ALLIED
ELECTRONICS DATA HANDBOOK

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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 electronics. It was felt also that such a book should serve only as a source of information and reference and that attempts to teach or explain the basic principles involved should be left to classroom instruction and to the 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 the various groups in the 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.

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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

$\pi = 3.14$

$2\pi = 6.28$

$(2\pi)^2 = 39.5$

$4\pi = 12.6$

$\pi^2 = 9.87$

$\frac{\pi}{2} = 1.57$

$\frac{1}{\pi} = 0.318$

$\frac{1}{2\pi} = 0.159$

$\frac{1}{\pi^2} = 0.101$

$\frac{1}{\sqrt{\pi}} = 0.564$

$\sqrt{\pi} = 1.77$

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

$\sqrt{2} = 1.41$

$\sqrt{3} = 1.73$

$\frac{1}{\sqrt{2}} = 0.707$

$\frac{1}{\sqrt{3}} = 0.577$

$\log \pi = 0.497$

$\log \frac{\pi}{2} = 0.196$

$\log \pi^2 = 0.994$

$\log \sqrt{\pi} = 0.248$

Decimal Inches

Inches $\times$ 2.540 = Centimeters

Inches $\times$ 1.578×10^{-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
.1	.98855	.011447	86.360	.005756	86.857
.2	.97724	.022763	42.931	.011512	43.426
.25	.97163	.028372	34.247	.014390	34.739
.3	.96605	.034046	28.456	.017268	28.947
.4	.95499	.045008	21.219	.023022	21.707
.5	.94406	.055939	16.876	.028774	17.362
.6	.93325	.066745	13.982	.034525	14.428
.7	.92257	.077429	11.915	.040274	12.395
.75	.91728	.082724	11.088	.043147	11.567
.8	.91201	.087989	10.365	.046019	10.842
.9	.90157	.098429	9.1596	.051762	9.6337
1.0	.89125	.10875	8.1955	.057501	8.6667
1.5	.84140	.15860	5.3050	.086133	5.7619
2.0	.79433	.20567	3.8621	.11462	4.3048
2.5	.74989	.25011	2.9983	.14293	3.4268
3.0	.70795	.29205	2.4240	.17100	2.8385
3.5	.66834	.33166	2.0152	.19879	2.4158
4.0	.63096	.36904	1.7097	.22627	2.0966
4.5	.59566	.40434	1.4732	.25340	1.8465
5.0	.56234	.43766	1.2849	.28013	1.6448
6.0	.50119	.49881	1.0048	.33228	1.3386
7.0	.44668	.55332	.80728	.38247	1.1160
7.5	.42170	.57830	.72920	.40677	1.0258
8.0	.39811	.60189	.66143	.43051	.94617
9.0	.35481	.64519	.54994	.47622	.81183
10.0	.31623	.68377	.46248	.51949	.70273
11.0	.28184	.71816	.39244	.56026	.61231
12.0	.25119	.74881	.33545	.59848	.53621
12.5	.23714	.76286	.31085	.61664	.50253
13.0	.22387	.77613	.28845	.63416	.47137
14.0	.19953	.80047	.24926	.66732	.41560
15.0	.17783	.82217	.21629	.69804	.36727
16.0	.15849	.84151	.18834	.72639	.32515
17.0	.14125	.85875	.16449	.75246	.28826
17.5	.13335	.86665	.15387	.76468	.27153
18.0	.12589	.87411	.14402	.77637	.25584
19.0	.11220	.88780	.12638	.79823	.22726
20.0	.100000	.90000	.111111	.81818	.20202
21.0	.089125	.91087	.097846	.83634	.17968
22.0	.079433	.92057	.086287	.85282	.15987
22.5	.074989	.92501	.081069	.86048	.15083
24.0	.063096	.93690	.067345	.88130	.12670
25.0	.056234	.94377	.059585	.89352	.11283
26.0	.050119	.94988	.052763	.90455	.10049

db	Voltage or Current Ratio	B	C	D	E
27.0	.044668	.95533	.046757	.91448	.089515
27.5	.042170	.95783	.044026	.91907	.084490
28.0	.039811	.96019	.041461	.92343	.079748
30.0	.031623	.96838	.032655	.93869	.063309
32.0	.025119	.97488	.025766	.95099	.050269
32.5	.023714	.97629	.024290	.95367	.047454
33.0	.022387	.97761	.022900	.95621	.044797
34.0	.019953	.98005	.020359	.96088	.039921
35.0	.017783	.98222	.018105	.96506	.035577
36.0	.015849	.98415	.016104	.96880	.031706
37.5	.013335	.98666	.013515	.97368	.026675
38.0	.012589	.98741	.012750	.97513	.025183
39.0	.011220	.98878	.011348	.97781	.022443
40.0	.010000	.99000	.010101	.98020	.020002
42.0	.0079433	.99206	.0080069	.98424	.015888
42.5	.0074989	.99250	.0075556	.98511	.014999
44.0	.0063096	.99369	.0063496	.98746	.012620
45.0	.0056234	.99438	.0056552	.98882	.011247
47.5	.0042170	.99578	.0042348	.99160	.0084341
48.0	.0039811	.99602	.0039970	.99207	.0079623
50.0	.0031623	.99684	.0031723	.99370	.0063246
51.0	.0028184	.99718	.0028264	.99438	.0056368
52.0	.0025119	.99749	.0025182	.99499	.0050238
54.0	.0019953	.99800	.0019993	.99602	.0039905
55.0	.0017783	.99822	.0017815	.99645	.0035566
56.0	.0015849	.99842	.0015874	.99684	.0031698
57.0	.0014125	.99859	.0014145	.99718	.0028251
60.0	.0010000	.99900	.00100100	.99800	.0020000
64.0	.00063096	.99937	.00063136	.99874	.0012619
65.0	.00056234	.99944	.00056266	.99888	.0011247
66.0	.00050119	.99950	.00050144	.99900	.0010024
68.0	.00039811	.99960	.00039827	.99920	.0007962
70.0	.00031623	.99968	.00031633	.99937	.0006325
72.0	.00025119	.99975	.00025125	.99950	.0005024
75.0	.00017783	.99982	.00017786	.99964	.0003557
76.0	.00015849	.99984	.00015851	.99968	.0003170
78.0	.00012589	.99987	.00012591	.99975	.0002518
80.0	.00010000	.99990	.00010000	.99980	.0002000
84.0	.00006310	.99994	.00006310	.99987	.0001262
85.0	.00005623	.99994	.00005624	.99989	.0001125
90.0	.00003162	.99997	.00003162	.99994	.00006325
95.0	.00001778	.99998	.00001778	.99996	.00003557
96.0	.00001585	.99998	.00001585	.99997	.00003170
100.0	.00001000	.99999	.00001000	.99998	.00002000

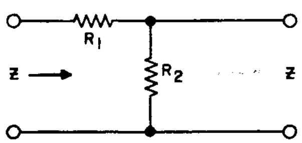
Attenuator Networks

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.

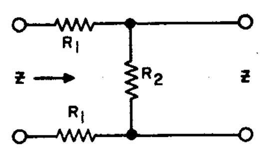
In the case of L and U networks where only the input or output can be matched, as required, the matched side is indicated by an arrow pointing toward the pad. On all other networks, both the input and output circuits are matched.



$$R_1 = ZB$$

$$R_2 = ZC$$

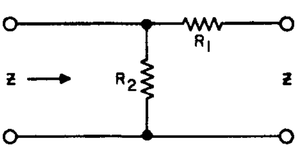
L



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

$$R_2 = ZC$$

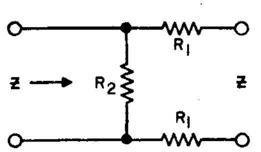
U



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

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

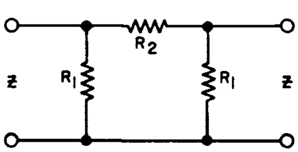
L



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

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

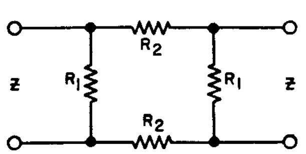
U



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

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

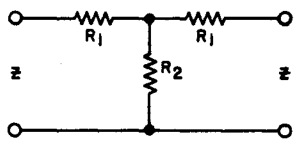
π



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

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

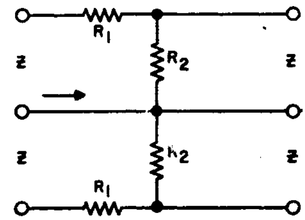
O



T

$R_1 = ZD$

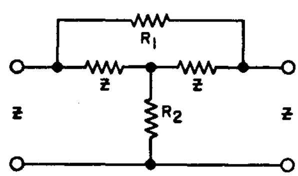
$R_2 = ZE$



Balanced U

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

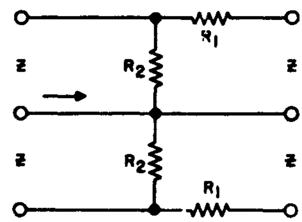
$$R_2 = \frac{ZC}{2}$$



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

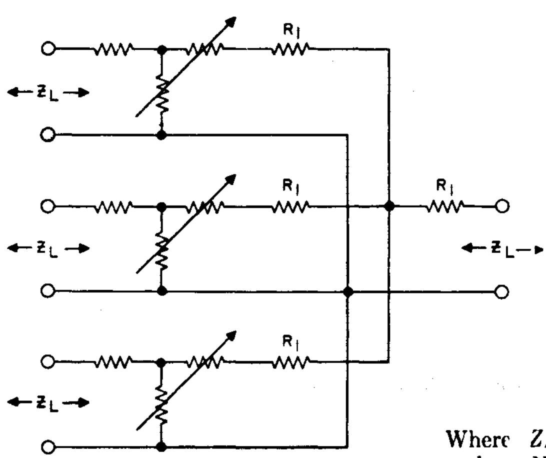


Table of R_1 Values in Ohms

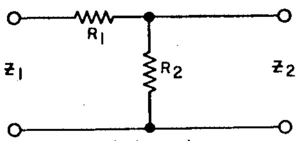
Z	Number of Channels				
	2	3	4	5	6
30	10	15	18	20	21.5
50	16.6	25	30	33.3	35.7
150	50	75	90	100	107
200	66.6	100	120	133	143
250	83.3	125	150	166	179
500	166	250	300	333	357
600	200	300	360	400	428
Network db Loss	6	9.5	12	14	15.5

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

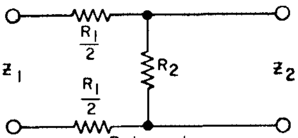
Insertion loss in $db = 20 \log_{10} N$

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

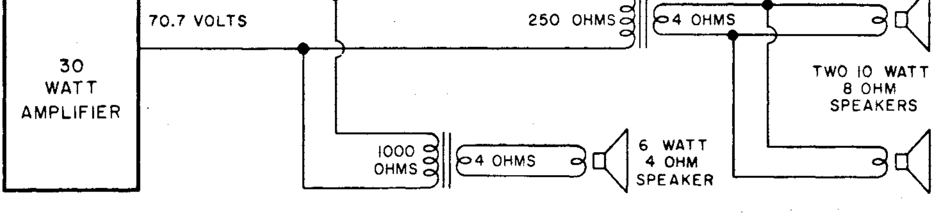
One 6 watt speaker with 4 ohm voice coil.
Two 10 watt speakers with 8 ohm voice coils (use one transformer at this location).

(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

$$X_L = 2\pi fL$$

of a capacitance is expressed by

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

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

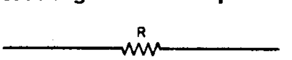
R_L = resistance in ohms acting in series with inductance,

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°.

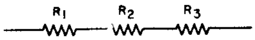
Numerical Magnitude of Impedance . . .



of resistance alone

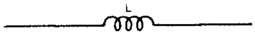
$$Z = R$$

$$\theta = 0°$$



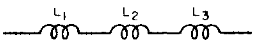
of resistance in series

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



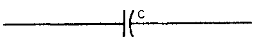
of inductance alone

$$Z = X_L$$
$$\theta = +\,90°$$



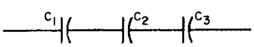
of inductance in series

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



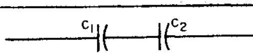
of capacitance alone

$$Z = X_C$$
$$\theta = -\,90°$$



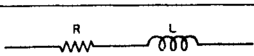
of capacitance in series

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



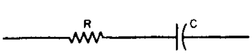
or where only 2 capacitances C_1 and C_2 are involved,

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



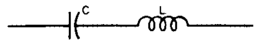
of resistance and inductance in series

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



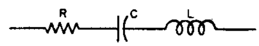
of resistance and capacitance in series

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



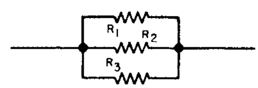
of inductance and capacitance in series

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



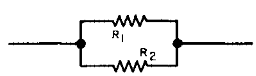
of resistance, inductance and capacitance in series

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



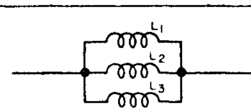
of resistance in parallel

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



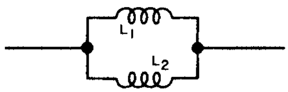
or where only 2 resistances R_1 and R_2 are involved,

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



of inductance in parallel

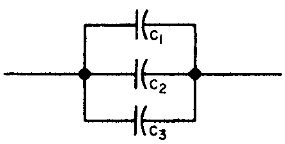
$$Z = \cfrac{1}{\cfrac{1}{X_{L1}} + \cfrac{1}{X_{L2}} + \cfrac{1}{X_{L3}} \ldots \text{etc.}}$$
$$\theta = +\,90°$$



or where only 2 inductances L_1 and L_2 are involved,

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

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



of capacitance in parallel

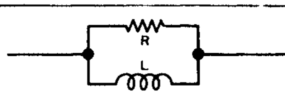
$$Z = \frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}} + \frac{1}{X_{C3}} \ldots \text{etc.}}$$

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

or where only 2 capacitances C_1 and C_2 are involved,

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

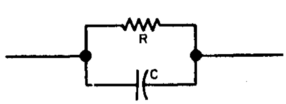
$$\theta = - 90^\circ$$



of inductance and resistance in parallel,

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

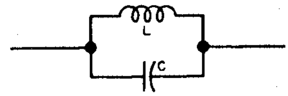
$$\theta = \text{arc tan}\,\frac{R}{X_L}$$



of capacitance and resistance in parallel,

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

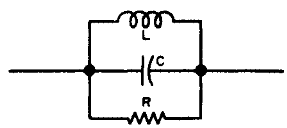
$$\theta = - \text{arc tan}\,\frac{R}{X_C}$$



of inductance and capacitance in parallel,

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

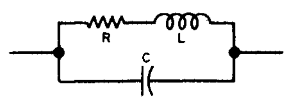
$$\theta = 0^\circ \text{ when } X_L = X_C$$



of inductance, resistance and capacitance in parallel

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

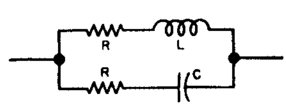
$$\theta = \text{arc tan}\,\frac{RX_C - RX_L}{X_L X_C}$$



of inductance and series resistance in parallel with capacitance

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

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



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

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

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

Conductance

In direct current circuits, conductance is expressed by

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

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

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

the total conductance is expressed by

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

and the total current by

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

and the amount of current in any single resistor, R_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.

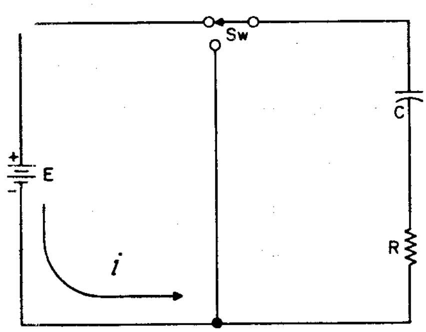
Transient *I* and *E* in *LCR* Circuits

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

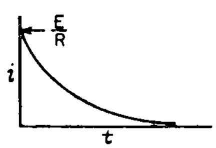
The time constant is defined as the time in seconds for current or voltage to fall to $\frac{1}{\epsilon}$ or 36.8% of its initial value or to rise to $\left(1-\frac{1}{\epsilon}\right)$ or approximately 63.2% of its final value.

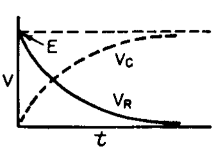
Charging a De-energized Capacitive Circuit



E = applied potential.

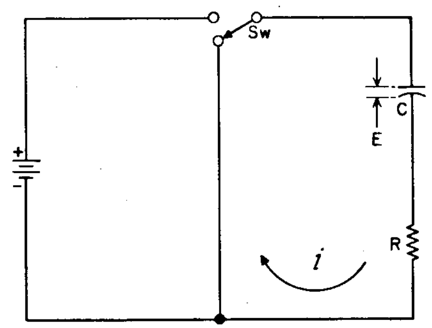
$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$





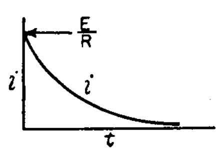
$$V_C = E\left(1 - \epsilon^{-\frac{t}{RC}}\right) \qquad V_R = E\,\epsilon^{-\frac{t}{RC}}.$$

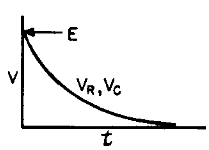
Discharging an Energized Capacitive Circuit



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

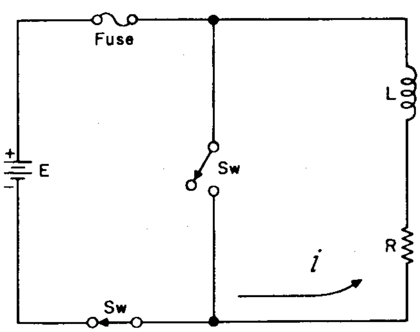
$$i = \frac{E}{R}\epsilon^{-\frac{t}{RC}}$$





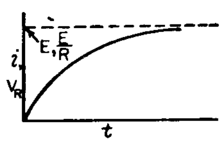
$$V_C = V_R = E\,\epsilon^{-\frac{t}{RC}}$$

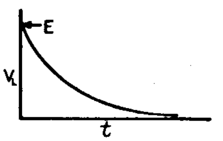
Voltage is Applied to a De-energized Inductive Circuit



E = applied potential

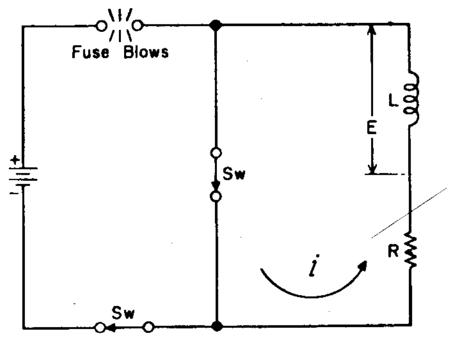
$$i = \frac{E}{R}\left(1 - \epsilon^{-\frac{Rt}{L}}\right)$$





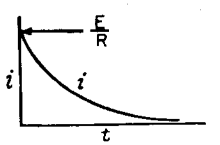
$$V_R = E\left(1 - \epsilon^{-\frac{Rt}{L}}\right) \qquad V_L = E\epsilon^{-\frac{Rt}{L}}$$

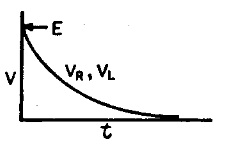
An Energized Inductive Circuit is Short Circuited



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

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

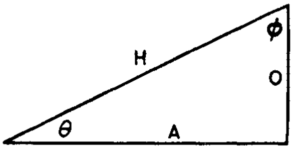
$$\text{cosine of } \theta = \cos\theta = \frac{A}{H}$$

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

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

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

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



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

$$\frac{1}{\sin\theta} = \csc\theta \qquad \frac{1}{\csc\theta} = \sin\theta$$

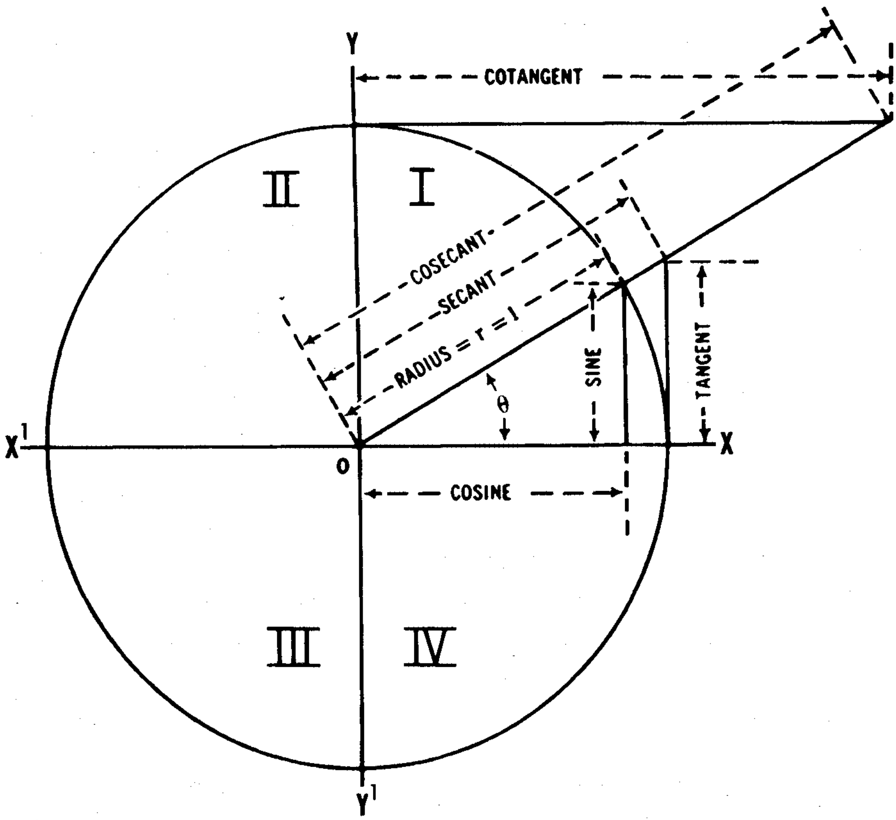
$$\frac{1}{\cos\theta} = \sec\theta \qquad \frac{1}{\sec\theta} = \cos\theta$$

$$\frac{1}{\tan\theta} = \cot\theta \qquad \frac{1}{\cot\theta} = \tan\theta$$

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	$H \sin\phi$	$H \cos\phi$		$90° - \phi$	

Graphic Relations of Angle Functions



Signs of the Functions by Quadrants

Quadrant	Sin θ	Cos θ	Tan θ	Csc θ	Sec θ	Cot θ
I	+	+	+	+	+	+
II	+	−	−	+	−	−
III	−	−	+	−	−	+
IV	−	+	−	−	+	−

Numerical Relations of Angle Functions

Angle	Sin	Cos	Tan	Angle	Sin	Cos	Tan
0°	.0000	1.000	.0000	45°	.7071	.7071	1.0000
1	.0175	.9998	.0175	46	.7193	.6947	1.0355
2	.0349	.9994	.0349	47	.7314	.6820	1.0724
3	.0523	.9986	.0524	48	.7431	.6691	1.1106
4	.0698	.9976	.0699	49	.7547	.6561	1.1504
5	.0872	.9962	.0875	50	.7660	.6428	1.1918
6	.1045	.9945	.1051	51	.7771	.6293	1.2349
7	.1219	.9925	.1228	52	.7880	.6157	1.2799
8	.1392	.9903	.1405	53	.7986	.6018	1.3270
9	.1564	.9877	.1584	54	.8090	.5878	1.3764
10	.1736	.9848	.1763	55	.8192	.5736	1.4281
11	.1908	.9816	.1944	56	.8290	.5592	1.4826
12	.2079	.9781	.2126	57	.8387	.5446	1.5399
13	.2250	.9744	.2309	58	.8480	.5299	1.6003
14	.2419	.9703	.2493	59	.8572	.5150	1.6643
15	.2588	.9659	.2679	60	.8660	.5000	1.7321
16	.2756	.9613	.2867	61	.8746	.4848	1.8040
17	.2924	.9563	.3057	62	.8829	.4695	1.8807
18	.3090	.9511	.3249	63	.8910	.4540	1.9626
19	.3256	.9455	.3443	64	.8988	.4384	2.0503
20	.3420	.9397	.3640	65	.9063	.4226	2.1445
21	.3584	.9336	.3839	66	.9135	.4067	2.2460
22	.3746	.9272	.4040	67	.9205	.3907	2.3559
23	.3907	.9205	.4245	68	.9272	.3746	2.4751
24	.4067	.9135	.4452	69	.9336	.3584	2.6051
25	.4226	.9063	.4663	70	.9397	.3420	2.7475
26	.4384	.8988	.4877	71	.9455	.3256	2.9042
27	.4540	.8910	.5095	72	.9511	.3090	3.0777
28	.4695	.8829	.5317	73	.9563	.2924	3.2709
29	.4848	.8746	.5543	74	.9613	.2756	3.4874
30	.5000	.8660	.5774	75	.9659	.2588	3.7321
31	.5150	.8572	.6009	76	.9703	.2419	4.0108
32	.5299	.8480	.6249	77	.9744	.2250	4.3315
33	.5446	.8387	.6494	78	.9781	.2079	4.7046
34	.5592	.8290	.6745	79	.9816	.1908	5.1446
35	.5736	.8192	.7002	80	.9848	.1736	5.6713
36	.5878	.8090	.7265	81	.9877	.1564	6.3138
37	.6018	.7986	.7536	82	.9903	.1392	7.1154
38	.6157	.7880	.7813	83	.9925	.1219	8.1443
39	.6293	.7771	.8098	84	.9945	.1045	9.5144
40	.6428	.7660	.8391	85	.9962	.0872	11.43
41	.6561	.7547	.8693	86	.9976	.0698	14.30
42	.6691	.7431	.9004	87	.9986	.0523	19.08
43	.6820	.7314	.9325	88	.9994	.0349	28.64
44	.6947	.7193	.9657	89	.9998	.0175	57.29

NOTE: See pages 80-85 for complete tables.

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.	

