Section 9

CHARTS AND GRAPHS

Table 9-1. Decibels

Power ratio	Voltage or current ratio	−Db+	Voltage or current ratio	Power ratio	Power ratio	Voltage or current ratio	−Db+	Voltage or current ratio	Power ratio
10^{-1}		10		10	0.316	0.562	5.0	1.78	3.16
10^{-2}	10^{-1}	20	10	10^{2}	0.309	0.556	5.1	1.80	3.24
10^{-3}		30		10^{3}	0.302	0.550	5.2	1.82	3.31
10^{-4}	10^{-2}	40	10^{2}	10^{4}	0.295	0.543	5.3	1.84	3.39
10^{-5}		50		10^{5}	0.288	0.537	5.4	1.86	3.47
10^{-6}	10^{-3}	60	10^{3}	10^{6}	0.282	0.530	5.5	1.88	3.55
10^{-7}		70		10^{7}	0.275	0.525	5.6	1.91	3.63
10^{-8}	10^{-4}	80	10^{4}	10^{8}	0.269	0.519	5.7	1.93	3.72
10^{-9}		90		10^{9}	0.263	0.513	5.8	1.95	3.80
10^{-10}	10^{-5}	100	10^{5}	10^{10}	0.257	0.507	5.9	1.97	3.89
1.000	1.000	0	1.00	1.00	0.251	0.501	6.0	2.00	3.98
0.977	0.989	0.1	1.01	1.02	0.246	0.496	6.1	2.02	4.07
0.955	0.977	0.2	1.02	1.05	0.240	0.490	6.2	2.04	4.17
0.933	0.966	0.3	1.04	1.07	0.234	0.484	6.3	2.07	4.27
0.912	0.955	0.4	1.05	1.10	0.229	0.479	6.4	2.09	4.37
0.891	0.944	0.5	1.06	1.12	0.224	0.473	6.5	2.11	4.47
0.871	0.933	0.6	1.07	1.15	0.219	0.468	6.6	2.14	4.57
0.851	0.923	0.7	1.08	1.18	0.214	0.462	6.7	2.16	4.68
0.832	0.912	0.8	1.10	1.20	0.209	0.457	6.8	2.19	4.79
0.813	0.902	0.9	1.11	1.23	0.204	0.452	6.9	2.21	4.90
0.794	0.891	1.0	1.12	1.26	0.200	0.447	7.0	2.24	5.01
0.776	0.881	1.1	1.14	1.29	0.195	0.442	7.1	2.27	5.13
0.759	0.871	1.2	1.15	1.32	0.191	0.437	7.2	2.29	5.25
0.741	0.861	1.3	1.16	1.35	0.186	0.432	7.3	2.32	5.37
0.724	0.851	1.4	1.18	1.38	0.182	0.427	7.4	2.34	5.50
0.708	0.841	1.5	1.19	1.41	0.178	0.422	7.5	2.37	5.62
0.692	0.832	1.6	1.20	1.45	0.174	0.417	7.6	2.40	5.75
0.676	0.822	1.7	1.22	1.48	0.170	0.412	7.7	2.43	5.89
0.661	0.813	1.8	1.23	1.51	0.166	0.407	7.8	2.46	6.03
0.646	0.804	1.9	1.25	1.55	0.162	0.403	7.9	2.48	6.17
0.631	0.794	2.0	1.26	1.59	0.159	0.398	8.0	2.51	6.31
0.617	0.785	2.1	1.27	1.62	0.155	0.394	8.1	2.54	6.46
0.603	0.776	2.2	1.29	1.66	0.151	0.389	8.2	2.57	6.61
0.589	0.767	2.3	1.30	1.70	0.148	0.385	8.3	2.60	6.76
0.575	0.759	2.4	1.32	1.74	0.145	0.380	8.4	2.63	6.92
0.562	0.750	2.5	1.33	1.78	0.141	0.376	8.5	2.66	7.08
0.550	0.741	2.6	1.35	1.82	0.138	0.372	8.6	2.69	7.24
0.537	0.733	2.7	1.37	1.86	0.135	0.367	8.7	2.72	7.41
0.525	0.724	2.8	1.38	1.91	0.132	0.363	8.8	2.75	7.59
0.513	0.716	2.9	1.40	1.95	0.129	0.359	8.9	2.79	7.76
0.501	0.708	3.0	1.41	2.00	0.126	0.355	9.0	2.82	7.94
0.490	0.700	3.1	1.43	2.04	0.123	0.351	9.1	2.85	8.13
0.479	0.692	3.2	1.45	2.09	0.120	0.347	9.2	2.88	8.32
0.468	0.684	3.3	1.46	2.14	0.118	0.343	9.3	2.92	8.51
0.457	0.676	3.4	1.48	2.19	0.115	0.339	9.4	2.95	8.71
0.447	0.668	3.5	1.50	2.24	0.112	0.335	9.5	2.99	8.91
0.437	0.661	3.6	1.51	2.29	0.110	0.331	9.6	3.02	9.12
0.427	0.653	3.7	1.53	2.34	0.107	0.327	9.7	3.06	9.33
0.417	0.646	3.8	1.55	2.40	0.105	0.324	9.8	3.09	9.55
0.407	0.638	3.9	1.57	2.46	0.102	0.320	9.9	3.13	9.77
0.398	0.631	4.0	1.59	2.51	0.1000	0.316	10.0	3.16	10.00
0.389	0.624	4.1	1.60	2.57	0.0977	0.313	10.1	3.20	10.23
0.380	0.617	4.2	1.62	2.63	0.0955	0.309	10.2	3.24	10.47
0.372	0.610	4.3	1.64	2.69	0.0933	0.306	10.3	3.27	10.72
0.363	0.603	4.4	1.66	2.75	0.0912	0.302	10.4	3.31	10.96
0.355	0.596	4.5	1.68	2.81	0.0891	0.299	10.5	3.35	11.22
0.347	0.589	4.6	1.70	2.88	0.0871	0.295	10.6	3.39	11.48
0.339	0.582	4.7	1.72	2.95	0.0851	0.292	10.7	3.43	11.75
0.331	0.575	4.8	1.74	3.02	0.0832	0.288	10.8	3.47	12.02
0.324	0.569	4.9	1.76	3.09	0.0813	0.285	10.9	3.51	12.30

Table 9-1. Decibels (*Continued*)

Power ratio	Voltage or current ratio	—Db+	Voltage or current ratio	Power ratio	Power ratio	Voltage or current ratio	—Db+	Voltage or current ratio	Power ratio
0.0794	0.282	11.0	3.55	12.59	0.0251	0.159	16.0	6.31	39.81
0.0776	0.279	11.1	3.59	12.88	0.0246	0.157	16.1	6.38	40.74
0.0759	0.275	11.2	3.63	13.18	0.0240	0.155	16.2	6.46	41.69
0.0741	0.272	11.3	3.67	13.49	0.0234	0.153	16.3	6.53	42.66
0.0724	0.269	11.4	3.72	13.80	0.0229	0.151	16.4	6.61	43.65
0.0708	0.266	11.5	3.76	14.13	0.0224	0.150	16.5	6.68	44.67
0.0691	0.263	11.6	3.80	14.45	0.0219	0.148	16.6	6.76	45.71
0.0676	0.260	11.7	3.85	14.79	0.0214	0.146	16.7	6.84	46.77
0.0661	0.257	11.8	3.89	15.14	0.0209	0.145	16.8	6.92	47.86
0.0646	0.254	11.9	3.94	15.49	0.0204	0.143	16.9	7.00	48.98
0.0631	0.251	12.0	3.98	15.85	0.0200	0.141	17.0	7.08	50.12
0.0617	0.248	12.1	4.03	16.22	0.0195	0.140	17.1	7.16	51.29
0.0603	0.246	12.2	4.07	16.60	0.0191	0.138	17.2	7.24	52.48
0.0589	0.243	12.3	4.12	16.98	0.0186	0.137	17.3	7.33	53.70
0.0575	0.240	12.4	4.17	17.38	0.0182	0.135	17.4	7.41	54.95
0.0562	0.237	12.5	4.22	17.78	0.0178	0.133	17.5	7.50	56.23
0.0550	0.234	12.6	4.27	18.20	0.0174	0.132	17.6	7.59	57.54
0.0537	0.232	12.7	4.32	18.62	0.0170	0.130	17.7	7.67	58.88
0.0525	0.229	12.8	4.37	19.05	0.0166	0.129	17.8	7.76	60.26
0.0513	0.227	12.9	4.42	19.50	0.0162	0.127	17.9	7.85	61.66
0.0501	0.224	13.0	4.47	19.95	0.0159	0.126	18.0	7.94	63.10
0.0490	0.221	13.1	4.52	20.42	0.0155	0.125	18.1	8.04	64.57
0.0479	0.219	13.2	4.57	20.89	0.0151	0.123	18.2	8.13	66.07
0.0468	0.216	13.3	4.62	21.38	0.0148	0.122	18.3	8.22	67.61
0.0457	0.214	13.4	4.68	21.88	0.0145	0.120	18.4	8.32	69.18
0.0447	0.211	13.5	4.73	22.39	0.0141	0.119	18.5	8.41	70.79
0.0437	0.209	13.6	4.79	22.91	0.0138	0.118	18.6	8.51	72.44
0.0427	0.207	13.7	4.84	23.44	0.0135	0.116	18.7	8.61	74.13
0.0417	0.204	13.8	4.90	23.99	0.0132	0.115	18.8	8.71	75.86
0.0407	0.202	13.9	4.96	24.55	0.0129	0.114	18.9	8.81	77.62
0.0398	0.200	14.0	5.01	25.12	0.0126	0.112	19.0	8.91	79.43
0.0389	0.197	14.1	5.07	25.70	0.0123	0.111	19.1	9.02	81.28
0.0380	0.195	14.2	5.13	26.30	0.0120	0.110	19.2	9.12	83.18
0.0372	0.193	14.3	5.19	26.92	0.0118	0.108	19.3	9.23	85.11
0.0363	0.191	14.4	5.25	27.54	0.0115	0.107	19.4	9.33	87.10
0.0355	0.188	14.5	5.31	28.18	0.0112	0.106	19.5	9.44	89.13
0.0347	0.186	14.6	5.37	28.84	0.0110	0.105	19.6	9.55	91.20
0.0339	0.184	14.7	5.43	29.51	0.0107	0.104	19.7	9.66	93.33
0.0331	0.182	14.8	5.50	30.20	0.0105	0.102	19.8	9.77	95.50
0.0324	0.180	14.9	5.56	30.90	0.0102	0.101	19.9	9.89	97.72
0.0316	0.178	15.0	5.62	31.62	0.0100	0.100	20.0	10.00	100.00
0.0309	0.176	15.1	5.69	32.36					
0.0302	0.174	15.2	5.75	33.11					
0.0295	0.172	15.3	5.82	33.88					
0.0288	0.170	15.4	5.89	34.67					
0.0282	0.168	15.5	5.96	35.48					
0.0275	0.166	15.6	6.03	36.31					
0.0269	0.164	15.7	6.10	37.15					
0.0263	0.162	15.8	6.17	38.02					
0.0257	0.160	15.9	6.24	38.90					

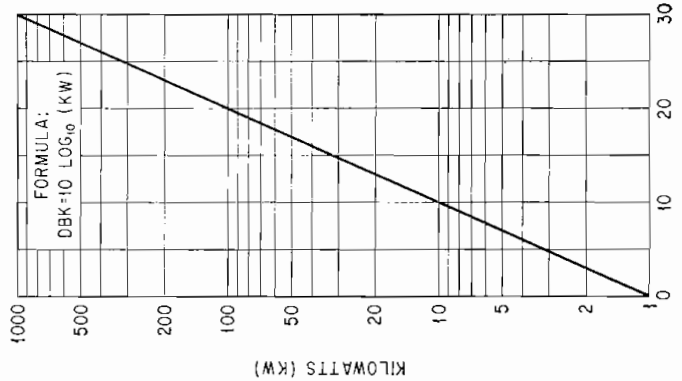


FIG. 9-2. Transformation of kilowatts to decibels above 1 kw.

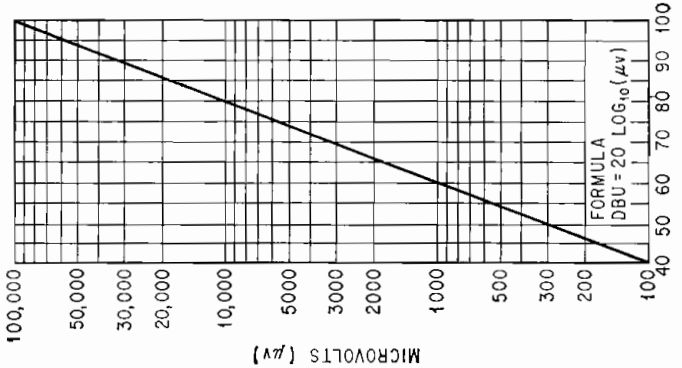


FIG. 9-1. Transformation of microvolts to decibels above 1 μv.

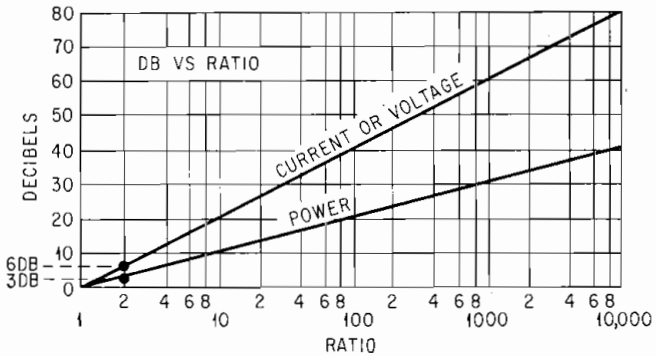


Fig. 9-3. Decibels vs. ratio.

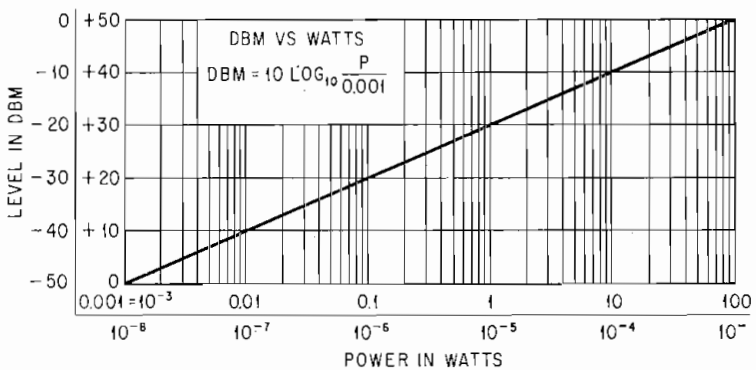


Fig. 9-4. Dbm vs. watts.

Table 9-2. Volume Level to Power and Voltage Conversion

Reference Level

0 dbm = 1 mw, 600 ohms

Milliwatts	Volts	Dbm
0.000001	0.0007746	−60
0.000010	0.002449	−50
0.000100	0.007746	−40
0.001	0.02449	−30
0.010	0.07746	−20
0.100	0.2449	−10
1.000	0.7746	0
Watts	**Volts**	**Dbm**
0.001000	0.7746	0
0.002512	1.228	+4
0.006310	1.946	+8
0.01000	2.449	+10
0.1000	7.746	+20
1.000	24.49	+30
10.00	77.46	+40

RESISTANCE VALUES OF SYMMETRICAL ATTENUATION NETWORKS *

For ready reference and to satisfy most of the practical needs of the various artificial line pads, the following charts have been prepared:

Figures 9-5 to 9-7, inclusive, are curves for determining the three components of pads which are symmetrical but have different input and output impedances. The curves are marked to indicate pad ratios for which it was calculated, and the values of *A* are for the higher pad series leg resistances shown in Fig. 9-5, while *C* values for the lower pad series leg resistances are shown in Fig. 9-7. *B* is for the shunt or transverse resistor shown in Fig. 9-6.

There is a minimum loss for each impedance ratio for which a pad can be designed and for convenience each curve on the figures is terminated by a circle at the lower value of resistance which corresponds to this minimum pad loss. For L networks double the values of *A* and *C*.

Figure 9-8 gives the resistance values for the series legs *A* of symmetrical pads having 1-to-1 impedance ratios. Figure 9-9 gives the transverse resistance values for these pads. For values not shown multiply the value shown for 100 ohms by the ratio of the desired value to 100. Double the series leg values for L networks.

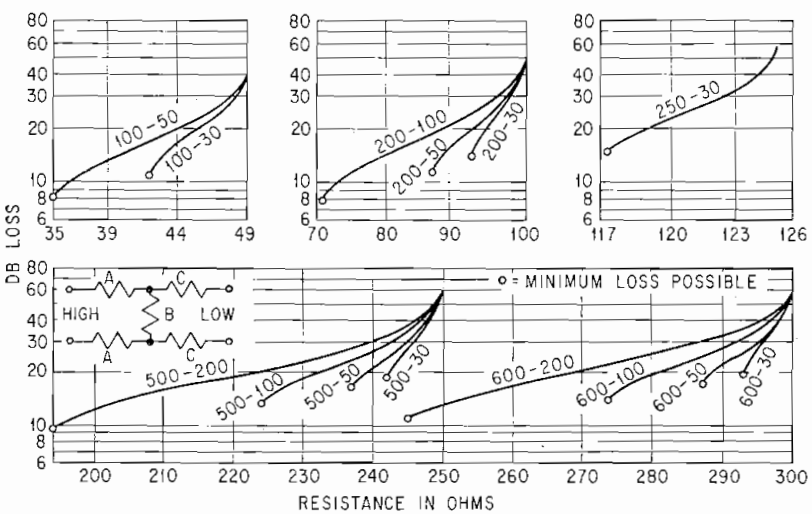


FIG. 9-5. Symmetrical attenuation networks for standard ratios—values of *A*.

* By Frank H. McIntosh, Consulting Radio Engineer, Washington, D.C.

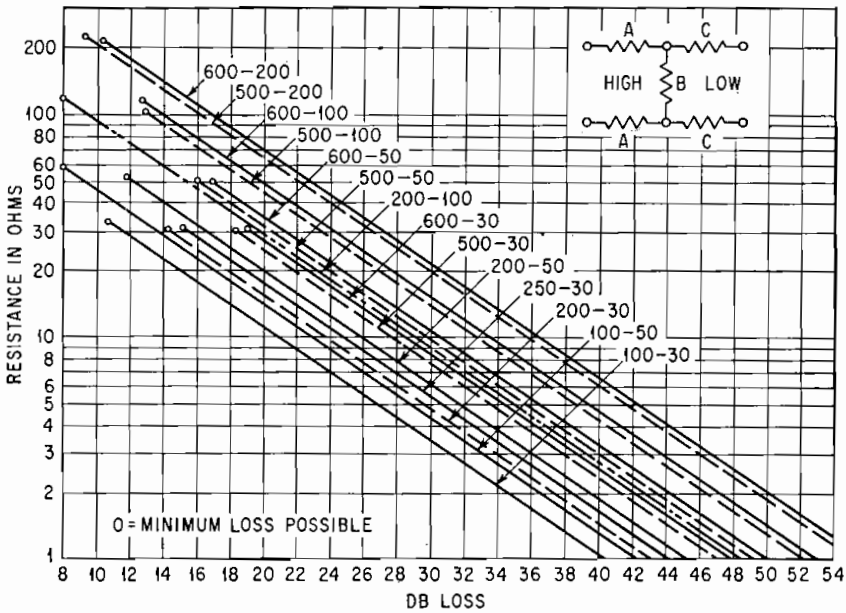


FIG. 9-6. Symmetrical attenuation networks for standard ratios—values of B.

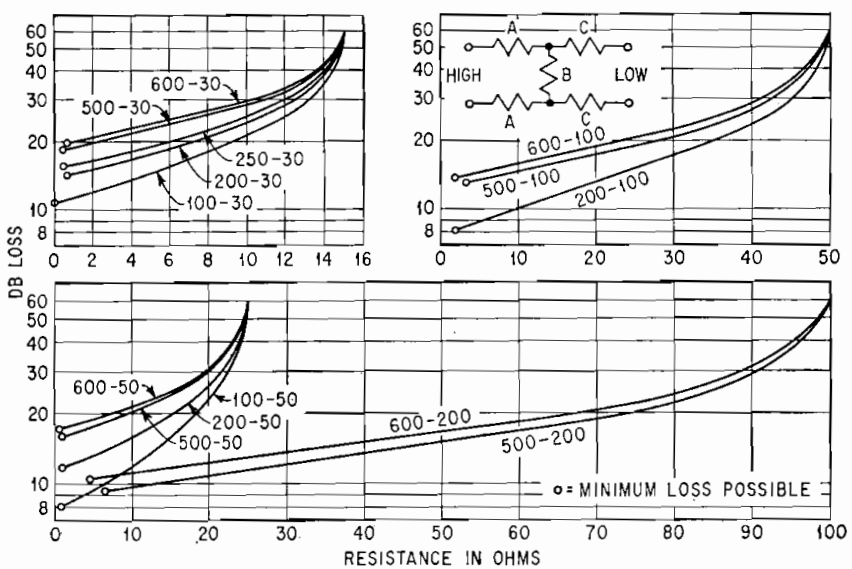


FIG. 9-7. Symmetrical attenuation networks for standard ratios—values of C.

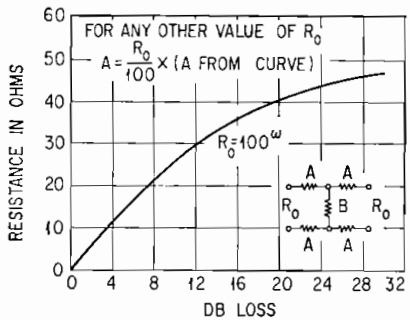


FIG. 9-8. *H*-type artificial line—value of series resistance *A*.

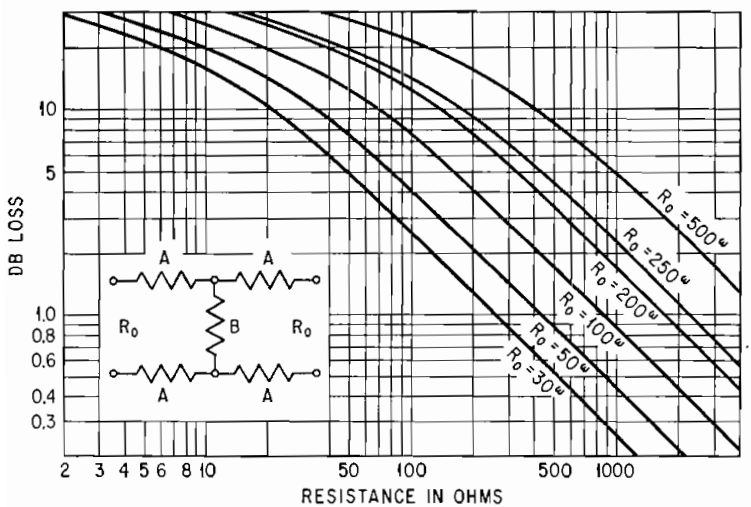
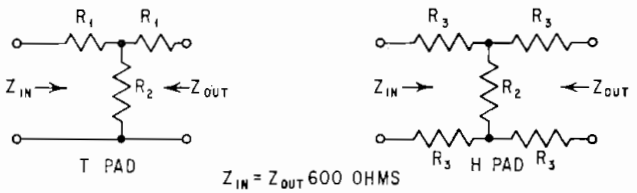


FIG. 9-9. *H*-type artificial line—value of transverse resistauce *B*.

Table 9-3. Resistive Pads

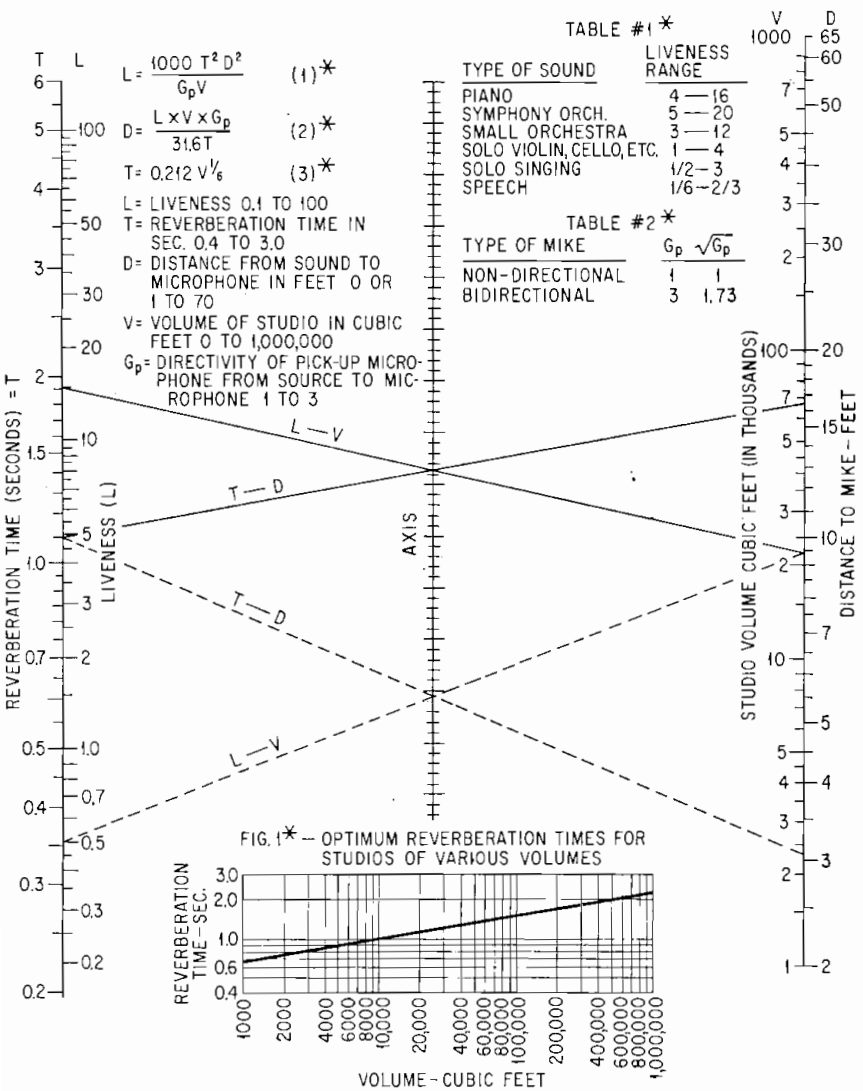


For impedances other than 600 ohms, multiply all resistors by factor $Zx/600$.

