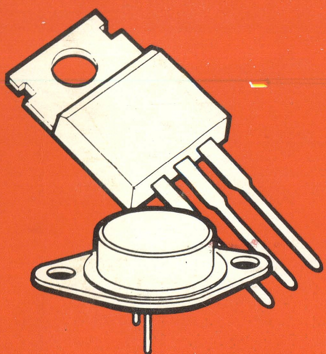
RCA Solid State

DATABOOK Series

SSD-204A

Power Transistors
and Power Hybrid Circuits

Selection Guide
Data
Application Notes



$2.00 Optional Price

1973 Edition

RCA Solid State
DATABOOK Series

Power Transistors and Power Hybrid Circuits

This DATABOOK contains complete data and related application notes on power transistors and power hybrid circuits presently available from RCA Solid State Division as standard products. For ease of type selection, product matrix charts for major power-transistor categories are given on pages 10–18. Data sheets are then grouped in the following categories: (a) hometaxial-base n-p-n power transistors, (b) epitaxial-base n-p-n and p-n-p power transistors, (c) high-voltage n-p-n power transistors, (d) high-speed switching power transistors, (e) other p-n-p power transistors, (f) monolithic n-p-n Darlington power transistors, (g) diffused-junction n-p-n silicon transistors, (h) special audio power transistors, (i) power-transistor chips, (j) power hybrid circuits. Application notes are included in numerical order following the data sheets.

A feature of this DATABOOK is the complete Guide to RCA Solid State Devices at the back of the book. This section includes a developmental-to-commercial-number cross-reference index, a comprehensive subject index, and a complete index to all standard devices in the solid-state product line: linear integrated circuits, MOS field-effect (MOS/FET) devices, COS/MOS integrated circuits, power transistors, power hybrid circuits, rf power devices, thyristors, rectifiers, and diacs. All listings include references to volume number and page number in the 1973 DATABOOK series.

Printed in Western Germany/12-72

RCA Solid State | Box 3200 | Somerville, N. J., U.S.A. 08876
RCA Limited | Sunbury-on-Thames | Middlesex TW16 7HW, England
RCA s.a. | 4400 Herstal | Liege, Belgium

RCA Solid State Total Data Service System

The RCA Solid State DATABOOKS are supplemented throughout the year by a comprehensive data service system that keeps you aware of all new device announcements and lets you obtain as much or as little product information as you need – when you need it.

New solid-state devices and related publications announced during the year are described in a monthly newsletter entitled "What's New in Solid State". If you obtained your DATABOOK(s) directly from RCA, your name is already on the mailing list for this newsletter. If you obtained your book(s) from a source other than RCA and wish to receive the newsletter, please fill out the form on page 4, detach it, and mail it to RCA.

Each newsletter issue contains a "bingo"-type fast-response form for your use in requesting information on new devices of interest to you. If you wish to receive all new product information published throughout the year, you may subscribe to a mailing service which will bring you all new data sheets, application notes, and product guides in a package every other month. You can also obtain a binder for easy filing of all your supplementary material. Provisions for obtaining information on the update mailing service and the binder are included in the order form on page 4.

Because we are interested in your reaction to this approach to data service, we invite you to add your comments to the form when you return it, or to send your remarks to one of the addresses listed at the top of the form. We solicit your constructive criticism to help us improve our service to you.

Index to Power Transistors and Power Hybrid Circuits

Type No.	Collector-to-Base Voltage (Max.) – V	Power Dissipation (Max.) – W	DC Current Transfer Ratio	Data Sheet File No.	Page No.
2N176	–	10	65 min.	14	572
2N217	-35	0.16	50 min.	14	572
2N274	-40	0.12	–	14	572
2N301	-60	30	50-165	14	572
2N301A	-80	30	50-165	14	572
2N351	-40	10	65 min.	14	572
2N376	-40	10	78 min.	14	572
2N404	-25	0.15	20 min.	14	572
2N414	-30	0.15	–	14	572
2N697	60	2	40-120	16	472
2N699	120	2	40-120	22	320
2N718A	75	1.8	40-120	14	572
2N720A	120	1.8	40-120	14	572
2N1066	-40	0.12	–	14	572
2N1183	-45	1	20 min.	14	572
2N1183A	-60	1	20 min.	14	572
2N1183B	-80	1	20 min.	14	572
2N1184	-45	1	40 min.	14	572
2N1184A	-60	1	40 min.	14	572
2N1184B	-80	1	40 min.	14	572
2N1224	-40	0.12	–	14	572
2N1225	-40	0.12	–	14	572
2N1226	-60	0.12	–	14	572
2N1285	-40	0.12	30-100	14	572
2N1395	-40	0.12	–	14	572
2N1396	-40	0.12	–	14	572
2N1397	-40	0.12	–	14	572
2N1479	60	5	20-60	135	474
2N1480	100	5	20 min.	135	474
2N1481	60	5	35-100	135	474
2N1482	100	5	35-100	135	474
2N1483	60	25	20-60	137	479
2N1484	100	25	20-60	137	479
2N1485	60	25	35-100	137	479
2N1486	100	25	35-100	137	479
2N1487	60	75	15-45	139	484
2N1488	100	75	15-45	139	484
2N1489	60	75	25-75	139	484
2N1490	100	75	25-75	139	484
2N1613	75	3	20 min.	106	323
2N1683	-13	0.15	85 min.	14	572
2N1700	60	5	20-80	141	489
2N1701	60	25	20-80	141	489
2N1702	60	75	15-60	141	489
2N1711	75	3	35 min.	26	328
2N1893	120	3	40-120	34	332
2N1905	-100	30	50-150	14	572
2N1906	-130	30	75-250	14	572
2N2015	100	150	15-50	12	500
2N2016	130	150	15-50	12	500
2N2102	120	5	20 min.	106	323
2N2147	-75	12.5	100-300	14	572
2N2148	-60	12.5	60 min.	14	572
2N2270	60	5	50-200	24	338
2N2338	60	150	15-60	141	489
2N2405	120	5	60-200	34	332
2N2869	-60	30	50-165	14	572
2N2870	-80	30	50-165	14	572
2N2895	120	1.8	40-120	143	342
2N2896	140	1.8	60-200	143	342
2N2897	60	1.8	50-200	143	342
2N3053	60	5	50-250	432	348
2N3054	90	25	25-100	527	20
2N3055	100	115	20-70	524	28
2N3263	150	20	25-75	54	354
2N3264	120	30	20-80	54	354
2N3265	150	24	25-75	54	354
2N3266	120	28	20-80	54	354
2N3439	450	10	40-160	64	222
2N3440	300	10	40-160	64	222
2N3441	160	25	25-100	529	36
2N3442	160	117	20-70	528	44
2N3583	250	2.5	40 min.	138	229
2N3584	375	2.5	25-100	138	229
2N3585	500	2.5	25-100	138	229

Type No.	Collector-to-Base Voltage (Max.) – V	Power Dissipation (Max.) – W	DC Current Transfer Ratio	Data Sheet File No.	Page No.
2N3730	-200	10	10-200	14	572
2N3731	-320	5	15 min.	14	572
2N3732	-100	3	35-500	14	572
2N3771	50	150	15-60	525	52
2N3772	100	150	15-60	525	52
2N3773	160	150	15-60	526	60
2N3878	120	35	50-200	299	360
2N3879	120	35	20-80	299	360
2N4036	-90	7	20-200	216	428
2N4037	-60	7	50-250	216	428
2N4063	450	–	40-160	64	222
2N4064	300	10	40-160	64	222
2N4240	500	2.5	30-150	138	229
2N4314	-90	7	50-250	216	428
2N4346	-320	5	–	14	572
2N4347	140	100	15-60	528	44
2N4348	140	120	15-60	526	60
2N5034	55	83	20-80	244	68
2N5035	55	83	20-80	244	68
2N5036	70	83	20-80	244	68
2N5037	70	83	20-80	244	68
2N5038	150	140	50-200	367	371
2N5039	120	140	30-150	367	371
2N5189	60	5	30 min.	296	378
2N5202	120	35	10-100	299	360
2N5239	300	100	20-80	321	241
2N5240	375	100	20-80	321	241
2N5262	75	5	35 min.	313	383
2N5293	80	36	30-120	332	76
2N5294	80	36	30-120	332	76
2N5295	60	36	30-120	332	76
2N5296	60	36	30-120	332	76
2N5297	80	36	20-80	332	76
2N5298	80	36	20-80	332	76
2N5320	100	10	30-130	325	389
2N5321	75	10	40-250	325	389
2N5322	-100	10	30-130	325	389
2N5323	-75	10	40-250	325	389
2N5415	-200	10	30-150	336	437
2N5416	-350	10	30-120	336	437
2N5490	60	50	20-100	353	85
2N5491	60	50	20-100	353	85
2N5492	75	50	20-100	353	85
2N5493	75	50	20-100	353	85
2N5494	60	50	20-100	353	85
2N5495	60	50	20-100	353	85
2N5496	90	50	20-100	353	85
2N5497	90	50	20-100	353	85
2N5575	70	300	10-40	359	92
2N5576	70	300	10-40	359	92
2N5577	70	300	10-40	359	92
2N5578	90	300	10-40	359	92
2N5579	90	300	10-40	359	92
2N5580	90	300	10-40	359	92
2N5671	120	140	20-100	383	395
2N5672	150	140	20-100	383	395
2N5781	-80	10	20-100	413	100
2N5782	-65	10	20-100	413	100
2N5783	-45	10	20-100	413	100
2N5784	80	10	20-100	413	100
2N5785	65	10	20-100	413	100
2N5786	45	10	20-100	413	100
2N5804	300	110	10-100	407	247
2N5805	375	110	10-100	407	247
2N5838	275	100	8-40	410	253
2N5839	300	100	10-50	410	253
2N5840	375	100	10-50	410	253
2N5954	-85	40	20-100	435	138
2N5955	-70	40	20-100	435	138
2N5956	-50	40	20-100	435	138
2N6032	120	140	10-50	462	401
2N6033	150	140	10-50	462	401
2N6055	60	100	100-18000	563	450
2N6056	60	100	100-18000	563	450
2N6077	300	45	12-70	492	260

Index to Power Transistors and Power Hybrid Circuits (Cont'd)

Type No.	Collector-to-Base Voltage (Max.) –V	Power Dissipation (Max.) – W	DC Current Transfer Ratio	Data Sheet File No.	Page No.
2N6078	275	45	12-70	492	260
2N6079	375	45	12-50	492	260
2N6098	70	75	20-80	485	111
2N6099	70	75	20-80	485	111
2N6100	80	75	20-80	485	111
2N6101	80	75	20-80	485	111
2N6102	45	75	15-60	485	111
2N6103	45	75	15-60	485	111
2N6106	-80	40	30-150	488	145
2N6107	-80	40	30-150	488	145
2N6108	-60	40	30-150	488	145
2N6109	-60	40	30-150	488	145
2N6110	-40	40	30-150	488	145
2N6111	-40	40	30-150	488	145
2N6175	300	20	30-190	508	268
2N6176	350	20	30-150	508	268
2N6177	450	20	30-150	508	268
2N6178	100	25	30-130	562	407
2N6179	75	25	40-250	562	407
2N6180	-100	25	30-130	562	407
2N6181	-75	25	40-250	562	407
2N6211	-275	35	30-175	507	443
2N6212	-350	35	30-175	507	443
2N6213	-400	35	30-150	507	443
2N6214	-450	20	10-100	507	443
2N6246	-70	125	20-100	541	153
2N6247	-90	125	20-100	541	153
2N6248	-110	125	20-100	541	153
2N6249	300	175	20-100	523	276
2N6250	375	175	20-100	523	276
2N6251	450	175	20-100	523	276
2N6253	55	115	20-70	524	28
2N6254	100	150	20-70	524	28
2N6257	50	150	15-75	525	52
2N6258	100	250	20-60	525	52
2N6259	170	250	15-60	526	60
2N6260	50	29	20-100	527	20
2N6261	90	50	25-100	527	20
2N6262	170	150	20-70	528	44
2N6263	140	20	20-100	529	36
2N6264	170	50	20-60	529	36
2N6288	40	40	30-150	542	161
2N6289	40	40	30-150	542	161
2N6290	60	40	30-150	542	161
2N6291	60	40	30-150	542	161
2N6292	80	40	30-150	542	161
2N6293	80	40	30-150	542	161
2N6354	150	140	20-150	582	415
2N6371	50	117	15-60	607	119
2N6372	50	40	20-100	608	169
2N6373	70	40	20-100	608	169
2N6374	90	40	20-100	608	169
2N6383	40	100	1000-20000	609	455
2N6384	60	100	1000-20000	609	455
2N6385	80	100	1000-20000	609	455
2N6386	40	40	1000-20000	610	461
2N6387	60	40	1000-20000	610	461
2N6388	80	40	1000-20000	610	461
29	40	30	15-75	583	175
29A	60	30	15-75	583	175
29B	80	30	15-75	583	175
29C	100	30	15-75	583	175
30	-40	30	15-75	584	180
30A	-60	30	15-75	584	180
30B	-80	30	15-75	584	180
30C	-100	30	15-75	584	180
31	40	40	10-50	585	185
31A	60	40	10-50	585	185
31B	80	40	10-50	585	185
31C	100	40	10-50	585	185
32	-40	40	10-50	586	190
32A	-60	40	10-50	586	190
32B	-80	40	10-50	586	190
32C	-100	40	10-50	586	190
41	40	65	15-75	587	195

Type No.	Collector-to-Base Voltage (Max.) – V	Power Dissipation (Max.) – W	DC Current Transfer Ratio	Data Sheet File No.	Page No.
41A	60	65	15-75	587	195
41B	80	65	15-75	587	195
41C	100	65	15-75	587	195
42	-40	65	15-75	588	200
42A	-60	65	15-75	588	200
42B	-80	65	15-75	588	200
42C	-100	65	15-75	588	200
101	-40	75	25-150	557	205
102	-60	75	25-150	557	205
103	-60	75	30-150	557	205
104	-80	75	30-150	557	205
105	-50	65	25-100	556	209
201	40	75	25-150	557	205
202	60	75	25-150	557	205
203	60	75	30-150	557	205
204	80	75	30-150	557	205
205	50	65	25-100	556	209
370	-30	40	25 min.	558	213
371	-40	40	40 min.	558	213
410	200	125	30-90	509	284
411	300	125	30-90	510	290
413	400	125	20-80	511	296
423	400	125	30-90	512	302
431	400	125	15-35	513	308
520	30	40	25 min.	558	213
521	40	40	40 min.	558	213
1000	60	90	750 min.	594	468
1001	80	90	750 min.	594	468
40022	-32	12.5	38 min.	14	572
40050	-40	12.5	50 min.	14	572
40051	-50	12.5	50 min.	14	572
40084	60	1.8	50-250	40	505
40250	50	29	25-100	112	124
40250V1	50	5.8	25-100	112	124
40251	50	117	15-60	112	124
40254	-32	12.5	30 min.	14	572
40309	18*	5	70-350	78	510
40310	35*	29	20-120	78	510
40311	30*	5	70-350	78	510
40312	60#	29	20-120	78	510
40313	300#	35	40-250	78	510
40314	40*	5	70-350	78	510
40315	35*	5	70-350	78	510
40316	40#	29	20-120	78	510
40317	40*	5	40-200	78	510
40318	300#	35	50 min.	78	510
40319	-40*	5	35-200	78	510
40320	40*	5	40-200	78	510
40321	300#	5	25-200	78	510
40322	300#	35	75 min.	78	510
40323	10*	5	70-350	78	510
40324	35*	29	20-120	78	510
40325	35*	117	12-60	78	510
40326	40*	5	40-200	78	510
40327	300#	5	40-250	78	510
40328	300#	35	40 min.	78	510
40346	175#	10	25 min.	211	237
40346V1	175#	10	25 min.	211	237
40346V2	175#	4	25 min.	211	237
40347	60	8.75	25-100	88	129
40347V1	60	4.4	25-100	88	129
40347V2	60	11.7	25-100	88	129
40348	90	8.75	30-125	88	129
40348V1	90	4.4	30-125	88	129
40348V2	90	11.7	30-125	88	129
40349	160	8.75	30-125	88	129
40349V1	160	4.4	30-125	88	129
40349V2	160	11.7	30-125	88	129
40360	70*	5	40-200	78	510
40361	70#	5	70-350	78	510
40362	-70#	5	35-200	78	510
40363	70#	115	20-70	78	510
40364	60#	35	35-175	78	510
40366	120	5	40-120	215	421
40367	100	5	35-100	215	421

Index to Power Transistors and Power Hybrid Circuits (Cont'd)

Type No.	Collector-to-Base Voltage (Max.) — V	Power Dissipation (Max.) — W	DC Current Transfer Ratio	Data Sheet File No.	Page No.
40368	100	25	35-100	215	421
40369	100	75	25-75	215	421
40372	90	25	25-100	527	20
40373	160	25	25-100	529	36
40374	250	5.8	40 min.	138	229
40375	120	5.8	50-200	299	360
40385	450	5	40-160	215	421
40389	60	3.5	50-250	432	348
40390	300	3.5	40-160	64	222
40391	-60	3.5	50-250	216	428
40392	60	7	50-250	432	348
40394	-60	7	50-250	216	428
40406	-50*	1	30-200	219	516
40407	50*	1	40-200	219	516
40408	90*	1	40-200	219	516
40409	90#	3	50-250	219	516
40410	-90#	3	50-250	219	516
40411	90#	150	35-100	219	516
40412	250#	10	40 min.	211	237
40412V1	250#	4	40 min;	211	237
40412V2	250#	10	40 min.	211	237
40421	-75	12.5	62-175	14	572
40439	-320	5	—	14	572
40440	-200	5	—	14	572
40462	-40	12.5	50 min.	14	572
40484	55*	25	50 min.	14	572
40513	45#	83	25-100	244	68
40514	45#	83	25-100	244	68
40537	-55#	5	50-300	302	523
40538	-55#	5	15-90	302	523
40539	55#	5	15-90	303	527
40542	50#	83	20-70	304	531
40543	60#	83	20-70	304	531
40544	50#	7	35-200	303	527
40546		8	50 min.	14	572
40594	95#	10	70-350	358	537
40595	-95#	10	70-350	358	537
40611	25*	5	70-500	358	537
40612	-25#	12.5	30-150	14	572
40613	25*	36	30-120	358	537
40616	32*	5	70-500	358	537
40618	30*	36	30-120	358	537
40621	32*	36	25-100	358	537
40622	40*	36	25-100	358	537
40623	-45#	12.5	50-170	14	572
40624	45*	50	20-100	358	537
40625	45*	3.5	100-300	358	537
40626	-55#	12.5	50-170	14	572
40627	55*	50	20-100	358	537
40628	55*	3.5	100-300	358	537
40629	35#	36	20-70	358	537
40630	40#	36	20-70	358	537
40631	45#	36	20-70	358	537
40632	60#	50	20-70	358	537
40633	75#	83	20-70	358	537
40634	-75#	5	50-250	358	537
40635	75#	5	50-250	358	537
40636	95#	115	20-70	358	537
40637	30	1	—	14	572
40850	450	35	25 min.	498	314
40851	450	45	12 min.	498	314
40852	450	100	12 min.	598	314
40853	450	100	10 min.	498	314
40854	450	110	10 min.	498	314
40885	300	20	30-190	508	268
40886	350	20	30-150	508	268
40887	450	20	30-150	508	268
40910	50	29	20-100	527	20
40911	90	50	25-100	527	20
40912	140	20	20-100	529	36
40913	170	50	20-60	529	36
45190	40	40	25-100	559	217
45191	60	40	25-100	559	217
45192	80	40	20-80	559	217
45193	-40	40	25-100	559	217
45194	-60	40	25-100	559	217
45195	-80	40	20-80	559	217
CH2102	60*	—	50 min.	469	544
CH2270	45*	—	50 min.	469	544
CH2405	90*	—	50 min.	469	544
CH3053	30*	—	50 min.	469	544
CH3439	325*	—	30 min.	469	544
CH3440	250	—	30 min.	469	544
CH4036	-65*	—	35 min.	469	544
CH4037	-40*	—	35 min.	469	544
CH5320	80*	—	30 min.	469	544
CH5321	55*	—	30 min.	469	544
CH5322	-80*	—	30 min.	469	544
CH5323	-55*	—	30 min.	469	544

Index to Power Hybrid Circuits

Type No.	Supply Voltage V	Power Dissipation W	Output Current A	File No.	Page No.
HC1000	75	35	7	565	550
HC1000H	75	35	7	565	550
HC2000	75	35	7	566	555
HC2000H	75	35	7	566	555
HC3000	70	20	10	539	560
HC3100	120	20	10	564	563
HC4005	40	62.5**	4.0**	571	566
HC4005A	40	62.5**	4.0**	571	566
HC4012	40	62.5**	4.0**	571	566
HC4012A	40	62.5**	4.0**	571	566
HC4015	40	62.5**	4.0**	571	566
HC4015A	40	62.5**	4.0**	571	566

* = V_{CEO}

= V_{CER}

** = pass transistor

Application Notes for Transistor and Power Hybrid Circuits

No.	Title	Page No.
1CE-402	"Operating Considerations for RCA Solid State Devices"	576
AN-3065	"Silicon Transistors for High-Voltage Applications"	581
AN-3565	"A 100-Watt, 18-KHz Inverter Using RCA-2N5202 Silicon Power Transistors"	591
AN-3576	"Power Output and Dissipation in Class B Transistor Amplifiers"	594
AN-3616	"Solid-State Ballasting of Mercury-Arc Lamps"	602
AN-4124	"Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors"	615
AN-4509	"Compact 5-Volt Power Supplies Using High-Voltage Power Transistors"	623
AN-4558	"A 60-Watt, 20-Volt Regulated Power Supply Using a Single Pass Transistor"	631
AN-4573	"Testing for Forward-Bias Second Breakdown in Power Transistors"	643
AN-4612	"Thermal-Cycling Rating System for Silicon Power Transistors"	649
AN-4673	"A 750-Watt Three-Phase Frequency Converter"	652
AN-4783	"Thermal-Cycling Ratings of Power Transistors"	657
AN-6045	"Off-Line 1-Kilowatt Driven Converter"	664
AN-4474	"Audio Applications of the RCA-HC1000 Hybrid Linear Power Amplifier"	669
AN-4483	"General Application Considerations for the RCA-HC1000 Hybrid Linear Power Amplifier"	673
AN-4782	"General Application Considerations for the RCA-HC2000 Power Hybrid Operational Amplifier"	678
AN-6026	"Application Considerations for Hybrid Series Voltage Regulators"	684

HOMETAXIAL-BASE N-P-N POWER TYPES

I_C to 80 A . . . P_T to 300 W . . . V_{CE} to 170 V

P_T = 8.75 W max. I_c = 1.5 A max. (TO-5)*	P_T = 10 W max. I_c = 3.5 A max. (TO-5)*	P_T = 36 W max. I_c = 4 A max. VERSAWATT (TO-220)	P_T = 50 W max. I_c = 7 A max. VERSAWATT (TO-220)	P_T = 75 W max. I_c = 16 A max. VERSAWATT (TO-220)	P_T = 50 W max. I_c = 3 A max. (TO-66)**
Familv Designation					
2N1482	**2N5786**	**2N5298**	**2N5496**	**2N6103**	**2N3441**
40347 V_{CEV}(sus) = 60 V h_{FE} = 25-100 @ 450 mA f_T = 1.5 MHz typ. File No. 88 Page 129	**2N5786** V_{CER}(sus) = 45 V h_{FE} = 20-100 @ 1.6 A f_T = 1 MHz min. CT File No. 413 Page 100	**2N5295** **2N5296** V_{CER}(sus) = 50 V h_{FE} = 30-120 @ 1 A f_T = 0.8 MHz min. CT File No. 322 Page 76	**2N5491** **2N5490** V_{CER}(sus) = 50 V h_{FE} = 20-100 @ 2 A f_T = 0.8 MHz min. CT File No. 353 Page 85	**2N6102** **2N6103** V_{CER}(sus) = 45 V h_{FE} = 15-60 @ 8 A f_T = 0.8 MHz min. I_c = 16 A max. File No. 485 Page 111	**2N6263** V_{CER}(sus) = 130 V h_{FE} = 20-100 @ 0.5 A f_T = 1.2 MHz typ. P_T = 20 W File No. 529 Page 36
40348 V_{CEV}(sus) = 90 V h_{FE} = 30-125 @ 300 mA f_T = 1.5 MHz typ. File No. 88 Page 129	**2N5785** V_{CER}(sus) = 65 V h_{FE} = 20-100 @ 1.2 A f_T = 1 MHz min. CT File No. 413 Page 100	**2N5297** **2N5298** V_{CER}(sus) = 70 V h_{FE} = 20-80 @ 1.5 A f_T = 0.8 MHz min. CT File No. 322 Page 76	**2N5495** **2N5494** V_{CER}(sus) = 50 V h_{FE} = 20-100 @ 3 A f_T = 0.8 MHz min. CT File No. 353 Page 85	**2N6098** **2N6099** V_{CER}(sus) = 65 V h_{FE} = 20-80 @ 4 A f_T = 0.8 MHz min. I_c = 10 A max. File No. 485 Page 111	**2N3441** V_{CER}(sus) = 150 V h_{FE} = 25-100 @ 0.5 A f_T = 1.2 MHz typ. P_T = 25 W CT File No. 529 Page 36
40349 V_{CEV}(sus) = 160 V h_{FE} = 30-125 @ 150 mA f_T = 1.5 MHz typ. File No. 88 Page 129	**2N5784** V_{CER}(sus) = 80 V h_{FE} = 20-100 @ 1 A f_T = 1 MHz min. CT File No. 413 Page 100	**2N5293** **2N5294** V_{CER}(sus) = 75 V h_{FE} = 30-120 @ 0.5 A f_T = 0.8 MHz min. CT File No. 322 Page 76	**2N5493** **2N5492** V_{CER}(sus) = 65 V h_{FE} = 20-100 @ 2.5 A f_T = 0.8 MHz min. CT File No. 353 Page 85	**2N6100** **2N6101** V_{CER}(sus) = 75 V h_{FE} = 20-80 @ 5 A f_T = 0.8 MHz min. I_c = 10 A max. File No. 485 Page 111	**2N6264** V_{CER}(sus) = 170 V h_{FE} = 20-60 @ 1 A f_T = 1.2 MHz typ. P_T = 50 W File No. 529 Page 36
			2N5497 **2N5496** V_{CER}(sus) = 80 V h_{FE} = 20-100 @ 3.5 A f_T = 0.8 MHz min. CT File No. 353 Page 85		

*Available with:
   a. flange for easy heat sinking $R_{\theta JC}$ = 15° C/W
   b. free-air radiator $R_{\theta JA}$ = 40-50° C/W

**Available with free-air radiator $R_{\theta JA}$ = 30° C/W.

■Also available with integral heat spreader.

CT—Complementary Type available

HOMETAXIAL-BASE N-P-N POWER TYPES

I_C to 80 A . . . P_T to 300 W . . . V_{CE} to 170 V

P_T = 50 W max. I_c = 4 A max. (TO-66)**	P_T = 150 W max. I_c = 10 A max. (TO-3)	P_T = 150 W max. I_c = 15 A max. (TO-3)	P_T = 250 W max. I_c = 16 A max. (TO-3)	P_T = 250 W max. I_c = 30 A max. (TO-3)	P_T = 300 W max. I_c = 80 A max. (Modified TO-3)■
Family Designation					
2N3054	**2N3442**	**2N3055**	**2N3773**	**2N3771**	**2N5578**
40250 $V_{CEV}(sus)$ = 50 V h_{FE} = 25-100 @ 1.5 A f_T = 1.2 MHz typ. P_T = 29 W CT File No. 112 Page 124	**2N4347** $V_{CEV}(sus)$ = 140 V h_{FE} = 20-70 @ 2 A f_T = 0.8 MHz typ. P_T = 100 W CT File No. 528 Page 44	**2N6371** $V_{CEV}(sus)$ = 50 V h_{FE} = 15-60 @ 8 A f_T = 1 MHz typ. P_T = 117 W CT File No. 607 Page 119	**2N4348** $V_{CEV}(sus)$ = 140 V h_{FE} = 15-60 @ 5 A f_T = 0.7 MHz typ. P_T = 120 W I_c = 10 A File No. 526 Page 60	**2N6257** $V_{CER}(sus)$ = 45 V h_{FE} = 15-75 @ 8 A f_T = 0.6 MHz min. P_T = 150 W I_c = 20 A File No. 525 Page 52	**2N5575** $V_{CEO}(SUS)$ = 50 V h_{FE} = 10–40 @ 60 A f_T = 0.4 MHz min. File No. 359 Page 92
2N6260 $V_{CEV}(sus)$ = 50 V h_{FE} = 20-100 @ 1.5 A f_T = 0.8 MHz min. P_T = 29 W File No. 527 Page 20	**2N3442** $V_{CEV}(sus)$ = 160 V h_{FE} = 20-70 @ 3 A f_T = 0.8 MHz typ. P_T = 117 W File No. 528 Page 44	**2N6253** $V_{CER}(sus)$ = 55 V h_{FE} = 20-70 @ 3 A f_T = 0.8 MHz min. P_T = 115 W File No. 524 Page 28	**2N3773** $V_{CEV}(sus)$ = 160 V h_{FE} = 15-60 @ 8 A f_T = 0.7 MHz typ. P_T = 150 W I_c = 16 A File No. 526 Page 60	**2N3771** $V_{CER}(sus)$ = 45 V h_{FE} = 15-60 @ 15 A f_T = 0.8 MHz min. P_T = 150 W I_c = 30 A File No. 525 Page 52	**2N5578** $V_{CEO}(sus)$ = 70 V h_{FE} = 10-40 @ 40 A f_T = 0.4 MHz min. File No. 359 Page 92
2N3054 $V_{CER}(sus)$ = 60 V h_{FE} = 25-100 @ 0.5 A f_T = 0.8 MHz min. P_T = 25 W CT File No. 527 Page 20	**2N6262** $V_{CEV}(sus)$ = 170 V h_{FE} = 20-70 @ 3 A f_T = 0.8 MHz min. P_T = 150 W File No. 528 Page 44	**2N3055** $V_{CER}(sus)$ = 70 V h_{FE} = 20-70 @ 4 A f_T = 0.8 MHz min. P_T = 115 W CT File No. 524 Page 28	**2N6259** $V_{CER}(sus)$ = 160 V h_{FE} = 15-60 @ 8 A f_T = 0.6 MHz min. P_T = 250 W I_c = 16 A File No. 526 Page 60	**2N3772** $V_{CER}(sus)$ = 70 V h_{FE} = 15-60 @ 10 A f_T = 0.8 MHz min. P_T = 150 W CT File No. 525 Page 52	
2N6261 $V_{CER}(sus)$ = 85 V h_{FE} = 25-100 @ 1.5 A f_T = 0.8 MHz min. P_T = 50 W File No. 527 Page 20		**2N6254** $V_{CER}(sus)$ = 85 V h_{FE} = 20-70 @ 5 A f_T = 0.8 MHz min. P_T = 150 W File No. 524 Page 28		**2N6258** $V_{CER}(sus)$ = 85 V h_{FE} = 20-60 @ 15 A f_T = 0.6 MHz min. P_T = 250 W I_c = 30 A File No. 525 Page 52	

HIGH-VOLTAGE N-P-N POWER TYPES

I_C to 30 A . . . f_T to 20 MHz . . . P_T to 175 W

P_T = 10 W max. I_c = 1 A max. (TO-5)*	P_T = 20 W max. I_c = 1 A max. (Plastic TO-5)	P_T = 35 W max. I_c = 5 A max. (TO-66)**	P_T = 45 W max. I_c = 10 A peak (TO-66)**
Family Designation			
2N3439	2N6177	2N3585	2N6079
2N3440 V_{CER}(sus) = 300 V h_{FE} = 40-160 @ 20 mA f_T 15 MHz min. CT File No. 64 Page 222	**2N6175** **40885■** "Plastic 2N3440" V_{CER}(sus) = 300 V h_{FE} = 30-190 @ 20 mA f_T = 20 MHz min. CT File No. 508 Page 268	**2N3583** V_{CER}(sus) = 250 V h_{FE} = 40 min. @ 100 mA h_{FE} 10 min. @ 1 A f_T = 15 MHz min. File No. 138 Page 229	**2N6078** V_{CER}(sus) = 275 V h_{FE} = 12-70 @ 1.2A t_r = 0.3 µs typ. t_f = 0.3 µs typ. File No. 492 Page 260
2N3439 V_{CER}(sus) = 400 V h_{FE} = 40-160 @ 20 mA f_T = 15 MHz min. CT File No. 64 Page 222	**2N6176** **40886■** V_{CER}(sus) = 350 V h_{FE} = 30-150 @ 20 mA f_T = 20 MHz min. CT File No. 508 Page 268	**2N3584** V_{CER}(sus) = 300 V h_{FE} = 40 min. @ 100 mA h_{FE} = 25-100 @ 1 A f_T = 15 MHz min. CT File No. 138 Page 229	**2N6077** V_{CER}(sus) = 300 V h_{FE} = 12-70 @ 1.2 A t_r = 0.3 µs typ. t_f = 0.3 µs typ. CT File No. 492 Page 260
	2N6177 **40887■** "Plastic 2N3439" V_{CER}(sus) = 400 V h_{FE} = 30-150 @ 50 mA f_T = 20 MHz min. File No. 508 Page 268	**2N3585** V_{CER}(sus) = 400 V h_{FE} = 40 min. @ 100 mA h_{FE} = 25-100 @ 1 A f_T = 15 MHz min. CT File No. 138 Page 229	**2N6079** V_{CER}(sus) = 375 V h_{FE} = 12-70 @ 1-2 A t_r = 0.3 µs typ. t_f = 0.3 µs typ. File No. 492 Page 260
		2N4240 V_{CER}(sus) = 400 V h_{FE} = 40 min. @ 100 mA h_{FE} = 30-150 @ 750 mA f_T = 15 MHz min. File No. 138 Page 229	**40851** V_{CER}(sus) = 375 V h_{FE} = 12 min. @ 1.2 A t_r = 0.3 µs typ. t_f = 0.3 µs typ. File No. 498 Page 314
		40850 V_{CER}(sus) = 400 V h_{FE} = 25 min. @ 750 mA f_T = 15 MHz min. File No. 498 Page 314	

*Available with:
  a. flange for easy heat sinking $R_{\theta JC}$ = 15°C/W
  b. free-air radiator $R_{\theta JA}$ = 45°C/W

**Available with free-air radiator $R_{\theta JA}$ = 30°C/W

■Type with a factorv-attached heat clip

CT—Complementary Type available

HIGH-VOLTAGE N-P-N POWER TYPES

I_C to 30 A . . . f_T to 20 MHz . . . P_T to 175 W

P_T = 100 W max. I_c = 10 A peak (TO-3) Switching	P_T = 100 W max. I_c = 10 A peak (TO-3) Linear	P_T = 110 W max. I_c = 15 A peak (TO-3)	P_T = 125 W max. I_c = 10 A peak (TO-3)	P_T = 175 W max. I_c = 30 A peak (TO-3) Switching
Family Designation				
2N5840	2N5240	2N5804	2N5840	2N6251
2N5838 V_{CER}(sus) = 275 V h_{FE} = 20 min. @0.5 A h_{FE} = 8-40 @ 3 A t_r = 0.8 µs typ. t_f = 0.4 µs typ. File No. 410 Page 253	**2N5239** V_{CER}(sus) = 250 V h_{FE} = 20 min. @ 2 A h_{FE} = 20-80 @ 0.4 A f_T = 5 MHz min. File No. 321 Page 241	**2N5804** V_{CER}(sus) = 300 V h_{FE} = 25-250 @ 0.5 A h_{FE} = 10-100 @ 5 A t_r = 0.4 µs typ. t_f = 1.2 µs typ. File No. 407 Page 247	**410** V_{CEO}(sus) = 200 V h_{FE} = 30-90 @ 1 A t_r = 0.35 µs typ. t_f = 0.15 µs typ. File No. 509 Page 284	**2N6249** V_{CER}(SUS) = 225 V h_{FE} = 10–50 @ 10 A t_r = 0.8 µs typ. t_f = 0.5 µs typ. File No. 523 Page 276
2N5839 V_{CER}(sus) = 300 V h_{FE} = 20 min. @ 0.5 A h_{FE} = 10-50 @ 2A t_r = 0.6 µs typ. t_f = 0.35 µs typ. File No. 410 Page 253	**2N5240** V_{CER}(sus) = 350 V h_{FE} = 20 min. @ 2 A h_{FE} = 20-80 @ 0.4 A f_T = 5 MHz min. File No. 321 Page 241	**2N5805** V_{CER}(sus) = 375 V h_{FE} = 25-250 @ 0.5 A h_{FE} = 10-100 @ 5 A t_r = 0.4 µs typ. t_f = 1.2 µs typ. File No. 407 Page 247	**411** V_{CEO}(sus) = 300 V h_{FE} = 30-90 @ 1 A t_r = 0.35 µs typ. t_f = 0.15 µs typ. File No. 510 Page 290	**2N6250** V_{CER}(SUS) = 300 V h_{FE} = 8–50 @ 10 A t_r = 0.8 µs typ. t_f = 0.5 µs typ. File No. 523 Page 276
2N5840 V_{CER}(sus) = 375 V h_{FE} = 20 min. @ 0.5 A h_{FE} = 10-50 @ 2 A t_r = 0.6 µs typ. t_f = 0.35 µs typ. File No. 410 Page 253		**40853** V_{CER}(sus) = 375 V h_{FE} = 10 min. @ 5 A t_r = 0.4 µs typ. t_f = 1.2 µs typ. File No. 498 Page 314	**413** V_{CEO}(sus) = 325 V h_{FE} = 20-80 @ 0.5 A t_r = 0.35 µs typ. t_f = 0.15 µs typ. File No. 511 Page 296	**2N6251** V_{CER}(SUS) = 375 V h_{FE} = 6–50 @ 10 A t_r = 0.8 µs typ. t_f = 0.5 µs typ. File No. 523 Page 276
40852 V_{CER}(sus) = 375 V h_{FE} = 12 min. @ 1.2 A t_r = 0.5 µs typ. t_f = 0.35 µs typ. File No. 498 Page 314			**423** V_{CEO}(sus) = 325 V h_{FE} = 30-90 @ 1 A t_r = 0.35 µs typ. t_f = 0.15 µs typ. File No. 512 Page 302	**40854** V_{CER}(sus) = 325 V h_{FE} = 8 min. @ 10 A t_r = 0.8 µs typ. t_f = 0.5 µs typ. File No. 498 Page 314
			431 V_{CEO}(sus) = 325 V h_{FE} = 15-35 @ 2.5 A t_r = 0.35 µs typ. t_f = 0.15 µs typ. File No. 513 Page 308	

HIGH-SPEED SWITCHING N-P-N POWER TYPES

f_T to 120 MHz . . . I_C to 60 A . . . P_T to 140 W

P_T = 5 W max. I_c = 1 A max. (TO-5)*	P_T = 5 W max. I_c = 2 A max. (Lo Profile TO-39)	P_T = 10 W max. I_c = 2 A max. (TO-5)*	P_T = 25 W max. I_c = 2 A max. (Plastic TO-5)	P_T = 35 W max. I_c = 7 A max. (TO-66)**
Family Designation				
2N2102	2N5262	2N5320	2N6179	2N3879
2N3053 V_{CER}(SUS) = 50 V h_{FE} = 50-250 @ 150 mA f_T = 100 MHz min. CT File No. 432 Page 348	**2N5189** V_{CEO}(SUS) = 35 V h_{FE} = 15 max. @ 1 A f_T = 250 MHz min t_{on} = 40 ns max. t_{off} = 70 ns max. File No. 296 Page 378	**2N5321** V_{CER}(SUS) = 65 V h_{FE} = 40-250 @ 500 mA f_T = 50 MHz min. t_{on} = 80 ns max. t_{off} = 800 ns max. CT File No. 325 Page 389	**2N6179** "Plastic 2N5321" V_{CER}(SUS) = 65 V h_{FE} = 40-250 @ 500 mA f_T = 50 MHz min. t_{on} = 80 ns max. t_{off} = 800 ns max. CT File No. 562 Page 407	**2N3878‡** V_{CER}(SUS) = 60 V h_{FE} = 20 min. @ 4 A h_{FE} = 50-200 @ 0.5 A f_T = 60 MHz min. t_r = 400 μs max. t_f = 400 μs max. File No. 299 Page 360
2N2102 V_{CER}(SUS) = 80 V h_{FE} = 40-120 @ 150 mA f_T = 120 MHz min. CT File No. 106 Page 323	**2N5262** V_{CEO}(SUS) = 50 V h_{FE} = 25 min. @ 1 A f_T = 250 MHz min. t_{on} = 30 ns max. t_{off} = 60 ns max. File No. 313 Page 383	**2N5320** V_{CER}(SUS) = 90 V h_{FE} = 30-130 @ 500 mA f_T = 50 MHz min. t_{on} = 80 ns max. t_{off} = 800 ns max. CT File No. 325 Page 389	**2N6178** "Plastic 2N5320" V_{CER}(SUS) = 90 V h_{FE} = 30-130 @ 500 mA f_T = 50 MHz min. t_{on} = 80 ns max. t_{off} = 800 ns max. CT File No. 562 Page 407	**2N3879** V_{CER}(SUS) = 90 V h_{FE} = 40 min. @ 0.4 A h_{FE} = 20-80 @ 4 A f_T = 60 MHz min. t_r = 400 μs max. t_f = 400 μs max. File No. 299 Page 360
				2N5202 V_{CER}(SUS) = 75 V h_{FE} = 10-100 @ 4 A. f_T = 60 MHz min. t_r = 400 μs max. t_f = 400 μs max. File No. 299 Page 360

*Available with:
- a. flange for easy heat sinking $R_{\theta JC}$ = 15° C/W
- b. free-air radiator $R_{\theta JA}$ = 50° C/W

**Available with free-air radiator $R_{\theta JA}$ = 30° C/W

‡Also available with heat radiator (40375)

■Flat radial lead version

CT—Complementary Type available

HIGH-SPEED SWITCHING N-P-N POWER TYPES

f_T to 120 MHz . . . I_C to 60 A . . . P_T to 140 W

P_T = 125 W max. I_c = 25 A max. (TO-63)	P_T = 140 W max. I_c = 20 A max. (TO-3)	P_T = 140 W max. I_c = 30 A max. (TO-3)	P_T = 140 W max. I_c = 60 A max. (Modified TO-3)
Family Designation			
2N3263	**2N5038**	**2N5671**	**2N6033**
2N3266 **2N3264■** V_{CER}(SUS) = 80 V h_{FE} = 20-80 @ 15 A f_T 20 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 54 Page 354	**2N5039** V_{CER}(SUS) = 95 V h_{FE} = 20 min. @ 10 A h_{FE} = 30-150 @ 2 A f_T 60 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 367 Page 371	**2N5671** V_{CER}(SUS) = 110 V h_{FE} = 20 min. @ 20 A h_{FE} = 20-100 @ 15 A f_T 50 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 383 Page 395	**2N6032** V_{CER}(SUS) = 110 V h_{FE} = 10-50 @ 50 A f_T = 50 MHz min. t_r = 1 μs max. t_f = 0.5 μs max. File No. 462 Page 401
2N3265 **2N3263■** V_{CER}(SUS) = 110 V h_{FE} = 25-75 @ 15 A f_T = 20 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 54 Page 354	**2N5038** V_{CER}(SUS) = 110 V h_{FE} = 20 min. @ 12 A h_{FE} = 50-200 @ 2 A f_T = 60 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 367 Page 371	**2N5672** V_{CER}(SUS) = 140 V h_{FE} = 20 min. @ 20 A h_{FE} = 20-100 @ 15 A f_T = 50 MHz min. t_{on} = 0.5 μs max. t_{off} = 2 μs max. File No. 383 Page 395	**2N6033** V_{CER}(SUS) = 140 V h_{FE} = 10-50 @ 40 A f_T = 50 MHz min. t_r = 1 μs max. t_f = 0.5 μs max. File No. 462 Page 401
	2N6354 V_{CER} (sus) = 130 V h_{FE} = 20–150 @ 5 A h_{FE} = 10–100 @ 10 A f_T = 80 MHz min. t_r = 0.3 μs max. t_f = 0.2 μs max. I_c = 12 A peak File No. 582 Page 415		

P-N-P POWER TYPES

I_C to −15 A . . . f_T to 60 MHz . . . P_T to 125 W

P_T = 7 W max. I_c = −1 A max. (TO-5)*	P_T = 10 W max. I_c = −1 A max. (TO-5)*	P_T = 10 W max. I_c = −2 A max. (TO-5)*	P_T = 10 W max. I_c = −3.5 max. (TO-5)*
Family Designation			
2N4036	2N5415	2N5322	2N5783
2N4037 V_{CER}(SUS) = −60 V h_{FE} = 50-250 @ −150 mA f_T = 60 MHz min. CT File No. 216 Page 428	**2N5415** V_{CEO}(SUS) = −200 V h_{FE} = 30-150 @ −50 mA f_T = 15 MHz min. CT File No. 336 Page 437	**2N5323** V_{CER}(SUS) = −65 V h_{FE} = 40-250 @ −500 mA f_T = 50 MHz min. CT File No. 325 Page 389	**2N5783** V_{CER}(SUS) = −45 V h_{FE} = 20-100 @ −1.6 A f_T = 8 MHz min. CT File No. 413 Page 100
2N4036 V_{CER}(SUS) = −85 V h_{FE} = 40-140 @ −150 mA f_T = 60 MHz min. CT File No. 216 Page 428	**2N5416** V_{CER}(SUS) = −350 V h_{FE} = 30-120 @ −50 mA f_T = 15 MHz min. CT File No. 336 Page 437	**2N5322** V_{CER}(SUS) = −90 V h_{FE} = 30-130 @−500 mA h_{FE} = 10 min. @ −1 A f_T = 50 MHz min. CT File No. 325 Page 389	**2N5782** V_{CER}(SUS) = −65 V h_{FE} = 20-100 @ −1.2 A f_T = 8 MHz min. CT File No. 413 Page 100
2N4314 V_{CER}(SUS) = −85 V h_{FE} = 50-250 @ −150 mA f_T = 60 MHz min. File No. 216 Page 428			**2N5781** V_{CER}(SUS) = −80 V h_{FE} = 20-100 @ −1 A f_T = 8 MHz min. CT File No. 413 Page 100

*Available with:

a. flange for easy heat sinking $R_{\theta JC}$ = 15° C/W

b. free-air radiator $R_{\theta JA}$ = 40-50° C/W

**Available with free-air radiator $R_{\theta JA}$ = 30° C/W

CT—Complementary Type available

P-N-P POWER TYPES

I_C to −15 A . . . f_T to 60 MHz . . . P_T to 125 W

P_T = 25 W max. I_c = −2 A max. (Plastic TO-5)	P_T = 35 W max. I_c = −5 A max. (TO-66)**	P_T = 40 W max. I_c = −6 A max. (TO-66)**	P_T = 40 W max. I_c = −7 A max. VERSAWATT (TO-220)	P_T = 125 W max. I_c = −15 A max. (TO-3)
Family Designation				
2N6181	**2N6214**	**2N5956**	**2N6107**	**2N6248**
2N6181 "Plastic 2N5323" V_{CER}(SUS) = −65 V h_{FE} = 40-250 @ −500 mA f_T = 50 MHz min. CT File No. 562 Page 407	**2N6211** V_{CER}(SUS) = −250 V h_{FE} = 30-175 @ −1 A f_T = 20 MHz min. CT File No. 507 Page 443	**2N5956** V_{CER}(SUS) = −45 V h_{FE} = 20-100 @ −3 A f_T = 5 MHz min. CT File No. 435 Page 138	**2N6110 2N6111** V_{CER}(SUS) = −40 V h_{FE} = 30-150 @ −3 A f_T = 10 MHz min. CT File No. 488 Page 145	**2N6246** V_{CER}(SUS) = −65 V h_{FE} = 20-100 @ −7 A f_T = 6 MHz min CT File No. 541 Page 153
2N6180 "Plastic 2N5322" V_{CER}(SUS) = −90V h_{FE} = 30-130 @ −500 mA h_{FE} = 10 min. @ −1 A f_T = 50 MHz min. CT File No. 562 Page 407	**2N6212** V_{CER}(SUS) = −325 V h_{FE} = 30-175 @ −1A f_T = 20 MHz min. CT File No. 507 Page 443	**2N5955** V_{CER}(SUS) = −65 V h_{FE} = 20-100 @ −2.5 A f_T = 5 MHz min. CT File No. 435 Page 138	**2N6108 2N6109** V_{CER}(SUS) = −60 V h_{FE} = 30-150 @ −2.5 A f_T = 10 MHz min. CT File No. 488 Page 145	**2N6247** V_{CER}(SUS) = −85 V h_{FE} = 20-100. @ −6 A f_T = 10 MHz min. CT File No. 541 Page 153
	2N6213 V_{CER}(SUS) = −375 V h_{FE} = 30-150 @ −1 A f_T = 20 MHz min. File No. 507 Page 443	**2N5954** V_{CER}(SUS) = −80 V h_{FE} = 20-100 @ −2 A f_T = 5 MHz min. CT File No. 435 Page 138	**2N6106 2N6107** V_{CER}(SUS) = −80 V h_{FE} = 30-150 @ −2 A f_T = 10 MHz min. CT File No. 488 Page 145	**2N6248** V_{CER}(SUS) = −105 V h_{FE} = 20-100 @ −5 A f_T = 6 MHz min. CT File No. 541 Page 153
	2N6214 V_{CER}(SUS) = 425 V h_{FE} = 10–100 @ −1A f_T = 20 MHz min. File No. 507 Page 443			

EPITAXIAL-BASE N-P-N & P-N-P POWER TYPES

I_C to 15 A . . . P_T to 125 W . . . V_{CE} to 120 V

NPN		PNP		
P_T = 40 W max. I_c = –7 A max. VERSAWATT (TO-220)	P_T = 40 W max. I_c = –6 A max. (TO-66)	P_T = 40 W max. I_c = 7 A max. VERSAWATT (TO-220)	P_T = 40 W max. I_c = 7 A max. (TO-66)	P_T = 125 W max. I_c = –15 A max. (TO-3)
Family Designation				
2N6292	**2N6374**	**2N6107**	**2N5954**	**2N6248**
2N6288 **2N6289** V_{CER}(SUS) = 40 V h_{FE} = 30-150 @ 3 A f_T = 4 MHz min. File No. 542 Page 415	**2N6372** V_{CER}(SUS) = 45 V h_{FE} = 20-100 @ 3 A f_T = 5 MHz typ. File No. 608 Page 169	**2N6110** **2N6111** V_{CER}(SUS) = –40 V h_{FE} = 30-150 @ –3 A f_T = 10 MHz min. File No. 488 Page 145	**2N5956** V_{CER}(SUS) = –45 V h_{FE} = 20-100 @ –3 A f_T = 5 MHz min. File No. 435 Page 138	**2N6246** V_{CER}(SUS) = –65 V h_{FE} = 20-100 @ –7 A f_T = 10 MHz min. File No. 541 Page 153
2N6290 **2N6291** V_{CER}(SUS) = 60 V h_{FE} = 30-150 @ 2.5 A f_T = 4 MHz min. File No. 542 Page 161	**2N6373** V_{CER}(SUS) = 65 V h_{FE} = 20-100 @ 2.5 A f_T = 5 MHz typ. File No. 608 Page 169	**2N6108** **2N6109** V_{CER}(SUS) = –60 V h_{FE} = 30-150 @ –2.5 A f_T = 10 MHz min. File No. 488 Page 145	**2N5955** V_{CER}(SUS) = –65 V h_{FE} = 20-100 @ –2.5 A f_T = 5 MHz min. File No. 435 Page 138	**2N6247** V_{CER}(SUS) = –85 V h_{FE} = 20-100 @ –6 A f_T = 10 MHz min. File No. 541 Page 153
2N6292■ **2N6293** V_{CER}(SUS) = 80 V h_{FE} = 30-150 @ 2 A f_T = 4 MHz min. File No. 542 Page 161	**2N6374** V_{CER}(SUS) = 80 A h_{FE} = 20-100 @ 2 A f_T = 5 MHz typ. File No. 608 Page 169	**2N6106■** **2N6107** V_{CER}(SUS) = –80 V h_{FE} = 30-150 @ –2 A f_T = 10 MHz min. File No. 488 Page 145	**2N5954** V_{CER}(SUS) = –80 V h_{FE} = 20-100 @ –2 A f_T = 5 MHz min. File No. 435 Page 138	**2N6248** V_{CER}(SUS) = –105 V h_{FE} = 20-100 @ –5 A f_T = 10 MHz min. File No. 541 Page 153

■Reverse lead versions selected from this family are also available

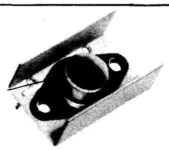
Hometaxial-Base n-p-n Power Transistors

RCA
Solid State
Division

Power Transistors

2N3054, 2N6260, 2N6261, 40372, 40910, 40911

JEDEC TO-66 H-1340



JEDEC TO-66
With Integral Heat Radiator H-1470A

Hometaxial II• Medium-Power Silicon N-P-N Transistors

Rugged Devices for Intermediate-Power Applications in Industrial and Commercial Equipment

Features:

- **Maximum safe-area-of-operation curves for dc and pulse operation**
- **V_{CEV}(sus) = 90 V min (2N3054, 2N6261)**
- **Low saturation voltage: V_{CE}(sat) = 1.0 V at I_C = 0.5 A (2N3054)**

RCA 2N3054, 2N6260, and 2N6061 are hometaxial-base• silicon n-p-n transistors intended for a wide variety of medium- to high-power applications.

Types 40372, 40910, and 40911 are the 2N3054, 2N6260, and 2N6061 with factory-attached heat radiators intended for printed-circuit-board applications.

• "Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity in the axial direction (emitter-to-collector).

Applications:

- **Power switching circuits**
- **Series- and shunt-regulator driver and output stages**
- **High-fidelity amplifiers**
- **Solenoid drivers**

"Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

		2N6260 40910	2N3054 40372	2N6261 40911	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	90	90	V
COLLECTOR-TO-EMITTER VOLTAGE:					
* With base open	V_{CEO}	40	55	80	V
* With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}(sus)	45	60	85	V
With base reverse-biased (V_{BE} = -1.5 V)	V_{CEV}(sus)	50	90	90	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	7	7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	3	4	4	A
*CONTINUOUS BASE CURRENT	I_B	2	2	2	A
TRANSISTOR DISSIPATION:	P_T				
* At case temperature up to 25°C		29 (2N6260)	25 (2N3054)	50 (2N6261)	W
At ambient temperatures up to 25°C		5.8 (40910)	5.8 (40372)	5.8 (40911)	W
* At temperatures above 25°C		*See Figs. 4 & 11*	*See Figs. 4 & 9*	*See Figs. 1 & 7*	
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		←	-65 to 200	→	°C
*PIN TEMPERATURE (During Soldering):					
At distance ≥1/32 in. (0.8 mm) from seating plane for 10 s max.		←	235	→	°C

*In accordance with JEDEC registration data format JS-9 RDF-10 (2N3054), JS-6 RDF-2 (2N6260, 2N6261)

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	DC Collector Voltage V	DC Emitter or Base Voltage V		DC Current A		LIMITS 2N6260 40910		2N3054 40372		2N6261 40911		UNITS
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
*Collector-Cutoff Current: With base open	I_{CEO}	30				0	–	1	–	0.5	–	–	mA
		60				0	–	–	–	–	–	0.5	
With base-emitter junction reverse-biased	I_{CEX}	40		−1.5			–	5	–	–	–	–	mA
		80		−1.5			–	–	–	–	–	0.5	
		90		−1.5			–	–	–	1.0	–	–	
At T_C = 150°C	I_{CEX}	40		−1.5			–	25	–	–	–	–	mA
		80		−1.5			–	–	–	–	–	1.0	
		90		−1.5			–	–	–	6.0	–	–	
*Emitter-Cutoff Current	I_{EBO}		5			0	–	5	–	–	–	–	mA
			7			0	–	–	–	1.0	–	0.2	
Collector-to-Emitter Sustaining Voltage: *With base open	$V_{CEO}(sus)$				0.1[a]	0	40	–	55	–	80	–	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$				0.1[a]		45	–	60	–	85	–	V
*DC Forward-Current Transfer Ratio	h_{FE}	2			4[a]		3	–	–	–	5	–	
		2			1.5[a]		–	–	–	–	25	100	
		4			3[a]		–	–	5	–	–	–	
		4			0.5[a]		–	–	25	100	–	–	
		4			1.5[a]		20	100	–	–	–	–	
*Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				0.5[a]	0.05[a]	–	–	–	1.0	–	–	V
					1.5[a]	0.15[a]	–	1.5	–	–	–	0.5	
					3[a]	1[a]	–	–	–	6.0	–	–	
*Base-to-Emitter Voltage	V_{BE}	2			1.5		–	–	–	–	–	1.5	V
		4			1.5		–	2.2	–	–	–	–	
		4			0.5		–	–	–	1.7	–	–	
*Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio Cutoff Frequency	f_{hfe}	4			0.1		0.03	–	0.03	–	0.03	–	MHz
*Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 0.4 MHz)	$\|h_{fe}\|$	4			0.1		2	–	–	–	2	–	
Gain-Bandwidth Product	f_T				0.2		–	–	800	–	–	–	kHz
*Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	4			0.1		25	–	25	–	25	–	
Forward-Bias Second Breakdown Collector Circuit	$I_{S/b}$	40			0.725		1	–	–	–	–	–	s
		80			0.625		–	–	–	–	1	–	
		55			0.455		–	–	1	–	–	–	
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$						6 (max.) 2N6260		7 (max.) 2N3054		3.5 (max.) 2N6261		°C/W
Junction-to-Ambient	$R_{\theta JA}$						30 (max.) 40910		30 (max.) 40372		30 (max.) 40911		

[a]Pulsed: Pulse duration = 300 μs, duty factor = 1.8%.

*In accordance with JEDEC registration data format JS- 9 RDF-10 (2N3054) JS-6 RDF-2 (2N6260-61)

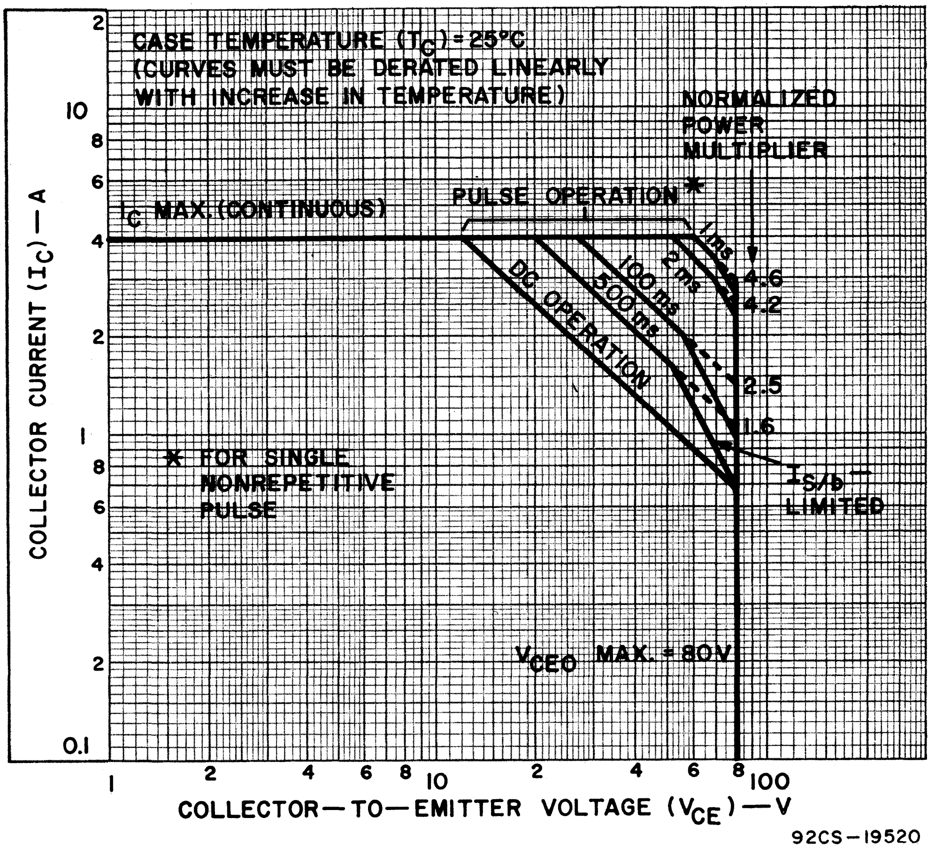


Fig.1—Maximum operating areas for type 2N6261.

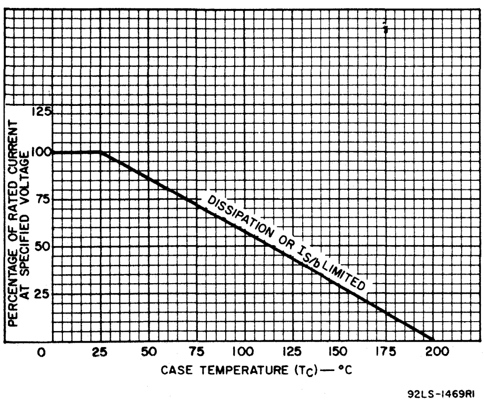


Fig.2—Current derating curve for all types.

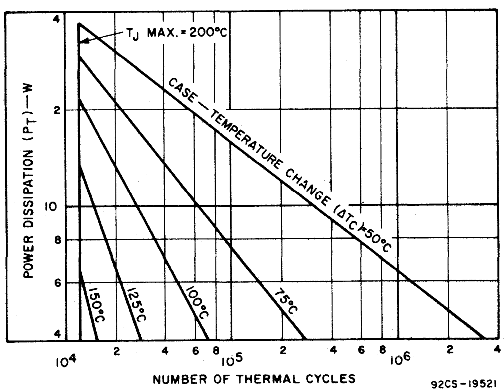


Fig.3—Thermal-cycle rating chart for type 2N6261.

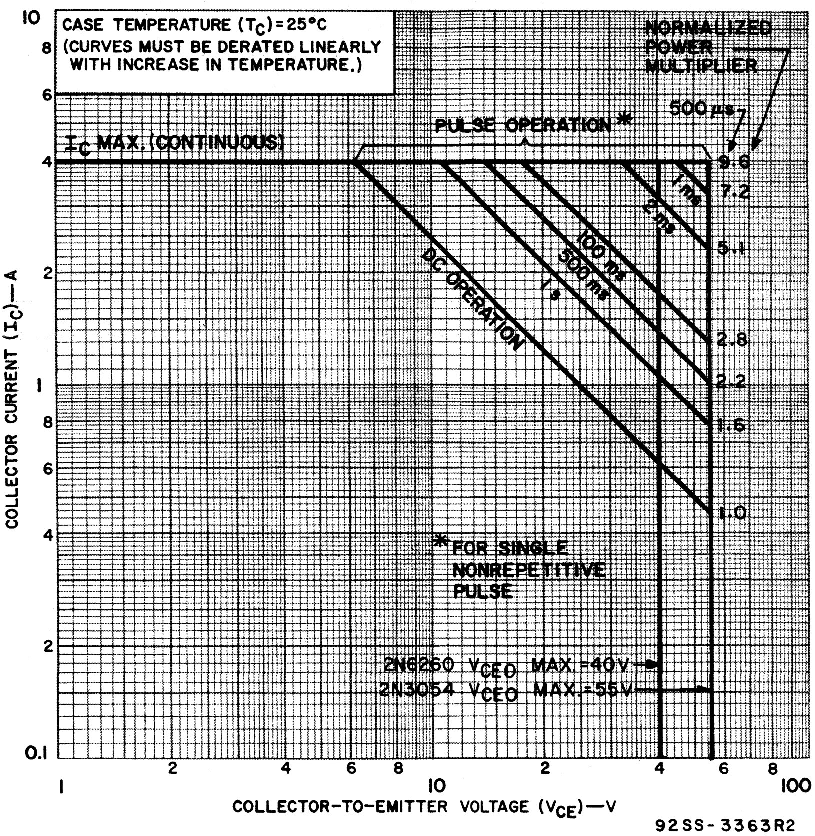


Fig.4—Maximum operating areas for types 2N3054 and 2N6260.

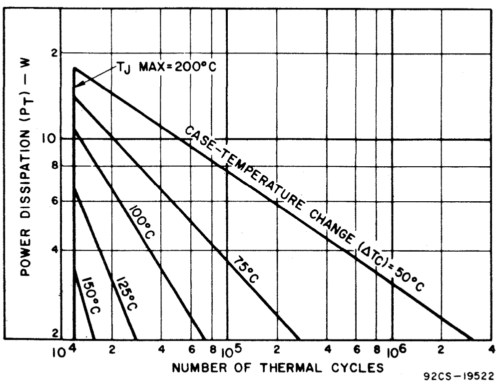


Fig.5— Thermal-cycle rating chart for type 2N3054.

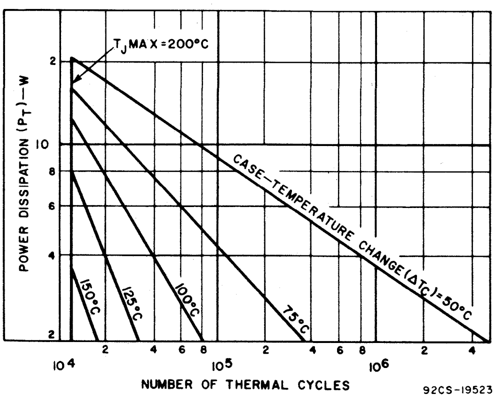


Fig.6—Thermal-cycle rating chart for type 2N6260.

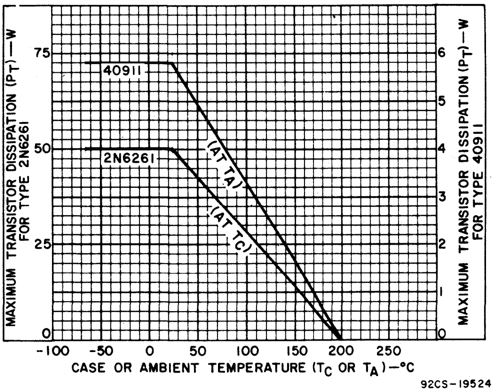


Fig.7—Dissipation derating curve for types 2N6261 and 40911.

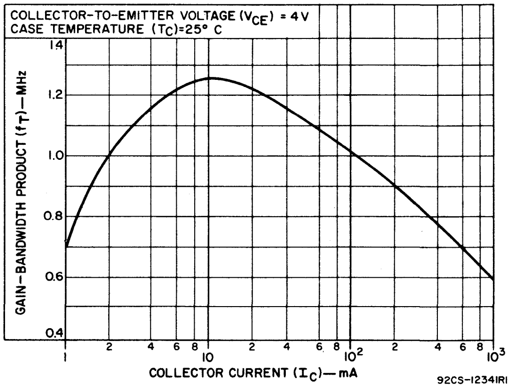


Fig.8—Typical gain-bandwidth product for all types.

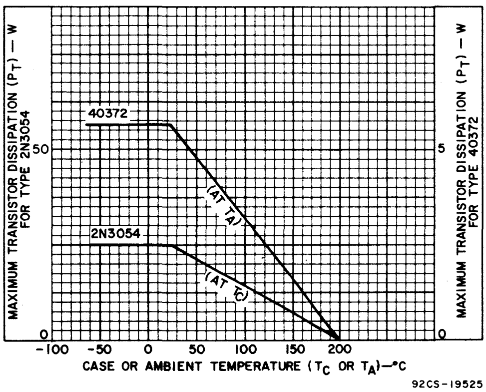


Fig.9—Dissipation derating curve for types 2N3054 and 40372.

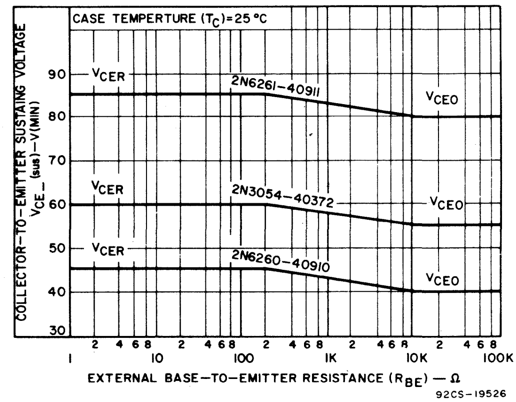


Fig.10—Sustaining voltage vs. base-to-emitter resistance for all types.

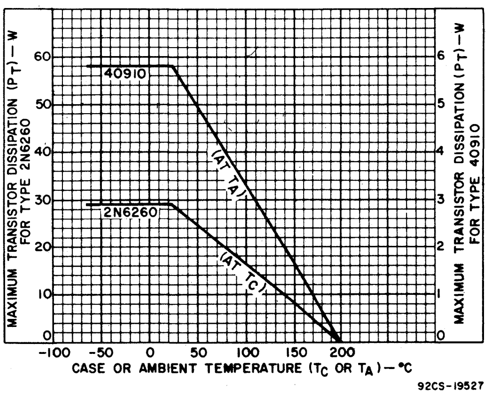


Fig.11—Dissipation derating curve for types 2N6260 and 40910.

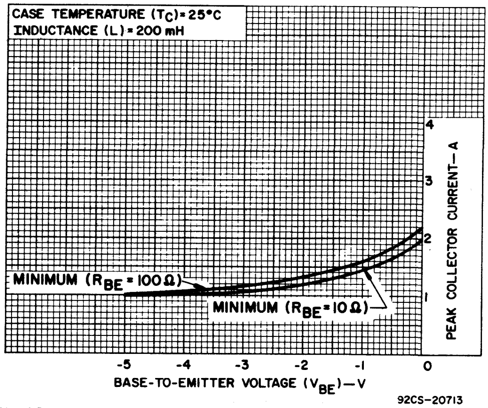


Fig.12—Reverse-bias second-breakdown characteristics for all types.

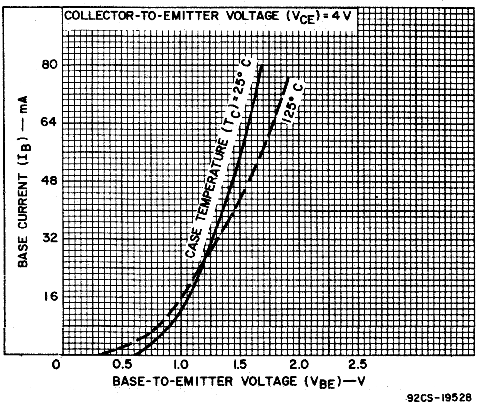


Fig.13—Typical input characteristics for types 2N6261 and 40911.

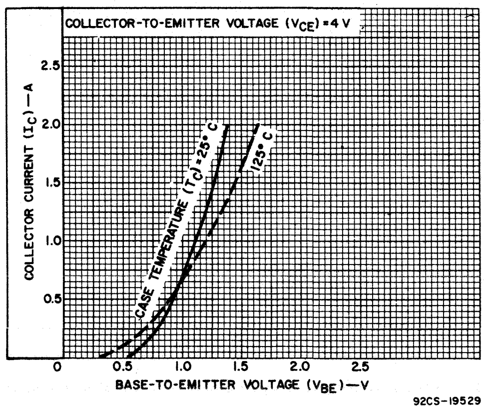


Fig.14—Typical transfer characteristics for types 2N6261 and 40911.

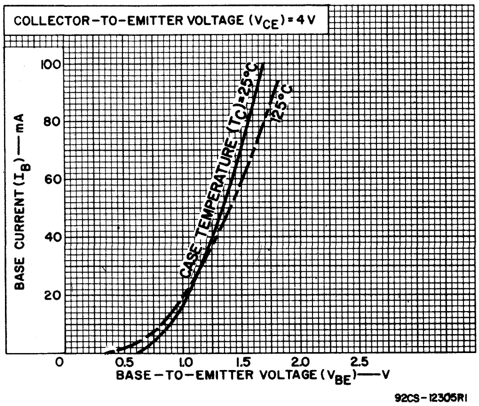


Fig.15—Typical input characteristics for types 2N3054 and 40372.

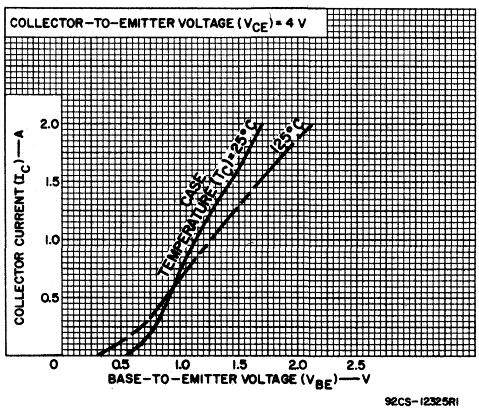


Fig.16—Typical transfer characteristics for types 2N3054 and 40372.

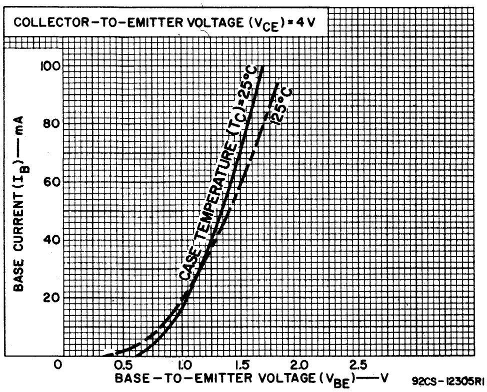


Fig.17—Typical input characteristics for types 2N6260 and 40910.

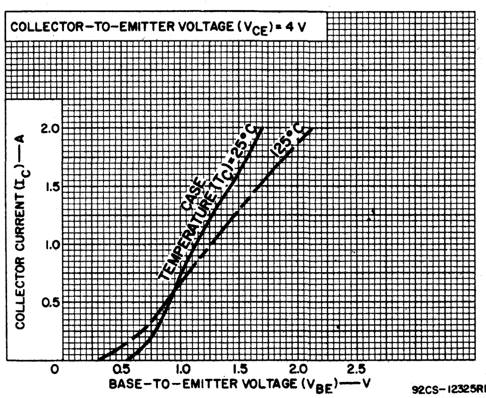


Fig.18—Typical transfer characteristics for types 2N6260 and 40910.

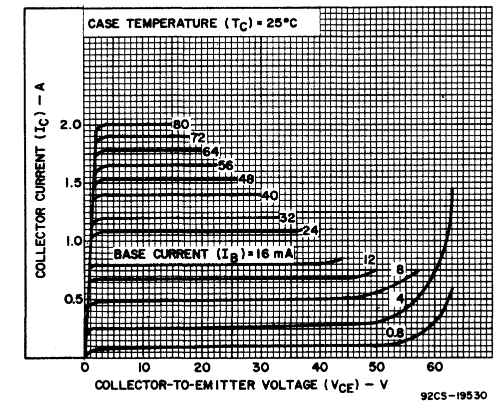


Fig.19—Typical output characteristics for types 2N6261 and 40911.

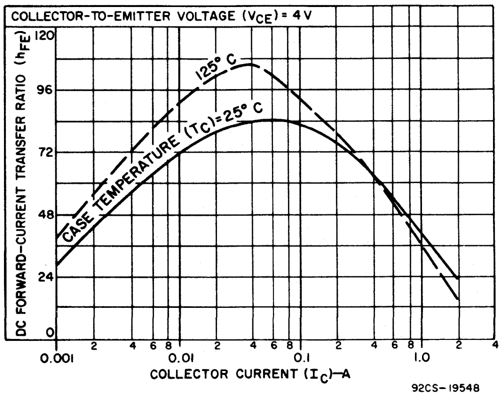


Fig.20—Typical dc beta characteristics for types 2N6261 and 40911.

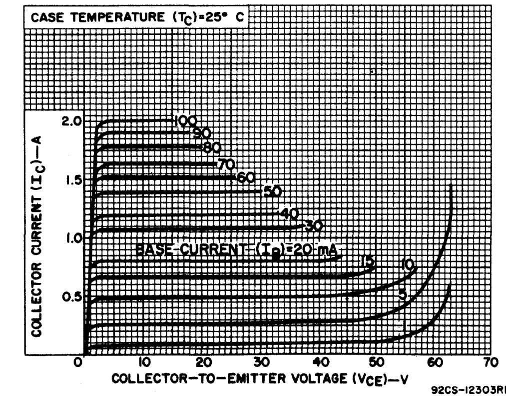


Fig.21—Typical output characteristics for types 2N3054 and 40372.

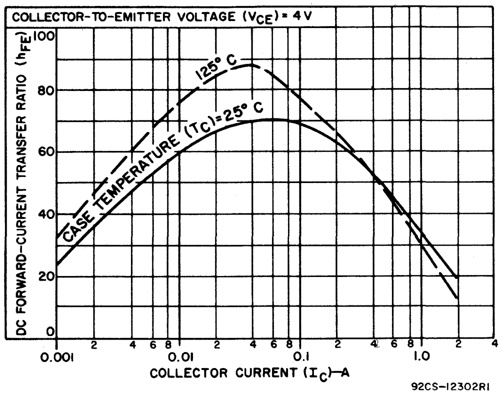


Fig.22—Typical dc beta characteristics for types 2N3054 and 40372.

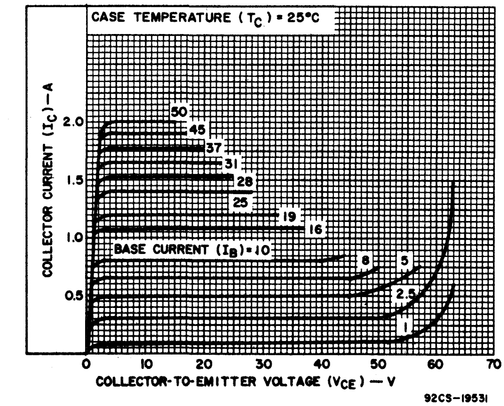


Fig.23—Typical output characteristics for types 2N6260 and 40910.

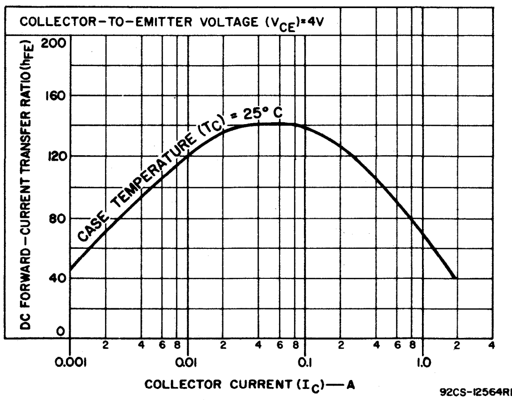


Fig.24—Typical dc beta characteristics for types 2N6260 and 40910.

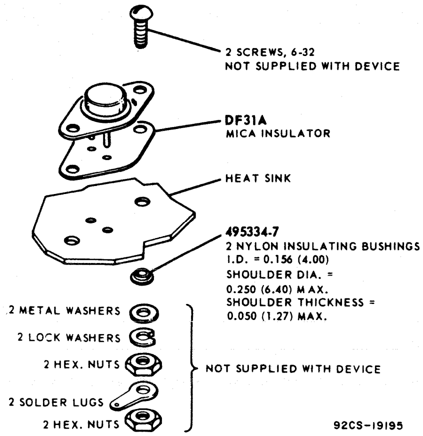
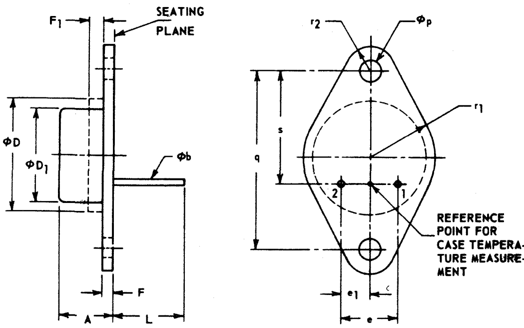


Fig.25—Suggested mounting hardware for 2N3054, 2N6260, and 2N6261.

DIMENSIONAL OUTLINE FOR 2N3054, 2N6260, and 2N6261 JEDEC TO-66



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD	—	0.620	—	15.75	
ϕD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1	—	0.050	—	1.27	1
L	0.360	—	9.14	—	
ϕp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r_1	—	0.350	—	8.89	
r_2	—	0.145	—	3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

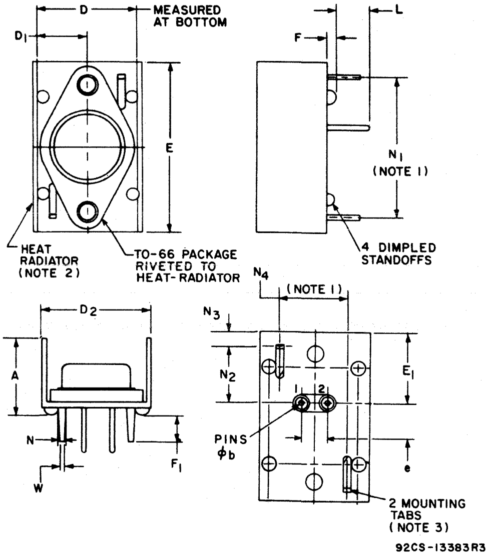
1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimensions does not include seating flanges.

92SS-3738

TERMINAL CONNECTIONS FOR 2N3054, 2N6260, & 2N6261

Pin 1 - Base
Pin 2 - Emitter
Case, Mounting Flange - Collector

DIMENSIONAL OUTLINE FOR JEDEC TO-66 WITH HEAT RADIATOR



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A		0.595		15.11	
ϕb	0.028	0.034	0.711	0.864	
D	0.750	0.760	19.05	19.30	
D_1	0.375	0.380	9.52	9.65	
D_2	0.820	0.920	20.83	23.37	
E	1.297	1.327	32.94	33.70	
E_1	0.551	0.561	13.99	14.25	
e	0.190	0.210	4.83	5.33	
F	0.040	0.055	1.02	1.40	
F_1	0.175	0.210	4.44	5.33	
L	0.270		0.686		
N	0.052	0.065	1.32	1.65	
N_1	1.098	1.102	27.89	27.99	1
N_2	0.448	0.452	11.38	11.47	
N_3	0.099	0.113	0.25	0.29	
N_4	0.498	0.502	12.65	12.75	
W	0.048	0.060	1.22	1.52	

NOTES:

1. Measured at bottom of heat radiator.
2. 0.035 in. (0.889) C.R.S., tin plated.
3. Recommended hole size for printed-circuit board is 0.070 in. (1.778) dia.

TERMINAL CONNECTIONS FOR 40372, 40910 & 40911

Pin 1 - Base
Pin 2 - Emitter
Heat Radiator-Collector

RCA
Solid State
Division

Power Transistors
2N6254
2N3055
2N6253

JEDEC TO-3

H-1570

Hometaxial II• High-Power Silicon N-P-N Transistors

Rugged, Broadly Applicable Devices
For Industrial and Commercial Use

Features:
- 2N6254: premium type from 2N3055 family
- Maximum safe-area-of-operation curves
- Low saturation voltages
- High dissipation ratings
- Thermal-cycle rating curves

Applications:
- Series and shunt regulators
- High-fidelity amplifiers
- Power-switching circuits
- Solenoid drivers

RCA 2N3055, 2N6253 and 2N6254 are silicon n-p-n transistors intended for a wide variety of high-power applications. The hometaxial•-base construction of these devices renders them highly resistant to second breakdown over a wide range of operating conditions.

•"Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector).

"Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

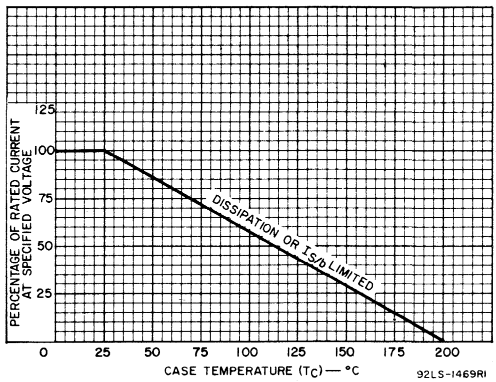


Fig. 1—Current derating curve.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6253	2N3055	2N6254	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	100	100	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
* With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}(sus)	55	70	85	V
* With base open	V_{CEO}(sus)	45	60	80	V
With base reverse-biased V_{BE} = -1.5 V	V_{CEV}(sus)	55	90	90	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	7	7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	15	15	15	A
*CONTINUOUS BASE CURRENT	I_B	7	7	7	A
*TRANSISTOR DISSIPATION	P_T				
At case temperatures up to 25°C		115	115	150	W
At case temperatures above 25°C		← See Fig. 1 →			
*TEMPERATURE RANGE:					
Storage and Operating (Junction)		← -65 to +200 →			°C
*PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		← 235 →			°C

*In accordance with JEDEC registration data formats (2N3055:JS-9 RDF-10/2N6253-4: JS-6 RDF-2).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE V	DC EMITTER OR BASE VOLTAGE V		DC CURRENT A		LIMITS						UNITS
							2N6253		2N3055		2N6254		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
* Collector-Cutoff Current: With base open	I_{CEO}	25				0	–	1.5	–	–	–	–	mA
		30				0	–	–	–	0.7	–	–	
		60				0	–	–	–	–	–	1	
With base-emitter junction reverse-biased	I_{CEX}	55		-1.5			–	2	–	–	–	–	
		100		-1.5			–	–	–	5	–	0.5	
At T_C = 150°C	I_{CEX}	50		-1.5			–	10	–	–	–	–	
		100		-1.5			–	–	–	30	–	5	
* Emitter-Cutoff Current	I_{EBO}		5				–	10	—	–	–	–	mA
			7				–	–	–	5	–	0.5	
Collector-to-Emitter Sustaining Voltage: * With base open	V_{CEO}(sus)				0.2[a]	0	45	–	60	–	80	–	V
* With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}(sus)				0.2[a]		55	–	70	–	85	–	
With base-emitter junction reverse-biased	V_{CEV}(sus)			-1.5	0.1[a]		55	–	90	–	90	–	
* DC Forward Current Transfer Ratio	h_{FE}	4			15[a]		3	–	–	–	5	–	
		4			10[a]		–	–	5	–	–	–	
		2			5[a]		–	–	–	–	20	70	
		4			4[a]		–	–	20	70	–	–	
		4			3[a]		20	70	–	–	–	–	
* Base-to-Emitter Volatge	V_{BE}	4			3[a]		–	1.7	–	–	–	–	V
		4			4[a]		–	–	–	1.8	–	–	
		2			5[a]		–	–	–	–	–	1.5	
* Collector-to-Emitter Saturation Voltage	V_{CE}(sat)				3[a]	0.3[a]	–	1	–	–	–	–	V
					4[a]	0.4[a]	–	–	–	1.1	–	–	
					5[a]	0.5[a]	–	–	–	–	–	0.5	
					10[a]	3.3[a]	–	–	–	8	–	–	
					15[a]	3[a]	–	–	–	–	–	4	
					15[a]	5[a]	–	4	–	–	–	–	
* Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	4			1		10	–	15	120	10	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 0.4 MHz)	$\|h_{fe}\|$	4			1		2	–	–	–	2	–	
Gain-Bandwidth Product	f_T				1		–	–	800	–	–	–	kHz
* Common-Emitter, Short-Circuit, Small-Signal, Forward Current Transfer Ratio Cutoff Frequency	f_{hfe}	4			1		10	–	10	–	10	–	kHz
Forward-Bias Second Breakdown Collector Current	$I_{S/b}$	80			1.87		–	–	–	–	1	–	s
		60			1.95		–	–	1	–	–	–	
		45			2.55		1	–	–	–	–	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	1.5	–	1.5	–	1.17	°C/W

[a] Pulsed: Pulse duration = 300 μs, duty factor = 1.8%.

* In accordance with JEDEC registration data formats JS-9 RDF-10 (2N3055) and JS-6 RDF-2 (2N6253–4).

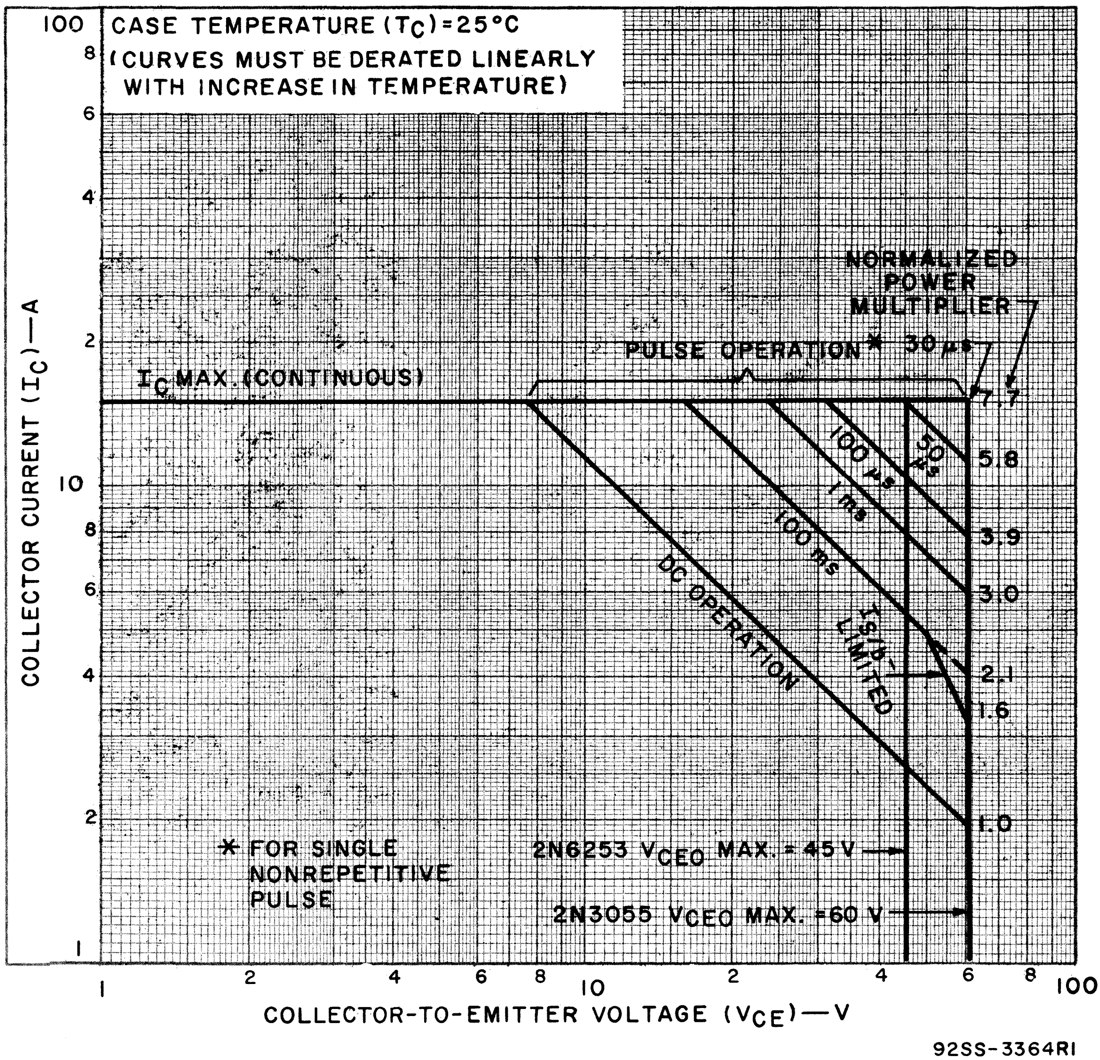


Fig.2—Maximum operating areas for types 2N6253 and 2N3055.

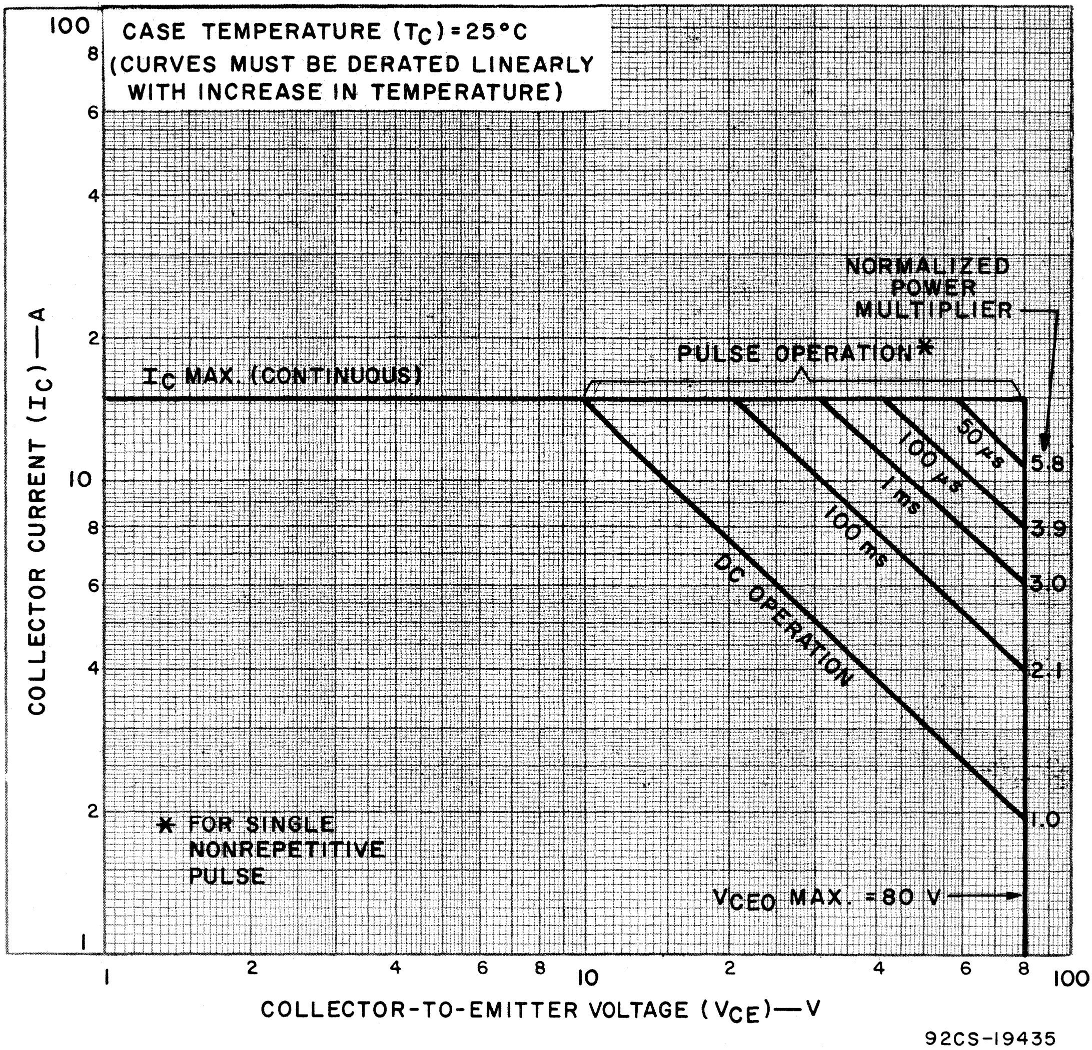


Fig.3—Maximum operating areas for 2N6254.

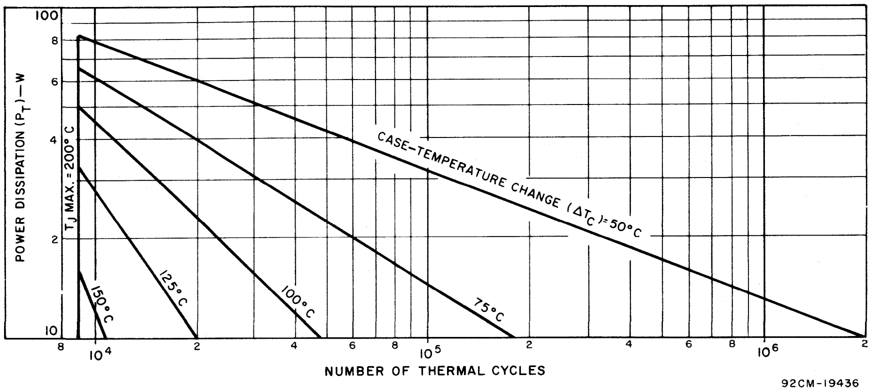


Fig.4—Thermal-cycle rating chart for types 2N3055 and 2N6253.

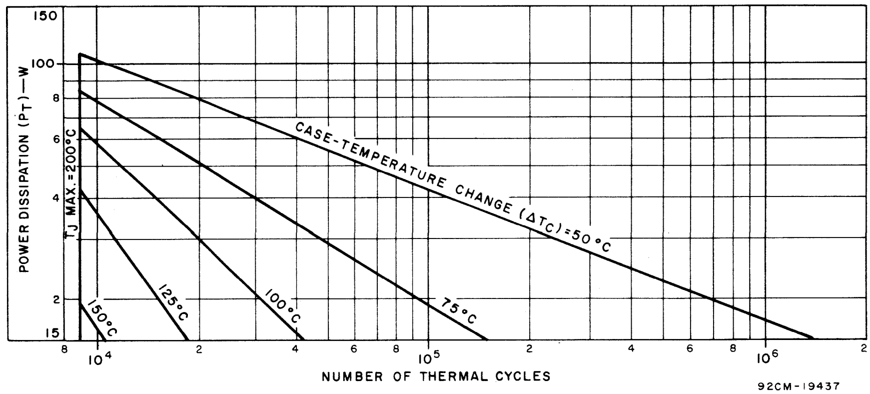


Fig.5—Thermal-cycle rating chart for type 2N6254.

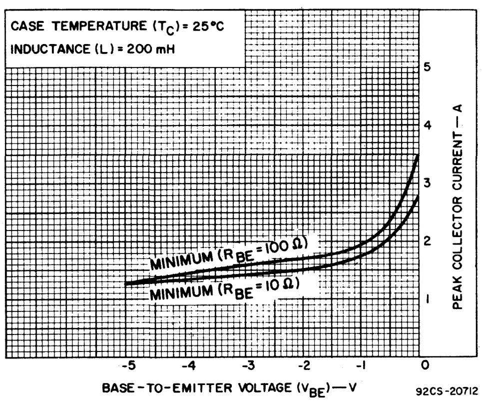


Fig.6—Reverse-bias, second-breakdown characteristics for all types.

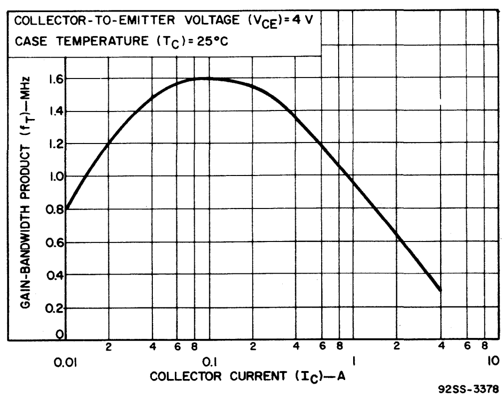


Fig.7—Typical gain-bandwidth product for all types.

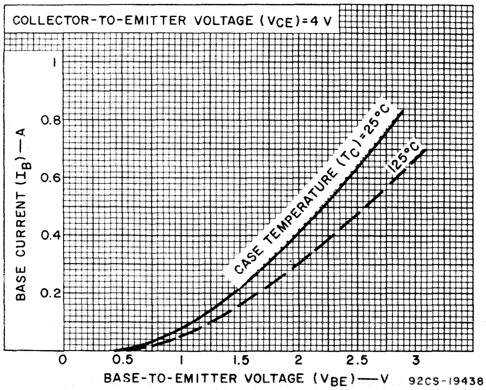


Fig.8—Typical input characteristics for type 2N6254.

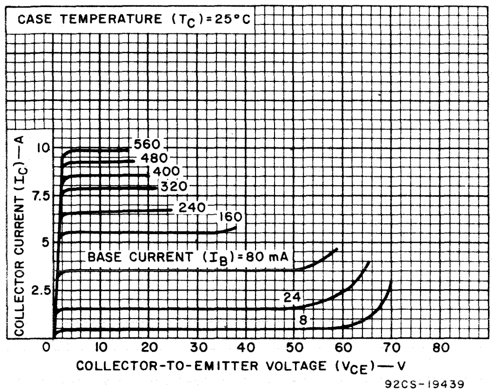


Fig.9—Typical output characteristics for type 2N6254.

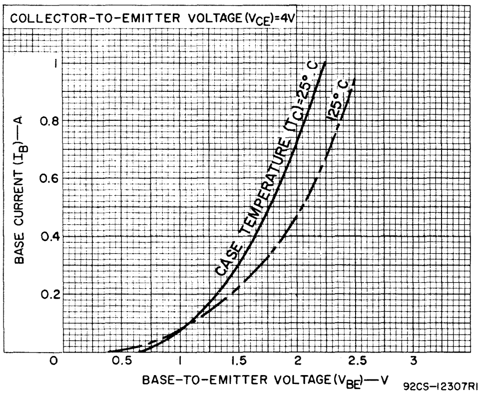


Fig.10—Typical input characteristics for type 2N3055.

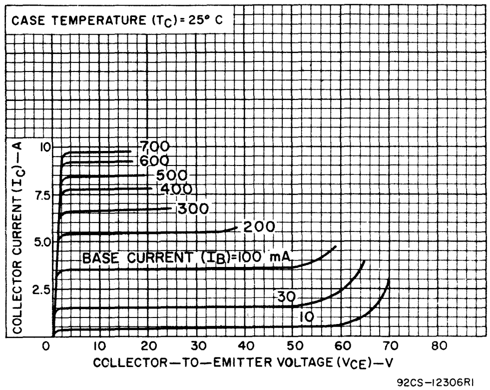


Fig.11—Typical output characteristics for type 2N3055.

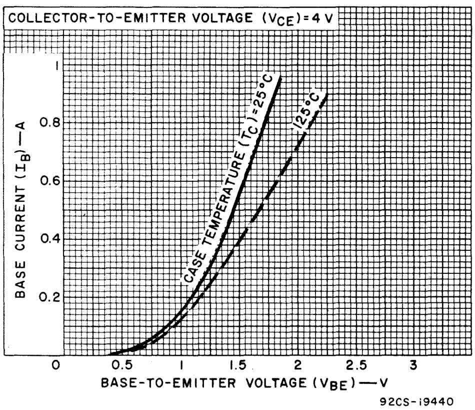


Fig.12—Typical input characteristics for type 2N6253.

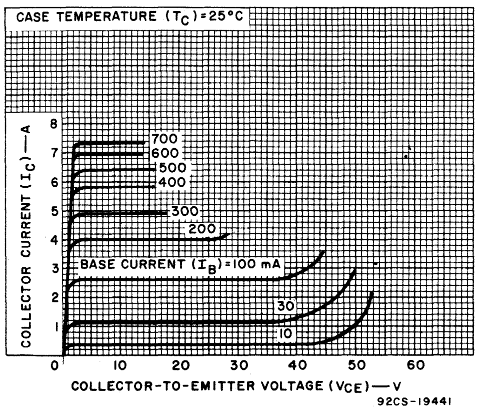


Fig.13—Typical output characteristics for type 2N6253.

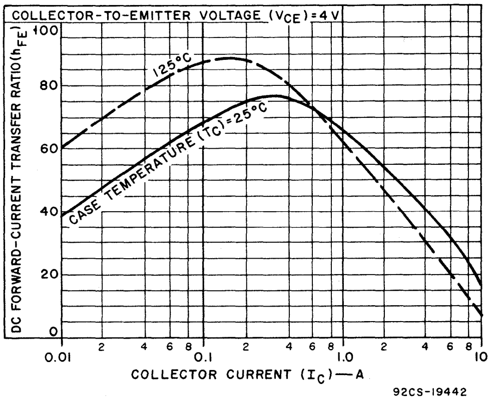


Fig.14—Typical dc-beta characteristics for type 2N6254.

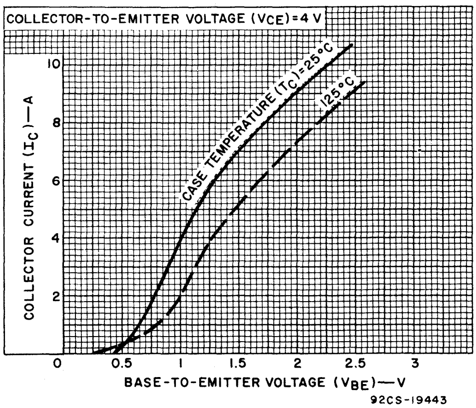


Fig.15—Typical transfer characteristics for type 2N6254.

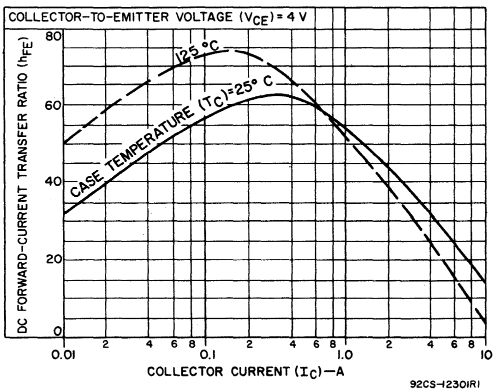


Fig.16—Typical dc-beta characteristics for type 2N3055.

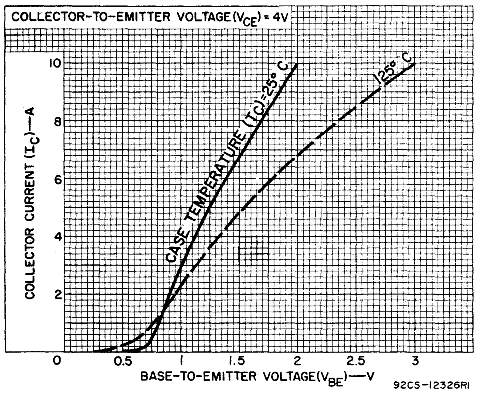


Fig.17—Typical transfer characteristics for types 2N6253 and 2N3055.

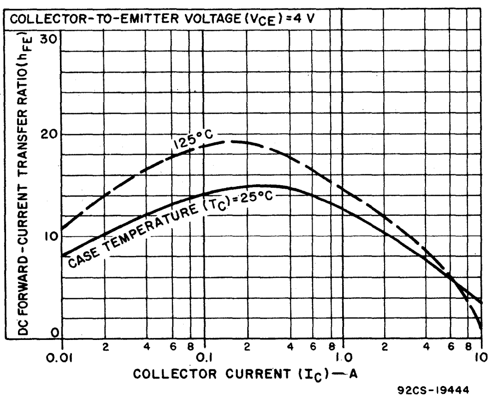


Fig.18—Typical dc-beta characteristics for type 2N6253.

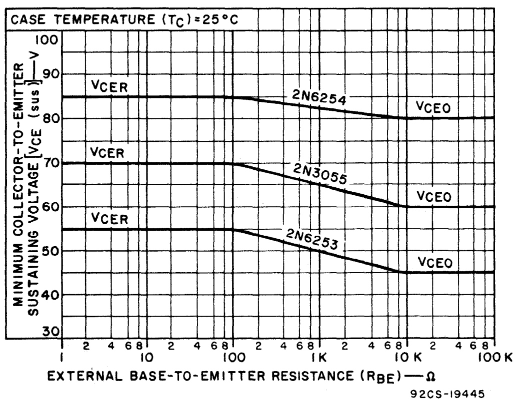


Fig.19—Sustaining voltage vs. base-to-emitter resistance for all types.

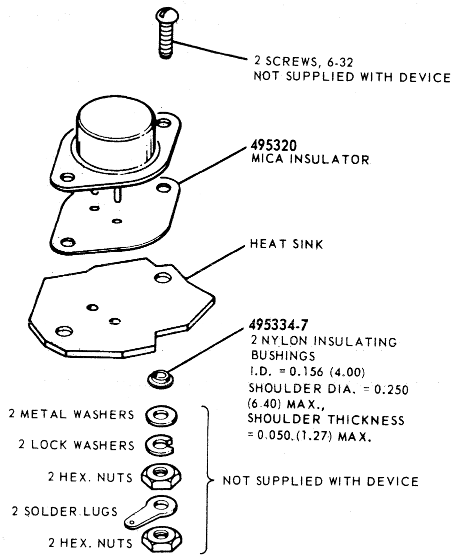
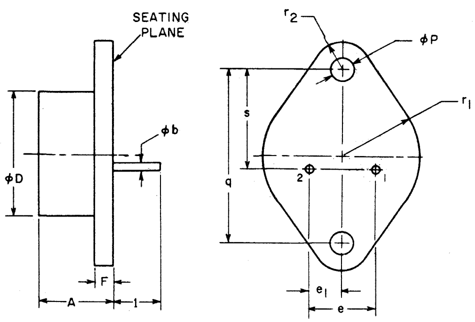


Fig.20–Suggested mounting hardware.

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

TERMINAL CONNECTIONS

Pin 1 – Base
Pin 2 – Emitter
Case – Collector
Mounting Flange – Collector

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

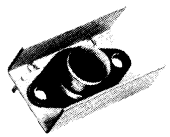
92CS–15222

RCA Solid State Division

Power Transistors

2N3441 2N6263 2N6264 40373 40912 40913

JEDEC TO-66 H-1340



JEDEC TO-66
With Integral Heat Radiator H-1470A

Hometaxial II* Medium-Power Silicon N-P-N Transistors

Rugged Devices for Intermediate, Power Applications in Industrial and Commercial Equipment

Features:
- 2N6264: premium type from 2N3441 family
- Maximum safe-area-of-operation curves for dc and pulse operation
- High voltage ratings
- Low saturation voltages
- Thermal-cycling rating curves

Applications:
- Series and shunt regulators
- High-fidelity amplifiers
- Power switching circuits
- Solenoid drivers

RCA 2N3441, 2N6263, and 2N6264 are hometaxial-base● silicon n-p-n transistors intended for a wide variety of medium- to-high power, high-voltage applications.

Types 40373, 40912, and 40913 are the 2N3441, 2N6263, and 2N6264 with factory-attached heat-radiators intended for printed-circuit-board applications.

● "Hometaxial" was coined by RCA from "homogenous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity in the axial direction (emitter-to-collector).

"Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6263 40912	2N3441 40373	2N6264 40913	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	140	160	170	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
* With base open	$V_{CEO}(sus)$	120	140	150	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$	130	150	160	V
With base reverse-biased (V_{BE} = -1.5 V)	$V_{CEV}(sus)$	140	160	170	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	3	3	3	A
PEAK COLLECTOR CURRENT		4	4	4	A
*CONTINUOUS BASE CURRENT	I_B	2	2	2	A
TRANSISTOR DISSIPATION:	P_T				
* At case temperature up to 25°C		20 (2N6263)	25 (2N3441)	50 (2N6264)	W
At ambient temperatures up to 25°C		5.8 (40912)	5.8 (40373)	5.8 (40913)	W
* At temperatures above 25°C		*See Figs. 4 & 7*	*See Figs. 4 & 8*	*See Figs. 1 & 7*	
*TEMPERATURE RANGE:					
Storage & Operating (Junction)			-65 to 200		°C
*PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.			235		°C

*In accordance with JEDEC registration data format JS-6 RDF-2

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C, Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		LIMITS						UNITS
							2N6263 40912		2N3441 40373		2N6264 40913		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current:													
		100				0	–	5	–	–	–	–	
* With base open	I_{CEO}	130				0	–	–	–	–	–	1	mA
		140				0	–	–	–	100	–	–	
Collector-Cutoff Current:													
		120		–1.5			–	2*	–	–	–	–	
	I_{CEX}	140		–1.5			–	–	–	5*	–	–	
		140		–1.5			–	–	–	1	–	–	
With base-emitter junction reversed biased		150		–1.5			–	–	–	–	–	0.05*	mA
		120		–1.5			–	10*	–	–	–	–	
	I_{CEX} (T_C = 150°C)	140		–1.5			–	–	–	6*	–	–	
		140		–1.5			–	–	–	5	–	–	
		150		–1.5			–	–	–	–	–	1*	
* Emitter-Cutoff Current	I_{EBO}		5				–	2	–	–	–	–	mA
			7				–	–	–	1	–	0.2	
Collector-to-Emitter Sustaining Voltage:[a]													
* With base open	$V_{CEO}(sus)$				0.1	0	120	–	140	–	150	–	
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				0.1		130	–	150	–	160	–	V
With base-emitter junction reversed biased	$V_{CEV}(sus)$			–1.5	0.1		140	–	160	–	170	–	
		2			1		–	–	–	–	20	60	
* DC Forward-Current Transfer Ratio	h_{FE}	2			3		3	–	–	–	5	–	
		4			0.5		20	100	25	100	–	–	
		4			2.7		–	–	5	–	–	–	
					0.5	0.05	–	1.2*	–	1	–	–	
Collector-to-Emitter Saturating Voltage	$V_{CE}(sat)$				1	0.1	–	–	–	–	–	0.5*	V
					2.7	0.9	–	–	–	6*	–	–	
		2			1		–	–	–	–	–	1.5*	
Base-to-Emitter Voltage	V_{BE}	4			0.5		–	2*	–	1.7	–	–	V
		4			2.7		–	–	–	6*	–	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 0.4 MHz)	$\|h_{fe}\|$	4			0.2		8	–	–	–	2	–	
		4			0.5		–	–	5	–	–	–	
Gain-Bandwidth Product	f_T	4			0.2		800	–	800	–	800	–	kHz
* Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	4			0.1		25	–	–	–	25	–	
		4			0.5		–	–	15	75	–	–	
Forward-Bias Second Breakdown Collector Current, Pulse Duration (non-repetitive) = 1 s	$I_{S/b}$	120					0.167	–	–	–	–	–	
		120					–	–	–	–	0.417	–	A
		120					–	–	0.21	–	–	–	
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$						8.75 (max.) 2N6263		7 (max.) 2N3441		3.5 (max.) 2N6264		°C/W
Junction-to-Free Air	$R_{\theta JA}$						30 (max.) 40912		30 (max.) 40373		30 (max.) 40913		

*In accordance with JEDEC registration data format (JS-6 RDF-2).

[a]**CAUTION:** The sustaining voltage $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 11.

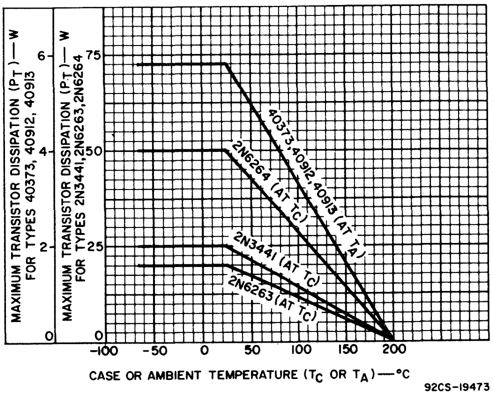


Fig.7—Dissipation derating curves for all types.

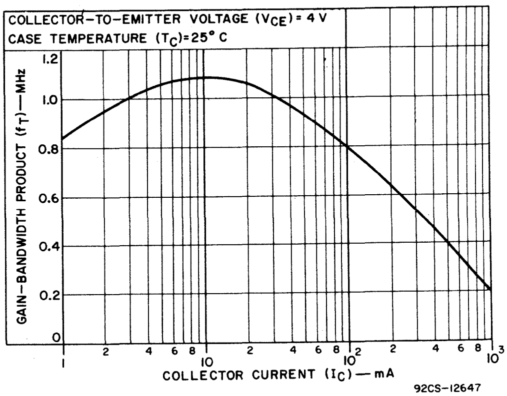


Fig.8—Typical gain-bandwidth product for all types.

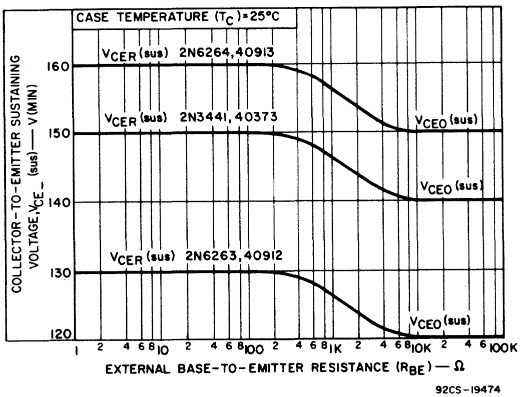


Fig.9—Sustaining voltage vs. base-to-emitter resistance for all types.

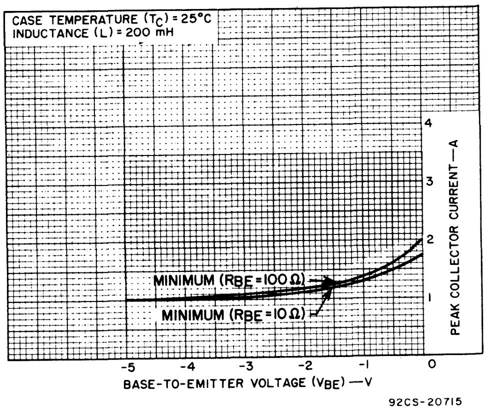


Fig.10—Reverse-bias second-breakdown characteristics for all types.

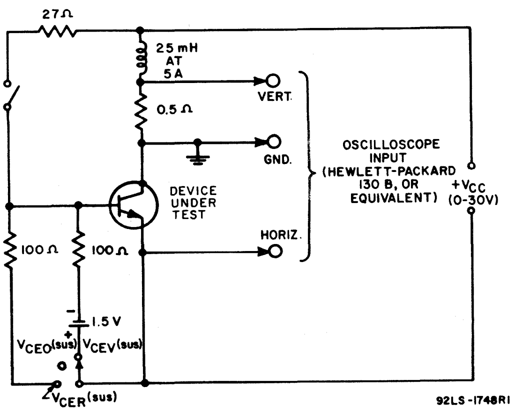
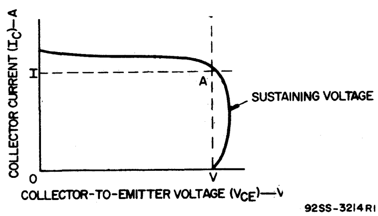


Fig.11—Circuit used to measure sustaining voltages, V_{CEO}(sus), V_{CER}(sus), and V_{CEV}(sus) for all types.



Note: The sustaining voltage, V_{CEO}(sus), V_{CER}(sus), or or V_{CEV}(sus) is acceptable when the trace falls to the right and above point "A" for all types. (For values of current and voltage, see *Electrical Characteristics)*

Fig.12—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 11).

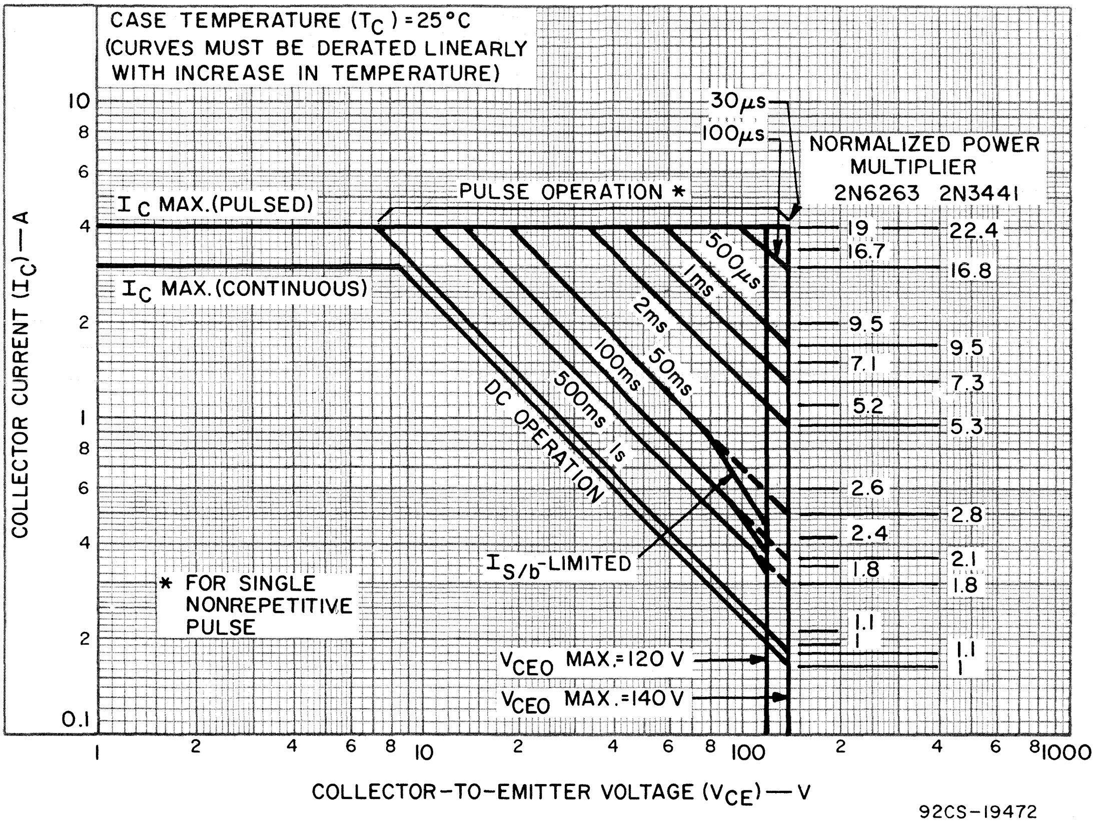


Fig.4—Maximum operating areas for type 2N6263 and 2N3441.

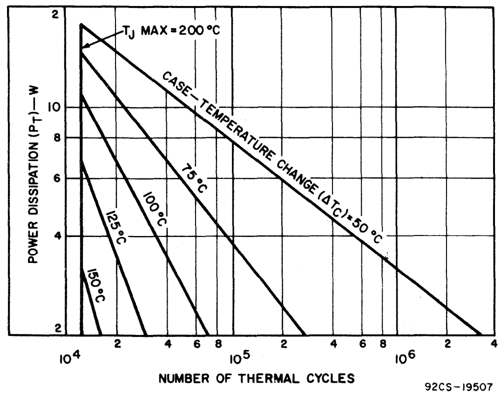


Fig.5—Thermal-cycle rating chart for type 2N3441.

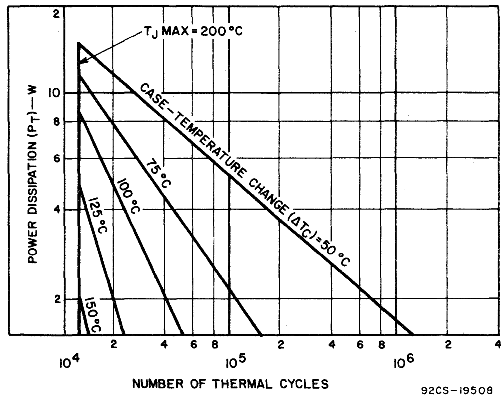


Fig.6—Thermal-cycle rating chart for type 2N6263.

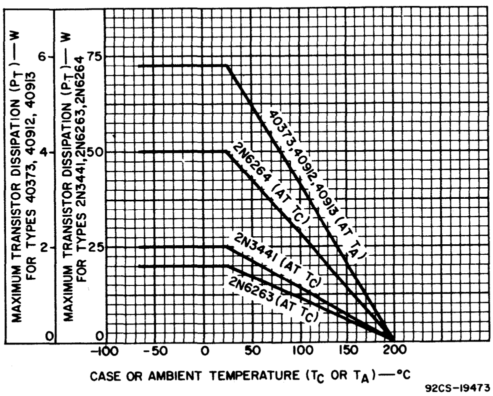


Fig.7—Dissipation derating curves for all types.

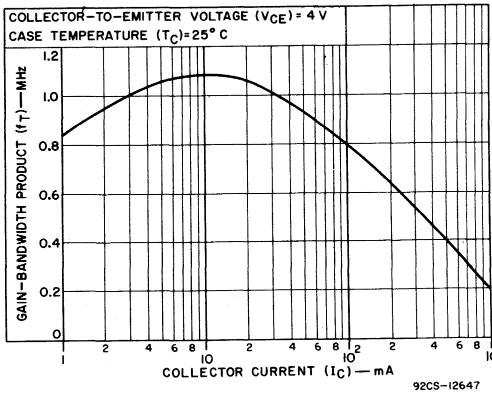


Fig.8—Typical gain-bandwidth product for all types.

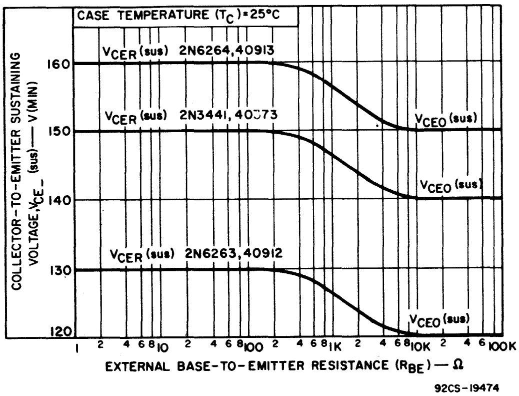


Fig.9—Sustaining voltage vs. base-to-emitter resistance for all types.

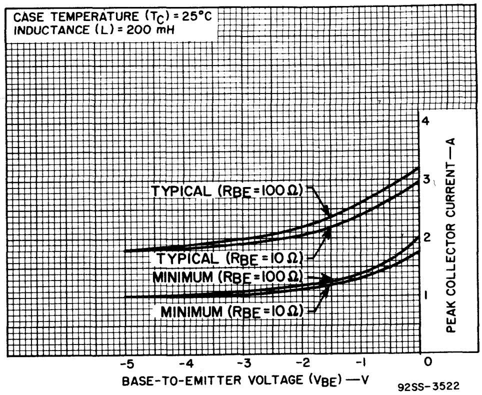


Fig.10—Reverse-bias second-breakdown characteristics for all types.

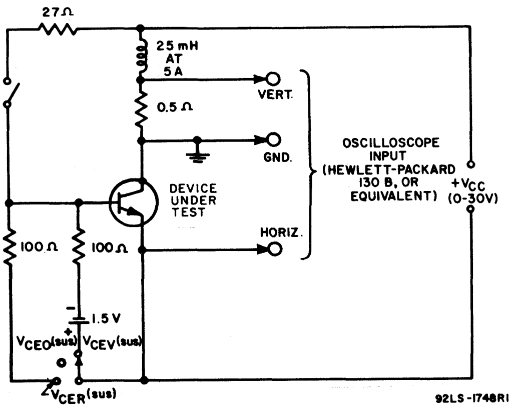
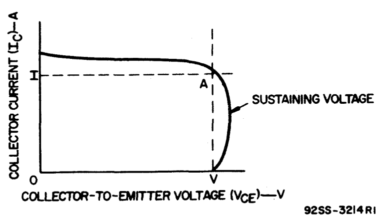


Fig.11—Circuit used to measure sustaining voltages, $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ for all types.



Note: The sustaining voltage, $V_{CEO}(sus)$, $V_{CER}(sus)$, or $V_{CEV}(sus)$ is acceptable when the trace falls to the right and above point "A" for all types. (For values of current and voltage, see *Electrical Characteristics*)

Fig.12—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 11).

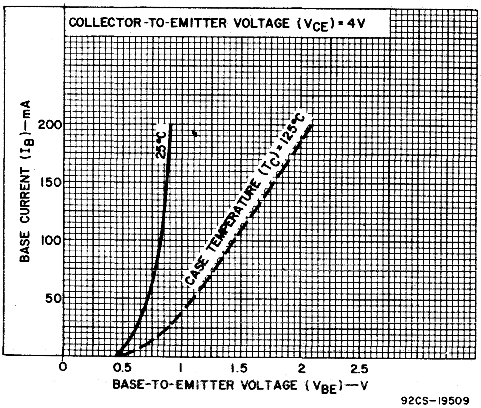


Fig. 13—Typical input characteristics for types 2N6264 and 40913.

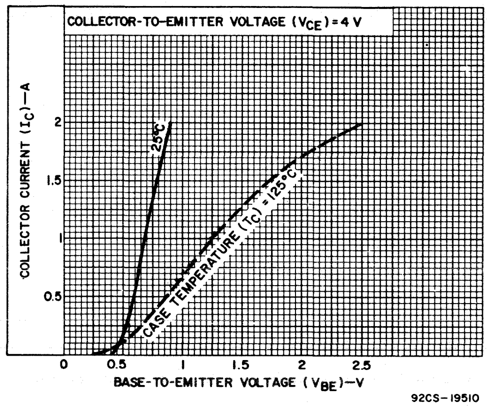


Fig. 14—Typical transfer characteristics for types 2N6264 and 40913.

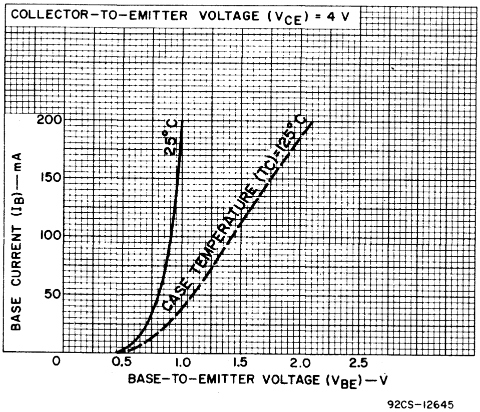


Fig. 15—Typical input characteristics for types 2N3441 and 40373.

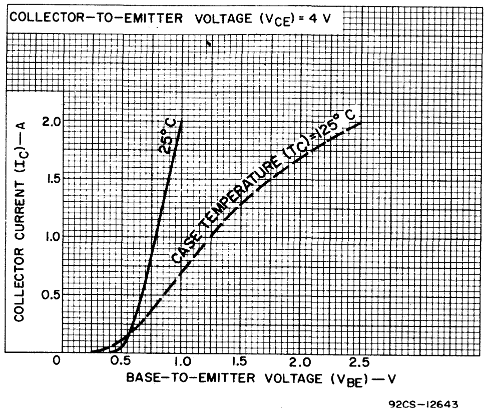


Fig. 16—Typical transfer characteristics for types 2N3441 and 40373.

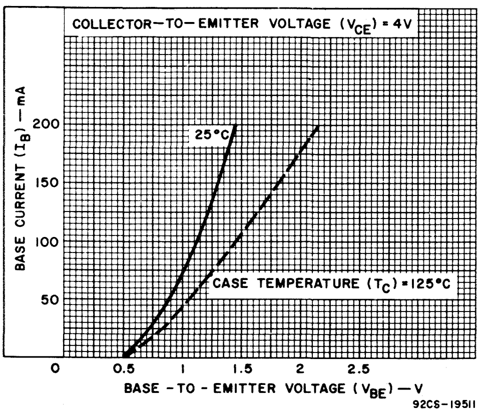


Fig. 17—Typical input characteristics for types 2N6263 and 40912.

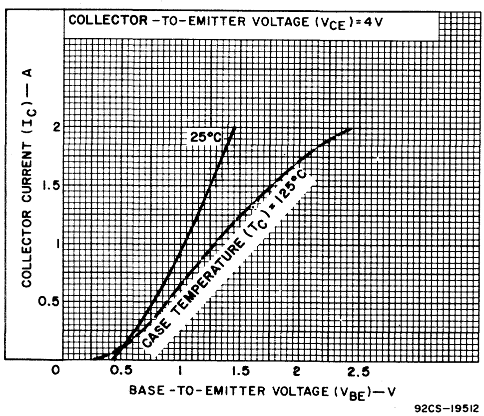


Fig. 18—Typical transfer characteristics for types 2N6263 and 40912.

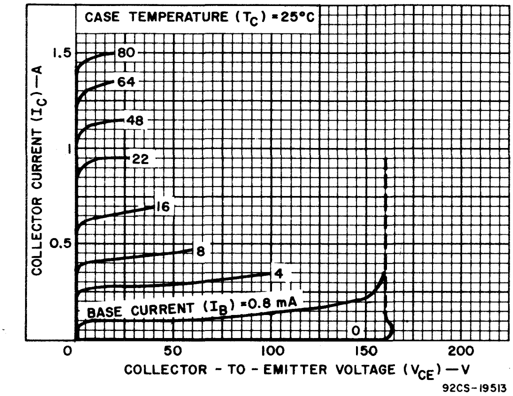


Fig.19—Typical output characteristics for types 2N6264 and 40913.

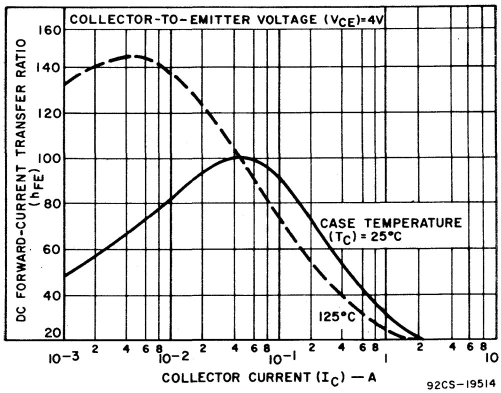


Fig.20—Typical dc-beta characteristics for types 2N6264 and 40913.

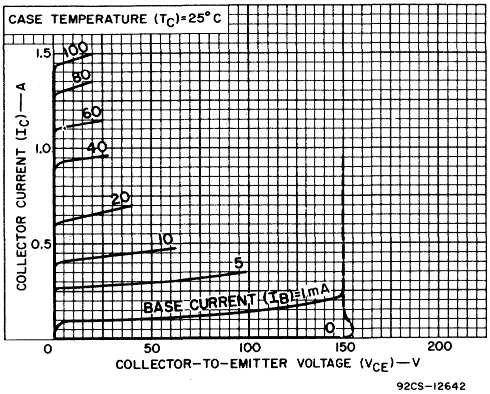


Fig.21—Typical output characteristics for types 2N3441 and 40373.

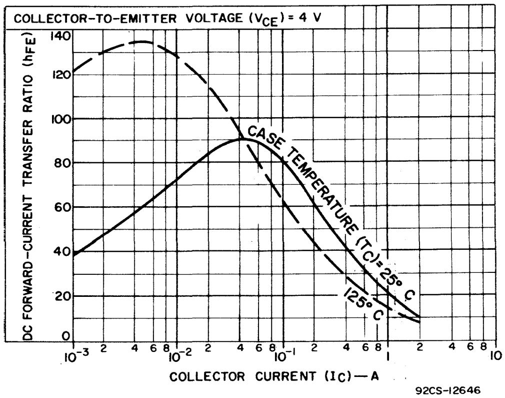


Fig.22—Typical dc-beta characteristics for types 2N3441 and 40373.

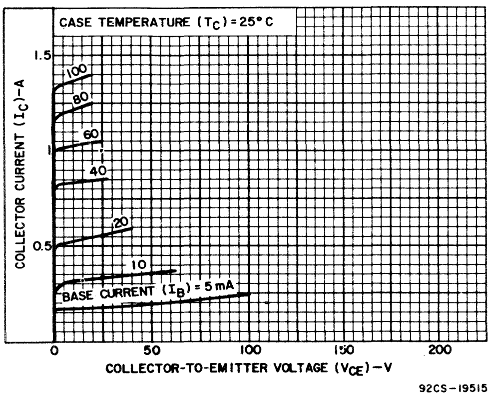


Fig.23—Typical output characteristics for types 2N6263 and 40912.

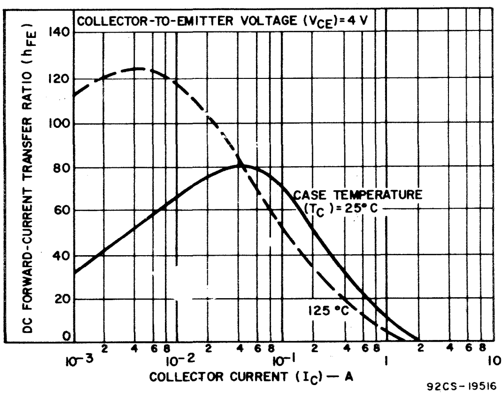


Fig.24—Typical dc-beta characteristics for types 2N6263 and 40912.

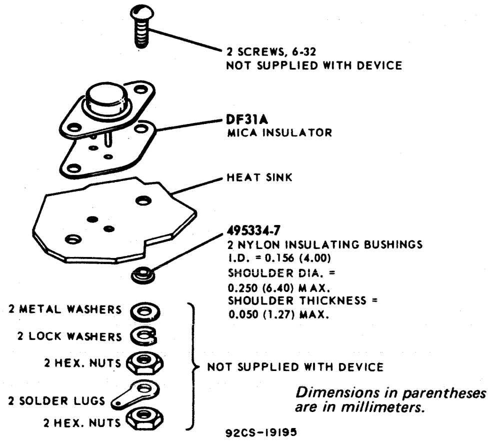
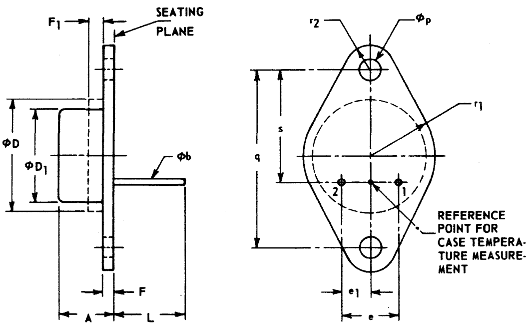


Fig.25—Suggested hardware for 2N3441, 2N6263, and 2N6264.

DIMENSIONAL OUTLINE FOR 2N3441, 2N6263, and 2N6264 JEDEC TO-66



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
φb	0.028	0.034	0.711	0.863	
φD	—	0.620	—	15.75	
φD1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F1	—	0.050	—	1.27	1
L	0.360	—	9.14	—	
φp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r1	—	0.350	—	8.89	
r2	—	0.145	—	3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

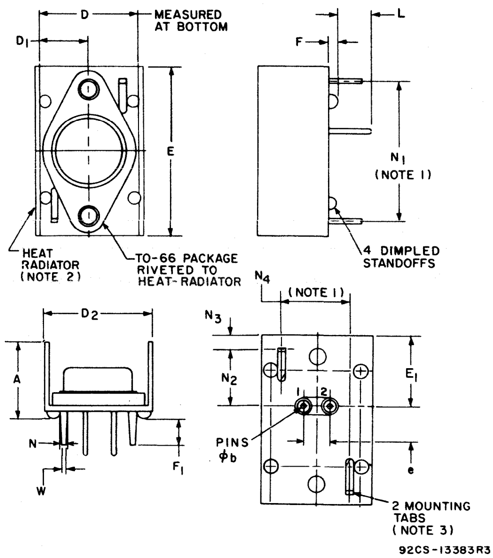
1. The outline contour is optional within zone defined by φD and F_1.
2. Dimensions does not include seating flanges.

92SS-3738

TERMINAL CONNECTIONS FOR 2N3441, 2N6263, & 2N6264

Pin 1 - Base
Pin 2 - Emitter
Case, Mounting Flange - Collector

DIMENSIONAL OUTLINE FOR JEDEC TO-66 WITH HEAT RADIATOR



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A		0.595		15.11	
φb	0.028	0.034	0.711	0.864	
D	0.750	0.760	19.05	19.30	
D1	0.375	0.380	9.52	9.65	
D2	0.820	0.920	20.83	23.37	
E	1.297	1.327	32.94	33.70	
E1	0.551	0.561	13.99	14.25	
e	0.190	0.210	4.83	5.33	
F	0.040	0.055	1.02	1.40	
F1	0.175	0.210	4.44	5.33	
L	0.270		0.686		
N	0.052	0.065	1.32	1.65	
N1	1.098	1.102	27.89	27.99	1
N2	0.448	0.452	11.38	11.47	
N3	0.099	0.113	0.25	0.29	
N4	0.498	0.502	12.65	12.75	
W	0.048	0.060	1.22	1.52	

NOTES:

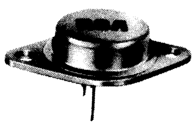
1. Measured at bottom of heat radiator.
2. 0.035 in. (0.889) C.R.S., tin plated.
3. Recommended hole size for printed-circuit board is 0.070 in. (1.778) dia.

TERMINAL CONNECTIONS FOR 40373, 40912, & 40913

Pin 1 - Base
Pin 2 - Emitter
Heat-Radiator - Collector

RCA
Solid State
Division

Power Transistors
2N6262
2N4347
2N3442



JEDEC TO-3 H-1570

Hometaxial II• High-Voltage Silicon N-P-N Transistors

Rugged High-Power Devices for Applications in Industrial and Commercial Equipment

Features:

- **Low saturation voltages**
- **Thermal-cycle rating charts**
- **High dissipation capability — 100 W (2N4347)**
  — 117 W (2N3442)
  — 150 W (2N6262)
- **Maximum area-of-operation curves for dc and pulse operation.**

RCA 2N3442, 2N4347, and 2N6262 are hometaxial-base●, silicon n-p-n transistors intended for a wide variety of high-power, high-voltage applications. Typical applications for these transistors include power-switching circuits, audio amplifiers, series- and shunt-regulator driver and output stages, dc-to-dc converters, inverters, and solenoid (hammer)/relay driver service.

These devices employ the popular JEDEC TO-3 package; they differ in maximum ratings for voltage, current, and power.

Applications:

- **Series and shunt regulators**
- **High-fidelity amplifiers**
- **Power-switching circuits**

●"Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector). "Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N4347	2N3442	2N6262	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	140	160	170	V
COLLECTOR-TO-EMITTER VOLTAGE:					
* With base open	V_{CEO}	120	140	150	V
With reverse bias (V_{BE}) of −1.5 V	V_{CEX}	140*	160	170	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	7	V
*COLLECTOR CURRENT:	I_C				
Continuous		5	10	10	A
Peak		10*	15	15	A
*BASE CURRENT:	I_B				
Continuous		3	7	7	A
Peak		8*	–	–	A
*TRANSISTOR DISSIPATION:	P_T				
At case temperature up to 25°C		100	117	150	W
At case temperatures above 25°C		← See Figs. 1, 4, 7, & 22 →			
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		← −65 to +200 →			°C
*PIN TEMPERATURE (During Soldering):					
At distances ≥1/32 in. (0.8 mm) from case for 10 s max.		235	235	235	°C

*In accordance with JEDEC registration data format (JS-6, RDF-2).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS							LIMITS						UNITS
		DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (A)			Type 2N4347		Type 2N3442		Type 2N6262		
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current: With emitter open	I_{CBO}	140					0		—	—	—	1*	—	1	mA
* With base-emitter junction reverse-biased	I_{CEX}		120		−1.5				—	2	—	—	—	—	
			140		−1.5				—	—	—	5	—	—	mA
			150		−1.5				—	—	—	—	—	0.1	
* With base-emitter junction reverse-biased and T_C = 150°C	I_{CEX}		125		−1.5				—	10	—	—	—	—	
			140		−1.5				—	—	—	30	—	—	mA
			150		−1.5				—	—	—	—	—	2	
* With base open	I_{CEO}		100						—	200	—	—	—	—	
			110						—	—	—	—	—	1	mA
			140						—	—	—	200	—	—	
* Emitter-Cutoff Current	I_{EBO}			7		0			—	5	—	5	—	0.2	mA
* DC Forward Current Transfer Ratio	h_{FE}		2			3[a]			—	—	—	—	20	70	
			2			10[a]			—	—	—	—	5	—	
			4			2[a]			15	60	—	—	—	—	
			4			3[a]			—	—	20	70	—	—	
			4			5[a]			10	—	—	—	—	—	
			4			10[a]			—	—	7.5	—	—	—	
Collector-to-Emitter Sustaining Voltage: With base-emitter junction reverse-biased	$V_{CEV}(sus)$				−1.5	0.1			140	—	160	—	—	—	V
					−1.5	0.2			—	—	—	—	170	—	
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$					0.1			130	—	—	—	—	—	V
						0.2			—	—	150	—	160	—	
* With base open	$V_{CEO}(sus)$					0.2[a]		0	120	—	140	—	—	—	V
						0.2[a]		0	—	—	—	—	150	—	
* Base-to-Emitter Voltage	V_{BE}		2			3[a]			—	—	—	—	—	1	
			4			3[a]			—	—	—	1.7	—	—	V
			4			2[a]			—	2	—	—	—	—	
			4			5[a]			—	3	—	—	—	—	
			4			10[a]			—	—	—	5.7	—	—	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					2[a]		0.2	—	1	—	—	—	—	
						3[a]		0.3	—	—	—	1	—	0.5	V
						5[a]		0.63	—	2	—	—	—	—	
						10[a]		2	—	—	—	5	—	—	
Power Rating Test	PRT		67			1.5			1	—	—	—	—	—	
			78			1.5			—	—	1	—	—	—	s
			100			1.5			—	—	—	—	1	—	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio: f = 50 kHz	$\|h_{fe}\|$		4			0.5			40	—	—	—	—	—	
f = 40 kHz	$\|h_{fe}\|$		4			1			—	—	—	—	2	—	
			4			2			—	—	2	—	—	—	
* Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}		4			0.5			40	—	—	—	—	—	
			4			1			—	—	—	—	10	—	
			4			2			—	—	12	72	—	—	
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$								—	1.75	—	1.5	—	1.17	°C/W

*In accordance with JEDEC registration data format JS-6 RDF-2.

[a] Pulse test; pulse duration = 300 μs, rep. rate = 60 Hz

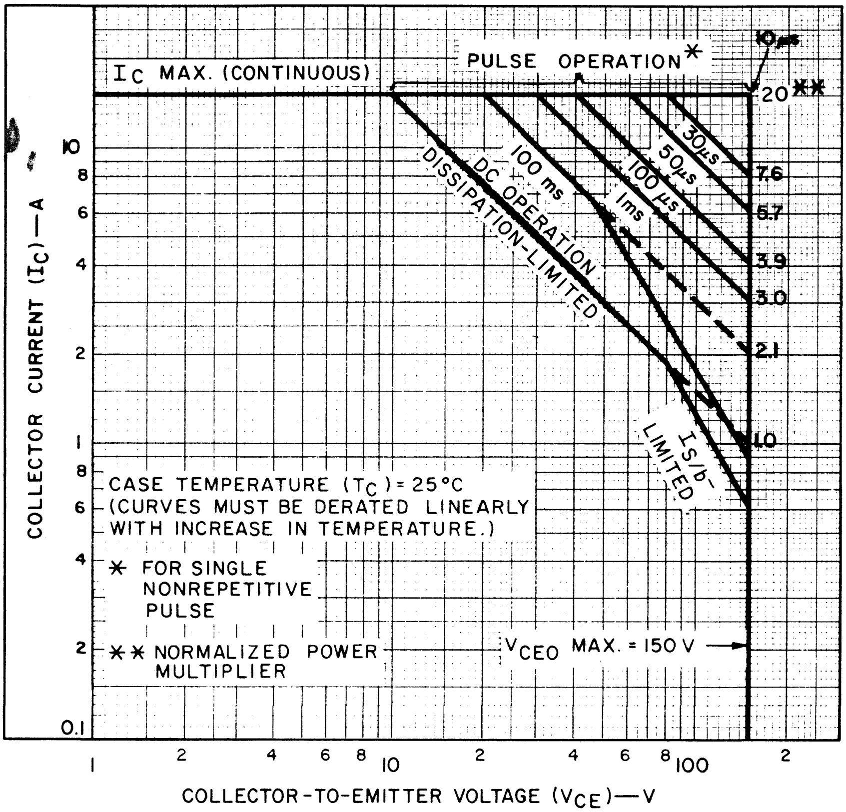


Fig. 1—Maximum operating areas for type 2N6262.

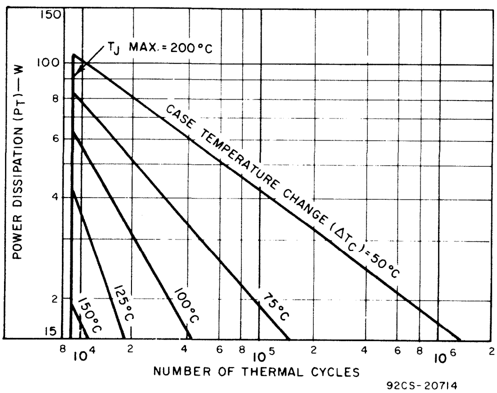


Fig.2—Thermal-cycle rating chart for type 2N6262.

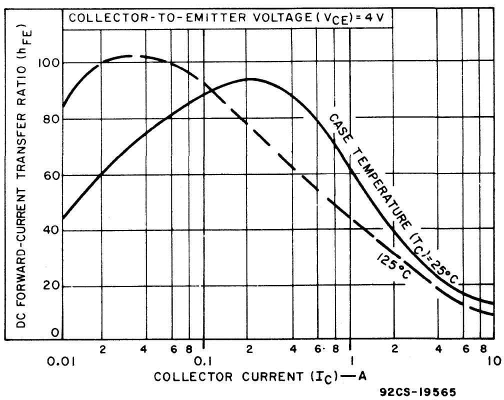


Fig.3—Typical dc beta characteristics for type 2N6262.

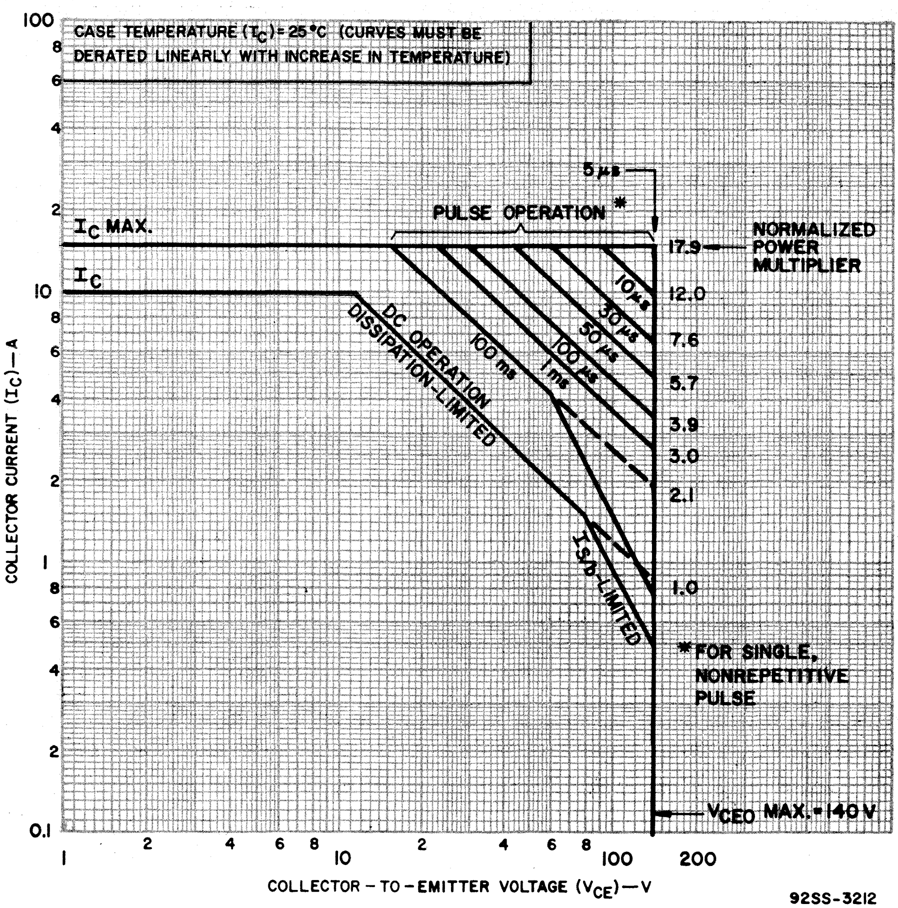


Fig.4— Maximum operating areas for type 2N3442.

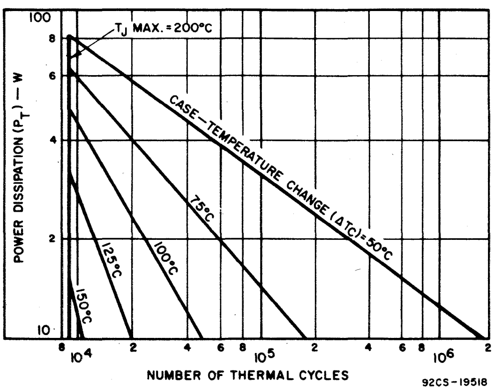


Fig.5— Thermal-cycle rating chart for type 2N3442.

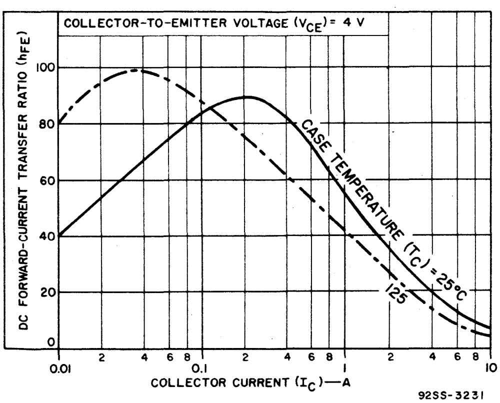


Fig.6— Typical dc beta characteristics for type 2N3442.

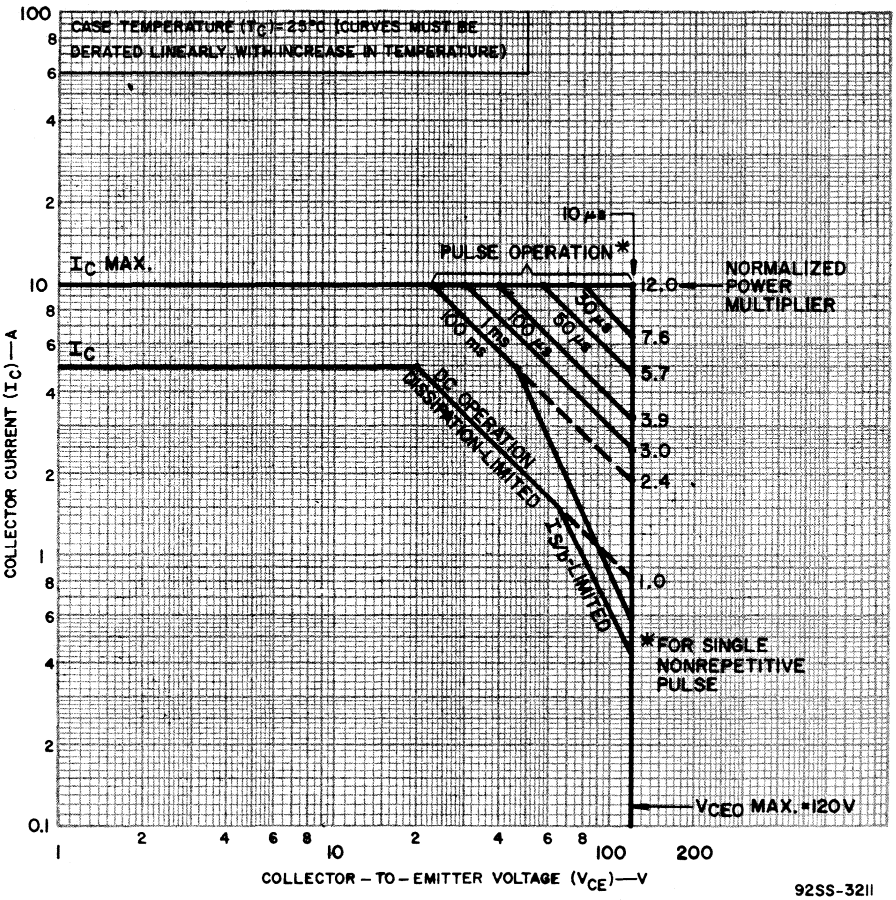


Fig.7— Maximum operating areas for type 2N4347.

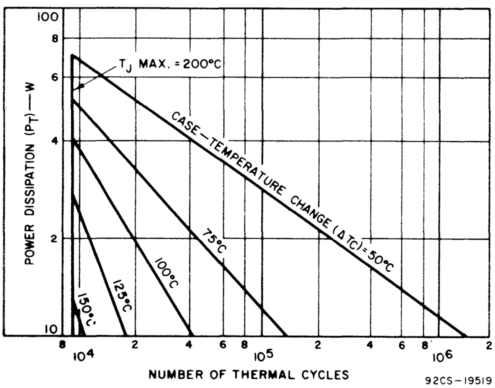


Fig.8— Thermal-cycle rating chart for type 2N4347.

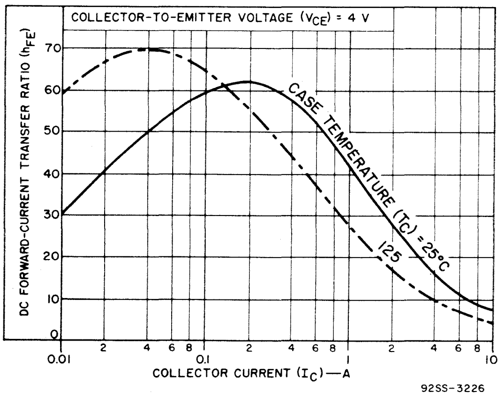


Fig.9— Typical dc beta characteristics for type 2N4347.

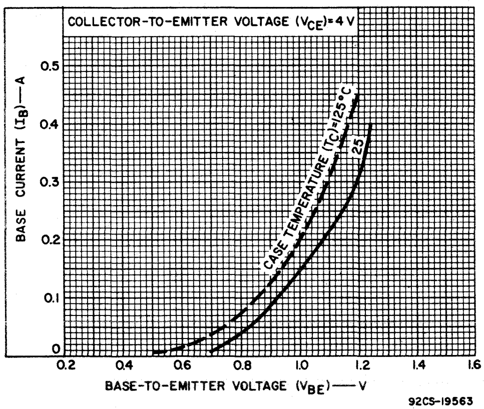


Fig.10—Typical input characteristics for type 2N6262.

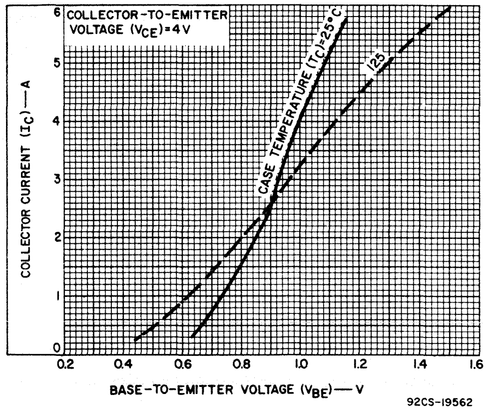


Fig.11—Typical transfer characteristics for type 2N6262.

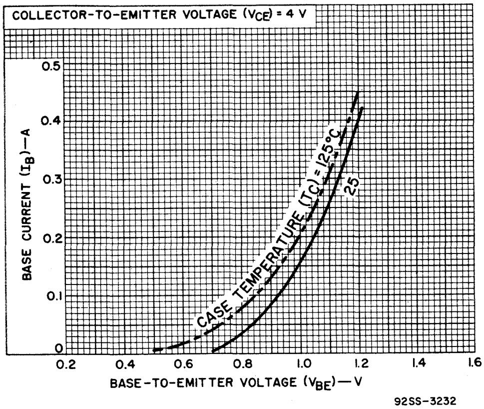


Fig.12—Typical input characteristics for type 2N3442.

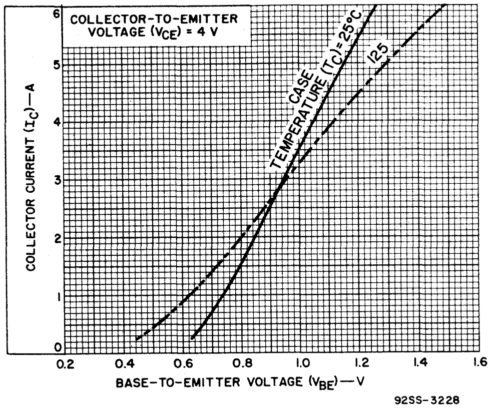


Fig.13—Typical transfer characteristics for types 2N3442 and 2N4347.

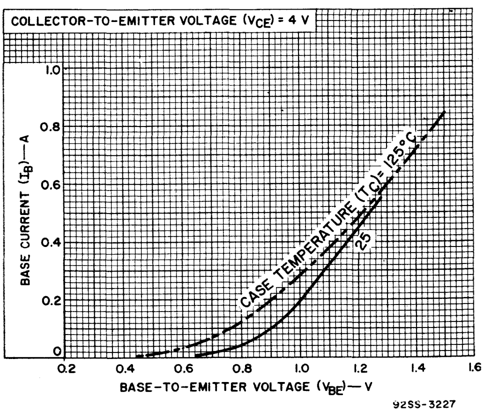


Fig.14—Typical input characteristics for type 2N4347.

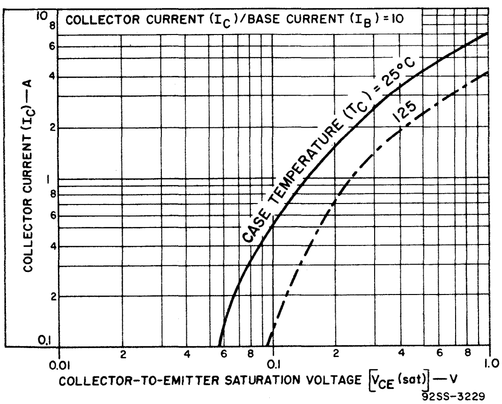


Fig.15—Typical saturation-voltage characteristics for all types.

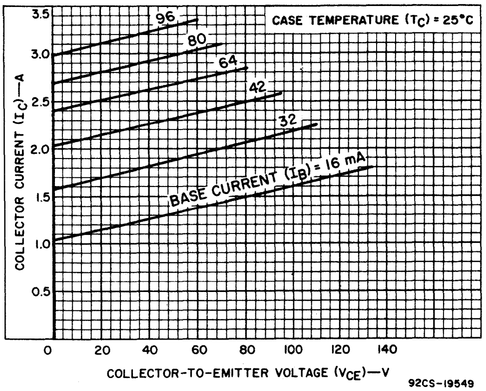


Fig.16—Typical large-signal output characteristics for type 2N6262.

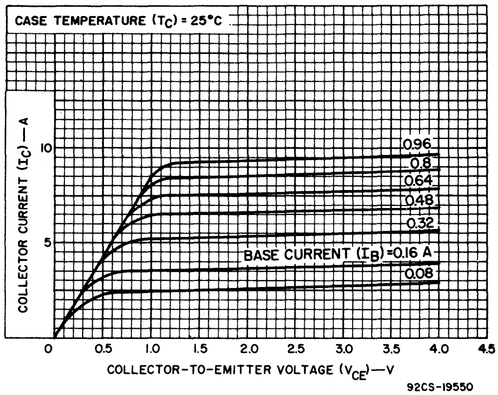


Fig.17—Typical small-signal output characteristics for type 2N6262.

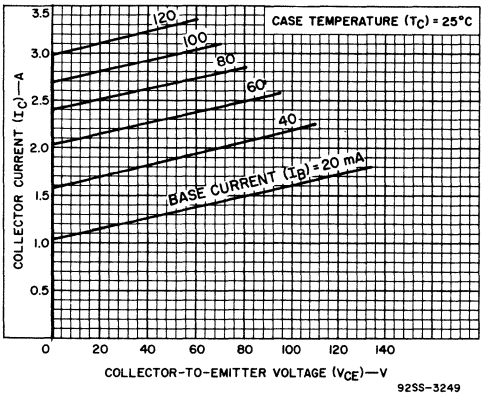


Fig.18—Typical large-signal output characteristics for type 2N3442.

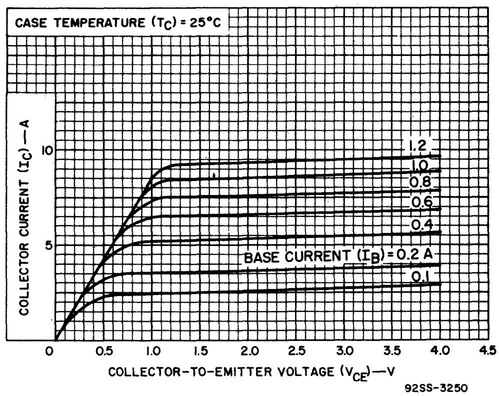


Fig.19—Typical small-signal output characteristics for type 2N3442.

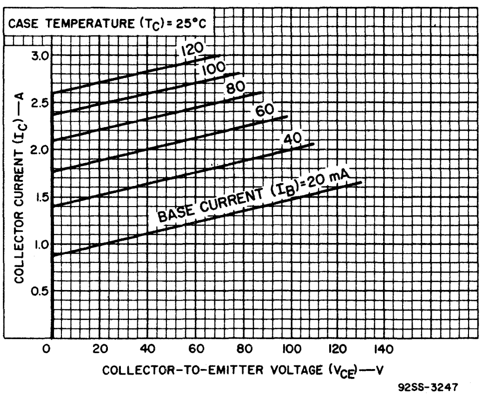


Fig.20—Typical large-signal output characteristics for type 2N4347.

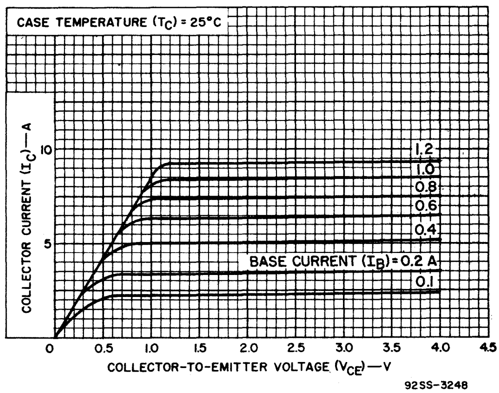


Fig.21—Typical small-signal output characteristics for type 2N4347.

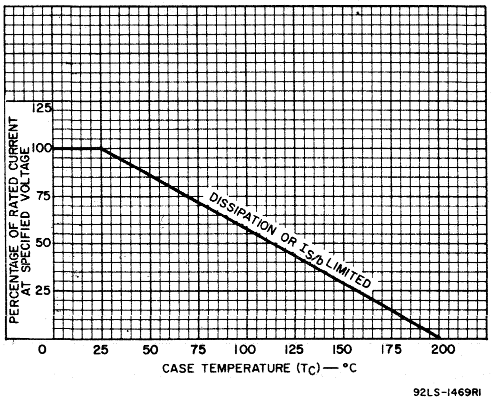


Fig.22—Current derating curve for all types.

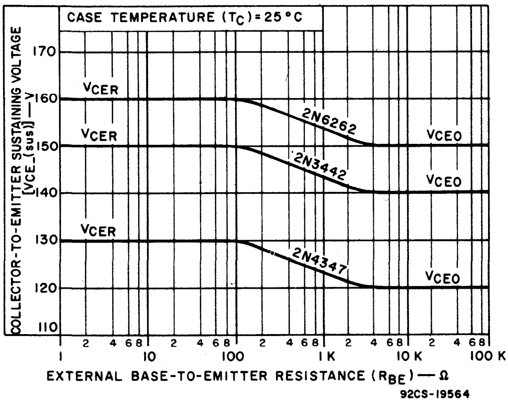


Fig.23—Sustaining voltage vs. base-to-emitter resistance for all types.

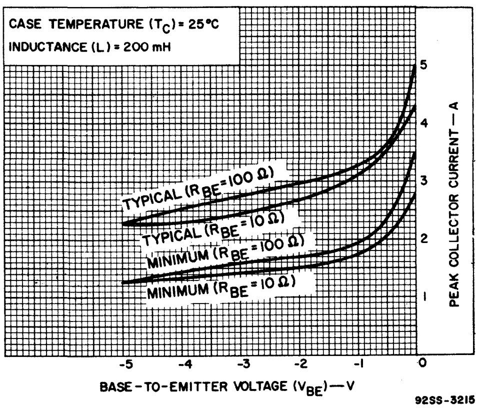


Fig.24—Reverse-bias, second-breakdown characteristics for all types.

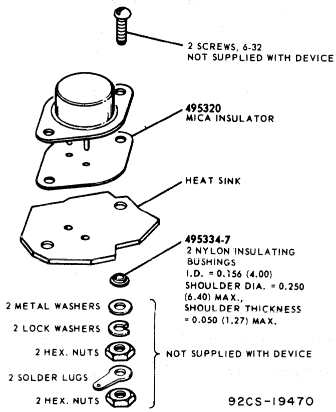
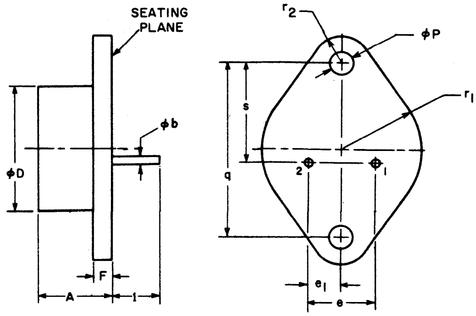


Fig.25—Suggested mounting hardware.

DIMENSIONAL OUTLINE — JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS—15222

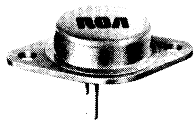
TERMINAL CONNECTIONS

Pin 1 - Base
Pin 2 - Emitter
Case - Collector
Mounting Flange - Collector

RCA Solid State Division

Power Transistors

2N3771 2N6257 2N3772 2N6258



JEDEC TO-3

H-1570

Hometaxial II• High-Power High-Current Transistors

Rugged Silicon N-P-N Devices for Applications in Industrial and Commercial Equipment

Features:

- **High dissipation capability**
- **V_{CEX}(sus) at 3 A = 50 V min. (2N3771, 2N6257); = 90 V min. (2N3772, 2N6258)**
- **15-A specification for: h_{FE}, V_{BE}, & V_{CE}(sat) (2N3771, 2N6257)**
- **10-A specification for: h_{FE}, V_{BE}, & V_{CE}(sat) (2N3772, 2N6258)**
- **Low saturation voltage with high beta**

RCA-2N3771, 2N3772, 2N6257, and 2N6258 are hometaxial-base•, silicon n-p-n transistors intended for a wide variety of high-power, high-current applications. Typical applications for these transistors include power-switching circuits, audio amplifiers, series- and shunt-regulator driver and output stages, dc-to-dc converters, inverters, and solenoid (hammer)/relay driver service.

All devices employ the popular JEDEC TO-3 package; they differ in maximum ratings for voltage, current, and power.

• "Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector). "Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		2N3771	2N3772	2N6257	2N6258	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	100	50	100	V
*COLLECTOR-TO-EMITTER VOLTAGE:						
With −1.5 V (V_{BE}) & R_{BE} = 100 Ω	V_{CEX}	50	80	50	90	V
With base open	V_{CEO}	40	60	40	80	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	7	5	7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	30	20	20	30	A
*PEAK COLLECTOR CURRENT		30	30	30	30	A
*CONTINUOUS BASE CURRENT	I_B	7.5	5	5	7.5	A
*PEAK BASE CURRENT		15	15	15	15	A
*TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		150	150	150	250	W
At case temperatures above 25°C		← See Figs. 1, 6, & 7 →				
*TEMPERATURE RANGE:						
Storage & Operating (Junction)		← −65 to 200 →				°C
*PIN TEMPERATURE (During soldering):						
At distance ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		← 230 →				°C

*In accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_E	I_B	LIMITS: Type 2N3771 Min.	Max.	Type 2N3772 Min.	Max.	Type 2N6257 Min.	Max.	Type 2N6258 Min.	Max.	Units
* Collector-Cutoff Current: With emitter open	I_{CBO}	50					0		–	2*	–	–	–	4	–	–	mA
		100					0		–	–	–	5*	–	–	–	1	
With base-emitter junction reverse-biased	I_{CEX}		45		−1.5				–	–	–	–	–	4	–	–	mA
			50		−1.5				–	2	–	–	–	–	–	–	
			100		−1.5				–	–	–	5	–	–	–	1	
With base-emitter junction reverse-biased & T_C = 150°C	I_{CEX}		30		−1.5				–	10	–	10	–	–	–	–	mA
			45		−1.5				–	–	–	–	–	20	–	–	
			100		−1.5				–	–	–	–	–	–	–	10	
With base open	I_{CEO}		25					0	–	–	–	–	–	10	–	–	mA
			30					0	–	10	–	–	–	–	–	–	
			50					0	–	–	–	10	–	–	–	–	
			60					0	–	–	–	–	–	–	–	2	
* Emitter-Cutoff Current	I_{EBO}			5		0			–	5	–	–	–	10	–	–	mA
				7		0			–	–	–	5	–	–	–	2	
* DC Forward Current Transfer Ratio	h_{FE}		4			30[a]			5	–	–	–	–	–	5	–	
			4			20[a]			–	–	5	–	5	–	–	–	
			2			15[a]			–	–	–	–	–	–	20	60	
			4			15[a]			15	60	–	–	–	–	–	–	
			4			10[a]			–	–	15	60	–	–	–	–	
			4			8[a]			–	–	–	–	15	75	–	–	
Collector-to-Emitter Sustaining Voltage (*See Fig. 5*) With base-emitter junction reverse-biased (R_{BE} = 100Ω)	$V_{CEX}(sus)$			−1.5		0.2			50	–	80	–	50	–	90	–	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$					0.2			45	–	70	–	45	–	85	–	V
* With base open	$V_{CEO}(sus)$					0.2		0	40	–	60	–	40	–	80	–	V
* Base-to-Emitter Voltage	V_{BE}		2			20[a]			–	–	–	–	–	–	–	2	V
			4			15[a]			–	2.7	–	–	–	–	–	–	
			4			10[a]			–	–	–	2.2	–	–	–	–	
			4			8[a]			–	–	–	–	–	2.2	–	–	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					30[a]		6	–	4	–	–	–	–	–	3	V
						20[a]		4	–	–	–	4	–	4	–	–	
						15[a]		1.5	–	2	–	–	–	–	–	0.75	
						10[a]		1	–	–	–	1.4	–	–	–	–	
						8[a]		0.8	–	–	–	–	–	1.5	–	–	
Second-Breakdown Collector Current With base forward-biased & 1−s, nonrepetitive pulse	$I_{S/b}$[b]		80						–	–	–	–	–	–	3.1	–	A
			60						–	–	2.5	–	–	–	–	–	
			40						3.75	–	–	–	3.75	–	–	–	
Second-Breakdown Energy With base reverse biased & L = 40 mH, R_{BE} = 100 Ω	$E_{S/b}$[c]			−1.5		5			500	–	500	–	500	–	500	–	mJ
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 0.05 MHz)	$\|h_{fe}\|$		4			1			4*	16 (Typ.)	4*	16 (Typ.)	4*	16 (Typ.)	4*	16 (Typ.)	
* Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}		4			1			40	–	40	–	40	–	40	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$								–	1.17	–	1.17	–	1.17	–	0.7	°C/W

* In accordance with JEDEC registration data format JS-6 RDF-2.

[a] Pulsed; pulse duration = 300 μs, rep. rate = 60 Hz.

[b] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[c] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse-bias conditions. $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

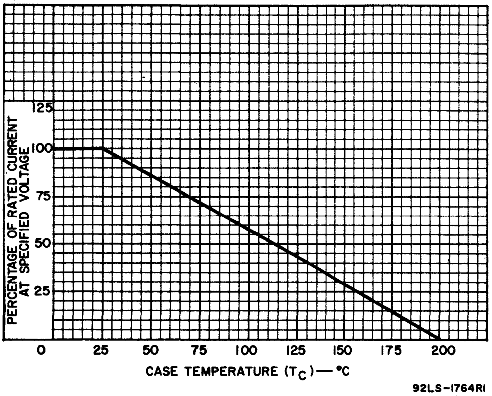


Fig.1—Derating curve for all types.

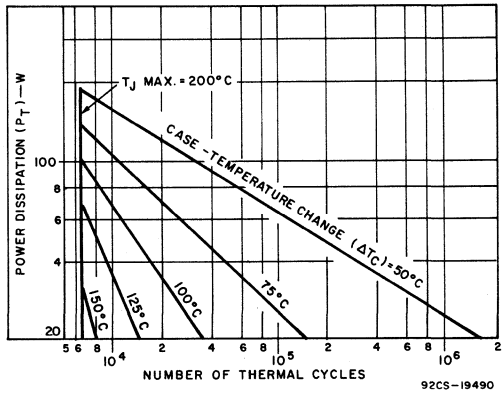


Fig.2—Thermal-cycle rating chart for type 2N6258.

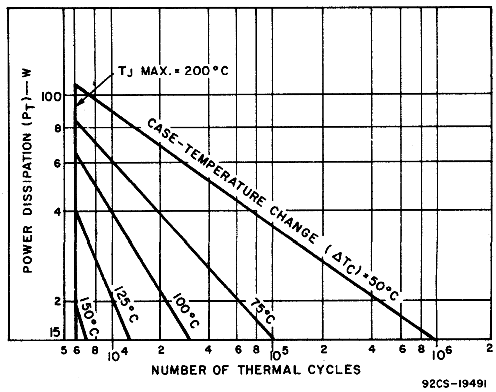


Fig.3—Thermal-cycle rating chart for types 2N3771, 2N3772, and 2N6257.

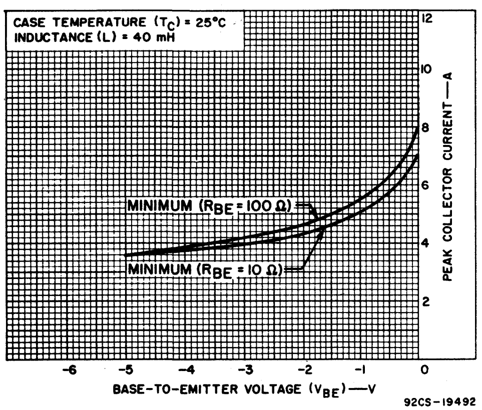


***Fig.4**—Reverse-bias second-breakdown characteristics for all types.*

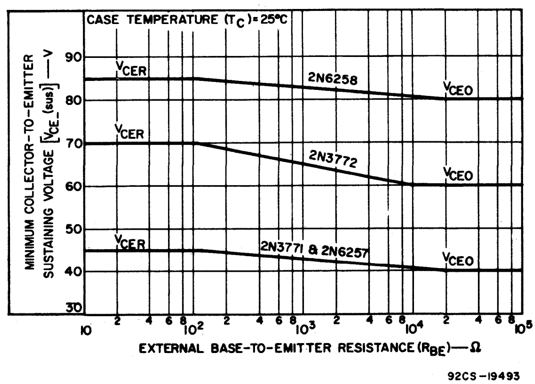


Fig.5—Sustaining voltage vs. base-to-emitter resistance for all types.

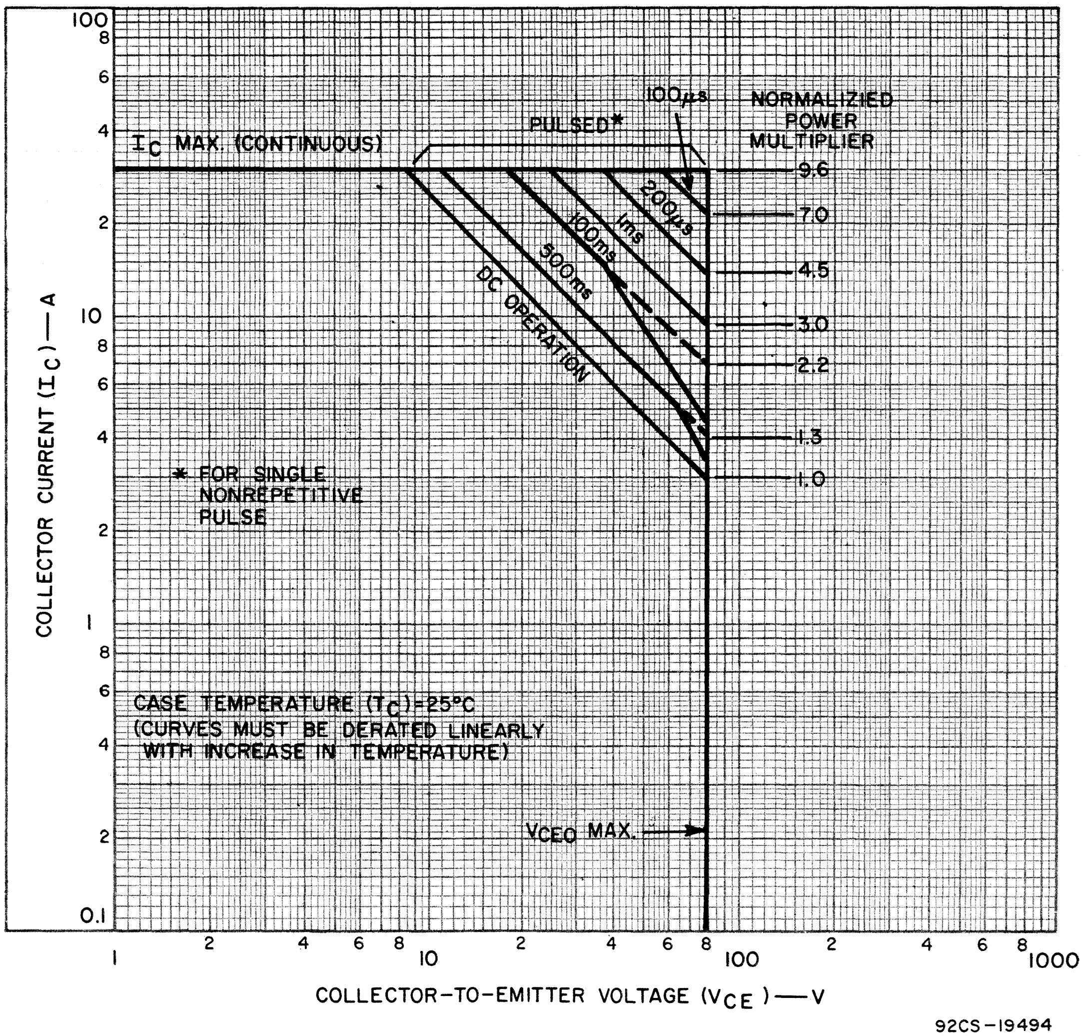


Fig.6—Maximum operating areas for types 2N6258.

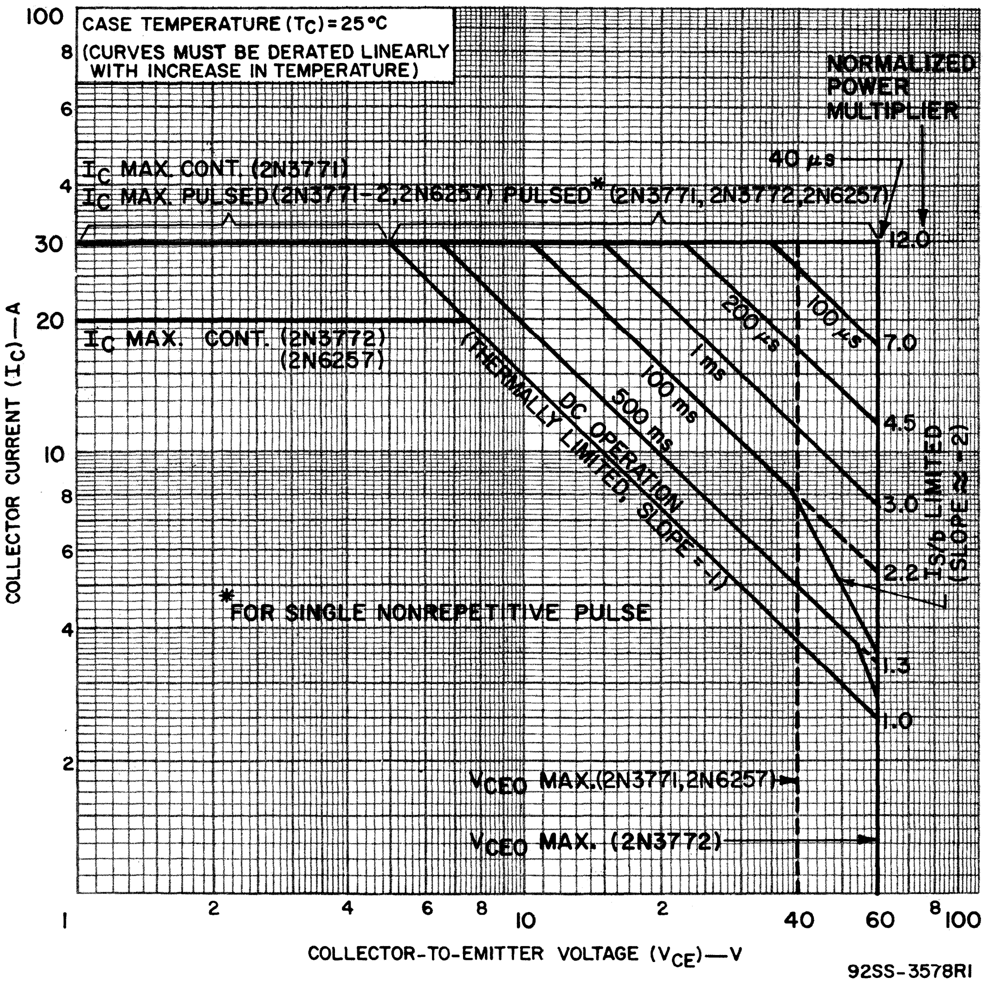


Fig.7—Maximum operating areas for types 2N3771, 2N3772, and 2N6257.

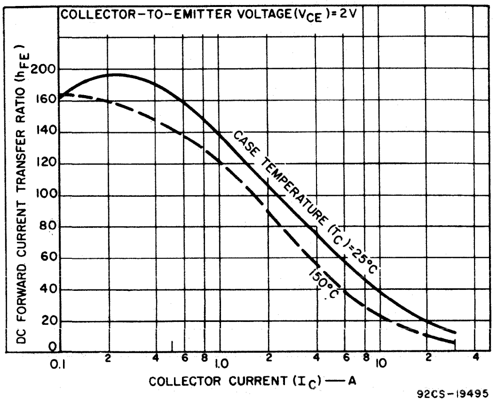


Fig.8—Typical dc beta characteristics for type 2N6258.

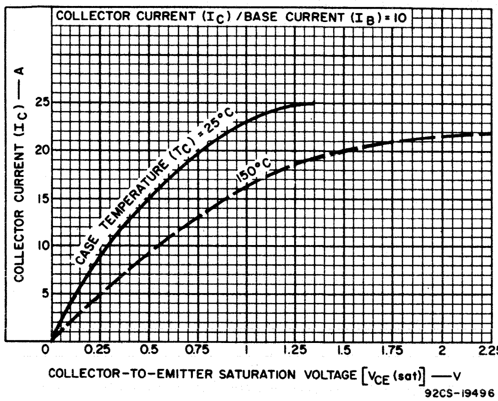


Fig.9—Typical saturation-voltage characteristics for type 2N6258.

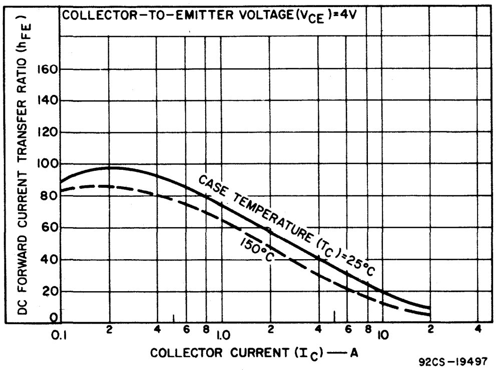


Fig.10—Typical dc beta characteristics for type 2N3772 and 2N6257.

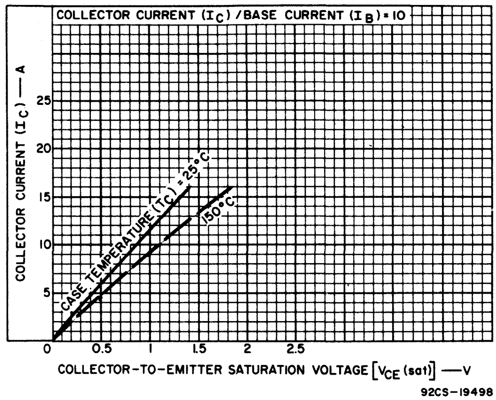


Fig.11—Typical saturation-voltage characteristics for types 2N3772 and 2N6257.

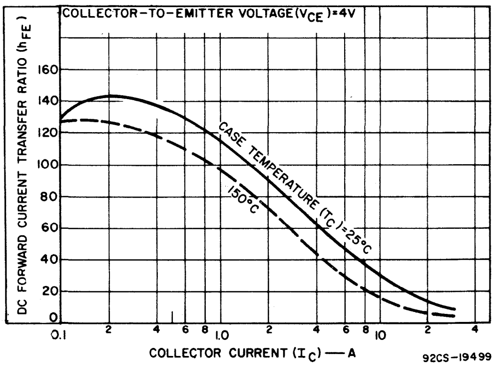


Fig.12—Typical dc beta characteristics for type 2N3771.

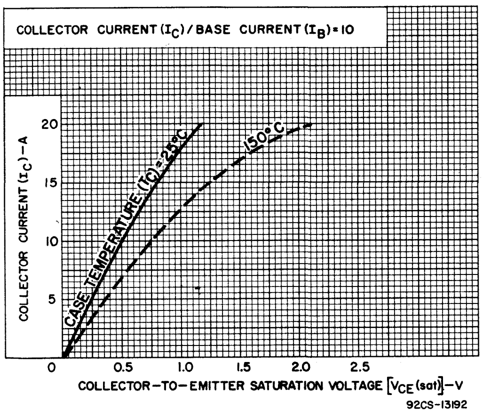


Fig.13—Typical saturation-voltage characteristics for type 2N3771.

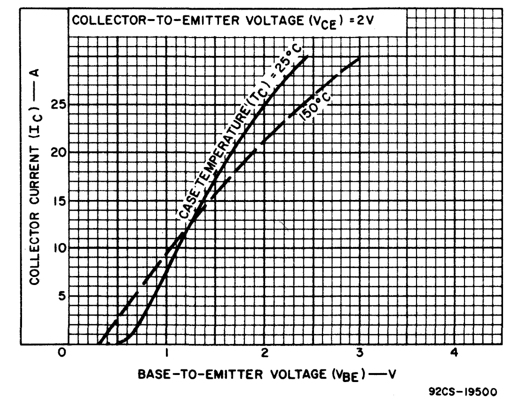


Fig.14—Typical transfer characteristics for type 2N6258.

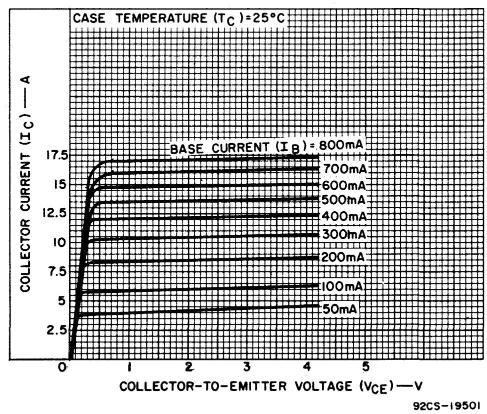


Fig.15—Typical output characteristics for type 2N6258.

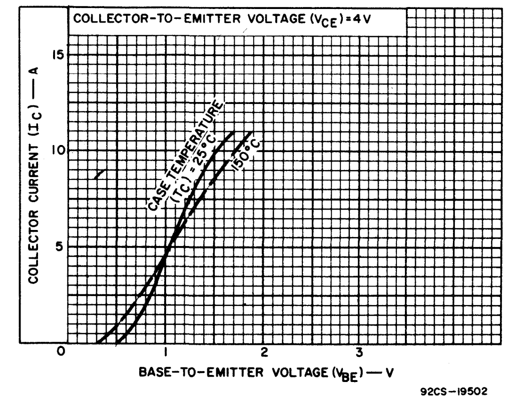


Fig.16—Typical transfer characteristics for types 2N3772 and 2N6257.

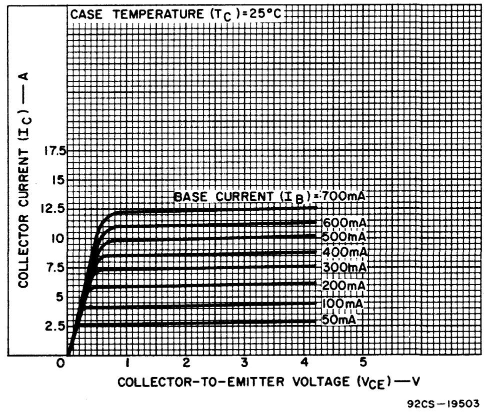


Fig.17—Typical output characteristics for types 2N3772 and 2N6257.

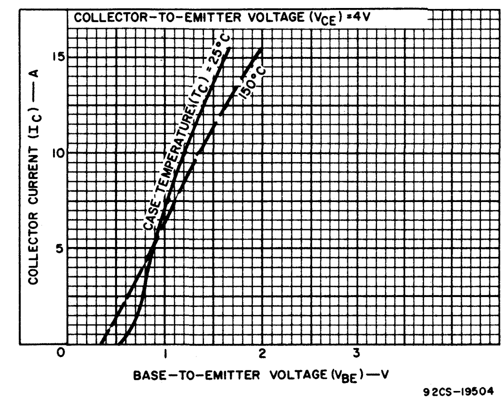


Fig.18—Typical transfer characteristics for type 2N3771.

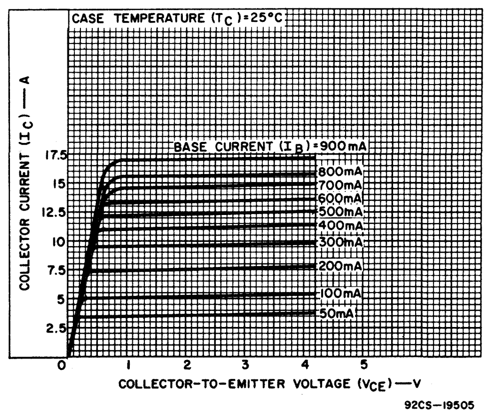


Fig.19—Typical output characteristics for type 2N3771.

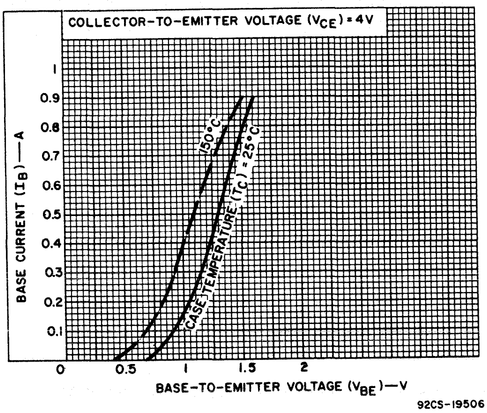


Fig.20—Typical input characteristics for type 2N6258.

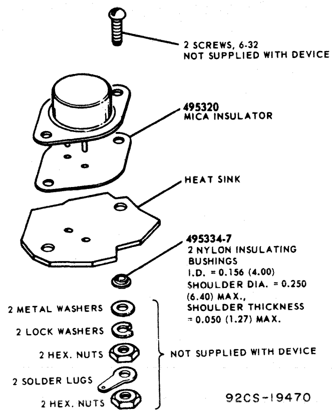


Fig.23—Suggested mounting hardware.

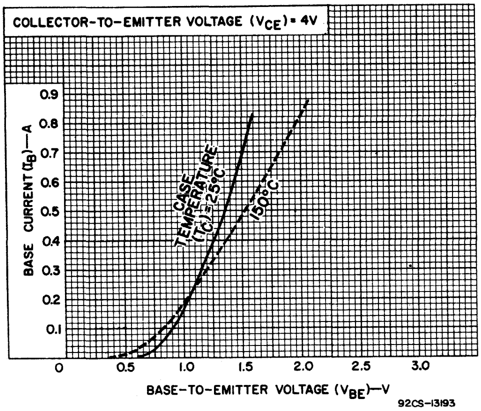


Fig.21—Typical input characteristics for types 2N3771 and 2N6257.

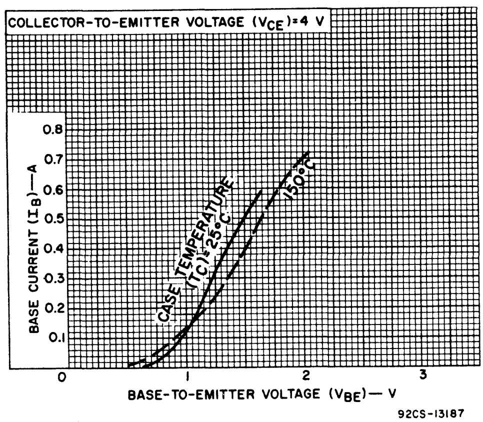
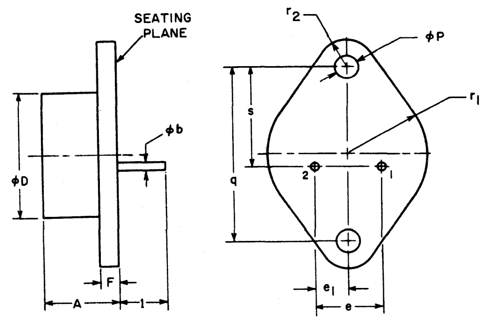


Fig.22—Typical input characteristics for type 2N3772.

DIMENSIONAL OUTLINE — JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

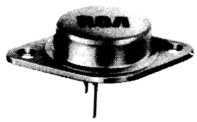
92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors
2N6259
2N4348
2N3773



JEDEC TO-3

H-1570

Hometaxial II• High-Current Silicon N-P-N Transistors

Rugged High-Voltage Devices for Applications in Industrial and Commercial Equipment

Features:

- **High dissipation capability —**
  120 W (2N4348), 150 W (2N3773), 250 W (2N6259)
- **5-A specification for h_{FE}, V_{BE}, & $V_{CE}(sat)$ (2N4348)**
- **8-A specification for h_{FE}, V_{BE}, & $V_{CE}(sat)$ (2N3773, 2N6259)**
- **V_{CEX} —**
  140 V min (2N4348), 160 V min (2N3773), 170 V min (2N6259)
- **Low saturation voltage with high beta**

RCA-2N3773, 2N4348, and 2N6259 are hometaxial-base• silicon n-p-n transistors intended for a wide variety of high-voltage high-current applications. Typical applications for these transistors include power-switching circuits, audio amplifiers, series- and shunt-regulator driver and output stages, dc-to-dc converters, inverters, and solenoid (hammer)/relay driver service.

These devices employ the popular JEDEC TO-3 package; they differ in maximum ratings for voltage, current, and power.

• "Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector). "Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N4348	2N3773	2N6259	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	140	160	170	V
COLLECTOR-TO-EMITTER VOLTAGE:					
* With base open	V_{CEO}	120	140	150	V
With reverse bias (V_{BE}) of −1.5 V	V_{CEX}	140	160	170	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	7	V
*COLLECTOR CURRENT:	I_C				
Continuous		10	16	16	A
Peak		30	30	30	A
*BASE CURRENT:	I_B				
Continuous		4	4	4	A
Peak		15	15	15	A
*TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		120	150	250	W
At case temperatures above 25°C		← See Figs. 1, 4, 7, & 22 →			
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		← −65 to +200 →			°C
*PIN TEMPERATURE (During Soldering):					
At distances ≥1/32 in. (0.8 mm) from case for 10 s max.		← 230 →			°C

* In accordance with JEDEC registration data format (JS-6, RDF-2).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_E	I_B	LIMITS: Type 2N4348 Min.	Max.	Type 2N3773 Min.	Max.	Type 2N6259 Min.	Max.	UNITS
* Collector-Cutoff Current: With emitter open	I_{CBO}	140					0		–	–	–	2	–	–	mA
With base-emitter junction reverse-biased	I_{CEX}		120		−1.5				–	2	–	–	–	–	mA
			140		−1.5				–	–	–	2	–	–	
			150		−1.5				–	–	–	–	–	0.2	
With base-emitter junction reverse-biased and T_C = 150°C	I_{CEX}		120		−1.5				–	10	–	–	–	–	mA
			140		−1.5				–	–	–	10	–	–	
			150		−1.5				–	–	–	–	–	4	
With base open	I_{CEO}		100						–	200	–	–	–	–	mA
			120						–	–	–	10	–	2	
* Emitter-Cutoff Current	I_{EBO}			7		0			–	5	–	5	–	2	mA
* DC Forward Current Transfer Ratio	h_{FE}		4			5[a]			15	60	–	–	–	–	
			4			8[a]			–	–	15	60	–	–	
			2			8[a]			–	–	–	–	15	60	
			4			10[a]			10	–	–	–	–	–	
			4			16[a]			–	–	5	–	10	–	
Collector-to-Emitter Sustaining Voltage: With base-emitter junction reverse-biased (R_{BE} = 100Ω)	$V_{CEX}(sus)$				−1.5	0.1			140	–	160	–	170	–	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$					0.2[a]			140	–	150	–	160	–	V
* With base open	$V_{CEO}(sus)$					0.2[a]		0	120	–	140	–	150	–	V
* Base-to-Emitter Voltage	V_{BE}		4			5[a]			–	2	–	–	–	–	V
			4			8[a]			–	–	–	2.2	–	–	
			2			8[a]			–	–	–	–	–	2	
			4			10[a]			–	3	–	–	–	–	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					5[a]		0.5	–	1	–	–	–	–	V
						8[a]		0.8	–	–	–	1.4	–	1	
						10[a]		1.25	–	2	–	–	–	–	
						16[a]		3.2	–	–	–	4	–	2.5	
Second-Breakdown Collector Current With base forward-biased and 1-s, nonrepetitive pulse	$I_{S/b}$[b]		80						1.5	–	–	–	–	–	A
			100						–	–	1.5	–	2.5	–	
Second-Breakdown Energy With base reverse-biased and L = 40 mH, R_{BE} = 100Ω	$E_{S/b}$[c]				−1.5	2.5			0.125	–	0.125	–	0.125	–	J
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 50 kHz)	$\|h_{fe}\|$		4			1			4	–	4	–	4	–	
* Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}		4			1			40	–	40	–	40	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$								–	1.46	–	1.17	–	0.7	°C/W

* In accordance with JEDEC registration data format JS-6 RDF-2.

[a] Pulsed; pulse duration = 300μs, rep. rate = 60 Hz.

[b] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

[c] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse-bias conditions. $E_{S/b} = 1/2 L I^2$ where L is a series load or leakage inductance and I is the peak collector current.

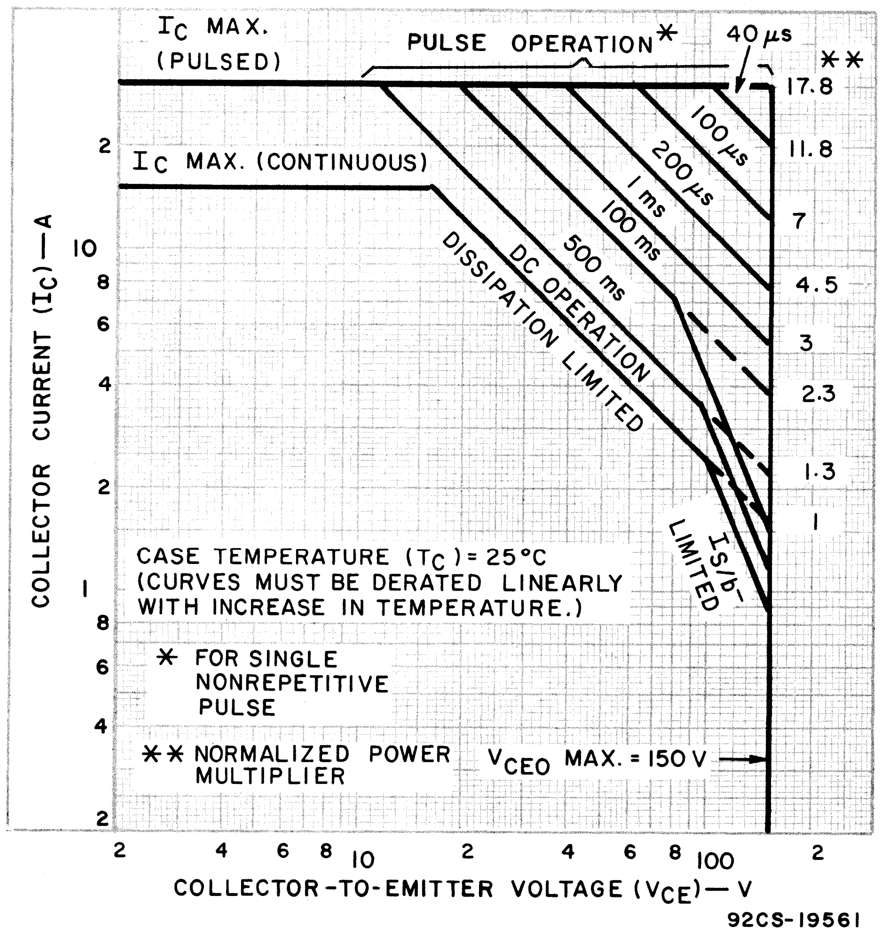


Fig.1—Maximum operating areas for type 2N6259.

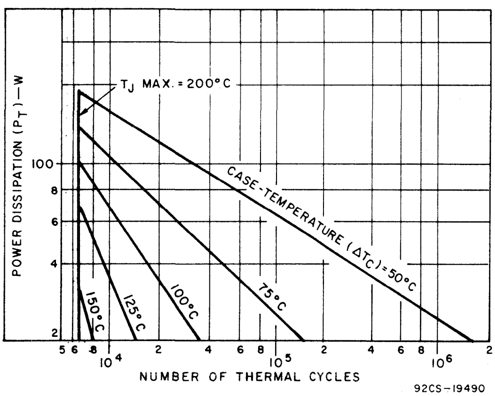


Fig.2—Thermal-cycle rating chart for type 2N6259.

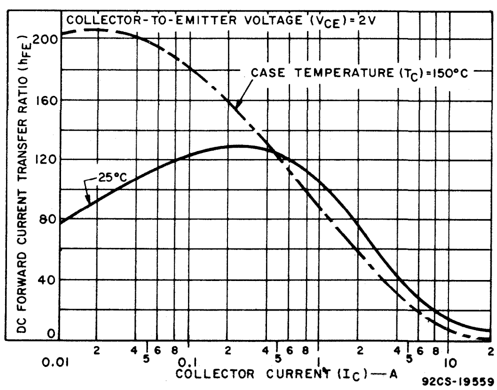


Fig.3—Typical dc beta characteristics for type 2N6259.

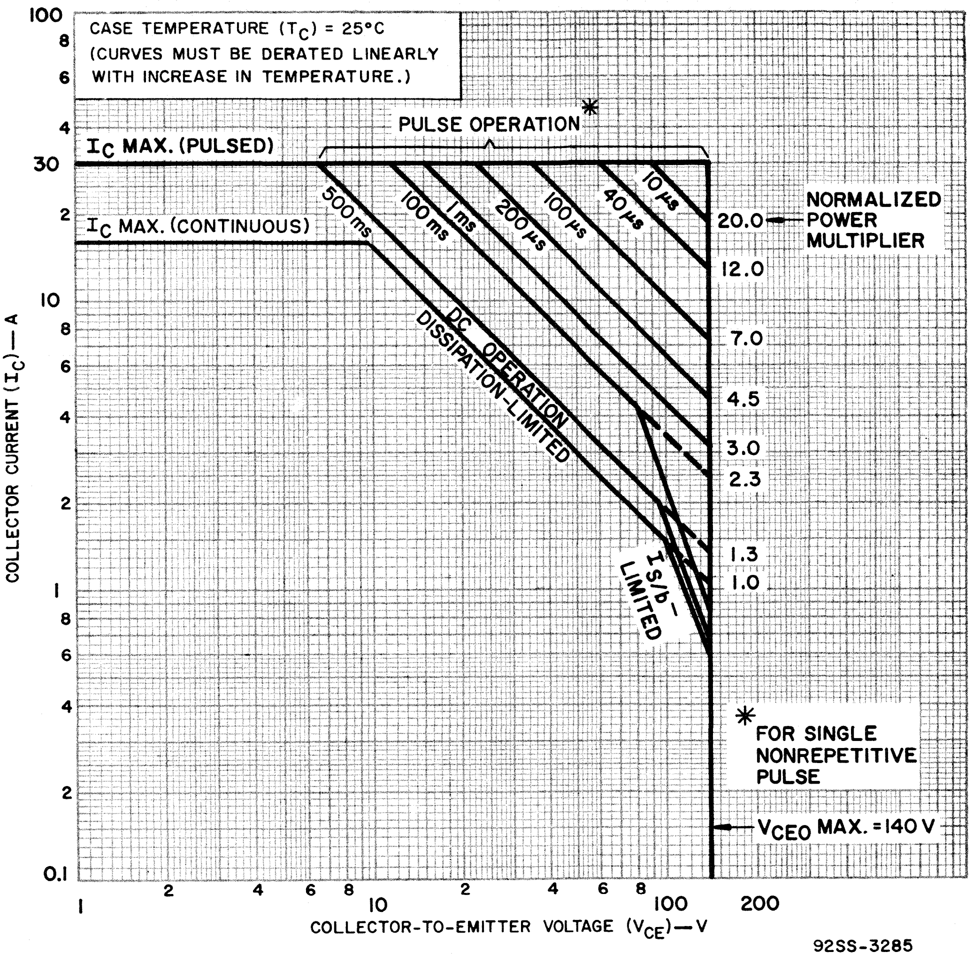


Fig.4—Maximum operating areas for type 2N3773.

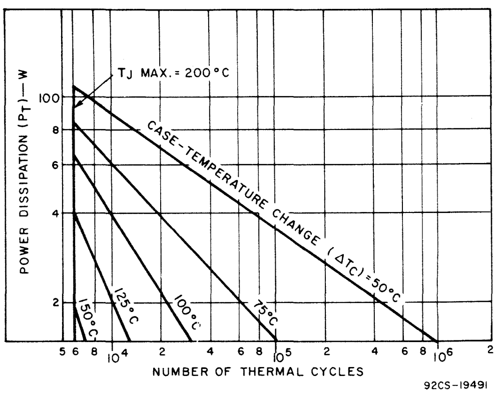


Fig.5—Thermal-cycle rating chart for type 2N3773.

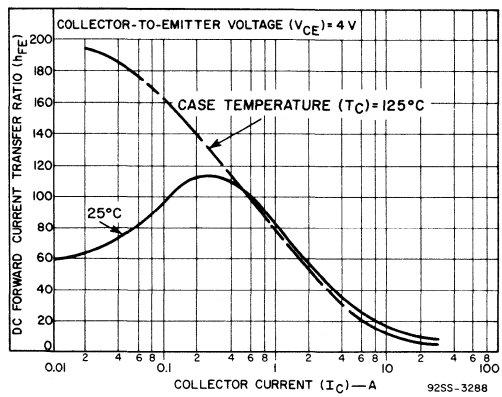


Fig.6—Typical dc beta characteristics for type 2N3773.

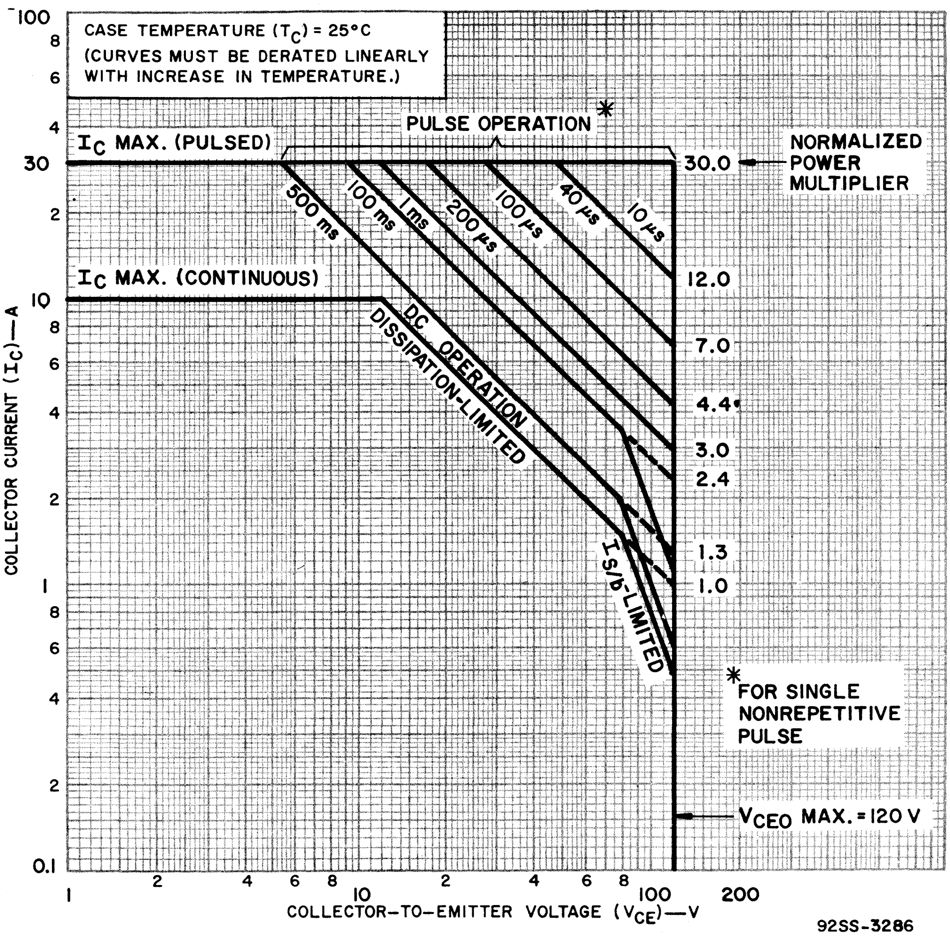


Fig.7—Maximum operating areas for type 2N4348.

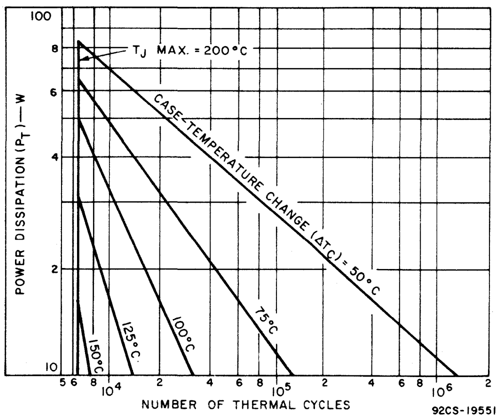


Fig.8—Thermal-cycle rating chart for type 2N4348.

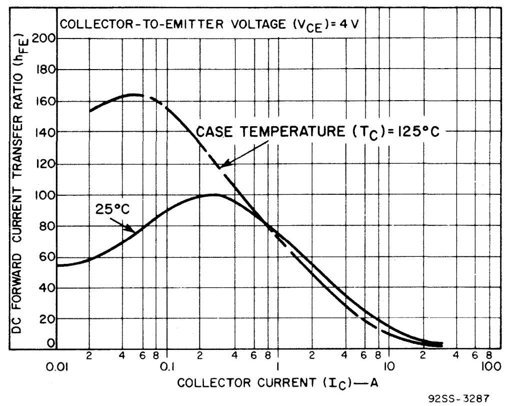


Fig.9—Typical dc beta characteristics for type 2N4348.

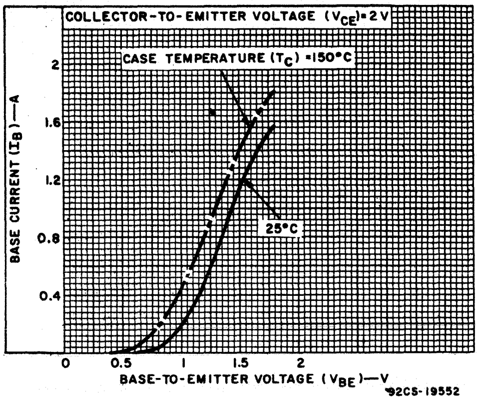


Fig.10—Typical input characteristics for type 2N6259.

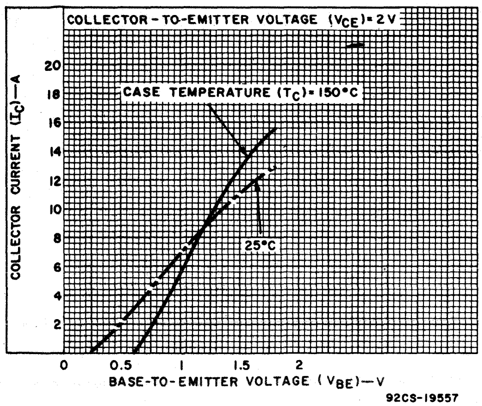


Fig.11—Typical transfer characteristics for type 2N6259.

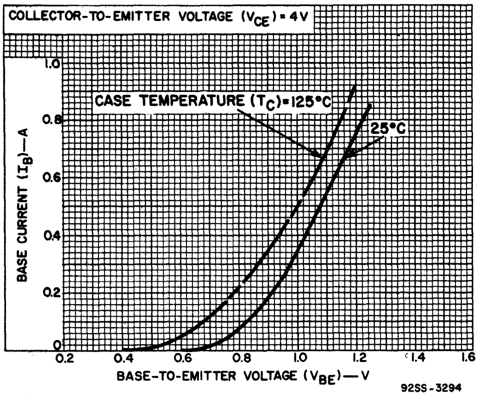


Fig.12—Typical input characteristics for type 2N3773.

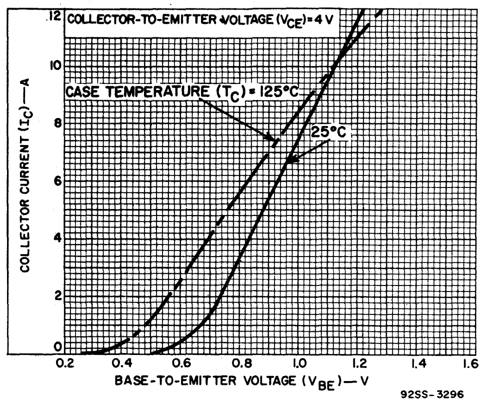


Fig.13—Typical transfer characteristics for type 2N3773.

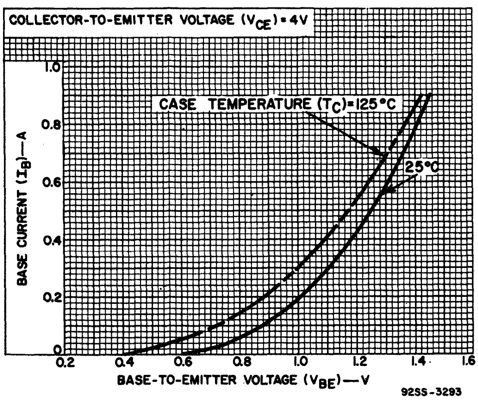


Fig.14—Typical input characteristics for type 2N4348.

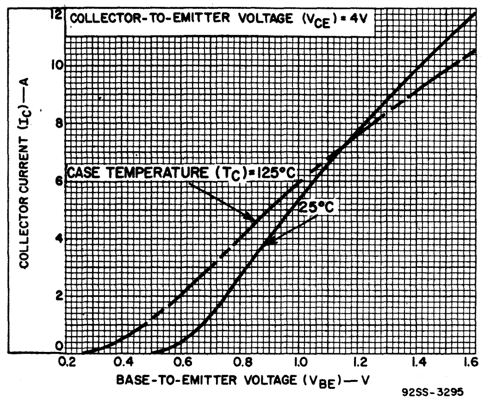


Fig.15—Typical transfer characteristics for type 2N4348.

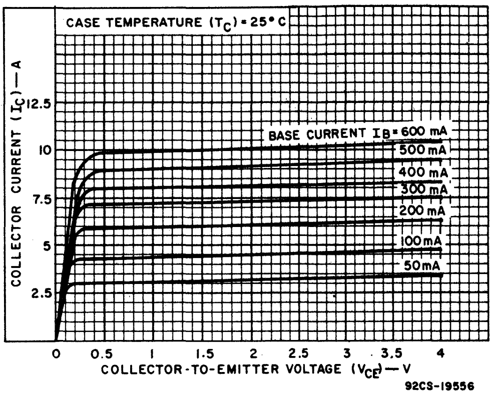


Fig. 16—Typical output characteristics for type 2N6259.

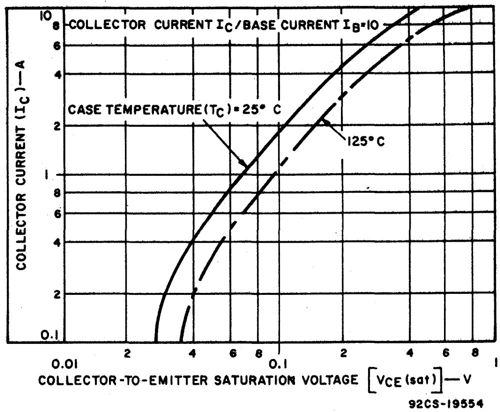


Fig. 17—Typical saturation-voltage characteristics for type 2N6259.

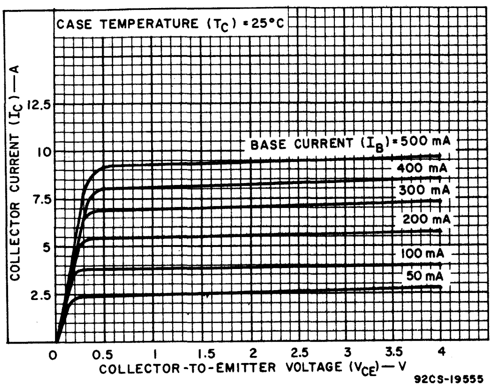


Fig. 18—Typical output characteristics for type 2N3773.

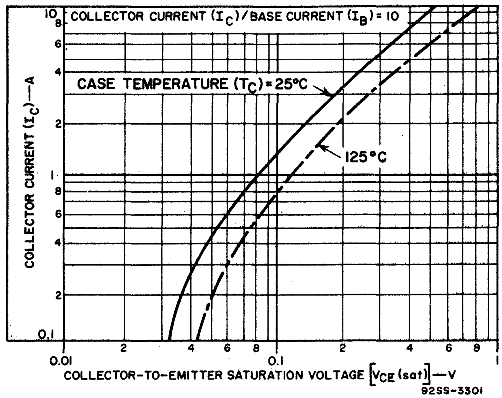


Fig. 19—Typical saturation-voltage characteristics for type 2N3773.

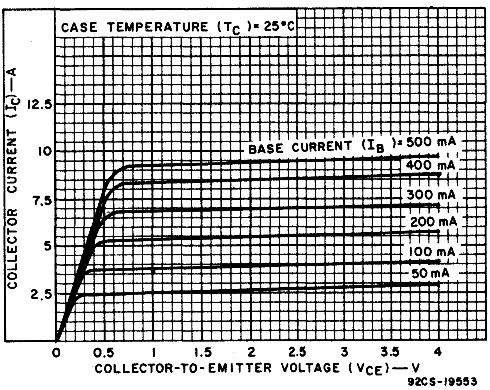


Fig. 20—Typical output characteristics for type 2N4348.

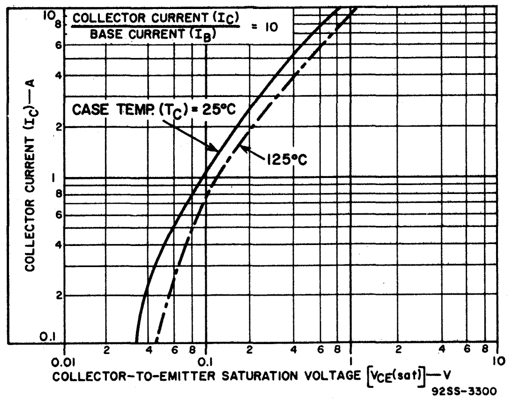


Fig. 21—Typical saturation-voltage characteristics for type 2N4348.

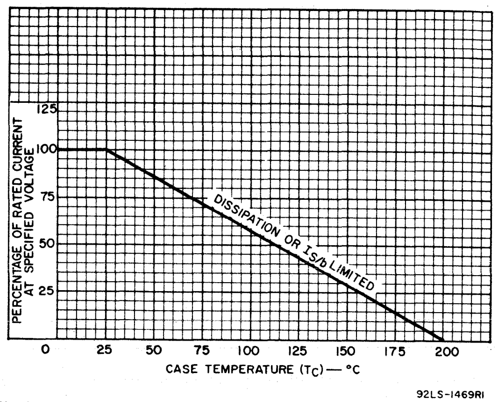


Fig.22—Dissipation derating curve for all types.

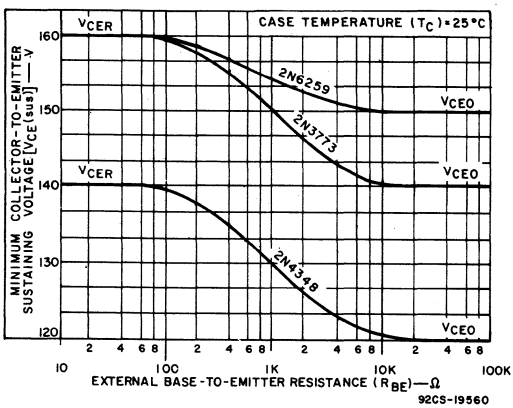


Fig.23—Sustaining voltage vs. base-to-emitter resistance for all types.

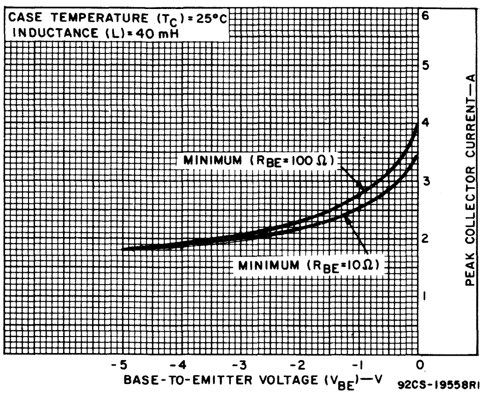


Fig.24—Reverse-bias, second-breakdown characteristics for all types.

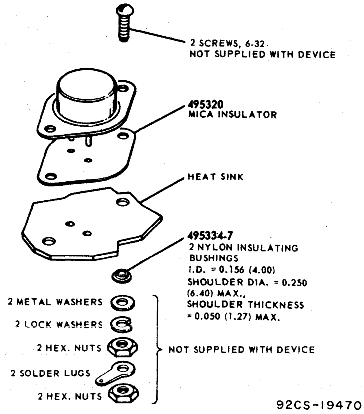
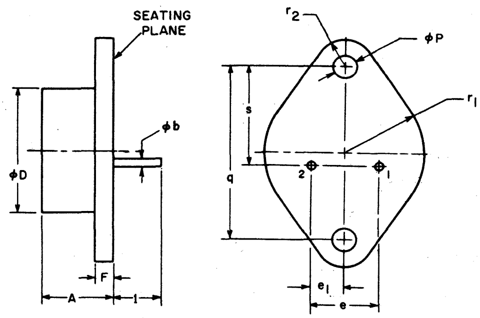


Fig.25—Suggested mounting hardware.

DIMENSIONAL OUTLINE – JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors

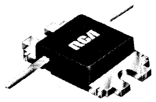
2N5034 2N5037
2N5035 40513
2N5036 40514

2N5034
2N5036
40514

H-1532

JEDEC TO-219AA

2N5035
2N5037
40513



H-1533

JEDEC TO-219AB

Molded Silicone-Plastic Hometaxial-Base Transistors

Silicon N-P-N Types for Industrial and Commercial Applications

Features:

- **Low thermal resistance: $\theta_{J\text{-}C}$ = 1.5°C/W max.**
- **Low saturation voltage**
- **High second breakdown ratings for both forward- and reverse-bias operation**
- **High peak collector current ratings**
- **Maximum-area-of-operation curves for DC and pulse operation**

RCA-2N5034, 2N5035, 2N5036, 2N5037*, 40513, and 40514 are hometaxial**-base silicon n-p-n power transistors employing two versions of a unique plastic package. This new plastic package is available with two different lead configurations: a "vertical-lead" version which will fit a TO-3 socket; a "horizontal-lead" type for mounting on a printed-circuit board.

Types 2N5034, 2N5036, and 40514 are the "TO-3" versions. The 2N5034, 2N5036, and 40514 differ in breakdown-voltage, collector-current ratings, and leakage-current limits. These devices may be plugged into a TO-3 socket and secured by means of an over-clamp whose mounting holes are identical to those in a TO-3 socket.

Types 2N5035, 2N5037, and 40513 are electrically identical to the 2N5034, 2N5036, and 40514, respectively, but employ the horizontal-lead package.

These plastic transistors are intended for a wide variety of high-power switching and amplifier applications such as series and shunt regulator driver and output stages and for high-fidelity amplifiers.

*Formerly Dev. Type Nos. TA7201, TA7202, TA7199, and TA7200 respectively.

**"Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector).

MAXIMUM RATINGS, *Absolute-Maximum Values:*		40514 40513	2N5034 2N5035	2N5036 2N5037	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	–	55	70	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With −1.5 volts (V_{BE}) of reverse bias	$V_{CEV}(sus)$	–	55	70	V
* With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	45	45	60	V
With base open	$V_{CEO}(sus)$	–	40	50	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	6	6	8	A
* PEAK COLLECTOR CURRENT		12	12	12	A
* CONTINUOUS BASE CURRENT	I_B	6	6	6	A
* TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		83	83	83	W
At temperatures above 25°C			See Fig. 1		
* TEMPERATURE RANGE:					
Storage & Operating (Junction)			−65 to 150		°C
* LEAD TEMPERATURE (During Soldering)					
2N5034, 2N5036, & 40514: At distance ≥ 1/16 in. (1.58mm) from seating plane for 10s max.			235		°C
2N5035, 2N5037, & 40513: At distances ≥ 1/8 in. (3.18mm) from case for 10s max.			235		°C

* Types 2N5034-2N5037, inclusive, in accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS *Case Temperature (T_C) = 25°C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (V) V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	DC Emitter or Base Voltage (V) V_{BE}	DC Current (A) I_C	DC Current (A) I_B	LIMITS: Types 40514, 40513 Min.	Types 40514, 40513 Max.	Types 2N5034, 2N5035 Min.	Types 2N5034, 2N5035 Max.	Types 2N5036, 2N5037 Min.	Types 2N5036, 2N5037 Max.	Units
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	20					–	2.5	–	–	–	–	mA
		35					–	–	–	1.0	–	–	
		50					–	–	–	–	–	1.0	
	I_{CER} (T_C = 150°C)	20					–	5.0	–	–	–	–	
		35					–	–	–	5.0	–	–	
		50					–	–	–	–	–	5.0	
* With base-emitter junction reverse biased	I_{CEV}	50		−1.5			–	–	–	1.0	–	–	mA
		65		−1.5			–	–	–	–	–	1.0	
	I_{CEV} (T_C = 150°C)	50		−1.5			–	–	–	5.0	–	–	
		65		−1.5			–	–	–	–	–	5.0	
* With base open	I_{CEO}	30				0	–	–	–	2	–	–	mA
		40				0	–	–	–	–	–	2	
* Emitter-Cutoff Current	I_{EBO}		5		0		–	5.0	–	5.0	–	5.0	mA
* DC Forward-Current Transfer Ratio	h_{FE}	4			3[a]		25	100	–	–	–	–	
		4			4[a]		–	–	20	80	–	–	
		4			5[a]		–	–	–	–	20	80	
		4			6[a]		–	–	5	–	–	–	
		4			8[a]		–	–	–	–	5	–	
Collector-to-Emitter Sustaining Voltage With base open	$V_{CEO}(sus)$				0.2[a]	0	–	–	40	–	50	–	V
With base-emitter junction reverse biased	$V_{CEV}(sus)$			−1.5	0.1[a]		–	–	55	–	70	–	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				0.2[a]		45	–	45	–	60	–	V
* Base-to-Emitter Voltage	V_{BE}	4			3[a]		–	1.7	–	–	–	–	V
		4			4[a]		–	–	–	1.7	–	–	
		4			5[a]		–	–	–	–	–	1.7	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				3[a]	0.3	–	1.0	–	–	–	–	V
					4[a]	0.4	–	–	–	1.0	–	–	
					5[a]	0.5	–	–	–	–	–	1.0	
* Common-Emitter, Small-Signal, Short-Circuit Forward-Current Transfer Ratio (f = 1 kHz)	h_{fe}	4			0.5		15	–	15	–	15	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 100 kHz)	$\|h_{fe}\|$	4			0.5		8	28	8	28	8	28	
Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$						–	1.5	–	1.5	–	1.5	°C/W

[a] Pulsed; pulse duration = 300 μs, duty factor = 1.8%.

*Types 2N5034-2N5037, inclusive, in accordance with JEDEC registration data format JS-6 RDF-2.

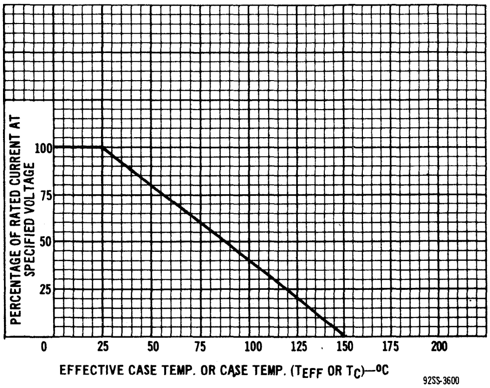


Fig.1—Dissipation derating curve for all types.

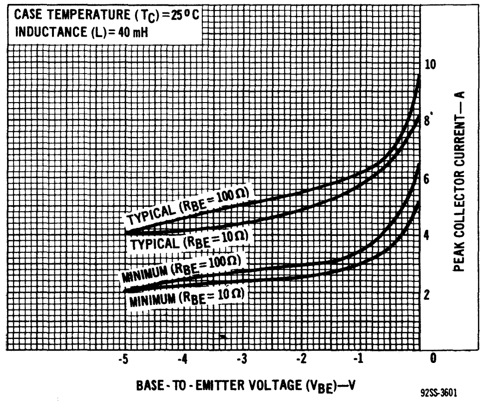


Fig.2—Reverse-bias, second breakdown characteristics for all types.

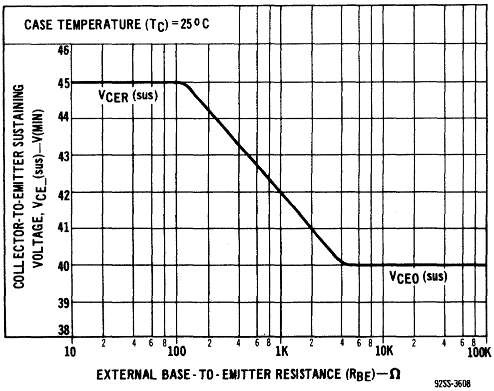


Fig.3—Sustaining voltage vs. base-to-emitter resistance for types 2N5034 & 2N5035.