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

Numerical Comparison Table

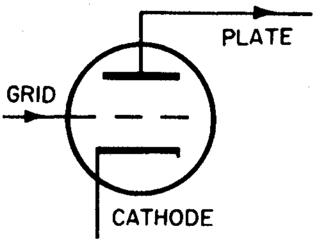
Peak	R. M. S.	Average
1	0.707	0.637
2	1.414	1.274
3	2.121	1.911
4	2.828	2.548
5	3.535	3.185
6	4.242	3.822
7	4.949	4.459
8	5.656	5.096
9	6.363	5.733
10	7.070	6.369
11	7.777	7.006
12	8.484	7.643
13	9.191	9.191
14	9.898	8.917
15	10.605	9.554
16	11.312	10.191
17	12.019	10.828
18	12.727	11.465
19	13.433	12.102
20	14.140	12.738
21	14.847	13.375
22	15.554	14.012
23	16.261	14.649
24	16.968	15.286
25	17.675	15.923
26	18.382	16.560
27	19.089	17.197
28	19.796	17.834
29	20.503	18.471
30	21.210	19.107
31	21.917	19.744
32	22.625	20.381
33	23.332	21.018
34	24.039	21.655
35	24.746	22.292
36	25.453	22.929
37	26.160	23.566
38	26.867	24.203
39	27.574	24.840
40	28.281	25.476
41	28.988	26.113
42	29.695	26.750
43	30.402	27.387
44	31.109	28.024
45	31.816	28.661
46	32.523	29.298
47	33.230	29.935
48	33.937	30.572
49	34.644	31.209
50	35.351	31.845

Peak	R. M. S.	Average
51	36.058	32.482
52	36.765	33.119
53	37.472	33.756
54	38.179	34.393
55	38.886	35.030
56	39.593	35.667
57	40.300	36.304
58	41.007	36.941
59	41.714	37.578
60	42.421	38.214
61	43.128	38.851
62	43.835	39.488
63	44.542	40.125
64	45.249	40.762
65	45.956	41.399
66	46.663	42.036
67	47.370	42.673
68	48.077	43.310
69	48.784	43.947
70	49.491	44.583
71	50.198	45.220
72	50.905	45.857
73	51.612	46.494
74	52.319	47.131
75	53.026	47.768
76	53.733	48.405
77	54.440	49.042
78	55.147	49.679
79	55.854	50.316
80	56.561	50.952
81	57.268	51.589
82	57.975	52.226
83	58.682	52.863
84	59.389	53.500
85	60.096	54.137
86	60.803	54.774
87	61.510	55.411
88	62.217	56.048
89	62.924	56.685
90	63.631	57.321
91	64.338	57.958
92	65.045	58.595
93	65.752	59.232
94	66.459	59.869
95	67.166	60.506
96	67.873	61.143
97	68.580	61.780
98	69.287	62.417
99	69.994	63.054
100	70.701	63.693

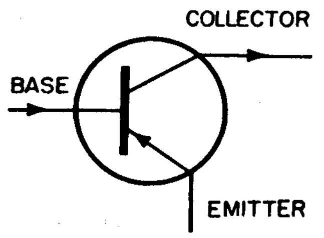
Transistor Formulas and Symbols

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 Alpha-Beta Relationships

Beta	Alpha
1	0.5000
2	0.6666
3	0.7500
4	0.8000
5	0.8333
6	0.8571
7	0.8750
8	0.8889
9	0.9000
10	0.9091
11	0.9167
12	0.9231
13	0.9286
14	0.9333
15	0.9375
16	0.9412
17	0.9444
18	0.9474
19	0.9500
20	0.9524
21	0.9545
22	0.9565
23	0.9583
24	0.9600
25	0.9615
26	0.9630
27	0.9643
28	0.9655
29	0.9667
30	0.9677
31	0.9688
32	0.9697
33	0.9706
34	0.9714
35	0.9722
36	0.9730
37	0.9737
38	0.9744
39	0.9750
40	0.9756

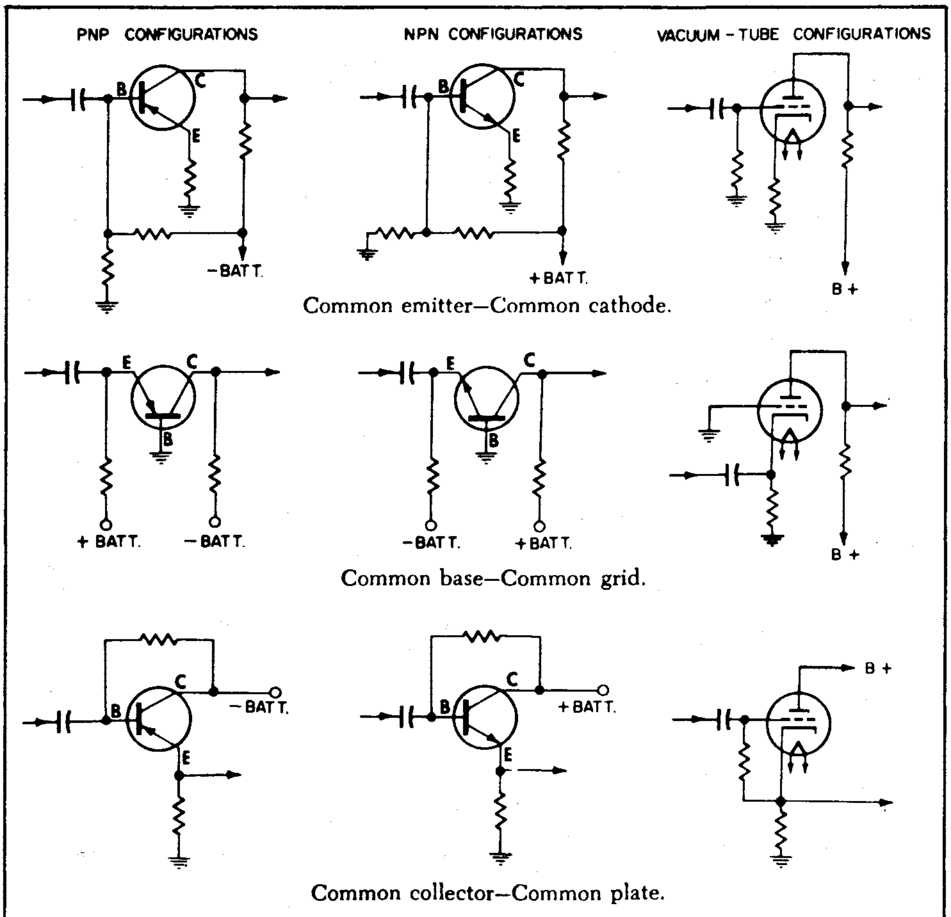
Beta	Alpha
41	0.9762
42	0.9767
43	0.9773
44	0.9778
45	0.9783
46	0.9787
47	0.9792
48	0.9796
49	0.9800
50	0.9804
51	0.9808
52	0.9811
53	0.9815
54	0.9818
55	0.9821
56	0.9825
57	0.9828
58	0.9831
59	0.9833
60	0.9836
61	0.9839
62	0.9841
63	0.9844
64	0.9846
65	0.9848
66	0.9851
67	0.9853
68	0.9855
69	0.9857
70	0.9859
71	0.9861
72	0.9863
73	0.9865
74	0.9867
75	0.9868
76	0.9870
77	0.9872
78	0.9873
79	0.9875
80	0.9877

Beta	Alpha
81	0.9878
82	0.9880
83	0.9881
84	0.9882
85	0.9884
86	0.9885
87	0.9886
88	0.9888
89	0.9889
90	0.9890
91	0.9891
92	0.9892
93	0.9894
94	0.9895
95	0.9896
96	0.9897
97	0.9898
98	0.9899
90	0.9900
100	0.9901
110	0.9910
120	0.9917
125	0.9921
130	0.9924
140	0.9929
150	0.9934
160	0.9938
170	0.9942
180	0.9945
190	0.9948
200	0.9950
210	0.9953
220	0.9955
230	0.9957
240	0.9959
250	0.9960
260	0.9962
270	0.9963
280	0.9964
290	0.9966

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.

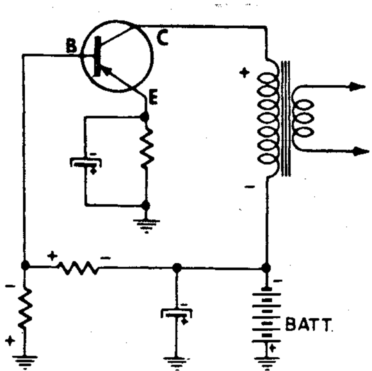
Common collector—Common plate.

Common-Emitter Amplifier Circuits

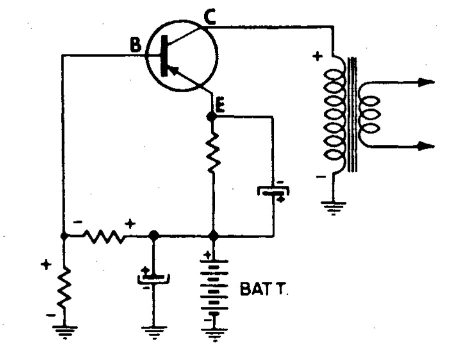
Using Transistors Only

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

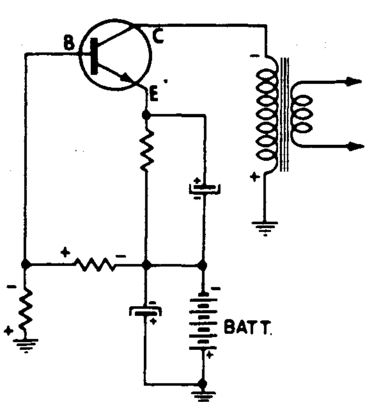


With Positive
Battery Terminal Grounded

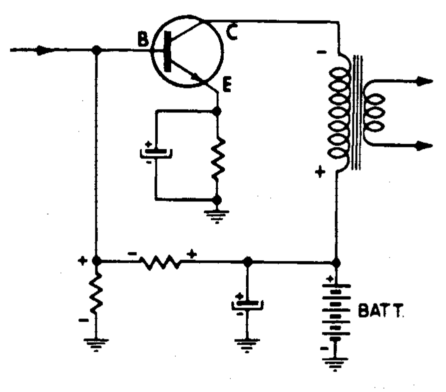


With Negative
Battery Terminal Grounded

Using NPN Transistors



With Positive
Battery Terminal Grounded

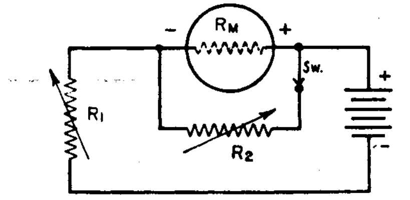


With Negative
Battery Terminal Grounded

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:

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

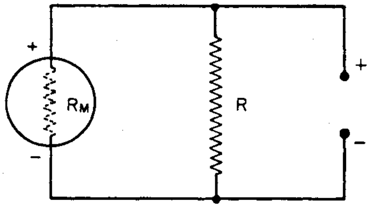
For safe results, use twice the value computed. Also, never attempt to measure the resistance of a meter with an ohmmeter. To do so would in all probability result in a burned-out or severely damaged meter, since the current required for the operation of some ohmmeters and bridges is far in excess of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

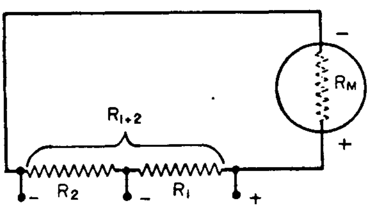
Fixed Current Shunts



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

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.

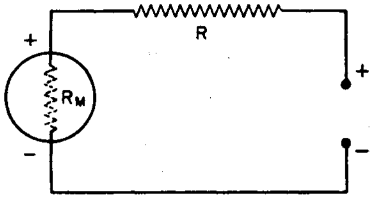
Multi-Range Shunts



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

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.

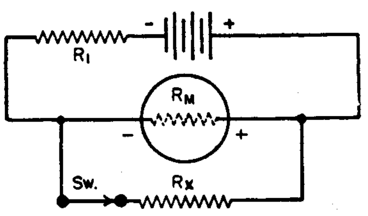
Voltage Multipliers



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

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*

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

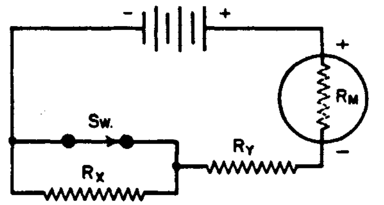
R_x = unknown resistance in ohms,
R_m = meter resistance in ohms, or effective meter resistance if a shunted range is used,
I_1 = current reading with switch open,
I_2 = current reading with switch closed,
R_1 = current limiting resistor of sufficient value to keep meter reading on scale when switch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

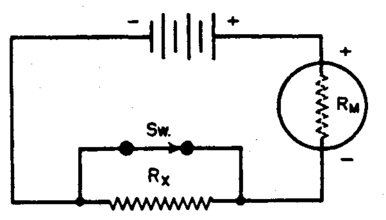
Measuring Resistance—(Continued)



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

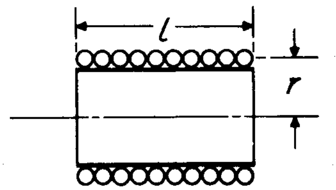
Gauge (AWG) or (B&S)	Number of Turns per Linear Inch			
	Enamel	S.S.C.	D.S.C. and S.C.C.	D.C.C.
1	—	—	3.3	3.3
2	—	—	3.8	3.6
3	—	—	4.2	4.0
4	—	—	4.7	4.5
5	—	—	5.2	5.0
6	—	—	5.9	5.6
7	—	—	6.5	6.2
8	7.6	—	7.4	7.1
9	8.6	—	8.2	7.8
10	9.6	—	9.3	8.9
11	10.7	—	10.3	9.8
12	12.0	—	11.5	10.9
13	13.5	—	12.8	12.0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

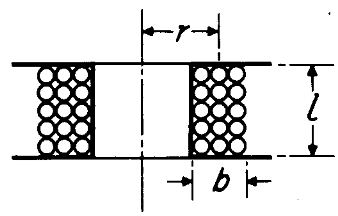
Single-Layer Wound Coils



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

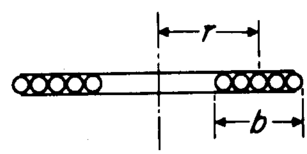
$$N = \frac{\sqrt{L(9r + 10l)}}{r}$$

Multi-Layer Wound Coils



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

Single-Layer Spiral Wound Coils



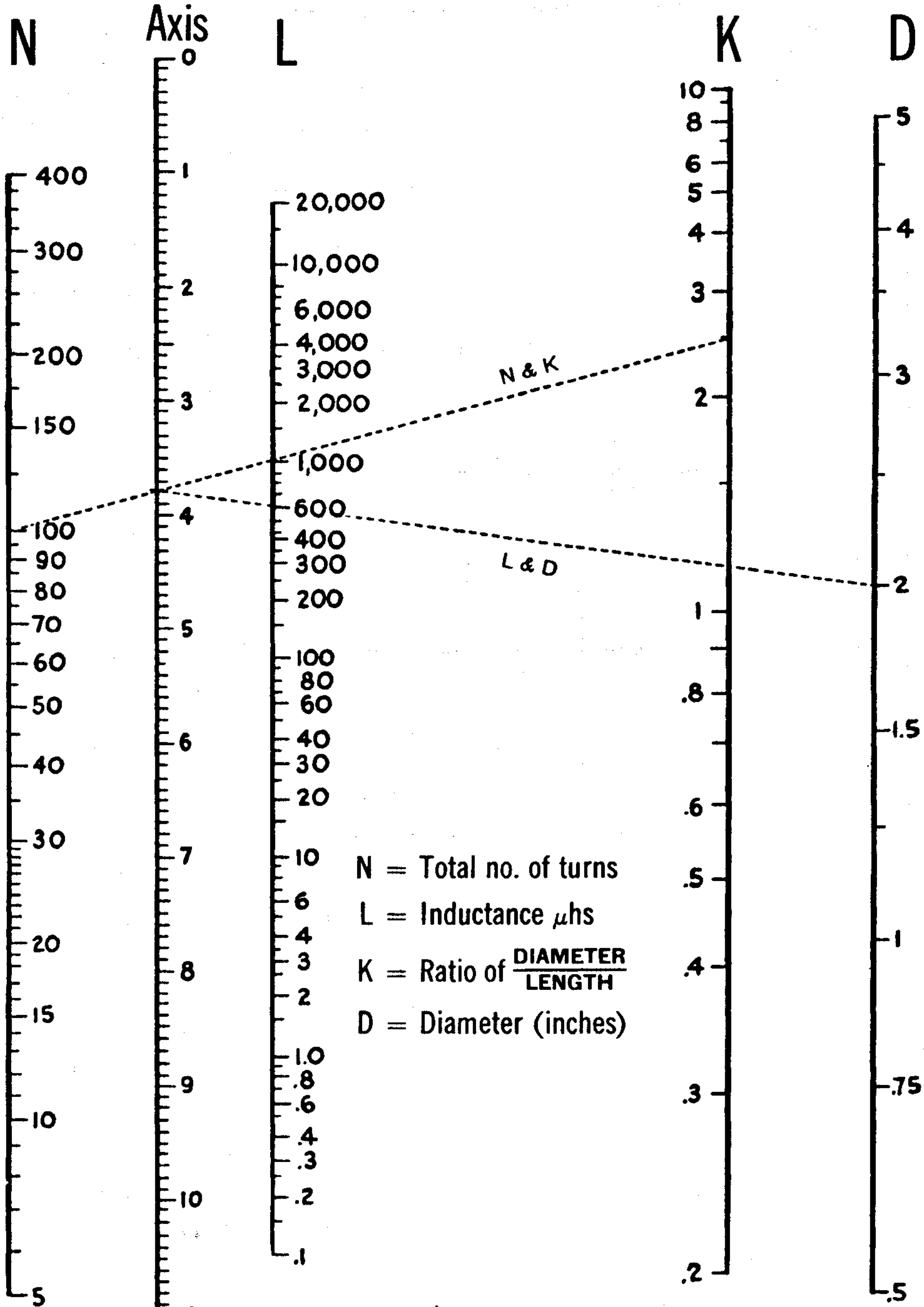
$$L = \frac{(rN)^2}{8r + 11b}$$

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



N = Total no. of turns

L = Inductance μhs

K = Ratio of $\frac{\text{DIAMETER}}{\text{LENGTH}}$

D = Diameter (inches)

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 34 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 38)—Covers the range from 1 cycle to 1000 cycles.

Chart II (page 39)—From 1 kilocycle to 1000 kilocycles.

Chart III (page 40)—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)

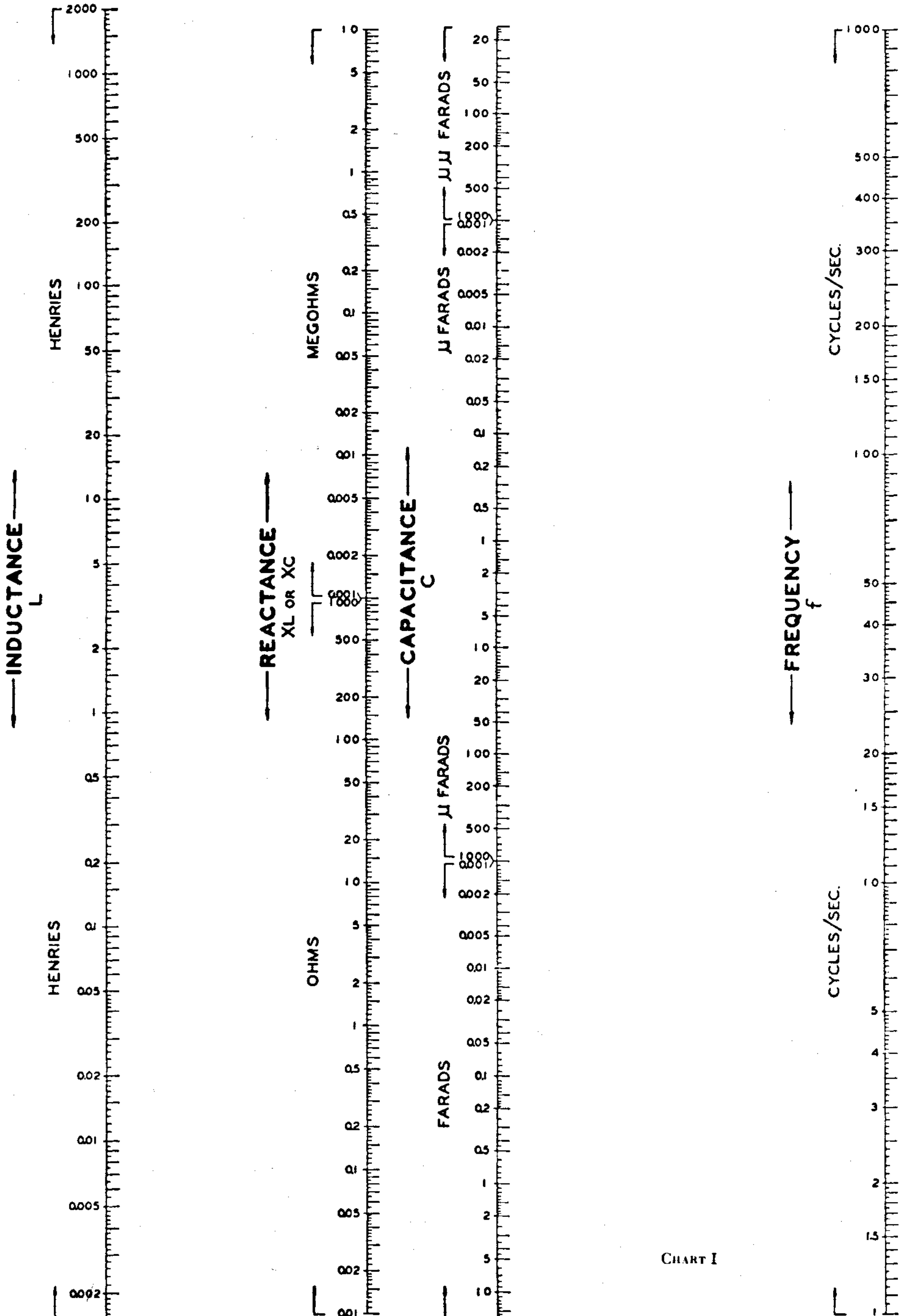


CHART I

Courtesy, Sylvania Electric Products Inc.

Inductance, Capacitance, Reactance—(Continued)

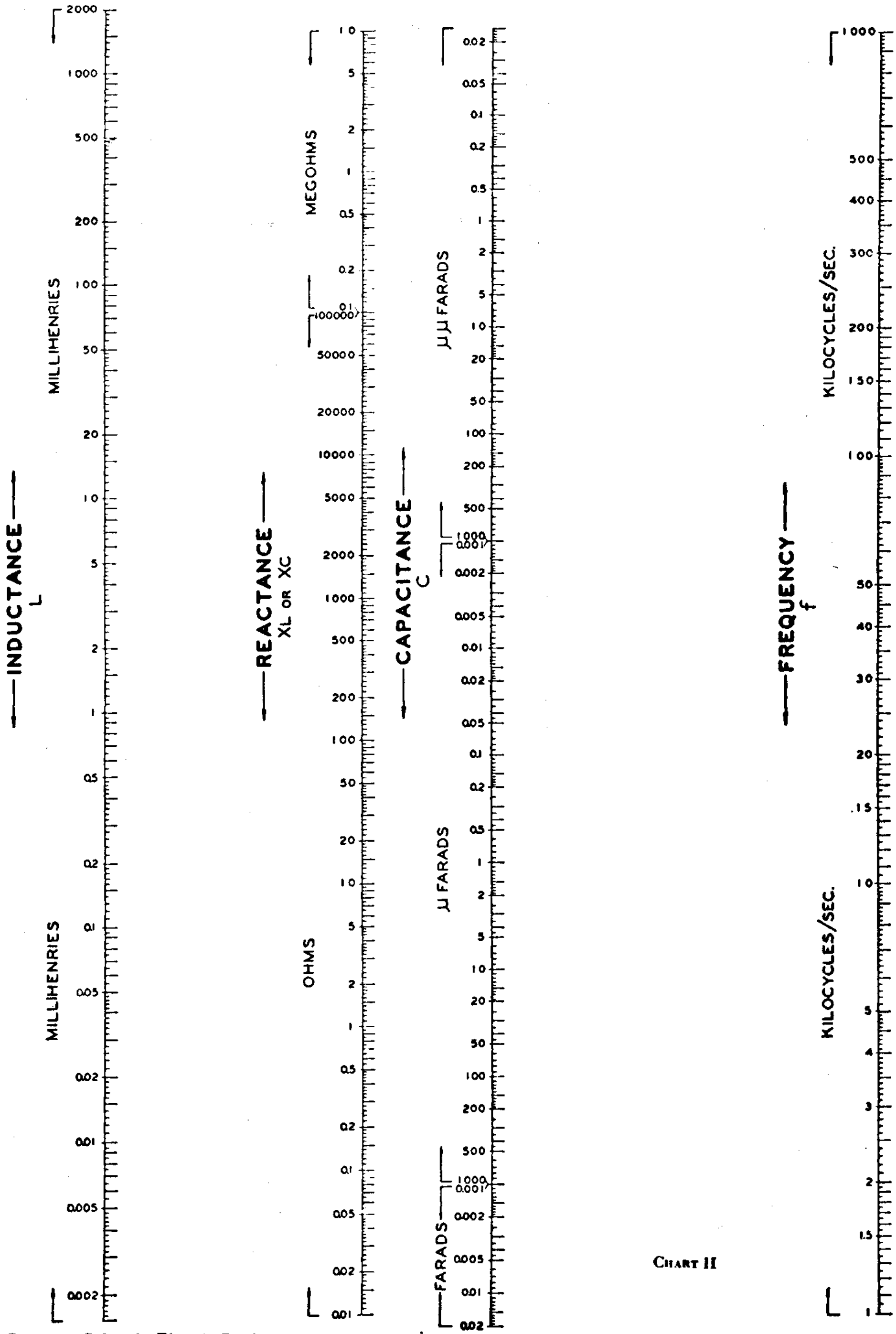


CHART II

Courtesy, Sylvania Electric Products Inc.

Inductance, Capacitance, Reactance—(Continued)

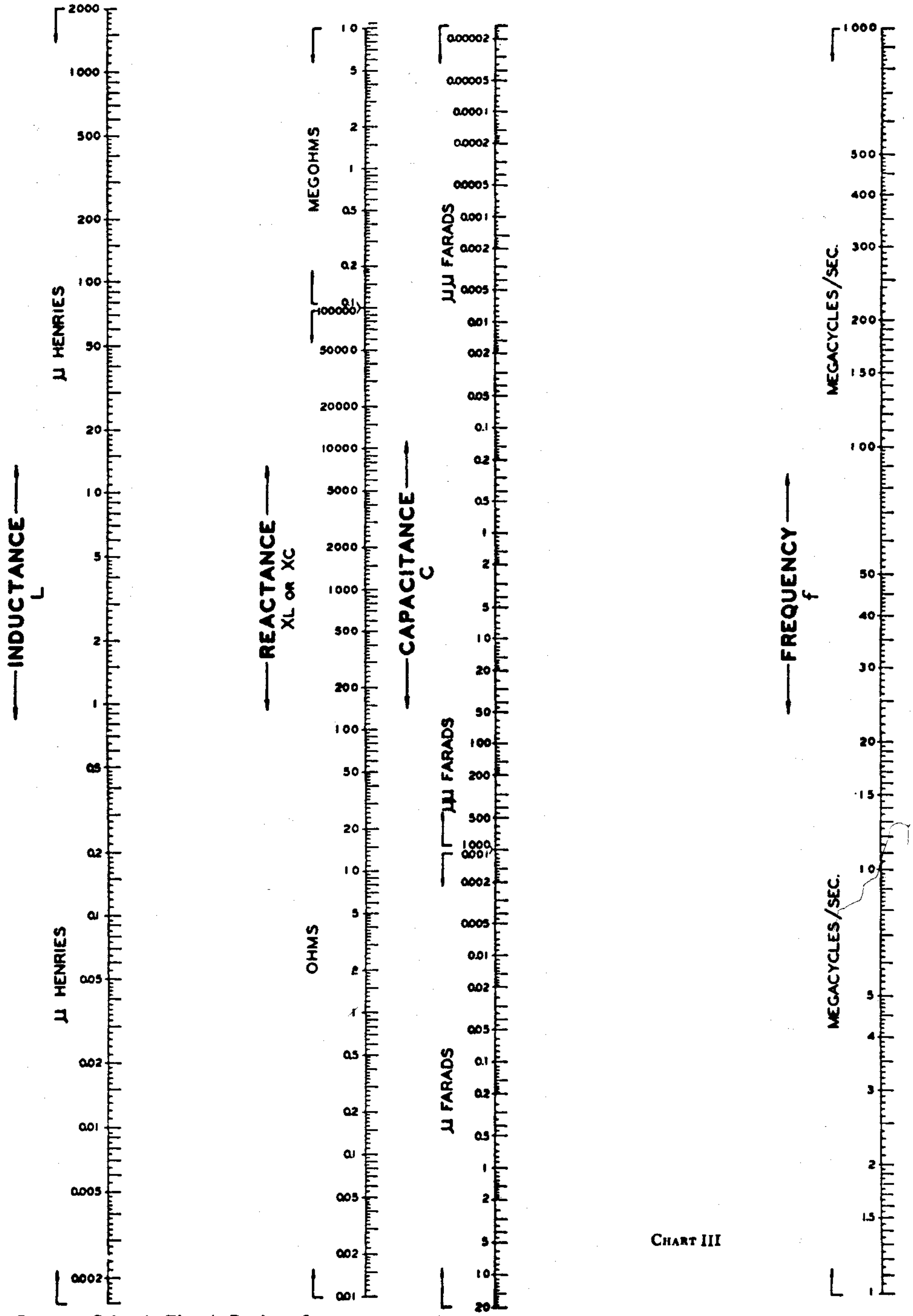
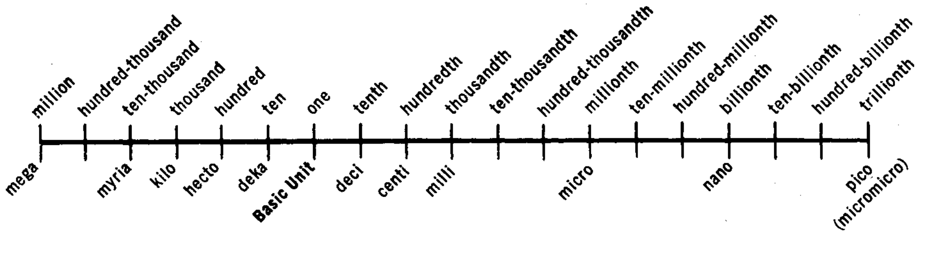


CHART III

Courtesy, Sylvania Electric Products Inc.

