	3EV5
3EH7	3EJ7
3EJ7	3EH7
3ER5	3FQ5, 3FQ5A, 3FY5
3EV5	3EA5
3FH5	3ES5, 3FQ5, 3FQ5A, 3GK5
3FQ5	3FQ5A, 3ES5, 3GK5
3FS5	3GU5
3FY5	3ER5
3GK5	3FQ5, 3FQ5A
3GS8	3BU8, 3BU8A, 3HS8
3GU5	3FS5
3HS8	3BU8, 3BU8A, 3GS8
3LE4	3LF4
3Q4	3S4
3Q5	3C5
3S4SF	3W4, 3Z4
3W4	3S4SF, 3Z4
3Z4	3S4SF, 3W4
4AU6	4BA6
4BA6	4AU6
4BC5	4CE5
4BC8	4BQ7A, 4BS8, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BE6	4CS6
4BQ7A	4BC8, 4BS8, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BS8	4BC8, 4BQ7A, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BU8	4GS8, 4HS8
4BX8	4BC8, 4BQ7A, 4BS8, 4BZ7, 4BZ8, 5BK7A
4BZ6	4CB6, 4DE6, 4DK6
4BZ7	4BC8, 4BQ7A, 4BS8, 4BX8, 4BZ8, 5BK7A
4BZ8	4BC8, 4BQ7A, 4BS8, 4BX8, 4BZ7, 5BK7A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
4CB6	4BZ6 4DE6 4DK6
4CE5	4BC5
4CS6	4BE6
4DE6	4BZ6 4CB6 4DK6
4DK6	4BZ6 4CB6 4DE6
4EH7	4EJ7
4EJ7	4EH7
4EW6	4GM6
4GS8	4BU8 4HS8
4HS8	4BU8 4GS8
5AS4	5AS4A 5DB4 5U4GB 5V3 5V3A
5AU4	5V3 5V3A
5AW4	5AS4 5AS4A 5AU4 5DB4 5R4G 5U4GB 5V3 5V3A
5AX4	5AR4 5AS4 5AS4A 5R4G 5T4 5U4GB 5V4
5AZ4	5AR4 5AX4 5CG4 5R4 5T4 5V4 5Y3 5Z4
5BK7A	4BC8 4BQ7A 4BS8 4BX8 4BZ7 4BZ8
5BQ7A	5BS8 5BZ7
5BS8	5BQ7A 5BZ7
5BZ7	5BQ7A 5BS8
5CG4	5AR4 5V4 5Z4
5CG8	5FG7
5CM6	5CZ5
5DB4	5AS4 5AS4A 5U4GB
5DH8	5CL8
5DJ4	5DN4
5DN4	5DJ4
5EA8	5GH8 5U8
5EW6	5GM6
5FV8	5BR8
5GH8	5EA8 5U8
5GM6	5EW6
5T4	5AR4 5R4
5U4G	5U4GA 5U4GB 5AR4 5AS4 5AS4A 5AU4 5DB4 5R4 5T4 5V3 5931
5U4GA	5U4GB 5AS4 5AS4A 5AU4 5DB4 5R4 5V3
5U4GB	5AS4 5AS4A 5DB4
5U8	5EA8 5GH8
5V4	5V4GY 5AR4
5W4	5AR4 5AZ4 5CG4 5R4 5T4 5V4 5Y3 5Z4
5X3	13 80 83V 88
5Y3	5AR4 5AX4 5AZ4 5CG4 5R4 5T4 5V4 5Z4 6087 6106
5Z3	83 1275
5Z4	5AR4 5CG4 5V4 6087
6AB5	6N5
6AB7	6AC7 6AJ7 1853
6AC5G	6AC5GT

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6AC7	6AB7 6AJ7 1852 6134
6AD4	5637 5719 5719A 5898 SD917A
6AD6	6AF6
6AE5	6AF5
6AF5	6AE5
6AF6	6AD6
6AF11	6AS11
6AG5	6BC5 6CE5 6186
6AJ7	6AB7 6AC7
6AK5	6AJ5 1220 5654 6096 6968
6AK7	6AG7
6AK8	6T8 6T8A
6AL5	6EB5 5726 6058 6097 6663 7631
6AM8	6HJ8
6AQ5	6AQ5A 6BM5 6005 6095 6669
6AS4	6DQ4
6AS7G	6AS7GA 6AS7GT 6080 6520
6AS11	6AF11
6AT6	6AV6 6BK6 6BT6 6066
6AU4GT	6AU4GTA
6AU5GT	6FW5
6AU6	6AU6A 6BA6 6136 7543
6AU7	7AU7
6AU8A	6AU8 6AW8A 6BA8A 6BH8
6AV5GA	6AV5GT 6FW5
6AV6	6AT6 6BK6 6BT6
6AW6	6CB6 6CB6A 6CF6 6CD6 6DE6
6AW8	6AU8A 6BA8A
6AW8A	6AW8 6AU8 6AU8A 6BA8 6BA8A
6AX4GT	6AX4GTA 6AX4GTB 6AS4GT 6DA4 6DA4A 6DM4 6DQ4
6AX4GTA	6AX4GTB 6DA4 6DA4A 6DM4 6DQ4
6AX8	6EA8 6GH8 6U8 6U8A
6AY3	6AY3A 6BA3
6AY3A	6AY3 6BA3
6B6	6Q7
6BA3	6AY3 6AY3A
6BA6	6AU6 6AU6A 6BD6 6CG6 5749 6660 7496 7543
6BA8	6AU8 6AW8A 6BH8
6BC5	6AG5 6CE5
6BC8	6BQ7 6BQ7A 6BS8 6BX8 6BZ7 6BZ8 6HK8 X155
6BD6	6BA6 6CG6
6BE6	6BY6 6CS6 5750 5915
6BF6	6BU6
6BG7	6BF7 6021
6BH8	6AU8 6AU8A 6AW8 6AW8A 6BA8 6BA8A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with	Tube Number	Replace with	Tube Number	Replace with
6BJ6	6BJ6A, 6662, 7694	6BU6	6BF6	6CA5	6EH5
6BK6	6AT6, 6AV6, 6BT6	6BU8	6BU8A, 6GS8, 6HS8	6CB5	6CB5A, 6CL5
6BL7GT	6BL7GTA, 6BX7GT, 6DN7	6BW7	6BX6, 6EL7	6CB5A	6CL5
6BL8	6U8, 6U8A	6BX6	6BW7, 6BY7, 6EL7	6CB6	6CB6A, 6AW6, 6CF6, 6DC6, 6DE6, 6DK6, 6HQ6, 6676, 7732
6BM5	6AQ5, 6AQ5A	6BX7GT	6BL7GT, 6BL7GTA, 6DN7	6CD6G	6DN6, 6EX6
6BQ5	7189, 7189A, 7320	6BX8	6BC8, 6BQ7, 6BQ7A, 6BS8, 6BZ7, 6BZ8, 6HK8, X155	6CF6	6AW6, 6BZ6, 6CB6, 6CB6A, 6DC6, 6DE6, 6DK6
6BQ6GT	6BQ6GTA, 6BQ6GTB, 6BQ6GTB/6CU6, 6CU6, 6DQ6A, 6DQ6B, 6FH6, 6GW6	6BY6	6BE6, 6CS6	6CG6	6BA6, 6BD6
6BQ7	6BQ7A, 6BC8, 6BS8, 6BX8, 6BZ7, 6BZ8, 6HK8, X155	6BY7	6BX6	6CG8	6CG8A, 6FG7
6BR5	6DA5	6BZ6	6DC6, 6HQ6	6CG8A	6FG7
6BR8	6BR8A, 6FV8, 6FV8A	6BZ7	6BC8, 6BQ7, 6BQ7A, 6BS8, 6BX8, 6BZ8, 6HK8, X155	6CH7	6CX7
6BR8A	6FV8, 6FV8A	6BZ8	6BC8, 6BQ7, 6BQ7A, 6BS8, 6BX8, 6BZ7, 6HK8, X155	6CJ6	6DR6
6BS8	6BC8, 6BQ7, 6BQ7A, 6BX8, 6BZ7, 6BZ8, 6HK8, X155	6C4	6100, 9002	6CM6	6CZ5
6BT6	6AT6, 6AV6, 6BK6	6C5	6J5, 6L5	6CS5	6DW5
		6C6	77, 1221, 1223, 7700	6CS6	6BE6, 6BY6
				6CU6	6BQ6GTB, 6BQ6GTB/6CU6, 6DQ6, 6DQ6A, 6DQ6B, 6FH6, 6GW6
				6CW4	6DS4, 7895
				6CW7	6CF7
				6CX7	6CH7
				6CX8	6EB8, 6GN8, 6HF8, 6JE8

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6CY5	6EA5 6EV5 7717
6D6	78
6DA4	6DA4A 6AX4GTA 6AX4GTB 6DM4 6DQ4
6DA4A	6DQ4
6DA5	6BR5
6DC6	6AW6 6BZ6 6CB6 6CB6A 6CF6 6DE6 6DK6
6DC8	6AD8 6N8
6DE4	6CQ4
6DE6	6AW6 6CB6 6CB6A 6CF6 6DC6 6DK6 6HQ6
6DJ8	6ES8
6DK6	6CB6 6CB6A 6CF6 6DC6 6DE6 6HQ6 8136
6DM4	6DA4A 6DQ4
6DN6	6CD6G 6CD6GA 6EX6
6DQ6	6DQ6A 6DQ6B 6FH6 6GW6
6DQ6A	6DQ6B 6FH6 6GW6
6DR6	6CJ6
6DR7	6FD7 6FR7
6DS4	6CW4 7895
6EA5	6EV5
6EA8	6U8A 6GH8
6EB5	6AL5
6EB8	6CX8 6GN8 6HF8 6JE8
6EH5	6CA5
6EH7	6EJ7
6EJ7	6EH7
6EL7	6BW7 6BX6
6ES6	6ET6 6FD6
6ES8	6DJ8
6ET6	6ES6 6FD6
6EV5	6EA5
6EW6	6GM6
6EX6	6CD6GA
6F4	6L4
6F7	6F7S
6FC7	6CW7
6FD6	6ES6 6ET6
6FD7	6FR7
6FH5	6ES5
6FH6	6DQ6B 6GW6
6FQ5	6FQ5A 6GK5
6FQ5A	6FQ5 6GK5
6FR7	6FD7
6FS5	6FG5
6FV8	6FV8A 6BR8A
6FV8A	6FV8 6BR8A
6G5	6T5 6U5
6GF5	6GE5
6GH8	6EA8 6U8A
6GK5	6FQ5 6FQ5A
6GL7	6EA7
6GM6	6EW6
6GN8	6CX8 6EB8 6HF8 6JE8
6GS8	6BU8 6BU8A 6HS8
6GW6	6DQ6B
6GX6	6GY6
6GY6	6GX6
6H5	6G5 6T5 6U5
6HF8	6CX8 6EB8 6GN8 6JE8
6HJ8	6AM8A
6HK8	6BC8 6BQ7 6BQ7A 6BS8 6BX8 6BZ7 6BZ8 X155
6HQ6	6BZ6 6CB6 6CB6A 6DE6 6DK6

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6HS8	6BU8, 6BU8A, 6GS8
6J5	6C5, 6L5
6J7	1233, 1620, 7000
6JE8	6EB8, 6GN8, 6HF8
6K4	6778
6K7	6U7, 5732
6K11	6Q11
6L4	6F4
6L6	6L6G, 6L6GA, 6L6GAY, 6L6GB, 6L6GC, 6L6GT, 6L6GX, 1622, 5881, 5932, 7581, 7581A
6L7	1612, 1620
6N5	6N5G, 6AB5
6N8	6AD8, 6DC8
6Q7	6B6, 6118
6SA7	6SB7Y, 5961
6SD7	6SE7
6SE7	6SD7
6SJ7	5693
6SK7	6137
6SL7	6113
6SN7	6SN7GTA, 6SN7GTB, 5692
6SQ7	6SQ7W
6SU7	6188
6T5	6G5, 6H5, 6U5
6T8	6T8A, 6AK8
6U4GT	6AS4GT, 6AX4GT, 6AX4GTA, 6AX4GTB, 6DA4, 6DA4A, 6DM4, 6DQ4, 6W4GT, 6W4GTA
6U5	6G5, 6H5, 6T5
6U7	6K7
6U8	6U8A, 6AX8, 6EA8, 6GH8, 1252, 6678, 7731
6U8A	6EA8, 6GH8
6V6	6V6G, 6V6GT, 6V6GTA, 6V6GTX, 6V6GTY, 6V6GX, 6V6GY, 7408, 7871
6W4GT	6W4GTA, 6AS4GT, 6AX4GT, 6AX4GTA, 6AX4GTB, 6DA4, 6DA4A, 6DM4, 6DQ4, 6U4GT
6W4GTA	6AX4GTA, 6AX4GTB, 6DA4, 6DA4A, 6DM4, 6DQ4, 6U4GT
6X5GT	0Z4
6X8	6X8A
6Z3	1V
7A4	XXL
7A7	7A7LM, 7H7
7AB7	1204
7AG7	7AH7
7AH7	7AG7, 7B7
7AJ7	1273
7AN7	7EK7
7AU7	6AU7
7B7	7AH7
7C4	1203, 1203A
7E5	1201
7E7	7R7
7EK7	7AN7
7ES8	7DJ8
7FC7	7EK7
7G7	1232
7H7	7A7, 7A7LM
7J7	7S7
7R7	7E7
7S7	7J7
7V7	7G7
8AU8A	8AW8A
8AW8A	8AU8A
8BA8A	8AU8, 8AU8A, 8AW8A, 8BH8
8BH8	8AU8, 8AU8A, 8AW8A, 8BA8A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
8CX8	8EB8 8GN8 8JE8
8EB8	8CX8 8GN8 8JE8
8GN8	8CX8 8EB8 8JE8
8JE8	8CX8 8EB8 9GN8
9A8	9U8 9U8A
9U8	9U8A 9A8
10DE7	10EW7
10DR7	10FD7 10FR7
10EB8	10GN8 10HF8 11JE8
10EG7	10EM7
10EM7	10EG7
10FD7	10FR7
10FR7	10FD7
10GN8	10EB8 10HF8 11JE8
10HF8	10EB8 10GN8 11JE8
11C5	12DM5
11JE8	10EB8 10GN8 10HF8
12AE6	12AE6A 12FT6
12AE6A	12AE6 12FT6
12AF6	12BL6 12AC6
12AG6	12AD6
12AT6	12AT6A 12AV6 12AV6A 12BK6 12BT6
12AT6A	12AV6A
12AT7	12AT7WA 12AT7WB 6060 6201 6671 6679 7492 7728
12AU6	12AU6A 12BA6 12BA6A
12AU7	12AU7A 12AU7W 12AU7WA 5963 6067 6189 6680 7316 7489 7730
12AV6	12AV6A 12AT6 12AT6A 12BK6 12BT6
12AV6A	12AT6A
12AX4GT	12AX4GTA 12AX4GTB 12D4 12D4A 12DM4 12DQ4
12AX7	12AX7A 12DF7 12DT7 5721 6057 6681 7025 7025A 7494 7729
12AZ7	12AZ7A
12B7	14A7 14H7
12BA6	12BA6A 12AU6 12AU6A
12BA6A	12AU6A
12BD6	12BA6 12BA6A
12BE6	12BE6A 12CS6
12BH7	12BH7A 6913
12BK6	12AT6 12AT6A 12AV6 12AV6A 12BT6
12BL6	12AF6
12BQ6GT	12BQ6/12CU6 12CU6 12DQ6A 12DQ6B 12GW6
12BT6	12AT6 12AT6A 12AV6 12AV6A 12BK6
12BU6	12BF6
12BV7	12BY7 12BY7A 12DQ7
12BY7	12BY7A 12BV7 12DQ7 7733
12BY7A	12DQ7
12C5/12CU5	12C5 12CU5 12R5
12CA5	12EH5