$Z_{in} = Z_{out} = 600$ ohms

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

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



*COURTESY OF WESTERN ELECTRIC CO.

FIG. 9-10. Nomograph for microphone distances in liveness broadcasting. (*Reprinted from Tele-Tech.*)

Constants V = 22,000 cu ft; T = 1.1 sec.

Example 1 (solid lines): Placement of general microphone. From Table 1 use liveness of 15. Connect 22,000 on V and 15 on L. Mark reference on the axis. Then extend a line from 1.1 on T through reference on axis to 16.5 ft on D. *Answer:* 16½ ft from mike to sound source.

Example 2 (dash lines): Placement of solo vocal microphone. From Table 1 use liveness of ½. Connect 22,000 on V and ½ on L. Mark reference on the axis. Then extend line from 1.1 on T through this reference to 3 ft on D. For bidirectional mike multiply 3 ft by $\sqrt{3}$, or 1.73. This yields 5 to 6 ft for actual distance.

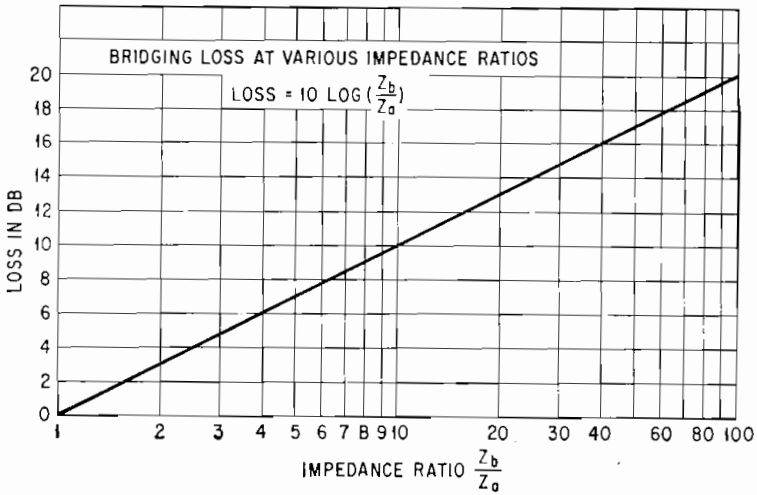


FIG. 9-11. Bridgiug loss at various impedance ratios. Loss = 10 log Z_b/Z_a.

PARALLEL-T NOMOGRAPH *

Summary: Values of five parameters for parallel-T networks are obtained directly with one setting of a straightedgc, for frequencies in audio and ultrasonic ranges, to expedite the design of the network used directly in an amplifier chain to eliminate a single frequency. The same network can be used in a negative feedback path to enhance a single frequency.

This nomograph (Fig. 9-12) facilitates calculating parallel-T networks for experimental work in multiplex FM equipment design. The subcarrier frequencies used are in the range from about 20 to 75 kc. With one setting of a straigbtedgc, all parameters of the parallel-T network needed to eliminate the undesired frequency f can be obtained to three significant figures.

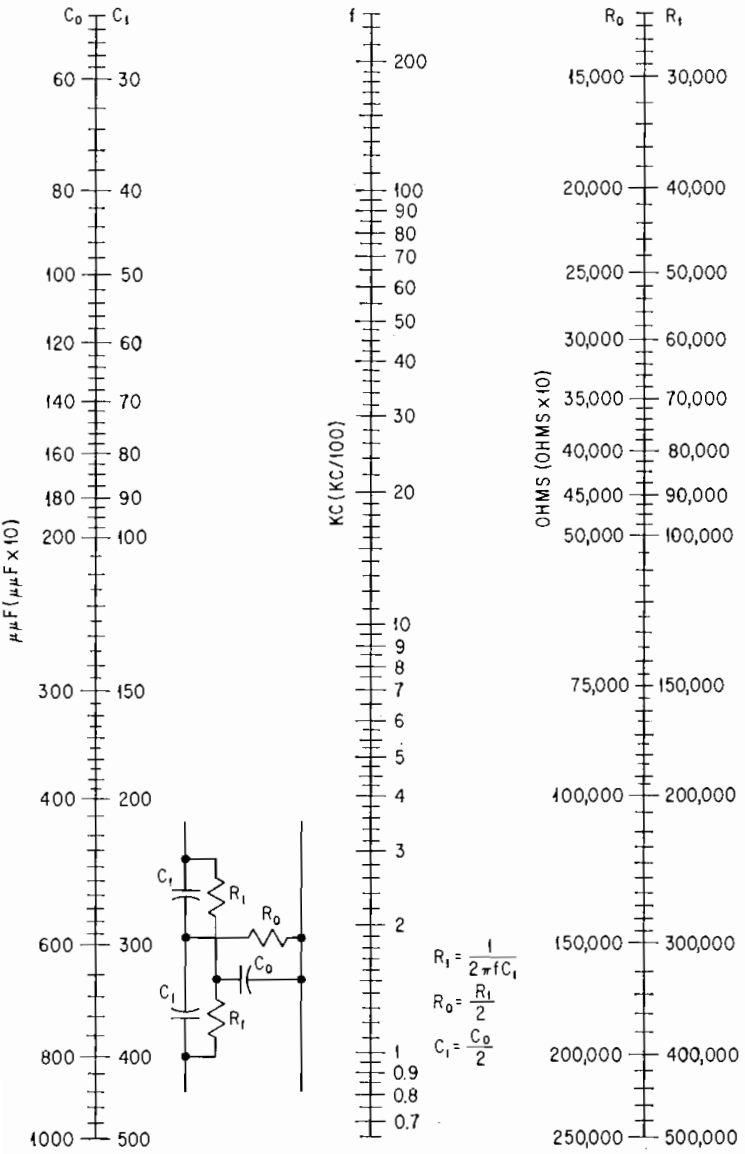
Example. If a specific frequency f of 10 kc is to be eliminated and C_1 is selected by the designer to be 100 $\mu\mu$f, run a straightedge from 100 $\mu\mu$f on the C_1 scale through 10 kc on the f scale. All other values can now be read directly from the nomograph. Thus, R_1 is 159,000 ohms, R_0 is 79,500 ohms and C_0 is 200 $\mu\mu$f.

Any two of the five parameters can be selected as the initial starting point of design. The other three can then be found with one setting of the straightedge.

If the f scale is divided by 100, the C and R scales must be multiplied by 10. This changes the range of the nomograph to cover from 7 cps at the low end to about 2,000 cps at the high end.

For a 100-cps elimination network and a value of 1,000 $\mu\mu$f for C_1, these scale-multiplying factors must be used. The other parameters are then R_1 = 1.59 megohms, R_0 = 795,000 ohms, and C_0 = 2,000 $\mu\mu$f.

* By Donald F. Carter, Chief Electrical Engineer, Harkins and Hershfield, Phoenix, Ariz.
Reprinted from *Electronics*, Nov. 1, 1957.



CENTER SCALE GIVES FREQUENCY ATTENUATED BY PARALLEL-T NETWORK

Fig. 9-12. Parallel-T nomograph.

MICROPHONE NOMOGRAPH *

Summary: The chart (Fig. 9-13) relates sound pressure level, microphone sensitivity, and output in decibels and volts as an aid in the design of microphone systems and related equipment. Typical sound levels for common sounds are indicated.

Microphone response is usually expressed in decibels referred to 1 volt/dyne/cm^2. Thus a microphone which produces 1 volt when exposed to a sound pressure of 1 dyne/cm^2 has a response of 0 db. Most microphones are far less sensitive than this.

Unless otherwise specified, the open-circuit voltage is used in arriving at the response figure.

The nomograph is based on the definition of pressure response in the American Standard Specification for Laboratory Standard Microphones.

Expressed symbolically, this definition becomes

$$\rho = 20 \log \frac{e_o}{p} \tag{9-1}$$

where ρ = pressure response
e_o = open-circuit output voltage
p = pressure, dynes/cm^2

Equation (9-1) can be rewritten

$$= 20 \log e_o - 20 \log p \tag{9-2}$$

Sound pressure is commonly expressed in decibels relative to a reference pressure $p_0 = 2 \times 10^{-4}$ dynes/cm^2. When so expressed it is called sound pressure level (SPL) and is defined by

$$SPL = 20 \log \frac{p}{p_0} \quad \text{db} \tag{9-3}$$

Equations (9-2) and (9-3) yield

$$\rho = 20 \log e_o - \text{SPL} + 74 \text{ db} \tag{9-4}$$

Should absolute sound pressures be required, they can be filled in on the left-hand scale by noting that 100 db = 20 dynes/cm^2, 80 db = 2 dynes/cm^2, 60 db = 0.2 dyne/cm^2, and so forth.

A microphone with a response of -50 db is to be used to measure sound levels of 35 db or more. For what minimum input voltage should the amplifier be designed?

A straight line drawn between 35 db on the SPL scale and -50 db on the ρ scale intersects the e_o scale at about 35 μv. This is the open-circuit microphone voltage.

Sound level in a jet-engine test control room is 112 db; a pneumatic chipper at a distance of 5 ft has a sound level of 122 db. At takeoff and 80 ft from the tail, an F-84 has a sound level of 130 db, all typical values.

* By William B. Conover, Transformer Laboratories Department, General Electric Company, Pittsfield, Mass. Reprinted from *Electronics*, October, 1955.

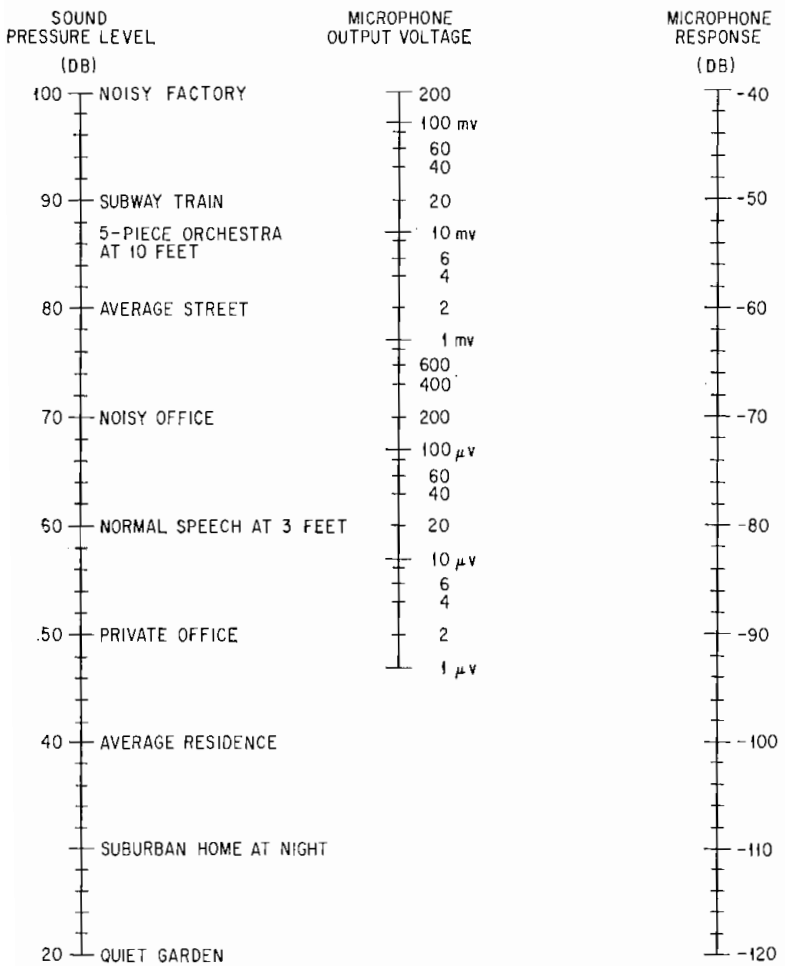
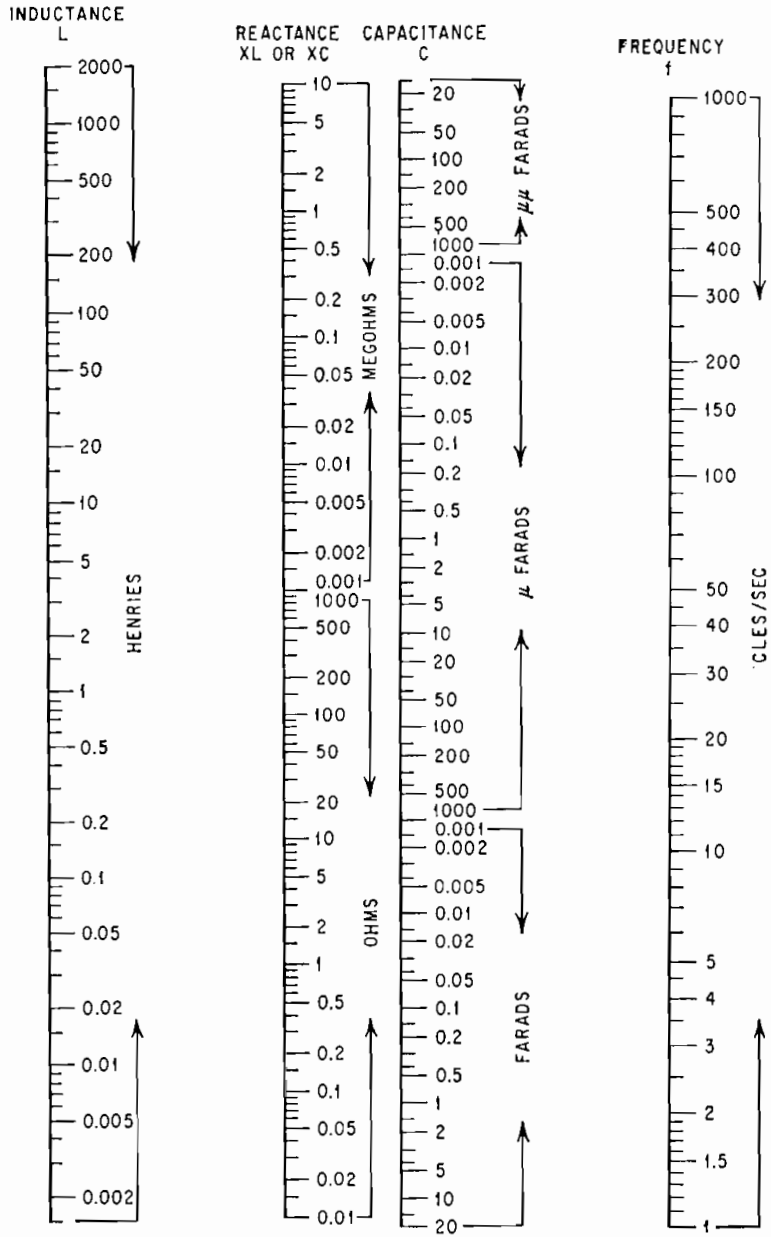

SOUND
PRESSURE LEVEL
(DB)
100
NOISY FACTORY
90
SUBWAY TRAIN
5-PIECE ORCHESTRA
AT 10 FEET
80
AVERAGE STREET
70
NOISY OFFICE
60
NORMAL SPEECH AT 3 FEET
50
PRIVATE OFFICE
40
AVERAGE RESIDENCE
SUBURBAN HOME AT NIGHT
20
QUIET GARDEN
MICROPHONE
OUTPUT VOLTAGE
200
100 mv
60
40
20
10 mv
6
4
2
1 mv
600
400
200
100 μv
60
40
20
10 μv
6
4
2
1 μv
MICROPHONE
RESPONSE
(DB)
-40
-50
-60
-70
-80
-90
-100
-110
-120

Fig. 9-13


INDUCTANCE
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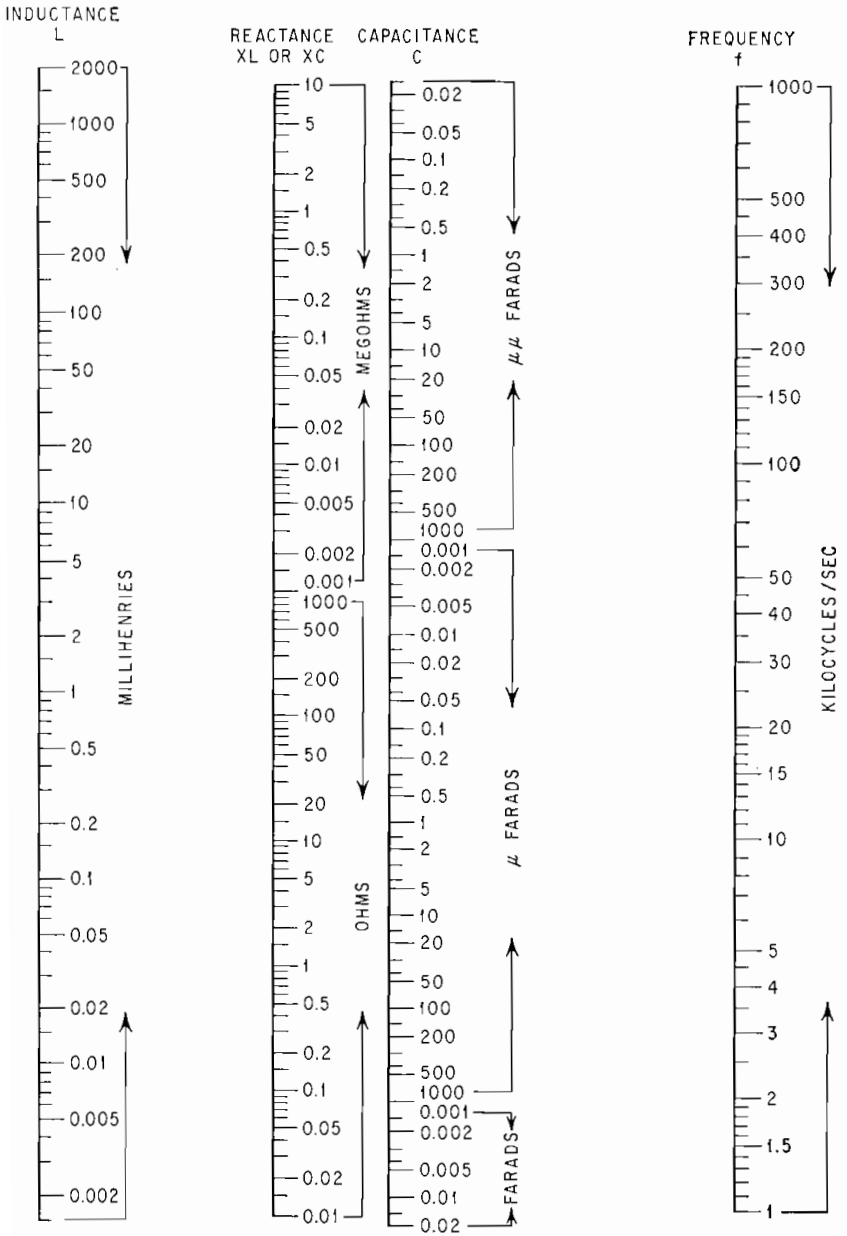
2000
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
HENRIES
REACTANCE
XL OR XC
CAPACITANCE
C
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
MEGOHMS
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
OHMS
20
50
100
200
500
1000
μμ FARADS
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
20
μ FARADS
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
20
FARADS
FREQUENCY
f
1000
500
400
300
200
150
100
50
40
30
20
15
10
5
4
3
2
1.5
1
CLES/SEC

Fig. 9-14*a*


INDUCTANCE
L
2000
1000
500
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20
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2
1
0.5
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0.1
0.05
0.02
0.01
0.005
0.002
MILLIHENRIES
REACTANCE
XL OR XC
CAPACITANCE
C
10
5
2
1
0.5
0.2
0.1
0.05
0.02
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0.005
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MEGOHMS
1000
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OHMS
0.02
0.05
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μμ FARADS
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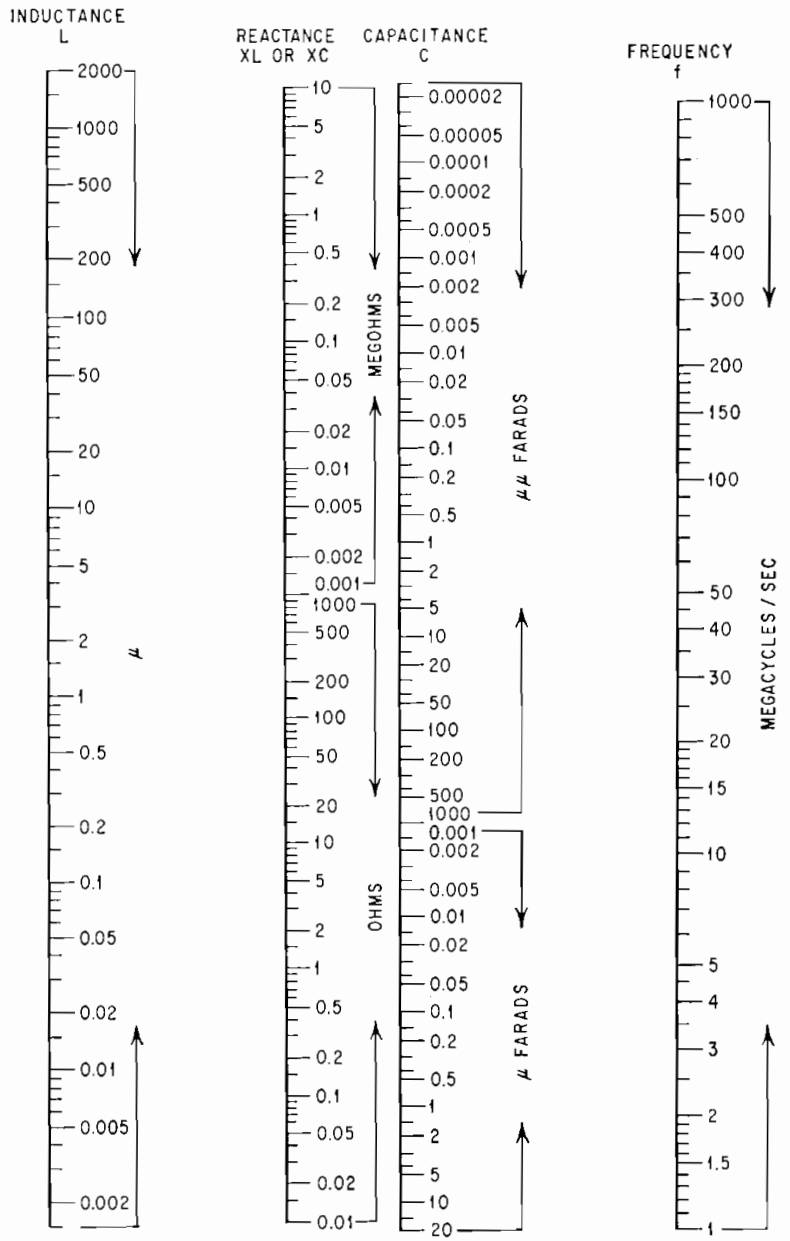
100
200
500
1000
μ FARADS
0.001
0.002
0.005
0.01
0.02
FARADS
FREQUENCY
f
1000
500
400
300
200
150
100
50
40
30
20
15
10
5
4
3
2
1.5
1
KILOCYCLES/SEC

Fig. 9-14*b*


INDUCTANCE
L
2000
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
μ
REACTANCE
XL OR XC
CAPACITANCE
C
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
MEGOHMS
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
OHMS
0.00002
0.00005
0.0001
0.0002
0.0005
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
20
50
100
200
500
1000
μμ FARADS
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
20
μ FARADS
FREQUENCY
f
1000
500
400
300
200
150
100
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40
30
20
15
10
5
4
3
2
1.5
1
MEGACYCLES / SEC

Fig. 9-14c

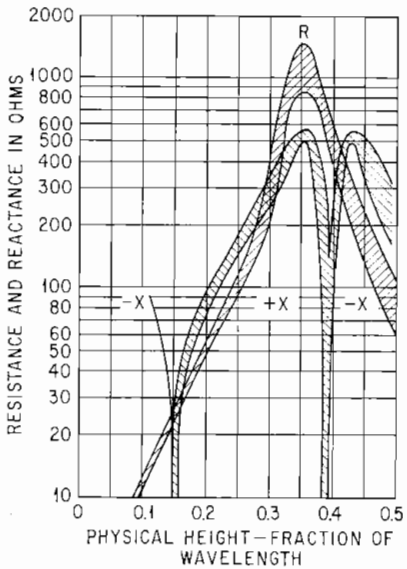


FIG. 9-15. Average characteristics for guyed radiators of uniform cross section. Data compiled from measurements of KNX and KIRO's 4-ft triangular radiators and a large number of 12- to 18-in. triangular radiators. (*Prepared by J. B. Hatfield.*)

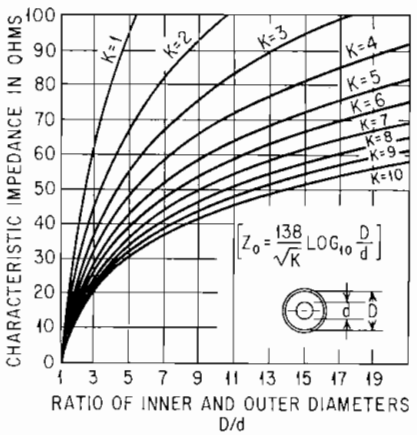


FIG. 9-16. Characteristic impedance of coaxial lines with various dielectrics.

COAXIAL-LINE IMPEDANCE CHART *

Summary: Characteristic impedances of coaxial lines are related graphically to dielectric constants and the ratios of outer to inner conductor diameters. Dielectric constants of common materials are also tabulated.

This chart (Fig. 9-16) simplifies the solution for the characteristic impedance of a single coaxial line.

Example. If a characteristic impedance of 50 ohms is desired and the insulating material is air, then from the chart the D/d ratio is 2.3. If metal tubing with an inside diameter $D = 0.250$ in. is chosen for the outer conductor, the outside diameter of the metal inner conductor is 0.109 in.