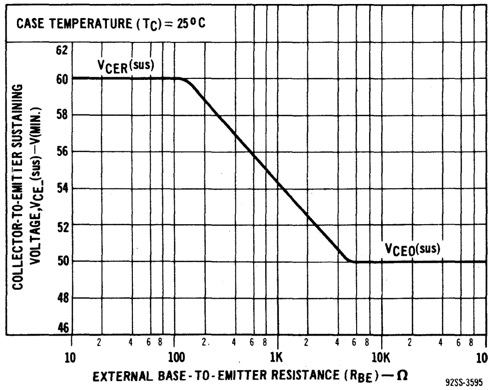


Fig.4—Sustaining voltage vs. base-to-emitter resistance for types 2N5036 & 2N5037.

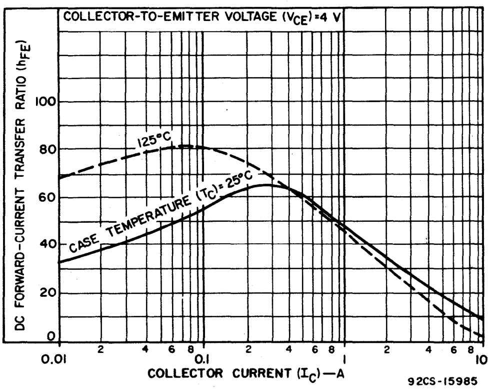


Fig.5—Typical dc beta characteristics for types 2N5034 2N5035, 40513, & 40514.

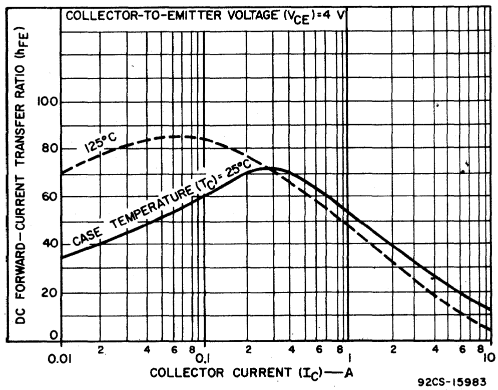


Fig.6—Typical dc beta characteristics for types 2N5036 & 2N5037.

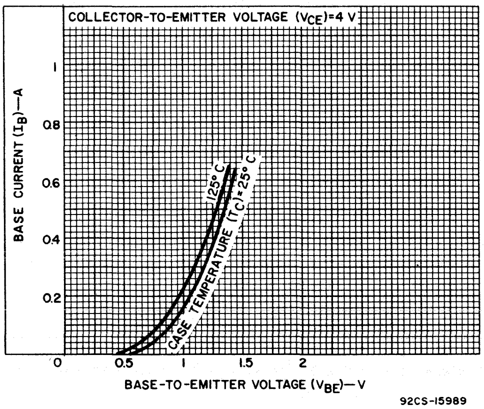


Fig.7—Typical input characteristics for types 2N5034, 2N5035, 40513, & 40514.

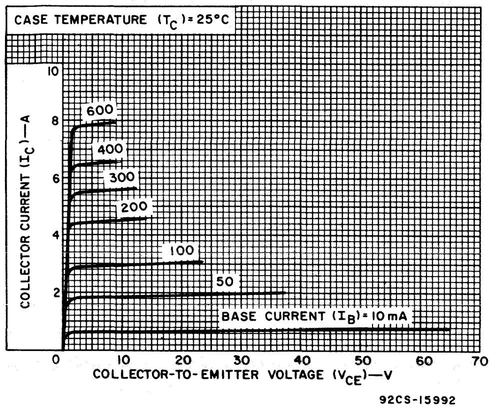


Fig.8—Typical output characteristics for types 2N5034, 2N5035, 40513, & 40514.

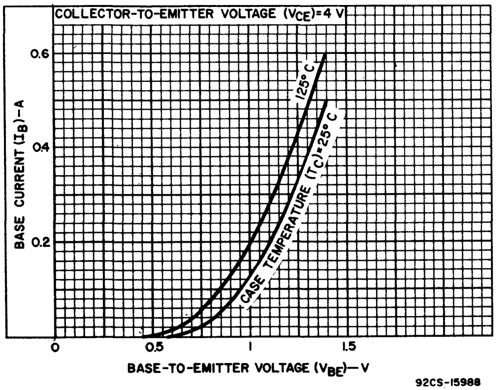


Fig.9—Typical input characteristics for types 2N5036 & 2N5037.

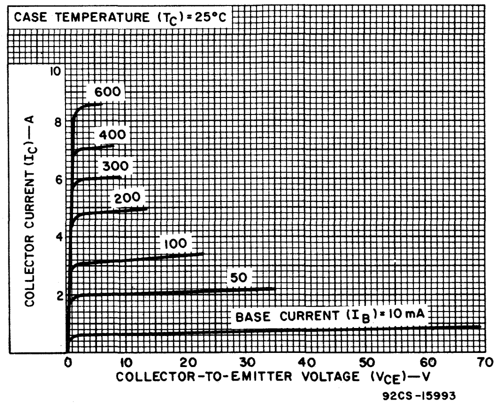


Fig.10—Typical output characteristics for types 2N5036 & 2N5037.

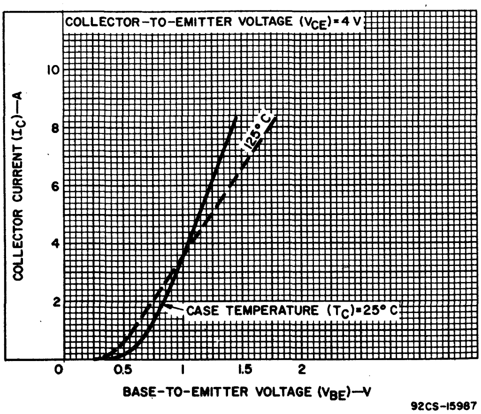


Fig.11—Typical transfer characteristics for all types.

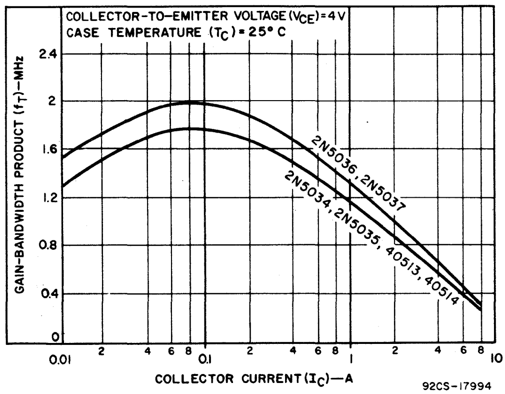


Fig.12—Typical gain-bandwidth product for all types.

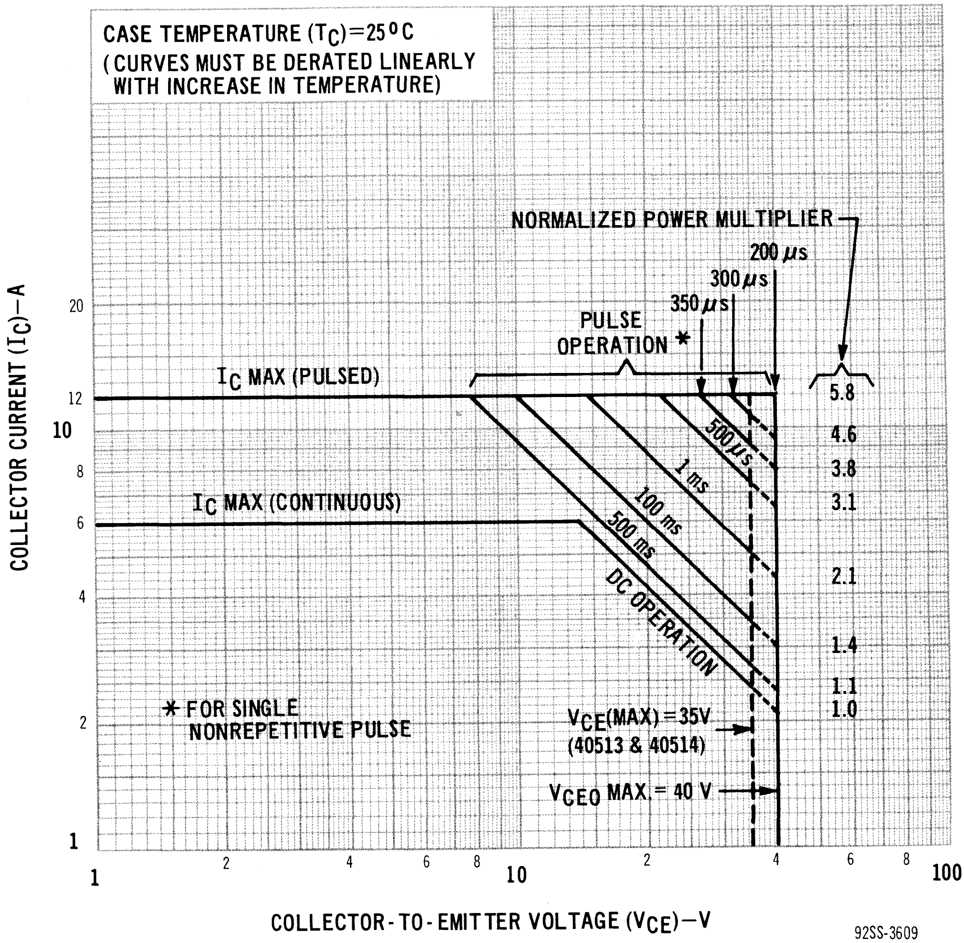


Fig. 13—Maximum operating areas for types 2N5034, 2N5035, 40513, & 40514.

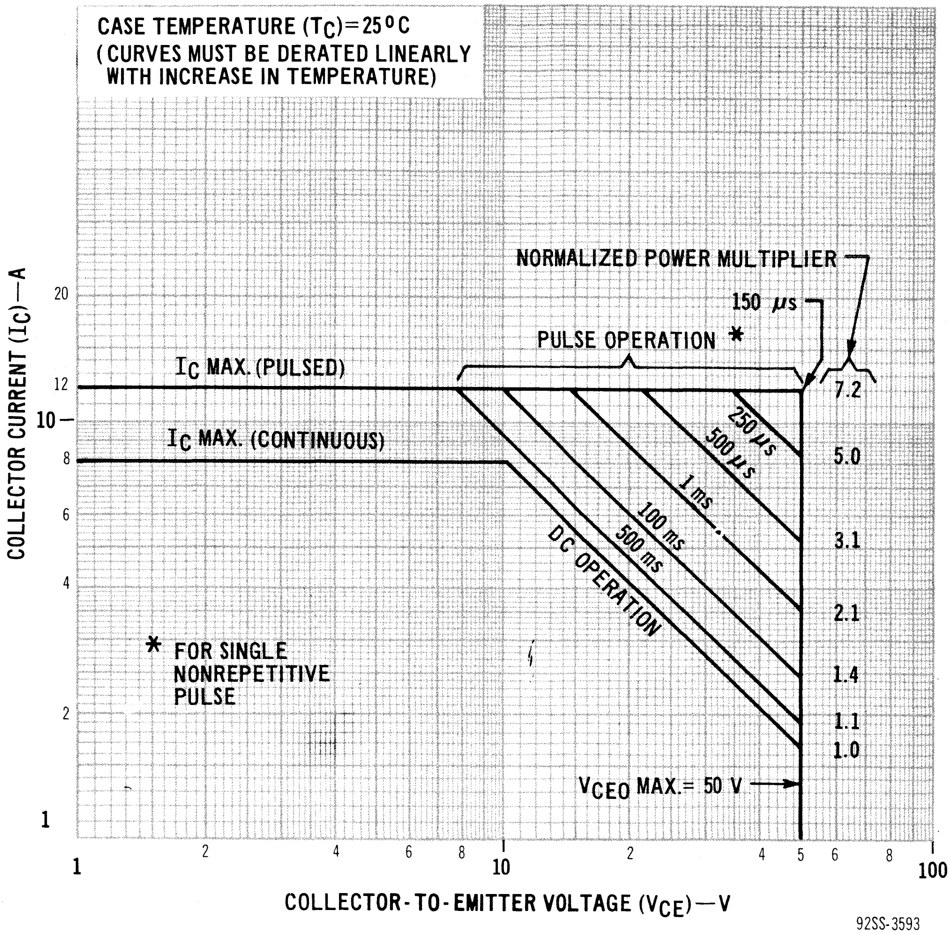


Fig. 14—Maximum operating areas for types 2N5036 & 2N5037.

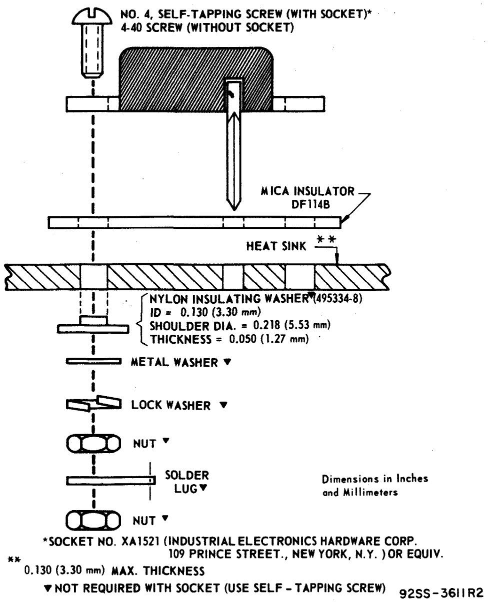


Fig.15—Suggested hardware for mounting types 2N5034, 2N5036, and 40514.

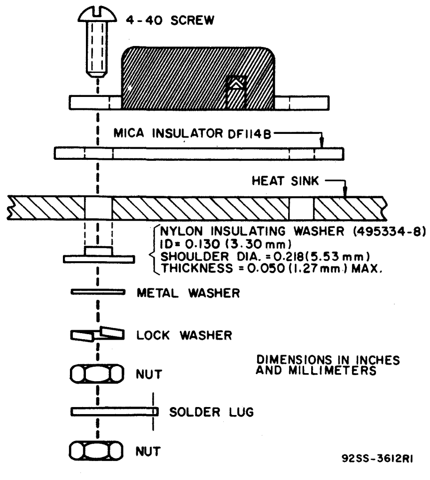


Fig.16—Suggested hardware for mounting types 2N5035, 2N5037, and 40513.

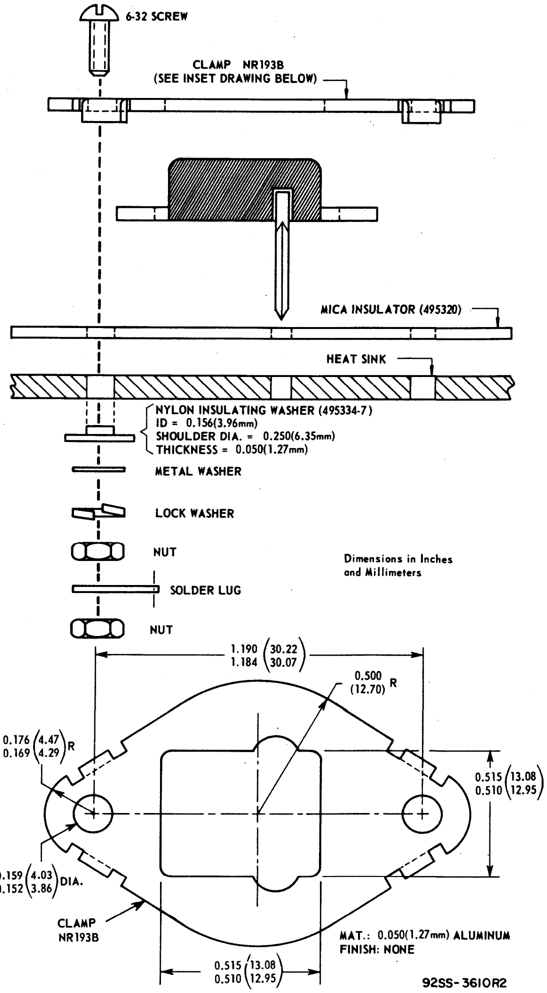
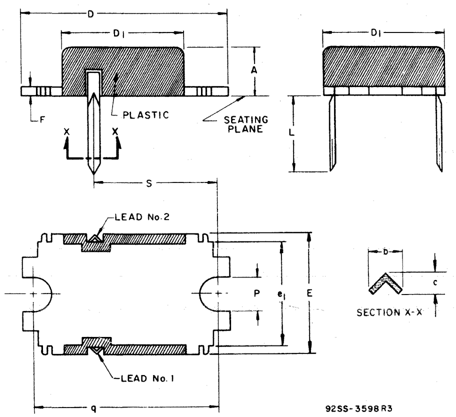
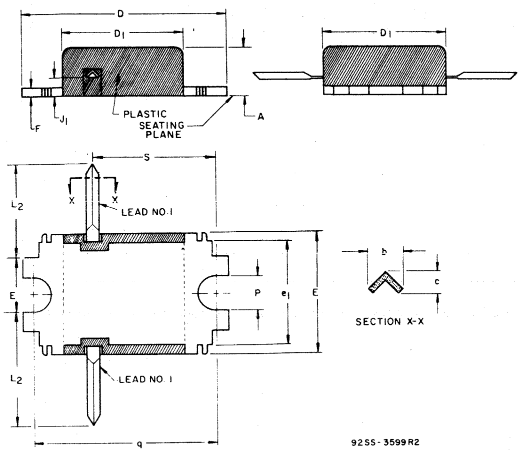


Fig.17—Suggested hardware for mounting types 2N5034, 2N5036, and 40514 in place of TO-3 types.

DIMENSIONAL OUTLINE FOR TYPES 2N5034, 2N5036, & 40514 JEDEC TO-219AA



DIMENSIONAL OUTLINE FOR TYPES 2N5035, 2N5037, & 40513 JEDEC TO-219AB



TERMINAL CONNECTIONS FOR ALL TYPES

Lead No. 1 — Base
Lead No. 2 — Emitter
Mounting Flange — Collector

Chart for dimensional outline 2N5034, 2N5036, & 40514.

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.160	0.200	4.07	5.08	
b	0.045	0.060	1.15	1.52	
c	0.025	0.045	0.64	1.14	
D	0.890	0.910	22.61	23.11	
D_1	0.480	0.515	12.20	13.08	
E	0.480	0.520	12.20	13.20	
e_1	0.460	0.505	11.69	12.82	1
F	0.055	0.070	1.40	1.77	
L	0.370	0.450	9.40	11.43	
P	0.128	0.150	3.26	3.81	
q	0.740	0.760	18.80	19.30	
s	0.500	0.520	12.70	13.20	

NOTES:

1. **e_1 is measured at seating plane.**
2. **Terminal end configurations are optional.**

Chart for dimensional outline 2N5035, 2N5037, & 40513.

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.200	4.07	5.08
b	0.045	0.060	1.15	1.52
c	0.025	0.045	0.64	1.14
D	0.890	0.910	22.61	23.11
D_1	0.480	0.515	12.20	13.03
E	0.480	0.520	12.20	13.20
F	0.055	0.070	1.40	1.77
J_1	0.100	0.120	2.54	3.04
L_2	0.415	0.560	10.54	14.22
P	0.128	0.150	3.26	3.81
q	0.740	0.760	18.80	19.30
s	0.500	0.520	12.70	13.20

NOTE: Terminal end configurations are optional.

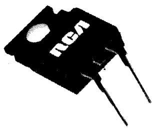
File No. 322

RCA

Solid State Division

Power Transistors

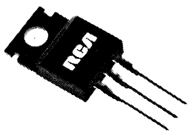
2N5293 2N5296
2N5294 2N5297
2N5295 2N5298



2N5293
2N5295
2N5297

For TO-66 Sockets

H-1534R1



2N5294
2N5296
2N5298

H-1535R1

Hometaxial-Base, Silicon N-P-N VERSAWATT Transistors

General-Purpose Types for Medium-Power Switching and Amplifier Applications in Military, Industrial, and Commercial Equipment

FEATURES

- Low saturation voltage—
  $V_{CE}(sat)$ = 1 V max. at I_C = 0.5 A (2N5293, 2N5294)
  = 1 V max. at I_C = 1 A (2N5295, 2N5296)
  = 1 V max. at I_C = 1.5 A (2N5297, 2N5298)
- VERSAWATT package (molded-silicone plastic)
- Maximum safe-area-of-operation curves specified for DC and pulse service

RCA-2N5293, 2N5294, 2N5295, 2N5296, 2N5297 and 2N5298* are hometaxial-base silicon n-p-n transistors. They are intended for a wide variety of medium-power switching and amplifier applications such as series and shunt regulators, and in driver and output stages of high-fidelity amplifiers. Types 2N5293, 2N5295, and 2N5297 have formed emitter and base leads for easy insertion into TO-66 sockets. Types 2N5294, 2N5296, and 2N5298 are electrically identical to the 2N5293, 2N5295, and 2N5297, respectively, but have straight leads.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N5293 2N5294	2N5295 2N5296	2N5297 2N5298	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	80	60	80	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With -1.5 volts (V_{BE}) of reverse bias	$V_{CEV}(sus)$	80	60	80	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	75	50	70	V
With base open	$V_{CEO}(sus)$	70	40	60	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	5	5	V
COLLECTOR CURRENT	I_C	4	4	4	A
BASE CURRENT	I_B	2	2	2	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		36	36	36	W
At case temperatures above 25°C		Derate linearly at 0.288 W/°C or see Fig.1 & 2.			
At ambient temperatures up to 25°C		1.8	1.8	1.8	W
At ambient temperatures above 25°C		Derate linearly at 0.0144 W/°C			
TEMPERATURE RANGE:					
Storage & Operating (Junction)		← -65 to +150 →			°C
LEAD TEMPERATURE (During Soldering):					
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →			°C

These new plastic power transistors differ in voltage ratings and in the currents at which the parameters are controlled.

* Formerly RCA Dev. Type Nos.TA7155, TA2911, TA7156, TA7137, TA7362, and TA7363, respectively.

OPTIONAL LEAD CONFIGURATION

An additional lead forming for printed-circuit-board mounting is also available. (See page 6).

Please submit requirements to your RCA Technical Sales Representative, or write to RCA Low-Frequency Power Marketing, Somerville, N. J. 08876.

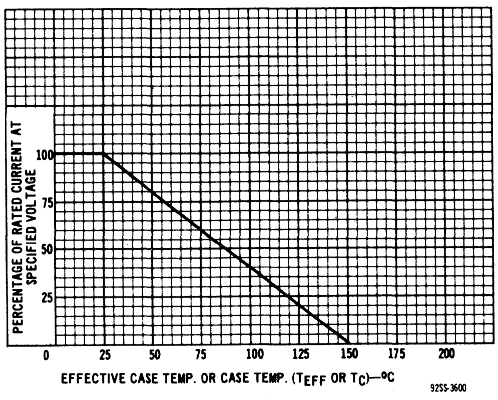


Fig. 1 - Derating curve for all types.

ELECTRICAL CHARACTERISTICS: *At Case Temperature (T_C) = 25°C, Unless Otherwise Specified.*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (V) V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	DC Emitter or Base Voltage (V) V_{BE}	DC Current (A) I_C	DC Current (A) I_B	LIMITS: 2N5293 2N5294 Min.	2N5293 2N5294 Max.	2N5295 2N5296 Min.	2N5295 2N5296 Max.	2N5297 2N5298 Min.	2N5297 2N5298 Max.	Units
Collector-Cutoff Current With base-emitter junction reverse biased	I_{CEV}	65		-1.5			–	0.5	–	–	–	0.5	mA
		35		-1.5			–	–	–	2	–	–	
	I_{CEV} (T_C = 150°C)	65		-1.5			–	3	–	–	–	3	mA
		35		-1.5			–	–	–	5	–	–	
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	50					–	0.5	–	–	–	0.5	mA
	I_{CER} (T_C = 150°C)	50					–	2	–	–	–	2	mA
Emitter-Cutoff Current	I_{EBO}		7				–	1	–	–	–	–	mA
			5				–	–	–	1	–	1	
DC Forward-Current Transfer Ratio	h_{FE}[c]	4			0.5		30	120	–	–	–	–	
		4			1		–	–	30	120	–	–	
		4			1.5		–	–	–	–	20	80	
Collector-to-Emitter Sustaining Voltage With base open	$V_{CEO}(sus)$[c]				0.1	0	70	–	–	–	–	–	V
					0.1	0	–	–	40	–	–	–	
					0.1	0	–	–	–	–	60	–	
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$[c]				0.1		75	–	–	–	–	–	V
					0.1		–	–	50	–	–	–	
					0.1		–	–	–	–	70	–	
With base-emitter junction reverse biased	$V_{CEV}(sus)$[c]			-1.5	0.1		80	–	–	–	–	–	V
				-1.5	0.1		–	–	60	–	–	–	
				-1.5	0.1		–	–	–	–	80	–	
Base-to-Emitter Voltage	V_{BE}[c]	4			0.5		–	1.1	–	–	–	–	V
		4			1		–	–	–	1.3	–	–	
		4			1.5		–	–	–	–	–	1.5	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[c]				0.5	0.05	–	1	–	–	–	–	V
					1	0.1	–	–	–	1	–	–	
					1.5	0.15	–	–	–	–	–	1	
Gain-Bandwidth Product	f_T	4			0.2		0.8	–	0.8	–	0.8	–	MHz
Sat. Switching Time Turn-On (See Figs. 21-23)	t_{on}	V_{CC} = 30			0.5	0.05[a]	–	5	–	–	–	–	μs
					1	0.1[a]	–	–	–	5	–	–	
					1.5	0.15[a]	–	–	–	–	–	5	
Turn-Off (See Figs. 21-23)	t_{off}	V_{CC} = 30			0.5	-0.05[a]	–	15	–	–	–	–	μs
					1	-0.1[b]	–	–	–	15	–	–	
					1.5	-0.15[b]	–	–	–	–	–	15	
Thermal Resistance (Junction-to-Case)	θ_{J-C}						–	3.5	–	3.5	–	3.5	°C/W
(Junction-to-Ambient)	θ_{J-A}						–	70	–	70	–	70	°C/W

[a] I_{B_1} value (turn-on base current).
[b] I_{B2} value (turn-off base current).
[c] Pulsed, pulse duration = 300 μs, duty factor = .018.

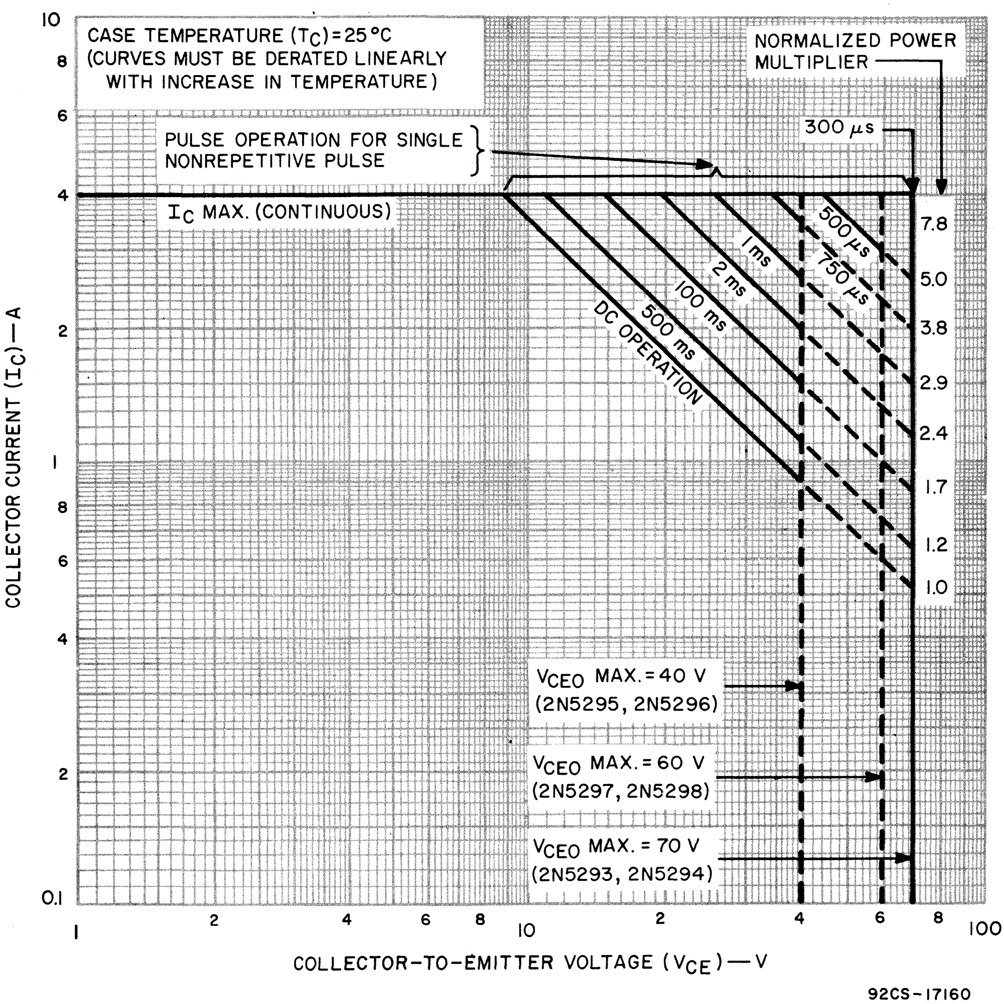


Fig. 2 - Maximum operating areas for all types.

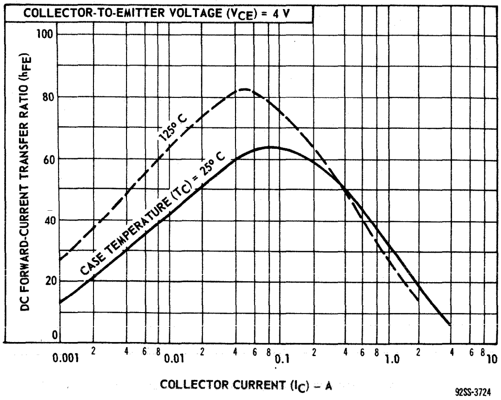


Fig. 3 - Typical DC beta for types 2N5293 & 2N5294.

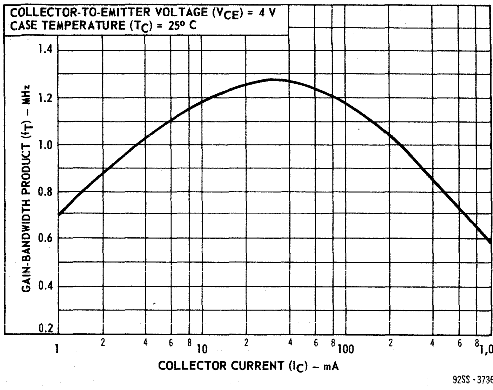


Fig. 4 - Typical gain-bandwidth product for types 2N5293 & 2N5294.

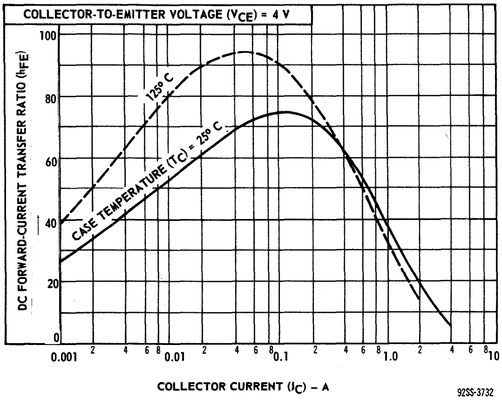


Fig. 5 - Typical DC beta for types 2N5295 & 2N5296.

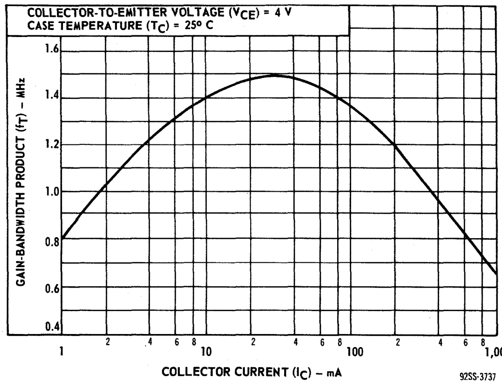


Fig. 6 - Typical gain-bandwidth product for types 2N5295 & 2N5296.

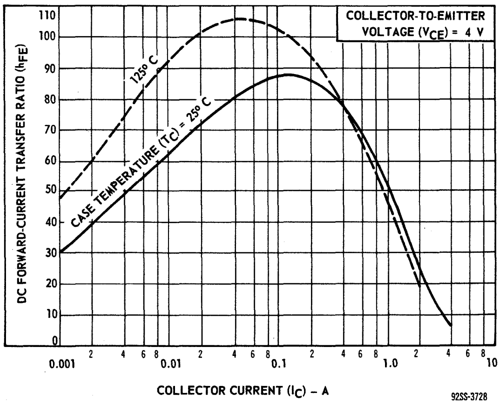


Fig. 7 - Typical DC beta for types 2N5297 & 2N5298.

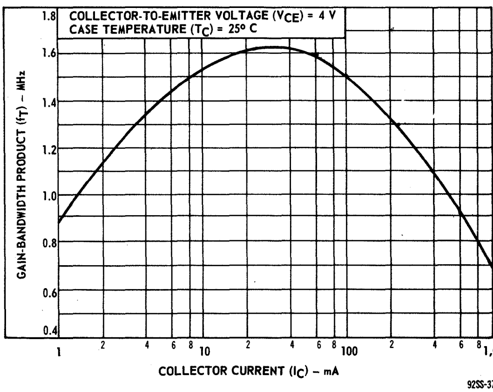


Fig. 8 - Typical gain-bandwidth product for types 2N5297 & 2N5298.

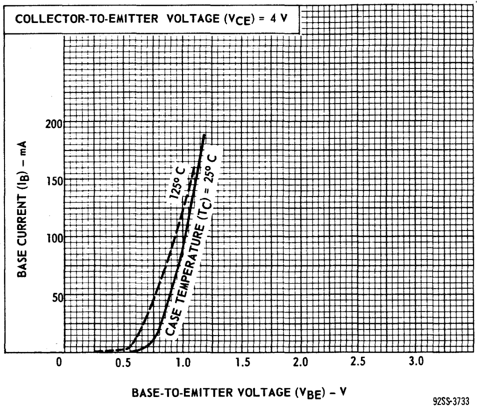


Fig. 9 - Typical input characteristics for types 2N5293 & 2N5294.

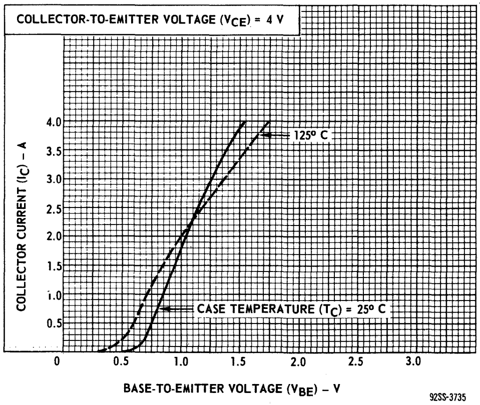


Fig. 10 - Typical transfer characteristics for types 2N5293 & 2N5294.

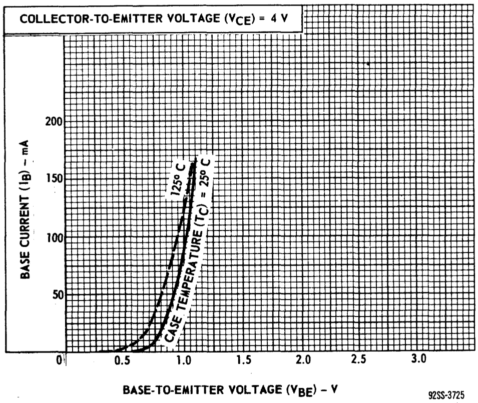


Fig. 11 - Typical input characteristics for types 2N5295 & 2N5296.

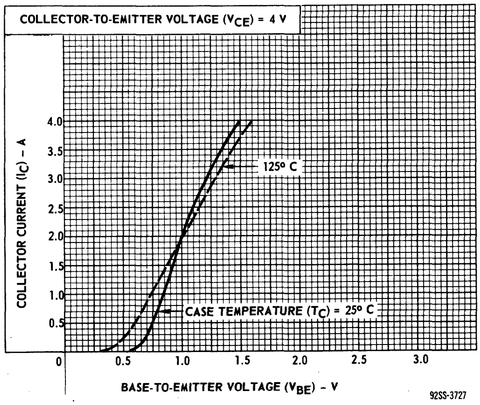


Fig. 12 - Typical transfer characteristics for types 2N5295 & 2N5296.

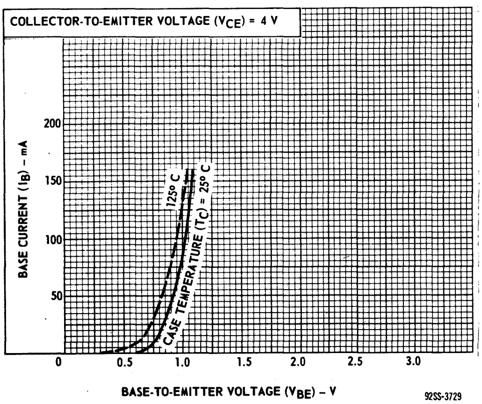


Fig. 13 - Typical input characteristics for types 2N5297 & 2N5298.

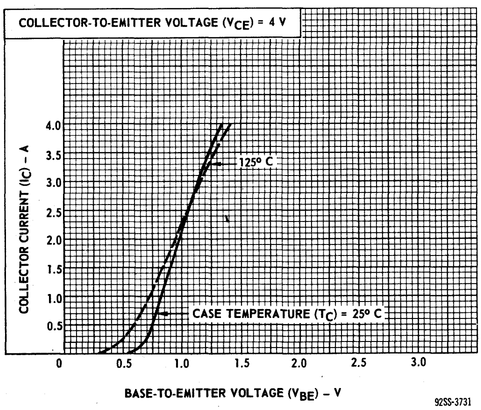


Fig. 14 - Typical transfer characteristics for types 2N5297 & 2N5298.

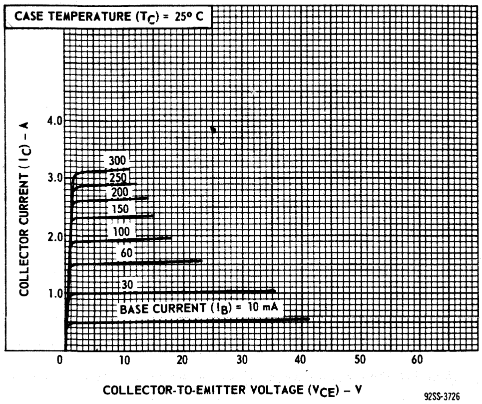


Fig. 15 - Typical output characteristics for types 2N5293 & 2N5294.

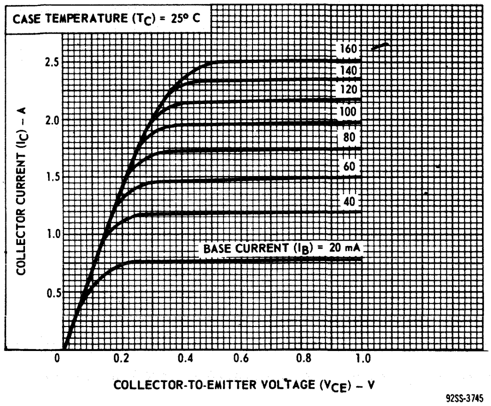


Fig. 16 - Typical output characteristics for types 2N5295 & 2N5296.

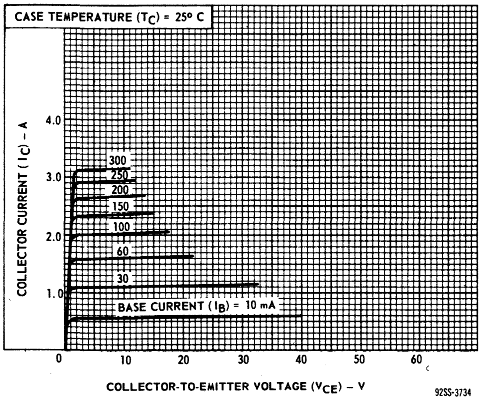


Fig. 17 - Typical output characteristics for types 2N5295 & 2N5296.

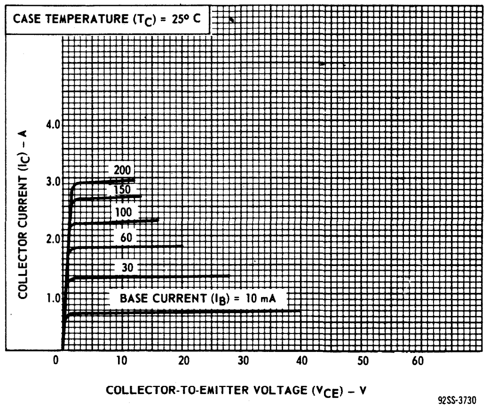


Fig. 18 - Typical output characteristics for types 2N5297 & 2N5298.

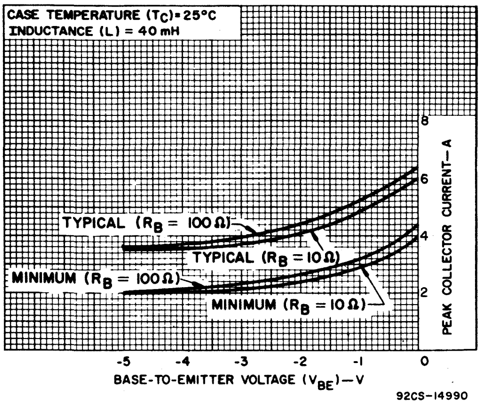


Fig. 19 - Reverse-bias, second-breakdown characteristics for all types.

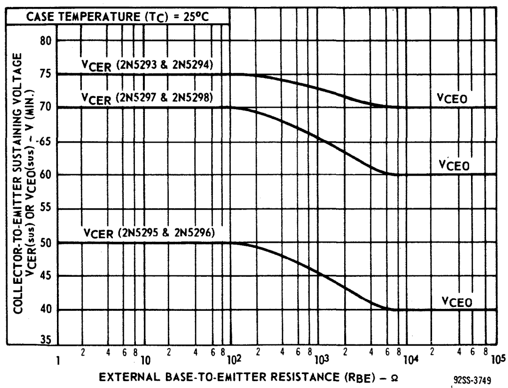


Fig. 20 - Sustaining voltage vs. base-to-emitter resistance for all types.

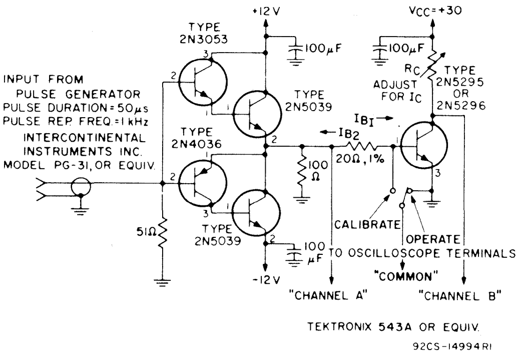


Fig. 21 - Circuit used to measure switching times for types 2N5295 & 2N5296.

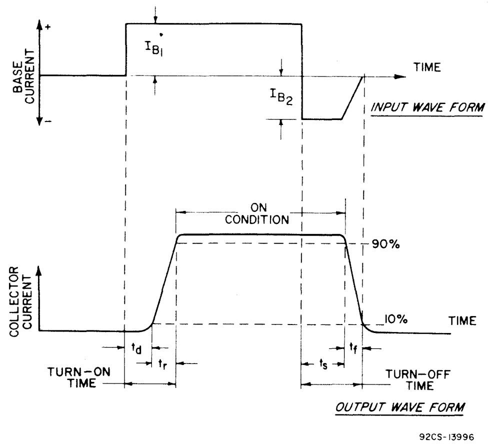


Fig. 22 - Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 21.)

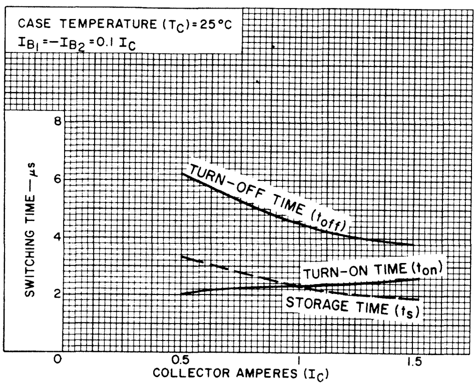


Fig. 23 - Typical saturated switching characteristics for types 2N5295 & 2N5296.

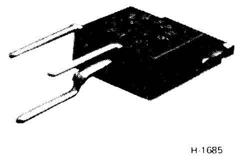
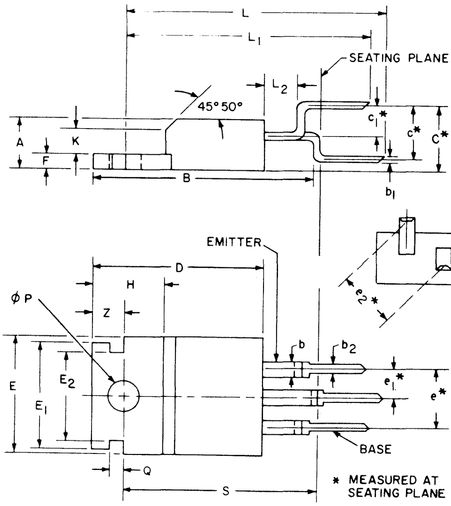


Fig. 24 - VERSAWATT package with optional lead configuration for printed-circiut-board mounting.



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	.140	.190	3.56	4.82
B		.850	—	21.59
b	.020	.038	.508	.965
b_1	.015	.030	.382	.762
b_2	.045	.070	1.15	1.77
C	.230	.270	5.85	6.85
c	.180	.220	4.58	5.58
c_1	.130	.170	3.31	4.31
D	.560	.625	14.23	15.87
E	.330	.420	8.39	10.41
E_1	.365	.385	9.28	9.77
E_2	.300	.320	7.62	8.12
e	.190	.210	4.83	5.33
e_1	.090	.110	2.29	2.79

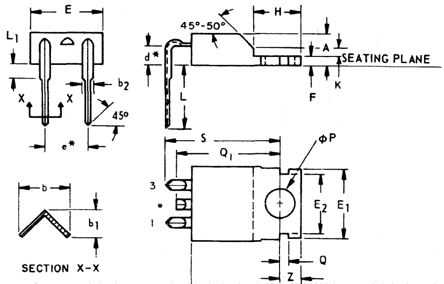
SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
e_2	.203	.243	5.16	6.17
F	.045	.055	1.15	1.39
H	.230	.270	5.85	6.85
K	.080	.085	2.032	2.159
L	.993	1.033	25.22	26.23
L_1	.895	.935	22.73	23.74
L_2	.070	.090	1.78	2.28
φP	.139	.147	3.531	3.734
Q	.040	.060	1.02	1.52
S	.655	.685	16.64	17.39
Z	.100	.120	2.54	3.04

92CS-17175

Fig. 25 - Dimensional outline of VERSAWATT transistor package designed for mounting on printed-circuit boards.

Please submit requirements for the optional lead configuration shown above to your RCA Technical Sales Representative, or write to RCA Low-Frequency Power Marketing, Somerville, N. J. 08876

DIMENSIONAL OUTLINE FOR TYPES 2N5293, 2N5295, AND 2N5297



* MEASURED AT SEATING PLANE
* DO NOT USE STUB AS TIE POINT

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.140	.190	3.56	4.82	
b	.020	.038	.51	.964	
b_1	.015	.030	.38	.762	
b_2	.045	.070	1.15	1.77	
D	.560	.625	14.23	15.87	
d	.080	.115	2.04	2.92	
E	.330	.420	8.39	10.66	2
E_1	.365	.385	9.28	9.77	
E_2	.300	.320	7.62	8.11	
e	.190	.210	4.83	5.33	3
F	.045	.055	1.15	1.39	
H	.230	.270	5.85	6.85	2
K	.080	.085	2.04	2.14	
L	.360	.422	9.15	10.71	
L_1		.050		1.27	
ϕP	.139	.147	3.531	3.733	
Q	.040	.060	1.02	1.52	
Q_1		.610		15.49	
S	.580	.610	14.74	15.49	
Z	.100	.120	2.54	3.04	

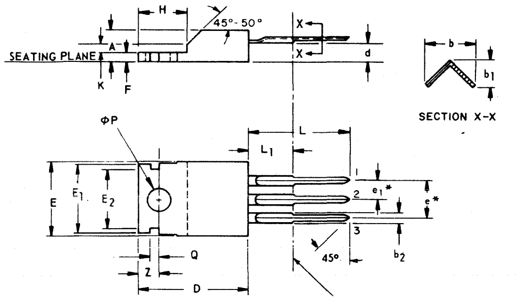
NOTES:
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured .050-.055 (1.27-1.40 mm) below seating plane.**

92CS-14995R1

TERMINAL CONNECTIONS FOR TYPES 2N5293, 2N5295, AND 2N5297

Lead No.1 - Base
Lead No.3 - Emitter
Mounting Flange - Collector
● - Do not use stub as tie point.

DIMENSIONAL OUTLINE FOR TYPES 2N5294, 2N5296, AND 2N5298



* POSITION OF LEADS TO BE MEASURED AT THIS PLANE

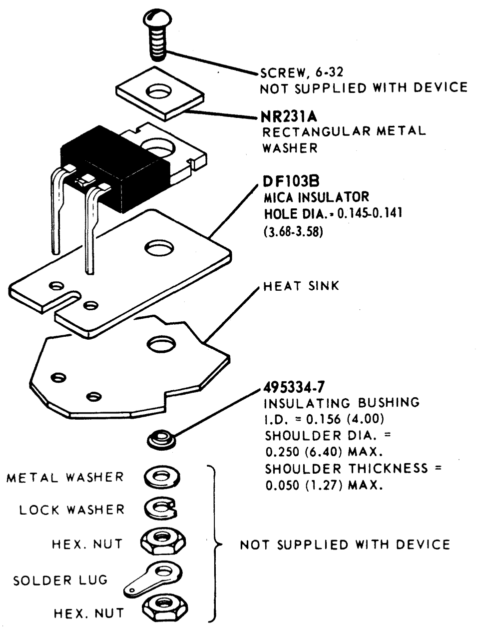
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.140	.190	3.56	4.82	
b	.020	.038	.51	.964	
b_1	.015	.030	.38	.762	
b_2	.045	.070	1.15	1.77	
D	.560	.625	14.23	15.87	
d	.080	.115	2.04	2.92	
E	.330	.420	8.39	10.66	2
E_1	.365	.385	9.28	9.77	
E_2	.300	.320	7.62	8.11	
e	.190	.210	4.83	5.33	3
e_1	.090	.110	2.29	2.79	3
F	.045	.055	1.15	1.39	
H	.230	.270	5.85	6.85	2
K	.080	.085	2.04	2.14	
L	.500	.562	12.70	14.27	
L_1		.250		6.35	
ϕP	.139	.147	3.531	3.733	
Q	.040	.060	1.02	1.52	
Z	.100	.120	2.54	3.04	

NOTES:
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured .250-.255 (6.35-6.48 mm) from bottom of dimension "D".**

92CS-14996R1

TERMINAL CONNECTIONS FOR TYPES 2N5294, 2N5296, AND 2N5298

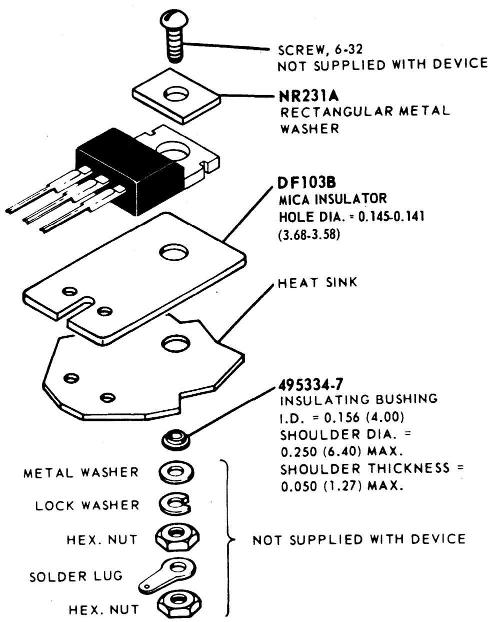
Lead No.1 - Base
Lead No.2 - Collector
Lead No.3 - Emitter
Mounting Flange - Collector



Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

92CS-17181

Fig. 26 - Suggested mounting hardware for types 2N5293, 2N5295 & 2N5297.



Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

92CS-17182

Fig. 27 - Suggested mounting hardware for types 2N5294, 2N5296 & 2N5298.

RCA

Solid State
Division

Power Transistors
2N5490 2N5491 2N5492 2N5493 2N5494 2N5495 2N5496 2N5497

RCA-2N5490, 2N5491, 2N5492, 2N5493, 2N5494, 2N5495, 2N5496 and 2N5497* are hometaxial-base silicon n-p-n transistors. They are intended for a wide variety of medium-power switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers.

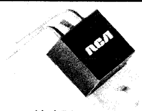
Types 2N5491, 2N5493, 2N5495, and 2N5497 have formed emitter and base leads for insertion into TO-66 sockets. Types 2N5490, 2N5492, 2N5494, and 2N5496 are electrically identical to the 2N5491, 2N5493, 2N5495, and 2N5497 but have straight leads for mounting on printed circuit boards.

These new plastic power transistors differ in voltage ratings and in the currents at which the parameters are controlled.

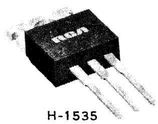
* Formerly RCA Dev. Nos. TA7317, TA7318, TA7315, TA7316, TA7313, TA7314, TA7311, TA7312, respectively.

SILICON N-P-N POWER TRANSISTORS

General-Purpose Types For Medium-Power Switching and Amplifier Applications in Military, Industrial, and Commercial Equipment


H-1534

2N5491, 2N5493, 2N5495, 2N5497
For TO-66 Sockets


H-1535

2N5490, 2N5492, 2N5494, 2N5496
For Printed-Circuit Boards

FEATURES

- Low saturation voltage—
  $V_{CE}(sat)$ = 1 V max. at I_C = 2 A (2N5490, 2N5491)
  = 1 V max. at I_C = 2.5 A (2N5492, 2N5493)
  = 1 V max. at I_C = 3 A (2N5494, 2N5495)
  = 1 V max. at I_C = 3.5 A (2N5496, 2N5497)
- Molded silicone-plastic package
- Maximum safe-area-of-operation curves specified for DC and pulse operation

Maximum Ratings, *Absolute-Maximum Values:*

		2N5490 2N5491 2N5494 2N5495	2N5492 2N5493	2N5496 2N5497	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	75	90	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With -1.5 volts (V_{BE}) of reverse bias	$V_{CEV}(sus)$	60	75	90	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	50	65	80	V
With base open	$V_{CEO}(sus)$	40	55	70	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	V
COLLECTOR CURRENT	I_C	7	7	7	A
BASE CURRENT	I_B	3	3	3	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		50	50	50	W
At ambient temperatures up to 25°C		1.8	1.8	1.8	W
At case temperatures above 25°C		Derate linearly at 0.4 W/°C or see Figs. 2 & 3.			
At ambient temperatures above 25°C		Derate linearly at 0.0144 W/°C			
TEMPERATURE RANGE:					
Storage & Operating (Junction)		← -65 to 150 →			°C
LEAD TEMPERATURE (During Soldering):					
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max		← 235 →			°C

ELECTRICAL CHARACTERISTICS *Case Temperature (T_C) = 25° C Unless Otherwise Specified*

Characteristics	Symbols	TEST CONDITIONS: DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		LIMITS: Types 2N5496 2N5497		Types 2N5494 2N5495		Types 2N5492 2N5493		Types 2N5490 2N5491		Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current With base-emitter junction reverse biased	I_{CEV}	85		-1.5			-	1	-	-	-	-	-	-	mA
		55		-1.5			-	-	-	1	-	-	-	-	
		70		-1.5			-	-	-	-	-	1	-	-	
	I_{CEV} (T_C = 150°C)	85		-1.5			-	5	-	-	-	-	-	-	mA
		55		-1.5			-	-	-	5	-	-	-	-	
		70		-1.5			-	-	-	-	-	5	-	-	
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	70					-	0.5	-	-	-	-	-	-	mA
		40					-	-	-	0.5	-	-	-	2	
		55					-	-	-	-	-	0.5	-	-	
	I_{CER} (T_C = 150°C)	70					-	3.5	-	-	-	-	-	-	mA
		40					-	-	-	3.5	-	-	-	5	
		55					-	-	-	-	-	3.5	-	-	
Emitter-Cutoff Current	I_{EBO}		5				-	1	-	1	-	1	-	1	mA
DC Forward-Current Transfer Ratio	h_{FE}[c]	4			3.5		20	100	-	-	-	-	-	-	
		4			3		-	-	20	100	-	-	-	-	
		4			2.5		-	-	-	-	20	100	-	-	
		4			2		-	-	-	-	-	-	20	100	
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$[c]				0.1	0	70	-	40	-	55	-	40	-	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$[c]				0.1		80	-	50	-	65	-	50	-	V
With base-emitter junction reverse biased	$V_{CEV}(sus)$[c]			-1.5	0.1		90	-	60	-	75	-	60	-	V
Base-to-Emitter Voltage	V_{BE}[c]	4			3.5		-	1.7	-	-	-	-	-	-	V
		4			3		-	-	-	1.5	-	-	-	-	
		4			2.5		-	-	-	-	-	1.3	-	-	
		4			2		-	-	-	-	-	-	-	1.1	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[c]				3.5	0.35	-	1	-	-	-	-	-	-	V
					3	0.3	-	-	-	1	-	-	-	-	
					2.5	0.25	-	-	-	-	-	1	-	-	
					2	0.2	-	-	-	-	-	-	-	1	
Gain-Bandwidth Product	f_T	4			0.5		0.8	-	0.8	-	0.8	-	0.8	-	MHz
Sat. Switching Time: Turn-On (See Figs.15 and 17)	t_{on}	V_{CC} = 30			3.5	0.35[a]	-	5	-	-	-	-	-	-	μs
					3	0.3[a]	-	-	-	5	-	-	-	-	
					2.5	0.25[a]	-	-	-	-	-	5	-	-	
					2	0.2	-	-	-	-	-	-	-	5	
Turn-Off (See Figs.15 and 17)	t_{off}	V_{CC} = 30			3.5	0.35[b]	-	15	-	-	-	-	-	-	μs
					3	0.3[b]	-	-	-	15	-	-	-	-	
					2.5	0.25[b]	-	-	-	-	-	15	-	-	
					2	0.2	-	-	-	-	-	-	-	15	
Thermal Resistance: Junction-to-Case	θ_{J-C}						-	2.5	-	2.5	-	2.5	-	2.5	°C/W
Junction-to-Ambient	θ_{J-A}						-	70	-	70	-	70	-	70	°C/W

[a] I_{B1} value (turn-on base current). [b] I_{B2} value (turn-off base current). [c] Pulsed, pulse duration = 300 μs, duty factor = .018.

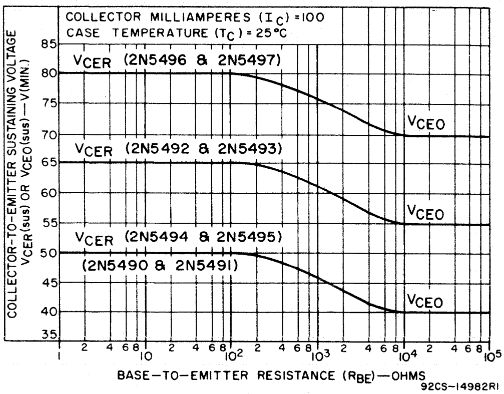


Fig.1 - Collector-to-emitter sustaining voltage characteristics for types 2N5490 through 2N5497 inclusive.

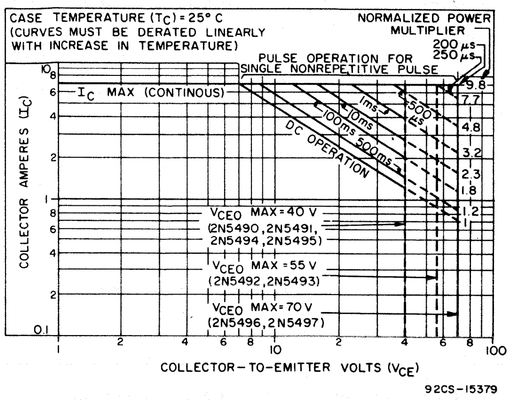


Fig.2 - Maximum operating areas for types 2N5490 through 2N5497 inclusive.

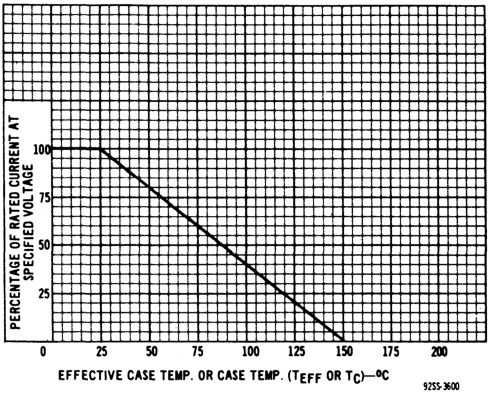


Fig.3 - Dissipation derating curve for types 2N5490 through 2N5497 inclusive.

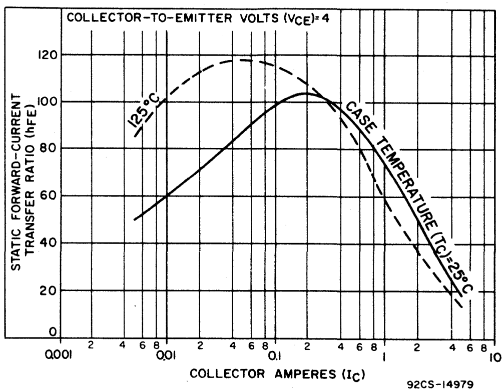


Fig.4 - Typical static beta characteristics for types 2N5496 and 2N5497.

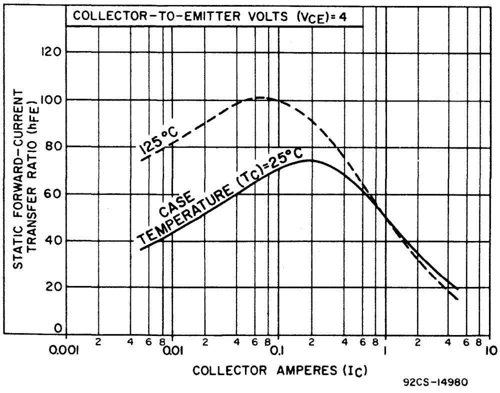


Fig.5 - Typical static beta characteristics for types 2N5494 and 2N5495.

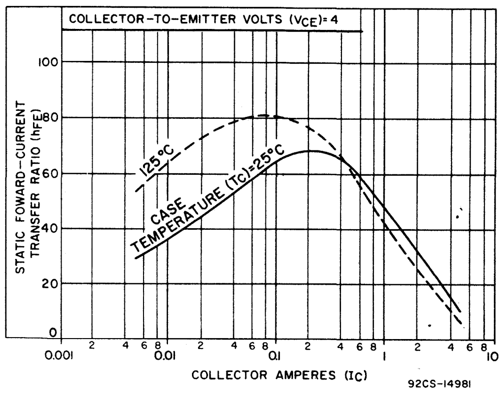


Fig.6 - Typical static beta characteristics for types 2N5490 through 2N5493 inclusive.

REVERSE-BIAS OPERATION

The energy required to induce second breakdown when the transistor is turned off depends on the current during the "on" condition, the emitter-to-base voltage and resistance when the transistor is turned off, and the amount of inductance in series with the collector. The curves shown in Fig.7 should prove useful in the design of circuits having inductive loads (such as solenoid- or relay-control circuits, magnetic-circuits, magnetic-deflection circuits, and switching regulators) without protective zener diodes across the collector-emitter junction. Also, these curves can be used in the design of circuits in which some leakage inductance is present (such as inverters, converters, and transformer-coupled power amplifiers.)

The curves shown in Fig.2 are based on the premise that the junction temperature must not exceed the maximum allowable junction temperature. Also, this limit must not be exceeded in the reverse-bias mode. After it is established that the operation of the unit lies within the capability shown in Fig.7, a computation is required to insure that the reverse bias energy will not exceed the derated power time as shown in Fig.2. Derating is accomplished as described in the preceding discussion of forward-bias operation.

In general, reverse-bias second-breakdown energy ($E_{S/b}$) capability increases with a decrease in inductance. Therefore, the allowable energy shown in the above-mentioned curves (calculated from $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current from the curves) will be conservative for smaller inductive loads. For further information on second breakdown, consult RCA "SILICON POWER CIRCUITS MANUAL." Form No. SP-50.

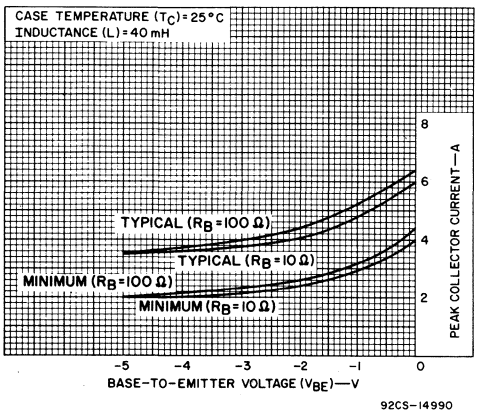


Fig.7 - Reverse-Bias, Second-Breakdown Characteristics for Types 2N5490 through 2N5497 inclusive.

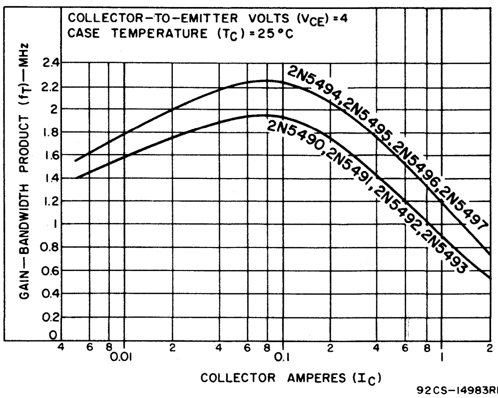


Fig.8 - Typical gain-bandwidth product for types 2N5490 through 2N5497 inclusive.

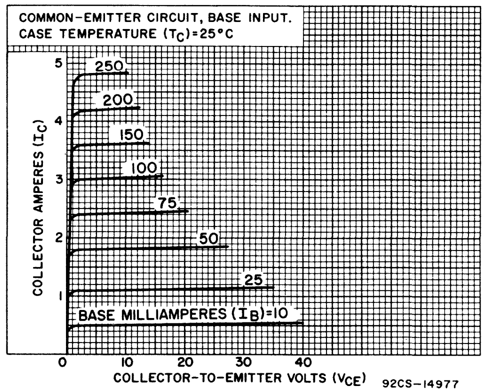


Fig.9 - Typical output characteristics for types 2N5494 through 2N5497 inclusive.

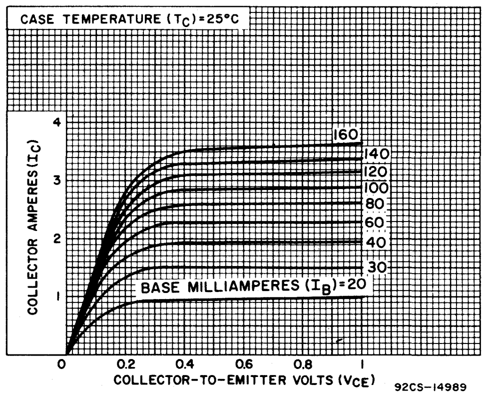


Fig.10 - Typical output characteristics for types 2N5494 and 2N5495.

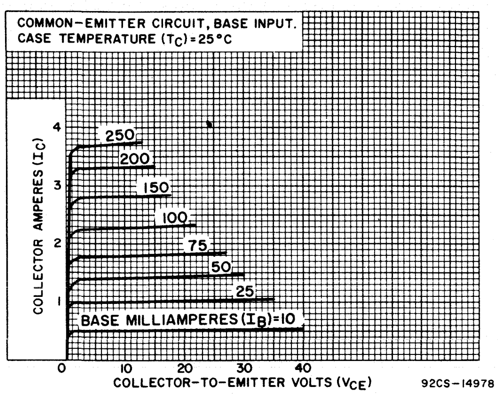


Fig.11 - Typical output characteristics for types 2N5490 through 2N5493 inclusive.

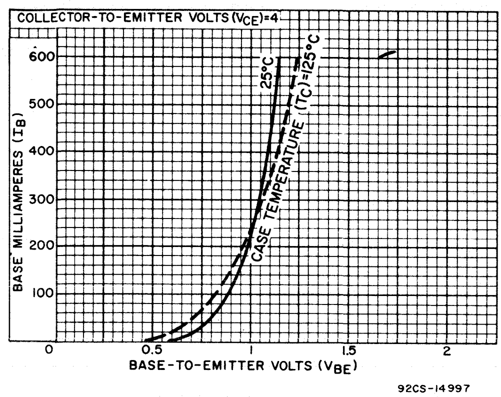


Fig.12 - Typical input characteristics for types 2N5494 through 2N5497 inclusive.

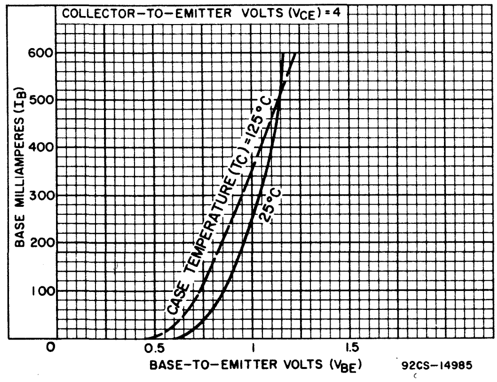


Fig.13 - Typical input characteristics for types 2N5490 through 2N5493 inclusive.

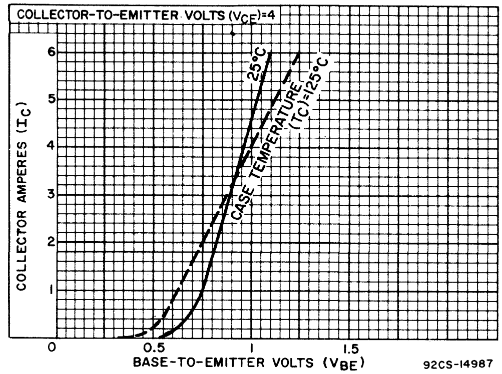


Fig.14 - Typical transfer characteristics for types 2N5494 through 2N5497 inclusive.

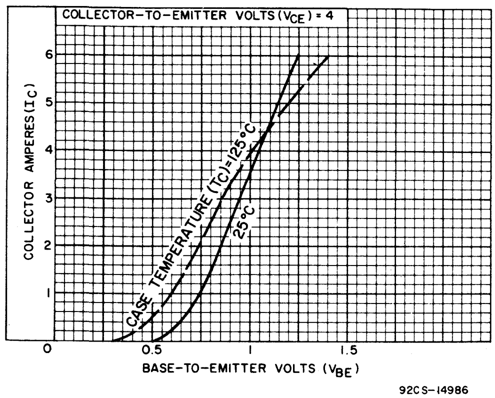


Fig.15 - Typical transfer characteristics for types 2N5490 through 2N5493 inclusive.

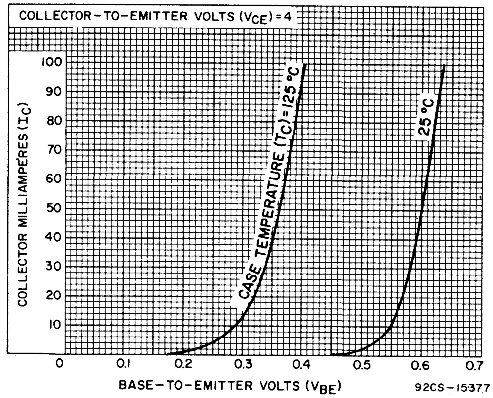


Fig.16 - Typical transfer characteristics for types 2N5490 through 2N5497 inclusive.

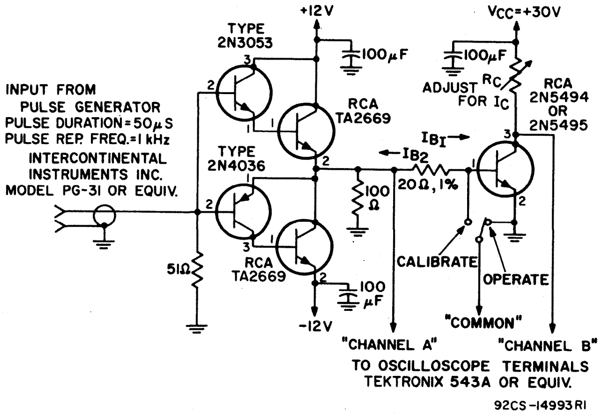


Fig.17 - Circuit used to measure switching times for types 2N5494 and 2N5495.

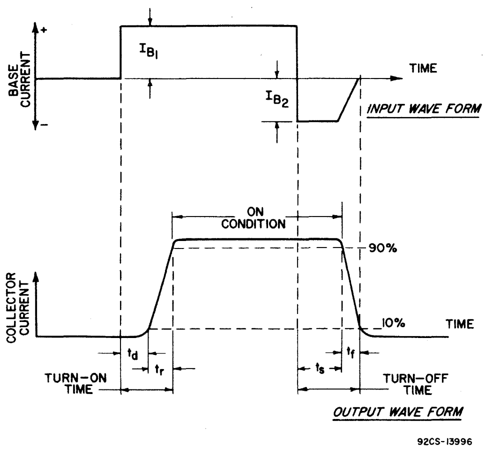


Fig.18 - Oscilloscope display for measurement of switching times (test circuit shown in Fig.17).

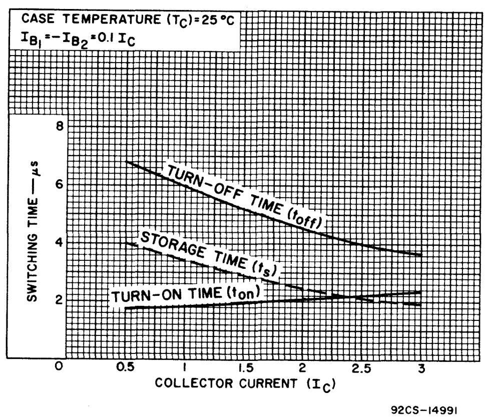


Fig.19 - Typical saturated switching characteristics for types 2N5494 and 2N5495.

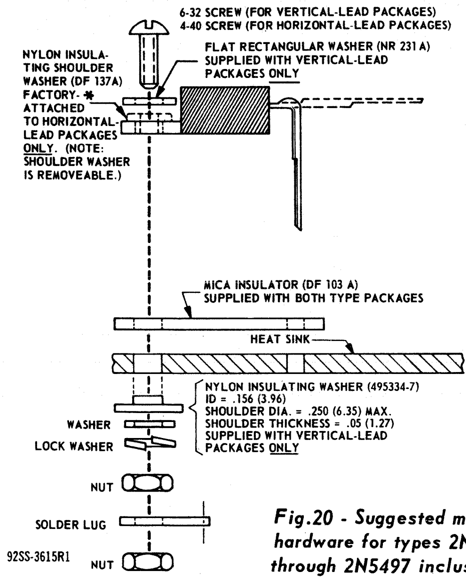


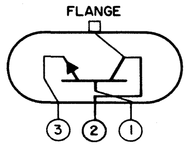
Fig.20 - Suggested mounting hardware for types 2N5490 through 2N5497 inclusive.

* Supplied on request.

TERMINAL CONNECTIONS

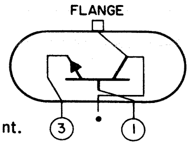
For Types 2N5490, 2N5492, 2N5494, 2N5496

Lead 1 - Base
Lead 2 - Collector
Lead 3 - Emitter
Mounting Flange - Collector

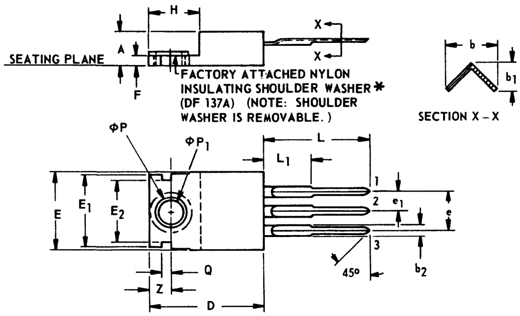


For Types 2N5491, 2N5493, 2N5495, 2N5497

Lead 1 - Base
Lead 3 - Emitter
Mounting Flange - Collector
● - Do not use stub as tie point.



DIMENSIONAL OUTLINE FOR TYPES 2N5490, 2N5492, 2N5494, & 2N5496

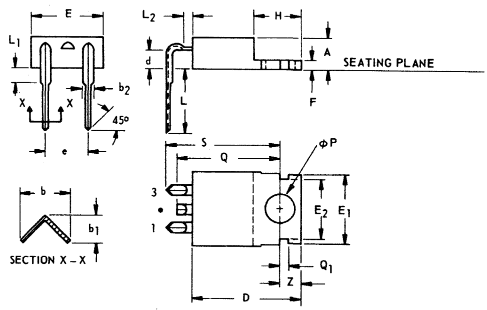


* Supplied on request.

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	.160	.190	4.07	4.82
b	.020	.045	.51	1.14
b_1	.015	.030	.39	.76
b_2	.045	.055	1.143	1.397
D	.575	.600	14.61	15.24
E	.395	.410	10.04	10.41
E_1	.365	.385	9.28	9.77
E_2	.300	.320	7.62	8.12
e	.190	.210	4.83	5.33
e_1	.095	.105	2.42	2.66
F	.020	.055	.51	1.39
H	.235	.265	5.97	6.73
L	.500		12.70	
L_1		.250		6.35
ΦP	.141	.145	3.582	3.683
$ΦP_1$	.115	.121	2.92	3.07
Q	.040	.060	1.02	1.52
Z	.100	.120	2.54	3.04

92CS-14996

DIMENSIONAL OUTLINE FOR TYPES 2N5491, 2N5493, 2N5495, & 2N5497



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.160	.190	4.07	4.82	
b	.020	.045	.51	1.14	
b_1	.015	.030	.39	.76	
b_2	.045	.055	1.143	1.397	
D	.575	.600	14.61	15.24	
d	.085	.115	2.16	2.92	
E	.395	.410	10.04	10.41	
E_1	.365	.385	9.28	9.77	
E_2	.300	.320	7.62	8.12	
e	.190	.210	4.83	5.33	1
F	.020	.055	.51	1.39	
H	.235	.265	5.97	6.73	
L	.360		9.15		
L_1		.050		1.27	
L_2		.050		1.27	
ΦP	.141	.145	3.582	3.683	
Q		.600		15.24	
Q_1	.040	.060	1.02	1.52	
S	.580	.610	14.74	15.49	1
Z	.100	.120	2.54	3.04	

NOTES:
1. POSITION OF LEADS TO BE MEASURED .050 – .055 (1.27 mm – 1.40 mm) BELOW SEATING PLANE.

92CS-14995

RCA
Solid State
Division

Power Transistors

2N5575 2N5578

RCA-2N5575 and 2N5578* are high current, high-power, Hometaxial-base silicon n-p-n transistors. They differ in maximum voltage and current ratings and in terminal arrangement.

These power transistors are intended for a wide variety of high-current, high-power linear and switching applications such as low-to-medium-frequency amplifiers, switching and linear regulators, power-switching circuits, series- or shunt-regulator driver and output stages, dc-to-dc converters, inverters, control circuits, and solenoid (hammer)/ relay drivers.

The high-current capability (100 A peak) makes these types particularly suitable for circuit designs that now require several low-current types connected in parallel.

* Formerly RCA Dev. Nos. TA7016 and TA7017, respectively.

Silicon N-P-N Power Transistors

For Linear and Switching Applications in Military, Industrial, and Commercial Equipment

2N5575
2N5578

H-1571

Modified JEDEC TO-3

MAXIMUM RATINGS,

Absolute-Maximum Values:

		2N5575	2N5578	
J COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	70	90	V
J COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With external base-emitter resistance (R_{BE}) = 10 Ω & V_{BE} = −1.5 V	$V_{CEX}(sus)$	70	90	V
With base open	$V_{CEO}(sus)$	50	70	V
J EMITTER-TO-BASE VOLTAGE	V_{EBO}	8	8	V
J CONTINUOUS COLLECTOR CURRENT	I_C	80	60	A
J PULSED COLLECTOR CURRENT	I_{CM}	100	80	A
J CONTINUOUS BASE CURRENT	I_B	20	15	A
J TRANSISTOR DISSIPATION:*	P_T			
At case temperatures up to 25 °C and V_{CE} up to 25 V		300	300	W
At case temperatures up to 25 °C and V_{CE} above 25 V		See Fig. 1.		
At case temperatures above 25 °C and V_{CE} above 25 V		See Figs. 1 & 2.		
J TEMPERATURE RANGE:				
Operating (Junction)		−65 to +175		°C
Storage		−65 to +200		°C
J TERMINAL TEMPERATURE (During Soldering): (Applies to all pin, lug, & flexible-lead types) At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		230		°C

*For those applications imposing consistently high dissipation requirements, a solid copper "heat spreader" should be used. Details of a typical heat spreader plate are shown in Fig. 18.

J In accordance with JEDEC registration data format (JS-6, RDF-1).

FEATURES

- Maximum Safe-Area-of-Operation Curve
- $I_{S/b}$–Limit Line Beginning at 25 V
- High-Current Capability
  I_C = 80 A continuous, 100 A peak (2N5575)
  60 A continuous, 80 A peak (2N5578)
- High-Dissipation Capability –
  P_T = 300 W max. at T_C = 25 °C
- h_{FE}, $V_{CE}(sat)$, & V_{BE} measured at:
  60 A for 2N5575
  40 A for 2N5578
- Low Saturation Voltage at High Beta –
  $V_{CE}(sat)$ = 2 V max. at h_{FE} = 10 (2N5575)
  1.5 V max. at h_{FE} = 10 (2N5578)
- Low Thermal Resistance –
  θ_{J-C} = 0.5 °C/W max.

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25° C Unless Otherwise Specified*

Characteristic	Symbol	Test Conditions							Limits				Units
		DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (A)			Type 2N5575		Type 2N5578		
		V_{CE}	V_{CB}	V_{EB}	V_{BE}	I_C	I_B	I_E	Min.	Max.	Min.	Max.	
J Collector-Cutoff Current: With base-emitter junction reversed biased	I_{CEV}	60 80			-1.5 -1.5				– –	10 –	– –	– 10	mA
With external base-emitter resistance (R_{BE}) = 10 Ω	I_{CER}	50 70							– –	5 –	– –	– 5	mA
J With base-emitter junction reverse biased	I_{CEV} (T_C = 150 °C)	60 80			-1.5 -1.5				– –	20 –	– –	– 20	mA
Emitter-Cutoff Current	I_{EBO}			8					–	10	–	10	mA
J DC Forward-Current Transfer Ratio	h_{FE}[a]	4 4				40 60			– 10	– 40	10 –	40 –	
Collector-to-Emitter Sustaining Voltage: *(See Figs. 4 & 5.)* With base open	$V_{CEO}(sus)$					0.2			50[b]	–	70[b]	–	V
With base-emitter junction reversed biased & R_{BE} = 10 Ω	$V_{CEX}(sus)$				-1.5	0.2			70[b]	–	90[b]	–	V
Base-to-Emitter Voltage	V_{BE}[a]	4 4				40 60			– –	– 3	– –	2.5 –	V
J Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]					40 60	4 6		– –	– 2	– –	1.5 –	V
J Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$[a]					40 60	4 6		– –	– 3	– –	2.5 –	V
Output Capacitance	C_{ob}		10					0	–	2000	–	2000	pF
Input Capacitance	C_{ib}			0.5		0			–	4000	–	4000	pF
Gain-Bandwidth Product	f_T	4				10			400	2000	400	2000	kHz
Second-Breakdown Collector Current (With base forward biased)	$I_{S/b}$[c]	25							12[d]	–	12[d]	–	A
Second Breakdown Energy (With base reverse biased, R_{BE} = 10 Ω, L = 33 mH)	$E_{S/b}$[e]				-1.5	7			0.8	–	0.8	–	J
Thermal Resistance (Junction-to-case)	$\theta_{J\text{-}C}$								–	0.5	–	0.5	°C/W

[a] Pulsed; pulse duration ≦ 350 μs, duty factor = 0.02. [J] In accordance with JEDEC registration data format (JS-6, RDF-1).

[b] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in *Fig. 4*.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[d] Pulsed; 1-s, non-repetitive pulse.

[e] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

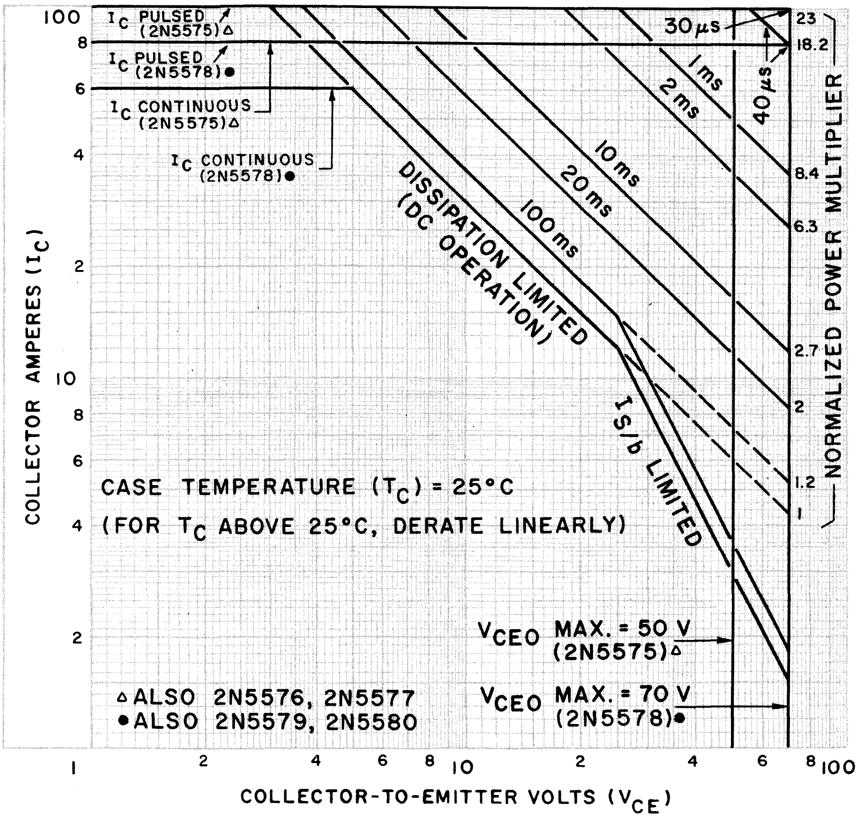


Fig. 1 - Maximum operating areas.

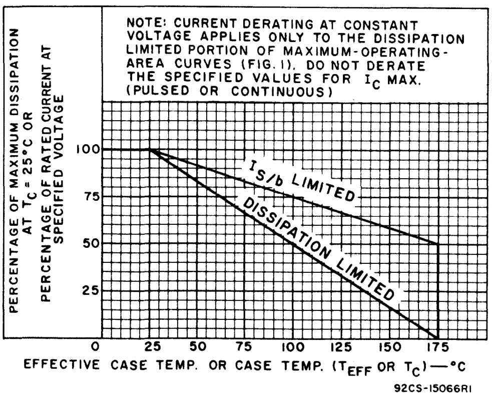


Fig. 2 - Dissipation derating curves.

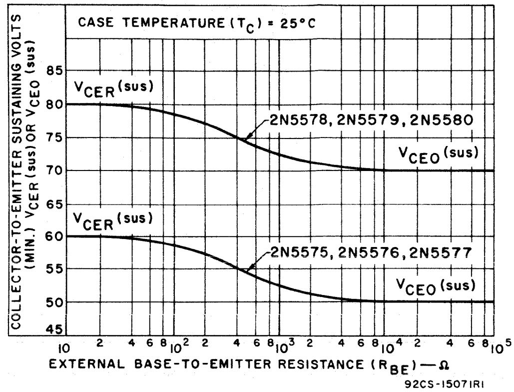


Fig. 3 - Collector-to-emitter sustaining voltage characteristics.

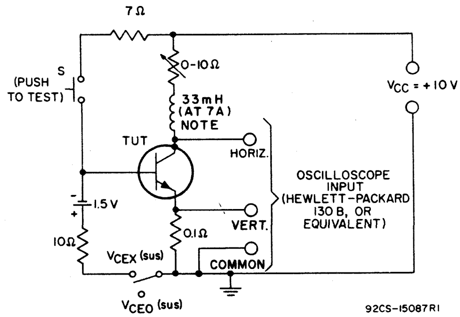
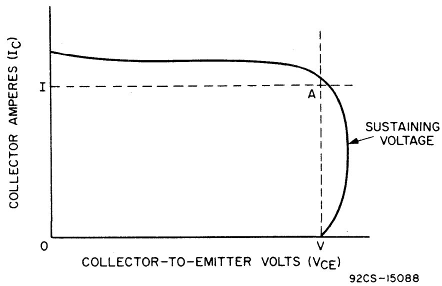


Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ & $V_{CEX}(sus)$.



NOTE: The sustaining Voltage V_{CEO}(sus) or V_{CEX}(sus) is acceptable when the trace falls to the right and above point "A". (For values of current and voltage, see Electrical Characteristics.)

Fig. 5 - Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 4).

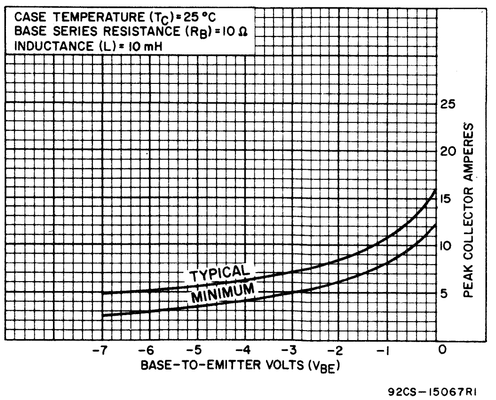


Fig. 6 - Reverse-bias, second-breakdown characteristics.

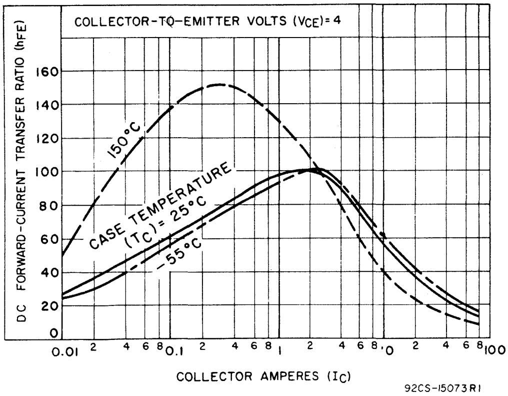


Fig. 7 - Typical dc beta characteristics for 2N5575.

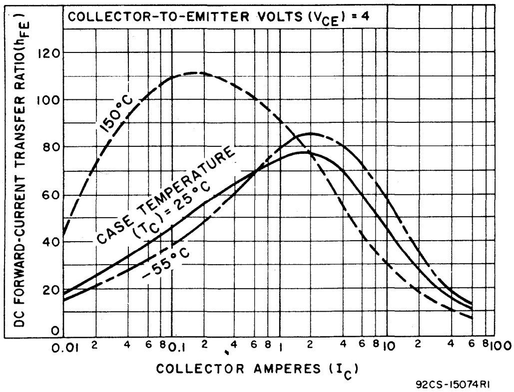


Fig. 8 - Typical dc beta characteristics for 2N5578.

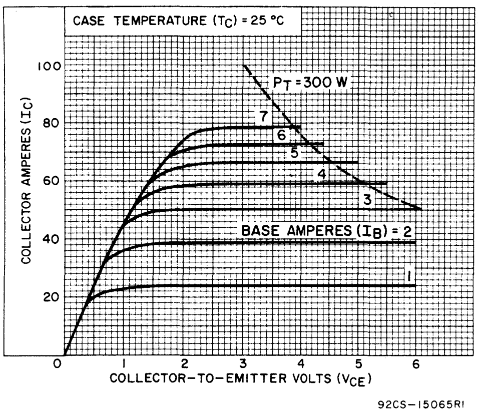


Fig. 9 - Typical output characteristics for 2N5575.

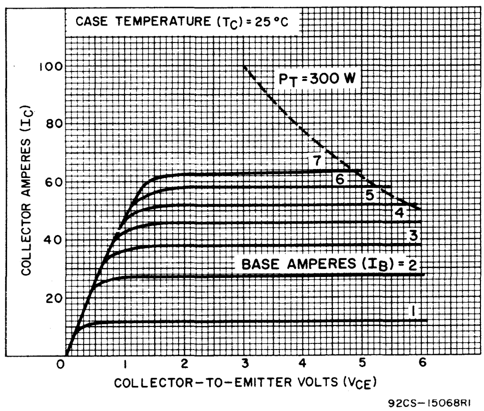


Fig. 10 - Typical output characteristics for 2N5578.

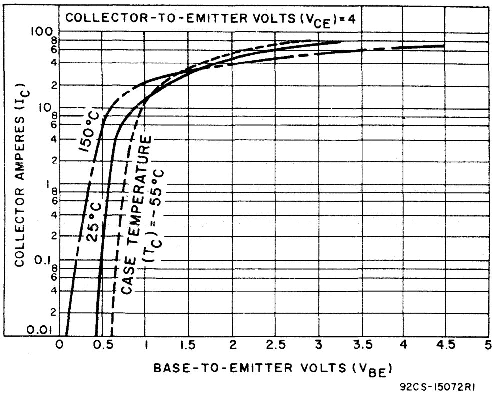


Fig. 11 - Typical transfer characteristics for 2N5575.

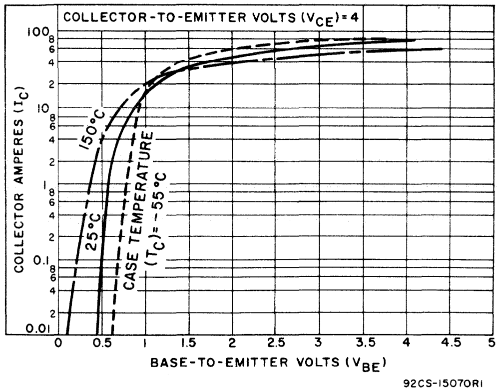


Fig. 12 - Typical transfer characteristics for 2N5578.

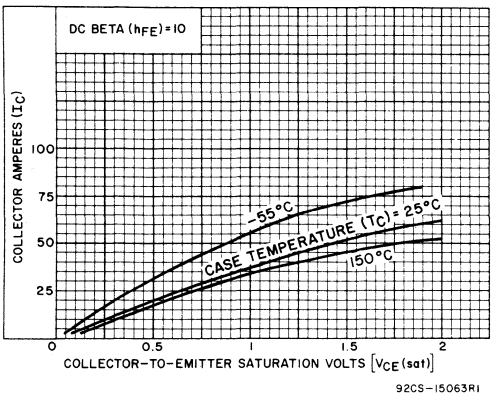


Fig. 13 - Typical saturation voltage characteristics for 2N5575.

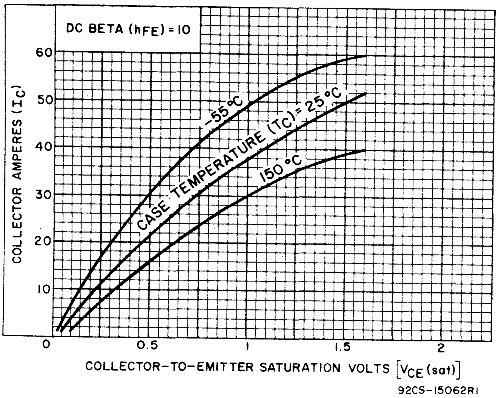


Fig. 14 - Typical saturation voltage characteristics for 2N5578.

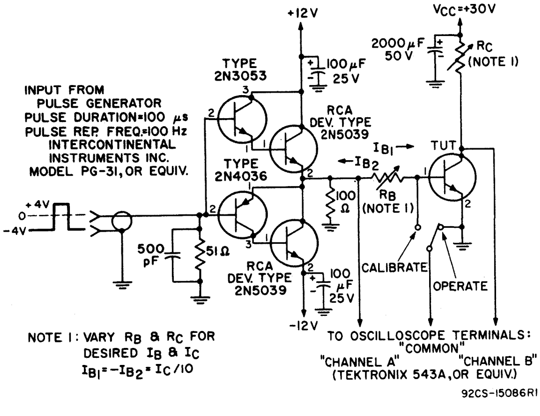


Fig. 15 - Circuit used to measure switching times.

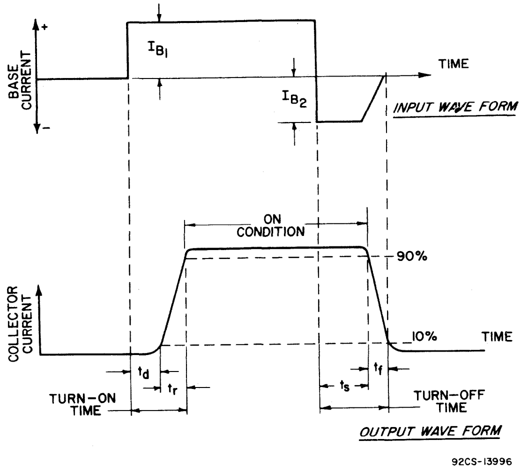


Fig. 16 - Oscilloscope display for measurement of switching times (Test circuit shown in Fig. 15).

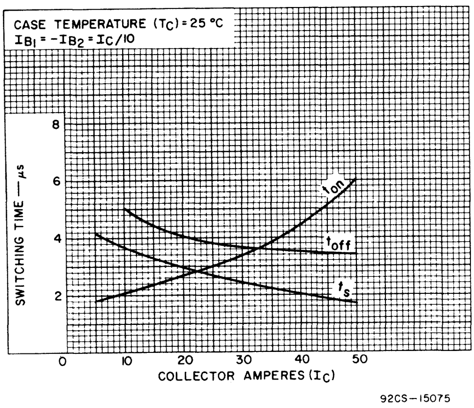
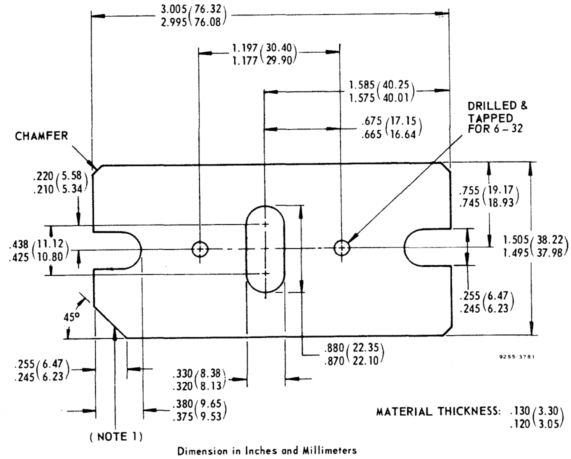


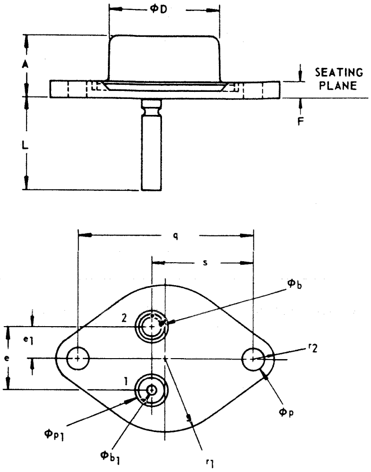
Fig. 17 - Typical saturated switching characteristics.



NOTE: 1. 45° CHAMFER INDICATES EMITTER SIDE OF HEAT SPREADER
2. DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS AND ARE DERIVED FROM THE BASIC INCH DIMENSIONS AS INDICATED

Fig. 18 - Heat spreader.

DIMENSIONAL OUTLINE FOR TYPES 2N5575 & 2N5578

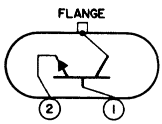


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.416	.450	10.57	11.43	
Φ b	.147	.153	3.734	3.886	
Φ b_1	.059	.061	1.499	1.549	
Φ D	.750	.755	19.05	19.17	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F	.100	.114	2.54	2.89	
L	.595	.625	15.12	15.87	1
Φ p	.151	.161	3.84	4.09	
Φ p_1	.280	.285	7.112	7.239	2
q	1.177	1.197	29.90	30.40	
r_1	—	.525	—	13.34	
r_2	—	.188	—	4.78	
s	.655	.675	16.64	17.15	

NOTES:
1. TWO PINS.
2. CLEARANCE HOLES FOR BOTH PINS SHOULD BE 0.285 in. (7.24 mm) MIN. DIA.

92SS-3771

TERMINAL CONNECTIONS



Pin 1 – Base
Pin 2 – Emitter
Case, Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors
2N5781 2N5782 2N5783 2N5784 2N5785 2N5786

RCA-2N5781, 2N5782, and 2N5783 are diffused, epitaxial-base mesa silicon p-n-p transistors-- complements of the hometaxial-base silicon n-p-n types 2N5784 , 2N5785, and 2N5786, ** respectively.

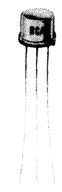
All six of these devices employ the JEDEC TO-5 package; the three types in each family differ primarily in voltage ratings and saturation characteristics.

These transistors are intended for medium-power switching and complementary-symmetry audio amplifier applications

**Formerly RCA Dev. Types TA7270, TA7271, TA7272, TA7289, TA7290, and TA7291 respectively.

SILICON N-P-N AND P-N-P TYPES

General-Purpose Complementary-Symmetry Types



JEDEC TO-5

For Switching and Amplifier Applications in Military, Industrial, and Commercial Equipment

FEATURES

- Low Saturation Voltages
- Maximum Safe-Area-of-Operation Curves
- Hermetically Sealed JEDEC TO-5 Package
- High Min. h_{FE} at High Current
- High Breakdown Voltages

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

P-N-P Types: 2N5781, 2N5782, 2N5783 — N-P-N Types: 2N5784, 2N5785, 2N5786

		2N5781	2N5782	2N5783	2N5784	2N5785	2N5786	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-80	-65	-45	80	65	45	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:								
*With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	-80	-65	-45	80	65	45	V
With base open	$V_{CEO}(sus)$	-65	-50	-40	65	50	40	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-3.5	5	5	3.5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	-3.5	-3.5	-3.5	3.5	3.5	3.5	A
* CONTINUOUS BASE CURRENT	I_B	-1	-1	-1	1	1	1	A
TRANSISTOR DISSIPATION:	P_T							
*At case temperatures up to 25 °C		10	10	10	10	10	10	W
At ambient temperatures up to 25 °C		1	1	1	1	1	1	W
*At case temperatures above 25 °C		Derate linearly at 0.057 W/°C, or see Fig. 3.						
At ambient temperatures above 25 °C		Derate linearly at 0.0057 W/°C.						
* TEMPERATURE RANGE:								
Storage & Operating (Junction)		← -65 to +200 →						°C
* LEAD TEMPERATURE (During Soldering):								
At distances > 1/32 in. (0.8 mm) from seating plane for 10 s max		← +230 →						°C

* In accordance with JEDEC registration data format (JS-6 RDF-2)

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25 °C, unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Volts V_{CE}▲	DC Emitter Volts V_{EB}▲	DC Current (Amperes) I_C▲	I_B▲	LIMITS P-N-P TYPES 2N5781 Min.	2N5781 Max.	2N5782 Min.	2N5782 Max.	2N5783 Min.	2N5783 Max.	N-P-N TYPES 2N5784 Min.	2N5784 Max.	2N5785 Min.	2N5785 Max.	2N5786 Min.	2N5786 Max.	UNITS
* Collector-Cutoff Current With base open	I_{CEO}	-50, 50				–	100	–	–	–	–	–	100	–	–	–	–	µA
		-35, 35				–	–	–	-100	–	–	–	–	–	100	–	–	
		-25, 25				–	–	–	–	–	-100	–	–	–	–	–	100	
With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	-65, 65				–	-10	–	–	–	–	–	10	–	–	–	–	µA
		-50, 50				–	–	–	-10	–	–	–	–	–	10	–	–	
		-40, 40				–	–	–	–	–	-10	–	–	–	–	–	10	
	I_{CER} (T_C = 150 °C)	-65, 65				–	-1	–	–	–	–	–	1	–	–	–	–	mA
		-50, 50				–	–	–	-1	–	–	–	–	–	1	–	–	
		-40, 40				–	–	–	–	–	-1	–	–	–	–	–	1	
* With base-emitter junction reverse-biased and external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CEX}	-75, 75	1.5, -1.5 (V_{BE})[g]			–	-10	–	–	–	–	–	10	–	–	–	–	µA
		-60, 60				–	–	–	-10	–	–	–	–	–	10	–	–	
		-45, 45				–	–	–	–	–	-10	–	–	–	–	–	10	
*	I_{CEX} (T_C = 150 °C)	-75, 75	1.5, -1.5 (V_{BE})[g]			–	-1	–	–	–	–	–	1	–	–	–	–	mA
		-60, 60				–	–	–	-1	–	–	–	–	–	1	–	–	
		-45, 45				–	–	–	–	–	-1	–	–	–	–	–	1	
* Emitter-Cutoff Current	I_{EBO}		-3.5, 3.5			–	–	–	–	–	-10	–	–	–	–	–	10	µA
			-5, 5			–	-10	–	-10	–	–	–	10	–	10	–	–	
* DC Forward-Current Transfer Ratio	h_{FE}	-2, 2		-1[c], 1[c]		20	100	–	–	–	–	20	100	–	–	–	–	
		-2, 2		-1.2[c], 1.2[c]		–	–	20	100	–	–	–	–	20	100	–	–	
		-2, 2		-1.6[c], 1.6[c]		–	–	–	–	20	100	–	–	–	–	20	100	
		-2, 2		-3.2[c], 3.2[c]		4	–	4	–	4	–	4	–	4	–	4	–	
* Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 1 kHz)	h_{fe}	-2, 2		-0.1, 0.1		25	–	25	–	25	–	25	–	25	–	25	–	
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$			-0.1, 0.1		-65	–	-50	–	-40	–	65	–	50	–	40	–	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω *(See Figs. 4 & 5)*	$V_{CER}(sus)$			-0.1, 0.1		-80	–	-65	–	-45	–	80	–	65	–	45	–	V
* Base-to-Emitter Voltage	V_{BE}	-2, 2		-1, 1		–	-1.5	–	–	–	–	–	1.5	–	–	–	–	V
		-2, 2		-1.2, 1.2		–	–	–	-1.5	–	–	–	–	–	1.5	–	–	
		-2, 2		-1.6, 1.6		–	–	–	–	–	-1.5	–	–	–	–	–	1.5	
* Collector-to-Emitter Saturation Voltage [Measured ¼ in. (6.35 mm) from case][f]	$V_{CE}(sat)$			-1, 1	-0.1, 0.1	–	-0.5	–	–	–	–	–	0.5	–	–	–	–	V
				-1.2, 1.2	-0.12, 0.12	–	–	–	-0.75	–	–	–	–	–	0.75	–	–	
				-1.6, 1.6	-0.16, 0.16	–	–	–	–	–	-1.0	–	–	–	–	–	1.0	
				-3.2, 3.2	-0.8, 0.8	–	-2	–	-2	–	-2	–	2	–	2	–	2	
* Magnitude of Common Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio	$\|h_{fe}\|$[e]	-2		-0.1	f = 4 MHz	2	15	2	15	2	15	–	–	–	–	–	–	
		2		0.1	f = 200 kHz	–	–	–	–	–	–	5	20	5	20	5	20	
Saturated Switching Time: Turn-on	t_{on}	-30[d], 30[d]		-1, 1	-0.1[a], 0.1[a]	–	.5	–	.5	–	.5	–	5	–	5	–	5	µs
Turn-off	t_{off}	-30[d], 30[d]		-1, 1	-0.1[b], 0.1[b]	–	2.5	–	2.5	–	2.5	–	15	–	15	–	15	µs
Thermal Resistance: Junction-to-Case	θ_{J-C}					–	17.5	–	17.5	–	17.5	–	17.5	–	17.5	–	17.5	°C/W
Junction-to-Ambient	θ_{J-A}					–	175	–	175	–	175	–	175	–	175	–	175	°C/W

[a] I_{B1} Value (turn-on base current)

[b] I_{B2} Value (turn-off base current)

[c] Pulsed, pulse duration = 300 µs, duty factor = 0.018

[d] V_{CC} Value

[e] Measured at a frequency where $|h_{fe}|$ is decreasing at approximately 6 dB per octave

▲ Use negative values for P-N-P types.

* In accordance with JEDEC registration data format (JS-6 RDF-2)

[f] Lead resistance is critical in this test.

[g] Reverse bias; use negative value for N-P-N

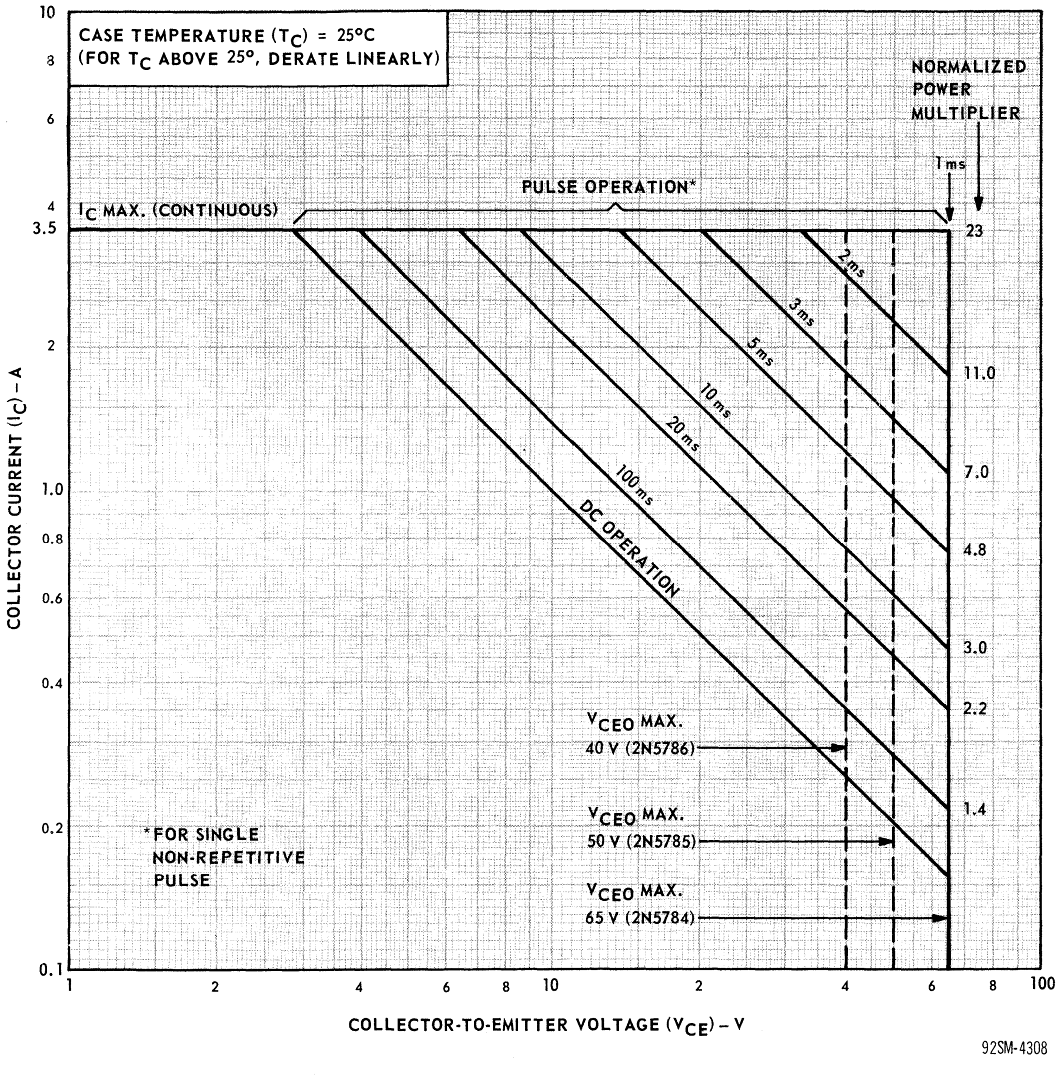


Fig. 1 - Maximum operating areas for types 2N5784, 2N5785, and 2N5786.

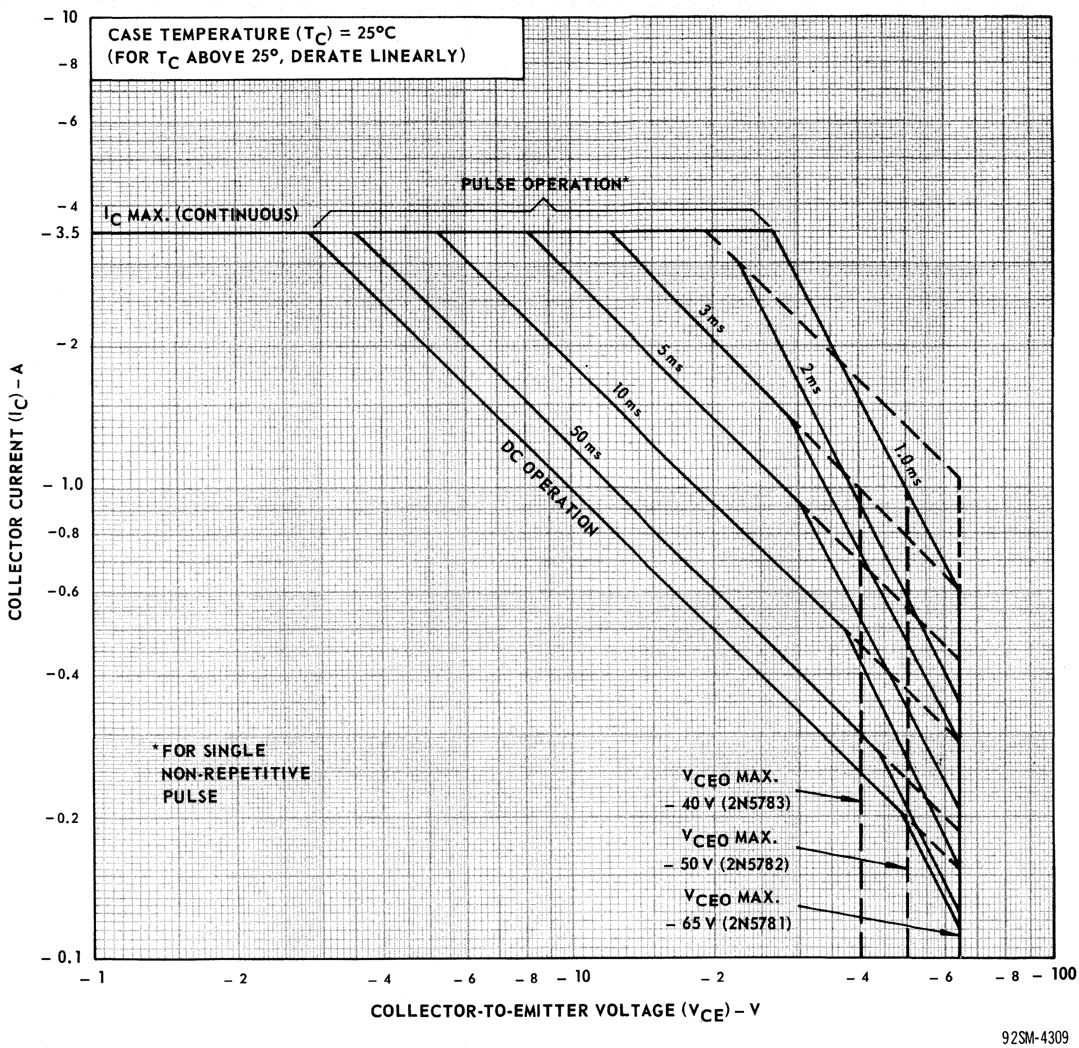


Fig. 2 - Maximum operating areas for types 2N5781, 2N5782, and 2N5783.

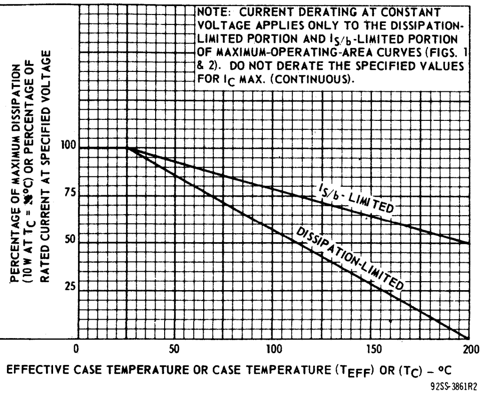
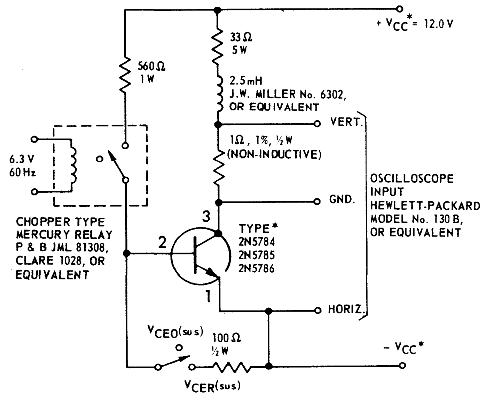
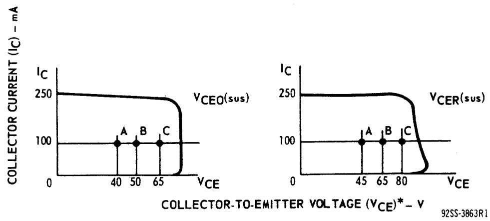


Fig. 3 - Dissipation derating curve for all types.



* FOR P-N-P TYPES 2N5781, 2N5782, & 2N5783, REVERSE POLARITY OF V_{CC}.

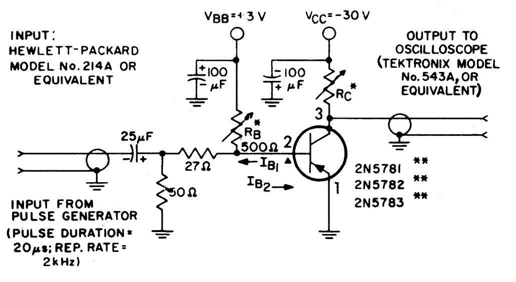
Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$.



*FOR TYPES 2N5781, 2N5782, AND 2N5783, THE VALUES FOR I_C AND V_{CE} ARE NEGATIVE.

The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ are acceptable when the trace falls to the right and above point "A" (2N5783 & 2N5786), "B" (2N5782 & 2N5785), or "C" (2N5781 & 2N5784).

Fig. 5 - Oscilloscope display for measurement of sustaining voltages. (Test circuit shown in Fig. 4.)



*ADJUST R_B FOR I_{B2} AND R_C FOR I_C

▲I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 AND TYPE 134 AMPLIFIER, OR EQUIVALENT

**For N-P-N types 2N5784, 2N5785, & 2N5786, reverse direction of I_{B1} and I_{B2} and reverse polarity of V_{BB} and V_{CC}.

92SS-1561R1

Fig. 6 - Circuit used to measure saturated switching times.

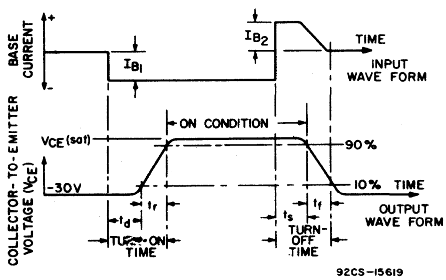


Fig. 7 - Oscilloscope display for measurement of switching times. (Test circuit shown in Fig. 6.)

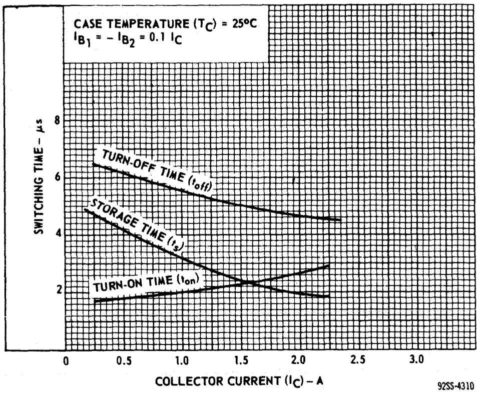


Fig. 8 - Typical saturated switching characteristics for types 2N5784, 2N5785, & 2N5786.

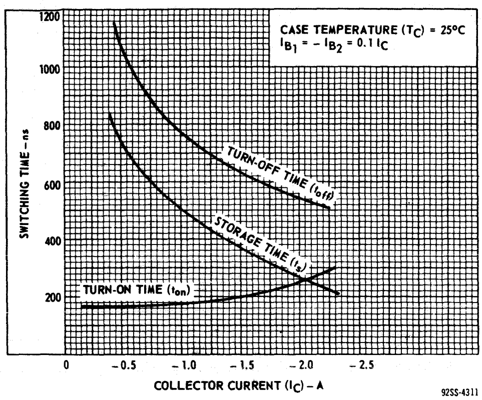


Fig. 9 - Typical saturated switching characteristics for types 2N5781, 2N5782, & 2N5783.

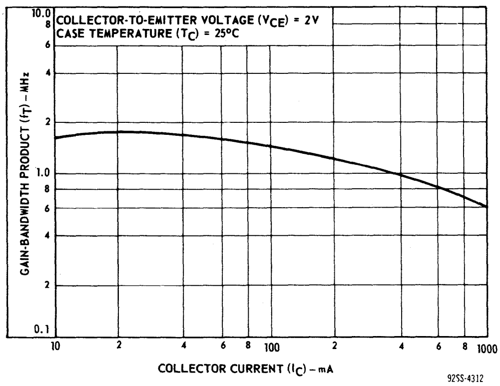


Fig. 10 - Typical gain-bandwidth product for types 2N5784, 2N5785, & 2N5786.

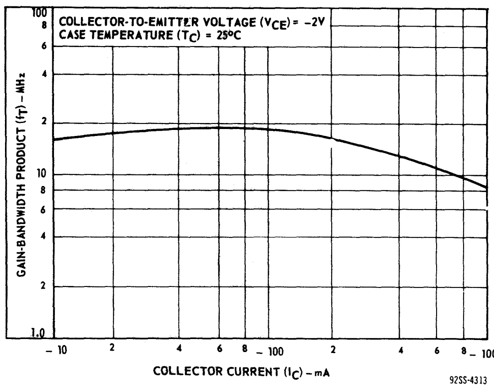


Fig. 11 - Typical gain-bandwidth product for types 2N5781, 2N5782, & 2N5783.

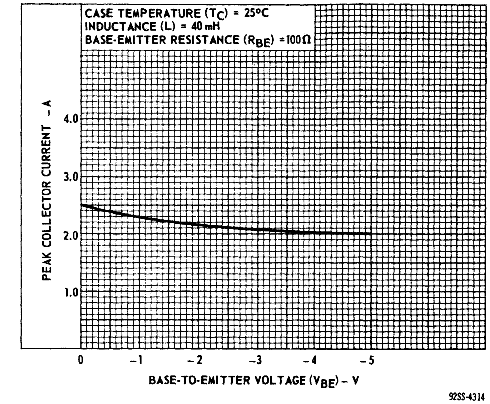


Fig. 12 - Reverse-bias second-breakdown characteristics for types 2N5784, 2N5785, & 2N5786.

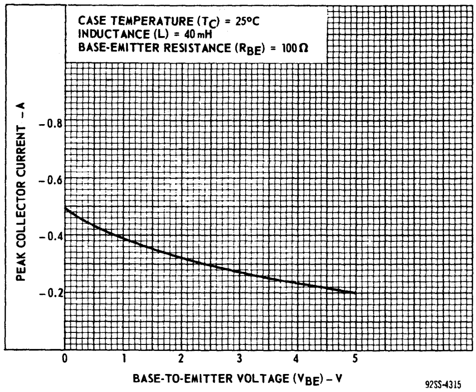


Fig. 13 - Reverse-bias second-breakdown characteristics for types 2N5781, 2N5782, & 2N5783.

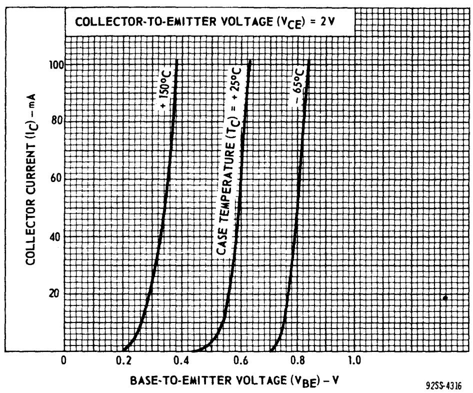


Fig. 14 - Typical transfer characteristics for types 2N5784, 2N5785, & 2N5786.

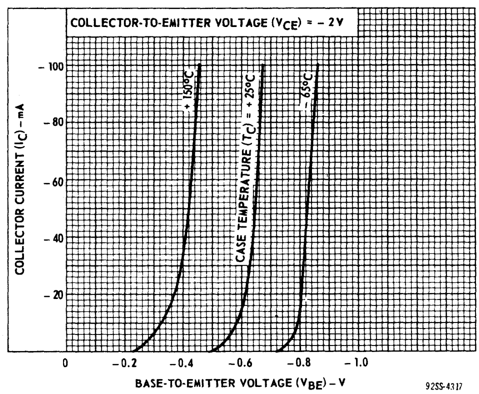


Fig. 15 - Typical transfer characteristics for types 2N5781, 2N5782, & 2N5783.

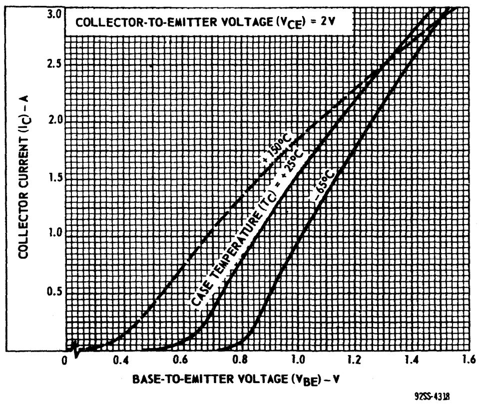


Fig. 16 - Typical transfer characteristics for types 2N5784, 2N5785, & 2N5786.

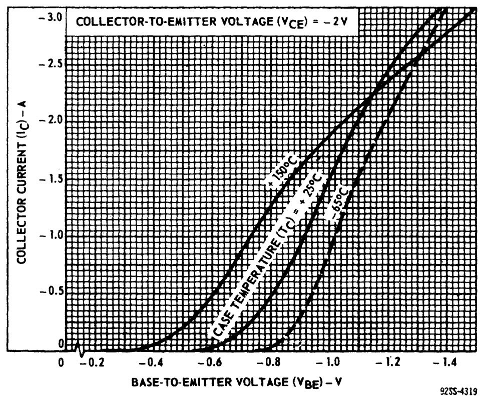


Fig. 17 - Typical transfer characteristics for types 2N5781, 2N5782, 2N5783.

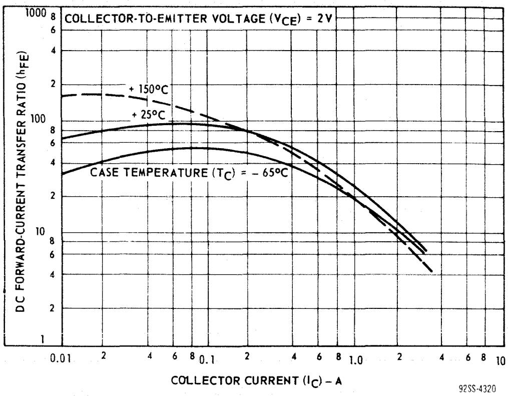


Fig. 18 - Typical DC-beta characteristics for type 2N5784.

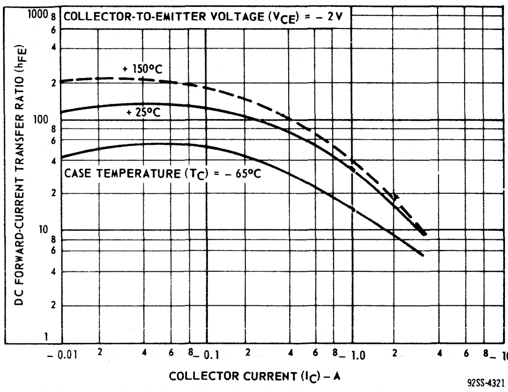


Fig. 19 - Typical DC-beta characteristics for type 2N5781.

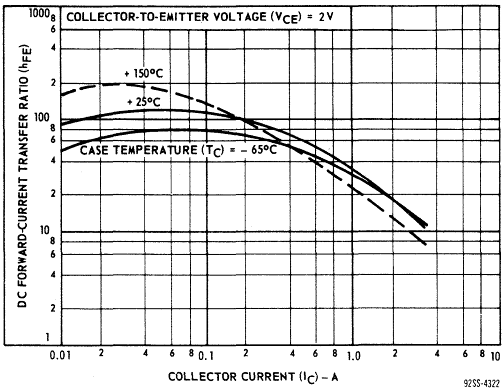


Fig. 20 - Typical DC-beta characteristics for type 2N5785.

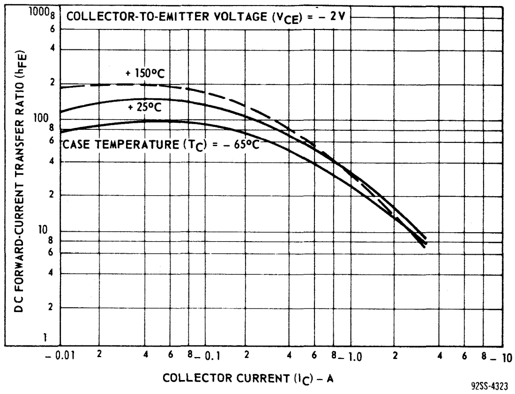


Fig. 21 - Typical DC-beta characteristics for type 2N5782.

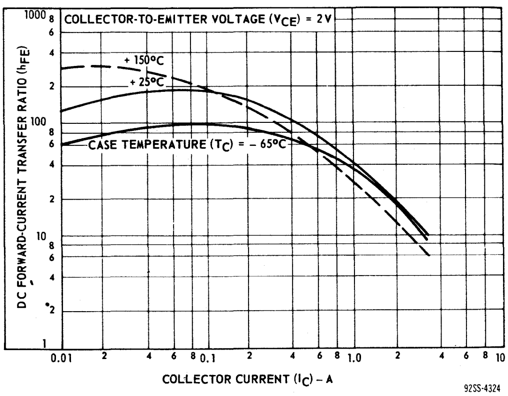


Fig. 22 - Typical DC-beta characteristics for type 2N5786.

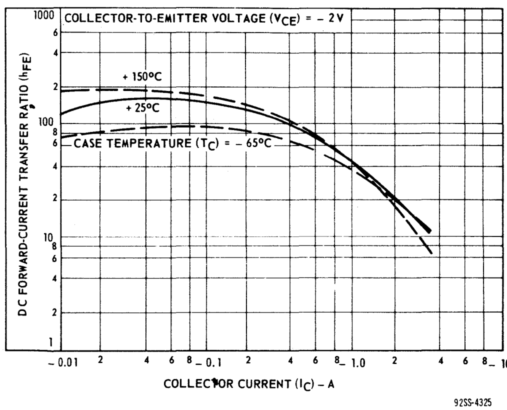


Fig. 23 - Typical DC-beta characteristics for type 2N5783.

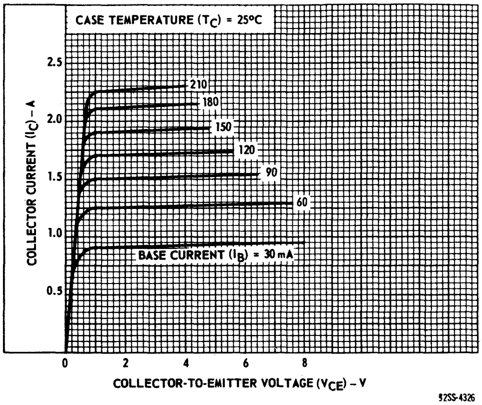


Fig. 24 - Typical output characteristics for type 2N5784.

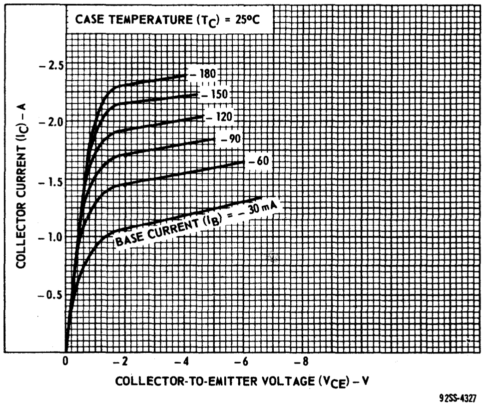


Fig. 25 - Typical output characteristics for type 2N5781.

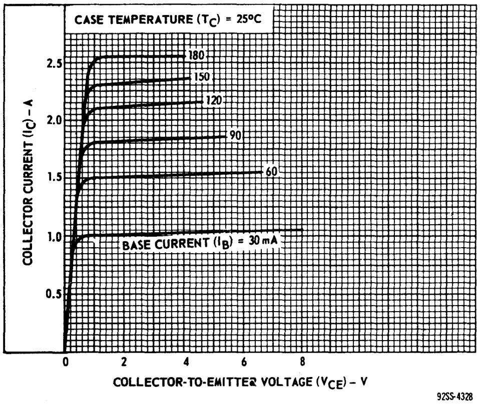


Fig. 26 - Typical output characteristics for type 2N5785.

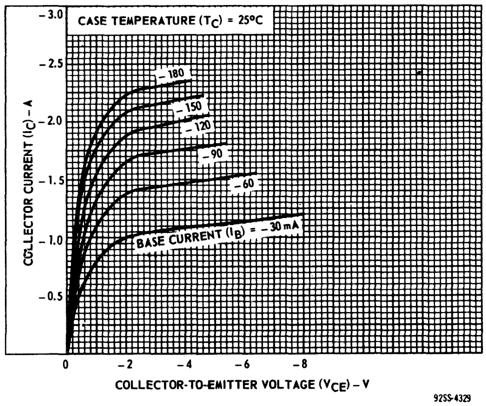


Fig. 27 - Typical output characteristics for type 2N5782.

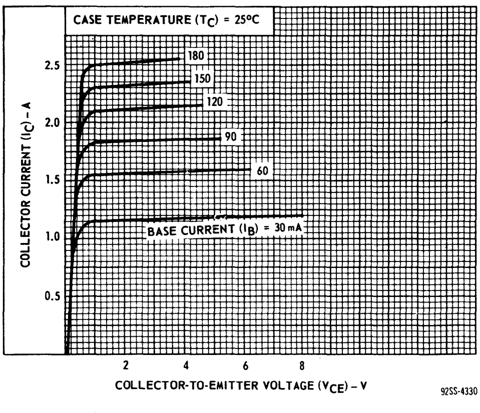


Fig. 28 - Typical output characteristics for type 2N5786.

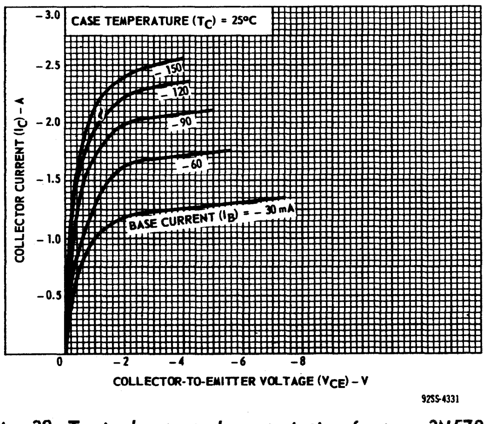


Fig. 29 - Typical output characteristics for type 2N5783.

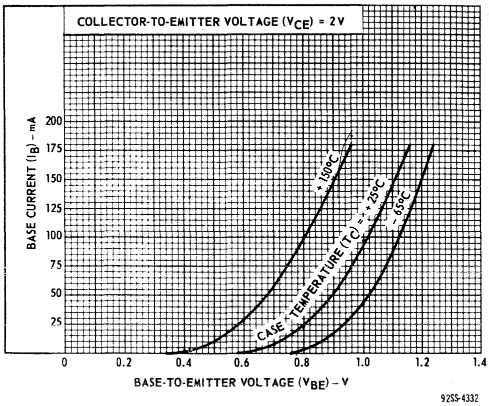


Fig. 30 - Typical input characteristics for type 2N5784.

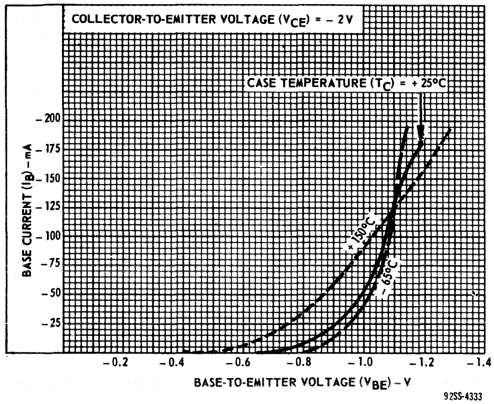


Fig. 31 - Typical input characteristics for type 2N5781.

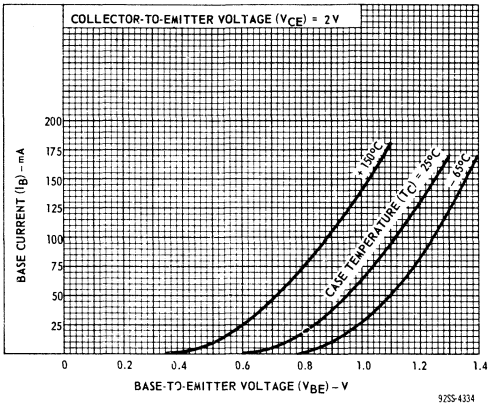


Fig. 32 - Typical input characteristics for type 2N5785.

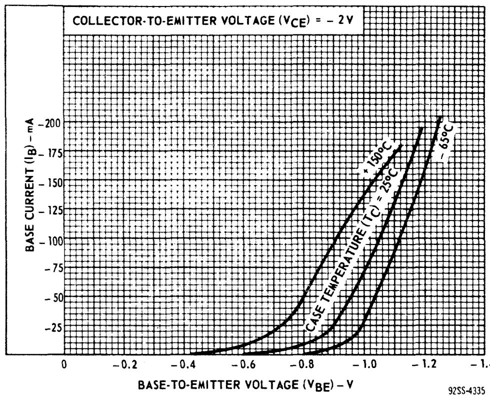


Fig. 33 - Typical input characteristics for type 2N5782.

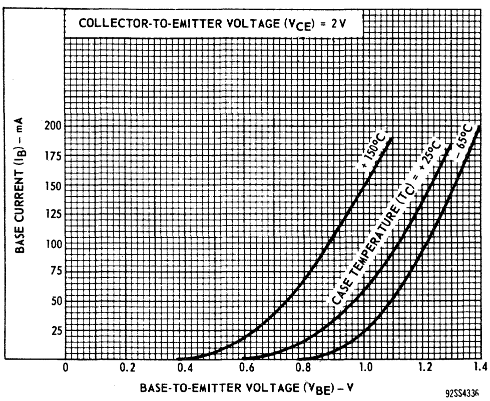


Fig. 34 - Typical input characteristics for type 2N5786.

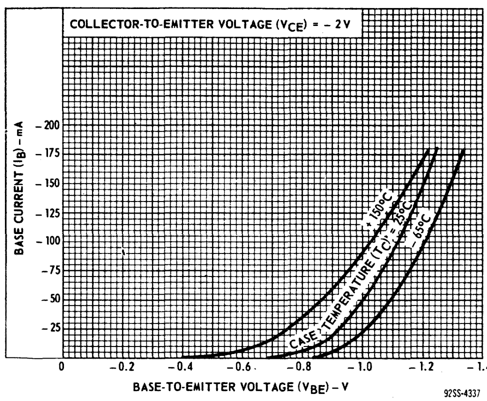
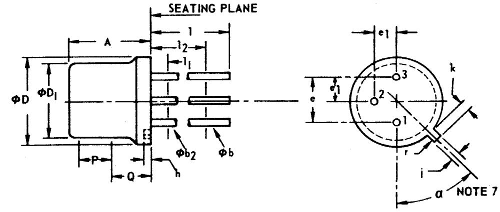


Fig. 35 - Typical input characteristics for type 2N5783.

DIMENSIONAL OUTLINE
(TO-5)



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
ϕb	.016	.021	.406	.533	2
ϕb_2	.016	.019	.406	.483	2
ϕD	.335	.370	8.51	9.40	
ϕD_1	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
i	.028	.034	.711	.864	5
k	.029	.045	.737	1.14	3,5
l	1.500		38.10		2
l_L		.050		1.27	2
l_2	.250		6.35		2
P	.100		2.54		1
Q					6
r		.007		.179	
α	45° T.P.				5,7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) ϕb_2 applies between l_1 and l_2. ϕb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS

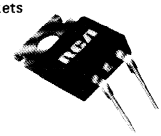
Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector
Case – Collector

RCA
Solid State
Division

Power Transistors

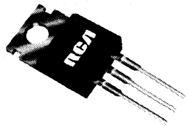
2N6098 2N6099
2N6100 2N6101
2N6102 2N6103

For TO-66 Sockets



2N6098
2N6100
2N6102

JEDEC TO-220AA H1534R1



2N6099
2N6101
2N6103

JEDEC TO-220AB H1535R1

High-Current, Silicon N-P-N VERSAWATT Transistors

Designed for Medium-Power Linear and Switching Service in Consumer, Automotive, and Industrial Applications

Features:

- **Low saturation voltage —**
  V_{CE}(sat) = 1 V max. at I_C = 4 A (2N6098, 2N6099)
  = 1 V max. at I_C = 5 A (2N6100, 2N6101)
  = 1 V max. at I_C = 8 A (2N6102, 2N6103)
- **VERSAWATT package (molded-silicone plastic)**
- **Maximum safe-area-of-operation curves**
- **Thermal-cycle rating curve**

These RCA types are hometaxial-base silicon n-p-n transistors. Types 2N6098, 2N6100, and 2N6102 have formed emitter and base leads for easy insertion into TO-66 sockets. Types 2N6099, 2N6101, and 2N6103 are electrically identical to the 2N6098, 2N6100, and 2N6102, respectively.

These new VERSAWATT-package transistors differ in voltage ratings and in the currents at which the parameters are controlled. They are intended for a wide variety of medium-power switching and linear applications, such as series and shunt regulators, solenoid drivers, motor-speed controls, inverters, and driver and output stages of high-fidelity amplifiers.

*Formerly RCA Dev. Nos. TA7381-86, inclusive.

OPTIONAL LEAD CONFIGURATION

An additional lead forming for printed-circuit board mounting is also available. (See page 8).
Please submit requirements to your RCA Technical Sales Representative, or write to RCA Linear Power Marketing, Somerville, N.J. 08876.

Maximum Ratings, *Absolute-Maximum Values:*

		2N6102 2N6103	2N6098 2N6099	2N6100 2N6101	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	45	70	80	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}(sus)	45	65	75	V
* With base open	V_{CEO}(sus)	40	60	70	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	8	8	V
*COLLECTOR CURRENT (Continuous)	I_C	16	10	10	A
*BASE CURRENT	I_B	4	4	4	A
TRANSISTOR DISSIPATION:	P_T				
* At case temperatures up to 25°C		75	75	75	W
At ambient temperatures up to 25°C		1.8	1.8	1.8	W
* At case temperatures above 25°C, derate linearly		←	0.6	→	W/°C
At ambient temperatures above 25°C, derate linearly		←	0.0144	→	W/°C
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		←	-65 to 150	→	°C
*LEAD TEMPERATURE (During Soldering):					
At distance ≥ 1/8 in. (3.17 mm) from case of 10 s max		←	235	→	°C

*In accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

	Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (V) V_{CE}	DC Emitter Voltage (V) V_{EB}	DC Current (A) I_C	DC Current (A) I_B	LIMITS 2N6102 2N6103 Min.	2N6102 2N6103 Max.	2N6098 2N6099 Min.	2N6098 2N6099 Max.	2N6100 2N6101 Min.	2N6100 2N6101 Max.	Units
*	Collector-Cutoff Current	I_{CEX}	40	1.5			-	2	-	-	-	-	mA
			65	1.5			-	-	-	2	-	-	
			75	1.5			-	-	-	-	-	2	
	With base-emitter junction reverse biased	I_{CEX} (T_C=150°C)	40	1.5			-	10	-	-	-	-	
			65	1.5			-	-	-	10	-	-	
			75	1.5			-	-	-	-	-	10	
	With base open	I_{CEO}	30			0	-	2	-	-	-	-	mA
			50			0	-	-	-	2	-	-	
			60			0	-	-	-	-	-	2	
*	Emitter-Cutoff Current	I_{EBO}		5			-	1	-	-	-	-	mA
				8			-	-	-	1	-	1	
	Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 100Ω [a]	V_{CER}(sus)			0.2		45	-	65	-	75	-	V
*	With base open [a]	V_{CEO}(sus)			0.2	0	40	-	60	-	70	-	V
*	DC Forward-Current Transfer Ratio [a]	h_{FE}	4		4		-	-	20	80	-	-	
			4		5		-	-	-	-	20	80	
			4		8		15	60	-	-	-	-	
			4		10		-	-	5	-	5	-	
			4		16		5	-	-	-	-	-	
*	Base-to-Emitter Voltage [a]	V_{BE}	4		4		-	-	-	1.7	-	-	V
			4		5		-	-	-	-	-	1.7	
			4		8		-	1.7	-	-	-	-	
*	Collector-to-Emitter Saturation Voltage [a]	V_{CE}(sat)			10	2	-	-	-	2.5	-	2.5	V
					16	3.2	-	2.5	-	-	-	-	
*	Common-Emitter, small-signal short-circuit, forward current transfer ratio	h_{fe}	4	f=1kHz	0.5		15	-	15	-	15	-	
*	Magnitude of common-emitter, small-signal, short circuit, forward current transfer ratio	$\|h_{fe}\|$	4	f=0.1MHz	0.5		8	28	8	28	8	28	
	Thermal Resistance: Junction-to-Case	θ_{J-C}					-	1.67	-		-	1.67	°C/W
	Junction-to-Ambient	θ_{J-A}					-	70	-		-	70	

*In accordance with JEDEC registration data format (JS-6, RDF-2)

[a] Pulsed, pulse duration = 300 μs, duty factor = 0.018

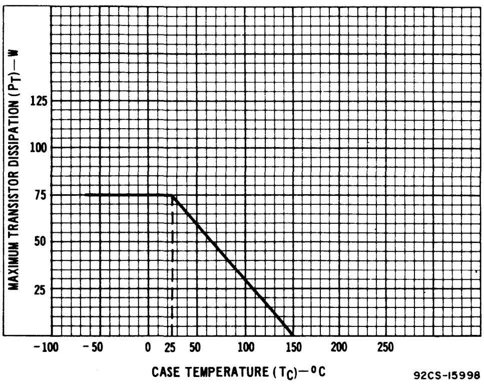


Fig.1—Derating curve for all types.

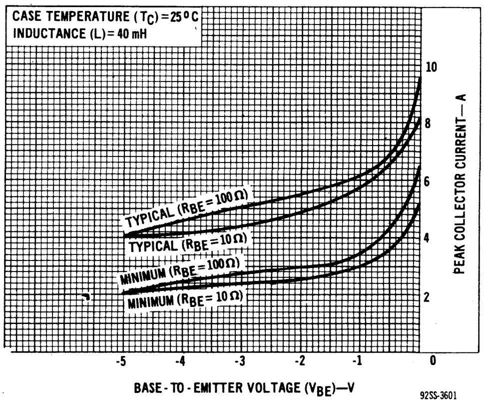


Fig.2—Reverse-bias, second-breakdown characteristics for all types.

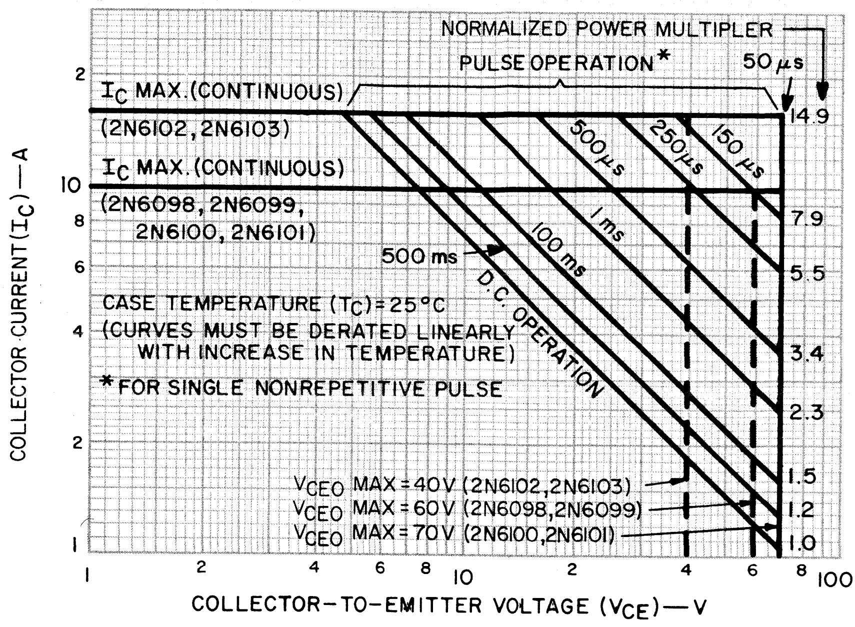


Fig.3—Maximum safe operating areas for all types.

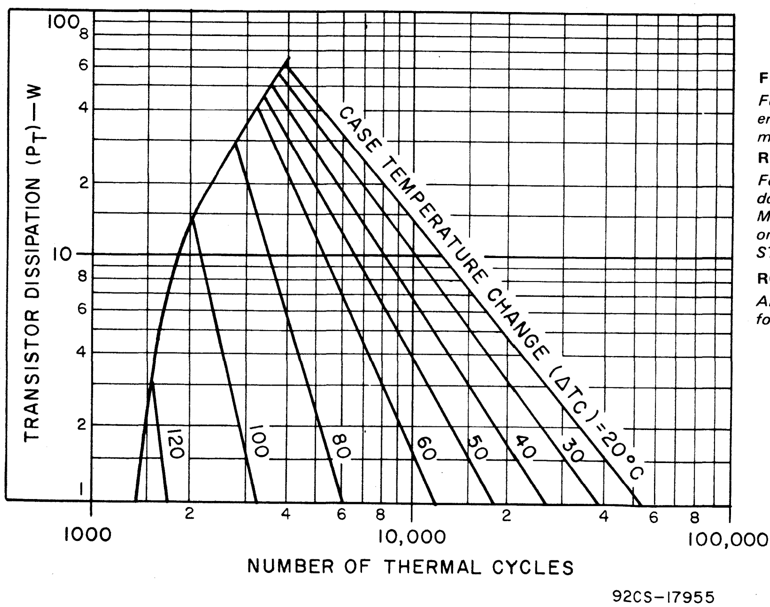


Fig.4—Thermal-cycling rating for all types.

FORWARD-BIAS OPERATION . . . . .

For complete discussion of maximum operating area, refer to "RCA Power Circuits" manual, Technical Series SP-51.

REVERSE-BIAS OPERATION . . . . .

For complete discussion of second breakdown, refer to "RCA Power Circuits" Manual, Technical Series SP-51 or "Second-breakdown" reprint, Publication No. ST3419.

RCA APPLICATION NOTE . . . . .

AN-4612 "Thermal-Cycling Rating System for Silicon Power Transistors".

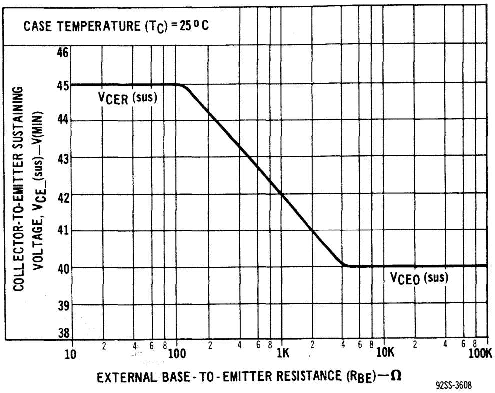


Fig.5—Sustaining voltage vs. base-to-emitter resistance for types 2N6102 & 2N6103.

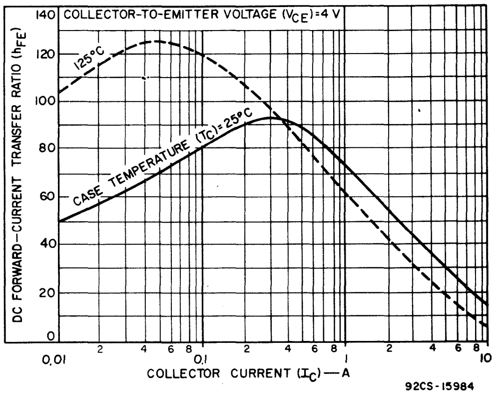


Fig.6—Typical dc beta characteristics for types 2N6102 & 2N6103.

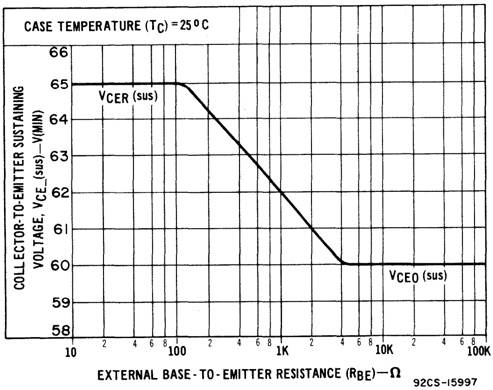


Fig.7—Sustaining voltage vs. base-to-emitter resistance for types 2N6098 & 2N6099.

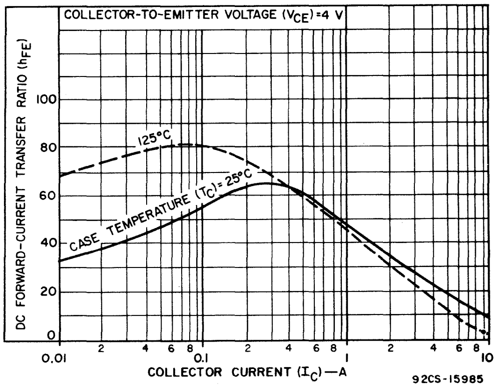


Fig.8—Typical dc-beta characteristics for types 2N6098 & 2N6099.

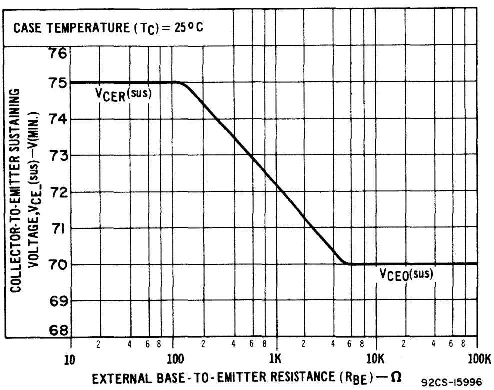


Fig.9—Sustaining voltage vs. base-to-emitter resistance for types 2N6100 & 2N6101.

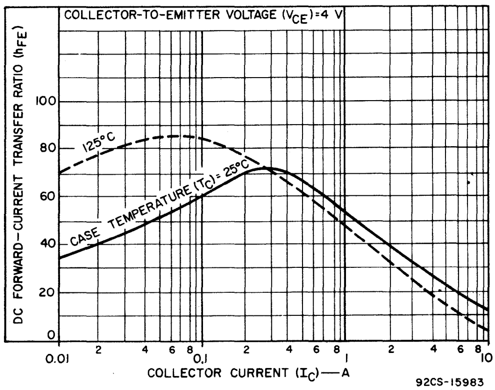


Fig.10—Typical dc beta characteristics for types 2N6100 & 6101.

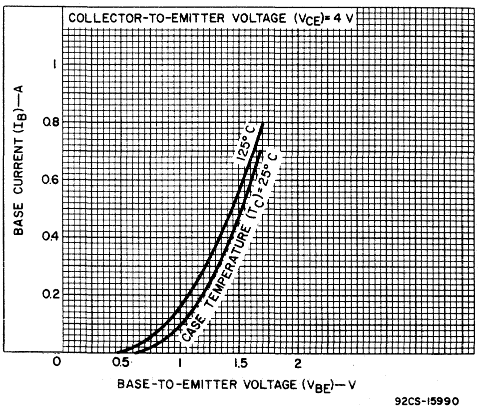


Fig. 11—Typical input characteristics for types 2N6102 & 2N6103.

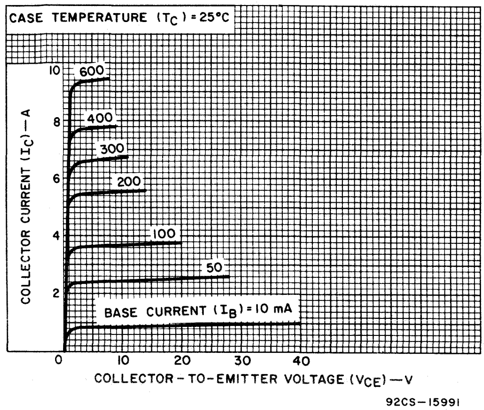


Fig. 12—Typical output characteristics for types 2N6102 & 2N6103.

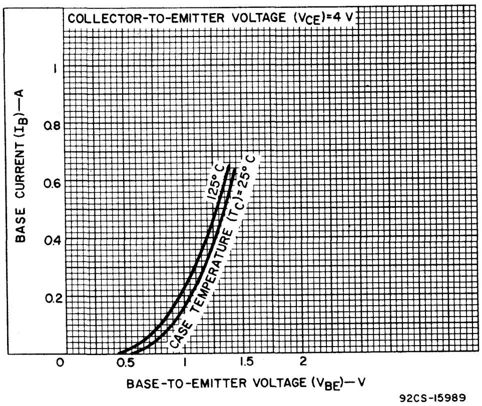


Fig. 13—Typical input characteristics for types 2N6098 & 2N6099.

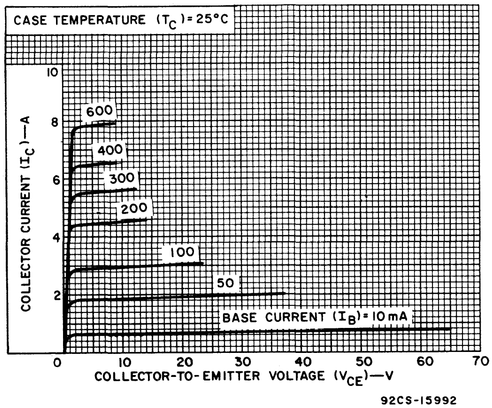


Fig. 14—Typical output characteristics for types 2N6098 & 2N6099.

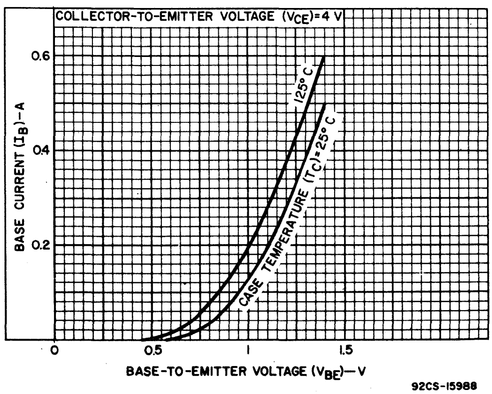


Fig. 15—Typical input characteristics for types 2N6100 & 2N6101.

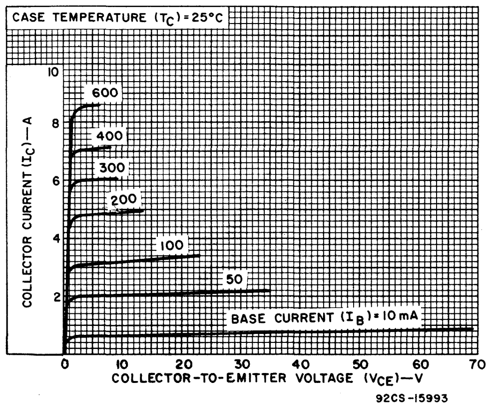


Fig. 16—Typical output characteristics for types 2N6100 & 2N6101.

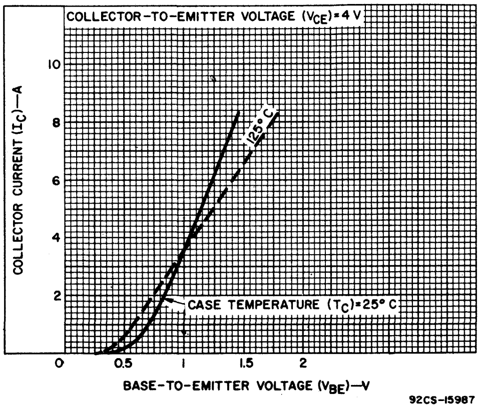


Fig. 17—Typical transfer characteristics for all types.

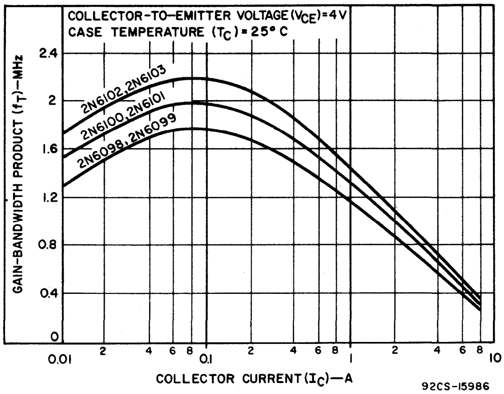


Fig. 18—Typical gain-bandwidth product for all types.

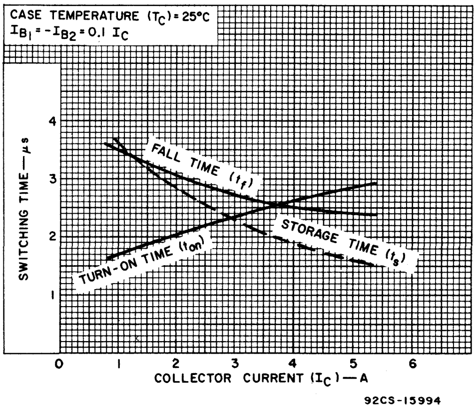
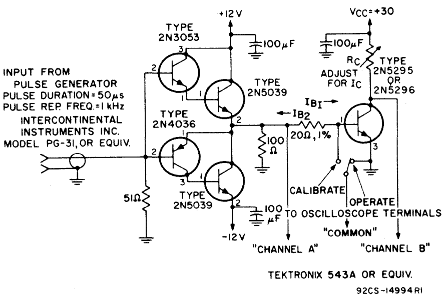


Fig. 19—Typical saturated switching characteristics for all types.



NOTE: Collector-terminal connection for transistor under test is mounting-flange (2N6098, 2N6100, 2N6102), lead No. 3 (2N6099, 2N6101, 2N6103).

Fig. 20—Circuit used to measure switching times for all types.

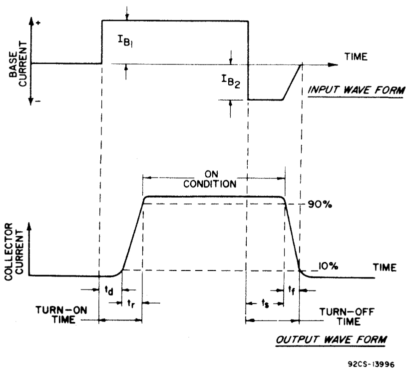
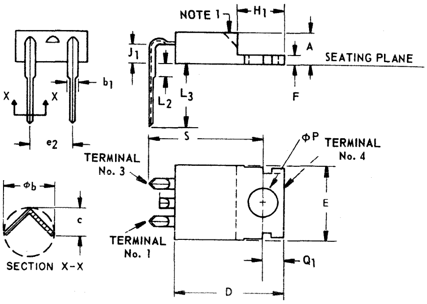


Fig. 21—Phase relationship between input current and output current showing reference points for specification of switching times. (Test circuit shown in Fig. 20).

DIMENSIONAL OUTLINE FOR TYPES 2N6098, 2N6100, 2N6102

JEDEC TO-220AA



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.140	0.190	3.56	4.82	
φb	0.020	0.045	0.51	1.14	
b_1	0.045	0.070	1.15	1.77	
c	0.015	0.030	0.38	0.762	
D	0.560	0.625	14.23	15.87	
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	
L_2	–	0.050	–	1.27	
L_3	0.360	0.422	9.15	10.71	
φP	0.139	0.147	3.531	3.733	
Q	0.100	0.120	2.54	3.04	
S	0.580	0.610	14.74	15.49	

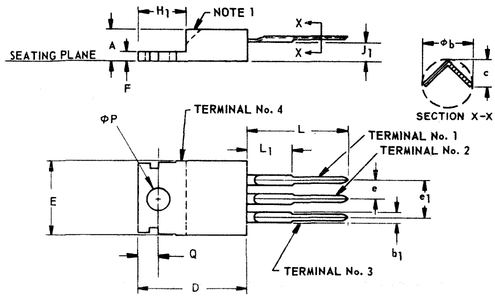
92CS-17990

NOTES:

1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured 0.050–0.050 (1.27–1.40 mm) below seating plane.**

DIMENSIONAL OUTLINE FOR TYPES 2N6099, 2N6101, 2N6103

JEDEC TO-220AB



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.140	0.190	3.56	4.82	
φb	0.020	0.045	0.51	1.14	
b_1	0.045	0.070	1.15	1.77	
c	0.015	0.030	0.38	0.762	
D	0.560	0.625	14.23	15.87	
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	
L	0.500	0.562	12.70	14.27	
L_1	–	0.250	–	6.35	
φP	0.139	0.147	3.531	3.733	
Q	0.100	0.120	2.54	3.04	

92CS-17991

NOTES:

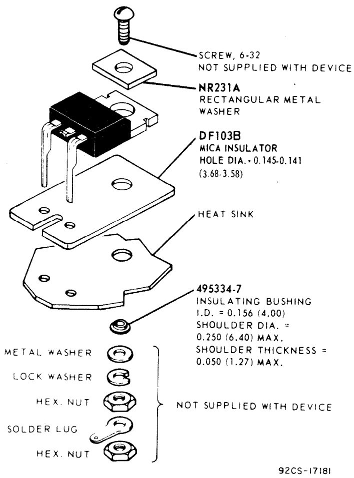
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured 0.250–0.255 (6.35–6.48 mm) from bottom of dimension D.**

TERMINAL CONNECTIONS FOR TYPES 2N6098, 2N6100, 2N6102

Terminal No. 1-Base
Terminal No. 3-Emitter
Terminal No. 4-Collector

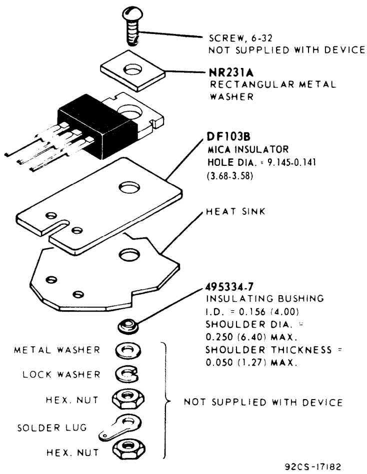
TERMINAL CONNECTIONS FOR TYPES 2N6099, 2N6101, 2N6103

Terminal No. 1-Base
Terminal No. 2-Collector
Terminal No. 3-Emitter
Terminal No. 4-Collector



Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig.22—Suggested mounting hardware for types 2N6098, 2N6100 & 2N6102.



Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig.23—Suggested mounting hardware for types 2N6099, 2N6101 & 2N6103.

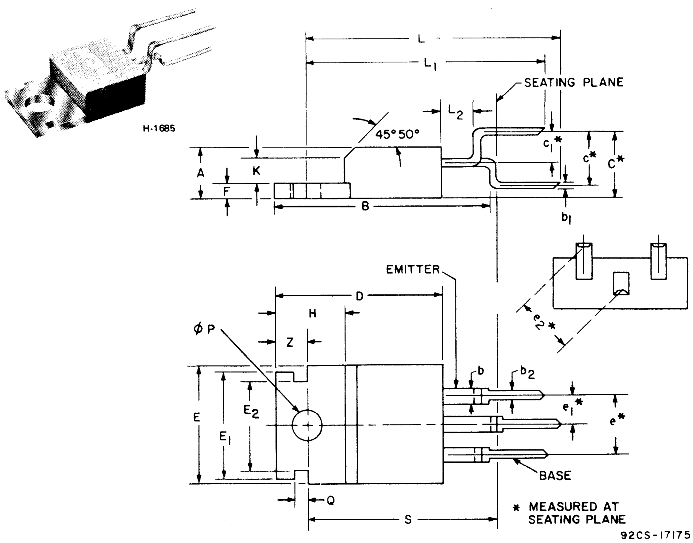


Fig.24—Dimensional outline of VERSAWATT transistor package designed for mounting on printed-circuit boards.

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.140	0.190	3.56	4.82
B	–	0.850	–	21.59
b	0.045	0.070	1.15	1.17
b_1	0.015	0.030	0.382	0.762
b_2	0.020	0.038	0.508	0.965
C	0.230	0.270	5.85	6.85
c	0.180	0.220	4.58	5.58
c_1	0.130	0.170	3.31	4.31
D	0.560	0.625	14.23	15.87
E	0.330	0.420	8.39	10.41
E_1	0.365	0.385	9.28	9.77
E_2	0.300	0.320	7.62	8.12
e	0.190	0.210	4.83	5.33
e_1	0.090	0.110	2.29	2.79

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
e_2	0.203	0.243	5.16	6.17
F	0.045	0.055	1.15	1.39
H	0.230	0.270	5.85	6.85
K	0.080	0.085	2.032	2.159
L	0.993	1.033	25.22	26.23
L_1	0.895	0.935	22.73	23.74
L_2	0.070	0.090	1.78	2.28
φP	0.139	0.147	3.531	3.734
Q	0.040	0.060	1.02	1.52
S	0.655	0.685	16.64	17.39
Z	0.100	0.120	2.54	3.04

Solid State
Division

Power Transistors

2N6371

JEDEC TO-3

H-1570

Hometaxial II* High-Power Silicon N-P-N Transistors

Rugged General-Purpose Device
For Industrial and Commercial Uses

Features:

- **Maximum-safe-area-of-operation curves**
- **Low saturation voltage**
- **High dissipation rating**
- **Thermal-cycle rating curve**

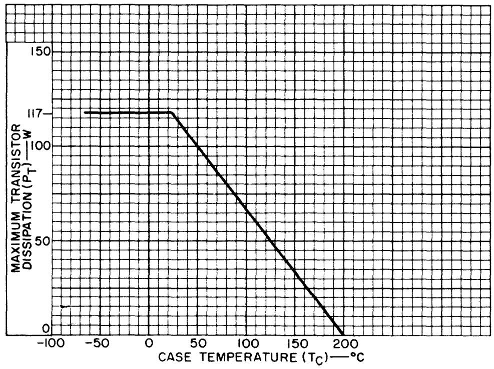
Applications:

- **Series and shunt regulators**
- **High-fidelity amplifiers**
- **Power-switching circuits**
- **Solenoid drivers**
- **12-V audio and inverter circuits**

The RCA-2N6371▲ is a hometaxial-base● diffused-junction silicon n-p-n transistor intended for a wide variety of intermediate-power and high-power applications. It is especially suited for use in audio and inverter circuits at 12 volts.

▲RCA-2N6371 is the direct replacement for RCA-40251.

●"Hometaxial" was coined by RCA from "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous-resistivity silicon in the axial direction (emitter-to-collector). "Hometaxial II" is a term used to describe RCA's expanded line of transistors produced by the hometaxial process.



92CS-13031R1

Fig. 1—Dissipation derating curve.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
* With external base-to-emitter resistance R_{BE} = 100 Ω	$V_{CER}(sus)$	45	V
* With base open	$V_{CEO}(sus)$	40	V
With base reverse bias V_{BE} = −1.5 V	$V_{CEX}(sus)$	50	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	16	A
*CONTINUOUS BASE CURRENT	I_B	7	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		117	W
At case temperatures above 25°C		See Fig. 1	
*TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to +200	°C
*PIN TEMPERATURE (During Soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		235	°C

*In accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS		UNITS
		VOLTAGE V dc			CURRENT A dc				
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	
* Collector Cutoff Current: With base open	I_{CEO}	25				0	–	1.5	mA
With base-emitter junction reverse-biased	I_{CEV}	45		−1.5			–	2	mA
At T_C = 150°C		40		−1.5			–	10	mA
* Emitter Cutoff Current	I_{EBO}		5				–	10	mA
Collector-to-Emitter Sustaining Voltage: * With base open	$V_{CEO}(sus)$				0.2	0	40	–	V
* With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				0.2		45	–	V
With base-emitter junction reverse-biased	$V_{CEX}(sus)$			−1.5	0.1		50	–	V
* DC Forward Current Transfer Ratio	h_{FE}	4			8[a]		15	60	
		4			16[a]		4	–	
* Base-to-Emitter Voltage	V_{BE}	4			16[a]		–	4	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				16[a]	4	–	4	V
					8[a]	0.8	–	1.5	V
* Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	4			1		10	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 0.4 MHz)	$\|h_{fe}\|$	4			1		2	–	
Gain-Bandwidth Product	f_T				1		800	–	kHz
Forward-Bias Second Breakdown Collector Current	$I_{S/b}$	40					2.9	–	A
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	1.5	°C/W

[a] Pulsed: Pulse duration = 300 μs, duty factor = 2%.
* In accordance with JEDEC registration data format JS-6 RDF-2.

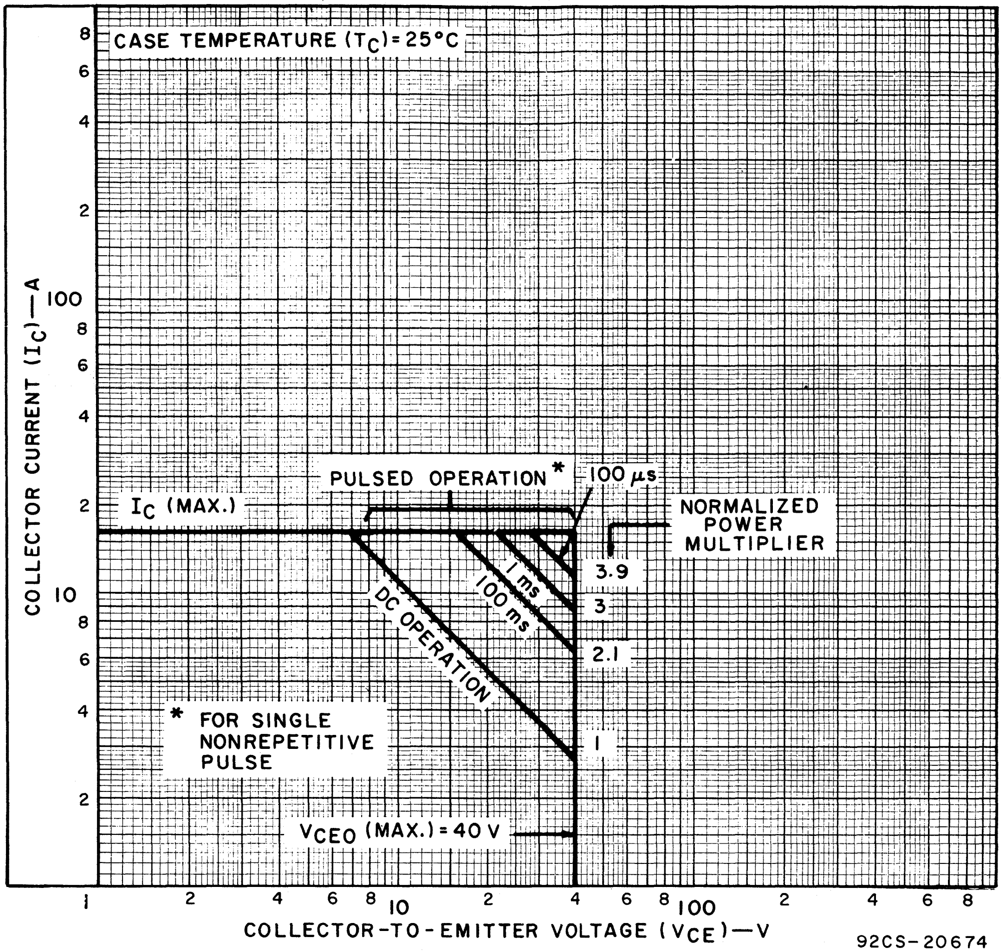


Fig. 2—Maximum safe area of operation at case temperature of 25°C.

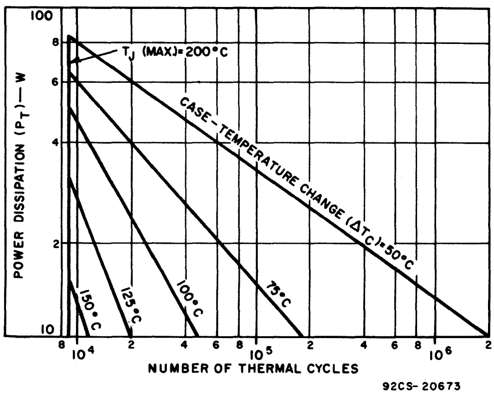


Fig. 3—Thermal-cycle rating chart.

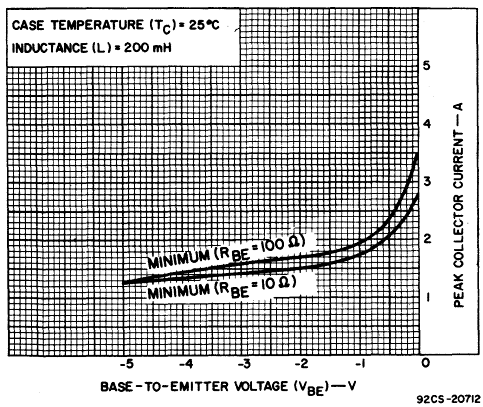


Fig. 4—Reverse-bias second-breakdown characteristics.

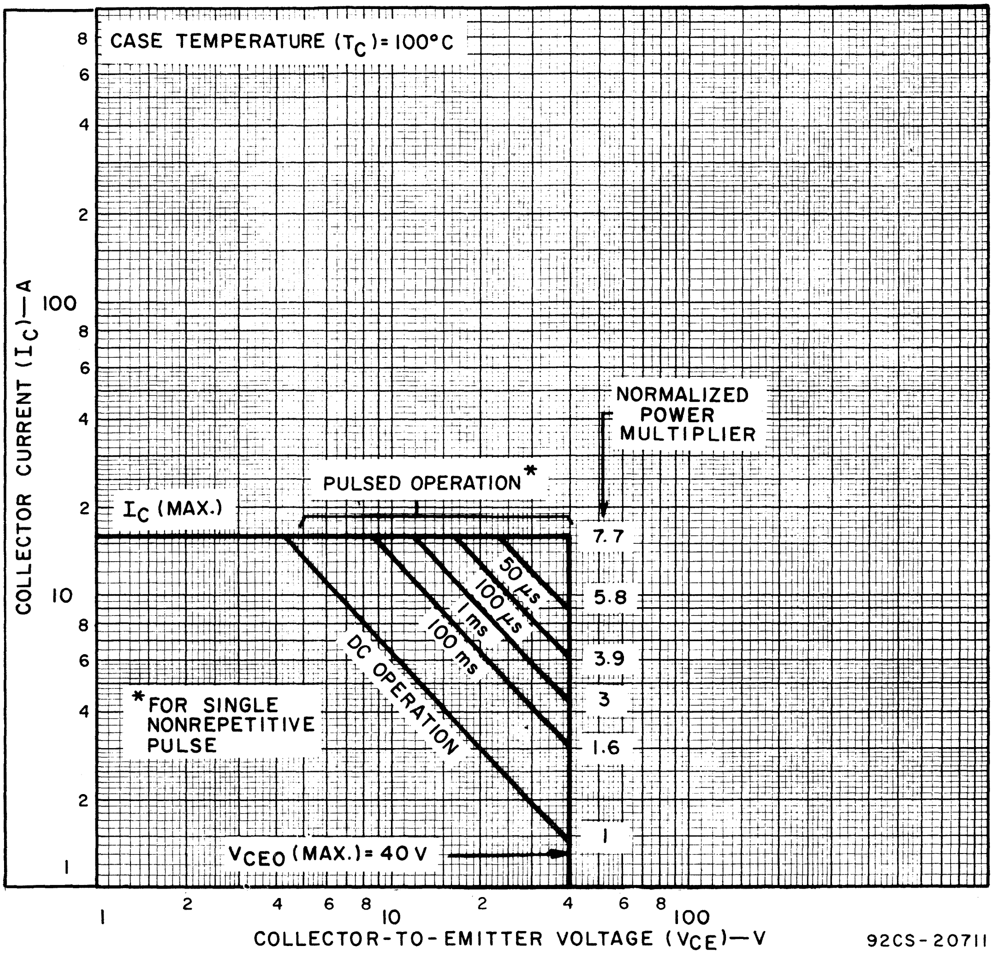


Fig. 5—Maximum safe area of operation at case temperature of 100°C.

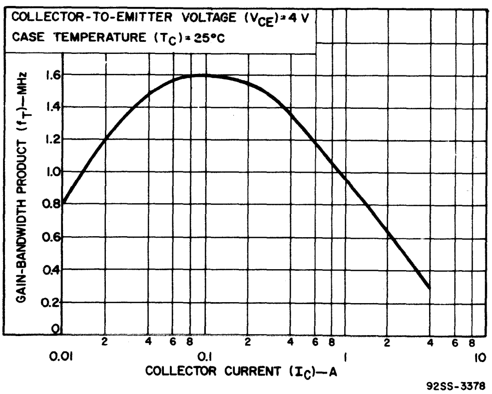


Fig. 6—Typical gain-bandwidth product.

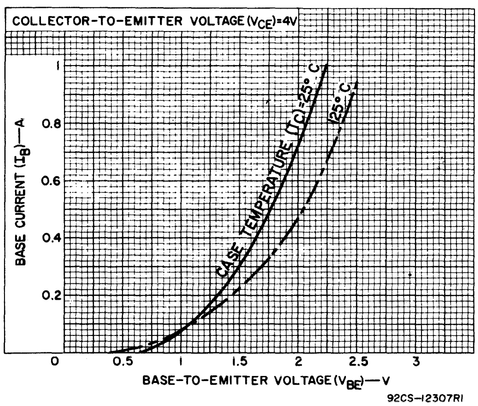


Fig. 7—Typical input characteristics.

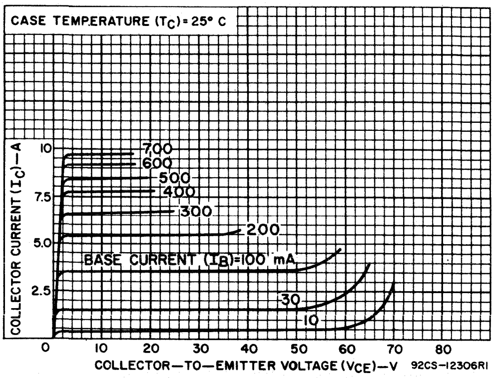


Fig. 8—Typical output characteristics.

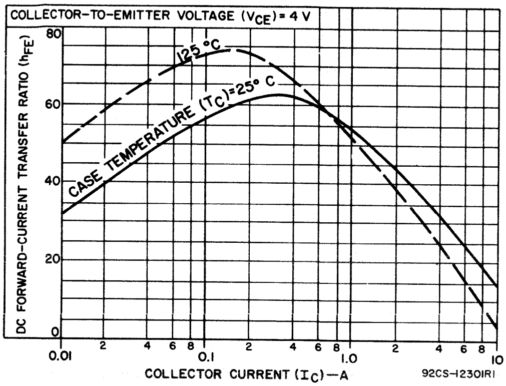
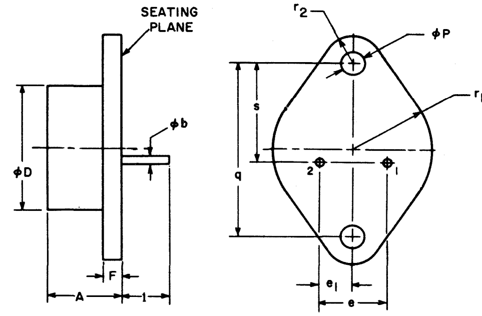


Fig. 9—Typical dc beta characteristics.

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

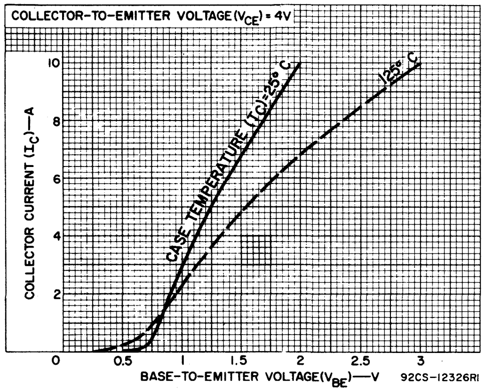


Fig. 10—Typical transfer characteristics.

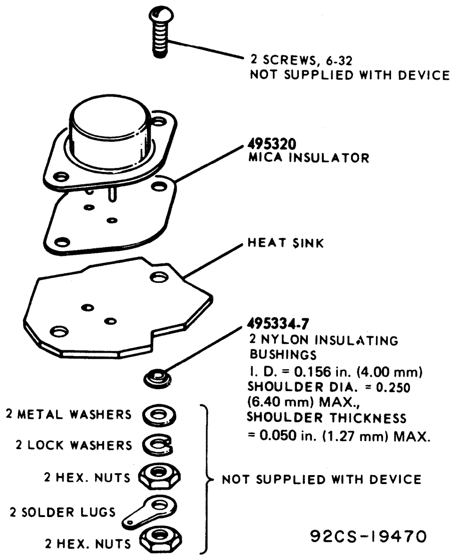


Fig. 11—Suggested mounting hardware.

For basic transistor theory, circuits, and application information, refer to "RCA Solid State Power Circuits Designer's Handbook", SP-52, or "RCA Transistor, Thyristor, & Diode Manual", SC-15.

RCA
Solid State Division

Power Transistors
40250
40250V1
40251

RCA-40250, 40250V1, and 40251 are "HOMETAXIAL"-BASE** diffused-junction, silicon n-p-n transistors intended for a wide variety of intermediate- and high-power applications. These transistors are especially suitable for use in audio and inverter circuits in 12-volt mobile radio and portable communications equipment.

Type 40250V1, with an attached heat radiator, is intended for those applications which require a rugged transistor for mounting on a printed-circuit board. Tabs are provided on the underside of the radiator for mounting purposes and for making electrical connection to the collector (which is connected internally to the mounting flange of the TO-66 Package).

- **Designed to assure freedom from second breakdown in class-A operation at maximum ratings**

40250
- **JEDEC TO-66 package for mounting convenience and positive heat-sink contact**
- **V_{CEV} = 50 V min.**
- **f_T = 1.0 Mc/s typ.**
- **R(sat) = 1 Ω max.**

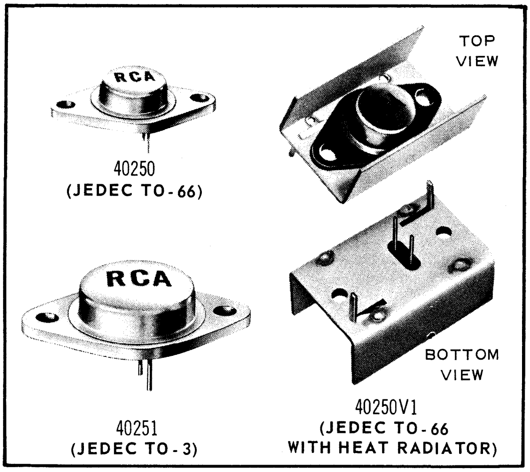
40250V1
- **Heat-radiator package with mounting tabs for printed-circuit-board application**
- **5.8-W dissipation capability (at 25°C free-air temperature)**
- **V_{CEV} = 50 V min.**
- **f_T = 1.0 Mc/s typ.**
- **R(sat) = 1 Ω max.**

40251
- **High-dissipation capability — 117 W max.**
- **V_{CEV} = 50 V min.**
- **R(sat) = 0.1875 Ω max.**
- **f_T = 0.5 Mc/s typ.**

General-Purpose Types for Industrial and Commercial Applications

* The "V1" suffix in the type number "40250V1" designates the first variant of the basic type 40250. The V1-version is a type 40250 transistor with an attached heat radiator for free-air operation.

** "Hometaxial" was coined by RCA from "homogeneous" and "axial". Hometaxial types employ a structure in which the base region has homogeneous resistivity silicon material in the axial direction (emitter-to-collector). These devices are made by using the single-diffused process.



MAXIMUM RATINGS

Absolute-Maximum Values:

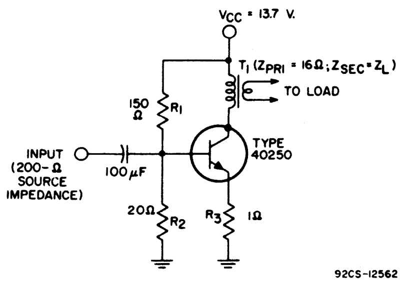
	40250	*40250V1*	*40251*	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	50	50	50	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With 1.5 volts of reverse bias, V_{CEV}	50	50	50	V
With base open, V_{CEO}	40	40	40	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	5	5	V
COLLECTOR CURRENT, I_C	4	4	15	A
BASE CURRENT, I_B	2	2	7	A
TRANSISTOR DISSIPATION, P_T:				
At case temperatures up to 25°C	29	–	117	W
At free-air temperatures up to 25°C	–	5.8	–	W
At temperatures above 25°C	See Fig.3	See Fig.4	See Fig.5	
TEMPERATURE RANGE:				
Storage & Operating (Junction)	←	-65 to 200	→	°C
PIN TEMPERATURE (During soldering):				
At distances ≥ 1/32 in. from seating plane for 10 s max	←	235	→	°C

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) of 25°C Unless Otherwise Specified

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Emitter or Base Volts V_{EB}	DC Emitter or Base Volts V_{BE}	DC Current (Amperes) I_C	DC Current (Amperes) I_E	DC Current (Amperes) I_B	LIMITS: Types 40250 40250V1 Min.	Types 40250 40250V1 Max.	Type 40251 Min.	Type 40251 Max.	Units
Collector-Cutoff Current	I_{CBO}	30					0		-	1	-	-	mA
	I_{CEV}		40		-1.5				-	-	-	2	mA
At T_C = 150° C	I_{CBO}	30					0		-	5	-	-	mA
	I_{CEV}		40		-1.5				-	-	-	10	mA
Emitter-Cutoff Current	I_{EBO}			5		0			-	5	-	10	mA
DC Forward-Current Transfer Ratio	h_{FE}		4• 4			1.5 8			25 -	100 -	- 15	- 60	
Collector-to-Base Breakdown Voltage	BV_{CBO}					0.05 0.1			50 -	- -	- 50	- -	V
Collector-to-Emitter Breakdown Voltage	BV_{CEV}				-1.5 -1.5	0.05 0.1			50 -	- -	- 50	- -	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$					0.1 0.2			40 -	- -	- 40	- -	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0 0	0.005 0.01		5 -	- -	- 5	- -	V
Base-to-Emitter Voltage	V_{BE}		4 4			1.5 8			- -	2.2 -	- -	- 2.2	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					1.5 8		0.15 0.8	- -	1.5 -	- -	- 1.5	V
Power Rating Test	PRT		39			3			-	-	-	1	s
Thermal Resistance: Junction-to-Case	θ_{J-C}								6.0 (max.) 40250		-	1.5	°C/W
Junction-to-Free-Air	θ_{J-FA}								30 (max.) 40250V1		-	-	°C/W

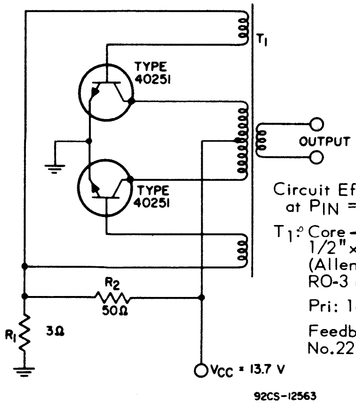
TYPICAL AUDIO-AMPLIFIER CIRCUIT FOR TYPE 40250



Distortion = 6.5% at P_{OUT} = 4 W
= 2% at P_{OUT} = 400 mW, f = 1 kc/s

Fig.1

TYPICAL INVERTER CIRCUIT EMPLOYING A PAIR OF TYPE 40251's



Circuit Efficiency = 82%
at P_{IN} = 110 W, f = 3.5 kc/s

T_1: Core – toroid, 3" o.d., 1/2" x 1" cross-section (Allen-Bradley T3000H 106B), RO-3 material or equivalent.
Pri: 16 turns, No.20 wire, c.t.
Feedback Winding: 8 turns, No.22 wire, c.t.

Fig.2

DISSIPATION DERATING CURVE
FOR TYPE 40250

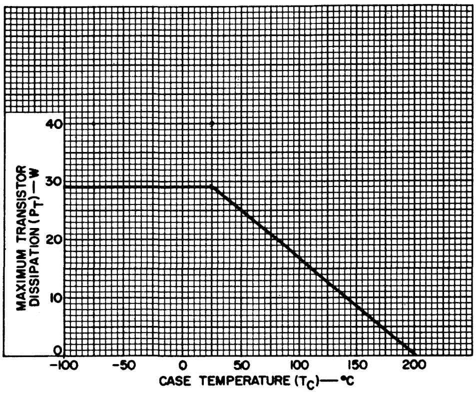


Fig.3 92CS-13005RI

TYPICAL OPERATION CHARACTERISTICS
FOR TYPES 40250 & 40250V1

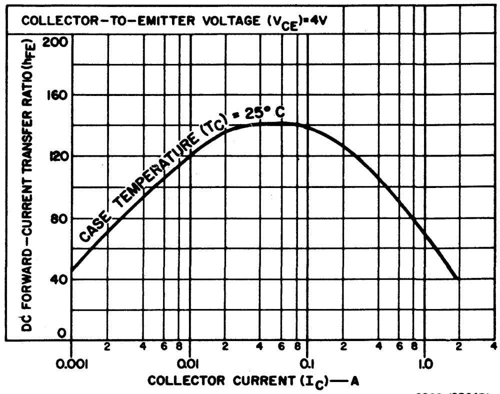


Fig.6 92CS-12564RI

DISSIPATION DERATING CURVE
FOR TYPE 40250V1

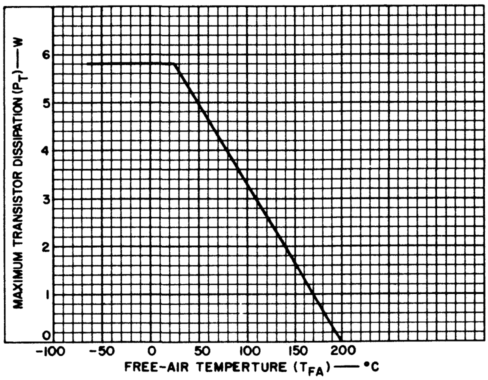


Fig.4 92CS-13373

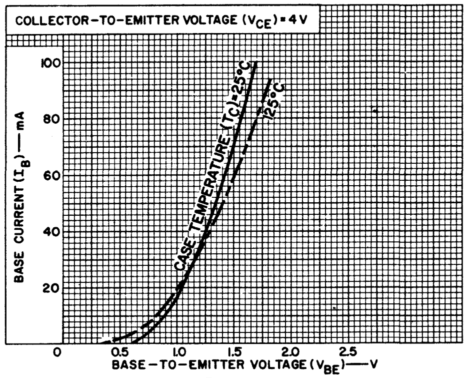


Fig.7 92CS-12305RI

DISSIPATION DERATING CURVE
FOR TYPE 40251

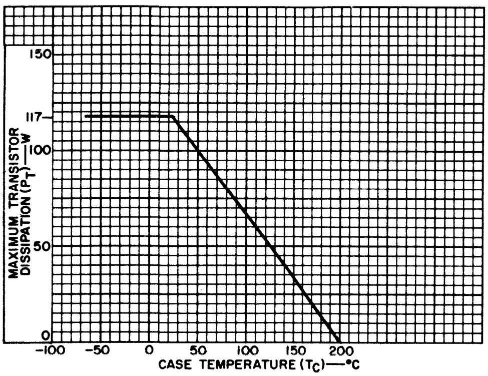


Fig.5 92CS-13031RI

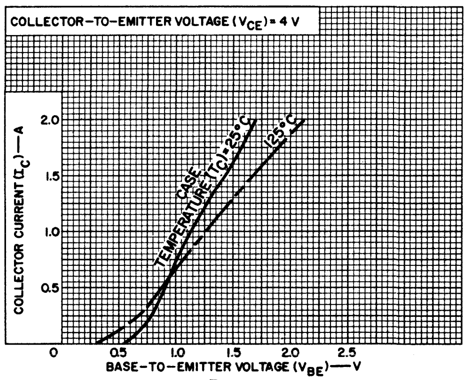


Fig.8 92CS-12325RI

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 40251

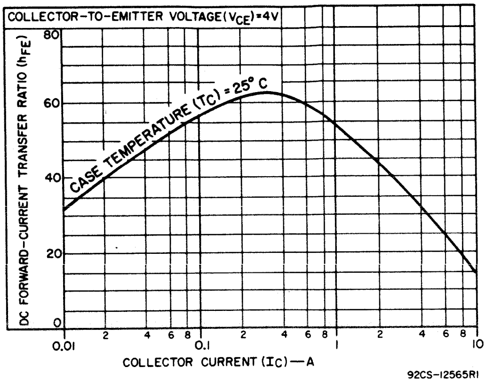


Fig.9

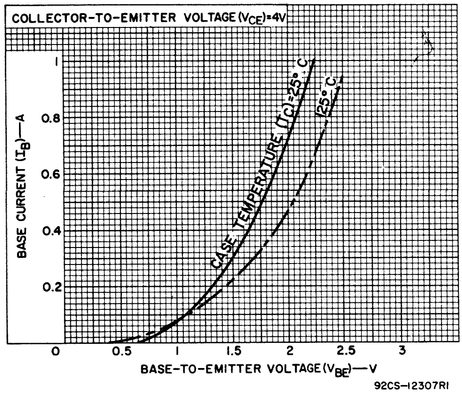


Fig.10

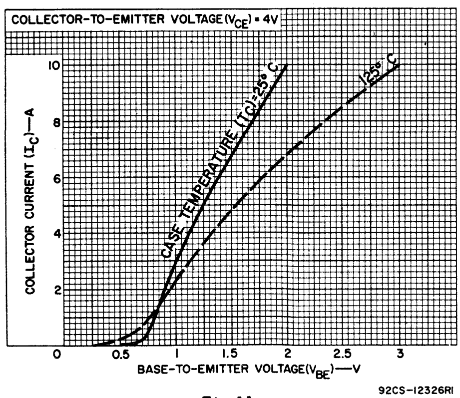
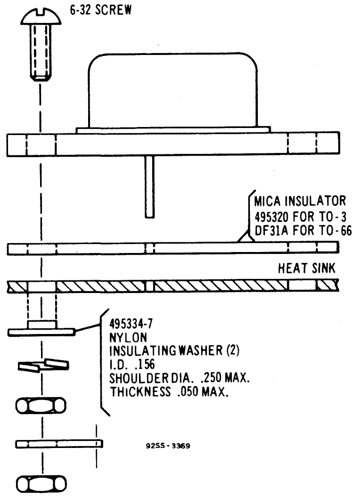


Fig.11

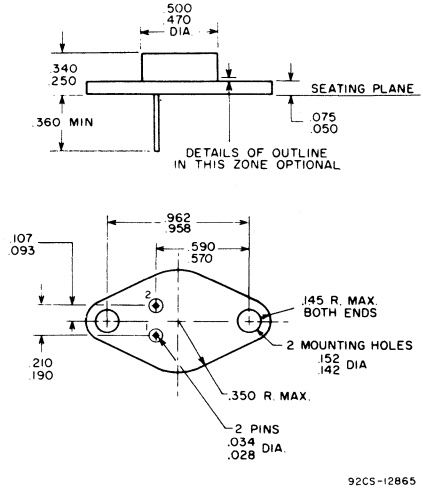
SUGGESTED MOUNTING ARRANGEMENT FOR TYPES 40250 & 40251



NOTE: Hardware With Part Numbers Supplied.

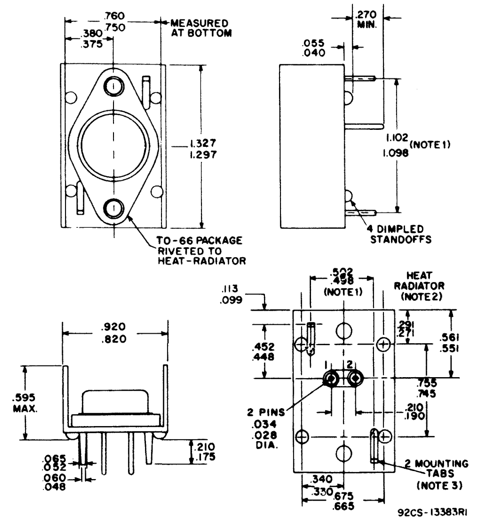
Fig.12

DIMENSIONAL OUTLINE FOR TYPE 40250 JEDEC No.TO-66



Dimensions in Inches

DIMENSIONAL OUTLINE FOR TYPE 40250V1 JEDEC No.TO-66 WITH HEAT RADIATOR



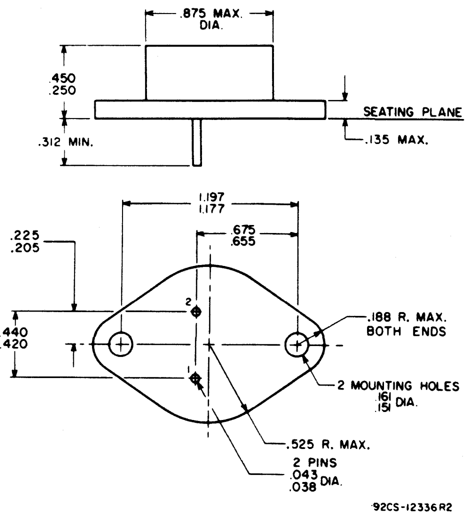
NOTE 1: Measured at bottom of heat-radiator.

NOTE 2: 0.035 C.R.S., tin plated.

NOTE 3: Recommended hole size for printed-circuit boards is 0.070 dia.

Dimensions in Inches

DIMENSIONAL OUTLINE FOR TYPE 40251 JEDEC No.TO-3



Dimensions in Inches

TERMINAL CONNECTIONS FOR TYPES 40250, 40250V1, & 40251

Pin 1 - Base

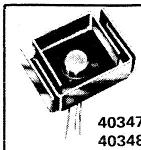
Pin 2 - Emitter

Flange, Case - Collector (For 40250 & 40251)

Heat Radiator - Collector (For 40250V1)

RCA
Solid State
Division

Power Transistors
40347
40348
40349

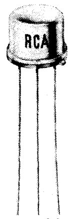


40347V1
40348V1
40349V1

H-1468

40347V2
40348V2
40349V2

H-1375



40347
40348
40349

JEDEC TO-5

H-1380

"Hometaxial"-Base Silicon N-P-N Medium- and High-Voltage Types

General-Purpose Transistors for Industrial and Commercial Equipment

Features

- **High second-breakdown resistance**
- **V_{CE}(sat) typically less than 1 volt at 1 ampere for types 40347 & 40348**
- **V_{CEV}(sus) for type 40349 is 160 volts min.**
- **Hermetically-sealed packages**

RCA-40347, 40348, and 40349 are Hometaxial-base*, silicon n-p-n transistors intended for a wide variety of low- and medium-power applications requiring medium- and high-voltage power transistors.

All three of these devices employ the popular TO-5 package; they differ primarily in their breakdown-voltage ratings.

Types 40347V1, 40348V1, and 40349V1 are 40347, 40348, and 40349, respectively, with factory-attached heat radiators; they are intended for printed circuit-board applications.

Types 40347V2, 40348V2, and 40349V2, are 40347, 40348, and 40349, respectively, with factory-attached diamond-shaped mounting flanges.

Typical applications for these transistors include switching regulators, converters, inverters, relay controls, oscillators, pulse amplifiers, and audio amplifiers (in low-power driver and output stages). These transistors are especially suitable for use in low-cost AC/DC af amplifier circuits.

* "Hometaxial" was coined by RCA for "homogeneous" and "axial" to describe a single-diffused transistor with a base region of homogeneous resistivity silicon in the axial direction.

MAXIMUM RATINGS, *Absolute-Maximum Values*		**40347 40347V1 40347V2**	**40348 40348V1 40348V2**	**40349 40349V1 40349V2**	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	90	160	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With – 1.5 V (V_{BE}) of reverse bias	V_{CEV}	60	90	160	V
With base open	V_{CEO}	40	65	140	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	7	V
CONTINUOUS COLLECTOR CURRENT	I_C	1.5	1.5	1.5	A
PEAK COLLECTOR CURRENT		3.0	3.0	3.0	A
CONTINUOUS BASE CURRENT	I_B	0.5	0.5	0.5	A
TRANSISTOR DISSIPATION	P_T				
At case temperature up to 25°C		11.7 (40347V2) 8.75 (40347)	11.7 (40348V2) 8.75 (40348)	11.7 (40349V2) 8.75 (40349)	W W
At case temperature above 25°C		←	See Figs. 2 & 3	→	
At free-air temperature up to 25°C		1.0 (40347) 4.4 (40347V1)	1.0 (40348) 4.4 (40348V1)	1.0 (40349) 4.4 (40349V1)	W W
At free-air temperature above 25°C		←	See Fig. 1	→	
TEMPERATURE RANGE:					
Storage & Operating (Junction)		←	–65 to 200	→	°C
LEAD TEMPERATURE (During soldering):					
At distances ≥ 1/32 in. from seating plane for 10 s max.		←	230	→	°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage-V V_{CE}	DC Emitter or Base Voltage-V V_{EB}	V_{BE}	DC Current A I_C	I_B	LIMITS: Type 40347 Min.	Max.	Type 40348 Min.	Max.	Type 40349 Min.	Max.	Units
Collector-Cutoff Current R_{BE} = 1,000 Ω	I_{CER}	30					–	1.0	–	–	–	–	μA
		60					–	–	–	1.0	–	–	
		90					–	–	–	–	–	1.0	
R_{BE} = 1,000 Ω, T_C = 150°C	I_{CER}	30					–	1.0	–	–	–	–	mA
		60					–	–	–	1.0	–	–	
		90					–	–	–	–	–	1.0	
Emitter-Cutoff Current	I_{EBO}		7				–	10	–	10	–	10	μA
DC Forward-Current Transfer Ratio	h_{FE}	4			0.15		–	–	–	–	30	125	
		4			0.30		–	–	30	125	–	–	
		4			0.45		25	100	–	–	10	–	
		4			1.00		–	–	10	–	–	–	
Collector-to-Emitter Sustaining Voltage: *(See Figs. 4, 5 & 6)* With base-emitter junction reverse biased	$V_{CEV}(sus)$			−1.5	.050		60	–	90	–	160[a]	–	V
With base open	$V_{CEO}(sus)$				.050		40	–	65	–	140[a]	–	V
Base-to-Emitter Voltage	V_{BE}	4			0.15		–	–	–	–	–	1.1	V
		4			0.30		–	–	–	1.3	–	–	
		4			0.45		–	1.5	–	–	–	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				0.15	15 mA	–	–	–	–	–	0.5	V
					0.30	30 mA	–	–	–	0.75	–	–	
					0.45	45 mA	–	1.0	–	–	–	–	
Thermal Resistance: Junction-to-Case	θ_{J-C}						20(max.) 40347 15(max.) 40347V2		20(max.) 40348 15(max.) 40348V2		20(max.) 40349 15(max.) 40349V2		°C/W
Thermal Resistance: Junction-to-Ambient	θ_{J-A}						40(max.) 40347V1		40(max.) 40348V1		40(max.) 40349V1		°C/W

a Pulsed; pulse duration = 300 μs, duty factor = 1.8%.

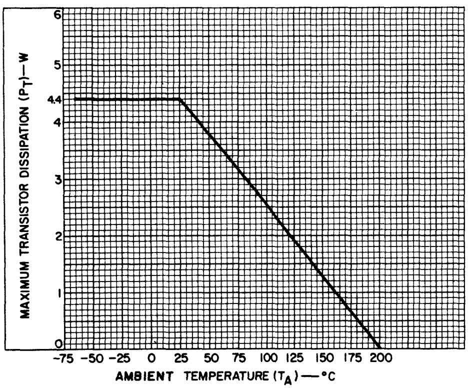


Fig. 1 - Dissipation derating curve for types 40347V1, 40348V1, and 40349V1.

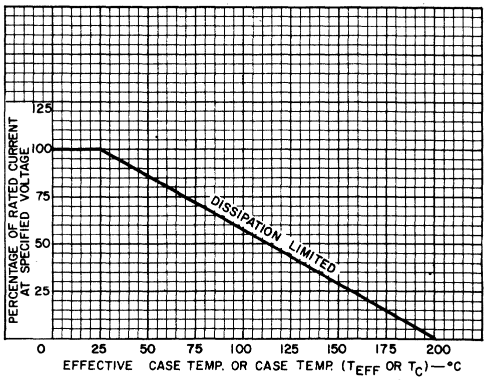


Fig. 2 - Dissipation derating curve for types 40347, 40348, and 40349.

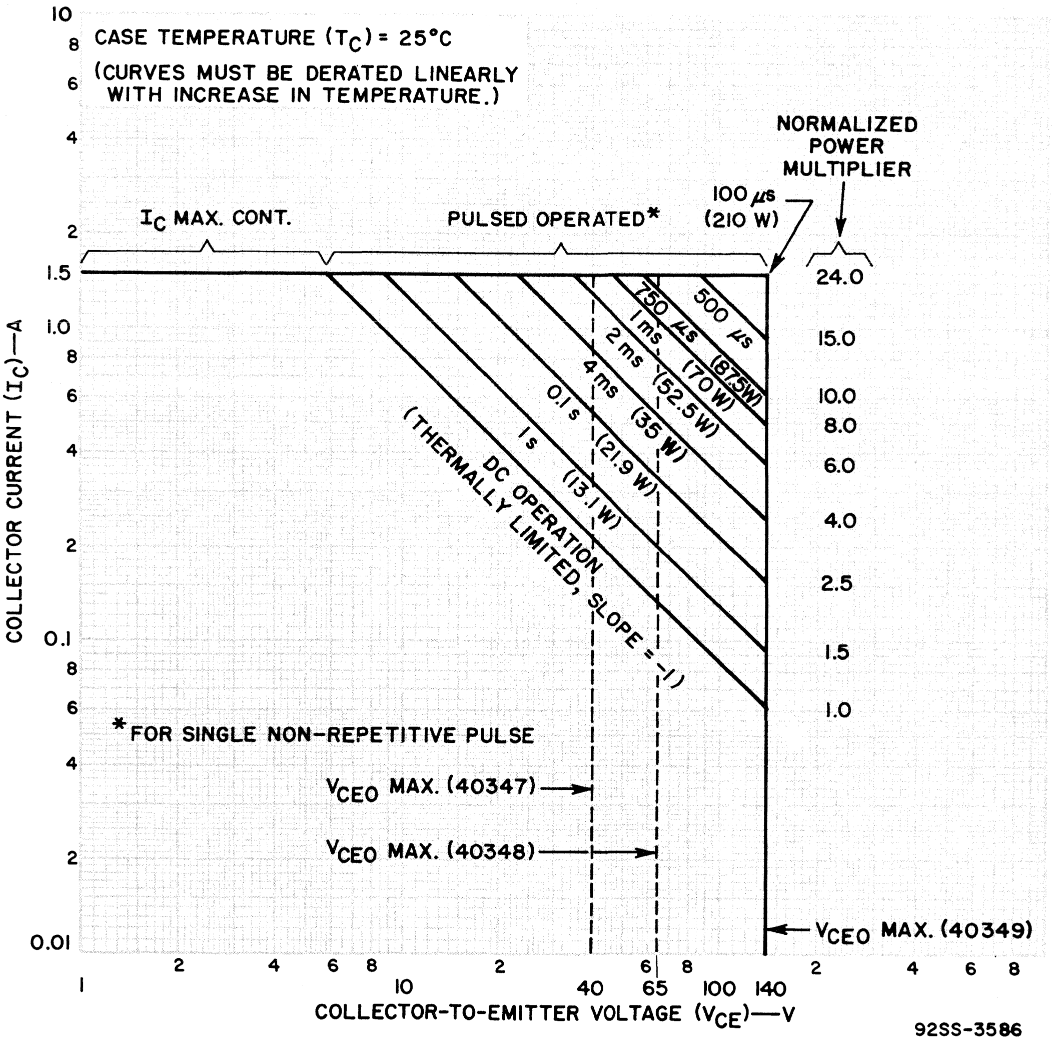


Fig. 3 - Maximum operating areas for types 40347, 40348 and 40349.

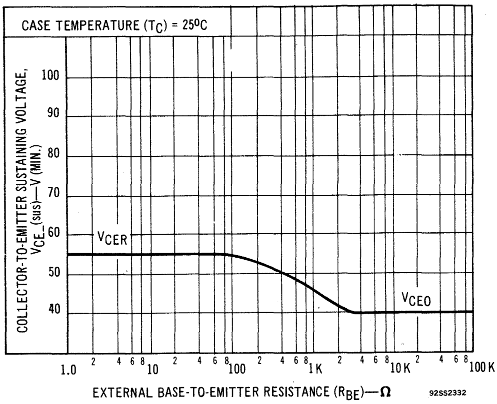


Fig. 4 - Sustaining voltage vs. base-to-emitter resistance for types 40347, 40347V1 and 40347V2.

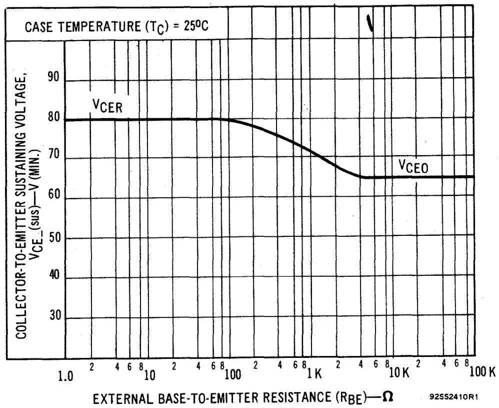


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for types 40348, 40348V1 and 40348V2.

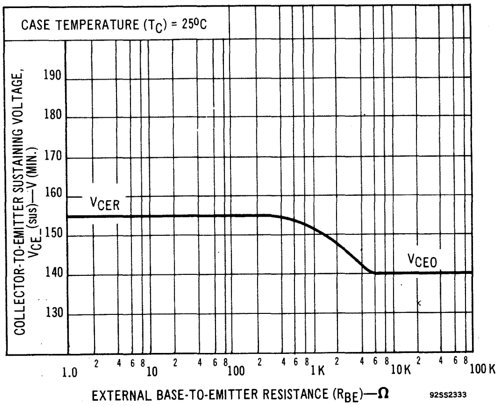


Fig. 6 - Sustaining voltage vs. base-to-emitter resistance for types 40349, 40349V1 and 40349V2.

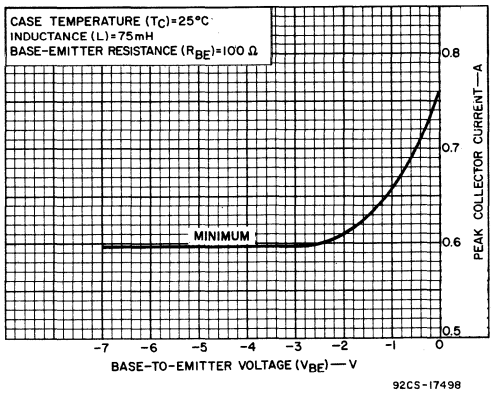


Fig. 7 - Reverse-bias second-breakdown characteristics for types 40347, 40348 and 40349.

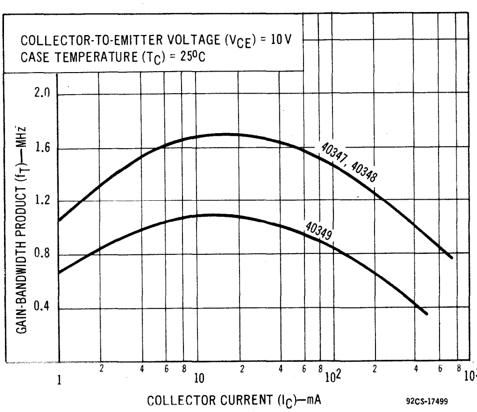


Fig. 8 - Typical gain-bandwidth product vs. collector current for types 40347, 40348 and 40349.

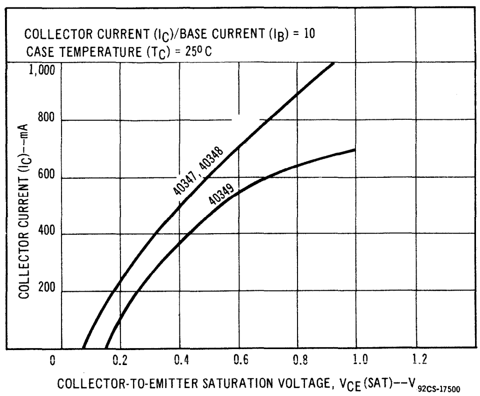


Fig. 9 - Typical saturation characteristic for types 40347, 40348 and 40349.

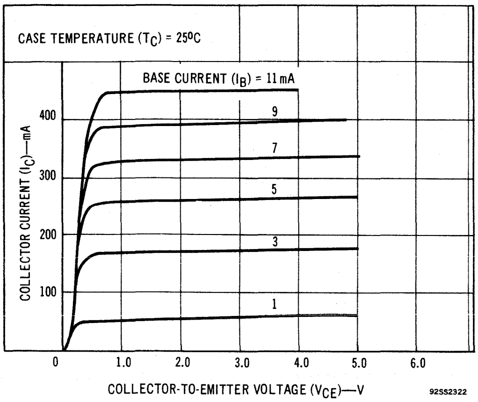


Fig. 10 - Typical output characteristics for type 40347.

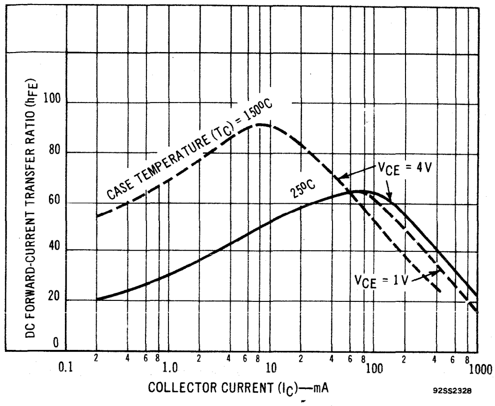


Fig. 11 - Typical dc beta characteristics for type 40347.

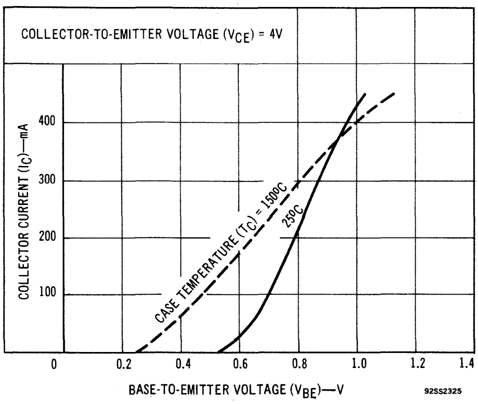


Fig. 12 - Typical transfer characteristics for type 40347.

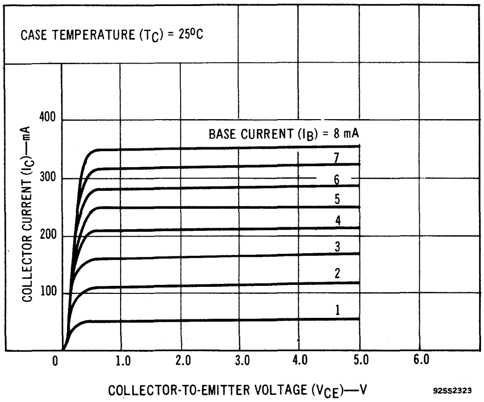


Fig. 13 - Typical output characteristics for type 40348.

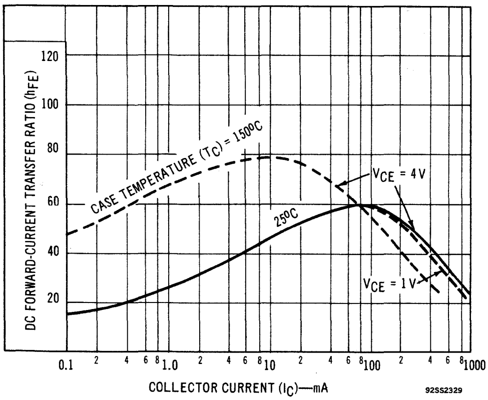


Fig. 14 - Typical dc beta characteristics for type 40348.

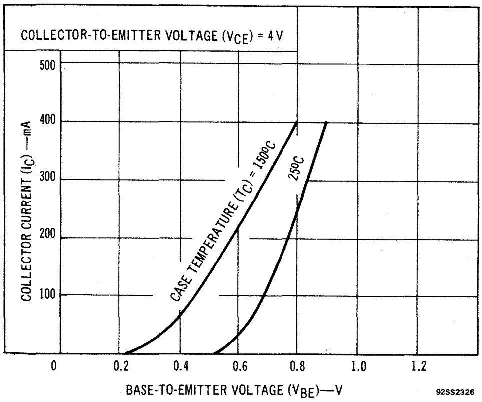


Fig. 15 - Typical transfer characteristics for type 40348.

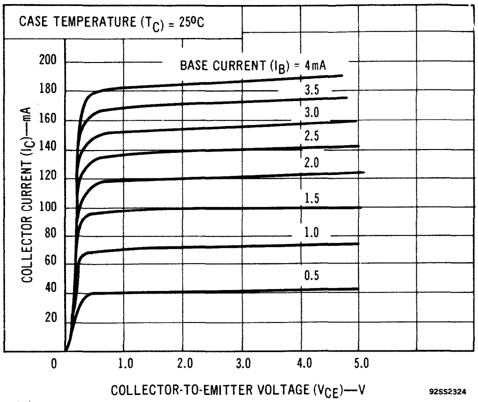


Fig. 16 - Typical output characteristics for type 40349.

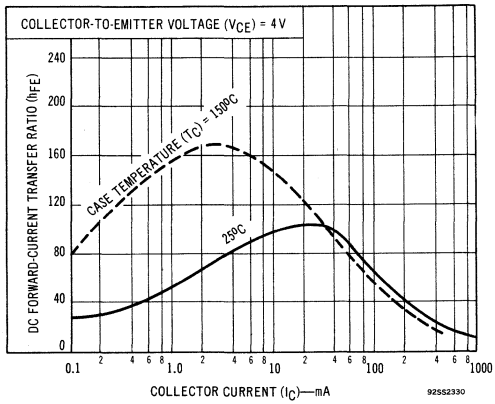


Fig. 17 - Typical dc beta characteristics for type 40349.

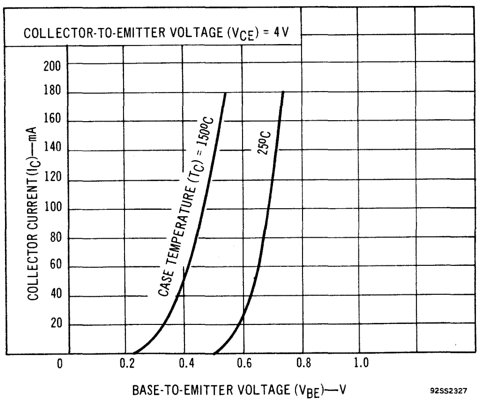


Fig. 18 - Typical transfer characteristics for type 40349.

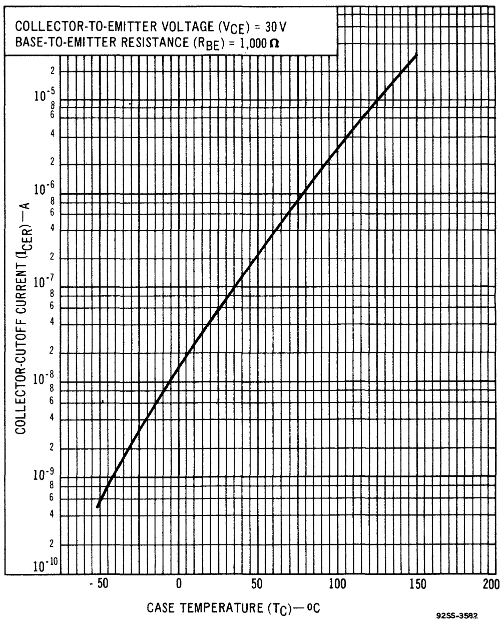


Fig. 19 - Collector-cutoff-current characteristic for type 40347.

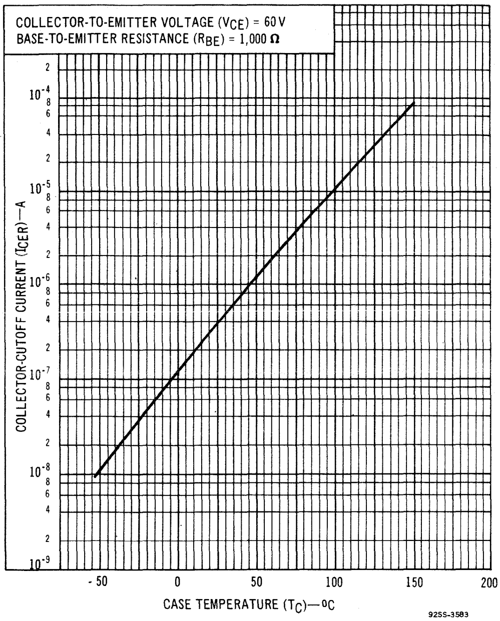


Fig. 20 - Collector-cutoff-current characteristic for type 40348.

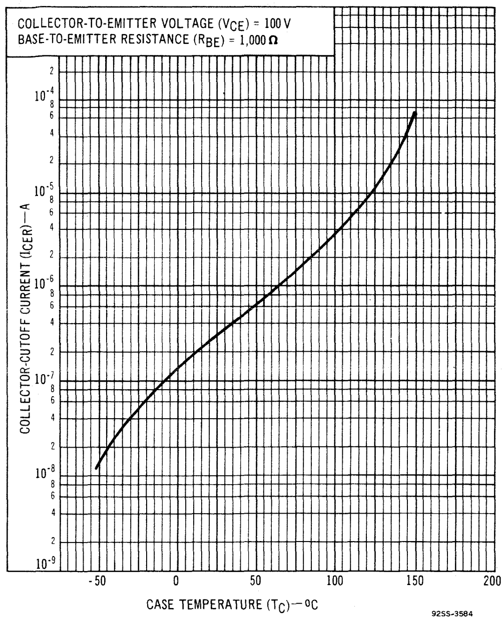
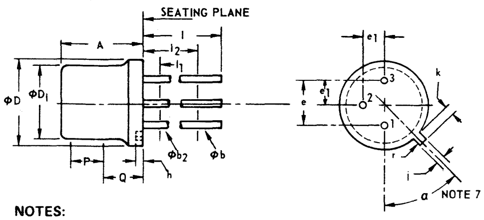


Fig. 21 - Collector-cutoff-current characteristic for type 40349.

DIMENSIONAL OUTLINE FOR TYPES 40347, 40348, 40349 JEDEC TO-5



NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) ϕb_2 applies between l_1 and l_2. ϕb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

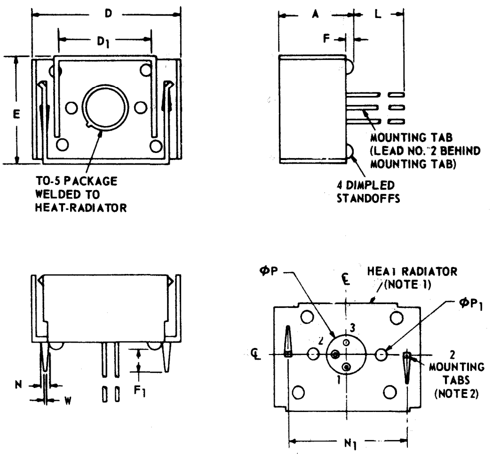
92SS-3821

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
ϕb	0.016	0.021	0.406	0.533	2
ϕb_2	0.016	0.019	0.406	0.483	2
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e_1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l_1	–	0.050	–	1.27	2
l_2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

TERMINAL CONNECTIONS FOR TYPES 40347, 40348, & 40349

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

DIMENSIONAL OUTLINE FOR TYPE 40347V1, 40348V1, 40349V1 JEDEC TO-5 WITH HEAT RADIATOR

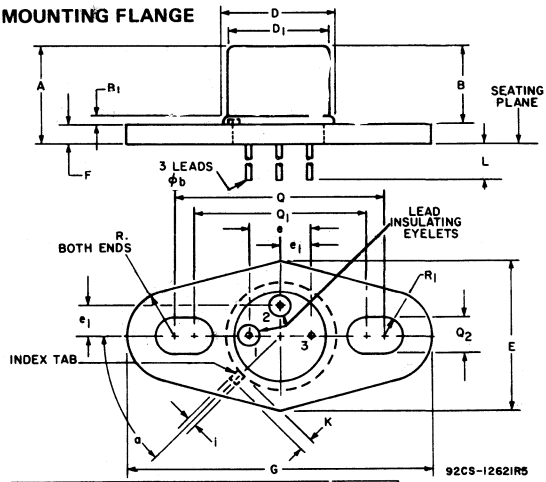


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	0.775	0.785	19.69	19.93	
E	0.875	0.905	22.22	22.99	
F	0.040	0.055	1.02	1.40	
F_1	0.160	0.195	4.06	4.95	
L	1.410	–	35.81	–	
ϕP	0.295	0.305	7.493	7.747	
ϕP_1	0.093	0.095	2.362	2.413	
N	0.048	0.062	1.21	1.57	
N_1	0.998	1.002	25.349	25.450	3
W	0.048	0.052	1.219	1.320	

NOTES:
1. 0.035 C.R.S., finish—electroless nickel plate.
2. Recommended hole size for printed-circuit board is 0.070 dia.
3. Measured at bottom of heat-radiator

92SS-2546R2

DIMENSIONAL OUTLINE FOR TYPE 40347V2, 40348V2, JEDEC TO-5 WITH MOUNTING FLANGE



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.328	–	8.33	
B	0.240	0.260	6.10	6.60	
B_1	0.009	0.125	0.229	3.18	
ϕb	0.016	0.019	0.406	0.483	
D	0.335	0.370	8.51	9.40	
D_1	0.305	0.335	7.75	8.51	
E	0.495	0.505	12.57	12.83	
e	0.200 T.P.		5.08 T.P.		1
e_1	0.100 T.P.		2.54 T.P.		1
F	0.062	0.068	1.57	1.74	
G	0.995	1.005	25.27	25.53	
i	0.028	0.034	0.711	0.864	
k	0.029	0.045	0.737	1.14	
L	1.43	–	36.32	–	
Q	0.685	0.691	17.40	17.55	
Q_1	0.559	0.565	14.20	14.35	
Q_2	0.128	0.132	3.25	3.35	
R	0.156 T.P.		3.96 T.P.		1
R_1	0.064	0.066	1.63	1.67	
α	45° T.P.				1, 2

NOTES:
1. True Position
2. Tab centerline

TERMINAL CONNECTIONS FOR TYPES 40347V1, 40348V1, & 4049V1

Lead 1 - Emitter
Lead 2 - Base
Heat Radiator, Lead 3 - Collector

TERMINAL CONNECTIONS FOR TYPES 40347V2, 40348V2, & 40349V2

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

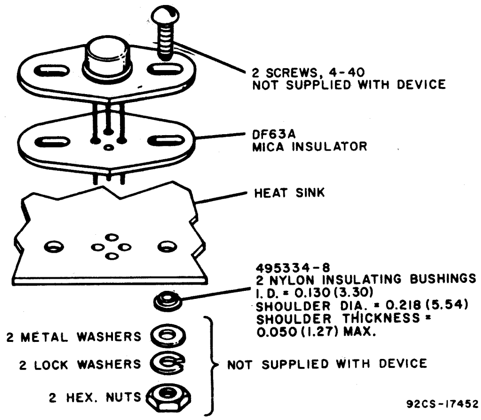


Fig. 22 - Suggested mounting hardware for types 40347V2. 40348V2 and 40349V2 (JEDEC TO-5 with mounting flange).

Epitaxial-Base n-p-n and p-n-p Power Transistors

RCA
Solid State
Division

Power Transistors

2N5954 2N5955 2N5956

JEDEC TO-66

H-1340

Silicon P-N-P Medium Power Transistors

General-Purpose Types for Switching Applications in Military, Industrial and Commercial Equipment

Features

- Low saturation voltages
- Maximum safe-area-of-operation curves
- Hermetically-sealed JEDEC TO-66 package
- High min. h_{FE} at high current

RCA 2N5954, 2N5955, 2N5956▲ are multiple-epitaxial, multiple diffused p-n-p transistors. These devices differ in voltage ratings and in the currents at which the parameters are controlled.