Metric Relationships



The above chart shows the relation of the most used values in 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 picofarads (micromicrofarads). Here the number of steps counted will be six to the right. Therefore 0.00035 microfarads is the equivalent of 350 picofarads.

New International Codes

The gradual adoption in this country of new international codes for metric prefixes and measurement terminology by government agencies, industry, technical magazines, book publishers and others, is slowly changing the system of measurement and evaluation codes in general use today.

Acceptance of the new codes here, however, has been slow. We have, therefore, continued to use the more familiar terminology in this handbook with the following exceptions which appear in the metric tables in the next two pages:

1. The cumbersome term "micromicro" has been replaced by "pico". Micromicrofarad" ($\mu\mu$f) now becomes "picofarad" (pf).
2. "Kilomega" (km) has been replaced by "giga" (G).

"Hertz". This term was recently adopted in the United States but it is not represented in this handbook. It is, however, already used by some publishers in place of "cycles" in references to frequency specifications.

The old familiar terms such as "cycles" (cyc), "kilocycles" (kc) and "megacycles" (Mc), are replaced by "Hertz" (Hz), "kilohertz" (kHz) and "megahertz" (MHz).

To combine two of these changes in one specification, the old term "kilomegacycles" (kMc) has become "gigahertz" (GHz).

Heinrich Rudolph Hertz, was born in Germany in 1857 and died in 1894. He was the first scientist to detect, create and measure electromagnetic waves.

Metric Unit Prefixes

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

Metric Conversion Table

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

The above metric conversion table provides a fast and automatic means of conversion from one metric notation to another. The term "Basic Unit" denotes 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	$1 5 \times 10^{-2}$	-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 102, 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:

$$\begin{aligned}
\log 21 &= 1.3222\\
\log 2.1 &= 0.3222\\
\log 210 &= 2.3222\\
\log .0021 &= 7.3222 - 10\\
\log 213 &= 2.3284\\
\log .0213 &= 8.3284 - 10\\
\log 3 &= 0.4771\\
\log 300 &= 2.4771\\
\log .003 &= 7.4771 - 10
\end{aligned}$$

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

$\therefore$ 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
0A2	6073 6626
0A3	VR75
0A4	1267
0B2	0B2WA 6074 6627
0B3	VR90
0C3	VR105
0D3	VR150
0Y4	0Y4G
0Z4	1003 0Z4A
1A4	1A4P 1A4T 1B4 1B4P 1B4T 32 34 951
1A5	1T5
1AC5	1V5
1AD5	1W5
1AF4	1AJ4 1AM4 1T4SF
1AF5	1AH5 1AR5
1AG5	2E41 2E42
1AH5	1AF5 1AR5
1AJ4	1AF4 1AM4 1T4SF
1AM4	1AF4 1AJ4 1T4SF
1AQ5	1R5SF
1AR5	1AF5 1AH5
1AS5	1U5SF
1AU3	1N2 1N2A
1AX2	1H2 1S2A
1B3GT	1AU3 1G3GT 1G3GT/1B3GT 1J3GT 1K3GT 1N2 1N2A
1B4	1A4 1A4P 1A4T 1B4P 1B4T 32 34 951
1B5	25
1C4	1K4
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
1K4	1C4
1K5	1M5
1LA4	1LA4E
1LA6	1LC6
1LC5	1LN5
1LC6	1LA6
1LE3	1LF3
1LF3	1LE3
1LN5	1LC5
1M3	1N3
1M5	1K5
1N2	1N2A 1AU3 1J3A
1N2A	1N2 1AU3 1J3A
1N3	1M3
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
2AV2	2BA2
2AZ2	2BJ2
2B7S	2B7
2BA2	2AV2
2CW4	2DS4
2CY5	2EA5 2EV5
2DS4	2CW4
2EA5	2EV5

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with	Tube Number	Replace with	Tube Number	Replace with
2ER5	2FQ5, 2FQ5A, 2FY5	3AW3	3A3, 3CA3	3ER5	3FQ5, 3FQ5A, 3FY5
2EV5	2EA5	3B2	3A3, 3AW3	3EV5	3EA5
2E30	5812	3B5	3C5, 3Q5	3FH5	3ES5, 3FQ5, 3FQ5A, 3GK5
2E31	2E32	3B7	1291	3FQ5	3FQ5A, 3ES5, 3GK5
2E32	2E31	3BA6	3AU6	3FS5	3GU5
2E35	2E36	3BC5	3CE5	3FY5	3ER5
2E36	2E35	3BE6	3BY6, 3CS6	3GK5	3FQ5, 3FQ5A
2E41	2E42	3BU8	3BU8A, 3GS8, 3HS8, 3KF8	3GS8	3BU8, 3BU8A, 3HS8, 3KF8
2E42	2E41	3BX6	3BY7	3GU5	3FS5
2FH5	2ES5, 2FQ5, 2FQ5A, 2GK5	3BY6	3BE6, 3CS6	3HA5	3HK5, 3HM5, 3HQ5
2FQ5	2FQ5A, 2ES5, 2GK5	3BY7	3BX6	3HK5	3HA5, 3HM5, 3HQ5
2FS5	2GU5	3BZ6	3CB6, 3CF6, 3DK6	3HM5	3HA5, 3HK5, 3HQ5
2FY5	2ER5, 2FQ5, 2FQ5A, 2GK5	3C4	3E5	3HM6	3HT6
2GK5	2FQ5, 2FQ5A	3C5	3B5, 3Q5	3HQ5	3HA5, 3HK5, 3HM5
2GU5	2FS5	3CA3	3A3, 3AW3	3HS8	3BU8, 3BU8A, 3GS8, 3KF8
2G21	2G22	3CB6	3BZ6, 3CF6, 3DK6	3HT6	3HM6
2G22	2G21	3CE5	3BC5	3KF8	3BU8, 3BU8A, 3GS8, 3HS8
2HA5	2HK5, 2HM5, 2HQ5	3CF6	3BZ6, 3CB6, 3DK6	3LE4	3LF4
2HK5	2HA5, 2HM5, 2HQ5	3CS6	3BE6, 3BY6	3Q4	3S4
2HM5	2HA5, 2HK5, 2HQ5	3CY5	3EA5, 3EV5	3Q5	3B5, 3C5
2HQ5	2HA5, 2HK5, 2HM5	3DK6	3BZ6, 3CB6, 3CF6	3S4SF	3W4, 3Z4
2X2	2Y2	3DZ4	3AF4B		
2Y2	2X2	3E5	3C4		
3A3	3AW3, 3CA3	3EA5	3EV5		
3AF4A	3AF4B	3EH7	3EJ7		
3AU6	3BA6	3EJ7	3EH7		

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
3W4	3S4SF, 3Z4
3Z4	3S4SF, 3W4
4AU6	4BA6
4BA6	4AU6
4BC5	4CE5
4BC8	4BQ7A, 4BS8, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BE6	4CS6
4BL8	5EA8, 5U8
4BQ7A	4BC8, 4BS8, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BS8	4BC8, 4BQ7A, 4BX8, 4BZ7, 4BZ8, 5BK7A
4BU8	4GS8, 4HS8, 4KF8
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
4CB6	4BZ6, 4DE6, 4DK6
4CE5	4BC5
4CF6	4BZ6, 4CB6, 4DK6
4CS6	4BE6
4DE6	4BZ6, 4CB6, 4DK6
4DK6	4BZ6, 4CB6, 4DE6
4EH7	4EJ7
4EJ7	4EH7
4ES8	4KN8
4EW6	4GM6
4FS7	4GH8
4GJ7	4GX7
4GM6	4EW6
4GS8	4BU8, 4HS8, 4KF8
4GX7	4GJ7
4HA5	4HM5, 4HQ5
4HK5	4HA5, 4HM5, 4HQ5
4HM5	4HA5, 4HQ5
4HM6	4HT6
4HQ5	4HA5, 4HM5
4HS8	4BU8, 4GS8, 4KF8
4HT6	4HM6
4JK6	4EW6, 4JL6
4JL6	4EW6, 4JK6
4KF8	4BU8, 4GS8, 4HS8
4KN8	4ES8
5AS4	5AS4A, 5DB4, 5U4GB, 5V3, 5V3A
5AU4	5V3, 5V3A
5AW4	5AS4, 5AS4A, 5AU4, 5DB4, 5R4G, 5U4GA, 5U4GB, 5V3, 5V3A
5AX4	5AXR4, 5AS4, 5AS4A, 5R4G, 5T4, 5U4GA, 5U4GB, 5V4
5BK7A	4BC8, 4BQ7A, 4BS8, 4BX8, 4BZ7, 4BZ8
5BQ7A	5BS8, 5BZ7
5BR8	5FV8
5BS8	5BQ7A, 5BZ7
5BZ7	5BQ7A, 5BS8
5CG4	5AR4, 5V4, 5Z4
5CG8	5FG7
5CM6	5CZ5
5DB4	5AS4, 5AS4A, 5U4GB

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
5DH8	5FV8
5DJ4	5DN4
5EA8	5U8
5EW6	5GM6
5FV8	5BR8
5GH8	5EA8 5U8
5GJ7	5GX7
5GM6	5EW6
5GX7	5GJ7
5JK6	5EW6 5JL6
5JL6	5EW6 5JK6
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 5AU4 5DB4 5V3 5V3A
5U8	5EA8
5V3	5V3A 5AU4
5V4	5V4GA 5AR4
5W4	5AR4 5CG4 5R4 5T4 5V4 5Y3 5Z4
5X3	13 80 83V 88
5Y3	5AR4 5AX4 5CG4 5R4 5T4 5V4 5Z4 6087 6106
5Z3	83 1275
5Z4	5AR4 5CG4 5V4 6087
6AB4	6664
6AB5	6N5
6AB7	6AC7 6AJ7 1853
6AC7	6AB7 6AJ7 1852 6134
6AD4	5637 5719 5719A 5898
6AD6	6AF6
6AD8	6DC8 6N8
6AE5	6AF5
6AF3	6BR3
6AF5	6AE5
6AF6	6AD6
6AF11	6AS11 6BD11
6AG5	6BC5 6CE5 6186
6AG7	6AK7
6AH6	6485
6AJ5	7755
6AJ7	6AB7 6AC7
6AK5	1220 5654 6096 6968
6AK7	6AG7
6AK8	6T8 6T8A
6AL5	6EB5 5726 6058 6097 6663 7631
6AM5	6516
6AM6	6064 7498
6AM8	6HJ8
6AQ5	6AQ5A 6BM5 7HG5 6005 6095 6669
6AR6	6098 6384 7756
6AS4	6DM4 6DM4A 6DQ4 6DT4
6AS6	5725 7752
6AS7G	6AS7GA 6AS7GT 6080 6520
6AS11	6AF11 6BD11

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6AT6	6AV6, 6BK6, 6BT6, 6066
6AU4GT	6AU4GTA
6AU5GT	6FW5
6AU6	6AU6A, 6BA6, 6136, 7543
6AU7	7AU7
6AU8	6AU8A, 6AW8A, 6BA8A, 6BH8
6AV5GT	6AV5GA, 6FW5
6AV6	6AT6, 6BK6, 6BT6, 6066
6AW6	6CB6, 6CB6A, 6CF6, 6CD6, 6DE6
6AW8	6AW8A, 6AU8, 6AU8A, 6BA8, 6BA8A, 6JV8, 6KS8, 6LF8
6AX4	6AX4GTA, 6AX4GTB, 6AS4GT, 6DA4, 6DA4A, 6DM4, 6DM4A, 6DQ4, 6DT4
6AX4GTA	6AX4GTB, 6DA4, 6DA4A, 6DM4, 6DM4A, 6DQ4, 6DT4
6AX8	6EA8, 6GH8, 6GH8A, 6LM8, 6U8, 6U8A
6AY3	6AY3A, 6AY3B, 6BA3, 6BS3, 6BS3A, 6DW4, 6DW4A, 6DW4B
6AY3A	6AY3, 6AY3B, 6BA3, 6BS3, 6BS3A, 6DW4, 6DW4A, 6DW4B
6AY3B	6AY3, 6AY3A, 6BA3, 6BS3, 6BS3A, 6DW4, 6DW4A, 6DW4B
6B6	6Q7
6BA3	6AY3, 6AY3A, 6AY3B, 6BS3, 6BS3A, 6DW4, 6DW4A, 6DW4B
6BA5	5638
6BA6	6AU6, 6AU6A, 6BD6, 6CG6, 5749, 6660, 7496, 7543
6BA8	6BA8A, 6AU8, 6AU8A, 6AW8, 6AW8A, 6BH8
6BA8A	6BA8, 6AU8, 6AU8A, 6AW8, 6AW8A, 6BH8
6BC5	6AG5, 6CE5
6BC8	6BQ7, 6BQ7A, 6BS8, 6BX8, 6BZ7, 6BZ8, 6HK8, X155
6BD6	6BA6, 6CG6
6BD11	6AF11
6BE6	6BY6, 6CS6, 5750, 5915
6BF6	6BU6
6BF7	6BG7, 6021
6BG7	6BF7, 6021
6BH6	6661, 7693
6BH8	6AU8, 6AU8A, 6AW8, 6AW8A, 6BA8, 6BA8A
6BJ3	6AX3
6BJ6	6BJ6A, 6662, 7694
6BK6	6AT6, 6AV6, 6BT6
6BL7GT	6BL7GTA, 6BX7GT, 6DN7
6BL8	6EA8, 6LN8, 6U8, 6U8A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6BM5	6AQ5 6AQ5A
6BQ5	7189 7189A 7320
6BQ6GT	6BQ6GTA 6BQ6GTB 6BQ6GTB/6CU6 6CU6 6DQ6A 6DQ6B 6FH6 6GW6
6BQ7	6BQ7A 6BC8 6BS8 6BX8 6BZ7 6BZ8 6HK8 X155
6BR5	6DA5
6BR7	6059
6BR8	6BR8A 6FV8 6FV8A 6JN8
6BR8A	6FV8 6FV8A 6JN8
6BS3	6BS3A 6DW4 6DW4A 6DW4B
6BS3A	6BS3 6DW4 6DW4A 6DW4B
6BS8	6BC8 6BQ7 6BQ7A 6BX8 6BZ7 6BZ8 6HK8 X155
6BT6	6AT6 6AV6 6BK6
6BU6	6BF6
6BU8	6BU8A 6GS8 6HS8 6KF8
6BU8A	6BU8 6GS8 6HS8 6KF8
6BW6	6061
6BW7	6BX6 6EL7
6BX6	6BW7 6BY7 6EL7
6BX7GT	6BL7GT 6BL7GTA 6DN7
6BX8	6BC8 6BQ7 6BQ7A 6BS8 6BZ7 6BZ8 6HK8 X155
6BY6	6BE6 6CS6
6BY7	6BX6
6BZ6	6DC6 6HQ6 6JH6
6BZ7	6BC8 6BQ7 6BQ7A 6BS8 6BX8 6BZ8 6HK8 X155
6BZ8	6BC8 6BQ7 6BQ7A 6BS8 6BX8 6BZ7 6HK8 X155
6C4	6100
6C5	6J5 6L5
6C6	77 1221 1223 7700
6CA5	6EH5
6CB5	6CB5A 6CL5
6CB5A	6CL5
6CB6	6CB6A 6AW6 6CF6 6DC6 6DE6 6DK6 6HQ6 6676 7732
6CD6G	6DN6 6EX6
6CE3	6CD3
6CF6	6AW6 6CB6 6CB6A 6DC6 6DE6 6DK6
6CG3	6CD3
6CG6	6BA6 6BD6
6CG8	6CG8A 6FG7
6CG8A	6FG7
6CH6	6132 7499
6CH7	6CX7
6CJ6	6DR6
6CL6	6197 6297 6677
6CQ4	6DE4
6CQ6	6065
6CS5	6DW5
6CS6	6BE6 6BY6

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6CU6	6BQ6GTB, 6BQ6GTB/6CU6, 6DQ6, 6DQ6A, 6DQ6B, 6FH6, 6GW6
6CW4	6DS4, 7895
6CW7	6CF7
6CX7	6CH7
6CX8	6EB8, 6GN8, 6HF8, 6JA8, 6JE8
6CY5	6EA5, 6EV5, 7717, 8113
6D6	78
6DA4	6DA4A, 6AX4GTA, 6AX4GTB, 6DM4, 6DM4A, 6DQ4, 6DT4
6DA4A	6DM4A, 6DQ4, 6DT4
6DA5	6BR5
6DB6	6954
6DC6	6AW6, 6BZ6, 6CB6, 6CB6A, 6CF6, 6DE6, 6DK6
6DC8	6AD8, 6N8
6DE4	6CQ4
6DE6	6AW6, 6CB6, 6CB6A, 6CF6, 6DC6, 6DK6, 6HQ6
6DE7	6EW7
6DG6GT	6W6GT
6DJ8	6ES8
6DK6	6CB6, 6CB6A, 6CF6, 6DC6, 6DE6, 6HQ6, 8136
6DM4	6DM4A, 6DA4A, 6DQ4, 6DT4
6DM4A	6DT4
6DN6	6CD6G, 6CD6GA, 6EX6
6DQ4	6DT4
6DQ6	6DQ6A, 6DQ6B, 6FH6, 6GW6
6DQ6A	6DQ6B, 6FH6, 6GW6
6DQ6B	6GW6
6DR6	6CJ6
6DR7	6FD7, 6FR7
6DS4	6CW4, 7895
6EA5	6EV5
6EA7	6EM7, 6GL7
6EA8	6LN8, 6U8A
6EB5	6AL5
6EB8	6CX8, 6GN8, 6HF8, 6JE8
6EH5	6CA5
6EH7	6EJ7
6EJ7	6EH7
6EL7	6BW7, 6BX6
6EM7	6EA7, 6GL7
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
6FW8	6KN8
6G5	6H5, 6T5, 6U5
6GE8	7734
6G5	6T5, 6U5
6GF5	6GE5
6GH8	6GH8A, 6EA8, 6U8A
6GH8A	6GH8, 6EA8, 6U8A
6GJ7	6GX7

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6GK5	6FQ5, 6FQ5A
6GL7	6EA7, 6EM7
6GM6	6EW6
6GN8	6CX8, 6EB8, 6HF8, 6JA8, 6JE8
6GS8	6BU8, 6BU8A, 6HS8, 6KF8
6GW6	6DQ6B
6GX6	6GY6, 6HZ6
6GX7	6GJ7
6GY6	6GX6, 6HZ6
6H5	6G5, 6T5, 6U5
6HA5	6HK5, 6HM5, 6HQ5
6HF8	6CX8, 6EB8, 6GN8, 6JA8, 6JE8
6HG5	6AQ5A
6HJ8	6AM8A
6HK5	6HA5, 6HM5, 6HQ5
6HK8	6BC8, 6BQ7, 6BQ7A, 6BS8, 6BX8, 6BZ7, 6BZ8, X155
6HL8	6BL8
6HM5	6HA5, 6HK5, 6HQ5
6HM6	6HT6
6HQ5	6HA5, 6HK5, 6HM5
6HQ6	6BZ6, 6CB6, 6CB6A, 6DE6, 6DK6, 6JH6
6HS8	6BU8, 6BU8A, 6GS8, 6KF8
6HT6	6HM6
6HZ6	6GX6, 6GY6
6J4	8532
6J5	6C5, 6L5
6J6	5964, 6030, 6099, 6101
6J7	1233, 1620, 7000
6JA8	6CX8, 6EB8, 6GN8, 6HF8, 6JE8, 6JT8
6JE8	6EB8, 6GN8, 6HF8, 6JA8
6JF6	6KM6
6JH6	6BZ6, 6HQ6
6JK6	6EW6, 6JL6
6JL6	6EW6, 6JK6
6JN8	6BR8A, 6FV8, 6FV8A
6JS6	6JS6A, 6KD6
6JS6A	6JS6, 6KD6
6JT8	6JA8, 6KR8, 6KV8, 6LK8, 6LY8
6JV8	6AW8, 6AW8A, 6KS8, 6LF8
6JW8	6LX8
6K4	6778
6K7	6U7, 5732
6K11	6Q11
6KD8	6EA8, 6GH8, 6GH8A, 6U8, 6U8A
6KF8	6BU8, 6BU8A, 6GS8, 6HS8
6KM6	6JF6
6KR8	6JT8, 6KV8, 6LB8, 6LY8
6KS8	6AU8, 6AU8A, 6AW8, 6AW8A, 6JV8, 6LF8
6KV8	6JT8, 6KR8, 6LB8, 6LY8
6L4	6F4

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
6L5	6C5 6J5
6L6	6L6G 6L6GA 6L6GAY 6L6GB 6L6GC 6L6GT 6L6GX 1622 5881 5932 7581 7581A
6L7	1612 1620
6LB8	6JT8 6KR8 6KV8 6LY8
6LF8	6AW8 6AW8A 6JV8 6KS8
6LM8	6AX8 6GH8 6GH8A
6LN8	6U8A
6LY8	6JT8 6KR8 6KV8 6LB8
6N3	6U3
6N5	6N5G 6AB5
6N8	6AD8 6DC8
6Q7	6B6 6118
6R8	6T8 6T8A
6SA7	6SB7Y 5961
6SD7	6SE7
6SE7	6SD7
6SG7	6SH7 6006
6SH7	6SG7 6006
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 6DM4A 6DQ4 6DT4 6W4GT 6W4GTA
6U5	6G5 6H5 6T5
6U7	6K7
6U8	6U8A 6EA8 6LN8 1252 6678 7731
6U8A	6EA8 6LN8
6V6	6V6G 6V6GT 6V6GTA 6V6GTX 6V6GTY 6V6GX 6V6GY 5871 7408
6W4GT	6W4GTA 6AS4GT 6AX4GT 6AX4GTA 6AX4GTB 6DA4 6DA4A 6DM4 6DM4A 6DQ4 6DT4 6U4GT
6W4GTA	6AX4GT 6AX4GTA 6AX4GTB 6DA4 6DA4A 6DM4 6DM4A 6DQ4 6DT4 6U4GT
6W6	6W6GT 6DG6GT
6X4	6BX4 6063 6202
6X5	6X5GT 024 024A
6X8	6X8A
6Z3	1V
7A4	XXL
7A6	5679
7A7	7A7LM 7H7
7AB7	1204
7AG7	7AH7
7AH7	7AG7 7B7
7AJ7	1273
7AN7	7EK7
7AU7	6AU7
7B7	7AH7
7C4	1203 1203A

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
7DJ8	7ES8
7E5	1201
7E7	7R7
7EK7	7AN7
7ES8	7DJ8
7FC7	7EK7
7G7	7V7, 1232
7H7	7A7, 7A7LM
7HG8	8HG8
7J7	7S7
7R7	7E7
7S7	7J7
7V7	7G7
7X7	XXFM
8A8	9A8, 9EA8, 9U8, 9U8A
8AU8	8AU8A, 8AW8A, 8BA8A, 8BH8
8AW8A	8AU8, 8AU8A, 8BA8A, 8BH8, 8JV8, 8KS8
8BA8A	8AU8, 8AU8A, 8AW8A, 8BH8
8BH8	8AU8, 8AU8A, 8AW8A, 8BA8A
8CX8	8EB8, 8GN8, 8JE8
8EB8	8CX8, 8GN8, 8JE8
8GJ7	8GX7
8GN8	8CX8, 8EB8, 8JE8
8GX7	8GJ7
8HG8	7HG8
8JE8	8CX8, 8EB8, 8GN8
8JV8	8AW8A, 8KS8
8KS8	8AU8, 8AU8A, 8AW8A, 8JV8
9A8	8A8, 9EA8, 9U8, 9U8A
9EA8	9U8A
9U8	9U8A, 8A8, 9A8, 9EA8
9U8A	9EA8
9A8	9U8, 9U8A
9U8	9U8A, 9A8
10DE7	10EW7
10DR7	10FD7, 10FR7
10EB8	10GN8, 10HF8, 10JA8, 10JY8, 10LZ8, 11JE8
10EG7	10EM7
10EM7	10EG7
10FD7	10FR7
10FR7	10FD7
10GN8	10EB8, 10HF8, 10JA8, 10JY8, 10LZ8, 11JE8
10HF8	10EB8, 10GN8, 10JA8, 10JY8, 10LZ8, 11JE8
10JA8	10EB8, 10GN8, 10HF8, 10JY8, 11JE8
10JT8	10KR8, 10LB8, 10LW8, 11KV8, 11LQ8
10JY8	10EB8, 10GN8, 10HF8, 10JA8, 10LZ8, 11JE8
10KR8	10JT8, 10LB8, 10LW8, 11KV8, 11LQ8
10LB8	10JT8, 10KR8, 10LW8, 11KV8, 11LQ8
10LW8	10JT8, 10KR8, 10LB8, 11KV8, 11LQ8
10LZ8	10EB8, 10GN8, 10HF8, 10JY8, 11JE8
11C5	12DM5
11JE8	10EB8, 10GN8, 10HF8, 10JA8, 10JY8, 10LZ8

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
11KV8	10JT8, 10KR8, 10LB8, 10LW8, 11LQ8
11LQ8	10JT8, 10KR8, 10LB8, 10LW8, 11KV8
12A6	5659
12AD6	12AG6
12AE6	12AE6A, 12FT6
12AE6A	12AE6, 12FT6
12AE10	13V10
12AF3	12BR3
12AF6	12BL6
12AG6	12AD6
12AT6	12AT6A, 12AV6, 12AV6A, 12BK6, 12BT6
12AT6A	12AV6A
12AT7	12AT7WA, 12AT7WB, 6060, 6201, 6671, 6679, 7492, 7728
12AU6	12AU6A, 12BA6, 12BA6A
12AU6A	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, 12DM4A, 12DQ4
12AX4GTA	12AX4GTB, 12D4, 12D4A, 12DM4, 12DM4A, 12DQ4
12AX4GTB	12DA4, 12DM4, 12DM4A, 12DQ4
12AX7	12AX7A, 12DF7, 12DT7, 5721, 6057, 6681, 7025, 7025A, 7494, 7729
12AY3	12AY3A, 12BS3, 12BS3A
12AY3A	12AY3, 12BS3, 12BS3A
12B7	14A7, 14H7
12BA6	12BA6A, 12AU6, 12AU6A
12BA6A	12AU6A
12BD6	12BA6, 12BA6A
12BE6	12BE6A, 12CS6
12BF6	12BU6
12BH7	12BH7A, 6913
12BK6	12AT6, 12AT6A, 12AV6, 12AV6A, 12BT6
12BL6	12AF6
12BQ6GT	12BQ6GA, 12BQ6GTA, 12BQ6GTB, 12CU6, 12DQ6, 12DQ6A, 12DQ6B
12BQ6GTA	12BQ6GA, 12BQ6GTB, 12CU6, 12DQ6, 12DQ6A, 12DQ6B, 12GW6
12BQ6GTB	12CU6, 12DQ6, 12DQ6A, 12DQ6B, 12GW6
12BT6	12AT6, 12AT6A, 12AV6, 12AV6A, 12BK6
12BU6	12BF6
12BV7	12BY7, 12BY7A, 12DQ7
12BY7	12BY7A, 12BV7, 12DQ7, 7733, 8448
12BY7A	12DQ7
12C5/12CU5	12C5, 12CU5, 12R5