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
12CS5	12DT5 12DW5
12CS6	12BE6 12BE6A
12CU6	12BQ6GTB 12BQ6GT/12CU6 12DQ6A 12DQ6B 12GW6
12CX6	12EZ6
12D4	12D4A 12AX4GTB 12DM4 12DQ4
12D4A	12DM4 12DQ4
12DF7	12AX7 12AX7A 12DT7 7025 7025A
12DM4	12D4A 12DQ4
12DM5	11C5
12DQ6	12DQ6A 12DQ6B 12GW6
12DQ6A	12DQ6B 12GW6
12DQ6B	12GW6
12DQ7	12BY7A
12DT7	12AX7 12AX7A 12DF7 7025 7025A
12DW7	7247
12DZ6	12EA6 12EK6
12EA6	12DZ6 12EK6
12EH5	12CA5
12EK6	12DZ6 12EA6
12EN6	12L6GT 12W6GT
12EZ6	12CX6
12FK6	12FM6
12FM6	12FK6
12FT6	12AE6 12AE6A
12G4	12H4
12GW6	12DQ6B
12L6GT	12EN6 12W6GT
12L8	1644
12SA7	12SY7
12SC7	1634
12SK7	5661
12SN7	12SX7
12SR7	12SW7
12SW7	12SR7
12SX7	12SN7
12SY7	12SA7
12W6GT	12EN6 12L6GT
13DR7	13FD7 13FR7
13EM7	15EA7
13FD7	13FR7
13FR7	13FD7
14A7	12B7 14H7
14AF7	XXD
14C7	1280
14E7	14R7
14GT8	14GT8A 14JG8 7724
14H7	12B7 14A7
14J7	14S7
14JG8	14GT8 14GT8A
14R7	14E7
14S7	14J7
15EA7	13EM7
16A5	15CW5
17AX3	17BE3
17AX4GT	17AX4GTA 17D4 17D4A 17DM4 17DQ4
17AX4GTA	17D4 17D4A 17DM4 17DQ4
17BQ6GTB	17DQ6A 17DQ6B 17GW6
17C5	17CU5 17R5
17CU5	17C5 17R5
17D4	17D4A 17AX4GTA 17DM4 17DQ4
17D4A	17DM4 17DQ4
17DM4	17D4A 17DQ4
17DQ6	17DQ6A 17DQ6B 17GW6
17DQ6A	17DQ6B 17GW6
17DQ6B	17GW6
17GW6	17DQ6B
17L6GT	17W6GT
17W6GT	17L6GT
18FW6	18FW6A 18GD6 18GD6A
18FW6A	18GD6A
18FY6	18FY6A 18GE6 18GE6A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
18FY6A	18GE6A
18GD6	18GD6A 18FW6 18FW6A
18GD6A	18FW6A
18GE6	18GE6A 18FY6 18FY6A
18GE6A	18FY6A
19AU4	19AU4GT 19AU4GTA 17DE4
19AU4GT	19AU4 19AU4GTA 17DE4
19C8	19T8 19T8A
19CL8A	19CL8B 19JN8
19EA8	19EA8A
19JN8	19CL8A 19CL8B
19T8	19T8A 19C8
21EX6	25CD6GB
25AX4GT	25D4
25BQ6GA	25BQ6GTB/25CU6 25CU6 25DQ6A
25CA5	25C5 25EH5
25CD6G	25CD6GA 25CD6GB 25DN6 21EX6
25CD6GA	25CD6GB 25DN6 21EX6
25CD6GB	21EX6
25CU6	25BQ6T 25BQ6GTB/25CU6 25DQ6A
25DN6	25CD6GB 21EX6
25EC6	25CD6GB 21EX6
25EH5	25CA5
25L6GT	25W6GT 6046
25S	25 1B5 1B5/25S
25U4GT	25AX4GT 25D4 25W4GT
25W4GT	25AX4GT 25D4 25U4GT
25W6GT	25L6GT 6046
25Y5	25Z5
27	56
27GB5	28GB5
32	1A4 1A4P 1A4T 1B4 1B4P 1B4T 34 951
32ET5	32ET5A 34GD5 34GD5A
32L7	25A7
34	1A4 1A4P 1A4T 1B4 1B4P 1B4T 32 951
34GD5	34GD5A 32ET5 32ET5A
34GD5A	32ET5A
37	76
39	39/44 44
39/44	39 44
44	39 39/44
50EH5	50EH5A 50CA5
50HK6	50HC6
50Y7	50Z7
50Z6	50AX6
50Z7	50Y7
56	27
76	37
77	6C6
78	6D6
80	5X3 13 83V 88
81	16 16B
83	5Z3, 80
117L7	117M7
117N7	117P7
807	5933
CK1005	0Y4 0Z4A
CK1013	5517
1201	7E5
1203	7C4
1204	7AB7
1206	768
1221	6C6
1223	6J7
1229	1A4
1230	30
1231	7V7
1232	7G7
1267	0A4
1273	7A7

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
1274	6X5
1275	5X3, 80, 83
1280	14H7
1284	12B7
1291	3B7
1294	1R4
1299	3D6
1612	6L7
1614	6L6
1620	6J7
1634	12SC7
1644	12L8
5517	CK1003
5590	5591, 9001, 9003
5591	5590
5608-A	53
5654	6AJ5, 6AK5
5672	5678
5678	5672
5691	6SN7, 5692
5692	5691, 6SN7
5693	6SJ7
5725	6AJ5, 6AK5
5731	955
5824	25A6, 25B6, 25C6, 25L6
5881	6L6GC, 7581, 7581A
5910	1U4
5915	6BE6
6080	6AS7
7025	7025A, 12AX7, 12AX7A, 12DF7, 12DT7
7247	12DW7
7408	6V6
7543	6AU6, 6AU6A
7581	7581A, 6L6GC
XXB	3C6
XXD	14AF7
XXFM	7X7
XXL	7A4
X155	6BC8, 6BQ7, 6BQ7A, 6BS8, 6BX8, 6BZ7, 6BZ8

Directly Interchangeable Tubes

Foreign to American Tubes

Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube
1C1	1R5	5M-HH3	5J6	6F22	6267
1C2	1AC6	5P29	6CN6	6F23	6EL7
1C3	1AB6	5S1	807	6F24	6EJ7
1D13	1A3	6AT7N	6DT8	6F25	6EH7
1F2	1L4	6B32	6AL5	6F26	6BY7
1F3	1T4	6BC32	6AV6	6F31	6BA6
1FD1	1AH5	6CC31	6J6	6F33	6AS6
1FD9	1S5	6D2	6AL5	6F36	6AH6
1H35	1AB6	6F10	6AC7	6FD12	6DC8
1P1	3C4	6F12	6AM6	6G-B3A	6GW6
1P10	3S4	6F16	6CJ5	6G-B6	6BQ6GT
1P11	3V4	6F18	6EC7	6G-B9	6DQ6A
4R-HH2	4BS8	6F19	6BY7	6G-K17	6AU4GT
4Y25	807	6F21	6CQ6	6H31	6BE6

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Directly Interchangeable Tubes—(Continued)

Foreign to American Tubes

Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube
6L10	6AG7	30P16	16A5	DF904	1U4
6L12	6AQ8	30P18	15CW5	DH77	6AT6
6L13	12AX7	30P19	25GF6	DH118	14L7
6L31	6AQ5	30PL1	13GC8	DH142	14L7
6L34	6AQ4	30PL13	16GK8	DH149	7C6
6L43	6CL6	52KU	5Z4G	DH150	6CV7
6LD3	6CV7	62DDT	6CV7	DH719	6AK8
6LD12	6AK8	62TH	6CU7	DK32	1A7GT
6LD13	6BD7	62VP	6CJ5	DK91	1R5
6M-HH3	6J6	63TP	6AB8	DK92	1AC6
6P9	6BM5	64ME	6CD7	DK96	1AB6
6P15	6BQ5	64SPT	6BX6	DL33	3Q5GT
6P17	6AM5	65ME	6BR5	DL35	1C5GT
6R-HH2	6BS8	66KU	6BT4	DL36	1Q5GT
6R-R8C	5847	67PT	6CK5	DL91	1S4
6S5G	6E5	108C1	0B2	DL92	3S4
6Z4	6BX4	121VP	12AC5	DL93	3A4
6Z31	6X4	141DDT	14L7	DL94	3V4
7D9	6AM5	141TH	14K7	DL95	3Q4
7D10	6CH6	150C2	0A2	DL96	3C4
7F16	6CJ5	150C3	0D3	DM70	1M3
8A8	9A8	171DDP	17C8	DM71	1N3
8D3	6AM6	213PEN	21A6	DY30	1B3GT
8D5	6BR7	311SU	31A3	DP61	6AK5
8D6	6BW7	451PT	45A5	DY70	5642
8D7	6BS7	A1834	6AS7G	DY80	1X2A
8D8	6267	AD	6Z3	DY86	1S2
8R-HP1	6CQ6	B36	12SN7GT	DY87	1S2A
9D6	6CQ6	B152	12AT7	EAA91	6AL5
9P5	9BM5	B309	12AT7	EABC80	6AK8
10C14	19D8	B319	7AN7	EAF42	6CT7
10LD3	14L7	B329	12AU7	EB91	6AL5
10P18	45B5	B339	12AX7	EBC41	6CV7
10PL12	50BM8	B739	12AT7	EBC8	6BD7
12BC32	12AV6	B749	12AU7	EBC90	6AT6
12F31	12BA6	B759	12AX7	EBC91	6AV6
12G-B3	12GW6	BF61	6CK5	EBF80	6N8
12G-B6	12BQ6GT	BPM04	6AQ5	EBF81	6AD8
12G-K17	12D4A	D2M9	6AL5	EBF83	6DR8
12H31	12BE6	D63	6H6	EBF89	6DC8
13D2	6SN7GT	D77	6AL5	EC84	6AJ4
17N8	17C8	D152	6AL5	EC86	6CM4
18AK5	6028	D717	6AL5	EC90	6C4
19AJ8	19D8	DA90	1A3	EC91	6AQ4
19BD	19X3	DAC32	1H5GT	EC92	6AB4
19M-R9	18GD6	DAF91	1S5	EC94	6AF4
19SU	19Y3	DAF92	1U5	EC95	6ER5
19U3	19X3	DAF96	1AH5	EC97	6FY5
20D3	12AH8	DD6	6AL5	ECC81	12AT7
20D4	6AJ8	DD7	6AM5	ECC82	12AU7
25G-B6	25BQ6GT	DDR7	6AM5	ECC83	12AX7
30C1	9A8	DF33	1N5GT	ECC84	6CW7
30F5	7ED7	DF62	1AD4	ECC85	6AQ8
30L1	7AN7	DF91	1T4	ECC86	6GM8
30L15	7EK7	DF92	1L4	ECC88	6DJ8
30P4	25GF6	DF96	1AJ4	ECC89	6FC7
30P12	12FB5	DF97	1AN5	ECC91	6J6

Directly Interchangeable Tubes—(Continued)
Foreign to American Tubes

Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube
ECC180	6BQ7A	EM81	6DA5	N77	6AM5
ECC189	6ES8	EM84	6FG6	N78	6BJ5
ECC230	6080	EM840	6FG6	N119	45B5
ECF80	6BL8	EQ80	6BE7	N142	45A5
ECF82	6U8	EY80	6U3	N144	6AM5
ECF86	6HG8	EY81	6R3	N150	6CK5
ECH42	6CU7	EY82	6N3	N152	21A6
ECH80	6AN7	EY86	6S2	N153	15A6
ECH81	6AJ8	EY87	6S2A	N154	16A5
ECH83	6DS8	EY88	6AL3	N308	25E5
ECL80	6AB8	EZ35	6X5G	N309	15A6
ECL82	6BM8	EZ40	6BT4	N329	16A5
ECL84	6DX8	EZ80	6V4	N359	21A6
ECL86	6GW8	EZ81	6CA4	N709	6BQ5
EF41	6CJ5	EZ90	6X4	OBC3	12SQ7
EF80	6BX6	EZ91	6AV4	OF1	6S7
EF81	6BH5	GZ30	5AZ4	OH4	12A8
EF82	6CH6	GZ32	5V4G	OSW2190	6AC7
EF85	6BY7	GZ34	5AR4	OSW2192	6AG7
EF86	6267	H63	6F5GT	OSW2600	6AC7
EF89	6DA6	HAA91	12AL5	OSW2601	6AG7
EF89F	6DG7	HABC80	19T8	OSW3104	6SA7
EF91	6AM6	HBC90	12AT6	OSW3105	6SQ7
EF92	6CQ6	HBC91	12AV6	OSW3106	6V6GT
EF93	6BA6	HCC85	17EW8	OSW3109	6H6
EF94	6AU6	HCH81	12AJ7	OSW3110	6E5
EF95	6AK5	HD14	1H5GT	OSW3111	6SK7
EF96	6AG5	HF61	6CJ5	OSW3112	6J5
EF97	6ES6	HF93	12BA6	P17A	807
EF98	6ET6	HF94	12AU6	PABC80	9AK8
EF183	6EH7	HF121	12AC5	PC86	4CM4
EF184	6EJ7	HK90	12BE6	PC95	4GK5
EF190	6CB6	HL90	19AQ5	PCC84	7AN7
EH90	6CS6	HL92	50C5	PCC85	9AQ8
EK90	6BE6	HL94	30A5	PCC88	7DJ8
EL34	6CA7	HM04	6BE6	PCC89	7FC7
EL36	6CM5	HP6	6AM6	PCF80	9A8
EL37	6L6	HY90	35W4	PCF82	9U8
EL38	6CN6	KT32	25W6GT	PCF86	7HG8
EL41	6CK5	KT63	6F6G	PCL82	16A8
EL80	6M5	KT66	6L6GC	PCL84	15DQ8
EL81	6CJ6	KT71	50L6GT	PF9	6K7
EL82	6DY5	KT77	6CA7	PH4	6A8
EL83	6CK6	KT88	6550	PL36	25E5
EL84	6BQ5	KTW61	6S7	PL81	21A6
EL85	6BN5	L63	6J5	PL82	16A5
EL86	6CW5	L77	6C4	PL83	15A6
EL90	6AQ5	LN152	6AB8	PL84	15CW5
EL91	6AM5	LZ319	9A8	PL500	27GB5
EL95	6DL5	LZ329	9A8	PL820	21A6
EL180	12BY7	N14	1C5GT	PL1267	0A4G
EL500	6GB5	N15	3Q5GT	PLL80	12HU8
EL821	6CH6	N16	3Q5GT	PM04	6BA6
EL822	6CH6	N17	3S4	PM07	6AM6
ELL80	6HU8	N18	3Q4	PY80	19X3
EM34	6CD7	N19	3V4	PY81	17Z3
EM80	6BR5	N25	3C4	PY82	19Y3

Directly Interchangeable Tubes—(Continued)
Foreign to American Tubes

Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Replace with American Tube
PY83	17Z3	UBC81	14G6	X63	6A8
QB65	6SN7GT	UBF80	17C8	X64	6L7
QB309	12AT7	UCH42	14K7	X77	6BE6
QE06/50	807	UCH81	19D8	X81	7S7
QL77	6C4	UCL82	50BM8	X119	19B8
QV05-25	807	UF41	12AC5	X142	14K7
QW77	6CQ6	UL41	45A5	X148	7S7
QZ77	6AM6	UL84	45B5	X719	6AJ8
R16	1T2	UU12	6CA4	X727	6BE6
R19	1X2A	UY41	31A3	XC95	2ER5
R52	5Z4G	UY42	31A3	XCC189	4ES8
SP6	6AM6	UY85	38A3	XCF80	4BL8
STV108/30	0B2	UY89	38A3	XF183	3EH7
STV150/30	0A2	V2M70	6X4	XF184	3EJ7
T2M05	6J6	V61	6BT4	XL36	13CM5
TM12	6J4	V884	6CQ6	XL84	8BQ5
U26	2J2	VP6	6CQ6	Y25	1M3
U37	1T2	VP12D	12C8	YF88	16AQ3
U41	1B3GT	W17	1T4	YF183	4EH7
U50	5Y3GT	W25	1AJ4	YF184	4EJ7
U52	5U4G	W61	6K7	Z14	1N5GT
U70	6X5G	W63	6K7	Z63	6J7
U76	35Z5GT	W76	12K7	Z77	6AM6
U119	38A3	W77	6CQ6	Z152	6BX6
U142	31A3	W119	13EC7	Z300T	0A4G
U147	6X5G	W142	12AC5	Z719	6BX6
U149	7Y4	W148	7A7	Z729	6267
U150	6BT4	W149	7B7	ZD17	1S5
U152	19X3	W719	6BY7	ZD25	1AH5
U153	17Z3	W727	6BA6	ZD152	6N8
U154	19Y3	W739	6EC7		
U192	19Y3	WD142	12S7		
U309	19X3	WD150	6CT7		
U319	19Y3	WD709	6N8		
U381	38A3	X14	1A7GT		
U707	6X4	X17	1R5		
UAA91	12AL5	X18	1AC6		
UAF42	12S7	X20	1AC6		
UBC41	14L7	X25	1AB6		

See Below to Page 58 for Listing of American to Foreign Directly Interchangeable Tubes.