▲ Formerly RCA Developmental types TA7264, TA7265, and TA7266.

Maximum Ratings, *Absolute-Maximum Values:*

		2N5956	2N5955	2N5954	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-50	-70	−90	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With 1.5 volts (V_{BE}) of reverse bias, and external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CEX}	-50	-70	−90	V
* With external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CER}	-45	-65	-85	V
With base open	V_{CEO}	-40	-60	−80	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	-6	-6	-6	A
* CONTINUOUS BASE CURRENT	I_B	-2	-2	-2	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		40	40	40	W
At case temperatures above 25°C		Derate linearly at 0.232 W/°C, or see Fig.2.			
* TEMPERATURE RANGE:					
Storage & Operating (Junction)			-65 to +200		°C
* PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.			+235		°C

* In accordance with JEDEC registration data format (JS-6 RDF-2)

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25° C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_B	I_E	LIMITS: Type 2N5956 Min.	Max.	Type 2N5955 Min.	Max.	Type 2N5954 Min.	Max.	UNITS
Collector-Cutoff Current: With external base-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	-35						-	-100	-	-	-	-	µA
		-55						-	-	-	-100	-	-	
		-75						-	-	-	-	-	-100	
	I_{CER} (T_C = 150°C)	-35						-	-2	-	-	-	-	mA
		-55						-	-	-	-2	-	-	
		-75						-	-	-	-	-	-2	
* With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CEX}	-45		1.5				-	-100	-	-	-	-	µA
		-65		1.5				-	-	-	-100	-	-	
		-85		1.5				-	-	-	-	-	-100	
	I_{CEX} (T_C = 150°C)	-45		1.5				-	-2	-	-	-	-	mA
		-65		1.5				-	-	-	-2	-	-	
		-85		1.5				-	-	-	-	-	-2	
* Collector-Cutoff Current, Base Open	I_{CEO}	-25						-	-1	-	-	-	-	mA
		-45						-	-	-	-1	-	-	
		-65						-	-	-	-	-	-1	
* Emitter-Cutoff Current	I_{EBO}		-5					-	-0.1	-	-0.1	-	-0.1	mA
* DC Forward-Current Transfer Ratio	h_{FE}	-4			-3[a]			20	100	-	-	-	-	
		-4			-2.5[a]			-	-	20	100	-	-	
		-4			-2[a]			-	-	-	-	20	100	
		-4			-6[a]			5	-	5	-	5	-	
* Collector-to-Emitter Sustaining Voltage: With base open (*See Figs. 17 and 18*)	$V_{CEO}(sus)$				-0.1			-40[b]	-	-60[b]	-	-80[b]	-	V
		[b] *CAUTION: Sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. They should be measured by means of the test circuit shown in Fig 17.*												
With external base-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				-0.1			-45[b]	-	-65[b]	-	-85[b]	-	
With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CEX}(sus)$			1.5	-0.1			-50[b]	-	-70[b]	-	-90[b]	-	
* Base-to-Emitter Voltage	V_{BE}	-4			-3[a]			-	-2	-	-	-	-	V
		-4			-2.5[a]			-	-	-	-2	-	-	
		-4			-2[a]			-	-	-	-	-	-2	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				-3[a]	-0.3		-	-1	-	-	-	-	V
					-2.5[a]	-0.25		-	-	-	-1	-	-	
					-2[a]	-0.2		-	-	-	-	-	-1	
					-6[a]	-1.2		-	-2	-	-2	-	-2	
* Common-Emitter Small Signal Current Transfer Ratio	$\|h_{FE}\|$ at f = 1 kHz	-4			-0.5			25	-	25	-	25		
* Gain-Bandwidth Product	f_T	-4			-1			5	-	5	-	5	-	MHz
Thermal Resistance (Junction-to-case)	θ_{J-C}							-	4.3	-	4.3	-	4.3	°C/W

[a] Pulsed; pulse duration = 300 µs, duty factor = 0.018.

*In accordance with JEDEC registration data format (JS-6 RDF-2)

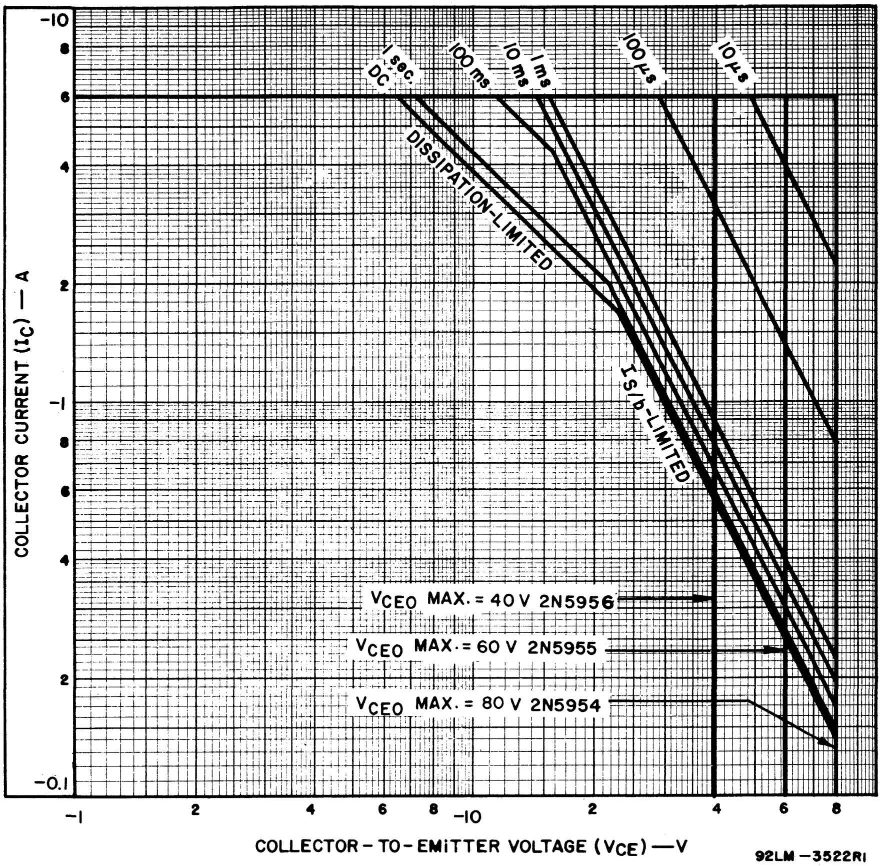


Fig. 1 Maximum operating areas for all types.

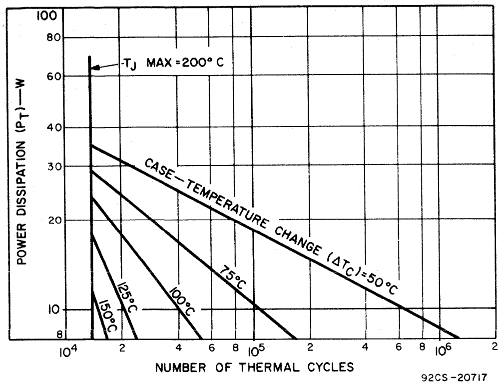


Fig. 2 Thermal-cycle rating chart for all types.

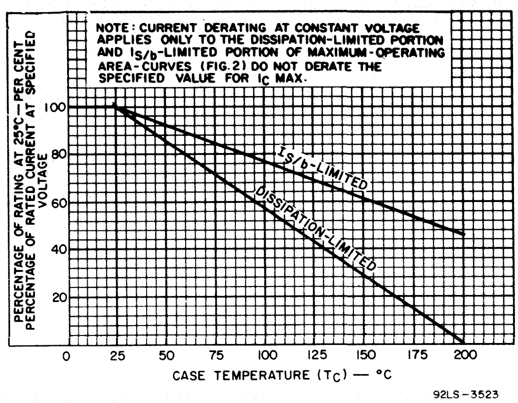


Fig. 3 Dissipation and $I_{s/b}$ derating of all types.

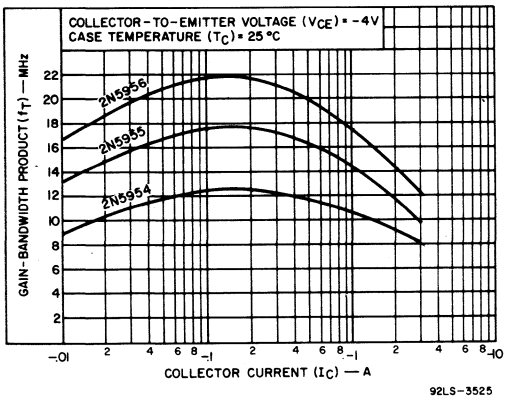


Fig. 4 Typical gain-bandwidth product vs. collector current in all types.

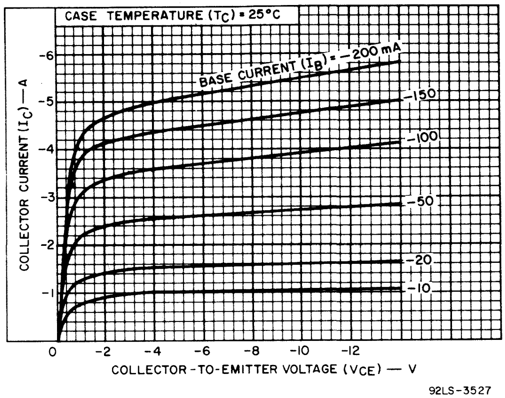


Fig. 5 Typical collector characteristics of all types.

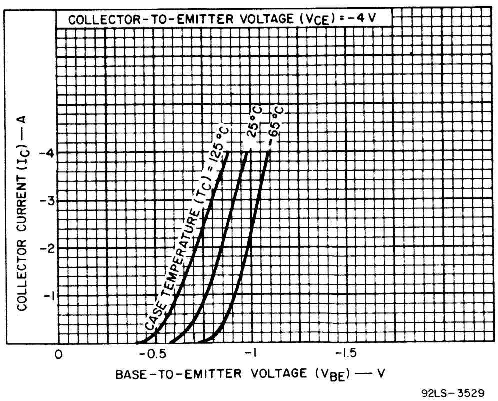


Fig. 6 Typical transfer characteristics of all types.

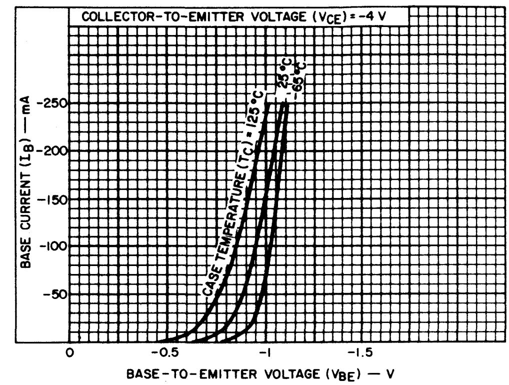


Fig. 7 Typical input characteristics of all types.

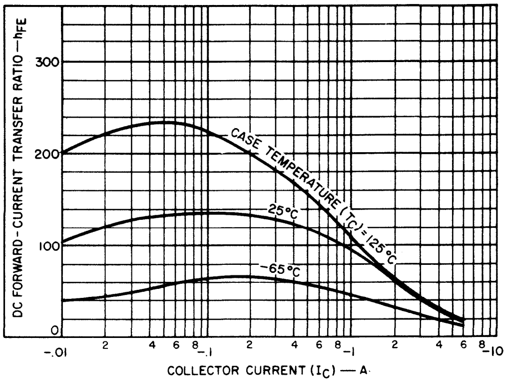


Fig. 8 Typical dc beta characteristics of all types.

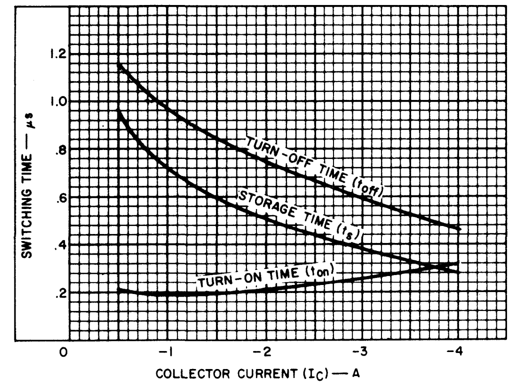


Fig. 9 Typical saturated switching characteristics for all types.

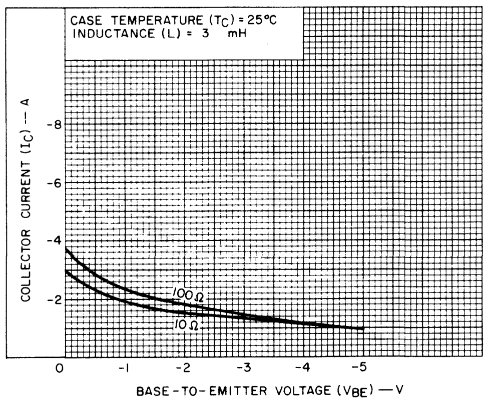


Fig. 10 Minimum reverse-bias second-breakdown characteristics for all types.

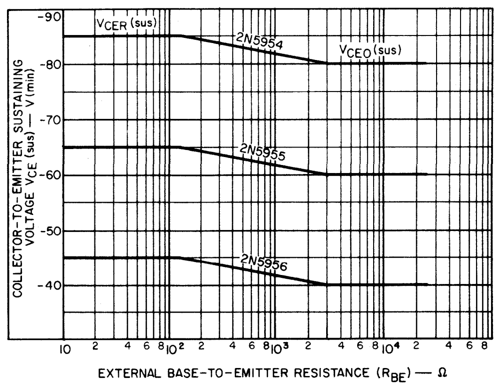


Fig. 11 Collector-to-emitter sustaining voltage characteristics for types 2N5954, 2N5955 and 2N5956.

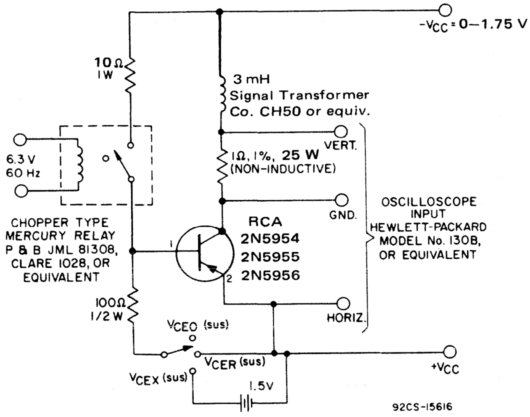
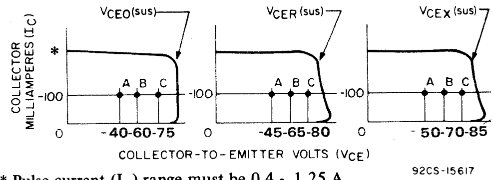


Fig. 12 Circuit used to measure sustaining voltages V_{CEO}(sus) V_{CER}(sus), & V_{CEX}(sus) for all types.



* Pulse current (I_p) range must be 0.4 - 1.25 A

The sustaining voltages V_{CEO}(sus), V_{CER}(sus), and V_{CEX}(sus) are acceptable when the traces fall to the right and above point "A" for type 2N5956; point "B" for type 2N5955; and point "C" for type 2N5954.

Fig. 13 Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 17).

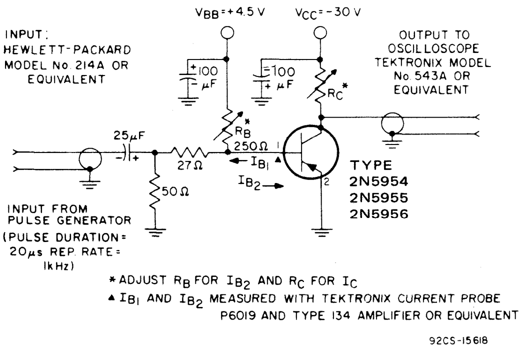


Fig. 14 ***Circuit used to measure saturated switching times.***

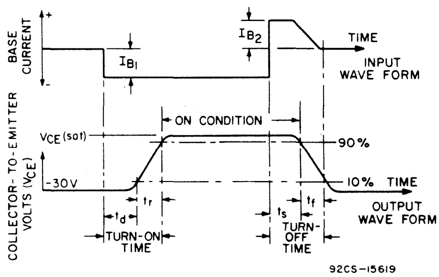


Fig. 15 ***Oscilloscope display for measurement of switching times.***

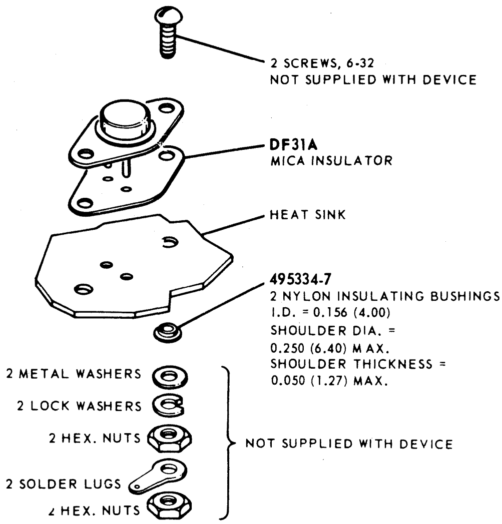
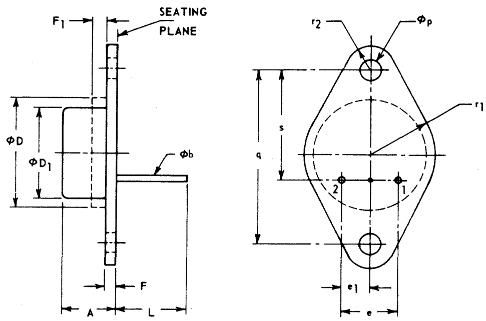


Fig. 16 Suggested hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.250	.340	6.35	8.64	
Φb	.028	.034	.711	.863	
ΦD		.620		15.75	
ΦD1	.470	.500	11.94	12.70	
e	.190	.210	4.83	5.33	
e1	.093	.107	2.36	2.72	
F	.050	.075	1.27	1.91	2
F1		.050		1.27	1
L	.360		9.14		
Φp	.142	.152	3.61	3.86	
q	.958	.962	24.33	24.43	
r1		.350		8.89	
r2		.145		3.68	
s	.570	.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimension does not include seating flanges.

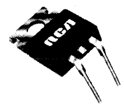
TERMINAL CONNECTIONS

Pin 1 - Base
Pin 2 - Emitter
Mounting Flange, Case - Collector

RCA
Solid State
Division

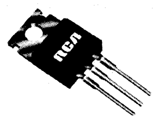
Power Transistors

2N6106 2N6107
2N6108 2N6109
2N6110 2N6111



2N6106
2N6108
2N6110

TO–220 AA H1534R1



2N6107
2N6109
2N6111

TO–220 AB H1535R1

Silicon P-N-P VERSAWATT Transistors

General-Purpose Types for Medium-Power Switching and Amplifier Applications

Features

- **Low saturation voltage—**
  V_{CE}(sat) = 1 V max. at I_C = 2 A (2N6106 & 2N6107)
  = 1 V max. at I_C = 2.5 A (2N6108 & 2N6109)
  = 1 V max. at I_C = 3 A (2N6110 & 2N6111)
- **Thermal-cycling ratings**
- **VERSAWATT package (molded green silicone plastic)**
- **Maximum safe-area-of-operation curves specified for dc operation**
- **Complements of types in 2N5496 family**

RCA – 2N6106, 2N6107, 2N6108, 2N6109, 2N6110, and 2N6111■ are epitaxial-base silicon p-n-p transistors. They are intended for a wide variety of medium-power switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers.

Types 2N6106, 2N6108, and 2N6110 have formed emitter and base leads for insertion into TO-66 sockets. Types 2N6107, 2N6109, and 2N6111 are electrically identical to the 2N6106, 2N6108, and 2N6110, respectively, but they have straight leads for mounting on printed-circuit boards. These new plastic power transistors differ in voltage ratings and in the currents at which the parameters are controlled.

■ Formerly RCA Dev. Nos. TA8210, TA7741, TA8211, TA7742, TA8212, and TA7743, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6110 2N6111	2N6108 2N6109	2N6106 2N6107	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-40	-60	-80	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}(sus)	-40	-60	-80	V
* With base open	V_{CEO}(sus)	-30	-50	-70	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	- 5	- 5	- 5	V
*COLLECTOR CURRENT (Continuous)	I_C	- 7	- 7	- 7	A
*BASE CURRENT (Continuous)	I_B	- 3	- 3	- 3	A
TRANSISTOR DISSIPATION:	P_T				
* At case temperatures up to 25°C		40	40	40	W
At ambient temperatures up to 25°C		1.8	1.8	1.8	W
* At case temperatures above 25°C		Derate linearly at 0.32W/°C, or see Fig.2.			
At ambient temperatures above 25°C		Derate linearly at 0.0144 W/°C			
TEMPERATURE RANGE:					
* Storage & Operating (Junction)		← -65 to 150 →			°C
*LEAD TEMPERATURE (During Soldering):					
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →			°C

*In accordance with JEDEC registration data format (JS-6 RFD-2).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C, Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE V	DC EMITTER OR BASE VOLTAGE V		DC CURRENT A		LIMITS						UNITS
							2N6106 2N6107		2N6108 2N6109		2N6110 2N6111		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	-75					—	-0.1	—	—	—	—	mA
		-55					—	—	—	-0.1	—	—	
		-35					—	—	—	—	—	-0.1	
	I_{CER} (T_C = 150°C)	-70					—	-2.0	—	—	—	—	mA
		-50					—	—	—	-2.0	—	—	
		-30					—	—	—	—	—	-2.0	
* Collector-Cutoff Current: With base-emitter junction reversed biased	I_{CEV}	-75		1.5			—	—	—	—	—	-0.1	mA
		-56		1.5			—	—	—	-0.1	—	—	
		-37.5		1.5			—	-0.1	—	—	—	—	
*	I_{CEV} (T_C = 150°C)	-30		1.5			—	—	—	—	—	-2	mA
		-50		1.5			—	—	—	-2	—	—	
		-70		1.5			—	-2	—	—	—	—	
* Emitter-Cutoff Current	I_{EBO}		-5		0		—	-1.0	—	-1.0	—	-1.0	mA
* Collector-Cutoff Current	I_{CEO}	-60				0	—	-1	—	—	—	—	mA
		-40				0	—	—	—	-1	—	—	
		-20				0	—	—	—	—	—	-1	
* Collector-to-Emitter Sustaining Voltage: With base open	V_{CEO}(sus)				-0.1	0	-70	—	-50	—	-30	—	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CER}(sus)				-0.1		-80	—	-60	—	-40	—	V
* DC Forward-Current Transfer Ratio	h_{FE}	- 4			-2.0[a]		30	150	—	—	—	—	
		- 4			-2.5[a]		—	—	30	150	—	—	
		- 4			-3.0[a]		—	—	—	—	30	150	
		- 4			-6.5[a]		5	—	5	—	5	—	
* Base-to-Emitter Voltage	V_{BE}	- 4			-2.0[a]		—	-1.5	—	—	—	—	V
		- 4			-2.5[a]		—	—	—	-1.5	—	—	
		- 4			-3.0[a]		—	—	—	—	—	-1.5	
* Collector-to-Emitter Saturation Voltage	V_{CE}(sat)				-2.0[a]	-0.2	—	-1.0	—	—	—	—	V
					-2.5[a]	-0.25	—	—	—	-1.0	—	—	
					-3.0[a]	-0.3	—	—	—	—	—	-1.0	
					-6.5[a]	-1.63	—	- 2	—	- 2	—	- 2	
* Small-Signal, Forward-Current Transfer Ratio (f = 50 kHz)	h_{fe}	- 4			-0.5		20	—	20	—	20	—	
Gain-Bandwidth Product	f_T	- 4			-0.5		10	—	10	—	10	—	MHz
* Small-Signal, Forward-Current Transfer Ratio Cutoff Frequency	f_{hfe}	- 4			-0.5		0.5	—	0.5	--	0.5	—	MHz
* Collector-to-Base Capacitance (@ f = 1 MHz)	C_{obo}	-10 (V_{CB})			0		—	250	—	250	—	250	pF
Thermal Resistance Junction-to-Case	θ_{J-C}						—	3.125	—	3.125	—	3.125	°C/W
Junction-to-Ambient	θ_{J-A}						—	70	—	70	—	70	

[a] Pulsed: Pulse duration = 300 μs, duty factor = 0.018.

* In accordance with JEDEC registration data format (JS-6 RDF-2).

CAUTION: The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) MUST NOT be measured on a curve tracer.

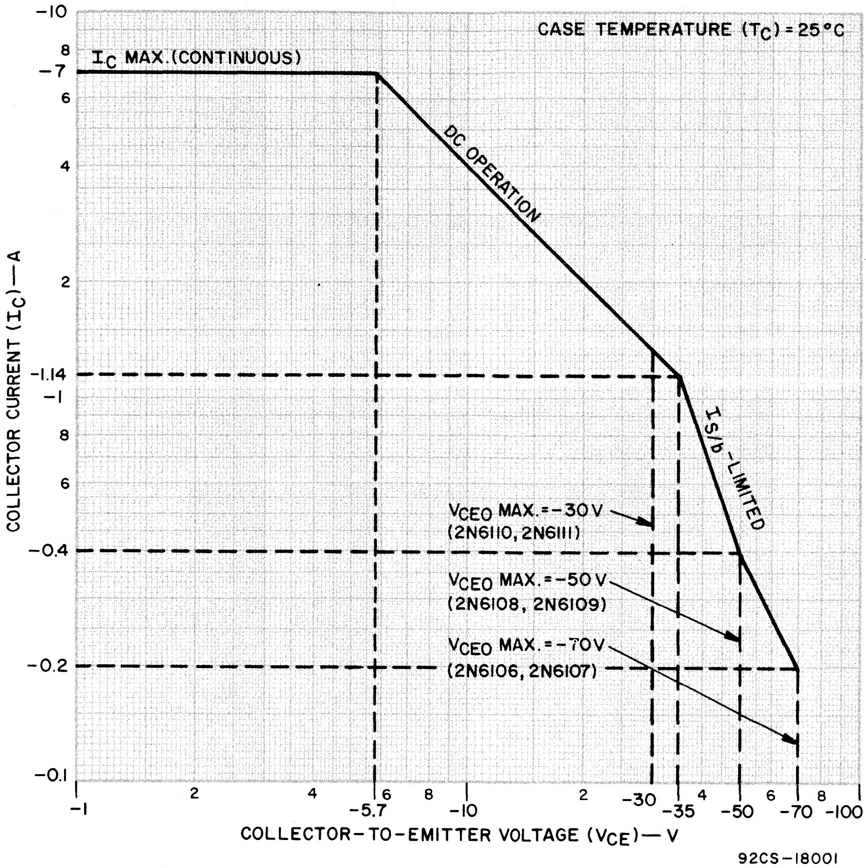


Fig.1—Maximum operating areas for types 2N6106—2N6111.

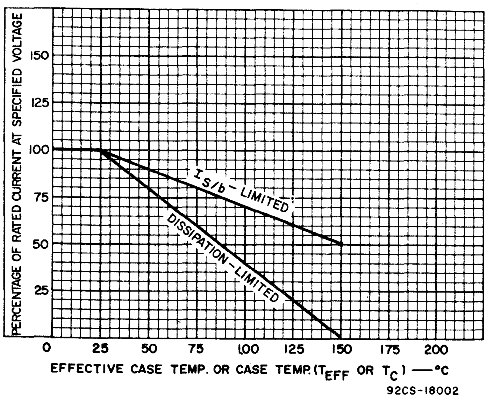


Fig.2—Derating curves for types 2N6106—2N6111.

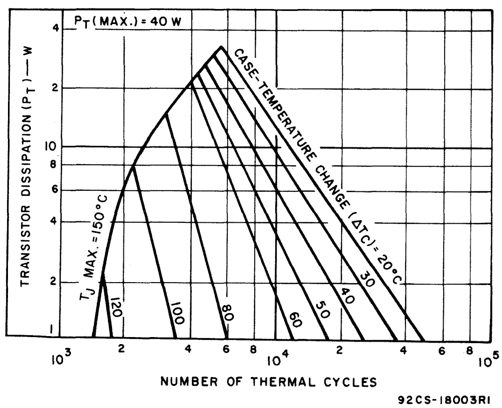


Fig.3—Thermal-cycling ratings for types 2N6106—2N6111.

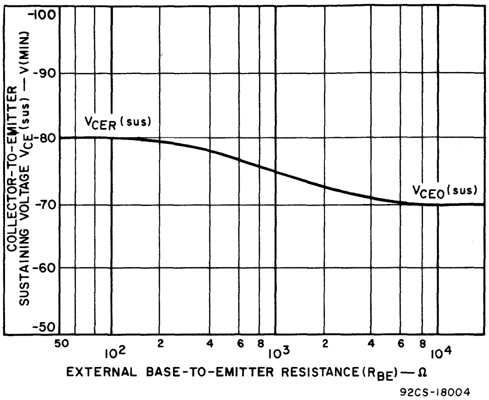


Fig.4—Collector-to-emitter sustaining-voltage characteristic for types 2N6106 & 2N6107.

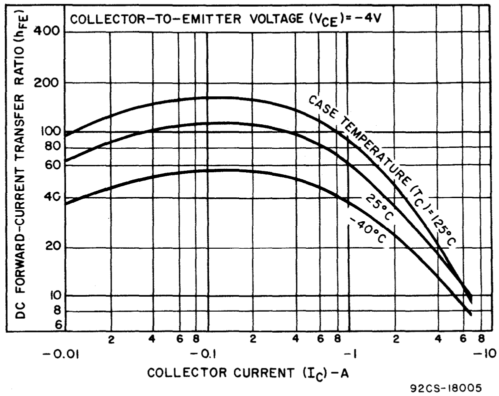


Fig.5—Typical dc beta characteristics for types 2N6106 & 2N6107.

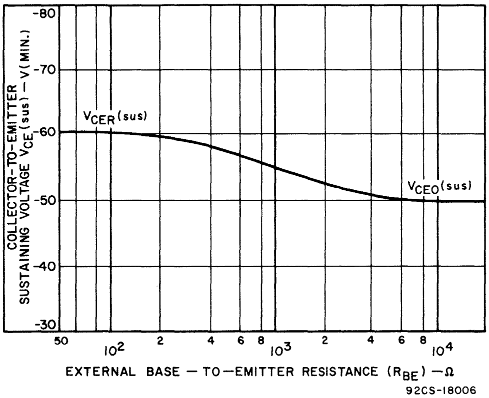


Fig.6—Collector-to-emitter sustaining-voltage characteristic for types 2N6108 & 2N6109.

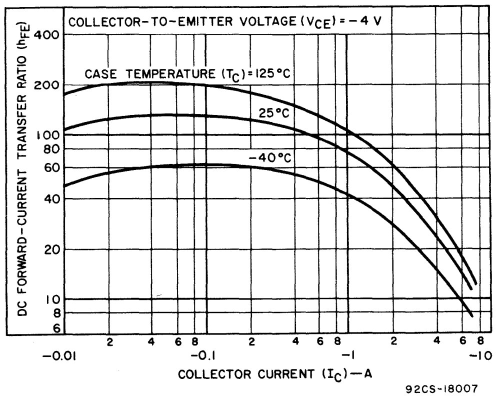


Fig.7—Typical dc beta characteristics for types 2N6108 & 2N6109.

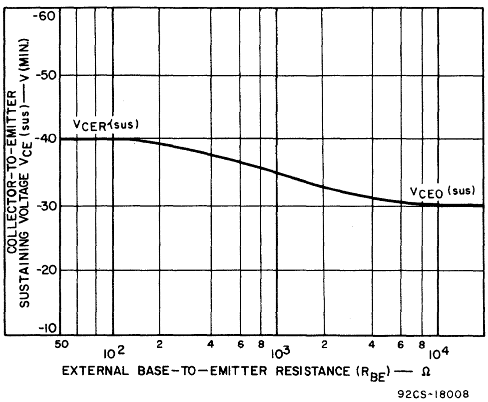


Fig.8—Collector-to-emitter sustaining-voltage characteristic for types 2N6110 & 2N6111.

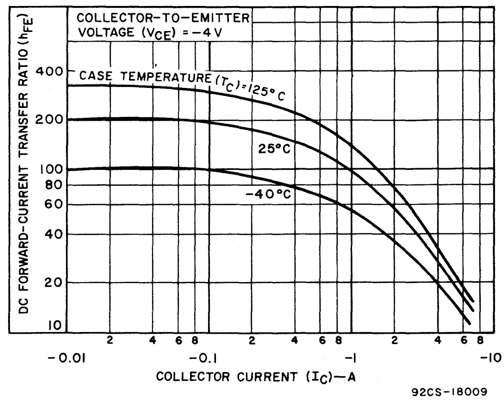


Fig.9—Typical dc beta characteristics for types 2N6110 & 2N6111.

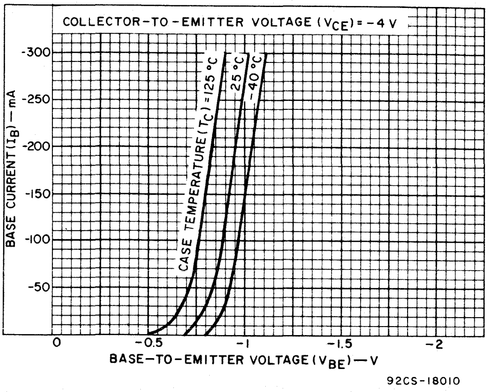


Fig.10—Typical input characteristics for types 2N6106 & 2N6107.

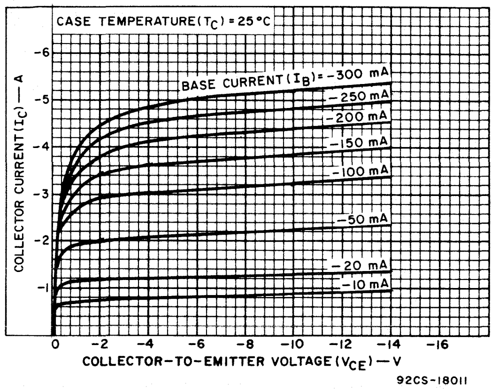


Fig.11—Typical output characteristics for types 2N6106 & 2N6107.

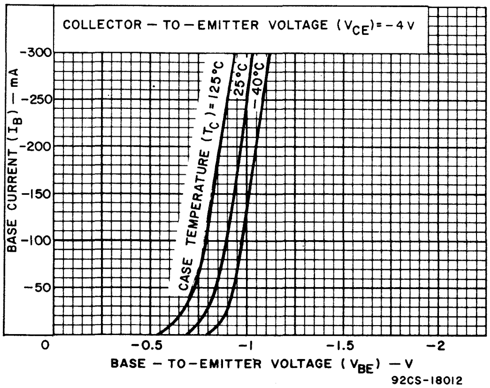


Fig.12—Typical input characteristics for types 2N6108 & 2N6109.

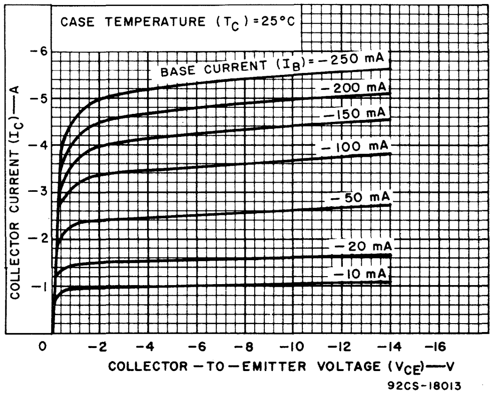


Fig.13—Typical output characteristics for types 2N6108 & 2N6109.

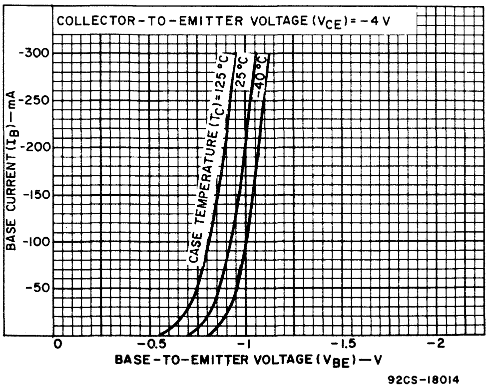


Fig.14—Typical input cnaracteristics for types 2N6110 & 2N6111.

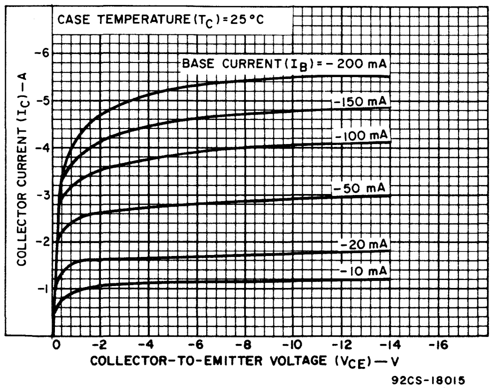


Fig.15—Typical output characteristics for types 2N6110 & 2N6111.

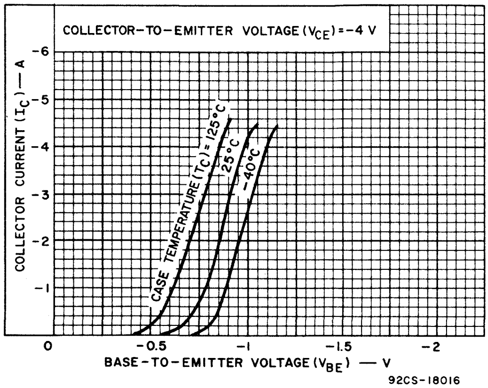


Fig.16—Typical transfer characteristics for types 2N6106—2N6111.

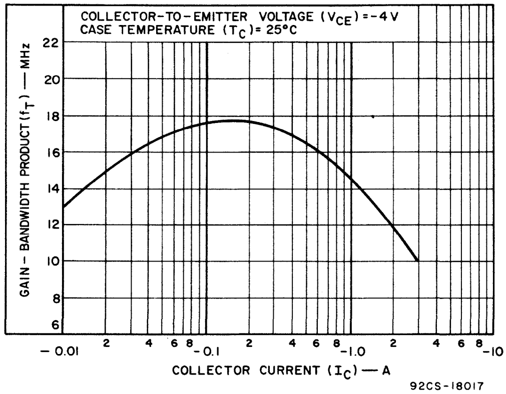


Fig.17—Typical gain-bandwidth product for types 2N6106—2N6111.

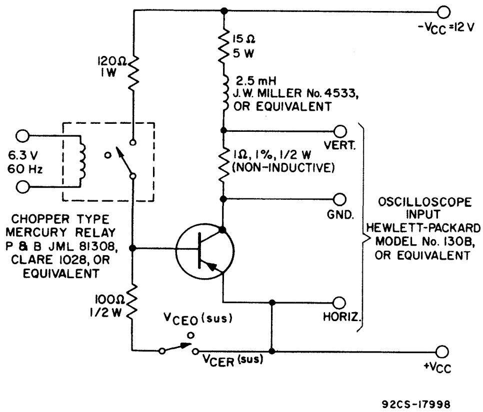
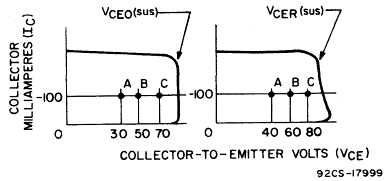


Fig.18—Circuit used to measure sustaining voltages V_{CEO}(sus) & V_{CER}(sus) for types 2N6106 — 2N6111.



The sustaining voltages V_{CEO}(sus) & V_{CER}(sus) are acceptable when the traces fall to the right and above point "A" for types 2N6110 & 2N6111, point "B" for types 2N6108 & 2N6109, & point "C" for types 2N6106 & 2N6107.

Fig.19—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig.18).

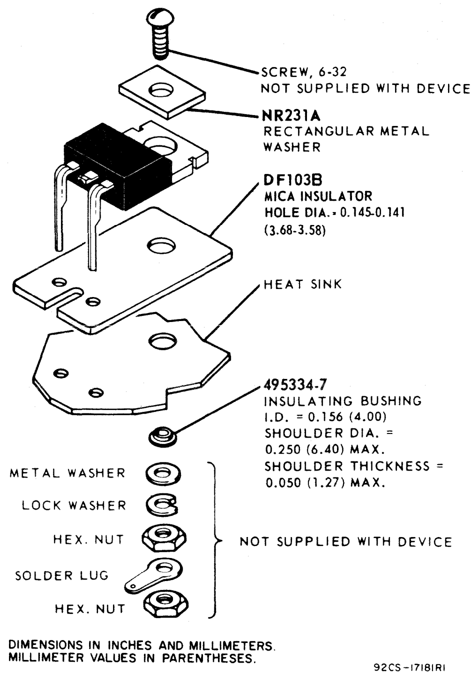


Fig.20—Suggested mounting hardware for types 2N6106, 2N6108, & 2N6110.

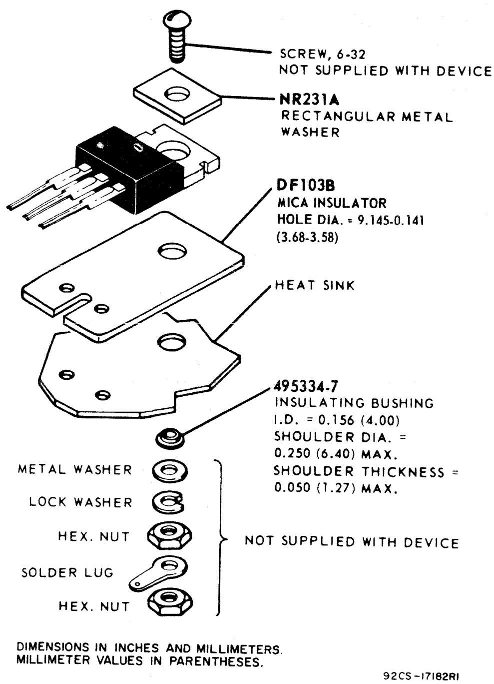
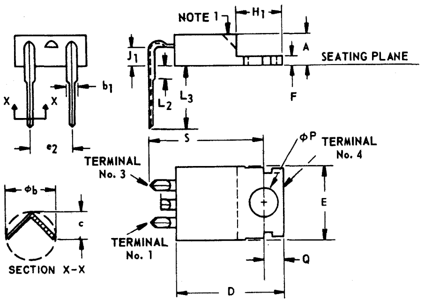


Fig.21—Suggested mounting hardware for types 2N6107, 2N6109, & 2N6111.

DIMENSIONAL OUTLINE FOR TYPES 2N6106, 2N6108, & 2N6110 (JEDEC TO-220AA)

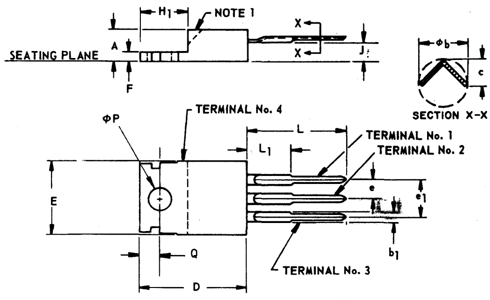


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.02	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L_2	–	0.050	–	1.27	–
L_3	0.360	0.422	9.15	10.71	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–
S	0.580	0.610	14.74	15.49	–

92CS-17990

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.050 – 0.055 (1.27 – 1.40 mm) below seating plane.

DIMENSIONAL OUTLINE FOR TYPES 2N6107, 2N6109, & 2N6111 (JEDEC TO-220AB)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

TERMINAL CONNECTIONS

For Types 2N6106, 2N6108, & 2N6110

Lead No.1 — Base
Lead No.3 — Emitter
Mounting Flange — Collector
● — Do not use stub as tie point.

TERMINAL CONNECTIONS

For Types 2N6107, 2N6109, & 2N6111

Lead No.1 — Base
Lead No.2 — Collector
Lead No.3 — Emitter
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors
2N6246
2N6247
2N6248

JEDEC TO-3 H-1570

Silicon P-N-P Epitaxial-Base High-Power Transistors

General-Purpose Types for
Switching Applications in Military,
Industrial, and Commercial Equipment

Features:

- **High dissipation capability: 125 W at 25°C**
- **Low saturation voltages**
- **Maximum safe-area-of-operation curves**
- **Hermetically sealed JEDEC TO-3 package**
- **High min. h_{FE} at high current**
- **Thermal-cycle rating curve**

RCA 2N6246, 2N6247, 2N4248• are epitaxial-base silicon p-n-p transistors featuring high minimum beta at high current. They have a dissipation capability of 125 watts at case temperatures up to 25°C.

These types can be used in complementary-symmetry circuits in combination with high-power n-p-n transistors such as the 2N3055 or 2N3772.

• Formerly RCA Dev. Nos. TA7281, TA7280, and TA7279, respectively.

Maximum Ratings, *Absolute-Maximum Values:*

		2N6246	2N6247	2N6248	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-70	-90	-110	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With 1.5 volts (V_{BE}) of reverse bias, and external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CEX}	-70	-90	-110	V
* With external base-to-emitter resistance (R_{BE}) = 100Ω	V_{CER}	-65	-85	-105	V
With base open	V_{CEO}	-60	-80	-100	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	-15	-15	-15	A
* CONTINUOUS BASE CURRENT	I_B	-5	-5	-5	A
* TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		125	125	125	W
At case temperatures above 25°C		← Derate linearly at 0.715 W/°C, or see Fig. 3 →			
* TEMPERATURE RANGE:					
Storage & Operating (Junction)		← -65 to +200 →			°C
* PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max		← +235 →			°C

* In accordance with JEDEC registration data data format (JS-6RDF-2)

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	DC Emitter or Base Voltage (V) V_{BE}	DC Current (A) I_C	DC Current (A) I_B	LIMITS: Type 2N6246 Min.	Type 2N6246 Max.	Type 2N6247 Min.	Type 2N6247 Max.	Type 2N6248 Min.	Type 2N6248 Max.	UNITS
Collector-Cutoff Current: With external base-emitter resistance (R_{BE}) = 100Ω	I_{CER}	−55					–	−200	–	–	–	–	μA
		−75					–	–	–	−200	–	–	
		−95					–	–	–	–	–	−200	
* With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100Ω	I_{CEX}	−65		1.5			–	−200	–	–	–	–	μA
		−85		1.5			–	–	–	−200	–	–	
		−100		1.5			–	–	–	–	–	−200	
	I_{CEX} (T_C = 150°C)	−55		1.5			–	−5	–	–	–	–	mA
		−70		1.5			–	–	–	−5	–	–	
		−90		1.5			–	–	–	–	–	−5	
* With base open	I_{CEO}	−30				0		−1	–	–	–	–	mA
		−40				0	–	–	–	−1	–	–	
		−50				0	–	–	–	–	–	−1	
* Emitter-Cutoff Current	I_{EBO}		−5				–	−5	–	−1	–	−1	mA
* DC Forward-Current Transfer Ratio	h_{FE}	−4			−7[a]		20	100	–	–	–	–	
		−4			−6[a]		–	–	20	100	–	–	
		−4			−5[a]		–	–	–	–	20	100	
		−4			−15[a]		5	–	5	–	5	–	
* Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 19 and 20)	$V_{CEO}(sus)$				−0.2	0	−60[b]	–	−80[b]	–	−100[b]	–	V
With external base-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$				−0.2		−65[b]	–	−85[b]	–	−105[b]	–	V
With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CEX}(sus)$			1.5	−0.2		−70[b]	–	−90[b]	–	−110[b]	–	V
* Base-to-Emitter Voltage	V_{BE}	−4			−7[a]		–	−2	–	–	–	–	V
		−4			−6[a]		–	–	–	−1.8	–	–	
		−4			−5[a]		–	–	–	–	–	−1.8	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				−7[a]	−0.7	–	−1.3	–	–	–	–	V
					−6[a]	−0.6	–	–	–	−1.3	–	–	
					−5[a]	−0.5	–	–	–	–	–	−1.3	
					−15[a]	−3	–	−2.5	–	–	–	–	
					−15[a]	−4	–	–	–	−3.5	–	−3.5	
* Magnitude of Common-Emitter Small-Signal Short-Circuit Forward-Current Transfer Ratio	$\|h_{fe}\|$ at f = 2 MHz	−4			−1		5	–	5	–	5	–	
* Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio	h_{fe} at f = 1 kHz	−4			−1		25	–	25	–	25	–	
Gain-Bandwidth Product	f_T	−4			−1		6	–	6	–	6	–	MHz
Thermal Resistance (Junction-to-case)	$R_{\theta JC}$						–	1.4	–	1.4	–	1.4	°C/W

[b] *CAUTION: Sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. They should be measured by means of the test circuit shown in Fig. 19.*

[a]Pulsed; pulse duration = 300 μs, duty factor = 0.018.

*In accordance with JEDEC registration data format (JS-6RDF-2)

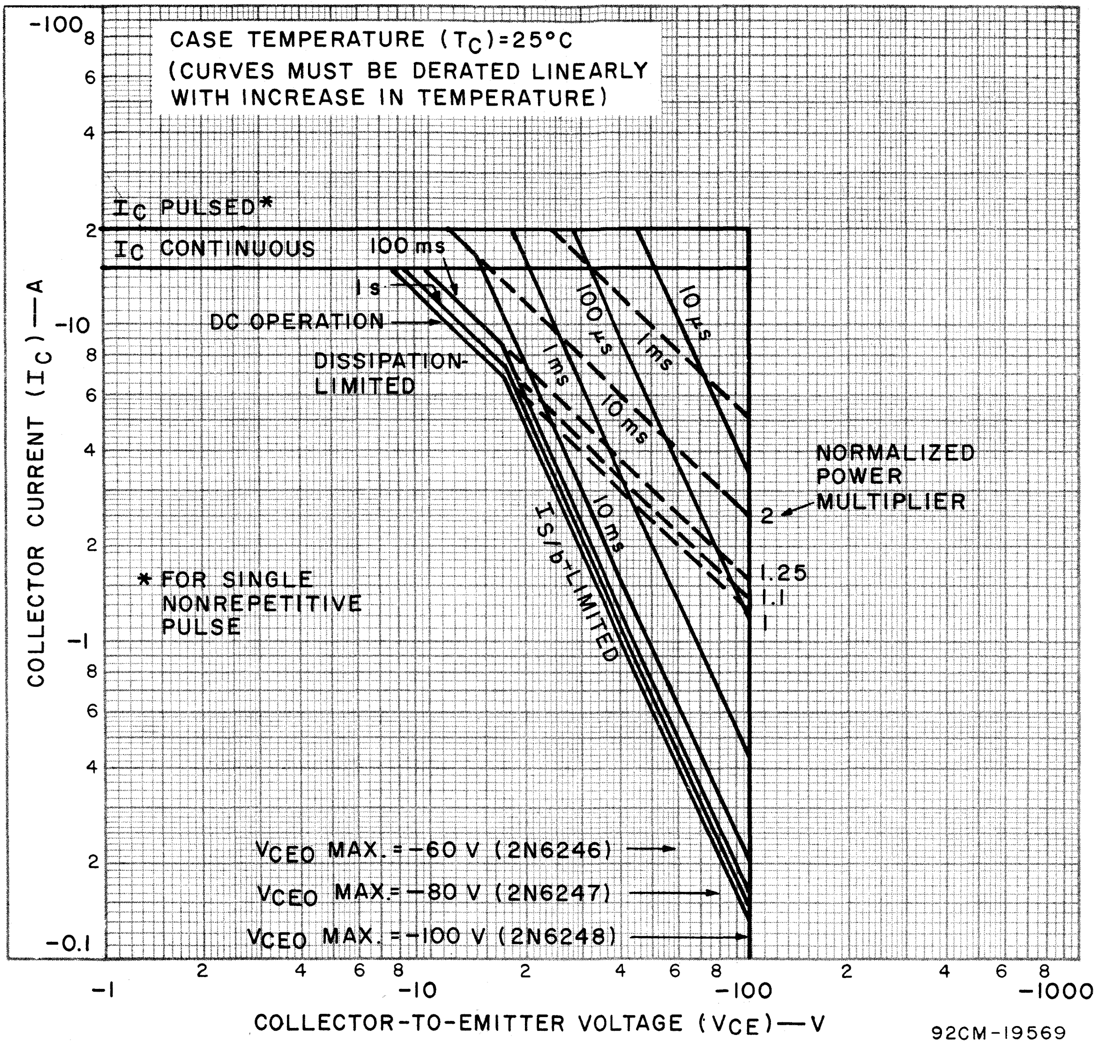


Fig. 1—Maximum operating area for all types.

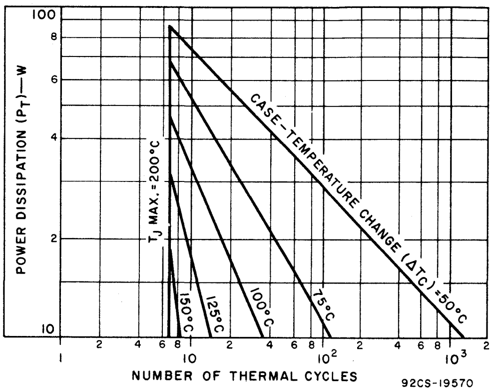


Fig.2—Thermal-cycle rating chart for all types.

The thermal-cycle rating chart is provided to guide the designer in selecting power dissipation and heat-sink parameters to assure freedom from equipment failures caused by transistor thermal fatigue. To utilize these curves, the designer selects the power dissipation and number of thermal cycles required for the application and reads the maximum allowable case-temperature change (ΔT_C) from the chart. He then selects a heat sink which will assure that the required ΔT_C is not exceeded. More detailed information on the interpretation and use of this chart is given in RCA Application Note AN-4612, "Thermal-Cycling Rating System for Silicon Power Transistors", available upon request from RCA Solid State Division, Box 3200, Somerville, N. J. 08876.

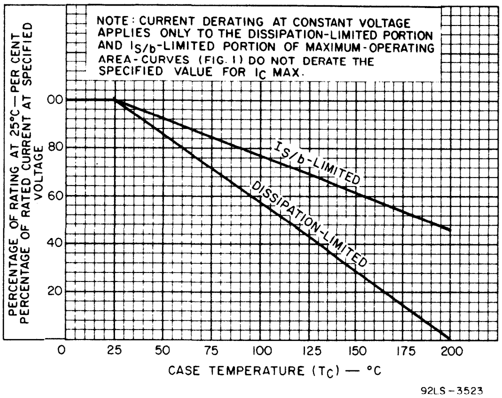


Fig.3—Dissipation and $I_{S/b}$ derating of all types.

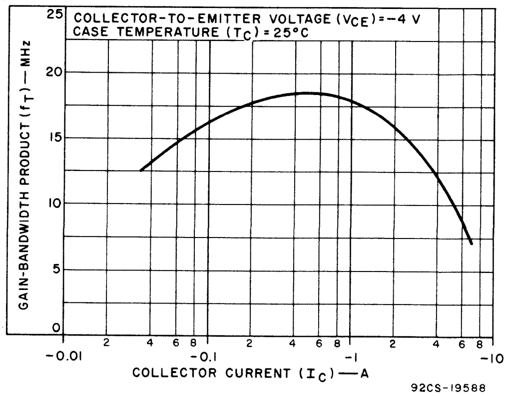


Fig.4—Typical gain-bandwidth product vs. collector current for all types.

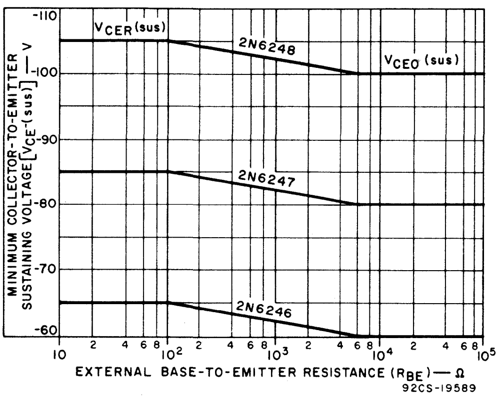


Fig.5—Collector-to-emitter sustaining voltage characteristics for all types.

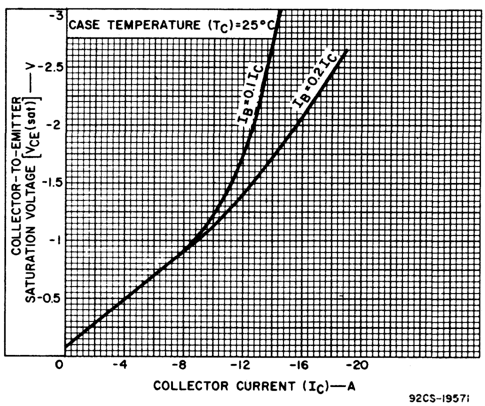


Fig.6—Typical collector-to-emitter saturation voltage vs. collector current for all types.

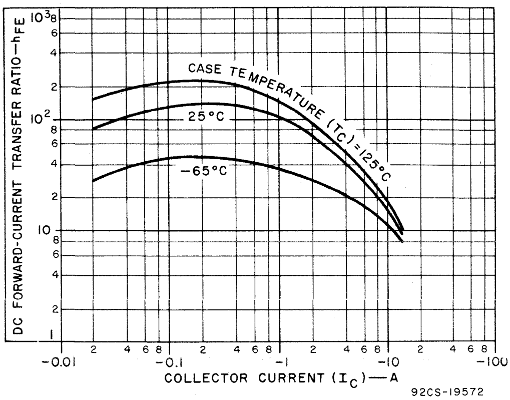


Fig.7—Typical dc beta characteristics of type 2N6248.

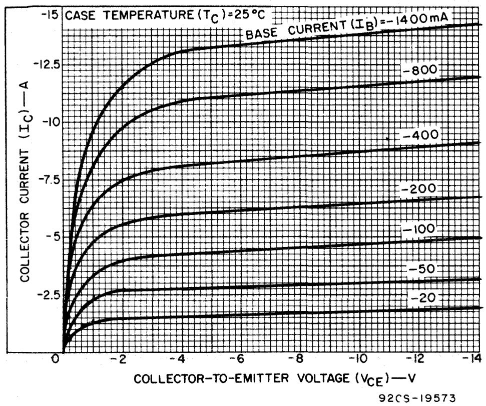


Fig.8—Typical collector characteristics of type 2N6248.

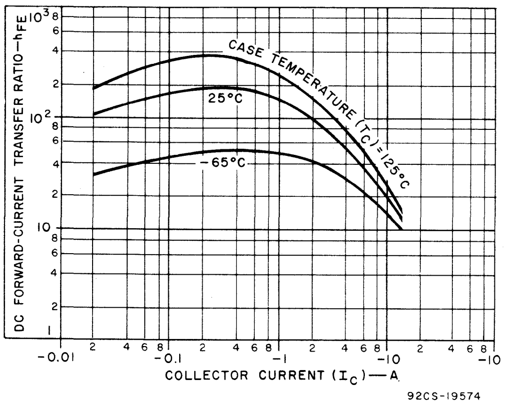


Fig.9—Typical dc beta characteristics of type 2N6247.

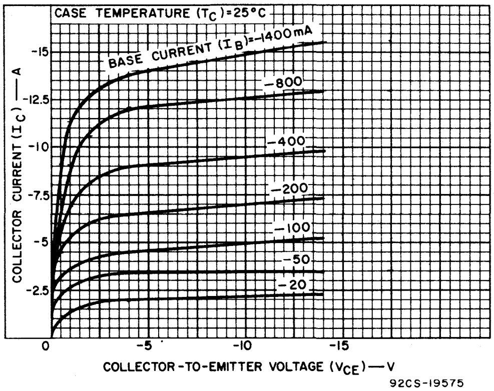


Fig.10—Typical collector characteristics of type 2N6247.

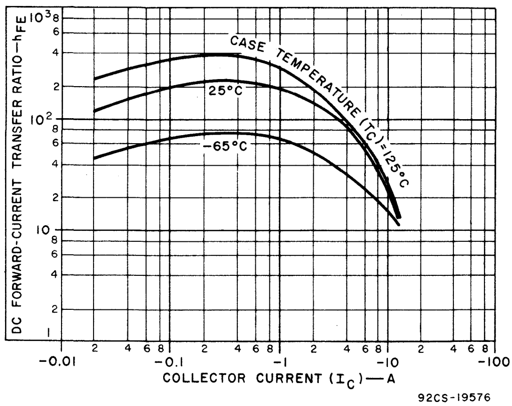


Fig.11—Typical dc beta characteristics of type 2N6246.

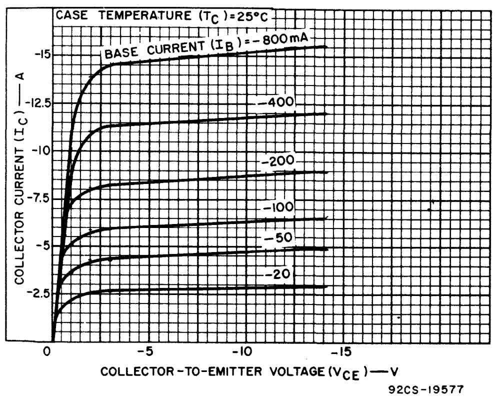


Fig.12—Typical collector characteristics of type 2N6246.

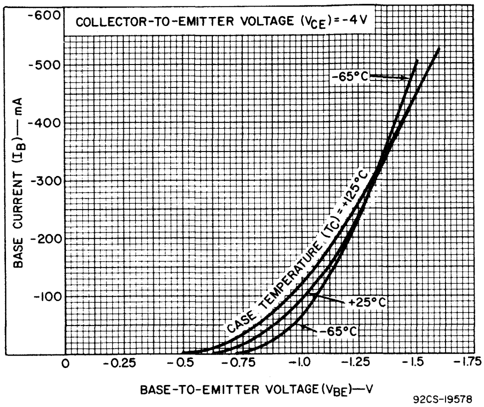


Fig.13—Typical input characteristics of type 2N6248.

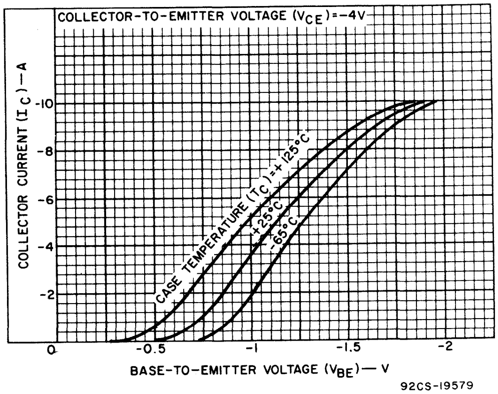


Fig.14—Typical transfer characteristics for all types.

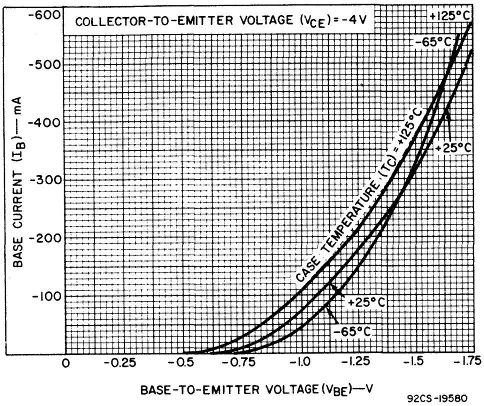


Fig.15—Typical input characteristics of type 2N6247.

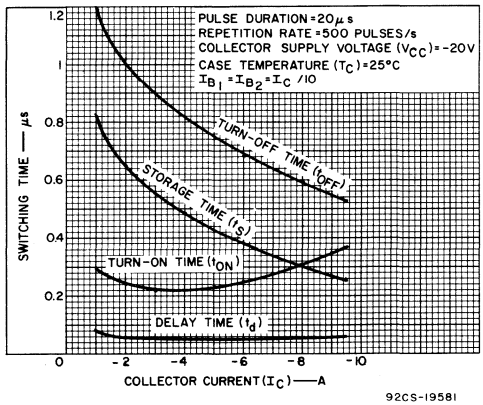


Fig.16—Typical saturated switching characteristics for all types.

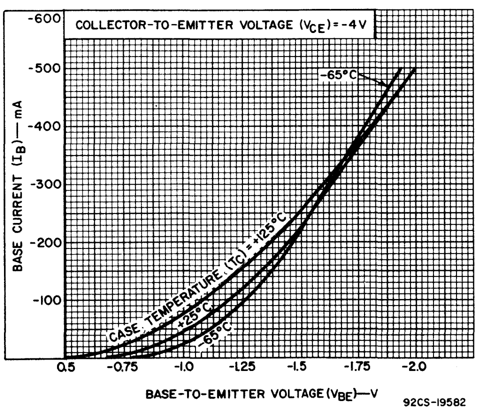


Fig.17—Typical input characteristics of type 2N6246.

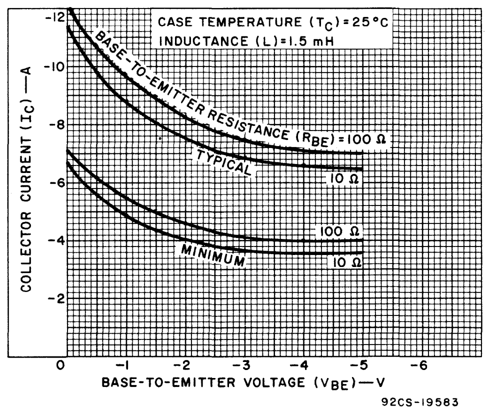


Fig.18—Reverse-bias second-breakdown characteristics for all types.

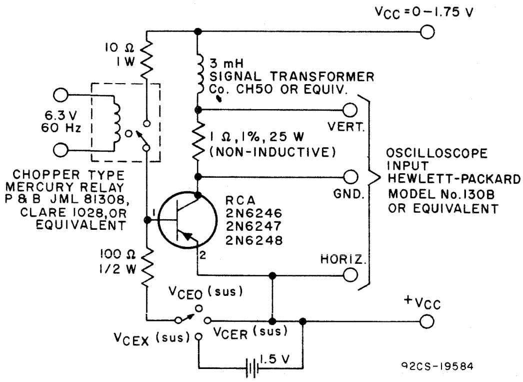
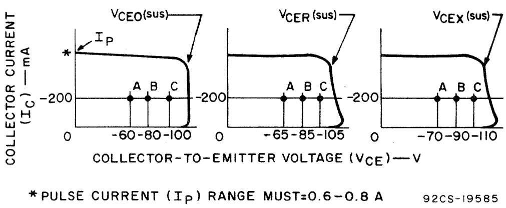


Fig.19—Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ for all types.



The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ are acceptable when the traces fall to the right and above point "A" for type 2N6246; point "B" for type 2N6247; and point "C" for type 2N6248.

Fig.20—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 19).

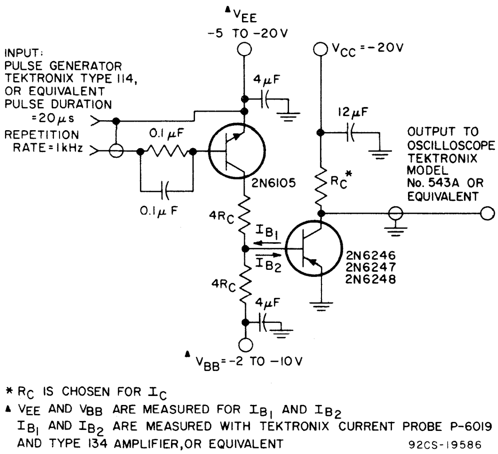


Fig.21—Circuit used to measure saturated switching times.

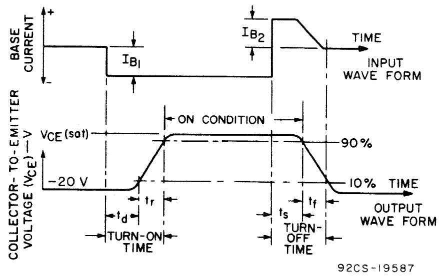


Fig.22—Oscilloscope display for measurement of switching times.

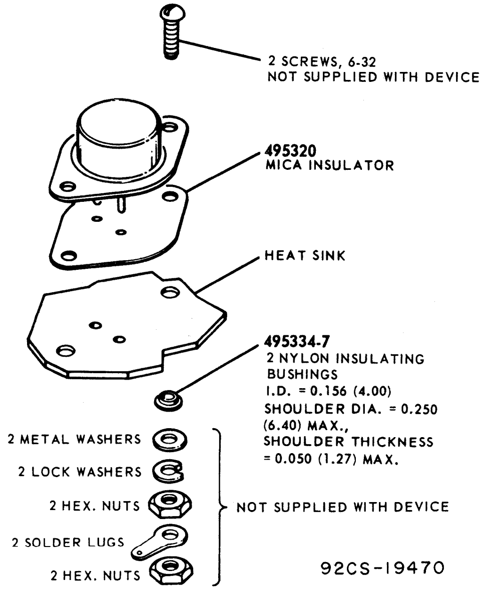
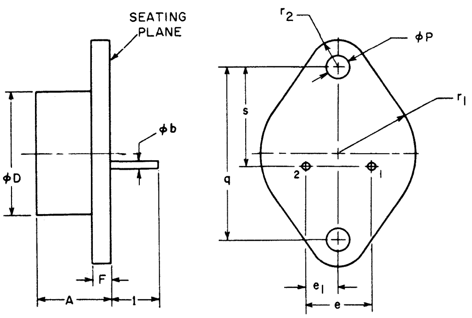


Fig.23—Suggested mounting hardware.

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

NOTES:

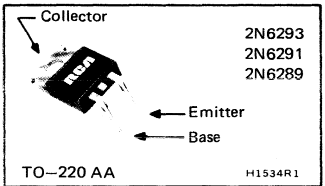
1. **These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.**
2. **Two pins.**

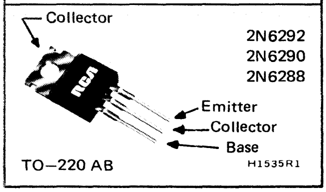
92CS—15222

RCA
Solid State
Division

Power Transistors

2N6288 2N6289 2N6290 2N6291 2N6292 2N6293





Epitaxial-Base, Silicon N-P-N VERSAWATT Transistors

General-Purpose Medium-Power Types for Switching and Amplifier Applications

Features:

- **Low saturation voltage:**
  V_{CE}(sat) = 1 V max. at I_C = 2 A (2N6292, 2N6293)
  1 V max. at I_C = 2.5 A (2N6290, 2N6291)
  1 V max. at I_C = 3 A (2N6288, 2N6289)
- **VERSAWATT package (molded silicone plastic)**
- **Maximum safe-area-of-operation curves specified for dc operation**
- **Complements of p-n-p types in 2N6111 family**

RCA – 2N6288, 2N6289, 2N6290, 2N6291, 2N6292, and 2N6293 are expitaxial-base, silicon n-p-n transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers.

Types 2N6293, 2N6291, and 2N6289 fit into TO-66 sockets. Types 2N6292, 2N6290, and 2N6288 are electrically identical to the 2N6293, 2N6291, and 2N6289, respectively, but they have straight leads for mounting on printed-circuit boards.

These new plastic power transistors differ in voltage ratings and in the currents at which the parameters are controlled.

*Formerly RCA Dev. Nos. TA7784, TA8233, TA7783, TA8232, TA7782, and TA8231, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6288 2N6289	2N6290 2N6291	2N6292 2N6293	
***COLLECTOR-TO-BASE VOLTAGE**	V_{CBO}	40	60	80	V
***COLLECTOR-TO-EMITTER VOLTAGE:**					
With external base-supply resistance (R_{BB}) = 100Ω, and base-supply voltage (V_{BB}) = 0	V_{CEX}	40	60	80	V
With base open	V_{CEO}	30	50	70	V
***EMITTER-TO-BASE VOLTAGE**	V_{EBO}	5	5	5	V
***COLLECTOR CURRENT (Continuous)**					
At case temperature ≤ 106°C	I_C	7	7	7	A
***BASE CURRENT (Continuous)**					
At case temperature ≤ 130°C	I_B	3	3	3	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		40	40	40	W
* At case temperatures up to 100°C		16	16	16	W
At ambient temperatures up to 25°C		1.8	1.8	1.8	W
At case temperatures above 25°C		Derate linearly at 0.32 W/°C, or see Fig. 2.			
* At case temperatures above 100°C		Derate linearly at 0.32 W/°C			
At ambient temperatures above 25°C		Derate linearly at 0.0144 W/°C			
TEMPERATURE RANGE:					
* Storage & Operating (Junction)		← -65 to 150 →			°C
***LEAD TEMPERATURE (During Soldering):**					
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max		← 235 →			°C

* In accordance with JEDEC registration data format (JS-6, RDF-2).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C, Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE (V) V_{CE}	DC EMITTER OR BASE VOLTAGE (V) V_{EB}	DC EMITTER OR BASE VOLTAGE (V) V_{BE}	DC CURRENT (A) I_C	DC CURRENT (A) I_B	LIMITS 2N6292 2N6293 MIN.	LIMITS 2N6292 2N6293 MAX.	LIMITS 2N6290 2N6291 MIN.	LIMITS 2N6290 2N6291 MAX.	LIMITS 2N6288 2N6289 MIN.	LIMITS 2N6288 2N6289 MAX.	UNITS
Collector-Cutoff Current: With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	75 55 35					– – –	0.1 – –	– – –	– 0.1 –	– – –	– – 0.1	mA
	I_{CER} (T_C = 150°C)	70 50 30					– – –	2.0 – –	– – –	– 2.0 –	– – –	– – 2.0	mA
* Collector-Cutoff Current: With base-emitter junction reversed biased	I_{CEV}	75 56 37.5		-1.5 -1.5 -1.5			– – –	0.1 – –	– – –	– 0.1 –	– – –	– – 0.1	mA
*	I_{CEV} (T_C = 150°C)	70 50 30		-1.5 -1.5 -1.5			– – –	2 – –	– – –	– 2 –	– – –	– – 2	mA
* Emitter-Cutoff Current	I_{EBO}		5		0		–	1	–	1	–	1	mA
* Collector-Cutoff Current	I_{CEO}	60 40 20				0 0 0	– – –	1 – –	– – –	– 1 –	– – –	– – 1	mA
* Collector-to-Emitter Breakdown Voltage: With base open	$V_{BR(CEO)}$				0.1	0	70	–	50	–	30	–	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				0.1[a]		80	–	60	–	40	–	V
* DC Forward-Current Transfer Ratio	h_{FE}	4 4 4 4			2.0[a] 2.5[a] 3.0[a] 6.5[a]		30 – – 5	150 – – –	– 30 – 5	– 150 – –	– – 30 5	– – 150 –	
* Base-to-Emitter Voltage	V_{BE}	4 4 4 4			2.0[a] 2.5[a] 3.0[a] 6.5[a]		– – – –	1.5 – – 3	– – – –	– 1.5 – 3	– – – –	– – 1.5 3	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				2.0[a] 2.5[a] 3.0[a] 6.5[a]	0.2 0.25 0.3 1.63	– – – –	1.0 – – 2	– – – –	– 1.0 – 2	– – – –	– – 1.0 2	V
* Small-Signal, Forward-Current Transfer Ratio (f = 50 kHz)	h_{fe}	4			0.5		20	–	20	–	20	–	
Gain-Bandwidth Product	f_T	4			0.5		4	–	4	–	4	–	MHz
* Small-Signal, Forward-Current Transfer Ratio Cutoff Frequency	f_{hfe}	4			0.5		50	–	50	–	50	–	kHz
* Collector-to-Base Capacitance (@ f = 1 MHz)	C_{obo}	10 (V_{CB})			0		–	250	–	250	–	250	pF
Thermal Resistance Junction-to-Case Junction-to-Ambient	$R_{\theta JC}$ $R_{\theta JA}$						–	3.125 70	–	3.125 70	–	3.125 70	°C/W

[a]Pulsed: Pulse duration = 300 μs, duty factor = 0.018.

CAUTION: The sustaining voltages V_{CEO} (sus) and V_{CER} (sus) MUST NOT be measured on a curve tracer.

*In accordance with JEDEC registration data format (JS-6, RDF-2).

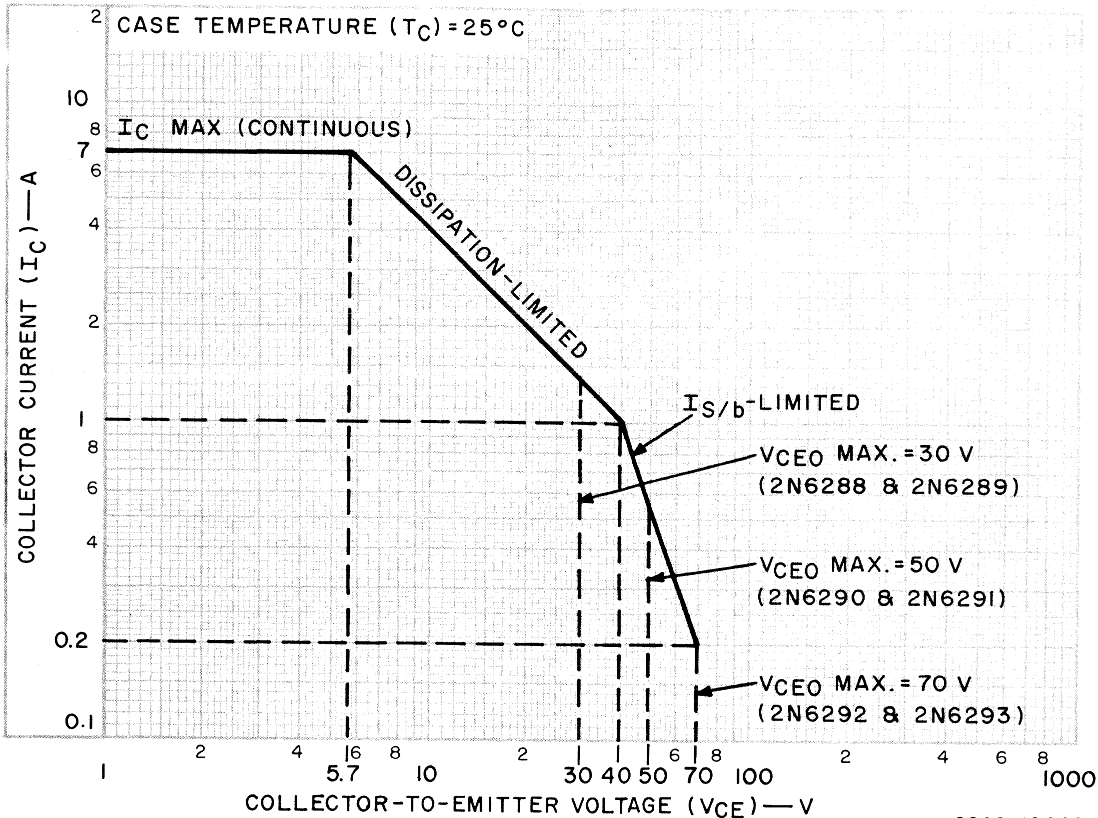


Fig. 1—Maximum operating areas for types 2N6288—2N6293.

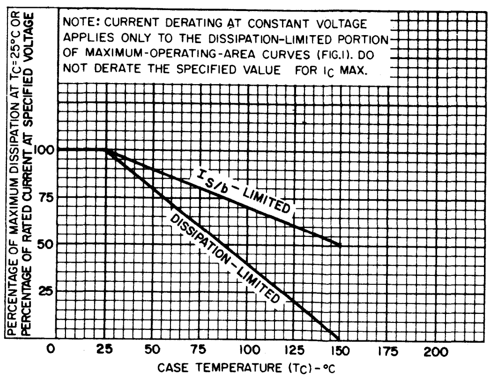


Fig. 2—Derating curves for types 2N6288—2N6293.

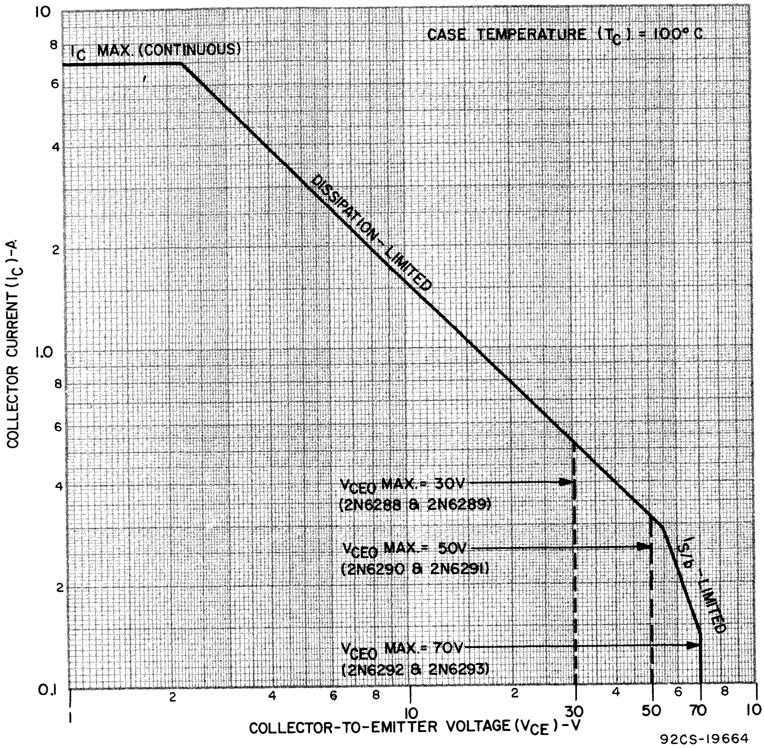


Fig.3—Maximum operating areas for types 2N6288—2N6293.

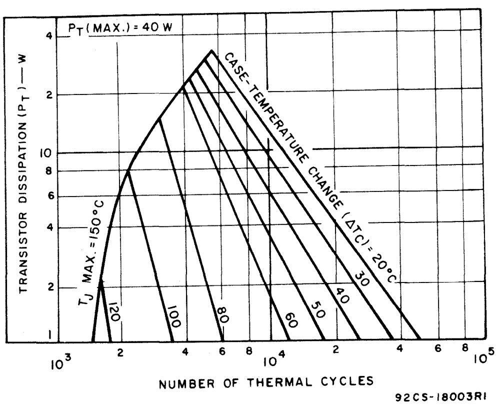


Fig.4—Thermal-cycling ratings for types 2N6288—2N6293.

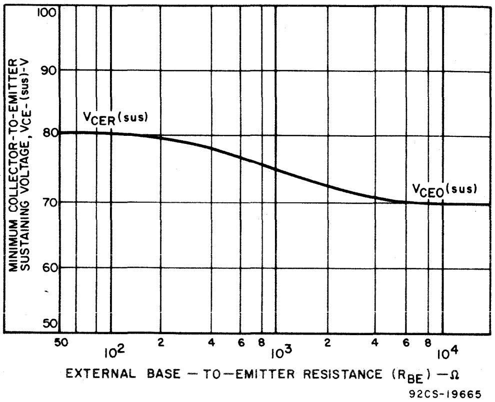


Fig. 5—Collector-to-emitter sustaining-voltage characteristic for types 2N6292 and 2N6293.

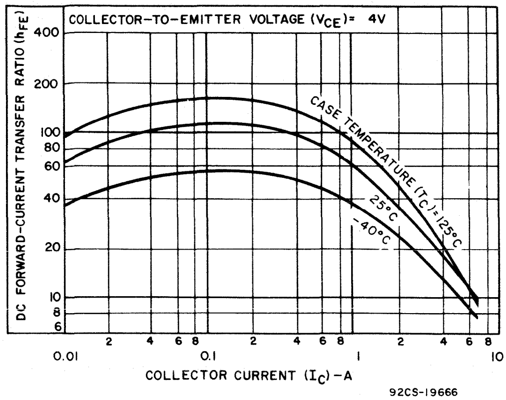


Fig. 6—Typical dc beta characteristics for types 2N6292 and 2N6293.

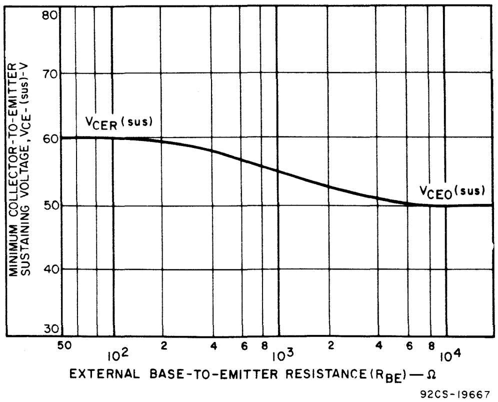


Fig. 7—Collector-to-emitter sustaining-voltage characteristic for types 2N6290 and2N6291.

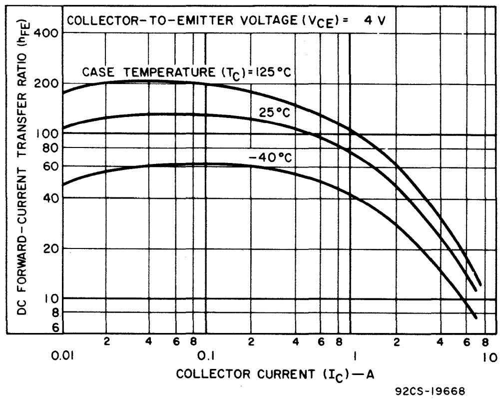


Fig. 8—Typical dc beta characteristics for types 2N6290 and 2N6291.

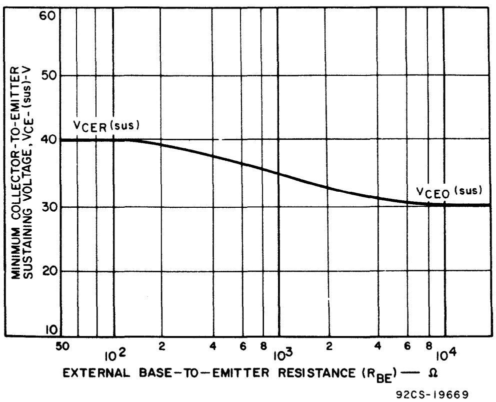


Fig. 9—Collector-to-emitter sustaining-voltage characteristic for types 2N6288 and 2N6289.

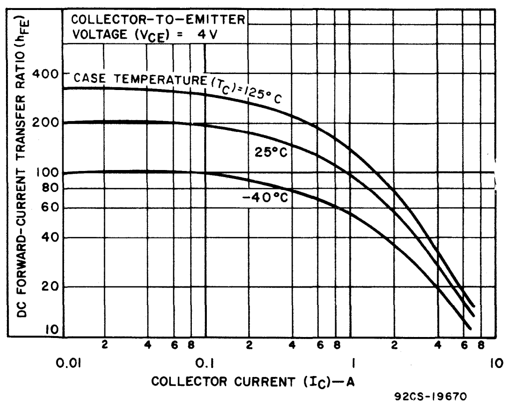


Fig. 10—Typical dc beta characteristics for types 2N6288 and 2N6289.

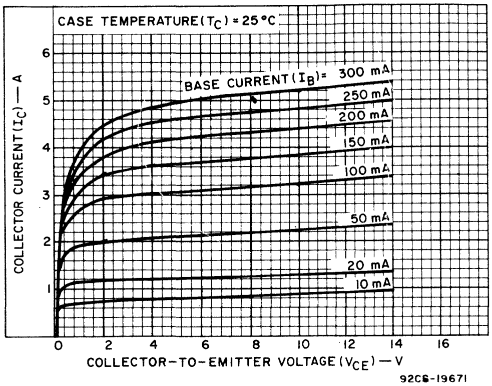


Fig. 11—Typical output characteristics for types 2N6292 and 2N6293.

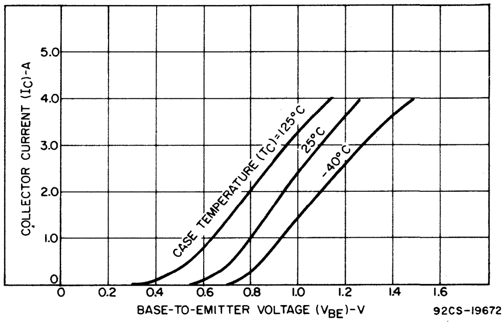


Fig. 12—Typical transfer characteristics of types 2N6288—2N6293.

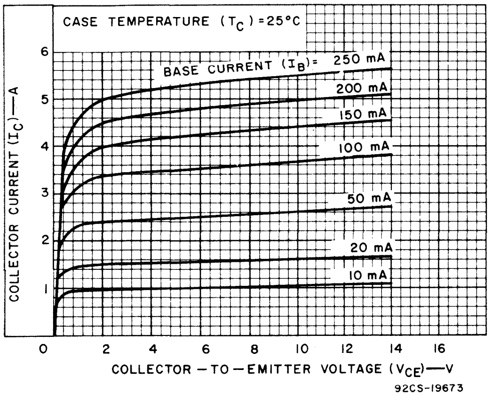


Fig. 13—Typical output characteristics for types 2N6290 and 2N6291.

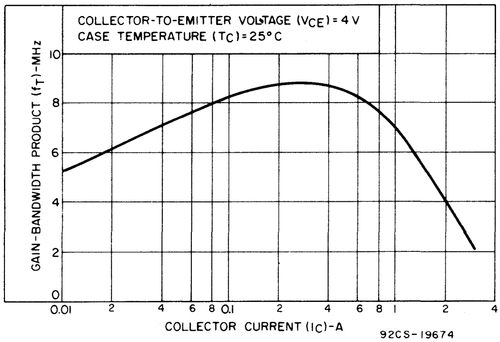


Fig. 14—Typical gain-bandwidth product for types 2N6288—2N6293.

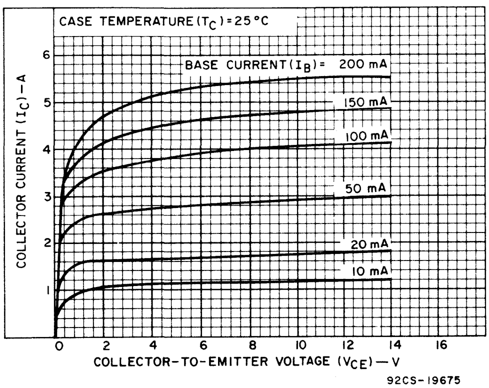


Fig. 15—Typical output characteristics for types 2N6288 and 2N6289.

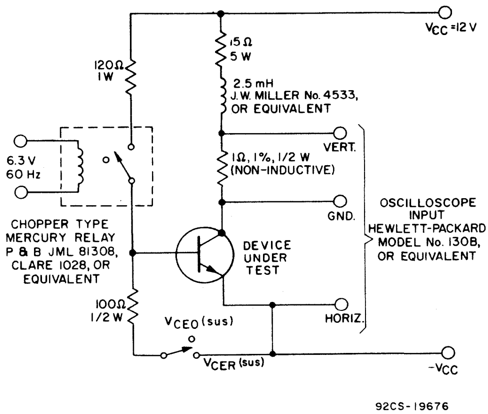
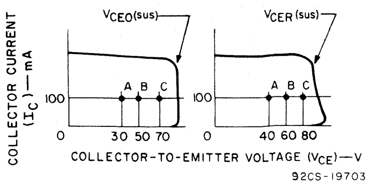


Fig. 16—Circuit used to measure sustaining voltages V_{CEO}(sus) and V_{CER}(sus) for types 2N6288—2N6293.



The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) are acceptable when the traces fall to the right and above point "A" for types 2N6288 and 2N6289, point "B" for types 2N6290 and 2N6291, and point "C" for types 2N6292 and 2N6293.

Fig. 17—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 16).

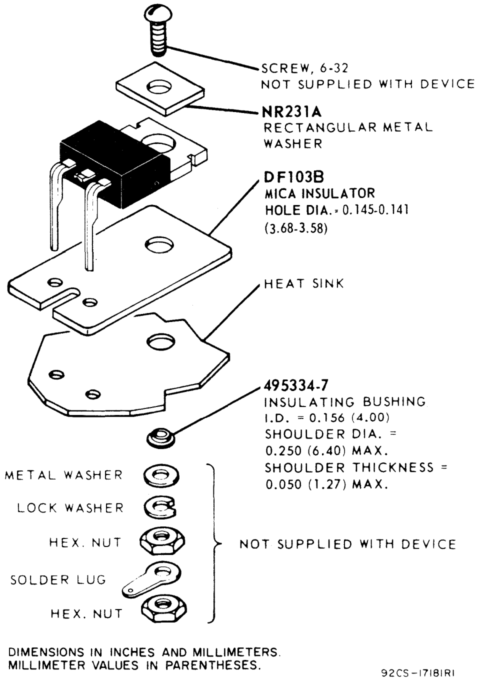


Fig. 18—Suggested mounting hardware for types 2N6293, 2N6291, and 2N6289.

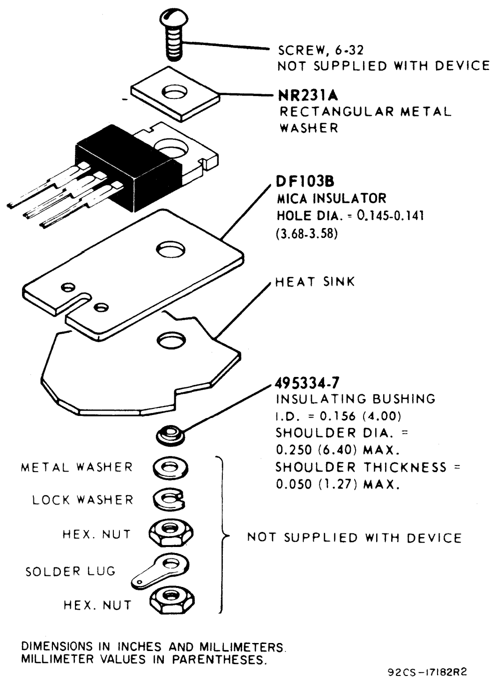
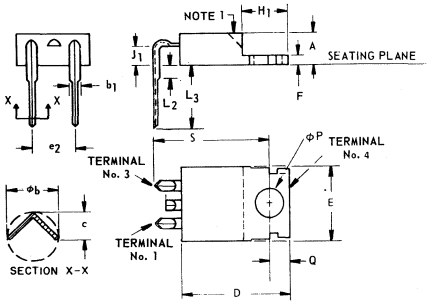


Fig. 19—Suggested mounting hardware for types 2N6292, 2N6290 and 2N6288.

DIMENSIONAL OUTLINE FOR TYPES 2N6293, 2N6291, and 2N6289 (JEDEC TO-220AA)

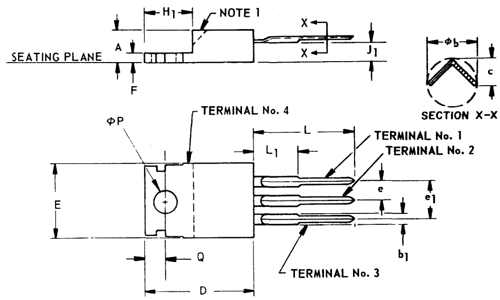


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.02	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L_2	–	0.050	–	1.27	–
L_3	0.360	0.422	9.15	10.71	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–
S	0.580	0.610	14.74	15.49	–

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.050 – 0.055 (1.27 – 1.40 mm) below seating plane.

92CS-17990

DIMENSIONAL OUTLINE FOR TYPES 2N6292, 2N6290, and 2N6288 (JEDEC TO-220AB)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

92CS-17991

TERMINAL CONNECTIONS FOR TYPES 2N6293, 2N6291, and 2N6289

Lead No.1 – Base*
Stub – Do not use stub as tie point.
Lead No.3 – Emitter*
Mounting Flange – Collector

TERMINAL CONNECTIONS FOR TYPES 2N6292, 2N6290, and 2N6288

Lead No.1 – Base*
Lead No.2 – Collector
Lead No.3 – Emitter
Mounting Flange – Collector

*Types are available with base and emitter leads interchanged. Additional information is available from the nearest RCA Solid State Sales Office.

RCA
Solid State
Division

Power Transistors

2N6372 2N6373 2N6374

JEDEC TO-66

H-1340

Silicon N-P-N Medium Power Transistors

General-Purpose Types for
Switching Applications in Military,
Industrial, and Commercial Equipment

Features:

- **Complements to 2N5954 family**
- **Low saturation voltages**
- **Maximum-safe-area-of-operation curves**
- **Thermal-cycle ratings**
- **Hermetically-sealed JEDEC TO-66 package**
- **High min. h_{FE} at high current**

RCA-2N6372, 2N6373, and 2N6374▲ are multiple-epitaxial multiple-diffused n-p-n transistors. They differ in voltage ratings and in the currents at which parameters are controlled.

▲Formerly RCA Dev. Nos. TA8352, TA8353, and TA8354.

Maximum Ratings, *Absolute-Maximum Values:*

		2N6374	2N6373	2N6372	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	70	90	V
COLLECTOR-TO-EMITTER VOLTAGE:					
* With 1.5 volts (V_{BE}) of reverse bias, and external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CEX}	50	70	90	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CER}	45	65	85	V
With base open	V_{CEO}	40	60	80	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	6	6	6	A
* CONTINUOUS BASE CURRENT	I_B	2	2	2	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		40	40	40	W
At case temperatures above 25°C		Derate linearly at 0.228 W/°C, or see Fig.1.			
* TEMPERATURE RANGE:					
Storage & Operating (Junction)		-65 to +200			°C
* PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		+235			°C

* In accordance with JEDEC registration data format (JS-6 RDF-2)

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified*

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS						UNITS
			VOLTAGE V dc			CURRENT A dc		2N6374		2N6373		2N6372		
			V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
*	Collector Cutoff Current: With external base-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	35					-	100	-	-	-	-	μA
			55					-	-	-	100	-	-	
			75					-	-	-	-	-	100	
		I_{CER} (T_C = 150°C)	35					-	2	-	-	-	-	mA
			55					-	-	-	2	-	-	
			75					-	-	-	-	-	2	
	With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CEX}	45		-1.5			-	100	-	-	-	-	μA
			65		-1.5			-	-	-	100	-	-	
			85		-1.5			-	-	-	-	-	100	
		I_{CEX} (T_C = 150°C)	45		-1.5			-	2	-	-	-	-	mA
			65		-1.5			-	-	-	2	-	-	
			85		-1.5			-	-	-	-	-	2	
*	Collector Cutoff Current	I_{CEO}	25					-	1	-	-	-	-	mA
			45					-	-	-	1	-	-	
			65					-	-	-	-	-	1	
*	Emitter Cutoff Current	I_{EBO}		5				-	0.1	-	0.1	-	0.1	mA
*	DC Forward-Current Transfer Ratio	h_{FE}	4			3[a]		20	100	-	-	-	-	
			4			2.5[a]		-	-	20	100	-	-	
			4			2[a]		-	-	-	-	20	100	
			4			6[a]		5	-	5	-	5	-	
*	Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$				0.1		40[b]	-	60[b]	-	80[b]	-	V
	With external base-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$				0.1		45[b]	-	65[b]	-	85[b]	-	V
	With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CEX}(sus)$			-1.5	0.1		50[b]	-	70[b]	-	90[b]	-	V
*	Base-to-Emitter Voltage	V_{BE}	4			3[a]		—	2	—	—	—	—	V
			4			2.5[a]		—	—	—	2	—	—	
			4			2[a]		—	—	—	—	—	2	
			4			6[a]		—	3	—	3	—	3	
*	Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				3[a]	0.3	-	1	-	-	-	-	V
						2.5[a]	0.25	-	-	-	1	-	-	
						2[a]	0.2	-	-	-	-	-	1	
						6[a]	1.2	-	2	-	2	-	2	
*	Common-Emitter Small Signal Current Transfer Ratio	$\|h_{fe}\|$ at f = 1 kHz	4			0.5		25	-	25	-	25	-	
*	Gain-Bandwidth Product	f_T at f=1 MHz	4			1		4	-	4	-	4	-	MHz
	Thermal Resistance (Junction-to-case)	$R_{\theta JC}$						-	4.3	-	4.3	-	4.3	°C/W

[a] Pulsed; pulse duration = 300 μs, duty factor = 1.8%.

[b] *CAUTION: Sustaining voltages V_{CEO} (sus), V_{CER} (sus), and V_{CEX} (sus) MUST NOT be measured on a curve tracer.*

* In accordance with JEDEC registration data format JS-6 RDF-2.

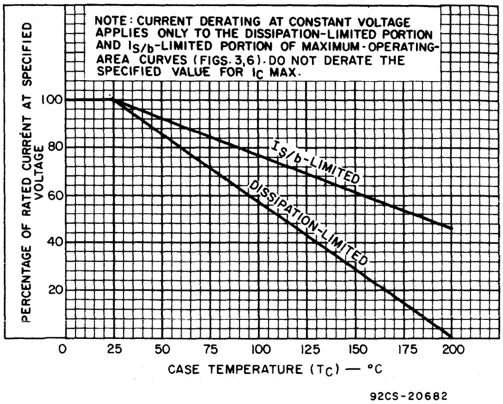


Fig.1 — Derating curves for all types.

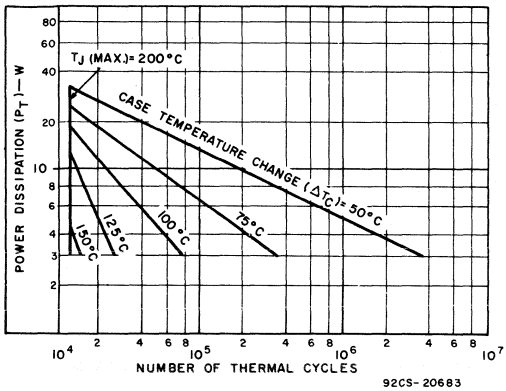


Fig.2 — Thermal-cycle ratings for all types.

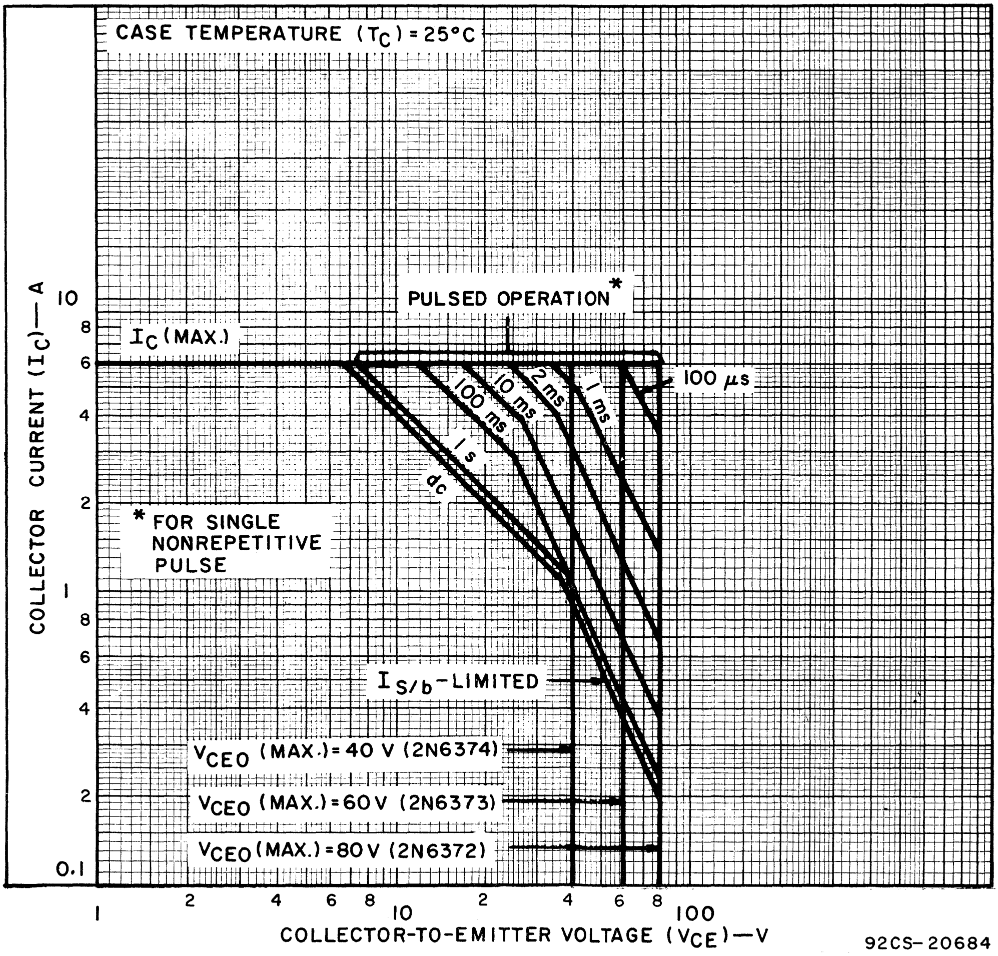


Fig.3 — Maximum safe area of operation for all types, at case temperature of 25°C.

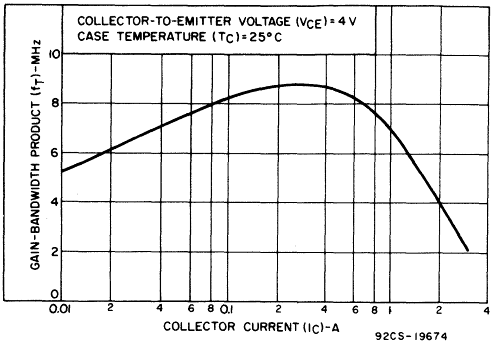


Fig.4 — Typical gain-bandwidth product for all types.

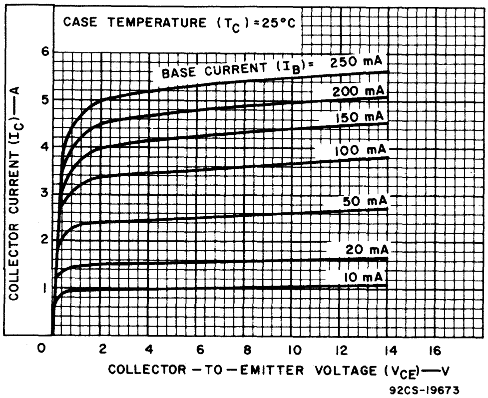


Fig.5 — Typical collector characteristics for all types.

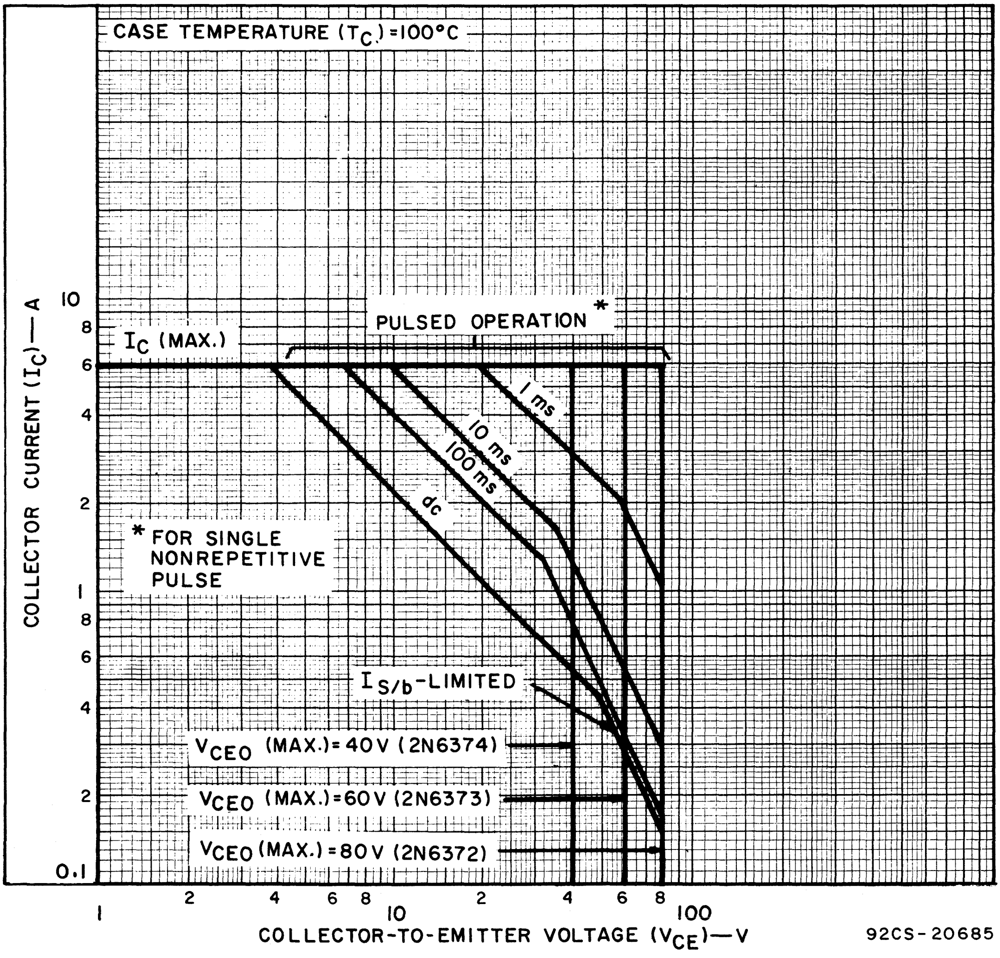


Fig.6 — Maximum safe area of operation for all types, at case temperature of 100°C.

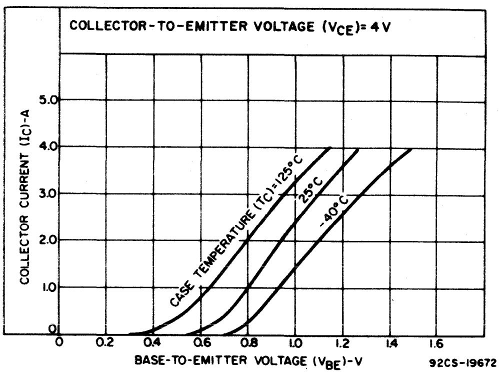


Fig.7 — Typical transfer characteristics for all types.

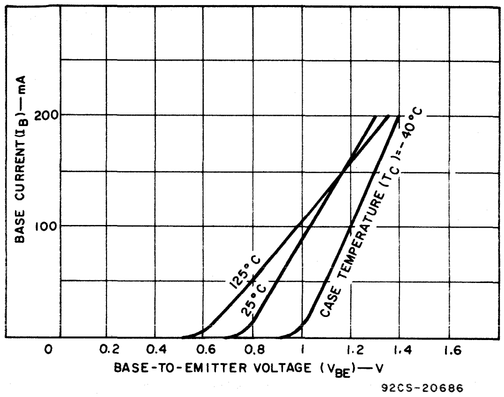


Fig.8 — Typical input characteristics for all types.

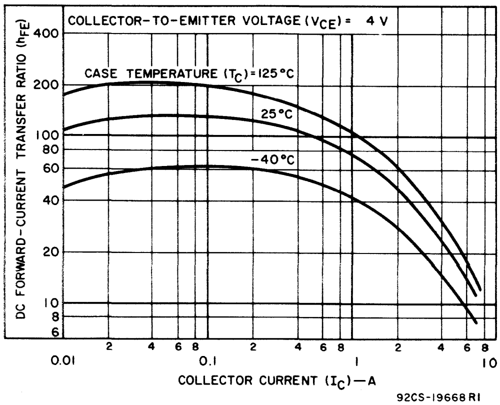


Fig.9 — Typical dc beta characteristics for all types.

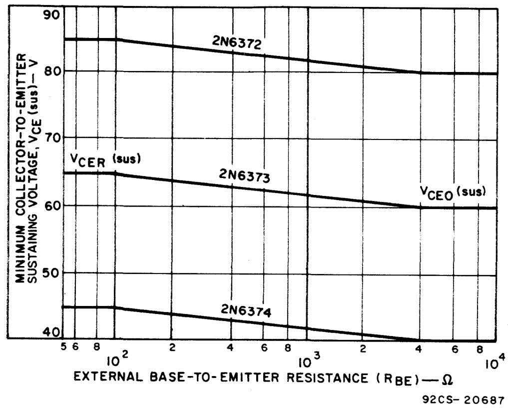


Fig.10 — Collector-to-emitter sustaining-voltage characteristics for all types.

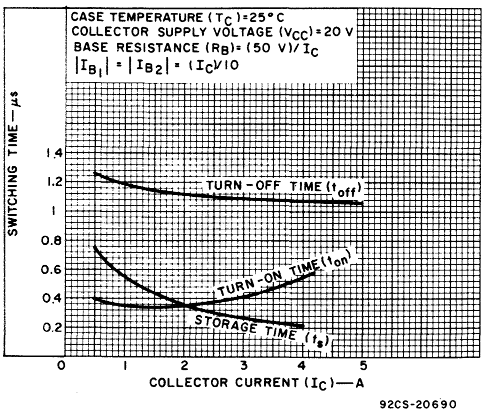


Fig.11 — Typical saturated switching characteristics for all types. (See Fig.13 for specifications of switching times).

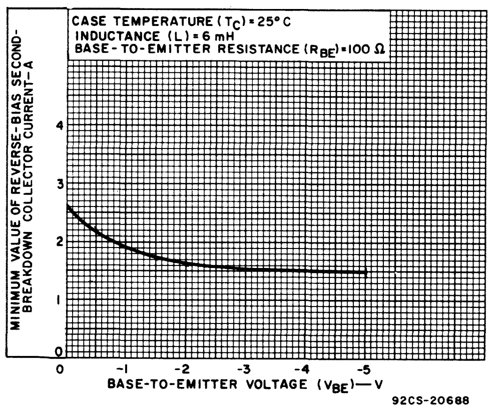
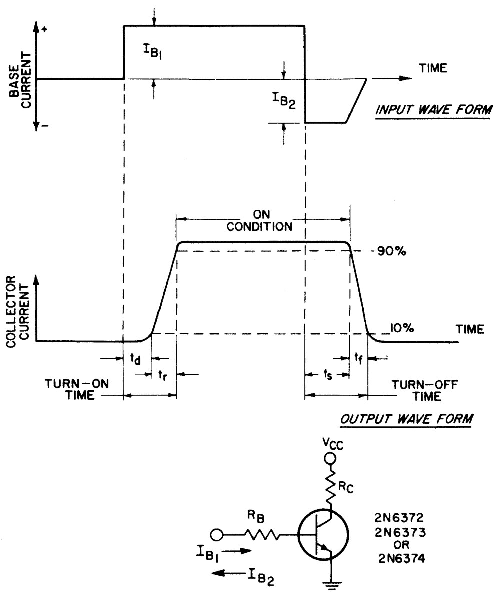
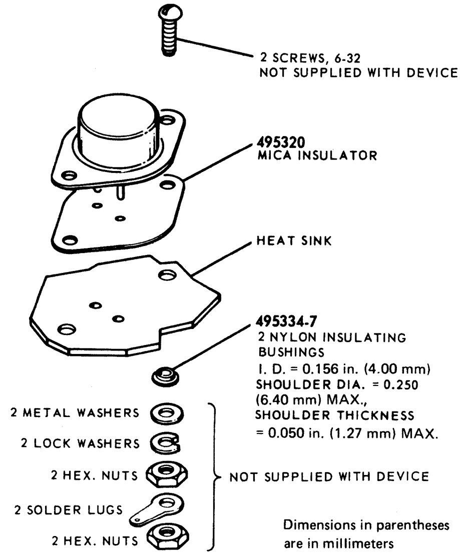


Fig.12 — Reverse-bias second-breakdown characteristic for all types.



92CS-20689

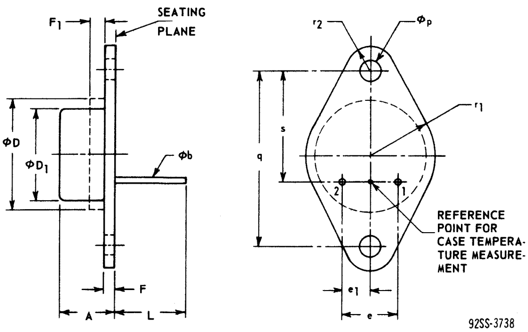
Fig.13 — Specifications of switching times.



92CS-19470

Fig.14 — Suggested hardware for all types.

DIMENSIONAL OUTLINE
JEDEC TO-66



92SS-3738

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD		0.620		15.75	
ϕD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1		0.050		1.27	1
L	0.360		9.14		
ϕp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r_1		0.350		8.89	
r_2		0.145		3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimension does not include sealing flange.

TERMINAL CONNECTIONS

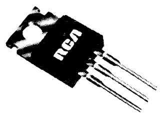
Pin 1 — Base
Pin 2 — Emitter
Case, Mounting Flange — Collector

RCA

Solid State
Division

Power Transistors

RCA29 RCA29B
RCA29A RCA29C



JEDEC TO-220 AB H-1535

Epitaxial-Base, Silicon N-P-N VERSAWATT Transistors

For Power-Amplifier and
High-Speed-Switching Applications

Features:

- **30 W at 25°C case temperature**
- **3 A rated collector current**
- **Min. f_T of 3 MHz at 10 V, 200 mA**
- **Designed for complementary use with RCA30, RCA30A, RCA30B, and RCA30C p-n-p types**

RCA29, RCA29A, RCA29B, and RCA29C are epitaxial-base, silicon n-p-n transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers. These new plastic power transistors are designed for complementary use with devices in the RCA30 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA29	RCA29A	RCA29B	RCA29C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	60	80	100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CEO}	40	60	80	100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	3	3	3	3	A
*CONTINUOUS BASE CURRENT	I_B	1	1	1	1	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		30	30	30	30	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage & Operating (Junction)		← -65 to 150 →				°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →				°C

*Differs from TIP series

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS								UNITS
		DC VOLTAGE (V)			DC CURRENT (A)		RCA29		RCA29A		RCA29B		RCA29C		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}	30				0	–	0.3	–	0.3	–	–	–	–	mA
		60				0	–	–	–	–	–	0.3	–	0.3	
With base-emitter junction short-circuited	I_{CES}	40		0			–	0.2	–	–	–	–	–	–	
		60		0			–	–	–	0.2	–	–	–	–	
		80		0			–	–	–	–	–	0.2	–	–	
		100		0			–	–	–	–	–	–	–	0.2	
Emitter-Cutoff Current	I_{EBO}		5		0		–	1	–	1	–	1	–	1	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{BR(CEO)}$				0.03[a]	0	40	–	60	–	80	–	100	–	V
DC Forward-Current Transfer Ratio	h_{FE}	4			0.2[a]		40	–	40	–	40	–	40	–	
		4			1[a]		15	75	15	75	15	75	15	75	
Base-to-Emitter Voltage	V_{BE}	4			1[a]		–	1.3	–	1.3	–	1.3	–	1.3	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				1[a]	0.125	–	0.7	–	0.7	–	0.7	–	0.7	V
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	10			0.2		20	–	20	–	20	–	20	–	
Magnitude of Common Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10			0.2		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 30 Ω) See Figs. 2 & 3 Turn-on time $t_d + t_r$	t_{ON}	(V_{CC}) 30			1	0.1[c]	0.5 (typ.)		0.5 (typ.)		(0.5 (typ.)		0.5 (typ.)		µs
Turn-off time $t_s + t_f$	t_{OFF}	(V_{CC}) 30			1	0.1[c]	2 (typ.)		2 (typ.)		2 (typ.)		2 (typ.)		
Unclamped Inductive Load Energy[b] (L = 20 mH) See Fig. 4		(V_{CC}) 10					–	32	–	32	–	32	–	32	mJ
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	4.17	–	4.17	–	4.17	–	4.17	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	

[a]Pulsed: Pulse duration = 300 µs, duty factor = 2%

[b]Based upon ability of device to perform in circuit shown in Fig. 4.

[c]$I_{B_1} = I_{B_2}$ = value shown.

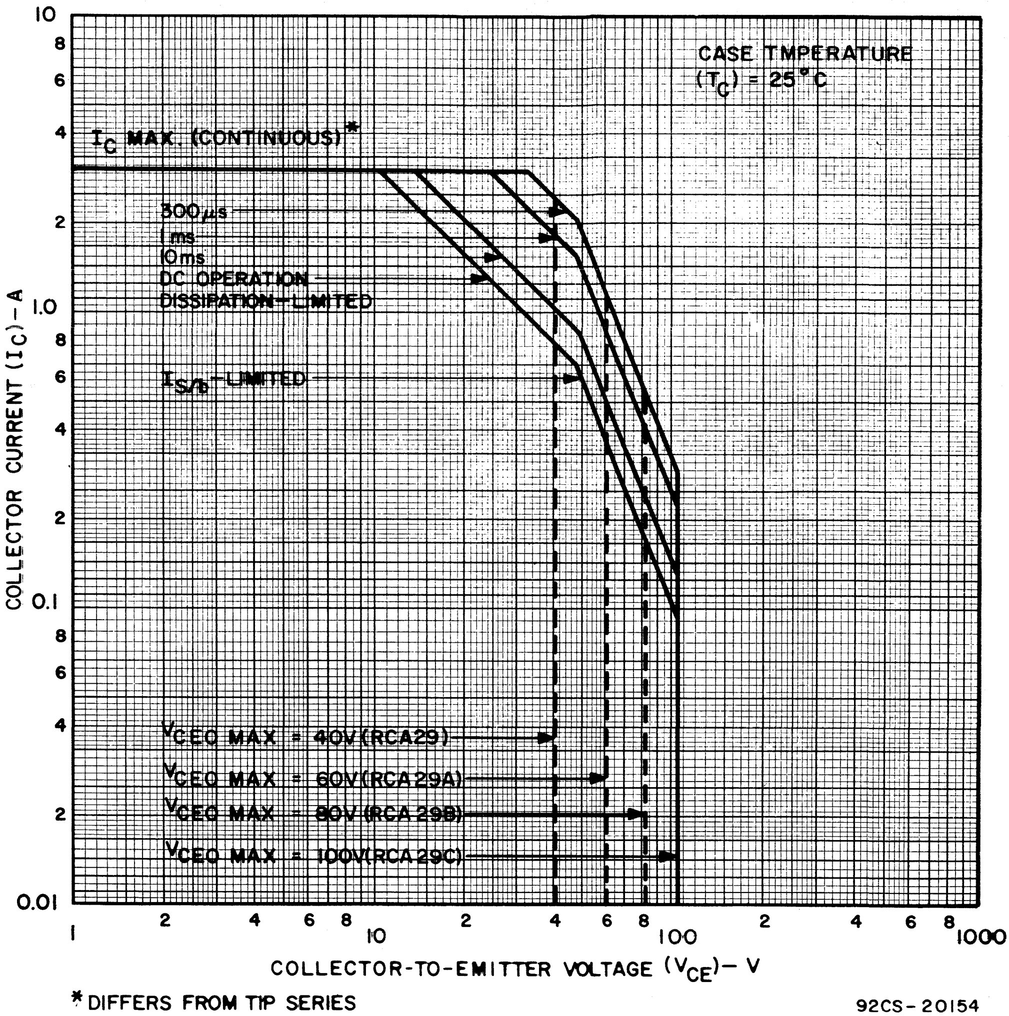


Fig. 1—Maximum safe operating areas for all types

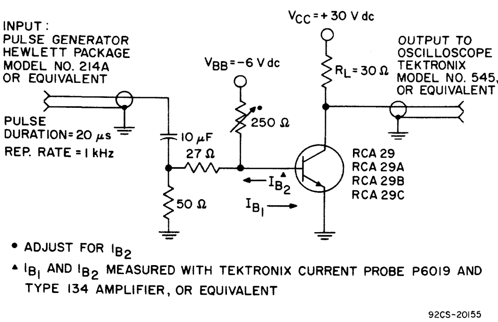


Fig. 2—Circuit used to measure switching times for all types

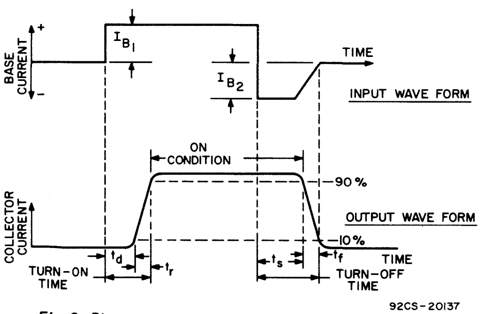


Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2)

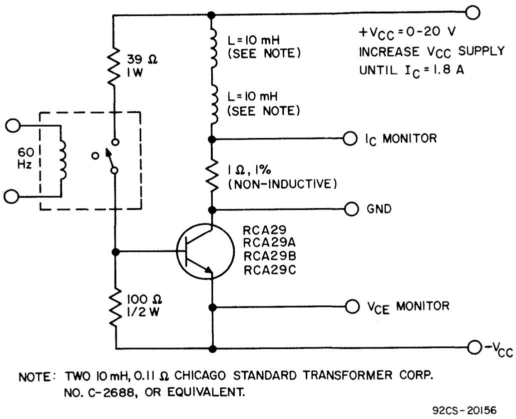


Fig. 4—Circuit for measuring inductive-load switching for all types

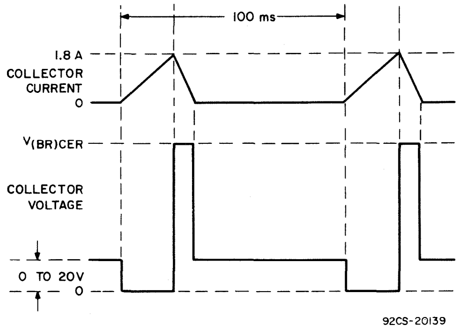


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4)

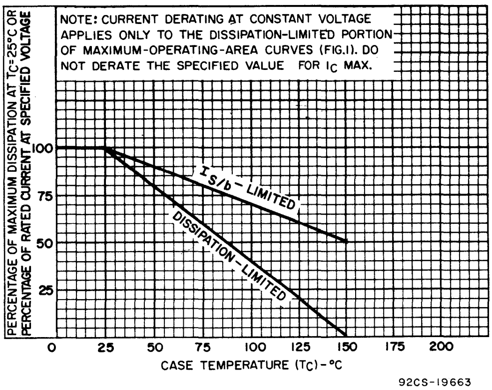


Fig. 6—Derating curves for all types

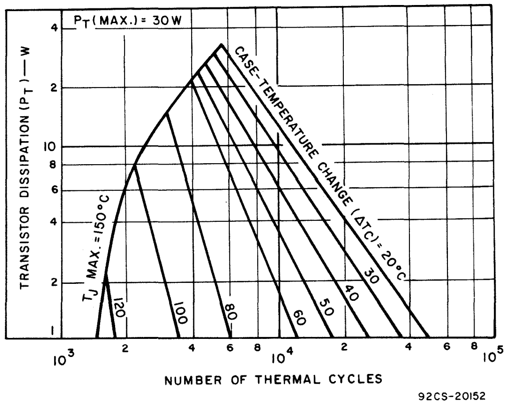


*Fig. 7—Thermal-cycling ratings for all types**

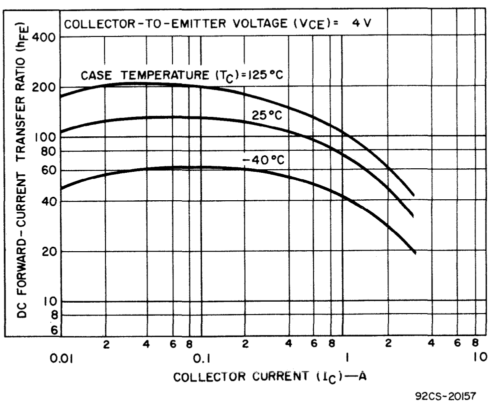
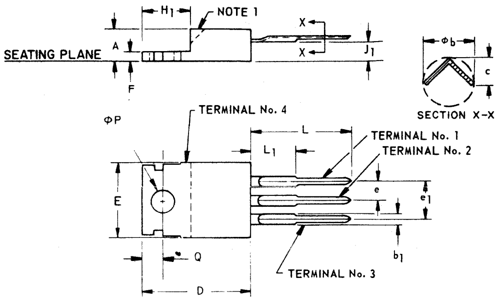


*Fig. 8—Typical dc beta characteristics for all types**

*Differs from TIP series

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

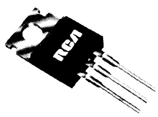
TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange, Lead No. 4 – Collector

RCA Solid State Division

Power Transistors

RCA30 RCA30B
RCA30A RCA30C



JEDEC TO-220 AB H-1535

Epitaxial-Base, Silicon P-N-P VERSAWATT Transistors

For Power-Amplifier and High-Speed-Switching Applications

Features:

- **30 W at 25°C case temperature**
- **3 A rated collector current**
- **Min. f_T of 3 MHz at 10 V, 200 mA**
- **Designed for complementary use with RCA29, RCA29A, RCA29B, and RCA29C n-p-n types**

RCA30, RCA30A, RCA30B, and RCA30C are epitaxial-base, silicon p-n-p transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers.

These new plastic power transistors are designed for complementary use with devices in the RCA29 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		RCA30	RCA30A	RCA30B	RCA30C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-40	-60	-80	-100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CEO}	-40	-60	-80	-100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-5	-5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	-3	-3	-3	-3	A
*CONTINUOUS BASE CURRENT	I_B	-1	-1	-1	-1	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		30	30	30	30	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage and Operating (Junction)		← -65 to 150 →				°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →				°C

*Differs from TIP series

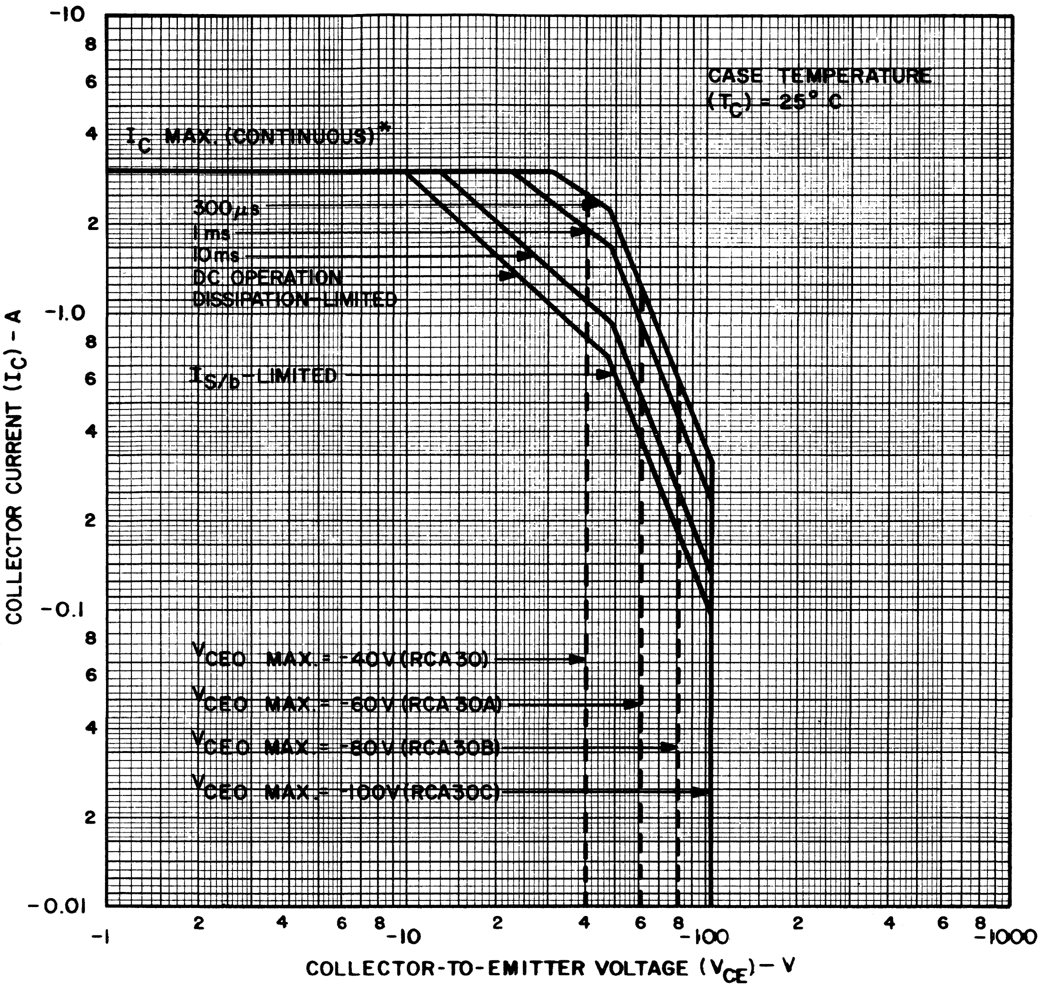
ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS								UNITS
		DC VOLTAGE (V)			DC CURRENT (A)		RCA30		RCA30A		RCA30B		RCA30C		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}	-30				0	–	-0.3	–	-0.3	–	–	–	–	
		-60				0	–	–	–	–	–	-0.3	–	-0.3	
With base emitter junction short-circuited	I_{CES}	-40		0			–	-0.2	–	–	–	–	–	–	mA
		-60		0			–	–	–	-0.2	–	–	–	–	
		-80		0			–	–	–	–	–	-0.2	–	–	
		-100		0			–	–	–	–	–	–	–	-0.2	
Emitter-Cutoff Current	I_{EBO}		-5		0		–	-1	–	-1	–	-1	–	-1	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{BR(CEO)}$				-0.03[a]	0	-40	–	-60	–	-80	–	-100	–	V
DC Forward-Current Transfer Ratio	h_{FE}	-4			-0.2[a]		40	–	40	–	40	–	40	–	
		-4			-1[a]		15	75	15	75	15	75	15	75	
Base-to-Emitter Voltage	V_{BE}	-4			-1[a]		–	-1.3	–	-1.3	–	-1.3	–	-1.3	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				-1[a]	-0.125	–	-0.7	–	-0.7	–	-0.7	–	-0.7	V
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	-10			-0.2		20	–	20	–	20	–	20	–	
Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Radio (f = 1 MHz)	$\|h_{fe}\|$	-10			-0.2		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 30 Ω) See Figs. 2 & 3															
Turn-on time $t_d + t_r$	t_{ON}	(V_{CC}) -30			-1	-0.1[c]	0.3 (typ.)		0.3 (typ.)		0.3 (typ.)		0.3 (typ.)		µs
Turn-off time $t_s + t_f$	t_{OFF}	(V_{CC}) -30			-1	-0.1[c]	1 (typ.)		1 (typ.)		1 (typ.)		1 (typ.)		
Unclamped Inductive Load Energy[b] (L = 20 mH) See Fig. 4		(V_{CC}) -10					–	32	–	32	–	32	–	32	mJ
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	4.17	–	4.17	–	4.17	–	4.17	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	

[a] Pulsed: Pulse duration = 300 µs, duty factor = 2%

[b] Based upon ability of device to perform in circuit shown in Fig. 4.

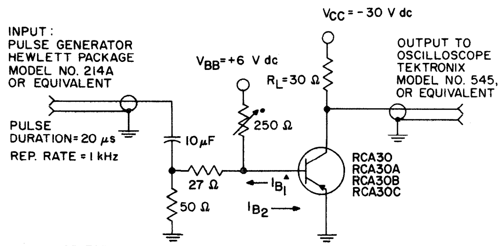
[c] $I_{B1} = I_{B2}$ = value shown.



*DIFFERS FROM TIP SERIES

92CS-20149

Fig. 1—Maximum safe operating areas for all types.

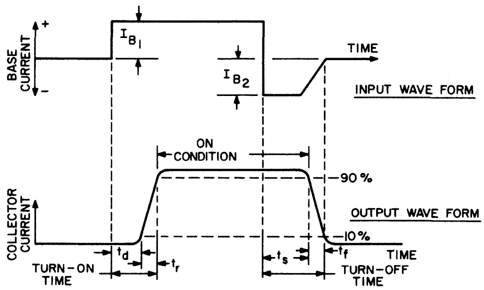


• ADJUST FOR I_{B_2}

▲ I_{B_1} AND I_{B_2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 AND TYPE 134 AMPLIFIER, OR EQUIVALENT

92CS-20150

Fig. 2—Circuit used to measure switching times for all types.



92CS-20137

Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2).

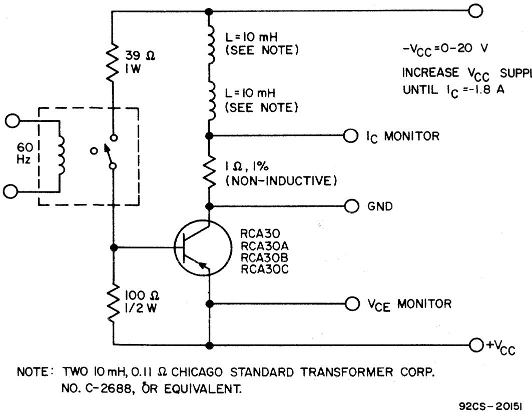


Fig. 4—Circuit for measuring inductive-load switching for all types.

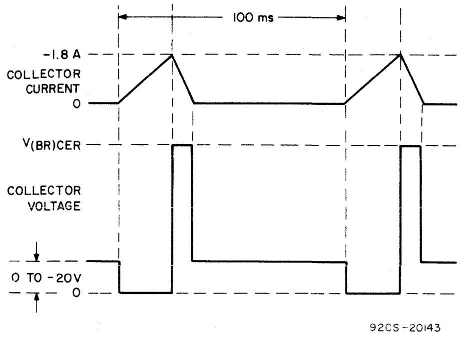


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4).

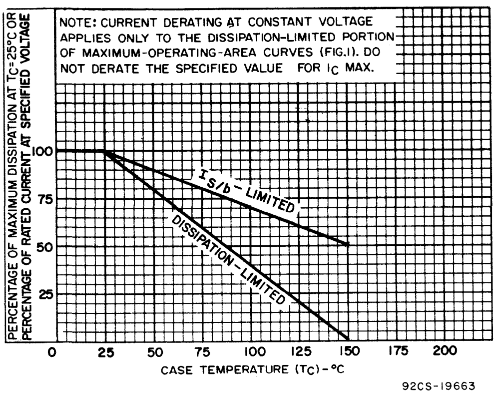


Fig. 6—Derating curves for all types.

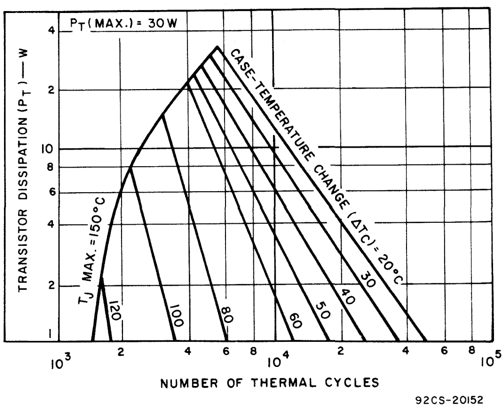


Fig. 7—Thermal cycling ratings for all types.*

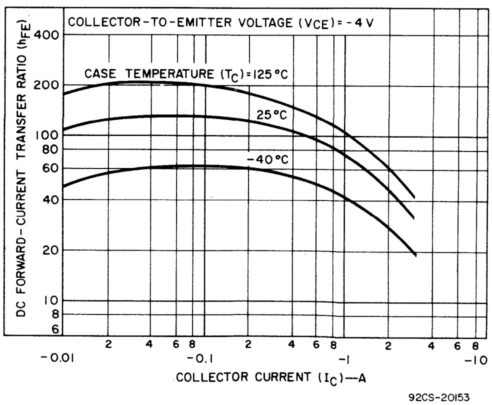
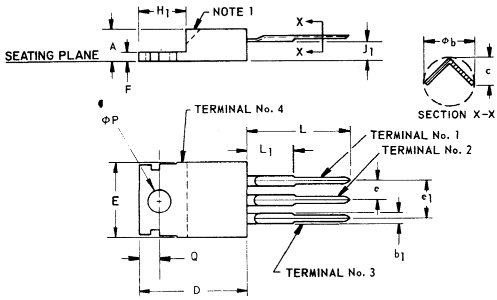


Fig. 8—Typical dc beta characteristics for all types.*

*Differs from TIP series

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

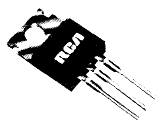
TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange, Lead No. 4 – Collector

Solid State Division

Power Transistors

RCA31 RCA31B RCA31A RCA31C



JEDEC TO-220 AB H-1535

Epitaxial-Base, Silicon N-P-N VERSAWATT Transistors

For Power-Amplifier and High-Speed-Switching Applications

Features:

- **40 W at 25°C case temperature**
- **5 A rated collector current**
- **Min. f_T of 3 MHz at 10 V, 500 mA**
- **Designed for complementary use with RCA32, RCA32A, RCA32B, and RCA32C p-n-p types**

RCA31, RCA31A, RCA31B, and RCA31C are epitaxial-base, silicon n-p-n transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers. These new plastic power transistors are designed for complementary use with devices in the RCA32 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		RCA31	RCA31A	RCA31B	RCA31C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	60	80	100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CEO}	40	60	80	100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	5	5	5	5	A
*CONTINUOUS BASE CURRENT	I_B	1	1	1	1	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		40	40	40	40	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage and Operating (Junction)		← −65 to 150 →				°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →				°C

*Differs from TIP series

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE (V) V_{CE}	V_{EB}	V_{BE}	DC CURRENT (A) I_C	I_B	LIMITS: RCA31 MIN.	RCA31 MAX.	RCA31A MIN.	RCA31A MAX.	RCA31B MIN.	RCA31B MAX.	RCA31C MIN.	RCA31C MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}	30				0	–	0.3	–	0.3	–	–	–	–	mA
		60				0	–	–	–	–	–	0.3	–	0.3	
With base-emitter junction short-circuited	I_{CES}	40		0			–	0.2	–	–	–	–	–	–	
		60		0			–	–	–	0.2	–	–	–	–	
		80		0			–	–	–	–	–	0.2	–	–	
		100		0			–	–	–	–	–	–	–	0.2	
Emitter-Cutoff Current	I_{EBO}		5		0		–	1	–	1	–	1	–	1	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{BR(CEO)}$				0.03[a]	0	40	–	60	–	80	–	100	–	V
DC Forward-Current Transfer Ratio	h_{FE}	4			1[a]		25	–	25	–	25	–	25	–	
		4			3[a]		10	50	10	50	10	50	10	50	
Base-to-Emitter Voltage	V_{BE}	4			3[a]		–	1.8	–	1.8	–	1.8	–	1.8	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				3[a]	0.375	–	1.2	–	1.2	–	1.2	–	1.2	V
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	10			0.5		20	–	20	–	20	–	20	–	
Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10			0.5		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 30 Ω) See Figs. 2 & 3 — Turn-on-time $t_d + t_r$	t_{ON}	(V_{CC}) 30			1	0.1[c]	0.5 (typ.)		0.5 (typ.)		0.5 (typ.)		0.5 (typ.)		µs
Turn-off time $t_s + t_f$	t_{OFF}	(V_{CC}) 30			1	0.1[c]	2 (typ.)		2 (typ.)		2 (typ.)		2 (typ.)		µs
Unclamped Inductive Load Energy[b] (L = 20 mH) See Fig. 4		(V_{CC}) 10					–	32	–	32	–	32	–	32	mJ
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	3.125	–	3.125	–	3.125	–	3.125	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	°C/W

[a]Pulsed: Pulse duration = 300 µs, duty factor = 2%
[b]Based upon ability of device to perform in circuit shown in Fig. 4.
[c]$I_{B_1} = I_{B_2}$ = value shown

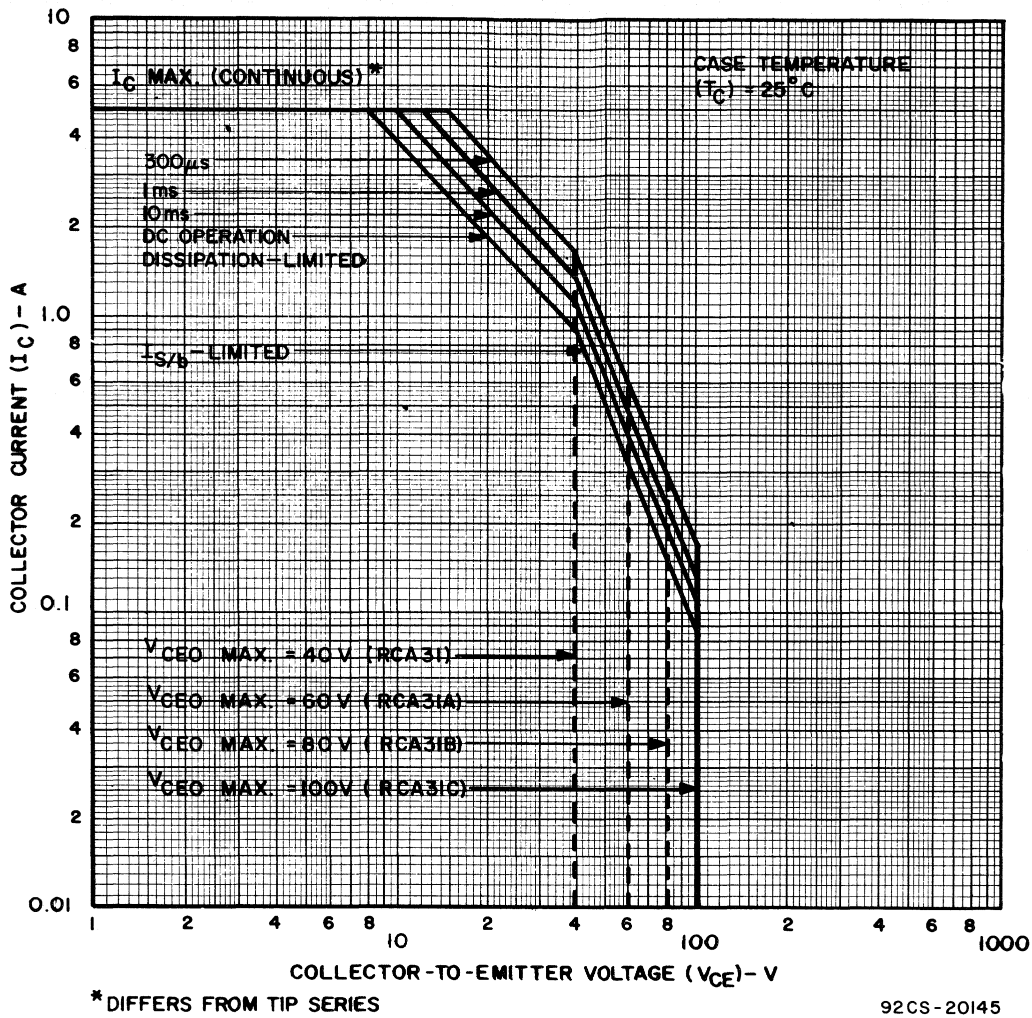


Fig. 1—Maximum safe operating areas for all types.

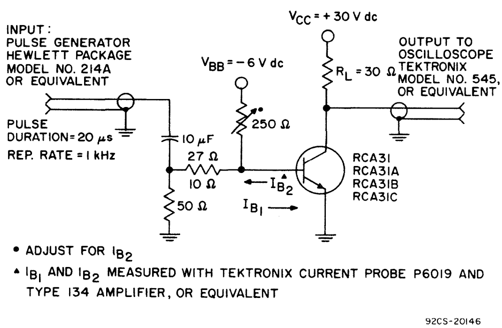


Fig. 2—Circuit used to measure switching times for all types.

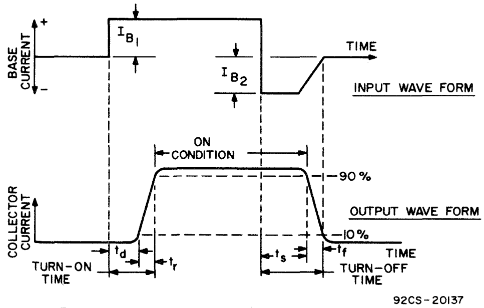


Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2).

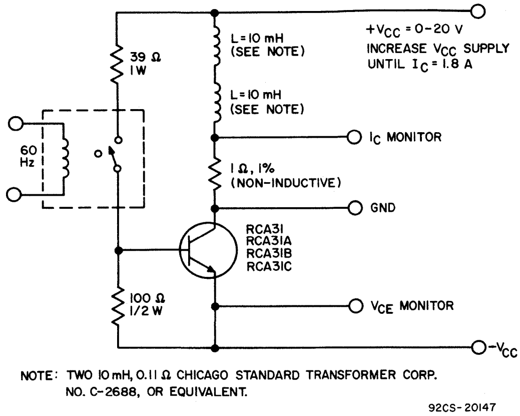


Fig. 4—Circuit for measuring inductive-load switching for all types.

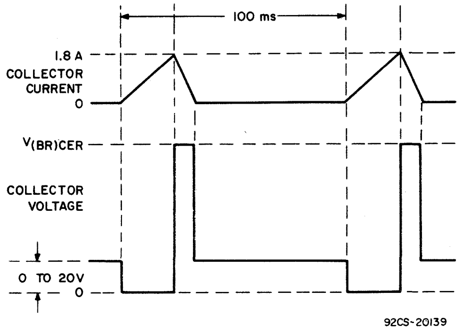


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4).

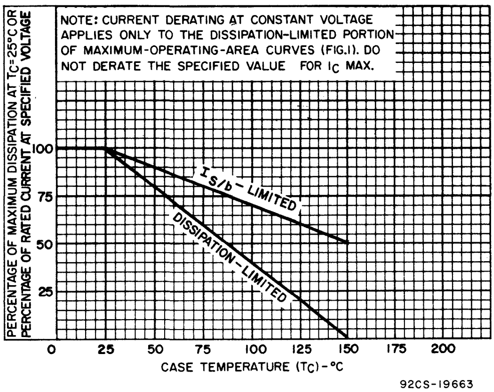


Fig. 6—Derating curves for all types.

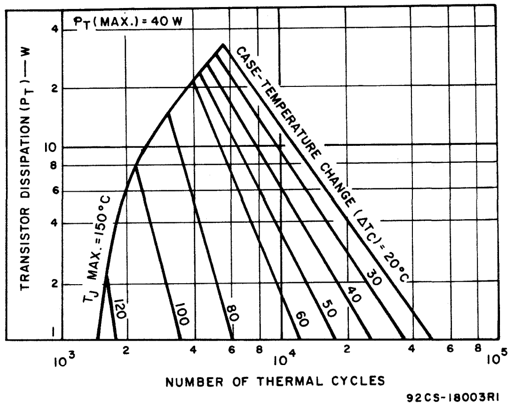


Fig. 7—Thermal-cycling ratings for all types.*

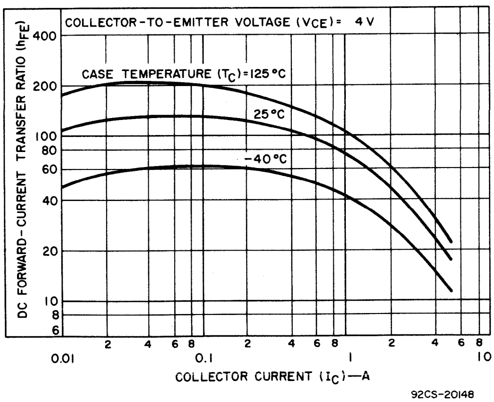
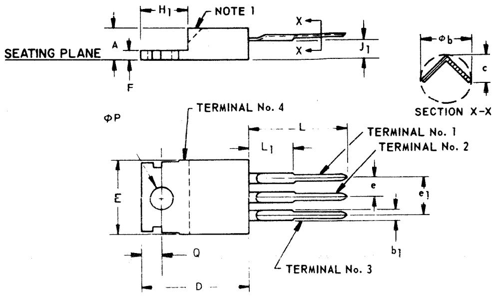


Fig. 8—Typical dc beta characteristics for all types.*

*Differs from TIP series

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

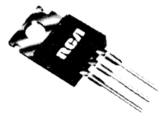
TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange, Lead No. 4 – Collector

RCA Solid State Division

Power Transistors

RCA32 RCA32B RCA32A RCA32C



JEDEC TO-220 AB

H-1535

Epitaxial-Base, Silicon P-N-P VERSAWATT Transistors

For Power-Amplifier and High-Speed-Switching Applications

Features:

- **40 W at 25°C case temperature**
- **5 A rated collector current**
- **Min. f_T of 3 MHz at 10 V, 500 mA**
- **Designed for complementary use with RCA31, RCA31A, RCA31B, and RCA31C n-p-n types**

RCA32, RCA32A, RCA32B, and RCA32C are epitaxial-base, silicon p-n-p transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers. These new plastic power transistors are designed for complementary use with devices in the RCA31 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA32	RCA32A	RCA32B	RCA32C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-40	-60	-80	-100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CEO}	-40	-60	-80	-100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-5	-5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	-5	-5	-5	-5	A
*CONTINUOUS BASE CURRENT	I_B	-1	-1	-1	-1	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		40	40	40	40	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage & Operating (Junction)		← -65 to 150 →				°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		← 235 →				°C

*Differs from TIP series

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS								UNITS
		DC VOLTAGE (V)			DC CURRENT (A)		RCA32		RCA32A		RCA32B		RCA32C		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Collector-Cutoff Current: With base open	I_{CEO}	-30				0	–	-0.3	–	-0.3	–	–	–	–	mA
		-60				0	–	–	–	–	–	-0.3	–	-0.3	mA
With base-emitter junction short-circuited	I_{CES}	-40		0			–	-0.2	–	–	–	–	–	–	mA
		-60		0			–	–	–	-0.2	–	–	–	–	mA
		-80		0			–	–	–	–	–	-0.2	–	–	mA
		-100		0			–	–	–	–	–	–	–	-0.2	mA
Emitter-Cutoff Current	I_{EBO}		-5		0		–	-1	–	-1	–	-1	–	-1	mA
Collector to Emitter Breakdown Voltage With base open	$V_{BR(CEO)}$				-0.03[a]	0	-40	–	-60	–	-80	–	-100	–	V
DC Forward Current Transfer Ratio	h_{FE}	-4			-1[a]		25	–	25	–	25	–	25	–	
		-4			-3[a]		10	50	10	50	10	50	10	50	
Base-to-Emitter Voltage	V_{BE}	-4			-3[a]		–	-1.8	–	-1.8	–	-1.8	–	-1.8	V
Collector to Emitter Saturation Voltage	V_{CE}(sat)				-3[a]	-0.375	–	-1.2	–	-1.2	–	-1.2	–	-1.2	V
Common-Emitter Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	-10			-0.5		20	–	20	–	20	–	20	–	
Magnitude of Common Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\lvert h_{fe} \rvert$	-10			-0.5		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 30Ω) See Figs. 2 & 3 Turn-on time $t_d + t_r$	t_{ON}	(V_{CC}) -30			-1	-0.1[c]	0.3 (typ.)		0.3 (typ.)		0.3 (typ.)		0.3 (typ.)		µs
Turn-off time $t_s + t_f$	t_{OFF}	(V_{CC}) -30			-1	-0.1[c]	1 (typ.)		1 (typ.)		1 (typ.)		1 (typ.)		µs
Unclamped Inductive Load Energy[b] (L = 20 mH) See Fig. 4		(V_{CC}) -10					–	32	–	32	–	32	–	32	mJ
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	3.125	–	3.125	–	3.125	–	3.125	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	°C/W

[a]Pulsed Pulse duration = 300 µs, duty factor = 2%

[b]Based upon ability of device to perform in circuit shown in Fig. 4.

[c]I_{B_1} = I_{B_2} = value shown

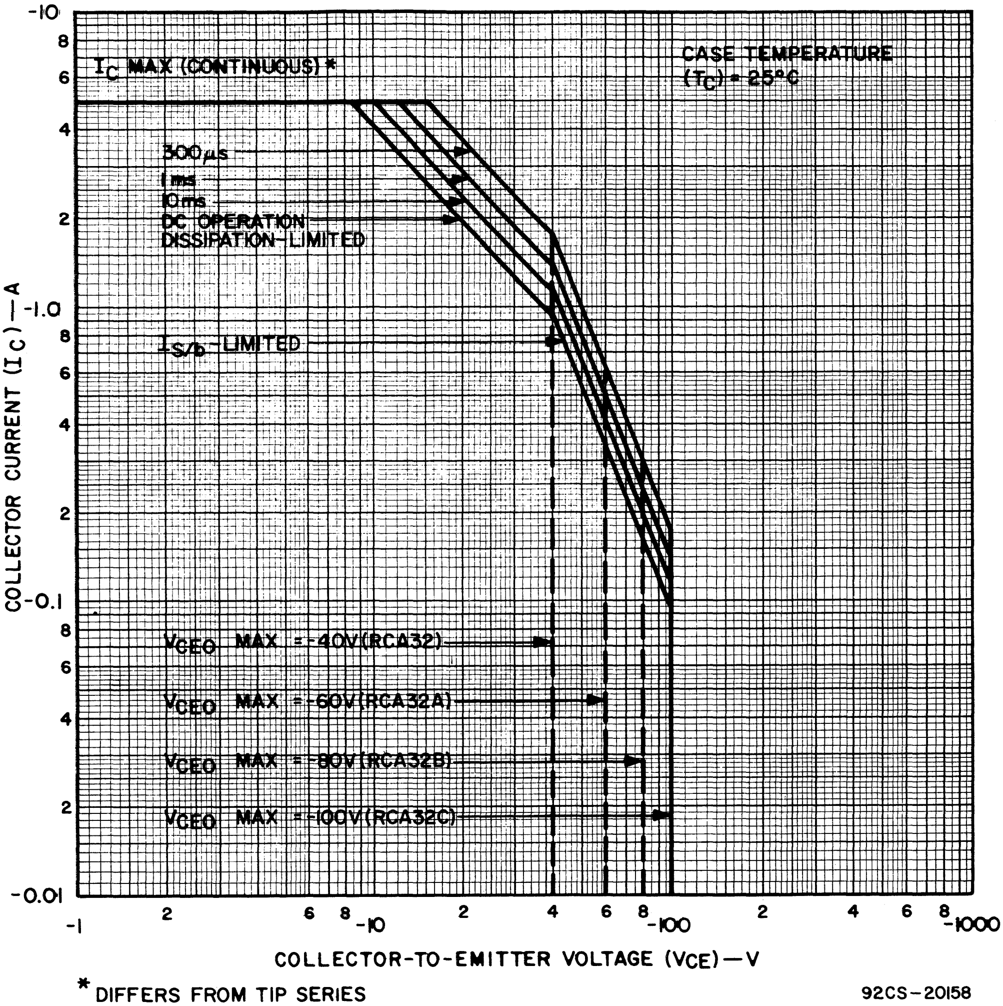


Fig. 1—Maximum safe operating areas for all types

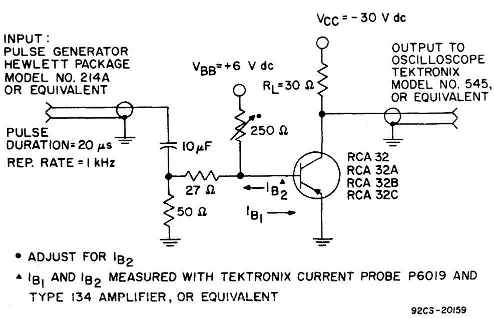


Fig. 2—Circuit used to measure switching times for all types

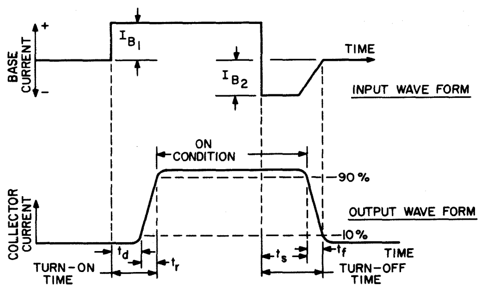


Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2)

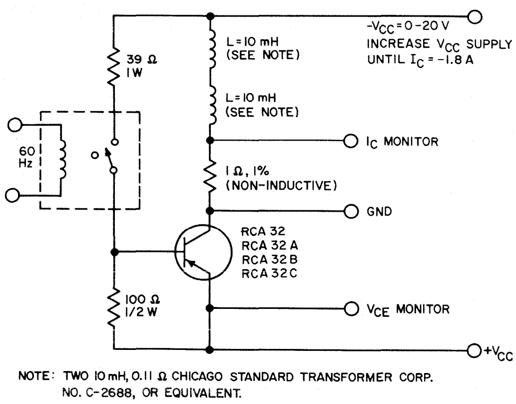


Fig. 4—Circuit for measuring inductive-load switching for all types

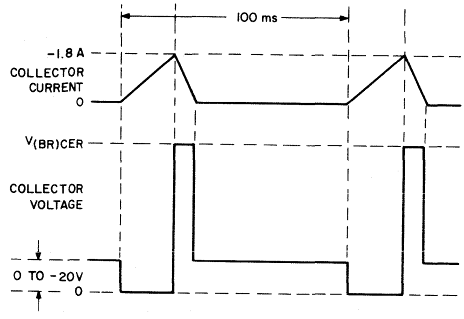


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4)

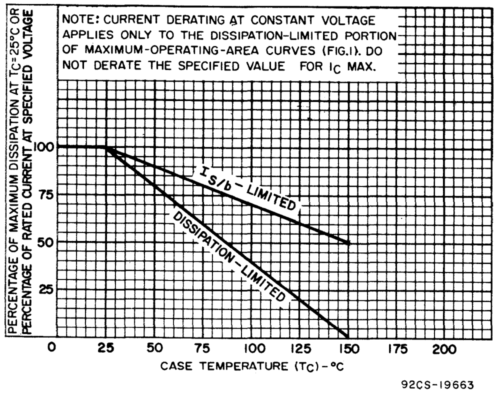


Fig. 6—Derating curves for all types

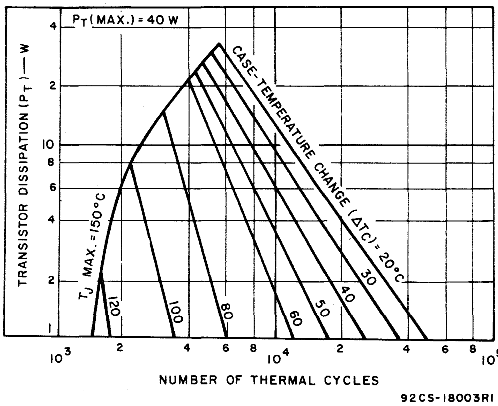


*Fig. 7—Thermal-cycling ratings for all types**

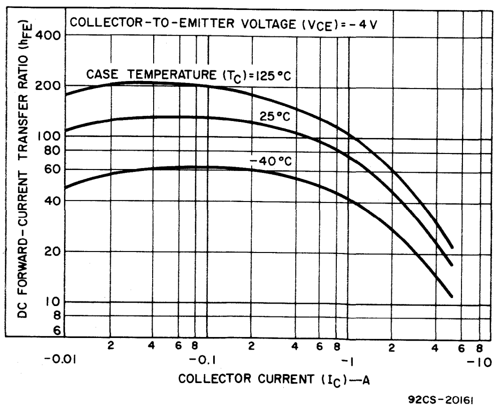
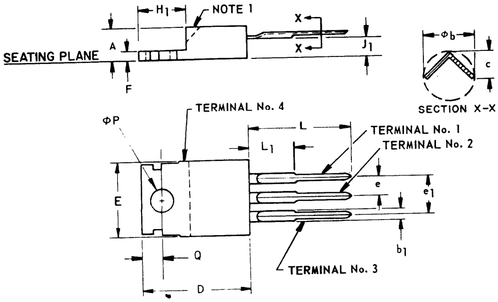


*Fig. 8—Typical dc beta characteristics for all types**

*Differs from TIP series

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

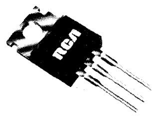
TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange, Lead No. 4 – Collector

RCA
Solid State
Division

Power Transistors

RCA41 RCA41B
RCA41A RCA41C



JEDEC TO-220 AB H-1535

Epitaxial-Base, Silicon N-P-N VERSAWATT Transistors

For Power-Amplifier and
High-Speed-Switching Applications

Features:

- 65 W at 25°C case temperature
- 7 A rated collector current
- Min. f_T of 3 MHz at 10 V, 500 mA
- Designed for complementary use with RCA42, RCA42A, RCA42B, and RCA42C p-n-p types

RCA41, RCA41A, RCA41B, and RCA41C are epitaxial-base, silicon n-p-n transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers. These new plastic power transistors are designed for complementary use with devices in the RCA42 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA41	RCA41A	RCA41B	RCA41C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	60	80	100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CEO}	40	60	80	100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	7	7	7	7	A
*CONTINUOUS BASE CURRENT	I_B	3	3	3	3	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		65	65	65	65	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage & Operating (Junction)		←— -65 to 150 —→				°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		←— 235 —→				°C

*Differs from TIP series

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS								UNITS
		DC VOLTAGE (V)			DC CURRENT (A)		RCA41		RCA41A		RCA41B		RCA41C		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}	30				0	–	0.7	–	0.7	–	–	–	–	mA
		60				0	–	–	–	–	–	0.7	–	0.7	
With base-emitter junction short-circuited	I_{CES}	40		0			–	0.4	–	–	–	–	–	–	
		60		0			–	–	–	0.4	–	–	–	–	
		80		0			–	–	–	–	–	0.4	–	–	
		100		0			–	–	–	–	–	–	–	0.4	
Emitter-Cutoff Current	I_{EBO}		5		0		–	1	–	1	–	1	–	1	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0.03[a]	0	40	–	60	–	80	–	100	–	V
DC Forward Current Transfer Ratio	h_{FE}	4			0.3[a]		30	–	30	–	30	–	30	–	
		4			3[a]		15	75	15	75	15	75	15	75	
* Base-to-Emitter Voltage	V_{BE}	4			6[a]		–	2.2	–	2.2	–	2.2	–	2.2	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				6[a]	0.6	–	2	–	2	–	2	–	2	V
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	10			0.5		20	–	20	–	20	–	20	–	
Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10			0.5		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 5 Ω) See Figs. 2 & 3 Turn-on time $t_d + t_r$	t_{ON}	(V_{CC}) 30			6	0.6[c]	0.6 (typ.)		0.6 (typ.)		0.6 (typ.)		0.6 (typ.)		μs
* Turn-off Time $t_s + t_f$	t_{OFF}	(V_{CC}) 30			6	0.6[c]	1.2 (typ.)		1.2 (typ.)		1.2 (typ.)		1.2 (typ.)		
Unclamped Inductive Load Energy[b] (L = 20 mH) (See Fig. 4)		(V_{CC}) 10					–	62.5	–	62.5	–	62.5	–	62.5	mJ
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$						–	1.92	–	1.92	–	1.92	–	1.92	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	

[a]Pulsed: Pulse duration = 300 μs, duty factor = 2%

[b]Based upon ability of device to perform in circuit shown in Fig. 4.

[c]$I_{B_1} = I_{B_2}$ = value shown

*Differs from TIP series

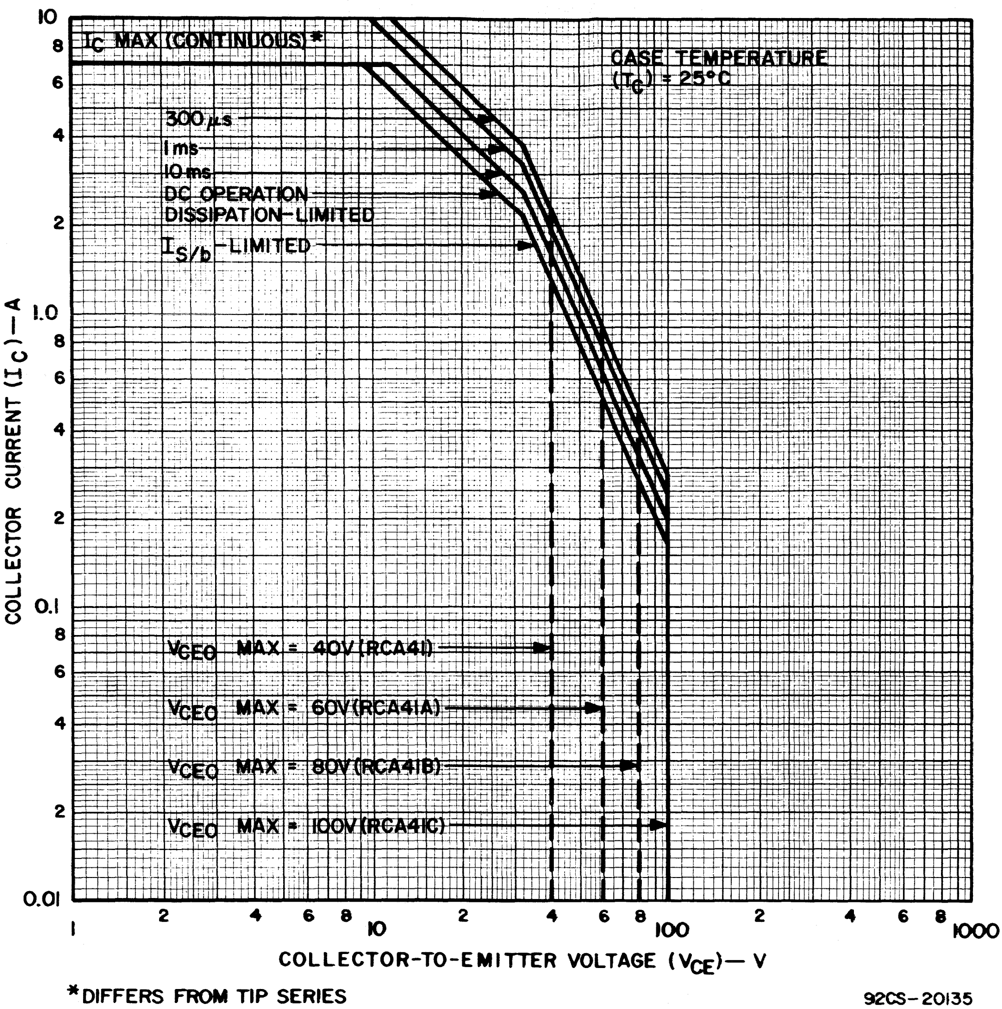


Fig. 1—Maximum safe operating areas for all types

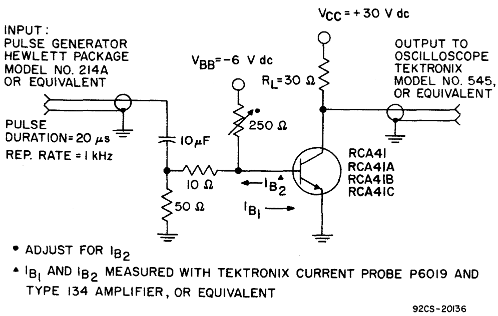


Fig. 2—Circuit used to measure switching times for all types

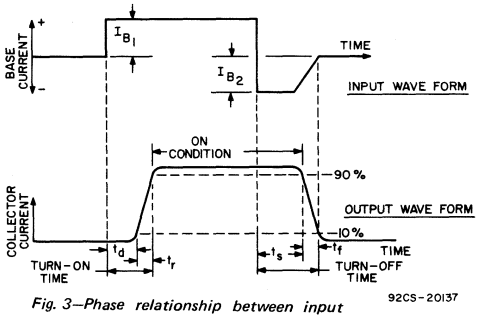


Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2)

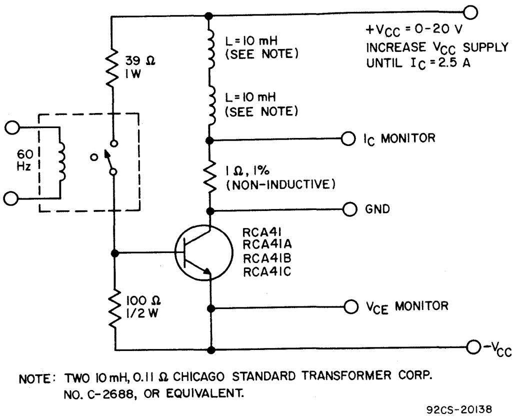


Fig. 4—Circuit for measuring inductive-load switching for all types

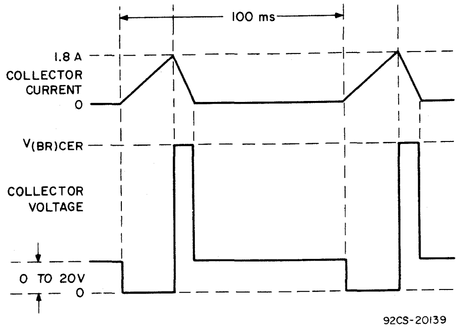


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4)

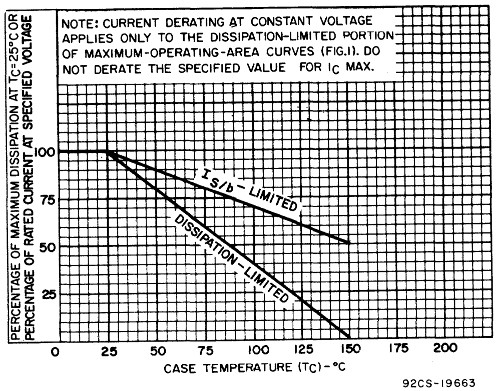


Fig. 6—Derating curves for all types

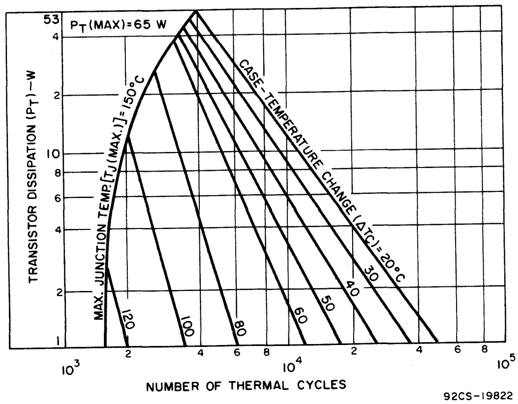


*Fig. 7—Thermal-cycling ratings for all types**

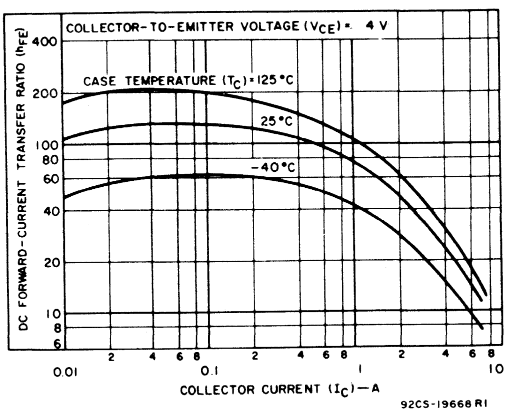
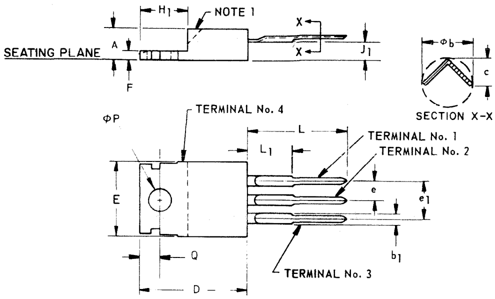


*Fig. 8—Typical dc beta characteristics for all types**

*Differs from TIP series

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

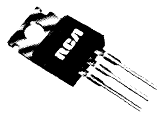
TERMINAL CONNECTIONS

Lead No. 1—Base
Lead No. 2—Collector
Lead No. 3—Emitter
Mounting Flange, Lead No. 4—Collector

RCA
Solid State
Division

Power Transistors

RCA42 RCA42B
RCA42A RCA42C



JEDEC TO-220 AB H-1535

Epitaxial-Base, Silicon P-N-P VERSAWATT Transistors

For Power-Amplifier and
High-Speed-Switching Applications

Features:

- **65 W at 25°C case temperature**
- **7 A rated collector current**
- **Min. f_T of 3 MHz at 10 V, 500 mA**
- **Designed for complementary use with RCA41, RCA41A, RCA41B, and RCA41C n-p-n types.**

RCA42, RCA42A, RCA42B, and RCA42C are epitaxial-base, silicon p-n-p transistors. They are intended for a wide variety of switching and amplifier applications, such as series and shunt regulators and driver and output stages of high-fidelity amplifiers.

These new plastic power transistors are designed for complementary use with devices in the RCA41 series. They differ from each other in voltage ratings and in the currents at which the parameters are controlled.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA42	RCA42A	RCA42B	RCA42C	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	-40	-60	-80	-100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With base open	V_{CBO}	-40	-60	-80	-100	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	-5	-5	-5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	-7	-7	-7	-7	A
*CONTINUOUS BASE CURRENT	I_B	-3	-3	-3	-3	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		65	65	65	65	W
At ambient temperatures up to 25°C		2	2	2	2	W
TEMPERATURE RANGE:						
Storage & Operating (Junction)		←	-65 to 150		→	°C
*LEAD TEMPERATURE (During Soldering):						
At distance 1/8 in. (3.17 mm) from case for 10 s max.		←	235		→	°C

*Differs from TIP series

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE (V) V_{CE}	V_{EB}	V_{BE}	DC CURRENT (A) I_C	I_B	LIMITS: RCA42 MIN.	RCA42 MAX.	RCA42A MIN.	RCA42A MAX.	RCA42B MIN.	RCA42B MAX.	RCA42C MIN.	RCA42C MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}	-30				0	–	-0.7	–	-0.7	–	–	–	–	mA
		-60				0						-0.7		-0.7	
With base-emitter junction short-circuited	I_{CES}	-40		0			–	-0.4	–	–	–	–	–	–	mA
		-60		0			–	–	–	-0.4	–	–	–	–	
		-80		0			–	–	–	–	–	-0.4	–	–	
		-100		0			–	–	–	–	–	–	–	-0.4	
Emitter-Cutoff Current	I_{EBO}		-5		0		–	-1	–	-1	–	-1	–	-1	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				-0.03^a	0	-40	–	-60	–	-80	–	-100	–	V
DC Forward-Current Transfer Ratio	h_{FE}	-4			-0.3^a		30	–	30	–	30	–	30	–	
		-4			-3^a		15	75	15	75	15	75	15	75	
* Base-to-Emitter Voltage	V_{BE}	-4			-6^a		–	-2.2	–	-2.2	–	-2.2	–	-2.2	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				-6^a	-0.6	–	-2	–	-2	–	-2	–	-2	V
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	-10			-0.5		20	–	20	–	20	–	20	–	
Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	-10			-0.5		3	–	3	–	3	–	3	–	
Saturated Switching Time: (R_L = 5 Ω) See Figs. 2 & 3															
Turn-on time $t_d + t_r$	t_{ON}	(V_{CC}) -30			-6	-0.6^c	0.4 (typ.)		0.4 (typ.)		0.4 (typ.)		0.4 (typ.)		µs
* Turn-off time $t_s + t_f$	t_{OFF}	(V_{CC}) -30			-6	-0.6^c	0.9 (typ.)		0.9 (typ.)		0.9 (typ.)		0.9 (typ.)		µs
Unclamped Inductive Load Energy[b] (L = 20 mH) See Fig. 4		(V_{CC}) -10					–	62.5	–	62.5	–	62.5	–	62.5	mJ
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$						–	1.92	–	1.92	–	1.92	–	1.92	°C/W
Junction-to-Ambient	$R_{\theta JA}$						–	62.5	–	62.5	–	62.5	–	62.5	°C/W

[a]Pulsed: Pulse duration = 300 µs, duty factor = 2%

[b]Based upon ability of device to perform in circuit shown in Fig. 4.

[c]$I_{B1} = I_{B2}$ = value shown

*Differs from TIP series

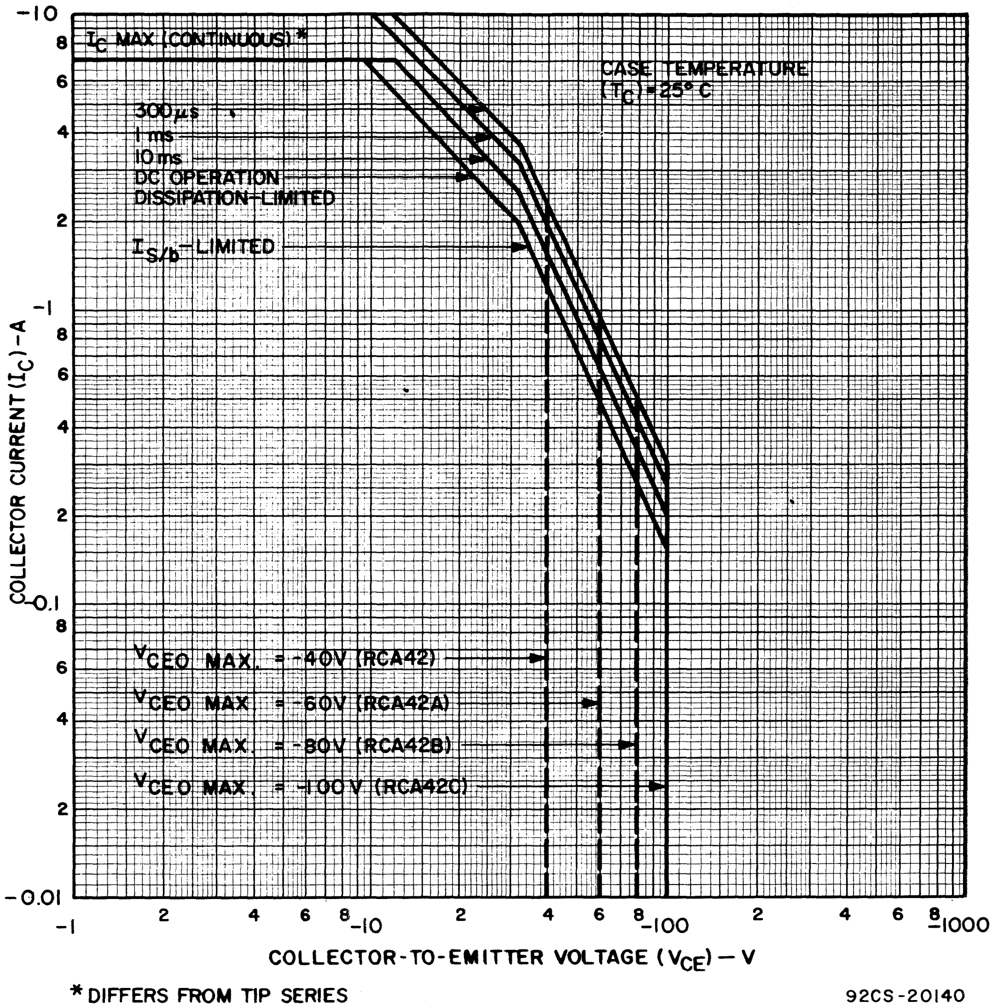


Fig. 1—Maximum safe operating areas for all types.

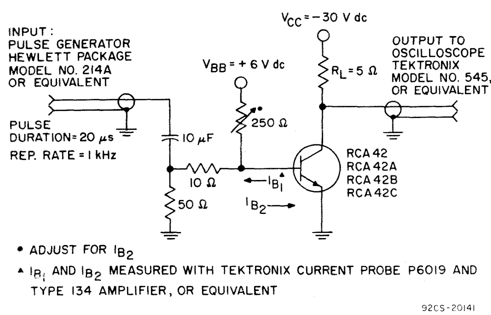


Fig. 2—Circuit used to measure switching times for all types.

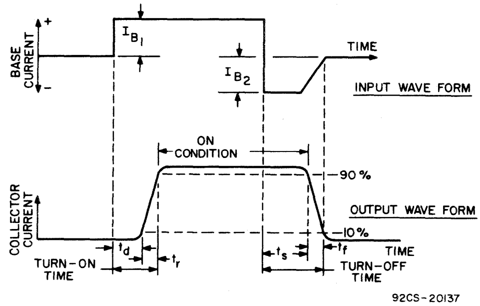


Fig. 3—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig. 2).

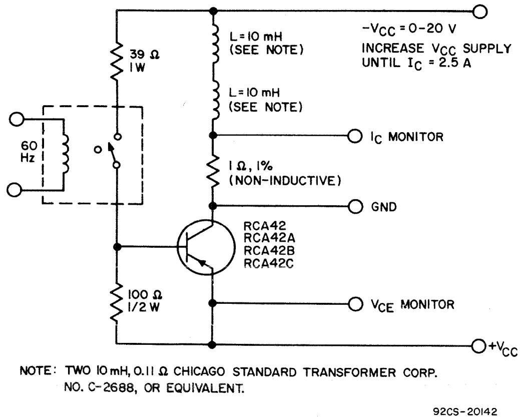


Fig. 4—Circuit for measuring inductive-load switching for all types.

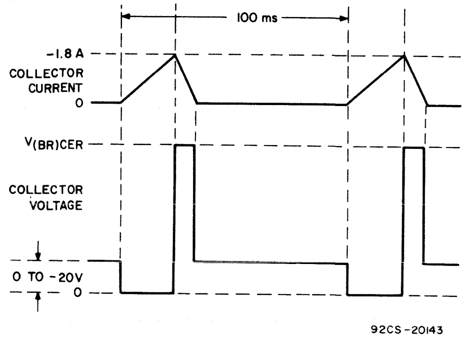


Fig. 5—Inductive-load switching voltage and current waveforms (test circuit shown in Fig. 4).

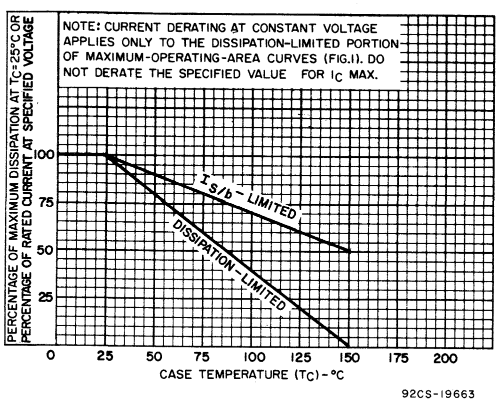


Fig. 6—Derating curves for all types.

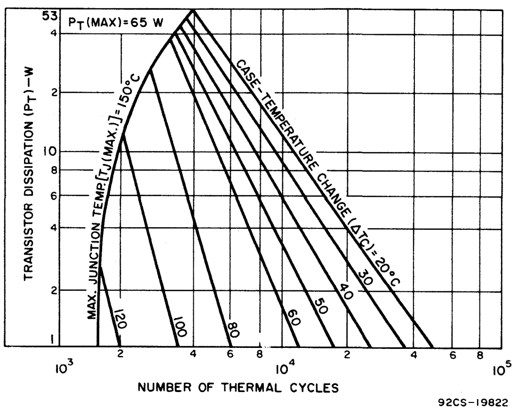


*Fig. 7—Thermal-cycling ratings for all types.**

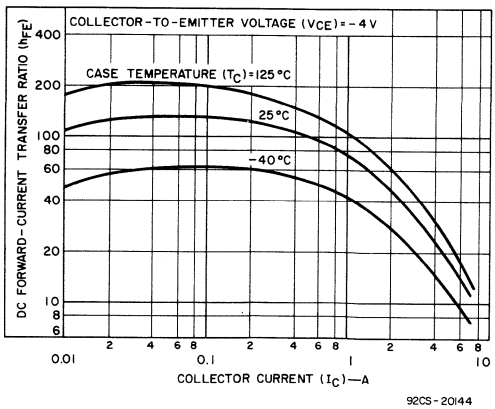
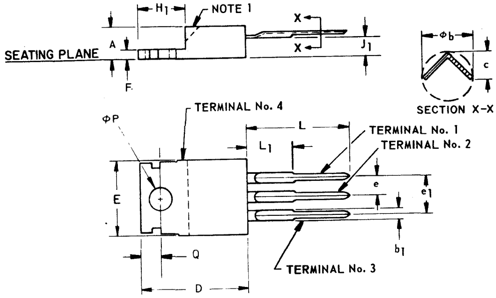


*Fig. 8—Typical dc beta characteristics for all types.**

**Differs from TIP series.*

DIMENSIONAL OUTLINE

JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-17991

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

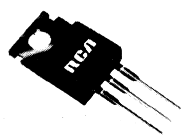
TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange, Lead No. 4 – Collector

RCA

Solid State
Division

Power Transistors
RCA-101, 201 RCA-103, 203
RCA-102, 202 RCA-104, 204



JEDEC TO-220AB H-1535

7-A, 75-W, Silicon N-P-N and P-N-P Epitaxial-Base REVERSAWATT Transistors

Complementary Pairs for Audio Amplifiers
—Up to 20 W Music Power per Channel

Features:

- **Thermal-cycling ratings**
- **Maximum safe-area-of-operation curves**
- **Color-coded packages of molded silicone plastic:**
  Green – p-n-p (RCA-101 – RCA-104)
  Gray – n-p-n (RCA-201 – RCA-204)

RCA-101 – 104 and 201 – 204 are epitaxial-base silicon p-n-p and n-p-n transistors. They are intended for use in output stages of high-fidelity amplifiers.

These devices are RCA REVERSAWATT transistors in color-coded molded silicone plastic packages; the 101 – 104 (p-n-p) units are green and the 201 – 204 (n-p-n) units are gray for ease of identification.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		101 201	102 103 202 203	104 204	
COLLECTOR-TO-BASE VOLTAGE: With emitter open	V_{CBO}	40	60	80	V
COLLECTOR-TO-EMITTER VOLTAGE: With base open	V_{CEO}	40	60	80	V
EMITTER-TO-BASE VOLTAGE: With collector open	V_{EBO}	← 4.0 →			V
COLLECTOR CURRENT (Continuous)	I_C	← 7.0 →			A
BASE CURRENT (Continuous)	I_B	← 3.0 →			A
TRANSISTOR DISSIPATION: At case temperatures up to 25°C	P_T	← 75 →			W
At case temperatures above 25°C		Derate linearly at 0.600 W/°C or see Fig. 2.			
TEMPERATURE RANGE: Storage & Operating (Junction)		← -65 to +150° →			°C
LEAD TEMPERATURE (During Soldering): At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.		← +235 →			°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE (V)		DC EMITTER OR BASE VOLTAGE (V)		DC CURRENT (A)			LIMITS								UNITS
									P-N-P TYPES 101 / N-P-N TYPES 201		102 / 202		103 / 203		104 / 204		
		V_{CE}	V_{CB}	V_{EB}	V_{BE}	I_C	I_B	I_E	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current: With emitter open	I_{CBO}		40					0	–	0.1	–	–	–	–	–	–	mA
			60					0	–	–	–	0.1	–	0.1	–	–	
			80					0	–	–	–	–	–	–	–	0.1	
At T_C = 150°C			40					0	–	2.0	–	–	–	–	–	–	
			60					0	–	–	–	2.0	–	2.0	–	–	
			80					0	–	–	–	–	–	–	–	2.0	
Emitter-Cutoff Current: With collector open	I_{EBO}			4.0		0			–	1.0	–	1.0	–	1.0	–	1.0	mA
Collector-to Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$					0.1*	0		40	–	60	–	60	–	80	–	V
Base-Emitter Voltage	V_{BE}	2.0				2.0*			–	1.2	–	1.2	–	–	–	–	V
		2.0				1.0			–	–	–	–	–	1.2	–	1.2	
DC Forward-Current Transfer Ratio	h_{FE}	2.0				1.0			–	–	–	–	30	150	30	150	–
		2.0				2.0			25	150	25	150	–	–	–	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$								–	1.66	–	1.66	–	1.66	–	1.66	°C/W

*Pulsed: Pulse duration = 300 μs, duty factor ⩽ 2%.

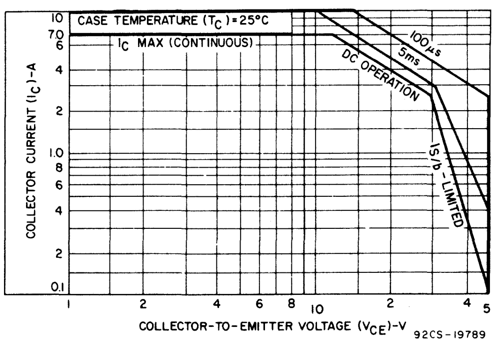


Fig. 1–Maximum operating areas for types 101–104 and 201–204.

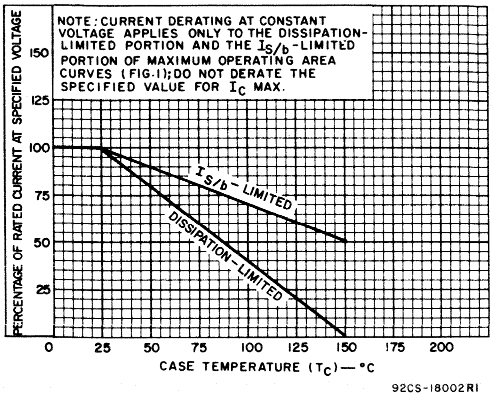


Fig. 2—Derating curves for all types.

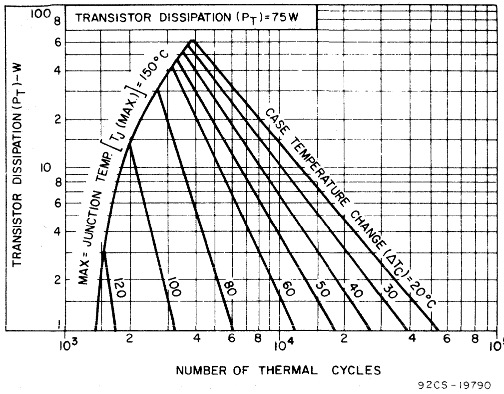


Fig. 3—Thermal-cycling ratings for all types.

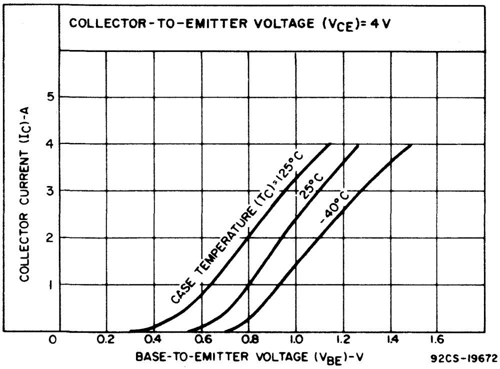


Fig. 4—Typical transfer characteristics for types 201—204.

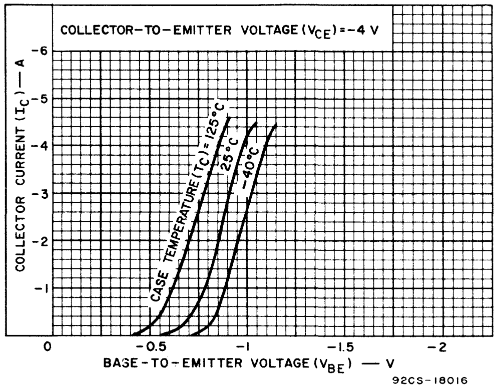


Fig. 5—Typical transfer characteristics for types 101—104.

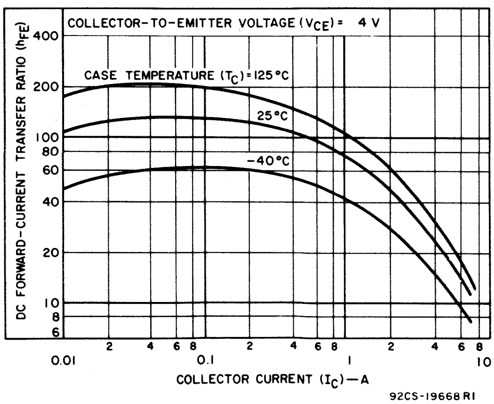


Fig. 6—Typical dc beta characteristics for types 101—104 and 201—204.

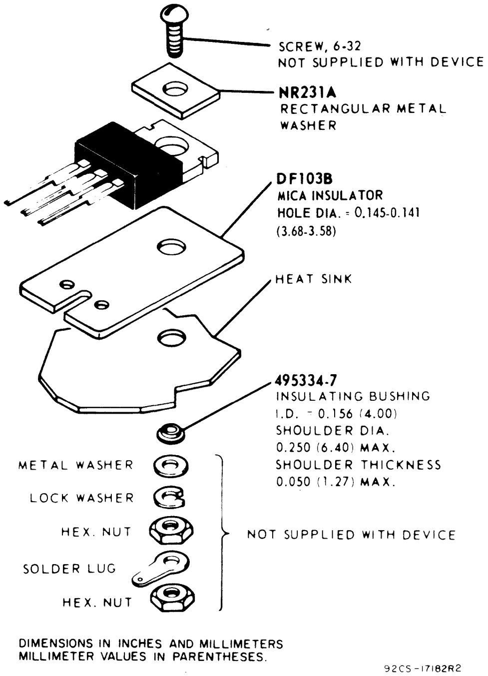
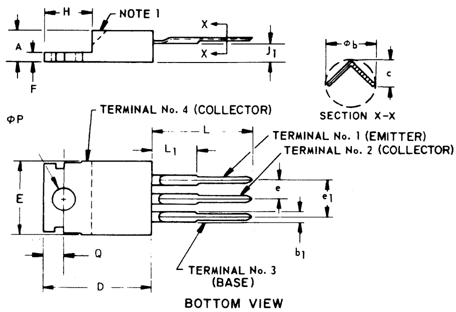


Fig. 7—Suggested mounting hardware for all types.

DIMENSIONAL OUTLINE JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776RI

NOTES:
1. Chamfer optional.
2. Tab contour optional within H and E.
3. Position of lead to be measured 0.250–0.255 (6.35–6.48 mm) from case.

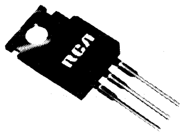
TERMINAL CONNECTIONS

Lead No. 1 – Emitter
Lead No. 2 – Collector
Lead No. 3 – Base
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors

RCA-105
RCA-205



JEDEC TO-220 AB H-1535

7-A, 65-W, Silicon N-P-N and P-N-P Epitaxial-Base REVERSAWATT Transistors

Complementary Pairs for Audio Amplifiers
—Up to 20 W Music Power Per Channel

Features:
- **Thermal-cycling ratings**
- **Maximum safe-area-of-operation curves**
- **Color-coded packages of molded silicone plastic:**
  - **Green — p-n-p (RCA-105)**
  - **Gray — n-p-n (RCA 205)**

RCA-105 and RCA-205 are epitaxial-base silicon p-n-p and n-p-n, respectively, transistors. They are intended for use in output stages of high-fidelity amplifiers.

These devices are RCA REVERSAWATT transistors in color-coded molded silicone plastic packages; the 105 (p-n-p) unit is green, and the 205 (n-p-n) unit is gray for ease of identification.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		105 205	
COLLECTOR-TO-BASE VOLTAGE:			
With emitter open	V_{CBO}	50	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	50	V
EMITTER-TO-BASE VOLTAGE:			
With collector open	V_{EBO}	4.0	V
COLLECTOR CURRENT (Continuous)	I_C	7.0	A
BASE CURRENT (Continuous)	I_B	2.5	A
TRANSISTOR DISSIPATION:			
At case temperatures up to 25°C	P_T	65	W
At case temperatures above 25°C		Derate linearly at 0.522 W/°C or see Fig. 2.	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to + 150°	°C
LEAD TEMPERATURE (During Soldering):			
At distance ⩾ 1/8 in. (3.17 mm) from case for 10 s max.		+235	°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless otherwise specified*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE (V)		DC EMITTER OR BASE VOLTAGE (V)		DC CURRENT (A)			LIMITS 105 205		UNITS
		V_{CE}	V_{CB}	V_{EB}	V_{BE}	I_C	I_B	I_E	MIN.	MAX.	
Collector-Cutoff Current: With emitter open	I_{CBO}		50					0	–	0.1	mA
At T_C = 150°C	I_{CBO}		50					0	–	2.0	mA
Emitter-Cutoff Current: With collector open	I_{EBO}			4.0		0		–	–	1.0	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$					0.1*	0		50	–	V
Base-Emitter Voltage	V_{BE}	2.0				2.0*			–	1.2	V
DC Forward-Current Transfer Ratio	h_{FE}	2.0				2.0*			25	100	–
Thermal Resistance Junction to Case	$R_{\theta JC}$								–	1.92	°C/W

*Pulsed: Pulse duration = 300 μs, duty factor ≤ 2%.

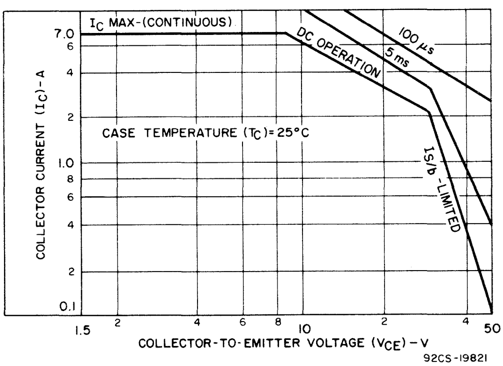


Fig. 1—Maximum operating areas for types 105 and 205.

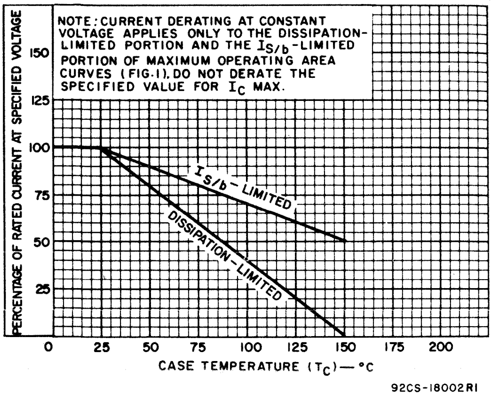


Fig. 2—Derating curves for types 105 and 205.

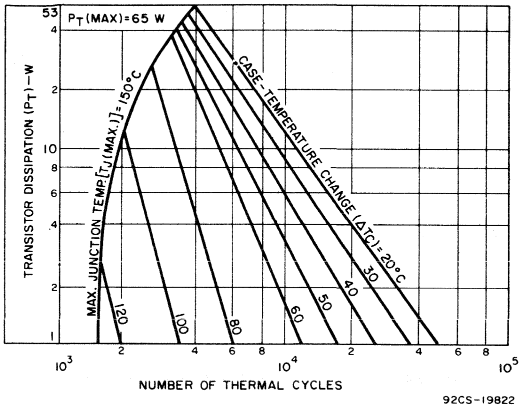


Fig. 3—Thermal-cycling ratings for types 105 and 205.

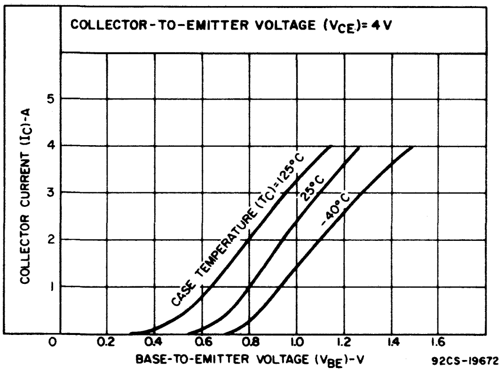


Fig. 4—Typical transfer characteristics for type 205.

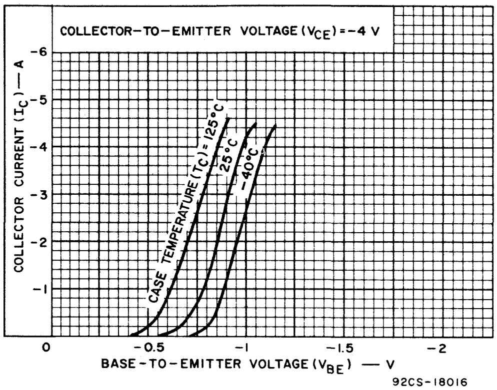


Fig. 5—Typical transfer characteristics for type 105.

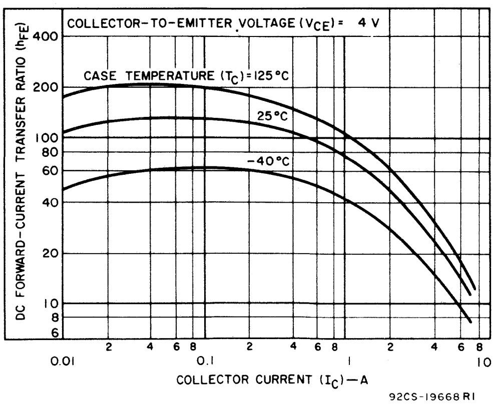
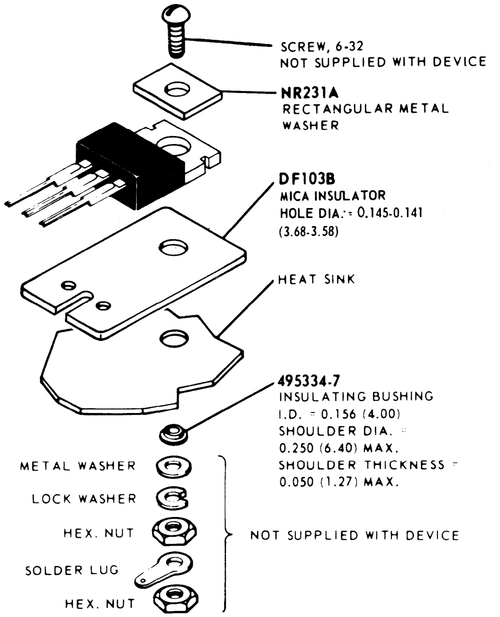


Fig. 6—Typical dc beta characteristics for types 105 and 205.

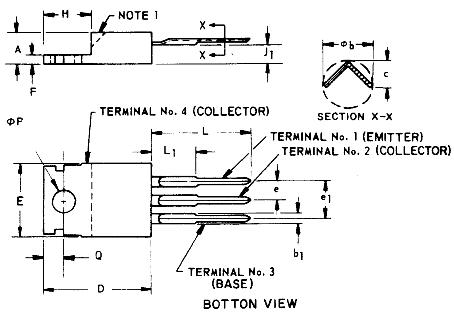


DIMENSIONS IN INCHES AND MILLIMETERS
MILLIMETER VALUES IN PARENTHESES.

92CS-17182R2

Fig. 7—Suggested mounting hardware for types 105 and 205.

DIMENSIONAL OUTLINE
JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776RI

NOTES:
1. Chamfer optional.
2. Tab contour optional within H and E.
3. Position of lead to be measured 0.250–0.255 (6.35–6.48 mm) from case.

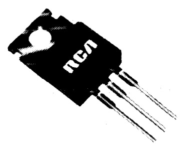
TERMINAL CONNECTIONS

Lead No. 1 – Emitter
Lead No. 2 – Collector
Lead No. 3 – Base
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors

RCA-370 RCA-520
RCA-371 RCA-521



JEDEC TO-220AB H1535R1

5-A, 40-W, Silicon N-P-N and P-N-P Epitaxial-Base REVERSAWATT Transistors

For Use in 5- to 10-Watt Audio Amplifiers Utilizing Complementary-Symmetry Circuits

Features:

- **Thermal-cycling ratings**
- **Maximum-safe-area-of-operation curves**
- **Color-coded packages of molded silicone plastic:**
  Green — p-n-p RCA-370-1
  Gray — n-p-n RCA-520-1

RCA–370, 371, 520, and 521 are epitaxial-base silicon p-n-p and n-p-n transistors. They are intended for medium-power amplifier applications, and are especially designed for use in 5- to 10-watt audio amplifiers utilizing complementary-symmetry circuits.

These devices are packaged in RCA REVERSAWATT molded silicone plastic packages; the 370 and 371 (p-n-p) devices are green, and the 520 and 521 (n-p-n) units gray for ease in identification.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		370 (p-n-p) 520 (n-p-n)	371 (p-n-p) 521 (n-p-n)	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	30	40	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open	V_{CEO}	30	40	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	4	V
CONTINUOUS COLLECTOR CURRENT	I_C	5	5	A
CONTINUOUS BASE CURRENT	I_B	2	2	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25°C		40	40	W
At case temperatures above 25°C		Derate linearly at 0.32 W/°C or See Fig. 3		
TEMPERATURE RANGE:				
Storage & Operating (Junction)		–65 to 150		°C
TERMINAL TEMPERATURE (During Soldering):				
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.		235		°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE (V)		DC EMITTER OR BASE VOLTAGE (V)		DC CURRENT (A)			LIMITS 370 (p-n-p) 520 (n-p-n)		LIMITS 371 (p-n-p) 521 (n-p-n)		UNITS
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_B	I_E	MIN.	MAX.	MIN.	MAX.	
Collector-Base Cutoff Current: With emitter open	I_{CBO}	30						0	–	100	–	–	µA
		40						0	–	–	–	100	
Emitter-Cutoff Current	I_{EBO}			4		0			–	100	–	100	µA
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)^a$					0.1	0		30	–	40	–	V
DC Forward Current Transfer Ratio	h_{FE}^a		1			1			25	–	40	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$								–	3.12	–	3.12	°C/W

[a]Pulsed: Pulse duration ≤ 300 µs, duty factor ≤ 2%.

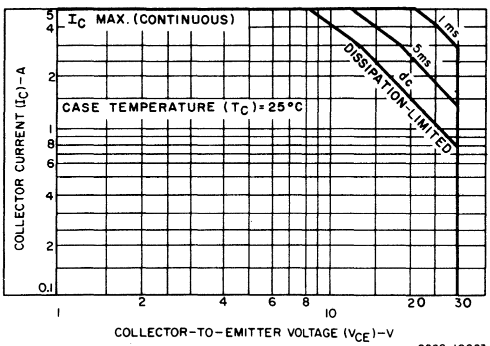


Fig. 1—Maximum operating areas for types 370 and 520.

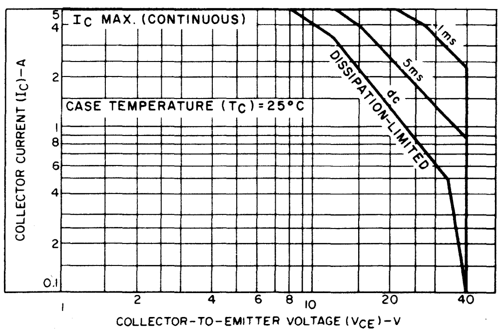


Fig. 2—Maximum operating areas for types 371 and 521.

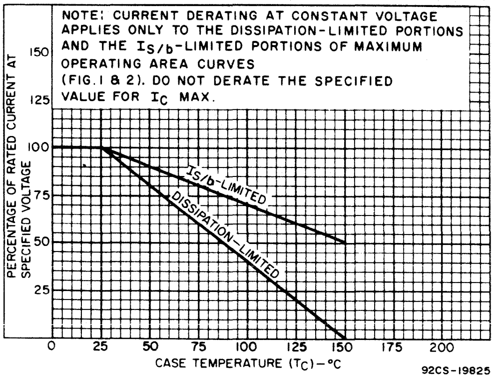


Fig. 3—Derating curves for all types.

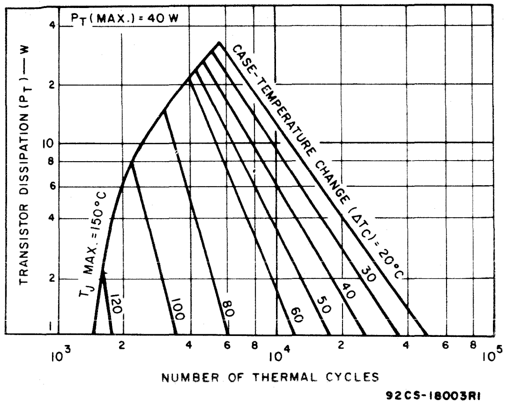


Fig. 4—Thermal-cycling ratings for all types.

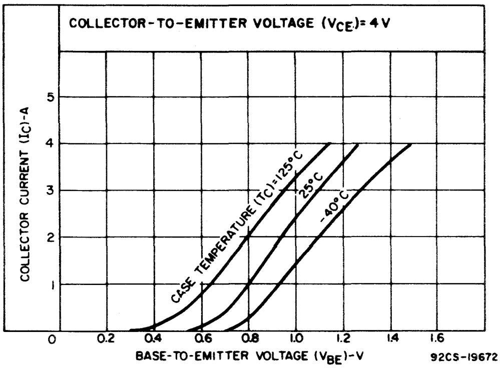


Fig. 5—Typical transfer characteristics for types 520 and 521.

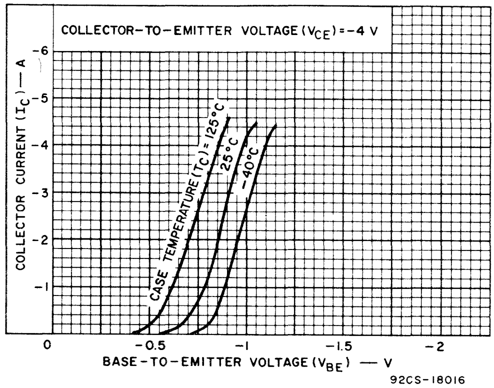


Fig. 6—Typical transfer characteristics for types 370 and 371.

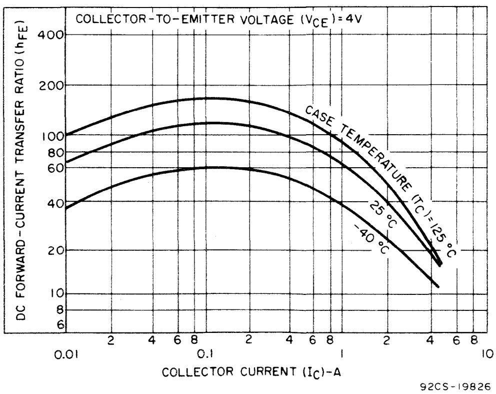
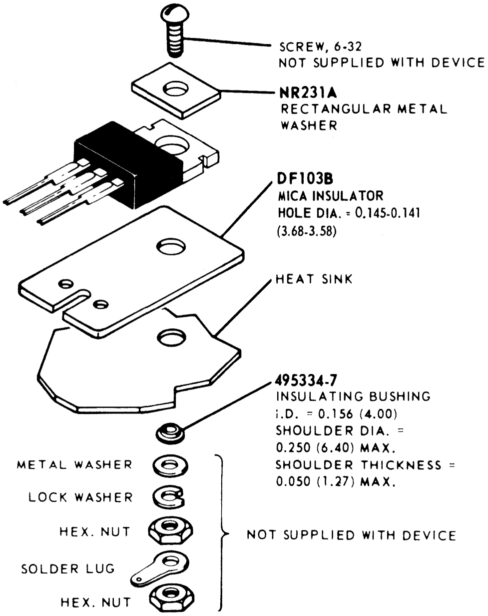


Fig. 7—Typical dc beta characteristics for all types.

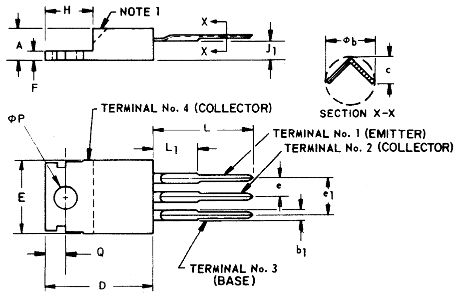


DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-17182R2

Fig. 8—Suggested mounting hardware for all types.

DIMENSIONAL OUTLINE
JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
φb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776

NOTES:
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured 0.250–0.255 (6.35–6.48 mm) from bottom of dimension D.**

TERMINAL CONNECTIONS

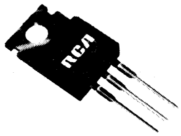
Terminal No. 1 – Emitter
Terminal No. 2 – Collector
Terminal No. 3 – Base
Mounting Flange, Terminal No. 4 – Collector

File No. 559

RCA

Solid State
Division

Power Transistors
RCA-45190 RCA-45193
RCA-45191 RCA-45194
RCA-45192 RCA-45195



JEDEC TO-220AB H-1535

7-A,40-W, Silicon N-P-N and P-N-P Epitaxial-Base REVERSAWATT Transistors

Complementary Pairs for Power Amplifiers and Switching Circuits

- **Thermal-cycling ratings**
- **Maximum safe-area-of-operation curves**
- **Color-coded packages of molded silicone plastic:**
  Green—p-n-p (RCA-45193-5)
  Gray —n-p-n (RCA 45190-2)

RCA-45190-45192 and RCA-45193-45195 are epitaxial-base silicon n-p-n and p-n-p transistors. They are intended for use in high-fidelity power amplifiers and in switching circuits.

These devices are packaged in RCA REVERSAWATT molded silicone plastic packages; the 45190-45192 (n-p-n) units are gray, and the 45193-45195 (p-n-p) units are green for ease in identification.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		45190 (n-p-n) 45193 (p-n-p)	45191 (n-p-n) 45194 (p-n-p)	45192 (n-p-n) 45195 (p-n-p)	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	60	80	V
COLLECTOR-TO-EMITTER VOLTAGE					
With base open	V_{CEO}	40	60	80	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	←	5	→	V
COLLECTOR CURRENT (Continuous)	I_C	←	7	→	A
BASE CURRENT (Continuous)	I_B	←	2	→	A
TRANSISTOR DISSIPATION	P_T				
At case temperatures up to 25°C		←	40	→	W
At case temperatures above 25°C			Derate linearly at 0.32 W/°C or see Fig. 2		
TEMPERATURE RANGE:					
Storage & Operating (Junction)		←	−65 to 150	→	°C
TERMINAL TEMPERATURE (During Soldering):					
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.		←	235	→	°C

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C unless otherwise specified.

CHARACTERISTIC	SYMBOL	DC COLLECTOR VOLTAGE V		DC EMITTER VOLTAGE V	DC CURRENT A			LIMITS 45190 (n-p-n) 45193 (p-n-p)		45191 (n-p-n) 45194 (p-n-p)		45192 (n-p-n) 45195 (p-n-p)		UNITS
		V_{CB}	V_{CE}	V_{EB}	I_C	I_B	I_E	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With emitter open	I_{CBO}	40					0	–	100	–	–	–	–	µA
		60					0	–	–	–	100	–	–	
		80					0	–	–	–	–	–	100	
Collector-Cutoff Current: With base open	I_{CEO}	40				0		–	1	–	–	–	–	mA
		60				0		–	–	–	1	–	–	
		80				0		–	–	–	–	–	1	
Collector-Cutoff Current: With base-emitter junction reverse-biased	I_{CEX}		40	1.5				–	0.1	–	–	–	–	mA
			60	1.5				–	–	–	0.1	–	–	
			80	1.5				–	–	–	–	–	0.1	
T_C = 125°C	I_{CEX} (T_C = 125°C)		40	1.5				–	2	–	–	–	–	
			60	1.5				–	–	–	2	–	–	
			80	1.5				–	–	–	–	–	2	
Emitter-Cutoff Current	I_{EBO}			5	0			–	1	–	1	–	1	mA
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$[a]				0.1	0		40	–	60	–	80	–	V
Base-to-Emitter Voltage	V_{BE}[a]		2		1.5			–	1.2	–	1.2	–	1.2	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]				1.5	0.15		–	0.6	–	0.6	–	0.6	V
					4	1		–	1.4	–	1.4	–	1.4	
Gain-Bandwidth Product (At f = 1 MHz)	f_T		10		1			2	–	2	–	2	–	MHz
DC Forward-Current Transfer Ratio	h_{FE}[a]		2		1.5			25	100	25	100	20	80	
			2		4			10	–	10	–	7	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$							–	3.12	–	3.12	–	3.12	°C/W

[a]Pulsed: Pulse duration ≤300 µs, duty factor ≤2%.

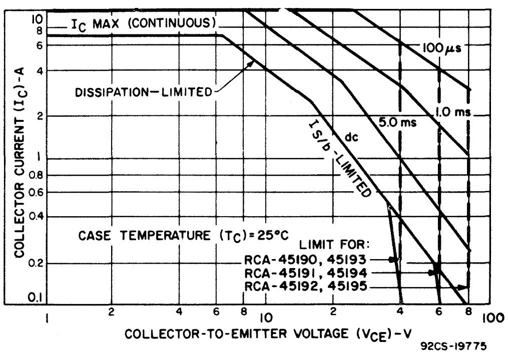


Fig. 1—Maximum operating areas for types 45190-5.

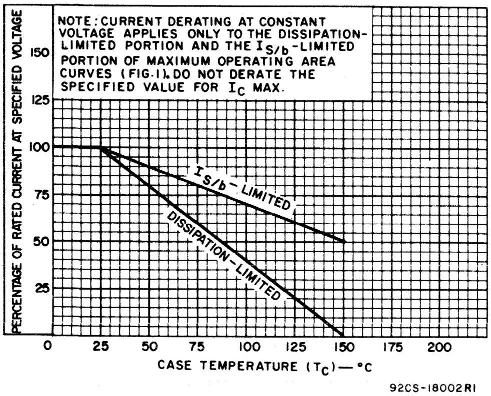


Fig. 2—Derating curves for types 45190-5.

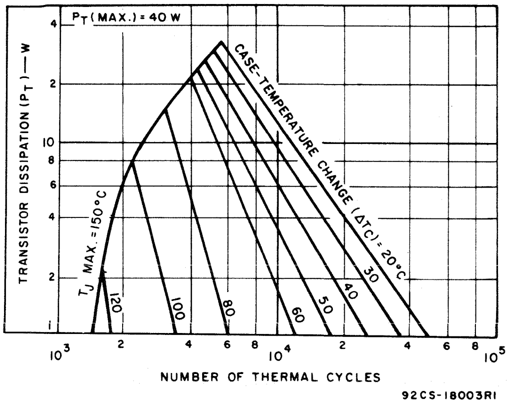


Fig. 3—Thermal-cycling ratings for types 45190-5.

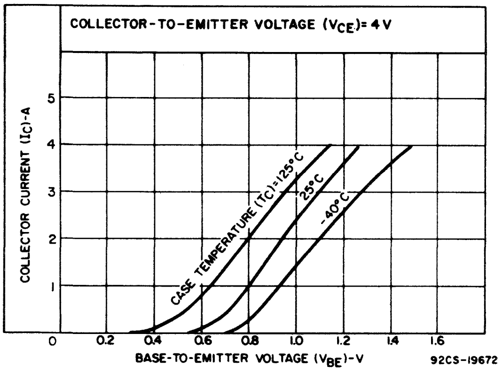


Fig. 4—Typical transfer characteristics for types 45190-2.

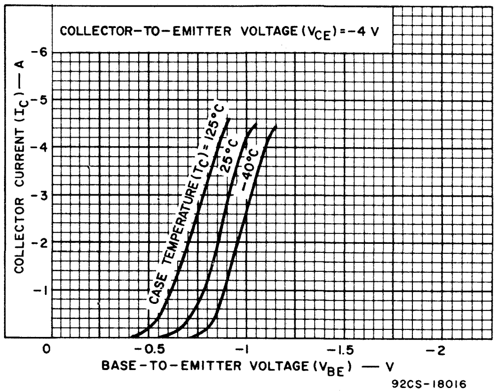


Fig. 5—Typical transfer characteristics for types 45193-5.

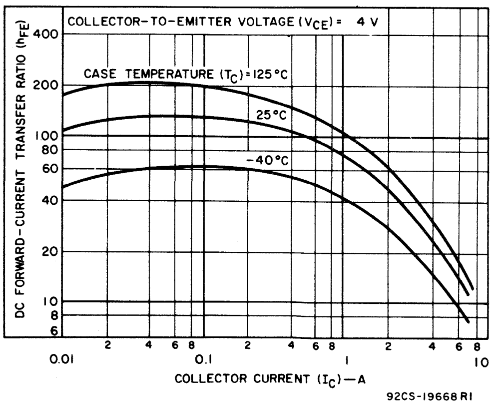


Fig. 6—Typical dc beta characteristics for types 45190-5.

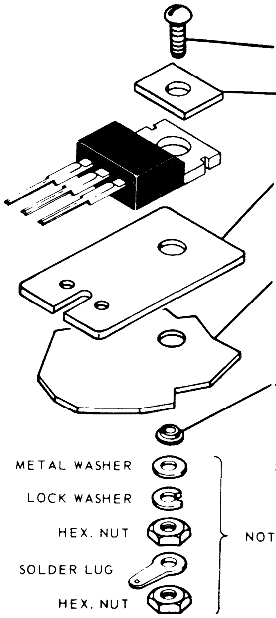
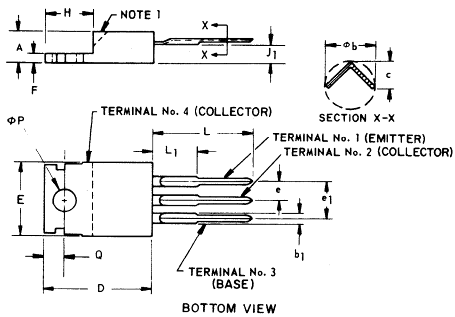


Fig. 7—Suggested mounting hardware for types 45190-5.

DIMENSIONAL OUTLINE
JEDEC TO-220AB



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

TERMINAL CONNECTIONS

Terminal No. 1 – Emitter
Terminal No. 2 – Collector
Terminal No. 3 – Base
Mounting Flange, Terminal No. 4 – Collector

High-Voltage n-p-n Power Transistors

RCA

Solid State Division

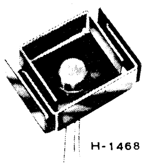
Power Transistors

2N3439 2N4063 2N3440 2N4064 40390

RCA-2N3439*, 2N3440**, 2N4063, & 2N4064 are triple-diffused silicon n-p-n transistors with high-breakdown voltages, high-frequency response, and fast-switching speeds. These transistors are intended for industrial, commercial, and military equipment. Typical applications include high-voltage differential and operational amplifiers, high-voltage inverters, and high-voltage, low-current switching and series regulators.

The 2N3439 and the 2N3440 differ primarily in their voltage ratings; the 2N4063 and 2N4064 have the same voltage ratings as the 2N3439 and 2N3440 respectively, but employ a flange package.

*Formerly Dev. Type No. TA2458.
**Formerly Dev. Type No. TA2470.



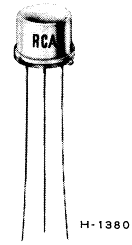
40390

ALSO AVAILABLE. . .

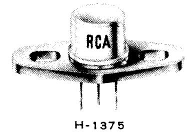
Type 40390 is a 2N3440 with a factory-attached heat radiator; it is intended for printed circuit-board applications.

- **Maximum area-of-operation curves for DC and pulse operation**
- **Designed to assure freedom from second breakdown in class −A, −B, and −C operation at maximum ratings**

SILICON N-P-N TYPES



2N3439, 2N3440
JEDEC TO-5



2N4063, 2N4064
JEDEC TO-5 + FLANGE

For High-Speed Switching and Linear-Amplifier Applications in Industrial Commercial, and Military Equipment

- **High-voltage ratings:**
  - V_{CBO} = 450 V max. (2N3439, 2N4063)
  - = 300 V max. (2N3440, 2N4064)
  - $V_{CEO}(sus)$ = 350 V max. (2N3439, 2N4063)
  - = 250 V max. (2N3440, 2N4064)
- **Low saturation voltage:**
  - $V_{CE}(sat)$ = 0.5 V max.

MAXIMUM RATINGS

Absolute-Maximum Values:		2N3439 2N4063	2N3440 2N4064 40390	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	450	300	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE	$V_{CEO}(sus)$	350	250	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	V
COLLECTOR CURRENT	I_C	1	1	A
BASE CURRENT	I_B	0.5	0.5	A
TRANSISTOR DISSIPATION	P_T			
At case temperatures up to 25°C		10	10(2N3440)	W
		—	10(2N4064)	W
At free-air temperatures up to 25°C		—	3.5(40390)	W
At free-air temperatures up to 50°C		1(2N3439)	1(2N3440)	W
At free-air temperatures above 25°C or 50°C		See Fig. 7.		
For pulse operation		See Fig. 6.		
TEMPERATURE RANGE:				
Storage & Operating (Junction)		−65 to 200		°C
LEAD TEMPERATURE (During soldering):				
At distance ≥ 1/32 in. from seating plane for 10 s max.		255		°C

ELECTRICAL CHARACTERISTICS

Case Temperature $(T_C) = 25^{o}C$

Characteristic	Symbol	TEST CONDITIONS							LIMITS				Units
		DC Collector Volts		DC Emitter or Base Volts		DC Current (milliamperes)			Types 2N3439 2N4063		Types 2N3440 2N4064 40390		
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	
Collector-Cutoff Current	I_{CEO}		300					0	-	20	-	-	µA
			200					0	-	-	-	50	µA
	I_{CEV}		450		-1.5				-	500	-	-	µA
			300		-1.5				-	-	-	500	µA
Emitter-Cutoff Current	I_{EBO}			6		0			-	20	-	20	µA
DC Forward-Current Transfer Ratio	h_{FE}		10			20			40	160	40	160	
			10			2			30	-	-	-	
Collector-to-Emitter Sustaining Voltage: *(See Figs. 1 & 2.)* With base open	$V_{CEO}(sus)$					50		0	350[a]	-	250[a]	-	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					50		4	-	1.3	-	1.3	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					50		4	-	0.5	-	0.5	V
Small-Signal, Forward-Current Transfer Ratio (at 5 MHz)	h_{fe}		10			10			3	-	3	-	
Output Capacitance (at 1 MHz)	C_{ob}	10					0		-	10	-	10	pF
Second-Breakdown[b] Collector Current: With base forward biased[c]	$I_{S/b}$[d]		200						50	-	50	-	mA
Thermal Resistance: Junction-to-Case	$\theta_{J\text{-}C}$								-	17.5	-	17.5	°C/W

[a]**CAUTION:** The sustaining voltage $V_{CEO}(sus)$ **MUST NOT** be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 1.

[b]Safe-operating region for second breakdown is explained under "SECOND BREAKDOWN" on page 6.

[c]Specified value of $I_{S/b}$ for given value of V_{CE} as base voltage is increased from zero in a positive direction.

[d]$I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

CIRCUIT USED TO MEASURE SUSTAINING VOLTAGE, $V_{CEO}(sus)$ FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

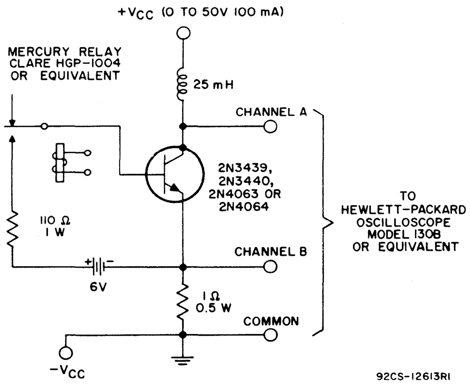
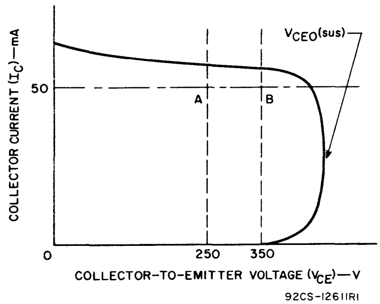


Fig. 1

OSCILLOSCOPE DISPLAY FOR MEASUREMENT OF SUSTAINING VOLTAGES (TEST CIRCUIT SHOWN IN FIG. 1)



The sustaining voltage $V_{CEO}(sus)$ is acceptable when the trace falls to the right and above point "A" for types 2N3440 and 2N4064. The trace must fall to the right and above point "B" for types 2N3439 and 2N4063.

Fig. 2

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPES 2N3439 & 2N4063

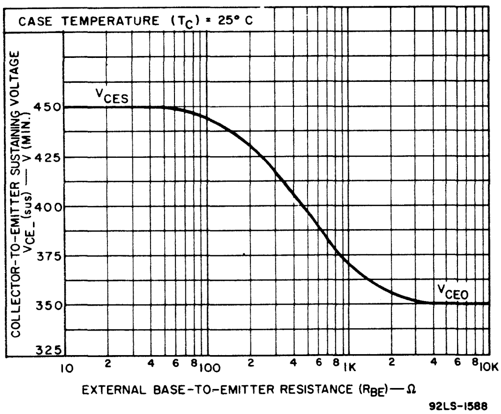


Fig. 3

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPES 2N3440, & 2N4064

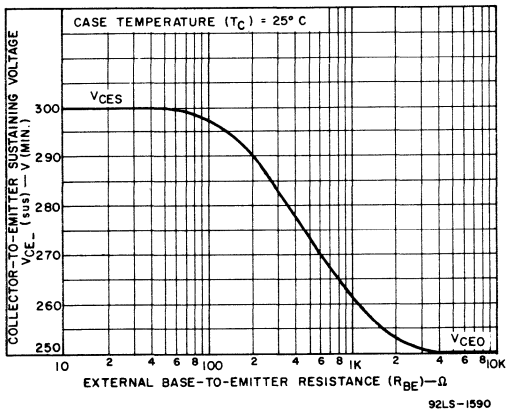


Fig. 4

MAXIMUM AREA-OF-OPERATION

For pulse operation at a temperature greater than 25° C, Fig. 5 is used together with Fig. 6 to obtain the maximum allowable power. This is done as follows:

(1) For a specified pulse width and collector-to-emitter voltage, V_{CE}, determine (from Fig. 6) the maximum collector current at 25°C, using the curve marked "THERMALLY LIMITED".

(2) Refer to Fig. 5 and determine the percentage current derating at the specified temperature. Apply this derating to the Value of I_C from step (1), to obtain the maximum current for thermally-limited operation.

(3) The maximum allowable current is the value obtained in step (2).

For repetitive-pulse operation, the actual case temperature to be use in Fig. 5 is the sum of the maximum ambient temperature and the rise in case temperature resulting from the average transistor power dissipation. The temperature rise is the product of average power dissipation and the thermal resistance from case to ambient, which depends on the heat-sink properties.