* By Herbert L. Levin, Electron Tube Laboratory, Federal Telecommunication Laboratories, Nutley, N.J. Reprinted from *Electronics*, Nov. 1, 1957.

Dielectric Constant K from 1 to 10,000 Mc at 25°C

Ceramics	
Alumina 85%	8.3–8.0
Alumina 95%	8.9–9.3
Alumina 97%	9.0–9.6
Aluminum silicate	5.5–5.2
Fosterite	6.2–6.0
Magnesium silicate	5.9–5.3
Steatite	6.5–5.3
Porcelain, standard electrical	5.5
Porcelain, zircon	9.2

Glasses	
Corning:	
7052	5.1
7070	4.0
7720 nonex	4.7
7740 Pyrex	4.6
7900 Vycor (96% silica)	3.8
8871 (lead potash)	8.4
9010 (lead free)	6.5
Quartz, fnsed	3.78
Sapphire, synthetic	8.6–10.6

Plastics	
Bakelite BM 120	3.7
Epoxy resin	3.1
Formica XX	3.6
Kel-F	2.3
Micarta 254	3.4
Nylon 610	2.8
Plexiglass	2.6
Polystyrene	2.6
Styrofoam 103.7	1.03
Teflon	2.1
Tenite II	2.9
Vinylite VG 5901	2.9

Miscellaneous	
Air	1
Butyl rubber	2.4
Mica	5.4
Neoprene 38% GN	4.0
Silastic 120	5.7
Silastic 152	2.9

If a ceramic such as Alumina 95 per cent with $K = 9$ were introduced as the dielectric and the Z_o of 50 ohms were still desired, then from Fig. 9-16 $D/d = 12.3$. If the D of 0.250 were also still desired, then $d = 0.020$ in.

The chart shows that if in this example d were not changed when the ceramic material replaced air, then Z_o would drop from 50 to 16.5 ohms.

COUPLING AND TUNING CAPACITOR FOR VARIOUS ANTENNAS

Figure 9-17 has been found to be a useful tool for adjusting the transmitter output circuit using capacity coupling to the antenna or transmission line. The values of capacity shown are approximate, but sufficiently close for practical purposes, since stray capacity of leads and components has not been taken into account. The capacity shown is the total capacity required for both the first and second sections of the low-pass filters.

The introduced resistance is the net resistance component when section is adjusted resulting from the effect of the R_a (antenna or line resistance) and the coupling capacity (CC).

The Z is the load impedance for the tubes determined by the dynamic characteristic for the particular tube and its operating voltages.

The value of introduced resistance used generally now lies between 50 and 100 ohms with the upper limit determined by the stray capacity. Formerly with high C ratios, introduced resistances were from 7 to 20 ohms, which resulted generally in higher circuit losses.

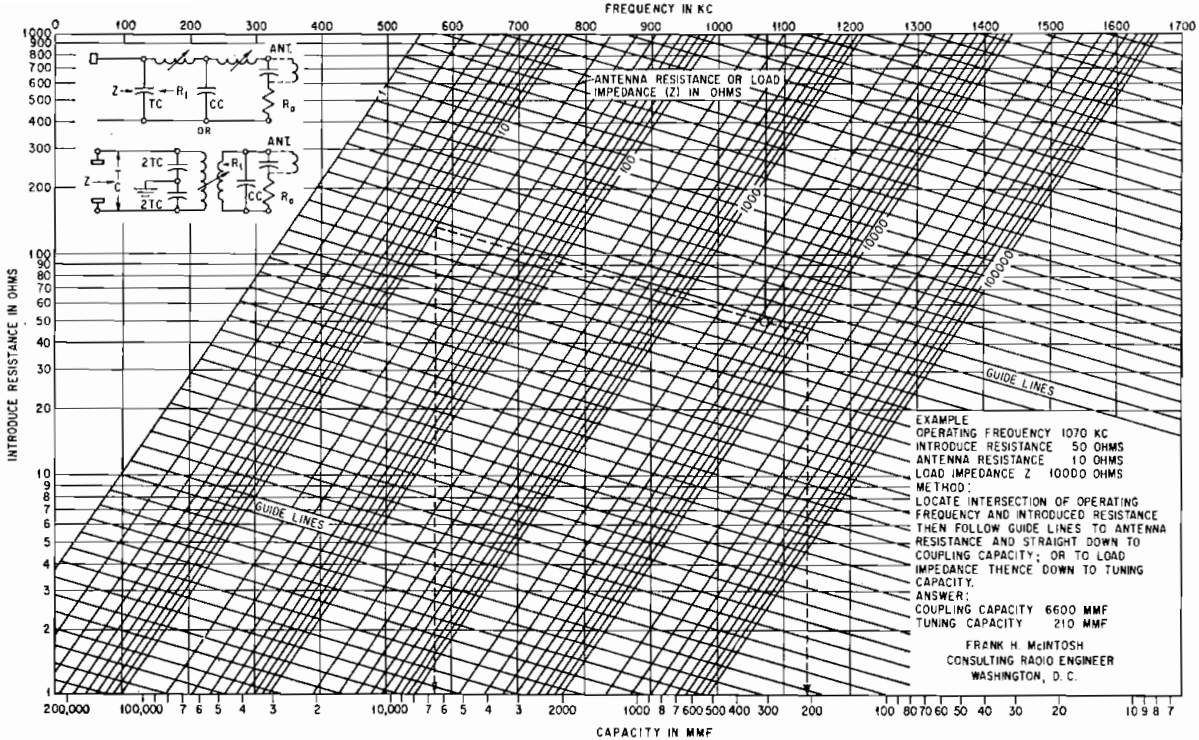


FIG. 9-17. Capacity-coupled circuits. Chart showing coupling and tuning capacities for various antenna resistances, tube load impedances, and introduced resistances for various given frequencies.

APPLICATION OF PROXIMITY-EFFECT CURVE *

1. The curve in Fig. 9-18 shows the amount by which the measured field strength, as measured by a field-strength meter which employs a shielded loop, will depart from an inverse distance function because of induction field or proximity effect due to measuring close to the antenna.

2. It is based upon the calculation of the horizontal component of magnetic field close to an antenna, after the manner of George H. Brown.

3. It can be used first as a guide determining how close one can measure to a given antenna before the correction due to proximity would be expected to exceed a given percentage.

4. It can be used to correct out the error due to proximity before plotting field-strength measurements to determine accurately the inverse distance field. This permits measurements to be made sufficiently close to the tower to eliminate the effects of conductivity.

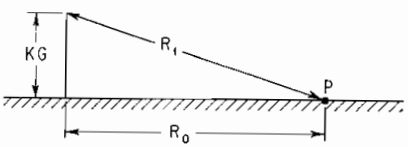
Derivation

1. G. H. Brown, Directional Antennas, *IRE*, January, 1937, on page 81 and in formula (7) gives the general formula for the magnetic flux density at any point in space from a vertical radiator over a perfectly conducting earth. By restricting this point P to the earth's surface, certain simplifications can be made in Brown's formula. Specifically Z goes to zero and $r_1 = r_2$ and $r_0 = x$.

2. The simplified formula becomes:

$$B_\phi = \frac{j2 \times 10^{-9} I_0}{r_0 \sin kG} [\epsilon^{-jkr_1} - \epsilon^{-jkr_0} \times \cos kG]$$

where $k = \dfrac{2\pi}{\lambda}$



3. Now when the distance r_0 becomes so great that $r_0 \approx r_1$

$$B_\phi(\text{far field}) = \frac{j2 \times 10^{-9} I_0}{r_0 \sin kG} [1 - \cos kG] \times \epsilon^{-jkr_0}$$

4. Now let $57.3kr_1 = r_1$ (degrees); $57.3kr_0 = r_0$ (degrees); $57.3kg = G$ (degrees).

5. Also convert from exponential to trigonometric form.

6. The resulting ratio is

$$\frac{B_\phi}{B_\phi \text{ (far field)}} = K = \frac{\{[\cos r_1 - \cos G \times \cos r_0]^2 + [\sin r_1 - \cos G \times \sin r_0]^2\}^{1/2}}{[1 - \cos G]}$$

7. Therefore:

$$\frac{\text{Field measurement}}{K} = \text{adjusted field}$$

* Silliman, Moffet, and Rohrer.

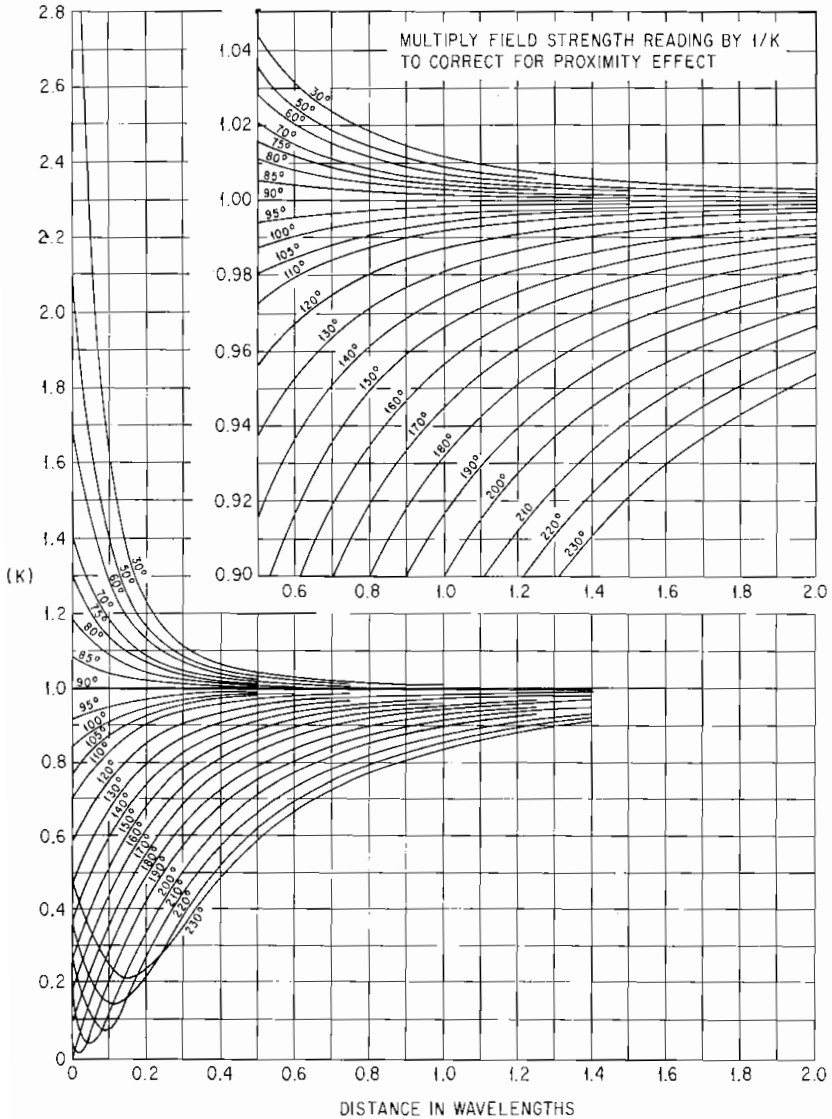


FIG. 9-18. Proximity effect for various tower heights.

WAVEGUIDE LOSS CHARTS *

Summary: Graphical presentation of attenuation values provides data for typical commercial microwave equipment. When effective resistivity is known or estimated, attenuation in decibels per foot can be determined at 1 to 75 kmc. Internal rectangular dimensions are also given.

Attenuation per foot of a particular commercial rectangular waveguide at a given frequency can be computed from published information, but for rapid extrapolation or comparison the accompanying charts (see Fig. 9-19) offer a ready solution.

One must know or be able to estimate the effective resistivity of the conducting surface. This is the product of d-c resistivity and a surface roughness factor K_T, which

Nominal Internal Dimensions for Standard Hollow Rectangular Waveguides

WR No.	*Wide*	*Narrow*	*WR No.*	*Wide*	*Narrow*
10	0.100	0.050	112	1.122	0.497
12	0.122	0.061	137	1.372	0.622
15	0.148	0.074	159	1.590	0.795
19	0.188	0.094	187	1.872	0.872
22	0.224	0.112	229	2.290	1.145
28	0.280	0.140	284	2.840	1.340
34	0.340	0.170	340	3.400	1.700
42	0.420	0.170	430	4.300	2.150
51	0.510	0.255	510	5.100	2.550
62	0.622	0.311	650	6.500	3.250
75	0.750	0.375	770	7.700	3.850
90	0.900	0.400	975	9.750	4.875

is unity for an ideal polished surface. Materials having low d-c resistivities require smooth surfaces for low effective resistivity and low loss. In materials having high d-c resistivities the current penetrates deeper into the material and K_T is near unity even for moderately rough surfaces. Thus surface roughness has almost no effect on high-resistivity materials.

Another factor is the size of the hollow waveguide cross section. Lowest losses are obtained by use of the largest possible waveguide. The chart shows the penalty resulting from use of a smaller size.

Measured attenuation of two sizes of rectangular copper waveguides shows that the effective resistivity is abont 2.2×10^{-6} ohm-cm from 4 to 6 kmc. This is about 28 per cent above the d-c resistivity of 1.72×10^{-6} ohm-cm. Measurements on WR-229 drawn of 90-10 brass show an effective resistivity of 4.3×10^{-6} ohm-cm at 4 kmc, which is about 7.5 per cent above the d-c resistivity of 4×10^{-6} ohm-cm.

Plotting points on the graph were determined from the equation

$$\alpha = \frac{5.963(RK_T/\lambda)^{1/2}(1/b + \lambda^2/2a^3)}{\sqrt{1 - \lambda^2/4a^2}}$$

where α = attenuation in rectangular waveguide, db/ft
R = d-c resistivity of conducting surface, ohm-cm
a = wide dimension of waveguide, in.
b = narrow dimension of waveguide, in.
λ = free-space wavelength, in.
K_T = surface roughness factor
RK_T = effective resistivity of conducting surface, ohm-cm

* By A. F. Pomeroy, Bell Telephone Laboratories, Murray Hill, N.J. Reprinted from *Electronics*, October 1, 1957.

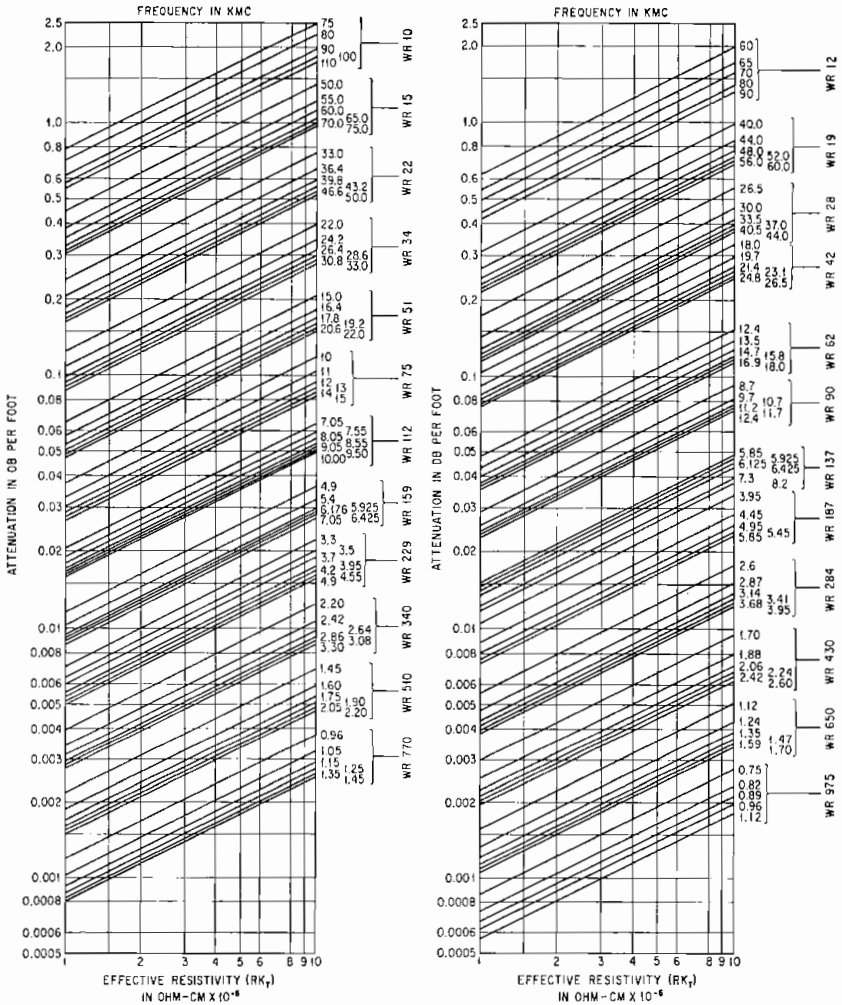


FIG. 9-19. Waveguide loss charts.

Example. Suppose it is necessary to find the attenuation of WR51 made of high-conductivity copper at frequencies from 16.4 to 20.6 kmc. Using 2.5×10^{-6} ohm-cm as an effective resistivity, we read on the chart 0.092 db/ft at 16.4 kmc and 0.078 db/ft at 20.6 kmc. The attenuation of other sizes can be found in a similar manner.

Representative frequencies in the recommended ranges were chosen for each size shown in Fig. 9-19. Interpolation between the characteristics to find the loss for other frequencies is straightforward.

The effective resistivity should be nearly constant over a small frequency interval, which leads to another use of these characteristics. To find an average effective resistivity over a band of frequencies, measured values of decibels per foot can be plotted on the characteristics and an ordinate drawn through the average value of effective resistivity. This result is probably more accurate than any one of the individual determinations.

Thanks are due Miss J. D. Goeltz and Mrs. Dolores G. Hill for their work in computing the attenuations used in plotting the characteristics.

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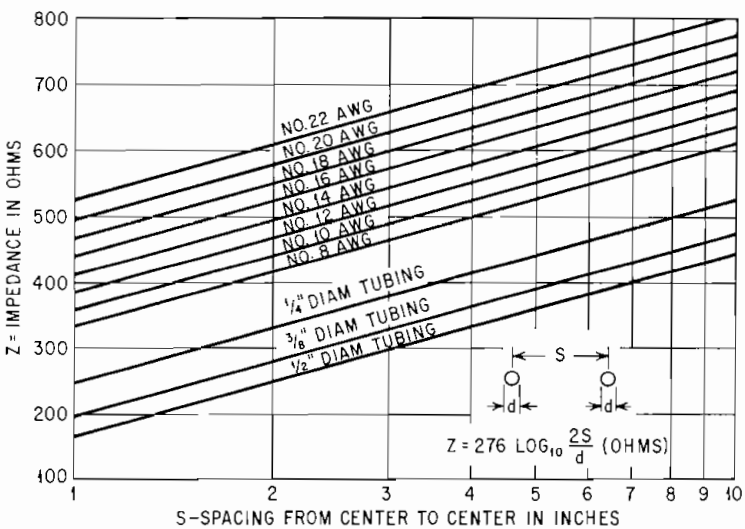

Fig. 9-20. Characteristic impedance of parallel-line wires.

L-NETWORK DESIGN *

Summary: Technique for using Smith chart to speed design of L matching networks for transmission lines and waveguides using lumped parameters. Shaded-area charts show at a glance impedance ranges that can be matched with each type of L network.

The familiar Smith chart for transmission lines is also a useful tool for designing matching networks. As an example, consider the case where it is desired to match an impedance $Z_L = (0.3 - j1.6)R_o$ to R_o with the L matching network shown in Fig. 9-21. It is assumed that the inductances are lossy so that $R_1 = X_1 \tan \theta = 0.2X_1$ and

* By H. F. Mathis, Goodyear Aircraft Corp., Akron, Ohio. Reprinted from *Electronics*, Feb. 1, 1957.

$G_2 = -B_2 \tan \theta = -0.2B_2$. All impedances and admittances are normalized with respect to R_o and $G_o = 1/R_o$, respectively.

Let $Z_A = Z_L + R_1 + jX_1$ and $Y_A = 1/Z_A$. Since $Y_A + G_2 + jB_2 = 1$, Y_A must lie on curve $Y = 1 - k(\tan \theta - j)$, where k is a real variable. This curve is circle OA' with center C. To locate C, lines OC and OD are drawn as indicated in Fig. 9-20. Point D bisects its line. Point C is located as indicated.

Point C is inverted to obtain C' on line OC so that $C'O = OC$. Since Y_A must lie on circle OA', Z_A must lie on circle OH whose center is C'. To determine Z_A, plot curve $Z = Z_L + p(\tan \theta + j)$, where p is a real variable. Point A, where this curve intersects circle OH, is the desired value of Z_A. The value of Y_A is found by inverting point A to obtain A'. Finally, $R_1 + jX_1 = (Z_A - Z_L)R_o = (0.498 - j0.610) - (0.3 - j1.6)R_o = (0.198 + j0.990)R_o$ and $G_2 + jB_2 = (1 - Y_A)G_o = 1 - (0.803 + j0.985)G_o = (0.197 - j0.985)G_o$.

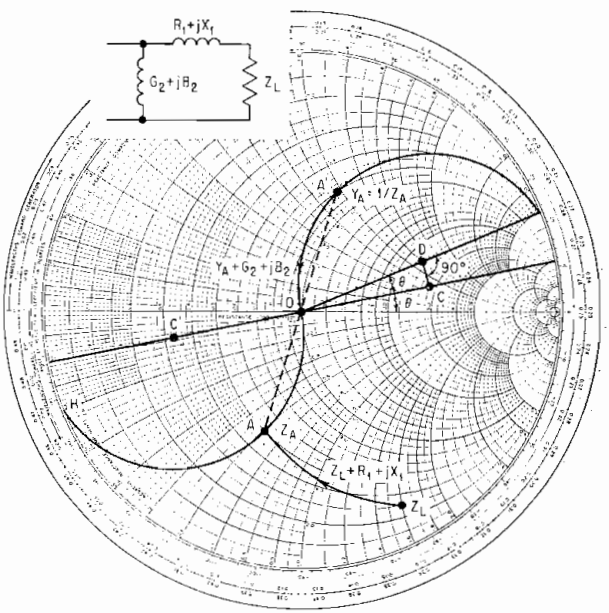

FIG. 9-21. Smith-chart procedure for determining parameters of L matching network.

General Procedure. In general, for L matching networks plot Z_L or Y_L first on the Smith chart. Next, plot the impedance or admittance into which Z_L is to be transformed, and find a suitable path connecting these points.

It is impossible to match all possible values of Z_L with a given type of L network. For example, if $Z_L = 0.5R_o$, the matching network shown in Fig. 9-21 could not be used. Impedances which can be matched with a given type of L network are shown as areas on Smith charts in Fig. 9-22. It is assumed that it is desired to transform Z_L into R_o and that Z_L is normalized with respect to R_o.

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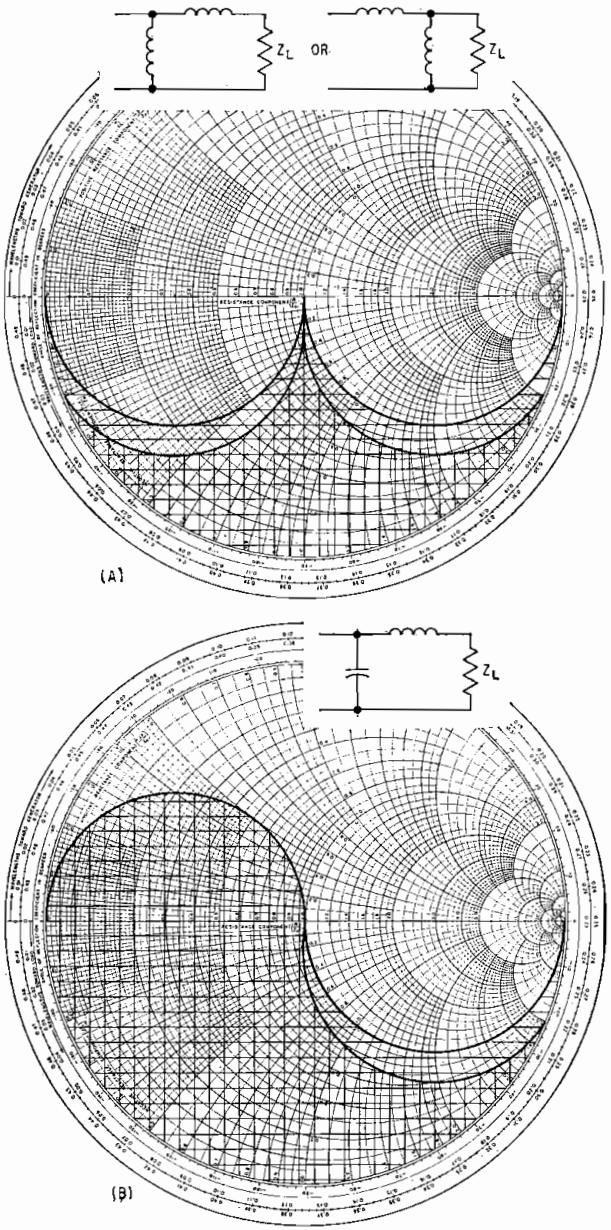
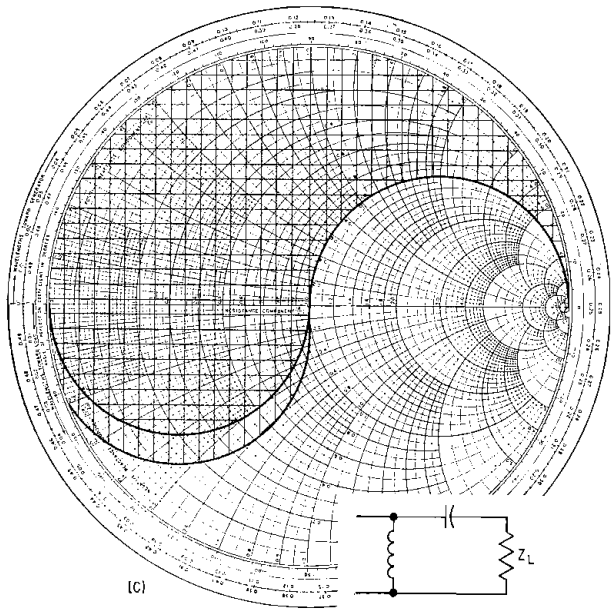


FIG. 9-22. For each network, horizontally shaded areas on the accompanying Smith chart show impedances which can be matched with lossless reactance. Vertically shaded areas can be matched with reactances for which $\tan \theta = 0.2$.