Directly Interchangeable Tubes
American to Foreign Tubes

American Tube Number	Replace with Foreign Tube	American Tube Number	Replace with Foreign Tube	American Tube Number	Replace with Foreign Tube
0A2	150C2 M8223 STV150/30	0B2	108C1 M8224 STV108/30	1A3	1D13 DA90
0A4G	PL1267 Z300T	0D3	150C3	1A7GT	DK32 X14

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
1AB6	1C3 1H35 DK96 X25
1AC6	1C2 DK92 X18 X20
1AD4	DF62
1AH5	1FD1 DAF96 ZD25
1AJ4	1F1 DF96 W25
1AN5	DF97
1B3GT	DY30 U41
1C5GT	DL35 N14
1E3	DC80
1H5GT	DAC32 HD14
1L4	1F2 DF92
1M3	DM70 DM71 Y25
1N3	DM70 DM71 Y25
1N5GT	DF33 Z14
1Q5GT	DL36
1R5	1C1 DK91 X17
1S2	DY86
1S2A	DY87
1S4	DL91
1S5	1FD9 DAF91 ZD17
1T2	R16 U37
1T4	1F3 DF91 W17
1U4	DF904
1U5	DAF92
1V6	DCF60
1X2A	DY80 R19
2ER5	XC95
2J2	U26
3A4	DL93
3C4	1P1 DL96 N25
3D6	DL29
3EH7	XF183
3EJ7	XF184
3Q4	DL95 N18
3Q5GT	DL33 N15 N16
3S4	1P10 DL92 N17
3V4	1P11 DL94 N19
4BL8	XCF80
4BS8	4R-HH2
4CM4	PC86
4EH7	Y183
4EJ7	Y184
4ES8	XCC189
4GK5	PC95
5AR4	GZ34 U77
5AZ4	GZ30
5J6	5M-HH3
5T4	U52
5U4G	U52
5V4G	53KU 54KU GZ32 GZ33 U77
5Y3GT	V50
5Z4G	52KU GZ30 R52 U77
6A6	B63
6A8	PH4 X63
6AB4	EC92
6AB8	63TP ECL80 LN152
6AC7	6F10 OSW2190 OSW2600
6AD8	EBF81
6AF4	EC94
6AG5	EF96
6AG7	6L10 OSW2192 OSW2601
6AH6	6F36
6AJ4	EC84
6AJ8	6C12 20D4 ECH81 X719
6AK5	DP61
6AK8	6LD12 DH719 EABC80
6AL3	EY88
6AL5	6B32 6D2 D2M9 D77 D152 D717 DD6 EAA91 EB91 EAA901 EAA901S M8079 M8212 QA2404

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
6AM5	6P17, 7D9, DD7, DDR7, EL91, N77, N144, QA2402
6AM6	6F12, 8D3, EF91, HP6, M8083, PM07, QA2403, QZ77, SP6, Z77
6AN7	ECH80
6AQ4	6L34, EC91, M8099
6AQ5	6L31, BPM04, EL90, M8245
6AQ8	6L12, ECC85
6AS6	6F33, M8196
6AS7G	A1834, ECC230
6AT6	DH77, EBC90
6AU4GT	6G-K17
6AU6	EF94
6AV4	EZ91
6AV6	6BC32, EBC91
6BA6	6F31, EF93, M8101, PM04, W727
6BD7	6LD13, EBC81
6BE6	6H31, EK90, HM04, X77, X727
6BE7	EQ80
6BH5	EF81
6BH6	E90F
6BJ5	N78
6BJ6	E99F
6BL8	ECF80
6BM5	6P9
6BM8	ECL82
6BN5	EL85
6BQ5	EL84, N709
6BQ6GT	6G-B6
6BQ7A	ECC180
6BR5	65ME, EM80
6BR7	8D5
6BS7	8D7
6BS8	6R-HH2
6BT4	66KU, EZ40, U150, V61
6BW7	8D6
6BX4	6Z4
6BX6	64SPT, EF80, Z152, Z719
6BY7	6F19, 6F26, EF85, W719
6C4	EC90, L77, M8080, QA2401, QL77
6CA4	EZ81, UU12
6CA7	EL34, KT77
6CB6	EF190
6CD7	64ME, EM34
6CF6	EF190
6CH6	7D10, EF82, EL821, EL822
6CJ5	6F16, 7F16, 62VP, EF41, HF61
6CJ6	EL81, EL820
6CK5	67PT, BF61, EL41, N150
6CK6	EL83
6CL6	6L43
6CM4	EC86
6CM5	EL36
6CN6	EL38, 5P29
6CQ6	6F21, 9D6, EF92, M8161, QA2400, QW77, V884, VP6, W77
6CS6	EH90
6CT7	EAF42, WD150
6CU7	62TH, ECH42, ECH43
6CV7	6LD3, 62DDT, DH150, DH718, EBC41

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
6CW5	EL86
6CW7	ECC84
6DA5	EM81
6DA6	EF89
6DC8	6FD12 EBF89
6DG7	EF89E
6DJ8	ECC88
6DL5	EL95
6DQ6A	6G-B9
6DR8	EBF83
6DS8	ECH83
6DT8	6AT7N
6DX8	ECL84
6DY5	EL82
6E5	6S5G OSW3110
6EC7	6F18 W739
6EH7	6F25 EF183
6EJ7	6F24 EF184
6EL7	6F23
6ER5	EC95
6ES6	EF97
6ES8	ECC189
6ET6	EF98
6F5GT	H63
6F6G	KT63
6FC7	ECC89
6FG6	EM84 EM840
6FY5	EC97
6GB5	EL500
6GM8	ECC86
6GW8	ECL86
6H6	D63 OSW3109
6HG8	ECF86
6HU8	ELL80
6J4	M8232 TM12
6J5	L63 OSW3112
6J6	6CC31 6M-HH3 ECC91 M8081 T2M05
6J7	A863 Z63
6K7	PF9 W61 W63
6L6	EL37
6L6GC	KT66
6L7	X64
6M5	EL80
6N3	EY82
6N8	EBF80 WD709 ZD152
6Q7	DH63
6R3	EY81
6S2	EY86
6S2A	EY87
6S7	KTW61 OF1
6SA7	OSW3104
6SK7	OSW3111
6SN7GT	13D2 B65 QA2408 QB65
6SQ7	OSW3105
6T8	6LD12 DH719 EABC80
6U3	EY80
6U8	ECF82
6V4	EZ80
6V6GT	OSW3106
6X4	6Z31 EZ90 U707 V2M70
6X5G	EZ35 U70 U147
7AN7	30L1 B319 PCC84
7A7	W148
7B6	DH81
7B7	W149
7C6	DH149
7DJ8	PCC88
7ED7	30F5
7EK7	30L15
7FC7	PCC89
7HG8	PCF86
7S7	X81 X148
7Y4	U149
8B8	8R-HP1
8BQ5	XL84
9A8	8A8 30C1 LZ319 LZ329 PCF80
9AK8	PABC80
9AQ8	PCC85
9BM5	9P9
9EN7	30C15
9GB8	30PL1
9U8	PCF82
12A8	OH4
12AC5	121VP HF121 UF41 WF41 W142
12AH8	20D3
12AJ7	HCH81
12AL5	HAA91 UAA91
12AT6	HBC90
12AT7	B152 B309 B739 ECC81 M8162 QA2406 QB309

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
12AU6	HF94
12AU7	B329, B749, ECC82, M8136
12AV6	12BC32, HBC91
12AX7	6L13, B339, B759, ECC83, M8137
12BA6	12F31, HF93
12BE6	12H31, HF90
12BQ6GT	12G-B6
12BY7	EL180
12C8	VP12D
12DF7	ECC83
12DT7	ECC83
12FB5	30P12
12HU8	PLL80
12K7	W76
12Q7GT	DH74, DH76
12SN7GT	B36
12SQ7	OBC3
12SX7GT	B36
13CM5	XL36
13EC7	10F18, W119
13GC8	30PL1
14G6	UBC81
14K7	141TH, UCH42, UCH43, X142
14L7	10LD3, 141DDT, DH118, DH142, UBC41
15A6	N153, N309, PL83
15CW5	30P18, PL84
15DQ8	PCL84
16A5	30P16, 163PEN, N154, N329, PL82, PL87
16A8	PCL82
16AQ3	XY88
16GK8	30PL13, 30PL14
17C8	17N8, 171DDP, UBF80
17EW8	HCC85
17Z3	PY81, PY83, U153
18GD6	19M-R9
19AQ5	HL90
19CS4	U191
19D8	10C14, UCH81, X119
19T8	HABC80
19X3	19BD, 19U3, PY80, U152, U309
19Y3	19SU, PY82, U154, U192, U319
21A6	213PEN, N152, N359, PL81, PL820
25BQ6GT	25G-B6
25E5	N308, PL36
25GF6	30P4
25W6	KT32
27GB5	PL500
30A5	HL94
31A3	311SU, U142, UY41, UY42
35W4	HY90
35Z4GT	U76
38A3	U119, U381, UY85
45A5	451PT, BF451, N142, UL41
45B5	10P18, N119, UL84
50BM8	10PL12, UCL82
50C5	HL92
50L6GT	KT71
807	4Y25, 5S1, P17A, QE06/50, QV05-25
5642	DY70
5847	6R-R8C
6080	A1834, ECC230
6267	8D8, 6F22, EF86, M8195, Z729
6550	KT88
7025	B339, B759, ECC83, M8137
7543	EF94
7581	KT66

Directly Interchangeable TV Picture Tubes

Tube Number	Replace with
7NP4	7WP4*
7WP4	7NP4
8AP4	8AP4A
8AP4A	8AP4
9AQP4	9AQP4A
9AQP4A	9AQP4
10ABP4	10ABP4A 10ABP4B 10ABP4C
10BP4	10BP4A 10FP4*
10BP4A	10FP4A*
10EP4	10CP4
10FP4	10FP4A
10FP4A	10FP4
10MP4	10MP4A
10MP4A	10MP4
12KP4	12KP4A
12KP4A	12KP4
12LP4	12LP4A 12LP4C 12KP4* 12KP4A*
12LP4A	12LP4 12LP4C 12KP4* 12KP4A*
12LP4C	12LP4 12LP4A 12KP4* 12KP4A*
12QP4	12QP4A 12RP4 12JP4*
12QP4A	12QP4 12RP4 12JP4*
12RP4	12JP4* 12QP4 12QP4A
12TP4	12LP4• 12LP4A• 12LP4C•
12UP4	12UP4A
12VP4	12VP4A
12XP4	12ZP4 12ZP4A
12ZP4	12ZP4A 12KP4* 12KP4A*
12ZP4A	12ZP4 12KP4* 12KP4A*
14ACP4	14AEP4*
14AJP4	14ASP4* 14AVP4*
14ASP4	14AVP4
14AUP4	14AWP4
14AVP4	14ASP4
14AWP4	14AUP4
14BP4	14BP4A 14CP4 14CP4A 14EP4
14BP4A	14BP4 14CP4 14CP4A 14EP4
14CP4	14CP4A 14BP4 14BP4A 14EP4
14CP4A	14CP4 14BP4 14BP4A 14EP4
14DP4	14UP4*
14EP4	14BP4 14BP4A 14CP4 14CP4A
14FP4	14UP4* 14CP4• 14CP4A• 14EP4•
14KP4	14KP4A
14NP4	14NP4A 14SP4 14WP4* 14ZP4*
14NP4A	14NP4 14SP4 14WP4* 14ZP4*
14QP4	14QP4A 14HP4
14QP4A	14QP4 14HP4
14RP4	14RP4A 14NP4 14NP4A 14SP4 14WP4* 14ZP4*
14RP4A	14RP4 14NP4 14NP4A 14SP4 14WP4* 14ZP4*
14SP4	14NP4 14NP4A 14WP4* 14ZP4*
14WP4	14ZP4
14XP4	14XP4A
14XP4A	14XP4
14ZP4	14WP4
15CP4	15AP4* 15DP4• 15DP4A•
15DP4	15DP4A 15AP4*
15DP4A	15DP4 15DP4*
16AEP4	16ARP4
16AP4	16AP4A 16AP4B
16AP4A	16AP4 16AP4B
16AP4B	16AP4 16AP4A

•Connect external connector to chassis.

*Remove ion trap

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
16CP4	15CP4
16DP4	16DP4A, 16HP4•
16DP4A	16DP4
16EP4	16EP4A, 16EP4B
16GP4	16GP4A, 16GP4B, 16GP4C
16GP4C	16GP4, 16GP4A, 16GP4B
16HP4	16HP4A
16HP4A	16HP4
16JP4	16HP4, 16HP4A, 16JP4A
16JP4A	16HP4, 16HP4A, 16JP4
16KP4	16KP4A, 16RP4, 16RP4A
16KP4A	16TP4
16LP4	16LP4A, 16ZP4
16LP4A	16LP4, 16ZP4
16MP4	16MP4A
16MP4A	16MP4
16QP4	16XP4
16RP4	16KP4, 16KP4A, 16TP4
16RP4A	16RP4, 16KP4, 16KP4A
16SP4	16SP4A
16SP4A	16SP4
16VP4	16YP4•
16WP4	16SP4•, 16SP4A•, 16WP4A•, 16WP4B•
16GP4A	16GP4, 16GP4B, 16GP4C
16GP4B	16GP4, 16GP4A, 16GP4C
16KP4A	16KP4, 16RP4, 16RP4A
16MP4	16MP4A, 16JP4, 16JP4A, 16HP4, 16HP4A
16MP4A	16MP4, 16JP4, 16JP4A, 16HP4, 16HP4A
16RP4	16RP4A, 16KP4, 16KP4A
16RP4A	16RP4, 16KP4, 16KP4A
16UP4	16XP4•
16WP4A	16SP4, 16SP4A
16XP4	16QP4
17ATP4	17ATP4A, 17AVP4, 17AVP4A, 17BUP4, 17CBP4, 17CLP4, 17BJP4*, 17DCP4*
17ATP4A	17ATP4, 17AVP4, 17AVP4A, 17AUP4, 17CBP4, 17CLP4, 17BJP4*, 17DCP4*
17AVP4	17AVP4A, 17ATP4, 17ATP4A, 17BUP4, 17CBP4, 17CLP4, 17BJP4*, 17DCP4*
17AVP4A	17AVP4, 17ATP4, 17ATP4A, 17BUP4, 17CBP4, 17CLP4, 17BJP4*, 17DCP4*
17BJP4	17CZP4
17BKP4	17BKP4A
17BKP4A	17BKP4
17BMP4	17BNP4*
17BP4	17AP4•, 17BP4A•, 17BP4B•, 17BP4C•, 17JP4•
17BP4A	17AP4, 17BP4B, 17BP4C, 17JP4
17BP4B	17AP4, 17BP4A, 17BP4C, 17JP4
17BP4C	17AP4, 17BP4A, 17BP4B, 17JP4
17BRP4	17CKP4*
17BUP4	17CBP4
17BVP4	17BWP4*, 17CSP4*
17BWP4	17CSP4
17BZP4	17CAP4, 17CKP4, 17CWP4, 17DSP4

•Connect external connector to chassis.

*Remove ion trap.

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
17CAP4	17BZP4 17CKP4 17CWP4 17DSP4
17CBP4	17BUP4
17CFP4	17CYP4
17CKP4	17DSP4
17CLP4	17ATP4 17ATP4A 17AVP4 17AVP4A 17BUP4 17CBP4 17BJP4*
17CP4	17CP4A
17CP4A	17CP4
17CRP4	17CXP4
17CSP4	17BWP4
17CTP4	17DHP4 17EBP4
17CUP4	17DCP4
17CWP4	17DSP4 17DTP4
17CXP4	17CRP4
17CYP4	17CFP4
17DAP4	17DRP4
17DCP4	17CUP4
17DHP4	17EBP4
17DLP4	17DSP4
17DRP4	17DAP4
17FP4	17FP4A
17FP4A	17FP4
17HP4	17HP4A 17HP4B 17KP4 17KP4A 17RP4 17RP4C 17DWP4*
17HP4A	17HP4 17HP4B 17KP4 17KP4A 17RP4 17RP4C 17DWP4*
17HP4B	17HP4 17HP4A 17KP4 17KP4A 17RP4 17RP4C 17DWP4*
17JP4	17AP4 17BP4A 17BP4B 17BP4C
17KP4	17KP4A
17KP4A	17KP4
17LP4	17LP4A 17VP4 17VP4B
17LP4A	17LP4 17VP4 17VP4B
17QP4	17QP4A 17YP4
17QP4A	17QP4 17YP4
17RP4	17RP4C 17HP4 17HP4A 17HP4B 17KP4 17KP4A 17DWP4*
17RP4C	17RP4 17HP4 17HP4A 17HP4B 17KP4 17KP4A 17DWP4*
17UP4	17QP4 17QP4A 17YP4
17VP4	17VP4B 17LP4 17LP4A
17VP4B	17VP4 17LP4 17LP4A
17YP4	17QP4A
19ACP4	19CHP4 19CKP4
19AFP4	19AUP4
19AP4	19AP4A 19AP4B 19AP4C 19AP4D
19AP4A	19AP4 19AP4B 19AP4C 19AP4D
19AP4B	19AP4 19AP4A 19AP4C 19AP4D
19AP4C	19AP4 19AP4A 19AP4B 19AP4D
19AP4D	19AP4 19AP4A 19AP4B 19AP4C
19AUP4	19AFP4
19AXP4	19AYP4
19BAP4	19BCP4 19CEP4
19BCP4	19BAP4 19CEP4
19BHP4	19AVP4
19BLP4	19AVP4 19BHP4 19XP4
19BNP4	19BQP4
19BQP4	19BNP4
19CFP4	19CHP4 19CKP4
19CHP4	19CKP4
19CKP4	19CHP4
19CLP4	19BDP4
19DP4	19DP4A
19DP4A	19DP4
19EP4	19JP4

•Connect external connector to chassis.