DISSIPATION DERATING CURVE FOR TYPES
2N3439, 2N3440, 2N4063, & 2N4064

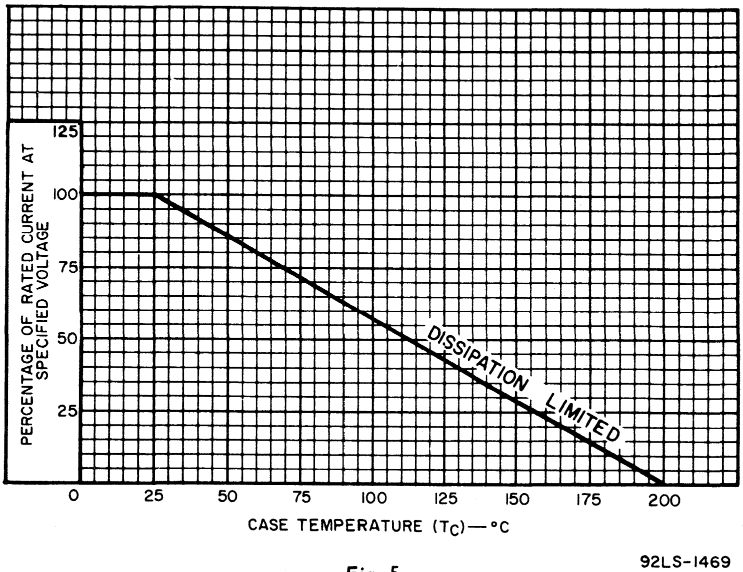
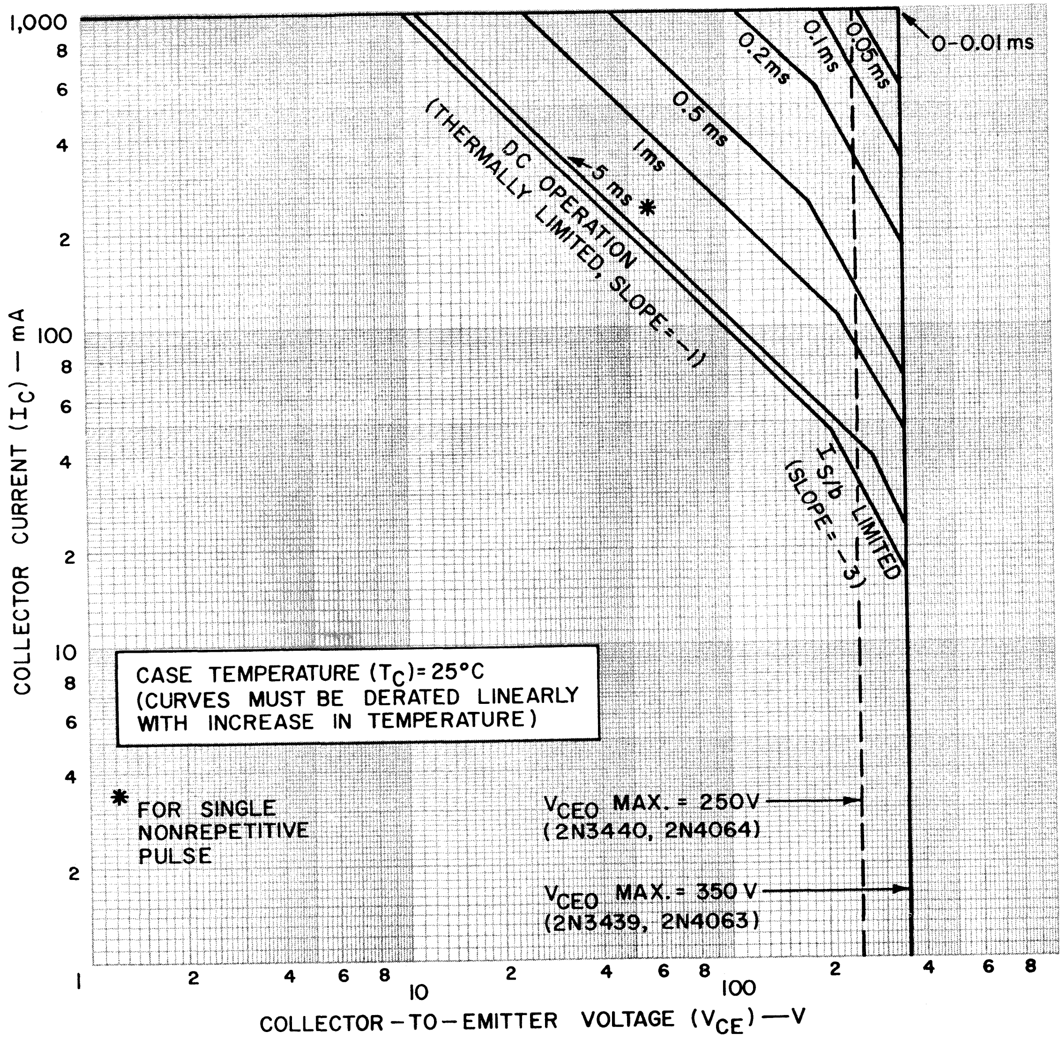
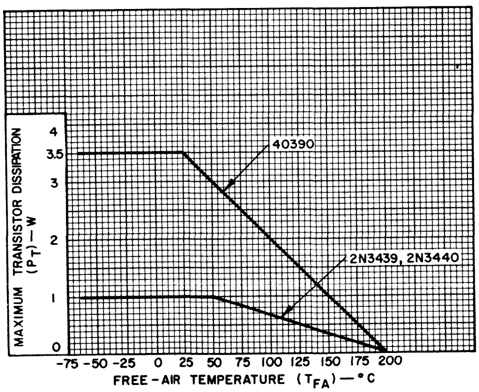


Fig. 5

MAXIMUM OPERATING AREAS FOR TYPES
2N3439, 2N3440, 2N4063, & 2N4064





DISSIPATION DERATING CURVES FOR TYPES
2N3439, 2N3440, & 40390

TYPICAL DC-BETA CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

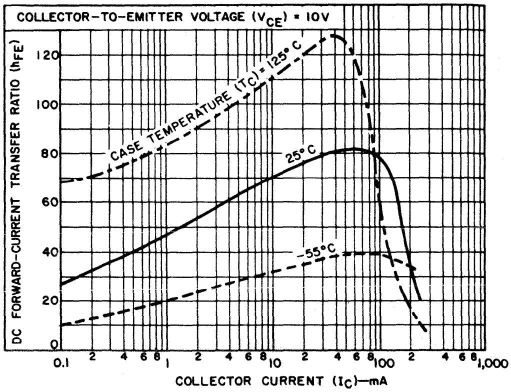


Fig. 8 92LS-1599

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

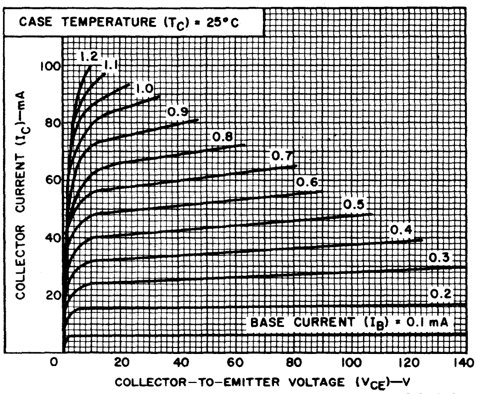


Fig. 9 92LS-1600

TYPICAL INPUT CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

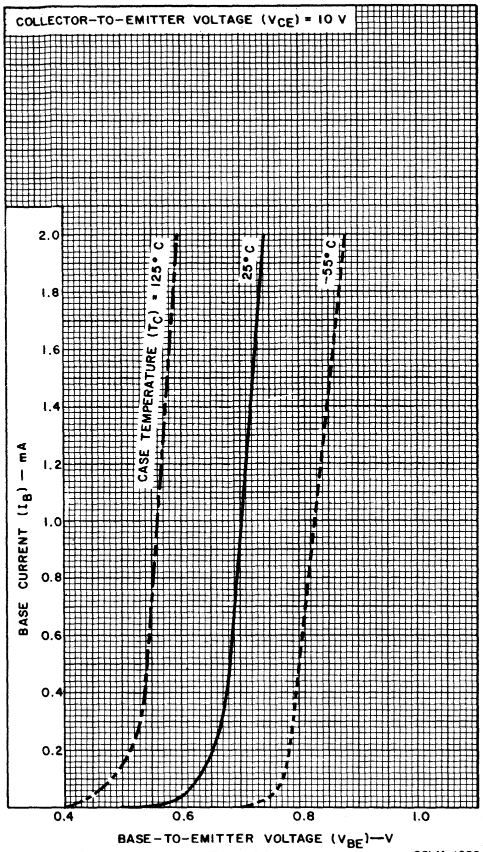


Fig. 10 92LM-1602

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

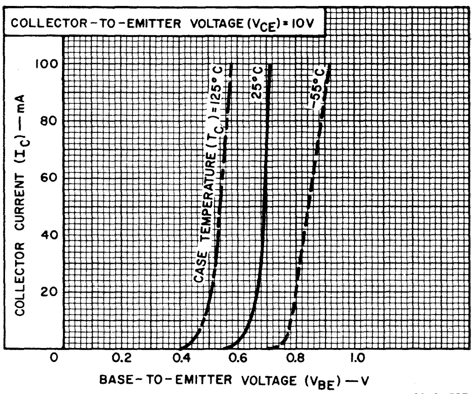


Fig. 11 92LS-1597

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

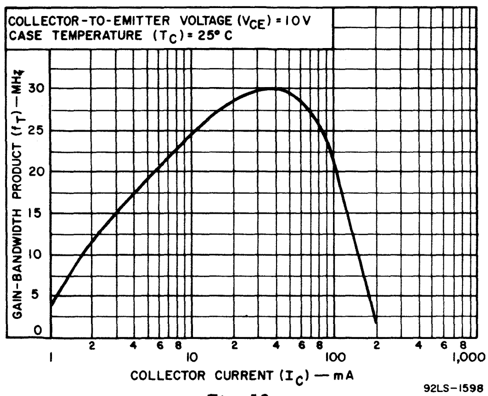
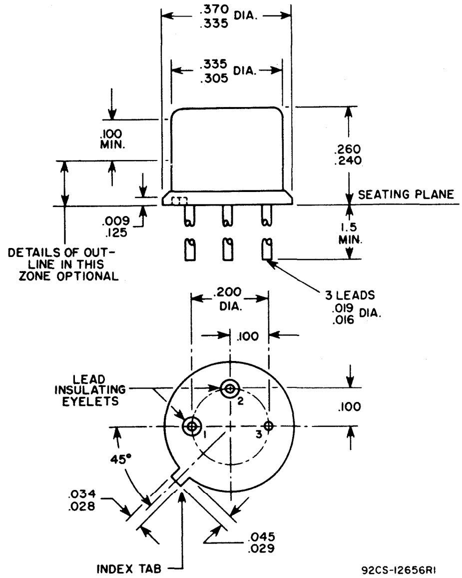


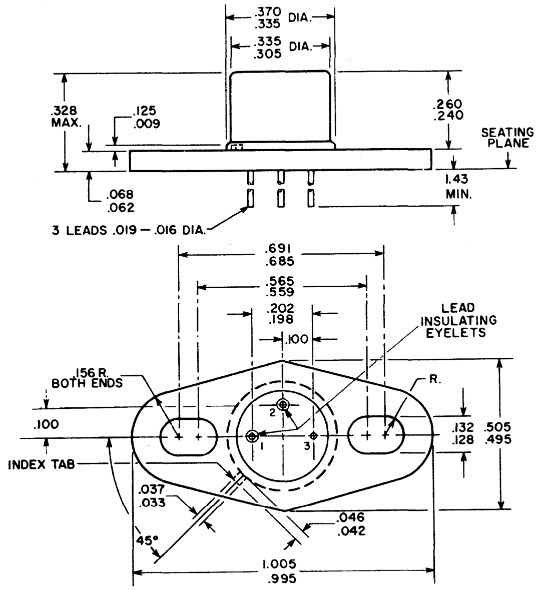
Fig. 12 92LS-1598

DIMENSIONAL OUTLINE FOR TYPES 2N3439 & 2N3440 JEDEC No. TO-5



DIMENSIONS IN INCHES

DIMENSIONAL OUTLINE FOR TYPES 2N4063 & 2N4064 JEDEC TO-5 WITH FLANGE

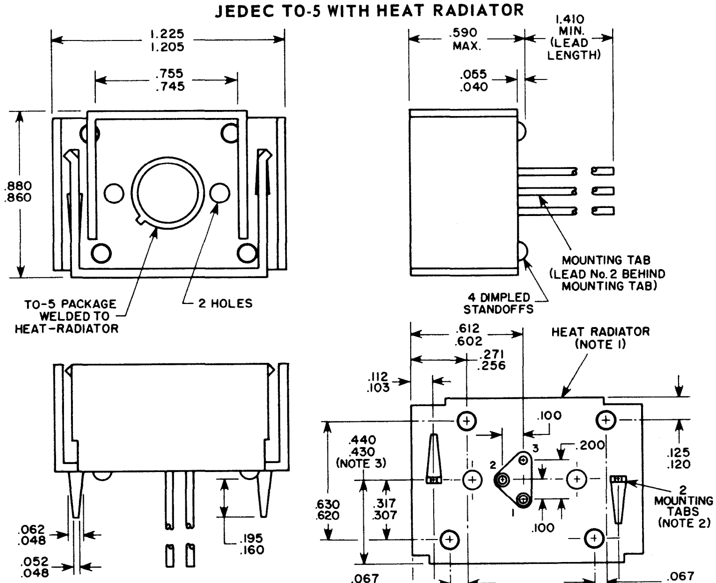


NOTE: SOME DEVICES MAY HAVE A FLANGE WITH A TRIANGULAR CUTOUT FOR LEADS.

92CS-12621R1

DIMENSIONS IN INCHES

DIMENSIONAL OUTLINE FOR TYPE 40390 JEDEC TO-5 WITH HEAT RADIATOR



NOTE 1: 0.035 C.R.S., FINISH—ELECTROLESS NICKEL PLATE

NOTE 2: RECOMMENDED HOLE SIZE FOR PRINTED-CIRCUIT BOARD IS 0.070 DIA.

NOTE 3: MEASURED AT BOTTOM OF HEAT-RADIATOR

DIMENSIONS IN INCHES

TERMINAL CONNECTIONS FOR TYPES 2N3439 & 2N3440

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

TERMINAL CONNECTIONS FOR TYPES 2N4063 & 2N4064

Lead 1 - Emitter
Lead 2 - Base
Flange, Lead 3 - Collector

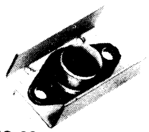
TERMINAL CONNECTIONS FOR TYPE 40390

Lead 1 - Emitter
Lead 2 - Base
Heat Radiator, Lead 3 - Collector

RCA Solid State Division

Power Transistors
2N3583-2N3585 40374, 2N4240

JEDEC TO-66 H-1340



JEDEC TO-66 With Integral Heat Radiator H-1470A

High-Voltage Silicon N-P-N Transistors

For High-Speed Switching and Linear-Amplifier Applications

Features

- 100-percent tested to assure freedom from second breakdown in both forward- and reverse-bias conditions when operated within specified limits
- JEDEC TO-66 package for 2N3583, 2N3584, 2N3585, and 2N4240
- JEDEC TO-66 package with heat radiator for 40374
- Economy types for ac/dc circuits
- Fast turn-on time at high collector current

RCA-2N3583,• 2N3584,• 2N3585,• 2N4240,• and 40374 are silicon n-p-n transistors with high breakdown voltages and fast switching speeds.

Type 40374 is a 2N3583 with a factory-attached heat radiator to increase the free-air dissipation rating. This device is intended for those applications which require a power transistor for mounting on a printed-circuit board. Tabs are provided on the underside of the radiator for mounting purposes and making electrical connection to the collector.

Typical applications for these transistors include high-voltage operational amplifiers, high-voltage switches, switching regulators, converters, inverters, deflection- and hi-fi amplifiers. These transistors are also intended for a wide variety of applications in ac/dc commercial equipment.

Heat-radiator versions of types 2N3584, 2N3585, and 2N4240 can also be supplied on special order.

•Formerly Dev. Nos. TA2510, TA2511, TA2512, and TA2871, respectively.

MAXIMUM RATINGS, *Absolute-maximum values:*

		2N3583	2N3584	2N3585 2N4240	40374	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	250	375	500	250	V
*COLLECTOR-TO-EMITTER VOLTAGE, sustaining	$V_{CEO}(sus)$	175	250	300	175	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	6	6	V
*CONTINUOUS COLLECTOR CURRENT	I_C	1	2	2	2	A
*PEAK COLLECTOR CURRENT		5	5	5	5	A
*CONTINUOUS BASE CURRENT	I_B	1	1	1	1	A
*TRANSISTOR DISSIPATION	P_T					
At case temperature (T_C) = 25°C		35	35	35	35	W
At case temperatures above 25°C		Derate linearly at 0.2 W/°C				
For other conditions		See Figs. 7, 8, 9, 21, 22, & 23				
*TEMPERATURE RANGE:						
Storage & Operating (Junction)		← −65 to 200 →				°C
*PIN TEMPERATURE:						
1/16 in. (1.58 mm) from seating plane for 10 s max.		235	235	235	235	°C

*In accordance with JEDEC registration data format JS-6 RDF-2 (2N3583), JS-6 RDF-1 (2N3584, 2N3585, 2N4240)

ELECTRICAL CHARACTERISTICS *at Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE–V		DC EMITTER OR BASE VOLTAGE–V		DC CURRENT mA			LIMITS: TYPES 2N3583 & 40374		TYPE 2N3584		TYPE 2N3585		TYPE 2N4240		UNITS
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
* Collector-Cutoff Current	I_{CEO}		150					0	–	10	–	5	–	5	–	5	mA
* Collector-Cutoff Current	I_{CEX}		225		–1.5				–	1.0	–	–	–	–	–	–	mA
			340		–1.5				–	–	–	1.0	–	–	–	–	
			450		–1.5				–	–	–	–	–	1.0	–	2.0	
At T_C = 150°C	I_{CEX}		225		–1.5				–	3	–	–	–	–	–	–	mA
			300		–1.5				–	–	–	3	–	3	–	5.0	
* Emitter-Cutoff Current	I_{EBO}			6		0			–	5.0	–	0.5	–	0.5	–	0.5	mA
* DC Forward-Current Transfer Ratio	h_{FE}		2			750			–	–	–	–	–	–	10	100	
			2			1 A			–	–	8	80	8	80	–	–	
			10			100			40	–	40	–	40	–	40	–	
			10			500			40	200	–	–	–	–	–	–	
			10			750			–	–	–	–	–	–	30	150	
			10			1 A			10	–	25	100	25	100	–	–	
Collector-to-Emitter Sustaining Voltage: (See Figs. 1, 2, & 12) * With base open	V_{CEO}(sus)					200		0	175●	–	250●	–	300●	–	300●	–	V
With external base-to-emitter resistance (R_{BE}) = 50Ω	V_{CER}(sus)					200			250●	–	300●	–	400●	–	400●	–	V
* Base-to-Emitter Saturation Voltage	V_{BE}(sat)					750		75	–	–	–	–	–	–	–	1.8	V
						1 A		100	–	1.4	–	1.4	–	1.4	–	–	
* Collector-to-Emitter Saturation Voltage	V_{CE}(sat)					750		75	–	–	–	–	–	–	–	1.0	V
						1 A		125	–	5	–	0.75	–	0.75	–	–	
Small-Signal Forward Current Transfer Ratio f = 5 MHz	h_{fe}		10			200			3	–	3	–	3	–	3	–	
* f = 1 kHz			30			100			25	350	–	–	–	–	–	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio f = 5 MHz	$\|h_{fe}\|$		10			200			2	–	2	–	2	–	3	–	
Output Capacitance (f = 1 MHz)	C_{obo}	10					0		–	120	–	120	–	120	–	120	pF
Second-Breakdown Collector Current with base forward-biased** (See Figs. 22 & 23)	$I_{S/b}$▲		100						350	–	350	–	350	–	350	–	mA
Second-Breakdown Energy with base reverse-biased R_{BE} = 20Ω, L = 100 μH	$E_{S/b}$†				–4				50	–	200	–	200	–	50	–	μJ
* Saturated Switching Time: Rise Time (See Figs. 13, 16, 17, & 18)	t_r	(V_{CC}) 200				1 A		100	–	–	–	3	–	3	–	–	μs
						750		75	–	–	–	–	–	–	–	0.5	
Storage Time (See Figs. 14, 16, 17, & 18)	t_s	(V_{CC}) 200				1 A		100	–	–	–	4	–	4	–	–	μs
						750		75	–	–	–	–	–	–	–	6	
Fall Time (See Figs. 15, 16, 17, & 18)	t_f	(V_{CC}) 200				750		75	–	–	–	–	–	–	–	3	μs
						1 A		100	–	–	–	3	–	3	–	–	
Thermal Resistance: Junction-to-Case	$R_{\Theta JC}$								5(Max.) 2N3583		–	5	–	5	–	5	°C/W
Junction-to-Ambient	$R_{\Theta JA}$								70 (Max.) 2N3583		–	70	–	70	–	70	°C/W
									30 (Max.) 40374		–	–	–	–	–	–	

*In accordance with JEDEC registration data format JS-6 RDF-2 (2N3583), JS-6 RDF-1 (2N3584, 2N3585, 2N4240)

● **CAUTION:** The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) **MUST NOT** be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 1.

▲ $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

** Specified value of $I_{S/b}$ for given value of V_{CE} as base voltage is increased from zero in a positive direction.

† $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b}$ = 1/2 LI^2, where L is a series load or leakage inductance and I is the peak collector current from Figs. 3, 4, and 5.

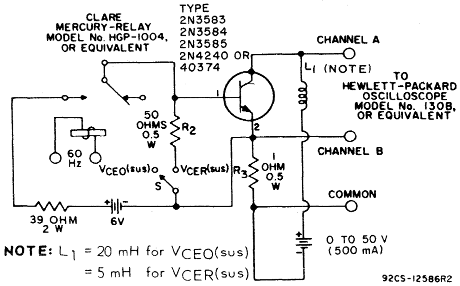


Fig. 1—Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ for all types.

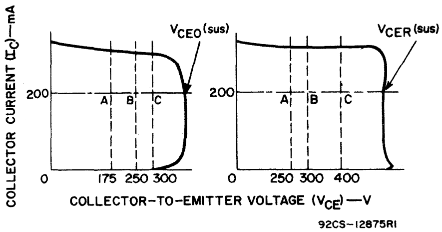


Fig. 2—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 1).

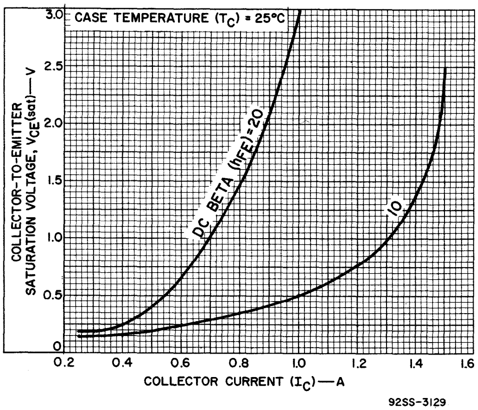


Fig. 3—Typical collector-to-emitter saturation voltage vs. current for types 2N3584 and 2N3585.

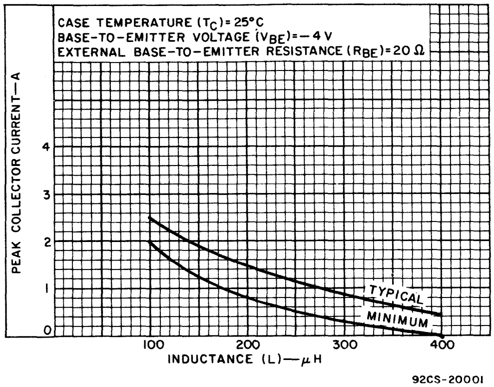


Fig. 4—Reverse-bias second breakdown characteristics for types 2N3584 and 2N3585.

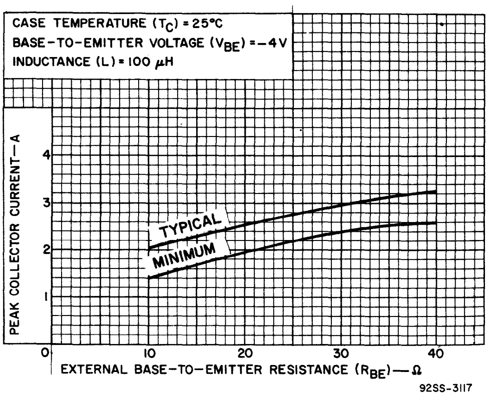


Fig. 5—Reverse-bias second breakdown characteristics for types 2N3584 and 2N3585.

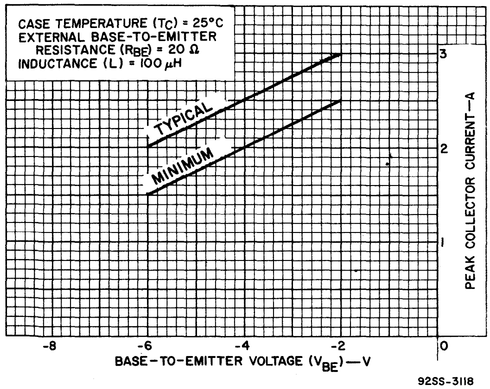


Fig. 6—Reverse-bias second breakdown characteristics for types 2N3584 and 2N3585.

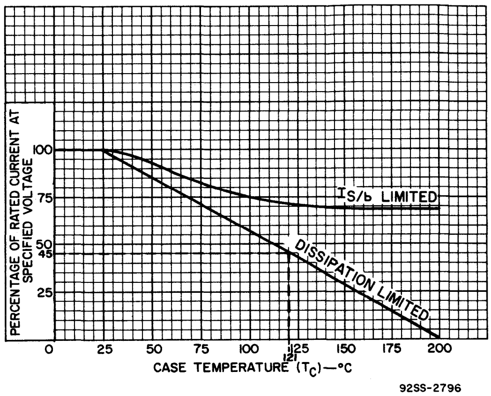


Fig.7—Dissipation derating curves for all types.

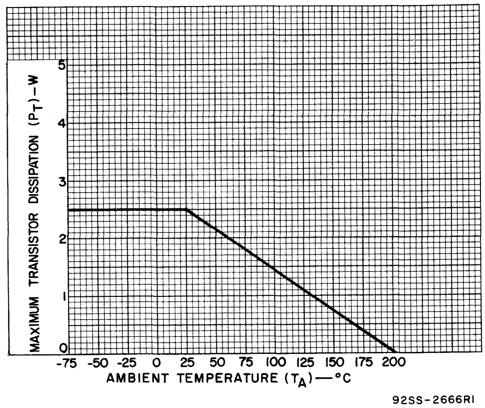


Fig. 8—Dissipation derating curve for types 2N3583, 2N3584, 2N3585, and 2N4240.

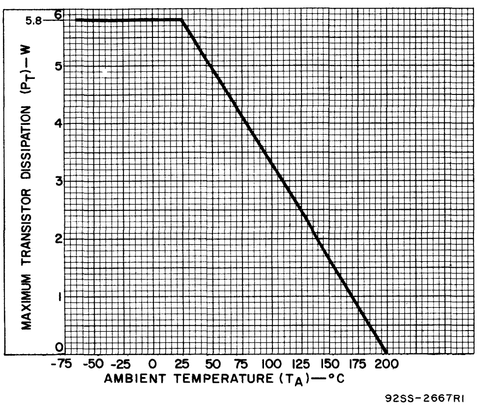


Fig. 9—Dissipation derating curve for type 40374.

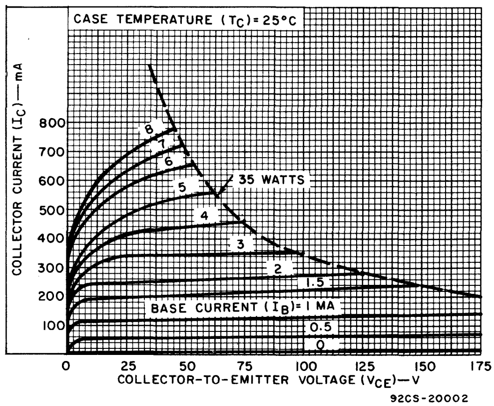


Fig. 10—Typical output characteristics for types 2N3583 and 40374.

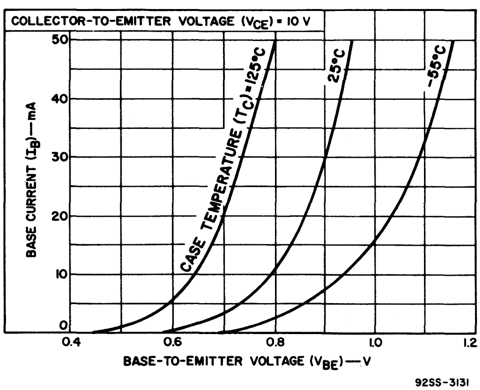


Fig. 11—Typical input characteristics for all types.

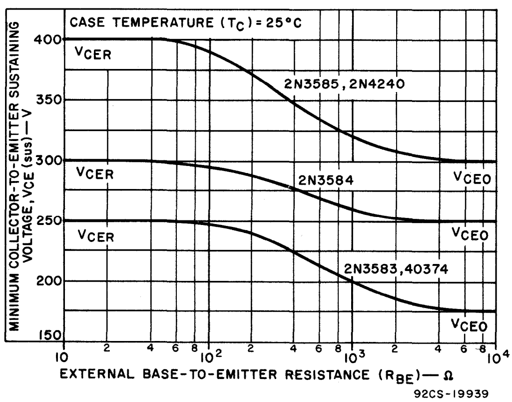


Fig. 12—Sustaining voltage vs. base-to-emitter resistance for all types.

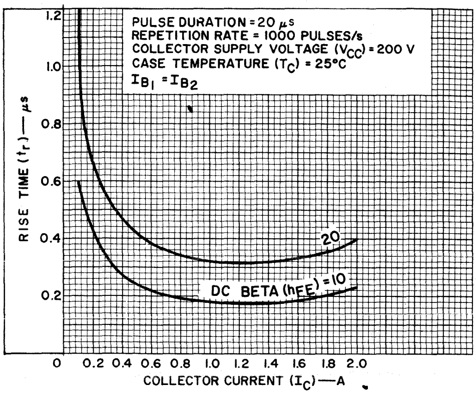


Fig. 13—Typical rise time vs. collector current for types 2N3584 and 2N3585.

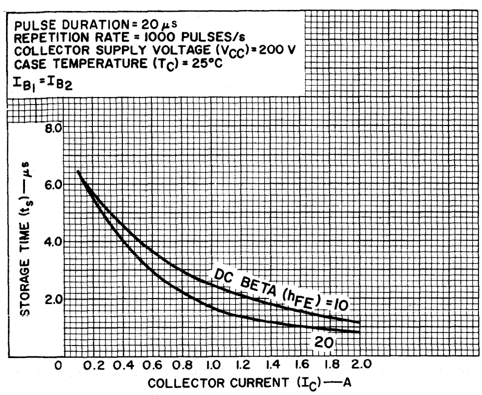


Fig. 14—Typical storage time vs. collector current for types 2N3584 and 2N3585.

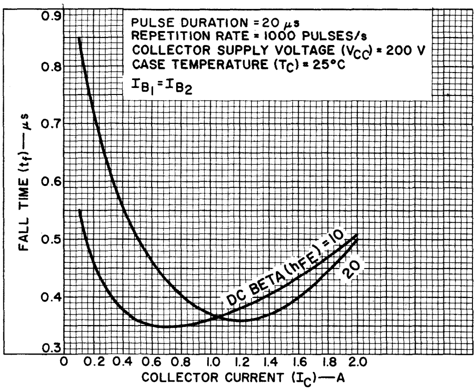


Fig. 15—Typical fall time vs. collector current for types 2N3584 and 2N3585.

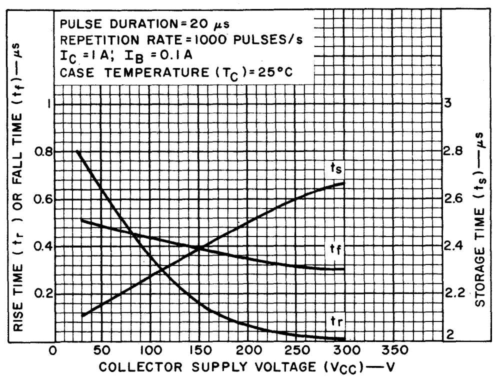


Fig. 16—Typical rise time, fall time, and storage time vs, collector supply voltage for types 2N3584 and 2N3585.

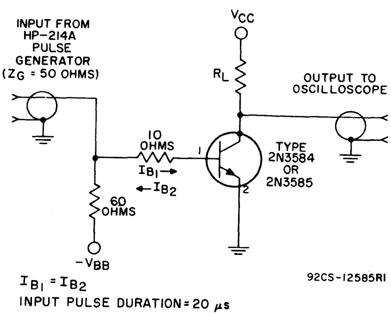


Fig. 17—Circuit used to measure switching times for types 2N3584 and 2N3585.

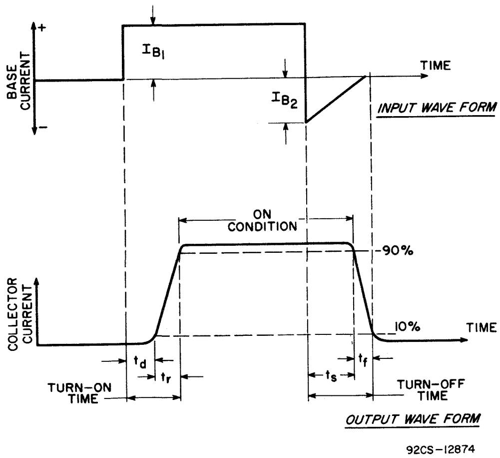


Fig. 18—Phase relationship between input and output currents, showing reference points for specification of switching times (test circuit shown in Fig. 17).

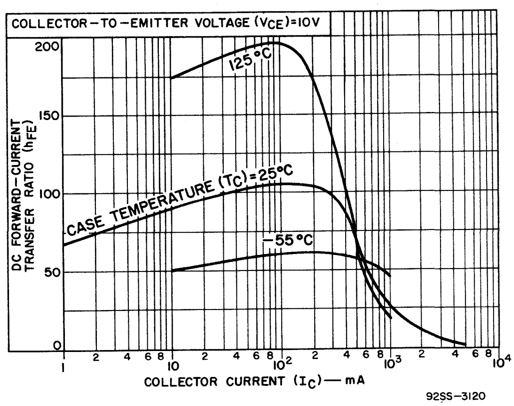


Fig. 19—Typical dc beta vs. collector current for types 2N3583, 2N4240, and 40374.

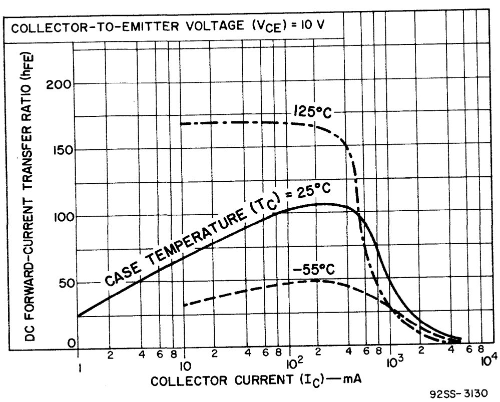


Fig. 20—Typical dc beta vs. collector current for types 2N3584 and 2N3585.

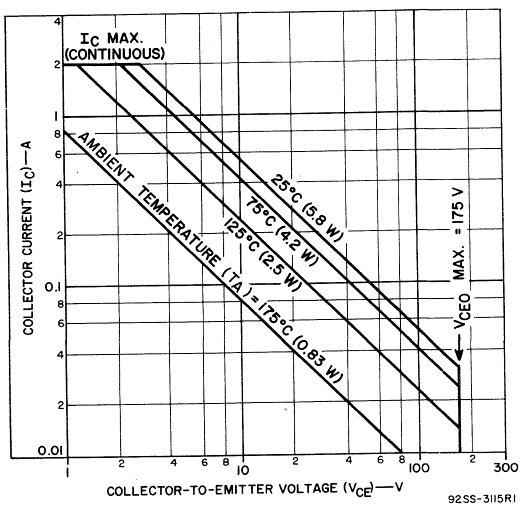


Fig. 21—Maximum operating areas for type 40374.

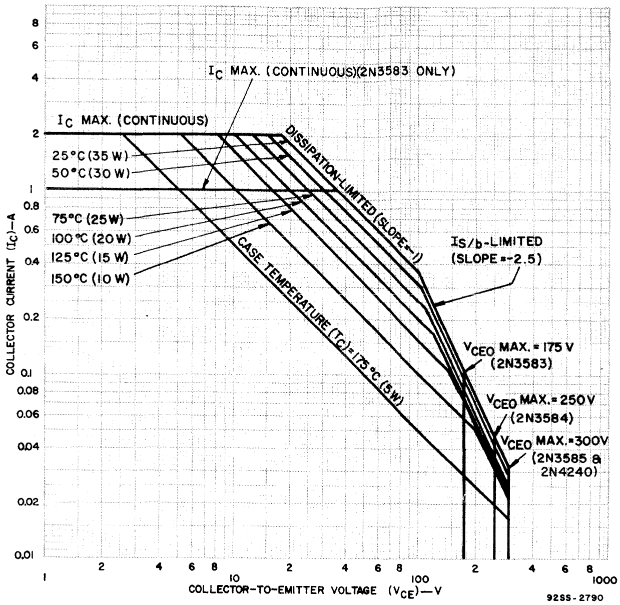


Fig. 22—Maximum operating areas for types 2N3583, 2N3584, 2N3585, and 2N4240 (dc conditions).

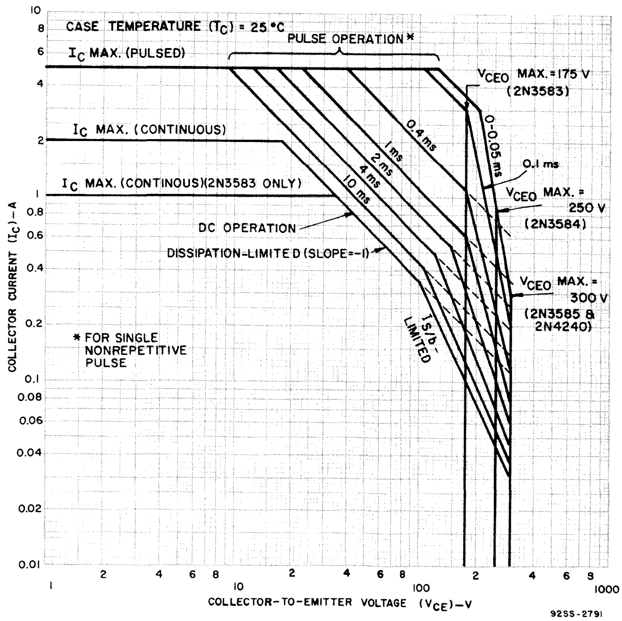


Fig. 23—Maximum operating areas for types 2N3583, 2N3584, 2N3585, and 2N4240 (pulse conditions).

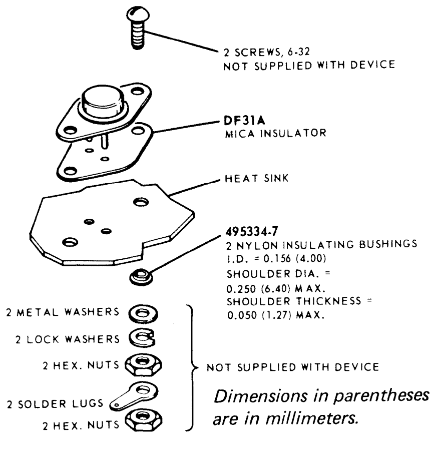
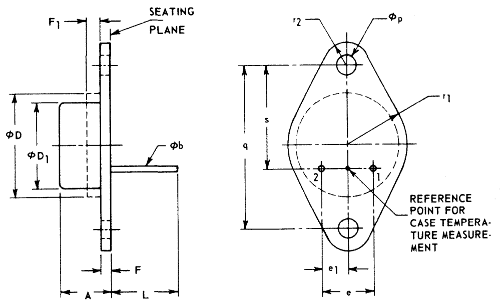


Fig. 24—Suggested mounting hardware for types 2N3583, 2N3584, 2N3585, and 2N4240.

DIMENSIONAL OUTLINE FOR TYPES 2N3583, 2N3584, 2N3585, AND 2N4240

JEDEC TO-66



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.250	0.340	6.35	8.64	
φb	0.028	0.034	0.711	0.863	
φD	—	0.620	—	15.75	
φD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1	—	0.050	—	1.27	1
L	0.360	—	9.14	—	
φp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r_1	—	0.350	—	8.89	
r_2	—	0.145	—	3.68	
s	0.570	0.590	14.48	14.99	

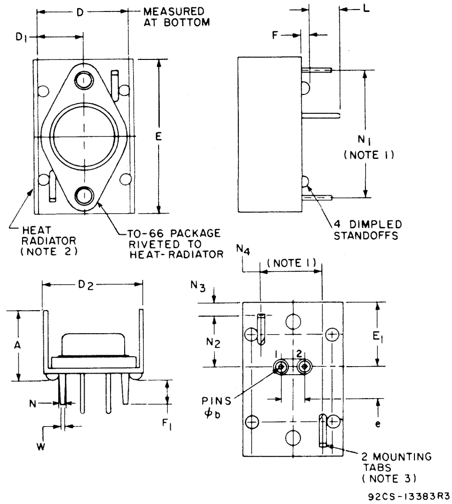
NOTES:
1. The outline contour is optional within zone defined by φD and F_1.
2. Dimension does not include sealing flange.

92SS 3738

TERMINAL CONNECTIONS FOR TYPES 2N3583, 2N3584, 2N3585, AND 2N4240

Pin 1 - Base
Pin 2 - Emitter
Case, Mounting Flange - Collector

DIMENSIONAL OUTLINE FOR TYPE 40374 JEDEC TO-66 WITH HEAT RADIATOR



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A		0.616		15.64	
φb	0.028	0.034	0.711	0.864	
D	0.750	0.760	19.05	19.30	
D_1	0.375	0.380	9.52	9.65	
D_2	0.820	0.920	20.83	23.37	
E	1.297	1.327	32.94	33.70	
E_1	0.551	0.561	13.99	14.25	
e	0.190	0.210	4.83	5.33	
F	0.30	0.55	7.62	13.97	
F_1	0.175	0.210	4.44	5.33	
L	0.170		4.31		
N	0.052	0.065	1.32	1.65	
N_1	1.098	1.102	27.89	27.99	1
N_2	0.448	0.452	11.38	11.47	
N_3	0.099	0.113	0.25	0.29	
N_4	0.498	0.502	12.65	12.75	
W	0.048	0.060	1.22	1.52	

NOTES:
1. Measured at bottom of heat radiator.
2. 0.035 in. (0.889 mm) C.R.S., tin plated.
3. Recommended hole size for printed-circuit board is 0.070 in. (1.778 mm) dia.

TERMINAL CONNECTIONS FOR TYPE 40374

Pin 1 - Base
Pin 2 - Emitter
Heat-Radiator - Collector

RCA
Solid State
Division

Power Transistors
40346 40412
40346V1 40412V1
40346V2 40412V2

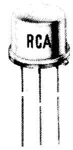
RCA-40346, -40346V1, -40346V2, -40412, -40412V1, and -40412V2 are triple-diffused silicon n-p-n transistors having high breakdown voltages, high frequency-response capability, and fast switching speeds.

These transistors are intended for a wide variety of low-and medium-power, high-voltage applications. Types 40346, 40346V1, and 40346V2 are especially useful in such devices as neon indicator and NIXIE* driver circuits and in differential and operational amplifiers. Types 40412, 40412V1, and 40412V2 are especially suited for Class-A AC/DC audio-amplifier service.

Types 40346 and 40412 are supplied in a JEDEC TO-5 package; types 40346V1 and 40412V1 in a JEDEC TO-5 package with a factory-attached heat radiator for greater free-air dissipation capability; and types 40346V2 and 40412V2 are supplied in a TO-5 package with an attached flange for increased power dissipation and mounting convenience.

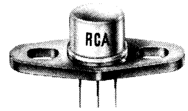
*Nixie is a Registered Trademark of Burroughs Corporation, Electronic Components Division, Plainfield, N. J.

For High-Voltage Switching and Linear-Amplifier Applications in Military, Industrial, and Commercial Applications



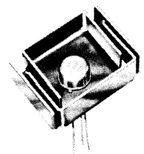
40346
40412

JEDEC TO-5 PACKAGE



40346V2
40412V2

JEDEC TO-5
PACKAGE WITH FLANGE



40346V1
40412V1

JEDEC TO-5 PACKAGE
WITH HEAT RADIATOR

MAXIMUM RATINGS

Absolute-Maximum Values:

	40346	40346V1	40346V2	40412	40412V1	40412V2	
COLLECTOR-TO-EMITTER VOLTAGE, $V_{CER}(sus)$:							
With R_{BE} = 1,000 ohms	175	175	175	–	–	–	V
With R_{BE} = 10,000 ohms	–	–	–	250	250	250	V
COLLECTOR CURRENT, I_C	1	1	1	1	1	1	A
BASE CURRENT, I_B	0.5	0.5	0.5	0.5	0.5	0.5	A
TRANSISTOR DISSIPATION, P_T:							
At case temperatures up to 25° C	10	–	10	10	–	10	W
At free-air temperatures up to 50° C	1	–	–	1	–	–	W
At free-air temperatures up to 25° C	–	4	–	–	4	–	W
At other temperatures	← See *Fig. 1* →						
OPERATING TEMPERATURE RANGE	← –65 to +200 →						°C

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) = 25° C, Unless Otherwise Specified

Characteristic	Symbol	DC Collector Volts		DC Emitter Volts	DC Current (mA)			LIMITS												UNITS
								40346		40346V1		40346V2		40412		40412V1		40412V2		
		V_{CE}	V_{CB}	V_{EB}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current:																				
With base open	I_{CEO}	100	—	—	—	—	—	—	5	—	5	—	5	—	—	—	—	—	—	µA
With R = 10,000 ohms	I_{CER}	100	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	mA
With base reverse-biased:																				
T_C=25° C	I_{CEV}	200	—	1.5	—	—	—	—	10	—	10	—	10	—	—	—	—	—	—	µA
T_C= 150° C	I_{CEV}	200	—	1.5	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	mA
T_C= 150° C	I_{CEV}	150	—	1.5	—	—	—	—	—	—	—	—	—	—	2	—	2	—	2	mA
Emitter-Cutoff Current	I_{EBO}	—	—	4	—	—	—	—	5	—	5	—	5	—	—	—	—	—	—	µA
	I_{EBO}	—	—	3	—	—	—	—	—	—	—	—	—	—	100	—	100	—	100	µA
Collector-To-Emitter Sustaining Voltage: With external base-emitter resistor																				
R_{BE}=1,000 ohms	$V_{CER(sus)}$	—	—	—	50	—	—	175	—	175	—	175	—	—	—	—	—	—	—	V
R_{BE}=10,000 ohms	$V_{CER(sus)}$	—	—	—	50	—	—	—	—	—	—	—	—	250	—	250	—	250	—	V
Collector-To-Emitter Saturation Voltage	$V_{CE(sat)}$	—	—	—	10	—	1	—	0.5	—	0.5	—	0.5	—	—	—	—	—	—	V
Base-To-Emitter Voltage	V_{BE}	10	—	—	10	—	—	—	1	—	1	—	1	—	—	—	—	—	—	V
Second-Breakdown Current (Safe-operating region)	$I_{S/b}$●	200	—	—	—	—	—	—	—	—	—	—	—	50	—	50	—	50	—	mA
DC Forward-Current Transfer Ratio	h_{FE}	10	—	—	10	—	—	25	—	25	—	25	—	—	—	—	—	—	—	
	h_{FE}	20	—	—	30	—	—	—	—	—	—	—	—	40	—	40	—	40	—	
Small-Signal Forward-Current Transfer Ratio at F=5 MHz	h_{fe}	10	—	—	10	—	—	2	—	2	—	2	—	2	—	2	—	2	—	
Output Capacitance (At 1 MHz)	C_{ob}	—	10	—	—	0	—	—	—	—	—	—	—	—	10	—	10	—	10	pF
Thermal Resistance: Junction-to-case	θ_{J-C}	—	—	—	—	—	—	—	15	—	—	—	15	—	15	—	—	—	15	°C/W
Junction-to-free air	θ_{J-FA}	—	—	—	—	—	—	—	—	—	45	—	—	—	—	—	45	—	—	°C/W

● $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

DISSIPATION DERATING CURVES

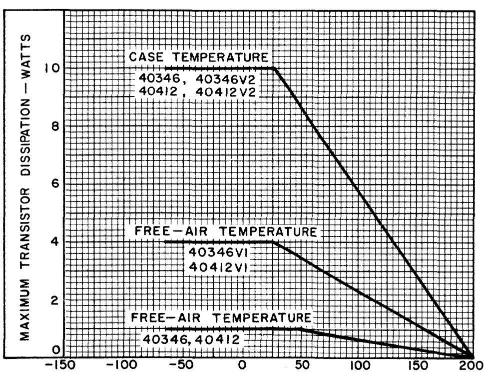


Fig. 1

TYPICAL DC-BETA CHARACTERISTICS FOR ALL TYPES

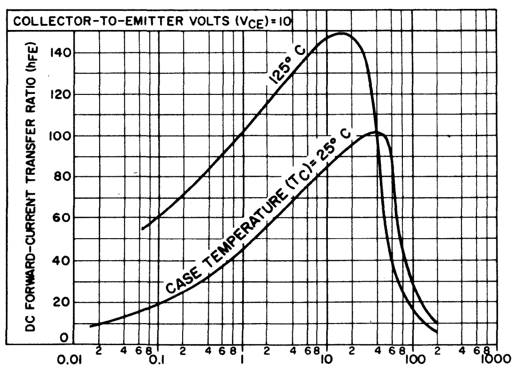


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS FOR ALL TYPES

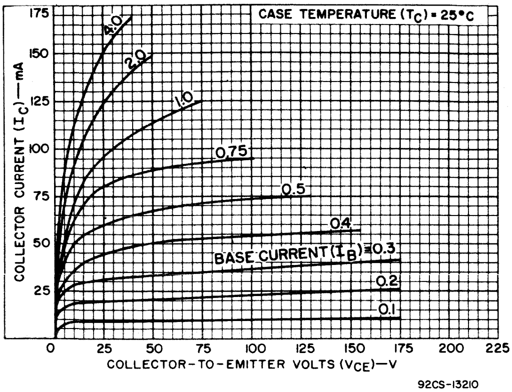


Fig. 3

TYPICAL OPERATION CHARACTERISTICS FOR ALL TYPES

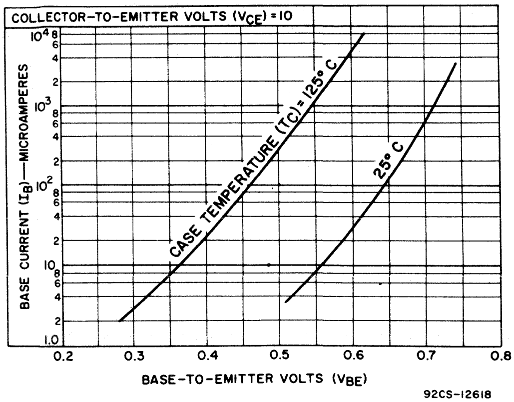


Fig. 4

TYPICAL OPERATION CHARACTERISTICS FOR ALL TYPES

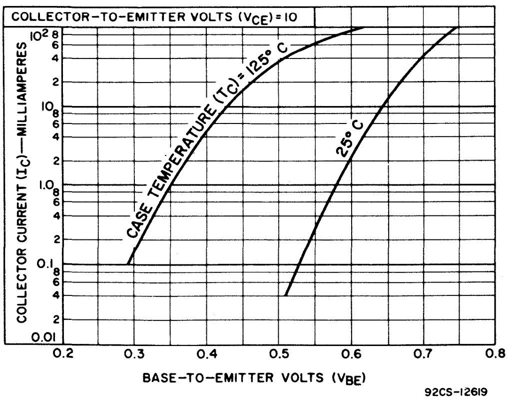
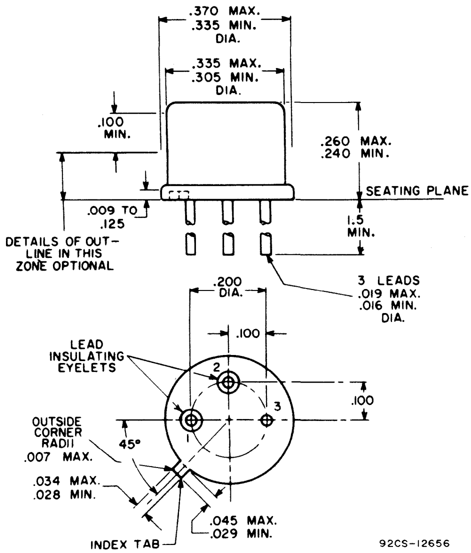


Fig. 5

DIMENSIONAL OUTLINE FOR TYPES 40346 & 40412 JEDEC TO-5

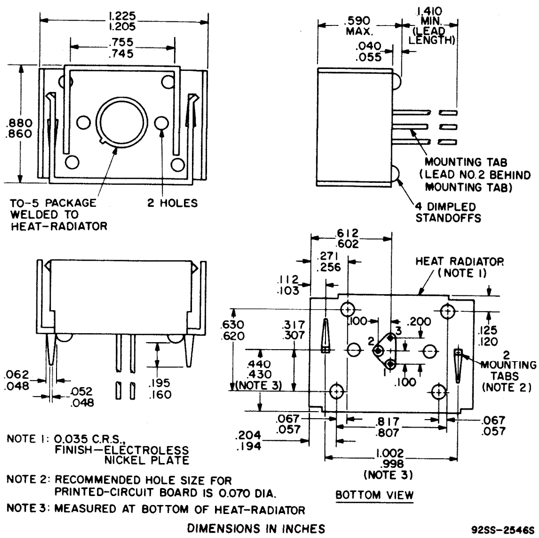


DIMENSIONS IN INCHES

TERMINAL CONNECTIONS

Lead 1: Emitter
Lead 2: Base
Lead 3: Collector, Case

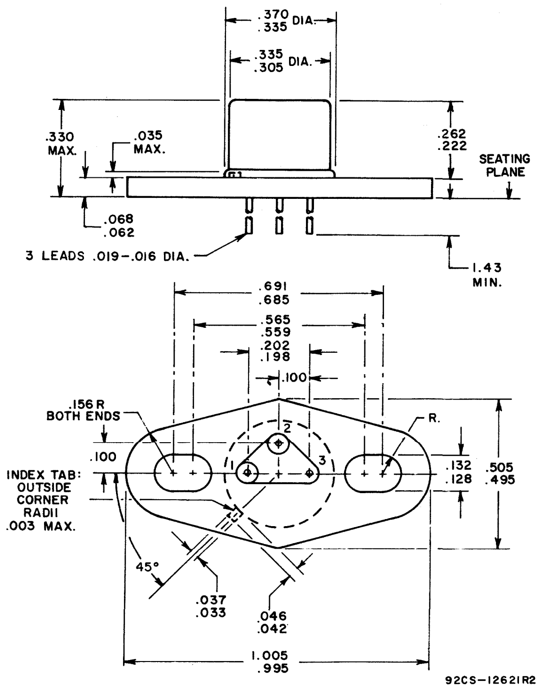
DIMENSIONAL OUTLINE FOR TYPES 40346V1, 40412V1 JEDEC TO-5 WITH HEAT RADIATOR



TERMINAL CONNECTIONS

Lead 1: Emitter
Lead 2: Base
Lead 3: Collector, Case

DIMENSIONAL OUTLINE FOR TYPES 40346V1, 40412V2



DIMENSIONS IN INCHES

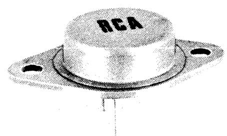
(Bottom View)

TERMINAL CONNECTIONS

Lead 1: Emitter
Lead 2: Base
Flange, Lead 3: Collector

RCA
Solid State
Division

Power Transistors
2N5239
2N5240



JEDEC TO-3

H-1570

Silicon N-P-N Power Transistors

High-Voltage, High-Power Types for
Applications in Industrial and Commercial Service

Features:

- **High voltage ratings: V_{CER}(sus) = 350 V, $R_{BE} \leq 50\ \Omega$ (2N5240)**
  = 250 V, $R_{BE} \leq 50\ \Omega$ (2N5239)
- **High power dissipation rating: P_T = 100 W at V_{CE} = 150 V, T_C = 25° C**
- **For switching applications where circuit values and operating conditions require a transistor with a high second breakdown rating ($I_{S/b}$) (limit line begins at 150 V)**
- **Maximum area-of-operation curves for dc and pulse operation**

RCA-2N5239 and 2N5240* are multiple epitaxial silicon n-p-n power transistors employing a new overlay construction with several emitter sites. Both devices employ the popular JEDEC TO-3 package; they differ in breakdown-voltage and leakage-current values.

The high breakdown voltage ratings and exceptional second-breakdown capabilities of these transistors make them especially suitable for use in series regulators, power amplifiers, inverters, deflection circuits, switching regulators, and high-voltage bridge amplifiers.

*RCA Dev. Nos. TA2765 and TA2765A, respectively.

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

	2N5239	2N5240	
*COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	300	375	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
* With base open, V_{CEO}(sus)	225	300	V
With external base-to-emitter resistance (R_{BE}) $\leq 50\ \Omega$, V_{CER}(sus)	250	350	V
*EMITTER-TO-BASE VOLTAGE, V_{EBO}	6	6	V
*COLLECTOR CURRENT, I_C	5	5	A
*BASE CURRENT, I_B	−2	−2	A
*TRANSISTOR DISSIPATION, P_T:			
At case temperatures up to 25° C and V_{CE} up to 150 V	100	100	W
At case temperatures up to 25° C and V_{CE} above 150 V	See Fig 2.		
At case temperatures above 25° C and V_{CE} above 150 V	See Figs. 1 & 2		
*TEMPERATURE RANGE:			
Storage & Operating (Junction)	−65 to +200		°C
*PIN TEMPERATURE (During Soldering)			
At distances ≥ 1/32 in. from seating plane for 10 s max	230		°C

*In accordance with JEDEC registration data format (JS-6,RDF-2)

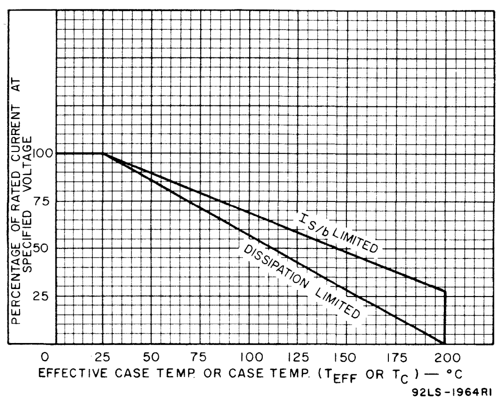


Fig. 1 - Dissipation derating curves for types 2N5239 & 2N5240

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25° C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (A)			LIMITS: Type 2N5239		Type 2N5240		Units
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	
Collector-Cutoff Current	I_{CEO}	—	200	—	—	—	—	0	—	5.0	—	2.0	mA
*	I_{CEV}	—	300	—	−1.5	—	—	—	—	4.0	—	—	mA
*	I_{CEV}	—	375	—	−1.5	—	—	—	—	-	—	2.0	mA
	I_{CEV} (T_C=150° C)	—	300	—	−1.5	—	—	—	—	5.0	—	3.0	mA
* Emitter-Cutoff Current	I_{EBO}	—	—	5.0	—	0	—	—	—	5.0	—	1.0	mA
* Collector-to-Emitter Sustaining Voltage: *(See Figs. 3 & 4)* With base open	$V_{CEO}(sus)$	—	—	—	—	0.2	—	0	225[b]	—	300[b]	—	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω	$V_{CER}(sus)$	—	—	—	—	0.2	—	0	250[b]	—	350[b]	—	V
* Emitter-to-Base Voltage	V_{EBO}	—	—	—	—	—	—	0.02	6	—	6	—	V
* Base-to-Emitter Voltage	V_{BE}	—	10	—	—	2.0[a]	—	—	—	3.0	—	3.0	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	—	—	—	—	2.0[a]	—	0.25	—	2.5	—	2.5	V
		—	—	—	—	4.5[a]	—	1.125	—	5	—	5	
DC Forward-Current Transfer Ratio	h_{FE}	—	10	—	—	0.4[a]	—	—	20	80	20	80	
*		—	10	—	—	2.0[a]	—	—	20	80	20	80	
*		—	10	—	—	4.5[a]	—	—	5	—	5	—	
Output Capacitance (At 1 MHz)	C_{ob}	10	—	—	—	—	0	—	—	150	—	150	pF
* Second-Breakdown[c] Collector Current[d] (With base forward biased)	$I_{S/b}$[c]	—	150	—	—	—	—	—	0.67	—	0.67	—	A
Second-Breakdown Energy (With base reverse biased) R_{BE} = 50Ω, L = 0.2 mH	$E_{S/b}$[e]	—	—	4.0	—	4.0	—	—	1.6	—	1.6	—	mJ
Gain-Bandwidth Product	f_T	—	10	—	—	0.2	—	—	5.0	—	5.0	—	MHz
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (at 1 MHz)	$\|h_{fe}\|$	—	10	—	—	0.2	—	—	5.0	—	5.0	—	
* Common-Emitter, Small-Signal Short-Circuit, Forward-Current Transfer Ratio (at 1 kHz)	h_{fe}	—	10	—	—	4.0	—	—	20	—	20	—	
Thermal Resistance (Junction-to-Case)	θ_{J-C}	—	—	—	—	—	—	—	—	1.75	—	1.75	°C/W

[a] Pulsed; pulse duration ≤ 350 μs, duty factor = 2%.

[b] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in *Fig. 3*.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[d] Pulsed; 1-s, non-repetitive pulse.

[e] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b}$ = $1/2LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

*In accordance with JEDEC registration data format (JS-6, RDF-2)

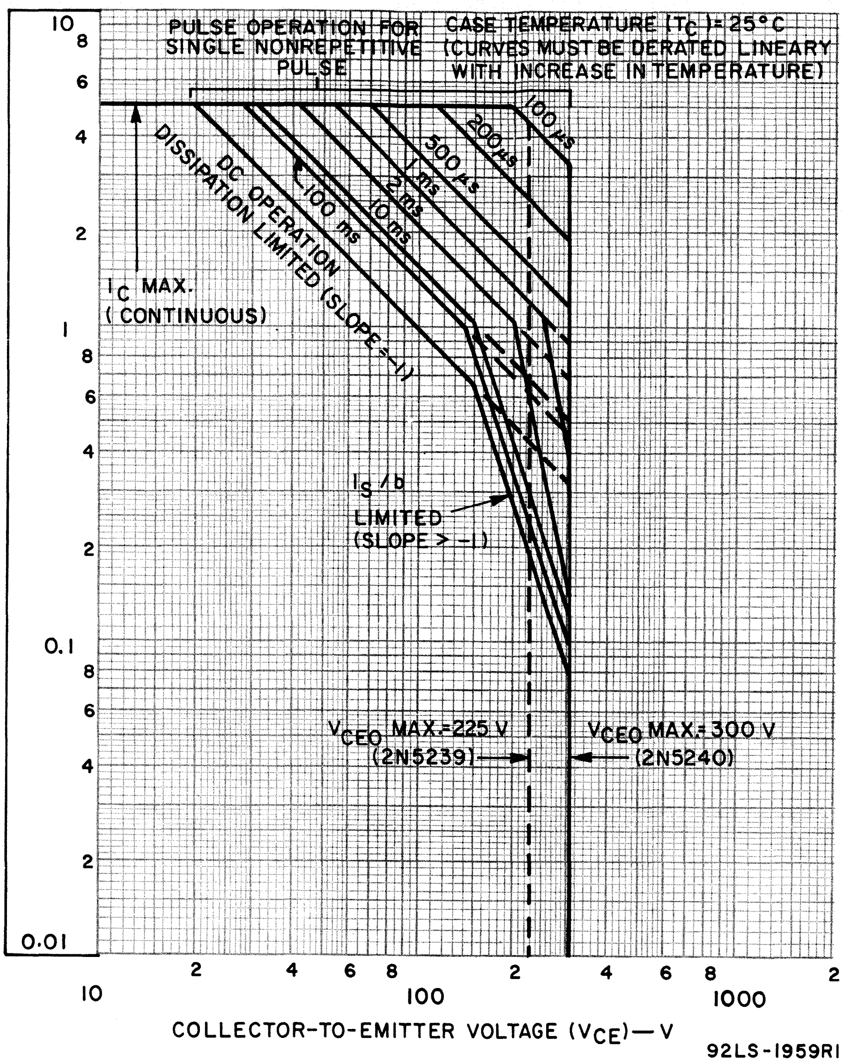


Fig. 2 - Maximum operating area for types 2N5239 & 2N5240

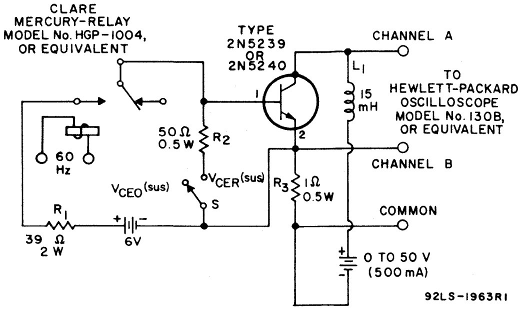
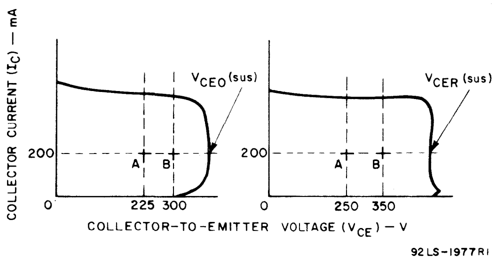


Fig. 3 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ for types 2N5239 & 2N5240



Note: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ are acceptable when the traces fall to the right and above points "A" and "B" for types 2N5239 and 2N5240

Fig. 4 - Oscilloscope display for measurement of sustaining voltages. (Test circuit shown in Fig. 3.)

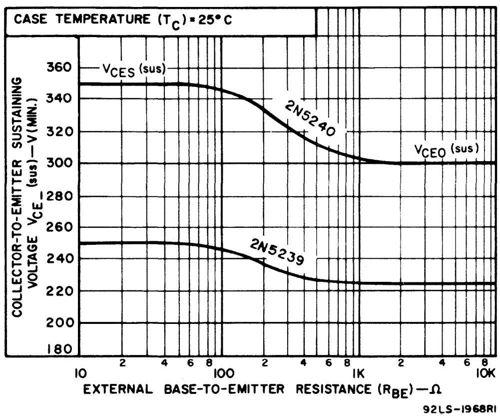


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for types 2N5239 & 2N5240

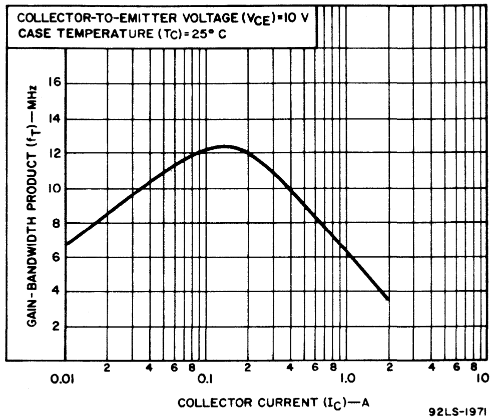


Fig. 6 - Typical gain-bandwidth product for types 2N5239 & 2N5240

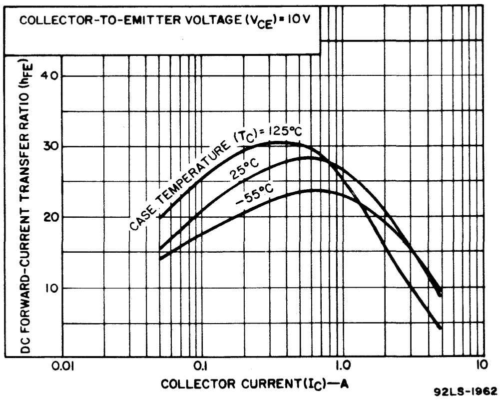


Fig. 7 - Typical DC beta for types 2N5239 & 2N5240

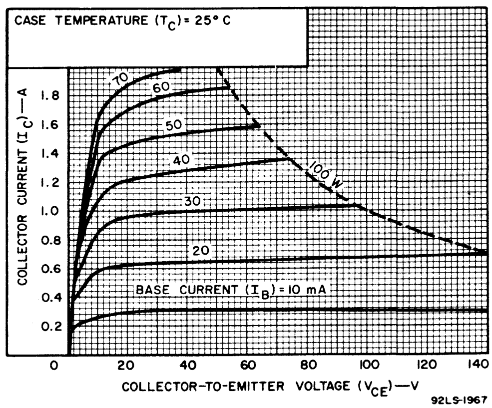


Fig. 8 - Typical output characteristics for types 2N5239 & 2N5240

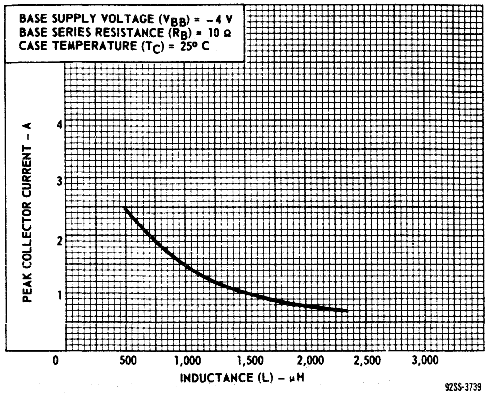


Fig. 9 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

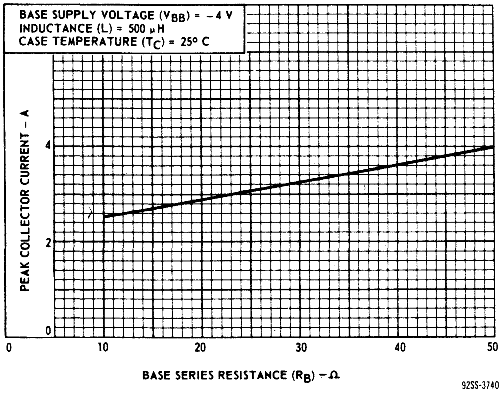


Fig. 10 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

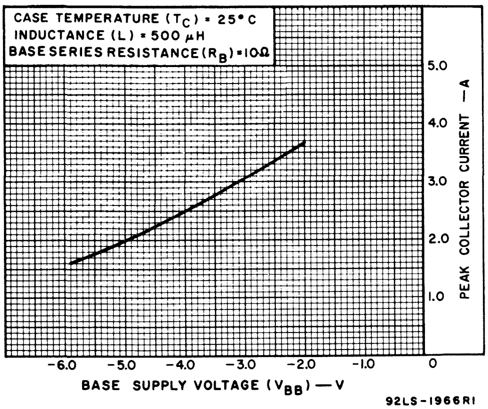


Fig. 11 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

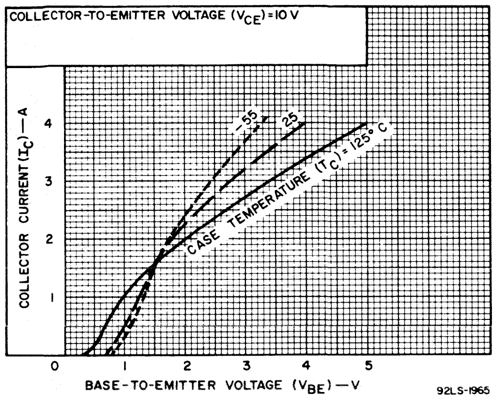


Fig. 12 - Typical transfer characteristics for types 2N5239 & 2N5240

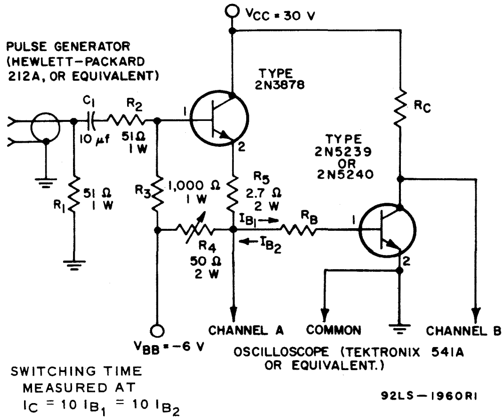


Fig. 13 - Circuit used to measure switching times for types 2N5239 & 2N5240

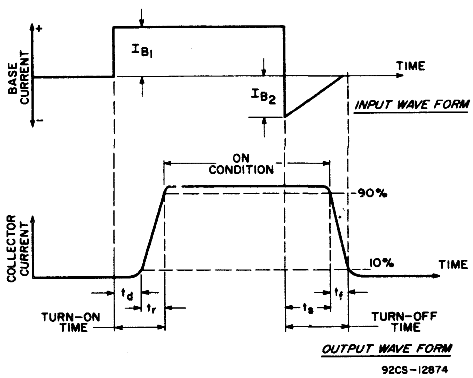


Fig. 14 - Oscilloscope display of switching times. (Test circuit shown in Fig. 13.)

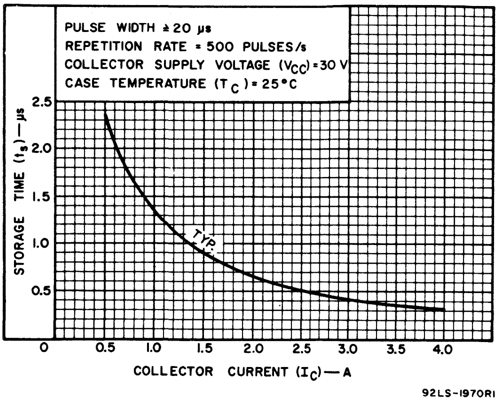


Fig. 15 - Saturated switching time (storage) vs. collector current for types 2N5239 & 2N5240

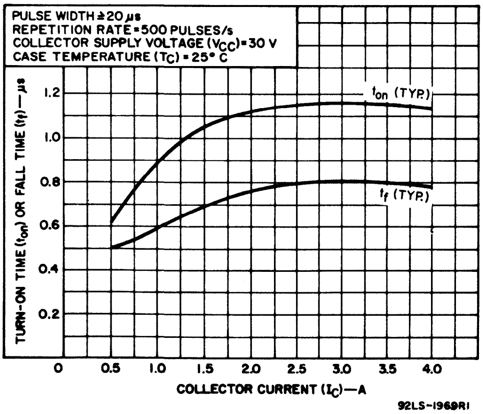


Fig. 16 - Saturated switching times (turn-on and fall) vs. collector current for types 2N5239 & 2N5240

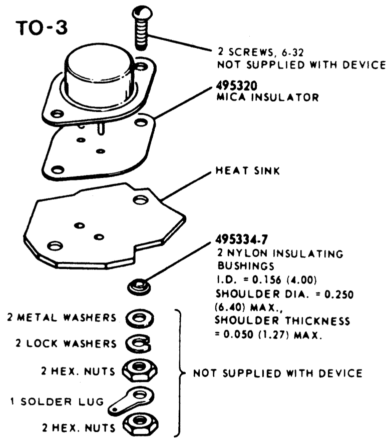
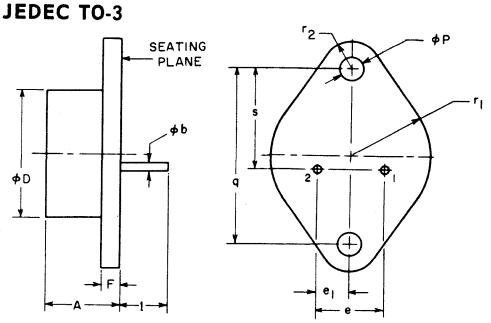


Fig. 17 - Suggested hardware for types 2N5239 & 2N5240

DIMENSIONAL OUTLINE FOR TYPES 2N5239 & 2N5240 JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

TERMINAL CONNECTIONS

Pin 1 - Base
Pin 2 - Emitter
Case, Flange - Collector

RCA
Solid State
Division

Power Transistors

2N5804
2N5805

JEDEC TO-3 H-1570

High-Voltage, High-Power Silicon N-P-N Power Transistors

For Switching and Amplifier Applications

Features:

- Power dissipation (P_T) = 110 W at 50 V
- High-voltage ratings:
  V_{CEO}(sus) = 300 V max. (2N5805)
  = 225 V max. (2N5804)
- Maximum-operating-area curves. . .for selection of maximum operating conditions for operation free from second breakdown.

RCA types 2N5804 and 2N5805** are triple-diffused, silicon n-p-n transistors with high breakdown-voltage ratings and fast switching speeds. Both devices employ the popular TO-3 package; they differ in breakdown-voltage ratings and leakage-current values.

These transistors are especially suitable for power-switching circuits, switching regulators, converters, inverters, and power amplifiers.

**Formerly RCA Dev. Nos. TA7130 and TA7130A, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N5804	2N5805	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	300	375	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
* With 1.5 volts (V_{BE}) of reverse bias, and external base-to-emitter resistance (R_{BE}) = 50Ω	V_{CEX}(sus)	300	375	V
With base open	V_{CEO}(sus)	225	300	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	V
*CONTINUOUS COLLECTOR CURRENT	I_C	5	5	A
PEAK COLLECTOR CURRENT		15	15	A
*CONTINUOUS BASE CURRENT	I_B	2	2	A
*TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25° C and V_{CE} up to 50 V		110	110	W
At case temperatures up to 25° C and V_{CE} above 50 V		See Fig. 1		
At case temperatures above 25° C and V_{CE} above 50 V		See Figs. 1 & 3		
*TEMPERATURE RANGE:				
Storage & Operating (Junction)		-65 to +200		°C
*PIN TEMPERATURE (During Soldering): At distances ⩾ 1/32 in. (0.8 mm) from seating plane for 10 s max		+230		°C

*In accordance with JEDEC registration data format (JS-6 RDF-1)

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V)		DC EMITTER OR BASE VOLTAGE (V)		DC CURRENT (A)			LIMITS: 2N5804		2N5805		UNITS
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}		150					0	–	15	–	5	mA
* With base-emitter junction reverse biased	I_{CEV}		270		−1.5				–	5	–	–	mA
			340		−1.5				–	–	–	5	
(T_C = 100°C)			270		−1.5				–	15	–	–	mA
			340		−1.5				–	–	–	15	
* Emitter-Cutoff Current	I_{EBO}			6		0			–	30	–	30	mA
				5		0			–	5	–	5	
* DC Forward-Current Transfer Ratio	h_{FE}[a]		10			0.5			25	250	25	250	
			4			5.0			10	100	10	100	
* Collector-to-Emitter Sustaining Voltage: (See Fig. 5, 6, & 7) With base open	$V_{CEO}(sus)$[b]					0.2		0	225	–	300	–	V
* With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CEX}(sus)$[b,g]				−1.5	0.2		0	300	–	375	–	V
Emitter-to-Base Voltage	V_{EBO}							0.03	6	–	6	–	V
* Base-to-Emitter Sat. Voltage	$V_{BE}(sat)$[a]					5.0		0.5	–	2	–	2	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]					5.0		0.5	–	2	–	2	V
Output Capacitance (At 1 MHz)	C_{obo}	10					0		–	450	–	450	pF
* Second-Breakdown[c] Collector Current (With base forward biased)	$I_{S/b}$[d,e]		50						2.2	–	2.2	–	A
Second-Breakdown[c] Energy (With base reverse biased) R_B = 20 Ω, L = 50 μH	$E_{S/b}$[f]			−4.0		5.0			0.62	–	0.62	–	mJ
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 5 MHz)	h_{fe}		10			1.0			3	–	3	–	
Saturated Switching Time: Turn-On (Delay Time + Rise Time)	t_{on}		200			5.0		0.5	–	0.5	–	0.5	μs
Storage (See Figs. 13 & 14)	t_s		200			5.0		0.5	–	3.5	–	3.5	μs
Fall (See Figs. 13 & 16)	t_f		200			5.0		0.5	–	2.0	–	2.0	μs
** Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$		10			5			–	1.6	–	1.6	°C/W

[a]Pulsed; pulse duration ⩽ 350 μs, duty factor = 2%

[b]CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 6.

[c]Safe-operating region for forward- and reverse-bias operation is explained in the RCA Solid-State Power Circuits Designer's Handbook (SP-52)

[d]$I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region at the specified collector current.

[e]Pulsed; 1-s non-repetitive pulse.

[f]$E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = 1/2LI^2$ where L is a series load or leakage inductance and I is the peak collector current.

[g]Pulsed: pulse duration = 8.33 ms; duty factor = 50%

*In accordance with JEDEC registration data format (JS-6 RDF-1).

**Specified in JEDEC registration data as a derating factor of 0.625 W/°C.

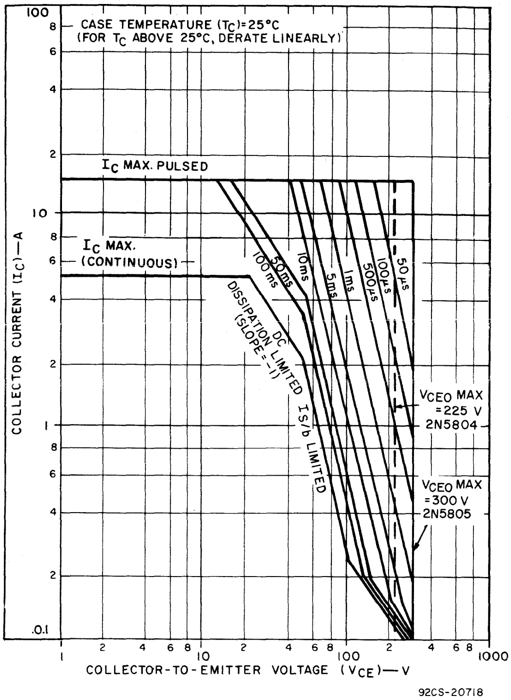


Fig. 1—Maximum operating areas for both types.

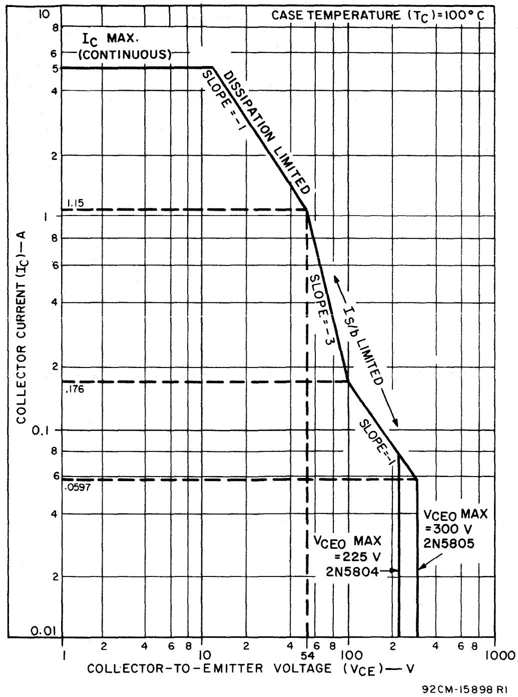


Fig. 2—Maximum operating areas for both types.

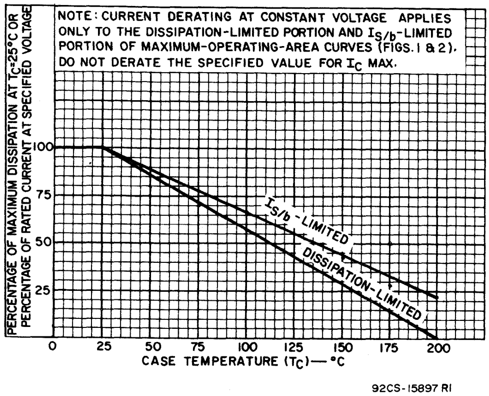


Fig. 3—Derating curves for both types.

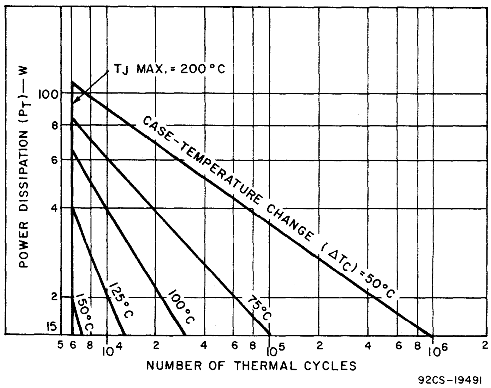


Fig. 4—Thermal-cycling rating chart.

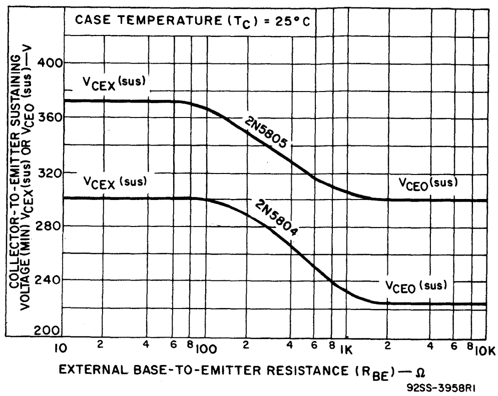


Fig. 5—Collector-to-emitter sustaining voltage characteristics.

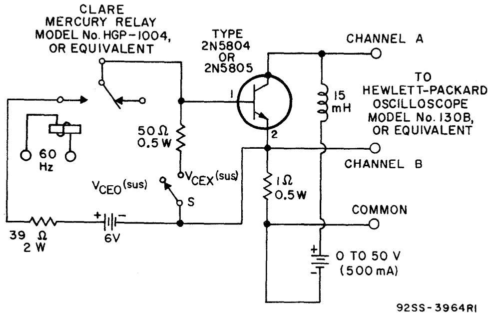


Fig. 6—Circuit used to measure sustaining voltages V_{CEO}(sus) and V_{CEX}(sus).

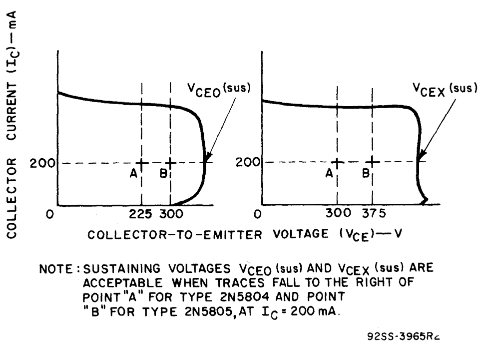


Fig. 7—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 6).

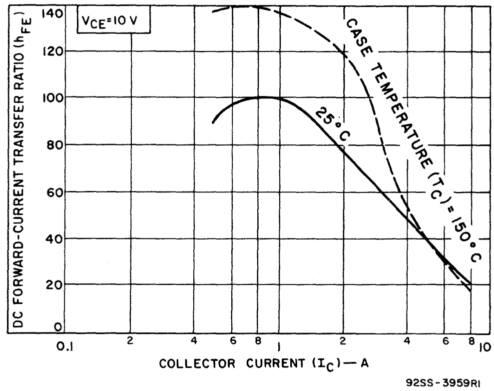


Fig. 8—Typical dc beta characteristics.

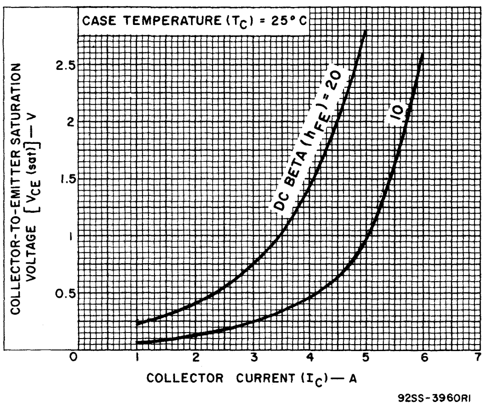


Fig. 9—Typical saturation-voltage characteristics.

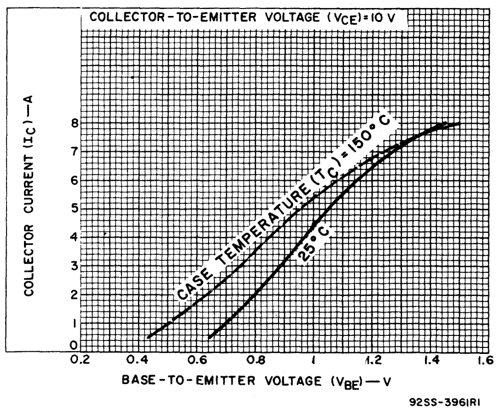


Fig. 10—Typical transfer characteristics.

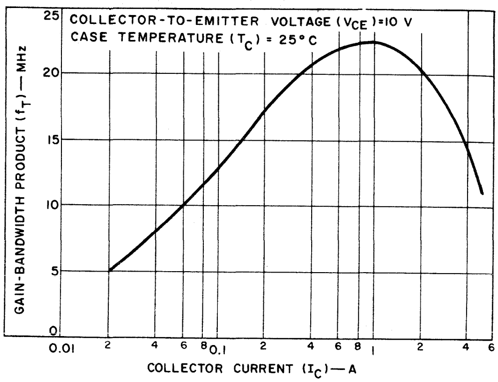


Fig. 11—Typical gain-bandwidth product.

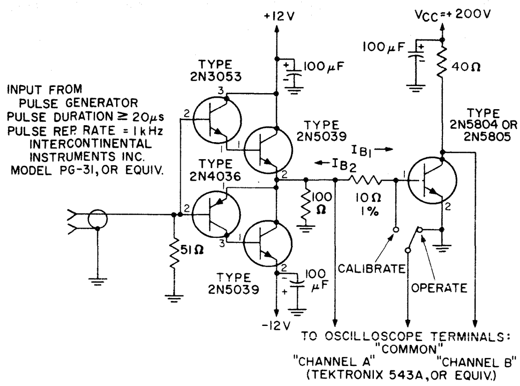


Fig. 12—Circuit used to measure switching times.

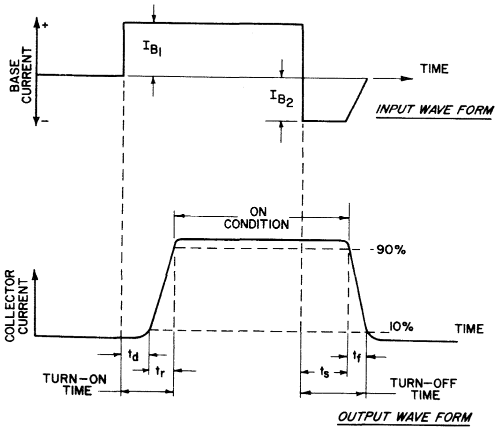


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times (test circuit shown in Fig. 12).

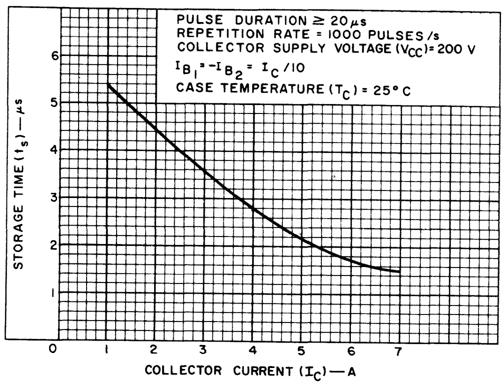


Fig. 14—Typical storage-time characteristic.

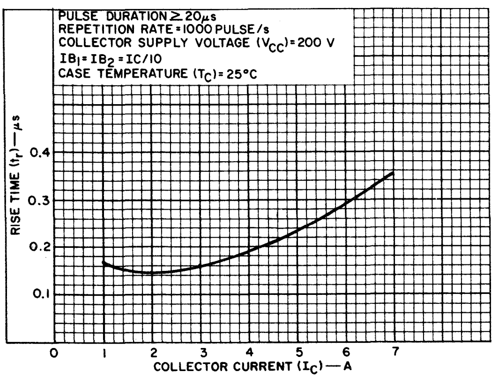


Fig. 15—Typical rise-time characteristic.

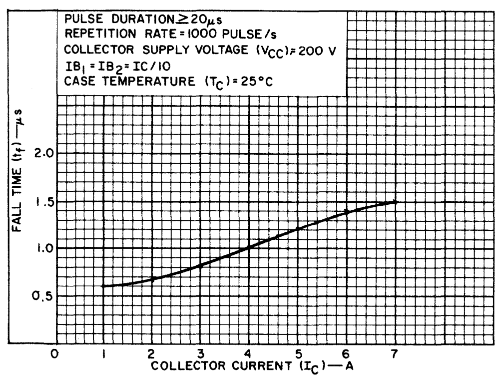
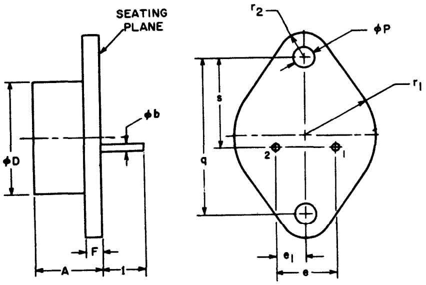


Fig. 16—Typical fall-time characteristic.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

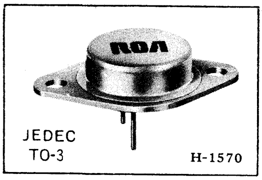
Pin 1 – Base
Pin 2 – Emitter
Case – Collector
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors

2N5838
2N5839
2N5840

SILICON N-P-N POWER TRANSISTORS



High-Voltage High-Power Types For Switching and Linear Applications in Military, Industrial, and Commercial Equipment

RCA 2N5838, 2N5839 and 2N5840** are epitaxial silicon n-p-n power transistors utilizing a multiple-emitter-site structure. These devices employ the popular JEDEC TO-3 package; they differ mainly in voltage, current-gain, and V_{CE}(sat) ratings.

Featuring high breakdown voltage ratings and low-saturation voltage values, the 2N5838, 2N5839 and 2N5840 are especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

** Formerly RCA Dev. types TA7513, TA7530, and TA7420 respectively.

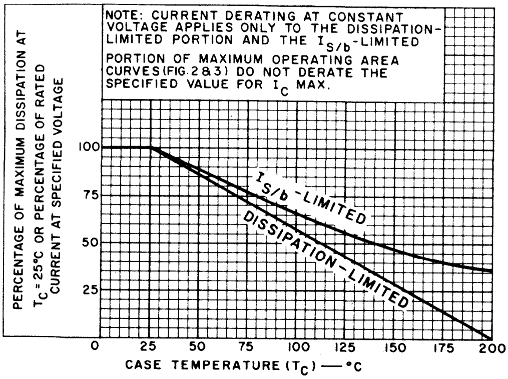
MAXIMUM RATINGS, *Absolute-Maximum Values:*

	2N5838	2N5839	2N5840	
*COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	275	300	375	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
* With base open, V_{CEO}(sus)	250	275	350	V
* With reverse bias (V_{BE}) of -1.5 V, V_{CEV}(sus)▲	275	300	375	V
With external base-to-emitter resistance (R_{BE}) $\leq$ 50 Ω, V_{CER}(sus)	275	300	375	V
*EMITTER-TO-BASE VOLTAGE, V_{EBO}	6	6	6	V
*COLLECTOR CURRENT, I_C				
Continuous	3	3	3	A
Peak	5	5	5	A
*CONTINUOUS BASE CURRENT, I_B	1.5	1.5	1.5	A
*TRANSISTOR DISSIPATION, P_T:				
At case temperature up to 25° C and V_{CE} up to 40 V	100	100	100	W
At case temperatures up to 25° C and V_{CE} above 40 V	See Fig. 2.			
At case temperatures above 25° C and V_{CE} above 40 V	See Figs. 1 & 2.			
*TEMPERATURE RANGE:				
Storage & Operating (Junction)	-65 to +200			°C
*PIN TEMPERATURE (During Soldering): At distances $\geq$ 1/32 in. (0.8 mm) from case for 10 s max	230			°C

* In accordance with JEDEC registration data format (JS-6, RDF-1).
▲ Shown as V_{CEX}(sus) in JEDEC Registration Data.

Features:

- Maximum safe-area-of-operation curves
- Low saturation voltages
- High voltage ratings
  V_{CER}(sus) = 375 V (2N5840)
  300 V (2N5839)
  275 V (2N5838)
- High dissipation rating
  P_T = 100 W



92SS-4072 RI

Fig. 1 - Derating curves for all types.

ELECTRICAL CHARACTERISTICS, *Case Temperature* (T_C) = 25°C

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)			Limits: Type 2N5838			Type 2N5839			Type 2N5840			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	I_E	Min.	Max.	Typ.	Min.	Max.	Typ.	Min.	Max.	Typ.	
Collector-Cutoff Current: With base open	I_{CEO}	200 250						- -	2 -	- -	- -	- 2	- -	- -	- 2	- -	mA
* With base-emitter junction reverse biased	I_{CEV}	265 290 360		-1.5 -1.5 -1.5				- - -	5 - -	- - -	- - -	- 2 -	- - -	- - -	- - 2	- - -	mA
* With base-emitter junction reverse biased	I_{CEV} T_C = 100 °C	265 290 360		-1.5 -1.5 -1.5				- - -	8 - -	- - -	- - -	- 5 -	- - -	- - -	- - 5	- - -	mA
* Emitter-Cutoff Current	I_{EBO}		6					-	1	-	-	1	-	-	1	-	mA
* Collector-to-Emitter Sustaining Voltage: *(See Figs. 4, 5, & 6)* With base open	$V_{CEO}(sus)^a$				0.2			250^b	-	-	275^b	-	-	350^b	-	-	V
* With base-emitter junction reversed biased	$V_{CEX}(sus)^a$			-1.5	0.1			275^b	-	-	300^b	-	-	375^b	-	-	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)^a$				0.2			275^b	-	-	300^b	-	-	375^b	-	-	V
* Emitter-to-Base Voltage	V_{EBO}				0.02			6	-	-	6	-	-	6	-	-	V
* DC Forward-Current * Transfer Ratio	h_{FE}	5 3 2			0.5^b 2^b 3^b			20 - 8	- - 40	- - -	20 10 -	- 50 -	- - -	20 10 -	- 50 -	- - -	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				2 3	0.2 0.375		- -	- 2	- -	- -	2 -	- -	- -	2 -	- -	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				2 3	0.2 0.375		- -	- 1	- -	- -	1.5 -	- -	- -	1.5 -	- -	V
Output Capacitance (At 1 MHz)	C_{obo}		10				0	-	150	-	-	150	-	-	150	-	pF
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10			0.2			5	-	-	5	-	-	5	-	-	
Second Breakdown Collector Current (With base forward biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}{}^c$	40						2.5	-	-	2.5	-	-	2.5	-	-	A
Second Breakdown[c] Energy (With base reverse biased) R_B = 50 Ω, L = 100 μH	$E_{S/b}{}^d$			-4				0.45	-	-	0.45	-	-	0.45	-	-	mJ
Switching Times: Delay *(See Figs. 11, 15, & 16)*	t_d	V_{CC} = 200			2 3	0.2^e 0.375^e		- -	- -	- 0.06	- -	- -	0.07 -	- -	- -	0.07 -	μs
* Rise *(See Figs. 12, 15, & 16)*	t_r	V_{CC} = 200			2 3	0.2^e 0.375^e		-	- 1.5	- 0.8	- -	1.5 -	0.6 -	- -	1.75 -	0.6 -	μs
* Storage *(See Figs. 13, 15, & 16)*	t_s	V_{CC} = 200			2 3	0.2^e 0.375^e		- -	- 3.0	- 1.0	- -	3.75 -	1.75 -	- -	3.0 -	1.75 -	μs
* Fall *(See Figs. 14, 15, & 16)*	t_f	V_{CC} = 200			2 3	0.2^e 0.375^e		- -	- 1.5	- 0.4	- -	1.5 -	0.35 -	- -	1.5 -	0.35 -	μs
Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$	10			5				1.75	-	-	1.75	-	-	1.75		°C/W

a Pulsed; pulse duration ≤ 350 μs, Duty factor = 2%.

b CAUTION: Ths sustaining voltages $V_{CEO}(sus)$, $V_{CEX}(sus)$ and $V_{CER}(sus)$, MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 4.

c $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

d $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = 1/2\ LI^2$ where L is a series load or leakage inductance, and I is the peak collector current.

e $I_{B1} = I_{B2}$ = value shown.

* In accordance with JEDEC registration data format (JS-6 RDF-1).

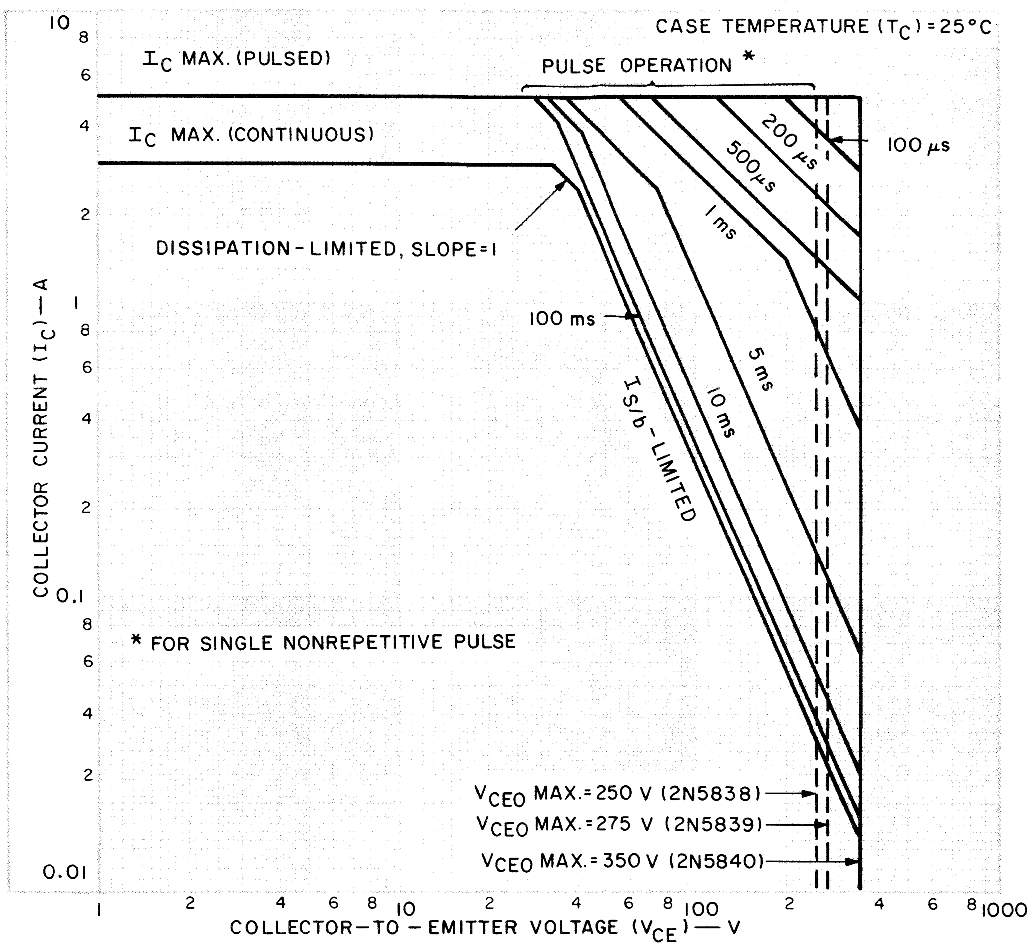


Fig. 2 - Maximum operating areas for all types.

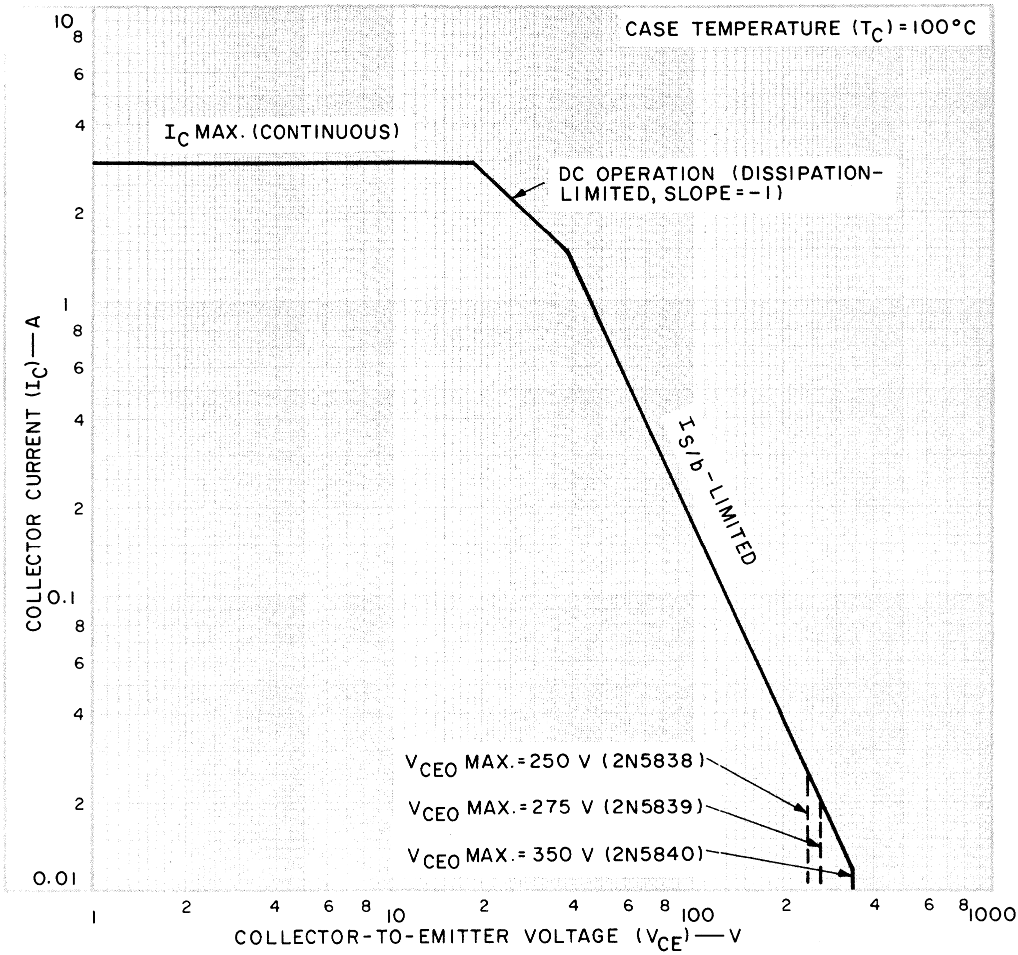


Fig. 3 - Maximum operating areas for all types.

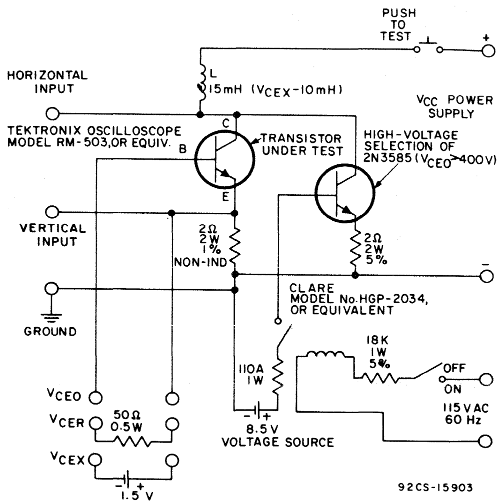


Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ for all types.

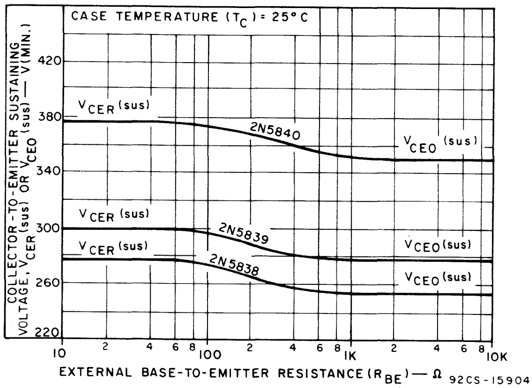


Fig. 6 - Collector-to-emitter sustaining voltage characteristics for all types.

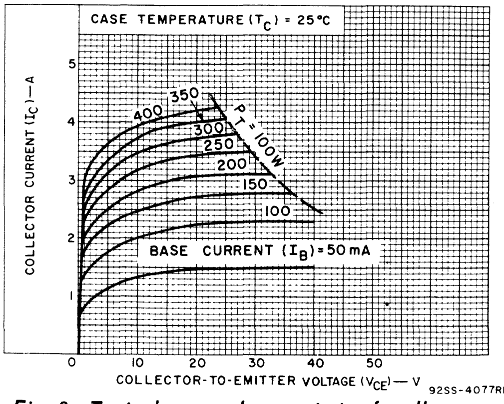
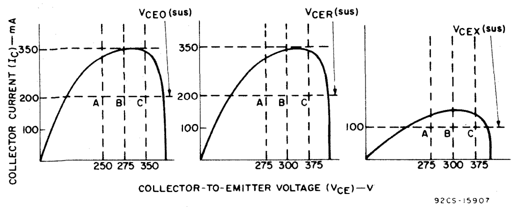


Fig. 8 - Typical output characteristics for all types.



The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ are acceptable when the traces fall to the right and above point "A" for type 2N5838, point "B" for type 2N5839, and point "C" for type 2N5840.

Fig. 5 - Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 4).

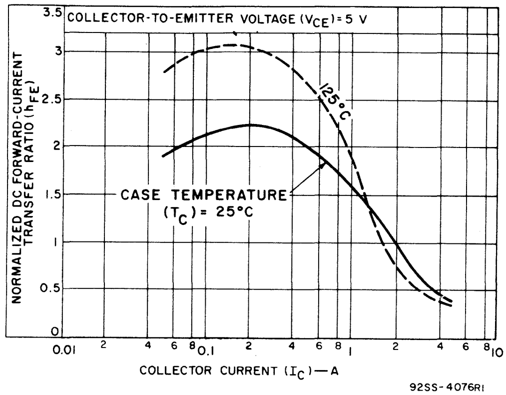


Fig. 7 - Typical normalized dc beta characteristics for all types.

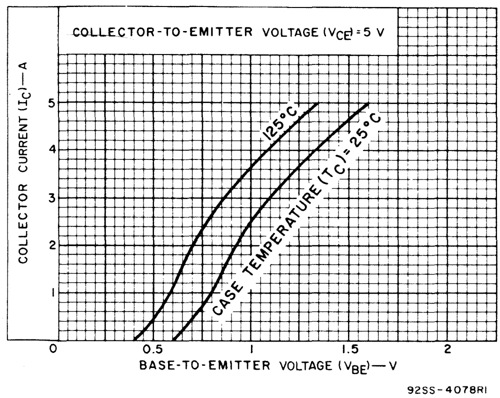


Fig. 9 - Typical transfer characteristics for all types.

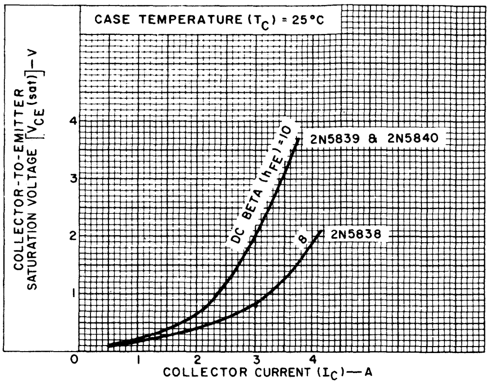


Fig. 10 - Typical saturation voltage characteristics for all types.

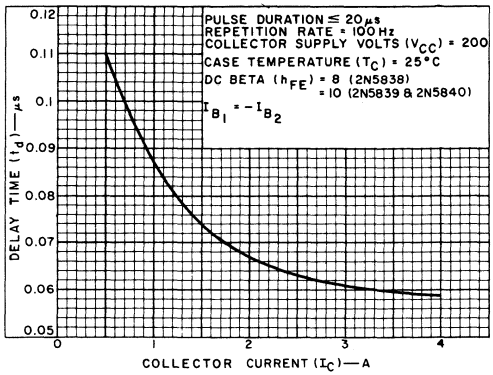


Fig. 11 - Typical delay-time characteristic for all types.

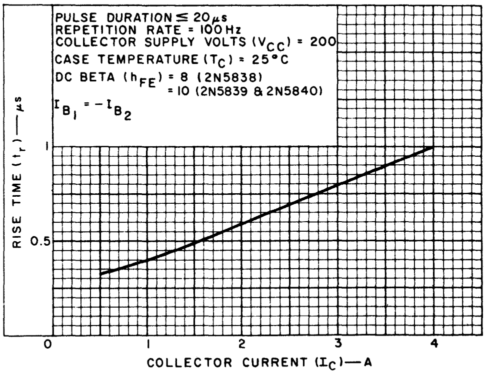


Fig. 12 - Typical rise-time characteristic for all types.

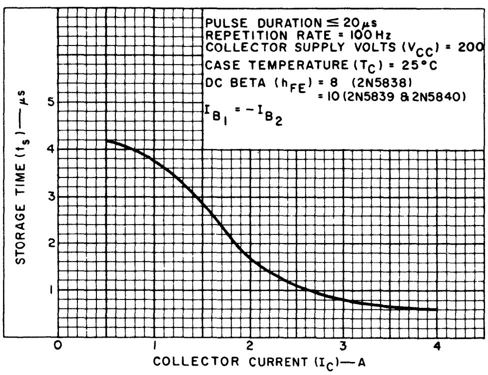


Fig. 13 - Typical storage-time characteristic for all types.

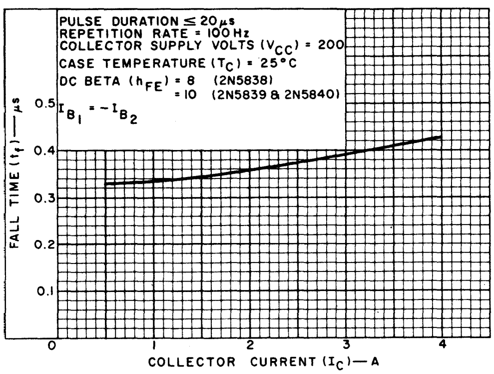


Fig. 14 - Typical fall-time characteristic for all types.

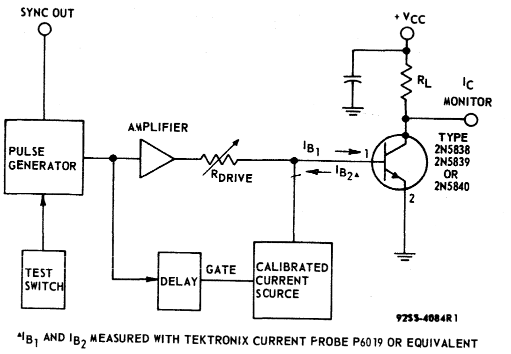


Fig. 15 - Circuit used to measure switching times for all types.

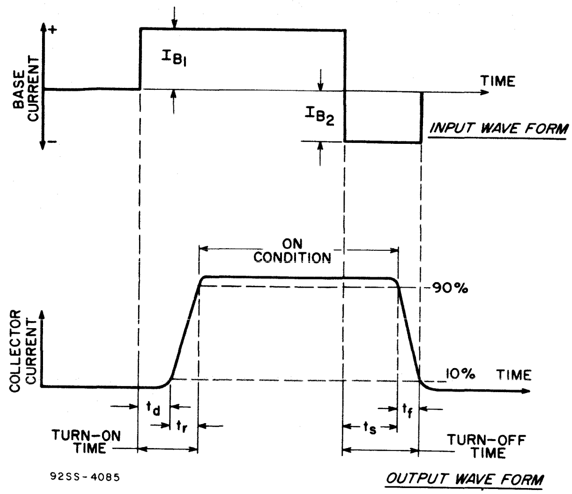


Fig. 16 - Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 15).

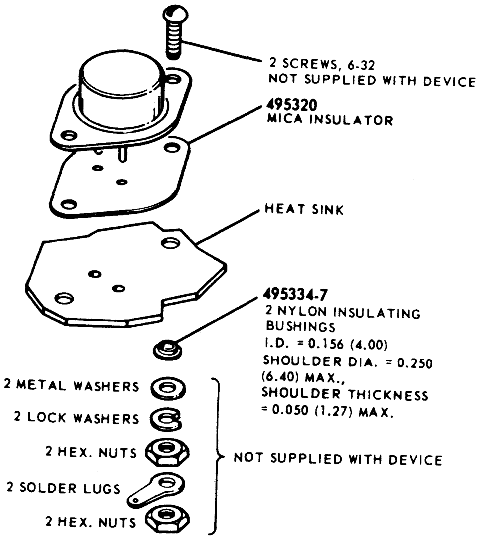
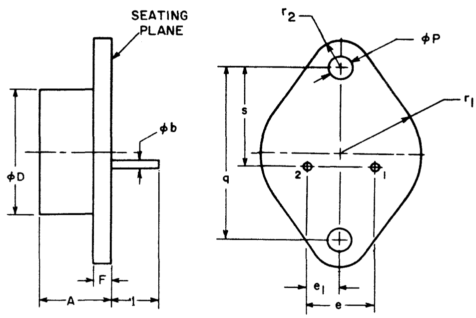


Fig. 17 - Suggested mounting hardware for all types.

TERMINAL CONNECTIONS

Pin 1 - Base
Pin 2 - Emitter
Mounting Flange, Case - Collector

DIMENSIONAL OUTLINE FOR TYPES 2N5838, 2N5839, 2N5840 JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.250	.450	6.35	11.43	
ϕb	.038	.043	.97	1.09	2
ϕD		.875		22.23	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F		.135		3.43	
1	.312		7.92		2
ϕP	.151	.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		.525		13.34	
r_2		.188		4.78	
s	.655	.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

RCA
Solid State
Division

Power Transistors
2N6077
2N6078
2N6079

JEDEC TO-66

H-1340

High-Voltage, High-Power Silicon N-P-N Transistors

For Switching and Linear Applications

Features

- **Maximum safe-area-of-operation curves**
- **Low saturation voltages**
- **High voltage ratings :**
  V_{CER}(sus) = 300 V (2N6077)
  275 V (2N6078)
  375 V (2N6079)
- **High dissipation rating : P_T = 45 W**

RCA-2N6077, 2N6078, and 2N6079 are multiple epitaxial silicon n-p-n power transistors utilizing a multiple-emitter-site structure. Multiple-epitaxial construction maximizes the volt-ampere characteristic of the device and provides fast switching speeds. Multiple-emitter-site design ensures uniform current flow throughout the structure, which produces a high $I_{S/b}$ and a large safe-operation area.

These devices use the popular JEDEC TO-66 package; they differ mainly in voltage ratings, leakage-current limits, and V_{CE}(sat) ratings.

The 2N6077 is characterized for switching applications with load lines in the active region. These applications include sweep circuits and all circuits using the transistor as an active voltage clamp.

Type 2N6078 is characterized for switching applications with the load line extending into the reverse-bias region. Its voltage ratings make this device useful for switching regulators operating directly from a rectified 110-V or 220-V power line. The unit is rated to take surge currents up to 5 A and maintain saturation.

The 2N6079 is characterized for use in inverters operating directly from a rectified 110-V power line. The leakage current is specified at 450 volts; therefore the device can also be used in a series bridge configuration on a 220-V line. The V_{EBO} rating of 9 volts eases requirements on the drive transformer in inverter applications. Storage time, an important factor in the frequency stability of an inverter, is specified in Fig. 12 , which shows variation in storage time with variation in load current from zero to maximum (4 A).

MAXIMUM RATINGS, *Absolute-Maximum Values:*		**2N6077**	**2N6078**	**2N6079**	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	300	275	375	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With base open	V_{CEO}(sus)	275	250	350	V
* With reverse bias (V_{BE}) of −1.5 V	V_{CEX}(sus)	300	275	375	V
With external base-to-emitter resistance (R_{BE}) $\leq 50\ \Omega$	V_{CER}(sus)	300	275	375	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	9	V
*COLLECTOR CURRENT:	I_C				
Continuous		7	7	7	A
Peak		10	10	10	A
*CONTINUOUS BASE CURRENT	I_B	4	4	4	A
*TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C and V_{CE} up to 40 V		45	45	45	W
At case temperatures up to 25°C and V_{CE} above 40 V			See Fig. 1		
At case temperatures above 25°C and V_{CE} above 40 V			See Figs. 1, 2, & 3		
*TEMPERATURE RANGE:					
Storage & Operating (Junction)			−65 to +200		°C
*PIN TEMPERATURE (During Soldering):					
At distances $\geq$ 1/32 in. (0.8 mm) from case for 10 s max.			230		°C

* In accordance with JEDEC registration data format (JS-6, RDF-1).

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C*

Characteristic	Symbol	Test Conditions						Limits									Units
		DC Collector Voltage (V)	DC Emitter Voltage (V)		DC Current (A)			Type 2N6077			Type 2N6078			Type 2N6079			
		V_{CE}	V_{CB}	V_{BE}	I_C	I_B	I_E	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	250				0		–	–	2	–	–	–	–	–	–	mA
* With base-emitter junction reverse biased	I_{CEV}	250 450		−1.5 −1.5				– –	– –	5 –	– –	– –	0.05 –	– –	– –	– 0.5	mA
* With base-emitter junction reverse biased	I_{CEV} T_C = 125°C	250 450		−1.5 −1.5				– –	– –	8 –	– –	– –	0.2 –	– –	– –	– 5	mA
* Emitter-Cutoff Current	I_{EBO}			−6 −9	0 0			– –	– –	1 –	– –	– –	1 –	– –	– –	– 1	mA
* Collector-to-Emitter Sustaining Voltage *(see Figs. 15 & 16)* With base open	$V_{CEO}(sus)$[b]				0.2			275[b]	–	–	250[b]	–	–	350[b]	–	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$[b]				0.2			300[b]	–	–	275[b]	–	–	375[b]	–	–	
* Emitter-to-Base Voltage	V_{EBO}						0.001	6	–	–	6	–	–	9	–	–	V
* DC Forward-Current Transfer Ratio	h_{FE}	1			1.2			12	28	70	12	28	70	12	28	50	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$[a]				1.2 3 4 5	0.2 0.6 0.8 1		– – – –	1.0 1.2 – –	1.6 1.9 – –	– – – –	1.0 – – 1.5	1.6 – – 2	– – – –	1.0 – 1.3 –	1.6 – 2 –	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]				1.2 3 4 5	0.2 0.6 0.8 1		– – – –	0.15 0.25 – –	0.5 1 – –	– – – –	0.15 – – 0.8	0.5 – – 3	– – – –	0.15 – 0.5 –	0.5 – 3 –	V
Output Capacitance (At 1 MHz)	C_{obo}		10				0	–	–	150	–	–	150	–	–	150	pF
* Magnitude of Common Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10			0.2			1	7	–	1	7	–	1	7	–	
Second Breakdown Collector Current (With base forward biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	50						0.9	–	–	0.9	–	–	0.9	–	–	A
Second Breakdown[c] Energy (With base reverse biased) R_B = 50 Ω, L = 100 μH	$E_{S/b}$[d]			−4	3			0.45	–	–	0.45	–	–	0.45	–	–	mJ
Switching Times: Delay *(See Figs. 10, 17, & 18)*	t_d	V_{CC} = 250 V			1.2	0.2[e]		–	0.02	–	–	0.02	–	–	0.02	–	μs
* Rise *(See Figs. 13, 17, & 18)*	t_r	V_{CC} = 250 V			1.2	0.2[e]		–	0.3	0.75	–	0.3	0.75	–	0.3	0.75	
* Storage *(See Figs. 11, 12, 17 & 18)*	t_s	V_{CC} = 250 V			1.2	0.2[e]		–	2.8	5	–	2.8	5	–	2.8	5	
* *(See Figs. 14, 17, & 18)*	t_f	V_{CC} = 250 V			1.2	0.2[e]		–	0.3	0.75	–	0.3	0.75	–	0.3	0.75	
Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$	20			2.5			–	–	3.9	–	–	3.9	–	–	3.9	°C/W

[a] Pulsed; pulse duration ≤350 μs, Duty factor = 2%.

[b] CAUTION: The sustaining voltages $V_{CEO}(sus)$, and $V_{CER}(sus)$, MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 15.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[d] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = 1/2\ LI^2$ where L is a series load or leakage inductance, and I is the peak collector current.

[e] $I_{B1} = I_{B2}$ = value shown.

* In accordance with JEDEC registration data format (JS-6 RDF-1).

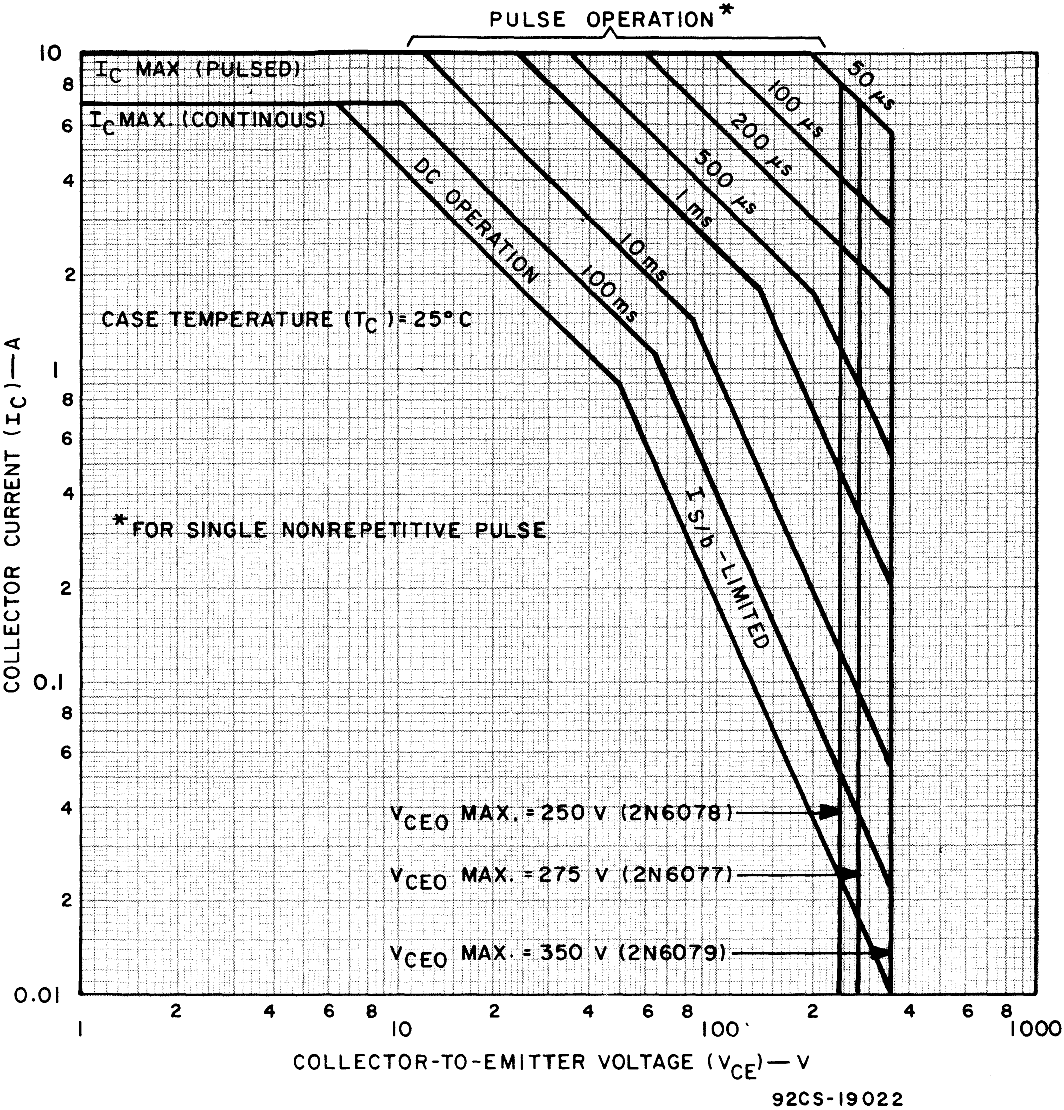


Fig. 1—Maximum operating areas for all types.

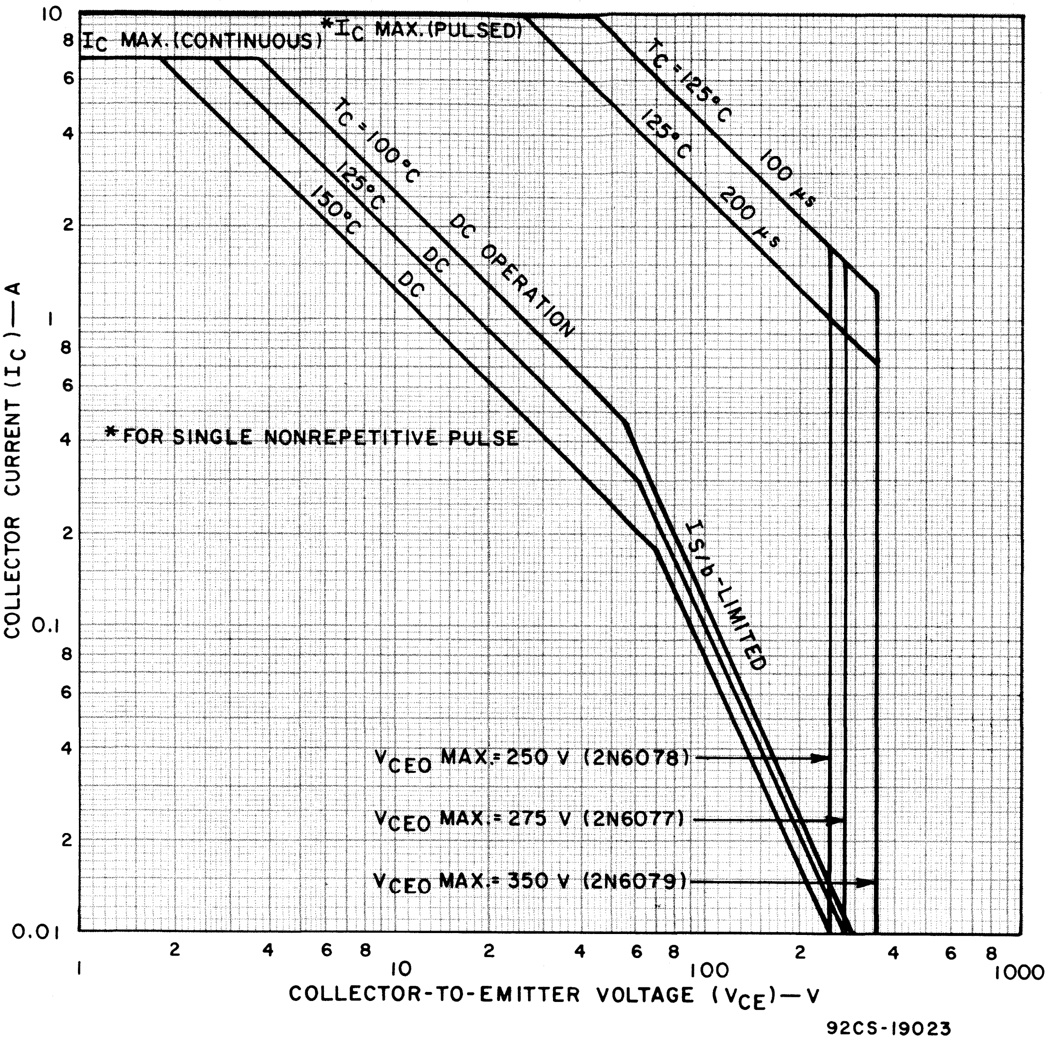


Fig.2—Maximum operating areas for all types.

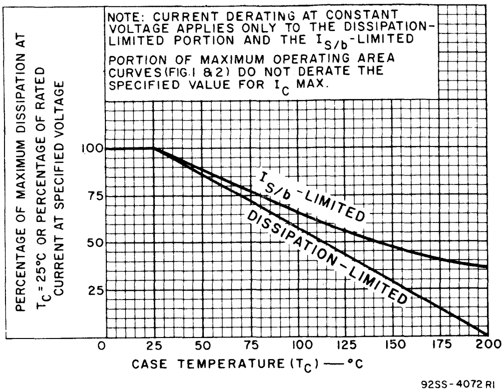


Fig.3—Derating curve for all types.

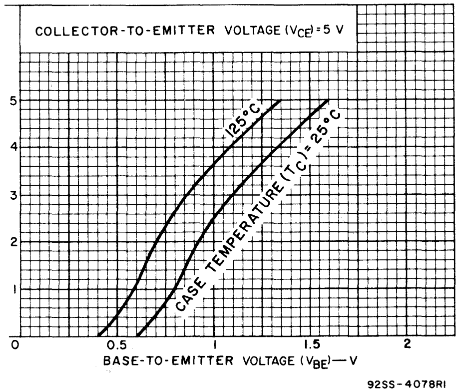


Fig.4—Typical transfer characteristics for all types.

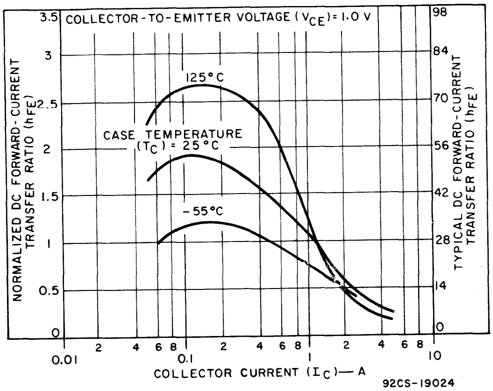


Fig.5—Typical normalized dc beta characteristics for all types.

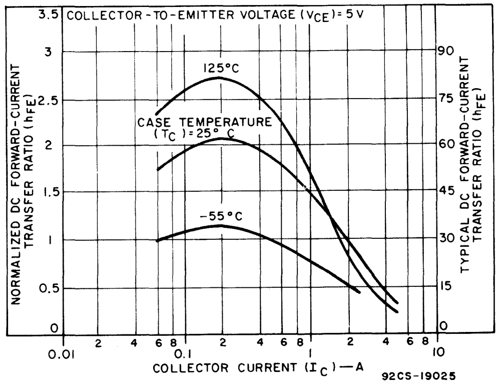


Fig.6—Typical normalized dc beta characteristics for all types.

Note (Figs. 5 & 6): To estimate min., max. h_{FE} at any current and temperature, read normalized dc forward-current transfer ratio and multiply by min., max. specifications given in Electrical Characteristics Chart (p. 2).

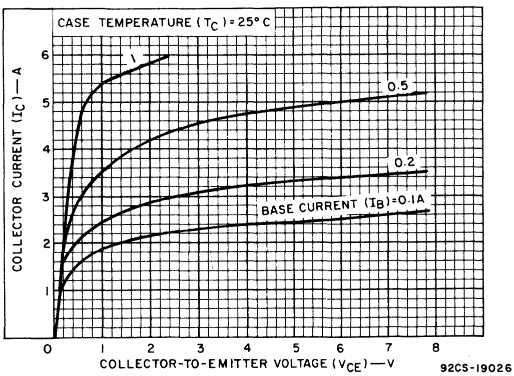


Fig.7—Typical output characteristics for all types.

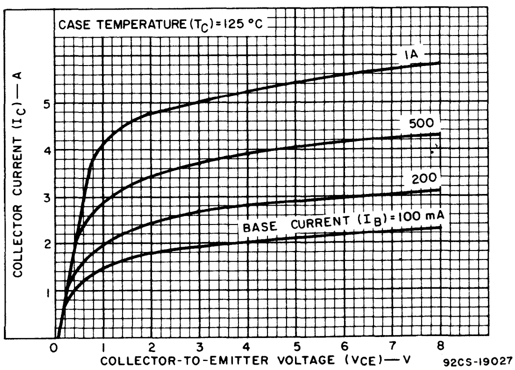


Fig.8—Typical output characteristics for all types.

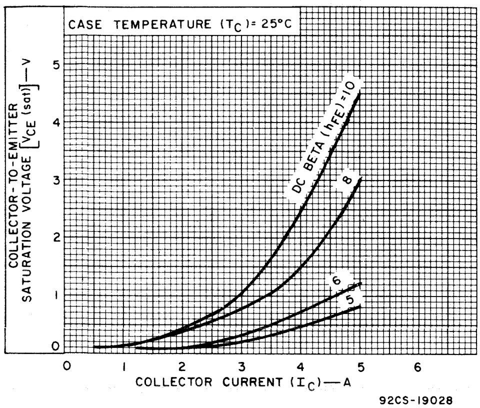


Fig.9—Typical saturation voltage characteristics for all types.

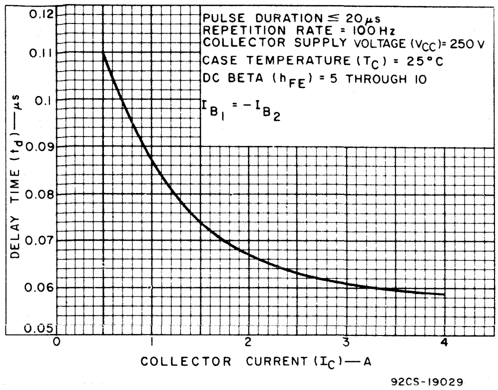


Fig.10—Typical delay-time characteristic for all types.

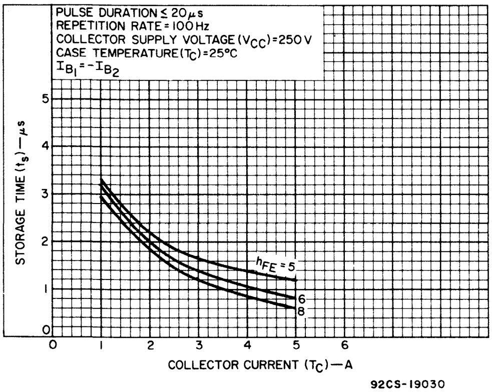


Fig.11—Typical storage-time characteristic for all types (with constant forced gain).

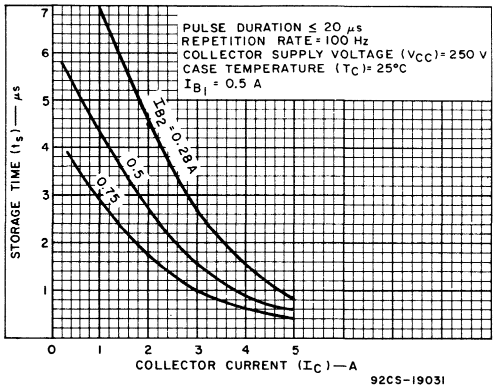


Fig.12—Typical storage-time characteristic for all types (with constant-base drives).

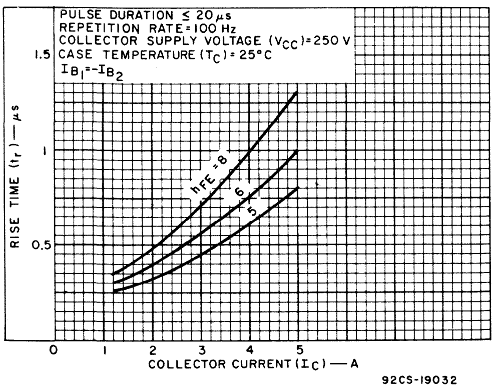


Fig.13—Typical rise-time characteristic for all types.

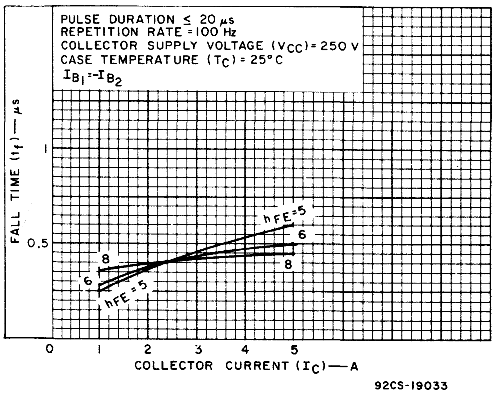


Fig.14—Typical fall-time characteristic for all types.

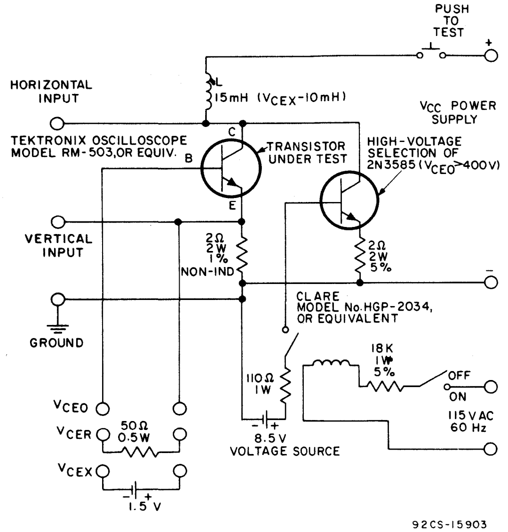
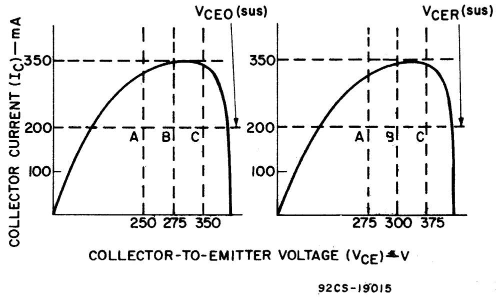


Fig.15—Circuit used to measure sustaining voltages V_{CEO}(sus), V_{CER}(sus) for all types.



The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) are acceptable when the traces fall to the right and above point "A" for type 2N6078 point "B" for type 2N6077 and point "C" for type 2N6079.

Fig.16—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 15).

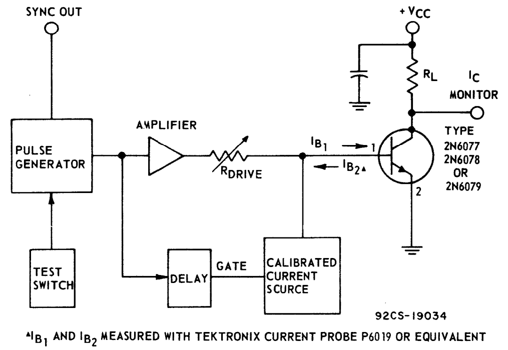


Fig.17—Circuit used to measure switching times for all types.

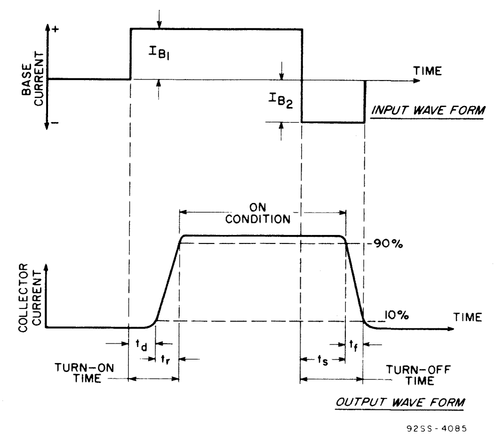


Fig.18—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 17).

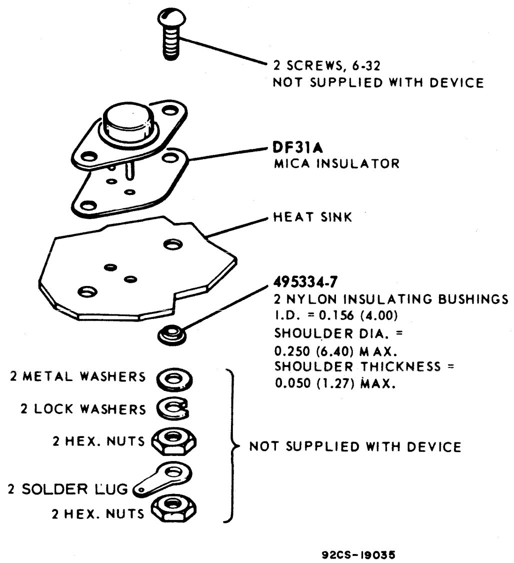
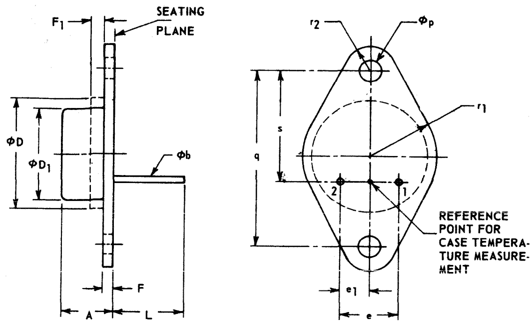


Fig.19— Suggested hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD		0.620		15.75	
ϕD1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e1	0.093	0.107	2.36	2.72	
F	0.060	0.075	1.27	1.91	2
F1		0.050		1.27	1
L	0.360		9.14		
ϕp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r1		0.350		8.89	
r2		0.145		3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by ϕD and F1.
2. Dimension does not include sealing flanges.

92SS-3738

TERMINAL CONNECTIONS

Pin 1 — Base

Pin 2 — Emitter

Mounting Flange, Case-Collector

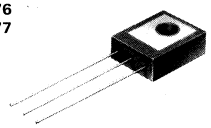
RCA

Solid State Division

Power Transistors

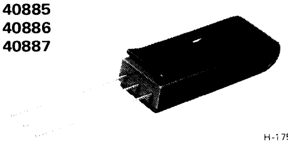
2N6175 40885
2N6176 40886
2N6177 40887

2N6175
2N6176
2N6177



H-1642

40885
40886
40887



H-1756

High-Voltage, Medium-Power Silicon N-P-N Transistors

For High-Speed Switching and Linear-Amplifier Applications

Features

- **Thermal fatigue ratings**
- **High frequency response: f_T = 20 MHz**
- **Maximum area-of-operation curves for DC and pulse operation**
- **Designed to assure freedom from second breakdown in class A, B, and C operation at maximum ratings**

RCA types 2N6175, 2N6176, and 2N6177* are triple-diffused silicon n-p-n transistors with high breakdown voltages, high frequency response, and fast switching speeds. Types 40885, 40886, and 40887 are electrically identical to the 2N6175 – 2N6177, respectively, but are supplied with factory-attached heat clips.

Typical applications for these devices include TV video output, RGB output, chroma output, TV blanking, solenoid drivers, off-line inverters, regulators, audio output, and electrostatic deflection in display circuits.

- **High voltage ratings:**
  V_{CEO}(sus) = 350 V max. (2N6177, 40887)
  = 300 V max. (2N6176, 40886)
  = 250 V max. (2N6175, 40885)
- **Low saturation voltage:**
  V_{CE}(sat) = 0.5 V max.

*Formerly Dev. Nos. TA7739, TA7740 and TA7134, respectively.

MAXIMUM RATINGS, Absolute-Maximum Values:

		2N6175 40885	2N6176 40886	2N6177 40887	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	300	350	450	V
*COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE	V_{CEO}(sus)	250	300	350	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	6	V
*COLLECTOR CURRENT	I_C	1.0	1.0	1.0	A
*BASE CURRENT	I_B	0.5	0.5	0.5	A
*TRANSISTOR DISSIPATION	P_T				
At case temperatures up to 25°C		20	20	20	W
		(2N6175, 2N6176, 2N6177)			
At case temperatures above 25°C		See Fig. 15			
At ambient temperatures up to 25°C		0.8	0.8	0.8	W
		(2N6175, 2N6176, 2N6177)			
		1.4	1.4	1.4	W
		(40885, 40886, 40887)			
At ambient temperatures above 25°C		See Fig. 16			
For pulse operation		See Figs. 6, 7, & 8			
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		← -65 to 135 →			°C
*LEAD TEMPERATURE (During soldering):					
At distance ≥ 1/16 in. (1.59 mm) from case for 10 s max.		← 230 →			°C

*Types 2N6175, 2N6176, and 2N6177 in accordance with JEDEC registration data format JS-9 RDF-8.

ELECTRICAL CHARACTERISTICS, at case temperature (T_C) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V) V_{CB}	V_{CE}	DC EMITTER OR BASE VOLTAGE (V) V_{EB}	V_{BE}	DC CURRENT (mA) I_C	I_E	I_B	LIMITS 2N6175 40885 MIN.	MAX.	2N6176 40886 MIN.	MAX.	2N6177 40887 MIN.	MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}		300					0	–	–	–	–	–	20	µA
			200					0	–	50	–	50	–	–	
* With emitter open	I_{CBO}	360							–	–	–	–	–	20	
		280							–	–	–	50	–	–	
		240							–	50	–	–	–	–	
With base-emitter junction reverse-biased	I_{CEV}		450		-1.5				–	–	–	–	–	500	
			300		-1.5				–	500	–	500	–	–	
* Emitter-Cutoff Current	I_{EBO}			6					–	20	–	20	–	20	µA
DC Forward-Current Transfer Ratio	h_{FE}		10			50			–	–	–	–	30*	150	
			10			20			30*	190	30*	150	–	–	
			10			5			–	–	15	–	15	–	
			10			1			15	–	–	–	–	–	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 9 & 10)	$V_{CEO}(sus)$					50		0	250[a]	–	300[a]	–	350[a]	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					50		4	–	1.3	–	1.3	–	1.3	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					50		4	–	0.5	–	0.5	–	0.5	V
* Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$					1	0		300		350		450		V
* Low-Frequency, Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 1 kHz)	h_{fe}		10			5			25	–	25	–	25	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 3 MHz)	$\|h_{fe}\|$		20			20			7	–	7	–	7	–	
* Real Part of Common-Emitter, Small-Signal, Short-Circuit Input Impedance (f = 1 MHz)	$Re(h_{ie})$		20			20			–	300	–	–	–	–	Ω
			10			5			–	–	–	300	–	300	
* Output Capacitance (at 1 MHz)	C_{cb}	20					0		–	8	–	8	–	8	pF
Second-Breakdown Collector Current: With base forward biased[c] tp = 0.4 s	$I_{S/b}$[b]		150						133	–	133	–	133	–	mA
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$								– (2N6175)	5.5	– (2N6176)	5.5	– (2N6177)	5.5	
Junction-to-Ambient	$R_{\theta JA}$								– (2N6175)	138	– (2N6176)	138	– (2N6177)	138	°C/W
									– (40885)	78.6	– (40886)	78.6	– (40887)	78.6	

* Types 2N6175, 2N6176, and 2N6177 in accordance with JEDEC registration data format JS-9 RDF-8.

[a] CAUTION: The sustaining votlage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 9.

[b] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

[c] Specified value of $I_{S/b}$ for given value of V_{CE} as base voltage is increased from zero in a positive direction.

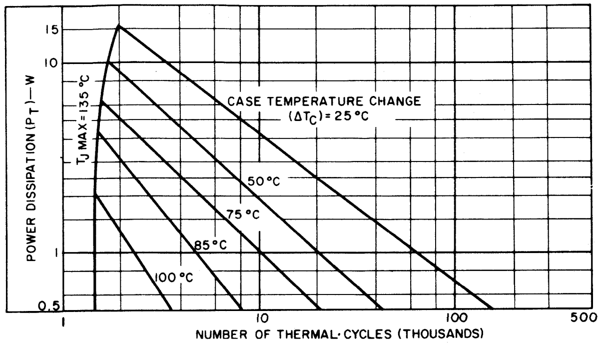


Fig.1—Thermal-cycling rating chart.

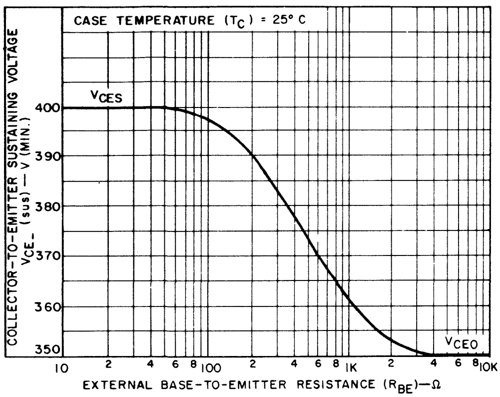


Fig.2—Sustaining voltage vs. base-to-emitter resistance for types 2N6177 and 40877.

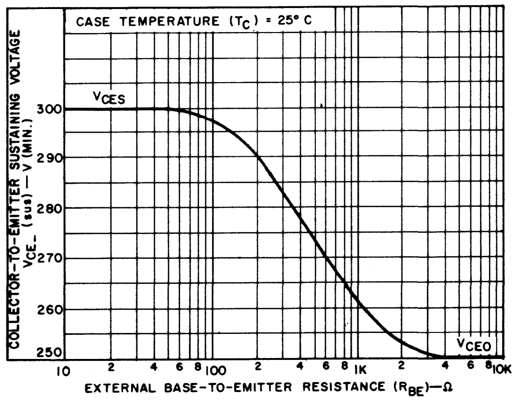


Fig.3—Sustaining voltage vs. base-to-emitter resistance for types 2N6175 and 40885.

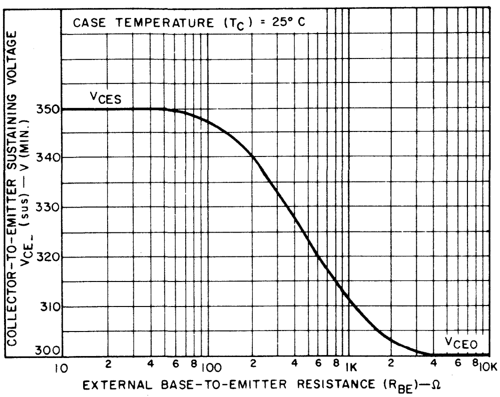


Fig.4—Sustaining voltage vs. base-to-emitter resistance for types 2N6176 and 40886.

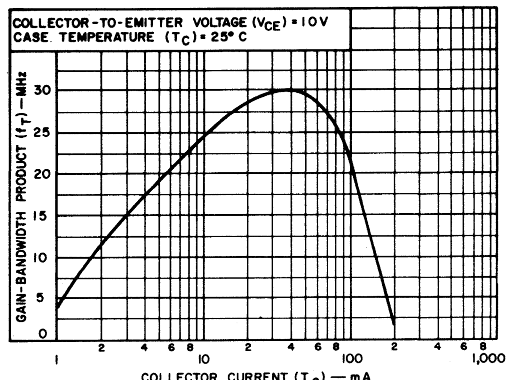


Fig.5—Typical gain-bandwidth product for all types.

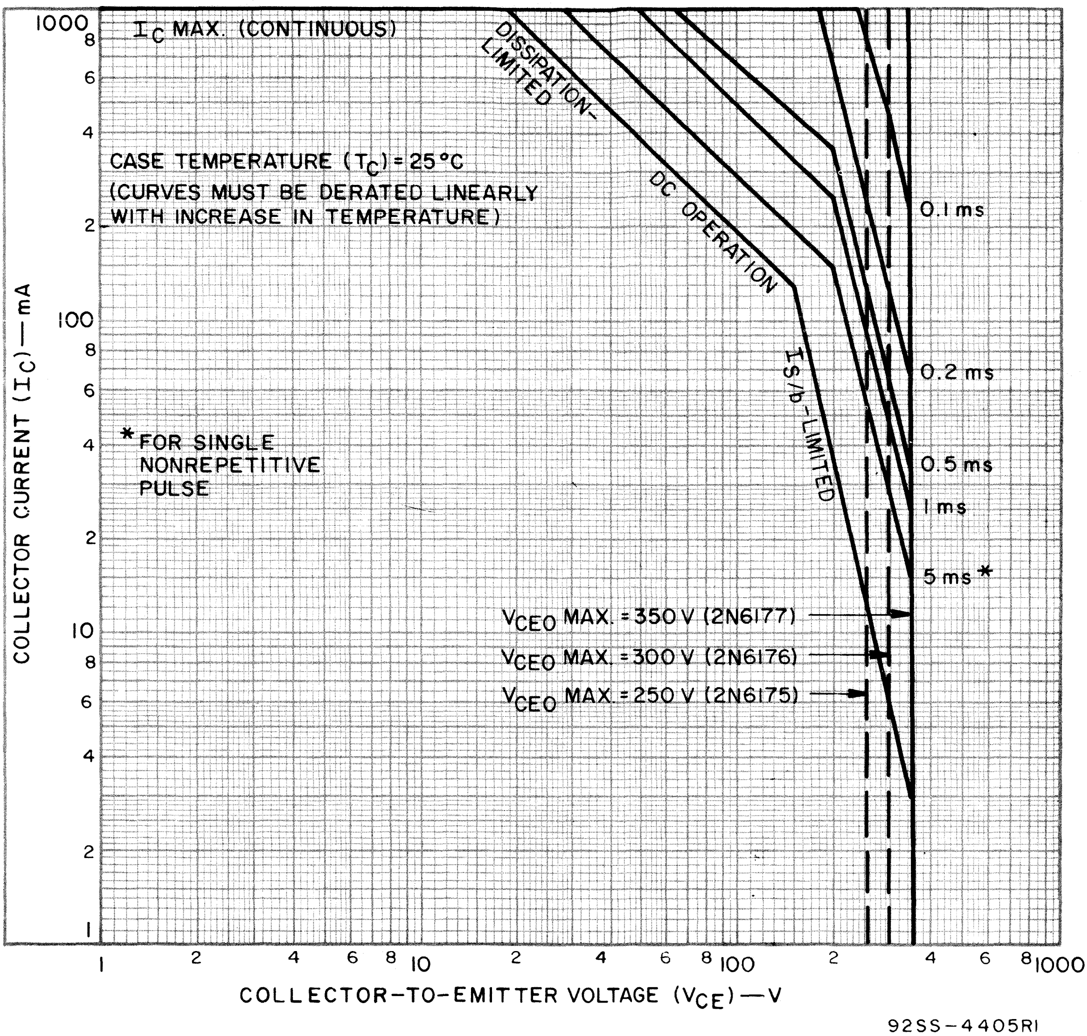


Fig.6—Maximum safe-operating-areas for types 2N6175, 2N6176, and 2N6177.

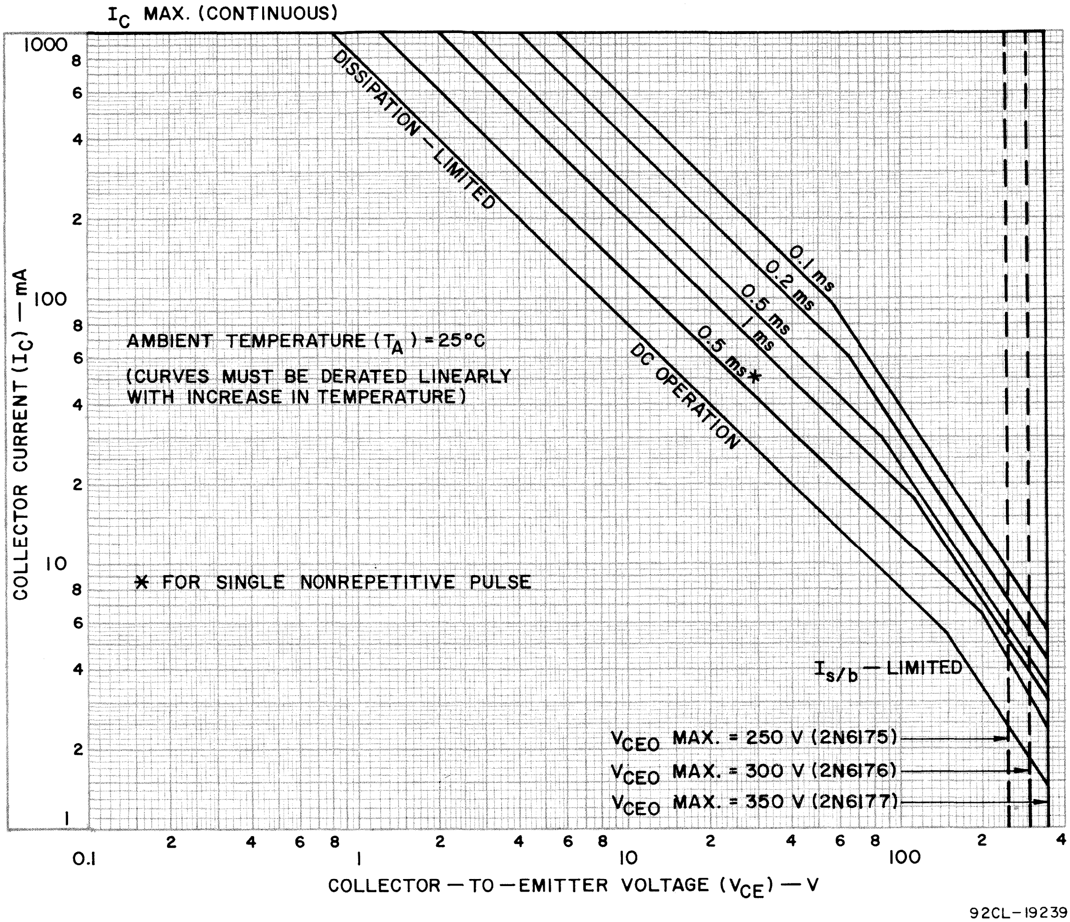


Fig.7—Maximum safe area-of-operation at ambient temperature for types 2N6175, 2N6176, and 2N6177.

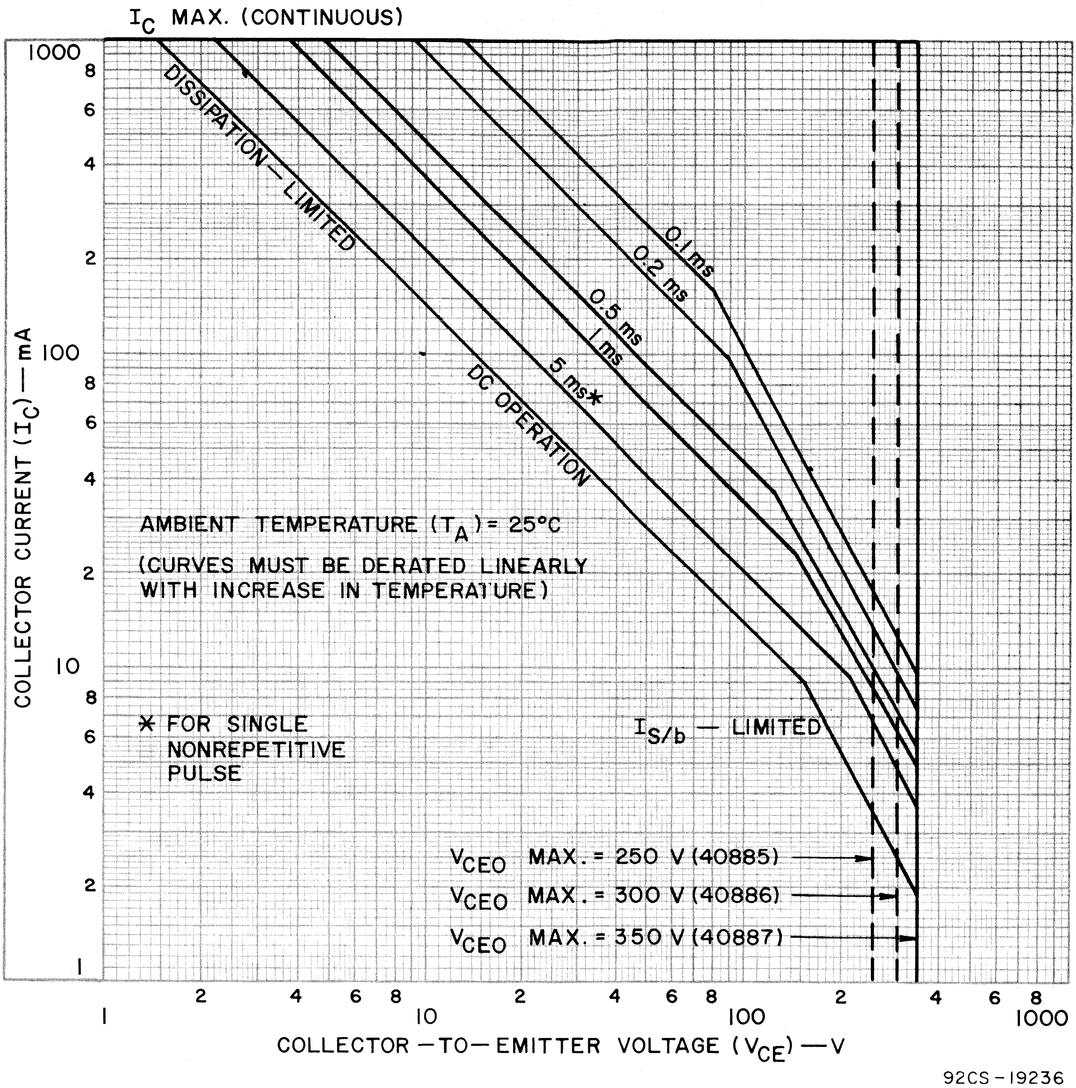


Fig.8—Maximum safe area-of-operation for types 40885, 40886, and 40887.

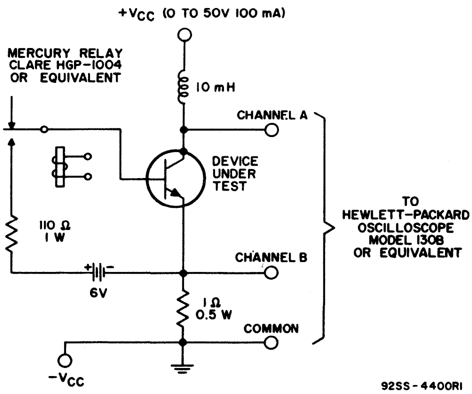
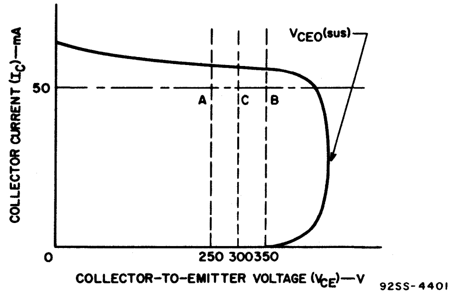


Fig.9—Circuit used to measure sustaining voltage, V_{CEO}(sus).



The sustaining voltage V_{CEO}(sus) is acceptable when the trace falls to the right and above point "A" for type 2N6175 or 40885. The trace must fall to the right and above point "B" for type 2N6177 or 40887 and above and to the right of point "C" for type 2N6176 or 40886.

Fig.10—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 9).

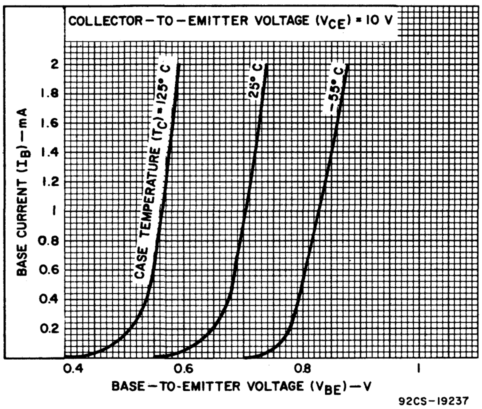


Fig.11—Typical input characteristics for all types.

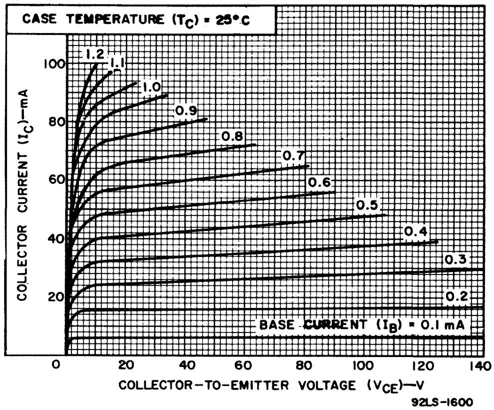


Fig.12—Typical output characteristics for all types.

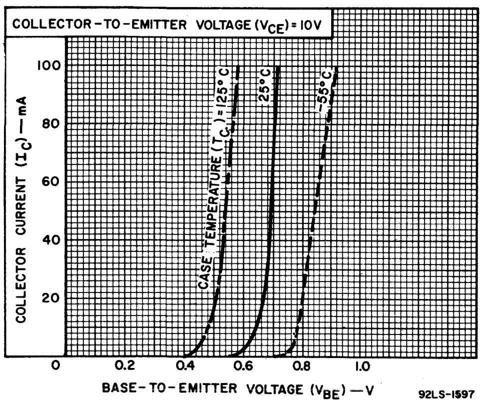


Fig.13—Typical transfer characteristics for all types.

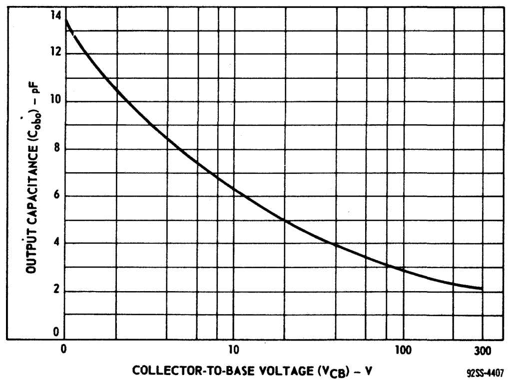


Fig.14—Typical output capacitance vs collector-to-base voltage for all types.

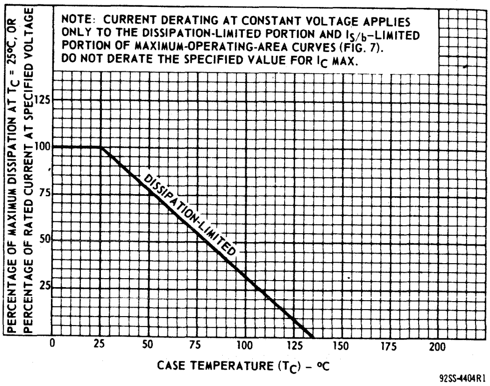


Fig.15—Dissipation derating curve for all types.

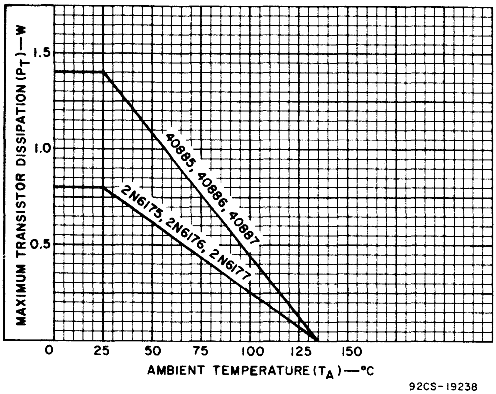


Fig.16—Dissipation derating curves for all types.

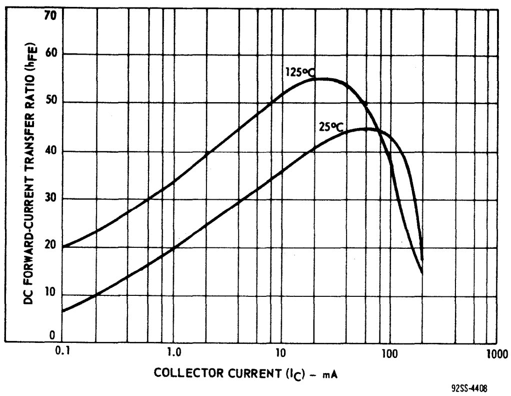
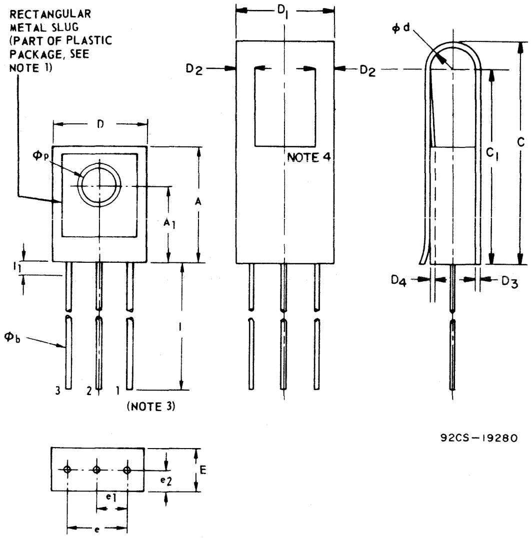


Fig.17—Typical DC-beta characteristics for all types.

DIMENSIONAL OUTLINE

"Plastic TO-5"



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.385	0.395	9.78	10.03	
A_1	0.251	0.261	6.37	6.63	
φb	0.016	0.019	0.41	0.48	2
C	0.858		21.79		
C_1	0.750		19.05		
D	0.305	0.315	7.75	8.00	
D_1	0.300		7.62		
D_2	0.070		1.77		
D_3	0.0329		0.813		
D_4	0.021	0.041	0.533	1.04	
φd	0.073	0.077	1.85	1.95	
E	0.145	0.155	3.68	3.94	
e	0.195	0.205	4.95	5.21	
e_1	0.095	0.105	2.41	2.67	
e_2	0.070	0.080	1.78	2.03	
ℓ	0.725	0.745	18.41	18.91	
$ℓ_1$	0.125	0.250	3.17	6.35	
φp	0.112	0.118	2.84	2.99	

NOTE 1: To attach to heat-sink, use a 4-40 binding-head screw and a No. 4 flat washer. The recommended screw torque (for even distribution of mounting pressure and optimum thermal contact) is 6 in.-lb.

NOTE 2: Three leads. Leads are pretinned to the $ℓ_1$ dimension.

NOTE 3: Lead numbering from right to left with rectangular metal slug facing observer.

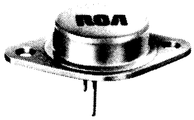
NOTE 4: Tab to be sheared through and set inward as shown.

When incorporating RCA Solid State Devices in equipment, it is recommended that the designer refer to "Operating Considerations for RCA Solid State Devices", Form No. 1CE-402, available on request from RCA, Commercial Engineering, Harrison, N. J. 07029.

RCA

Solid State
Division

Power Transistors
2N6249
2N6250
2N6251



JEDEC TO-3

H-1570

450-V, 30-A, 175-W Silicon N-P-N Switching Transistors

For Switching Applications in Industrial and Commercial Equipment

Features:
- **High voltage ratings:**
  V_{CBO} = 450 V (2N6251)
  375 V (2N6250)
  300 V (2N6249)
- **High dissipation rating: P_T = 175 W**
- **Low saturation voltages**
- **Maximum safe-area-of-operation curves**

RCA-2N6249, 2N6250, and 2N6251● are multiple epitaxial silicon n-p-n power transistors utilizing a multiple-emitter-site structure. Multiple-epitaxial construction maximizes the volt-ampere characteristic of the device and provides fast switching speeds. Multiple-emitter-site design assures uniform current flow throughout the structure, which produces a high $I_{S/b}$ and a large safe- operation area.

These devices use the popular JEDEC TO-3 package; they differ mainly in voltage ratings, leakage-current limits, and V_{CE}(sat) ratings.

The exceptional second-breakdown capabilities and high voltage-breakdown ratings make these transistors especially suitable for off-line inverters, switching regulators, motor controls, and deflection circuit applications.

The high gain and high $E_{S/b}$ energy-handling capability of the 2N6249 make it an excellent choice for motor-control applications in which large winding inductances are encountered and high surge currents are required to start the motor.

The high breakdown voltages, low saturation voltages, and fast-switching capability of the 2N6250 and 2N6251 make them especially suitable for inverter circuits operating directly off the rectified 115-V power line or in a bridge configuration operating from the rectified 220-V line.

● Formerly RCA Dev. Nos. TA7005, TA7006, and TA7007.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6249	2N6250	2N6251	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	300	375	450	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With base open	V_{CEO}(sus)	200	275	350	V
* With reverse bias (V_{BE}) = 0 V (with base-emitter shorted)	V_{CEX}(sus)	225	300	375	V
With external base-to-emitter resistance (R_{BE}) $\leq$ 50 Ω	V_{CER}(sus)	225	300	375	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	6	V
COLLECTOR CURRENT:	I_C				
* Continuous		10	10	10	A
Peak		30	30	30	A
*CONTINUOUS BASE CURRENT	I_B	10	10	10	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C and V_{CE} up to 30 V		175	175	175	W
At case temperatures up to 25°C and V_{CE} above 30 V		← See Fig. 1 →			
* At case temperatures above 25°C and V_{CE} above 30 V		← See Figs. 1, 2, & 4 →			
*TEMPERATURE RANGE:					
Storage & Operating (Junction)		← −65 to +200 →			°C
*PIN TEMPERATURE (During Soldering):					
At distances $\geq$ 1/32 in. (0.8 mm) from case for 10 s max.		← 230 →			°C

* In accordance with JEDEC registration data format (JS-6, RDF-1).

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

Characteristic	Symbol	Test Conditions					Limits									Units
		DC Collector or Emitter Voltage (V)		DC Current (A)			Type 2N6249			Type 2N6250			Type 2N6251			
		V_{CE}	V_{BE}	I_C	I_B	I_E	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	150 225 300			0 0 0		– – –	– – –	5 – –	– – –	– – –	– 5 –	– – –	– – –	– – 5	
* With base-emitter junction reverse-biased	I_{CEV}	225 300 375	−1.5 −1.5 −1.5				– – –	– – –	5 – –	– – –	– – –	– 5 –	– – –	– – –	– – 5	mA
* With base-emitter junction reverse-biased	I_{CEV} T_C = 125°C	225 300 375	−1.5 −1.5 −1.5				– – –	– – –	10 – –	– – –	– – –	– 10 –	– – –	– – –	– – 10	
* Emitter-Cutoff Current	I_{EBO}		−6				–	–	1	–	–	1	–	–	1	mA
* Collector-to-Emitter Sustaining Voltage *(see Figs. 15 & 16)* With base open	$V_{CEO}(sus)$[b]			0.2			200[b]	–	–	275[b]	–	–	350[b]	–	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$[b]			0.2			225[b]	–	–	300[b]	–	–	375[b]	–	–	V
* Emitter-to-Base Voltage	V_{EBO}					0.001	6	–	–	6	–	–	6	–	–	V
* DC Forward-Current Transfer Ratio	h_{FE}	3 3 3		10 10 10			10 – –	– – –	50 – –	– 8 –	– – –	– 50 –	– – 6	– – –	– – 50	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$[a]			10 10 10	1 1.25 1.67		– – –	– – –	2.25 – –	– – –	– – –	– 2.25 –	– – –	– – –	– – 2.25	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]			10 10 10	1 1.25 1.67		– – –	– – –	1.5 – –	– – –	– – –	– 1.5 –	– – –	– – –	– – 1.5	V
* Magnitude of Common Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	10		1			2.5	8	–	2.5	8	–	2.5	8	–	
Second Breakdown Collector Current (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	30					5.8	–	–	5.8	–	–	5.8	–	–	A
* Second Breakdown[c] Energy (With base reverse-biased) R_B = 50 Ω, L = 50 µH	$E_{S/b}$[d]		−4	10			2.5	–	–	2.5	–	–	2.5	–	–	mJ
* Switching Times: Rise *(See Figs. 13, 17, & 18)*	t_r[e]	V_{CC} = 200 V		10 10 10	1 1.25 1.67		– – –	0.8 – –	2 – –	– – –	– 0.8 –	– 2 –	– – –	– – 0.8	– – 2	
Storage *(See Figs. 11, 12, 17, & 18)*	t_s[e]	V_{CC} = 200 V		10 10 10	1 1.25 1.67		– – –	1.8 – –	3.5 – –	– – –	– 1.8 –	– 3.5 –	– – –	– – 1.8	– – 3.5	µs
Fall *(See Figs. 14, 17, & 18)*	t_f[e]	V_{CC} = 200 V		10 10 10	1 1.25 1.67		– – –	0.5 – –	1 – –	– – –	– 0.5 –	– 1 –	– – –	– – 0.5	– – 1	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10		5			–	–	1	–	–	1	–	–	1	°C/W

[a] Pulsed; pulse duration ≤350 µs, duty factor = 2%.

[b] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 15.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

[d] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse-bias conditions. $E_{S/b} = 1/2\ LI^2$ where L is a series load or leakage inductance, and I is the peak collector current.

[e] $I_{B1} = I_{B2}$ = value shown.

* In accordance with JEDEC registration data format (JS-6 RDF-1).

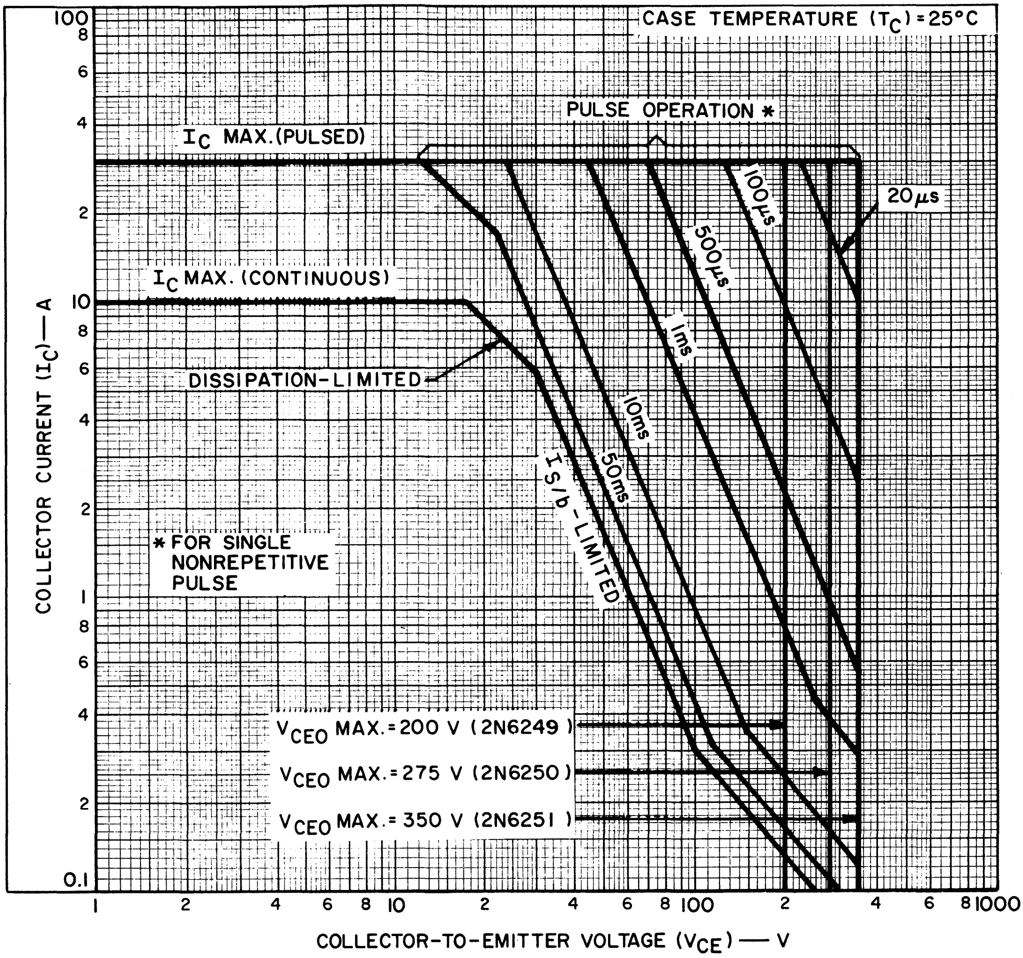


Fig. 1—Maximum operating areas for all types.

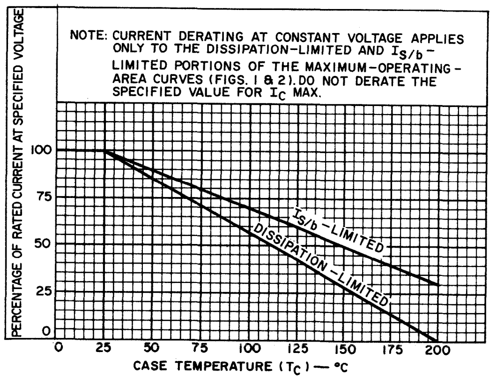


Fig. 2—Dissipation derating and $I_{S/b}$ derating for all types.

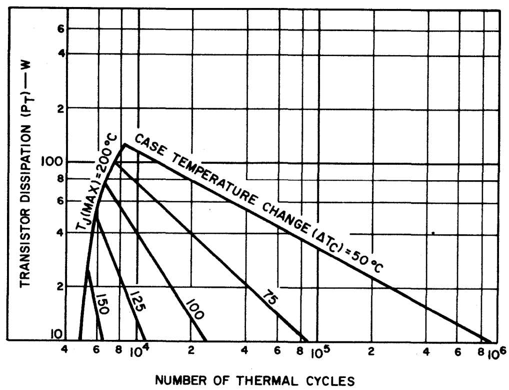


Fig. 3—Thermal-cycle rating chart for all types.

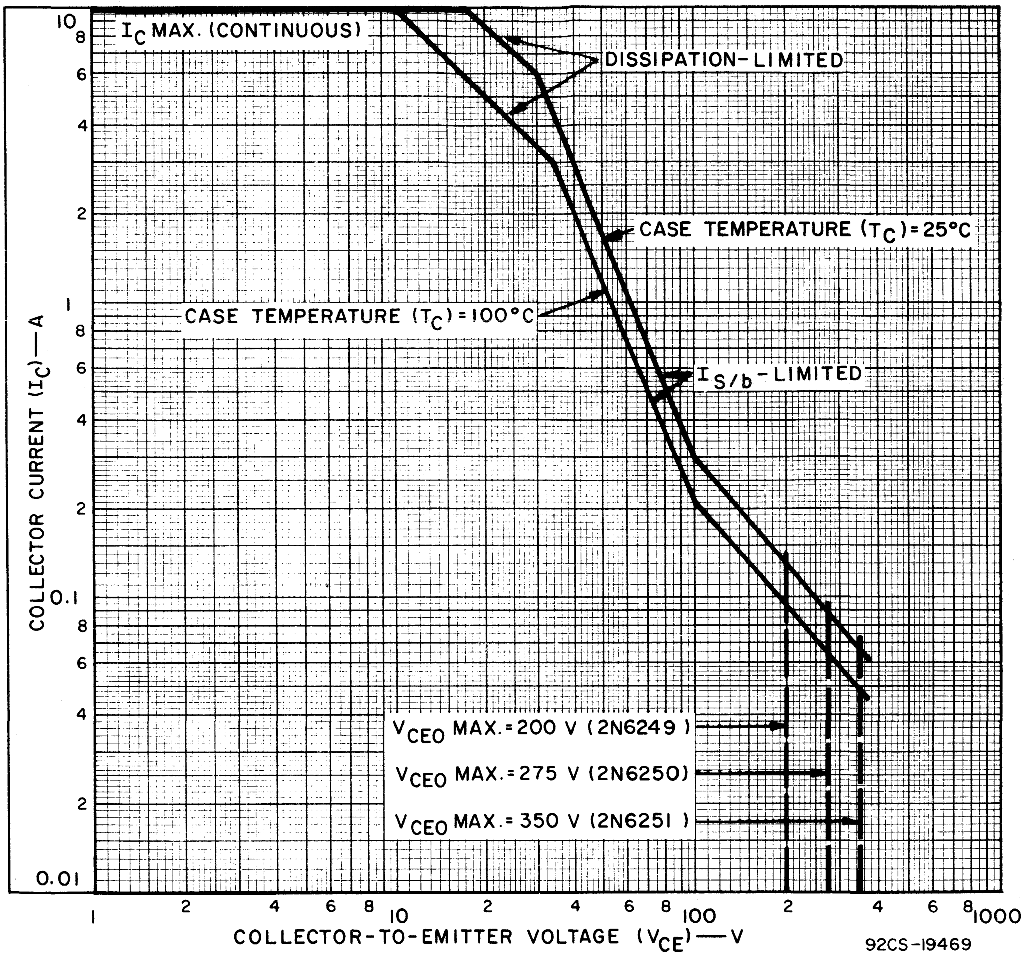


Fig.4 —Maximum operating areas for all types.

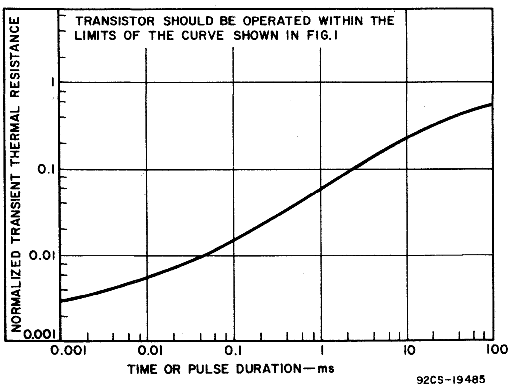


Fig.5—Typical thermal response characteristic for all types.

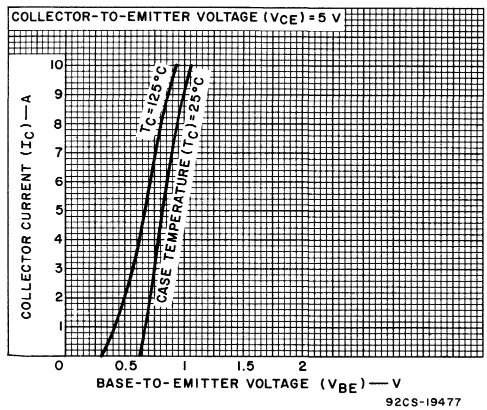


Fig.6—Typical transfer characteristics for all types.

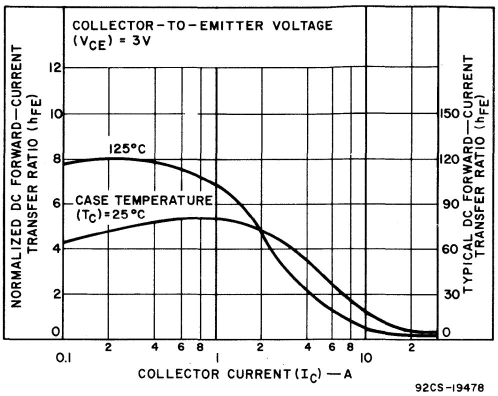


Fig.7—Typical normalized dc beta characteristics for all types.

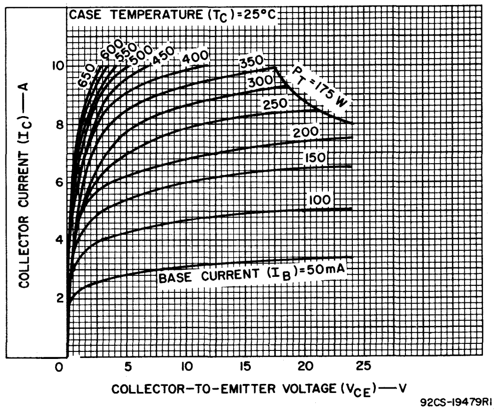


Fig.8—Typical output characteristics for all types.

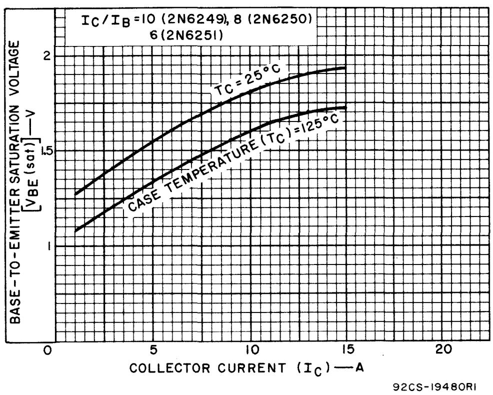


Fig.9—Typical base-to-emitter saturation voltage characteristics for all types.

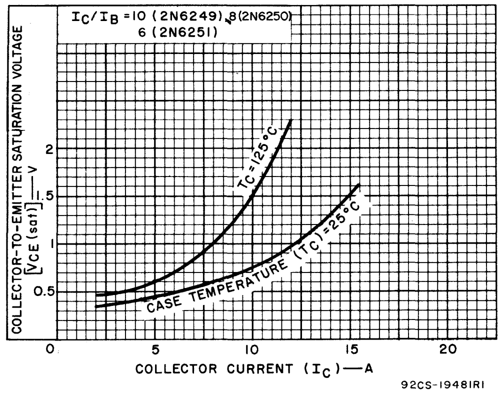


Fig. 10—Typical collector-to-emitter saturation voltage characteristics for all types.

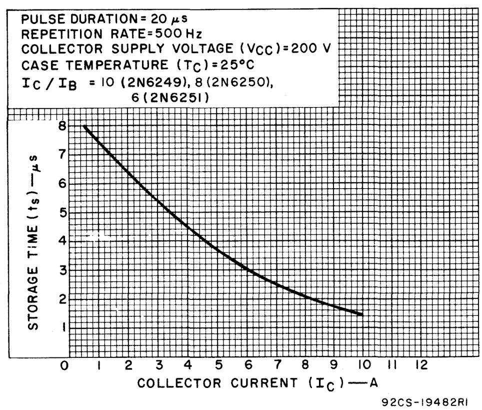


Fig. 11—Typical storage-time characteristics for all types (with constant forced gain).

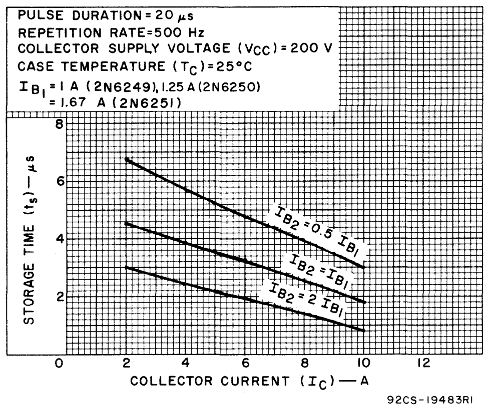


Fig. 12—Typical storage-time characteristics for all types (with constant base drive).

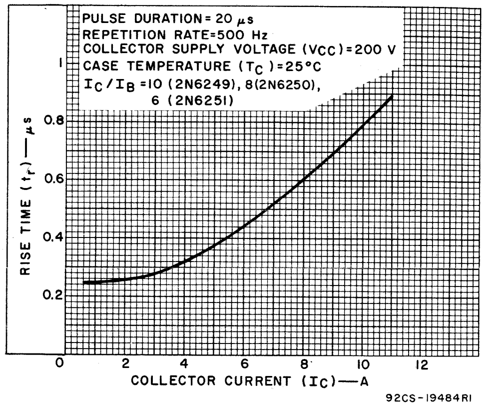


Fig. 13—Typical rise-time characteristic for all types.

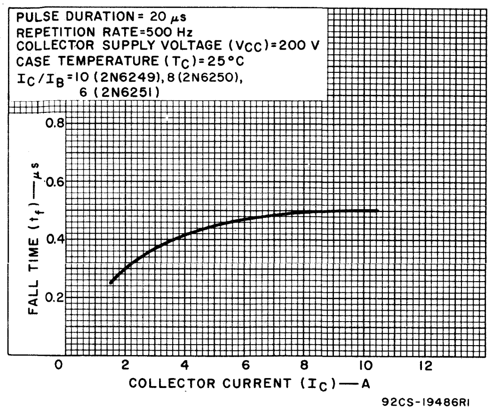


Fig. 14—Typical fall-time characteristic for all types.

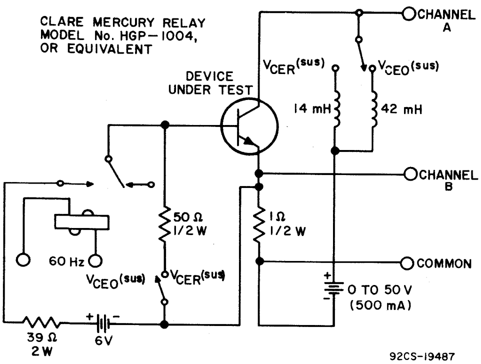
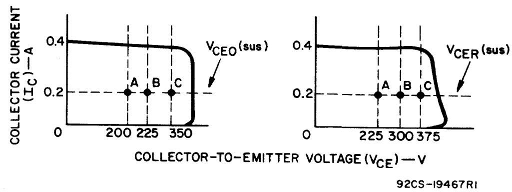


Fig. 15—Circuit used to measure sustaining voltages V_{CEO}(sus) and V_{CER}(sus) for all types.



The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) are acceptable when the traces fall to the right of point "A" for type 2N6249, point "B" for type 2N6250, and point "C" for type 2N6251 (I_C = 0.2 A).

Fig. 16—Oscilloscope display for measurement of sustaining voltages. (Test circuit shown in Fig. 15).

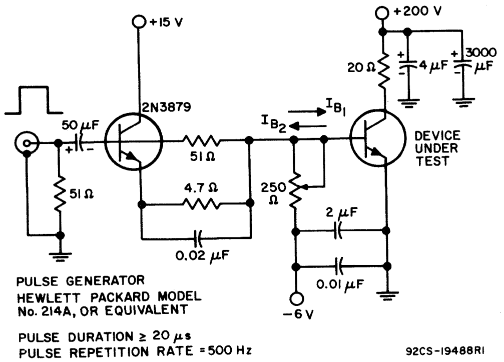


Fig. 17—Circuit used to measure switching times for all types.

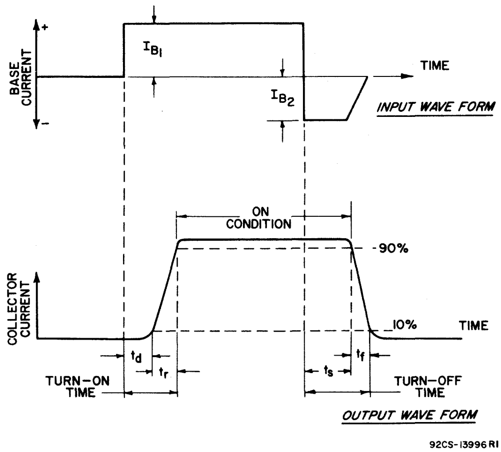
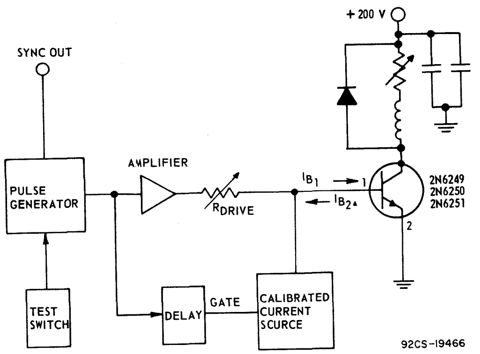


Fig. 18—Phase relationship between input and output currents showing reference points for specification of switching times (Test circuit shown in Fig. 17).



*I_{B_1} AND I_{B_2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig. 19—Circuit used to measure inductive-load switching times for all types.

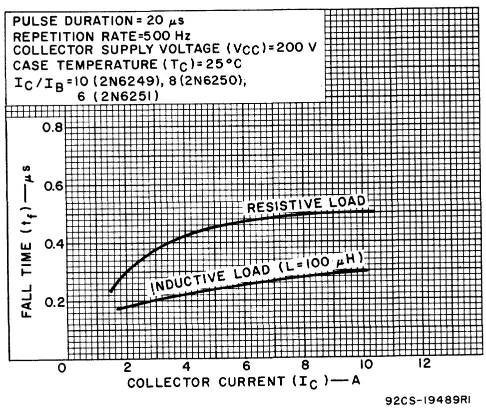
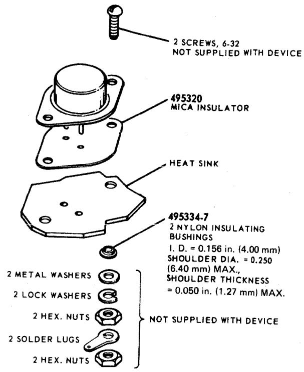


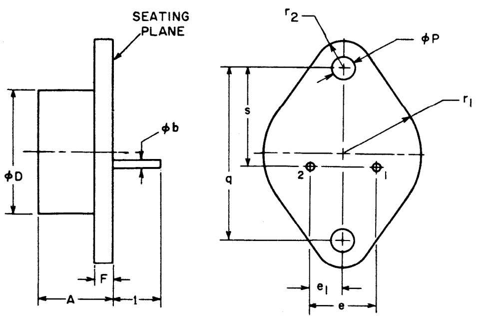
Fig. 20—Typical inductive- and resistive-load fall-time characteristics for all types.



92CS-19470

Fig.21—Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

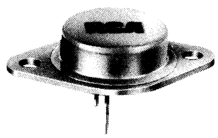
TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors

410



JEDEC
TO-3

H-1570

High-Voltage, High-Power Silicon N-P-N Power Transistor

For Switching and Linear Applications in
Military, Industrial, and Commercial Equipment

Features:

- **Maximum safe-area-of-operation curves**
- **Low saturation voltage: V_{CE}(sat) = 0.8 V (max.)**
- **High voltage rating: V_{CEO}(sus) = 200 V**
- **High dissipation rating: P_T = 125 W**

RCA-410 is an epitaxial silicon n-p-n power transistor utilizing a multiple-emitter-site structure. This device employs the popular JEDEC TO-3 package.

Featuring high breakdown-voltage ratings and low saturation-voltage values, the RCA-410 is especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	200	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE		
With base open, V_{CEO}(sus)	200	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	V
COLLECTOR CURRENT:		
Continuous, I_C	7	A
Peak	10	A
BASE CURRENT (Continuous), I_B	2	A
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25°C and V_{CE} up to 75 V	125	W
At case temperatures up to 25°C and V_{CE} above 75 V	See Fig. 2.	
At case temperatures above 25°C and V_{CE} above 75 V	See Figs. 1 & 2.	
TEMPERATURE RANGE:		
Storage & Operating (Junction)	−65 to +200	°C
PIN TEMPERATURE (During Soldering):		
At distances ≥ 1/32 in. (0.8 mm) from case for 10 s max.	230	°C

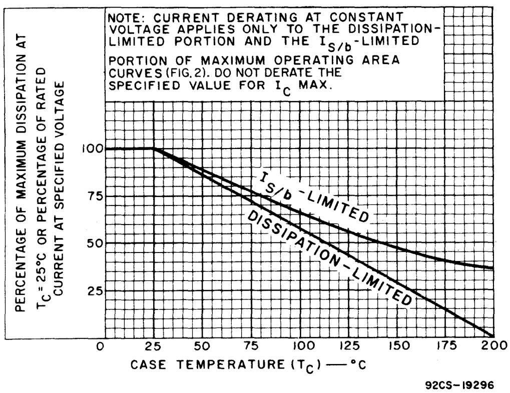


Fig. 1—Dissipation and current derating curves.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		Limits			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	200					–	–	0.25	mA
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}	200		−1.5			–	–	0.5	mA
Emitter-Cutoff Current	I_{EBO}		5				–	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5 5			1.0[a] 2.5[a]		30 10	– –	90 –	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 3 & 4.)	$V_{CEO}(sus)$[b]				0.1		200[b]	–	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				1.0[a]	0.1	–	0.9	1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				1.0[a]	0.1	–	0.2	0.8	V
Second-Breakdown Collector Current: (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	150					0.3	–	–	A
Gain-Bandwidth Product	f_T	10			0.2		–	4.0	–	MHz
Switching Time: Rise (See Figs. 10, 12, & 13.)	t_s				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.35	–	μs
Storage (See Figs. 11, 12, & 13.)	I_S				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	1.4	–	μs
Fall (See Figs. 9, 12, & 13.)	t_f				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.15	–	μs
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10			5		–	–	1.4	°C/W

[a] Pulsed; pulse duration $\leq$350 μs, duty factor = 2%

[b] CAUTION: The sustaining voltage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

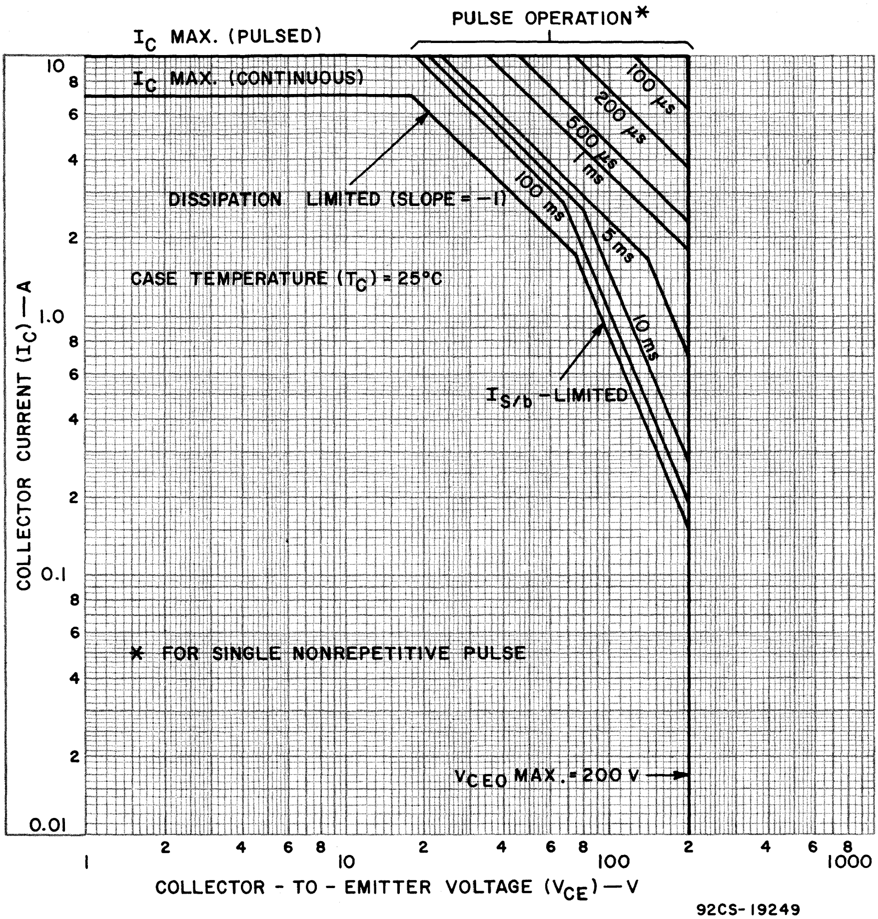


Fig.2—Maximum operating areas.

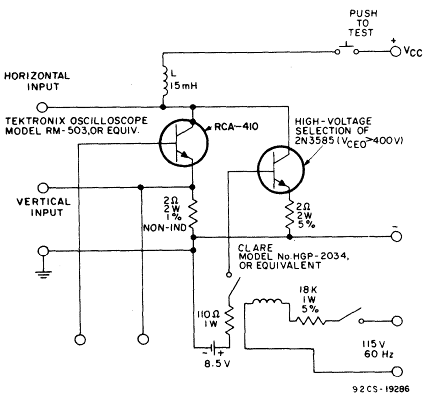


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

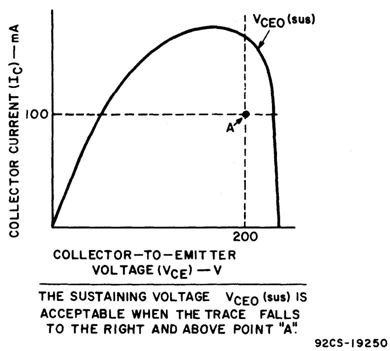


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

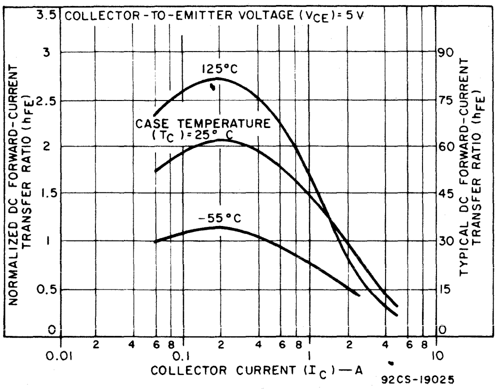


Fig.5—Typical dc beta characteristics.

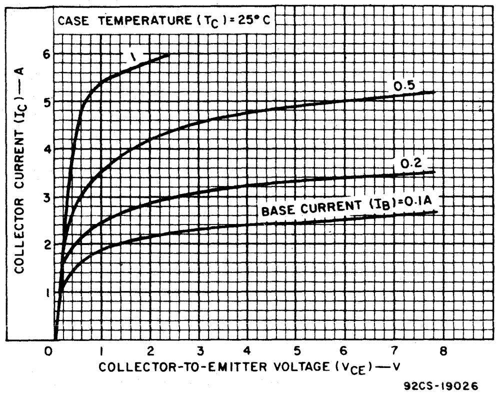


Fig.6—Typical output characteristics.

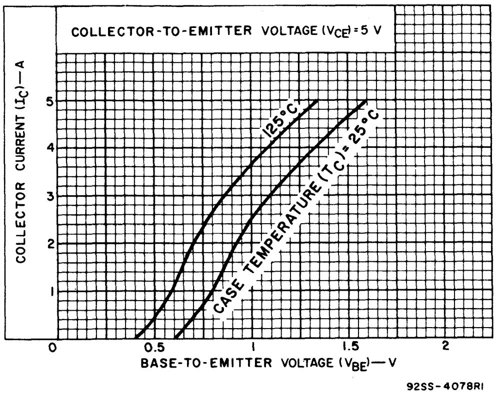


Fig.7—Typical transfer characteristics.

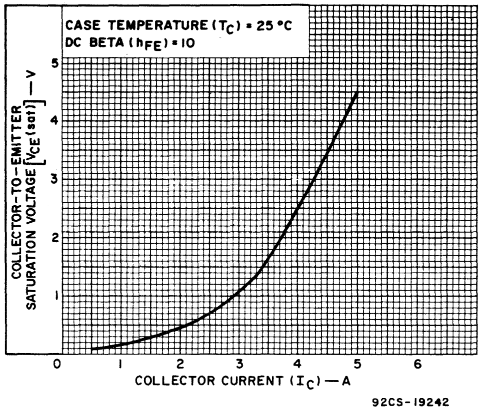


Fig.8—Typical saturation voltage characteristic.

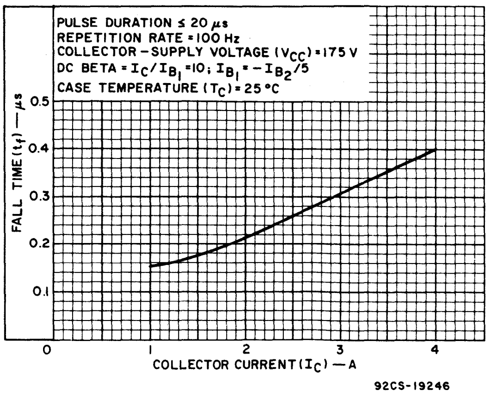


Fig.9—Typical fall time vs. collector current.

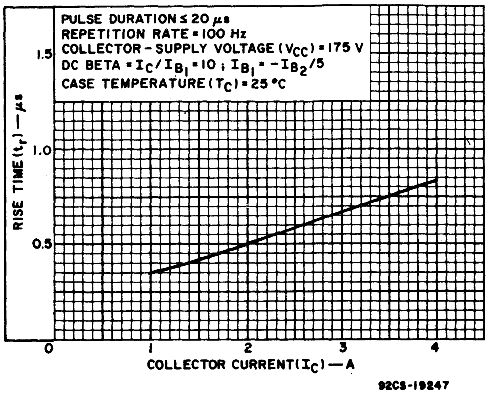


Fig. 10—Typical rise time vs. collector current.

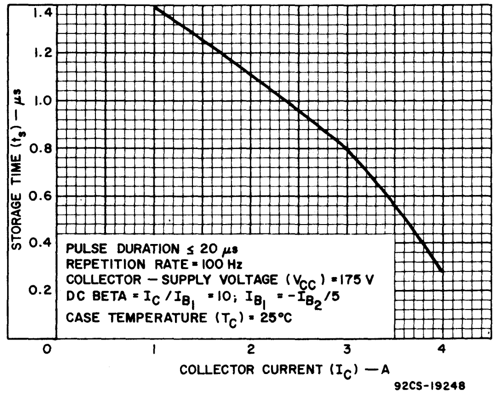


Fig. 11—Typical storage time vs. collector current.

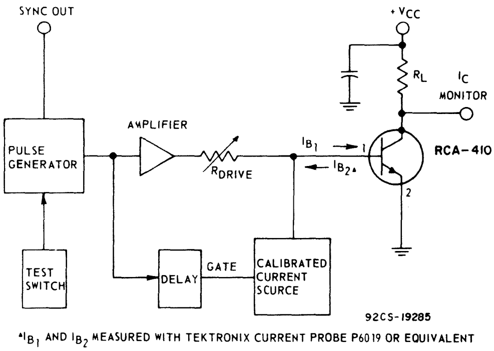


Fig. 12—Circuit used to measure switching times.

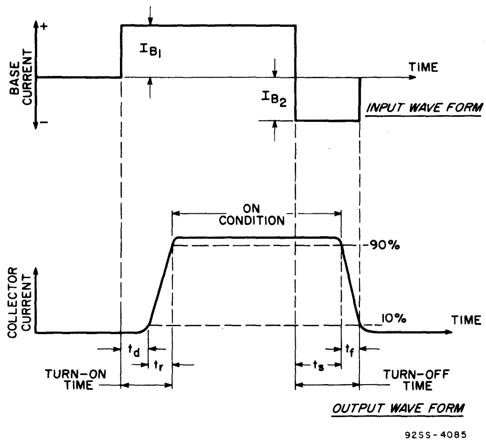


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times. Test circuit shown in Fig. 12).

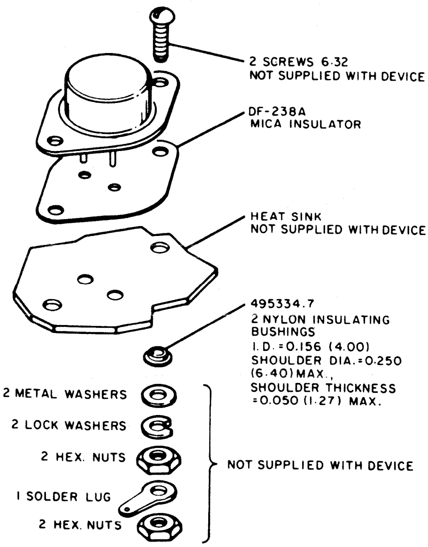
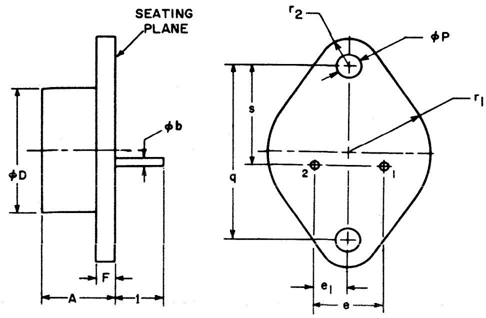


Fig. 14–Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

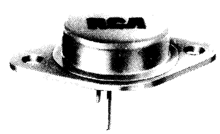
TERMINAL CONNECTIONS

Pin 1 – Base
Pin 2 – Emitter
Mounting Flange, Case – Collector

Solid State
Division

Power Transistors

411



JEDEC
TO-3

H-1570

High-Voltage, High-Power Silicon N-P-N Power Transistor

For Switching and Linear Applications in
Military, Industrial, and Commercial Equipment

Features:

- **Maximum safe-area-of-operation curves**
- **Low saturation voltage: $V_{CE}(sat)$ = 0.8 V (max.)**
- **High voltage rating: $V_{CEO}(sus)$ = 300 V**
- **High dissipation rating: P_T = 125 W**

RCA-411 is an epitaxial silicon n-p-n power transistor utilizing a multiple-emitter-site structure. This device employs the popular JEDEC TO-3 package.

Featuring high breakdown-voltage ratings and low saturation-voltage values, the RCA-411 is especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	300	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE: With base open, $V_{CEO}(sus)$	300	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	V
COLLECTOR CURRENT: Continuous, I_C	7	A
Peak	10	A
BASE CURRENT (Continuous), I_B	2	A
TRANSISTOR DISSIPATION, P_T: At case temperatures up to 25°C and V_{CE} up to 75 V	125	W
At case temperatures up to 25°C and V_{CE} above 75 V	See Fig. 2.	
At case temperatures above 25°C and V_{CE} above 75 V	See Figs. 1 & 2.	
TEMPERATURE RANGE: Storage & Operating (Junction)	−65 to +200	°C
PIN TEMPERATURE (During Soldering): At distances ≥ 1/32 in. (0.8 mm) from case for 10 s max.	230	°C

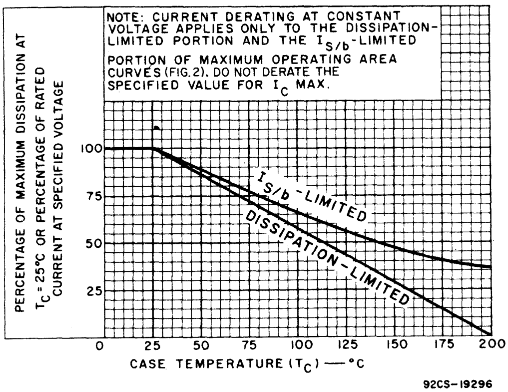


Fig. 1—Dissipation and current derating curves.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	Test Conditions: DC Emitter or Base Voltage (V)		Test Conditions: DC Current (A)		Limits			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	300					–	–	0.25	
With base-emitter junction reverse-biased	I_{CEV}	300		−1.5			–	–	0.25	mA
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}	300		−1.5			–	–	0.5	
Emitter-Cutoff Current	I_{EBO}		5				–	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5 5			1.0[a] 2.5[a]		30 10	– –	90 –	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 3 & 4.)	$V_{CEO}(sus)$[b]				0.1		300[b]	–	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				1.0[a]	0.1	–	0.9	1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				1.0[a]	0.1	–	0.2	0.8	V
Second-Breakdown Collector Current: (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	150					0.3	–	–	A
Gain-Bandwidth Product	f_T	10			0.2		–	2.5	–	MHz
Switching Time: Rise (See Figs. 10, 12, & 13.)	t_r				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.35	–	
Storage (See Figs. 11, 12, & 13.)	t_s				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	1.4	–	µs
Fall (See Figs. 9, 12, & 13.)	t_f				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.15	–	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10			5		–	–	1.4	°C/W

[a] Pulsed; pulse duration ≤350 µs, duty factor = 2%.

[b] CAUTION: The sustaining voltage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

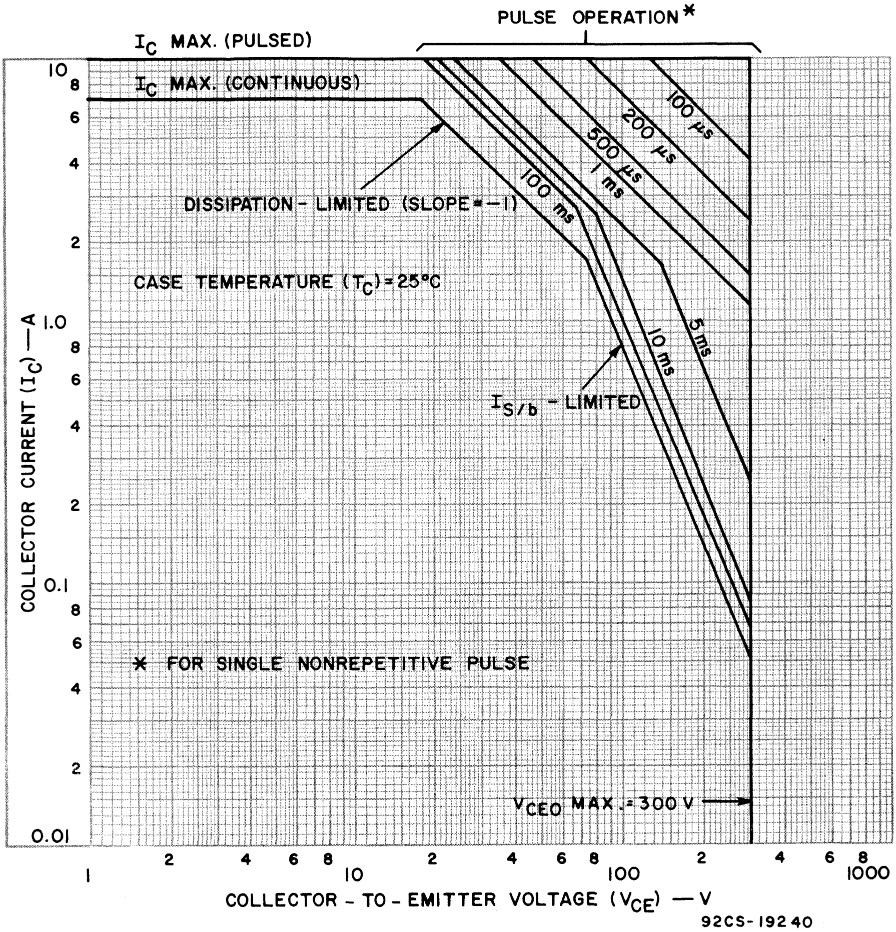


Fig.2—Maximum operating areas.

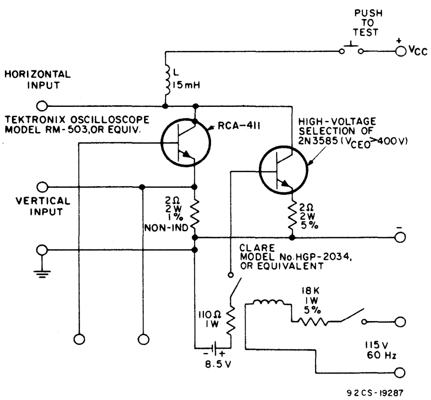


Fig.3—Circuit used to measure sustaining voltage, $V_{CEO}(sus)$.

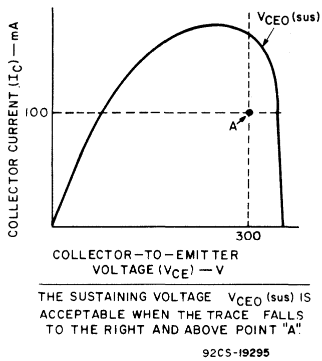


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig.3).

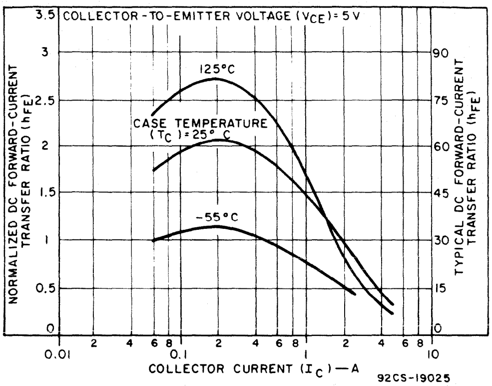


Fig.5—Typical dc beta characteristics.

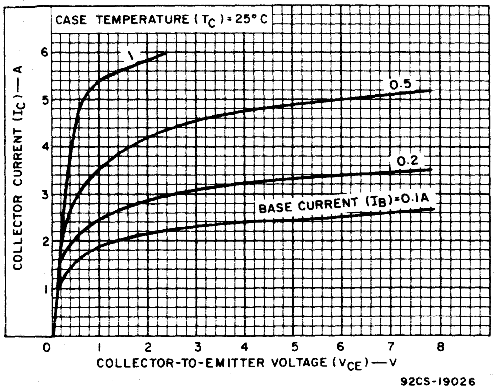


Fig.6—Typical output characteristics.

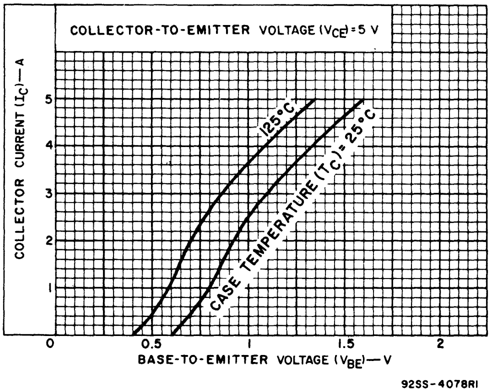


Fig.7—Typical transfer characteristics.

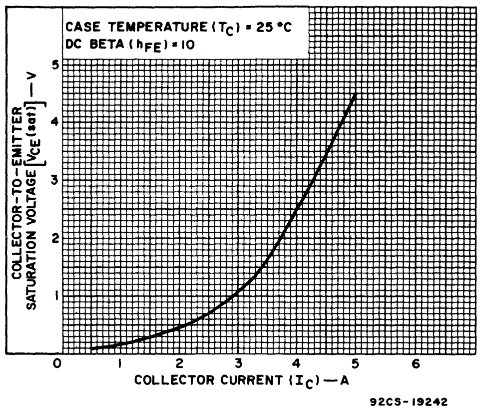


Fig.8—Typical saturation voltage characteristic.

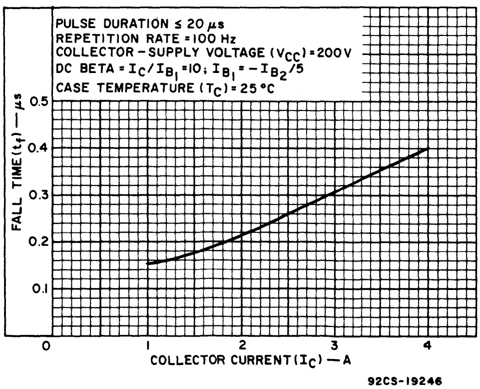


Fig.9—Typical fall time vs. collector current.

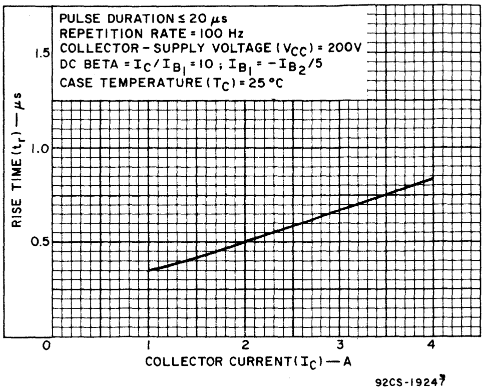


Fig. 10—Typical rise time vs. collector current.

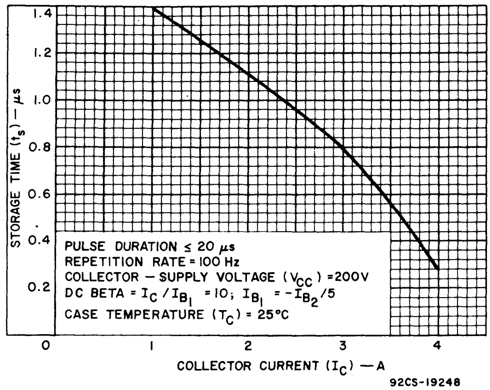


Fig. 11—Typical storage time vs. collector current.

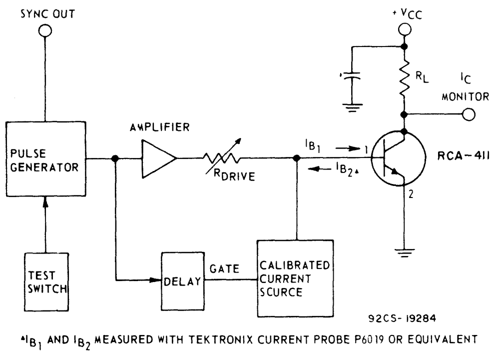


Fig. 12—Circuit used to measure switching times.

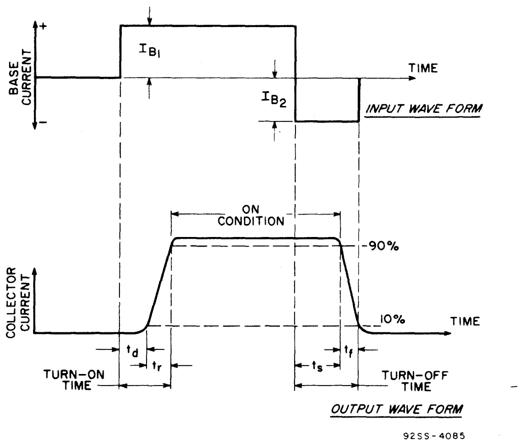


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times. Test circuit shown in Fig. 12).

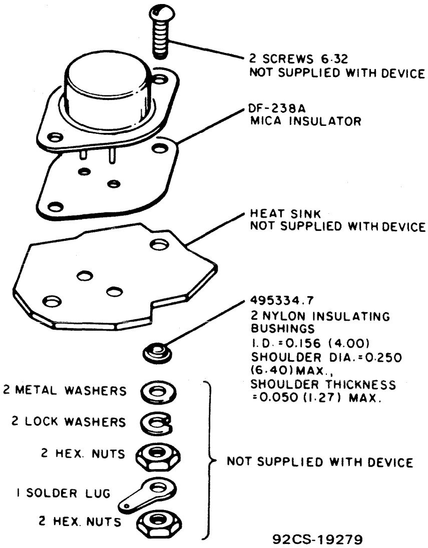
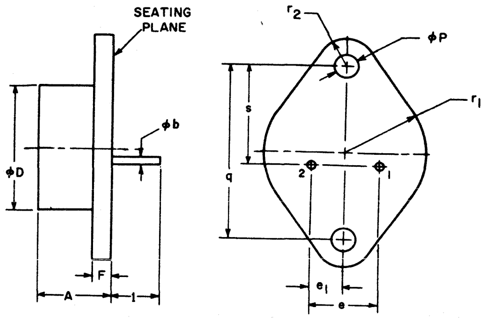


Fig. 14—Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

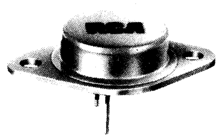
TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Mounting Flange, Case — Collector

RCA Solid State Division

Power Transistors

413



JEDEC TO-3

H-1570

High-Voltage, High-Power Silicon N-P-N Power Transistor

For Switching and Linear Applications in Military, Industrial, and Commercial Equipment

Features:

- **Maximum safe-area-of-operation curves**
- **Low saturation voltage: $V_{CE}(sat)$ = 0.8 V (max.)**
- **High voltage rating: $V_{CEO}(sus)$ = 325 V**
- **High dissipation rating: P_T = 125 W**

RCA-413 is an epitaxial silicon n-p-n power transistor utilizing a multiple-emitter-site structure. This device employs the popular JEDEC TO-3 package.

Featuring high breakdown-voltage ratings and low saturation-voltage values, the RCA-413 is especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	400	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE		
With base open, $V_{CEO}(sus)$	325	V
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:		
With base open, $V_{(BR)CEO}$	400	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	V
COLLECTOR CURRENT:		
Continuous, I_C	7	A
Peak	10	A
BASE CURRENT (Continuous), I_B	2	A
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25°C and V_{CE} up to 75 V	125	W
At case temperatures up to 25°C and V_{CE} above 75 V	See Fig. 2.	
At case temperatures above 25°C and V_{CE} above 75 V	See Figs. 1 & 2.	
TEMPERATURE RANGE:		
Storage & Operating (Junction)	−65 to +200	°C
PIN TEMPERATURE (During Soldering):		
At distances ≥ 1/32 in. (0.8 mm) from case for 10 s max.	230	°C

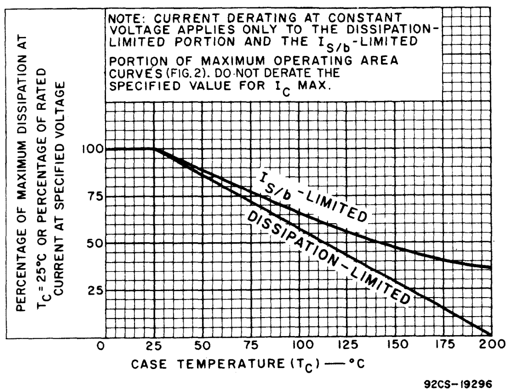


Fig. 1—Dissipation and current derating curves.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		Limits			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	400					–	–	0.25	mA
With base-emitter junction reverse-biased	I_{CEV}	400		–1.5			–	–	0.25	mA
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}	400		–1.5			–	–	0.5	mA
Emitter-Cutoff Current	I_{EBO}		5				–	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5 5			0.5[a] 1.0[a]		20 15	– –	80 –	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 3 & 4.)	$V_{CEO}(sus)$[b]				0.1		325[b]	–	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				0.5[a]	0.05	–	0.8	1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				0.5[a]	0.05	–	0.15	0.8	V
Second-Breakdown Collector Current: (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	150					0.3	–	–	A
Gain-Bandwidth Product	f_T	10			0.2		–	4.0	–	MHz
Switching Time: Rise (See Figs. 10, 12, & 13.)	t_r				1.0	0.1 (I_{B1}) –0.5 (I_{B2})	–	0.35	–	µs
Storage (See Figs. 11, 12, & 13.)	t_s				1.0	0.1 (I_{B1}) –0.5 (I_{B2})	–	1.4	–	µs
Fall (See Figs. 9, 12, & 13.)	t_f				1.0	0.1 (I_{B1}) –0.5 (I_{B2})	–	0.15	–	µs
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10			5		–	–	1.4	°C/W

[a] Pulsed; pulse duration $\leq$ 350 µs, duty factor = 2%

[b] CAUTION: The sustaining voltage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

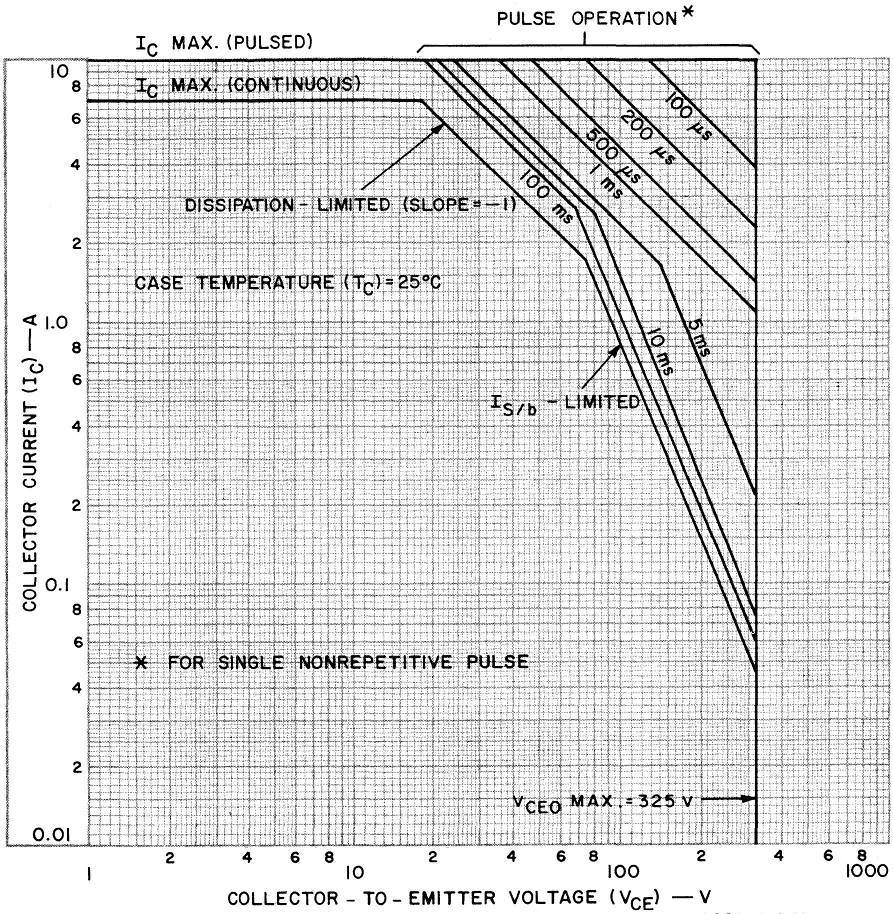


Fig.2—Maximum operating areas.