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
12CA5	12EH5
12CS5	12DW5
12CS6	12BE6 12BE6A
12CU6	12BQ6GTB 12BQ6GTB/12CUG 12DQ6 12DQ6A 12DQ6B 12GW6
12CX6	12EZ6
12D4	12D4A 12AX4GTB 12DM4 12DM4A 12DQ4
12D4A	12DM4 12DM4A 12DQ4
12DF7	12AX7 12AX7A 12DT7 7025 7025A
12DM4	12DM4A 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
12E5	12J5
12EA6	12DZ6 12EK6
12ED5	12FX5
12EH5	12CA5
12EK6	12DZ6 12EA6
12EN6	12L6GT 12W6GT
12EZ6	12CX6
12FK6	12FM6
12FM6	12FK6
12FT6	12AE6 12AE6A
12FX5	12ED5
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
13DE7	15EW7
13DR7	13FD7 13FR7
13EM7	15EA7
13FD7	13FR7
13FR7	13FD7
13V10	12AE10
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
15AB9	17AB9
15AF11	15BD11
15BD11	15AF11
15EA7	13EM7
16A5	15CW5
17A8	19EA8 19EA8A
17AB9	15AB9
17AX3	17BE3
17AX4GT	17AX4GTA 17D4 17D4A 17DM4 17DM4A 17DQ4
17AX4GTA	17D4 17D4A 17DM4 17DM4A 17DQ4
17AY3	17AY3A 17BS3 17BS3A
17AY3A	17AY3 17BS3 17BS3A
17BQ6GTB	17DQ6 17DQ6A 17DQ6B 17GW6
17BZ3	17BE3 17BE3A
17C5	17CU5 17R5
17CQ4	17DE4
17CU5	17C5 17R5
17D4	17D4A 17AX4GTA 17DM4 17DM4A 17DQ4

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
17D4A	17DM4, 17DM4A, 17DQ4
17DE4	17CQ4
17DM4	17DM4A, 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
18FY6A	18GE6A
18GD6	18GD6A, 18FW6, 18FW6A
18GD6A	18FW6A
18GE6	18GE6A, 18FY6, 18FY6A
18GE6A	18FY6A
19AU4	19AU4GT, 19AU4GTA, 17CQ4, 17DE4
19AU4GT	19AU4, 19AU4GTA, 17CQ4, 17DE4
19C8	19T8, 19T8A
19CL8A	19CL8B, 19JN8
19DE7	19EW7, 20EW7
19EA8	19EA8A, 17A8

Tube Number	Replace with
19EW7	20EW7
19JN8	19CL8A, 19CL8B
19T8	19T8A, 19C8
19Y3	19X3
20EW7	19EW7
21A6	21B6
21B6	21A6
21EX6	25CD6GB
25AX4GT	25D4
25B6G	5824
25BQ6GA	25BQ6GTB, 25BQ6GTB/25CU6, 25CU6, 25DQ6, 25DQ6A
25BQ6GTB	25BQ6GTB/25CU6, 25CU6, 25DQ6, 25DQ6A
25CA5	25C5, 25EH5
25CD6G	25CD6GA, 25CD6GB, 25DN6, 21EX6
25CD6GA	25CD6GB, 25DN6, 21EX6
25CD6GB	21EX6
25CU6	25BQ6GTB/25CU6, 25BQ6GTB, 25DQ6, 25DQ6A
25DN6	25CD6GB, 21EX6
25EC6	25CD6GB, 21EX6
25EH5	25CA5
25L6GT	25W6GT, 6046
25S	25, 1B5, 1B5/25S

Tube Number	Replace with
25U4GT	25AX4GT, 25D4, 25W4GT
25W4GT	25AX4GT, 25D4, 25U4GT
25W6GT	25L6GT, 6046
25Y5	25Z5
25Z5	25Y5
26A6	26CG6
26B6	26D6
26CG6	26A6
26D6	26B6
27	56
27GB5	28GB5
28GB5	27GB5
28HD5	30HD5
30A5	35C5, 35C5A
30HD5	28HD5
32	1A4, 1A4P, 1A4T, 1B4, 1B4P, 1B4T, 34, 951
32ET5	32ET5A, 34GD5, 34GD5A
32ET5A	34GD5A
32L7	25A7
34	1A4, 1A4P, 1A4T, 1B4, 1B4P, 1B4T, 32, 951
34CE3	34CD3
34GD5	34GD5A, 32ET5, 32ET5A
34GD5A	32ET5A
35A3	35C3
35C3	35A3

Directly Interchangeable Tubes—(Continued)

Tube Number	Replace with
35C5	35C5A 30A5
37	76
38HK7	38HE7
39	39/44 44
39/44	39 44
40Z5GT	45Z5GT
45Z5GT	40Z5GT
44	39 39/44
50CA5	50EH5 50EH5A
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
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	1D13	1A3	1F3	1T4
1C2	1AC6	1F1	1AJ4	1FD1	1AH5
1C3	1AB6	1F2	1L4	1FD9	1S5

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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
1H33	1AQ5	6L43	6CL6	30F5	7ED7
1H35	1AB6	6LD3	6CV7	30FL1	9GB8
1P1	3C4	6LD12	6AK8	30L1	7AN7
1P10	3S4	6LD13	6BD7	30L15	7EK7
1P11	3V4	6LP12	6BM8	30P4	25GF6
1RK23	1S2	6M-H1	6J4	30P12	12FB5
3D-HH13	3FX7	6M-HH3	6J6	30P16	16A5
3M-R24	3DK6	6P9	6BM5	30P18	15CW5
3M-V7	3BZ6	6P15	6BQ5	30P19	25GF6
4R-HH2	4BS8	6P17	6AM5	30PL1	13GC8
4R-HH8	4KN8	6R-HH2	6BS8	30PL12	16A8
4Y25	807	6R-HH8	6KN8	30PL13	16GK8
5M-HH3	5J6	6R-R8C	5847	52KU	5Z4G
5P29	6CN6	6S5G	6E5	62DDT	6CV7
5R-HP1	4BL8	6Z4	6BX4	62TH	6CU7
5S1	807	6Z31	6X4	62VP	6CJ5
5Z10	5U4G	7D9	6AM5	63TP	6AB8
6/30L2	6GA8	7D10	6CH6	64ME	6CD7
6AT7N	6DT8	7F16	6CJ5	64SPT	6BX6
6B32	6AL5	8D3	6AM6	65ME	6BR5
6BC32	6AV6	8D5	6BR7	66KU	6BT4
6C12	6AJ8	8D6	6BW7	67PT	6CK5
6C16	6BL8	8D7	6BS7	108C1	0B2
6C18	6GV7	8D8	6267	121VP	12AC5
6CC10	5692	8R-HP1	6CQ6	141DDT	14L7
6CC31	6J6	9D6	6CQ6	141TH	14K7
6CC342	5670	9P9	9BM5	150C2	0A2
6CF8	6267	10C14	19D8	150C3	0D3
6D2	6AL5	10F18	13EC7	163PEN	16A5
6F10	6AC7	10LD3	14L7	171DDP	17C8
6F12	6AM6	10LD13	14G6	213PEN	21A6
6F16	6CJ5	10P18	45B5	311SU	31A3
6F18	6EC7	10PL12	50BM8	451PT	45A5
6F19	6BY7	12BC32	12AV6	A863	6J7GT
6F21	6CQ6	12E13	6550	A1834	6AS7G
6F22	6267	12F31	12BA6	AD	6Z3
6F23	6EL7	12G-B3	12GW6	B36	12SN7GT
6F24	6EJ7	12G-B6	12BQ6GT	B63	6A6
6F25	6EH7	12G-K17	12D4A	B152	12AT7
6F26	6BY7	12H31	12BE6	B309	12AT7
6F29	6EH7	12R-K19	12BR3	B319	7AN7
6F30	6EJ7	13D2	6SN7GT	B329	12AU7
6F31	6BA6	13D3	6158	B339	12AX7
6F33	6AS6	17N8	17C8	B349	7EK7
6F35	6AJ5	18AK5	6028	B719	6AQ8
6F36	6AH6	19AJ8	19D8	B729	6GA8
6FD12	6DC8	19BD	19X3	B739	12AT7
6G-B3A	6GW6	19M-R9	18GD6	B749	12AU7
6G-B6	6BQ6GT	19SU	19Y3	B759	12AX7
6G-B9	6DQ6A	19U3	19X3	BF61	6CK5
6G-K17	6AU4GT	19W3	19X3	BF451	45A5
6H31	6BE6	20D3	12AH8	BPM04	6AQ5
6L10	6AG7	20D4	6AJ8	D1C	957
6L12	6AQ8	25G-B6	25BQ6GT	D2C	958A
6L13	12AX7	30C1	9A8	D2M9	6AL5
6L31	6AQ5	30C15	9EN7	D3F	959
6L34	6AQ4	30C18	7GV7	D63	6H6

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
D77	6AL5	DY70	5642	ECC83	12AX7
D152	6AL5	DY80	1X2A	ECC84	6CW7
D717	6AL5	DY86	1S2	ECC85	6AQ8
DA90	1A3	DY87	1S2A	ECC86	6GM8
DAC32	1H5GT	E1F	954	ECC88	6DJ8
DAF91	1S5	E2F	956	ECC89	6FC7
DAF92	1U5	E55L	8233	ECC91	6J6
DAF96	1AH5	E80CC	6085	ECC180	6BQ7A
DC80	1E3	E80F	6084	ECC186	12AU7
DCC90	3A5	E80L	6227	ECC189	6ES8
DCF60	1V6	E80T	6218	ECC230	6080
DD6	6AL5	E81CC	6201	ECC804	6GA8
DD7	6AM5	E81L	6686	ECC813	6463
DDR7	6AM5	E82CC	6189	ECF80	6BL8
DF33	1N5GT	E88C	8255	ECF82	6U8
DF60	5678	E88CC	6922	ECF86	6HG8
DF62	1AD4	E90C	5920	ECF801	6GJ7
DF67	5911	E90CC	5920	ECF802	6JW8
DF91	1T4	E91H	6687	ECF805	6GV7
DF92	1L4	E95F	5654	ECH42	6CU7
DF96	1AJ4	E180F	6688	ECH80	6AN7
DF97	1AN5	E180L	7534	ECH81	6AJ8
DF904	1U4	E182CC	7119	ECH83	6DS8
DH63	6Q7	E186F	7737	ECH84	6JX8
DH74	12Q7GT	E188CC	7308	ECL80	6AB8
DH76	12Q7GT	E280F	7722	ECL82	6BM8
DH77	6AT6	E288CC	8223	ECL84	6DX8
DH81	7B6	EAA91	6AL5	ECL85	6GV8
DH118	14L7	EABC80	6AK8	ECL86	6GW8
DH119	14G6	EAF42	6CT7	EF41	6CJ5
DH142	14L7	EB91	6AL5	EF71	5899
DH149	7C6	EBC41	6CV7	EF72	5840
DH150	6CV7	EBC81	6BD7	EF80	6BX6
DH718	6CV7	EBC90	6AT6	EF81	6BH5
DH719	6AK8	EBC91	6AV6	EF82	6CH6
DK32	1A7GT	EBF80	6N8	EF83	6BK8
DK91	1R5	EBF81	6AD8	EF85	6BY7
DK92	1AC6	EBF83	6DR8	EF86	6267
DK96	1AB6	EBF85	6DC8	EF87	6267
DL29	3D6	EBF89	6DC8	EF89	6DA6
DL31	1A5	EC55	5861	EF89F	6DG7
DL33	3Q5GT	EC80	6Q4	EF91	6AM6
DL35	1C5GT	EC81	6R4	EF92	6CQ6
DL36	1Q5GT	EC84	6AJ4	EF93	6BA6
DL67	5913	EC86	6CM4	EF94	6AU6
DL91	1S4	EC88	6DL4	EF95	6AK5
DL92	3S4	EC90	6C4	EF96	6AG5
DL93	3A4	EC91	6AQ4	EF97	6ES6
DL94	3V4	EC92	6AB4	EF98	6ET6
DL95	3Q4	EC94	6AF4	EF183	6EH7
DL96	3C4	EC95	6ER5	EF184	6EJ7
DL98	3B4	EC97	6FY5	EF190	6CB6
DM70	1M3	EC900	6HA5	EF730	5636
DM71	1N3	EC1000	8254	EF731	5899
DY30	1B3GT	ECC70	6021	EF732	5901
DY51	1BG2	ECC81	12AT7	EF734	6205
DP61	6AK5	ECC82	12AU7	EF811	6EH7

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
EF812	6EL7	HCC85	17EW8	N369	16A8
EF814	6EJ7	HCH81	12AJ7	N379	15CW5
EF905	5654	HD14	1H5GT	N709	6BQ5
EH90	6CS6	HF61	6CJ5	N727	6AQ5
EK90	6BE6	HF93	12BA6	OBC3	12SQ7
EL34	6CA7	HF94	12AU6	OF1	6S7
EL36	6CM5	HF121	12AC5	OF5	12K4GT
EL37	6L6	HK90	12BE6	OH4	12A8
EL38	6CN6	HL90	19AQ5	OSW2190	6AC7
EL41	6CK5	HL92	50C5	OSW2192	6AG7
EL71	5902	HL94	30A5	OSW2600	6AC7
EL80	6M5	HM04	6BE6	OSW2601	6AG7
EL81	6CJ6	HP6	6AM6	OSW3104	6SA7
EL82	6DY5	HY90	35W4	OSW3105	6SQ7
EL83	6CK6	KD21	OA3	OSW3107	5CG4
EL84	6BQ5	KD24	OC3	OSW3109	6H6
EL85	6BN5	KC25	OD3	OSW3110	6E5
EL86	6CW5	KT32	25W6GT	OSW3111	6SK7
EL90	6AQ5	KT63	6F6G	OSW3112	6J5
EL91	6AM5	KT66	6L6GC	P17A	807
EL95	6DL5	KT71	50L6GT	PABC80	9AK8
EL180	12BY7	KT77	6CA7	PC86	4CM4
EL500	6GB5	KT88	6550	PC95	4GK5
EL820	6CK6	KTZ63	6K7GT	PC900	4HA5
EL821	6CH6	L63	6J5	PCC84	7AN7
EL822	6CH6	L77	6C4	PCC85	9AQ8
ELL80	6HU8	LC900	3HA5	PCC88	7DJ8
EM34	6CD7	LCF80	6LN8	PCC89	7FC7
EM80	6BR5	LCF802	6LX8	PCC186	7AU7
EM81	6DA5	LF183	4EH7	PCC189	7ES8
EM84	6FG6	LF184	4EJ7	PCC805	7EK7
EM87	6HU6	LL505	27KG6	PCE800	9GB8
EM840	6FG6	LN119	50BM8	PCF80	9A8
EQ80	6BE7	LN319	13GC8	PCF82	9U8
EY51	6X2	LN152	6AB8	PCF86	7HG8
EY80	6U3	LZ319	9A8	PCF800	9EN7
EY81	6R3	LZ329	9A8	PCF801	8GJ7
EY81F	6V3	N14	1C5GT	PCF805	7GV7
EY82	6N3	N15	3Q5GT	PCF806	8GJ7
EY84	6374	N16	3Q5GT	PCL82	16A8
EY86	6S2	N17	3S4	PCL84	15DQ8
EY87	6S2A	N18	3Q4	PCL85	18GV8
EY88	6AL3	N19	3V4	PCL800	16GK8
EZ35	6X5G	N25	3C4	PF9	6K7
EZ40	6BT4	N77	6AM5	PH4	6A8
EZ80	6V4	N78	6BJ5	PL36	25E5
EZ81	6CA4	N119	45B5	PL81	21A6
EZ90	6X4	N142	45A5	PL82	16A5
EZ91	6AV4	N144	6AM5	PL83	15A6
EZ900	6063	N150	6CK5	PL84	15CW5
GZ30	5Z4G	N152	21A6	PL302	25GF6
GZ34	5AR4	N153	15A6	PL500	27GB5
H63	6F5GT	N154	16A5	PL505	40KG6
HAA91	12AL5	N308	25E5	PL820	21A6
HABC80	19T8	N309	15A6	PL1267	0A4G
HBC90	12AT6	N329	16A5	PLL80	12HU8
HBC91	12AV6	N359	21A6	PM04	6BA6

Directly Interchangeable Tubes—(Continued)

Foreign to American Tubes

Foreign Tube Number	Replace with American Tube	Foreign Tube Number	Repalce with American Tube	Foreign Tube Number	Replace with American Tube
PM07	6AM6	UAF42	12S7	X719	6AJ8
PY80	19X3	UBC41	14L7	X727	6BE6
PY81	17Z3	UBC81	14G6	XC95	2ER5
PY82	19Y3	UBF80	17C8	XC97	2FY5
PY83	17Z3	UCH42	14K7	XC900	2HA5
PY88	30AE3	UCH81	19D8	XCC82	7AU7
PY800	17Z3	UCL82	50BM8	XCC189	4ES8
PY801	17Z3	UF41	12AC5	XCF80	4BL8
QB65	6SN7GT	UL41	45A5	XCF801	4GJ7
QB309	12AT7	UL84	45B5	XCH81	3AJ8
QE06/50	807	UN954	954	XCL82	8B8
QL77	6C4	UN955	955	XCL85	9GV8
QV05-25	807	UU12	6CA4	XF80	3BX6
QW77	6CQ6	UY41	31A3	XF85	3BY7
QZ77	6AM6	UY42	31A3	XF183	3EH7
R12	6X2	UY82	55N3	XF184	3EJ7
R16	1T2	UY85	38A3	XL36	13CM5
R19	1X2A	UY89	38A3	XL84	8BQ5
R52	5Z4G	V2M70	6X4	XL86	8CW5
R144	6AM6	V61	6BT4	XY88	16AQ3
RL21	2D21	V177	6CQ6	Y25	1M3
S6F12	6AM6	V311	31A3	YC95	3ER5
SP6	6AM6	V312	31A3	YC97	3FY5
STV108/30	0B2	V884	6CQ6	YF183	4EH7
STV150/30	0A2	VP6	6CQ6	YF184	4EJ7
SU61	6X2	VP12D	12C8	Z14	1N5GT
T2M05	6J6	W17	1T4	Z63	6J7
TM12	6J4	W25	1AJ4	Z77	6AM6
U25	2L2	W61	6K7	Z152	6BX6
U26	2J2	W63	6K7	Z300T	0A4G
U37	1T2	W76	12K7	Z319	6351
U41	1B3GT	W77	6CQ6	Z329	7ED7
U43	6X2	W81	7A7	Z719	6BX6
U49	2J2	W119	13EC7	Z729	6267
U50	5Y3GT	W142	12AC5	Z749	6EL7
U52	5U4G	W148	7A7	ZD17	1S5
U70	6X5G	W149	7B7	ZD25	1AH5
U76	35Z5GT	W719	6BY7	ZD152	6N8
U77	5AR4	W727	6BA6		
U119	38A3	W739	6EC7		
U142	31A3	WD142	12S7		
U147	6X5G	WD150	6CT7		
U149	7Y4	WD709	6N8		
U150	6BT4	X14	1A7GT		
U151	6X2	X17	1R5		
U152	19X3	X18	1AC6		
U153	17Z3	X20	1AC6		
U154	19Y3	X25	1AB6		
U191	19CS4	X61M	6E8G		
U192	19Y3	X63	6A8		
U193	17Z3	X64	6L7		
U251	17Z3	X77	6BE6		
U309	19X3	X81	7S7		
U319	19Y3	X119	19D8		
U339	19CS4	X142	14K7		
U381	38A3	X147	6E8G		
U707	6X4	X148	7S7		

See Pages 65 to 70 for Listing of American to Foreign Directly Interchangeable Tubes.

Directly Interchangeable Tubes

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
0A2	150C2, 150C4, M8223, STV150/30
0A3	KD21
0A4G	PL1267, Z300T
0B2	108C1, M8224, STV108/30
0C3	KD24
0D3	150C3, KD25
0E3	85A1
0G3	85A2
1A3	1D13, DA90
1A5G	DL31
1A7GT	DK32, X14
1AB6	1C3, 1H35, DK96, X25
1AC6	1C2, DK92, X18, X20
1AD4	DF62
1AH5	1FD1, DAF96, ZD25
1AJ4	1F1, DF96, W25
1AN5	DF97
1AQ5	1H33
1B3GT	DY30, U41
1BG2	DY51
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
1R5SF	1H33
1S2	1RK23, DY86, DY87
1S2A	DY87
1S4	DL91
1S5	1FD9, DAF91, ZD17
1T2	R16, U37
1T4	1F3, DF91, W17
1U4	DF904
1U5	DAF92
1V6	DCF60
1X2A	DY80, R19
2D21	E91N, EN91, M8204, PL21
2ER5	XC95
2FY5	XC97
2HA5	XC900
2J2	U26, U49
2L2	U25
3A4	DL93
3A5	DCC90
3AJ8	XCH81
3AL5	XAA91
3AU6	XF94
3B4	DL98
3BX6	XF80
3BY7	XF85
3BZ6	3M-V7
3C4	1P1, DL96, N25
3D6	DL29
3DK6	3M-R24
3EH7	XF183
3EJ7	XF184
3ER5	YC95
3FX7	3D-HH13
3FY5	YC97
3HA5	LC900
3Q4	DL95, N18
3Q5GT	DL33, N15, N16
3S4	1P10, DL92, N17
3V4	1P11, DL94, N19
4BL8	5R-HP1, XCF80
4BS8	4R-HH2
4CM4	PC86
4EH7	LF183, YF183
4EJ7	LF184, YF184

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
4ES8	XCC189
4GJ7	XCF801
4GK5	PC95
4HA5	PC900
4KN8	4R-HH8
5AR4	52KU, 53KU, 54KU, GZ30, GZ32, GZ33, GZ34, GZ37, R52, U54
5AW4	U54
5AX4GT	U54
5CG4	OSW3107
5J6	5M-HH3
5T4	GZ31, U52
5U4G	5Z10, GZ32, U52
5V4G	52KU, 53KU, 54KU, GZ30, GZ32, GZ33, GZ34, OSW3107, R52, U54
5W4	U50, U51
5Y3GT	U50
524	52KU, 53KU, 54KU, GZ30, GZ32, GZ33, GZ34, OSW3107, R52, U54, 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
6AJ5	6F35
6AJ7	6F10, OSW2190, OSW2600
6AJ8	6C12, 20D4, ECH81, X719
6AK5	DP61, E95F, EF905
6AK8	6LD12, DH719, EABC80
6AL3	EY88
6AL5	6B32, 6D2, D2M9, D77, D152, D717, DD6, EAA91, EAA901, EAA901S, EB91, M8079, M8212, QA2404
6AM5	6P17, 7D9, DD7, DDR7, EL91, N77, N144, QA2402
6AM6	6F12, 8D3, EF91, HP6, M8083, PM07, QA2403, QZ77, R144, S6F12, SP6, Z77
6AN7	ECH80
6AQ4	6L34, EC91, M8099
6ZQ5	6L31, BPM04, EL90, M8245, N727
6AQ8	6L12, B719, 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

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
6BD7	EBC80 EBC81
6BE6	6H31 EK90 HM04 X77 X727
6BE7	EQ80
6BH5	EF81
6BH6	E90F
6BJ5	N78
6BJ6	E99F
6BK8	EF83
6BL8	6C16 ECF80
6BM5	6P9
6BM8	6LP12 ECL82
6BN5	EL85
6BQ5	6P15 E84L 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	7D11 12E13 EL34 KT77 KT88
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 EL820
6CL6	6L43
6CM4	EC86
6CM5	6G-B7 EL36 EL360
6CN6	5P29 EL38
6CQ6	6F21 9D6 EF92 M8161 QA2400 QW77 V177 V884 VP6 W77
6CS6	EH90
6CT7	EAF42 WD150
6CU7	62TH ECH42 ECH43 ECH113
6CV7	6LD3 62DDT DH150 DH718 EBC41
6CW5	EL86
6CW7	ECC84
6DA5	EM81
6DA6	EF89
6DC8	6FD12 EBF85 EBF89
6DG7	EF89E
6DJ8	ECC88 ECC189
6DL4	EC88
6DL5	EL95
6DQ6A	6G-B9
6DR8	EBF83
6DS8	ECH83
6DT8	6AT7N
6DX8	ECL84
6DY5	EL82
6E5	6S5G OSW3110
6E8G	X61M X147
6EC7	6F18 W739
6EH7	6F25 6F29 EF183 EF811
6EJ7	6F24 6F30 EF184 EF814

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
6EL7	6F23 EF812 Z749
6ER5	EC95
6ES6	EF97
6ES8	ECC189
6ET6	EF98
6F5GT	H63
6F6G	KT63
6FC7	ECC89
6FG6	EM84 EM840
6FY5	EC97
6GA8	6/30L2 B729 ECC804
6GB5	EL500
6GJ7	ECF801
6GM8	ECC86
6GV7	6C18 ECF805
6GV8	ECL85
6GW8	ECL86
6H6	D63 OSW3109
6HA5	EC900
6HG8	ECF86
6HU6	EM87
6HU8	ELL80
6J4	6M-H1 M8232 TM12
6J5	L63 OSW3112
6J6	6CC31 6M-HH3 ECC91 M8081 T2M05
6J7	A863 Z63
6JW8	ECF802
6JX8	ECH84
6K7	PF9 W61 W63
6KN8	6R-HH8
6L6	EL37
6L6GC	KT66
6L7	X64
6LN8	LCF80
6LX8	LCF802
6M5	EL80
6N3	EY82
6N8	EBF80 WD709 ZD152
6Q4	EC80
6Q7	DH63
6R3	EY81
6R4	EC81
6S2	EY86
6S2A	EY87
6S7	OF1
6SA7	OSW3104
6SK7	OSW3111
6SN7GT	13D2 B65 QA2408 QB65
6SQ7	OSW3105
6T8	6LD12 DH719 EABC80
6U3	EY80
6U8	ECF80 ECF82
6V3	EY81F
6V4	EZ80
6X2	EY51 R12 SU61 U43 U151
6X4	6Z31 EZ90 EZ902 EZ900 U707 V2M70
6X5G	EZ35 U147
7A7	W81 W148
7AN7	30L1 B319 PCC84
7AU7	PCC186 XCC82
7B5	EL22 KT81 N148
7B6	DH81 DL82
7B7	W149
7C5	EL22 KT81 N148
7C6	DH149
7DJ8	PCC88
7ED7	30F5 Z329
7EK7	30L15 B349 PCC805
7ES8	PCC189
7FC7	PCC89
7GV7	30C18 PCF805
7HG8	PCF86
7S7	X81 X148
7Y4	U149