*Remove ion trap.

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
19FP4	19DP4• 19DP4A• 19GP4
19GP4	19DP4 19DP4A
19JP4	19EP4
19XP4	19AVP4
19YP4	19BTP4
19ZP4	19AVP4 19BLP4 19XP4
20CP4	20CP4B 20CP4C 20DP4 20DP4B 20CP4A 20CP4D 20DP4A 20DP4C
20CP4A	20CP4D 20DP4A 20DP4C
20CP4B	20CP4 20CP4C 20DP4 20DP4B 20CP4A• 20CP4D• 20DP4A• 20DP4C•
20CP4C	20CP4 20CP4B 20DP4 20DP4B 20CP4A• 20CP4D• 20DP4A• 20DP4C•
20CP4D	20CP4A 20DP4A 20DP4C
20DP4	20CP4 20CP4C 20CP4A• 20DP4A•
20FP4	20GP4•
20HP4	20HP4A• 20HP4B 20HP4C 20HP4D• 20JP4• 20LP4• 20MP4•
20HP4A	20HP4B• 20HP4D 20JP4 20LP4 20MP4
20HP4B	20HP4 20HP4A• 20HP4C 20HP4D• 20JP4• 20LP4• 20MP4•
20HP4C	20HP4 20HP4A• 20HP4B• 20HP4D• 20JP4• 20LP4• 20MP4•
20HP4D	20HP4A 20JP4 20LP4 20MP4
20LP4	20HP4A 20HP4D 20JP4 20MP4
20MP4	20HP4A 20HP4D 20JP4 20LP4
21ACP4	21ACP4A 21BSP4 21CUP4
21ACP4A	21ACP4 21BSP4 21CUP4
21AFP4	21BCP4•* 21YP4• 21YP4A•
21ALP4	21ALP4A 21ALP4B 21ATP4 21ATP4A 21ATP4B 21BTP4 21CWP4 21BAP4* 21BNP4* 21CVP4*
21ALP4A	21ALP4 21ALP4B 21ATP4 21ATP4A 21ATP4B 21BTP4 21CWP4 21BAP4* 21BNP4* 21CVP4*
21ALP4B	21ATP4A 21ATP4B 21BTP4 21BAP4* 21BNP4* 21CVP4*
21AMP4	21AMP4A 21ACP4 21ACP4A 21BSP4 21CUP4
21AMP4A	21AMP4 21ACP4 21ACP4A 21BSP4 21CUP4
21ANP4	21ANP4A 21ALP4• 21ALP4A• 21ATP4• 21ATP4A• 21ATP4B• 21BAP4•* 21BNP4•* 21BTP4• 21CVP4•* 21CWP4•

•Connect external connector to chassis.

*Remove ion trap.

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
21ANP4A	21ANP4, 21ALP4•, 21ALP4A•, 21ALP4B•, 21ATP4•, 21ATP4A•, 21ATP4B•, 21BAP4•*, 21BNP4•*, 21BTP4•, 21CVP4•*, 21CWP4•
21AQP4	21AQP4A, 21ACP4•, 21ACP4A•, 21AMP4•, 21AMP4A•, 21BSP4•, 21CUP4•
21AQP4A	21AQP4, 21ACP4•, 21ACP4A•, 21AMP4•, 21AMP4A•, 21BSP4A•, 21CUP4•
21ARP4	21ARP4A
21ARP4A	21ARP4
21ASP4	21AYP4•, 21XP4•, 21XP4A•
21ATP4	21ATP4A, 21ATP4B, 21ALP4, 21ALP4A, 21ALP4B, 21BTP4, 21CWP4, 21BAP4*, 21BNP4*, 21CVP4*
21ATP4A	21ATP4B, 21ALP4B, 21BTP4, 21BAP4*, 21BNP4*, 21CVP4*
21ATP4B	21ATP4A, 21ALP4A, 21ALP4B, 21BTP4, 21CWP4, 21BAP4*, 21BNP4*, 21CVP4*
21AUP4	21AUP4A, 21AUP4B, 21AVP4, 21AVP4A, 21AVP4B, 21BDP4*
21AUP4A	21AUP4, 21AUP4B, 21AVP4, 21AVP4A, 21AVP4B, 21BDP4*
21AUP4B	21AUP4, 21AUP4A, 21AVP4, 21AVP4A, 21AVP4B, 21BDP4*
21AVP4	21AVP4A, 21AVP4B, 21AUP4, 21AUP4A, 21AUP4B, 21BDP4*
21AVP4A	21AVP4, 21AVP4B, 21AUP4, 21AUP4A, 21AUP4B, 21BDP4*
21AVP4B	21AVP4, 21AVP4A, 21AUP4, 21AUP4A, 21AUP4B, 21BDP4*
21AYP4	21XP4, 21XP4A
21BAP4	21BNP4, 21CVP4
21BNP4	21BAP4, 21CVP4
21BSP4	21ACP4, 21ACP4A, 21CUP4
21BTP4	21BAP4*, 21ALP4B, 21BNP4*, 21ATP4A, 21CVP4*
21CBP4	21CBP4A, 21CBP4B, 21DQP4, 21DRP4, 21FLP4
21CBP4A	21CBP4B, 21DRP4, 21FLP4
21CBP4B	21CBP4A, 21DRP4, 21FLP4
21CDP4A	21CDP4
21CEP4	21ECP4A
21CGP4	21CHP4*
21CKP4	21CBP4A
21CMP4	21DNP4, 21CBP4A*, 21CBP4B*, 21DRP4*, 21FLP4*
21CUP4	21ACP4, 21ACP4A, 21BSP4
21CVP4	21BAP4, 21BNP4
21CWP4	21ALP4A, 21ALP4B, 21ATP4, 21ATP4A, 21ATP4B, 21BTP4, 21BAP4*, 21BNP4*, 21CVP4*

•Connect external connector to chassis.
*Remove ion trap.

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
21CXP4	21DSP4
21CZP4	21DAP4* 21DEP4* 21DEP4A*
21DAP4	21DEP4 21DEP4A
21DEP4	21DEP4A 21DAP4
21DFP4	21CEP4 21CEP4A
21DLP4	21DQP4
21DRP4	21CBP4A 21CBP4B 21FLP4
21DSP4	21CXP4
21ELP4	21DJP4
21EP4	21EP4A 21EP4B
21EP4A	21EP4B
21EP4B	21EP4A
21FJP22	21FKP22
21FKP22	21FJP22
21FLP4	21CBP4A 21CBP4B 21DRP4
21FP4	21FP4A 21FP4C 21KP4 21KP4A
21FP4A	21FP4C 21KP4A
21FP4C	21FP4A 21KP4A
21JP4	21JP4A
21JP4A	21JP4
21KP4	21KP4A•
21WP4	21WP4A
21WP4A	21WP4
21XP4	21XP4A 21AYP4
21XP4A	21XP4 21AYP4
21YP4	21YP4A
21YP4A	21YP4
21ZP4	21ZP4A• 21ZP4B• 21AWP4•
21ZP4A	21ZP4B 21AWP4
21ZP4B	21ZP4A 21AWP4
22AP4	22AP4A
22AP4A	22AP4
23ACP4	23TP4
23AFP4	23BTP4 23BVP4
23AHP4	23AUP4 23CZP4
23ANP4	23ATP4 23BKP4 23BLP4
23ASP4	23AUP4
23ATP4	23ANP4 23BKP4 23BLP4
23AUP4	23CZP4
23AVP4	23BNP4 23CP4 23CP4A 23GP4
23AWP4	23BJP4
23AYP4	23BEP4 23BSP4 23SP4
23BAP4	23BP4
23BCP4	23CMP4
23BDP4	23BMP4 23BTP4 23YP4
23BEP4	23BSP4
23BGP4	23BHP4
23BHP4	23BGP4
23BKP4	23ANP4 23ATP4 23BLP4
23BLP4	23ANP4 23ATP4 23BKP4
23BMP4	23BDP4 23BTP4 23YP4
23BNP4	23CBP4 23CP4 23CP4A 23GP4 23SP4
23BP4	23BAP4
23BQP4	23CBP4
23BRP4	23BYP4 23CSP4 23RP4
23BSP4	23BEP4
23BVP4	23AFP4
23BYP4	23CSP4
23CBP4	23BQP4
23CP4	23CP4A 23BNP4
23CSP4	23BYP4
23CUP4	23DP4
23CUP4	23AUP4
23FP4	23FP4A
23GP4	23AVP4 23BNP4 23CP4 23CP4A
23HP4	23AVP4 23BNP4 23CP4 23CP4A 23GP4
23KP4	23KP4A

•Connect external connector to chassis.

**Remove ion trap.*

Directly Interchangeable TV Picture Tubes—(Continued)

Tube Number	Replace with
23MP4	23MP4A, 23FP4, 23FP4A
23MP4A	23FP4A
23RP4	23BRP4, 23BYP4, 23CSP4
23SP4	23AYP4, 23BEP4, 23BSP4
23UP4	23BQP4, 23CBP4
23WP4	23MP4, 23MP4A
23XP4	23BDP4, 23BMP4, 23BTP4, 23YP4
23YP4	23BDP4, 23BMP4, 23BTP4
24ADP4	24VP4, 24VP4A
24AEP4	24AUP4
24AHP4	24ALP4
24AJP4	24ATP4
24ALP4	24AHP4
24ANP4	24AUP4*
24AP4	24AP4A, 24AP4B
24AP4A	24AP4, 24AP4B
24AP4B	24AP4, 24AP4A
24CP4	24CP4A, 24ADP4, 24QP4, 24TP4, 24VP4, 24VP4A
24CP4A	24CP4, 24ADP4, 24TP4, 24VP4, 24VP4A
24DP4	24DP4A, 24ANP4, 24YP4, 24AEP4*, 24ZP4*
24DP4A	24DP4, 24ANP4, 24YP4, 24AEP4*, 24ZP4*
24QP4	24ADP4, 24CP4, 24CP4A, 24TP4, 24VP4, 24VP4A
24TP4	24ADP4, 24CP4, 24CP4A, 24VP4, 24VP4A
24VP4	24VP4A, 24ADP4
24VP4A	24VP4, 24ADP4
24XP4	24ADP4*, 24CP4*, 24CP4A*, 24TP4*, 24VP4*, 24VP4A*
24YP4	24AEP4*, 24ANP4, 24DP4, 24DP4A, 24ZP4*
24ZP4	24EP4
27EP4	27GP4, 27RP4•
27GP4	27EP4, 27RP4•
27NP4	27RP4
27SP4	27UP4
27UP4	27SP4
27VP4	27XP4

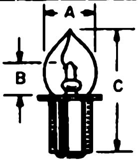
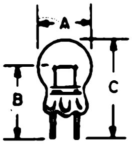
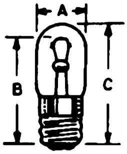
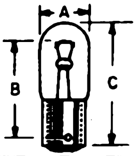
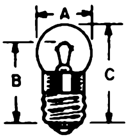
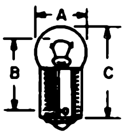
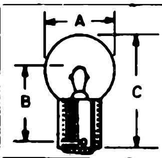
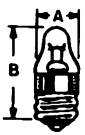
•Connect external connector to chassis.

*Remove ion trap.

Greek Alphabet Designations

Name	Capital	Lower Case	Commonly used to designate	Name	Capital	Lower Case	Commonly used to designate
Alpha	Α	α	Angles. Area. Coefficients	Nu	Ν	ν	Reluctivity
Beta	Β	β	Angles. Flux density. Coefficients	Xi	Ξ	ξ	Co-ordinates
Gamma	Γ	γ	Conductivity. Specific gravity	Omicron	Ο	ο	....
Delta	Δ	δ	Variation. Density	Pi	Π	π	3.1416 (Ratio of circumference to diameter)
Epsilon	Ε	ε	Base of natural logarithms	Rho	Ρ	ρ	Resistivity
Zeta	Ζ	ζ	Impedance. Coefficients. Coordinates	Sigma	Σ	σ	Sign of summation
Eta	Η	η	Hysteresis coefficient. Efficiency	Tau	Τ	τ	Time constant. Time phase displacement
Theta	Θ	θ	Temperature. Phase angle	Upsilon	Υ	υ	....
Iota	Ι	ι	Unit vector.	Phi	Φ	φ	Magnetic flux. Angles
Kappa	Κ	κ	Dielectric constant. Susceptibility	Chi	Χ	χ	Electric susceptibility. Angles
Lambda	Λ	λ	Wave length	Psi	Ψ	ψ	Dielectric flux. Phase difference
Mu	Μ	μ	Micro. Amplification factor. Permeability	Omega	Ω	ω	Capital, ohms. Lower case, angular velocity

Pilot Lamp Data

Bulb Silhouette	Maximum Size (See Chart Below) A	B	C	Bulb No.	Base	Bulb Type	Lamp Numbers
	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 Volts	Rating Amps.	Used For
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

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-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 7/32"	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 7/32"	Cand. Screw	2.0	110-125	¼
NE-58	7,500	1 7/32"	Cand. Screw	2.0	220-250	½
NE-79	10,000	2"	D.C. Bay	12.0	110-125	1

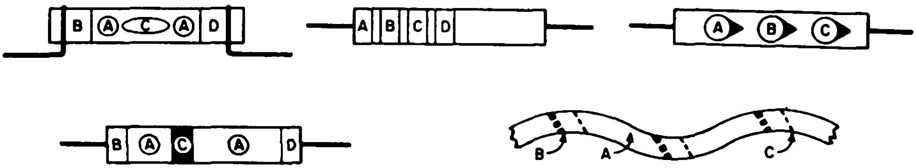
Argon Glow Lamps

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.
AR-1	1,000	3½"	Med. Screw	18.0	110-125	2
AR-3	150	1 7/32"	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.

Resistor Color Code

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



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%

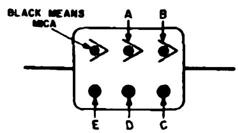
INSULATION CODING

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 resistance value.