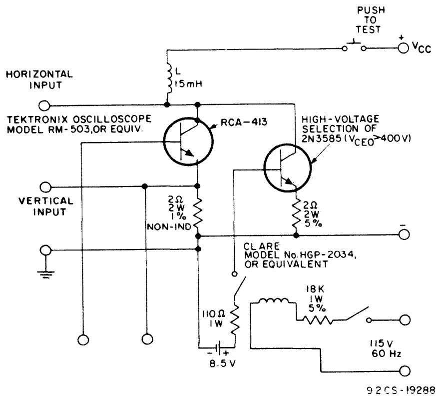


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

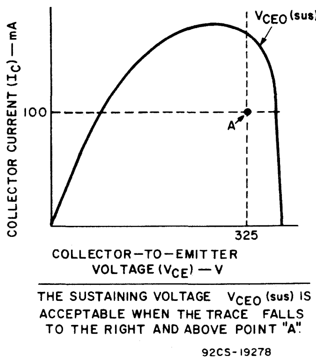


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

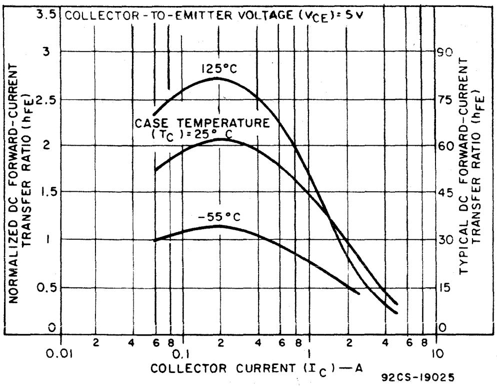


Fig.5—Typical dc beta characteristics.

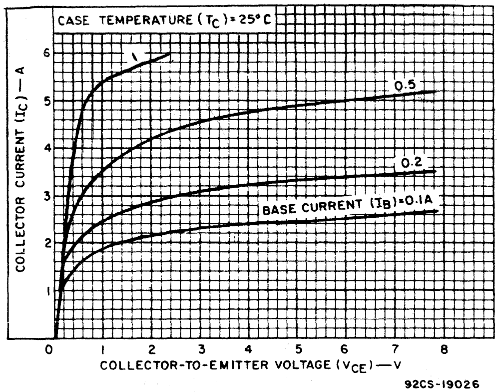


Fig.6—Typical output characteristics.

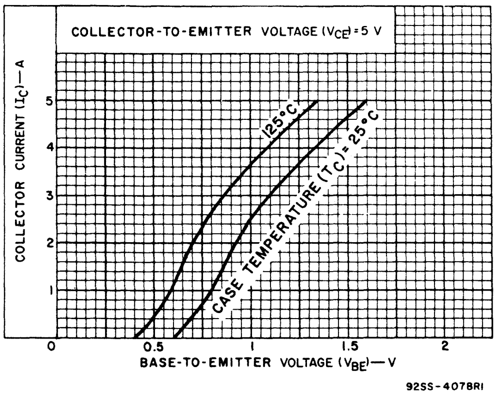


Fig.7—Typical transfer characteristics.

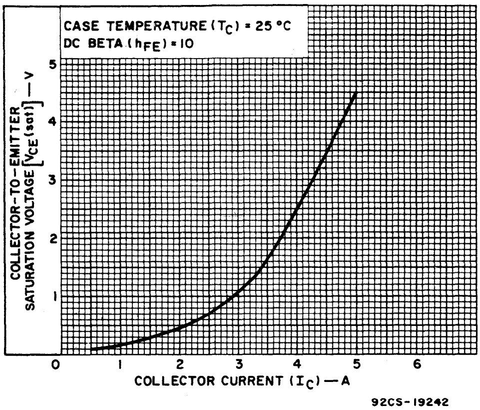


Fig.8—Typical saturation voltage characteristic.

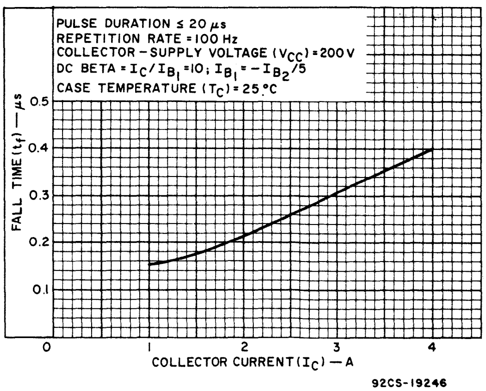


Fig.9—Typical fall time vs. collector current.

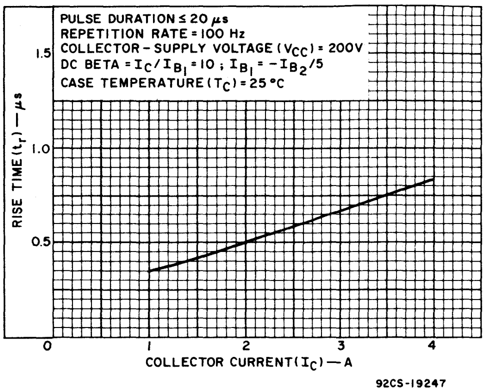


Fig.10—Typical rise time vs. collector current.

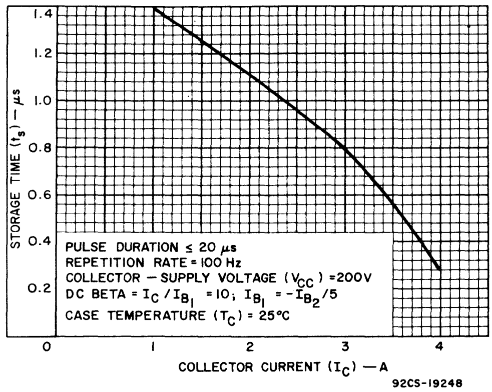


Fig.11—Typical storage time vs. collector current.

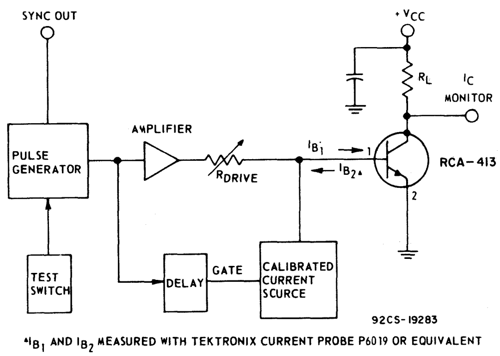


Fig.12—Circuit used to measure switching times.

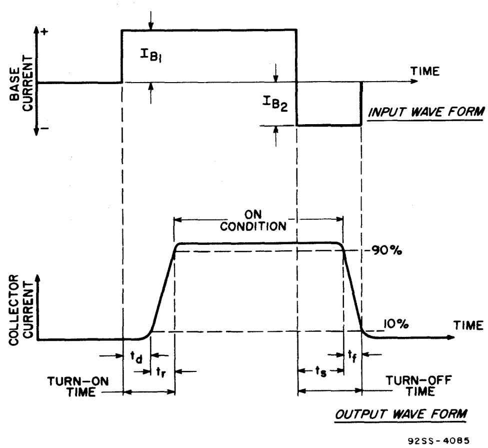
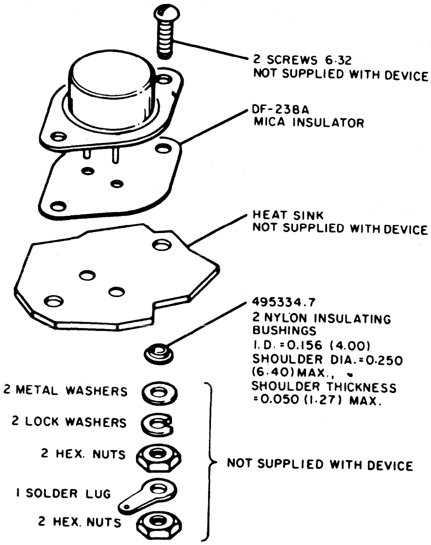


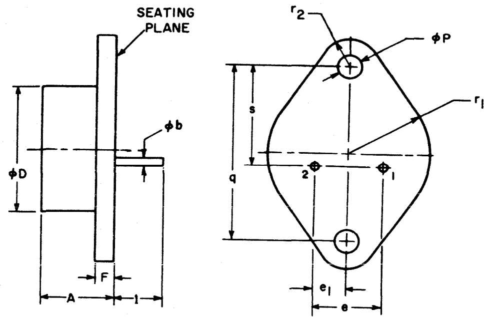
Fig.13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig.12).



92CS-19279

Fig. 14—Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

TERMINAL CONNECTIONS

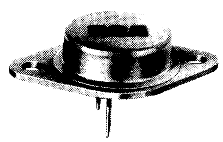
Pin 1 — Base
Pin 2 — Emitter
Mounting Flange, Case — Collector

RCA

Solid State Division

Power Transistors

423



High-Voltage, High-Power Silicon N-P-N Power Transistor

For Switching and Linear Applications in Military, Industrial, and Commercial Equipment

Features:

- **Maximum safe-area-of-operation curves**
- **Low saturation voltage: V_{CE}(sat) = 0.8 V (max.)**
- **High voltage rating: V_{CEO}(sus) = 325 V**
- **High dissipation rating: P_T = 125 W**

RCA-423 is an epitaxial silicon n-p-n power transistor utilizing a multiple-emitter-site structure. This device employs the popular JEDEC TO-3 package.

Featuring high breakdown-voltage ratings and low saturation-voltage values, the RCA-423 is especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	400	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:		
With base open, V_{CEO}(sus)	325	V
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:		
With base open, $V_{(BR)CEO}$	400	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	V
COLLECTOR CURRENT:		
Continuous, I_C	7	A
Peak	10	A
BASE CURRENT (Continuous), I_B	2	A
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25°C and V_{CE} up to 75 V	125	W
At case temperatures up to 25°C and V_{CE} above 75 V	See Fig. 2.	
At case temperatures above 25°C and V_{CE} above 75 V	See Figs. 1 & 2.	
TEMPERATURE RANGE:		
Storage & Operating (Junction)	−65 to +200	°C
PIN TEMPERATURE (During Soldering):		
At distances ≥ 1/32 in. (0.8 mm) from case for 10 s max.	230	°C

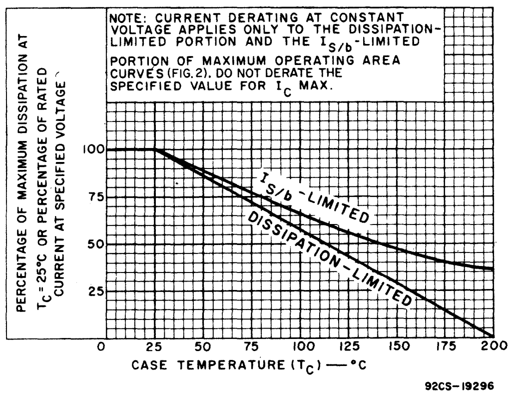


Fig. 1—Dissipation and current derating curves.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		Limits			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	400					–	–	0.25	
With base-emitter junction reverse-biased	I_{CEV}	400		−1.5			–	–	0.25	mA
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}			−1.5			–	–	0.5	
Emitter-Cutoff Current	I_{EBO}		5				–	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5 5			1.0[a] 2.5[a]		30 10	– –	90 –	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 3 & 4.)	$V_{CEO}(sus)$[b]				0.1		325[b]	–	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				1.0[a]	0.1	–	0.9	1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				1.0[a]	0.1	–	0.2	0.8	V
Second-Breakdown Collector Current: (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	150					0.3	–	–	A
Gain-Bandwidth Product	f_T	10			0.2		–	4.0	–	MHz
Switching Time: Rise (See Figs. 10, 12, & 13.)	t_r				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.35	–	
Storage (See Figs. 11, 12, & 13.)	t_s				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	1.4	–	µs
Fall (See Figs. 9, 12, & 13.)	t_f				1.0	0.1 (I_{B1}) −0.5 (I_{B2})	–	0.15	–	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10			5		–	–	1.4	°C/W

[a] Pulsed; pulse duration $\leq$350 µs, duty factor = 2%.

[b] CAUTION: The sustaining voltage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

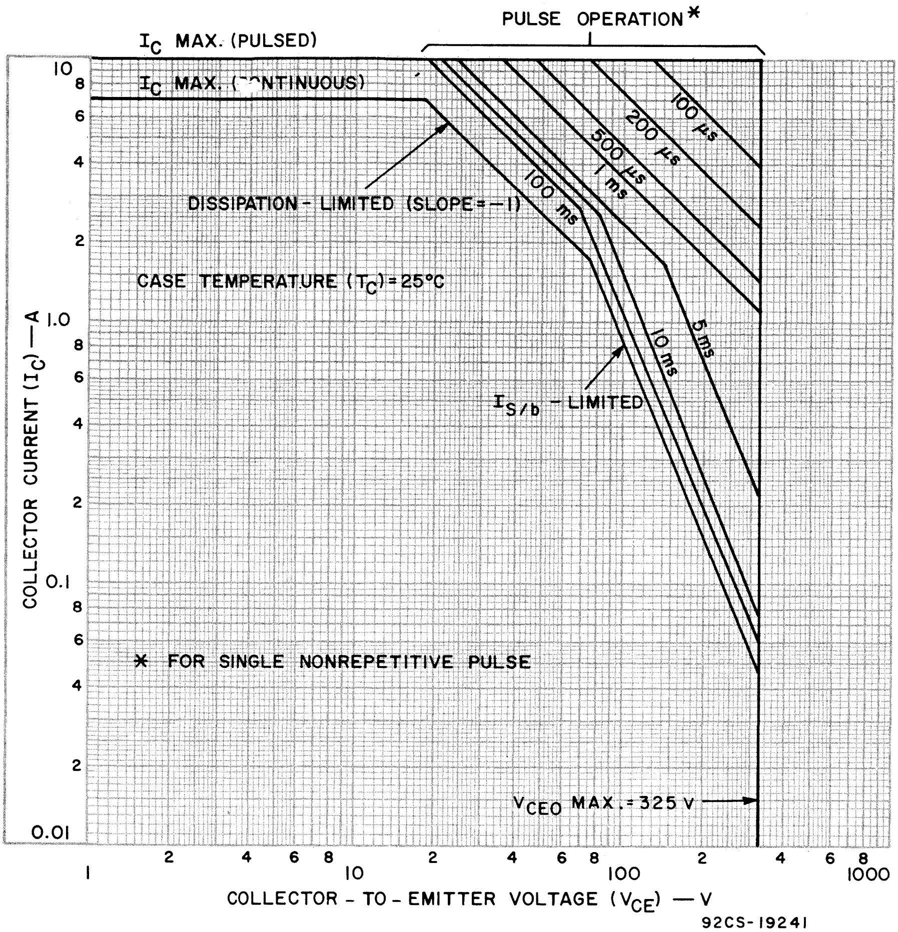


Fig.2—Maximum operating areas.

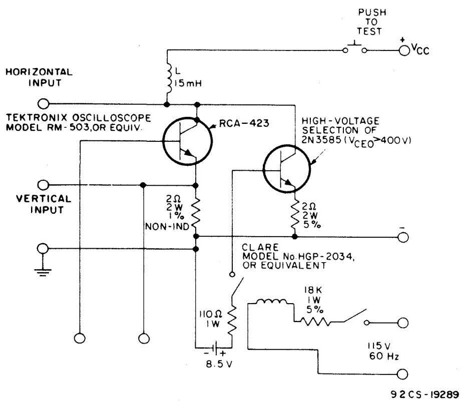


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

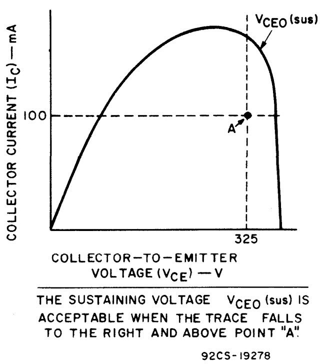


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig.3).

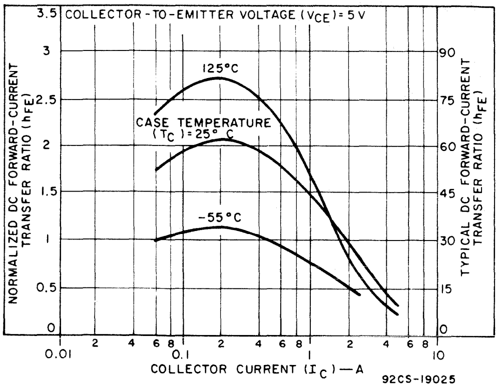


Fig.5—Typical dc beta characteristics.

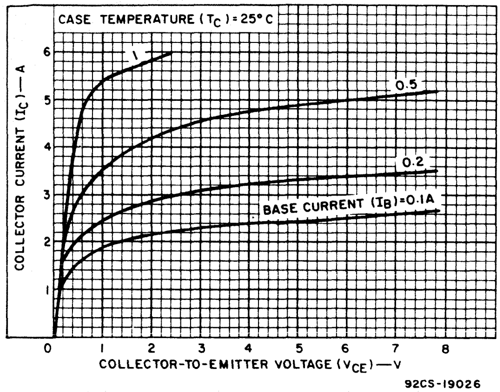


Fig.6—Typical output characteristics.

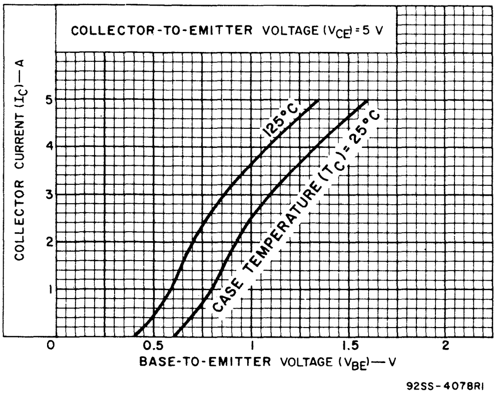


Fig.7—Typical transfer characteristics.

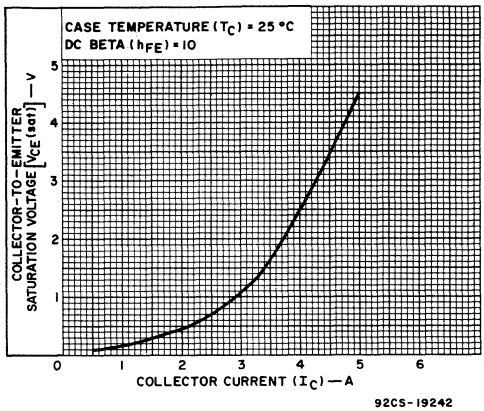


Fig.8—Typical saturation voltage characteristic.

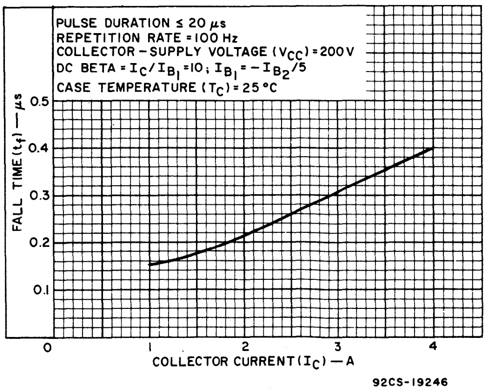


Fig.9—Typical fall time vs. collector current.

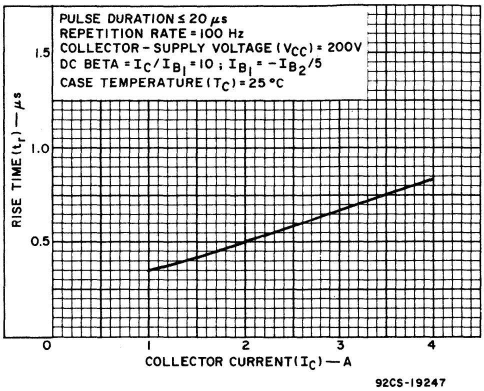


Fig.10—Typical rise time vs. collector current.

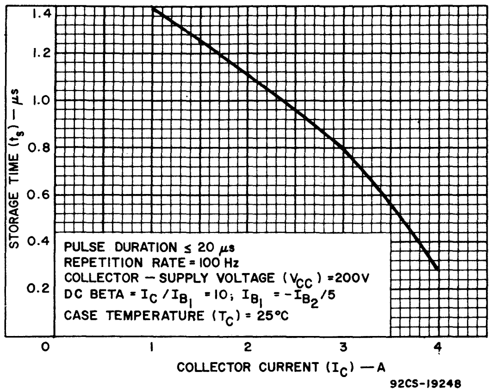


Fig.11—Typical storage time vs. collector current.

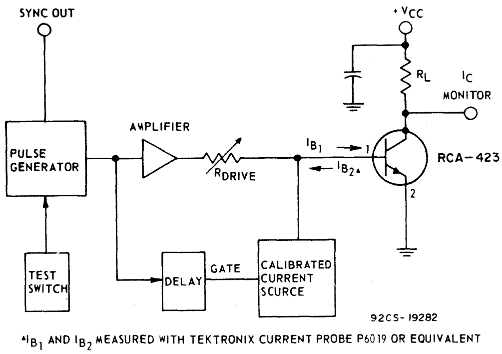


Fig.12—Circuit used to measure switching times.

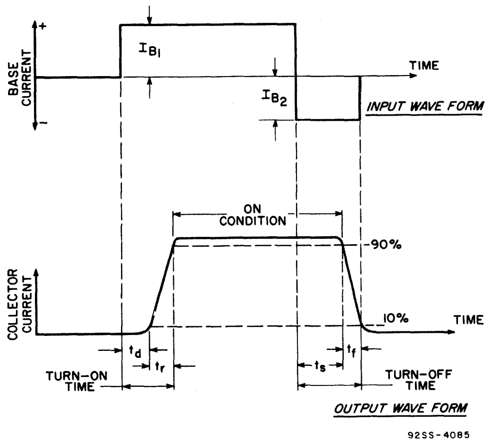


Fig.13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig.12).

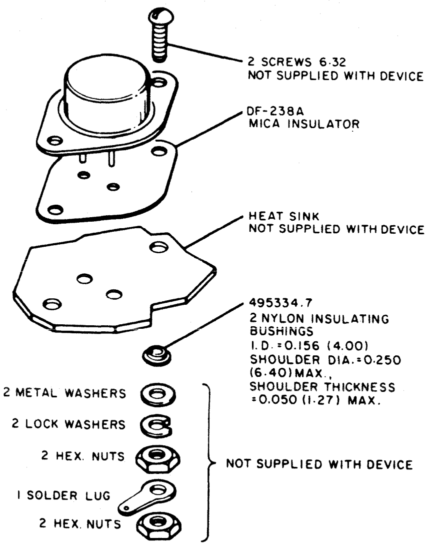
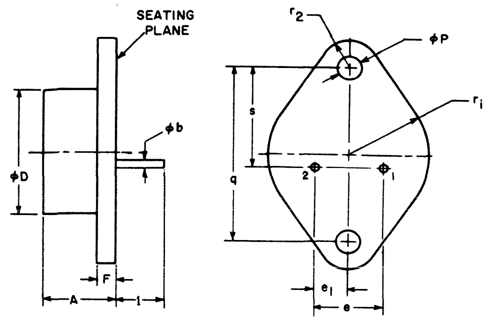


Fig. 14–Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

TERMINAL CONNECTIONS

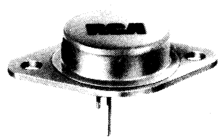
Pin 1 – Base
Pin 2 – Emitter
Mounting Flange, Case – Collector

RCA

Solid State
Division

Power Transistors

431



JEDEC
TO-3

H-1570

High-Voltage, High-Power Silicon N-P-N Power Transistor

For Switching and Linear Applications in Military, Industrial, and Commercial Equipment

Features:

- **Maximum safe-area-of operation curves**
- **Low saturation voltage: V_{CE}(sat) = 0.7 V (max.)**
- **High voltage rating: V_{CEO}(sus) = 325 V**
- **High dissipation rating: P_T = 125 W**

RCA-431 is an epitaxial silicon n-p-n power transistor utilizing a multiple-emitter-site structure. This device employs the popular JEDEC TO-3 package.

Featuring high breakdown-voltage ratings and low saturation-voltage values, the RCA-431 is especially suitable for use in inverters, deflection circuits, switching regulators, high-voltage bridge amplifiers, ignition circuits, and other high-voltage switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	400	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE		
With base open, V_{CEO}(sus)	325	V
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:		
With base open, $V_{(BR)CEO}$	400	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	V
COLLECTOR CURRENT:		
Continuous, I_C	7	A
Peak	10	A
BASE CURRENT (Continuous), I_B	2	A
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25°C and V_{CE} up to 75 V	125	W
At case temperatures up to 25°C and V_{CE} above 75 V	See Fig. 2.	
At case temperatures above 25°C and V_{CE} above 75 V	See Figs. 1 & 2.	
TEMPERATURE RANGE:		
Storage & Operating (Junction)	−65 to +200	°C
PIN TEMPERATURE (During Soldering):		
At distances ≥ 1/32 in. (0.8 mm) from case for 10 s max.	230	°C

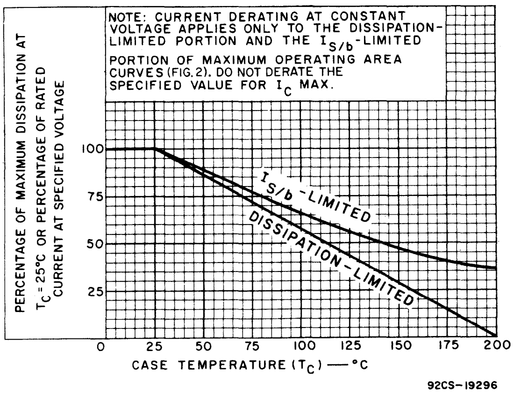


Fig. 1—Dissipation and current derating curves.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	Test Conditions: DC Emitter or Base Voltage (V)		Test Conditions: DC Current (A)		Limits			Units
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Typ.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}	400					–	–	2.5	mA
With base-emitter junction reverse-biased	I_{CEV}	400		−1.5			–	–	2.5	mA
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}	400		−1.5			–	–	5.0	mA
Emitter-Cutoff Current	I_{EBO}		5				–	–	2.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5 5			2.5[a] 3.5[a]		15 10	– –	35 –	
Collector-to-Emitter Sustaining Voltage: With base open (See Figs. 3 & 4.)	$V_{CEO}(sus)$[b]				0.1		325[b]	–	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				2.5[a]	0.5	–	–	1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				2.5[a]	0.5	–	0.25	0.7	V
Second-Breakdown Collector Current: (With base forward-biased) Pulse duration (non-repetitive) = 1 s	$I_{S/b}$[c]	150					0.3	–	–	A
Gain-Bandwidth Product	f_T	10			0.2		–	4.0	–	MHz
Switching Time: Rise (See Figs. 10, 12, & 13.)	t_r				2.5	0.5 (I_{B1})[d]	–	0.35	–	μs
Storage (See Figs. 11, 12, & 13.)	t_s				2.5	0.5 (I_{B1})[d]	–	1.8	–	μs
Fall (See Figs. 9, 12, & 13.)	t_f				2.5	0.5 (I_{B1})[d]	–	0.4	–	μs
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	10			5		–	–	1.4	°C/W

[a] Pulsed; pulse duration $\leq$350 μs, duty factor = 2%

[b] CAUTION: The sustaining voltage $V_{CEO}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

[d] $I_{B1} = -I_{B2}$ = value shown.

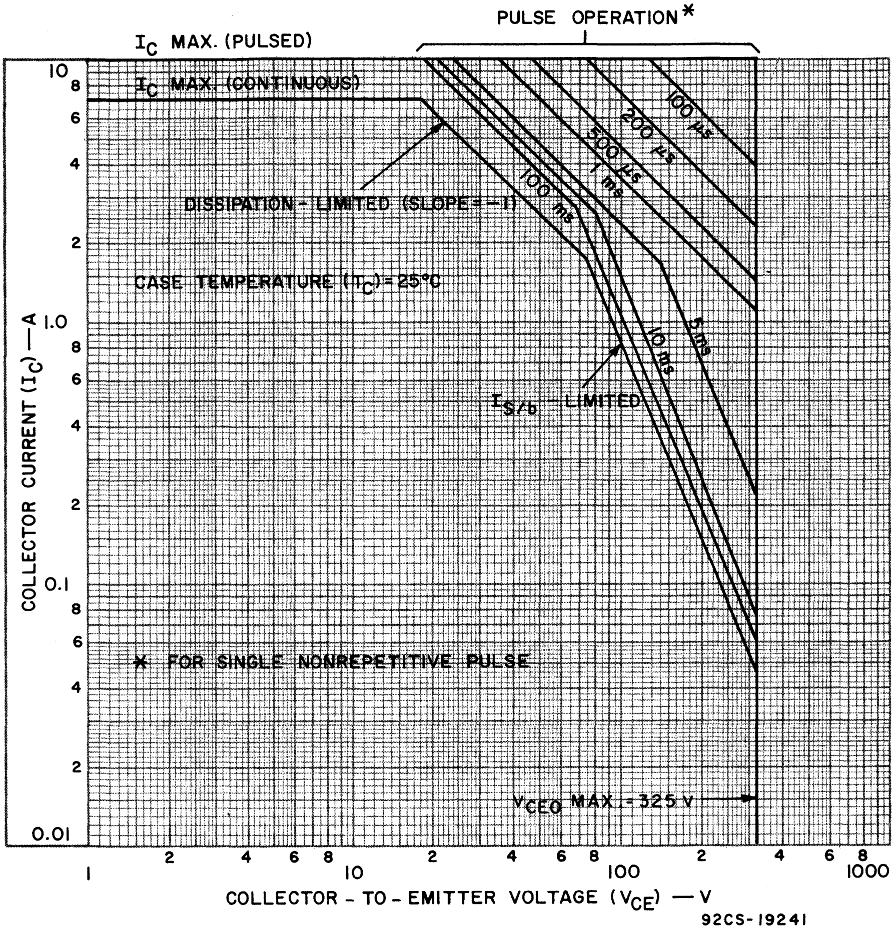


Fig.2—Maximum operating areas.

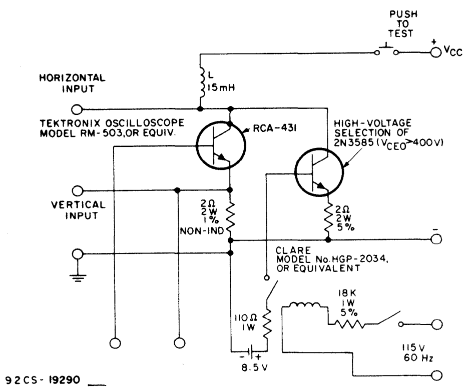


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

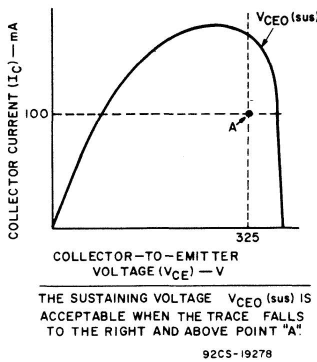


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

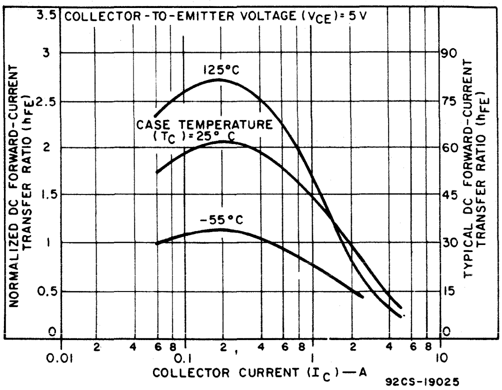


Fig.5—Typical dc beta characteristics.

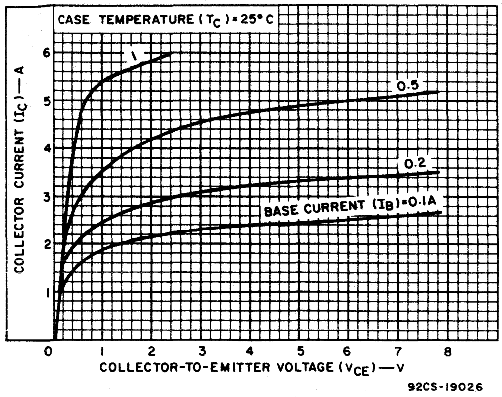


Fig.6—Typical output characteristics.

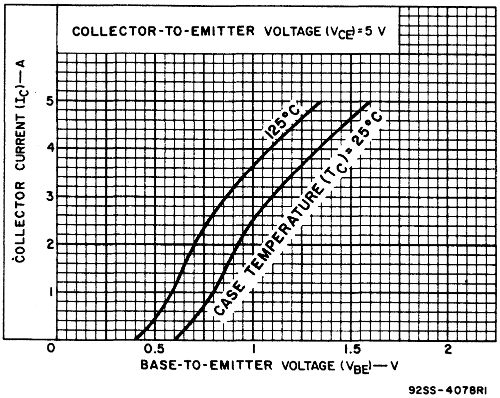


Fig.7—Typical transfer characteristics.

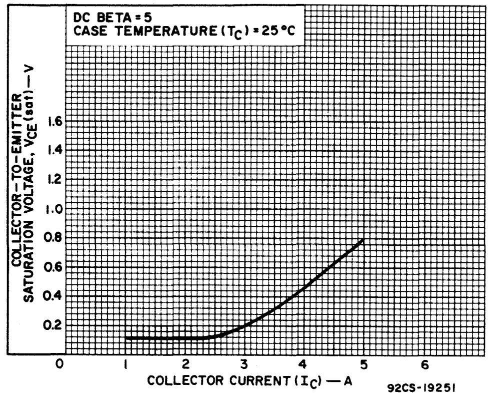


Fig.8—Saturation voltage vs. collector current.

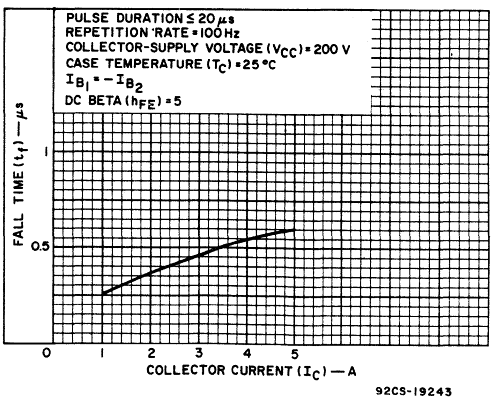


Fig.9—Typical fall-time characteristic.

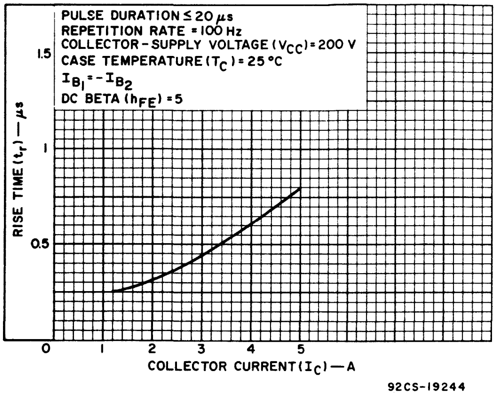


Fig. 10—Typical rise-time characteristic.

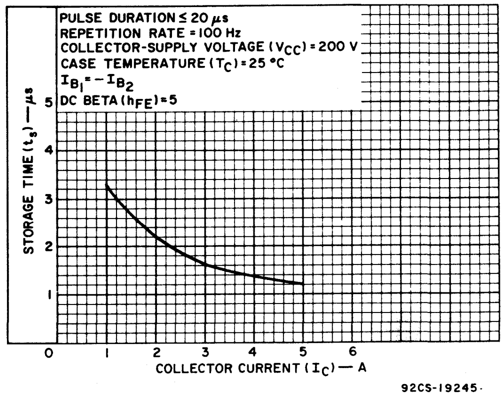


Fig. 11—Typical storage-time characteristic (with constant forced gain).

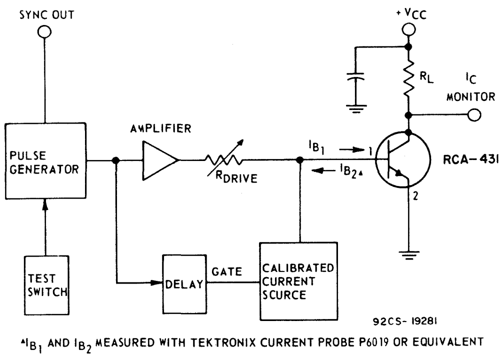


Fig. 12—Circuit used to measure switching times.

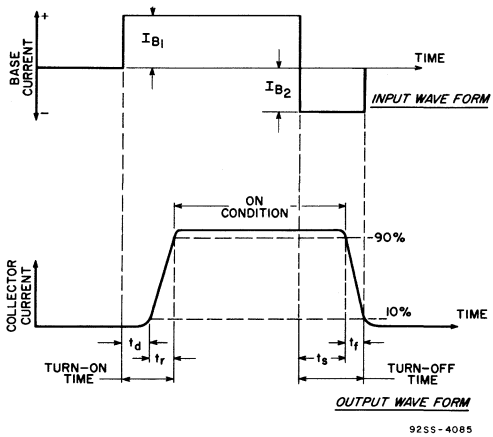


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 12).

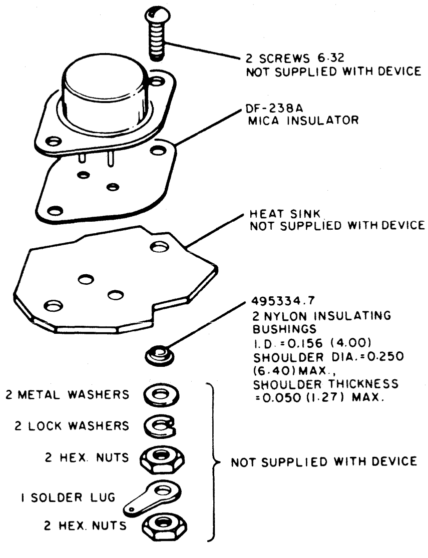
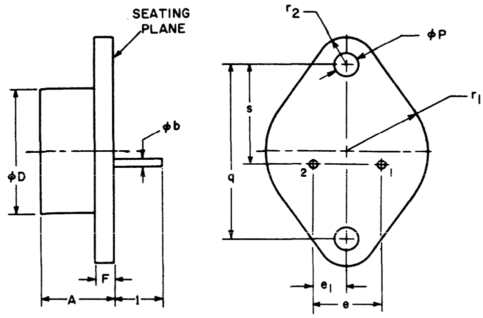


Fig. 14—Suggested mounting hardware.

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

TERMINAL CONNECTIONS

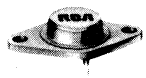
Pin 1 — Base
Pin 2 — Emitter
Mounting Flange, Case — Collector

RCA
Solid State
Division

Power Transistors

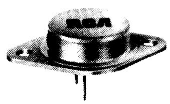
40850 40851
40852 40853
40854

40850
40851



JEDEC TO-66 H 1340

40852
40853
40854



H 1570

JEDEC TO-3

450-V Silicon N-P-N Types

For Off-Line Switching-Regulator Type Power-Supply Applications

Features:

- **High-voltage ratings for operation from power lines without a step-down transformer**
- **Popular JEDEC TO-3 and TO-66 hermetic packages**

Applications:

- **For use in switching-regulator supplies which feature:**
  - **– A substantial reduction in size and weight due to elimination of the 60-Hz power transformer.**
  - **– Operation with a substantial reduction of heat**
- **5-V, off-line supplies with current ratings of 25, 50, 100, or 200 A**
- **30-V, off-line supplies with current ratings of 5, 10, 20, or 40 A**

RCA 40850–40854, inclusive, are silicon n-p-n power transistors, selected from RCA's line of silicon power transistors, for power-supply applications. Their high-voltage ratings (450 V) permit operation directly off the power line thereby eliminating the heavy and bulky 60-Hz power transformer.

Their fast switching speeds (t_r plus t_f equal to less than 2.0 μs) permit operation above the audio-frequency range (20 to 30 kHz) for quiet performance, and permit the use of small ferrite-core transformers for changing the voltage level.

These types have sufficient voltage capability to be used as push-pull inverters or pulse-width-modulated inverters operating directly off the 120-V power line.

Types 40850–40854 have sufficient voltage capability to operate as switching regulators off a 240-V line; for 120-V lines, the prototypes can be used.

A brief description of these types, together with prototype identification, is given in the tables on pages 2, 3, and 4.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	40850	40851	40852■	40853	40854	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	450	450	450	450	450	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:						
With base open, $V_{CEO}(sus)$	300	350	350	300	300	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω, $V_{CER}(sus)$	400	375	375	375	325	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	6	9	9	6	6	V
COLLECTOR CURRENT, I_C						
Continuous and Average	2	7	7	10	15	A
Peak (10 ms max.)	5	10	10	15	30	A
CONTINUOUS BASE CURRENT, I_B	1	4	4	5	10	A

■ Formerly RCA-40832.

Continued on following page.

MAXIMUM RATINGS (cont'd):

	40850	40851	40852■	40853	40854	
TRANSISTOR DISSIPATION, P_T:						
(Power Dissipation-Limited Region*)						
At case temperaures up to 25°C	35	45	100	100	175	W
At case temperaures above 25°C and in the $I_{S/b}$-Limited Region*	See derating curves in prototype bulletins.					
TEMPERATURE RANGE:						
Storage & Operating (Junction)	← -65 to +200 °C →					
PIN TEMPERATURE (During Soldering):						
At distances ≥1/32 in. (0.8 mm) from case for 10 s max.	← 230°C →					

* Safe-operating-area curves for prototype devices should be extended to the maximum values of collector current given for these devices.
■ Formerly RCA-40832

Type 40850 (For 5-V, 25-A & 30-V, 5-A Power Supplies)
Package: JEDEC TO-66
Construction: Silicon n-p-n, triple-diffused mesa
Application Information: See "RCA Power Circuits" manual SP-51 and RCA Application Note AN3065

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS		UNITS
			MIN.	MAX.	
Collector-Cutoff Current: With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V	–	0.2	mA
	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125°C	–	2	mA
Collector-to-Emitter Voltage With base open	V_{CEO} [a]	I_C = 0.2 A, I_B = 0	300	–	V
Collector-to-Emitter Voltage With external base-to-emitter resistance (R_{BE})	V_{CER} [a]	I_C = 0.2 A, R_{BE} = 50 Ω	400	–	V
Emitter-to-Base Voltage	V_{EBO}	I_E = 5 mA, I_C = 0	6	–	V
DC Forward-Current Transfer Ratio	h_{FE}	I_C = 0.75 A, V_{CE} = 10 V	25	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	I_C = 2 A, I_B = 0.4 A	–	2.0	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 2 A, I_B = 0.4 A	–	2.0	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$ [a]	V_{CE} = 100 V	0.35	–	A
Second-Breakdown Energy: With base reversed biased	$E_{S/b}$ [a]	L = 100 μH, I_C(PEAK) = 2 A, R = 20 Ω V_{BE} = -4 V	0.2	–	mJ

[a] For characteristics curves and test conditions, refer to published data for prototype 2N3585 (File 138).

Type 40851 (For 5-V, 50-A & 30-V, 10-A Power Supplies)
Package: JEDEC TO-66
Construction: Silicon N-P-N, multiple-epitaxial, multiple-emitter-site mesa
Applications Information: See "RCA Power Circuits" manual SP-51 and RCA Application Note AN4509

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS		UNITS
			MIN.	MAX.	
Collector-Cutoff Current:	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V	–	0.5	mA
With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125°C	–	5	mA
Collector-to-Emitter Voltage With base open	V_{CEO} [a]	I_C = 0.2 A, I_B = 0	350	–	V
Collector-to-Emitter Voltage With external base-to-emitter resistance (R_{BE})	V_{CER} [a]	I_C = 0.2 A, R_{BE} = 50 Ω	375	–	V
Emitter-to-Base Voltage	V_{EBO}	I_E = 1 mA, I_C = 0	9	–	V
DC Forward-Current Transfer Ratio	h_{FE}	I_C = 1.2 A, V_{CE} = 1.0 V	12	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	I_C = 4 A, I_B = 0.8 A	–	3	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 4 A, I_B = 0.8 A	–	2	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$ [a]	V_{CE} = 50 V	0.9	–	A
Second-Breakdown Energy: With base reversed biased	$E_{S/b}$ [a]	L = 100 μH, I_C(PEAK) = 3 A, R = 50 Ω V_{BE} = -4 V	0.45	–	mJ

[a] For characteristics curves and test conditions, refer to published data for prototype 2N6079 (File 492).

Type 40852 (For 5-V, 50-A & 30-V, 10-A Power Supplies)
Package: JEDEC TO-3
Construction: Silicon N-P-N multiple-epitaxial, multiple-emitter-site mesa
Applications Information: See "RCA Power Circuits" manual SP-51 and RCA Application Note AN4509

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS		UNITS
			MIN.	MAX.	
Collector-Cutoff Current:	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V	–	0.5	mA
With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125°C	–	5	mA
Collector-to-Emitter Voltage With base open	V_{CEO} [a]	I_C = 0.2 A, I_B = 0	350	–	V
Collector-to-Emitter Voltage With external base-to-emitter resistance (R_{BE})	V_{CER} [a]	I_C = 0.2 A, R_{BE} = 50 Ω	375	–	V
Emitter-to-Base Voltage	V_{EBO}	I_E = 1 mA, I_C = 0	9	–	V
DC Forward-Current Transfer Ratio	h_{FE}	I_C = 1.2 A, V_{CE} = 1.0 V	12	–	
Collector-to-Emitter Saturation Voltage	V_{CE} (sat)	I_C = 4 A, I_B = 0.8 A	–	3.0	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 4 A, I_B = 0.8 A	–	2.0	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$ [a]	V_{CE} = 40 V	2.5	–	A
Second-Breakdown Energy: With base reversed biased	$E_{S/b}$ [a]	L = 100 μH, I_C(PEAK) = 3 A, R = 50 Ω V_{BE} = -4 V	0.45	–	mJ

[a] For characteristics curves and test conditions, refer to published data for prototype 2N5840 (File 410).

Type 40853 (For 5-V, 100-A & 30-V, 20-A Power Supplies)
Package: JEDEC TO-3
Construction: Silicon N-P-N, triple-diffused mesa
Applications Information: See "RCA Power Circuits" manual SP-51

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS MIN.	LIMITS MAX.	UNITS
Collector-Cutoff Current:	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V	–	1.0	mA
With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125°C	–	10	mA
Collector-to-Emitter Voltage With base open	V_{CEO}[a]	I_C = 0.2 A, I_B = 0	300	–	V
Collector-to-Emitter Voltage With external base-to-emitter resistance (R_{BE})	V_{CER}[a]	I_C = 0.2 A, R_{BE} = 50 Ω	375	–	V
Emitter-to-Base Voltage	V_{EBO}	I_E = 5 mA, I_C = 0	6	–	V
DC Forward-Current Transfer Ratio	h_{FE}	I_C = 5 A, V_{CE} = 4 V	10	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	I_C = 8 A, I_B = 1.6 A	–	3.0	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 8 A, I_B = 1.6A	–	2.0	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$[a]	V_{CE} = 50 V	2.2	–	A
Second-Breakdown Energy: With base reversed biased	$E_{S/b}$[a]	L = 50 μH, I_C(PEAK) = 5 A, R = 20 Ω V_{BE} = -4 V	0.62	–	mJ

[a] For characteristics curves and test conditions, refer to published data for prototype 2N5805 (File 407).

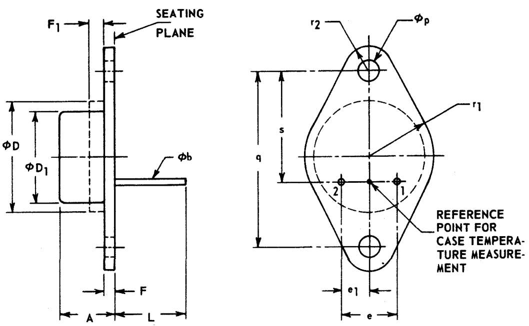
Type 40854 (For 5-V, 200-A & 30-V, 40-A Power Supplies)
Package: JEDEC TO-3
Construction: Silicon N-P-N, multiple-epitaxial, multiple-emitter-site mesa
Applications Information: See "RCA Power Circuits" manual SP-51

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS MIN.	LIMITS MAX.	UNITS
Collector-Cutoff Current:	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V	–	1.0	mA
With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125°C	–	10	mA
Collector-to-Emitter Voltage With base open	V_{CEO}[a]	I_C = 0.2 A, I_B = 0	300	–	V
Collector-to-Emitter Voltage With external base-to-emitter resistance (R_{BE})	V_{CER}[a]	I_C = 0.2 A, R_{BE} = 50 Ω	325	–	V
Emitter-to-Base Voltage	V_{EBO}	I_E = 5 mA, I_C = 0	6	–	V
DC Forward-Current Transfer Ratio	h_{FE}	I_C = 10 A, V_{CE} = 4 V	8	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	I_C = 16 A, I_B = 3.2 A	–	3.0	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 16 A, I_B = 3.2 A	–	3.0	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$[a]	V_{CE} = 30 V	5.8	–	A
Second-Breakdown Energy: With base reversed biased	$E_{S/b}$[a]	L = 50 μH, I_C(PEAK) = 10 A, R = 50 Ω V_{BE} = -4 V	2.5	–	mJ

[a] For characteristics curves and test conditions, refer to published data for prototype 2N6251 (File 523).

DIMENSIONAL OUTLINE (JEDEC TO-66)



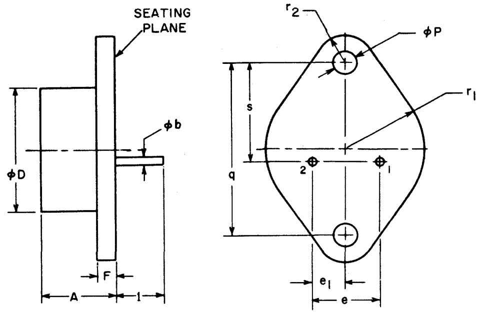
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
φb	0.028	0.034	0.711	0.863	
φD		0.620		15.75	
φD1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F1		0.050		1.27	1
L	0.360		9.14		
φp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r1		0.350		8.89	
r2		0.145		3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by φD and F_1.
2. Dimensions does not include sealing flanges.

92SS-3738

DIMENSIONAL OUTLINE (JEDEC TO-3)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. **These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.**
2. **Two pins.**

92CS–15222

TERMINAL CONNECTIONS (All Types)

Pin 1 - Base

Pin 2 - Emitter

Mounting Flange, Case - Collector

High-Speed Switching n-p-n Power Transistors

RCA

Solid State Division

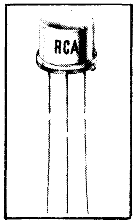
Power Transistors

2N699

RCA-2N699 is a triple-diffused-junction planar transistor of the silicon n-p-n type intended for a wide variety of small-signal and medium-power applications in military and industrial equipment. The 2N699 features a minimum gain-bandwidth product of 50 Mc making it well suited for vhf and video applications.

The triple-diffused-junction design of the 2N699 makes possible higher breakdown voltage ratings, lower saturation voltages, higher sustaining voltages, and lower output capacitance.

For Small-Signal and Medium-Power Applications



JEDEC TO-5

- minimum gain-bandwidth product = 50 Mc
- planar construction — insures low noise and low leakage characteristics
- low output capacitance
- high breakdown voltage (BV_{CBO}) = 120 volts minimum at I_C = 0.1 ma
- low saturation voltage

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE:		
With emitter open	120 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:		
With external $R_{BE} \le 10$ ohms	80 max.	volts
EMITTER-TO-BASE VOLTAGE:		
With collector open	5 max.	volts
TRANSISTOR DISSIPATION:		
At case temperatures up to 25° C	2 max.	watts
At case temperatures above 25° C	See *Rating Chart*	
At free-air temperatures up to 25° C	0.6 max.	watt
At free-air temperatures above 25° C	See *Rating Chart*	
TEMPERATURE RANGE:		
Storage	-65 to +300	°C
Operating (Junction)	175	°C

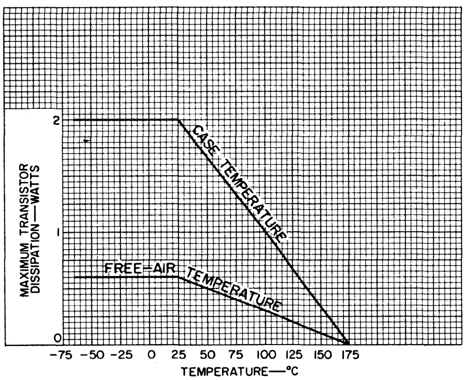


Fig. 1—Rating Chart for Type 2N699.

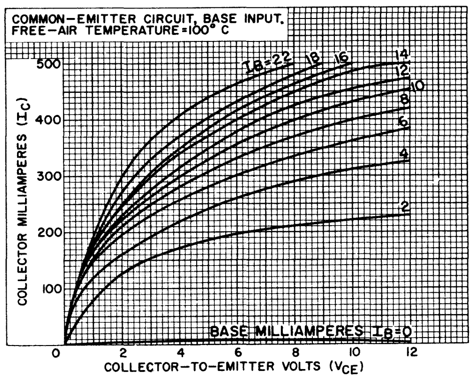


Fig. 2—Typical Collector Characteristics at 100° C for Type 2N699.

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	TEST CONDITIONS: Case Temperature °C	Frequency Kc	DC Collector-to-Base Voltage (volts) V_{CB}	DC Collector-to-Emitter Voltage (volts) V_{CE}	DC Emitter-to-Base Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Emitter Current (ma) I_E	DC Base Current (ma) I_B	LIMITS Min.	LIMITS Max.	Units
Collector-Cutoff Current	I_{CBO}	25		60				0		-	2	μa
Emitter-Cutoff Current	I_{EBO}	25				2	0			-	100	μa
Collector-to-Base Breakdown Voltage	BV_{CBO}	25					0.1	0		120	-	volts
DC-Pulse Forward-Current Transfer Ratio *	h_{FE}	25			10		150			40	120	
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance = 10 ohms*	$V_{CER}(sus)$	25					100			80	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25					150		15	-	5	volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25					150		15	-	1.3	volts
Small-Signal Forward-Current Transfer Ratio	h_{fe}	25 25 25	1 1 20 Mc		5 10 10		1 5 50			35 45 2.5	100 - -	
Output Capacitance	C_{ob}	25		10				0		-	20	pf
Input Resistance	h_{ib}	25 25	1 1		5 10		1 5			20 -	30 10	ohms ohms
Voltage-Feedback Ratio	h_{rb}	25 25	1 1		5 10		1 5			- -	2.5×10^{-4} 3×10^{-4}	
Output Conductance	h_{ob}	25 25	1 1		5 10		1 5			0.1 -	0.5 1	μmho μmho
Thermal Resistance: Junction-to-case Junction-to-free air	$\theta_{J\text{-}C}$ $\theta_{J\text{-}FA}$	- -								- -	75 250	°C/watt °C/watt

* Pulse width ≤ 300 μsec, duty factor ≤ 2%.

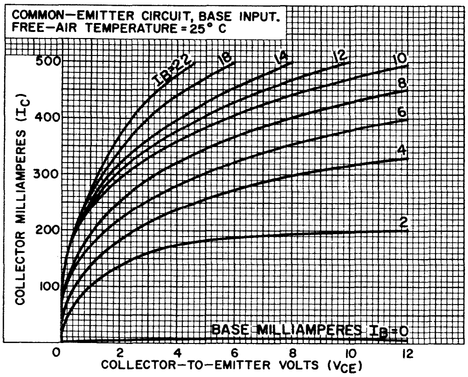


Fig.3 – Typical Collector Characteristics at 25° C for Type 2N699.

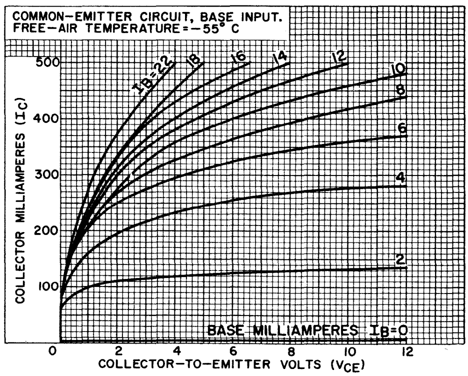


Fig.4 – Typical Collector Characteristics at -55° C for Type 2N699.

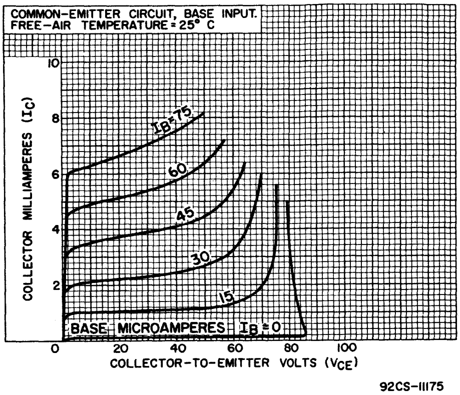


Fig.5 – Typical Collector Characteristics at 25° C for Type 2N699.

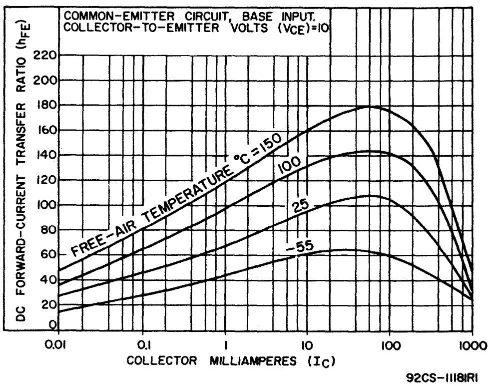


Fig.6 – Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N699.

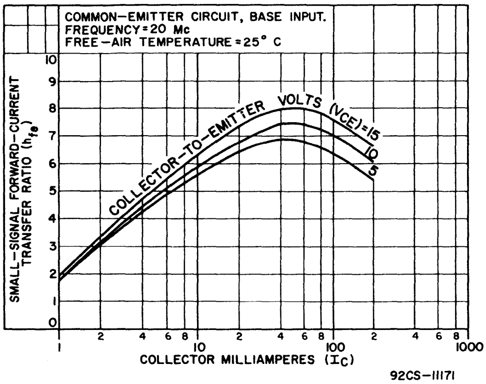


Fig.7 – Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N699.

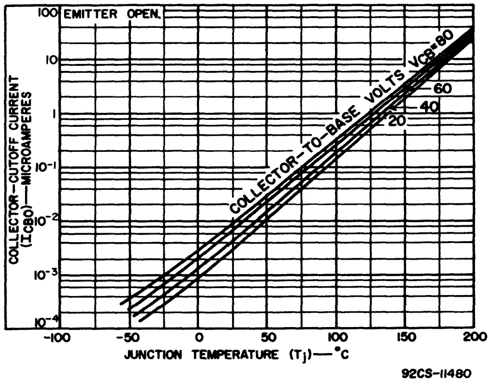
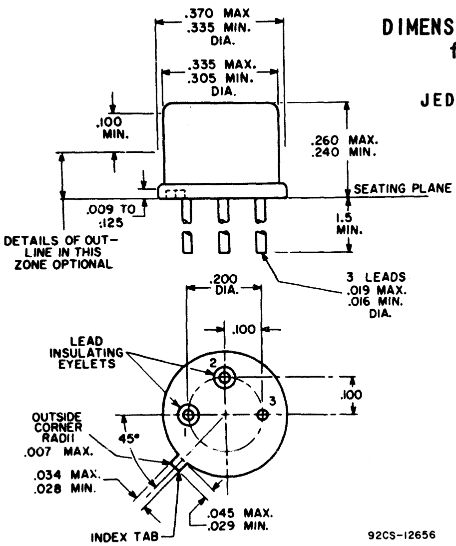


Fig.8 – Typical Collector-Cutoff-Current Characteristics for Type 2N699.

DIMENSIONAL OUTLINE for Type 2N699

JEDEC No. TO-5

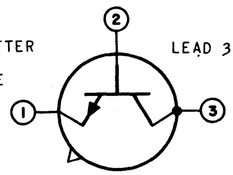


TERMINAL DIAGRAM

LEAD 1 – EMITTER

LEAD 2 – BASE

LEAD 3 – COLLECTOR, CASE



RCA

Solid State Division

Power Transistors

2N1613
2N2102

RCA-2N2102 is a triple-diffused, silicon n-p-n planar transistor intended for a wide variety of small-signal and medium-power applications in military and industrial equipment. It features exceptionally low noise, low leakage characteristics, high switching speed, and high pulse beta.

RCA-2N2102 is a direct replacement for the 2N1613 family of transistors. In addition, because of its triple-diffused-junction design, the 2N2102 has higher breakdown voltage ratings, higher dissipation ratings, lower saturation voltages, higher sustaining voltages, and lower output capacitance.

Maximum Ratings, *Absolute-Maximum Values:*

	2N2102	2N1613	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	120	75 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:			
With external R_{BE} $\leq$ 10 ohms, V_{CER}	80	50 max.	volts
With base open, V_{CEO} . . .	65	- max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	7	7 max.	volts
COLLECTOR CURRENT, I_C	1	1 max.	amp
TRANSISTOR DISSIPATION, P_T			
At case temperatures up to 25° C.	5	3 max.	watts
At free-air temperatures up to 25° C.	1	0.8 max.	watt
At temperatures above 25° C	See *Figures 1 and 2.*		
TEMPERATURE RANGE:			
Operating (Junction)	-65 to 200		°C
LEAD TEMPERATURE:			
1/16" ± 1/32" from case for 10 sec. max.	300	265 max.	°C

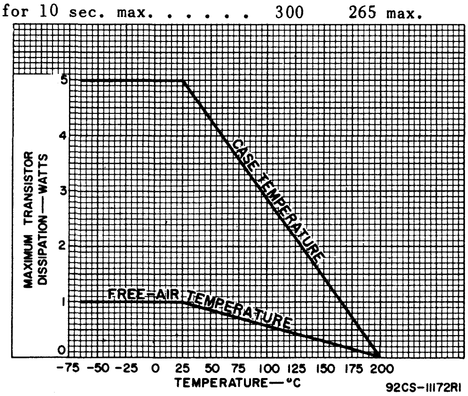
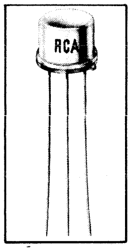


Fig. 1 RATING CHART FOR TYPE 2N2102

For Small-Signal and Medium-Power Applications



JEDEC TO-5

- For operation at high junction temperatures — up to 200° C
- Planar construction — Insures low noise and low leakage characteristics
- Low output capacitance

RCA-2N2102 Features:

- Minimum gain-bandwidth product (f_T) — 120 Mc; useful in applications from dc to 20 Mc
- High breakdown voltage (BV_{CBO}) — 120 volts min. at I_C = 0.1 ma
- Low saturation voltages —
  $V_{CE}(sat)$ = 0.5 volt max. at I_C = 150 ma
  $V_{BE}(sat)$ = 1.1 volts max. at I_C = 150 ma
- Beta (h_{FE}) controlled over 5 decades of I_C
- High pulse h_{FE} at high I_C — 10 min. at I_C = 1 ampere

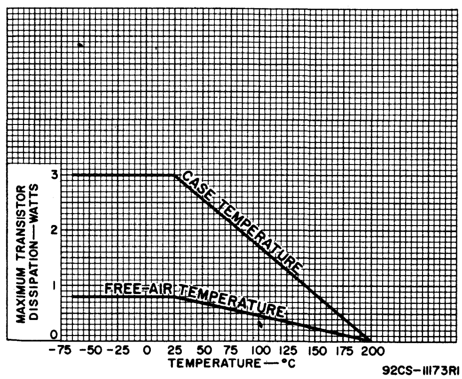


Fig. 2 RATING CHART FOR TYPE 2N1613

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) = 25° C, Unless Otherwise Specified

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Emitter Volts V_{EB}	DC Current (Milliamperes) I_E	I_B	I_C	LIMITS: Type 2N2102 Min.	Type 2N2102 Max.	Type 2N1613 Min.	Type 2N1613 Max.	Units
Collector-Cutoff Current: (At T_C = 25° C)	I_{CBO}	60			0			-	0.002	-	0.01	μa
(AT T_C = 150° C)		60			0			-	2	-	10	μa
Emitter-Cutoff Current	I_{EBO}			5			0	-	0.005	-	0.01	μa
Collector-to-Base Breakdown Voltage	BV_{CBO}				0		0.1	120	-	75	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	7	-	7	-	volts
Collector-to-Emitter Sustaining Voltage: With external R_{BE} = 10 ohms	V_{CER}(sus)						100●	80	-	50	-	volts
With base open	V_{CEO}(sus)					0	100●	65	-	-	-	volts
Collector-to-Emitter Saturation Voltage	V_{CE}(sat)					15	150●	-	0.5	-	1.5	volts
Base-to-Emitter Saturation Voltage	V_{BE}(sat)					15	150●	-	1.1	-	1.3	volts
DC Forward-Current Transfer Ratio:	h_{FE}		10				0.01	10	-	-	-	
			10				0.1	20	-	20	-	
			10				10●	35	-	35	-	
			10				150●	40	120	40	120	
			10				500●	25	-	20	-	
			10				1000●	10	-	-	-	
(At T_C = -55° C)	h_{FE}		10				10●	20	-	20	-	
Small-Signal Forward-Current Transfer Ratio: At f = 1 kc	h_{fe}		5				1	40	125	30	100	
1 kc			10				5	45	190	35	150	
20 Mc			10				50	6	-	3	-	
Input Resistance (At f = 1 kc)	h_{ib}	5					1	24	34	24	34	ohms
		10					5	4	8	4	8	ohms
Small-Signal Reverse Voltage Transfer (Feedback) Ratio (At f = 1 kc)	h_{rb}	5					1	-	3×10^{-4}	-	3×10^{-4}	
		10					5	-	3×10^{-4}	-	3×10^{-4}	
Output Conductance (At f = 1 kc)	h_{ob}	5					1	0.1	0.5	0.1	0.5	μmho
		10					5	0.1	1	0.1	1	μmho
Output Capacitance	C_{ob}	10			0			-	15	-	25	pf
Input Capacitance	C_{ib}			0.5			0	-	80	-	80	pf
Noise Figure: Circuit Bandwidth (BW) = 1 cps; Reference signal freq. = 1 kc; Generator resistance (R_G) = 510 ohms	NF		10				0.3	-	6	-	12	db
Thermal Resistance: Junction-to-case	θ_{J-C}							-	35	-	58.3	°C/watt
Junction-to-free air	θ_{J-FA}							-	175	-	219	°C/watt

● Pulsed. Pulse duration = 300 μsec; duty factor = 1.8%.

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 2N2102 & 2N1613

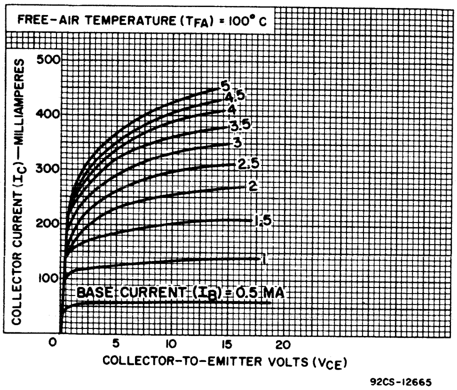


Fig.3

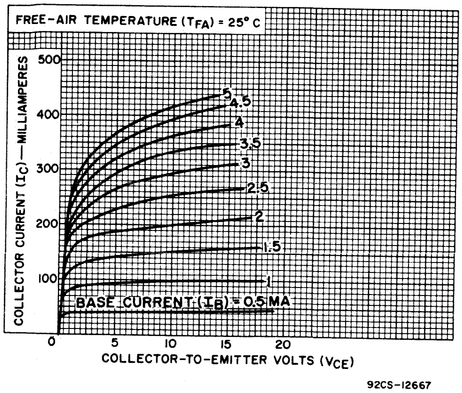


Fig.4

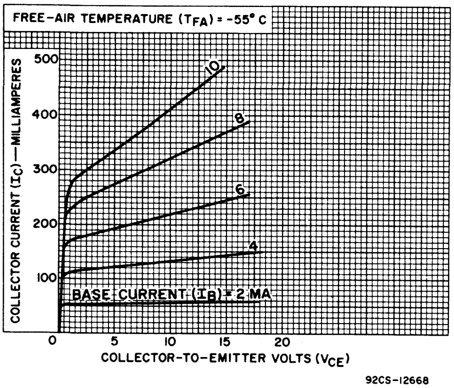


Fig.5

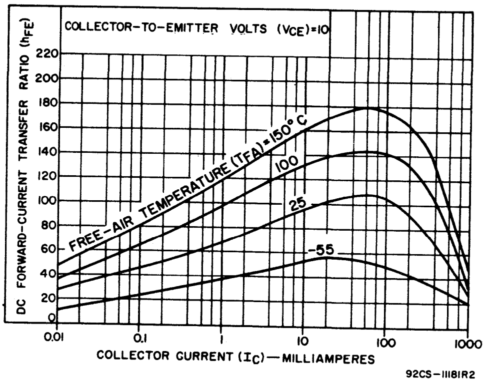


Fig.6

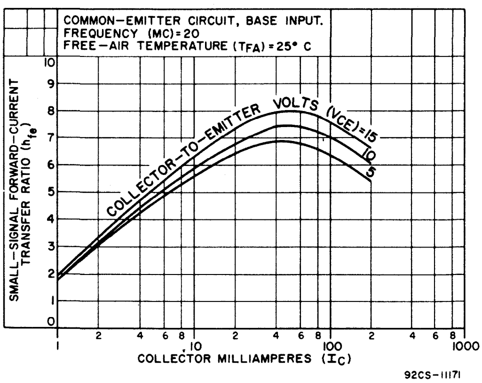


Fig.7

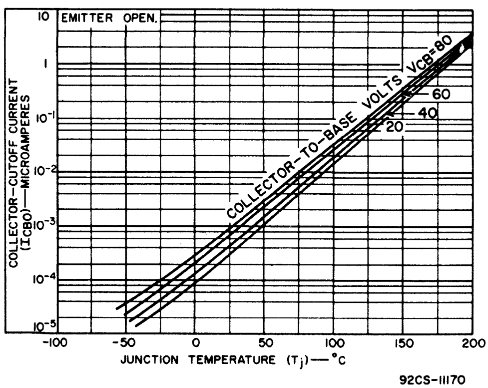


Fig.8

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 2N2102 & 2N1613

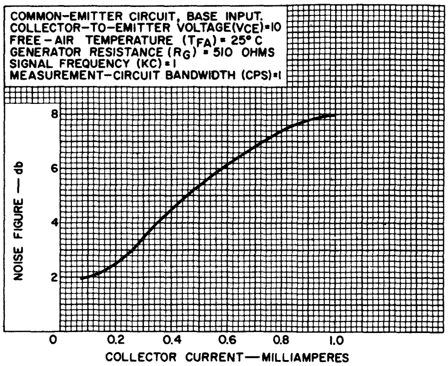


Fig.9

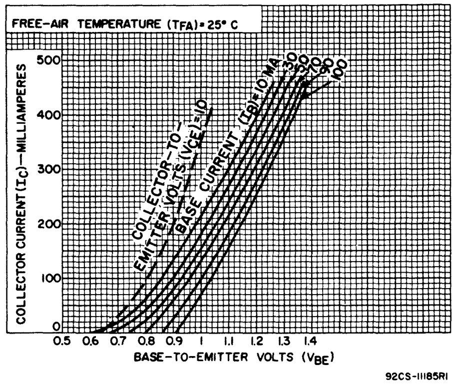


Fig.10

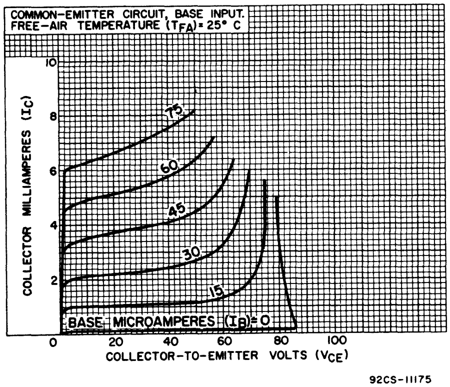


Fig.11

TYPICAL SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N1613

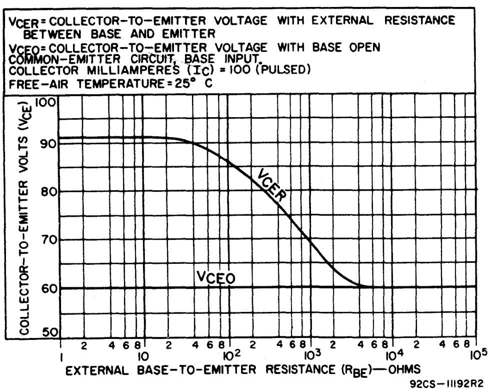


Fig.12

TYPICAL SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N2102

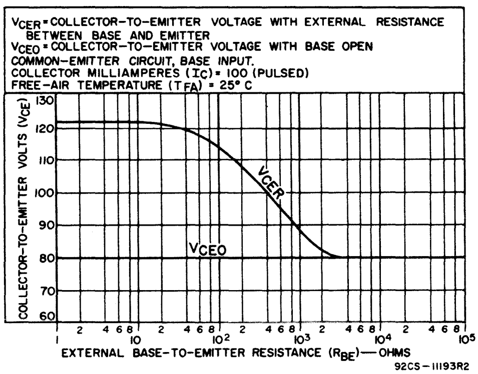
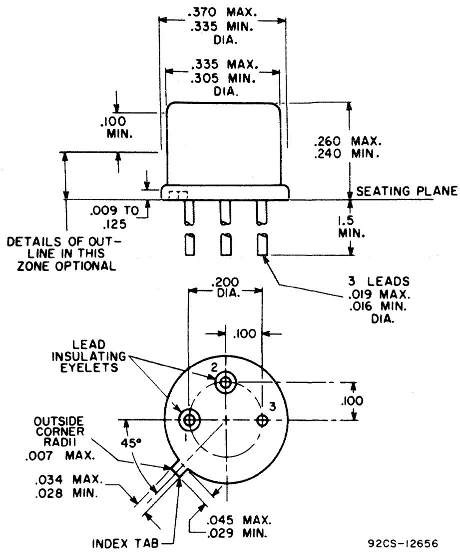


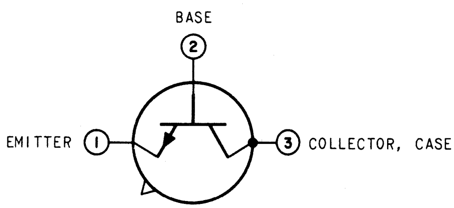
Fig.13

DIMENSIONAL OUTLINE FOR TYPES 2N2102 & 2N1613

JEDEC TO-5



TERMINAL DIAGRAM FOR TYPES 2N2102 & 2N1613



(Bottom View)

RCA

Solid State
Division

Power Transistors

2N1711

RCA-2N1711 is a triple-diffused-junction planar transistor of the silicon n-p-n type intended for a wide variety of small-signal and medium-power applications in military and industrial equipment. It features exceptionally low noise and low leakage characteristics, high pulse beta (h_{FE}), high breakdown voltage ratings, low saturation voltages, high sustaining voltages, and low output capacitance.

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	75 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CER}		
With external $R_{BE} \leq$ 10 ohms.	50 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	7 max.	volts
COLLECTOR CURRENT, I_C	1 max.	amp
TRANSISTOR DISSIPATION:		
At case temperatures up to 25° C.	3 max.	watts
At case temperatures above 25° C.		See *Fig.1*
At free-air temperatures up to 25° C.	0.8 max.	watt
At free-air temperatures above 25° C.		See *Fig.1*
TEMPERATURE RANGE:		
Storage.	-65 to +300	°C
Operating (Junction) . . .	-65 to +200	°C

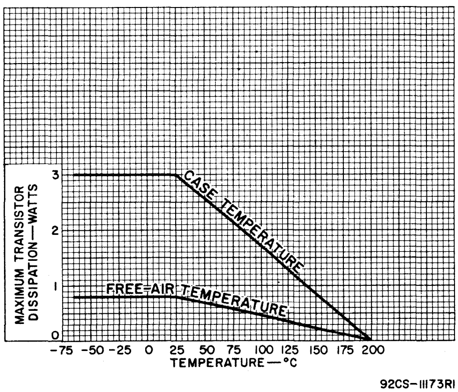
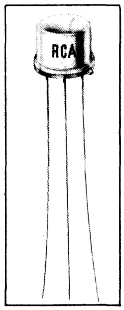


Fig. 1 - Rating Chart for Type 2N1711.

For Small-Signal and Medium-Power Applications



JEDEC TO-5

- minimum gain-bandwidth product = 70 Mc, useful in applications from dc to 25 Mc
- operation at high junction temperatures—up to 200° C
- planar construction—insures low noise and low leakage characteristics
- low saturation voltages:
  $V_{CE}(sat)$ = 0.5 volt typical at I_C = 150 ma
  $V_{BE}(sat)$ = 1.1 volts typical at I_C = 150 ma
- low output capacitance

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	TEST CONDITIONS								LIMITS		Units
		Case Temperature °C	Frequency kc	DC Collector-to-Base Voltage (volts) V_{CB}	DC Collector-to-Emitter Voltage (volts) V_{CE}	DC Emitter-to-Base Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Emitter Current (ma) I_E	DC Base Current (ma) I_B	Min.	Max.	
Collector-Cutoff Current	I_{CBO}	25 150		60 60				0 0		- -	0.01 10	μa μa
Emitter-Cutoff Current	I_{EBO}	25				5	0			-	0.005	μa
DC-Pulse Forward-Current Transfer Ratio[a]	h_{FE}	25 25 25			10 10 10		10 150 500			75 100 40	- 300 -	
DC Forward-Current Transfer Ratio	h_{FE}	25 25 -55			10 10 10		0.01 0.1 10			20 35 35	- - -	
Collector-to-Base Breakdown Voltage	BV_{CBO}	25					0.1	0		75	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}	25					0	0.1		7	-	volts
Collector-to-Emitter Reach-Through Voltage	V_{RT}	25				1.5[b]	0.1			75	-	volts
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance = 10 ohms	$V_{CER}(sus)$	25					100 (pulsed)			50	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25					150		15	-	1.5	volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25					150		15	-	1.3	volts
Small-Signal Forward-Current Transfer Ratio	h_{fe}	25 25 25	1 1 20 Mc		5 10 10		1 5 50			50 70 3.5	200 300 -	
Noise Figure: Generator resistance (R_G) = 510 ohms, circuit bandwidth (BW) = 1 cycle	NF	25	1	10			0.3			-	8	db
Output Capacitance	C_{ob}	25		10				0		-	25	pf
Input Capacitance	C_{ib}	25				0.5	0			-	80	pf
Input Resistance	h_{ib}	25 25	1 1	5 10			1 5			24 4	34 8	ohms ohms
Voltage-Feedback Ratio	h_{rb}	25 25	1 1	5 10			1 5			- -	5×10^{-4} 5×10^{-4}	
Output Conductance	h_{ob}	25 25	1 1	5 10			1 5			0.1 0.1	0.5 1	μmho μmho
Thermal Resistance: Junction-to-case Junction-to-free air	θ_{J-C} θ_{J-FA}	- -								- -	58.3 219	°C/watt °C/watt

[a] Pulse duration, 300 μsec; duty factor, 1.8%.

[b] V_{FBF} = Emitter-to-base floating potential.

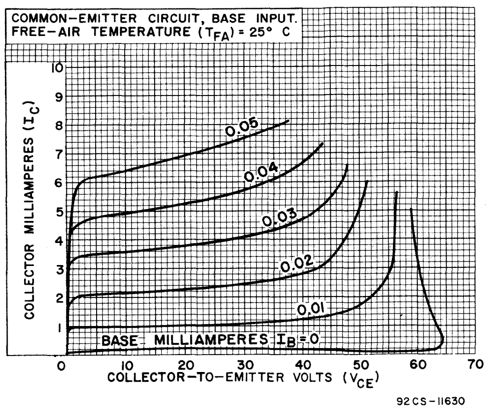


Fig. 2 - Typical Collector Characteristics at 25° C for Type 2N1711.

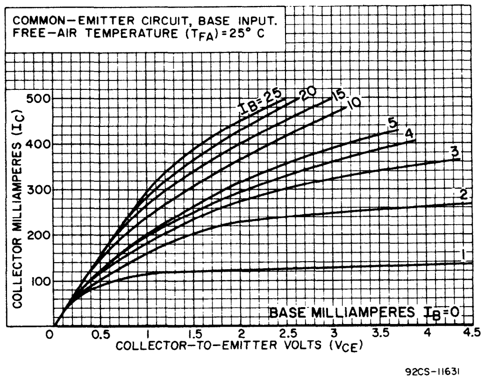


Fig. 5 - Typical Collector Characteristics at 25° C for Type 2N1711.

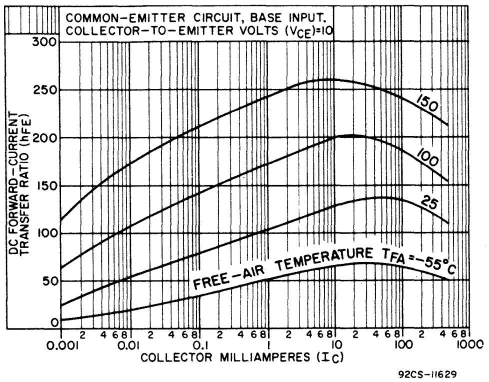


Fig. 3 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N1711.

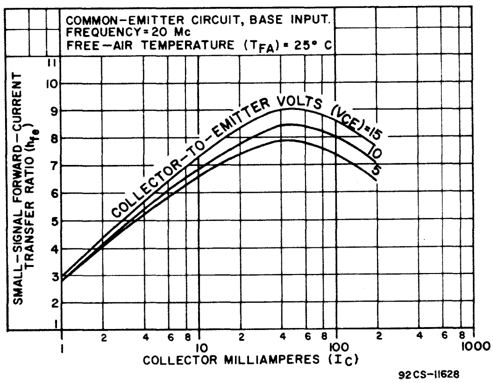


Fig. 6 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N1711.

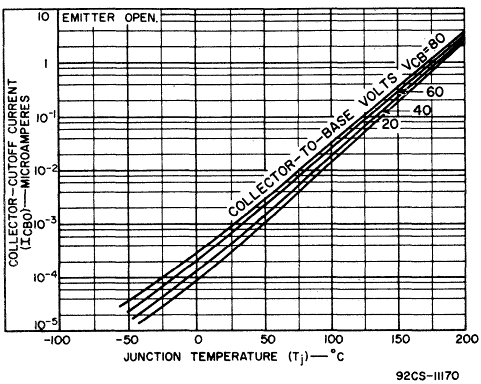


Fig. 4 - Typical Collector-Cutoff-Current Characteristics for Type 2N1711.

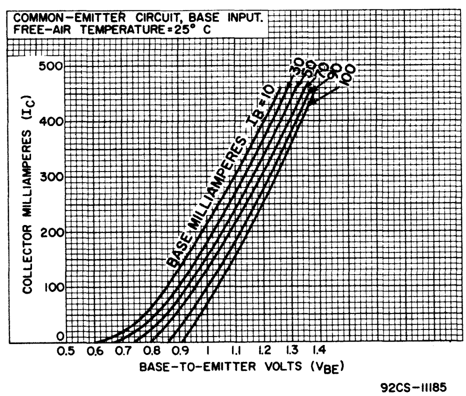


Fig. 7 - Typical Transfer Characteristics for Type 2N1711.

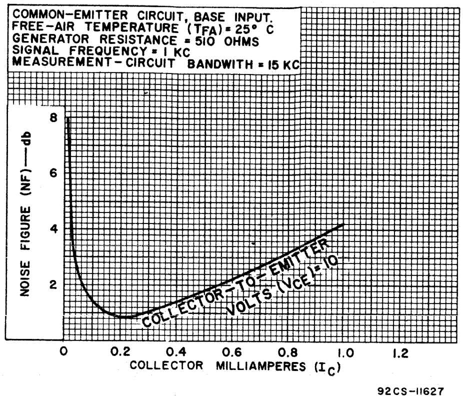
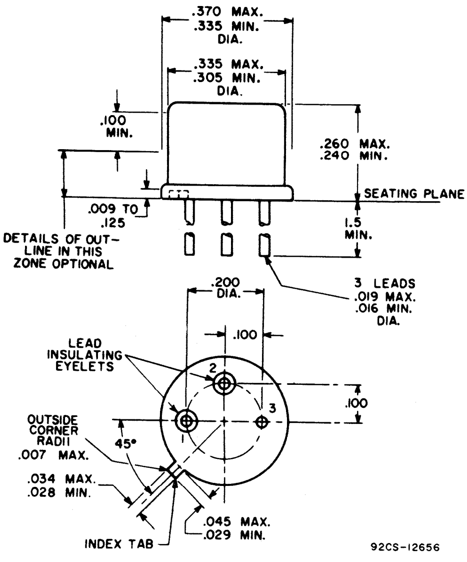
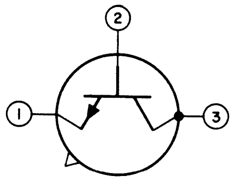


Fig. 8 - Typical AF-Noise-Figure Characteristic for Type 2N1711.

DIMENSIONAL OUTLINE
JEDEC No. TO-5



TERMINAL DIAGRAM



LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

Power Transistors

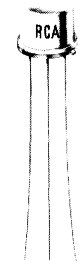
2N2405
2N1893

RCA

Solid State
Division

SILICON N-P-N POWER TRANSISTORS

For Small-Signal and Medium-Power Applications in Military and Industrial Equipment



JEDEC
TO-5

H-1380

RCA 2N2405▲ and 2N1893 are triple-diffused planar transistors of the silicon n-p-n type intended for a variety of small-signal and medium-power applications. They feature exceptionally high collector-to-emitter sustaining voltage, low leakage characteristics, high switching speeds, and high pulse beta (h_{FE}).

RCA 2N2405 is a direct replacement for type 2N1893 for most applications. In addition, the 2N2405 has higher voltage ratings, lower saturation voltages, and higher sustaining voltages than the 2N1893.

▲ Formerly Dev. Type TA2235A.

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

	2N2405	2N1893	
COLLECTOR-TO-BASE VOLTAGE (V_{CBV}):			
With 1.5 volts reverse bias between base and emitter	120	-	V
*COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	120	120	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
* With base open, $V_{CEO}(sus)$	90	80	V
With external base-to-emitter resistance (R_{BE}) ≤ 10 Ω, $V_{CER}(sus)$	140	100	V
With external base-to-emitter resistance (R_{BE}) = 500 Ω & V_{BE} = -1.5, $V_{CEX}(sus)$	120	-	V
*EMITTER-TO-BASE VOLTAGE, V_{EBO} .	7	7	V
*COLLECTOR CURRENT, I_C	1	0.5	A
*TRANSISTOR DISSIPATION, P_T:			
At case temperatures up to 25°C	5	3	W
At case temperatures above 25°C	See Figs.1&2.		
At free-air temperatures up to 25°C . . .	1	0.8	W
At free-air temperatures above 25°C . .	See Figs.1&2.		
*TEMPERATURE RANGE:			
Storage & Operating (Junction)	-65 to + 200		°C
*LEAD TEMPERATURE (During Soldering)			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10s max	255	-	°C
At distances ≥ 1/16 in. (1.58 mm) from seating plane for 10s max	-	255	°C

* In accordance with JEDEC registration data format (JS-9, RDF-2)

Features

- operation at high junction temperature — up to 200°C
- planar construction — insures low noise and low leakage characteristics
- low output capacitance

RCA-2N2405 Features

- minimum gain bandwidth product = 120 MHz, useful in applications from dc to 50 MHz
- high sustaining voltage — $V_{CEO}(sus)$ = 90 volts min.
- very low saturation voltages —

  $V_{CE}(sat)$ = 0.5 volt maximum at I_C = 150 mA

  $V_{BE}(sat)$ = 1.1 volts maximum at I_C = 150 mA

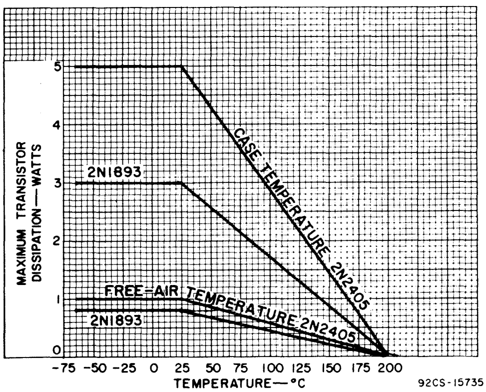


Fig.1 - Dissipation derating curves for types 2N2405 and 2N1893.

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	DC Collector Voltage (V) V_{CE}	DC Emitter Voltage (V) V_{EB}	DC Current (mA) I_C	DC Current (mA) I_E	DC Current (mA) I_B	LIMITS: Type 2N2405 Min.	Type 2N2405 Max.	Type 2N1893 Min.	Type 2N1893 Max.	UNITS
* Collector-Cutoff Current:	I_{CBO}	90				0		-	0.01	-	0.01	μA
T_C = 150°C		90				0		-	10	-	15	μA
* Emitter-Cutoff Current	I_{EBO}			5	0			-	0.01	-	0.01	μA
Collector-to-Emitter Sustaining Voltage: * With base open	$V_{CEO}(sus)$				100[a]		0	90	-	-	-	V
					30[a]		0	90	-	80	-	V
* With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$				100[a]			140	-	100	-	V
(R_{BE}) = 500 Ω					100[a]			120	-	-	-	V
* Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0.1	0		120	-	120	-	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0	0.1		7	-	7	-	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				150[a]		15	-	0.5	-	5	V
					50[a]		5	-	0.2	-	1.2	V
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				150[a]		15	-	1.1	-	1.3	V
					50[a]		5	-	0.9	-	0.9	V
* DC Forward-Current Transfer Ratio	h_{FE}		10		150[a]			60	200	40	120	
*			10		10[a]			35	-	35	-	
*			10		0.1			-	-	20	-	
* T_C = -55°C	h_{FE}		10		10			20	-	-	-	
			10		10			-	-	20	-	
Small-Signal Forward-Current Transfer Ratio: * f = 1 kHz	h_{fe}		5		1			-	-	30	100	
* 1 kHz			5		5			50	275	-	-	
* 1 kHz			10		5			-	-	45	-	
* 20 MHz			10		50			-	-	2.5	-	
20 MHz			10		50			6	-	-	-	
* Input Resistance (at f = 1 kHz)	h_{ib}	5			1			24	34	20	30	Ω
		10			5			4	8	4	8	Ω
* Voltage-Feedback Ratio (at f = 1 kHz)	h_{rb}	5			1			-	3×10^{-4}	-	1.25×10^{-4}	
		10			5			-	3×10^{-4}	-	1.5×10^{-4}	
* Output Conductance (at f = 1 kHz)	h_{ob}	5			1			-	0.5	-	0.5	μmho
		10			5			-	0.5	-	0.5	μmho
* Output Capacitance	C_{obo}	10				0		-	15	-	15	pF
* Input Capacitance	C_{ibo}			0.5	0			-	80	-	85	pF
Noise Figure (Wide-Band) Generator resistance (R_G) = 500 Ω Circuit Bandwidth (BW) = 15 kHz Reference signal frequency = 1 kHz	NF	10			0.3			-	6	-	-	dB
* Thermal Resistance: Junction-to-case	θ_{J-C}							-	35	-	58.3	°C/W
Junction-to-ambient	θ_{J-A}							-	175	-	219	°C/W

a Pulsed. Pulse duration = 300 μsec max.; duty factor ≤ 2%.

* In accordance with JEDEC registration data format (JS-9 RDF-2).

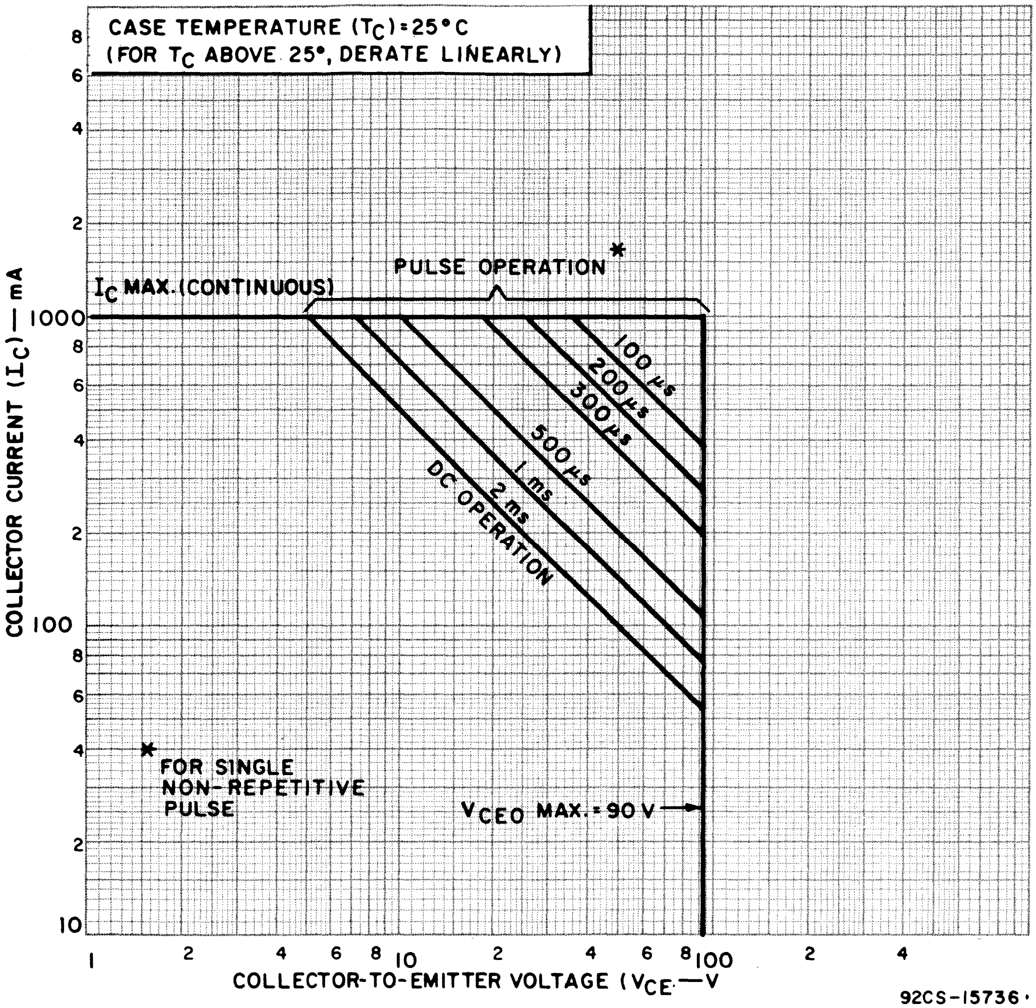


Fig.2 - Maximum operating areas for type 2N2405.

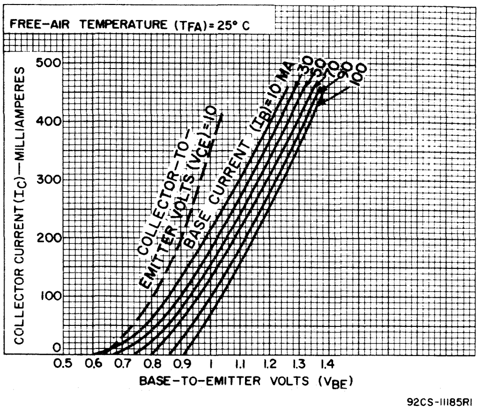


Fig.3 - Typical transfer characteristics for types 2N2405 and 2N1893.

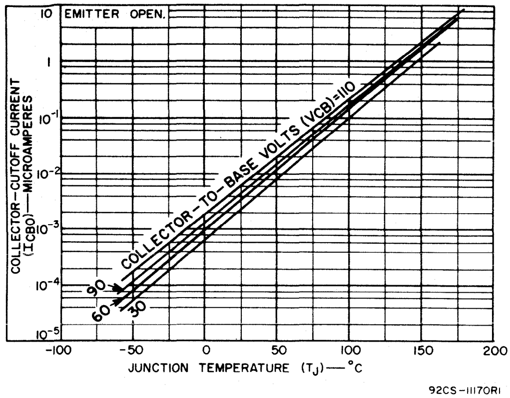


Fig.4 - Typical cutoff characteristics for types 2N2405 and 2N1893.

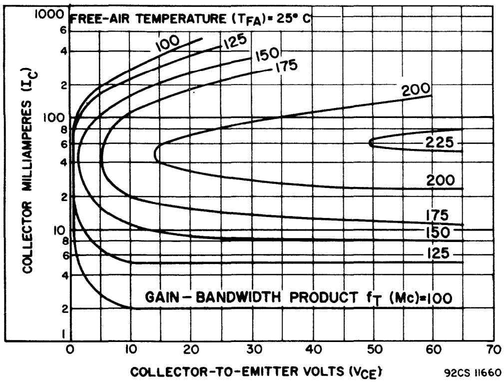


Fig.5 - Typical gain bandwidth product characteristics for types 2N2405 and 2N1893.

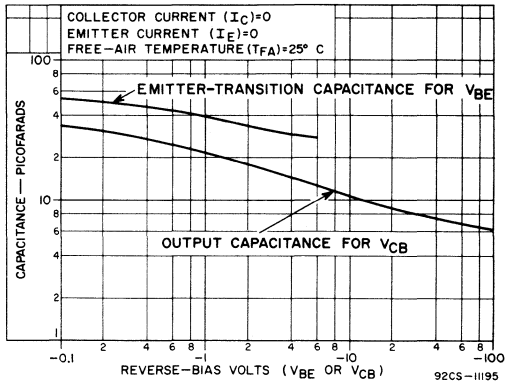


Fig.6 - Typical capacitance characteristics for types 2N2405 and 2N1893.

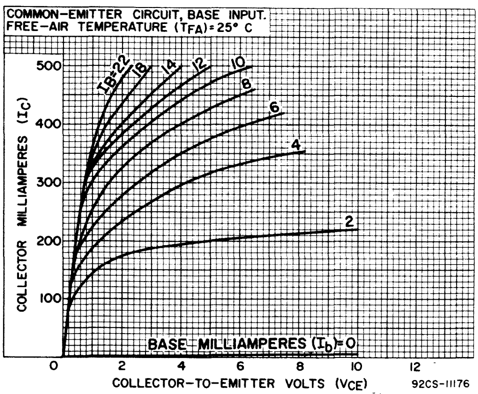


Fig.7 - Typical collector characteristics at 25°C for type 2N2405.

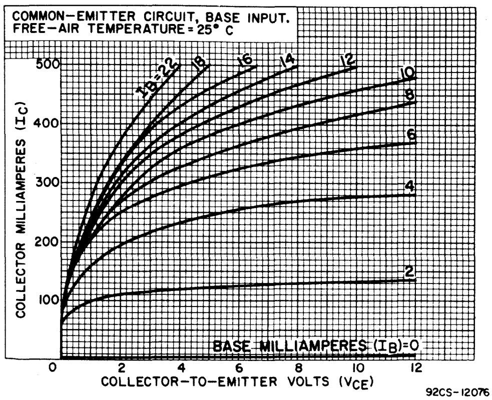


Fig.8 - Typical collector characteristics at 25°C for type 2N1893.

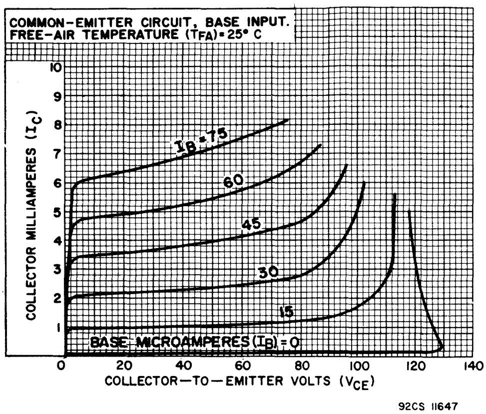


Fig.9 - Typical collector characteristics at 25°C for type 2N2405.

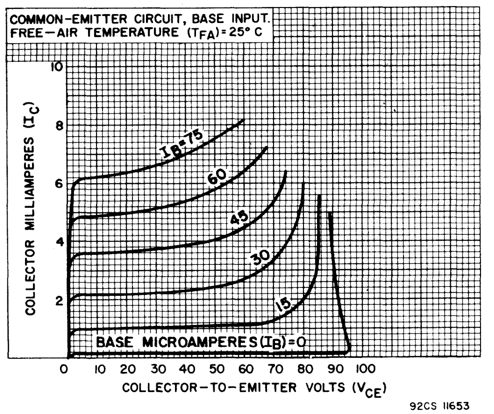


Fig.10 - Typical collector characteristics at 25°C for type 2N1893.

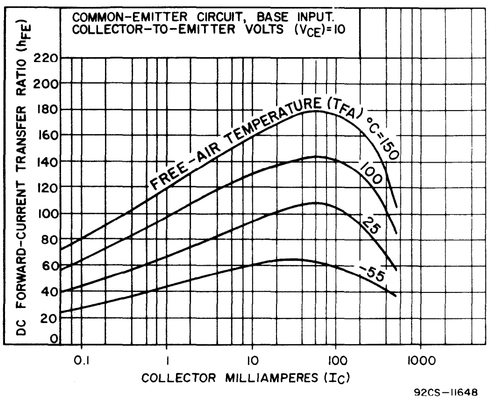


Fig.11 - Typical dc-beta characteristics for types 2N2405 and 2N1893.

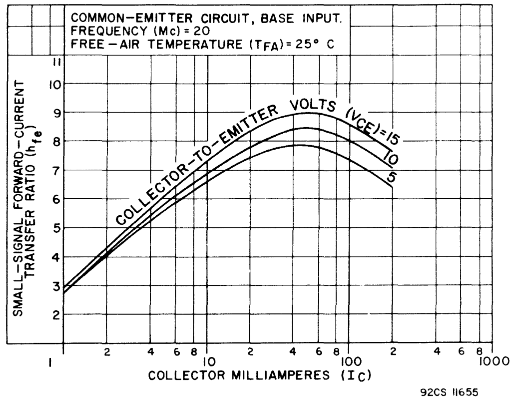


Fig.12 - Typical small-signal beta characteristics for types 2N2405 and 2N1893.

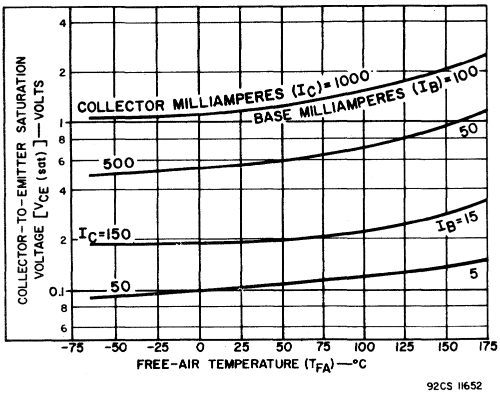


Fig.13 - Typical saturation characteristics for types 2N2405 and 2N1893.

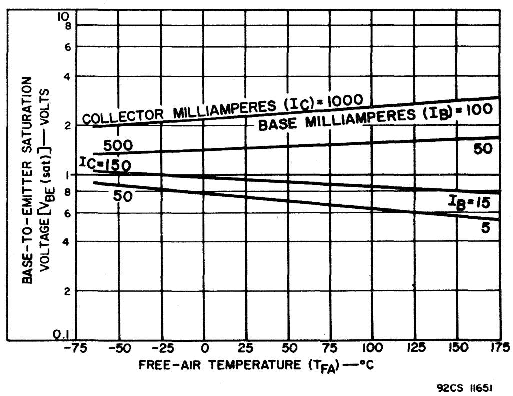


Fig.14 - Typical saturation characteristics for types 2N2405 and 2N1893.

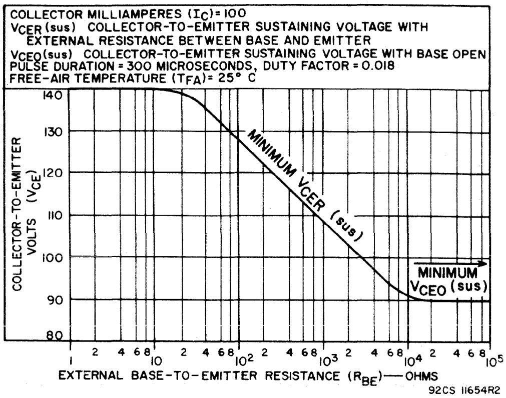


Fig.15 - Sustaining voltage characteristic for type 2N2405.

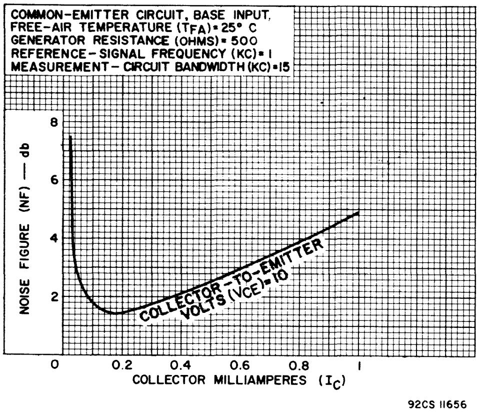


Fig.16 - Typical wide-band noise characteristic for type 2N2405.

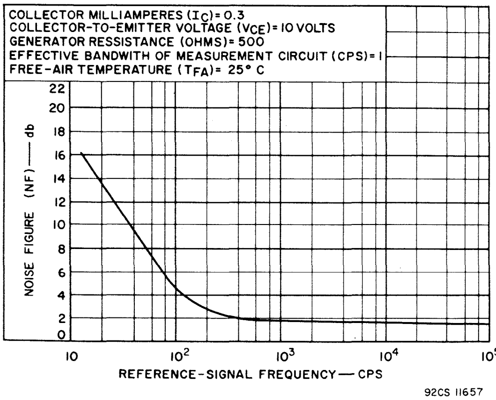
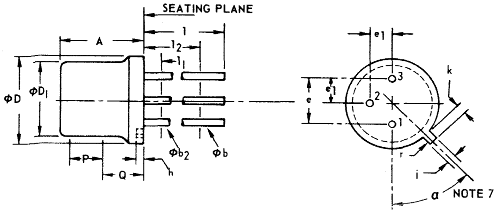


Fig.17 - Typical narrow-band noise characteristic for type 2N2405.

DIMENSIONAL OUTLINE FOR JEDEC TO-5



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.016	.021	.406	.533	2
$Φb_2$	.016	.019	.406	.483	2
ΦD	.335	.370	8.51	9.40	
$ΦD_1$	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
i	.028	.034	.711	.864	5
k	.029	.045	.737	1.14	3,5
l	1.500		38.10		2
l_L		.050		1.27	2
l_2	.250		6.35		2
P	.100		2.54		1
Q					6
r		.007		.179	
α	45° T.P.				5,7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) $Φb_2$ applies between l_1 and l_2. Φb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) − 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL DESIGNATIONS

Lead 1 - Emitter
Lead 2 - Base
Lead 3 - Collector, Case

RCA
Solid State
Division

Power Transistors

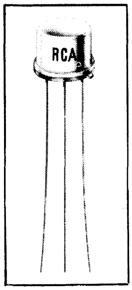
2N2270

RCA-2N2270 is a *triple-diffused-junction* planar transistor of the silicon n-p-n type intended for a wide variety of small-signal and medium-power applications in military and industrial equipment. It features exceptionally low noise and leakage characteristics, and very low output capacitance.

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE:		
With emitter open	60 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:		
With external $R_{BE} \leq 10$ ohms	60 max.	volts
With base open	45 max.	volts
EMITTER-TO-BASE VOLTAGE:		
With collector open	7 max.	volts
COLLECTOR CURRENT	1 max.	amp
TRANSISTOR DISSIPATION:		
At case temperatures up to 25° C	5 max.	watts
At case temperatures above 25° C	See *Rating Chart*	
At free-air temperature up to 25° C	1 max.	watt
At free-air temperature above 25° C	See *Rating Chart*	
TEMPERATURE RANGE:		
Storage	-65 to +200	°C
Operating (Junction)	-65 to +200	°C
LEAD TEMPERATURE:		
1/16" ± 1/32" from case for 10 sec. max. immersion	255 max.	°C

For Small-Signal and Medium-Power Applications



JEDEC TO-5

- minimum gain-bandwidth product = 60 Mc, useful in applications from dc to 20 Mc
- operation at high junction temperatures — up to 200° C
- planar construction — insures low noise and low leakage characteristics
- very low output capacitance

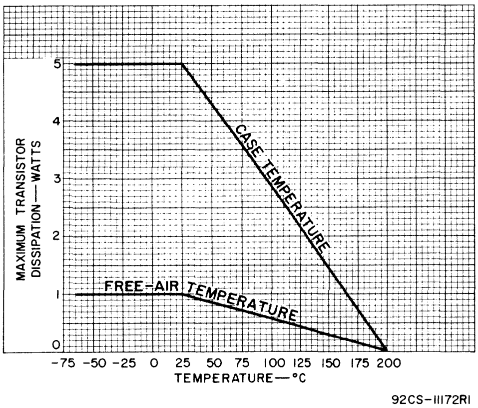


Fig. 1 Rating Chart for Type 2N2270.

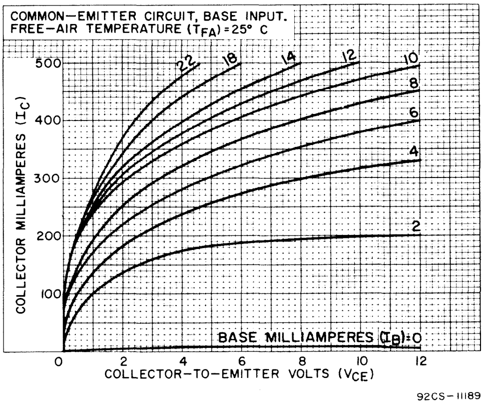


Fig. 2 - Typical Collector Characteristics at 25° C for Type 2N2270.

ELECTRICAL CHARACTERISTICS:

At Case Temperature (T_C) of 25° C, unless otherwise specified.

Characteristic	Symbol	TEST CONDITIONS						LIMITS		Units
		DC Collector-to-Base Voltage V_{CB}	DC Collector-to-Emitter Voltage V_{CE}	DC Emitter-to-Base Voltage V_{EB}	DC Collector Current I_C	DC Emitter Current I_E	DC Base Current I_B	Type 2N2270		
		volts	volts	volts	ma	ma	ma	Min.	Max.	
Collector-Cutoff Current: T_C = 25° C	I_{CBO}	60				0		-	0.1	μa
= 150° C		60				0		-	50	μa
Emitter-Cutoff Current	I_{EBO}			5	0			-	0.1	μa
DC Forward-Current Transfer Ratio	h_{FE}		10		150*			50	200	
			10		1			35	-	
Collector-to-Base Breakdown Voltage	BV_{CBO}				0.1			60	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0.1		7	-	volts
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$				100*			45	-	volts
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance (R_{BE}) = 10 ohms	$V_{CER}(sus)$				100*			60	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				150		15	-	0.9	volt
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				150		15	-	1.2	volts
Small-Signal Forward-Current Transfer Ratio: At frequency of 1 Kc	h_{fe}		10		5			30	180	
20 Mc			10		50			3	-	
Noise Figure: Generator resistance (R_G) = 1000 ohms, circuit band-width (BW) = 15 Kc, input frequency (f) = 1 Kc	NF		10		0.3			-	6	db
Output Capacitance	C_{ob}	10				0		-	15	pf
Input Capacitance	C_{ib}			0.5	0			-	80	pf
Thermal Resistance: Junction-to-case	θ_{J-C}							-	35	°C/W
Junction-to-free air	θ_{J-FA}							-	175	°C/W

* Pulse Test: Pulse duration, 300 μsec; duty factor, 1.8%.

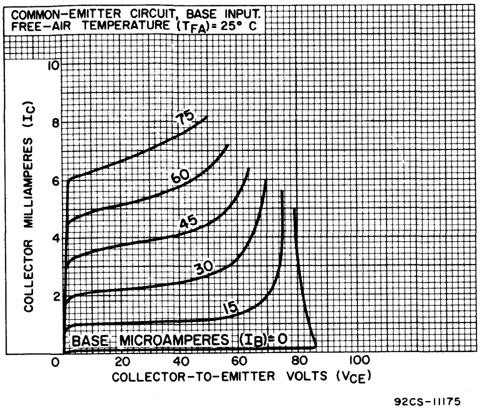


Fig.3 - Typical Collector Characteristics at 25° C for Type 2N2270.

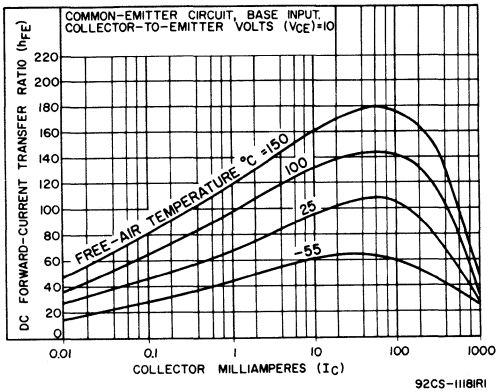


Fig.4 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N2270.

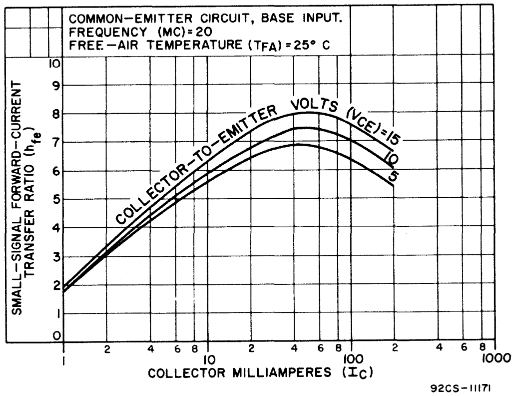


Fig.5 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N2270.

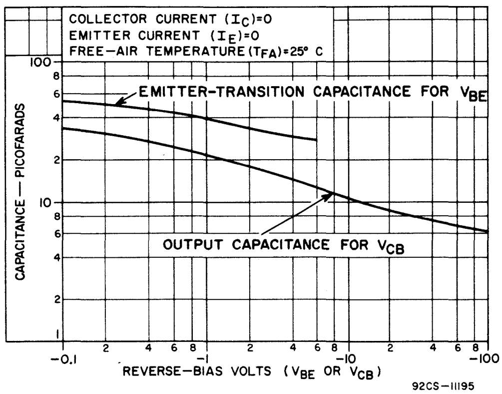


Fig.6 - Typical Emitter-Transition-Capacitance and Output-Capacitance Characteristics for Type 2N2270.

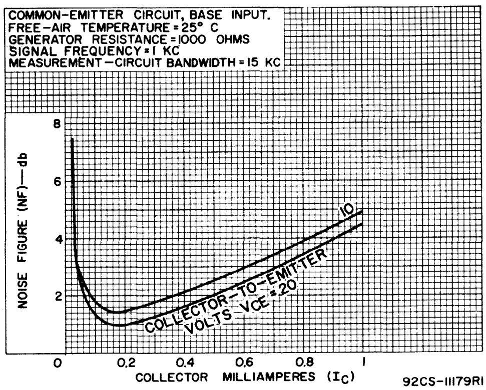
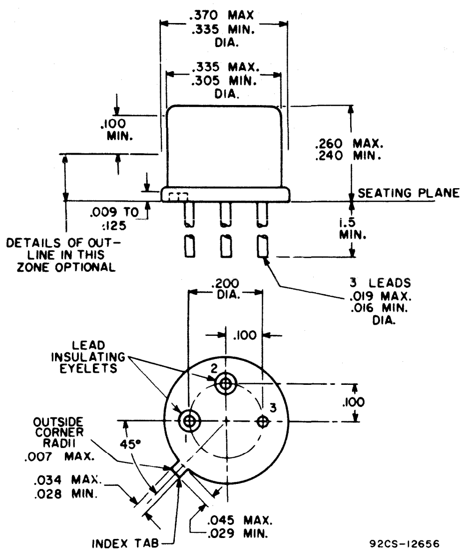


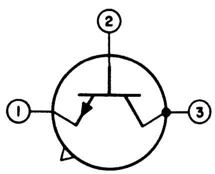
Fig. 7 - Typical AF-Noise-Figure Characteristics for Type 2N2270.

DIMENSIONAL OUTLINE
for Type 2N2270
JEDEC No. TO-5



TERMINAL DIAGRAM

LEAD 1 – EMITTER
LEAD 2 – BASE



LEAD 3 – COLLECTOR, CASE

RCA
Solid State
Division

Power Transistors
2N2895
2N2896
2N2897

RCA-2N2895, 2N2896, and 2N2897 are triple-diffused-junction planar transistors of the silicon n-p-n type intended for a wide variety of small-signal and low-to-medium-power applications in military and industrial equipment.

These transistors are TO-18 versions of RCA's versatile 2N2102 family of n-p-n triple-diffused silicon transistors for small-signal and medium-power military and industrial applications.

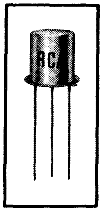
Like the 2N2102, the 2N2895 offers five levels of beta control from 0.1 ma to 0.5 ampere.

High-voltage type 2N2896 offers a BV_{CEO} of 90 volts min. and V_{CER} (sus) of 140 volts min., controlled for values of R_{BE} from 0 to 100,000 ohms.

RCA-2N2897 is an economy version offering many of the advantages of the 2N2896.

These transistors feature extremely low leakage characteristics, high pulse dc beta, high small-signal beta, very low output capacitance, and large gain-bandwidth products. Type 2N2895 also has an exceptionally low noise figure of 8 db max.

For Small-Signal and Low-to-Medium-Power Applications



JEDEC TO-18

FEATURES:

- high mimimum gain-bandwidth products – 120 Mc for 2N2895, 2N2896; 100 Mc for 2N2897; useful in applications from dc to 40 Mc
- planar construction – for low noise and low leakage characteristics
- operation at high junction temperatures – up to 200° C
- very low output capacitance – 15 pf max.
- high switching-speed capabilities (non-sat)

Maximum Ratings, *Absolute-Maximum Values:*

	2N2895	2N2896	2N2897	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO} . .	120	140	60 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	65	90	45 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CER} (With $R_{BE} \leq$ 10 ohms)	80	140	60 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO} . .	7	7	7 max.	volts
COLLECTOR CURRENT, I_C	1	1	1 max.	amp
TRANSISTOR DISSIPATION, P_T:				
For case temperatures up to 25° C. .	1.8	1.8	1.8 max.	watts
above 25° C. .	See Rating Chart (Fig. 1)			

	2N2895	2N2896	2N2897	
TRANSISTOR DISSIPATION, P_T (Cont'd):				
For free-air temperatures up to 25° C. .	0.5	0.5	0.5 max.	watt
above 25° C. .	See Rating Chart (Fig. 1)			
TEMPERATURE RANGE:				
Storage and Operating (Junction) . . .		-65 to +200		°C
LEAD TEMPERATURE (During Soldering): At distances ≥ 1/32 inch from lead seals for 10 seconds max. .	255	255	255 max.	°C

2N2895, formerly Dev. No. TA2275
2N2896, formerly Dev. No. TA2276
2N2897, formerly Dev. No. TA2277

ELECTRICAL CHARACTERISTICS

Characteristics	Symbols	TEST CONDITIONS: Case Temperature T_C (°C)	Frequency f (kc)	DC Collector-to-Base Voltage V_{CB} (volts)	DC Collector-to-Emitter Voltage V_{CE} (volts)	DC Emitter-to-Base Voltage V_{EB} (volts)	DC Collector Current I_C (ma)	DC Emitter Current I_E (ma)	DC Base Current I_B (ma)	LIMITS: Type 2N2895 Min.	Type 2N2895 Max.	Type 2N2896 Min.	Type 2N2896 Max.	Type 2N2897 Min.	Type 2N2897 Max.	Units
Collector-Cutoff Current	I_{CBO}	25		90				0		-	-	-	0.01	-	-	μa
		150		90				0		-	-	-	10	-	-	μa
		25		60				0		-	0.002	-	-	-	0.05	μa
		150		60				0		-	2	-	-	-	50	μa
Emitter-Cutoff Current	I_{EBO}	25				5	0			-	0.002	-	0.01	-	0.05	μa
DC Forward-Current Transfer Ratio	h_{FE}	25			10		150[b]			40	120	60	200	50	200	
		25			10		500[b]			25	-	-	-	-	-	
		25			10		0.1			20	-	-	-	-	-	
		25			10		1			-	-	35	-	35	-	
		25			10		10			35	-	-	-	-	-	
		-55			10		10			20	-	20	-	-	-	
Collector-to-Base Breakdown Voltage	BV_{CBO}	25					0.1	0		120	-	140	-	60	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}	25					0	0.1		7	-	7	-	7	-	volts
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$	25					100[b]		0	65	-	90	-	45	-	volts
Collector-to-Emitter Sustaining Voltage with R_{BE} = 10 ohms	$V_{CER}(sus)$	25					100[b]			80	-	140	-	60	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25					150[b]		15	-	0.6	-	0.6	-	1	volt
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25					150[b]		15	-	1.2	-	1.2	-	1.3	volts
Small-Signal Forward-Current Transfer Ratio	h_{fe}	25	1		5		5			50	200	50	275	50	275	
		25	20 Mc		10		50			6	-	6	-	5	-	
Noise Figure: Generator resistance = 510 ohms, circuit bandwidth = 1 cps	NF	25	1		10		0.3			-	8	-	-	-	-	db
Output Capacitance	C_{ob}	25	140	10				0		-	15	-	15	-	15	pf
Input Capacitance	C_{ib}	25	140			0.5	0			-	80	-	80	-	80	pf
Thermal Resistance: Junction-to-Base	$\theta_{J\text{-}C}$	-								-	97	-	97	-	97	°C/watt
Junction-to-Free Air	$\theta_{J\text{-}FA}$	-								-	350	-	350	-	350	°C/watt

[b] Pulse test: Pulse duration = 300 μsec; duty factor = 1.8%.

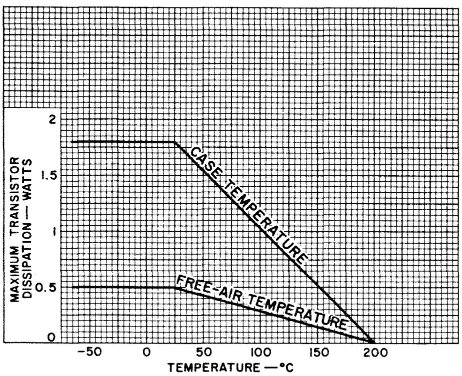


Fig. 1 - Rating Chart for Types 2N2895 2N2896, and 2N2897

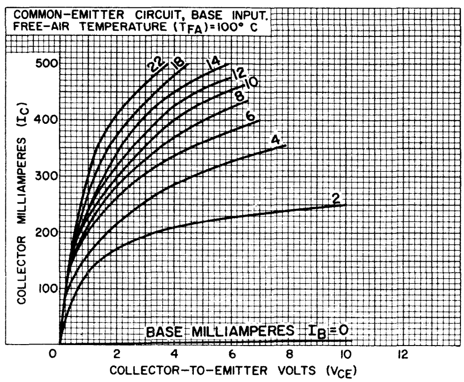


Fig. 2 - Typical Collector Characteristics at 100° C for Type 2N2895

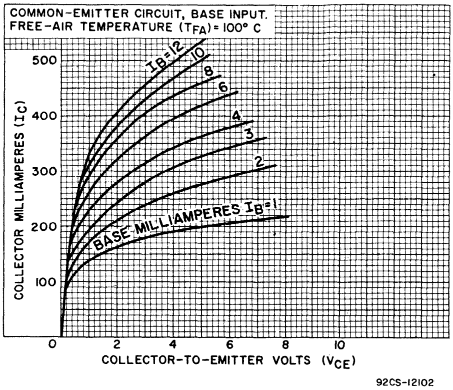


Fig. 3 - Typical Collector Characteristics at 100° C for Types 2N2896 and 2N2897.

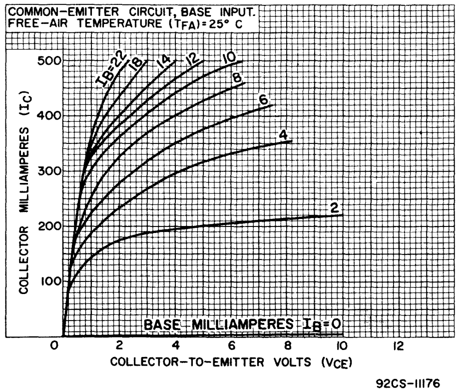


Fig. 4 - Typical Collector Characteristics at 25° C for Type 2N2895.

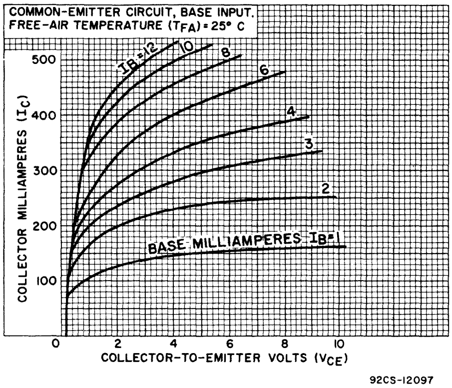


Fig. 5 - Typical Collector Characteristics at 25° C for Types 2N2896 and 2N2897.

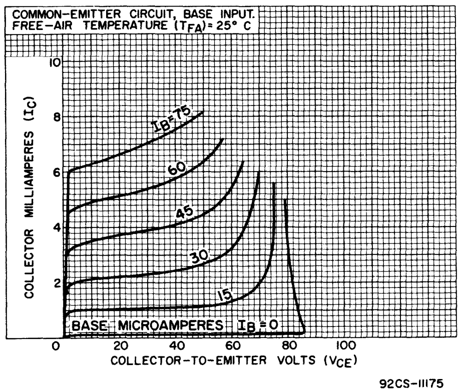


Fig. 6 - Typical Collector Characteristics at 25° C for Type 2N2895.

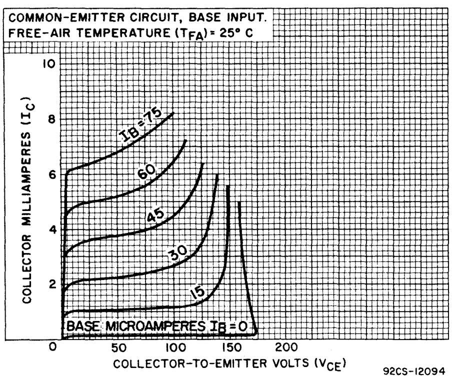


Fig. 7 - Typical Collector Characteristics at 25° C for Type 2N2896.

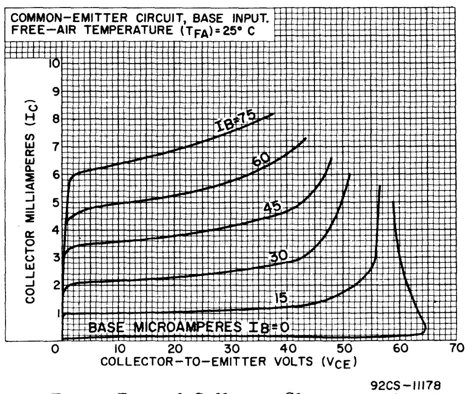


Fig. 8 - Typical Collector Characteristics at 25° C for Type 2N2897.

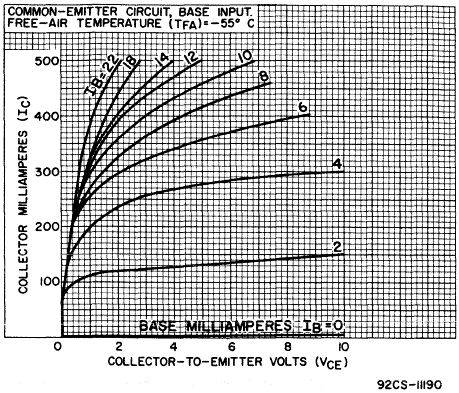


Fig. 9 - Typical Collector Characteristics at -55° C for Type 2N2895.

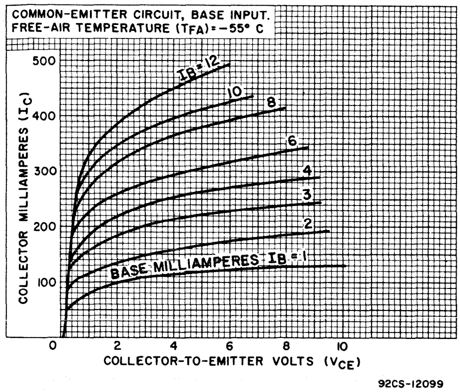


Fig. 10 - Typical Collector Characteristics at -55° C for Types 2N2896 and 2N2897.

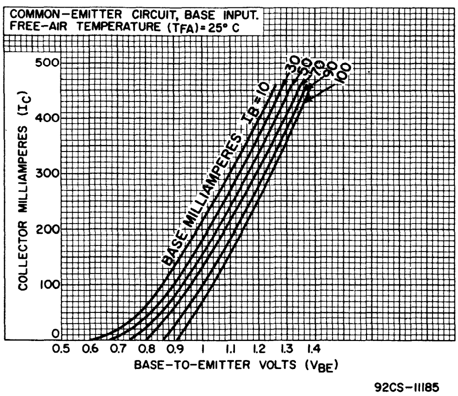


Fig. 11 - Typical Transfer Characteristics for Types 2N2895 and 2N2896.

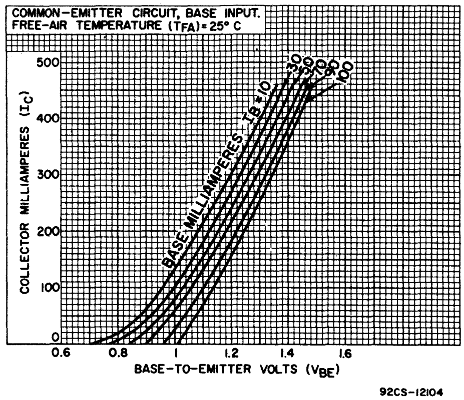


Fig. 12 - Typical Transfer Characteristics for Type 2N2897.

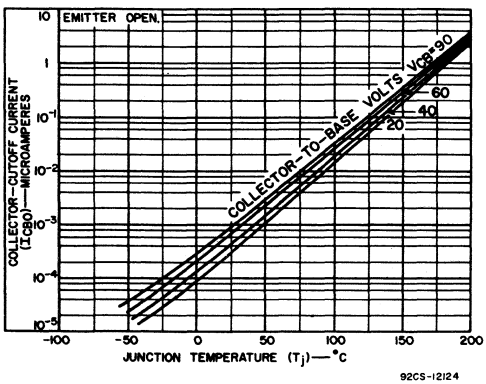


Fig. 13 - Typical Collector-Cutoff-Current Characteristics for Types 2N2895 and 2N2896.

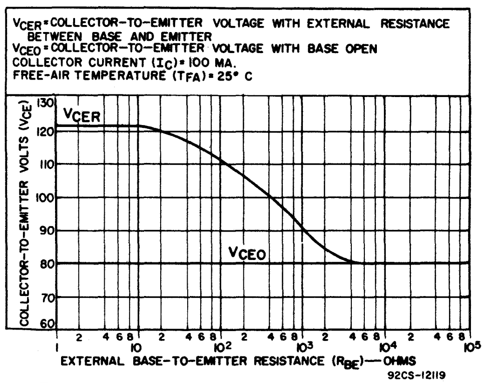


Fig. 14 - Typical Collector-to-Emitter-Voltage Characteristic for Type 2N2895.

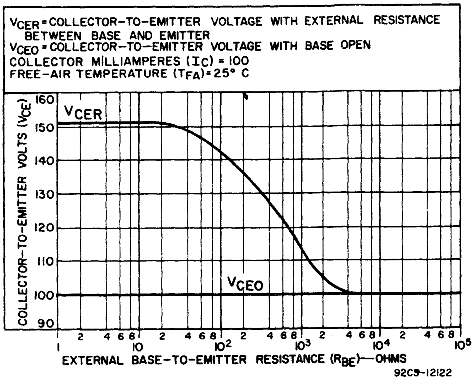


Fig. 15 - Typical Collector-to-Emitter-Voltage Characteristic for Type 2N2896.

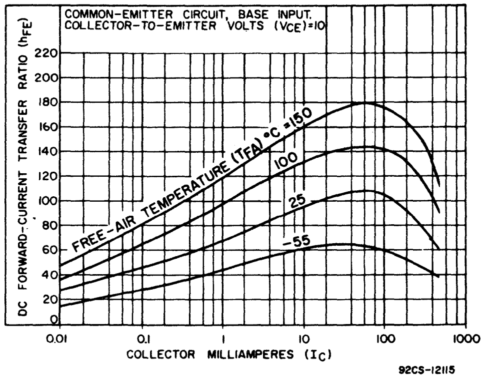


Fig. 16 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N2895.

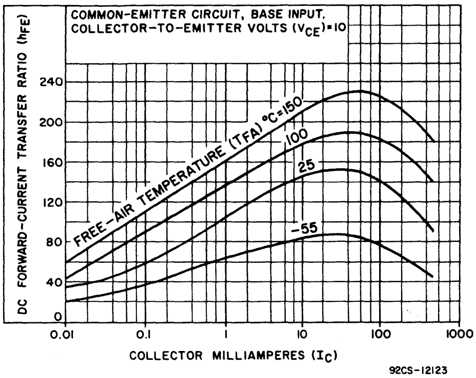


Fig. 17 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Types 2N2896 and 2N2897.

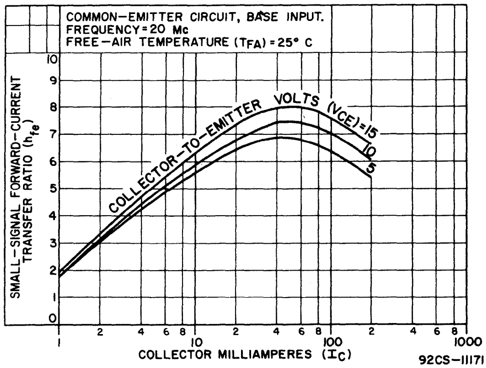


Fig. 18 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Types 2N2895, 2N2896 and 2N2897 .

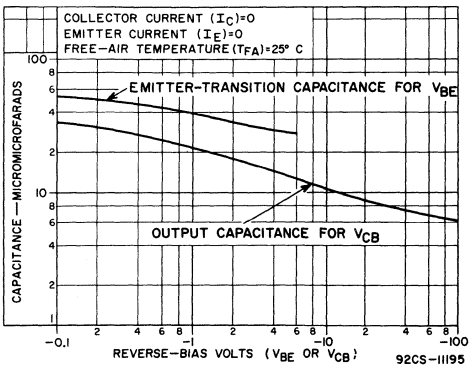


Fig. 19 - Typical Emitter-Transition-Capacitance and Output-Capacitance Characteristics for Types 2N2895, 2N2896 and 2N2897.

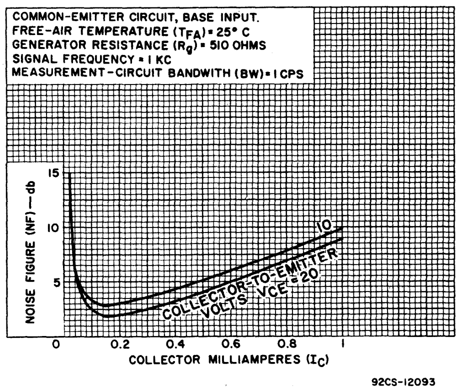
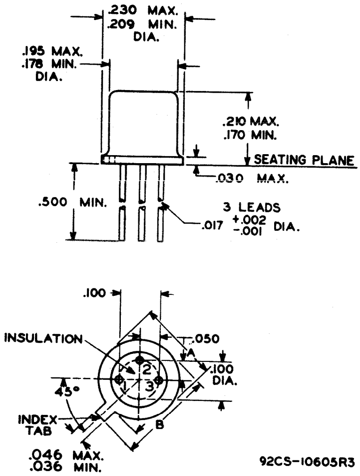


Fig. 20 - Typical AF-Noise-Figure Characteristics for Type 2N2895.

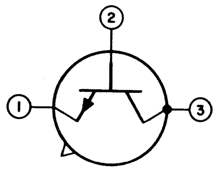
2N2895, 2N2896, and 2N2897
DIMENSIONAL OUTLINE
JEDEC No. TO-18



92CS-10605R3

TERMINAL DIAGRAM
(Bottom View)
For All Types

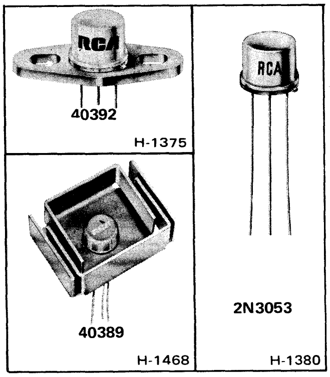
LEAD 1 – EMITTER
LEAD 2 – BASE



LEAD 3 – COLLECTOR, CASE

RCA
Solid State
Division

Power Transistors
2N3053
40389 40392



General-Purpose Medium-Power Types

Silicon N-P-N Transistors

For Small-Signal Applications
In Industrial and Commercial Equipment

Features

- **Maximum Safe-Area-of-Operation Curve**
- **Forward- and reverse-bias operation without second breakdown**
- **Low leakage current**

RCA-2N3053 is a triple-diffused planar transistor useful up to 20 MHz in small-signal, medium-power applications. Type 40389 is a 2N3053 with a factory-attached heat radiator. Type 40392 is a 2N3053 with a factory-attached diamond-shaped mounting flange.

MAXIMUM RATINGS, *Absolute Maximum Values:*

		2N3053 40389, 40392	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
With base open	$V_{CEO}(sus)$	40	V
With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$	50	V
With base reverse biased (V_{BE} = 1.5 V)	$V_{CEV}(sus)$	60	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	V
CONTINUOUS COLLECTOR CURRENT .	I_C	0.7	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		5 (2N3053)	W
		7 (40392)	W
At free-air temperatures up to 25°C . . .		1 (2N3053)	W
		3.5 (40389)	W
At temperatures above 25°C		See Figs. 1, 2 & 3	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to 200	°C
LEAD TEMPERATURE (During Soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max		235	°C

Applications

- **Audio amplifiers**
- **Controlled amplifiers**
- **Power supplies**
- **Power oscillators**

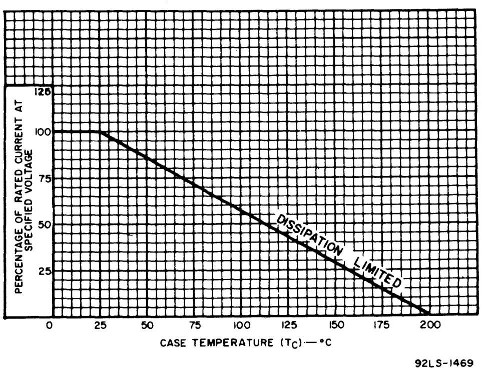


Fig. 1 - Derating curve for type 2N3053.

ELECTRICAL CHARACTERISTICS *Case Temperature (T_C) = 25°C, Unless Otherwise Specified*

Characteristics	Symbol	TEST CONDITIONS: DC Collector Voltage V		DC Emitter or Base Voltage V		DC Current mA			LIMITS: Types 2N3053 40389 40392		Units
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	
Collector-Cutoff Current	I_{CBO}	30					0		—	0.25	μA
Emitter-Cutoff Current	I_{EBO}			4		0			—	0.25	μA
DC Forward-Current Transfer Ratio	h_{FE}		10			150[a]			50	250	
Collector-to-Base Breakdown Voltage	BV_{CBO}					0.1	0		60	—	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0	0.1		5	—	V
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$					100[a]		0	40	—	V
With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$					100[a]			50	—	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					150		15	—	1.7	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					150		15	—	1.4	V
Small-Signal, Forward Current Transfer Ratio (At 20 MHz)	h_{fe}		10			50			5	—	
Output Capacitance	C_{ob}	10					0		—	15	pF
Input Capacitance	C_{ib}			0.5		0			—	80	pF
Thermal Resistance: Junction-to-Case	θ_{J-C}								35(max.) 2N3053		°C/W
									25(max.) 40392		°C/W
Junction-to-Free Air	θ_{J-FA}								175(max.) 2N3053		°C/W
									50(max.) 40389		°C/W

[a]Pulsed; pulse duration = 300μs, duty factor = 1.8%.

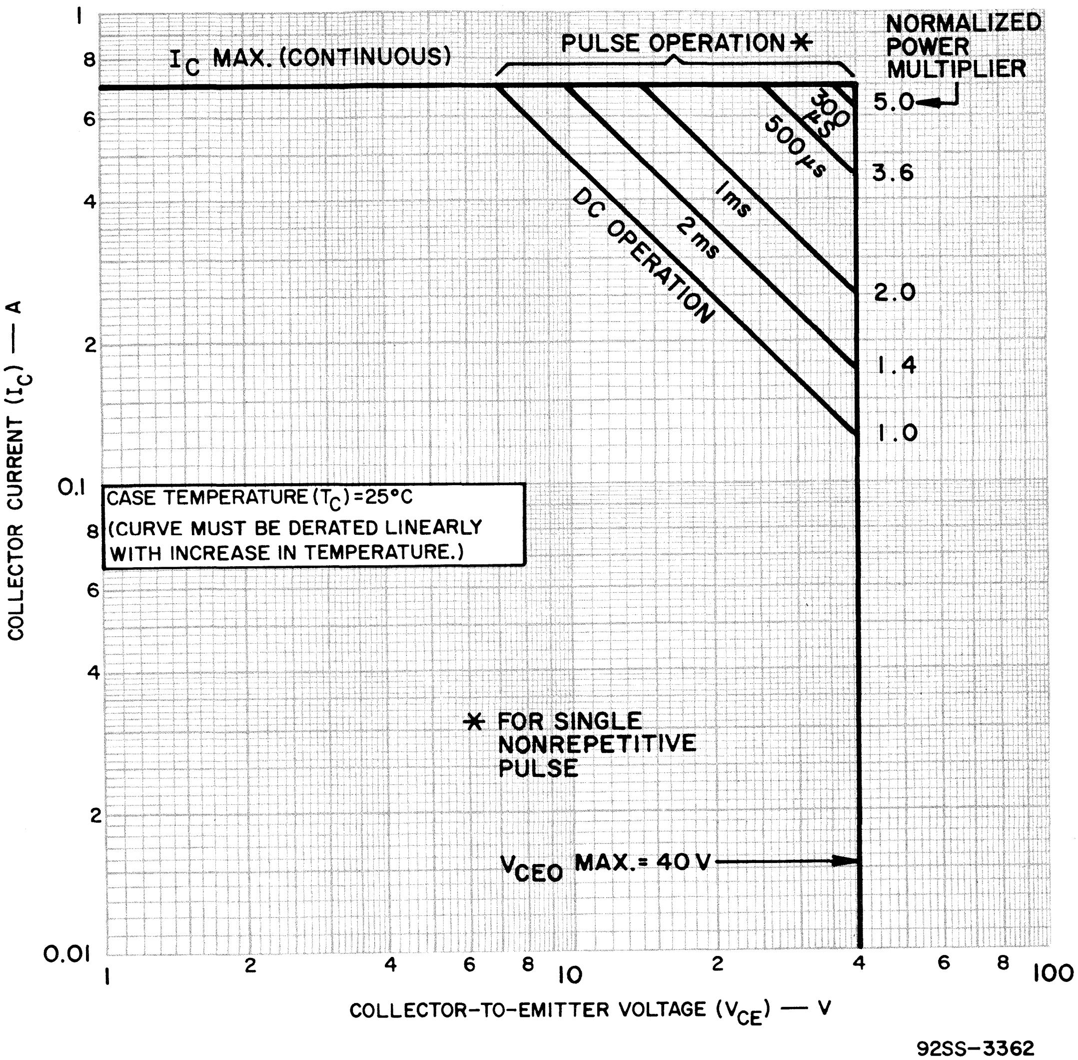


Fig. 2 - Maximum operating areas for type 2N3053.

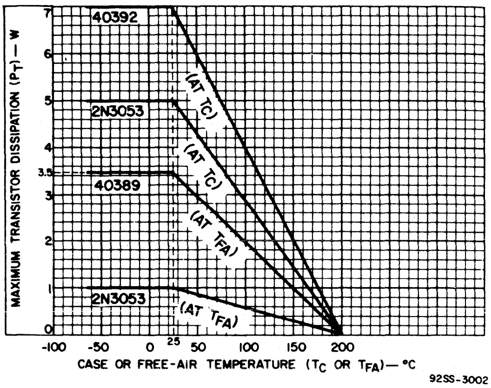


Fig. 3 - Dissipation derating curves for all types.

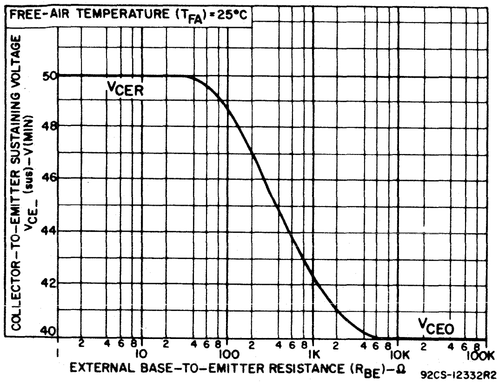


Fig. 4 - Sustaining voltage vs. base-to-emitter resistance for all types.

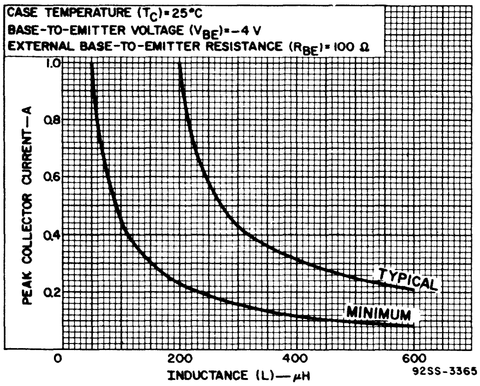


Fig. 5 - Reverse-bias, second-breakdown characteristics for all types.

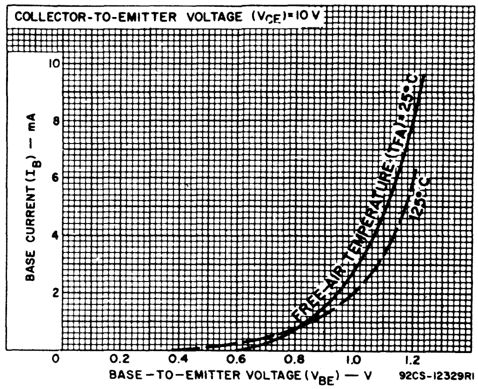


Fig. 6 - Typical dc-beta characteristics for all types.

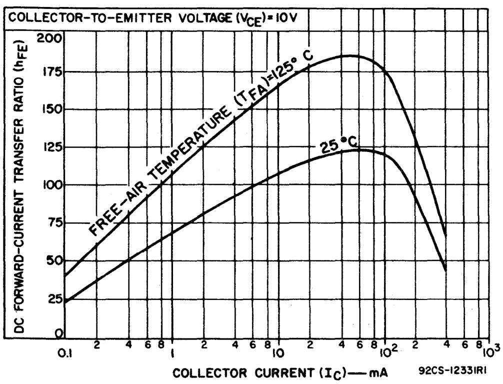


Fig. 7 - Typical input characteristics for all types.

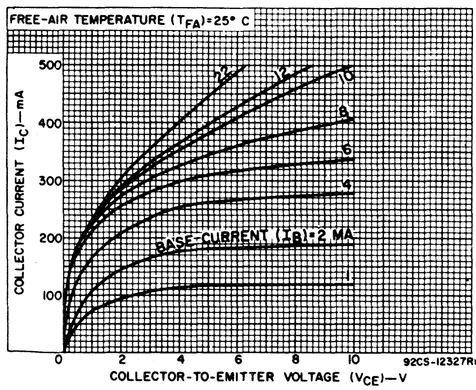


Fig. 8 - Typical output characteristics for all types.

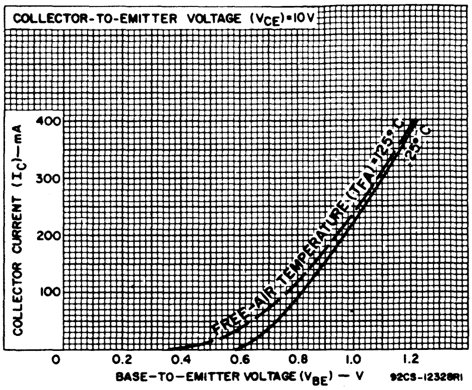


Fig. 9 - Typical transfer characteristics for all types.

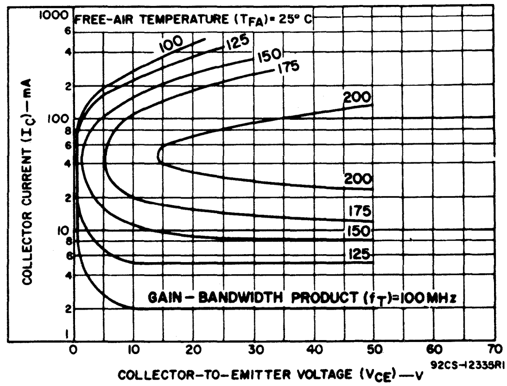


Fig. 10 - Typical variation of gain-bandwidth product with I_C and V_{CE} for all types.

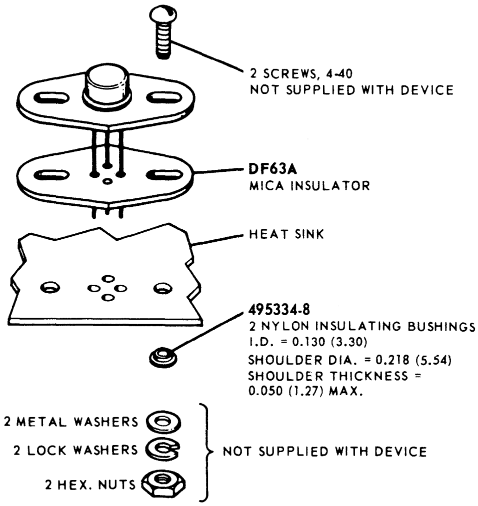
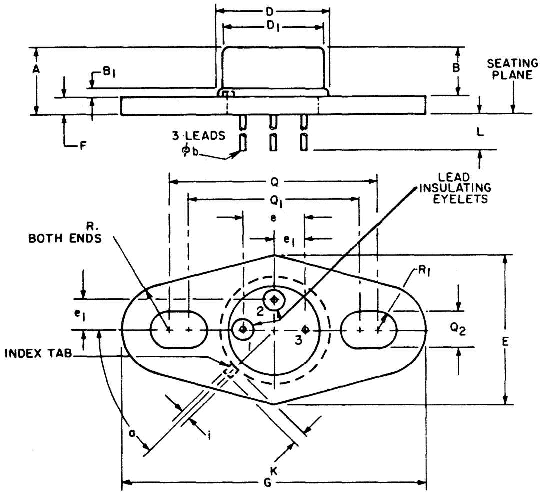


Fig. 11 - Suggested mounting hardware for type 40392 (JEDEC TO-5 with mounting flange).

DIMENSIONAL OUTLINE FOR TYPE 40392 JEDEC TO-5 WITH MOUNTING FLANGE



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A		.328		8.33	
B	.240	.260	6.10	6.60	
B_1	.009	.125	.229	3.18	
φb	.016	.019	.406	.483	
D	.335	.370	8.51	9.40	
D_1	.305	.335	7.75	8.51	
E	.495	.505	12.57	12.83	
e	.200 T.P.		5.08 T.P.		1
e_1	.100 T.P.		2.54 T.P.		1
F	.062	.068	1.57	1.74	
G	.995	1.005	25.27	25.53	
i	.028	.034	.711	.864	
k	.029	.045	.737	1.14	
L	1.43	-	36.32	-	
Q	.685	.691	17.40	17.55	
Q_1	.559	.565	14.20	14.35	
Q_2	.128	.132	3.25	3.35	
R	.156 T.P.		3.96 T.P.		1
R_1	.064	.066	1.63	1.67	
α	45° T.P.				1,2

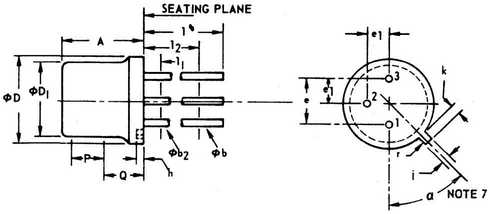
NOTES:
1. True Position
2. Tab centerline

92CS-12621R5

TERMINAL CONNECTIONS
FOR TYPE 40392

Lead 1 - Emitter
Lead 2 - Base
Flange, Lead 3 - Collector

DIMENSIONAL OUTLINE FOR TYPE 2N3053 JEDEC TO-5



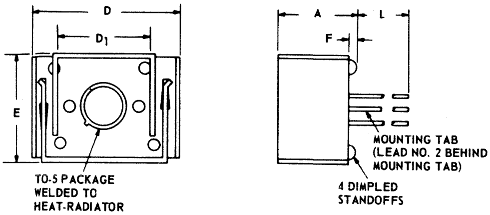
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.016	.021	.406	.533	2
Φb_2	.016	.019	.406	.483	2
ΦD	.335	.370	8.51	9.40	
ΦD_1	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
j	.028	.034	.711	.864	5
k	.029	.045	.737	1.14	3,5
l	1.500		38.10		2
l_L		.050		1.27	2
l_2	.250		6.35		2
P	.100		2.54		1
Q					6
r		.007		.179	
α	45° T.P.				5,7

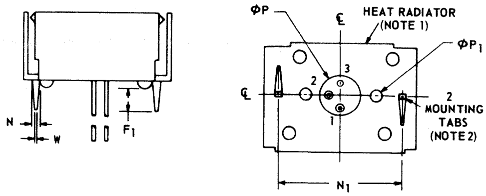
NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) Φb_2 applies between l_1 and l_2. Φb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

DIMENSIONAL OUTLINE FOR TYPE 40389 JEDEC TO-5 WITH HEAT RADIATOR





SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	–	.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	.745	.755	18.923	19.177	
E	.875	.905	22.22	22.99	
F	.040	.055	1.02	1.40	
F_1	.170	.225	4.32	5.72	
L	1.410	–	35.81	–	
ΦP	.295	.305	7.493	7.747	
ΦP_1	.093	.095	2.362	2.413	
N	.048	.062	1.21	1.57	
N_1	.998	1.002	25.349	25.450	3
W	.048	.052	1.219	1.320	

NOTES:

1. 0.035 C.R.S., finish–electroless nickel plate
2. Recommended hole size for printed-circuit board is 0.070 dia.
3. Measured at bottom of heat-radiator

92SS-2546R2

TERMINAL CONNECTIONS

FOR TYPE 2N3053

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

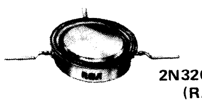
FOR TYPE 40389

Lead 1 - Emitter
Lead 2 - Base
Heat-Radiator, Lead 3 - Collector

RCA Solid State Division

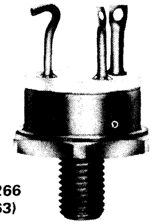
Power Transistors

2N3263 2N3264 2N3265 2N3266



H-1354

2N3263, 2N3264 (RADIAL)



H-1785

2N3265, 2N3266 (JEDEC TO-63)

High-Power, High-Speed, High-Current Silicon N-P-N Power Transistors

Epitaxial Types for Aerospace, Military, and Industrial Applications

Features:

- **Low saturation voltages —**
  - **2N3263 and 2N3265**
    - **V_{CE}(sat) = 0.75 V (max.) at I_C = 15 A**
    - **V_{BE}(sat) = 1.60 V (max.) at I_C = 15 A**
  - **2N3264 and 2N3266**
    - **V_{CE} (sat) = 1.20 V (max.) at I_C = 15 A**
    - **V_{BE} (sat) = 1.80 V (max.) at I_C = 15 A**
- **High reliability and uniformity of characteristics**
- **High power dissipation**
- **Fast rise time at high collector current — 0.2 μs at 10 A (typical)**

RCA-2N3263, 2N3264, 2N3265, and 2N3266● are n-p-n epitaxial silicon power transistors designed for high-reliability aerospace, military, and industrial equipment. Their high current-handling capability and fast switching speed make them desirable in applications where high circuit efficiency is required.

The 2N3263 and 2N3264 are sealed in flat 3/4-inch-diameter packages with radial leads. Types 2N3265 and 2N3266 utilize the JEDEC TO-63 package.

Typical high-speed switching applications for these transistors include switching-control amplifiers, power gates, switching regulators, dc-dc converters, and dc-ac inverters. Other recommended applications include dc-rf amplifiers and power oscillators.

● Formerly RCA Dev. Nos. TA2492, TA2493, TA2494, and TA2495, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N3264 2N3266	2N3263 2N3265	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	120	150	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With 1.5 volts (V_{BE}) of reverse bias	V_{CEX}(sus)	120	150	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω	V_{CER}(sus)	80	110	V
* With base open	V_{CEO} (sus)	60	90	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	V
* COLLECTOR CURRENT	I_C	25	25	A
* BASE CURRENT	I_B	10	10	A
* TRANSISTOR DISSIPATION	P_T	*See Figs. 1 & 2*		
* TEMPERATURE RANGE:				
Storage and operating (Junction)		−65 to +200		°C
LEAD TEMPERATURE (During soldering):				
At distance ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		230		°C

* In accordance with JEDEC registration data format.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc: V_{CB}	VOLTAGE V dc: V_{CE}	VOLTAGE V dc: V_{EB}	CURRENT A dc: I_E	CURRENT A dc: I_B	CURRENT A dc: I_C	LIMITS 2N3264 2N3266 MIN.	LIMITS 2N3264 2N3266 MAX.	LIMITS 2N3263 2N3265 MIN.	LIMITS 2N3263 2N3265 MAX.	UNITS
Collector Cutoff Current: With emitter open	I_{CBO}	60			0			–	10	–	–	mA
		80			0			–	–	–	4	
At T_C = 125°C		60			0			–	10	–	–	
		80			0			–	–	–	4	
* With base reverse-biased	I_{CEX}		120	1.5				–	20	–	–	
			150	1.5				–	–	–	20	
* Emitter Cutoff Current:	I_{EBO}			7			0	–	15	–	5	mA
* At T_C = 125°C				7			0	–	15	–	5	
Emitter-to-Base Voltage	V_{EBO}				0.02		0	7	–	7	–	V
Collector-to-Emitter Sustaining Voltage: * With base open	$V_{CEO}(sus)$●					0	0.2	60	–	90	–	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω	$V_{CER}(sus)$●					0	0.2	80	–	110	–	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$●					2	20	–	1.6	–	1	V
						1.2	15	–	1.2	–	0.75	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$●					2	20	–	2.2	–	1.8	V
						1.2	15	–	1.8	–	1.6	
* DC Forward Current * Transfer Ratio	h_{FE}●		3				5	35	–	40	–	
			3				15	20	80	25	75	
			2				15	–	–	20	55	
* Second-Breakdown Collector Current: (See Fig. 7) DC forward-biased	$I_{S/b}$▲	50						700	–	–	–	mA
		75						–	–	350	–	
* Pulsed, forward-biased, t_p = 250 µs		75						13.3	–	13.3	–	A
* Second-Breakdown Energy With base reverse-biased, and R_{BE} = 20Ω, L = 40µH	$E_{S/b}$**			6			10	2	–	2	–	mJ
* Saturated Switching Time: (See Figs. 3 & 4) Turn-on ($t_d + t_r$)	t_{ON}	V_{CC} = 30				1.2♣	15	–	0.5	–	0.5	µs
Storage	t_s					1.2♣	15	–	1.5	–	1.5	
Fall	t_f					1.2♣	15	–	0.5	–	0.5	
* Gain-Bandwidth Product (f = 1 MHz)	f_T		10				3	20	–	20	–	MHz
Collector-to-Base Feedback Capacitance (f = 1 MHz)	C_{ob}	10			0			–	500	–	500	pF
* Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$		10				10	2N3263 2N3264: –	1.5	2N3265 2N3266: –	1	°C/W

* In accordance with JEDEC registration data format.

● Pulsed; pulse duration ≤ 350 µs, duty factor ≤ 2%. CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 5.

▲ $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

** $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = 1/2\ LI^2$, where L is a series load or leakage inductance and I is the collector current.

♣ $I_{B_1} = I_{B_2}$.

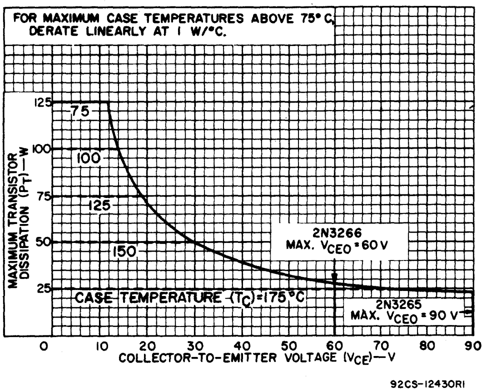


Fig.1—Rating chart for 2N3265 and 2N3266.

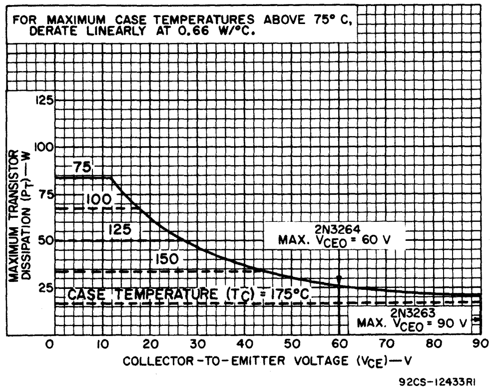


Fig.2—Rating chart for 2N3263 and 2N3264.

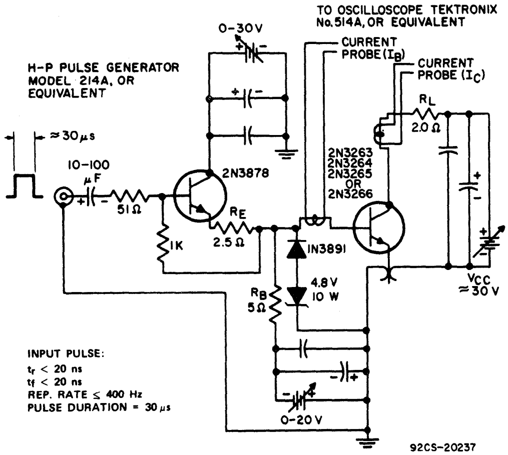


Fig.3—Circuit used to measure saturated switching times.

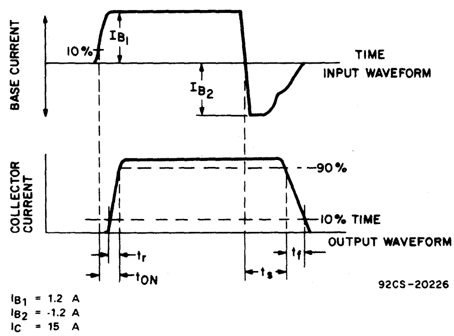


Fig.4—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 3.)

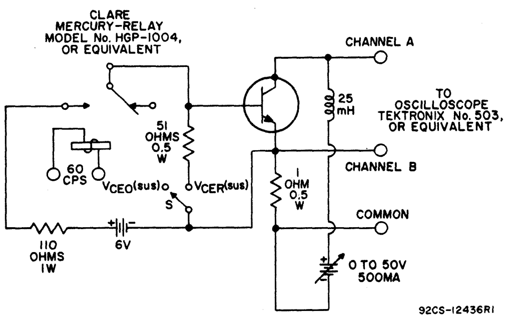
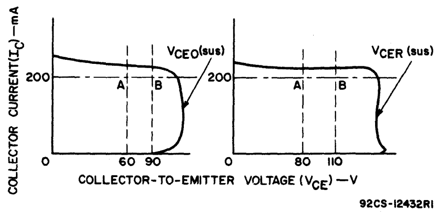


Fig.5—Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$.



The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) are acceptable when the traces fall to the right of point "A" for types 2N3264 and 2N3266. The traces must fall to the right of point "B" for types 2N3263 and 2N3265.

Fig.6—Oscilloscope display for $V_{CEO}(sus)$ and $V_{CER}(sus)$ measurement. (Test circuit shown in Fig. 5.)

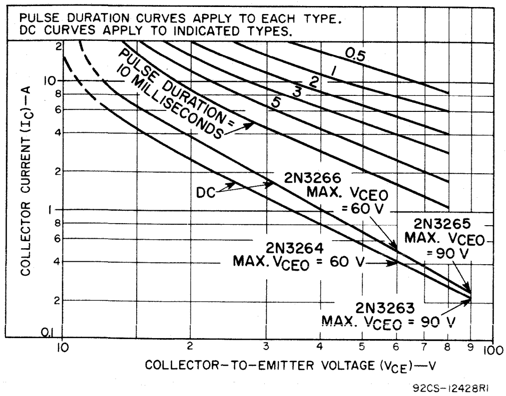


Fig.7—Safe-operating region as a function of pulse width.

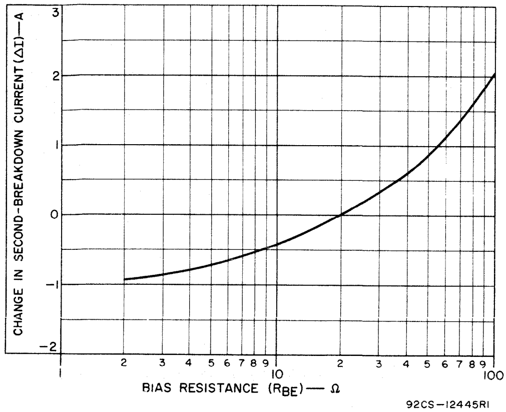


Fig.8—Typical change in $E_{S/b}$ as a function of base-to-emitter resistance.

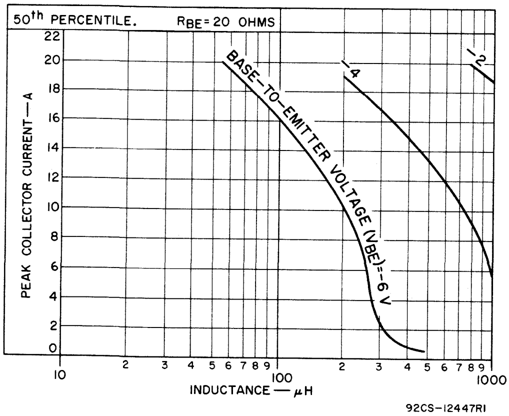


Fig.9—Collector current as a function of inductance (10th percentile).

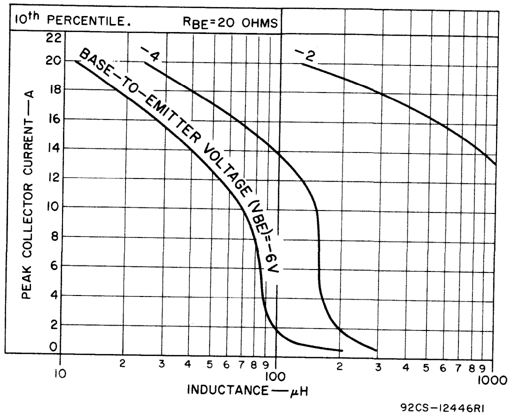


Fig.10—Collector current as a function of inductance (50th percentile).

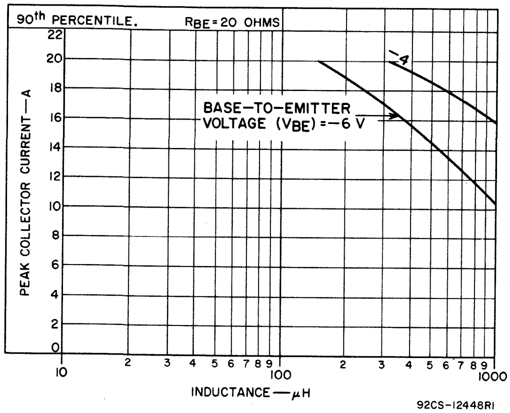


Fig.11—Collector current as a function of inductance (90th percentile).

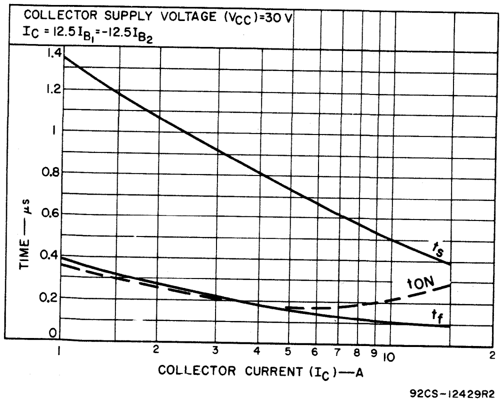


Fig.12—Typical saturated-switching characteristics.

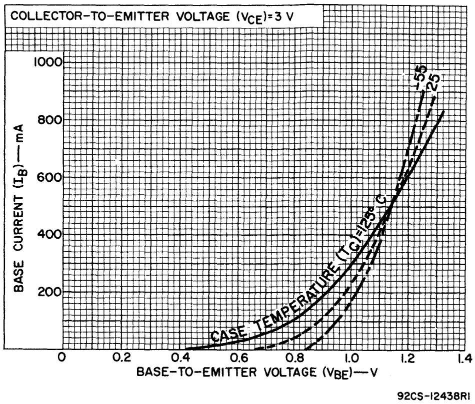


Fig.13—Typical input characteristics.

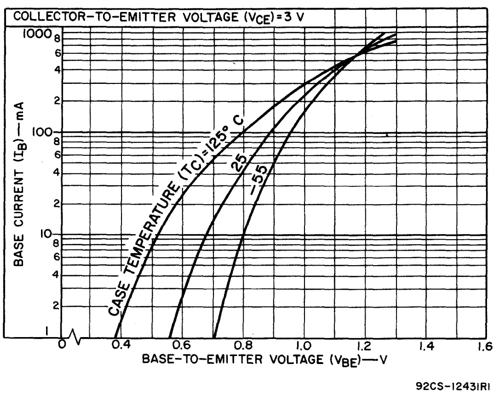


Fig.14—Typical input characteristics.

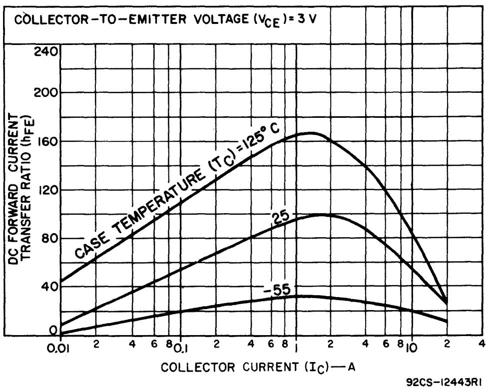


Fig.15—Typical dc beta characteristics (median values).

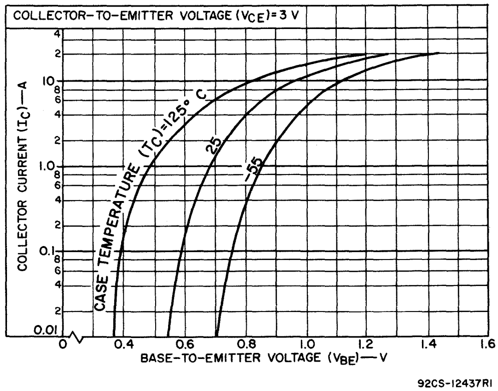


Fig.16—Typical transfer characteristics.

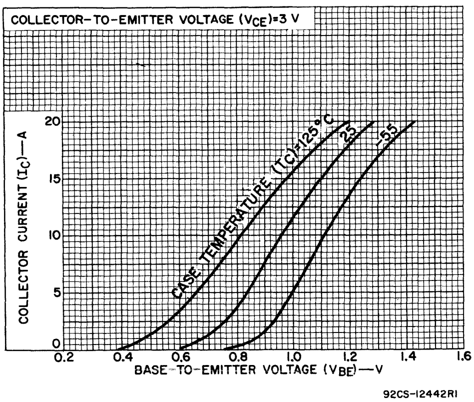


Fig.17—Typical transfer characteristics.

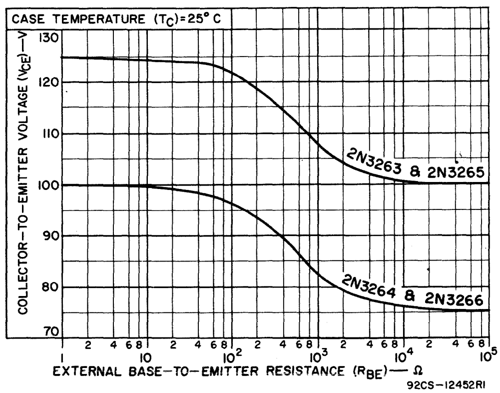
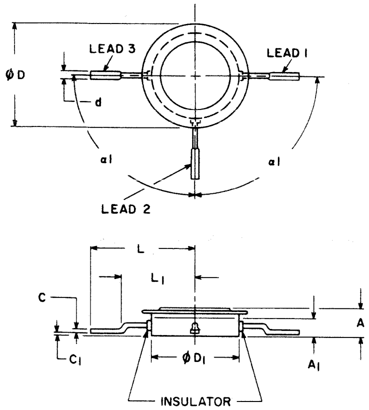


Fig. 18—Typical sustaining voltage vs. base-to-emitter resistance.

DIMENSIONAL OUTLINE
TYPES 2N3263 and 2N3264



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.200	–	5.08	
A_1	–	0.125	–	3.17	1
c	0.015	0.019	0.38	0.48	
c_1	–	0.015	–	0.38	
φD	–	0.710	–	18.03	
$φD_1$	0.615	0.690	15.62	17.52	1
d	0.042	0.046	1.06	1.16	
L	–	0.705	–	17.90	
L_1	–	0.510	–	12.95	
$α_1$	$90° \pm 2°$		$90° \pm 2°$		

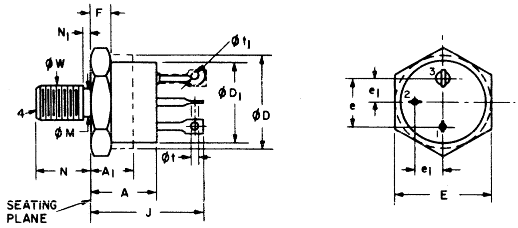
92CS- 20224

NOTE:
1. CONTROLLED AREA OF THE DIAMETER DOES NOT INCLUDE THE BRAZED AREA AROUND THE CERAMIC AND TERMINAL 2.

TERMINAL CONNECTIONS

Lead 1 — Base
Case, Lead 2 — Collector
Lead 3 — Emitter

DIMENSIONAL OUTLINE
TYPES 2N3265 and 2N3266
JEDEC TO-63



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.480	0.535	12.19	13.59	
A_1	–	0.300	–	7.62	2
φD	0.775	0.875	19.69	22.23	2
$φD_1$	0.745	0.775	18.92	19.69	
E	0.855	0.875	21.72	22.23	
e	0.485	0.515	12.32	13.08	5
e_1	0.240	0.260	6.10	6.60	5
F	0.090	0.167	2.29	4.24	1
J	0.937	1.030	23.80	26.16	
φM	0.278	0.312	7.06	7.92	
N	0.460	0.495	11.68	12.57	
N_1	–	0.105	–	2.67	
φt	0.060	0.105	1.52	2.67	
$φt_1$	0.060	0.105	1.52	2.67	4
φW	0.2806	0.2854	7.127	7.249	3

92CS-20225

NOTES:
1. DIMENSION DOES NOT INCLUDE SEALING FLANGES.
2. PACKAGE CONTOUR OPTIONAL WITHIN DIMENSIONS SPECIFIED.
3. PITCH DIAMETER - THREAD 5/16-24 UNF-2A (COATED). REFERENCE (SCREW THREAD STANDARDS FOR FEDERAL SERVICES - HANDBOOK H-2B).
4. THIS TERMINAL CAN BE FLATTENED AND PIERCED OR HOOK TYPE.
5. POSITION OF LEADS IN RELATION TO THE HEXAGON IS NOT CONTROLLED.

TERMINAL CONNECTIONS

Pin 1 — Emitter
Pin 2 — Base
Case, Pin 3 — Collector

RCA Solid State Division

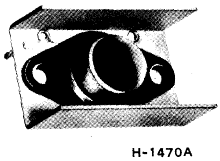
Power Transistors

2N3878 2N5202
2N3879 40375

RCA-2N3878, 2N3879, 2N5202* are epitaxial silicon n-p-n transistors. The 2N3878 is an amplifier type intended for audio-, ultrasonic-, and radio-frequency circuits. Types 2N3879 and 2N5202 are switching transistors intended for use in high-current, high-speed switching circuits.

Typical applications for these transistors include: low-distortion power amplifiers, oscillators, switching regulators, series regulators, converters, and inverters.

Formerly RCA Dev. Type Nos. TA2509, TA2509A, and TA7285, respectively.



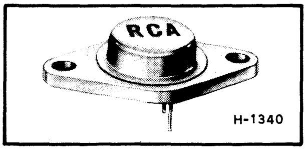
40375

ALSO AVAILABLE...

Type 40375 is a 2N3878 with a factory-attached heat radiator; it is intended for printed circuit-board applications.

SILICON N-P-N TRANSISTORS

Amplifier and Switching Types for Industrial and Commercial Applications



2N3878, 2N3879, & 2N5202 (JEDEC TO-66)

- Maximum operating-area curves for DC and pulse operation.
  $I_{S/b}$-limit line begins at: 36 V (2N3878)
  28 V (2N3879)
  23 V (2N5202)
- $V_{CER}(sus)$ = 90 V (2N3879)
  75 V (2N5202)
  65 V (2N3878)
- V_{CBO} = 120 V Max. (2N3878, 2N3879, 2N5202)
- Rated for safe operation in both forward- and reverse-bias conditions.
- Total saturated switching time typically less than 1 μs at 4 A for 2N3879 and 2N5202.

MAXIMUM RATINGS

Absolute-Maximum Values:		2N3878 40375	2N3879	2N5202	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	120	120	120	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$	65	90	75	V
With base open	$V_{CEO}(sus)$	50	75	–	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	7	V
CONTINUOUS COLLECTOR CURRENT	I_C	7	7	4	A
PEAK COLLECTOR CURRENT		10	10	5	A
CONTINUOUS BASE CURRENT	I_B	5	5	2	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25° C and V_{CE}					
up to 36 V		35 (2N3878)	–	–	W
28 V		–	35	–	W
23 V		–	–	35	W
At case temperatures up to 25° C and V_{CE}					
above 36 V		See *Fig.5*	–	–	
28 V		–	See *Fig.6*	–	
23 V		–	–	See *Fig.6*	
At case temperatures above 25° C and V_{CE}					
above 36 V		See *Figs.4 & 5*	–	–	
28 V		–	See *Figs.4 & 6*	–	
23 V		–	–	See *Figs.4 & 6*	
At free-air temperatures up to 25° C		5.8 (40375)	–	–	W
At free-air temperatures above 25° C		See *Fig.7*	–	–	
TEMPERATURE RANGE:					
Storage & Operating (Junction)		← –65 to 200 →			°C
PIN TEMPERATURE (During soldering):					
At distances ≥ 1/32 in. from seating plane for 10 s max.		← 255 →			°C

ELECTRICAL CHARACTERISTICS *Case Temperature (T_C) = 25° Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Emitter or Base Volts V_{EB}	DC Emitter or Base Volts V_{BE}	DC Current (Amperes) I_C	DC Current (Amperes) I_E	DC Current (Amperes) I_B	LIMITS: Types 2N3878 40375 Min.	Types 2N3878 40375 Max.	Type 2N3879 Min.	Type 2N3879 Max.	Type 2N5202 Min.	Type 2N5202 Max.	Units
Collector-Cutoff Current	I_{CEO}		40					0	–	5	–	5	–	–	mA
	I_{CEV}		100		−1.5				–	4	–	4	–	10	mA
	I_{CEV} (T_C = 150°C)		100		−1.5				–	4	–	4	–	10	mA
Emitter-Cutoff Current	I_{EBO}			4		0			–	4	–	2	–	–	mA
				6		0			–	–	–	–	–	10	
DC Forward-Current Transfer Ratio	h_{FE}		1.2			4			–	–	–	–	10	100	
			2			4			8	–	12	–	–	–	
			5			0.5			50	200	40	–	–	–	
			5			4			20	–	20	80	–	–	
Collector-to-Emitter Sustaining Voltage: *(See Fig. 1 & 2)* With base open	$V_{CEO}(sus)$					0.2		0	50[a]	–	75[a]	–	–	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$					0.2			65[a]	–	90[a]	–	75[a]	–	V
Base-to-Emitter Voltage	V_{BE}		1.2			4			–	–	–	–	–	1.9	V
			2			4			–	2.5	–	1.8	–	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					4		0.4	–	–	–	1.2	–	1.2	V
						4		0.5	–	2.0	–	–	–	–	V
Output Capacitance (At 1 MHz)	C_{ob}	10					0		–	175	–	175	–	175	pF
Second-Breakdown[b] Collector Current[d] (With base forward biased)	$I_{S/b}$[c]		40						750	–	500	–	400	–	mA
Second-Breakdown[b] Energy: With base reverse biased, R_B = 50 Ω, L = 50 μH	$E_{S/b}$[e]				V_{BB} = −4				–	–	–	–	0.4	–	mJ
With base reverse biased, R_B = 50 Ω, L = 125 μH					V_{BB} = −4				1	–	1	–	–	–	mJ
Small-Signal, Forward-Current Transfer Ratio (At 10 MHz)	h_{fe}		10			0.5			6.0	–	6.0	–	6.0	–	
Sat. Switching Turn-On Time: Delay Time	t_d		V_{CC} = 30			4		0.4[f]	–	–	–	40	–	40	ns
Rise Time *(See Fig. 24, 25, & 26)*	t_r		V_{CC} = 30			4		0.4[f]	–	–	–	400	–	400	ns
Sat. Switching Storage Time *(See Fig. 24, 25, & 27)*	t_s		V_{CC} = 30			4		−0.4[g]	–	–	–	800	–	800	ns
Sat. Switching Fall Time *(See Fig. 24, 25, & 28)*	t_f		V_{CC} = 30			4		−0.4[g]	–	–	–	400	–	400	ns
Thermal Resistance (Junction-to-Case)	θ_{J-C}								5 Max. 2N3878		–	5	–	5	°C/W
(Junction-to-Free Air)	θ_{J-FA}								30 Max. 40375		–	–	–	–	°C/W

CIRCUIT USED TO MEASURE SUSTAINING VOLTAGES $V_{CEO}(sus)$ & $V_{CER}(sus)$ FOR TYPES 2N3878, 2N3879, & 2N5202

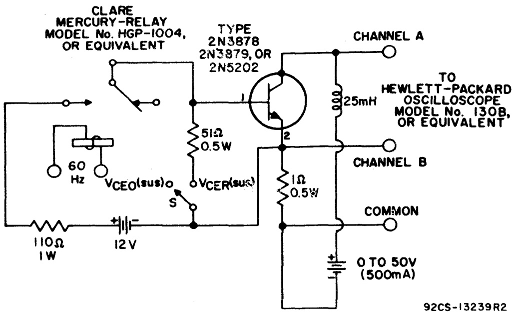
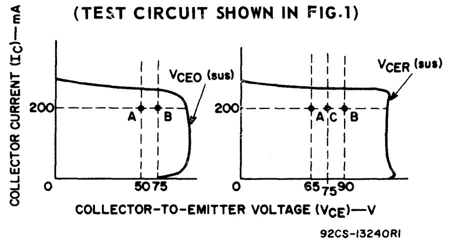


Fig. 1

OSCILLOSCOPE DISPLAY FOR MEASUREMENT OF SUSTAINING VOLTAGES (TEST CIRCUIT SHOWN IN FIG.1)



The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ are acceptable when the traces fall to the right and above point "A" for type 2N3878; and point "B" for type 2N3879. The sustaining voltage $V_{CER}(sus)$ is acceptable when the trace falls to the right and above point "C" for type 2N5202.

Fig. 2

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPES 2N3878 & 2N3879

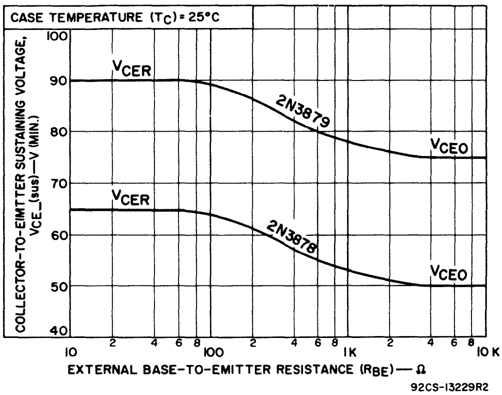


Fig. 3

DISSIPATION DERATING CURVE FOR TYPES 2N3878, 2N3879, & 2N5202

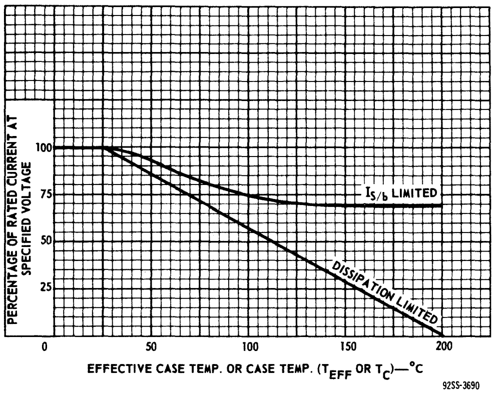


Fig. 4

FOOTNOTES (For Table of Electrical Characteristics)

[a] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in *Fig.1*.

[b] Safe-operating region for forward- and reverse-bias operation is explained on pages 4 and 8.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[d] Pulsed; 1-s, non-repetitive pulse.

[e] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = 1/2LI^2$. where L is a series load or leakage inductance and I is the peak collector current.

[f] I_{B1} value (turn-on base current).

[g] I_{B2} value (turn-off base current).

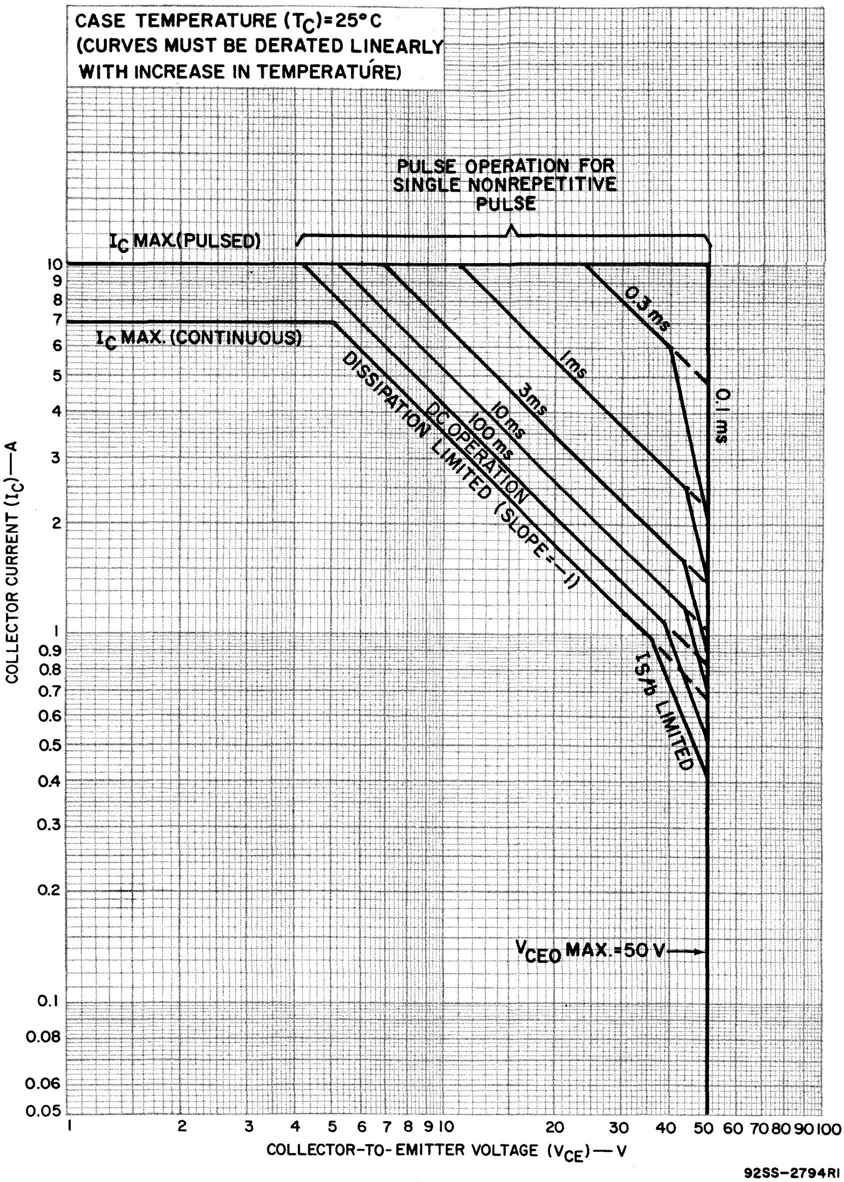

CASE TEMPERATURE (T_C)=25°C
(CURVES MUST BE DERATED LINEARLY WITH INCREASE IN TEMPERATURE)
PULSE OPERATION FOR SINGLE NONREPETITIVE PULSE
I_C MAX.(PULSED)
I_C MAX. (CONTINUOUS)
0.3 ms
1ms
3ms
10 ms
100 ms
DC OPERATION
DISSIPATION LIMITED (SLOPE=-1)
0.1 ms
IS/b LIMITED
V_{CEO} MAX.=50 V
COLLECTOR CURRENT (I_C)—A
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.08
0.06
0.05
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
COLLECTOR-TO-EMITTER VOLTAGE (V_{CE})—V
92SS-2794R1

Fig. 5

MAXIMUM OPERATING AREAS FOR TYPES 2N3879 & 2N5202

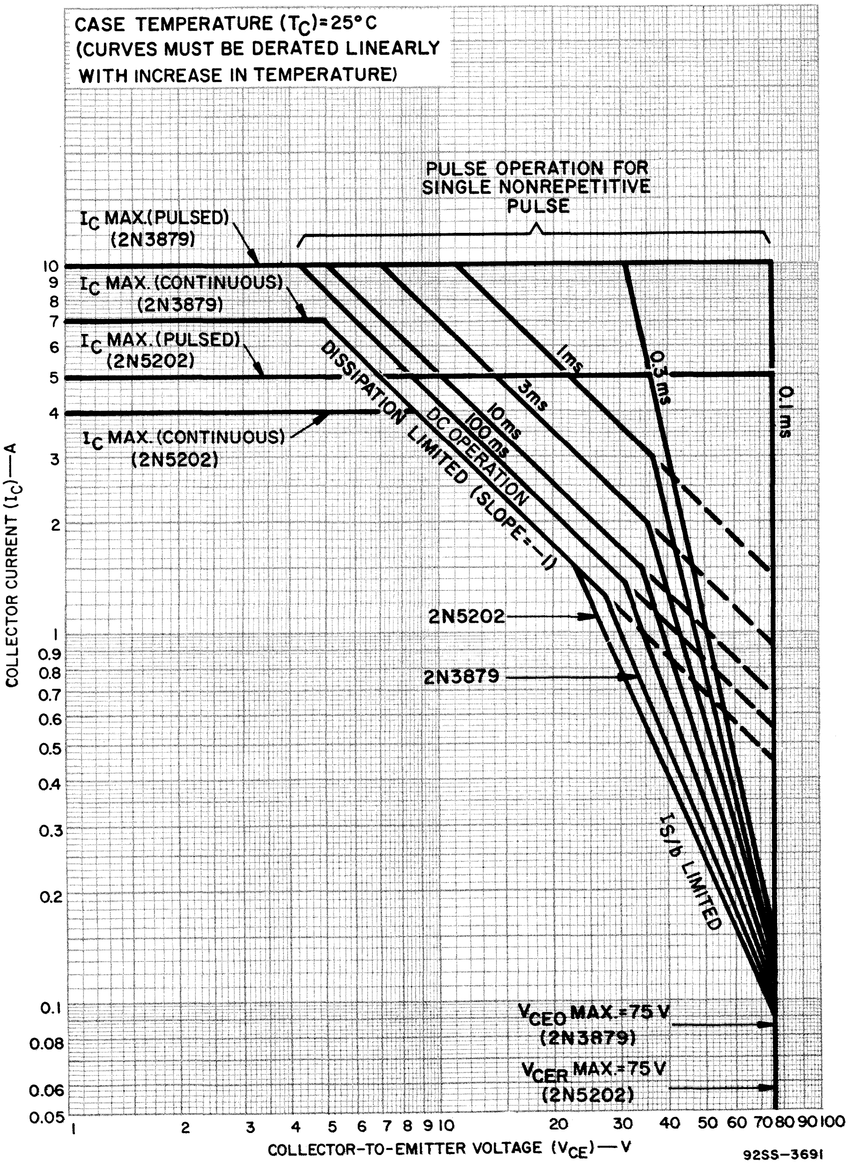


Fig. 6

MAXIMUM OPERATING AREAS FOR TYPE 40375

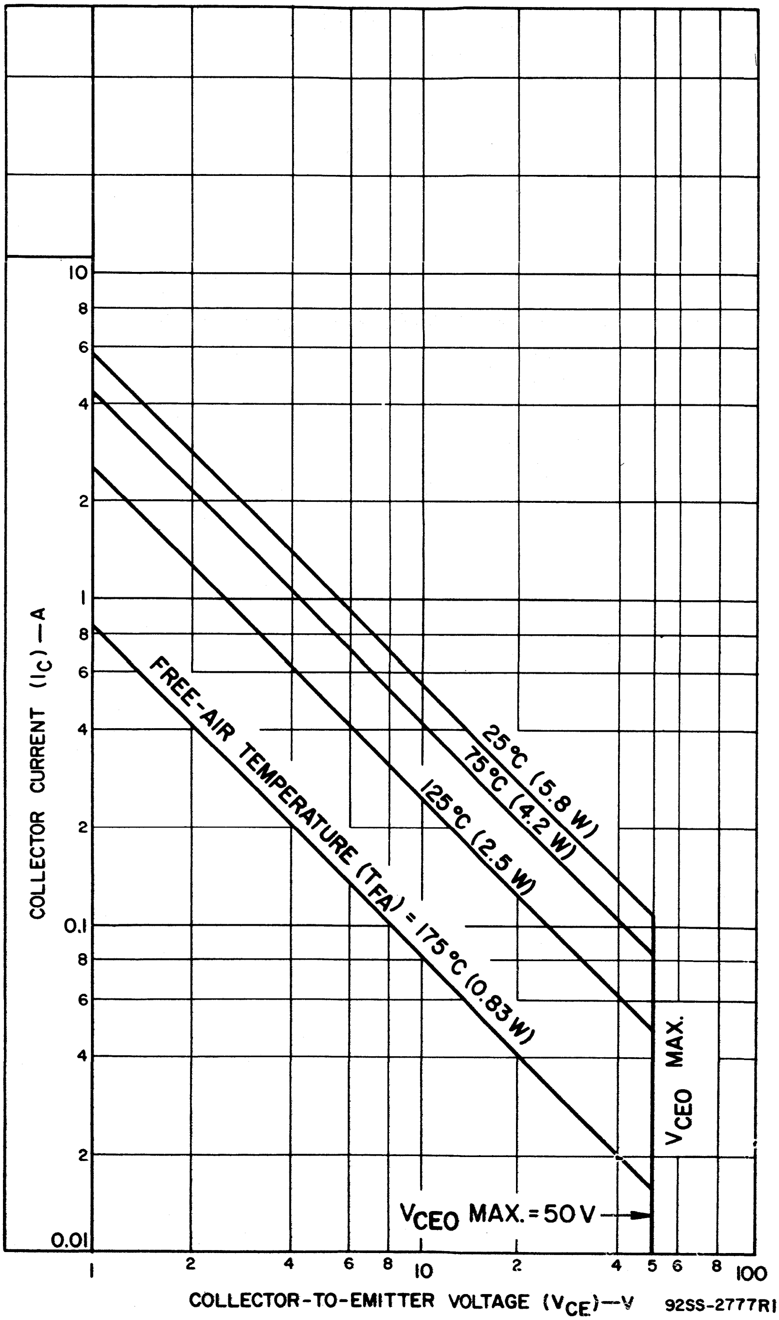


Fig. 7

REVERSE-BIAS OPERATION

The energy required to induce second breakdown when the transistor is turned off depends on the current during the "on" condition, the emitter-to-base voltage and resistance when the transistor is turned off, and the amount of inductance in series with the collector. The curves shown in *Fig. 8, 9, 10* (2N3878, 2N3879) or *Fig. 11, 12, 13* (2N5202) should prove useful in the design of circuits having inductive loads (such as solenoid- or relay-control circuits, magnetic-amplifier and -deflection circuits, and switching regulators) without protective zener diodes across the collector-to-emitter terminals. Also, these curves can be used when designing circuits where some leakage inductance is present (such as in inverters, converters, and transformer-coupled power amplifiers.)

In general, reverse-bias, second breakdown energy ($E_{S/b}$) capability increases with a decrease in inductance. Therefore, the allowable energy shown in the above-mentioned curves (calculated from $E_{S/b} = 1/2LI^2$, where L is a series load or leakage inductance and I is the peak collector current from the curves) will be conservative for smaller inductive loads. For further information on second breakdown, consult RCA "Silicon Power Circuits Manual" Form No. (SP-50) and SMA-30, "Second Breakdown in Transistors Under Conditions of Cut-off."

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPES 2N3878 & 2N3879

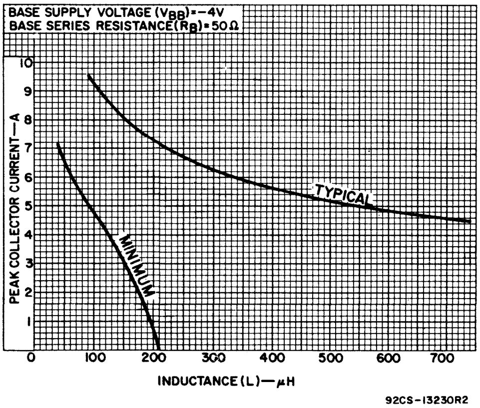


Fig. 8

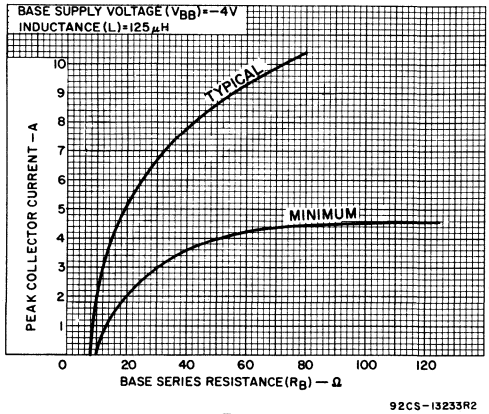


Fig. 9

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPES 2N3878 & 2N3879

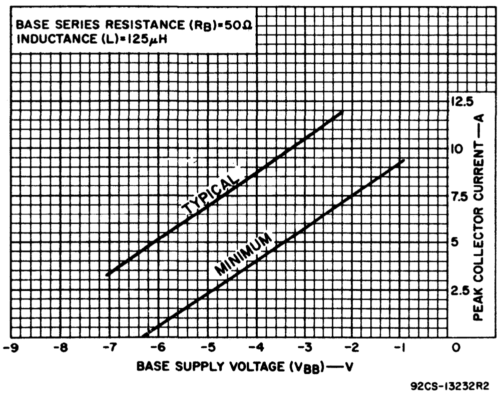


Fig. 10

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPE 2N5202

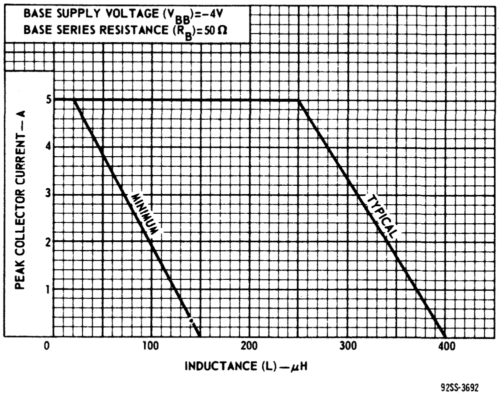


Fig. 11

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPE 2N5202

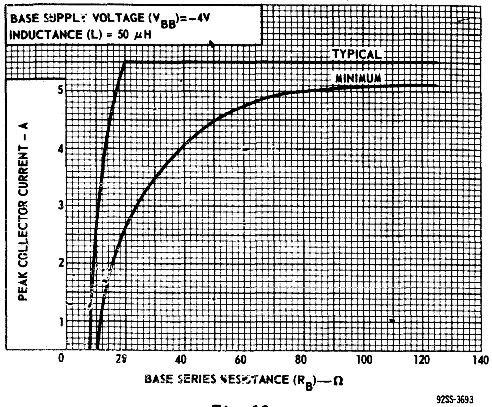


Fig. 12

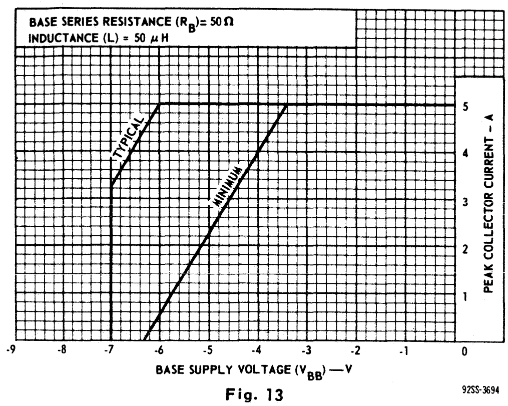


Fig. 13

TYPICAL DC BETA FOR TYPES 2N3878 & 2N3879

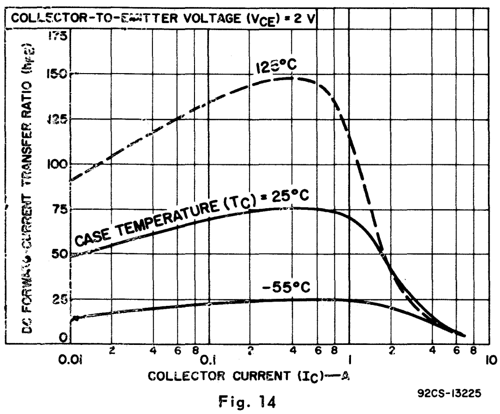


Fig. 14

TYPICAL DC BETA FOR TYPES 2N3878 & 2N3879

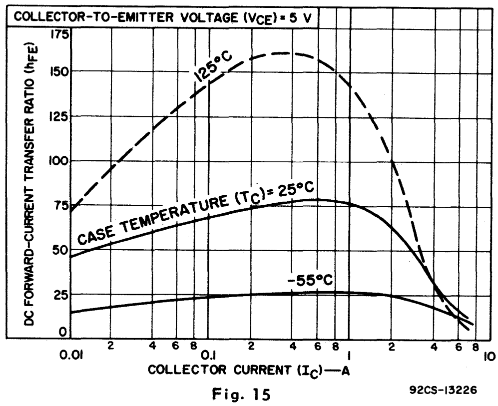


Fig. 15

TYPICAL DC BETA FOR TYPE 2N5202

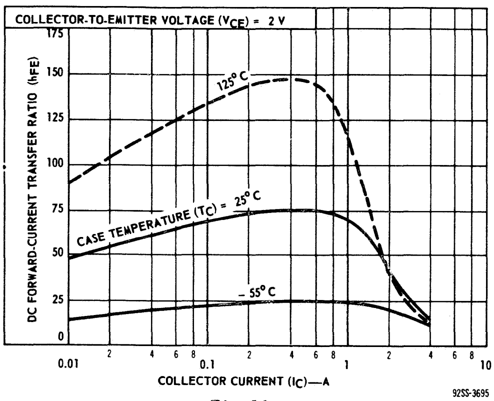


Fig. 16

TYPICAL DC BETA FOR TYPE 2N5202

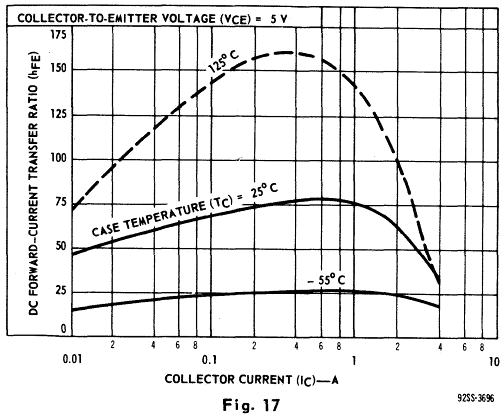


Fig. 17

TYPICAL INPUT CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

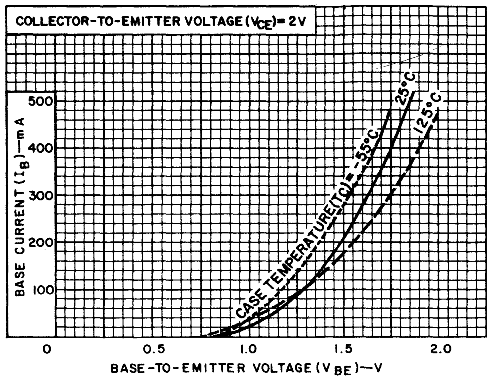


Fig. 18

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

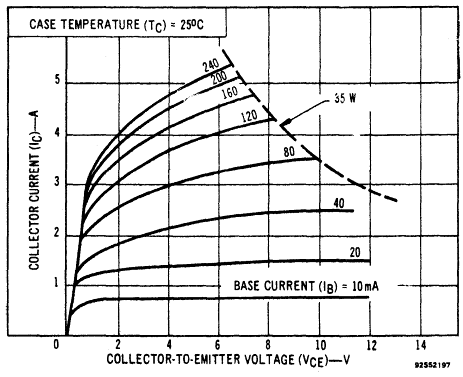


Fig. 19

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

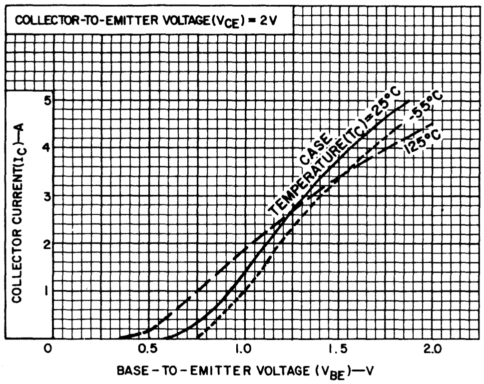


Fig. 20

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPES 2N3878, 2N3879, & 2N5202

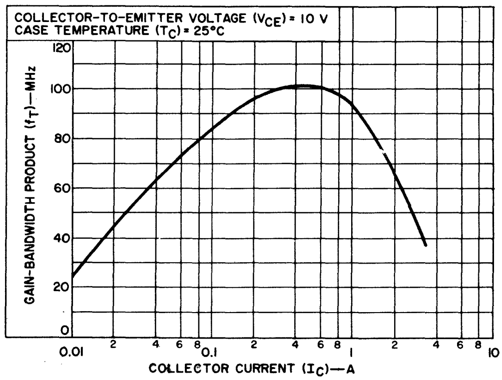


Fig. 21

TYPICAL SATURATION VOLTAGE CHARACTERISTICS FOR TYPES 2N3878 & 2N3879

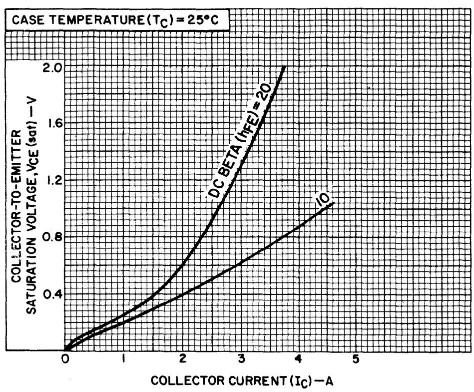


Fig. 22

TYPICAL SATURATION VOLTAGE CHARACTERISTICS FOR TYPE 2N5202

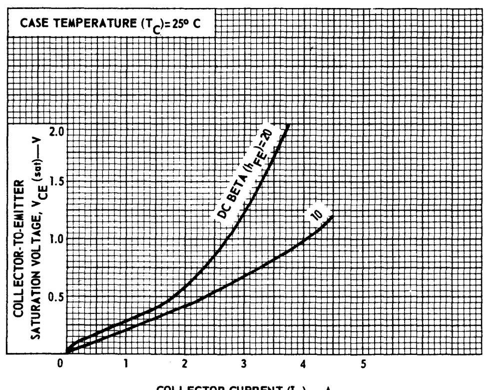
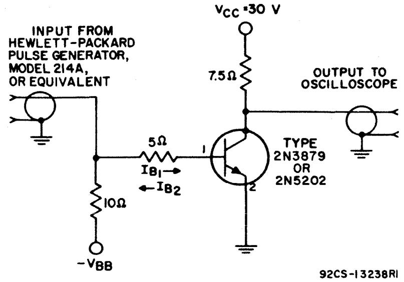


Fig. 23

CIRCUIT USED TO MEASURE SWITCHING TIMES FOR TYPES 2N3879 & 2N5202



INPUT PULSE:

Pulse rep. rate = 1,000 pulses/s
Pulse width = 20 μs

Fig. 24

OSCILLOSCOPE DISPLAY FOR MEASUREMENT OF SWITCHING TIMES (TEST CIRCUIT SHOWN IN FIG.24)

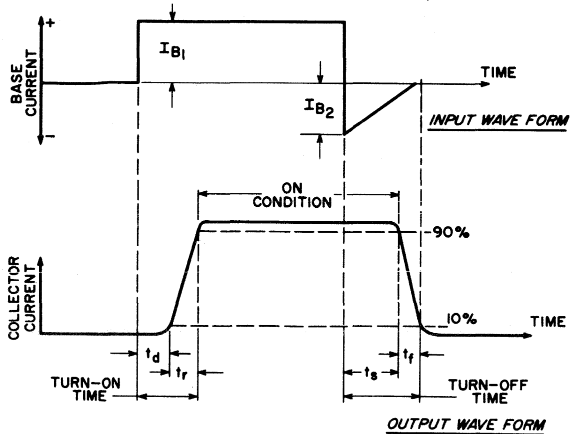


Fig. 25

92CS-12874

TYPICAL TURN-ON TIME FOR TYPES 2N3879 & 2N5202

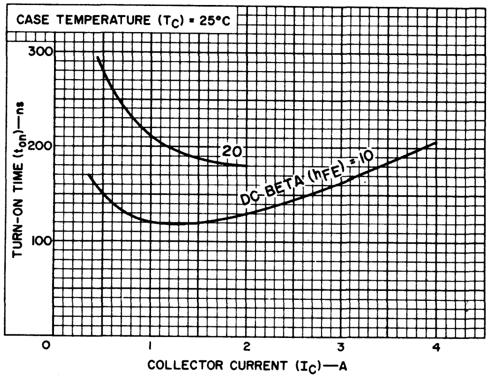


Fig. 26

TYPICAL STORAGE-TIME FOR TYPES 2N3879 & 2N5202

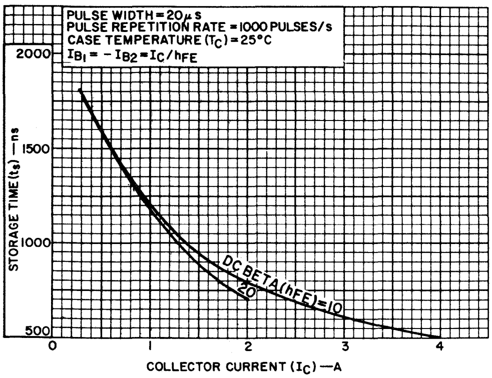


Fig. 27

92CS-13237

TYPICAL FALL-TIME FOR TYPES 2N3879 & 2N5202

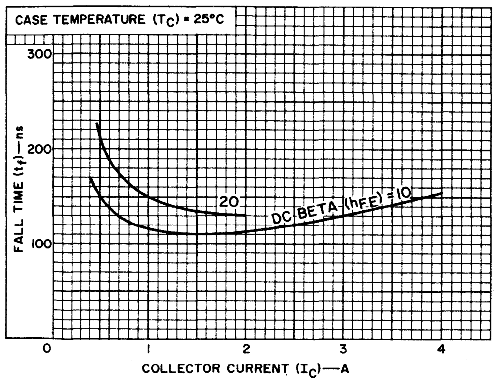


Fig. 28

92CS-13235

SUGGESTED HARDWARE FOR MOUNTING TYPES 2N3878, 2N3879, & 2N5202

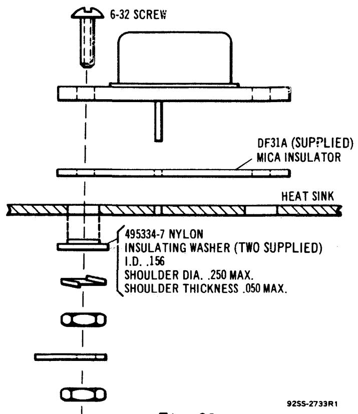
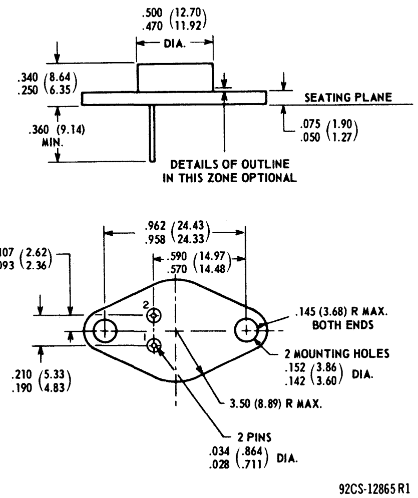


Fig. 29

DIMENSIONAL OUTLINE FOR TYPES 2N3878, 2N3879, & 2N5202

JEDEC TO-66

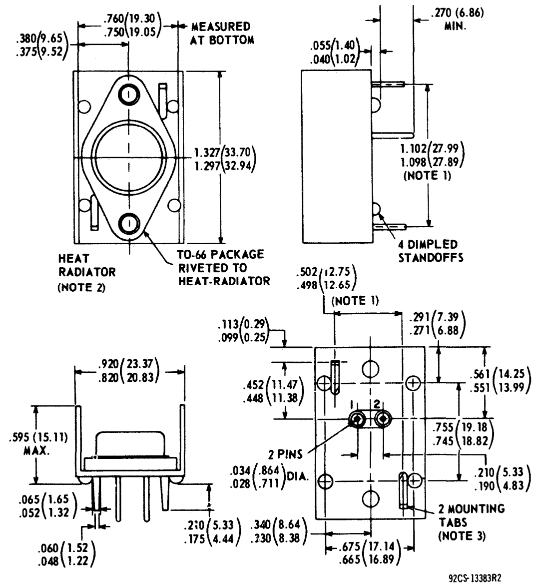


Dimensions in Inches and Millimeters

NOTE: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

DIMENSIONAL OUTLINE FOR TYPE 40375

JEDEC TO-66 WITH HEAT-RADIATOR



Dimensions in Inches and Millimeters

NOTE: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Note 1: Measured at bottom of heat-radiator.

Note 2: 0.035" C.R.S., tin plated.

Note 3: Recommended hole size for printed-circuit board is 0.070" dia.

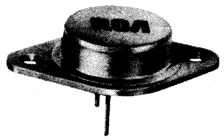
TERMINAL CONNECTIONS FOR TYPES 2N3878, 2N3879, 2N5202, & 40375

Pin 1 - Base
Pin 2 - Emitter
Flange, Case - Collector (For 2N3878, 2N3879, & 2N5202)
Heat Radiator - Collector (For 40375)

RCA
Solid State
Division

Power Transistors

2N5038
2N5039



JEDEC TO-3 H-1570

High-Current, High-Power, High-Speed Silicon N-P-N Power Transistors

Devices for Switching and Amplifier Circuits in Industrial and Commercial Applications

Features:

- **Maximum operating area curves for dc and pulse operation**
- **$I_{S/b}$-limit line beginning at 28 V**
- **High collector current ratings . . .**
  30 A (peak) 20 A (continuous)
- **High-dissipation capability . . .**
  P_T = 140 W max. at T_C = 25° C
- **h_{FE} & t_{on} measured at 12 A (2N5038) & 10 A (2N5039)**
  h_{FE} = 20 min.
  t_{on} = 0.5 μs max.
  t_s = 1.5 μs max.
  t_f = 0.5 μs max.
  } **2N5038, 2N5039**

RCA-2N5038 and 2N5039* are epitaxial silicon n-p-n power transistors utilizing a multiple-emitter-site structure. They differ in breakdown-voltage ratings, leakage-current, and dc-beta values.

The high current-handling capability of these transistors in conjunction with fast switching speeds make the 2N5038 and 2N5039 especially suitable for switching-control amplifiers, power gates, switching regulators, converters, and inverters. Other recommended applications include dc-rf amplifiers and power oscillators. The 2N5038 and 2N5039 utilize the JEDEC TO-3 package.

*Formerly RCA Dev. Nos. TA2669A and TA2669, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N5038	2N5039	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	150	120	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With – 1.5 volts (V_{BE}) of reverse bias and external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CEX}(sus)$	150	120	V
With $R_{BE} \leq 50$ Ω	$V_{CER}(sus)$	110	95	V
With base open	$V_{CEO}(sus)$	90	75	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	20	20	A
*PEAK COLLECTOR CURRENT		30	30	A
*CONTINUOUS BASE CURRENT	I_B	5	5	A
TRANSISTOR DISSIPATION:	P_T			
* At case temperatures up to 25°C and V_{CE} up to 28 V		140	140	W
At case temperatures up to 25°C and V_{CE} above 28 V		See Fig. 1.		
At case temperatures above 25°C and V_{CE} above 28 V		See Figs. 1 & 2.		
*TEMPERATURE RANGE:				
Storage & Operating (Junction)		–65 to 200		°C
PIN TEMPERATURE (During Soldering)				
At distances ≥1/32 in. (0.8 mm) from seating plane for 10 s max.		230		°C

*In accordance with JEDEC registration data format (JS-6, RFD-1)

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS							LIMITS				Units
		Voltage V dc				Current A dc			2N5038		2N5039		
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	
Collector Cutoff Current: With base open	I_{CEO}		55					0	–	–	–	20	mA
			70					0	–	20	–	–	
* With base-emitter junction reverse-biased	I_{CEV}		110		-1.5				–	–	–	50	mA
*			140		-1.5				–	50	–	–	
* At T_C = 150°C			85		-1.5				–	–	–	10	mA
*			100		-1.5				–	10	–	–	
* Emitter Cutoff Current	I_{EBO}			5		0			–	5	–	15	mA
				7		0			–	50	–	50	
DC Forward Current Transfer Ratio	h_{FE} [a]		5			2			50	200	30	150	
*			5			10			–	–	20	100	
*			5			12			20	100	–	–	
* Magnitude of Small-Signal Forward Current Transfer Ratio (At f = 5 MHz)	$\|h_{fe}\|$		10			2			12	–	12	–	
Collector-to-Emitter Sustaining Voltage: (See Figs. 20 & 21) * With base open	$V_{CEO}(sus)$ [b]					0.2		0	90	–	75	–	V
With base-emitter junction reverse biased and external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CEX}(sus)$ [b]				-1.5	0.2		0	150	–	120	–	
With $R_{BE} \leq 50$ Ω	$V_{CER}(sus)$ [b]					0.2		0	110	–	95	–	
Emitter-to-Base Voltage	V_{EBO}					0	0.05		7	–	7	–	V
Base-to-Emitter Voltage	V_{BE} [a]		5			10			–	–	–	1.8	V
			5			12			–	1.8	–	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$ [a]					10		1.0	–	–	–	1.0	V
						12		1.2	–	1.0	–	–	
*						20		5	–	2.5	–	2.5	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$ [a]		5			20		5	–	3.3	–	3.3	V
Output Capacitance (At 1 MHz)	C_{ob}	10					0		–	300	–	300	pF
Second-Breakdown Collector Current [e] (With base forward biased)	$I_{S/b}$ [d]		28						5.0	–	5.0	–	A
			45						0.9	–	0.9	–	
Second-Breakdown Energy (With base reverse biased, R_B = 20 Ω, L = 180 μH)	$E_{S/b}$ [f]				-4	12			13	–	13	–	mJ
Gain-Bandwidth Product (At 5 MHz)	f_T		10			2			60	–	60	–	MHz
* Sat. Switching Rise Time (See Fig. 16, 18 & 19)	t_r	V_{CC} = 30 V				10		1.0[c]	–	–	–	0.5	μs
						12		1.2[c]	–	0.5	–	–	
* Sat. Switching Storage Time (See Fig. 17, 18 & 19)	t_s	V_{CC} = 30 V				10		1.0[c]	–	–	–	1.5	μs
						12		1.2[c]	–	1.5	–	–	
* Sat. Switching Fall Time (See Fig. 16, 18 & 19)	t_f	V_{CC} = 30 V				10		1.0[c]	–	–	–	0.5	μs
						12		1.2[c]	–	0.5	–	–	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$		10			10			–	1.25	–	1.25	°C/W

[a] Pulsed; pulse duration ≤350 μs, duty factor = 2%.

[b] CAUTION: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 20.

[c] $I_{B_1} = I_{B_2}$ = value shown.

[d] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[e] Pulsed; 1-s non-repetitive pulse.

[f] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$ where L is a series load or leakage inductance and I is the peak collector current.

*In accordance with JEDEC registration data format (JS-6, RDF-1)

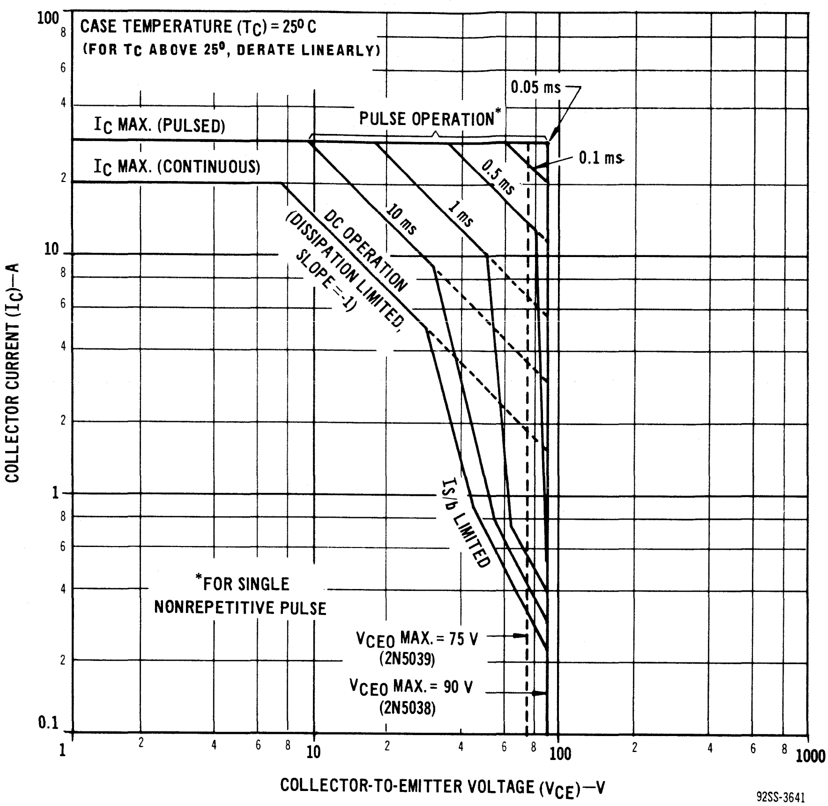


Fig.1— Maximum operating areas for types 2N5038 and 2N5039.

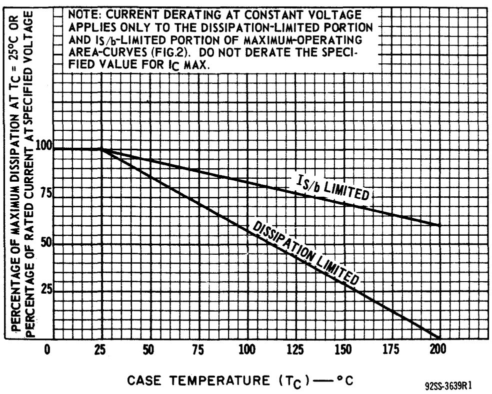


Fig.2— Dissipation derating curves for both types.

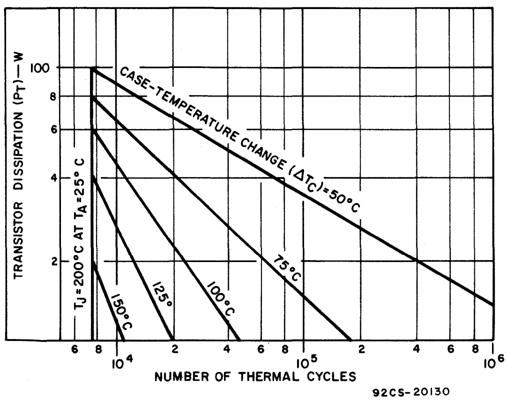


Fig.3— Thermal-cycling rating chart for both types.

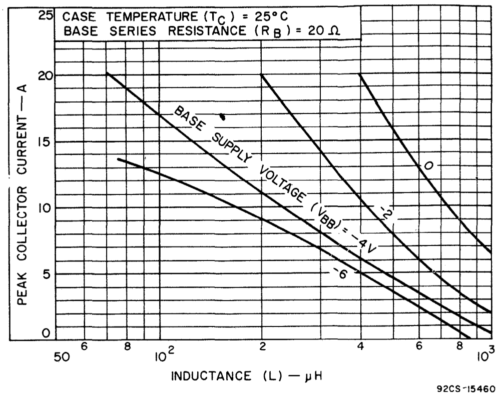


Fig.4— Maximum reverse-bias, second-breakdown characteristics for both types.

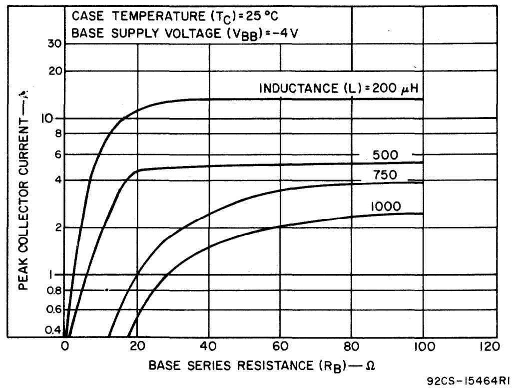


Fig.5— Maximum reverse-bias, second-breakdown characteristics for both types.

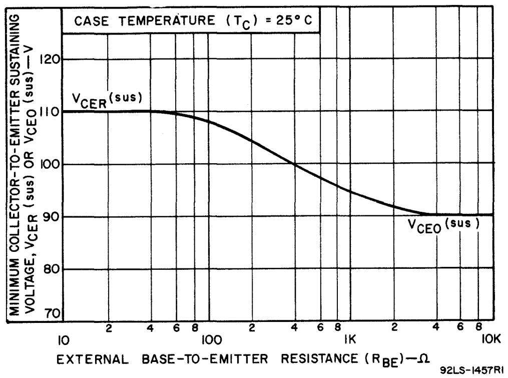


Fig.6— Collector-to-emitter sustaining voltage characteristic for type 2N5038.

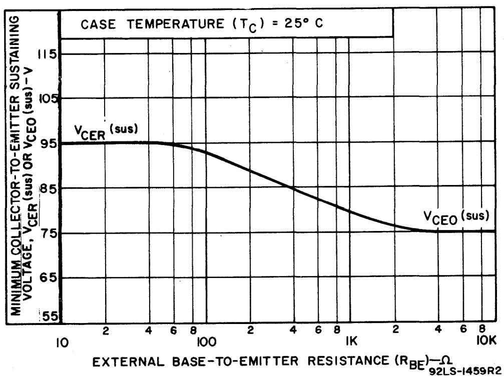


Fig.7— Collector-to-emitter sustaining voltage characteristic for type 2N5039.

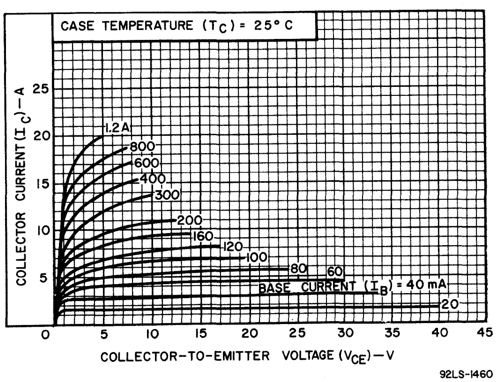


Fig.8— Typical output characteristics for type 2N5038.

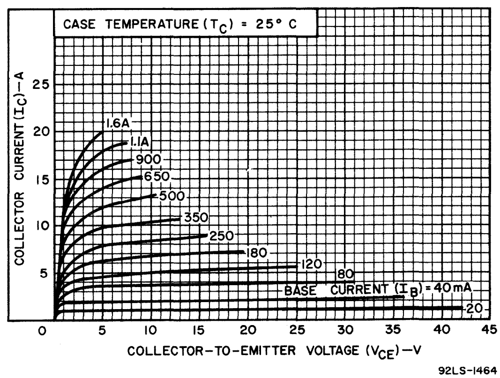


Fig.9— Typical output characteristics for type 2N5039.

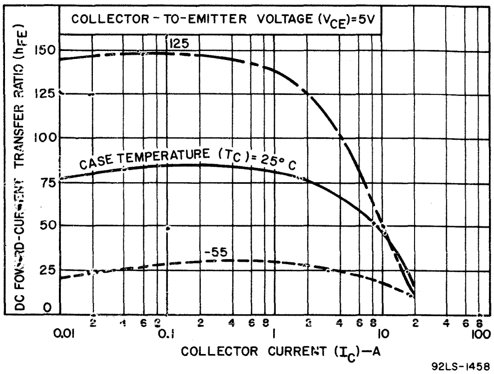


Fig.10— Typical dc beta characteristics for type 2N5038.

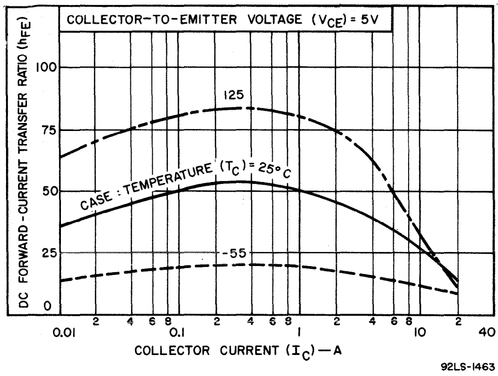


Fig.11— Typical dc beta characteristics for type 2N5039.

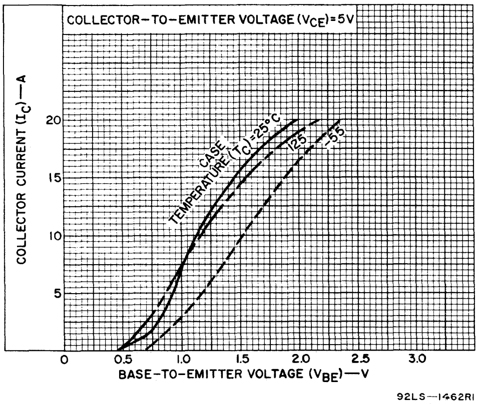


Fig.12— Typical transfer characteristics for type 2N5038.

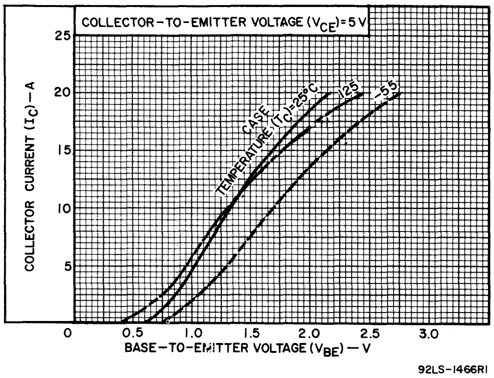


Fig.13— Typical transfer characteristics for type 2N5039.

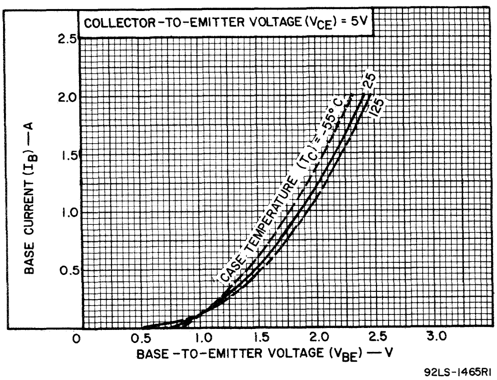


Fig.14— Typical input characteristics for both types.

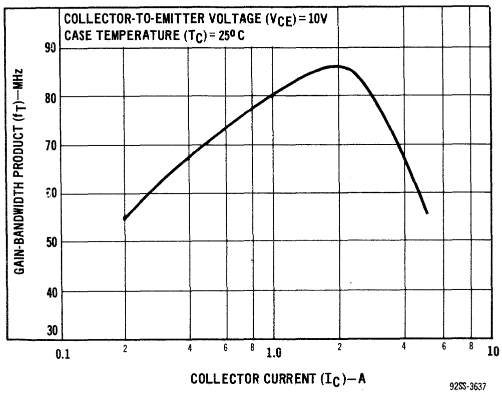


Fig.15— Typical gain-bandwidth product for both types.