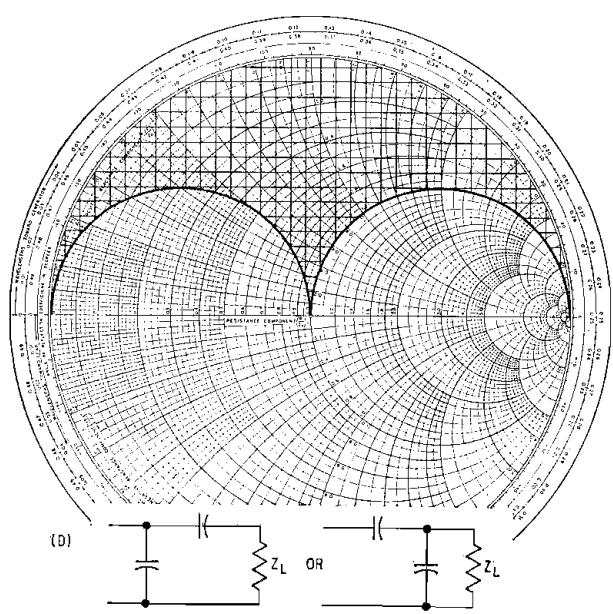


FIG. 9-22. (*Continued on next page.*)

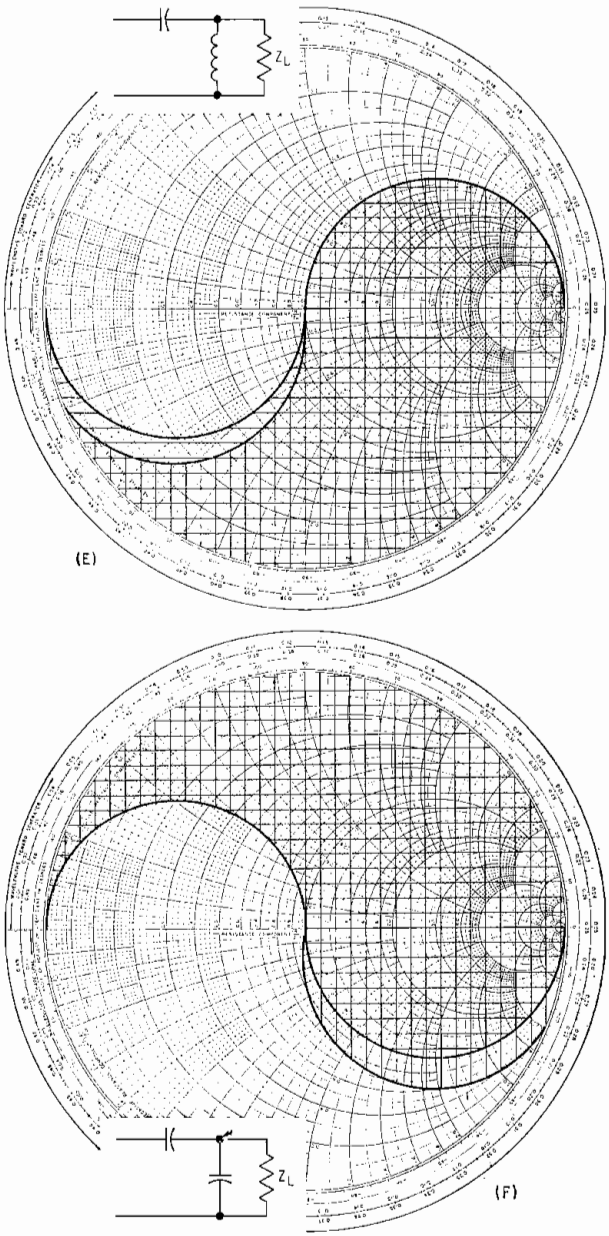


FIG. 9-22. (*Continued.*)

Table 9-4. Comparison of Open-wire Solid-dielectric Lines and Waveguides

Characteristics	Parallel open wires	Bead supported	Stub supported	Solid dielectric (Polyethylene)	Coaxial rubber	Waveguide	Pulse cables
Insulation resistance	O.K. in dry air, drops in rain	O.K. in dry air or nitrogen	O.K. dry or slightly wet	O.K. dry or wet	O.K. dry, drops when wet. Varies with temperature	O.K.	Same as rubber
Corona voltage and dielectric strength	Depends on dry air and spacing, low	Depends on dry air, depends on size, low	Depends on size, low	Depends on size, high	Depends on dry air, size, medium high	Depends on size, dry air, pressure, low	Depends on size, dry air, high
Dielectric constant	Low, air (1)	Low, air plus beads (1+)	Low, air (1)	Medium (2.3)	Medium high (3–4)	.....	High (5–6)
Power factor	Low in dry air, goes up in wet	Low in dry air, goes up in wet	O.K. dry or slightly wet	O.K. dry or wet	High dry, higher wet. No good for HF	.....	Same as rubber
D-c conductor resistance	Low, goes down with size	Same	Same	Higher than concentrics, goes down with size	High, goes down with size	Low, goes down with size	High, goes down with size
Ease of installation	Easy	More difficult	Difficult	Easier than concentric	Same as solid dielectric	Same as bead-supported	Same as rubber
Ease of maintenance	Easy	Very difficult	Not very	Easy	do	Easy	
Flexible	Somewhat, depends on size	Some, depends on size	No	Yes, flexibility goes down with size	Yes, more than solid dieleetric	No	Same as rubber
Mechanically strong	Yes, but separators are weak points	Yes, beads are weak points	Yes, but stubs are fragile	Yes, but can be mistreated	Yes	Yes, but can be crushed	Yes
Can be sealed	Yes	Yes, but you have to do the right job	Yes	Yes	Yes	Yes	Yes
Self-shielding (electrical)	No	Yes	Yes	Yes, depends on the braid construction	Same as solid dielectric	Yes	Same as solid dielectric
Fire resistive	Yes	Yes	Yes	Yes, except largest size	Not completely	Yes	Same as rubber
High-temperature resistant	Yes. depends on material of separators	Yes, depends on rubber gaskets or solder	Yes, same as bead supported	180–200°F for short time	220–250°F for short time	Yes, depends on rubber gasket or solder	Same as rubber
Transmission at high frequency	Limited by spacing	Good at low, medium frequency losses high at microwave	Good at high frequency not at low, need spec for each	Good, at low and medium not so good at microwave	Poor, loss too high	Best, but each frequency needs spec guide	Poor, loss too high
Stand shock vibration	Good	Fair, beads are weak points	Good, stubs are weak points	Very good	Very good	Very good	Very good
Low temperatures	Yes	Yes, but allow for expansion	Same as beaded	Yes	Yes	Yes, but allow for expansion	Yes

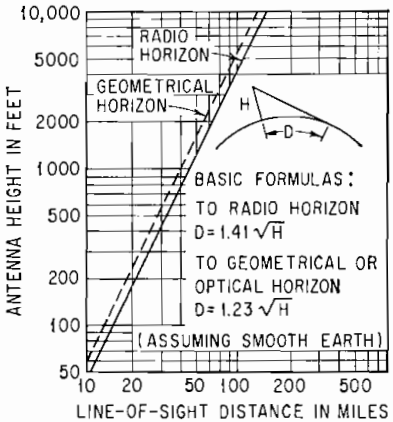


FIG. 9-23. Distance to horizon vs. height of transmitting antenna.

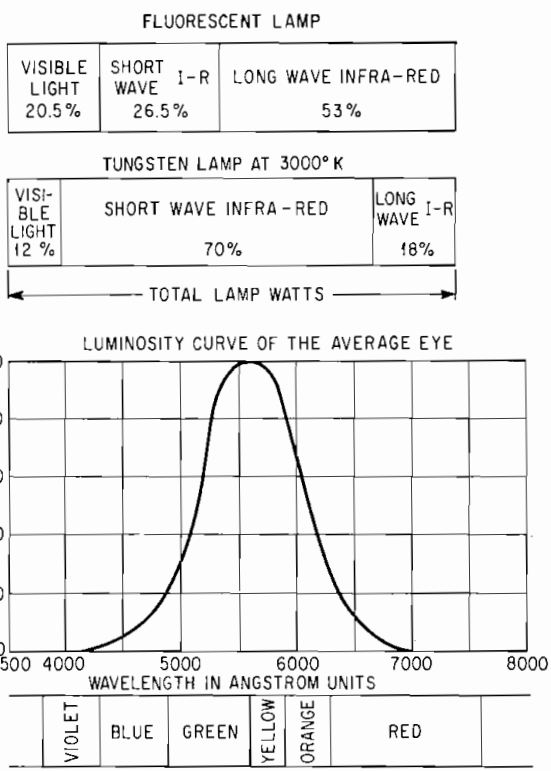


FIG. 9-24. Fluorescent and tungsten lamp spectral distribution and luminosity curve of the average human eye.

HEATER SURGE CHART *

Summary: The effect of heater current surges when voltage is applied to cold tube and efficiency of surge-restricting arrangements can be evaluated with this chart. Hot and cold characteristic curves are typical for most tubes.

To minimize damaging effects of high initial current when heater voltage is applied to a cold tube, starting current surges should be restricted.

The magnitude of heater current surges under various conditions can be calculated by use of the graph (Fig. 9-25), which consists basically of two curves plotted on coordinates of heater current and voltage relative to normal full-voltage conditions. The first curve, a straight line, represents the resistance of a cold heater. It represents a resistance which is 0.15 of the normal operating resistance. This is typical of most receiving tubes. The second curve shows the locus of points at which thermal equilibrium is obtained for steadily applied voltages. Deviations from this curve are relatively small for common receiving-type tubes.

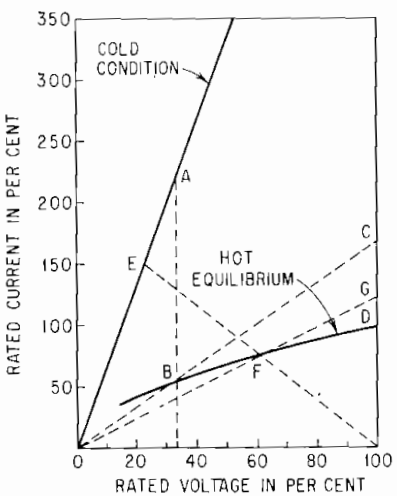


FIG. 9-25. Current-voltage plot for hot and cold tube conditions used to evaluate surge.

The results of applying heater voltage in steps can be shown by simple constructions. If a line is constructed at a chosen value of initial voltage, the magnitude of the initial cold-resistance surge is shown by point *A* and thermal equilibrium occurs at point *B*. A line through the origin and point *B* represents the heater resistance attained in the partially heated equilibrium condition. If 100 per cent voltage is then applied, a current surge of magnitude indicated by point *C* occurs, and final equilibrium is attained at the normal operating point *D*.

The effect of applying 100 per cent rated voltage through a series resistor can be shown by the construction of a line having a slope based on the ratio of the series resistance to the normal hot resistance of the tube. The cold-tube surge is indicated by point *E*, and equilibrium occurs at *F*. Construction of a line from the origin through point *F* then represents this equilibrium heater resistance. If the resistor is then shorted out, 100 per cent voltage will be applied and will result in a momentary current indicated by point *G*. Final equilibrium will occur at the normal operating point *D*.

* By M. P. Feyerherm, Defense Electronic Products, Radio Corporation of America, Camden, N.J. Reprinted from *Electronics*, June 1, 1957.

A CONVENIENT SLIDE-RULE SHORT CUT TO CONVERT ELECTRICAL DEGREES TO FEET, OR VICE VERSA WHEN FREQUENCY AND EITHER FEET OR DEGREES IS KNOWN

From the expression

$$\text{Feet} = \frac{\text{degrees}}{360°} \times \frac{300}{f(\text{Mc})} \times 3.281 = \text{degrees} \times \frac{2.734}{f(\text{Mc})}$$

the following ratio may be set up on the slide rule using C and D scales:

$$\frac{2.734}{f(\text{Mc})} = \frac{\text{feet}}{\text{degrees}}$$

Set 2.734 on scale C over frequency in megacycles on scale D; read feet and degrees on scales C and D, respectively. In some instances it may be convenient to use the folded scales CF and DF.

GREAT-CIRCLE DISTANCE AND BEARING CALCULATIONS

The need often arises in allocations problems for a simple and reliable method of computing the position of one radio station or area with respect to another expressed in degrees clockwise from true north. It is often equally important that the distance between these two points be known.

Bearings and distance can be computed in many ways. The method set forth here utilizes a table developed by Lieutenant Arthur A. Ageton, USN, which permits the simple solution of navigational problems. If the table is properly read and interpolations carefully made, the bearings and distances derived through use of the calculation sheet will be found to be in very close agreement with lengthy mathematical computations.

To use this method one must first obtain Hydrographic Office Publication No. 211, entitled "Dead Reckoning Altitude and Azimuth Table" from the Hydrographic Office, Washington, D.C., or the Superintendent of Documents, Government Printing Office, Washington, D.C.

The calculation sheet can be shortened in some respects if used only for determining bearings and distances between points within a limited area such as the United States or North America. As shown, bearings and distances can be calculated between any two points on the surface of the earth if the latitude and longitude of the two positions are known.

If a considerable number of calculations are to be made, it is suggested that the calculation sheet be duplicated in quantity. Furthermore, it is suggested that until one becomes thoroughly acquainted with the method the various *steps* be check-marked as they are completed.

Great Circle Distance and Bearing Calculation Sheet

(Based on Ageton, *H.O. Publ.* 211, Tables)

FROM: Location_____ (La)___° ___′ ___″ (Lo)___° ___′ ___″
TO: Location_____ (La′)___° ___′ ___″ (Lo′)___° ___′ ___″

Symbols Used

- *A* Numbers in the *A* columns of the H.O. 211 tables
- *B* Numbers in the *B* columns of the H.O. 211 tables
- *t* (*Lo* ~ *Lo′*) The smaller angle between the two meridians, *Lo* and *Lo′*
- *C* Bearing East or West of 0° true
- *D* Great-circle distance when converted to minutes of arc
- *K* An arc used in the calculations
- *Dn* The great-circle distance in nautical miles
- *Ds* The great-circle distance in statute miles
- (*K* ~ *La*) The magnitude of the difference between arc *K* and *La*

Rules

If *La* and *La′* are in the same hemisphere: (N or *S*)

- *K*: Take *K* from bottom of columns in H.O. No. 211 tables if *t* is greater than 90°.
- *D*: Take *D* from bottom of columns in H.O. No. 211 when *t* and (*K* ~ *La*) are each greater than 90°.
- *C*: Take *C* from bottom of columns in H.O. No. 211 when *K* is less than *La*.
- (*K* ~ *La*): Subtract *K* and *La* to find difference.

If *La* and *La′* are in different hemispheres: (N and *S*)

- *K*: Take *K* from bottom of columns in H.O. No. 211 tables if *t* is greater than 90°.
- *D*: If *t* and (*K* ~ *La*) are each less than 90°, take *D* from top of table, *otherwise*, from *bottom*.
- *C*: Take *C* from bottom of tables in H.O. No. 211 tables unless (*K* ~ *La*) is greater than 180°.
- (*K* ~ *La*): Add *K* and *La* to find magnitude. If (*K* ~ *La*) exceeds 180°, subtract 180° before entering H.O. No. 211 table to find *B*3.

Calculations

[Follow rules closely for *K*, *D*, *C*, and *B*3—also (*K* ~ *La*)]

	ADD	SUBTRACT	ADD	SUBTRACT
*Lo′*_____	*A*1_____	*A*3_____	*B*2_____	*A*2_____
*Lo*_____	*B*1+_____	*B*2−_____	*B*3+_____	*A*5−_____
t =_____	*A*2 =_____	*A*4 =_____	*B*4 =_____	*A*6 =_____
*La′*_____				
K =_____				
*La*_____				
(*K* ~ *La*) =_____				

D =___° ___′ ___″
D: ___° × 60 = ___′ + ___′ = *Dn* ___ miles
Dn ___ miles × 1.152 = *Ds* ___ miles

*C** = ___° ___′ ___″ $\frac{E}{W}$ of 0° true

* NOTE: When *Lo′* is *west* of *Lo*, *C* will indicate bearings in degrees *west* of 0° true. When *Lo′* is *east* of *Lo*, *C* will indicate bearings in degrees *east* of 0° true.

Steps

1. List coordinates for locations.
2. Subtract *Lo* and *Lo′* to find arc *t*.
3. Enter H.O. No. 211 with *t* to find *A*1.
4. Enter table with *La′* to find *B*1 and *A*3.
5. Add *A*1 and *B*1 for *A*2.
6. Enter table with *A*2 to find *B*2.
7. Subtract *B*2 from *A*3 for *A*4.
8. Enter table with *A*4 for arc *K*.
9. Determine arc for (*K* ~ *La*).
10. Enter table with (*K* ~ *La*) for *B*3.
11. Add *B*2 and *B*3 for *B*4.
12. Enter table with *B*4 to find *A*5 and arc *D*.
13. Subtract *A*5 from *A*2 for *A*6.
14. Enter table with *A*6 for bearing *C*.
15. Follow steps shown to find *Ds* and *Dn*.

Table 9-5. Temperature-conversion Chart *

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
−200	−328.0	−100	−148.0	0	32.0	0	32.0	100	212.0	200	392.0	300	572.0	400	752.0	500	932.0	600	1,112.0	700	1,292.0
−201	−329.8	−101	−149.8	−1	30.2	1	33.8	101	213.8	201	393.8	301	573.8	401	753.8	501	933.8	601	1,113.8	701	1,293.8
−202	−331.6	−102	−151.6	−2	28.4	2	35.6	102	215.6	202	395.6	302	575.6	402	755.6	502	935.6	602	1,115.6	702	1,295.6
−203	−333.4	−103	−153.4	−3	26.6	3	37.4	103	217.4	203	397.4	303	577.4	403	757.4	503	937.4	603	1,117.4	703	1,297.4
−204	−335.2	−104	−155.2	−4	24.8	4	39.2	104	219.2	204	399.2	304	579.2	404	759.2	504	939.2	604	1,119.2	704	1,299.2
−205	−337.0	−105	−157.0	−5	23.0	5	41.0	105	221.0	205	401.0	305	581.0	405	761.0	505	941.0	605	1,121.0	705	1,301.0
−206	−338.8	−106	−158.8	−6	21.2	6	42.8	106	222.8	206	402.8	306	582.8	406	762.8	506	942.8	606	1,122.8	706	1,302.8
−207	−340.6	−107	−160.6	−7	19.4	7	44.6	107	224.6	207	404.6	307	584.6	407	764.6	507	944.6	607	1,124.6	707	1,304.6
−208	−342.4	−108	−162.4	−8	17.6	8	46.4	108	226.4	208	406.4	308	586.4	408	766.4	508	946.4	608	1,126.4	708	1,306.4
−209	−344.2	−109	−164.2	−9	15.8	9	48.2	109	228.2	209	408.2	309	588.2	409	768.2	509	948.2	609	1,128.2	709	1,308.2
−210	−346.0	−110	−166.0	−10	14.0	10	50.0	110	230.0	210	410.0	310	590.0	410	770.0	510	950.0	610	1,130.0	710	1,310.0
−211	−347.8	−111	−167.8	−11	12.2	11	51.8	111	231.8	211	411.8	311	591.8	411	771.8	511	951.8	611	1,131.8	711	1,311.8
−212	−349.6	−112	−169.6	−12	10.4	12	53.6	112	233.6	212	413.6	312	593.6	412	773.6	512	953.6	612	1,133.6	712	1,313.6
−213	−351.4	−113	−171.4	−13	8.6	13	55.4	113	235.4	213	415.4	313	595.4	413	775.4	513	955.4	613	1,135.4	713	1,315.4
−214	−353.2	−114	−173.2	−14	6.8	14	57.2	114	237.2	214	417.2	314	597.2	414	777.2	514	957.2	614	1,137.2	714	1,317.2
−215	−355.0	−115	−175.0	−15	5.0	15	59.0	115	239.0	215	419.0	315	599.0	415	779.0	515	959.0	615	1,139.0	715	1,319.0
−216	−356.8	−116	−176.8	−16	3.2	16	60.8	116	240.8	216	420.8	316	600.8	416	780.8	516	960.8	616	1,140.8	716	1,320.8
−217	−358.6	−117	−178.6	−17	1.4	17	62.6	117	242.6	217	422.6	317	602.6	417	782.6	517	962.6	617	1,142.6	717	1,322.6
−218	−360.4	−118	−180.4	−18	−0.4	18	64.4	118	244.4	218	424.4	318	604.4	418	784.4	518	964.4	618	1,144.4	718	1,324.4
−219	−362.2	−119	−182.2	−19	−2.2	19	66.2	119	246.2	219	426.2	319	606.2	419	786.2	519	966.2	619	1,146.2	719	1,326.2
−220	−364.0	−120	−184.0	−20	−4.0	20	68.0	120	248.0	220	428.0	320	608.0	420	788.0	520	968.0	620	1,148.0	720	1,328.0
−221	−365.8	−121	−185.8	−21	−5.8	21	69.8	121	249.8	221	429.8	321	609.8	421	789.8	521	969.8	621	1,148.8	721	1,329.8
−222	−367.6	−122	−187.6	−22	−7.6	22	71.6	122	251.6	222	431.6	322	611.6	422	791.6	522	971.6	622	1,151.6	722	1,331.6
−223	−369.4	−123	−189.4	−23	−9.4	23	73.4	123	253.4	223	433.4	323	613.4	423	793.4	523	973.4	623	1,153.4	723	1,333.4
−224	−371.2	−124	−191.2	−24	−11.2	24	75.2	124	255.2	224	435.2	324	615.2	424	795.2	524	975.2	624	1,155.2	724	1,335.2
−225	−373.0	−125	−193.0	−25	−13.0	25	77.0	125	257.0	225	437.0	325	617.0	425	797.0	525	977.0	625	1,157.0	725	1,337.0
−226	−374.8	−126	−194.8	−26	−14.8	26	78.8	126	258.8	226	438.8	326	618.8	426	798.8	526	978.8	626	1,158.8	726	1,338.8
−227	−376.6	−127	−196.6	−27	−16.6	27	80.6	127	260.6	227	440.6	327	620.6	427	800.6	527	980.6	627	1,160.6	727	1,340.6
−228	−378.4	−128	−198.4	−28	−18.4	28	82.4	128	262.4	228	442.4	328	622.4	428	802.4	528	982.4	628	1,162.4	728	1,342.4
−229	−380.2	−129	−200.2	−29	−20.2	29	84.2	129	264.2	229	444.2	329	624.2	429	804.2	529	984.2	629	1,164.2	729	1,344.2
−230	−382.0	−130	−202.0	−30	−22.0	30	86.0	130	266.0	230	446.0	330	626.0	430	806.0	530	986.0	630	1,166.0	730	1,346.0
−231	−383.8	−131	−203.8	−31	−23.8	31	87.8	131	267.8	231	447.8	331	627.8	431	807.8	531	987.8	631	1,167.8	731	1,347.8
−232	−385.6	−132	−205.6	−32	−25.6	32	89.6	132	269.6	232	449.6	332	629.6	432	809.6	532	989.6	632	1,169.6	732	1,349.6
−233	−387.4	−133	−207.4	−33	−27.4	33	91.4	133	271.4	233	451.4	333	631.4	433	811.4	533	991.4	633	1,171.4	733	1,351.4
−234	−389.2	−134	−209.2	−34	−29.2	34	93.2	134	273.2	234	453.2	334	633.2	434	813.2	534	993.2	634	1,173.2	734	1,353.2