Mica Capacitor Color Code

MILITARY STANDARD MIL-C-5B



Color	Digits of Capacitance ($\mu\mu f$) A	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 $\mu\mu f$)	7500
F	+70	±(0.05% +0.1 $\mu\mu f$)	7500

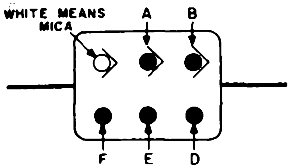
VOLTAGE RATING

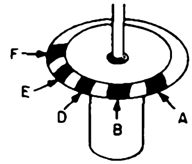
(Indicated by dimensions rather than color coding)

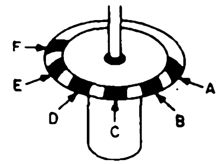
Maximum Inches Long	Wide	Thick	*Style CM*	*Capacitance ($\mu\mu f$)*	*Rating (v d-c)*
35/64	5/16	7/32	15	5–510	300
51/64	15/32	7/32	20	5–510 560–1000	500 300
1 7/64	15/32	7/32	25	51–1000	500
53/64	53/64	9/32	30	560–3300	500
53/64	53/64	11/32	35	3600–6200 6800–10,000	500 300
1 1/32	41/64	11/32	40	3300–8200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

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
—	——	——	——
—	——	——	——

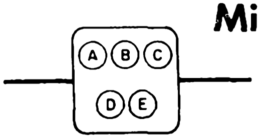
VOLTAGE RATING

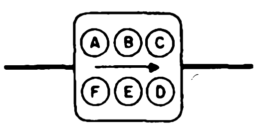
(Indicated by dimensions rather than color coding)

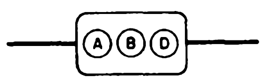
Maximum Inches Long	*Wide*	*Thick*	*Style*	*Capacitance (μμf)*	*Rating (v d-c)*
51/64	15/32	7/32	20	5-510 560–1000	500 300
1 7/64	15/32	7/32	25	5–1000 1100–1500	500 300
33/64	53/64	9/32	30	470–6200 Over 6200	500 300
53/64	53/64	3/8	35	3300–6200 Over 6200	500 300
1 1/32	41/64	11/32	40	100–2400 2700–7500 Over 7500	1000 500 300

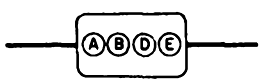
Mica Capacitor Color Code

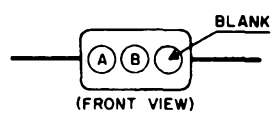
Obsolete Style

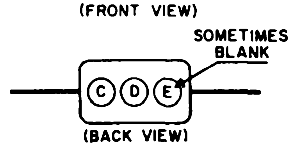






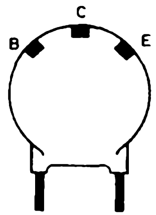




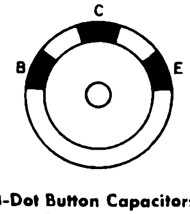


Dot Color	Digits of Capacitance (μμf) A	B	C	Multiplier D	Tolerance % E	Voltage Rating (v d-c) F
Black	0	0	0	1	± 20	—
Brown	1	1	1	10	± 1	100
Red	2	2	2	100	± 2	200
Orange	3	3	3	1,000	± 3	300
Yellow	4	4	4	10,000	± 4	400
Green	5	5	5	100,000	± 5	500
Blue	6	6	6	1,000,000	± 6	600
Violet	7	7	7	10,000,000	± 7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

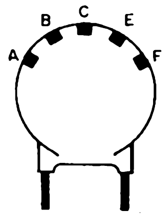
Ceramic Capacitor Color Code
EIA STANDARD RS-198
MILITARY STANDARD JAN-C-20A
Proposed Mil-C-20C



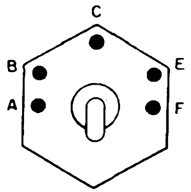
3-Dot Disc Capacitors
(RETMA ONLY)
(Voltage rating is always 500 v., tolerance is always —0.)



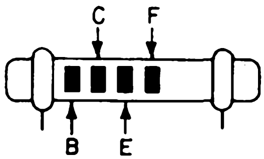
3-Dot Button Capacitors
(EIA ONLY)



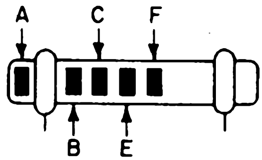
5-Dot Disc Capacitors
(EIA ONLY)
(Voltage rating is always 500 v.)



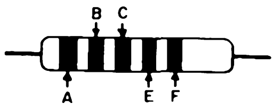
Feed Through Capacitors
(EIA ONLY)



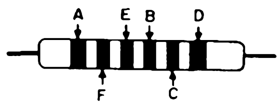
High Capacity Tubulars
(Insulated or Non-Insulated)



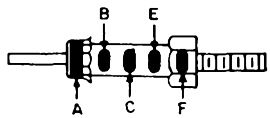
Temperature Compensating Tubulars



Tubular Capacitors
(Voltage rating is always 500 v.)



Tubular Capacitors
(Old RMA)



Stand-Off Capacitors
(EIA ONLY)

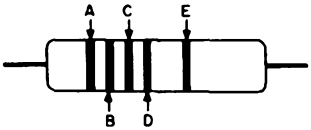
Color	Digits of Capacitance ($\mu\mu$f) B	C	D	Multiplier E	Tolerance F: 10 $\mu\mu$f or less ($\mu\mu$f)	Tolerance F: Over 10 $\mu\mu$f (%)	Temp. Coef. A (Parts per million per °C.): EIA	MILITARY
Black	0	0	0	1	±2.0	±20*	0	0
Brown	1	1	1	10	±0.1*	±1	— 33	— 30
Red	2	2	2	100	—	±2	— 75	— 80
Orange	3	3	3	1,000	—	±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

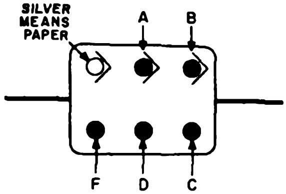
Paper Capacitor Color Code

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)



Tubular Capacitors (Commercial Only)



Rectangular Capacitors

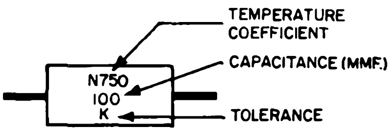
Color	Digits of Capacitance ($\mu\mu f$) A	B	Multiplier C	Tolerance % D	Tubular Voltage Rating (v d-c) E	Temp. Rating °C and Characteristic F
Black	0	0	1	± 20	—	85-A
Brown	1	1	10	—	100	85-E
Red	2	2	100	—	200	—
Orange	3	3	1,000	± 30	300	—
Yellow	4	4	10,000	—	400	—
Green	5	5	—	—	500	—
Blue	6	6	—	—	600	—
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)*
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
1 1/4	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 13/32	49/64	13/32	43	10,000 20,000–30,000 50,000–100,000 200,000	1000 600 400 120

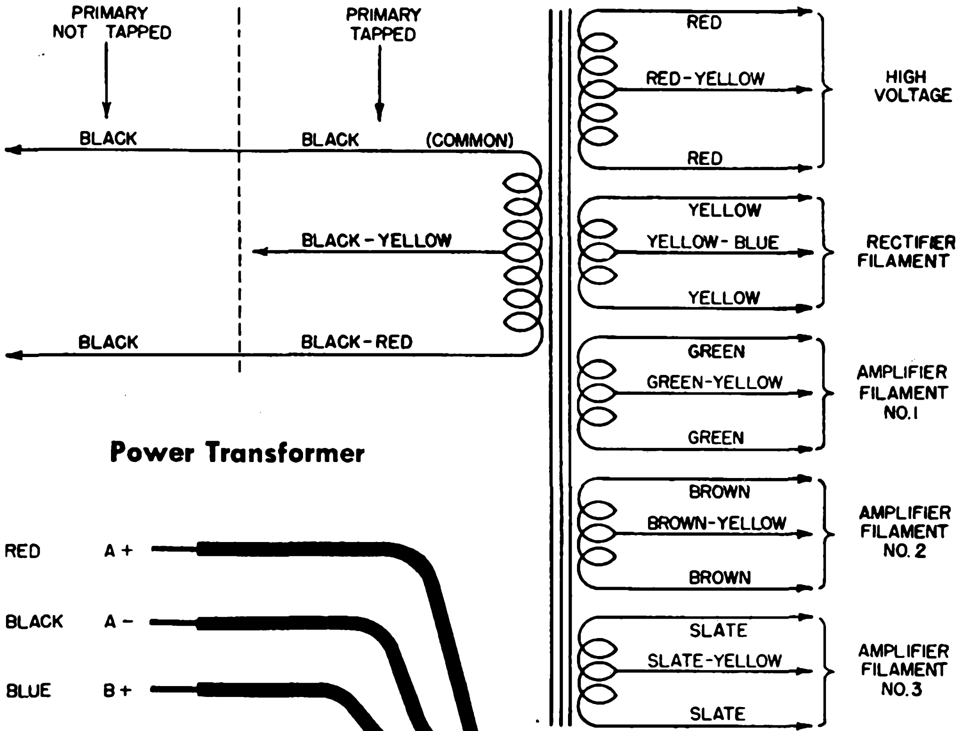
TYPOGRAPHICALLY MARKED TUBULAR CERAMICS



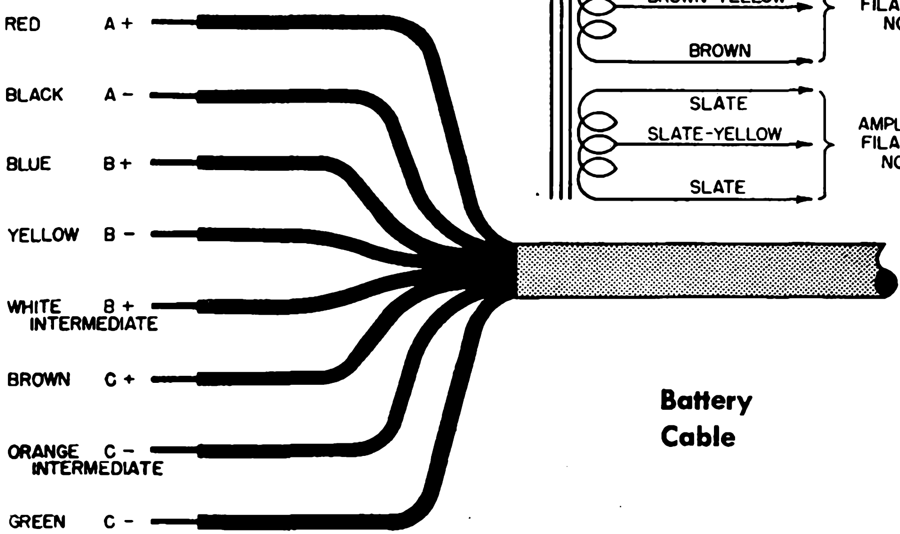
JAN LETTER	*TOLERANCE* *10 $\mu\mu f$ or Less*	*Over 10 $\mu\mu f$*
C	± 0.25 $\mu\mu f$	....
D	± 0.5 $\mu\mu f$	....
F	± 1.0 $\mu\mu f$	± 1%
G	± 2.0 $\mu\mu f$	± 2%
J	....	± 5%
K	....	± 10%
M	....	± 20%

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.

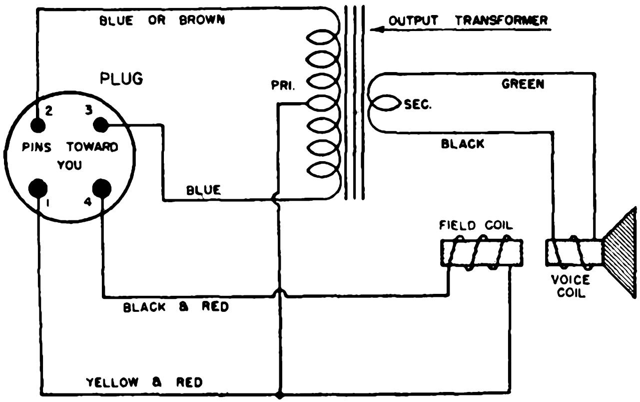


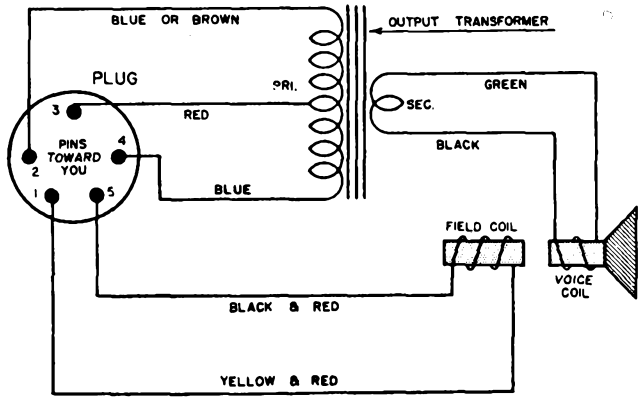
Power Transformer



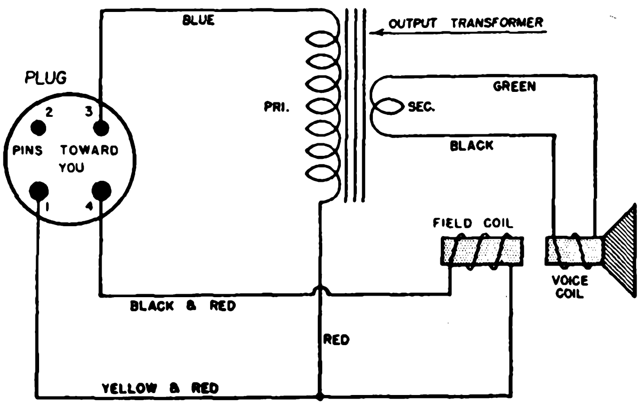
Battery Cable

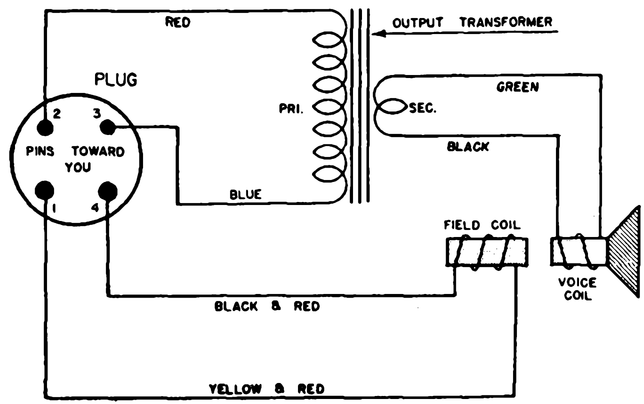
Speaker Leads and Plug Connections



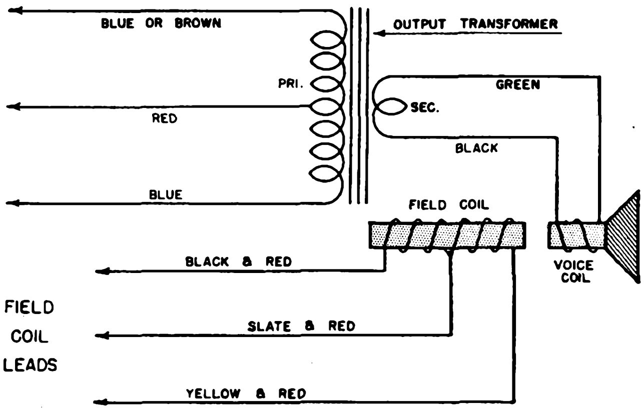


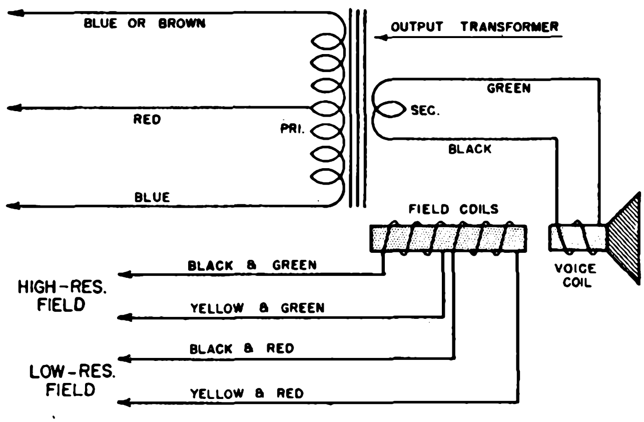
Speaker Leads and Plug Connections



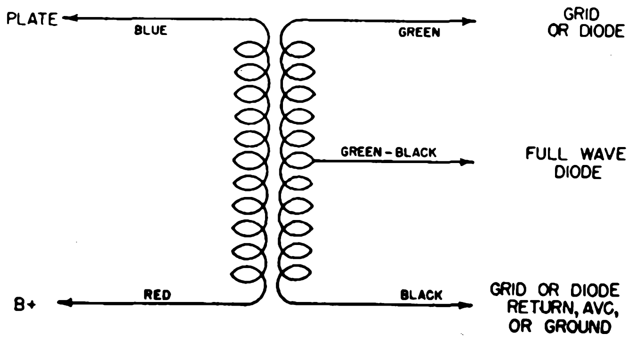


Speaker Lead Color Codes—(Continued)

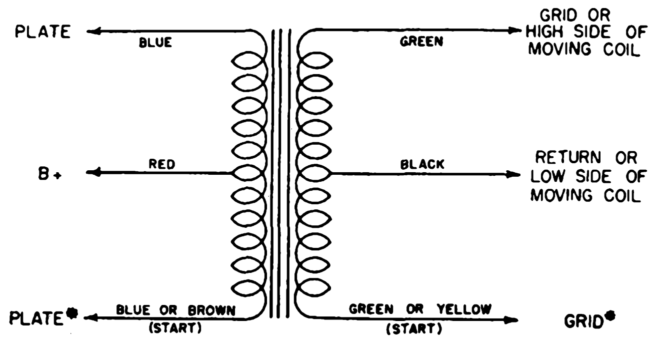




I-F Transformers



Audio & Output Transformers



*FOUND ONLY ON PUSH-PULL PRIMARY OR SECONDARY WINDINGS

Abbreviations and Letter Symbols*

Many of the abbreviations given are in lower-case letters. Obviously, however, there will be occasions such as when the abbreviations are used in titles where the original word would have been capitalized. In these cases, the abbreviation should be similarly capitalized.