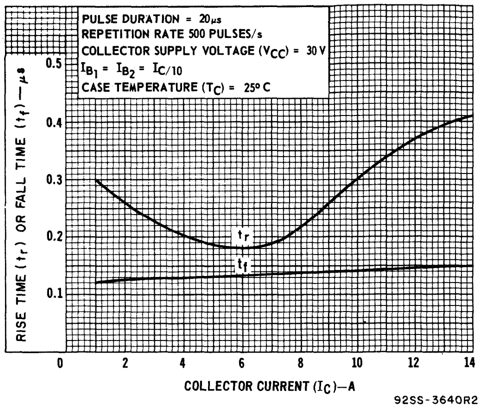


Fig.16— Typical rise-time and fall-time characteristics for both types.

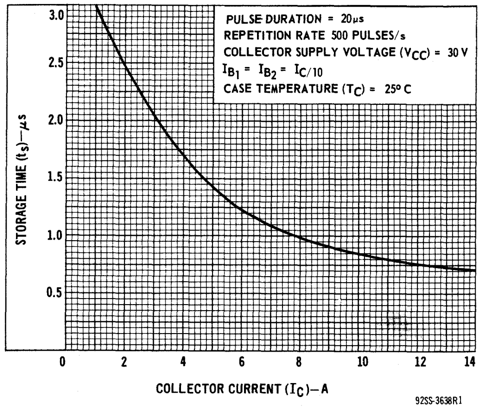
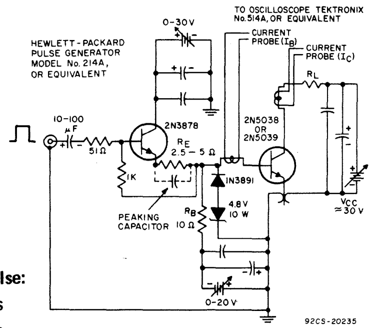


Fig.17— Typical storage time characteristic for both types.



Input Pulse:

$t_r < 20$ ns

$t_f < 20$ ns

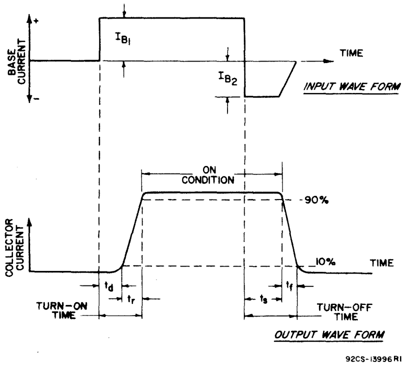
Rep. Rate = 500 Hz

Pulse Duration ⩾20 µs

R_L = 3Ω, 12 W (non-inductive) for 10-A test

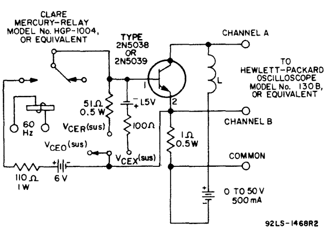
R_L = 2.5Ω, 12 W (non-inductive) for 12-A test

Fig.18— Circuit used to measure switching times for types 2N5038 and 2N5039.



t_{on}	t_{off}	Type	Test Conditions
0.5 µs	2.0 µs	2N5039	I_{B1} = 1.0 A, B_2 = −1.0 A, I_C = 10 A
0.5 µs	2.0 µs	2N5038	I_{B1} = 1.2 A, B_2 = −1.2 A, I_C = 12 A

Fig.19—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 18.)

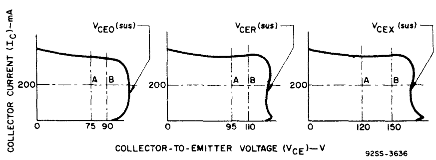


L = 15mH for V_{CEO}(sus) &

V_{CER}(sus) measurements

L = 2mH for V_{CEX}(sus) measurements.

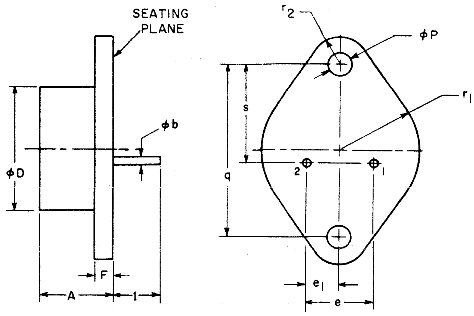
Fig.20— Circuit used to measure sustaining voltages V_{CEO}(sus), V_{CER}(sus), & V_{CEX}(sus) for types 2N5038 and 2N5039.



The sustaining voltages V_{CEO}(sus), V_{CER}(sus), and V_{CEX}(sus) are acceptable when the traces fall to the right of point "A" for type 2N5039 and point "B" for type 2N5038, at I_C = 200 mA.

Fig.21—Oscilloscope display for measurement of sustaining voltages. (Test circuit shown in Fig. 20.)

DIMENSIONAL OUTLINE
JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA Solid State Division

Power Transistors

2N5189

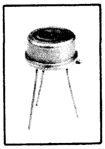
RCA-2N5189* is a double-diffused epitaxial planar transistor of the silicon n-p-n type featuring high breakdown voltages, low saturation voltages, and high switching speeds over a wide range of collector current.

It is especially useful in switching applications of high-performance computers and in other critical industrial applications where high-voltage and high-current handling capabilities and short "turn-off" and "turn-on" times are important design features. These features also make the 2N5189 particularly useful in class C circuits for mobile and portable equipment.

The 2N5189 is hermetically sealed in a metal package like the JEDEC TO-39 but with a reduced height (0.195″ max, 0.175″ min) and 0.5″ min. leads.

* Formerly Dev. No. TA7322.

SILICON N-P-N HIGH-VOLTAGE TRANSISTOR



For Core-Driver and Line-Driver Service in Data-Processing Equipment and Other Critical Applications in Military and Industrial Equipment

Maximum Ratings, Absolute-Maximum Values:

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}		60 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}		35 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}		5 max.	V
COLLECTOR CURRENT, I_C		Limited by dissipation	
TRANSISTOR DISSIPATION, P_T:			
For case temperatures[a]	up to 25°C	5 max.	W
	above 25°C	Derate at 28.5mW/°C	
For ambient temperatures	up to 25°C	0.8 max.	W
	above 25°C	Derate at 4.57 mW/°C	
TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to +200	°C
LEAD TEMPERATURE (During Soldering):			
At distances ≥ 1/32″ from seating surface for 10 seconds max.		265 max.	°C

[a] Measured at center of seating surface.

Features

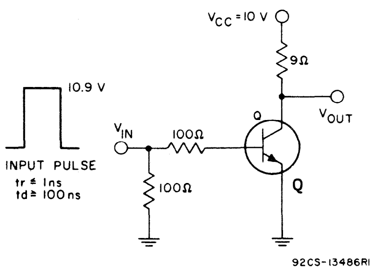
- **excellent power handling capability —**
  P_T = 5W max. at T_C = 25°C
  0.8 W max. at T_A = 25°C
- **high switching speeds at high currents —**
  t_{on} = 40ns max. at I_C = 1A
  t_{off} = 70ns max. at I_C = 1A
- **high breakdown-voltage capabilities —**
  $V_{(BR)CBO}$ = 60V min.
  $V_{(BR)CEO}$ = 35V min.

ELECTRICAL CHARACTERISTICS, at T_A = 25°C

Characteristics	Symbols	TEST CONDITIONS							LIMITS		Units
		T_A	f	V_{CB}	V_{CE}	I_C	I_E	I_B	Type 2N5189		
		°C	MHz	Volts			mA		Min.	Max.	
Collector-Cutoff Current	I_{CBO}	25			30					0.5	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$	25				0.1			60		V
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$	25				10			35		V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$	25					-0.1			5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25				1000		100		1	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25				1000		100		1.5	V
Static Forward Current-Transfer Ratio	h_{FE}	25 25 25			1 1 1	100 500 1000			30 35 15*		
Small-Signal Forward-Current Transfer Ratio	h_{fe}		100		10	50			2.5		
Common-Base, Open-Circuit Output Capacitance	C_{ob}		0.1	10			0			15	pF
Turn-On Time (Delay Time + Rise Time)	$t_{on} = (t_d + t_r)$					I_C 1000	I_{B1} 100	I_{B2}		40	ns
Turn-Off Time (Storage Time + Fall Time)	$t_{off} = (t_s + t_f)$					1000	100	-100		70	ns

*Pulsed condition—Pulse duration ≤ 400 μs, duty factor ≤ 0.03.

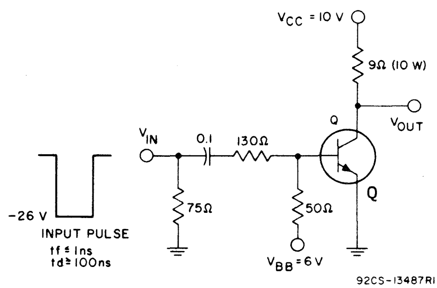
CIRCUIT USED TO MEASURE TURN-ON TIME (t_{on})



Q = Type 2N5189

Fig. 1

CIRCUIT USED TO MEASURE TURN-OFF TIME (t_{off})



Q = Type 2N5189

Fig. 2

TYPICAL CHARACTERISTICS

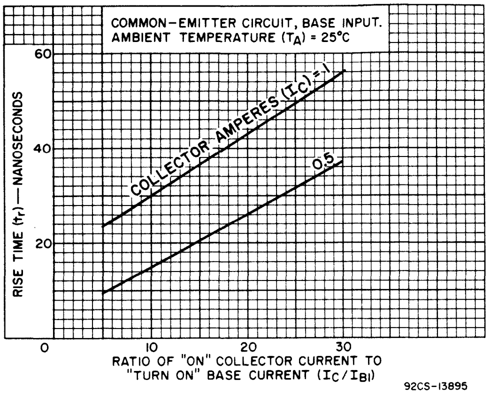


Fig. 3 — Rise Time vs I_C/I_{B1}

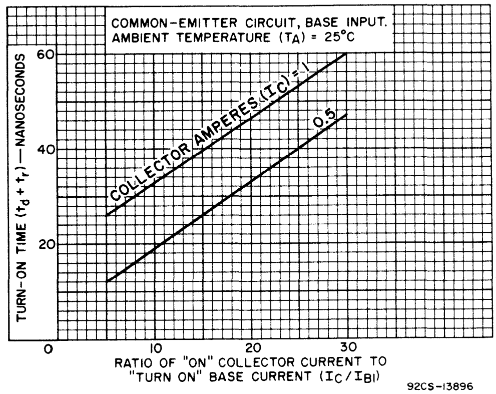


Fig. 4 — Turn-On Time vs I_C/I_{B1}

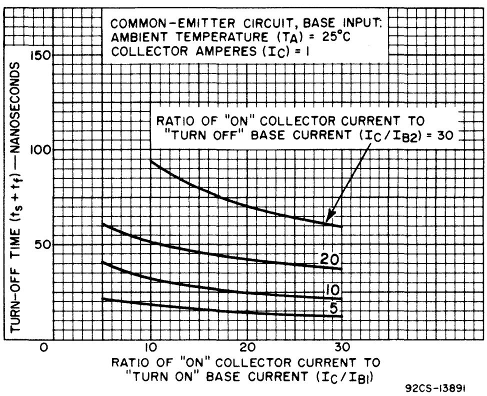


Fig. 5 — Turn-Off Time vs I_C/I_{B1}

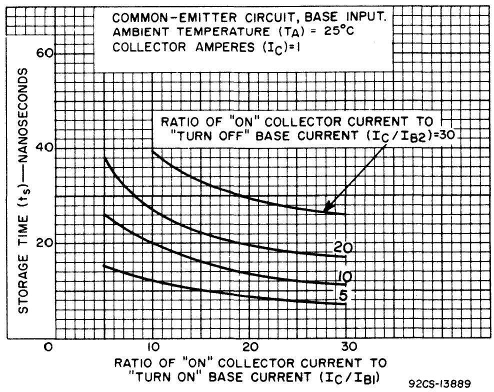


Fig. 6 — Storage Time vs I_C/I_{B1}

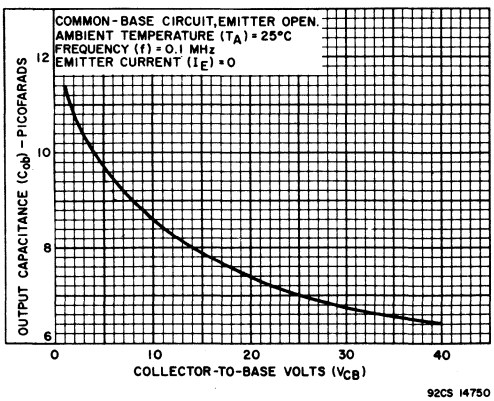


Fig. 7 — Output Capacitance vs Collector-to-Base Voltage

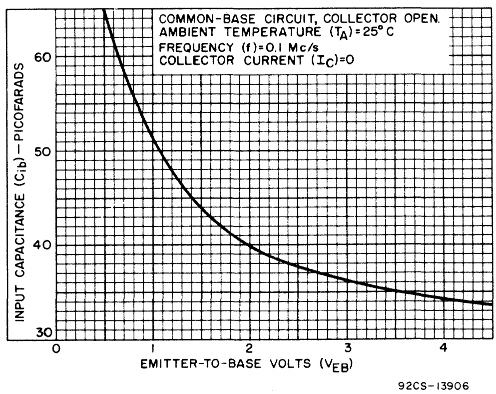


Fig. 8 — Input Capacitance vs Emitter-to-Base Voltage

TYPICAL CHARACTERISTICS

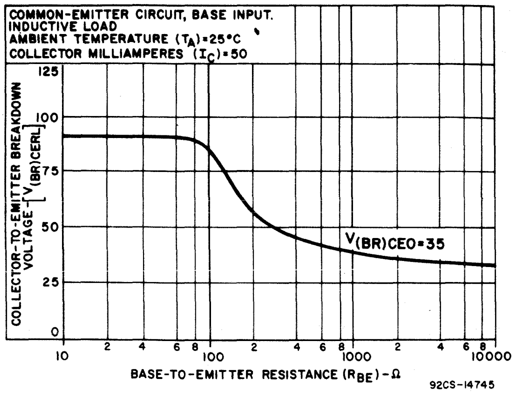


Fig. 9 — Collector-Cutoff Current vs Ambient Temperature

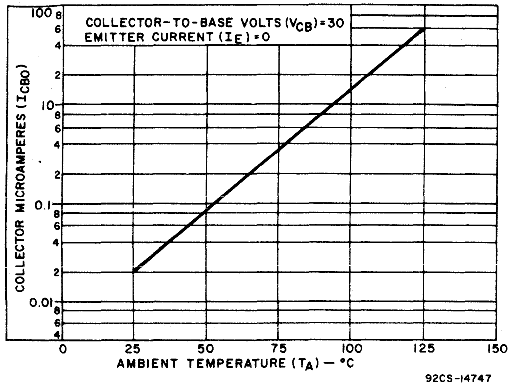


Fig. 10 — Collector-to-Emitter Breakdown Voltage vs Base-to-Emitter Resistance

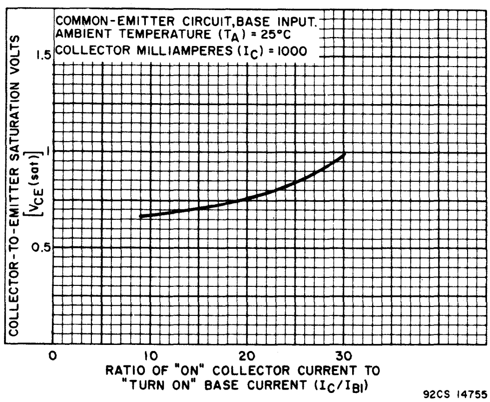


Fig. 11 — Collector-to-Emitter Saturation Voltage vs I_C/I_{B1}

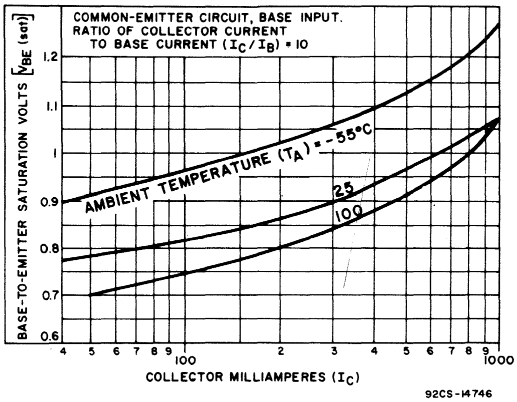


Fig. 12 — Base-to-Emitter Saturation Voltage vs I_C

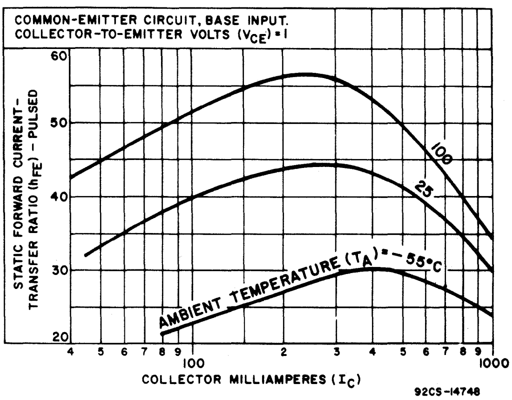


Fig. 13 — Static Forward Current-Transfer Ratio (Pulsed) vs I_C

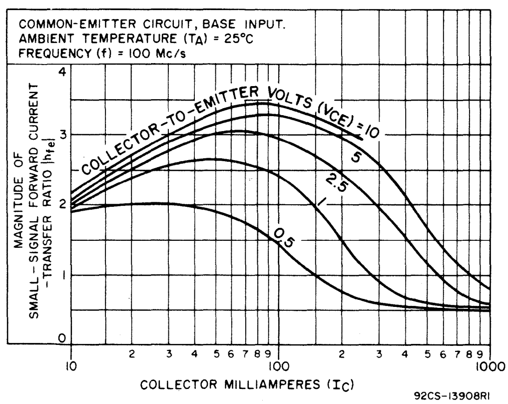
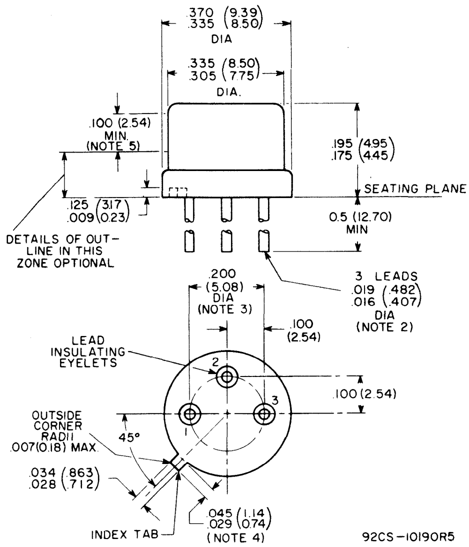


Fig. 14 — Small-Signal Forward Current-Transfer Ratio vs I_C

DIMENSIONAL OUTLINE



Dimensions in Inches and Millimeters

Note 1: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Note 2: The specified lead diameter applies in the zone between 0.050" (1.27 mm) and 0.250" (6.35 mm) from the seating plane. From 0.250" (6.35 mm) to the end of the lead a maximum diameter of 0.021" (0.533 mm) is held. Outside of these zones, the lead diameter is not controlled.

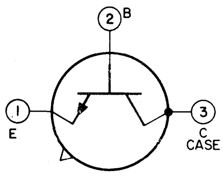
Note 3: Leads having a maximum diameter of 0.019" (0.482 mm) at a gauging plane of 0.054" (1.372 mm) + 0.001" (0.025 mm) - 0.000" (0.000 mm) below seating plane shall be within 0.007" (0.177 mm) of their true position (location) relative to a maximum width of tab.

Note 4: Measured from actual maximum diameter.

Note 5: This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010" (0.25 mm).

TERMINAL DIAGRAM

Bottom View



LEAD 1 — EMITTER

LEAD 2 — BASE

LEAD 3 — COLLECTOR, CASE

RCA
Solid State
Division

Power Transistors

2N5262

RCA-2N5262* is a silicon n-p-n, epitaxial planar transistor with characteristics which make it exceptionally desirable for high-speed, high-voltage, high-current switching applications. In addition, the 2N5262 features very short turn-on and turn-off times and low saturation voltages. It is also controlled for freedom from second breakdown under both forward-bias and reverse-bias conditions, when operated within specified maximum ratings.

The 2N5262 meets the requirements of the basic military specification MIL-S-19500, and is hermetically sealed in a metal low-profile JEDEC TO-39 package.

RCA-2N5262 is primarily intended for use as a driver for "2-1/2D" coincident-current and word-organized magnetic-memory systems, and in the other critical industrial applications requiring switching of large currents through inductive loads.

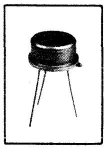
* Developmental number TA-7238 is a reduced-height version of the former developmental number TA-2626.

Maximum Ratings, *Absolute-Maximum Values*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	75 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	50 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5 max.	V
Continuous	2 max.	A
Instantaneous (See Fig. 4)	3 max.	A
TRANSISTOR DISSIPATION, P_T:		
For case temperatures[a]: up to 25°C	5 max.	W
For case temperatures[a]: above 25°C	Derate at 28.5 mw/°C	
For ambient temperatures: up to 25°C	1 max.	W
For ambient temperatures: above 25°C	Derate at 5.7 mw/°C	
TEMPERATURE RANGE:		
Storage and Operating (Junction)	-65 to +200	°C
LEAD TEMPERATURE (During Soldering):		
At distances ≥ 1/32" from seating surface for 10 seconds max	265 max.	°C

a Measured at center of seating surface.

SILICON N-P-N HIGH-VOLTAGE ULTRA-HIGH-SPEED TRANSISTOR



For Memory Driver Service in Data-Processing Equipment and Other Critical Industrial Applications

Features

- high dc beta at high collector current
  h_{fe} = 25 min at I_C = 1 A
- controlled for safe operation without damage due to second breakdown under both forward-and reverse-bias conditions
- meets the requirements of Military Specification MIL-S-19500
- excellent power handling capability—
  P_T = 5 W max. at T_C = 25°C
  P_T = 1 W max. at T_A = 25°C
- high switching speeds at high currents—
  t_{on} = 30 ns max. at I_C = 1 A
  t_{off} = 60 ns max. at I_C = 1 A
- high breakdown-voltage capabilities—
  $V_{(BR)CBO}$ = 75 V min.
  $V_{(BR)CEO}$ = 50 V min.
- hermetically sealed low-profile TO-39 metal package
- low saturation voltage at high current—
  V_{CE} = 0.5 V typ. at I_C = 1 A

ELECTRICAL CHARACTERISTICS, $T_A = 25^o$ *C unless otherwise specified*

Characteristics	Symbols	TEST CONDITIONS f	V_{CE}	I_C	I_E	I_B	LIMITS 2N5262 Min.	Typ.	Max.	UNITS
		MHz	Volts	mA						
Collector-Cutoff Current	I_{CES}		60 30 30▲				- - -	- 0.4 -	10 1 100	μA μA μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0.1			75	110	-	V
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$			10			50	56	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				-0.1		5	8	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			1000		100	-	0.5	0.8	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$			1000		100	-	1	1.4	V
Static Forward Current-Transfer Ratio	h_{FE}		1 1 1	100 500 1000*			35 40 25	55 65 45	- - -	
Small-Signal Forward Current Transfer Ratio	h_{fe}	100	10	50			2.5	3.5	-	
Common-Base, Open-Circuit Output Capacitance	C_{ob}	0.1 to 1	V_{CB} = 10		0		-	9	12	pF
				I_C	I_{B1}	I_{B2}				
Turn-On Time Delay Time + Rise Time	$t_{on} = (t_d + t_r)$			1000	100	-	-	18	30	ns
Turn-Off Time Storage Time + Fall Time	$t_{off} = (t_s + t_f)$			1000	100	-100	-	35	60	ns

* Pulsed condition - Pulse duration ≤ 400 μs, duty factor ≤ 0.03.

▲ $T_A = 100^oC$

CIRCUIT USED TO MEASURE TURN-ON TIME (t_{on})

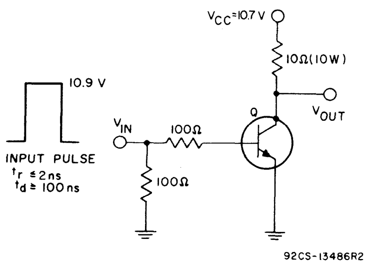


Fig.1

CIRCUIT USED TO MEASURE TURN-OFF TIME (t_{off})

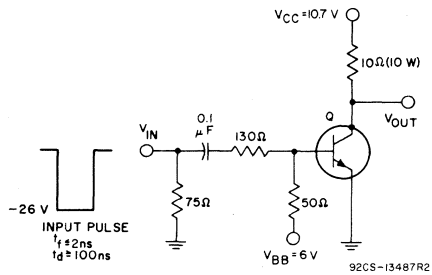


Fig.2

RATING CHART

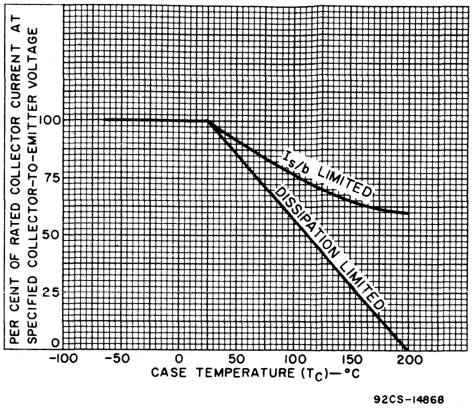


Fig.3

SECOND BREAKDOWN CHARACTERISTICS AND RATINGS

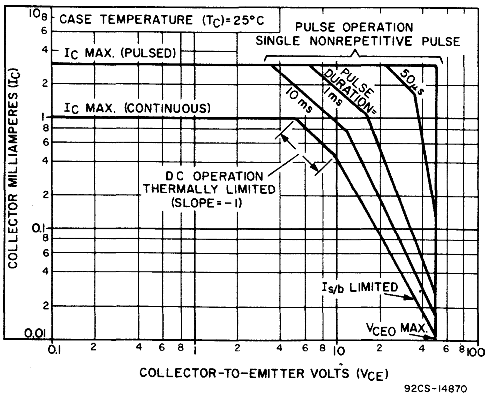


Fig.4

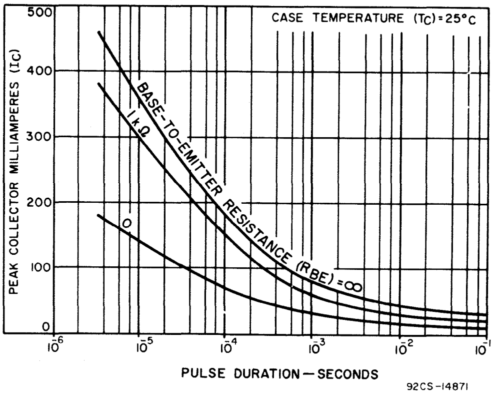


Fig.5

TYPICAL CHARACTERISTICS

h_{fe} vs I_C

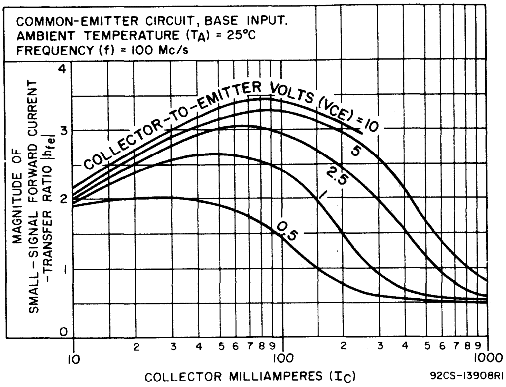


Fig.6

h_{FE} vs I_C

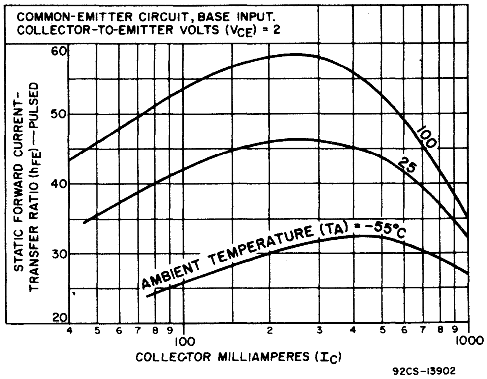


Fig.7

$V_{CE}(sat)$ vs I_C/I_B

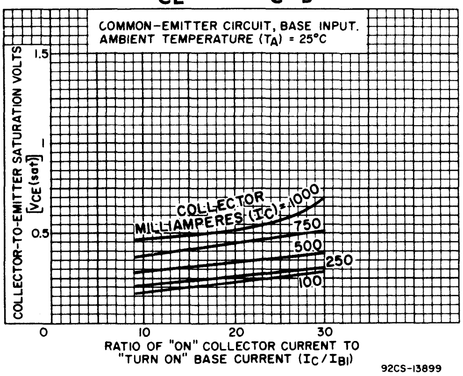


Fig.8

$V_{CE}(sat)$ vs β_T/β_C

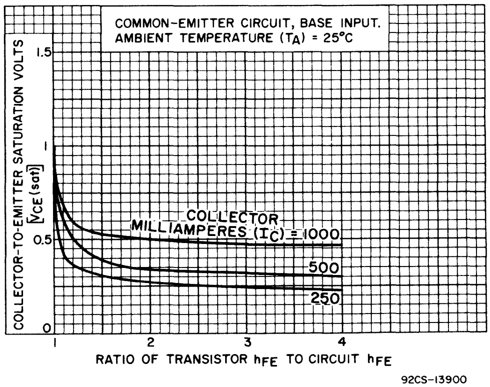


Fig.9

$V_{BE}(sat)$ vs I_C

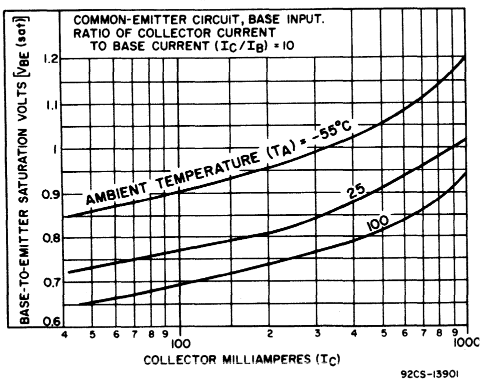


Fig.10

I_C & I_B vs V_{BE}

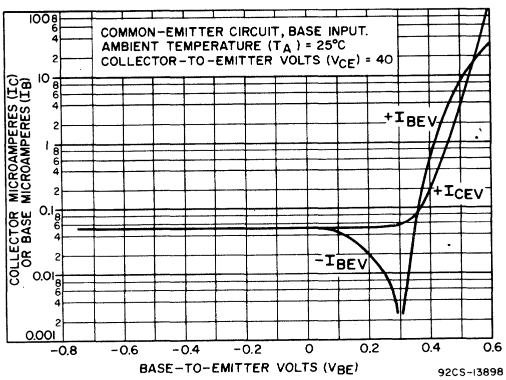


Fig.11

TYPICAL CHARACTERISTICS

t_r vs I_C/I_{B1}

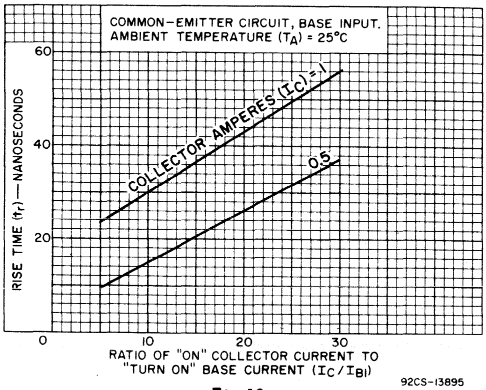


Fig.12

t_s vs I_C/I_{B1}

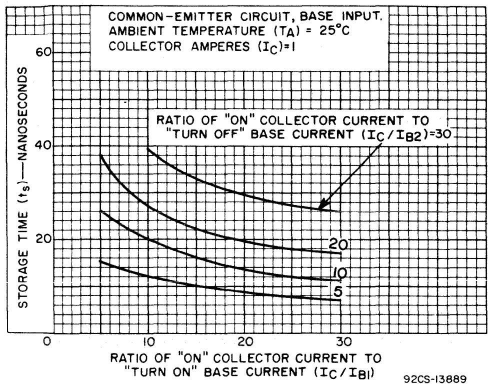


Fig.13

t_{on} vs I_C/I_{B1}

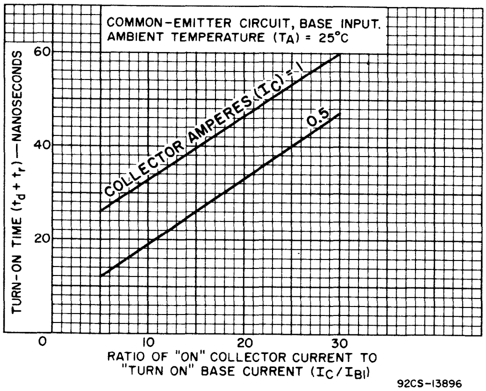


Fig.14

t_{off} vs I_C/I_{B1}

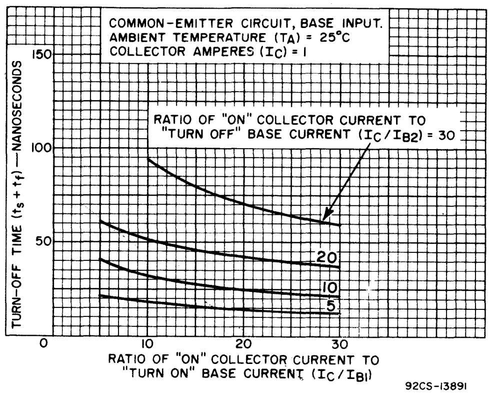


Fig.15

I_{CES} vs T_A

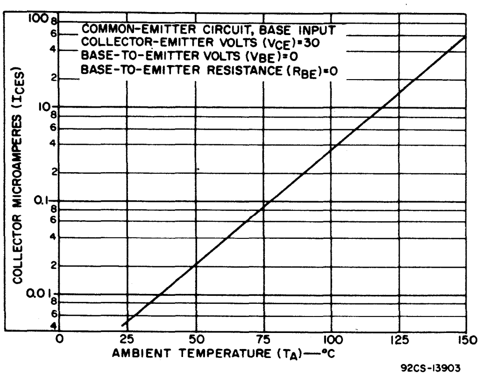


Fig.16

BV_{CERL} vs R_{BE}

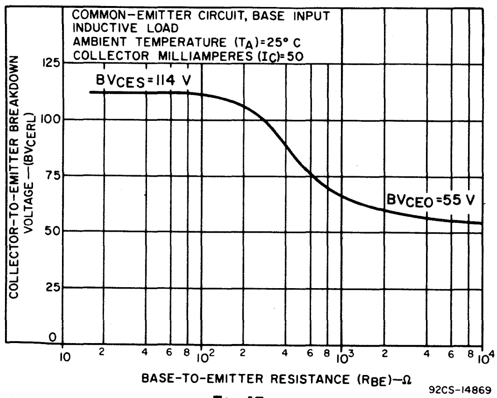


Fig.17

TYPICAL CHARACTERISTICS

C_{ob} vs V_{CB}

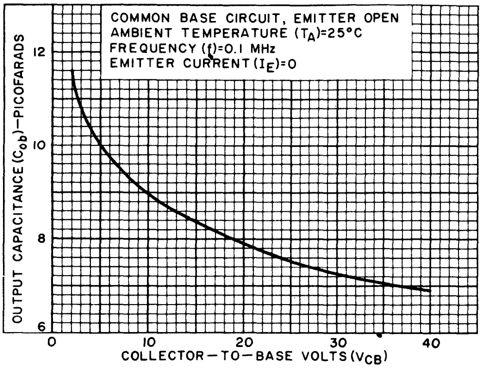


Fig.18

C_{ib} vs V_{EB}

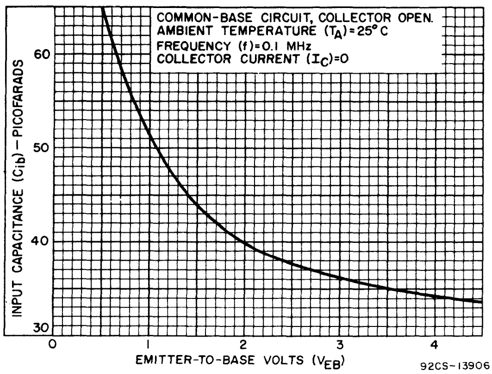
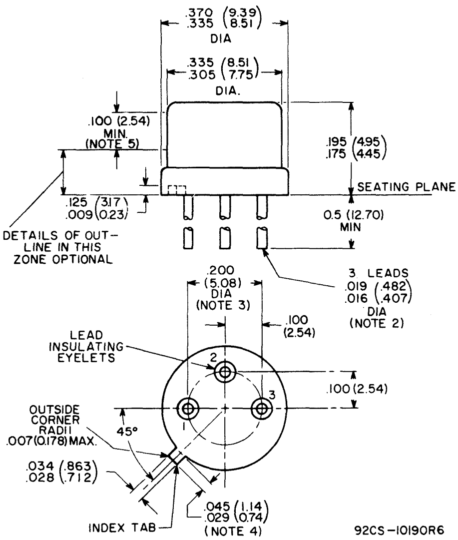


Fig.19

DIMENSIONAL OUTLINE



Dimensions in Inches and Millimeters

Note 1: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Note 2: The specified lead diameter applies in the zone between 0.050" (1.27 mm) and 0.250" (6.35 mm) from the seating plane. From 0.250" (6.35 mm) to the end of the lead a maximum diameter of 0.021" (0.533 mm) is held. Outside of these zones, the lead diameter is not controlled.

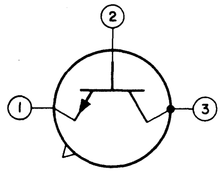
Note 3: Leads having a maximum diameter of 0.019" (0.482 mm) at a gauging plane of 0.054" (1.372 mm) + 0.001" (0.025 mm) - 0.000" (0.000 mm) below seating plane shall be within 0.007" (0.178 mm) of their true position (location) relative to a maximum width of tab.

Note 4: Measured from actual maximum diameter.

Note 5: This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010" (0.25 mm).

TERMINAL DIAGRAM

Bottom View



LEAD 1 — EMITTER

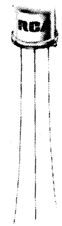
LEAD 2 — BASE

LEAD 3 — COLLECTOR, CASE

RCA
Solid State
Division

Power Transistors

2N5320 2N5322
2N5321 2N5323



JEDEC TO-5

H-1380

Complementary N-P-N & P-N-P Silicon Power Transistors

General-Purpose Types for Small-Signal, Medium-Power Applications

Features:

- 2N5322, 2N5323 -- P—N—P Complements of: 2N5320, 2N5321
- Maximum safe-area-of-operation curves
- Planar construction for low-noise and low-leakage characteristics
- Low saturation voltage: V_{CE}(sat) = 0.5 V max. (2N5320)
  -0.7 V max. (2N5322)
- High beta at high collector current

RCA-2N5320, 2N5321, 2N5322 and 2N5323 are multiple-diffused silicon power transistors intended for small-signal medium-power applications. The 2N5320 and 2N5321 are triple-diffused silicon n-p-n planar types. They are actually high-current, high-dissipation versions of the 2N2102 with all of the salient features of that device. The 2N5322 and 2N5323, p-n-p complements of the 2N5320 and 2N5321 are double-diffused, epitaxial-planar types, actually high-current, high-power versions of the 2N4036 with all of its additional outstanding features.

ALSO AVAILABLE ....

On special request, these transistor types can be supplied with a factory-attached heat radiator or mounting flange, as illustrated on page 6.

Please submit requirements to your RCA Technical Sales Representative, or write to RCA, Low-Frequency Transistor Marketing, Somerville, N. J. 08876.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N5321	2N5323	2N5320	2N5322	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	75	-75	100	-100	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:						
With 1.5 volts (V_{BE}) of reverse bias	V_{CEV}(sus)	75	-75	100	-100	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CER}(sus)	65	-65	90	-90	V
* With base open	V_{CEO}(sus)	50	-50	75	-75	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	-5	7	-7	V
* COLLECTOR CURRENT	I_C	2	-2	2	-2	A
* BASE CURRENT	I_B	1	-1	1	-1	A
* TRANSISTOR DISSIPATION.	P_T	10	10	10	10	W
At case temperatures up to 25° C		See Figs. 3 & 6				
At case temperatures above 25° C		Derate linearly at 0.057 W/°C				
* TEMPERATURE RANGE:						
Storage and operating (Junction)		-65 to + 200				°C
* LEAD TEMPERATURE (During soldering):						
At distance ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max		230				°C

*In accordance with JEDEC registration data format (JS-6 RDF-1)

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25° C, unless otherwise specified

CHARACTERISTIC	Symbol	TEST CONDITIONS: DC Collector Voltage V		DC Emitter or Base Voltage V		DC Current mA			LIMITS: Type 2N5320		Type 2N5321		Type 2N5322		Type 2N5323		Units
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current: With base open	I_{CBO}	80					0		-	0.5	-	-	-	-	-	-	µA
		60					0		-	-	-	5	-	-	-	-	
		-80					0		-	-	-	-	-	-0.5	-	-	
		-60					0		-	-	-	-	-	-	-	-5	
* With base-emitter junction reverse biased	I_{CEX}		100		-1.5				-	0.1	-	-	-	-	-	-	mA
			75		-1.5				-	-	-	0.1	-	-	-	-	
			-100		1.5				-	-	-	-	-	-0.1	-	-	
			-75		1.5				-	-	-	-	-	-	-	-0.1	
T_C=150°C			70		-1.5				-	5	-	-	-	-	-	-	mA
			45		-1.5				-	-	-	5	-	-	-	-	
			-70		1.5				-	-	-	-	-	-5	-	-	
			-45		1.5				-	-	-	-	-	-	-	-5	
* Emitter-Cutoff Current	I_{EBO}			7		0			-	0.1	-	-	-	-	-	-	mA
				5		0			-	-	-	0.1	-	-	-	-	
				-7		0			-	-	-	-	-	-0.1	-	-	
				-5		0			-	-	-	-	-	-	-	-0.1	
				5		0			-	0.1	-		-	-	-	-	µA
				4		0			-	-	-	0.5	-	-	-	-	
				-5		0			-	-	-	-	-	-0.1	-	-	
				-4		0			-	-	-	-	-		-	-0.5	
Collector-to-Emitter Breakdown Voltage: With base-emitter junction reverse biased	$V_{(BR)CEV}$				-1.5	0.1			100	-	75	-	-	-	-	-	V
					1.5	-0.1			-	-	-	-	-100	-	-75	-	
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER(sus)}$ [a]					100			90	-	65	-	-	-	-	-	V
						-100			-	-	-	-	-90	-	-65	-	
* With base open	$V_{CEO(sus)}$ [a]					100		0	75	-	50	-	-	-	-	-	V
						-100		0	-	-	-	-	-75	-	-50	-	
* Collector-to-Emitter Saturation Voltage	$V_{CE(sat)}$					500		50	-	0.5	-	0.8	-	-	-	-	V
						-500		-50	-	-	-	-	-	-0.7	-	-1.2	
* Base-to-Emitter Voltage	V_{BE}		4			500			-	1.1	-	1.4	-	-	-	-	V
			-4			-500			-	-	-	-	-	-1.1	-	-1.4	
* DC Forward Current Transfer Ratio	h_{FE} [b] See NOTE		4			500			30	130	40	250	-	-	-	-	
			-4			-500			-	-	-	-	30	130	40	250	
			2			1000			10	-	-	-	-	-	-	-	
			-2			-1000			-	-	-	-	10	-	-	-	
Gain-Bandwidth Product	f_T		4			50			50	-	50	-	-	-	-	-	MHz
			-4			-50			-	-	-	-	50	-	50	-	
* Magnitude of common-emitter, small-signal, short circuit, forward current transfer ratio (f=10 MHz)	$\|h_{fe}\|$		4			50			5	-	5	-	-	-	-	-	
			-4			-50			-	-	-	-	5	-	5	-	

ELECTRICAL CHARACTERISTICS, (Cont'd)

CHARACTERISTIC	Symbol	TEST CONDITIONS: DC Collector Voltage V: V_{CB}	V_{CE}	DC Emitter or Base Voltage V: V_{EB}	V_{BE}	DC Current mA: I_C	I_E	I_B	LIMITS: Type 2N5320 Min.	Max.	Type 2N5321 Min.	Max.	Type 2N5322 Min.	Max.	Type 2N5323 Min.	Max.	Units
Second Breakdown Collector Current[c,e] (With base forward biased)	$I_{S/b}$[d]		50 -35						200 -	- -	200 -	- -	- -285	- -	- -285	- -	mA
* Sat. Switching Time: (See Fig.11.) Turn-on Time	t_{on}		30 -30			500 -500		50 -50	- -	80 -	- -	80 -	- -	- 100	- -	- 100	ns
Turn-off Time	t_{off}		30 -30			500 -500		50 -50	- -	800 –	- -	800 -	– –	– 1000	- -	- 1000	ns
Thermal Resistance: * Junction-to-Case	$\theta_{J\text{-}C}$								-	17.5	-	17.5	-	17.5	-	17.5	°C/W
Junction-to-Ambient	$\theta_{J\text{-}A}$								–	150	-	150	-	150	-	150	°C/W

[a] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer.

[b] Pulsed; pulse duration $\leq$ 300 μs, duty factor $\leq$ 0.02.

[c] Safe operating regions for forward-bias operation are shown on pages 4 & 5.

[d] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[e] Pulsed; 0.4 s non-repetitive pulse.

*In accordance with JEDEC registration data format (JS-6 RDF-1)

NOTE: RCA 2N5320, 2N5321, 2N5322, and 2N5323 can be shipped with color dots on the device case to indicate the following ranges of beta values within the beta limits specified for each device.

Color Code	Beta Range	Color Code	Beta Range
Brown	25-38	Green	73-110
Red	33-50	Blue	95-145
Orange	43-65	Violet	125-190
Yellow	56-85	White	165-250

Specific beta distributions or beta matching are available as custom types only on special order. For further details, contact your local RCA Sales office.

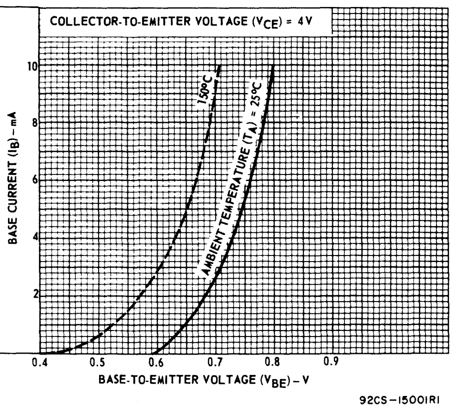


Fig. 1 - Typical input characteristics for types 2N5320 and 2N5321.

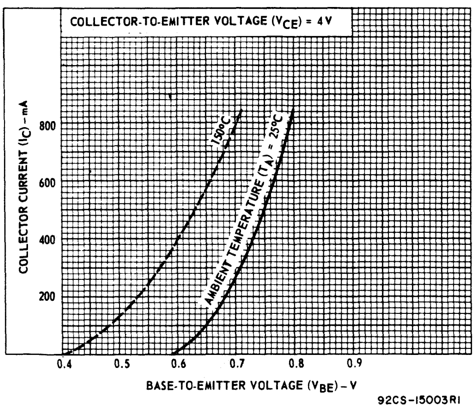


Fig. 2 - Typical transfer characteristics for types 2N5320 and 2N5321.

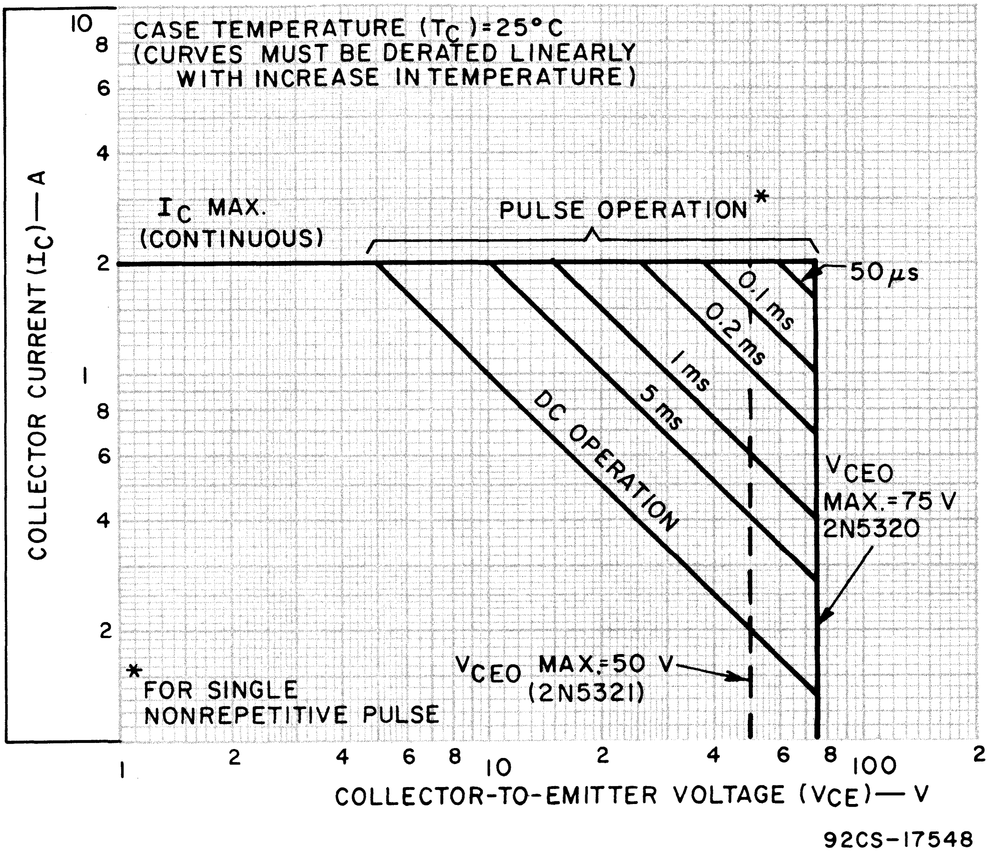


Fig. 3 - Maximum operating areas for types 2N5320 and 2N5321.

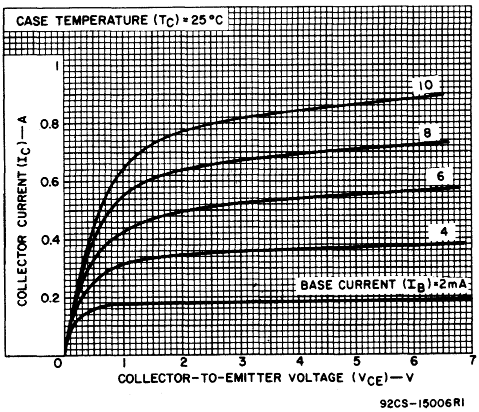


Fig. 4 - Typical output characteristics for types 2N5320 and 2N5321.

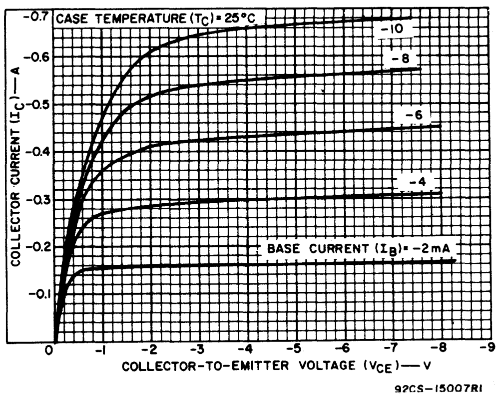


Fig. 5 - Typical output characteristics for types 2N5322 and 2N5323.

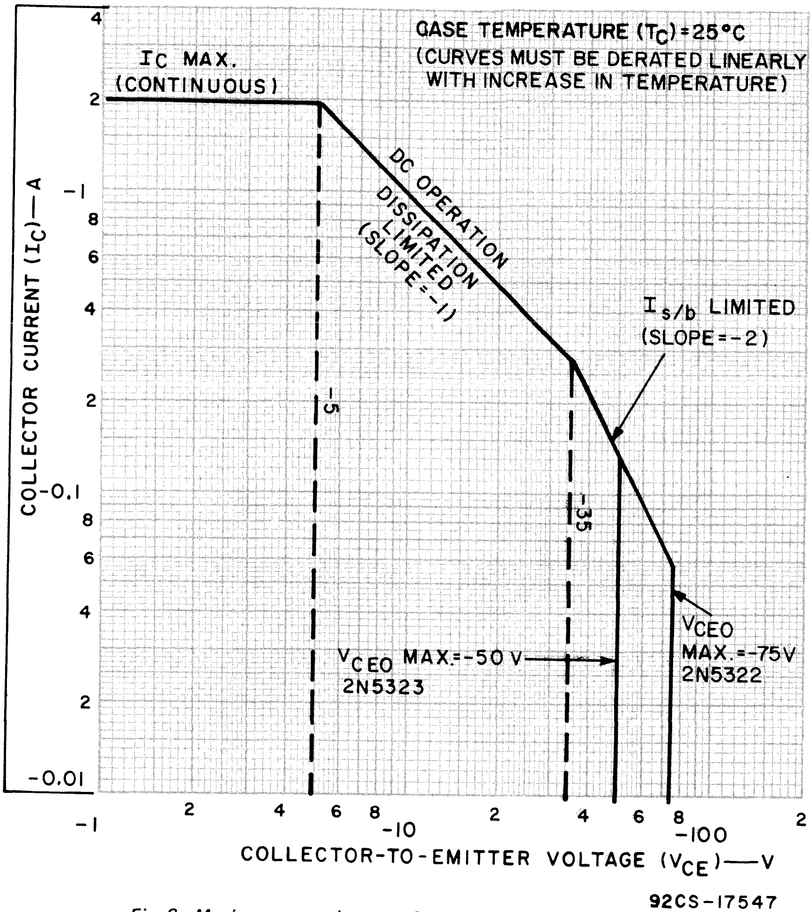


Fig. 6 - Maximum operating areas for types 2N5322 and 2N5323.

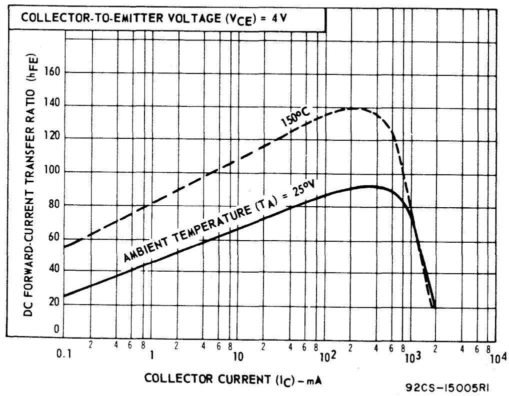


Fig. 7 - Typical static beta characteristics for types 2N5320 and 2N5321.

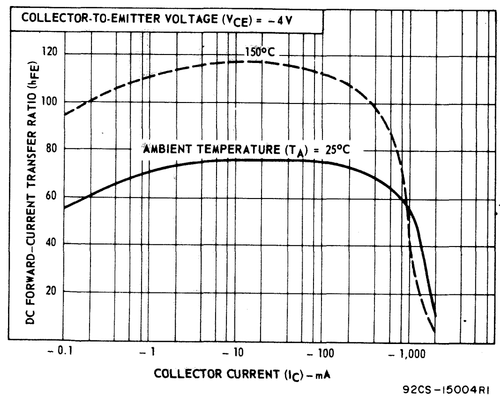


Fig. 8 - Typical static beta characteristics for types 2N5322 and 2N5323.

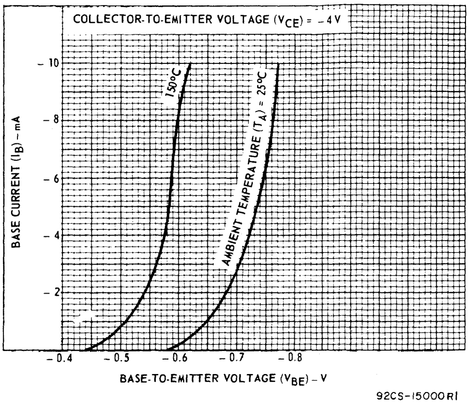


Fig. 9 - Typical input characteristics for types 2N5322 and 2N5323.

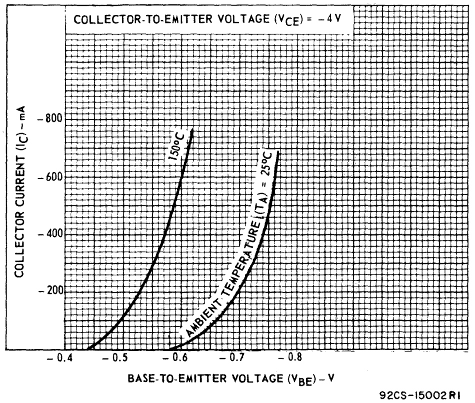


Fig. 10 - Typical transfer characteristics for types 2N5322 and 2N5323.

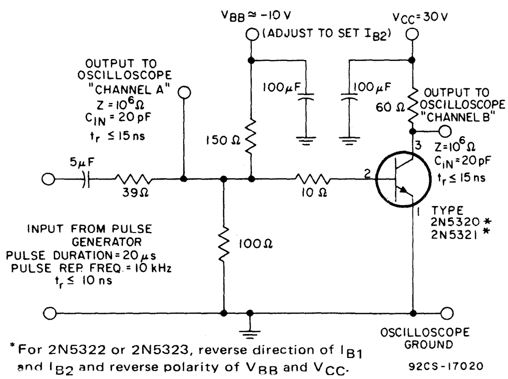


Fig. 11 - Circuit used to measure switching times for all types.

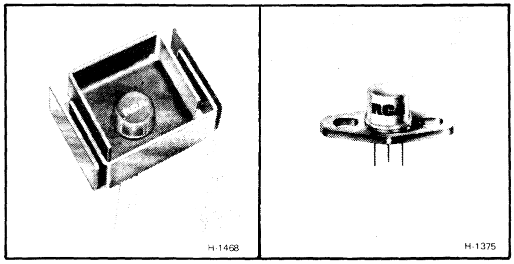
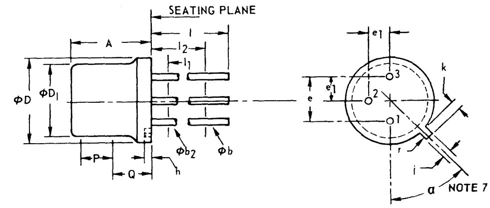


Fig. 12 - 2N5320 — 23 in JEDEC TO-5 package with factory-attached heat radiator or mounting flange, available upon special request. (See page 1.).

DIMENSIONAL OUTLINE FOR ALL TYPES

JEDEC TO-5



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
φb_2	0.016	0.019	0.406	0.483	2
φD	0.335	0.370	8.51	9.40	
φD_1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e_1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l_1	–	0.050	–	1.27	2
l_2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) φb_2 applies between l_1 and l_2. φb applies between l_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS

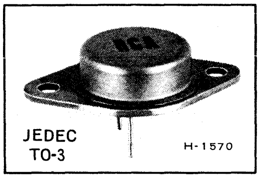
Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, case

RCA
Solid State Division

Power Transistors
2N5671
2N5672

SILICON N-P-N POWER TRANSISTORS

High-Current, High-Speed High-Power Types
For Switching and Amplifier Applications in Military, Industrial, and Commercial Equipment



RCA Types 2N5671 and 2N5672▲ are epitaxial silicon n-p-n transistors having high current and high power handling capability and fast switching speed. The 2N5672 is similar to the 2N5671 except that it has higher voltage ratings and lower leakage currents. These devices are especially suitable for switching-control amplifiers, power gates, switching regulators, power-switching circuits, converters, inverters, control circuits. Other recommended applications included DC-RF amplifiers and power oscillators.

▲Formerly Dev. Types TA7323 and TA7323A, respectively

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

	2N5671	2N5672	
*COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	120	150	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
With base open, $V_{CEO}(sus)$	90	120	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω, $V_{CER}(sus)$	110	140	V
With external base-to-emitter resistance (R_{BE}) ≤ 50 Ω & V_{BE} = -1.5, $V_{CEX}(sus)$	120	150	V
*EMITTER-TO-BASE VOLTAGE, V_{EBO}	7	7	V
*COLLECTOR CURRENT, I_C	30	30	A
*BASE CURRENT, I_B	10	10	A
*TRANSISTOR DISSIPATION, P_T:			
At case temperatures up to 25° C and V_{CE} up to 24 V	140	140	W
At case temperatures up to 25° C and V_{CE} above 24 V	See Fig. 2.		
At case temperatures above 25° C and V_{CE} above 24 V	See Figs. 1&2.		
*TEMPERATURE RANGE:			
Storage & Operating (Junction)	–65 to +200		°C
*PIN TEMPERATURE (During Soldering)			
At distances ≥ 1/32 in. from seating plane for 10 s max	230		°C

*In accordance with JEDEC registration data format (JS-6, RFD-1)

Features

- **Maximum Safe-Area-of-Operation Curves . . .** $I_{S/b}$ **limit line beginning at 24 V**
- **Fast Turn-On Time . . .** t_{on} **= 0.5μs max. at** I_C **= 15 A**
- **High-Current Capability . . .** h_{FE}, $V_{CE}(sat)$, $V_{BE}(sat)$, **&** V_{BE} **measured at** I_C **= 15 A**
- **Low** $V_{CE}(sat)$ **= 0.75 V max.**
- **High** P_T **= 140 W max. at** T_C **= 25° C**

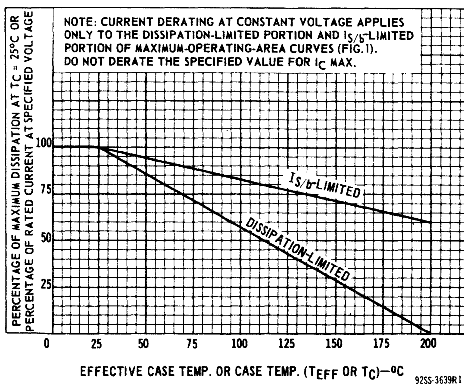


Fig. 1 - Dissipation derating curves for types 2N5671 & 2N5672

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C Unless Otherwise Specified*

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (A)			LIMITS: Type 2N5671		Type 2N5672		UNITS
			V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	
	Collector-Cutoff Current	I_{CEO}	–	80	–	–	–	–	0	–	10	–	10	mA
*		I_{CEV}	–	110	–	-1.5	–	–	–	–	12	–	–	mA
			–	135	–	-1.5	–	–	–	–	–	–	10	mA
*		I_{CEV} (T_C=150° C)	–	100	–	-1.5	–	–	–	–	15	–	10	mA
*	Emitter-Cutoff Current	I_{EBO}	–	–	7	–	0	–	–	–	10	–	10	mA
	Collector-to-Emitter Sustaining Voltage: (See Figs. 3,4, & 5) With base open	$V_{CEO}(sus)$	–	–	–	–	0.2	–	0	90[a]	–	120[a]	–	V
	With external base-to-emitter resistance (R_{BE}) ≤50 Ω	$V_{CER}(sus)$	–	–	–	–	0.2	–	0	110[a]	–	140[a]	–	V
	With base-emitter junction reverse biased & R_{BE} ≤ 50 Ω	$V_{CEX}(sus)$	–	–	–	-1.5	0.2	–	–	120[a]	–	150[a]	–	V
*	Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	–	–	–	–	15	–	1.2	–	1.5	–	1.5	V
	Base-to-Emitter Voltage	V_{BE}	–	5	–	–	15	–	–	–	1.6	–	1.6	V
*	Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	–	–	–	–	15	–	1.2	–	0.75	–	0.75	V
*	DC Forward-Current Transfer Ratio	h_{FE}	–	2	–	–	15	–	–	20	[illegible]	20	100	
			–	5	–	–	20	–	–	20	–	20	–	
	Second-Breakdown Collector Current[c] With base forward biased	$I_{S/b}$[b]	–	24	–	–	–	–	–	5.8[c]	–	5.8[c]	–	A
			–	45	–	–	–	–	–	0.9[c]	–	0.9[c]	–	A
	Second-Breakdown Energy With base reverse biased R_{BE} = 20 Ω, L = 180 μH	$E_{S/b}$[d]	–	–	–	-4	15	–	–	20	–	20	–	mJ
	Gain-Bandwidth Product	f_T	–	10	–	–	2	–	–	50	–	50	–	MHz
	Output Capacitance (At 1 MHz)	C_{ob}	10	–	–	–	–	0	–	–	900	–	900	pF
*	Saturated Switching Turn-On Time (Delay Time + Rise Time)	t_{on}	V_{CC}= 30 V	–	–	–	15	–	I_{B1}= I_{B2}= 1.2	–	0.5	–	0.5	μs
*	Saturated Switching Storage Time	t_s	V_{CC}= 30 V	–	–	–	15	–	I_{B1}= I_{B2}= 1.2	–	1.5	–	1.5	μs
*	Saturated Switching Fall Time	t_f	V_{CC}= 30 V	–	–	–	15	–	I_{B1}= I_{B2}= 1.2	–	0.5	–	0.5	μs
	Thermal Resistance (Junction-to-Case)	θ_{J-C}	–	40	–	–	0.5	–	–	–	1.25	–	1.25	°C/W

[a] CAUTION: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 3.

[b] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[c] Pulsed; 1-s, non-repetitive pulse.

[d] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = ½LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

* In accordance with JEDEC registration data format (JS-6, RFD-1)

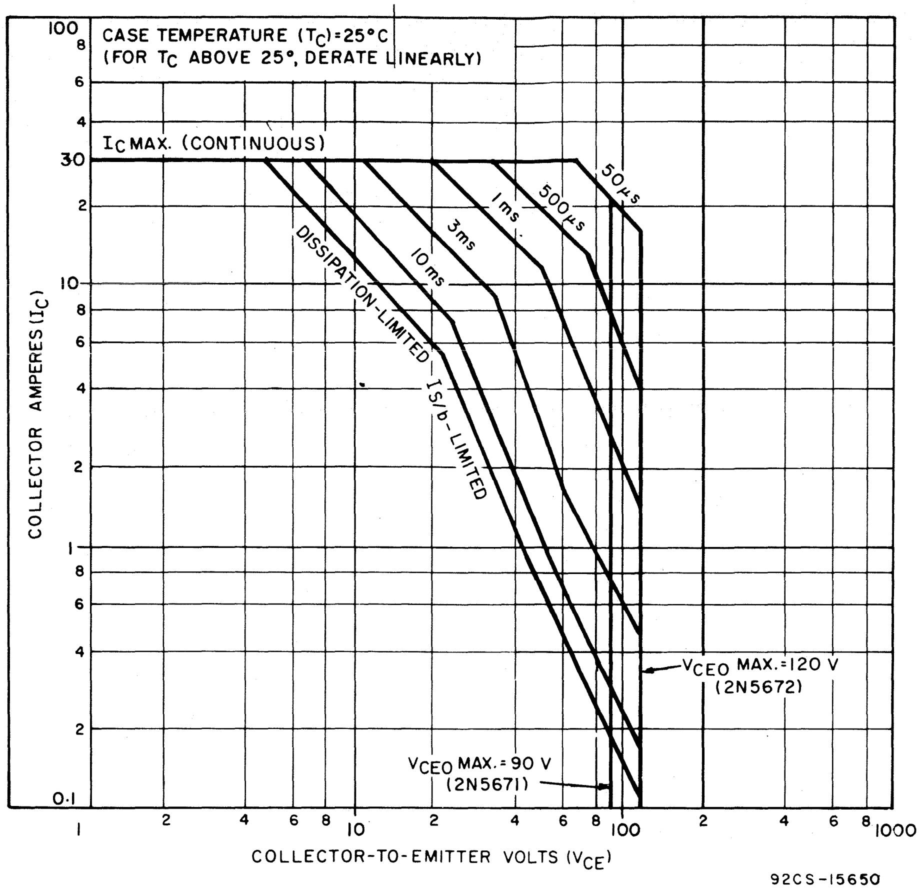
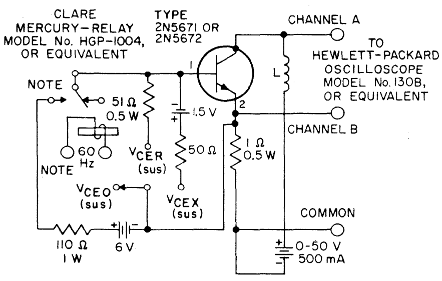


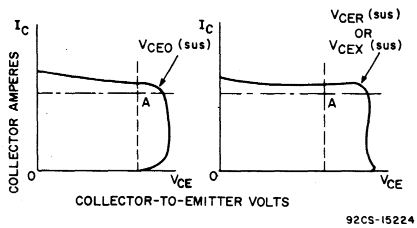
Fig.2 - Maximum operating areas for types 2N5671 & 2N5672



L = 15mH (V_{CEO}(sus) & V_{CER}(sus))
L = 2mH (V_{CEX}(sus))
NOTE: Relay vibrates 60 times per second.

92CS-15227R1

Fig. 3 - Circuit used to measure sustaining voltages V_{CEO}(sus), V_{CER}(sus), & V_{CEX}(sus) for types 2N5671 & 2N5672



NOTE: The sustaining Voltages V_{CEO}(sus), V_{CER}(sus) or, V_{CEX}(sus) are acceptable when the trace falls to the right and above point "A". (For values of current and voltage, see Electrical Characteristics.)

Fig. 4 - Oscilloscope display for measurement of sustaining voltages for types 2N5671 & 2N5672 (Test circuit shown in Fig. 3.)

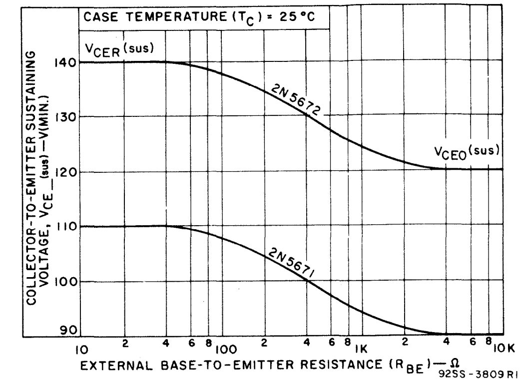


Fig. 5 - Collector-to-emitter sustaining voltage characteristics for types 2N5671 & 2N5672

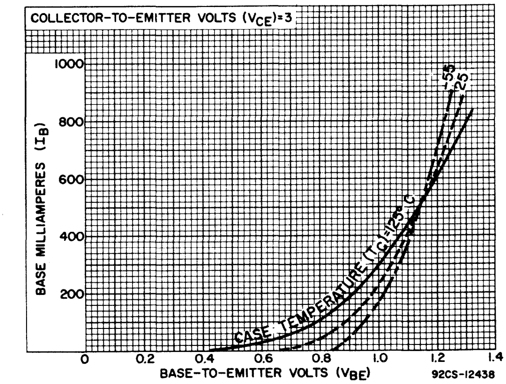


Fig. 6 - Typical input characteristics for types 2N5671 & 2N5672

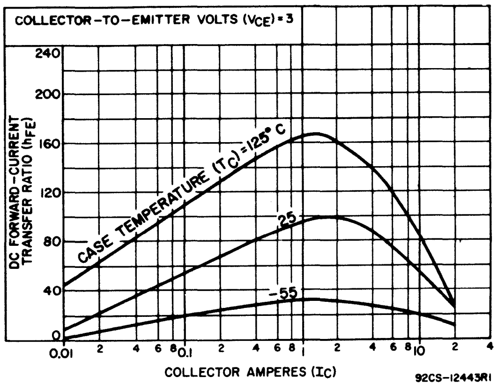


Fig. 7 - Typical DC beta characteristics for types 2N5671 & 2N5672

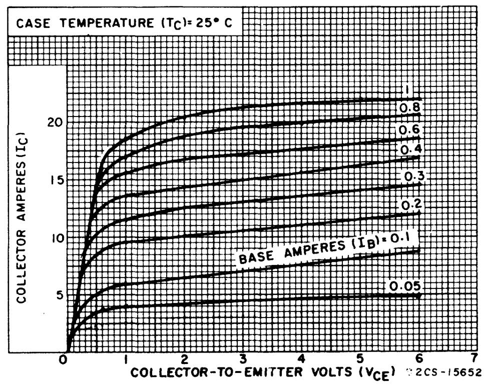


Fig. 8 - Typical output characteristics for types 2N5671 & 2N5672

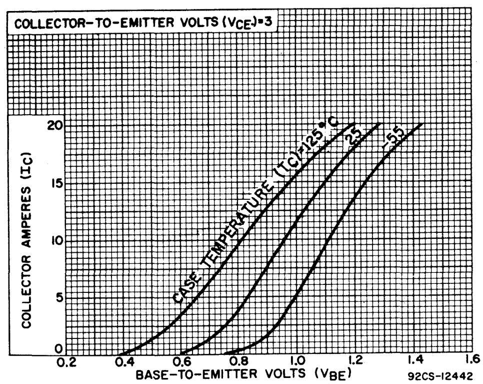


Fig. - 9 Typical transfer characteristics for types 2N5671 & 2N5672

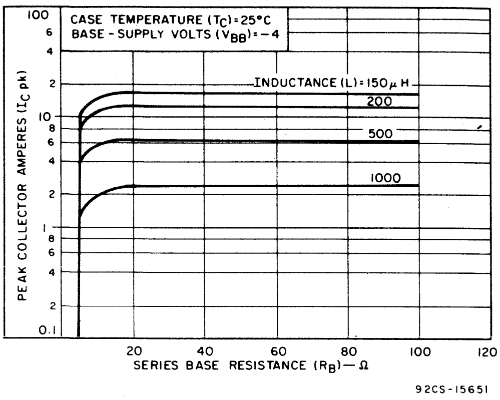


Fig. 10 - Maximum reverse-bias, second-breakdown characteristics for types 2N5671 & 2N5672

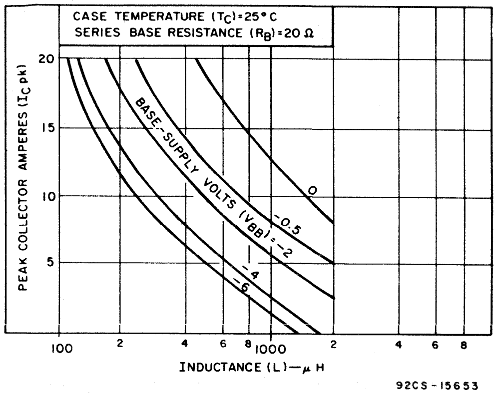


Fig. 11 - Maximum reverse-bias, second-breakdown characteristics for types 2N5671 & 2N5672

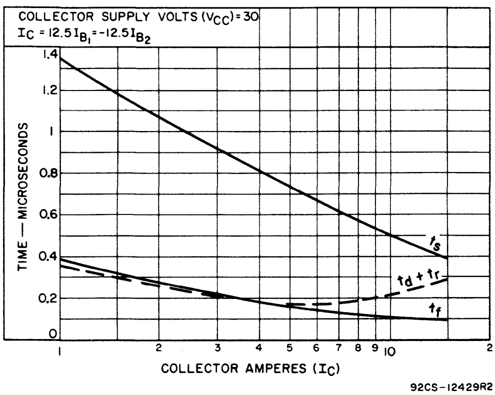
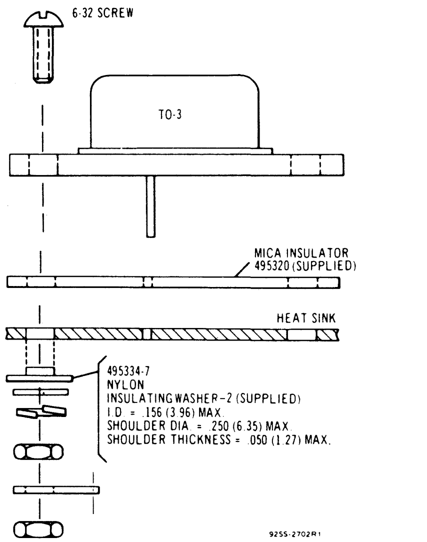


Fig. 12 - Typical saturated switching characteristics for types 2N5671 & 2N5672

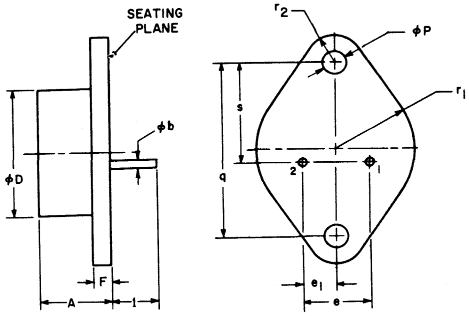


Dimensions in Inches and Millimeters

NOTE: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Fig. 13 - Suggested hardware for mounting types 2N5671 & 2N5672

DIMENSIONAL OUTLINE for Types 2N5671 & 2N5672 JEDEC TO-3



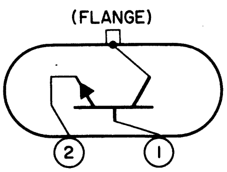
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.250	.450	6.35	11.43	
φb	.038	.043	.97	1.09	2
φD		.875		22.23	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F		.135		3.43	
l	.312		7.92		2
φP	.151	.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		.525		13.34	
r_2		.188		4.78	
s	.655	.675	16.64	17.15	1

92CS-15222

NOTES:

1. These dimensions should be measured at points .050 in. (1.27 mm) to .055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

TERMINAL DIAGRAM

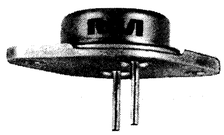


Pin 1 – Base
Pin 2 – Emitter
Mounting Flange, Case – Collector

RCA
Solid State
Division

Power Transistors

2N6032
2N6033



Modified JEDEC TO-3
(0.060-In. – Dia. Pins)

H-1627

High-Current, High-Speed, High-Power Transistors

Silicon N-P-N Types

For Switching and Amplifier Applications
in Military, Industrial, and Commercial Equipment

Features:

- **Low V_{CE}(sat) = 1.0 V max. at 40 A, 1.3 V max. at 50 A**
- **Maximum Safe-Area-of-Operation Curve. . . $I_{S/b}$ limit line beginning at 24 V**
- **Fast Storage Time . . . t_s = 1.5 μs max at I_C = 40 A (2N6033) 50A (2N6032)**
- **High-Current Capability . . . V_{CE}(sat) & V_{BE} measured at I_C = 40 A (2N6033)
= 50 A (2N6032)**
- **High P_T (140 W max. at T_C = 25°C)**

RCA Types 2N6032 and 2N6033* are epitaxial silicon n-p-n transistors having high-current and high-power handling capability and fast switching speed. The 2N6033 is similar to the 2N6032; they differ in maximum values for continuous collector current and sustaining voltage.

*Formerly RCA Dev. Types TA7337 and TA7337A, respectively.

MAXIMUM RATINGS, *Absolute Maximum Values:*

		2N6032	2N6033	
* COLLECTOR-TO-BASE VOLTAGE . . .	V_{CBO}	120	150	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With base open	V_{CEO}(sus)	90	120	V
With external base-to-emitter resistance (R_{BE}) $\leq$ 50 Ω	V_{CER}(sus)	110	140	V
* With external base-to-emitter resistance (R_{BE}) $\leq$ 50 Ω & V_{BE} = -1.5 V	V_{CEX}(sus)	120	150	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	7	V
* CONTINUOUS COLLECTOR CURRENT	I_C	50	40	A
* BASE CURRENT	I_B	10	10	A
* EMITTER CURRENT	I_E	50	40	A
* TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25°C and V_{CE} up to 24 V		140	140	W
At case temperatures up to 25°C and V_{CE} above 24 V		See Fig. 2.		
At case temperatures above 25°C and V_{CE} above 24 V		See Figs. 2 & 5		
* TEMPERATURE RANGE:				
Storage & Operating (Junction)		-65 to +200		°C
* PIN TEMPERATURE (During Soldering):				
At distances $\geq$ 1/32 in. (0.8 mm) from seating plane for 10 s max		230		°C

*In accordance with JEDEC registration data format JS-6 RDF-1.

Applications:

- **Switching-control amplifiers**
- **Power gates**
- **Switching regulators**
- **Power-switching circuits**
- **Power oscillators**
- **DC-RF amplifiers**
- **Converters**
- **Inverters**
- **Control circuits**

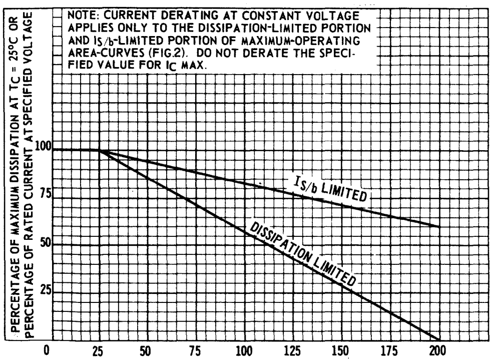


Fig. 1 — Derating curves for both types.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_E	I_B	LIMITS: Type 2N6032 Min.	Max.	Type 2N6033 Min.	Max.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}	–	80	–	–	–	–	0	–	10	–	10	mA
* With base-emitter junction reverse biased	I_{CEV}	–	110	–	-1.5	–	–	–	–	12	–	–	mA
		–	135	–	-1.5	–	–	–	–	–	–	10	
(T_C = 150°C)	I_{CEV}	–	100	–	-1.5	–	–	–	–	15	–	10	mA
* Emitter-Cutoff Current	I_{EBO}	–	–	7	–	0	–	–	–	10	–	10	mA
Collector-to-Emitter Sustaining Voltage: *(See Figs. 12 & 13)* * With base open	$V_{CEO}(sus)$	–	–	–	–	0.2	–	0	90[a]	–	120[a]	–	V
With external base to emitter resistance (R_{BE}) ≤ 50 Ω	$V_{CER}(sus)$	–	–	–	–	0.2	–	0	110[a]	–	140[a]	–	V
With base-emitter junction reverse biased & R_{BE} ≤ 50 Ω	$V_{CEX}(sus)$	–	–	–	-1.5	0.2	–	0	120[a]	–	150[a]	–	V
* Base-to-Emitter Saturation Voltage[c]	$V_{BE}(sat)$	–	–	–	–	50	–	5	–	2	–	–	V
		–	–	–	–	40	–	4	–	–	–	2	
Base-to-Emitter Voltage	V_{BE}	–	2	–	–	50	–	–	–	2	–	–	V
		–	2	–	–	40	–	–	–	–	–	2	
* Collector-to-Emitter Saturation Voltage[c]	$V_{CE}(sat)$	–	–	–	–	50	–	5	–	1.3	–	–	V
		–	–	–	–	40	–	4	–	–	–	1	
* DC Forward-Current Transfer Ratio[c]	h_{FE}	–	2.6	–	–	50	–	–	10	50	–	–	
		–	2	–	–	40	–	–	–	–	10	50	
Second-Breakdown Collector Current With base forward biased	$I_{S/b}$[b]	–	24	–	–	–	–	–	5.8[c]	–	5.8[c]	–	A
		–	40	–	–	–	–	–	0.9[c]	–	0.9[c]	–	
Second-Breakdown Energy With base reverse biased (L = 310 µH, R_{BE} = 5 Ω)	$E_{S/b}$[d]	–	–	–	-4	20	–	–	62	–	62	–	mJ
* Magnitude of common-emitter small-signal, short-circuit, forward-current transfer ratio (at 5 MHz)	$\|h_{fe}\|$		10			2			10	–	10	–	
Gain-Bandwidth Product	f_T	–	10	–	–	2	–	–	50	–	50	–	MHz
Output Capacitance (at 1 MHz)	C_{obo}	10	–	–	–	–	0	–	–	800	–	800	pF
Saturated Switching Time: Turn-On (Delay Time + Rise Time)	t_{on}	V_{CC}= 30V	–	–	–	50		5[e]	–	1	–	–	µs
			–	–	–	40	–	4[e]	–	–	–	1	
* Rise	t_r	V_{CC}= 30V	–	–	–	50	–	5[e]	–	1	–	–	µs
			–	–	–	40	–	4[e]	–	–	–	1	
* Storage	t_s	V_{CC}= 30V	–	–	–	50	–	5[e]	–	1.5	–	–	µs
			–	–	–	40	–	4[e]	–	–	–	1.5	
* Fall	t_f	V_{CC}= 30V	–	–	–	50	–	5[e]	–	0.5	–	–	µs
			–	–	–	40	–	4[e]	–	–	–	0.5	
Thermal Resistance (Junction-to-Case)	θ_{J-C}	–	20	–	–	2.5	–	–	–	1.25	–	1.25	°C/W

[a] CAUTION: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 12.

[b] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

[c] Pulsed; 1-s, non-repetitive pulse.

[d] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse-bias conditions. $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

[e] $I_{B1} = I_{B2}$ *In accordance with JEDEC registration format JS-6 RDF-1.

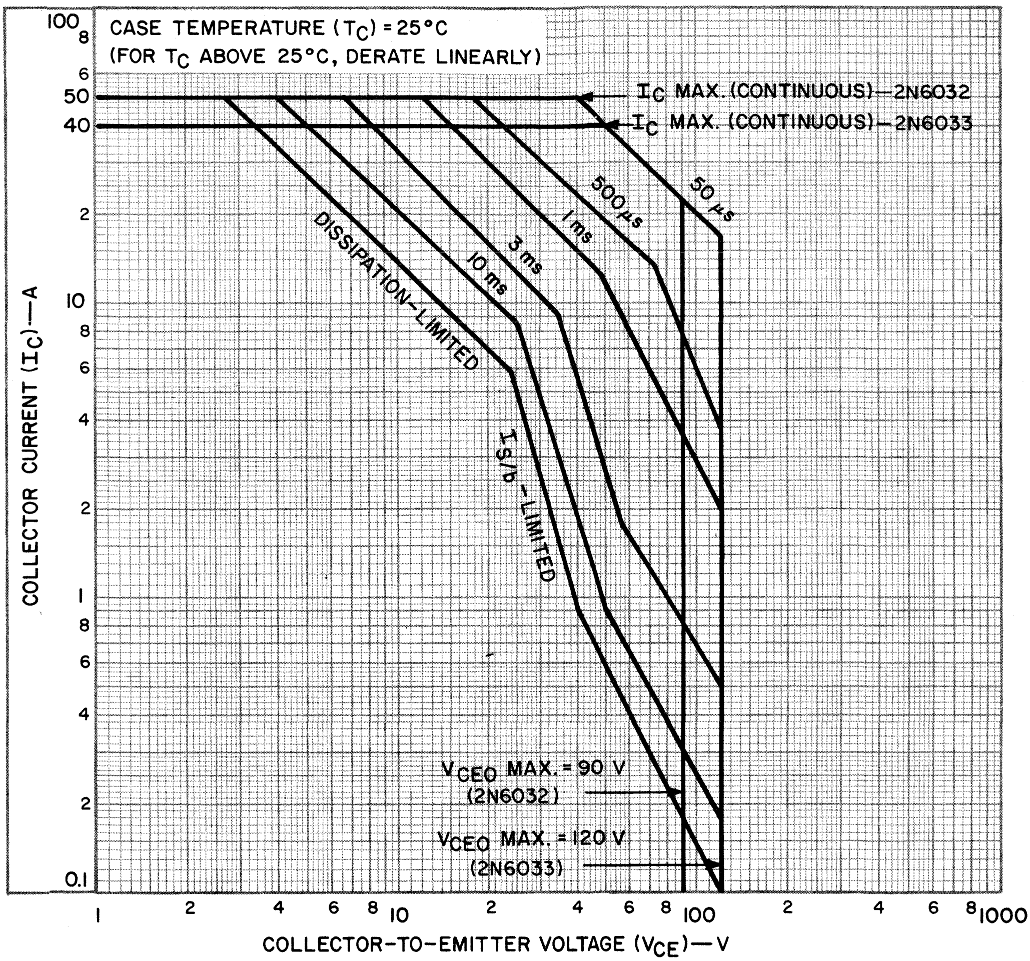


Fig. 2 — Maximum operating areas for both types.

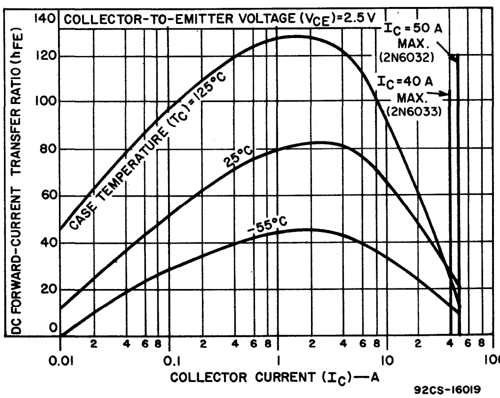


Fig. 3 – Typical dc-beta characteristic for both types.

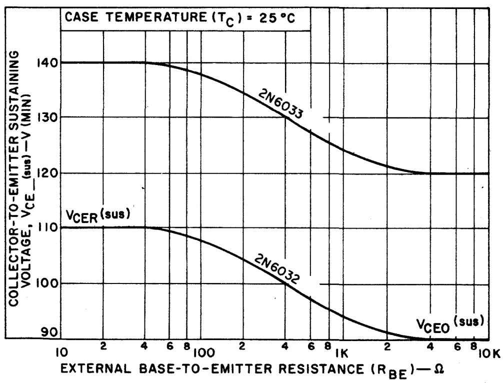


Fig. 4 – Collector-to-emitter sustaining voltage characteristics for both types.

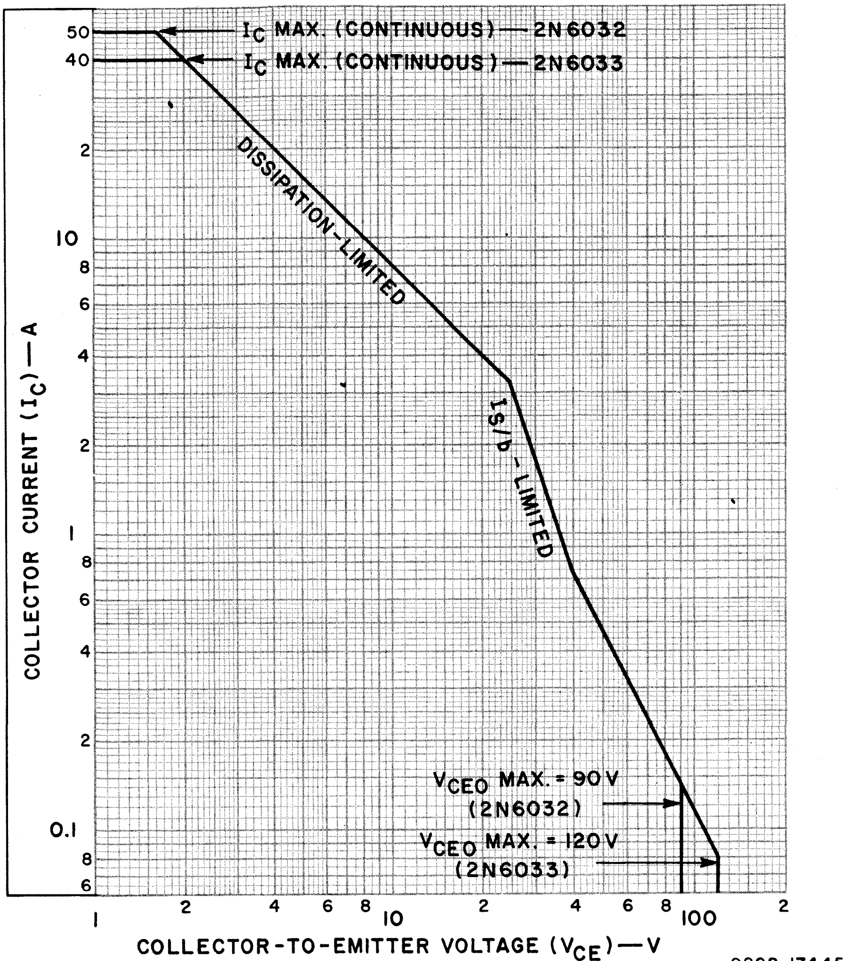


Fig. 5 – Maximum operating areas for both types at case temperature (T_C) = 100°C.

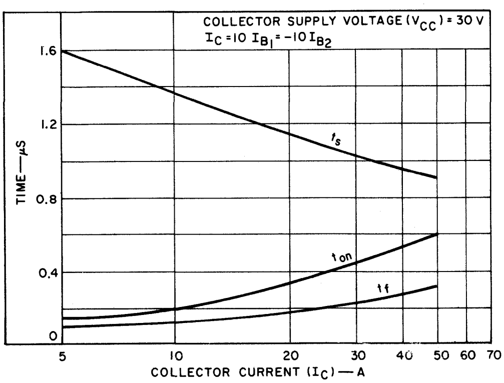


Fig. 6 – Typical saturated switching characteristics for both types.

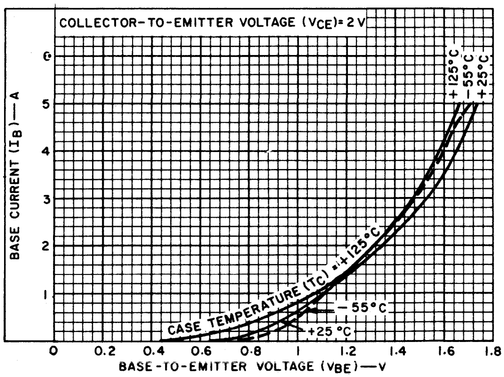


Fig. 7 – Typical input characteristics for both types.

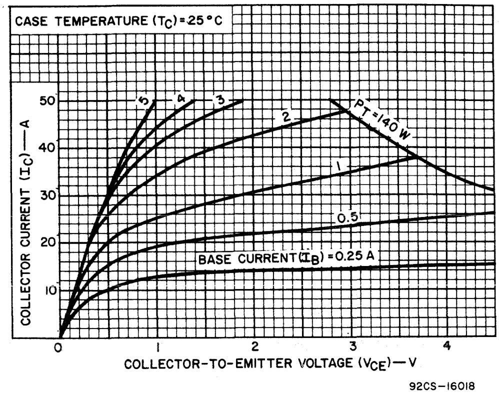


Fig. 8 — Typical collector characteristics for both types.

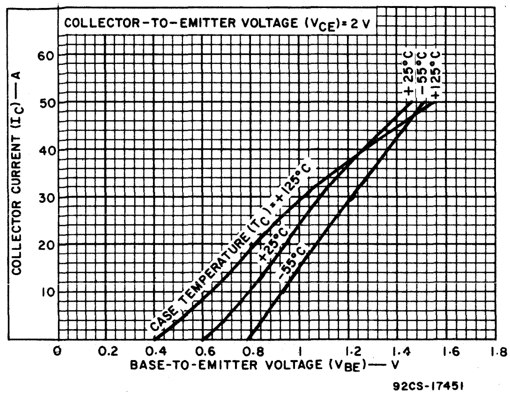


Fig. 9 — Typical transfer characteristics for both types.

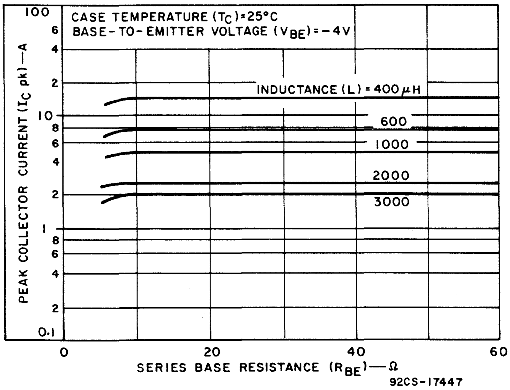


Fig. 10 — Maximum reverse-bias second-breakdown characteristics for both types.

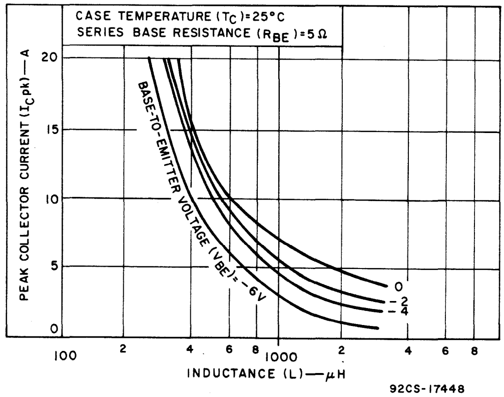


Fig. 11 — Maximum reverse-bias second-breakdown characteristics for both types.

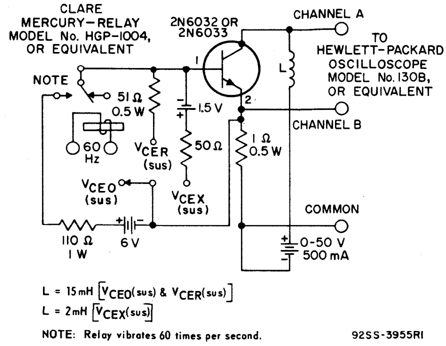
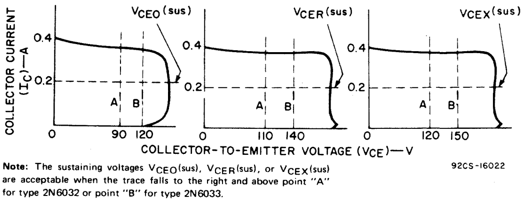


Fig. 12 — Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, & $V_{CEX}(sus)$ for both types.



Note: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, or $V_{CEX}(sus)$ are acceptable when the trace falls to the right and above point "A" for type 2N6032 or point "B" for type 2N6033.

Fig. 13 — Oscilloscope display for measurement of sustaining voltages for both types. (Test circuit shown in Fig. 5).

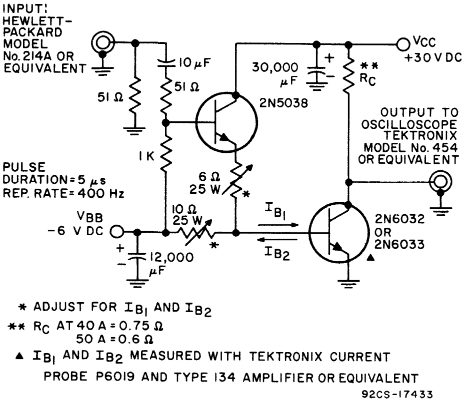


Fig. 14 — Switching-time test set.

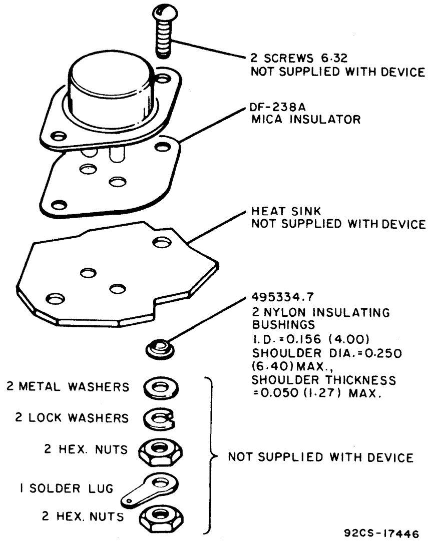
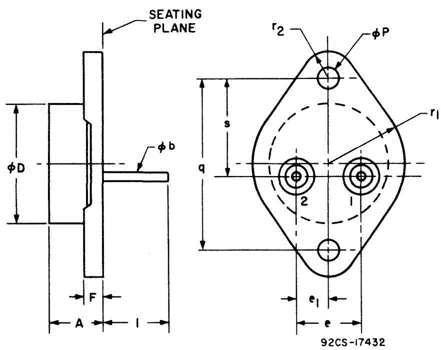


Fig. 15 — Suggested mounting hardware.

DIMENSIONAL OUTLINE
MODIFIED JEDEC TO-3 (0.060-Inch, Dia., Pins)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.300	0.350	7.62	8.89	
ϕb	0.059	0.061	1.50	1.55	2
ϕD		0.800		20.32	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.114		2.90	
I	0.440	0.470	11.18	11.94	2
ϕp	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:
1. THESE DIMENSIONS SHOULD BE MEASURED AT POINTS 0.050" (1.27 mm) TO 0.055" (1.40 mm) BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.
2. TWO LEADS.

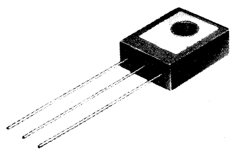
TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors

2N6178 2N6180
2N6179 2N6181



"Plastic TO-5"

H-1642

Silicon N-P-N & P-N-P Power Transistors

"Plastic TO-5" General-Purpose Types for Large-Signal, Medium-Power Applications

Features:

- **Maximum area-of-operation curves**
- **Planar construction for low-noise and low-leakage characteristics**
- **Low saturation voltage (2N6178, 2N6180)**
- **High beta (2N6179, 2N6181)**
- **Fast switching (2N6178, 2N6179)**
- **"Plastic TO-5" package with insulated mounting hole**

RCA types 2N6178, 2N6179, 2N6180, and 2N6181• are silicon power transistors intended for large-signal, medium-power applications in industrial and commercial equipment.

The 2N6178 and 2N6179 are triple-diffused silicon n-p-n planar types. These types have features similar to the popular 2N2102 plus higher collector-current ratings and dissipation capability.

Types 2N6180 and 2N6181 (p-n-p complements of the 2N6178 and 2N6179, respectively) are double-diffused, epitaxial-planar devices. These types have features similar to the 2N4036 plus higher collector-current ratings and dissipation capability.

Complementary N-P-N & P-N-P Types . . .

2N6178, 2N6179 } N-P-N 2N6180, 2N6181 } P-N-P

In addition, these types utilize the new RCA-developed "Plastic TO-5" package. This plastic package has an insulated mounting hole for ease of mounting and heat sinking for optimum thermal contact.

• Formerly RCA Dev. Nos. TA7554–TA7557, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6179	2N6181	2N6178	2N6180	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	75	-75	100	-100	V
COLLECTOR-TO-EMITTER VOLTAGE:						
* With 1.5 volts (V_{BE}) of reverse bias	V_{CEX}	75	-75	100	-100	V
With external base-to-emitter resistance (R_{BE}) = 100Ω, sustaining	$V_{CER}(sus)$	65	-65	90	-90	V
With base open, sustaining	$V_{CEO}(sus)$	50	-50	75	-75	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	-5	7	-7	V
*CONTINUOUS COLLECTOR CURRENT	I_C	2	-2	2	-2	A
*CONTINUOUS BASE CURRENT	I_B	1	-1	1	-1	A
*TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		25	25	25	25	W
At case temperatures above 25°C			See Figs. 1, 2, & 3			
At case temperatures up to 100°C		10	10	10	10	W
At case temperatures above 100°C			See Figs. 3, 4, & 5			
*TEMPERATURE RANGE:						
Storage and operating (Junction)			-65 to 150			°C
*LEAD TEMPERATURE (During soldering): At distance ≥1/32 in (0.8 mm) from seating plane for 10 s max			230			°C

*In accordance with JEDEC registration data format JS-6/RDF-1.

ELECTRICAL CHARACTERISTICS, *at case temperature (T_C) = 25°C, unless otherwise specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (mA) I_C	I_E	I_B	LIMITS: Type 2N6178 Min.	Max.	Type 2N6179 Min.	Max.	Type 2N6180 Min.	Max.	Type 2N6181 Min.	Max.	UNITS
Collector-Cutoff Current With emitter open	I_{CBO}	80					0		–	0.5	–	–	–	–	–	–	µA
		60					0		–	–	–	0.5	–	–	–	–	
		–80					0		–	–	–	–	–	–0.5	–	–	
		–60					0		–	–	–	–	–	–	–	–0.5	
With base open	I_{CEO}		60					0	–	1	–	–	–	–	–	–	mA
			45					0	–	–	–	1	–	–	–	–	
			–60					0	–	–	–	–	–	–1	–	–	
			–45					0	–	–	–	–	–	–	–	–1	
* With base reverse-biased	I_{CEV}		100		–1.5				–	0.1	–	–	–	–	–	–	mA
			75		–1.5				–	–	–	0.1	–	–	–	–	
			–100		1.5				–	–	–	–	–	–0.1	–	–	
			–75		1.5				–	–	–	–	–	–	–	–0.1	
* With base reverse-biased and T_C = 100°C	I_{CEV}		70		–1.5				–	0.5	–	–	–	–	–	–	mA
			45		–1.5				–	–	–	0.5	–	–	–	–	
			–70		1.5				–	–	–	–	–	–0.5	–	–	
			–45		1.5				–	–	–	–	–	–	–	–0.5	
* Emitter-Cutoff Current	I_{EBO}			7		0			–	0.1	–	–	–	–	–	–	mA
				5		0			–	–	–	0.1	–	–	–	–	
				–7		0			–	–	–	–	–	–0.1	–	–	
				–5		0			–	–	–	–	–	–	–	–0.1	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					0	0.1		7	–	5	–	–	–	–	–	V
						0	–0.1		–	–	–	–	–7	–	–5	–	
* Collector-to-Emitter Breakdown Voltage: With base-emitter junction reverse-biased	$V_{(BR)CEV}$				–1.5	0.1			100	–	75	–	–	–	–	–	V
					1.5	–0.1			–	–	–	–	–100	–	–75	–	
* With base open	$V_{(BR)CEO}$					100		0	75	–	50	–	–	–	–	–	V
						–100		0	–	–	–	–	–75	–	–50	–	
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER(sus)}$[a]					100			90	–	65	–	–	–	–	–	V
						–100			–	–	–	–	–90	–	–65	–	
With base open	$V_{CEO(sus)}$[a]					100		0	75	–	50	–	–	–	–	–	V
						–100		0	–	–	–	–	–75	–	–50	–	
* Collector-to-Emitter Saturation Voltage	$V_{CE(sat)}$					500		50	–	0.5	–	0.8	–	–	–	–	V
						–500		–50	–	–	–	–	–	–0.7	–	–1.2	
* Base-to-Emitter Saturation Voltage	$V_{BE(sat)}$					500		50	–	1.2	–	1.5	–	–	–	–	V
						–500		–50	–	–	–	–	–	–1.2	–	–1.5	
Output Capacitance (At 1 MHz)	C_{obo}	10							12	20	12	20	–	–	–	–	pF
		–10							–	–	–	–	25	40	25	40	
* DC Forward-Current Transfer Ratio	h_{FE}		4			50			–	–	30	–	–	–	–	–	
			–4			–50			–	–	–	–	–	–	30	–	
			2			500[b]			30	130	40	250	–	–	–	–	
			–2			–500[b]			–	–	–	–	30	130	40	250	
			2			1000[b]			10	–	–	–	–	–	–	–	
			–2			–1000[b]			–	–	–	–	10	–	–	–	
Second-Breakdown Collector Current [c, d] (With base forward-biased)	$I_{S/b}$[e]		V_{CC}= 50						200	–	200	–	–	–	–	–	mA
			–50						–	–	–	–	–150	–	–150	–	
Gain-Bandwidth Product	f_T		4			50			50	–	50	–	–	–	–	–	MHz
			–4			–50			–	–	–	–	50	–	50	–	
* Magnitude of Common Emitter, Small-Signal, Short-Circuit Forward-Current Transfer Ratio (f = 10 MHz)	$\|h_{fe}\|$		4			50			5	–	5	–	–	–	–	–	
			–4			–50			–	–	–	–	5	–	5	–	

Chart continued on page 3.

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (mA)			LIMITS: Type 2N6178		Type 2N6179		Type 2N6180		Type 2N6181		UNITS
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Saturated Switching Time: (See Fig. 30 & 31) Turn-on Time	t_{on}		V_{CC}= 30			500		50	–	80	–	80	–	–	–	–	ns
			–30			–500		–50	–	–	–	–	–	100	–	100	
Turn-off Time	t_{off}		V_{CC}= 30			500		50	–	800	–	800	–	–	–	–	ns
			–30			–500		–50	–	–	–	–	–	1000	–	1000	
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$								–	5	–	5	–	5	–	5	°C/W
Junction-to-Ambient	$R_{\theta JA}$								–	156	–	156	–	156	–	156	°C/W

* In accordance with JEDEC registration data format JS-6/RDF-1.

a CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer.

b Pulsed; pulse duration $\leq 300\ \mu s$, duty factor ≤ 0.02.

c Safe operating regions for forward-bias operation are shown on Figs. 1, 2, 4, and 5.

d Pulsed: 0.4s, non-repetitive pulse.

e $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased for transistor operation in the active region.

N-P-N

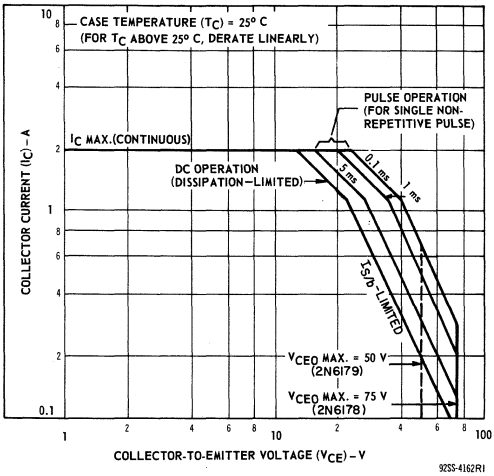


Fig.1—Maximum operating areas for 2N6178 and 2N6179 at T_C=25°C.

P-N-P

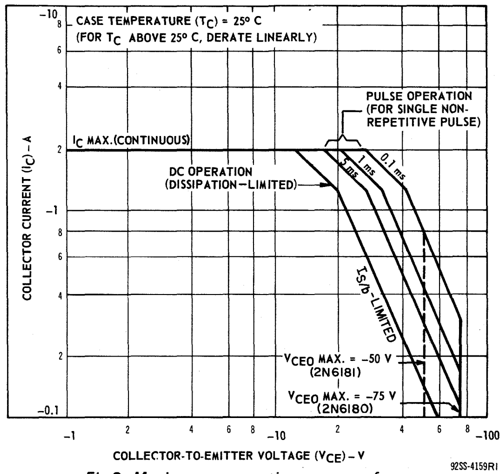


Fig.2—Maximum operating areas for 2N2180 and 2N6181 at T_C=25°C.

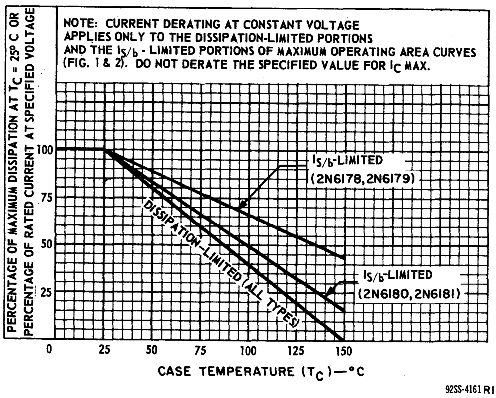


Fig.3—Derating curves for all types.

N-P-N

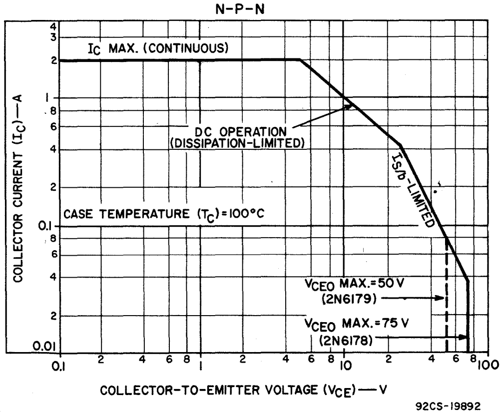


Fig.4—Maximum operating areas for 2N6178 and 2N6179 at T_C=100°C.

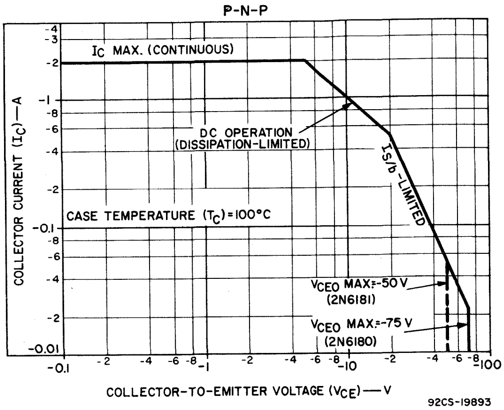


Fig.5—Maximum operating areas for 2N6180 and 2N6181 at T_C=100°C.

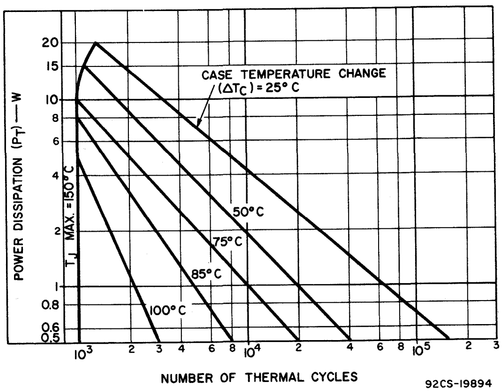


Fig.6—Thermal-cycling rating chart for all types.

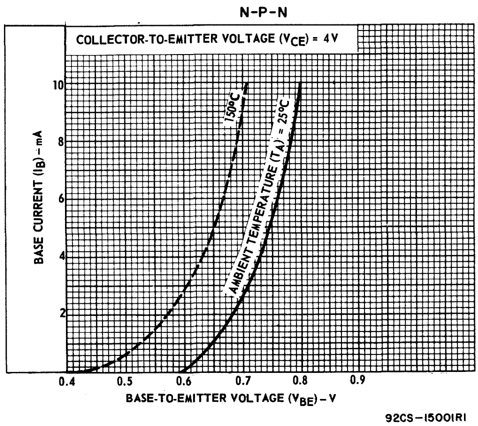


Fig.7—Typical input characteristics for 2N6178 and 2N6179.

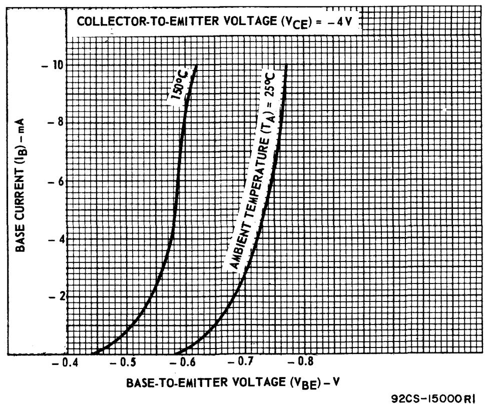


Fig.8—Typical input characteristics for 2N6180 and 2N6181.

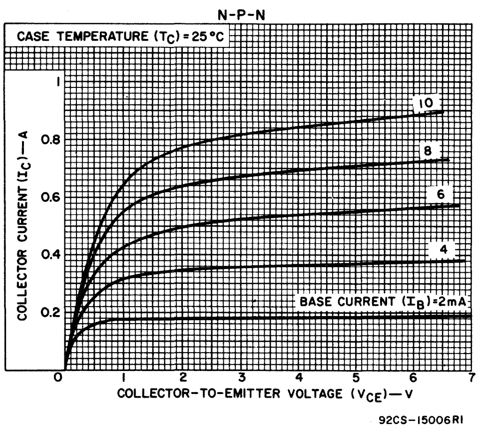


Fig.9—Typical output characteristics for 2N6178 and 2N6179.

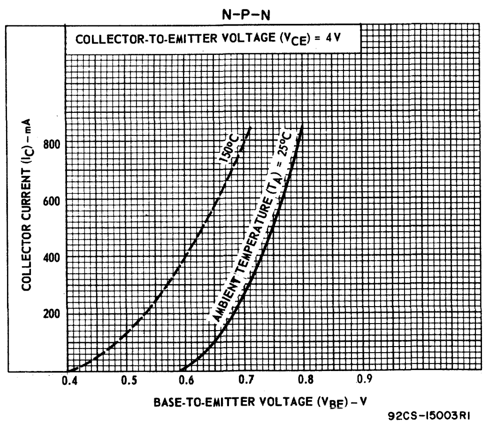


Fig.10—Typical transfer characteristics for 2N6178 and 2N6179.

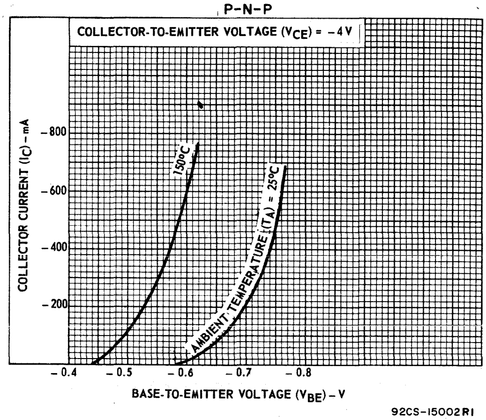


Fig.11—Typical transfer characteristics for 2N6180 and 2N6181.

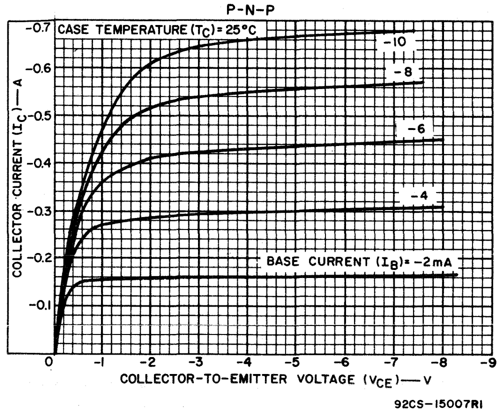


Fig.12—Typical output characteristics for 2N6180 and 2N6181.

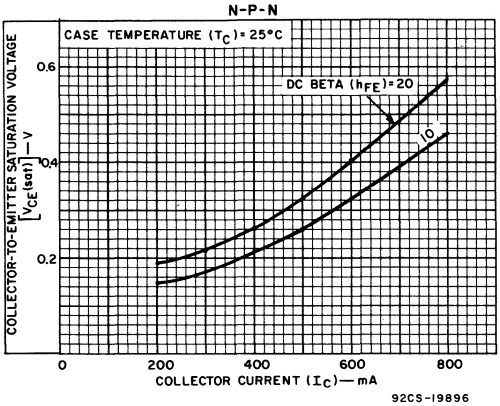


Fig.13—Typical saturation-voltage characteristics for 2N6178 and 2N6179.

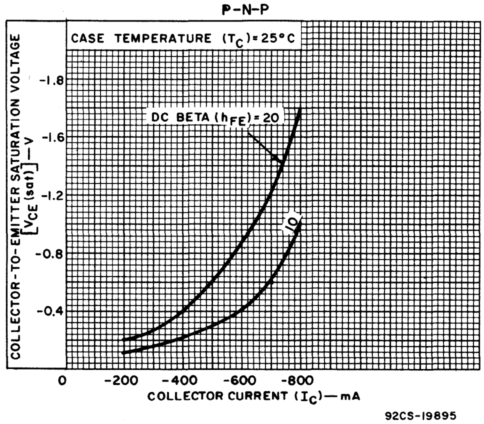


Fig.14—Typical saturation-voltage characteristics for 2N6180 and 2N6181.

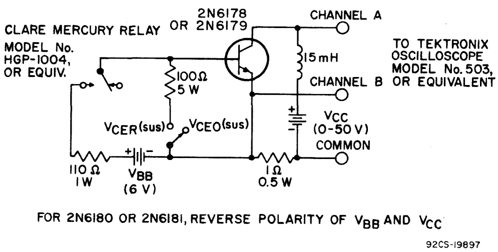


Fig.15—Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$.

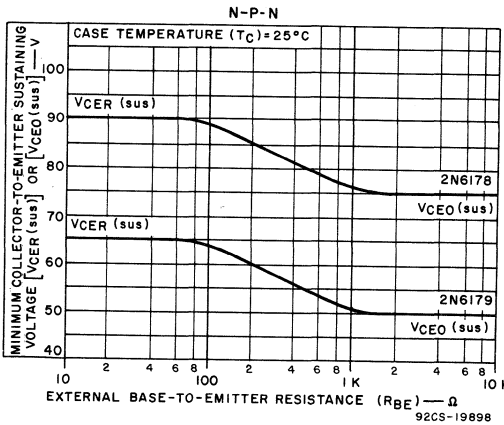


Fig.16—Collector-to-emitter sustaining voltage characteristics for 2N6178 and 2N6179.

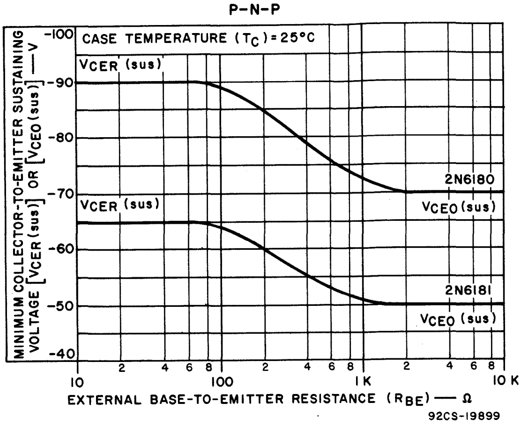
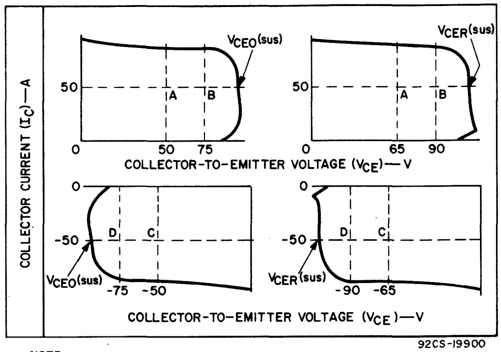


Fig.17—Collector-to-emitter sustaining voltage characteristics for 2N6180 and 2N6181.



NOTE:
SUSTAINING VOLTAGES $V_{CEO(sus)}$ AND $V_{CER(sus)}$ ARE ACCEPTABLE WHEN TRACES FALL TO THE RIGHT AND ABOVE POINTS "A" FOR TYPE 2N6179, POINTS "B" FOR TYPE 2N6178, TO THE LEFT AND BELOW POINTS "C" FOR TYPE 2N6181, AND POINTS "D" FOR TYPE 2N6180.

Fig.18—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig.15).

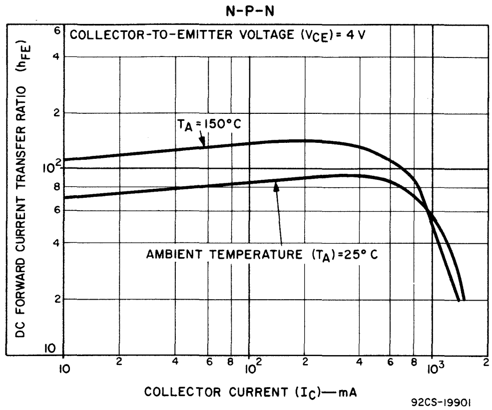


Fig.19—Typical dc beta characteristics for 2N6178 and 2N6179.

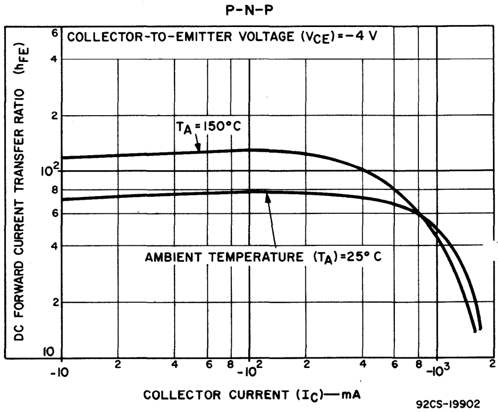


Fig.20—Typical dc beta characteristics for 2N6180 and 2N6181.

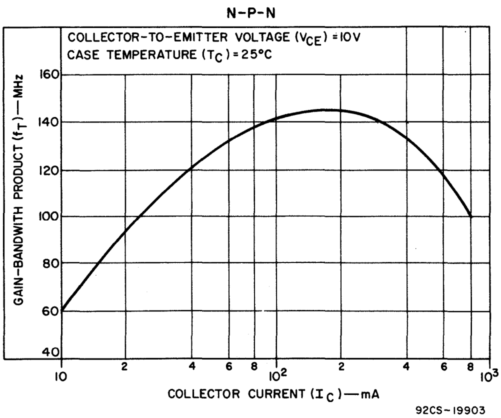


Fig.21—Typical gain-bandwidth product for 2N6178 and 2N6179.

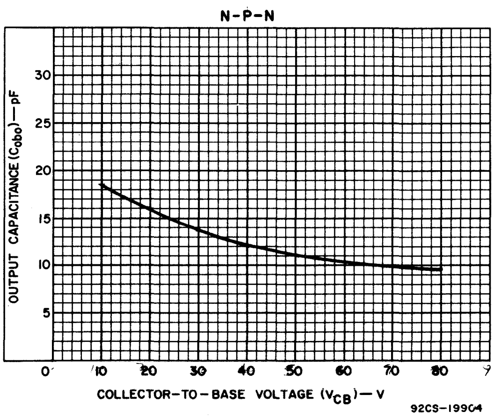


Fig.22—Typical output capacitance vs. collector-to-base voltage for 2N6178 and 2N6179.

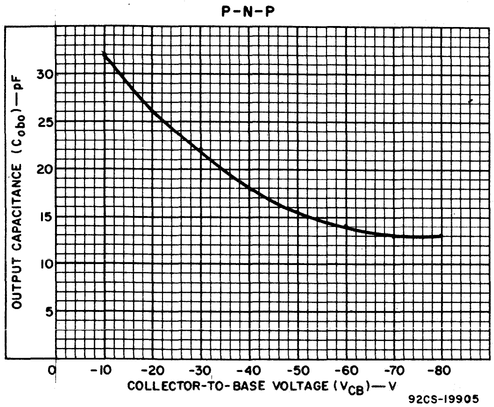


Fig.23—Typical output capacitance vs. collector-to-base voltage for 2N6180 and 2N6181.

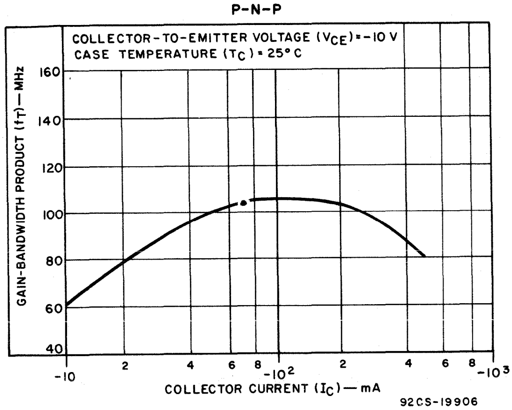


Fig.24—Typical gain-bandwidth product for 2N6180 and 2N6181.

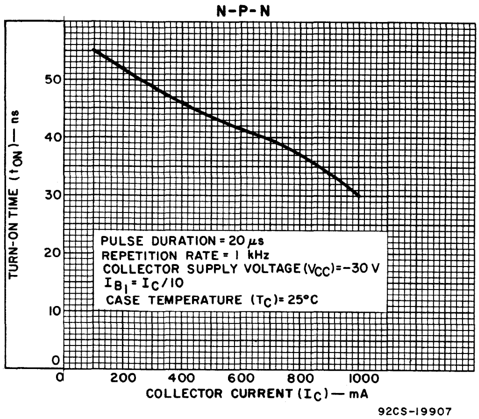


Fig.25—Typical turn-on time for 2N6178 and 2N6179.

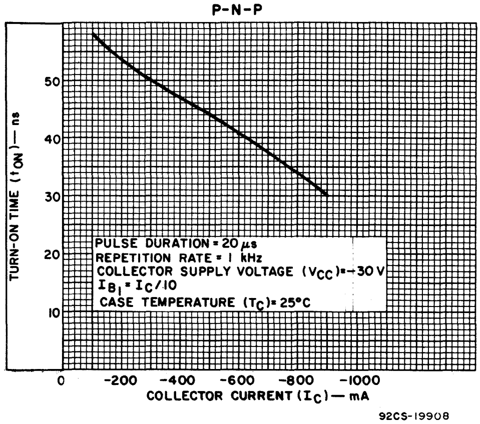


Fig.26—Typical turn-on time for 2N6180 and 2N6181.

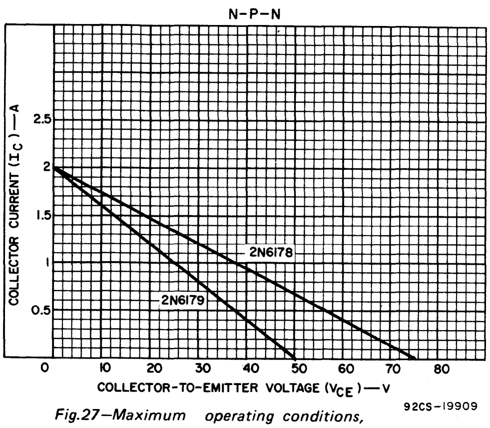


Fig.27—Maximum operating conditions, resistive-load switching between saturation and cutoff for 2N6178 and 2N6179.

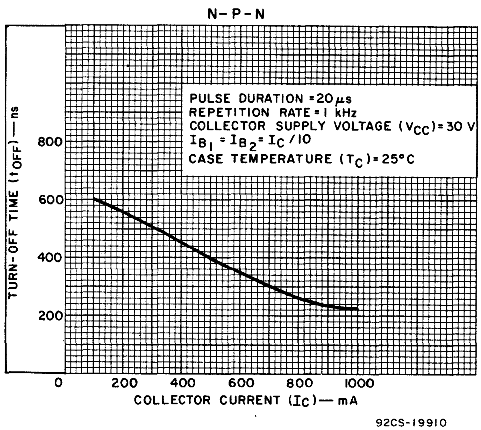


Fig.28—Typical turn-off time for 2N6178 and 2N6179.

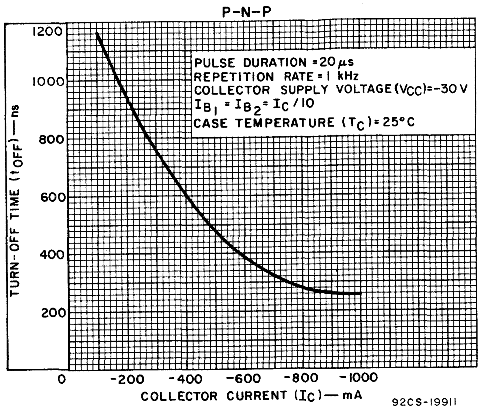


Fig.29—Typical turn-off time for 2N6180 and 2N6181.

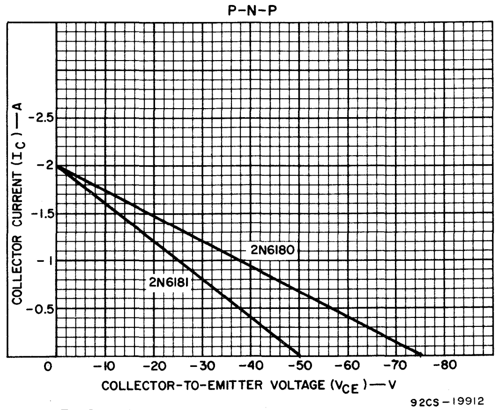


Fig.30—Maximum operating conditions, resistive-load switching between saturation and cutoff for 2N6180 and 2N6181.

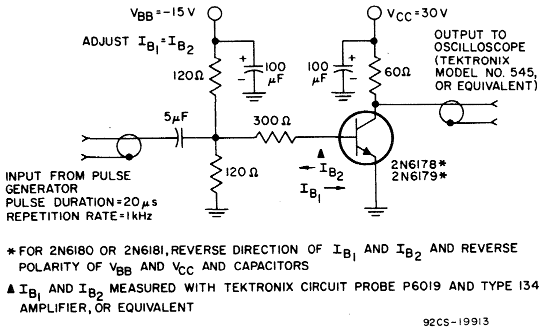


Fig.31—Circuit used to measure switching times for all types.

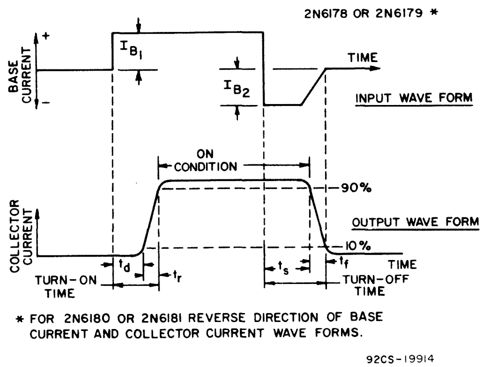
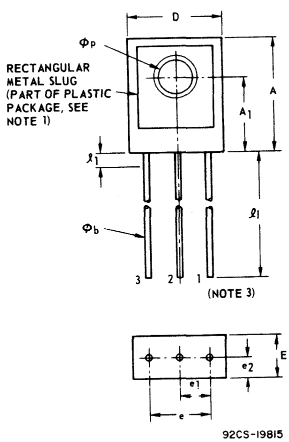


Fig.32—Phase relationship between input current and output voltage showing reference points for specification of switching times (test circuit shown in Fig.31).

DIMENSIONAL OUTLINE
"Plastic TO-5"



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.385	0.395	9.78	10.03	
A_1	0.251	0.261	6.37	6.63	
φb	0.016	0.019	0.41	0.48	2
D	0.305	0.315	7.75	8.00	
E	0.145	0.155	3.68	3.94	
e	0.195	0.205	4.95	5.21	
e_1	0.095	0.105	2.41	2.67	
e_2	0.070	0.080	1.78	2.03	
ℓ	0.725	0.745	18.41	18.91	
$ℓ_1$	0.125	0.250	3.17	6.35	
φp	0.112	0.118	2.84	2.99	

NOTE 1: To attach to heat sink, use a 4-40 binding-head screw and a No. 4 flat washer. The recommended screw torque (for even distribution of mounting pressure and optimum thermal contact) is 6 in.-lb.
NOTE 2: Three leads. Leads are pretinned to the $ℓ_1$ dimension.
NOTE 3: Lead numbering from right to left with rectangular metal slug facing observer.

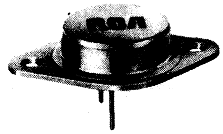
TERMINAL CONNECTIONS
Lead 1 — Emitter
Lead 2 — Base
Lead 3 — Collector
Rectangular Metal Slug-Collector

RCA

Solid State
Division

Power Transistors

2N6354



JEDEC TO-3 H-1570

120-V, 10-A, 140-W Silicon N-P-N Transistor

For Switching Applications in Military and Industrial Equipment

Features:

- **High V_{CEO}(sus): 120 V**
- **Maximum safe-area-of operation curves**
- **Low saturation voltage: V_{CE}(sat) $\leq$ 0.5 V**
- **Fast switching speeds at I_C = 5 A:**
  - $t_r \leq 0.3\ \mu s$
  - $t_s \leq 1\ \mu s$
  - $t_f \leq 0.2\ \mu s$
- **High dissipation rating: P_T = 80 W at 100°C**
  = 140 W at 25°C

RCA type 2N6354● is an epitaxial silicon n-p-n power transistor with a multiple-emitter-site structure. The device is supplied in the JEDEC TO-3 package.

Typical high-speed switching applications for the 2N6354 include switching-control amplifiers operated from a 48-V (nominal) power supply, power gates, switching regulators, dc-dc converters, and power oscillators.

● Formerly RCA Dev. No. TA7534.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	150	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base open, sustaining	V_{CEO}(sus)	120	V
* With external base-to-emitter resistance (R_{BE}) = 500Ω	V_{CEX}	130	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	6.5	V
*COLLECTOR CURRENT (Continuous)	I_C	10	A
COLLECTOR CURRENT (Peak)		12	A
*BASE CURRENT (Continuous)	I_B	5	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C and V_{CE} up to 25 V		140	W
At case temperature of 100°C and V_{CB} of 20 V		80	W
At case temperatures up to 25°C and V_{CE} above 25 V		See Figs. 1 & 2	
At case temperatures above 25°C and V_{CE} above 25 V		See Figs. 1, 2, & 4	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
*PIN TEMPERATURE (During Soldering):			
At distance ≥ 1/32 in. (0.8 mm) from case for 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-1.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE (V) V_{CE}	V_{CB}	V_{EB}	V_{BE}	DC CURRENT (A) I_C	I_B	LIMITS 2N6354 MIN.	MAX.	UNITS
* Collector-Cutoff Current‡ With emitter open	I_{CBO}		150					–	5	mA
With base open	I_{CEO}	100					0	–	20	mA
* With base-emitter junction reverse-biased	I_{CEV}	140			0			–	10	mA
* At T_C = 125°C	I_{CEV}	140			0			–	20	mA
* Emitter-Cutoff Current	I_{EBO}			6.5		0		–	5	mA
* Emitter-to-Base Voltage	V_{EBO}						0.005	6.5	–	V
* Collector-to-Emitter Voltage: At breakdown, with base open	$V_{(BR)CEO}$					0.2	0	120[b]	–	V
With external base-to emitter resistance (R_{BE}) ≤ 100 Ω	$V_{CER}(sus)$[f]					0.2	0	130[b]	–	V
* Saturation Voltage: Collector-to-Emitter	$V_{CE}(sat)$					5[a] 10[a]	0.5 1.0	– –	0.5 1	V
Base-to-Emitter	$V_{BE}(sat)$					5[a] 10[a]	0.5 1.0	– –	1.3 2	V
* DC Forward Current Transfer Ratio	h_{FE}	2 2				5[a] 10[a]		20 10	150 100	
Forward-Bias Second-Breakdown Collector Current[d]	$I_{S/b}$[c]	25 45						5.5 0.5	– –	A
Second-Breakdown Energy (With base reverse biased, R_{BE}=51 Ω, L = 25 µH)	$E_{S/b}$[g]			1		5		0.3	–	mJ
* Magnitude of Common Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 10 MHz)	$\|h_{fe}\|$	10				1		8	–	
* Saturated Switching Time: (See Figs. 11 & 12) Rise Time	t_r	V_{CC} = 30				5 10	0.5[e] 1[e]	– –	0.3 1	µs
Storage Time	t_{s1}	V_{CC} = 30				5 10	0.5[e] 1[e]	– –	1 0.6	µs
Storage Time (No Load)	t_{s2}	V_{CC} = 30				0.5	0.5[e]	–	2	µs
Fall Time	t_f	V_{CC} = 30				5 10	0.5[e] 1[e]	– –	0.2 0.2	µs
Output Capacitance (f = 1 MHz)	C_{obo}		10					–	300	pF
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$	20				1		–	1.25	°C/W

*In accordance with JEDEC registration data format JS-6 RDF-1.

[a] Pulsed: pulse duration ≤ 350 µs, duty factor = 2%.

[b] CAUTION: The collector-to-emitter voltages, $V_{(BR)CEO}$ and $V_{CER}(sus)$, MUST NOT be measured on a curve tracer. These voltages should be measured by means of the test circuit shown in Fig.5.

[c] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward-biased for transistor operation in the active region.

[d] Pulsed; 1-s non-repetitive pulse.

[e] $I_{B_1} = I_{B_2}$ = value shown.

[f] L = 15 mH

[g] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$ where L is a series load or leakage inductance and I is the peak collector current.

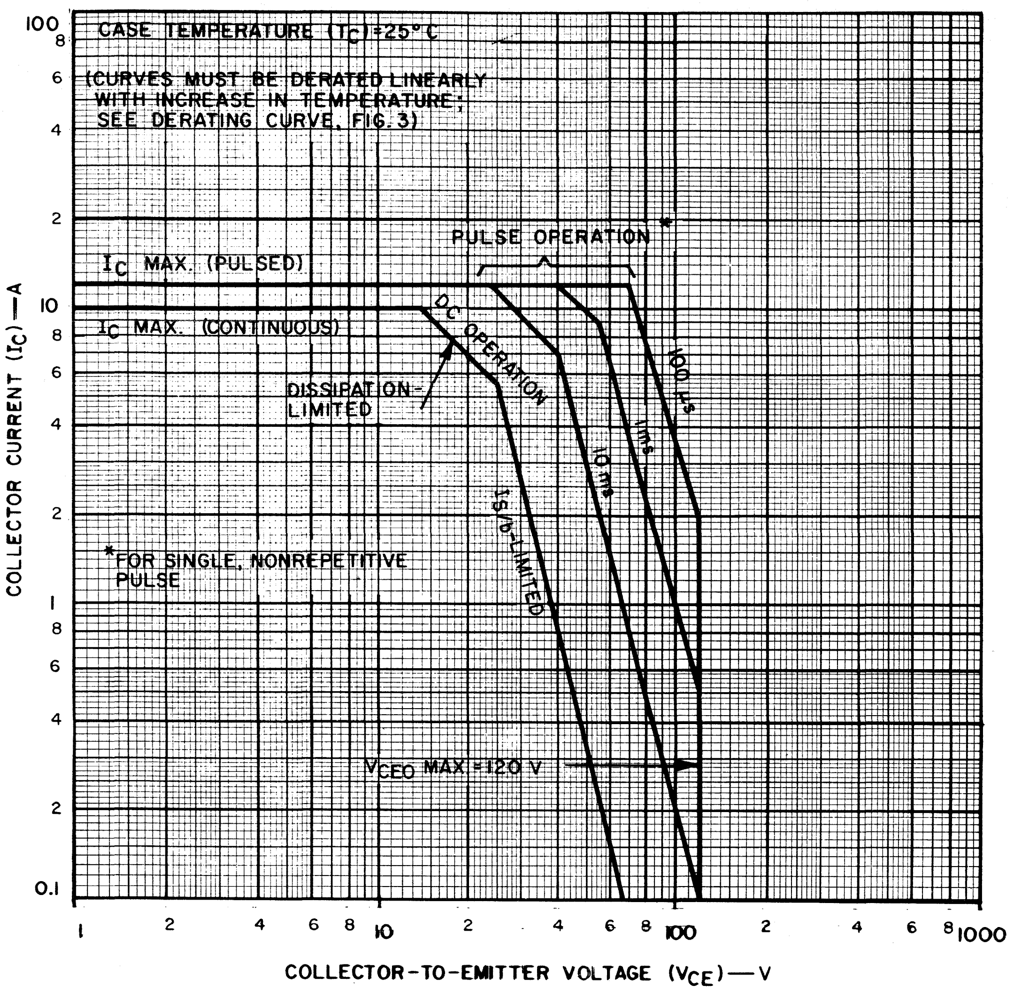


Fig.1—Maximum operating areas.

92CS-20133

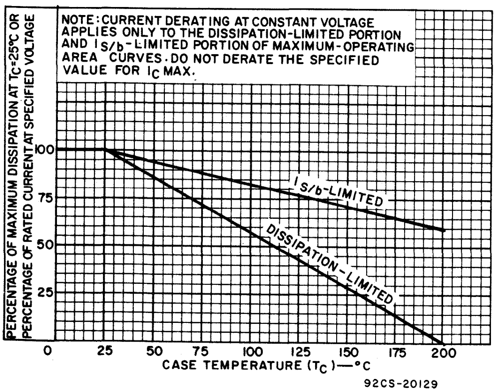


Fig.2 —Derating curves.

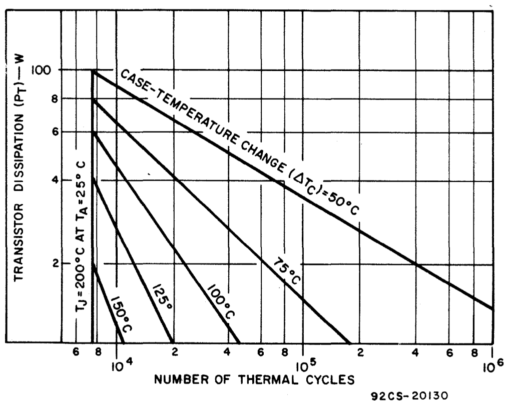


Fig.3—Thermal-cycling rating chart.

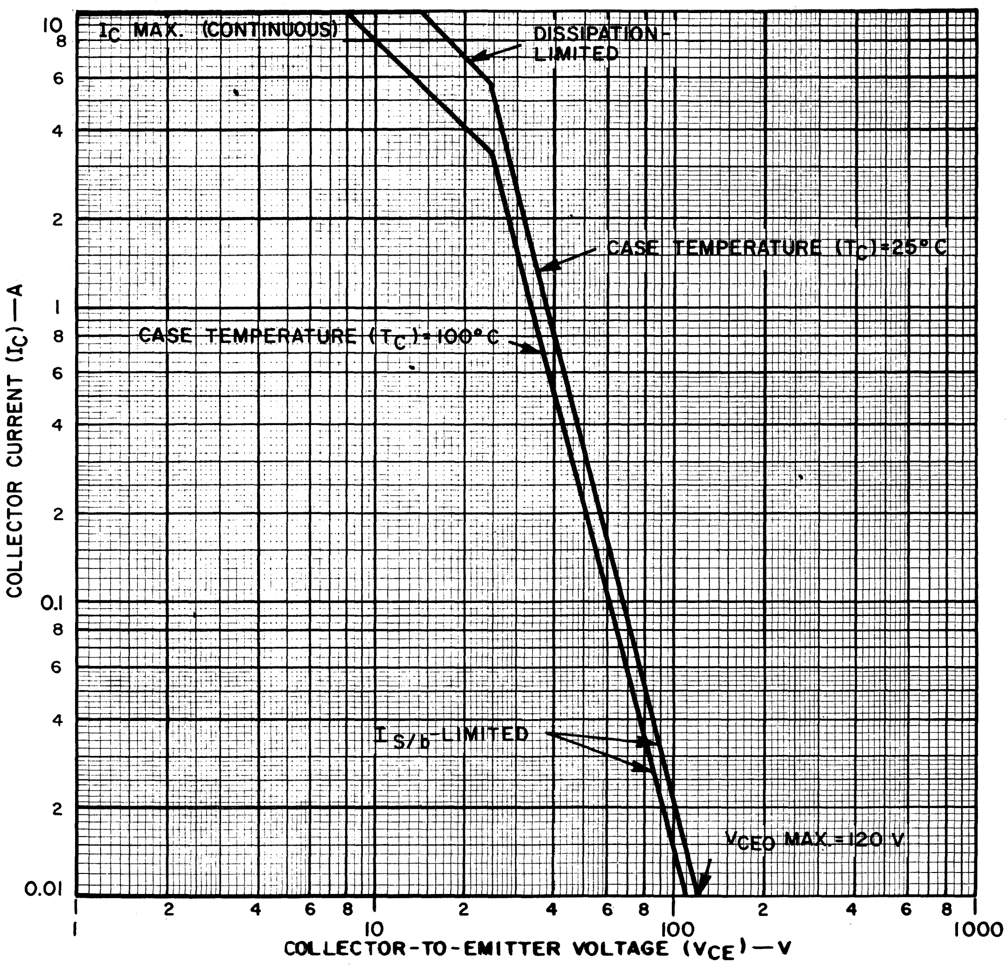


Fig.4—Maximum operating areas.

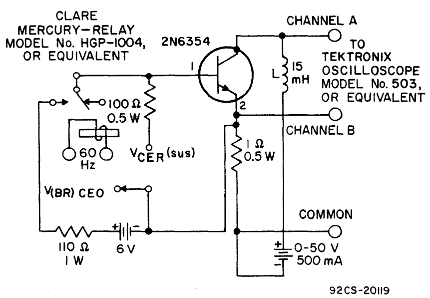
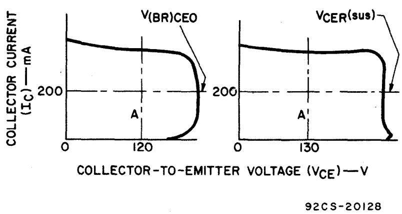


Fig.5—Circuit used to measure voltages $V_{(BR)CEO}$ and $V_{CER}(sus)$.



NOTE: The voltages, $V_{(BR)CEO}$ and $V_{CER}(sus)$ are acceptable when the trace falls to the right of and above point "A".

Fig.6—Oscilloscope display for $V_{(BR)CEO}$ and $V_{CER}(sus)$ measurement (test circuit shown in Fig.5).

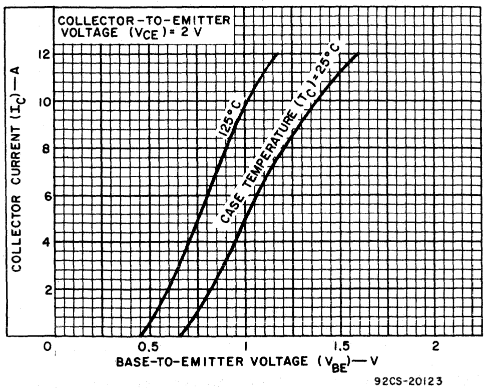


Fig. 7—Typical transfer characteristics.

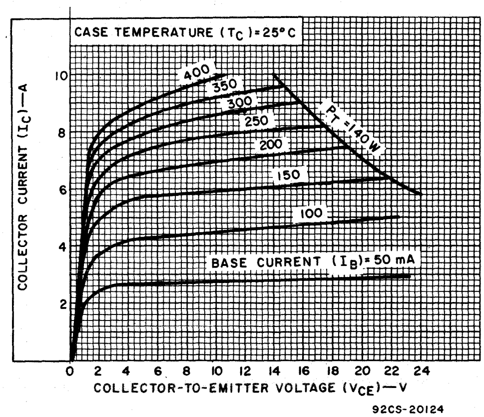


Fig. 8—Typical output characteristics.

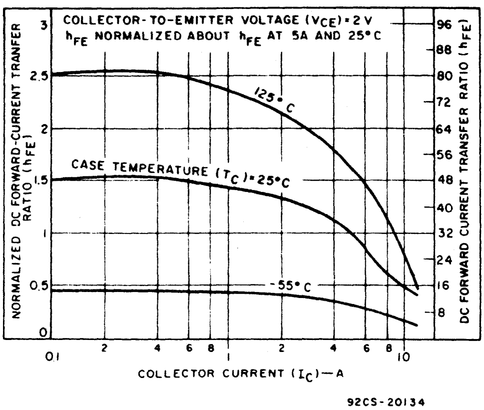


Fig. 9—Typical normalized dc beta characteristics.

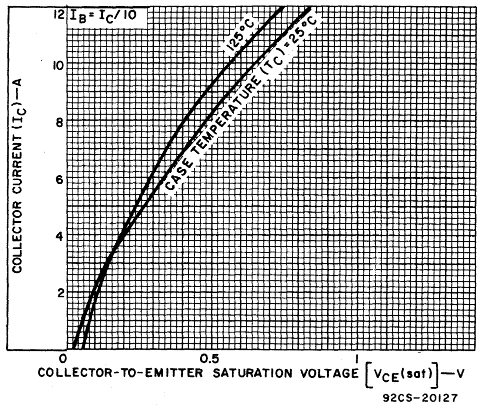


Fig. 10—Typical saturation voltage characteristics.

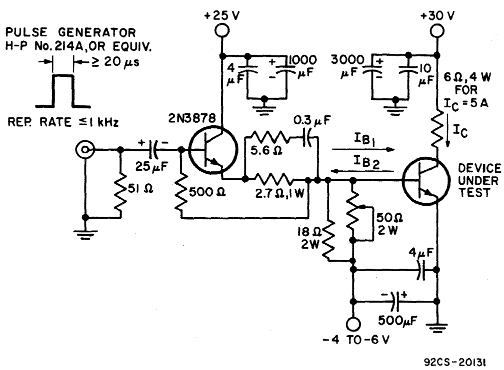


Fig. 11—Circuit used to measure switching times.

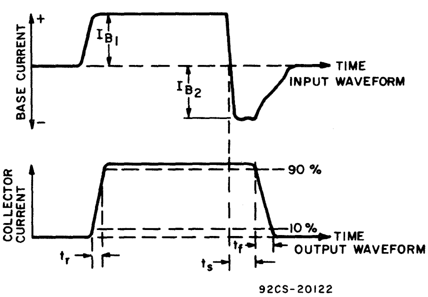


Fig. 12—Phase relationship between input and output currents showing reference points for specification of switching times (test circuit shown in Fig. 11).

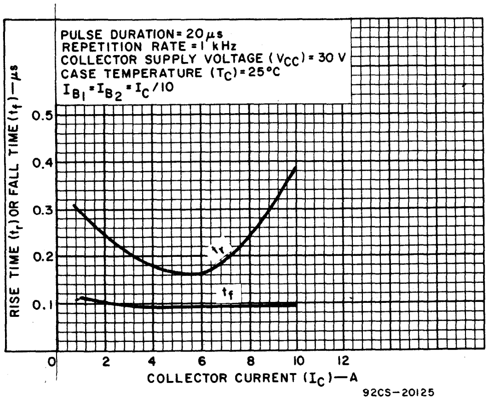


Fig. 13—Typical rise- and fall-time characteristics.

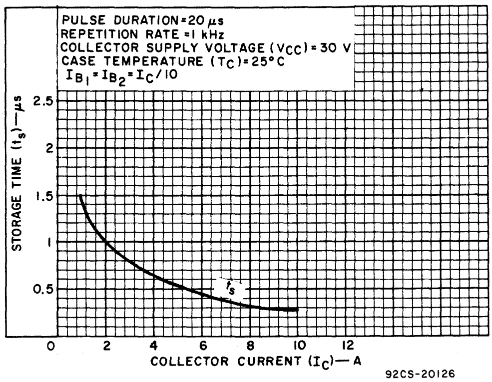
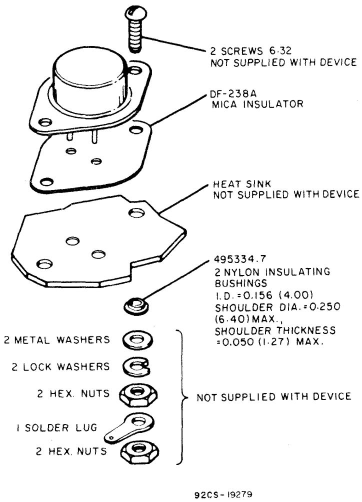


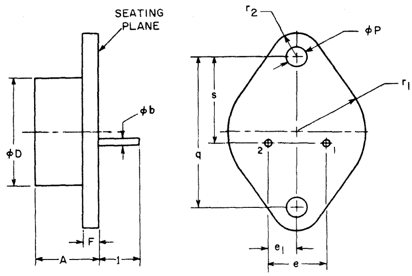
Fig. 14—Typical storage-time characteristics.



Dimensions in inches and millimeters.
Millimeter values in parentheses.

Fig. 15—Suggested mounting hardware.

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS-15222

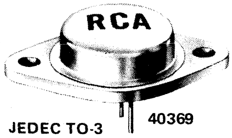
TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Mounting Flange, Case — Collector

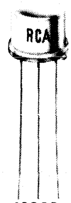
RCA Solid State Division

Power Transistors

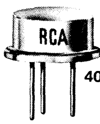
40366-40369 40385



JEDEC TO-3 40369 H-1570



40366 40367 40385 JEDEC TO-5 H-1380



40368 H-1015 JEDEC TO-8

High-Reliability Silicon N-P-N Power Transistors

For Power Switching and Amplifier Applications

Features

- High reliability assured by five preconditioning steps
- Group A test data included*
- Transistors utilize JEDEC hermetic packages;
  TO–5 (40366, 40367 & 40385)
  TO–8 (40368)
  TO–3 (40369)

RCA-40366–40369 and 40385 are silicon n-p-n power transistors derived from JEDEC types 2N2102, 2N1482, 2N1486, 2N1490, and 2N3439. They are specially preconditioned for use in power-switching and amplifier applications in those instances where high reliability is a requisite.

- High voltage ratings:
  V_{CER} = 80 V max. (40366)
  V_{CEV} = 100 V max. (40367, 40368 & 40369)
  V_{CEO} = 350 V max. (40385)
- High power-dissipation capability:
  P_T = 5 W max. (40366, 40367 & 40385)
  = 25 W max. (40368)
  = 75 W max. (40369)

* Group A test data shown on pages 2 & 3.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		40366	40367	40368	40369	40385	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	120	100	100	100	450	V
COLLECTOR-TO-EMITTER VOLTAGE:							
With external base-to-emitter resistance (R_{BE}) $\leq$ 10 Ω	V_{CER}	80	–	–	–	–	V
With –1.5 V (V_{BE}) of reverse bias	V_{CEV}	–	100	100	100	–	V
With base open	V_{CEO}	65	55	55	55	350	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	7	12	12	10	7	V
CONTINUOUS COLLECTOR CURRENT	I_C	1	1.5	3	6	1	A
CONTINUOUS BASE CURRENT	I_B	–	1	1.5	3	–	A
TRANSISTOR DISSIPATION:	P_T						
At case temperature up to 25°C		5	5	25	75	10	W
At free-air temperature up to 25°C		1	1	–	–	1	W
At temperatures above 25°C		← Derate linearly to 0 watts at 200°C →					
TEMPERATURE RANGE:							
Storage & Operating (Junction)		← –65 to 200 →					°C
PIN or LEAD TEMPERATURE (During soldering):							
At distances $\geq$ 1/32 in. (0.79 mm) from seating plane for 10 s max.		255	255	235	235	255	°C

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Emitter Volts V_{EB}	DC Current (Milliamperes) I_C	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	LIMITS Type 40366 Min.	Type 40366 Max.	Type 40367 Min.	Type 40367 Max.	Type 40368 Min.	Type 40368 Max.	Type 40369 Min.	Type 40369 Max.	Type 40385 Min.	Type 40385 Max.	Units
Collector-Cutoff Current	I_{CBO}	30				0		–	–	–	4.0	–	9.0	–	10	–	–	μA
		60				0		–	2.0	–	–	–	–	–	–	–	–	nA
	I_{CEO}		300				0	–	–	–	–	–	–	–	–	–	20	μA
	I_{CEV}		450	1.5				–	–	–	–	–	–	–	–	–	500	μA
Emitter-Cutoff Current	I_{EBO}			5	0			–	5.0	–	–	–	–	–	–	–	–	nA
				6	0			–	–	–	–	–	–	–	–	–	20	μA
				10	0			–	–	–	–	–	–	–	6.0	–	–	μA
				12	0			–	–	–	2.0	–	5.0	–	–	–	–	μA
DC Forward-Current Transfer Ratio	h_{FE}		4		200			–	–	35	100	–	–	–	–	–	–	
			4		750			–	–	–	–	35	100	–	–	–	–	
			4		1500			–	–	–	–	–	–	25	75	–	–	
			10		0.01			10	–	–	–	–	–	–	–	–	–	
			10		0.1			20	–	–	–	–	–	–	–	–	–	
			10		2			–	–	–	–	–	–	–	–	30	–	
			10		20			–	–	–	–	–	–	–	–	40	160	
			10		150•			40	120	–	–	–	–	–	–	–	–	
			10		500•			25	–	–	–	–	–	–	–	–	–	
			10		1000•			10	–	–	–	–	–	–	–	–	–	
Collector-to-Base Breakdown Voltage	BV_{CBV}			1.5	0.1			120	–	–	–	–	–	–	–	–	–	V
Collector-to-Emitter Breakdown Voltage	BV_{CEV}			1.5	0.25			–	–	100	–	100	–	100	–	–	–	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0.1		7.0	–	–	–	–	–	–	–	–	–	V
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER(sus)}$				100•			80	–	–	–	–	–	–	–	–	–	V
With base open	$V_{CEO(sus)}$				50		0	–	–	55	–	–	–	–	–	350	–	V
					100•		0	65	–	–	–	–	–	–	–	–	–	
					100		0	–	–	–	–	55	–	55	–	–	–	
Collector-to-Emitter Saturation Voltage	$V_{CE(sat)}$				50		4	–	–	–	–	–	–	–	–	–	0.5	V
					150•		15	–	0.5	–	–	–	–	–	–	–	–	
					200		10	–	–	–	1.4	–	–	–	–	–	–	
					750		40	–	–	–	–	–	0.75	–	–	–	–	
					1300		100	–	–	–	–	–	–	–	1.0	–	–	
Base-to-Emitter Saturation Voltage	$V_{BE(sat)}$				150•		15	–	1.1	–	–	–	–	–	–	–	–	V
					50		4	–	–	–	–	–	–	–	–	–	1.3	
Base-to-Emitter Voltage	V_{BE}		4		200		–	–	–	–	3.0	–	–	–	–	–	–	V
			4		750		–	–	–	–	–	–	2.5	–	–	–	–	
			4		1500		–	–	–	–	–	–	–	–	2.5	–	–	

•Pulsed; pulse duration = 300 μs, duty factor = 1.8%.

GROUP-A TESTS (IN ACCORDANCE WITH MIL-S-19500)

TEST METHOD PER MIL-STD-750	EXAMINATION OR TEST	CONDITIONS	LTPD*	SYMBOL	LIMITS 40366 Min.	40366 Max.	40367 Min.	40367 Max.	40368 Min.	40368 Max.	40369 Min.	40369 Max.	40385 Min.	40385 Max.	UNITS
2071	**Subgroup 1** Visual and Mechanical Examination	–	10	–	–	–	–	–	–	–	–	–	–	–	–
3036D	**Subgroup 2** Collector-Cutoff Current	V_{CB} = 30V, I_E = 0	5	I_{CBO}	–	–	–	4.0	–	9.0	–	10	–	–	μA
		V_{CB} = 60V, I_E = 0	–	I_{CBO}	–	2.0	–	–	–	–	–	–	–	–	nA
3041A	Collector-Cutoff Current	V_{CE} = 450V, V_{BE} = -1.5V	–	I_{CEV}	–	–	–	–	–	–	–	–	–	500	μA
3041D	Collector-Cutoff Current	V_{CE} = 300V, I_E = 0	–	I_{CEO}	–	–	–	–	–	–	–	–	–	20	μA

GROUP-A TESTS (CONT.)

TEST METHOD PER MIL-STD-750	EXAMINATION OR TEST	CONDITIONS	LTPD*	SYMBOL	LIMITS 40366 Min.	40366 Max.	40367 Min.	40367 Max.	40368 Min.	40368 Max.	40369 Min.	40369 Max.	40385 Min.	40385 Max.	UNITS
3061D	Emitter-Cutoff Current	V_{EB} = 5V, I_C = 0	–	I_{EBO}	–	5.0	–	–	–	–	–	–	–	–	nA
		V_{EB} = 6V, I_C = 0	–	I_{EBO}	–	–	–	–	–	–	–	–	–	20	μA
		V_{EB} = 10V, I_C = 0	–	I_{EBO}	–	–	–	–	–	–	–	6.0	–	–	μA
		V_{EB} = 12V, I_C = 0	–	I_{EBO}	–	–	–	2.0	–	5.0	–	–	–	–	μA
3001A	Collector-to-Base Breakdown Voltage	I_C = 100 μA, V_{EB} = 1.5V	–	BV_{CBV}	120	–	–	–	–	–	–	–	–	–	V
3026D	Emitter-to-Base Breakdown Voltage	I_E = 100 μA, I_C = 0	–	BV_{EBO}	7.0	–	–	–	–	–	–	–	–	–	V
3011A	Collector-to-Emitter Breakdown Voltage	I_C = 0.25 mA, V_{EB} = 1.5V	–	BV_{CEV}	–	–	100	–	100	–	–	–	–	–	V
		I_C = 0.5 mA, V_{EB} = 1.5V	–	BV_{CEV}	–	–	–	–	–	–	100	–	–	–	V
3011D	Collector-to-Emitter Sustaining Voltage	I_C = 50 mA, I_B = 0	–	$V_{CEO}(sus)$	–	–	55	–	–	–	–	–	350	–	V
		I_C = 100 mA●, I_B = 0	–	$V_{CEO}(sus)$	65	–	–	–	–	–	–	–	–	–	V
		I_C = 100 mA, I_B = 0	–	$V_{CEO}(sus)$	–	–	–	–	55	–	55	–	–	–	V
3011B	Collector-to-Emitter Sustaining Voltage	I_C = 100 mA●, R_{BE} = 10 Ω	–	$V_{CER}(sus)$	80	–	–	–	–	–	–	–	–	–	V
3071	Subgroup 3 Collector-to-Emitter Saturation Voltage	I_C = 50 mA, I_B = 4 mA	–	$V_{CE}(sat)$	–	–	–	–	–	–	–	–	–	0.5	V
		I_C = 150 mA●, I_B = 15 mA	5	$V_{CE}(sat)$	–	0.5	–	–	–	–	–	–	–	–	V
		I_C = 200 mA, I_B = 10 mA	–	$V_{CE}(sat)$	–	–	–	1.4	–	–	–	–	–	–	V
		I_C = 750 mA, I_B = 40 mA	–	$V_{CE}(sat)$	–	–	–	–	–	0.75	–	–	–	–	V
		I_C = 1.5A, I_B = 100 mA	–	$V_{CE}(sat)$	–	–	–	–	–	–	–	1.0	–	–	V
3066A	Base-to-Emitter Saturation Voltage	I_C = 50 mA, I_B = 4 mA	–	$V_{BE}(sat)$	–	–	–	–	–	–	–	–	–	1.3	V
		I_C = 150 mA●, I_B = 15 mA	–	$V_{BE}(sat)$	–	1.1	–	–	–	–	–	–	–	–	V
3066A	Base-to-Emitter Voltage	I_C = 200 mA, V_{CE} = 4V	–	V_{BE}	–	–	–	3.0	–	–	–	–	–	–	V
		I_C = 750 mA, V_{CE} = 4V	–	V_{BE}	–	–	–	–	–	2.5	–	–	–	–	V
3076	DC Forward-Current Transfer Ratio	I_C = 0.01 mA, V_{CE} = 10V	–	h_{FE}	10	–	–	–	–	–	–	–	–	–	
		I_C = 0.1 mA, V_{CE} = 10V	–	h_{FE}	20	–	–	–	–	–	–	–	–	–	
		I_C = 2 mA, V_{CE} = 10V	–	h_{FE}	–	–	–	–	–	–	–	–	30	–	
		I_C = 20 mA, V_{CE} = 10V	–	h_{FE}	–	–			–	–	–	–	17	60	
		I_C = 150 mA●, V_{CE} = 10V	–	h_{FE}	40	120	–	–	–	–	–	–	–	–	
		I_C = 200 mA, V_{CE} = 4V	–	h_{FE}	–	–	35	100	–	–	–	–	–	–	
		I_C = 500 mA●, V_{CE} = 10V	–	h_{FE}	25	–	–	–	–	–	–	–	–	–	
		I_C = 750 mA, V_{CE} = 4V	–	h_{FE}	–	–	–	–	35	100	–	–	–	–	
		I_C = 1 A●, V_{CE} = 10V	–	h_{FE}	10	–	–	–	–	–	–	–	–	–	
		I_C = 1.5 A, V_{CE} = 4V	–	h_{FE}	–	–	–	–	–	–	25	75	–	–	

The RCA-40366, 40367, 40368, 40369, and 40385 are high-reliability versions of the RCA-2N2102, 2N1482, 2N1486, 2N1490 and 2N3439*, respectively. These transistors are intended for medium- and high-power switching and amplifier applications in military and industrial equipment.

The 40366 and 40385 are triple-diffused, silicon n-p-n types that utilize the popular JEDEC TO-5 package and have a power-dissipation capability of 5 watts each.

The 40367 is a silicon n-p-n hometaxial type that utilizes a JEDEC TO-5 package and has a power-dissipation capability of 5 watts.

The 40368 is a silicon n-p-n hometaxial type in a JEDEC TO-8 package with a power-dissipation capability of 25 watts.

The 40369 is a silicon n-p-n hometaxial type in the popular JEDEC TO-3 package and has a dissipation capability of 75 watts.

The 40366, the high-reliability version of the 2N2102, features linear beta characteristics which are controlled over a wide range of collector currents (0.01 mA to 1 A).

The 40367, 40368, and 40369, the high-reliability versions of the 2N1482, 2N1486, and 2N1490, respectively, feature rugged construction, low saturation voltage, and high beta at high currents, and are designed to assure freedom from forward-bias second breakdown when operated with specified limits.

Typical applications for these transistors include: power-switching circuits such as dc-to-dc converters, inverters, choppers, solenoid- and relay-controls; oscillator, regulator, and pulse-amplifier circuits; Class A and Class B push-pull audio- and servo-amplifiers.

* Complete data for types 2N1482, 2N1486, 2N1490, 2N2102 & 2N3439 are given in separate technical bulletins. Bulletins are available upon request from RCA Solid State Division, Box 3200, Somerville, N.J. 08876.

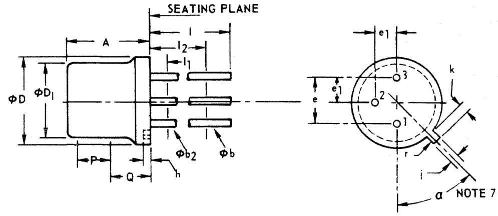
RELIABILITY TESTING

Each RCA-40366, 40367, 40368, 40369 and 40385 is subjected to the following preconditioning steps:

1. Temperature Cycling-Method 102A of MIL-STD-202, 5 cycles, -65° C to 200° C
2. Bake, 72 hours min., 200° C
3. Helium Leak, 1 x 10^{-8} cc/s max.
4. (a) Methanol Bomb, 70 psig, 16 hours min. (For 40366)
   (b) Bubble Test (Per MIL-STD-202, COND. A), 125° C min., 1 minute, ethylene glycol (For 40367, 40368, 40369 & 40385)
5. Serialization
6. (a) Record I_{CBO} and h_{FE} (150 mA) (For 40366)
   (b) Record I_{CBO} and h_{FE} (For 40367, 40368, & 40369)
   (c) Record I_{CEV} and h_{FE} (20 mA) (For 40385)
7. (a) Power Age, $T_{FA} = 25^\circ$ C, V_{CB} = 60 V, t= 168 hours, P_T = 1 W, free-air (For 40366 & 40367)
   (b) Power Age, $T_C = 125^\circ$ C, V_{CB} = 24 V, t= 168 hours, P_T = 10.5 W, with heat-sink (For 40368) P_T = 32 W, with heat-sink (For 40369)
   (c) Power Age, $T_{FA} = 25^\circ$ C, V_{CB} = 200 V, t= 168 hours, P_T = 800 mW, free air (For 40385)
8. (a) For 40366, †record I_{CBO}, h_{FE}(150 mA), BV_{CBV}, $V_{CEO}(sus)$, BV_{EBO}, $V_{CE}(sat)$. Data furnished with transistor.
   (b) For 40367, 40368, & 40369, †record I_{CBO}, h_{FE}, BV_{CEV}, $V_{CEO}(sus)$, I_{EBO}, $V_{CE}(sat)$. Data furnished with transistors.
   (c) For 40385, †record I_{CEO}, I_{EBO}, $V_{CEO}(sus)$, I_{CEV}, $V_{CE}(sat)$, and h_{FE}(20 mA). Data furnished with transistor.

† Delta criteria after 168 hours Power Age:
$\Delta h_{FE} \pm 25\%$ (For all types) ΔI_{CBO} + 1 μA (For 40367, 40368, & 40369)

DIMENSIONAL OUTLINE JEDEC TO-5



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
φb$_2$	0.016	0.019	0.406	0.483	2
φD	0.335	0.370	8.51	9.40	
φD$_1$	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e$_1$	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l$_1$	–	0.050	–	1.27	2
l$_2$	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

NOTES:

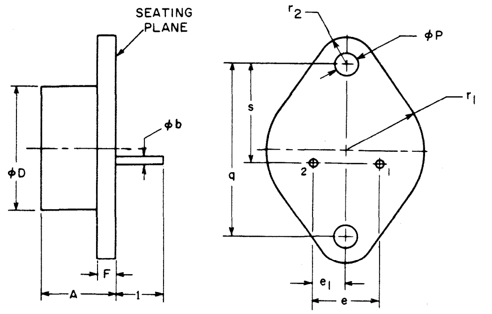
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) φb$_2$ applies between l$_1$ and l$_2$. φb applies between l$_2$ and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in l$_1$ and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS

Lead 1 — Emitter
Lead 2 — Base
Case, Lead 3 — Collector

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e$_1$	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r$_1$		0.525		13.34	
r$_2$		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

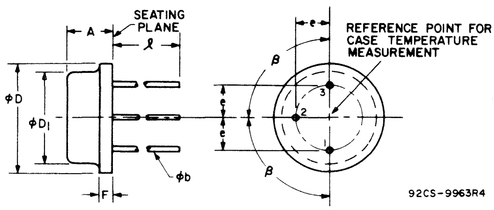
1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

DIMENSIONAL OUTLINE JEDEC TO-8



92CS-9963R4

SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.270	0.330	6.86	8.38	–
φb	0.027	0.033	0.686	0.838	1
φD	0.550	0.650	13.97	16.51	–
φD$_1$	0.444	0.524	11.28	13.31	–
e	0.136	0.146	3.45	3.71	–
F	–	0.115	–	2.92	–
ℓ	0.360	0.440	9.14	11.18	1
β	90° NOMINAL				

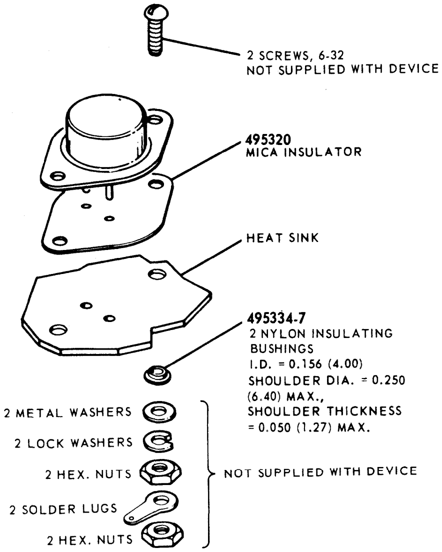
NOTE:

1. Three leads.

TERMINAL CONNECTIONS

Pin 1 — Emitter
Pin 2 — Base
Case, Pin 3 — Collector

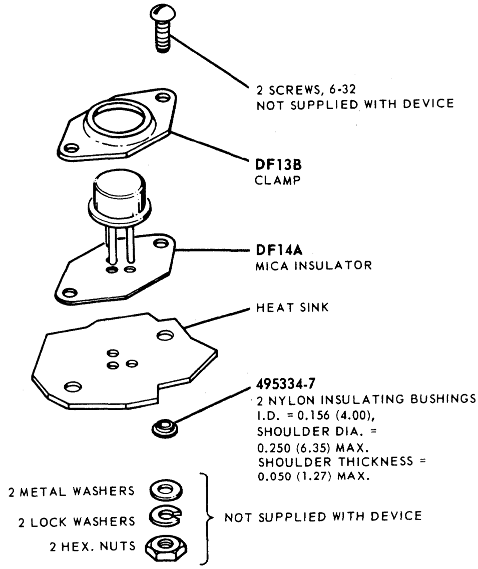
Suggested mounting hardware for use with JEDEC TO-3 package



NOTE: Dimensions in parentheses are in millimeters.

92CS-19470

Suggested mounting hardware for use with JEDEC TO-8 package



NOTE: Dimensions in parentheses are in millimeters.

92CS-19963

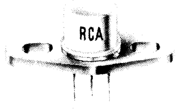
Other p-n-p Power Transistors

RCA

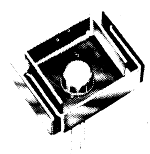
Solid State Division

Power Transistors

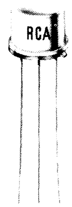
2N4036 2N4314
2N4037 40391
40394



40394 H-1375



40391 H-1468



2N4036
2N4037
2N4314 H-1380

Silicon P-N-P Medium Power Transistors

General-Purpose Types for Industrial and Commercial Applications

Features:

- **2N4036, 2N4037 } P-N-P Complements of { 2N2102▲▲, 2N3053**
- **Gain-bandwidth product (f_T) = 60 MHz min.**
- **High breakdown voltages**
- **Maximum area-of-operation curves for DC and pulse operation**
- **Planar construction provides low noise and low leakage characteristics**
- **Low saturation voltages**
- **High pulse beta at high collector current**
- **Low saturated switching speed**

RCA-2N4036, 2N4037, 2N4314▲, 40391 and 40394 are double-diffused, epitaxial-planar, silicon p-n-p transistors. The devices employ the popular JEDEC TO-5 package; they differ in breakdown-voltage ratings, leakage-current, and saturation characteristics. The 40391 is a 2N4037 with a factory-attached heat radiator intended for printed circuit-board applications. Type 40394 is a 2N4037 with a factory-attached diamond-shaped mounting flange.

These transistors are intended for a wide variety of small-signal, medium-power applications. With a minimum gain-bandwidth product (f_T) of 60 MHz, these types will provide useful gain at high frequencies.

In addition, the 2N4036 is useful in high-speed saturated switching applications.

▲ Formerly Dev. Type Nos. TA2651, TA2670, and TA2670A, respectively.

▲▲ 2N2102 is a linear-beta type; the 2N3053 is a general-purpose type. For technical bulletins for these types, write RCA, Commercial Engineering, Harrison, N.J. 07029.

MAXIMUM RATINGS, *Absolute Maximum Values:*

		2N4036	2N4037, 40391, 40394	2N4314	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	−90	−60	−90	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With 1.5 volts (V_{BE}) of reverse bias	$V_{CEV}(sus)$	−85	−60	−85	V
With external base-to-emitter resistance (R_{BE}) ≤200 Ω	$V_{CER}(sus)$	−85	−60	−85	V
* With base open	$V_{CEO}(sus)$	−65	−40	−65	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	−7	−7	−7	V
* COLLECTOR CURRENT	I_C	−1.0	−1.0	−1.0	A
* BASE CURRENT	I_B	−0.5	−0.5	−0.5	A
* TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		7	7(2N4037)	7	W
		–	7(40394)	–	W
At free-air temperatures up to 25°C		1	3.5(40391)	1	W
		–	1(2N4037, 40394)	–	W
At temperatures above 25°C		←	See Fig. 6	→	
For pulse operation		←	See Fig. 1	→	
* TEMPERATURE RANGE:					
Storage & Operating (Junction)		←	65 to 200	→	°C
* LEAD TEMPERATURE (During soldering):					
At distance ≥ 1/16 in. (1.58 mm) from seating plane for 10 s max.		←	230	→	°C

* In accordance with JEDEC registration data format (JS-6 RDF-1 2N4036; JS-9 RDF-2 2N4037, 2N4314).

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage-V V_{CB}	V_{CE}	DC Emitter or Base Voltage-V V_{EB}	V_{BE}	DC Current mA I_C	I_E	I_B	LIMITS: Type 2N4036 Min.	Max.	Types 2N4037 40391 40394 Min.	Max.	Type 2N4314 Min.	Max.	Units
Collector-Cutoff Current: With emitter open	I_{CBO}	– 90					0		–	– 0.1*	–	–	–	–	mA
		– 60					0		–	– 0.02	–	– 0.25*	–	– 0.25*	μA
With base open	I_{CEO}		– 30					0	–	– 0.5*	–	– 5*	–	– 5*	μA
With base-emitter junction reverse biased	I_{CEX}		– 85		1.5				–	– 100*	–	–	–	–	mA
T_C = 150°C			– 30		1.5				–	– 0.1*	–	–	–	–	mA
Emitter-Cutoff Current	I_{EBO}			– 7		0			–	– 0.1*	–	–	–	–	mA
				– 5		0			–	– 0.02	–	– 1*	–	– 1*	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$					– 0.1	0		– 90	–	– 60*	–	– 90*	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					0	– 0.1		– 7	–	– 7	–	– 7	–	V
Collector-to-Emitter Sustaining Voltage: *(See Figs. 2 & 3)* With base-emitter junction reverse biased	$V_{CEV}(sus)$				1.5	– 100			– 85[a]	–	– 60[a]	–	– 85[a]	–	V
With external base-to-emitter resistance (R_{BE}) ≤ 200 Ω	$V_{CER}(sus)$					– 100			– 85[a]	–	– 60[a]	–	– 85[a]	–	V
* With base open	$V_{CEO}(sus)$					– 100		0	– 65[a]	–	– 40[a]	–	– 65[a]	–	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					– 150		– 15	–	– 0.65	–	– 1.4	–	– 1.4	V
Base-to-Emitter Voltage	V_{BE}		– 10			– 150			–	– 1.1	–	– 1.5*	–	– 1.5*	V
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					– 150		– 15	–	– 1.4	–	–	–	–	V
* DC Forward-Current Transfer Ratio	h_{FE}		– 2			– 150			20	200	–	–	–	–	
			– 10			– 0.1			20	–	–	–	–	–	
			– 10			– 1.0			–	–	15	–	15	–	
			– 10			– 150[b]			40	140	50	250	50	250	
			– 10			– 500[b]			20	–	–	–	–	–	
Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (at f = 20 MHz)	h_{fe}		– 10			– 50			3.0	–	3.0	–	3.0	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (at f = 20 MHz)	$\|h_{fe}\|$		– 10			– 50			3.0	–	3.0	10	3.0	10	
Collector-Base Capacitance (at f = 1 MHz)	C_{cb}	– 10					0		–	30	–	30*	–	30*	pF
Input Capacitance	C_{ib}			– 0.5		0			–	90	–	90	–	90	pF
* Sat. Switching Time: *(See Figs. 9 & 10)* Rise time	t_r		– 30			– 150		– 15	–	70	–	–	–	–	ns
Storage time	t_s		– 30			– 150		– 15	–	600	–	–	–	–	ns
Fall time	t_f		– 30			– 150		– 15	–	100	–	–	–	–	ns
Turn-on time	t_{on}		– 30			– 150		– 15	–	110	–	–	–	–	ns
Turn-off time	t_{off}		– 30			– 150		– 15	–	700	–	–	–	–	ns
Thermal Resistance: Junction-to-Case	θ_{J-C}								–	25*	25 (max.) 2N4037 & 40394		–	25	°C/W
									–	–			–	–	
Junction-to-Ambient	θ_{J-A}								–	165	165 (max.) 2N4037 & 40394		–	165	°C/W
									–	–	50 (max.) 40391		–	–	°C/W

[a] CAUTION: The sustaining voltages V_{CEO}(sus), V_{CER}(sus), and V_{CEV}(sus) MUST NOT be measured on a curve tracer. These sustaining voltages should be measured by means of the test circuit shown in Fig. 1.

[b] Pulsed; pulse duration = 300 μs, duty factor < 2%.

* In accordance with JEDEC registration data format (JS-6 RDF-1 2N4036; JS-9 RDF-2 2N4037, 2N4314).

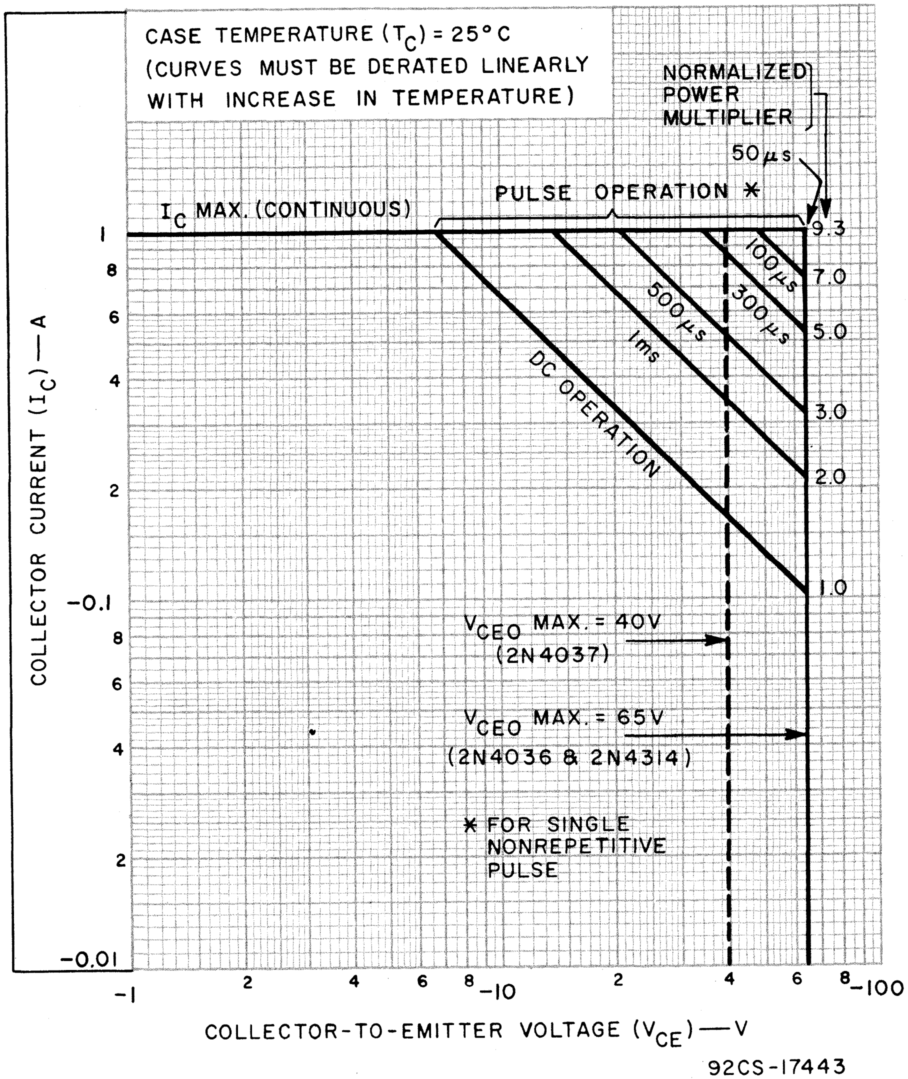


Fig. 1 – Maximum operating areas for types 2N4036, 2N4037 and 2N4314.

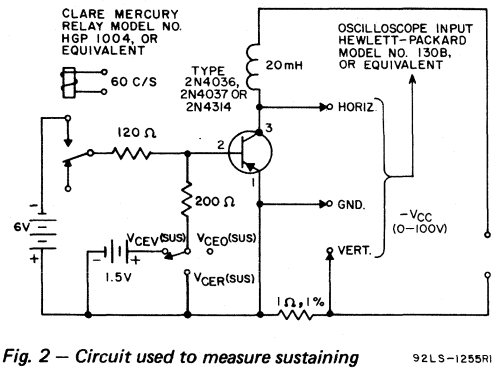
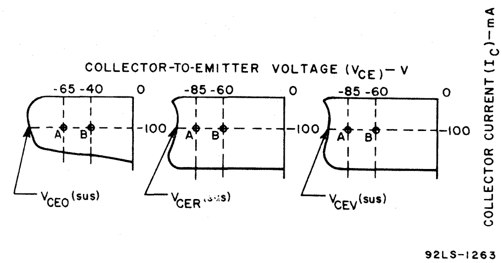


Fig. 2 – Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ for all types.



NOTE: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ are acceptable when the traces fall to the left and below point "A" for type 2N4036 and 2N4314, and point "B" for type 2N4037.

Fig. 3 – Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 2).

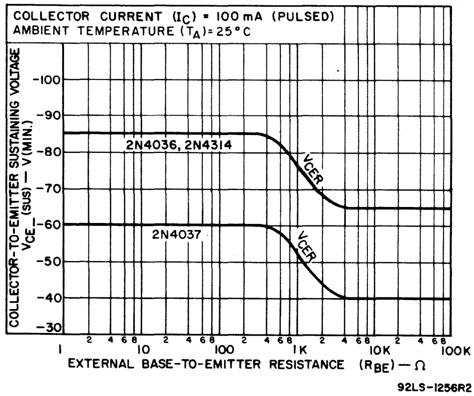


Fig. 4 – Sustaining voltage vs. base-to-emitter resistance for all types.

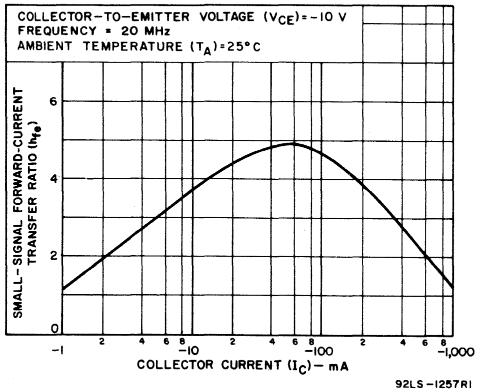


Fig. 5 – Typical small-signal beta characteristic for all types.

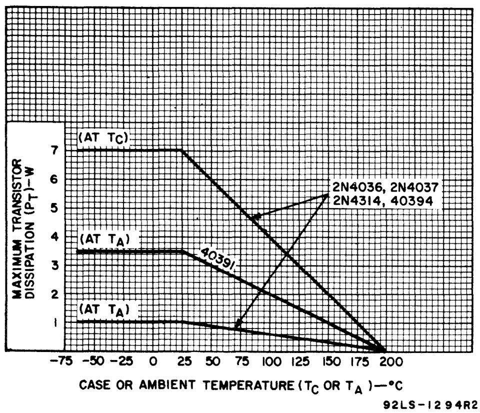


Fig. 6 – Dissipation derating curve for all types.

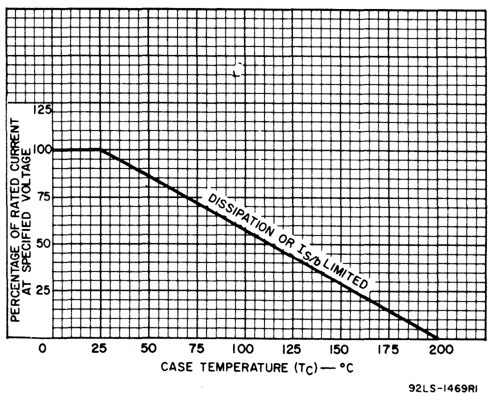


Fig. 7 – Dissipation derating curve for types 2N4036, 2N4037 and 2N4314.

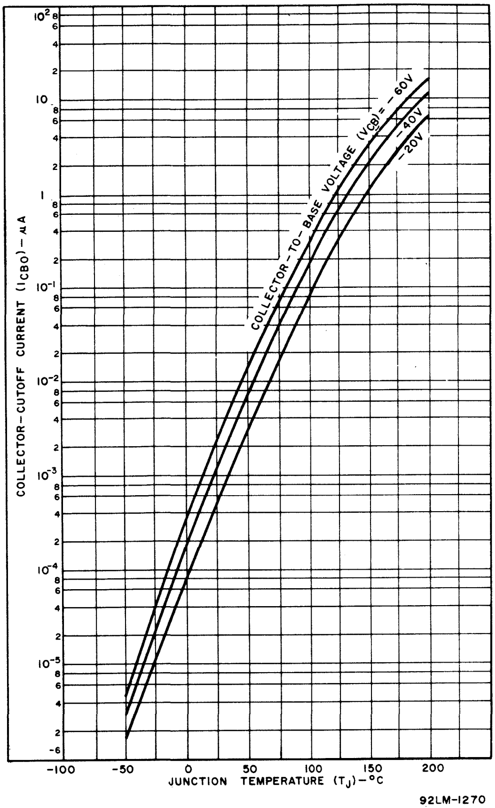


Fig. 8 — Typical collector-cutoff current vs. junction temperature for type 2N4036.

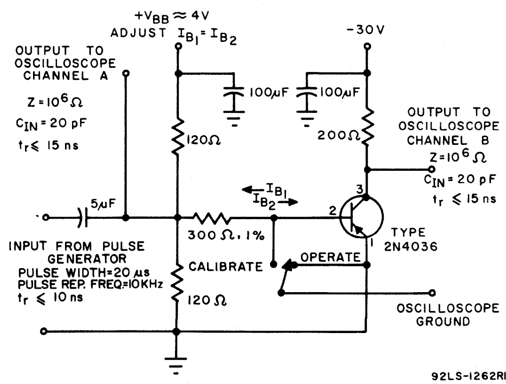


Fig. 9 — Circuit used to measure switching times for type 2N4036.

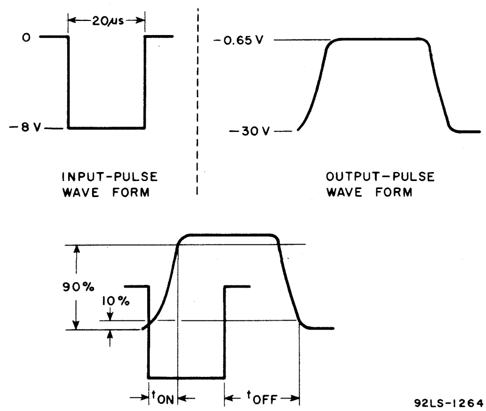


Fig. 10 — Oscilloscope display for measurement of switching times (test circuit shown in Fig. 9).

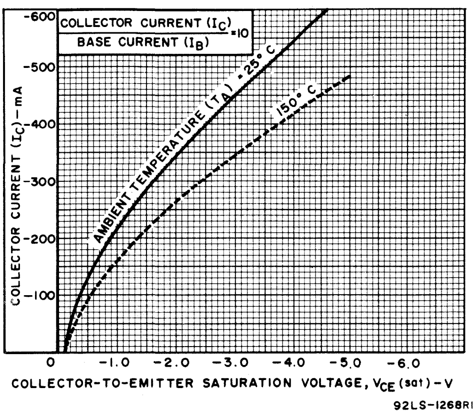


Fig. 11 — Typical saturation-voltage characteristics for type 2N4036.

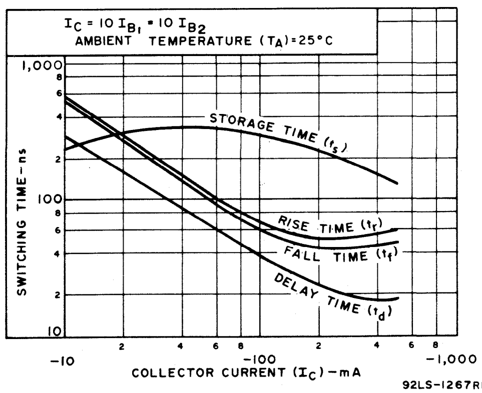


Fig. 12 — Typical saturated switching times for type 2N4036.

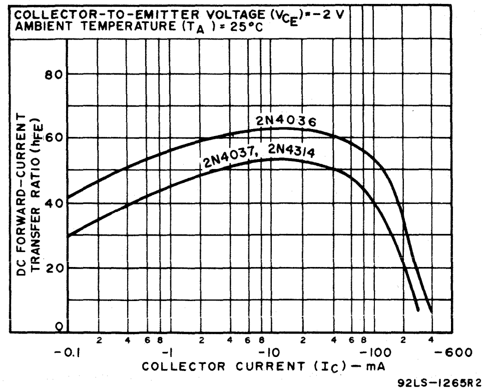


Fig. 13 — Typical dc beta characteristics for all types.

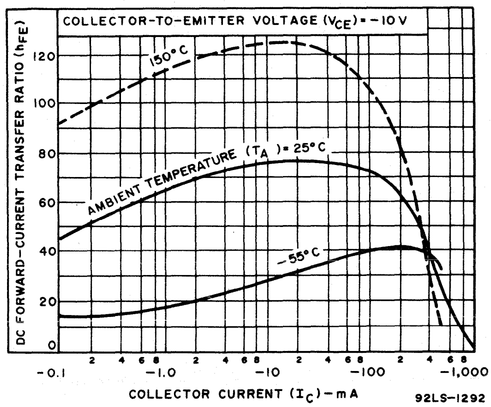


Fig. 14 — Typical dc beta characteristics for types 2N4037 and 2N4314.

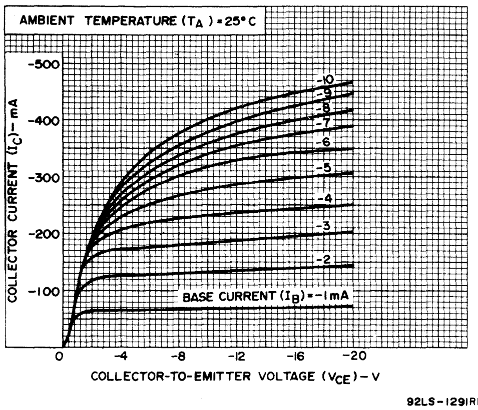


Fig. 15 — Typical output characteristics for types 2N4037 and 2N4314.

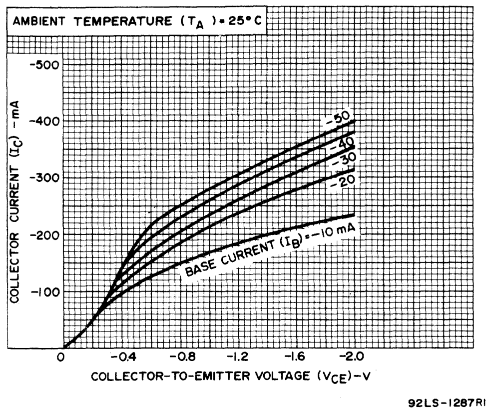


Fig. 16 — Typical output characteristics for types 2N4037 and 2N4314.

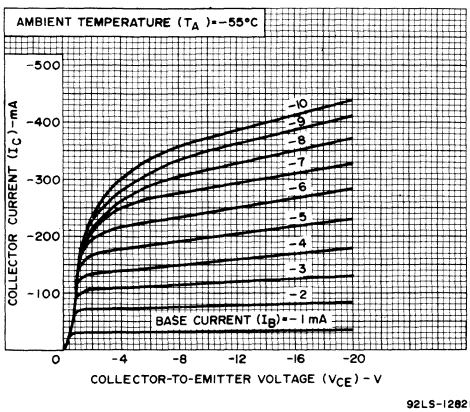


Fig. 17 — Typical output characteristics for types 2N4037 and 2N4314.

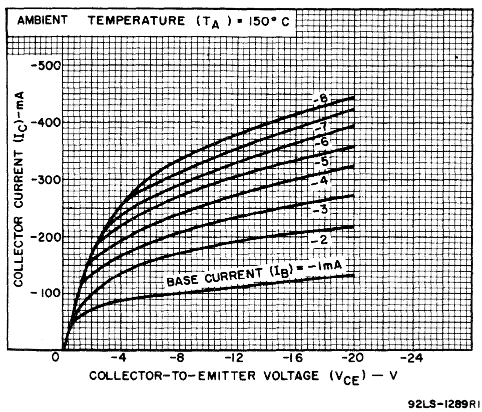


Fig. 18 — Typical output characteristics for types 2N4037 and 2N4314.

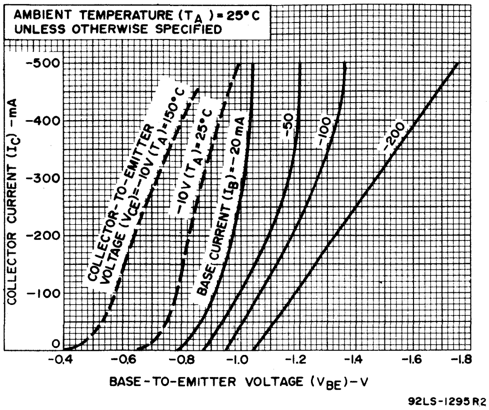
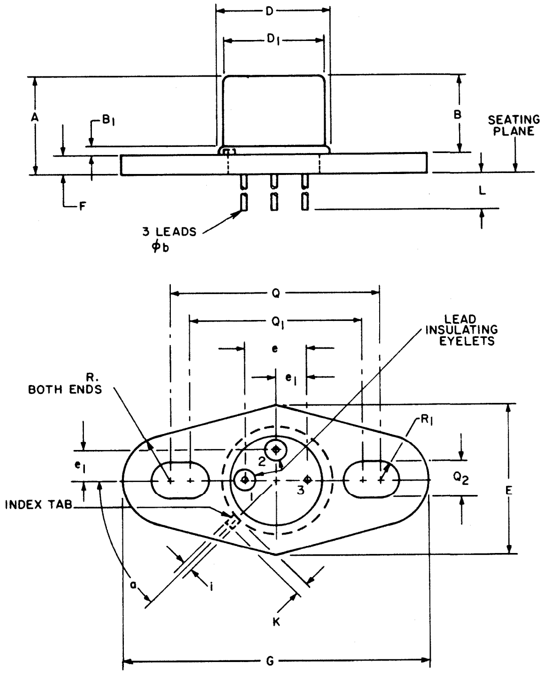


Fig. 19 — Typical transfer characteristics for types 2N4037 and 2N4314.

DIMENSIONAL OUTLINE FOR TYPE 40394
JEDEC TO-5 WITH MOUNTING FLANGE



NOTES:

1. True position.
2. Tab centerline.

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.328	–	8.33	
B	0.240	0.260	6.10	6.60	
B_1	0.009	0.125	0.229	3.18	
ϕ_b	0.016	0.019	0.406	0.483	
D	0.335	0.370	8.51	9.40	
D_1	0.305	0.335	7.75	8.51	
E	0.495	0.505	12.57	12.83	
e	0.200 T.P.		5.08 T.P.		1
e_1	0.100 T.P.		2.54 T.P.		1
F	0.062	0.068	1.57	1.74	
G	0.995	1.005	25.27	25.53	
i	0.028	0.034	0.711	0.864	
k	0.029	0.045	0.737	1.14	
L	1.43	–	36.32	–	
Q	0.685	0.691	17.40	17.55	
Q_1	0.559	0.565	14.20	14.35	
Q_2	0.128	0.132	3.25	3.35	
R	0.156 T.P.		3.96 T.P.		1
R_1	0.064	0.066	1.63	1.67	
a	45° T.P.				1, 2

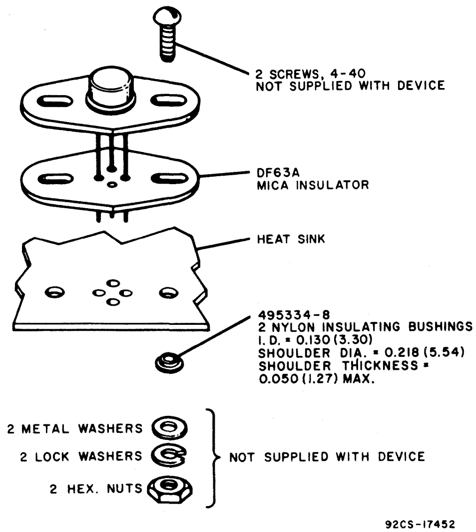
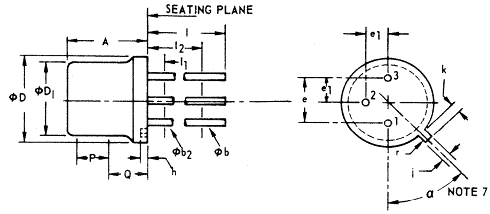


Fig. 20 — Suggested mounting hardware for type 40392 (JEDEC TO-5 with mounting flange).

TERMINAL CONNECTIONS
FOR TYPE 40394

Lead 1 - Emitter
Lead 2 - Base
Flange, Lead 3 - Collector

DIMENSIONAL OUTLINE FOR TYPES 2N4036, 2N4037 and 2N4314 JEDEC TO-5



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
φb2	0.016	0.019	0.406	0.483	2
φD	0.335	0.370	8.51	9.40	
φD1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	—	2
l1	–	0.050	–	1.27	2
l2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

NOTES:

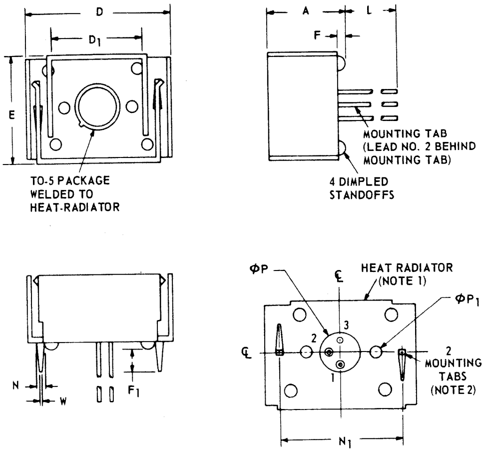
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) ϕb_2 applies between 1_1 and 1_2. ϕb applies between 1_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in 1_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS FOR TYPES 2N4036, 2N4037 and 2N4314

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

DIMENSIONAL OUTLINE FOR TYPE 40391
JEDEC TO-5 WITH HEAT RADIATOR



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	0.775	0.785	19.69	19.93	
E	0.875	0.905	22.22	22.99	
F	0.040	0.055	1.02	1.40	
F_1	0.160	0.195	4.06	4.95	
L	1.410	–	35.81	–	
ϕP	0.295	0.305	7.493	7.747	
ϕP_1	0.093	0.095	2.362	2.413	
N	0.048	0.062	1.21	1.57	
N_1	0.998	1.002	25.349	25.450	3
W	0.048	0.052	1.219	1.320	

NOTES:
1. 0.035 C.R.S., finish—electroless nickel plate.
2. Recommended hole size for printed-circuit board is 0.070 dia.
3. Measured at bottom of heat-radiator

92SS-2546R2

TERMINAL CONNECTIONS FOR TYPE 40391

Lead 1 - Emitter
Lead 2 - Base
Heat-Radiator, Lead 3 - Collector

RCA
Solid State
Division

Power Transistors
2N5415
2N5416

JEDEC TO–5

H-1380

Silicon P-N-P High-Voltage Transistors

For High-Speed Switching and Linear-Amplifier Applications in Military, Industrial and Commercial Equipment

Features:

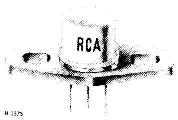
- 2N5415, 2N5416 — P—N—P Complements of: 2N3440, 2N3439 (respectively)
- Maximum safe-area-of-operation curves
- High voltage ratings:
  V_{CBO} = −350 V max. (2N5416)
  V_{CEO}(sus) = −300 V max. (2N5416); −200 V max. (2N5415)

RCA-2N5415 and 2N5416* are triple-diffused silicon p–n–p transistors with high breakdown voltages, high frequency response, and fast switching speeds.

These transistors differ primarily in their voltage ratings. Typical applications include high-voltage differential and operational amplifiers; high-voltage inverters; and high-voltage, low-current switching and series regulators.

* Formerly RCA Dev. Types TA2819 and TA2819A, respectively.

ALSO AVAILABLE . . .



H-1375

Types 2N5415 and 2N5416 are also available with a factory-attached mounting flange.

Please submit requirements to your RCA Technical Sales Representative, or write to RCA Low-Frequency Transistor Marketing, Somerville, N.J. 08876.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	2N5415	2N5416	
*COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	−200	−350	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
* With base open, V_{CEO}(sus)	−200	−300	V
With external base-to-emitter resistance (R_{BE}) = 50Ω, V_{CER}(sus)	—	−350	V
*EMITTER-TO-BASE VOLTAGE, V_{EBO}	−4	−6	V
*COLLECTOR CURRENT, I_C	−1	−1	A
*BASE CURRENT, I_B	−0.5	−0.5	A
*TRANSISTOR DISSIPATION, P_T			
At case temperatures up to 25°C	10	10	W
At case temperatures above 25°C	*See Figs. 1 & 2.*		
At ambient temperatures up to 50°C	1	1	W
At ambient temperatures above 50°C	Derate linearly at 6.7		mW/°C
*TEMPERATURE RANGE:			
Storage & Operating (Junction)	−65 to +200		°C
*LEAD TEMPERATURE (During Soldering): At distance ≥1/32 in. (0.8 mm) from seating plane for 10s max.	255		°C

*In accordance with JEDEC registration data format (JS–9 RDF–8)

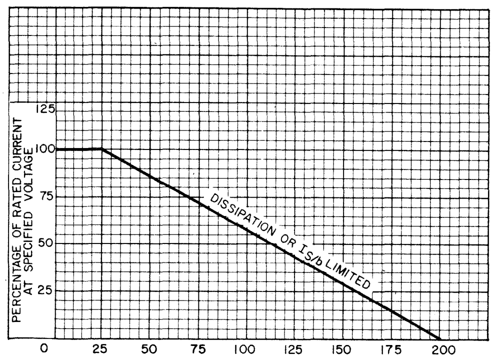


Fig. 1 - Dissipation derating curve

92LS-1469R1

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (mA)			LIMITS: Type 2N5415		Type 2N5416		UNITS
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	
Collector-Cutoff Current: With base open	I_{CEO}		−250 −150					0 0	– –	– −50	– –	−50 –	μA
* With emitter open	I_{CBO}	−280 −175						0 0	– –	– −50	– –	−50 –	μA
* With base-emitter junction reverse-biased	I_{CEV}		−300 −200		1.5 1.5				– –	– −50	– –	−50 –	μA
* Emitter-Cutoff Current	I_{EBO}			−6 −4		0 0			– –	– −20	– –	−20 –	μA
* DC Forward-Current Transfer Ratio	h_{FE}		−10 −10			−50 −50			– 30	– 150	30 –	120 –	
Collector-to-Emitter Sustaining Voltage: With base open *(See Fig. 3 & 4)*	$V_{CEO}(sus)$					−50		0	−200[a]	–	−300[a]	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$					−50			–	–	−350[a]	–	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$		−10			−50			–	−1.5	–	−1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					−50		5	–	−2.5	–	−2	V
* Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (at 1 kHz)	h_{fe}		−10			−5			25	–	25	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward-Current Transfer Ratio (at 5 MHz)	$\|h_{fe}\|$		−10			−10			3	–	3	–	
* Real Part of Common-Emitter Small-Signal, Short-Circuit Impedance (at 1 MHz)	$Re(h_{ie})$		-10			−5			–	300	–	300	Ω
* Common-Base, Short-Circuit, Input Capacitance (at 1 MHz)	C_{ib}			−5		0			–	75	–	75	pF
Output Capacitance (at 1 MHz)	C_{ob}	−10					0		–	15	–	15	pF
Second-Breakdown[b] Collector Current: With base forward biased[c]	$I_{S/b}$[d]		−100						−100	–	−100	–	mA
Thermal Resistance: (Junction-to-Case)	θ_{J-C}								–	17.5	–	17.5	°C/W

[a] CAUTION: The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ MUST NOT be measured on a curve tracer. The sustaining voltage should be measured by means of the test circuit shown in Fig. 3.

[b] Regions for safe-operation with forward bias are shown in Fig. 2.

[c] Specified value of $I_{S/b}$ for given value of V_{CE} as base voltage is increased from zero in a positive direction.

[d] $I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage.

* In accordance with JEDEC registration data format (JS-9 RDF-3)

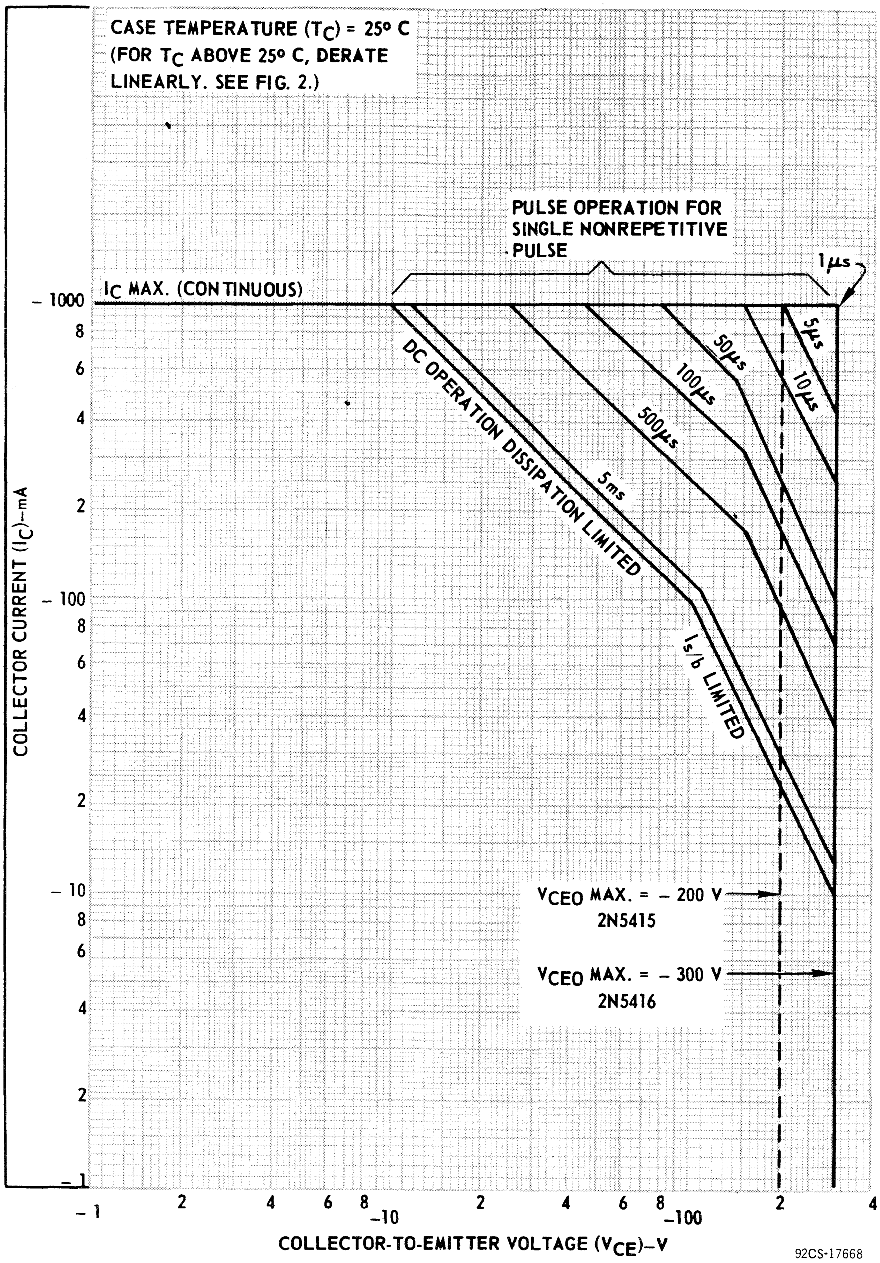


Fig. 2 - Maximum safe operating areas

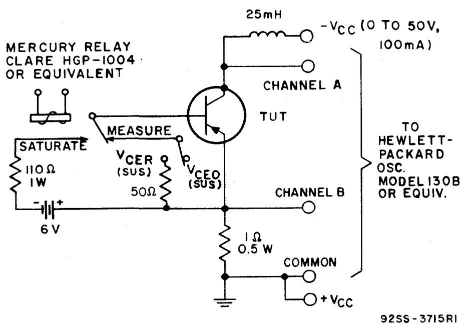
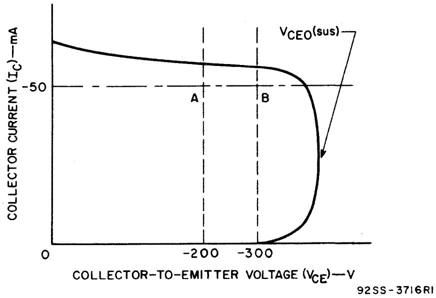


Fig. 3 - Circuit used to measure sustaining voltages, V_{CEO}(sus) and V_{CER}(sus) for both types



The sustaining voltage V_{CEO} (sus) is acceptable when the trace falls to the right and above point "A" for type 2N5415. The trace must fall to the right and above point "B" for type 2N5416.

Fig. 4 - Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 3)

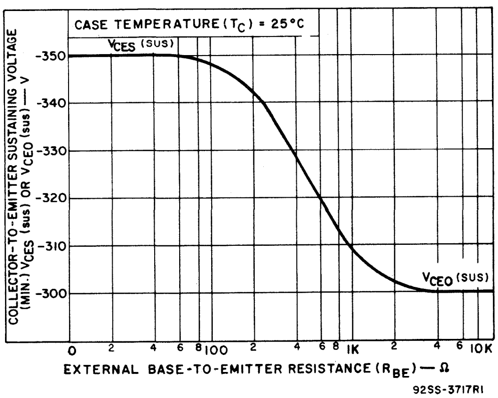


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for type 2N5416

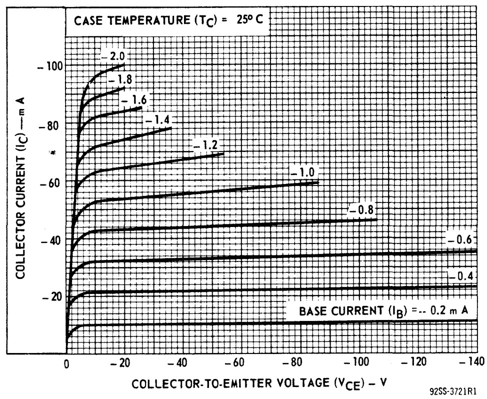


Fig. 6 - Typical output characteristics for both types

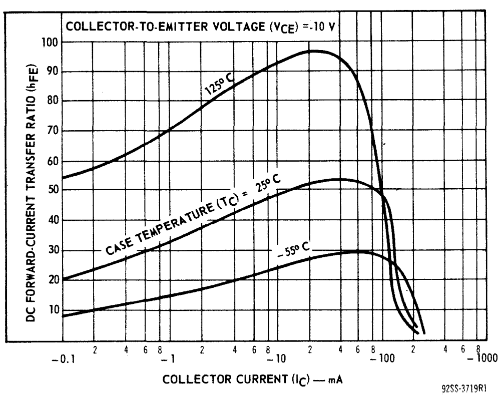


Fig. 7 - Typical dc beta for both types

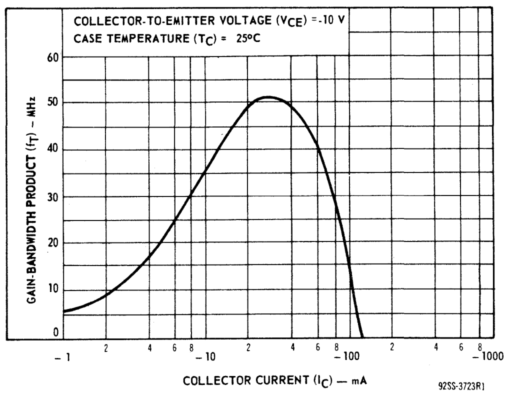


Fig. 8 - Typical gain-bandwidth product for both types

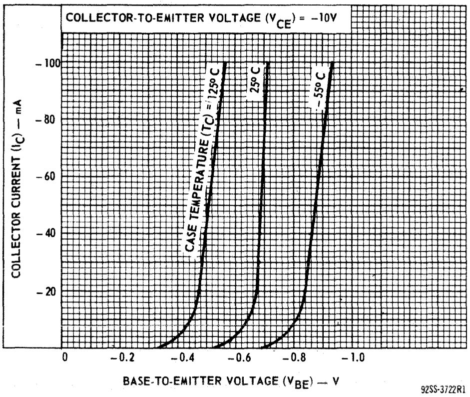


Fig. 9 - Typical transfer characteristics for both types

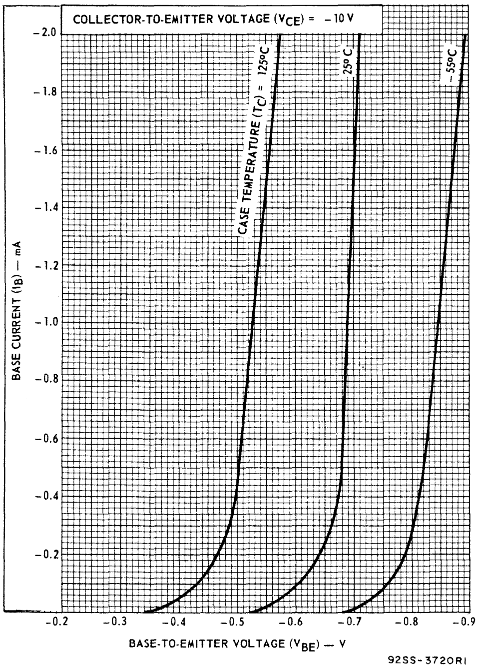


Fig. 10 - Typical input characteristics for both types

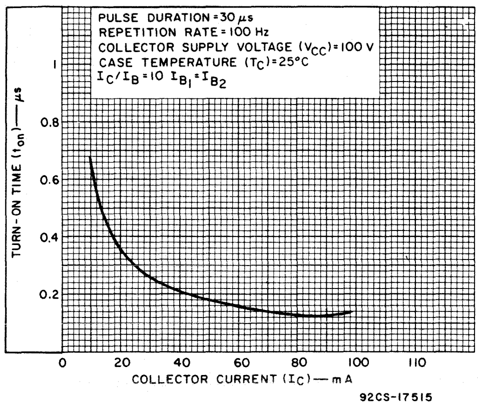


Fig. 11 - Typical turn-on time characteristic for both types

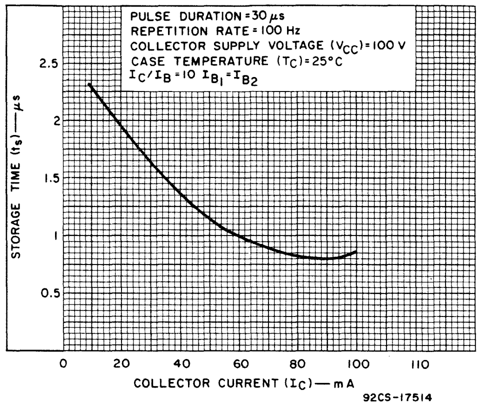


Fig. 12 - Typical storage-time characteristic for both types

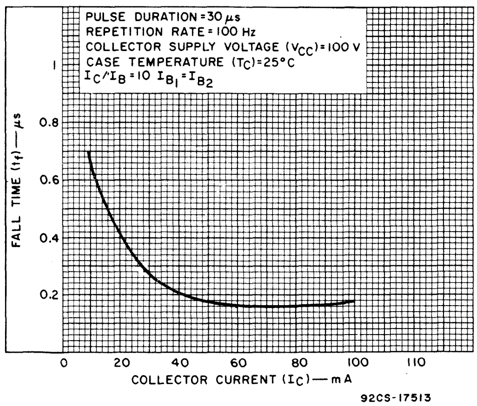


Fig. 13 - Typical fall-time characteristic for both types

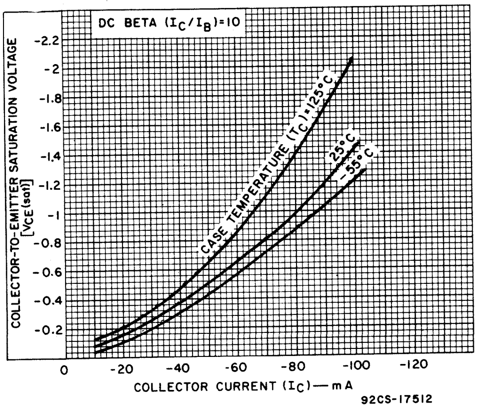
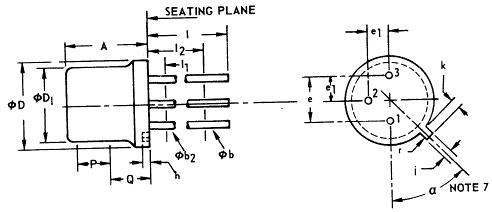


Fig. 14 - Typical collector-to-emitter saturation voltage for both types

DIMENSIONAL OUTLINE
JEDEC TO–5



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
$φb_2$	0.016	0.019	0.406	0.483	2
φD	0.335	0.370	8.51	9.40	
$φD_1$	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e_1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l_1	–	0.050	–	1.27	2
l_2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) $φb_2$ applies between l_1 and l_2. φb applies between l_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Case, Lead 3 – Collector

File No. 507

RCA
Solid State
Division

Power Transistors

2N6211, 2N6212
2N6213, 2N6214

JEDEC TO-66

H-1340

High-Voltage, Medium-Power Silicon P-N-P Transistors

For Switching and Amplifier Applications
In Military, Industrial, and Commercial Equipment

Features:

- **High voltage ratings:**
  - $V_{CEO}(sus)$ = −400 V max. (2N6214)
  - = −350 V max. (2N6213)
  - = −300 V max. (2N6212)
  - = −225 V max. (2N6211)
- **Large safe-operating area**
- **Complements to 2N3585 transistor family**
- **Thermal-cycling rating**

RCA types 2N6211, 2N6212, 2N6213, and 2N6214● are triple-diffused, silicon p-n-p transistors with high breakdown-voltage ratings and fast switching speeds. They are supplied in the popular JEDEC TO-66 package; they differ in breakdown-voltage ratings and leakage-current values.

● Formerly RCA Dev. Nos. TA7719, TA7410, TA8330, and TA8331, respectively.

Applications:

- **Power-Switching Circuits**
- **Switching Regulators**
- **Converters**
- **Inverters**
- **High-Fidelity Amplifiers**

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6211	2N6212	2N6213	2N6214	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	−275	−350	−400	−450	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:						
With base open	$V_{CEO}(sus)$	−225	−300	−350	−400	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$	−250	−325	−375	−425	V
* With base-emitter junction reverse-biased (V_{BE} = 1.5 V)	$V_{CEX}(sus)$	−275	−350	−400	−450	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	−6	−6	−6	−6	V
*COLLECTOR CURRENT (Continuous)	I_C	−2	−2	−2	−2	A
*BASE CURRENT (Continuous)	I_B	−1	−1	−1	−1	A
TRANSISTOR DISSIPATION:	P_T					
* At case temperatures up to 100°C and V_{CE} up to 50 V		20	20	20	20	W
At case temperatures up to 25°C and V_{CE} up to 40 V		35	35	35	35	W
At case temperatures up to 25°C and V_{CE} above 40 V		See Fig. 1				
At case temperatures above 25°C and V_{CE} above 40 V		See Figs. 1 & 6.				
*TEMPERATURE RANGE:						
Storage & Operating (Junction)		← −65 to 200 →				°C
*LEAD TEMPERATURE (During Soldering):						
At distance ≥ 1/32 in. (0.8 mm) from case for 10 s max.		← 230 →				°C

*In accordance with JEDEC registration data format (JS-6 RDF-1)

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector or Base Voltage (V) V_{CE}	V_{BE}	DC Current (A) I_C	I_E	I_B	LIMITS 2N6211 Min.	2N6211 Max.	2N6212 Min.	2N6212 Max.	2N6213 Min.	2N6213 Max.	2N6214 Min.	2N6214 Max.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}	−150				0	–	−5	–	−5	–	−5	–	−5	mA
* With base-emitter junction reverse-biased	I_{CEV}	−250	1.5				–	−0.5	–	–	–	–	–	–	mA
		−315	1.5				–	–	–	−0.5	–	–	–	–	
		−360	1.5				–	–	–	–	–	−0.5	–	–	
		−410	1.5				–	–	–	–	–	–	–	−1	
* With base-emitter junction reverse biased and T_C = 100°C	I_{CEV}	−250	1.5				–	−5	–	–	–	–	–	–	
		−315	1.5				–	–	–	−5	–	–	–	–	
		−360	1.5				–	–	–	–	–	−5	–	–	
		−410	1.5				–	–	–	–	–	–	–	−10	
* Emitter-Cutoff Current	I_{EBO}		6	0			–	−1	–	−0.5	–	−0.5	–	−0.5	mA
* DC Forward-Current Transfer Ratio	h_{FE}	−2.8		−1			10	100	–	–	–	–	–	–	
		−3.2		−1			–	–	10	100	–	–	–	–	
		−4		−1			–	–	–	–	10	100	–	–	
		−5		−1			–	–	–	–	–	–	10	100	
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$			−0.2		0	−225	–	−300	–	−350	–	−400	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$			−0.2			−250	–	−325	–	−375	–	−425	–	V
With base-emitter junction reverse-biased and external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CEX}(sus)$		1.5	−0.2			275	–	−350	–	−400	–	−450	–	V
Emitter-to-Base Voltage	V_{EBO}					0.5 mA		–	−6	–	−6	–	−6	–	V
						1 mA	6				–	–	–	–	
* Emitter-to-Base Saturation Voltage	$V_{BE}(sat)$			−1		−0.125		1.4		−1.4	–	−1.4	–	−1.4	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			−1		−0.125		1.4		−1.6	–	−2	–	−2.5	V
Output Capacitance (f = 1 MHz)	C_{obo}	−10 (V_{CB})			0			220		220	–	220	–	220	pF
Second-Breakdown Collector Current (Base forward-biased)	$I_{S/b}$	−40					−0.875	–	−0.875	–	−0.875	–	−0.875	–	A
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio (f = 5 MHz)	$\|h_{fe}\|$	−10		−0.2			4	–	4	–	4	–	4	–	
* Saturated Switching Times: Rise time	t_r	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	0.6	–	0.6	–	0.6	–	0.6	μs
Storage time	t_s	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	2.5	–	2.5	–	2.5	–	2.5	μs
Fall time	t_f	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	0.6	–	0.6	–	0.6	–	0.6	μs
Thermal Resistance (Junction-to-case)	$R_{\theta JC}$	−10		−1			–	5	–	5	–	5	–	5	°C/W

*In accordance with JEDEC registration data format JS-6 RDF-1.

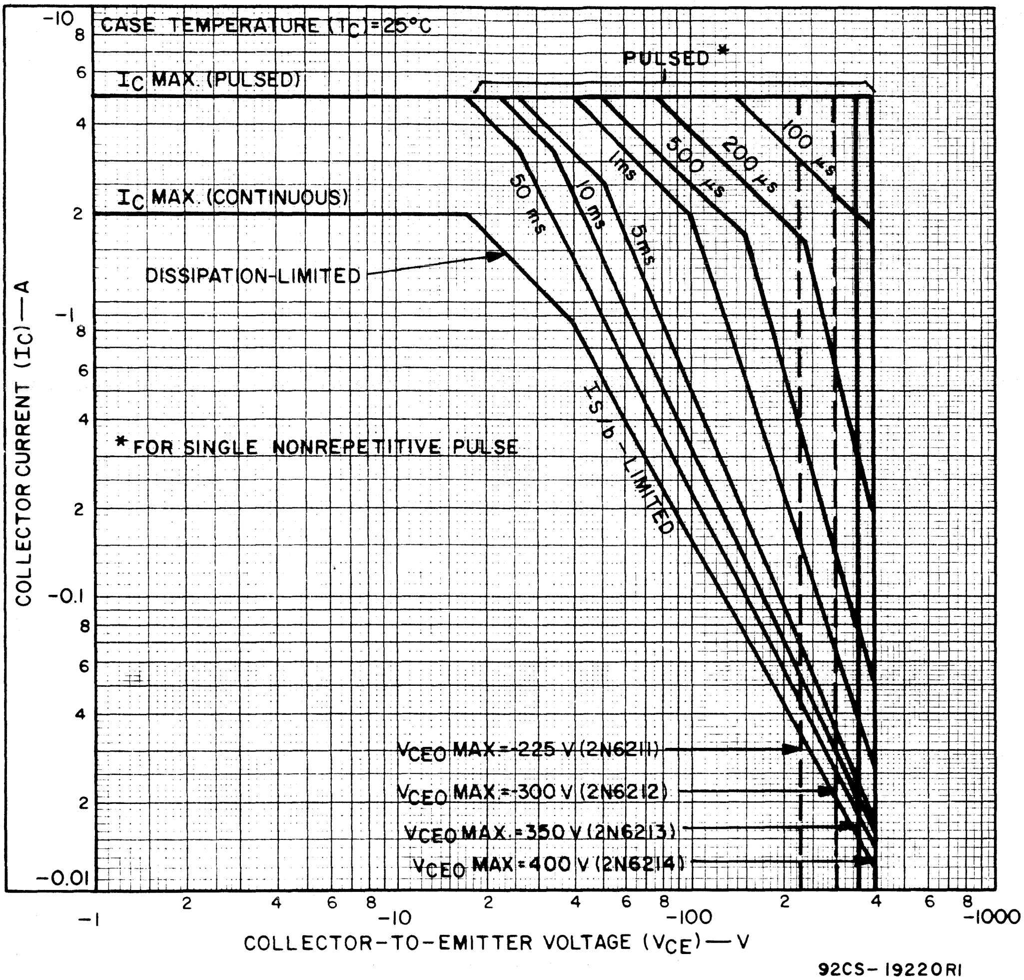


Fig.1—Maximum operating areas for all types.

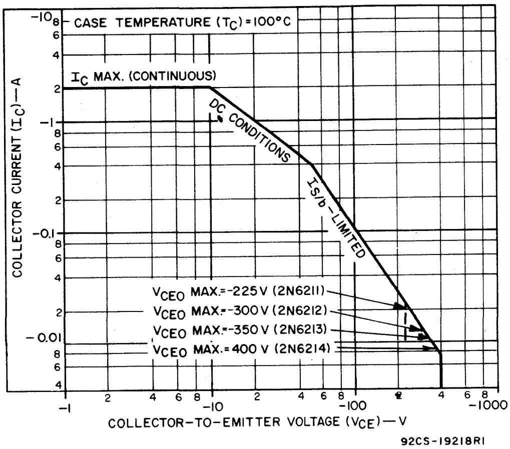


Fig.2—Maximum operating areas for all types.

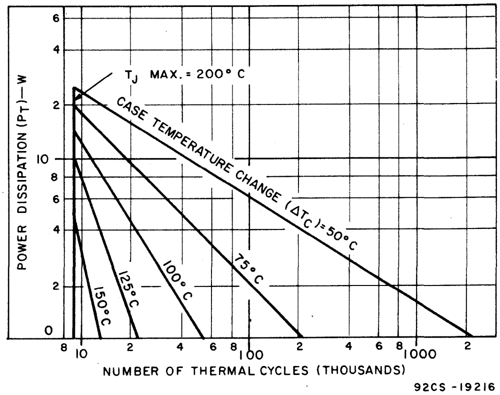


Fig.3—Thermal-cycling rating chart.

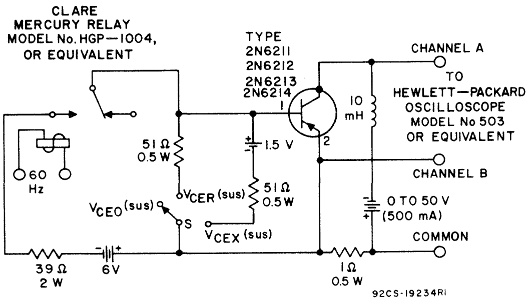


Fig.4—Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$ and $V_{CEX}(sus)$ for all types.

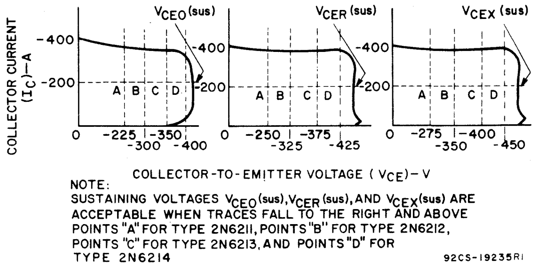


Fig.5—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig.3).