−235	−391.0	−135	−211.0	−35	−31.0	35	95.0	135	275.0	235	455.0	335	635.0	435	815.0	535	995.0	635	1,175.0	735	1,355.0
−236	−392.8	−136	−212.8	−36	−32.8	36	96.8	136	276.8	236	456.8	336	636.8	436	816.8	536	996.8	636	1,176.8	736	1,356.8
−237	−394.6	−137	−214.6	−37	−34.6	37	98.6	137	278.6	237	458.6	337	638.6	437	818.6	537	998.6	637	1,178.6	737	1,358.6
−238	−396.4	−138	−216.4	−38	−36.4	38	100.4	138	280.4	238	460.4	338	640.4	438	820.4	538	1,000.4	638	1,180.4	738	1,360.4
−239	−398.2	−139	−218.2	−39	−38.2	39	102.2	139	282.2	239	462.2	339	642.2	439	822.2	539	1,002.2	639	1,182.2	739	1,362.2
−240	−400.0	−140	−220.0	−40	−40.0	40	104.0	140	284.0	240	464.0	340	644.0	440	824.0	540	1,004.0	640	1,184.0	740	1,364.0
−241	−401.8	−141	−221.8	−41	−41.8	41	105.8	141	285.8	241	465.8	341	645.8	441	825.8	541	1,005.8	641	1,185.8	741	1,365.8
−242	−403.6	−142	−223.6	−42	−43.6	42	107.6	142	287.6	242	467.6	342	647.6	442	827.6	542	1,007.6	642	1,187.6	742	1,367.6
−243	−405.4	−143	−225.4	−43	−45.4	43	109.4	143	289.4	243	469.4	343	649.4	443	829.4	543	1,009.4	643	1,189.4	743	1,369.4
−244	−407.2	−144	−227.2	−44	−47.2	44	111.2	144	291.2	244	471.2	344	651.2	444	831.2	544	1,011.2	644	1,191.2	744	1,371.2
−245	−409.0	−145	−229.0	−45	−49.0	45	113.0	145	293.0	245	473.0	345	653.0	445	833.0	545	1,013.0	645	1,193.0	745	1,373.0
−246	−410.8	−146	−230.8	−46	−50.8	46	114.8	146	294.8	246	474.8	346	654.8	446	834.8	546	1,014.8	646	1,194.8	746	1,374.8
−247	−412.6	−147	−232.6	−47	−52.6	47	116.6	147	296.6	247	476.6	347	656.6	447	836.6	547	1,016.6	647	1,196.6	747	1,376.6
−248	−414.4	−148	−234.4	−48	−54.4	48	118.4	148	298.4	248	478.4	348	658.4	448	838.4	548	1,018.4	648	1,198.4	748	1,378.4
−249	−416.2	−149	−236.2	−49	−56.2	49	120.2	149	300.2	249	480.2	349	660.2	449	840.2	549	1,020.2	649	1,200.2	749	1,380.2
−250	−418.0	−150	−238.0	−50	−58.0	50	122.0	150	302.0	250	482.0	350	662.0	450	842.0	550	1,022.0	650	1,202.0	750	1,382.0
−251	−419.8	−151	−239.8	−51	−59.8	51	123.8	151	303.8	251	483.8	351	663.8	451	843.8	551	1,023.8	651	1,203.8	751	1,383.8
−252	−421.6	−152	−241.6	−52	−61.6	52	125.6	152	305.6	252	485.6	352	665.6	452	845.6	552	1,025.6	652	1,205.6	752	1,385.6
−253	−423.4	−153	−243.4	−53	−63.4	53	127.4	153	307.4	253	487.4	353	667.4	453	847.4	553	1,027.4	653	1,207.4	753	1,387.4
−254	−425.2	−154	−245.2	−54	−65.2	54	129.2	154	309.2	254	489.2	354	669.2	454	849.2	554	1,029.2	654	1,209.2	754	1,389.2
−255	−427.0	−155	−247.0	−55	−67.0	55	131.0	155	311.0	255	491.0	355	671.0	455	851.0	555	1,031.0	655	1,211.0	755	1,391.0
−256	−428.8	−156	−248.8	−56	−68.8	56	132.8	156	312.8	256	492.8	356	672.8	456	852.8	556	1,032.8	656	1,212.8	756	1,392.8
−257	−430.6	−157	−250.6	−57	−70.6	57	134.6	157	314.6	257	494.6	357	674.6	457	854.6	557	1,034.6	657	1,214.6	757	1,394.6
−258	−432.4	−158	−252.4	−58	−72.4	58	136.4	158	316.4	258	496.4	358	676.4	458	856.4	558	1,036.4	658	1,216.4	758	1,396.4
−259	−434.2	−159	−254.2	−59	−74.2	59	138.2	159	318.2	259	498.2	359	678.2	459	858.2	559	1,038.2	659	1,218.2	759	1,398.2
−260	−436.0	−160	−256.0	−60	−76.0	60	140.0	160	320.0	260	500.0	360	680.0	460	860.0	560	1,040.0	660	1,220.0	760	1,400.0
−261	−437.8	−161	−257.8	−61	−77.8	61	141.8	161	321.8	261	501.8	361	681.8	461	861.8	561	1,041.8	661	1,221.8	761	1,401.8
−262	−439.6	−162	−259.6	−62	−79.6	62	143.6	162	323.6	262	503.6	362	683.6	462	863.6	562	1,043.6	662	1,223.6	762	1,403.6
−263	−441.4	−163	−261.4	−63	−81.4	63	145.4	163	325.4	263	505.4	363	685.4	463	865.4	563	1,045.4	663	1,225.4	763	1,405.4
−264	−443.2	−164	−263.2	−64	−83.2	64	147.2	164	327.2	264	507.2	364	687.2	464	867.2	564	1,047.2	664	1,227.2	764	1,407.2
−265	−445.0	−165	−265.0	−65	−85.0	65	149.0	165	329.0	265	509.0	365	689.0	465	869.0	565	1,049.0	665	1,229.0	765	1,409.0
−266	−446.8	−166	−266.8	−66	−86.8	66	150.8	166	330.8	266	510.8	366	690.8	466	870.8	566	1,050.8	666	1,230.8	766	1,410.8
−267	−448.6	−167	−268.6	−67	−88.6	67	152.6	167	332.6	267	512.6	367	692.6	467	872.6	567	1,052.6	667	1,232.6	767	1,412.6
−268	−450.4	−168	−270.4	−68	−90.4	68	154.4	168	334.4	268	514.4	368	694.4	468	874.4	568	1,054.4	668	1,234.4	768	1,414.4
−269	−452.2	−169	−272.2	−69	−92.2	69	156.2	169	336.2	269	516.2	369	696.2	469	876.2	569	1,056.2	669	1,236.2	769	1,416.2
−270	−454.0	−170	−274.0	−70	−94.0	70	158.0	170	338.0	270	518.0	370	698.0	470	878.0	570	1,058.0	670	1,238.0	770	1,418.0
−271	−455.8	−171	−275.8	−71	−95.8	71	159.8	171	339.8	271	519.8	371	699.8	471	879.8	571	1,059.8	671	1,239.8	771	1,419.8
−272	−457.6	−172	−277.6	−72	−97.6	72	161.6	172	341.6	272	521.6	372	701.6	472	881.6	572	1,061.6	672	1,241.6	772	1,421.6
−273	−459.4	−173	−279.4	−73	−99.4	73	163.4	173	343.4	273	523.4	373	703.4	473	883.4	573	1,063.4	673	1,243.4	773	1,423.4
−273.2	−459.7	−174	−281.2	−74	−101.2	74	165.2	174	345.2	274	525.2	374	705.2	474	885.2	574	1,065.2	674	1,245.2	774	1,425.2

Absolute zero.

Table 9-5. Temperature-conversion Chart * (*Continued*)

°C °F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
Absolute Zero	−175	−283.0	−75	−103.0	75	167.0	175	347.0	275	527.0	375	707.0	475	887.0	575	1,067.0	675	1,247.0	775	1,427.0
	−176	−284.8	−76	−104.8	76	168.8	176	348.8	276	528.8	376	708.8	476	888.8	576	1,068.8	676	1,248.8	776	1,428.8
	−177	−286.6	−77	−106.6	77	170.6	177	350.6	277	530.6	377	710.6	477	890.6	577	1,070.6	677	1,250.6	777	1,430.6
	−178	−288.4	−78	−108.4	78	172.4	178	352.4	278	532.4	378	712.4	478	892.4	578	1,072.4	678	1,252.4	778	1,432.4
	−179	−290.2	−79	−110.2	79	174.2	179	354.2	279	534.2	379	714.2	479	894.2	579	1,074.2	679	1,254.2	779	1,434.2
	−180	−292.0	−80	−112.0	80	176.0	180	356.0	280	536.0	380	716.0	480	896.0	580	1,076.0	680	1,256.0	780	1,436.0
Formulas:	−181	−293.8	−81	−113.8	81	177.8	181	357.8	281	537.8	381	717.8	481	897.8	581	1,077.8	681	1,257.8	781	1,437.8
	−182	−295.6	−82	−115.6	82	179.6	182	359.6	282	539.6	382	719.6	482	899.6	582	1,079.6	682	1,259.6	782	1,439.6
	−183	−297.4	−83	−117.4	83	181.4	183	361.4	283	541.4	383	721.4	483	901.4	583	1,081.4	683	1,261.4	783	1,441.4
$C = \frac{5}{9}(F - 32)$	−184	−299.2	−84	−119.2	84	183.2	184	363.2	284	543.2	384	723.2	484	903.2	584	1,083.2	684	1,263.2	784	1,443.2
	−185	−301.0	−85	−121.0	85	185.0	185	365.0	285	545.0	385	725.0	485	905.0	585	1,085.0	685	1,265.0	785	1,445.0
$F = \frac{9}{5}C + 32$	−186	−302.8	−86	−122.8	86	186.8	186	366.8	286	546.8	386	726.8	486	906.8	586	1,086.8	686	1,266.8	786	1,446.8
	−187	−304.6	−87	−124.6	87	188.6	187	368.6	287	548.6	387	728.6	487	908.6	587	1,088.6	687	1,268.6	787	1,448.6
	−188	−306.4	−88	−126.4	88	190.4	188	370.4	288	550.4	388	730.4	488	910.4	588	1,090.4	688	1,270.4	788	1,450.4
	−189	−308.2	−89	−128.2	89	192.2	189	372.2	289	552.2	389	732.2	489	912.2	589	1,092.2	689	1,272.2	789	1,452.2
	−190	−310.0	−90	−130.0	90	194.0	190	374.0	290	554.0	390	734.0	490	914.0	590	1,094.0	690	1,274.0	790	1,454.0
	−191	−311.8	−91	−131.8	91	195.8	191	375.8	291	555.8	391	735.8	491	915.8	591	1,095.8	691	1,275.8	791	1,455.8
	−192	−313.6	−92	−133.6	92	197.6	192	377.6	292	557.6	392	737.6	492	917.6	592	1,097.6	692	1,277.6	792	1,457.6
	−193	−315.4	−93	−135.4	93	199.4	193	379.4	293	559.4	393	739.4	493	919.4	593	1,099.4	693	1,279.4	793	1,459.4
	−194	−317.2	−94	−137.2	94	201.2	194	381.2	294	561.2	394	741.2	494	921.2	594	1,101.2	694	1,281.2	794	1,461.2
	−195	−319.0	−95	−139.0	95	203.0	195	383.0	295	563.0	395	743.0	495	923.0	595	1,103.0	695	1,283.0	795	1,463.0
	−196	−320.8	−96	−140.8	96	204.8	196	384.8	296	564.8	396	744.8	496	924.8	596	1,104.8	696	1,284.8	796	1,464.8
	−197	−322.6	−97	−142.6	97	206.6	197	386.6	297	566.6	397	746.6	497	926.6	597	1,106.6	697	1,286.6	797	1,466.6
	−198	−324.4	−98	−144.4	98	208.4	198	388.4	298	568.4	398	748.4	498	928.4	598	1,108.4	698	1,288.4	798	1,468.4
	−199	−326.2	−99	−146.2	99	210.2	199	390.2	299	570.2	399	750.2	499	930.2	599	1,110.2	699	1,290.2	799	1,470.2

* Reprinted from *Electronics*, May 1, 1957.

Table 9-6. Conversion Table for Units of Length

MULTIPLY NUMBER OF → / TO OBTAIN NUMBER OF ↓	ANGSTROMS	MICRONS	MILS	INCHES	FEET	MILES	MILLIMETERS	CENTIMETERS	KILOMETERS
ANGSTROMS	1	10^{4}	2.540×10^{5}	2.540×10^{8}	3.048×10^{9}	1.609×10^{13}	10^{7}	10^{8}	10^{13}
MICRONS	10^{-4}	1	2.540×10	2.540×10^{4}	3.048×10^{5}	1.609×10^{9}	10^{3}	10^{4}	10^{9}
MILS	3.937×10^{-6}	3.937×10^{-2}	1	10^{3}	1.2×10^{4}	6.336×10^{7}	3.937×10	3.937×10^{2}	3.937×10^{7}
INCHES	3.937×10^{-9}	3.937×10^{-5}	10^{-3}	1	12	6.336×10^{4}	3.937×10^{-2}	3.937×10^{-1}	3.937×10^{4}
FEET	3.281×10^{-10}	3.281×10^{-6}	8.333×10^{-5}	8.333×10^{-2}	1	5.280×10^{3}	3.281×10^{-3}	3.281×10^{-2}	3.281×10^{3}
MILES	6.214×10^{-14}	6.214×10^{-10}	1.578×10^{-8}	1.578×10^{-5}	1.894×10^{-4}	1	6.214×10^{-7}	6.214×10^{-6}	6.214×10^{-1}
MILLIMETERS	10^{-7}	10^{-3}	2.540×10^{-2}	2.540×10	3.048×10^{2}	1.609×10^{6}	1	10	10^{6}
CENTIMETERS	10^{-8}	10^{-4}	2.540×10^{-3}	2.540	3.048×10	1.609×10^{5}	0.1	1	10^{5}
KILOMETERS	10^{-13}	10^{-9}	2.540×10^{-8}	2.540×10^{-5}	3.048×10^{-4}	1.609	10^{-6}	10^{-5}	1

TRANSISTOR CHARACTERISTICS FOR CIRCUIT DESIGNERS °

Summary: Tables indicate physical properties, maximum electrical ratings, small-signal low-frequency parameters, and average characteristics for grounded-base, grounded-emitter, grounded-collector, and switching circuits for 218 transistor types: 106 junction triodes, 46 high-frequency triodes, 6 tetrodes, 23 high-power units, 25 point-contact, and 12 phototransistors.

Abbreviations Used in Tables

α	Current gain	I_e	Emitter current
β	Base-current amplification factor	I_{eo}	Emitter cutoff current
BW	Bandwidth	NF	Noise figure
C_c	Collector capacitance	r_b	Base resistance
$f_{\alpha o}$	Alpha cutoff frequency	r_c	Collector resistance
g-b	Grounded base	r_e	Emitter resistance
g-c	Grounded collector	R_g	Generator resistance
g-e	Grounded emitter	R_i	Input resistance
I_b	Base current	R_L	Load resistance
I_{b2}	Second base current (tetrode)	R_o	Output resistance
I_c	Collector current	V_c	Collector voltage
I_{co}	Collector cutoff current		

° By Seymour Schwartz, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass. Reprinted from *Electronics*, January, 1956.

Successful transistor circuit design requires not only familiarity with transistor equivalent circuits and characteristic curves but also an understanding of the behavior of the parameters describing the transistor and the variation of these parameters with bias and temperature. Tables 9-7 to 9-12 have been compiled as a systematic presentation of data necessary for transistor circuit design.

Each of the charts presents physical properties; maximum electrical ratings; typical small-signal low-frequency parameters; average characteristics for grounded-emitter, grounded-base, and grounded-collector circuits; and switching characteristics. Figure 9-27 illustrates the circuits referenced in Tables 9-8 and 9-9.

Small-signal parameters are expressed as resistances. This permits a familiar physical representation of the transistor in circuit design. The box on page 9-50 enables transformation between h and r parameters.

All the characteristics are for fixed-bias conditions. However, these values vary with operating conditions. Examples of these variations are shown in Fig. 9-26*a* to *c*.

Figure 9-26*a* illustrates how collector capacitance C_c varies with collector voltage V_c. In designing an IF tuned circuit, the tuning capacitor must be large enough to swamp out the effects of the variation of collector capacitance. If the IF stage is a grounded-emitter rather than a grounded-base stage, the collector capacitance is magnified by the base-current amplification factor β.

In IF stages where neutralization is used to maximize gain by balancing out C_c, instability may occur when the battery voltage decreases. This variation of C_c with V_c permits use of the transistor as a reactance element in FM applications.

At low current bias (Fig. 9-26*b* to *d*) the noise factor of the transistor decreases and emitter resistance r_e, base resistance r_b, and collector resistance r_c increase, providing increased power gain and larger values of input and output impedance. This is advantageous in hearing aids where low bias currents are used.

Temperature Effects

In the germanium transistor, noticeable changes in α, β, and I_{co} take place at approximately 60°C as shown in Fig. 9-26*e*. These changes can lead to instability at high temperatures by α becoming equal to or greater than unity or by I_{co} increasing and causing a collector runaway effect due to self-heating.

Temperature problems are minimized in silicon transistors as seen in Fig. 9-26*f*. The value I_{co} becomes almost negligible in design consideration as the upper limit or temperature range is above 100°C. In such special applications as d-c amplifiers, the slightest change in α over the normal temperature operating range can produce a significant change in d-c gain of the grounded-emitter stage.

The low-frequency low-power triode junction transistor, Table 9-7, is most commonly used. The majority are utilized in hearing aids, audio systems, low-power control systems, and low-speed computing circuits. Present units are available in the *p-n-p* and *n-p-n* fused germanium, the *n-p-n* grown silicon types. Of the fused type of transistor, the *p-n-p* is more available commercially and consequently has found a wider range of applications. The *n-p-n* fused type is suitable for complementary symmetry circuitry. The grown silicon type is used for high-temperature and low-I_{co} applications.

The germanium and silicon grown transistors are used in almost the same manner as the fused transistor. Frequently, the grown types, owing to their lower value of collector capacitance and higher value of a cutoff, can be employed as high-frequency transistors.

The maximum power ratings on most of the low-power transistors are of the order of 50-mw collector dissipation at room temperature. Some of these units have external heat sinks and are able to dissipate considerably more power.

The rating most commonly employed is the maximum power rating. Maximum current and maximum voltage ratings cannot be achieved simultaneously because the product of these two ratings usually exceeds maximum rating. The maximum voltage rating is set at a value safely below the collector voltage breakdown value while the maximum current is selected where β has not decreased to too low a value.

Table 9-8, high-frequency transistors, includes *p-n-p* and *n-p-n* fused junction, *n-p-n* grown junction, and *p-n-p* surface-barrier units. Except for the *n-p-n* grown type, which is of either germanium or silicon, all these units use germanium.

Physically, one of the main distinctions between these units and the low-frequency units is the closer spacing between emitter and collector junctions. Electrical characteristics are higher α cutoff, lower collector voltage breakdown, and in many units lower collector capacitance and lower base resistance. The widest application is in radio receivers and high-speed switching circuits.

In selecting a high-frequency transistor for a grounded-emitter IF amplifier, note that the β-cutoff frequency of the amplifier is equal to a cutoff frequency divided by β.

Table 9-9 lists tetrode junction transistors which are high-frequency triode *n-p-n* grown junction transistors with an extra base lead and a narrower base region. The electrical characteristics of the grown tetrode transistor are almost identical to the grown triode transistor except for a lower value of base resistance and higher value of α-cutoff frequency. The extra base lead makes the tetrode applicable in specialized control circuits and AVC applications. Bias for the extra base lead is usually obtained from a bleeder across the main supply.

High-power Units

The high-power transistor, Table 9-10, is in most cases the largest of all transistors. One element is attached to the container. In most units the case can be connected to the chassis either directly or through a thin mica spacer. The types used as power transistors are the germanium *p-n-p* fused and silicon *n-p-n* grown.

The *p-n-p* fused transistors are usually the high-power units whose larger physical size provides collector power dissipation up to 20 watts. The larger physical size also contributes a high collector capacitance and lower α-cutoff frequency. Medium-power *p-n-p* and *n-p-n* fused units which retain their smaller physical size and most of the electrical characteristics of the low-power transistors are used in applications requiring collector power dissipation below $\frac{1}{2}$ watt.

The characteristics peculiar to the high-power transistor are the lower values of input resistance, output resistance, and α, resulting from the higher values of bias currents employed. Bias stability techniques are used to minimize the effect of runaway due to self-heating of the collector.

The point-contact transistor, Table 9-11, is limited to high-speed switching circuitry. Phototransistor devices, Table 9-12, are divided into two basic types: the two-lead and three-lead devices. In the two-lead unit, one lead is attached to the base and the other to the collector. The three-lead device has leads going to the emitter, base, and collector, respectively.

The two-lead device is used in circuits providing d-c amplification for unmodulated light, while the three-lead device can be used in circuits employing a-c amplification for modulated light.

Acknowledgment is given to Ann M. Field and Elizabeth A. Sewell for their assistance in compiling these data.

Table 9-7. Junction-triode

Manufacturer	Type No.	Type	Max coll power, mw	Max coll voltage, volts	Max coll current, ma	Max ambient temp, °C	Small-signal low-			
							Bias			
							V_c, volts	I_e, ma	β	r_e, ohms
Amperex Electronic Corp.	OC70	p-n-p fused [a]	25 (45°C)	−10	−10	45	−2	0.5	30	39
230 Duffy Ave.	OC71	p-n-p fused [a]	25 (45°C)	−10	−10	45	−2	3	47	6.5
Hicksville, N.Y.										
CBS-Hytron	2N36	p-n-p fused	50	−20	−8	50	−6	1	45	30
Danvers, Mass.	2N37	p-n-p fused	50	−20	−8	50	−6	1	30	30
	2N38	p-n-p fused	50	−20	−8	50	−6	1	15	25
	HA-1	p-n-p fused	50	−20	−8	50	−3	0.5	40	24
	HA-2	p-n-p fused	50	−20	−8	50	−3	0.5	30	35
	HA-3	p-n-p fused	50	−20	−8	50	−3	0.5	35	30
	HC-1	p-n-p fused	50	−20	−8	50	−6	1	45	30
Germanium Prod. Corp.	NPN-3/ 2N103	n-p-n grown	50 (25°C)	35	10	75	4.5	−1	4	25
26 Cornelison Ave.	RD2517A/ 2N97	n-p-n grown	50 (25°C)	30	10	75	4.5	−1	13.3	25
Jersey City, N.J.	RD2518A/ 2N97A	n-p-n grown	50 (25°C)	40	10	85	4.5	−1	13.3	25
	RD2521A/ 2N98	n-p-n grown	50 (25°C)	40	10	75	4.5	−1	40	25
	RD2522A/ 2N98A	n-p-n grown	50 (25°C)	40	10	85	4.5	−1	40	25
	RD2523A/ 2N99	n-p-n grown	50 (25°C)	40	10	75	4.5	−1	40	25
	RD2525A/ 2N100	n-p-n grown	25 (25°C)	25	5	50	4.5	−1	140	25
General Electric Co.	2N43	p-n-p fused	150 (25°C)	−45 [e]	−50	100	−5	1	49	32
Electronics Park	2N44	p-n-p fused	150 (25°C)	−45 [e]	−50	100	−5	1	21.2	26.5
Syracuse, N.Y.	2N45	p-n-p fused	150 (25°C)	−45 [e]	−50	100	−5	1	11.5	20
	2N43A	p-n-p fused	150 (25°C)	−45 [e]	−50	100	−5	1	43.4	15
	2N43A USAF	p-n-p fused	150 (25°C)	−45	−50	100	−5	1	43.4	15
	2N76	p-n-p fused	50 (25°C)	−20 [e]	−10	60	−5	1	19	17
General Transistor Corp.	GT-14	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	28	30
95-18 Sutphin Blvd.	GT-20	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	45	30
Jamaica, N.Y.	GT-34	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	15	30
	GT-81	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	65	30
	GT-83	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	45	30
	GT-87	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	28	30
	GT-88	p-n-p fused	70 (50°C)	−25	.....	85	.....	.....	65	30
	2N34	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	40	30
	2N36	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	45	30
	2N37	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	30	30
	2N38	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	15	30
	2N39	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	45	30
	2N40	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	28	30
	2N42	p-n-p fused	70 (50°C)	−25	.....	85	−4.5	1	13	30
Hughes Aircraft Co.	HA5001	n-p-n alloyed	500 (25°C)	30	100	85	5	1	65.6	16.5
Culver City, Calif.	HA5002	n-p-n alloyed	500 (25°C)	20	100	85	5	1	27.5	16
	HA5003	n-p-n alloyed	500 (25°C)	20	100	85	5	1	99	26
Hydro-Aire Inc.	J-1	p-n-p fused	150 (25°C)	−40	−10	50	−6	1	34	30
Burbank, Calif.	J-2	p-n-p fused	150 (25°C)	−40	−10	50	−6	1	15	30
	J-3	p-n-p fused	150 (25°C)	−40	−10	50	−6	1	9	30
	HA-1	p-n-p fused	100 (25°C)	−20	−10	50	−6	1	40	30
	CQ-1	p-n-p fused	150 (25°C)	−40	−10	50	−6	1	9	30
Nat'l Union Electric	2N39	p-n-p fused	47 (25°C)	−27	−12	60	−4.5	1	32.4	.....
350 Scotland Rd.	2N40	p-n-p fused	47 (25°C)	−27	−12	60	−4.5	1	15.7-32.4	.....
Orange, N.J.	2N42	p-n-p fused	47 (25°C)	−18	−12	60	−4.5	1	9	.....
	T34D	p-n-p fused [a]	56 (25°C)	−27	−12	70	−4.5	1	32.4	20
	T34E	p-n-p fused [a]	56 (25°C)	−27	−12	70	−4.5	1	15.7-32.4	20
	T34F	p-n-p fused [a]	56 (25°C)	−18	−12	70	−4.5	1	9	20
Philco Corp.	2N47	p-n-p fused [a]	50 (25°C)	−35	−20	...	−5	1	39	25
4700 Wissahickon Ave. Philadelphia, Pa.	2N49	p-n-p fused [a]	50 (25°C)	−35	−20	...	−5	1	39	25
RCA	2N104	p-n-p fused [b]	110 (25°C)	−30	50	85	−6	1	44	24.5
Harrison, N.J.	2N77	p-n-p fused [a]	35 (25°C)	−25	15	50	−4	0.7	40	36
Raytheon Mfg. Co.	CK721	p-n-p fused [c]	.....	−15 [f]	−10	70	−6	1	45	25
55 Chapel St. Newton, Mass.	CK722	p-n-p fused [c]	.....	−22 [f]	−10	70	−6	1	22	25
	CK725	p-n-p fused [c]	.....	−12 [f]	−10	70	−6	1	90	25
	CK727	p-n-p fused [c]	.....	−6 [f]	−10	70	−1.5	0.5	35	50
	2N63	p-n-p fused	.....	−22 [f]	−10	85	−6	1	22	25