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

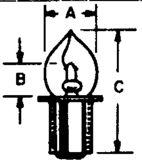
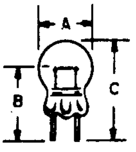
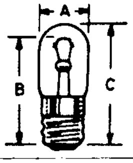
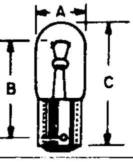
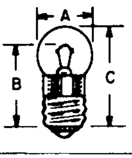
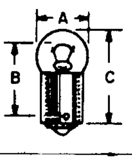
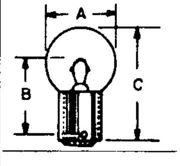
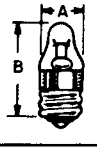
American Tube Number	Replace with Foreign Tube
8A8	30C1, LZ319, LZ329, PCF80
8B8	8R-HP1, XCL82
8BQ5	XL84
8CW5	XL86
8GJ7	PCF801, PCF806
8HG8	PCF86
9A8	30C1, LZ319, LZ329, PCF80
9AK8	PABC80
9AQ8	PCC85
9BM5	9P9
9EN7	30C15, PCF800
9GB8	30FL1, PCE800
9GV8	XCL85
9U8	PCF82
10DE7	9R-AL1
12A8	OH4
12AC5	10F9, 121VP, HF121, UF41, W118, W142, W145
12AF3	12R-K19
12AH8	20D3
12AJ7	HCH81
12AL5	10D2, HAA91, UB91
12AT6	HBC90
12AT7	B152, B309, B739, E81CC, ECC81, ECC801, ECC8015, M8162, QA2406, QB309
12AU6	HF94
12AU7	B329, B749, E82CC, ECC82, ECC186, ECC802, ECC802S, M8136
12AV6	12BC32, HBC91
12AX7	6L13, B339, B759, E83CC, ECC83, ECC803, M8137
12BA6	12F31, HF93
12BE6	12H31, HK90
12BQ6GT	12G-B6
12BR3	12R-K19
12BY7	EL180
12C8	VP12D
12DF7	ECC83
12DT7	ECC83
12FB5	30P12
12HU8	PLL80
12K7	OF5, W76
12K8	X71M, X76M
12Q7GT	DH74, DH76, DL74M
12SN7GT	13D2, B36
12SQ7	OBC3
12SX7GT	B36
12Z3	HZ90
13CM5	12G-B7, XL36
13EC7	10F18, W119
13GC8	30PL1, LN319
14G6	10LD13, DH119, UBC81
14K7	141TH, UCH42, UCH43, X142
14L7	10LD3, 141DDT, DH118, DH142, UBC41
14Z3	HZ90
15A6	N153, N309, PL83
15CW5	30P18, N379, PL84
15DQ8	PCL84
16A5	30P16, 163PEN, N154, N329, PL82, PL87
16A8	30PL12, N369, PCL82
16AQ3	XY88

Directly Interchangeable Tubes—(Continued)

American to Foreign Tubes

American Tube Number	Replace with Foreign Tube
16GK8	30PL13 30PL14 PCL88 PCL800
17C8	17N8 171DDP UBF80
17EW8	HCC85
17Z3	PY81 PY83 PY800 PY801 U153 U193 U251 U329
18GD6	19M-R9
18GV8	PCL85
19AQ5	HL90
19CS4	U191 U339
19D8	10C14 19AJ8 UCH81 X119
19T8	HABC80
19X3	19BD 19U3 19W3 PY8 U152 U309
19Y3	19SU PY82 U154 U192 U319
21A6	213PEN N152 N339 N359 PL81 PL820
25A6	KT33
25BQ6GT	25G-B6
25E5	30P4 30P19 N308 PL36
25GF6	30P4 PL302
25GF6	30P4
25W6	KT32
25Y4	PY31 U31
27GB5	PL500
27KG6	LL505
30A5	HL94
30AE3	PY88
31A3	311SU U118 U142 U145 U404 UY41 UY42 V311 V312
31A3	311SU U142 UY41 UY42
35W4	HY90
35Z46T	U74 U76
38A3	U119 U381 UY85
40KG6	PL505
45A5	10P14 451PT BF41 N142 UL41 UL46
45A5	451PT BF451 N142 UL41
45B5	10P18 N119 UL84
50BM8	10PL12 48A8 LN119 UCL82
50C5	HL92
50L6GT	KT71
55N3	UY82
807	4Y25 5S1 P17A QE06/50 QV05-25
954	E1F UN954
955	E1C HA2 UN955
956	E2F
957	D1C
958A	D2C
959	D3F
5642	DY70
5670	6CC42
5847	6R-R8C
6080	A1834 ECC230
6267	8D8 6F22 EF86 M8195 Z729
6550	KT88
7025	B339 B759 ECC83 M8137
7027	KT66
7027A	KT88
7543	EF94
7581	KT66

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-3 1/2	S.C. Flange (Miniature)	Small Round	PR2 PR3 PR4 PR6 PR12
	7/16"	5/8"	11/16"	G-3 1/2	2-Pin (Miniature)	Small Round	12
	13/32"	15/16"	1 3/16"	T-3 1/4	Screw (Miniature)	Tubular	40 41 42 46 48 1892
	13/32"	3/4"	1 3/16"	T-3 1/4	Bayonet (Miniature)	Tubular	43 44 45 47 49 1490 1891
	7/16"	23/32"	15/16"	G-3 1/2	Screw (Miniature)	Small Round	50
	7/16"	1/2"	15/16"	G-3 1/2	Bayonet (Miniature)	Small Round	51
	9/16"	1/2"	1 1/16"	G-4 1/2	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

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

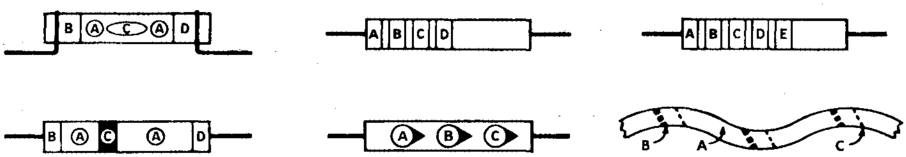
Argon Glow Lamps

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

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

Resistor Color Code

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



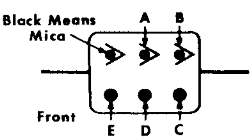
Color	1st Digit A	2nd Digit B	Multiplier C	Tolerance D	Failure Rate* E
Black	0	0	1	—	—
Brown	1	1	10	± 1%	1.0
Red	2	2	100	± 2%	0.1
Orange	3	3	1,000	± 3%	0.01
Yellow	4	4	10,000	± 4%	0.001
Green	5	5	100,000	—	—
Blue	6	6	1,000,000	—	—
Violet	7	7	10,000,000	—	—
Gray	8	8	100,000,000	—	—
White	9	9	—	—	Solderable*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

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

INSULATION CODING

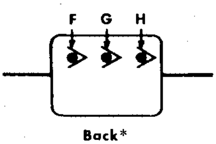
EIA: Insulated resistors with axial leads are designated by a background of any color except black. The usual color is natural tan. Noninsulated resistors with axial leads are designated by a black background color.

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



Mica Capacitor Color Code

MILITARY STANDARD MIL-C-5C



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

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

DESCRIPTION OF CHARACTERISTIC

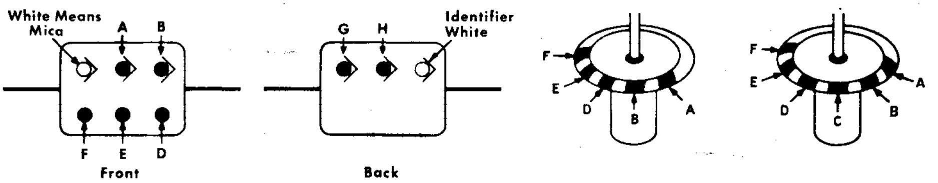
Characteristic	*Temperature Coefficient (parts per million per °C)*	*Maximum Capacitance Drift*	*Minimum Insulation Resistance (megohms)*
B	Not specified	Not specified	7500
C	±200	±0.5%	7500
D	±100	±0.3%	7500
E	−20 to +100	±(0.1% +0.1 μμf)	7500
F	0 to +70	±(0.05% +0.1 μμf)	7500

VOLTAGE RATING

(Indicated by dimensions rather than color coding)

Maximum Inches			*Style CM*	*Capacitance (μμf)*	*Rating (v d-c)*
Long	*Wide*	*Thick*			
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 A



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

*or ± 1 μμf, whichever is greater.

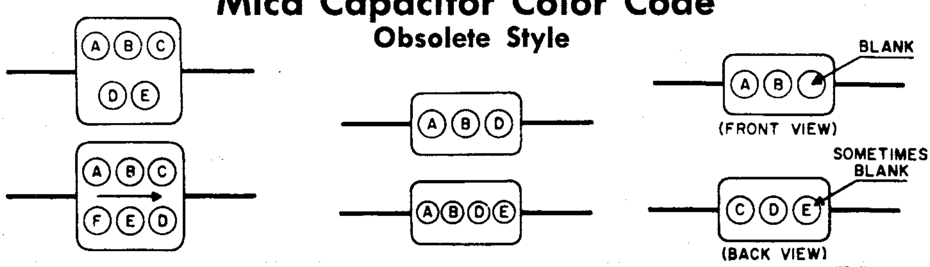
DESCRIPTION OF CHARACTERISTIC

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

VOLTAGE RATING
(Indicated by dimensions rather than color coding)

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

Mica Capacitor Color Code
Obsolete Style

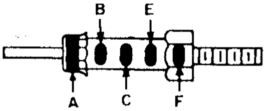


Dot Color	Digits of Capacitance (μμf) A	B	C	Multiplier D	Tolerance % E	Voltage Rating (v d-c) F
Black	0	0	0	1	±20	—
Brown	1	1	1	10	± 1	100
Red	2	2	2	100	± 2	200
Orange	3	3	3	1,000	± 3	300
Yellow	4	4	4	10,000	± 4	400
Green	5	5	5	100,000	± 5	500
Blue	6	6	6	1,000,000	± 6	600
Violet	7	7	7	10,000,000	± 7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

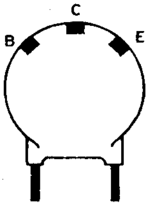
Ceramic Capacitor Color Code

EIA STANDARD RS-198

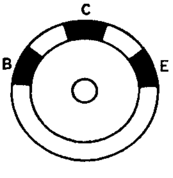
MILITARY STANDARD MIL-C-20D



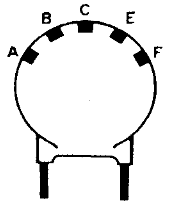
Stand-Off Capacitors (EIA ONLY)



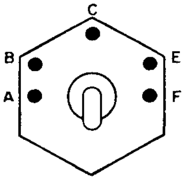
3-Dot Disc Capacitors (RETMA ONLY) (Voltage rating is always 500 v., tolerance is always —0.)



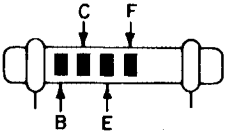
3-Dot Button Capacitors (EIA ONLY)



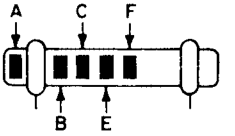
5-Dot Disc Capacitors (EIA ONLY) (Voltage rating is always 500 v.)



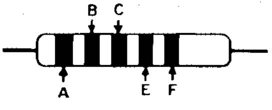
Feed Through Capacitors (EIA ONLY)



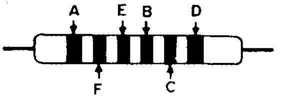
High Capacity Tubulars (Insulated or Non-Insulated)



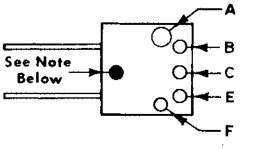
Temperature Compensating Tubulars



Tubular Capacitors (Voltage rating is always 500 v.)



Tubular Capacitors (Old RMA)



MIL Style CC Rectangular

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

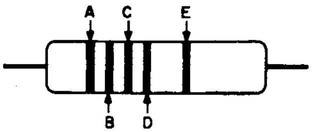
Color	Digits of Capacitance (μμf)			Multiplier E	Tolerance F		Temp. Coef. A (Parts per million per °C.)	
	B	C	D		10 μμf or less (μμf)	Over 10 μμf (%)	EIA	MILITARY†
Black	0	0	0	1	±2.0	±20*	±0	±0
Brown	1	1	1	10	±0.1*	±1	− 33	− 30
Red	2	2	2	100	±0.25	±2	− 75	− 80
Orange	3	3	3	1,000	—	±2.5*	−150	−150
Yellow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

*EIA only †Per charts in MIL-C-20D

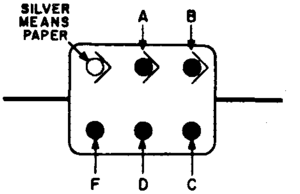
Paper Capacitor Color Code

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)



Tubular Capacitors (Commercial Only)



Rectangular Capacitors

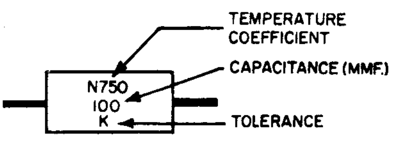
Color	Digits of Capacitance (μμf)		Multiplier	Tolerance %	Tubular Voltage Rating (v d-c)	Temp. Rating °C and Characteristic
	A	B	C	D	E	F
Black	0	0	1	± 20	—	85-A
Brown	1	1	10	—	100	85-E
Red	2	2	100	—	200	—
Orange	3	3	1,000	± 30	300	—
Yellow	4	4	10,000	—	400	—
Green	5	5	—	—	500	—
Blue	6	6	—	—	600	—
Violet	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)			*Style CN*	*Capacitance (μμf)*	*Voltage Rating (v d-c)*
Length	*Width*	*Thick-ness*			
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 15/32	49/64	13/32	43	10,000 20,000–30,000 50,000–100,000 200,000	1000 600 400 120

TYPOGRAPHICALLY MARKED TUBULAR CERAMICS



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

Military Capacitor Letter-Number Codes

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

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

MIL-C-91A TYPE CN

Capacitors • Fixed • Paper Dielectric • Nonmetallic Cases

CN 22 A E 202 N

(1) (2) (3) (4) (5)

(1) STYLE

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

(2) CHARACTERISTIC

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

(3) VOLTAGE

DC working at 40°C.

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

(4) CAPACITANCE

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

(5) CAPACITANCE TOLERANCE

K = ±10%
M = ±20%
N = ±30%

Military Capacitor Letter-Number Codes

MIL-C-20D TYPE CC

Capacitors • Fixed • Ceramic Dielectric • Temperature Compensating

CC	20	A	K	OR5	C
	①	②	③	④	⑤

① STYLE

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

② TEMPERATURE COEFFICIENT

A = P100 = +100
C = NPO = ±0
H = N30 = −30
L = N80 = −80
P = N150 = −150
R = N220 = −220
S = N330 = −330
T = N470 = −470
U = N750 = −750
all as per charts in MIL-C-20D

③ T-C TOLERANCE BAND ENVELOPE

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

④ CAPACITANCE

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

⑤ CAPACITANCE TOLERANCE

C = ±0.25 picofarads

D = ±0.5 picofarads

F = ±1% (±1.0 pf @ ≦ 10 pf)

G = ±2% (±2.0 pf @ ≦ 10 pf)

J = ±5%

K = ±10%

Military Capacitor Letter-Number Codes

MIL-C-5C TYPE CM

Capacitors • Fixed • Mica Dielectric

CM	15	C	D	100	K	N	3
	①	②	③	④	⑤	⑥	⑦

① STYLE

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

② CHARACTERISTIC

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

③ VOLTAGE RATING

This rating not shown on earlier production.

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

④ CAPACITANCE

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

⑤ CAPACITANCE TOLERANCE

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

⑥ OPERATING TEMPERATURE RANGE

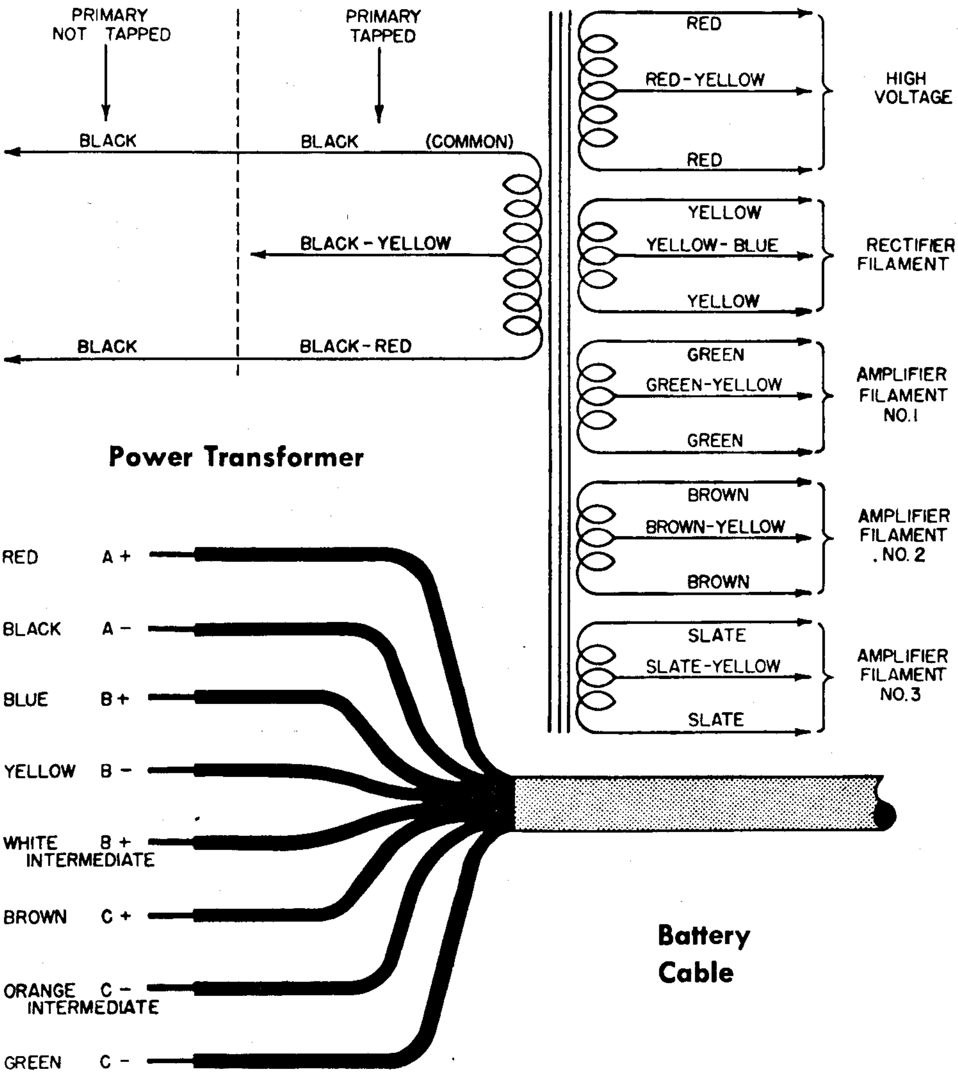
M = −55°C to + 70°C
N = −55°C to + 85°C
O = −55°C to +125°C
P = −55°C to +150°C

⑦ VIBRATION GRADE

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

EIA Color Codes

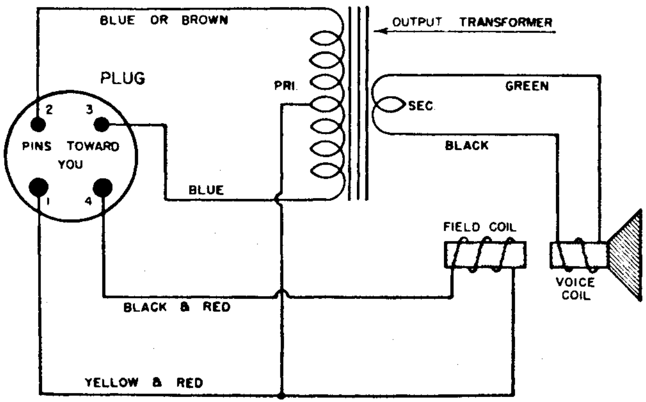
The color codes on the preceding and two following pages are used by most radio and instrument manufacturers in the wiring of their products, and by parts manufacturers for identifying lead placement or resistor and capacitor values, ratings, and tolerances. These have been included for whatever help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

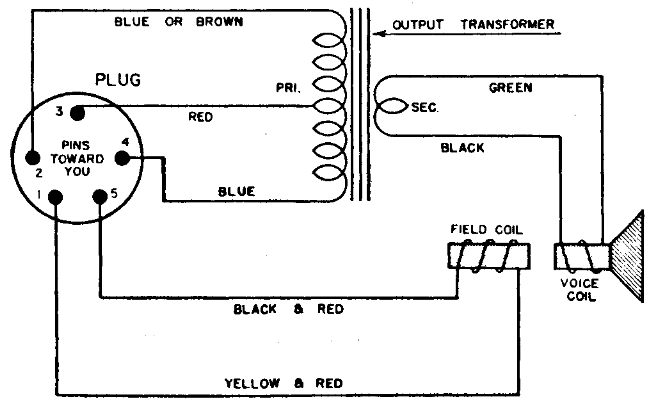


Power Transformer

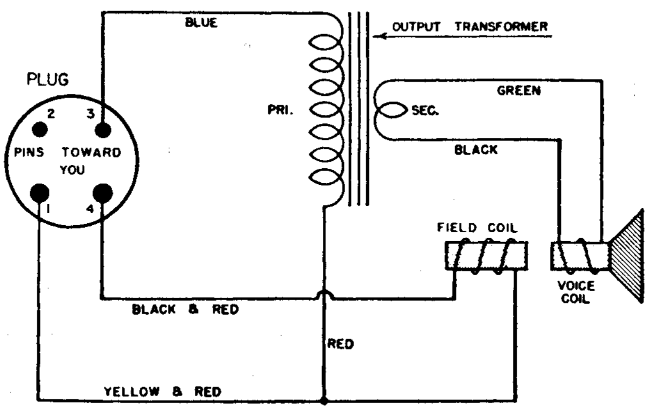
Battery Cable

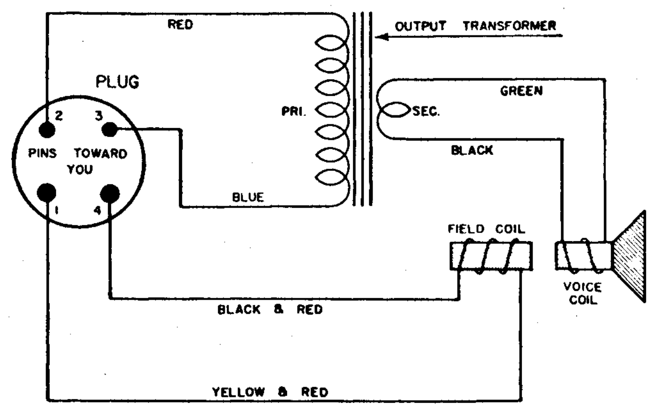
Speaker Leads and Plug Connections





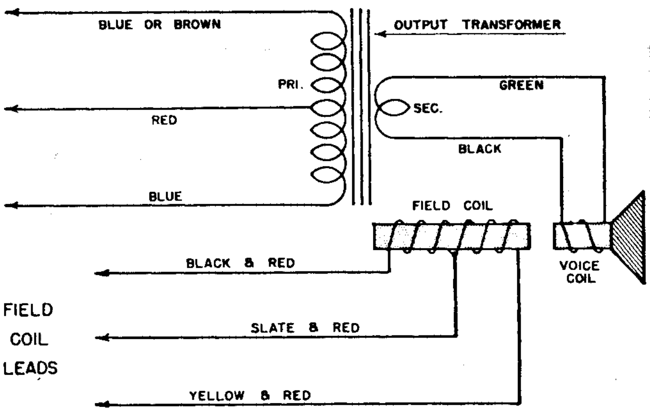
Speaker Leads and Plug Connections

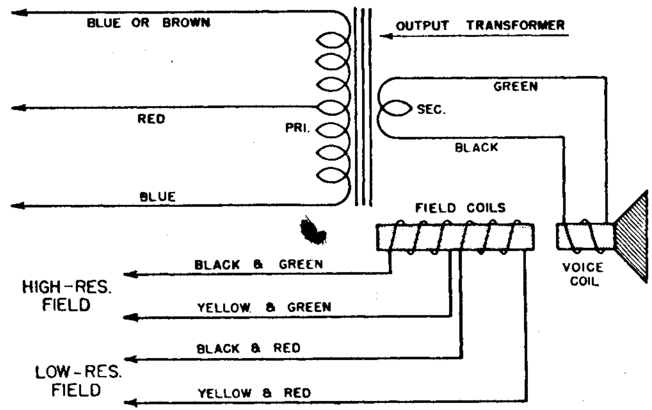




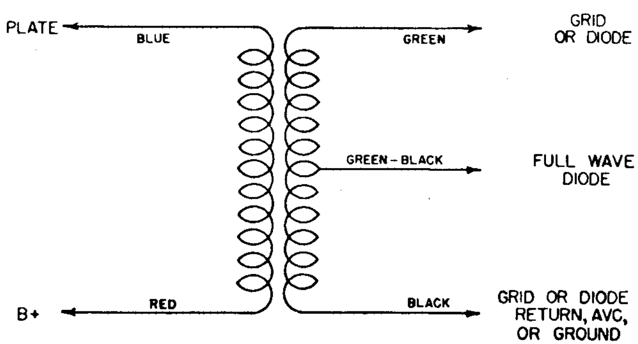
EIA Color Codes—(Continued)

Speaker Lead Color Codes—(Continued)

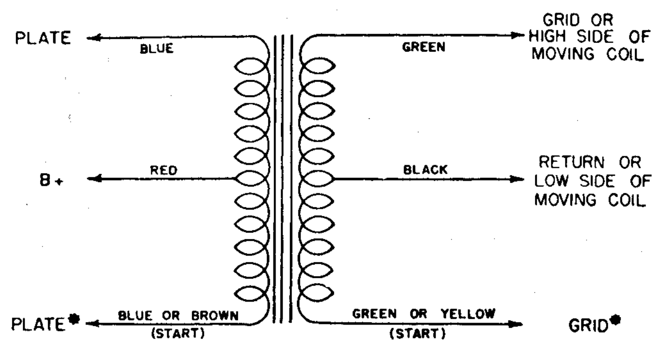




I-F Transformers



Audio & Output Transformers



* FOUND ONLY ON PUSH-PULL PRIMARY OR SECONDARY WINDINGS

Radio Frequency Allocations

Frequency Classification

Frequency	Classification	Abbreviation
3-30 kc	Very low frequencies	VLF
30-300 kc	Low frequencies	LF
300-3,000 kc	Medium frequencies	MF
3-30 Mc	High frequencies	HF
30-300 Mc	Very high frequencies	VHF
300-3,000 Mc	Ultra-high frequencies	UHF
3,000-30,000 Mc	Super-high frequencies	SHF
30,000-300,000 Mc	Extremely high frequencies	EHF
300,000-3,000,000 Mc	....	....

U. S. Amateur Radio Bands

Bands	Frequency (Mc)
160 Meter Band	1.80-2.00*
80 Meter Band	3.50-4.00
40 Meter Band	7.00-7.30
20 Meter Band	14.00-14.35
15 Meter Band	21.00-21.45
10 Meter Band	28.00-29.70
6 Meter Band	50-54
2 Meter Band	144-148
1 ¼ Meter Band	220-225
¾ Meter Band	420-450
....	1,215-1,300
....	2,300-2,450
....	3,300-3,500
....	5,650-5,925
....	10,000-10,500
....	21,000-22,000
....	All above 40,000

Subject to change by FCC

* Use of this band is on a shared basis with Loran-A system of navigation.

Television Channel Frequencies

Channels 2-13 VHF

Channels 14-83 UHF

Bandwidth per channel, 6 megacycles.

Picture carrier frequency is 1.25 megacycles above the low frequency edge of the band.

Sound carrier frequency is 0.25 megacycles below the high frequency edge of the band, and 4.5 megacycles above the picture carrier frequency.