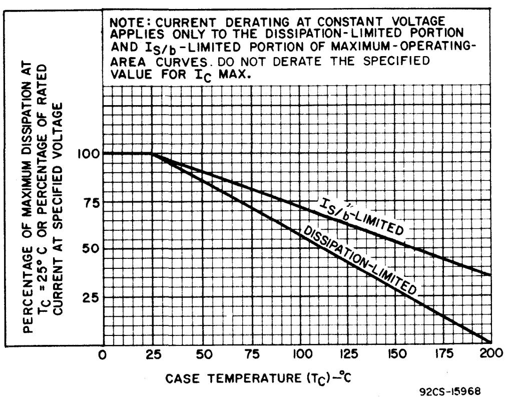


Fig.6—Derating curves for all types.

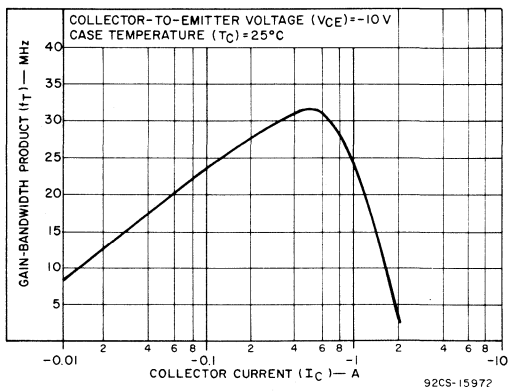


Fig.7—Typical gain-bandwidth product for all types.

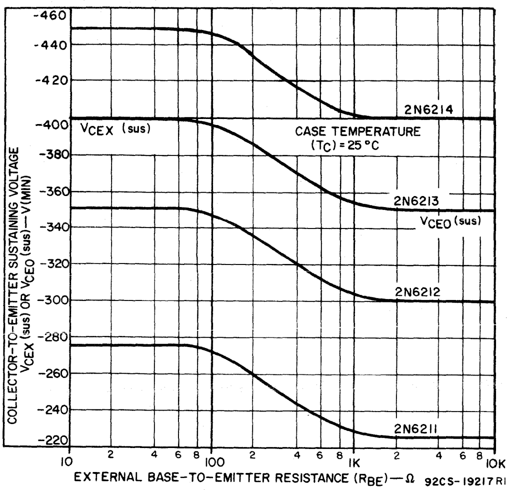


Fig.8—Collector-to-emitter sustaining-voltage characteristics for all types.

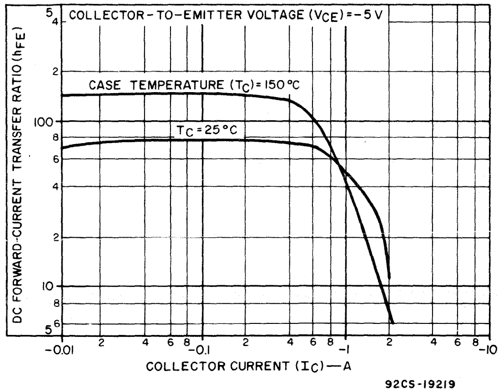


Fig.9—Typical dc beta characteristic for all types.

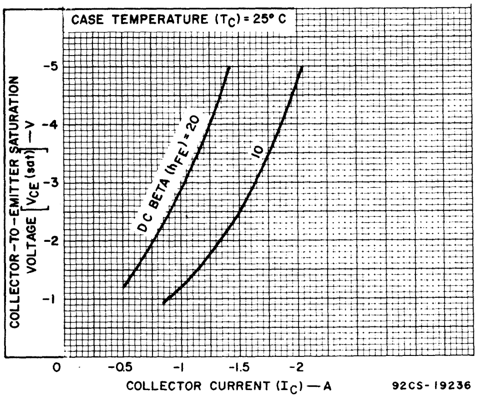


Fig.10—Typical saturation-voltage characteristics for all types.

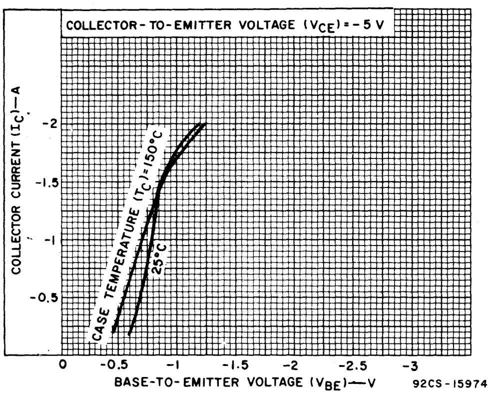


Fig.11—Typical transfer characteristics for all types.

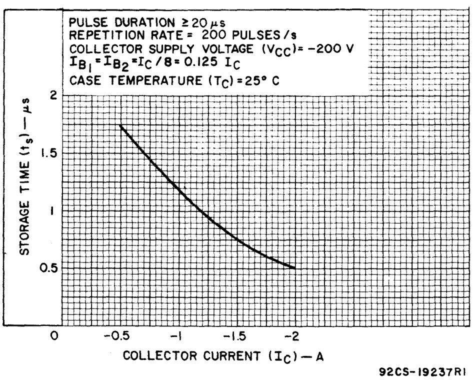


Fig.12—Typical storage-time characteristic for all types.

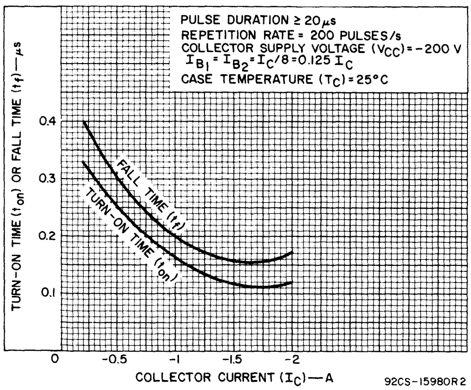


Fig.13—Typical turn-on time and fall-time characteristics for all types.

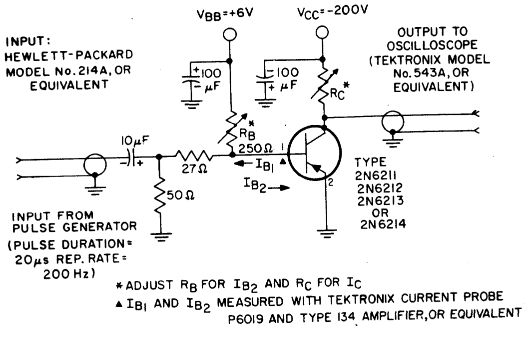


Fig.14—Circuit used to measure saturated switching times for all types.

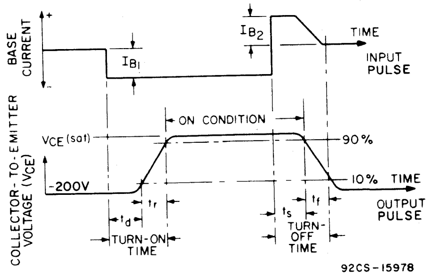


Fig.15—Phase relationship between input current and output voltage showing reference points for specification of switching times. (Test circuit shown in Fig.14).

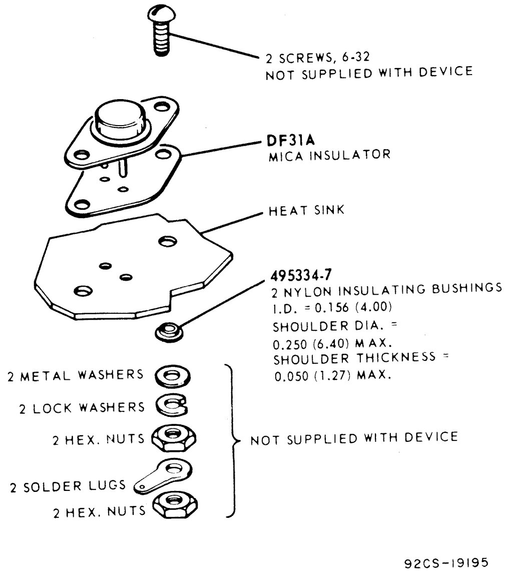
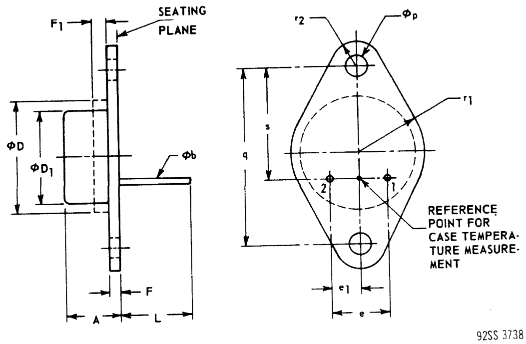


Fig.16—Suggested mounting hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
φb	0.028	0.034	0.711	0.863	
φD		0.620		15.75	
φD1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F1		0.050		1.27	1
L	0.360		9.14		
φp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r1		0.350		8.89	
r2		0.145		3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by φD and F_1.
2. Dimensions does not include sealing flanges.

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

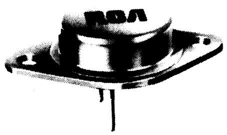
Monolithic n-p-n Darlington Power Transistors

RCA

Solid State
Division

Power Transistors

2N6055
2N6056



JEDEC TO-3

H-1570

8-Ampere Silicon N-P-N Darlington Power Transistors

60- and 80-Volt, 100-Watt Types
With Gain of 750 at 4 Amperes

Features:

- Operation from IC without predriver
- Low leakage at high temperature
- High reverse-second-breakdown capability

Applications:

- Power switching
- Hammer drivers
- Audio amplifiers
- Series and shunt regulators

RCA-2N6055 and 2N6056 are monolithic n-p-n silicon Darlington transistors designed for low- and medium-frequency power applications. The double epitaxial construction of these devices provides good forward and reverse second-breakdown capability. Their high gain makes it possible for them to be driven directly from integrated circuits.

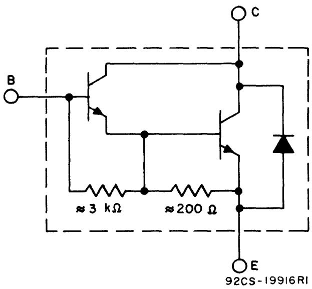


Fig. 1— Schematic diagram of 2N6055 and 2N6056 Darlington power transistors.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6055	2N6056	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	80	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With base reverse-biased, V_{BE} = −1.5 V, sustaining	V_{CEV} (sus)	60	80	V
With external base-to-emitter resistance (R_{BE}) = 100Ω, sustaining	V_{CER} (sus)	60	80	V
* With base open	V_{CEO}	60	80	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	V
COLLECTOR CURRENT:	I_C			
* Continuous		8	8	A
Peak		16	16	A
* CONTINUOUS BASE CURRENT	I_B	120	120	mA
* TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25°C		100	100	W
At case temperatures above 25°C		See Figs. 2 and 3		
* TEMPERATURE RANGE:				
Storage & Operating (Junction)		−65 to +200		°C
* PIN TEMPERATURE (During Soldering):				
At distances ≥ 1/16 in. (1.58 mm) from seating plane for 10 s max		235		°C

* In accordance with JEDEC registration data format JS-6 RDF-2

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE V: V_{CE}	V_{EB}	V_{BE}	DC CURRENT A: I_C	I_E	I_B	LIMITS 2N6055 MIN.	2N6055 MAX.	2N6056 MIN.	2N6056 MAX.	UNITS
* Collector Cutoff Current: With base open	I_{CEO}	30					0	–	0.5	–	–	mA
		40					0	–	–	–	0.5	
With base-emitter junction reverse-biased	I_{CEX}	60		−1.5				–	0.5	–	–	
		80		−1.5				–	–	–	0.5	
At T_C = 150°C	I_{CEX}	60		−1.5				–	5	–	–	
		80		−1.5				–	–	–	5	
* Emitter Cutoff Current	I_{EBO}		5		0			–	2	–	2	mA
* DC Forward Current Transfer Ratio	h_{FE}	3			8[a]			100	–	100	–	
		3			4[a]			750	18,000	750	18,000	
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$				0.1[a]			60[a]	–	80[a]	–	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$				0.1[a]			60[a]	–	80[a]	–	V
With base-emitter junction reverse-biased	$V_{CEX}(sus)$			−1.5	0.1[a]			60[a]	–	80[a]	–	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				4[a]		0.016	–	2	–	2	V
					8[a]		0.08	–	3	–	3	
* Base-to-Emitter Voltage	V_{BE}	3			4[a]			–	2.8	–	2.8	V
At saturation	$V_{BE}(sat)$				8[a]		0.08	–	4	–	4	
* Magnitude of Common-Emitter, Small-Signal Short-Circuit, Forward Current Transfer Ratio (f = 1 MHz)	$\|h_{fe}\|$	3			3			4	–	4	–	
* Common-Base Output Capacitance (f = 0.1 MHz), V_{CB} = 10V	C_{obo}					0		–	200	–	200	pF
* Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	3			3			300	–	300	–	–
Second Breakdown Energy With base reverse-biased and L = 12 mH, R_{BE} = 100Ω	$E_{S/b}$[b]			−1.5	5			150	–	150	–	mJ
Forward-Bias Second Breakdown Collector Current (1-s non-repetitive pulse)	$I_{S/b}$	33.3						3	–	3	–	A
		40						–	–	2	–	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$							–	1.75	–	1.75	°C/W

* In accordance with JEDEC registration data format JS-6 RDF-2.

[a] Pulsed: Pulse duration = 300 μs, duty factor = 2%.

[b] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

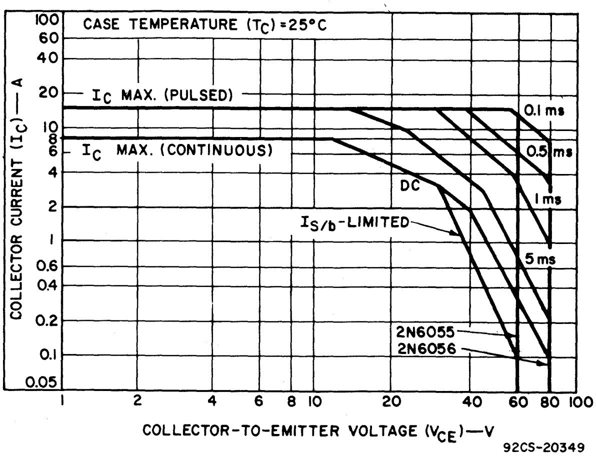


Fig. 2– Maximum operating areas for types 2N6055 and 2N6056.

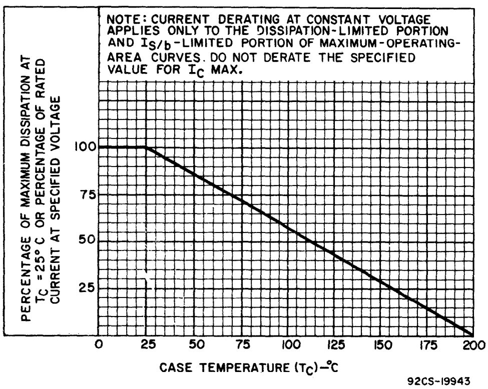


Fig. 3– Derating curve for both types.

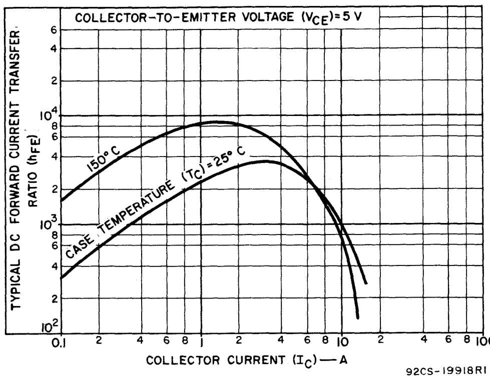


Fig. 4– Typical dc beta characteristics for both types.

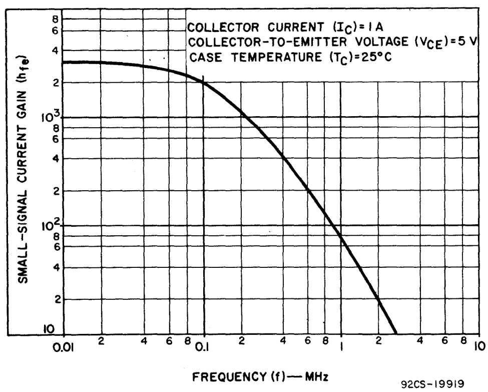


Fig. 5– Typical small-signal gain for both types.

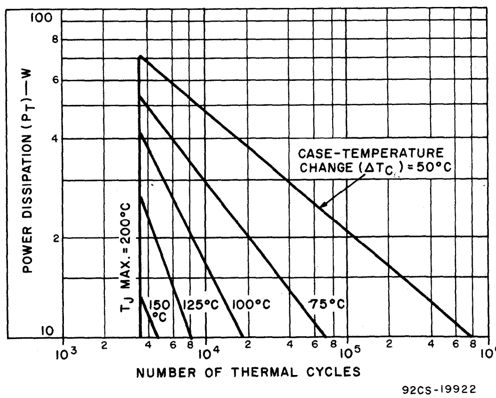


Fig. 6– Thermal-cycling rating chart for both types.

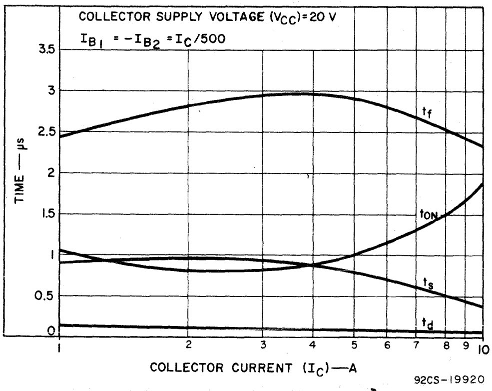


Fig. 7— Typical saturated switching-time characteristics for both types.

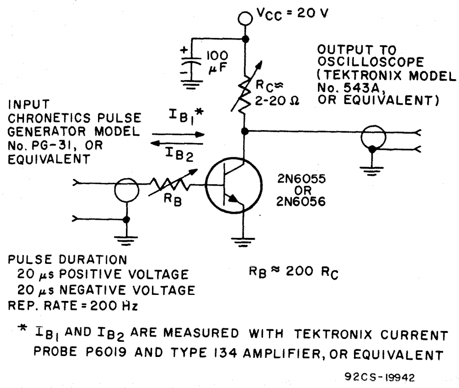


Fig. 8— Circuit used to measure saturated switching times.

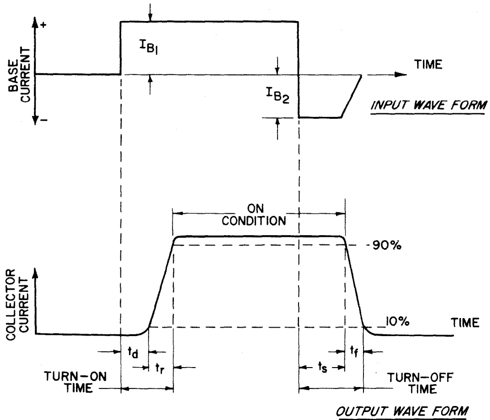


Fig. 9— Phase relationship between input current and output current showing reference points for specification of switching times (test circuit shown in Fig. 8).

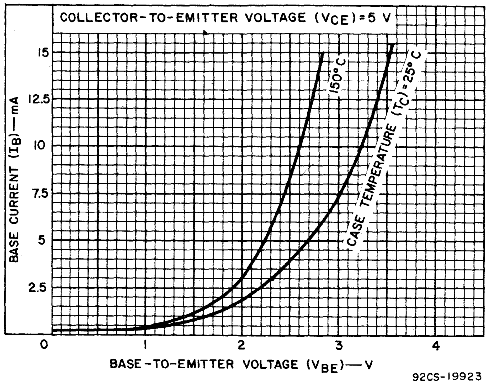


Fig. 10—Typical input characteristics for both types.

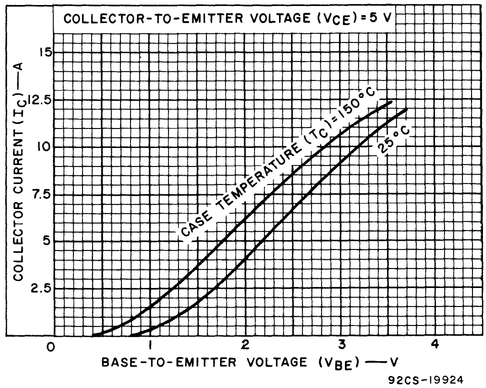


Fig. 11—Typical transfer characteristics for both types.

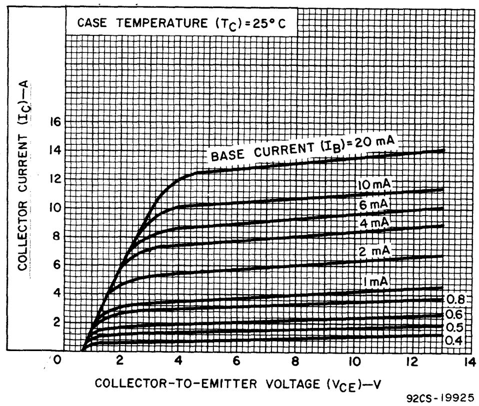


Fig. 12—Typical output characteristics for both types.

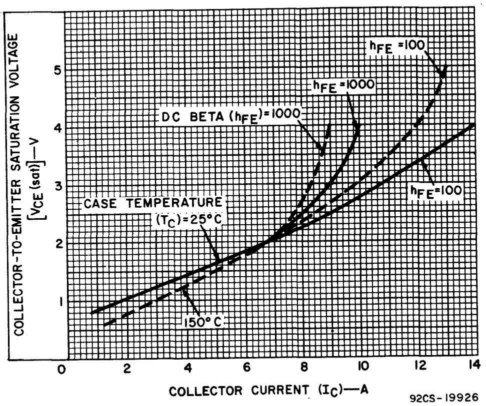


Fig. 13—Typical saturation-voltage characteristics for both types.

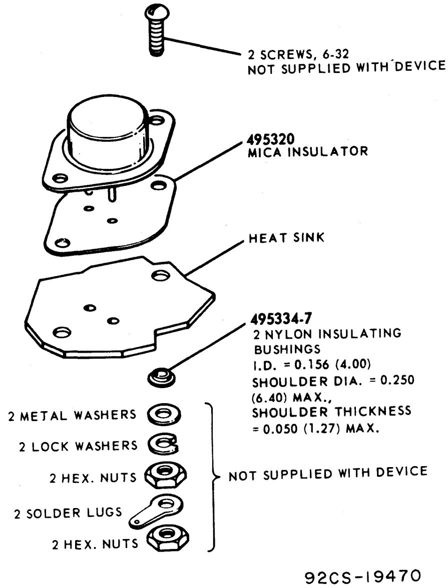
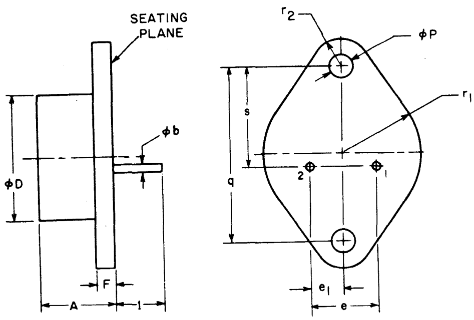


Fig. 14—Suggested mounting hardware.

DIMENSIONAL OUTLINE JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

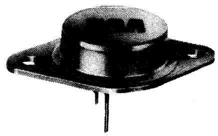
TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

RCA
Solid State
Division

Power Transistors

2N6383 2N6384 2N6385



JEDEC TO-3

H-1570

10-Ampere, N-P-N Darlington Power Transistors

40-60-80 Volts, 100 Watts
Gain of 1000 at 5 A

Features:
- Operates from IC without predriver
- Low leakage at high temperature
- High reverse second-breakdown capability

Applications:
- Power switching
- Audio amplifiers
- Hammer drivers
- Series and shunt regulators

The 2N6383, 2N6384, and 2N6385● are monolithic n-p-n silicon Darlington transistors designed for low- and medium-frequency power applications. The double epitaxial construction of these devices provides good forward and reverse second-breakdown capability; their high gain makes it possible for them to be driven directly from integrated circuits.

●Formerly RCA Dev. Nos. TA8349, TA8486, and TA8348.

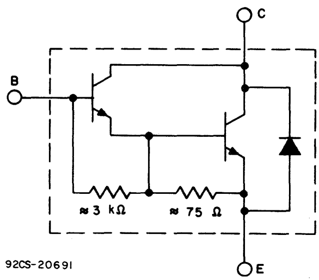


Fig. 1—Schematic diagram for all types.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6385	2N6384	2N6383	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	80	60	40	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 100Ω, sustaining	V_{CER}(sus)	80	60	40	V
With base open, sustaining	V_{CEO}(sus)	80	60	40	V
* With base reverse-biased V_{BE} = −1.5 V, R_{BB} = 100Ω	V_{CEX}	80	60	40	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	V
COLLECTOR CURRENT:	I_C				
* Continuous		10	10	10	A
Peak		15	15	15	A
* CONTINUOUS BASE CURRENT	I_B	0.25	0.25	0.25	A
* TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		100	100	100	W
At case temperatures above 25°C		←	See Fig. 3	→	
* TEMPERATURE RANGE:					
Storage and Operating (Junction)		←	−65 to +200	→	°C
* PIN TEMPERATURE (During Soldering):					
At distances ≥ 1/32 in. 0.8 mm from seating plane for 10 s max.		←	235	→	°C

*In accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc			CURRENT A dc		LIMITS: 2N6385		2N6384		2N6383		UNITS
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
* Collector-Cutoff Current: With base open	I_{CEO}	80				0	–	1	–	–	–	–	mA
		60				0	–	–	–	1	–	–	
		40				0	–	–	–	–	–	1	
With base open and T_C = 150°C		80				0	–	10	–	–	–	–	
		60				0	–	–	–	10	–	–	
		40				0	–	–	–	–	–	10	
* With base reverse-biased	I_{CEV}	80		−1.5			–	0.3	–	–	–	–	
		60		−1.5			–	–	–	0.3	–	–	
		40		−1.5			–	–	–	–	–	0.3	
* With base reverse-biased and T_C = 150°C		80		−1.5			–	3	–	–	–	–	
		60		−1.5			–	–	–	3	–	–	
		40		−1.5			–	–	–	–	–	3	
* Emitter-Cutoff Current	I_{EBO}		5		0		–	5	–	5	–	5	mA
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$				0.2[a]	0	80	–	60	–	40	–	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$				0.2[a]		80	–	60	–	40	–	
With base-emitter junction reverse-biased	$V_{CEV}(sus)$			−1.5	0.2[a]		80	–	60	–	40	–	
* DC Forward Current Transfer Ratio	h_{FE}	3			5[a]		1000	20,000	1000	20,000	1000	20,000	
		3			10[a]		100	–	100	–	100	–	
* Base-to-Emitter Voltage	V_{BE}	3			5[a]		–	2.8	–	2.8	–	2.8	V
		3			10[a]		–	4.5	–	4.5	–	4.5	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				5[a]	0.01[a]	–	2	–	2	–	2	V
					10[a]	0.1[a]	–	3	–	3	–	3	
Parallel Diode Forward Voltage Drop	V_F				−10		–	4	–	4	–	4	V
* Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	5			1		1000	–	1000	–	1000	–	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1.0 MHz)	$\|h_{fe}\|$	5			1		20	–	20	–	20	–	
* Common Base Output Capacitance (f = 1 MHz)	C_{ob}	V_{CB} = 10				I_E = 0	–	200	–	200	–	200	pF
Second Breakdown Energy With base reverse-biased and L = 12 mH, R_{BE} = 100Ω	$E_{S/b}$[b]			−1.5	4.5		120	–	120	–	120	–	mJ
Forward-Bias Second Breakdown Collector Current (1-s non-repetitive pulse)	$I_{S/b}$	75					0.22	–	–	–	–	–	A
		55					–	–	0.62	–	–	–	
		35					–	–	–	–	2.85	–	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	1.75	–	1.75	–	1.75	°C/W

[a] Pulsed: Pulse duration = 300 μs, duty factor = 1.8%.

[b] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$ where L is a series load or leakage inductance, and I is the peak collector current.

* In accordance with JEDEC registration data format JS-6 RDF-2.

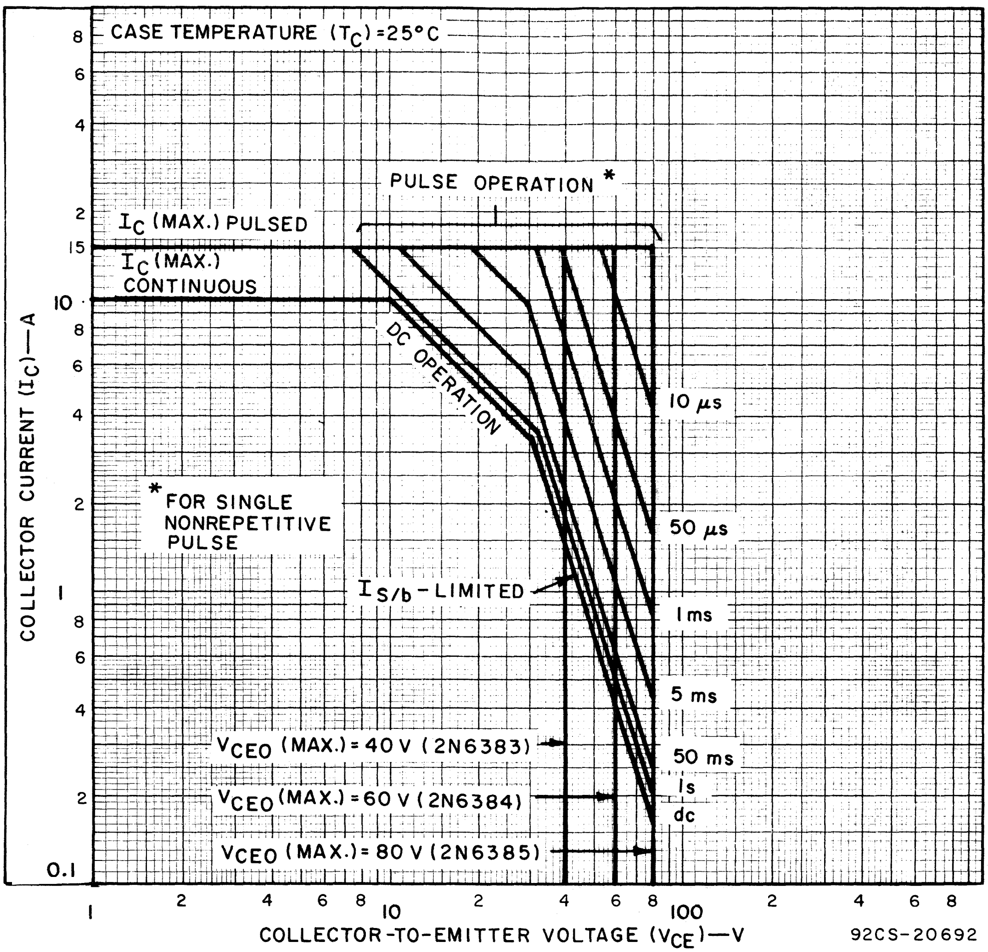


Fig. 2—Maximum operating area for all types.

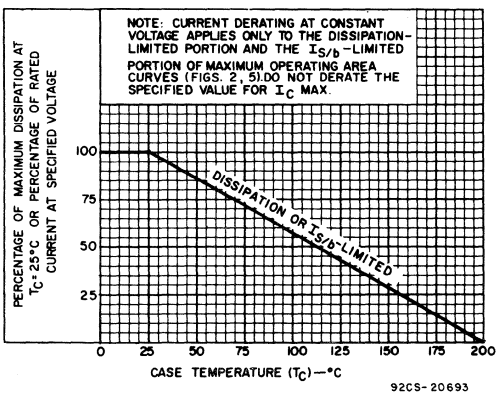


Fig. 3—Derating curves for all types.

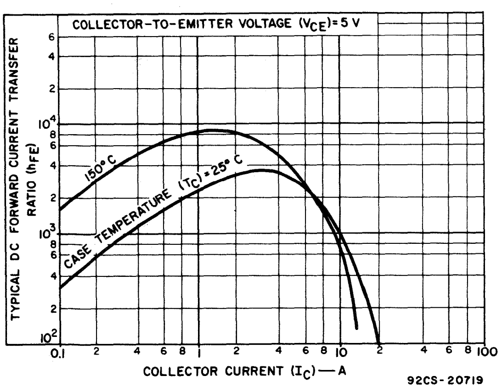


Fig. 4—Typical dc-beta characteristics for all types.

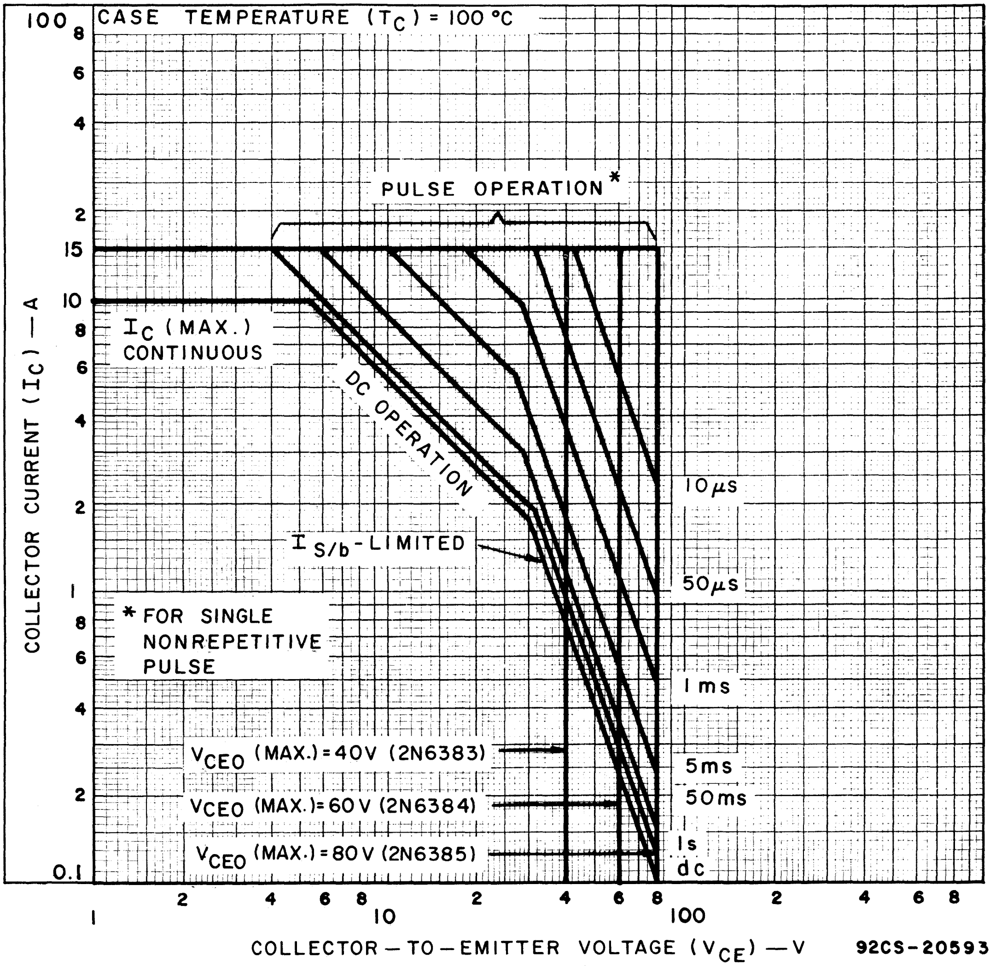


Fig. 5—Maximum operating area for all types.

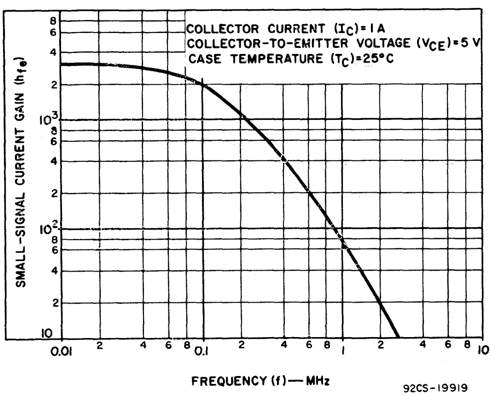


Fig. 6—Typical small-signal gain for all types.

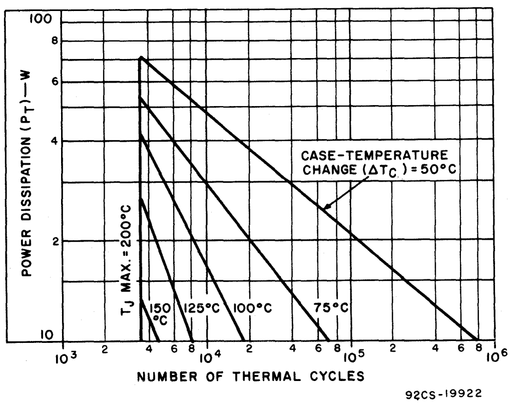


Fig. 7—Thermal-cycling rating chart for all types.

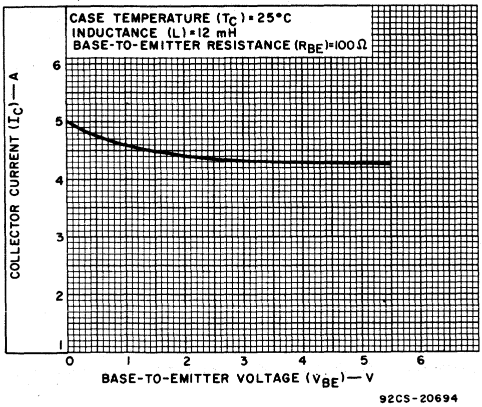


Fig. 8—Minimum values of reverse-bias second breakdown characteristic ($E_{S/b}$) for all types.

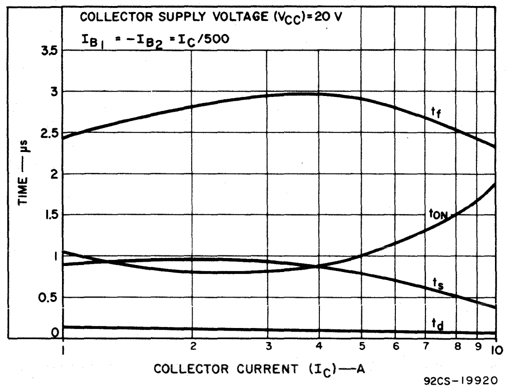


Fig. 9—Typical saturated switching-time characteristics for all types.

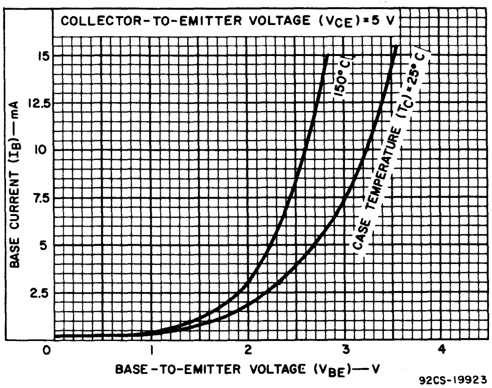


Fig. 10—Typical input characteristics for all types.

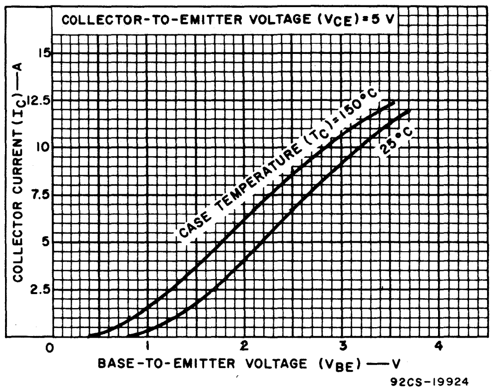


Fig. 11—Typical transfer characteristics for all types.

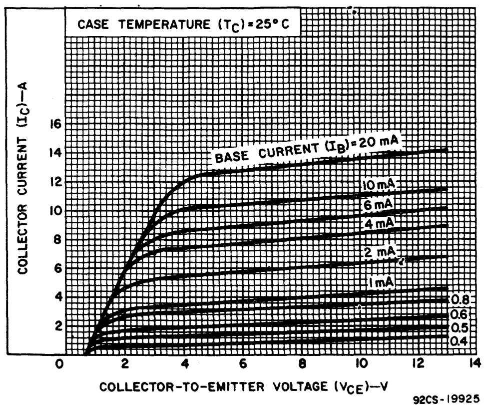


Fig. 12—Typical output characteristics for all types.

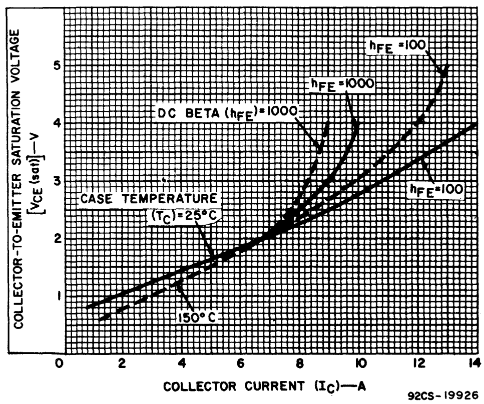


Fig. 13—Typical saturation characteristics for all types.

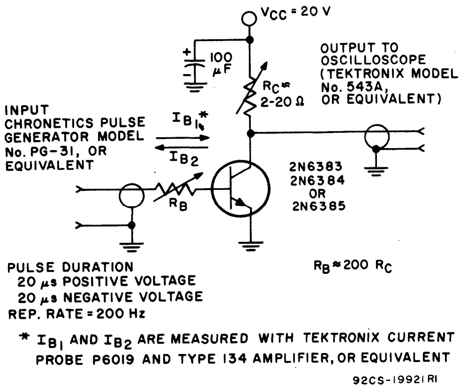


Fig. 14—Circuit used to measure saturated switching times.

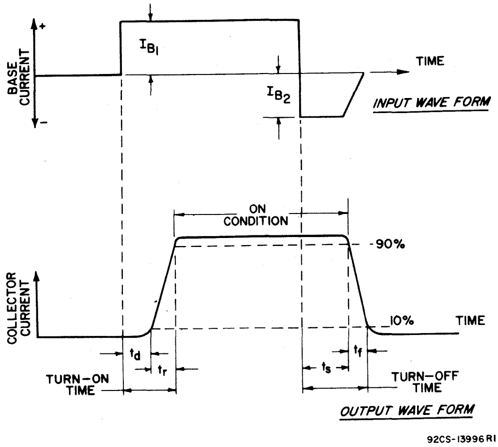
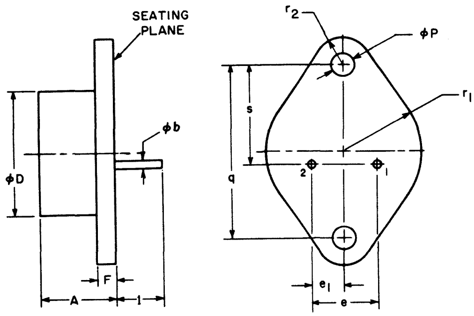


Fig. 15—Phase relationship between input current and output current showing reference points for specification of switching times (test circuit shown in Fig. 14).

DIMENSIONAL OUTLINE - JEDEC TO-3



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
φb	0.038	0.043	0.97	1.09	2
φD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
1	0.312		7.92		2
φP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r1		0.525		13.34	
r2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS—15222

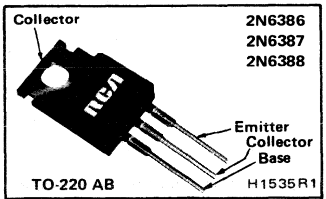
TERMINAL CONNECTIONS

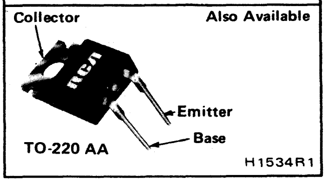
Pin 1 - Base
Pin 2 - Emitter
Case - Collector
Mounting Flange - Collector

RCA
Solid State
Division

Power Transistors

2N6386 2N6387 2N6388





10-Ampere, N-P-N Darlington Power Transistors

40-60-80 Volts, 40 Watts
Gain of 1000 at 5 A (2N6387, 2N6388)
Gain of 1000 at 3 A (2N6386)

Features:

- Operates from IC without predriver
- Low leakage at high temperature
- High reverse second-breakdown capability

Applications:

- Power switching
- Audio amplifiers
- Hammer drivers
- Series and shunt regulators

The 2N6386, 2N6387, and 2N6388● are monolithic n-p-n silicon Darlington transistors designed for low- and medium-frequency power applications. The double epitaxial construction of these devices provides good forward and reverse second-breakdown capability; their high gain makes it possible for them to be driven directly from integrated circuits.

● Formerly RCA Dev. Nos. TA8202, TA8485, and TA8201, respectively.

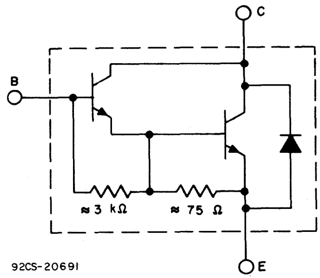


Fig. 1—Schematic diagram for all types.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6388	2N6387	2N6386	
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	80	60	40	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 100Ω, sustaining	V_{CER}(sus)	80	60	40	V
With base open, sustaining	V_{CEO}(sus)	80	60	40	V
* With base reverse-biased V_{BE} = −1.5 V	V_{CEX}	80	60	40	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	5	V
COLLECTOR CURRENT:	I_C				
* Continuous		10	10	8	A
Peak		15	15	15	A
* CONTINUOUS BASE CURRENT	I_B	0.25	0.25	0.25	A
* TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 25°C		40	40	40	W
At case temperatures above 25°C		←	See Fig. 3	→	
TEMPERATURE RANGE:					
Storage and Operating (Junction)		←	−65 to +150	→	°C
* LEAD TEMPERATURE (During Soldering):					
At distances ≥ 1/8 in. (3.17 mm) from case for 10 s max.		←	235	→	°C

*In accordance with JEDEC registration data format JS-6 RDF-2.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc: V_{CE}	V_{EB}	V_{BE}	CURRENT A dc: I_C	I_B	LIMITS 2N6388 MIN.	2N6388 MAX.	2N6387 MIN.	2N6387 MAX.	2N6386 MIN.	2N6386 MAX.	UNITS
*	Collector-Cutoff Current: With base open	I_{CEO}	80 60 40				0 0 0	– – –	1 – –	– – –	– 1 –	– – –	– – 1	mA
	With base open and T_C = 150°C	I_{CEO}	80 60 40				0 0 0	– – –	10 – –	– – –	– 10 –	– – –	– – 10	mA
*	With base reverse-biased	I_{CEV}	80 60 40		−1.5 −1.5 −1.5			– – –	0.3 – –	– – –	– 0.3 –	– – –	– – 0.3	mA
*	With base reverse-biased and T_C = 150°C	I_{CEV}	80 60 40		−1.5 −1.5 −1.5			– – –	3 – –	– – –	– 3 –	– – –	– – 3	mA
*	Emitter-Cutoff Current	I_{EBO}		5		0		–	5	–	5	–	5	mA
*	Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO(sus)}$				0.2[a]	0	80	–	60	–	40	–	V
	With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER(sus)}$				0.2[a]		80	–	60	–	40	–	V
	With base-emitter junction reverse-biased	$V_{CEV(sus)}$			−1.5	0.2[a]		80	–	60	–	40	–	V
*	DC Forward Current Transfer Ratio	h_{FE}	3 3 3 3			3[a] 5[a] 8[a] 10[a]		– 1000 – 100	– 20,000 – –	– 1000 – 100	– 20,000 – –	1000 – 100 –	20,000 – – –	
*	Base-to-Emitter Voltage	V_{BE}	3 3 3 3			3[a] 5[a] 8[a] 10[a]		– – – –	– 2.8 – 4.5	– – – –	– 2.8 – 4.5	– – – –	2.8 – 4.5 –	V
*	Collector-to-Emitter Saturation Voltage	$V_{CE(sat)}$				3[a] 5[a] 8[a] 10[a]	0.006[a] 0.01[a] 0.08[a] 0.1[a]	– – – –	– 2 – 3	– – – –	– 2 – 3	– – – –	2 – 3 –	V
	Parallel Diode Forward Voltage Drop	V_F				−8 −10		– –	– 4	– –	– 4	– –	4 –	V
*	Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}	5			1		1000	–	1000	–	1000	–	
*	Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 1.0 MHz)	$\|h_{fe}\|$	5			1		20	–	20	–	20	–	
*	Common Base Output Capacitance (f = 1 MHz)	C_{ob}	V_{CB} = 10				I_E = 0	–	200	–	200	–	200	pF
	Second Breakdown Energy With base reverse-biased and L = 12 mH, R_{BE} = 100Ω	$E_{S/b}$[b]			−1.5	4.5		120	–	120	–	120	–	mJ
	Forward-Bias Second Breakdown Collector Current (0.5-s non-repetitive pulse)	$I_{S/b}$	35					1.2	–	1.2	–	1.2	–	A
	Thermal Resistance Junction-to-Case	$R_{\theta JC}$						–	3.12	–	3.12	–	3.12	°C/W

[a] Pulsed: Pulse duration = 300 μs, duty factor = 1.8%.

[b] $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$ where L is a series load or leakage inductance, and I is the peak collector current.

* In accordance with JEDEC registration data format JS-6 RDF-2.

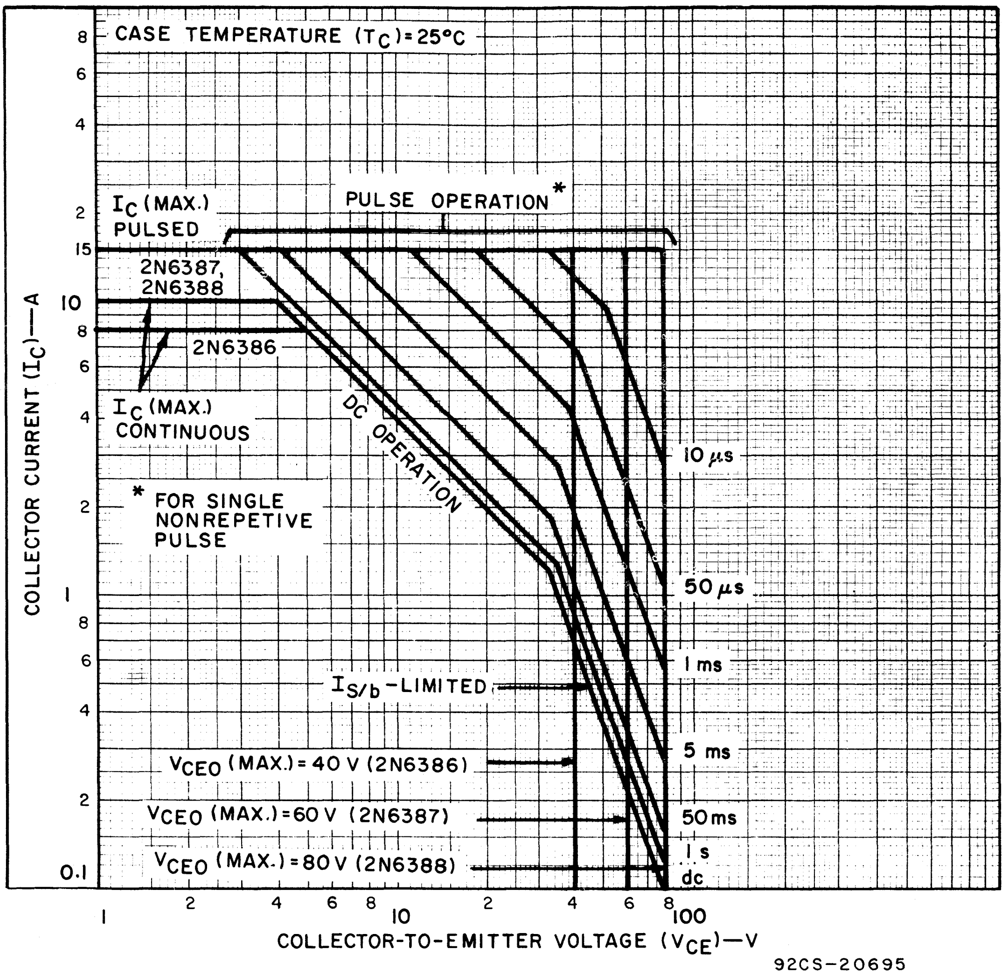


Fig. 2—Maximum operating area for all types.

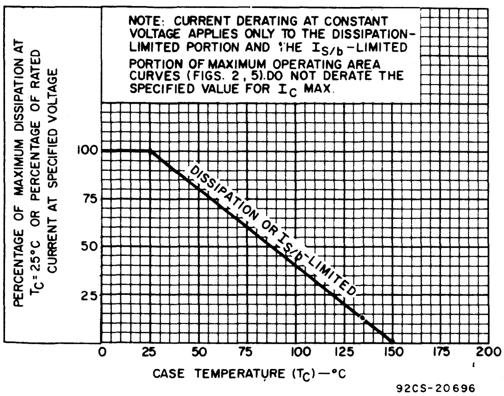


Fig. 3—Derating curves for all types.

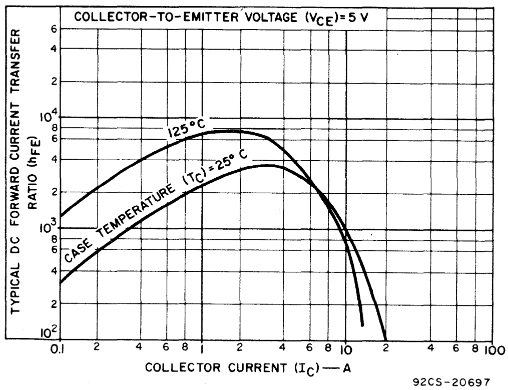


Fig. 4—Typical dc-beta characteristics for all types.

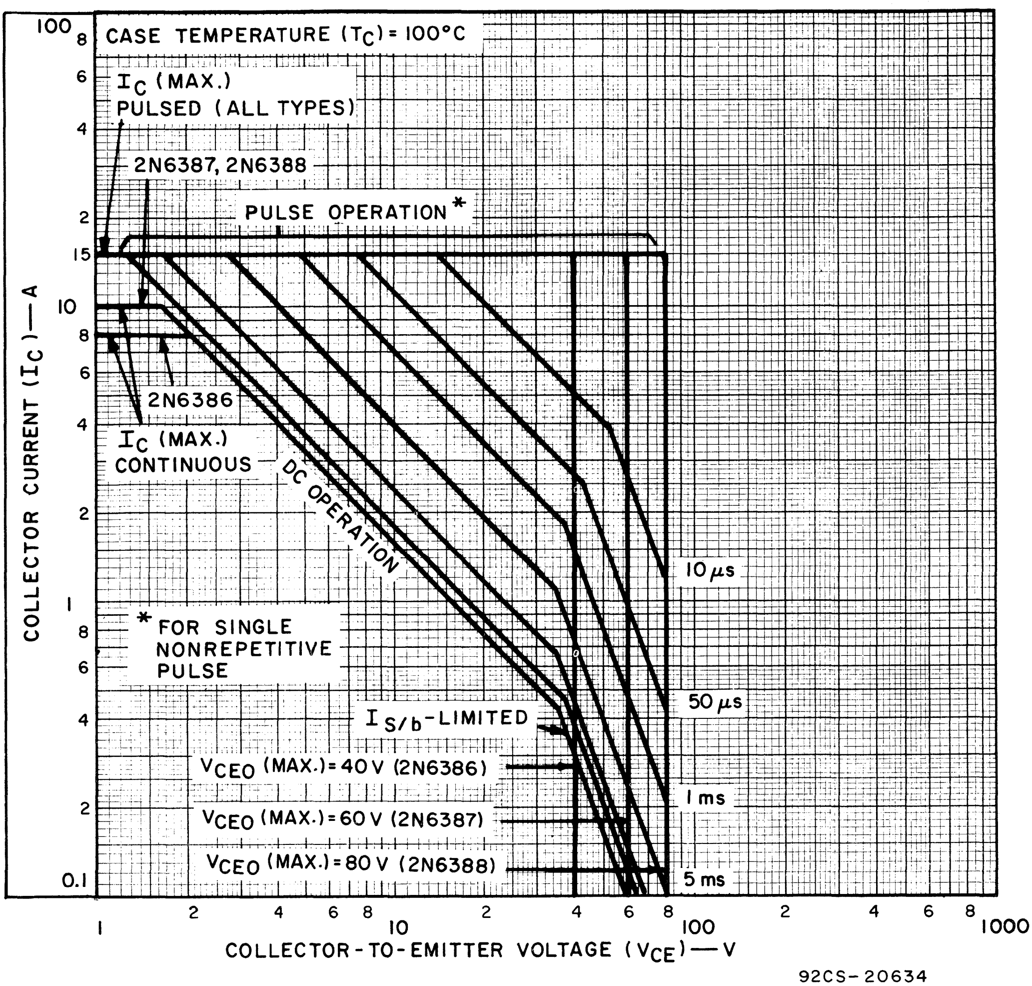


Fig. 5—Maximum operating area for all types.

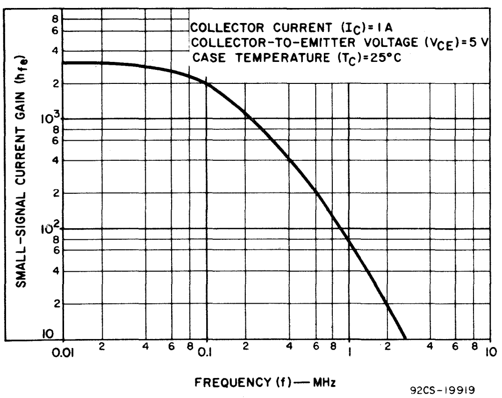


Fig. 6—Typical small-signal gain for all types.

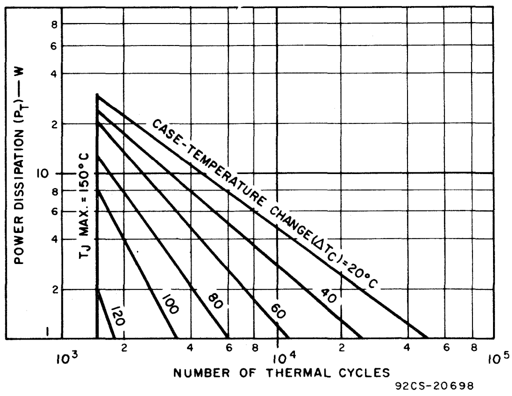


Fig. 7—Thermal-cycling rating chart for all types.

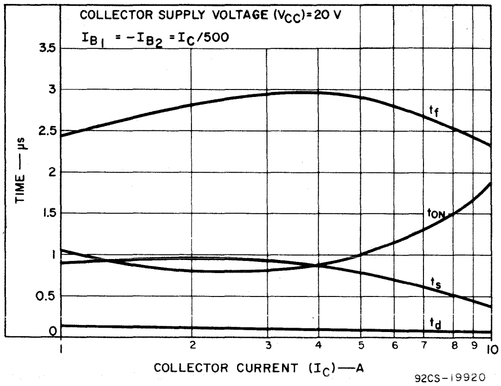


Fig. 8—Typical saturated switching-time characteristics for all types.

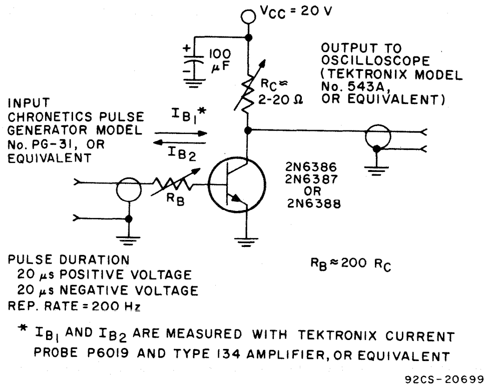


Fig. 9—Circuit used to measure saturated switching times.

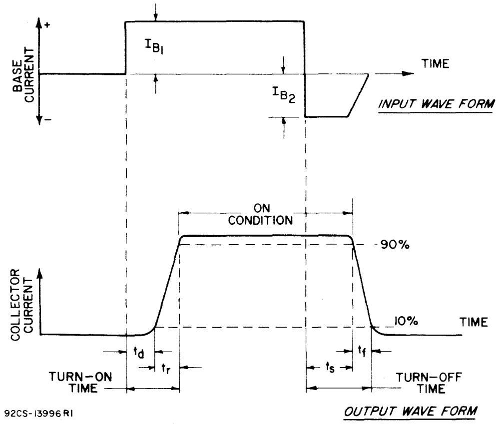


Fig. 10—Phase relationship between input current and output current showing reference points for specification of switching times (test circuit shown in Fig. 9).

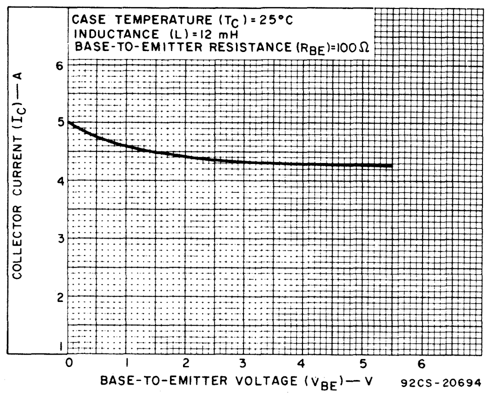


Fig. 11—Minimum values of reverse-bias second breakdown characteristic ($E_{S/b}$) for all types.

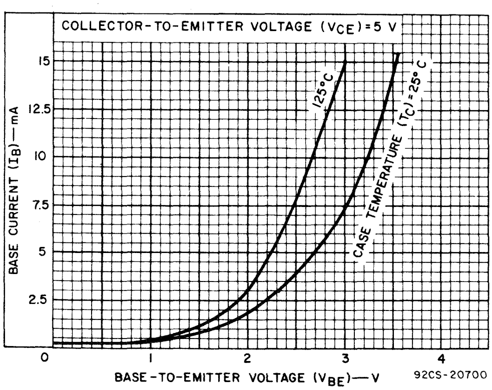


Fig. 12—Typical input characteristics for all types.

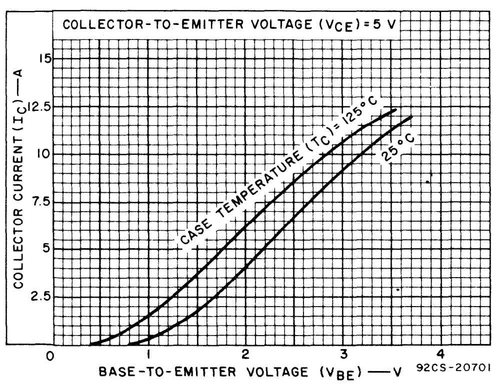


Fig. 13—Typical transfer characteristics for all types.

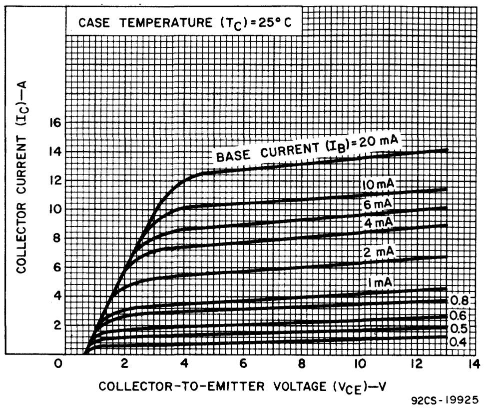


Fig. 14—Typical output characteristics for all types.

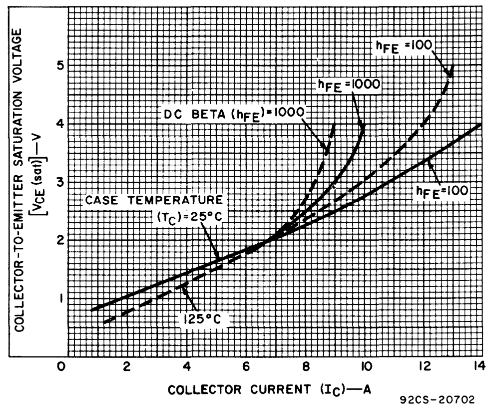
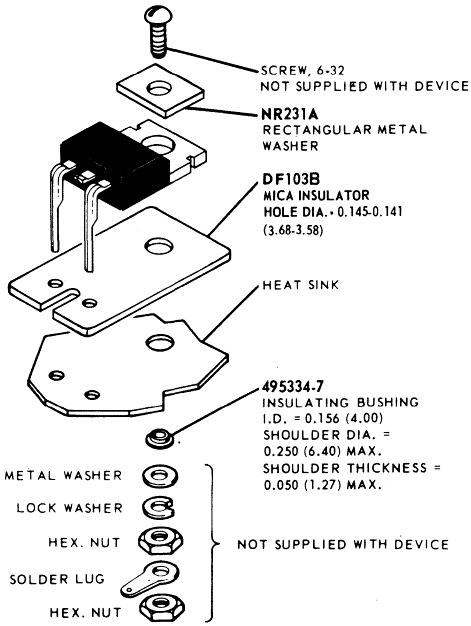


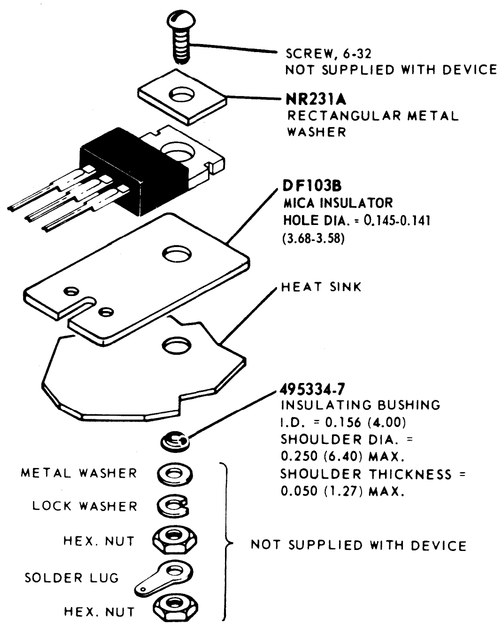
Fig. 15—Typical saturation characteristics for all types.



DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-17181R1

Fig. 16—Suggested mounting hardware for use with JEDEC TO-220 AA package.



DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-17182R2

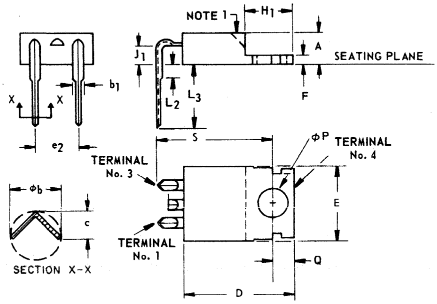
Fig. 17—Suggested mounting hardware for use with JEDEC TO-220 AB package.

VERSAWATT PACKAGE MOUNTING

For complete discussion on handling and mounting of RCA molded-plastic power devices, refer to RCA Application Note AN-4124.

For basic transistor theory, circuits, and application information, refer to "RCA Solid State Power Circuits Designer's Handbook", SP-52 or "RCA Transistor, Thyristor, & Diode" manual, SC-15.

DIMENSIONAL OUTLINE FOR OPTIONAL LEAD CONFIGURATION (JEDEC TO-220 AA)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.02	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L_2	–	0.050	–	1.27	–
L_3	0.360	0.422	9.15	10.71	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–
S	0.580	0.610	14.74	15.49	–

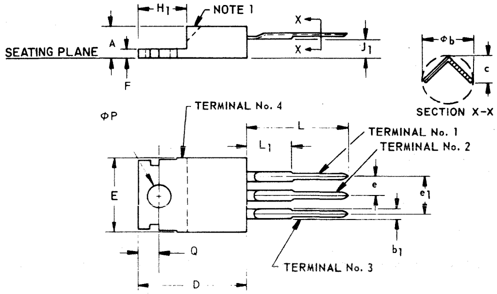
NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.050 – 0.055 (1.27 – 1.40 mm) below seating plane.

92CS-17990

TERMINAL CONNECTIONS

Lead No. 1 – Base
Stub – Do not use stub as tie point.
Lead No. 3 – Emitter
Mounting Flange – Collector

STANDARD DIMENSIONAL OUTLINE FOR 2N6386, 2N6387, and 2N6388 (JEDEC TO-220 AB)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.020	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e	0.090	0.110	2.29	2.79	3
e_1	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L_1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

NOTES:
1. Chamfer optional.
2. Tab contour optional within H_1 and E.
3. Position of lead to be measured 0.250 – 0.255 (6.35 – 6.48 mm) from case.

92CS-17991

TERMINAL CONNECTIONS

Lead No. 1 – Base
Lead No. 2 – Collector
Lead No. 3 – Emitter
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors

RCA-1000
RCA-1001

H-1570 JEDEC TO-3

8-Ampere Silicon N-P-N Darlington Power Transistors

For Use as Output Devices in General-Purpose Switching and Amplifier Applications

Features:

- **High dc current gain:**
  h_{FE} = 1000 min. at I_C = 3 A
- **Monolithic construction with built-in base-emitter shunt resistors**

RCA-1000 and 1001 are monolithic silicon n-p-n Darlington transistors intended for medium-power applications as output devices. The double epitaxial construction of these units provides good forward and reverse second-breakdown capability. Their high gain makes it possible for them to be driven directly from integrated circuits.

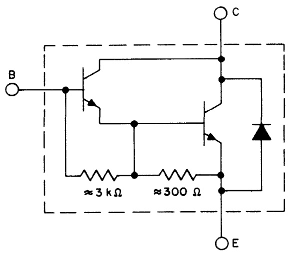


Fig.1—Schematic diagram of RCA-1000 and RCA-1001 Darlington power transistors.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA-1000	RCA-1001	
COLLECTOR-TO-BASE VOLTAGE:				
With emitter open	V_{CBO}	60	80	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open	V_{CEO}	60	80	V
EMITTER-TO-BASE VOLTAGE:				
With collector open	V_{EBO}	5	5	V
COLLECTOR CURRENT:	I_C			
Continuous		8	8	A
Pulsed		15	15	A
BASE CURRENT (Continuous)	I_B	0.1	0.1	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25°C		90	90	W
At case temperatures above 25°C, derate linearly at		0.515		W/°C
TEMPERATURE RANGE:				
Storage & Operating (Junction)		−55 to +200		°C
LEAD TEMPERATURE (During Soldering):				
At distance ≥ 1/8 in. (3.17 mm) from case to 10 s max.		235		°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE (V)			TEST CONDITIONS: DC CURRENT (A)		LIMITS: RCA-1000		LIMITS: RCA-1001		UNITS
		V_{CB}	V_{CE}	V_{BE}	I_C	I_B	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: With base open	I_{CEO}		30			0	–	500	–	–	µA
			40			0	–	–	–	500	
With external base-to-emitter resistance (R_{BE}) = 1 kΩ	I_{CER}	60					–	1	–	–	mA
		80					–	–	–	1	
At T_C = 150°C		60					–	5	–	–	
		80					–	–	–	5	
Emitter Cutoff Current	I_{EBO}			5	0		–	2	–	2	mA
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$				0.1[a]	0	60	–	–	–	V
					0.1[a]	0	–	–	80	–	
DC Forward Current Transfer Ratio	h_{FE}		3		3		1000	–	1000	–	
			3		4		750	–	750	–	
Base-to-Emitter Voltage	V_{BE}		3		3[a]		–	2.5	–	2.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				3[a]	0.012	–	2	–	2	V
					8[a]	0.04	–	4	–	4	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						–	1.94	–	1.94	°C/W

[a] Pulsed: Pulse duration ≤ 300 µs, duty factor ≤ 2%.

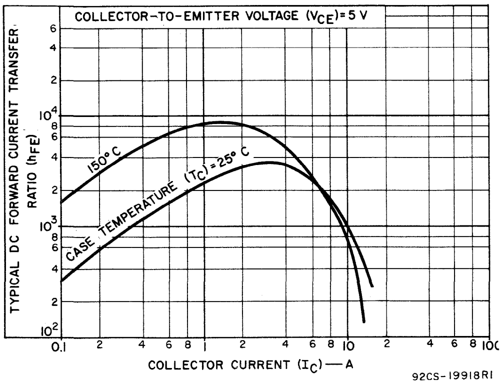


Fig.2—Typical dc beta characteristics for both types.

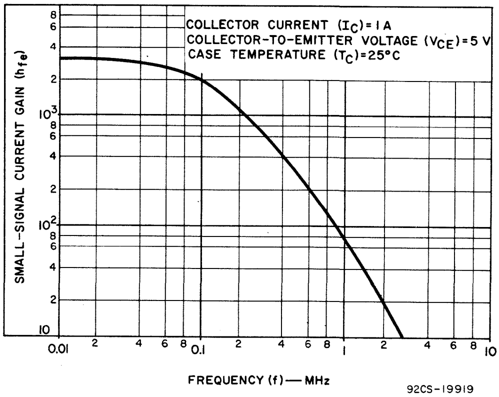


Fig.3—Typical small-signal gain for both types.

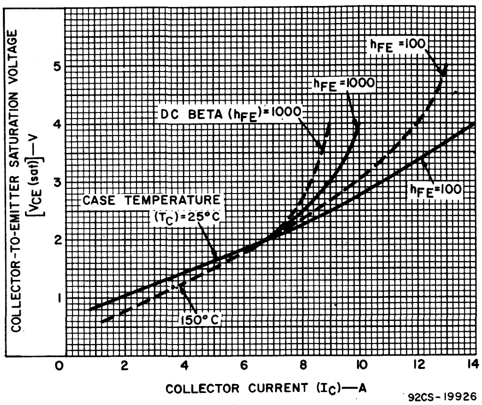


Fig.4—Typical saturation characteristics for both types.

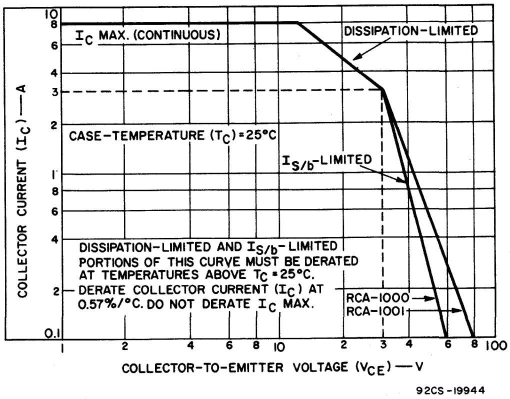


Fig.5—DC safe-area-of-operation for both types.

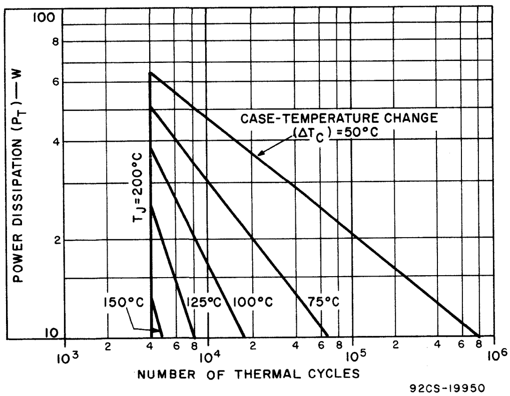
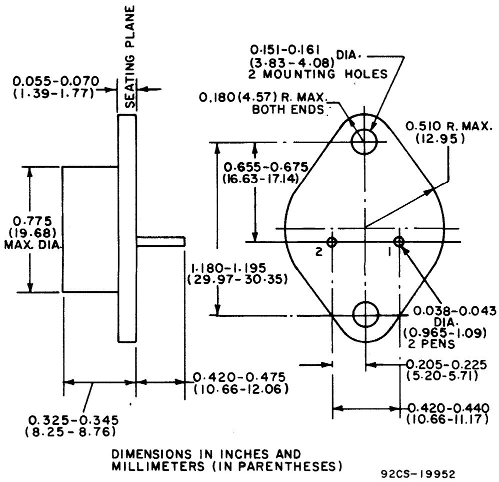


Fig.6—Thermal-cycling rating chart for both types.

DIMENSIONAL OUTLINE—JEDEC TO-3



TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

Diffused-Junction n-p-n Silicon Transistors

RCA

Solid State Division

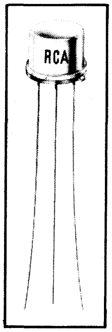
Power Transistors

2N697

RCA-2N697 is a double-diffused-junction transistor of the silicon n-p-n type designed for use in high-speed-switching applications in military and industrial data-processing equipment.

This transistor is especially designed and processed to assure stability of characteristics and reliable performance under conditions of severe thermal and mechanical stress, and other environmental hazards.

For High-Speed Switching Service In Electronic Data-Processing Systems



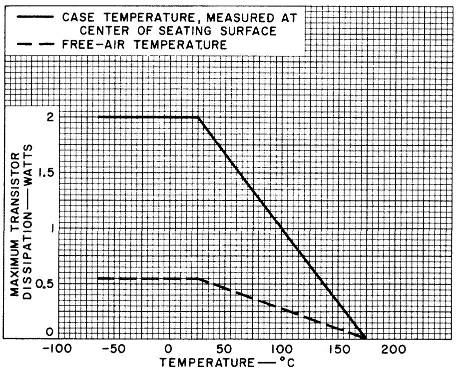
JEDEC TO-5

- tested in accordance with military specification MIL-S-19500B
- exceptional reliability
- exceptional stability of characteristics–stabilized by prolonged baking at 300°C
- typical pulse beta = 75
- low saturation voltages:
  $V_{CE}(sat)$ = 1.5 volts max. at I_C = 150 ma
  $V_{BE}(sat)$ = 1.3 volts max. at I_C = 150 ma

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE		
With emitter open	60 max.	volts
EMITTER-TO-BASE VOLTAGE		
With collector open	5 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE		
With external $R_{BE} \leq$ 10 ohms .	40 max.	volts
COLLECTOR CURRENT	500 max.	ma
TRANSISTOR DISSIPATION:		
At case temperatures { up to 25° C. .	2 max.	watts
At case temperatures { above 25° C. .	See *Rating*	*Chart*
At free-air temperatures { up to 25° C. .	0.6 max.	watt
At free-air temperatures { above 25° C. .	See *Rating*	*Chart*
OPERATING TEMPERATURE RANGE:		
(Case or free-air).	-65 to +175	°C
LEAD TEMPERATURE:		
1/16" ± 1/32" from case, for immersion for 10 seconds max.	255 max.	°C

R_{BE} = Base-to-emitter resistance.



92CS-11161

Rating Chart for Type 2N697.

ELECTRICAL CHARACTERISTICS

At a free-air temperature of 25° C unless otherwise indicated

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR-TO-BASE VOLTAGE V_{CB} volts	DC COLLECTOR-TO-EMITTER VOLTAGE V_{CE} volts	DC COLLECTOR CURRENT I_C ma	DC EMITTER CURRENT I_E ma	DC BASE CURRENT I_B ma	LIMITS min.	LIMITS typ.	LIMITS max.	UNITS
Collector-to-Base Breakdown Voltage	BV_{CBO}			0.1	0		60	75	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}			0	0.1		5	7.5	-	volts
Collector-to-Emitter Voltage (R_{BE} = 10 ohms)	V_{CER}			100[a]			40	50	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			150		15	-	0.8	1.5	volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$			150		15	-	1	1.3	volts
Collector-Cutoff Current:	I_{CBO}									
At T_{FA} = 25° C		30			0		-	0.01	1	µa
At T_{FA} = 150° C		30			0		-	1	100	µa
DC-Pulse Forward-Current Transfer Ratio[b]	h_{FE}		10	150			40	75	120	
Small-Signal Forward-Current Transfer Ratio	h_{fe} at 20 Mc		10	50			2.5	5	-	
Output Capacitance	C_{ob}	10			0		-	20	35	µµf
Gain-Bandwidth Product[c]	f_T						-	100	-	Mc

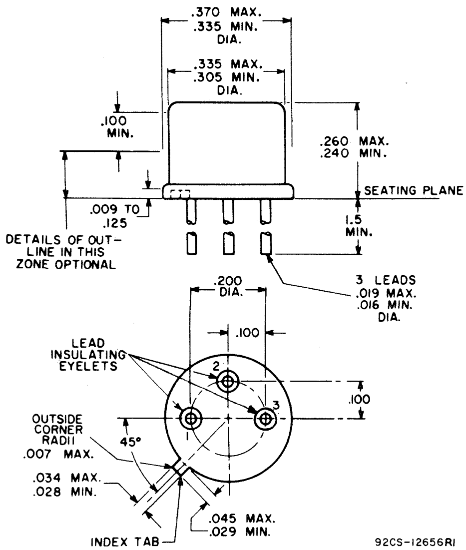
[a] Pulsed to prevent excessive heating of collector junction.

[b] Pulse width ≦ 12 msec, duty cycle ≦ 2%. R_{BE} = External base-to-emitter resistance.

[c] Frequency at which h_{fe} = 1. T_{FA} = Free-air temperature.

DIMENSIONAL OUTLINE FOR TYPE 2N697

JEDEC TO-5



TERMINAL CONNECTIONS

Lead No.1 - Emitter
Lead No.2 - Base
Lead No.3 - Collector

Solid State
Division

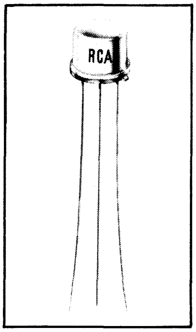
Power Transistors

2N1479 2N1481
2N1480 2N1482

RCA-2N1479–2N1482 are diffused-junction power transistors of the silicon n-p-n type. These transistors are intended for a wide variety of applications in industrial and military equipment. They are particularly useful in power-switching circuits such as in dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillator, regulator, and pulse-amplifier circuits; and as class-A and class-B push-pull audio and servo amplifiers.

These transistors feature high beta at high current, and excellent high temperature performance.

Medium-Power Types



JEDEC-TO-5

- Maximum dissipation rating of 5 watts at a case temperature of 25°C

Maximum Ratings, *Absolute-Maximum Values:*

	2N1479 2N1481	*2N1480 2N1482*		
COLLECTOR-TO-BASE VOLTAGE	60	100	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open (sustaining voltage)	40	55	max.	volts
With emitter-to-base reverse biased (V_{EB} = 1.5 volts)	60	100	max.	volts
EMITTER-TO-BASE VOLTAGE	12	12	max.	volts
COLLECTOR CURRENT	1.5	1.5	max.	amp
EMITTER CURRENT	-1.75	-1.75	max.	amp
BASE CURRENT	1	1	max.	amp
TRANSISTOR DISSIPATION:▲ (See Rating Chart Fig. 1):				
At case temperature of 25°C	5	5	max.	watts
At case temperature of 100°C	2.86	2.86	max.	watts
TEMPERATURE RANGE:				
Operating and Storage	-65 to +200			°C

▲For Transistor dissipation in pulse operation refer to RCA Application Note AN-181, "Transistor Dissipation Ratings for Pulse and Switching Service."

ELECTRICAL CHARACTERISTICS

Case temperature = 25°C unless otherwise specified

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (volts) V_{CB}	DC Collector Voltage (volts) V_{CE}	DC Emitter Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Base Current (ma) I_B	LIMITS: Type 2N1479 Min.	Type 2N1479 Max.	Type 2N1480 Min.	Type 2N1480 Max.	Type 2N1481 Min.	Type 2N1481 Max.	Type 2N1482 Min.	Type 2N1482 Max.	Units
Collector-Cutoff Current: With I_E = 0 and at a case temperature of;	I_{CBO}														
25°C		30						10		10		10		10	μa
150°C		30						500		500		500		500	μa
Emitter-Cutoff Current	I_{EBO}			12	0			10		10		10		10	μa
Collector-To-Emitter Voltage: (Emitter-to-base reverse bias)	V_{CEX}			1.5	0.25		60		100		60		100		volts
(Base-open sustaining voltage)	V_{CEO} (sus)				50	0	40		55		40		55		volts
DC Current Transfer Ratio	h_{FE}		4		200		20	60	20		35	100	35	100	
DC Collector-To-Emitter Saturation Resistance	R_s				200	20		7		7					ohms
					200	10						7		7	ohms
Base-To-Emitter Voltage	V_{BE}		4		200			3		3		3		3	volts
Thermal Resistance:	R_T														
Junction-to-case								35		35		35		35	°C/w
Junction-to-free air								200		200		200		200	°C/w

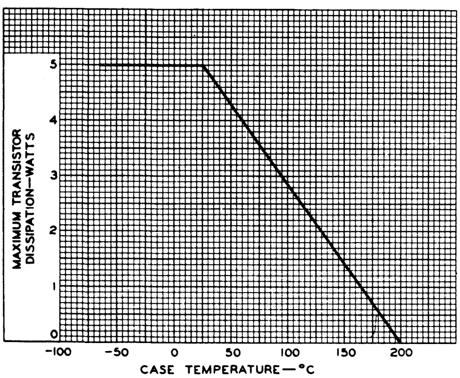


Fig. 1 - Rating Chart for Types 2N1479, 2N1480, 2N1481, and 2N1482.

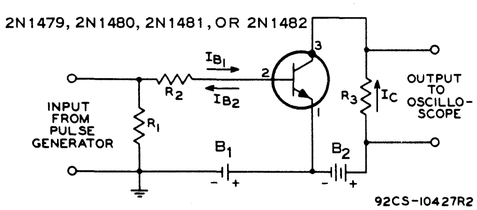
Typical Operation of the 2N1479, 2N1480, 2N1481, and 2N1482 in the Power–Switching Circuit of Fig. 2:

At a Case Temperature of 25°C

DC Supply Voltage (B_2)	12	volts
DC Base Bias Voltage (B_1)	-8.5	volts
Generator Resistance	50	ohms
"On" DC Collector Current	200	ma
"Turn-On" Base Current (I_{B_1})	20	ma
"Turn-Off" Base Current (I_{B_2})	-8.5	ma
Switching Time:		
Delay Time (t_d)	0.2	μsec
Rise Time (t_r)	1.0	μsec
Storage Time (t_s)	0.6	μsec
Fall Time (t_f)	1.0	μsec

Typical Characteristics of the 2N1479, 2N1480, 2N1481, and 2N1482, at a Case Temperature of 25°C:

Small-Signal Current Transfer Ratio: h_{fe} (I_C = 5ma, V_{CE} = 4volts)	50	
Collector-to-Base Capacitance: C_{ob} (V_{CB} = 40volts)	150	μμf
Thermal Time Constant, τ_1	10	msec
Alpha-Cutoff Frequency: f_{a_b} (V_{CB} = 28volts, I_C = 5ma)	1.5	Mc



B_1 = 8.5 volts
B_2 = 12 volts

R_1 = 50 ohms, 1 watt
R_2 = 700 ohms, 1 watt
R_3 = 59 ohms, 2 watts

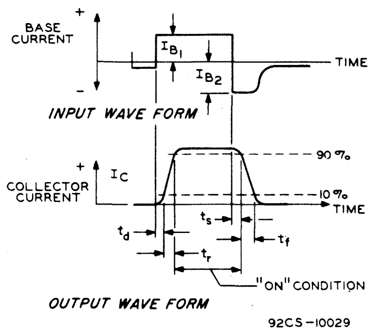


Fig. 2 - Typical Power-Switching Circuit.

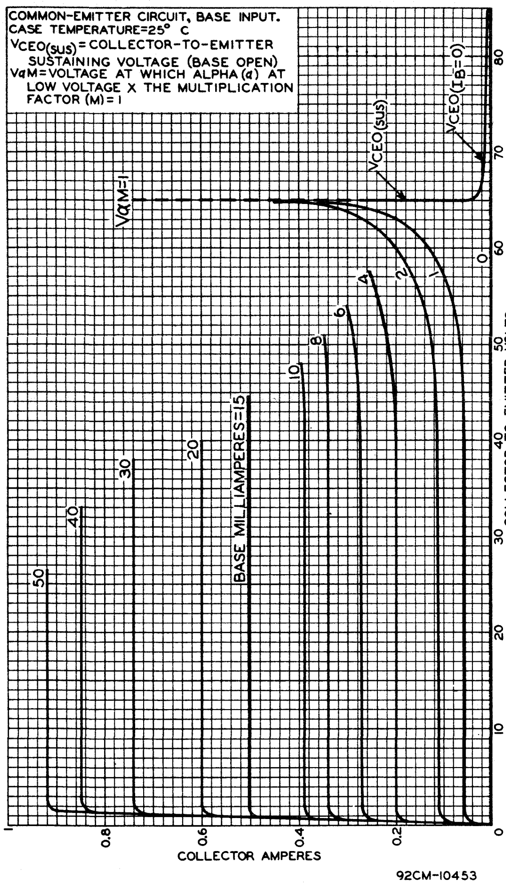


Fig. 3 - Typical Collector Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

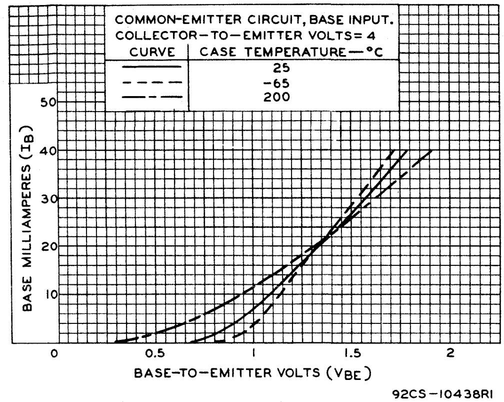


Fig. 4 - Typical Input Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

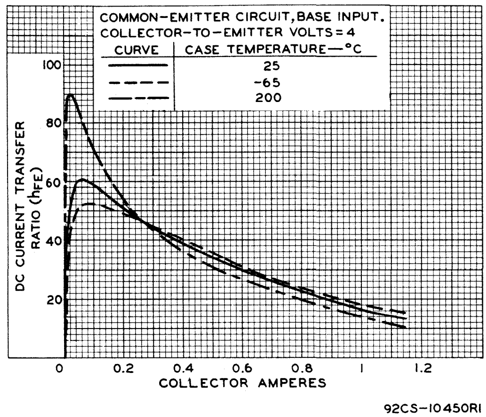


Fig. 5 - Typical Operation Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

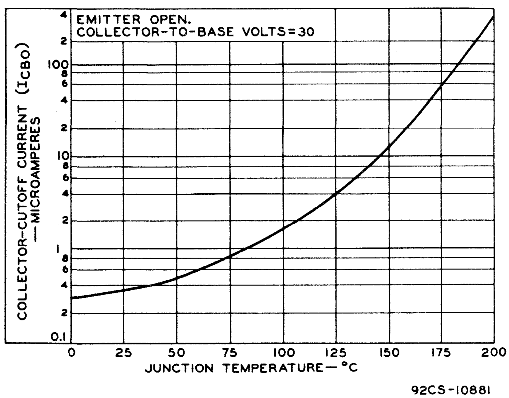
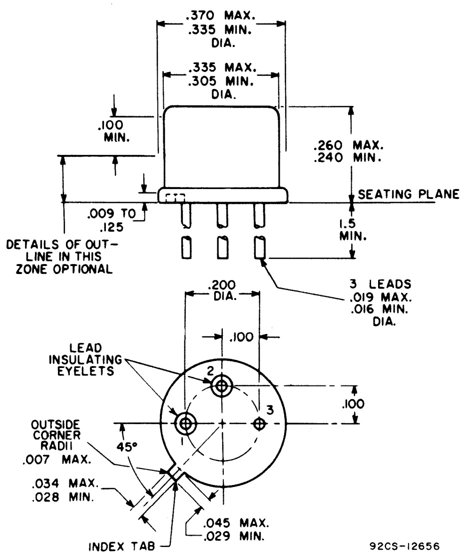


Fig. 6 - Typical Operation Characteristic for Types 2N1479, 2N1480, 2N1481, and 2N1482.

DIMENSIONAL OUTLINE
for Types
2N1479, 2N1480, 2N1481, and 2N1482

JEDEC No. TO-5



TERMINAL CONNECTIONS

Lead No. 1 - Emitter

Lead No. 2 - Base

Lead No. 3 - Collector, Case

RCA

Solid State Division

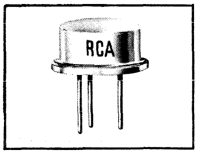
Power Transistors

2N1483 2N1485 2N1484 2N1486

RCA-2N1483–2N1486 are diffused-junction power transistors of the silicon n-p-n type. These transistors are intended for a wide variety of applications in industrial and military equipment. They are particularly useful in power-switching circuits such as in dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillator, regulator, and pulse amplifier circuits; and as class-A and class-B push-pull audio and servo amplifiers.

These transistors feature high beta at high current, and excellent high temperature performance.

Intermediate-Power Types



JEDEC-TO-8

- Maximum dissipation rating of 25 watts at a case temperature of 25°C
- 2N1485 and 2N1486 have a maximum saturation resistance of 1 ohm

Maximum Ratings, *Absolute-Maximum Values:*

	2N1483 2N1485	*2N1484 2N1486*		
COLLECTOR-TO-BASE VOLTAGE	60	100	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open (sustaining voltage)	40	55	max.	volts
With emitter-to-base reverse biased (V_{EB} = 1.5 volts)	60	100	max.	volts
EMITTER-TO-BASE VOLTAGE	12	12	max.	volts
COLLECTOR CURRENT	3	3	max.	amp
EMITTER CURRENT	-3.5	-3.5	max.	amp
BASE CURRENT	1.5	1.5	max.	amp
TRANSISTOR DISSIPATION:▲ (See Rating Chart Fig. 1):				
At case temperature of 25°C	25	25	max.	watts
At case temperature of 100°C	14.1	14.1	max.	watts
TEMPERATURE RANGE:				
Operating and Storage	-65 to +200			°C

▲For Transistor dissipation in pulse operation refer to RCA Application Note AN-181, "Transistor Dissipation Ratings for Pulse and Switching Service."

ELECTRICAL CHARACTERISTICS

Case temperature = 25°C unless otherwise specified.

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (volts) V_{CB}	DC Collector Voltage (volts) V_{CE}	DC Emitter Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Base Current (ma) I_B	LIMITS: Type 2N1483 Min.	Type 2N1483 Max.	Type 2N1484 Min.	Type 2N1484 Max.	Type 2N1485 Min.	Type 2N1485 Max.	Type 2N1486 Min.	Type 2N1486 Max.	Units
Collector-Cutoff Current: With I_E = 0 and at a Case Temperature of;	I_{CBO}														
25°C		30						15		15		15		15	µa
150°C		30						750		750		750		750	µa
Emitter-Cutoff Current	I_{EBO}			12	0			15		15		15		15	µa
Collector-To-Emitter Voltage: (Emitter-to-base reverse bias)	V_{CEX}			1.5	0.25		60		100		60		100		volts
(Base open sustaining voltage)	V_{CEO} (sus)				100	0	40		55		40		55		volts
DC Current Transfer Ratio	h_{FE}		4		750		20	60	20	60	35	100	35	100	
DC Collector-To-Emitter Saturation Resistance	R_S				750	75		2.67		2.67					ohms
					750	40						1		1	ohm
Base-To-Emitter Voltage	V_{BE}		4		750			3.5		3.5		2.5		2.5	volts
Thermal Resistance: Junction-to-case	R_T							7		7		7		7	°C/w
Junction-to-free air								100		100		100		100	°C/w

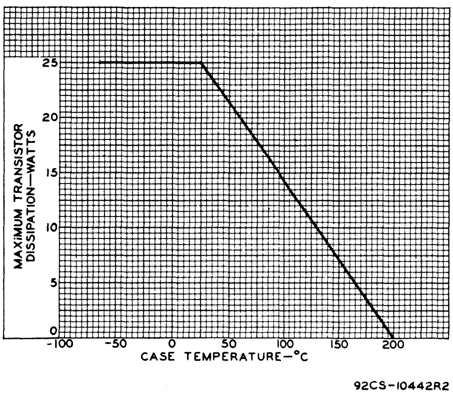


Fig. 1 - Rating Chart for Types 2N1483, 2N1484, 2N1485, and 2N1486.

Typical Operation of the 2N1483, 2N1484, 2N1485, and 2N1486 in the Power–Switching Circuit of Fig. 2:

At a Case Temperature of 25°C

DC Supply Voltage (B_2)	12	volts
DC Base Bias Voltage (B_1)	-8.5	volts
Generator Resistance	50	ohms
"On" DC Collector Current	750	ma
"Turn-On" Base Current (I_{B_1})	65	ma
"Turn-Off" Base Current (I_{B_2})	-35	ma
Switching Time:		
Delay Time (t_d)	0.2	μsec
Rise Time (t_r)	1.0	μsec
Storage Time (t_s)	0.8	μsec
Fall Time (t_f)	1.1	μsec

Typical Characteristics of the 2N1483, 2N1484, 2N1485, and 2N1486 at a Case Temperature of 25°C:

Collector-to-Base Capacitance: C_{ob} (V_{CB} = 40 volts)	175	μμf
Thermal Time Constant, τ_1	10	msec
Alpha-Cutoff Frequency: f_{ab} (V_{CB} = 28 volts, I_C = 5 ma)	1.25	Mc

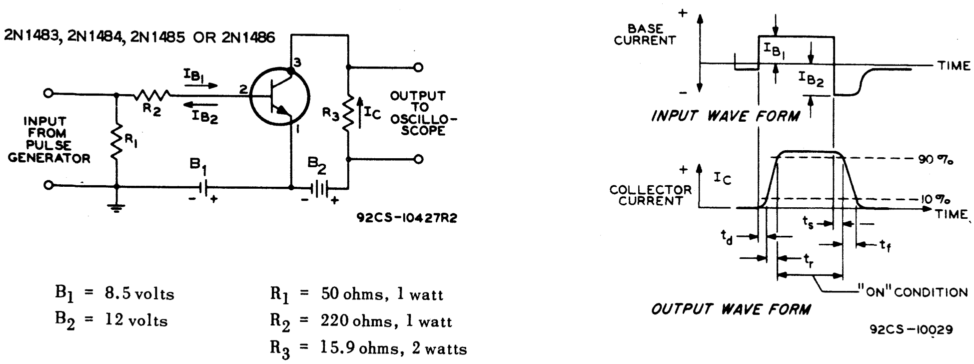


Fig. 2 - Typical Power-Switching Circuit.

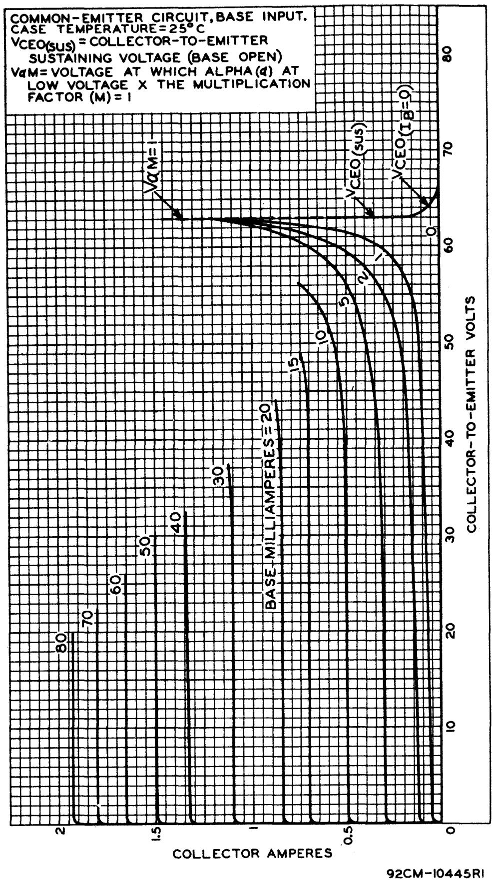


Fig. 3 - Typical Collector Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

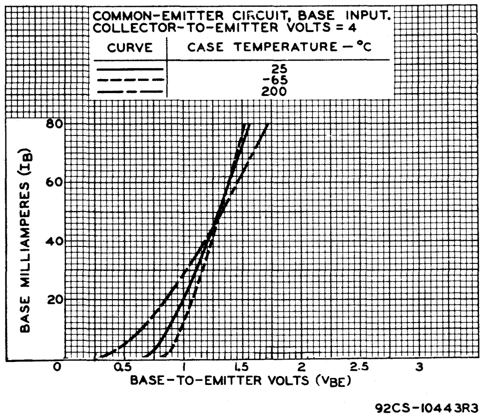


Fig. 4 - Typical Input Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

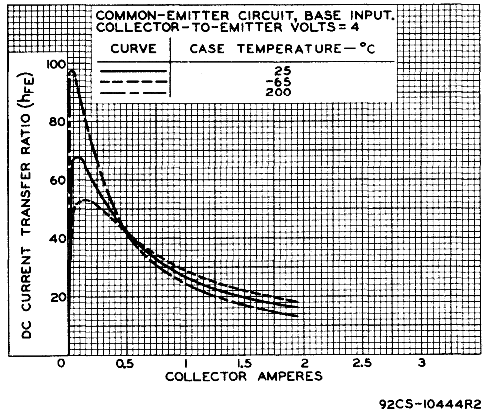


Fig. 5 - Typical Operation Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

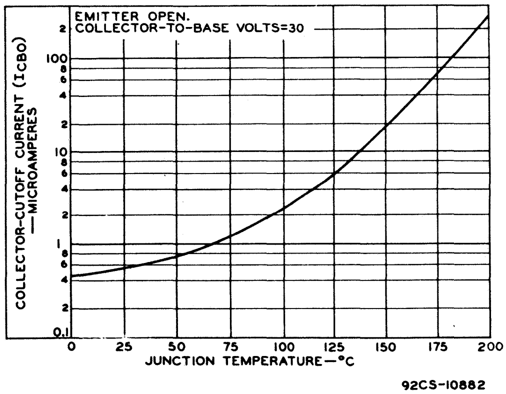


Fig. 6 - Typical Operation Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

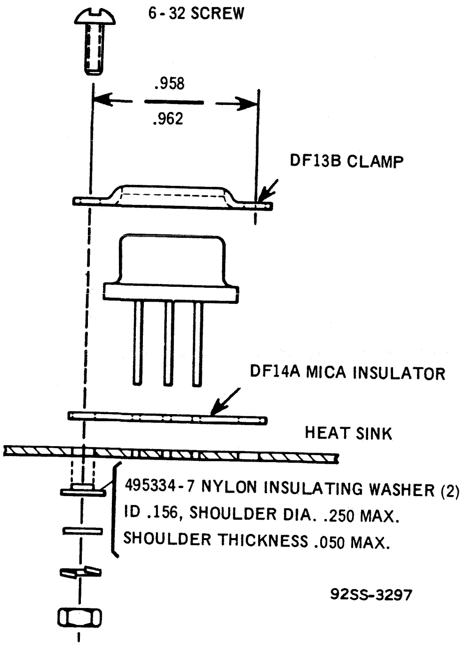
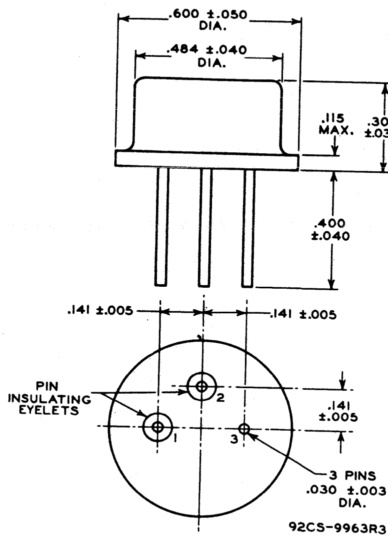


Fig. 7 - Suggested Mounting Arrangement for Types 2N1483, 2N1484, 2N1485, or 2N1486.

DIMENSIONAL OUTLINE
for Types
2N1483, 2N1484, 2N1485, and 2N1486

JEDEC TO-8



TERMINAL CONNECTIONS

Lead No. 1 - Emitter
Lead No. 2 - Base
Lead No. 3 - Collector, Case

RCA

Solid State Division

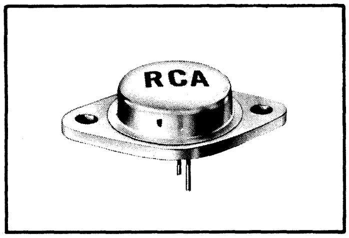
Power Transistors

2N1487 2N1489 2N1488 2N1490

High-Power Types

RCA-2N1487—2N1490 are diffused-junction power transistors of the silicon n-p-n type. These transistors are intended for a wide variety of applications in industrial and military equipment. They are particularly useful in power-switching circuits such as in dc-to-dc converters, inverters, choppers, solenoid and relay controls; in oscillator, regulator, and pulse-amplifier circuits; and as class-A and class-B push-pull audio and servo amplifiers.

These transistors feature high power-dissipation ratings, high beta at high current, and excellent high temperature performance.



JEDEC TO-3

- Maximum dissipation rating of 75 watts at a mounting flange temperature of 25°C
- 2N1489 and 2N1490 have a maximum saturation resistance of 0.67 ohm

Maximum Ratings, *Absolute-Maximum Values:*

	2N1487 2N1489	*2N1488 2N1490*		
COLLECTOR-TO-BASE VOLTAGE	60	100	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open (sustaining voltage)	40	55	max.	volts
With emitter-to-base reverse biased (V_{EB} = 1.5 volts)	60	100	max.	volts
EMITTER-TO-BASE VOLTAGE	10	10	max.	volts
COLLECTOR CURRENT	6	6	max.	amp
EMITTER CURRENT	-8	-8	max.	amp
BASE CURRENT	3	3	max.	amp
TRANSISTOR DISSIPATION:▲ (See Rating Chart Fig. 1):				
At mounting-flange temperature of 25°C	75	75	max.	watts
At mounting-flange temperature of 100°C	43	43	max.	watts
TEMPERATURE RANGE:				
Operating and Storage	-65 to +200			°C

▲For Transistor dissipation in pulse operation refer to RCA Application Note AN-181, "Transistor Dissipation Ratings for Pulse and Switching Service."

ELECTRICAL CHARACTERISTICS

Mounting-flange temperature = 25°C unless otherwise specified.

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (volts) V_{CB}	DC Collector Voltage (volts) V_{CE}	DC Emitter Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Base Current (ma) I_B	LIMITS: Type 2N1487 Min.	Type 2N1487 Max.	Type 2N1488 Min.	Type 2N1488 Max.	Type 2N1489 Min.	Type 2N1489 Max.	Type 2N1490 Min.	Type 2N1490 Max.	Units
Collector-Cutoff Current: With I_E = 0 and at mounting flange temperature of;	I_{CBO}														
25°C		30						25		25		25		25	µa
150°C		30						1000		1000		1000		1000	µa
Emitter-Cutoff Current	I_{EBO}			10	0			25		25		25		25	µa
Collector-To-Emitter Voltage: (Emitter-to-base reverse bias)	V_{CEX}			1.5	0.5		60		100		60		100		volts
(Base open sustaining voltage)	V_{CEO} (sus)				100	0	40		55		40		55		volts
DC Current Transfer Ratio	h_{FE}		4		1.5amps		15	45	15	45	25	75	25	75	
DC Collector-To-Emitter Saturation Resistance	R_S				1.5amps	300		2		2					ohms
					1.5amps	100						0.67		0.67	ohm
Base-To-Emitter Voltage	V_{BE}		4		1.5amps			3.5		3.5		2.5		2.5	volts
Thermal Resistance: Junction-to-mounting flange flange	R_T							2.33		2.33		2.33		2.33	°C/w

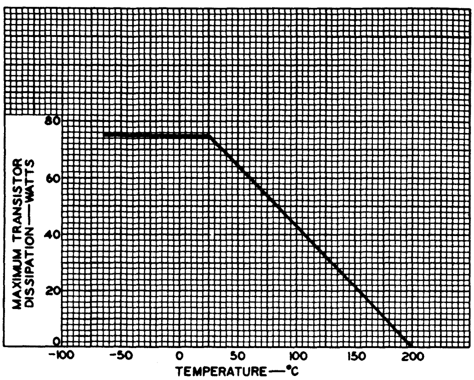


Fig. 1 - Rating Chart for Types 2N1487, 2N1488, 2N1489, and 2N1490.

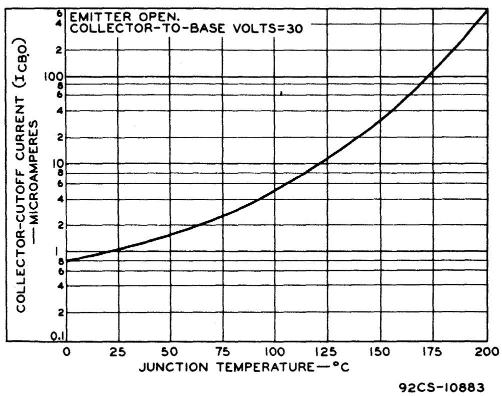


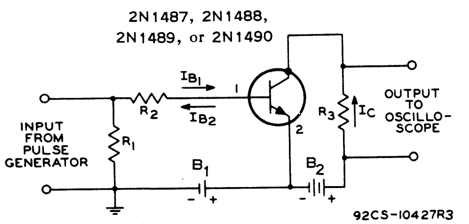
Fig. 2 - Typical Operation Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

Typical Operation of the 2N1487, 2N1488, 2N1489, and 2N1490 in the Power–Switching Circuit of Fig. 3:

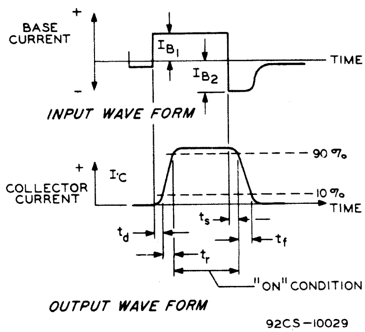
DC Supply Voltage (B_2)	12	volts
DC Base Bias Voltage (B_1)	-8.5	volts
Generator Resistance	50	ohms
"On" DC Collector Current	1.5	amp
"Turn-On" Base Current (I_{B_1})	300	ma
"Turn-Off" Base Current (I_{B_2})	-150	ma
Switching Time:		
Delay Time (t_d)	0.2	μsec
Rise Time (t_r)	1.0	μsec
Storage Time (t_s)	1.0	μsec
Fall Time (t_f)	1.2	μsec

Typical Characteristics of the 2N1487, 2N1488, 2N1489, and 2N1490 at a Mounting-Flange Temperature of 25°C:

Collector-to-base capacitance: C_{ob} (V_{CB} = 40 volts)	200	μμf
Thermal Time Constant, τ_1	12	msec
Alpha-Cutoff Frequency f_{ab} (V_{CB} = 12 volts, I_c = 100 ma)	1	Mc



B_1 = 8.5 volts
B_2 = 12 volts
R_1 = 50 ohms, 1 watt
R_2 = 30 ohms, 1 watt
R_3 = 7.8 ohms, 2 watts



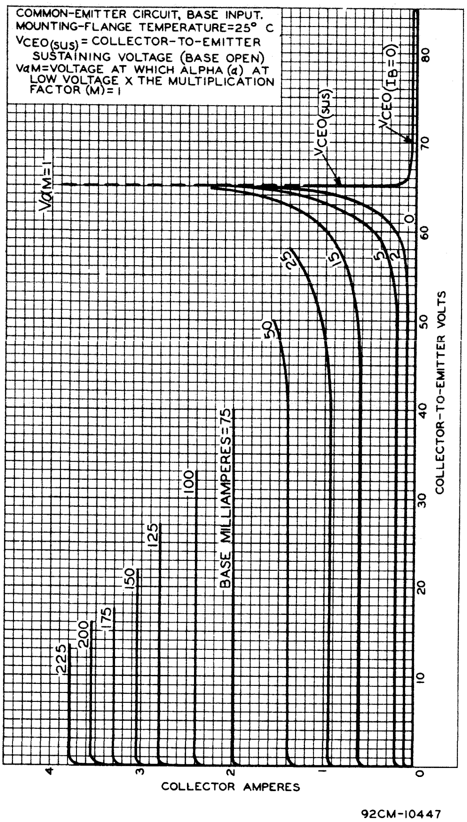


Fig. 4 - Typical Collector Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

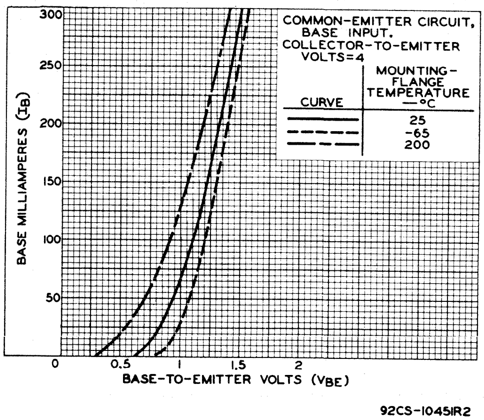


Fig. 5 - Typical Input Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

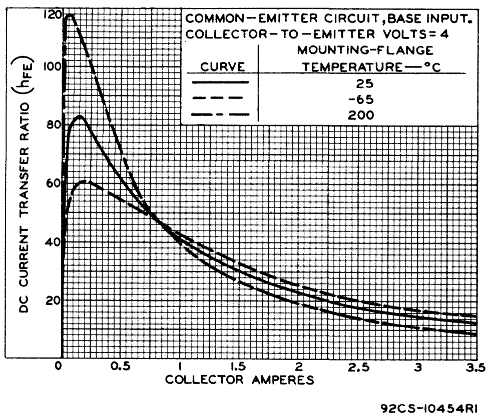
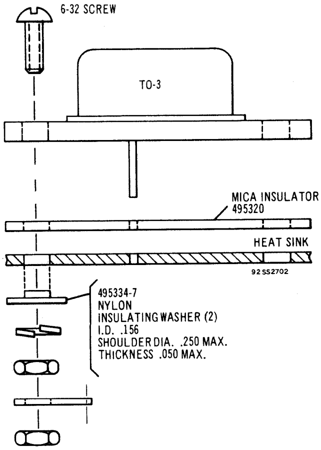


Fig. 6 - Typical Operation Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

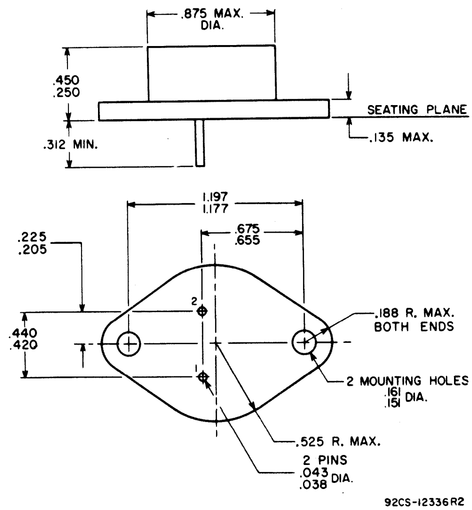


NOTE: Hardware With Part Numbers Supplied.

Fig. 7 - Suggested Mounting Arrangement for Types 2N1487, 2N1488, 2N1489, and 2N1490.

DIMENSIONAL OUTLINE for Types 2N1487, 2N1488, 2N1489, and 2N1490

JEDEC No. TO-3



TERMINAL CONNECTIONS

Pin No. 1 - Base

Pin No. 2 - Emitter

Mounting Flange - Collector, Case

RCA
Solid State
Division

Power Transistors

2N1700 2N1702
2N1701 2N2338

RCA 2N1700, 2N1701, 2N1702, and 2N2338 are diffused-junction silicon power transistors of the n-p-n type intended for a wide variety of applications in industrial equipment. They are particularly useful in dc-to-dc converter, inverter, chopper, voltage-and-current regulator, dc and servo amplifier, and realy-actuating circuits of such equipment.

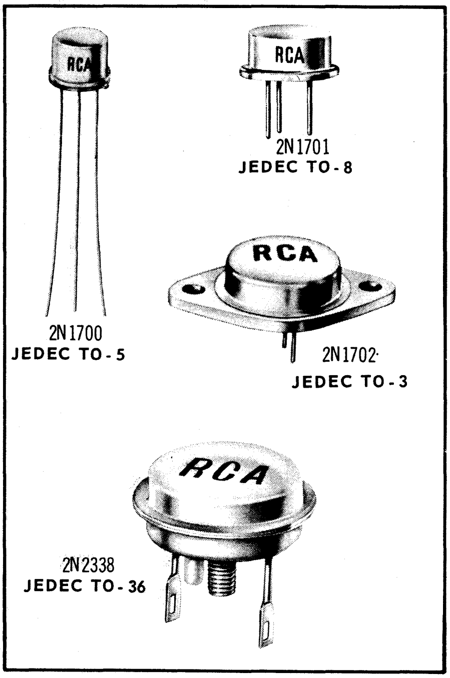
- for operation at high junction temperatures—up to 200° C
- high dissipation ratings—up to 150 watts
- choice of industry-preferred cases

Maximum Ratings, *Absolute-Maximum Values:*

	2N1700	2N1701	2N1702	2N2338	
COLLECTOR-TO-BASE VOLTAGE . .	60	60	60	60	volts
COLLECTOR-TO-EMITTER VOLTAGE:					
With base open (sustaining voltage) . .	40	40	40	40	volts
With emitter-to-base reverse bias (V_{EB} = 1.5 volts). . . .	60	60	60	60	volts
EMITTER-TO-BASE VOLTAGE	6	6	6	6	volts
COLLECTOR CURRENT	1	2.5	5	7.5	amp
BASE CURRENT. . .	0.75	1	2.5	5	amp
TRANSISTOR DISSIPATION:* *(See Rating Charts)*					
At or below 25° C case or mounting-flange temperature . .	5	25	75	150	watts
TEMPERATURE RANGE:					
Storage		-65 to +200			°C
Operating Junction. . .		-65 to +200			°C
LEAD TEMPERATURE:					
1/16" ± 1/32" from case for 10 seconds. . .	255	235	-	-	°C

* For Transistor Dissipation in pulse operation refer to RCA Application Note AN-181, "Transistor Dissipation Ratings for Pulse and Switching Service".

For Industrial Applications



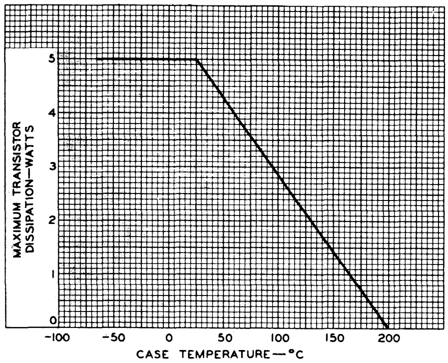


Fig. 1 - Rating Chart for Type 2N1700.

Typical Characteristics:

At a Case and/or Mounting-Flange Temperature of 25° C

	2N1700	2N1701	2N1702	2N2338	
Small-Signal Forward-Current Transfer Ratio: h_{fe} (I_C = 5 ma, V_{CE} = 4 volts).	40	-	-	-	
Collector-to-Base Capacitance: C_{ob} (V_{CB} = 40 volts)	150	175	200	400	pf
Thermal Time Constant: τ_1.	10	10	12	30	msec
Alpha-Cutoff Frequency: f_{ab} (V_{CB} = 28 volts, I_C = 5 ma)	1.2	1	1	-	Mc
Small-Signal Short-Circuit Forward-Current Transfer-Ratio Cutoff Frequency: f_{hfe} (V_{CE} = 4 volts, I_C = 5 amp) . . .	-	-	-	20	Kc

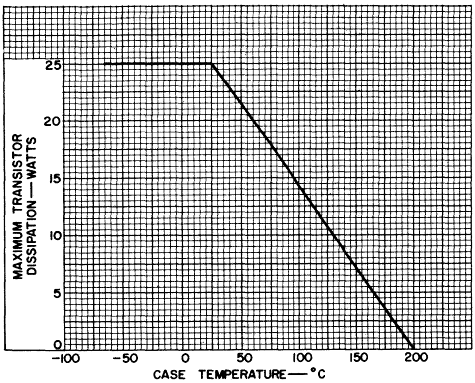


Fig. 2 - Rating Chart for Type 2N1701.

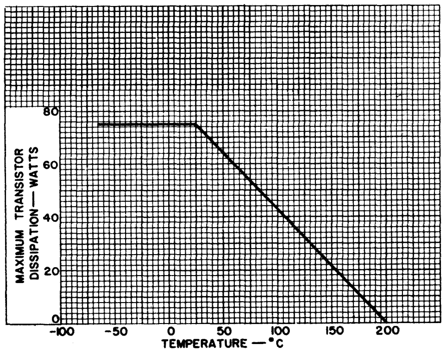


Fig. 3 - Rating Chart for Type 2N1702.

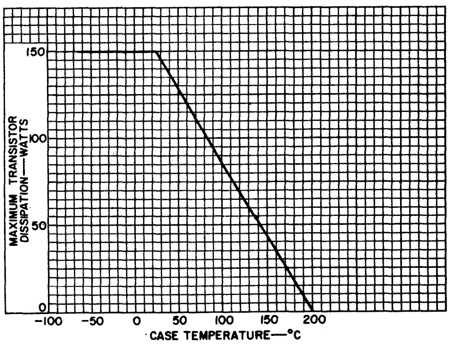


Fig. 4 - Rating Chart for Type 2N2338.

ELECTRICAL CHARACTERISTICS

At case or mounting-flange temperature of 25° C, unless otherwise specified.

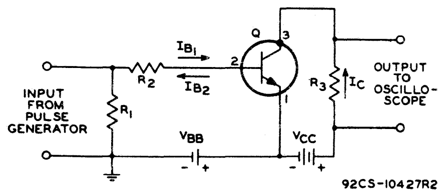
Characteristic	Symbol	TEST CONDITIONS: DC Collector-to-Base Voltage (V_{CB}) volts	DC Collector-to-Emitter Voltage (V_{CE}) volts	DC Emitter-to-Base Voltage (V_{EB}) volts	DC Base Current (I_B) ma	DC Collector Current (I_C) ma	LIMITS: Type 2N1700 Min.	Type 2N1700 Max.	Type 2N1701 Min.	Type 2N1701 Max.	Type 2N1702 Min.	Type 2N1702 Max.	Type 2N2338 Min.	Type 2N2338 Max.	Units
Collector-Cutoff Current: With $I_E = 0$ and at a temperature of;	I_{CBO}														
25° C		30						75		100		200		200	µa
150° C		30						1000		1500		2000		3000	µa
Emitter-Cutoff Current	I_{EBO}			6		0		25		50		100		100	µa
Collector-to-Emitter Voltage with reverse bias between emitter and base	V_{CEX}			1.5		0.5	60								volts
				1.5		0.75			60						volts
				1.5		1					60				volts
				1.5		2							60		volts
Collector-to-Emitter Sustaining Voltage with base open	$V_{CEO(sus)}$				0	50	40								volts
					0	100			40		40				volts
					0	200							40		volts
DC Forward-Current Transfer Ratio	h_{FE}		4			100	20	80							
			4			300			20	80					
			4			800					15	60			
			4			3000							15	60	
DC Collector-to-Emitter Saturation Resistance	R_S				10	100		10							ohms
					30	300				5					ohms
					80	800						4			ohms
					300	3000								0.5	ohm
Base-to-Emitter Voltage	V_{BE}		4			100		2							volts
			4			300				3					volts
			4			800						4			volts
			4			3000								3	volts
Thermal Resistance: Junction-to-case or mounting flange	θ_{J-C}							35		7		2.33		1.17	°C/w
Junction-to-free air	θ_{J-FA}							200		100					°C/w

Typical Operation of Type 2N1700 in the Power-Switching Circuit of Fig.6:

At a Case Temperature of 25° C

Common-Emitter Circuit, Base Input

DC Collector Supply Voltage (V_{CC})	12	volts
DC Base Bias Voltage (V_{BB})	-8.5	volts
Generator Resistance	50	ohms
DC Collector Current ("On" condition)	200	ma
"Turn-On" Base Current (I_{B1})	20	ma
"Turn-Off" Base Current (I_{B2})	-8.5	ma
Switching Time:		
Delay time (t_d)	0.2	µsec
Rise time (t_r)	1	µsec
Storage time (t_s)	0.6	µsec
Fall time (t_f)	1	µsec



R_1 = 50 ohms, 1 watt
R_2 = 700 ohms, 1 watt
R_3 = 59 ohms, 2 watts
Q = Type 2N1700
V_{BB} = 8.5 volts
V_{CC} = 12 volts

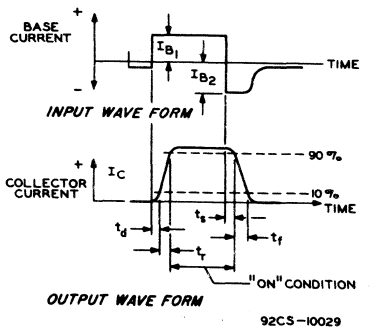


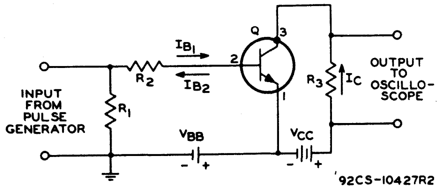
Fig. 5 - Typical Power-Switching Circuit for Type 2N1700.

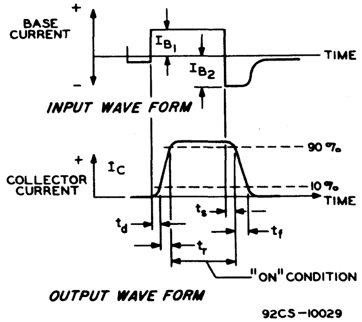
Typical Operation of Type 2N1701 in the Power-Switching Circuit of Fig. 6:

At a Case Temperature[c] of 25° C

Common-Emitter Circuit, Base Input

DC Collector Supply Voltage (V_{CC})	12	volts
DC Base Bias Voltage (V_{BB})	-8.5	volts
Generator Resistance	50	ohms
DC Collector Current ("On" condition)	750	ma
"Turn-On" Base Current (I_{B1})	65	ma
"Turn-Off" Base Current (I_{B2})	-35	ma
Switching Time:		
Delay time (t_d)	0.2	μsec
Rise time (t_r)	1	μsec
Storage time (t_s)	0.8	μsec
Fall time (t_f)	1.1	μsec





Q = Type 2N1701
V_{BB} = 8.5 volts
V_{CC} = 12 volts

R_1 = 50 ohms, 1 watt
R_2 = 220 ohms, 1 watt
R_3 = 15.9 ohms, 2 watts

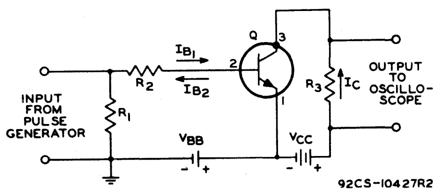
Fig. 6 - Typical Power-Switching Circuit for Type 2N1701.

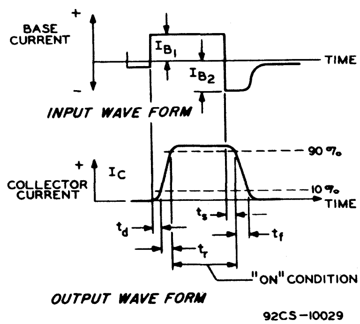
Typical Operation of Types 2N1702 and 2N1703 in the Power-Switching Circuit of Fig. 7:

At a Mounting-Flange and/or Case Temperature of 25° C

Common-Emitter Circuit, Base Input

DC Collector Supply Voltage (V_{CC})	12	volts
DC Base Bias Voltage (V_{BB})	-8.5	volts
Generator Resistance	50	ohms
DC Collector Current ("On" condition)	1.5	amp
"Turn-On" Base Current (I_{B1})	300	ma
"Turn-Off" Base Current (I_{B2})	-150	ma
Switching Time:		
Delay time (t_d)	0.2	μsec
Rise time (t_r)	1	μsec
Storage time (t_s)	1	μsec
Fall time (t_f)	1.2	μsec



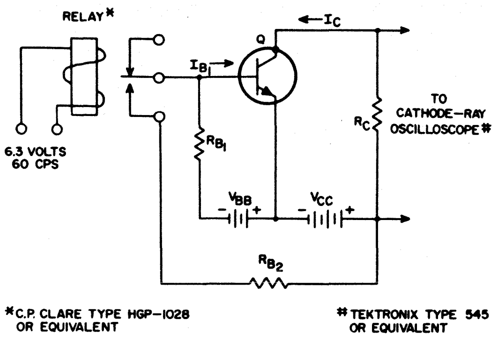


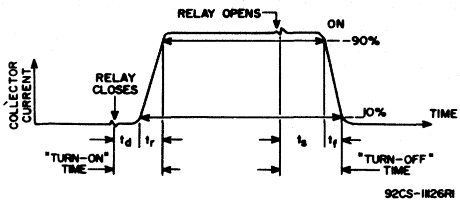
Q = Type 2N1702
V_{BB} = 8.5 volts
V_{CC} = 12 volts

R_1 = 50 ohms, 1 watt
R_2 = 30 ohms, 1 watt
R_3 = 7.8 ohms, 2 watts

[c] Measured at center of seating surface.

Fig. 7 - Typical Power-Switching Circuit for Type 2N1702.





Q = Type 2N2338

DC Collector Supply Voltage (V_{CC})	24	volts
DC Base Bias Voltage (V_{BB})	6	volts
DC Collector Current ("On" condition)	10	amp

"Turn-On" Base Current (I_{B1})	2	amp
Base Circuit Resistance (R_{B1})	10	ohms
Base Circuit Resistance (R_{B2})	10	ohms
Collector Circuit Resistance (R_C)	2	ohms
Switching Time:		
"On" Time		
[Delay time (t_d) + Rise time (t_r)]	4	μsec
"Off" Time		
[Storage time (t_s) + Fall time (t_f)]	7	μsec

Fig. 8 - Pulse-Response Test Circuit for Type 2N2338.

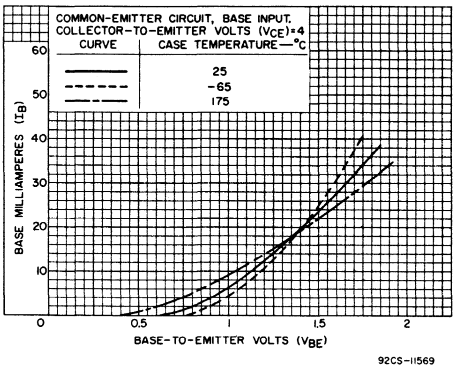


Fig. 9 - Typical Input Characteristics for Type 2N1700.

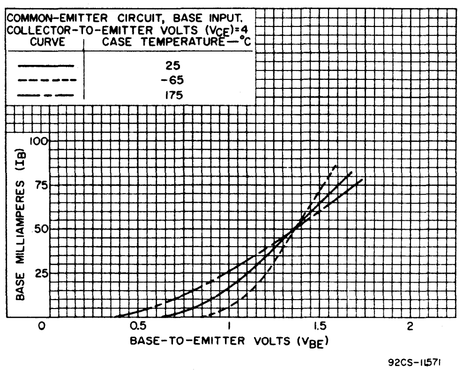


Fig. 10 - Typical Input Characteristics for Type 2N1701.

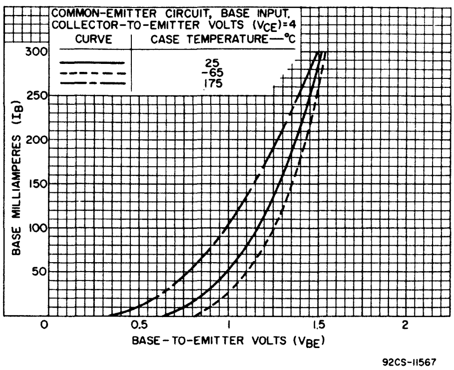


Fig. 11 - Typical Input Characteristics for Type 2N1702.

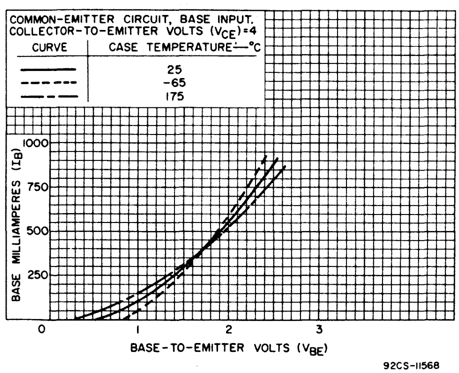


Fig. 12 - Typical Input Characteristics for Type 2N2338.

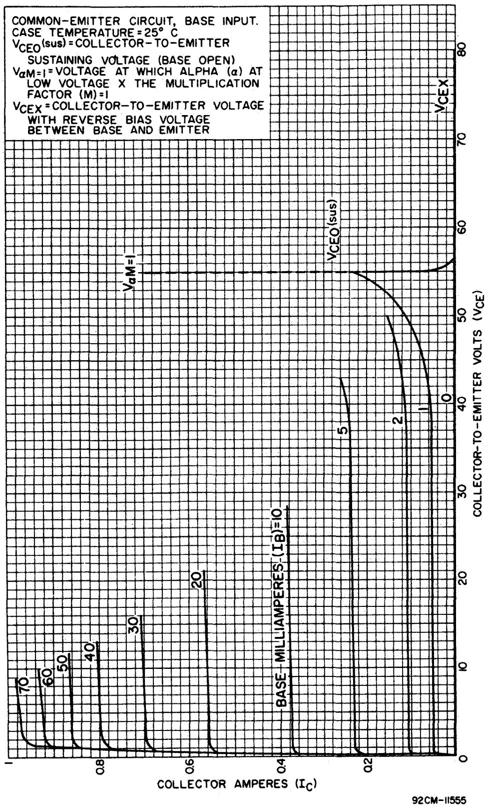


Fig. 13 - Typical Collector Characteristics for Type 2N1700.

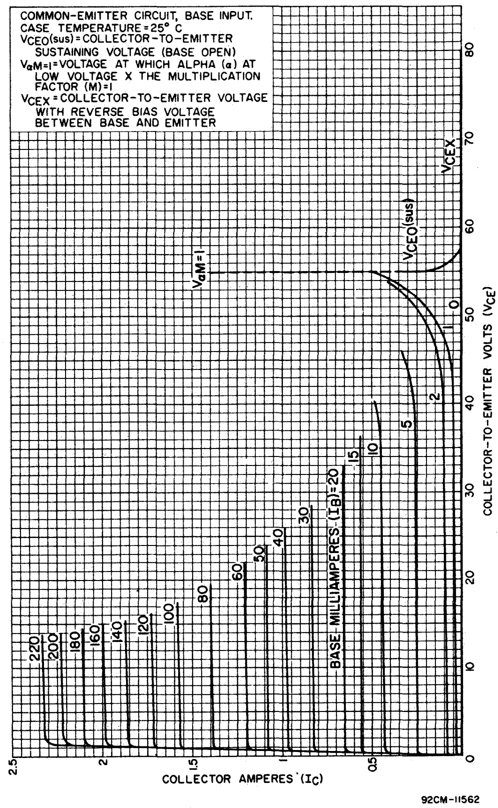


Fig. 14 - Typical Collector Characteristics for Type 2N1701.

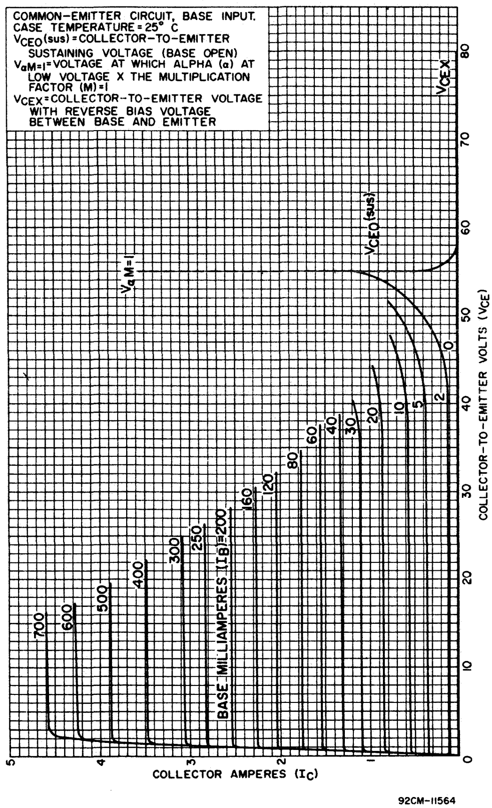


Fig. 15 - Typical Collector Characteristics for Type 2N1702.

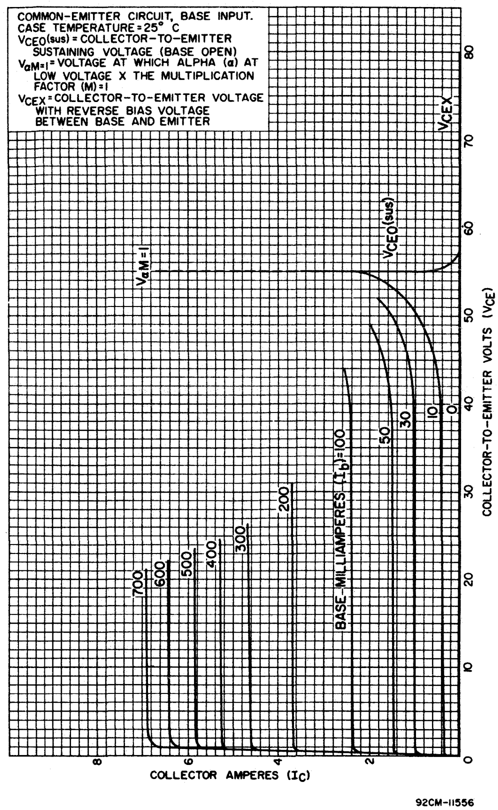


Fig. 16 - Typical Collector Characteristics for Type 2N2338.

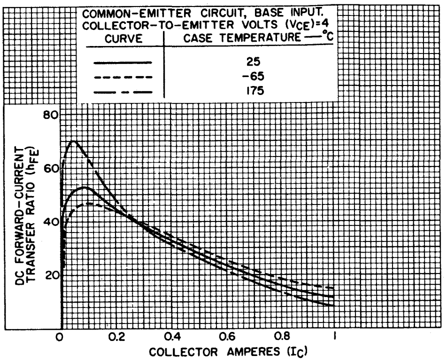


Fig. 17 - Typical Operation Characteristics for Type 2N1700.

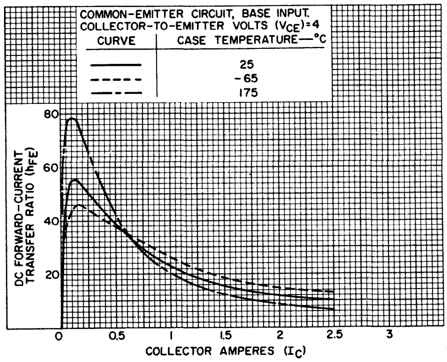


Fig. 18 - Typical Operation Characteristics for Type 2N1701.

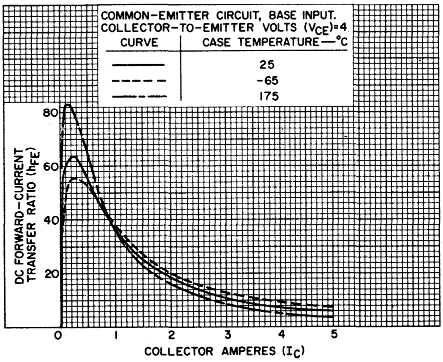


Fig. 19 - Typical Operation Characteristics for Type 2N1702.

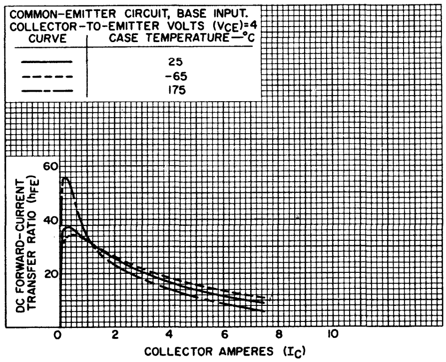


Fig. 20 - Typical Operation Characteristics for Type 2N2338.

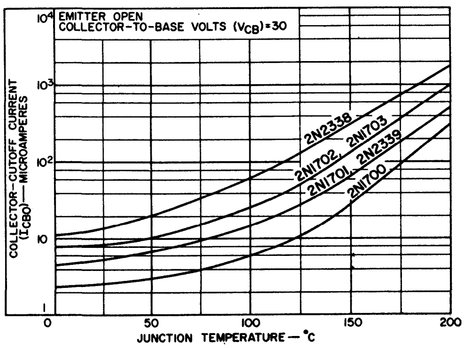
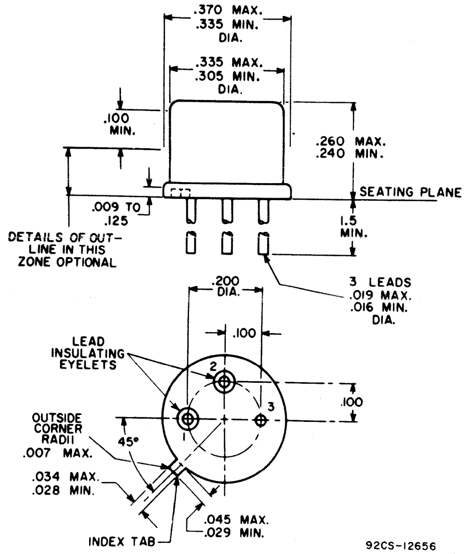


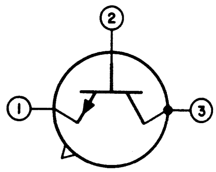
Fig. 21 - Typical Operation Characteristics for Types 2N1700, 2N1701, 2N1702 and 2N2338.

DIMENSIONAL OUTLINE for Type 2N1700

JEDEC No. TO-5



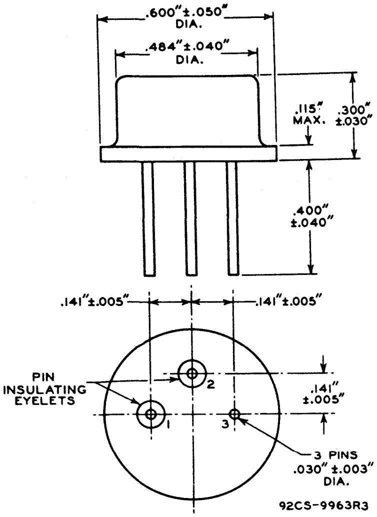
TERMINAL DIAGRAM (Bottom View) for Type 2N1700



LEAD 1 – EMITTER LEAD 3 – COLLECTOR, CASE

LEAD 2 – BASE

DIMENSIONAL OUTLINE for Type 2N1701
JEDEC No. TO-8



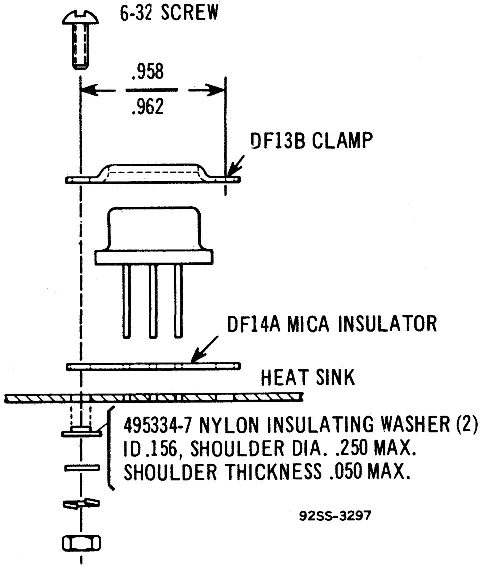
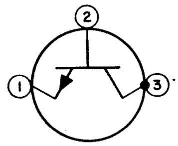


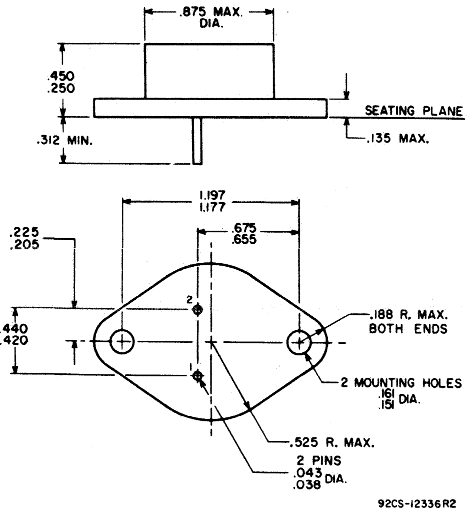
Fig. 22 - Suggested Mounting Arrangement for Type 2N1701.

TERMINAL DIAGRAM (Bottom View) for Type 2N1701



LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

DIMENSIONAL OUTLINE for Type 2N1702



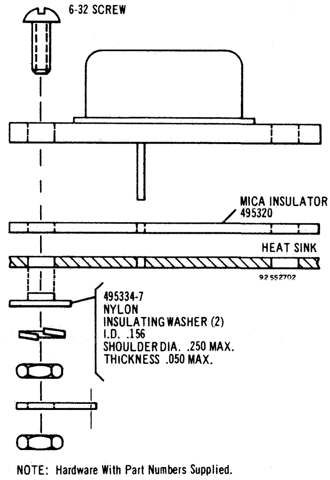
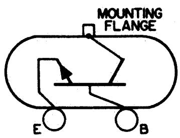


Fig. 23 - Suggested Mounting Arrangement for Type 2N1702.

TERMINAL DIAGRAM (Bottom View) for Type 2N1702

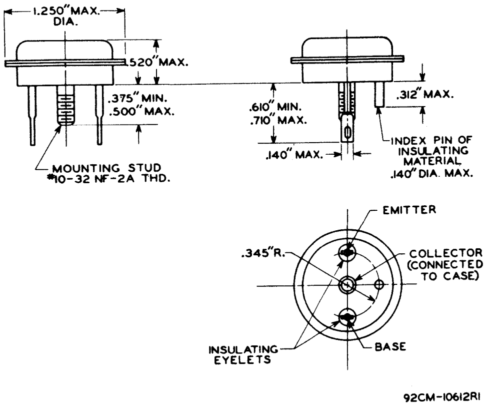


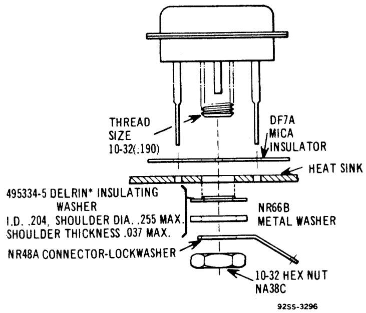
E – EMITTER

B – BASE

MOUNTING FLANGE – COLLECTOR, CASE

DIMENSIONAL OUTLINE
for Type 2N2338
JEDEC No. TO-36

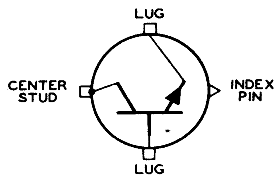




*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

Fig. 24 - Suggested Mounting Arrangement for Type 2N2338.

TERMINAL DIAGRAM (Bottom View)
for Type 2N2338



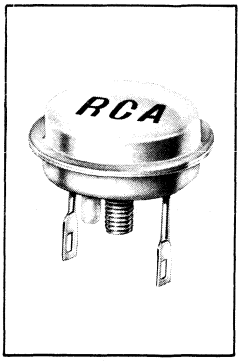
Solid State
Division

Power Transistors

2N2015
2N2016

RCA 2N2015 and 2N2016 are diffused-junction power transistors of the silicon n-p-n type having very high power-dissipation capabilities (150 watts). The 2N2015 and 2N2016 are particularly useful in power-switching circuits such as those employed in dc-to-dc converters, inverters, choppers, and relay-control equipment. They are also extremely useful in oscillator, regulator, and pulse-amplifier circuits, and as class A and class B push-pull amplifiers for af and servo applications.

High-Power Types for Military and Industrial Applications



JEDEC TO-36

- for operation at high junction temperatures – up to 200° C
- very high dissipation rating – 150 watts
- very low thermal resistance, junction-to-case – 1.17° C/Watt
- very low saturation resistance – 0.25 ohm max. at I_C=5 amp, I_B =0.5 amp
- JEDEC TO-36 single-ended stud-type package with cold-weld hermetic seals

Maximum Ratings, *Absolute-Maximum Values:*

	2N2015	*2N2016*		
COLLECTOR-TO-BASE VOLTAGE.	100	130	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open (Sustaining voltage) .	50	65	max.	volts
EMITTER-TO-BASE VOLTAGE. .	10	10	max.	volts
COLLECTOR CURRENT.	10	10	max.	amp
EMITTER CURRENT.	-13	-13	max.	amp
BASE CURRENT	6	6	max.	amp
TRANSISTOR DISSIPATION:*				
At case temperatures up to 25° C.	150	150	max.	watts
At other case temperatures	See *Fig.1*			
TEMPERATURE RANGE:				
Operating and Storage. .	-65 to +200			°C
LEAD TEMPERATURE, 1/16" ± 1/32" from case, for immersion in molten solder for 10 sec. max..	235	235	max.	°C

Typical Characteristics of 2N2015 and 2N2016 at a Case Temperature[c] of 25° C:

Collector-to-Base Capacitance, C_{ob}: (V_{CB} = 40 volts)	400 μμf
Thermal Time Constant, τ_1.	30 msec
Forward Current-Transfer-Ratio Cutoff Frequency, $f_{\alpha e}$.	25 Kc

* For transistor dissipation in pulse operation refer to RCA Application Note AN-181, "Transistor Dissipation Ratings for Pulse and Switching Service".

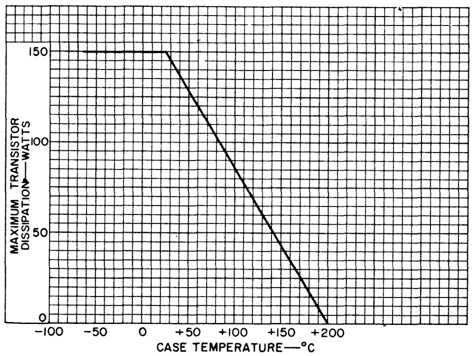
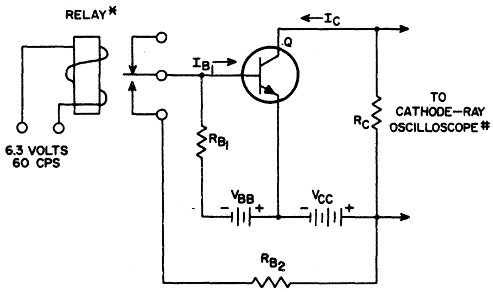


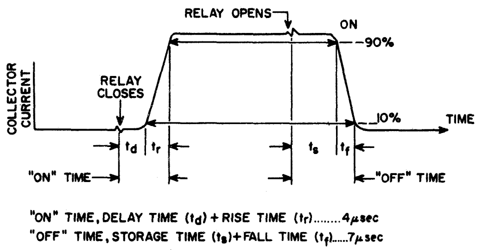
Fig. 1 - Rating Chart for Types 2N2015 and 2N2016.

ELECTRICAL CHARACTERISTICS

Case temperature = 25° C unless otherwise specified.

Characteristic	Symbol	TEST CONDITIONS: DC Collector-to-Base Voltage V_{CB} (Volts)	DC Collector-to-Emitter Voltage V_{CE} (Volts)	DC Emitter-to-Base Voltage V_{EB} (Volts)	DC Collector Current I_C (Amperes)	DC Base Current I_B (Amperes)	LIMITS: Type 2N2015 Min.	Type 2N2015 Max.	Type 2N2016 Min.	Type 2N2016 Max.	Units
Collector-Cutoff Current ($I_E=0$) at case temperature of:	I_{CBO}										
25° C		30					-	50	-	50	μA
150° C		30					-	2	-	2	mA
Emitter-Cutoff Current	I_{EBO}			10			-	50	-	50	μA
DC Forward-Current Transfer Ratio	h_{FE}		4		5		15	50	15	50	
			4		10		7.5	-	7.5	-	
Collector-to-Emitter Saturation Resistance	R_s				5	0.5	-	0.25	-	0.25	ohm
Base-to-Emitter Voltage	V_{BE}		4		5		-	2.2	-	2.2	volts
Collector-to-Emitter Voltage: Sustaining voltage with base open	V_{CEO} (sus)				0.2	0	-	50	-	65	volts
With reverse bias between emitter and base	V_{CEX}			1.5	2 mA		-	100	-	130	volts
Thermal Resistance Junction-to-case	R_T						-	1.17	-	1.17	°C/W





*C.P. CLARE TYPE HGP-1028 OR EQUIVALENT

TEKTRONIX TYPE 545 OR EQUIVALENT

Collector Supply Voltage (V_{CC})	24	volts
DC Base Bias Voltage (V_{BB})	6	volts
"On" DC Collector Current	10	amperes
"Turn-On" Base Current (I_{B1})	2	amperes

Base Resistance (R_{B1})	10	ohms
Base Resistance (R_{B2})	10	ohms
Collector Resistance (R_C)	2	ohms
Switching Time:		
"On" Time [Delay time (t_d) + Rise time (t_r)].	4	μsec
"Off" Time [Storage time (t_s) + Fall time (t_f)].	7	μsec

Fig. 2 - Pulse-Response Test Circuit for Types 2N2015 and 2N2016.

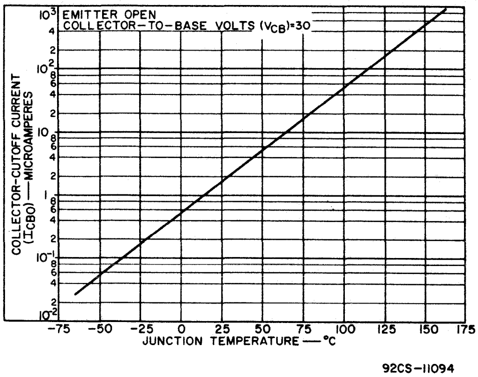


Fig.3 - Typical Operation Characteristic for Types 2N2015 and 2N2016.

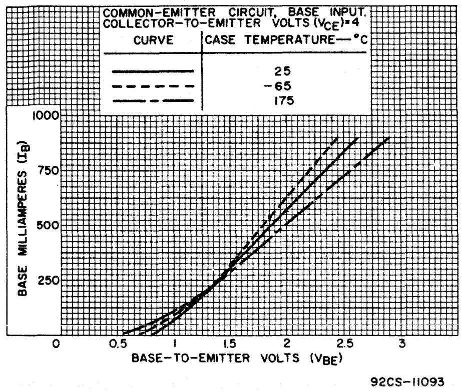


Fig.5 - Typical Input Characteristics for Types 2N2015 and 2N2016.

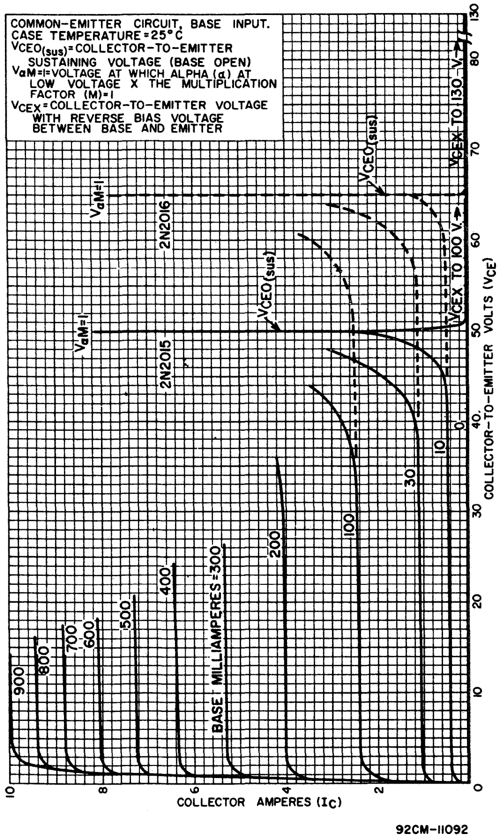


Fig.4 - Typical Collector Characteristics for Types 2N2015 and 2N2016.

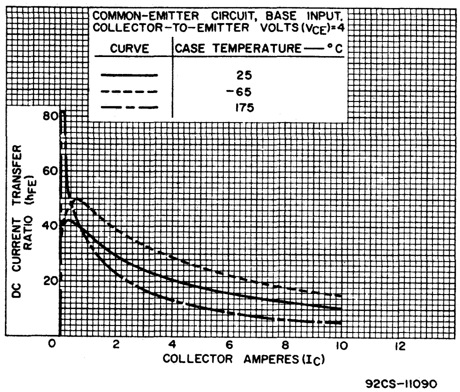


Fig.6 - Typical Operation Characteristics for Types 2N2015 and 2N2016.

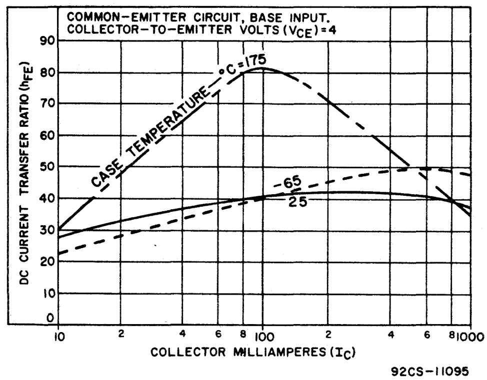


Fig.7 - Typical Operation Characteristics for Types 2N2015 and 2N2016.

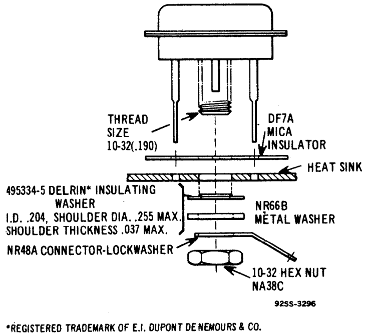
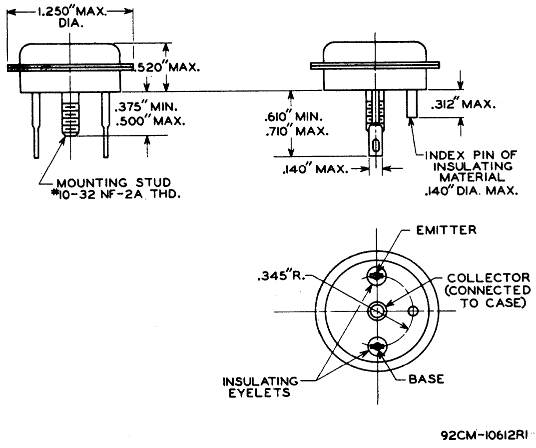


Fig. 8 – Suggested Mounting Arrangement for Types 2N2015 and 2N2016.

DIMENSIONAL OUTLINE for Types 2N2015 and 2N2016

JEDEC No. TO-36



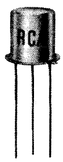
RCA
Solid State
Division

Power Transistors

40084

Silicon N-P-N Planar Transistor

General-Purpose Type for Small-Signal
and Medium-Power Applications



JEDEC TO-18

H-1311

Features:

- **Min. gain-bandwidth product = 100 MHz; useful in applications from dc to 20 MHz**
- **Operation at high junction temperatures**
- **Low-noise and low-leakage characteristics**
- **High non-saturated switching speed — 30 ns max.**
- **Very low output capacitance — 15 pF max.**

RCA-40084 is a general-purpose silicon n-p-n planar transistor intended for a wide variety of small-signal and medium-power applications in industrial equipment. It features low noise and leakage characteristics, high switching speed (non-saturating mode), high pulse beta, and very low output capacitance.

The 40084 employs the JEDEC TO-18 hermetic package.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	V
COLLECTOR-TO-EMITTER VOLTAGE			
With external base-to-emitter resistance (R_{BE}) $\leq$10 Ω	V_{CER}	50	V
With base open	V_{CEO}	40	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	V
COLLECTOR CURRENT	I_C	1	A
TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 25°C		1.8	W
At case temperatures above 25°C		See Fig. 1	
At free-air temperatures up to 25°C		0.5	W
At free-air temperatures above 25°C		See Fig. 1	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
CASE TEMPERATURE (During soldering):			
At distances $\geq$ 1/32 in. (0.8 mm) from seating surface for 10 seconds max.		225	°C

ELECTRICAL CHARACTERISTICS

At Case Temperature (T_C) of 25° C

Characteristic	Symbol	TEST CONDITIONS: DC Collector-to-Base Voltage V_{CB} (volts)	DC Collector-to-Emitter Voltage V_{CE} (volts)	DC Emitter-to-Base Voltage V_{EB} (volts)	DC Collector Current I_C (ma)	DC Emitter Current I_E (ma)	DC Base Current I_B (ma)	LIMITS: RCA 40084 Min.	Max.	Units
Collector-Cutoff Current	I_{CBO}	30				0		-	0.25	µa
Emitter-Cutoff Current	I_{EBO}			4	0			-	0.25	µa
DC Forward-Current Transfer Ratio	h_{FE}		10		150**			50	250	
Collector-to-Base Breakdown Voltage	BV_{CBO}				0.1			60	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0.1		5	-	volts
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$				100**			40	-	volts
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance (R_{BE}) = 10 ohms	$V_{CER}(sus)$				100**			50	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				150**		15	-	1.4	volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				150**		15	-	1.7	volts
Small-Signal Forward-Current Transfer Ratio: At frequency of 20 Mc	h_{fe}		10		50			5	-	
Noise Figure: Generator resistance (R_G) = 500 ohms, circuit band-width (BW) = 15 Kc, input frequency (f) = 1 Kc	NF		10		0.3			-	8	db
Output Capacitance	C_{ob}	10				0		-	15	pf
Input Capacitance	C_{ib}			0.5	0			-	80	pf
Thermal Resistance: Junction-to-case Junction-to-free air	$\theta_{J\text{-}C}$ $\theta_{J\text{-}FA}$							- -	97 350	°C/W °C/W

** Pulse Test: Pulse duration, 300 µsec; duty factor, 1.8%.

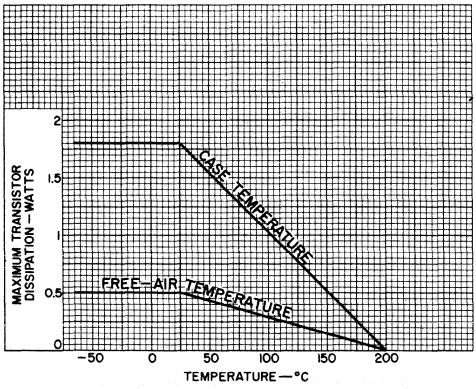


Fig.1— Rating chart.

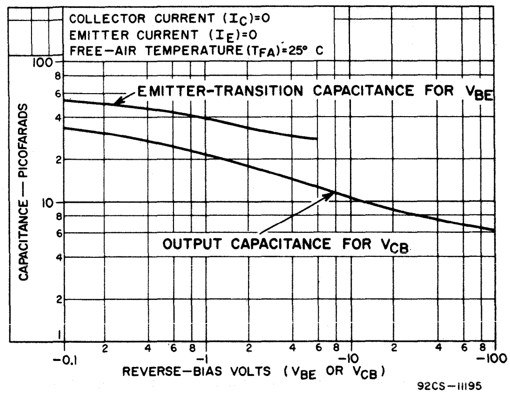


Fig.2— Typical emitter-transition-capacitance and output-capacitance characteristics.

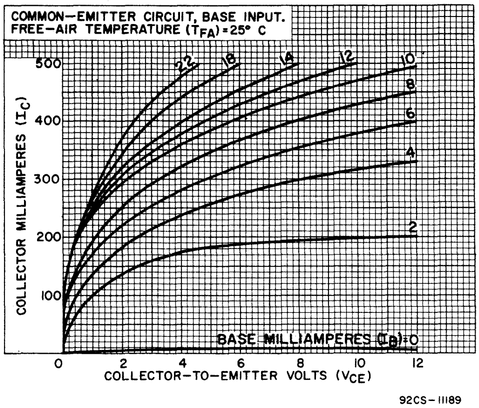


Fig.3— Typical collector characteristics at 25°C.

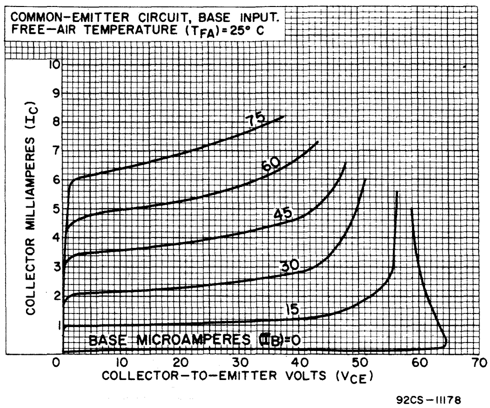


Fig.4— Typical collector characteristics at 25°C.

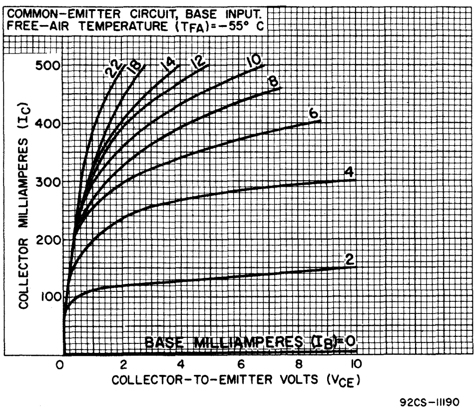


Fig.5— Typical collector characteristics at -55°C.

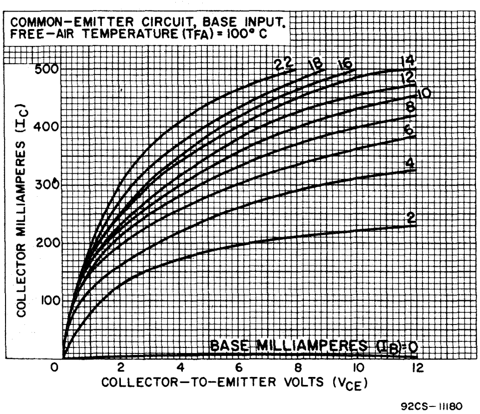
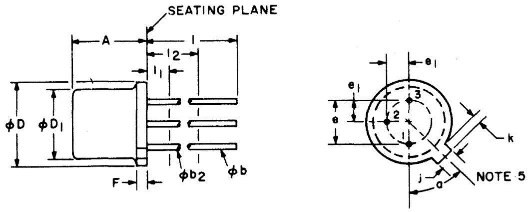


Fig.6— Typical collector characteristics at 100°C.

DIMENSIONAL OUTLINE
JEDEC TO-18



92CS-20223

SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.170	0.210	4.32	5.33	
φb	0.016	0.021	0.406	0.533	1
φb2	0.016	0.019	0.406	0.483	1
φD	0.209	0.230	5.31	5.84	
φD1	0.178	0.195	4.52	4.95	
e	0.100 T.P.		2.54 T.P.		2, 4
e1	0.050 T.P.		1.27 T.P.		2, 4
F		0.030		0.762	
j	0.036	0.046	0.914	1.17	4
k	0.028	0.048	0.711	1.22	3
l	0.500		12.70		1
l1		0.050		1.27	1
l2	0.250		6.35		1
α	45° T.P.				5

NOTES:

1. (Three leads) ϕb_2 applies between l_1 and l_2. ϕb applies between l_2 and 0.5 in. (12.70 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 0.5 in. (12.70 mm) from seating plane.
2. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.025 mm) − 0.00 in. (0.00 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to a maximum-width tab.
3. Measured from maximum diameter of the actual device.
4. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-2.
5. Tab centerline.

TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Case, Lead 3 – Collector

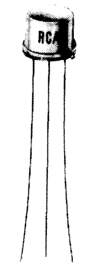
Special Audio Power Transistors

RCA
Solid State
Division

Power Transistors

40309—40328
40360—40364

B

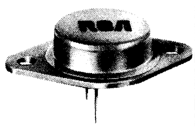


JEDEC TO-5
H-1380

C

JEDEC TO-66
H-1340

A



JEDEC TO-3
H-1570

N-P-N and P-N-P Silicon Power Transistors

For Audio-Frequency Amplifier Applications

Features:

- **JEDEC TO-3, TO-5, and TO-66 hermetically-sealed packages**
- **Operation at case temperatures up to 257°F**
- **Freedom from second breakdown in operating region**
- **Pellet bonded to header**
  - **- for greater power-handling capability**
  - **- for greater shock resistance**

RCA transistors 40309—40328 and 40360—40364 are diffused-junction silicon n-p-n and p-n-p transistors intended for specific applications in audio amplifiers, giving high-quality performance economically. These types cover applications from low-level input stages to high-power output stages of 5 to 50 watts. Supply voltages range from the nominal 12-volt vehicular type to 117-volt ac-dc type.

The use of all-silicon devices permits more flexibility in the mechanical and electrical design of amplifiers since the output heat sinks can be held to a minimum.

40325
40363

JEDEC TO-3 PACKAGE
See page 2 for electrical characteristics

40309 40319 40327
40311 40320 40360
40314 40321 40361
40315 40323 40362
40317 40326

JEDEC TO-5 PACKAGE
See page 3 for electrical characteristics

40310 40322
40312 40324
40313 40328
40316 40364
40318

JEDEC TO-66 PACKAGE
See page 4 for electrical characteristics

MAXIMUM RATINGS (Absolute-Maximum Values)

CHARACTERISTIC	40325	40363	40309	40323	40311	40315	40314	40317	40319	40320	40326	40321	40327	40360	40361	40362	40310	40324	40316	40312	40313	40318	40322	40328	40364	UNITS
V_{CEO}(sus)	35	–	18	18	30	35	40	40	-40	40	40	–	–	70	–	–	35	35	–	–	–	–	–	–	–	V
V_{CER}(sus)*	–	70	–	–	–	–	–	–	–	–	–	300	300	–	70	-70	–	–	40	60	300	300	300	300	60	V
V_{CEV}**	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	V
V_{EBO}	5	4	2.5	2.5	2.5	2.5	2.5	2.5	-2.5	2.5	2.5	5	5	4	4	-4	2.5	2.5	5	2.5	2.5	6	6	6	4	V
V_{CBO}	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	V
I_C	15	15	0.7	0.7	0.7	0.7	0.7	0.7	-0.7	0.7	0.7	1	1	0.7	0.7	-0.7	4	4	4	4	2	2	2	2	7	A
I_B	7	7	0.2	0.2	0.2	0.2	0.2	0.2	-0.2	0.2	0.2	0.5	0.5	0.2	0.2	-0.2	2	2	2	2	1	1	1	1	5	A
P_T***																										
T_C up to 25°C	117	115	5	5	5	5	5	5	5	5	5	5	5	5	5	5	29	29	29	29	35	35	35	35	35	W
T_{FA} up to 25°C	–	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	–	–	–	–	–	–	–	W
T_C of 175°C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	5	5	5	–	W
TEMP. RANGE: Oper. Junction	← -65 to 200°C →																									°C

*R_{BE} = 500 Ω
R_{BE} = 1,000 Ω for 40327
R_{BE} = 200 Ω for 40361, 40362, & 40363
R_{BE} = 150 Ω for 40364

**V_{BE} = -1.5V

*** At other temperatures see derating curves

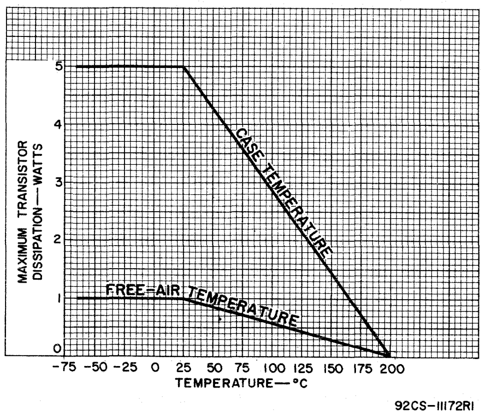


Fig. 1—Dissipation Rating Curves For Types 4309, 40311, 40314, 40315, 40317, 40319, 40320, 40323, 40326, 40360, 40361, and 40362

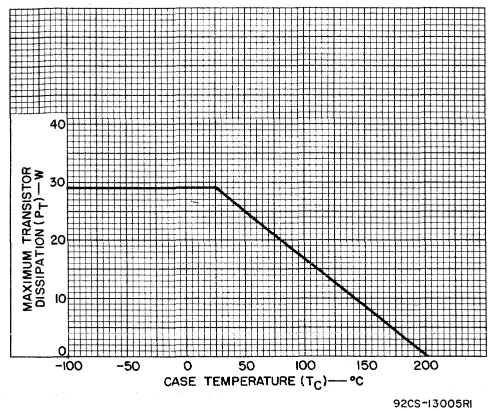


Fig. 2—Dissipation Derating Curve For Types 40310, 40312, 40316, and 40324

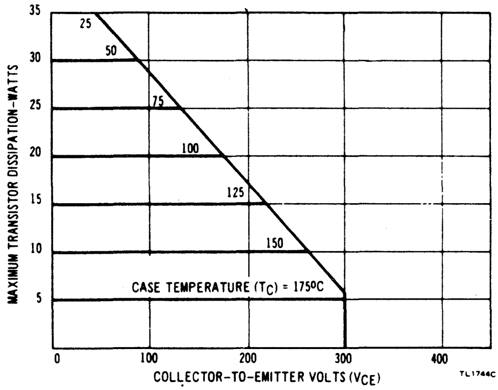


Fig. 3—Dissipation Derating Curve For Type 40313

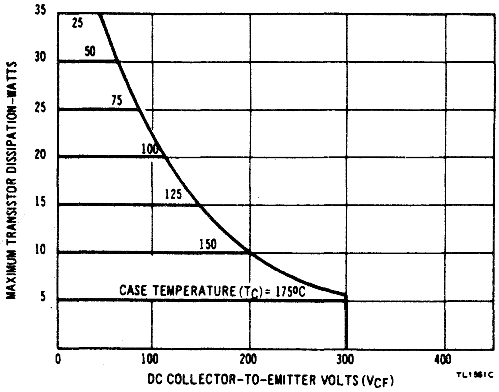


Fig. 4—Dissipation Derating Curve For Types 40318, 40322, and 40328

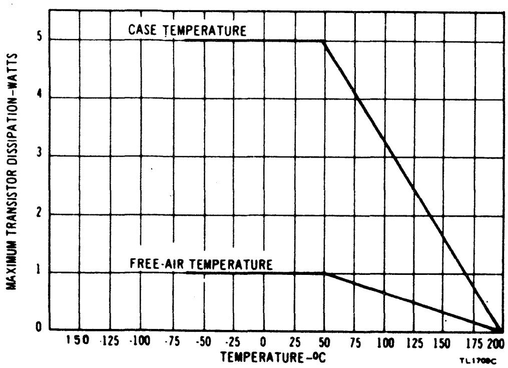


Fig. 5—Dissipation Derating Curves For Types 40321 and 40327

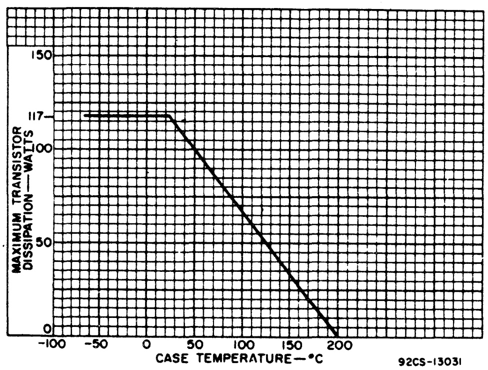


Fig. 6—Dissipation Derating Curve For Type 40325

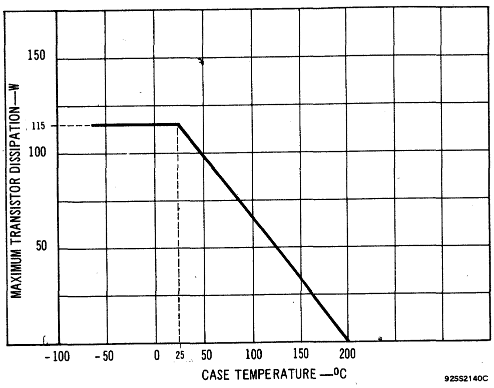


Fig. 7—Dissipation Derating Curve For Type 40363

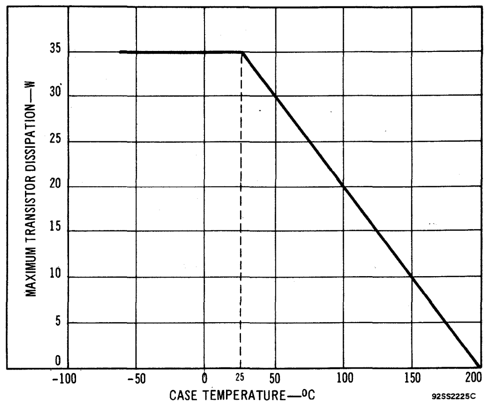


Fig. 8—Dissipation Derating Curve For Type 40364

ELECTRICAL CHARACTERISTICS *For RCA-40325 and 40363*

CHARACTERISTIC	TEST CONDITIONS					LIMITS	
	V_{CB}	V_{CE}	V_{EB}	I_C	T_C	40325	40363
	Volts			mA	°C		
I_{CBO}	30				25	5 mA (Max.)	
	30				150	10 mA (Max.)	
I_{CER}▲		60			25		1 mA (Max.)
		60			150		10 mA (Max.)
I_{EBO}			5			10 mA (Max.)	
			4				5 mA (Max.)
BV_{CEO} (sus)				200		35 V (Min.)	
V_{CER} (sus)▲				200			70 V (Min.)
BV_{CBO}				100		35 V (Min.)	
V_{BE}		4		8 A		2 V (Max.)	
		4		4 A			1.8 V (Max.)
V_{CE} (sat)				8 A*		1.5 V (Max.)	
				4 A**			1.1 V (Max.)
h_{FE}		4		8 A		12-60	
		4		4 A			20-70
θ_{J-C}						1.5°C/W (Max.)	1.5°C/W (Max.)
f_T		4		3 A			700 kc/s (Typ.)

*I_B = 800 mA   **I_B = 400 mA   ▲R_{BE} = 200 Ω

ELECTRICAL CHARACTERISTICS *For RCA—40309, 40311, 40314, 40315, 40317, 40319, 40320, 40321, 40323, 40326, 40327, 40360, 60361, and 40362*

CHARACTERISTIC	TEST CONDITIONS V_{CB} (Volts)	V_{CE} (Volts)	V_{EB} (Volts)	I_C (mA)	T_C (°C)	LIMITS 40309	40311	40314	40315	40317	40319	40320	40321	40323	40326	40327	40360	40361	40362
I_{CEO}		60			25												1 µA (Max.)		
		60			150												250 µA (Max.)		
I_{CBO}	15				25	0.25 µA (Max.)	0.25 µA (Max.)	0.25 µA (Max.)	0.25 µA (Max.)	0.25 µA (Max.)		0.25 µA (Max.)		0.25 µA (Max.)	0.25 µA (Max.)				
	-15				25						-0.25 µA (Max.)								
	15				150	1 mA (Max.)	1 mA (Max.)	1 mA (Max.)	1 mA (Max.)	1 mA (Max.)		1 mA (Max.)		1 mA (Max.)	1 mA (Max.)				
	-15				150						-1 mA (Max.)								
	150				150								100 µA (Max.)			100 µA (Max.)			
I_{CER}■		150											5 µA (Max.)			5 µA (Max.)			
		60†			25													1 µA (Max.)	-1 µA (Max.)
		60†			150													100 µA (Max.)	-100 µA (Max.)
I_{EBO}			2.5			1 mA (Max.)	1 mA (Max.)	1 mA (Max.)	1 mA (Max.)	1 mA (Max.)		1 mA (Max.)		1 mA (Max.)	1 mA (Max.)				
			-2.5								-1 mA (Max.)								
			5										100 µA (Max.)			100 µA (Max.)			
			4†														1 mA (Max.)	1 mA (Max.)	-1 mA (Max.)
V_{CEO} (sus)				100*		18 V• (Min.)	30 V (Min.)	40 V (Min.)	35 V• (Min.)	40 V (Min.)		40 V (Min.)		18 V• (Min.)	40 V (Min.)		70 V (Min.)		
				-100*							-40 V♦ (Min.)								
V_{BE}		4		50		1 V (Max.)	1 V (Max.)	1 V (Max.)	1 V (Max.)					1 V (Max.)				1 V (Max.)	
		4		10						1 V (Max.)		1 V (Max.)			1 V (Max.)		1 V (Max.)		
		-4		-50							-1.0 V (Max.)								-1 V (Max.)
		10		50									2 V (Max.)			2 V (Max.)			
V_{CE} (sat)				150♦				1.4 V (Max.)			-1.4 V (Max.)						1.4V (Max.)	1.4V (Max.)	-1.4V (Max.)
V_{CER} (sus)■				50									300 V (Min.)			300 V (Min.)			
				100														70 V (Min.)	-70 V (Min.)
h_{FE}		4		50		70-350	70-350	70-350	70-350					70-350				70-350	
		-4		-50							35-200								35-200
		4		10						40-200		40-200			40-200		40-200		
		10		20									25-200			40-250			
$\theta_{J\text{-}C}$						35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	30°C/W (Max.)	35°C/W (Max.)	30°C/W (Max.)	30°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)	35°C/W (Max.)
$\theta_{J\text{-}FA}$						175°C/W (Max.)	175°C/W (Max.)	175°C/W (Max.)	175°C/W (Max.)	175°C/W (Max.)	175°C/W (Max.)			175°C/W (Max.)			175°C/W (Max.)	175°C/W (Max.)	175°C/W (Max.)
f_T		10		50		100 Mc/s (Typ.)	100 Mc/s (Typ.)		100 Mc/s (Typ.)					100 Mc/s (Typ.)					
		-4		-50							100 Mc/s (Typ.)								100 Mc/s (Typ.)
		4		50				100 Mc/s (Typ.)									100 Mc/s (Typ.)	100 Mc/s (Typ.)	

* Pulsed; pulse duration = 300 µsec, duty factor ≤ 2%

♦ I_B = 15 mA

■ R_{BE} = 1,000 ohms

• BV_{CEO} value

R_{BE} = 200 Ω for 40361 & 40362

† Negative value for 40362

ELECTRICAL CHARACTERISTICS *For RCA–40310, 40312, 40313, 40316, 40318, 40322, 40324, 40328, and 40364*

CHARACTERISTIC	CONDITIONS V_{CB} (Volts)	V_{CE} (Volts)	V_{EB} (Volts)	I_C	T_C (°C)	LIMITS 40310	40312	40313	40316	40318	40322	40324	40328	40364
I_{CEO}		150						5 mA (Max.)		5 mA (Max.)			5 mA (Max.)	
I_{CEV}		300	1.5⊞		25			10 mA (Max.)						
		300	1.5⊞		150			10 mA (Max.)						
		150	1.5⊞		150					10 mA (Max.)			10 mA (Max.)	
		150	1.5⊞		25					5 mA (Max.)			10 mA (Max.)	
I_{CER}▲		50			25									0.5 mA (Max.)
		50			150									2 mA (Max.)
I_{CBO}	15				25	10 μA (Max.)	10 μA (Max.)		10 μA			10 μA (Max.)		
	15				150	5 mA (Max.)	5 mA (Max.)		5 mA (Max.)			5 mA (Max.)		
I_{EBO}			2.5			5 mA (Max.)	5 mA (Max.)	5 mA (Max.)				5 mA (Max.)		
			5						5 mA (Max.)					
			6							5 mA (Max.)	5 mA (Max.)		5 mA (Max.)	
			4											5 mA (Max.)
V_{CEO}(sus)				100• mA		35 V● (Min.)						35 V● (Min.)		
V_{BE}		2		1 A		1.4 V (Max.)	1.4 V (Max.)		1.4 V (Max.)			1.4 V (Max.)		
		10		100 mA				1.5 V (Max.)						
		10		500 mA						1.5 V (Max.)				
		10		1 A									1.5 V (Max.)	
		5		2.5 A										1.8 V (Max.)
V_{CE}(sat)				2.5 A										2 V□ (Max.)
V_{CER}(sus)				100• mA			60 V (Min.)		40 V (Min.)					
				200 mA				300 V◆ (Min.)		300 V◆ (Min.)	300 V◆ (Min.)		300 V◆ (Min.)	70 V▲ (Min.)
h_{FE}		2		1 A		20-120	20-120		20-120			20-120		
		5		0.5 A										35-175
		5		2.5 A										20 (Min.)
		10		100 mA				40-250						
		10		500 mA				40 (Min.)		50 (Min.)	75 (Min.)			
		10		20 mA						40 (Min.)	40 (Min.)		40 (Min.)	
		10		1 A									20 (Min.)	
f_T		4		500 mA		750 kc/s (Typ.)	750 kc/s (Typ.)		750 kc/s (Typ.)			750 kc/s (Typ.)		
		10		2.5 A										15 Mc/s (Typ.)
$I_{S/b}$#		150						150 mA (Min.)		100 mA# (Min.)	100 mA (Min.)		100 mA (Min.)	
		40												750 mA (Min.)
$E_{S/b}$■			4							50 μJ (Min.)	50 μJ (Min.)			
$\theta_{J\text{-}C}$						6°C/W (Max.)	6°C/W (Max.)	5°C/W (Max.)	6°C/W (Max.)	5°C/W (Max.)	5°C/W (Max.)	6°C/W (Max.)	5°C/W (Max.)	5°C/W (Max.)

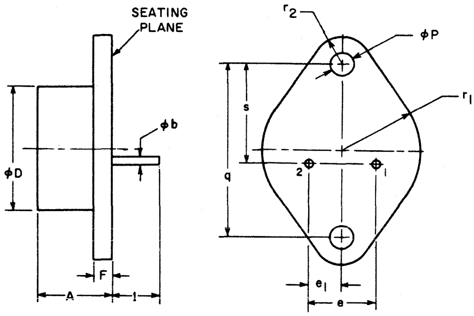
• Pulsed; Pulse duration = 300 μsec, duty factor < 2%. ⊞ R_{BE} value ◆ R_{BE} = 200 Ω, L = 5 mH

$I_{S/b}$ is defined as the current at which second breakdown occurs at a specified collector voltage with the emitter-base junction forward biased

■ $E_{S/b}$ is defined as the energy at which second breakdown occurs under specified reverse bias conditions. $E_{S/b} = \frac{1}{2}LI^2$, where L is a series load or leakage inductance and I is the peak collector current. R_{BE} = 20 ohms & L = 100 μh.

▲ R_{BE} = 150 Ω □ I_B = 0.25 A ● BV_{CEO} value.

DIMENSIONAL OUTLINE JEDEC TO-3 (A)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.450	6.35	11.43	
ϕb	0.038	0.043	0.97	1.09	2
ϕD		0.875		22.23	
e	0.420	0.440	10.67	11.18	
e_1	0.205	0.225	5.21	5.72	
F		0.135		3.43	
l	0.312		7.92		2
ϕP	0.151	0.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		0.525		13.34	
r_2		0.188		4.78	
s	0.655	0.675	16.64	17.15	1

NOTES:

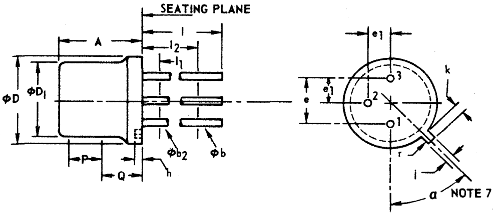
1. These dimensions should be measured at points 0.050 in. (1.27 mm) to 0.055 in. (1.40 mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two pins.

92CS–15222

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Case — Collector
Mounting Flange — Collector

DIMENSIONAL OUTLINE JEDEC TO-5 (B)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
ϕb	0.016	0.021	0.406	0.533	2
ϕb_2	0.016	0.019	0.406	0.483	2
ϕD	0.335	0.370	8.51	9.40	
ϕD_1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e_1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l_1	–	0.050	–	1.27	2
l_2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

NOTES:

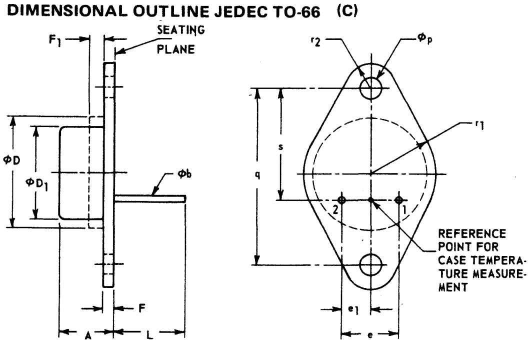
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) ϕb_2 applies between l_1 and l_2. ϕb applies between l_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TERMINAL CONNECTIONS

Lead 1 — Emitter
Lead 2 — Base
Lead 3 — Collector, case

DIMENSIONAL OUTLINE JEDEC TO-66 (C)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD		0.620		15.75	
ϕD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1		0.050		1.27	1
L	0.360		9.14		
ϕp	0.142	0.152	3.61	3.86	
q	0.958	0.962	24.33	24.43	
r_1		0.350		8.89	
r_2		0.145		3.68	
s	0.570	0.590	14.48	14.99	

NOTES:

1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimension does not include sealing flanges.

92SS-3738

TERMINAL CONNECTIONS

Pin 1 — Base
Pin 2 — Emitter
Mounting Flange, Case-Collector

RCA

Solid State
Division

Power Transistors

40406
40411

RCA-40406 through 40411 are diffused-junction, silicon n-p-n and p-n-p transistors intended for a variety of uses in audio amplifiers. Giving high-quality performance economically, these 6 devices have power dissipation ratings of 1 to 150 watts. Supply voltages for these types range from 50 volts for the 40406 and 40407, to 90 volts for the 40408-40411.

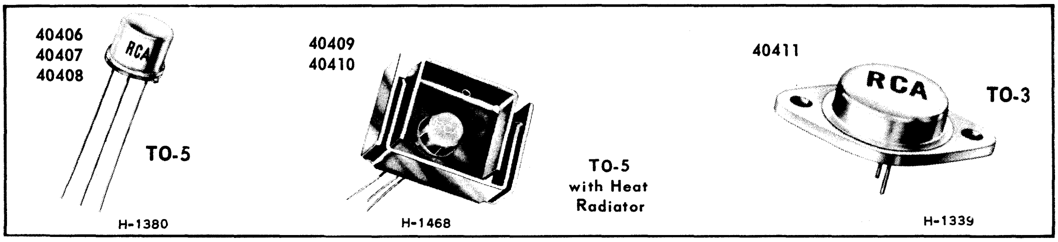
Silicon N-P-N & P-N-P Power Transistors for Audio Amplifier Applications

40406 & 40407
- $V_{CEO}(sus)$ = −50 V max. (40406)
- $V_{CEO}(sus)$ = 50 V max. (40407)
- Type 40406 is P-N-P complement of type 40407
- 1 watt dissipation rating
- TO-5 package

40408
- $V_{CEO}(sus)$ = 90 V max.
- 1 watt dissipation rating
- N-P-N type in JEDEC TO-5 package

40409 & 40410
- $V_{CER}(sus)$ = 90 V max. (40409)
- $V_{CER}(sus)$ = −90 V max. (40410)
- Type 40410 is P-N-P complement of type 40409
- 3 watt free-air dissipation rating
- TO-5 package with heat radiator

40411
- $V_{CER}(sus)$ = 90 V max.
- "Hometaxial-base" type
- 150 watt dissipation rating
- N-P-N type in JEDEC TO-3 package



MAXIMUM RATINGS *Absolute-Maximum Values:*	40406	40407	40408	40409	40410	40411	UNITS
DC Collector-to-Emitter Sustaining Voltage:							
With Base Open, $V_{CEO}(sus)$	−50	50	90	–	–	–	V
With R_{BE} = 100 Ω, $V_{CER}(sus)$	–	–	–	90	−90	90	V
DC Emitter-to-Base Voltage:							
With Collector Open, V_{EBO}	−4	4	4	4	−4	4	V
DC Collector Current, I_C	−0.7	0.7	0.7	0.7	−0.7	30	A
DC Base Current, I_B	−0.2	0.2	0.2	0.2	−0.2	15	A
Transistor Power Dissipation (P_T):							
At Free Air Temperatures up to 25° C	1	1	1	–	–	–	W
At Free Air Temperatures up to 50° C	–	–	–	3	3	–	W
At Case Temperatures up to 25° C	–	–	–	–	–	150	W
At Other Temperatures	See *Fig.1*			See *Fig.2*		See *Fig.3*	
Operating Junction Temperature Range	−65 to +200						°C

ELECTRICAL CHARACTERISTICS

Characteristic	TEST CONDITIONS						LIMITS											
	V_{CB}	V_{CE}	V_{EB}	I_C	I_B	T_C	40406		40407		40408		40409		40410		40411	
	Volts			mA		°C	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
I_{CEO}		40[a]				25		-1µA		1µA								
		80				25						1µA						
		40[a]				150		-10µA		100µA								
		80				150						250µA						
I_{CER}[b]		80[a]				25								1µA		-1µA		500µA
		80[a]				150								100µA		-100µA		2mA
I_{CBO}	10									0.25 µA								
I_{EBO}			4[a]					-1 mA		1 mA		1 mA		1 mA		-1 mA		5 mA
V_{CEO}(sus)				100[a]			-50 V		50 V		90 V							
V_{CER}(sus)[b]				100[a]									90 V		-90 V			
				200													90 V	
V_{CE}(sat)				150[a]	15							1.4 V		1.4 V		-1.4 V		
				4A	400													0.8 V
V_{BE}		-10		-0.1				-0.8 V										
		10		1						0.8 V								
		4		10								1V						
		4[a]		150[a]										1 V		-1 V		
		4		4 A														1.2 V
h_{FE}		-10		-0.1			30	200										
		10		1					40	200								
		4		10							40	200						
		4		150									50	250				
		-4		-150											50	250		
		4		4 A													35	100
h_{fe}[c]		10		50					6									
f_T		4[a]		50[a]			← 100 MHz (Typ) →											
		4		4 A													800 kHz (Typ)	
θ_{J-C}								35° C/W		35° C/W		35° C/W						1.17° C/W
θ_{J-FA}								175° C/W		175° C/W		175° C/W		50° C/W		50° C/W		
C_{ob}[d]	10								15 pF									
PRT[e]		40		5 A													1 sec	

[a] Negative for types 40406 & 40410

[b] R_{BE} = 100 Ω

[c] F = 20 MHz

[d] F = 1 MHz, I_E = O

[e] Power rating test at 200 watts

DISSIPATION DERATING CURVE FOR TYPES 40406, 40407, AND 40408

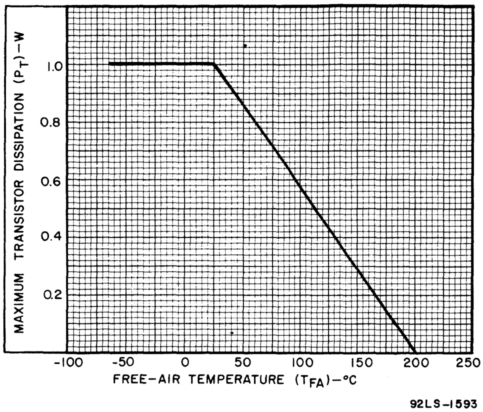


Fig. 1

DISSIPATION DERATING CURVE FOR TYPES 40409 AND 40410

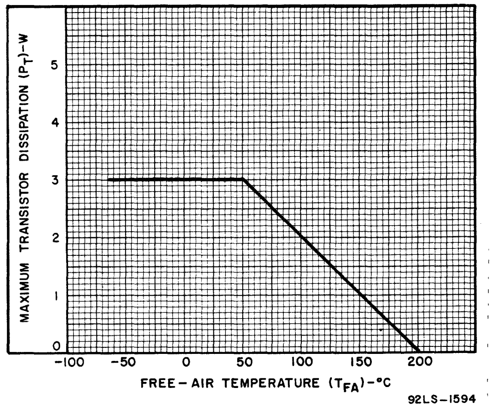


Fig. 2

DISSIPATION DERATING CURVE FOR TYPE 40411

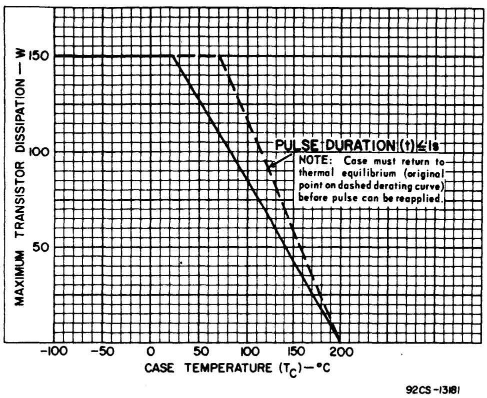


Fig. 3

TYPICAL OPERATION CHARACTERISTIC FOR TYPE 40411

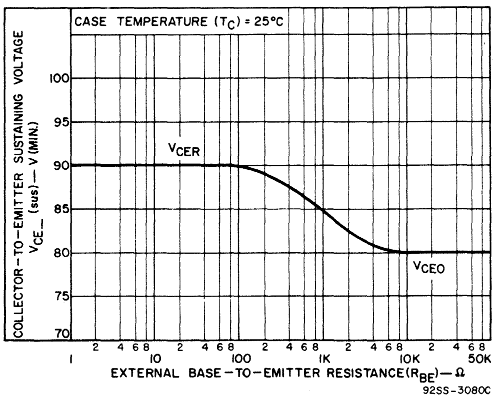


Fig. 4

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 40406 & 40410

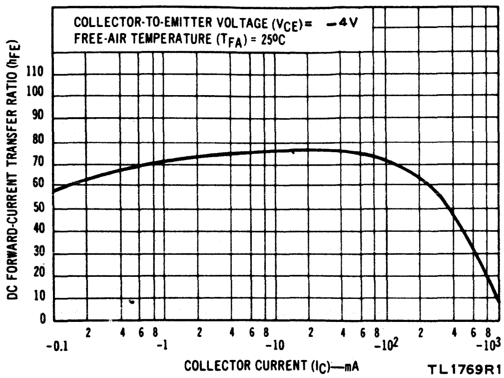


Fig. 5

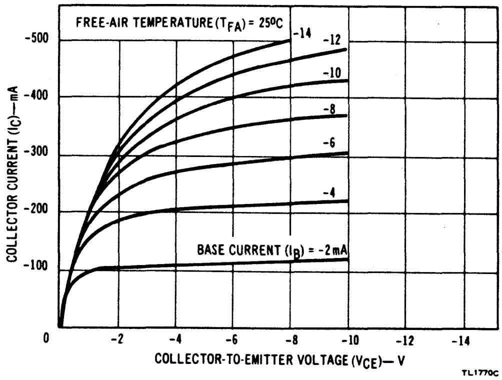


Fig. 6

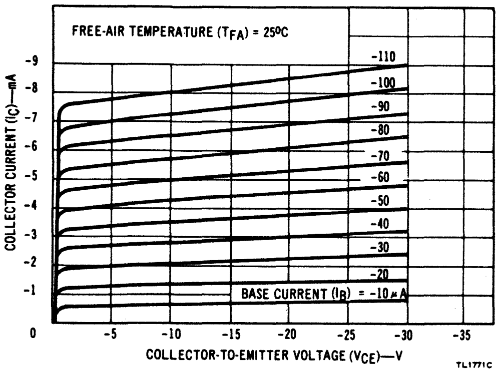


Fig. 7

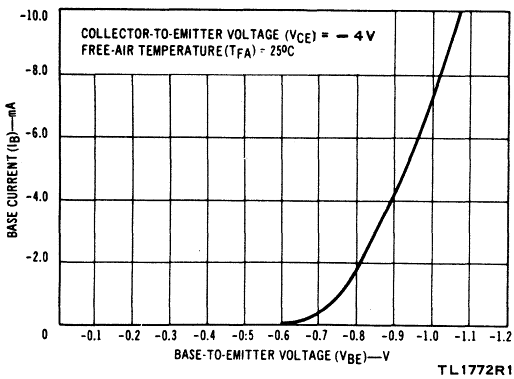


Fig. 8

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 40407, 40408, & 40409

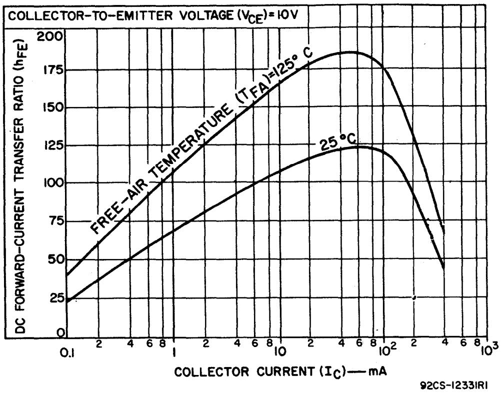


Fig. 9

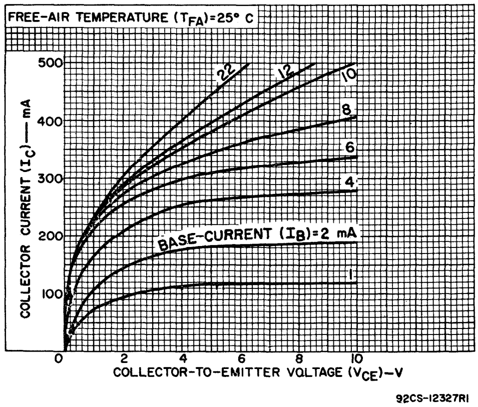


Fig. 10

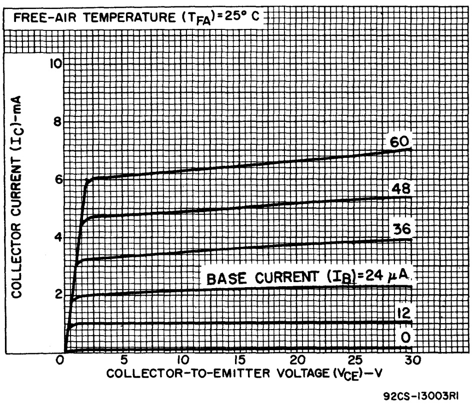


Fig. 11

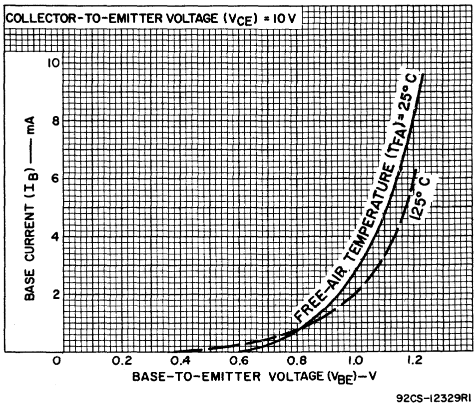


Fig. 12

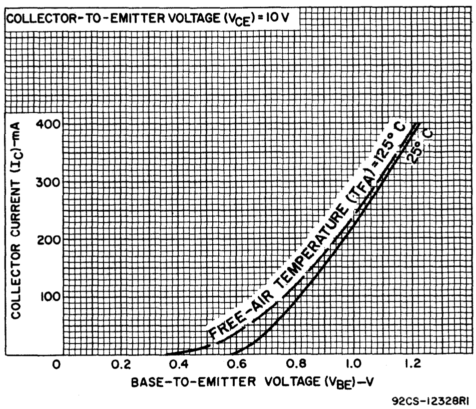


Fig. 13

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 40411

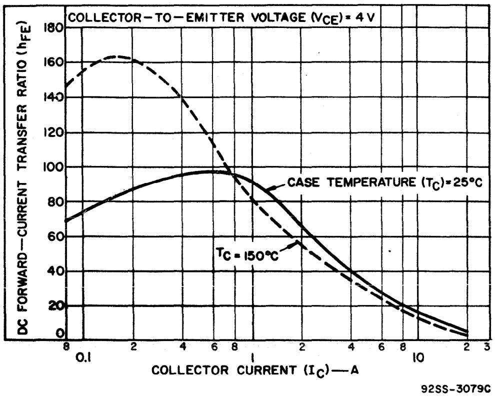


Fig. 14

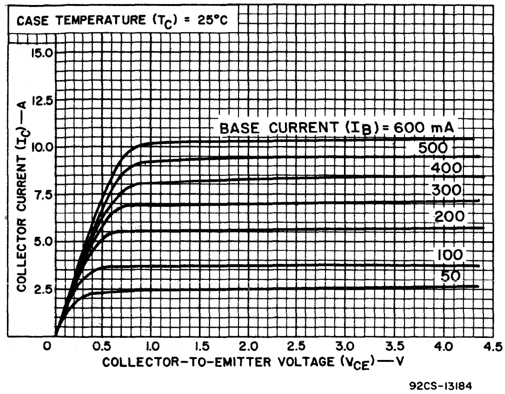


Fig. 15

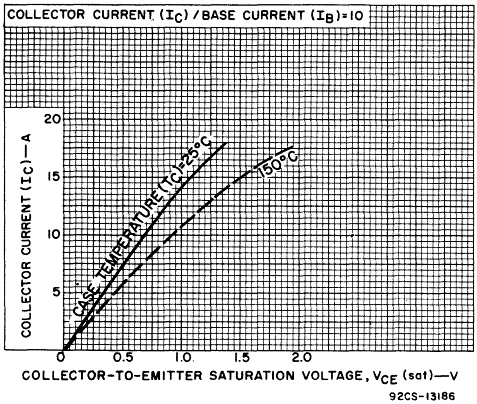


Fig. 16

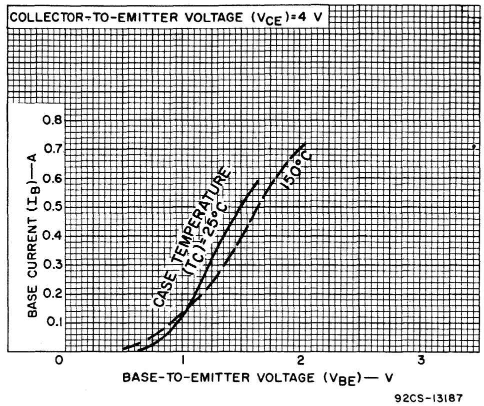


Fig. 17

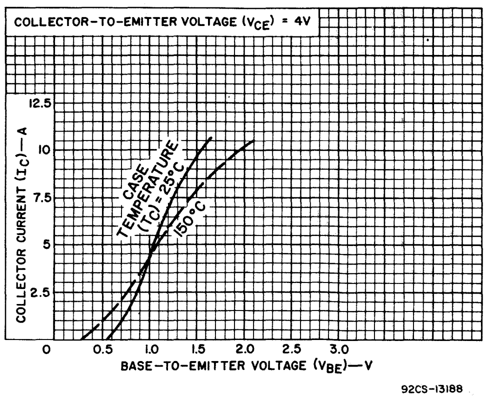
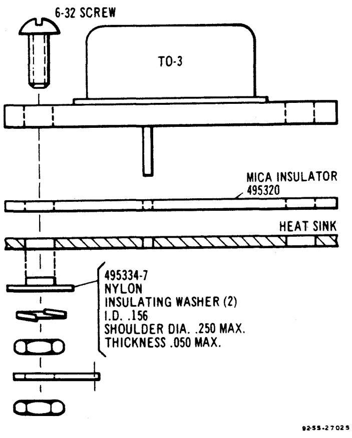


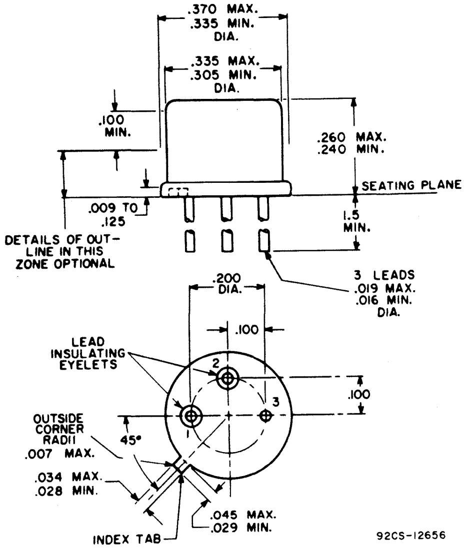
Fig. 18

SUGGESTED HARDWARE FOR TYPE 40411

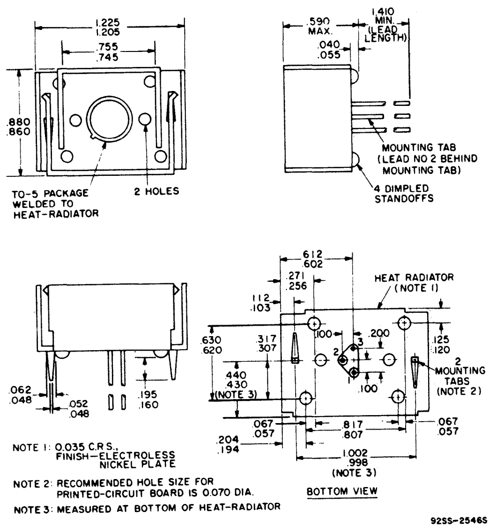


NOTE: Hardware with part numbers supplied.

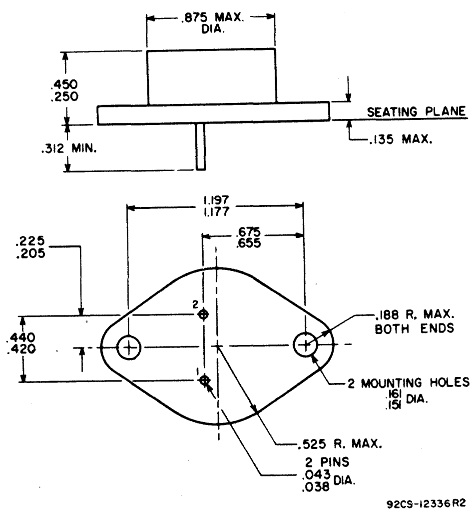
DIMENSIONAL OUTLINE FOR TYPES 40406, 40407, & 40408 JEDEC No. TO-5



DIMENSIONAL OUTLINE FOR TYPES 40409 & 40410 JEDEC TO-5 WITH HEAT RADIATOR



DIMENSIONAL OUTLINE FOR TYPE 40411 JEDEC No. TO-3



DIMENSIONS IN INCHES

TERMINAL CONNECTIONS

FOR TYPES 40406, 40407, 40408, 40409, & 40410

Lead 1-Emitter
Lead 2-Base
Case, Lead 3-Collector (For 40406, 40407, & 40408)
Heat Radiator, Lead 3-Collector (For 40409, & 40410)

FOR TYPE 40411

Pin 1-Base
Pin 2-Emitter
Case, Flange-Collector

RCA

Solid State
Division

Power Transistors

40537
40538

RCA-40537 and 40538 are double-diffused, epitaxial-planar, silicon p-n-p transistors. These types employ the popular JEDEC TO-5 package; they differ in the current at which the parameters are controlled.

The 40537 was designed specifically for use as a driver in audio-amplifier circuits. The 40538 is intended as a complement to n-p-n type 40539 in complementry-symmetry output stages**.

*Data for type 40539 appears in File No. 303.

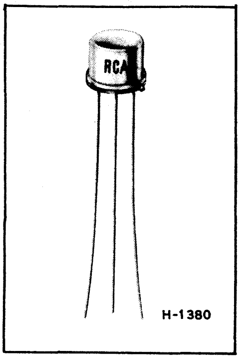
**Typical audio-amplifier circuit using the 40537 and 40538 is shown as Circuit No. 4 in "RCA POWER TRANSISTORS, Typical Audio-Amplifier Circuits", publication No. ATC-500 (6/67).

- **Planar construction provides low-noise and low-leakage characteristics**
- **Gain-bandwidth product (f_T) = 50 MHz min.**
- **Low saturation voltage:**
  $V_{CE}(sat)$ = -1.1 V max. (40537)
  = -2.0 V max. (40538)
- **High pulse beta at high collector current:**
  h_{FE} = 50 min. at I_C = -50 mA (40537)
  = 15 min. at I_C = -500 mA (40538)

SILICON P-N-P TRANSISTORS

For Driver and Output Stages in Audio-Amplifier Circuits

40538 – P-N-P Complement of 40539*



40537, 40538
(JEDEC TO-5)

MAXIMUM RATINGS

Absolute-Maximum Values:

		40537 40538	
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 500 Ω	$V_{CER}(sus)$	-55	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	-5	V
COLLECTOR CURRENT	I_C	-0.7	A
BASE CURRENT	I_B	-0.2	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25° C		5	W
At free-air temperatures up to 25° C		1	W
At temperatures above 25° C		Derate linearly to 0 W at 200° C.	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to 200	°C
LEAD TEMPERATURE (During soldering):			
At distance ≥ 1/32 in. from seating plane for 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) = 25° C

Characteristic	Symbol	TEST CONDITIONS				LIMITS				Units
		DC Voltage (V)		DC Current (mA)		Type 40537		Type 40538		
		V_{CE}	V_{EB}	I_C	I_B	Min.	Max.	Min.	Max.	
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 500 Ω	I_{CER}	–45				–	–10	–	–10	μA
Emitter-Cutoff Current	I_{EBO}		–5	0		–	–1	–	–1	mA
DC Forward-Current Transfer Ratio	h_{FE}	–4 –4		–50 –500[a]		50 –	300 –	– 15	– 90	
Collector-to-Emitter Sustaining Voltage With external base-to-emitter resistance (R_{BE}) = 500 Ω	$V_{CER}(sus)$			–100		–55	–	–55	–	V
Base-to-Emitter Voltage	V_{BE}	–4 –4		–50 –500		– –	–1.8 –	– –	– –2.7	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			–50 –500	–5 –50	– –	–1.1 –	– –	– –2.0	V
Gain-Bandwidth Product	f_T	–4		–50		100 (Typ.)		100 (Typ.)		MHz
Thermal Resistance (Junction-to-Free Air)	$\theta_{J\text{-}FA}$					–	175	–	175	°C/W

[a]Pulsed; pulse duration = 300 μs, duty factor < 2%.

TYPICAL DC-BETA
FOR TYPES 40537 & 40538

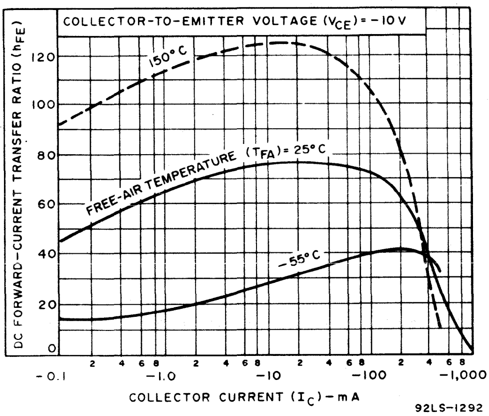


Fig. 1

TYPICAL TRANSFER CHARACTERISTICS
FOR TYPES 40537 & 40538

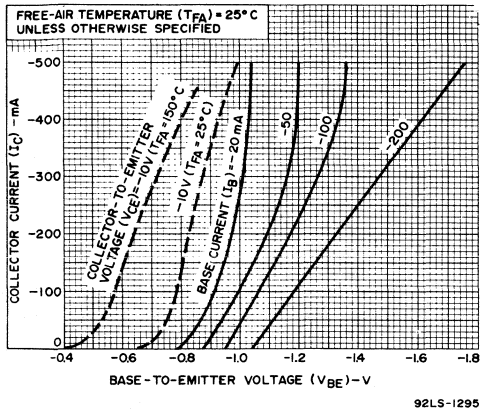


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS
FOR TYPES 40537 & 40538

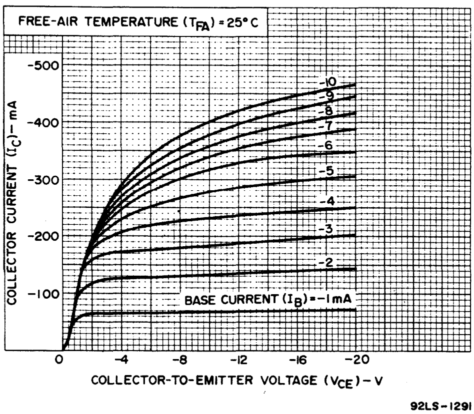


Fig. 3

TYPICAL OUTPUT CHARACTERISTICS
FOR TYPES 40537 & 40538

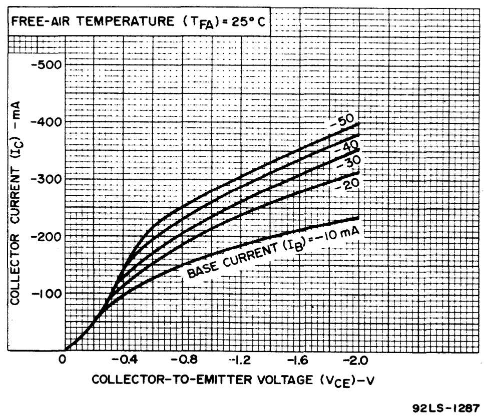
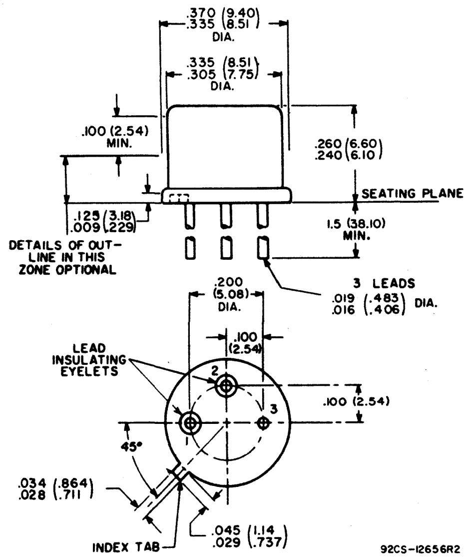


Fig. 4

DIMENSIONAL OUTLINE

FOR TYPES 40537 & 40538

JEDEC TO-5



DIMENSIONS IN INCHES AND MILLIMETERS

Note: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

TERMINAL CONNECTIONS FOR TYPES 40537 & 40538

Lead No.1 - Emitter
Lead No.2 - Base
Case, Lead No.3 - Collector

RCA

Solid State Division

Power Transistors

40539
40544

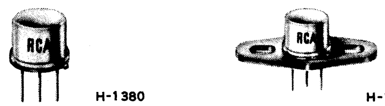
SILICON N-P-N TRANSISTORS

For Driver and Output Stages in Audio-Amplifier Circuits

40539 – N-P-N Complement of 40538*

RCA-40539 and 40544 are triple-diffused, planar, silicon n-p-n transistors. Type 40539 employs the popular JEDEC TO-5 package; type 40544 employs a JEDEC TO-5 package with a factory-attached, diamond-shaped mounting flange.

The 40539 is intended as a complement to p-n-p type 40538 in complementry-symmetry output stages. The 40544 was designed specifically as a driver in audio-amplifier circuits.



40539 (JEDEC TO-5) 40544 (TO-5 with Flange)

*Data for type 40538 appears in File No. 302.

- **Factory-attached, diamond-shaped mounting flange**
- **Low leakage current**
- **Low saturation voltage:**
  $V_{CE}(sat)$ = 1.0 V Max. (40544)
  = 2.0 V Max. (40539)

MAXIMUM RATINGS

Absolute-Maximum Values:

		40539	40544	
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	–	50	V
= 500 Ω	$V_{CER}(sus)$	55	–	
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	V
COLLECTOR CURRENT	I_C	0.7	0.7	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25° C		5	7	W
At free-air temperatures up to 25° C		1	–	W
At temperatures above 25° C		Derate linearly to 0 W at 200° C.		
TEMPERATURE RANGE:				
Storage & Operating (Junction)		← –65 to 200 →		°C
LEAD TEMPERATURE (During solding):				
At distance ≥ 1/32" from seating plane for 10 s max.		← 255 →		°C

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) = 25° C

Characteristic	Symbol	TEST CONDITIONS DC Voltage (V) V_{CE}	DC Voltage (V) V_{EB}	DC Current (mA) I_C	DC Current (mA) I_B	LIMITS Type 40539 Min.	Type 40539 Max.	Type 40544 Min.	Type 40544 Max.	Units
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	40				–	–	–	10	µA
= 500 Ω		45				–	10	–	–	
Emitter-Cutoff Current	I_{EBO}		5	0		–	1.0	–	1.0	mA
DC Forward-Current Transfer Ratio	h_{FE}		4	500		15	90	–	–	
			4	50		–	–	35	200	
Collector-to-Emitter Sustaining Voltage With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$			100		–	–	50	–	V
= 500 Ω				100		55	–	–	–	
Base-to-Emitter Voltage	V_{BE}	4		500		–	2.7	–	–	V
		4		50		–	–	–	1.7	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			500	50	–	2.0	–	–	V
				150	15	–	–	–	1.0	
Gain-Bandwidth Product	f_T	4		50		100 (Typ.)		100 (Typ.)		MHz
Thermal Resistance (Junction-to-Case)	θ_{J-C}					–	35	–	25	°C/W

TYPICAL DC-BETA
FOR TYPES 40539 & 40544

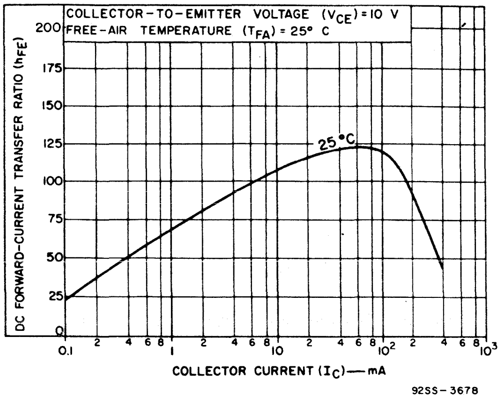


Fig. 1

TYPICAL INPUT CHARACTERISTICS
FOR TYPES 40539 & 40544

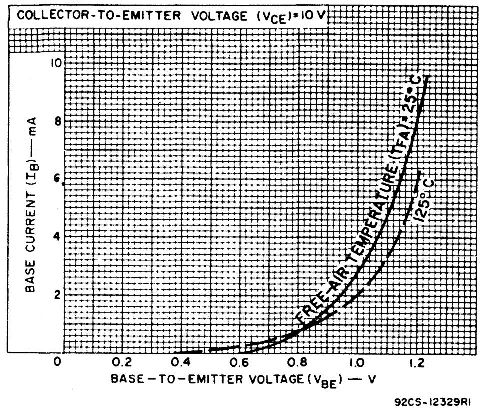


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS
FOR TYPES 40539 & 40544

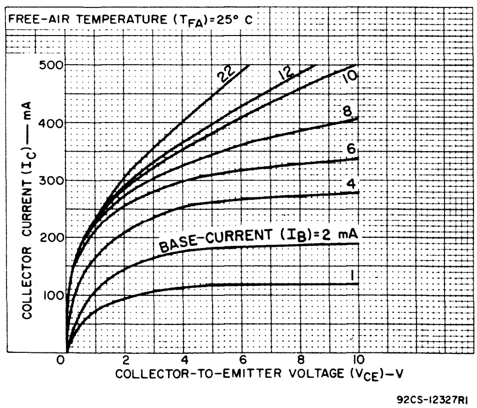


Fig. 3

TYPICAL TRANSFER CHARACTERISTICS
FOR TYPES 40539 & 40544

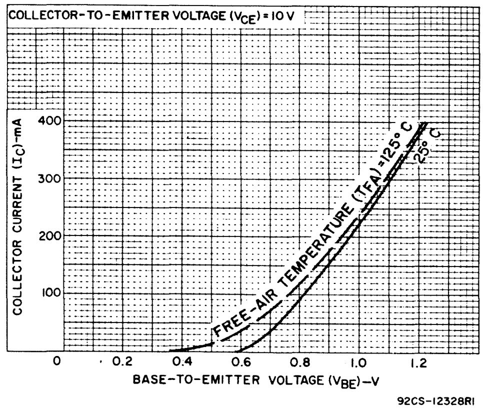
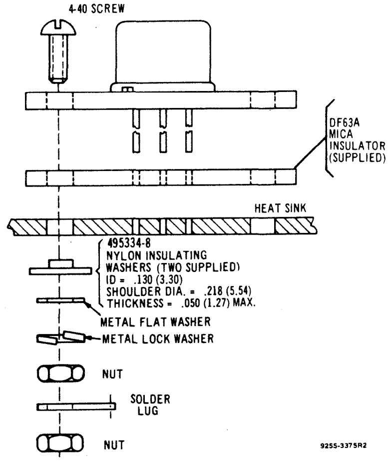


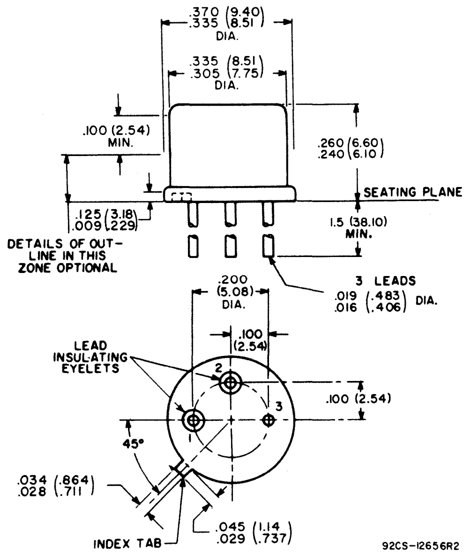
Fig. 4

SUGGESTED HARDWARE FOR MOUNTING TYPE 40544



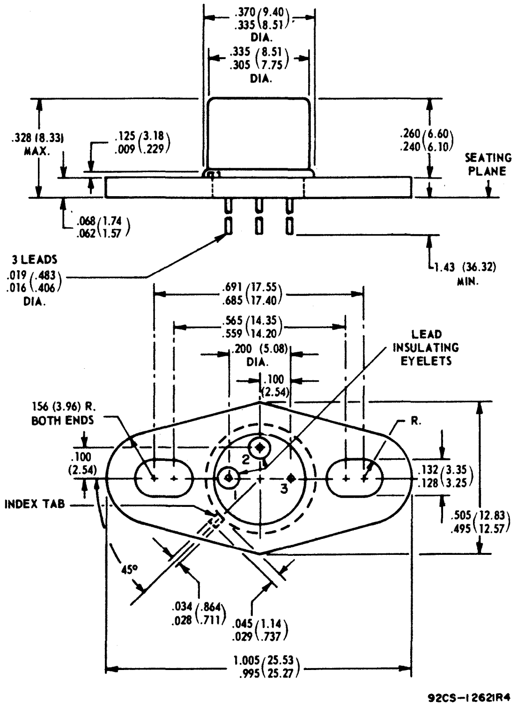
DIMENSIONAL OUTLINE FOR TYPE 40539

JEDEC TO-5



DIMENSIONAL OUTLINE FOR TYPE 40544

JEDEC TO-5 WITH FLANGE



Dimensions in Inches and Millimeters

NOTE: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

TERMINAL CONNECTIONS FOR TYPES 40539 & 40544

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector (40539)
Flange, Lead 3 - Collector (40544)

RCA

Solid State
Division

Power Transistors

40542
40543

SILICON N-P-N, MOLDED SILICONE-PLASTIC HOMETAXIAL-BASE TRANSISTORS

RCA-40542 and -40543 are hometaxial**-base silicon n-p-n power transistors employing a new plastic package with formed leads which can be inserted into a TO-3 socket.

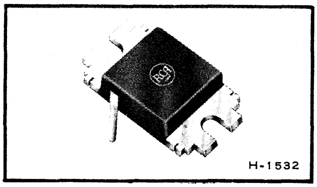
These types differ in voltage ratings and in the current at which the parameters are controlled. The 40542 is intended as a complement to p-n-p type 40051 in complementry-symmetry output stages of audio-amplifier circuits. The 40543 was designed specifically for amplifier applications.

*Data for type 40051 appears in File No. 67.

**"HOMETAXIAL" was coined by RCA from two words, "homogeneous" and "axial," to provide a name for a transistor structure in which the base region comprises homogeneous resistivity silicon material in the axial direction (emitter-to-collector). Hometaxial types provide greater power-handling capability, lower saturation resistance, and freedom from second breakdown.

FOR OUTPUT STAGES IN AUDIO-AMPLIFIER CIRCUITS

40542 -- N-P-N Complement of 40051*



40542 & 40543
For TO-3 Sockets

- **Molded silicone-plastic package**
- **Low saturation voltage:**
  $V_{CE}(sat)$ = 1.0 V max. at I_C = 2.5 A (40542)
  = 1.0 V max. at I_C = 3.0 A (40543)
- **Low thermal resistance:**
  $\theta_{J\text{-}C}$ = 1.5 °C/W max.

MAXIMUM RATINGS

Absolute-Maximum Values:		40542	40543	
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:				
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$	50	60	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	5	V
COLLECTOR CURRENT	I_C	6	8	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 25° C		83	83	W
At temperatures above 25° C		Derate linearly to 0 W at 150° C.		
TEMPERATURE RANGE:				
Storage & Operating (Junction)		−65 to 150		°C
LEAD TEMPERATURE (During Soldering):				
At distances ≥ 1/16 in. from seating plane for 10 s max.		235		°C

ELECTRICAL CHARACTERISTICS

Case Temperature (T_C) = 25° C

Characteristic	Symbol	TEST CONDITIONS				LIMITS				Units
		DC Voltage (V)		DC Current (A)		Type 40542		Type 40543		
		V_{CE}	V_{EB}	I_C	I_B	Min.	Max.	Min.	Max.	
Collector-Cutoff Current With external base-to-emitter resistance (R_{BE}) = 100 Ω	I_{CER}	40 50				– –	1.0 –	– –	– 1.0	mA
Emitter-Cutoff Current	I_{EBO}		5	0		–	5.0	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	4 4		2.5[a] 3.0[a]		20 –	70 –	– 20.	– 70	
Collector-to-Emitter Sustaining Voltage With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$			0.2[a]		50	–	60	–	V
Base-to-Emitter Voltage	V_{BE}	4 4		2.5[a] 3.0[a]		– –	1.7 –	– –	– 1.7	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			2.5[a] 3.0[a]	0.25 0.3	– –	1.0 –	– –	– 1.0	V
Gain-Bandwidth Product	f_T	4		0.5		0.8	2.8	0.8	2.8	MHz
Thermal Resistance (Junction-to-Case)	θ_{J-C}					–	1.5	–	1.5	°C/W

[a]Pulsed; pulse duration = 300 μs, duty factor = 1.8%.