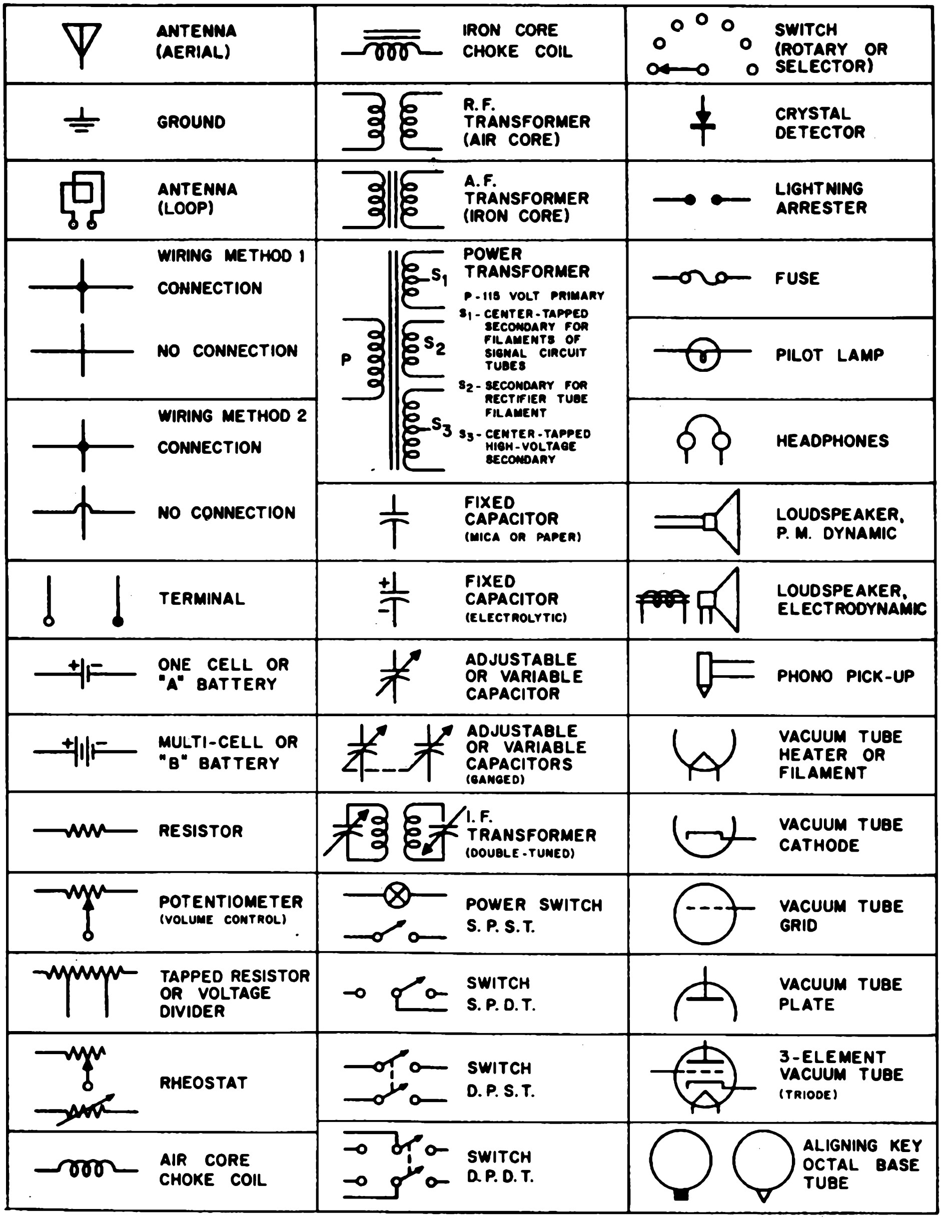
A two-word adjective expression should contain a hyphen.

Term	*Abbreviation*
Admittance	*Y*
Alternating-current (adjective)	a-c
Alternating current (noun)	a.c.
Ampere	a
Angular velocity ($2\pi f$)	ω
Antenna	ant.
Audio-frequency (adjective)	a-f
Audio frequency (noun)	a.f.
Automatic volume control	a.v.c.
Automatic volume expansion	a.v.e.
Capacitance	*C*
Capacitive reactance	X_C
Centimeter	cm
Conductance	*G*
Continuous waves	c.w.
Current	*I*, *i*
Cycles per second	~
Decibel	db
Direct-current (adjective)	d-c
Direct current (noun)	d.c.
Double cotton covered	d.c.c.
Double pole, double throw	d.p.d.t.
Double pole, single throw	d.p.s.t.
Double silk covered	d.s.c.
Electric field intensity	*E*
Electromotive force	e.m.f.
Frequency	*f*
Frequency modulation	f.m.
Ground	gnd.
Henry	*h*
High-frequency (adjective)	h-f
High frequency (noun)	h.f.
Impedance	*Z*
Inductance	*L*
Inductive reactance	X_L
Intermediate-frequency (adjective)	i-f
Intermediate frequency (noun)	i.f.
Interrupted continuous waves	i.c.w.
Kilocycle	kc
Kilohm	kΩ
Kilovolt	kv
Kilovolt ampere	kva
Kilowatt	kw

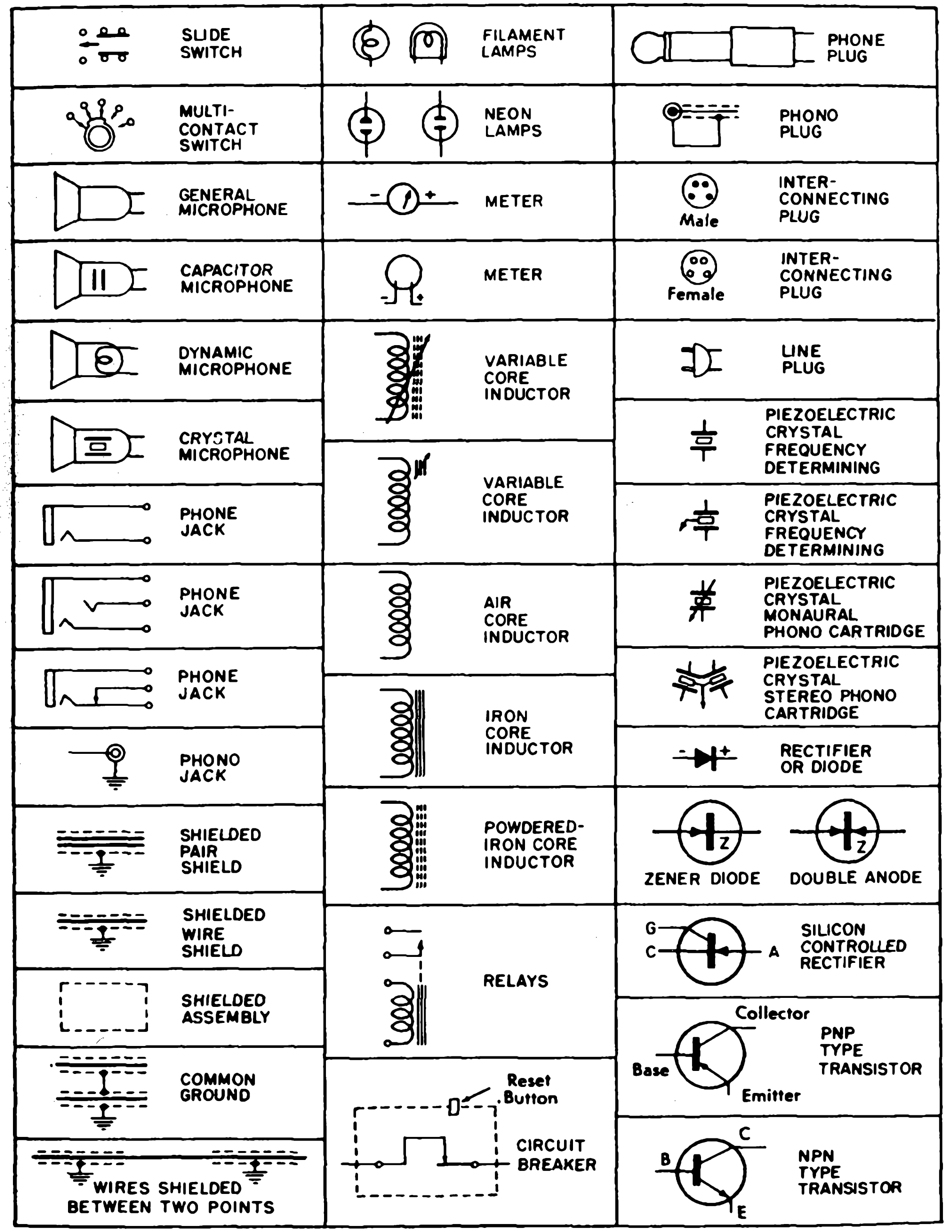
Term	*Abbreviation*
Low-frequency (adjective)	l-f
Low frequency (noun)	l.f.
Magnetic field intensity	*H*
Megacycle	Mc
Megohm	MΩ
Meter	m
Microampere	μa
Microfarad (mfd)	μf
Microhenry	μh
Micromicrofarad (mmfd)	μμf
Microvolt	μv
Microvolt per meter	μv/m
Microwatt	μw
Milliampere	ma
Millihenry	mh
Millivolt	mv
Millivolt per meter	mv/m
Milliwatt	mw
Modulated continuous waves	m.c.w.
Mutual inductance	*M*
Ohm	Ω
Power	*P*
Power factor	p.f.
Radio-frequency (adjective)	r-f
Radio frequency (noun)	r.f.
Reactance	*X*
Resistance	*R*
Revolutions per minute	r.p.m.
Root mean square	r.m.s.
Self-inductance	*L*
Short wave	s.w.
Single cotton covered	s.c.c.
Single cotton enamel	s.c.e.
Single pole, double throw	s.p.d.t.
Single pole, single throw	s.p.s.t.
Single silk covered	s.s.c.
Tuned radio frequency	t.r.f.
Ultra high frequency	u.h.f.
Vacuum tube voltmeter	v.t.v.m
Volt	v
Voltage	*E*, *e*
Volt-Ohm-Milliammeter	v.o.m.
Watt	w

* See Page 23 for Transistor Symbols.

Schematic Symbols
Used in Radio Diagrams



Schematic Symbols
Used in Radio Diagrams



Common Logarithms

N	0	1	2	3	4	5	6	7	8	9	N
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	10
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	11
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	12
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	13
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	14
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	15
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	16
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	17
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	18
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	20
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	21
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	22
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	23
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	24
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	25
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	26
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	27
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	28
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	29
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	30
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	31
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	32
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	33
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	34
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	35
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	36
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	37
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	38
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	39
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	40
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	41
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	42
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	43
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	44
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	45
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	46
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	47
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	48
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	49
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	50
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	51
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	52
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	53
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	54
N	0	1	2	3	4	5	6	7	8	9	N

Common Logarithms (Continued)

N	0	1	2	3	4	5	6	7	8	9	N
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	55
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	56
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	57
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	58
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	59
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	60
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	61
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	62
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	63
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	64
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	65
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	66
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	67
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	68
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	69
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	70
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	71
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	72
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	73
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	74
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	75
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	76
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	77
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	78
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	79
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	80
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	81
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	82
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	83
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	84
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	85
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	86
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	87
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	88
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	89
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	90
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	91
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	92
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	93
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	94
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	95
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	96
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	97
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	98
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	99
N	0	1	2	3	4	5	6	7	8	9	N

Natural Sines, Cosines, and Tangents
0°-14.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
0	sin	0.0000	0.0017	0.0035	0.0052	0.0070	0.0087	0.0105	0.0122	0.0140	0.0157
	cos	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	0.9999	0.9999
	tan	0.0000	0.0017	0.0035	0.0052	0.0070	0.0087	0.0105	0.0122	0.0140	0.0157
1	sin	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332
	cos	0.9998	0.9998	0.9998	0.9997	0.9997	0.9997	0.9996	0.9996	0.9995	0.9995
	tan	0.0175	0.0192	0.0209	0.0227	0.0244	0.0262	0.0279	0.0297	0.0314	0.0332
2	sin	0.0349	0.0366	0.0384	0.0401	0.0419	0.0436	0.0454	0.0471	0.0488	0.0506
	cos	0.9994	0.9993	0.9993	0.9992	0.9991	0.9990	0.9990	0.9989	0.9988	0.9987
	tan	0.0349	0.0367	0.0384	0.0402	0.0419	0.0437	0.0454	0.0472	0.0489	0.0507
3	sin	0.0523	0.0541	0.0558	0.0576	0.0593	0.0610	0.0628	0.0645	0.0663	0.0680
	cos	0.9986	0.9985	0.9984	0.9983	0.9982	0.9981	0.9980	0.9979	0.9978	0.9977
	tan	0.0524	0.0542	0.0559	0.0577	0.0594	0.0612	0.0629	0.0647	0.0664	0.0682
4	sin	0.0698	0.0715	0.0732	0.0750	0.0767	0.0785	0.0802	0.0819	0.0837	0.0854
	cos	0.9976	0.9974	0.9973	0.9972	0.9971	0.9969	0.9968	0.9966	0.9965	0.9963
	tan	0.0699	0.0717	0.0734	0.0752	0.0769	0.0787	0.0805	0.0822	0.0840	0.0857
5	sin	0.0872	0.0889	0.0906	0.0924	0.0941	0.0958	0.0976	0.0993	0.1011	0.1028
	cos	0.9962	0.9960	0.9959	0.9957	0.9956	0.9954	0.9952	0.9951	0.9949	0.9947
	tan	0.0875	0.0892	0.0910	0.0928	0.0945	0.0963	0.0981	0.0998	0.1016	0.1033
6	sin	0.1045	0.1063	0.1080	0.1097	0.1115	0.1132	0.1149	0.1167	0.1184	0.1201
	cos	0.9945	0.9943	0.9942	0.9940	0.9938	0.9936	0.9934	0.9932	0.9930	0.9928
	tan	0.1051	0.1069	0.1086	0.1104	0.1122	0.1139	0.1157	0.1175	0.1192	0.1210
7	sin	0.1219	0.1236	0.1253	0.1271	0.1288	0.1305	0.1323	0.1340	0.1357	0.1374
	cos	0.9925	0.9923	0.9921	0.9919	0.9917	0.9914	0.9912	0.9910	0.9907	0.9905
	tan	0.1228	0.1246	0.1263	0.1281	0.1299	0.1317	0.1334	0.1352	0.1370	0.1388
8	sin	0.1392	0.1409	0.1426	0.1444	0.1461	0.1478	0.1495	0.1513	0.1530	0.1547
	cos	0.9903	0.9900	0.9898	0.9895	0.9893	0.9890	0.9888	0.9885	0.9882	0.9880
	tan	0.1405	0.1423	0.1441	0.1459	0.1477	0.1495	0.1512	0.1530	0.1548	0.1566
9	sin	0.1564	0.1582	0.1599	0.1616	0.1633	0.1650	0.1668	0.1685	0.1702	0.1719
	cos	0.9877	0.9874	0.9871	0.9869	0.9866	0.9863	0.9860	0.9857	0.9854	0.9851
	tan	0.1584	0.1602	0.1620	0.1638	0.1655	0.1673	0.1691	0.1709	0.1727	0.1745
10	sin	0.1736	0.1754	0.1771	0.1788	0.1805	0.1822	0.1840	0.1857	0.1874	0.1891
	cos	0.9848	0.9845	0.9842	0.9839	0.9836	0.9833	0.9829	0.9826	0.9823	0.9820
	tan	0.1763	0.1781	0.1799	0.1817	0.1835	0.1853	0.1871	0.1890	0.1908	0.1926
11	sin	0.1908	0.1925	0.1942	0.1959	0.1977	0.1994	0.2011	0.2028	0.2045	0.2062
	cos	0.9816	0.9813	0.9810	0.9806	0.9803	0.9799	0.9796	0.9792	0.9789	0.9785
	tan	0.1944	0.1962	0.1980	0.1998	0.2016	0.2035	0.2053	0.2071	0.2089	0.2107
12	sin	0.2079	0.2096	0.2113	0.2130	0.2147	0.2164	0.2181	0.2198	0.2215	0.2232
	cos	0.9781	0.9778	0.9774	0.9770	0.9767	0.9763	0.9759	0.9755	0.9751	0.9748
	tan	0.2126	0.2144	0.2162	0.2180	0.2199	0.2217	0.2235	0.2254	0.2272	0.2290
13	sin	0.2250	0.2267	0.2284	0.2300	0.2318	0.2334	0.2351	0.2368	0.2385	0.2402
	cos	0.9744	0.9740	0.9736	0.9732	0.9728	0.9724	0.9720	0.9715	0.9711	0.9707
	tan	0.2309	0.2327	0.2345	0.2364	0.2382	0.2401	0.2419	0.2438	0.2456	0.2475
14	sin	0.2419	0.2436	0.2453	0.2470	0.2487	0.2504	0.2521	0.2538	0.2554	0.2571
	cos	0.9703	0.9699	0.9694	0.9690	0.9686	0.9681	0.9677	0.9673	0.9668	0.9664
	tan	0.2493	0.2512	0.2530	0.2549	0.2568	0.2586	0.2605	0.2623	0.2642	0.2661
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