Low-power Transistors

Frequency parameters						Grounded-emitter connection					Grounded-base				Grounded-collector			
r_b, ohms	r_c, megohms	$f_{\alpha co}$, Mc	C_c, $\mu\mu f$	I_{co}, μa	NF, db	I_b, ma	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db
1,000	1.43	.....	..	−8	10													
500	0.625	.....	..	−8	10													
450	0.95	0.5	..	....	..	.....	.....	30,000	1,000	40								
350	0.55	0.5	..	....	..	.....	.....	30,000	1,000	36								
350	0.5	0.5	..	....	..	.....	.....	30,000	1,000	32								
700	1.7	.....	..	−12	12	.....	.....	30,000	1,000	30								
350	0.8	.....	..	−12	27	.....	.....	30,000	1,000	30								
450	0.6	.....	..	....	..	.....	.....	1,200	1,000	35								
450	0.95	0.7	..	−12	..	.....	.....	30,000	1,000	40								
100	2.0	0.75	20	5	22	0.25	225	100,000 matched		33	45	250,000 matched		30	2,500	500 matched		7
100	3.0	1.0	19	2	20	0.07	400	100,000 matched		38	35	250,000 matched		32	7,000	500 matched		11
100	10.0	1.0	19	2	15	0.07	400	100,000 matched		38	35	250,000 matched		32	7,000	500 matched		11
150	5.0	2.5	14	2	20	0.025	850	100,000 matched		47	35	250,000 matched		35	20,000	500 matched		15
150	10.0	2.5	14	2	15	0.025	850	100,000 matched		47	35	250,000 matched		35	20,000	500 matched		15
150	5.0	3.5	10	2	15	0.025	850	100,000 matched		47	35	250,000 matched		35	20,000	500 matched		15
400	5.0	5.0	14	2	20	0.007	3,500	100,000 matched		53	45	250,000 matched		35	70,000	500 matched		20
400	1.0	1.0	40	−10	22	.....	1,000	30,000	600	39	60	50,000	100	28	30,000	600	30,000	15
300	1.0	1.0	40	−10	22	.....	700	30,000	600	38	55	50,000	100	28	15,000	600	15,000	12
250	1.0	1.0	40	−10	22	.....	450	30,000	600	36	50	50,000	100	28	7,500	600	7,500	11
575	1.43	1.0	40	−5	10	.....	1,000	30,000	600	39	60	50,000	100	28	30,000	600	30,000	15
575	1.43	1.0	40	−5	30	.....	1,000	30,000	600	39	60	50,000	100	28	30,000	600	30,000	15
300	1.0	1.0	40	−5	18	.....	1,000	30,000	600	38	55	50,000	100	28	15,000	600	15,000	12
800	1.5	0.65	..	−10	16													
800	1.5	0.65	..	−10	16													
800	1.5	0.65	..	−10	16													
800	1.5	0.65	..	−10	16													
800	1.5	0.70	..	−10	16													
800	1.5	0.50	..	−10	16													
800	1.5	1.0	..	−10	16													
350	2.0	.....	..	−15	24													
850	2.0	.....	..	−15	24													
600	2.0	.....	..	−15	24													
400	2.0	.....	..	−15	24													
850	2.0	.....	..	−15	24													
600	2.0	.....	..	−15	24													
400	2.0	.....	..	−15	24													
900	2	2.5	15	5														
400	1	0.8	..	12	15													
400	1	1.5	..	10	15													
400	1.0	1.0	..	−10	11	.....	.....	.....	.....	40								
300	0.7	0.5	..	−15	22	.....	.....	.....	.....	35								
300	0.5	0.5	..	−20	33	.....	.....	.....	.....	30								
350	0.75	.....	..	−10	20													
200	0.5	0.5	..	−20	33													
.....	1–2	.....	..	−10	20	.....	.....	30,000	500	39								
.....	1–2	.....	..	−10	24	.....	.....	30,000	500	38								
.....	0.5–2	.....	..	−20	28	.....	.....	30,000	500	36								
.....	1–2	.....	..	−10	20	.....	.....	30,000	500	39								
.....	1–2	.....	..	−10	24	.....	.....	30,000	500	38								
.....	0.5–2	.....	..	−20	28	.....	.....	30,000	500	36								
600	1.0	1.0	49	−10	15	.....	1,000	50,000 matched		42								
600	1.0	1.0	49	−10	12	.....	1,000	50,000 matched		42								
750	2.25	0.7	..	−10	12	.....	1,200	50,000 matched		43	140	400,000 matched		32.8	500,000	20,000 matched		13.9
560	2.3	0.7	..	−10	9	.....	1,350	50,000 matched		42.6	130	400,000 matched		33.2	10,000	300 matched		16.2
700	2.0	.....	..	−6	22	.....	1,500	20,000 matched		41	70	100,000 matched		31	600,000	20,000 matched		15
250	2.0	.....	..	−6	25	.....	500	20,000 matched		36	45	100,000 matched		32	200,000	20,000 matched		10
1,500	2.0	.....	..	−6	20	.....	2,700	20,000 matched		42	110	100,000 matched		30	1,000,000	20,000 matched		16
500	2.0	.....	..	−6	12	.....	.....	20,000	1,000	36	...	200,000	100	28	540,000	10,000	100,000	14
350	2.0	.....	..	−6	25	.....	800	20,000 matched		39	50	100,000 matched		32	350,000	20,000 matched		13

Table 9-7. Junction-triode Low-

Manufacturer	Type No.	Type	Max coll power, mw	Max coll voltage, volts	Max coll current, ma	Max ambient temp, °C	Small-signal low-			
							Bias			
							V_c, volts	I_e, ma	β	r_e, ohms
Raytheon (*Continued*)	2N64	*p-n-p* fused	.....	−15[f]	−10	85	−6	1	45	25
	2N65	*p-n-p* fused	.....	−12[f]	−10	85	−6	1	90	25
Sylvania Electric	2N34	*p-n-p* fused	50 (25°C)	−40	−10	...	−6	1	40	26
1740 Broadway	2N35	*n-p-n* fused	50 (25°C)	−40	−10	...	6	−1	40	26
New York, N.Y.										
Texas Instruments	200	*n-p-n* grown	50 (25°C)	30	5	50	5	−1	9	22
6000 Lemmon Ave.	201	*n-p-n* grown	50 (25°C)	30	5	50	5	−1	19	22
Dallas, Tex.	202	*n-p-n* grown	50 (25°C)	30	5	50	5	−1	49	35
	206S	*n-p-n* grown[a]	50 (25°C)	30	5	50	2.5	−0.5	35	.....
	207S	*n-p-n* grown[a]	50 (25°C)	30	5	50	2.5	−0.5	19	.....
	208S	*n-p-n* grown[a]	50 (25°C)	30	10	50	2.5	−10	19	.....
	300	*p-n-p* fused	50 (25°C)	−30	−10	50	−5	1	9	.....
	301	*p-n-p* fused	50 (25°C)	−30	−10	50	−5	1	19	.....
	903	*n-p-n* grown	150 (25°C)	30	10	150	5	−1	9–19	150
	904	*n-p-n* grown	150 (25°C)	30	10	150	5	−1	19–39	150
	905	*n-p-n* grown	150 (25°C)	30	10	150	5	−1	V|V| 39	150
	904A	*n-p-n* grown	150 (25°C)	30	10	150	5	−1	V|V| 19	150
	210	*n-p-n* grown	50 (25°C)	30[g]	5	50	22.5	−2	.....	.....
	302	*p-n-p* fused	50 (25°C)	−30	−10	50	−5	1	44	.....
	350	.....	50 (25°C)	−12						
Transitron	2N85	*p-n-p* fused	750	−45	−100	100	−12	10	40	2.5
407 Main St.	2N86	*p-n-p* fused	750	−60	−100	100	−12	10	20	2.5
Melrose, Mass.	2N87	*p-n-p* fused	750	−30	−100	100	−12	10	20	2.5
	2N88	*p-n-p* fused[a]	25	−12	−10	85	−1.3	0.5	25	50
	2N89	*p-n-p* fused[a]	25	−12	−10	85	−1.3	0.5	25	50
	2N90	*p-n-p* fused[a]	25	−12	−10	85	−1.3	2.5	40	10
	2N91	*p-n-p* fused	125	−15	−500	85	−3	30	25	1.5
	2N92	*p-n-p* fused	125	−25	−200	85	−3	5	30	5
	2N34	*p-n-p* fused	125	−25	−20	100	−6	1	40	18
	2N36	*p-n-p* fused	125	−25	−20	100	−6	1	45	18
	2N37	*p-n-p* fused	125	−25	−20	100	−6	1	30	20
	2N38	*p-n-p* fused	125	−25	−20	100	−6	1	15	20
	2N43	*p-n-p* fused	375	−45	−50	100	−6	1	33	20
	2N44	*p-n-p* fused	375	−45	−50	100	−6	1	16	20
	2N45	*p-n-p* fused	375	−45	−50	100	−6	1	9	20
	2N63	*p-n-p* fused	125	−25	−20	100	−6	1	20	20
	2N64	*p-n-p* fused	125	−25	−20	100	−6	1	30	20
	2N65	*p-n-p* fused	125	−25	−20	100	−6	1	50	18
Tung-Sol Electric	DR126	*p-n-p* fused[d]	50 (25°C)	−10[g]	.....	85	−1.5	0.5	24	26
100 Eighth Ave.	DR128	*p-n-p* fused[d]	50 (25°C)	−10[g]	.....	85	−1.5	0.5	49	34
Newark, N.J.	DR129	*p-n-p* fused[d]	50 (25°C)	−25[g]	.....	85	−1.5	0.5	32.4	26
	DR130	*p-n-p* fused[d]	50 (25°C)	−25[g]	.....	85	−1.5	0.5	13	20.5
	DR154	*p-n-p* fused[d]	50 (25°C)	−25[g]	.....	85	−1.5	0.5	124	55
Western Electric	2N27	*n-p-n* grown	50 (60°C)	30	5	85	4.5	−1	19–198	50
120 Broadway	2N28	*n-p-n* grown	50 (60°C)	30	5	85	4.5	−1	5–198	125
New York, N.Y.										
Westinghouse	2N54	*p-n-p* fused[a]	200 (25°C)	−45	−10	60	−6	1	33	25
Box 284	2N55	*p-n-p* fused[a]	200 (25°C)	−45	−10	60	−6	1	20	20
Elmira, N.Y.	2N56	*p-n-p* fused[a]	200 (25°C)	−45	−10	60	−6	1	13	5

All sockets A to H except where otherwise noted.
[a] Socket type A.
[b] Socket types B to H.
[c] Socket types A, I, and J.
[d] Socket type not given.

power Transistors (*Continued*)

Frequency parameters						Grounded-emitter connection					Grounded-base				Grounded-collector			
r_b, ohms	r_c, megohms	$f_{\alpha co}$, Mc	C_c, μμf	I_{eo}, μa	NF, db	I_b, ma	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db	R_i, ohms	R_L, ohms	R_g, ohms	Gain, db
700	2.0	.....	..	−6	22	.....	1,500	20,000 matched		41	70	100,000 matched		31	600,000	20,000 matched		15
1,500	2.0	.....	..	−6	20	.....	2,700	20,000 matched		42	110	100,000 matched		30	1,000,000	20,000 matched		16
800	2.0	0.6	15	−5	18	−0.03	1,200	30,000	500	40	...	.....	...	....	20,000	500 matched		16
800	2.0	0.8	18	5	16	0.03	1,200	30,000	500	40	...	.....	...	....	20,000	500 matched		16
150	0.4	0.9	15	10	26	.....	480	20,000	500	37	35	100,000	60	30	9,500	500	15,000	12
170	0.4	1.1	17	10	23	.....	970	20,000	500	40	40	100,000	60	30	15,500	500	15,000	14.5
200	0.4	1.3	19	10	20	.....	1,250	20,000	1,250	43	45	100,000	60	31	32,000	500	15,000	17
.....	.....	.....	..	3	11	.....	.....	20,000	1,000	32								
.....	.....	.....	..	3.5	21	.....	.....	20,000	1,000	29								
.....	.....	.....	..	4	26	.....	.....	300	1,000	26								
550	0.4	.....	..	−10	25													
1,000	0.4	.....	..	−10	20													
500	0.5	3	..	1 (25°C)	23													
1,250	0.5	3	..	1 (25°C)	23													
2,500	0.5	3	..	1 (25°C)	23													
1,250	0.5	[g]	..	1 (25°C)	23													
.....	.....	.....	..	50 (25°C)	..	.....	.....	10,000	500	39								
.....	.....	.....	..	−10														
300	0.16	0.8	..	−10	20	.....	.....	1,000	500	30								
300	0.125	0.8	..	−10	20	.....	.....	1,000	500	26								
300	0.125	0.8	..	−20	20	.....	.....	1,000	500	26								
1,000	0.5	0.5	..	−10	10	.....	.....	20,000	1,000	36								
1,000	2.0	0.5	..	−10	20	.....	.....	20,000	1,000	36								
600	0.5	0.5	..	−10	20	.....	.....	600	1,000	26								
50	2.0	.....	..	−15														
500	1.0	.....	..	−10														
600	1.0	.....	..	−10	20	.....	.....	30,000	1,000	40								
700	1.0	.....	..	−10	20	.....	.....	30,000	1,000	40								
500	1.0	.....	..	−15	22	.....	.....	30,000	1,000	36								
250	1.0	.....	..	−25	24	.....	.....	30,000	1,000	32								
500	1.0	.....	..	−15	20	.....	.....	30,000	1,000	40								
300	1.0	.....	..	−15	22	.....	.....	30,000	1,000	37								
250	1.0	.....	..	−15	22	.....	.....	30,000	1,000	33								
350	2.0	.....	..	−10	25	.....	.....	30,000	1,000	38								
700	2.0	.....	..	−10	22	.....	.....	30,000	1,000	39								
1,500	2.0	.....	..	−10	20	.....	.....	30,000	1,000	41								
900	1.5	0.9	..	−9	14	−0.006	.....	30,000	1,000	33								
1,400	2.0	0.9	..	−8	18	−1.5	.....	300	.....	24								
1,200	2.0	0.7	..	−10	18	−0.006	.....	30,000	1,000	35								
650	1.3	0.5	..	−14	21	−0.006	.....	30,000	1,000	27								
600	1.2	0.7	..	−10	18	−0.006	.....	30,000	1,000	40								
700	2.0	2	17	10	30													
1,000	1.0	0.95	25	10	30													
400	1.0	0.5	..	−6	..	.....	700	50,000	700	39.5	125	300,000	125	31	35,000	1,000	35,000	15
400	1.0	0.5	..	−6	..	.....	550	67,000	550	39	125	300,000	125	31	27,000	1,000	27,000	13
400	1.0	0.5	..	−6	..	.....	450	85,000	450	37	125	300,000	125	31	20,000	1,000	20,000	11

Characteristics measured at 25°C unless otherwise noted.
[e] Characteristics measured at 30°C.
[f] Characteristics measured at 27°C.
[g] Temperature not given.

Table 9-8. High-

Manufacturer	Type No.	Type	Max coll power, mw	Max coll voltage, volts	Max coll current, ma	Max ambient temp, °C	Storage temp, °C	Typical small-signal			
								Bias			
								V_c, volts	I_e, ma	β	r_e, ohms
General Electric	2N78	*n-p-n* rate grown	50 (30°C)	15	20	100	100 max	5	−1	27.5	...
	2N123	*p-n-p* fused	150 (25°C)	−15	150	...	85	−5	1	30–150	...
	2N135	*p-n-p* alloyed	100 (25°C)	−20	−50	...	85	−5	1	20	...
	2N136	*p-n-p* alloyed	100 (25°C)	−20	−50	...	85	−5	1	40	...
	2N137	*p-n-p* alloyed	100 (25°C)	−10	−50	...	85	−5	1	60	...
Germanium Prod.	RD2523A (2N99)	*n-p-n* grown	50 (25°C)	40	10	75	.....	5	−1	40	25
	RD2525A (2N100)	*n-p-n* grown	25 (25°C)	25	5	50	.....	5	−1	100	25
	RD2521A (2N98)	*n-p-n* grown	50 (25°C)	40	10	75	.....	5	−1	40	25
	RD2517A	*n-p-n* grown	50 (25°C)	30	10	75	.....	5	−1	13	25
Hydro-Aire	HF-1	*p-n-p* fused	35 (25°C)	−15	−5	55	.....	−4.5	1	25	30
	IF-1	*p-n-p* fused	35 (25°C)	−15	−5	55	.....	−4.5	1	20	30
Philco	SB-100	surface barrier [a]	10 (40°C)	−4.5	−5	...	−55 to 85	−3	0.5	19	50
Raytheon	CK-760	*p-n-p* fused	.....	−6 [c]	−5	...	−55 to 85	−6	1	45	22
	CK-761	*p-n-p* fused	.....	−6 [c]	−5	...	−55 to 85	−6	1	50	22
	CK-762	*p-n-p* fused	.....	−6 [c]	−5	...	−55 to 85	−6	1	60	22
Sylvania	2N94	*n-p-n* alloyed	50 (25°C)	20	10	...	−55 to 85	6	−0.5	30	52
	2N94A	*n-p-n* alloyed	50 (25°C)	20	10	...	−55 to 85	6	−0.5	30	52
Texas Inst.	220	*n-p-n* grown [a]	50 (25°C)	30	5	50	.....	22.5	...	...	...
	221	*n-p-n* grown [a]	50 (25°C)	30	5	50	.....	22.5	...	...	...
	222	*n-p-n* grown [a]	50 (25°C)	30	5	50	.....	22.5	...	...	...
	223	*n-p-n* grown [a]	50 (25°C)	30	5	50	.....	22.5	...	...	...
	904A	*n-p-n* grown	150 (25°C)	30	10	150	.....	5	−1	≥19	150
	224–1	.....	.....	...	...	...	.....	...	...	...	...
	2	.....	.....	...	...	...	.....	...	...	...	...
	3	.....	.....	...	...	...	.....	...	...	...	...
	4	.....	.....	...	...	...	.....	...	...	...	...
	5	.....	.....	...	...	...	.....	...	...	...	...
	225–1	.....	.....	...	...	...	.....	...	...	...	...
	2	.....	.....	...	...	...	.....	...	...	...	...
	3	.....	.....	...	...	...	.....	...	...	...	...
	4	.....	.....	...	...	...	.....	...	...	...	...
	5	.....	.....	...	...	...	.....	...	...	...	...
	226–1	.....	.....	...	...	...	.....	...	...	...	...
	2	.....	.....	...	...	...	.....	...	...	...	...
	3	.....	.....	...	...	...	.....	...	...	...	...
	4	.....	.....	...	...	...	.....	...	...	...	...
	5	.....	.....	...	...	...	.....	...	...	...	...
	227–1	.....	.....	...	...	...	.....	...	...	...	...
	2	.....	.....	...	...	...	.....	...	...	...	...
	3	.....	.....	...	...	...	.....	...	...	...	...
	4	.....	.....	...	...	...	.....	...	...	...	...
	5	.....	.....	...	...	...	.....	...	...	...	...
Tung-Sol	DR-155	*p-n-p* fused [b]	50 (25°C)	−10	...	85	−55 to 85	−1.5	0.5	32	...
	2N112	*p-n-p* fused	50 (25°C)	−10	−8	85	−55 to 85	−6	1	32	31
	2N113	*p-n-p* fused	50 (25°C)	−10	−8	85	−55 to 85	−6	1	32	31
Western Electric	2N27	*n-p-n* grown	50 (60°C)	30	5	85	.....	4.5	−1	20–198	50

Socket types A to H unless otherwise noted.
[a] Socket type A only.
[b] Socket types A and J.

frequency Transistors

low-frequency parameters							HF parameters	High-frequency circuit conditions					High-speed switching characteristics			
r_b, ohms	r_c, megohms	$f_{\alpha co}$, Mc	C_c, $\mu\mu f$	I_{co}, μa	I_{eo}, μa	NF, db	$r_b C_c$, $\mu\mu$ sec	Application	R_i, ohms	R_o, ohms	Power gain, db	Circuit	Rise time, μsec	Fall time, μsec	Reverse emitter voltage, volts	Circuit
...	...	5.5	6	1	...	14	....	RF amp	1,000	6,000	20					
								IF amp	1,500	10,000	30					
...	...	7.5	14	−2	5	10	1,000	Switching	...	.....	..	..	0.1	0.2	5	
...	...	4.5	14	5	...	..	....	RF/IF amp	...	.....	29					
...	...	6.5	14	5	...	..	....	RF/IF amp	...	.....	31					
...	...	10	14	5	...	..	....	RF/IF amp	...	.....	33					
150	5.0	3.5	10	2	...	15	....	IF amp unneut	500	10,000	22	..	<0.2	<0.3		
400	5.0	5.0	14	2	...	20	....	IF amp unneut	750	10,000	23	..	<0.2	<0.3		
150	5.0	2.0	14	2	...	20	....	IF amp unneut	500	10,000	22	..	<0.2	<0.3		
100	3.0	1.0	19	2	...	20	....	IF amp unneut	350	10,000	20	..	<0.2	<0.3		
500	1.0	5.0	10	−10												
500	1.0	2.9	10	−10												
...	0.4	30 (osc)	2.2	−0.5	0.5	..	800									
70	1.0	5	14	−2	2	25	1,000									
70	1.0	10	14	−2	2	25	1,000									
70	1.0	20	14	−2	2	25	1,000									
500	2.0	3.5	10	3	−3	15	1,000	IF (g-b)	80	100,000	25 [d]	C	0.15	0.15	≥0	F
								IF (g-e)	500	25,000	32 [d]	D				
500	2.0	6.0	10	3	−3	15	1,200	IF (g-b)	80	100,000	25 [d]	C	0.1	0.1	≥0	
								IF (g-e)	800	25,000	35 [d]	D				
								RF (g-b)	80	15,000	20 [e]	E				
...	...	...	...	50	...	..	....	262-kc (g-e) IF	750	70,000	31	A				
...	...	...	...	50	...	..	....	262-kc (g-e) IF	750	70,000	33	A				
...	...	...	...	50	...	..	....	262-kc (g-e) IF	750	70,000	35	A				
...	...	...	...	50	...	..	....	262-kc conv	300	60,000	20	B				
1,250	0.5	≥8	...	1												
...	...	...	...	...	...	..	....	Neut 262-kc g-e IF	600	70,000	26	H				
...	...	...	...	...	...	..	....		...	.....	28					
...	...	...	...	...	...	..	....	.....	...	.....	30					
...	...	...	...	...	...	..	....	.....	...	.....	32					
...	...	...	...	...	...	..	....	.....	...	.....	34					
...	...	...	...	...	...	..	....	Neut 455-kc g-e IF	500	50,000	24	H				
...	...	...	...	...	...	..	....		...	.....	26					
...	...	...	...	...	...	..	....	.....	...	.....	28					
...	...	...	...	...	...	..	....	.....	...	.....	30					
...	...	...	...	...	...	..	....	.....	...	.....	32					
...	...	...	...	...	...	..	....	Neut 262-kc g-b IF	65	120,000	18	I				
...	...	...	...	...	...	..	....		...	.....	20					
...	...	...	...	...	...	..	....	.....	...	.....	22					
...	...	...	...	...	...	..	....	.....	...	.....	24					
...	...	...	...	...	...	..	....	.....	...	.....	26					
...	...	...	...	...	...	..	....	Neut 455-kc g-b IF	65	150,000	18	I				
...	...	...	...	...	...	..	....		...	.....	20					
...	...	...	...	...	...	..	....	.....	...	.....	22					
...	...	...	...	...	...	..	....	.....	...	.....	24					
...	...	...	...	...	...	..	....	.....	...	.....	26					
...	1.0	1.4	...	−15	...	28										
110	1.2	5	...	−10	...	28	....	IF	600	25,000	32	G				
110	1.2	10	...	−10	...	28	....	IF	600	25,000	33	G				
700	2.0	2	17	10												

Characteristics measured at 25°C unless otherwise noted.
[c] Characteristics measured at 27°C.
[d] Bandwidth 12 kc.
[e] Bandwidth 25 kc.

Table 9-9. Grown *n-p-n*

Manufacturer	Type No.	Max coll power, mw	Max coll voltage, volts	Max coll current, ma	Max base-to-base current, ma	Application
Germanium Prod.	RDX-302/3N23	50 (25°C)	30	5	5	Video amp, switching 10-Mc osc
	RDX-301/3N23A	50 (25°C)	30	5	5	Video amp, switching 20-Mc osc
	RDX-300/3N23B	50 (25°C)	30	5	5	Video amp, switching 35-Mc osc 20-Mc IF
	RDX-300A/3N23C	50 (25°C)	30	5	5	Video amp, switching 50-Mc osc 20- to 30-Mc IF
Texas Inst.	700	50 (25°C)	30	5	5	Low-level, low-freq age
Western Electric	3N22	30 (25°C)	12	5	5	Video amp, R-F

All sockets A, F, G, H, and M.

Table 9-10.

Manufacturer	Type No.	Type	Max power output, watts: Class A	Class B (push-pull)	D-C switch	Max coll power, watts	Max coll voltage, volts: Circuit g-e	g-b	Max coll current, amp	Small signal: Bias f_{max}, kc	V_c, volts	I_c, ma
Amperex	2N115	*p-n-p* fused *	1.5	2.5	...	2 (45°C)	−12(B) −6(A)	...	−1	300	...	...
	2-OC72	*p-n-p* fused *	...	...	...	0.045 (45°C)	13(B)	...	0.045	10	...	...
CBS-Hytron	HD-197	*p-n-p* fused *	...	...	...	0.5 (25°C)	−40	...	...	150	−10	50
Hydro-Aire	JP-1	*p-n-p* fused *	0.45	0.9	1.5	0.5 (25°C)	...	−45	−0.1	50	−22.5	20
Minneapolis-Honeywell Regulator Co. 2753 4th Ave. S Minneapolis, Minn.	H-1	*p-n-p* fused *	5	10	40	20 (21°C)	−30	−60	−0.8	20	−2	...
	2N57	*p-n-p* fused *	6	12	48	20 (21°C)	−30	−60	−1	20	−2	...
	H-2	*p-n-p* fused *	8.5	18	68	20 (21°C)	−30	−60	−1.4	20	−2	...
	H-3	*p-n-p* fused *	2	4	16	5 (21°C)	−30	−60	−0.35	20	−2	...
	H-4	*p-n-p* fused †	2	6	16	5 (21°C)	−30	−60	−0.5	20	−2	...
Sylvania	2N68	*p-n-p* alloyed †	0.75	10	...	4 (25°C)	...	−25	−1.5	...	−6	50
	2N95	*n-p-n* alloyed †	0.75	10	...	4 (25°C)	...	25	1.5	...	6	−50
	2N101	*p-n-p* alloyed	Electrically identical to 2N68									
	2N102	*n-p-n* alloyed	Electrically identical to 2N95									
Texas Inst.	X-2	*n-p-n* grown	...	...	...	...	...	35	0.075	225	5	−1
	951	*n-p-n* grown	...	0.45 (25°C)	...	1 (25°C)	50	...	0.06	...	...	...
		Silicon	...	0.3 (100°C)	...	0.5 (100°C)	...	...	...	...	...	...
				0.15 (150°C)	...	0.15 (150°C)						
	952	*n-p-n* grown	...	0.6 (25°C)	...	1 (25°C)	80	...	0.03	...	...	...
		Silicon	...	0.4 (100°C)	...	0.5 (100°C)	...	...	...	...	...	...
				0.15 (150°C)	...	0.15 (150°C)						
	953	*n-p-n* grown	...	1 (25°C)	...	1 (25°C)	120	...	0.04	...	...	...
		Silicon	...	0.5 (100°C)	...	0.5 (100°C)	...	...	...	...	...	...
				0.15 (150°C)	...	0.14 (150°C)						
Transistor Products 241-251 Crescent Ave. Waltham, Mass.	X-107	*p-n-p* fused *	1	...	...	2 (25°C)	−30	−60	−1	...	−24	80
	X-120	*p-n-p* fused *	7.5	...	...	15 (25°C)	−30	−60	−4	...	−28	360
Transitron	2N83	*p-n-p* fused ‡	5	15	40	10 (25°C)	−30	−45	−1	200	−20	100
	2N84	*p-n-p* fused ‡	5	10	30	10 (25°C)	−22	−30	−1	200	−20	100
Tung-Sol	DR-150	*p-n-p* fused	...	1	3.5	5 (25°C)	...	−25	−1	250	−15	10
Western Electric	2N66	*p-n-p* fused *	...	...	...	5 (25°C)	−40	−60	−0.8	500	−4.5	100
											−40	0

* Type A sockets.
† Socket types A to H.