Channel Number	Frequency Limits (Mc)	Picture Carrier (Mc)	Sound Carrier (Mc)
1	(Not assigned)		
2	54-60	55.25	59.75
3	60-66	61.25	65.75
4	66-72	67.25	71.75
5	76-82	77.25	81.75
6	82-88	83.25	87.75
7	174-180	175.25	179.75
8	180-186	181.25	185.75
9	186-192	187.25	191.75
10	192-198	193.25	197.75
11	198-204	199.25	203.75
12	204-210	205.25	209.75
13	210-216	211.25	215.75
14	470-476	471.25	475.75
15	476-482	477.25	481.75

Television Channel Frequencies (Continued)

Channel Number	Frequency Limits (Mc)	Picture Carrier (Mc)	Sound Carrier (Mc)
16	482-488	483.25	487.75
17	488-494	489.25	493.75
18	494-500	495.25	499.75
19	500-506	501.25	505.75
20	506-512	507.25	511.75
21	512-518	513.25	517.75
22	518-524	519.25	523.75
23	524-530	525.25	529.75
24	530-536	531.25	535.75
25	536-542	537.25	541.75
26	542-548	543.25	547.75
27	548-554	549.25	553.75
28	554-560	555.25	559.75
29	560-566	561.25	565.75
30	566-572	567.25	571.75
31	572-578	573.25	577.75
32	578-584	579.25	583.75
33	584-590	585.25	589.75
34	590-596	591.25	595.75
35	596-602	597.25	601.75
36	602-608	603.25	607.75
37	608-614	609.25	613.75
38	614-620	615.25	619.75
39	620-626	621.25	625.75
40	626-632	627.25	631.75
41	632-638	633.25	637.75
42	638-644	639.25	643.75
43	644-650	645.25	649.75
44	650-656	651.25	655.75
45	656-662	657.25	661.75
46	662-668	663.25	667.75
47	668-674	669.25	673.75
48	674-680	675.25	679.75
49	680-686	681.25	685.75
50	686-692	687.25	691.75

Television Channel Frequencies (Continued)

Channel Number	Frequency Limits (Mc)	Picture Carrier (Mc)	Sound Carrier (Mc)
51	692-698	693.25	697.75
52	698-704	699.25	703.75
53	704-710	705.25	709.75
54	710-716	711.25	715.75
55	716-722	717.25	721.75
56	722-728	723.25	727.75
57	728-734	729.25	733.75
58	734-740	735.25	739.75
59	740-746	741.25	745.75
60	746-752	747.25	751.75
61	752-758	753.25	757.75
62	758-764	759.25	763.75
63	764-770	765.25	769.75
64	770-776	771.25	775.75
65	776-782	777.25	781.75
66	782-788	783.25	787.75
67	788-794	789.25	793.75
68	794-800	795.25	799.75
69	800-806	801.25	805.75
70	806-812	807-25	811.75
71	812-818	813.25	817.75
72	818-824	819.25	823.75
73	824-830	825.25	829.75
74	830-836	831.25	835.75
75	836-842	837.25	841.75
76	842-848	843.25	847.75
77	848-854	849.25	853.75
78	854-860	855.25	859.75
79	860-866	861.25	865.75
80	866-872	867.25	871.75
81	872-878	873.25	877.75
82	878-884	879.25	883.75
83	884-890	885.25	889.75

Recording Tape—Record / Play Time

To The Nearest Full Minute

NO. OF FEET	NO. OF TRACKS	SPEED IN INCHES PER SECOND				
		15	7½	3¾	1⅞	15/16
4800	1 Track	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.
	2 Tracks	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.	34 hrs. 8 min.
	4 Tracks	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.	34 hrs. 8 min.	68 hrs. 16 min.
3600	1 Track	48 min.	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.
	2 Tracks	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.	25 hrs. 36 min.
	4 Tracks	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.	25 hrs. 36 min.	51 hrs. 12 min.
2500	1 Track	33 min.	1 hr. 6 min.	2 hrs. 13 min.	4 hrs. 26 min.	8 hrs. 52 min.
	2 Tracks	1 hr. 6 min.	2 hrs. 12 min.	4 hrs. 26 min.	8 hrs. 52 min.	17 hrs. 44 min.
	4 Tracks	2 hrs. 12 min.	4 hrs. 24 min.	8 hrs. 52 min.	17 hrs. 44 min.	35 hrs. 28 min.
2400	1 Track	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.
	2 Tracks	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.
	4 Tracks	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.	34 hrs. 8 min.
1800	1 Track	24 min.	48 min.	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.
	2 Tracks	48 min.	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.
	4 Tracks	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.	25 hrs. 36 min.
1200	1 Track	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.
	2 Tracks	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.
	4 Tracks	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.	17 hrs. 4 min.
900	1 Track	12 min.	24 min.	48 min.	1 hr. 36 min.	3 hrs. 12 min.
	2 Tracks	24 min.	48 min.	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.
	4 Tracks	48 min.	1 hr. 36 min.	3 hrs. 12 min.	6 hrs. 24 min.	12 hrs. 48 min.
600	1 Track	8 min.	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.
	2 Tracks	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.
	4 Tracks	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.	8 hrs. 32 min.
300	1 Track	4 min.	8 min.	16 min.	32 min.	1 hr. 4 min.
	2 Tracks	8 min.	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.
	4 Tracks	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.	4 hrs. 16 min.
225	1 Track	3 min.	6 min.	12 min.	24 min.	48 min.
	2 Tracks	6 min.	12 min.	24 min.	48 min.	1 hr. 36 min.
	4 Tracks	12 min.	24 min.	48 min.	1 hr. 36 min.	3 hrs. 12 min.
150	1 Track	2 min.	4 min.	8 min.	16 min.	32 min.
	2 Tracks	4 min.	8 min.	16 min.	32 min.	1 hr. 4 min.
	4 Tracks	8 min.	16 min.	32 min.	1 hr. 4 min.	2 hrs. 8 min.

NOTE: One-Way Stereo provides same timing as 1-track tapes.
Two-Way Stereo provides same timing as 2-track tapes.

Greek Alphabet Designations

Name	Capital	Lower Case	Commonly used to designate
Alpha	A	α	Angles. Area. Coefficients. Attenuation constant. Absorption factor. Current gain of common base configuration
Beta	B	β	Angles. Flux density. Phase constant. Current gain of common emitter
Gamma	Γ	γ	Angles. Conductivity. Specific gravity
Delta	Δ	δ	Variation. Density. Angles
Epsilon	E	ϵ	Base of natural logarithms. Electric intensity
Zeta	Z	ζ	Impedance. Coefficients. Coordinates
Eta	H	η	Hysteresis coefficient. Efficiency. Surface charge density
Theta	Θ	θ	Temperature. Phase angle. Time Constant. Reluctance. Angles
Iota	I	ι	Unit vector
Kappa	K	κ	Dielectric constant. Susceptibility
Lambda	Λ	λ	Wavelength. Attenuation constant
Mu	M	μ	Micro-. Amplification factor. Permeability
Nu	N	ν	Reluctivity. Frequency
Xi	Ξ	ξ	Coordinates
Omicron	O	ο	———
Pi	Π	π	3.1416 (Ratio of circumference to diameter)
Rho	P	ρ	Resistivity. Coordinates
Sigma	Σ	σ	Summation (cap). Electrical conductivity. Leakage coefficient. Surface charge density. Complex propagation constant
Tau	T	τ	Time constant. Time phase displacement. Density. Transmission factor
Upsilon	Υ	υ	———
Phi	Φ	φ	Magnetic flux. Angles. Scalar potential (cap)
Chi	X	χ	Electric susceptibility. Angles
Psi	Ψ	ψ	Dielectric flux. Phase difference. Coordinates. Angles
Omega	Ω	ω	Angular velocity. Resistance in ohms (cap). Solid angles (cap)

NOTE: Lower case letters are used for all designations except where capital (cap) is indicated.

Abbreviations and Letter Symbols*

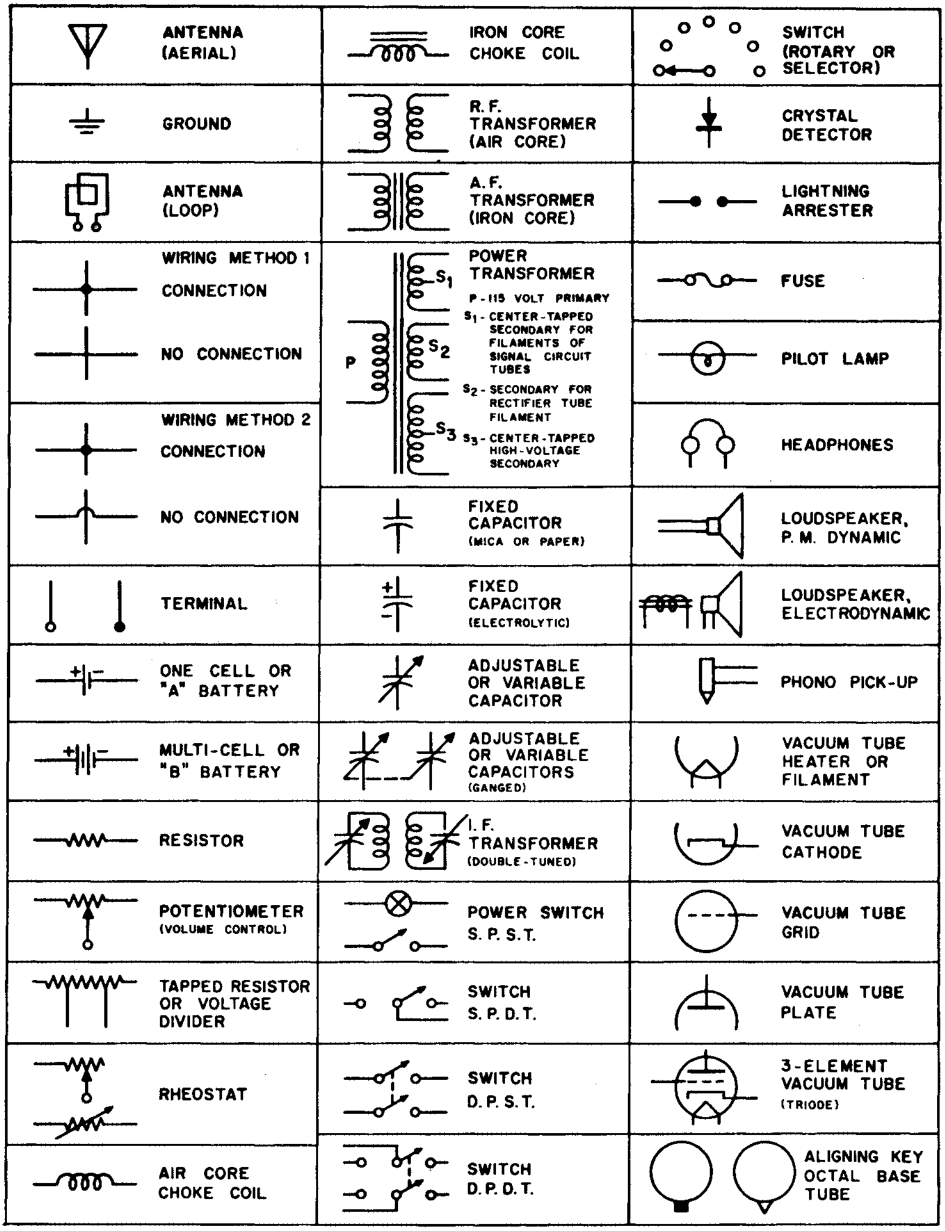
Term	Abbreviation
Admittance	Y
Alternating current	AC
American Wire Gauge	AWG
Ampere	A
Amplification factor	μ
Amplitude modulation	AM
Angular velocity ($2\pi f$)	ω
Antenna	ant
Audio frequency	AF
Automatic frequency control	AFC
Automatic load control	ALC
Automatic noise limiter	ANL
Automatic volume control	AVC
Automatic volume expansion	AVE
Beat-frequency oscillator	BFO
Brown and Sharp wire gauge (now American Wire Gauge)	B&S
Capacitance	C
Capacitive reactance	X_C
Cathode-ray tube	CRT
Centimeter	cm
Conductance	G
Continuous wave	CW
Current	I
Cycles per second	Hz or cps
Decibel	dB
Direct current	DC
Double-pole, double-throw	DPDT
Double-pole, single-throw	DPST
Double-sideband suppressed carrier	DSB
Electric field intensity	E
Electromotive force	emf
Farad or Frequency	F
Frequency modulation	FM
Ground	gnd
Henry	H
High frequency	HF
Impedance	Z
Inductance	L
Inductive reactance	X_L
Intermediate frequency	IF
Interrupted continuous waves	icw
Kilocycles per second	kHz or kc
Kilovolt	kV
Kilovolt ampere	kVA
Kilowatt	kW
Load resistance	R_L
Low frequency	LF
Lower sideband	LSB

*See Page 26 for Transistor Symbols.
See page 41 for explanation of Hertz (Hz).

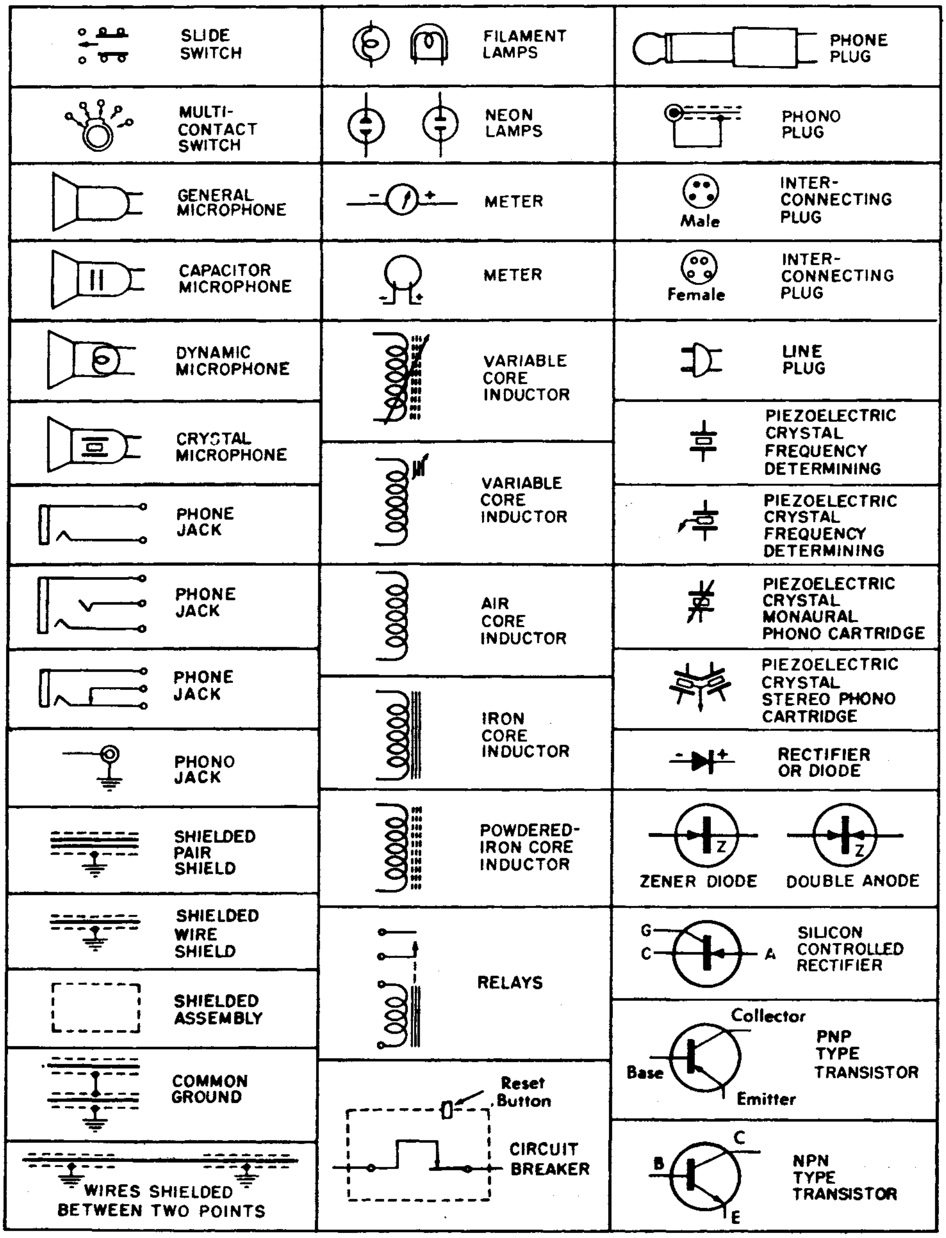
Term	Abbreviation
Magnetic field intensity	H
Medium frequency	MF
Megacycles per second	MHz or Mc
Megohm	MΩ
Meter	m
Microampere	μA
Microfarad	μF
Microhenry	μH
Micromicrofarad	μμF
Microvolt	μV
Microvolt per meter	μV/m
Microwatt	μW
Milliampere	mA
Millihenry	mH
Millivolt	mV
Millivolt per meter	mV/m
Milliwatt	mW
Modulated continuous wave	MCW
Mutual inductance	M
Ohm	Ω (omega)
Phase displacement (degrees)	θ (theta)
Picofarad	pF
Power	P
Power amplifier	PA
Power factor	PF
Public Address	PA
Push-to-talk control	PTT
Radio frequency	RF
Reactance	X
Resistance	R
Revolutions per minute	rpm
Root-mean-square	rms
Self-inductance	L
Short wave	SW
Single-pole, double-throw	SPDT
Single-pole, single-throw	SPST
Single-sideband suppressed carrier	SSB
Standing-wave ratio	SWR
Tuned radio frequency	TRF
Ultrahigh frequency	UHF
Upper sideband	USB
Vacuum-tube voltmeter	VTVM
Variable-frequency oscillator	VFO
Very high frequency	VHF
Voice-operated transmission	VOX
Volt	V
Voltage	E
Volt-ohmmeter	VOM
Watt	W
Wavelength	λ (lambda)

See pages 41-42 for Metric Prefix Symbols.

Schematic Symbols
Used in Radio Diagrams



Schematic Symbols
Used in Radio Diagrams



Powers, Roots and Reciprocals

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
1	1	1	1.0000	1.0000	1000.000	51	2601	132651	7.1414	3.7084	19.6078
2	4	8	1.4142	1.2599	500.000	52	2704	140608	7.2111	3.7325	19.2308
3	9	27	1.7321	1.4422	333.333	53	2809	148877	7.2801	3.7563	18.8679
4	16	64	2.0000	1.5874	250.000	54	2916	157464	7.3485	3.7798	18.5185
5	25	125	2.2361	1.7100	200.000	55	3025	166375	7.4162	3.8030	18.1818
6	36	216	2.4495	1.8171	166.667	56	3136	175616	7.4833	3.8259	17.8571
7	49	343	2.6458	1.9129	142.857	57	3249	185193	7.5498	3.8485	17.5439
8	64	512	2.8284	2.0000	125.000	58	3364	195112	7.6158	3.8709	17.2414
9	81	729	3.0000	2.0801	111.111	59	3481	205379	7.6811	3.8930	16.9492
10	100	1000	3.1623	2.1544	100.000	**60**	3600	216000	7.7460	3.9149	16.6667
11	121	1331	3.3166	2.2240	90.9091	61	3721	226981	7.8102	3.9365	16.3934
12	144	1728	3.4641	2.2894	83.3333	62	3844	238328	7.8740	3.9579	16.1290
13	169	2197	3.6056	2.3513	76.9231	63	3969	250047	7.9373	3.9791	15.8730
14	196	2744	3.7417	2.4101	71.4286	64	4096	262144	8.0000	4.0000	15.6250
15	225	3375	3.8730	2.4662	66.6667	65	4225	274625	8.0623	4.0207	15.3846
16	256	4096	4.0000	2.5198	62.5000	66	4356	287496	8.1240	4.0412	15.1515
17	289	4913	4.1231	2.5713	58.8235	67	4489	300763	8.1854	4.0615	14.9254
18	324	5832	4.2426	2.6207	55.5556	68	4624	314432	8.2462	4.0817	14.7059
19	361	6859	4.3589	2.6684	52.6316	69	4761	328509	8.3066	4.1016	14.4928
20	400	8000	4.4721	2.7144	50.0000	**70**	4900	343000	8.3666	4.1213	14.2857
21	441	9261	4.5826	2.7589	47.6190	71	5041	357911	8.4261	4.1408	14.0845
22	484	10648	4.6904	2.8020	45.4545	72	5184	373248	8.4853	4.1602	13.8889
23	529	12167	4.7958	2.8439	43.4783	73	5329	389017	8.5440	4.1793	13.6986
24	576	13824	4.8990	2.8845	41.6667	74	5476	405224	8.6023	4.1983	13.5135
25	625	15625	5.0000	2.9240	40.0000	75	5625	421875	8.6603	4.2172	13.3333
26	676	17576	5.0990	2.9625	38.4615	76	5776	438976	8.7178	4.2358	13.1579
27	729	19683	5.1962	3.0000	37.0370	77	5929	456533	8.7750	4.2543	12.9870
28	784	21952	5.2915	3.0366	35.7143	78	6084	474552	8.8318	4.2727	12.8205
29	841	24389	5.3852	3.0723	34.4828	79	6241	493039	8.8882	4.2908	12.6582
30	900	27000	5.4772	3.1072	33.3333	**80**	6400	512000	8.9443	4.3089	12.5000
31	961	29791	5.5678	3.1414	32.2581	81	6561	531441	9.0000	4.3267	12.3457
32	1024	32768	5.6569	3.1748	31.2500	82	6724	551368	9.0554	4.3445	12.1951
33	1089	35937	5.7446	3.2075	30.3030	83	6889	571787	9.1104	4.3621	12.0482
34	1156	39304	5.8310	3.2396	29.4118	84	7056	592704	9.1652	4.3795	11.9048
35	1225	42875	5.9161	3.2711	28.5714	85	7225	614125	9.2195	4.3968	11.7647
36	1296	46656	6.0000	3.3019	27.7778	86	7396	636056	9.2736	4.4140	11.6279
37	1369	50653	6.0828	3.3322	27.0270	87	7569	658503	9.3274	4.4310	11.4943
38	1444	54872	6.1644	3.3620	26.3158	88	7744	681472	9.3808	4.4480	11.3636
39	1521	59319	6.2450	3.3912	25.6410	89	7921	704969	9.4340	4.4647	11.2360
40	1600	64000	6.3246	3.4200	25.0000	**90**	8100	729000	9.4868	4.4814	11.1111
41	1681	68921	6.4031	3.4482	24.3902	91	8281	753571	9.5394	4.4979	10.9890
42	1764	74088	6.4807	3.4760	23.8095	92	8464	778688	9.5917	4.5144	10.8696
43	1849	79507	6.5574	3.5034	23.2558	93	8649	804357	9.6437	4.5307	10.7527
44	1936	85184	6.6332	3.5303	22.7273	94	8836	830584	9.6954	4.5468	10.6383
45	2025	91125	6.7082	3.5569	22.2222	95	9025	857375	9.7468	4.5629	10.5263
46	2116	97336	6.7823	3.5830	21.7391	96	9216	884736	9.7980	4.5789	10.4167
47	2209	103823	6.8557	3.6088	21.2766	97	9409	912673	9.8489	4.5947	10.3093
48	2304	110592	6.9282	3.6342	20.8333	98	9604	941192	9.8995	4.6104	10.2041
49	2401	117649	7.0000	3.6593	20.4082	99	9801	970299	9.9499	4.6261	10.1010
50	2500	125000	7.0711	3.6840	20.0000	**100**	10000	1000000	10.0000	4.6416	10.0000

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
101	10201	1030301	10.0499	4.6570	9.90099	151	22801	3442951	12.2882	5.3251	6.62252
102	10404	1061208	10.0995	4.6723	9.80392	152	23104	3511808	12.3288	5.3368	6.57895
103	10609	1092727	10.1489	4.6875	9.70874	153	23409	3581577	12.3693	5.3485	6.53595
104	10816	1124864	10.1980	4.7027	9.61538	154	23716	3652264	12.4097	5.3601	6.49351
105	11025	1157625	10.2470	4.7177	9.52381	155	24025	3723875	12.4499	5.3717	6.45161
106	11236	1191016	10.2956	4.7326	9.43396	156	24336	3796416	12.4900	5.3832	6.41026
107	11449	1225043	10.3441	4.7475	9.34579	157	24649	3869893	12.5300	5.3947	6.36943
108	11664	1259712	10.3923	4.7622	9.25926	158	24964	3944312	12.5698	5.4061	6.32911
109	11881	1295029	10.4403	4.7769	9.17431	159	25281	4019679	12.6095	5.4175	6.28931
110	12100	1331000	10.4881	4.7914	9.09091	**160**	25600	4096000	12.6491	5.4288	6.25000
111	12321	1367631	10.5357	4.8059	9.00901	161	25921	4173281	12.6886	5.4401	6.21118
112	12544	1404928	10.5830	4.8203	8.92857	162	26244	4251528	12.7279	5.4514	6.17284
113	12769	1442897	10.6301	4.8346	8.84956	163	26569	4330747	12.7671	5.4626	6.13497
114	12996	1481544	10.6771	4.8488	8.77193	164	26896	4410944	12.8062	5.4737	6.09756
115	13225	1520875	10.7238	4.8629	8.69565	165	27225	4492125	12.8452	5.4848	6.06061
116	13456	1560896	10.7703	4.8770	8.62069	166	27556	4574296	12.8841	5.4959	6.02410
117	13689	1601613	10.8167	4.8910	8.54701	167	27889	4657463	12.9228	5.5069	5.98802
118	13924	1643032	10.8628	4.9049	8.47458	168	28224	4741632	12.9615	5.5178	5.95238
119	14161	1685159	10.9087	4.9187	8.40336	169	28561	4826809	13.0000	5.5288	5.91716
120	14400	1728000	10.9545	4.9324	8.33333	**170**	28900	4913000	13.0384	5.5397	5.88235
121	14641	1771561	11.0000	4.9461	8.26446	171	29241	5000211	13.0767	5.5505	5.84795
122	14884	1815848	11.0454	4.9597	8.19672	172	29584	5088448	13.1149	5.5613	5.81395
123	15129	1860867	11.0905	4.9732	8.13008	173	29929	5177717	13.1529	5.5721	5.78035
124	15376	1906624	11.1355	4.9866	8.06452	174	30276	5268024	13.1909	5.5828	5.74713
125	15625	1953125	11.1803	5.0000	8.00000	175	30625	5359375	13.2288	5.5934	5.71429
126	15876	2000376	11.2250	5.0133	7.93651	176	30976	5451776	13.2665	5.6041	5.68182
127	16129	2048383	11.2694	5.0265	7.87402	177	31329	5545233	13.3041	5.6147	5.64972
128	16384	2097152	11.3137	5.0397	7.81250	178	31684	5639752	13.3417	5.6252	5.61798
129	16641	2146689	11.3578	5.0528	7.75194	179	32041	5735339	13.3791	5.6357	5.58659
130	16900	2197000	11.4018	5.0658	7.69231	**180**	32400	5832000	13.4164	5.6462	5.55556
131	17161	2248091	11.4455	5.0788	7.63359	181	32761	5929741	13.4536	5.6567	5.52486
132	17424	2299968	11.4891	5.0916	7.57576	182	33124	6028568	13.4907	5.6671	5.49451
133	17689	2352637	11.5326	5.1045	7.51880	183	33489	6128487	13.5277	5.6774	5.46448
134	17956	2406104	11.5758	5.1172	7.46269	184	33856	6229504	13.5647	5.6877	5.43478
135	18225	2460375	11.6190	5.1299	7.40741	185	34225	6331625	13.6015	5.6980	5.40541
136	18496	2515456	11.6619	5.1426	7.35294	186	34596	6434856	13.6382	5.7083	5.37634
137	18769	2571353	11.7047	5.1551	7.29927	187	34969	6539203	13.6748	5.7185	5.34759
138	19044	2628072	11.7473	5.1676	7.24638	188	35344	6644672	13.7113	5.7287	5.31915
139	19321	2685619	11.7898	5.1801	7.19424	189	35721	6751269	13.7477	5.7388	5.29101
140	19600	2744000	11.8322	5.1925	7.14286	**190**	36100	6859000	13.7840	5.7489	5.26316
141	19881	2803221	11.8743	5.2048	7.09220	191	36481	6967871	13.8203	5.7590	5.23560
142	20164	2863288	11.9164	5.2171	7.04255	192	36864	7077888	13.8564	5.7690	5.20833
143	20449	2924207	11.9583	5.2293	6.99301	193	37249	7189057	13.8924	5.7790	5.18135
144	20736	2985984	12.0000	5.2415	6.94444	194	37636	7301384	13.9284	5.7890	5.15464
145	21025	3048625	12.0416	5.2536	6.89655	195	38025	7414875	13.9642	5.7989	5.12821
146	21316	3112136	12.0830	5.2656	6.84932	196	38416	7529536	14.0000	5.8088	5.10204
147	21609	3176523	12.1244	5.2776	6.80272	197	38809	7645373	14.0357	5.8186	5.07614
148	21904	3241792	12.1655	5.2896	6.75676	198	39204	7762392	14.0712	5.8285	5.05051
149	22201	3307949	12.2066	5.3015	6.71141	199	39601	7880599	14.1067	5.8383	5.02513
150	22500	3375000	12.2474	5.3133	6.66667	**200**	40000	8000000	14.1421	5.8480	5.00000