Natural Sines, Cosines, and Tangents—*(Continued)*
15°-29.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
15	sin	0.2588	0.2605	0.2622	0.2639	0.2656	0.2672	0.2689	0.2706	0.2723	0.2740
	cos	0.9659	0.9655	0.9650	0.9646	0.9641	0.9636	0.9632	0.9627	0.9622	0.9617
	tan	0.2679	0.2698	0.2717	0.2736	0.2754	0.2773	0.2792	0.2811	0.2830	0.2849
16	sin	0.2756	0.2773	0.2790	0.2807	0.2823	0.2840	0.2857	0.2874	0.2890	0.2907
	cos	0.9613	0.9608	0.9603	0.9598	0.9593	0.9588	0.9583	0.9578	0.9573	0.9568
	tan	0.2867	0.2886	0.2905	0.2924	0.2943	0.2962	0.2981	0.3000	0.3019	0.3038
17	sin	0.2924	0.2940	0.2957	0.2974	0.2990	0.3007	0.3024	0.3040	0.3057	0.3074
	cos	0.9563	0.9558	0.9553	0.9548	0.9542	0.9537	0.9532	0.9527	0.9521	0.9516
	tan	0.3057	0.3076	0.3096	0.3115	0.3134	0.3153	0.3172	0.3191	0.3211	0.3230
18	sin	0.3090	0.3107	0.3123	0.3140	0.3156	0.3173	0.3190	0.3206	0.3223	0.3239
	cos	0.9511	0.9505	0.9500	0.9494	0.9489	0.9483	0.9478	0.9472	0.9466	0.9461
	tan	0.3249	0.3269	0.3288	0.3307	0.3327	0.3346	0.3365	0.3385	0.3404	0.3424
19	sin	0.3256	0.3272	0.3289	0.3305	0.3322	0.3338	0.3355	0.3371	0.3387	0.3404
	cos	0.9455	0.9449	0.9444	0.9438	0.9432	0.9426	0.9421	0.9415	0.9409	0.9403
	tan	0.3443	0.3463	0.3482	0.3502	0.3522	0.3541	0.3561	0.3581	0.3600	0.3620
20	sin	0.3420	0.3437	0.3453	0.3469	0.3486	0.3502	0.3518	0.3535	0.3551	0.3567
	cos	0.9397	0.9391	0.9385	0.9379	0.9373	0.9367	0.9361	0.9354	0.9348	0.9342
	tan	0.3640	0.3659	0.3679	0.3699	0.3719	0.3739	0.3759	0.3779	0.3799	0 3819
21	sin	.3584	0.3600	0.3616	0.3633	0.3649	0.3665	0.3681	0.3697	0.3714	0.3730
	cos	0.9336	0.9330	0.9323	0.9317	0.9311	0.9304	0.9298	0.9291	0.9285	0.9278
	tan	0.3839	0.3859	0.3879	0.3899	0.3919	0.3939	0.3959	0.3979	0.4000	0.4020
22	sin	0.3746	0.3762	0.3778	0.3795	0.3811	0.3827	0.3843	0.3859	0.3875	0.3891
	cos	0.9272	0.9265	0.9259	0.9252	0.9245	0.9239	0.9232	0.9225	0.9219	0.9212
	tan	0.4040	0.4061	0.4081	0.4101	0.4122	0.4142	0.4163	0.4183	0.4204	0.4224
23	sin	0.3907	0.3923	0.3939	0.3955	0.3971	0.3987	0.4003	0.4019	0.4035	0.4051
	cos	0.9205	0.9198	0.9191	0.9184	0.9178	0.9171	0.9164	0.9157	0.9150	0.9143
	tan	0.4245	0.4265	0.4286	0.4307	0.4327	0.4348	0.4369	0.4390	0.4411	0.4431
24	sin	0.4067	0.4083	0.4099	0.4115	0.4131	0.4147	0.4163	0.4179	0.4195	0.4210
	cos	0.9135	0.9128	0.9121	0.9114	0.9107	0.9100	0.9092	0.9085	0.9078	0.9070
	tan	0.4452	0.4473	0.4494	0.4515	0.4536	0.4557	0.4578	0.4599	0.4621	0.4642
25	sin	0.4226	0.4242	0.4258	0.4274	0.4289	0.4305	0.4321	0.4337	0.4352	0.4368
	cos	0.9063	0.9056	0.9048	0.9041	0.9033	0.9026	0.9018	0.9011	0.9003	0.8996
	tan	0.4663	0.4684	0.4706	0.4727	0.4748	0.4770	0.4791	0.4813	0.4834	0.4856
26	sin	0.4384	0.4399	0.4415	0.4431	0.4446	0.4462	0.4478	0.4493	0.4509	0.4524
	cos	0.8988	0.8980	0.8973	0.8965	0.8957	0.8949	0.8942	0.8934	0.8926	0.8918
	tan	0.4877	0.4899	0.4921	0.4942	0.4964	0.4986	0.5008	0.5029	0.5051	0.5073
27	sin	0.4540	0.4555	0.4571	0.4586	0.4602	0.4617	0.4633	0.4648	0.4664	0.4679
	cos	0.8910	0.8902	0.8894	0.8886	0.8878	0.8870	0.8862	0.8854	0.8846	0.8838
	tan	0.5095	0.5117	0.5139	0.5161	0.5184	0.5206	0.5228	0.5250	0.5272	0.5295
28	sin	0.4695	0.4710	0.4726	0.4741	0.4756	0.4772	0.4787	0.4802	0.4818	0.4833
	cos	0.8829	0.8821	0.8813	0.8805	0.8796	0.8788	0.8780	0.8771	0.8763	0.8755
	tan	0.5317	0.5340	0.5362	0.5384	0.5407	0.5430	0.5452	0.5475	0.5498	0.5520
29	sin	0.4848	0.4863	0.4879	0.4894	0.4909	0.4924	0.4939	0.4955	0.4970	0.4985
	cos	0.8746	0.8738	0.8729	0.8721	0.8712	0.8704	0.8695	0.8686	0.8678	0.8669
	tan	0.5543	0.5566	0.5589	0.5612	0.5635	0.5658	0.5681	0.5704	0.5727	0.5750
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

Natural Sines, Cosines, and Tangents—*(Continued)*

30°-44.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
30	sin	0.5000	0.5015	0.5030	0.5045	0.5060	0.5075	0.5090	0.5105	0.5120	0.5135
	cos	0.8660	0.8652	0.8643	0.8634	0.8625	0.8616	0.8607	0.8599	0.8590	0.8581
	tan	0.5774	0.5797	0.5820	0.5844	0.5867	0.5890	0.5914	0.5938	0.5961	0.5985
31	sin	0.5150	0.5165	0.5180	0.5195	0.5210	0.5225	0.5240	0.5255	0.5270	0.5284
	cos	0.8572	0.8563	0.8554	0.8545	0.8536	0.8526	0.8517	0.8508	0.8499	0.8490
	tan	0.6009	0.6032	0.6056	0.6080	0.6104	0.6128	0.6152	0.6176	0.6200	0.6224
32	sin	0.5299	0.5314	0.5329	0.5344	0.5358	0.5373	0.5388	0.5402	0.5417	0.5432
	cos	0.8480	0.8471	0.8462	0.8453	0.8443	0.8434	0.8425	0.8415	0.8406	0.8396
	tan	0.6249	0.6273	0.6297	0.6322	0.6346	0.6371	0.6395	0.6420	0.6445	0.6469
33	sin	0.5446	0.5461	0.5476	0.5490	0.5505	0.5519	0.5534	0.5548	0.5563	0.5577
	cos	0.8387	0.8377	0.8368	0.8358	0.8348	0.8339	0.8329	0.8320	0.8310	0.8300
	tan	0.6494	0.6519	0.6544	0.6569	0.6594	0.6619	0.6644	0.6669	0.6694	0.6720
34	sin	0.5592	0.5606	0.5621	0.5635	0.5650	0.5664	0.5678	0.5693	0.5707	0.5721
	cos	0.8290	0.8281	0.8271	0.8261	0.8251	0.8241	0.8231	0.8221	0.8211	0.8202
	tan	0.6745	0.6771	0.6796	0.6822	0.6847	0.6873	0.6899	0.6924	0.6950	0.6976
35	sin	0.5736	0.5750	0.5764	0.5779	0.5793	0.5807	0.5821	0.5835	0.5850	0.5864
	cos	0.8192	0.8181	0.8171	0.8161	0.8151	0.8141	0.8131	0.8121	0.8111	0.8100
	tan	0.7002	0.7028	0.7054	0.7080	0.7107	0.7133	0.7159	0.7186	0.7212	0.7239
36	sin	0.5878	0.5892	0.5906	0.5920	0.5934	0.5948	0.5962	0.5976	0.5990	0.6004
	cos	0.8090	0.8080	0.8070	0.8059	0.8049	0.8039	0.8028	0.8018	0.8007	0.7997
	tan	0.7265	0.7292	0.7319	0.7346	0.7373	0.7400	0.7427	0.7454	0.7481	0.7508
37	sin	0.6018	0.6032	0.6046	0.6060	0.6074	0.6088	0.6101	0.6115	0.6129	0.6143
	cos	0.7986	0.7976	0.7965	0.7955	0.7944	0.7934	0.7923	0.7912	0.7902	0.7891
	tan	0.7536	0.7563	0.7590	0.7618	0.7646	0.7673	0.7701	0.7729	0.7757	0.7785
38	sin	0.6157	0.6170	0.6184	0.6198	0.6211	0.6225	0.6239	0.6252	0.6266	0.6280
	cos	0.7880	0.7869	0.7859	0.7848	0.7837	0.7826	0.7815	0.7804	0.7793	0.7782
	tan	0.7813	0.7841	0.7869	0.7898	0.7926	0.7954	0.7983	0.8012	0.8040	0.8069
39	sin	0.6293	0.6307	0.6320	0.6334	0.6347	0.6361	0.6374	0.6388	0.6401	0.6414
	cos	0.7771	0.7760	0.7749	0.7738	0.7727	0.7716	0.7705	0.7694	0.7683	0.7672
	tan	0.8098	0.8127	0.8156	0.8185	0.8214	0.8243	0.8273	0.8302	0.8332	0.8361
40	sin	0.6428	0.6441	0.6455	0.6468	0.6481	0.6494	0.6508	0.6521	0.6534	0.6547
	cos	0.7660	0.7649	0.7638	0.7627	0.7615	0.7604	0.7593	0.7581	0.7570	0.7559
	tan	0.8391	0.8421	0.8451	0.8481	0.8511	0.8541	0.8571	0.8601	0.8632	0.8662
41	sin	0.6561	0.6574	0.6587	0.6600	0.6613	0.6626	0.6639	0.6652	0.6665	0.6678
	cos	0.7547	0.7536	0.7524	0.7513	0.7501	0.7490	0.7478	0.7466	0.7455	0.7443
	tan	0.8693	0.8724	0.8754	0.8785	0.8816	0.8847	0.8878	0.8910	0.8941	0.8972
42	sin	0.6691	0.6704	0.6717	0.6730	0.6743	0.6756	0.6769	0.6782	0.6794	0.6807
	cos	0.7431	0.7420	0.7408	0.7396	0.7385	0.7373	0.7361	0.7349	0.7337	0.7325
	tan	0.9004	0.9036	0.9067	0.9099	0.9131	0.9163	0.9195	0.9228	0.9260	0.9293
43	sin	0.6820	0.6833	0.6845	0.6858	0.6871	0.6884	0.6896	0.6909	0.6921	0.6934
	cos	0.7314	0.7302	0.7290	0.7278	0.7266	0.7254	0.7242	0.7230	0.7218	0.7206
	tan	0.9325	0.9358	0.9391	0.9424	0.9457	0.9490	0.9523	0.9556	0.9590	0.9623
44	sin	0.6947	0.6959	0.6972	0.6984	0.6997	0.7009	0.7022	0.7034	0.7046	0.7059
	cos	0.7193	0.7181	0.7169	0.7157	0.7145	0.7133	0.7120	0.7108	0.7096	0.7083
	tan	0.9657	0.9691	0.9725	0.9759	0.9793	0.9827	0.9861	0.9896	0.9930	0.9965
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

Natural Sines, Cosines, and Tangents—*(Continued)*

45°-59.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
45	sin	0.7071	0.7083	0.7096	0.7108	0.7120	0.7133	0.7145	0.7157	0.7169	0.7181
	cos	0.7071	0.7059	0.7046	0.7034	0.7022	0.7009	0.6997	0.6984	0.6972	0.6959
	tan	1.0000	1.0035	1.0070	1.0105	1.0141	1.0176	1.0212	1.0247	1.0283	1.0319
46	sin	0.7193	0.7206	0.7218	0.7230	0.7242	0.7254	0.7266	0.7278	0.7290	0.7302
	cos	0.6947	0.6934	0.6921	0.6909	0.6896	0.6884	0.6871	0.6858	0.6845	0.6833
	tan	1.0355	1.0392	1.0428	1.0464	1.0501	1.0538	1.0575	1.0612	1.0649	1.0686
47	sin	0.7314	0.7325	0.7337	0.7349	0.7361	0.7373	0.7385	0.7396	0.7408	0.7420
	cos	0.6820	0.6807	0.6794	0.6782	0.6769	0.6756	0.6743	0.6730	0.6717	0.6704
	tan	1.0724	1.0761	1.0799	1.0837	1.0875	1.0913	1.0951	1.0990	1.1028	1.1067
48	sin	0.7431	0.7443	0.7455	0.7466	0.7478	0.7490	0.7501	0.7513	0.7524	0.7536
	cos	0.6691	0.6678	0.6665	0.6652	0.6639	0.6626	0.6613	0.6600	0.6587	0.6574
	tan	1.1106	1.1145	1.1184	1.1224	1.1263	1.1303	1.1343	1.1383	1.1423	1.1463
49	sin	0.7547	0.7559	0.7570	0.7581	0.7593	0.7604	0.7615	0.7627	0.7638	0.7649
	cos	0.6561	0.6547	0.6534	0.6521	0.6508	0.6494	0.6481	0.6468	0.6455	0.6441
	tan	1.1504	1.1544	1.1585	1.1626	1.1667	1.1708	1.1750	1.1792	1.1833	1.1875
50	sin	0.7660	0.7672	0.7683	0.7694	0.7705	0.7716	0.7727	0.7738	0.7749	0.7760
	cos	0.6428	0.6414	0.6401	0.6388	0.6374	0.6361	0.6347	0.6334	0.6320	0.6307
	tan	1.1918	1.1960	1.2002	1.2045	1.2088	1.2131	1.2174	1.2218	1.2261	1.2305
51	sin	0.7771	0.7782	0.7793	0.7804	0.7815	0.7826	0.7837	0.7848	0.7859	0.7869
	cos	0.6293	0.6280	0.6266	0.6252	0.6239	0.6225	0.6211	0.6198	0.6184	0.6170
	tan	1.2349	1.2393	1.2437	1.2482	1.2527	1.2572	1.2617	1.2662	1.2708	1.2753
52	sin	0.7880	0.7891	0.7902	0.7912	0.7923	0.7934	0.7944	0.7955	0.7965	0.7976
	cos	0.6157	0.6143	0.6129	0.6115	0.6101	0.6088	0.6074	0.6060	0.6046	0.6032
	tan	1.2799	1.2846	1.2892	1.2938	1.2985	1.3032	1.3079	1.3127	1.3175	1.3222
53	sin	0.7986	0.7997	0.8007	0.8018	0.8028	0.8039	0.8049	0.8059	0.8070	0.8080
	cos	0.6018	0.6004	0.5990	0.5976	0.5962	0.5948	0.5934	0.5920	0.5906	0.5892
	tan	1.3270	1.3319	1.3367	1.3416	1.3465	1.3514	1.3564	1.3613	1.3663	1.3713
54	sin	0.8090	0.8100	0.8111	0.8121	0.8131	0.8141	0.8151	0.8161	0.8171	0.8181
	cos	0.5878	0.5864	0.5850	0.5835	0.5821	0.5807	0.5793	0.5779	0.5764	0.5750
	tan	1.3764	1.3814	1.3865	1.3916	1.3968	1.4019	1.4071	1.4124	1.4176	1.4229
55	sin	0.8192	0.8202	0.8211	0.8221	0.8231	0.8241	0.8251	0.8261	0.8271	0.8281
	cos	0.5736	0.5721	0.5707	0.5693	0.5678	0.5664	0.5650	0.5635	0.5621	0.5606
	tan	1.4281	1.4335	1.4388	1.4442	1.4496	1.4550	1.4605	1.4659	1.4715	1.4770
56	sin	0.8290	0.8300	0.8310	0.8320	0.8329	0.8339	0.8348	0.8358	0.8368	0.8377
	cos	0.5592	0.5577	0.5563	0.5548	0.5534	0.5519	0.5505	0.5490	0.5476	0.5461
	tan	1.4826	1.4882	1.4938	1.4994	1.5051	1.5108	1.5166	1.5224	1.5282	1.5340
57	sin	0.8387	0.8396	0.8406	0.8415	0.8425	0.8434	0.8443	0.8453	0.8462	0.8471
	cos	0.5446	0.5432	0.5417	0.5402	0.5388	0.5373	0.5358	0.5344	0.5329	0.5314
	tan	1.5399	1.5458	1.5517	1.5577	1.5637	1.5697	1.5757	1.5818	1.5880	1.5941
58	sin	0.8480	0.8490	0.8499	0.8508	0.8517	0.8526	0.8536	0.8545	0.8554	0.8563
	cos	0.5299	0.5284	0.5270	0.5255	0.5240	0.5225	0.5210	0.5195	0.5180	0.5165
	tan	1.6003	1.6066	1.6128	1.6191	1.6255	1.6319	1.6383	1.6447	1.6512	1.6577
59	sin	0.8572	0.8581	0.8590	0.8599	0.8607	0.8616	0.8625	0.8634	0.8643	0.8652
	cos	0.5150	0.5135	0.5120	0.5105	0.5090	0.5075	0.5060	0.5045	0.5030	0.5015
	tan	1.6643	1.6709	1.6775	1.6842	1.6909	1.6977	1.7045	1.7113	1.7182	1.7251
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