Junction-tetrode Transistors

Small-signal low-frequency Parameters								Typical operation	
Bias									
V_c, volts	I_e, ma	I_{b2}, ma	α	r_e, ohms	r_b, ohms	r_c, megohms	I_{cv}, μa	Freq. Mc Circuit *J*	Power-gain at 5 Mc Circuit *K*
4.5	1	0	0.95	30	70	2	10	10–20	12
4.5	1	0	0.97	30	100	2	10	20–35	14
4.5	1	0	0.98	30	200	2	10	35–50	15
4.5	1	0	0.99	30	300	2	10	50–80	17
5	−1	0	0.95	30	1,000	1	10		
9	−2	−4.5	0.90	25	100	1	10	15	
9	−2	0	0.975	25	1,000	1			

Characteristics measured at 25°C.

Power Transistors

low-frequency parameters						Typical operating conditions										
β	r_e, ohms	r_b, ohms	r_c, ohms	C_c, $\mu\mu$f	Rise time, μsec	I_{cv}, μa	Class and circuit	Supply voltage, volts	Coll current, ma	Base current, ma	Zero signal current, ma	Power output, watts	Power gain, db	Driving power, mw	R_c, ohms	R_L, ohms	R_g, ohms
..	...	...	...	...	..	...	B(g-e)	−6	−1,280	...	−5	5 ¶	27				
..	...	...	...	...	..	...	B(g-e)	−6	...	...	...	0.2 ¶	27				
10	...	70	5,000	...	..	...	A	...	−50	...	...	...	30	...	...	5,000	100
9	2	150	100,000	...	..	−500	B(g-b)	−22.5	−40	...	...	0.7 ¶	20				
..	...	...	...	...	1.5	−8,000	A(g-e)	−28	400	50	...	5	15	158	20	70	4
							B(g-e)	−28	510	...	4	10 ¶	12	630	100	140	4
..	...	...	...	...	1.2	−8,000	A(g-e)	−28	500	45	...	6.25	16	156	35	56	4
							B(g-e)	−28	640	...	4	12.5 ¶	13	625	140	128	4
..	...	...	...	...	0.5	−8,000	A(g-e)	−28	600	30	...	7.5	20	75	40	47	4
							B(g-e)	−28	890	...	4	17.5 ¶	16	440	100	80	4
..	...	...	...	...	1.2	−1,000	A(g-e)	−28	150	15	...	1.9	16	48	100	187	4
							B(g-e	−28	220	...	0.5	4.4 ¶	12	278	240	320	4
..	...	...	...	...	0.6	−1,000	A(g-e)	−28	150	10	...	1.9	21	15	60	187	4
							B(g-e)	−28	318	...	0.5	6.25 ¶	14	250	200	224	4
40	1	30	100,000	300	..	−100	A(g-b)	−12	−150	...	...	0.6	23	...	75	100	50
							B(g-e)	−12	−550	...	−1	5 ¶	15	...	50	12	50
							B(g-e)	−12	−550	...	−1	5 ¶	10	...	250	12	100
							B(g-b)	−24	−950	...	−1	10 ¶	10	...	2	24	2
40	1	30	100,000	300	..	100	A(g-b)	12	150	...	...	0.6	23	...	75	100	
							B(g-e)	12	550	...	1	5 ¶	15	...	50	12	
							B(g-e)	12	550	...	1	5 ¶	10	...	250	12	
							B(g-b)	24	950	...	1	10 ¶	10	...	2	24	
9	25	0.75	200,000	...	..	25	B(g-b)	22.5	40	...	...	0.5 ¶	9.5	...	...	1,000	
							B(g-b)	22.5	40	...	...	0.5	22.7	...	...	1,000	
..	...	...	...	...	..	5	B(g-e)	28	30	...	...	0.45 (25°C) ¶	20	...	...	1,500	1,000
..	...	...	...	...	..	...	...	...	...	...	...	0.15 (150°C)					
..	...	...	...	...	..	6	B(g-e)	45	25	...	...	0.6 (25°C) ¶	21	...	...	4,000	1,000
..	...	...	...	...	..	...	...	...	...	...	...	0.15 (150°C)					
..	...	...	...	...	..	8	B(g-e)	67.5	20	...	...	1 (25°C) ¶	23	...	...	8,000	1,000
..	...	...	...	...	..	...	...	...	...	...	...	0.15 (150°C)					
22	0.85	12	50,000	...	..	−120	A(g-b)	−28	−80	...	...	1	24	1	1.5	375	
20	0.65	1	10,000	...	..	−200	A(g-b)	−28	−360	...	...	5	20	50	0.8	100	
8	0.3	15	20,000	400	1.5	−100	B(g-e)	−30	−160	..	...	2.5 ¶	24	...	...	600	100
12	0.3	15	20,000	400	1.5	−100	B(g-e)	−20	−160	...	...	2.0 ¶	22	...	...	400	100
33	...	...	30,000														
45	...	...	...	400	..	75											
..	...	...	...	...	..	300											

‡ Socket types A and K.
¶ Push-pull connection.

Table 9-11. Point-

Manufacturer	Type No.	Application	Max coll power, mw	Max coll voltage, volts	Max coll current, ma	Max reverse emitter voltage, volts	Max emitter current, ma	Max emitter power, mw
Hydro-Aire	A-0	Amp, osc	0 (25°C)	−20	−8	...	...	...
	A-1	Amp, osc	50 (25°C)	−20	−8	...	...	...
	A-2	Amp, osc	50 (25°C)	−20	−8	...	...	...
	A-3	Amp, osc	50 (25°C)	−20	−8	...	...	...
	S-0	Switching	50 (25°C)	−40	−8	−30	...	...
	S-1	Switching	50 (25°C)	−40	−8	−30	...	...
	S-2	Switching	50 (25°C)	−30	−8	−30	...	...
Sprague Electric	5A	Switching	80 (25°C)	−50	−10	−50	...	...
Transistor Prod.	2A	Amp, osc, sw	120 (25°C)	−50	−8	−50		
	2C	Switching [a]	100 (25°C)	−50	−8	−50		
	2D	Amp, osc [a]	100 (25°C)	−50	−8	−50		
	2E	Amplifier [a]	100 (25°C)	−50	−8	−50		
	2G	Switching [a]	120 (25°C)	−50	−8	−50		
	2H	Amplifier [a]	100 (25°C)	−50	−8	−50		
	2L	Switching [a]	50 (25°C)	−50	−8	−50		
	2N32	Switching [a]	50 (25°C)	−40	−8	−40		
	2N33	Switching [a]	30 (25°C)	−8.5	−7			
	2N50	Switching [a]	50 (25°C)	−15	−1	−15		
	2N51	Sw, osc [a]	100 (25°C)	−50	−8	−50		
	2N52	Amp, osc [a]	120 (25°C)	−50	−8	−50		
	2N53	Switching [a]	120 (25°C)	−50	−8	−50		
Western Electric	2N21	Switching	120 (25°C)	−100	−60	−100	60	80 (25°C) [b]
	2N21A	Amp, osc, sw	120 (25°C)	−100	−60	−100	60	80 (25°C) [b]
	2N110	Switching	200 (25°C)	−100	−75	−100	75	100 (25°C) [b]
	2N67	High-speed sw	100 (25°C)	−100	−60	−100	60	60 (25°C) [b]

Socket types A to H unless otherwise noted.
[a] Socket types A and L
Maximum ambient temperature 50°C unless otherwise noted.
[b] Maximum ambient temperature 85°C.
Characteristics of A-0, A-1, A-2, A-3, 2N21, 2N21A, 2N110 and 2N67 measured at 25°C.

Parameter Conversion Formulas

$$H_{21} = \frac{R_{21}}{R_{22}} = -\alpha$$

$$H_{11} = R_{11} - \frac{R_{21}R_{12}}{R_{22}} \doteq r_e + (1 - \alpha)r_b$$

$$H_{12} = \frac{R_{12}}{R_{22}} \doteq \frac{r_b}{r_c}$$

$$H_{22} = \frac{1}{R_{22}} \doteq \frac{1}{r_c}$$

$$r_c = \frac{1}{H_{22}}$$

$$r_b = r_c H_{12}$$

$$|\alpha| = |H_{21}|$$

$$r_e = H_{11} - r_b(1 - \alpha)$$

Transistor Sockets

	Code Manufacturer	*Type*
A	Solder connections	.....
B	Elco Corp.	3-pin polarized 3-pin printed-circuit
C	Cinch Mfg. Corp.	3-pin polarized
D	Super-Ear Prod. Co.	3-pin polarized
E	Mycalex Tube Socket Corp.	3-pin polarized
F	Elco Corp.	4-pin polarized 4-pin printed-circuit
G	Super-Ear Prod. Co.	5-pin
H	Elco Corp.	5-pin 5-pin printed-circuit
I	Super-Ear Prod. Co.	3-pin equal spacing
J	Cinch Mfg. Corp.	5-pin
K	Amphenol Co.	.....
L	Cinch Mfg. Corp.	.....
M	Cinch Mfg. Corp.	4-pin polarized

contact Transistors

Small-signal low-frequency parameters										Large-signal parameters					
Bias															
V_c, volts	I_e, ma	$-\alpha$	r_e, ohms	r_b, ohms	r_c, ohms	$f_{\alpha co}$, Mc	C_c, μμf	NF, db	I_{co}, μa	Rise time, μsec	Turnoff time μsec	Off I_c, ma	On V_c, volts	Emitter rev resist., ohms	α (at max rise time)
−8	0.3	2	425	200	13,000	3	....	.....	−1,200						
−8	0.3	2	425	200	13,000	2	....	.....	−1,500						
−8	0.3	2	375	175	13,000	1	....	.....	−2,000						
−8	0.3	2	350	150	13,000	0.3	....	.....	−2,000						
....	...	....	...	...	.....	....	....	.....	...	0.2 [c]	...	−1	−2	50,000	
....	...	....	...	...	.....	....	....	.....	...	0.5 [d]	...	−1	−2	50,000	
....	...	....	...	...	.....	....	....	.....	...	1 [e]	...	−1	−2	50,000	
−10	1	3	...	...	.....	5	....	43	...	0.12	0.5				
−10	1	2.5 [f]	200	90	10,000	2	....	45	−1.1	0.2	1.3	−1.1	−1	200,000	5
−10	1	2.5 [f]	200	90	10,000	2	....	45	−1.1	0.2	1.3	−1.1	−1	200,000	5
−10	1	2.5 [f]	200	90	15,000	1.5	....	.....	−0.9	0.3	1.3	−0.9	−1	200,000	4
−10	1	3	900	500	20,000	20	....	.....	−0.9	0.02	0.9	−0.9	−0.8	2,000,000	7

[c] Fall time = 1 μsec.
[d] Fall time = 2 μsec.
[e] Fall time = 6 μsec.
[f] Large-signal α = 2.4.

Table 9-12. Phototransistors

Manufacturer	Type No.	Type	Max coll voltage, volts	Max coll current, ma	Max coll power, mw	Max dark current, μa	Max ambient temp., °C	Cutoff freq., kc	Noise, ft-c	Sensitivity, μa/ft-c
General Transistor	GT-66	Fused, 3 lead *	12	20	50 (25°C)	15	..	750	6×10^{-5}	25
Texas Inst.	800	Grown, 2 lead †	20	20	50 (25°C)	250	40	20	.....	35
Transistor Prod.	1N188	Grown, 2 lead	100	..	40 (25°C)	.....	50	...	3–10 μv	10 μa/millilumen
	1N189	Nonrect, 2 lead	...	..	30 (25°C)	20	50	...	.....	0.08%/ft-c
	10A	Grown, 2 lead	15	..	100 (25°C)	500	50	...	15–100 μv	4 ma for 300 ft-c
	10B	Grown, 2 lead	15	..	100 (25°C)	50	50	...	15–100 μv	50% for 10 ft-c
	5B	Grown, 2 lead	50	..	100 (25°C)	20	50	...	3–10 μv	1 ma for 300 ft-c
	5C	Grown, 2 lead	50	..	100 (25°C)	5	50	...	3–10 μv	50% for 40 ft-c
	11A	Nonrect, 2 lead	15	..	50 (25°C)	4,000 ohms	50	...	.....	2,000 ohms for 300 ft-c
	11B	Nonrect, 2 lead	15	..	50 (25°C)	4,000 ohms	50	...	.....	3,000 ohms for 300 ft-c
	17A	Grown, 2 lead	..	..	.....	...	..	...	Be ow 1 μv	
Western Electric	1N85	Grown, 2 lead *	90	1	50	20	85	25	2×10^{-6} μa	0.35 μa/μw

* Socket type A.
† Socket type A to H.

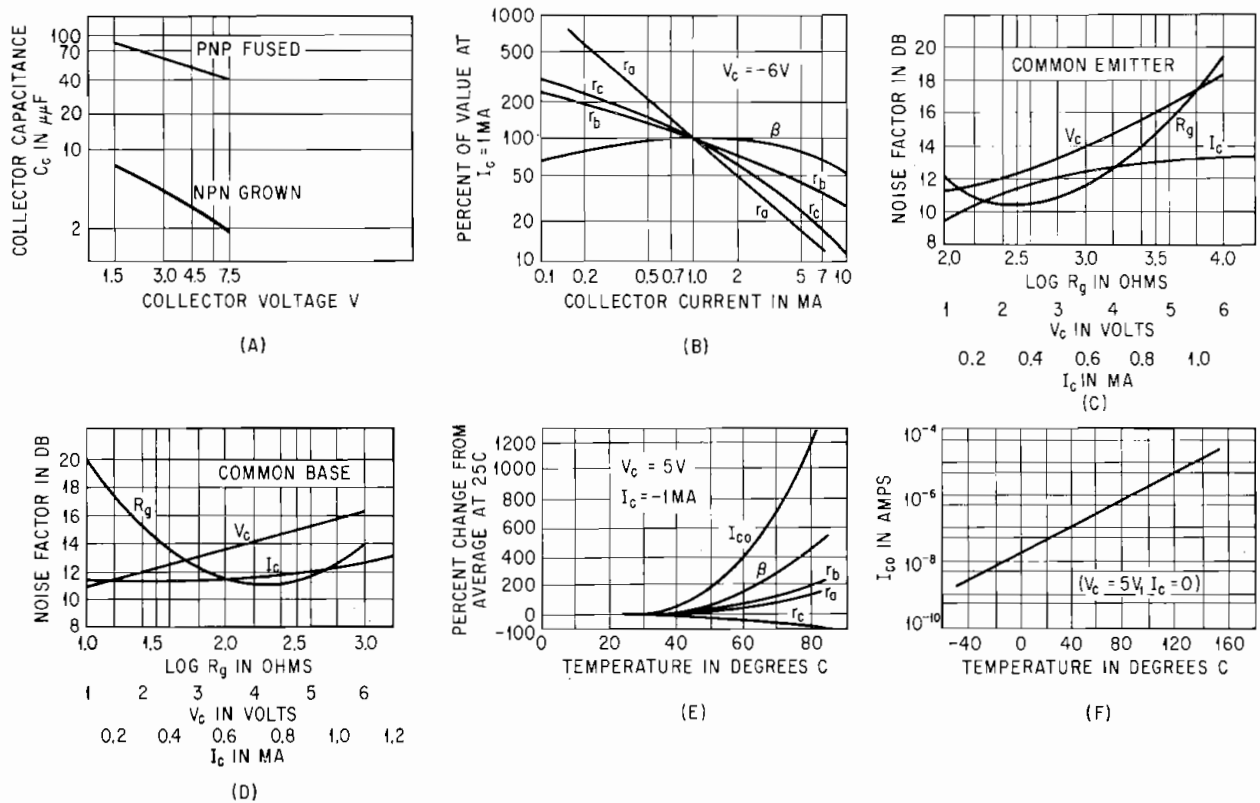


FIG. 9-26. Variation of transistor parameters with operating point (*A* to *D*) and ambient temperature (*E*, *F*).

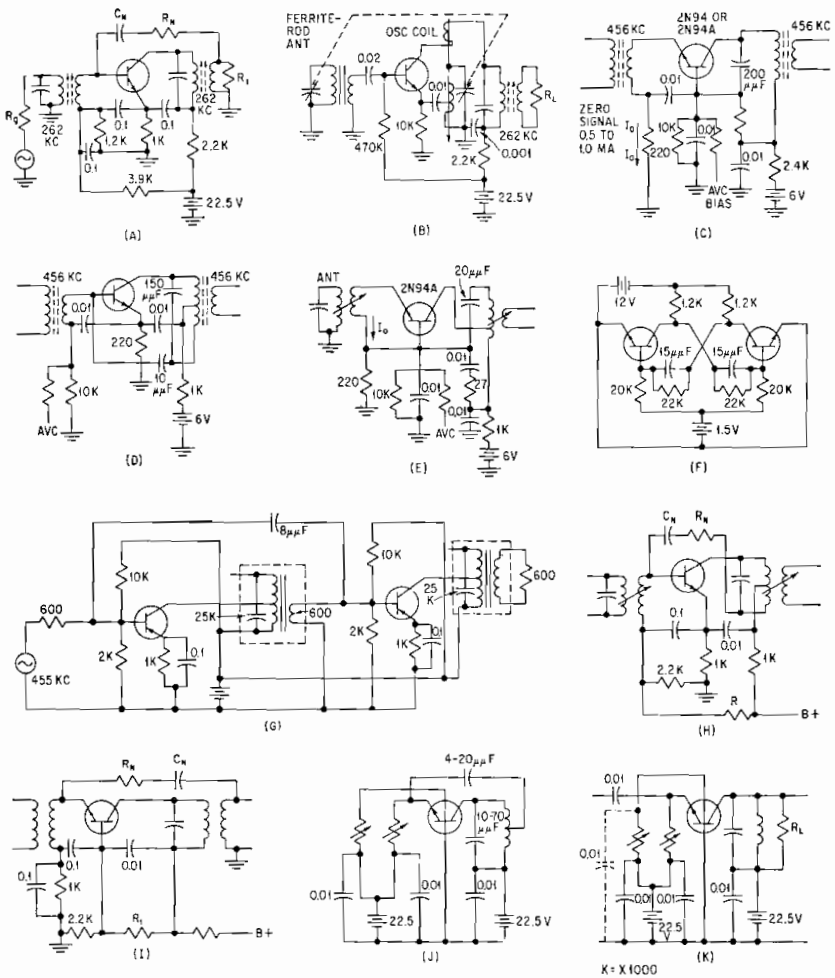


FIG. 9-27. Typical circuits for high-frequency transistors (*A* to *I*) and junction tetrode transistors (*J*, *K*) referred to in Tables 9-8 and 9-9.

Table 9-13. NAB Data Concerning Tower Failures

Information obtained from 298 television stations during 1958 indicated that 11 towers failed for various reasons. Briefly, 6 towers failed because of high winds, 2 fell during construction, and 3 failed because of structural weakness or faulty design. The following is a detailed breakdown of these 11 failures:

Height, ft	*Type*	*Weather conditions*	*Cause and comments*
826	SS	High wind	Broke in half during high wind
487	SS	97-mph wind	Failed at 125 ft above ground in wind
370	SS	Est. wind 190 knots	Due to gusty turbulence
570	SS	Hurricane "Carol"	Broke off TV tower at 200-ft level, Aug. 31, 1954
1250	G	50- to 60-mph winds	"Tower was completed to the 1,250 point. However, the top set of guys were not completely installed and in the process of tensioning these guys, high winds came up (50 to 60 m.p.h.), the unguyed portion of the tower began to oscillate, finally broke off at the 1150′ point and in falling, cut a permanent guy at the 1000′ level which in turn caused the entire structure to fail."
100	G	High winds	During process of erecting, 100 ft had been erected and temporary guy lines attached. Under high winds the temporary lines failed
450	SS	40-mile squall	Faulty design of tower
500	G	High level winds	Structural weakness
1262	G	.....	Fell during erection, Feb. 4, 1957
649	G	.....	Due to excessive strain during the process of attempting to lower a 12-bay antenna from it all at once. Actual cause of collapse not known, but it is not believed to have been caused by tower weakness
550	G	.....	Collapsed during construction. Cause not fully determined, but accident was during guy tensioning

Table 9-14. Decimal Equivalents

1/32	0.03125	17/32	0.53125
1/16	0.0625	9/16	0.5625
3/32	0.09375	19/32	0.59375
1/8	0.125	5/8	0.625
5/32	0.15625	21/32	0.65625
3/16	0.1875	11/16	0.6875
7/32	0.21875	23/32	0.71875
1/4	0.25	3/4	0.75
9/32	0.28125	25/32	0.78125
5/16	0.3125	13/16	0.8125
11/32	0.34375	27/32	0.84375
3/8	0.375	7/8	0.875
13/32	0.40625	29/32	0.90625
7/16	0.4375	15/16	0.9375
15/32	0.46875	31/32	0.96875
1/2	0.5	1.0	1.0

Table 9-15. Standard Metal Gauges

No.	*American or B & S* *	*U.S. Standard* †	*Birmingham or Stubs* ‡
1	0.2893	0.28125	0.300
2	0.2576	0.265625	0.284
3	0.2294	0.250	0.259
4	0.2043	0.234375	0.238
5	0.1819	0.21875	0.220
6	0.1620	0.203125	0.203
7	0.1443	0.1875	0.180
8	0.1285	0.171875	0.165
9	0.1144	0.15625	0.148
10	0.1019	0.140625	0.134
11	0.09074	0.1250	0.120
12	0.08081	0.109375	0.109
13	0.07196	0.09375	0.095
14	0.06408	0.078125	0.083
15	0.05707	0.0703125	0.072
16	0.05082	0.0625	0.065
17	0.04526	0.05625	0.058
18	0.04030	0.050	0.049
19	0.03589	0.04375	0.042
20	0.03196	0.0375	0.035
21	0.02846	0.034375	0.032
22	0.02535	0.03125	0.028
23	0.02257	0.028125	0.025
24	0.02010	0.025	0.022
25	0.01790	0.021875	0.020
26	0.01594	0.01875	0.018
27	0.01420	0.0171875	0.016
28	0.01264	0.015625	0.014
29	0.01126	0.0140625	0.013
30	0.01003	0.0125	0.012
31	0.008928	0.0109375	0.010
32	0.007950	0.01015625	0.009
33	0.007080	0.009375	0.008
34	0.006350	0.00859375	0.007
35	0.005615	0.0078125	0.005
36	0.005000	0.00703125	0.004
37	0.004453	0.006640626	
38	0.003965	0.00625	
39	0.003531		
40	0.003145		

* Used for copper, brass, aluminum, etc.; nonferrous alloy sheets, rods, and wire.
† Used for iron, steel, nickel, and ferrous alloy materials.
‡ Used for seamless tubes and by some manufacturers for brass and copper materials.

Table 9-16. Drill Sizes

Number	*Will clear screw*	*Brass, iron, steel tapping* *
1		
2	12–24	
3	. . . . .	14–24
4	12–20	
5		
6		
7		
8		
9		
10	10–32	
11	10–24	
12		
13		
14		
15		
16	. . . . .	12–24
17		
18	8–32	
19	. . . . .	12–20
20		
21	. . . . .	10–32
22		
23		
24		
25	. . . . .	10–24
26		
27		
28	6–32	
29	. . . . .	8–32
30		
31		
32		
33	4–36, 4–40	
34		
35	. . . . .	6–32
36		
37		
38		
39	3–48	
40		
41		
42	. . . . .	4–36, 4–40
43	2–56	
44		
45	. . . . .	3–48
46		
47		
48		
49	. . . . .	2–56
50		
51		
52		
53		
54		

* For tapping plastic, bakelite, lucite, hard rubber, micalex, etc., use one size larger drill.

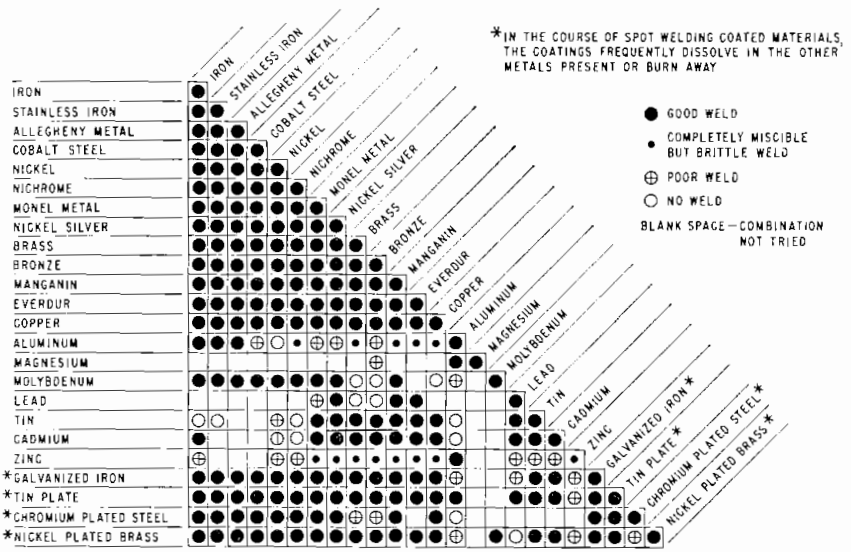


FIG. 9-28. The welding characteristics of some 250 combinations of metals.