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
201	40401	8120601	14.1774	5.8578	4.97512	251	63001	15813251	15.8430	6.3080	3.98406
202	40804	8242408	14.2127	5.8675	4.95050	252	63504	16003008	15.8745	6.3164	3.96825
203	41209	8365427	14.2478	5.8771	4.92611	253	64009	16194277	15.9060	6.3247	3.95257
204	41616	8489664	14.2829	5.8868	4.90196	254	64516	16387064	15.9374	6.3330	3.93701
205	42025	8615125	14.3178	5.8964	4.87805	255	65025	16581375	15.9687	6.3413	3.92157
206	42436	8741816	14.3527	5.9059	4.85437	256	65536	16777216	16.0000	6.3496	3.90625
207	42849	8869743	14.3875	5.9155	4.83092	257	66049	16974593	16.0312	6.3579	3.89105
208	43264	8998912	14.4222	5.9250	4.80769	258	66564	17173512	16.0624	6.3661	3.87597
209	43681	9129329	14.4568	5.9345	4.78469	259	67081	17373979	16.0935	6.3743	3.86100
210	44100	9261000	14.4914	5.9439	4.76190	**260**	67600	17576000	16.1245	6.3825	3.84615
211	44521	9393931	14.5258	5.9533	4.73934	261	68121	17779581	16.1555	6.3907	3.83142
212	44944	9528128	14.5602	5.9627	4.71698	262	68644	17984728	16.1864	6.3988	3.81679
213	45369	9663597	14.5945	5.9721	4.69484	263	69169	18191447	16.2173	6.4070	3.80228
214	45796	9800344	14.6287	5.9814	4.67290	264	69696	18399744	16.2481	6.4151	3.78788
215	46225	9938375	14.6629	5.9907	4.65116	265	70225	18609625	16.2788	6.4232	3.77358
216	46656	10077696	14.6969	6.0000	4.62963	266	70756	18821096	16.3095	6.4312	3.75940
217	47089	10218313	14.7309	6.0092	4.60829	267	71289	19034163	16.3401	6.4393	3.74532
218	47524	10360232	14.7648	6.0185	4.58716	268	71824	19248832	16.3707	6.4473	3.73134
219	47961	10503459	14.7986	6.0277	4.56621	269	72361	19465109	16.4012	6.4553	3.71747
220	48400	10648000	14.8324	6.0368	4.54545	**270**	72900	19683000	16.4317	6.4633	3.70370
221	48841	10793861	14.8661	6.0459	4.52489	271	73441	19902511	16.4621	6.4713	3.69004
222	49284	10941048	14.8997	6.0550	4.50450	272	73984	20123648	16.4924	6.4792	3.67647
223	49729	11089567	14.9332	6.0641	4.48431	273	74529	20346417	16.5227	6.4872	3.66300
224	50176	11239424	14.9666	6.0732	4.46429	274	75076	20570824	16.5529	6.4951	3.64964
225	50625	11390625	15.0000	6.0822	4.44444	275	75625	20796875	16.5831	6.5030	3.63636
226	51076	11543176	15.0333	6.0912	4.42478	276	76176	21024576	16.6132	6.5108	3.62319
227	51529	11697083	15.0665	6.1002	4.40529	277	76729	21253933	16.6433	6.5187	3.61011
228	51984	11852352	15.0997	6.1091	4.38596	278	77284	21484952	16.6733	6.5265	3.59712
229	52441	12008989	15.1327	6.1180	4.36681	279	77841	21717639	16.7033	6.5343	3.58423
230	52900	12167000	15.1658	6.1269	4.34783	**280**	78400	21952000	16.7332	6.5421	3.57143
231	53361	12326391	15.1987	6.1358	4.32900	281	78961	22188041	16.7631	6.5499	3.55872
232	53824	12487168	15.2315	6.1446	4.31034	282	79524	22425768	16.7929	6.5577	3.54610
233	54289	12649337	15.2643	6.1534	4.29185	283	80089	22665187	16.8226	6.5654	3.53357
234	54756	12812904	15.2971	6.1622	4.27350	284	80656	22906304	16.8523	6.5731	3.52113
235	55225	12977875	15.3297	6.1710	4.25532	285	81225	23149125	16.8819	6.5808	3.50877
236	55696	13144256	15.3623	6.1797	4.23729	286	81796	23393656	16.9115	6.5885	3.49650
237	56169	13312053	15.3948	6.1885	4.21941	287	82369	23639903	16.9411	6.5962	3.48432
238	56644	13481272	15.4272	6.1972	4.20168	288	82944	23887872	16.9706	6.6039	3.47222
239	57121	13651919	15.4596	6.2058	4.18410	289	83521	24137569	17.0000	6.6115	3.46021
240	57600	13824000	15.4919	6.2145	4.16667	**290**	84100	24389000	17.0294	6.6191	3.44828
241	58081	13997521	15.5242	6.2231	4.14938	291	84681	24642171	17.0587	6.6267	3.43643
242	58564	14172488	15.5563	6.2317	4.13223	292	85264	24897088	17.0880	6.6343	3.42466
243	59049	14348907	15.5885	6.2403	4.11523	293	85849	25153757	17.1172	6.6419	3.41297
244	59536	14526784	15.6205	6.2488	4.09836	294	86436	25412184	17.1464	6.6494	3.40136
245	60025	14706125	15.6525	6.2573	4.08163	295	87025	25672375	17.1756	6.6569	3.38983
246	60516	14886936	15.6844	6.2658	4.06504	296	87616	25934336	17.2047	6.6644	3.37838
247	61009	15069223	15.7162	6.2743	4.04858	297	88209	26198073	17.2337	6.6719	3.36700
248	61504	15252992	15.7480	6.2828	4.03226	298	88804	26463592	17.2627	6.6794	3.35570
249	62001	15438249	15.7797	6.2912	4.01606	299	89401	26730899	17.2916	6.6869	3.34448
250	62500	15625000	15.8114	6.2996	4.00000	**300**	90000	27000000	17.3205	6.6943	3.33333

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
301	90601	27270901	17.3494	6.7018	3.32226	351	123201	43243551	18.7350	7.0540	2.84900
302	91204	27543608	17.3781	6.7092	3.31126	352	123904	43614208	18.7617	7.0607	2.84091
303	91809	27818127	17.4069	6.7166	3.30033	353	124609	43986977	18.7883	7.0674	2.83286
304	92416	28094464	17.4356	6.7240	3.28947	354	125316	44361864	18.8149	7.0740	2.82486
305	93025	28372625	17.4642	6.7313	3.27869	355	126025	44738875	18.8414	7.0807	2.81690
306	93636	28652616	17.4929	6.7387	3.26797	356	126736	45118016	18.8680	7.0873	2.80899
307	94249	28934443	17.5214	6.7460	3.25733	357	127449	45499293	18.8944	7.0940	2.80112
308	94864	29218112	17.5499	6.7533	3.24675	358	128164	45882712	18.9209	7.1006	2.79330
309	95481	29503629	17.5784	6.7606	3.23625	359	128881	46268279	18.9473	7.1072	2.78552
310	96100	29791000	17.6068	6.7679	3.22581	**360**	129600	46656000	18.9737	7.1138	2.77778
311	96721	30080231	17.6352	6.7752	3.21543	361	130321	47045881	19.0000	7.1204	2.77008
312	97344	30371328	17.6635	6.7824	3.20513	362	131044	47437928	19.0263	7.1269	2.76243
313	97969	30664297	17.6918	6.7897	3.19489	363	131769	47832147	19.9526	7.1335	2.75482
314	98596	30959144	17.7200	6.7969	3.18471	364	132496	48228544	19.0788	7.1400	2.74725
315	99225	31255875	17.7482	6.8041	3.17460	365	133225	48627125	19.1050	7.1466	2.73973
316	99856	31554496	17.7764	6.8113	3.16456	366	133956	49027896	19.1311	7.1531	2.73224
317	100489	31855013	17.8045	6.8185	3.15457	367	134689	49430863	19.1572	7.1596	2.72480
318	101124	32157432	17.8326	6.8256	3.14465	368	135424	49836032	19.1833	7.1661	2.71739
319	101761	32461759	17.8606	6.8328	3.13480	369	136161	50243409	19.2094	7.1726	2.71003
320	102400	32768000	17.8885	6.8399	3.12500	**370**	136900	50653000	19.2354	7.1791	2.70270
321	103041	33076161	17.9165	6.8470	3.11527	371	137641	51064811	19.2614	7.1855	2.69542
322	103684	33386248	17.9444	6.8541	3.10559	372	138384	51478848	19.2873	7.1920	2.68817
323	104329	33698267	17.9722	6.8612	3.09598	373	139129	51895117	19.3132	7.1984	2.68097
324	104976	34012224	18.0000	6.8683	3.08642	374	139876	52313624	19.3391	7.2048	2.67380
325	105625	34328125	18.0278	6.8753	3.07692	375	140625	52734375	19.3649	7.2112	2.66667
326	106276	34645976	18.0555	6.8824	3.06749	376	141376	53157376	19.3907	7.2177	2.65957
327	106929	34965783	18.0831	6.8894	3.05810	377	142129	53582633	19.4165	7.2240	2.65252
328	107584	35287552	18.1108	6.8964	3.04878	378	142884	54010152	19.4422	7.2304	2.64550
329	108241	35611289	18.1384	6.9034	3.03951	379	143641	54439939	19.4679	7.2368	2.63852
330	108900	35937000	18.1659	6.9104	3.03030	**380**	144400	54872000	19.4936	7.2432	2.63158
331	109561	36264691	18.1934	6.9174	3.02115	381	145161	55306341	19.5192	7.2495	2.62467
332	110224	36594368	18.2209	6.9244	3.01205	382	145924	55742968	19.5448	7.2558	2.61780
333	110889	36926037	18.2483	6.9313	3.00300	383	146689	56181887	19.5704	7.2622	2.61097
334	111556	37259704	18.2757	6.9382	2.99401	384	147456	56623104	19.5959	7.2685	2.60417
335	112225	37595375	18.3030	6.9451	2.98507	385	148225	57066625	19.6214	7.2748	2.59740
336	112896	37933056	18.3303	6.9521	2.97619	386	148996	57512456	19.6469	7.2811	2.59067
337	113569	38272753	18.3576	6.9589	2.96736	387	149769	57960603	19.6723	7.2874	2.58398
338	114244	38614472	18.3848	6.9658	2.95858	388	150544	58411072	19.6977	7.2936	2.57732
339	114921	38958219	18.4120	6.9727	2.94985	389	151321	58863869	19.7231	7.2999	2.57069
340	115600	39304000	18.4391	6.9795	2.94118	**390**	152100	59319000	19.7484	7.3061	2.56410
341	116281	39651821	18.4662	6.9864	2.93255	391	152881	59776471	19.7737	7.3124	2.55755
342	116964	40001688	18.4932	6.9932	2.92398	392	153664	60236288	19.7990	7.3186	2.55102
343	117649	40353607	18.5203	7.0000	2.91545	393	154449	60698457	19.8242	7.3248	2.54453
344	118336	40707584	18.5472	7.0068	2.90698	394	155236	61162984	19.8494	7.3310	2.53807
345	119025	41063625	18.5742	7.0136	2.89855	395	156025	61629875	19.8746	7.3372	2.53165
346	119716	41421736	18.6011	7.0203	2.89017	396	156816	62099136	19.8997	7.3434	2.52525
347	120409	41781923	18.6279	7.0271	2.88184	397	157609	62570773	19.9249	7.3496	2.51889
348	121104	42144192	18.6548	7.0338	2.87356	398	158404	63044792	19.9499	7.3558	2.51256
349	121801	42508549	18.6815	7.0406	2.86533	399	159201	63521199	19.9750	7.3619	2.50627
350	122500	42875000	18.7083	7.0473	2.85714	**400**	160000	64000000	20.0000	7.3681	2.50000

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
401	160801	64481201	20.0250	7.3742	2.49377	451	203401	91733851	21.2368	7.6688	2.21730
402	161604	64964808	20.0499	7.3803	2.48756	452	204304	92345408	21.2603	7.6744	2.21239
403	162409	65450827	20.0749	7.3864	2.48139	453	205209	92959677	21.2838	7.6801	2.20751
404	163216	65939264	20.0998	7.3925	2.47525	454	206116	93576664	21.3073	7.6857	2.20264
405	164025	66430125	20.1246	7.3986	2.46914	455	207025	94196375	21.3307	7.6914	2.19780
406	164836	66923416	20.1494	7.4047	2.46305	456	207936	94818816	21.3542	7.6970	2.19298
407	165649	67419143	20.1742	7.4108	2.45700	457	208849	95443993	21.3776	7.7026	2.18818
408	166464	67917312	20.1990	7.4169	2.45098	458	209764	96071912	21.4009	7.7082	2.18341
409	167281	68417929	20.2237	7.4229	2.44499	459	210681	96702579	21.4243	7.7138	2.17865
410	168100	68921000	20.2485	7.4290	2.43902	**460**	211600	97336000	21.4476	7.7194	2.17391
411	168921	69426531	20.2731	7.4350	2.43309	461	212521	97972181	21.4709	7.7250	2.16920
412	169744	69934528	20.2978	7.4410	2.42718	462	213444	98611128	21.4942	7.7306	2.16450
413	170569	70444997	20.3224	7.4470	2.42131	463	214369	99252847	21.5174	7.7362	2.15983
414	171396	70957944	20.3470	7.4530	2.41546	464	215296	99897344	21.5407	7.7418	2.15517
415	172225	71473375	20.3715	7.4590	2.40964	465	216225	100544625	21.5639	7.7473	2.15054
416	173056	71991296	20.3961	7.4650	2.40385	466	217156	101194696	21.5870	7.7529	2.14592
417	173889	72511713	20.4206	7.4710	2.39808	467	218089	101847563	21.6102	7.7584	2.14133
418	174724	73034632	20.4450	7.4770	2.39234	468	219024	102503232	21.6333	7.7639	2.13675
419	175561	73560059	20.4695	7.4829	2.38664	469	219961	103161709	21.6564	7.7695	2.13220
420	176400	74088000	20.4939	7.4889	2.38095	**470**	220900	103823000	21.6795	7.7750	2.12766
421	177241	74618461	20.5183	7.4948	2.37530	471	221841	104487111	21.7025	7.7805	2.12314
422	178084	75151448	20.5426	7.5007	2.36967	472	222784	105154048	21.7256	7.7860	2.11864
423	178929	75686967	20.5670	7.5067	2.36407	473	223729	105823817	21.7486	7.7915	2.11417
424	179776	76225024	20.5913	7.5126	2.35849	474	224676	106496424	21.7715	7.7970	2.10971
425	180625	76765625	20.6155	7.5185	2.35294	475	225625	107171875	21.7945	7.8025	2.10526
426	181476	77308776	20.6398	7.5244	2.34742	476	226576	107850176	21.8174	7.8079	2.10084
427	182329	77854483	20.6640	7.5302	2.34192	477	227529	108531333	21.8403	7.8134	2.09644
428	183184	78402752	20.6882	7.5361	2.33645	478	228484	109215352	21.8632	7.8188	2.09205
429	184041	78953589	20.7123	7.5420	2.33100	479	229441	109902239	21.8861	7.8243	2.08768
430	184900	79507000	20.7364	7.5478	2.32558	**480**	230400	110592000	21.9089	7.8297	2.08333
431	185761	80062991	20.7605	7.5537	2.32019	481	231361	111284641	21.9317	7.8352	2.07900
432	186624	80621568	20.7846	7.5595	2.31482	482	232324	111980168	21.9545	7.8406	2.07469
433	187489	81182737	20.8087	7.5654	2.30947	483	233289	112678587	21.9773	7.8460	2.07039
434	188356	81746504	20.8237	7.5712	2.30415	484	234256	113379904	22.0000	7.8514	2.06612
435	189225	82312875	20.8567	7.5770	2.29885	485	235225	114084125	22.0227	7.8568	2.06186
436	190096	82881856	20.8806	7.5828	2.29358	486	236196	114791256	22.0454	7.8622	2.05761
437	190969	83453453	20.9045	7.5886	2.28833	487	237169	115501303	22.0681	7.8676	2.05339
438	191844	84027672	20.9284	7.5944	2.28311	488	238144	116214272	22.0907	7.8730	2.04918
439	192721	84604519	20.9523	7.6001	2.27790	489	239121	116930169	22.1133	7.8784	2.04499
440	193600	85184000	20.9762	7.6059	2.27273	**490**	240100	117649000	22.1359	7.8837	2.04082
441	194481	85766121	21.0000	7.6117	2.26757	491	241081	118370771	22.1585	7.8891	2.03666
442	195364	86350888	21.0238	7.6174	2.26244	492	242064	119095488	22.1811	7.8944	2.03252
443	196249	86938307	21.0476	7.6232	2.25734	493	243049	119823157	22.2036	7.8998	2.02840
444	197136	87528384	21.0713	7.6289	2.25225	494	244036	120553784	22.2261	7.9051	2.02429
445	198025	88121125	21.0950	7.6346	2.24719	495	245025	121287375	22.2486	7.9105	2.02020
446	198916	88716536	21.1187	7.6403	2.24215	496	246016	122023936	22.2711	7.9158	2.01613
447	199809	89314623	21.1424	7.6460	2.23714	497	247009	122763473	22.2935	7.9211	2.01207
448	200704	89915392	21.1660	7.6517	2.23214	498	248004	123505992	22.3159	7.9264	2.00803
449	201601	90518849	21.1896	7.6574	2.22717	499	249001	124251499	22.3383	7.9317	2.00401
450	202500	91125000	21.2132	7.6631	2.22222	**500**	250000	125000000	22.3607	7.9370	2.00000

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
501	251001	125751501	22.3830	7.9423	1.99601	551	303601	167284151	23.4734	8.1982	1.81488
502	252004	126506008	22.4054	7.9476	1.99203	552	304704	168196608	23.4947	8.2031	1.81159
503	253009	127263527	22.4277	7.9528	1.98807	553	305809	169112377	23.5160	8.2081	1.80832
504	254016	128024064	22.4499	7.9581	1.98413	554	306916	170031464	23.5372	8.2130	1.80505
505	255025	128787625	22.4722	7.9634	1.98020	555	308025	170953875	23.5584	8.2180	1.80180
506	256036	129554216	22.4944	7.9686	1.97629	556	309136	171879616	23.5797	8.2229	1.79856
507	257049	130323843	22.5167	7.9739	1.97239	557	310249	172808693	23.6008	8.2278	1.79533
508	258064	131096512	22.5389	7.9791	1.96850	558	311364	173741112	23.6220	8.2327	1.79211
509	259081	131872229	22.5610	7.9843	1.96464	559	312481	174676879	23.6432	8.2377	1.78891
510	260100	132651000	22.5832	7.9896	1.96078	**560**	313600	175616000	23.6643	8.2426	1.78571
511	261121	133432831	22.6053	7.9948	1.95695	561	314721	176558481	23.6854	8.2475	1.78253
512	262144	134217728	22.6274	8.0000	1.95312	562	315844	177504328	23.7065	8.2524	1.77936
513	263169	135005697	22.6495	8.0052	1.94932	563	316969	178453547	23.7276	8.2573	1.77620
514	264196	135796744	22.6716	8.0104	1.94553	564	318096	179406144	23.7487	8.2621	1.77305
515	265225	136590875	22.6936	8.0156	1.94175	565	319225	180362125	23.7697	8.2670	1.76991
516	266256	137388096	22.7156	8.0208	1.93798	566	320356	181321496	23.7908	8.2719	1.76678
517	267289	138188413	22.7376	8.0260	1.93424	567	321489	182284263	23.8118	8.2768	1.76367
518	268324	138991832	22.7596	8.0311	1.93050	568	322624	183250432	23.8328	8.2816	1.76056
519	269361	139798359	22.7816	8.0363	1.92678	569	323761	184220009	23.8537	8.2865	1.75747
520	270400	140608000	22.8035	8.0415	1.92308	**570**	324900	185193000	23.8747	8.2913	1.75439
521	271441	141420761	22.8254	8.0466	1.91939	571	326041	186169411	23.8956	8.2962	1.75131
522	272484	142236648	22.8473	8.0517	1.91571	572	327184	187149248	23.9165	8.3010	1.74825
523	273529	143055667	22.8692	8.0569	1.91205	573	328329	188132517	23.9374	8.3059	1.74520
524	274576	143877824	22.8910	8.0620	1.90840	574	329476	189119224	23.9583	8.3107	1.74216
525	275625	144703125	22.9129	8.0671	1.90476	575	330625	190109375	23.9792	8.3155	1.73913
526	276676	145531576	22.9347	8.0723	1.90114	576	331776	191102976	24.0000	8.3203	1.73611
527	277729	146363183	22.9565	8.0774	1.89753	577	332929	192100033	24.0208	8.3251	1.73310
528	278784	147197952	22.9783	8.0825	1.89394	578	334084	193100552	24.0416	8.3300	1.73010
529	279841	148035889	23.0000	8.0876	1.89036	579	335241	194104539	24.0624	8.3348	1.72712
530	280900	148877000	23.0217	8.0927	1.88679	**580**	336400	195112000	24.0832	8.3396	1.72414
531	281961	149721291	23.0434	8.0978	1.88324	581	337561	196122941	24.1039	8.3443	1.72117
532	283024	150568768	23.0651	8.1028	1.87970	582	338724	197137368	24.1247	8.3491	1.71821
533	284089	151419437	23.0868	8.1079	1.87617	583	339889	198155287	24.1454	8.3539	1.71527
534	285156	152273304	23.1084	8.1130	1.87266	584	341056	199176704	24.1661	8.3587	1.71233
535	286225	153130375	23.1301	8.1180	1.86916	585	342225	200201625	24.1868	8.3634	1.70940
536	287296	153990656	23.1517	8.1231	1.86567	586	343396	201230056	24.2074	8.3682	1.70649
537	288369	154854153	23.1733	8.1281	1.86220	587	344569	202262003	24.2281	8.3730	1.70358
538	289444	155720872	23.1948	8.1332	1.85874	588	345744	203297472	24.2487	8.3777	1.70068
539	290521	156590819	23.2164	8.1382	1.85529	589	346921	204336469	24.2693	8.3825	1.69779
540	291600	157464000	23.2379	8.1433	1.85185	**590**	348100	205379000	24.2899	8.3872	1.69492
541	292681	158340421	23.2594	8.1483	1.84843	591	349281	206425071	24.3105	8.3919	1.69205
542	293764	159220088	23.2809	8.1533	1.84502	592	350464	207474688	24.3311	8.3967	1.68919
543	294849	160103007	23.3024	8.1583	1.84162	593	351649	208527857	24.3516	8.4014	1.68634
544	295936	160989184	23.3238	8.1633	1.83824	594	352836	209584584	24.3721	8.4061	1.68350
545	297025	161878625	23.3452	8.1683	1.83486	595	354025	210644875	24.3926	8.4108	1.68067
546	298116	162771336	23.3666	8.1733	1.83150	596	355216	211708736	24.4131	8.4155	1.67785
547	299209	163667323	23.3880	8.1783	1.82815	597	356409	212776173	24.4336	8.4202	1.67504
548	300304	164566592	23.4094	8.1833	1.82482	598	357604	213847192	24.4540	8.4249	1.67224
549	301401	165469149	23.4307	8.1882	1.82149	599	358801	214921799	24.4745	8.4296	1.66945
550	302500	166375000	23.4521	8.1932	1.81818	**600**	360000	216000000	24.4949	8.4343	1.66667