Natural Sines, Cosines, and Tangents—*(Continued)*

60°-74.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
	sin	0.8660	0.8669	0.8678	0.8686	0.8695	0.8704	0.8712	0.8721	0.8729	0.8738
60	cos	0.5000	0.4985	0.4970	0.4955	0.4939	0.4924	0.4909	0.4894	0.4879	0.4863
	tan	1.7321	1.7391	1.7461	1.7532	1.7603	1.7675	1.7747	1.7820	1.7893	1.7966
	sin	0.8746	0.8755	0.8763	0.8771	0.8780	0.8788	0.8796	0.8805	0.8813	0.8821
61	cos	0.4848	0.4833	0.4818	0.4802	0.4787	0.4772	0.4756	0.4741	0.4726	0.4710
	tan	1.8040	1.8115	1.8190	1.8265	1.8341	1.8418	1.8495	1.8572	1.8650	1.8728
	sin	0.8829	0.8838	0.8846	0.8854	0.8862	0.8870	0.8878	0.8886	0.8894	0.8902
62	cos	0.4695	0.4679	0.4664	0.4648	0.4633	0.4617	0.4602	0.4586	0.4571	0.4555
	tan	1.8807	1.8887	1.8967	1.9047	1.9128	1.9210	1.9292	1.9375	1.9458	1.9542
	sin	0.8910	0.8918	0.8926	0.8934	0.8942	0.8949	0.8957	0.8965	0.8973	0.8980
63	cos	0.4540	0.4524	0.4509	0.4493	0.4478	0.4462	0.4446	0.4431	0.4415	0.4399
	tan	1.9626	1.9711	1.9797	1.9883	1.9970	2.0057	2.0145	2.0233	2.0323	2.0413
	sin	0.8988	0.8996	0.9003	0.9011	0.9018	0.9026	0.9033	0.9041	0.9048	0.9056
64	cos	0.4384	0.4368	0.4352	0.4337	0.4321	0.4305	0.4289	0.4274	0.4258	0.4242
	tan	2.0503	2.0594	2.0686	2.0778	2.0872	2.0965	2.1060	2.1155	2.1251	2.1348
	sin	0.9063	0.9070	0.9078	0.9085	0.9092	0.9100	0.9107	0.9114	0.9121	0.9128
65	cos	0.4226	0.4210	0.4195	0.4179	0.4163	0.4147	0.4131	0.4115	0.4099	0.4083
	tan	2.1445	2.1543	2.1642	2.1742	2.1842	2.1943	2.2045	2.2148	2.2251	2.2355
	sin	0.9135	0.9143	0.9150	0.9157	0.9164	0.9171	0.9178	0.9184	0.9191	0.9198
66	cos	0.4067	0.4051	0.4035	0.4019	0.4003	0.3987	0.3971	0.3955	0.3939	0.3923
	tan	2.2460	2.2566	2.2673	2.2781	2.2889	2.2998	2.3109	2.3220	2.3332	2.3445
	sin	0.9205	0.9212	0.9219	0.9225	0.9232	0.9239	0.9245	0.9252	0.9259	0.9265
67	cos	0.3907	0.3891	0.3875	0.3859	0.3843	0.3827	0.3811	0.3795	0.3778	0.3762
	tan	2.3559	2.3673	2.3789	2.3906	2.4023	2.4142	2.4262	2.4383	2.4504	2.4627
	sin	0.9272	0.9278	0.9285	0.9291	0.9298	0.9304	0.9311	0.9317	0.9323	0.9330
68	cos	0.3746	0.3730	0.3714	0.3697	0.3681	0.3665	0.3649	0.3633	0.3616	0.3600
	tan	2.4751	2.4876	2.5002	2.5129	2.5257	2.5386	2.5517	2.5649	2.5782	2.5916
	sin	0.9336	0.9342	0.9348	0.9354	0.9361	0.9367	0.9373	0.9379	0.9385	0.9391
69	cos	0.3584	0.3567	0.3551	0.3535	0.3518	0.3502	0.3486	0.3469	0.3453	0.3437
	tan	2.6051	2.6187	2.6325	2.6464	2.6605	2.6746	2.6889	2.7034	2.7179	2.7326
	sin	0.9397	0.9403	0.9409	0.9415	0.9421	0.9426	0.9432	0.9438	0.9444	0.9449
70	cos	0.3420	0.3404	0.3387	0.3371	0.3355	0.3338	0.3322	0.3305	0.3289	0.3272
	tan	2.7475	2.7625	2.7776	2.7929	2.8083	2.8239	2.8397	2.8556	2.8716	2.8878
	sin	0.9455	0.9461	0.9466	0.9472	0.9478	0.9483	0.9489	0.9494	0.9500	0.9505
71	cos	0.3256	0.3239	0.3223	0.3206	0.3190	0.3173	0.3156	0.3140	0.3123	0.3107
	tan	2.9042	2.9208	2.9375	2.9544	2.9714	2.9887	3.0061	3.0237	3.0415	3.0595
	sin	0.9511	0.9516	0.9521	0.9527	0.9532	0.9537	0.9542	0.9548	0.9553	0.9558
72	cos	0.3090	0.3074	0.3057	0.3040	0.3024	0.3007	0.2990	0.2974	0.2957	0.2940
	tan	3.0777	3.0961	3.1146	3.1334	3.1524	3.1716	3.1910	3.2106	3.2305	3.2506
	sin	0.9563	0.9568	0.9573	0.9578	0.9583	0.9588	0.9593	0.9598	0.9603	0.9608
73	cos	0.2924	0.2907	0.2890	0.2874	0.2857	0.2840	0.2823	0.2807	0.2790	0.2773
	tan	3.2709	3.2914	3.3122	3.3332	3.3544	3.3759	3.3977	3.4197	3.4420	3.4646
	sin	0.9613	0.9617	0.9622	0.9627	0.9632	0.9636	0.9641	0.9646	0.9650	0.9655
74	cos	0.2756	0.2740	0.2723	0.2706	0.2689	0.2672	0.2656	0.2639	0.2622	0.2605
	tan	3.4874	3.5105	3.5339	3.5576	3.5816	3.6059	3.6305	3.6554	3.6806	3.7062
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

Natural Sines, Cosines, and Tangents—*(Continued)*

75°-89.9°

Degs.	Function	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°
75	sin	0.9659	0.9664	0.9668	0.9673	0.9677	0.9681	0.9686	0.9690	0.9694	0.9699
	cos	0.2588	0.2571	0.2554	0.2538	0.2521	0.2504	0.2487	0.2470	0.2453	0.2436
	tan	3.7321	3.7583	3.7848	3.8118	3.8391	3.8667	3.8947	3.9232	3.9520	3.9812
76	sin	0.9703	0.9707	0.9711	0.9715	0.9720	0.9724	0.9728	0.9732	0.9736	0.9740
	cos	0.2419	0.2402	0.2385	0.2368	0.2351	0.2334	0.2317	0.2300	0.2284	0.2267
	tan	4.0108	4.0408	4.0713	4.1022	4.1335	4.1653	4.1976	4.2303	4.2635	4.2972
77	sin	0.9744	0.9748	0.9751	0.9755	0.9759	0.9763	0.9767	0.9770	0.9774	0.9778
	cos	0.2250	0.2232	0.2215	0.2198	0.2181	0.2164	0.2147	0.2130	0.2113	0.2096
	tan	4.3315	4.3662	4.4015	4.4374	4.4737	4.5107	4.5483	4.5864	4.6252	4.6646
78	sin	0.9781	0.9785	0.9789	0.9792	0.9796	0.9799	0.9803	0.9806	0.9810	0.9813
	cos	0.2079	0.2062	0.2045	0.2028	0.2011	0.1994	0.1977	0.1959	0.1942	0.1925
	tan	4.7046	4.7453	4.7867	4.8288	4.8716	4.9152	4.9594	5.0045	5.0504	5.0970
79	sin	0.9816	0.9820	0.9823	0.9826	0.9829	0.9833	0.9836	0.9839	0.9842	0.9845
	cos	0.1908	0.1891	0.1874	0.1857	0.1840	0.1822	0.1805	0.1788	0.1771	0.1754
	tan	5.1446	5.1929	5.2422	5.2924	5.3435	5.3955	5.4486	5.5026	5.5578	5.6140
80	sin	0.9848	0.9851	0.9854	0.9857	0.9860	0.9863	0.9866	0.9869	0.9871	0.9874
	cos	0.1736	0.1719	0.1702	0.1685	0.1668	0.1650	0.1633	0.1616	0.1599	0.1582
	tan	5.6713	5.7297	5.7894	5.8502	5.9124	5.9758	6.0405	6.1066	6.1742	6.2432
81	sin	0.9877	0.9880	0.9882	0.9885	0.9888	0.9890	0.9893	0.9895	0.9898	0.9900
	cos	0.1564	0.1547	0.1530	0.1513	0.1495	0.1478	0.1461	0.1444	0.1426	0.1409
	tan	6.3138	6.3859	6.4596	6.5350	6.6122	6.6912	6.7720	6.8548	6.9395	7.0264
82	sin	0.9903	0.9905	0.9907	0.9910	0.9912	0.9914	0.9917	0.9919	0.9921	0.9923
	cos	0.1392	0.1374	0.1357	0.1340	0.1323	0.1305	0.1288	0.1271	0.1253	0.1236
	tan	7.1154	7.2066	7.3002	7.3962	7.4947	7.5958	7.6996	7.8062	7.9158	8.0285
83	sin	0.9925	0.9928	0.9930	0.9932	0.9934	0.9936	0.9938	0.9940	0.9942	0.9943
	cos	0.1219	0.1201	0.1184	0.1167	0.1149	0.1132	0.1115	0.1097	0.1080	0.1063
	tan	8.1443	8.2636	8.3863	8.5126	8.6427	8.7769	8.9152	9.0579	9.2052	9.3572
84	sin	0.9945	0.9947	0.9949	0.9951	0.9952	0.9954	0.9956	0.9957	0.9959	0.9960
	cos	0.1045	0.1028	0.1011	0.0993	0.0976	0.0958	0.0941	0.0924	0.0906	0.0889
	tan	9.5144	9.6768	9.8448	10.02	10.20	10.39	10.58	10.78	10.99	11.20
85	sin	0.9962	0.9963	0.9965	0.9966	0.9968	0.9969	0.9971	0.9972	0.9973	0.9974
	cos	0.0872	0.0854	0.0837	0.0819	0.0802	0.0785	0.0767	0.0750	0.0732	0.0715
	tan	11.43	11.66	11.91	12.16	12.43	12.71	13.00	13.30	13.62	13.95
86	sin	0.9976	0.9977	0.9978	0.9979	0.9980	0.9981	0.9982	0.9983	0.9984	0.9985
	cos	0.0698	0.0680	0.0663	0.0645	0.0628	0.0610	0.0593	0.0576	0.0558	0.0541
	tan	14.30	14.67	15.06	15.46	15.89	16.35	16.83	17.34	17.89	18.46
87	sin	0.9986	0.9987	0.9988	0.9989	0.9990	0.9990	0.9991	0.9992	0.9993	0.9993
	cos	0.0523	0.0506	0.0488	0.0471	0.0454	0.0436	0.0419	0.0401	0.0384	0.0366
	tan	19.08	19.74	20.45	21.20	22.02	22.90	23.86	24.90	26.03	27.27
88	sin	0.9994	0.9995	0.9995	0.9996	0.9996	0.9997	0.9997	0.9997	0.9998	0.9998
	cos	0.0349	0.0332	0.0314	0.0297	0.0279	0.0262	0.0244	0.0227	0.0209	0.0192
	tan	28.64	30.14	31.82	33.69	35.80	38.19	40.92	44.07	47.74	52.08
89	sin	0.9998	0.9999	0.9999	0.9999	0.9999	1.000	1.000	1.000	1.000	1.000
	cos	0.0175	0.0157	0.0140	0.0122	0.0105	0.0087	0.0070	0.0052	0.0035	0.0017
	tan	57.29	63.66	71.62	81.85	95.49	114.6	143.2	191.0	286.5	573.0
Degs.	Function	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′

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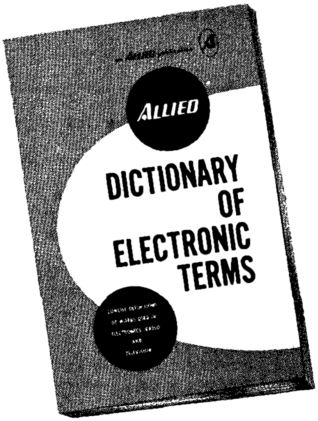

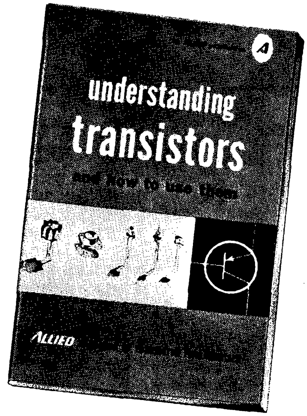

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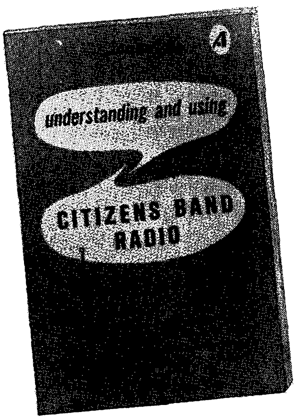

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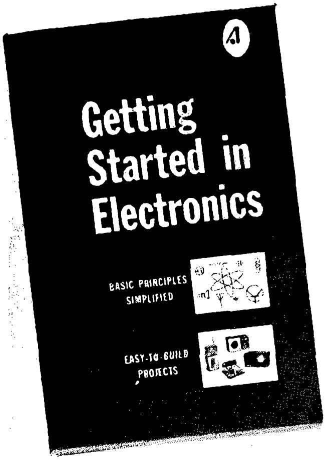

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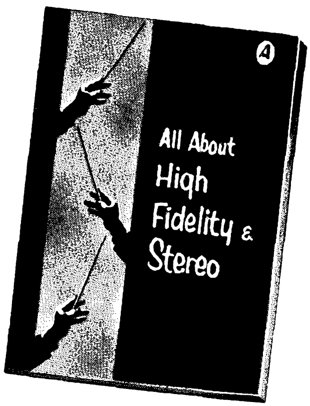

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