STANDARD SYMBOLS FOR ELECTRONICS

The most-used schematic symbols for electronic components are collected here for convenient reference, as abstracted from the 54-page American Standards Association publication Y32.2-1954, "Graphical Symbols for Electrical Diagrams" and (for transistors) from MIL-STD-15A, "Military Standard Electrical and Electronic Symbols." (See Figs. 9-29*a*, 9-29*b*, and 9-29*c*.)

Symbols may have any orientation, size, and line weight. The open-circle terminal symbol can be added to leads if desired. Arrowheads can be either filled or open unless otherwise noted. Electrically actuated devices are normally shown in the power-off position. One-line symbolism has been adopted for waveguide diagrams, as indicated for microwave symbols.

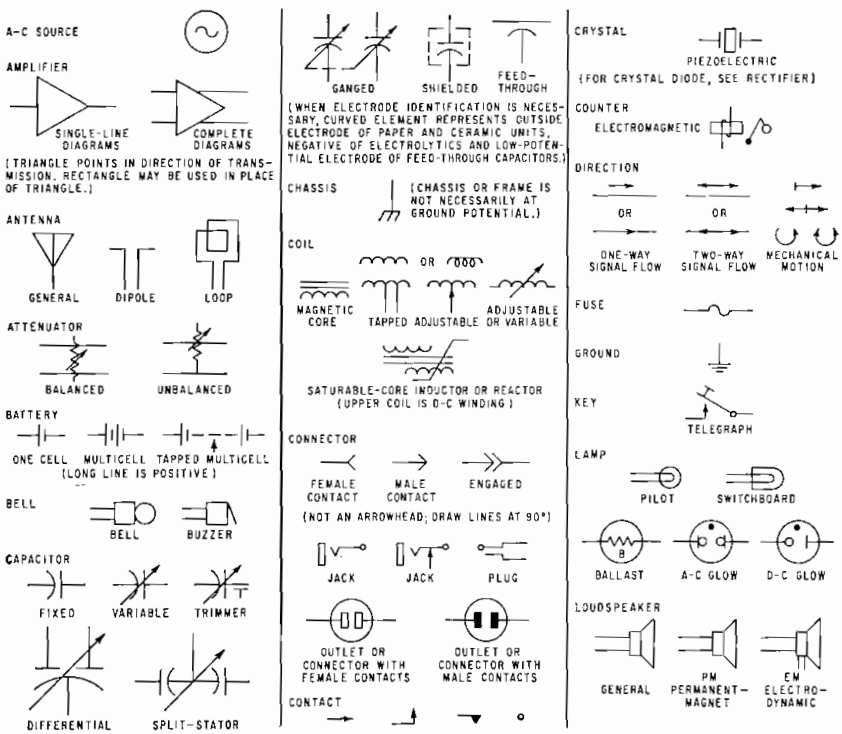


FIG. 9-29*a*

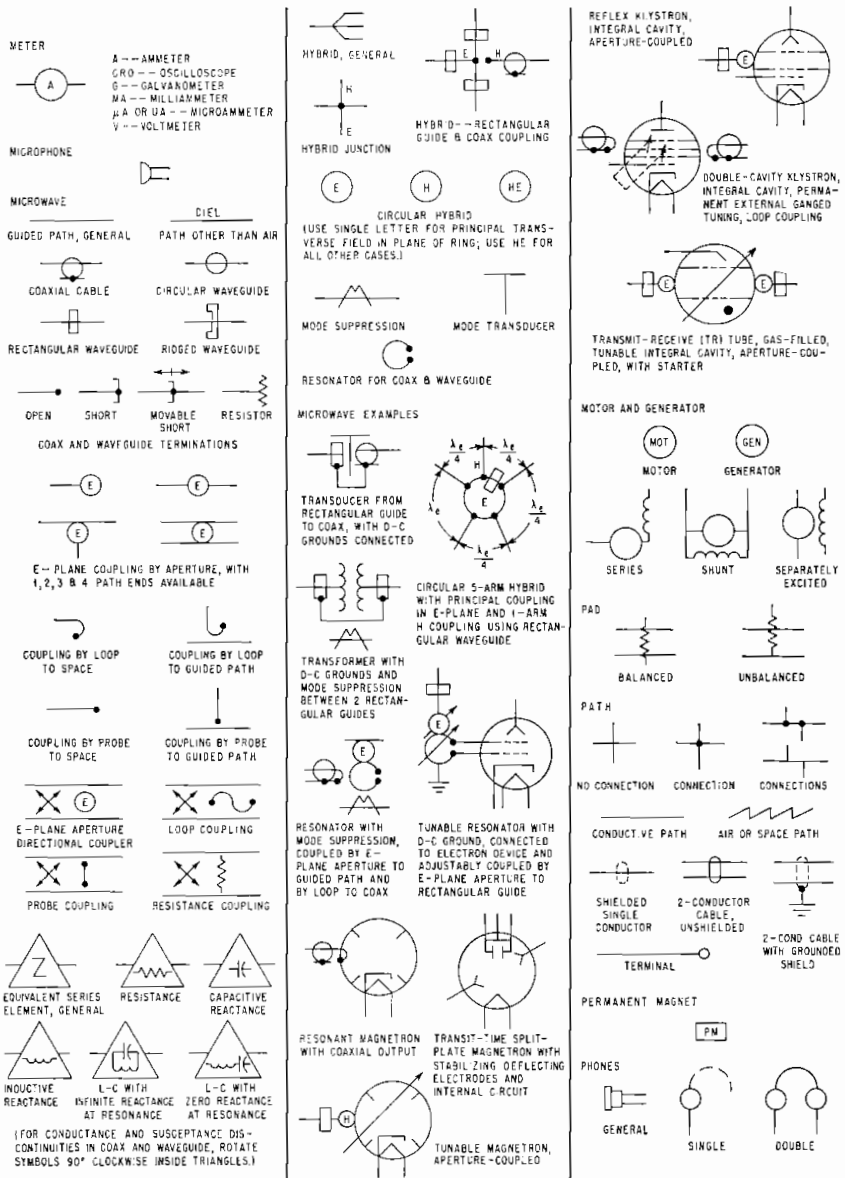

METER
A
A – – AMMETER
CRO – – OSCILLOSCOPE
G – – GALVANOMETER
MA – – MILLIAMMETER
μA OR UA – – MICROAMMETER
V – – VOLTMETER
MICROPHONE
MICROWAVE
GUIDED PATH, GENERAL
DIEL
PATH OTHER THAN AIR
COAXIAL CABLE
CIRCULAR WAVEGUIDE
RECTANGULAR WAVEGUIDE
RIDGED WAVEGUIDE
OPEN
SHORT
MOVABLE SHORT
RESISTOR
COAX AND WAVEGUIDE TERMINATIONS
E
E – PLANE COUPLING BY APERTURE, WITH 1, 2, 3 & 4 PATH ENDS AVAILABLE
COUPLING BY LOOP TO SPACE
COUPLING BY LOOP TO GUIDED PATH
COUPLING BY PROBE TO SPACE
COUPLING BY PROBE TO GUIDED PATH
E – PLANE APERTURE DIRECTIONAL COUPLER
LOOP COUPLING
PROBE COUPLING
RESISTANCE COUPLING
Z
EQUIVALENT SERIES ELEMENT, GENERAL
RESISTANCE
CAPACITIVE REACTANCE
INDUCTIVE REACTANCE
L–C WITH INFINITE REACTANCE AT RESONANCE
L–C WITH ZERO REACTANCE AT RESONANCE
(FOR CONDUCTANCE AND SUSCEPTANCE DISCONTINUITIES IN COAX AND WAVEGUIDE, ROTATE SYMBOLS 90° CLOCKWISE INSIDE TRIANGLES.)
HYBRID, GENERAL
H
E
HYBRID JUNCTION
E
H
HYBRID – – RECTANGULAR GUIDE & COAX COUPLING
E
H
HE
CIRCULAR HYBRID
(USE SINGLE LETTER FOR PRINCIPAL TRANSVERSE FIELD IN PLANE OF RING; USE HE FOR ALL OTHER CASES.)
MODE SUPPRESSION
MODE TRANSDUCER
RESONATOR FOR COAX & WAVEGUIDE
MICROWAVE EXAMPLES
TRANSDUCER FROM RECTANGULAR GUIDE TO COAX, WITH D–C GROUNDS CONNECTED
CIRCULAR 5–ARM HYBRID WITH PRINCIPAL COUPLING IN E–PLANE AND 1–ARM H COUPLING USING RECTANGULAR WAVEGUIDE
TRANSFORMER WITH D–C GROUNDS AND MODE SUPPRESSION BETWEEN 2 RECTANGULAR GUIDES
RESONATOR WITH MODE SUPPRESSION, COUPLED BY E–PLANE APERTURE TO GUIDED PATH AND BY LOOP TO COAX
TUNABLE RESONATOR WITH D–C GROUND, CONNECTED TO ELECTRON DEVICE AND ADJUSTABLY COUPLED BY E–PLANE APERTURE TO RECTANGULAR GUIDE
RESONANT MAGNETRON WITH COAXIAL OUTPUT
TRANSIT–TIME SPLIT–PLATE MAGNETRON WITH STABILIZING DEFLECTING ELECTRODES AND INTERNAL CIRCUIT
TUNABLE MAGNETRON, APERTURE–COUPLED
REFLEX KLYSTRON, INTEGRAL CAVITY, APERTURE–COUPLED
DOUBLE–CAVITY KLYSTRON, INTEGRAL CAVITY, PERMANENT EXTERNAL GANGED TUNING, LOOP COUPLING
TRANSMIT–RECEIVE (TR) TUBE, GAS–FILLED, TUNABLE, INTEGRAL CAVITY, APERTURE–COUPLED, WITH STARTER
MOTOR AND GENERATOR
MOT
GEN
MOTOR
GENERATOR
SERIES
SHUNT
SEPARATELY EXCITED
PAD
BALANCED
UNBALANCED
PATH
NO CONNECTION
CONNECTION
CONNECTIONS
CONDUCTIVE PATH
AIR OR SPACE PATH
SHIELDED SINGLE CONDUCTOR
2–CONDUCTOR CABLE, UNSHIELDED
2–COND CABLE WITH GROUNDED SHIELD
TERMINAL
PERMANENT MAGNET
PM
PHONES
GENERAL
SINGLE
DOUBLE

FIG. 9-29*b*

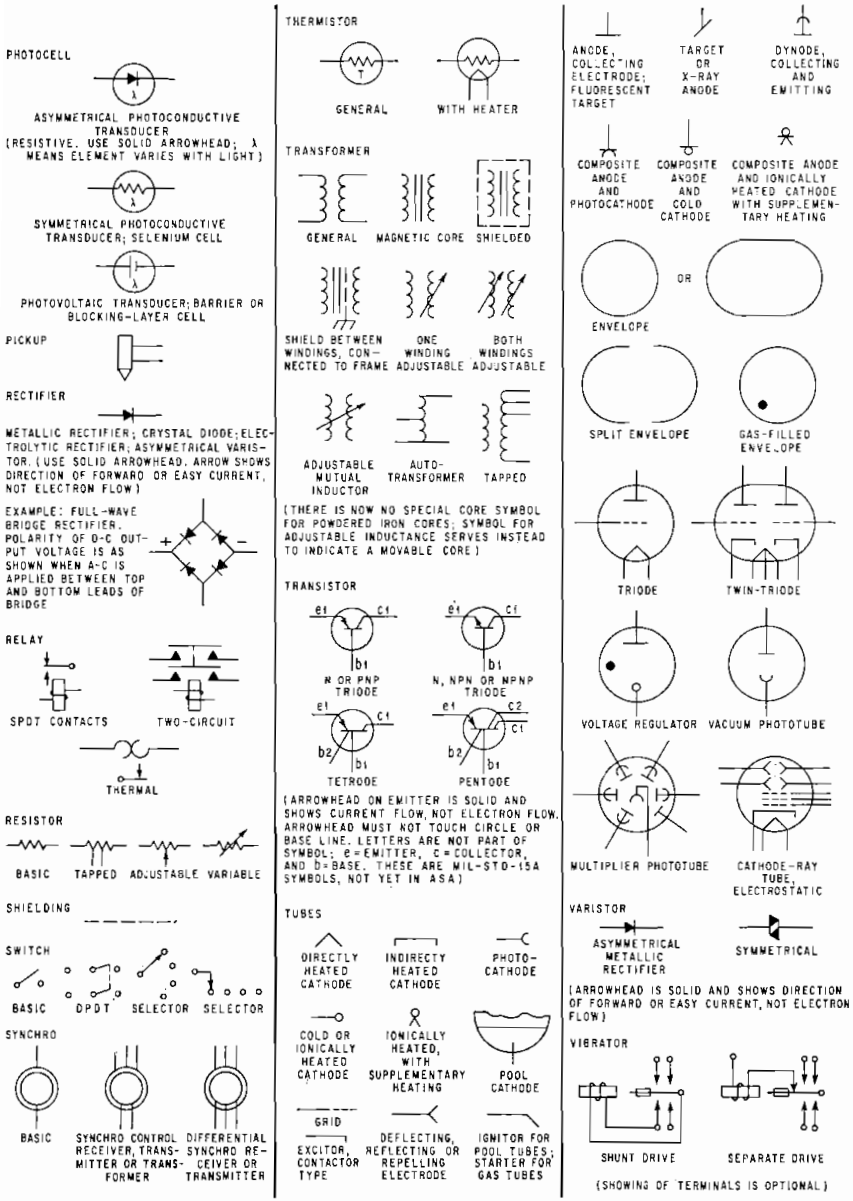

PHOTOCELL
ASYMMETRICAL PHOTOCONDUCTIVE TRANSDUCER (RESISTIVE. USE SOLID ARROWHEAD; λ MEANS ELEMENT VARIES WITH LIGHT)
SYMMETRICAL PHOTOCONDUCTIVE TRANSDUCER; SELENIUM CELL
PHOTOVOLTAIC TRANSDUCER; BARRIER OR BLOCKING-LAYER CELL
PICKUP
RECTIFIER
METALLIC RECTIFIER; CRYSTAL DIODE; ELECTROLYTIC RECTIFIER; ASYMMETRICAL VARISTOR. (USE SOLID ARROWHEAD. ARROW SHOWS DIRECTION OF FORWARD OR EASY CURRENT, NOT ELECTRON FLOW.)
EXAMPLE: FULL-WAVE BRIDGE RECTIFIER. POLARITY OF D-C OUTPUT VOLTAGE IS AS SHOWN WHEN A-C IS APPLIED BETWEEN TOP AND BOTTOM LEADS OF BRIDGE
RELAY
SPDT CONTACTS
TWO-CIRCUIT
THERMAL
RESISTOR
BASIC
TAPPED
ADJUSTABLE
VARIABLE
SHIELDING
SWITCH
BASIC
DPDT
SELECTOR
SELECTOR
SYNCHRO
BASIC
SYNCHRO CONTROL RECEIVER, TRANSMITTER OR TRANSFORMER
DIFFERENTIAL SYNCHRO RECEIVER OR TRANSMITTER
THERMISTOR
GENERAL
WITH HEATER
TRANSFORMER
GENERAL
MAGNETIC CORE
SHIELDED
SHIELD BETWEEN WINDINGS, CONNECTED TO FRAME
ONE WINDING ADJUSTABLE
BOTH WINDINGS ADJUSTABLE
ADJUSTABLE MUTUAL INDUCTOR
AUTO-TRANSFORMER
TAPPED
(THERE IS NOW NO SPECIAL CORE SYMBOL FOR POWDERED IRON CORES; SYMBOL FOR ADJUSTABLE INDUCTANCE SERVES INSTEAD TO INDICATE A MOVABLE CORE.)
TRANSISTOR
e1
c1
b1
P OR PNP TRIODE
N, NPN OR NPNP TRIODE
c2
b2
TETRODE
PENTODE
(ARROWHEAD ON EMITTER IS SOLID AND SHOWS CURRENT FLOW, NOT ELECTRON FLOW. ARROWHEAD MUST NOT TOUCH CIRCLE OR BASE LINE. LETTERS ARE NOT PART OF SYMBOL; e = EMITTER, c = COLLECTOR, AND b = BASE. THESE ARE MIL-STD-15A SYMBOLS, NOT YET IN ASA.)
TUBES
DIRECTLY HEATED CATHODE
INDIRECTLY HEATED CATHODE
PHOTO-CATHODE
COLD OR IONICALLY HEATED CATHODE
IONICALLY HEATED, WITH SUPPLEMENTARY HEATING
POOL CATHODE
GRID
EXCITOR, CONTACTOR TYPE
DEFLECTING, REFLECTING OR REPELLING ELECTRODE
IGNITOR FOR POOL TUBES; STARTER FOR GAS TUBES
ANODE, COLLECTING ELECTRODE; FLUORESCENT TARGET
TARGET OR X-RAY ANODE
DYNODE, COLLECTING AND EMITTING
COMPOSITE ANODE AND PHOTOCATHODE
COMPOSITE ANODE AND COLD CATHODE
COMPOSITE ANODE AND IONICALLY HEATED CATHODE WITH SUPPLEMENTARY HEATING
OR
ENVELOPE
SPLIT ENVELOPE
GAS-FILLED ENVELOPE
TRIODE
TWIN-TRIODE
VOLTAGE REGULATOR
VACUUM PHOTOTUBE
MULTIPLIER PHOTOTUBE
CATHODE-RAY TUBE, ELECTROSTATIC
VARISTOR
ASYMMETRICAL METALLIC RECTIFIER
SYMMETRICAL
(ARROWHEAD IS SOLID AND SHOWS DIRECTION OF FORWARD OR EASY CURRENT, NOT ELECTRON FLOW.)
VIBRATOR
SHUNT DRIVE
SEPARATE DRIVE
(SHOWING OF TERMINALS IS OPTIONAL.)

FIG. 9-29*c*

Table 9-17. Standard Telephone-cable Color Code

Pair No.	*Color*	*Mate*	*Pair No.*	*Color*	*Mate*
1	Blue	White	26	Blue White	Red
2	Orange	White	27	Blue Orange	Red
3	Green	White	28	Blue Green	Red
4	Brown	White	29	Blue Brown	Red
5	Slate	White	30	Blue Slate	Red
6	Blue White	White	31	Orange White	Red
7	Blue Orange	White	32	Orange Green	Red
8	Blue Green	White	33	Orange Brown	Red
9	Blue Brown	White	34	Orange Slate	Red
10	Blue Slate	White	35	Green White	Red
11	Orange White	White	36	Green Brown	Red
12	Orange Green	White	37	Green Slate	Red
13	Orange Brown	White	38	Brown White	Red
14	Orange Slate	White	39	Brown Slate	Red
15	Green White	White	40	Slate White	Red
16	Green Brown	White	41	Blue	Black
17	Green Slate	White	42	Orange	Black
18	Brown White	White	43	Green	Black
19	Brown Slate	White	44	Brown	Black
20	Slate White	White	45	Slate	Black
21	Blue	Red	46	Blue White	Black
22	Orange	Red	47	Blue Orange	Black
23	Green	Red	48	Blue Green	Black
24	Brown	Red	49	Blue Brown	Black
25	Slate	Red	50	Blue Slate	Black

NOTE: The last pair in all cables is a red with white mate, viz.,

6-pair cable	6th pair	Red	White
11-pair cable	11th pair	Red	White
16-pair cable	16th pair	Red	White
26-pair cable	26th pair	Red	White
51-pair cable	51st pair	Red	White

RESISTOR COLOR CODE

The chart shown in Fig. 9-30*a* indicates the appropriate significant figure of resistance and the multiplier. The fourth colored band, if any, indicates the tolerance. If none is shown, the tolerance is 20 per cent, with other tolerances as follows: gold, 5 per cent; silver, 10 per cent.

CAPACITOR COLOR CODE

The value of capacitors is similarly shown by colored bands or dots as indicated in Figs. 9-30*a* and 9-30*b*. Note that the bands and dots (for disc ceramics) apply for the ceramic-type capacitors, while the various dot systems are applicable to mica- and paper-type condensers. The various systems that have been used in recent years are included, even though some of them are obsolete. The tolerances are indicated by the appropriate colored dot, and the voltage rating is obtained by multiplying the value of the appropriate dot by 100.

STANDARD COLOR CODE — RESISTORS AND CAPACITORS

INSULATED UNINSULATED COLOR	FIRST RING BODY COLOR FIRST FIGURE	SECOND RING END COLOR SECOND FIGURE	THIRD RING DOT COLOR MULTIPLIER
BLACK	0	0	NONE
BROWN	1	1	0
RED	2	2	00
ORANGE	3	3	,000
YELLOW	4	4	0,000
GREEN	5	5	00,000
BLUE	6	6	,000,000
VIOLET	7	7	0,000,000
GRAY	8	8	00,000,000
WHITE	9	9	000,000,000

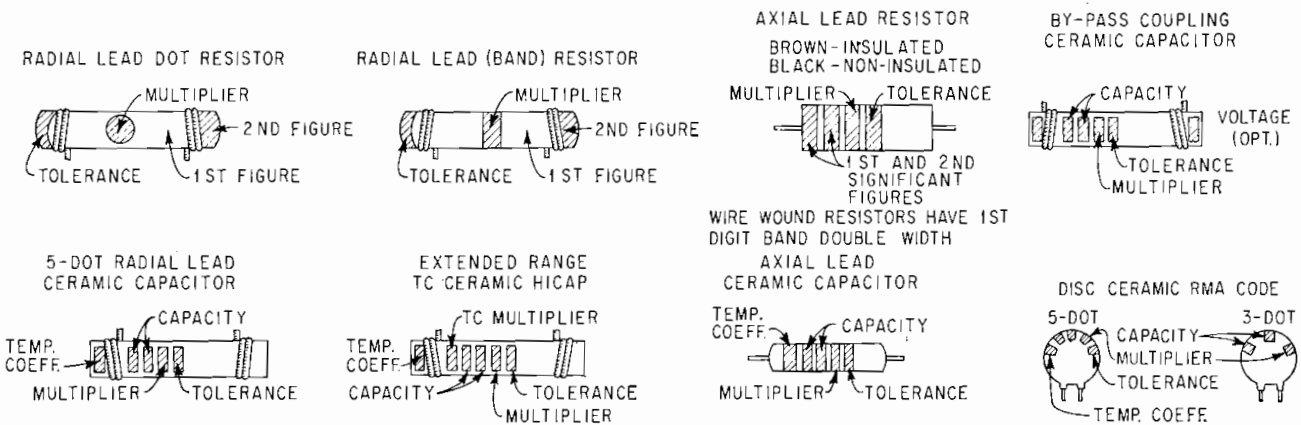


FIG. 9-30*a*. Standard color code—resistors and capacitors.

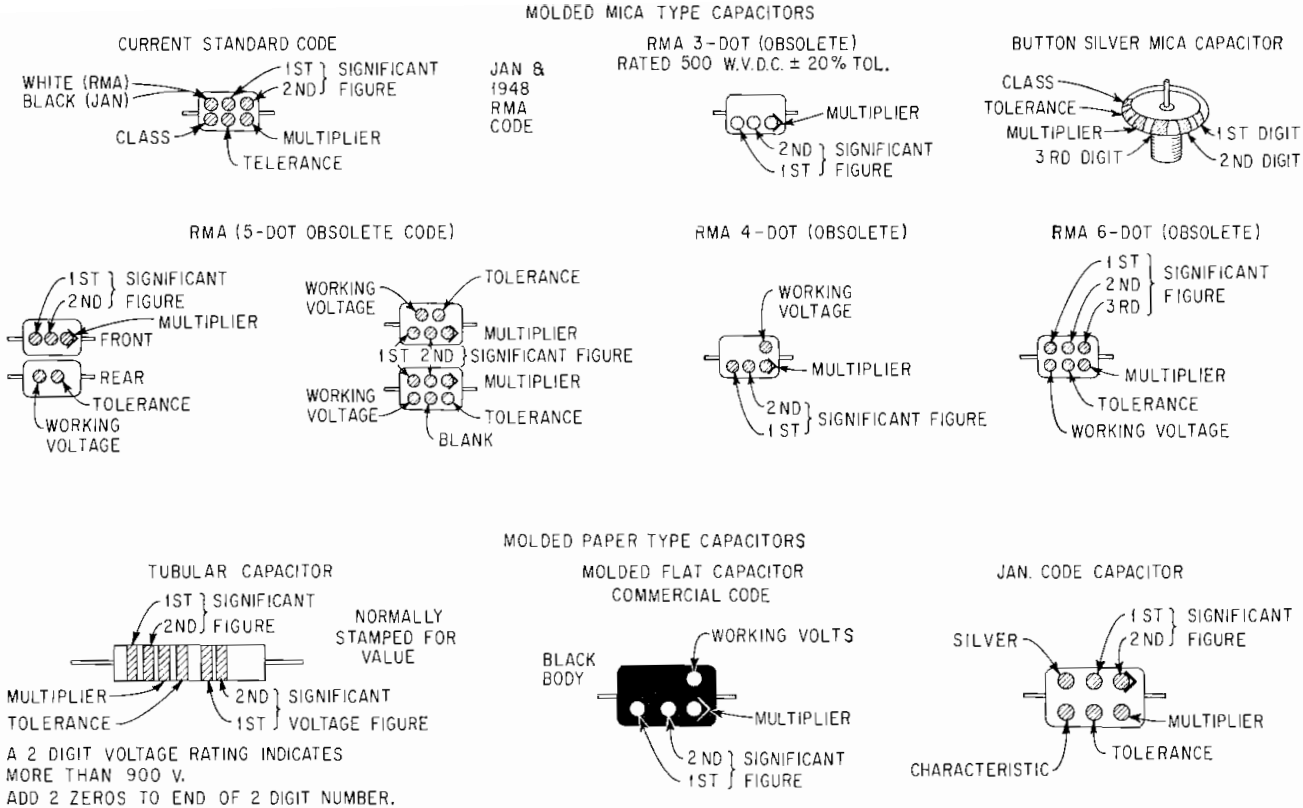


FIG. 9-30*b*. Standard color code.

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