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
601	361201	217081801	24.5153	8.4390	1.66389	651	423801	275894451	25.5147	8.6668	1.53610
602	362404	218167208	24.5357	8.4437	1.66113	652	425104	277167808	25.5343	8.6713	1.53374
603	363609	219256227	24.5561	8.4484	1.65837	653	426409	278445077	25.5539	8.6757	1.53139
604	364816	220348864	24.5764	8.4530	1.65563	654	427716	279726264	25.5734	8.6801	1.52905
605	366025	221445125	24.5967	8.4577	1.65289	655	429025	281011375	25.5930	8.6845	1.52672
606	367236	222545016	24.6171	8.4623	1.65017	656	430336	282300416	25.6125	8.6890	1.52439
607	368449	223648543	24.6374	8.4670	1.64745	657	431649	283593393	25.6320	8.6934	1.52207
608	369664	224755712	24.6577	8.4716	1.64474	658	432964	284890312	25.6515	8.6978	1.51976
609	370881	225866529	24.6779	8.4763	1.64204	659	434281	286191179	25.6710	8.7022	1.51745
610	372100	226981000	24.6982	8.4809	1.63934	**660**	435600	287496000	25.6905	8.7066	1.51515
611	373321	228099131	24.7184	8.4856	1.63666	661	436921	288804781	25.7099	8.7110	1.51286
612	374544	229220928	24.7386	8.4902	1.63399	662	438244	290117528	25.7294	8.7154	1.51057
613	375769	230346397	24.7588	8.4948	1.63132	663	439569	291434247	25.7488	8.7198	1.50830
614	376996	231475544	24.7790	8.4994	1.62866	664	440896	292754944	25.7682	8.7241	1.50602
615	378225	232608375	24.7992	8.5040	1.62602	665	442225	294079625	25.7876	8.7285	1.50376
616	379456	233744896	24.8193	8.5086	1.62338	666	443556	295408296	25.8070	8.7329	1.50150
617	380689	234885113	24.8395	8.5132	1.62075	667	444889	296740963	25.8263	8.7373	1.49925
618	381924	236029032	24.8596	8.5178	1.61812	668	446224	298077632	25.8457	8.7416	1.49701
619	383161	237176659	24.8797	8.5224	1.61551	669	447561	299418309	25.8650	8.7460	1.49477
620	384400	238328000	24.8998	8.5270	1.61290	**670**	448900	300763000	25.8844	8.7503	1.49254
621	385641	239483061	24.9199	8.5316	1.61031	671	450241	302111711	25.9037	8.7547	1.49031
622	386884	240641848	24.9399	8.5362	1.60772	672	451584	303464448	25.9230	8.7590	1.48810
623	388129	241804367	24.9600	8.5408	1.60514	673	452929	304821217	25.9422	8.7634	1.48588
624	389376	242970624	24.9800	8.5453	1.60256	674	454276	306182024	25.9615	8.7677	1.48368
625	390625	244140625	25.0000	8.5499	1.60000	675	455625	307546875	25.9808	8.7721	1.48148
626	391876	245314376	25.0200	8.5544	1.59744	676	456976	308915776	26.0000	8.7764	1.47929
627	393129	246491883	25.0400	8.5590	1.59490	677	458329	310288733	26.0192	8.7807	1.47711
628	394384	247673152	25.0599	8.5635	1.59236	678	459684	311665752	26.0384	8.7850	1.47493
629	395641	248858189	25.0799	8.5681	1.58983	679	461041	313046839	26.0576	8.7893	1.47275
630	396900	250047000	25.0998	8.5726	1.58730	**680**	462400	314432000	26.0768	8.7937	1.47059
631	398161	251239591	25.1197	8.5772	1.58479	681	463761	315821241	26.0960	8.7980	1.46843
632	399424	252435968	25.1396	8.5817	1.58228	682	465124	317214568	26.1151	8.8023	1.46628
633	400689	253636137	25.1595	8.5862	1.57978	683	466489	318611987	26.1343	8.8066	1.46413
634	401956	254840104	25.1794	8.5907	1.57729	684	467856	320013504	26.1534	8.8109	1.46199
635	403225	256047875	25.1992	8.5952	1.57480	685	469225	321419125	26.1725	8.8152	1.45985
636	404496	257259456	25.2190	8.5997	1.57233	686	470596	322828856	26.1916	8.8194	1.45773
637	405769	258474853	25.2389	8.6043	1.56986	687	471969	324242703	26.2107	8.8237	1.45560
638	407044	259694072	25.2587	8.6088	1.56740	688	473344	325660672	26.2298	8.8280	1.45349
639	408321	260917119	25.2784	8.6132	1.56495	689	474721	327082769	26.2488	8.8323	1.45138
640	409600	262144000	25.2982	8.6177	1.56250	**690**	476100	328509000	26.2679	8.8366	1.44928
641	410881	263374721	25.3180	8.6222	1.56006	691	477481	329939371	26.2869	8.8408	1.44718
642	412164	264609288	25.3377	8.6267	1.55763	692	478864	331373888	26.3059	8.8451	1.44509
643	413449	265847707	25.3574	8.6312	1.55521	693	480249	332812557	26.3249	8.8493	1.44300
644	414736	267089984	25.3772	8.6357	1.55280	694	481636	334255384	26.3439	8.8536	1.44092
645	416025	268336125	25.3969	8.6401	1.55039	695	483025	335702375	26.3629	8.8578	1.43885
646	417316	269586136	25.4165	8.6446	1.54799	696	484416	337153536	26.3818	8.8621	1.43678
647	418609	270840023	25.4362	8.6490	1.54560	697	485809	338608873	26.4008	8.8663	1.43472
648	419904	272097792	25.4558	8.6535	1.54321	698	487204	340068392	26.4197	8.8706	1.43267
649	421201	273359449	25.4755	8.6579	1.54083	699	488601	341532099	26.4386	8.8748	1.43062
650	422500	274625000	25.4951	8.6624	1.53846	**700**	490000	343000000	26.4575	8.8790	1.42857

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
701	491401	344472101	26.4764	8.8833	1.42653
702	492804	345948408	26.4953	8.8875	1.42450
703	494209	347428927	26.5141	8.8917	1.42248
704	495616	348913664	26.5330	8.8959	1.42046
705	497025	350402625	26.5518	8.9001	1.41844
706	498436	351895816	26.5707	8.9043	1.41643
707	499849	353393243	26.5895	8.9085	1.41443
708	501264	354894912	26.6083	8.9127	1.41243
709	502681	356400829	26.6271	8.9169	1.41044
710	504100	357911000	26.6458	8.9211	1.40845
711	505521	359425431	26.6646	8.9253	1.40647
712	506944	360944128	26.6833	8.9295	1.40449
713	508369	362467097	26.7021	8.9337	1.40253
714	509796	363994344	26.7208	8.9378	1.40056
715	511225	365525875	26.7395	8.9420	1.39860
716	512656	367061696	26.7582	8.9462	1.39665
717	514089	368601813	26.7769	8.9503	1.39470
718	515524	370146232	26.7955	8.9545	1.39276
719	516961	371694959	26.8142	8.9587	1.39082
720	518400	373248000	26.8328	8.9628	1.38889
721	519841	374805361	26.8514	8.9670	1.38696
722	521284	376367048	26.8701	8.9711	1.38504
723	522729	377933067	26.8887	8.9752	1.38313
724	524176	379503424	26.9072	8.9794	1.38122
725	525625	381078125	26.9258	8.9835	1.37931
726	527076	382657176	26.9444	8.9876	1.37741
727	528529	384240583	26.9629	8.9918	1.37552
728	529984	385828352	26.9815	8.9959	1.37363
729	531441	387420489	27.0000	9.0000	1.37174
730	532900	389017000	27.0185	9.0041	1.36986
731	534361	390617891	27.0370	9.0082	1.36799
732	535824	392223168	27.0555	9.0123	1.36612
733	537289	393832837	27.0740	9.0164	1.36426
734	538756	395446904	27.0924	9.0205	1.36240
735	540225	397065375	27.1109	9.0246	1.36054
736	541696	398688256	27.1293	9.0287	1.35870
737	543169	400315553	27.1477	9.0328	1.35685
738	544644	401947272	27.1662	9.0369	1.35501
739	546121	403583419	27.1846	9.0410	1.35318
740	547600	405224000	27.2029	9.0450	1.35135
741	549081	406869021	27.2213	9.0491	1.34953
742	550564	408518488	27.2397	9.0532	1.34771
743	552049	410172407	27.2580	9.0572	1.34590
744	553536	411830784	27.2764	9.0613	1.34409
745	555025	413493625	27.2947	9.0654	1.34228
746	556516	415160936	27.3130	9.0694	1.34048
747	558009	416832723	27.3313	9.0735	1.33869
748	559504	418508992	27.3496	9.0775	1.33690
749	561001	420189749	27.3679	9.0816	1.33511
750	562500	421875000	27.3861	9.0856	1.33333

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
751	564001	423564751	27.4044	9.0896	1.33156
752	565504	425259008	27.4226	9.0937	1.32979
753	567009	426957777	27.4408	9.0977	1.32802
754	568516	428661064	27.4591	9.1017	1.32626
755	570025	430368875	27.4773	9.1057	1.32450
756	571536	432081216	27.4955	9.1098	1.32275
757	573049	433798093	27.5136	9.1138	1.32100
758	574564	435519512	27.5318	9.1178	1.31926
759	576081	437245479	27.5500	9.1218	1.31752
760	577600	438976000	27.5681	9.1258	1.31579
761	579121	440711081	27.5862	9.1298	1.31406
762	580644	442450728	27.6043	9.1338	1.31234
763	582169	444194947	27.6225	9.1378	1.31062
764	583696	445943744	27.6405	9.1418	1.30890
765	585225	447697125	27.6586	9.1458	1.30719
766	586756	449455096	27.6767	9.1498	1.30548
767	588289	451217663	27.6948	9.1537	1.30378
768	589824	452984832	27.7128	9.1577	1.30208
769	591361	454756609	27.7308	9.1617	1.30039
770	592900	456533000	27.7489	9.1657	1.29870
771	594441	458314011	27.7669	9.1696	1.29702
772	595984	460099648	27.7849	9.1736	1.29534
773	597529	461889917	27.8029	9.1775	1.29366
774	599076	463684824	27.8209	9.1815	1.29199
775	600625	465484375	27.8388	9.1855	1.29032
776	602176	467288576	27.8568	9.1894	1.28866
777	603729	469097433	27.8747	9.1933	1.28700
778	605284	470910952	27.8927	9.1973	1.28535
779	606841	472729139	27.9106	9.2012	1.28370
780	608400	474552000	27.9285	9.2052	1.28205
781	609961	476379541	27.9464	9.2091	1.28041
782	611524	478211768	27.9643	9.2130	1.27877
783	613089	480048687	27.9821	9.2170	1.27714
784	614656	481890304	28.0000	9.2209	1.27551
785	616225	483736625	28.0179	9.2248	1.27389
786	617796	485587656	28.0357	9.2287	1.27226
787	619369	487443403	28.0535	9.2326	1.27065
788	620944	489303872	28.0713	9.2365	1.26904
789	622521	491169069	28.0891	9.2404	1.26743
790	624100	493039000	28.1069	9.2443	1.26582
791	625681	494913671	28.1247	9.2482	1.26422
792	627264	496793088	28.1425	9.2521	1.26263
793	628849	498677257	28.1603	9.2560	1.26103
794	630436	500566184	28.1780	9.2599	1.25945
795	632025	502459875	28.1957	9.2638	1.25786
796	633616	504358336	28.2135	9.2677	1.25628
797	635209	506261573	28.2312	9.2716	1.25471
798	636804	508169592	28.2489	9.2754	1.25313
799	638401	510082399	28.2666	9.2793	1.25156
800	640000	512000000	28.2843	9.2832	1.25000

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
801	641601	513922401	28.3019	9.2870	1.24844	851	724201	616295051	29.1719	9.4764	1.17509
802	643204	515849608	28.3196	9.2909	1.24688	852	725904	618470208	29.1890	9.4801	1.17371
803	644809	517781627	28.3373	9.2948	1.24533	853	727609	620650477	29.2062	9.4838	1.17233
804	646416	519718464	28.3549	9.2986	1.24378	854	729316	622835864	29.2233	9.4875	1.17096
805	648025	521660125	28.3725	9.3025	1.24224	855	731025	625026375	29.2404	9.4912	1.16959
806	649636	523606616	28.3901	9.3063	1.24069	856	732736	627222016	29.2575	9.4949	1.16822
807	651249	525557943	28.4077	9.3102	1.23916	857	734449	629422793	29.2746	9.4986	1.16686
808	652864	527514112	28.4253	9.3140	1.23762	858	736164	631628712	29.2916	9.5023	1.16550
809	654481	529475129	28.4429	9.3179	1.23609	859	737881	633839779	29.3087	9.5060	1.16414
810	656100	531441000	28.4605	9.3217	1.23457	**860**	739600	636056000	29.3258	9.5097	1.16279
811	657721	533411731	28.4781	9.3255	1.23305	861	741321	638277381	29.3428	9.5134	1.16144
812	659344	535387328	28.4956	9.3294	1.23153	862	743044	640503928	29.3598	9.5171	1.16009
813	660969	537367797	28.5132	9.3332	1.23001	863	744769	642735647	29.3769	9.5207	1.15875
814	662596	539353144	28.5307	9.3370	1.22850	864	746496	644972544	29.3939	9.5244	1.15741
815	664225	541343375	28.5482	9.3408	1.22699	865	748225	647214625	29.4109	9.5281	1.15607
816	665856	543338496	28.5657	9.3447	1.22549	866	749956	649461896	29.4279	9.5317	1.15473
817	667489	545338513	28.5832	9.3485	1.22399	867	751689	651714363	29.4449	9.5354	1.15340
818	669124	547343432	28.6007	9.3523	1.22249	868	753424	653972032	29.4618	9.5391	1.15207
819	670761	549353259	28.6182	9.3561	1.22100	869	755161	656234909	29.4788	9.5427	1.15075
820	672400	551368000	28.6356	9.3599	1.21951	**870**	756900	658503000	29.4958	9.5464	1.14943
821	674041	553387661	28.6531	9.3637	1.21803	871	758641	660776311	29.5127	9.5501	1.14811
822	675684	555412248	28.6705	9.3675	1.21655	872	760384	663054848	29.5296	9.5537	1.14679
823	677329	557441767	28.6880	9.3713	1.21507	873	762129	665338617	29.5466	9.5574	1.14548
824	678976	559476224	28.7054	9.3751	1.21359	874	763876	667627624	29.5635	9.5610	1.14416
825	680625	561515625	28.7228	9.3789	1.21212	875	765625	669921875	29.5804	9.5647	1.14286
826	682276	563559976	28.7402	9.3827	1.21065	876	767376	672221376	29.5973	9.5683	1.14155
827	683929	565609283	28.7576	9.3865	1.20919	877	769129	674526133	29.6142	9.5719	1.14025
828	685584	567663552	28.7750	9.3902	1.20773	878	770884	676836152	29.6311	9.5756	1.13895
829	687241	569722789	28.7924	9.3940	1.20627	879	772641	679151439	29.6479	9.5792	1.13766
830	688900	571787000	28.8097	9.3978	1.20482	**880**	774400	681472000	29.6648	9.5828	1.13636
831	690561	573856191	28.8271	9.4016	1.20337	881	776161	683797841	29.6816	9.5865	1.13507
832	692224	575930368	28.8444	9.4053	1.20192	882	777924	686128968	29.6985	9.5901	1.13379
833	693889	578009537	28.8617	9.4091	1.20048	883	779689	688465387	29.7153	9.5937	1.13250
834	695556	580093704	28.8791	9.4129	1.19904	884	781456	690807104	29.7321	9.5973	1.13122
835	697225	582182875	28.8964	9.4166	1.19760	885	783225	693154125	29.7489	9.6010	1.12994
836	698896	584277056	28.9137	9.4204	1.19617	886	784996	695506456	29.7658	9.6046	1.12867
837	700569	586376253	28.9310	9.4241	1.19474	887	786769	697864103	29.7825	9.6082	1.12740
838	702244	588480472	28.9482	9.4279	1.19332	888	788544	700227072	29.7993	9.6118	1.12613
839	703921	590589719	28.9655	9.4316	1.19189	889	790321	702595369	29.8161	9.6154	1.12486
840	705600	592704000	28.9828	9.4354	1.19048	**890**	792100	704969000	29.8329	9.6190	1.12360
841	707281	594823321	29.0000	9.4391	1.18906	891	793881	707347971	29.8496	9.6226	1.12233
842	708964	596947688	29.0172	9.4429	1.18765	892	795664	709732288	29.8664	9.6262	1.12108
843	710649	599077107	29.0345	9.4466	1.18624	893	797449	712121957	29.8831	9.6298	1.11982
844	712336	601211584	29.0517	9.4503	1.18483	894	799236	714516984	29.8998	9.6334	1.11857
845	714025	603351125	29.0689	9.4541	1.18343	895	801025	716917375	29.9166	9.6370	1.11732
846	715716	605495736	29.0861	9.4578	1.18203	896	802816	719323136	29.9333	9.6406	1.11607
847	717409	607645423	29.1033	9.4615	1.18064	897	804609	721734273	29.9500	9.6442	1.11483
848	719104	609800192	29.1204	9.4652	1.17925	898	806404	724150792	29.9666	9.6477	1.11359
849	720801	611960049	29.1376	9.4690	1.17786	899	808201	726572699	29.9833	9.6513	1.11235
850	722500	614125000	29.1548	9.4727	1.17647	**900**	810000	729000000	30.0000	9.6549	1.11111

Powers, Roots and Reciprocals—(Continued)

No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000	No.	Square	Cube	Square Root	Cube Root	Reciprocal X 1,000
901	811801	731432701	30.0167	9.6585	1.10988	951	904401	860085351	30.8383	9.8339	1.05152
902	813604	733870808	30.0333	9.6620	1.10865	952	906304	862801408	30.8545	9.8374	1.05042
903	815409	736314327	30.0500	9.6656	1.10742	953	908209	865523177	30.8707	9.8408	1.04932
904	817216	738763264	30.0666	9.6692	1.10619	954	910116	868250664	30.8869	9.8443	1.04822
905	819025	741217625	30.0832	9.6727	1.10497	955	912025	870983875	30.9031	9.8477	1.04712
906	820836	743677416	30.0998	9.6763	1.10375	956	913936	873722816	30.9192	9.8511	1.04603
907	822649	746142643	30.1164	9.6799	1.10254	957	915849	876467493	30.9354	9.8546	1.04493
908	824464	748613312	30.1330	9.6834	1.10132	958	917764	879217912	30.9516	9.8580	1.04384
909	826281	751089429	30.1496	9.6870	1.10011	959	919681	881974079	30.9677	9.8614	1.04275
910	828100	753571000	30.1662	9.6905	1.09890	**960**	921600	884736000	30.9839	9.8648	1.04167
911	829921	756058031	30.1828	9.6941	1.09769	961	923521	887503681	31.0000	9.8683	1.04058
912	831744	758550528	30.1993	9.6976	1.09649	962	925444	890277128	31.0161	9.8717	1.03950
913	833569	761048497	30.2159	9.7012	1.09529	963	927369	893056347	31.0322	9.8751	1.03842
914	835396	763551944	30.2324	9.7047	1.09409	964	929296	895841344	31.0483	9.8785	1.03734
915	837225	766060875	30.2490	9.7082	1.09290	965	931225	898632125	31.0644	9.8819	1.03627
916	839056	768575296	30.2655	9.7118	1.09170	966	933156	901428696	31.0805	9.8854	1.03520
917	840889	771095213	30.2820	9.7153	1.09051	967	935089	904231063	31.0966	9.8888	1.03413
918	842724	773620632	30.2985	9.7188	1.08932	968	937024	907039232	31.1127	9.8922	1.03306
919	844561	776151559	30.3150	9.7224	1.08814	969	938961	909853209	31.1288	9.8956	1.03199
920	846400	778688000	30.3315	9.7259	1.08696	**970**	940900	912673000	31.1448	9.8990	1.03093
921	848241	781229961	30.3480	9.7294	1.08578	971	942841	915498611	31.1609	9.9024	1.02987
922	850084	783777448	30.3645	9.7329	1.08460	972	944784	918330048	31.1769	9.9058	1.02881
923	851929	786330467	30.3809	9.7364	1.08342	973	946729	921167317	31.1929	9.9092	1.02775
924	853776	788889024	30.3974	9.7400	1.08225	974	948676	924010424	31.2090	9.9126	1.02669
925	855625	791453125	30.4138	9.7435	1.08108	975	950625	926859375	31.2250	9.9160	1.02564
926	857476	794022776	30.4302	9.7470	1.07991	976	952576	929714176	31.2410	9.9194	1.02459
927	859329	796597983	30.4467	9.7505	1.07875	977	954529	932574833	31.2570	9.9227	1.02354
928	861184	799178752	30.4631	9.7540	1.07759	978	956484	935441352	31.2730	9.9261	1.02249
929	863041	801765089	30.4795	9.7575	1.07643	979	958441	938313739	31.2890	9.9295	1.02145
930	864900	804357000	30.4959	9.7610	1.07527	**980**	960400	941192000	31.3050	9.9329	1.02041
931	866761	806954491	30.5123	9.7645	1.07411	981	962361	944076141	31.3209	9.9363	1.01937
932	868624	809557568	30.5287	9.7680	1.07296	982	964324	946966168	31.3369	9.9396	1.01833
933	870489	812166237	30.5450	9.7715	1.07181	983	966289	949862087	31.3528	9.9430	1.01729
934	872356	814780504	30.5614	9.7750	1.07066	984	968256	952763904	31.3688	9.9464	1.01626
935	874225	817400375	30.5778	9.7785	1.06952	985	970225	955671625	31.3847	9.9497	1.01523
936	876096	820025856	30.5941	9.7819	1.06838	986	972196	958585256	31.4006	9.9531	1.01420
937	877969	822656953	30.6105	9.7854	1.06724	987	974169	961504803	31.4166	9.9565	1.01317
938	879844	825293672	30.6268	9.7889	1.06610	988	976144	964430272	31.4325	9.9598	1.01215
939	881721	827936019	30.6431	9.7924	1.06496	989	978121	967361669	31.4484	9.9632	1.01112
940	883600	830584000	30.6594	9.7959	1.06383	**990**	980100	970299000	31.4643	9.9666	1.01010
941	885481	833237621	30.6757	9.7993	1.06270	991	982081	973242271	31.4802	9.9699	1.00908
942	887364	835896888	30.6920	9.8028	1.06157	992	984064	976191488	31.4960	9.9733	1.00806
943	889249	838561807	30.7083	9.8063	1.06045	993	986049	979146657	31.5119	9.9766	1.00705
944	891136	841232384	30.7246	9.8097	1.05932	994	988036	982107784	31.5278	9.9800	1.00604
945	893025	843908625	30.7409	9.8132	1.05820	995	990025	985074875	31.5436	9.9833	1.00503
946	894916	846590536	30.7571	9.8167	1.05708	996	992016	988047936	31.5595	9.9866	1.00402
947	896809	849278123	30.7734	9.8201	1.05597	997	994009	991026973	31.5753	9.9900	1.00301
948	898704	851971392	30.7896	9.8236	1.05485	998	996004	994011992	31.5911	9.9933	1.00200
949	900601	854670349	30.8058	9.8270	1.05374	999	998001	997002999	31.6070	9.9967	1.00100
950	902500	857375000	30.8221	9.8305	1.05263	**1000**	1000000	1000000000	31.6228	10.0000	1.00000

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°
60	sin	0.8660	0.8669	0.8678	0.8686	0.8695	0.8704	0.8712	0.8721	0.8729	0.8738
	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
61	sin	0.8746	0.8755	0.8763	0.8771	0.8780	0.8788	0.8796	0.8805	0.8813	0.8821
	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
62	sin	0.8829	0.8838	0.8846	0.8854	0.8862	0.8870	0.8878	0.8886	0.8894	0.8902
	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
63	sin	0.8910	0.8918	0.8926	0.8934	0.8942	0.8949	0.8957	0.8965	0.8973	0.8980
	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
64	sin	0.8988	0.8996	0.9003	0.9011	0.9018	0.9026	0.9033	0.9041	0.9048	0.9056
	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
65	sin	0.9063	0.9070	0.9078	0.9085	0.9092	0.9100	0.9107	0.9114	0.9121	0.9128
	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
66	sin	0.9135	0.9143	0.9150	0.9157	0.9164	0.9171	0.9178	0.9184	0.9191	0.9198
	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
67	sin	0.9205	0.9212	0.9219	0.9225	0.9232	0.9239	0.9245	0.9252	0.9259	0.9265
	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
68	sin	0.9272	0.9278	0.9285	0.9291	0.9298	0.9304	0.9311	0.9317	0.9323	0.9330
	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
69	sin	0.9336	0.9342	0.9348	0.9354	0.9361	0.9367	0.9373	0.9379	0.9385	0.9391
	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
70	sin	0.9397	0.9403	0.9409	0.9415	0.9421	0.9426	0.9432	0.9438	0.9444	0.9449
	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
71	sin	0.9455	0.9461	0.9466	0.9472	0.9478	0.9483	0.9489	0.9494	0.9500	0.9505
	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
72	sin	0.9511	0.9516	0.9521	0.9527	0.9532	0.9537	0.9542	0.9548	0.9553	0.9558
	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
73	sin	0.9563	0.9568	0.9573	0.9578	0.9583	0.9588	0.9593	0.9598	0.9603	0.9608
	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
74	sin	0.9613	0.9617	0.9622	0.9627	0.9632	0.9636	0.9641	0.9646	0.9650	0.9655
	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′**

Coaxial Cable Characteristics

Type RG.../U	Imp. (ohms)	Cap. (mmf per ft.)	Diam. (inches)	Attenuation—db per 100 ft. 1 mc	10 mc	100 mc	400 mc	1000 mc	REMARKS
5	52.5	28.5	.332	.21	.77	2.9	6.5	11.5	Small, double braid
5A	50	29	.328	.16	.66	2.4	5.25	8.8	Small, low loss
6	76	20	.332	.21	.78	2.9	6.5	11.2	IF & video
8	52	29.5	.405	.16	.55	2.0	4.5	8.5	General purpose
9	51	30	.420	.12	.47	1.9	4.4	8.5	General purpose
9A	51	30	.420	.16	.59	2.3	5.2	8.6	Stable attenuation
11	75	20.5	.405	.18	.62	2.2	4.7	8.2	Community TV
13	74	20.5	.420	.18	.62	2.2	4.7	8.2	IF
14	52	29.5	.545	.10	.38	1.5	3.5	6.0	RF power
16	52	29.5	.630	—	—	—	—	—	RF power
17	52	29.5	.870	.06	.24	.95	2.4	4.4	RF power
19	52	29.5	1.120	.04	.17	.68	1.28	3.5	Low-loss RF
21	53	29	.332	1.4	4.4	14.0	29.0	46.0	Attenuating cable
22	95	16	.405	.41	1.3	4.3	8.8	—	Twin conductors
23	125	12	.65 X .945	—	.4	1.7	—	—	Twin conductors (balanced)
25	48	50	.565	—	—	—	—	—	Pulse
26	48	50	.525	—	—	—	—	—	Pulse
27	48	50	.675	—	—	—	—	—	Pulse
28	48	50	.805	—	—	—	—	—	Pulse
33	51	30	.470	—	—	—	—	—	Pulse
34	71	21.5	.625	.065	.29	1.3	3.3	6.0	Flexible, medium
35	71	21.5	.945	.064	.22	.85	2.3	4.2	Low-loss video
36	69	22	1.180	—	—	—	—	—	—
41	67.5	27	.425	—	—	—	—	—	Special twist
54A	58	26.5	.250	.18	.74	3.1	6.7	11.5	Flexible, small
55	53.5	28.5	.206	.36	1.3	4.8	10.4	17.0	Flexible, small
56	—	—	.535	—	—	—	—	—	Pulse
57	95	17	.625	.18	.71	3.0	7.3	13.0	Twin conductors
58	53.5	30	.195	.38	1.4	5.2	11.2	20.0	General purpose
58A	50	30	.195	.42	1.6	6.2	14.0	24.0	Test leads
59	73	21	.242	.30	1.1	3.8	8.5	14.0	TV lead-in
60	50	—	.425	—	—	—	—	—	Pulse cable
61	500	—	—	—	—	—	—	—	Special 500-ohm twin-lead
62	93	13.5	.242	.25	.83	2.7	5.6	9.0	Low capacity, small
63	125	10	.405	.19	.61	2.0	4.0	6.3	Low capacity
64	48	50	.495	—	—	—	—	—	Pulse
65	950	44	.405	—	—	—	—	—	Coaxial delay line
71	93	13.5	.250	.25	.83	2.7	5.6	9.0	Low capacity, small
77	48	50	.415	—	—	—	—	—	Pulse
78	48	50	.385	—	—	—	—	—	Pulse
87A	50	29.5	.425	.13	.52	2.0	4.4	7.6	Teflon dielectric
88	48	50	.490	—	—	—	—	—	Pulse
101	75	—	.588	—	—	—	—	—	—
102	140	—	1.088	—	—	—	—	—	—
108	76	25	.245	—	—	—	—	—	Twin conductors
114	185	6.5	.405	—	—	—	—	—	Extra flexible
117	50	29	.730	.05	.20	.85	2.0	3.6	Teflon & Fiberglas
119	50	29	.470	—	—	—	—	—	Teflon & Fiberglas
122	50	29.3	.160	.40	1.70	7.0	16.5	29.0	—
126	50	29	.290	3.20	9.0	25.0	47.0	72.0	Teflon & Fiberglas
140	73	21	.242	.33	1.03	3.3	6.9	11.7	Teflon & Fiberglas
141	50	29	.195	.35	1.12	3.8	8.0	13.8	Teflon & Fiberglas
142	50	29	.206	.35	1.12	3.8	8.0	13.8	Teflon & Fiberglas
143	50	29	.325	.24	.77	2.5	5.3	9.0	Teflon & Fiberglas
144	72	21	.395	.16	.53	1.8	3.9	7.0	Teflon & Fiberglas
174	50	30	.10	—	—	—	19.0	—	Miniature coaxial

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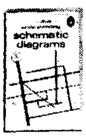

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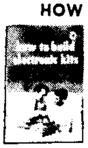

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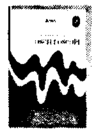

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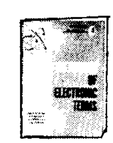

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