TYPICAL DC BETA FOR TYPE 40542

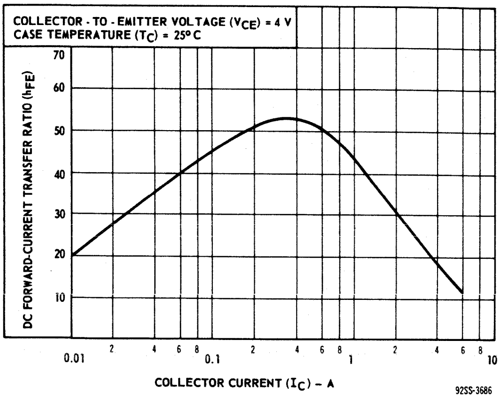


Fig. 1

TYPICAL INPUT CHARACTERISTICS FOR TYPE 40542

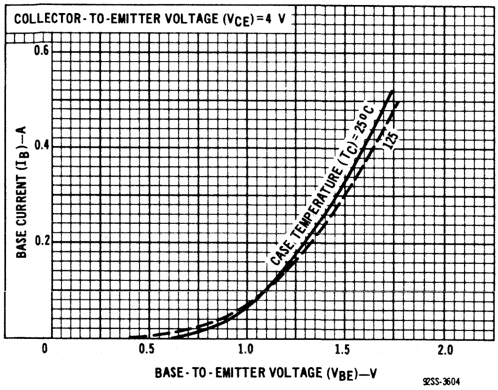


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS FOR TYPE 40542

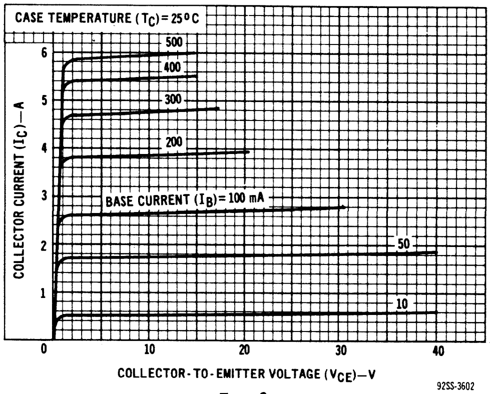


Fig. 3

TYPICAL TRANSFER CHARACTERISTICS FOR TYPE 40542

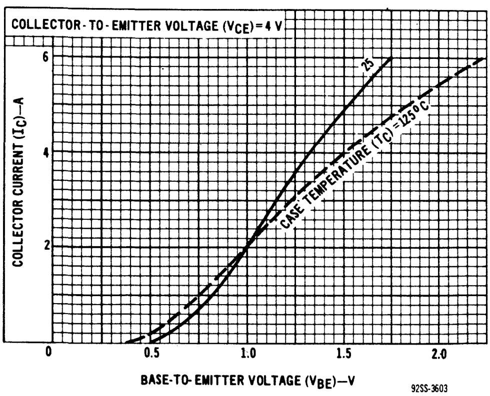


Fig. 4

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPE 40542

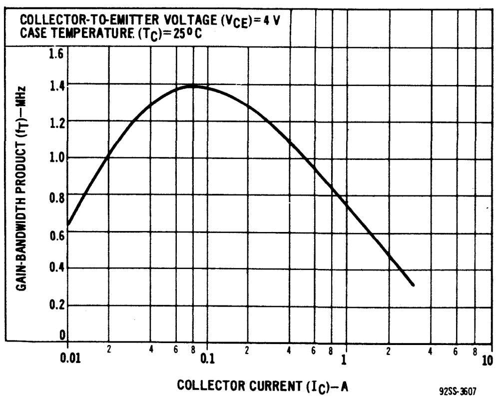


Fig. 5

TYPICAL DC BETA FOR TYPE 40543

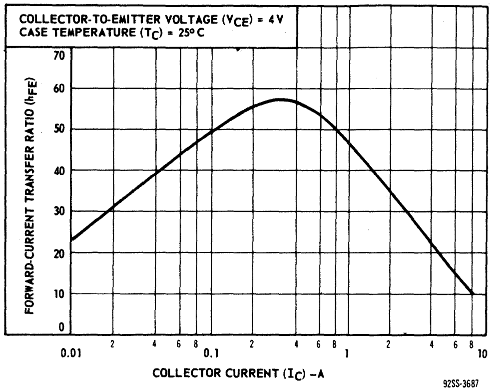


Fig. 6

TYPICAL INPUT CHARACTERISTICS FOR TYPE 40543

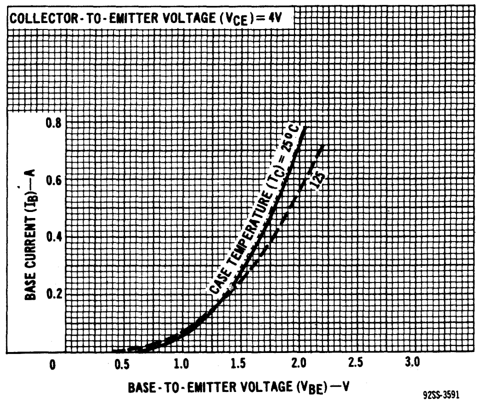


Fig. 7

TYPICAL OUTPUT CHARACTERISTICS FOR TYPE 40543

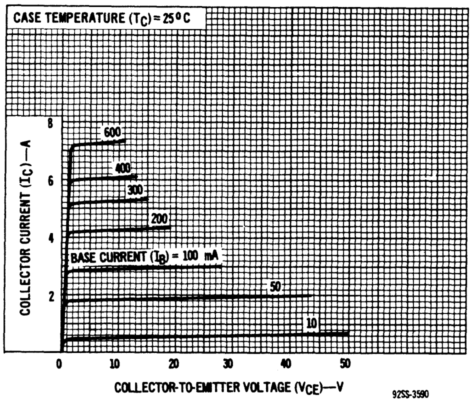


Fig. 8

TYPICAL TRANSFER CHARACTERISTICS FOR TYPE 40543

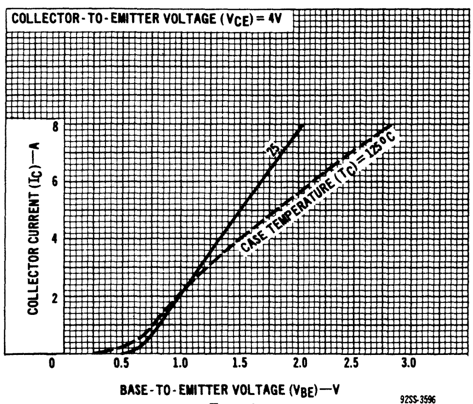


Fig. 9

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPE 40543

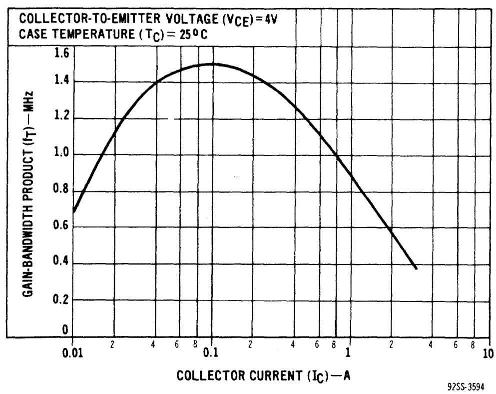
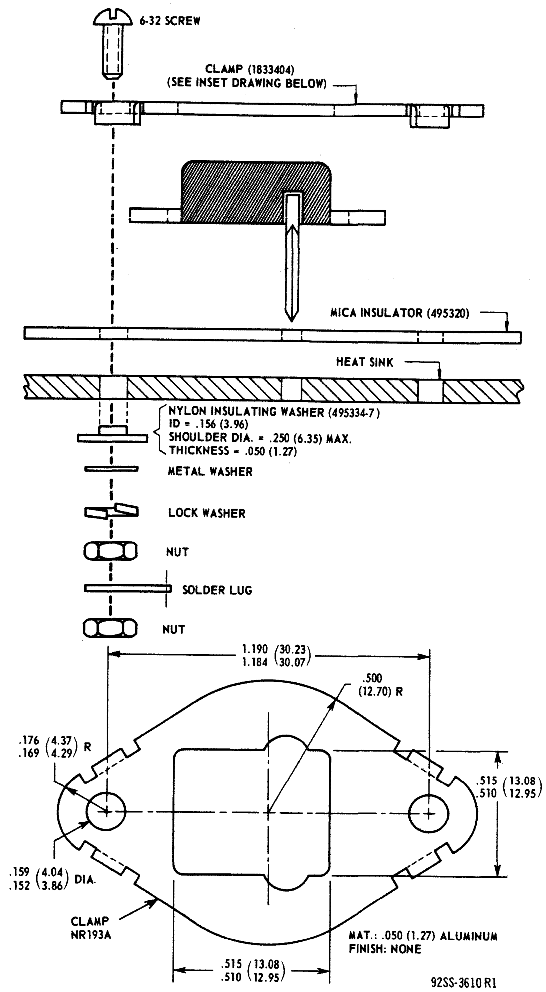


Fig. 10

SUGGESTED HARDWARE FOR MOUNTING TYPES 40542 & 40543 IN PLACE OF TO-3 TYPES

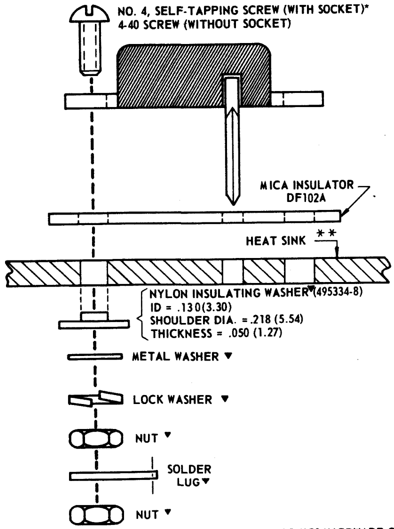


Dimensions in Inches and Millimeters

Note: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Fig. 11

SUGGESTED HARDWARE FOR MOUNTING TYPES 40542 & 40543



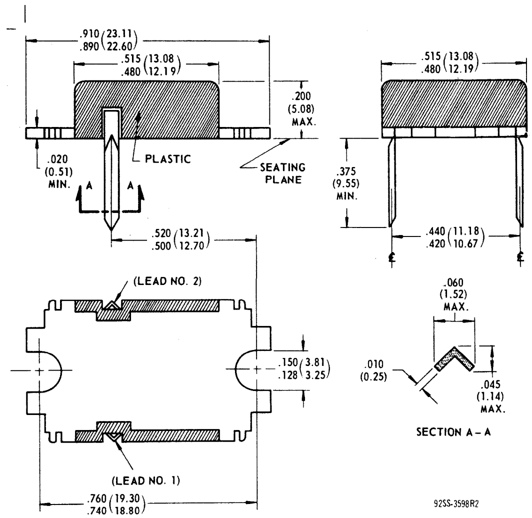
*SOCKET NO. XA1521 (INDUSTRIAL ELECTRONICS HARDWARE CORP. 109 PRINCE STREET., NEW YORK, N.Y.) OR EQUIV.

**.130 (3.30) MAX. THICKNESS

▼NOT REQUIRED WITH SOCKET (USE SELF - TAPPING SCREW) 92SS-3611R1

Fig. 12

DIMENSIONAL OUTLINE FOR TYPES 40542 & 40543



Dimensions in Inches and Millimeters

Note: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

TERMINAL CONNECTIONS FOR TYPES 40542 & 40543

Lead No. 1 – Base
Lead No. 2 – Emitter
Mounting Flange – Collector

RCA

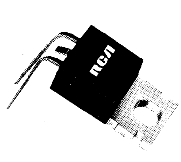
Solid State
Division

Power Transistors
40594, 40595, 40611, 40612, 40613, 40616, 40618, 40621–40636 Inclusive

RCA-40594 & 40595, 40611, 40612, 40613, 40616, 40618, 40621–40636, inclusive are silicon n-p-n and p-n-p, and germanium p-n-p transistors intended for driver and output stages in high-fidelity amplifier circuits.

These devices have been specifically designed for use in RCA's complementary and quasi-complementary symmetry circuits – two basic circuits which permit the equipment designer, with only minor changes in component values, transistor types, and supply voltages, to design audio circuits capable of providing from 3 watts to 70 watts (rms) of audio power. See page 4 for a listing of these circuits which are described in detail in RCA's "Audio Design Phase 2" Universal Amplifier Program brochure, Form No. 2L1111. This publication is available on request from Commercial Engineering, RCA Electronic Components, Harrison, N.J. 07029.

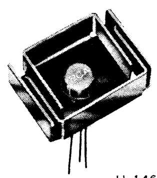
SILICON N-P-N and P-N-P GERMANIUM P-N-P TYPES for AUDIO AMPLIFIER CIRCUITS



H-1534

40613 40627
40618 40629
40621 40630
40622 40631
40624 40632

"Plastic TO-66"
(For TO-66 Sockets)



H-1468

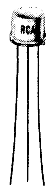
40625
40628

TO-5
With Heat-Radiator

H-1570

40612 40626
40623 40636

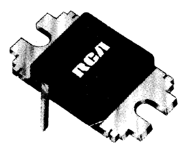
JEDEC TO-3



H-1380

40594
40595
40611
40616
40634
40635

JEDEC TO-5



H-1532

40633

"Plastic TO-3"
(For TO-3 Sockets)

Transistor Types for Driver Applications...

Type	Constr.	Type	Constr.	Type	Constr.
40594	Si N-P-N	40616	Si N-P-N	40634	Si P-N-P
40595	Si P-N-P	40625	Si N-P-N	40635	Si N-P-N
40611	Si N-P-N	40628	Si N-P-N		

Transistor Types for Output Applications...

Type	Constr.	Type	Constr.	Type	Constr.
40612	Ge P-N-P	40623	Ge P-N-P	40630	Si N-P-N
40613	Si N-P-N	40624	Si N-P-N	40631	Si N-P-N
40618	Si N-P-N	40626	Ge P-N-P	40632	Si N-P-N
40621	Si N-P-N	40627	Si N-P-N	40633	Si N-P-N
40622	Si N-P-N	40629	Si N-P-N	40636	Si N-P-N

MAXIMUM RATINGS▲, Absolute-Maximum Values:

RCA Type	$V_{CEO}(sus)$	$V_{CER}(sus)$*	V_{EBO}	I_C	I_B	P_T – W●		Temp. Range (Storage & Operating)		
	V	V	V	A	A	$T_C = 25^oC$	$T_A = 25^oC$	°C		
								–		+
40594	–	95	4	2	1	10	1.2	65	to	200
40595	–	–95	–4	–2	–1	10	1.2	65	to	200
40611	25	–	2.5	0.7	0.2	5	1	65	to	200
40612	–	–25	–5	–5	–1	12.5	–	65	to	100
40613	25	–	5	4	2	36	1.8	65	to	150
40616	32	–	2.5	0.7	0.2	5	1	65	to	200
40618	30	–	5	4	2	36	1.8	65	to	150
40621	32	–	5	4	2	36	1.8	65	to	150
40622	40	–	5	4	2	36	1.8	65	to	150
40623	–	–45	–5	–5	–1	12.5	–	65	to	100
40624	45	–	5	6	3	50	1.8	65	to	150
40625	45	–	7	1	–	–	3.5	65	to	200
40626	–	–55	–5	–5	–1	12.5	–	65	to	100
40627	55	–	5	6	3	50	1.8	65	to	150
40628	55	–	7	1	–	–	3.5	65	to	200
40629	–	35	5	4	2	36	1.8	65	to	150
40630	–	40	5	4	2	36	1.8	65	to	150
40631	–	45	5	4	2	36	1.8	65	to	150
40632	–	60	5	6	3	50	1.8	65	to	150
40633	–	75	5	8	6	83	2	65	to	150
40634	–	–75	–7	–0.7	–0.2	5	1	65	to	200
40635	–	75	7	0.7	0.2	5	1	65	to	200
40636	–	95	7	15	7	115	–	65	to	200

▲For further technical information on these types, see the technical bulletins for the prototypes. A list of the 40,000-Series types and their prototypes is shown on Page 4.

* R_{BE} = 68 Ω (40612, 40623, & 40626)
= 100 Ω (40594, 40595, 40629, 40630, 40631, 40632, 40633, 40634, 40635, & 40636)

● P_T at temperatures above 25°C, derate linearly to 0 watts at maximum temperature (e.g. + 100, + 150, or + 200°C).

ELECTRICAL CHARACTERISTICS▲ at T_A = 25° C

RCA Type	I_{CBO} Max.		I_{CER} Max.				I_{EBO} Max.			V_{CEO}(sus) Min.	
		V_{CB}			V_{CE}	R_{BE}			V_{EB}		I_C
	µA	V	µA	mA	V	Ω	µA	mA	V	V	mA
40611	0.5	15	–	–	–	–	–	1	2.5	25	100
40612	– 3	– 30	–	–	–	–	–	– 2	– 5	–	–
40613	2	25	–	–	–	–	–	1	5	25	100
40616	0.5	15	–	–	–	–	–	1	5	32	100
40618	2	30	–	–	–	–	–	1	5	30	100
40621	0.5	30	–	–	–	–	–	1	5	32	100
40622	–	–	500	–	40	100	–	1	5	40	100
40623	– 500	– 30	–	–	–	–	–	– 2	– 5	–	–
40624	–	–	500	–	45	100	–	1	5	45	100
40625	0.25	60	–	–	–	–	1	–	5	45	100
40626	– 500	– 30	–	–	–	–	–	– 2	– 5	–	–
40627	–	–	500	–	55	100	–	1	5	55	100
40628	0.25	60	–	–	–	–	1	–	5	55	100
40629	–	–	–	0.5	30	100	–	1	5	–	–
40630	–	–	–	0.5	35	100	–	1	5	–	–
40631	–	–	–	0.5	40	100	–	1	5	–	–
40632	–	–	–	0.5	50	100	–	1	5	–	–
40633	–	–	–	0.5	65	100	–	1	5	–	–
40634	–	–	– 10	–	– 65	100	–	– 0.1	– 4	–	–
40635	–	–	10	–	65	100	–	0.1	4	–	–
40636	–	–	–	0.5	85	100	–	1	4	–	–
40594	–	–	10	–	85	100	–	0.1	4	–	–
40595	–	–	– 10	–	– 85	100	–	– 0.1	– 4	–	–

▲ For further technical information on these types, see the technical bulletins for the prototypes.

$V_{CER}(sus)$ Min.			$V_{CE}(sat)$ Max.			V_{BE} Max.			h_{FE}				RCA Type
	I_C	R_{BE}		I_C	I_B		V_{CE}	I_C			I_C	V_{CE}	
V	mA	Ω	V	mA	mA	V	V	mA	Min.	Max.	mA	V	
–	–	–	–	–	–	–	–	–	70	500	50	4	40611
– 25	– 200	68	–	–	–	–	–	–	30	150	– 1000	– 2	40612
–	–	–	–	–	–	1.3	4	1000	30	120	1000	4	40613
–	–	–	–	–	–	–	–	–	70	500	50	4	40616
–	–	–	–	–	–	–	–	–	30	120	1000	4	40618
–	–	–	1	1500	150	1.5	4	1500	25	100	1500	4	40621
–	–	–	1	1500	150	1.5	4	1500	25	100	1500	4	40622
– 45	– 200	68	–	–	–	–	–	–	50	170	– 1000	– 2	40623
–	–	–	1	2500	250	1.7	4	2500	20	100	2500	4	40624
–	–	–	0.5	150	15	1	4	150	100	300	150	10	40625
– 55	– 200	68	–	–	–	–	–	–	50	170	– 1000	– 2	40626
–	–	–	1	2500	250	1.7	4	2500	20	100	2500	4	40627
–	–	–	0.5	150	15	1	4	150	100	300	150	10	40628
35	100	100	1	1000	100	1.3	4	1000	20	70	1000	4	40629
40	100	100	1	1500	150	1.4	4	1500	20	70	1500	4	40630
45	100	100	1	2000	200	1.5	4	2000	20	70	2000	4	40631
60	100	100	1	3000	300	1.4	4	3000	20	70	3000	4	40632
75	200	100	1	4000	400	1.4	4	4000	20	70	4000	4	40633
– 75	– 100	100	– 0.8	– 150	– 15	– 1.4	– 4	– 150	50	250	– 150	– 4	40634
75	100	100	0.8	150	15	1.4	4	150	50	250	150	4	40635
95	200	100	1	4000	400	1.4	4	4000	20	70	4000	4	40636
95	100	100	0.8	300	30	1.4	4	300	70	350	300	4	40594
– 95	– 100	100	– 0.8	– 300	– 30	– 1.4	– 4	– 300	70	350	– 300	– 4	40595

RCA 40,000-Series Types and Prototypes

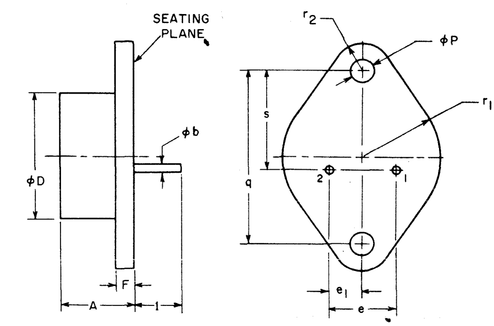
RCA Type	RCA Prototype	Publication and Issue Date
40022	–	Tech. Bull. File No. 69 (7-66)
40050	–	Tech. Bull. File No. 67 (7-66)
40389	–	Tech. Bull. File No. 145 (8-66)
40594	2N5320	Tech. Bull. File No. 325 (3-68)
40595	2N5322	Tech. Bull. File No. 325 (3-68)
40611	40311	Tech. Bull. File No. 78 (6-66)
40612	40254	Tech. Bull. File No. 69 (7-66)
40613	2N5295	Tech. Bull. File No. 322 (2-68)
40616	40311	Tech. Bull. File No. 78 (6-66)
40618	2N5295	Tech. Bull. File No. 322 (2-68)
40621	2N5297	Tech. Bull. File No. 322 (2-68)
40622	2N5297	Tech. Bull. File No. 322 (2-68)
40623	40051	Tech. Bull. File No. 67 (7-66)
40624	TA7316	DT Data Sheet (2-68)
40625	2N1711	Tech. Bull. File No. 26 (6-66)
40626	40051	Tech. Bull. File No. 67 (7-66)
40627	TA7316	DT Data Sheet (2-68)
40628	2N1711	Tech. Bull. File No. 26 (6-66)
40629	2N5295	Tech. Bull. File No. 322 (2-68)
40630	2N5297	Tech. Bull. File No. 322 (2-68)
40631	2N5297	Tech. Bull. File No. 322 (2-68)
40632	TA7314	DT Data Sheet (2-68)
40633	2N5036	Tech. Bull. File No. 244 (3-67)
40634	2N4036	Tech. Bull. File No. 216 (8-66)
40635	2N3053	Tech. Bull. File No. 145 (8-66)
40636	2N3055	Tech. Bull. File No. 145 (8-66)

RCA's Universal Amplifiers Circuits

Complementary-Symmetry		Quasi-Complementary-Symmetry	
Description	Transistor Complement	Description	Transistor Complement
3-Watt All Silicon	TA7271, TA7290, & 40611	12-Watt*	40631
3-Watt Silicon & Germanium	40611, 40612, & 40613	25-Watt*	40632
5-Watt All Silicon	TA7271, TA7290, & 40616	40-Watt*	40633, 40634, & 40635
5-Watt Silicon & Germanium	40022, 40616, & 40618	70-Watt*	40594, 40595, & 40636
7-Watt All Silicon	40616, TA7272, & TA7291		
7-Watt Silicon & Germanium	40022, 40616, & 40621		
12-Watt Silicon & Germanium	40050, 40389, & 40622		
16-Watt Silicon & Germanium	40623, 40624, & 40625		
20-Watt Silicon & Germanium	40626, 40627, & 40628		

*All silicon

DIMENSIONAL OUTLINE FOR JEDEC TO-3



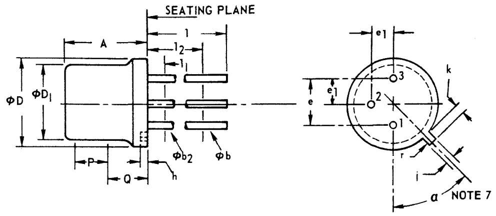
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.250	.450	6.35	11.43	
φb	.038	.043	.97	1.09	2
φD		.875		22.23	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F		.135		3.43	
l	.312		7.92		2
φP	.151	.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		.525		13.34	
r_2		.188		4.78	
s	.655	.675	16.64	17.15	1

NOTES:

1. These dimensions should be measured at points 0.050 in. (1.27 MM) to 0.055 in. (1.40 MM) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two leads.

92CS-15222

DIMENSIONAL OUTLINE FOR JEDEC TO-5



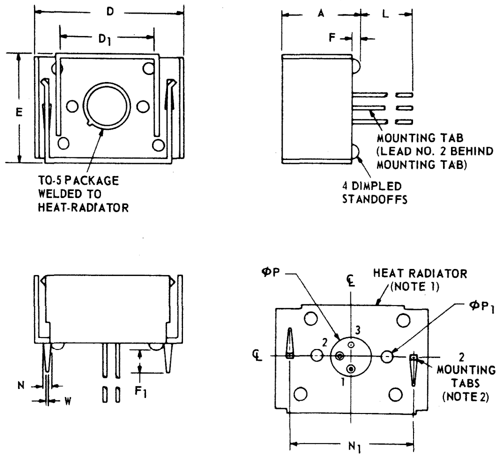
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.240	.260	6.10	6.60	
φb	.016	.021	.406	.533	2
$φb_2$	.016	.019	.406	.483	2
φD	.335	.370	8.51	9.40	
$φD_1$	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
i	.028	.034	.711	.864	5
k	.029	.045	.737	1.14	3,5
l	1.500		38.10		2
l_1		.050		1.27	2
l_2	.250		6.35		2
P	.100		2.54		1
Q					6
r		.007		.179	
α	45° T.P.				5,7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 MM).
2. (Three leads) $φb_2$ applies between l_1 and l_2. φb applies between l_2 and 1.5 in. (38.10 MM) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 MM) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 MM) measured in gaging plane 0.054 in. (1.37 MM) + 0.001 in. (0.25 MM) – 0.000 in. (0.000 MM) below the seating plane of the device shall be within 0.007 in. (0.178 MM) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

DIMENSIONAL OUTLINE FOR JEDEC TO-5 WITH HEAT RADIATOR



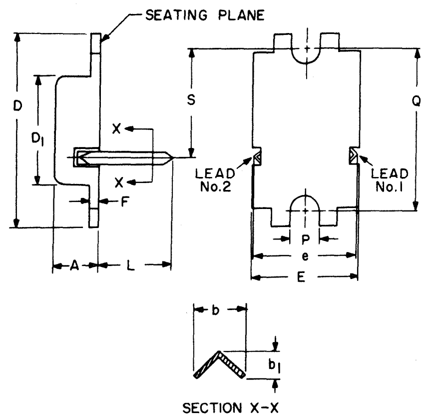
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	.745	.755	18.923	19.177	
E	.875	.905	22.22	22.99	
F	.040	.055	1.02	1.40	
F_1	.170	.225	4.32	5.72	
L	1.410	–	35.81	–	
φP	.295	.305	7.493	7.747	
$φP_1$	.093	.095	2.362	2.413	
N	.048	.062	1.21	1.57	
N_1	.998	1.002	25.349	25.450	3
W	.048	.052	1.219	1.320	

NOTES:

1. 0.035 C.R.S., finish—electroless nickel plate
2. Recommended hole size for printed-circuit board is 0.070 dia.
3. Measured at bottom of heat-radiator

92SS-2546R2

DIMENSIONAL OUTLINE FOR "PLASTIC TO-3"

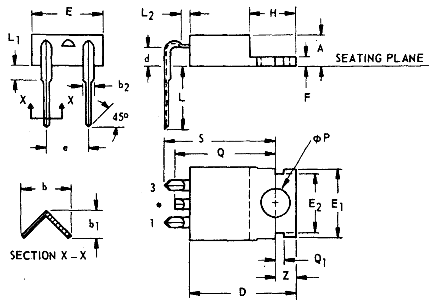


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.200	–	5.08	
b	.045	.060	1.15	1.52	
b1	.025	.045	.64	1.14	
D	.890	.910	22.61	23.11	
D1	.480	.515	12.20	13.08	
E	.480	.520	12.20	13.20	
e	.460	.505	11.69	12.82	1
F	.020	.065	.51	1.65	
L	.312	–	7.93	–	
P	.128	.150	3.26	3.81	
Q	.740	.760	18.80	19.30	
S	.500	.520	12.70	13.20	1

NOTE: 92CS-15191

1. Position of leads to be measured at the seating plane.

DIMENSIONAL OUTLINE FOR "PLASTIC TO-66"



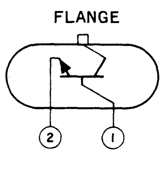
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.160	.190	4.07	4.82	
b	.020	.045	.51	1.14	
b1	.015	.030	.39	.76	
b2	.045	.055	1.143	1.397	
D	.575	.600	14.61	15.24	
d	.085	.115	2.16	2.92	
E	.395	.410	10.04	10.41	
E1	.365	.385	9.28	9.77	
E2	.300	.320	7.62	8.12	
e	.190	.210	4.83	5.33	1
F	.020	.055	.51	1.39	
H	.235	.265	5.97	6.73	
L	.360		9.15		
L1		.050		1.27	
L2		.050		1.27	
ΦP	.141	.145	3.582	3.683	
Q		.600		15.24	
Q1	.040	.060	1.02	1.52	
S	.580	.610	14.74	15.49	1
Z	.100	.120	2.54	3.04	

NOTE: 92CS-14995

1. Position of leads to be measured 0.050 in. (1.27 MM) to 0.055 in. (1.40 MM) below seating plane.

TERMINAL DIAGRAMS

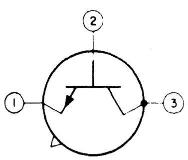
TO-3



Pin 1 – Base
Pin 2 – Emitter
Mounting Flange – Collector, Case

40612 (P-N-P)
40623 (P-N-P)
40626 (P-N-P)
40633
40636

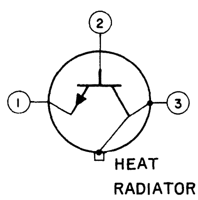
TO-5



Lead 1 – Emitter
Lead 2 – Base
Lead 3 Collector, Case

40594
40595 (P-N-P)
40611
40616
40634 (P-N-P)
40635

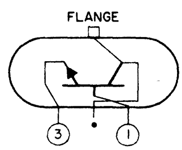
TO-5 WITH HEAT RADIATOR



Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, Heat Radiator

40625
40628

TO-66



Lead 1 - Base
Lead 3 - Emitter
Mounting Flange - Collector
● - Do not use stub as tie point.

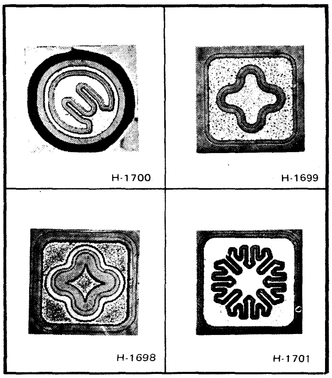
40613	40627
40618	40629
40621	40630
40622	40631
40624	40632

Power-Transistor Chips

RCA
Solid State
Division

Power Transistors

CH3439 CH3440 CH3053 CH2270 CH2102 CH2405 CH4036 CH4037 CH5320 CH5321 CH5322 CH5323



Unmounted and Unencapsulated N-P-N and P-N-P Power Transistor Chips

Features:

- Prepared and tested for use in hybrid circuits
- h_{FE} ratings from 30 to 50 (min.)
- I_{CBO} leakage ratings in the 10 to 50 μA range
- V_{CEO} ratings up to 90 V on planar transistor chips; up to 325 V on passivated mesa types

The five transistor chip families described in this bulletin are selected from the broad line of RCA discrete power transistors. Known also as pellets or dies, these chips represent the essential electronic portion of the transistor. They are especially suited for direct mounting on a heat sink in hybrid circuits. The n-p-n and p-n-p types can be used either singly or in complementary-pair configurations for large-signal, medium-power applications.

Four of the chip families are of the planar construction; two are double-diffused epitaxial p-n-p types, and two are triple-diffused n-p-n types. The fifth chip family is a triple-diffused n-p-n passivated mesa construction. The oxide layer that results from conventional planar processing protects the planar types. The junctions and surfaces of the mesa transistor chips are protected by deposited glass passivated coverings.

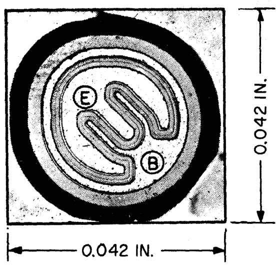
Aluminum has been deposited at the base and emitter electrodes of all the transistor chips for ease of bonding. The base and emitter bonding areas on each chip will accommodate up to a 0.003-inch-diameter wire bond. Either thermo-compression or ultrasonic bonding can be used to attach gold wires to these electrodes; aluminum wires can also be bonded by conventional ultrasonic techniques.

The collector contact, which is on the underside of the chip, has been metallized with gold. The collector can be attached directly to a heat sink by adhesive or gold-silicon or gold-germanium eutectic bonding methods. During mounting of the chip in a circuit, the mounting temperature must not exceed 400°C for a maximum of one minute.

The chips are supplied in plastic containers in quantities of 100 or 400. Each chip is securely held in a recessed partition of the container by a clear plastic cover that also protects the surface from dust and abrasion. For additional protection, the container is sealed in a clear plastic bag. If the sealed shipping container is opened or broken, ruptured, punctured, or damaged in any way, the chips must be stored at a temperature of not more than 40°C and a relative humidity of not more than 50% in a clean, dust-free environment. If the sealed shipping container is damaged on receipt as described above, the product should be immediately returned to RCA.

These unmounted and unencapsulated chips are tested electrically and visually inspected to meet the specifications shown on the following pages. Written notification of non-conformance to such specifications must be made to RCA within 90 days of the date of the shipment by RCA. RCA assumes no responsibility for chips which have been subjected to further processing, such as, but not limited to, lead-bonding or pellet-mounting operations.

RCA has the right to change the chip design and processing without notification.



2N3439 Family

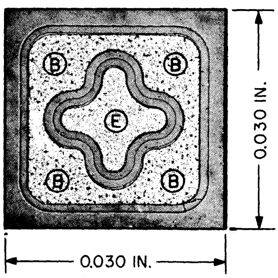
CH3440
CH3439

RCA–CH3440 and CH3439 are passivated mesa n-p-n transistor chips similar to those used in RCA–2N3440 and 2N3439 high-voltage silicon power transistors. Because of their high breakdown voltages, good high-frequency response, and fast switching speeds, these transistor chips can be used in high-voltage differential and operational amplifiers, high-voltage inverters and high-voltage, low-current switching regulators.

(B) Base Bonding Area 0.005 in. diameter (E) Emitter Bonding Area 0.005 in. diameter

ELECTRICAL CHARACTERISTICS, Chip Temperature = 25°C, unless otherwise specified.

Characteristic	Symbol	DC Collector Voltage V		DC Current mA		Limits				Units
						CH3439		CH3440		
		V_{CB}	V_{CE}	I_C	I_E	Min.	Max.	Min.	Max.	
Collector Cut-off Current	I_{CBO}	200					20		50	µA
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.02	5		5		V
Collector-to-Emitter Sustaining Voltage: Base open [a]	$V_{CEO(sus)}$			20		325		250		V
DC Forward-Current Transfer Ratio [b]	h_{FE}		10	20		30		30		



2N2102 Family

CH3053 CH2102
CH2270 CH2405

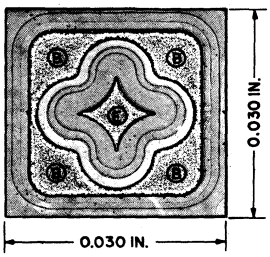
RCA–CH3053, CH2270, CH2102, and CH2405 are triple-diffused n-p-n planar transistor chips similar to RCA–2N3053, 2N2270, 2N2102, and 2N2405 transistors, respectively. They can be used either singly or in complementary-pair configurations with RCA p-n-p chips CH4037 and CH4036 for large-signal, medium-power applications.

(B) 4 Base Bonding Areas 0.008 in. diameter (E) Emitter Bonding Area 0.008 in. diameter

ELECTRICAL CHARACTERISTICS, Chip Temperature = 25°C, unless otherwise specified.

Characteristic	Symbol	DC Collector Voltage V		DC Current mA		Limits								Units
						CH3053		CH2270		CH2102		CH2405		
		V_{CB}	V_{CE}	I_C	I_E	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current	I_{CBO}	60					10		10		10		10	µA
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.01	5		5		5		5		V
Collector-to-Emitter Sustaining Voltage: Base open[a]	$V_{CEO(sus)}$			20		30		45		60		90		V
DC Forward-Current Transfer Ratio[b]	h_{FE}		10	150		50		50		50		50		

[a]CAUTION: This voltage MUST NOT be measured on a curve tracer. [b]Pulse tested; 2% duty factor, less than or equal to 300 µs duration.



2N4036 Family

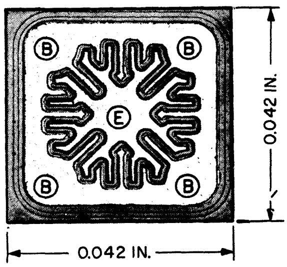
CH4037
CH4036

RCA–CH4037 and CH4036 are double-diffused p-n-p planar transistor chips similar to RCA–2N4037 and 2N4036 transistors. Their high voltage ratings and heat-dissipating ability make them ideal for amplifying large signals at a medium power level. They can be used singly or as complements of RCA n-p-n chips CH3053, CH2270, CH2102, and CH2405.

(B) 4 Base Bonding Areas 0.008 in. diameter (E) Emitter Bonding Area 0.008 in. diameter

ELECTRICAL CHARACTERISTICS, Chip Temperature = 25°C, unless otherwise specified.

Characteristic	Symbol	DC Collector Voltage V		DC Current mA		Limits				Units
						CH4036		CH4037		
		V_{CB}	V_{CE}	I_C	I_E	Min.	Max.	Min.	Max.	
Collector Cut-off Current	I_{CBO}	-60					-10		-10	μA
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				-0.01	-6.5		-6.6		V
Collector-to-Emitter Sustaining Voltage: Base open [a]	$V_{CEO(sus)}$			-20		-65		-40		V
DC Forward-Current Transfer Ratio [b]	h_{FE}		-10	-150		35		35		



2N5320 Family

CH5321
CH5320

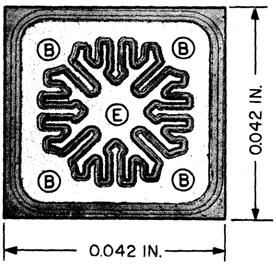
RCA–CH5321 and CH5320 are triple-diffused n-p-n planar transistor chips similar to RCA–2N5321 and 2N5320 transistors. They can be used singly or as complements of RCA p-n-p chips CH5323 and CH5322.

(B) 4 Base Bonding Areas 0.008 in. diameter (E) Emitter Bonding Area 0.008 in. diameter

ELECTRICAL CHARACTERISTICS, Chip Temperature = 25°C, unless otherwise specified.

Characteristic	Symbol	DC Collector Voltage V		DC Current mA		Limits				Units
						CH5320		CH5321		
		V_{CB}	V_{CE}	I_C	I_E	Min.	Max.	Min.	Max.	
Collector Cut-off Current	I_{CBO}	60					10		10	μA
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.01	5		5		V
Collector-to-Emitter Sustaining Voltage: Base open [a]	$V_{CEO(sus)}$			20		80		55		V
DC Forward-Current Transfer Ratio [b]	h_{FE}		10	250		30		30		

[a] CAUTION: This voltage MUST NOT be measured on a curve tracer. [b] Pulse tested; 2% duty factor, less than or equal to 300 μs duration.



2N5323 Family

CH5323
CH5322

RCA–CH5323 and CH5322 are double-diffused p-n-p planar transistor chips similar to RCA–2N5323 and 2N5322 transistors. They can be used singly or as complements of RCA n-p-n chips CH5321 and CH5320 for amplifying large signals at a medium power level.

(B) 4 Base Bonding Areas 0.008 in. diameter (E) Emitter Bonding Area 0.008 in. diameter

ELECTRICAL CHARACTERISTICS, Chip Temperaturre = 25°C, unless otherwise specified.

Characteristic	Symbol	DC Collector Voltage V		DC Current mA		Limits				Units
						CH5322		CH5323		
		V_{CB}	V_{CE}	I_C	I_E	Min.	Max.	Min.	Max.	
Collector Cut-off Current	I_{CBO}	-60					-10		-10	µA
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				-0.01	-5		-5		V
Collector-to-Emitter Sustaining Voltage: Base open [a]	$V_{CEO(sus)}$			-20		-80		-55		V
DC Forward-Current Transfer Ratio [b]	h_{FE}		-10	-250		30		30		

[a]CAUTION: This voltage MUST NOT be measured on a curve tracer. [b]Pulse tested; 2% duty factor, less than or equal to 300 µs duration.

CHIP INSPECTION INFORMATION

Each lot is inspected to a 2.5% AQL (cumulative) according to Mil Std. 105 using 20 times magnification. The following defects determine the inspection criteria:

Foreign matter adhering to the base and emitter bond areas.

Improperly cut pellets that include a portion of another pellet.

Bridging by the metallization which causes a short.

Blistering, lifting or absence of the aluminum metallization.

Fractures or edges within 0.0005 in. of the base collector junction.

Severed base-contact rings that isolate all the bonding pads and most of the base area.

Oxide missing from the junction area.

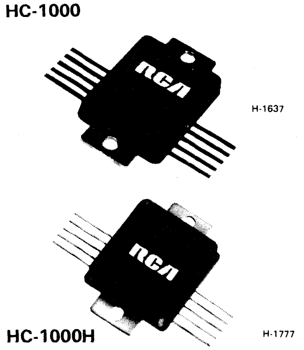
Power Hybrid Circuits

RCA

Solid State Division

Power Hybrid Circuits

HC1000
HC1000H



Multi-Purpose, All-Silicon 7-Ampere Power Amplifiers

Linear Amplifiers for Applications in Industrial and Commercial Equipment

Features:

- **Bandwidth: 30 kHz at 60 W**
- **High power output: up to 100 W(rms)**
- **High output current: 7 A (peak)**
- **Built-in load-line limiting circuit to protect amplifiers from accidentally short-circuited output terminals**
- **Stability with resistive or reactive loads**
- **Reactive-load fault protection**
- **Single or split power supply (30 to 75 V, total)**
- **Provision for gain control**
- **Direct coupling to load**
- **Class B output stage**
- **Rugged package with heavy leads**
- **Light weight: 100 grams**

RCA-HC1000* is a complete solid-state hybrid amplifier in a compact molded-epoxy package. The HC1000H* is electrically identical to the HC1000 but is supplied in a metal hermatic package. The HC1000H is intended for military and critical industrial applications, and can be supplied in accordance with applicable portions of MIL-STD. 883.

Each device employs a quasi-complementary-symmetry class B output circuit with built-in load-fault protection and hometaxial output transistors. The circuit may be operated from a single or split power supply.

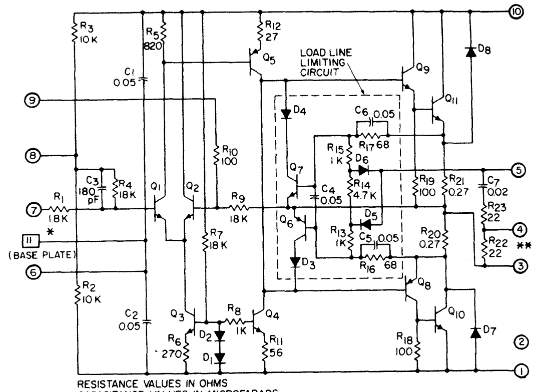
Types HC1000 and HC1000H are recommended for use in servo amplifiers (ac, dc, PWM); deflection amplifiers; power operational amplifiers; audio amplifiers; voltage regulators; and driven inverters.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	HC1000 HC1000H
SUPPLY VOLTAGE:	
Between leads 1 & 10	75 V
OUTPUT CURRENT (Peak)	7 A
TOTAL DISSIPATION:	
Per Output Device	See Fig. 4 & 5
TEMPERATURE RANGE:	
Storage	−55 to +125°C
Output Junction	−55 to +150°C
LEAD TEMPERATURE (During Soldering):	
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.	235°C
LEAD-BENDING RADIUS (Min.)	
At distance ≥ 0.075 in. (1.91 mm) from case	0.04 in. (1.02 mm)

Additional information on the HC1000 is contained in two RCA Application Notes: AN-4483, "General Application Considerations for the RCA HC1000 Hybrid Linear Power Amplifier," and AN-4474, "Audio Applications of the RCA-HC1000 Hybrid Linear Power Amplifier." Single Copies of these publications are available upon request from RCA Solid State Division, Box 3200, Somerville, N.J. 08876.

*Formerly RCA Dev. Nos. TA7625 and TA7626, respectively.



RESISTANCE VALUES IN OHMS
CAPACITANCE VALUES IN MICROFARADS
UNLESS OTHERWISE SPECIFIED
* BASE PLATE/MOUNTING FLANGE; SEE DIMENSIONAL OUTLINE
**CAUTION: THE EXTERNAL DC RESISTANCE BETWEEN LEADS 3 AND 4 MUST BE MAINTAINED AT 0.5Ω OR LESS IN ORDER TO PROTECT R_{22} FROM EXCESSIVE DISSIPATION AND POSSIBLE DAMAGE. CARE SHOULD BE TAKEN TO INSURE GOOD ELECTRICAL CONNECTIONS TO LEADS 3 AND 4

92SS-4514R2

Fig. 1—Schematic diagram of types HC1000 and HC1000H power hybrid circuits.

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS			UNITS
		SUPPLY VOLTAGE (V_S)–V	FREQ. (f)–kHz	OUTPUT POWER (P_O)–W	LOAD RESIST. (R_L)–Ω	MIN.	TYP.	MAX.	
Voltage Gain (See Fig.3)	$\frac{V_{OUT}}{V_{IN}}$	±37.5	1	1	4	28	30	–	–
Input Impedance Measured between leads 7 & 8 (See Fig.3)	Z_{IN}	–	–	–	0	16	18	–	kΩ
Quiescent Current	I_o	±37.5	–	–	–	15	–	30	mA
Offset Voltage Measured between leads 4 & 5 (See Fig.3)	V_{offset}	±37.5	–	–	4	0	±75	±250	mV
Bandwidth (See Figs. 3 & 8)	f_H	±37.5	–	1	4	43	–	–	kHz
Total Harmonic Distortion (See Figs.3 & 9)	THD	±37.5	1	60	4	–	0.4	0.5	%
Short-Circuit Current (See Fig. 11)	I_S	±37.5	1	–	0	2	–	3	A
Signal-to-Noise Ratio Signal source impedance = 600 Ω	S/N	±37.5	–	–	–	–	+78	–	dB
Thermal Resistance Per Output Device (Junction-to-Case) (See Figs. 4 & 5)	$R_{\theta JC}$	–	–	–	–	–	–	2	°C/W

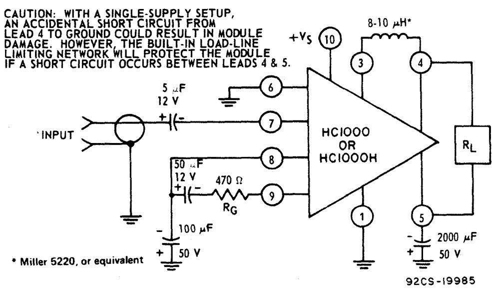


Fig. 2–Type HC1000 or HC1000H power hybrid circuit with external connections for operation with a single power supply.

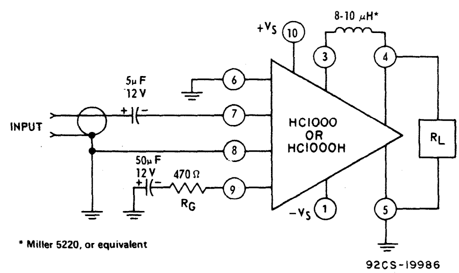


Fig. 3–Type HC1000 or HC1000H power hybrid circuit with external connections (& split power supply) for measuring relative response & distortion; see Figs. 8 & 9.

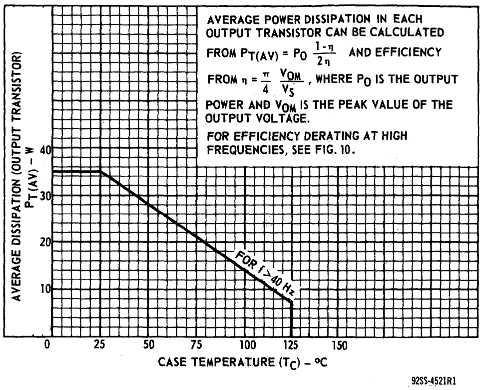


Fig. 4—Dissipation (average) derating curve for each output transistor (for symmetrical waveforms with f > 40 Hz).

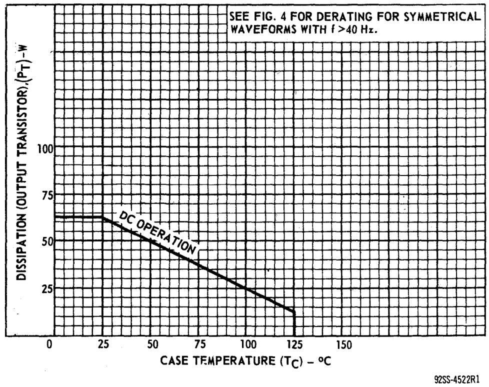


Fig. 5—Dissipation (dc) derating curve for each output transistor.

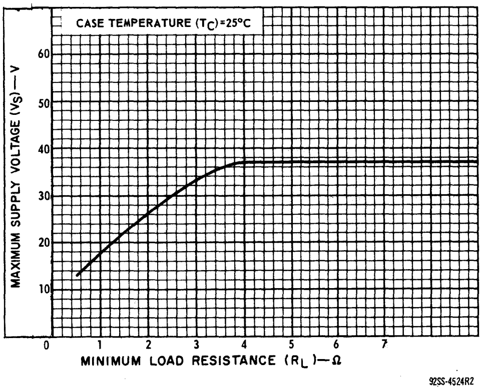


Fig. 6—Maximum allowable supply voltage vs. load resistance.

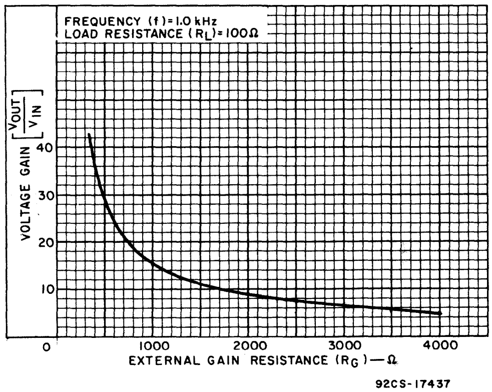


Fig. 7—Voltage gain vs. external gain resistance.

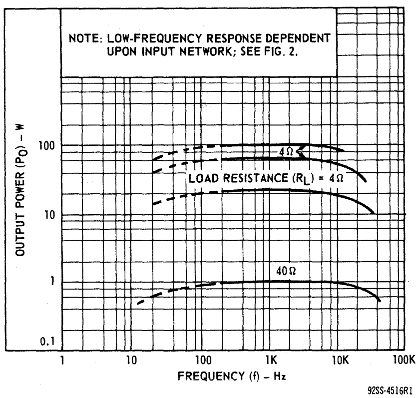


Fig. 8—Output power vs. frequency.

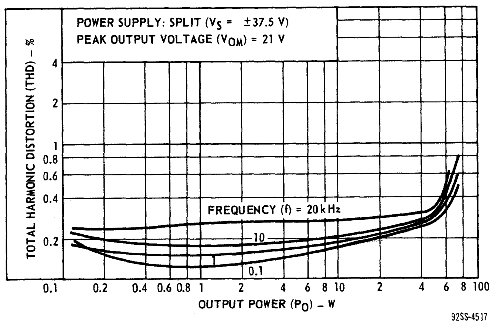


Fig. 9—Total harmonic distortion with split supply.

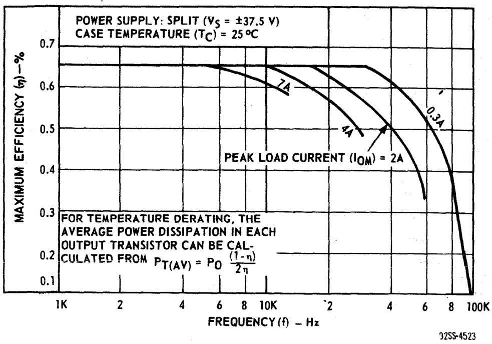


Fig. 10—Maximum efficiency vs. frequency for several values of peak load current.

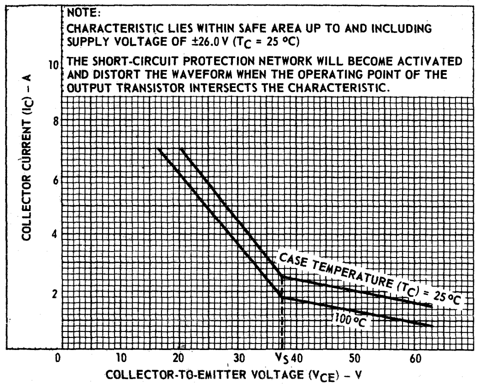


Fig. 11—Characteristics of built-in load-line limiting circuit.

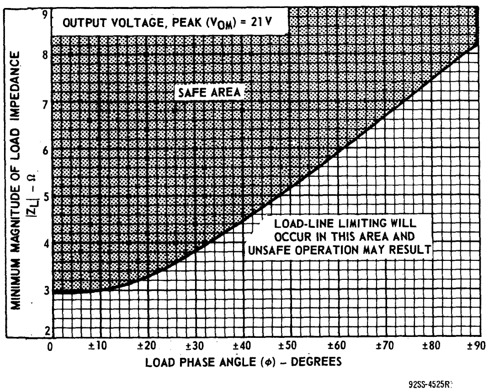


Fig. 12—Minimum load impedance vs. load phase angle and safe area of operation.

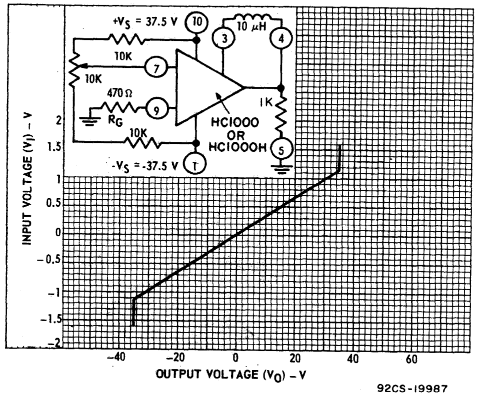


Fig. 13—Gain linearity characteristic.

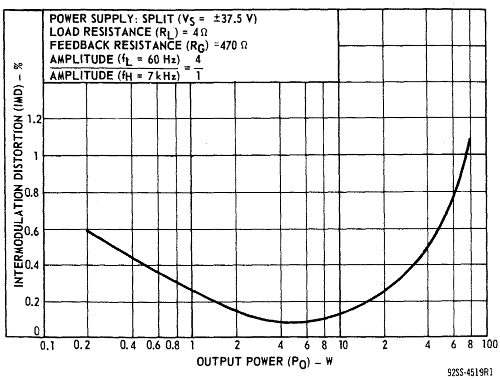


Fig. 14—Intermodulation distortion with split supply and 4-ohm load.

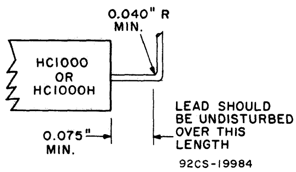
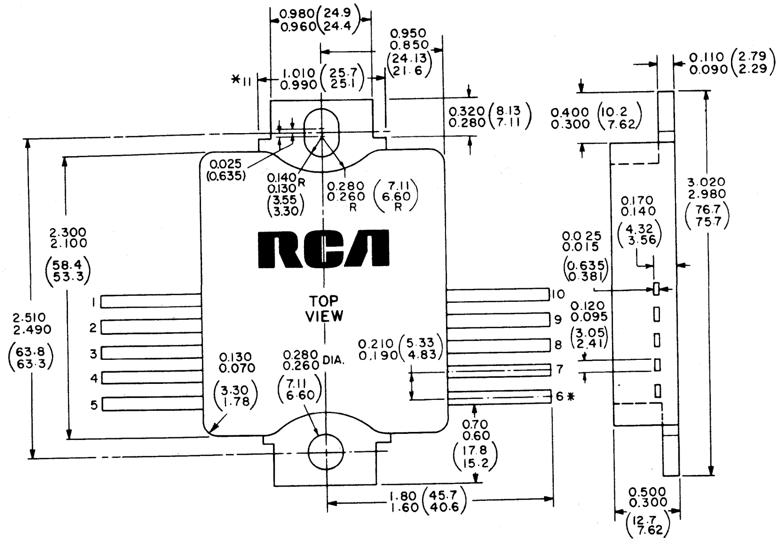


Fig. 15—Recommended lead-bending specification.

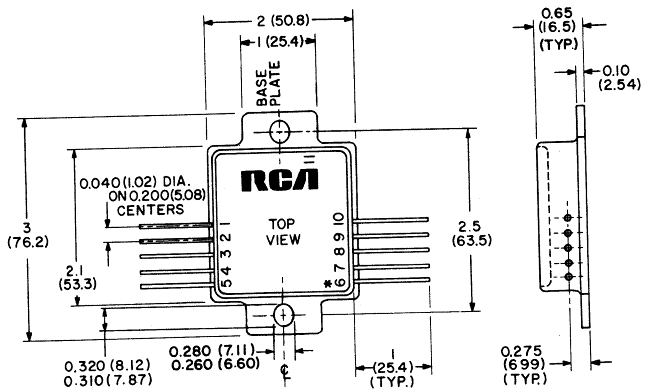
DIMENSIONAL OUTLINE
HC1000



* TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY
DIMENSIONS IN INCHES AND MILLIMETERS
(MILLIMETER VALUES IN PARENTHESES)

92CM-17434R1

DIMENSIONAL OUTLINE
HC1000H



DIMENSIONS IN INCHES AND
MILLIMETERS (VALUES IN PARENTHESES)

92CS-18037R1

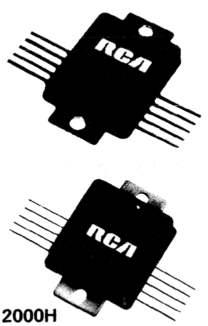
*TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY

RCA
Solid State
Division

Power Hybrid Circuits

HC2000
HC2000H

HC 2000



HC 2000H

Multi-Purpose All-Silicon 7-Ampere Operational Amplifiers

Linear Amplifiers for Applications in Industrial and Commercial Equipment

Features:

- **Bandwidth: 30 kHz at 60 W**
- **High power output: up to 100 W(rms)**
- **High output current: 7 A (peak)**
- **Built-in load-line-limiting circuit to protect amplifiers from accidentally short-circuited output terminals**
- **Stability with resistive or reactive loads**
- **Reactive-load fault protection**
- **Single or split power supply (30 to 75 V, total)**
- **Provision for feedback control**
- **Direct coupling to load**
- **Class B output stage**
- **Rugged package with heavy leads**
- **Light weight: 100 grams**
- **Low crossover distortion**

RCA-HC2000* is a complete solid-state hybrid operational amplifier in a compact molded-epoxy package. Type HC2000H* is electrically identical to the HC2000 but is supplied in a metal hermetic package. The HC2000H is intended for military and critical industrial applications and can be supplied in accordance with applicable portions of MIL-STD. 883.

The devices employ a quasi-complementary-symmetry class B output circuit with built-in load-fault protection and hometaxial output transistors. The circuit may be operated from a single or split power supply.

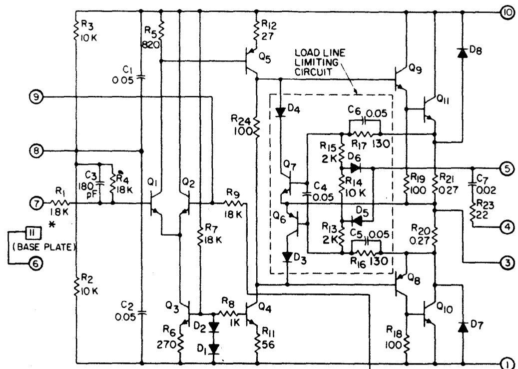
Types HC2000 and HC2000H are recommended for the following applications: servo amplifiers (ac, dc, PWM); deflection amplifiers; power operational amplifiers; audio amplifiers; voltage regulators; and driven inverters.

Additional information on the HC2000 is contained in RCA Application Note AN-4782, "General Application Considerations for the RCA-HC2000 Power Hybrid Operational Amplifier." Single copies of this publication are available upon request from RCA Solid State Division, Box 3200, Somerville, N.J. 08876.

*Formerly RCA Dev. Nos.TA7625A and TA7626A, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	HC 2000 HC 2000H
SUPPLY VOLTAGE:	
Between leads 1 & 10	75 V
OUTPUT CURRENT (Peak)	7 A
TOTAL DISSIPATION:	
Per Output Device	See Fig. 4 & 5
TEMPERATURE RANGE:	
Storage	−55 to +125°C
Output Junction	−55 to +150°C
LEAD TEMPERATURE (During Soldering):	
At distance ≥ 1/8 in. (3.17 mm) from case for 10 s max.	235°C
LEAD-BENDING RADIUS (Min.)	
At distance ≥ 0.075 (1.91 mm) from case	0.04 in. (1.02 mm)



RESISTANCE VALUES IN OHMS
CAPACITANCE VALUES IN MICROFARADS
UNLESS OTHERWISE SPECIFIED
* BASE PLATE/MOUNTING FLANGE; SEE DIMENSIONAL OUTLINE

92CS-17574R1

Fig. 1—Schematic diagram of types HC2000 and HC2000H power hybrid circuit operational amplifiers.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS			UNITS
		SUPPLY VOLTAGE (V_S)–V	FREQ. (f)–kHz	OUTPUT POWER (P_O)–W	LOAD RESIST. (R_L)–Ω	MIN.	TYP.	MAX.	
Open-Loop Voltage Gain	$\frac{V_{OUT}}{V_{IN}}$	±37.5	4	25	4	4k	5k	–	–
Closed-Loop Voltage Gain (See Fig. 3)	$\frac{V_{OUT}}{V_{IN}}$	±37.5	1	1	4	26	30	–	–
Input Impedance Measured between leads 7 & 8 (See Fig. 3)	Z_{IN}	–	–	–	0	16	18	–	kΩ
Quiescent Current	I_o	±37.5	–	–	–	15	–	30	mA
Initial Offset Voltage Measured between leads 4 & 5 (See Fig. 3)	V_{offset}	±37.5	–	–	4	0	±30	±250	mV
Offset Voltage Drift with Temperature	$\Delta V_{offset}/\Delta T$	±37.5	–	–	4	0.5	–	0.7	mV/°C
Bandwidth (See Figs. 3 & 8)	f_H	±37.5	–	1	4	43	–	–	kHz
Total Harmonic Distortion (See Figs. 3 & 9)	THD	±37.5	1	60	4	–	0.4	0.5	%
Short-Circuit Current (See Fig. 11)	I_S	±37.5	1	–	0	2	–	3	A
Signal-to-Noise Ratio Signal Source Impedance = 600 Ω	S/N	±37.5	–	–	–	–	+78	–	dB
Slew Rate	SR	±37.5	1	100	4	–	25	50	V/μs
Thermal Resistance Per Output Device (Junction-to-Case) (See Figs. 4 & 5)	$R_{\theta J\text{-}C}$	–	–	–	–	–	–	2	°C/W

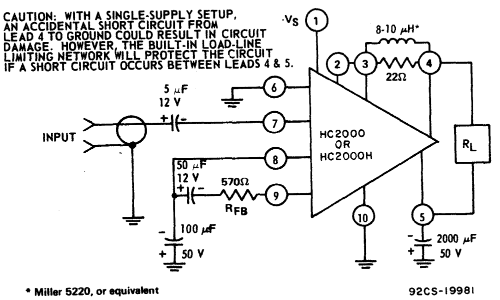


Fig. 2—Type HC2000 or HC2000H power hybrid circuit with external connections for operation with a single power supply.

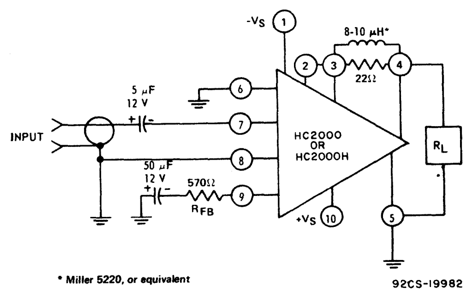


Fig. 3—Type HC2000 or HC2000H power hybrid circuit with external connections (and split power supply) for measuring relative response and distortion; see Figs. 8 & 9.

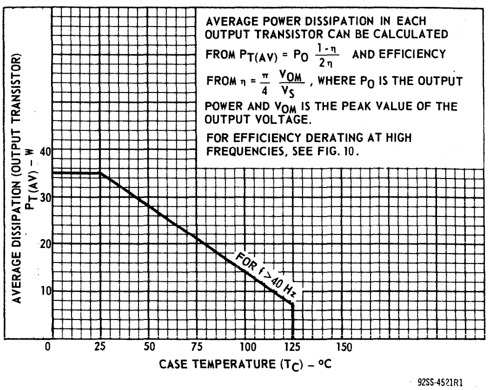


Fig. 4—Dissipation (average) derating curve for each output transistor (for symmetrical waveforms with f > 40 Hz).

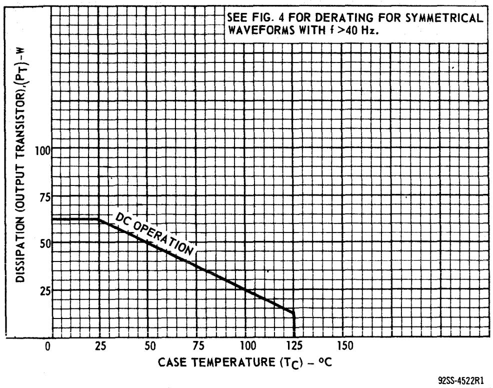


Fig. 5—Dissipation (dc) derating curve for each output transistor.

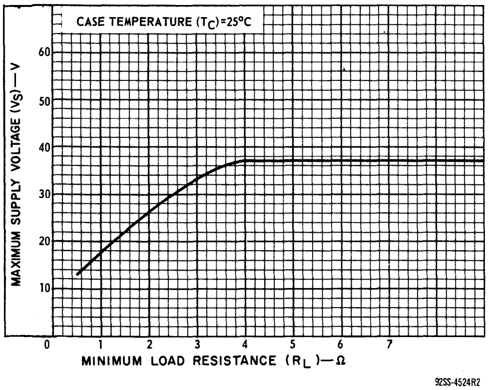


Fig. 6—Maximum allowable supply voltage vs. load resistance.

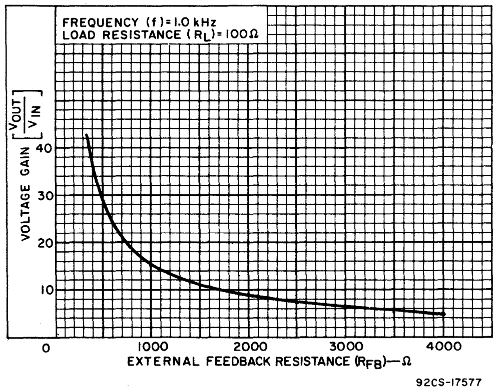


Fig. 7—Closed-loop voltage gain vs. external feedback resistance.

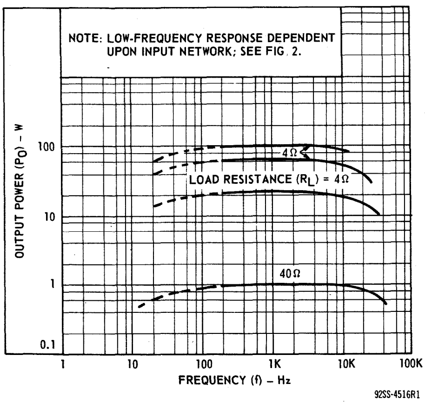


Fig. 8—Output power vs. frequency.

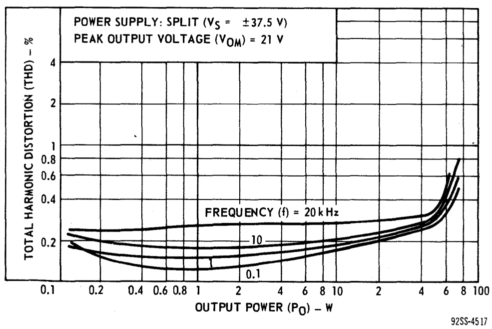


Fig. 9—Total harmonic distortion with split power supply.

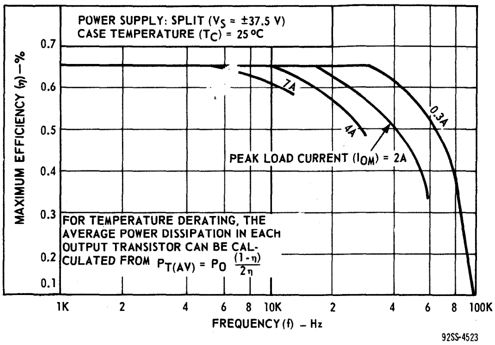


Fig. 10—Maximum efficiency vs. frequency for several values of peak load current.

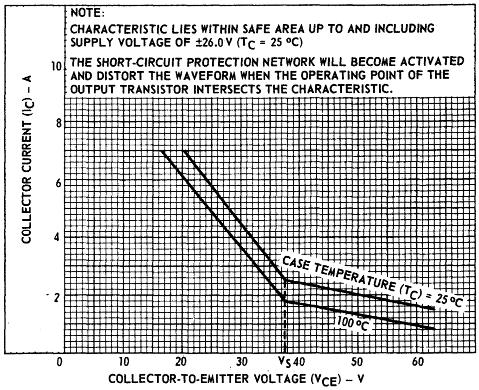


Fig. 11—Characteristics of built-in load-line-limiting circuit.

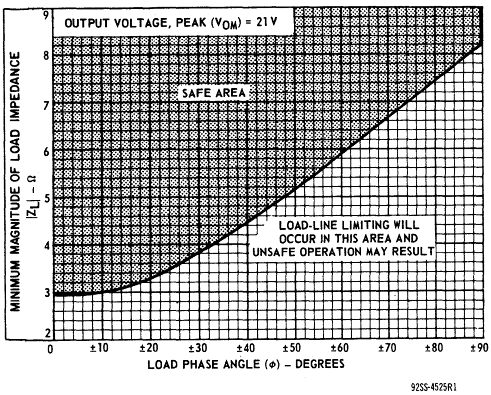


Fig. 12—Minimum load impedance vs. load phase angle and safe area of operation.

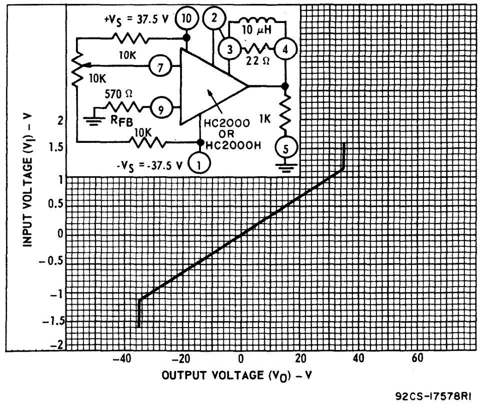


Fig. 13—Gain linearity characteristic.

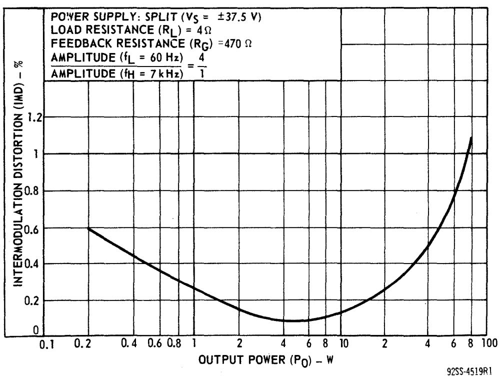


Fig. 14—Intermodulation distortion with split supply and 4-ohm load.

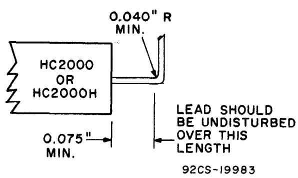
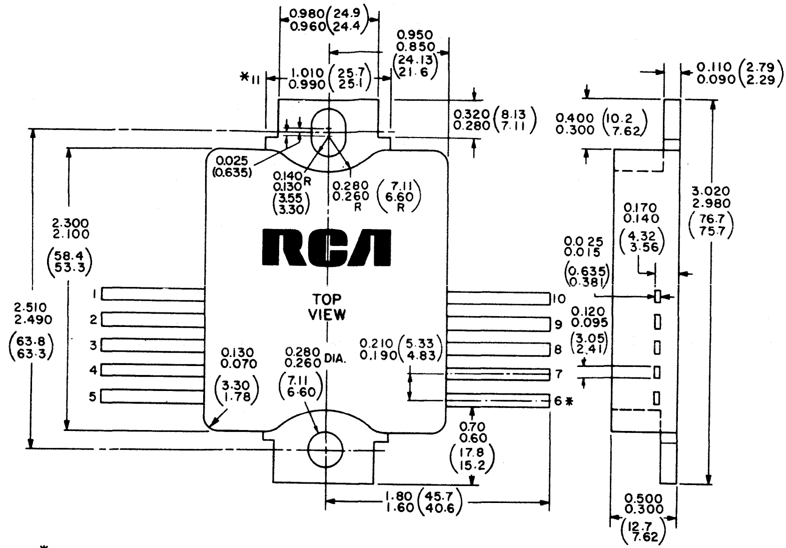


Fig. 15—Recommended lead-bending specification.

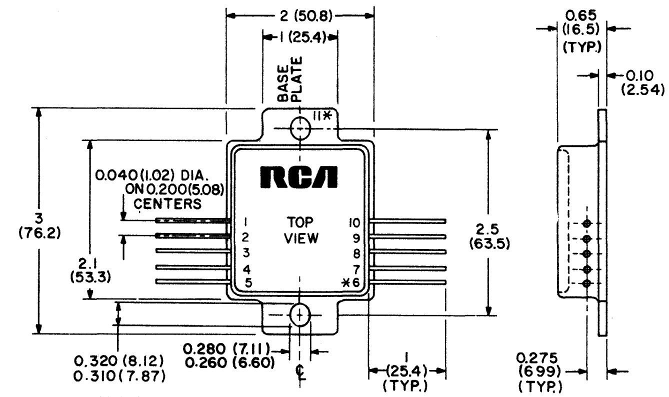
DIMENSIONAL OUTLINE
HC2000



* TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY
DIMENSIONS IN INCHES AND MILLIMETERS
(MILLIMETER VALUES IN PARENTHESES)

92CM-17434RI

DIMENSIONAL OUTLINE
HC2000H



DIMENSIONS IN INCHES AND
MILLIMETERS (VALUES IN PARENTHESES)

92CS-18037R2

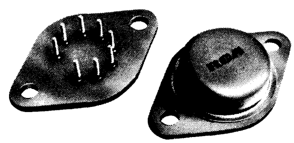
*TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY

RCA

Solid State
Division

Power Hybrid Circuits

HC3000



8-PIN "TO-3"

H-1710

High-Gain Current-Amplifier Pair

Two Darlington Circuits for Driving Inductive Loads

Features:

- **Two isolated Darlington circuits**
- **High current gain: 500 (min.) for 5-A load**
  600 (min.) for 3-A load
- **Integral diodes for commutating inductive loads**
- **For operation from power supplies up to 70 V**
- **8-pin TO-3 hermetic package**
- **All elements isolated from case**
- **Rugged hometaxial-base output transistors**
- **Thick-film base-emitter resistors**

RCA–HC3000* is a power hybrid device containing two Darlington circuits in a compact 8-pin TO-3 hermetic package. It is ideally suited for driving inductive loads, and integral diodes are included for load-current commutation.

*Formerly RCA Dev. No. TA8141.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

Per Darlington Circuit

Supply Voltage	70	V
Peak Current	10	A
Power Dissipation (at T_C = 25°C)	20	W

Temperature Range:

Storage	-45 to +125°C
Operating (Junction)	-45 to +150°C

Per Commutating Diode

Peak Forward Current (at T_C = 25°C)	10	A

APPLICATIONS:

- Hammer driver
- Solenoid driver
- Stepper-motor driver
- Regulators
- Amplifiers

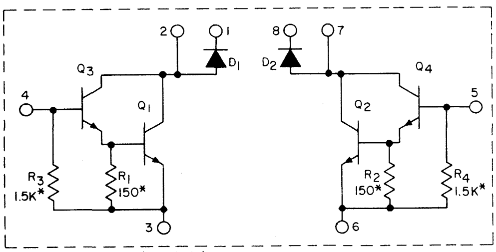


Fig. 1—Schematic diagram of type HC3000 power hybrid circuit.

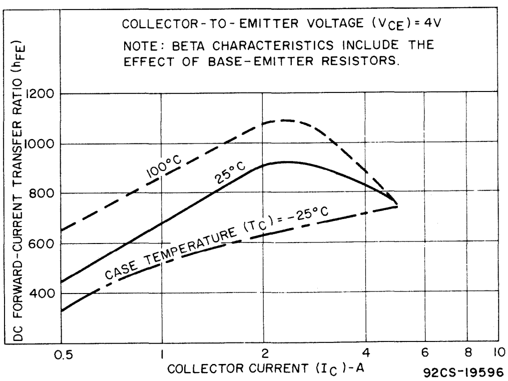


Fig. 2—Typical dc beta vs. collector current for each Darlington circuit.

ELECTRICAL CHARACTERISTICS (Each Darlington Circuit*), at Case Temperature (T_C) = 25°C

CHARACTERISTIC*	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V)	TEST CONDITIONS: DC CURRENT (A)		LIMITS		UNITS
		V_{CE}	I_C	I_B	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}	70				5.0	mA
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$		0.2[a]		70		V
Emitter-to-Base Breakdown Voltage: With collector open	$V_{(BR)EBO}$			0.005	5.0		V
Base-to-Emitter Voltage During conduction	$V_{BE}(ON)$	4	3.0			2.2	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(SAT)$		3.0	0.006		1.7	V
DC Forward–Current Transfer Ratio	h_{FE}	2 4	3.0 5.0		600 500		
Power-Rating Test	PRT	10.0	2.0		1		s
Switching Times: Turn-on ($t_d + t_r$)	t_{on}		3.0	0.006 (I_{B1})		5	μs
Turn-off ($t_s + t_f$) See Fig. 3.	t_{off}		3.0	-0.006 (I_{B2})		20	μs
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$					6.0	°C/W
Commutating Diode: Leakage Current	I_R	V_R = 100 V				0.3	mA
Forward Voltage Drop	V_F	I_F = 2.5 A				2.2	V

*"Base", "emitter", and "collector" are elements of an equivalent transistor with the following terminal connections:

Base — Terminal No. 4(5)
Emitter — Terminal No. 3(6)
Collector — Terminal No. 2(7)

[a]Pulse test: pulse duration = 300 μs; duty factor = 1.8%.

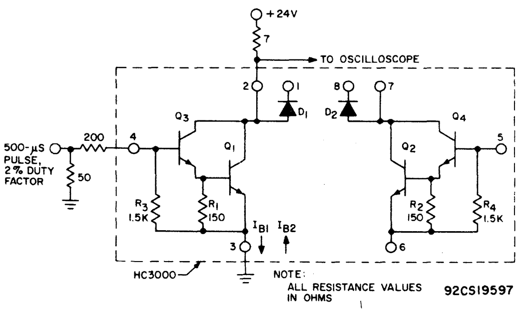


Fig. 3—Test circuit for measurement of switching times.

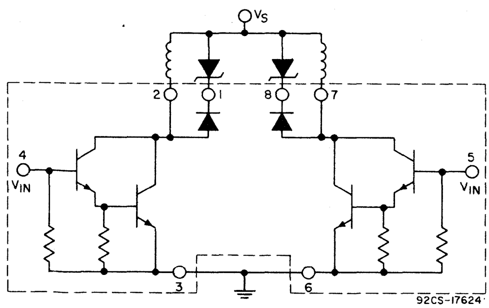


Fig. 4—Type HC3000 in a typical hammer-driver application.

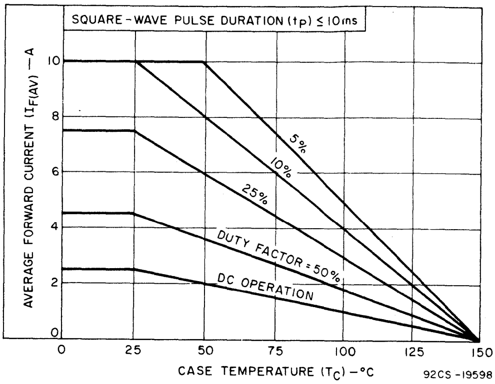


Fig. 5—Current derating curves for each commutating diode.

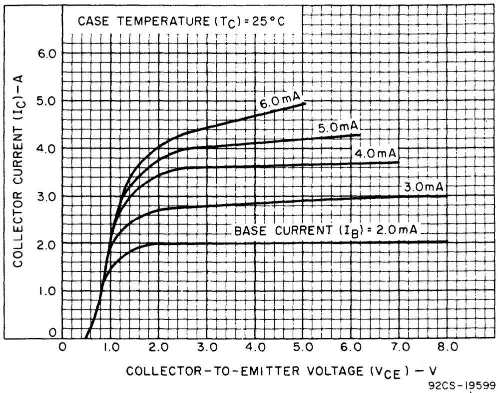


Fig. 6—Typical output characteristics of each Darlington circuit.

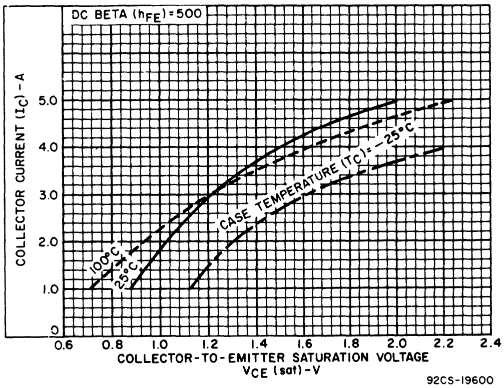


Fig. 7—Typical saturation-voltage characteristics of each Darlington circuit.

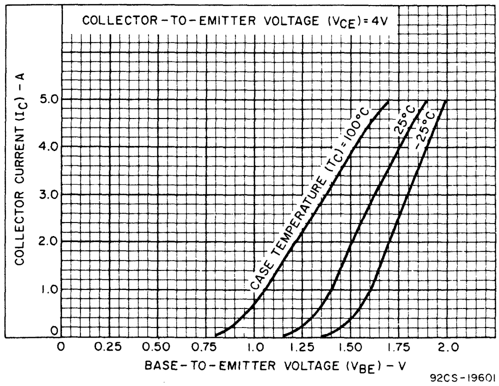


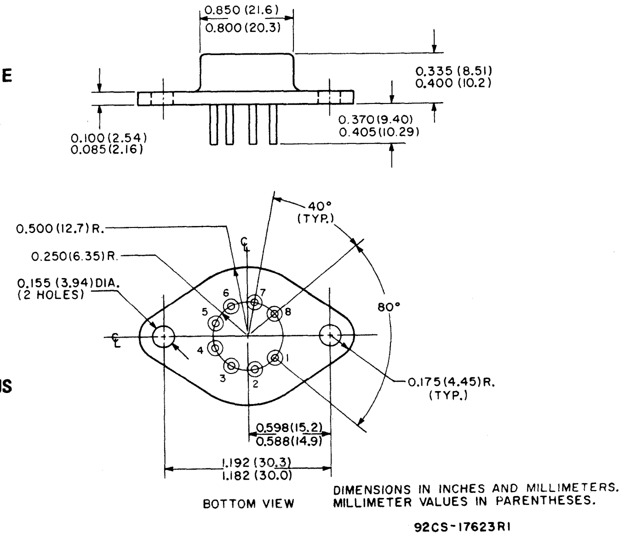
Fig. 8—Typical transfer characteristics of each Darlington circuit.

DIMENSIONAL OUTLINE

TERMINAL CONNECTIONS

See Fig. 1.

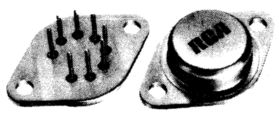
Socket:
RCA DF-263A



RCA
Solid State
Division

Power Hybrid Circuits

HC3100



H-1776

High-Gain, High-Voltage Current-Amplifier Pair

Two Darlington Circuits for
Driving Inductive Loads

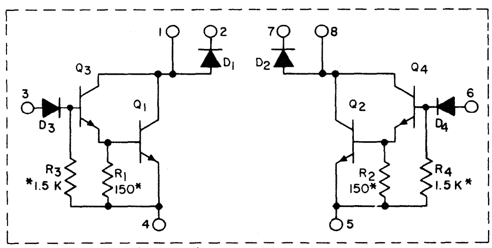
Features:

- Operation from power supplies up to 120V
- Protective diodes for logic drive circuit
- Two isolated Darlington circuits
- Integral diodes for commutating inductive loads
- High current gain:
  650 (Min.) for 2-A loads
- 8-pin "TO-3" hermetic package
- Rugged hometaxial-base output transistors
- Thick-film, base-emitter resistors
- All elements isolated from case

RCA type HC3100 contains two Darlington circuits in a compact, 8-pin TO-3 hermetic package. The output devices, Q_1 and Q_2, are similar to the JEDEC 2N3442; the drivers are similar to RCA 40349 transistors. Both circuits are electrically isolated from the package so that the chassis can be used as a heat sink. The HC3100 is ideally suited for driving inductive loads. Integral diodes (D_1, D_2) are included for load-current commutation.

APPLICATIONS:

- Hammer driver
- Solenoid driver
- Stepper-motor driver
- Regulators



* NOMINAL VALUE (IN OHMS)

92CS-19933

Fig. 1—Schematic diagram of the HC3100.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

Per Darlington Circuit		
Supply Voltage	120	V
Peak Current	10	A
Power Dissipation, at case temperature (T_C) = 25°C	20	W
Temperature Range:		
Storage	−45 to +125	°C
Operating (Junction)	−45 to +150	°C

ELECTRICAL CHARACTERISTICS FOR EACH DARLINGTON CIRCUIT*, *at Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE—V	TEST CONDITIONS: DC CURRENT A		LIMITS		UNITS
		V_{CE}	I_C	I_B	MIN.	MAX.	
Collector-Cutoff Current: With base open	I_{CEO}	120			–	5	mA
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$		0.2[a]		120	–	V
Emitter-to-Base Cutoff Current: With collector open	I_{EBO}	120			–	0.3	mA
Base-to-Emitter Voltage During Conduction	$V_{BE(ON)}$	4	2		–	2.8	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$		2	0.004	–	1.7	V
DC Forward Current Transfer Ratio	h_{FE}	2	2		650	–	
Power-Rating Test	PRT	10	2		1	–	s
Saturated Switching Times: Turn-on ($t_d + t_r$)	t_{on}		2	0.004 (I_{B1})	–	8	μs
Turn-off ($t_s + t_f$)	t_{off}		2	–0.004 (I_{B2})	–	28	μs
Thermal Resistance Junction-to-case	$R_{\theta JC}$				–	6	°C/W
Commutating-Diode Leakage Current	I_R	120 (V_R)			–	0.3	mA
Commutating-Diode Forward Voltage Drop	V_F		2.5		–	2.2	V

*"Base," "emitter," and "collector" are elements of an equivalent transistor with the following terminal connections:

Base — Terminal Nos. 3 and/or 6

Emitter — Terminal Nos. 4 and/or 5

Collector — Terminal Nos. 1 and/or 8

[a]Pulsed: pulse duration = 300 μs; duty factor = 1.8%

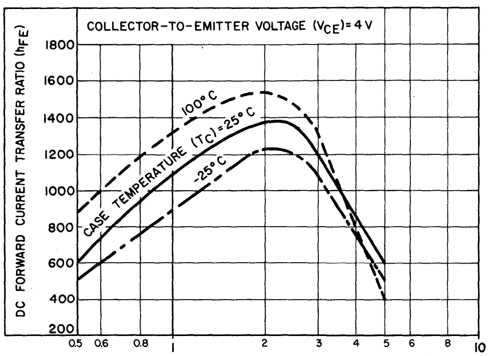


Fig. 2—Typical dc-beta characteristics.

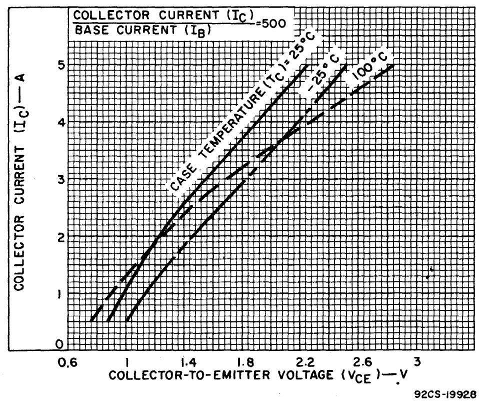


Fig. 3—Typical saturation-voltage characteristics.

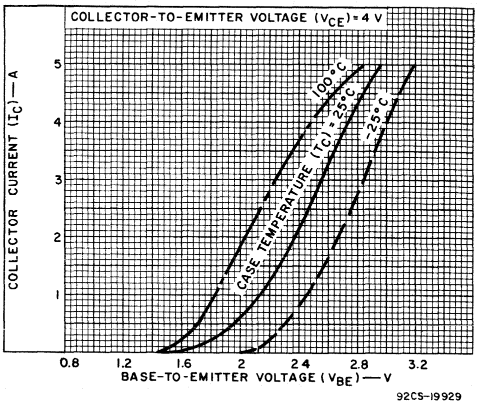


Fig. 4—Typical transfer characteristics.

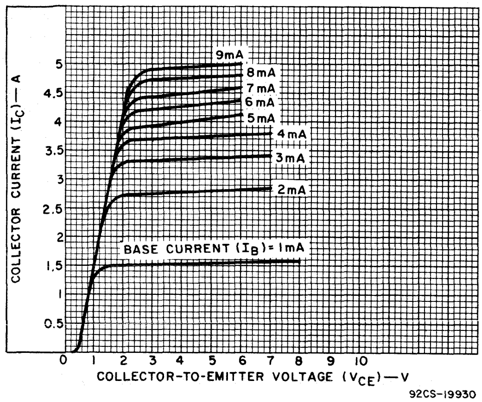


Fig. 5—Typical output characteristics.

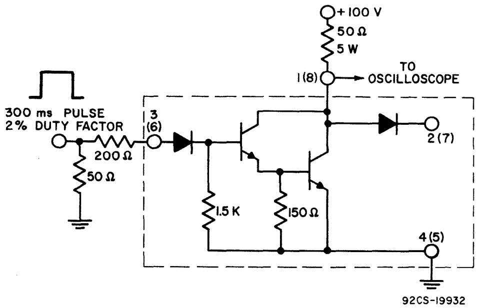


Fig. 6—Test circuit for measurement of switching time.

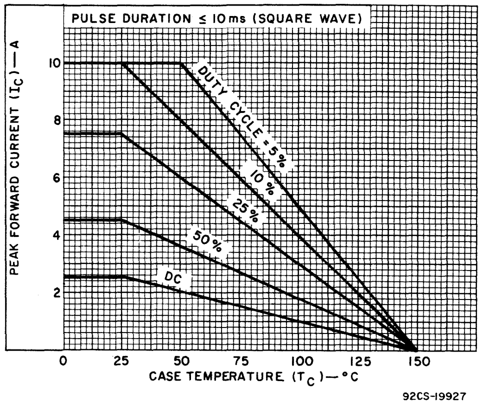


Fig. 7—Average forward-current derating curve for commutating diode.

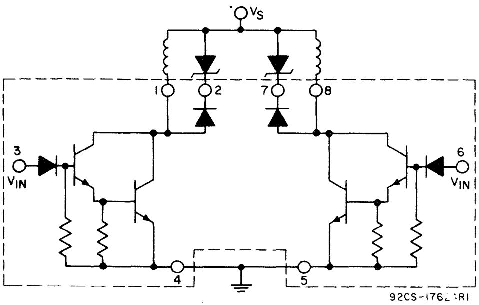
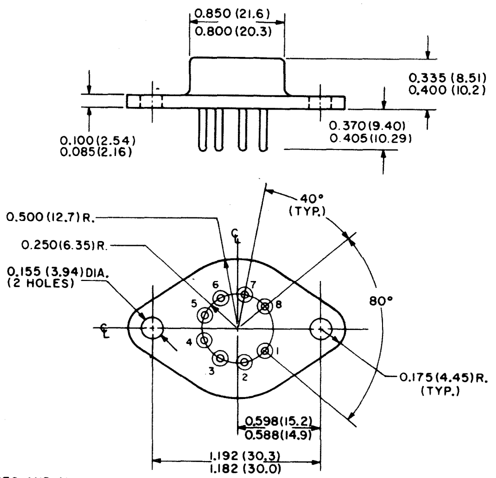


Fig. 8—Type HC3100 in a typical hammer-driver application.

TERMINAL CONNECTIONS

See Fig. 1.

Socket:
RCA DF-263A

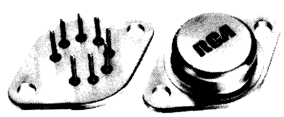


DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

BOTTOM VIEW 92CS-17623R1

RCA
Solid State
Division

Packaged Circuit Functions
HC4005, HC4012, HC4015
HC4005A, HC4012A, HC4015A



"8-Pin TO-3" H-1776

5-, 12-, & 15-Volt High-Current Series Voltage Regulators

Power Hybrid Modules Employing Integrated-Circuit Voltage Regulator and Hometaxial-Base Pass Transistor

Features:

- **4-A current rating**
- **Internal emitter-ballast resistors for external booster transistors for increased regulated-current capability (to 12 A)**
- **Remote sensing capability**
- **40-V line-voltage capability**
- **Internal foldback-protection circuit**
- **Terminal connection for external adjustment of foldback characteristic**
- **Crowbar trigger circuit**
- **Total regulation: ±1% – HC4005A, HC4012A, HC4015A**
  ±3% – HC4005, HC4012, HC4015
- **Rugged hometaxial-base pass transistor**
- **Dissipation: 62.5 watts (pass transistor)**
- **Terminal connection to permit connection of regulator as a Darlington driver for external transistor(s) to increase current-handling capability (to 100 A)**
- **"8-pin TO-3" hermetic package**

RCA HC4005, HC4005A, HC4012, HC4012A, HC4015, and HC4015A* are complete solid-state hybrid series voltage regulators in compact hermetic packages. They have output-voltage ratings of 5, 12, and 15 volts, respectively. The HC4005, HC4012, and HC4015 provide voltage regulation within ±3%; the "A" versions provide regulation of ±1%.

The HC4000 series of hybrid circuits is intended for voltage-regulator applications with load currents up to 4.0 amperes. With two external booster transistors, these circuits can regulate voltage for load currents up to 12 amperes (see Fig. 9). For load currents greater than 12 amperes, additional current-handling capability can be provided by employing the regulator as a Darlington driver (see Figs. 10 and 11).

*Formerly RCA Dev. Nos. TA7955, TA7957, and TA8397, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

UNREGULATED INPUT VOLTAGE	40	V
REGULATED CURRENT (PASS TRANSISTOR, Q_4)	4.8	A
POWER DISSIPATION (PASS TRANSISTOR, Q_4):		
At case temperature of 25°C	62.5	W
At case temperature above 25°C, see Fig. 3.		
POWER DISSIPATION (DRIVER TRANSISTOR, Q_2):		
(Due to external drive current)		
At case temperature of 25°C	7	W
At case temperature above 25°C, see Fig. 4.		
EXTERNAL DRIVE CURRENT (FROM TERMINAL 8)	550	mA
TEMPERATURE RANGE:		
Storage	–45 to 125	°C
Operating (Junction)	–45 to 150	°C
PIN TEMPERATURE (DURING SOLDERING):		
At distance ≥ 1/16 in. (1.59 mm) from case for 10 s max.	220	°C
(T_C = 150°C Max.)		

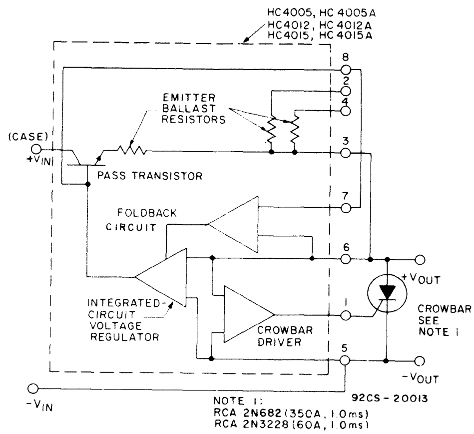
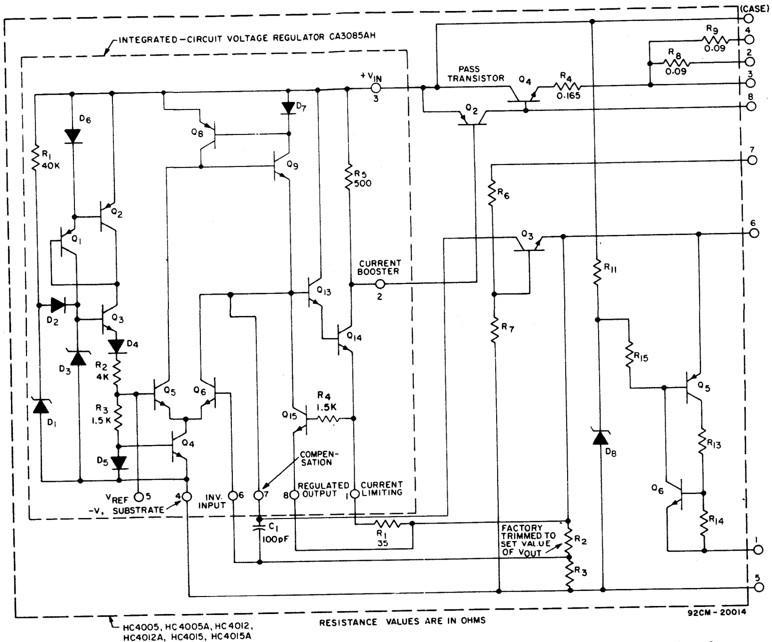


Fig. 1–Type HC4005, HC4005A, HC4012, HC4012A, HC4015, or HC4015A connected as a 4-A series regulator.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		LIMITS MIN.	LIMITS TYP.	LIMITS MAX.	UNITS
INPUT VOLTAGE RANGE	V_{IN}			7.5	–	40	V
INPUT-OUTPUT VOLTAGE DIFFERENTIAL (See Fig. 6)	$V_{IN}-V_{OUT}$	I_{LOAD} = 4A		4.0	–	–	V
FOLDBACK CURRENT (See Fig. 5)	$I_{F.B.}$			4.1	–	4.8	A
SHORT-CIRCUIT FOLDBACK CURRENT (See Fig. 5)	$I_{S.C.}$			–	–	2.0	A
OUTPUT VOLTAGE	V_{OUT}	$V_{IN} = V_{NOM}$ = 11.5V, HC4005, HC4005A		–	5	–	V
		$V_{IN} = V_{NOM}$ = 18.2V, HC4012, HC4012A		–	12	–	V
		$V_{IN} = V_{NOM}$ = 21.7V, HC4015, HC4015A		–	15	–	V
LOAD REGULATION		I_{LOAD} = 0.1 to 4A, $V_{IN} = V_{NOM}$	HC4005, HC4012, HC4015	–	–	± 0.6	$\%V_{OUT}$
			HC4005A, HC4012A, HC4015A	–	–	± 0.3	$\%V_{OUT}$
LINE REGULATION		I_{LOAD} = 1A, V_{IN} = ±15% V_{NOM}	HC4005, HC4012, HC4015	–	–	± 0.6	$\%V_{OUT}$
			HC4005A, HC4012A, HC4015A	–	–	± 0.3	$\%V_{OUT}$
TOTAL REGULATION INCLUDING LINE AND LOAD REGULATION, ACCURACY, OUTPUT-VOLTAGE STABILITY AND CASE-TEMPERATURE VARIATION FROM –45°C TO +100°C		I_{LOAD} = 0.1 to 4A	HC4005, HC4012, HC4015	–	–	± 3.0	$\%V_{OUT}$
			HC4005A, HC4012A, HC4015A	–	–	± 1.0	$\%V_{OUT}$
EQUIVALENT NOISE OUTPUT VOLTAGE	V_{NOISE}			–	–	0.5	mV p-p
RIPPLE REJECTION RATIO	$\frac{V_{IN(AC)}}{V_{OUT(AC)}}$	I_{LOAD} = 500 mA, $V_{IN(AC)}$ = 1.0 V(p-p), f = 120 Hz		175	–	–	
TEMPERATURE COEFFICIENT OF OUTPUT VOLTAGE	ΔV_o	T_C = –45°C to + 100°C, I_{LOAD} = 100 mA		–	0.0035	–	%/°C
TEMPERATURE COEFFICIENT OF FOLDBACK CURRENT	$\Delta I_{F.B.}$	T_C = –45°C to + 125°C		–	–4.3	–	mA/°C
CROWBAR TRIP VOLTAGE (See Fig. 8)	V_{CB}	T_C = –45°C to +125°C	V_{OUT} = 5.0V	5.75	–	7.00	V
			V_{OUT} = 12.0V	13.9	–	17.3	V
			V_{OUT} = 15.0V	16.6	–	20.6	V
CROWBAR CURRENT (ON) (See Fig. 8)	I_{CB}	Max. "On-Time" = 1.0s		100	–	350	mA
LOAD TRANSIENT RECOVERY TIME (See Fig. 12)	t_R	1-A STEP		–	10	–	μs
OUTPUT-VOLTAGE STABILITY		P_D = 10W, $R_{\theta CA}$ = 2.0° C/W		–	–	± 0.1	$\%V_{OUT}$
FOLDBACK RESPONSE TIME				–	–	50	μs



TYPE	V_{OUT}	R_6	R_7	R_3	R_{11}	R_{15}	R_{13}	R_{14}	D_8
HC4005/A	5.0	760	4.2K	2.2K	1.4K	1K	1K	4K	5.6V
HC4012/A	12.0	1.3K	17K	1150	2.0K	1K	2.7K	1.6K	15.0V
HC4015/A	15.0	1.1K	17K	1150	2.0K	1K	3.7K	1.6K	17.0V

A complete description of these circuits and their operation is contained in RCA Application Note AN-6026, "Application Considerations for Hybrid Series Voltage Regulators". Single copies of this publication are available upon request from RCA Solid State Division, Box 3200, Somerville, N. J. 08876.

Fig. 2—Schematic diagram of HC4000-type series voltage-regulator hybrid circuits.

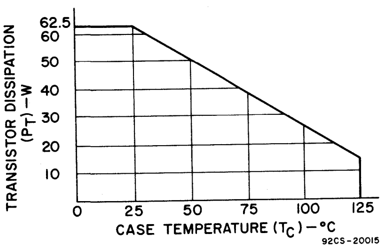


Fig. 3—Allowable power dissipation in pass transistor Q_4.

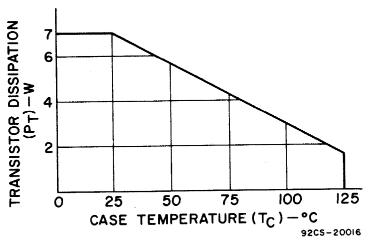


Fig.4 — Allowable power dissipatior in driver transistor Q_2 (due to external drive current).

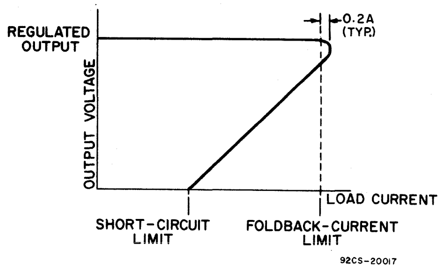


Fig. 5—Typical foldback characteristic for all types.

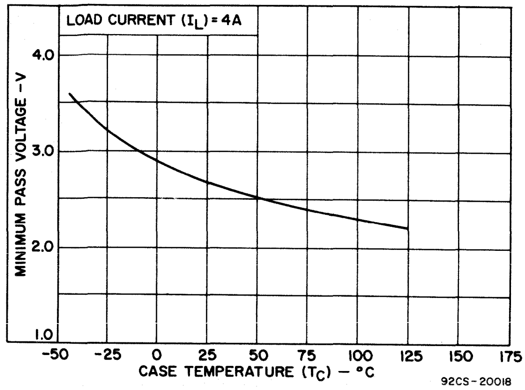


Fig. 6—Typical input-output voltage differential vs. case temperature.

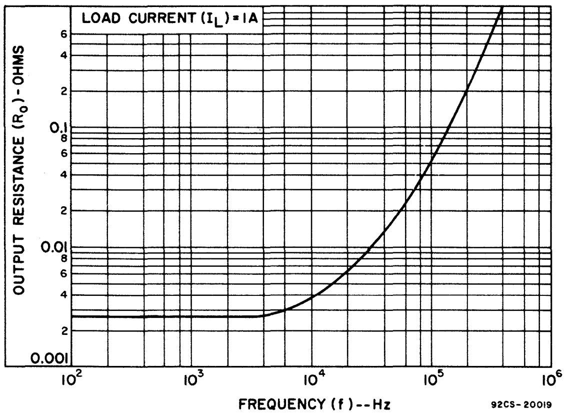


Fig. 7—Output resistance vs. frequency.

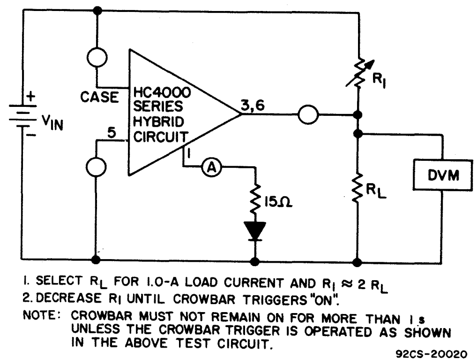


Fig. 8—Crowbar test circuit.

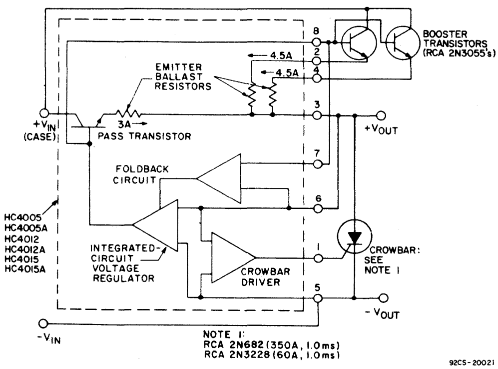


Fig. 9—HC4000-series module connected as a 12-A series regulator.

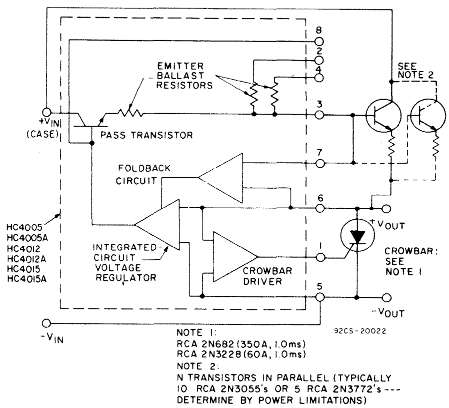


Fig. 10—HC4000-series module connected as a 40-A series regulator.

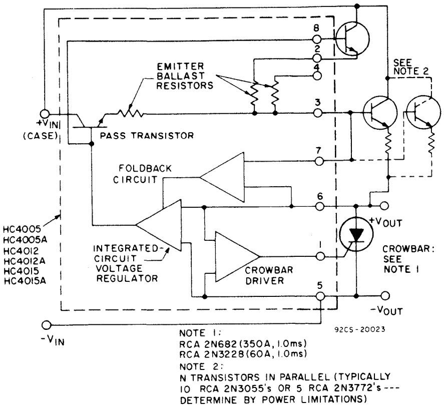


Fig. 11—HC4000-series module connected as a 100-A series regulator.

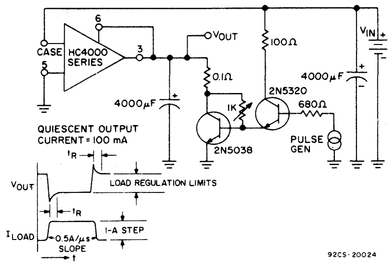
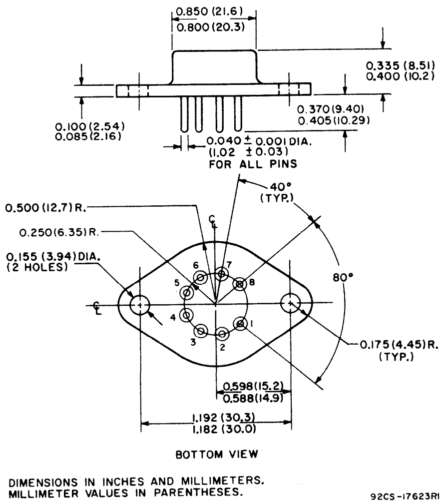


Fig. 12—Recovery-time test circuit with associated waveforms.

HANDLING CONSIDERATIONS

1. The leads of the 8-lead package should not be bent more than 15° from their centerline, nor with a radius of curvature less than 10 diameters at any point.
2. Leads should not be sheared closer than 0.150-inch from the seating plane.
3. Leads should be sheared after attachment whenever possible. When leads must be sheared before mounting, they should be passed through a hardened die of thickness determined by (2) above. This die should constrain each lead from lateral and axial deflection during shearing.

DIMENSIONAL OUTLINE



TERMINAL CONNECTIONS

See Fig. 1.

Mica Insulating Spacer: RCA Part No. 495320-2
Socket: Electronic Essentials Part No. RCA-DF-263A
Electronic Essentials, Inc.
49 Bleecker St., N.Y., N.Y. 10012

Types Not Recommended for New Equipment Design

RCA

Solid State Division

Solid State Devices

Types Not Recommended for New Equipment Design

This bulletin gives basic data for RCA transistors not recommended for new equipment design. These devices are no longer being manufactured by RCA and are available only to the extent of limited inventory.

RCA Type No.	Mate-rial	Pkg.	V_{CE}(sat)• or V_{CEO} max. V	P_T max. W	f_T min. MHz	h_{FE} or h_{fe}* min.	Term. See Pg. 2 Lead 1 2 3 4
2N176	Ge	TO-3	-30	10	–	65	B E C –
2N217	Ge	TO-1	-18	0.16	–	50	E B C –
2N274	Ge	TO-44	–	0.12	–	20*	E B C x
2N351	Ge	TO-3	-30	10	–	65	B E C –
2N376	Ge	TO-3	-50	10	–	78	B E C –
2N404	Ge	TO-5	-0.15•	0.15	4	20	E B C –
2N414	Ge	TO-5	-14	0.15	8	80*	E B C –
2N718A	Si	TO-18	32	1.8	–	40	E B C –
2N720A	Si	TO-18	80	1.8	–	40	E B C –
2N1066	Ge	TO-33	–	0.12	–	20*	E B C x
2N1183	Ge	TO-8	-20	1	–	20	E B C –
2N1183A	Ge	TO-8	-30	1	–	20	E B C –
2N1183B	Ge	TO-8	-40	1	–	20	E B C –
2N1184	Ge	TO-8	-20	1	–	40	E B C –
2N1184A	Ge	TO-8	-30	1	–	40	E B C –
2N1184B	Ge	TO-8	-40	1	–	40	E B C –
2N1224	Ge	TO-33	–	0.12	–	20*	E B C x
2N1225	Ge	TO-33	–	0.12	–	20*	E B C x
2N1226	Ge	TO-33	–	0.12	–	20*	E B C x
2N1285	Ge	TO-33	–	0.12	–	30*	E B C x
2N1395	Ge	TO-33	–	0.12	–	50*	E B C x
2N1396	Ge	TO-33	–	0.12	–	50*	E B C x
2N1397	Ge	TO-33	–	0.12	–	50*	E B C x
2N1683	Ge	TO-5	-12	0.15	50	50	E B C –
2N1905	Ge	TO-3	-50	30	2	30	B E C –

x Lead 4 connected to case.

RCA Type No.	Mate-rial	Pkg.	V_{CE}(sat)• or V_{CEO} max. V	P_T max. W	f_T min. MHz	h_{FE} or h_{fe}* min.	Term. See Pg. 2 Lead 1 2 3 4
2N1906	Ge	TO-3	-60	30	3	75	B E C –
2N2147	Ge	TO-3	-50	12.5	3	75	B E C –
2N2148	Ge	TO-3	-40	12.5	2	40	B E C –
2N2869	Ge	TO-3	-50	30	0.2	50	B E C –
2N2870	Ge	TO-3	-50	30	0.2	50	B E C –
2N3730	Ge	TO-3	-2•	10	–	–	B E C –
2N3731	Ge	TO-3	-1.5•	5	–	–	B E C –
2N3732	Ge	TO-3	-2•	3	–	–	B E C –
2N4346	Ge	TO-3	-0.75	5	–	–	B E C –
40022	Ge	TO-3	–	12.5	0.3	38	B E C –
40050	Ge	TO-3	-40	12.5	0.5	50	B E C –
40051	Ge	TO-3	-50	12.5	0.5	50	B E C –
40254	Ge	TO-3	–	12.5	0.3	30	B E C –
40396	Ge	TO-1	-18	0.3	–	50	E B C –
40421	Ge	TO-3	-50	12.5	2	40	B E C –
40439	Ge	TO-3	-1.5•	5	–	–	B E C –
40440	Ge	TO-3	-0.75•	5	–	–	B E C –
40462	Ge	TO-3	-40	12.5	0.6	50	B E C –
40484	Si	TO-8	55	25	–	50	E B C –
40546	Si	TO-66	–	8	25	50	B E C –
40612	Ge	TO-3	–	12.5	–	30	B E C –
40623	Ge	TO-3	–	12.5	–	50	B E C –
40626	Ge	TO-3	–	12.5	–	50	B E C –
40637	Si	TO-52	–	1	300	–	E B C –

x Lead 4 connected to case.

SYMBOL DEFINITIONS

f_T	gain-bandwidth product
h_{FE}	static forward current transfer ratio
h_{fe}	small-signal forward current transfer ratio
P_T	transistor dissipation
V_{CEO}	collector-to-emitter voltage
V_{CE}(sat)	collector-to-emitter saturation voltage

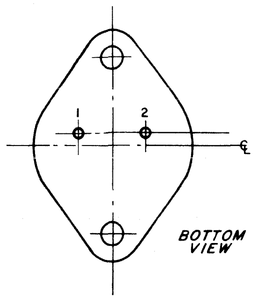
LEAD NUMBERING

The leads on two-lead packages are located off center, as shown below. When the package is viewed from the bottom and turned so that the leads are above the center line, lead No. 1 is at the left. The third connection is made directly to the case, which functions as lead No. 3 in the numbering system.

Two-Lead Packages

TO-3

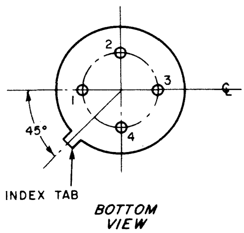
TO-66



92CS-20162

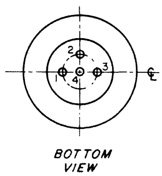
On the three-lead packages and four-lead packages listed below, the leads are numbered as indicated. The fourth lead is connected to the case.

Three-Lead Packages	**Four-Lead Packages**
TO-5	TO-33
TO-18	TO-72
TO-52	



92CS-20163

TO-1	TO-44
TO-8	



92CS-20301

Application Notes

Operating Considerations for RCA Solid State Devices

Solid state devices are being designed into an increasing variety of electronic equipment because of their high standards of reliability and performance. However, it is essential that equipment designers be mindful of good engineering practices in the use of these devices to achieve the desired performance.

This Note summarizes important operating recommendations and precautions which should be followed in the interest of maintaining the high standards of performance of solid state devices.

The ratings included in RCA Solid State Devices data bulletins are based on the Absolute Maximum Rating System, which is defined by the following Industry Standard (JEDEC) statement:

Absolute-Maximum Ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in device characteristics.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in device characteristics.

It is recommended that equipment manufacturers consult RCA whenever device applications involve unusual electrical, mechanical or environmental operating conditions.

GENERAL CONSIDERATIONS

The design flexibility provided by these devices makes possible their use in a broad range of applications and under many different operating conditions. When incorporating these devices in equipment, therefore, designers should anticipate the rare possibility of device failure and make certain that no safety hazard would result from such an occurrence.

The small size of most solid state products provides obvious advantages to the designers of electronic equipment. However, it should be recognized that these compact devices usually provide only relatively small insulation area between adjacent leads and the metal envelope. When these devices are used in moist or contaminated atmospheres, therefore, supplemental protection must be provided to prevent the development of electrical conductive paths across the relatively small insulating surfaces. For specific information on voltage creepage, the user should consult references such as the JEDEC Standard No. 7 "Suggested Standard on Thyristors," and JEDEC Standard RS282 "Standards for Silicon Rectifier Diodes and Stacks".

The metal shells of some solid state devices operate at the collector voltage and for some rectifiers and thyristors at the anode voltage. Therefore, consideration should be given to the possibility of shock hazard if the shells are to operate at voltages appreciably above or below ground potential. In general, in any application in which devices are operated at voltages which may be dangerous to personnel, suitable precautionary measures should be taken to prevent direct contact with these devices.

Devices should not be connected into or disconnected from circuits with the power on because high transient voltages may cause permanent damage to the devices.

TRANSISTORS WITH FLEXIBLE LEADS

Flexible leads are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in each lead, to prevent excessive tension on the leads. It is important during the soldering operation to avoid excessive heat in order to prevent possible damage to the devices. Some of the heat can be absorbed if the flexible lead of the device is grasped between the case and the soldering point with a pair of pliers.

TRANSISTORS WITH MOUNTING FLANGES

The mounting flanges of JEDEC-type packages such as the TO-3 or TO-66 often serve as the collector or anode terminal. In such cases, it is essential that the mounting flange be securely fastened to the heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED DIRECTLY TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION COULD PERMANENTLY DAMAGE THE DEVICE.

Such devices can be installed in commercially available sockets. Electrical connections may also be made by soldering directly to the terminal pins. Such connections may be soldered to the pins close to the pin seals provided care is taken to conduct excessive heat away from the seals; otherwise the heat of the soldering operation could crack the pin seals and damage the device.

During operation, the mounting-flange temperature is higher than the ambient temperature by an amount which depends on the heat sink used. The heat sink must have sufficient thermal capacity to assure that the heat dissipated in the heat sink itself does not raise the device mounting-flange temperature above the rated value. The heat sink or chassis may be connected to either the positive or negative supply.

In many applications the chassis is connected to the voltage-supply terminal. If the recommended mounting hardware shown in the data bulletin for the specific solid-state device is not available, it is necessary to use either an anodized aluminum insulator having high thermal conductivity or a mica insulator between the mounting-flange and the chassis. If an insulating aluminum washer is required, it should be drilled or punched to provide the two mounting holes for the terminal pins. The burrs should then be removed from the washer and the washer anodized. To insure that the anodized insulating layer is not destroyed during mounting, it is necessary to remove the burrs from the holes in the chassis.

It is also important that an insulating bushing, such as glass-filled nylon, be used between each mounting bolt and the chassis to prevent a short circuit. However, the insulating bushing should not exhibit shrinkage or softening under the operating temperatures encountered. Otherwise the thermal resistance at the interface between transistor and heat sink may increase as a result of decreasing pressure.

PLASTIC POWER TRANSISTORS AND THYRISTORS

RCA power transistors and thyristors (SCR's and triacs) in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations. The following paragraphs provide guidelines for handling and mounting of these plastic-package devices, recommend forming of leads to meet specific mounting requirements, and describe various mounting arrangements, thermal considerations, and cleaning methods. This information is intended to augment the data on electrical characteristics, safe operating area, and performance capabilities in the technical bulletin for each type of plastic-package transistor or thyristor.

Lead-Forming Techniques

The leads of the RCA VERSAWATT in-line plastic packages can be formed to a custom shape, provided they are not indiscriminately twisted or bent. Although these leads can be formed, they are not flexible in the general sense, nor are they sufficiently rigid for unrestrained wire wrapping

Before an attempt is made to form the leads of an in-line package to meet the requirements of a specific application, the desired lead configuration should be determined, and a lead-bending fixture should be designed and constructed. The use of a properly designed fixture for this operation eliminates the need for repeated lead bending. When the use of a special bending fixture is not practical, a pair of long-nosed pliers may be used. The pliers should hold the lead firmly between the bending point and the case, but should not touch the case.

When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, make the bend at least 1/8 inch from the plastic case.
4. Do not use a lead-bend radius of less than 1/16 inch.
5. Avoid repeated bending of leads.

The leads of the TO-220AB VERSAWATT in-line package are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised.

Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed. The maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance not less than 1/8 inch from the plastic case. When wires are used for connections, care should be exercised to assure that movement of the wire does not cause movement of the lead at the lead-to-plastic junctions.

The leads of RCA molded-plastic high-power packages are not designed to be reshaped. However, simple bending of the leads is permitted to change them from a standard vertical to a standard horizontal configuration, or conversely. Bending of the leads in this manner is restricted to three 90-degree bends; repeated bendings should be avoided.

Mounting

Recommended mounting arrangements and suggested hardware for the VERSAWATT transistors are given in the data bulletins for specific devices and in RCA Application Note AN-4124. When the transistor is fastened to a heat sink, a rectangular washer (RCA Part No. NR231A) is recommended to minimize distortion of the mounting flange. Excessive distortion of the flange could cause damage to the transistor. The washer is particularly important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings; however, the holes should not be larger than necessary to provide hardware clearance and, in any case, should not exceed a diameter of 0.250 inch.

Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8 inch-pounds is specified. Care should be exercised to assure that the tool used to drive the mounting screw never comes in contact with the plastic body during the driving operation. Such contact can result in damage to the plastic body and internal device connections. An excellent method of avoiding this problem is to use a spacer or combination spacer-isolating bushing which raises the screw head or nut above the top surface of the plastic body. The material used for such a spacer or spacer-isolating bushing should, of course, be carefully selected to avoid "cold flow" and consequent reduction in mounting force. Suggested materials for these bushings are diallphtalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate. Unfilled nylon should be avoided.

Modification of the flange can also result in flange distortion and should not be attempted. The transistor should not be soldered to the heat sink by use of lead-tin solder because the heat required with this type of solder will cause the junction temperature of the transistor to become excessively high.

The TO-220AA plastic transistor can be mounted in commercially available TO-66 sockets, such as UID Electronics Corp. Socket No. PTS-4 or equivalent. For testing purposes, the TO-220AB in-line package can be mounted in a Jetron Socket No. CD74-104 or equivalent. Regardless of the mounting method, the following precautions should be taken:

1. Use appropriate hardware.
2. Always fasten the transistor to the heat sink before the leads are soldered to fixed terminals.
3. Never allow the mounting tool to come in contact with the plastic case.
4. Never exceed a torque of 8 inch-pounds.
5. Avoid oversize mounting holes.
6. Provide strain relief if there is any probability that axial stress will be applied to the leads.
7. Use insulating bushings to prevent hot-creep problems. Such bushings should be made of diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate.

The maximum allowable power dissipation in a solid state device is limited by the junction temperature. An important factor in assuring that the junction temperature remains below the specified maximum value is the ability of the associated thermal circuit to conduct heat away from the device.

When a solid state device is operated in free air, without a heat sink, the steady-state thermal circuit is defined by the junction-to-free-air thermal resistance given in the published data for the device. Thermal considerations require that a free flow of air around the device is always present and that the power dissipation be maintained below the level which would cause the junction temperature to rise above the maximum rating. However, when the device is mounted on a heat sink, care must be taken to assure that all portions of the thermal circuit are considered.

To assure efficient heat transfer from case to heat sink when mounting RCA molded-plastic solid state power devices, the following special precautions should be observed:

1. Mounting torque should be between 4 and 8 inch-pounds.
2. The mounting holes should be kept as small as possible.
3. Holes should be drilled or punched clean with no burrs or ridges, and chamfered to a maximum radius of 0.010 inch.
4. The mounting surface should be flat within 0.002 inch/inch.
5. Thermal grease (Dow Corning 340 or equivalent) should always be used on both sides of the insulating washer if one is employed.
6. Thin insulating washers should be used. (Thickness of factory-supplied mica washers range from 2 to 4 mils).
7. A lock washer or torque washer, made of material having sufficient creep strength, should be used to prevent degradation of heat sink efficiency during life.

A wide variety of solvents is available for degreasing and flux removal. The usual practice is to submerge components in a solvent bath for a specified time. However, from a reliability stand point it is extremely important that the solvent, together with other chemicals in the solder-cleaning system (such as flux and solder covers), do not adversely affect the life of the component. This consideration applies to all non-hermetic and molded-plastic components.

It is, of course, impractical to evaluate the effect on long-term transistor life of all cleaning solvents, which are marketed with numerous additives under a variety of brand names. These solvents can, however, be classified with respect to their component parts, as either acceptable or unacceptable. Chlorinated solvents tend to dissolve the outer package and, therefore, make operation in a humid atmosphere unreliable. Gasoline and other hydrocarbons cause the inner encapsulant to swell and damage the transistor. Alcohol and unchlorinated freons are acceptable solvents. Examples of such solvents are:

1. Freon TE
2. Freon TE-35
3. Freon TP-35 (Freon PC)
4. Alcohol (isopropanol, methanol, and special denatured alcohols, such as SDA1, SDA30, SDA34, and SDA44)

Care must also be used in the selection of fluxes for lead soldering. Rosin or activated rosin fluxes are recommended, while organic or acid fluxes are not. Examples of acceptable fluxes are:

1. Alpha Reliaros No. 320-33
2. Alpha Reliaros No. 346
3. Alpha Reliaros No. 711
4. Alpha Reliafoam No. 807
5. Alpha Reliafoam No. 809
6. Alpha Reliafoam No. 811-13
7. Alpha Reliafoam No. 815-35
8. Kester No. 44

If the completed assembly is to be encapsulated, the effect on the molded-plastic transistor must be studied from both a chemical and a physical standpoint.

RECTIFIERS AND THYRISTORS

A surge-limiting impedance should always be used in series with silicon rectifiers and thyristors. The impedance value must be sufficient to limit the surge current to the value specified under the maximum ratings. This impedance may be provided by the power transformer winding, or by an external resistor or choke.

A very efficient method for mounting thyristors utilizing packages such as the JEDEC TO-5 and "modified TO-5" is to provide intimate contact between the heat sink and at least one half of the base of the device opposite the leads. These packages can be mounted to the heat sink mechanically with glue or an epoxy adhesive, or by soldering. Soldering to the heat sink is preferable because it is the most efficient method.

The use of a "self-jigging" arrangement and a solder preform is recommended. Such an arrangement is illustrated in RCA Publication MHI-300B, "Mounting Hardware Supplied with RCA Semiconductor Devices". If each unit is soldered individually, the heat source should be held on the heat sink and the solder on the unit. Heat should be applied only long enough to permit solder to flow freely. For more detailed thyristor mounting considerations, refer to Application Note AN3822, "Thermal Considerations in Mounting of RCA Thyristors".

MOS FIELD-EFFECT TRANSISTORS

Insulated-Gate Metal Oxide-Semiconductor Field-Effect Transistors (MOS FETs), like bipolar high-frequency transistors, are susceptible to gate insulation damage by the electrostatic discharge of energy through the devices. Electrostatic discharges can occur in an MOS FET if a type with an unprotected gate is picked up and the static charge, built in the handler's body capacitance, is discharged through the device. With proper handling and applications procedures, however, MOS transistors are currently being extensively used in production by numerous equipment manufacturers in military, industrial, and consumer applications, with virtually no problems of damage due to electrostatic discharge.

In some MOS FETs, diodes are electrically connected between each insulated gate and the transistor's source. These diodes offer protection against static discharge and in-circuit transients without the need for external shorting mechanisms. MOS FETs which do not include gate-protection diodes can be handled safely if the following basic precautions are taken:

1. Prior to assembly into a circuit, all leads should be kept shorted together either by the use of metal shorting springs attached to the device by the vendor, or by the insertion into conductive material such as "ECCOSORB* LD26" or equivalent.
   (NOTE: Polystyrene *insulating* "SNOW" is not sufficiently conductive and should not be used.)
2. When devices are removed by hand from their carriers, the hand being used should be grounded by any suitable means, for example, with a metallic wristband.
3. Tips of soldering irons should be grounded.
4. Devices should never be inserted into or removed from circuits with power on.

*Trade Mark: Emerson and Cumming, Inc.

INTEGRATED CIRCUITS

In any method of mounting integrated circuits which involves bending or forming of the device leads, it is extremely important that the lead be supported and clamped between the bend and the package seal, and that bending be done with care to avoid damage to lead plating. In no case should the radius of the bend be less than the diameter of the lead, or in the case of rectangular leads,such as those used in RCA 14-lead and 16-lead flat-packages, less than the lead thickness. It is also extremely important that the ends of the bent leads be straight to assure proper insertion through the holes in the printed-circuit board.

COS/MOS (Complementary-Symmetry MOS) Integrated Circuits

Although protection against electrostatic effects is provided by built-in circuitry, the following precautions should be taken in handling these circuits:

1. Soldering-iron tips and test equipment should be grounded.
2. Devices should not be inserted in non-conductive containers such as conventional plastic snow or trays. A conductive material such as "ECCOSORB LD26" or equivalent should be used.

Low-source-impedance pulse generators connected to the inputs of these devices must be disconnected before the dc power supply is turned off. All unused input leads must be connected to either V_{SS} or V_{DD}, whichever is appropriate for the logic circuit operation desired.

SOLID STATE CHIPS

Solid state chips, unlike packaged devices, are non-hermetic devices, normally fragile and small in physical size, and therefore, require special handling considerations as follows:

1. Chips must be stored under proper conditions to insure that they are not subjected to a moist and/or contaminated atmosphere that could alter their electrical, physical, or mechanical characteristics. After the shipping container is opened, the chip must be stored under the following conditions:
   A. Storage temperature, 40°C max.
   B. Relative humidity, 50% max.
   C. Clean, dust-free environment.
2. The user must exercise proper care when handling chips to prevent even the slightest physical damage to the chip.
3. During mounting and lead bonding of chips the user must use proper assembly techniques to obtain proper electrical, thermal, and mechanical performance.
4. After the chip has been mounted and bonded, any necessary procedure must be followed by the user to insure that these non-hermetic chips are not subjected to

moist or contaminated atmosphere which might cause the development of electrical conductive paths across the relatively small insulating surfaces. In addition, proper consideration must be given to the protection of these devices from other harmful environments which could conceivably adversely affect their proper performance.

SOLID STATE LASERS AND EMITTING DIODES

Optoelectronic devices should employ the same mounting and heat-sink procedures utilized with other solid state devices. The temperature ratings established for storing, mounting, and operating these devices must not be exceeded to avoid damaging the emitters. Because the extremely small size and high driving-current requirements of some of these devices preclude the use of polarity marks on the housing and package configurations, care must be taken to insure that voltage is always applied in the proper direction. It is important, therefore, to refer to the data bulletin for the proper polarity before applying voltage to the device. Pulse driving circuitry should be designed to prevent transients (positive or negative) or momentary surges from exceeding drive conditions. The following suggestions are offered:

1. High-speed clipping diodes should be placed at terminals to bypass negative transients.
2. High-speed, sense-and-clamp circuitry should be used to prevent overdrive in peak or average current by clamping or disconnect techniques. For short pulses, ordinary thermal fuses should not be used because they do not provide adequate device protection.

The characteristics of solid state emitters vary substantially with changes in ambient temperature. Threshold, the point at which lasing starts, is highly dependent on temperature and requires compensation of drive current in applications where operation over a wide temperature range is a design requirement. A room-temperature laser can be damaged if a constant drive current is maintained while the ambient temperature is reduced to cryogenic levels. Published data bulletins for individual devices specify safe levels of operation.

In most cases, the voltage drop across a solid state emitter is of comparatively low amplitude; however, the required drive current may be many amperes. As in the case of other high-operating-current devices, therefore, clean and low-impedance contacts are required in all applications.

High voltage may be present in pulse-driven circuits utilizing these devices. Therefore, consideration should be given to the possibility of shock hazard which may result from contact with these high voltages. In general, where devices are operating at potentials which may be dangerous to personnel, suitable precautionary measures should be taken to prevent direct contact with these devices.

Radiation Safety Considerations

Injection laser diodes emit electromagnetic radiation at wavelengths which may be invisible to the human eye. Suitable precautions must be taken to avoid possible damage to the eye from overexposure to this radiant energy. Precautionary measures include the following:

1. *In Systems with No External Lens* – Avoid viewing the laser source at close range. Since the emitted beam is not collimated, increasing the distance to the laser source greatly reduces the risk of overexposure.
2. *In Systems Utilizing External Optics* – Avoid viewing the emitter directly along the optical axis of the radiated beam.
3. *Reflections From Surfaces* – Minimize unwanted specular reflections in the system.

ADDITIONAL DATA

Additional information on handling, mounting, and operating RCA Solid State Devices is given in the following publications which are available on request from RCA/Commercial Engineering, Harrison, N.J. 07029.

MHI-300B	"RCA Mounting Hardware Supplied with RCA Semiconductor Devices"
1CE-338	"RCA Integrated Circuits Mounting and Connection Techniques"
AN-3822	"Thermal Considerations in Mounting of RCA Thyristors"
AN-4124	"Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors"

Silicon Transistors for High-Voltage Application

by

D. T. DeFino

This note discusses several new applications for RCA high-voltage silicon transistors (2N3583, 2N3584, 2N3585, 2N3439 and 2N3440). These devices are triple-diffused n-p-n types featuring high frequency response, fast switching speeds, and low cost. Electrical characteristics are listed in Table I.

The advent of these types has made possible many new applications for transistors. Among these applications are circuits in which, until now, the use of transistors was restricted because of high operating voltages (horizontal-deflection circuits, for example). Other applications include those in which the use of a higher supply voltage can enhance circuit design, performance, and economy. High supply voltages reduce the cost of line-operated amplifiers, and improve the efficiency of inverters. Several other important applications are illustrated.

Series Voltage Regulator

A voltage regulator provides a constant output voltage when the input voltage and/or output current is varied over a limited range. As shown in Fig. 1, the pass transistor, acting on a signal from the control circuit, prevents the output voltage V_{out} from varying. The control circuit receives a sample of the output voltage, compares it with a reference voltage, and amplifies the difference. The resulting error signal corrects the collector current I_C of the pass transistor so that the collector-to-emitter voltage V_{CE} is always

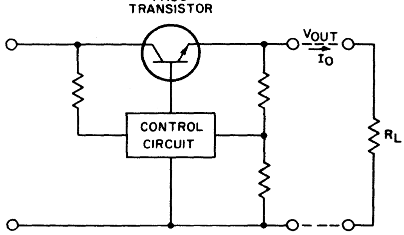


Fig. 1 - Basic form of a transistorized series voltage regulator.

Maximum Ratings, *Absolute-Maximum Values:*

	2N3583	2N3584	2N3585	2N3439	2N3440	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO} . .	250	375	500	450	300	Volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}(sus)	175	250	300	350	250	Volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	6	6	6	7	7	Volts
CONTINUOUS COLLECTOR CURRENT, I_C .	2	2	2	1	1	Amp
PEAK COLLECTOR CURRENT.	5	5	5	-	-	Amp
BASE CURRENT, I_B	1	1	1	0.5	0.5	Amp
TRANSISTOR DISSIPATION, P_T	35	35	35	5	5	Watts

Table I - Electrical characteristics of RCA high-voltage silicon transistors.

the difference between the input voltage V_{in} and the desired output voltage.

The simplest circuit arrangement for a transistor voltage regulator is shown in Fig.2. The circuit consists of a transistor, a resistor, and a zener diode. Because the zener diode maintains the base of the transistor at a constant voltage, changes in output can result only from variations in the base-to-emitter voltage V_{BE} with current and temperature. A zener diode having a high current rating is required if large currents are drawn from the transistor.

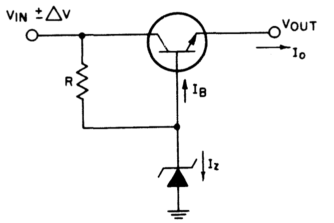


Fig.2 - Simplest circuit arrangement for a transistor voltage regulator.

The maximum value of resistance R which can be used in the circuit is determined as follows:

$$R = \frac{V_{in} - \Delta V - V_{out}}{I_B(\max)}$$

Because the maximum base current $I_B(\max)$ is equal to $I_o(\max)/h_{FE}(\min)$, where I_o is the output current and h_{FE} is the dc forward-current transfer ratio, the resistance equation can be rewritten as follows:

$$R = \frac{V_{in} - \Delta V - V_{out}}{I_o(\max)} \times h_{FE}(\min)$$

The zener diode must be capable of handling a peak current I_Z given by

$$I_Z = \frac{V_{in} + \Delta V - V_{out}}{R} = \frac{[V_{in} + \Delta V - V_{out}]\,[I_o(\max)]}{[V_{in} - \Delta V - V_{out}]\,[h_{FE}(\min)]}$$

In the series regulator, the pass transistor must remain always in the active region. For this reason, the pass transistor must be chosen carefully to avoid dc forward-bias second breakdown. As shown in Fig.3, under the worst-case condition $I_o(\max)$, $V_{in}(\min)$, the bias point of the transistor must be within the dc forward-bias second-breakdown rating $P_{s/b}$, or the dc power-dissipation rating P_{dc}, whichever is the limiting factor. From the equations given above, it is obvious that near the operating point h_{FE} should be as high as possible. In general, leakage current and saturation voltage are not important.

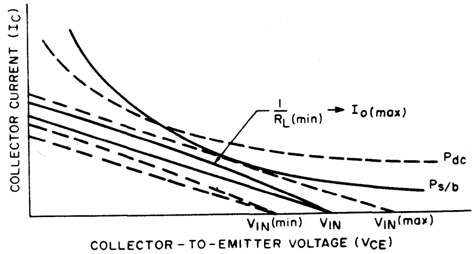


Fig.3 - Transistor load line.

Design Example

The following conditions are specified for a series voltage regulator:

$$V_{out} = 100\ \text{V}$$
$$I_o(\max) = 400\ \text{mA}$$
$$V_{in} = 135 \pm 15\ \text{V}$$
$$h_{FE}(\min) = 20$$

Circuit values are then determined as follows:

$$R = \frac{(135 - 15 - 100)\ 20}{0.4} = \frac{400}{0.4} = 1\ \text{k}\Omega \text{ at } 2.5\ \text{W}$$

$$I_B(\max) = \frac{0.4}{20} = 20\ \text{mA}$$

$$I_Z = \frac{135 + 15 - 100}{1000} = \frac{50}{1000} = 50\ \text{mA}$$

Therefore, the zener-diode requirements are $V_Z = 100$ V, $I_Z = 50$ mA, $P_Z = 5$ W. Under worst-case conditions, the transistor must be capable of handling 400 milliamperes at 50 volts, or a dissipation of 20 watts. In addition, the point 50 V and 400 mA must be within the dc second-breakdown rating of the transistor. Fig.4 shows the circuit values for this regulator.

The power-dissipation rating of the resistor and zener diode can be reduced by addition of another transistor (usually much smaller in dissipation) in a configuration such as that shown in Fig.5. This arrangement effectively increases the over-all minimum gain. The two transistors can be regarded as one in which the effective h_{FE} (approximately the product of the gain of the two transistors) can be substituted for h_{FE} in the previous equations. Because the 2N3440 has a minimum gain of 40 at 20 mA, the minimum effective gain is (40)(20) = 800. From this value, the new resistor and zener diode requirements can be calculated as follows:

$$R = \frac{(135 - 15 - 100)\ 800}{0.4} = 40\ \text{k}\Omega \text{ at } 0.062\ \text{W}$$

$$I_Z = \frac{135 + 15 - 100}{40000} = \frac{50}{40000} = 1.25\ \text{mA}$$

$$P_Z = 125\ \text{mW}$$

The maximum power dissipated by the 2N3440 transistor in this circuit is (20 mA)(50 V) = 1 W.

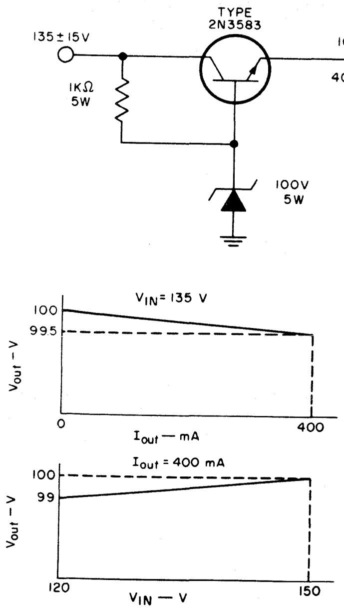


Fig.4 - Schematic diagram of a simple transistor voltage regulator.

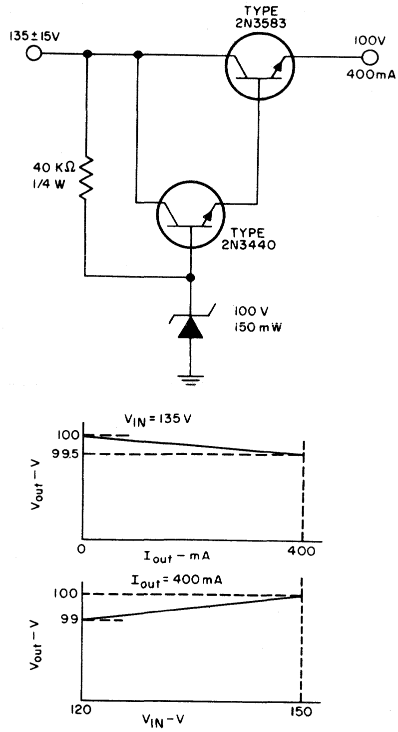


Fig.5 - Schematic diagram of a series voltage regulator using darlington driver.

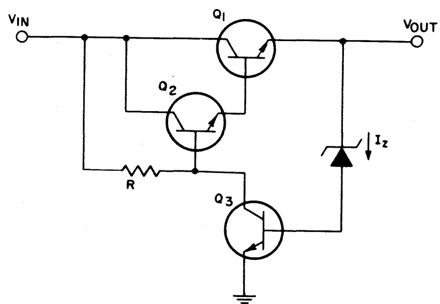


Fig.6 - Schematic diagram of a series voltage regulator employing feedback amplifier.

The disadvantage of the circuit of Fig.5 as compared with that of Fig.4 is that voltage regulation is less sensitive because there are two junctions to create V_{BE} variations with current and voltage changes.

Fig.6 shows a feedback arrangement designed to improve regulation. In this circuit, the output is sampled and compared with a very stable reference voltage. The resulting error signal is used to adjust the bias on the pass transistor. The requirements for Q3 are determined in the same manner as those for the zener diode in the preceding circuits. The zener-diode current I_Z(max) is equal to the collector current I_C(max) of Q3 divided by the minimum gain of Q3 at I_C(max).

In general, the full load voltage need not be fed back. Instead, a voltage divider can be used to reduce the voltage requirement on the zener diode. Although the voltage divider also degrades the performance, this method must be used if a variable output voltage is required. Fig.7 shows a typical high-voltage regulator that provides an output variable from 175 to 225 volts and delivers up to 150 mA. Performance curves for this circuit are shown in Fig.8.

Switching Regulator

The advantage of a transistorized switching regulator, such as that shown in Fig.9, is its extremely high efficiency. It does not, however, provide the excellent regulation obtainable from a series-type regulator. For this reason, a switching regulator is normally used as a coarse or pre-regulator preceding a series regulator. The switching regulator is highly efficient because the transistor switch is either saturated or cut off. Because both of these conditions are states of low dissipation, very little power is lost in the transistor.

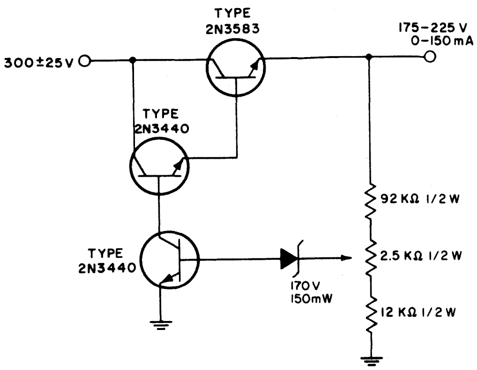


Fig.7 - Schematic diagram of a typical series high-voltage regulator.

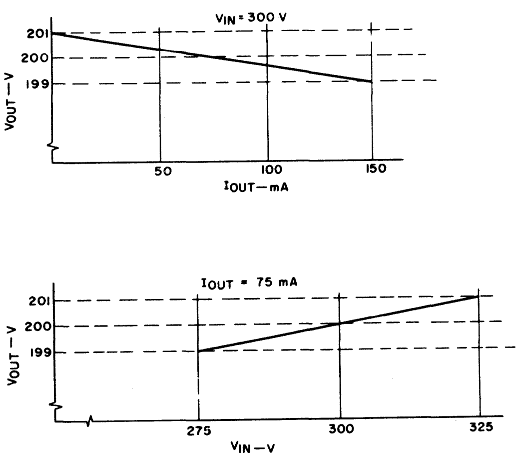


Fig.8 - Regulation characteristics for circuit shown in Fig.7.

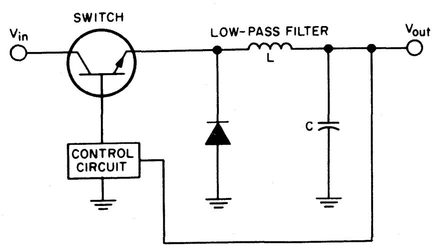


Fig.9 - Simplest form of a transistor switching regulator.

The function of the feedback circuit is to sample the output voltage and compare it with a reference voltage. The difference between these two voltages is used to modulate the pulse width of a pulse generator. This modulated pulse signal is then applied to the base of the switch. Thus, if the output voltage tends to decrease, the pulse width is increased so that the switch remains ON longer to allow the output to increase. Conversely, if the output tends to increase above the desired value, the duty cycle decreases.

When the transistor switch is ON, current flows into the load and into the output capacitor through the inductor. Energy is stored in the inductor and capacitor so that when the switch is OFF, this energy is available to supply the load. During the ON time, the current through the inductor is a linear ramp. The rate of increase of current ($\Delta I/\Delta t$) is determined by the value of the inductance L and the voltage across it ($V_{in} - V_{out}$) as follows:

$$\frac{\Delta I}{\Delta t} = \frac{1}{L}(V_{in} - V_{out})$$

The peak current is therefore given by

$$I_p = \frac{V_{in} - V_{out}}{L}(t_{on})$$

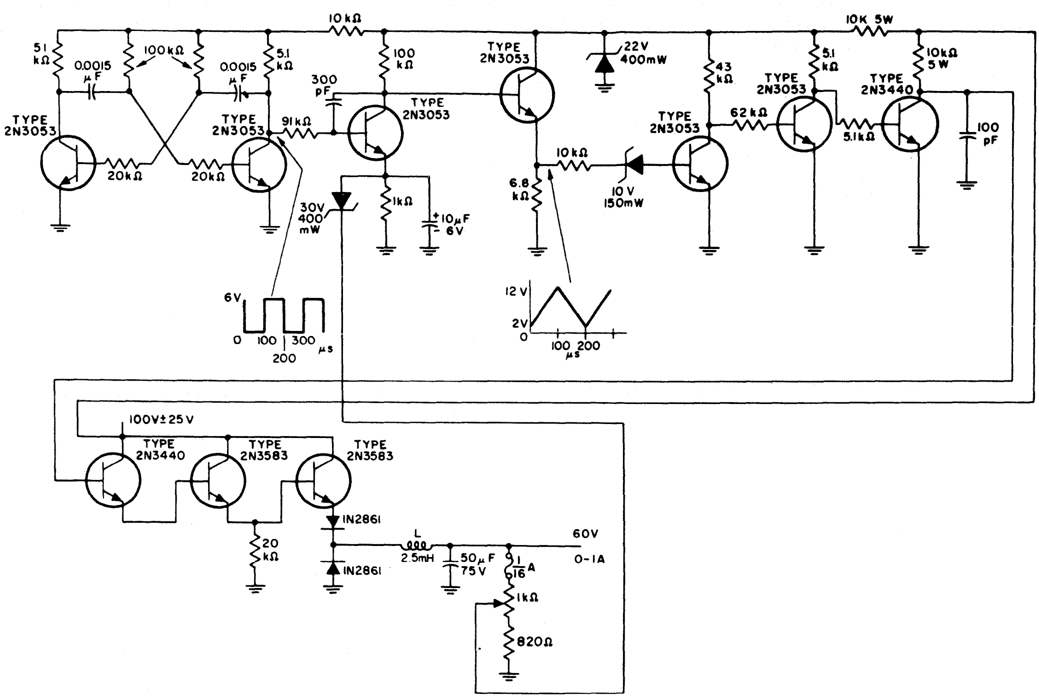
The transistor chosen for this application must provide sufficiently fast switching times, i.e., rise time t_r and fall time t_f. For good regulation over a wide range of input voltage and output current, the duty cycle must be variable from 10 to 90 per cent. Consequently, the minimum pulse width should be one-tenth of the period (1/10f). For low switching losses, the rise and fall times should be about one-fifth of the minimum pulse width, or one-fiftieth of the frequency of the pulse generator (1/50f).

A switching regulator can also be used as a dc step-down transformer. In this application, the regulator provides a very efficient method of obtaining low dc voltage directly from a high-voltage ac line. Fig.10 shows a typical step-down switching regulator which utilizes the dc voltage obtained by rectification of a 117-volt ac line source to provide a regulated 60-volt supply. Performance characteristics for the circuit are shown in Fig.11.

Inverters

An inverter is used to transform dc power to ac power. If the ac output is rectified and filtered to provide dc again, the over-all circuit is referred to as a converter. A converter is normally employed to change the magnitude of an available dc supply.

A transistorized inverter can be made very light in weight and small in size. It is a highly efficient circuit and, unlike its mechanical counterpart, has no



L = 60-turns #18 wire,
core: Carpenter 49 or equiv., 21 E I 0.014-in. laminations
not interleaved. Use 0.015-in. air gap.

All resistors 1/2-watt unless specified otherwise

Fig.10 - Schematic diagram of a typical step-down switching regulator.

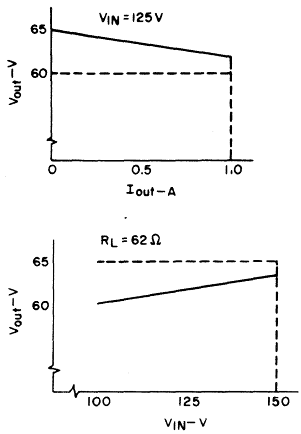


Fig.11 - Performance curves for circuit shown in Fig.10.

moving components. The output from the inverter can be used to drive any equipment which requires an ac supply (motors, ac radios, television receivers, fluorescent lights, and the like). Another very important application of an inverter is in driving the electro-mechanical transducers used in ultrasonic equipment (such as ultrasonic cleaners and sonar detection devices).

The operating frequency of an inverter is usually fixed between 60 Hz and 100 kHz, depending upon the application. For applications in which the operating frequency can be chosen by the designer, the highest possible frequency should be selected.

In general, the size and weight of the inverter can be decreased as the supply voltage and frequency are increased. This relation results mainly from the decreasing size of the transformer needed. The upper frequency and supply voltage are limited by the transistors used. The collector-to-emitter breakdown voltage, for example, must be greater than twice the supply voltage, and the gain-bandwidth product f_T of the device should be greater than ten times the operating frequency. The latter requirement is necessary because switching losses become significant when the rise and fall times of the transistor are greater than about one-fifth of the pulse width.

The important parameters to be considered in the selection of a transistor for an inverter circuit are summarized below:

$V_{CER}(sus) \geq 2V_{CC}$ + leakage reactance spikes

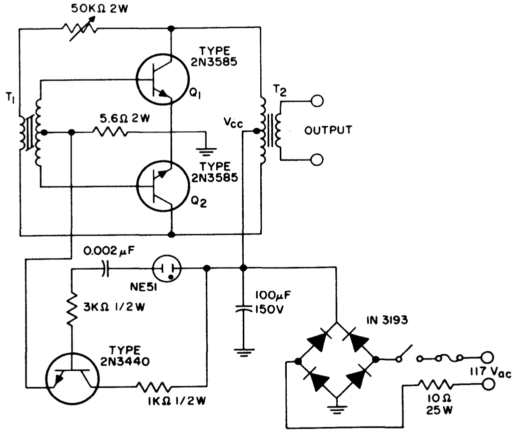
High gain (to reduce feedback power and increase efficiency)

$f_T \geq 10f$ (to reduce switching losses)

$I_{S/b} \geq$ highest starting bias current at V_{CC}

$E_{S/b} \geq$ max. energy stored in the output-transformer leakage inductance.

Fig.12 shows the circuit diagram for a 100-watt inverter which operates directly from a rectified ac-line voltage. The frequency is varied from 25 kHz to 40 kHz by adjustment of the feedback resistor. At 100 watts output, the efficiency is about 90 to 95 per cent, depending upon the frequency. The supply voltage is nominally 140 volts, but can rise to 155 volts during high ac-line-voltage conditions.



T_1 = Allen Bradley RO-3 (E I 102 H 142 A) or equiv.
primary: 160-turn #32 wire;
secondary: each 3-turns #32 wire.

T_2 = Indiana General C2 material (CF216) or equiv.
primary and secondary: 80-turns #28 wire.

Fig.12 - Schematic diagram of a line-operated 100-watt inverter.

Magnetic Deflection Circuit

The electron beam of a magnetically driven display tube is swept across the face of the tube by a linearly changing magnetic field. This deflecting field is produced by a linear ramp of current through the deflection yoke which surrounds the neck of the tube. Fig.13 shows a transistorized magnetic deflection circuit and the corresponding current and voltage waveforms.

The transistor acts as a switch to apply a constant voltage to the inductor. Then, according to the following equation, the current increases linearly to I_p during one-half the sweep time t_s:

$$\frac{\Delta I}{\Delta t} = \frac{V}{L} \quad \Delta I = \frac{V_{CC}}{L}\Delta t, \; I_p = \frac{V_{CC}}{L}\frac{t_s}{2}$$

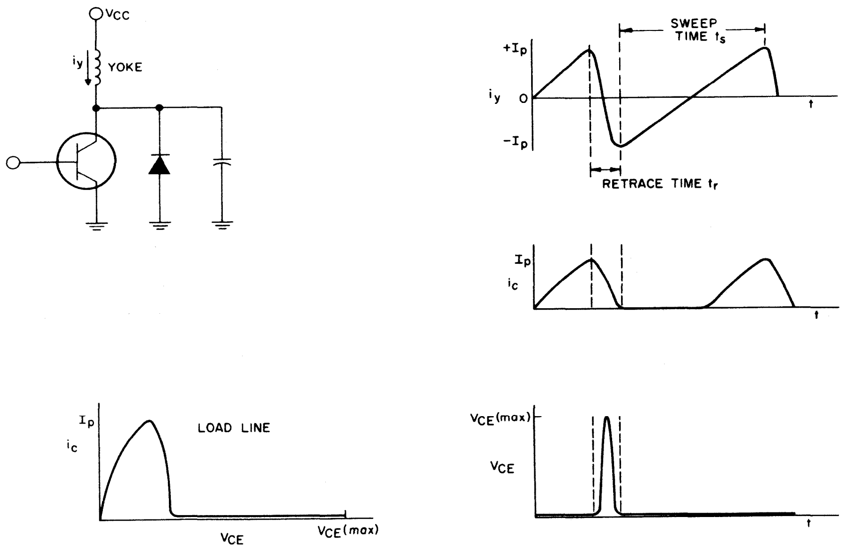


Fig.13 - Basic configuration for a transistor magnetic deflection circuit showing corresponding current and voltage waveforms.

When the transistor is turned off, LC forms a tuned circuit in which the yoke current decreases very rapidly (retrace time t_r) through zero to $-I_p$. At this point capacitor C has a negative voltage across it, the diode is forward-biased, and the yoke current begins to increase toward zero. At this point the cycle begins again.

During the retrace time, when the yoke current is decreasing from I_p to $-I_p$, the voltage across the transistor becomes quite high. The collector-to-emitter voltage is given by

$$V_{CE}(max) = V_{CC} + I_p \omega L$$

The term ω can be expressed as follows:

$$\omega = \frac{1}{\sqrt{LC}} = \frac{\pi}{t_r}$$

Therefore, the equation for $V_{CE}(max)$ may be rewritten as follows:

$$V_{CE}(max) = V_{CC} + \sqrt{\frac{L}{C}}\, I_p.$$

The energy E supplied to the yoke is given by

$$E = ½\, L\, I_p^2$$

In the design of a deflection circuit, this required energy is fixed by the picture tube being used. The sweep time and retrace time are both fixed by the application. There are, therefore, only three parameters which can be varied by the designer: I_p, V_{CC}, and L. From the energy equation, it is evident that the value chosen for L determines I_p, and vice versa. However, the value of I_p is given by

$$I_p = \frac{V_{CC}}{L}\frac{t_s}{2}$$

Therefore, for a given value of I_p it is apparent that V_{CC} also becomes fixed. At this point, the peak voltage swing across the transistor can be calculated from the following equation:

$$V_{CE}(max) = V_{CC} + I_p \frac{\pi}{t_r} L$$

When these values have been determined, the designer must choose a transistor to meet the requirements imposed by the circuit.

The breakdown voltage (BV_{CEO}, BV_{CER}, BV_{CES}, BV_{CEX}, depending upon the drive-circuit impedance between the base to emitter of the output transistor), should be greater than 1.3 $V_{EE}(max)$, as determined above. This safety factor allows for stray inductance and transients.

A sustaining voltage rating is not required because the collector current drops to zero before the voltage swings out (as shown by the waveform in Fig.13) if the transistor turn-off time is less than half the retrace time. However, if the turn-off is greater than one-half the retrace time, a sustaining voltage rating should be used. In addition, the transistor not only must be able to handle the peak collector current, but should also have usable current gain at this level ($I_c = I_p$). At the same time, the $V_{CE}(sat)$ of the transistor at I_p should be as low as possible to minimize the power dissipation. In practice, both of these requirements are guaranteed by a specification such as:

$$V_{CE}(sat)\ \left(\text{at } I_C = I_p,\ I_B = \frac{I_p}{15}\right) = 1.5\ \text{V max.}$$

Another important parameter of the output transistor is switching speed. For good linearity, the turn-on time of the transistor should be less than one-tenth of the total on-time of the device (approximately half the sweep time). The turn-off time, meanwhile, should be at least one-quarter of the retrace time to reduce the high-energy dissipation, which could cause reverse-biased second-breakdown problems.

Design Example

The object of this example is to illustrate the design of a magnetic deflection circuit for a specific yoke. The yoke, Celco HD 428-S560 or equivalent, is used to drive a cathode-ray tube for an alpha-numeric display with a 36-degree full-deflection angle and a 12-kilovolt acceleration potential. The yoke inductance is 250 microhenries and the energy required is 225 microjoules. The sweep time is 50 microseconds and the retrace time 10 microseconds.

From this information, the peak collector current I_p of the deflection-circuit transistor is calculated as follows:

$$I_p = \sqrt{\frac{2\ (225)\ 10^{-6}}{250\cdot10^{-6}}} = 1.35\ \text{A}$$

The supply voltage V_{CC} required is given by

$$V_{CC} = \frac{2\ L\ I_p}{t_s} = \frac{2\ (250\cdot10^{-6})\ (1.35)}{50\cdot10^{-6}} = 13.5\ \text{V}$$

The tuning-capacitor value C is given by

$$C = \left(\frac{t_r}{\pi}\right)^2 \left(\frac{1}{L}\right) = \frac{100\cdot10^{-12}}{(\pi)^2\ 250\cdot10^{-6}} = .040\ \mu\text{F}$$

Finally, the maximum collector voltage V_{CE} is given by

$$V_{CE} = 13.5 + (1.35)\ \frac{\pi}{(10)\cdot10^{-6}}\ 250\cdot10^{-6} = 118\ \text{V}$$

The breakdown voltage, therefore, must be greater than (118) (1.3) = 155 V.

The 2N3584 meets all of the requirements for this application. The transistor switching times are short, its gain is 25 minimum at 1 ampere, and its voltage ratings are well above the required minimum. The circuit diagram and waveforms are shown in Figs.14 and 15, respectively.

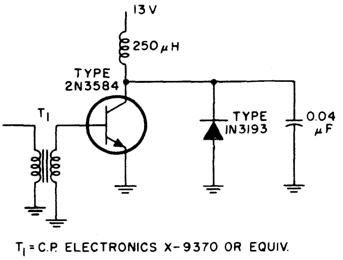


Fig.14 - Schematic diagram of a typical transistor magnetic deflection circuit.

Line-Operated Audio Amplifier

Fig.16 illustrates how high-voltage silicon transistors can be used to produce a compact, low-cost, high-quality audio-power amplifier. This particular circuit shows a class A, 5-watt, line-operated unit. The line voltage is rectified and filtered directly to provide the required dc supply voltage. This method reduces considerably the size, weight, and cost of the circuit by eliminating the need for a power-supply transformer. Negative feedback from the output transformer produces a linear output and good frequency response. Operation is relatively unaffected by normal line variations between 105 and 135 volts, and by temperatures up to 257° F. Amplifier performance curves are shown in Figs.17, 18, and 19. A summary of the amplifier characteristics is listed below:*

Frequency Response: -3 dB from 35 Hz to 35 kHz

Total Harmonic Distortion:
0.6% at 400 Hz and 4 W output
1.5% at 400 Hz and 5 W output

Hum and Noise: 65 dB below 4 W

Input Impedance: 300 ohms

Input Voltage: 0.6 V for power output of 4 W

The 2N3584 transistor used in the output stage satisfies three very important requirements for the successful operation of this amplifier: (1) a high value of voltage breakdown V_{CER}; (2) good gain linearity; (3) a high gain-bandwidth product.

Because the dc supply voltage conceivably can reach 140 volts, the sustaining-voltage rating V_{CER} for the output transistor, at R_{BE} = 500 ohms, must be greater than 280 volts. Circuits designed to permit the use of a transistor having a lower V_{CER} generally compromise performance and should be avoided. For example, one method of reducing this rating involves decreasing the supply voltage by increasing the size of the current-limiting resistors in the power supply. This procedure, however, not only requires the use of expensive power resistors, but also creates high dissipation losses and reduces the power output of the amplifier.

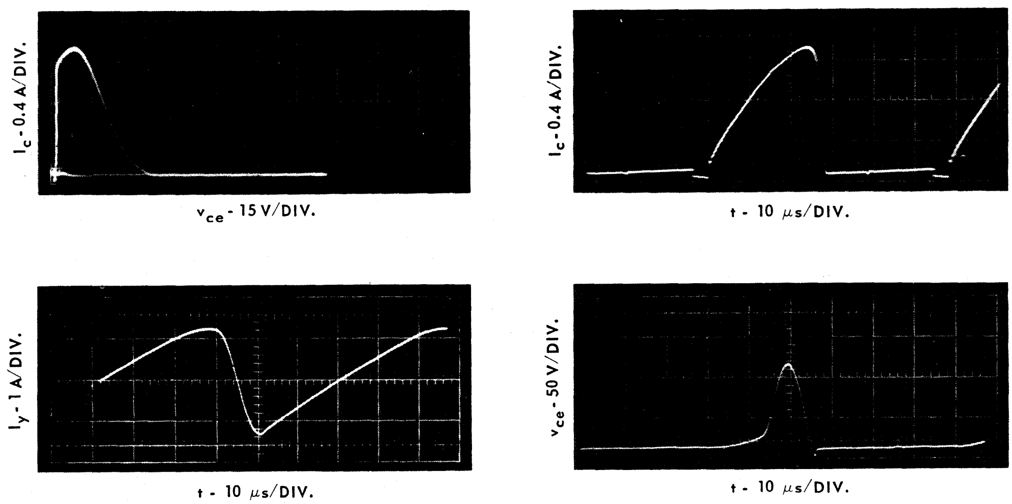
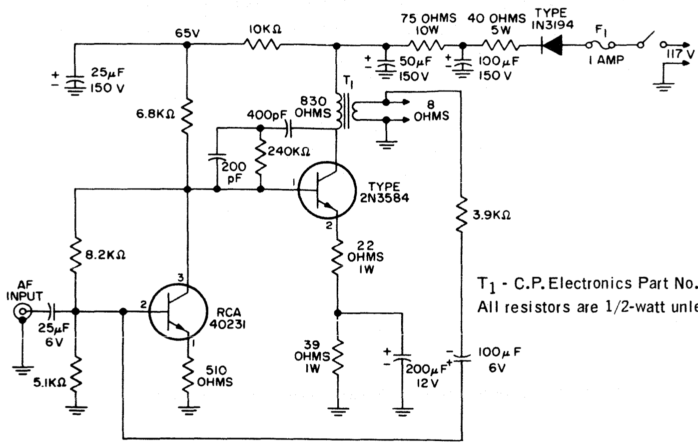


Fig.15 - Current and voltage waveforms produced by circuit shown in Fig.14.

* Additional information concerning this amplifier circuit is given in RCA publication ATC-402.



T1 - C.P.Electronics Part No.X-9600, or equiv.
All resistors are 1/2-watt unless specified otherwise.

Fig.16 - Schematic diagram of a line-operated, class A, 5-watt audio amplifier.

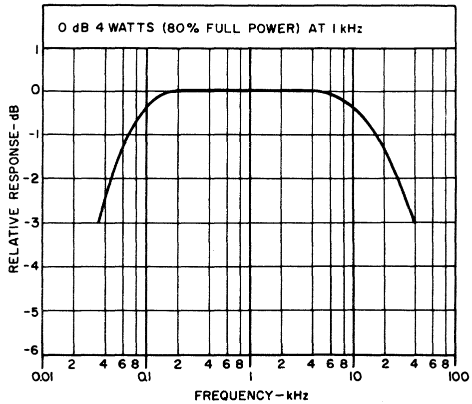


Fig.17 - Response curve for circuit shown in Fig.16.

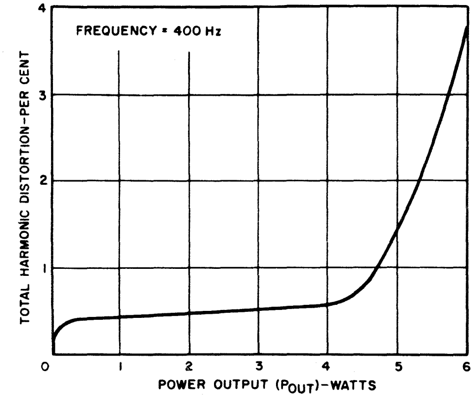


Fig.19 - Harmonic distortion as a function of power output for circuit shown in Fig.16.

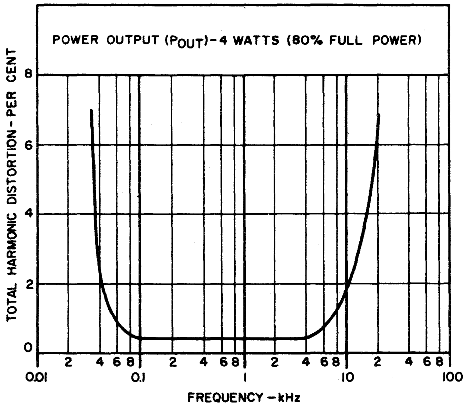


Fig.18 - Total harmonic distortion as a function of frequency for circuit shown in Fig.16.

Changing the design of the circuit may change the conditions on the required breakdown voltage. For example, if the circuit is altered so that the impedance presented to the base-emitter junction is increased to 1000 ohms and the maximum supply voltage is limited to 130 volts, the designer must choose a transistor that has a $V_{CER}(sus)$ rating (R_{BE} = 1000 ohms) of greater than 260 volts.

The excellent gain linearity of the 2N3584 (±10%) from 10 to 300 milliamperes keeps distortion at a very low level. Moreover, the high gain-bandwidth product (1 MHz) provides wide frequency response, and also permits the use of a large negative feedback without affecting circuit stability.

One final consideration is the safe operating area. Under high line voltages and worst-case temperature conditions, the dc bias point for the output transistor must be within the maximum power rating and second-breakdown rating of the device. Fig.20 illustrates this safe-operating region for the 2N3584.

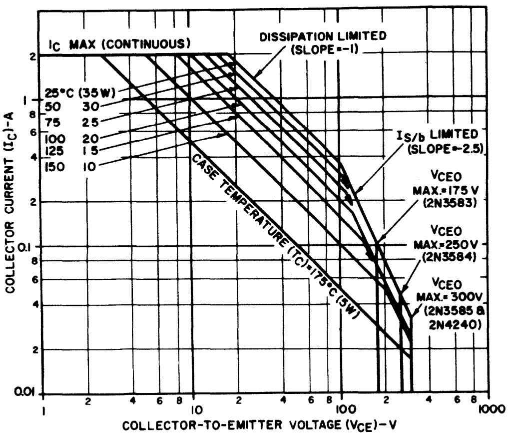


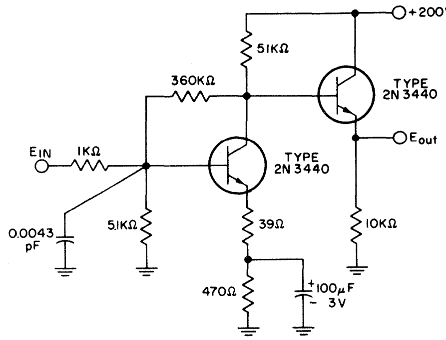
Fig.20 - Safe operating area for the 2N3584 transistor.

Operational Amplifier

Operational amplifiers are used to perform mathematical operations on voltage waveforms. Among other things, an operational amplifier can be used to multiply, add, and integrate electrical signals. It is generally used in one of these capacities in an analog computer. Wave-shaping circuits are another important application; for example, a pulse can be integrated to form a linear voltage ramp.

To function properly, an operational amplifier must have very high open-loop gain. It must also be capable of amplification over a wide passband extending from dc to perhaps 50 kHz. Its phase-shift characteristics must be such that a large negative feedback can be applied without causing oscillations. DC drift must be very low. In addition, the amplifier should have very high input impedance and low output impedance, or vice versa. Generally, the high-input-impedance type is used.

To meet all of these requirements, an operational amplifier normally utilizes a chopper amplifier and other stabilizing circuits. This portion of the amplifier can be designed to operate at low supply voltages. The final stage, however, requires a high supply voltage because it must provide a large voltage swing to drive the high input impedance of the next operational amplifier. A typical final stage that meets this requirement and also provides the necessary low output impedance is shown in Figure 21. Fig.22 shows the performance curves for this circuit.



All resistors are 1/2-watt.

Fig.21 - Schematic diagram of a typical final stage of an operational amplifier.

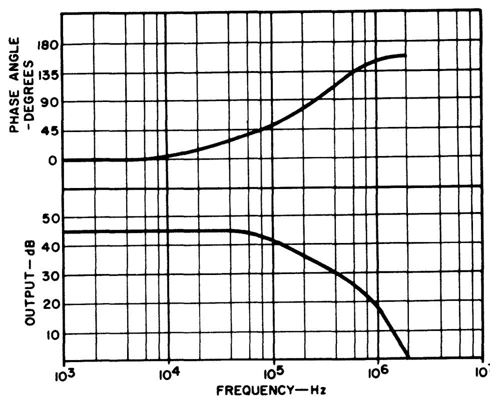


Fig.22 - Performance curves for circuit shown in Fig.21.

In general the transistor requirements for an operational amplifier output are the same as for a class A audio amplifier. These requirements were discussed in detail in the section "Line-Operated Audio Amplifier," and are summarized below:

$V_{CER}(sus) > 2\ V_{CC}$

h_{FE}: must be linear over the operating-current range.

$P_{S/b}/P_D$: the dc bias point must be within the safe operating region.

f_T: the gain-bandwidth product should be as high as possible; a rule-of-thumb minimum is 10 MHz.

RCA

Solid State Division

Power Transistors Application Note

AN-3565

A 100-Watt, 18-kHz Inverter Using RCA-2N5202 Silicon Power Transistors

by

D.T. DeFino

This Note describes a two-transistor, two-transformer inverter that demonstrates the excellent switching capabilities of the new RCA-2N5202 power transistor. This silicon epitaxial n-p-n device is supplied in the popular TO-66 package. Its fast switching speed makes it especially suitable for use in switching regulators, switching control amplifiers, converters, and inverters. Pertinent characteristics of the 2N5202 are shown in Table I.

Fig.1 shows a schematic diagram of the two-transistor, two-transformer circuit. A saturable base-drive transformer T_2 controls the inverter switching operation. A linearly operating output transformer T_1 transfers the output power to the load. The output transformer T_1 is not allowed to saturate; therefore, the peak collector current through the transistor is determined principally by the value of the load impedance.

Because no two transistors are perfectly matched, one of the transistors in the inverter circuit conducts more rapidly than the other when the power is turned on. This transistor, Q_2 for example, tends toward saturation and causes positive voltages to appear at the dotted ends of the transformers. Thus, there is an effective positive feedback that causes Q_1 to switch off and Q_2 to switch on. The voltage from the collector of Q_1 to the collector of Q_2 is then positive and equal to twice the collector supply voltage V_{CC}. The voltage V_{Rfb} across the feedback resistor R_{fb} is essentially the product of the resistance R_{fb} and the base current referred to the primary of T_2. The voltage across T_2 is equal to $2\ V_{CC} - V_{Rfb}$.

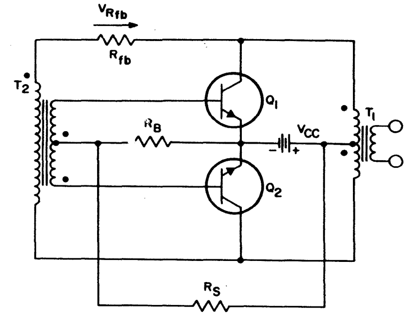


Fig.1 - Schematic diagram of two-transistor/two-transformer inverter.

At the beginning of the next half-cycle, the voltage across R_{fb} increases very slowly with the slowly increasing magnetizing current through T_2. When T_2 reaches its saturation flux density, the magnetizing current increases very rapidly and causes a rapid increase in V_{Rfb}. As a result, the voltage across T_2 decreases rapidly and Q_2 comes out of saturation. The collector voltage of Q_2 then rises, and regenerative action causes Q_1 and Q_2 to reverse states. As these processes are repeated during succeeding half-cycles, oscillations are sustained.

Characteristics of the drive transformer and the output transformer used in the circuit of Fig.1 are de-

TABLE I - TYPICAL CHARACTERISTICS OF RCA-2N5202 SILICON POWER TRANSISTOR

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS	MIN	MAX	UNITS
Collector-Cutoff Current	I_{CEV}	V_{CE} = 100 V, V_{BE} = -1.5 V V_{CE} = 100 V, V_{BE} = -1.5 V, T_C = 150°C	- -	10 10	mA mA
Emitter-Cutoff Current	I_{EBO}	V_{EB} = 6 V, I_C = 0	-	10	mA
DC Forward-Current Transfer Ratio	h_{FE}	V_{CE} = 1.2 V, I_C = 4 A	10	100	
Collector-to-Emitter Sustaining Voltage	$V_{CER}(sus)$	R_{BE} = 50 Ω, I_C = 0.2 A	75	-	V
Base-to-Emitter Voltage	V_{BE}	V_{CE} = 1.2 V, I_C = 4 A	-	1.9	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	I_C = 4 A, I_B = 0.4 A	-	1.2	V
Small-Signal Forward-Current Transfer Ratio	h_{fe}	V_{CE} = 10 V, I_C = 0.5 A, f = 10 MHz	6	-	
Output Capacitance	C_{ob}	V_{CB} = 10 V, I_E = 0, f = 1 MHz	-	175	pF
Second-Breakdown Collector Current	$I_{S/b}$	V_{CE} = 40 V (base forward-biased)	400	-	mA
Second-Breakdown Energy	$E_{S/b}$	V_{BB} = -4 V, R_{BE} = 50 Ω, L = 50 μH	0.4	-	mJ
Saturating Switching Times:					
Delay Time	t_d	V_{CC} = 30 V, I_C = 4 A, I_{B1} = 0.4 A	-	40	ns
Rise Time	t_r	V_{CC} = 30 V, I_C = 4 A, I_{B1} = 0.4 A	-	400	ns
Storage Time	t_s	V_{CC} = 30 V, I_C = 4 A, I_{B1} = 0.4 A, I_{B2} = -0.4 A	-	800	ns
Fall Time	t_f	V_{CC} = 30 V, I_C = 4 A, I_{B1} = 0.4 A, I_{B2} = -0.4 A	-	400	ns
Thermal Resistance, Junction to Case	$\theta_{J\text{-}C}$		-	5	°C/W

termined by means of the following equation:

$$N_p = \frac{V}{4fAB} \times 10^8$$

where N_P is the number of turns in the primary winding, V is the peak voltage across the primary winding, f is the operating frequency in hertz, A is the cross-sectional area of the core in square centimeters, and B is the flux density in gauss. In the design of the drive transformer T_2, the value of flux density B is selected to cause the core to saturate. For the output transformer T_1, the value of B is selected to assure that T_1 will not saturate. The base resistor R_B is determined by the voltage at the secondary of T_2 and the base drive required for the transistor. The resistor R_S is selected so that a voltage of 0.7 volt appears across R_B when the power is turned on initially.*

* A complete discussion of inverter design considerations and design information is given in RCA Application Note SMA-37: "High-Speed Inverters Using Silicon Power Transistors" by H.T. Breece.

Fig.2 shows the circuit diagram for a practical 100-watt, 18-kHz inverter using RCA-2N5202 transistors. Performance characteristics for this inverter are shown in Fig.3, and waveforms of output voltage, collector voltage, and collector current as functions of time are shown in Fig.4.

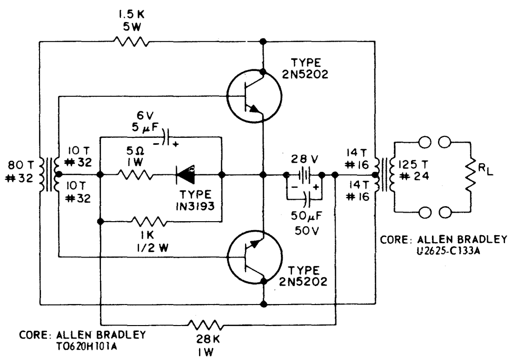


Fig.2 - Circuit diagram for 100-watt, 18-kHz inverter.

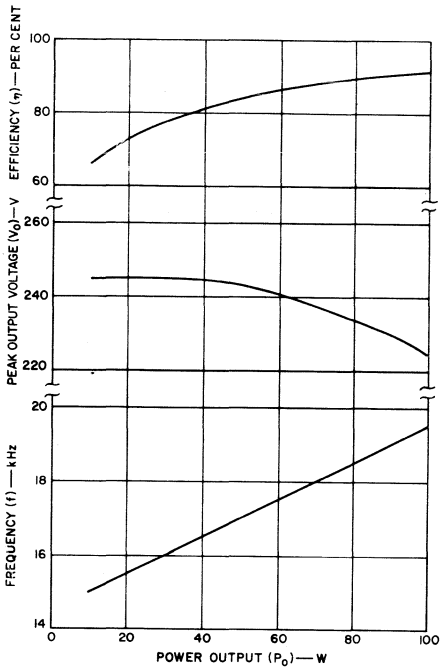


Fig.3 - Performance characteristics of inverter shown in Fig.2.

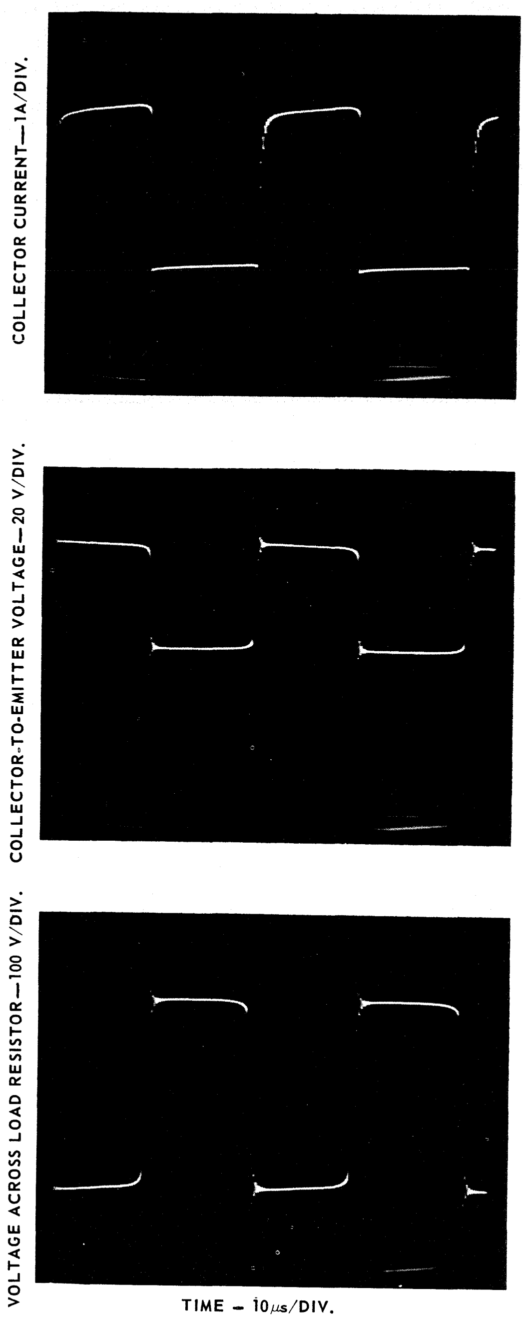


Fig.4 - Waveforms of output voltage, collector voltage, and collector current in inverter of Fig.2.

Power Output and Dissipation in Class B Transistor Amplifiers

by

R. S. Hartz and F. S. Kamp

Calculations have been presented[1,2] to show that maximum transistor power dissipation in a class B amplifier occurs when the output stage is delivering about 40 per cent of maximum power output to the load and maximum transistor power dissipation amounts to about 20 per cent of maximum sine-wave power output in class B output stages. These calculations are based on several important assumptions, including that of perfect power-supply regulation. This Note considers the effect of power-supply regulation on the ratio of music power to continuous power, the ability of the amplifier to reproduce program material, and the economics of amplifier construction.

POWER-SUPPLY REGULATION

Regulation curves for typical rectifier power supplies with capacitive input filters show that the drop in dc output voltage E_{dc} is nearly a linear function of the dc output current I_{dc} over the entire useful range of the supply. Fig.1 shows a regulation curve for a typical transformer/rectifier supply with a capacitive input filter. The slope of the curve is equal to the effective value of the internal resistance of the supply. The supply voltage E_S may be related to the no-load supply voltage E_o as follows:

$$E_S = E_o - R_S I_{dc} \quad (1)$$

where R_S is the internal resistance of the supply. (This equation is discussed further in Appendix A.)

A single-ended power supply in a class B amplifier delivers current on alternate half cycles. The output current I_{dc} is then equal to the peak output current I_{pk} divided by π, and the supply voltage is given by

$$E_S = E_o - R_S (I_{pk}/\pi) \quad (2)$$

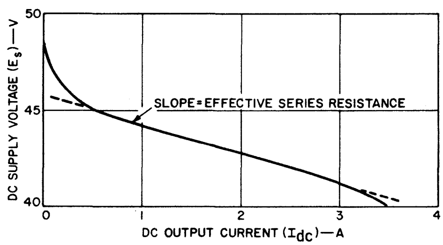


Fig.1 - Typical regulation curve for a transformer/rectifier power supply with a capacitive input filter.

Each half of a balanced split supply delivers the same magnitude of current on alternate half cycles. For the split supply, E_S and E_o in Eq. (2) represent the sum of the voltages of both sides; R_S is the sum of the effective series resistance of both sides.

POWER OUTPUT AND TRANSISTOR POWER DISSIPATION

When the value of E_S derived from Eq. (2) is used as the supply voltage, the maximum transistor dissipation $P_{T(max)}$ may be expressed as follows:

$$P_{T(max)} = E_o^2/(8R_S + 4\pi^2 R_L) \quad (3)$$

where R_L is the resistance of the load.

The maximum unclipped power output for an amplifier with a perfectly regulated supply is often called the music power output,* P.O.(music), and is given by

$$\text{P.O.(music)} = E_o^2/8R_L \quad (4)$$

Maximum average transistor dissipation is related to the music power output by the following expression:

$$\frac{P_{T(max)}}{\text{P.O.(music)}} = \left[\frac{\pi^2}{2} + \frac{R_S}{R_L}\right]^{-1} \quad (5)$$

The power output at which maximum average transister dissipation occurs, P.O. (max diss), is related to the music power output as follows:

$$\frac{\text{P.O.(max diss)}}{\text{P.O.(music)}} = \left[\frac{\pi^2}{4} + \frac{R_S}{R_L} + \frac{R_S^2}{\pi^2 R_L^2}\right]^{-1} \quad (6)$$

The continuous power output at the clipping level, P.O. (clipping), is related to the music power output by the following expression:

$$\frac{\text{P.O.(clipping)}}{\text{P.O.(music)}} = \left[1 + \frac{R_S}{\pi R_L} + \frac{R_S^2}{4\pi^2 R_L^2}\right]^{-1} \quad (7)$$

Eqs. (5), (6), and (7) are plotted in Fig.2. Power levels are normalized with respect to the music power output and are plotted as a function of R_S/R_L. These equations are derived in Appendix A.

Fig.2 shows that transistor power dissipation is only a small fraction of the clipping power output for higher ratios of R_S/R_L. For example, a 100-watt amplifier can use transistors and associated heat sinks capable of a maximum dissipation of only about 7 watts each. However, Eqs. (5), (6), and (7) (and consequently the curves of Fig.2) do not reflect high line voltage or the effects of ripple voltage. Calculations of average power dissipation in transistors should also include no-signal bias dissipation, the increase in bias dissipation with increasing ambient and junction temperatures in class AB circuits, storage effects, phase shift, and thermal tracking.[3,4]

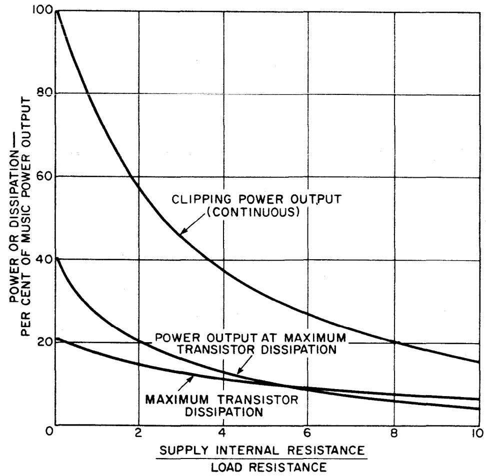


Fig.2 - Power output and dissipation as a function of the ratio of internal supply to load resistance.

Of the above factors, bias dissipation probably contributes the greatest percentage of average worst-case transistor dissipation. The output stage is usually biased "on" slightly (class AB) to reduce crossover distortion.

A Practical Class B Amplifier

Fig.3 shows a class B complementary-symmetry power-amplifier circuit in which bias dissipation is not a problem; it is negligible at all practical temperatures. One side of the amplifier operates at cutoff and the other conducts less than one milliampere. Thermal runaway cannot be initiated in the output-stage transistors at any junction temperature below the maximum transistor rating. Consequently, thermal tracking may also be neglected as long as the sum of the ambient temperature plus the product of the instantaneous dissipation and the junction-to-ambient thermal resistance is below the maximum junction-temperature rating.

Storage effects are also negligible in the amplifier because of the reverse bias provided for the "off" transistor by the "on" transistor in the complementary-

* Although the EIA standard (RS-234A) refers to the point at which total harmonic distortion is 5 per cent when a regulated supply is used, for the purpose of this discussion the maximum unclipped sine-wave power output is referred to as the music power output. The EIA value is about 10 percent greater.

symmetry configuration. Fig.3, then, represents a practical example of an amplifier capable of achieving the characteristics shown in Fig.2. The amplifier circuit is discussed in further detail in Appendix B.

Amplifier Economics

Some economic advantages afforded by the class B amplifier using high values of R_S/R_L and correspondingly high ratios of music-power output to transistor dissipation are as follows:

1. Reduced transistor or heat-sink cost. (Because the volt-ampere capacity of the transistor is determined by the music power output, it is not likely that reduced thermal resistance requirements will result in significant reduction in transistor cost. Alternatively, heat-sink requirements may be reduced and a less expensive heat sink used.)
2. Reduced power-supply costs. (Transformer and/ or filter-capacitor specifications may be relaxed.)
3. Reduced speaker cost. (Continuous power-handling capability may be relaxed.)

These cost reductions can be passed along to the consumer in the form of more music power per dollar.

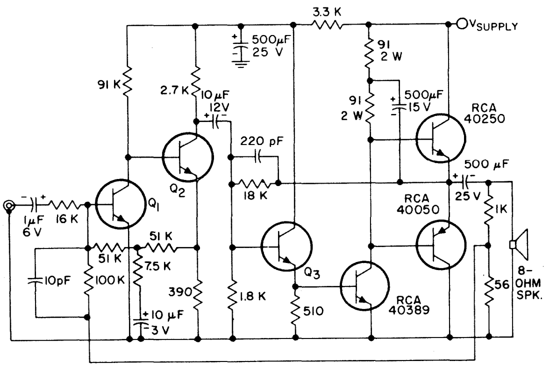


Fig.3 - A practical class B amplifier circuit.

Amplifier Fidelity

The question arises as to how high the ratio of R_S/R_L and the corresponding ratio of music-power output to continuous-power output may go before amplifier fidelity, the capability of the amplifier to reproduce program material, is impaired.

The objective in any high-fidelity amplifier is to provide the listener with a close approximation of the original "live" performance. This goal requires the reproduction of sound-pressure levels approaching those of the concert hall. Although the peak sound-pressure level of the live performance is about 100 dB, the average listener prefers to operate his system at a peak sound-pressure level of about 80 dB.[5] However, the amplifier should also accommodate those who wish to listen at higher-than-average levels, perhaps to peaks of 100 dB.

A sound-pressure level of 100 dB corresponds to a power of about 0.4 acoustical watt for an average room of about 3,000 cubic feet.[5] If speaker efficiencies in the range of one per cent are assumed, a stereophonic amplifier must be capable of delivering about 20 watts per channel. The peak-to-average level for most program material is between 20 and 23 dB. A system capable of providing a continuous level of 77 dB and peaks of 100 dB satisfies the requirements of nearly all listeners. To achieve this output level, the power-supply voltage cannot drop below the voltage required for 100 dB of acoustical power while delivering the average current required for 77 dB. Furthermore, because sustained passages 10 dB above the average may occur, the power-supply voltage cannot drop below the voltage required for 100 dB of acoustic power while delivering 87 dB (87 dB corresponds to about 1 watt per channel). For 8-ohm loads, therefore, neglecting output-circuit losses, the power-supply voltage must not drop below 36 volts while delivering the average current required for 1 watt per channel (0.225 ampere dc).

The power-output capability of the amplifier on peaks, while the amplifier is delivering a total of two watts, does not represent the music-power rating of the amplifier because the power-supply voltage is below its no-signal value by an amount depending on its effective series resistance.

Maximum Effective Series Resistance

There must be a relationship between the maximum effective series resistance R_S of the power supply and the music-power rating of the amplifier if the amplifier is to perform according to the standards described above. R_S may be expressed as a function of music-power output as follows:

$$R_S = \left[\frac{(8R_L)\ \text{P.O.(music)}}{\bar{I}^2} \right]^{1/2} - \frac{E_{S(min)}}{\bar{I}} \qquad (8)$$

where $E_{S(min)}$ is the minimum voltage required for 100 dB of acoustical power output, and $\bar{I}$ is the current required for 87 dB of acoustical power output; $\bar{I}$ does not include idle current. This relationship is discussed further in Appendix C. In practice, $E_{S(min)}$ is increased by peak output-circuit voltage losses.

Eq. (8) is plotted in Fig.4. Each value of R_S represents the absolute maximum value of effective supply resistance corresponding to a music-power value that will allow the amplifier to deliver a minimum of 100 dB of acoustical power output as described above.

Comparison of Fig.4 with Fig.2 shows that very high ratios of music-power output to continuous-power output may be utilized without sacrificing the ability of the amplifier to reproduce program material. This technique provides economic advantages while adhering to a minimum "power margin" for the faithful reproduction of program material, even at high peak listening levels.

The information presented in this Note covers the requirements of nearly all home listening environments and defines the minimum "power margin" for power amplifiers, as well as the minimum performance objectives for nearly all listeners. Component-type amplifier systems, which are sometimes used in conjunction with acoustic suspension speaker systems, may require an increase in the minimum power margin to accommodate reduced efficiencies, especially in the bass region. This increase, however, is probably less than 3 dB.

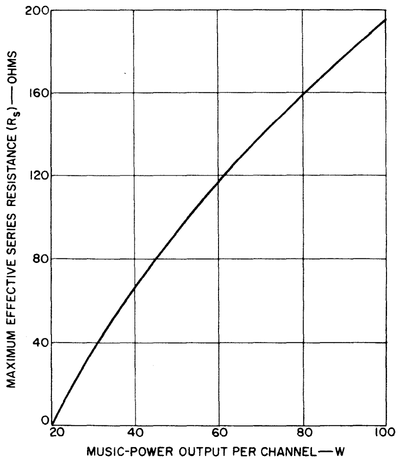


Fig.4 - Maximum effective series resistance as a function of music power.

APPENDIX A

Ideal Power Dissipation (Regulated Supply)

Typical complementary-symmetry circuits are shown in Fig.5. Under no-signal conditions, the capacitor C is charged to a voltage equal to $E_S/2$ at the clipping level. The maximum peak load current $I_{pk(max)}$ is given by

$$I_{pk(max)} = E_S/2R_L \quad (A1)$$

Because the supply delivers current on alternate half-cycles, the average supply current I_S is given by

$$I_S = I_{pk}/\pi \quad (A2)$$

The power delivered by the supply P_S can then be expressed as follows:

$$P_S = (I_{pk}E_S)/\pi \quad (A3)$$

The power delivered to the load, P.O., is given by

$$P.O. = (I_{pk}^2 R_L)/2 \quad (A4)$$

The dissipation P_C for each transistor is equal to half the difference between the supply power delivered P_S and the power dissipated in the load, P.O., as follows:

$$P_C = (P_S - P.O.)/2$$

$$P_C = \frac{I_{pk}E_S}{2\pi} - \frac{I_{pk}^2 R_L}{4} \quad (A5)$$

If Eq. (A5) is differentiated and solved for the peak load current I_{pk} at maximum average transistor dissipation, the following expression is obtained:

$$I_{pk} = E_S/(\pi R_L) \quad (A6)$$

When this value is substituted in Eq. (A5), the ratio of maximum average transistor dissipation P_C(max) to power delivered to the load at full power output P.O. (max) can be expressed as follows:

$$\frac{P_C(max)}{P.O.(max)} = \frac{2}{\pi^2} \quad (A7)$$

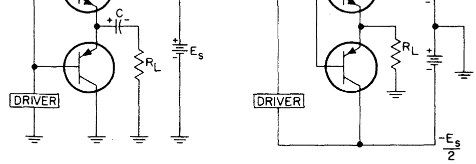


Fig.5 - Typical complementary-symmetry circuits.

Eq. (A7) indicates that maximum transistor dissipation is approximately 20 per cent of full power output. At the point of maximum dissipation, the power output is given by

$$P.O.(\text{max diss}) = \frac{E_S^2}{2\pi^2 R_L} \qquad (A8)$$

The ratio of the power output at maximum dissipation P.O. (max diss) to maximum power output P.O, (max) is then given by

$$\frac{P.O.(\text{max diss})}{P.O.(\text{max})} = \frac{4}{\pi^2} \qquad (A9)$$

Non-Regulated Supply

Fig.6 shows a typical regulation curve for a rectifier power supply that has a capacitive input filter. The voltage is a linear function of the average supply current over most of the useful range of the supply. However, a rapid change in slope occurs in the regions of both very small and very large currents. In class B amplifiers, the no-signal supply current normally occurs beyond the low-current knee, and the current required for the amplifier at the clipping level occurs before the high-current knee. The slope between these points is nearly linear and may be used as an approximation of the equivalent series resistance of the supply.

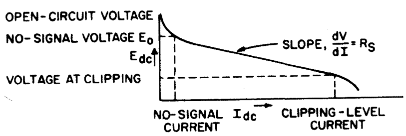


Fig.6 - Typical regulation curve for a rectifier power supply with a capacitive input filter.

Figs.7 and 8 show equivalent circuits for capacitive-input rectifier supplies. In these circuits, I_{dc} is the average supply current, R_S is the equivalent series resistance of the power supply, E_o is the no-signal supply voltage, and E_S is the steady-state supply voltage. The steady-state voltage E_S is related to the no-signal voltage E_o as follows:

$$E_S = E_o - R_S I_{dc} \qquad (A10)$$

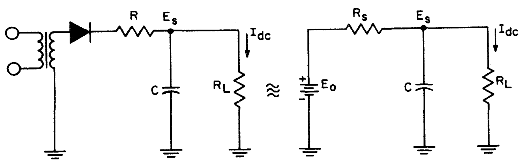


Fig.7 - Equivalent circuits for a single-ended capacitive-input rectifier power supply.

If this value is substituted for the supply voltage E_S in Eq. (A3), Eq. (A5) can be rewritten as follows:

$$P_C = \frac{I_{pk}E_o}{2\pi} - \frac{R_S I_{pk}^2}{2\pi^2} - \frac{I_{pk}^2 R_L}{4} \qquad (A11)$$

The partial derivative of this equation with respect to I_{pk} is set equal to zero, tested for a maximum value, and solved for I_{pk}. This value of I_{pk} is then used in Eq. (A11) to determine the maximum transistor dissipation P_C(max), as follows:

$$\frac{\partial P_C}{\partial I_{pk}} = \frac{E_o}{2\pi} - I_{pk}\frac{2R_S + \pi^2 R_L}{2\pi^2} \qquad (A12)$$

$$I_{pk} = \frac{E_o \pi}{2R_S + \pi^2 R_L} \qquad (A13)$$

$$P_C(\text{max}) = \frac{E_o^2}{8R_S + 4\pi^2 R_L} \qquad (A14)$$

Clipping begins at the point where the peak collector current I_{pk} is given by

$$I_{pk} \simeq \frac{E_o \pi}{R_S + 2\pi R_L} \qquad (A15)$$

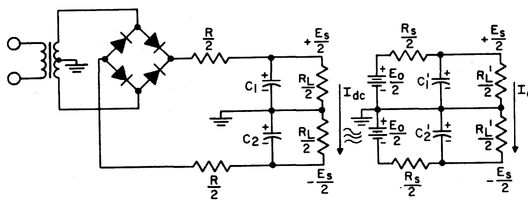


Fig.8 - Equivalent circuits for a split capacitive-input rectifier power supply.

Power output at clipping can then be expressed as follows:

$$P.O.(clipping) = \frac{E_o^2 \pi^2 R_L}{2(R_S + 2\pi R_L)^2} \qquad (A16)$$

If $R_S = 0$ is substituted in Eq. (A16), the music power may be shown to be equal to $E_o^2/8R_L$. The ratio of clipping power to music power output is given by

$$\frac{P.O.(clipping)}{P.O.(music)} = \left[1 + \frac{R_S}{\pi R_L} + \frac{R_S^2}{4\pi^2 R_L^2}\right]^{-1} \qquad (A17)$$

Maximum transistor dissipation occurs at the peak-current level given in Eq. (A13). The power output at maximum dissipation is given by

$$P.O.(max\ diss) = \frac{E_o^2 \pi^2 R_L}{2(2R_S + \pi^2 R_L)^2} \qquad (A18)$$

The ratio of power output at maximum dissipation to music power can then be expressed as follows:

$$\frac{P.O.(max\ diss)}{P.O.(music)} = \left[\frac{\pi^2}{4} + \frac{R_S}{R_L} + \frac{R_S^2}{\pi^2 R_L^2}\right]^{-1} \qquad (A19)$$

APPENDIX B

Class B Amplifier (Circuit Description)

The amplifier shown in Fig.3 is, for all practical purposes, a true class B amplifier. There are no emitter resistors in the output stage and the bases of the output transistors are tied together. If there were no dc feedback current through the voltage-divider network (i.e., the resistors from the emitters of the output transistors to the base of the pre-driver transistor and then to ground) used to establish the center voltage of the output stage, both output transistors would be cut off or reverse-biased. However, because of the dc feedback the upper transistor in the output stage turns on at a current level determined by the voltage-divider network. In the amplifier of Fig.3, this current is at least one order of magnitude less than the idle current normally used in the output stage to reduce crossover distortion. When the upper transistor is "on", the bottom transistor is reverse-biased by the amount of the forward base-to-emitter voltage of the upper transistor required to supply the dc feedback current. The dissipation in the upper transistor resulting from the dc feedback current is negligible and is reduced further as a result of the inverse proportion that exists between dc feedback current and temperature; dc feedback current decreases with reductions in base-to-emitter voltage in the transistors in the driver and pre-driver stages as transistor temperatures in those stages increase. The fact that the no-signal current in the upper transistor is negligible and the bottom transistor is reverse-biased further demonstrates that the circuit shown in Fig.3 acts as a true class B amplifier.

Some advantages derived from the class B mode of amplifier operation and from the complementary-symmetry amplifier design shown in Fig.3 in particular are as follows:

1. There is no dissipation in the output stage under zero-signal conditions, for the reasons discussed above.
2. Hum and noise at the output are reduced. The bottom half of the output stage is normally reverse-biased or "off" and is not turned on by hum and noise. Only that hum and noise amplified by the top transistor appears at the output.
3. The total harmonic distortion is low as a direct result of the large amounts of feedback necessary to reduce the crossover distortion. An additional gain stage is required by this amplifier because of this feedback. The output-stage bias diode and emitter resistors are no longer necessary with the added gain stage and feedback. The crossover distortion is always larger in class B than in class AB amplifiers; however, the class B amplifier can be designed with an acceptable intermodulation (IM) distortion level. (Crossover distortion appears as IM distortion.)
4. There is no storage effect in the output transistors. This feature is an advantage of all true complementary-symmetry amplifiers: when one of the output transistors turns "on" it automatically reverse-biases the other and thus pulls the stored charge out of the base region of the "off" transistor.
5. A lower power-supply voltage is required as a result of the absence of emitter resistors in the output stage. There are no voltage drops between the power supply and the speaker except those in the transistor; therefore, the power-supply voltage can be reduced by $2(R_E I_p)$, where R_E is emitter resistance and I_{pk} is peak collector current.

In summary, the many advantages of the amplifier circuit of Fig.3 overshadow the presence of a very slight but acceptable crossover distortion. Furthermore, the cost of the extra transistor stage, the pre-driver stage, is partially offset by the elimination of bias diodes and emitter resistors.

APPENDIX C

Maximum Allowable Effective Series Resistance and Music-Power Output

During sustained passages of a high average sound-pressure level of the order of 10 dB above the normal listening level, the power-supply voltage should not collapse below the point at which the amplifier with its speaker system can deliver a peak sound-pressure level of 100 dB.[5] This point corresponds to a stereo power output of 20 watts per channel. The normal sound-pressure level is 77 dB, which corresponds to an amplifier power output of 0.1 watt per channel. The sustained high average sound-pressure level is, then, 87 dB, which corresponds to an amplifier power output of 1.0 watt per channel. Both of these power outputs are based on a speaker efficiency of 1 per cent and a room volume of 3,000 cubic feet.[5] To determine the relationship between maximum allowable effective series resistance, R_S, and music-power output, P.O. (music), only the load resistance R_L or speaker impedance need be known. It was determined above that the dc power-supply voltage E_S(min) must be large enough for the amplifier to deliver 20 watts per channel for a short time when it is delivering an average of 1 watt per channel. Fig.9 shows a power-supply regulation curve. The power-supply voltage at zero signal is E_o; the power-supply voltage is $E_{S(min)}$ when the amplifier is delivering 1 watt per channel or 2 watts total. The zero-signal current I_o and the difference between I_o and the steady-state current drain at a total power output of 2 watts is $\bar{I}$. For this discussion, R_L is 8 ohms.

The rms current I_{rms} in the load resistance R_L at a total output P_{out} of 2 watts is given by

$$I_{RMS} = \sqrt{\frac{P_{out}}{R_L}} = 0.5 \text{ ampere} \qquad \text{(C1)}$$

At this current level the difference $\bar{I}$ between the zero-signal current I_o and the steady-state current drain at a total power output of 2 watts is given by

$$\bar{I} = \frac{I_{RMS}\sqrt{2}}{\pi} = 0.225 \text{ ampere} \qquad \text{(C2)}$$

The power-supply voltage at zero signal, E_o, can be determined from the following equation:

$$E_o = E_{S(min)} + \bar{I}R_S \qquad \text{(C3)}$$

where $E_{S(min)}$ is the power-supply voltage at a total power output of 2 watts and R_S is the maximum allowable effective series resistance.

The music-power output P.O.(music) is

$$\text{P.O.(music)} = \frac{E_o^{\,2}}{8R_L} \qquad \text{(C4)}$$

Combination of Eqs. (C3) and (C4) results in the following relation:

$$\text{P.O.(music)} = \frac{\left[E_{S(min)} + \bar{I}R_S\right]^2}{8R_L} \qquad \text{(C5)}$$

The solution of Eq. (C5) for R_S is as follows:

$$R_S = \frac{\sqrt{8R_L\ \text{P.O.(music)}}}{\bar{I}} - \frac{E_{S(min)}}{\bar{I}} \qquad \text{(C6)}$$

For a load resistance of 8 ohms, R_L is given by

$$R_S = \frac{8}{\bar{I}}\sqrt{\text{P.O.(music)}} - \frac{E_{S(min)}}{\bar{I}} \qquad \text{(C7)}$$

The required $E_{S(min)}$ for a music-power output of 20 watts per channel is

$$E_{S(min)} = \sqrt{20\,(8R_L)} = 35.8 \text{ volts} \qquad \text{(C8)}$$

Substitution of $\bar{I}$ and E_S then provides the following expression for R_S:

$$R_S = 35.6\sqrt{\text{P.O.(music)}} - 159 \qquad \text{(C9)}$$

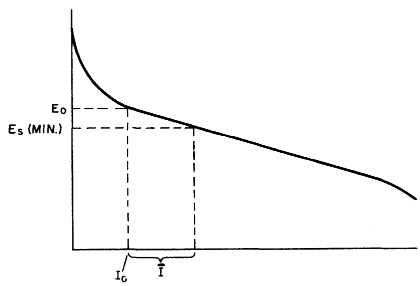


Fig.9 - A power-supply regulation curve.

References

1. C. F. Wheatley, *"Power Dissipation in Class B Circuits,"* ELECTRONIC DESIGN, September 1958.
2. M. V. Joyce and K. K. Clarke, TRANSISTOR CIRCUIT ANALYSIS, Addison-Wesley, 1961, pp. 193-195.
3. M. S. Fisher, *"Reliability Considerations in Audio Power-Output Stages of Transistor Amplifiers,"* RCA Application Note AN-3448, April 1967.
4. C. F. Wheatley and J. W. Englund, *"Reliability Considerations in the Application of Power Transistors to Consumer Products,"* IRE TRANSACTIONS ON BROADCAST AND TV RECEIVERS, July 1962.
5. H. F. Olsen, MUSIC, PHYSICS AND ENGINEERING, Dover Publications, Inc., *2nd Edition,* 1967.

RCA
Solid State
Division

Power Transistors
Application Note
AN-3616

Solid-State Ballasting of Mercury-Arc Lamps

by

Peter Schiff

Recent advances in the voltage- and current-handling capabilities of power transistors have made possible the design of solid-state switching-regulator ballasts that offer significant advantages over conventional ballasting devices for high-pressure mercury-arc lighting systems. In addition to the usual transistor-circuit benefits of reduced weight and bulk, the new solid-state ballasts provide unmatched power regulation for line-voltage fluctuations and exceptional versatility. The basic solid-state ballast circuit includes a built-in lamp-dimming feature that permits a single design to be used with lamps of various power ratings over a range of 50 to 150 per cent of the power rating specified for the ballast design. Moreover, transistor ballast circuits eliminate the annoying strobe effect associated with conventional ballasting devices and thereby make the long-life, efficient mercury-arc lamps suitable for use in studios and similar critical lighting areas.

RELATIVE MERITS OF VARIOUS LIGHTING SYSTEMS

Table I compares the characteristics and provides a brief cost analysis of incandescent, fluorescent, mercury-arc, Lucalox,* and sodium-lamp lighting systems. The over-all cost of each system is determined by three main factors: (1) power consumed during operation, (2) replacement and maintenance, and (3) initial installation. The cost of initial installation is almost insignificant when compared to the other cost items. In general, power-consumption costs are approximately seven times greater than the costs of initial installation. Replacement-and-maintenance costs, at present, represent two or three times the initial-installation costs, but are rising at a very rapid rate. Because of the higher efficiency and reduced maintenance requirements of gas-discharge (arc) lamps, lighting systems that use these types of lamps have displaced those that use incandescent (tungsten-filament) lamps in most industrial and highway installations.

Fluorescent lighting systems are currently the most widely used of the various gas-discharge types. In view of the rapid rise in maintenance costs, however, the long-life (approximately 20,000 hours) mercury-arc bulbs have become increasingly attractive. The use of mercury-arc lighting systems is increasing at a rate that far exceeds that of fluorescent systems, and mercury-arc lamps are now being used in numerous applications for which fluorescent types were previously employed, as well as in many new applications in the home. In addition, greater expansion of the application of mercury-arc lamps is expected to result from new phosphors which will further develop the light characteristics of these devices.

Another important consideration in selection of a gas-discharge lighting system is whether the lamp is to be operated from an ac or a dc power source. Neither fluorescent nor Lucalox lamps are particularly well suited for dc operation. When fluorescent lamps are operated from dc voltages, the direct currents force the mercury atoms to one end of the arc tube with a resultant dimming of the other end. Moreover, the lamp efficiency for dc operation may be only 70 per cent of that for high-frequency ac operation, and the life of a dc-operated fluorescent is derated 20 per cent. The Lucalox arc tube cannot withstand the temperature differential between the electrodes that is characteristic of dc operation. This temperature differential results because the positive electrode is disproportionately heated by electron bombardment.

* Trade name of the General Electric Company

TABLE I – A COMPARISON OF THE CHARACTERISTICS OF VARIOUS LIGHTING SOURCES

Type	Description	Ingredients	Light Quality	Percent Eff.	Life (hrs)	Warmup Time	Time Before Restart	400W Bulb or Equivalent: Bulb Cost	Indoor Fixture Cost	Ballast Cost	Cents/ lumen-hr x 10^{-4}
Incandescent	Filament (point light source)	Tungsten in Nitrogen	Good - much red, no blue (continuous spectrum)	2.6	2,000	None	None	$ 1.25	$10.00		1.80
Fluorescent	Low-pressure vapor with phosphor correction	Mercury	Good	9.5	10,000	Few Seconds	None	$16.00	$25.00	$ 20.00	0.56
Mercury Arc (Color Corrected)	High-pressure vapor with phosphor correction (point source)	Mercury and Argon in Quartz burner	Slightly cold	7.5	20,000	4 min.	5 min.	$20.00	$30.00	$ 45.00	0.70
Lucalox	High-pressure, high-temperature vapor (point source)	Sodium and Mercury in Alumina burner	Sunny, much yellow	15.0	6,000	3.0 min.	1 min.	$45.00	$30.00	$120.00	0.54
Sodium Vapor	High-pressure vapor (point source)	Sodium, Neon	Yellow monochromatic	15.0	6,000	18 min.	None				

NOTE: In the cost analysis, the maintenance factor proportional to life of bulb was not included. The electrical power cost was assumed to cost three cents per kilowatt hour, and the life of the ballast and fixture was estimated to be 60,000 hours.

High-pressure mercury-arc lamps provide the same efficiency for either ac or dc operation. For dc operation, the mercury-arc lamp offers the advantage of no strobe effect. However, because only one arc-tube electrode is bombarded by electrons during dc operation, a slight decrease in tube life results from the overheating of this electrode. A redesign of the electrodes should alleviate this condition.

CHARACTERISTICS OF MERCURY-ARC LAMPS

Fig.1 shows the basic construction of a mercury-arc lamp. The arc tube is made of quartz to withstand the wide extremes and sharp gradients of temperature to which it is subjected. This quarts tube contains some argon in addition to the mercury which evaporated and ionized to provide the arc lighting. The argon is a starting aid and also prolongs the life of the lamp electrodes by retarding electron bombardment and evaporation of the electrodes.

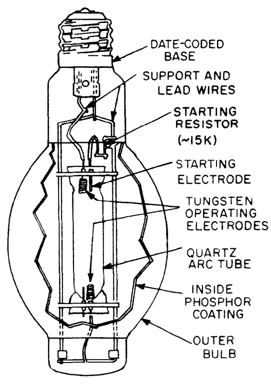


Fig.1 - Cutaway view of a mercury-arc lamp.

A mercury-arc lamp is essentially a varying impedance which is driven from the ac line through an inductive ballast. Fig.2 shows the voltage and current characteristics of the mercury-arc bulb during warmup. The argon in the arc tube ionizes when the voltage across the lamp electrodes rises to 200 volts (point 1 in Fig.2); the voltage then decreases rapidly to 18 volts (point 2 in Fig.2). The lag in current with respect to the bulb voltage, shown in Fig.2(b), results because of the ballasting inductor in series with the lamp electrodes. Warm up of the mercury-arc bulb is completed in approximately 3 minutes. During this period, the mercury vaporizes, and a stable operating point is then attained (point

3 in Fig.2). The inductive ballast is designed so that the slope of the change in voltage between points 2 and 3 results in a reduced warm-up time. If the mercury-arc bulb is turned-off, the mercury cannot be re-ionized until approximately 5 minutes have elapsed, i.e., until the pressure and temperature in the arc tube have decreased sufficiently.

CONVENTIONAL BALLASTING METHODS

For operation of the mercury-arc lamp in 120-volt line applications, a voltage step-up transformer ballast must be used to develop the high starting potential (200 volts) and the required current-voltage slopes [shown in Fig.2(b)]. This transformer ballast, however, must have a large leakage inductance to accommodate the varying bulb characteristics. For operation of the mercury-arc lamp from ac voltages of 220 volts or higher, ballasting may be provided by a simple series reactor. Fig.3 shows the two ballasting arrangements. As shown in the circuit diagrams, a power-factor-correction capacitor (usually an oil type) should be used with each ballast circuit. The efficiency of these circuits ranges from 75 to 95 per cent.

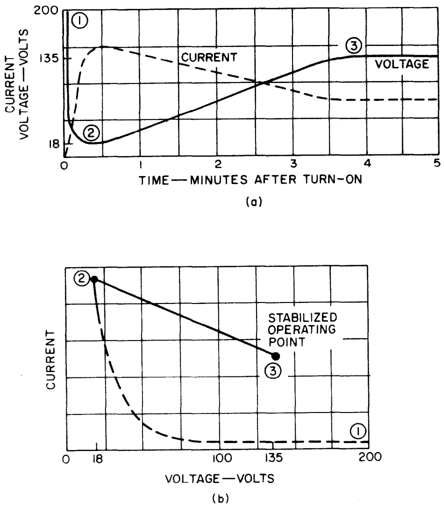


Fig.2 - Warm-up characteristics of a typical (135-volt) mercury-arc lamp: (a) current and voltage as a function time; (b) current as a function of voltage.

A major disadvantage of conventional ballasting reactors is poor power regulation for line-voltage fluctuations. The power regulation can be improved, as shown in Fig.4(a), by use of a saturating (constant-current) type of ballasting reactor. When this type of ballasting is employed, however, circuit efficiency is reduced, and a longer bulb warm-up period is required. Voltage and current waveshapes of conventional ballasts are shown in Fig.4(b).

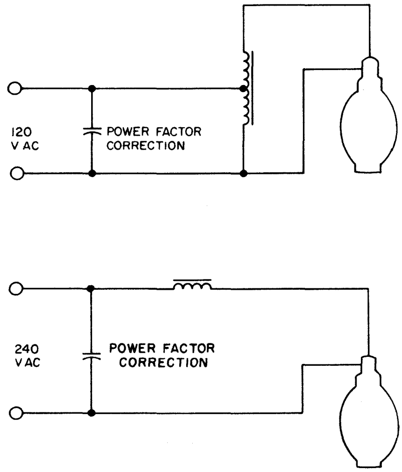


Fig.3 - Conventional ballasts for 120- and 240-volt ac mercury-arc lamps.

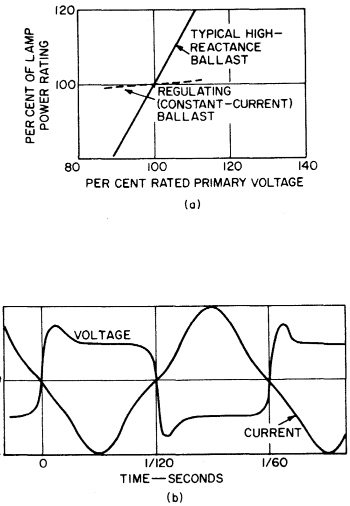


Fig.4 - Characteristics of conventional mercury-arc-lamp ballasts: (a) regulation characteristics; (b) voltage and current as a function of time.

SOLID-STATE BALLASTING CIRCUITS

The block diagram in Fig.5 shows the basic requirements of an electronic type of ballasting circuit for mercury-arc lamps. This type of ballast may be operated from either an ac or dc voltage source; the rectifier bridge, or course, is not required for dc source voltages. AC input voltages are first rectified, and the resultant dc voltage is then converted to the level required for

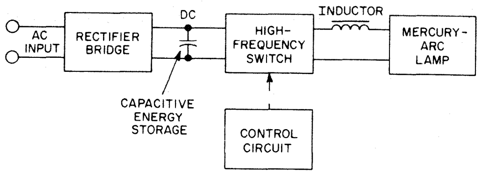


Fig.5 - Block diagram of an electronic ballasting system for mercury-arc lamps.

application to the mercury-arc lamp by some type of inverter or converter (solid-state switch and associated control circuit).

Efficient conversion of a voltage from one level to another level requires the use of an inductive component. If a size advantage is to be realized from the use of an electronic ballasting circuit, the frequency of the solid-state switch must be high enough so that the converter inductor is significantly smaller than a conventional 60-Hz ballasting reactor. A small inductor, however, cannot maintain the arc in a mercury-arc bulb as the ac source voltage swings through zero. If no other storage element were included in the electronic ballasting circuit, the arc would be extinguished; the mercury-arc lamp must then be allowed to cool sufficiently before a new arc can be produced. The electronic ballast, therefore, includes a capacitor for additional energy storage when the circuit is operated from an ac voltage source.

Fig.6 shows three prospective electronic ballasting circuits: a ringing-choke converter, a push-pull inverter, and a switching regulator. Table II summarizes the characteristics of each type. The important considerations in the selection of one circuit in preference to the other circuits are power-regulation capabilities, operating efficiency, small size, and requirements of the solid-state switching element.

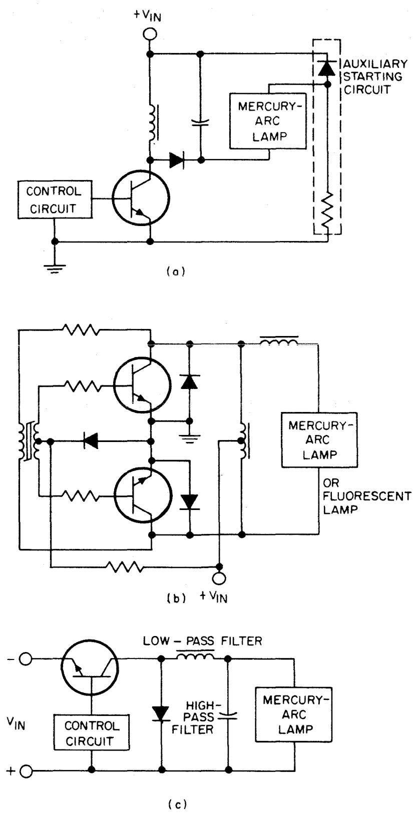


Fig.6 - Three basic circuit configurations that may be used in electronic ballasting systems: (a) ringing-choke converter; (b) push-pull inverter; (c) switching regulator.

TABLE II — CHARACTERISTICS OF VARIOUS ELECTRONIC BALLASTING CIRCUITS

CIRCUIT	V_{IN} - V_{OUT}	DC or AC OUT	REMARKS	REGULATION	APPROX. EFF.	Switching Transistor: No. of Devices	Switching Transistor: V_{CE}	Switching Transistor: I_C(peak)
Ringing Choke	Independent	DC	Complex Circuit (Open-load protection)	Excellent	70%	1	$V_{IN} + V_{OUT}$	~(4X) I_{OUT}
Push-Pull	Independent	AC	Three magnetic elements	Limited	80%	2	$2V_{IN}$	(4X) I_{OUT}
Switching Regulator*	$V_{IN} > V_{OUT}$	DC	Simple Circuit -	Excellent	90%	1	V_{IN}	(2X) I_{OUT}

* The switching regulator offers the greatest efficiency and least stringent switching-transistor requirement.

The ringing-choke inverter offers the advantage of a dc output which is completely independent of the input voltage; its operating efficiency, however, is low in comparison to the other types of ballasting circuits. The push-pull inverter suffers from the fact that it provides an ac output with poor regulation. In addition, this circuit requires three magnetic components, which substantially add to the bulk of the ballast. The switching regulator is the most efficient and provides the best power regulation of the three types of electronic ballasting circuits. This ballasting circuit also imposes the least stringent requirements on the solid-stage power-switching element, the most critical component of any electronic ballast. These factors make the switching regulator the most economical choice for an electronic ballasting circuit. An additional advantage of this circuit is that it requires only a single magnetic component; integrated-circuit construction techniques, therefore can be readily applied to achieve the small sizes desired for ballasting elements. A disadvantage of the switching-regulator ballast is that the output voltage is always less than the input voltage.

120-Volt Switching-Regulator Ballast

For operation in 120-volt line applications, the basic switching-regulator circuit is modified, as shown in Fig.7, so that the solid-state switching element (transistor Q_1) is operated in the positive feedback mode. The rectified 120-volt ac input appears as a dc voltage across the V_{IN} terminals of the circuit. This voltage drives transistor Q_1 into saturation. The collector current of transistor Q_1 rises linearly through the primary (L_1) winding of transformer T_1 until the voltage drop across the current-sensing resistor R_2 increases above a predetermined threshold level. At this point, transistor Q_3 is turned on, and the collector current of this transistor, in turn, drives transistor Q_2 into conduction to create a virtual short between base and emitter of transistor Q_1. In this way, the drive input to transistor Q_1 is effectively removed. The inductive kick from the L_1 primary winding of transformer T_1 that results from the decrease in the collector current of transsistor Q_1 is clamped by the commutating diode D_3 so that the current decays linearly through the winding. Positive feedback coupled from the secondary (L_2) winding of transformer T_1 holds switching transistor Q_1 in the "off" state until the current through the transformer primary winding decreases to zero. The cycle is then repeated. Fig.8 shows the significant current and voltage waveshapes for the circuit. It is apparent from these waveshapes that switching losses occur only during turn-off.

The equations for the turn-on (t_{on}) and turn-off (t_{off}) times and the switching frequency (f) of the switching-regulator ballasting circuit can be derived from the following basic relationship for the voltage developed across an inductor:

$$E_L = L \frac{di}{dt} \quad (1)$$

During turn on, the voltage across the regulator inductor is essentially the algebraic difference between the input and output voltages (i.e., $E_L = V_{in} - V_{out}$). Because both of these voltages are constant, their difference results in a linearly increasing current through inductor L_1. The rate of change of the current (di/dt) is then the peak value to which the current rises divided by the turn-on period (i.e., $di/dt = I_{peak}/t_{on}$). For those conditions, Eq. (1) may be rewritten in the following form:

$$V_{in} - V_{out} = L_1 \frac{(I_{peak})}{t_{on}} \quad (2)$$

If this equation is solved for t_{on}, the following result is obtained:

$$t_{on} = \frac{L_1 (I_{peak})}{V_{in} - V_{out}} \quad (3)$$

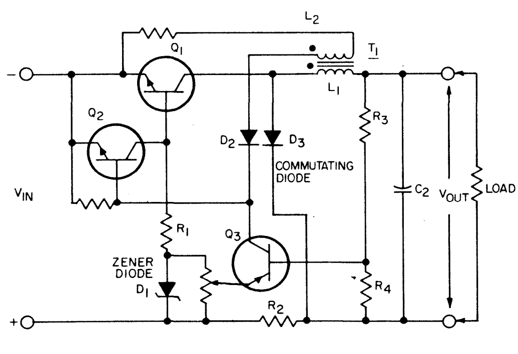


Fig.7 - 120-volt switching regulator.

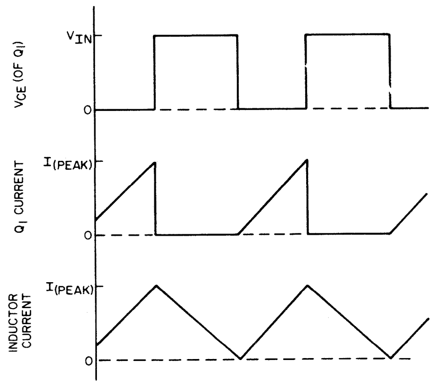


Fig.8 - Typical voltage and current waveforms for the switching regulator shown in Fig.7.

The equation for the turn-off time can be similarly derived. During this period, however, the voltage across inductor L_1 is essentially equal to the output voltage. The current decays linearly through the inductor so that the rate of change of current is constant over the turn-off period. When these conditions are imposed on Eq. (1), the following equation for the turn-off time can be derived:

$$t_{off} = \frac{L_1 (I_{peak})}{V_{out}} \qquad (4)$$

By use of Eqs. (3) and (4), the switching frequency of the switching-regulator ballast can be expressed in terms of the inductor L_1, the peak current, and the input and output voltages:

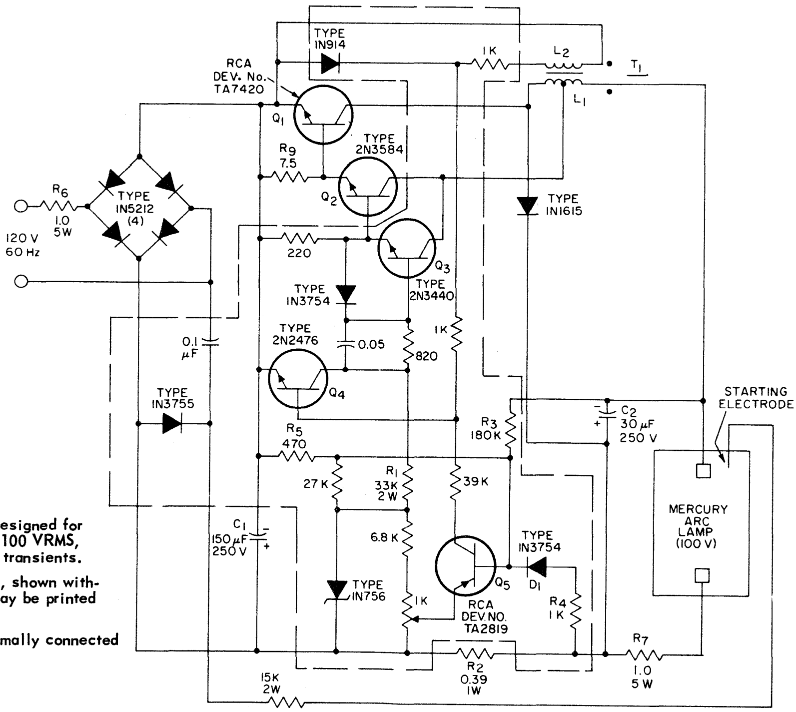
$$f = \frac{1}{t_{on} + t_{off}}$$

$$= \frac{V_{out} + (V_{in} - V_{out})}{L_1 (I_{peak}) (V_{in})} \qquad (5)$$

The peak current and associated output voltage of the switching-regulator circuit can be varied by adjustment of potentiometer R_6. For any given setting of the potentiometer, however, these quantities are constant and are independent of the input voltage. Another factor of interest, which is apparent from Eq. (5), is that a change in power level (i.e., in V_{in} or I_{peak}) results in an inverse change in switching frequency.

Fig.9 shows a practical 100-watt switching-regulator ballasting circuit designed for 120-volt line applications in which the output voltage and current are both sampled to reduce bulb warm-up time. This circuit has a voltage-current characteristic very similar to that shown in Fig.2(b) for a conventional ballasting reactor.

The 120-volt ac input is rectified by a full-wave bridge rectifier. The dc output from the rectifier, is developed across filter capacitor C_1. Because the input drive to the emitter-base circuit of the switching transistor is applied through a resistance network, the relatively high supply voltage can lead to serious I^2R loss-



NOTES: 1. This circuit is designed for operation above 100 VRMS, with 250 V peak transients.

2. Control circuitry, shown within dotted line, may be printed circuit.

3. Diode D_1 is thermally connected to transistor Q_5.

Mercury arc lamp = 90-to-100-volt type with separate starting electrodes

L_1 = 120 turns of No.22 wire tapped 1 turn from collector

L_2 = 18 turns of No.34 wire

T_1 = Arnold AH 361 (or equiv.) with 0.036" gap (6.7:1 turns ratio)

Fig.9 - 100-watt, 120-volt ac switching-regulator ballasting circuit.

es unless the drive current is maintained at a very small value. This condition is made possible by use of two transistors Q_2 and Q_3 in a Darlington configuration to provide the current gain necessary to increase the low value of drive current to the level required to saturate the switching transistor.

Because the switching regulator is a "down converter," has limited filtering, and operates from relatively low line voltages, a special low-voltage (100-volt rather than the more common 135-volt) mercury-arc lamp is used with the 100-watt, 120-volt ballasting circuit. The low-voltage arc tube contains slightly less mercury than the higher-voltage type. High starting potentials are obtained by use of a half-wave voltage doubler, wired to a separate starting electrode (with a current-limiting resistor).

Performance data of the 100-watt switching regulator are shown in Fig.10. These data are shown as a function of the dc input voltage to filter capacitor C_1. The overall efficiency of the circuit, including the rectifier bridge and filter capacitor, is 87 per cent for a 120-volt ac input. The output is adjustable from 15 to 150 watts for operation of the circuit into a 100-ohm load impedance. The excellent regulation characteristics are achieved in part, by the action of resistor R_5, which offsets a rise in output voltage with a corresponding rise in input voltage. Fig.11 shows a photograph of the 100-watt, 120-volt switching-regulator ballasting circuit, together with a mercury-arc lamp.

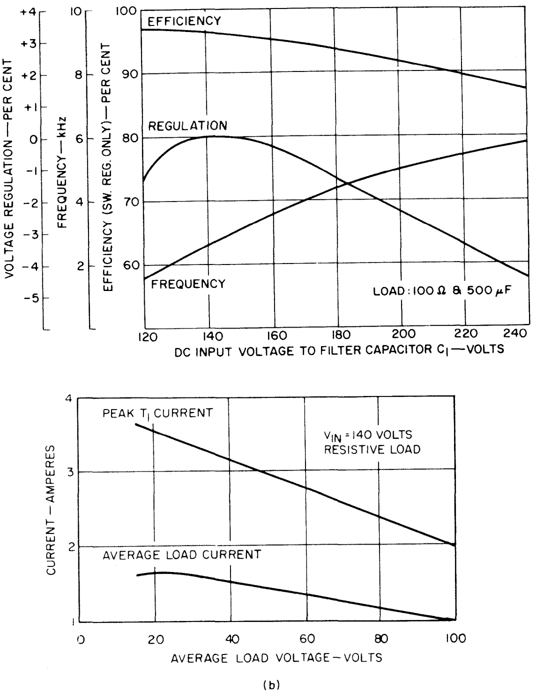


Fig.10 - Performance characteristics of the 100-watt, 100-volt switching-regulator ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.

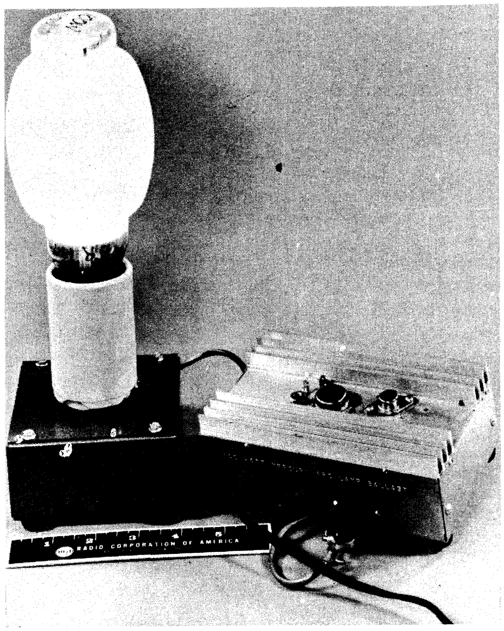


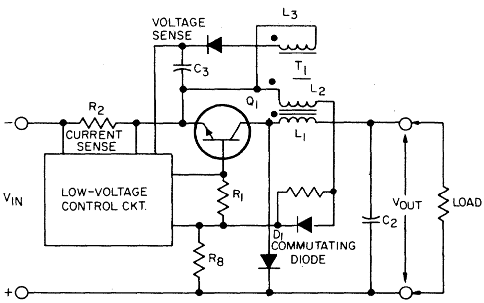
Fig.11 - Photograph of the 100-watt, 120-volt switching-regulator ballasting circuit.

The 120-volt ballast circuit has a relatively small conduction angle, because of a necessarily large filter capacitor (C_1). The associated surge currents make the use of bulbs in excess of 200 watts impractical. The ballast has two 1-ohm surge-current-limiting resistors, R_7 and R_{10}. Resistor R_{10} limits ac line transients; the resistor R_7 limits bulb current during ionization.

200-to-300-Volt Switching-Regulator Ballasts

For industrial and highway lighting installations, 240-volt single-phase, 277-volt single-phase, and 208-volt three-phase ac power sources are readily available. For these voltages, a sufficient differential between the arc-tube voltage and input voltage exists to permit the transistor switching element to be driven from a secondary winding on the inductor of a low-pass filter. Relatively high drive currents can then be obtained without high power losses.

Fig.12 shows the basic configuration for a switching regulator designed to operate from ac source voltages between 200 and 300 volts. Eqs. (1) through (5) and the waveshapes shown in Fig.8, given for the 120-volt switching-regulator ballasts, are also applicable to higher-voltage ballasts of the type shown in Fig.12. A unique feature of the higher-voltage circuits is that only the high-current switching transistor Q_1 is required to have a breakdown-voltage capability sufficient to withstand the full value of the dc input voltage including transients applied across the V_{IN} terminals. All the transistors in the control circuit are low-voltage, low-dissipation types. The design for the higher-voltage ballast also features built-in short-circuit protection.

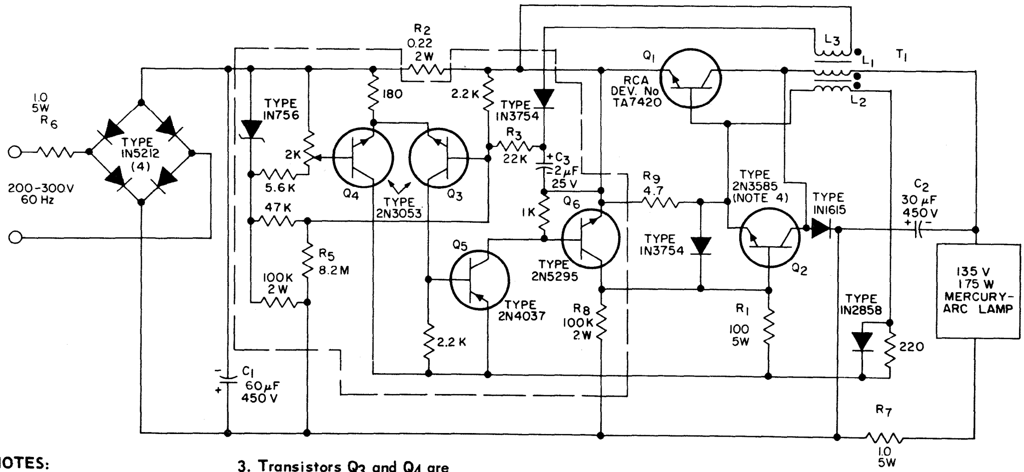


NOTE: This circuit needs only one high-voltage switching element.

Fig.12 - 200-to-300-volt ac switching regulator.

In the switching-regulator circuit shown in Fig.12, the dc voltage applied in the V_{IN} terminals drives a switching transistor (Q_1) that is slightly forward-biased by a small current (approximately 3 milliamperes) through a base-circuit resistor (R_8). Transistor Q_1 is immediately driven into saturation by the positive feedback from its collector circuit supplied by the L_2 secondary winding of transformer T_1. The L_2 secondary winding also supplies the drive power to the control circuit. The collector current of switching transistor Q_1 rises linearly through the L_1 primary winding of transformer T_1 until the voltage across the current-sensing resistor R_2 triggers the control circuit in shunt with the base-emitter junction of transistor Q_1. The transistor is then held cut off by the feedback voltage from the L_2 secondary winding of the transformer until the current through L_1 primary winding decays to zero. The inductive kickback that results from the decrease in current through L_1 is clamped by the commutating diode D_1 and, therefore, is the same as the output voltage on C_2. The L_3 winding of transformer T_1 then charges capacitor C_3 to a voltage proportional to the output voltage. During the next cycle, the control circuit samples a combination of the voltage across capacitor C_3 and the current through resistor R_2. In this way, an output characteristic similar to that of a conventional ballast, shown in Fig.2(b), is obtained.

The schematic diagrams and performance data for two practical ballasting circuits, designed for use with 175-watt and 400-watt memory-arc bulbs, that use the approach illustrated by the basic circuit configuration shown in Fig.12 are shown in Figs.13 and 14 and Figs.15



NOTES:
1. Maximum transient voltage = 450 V.
2. Control circuit shown within dotted line may be printed circuit.
3. Transistors Q_3 and Q_4 are thermally connected.
4. Transistor Q_2 is selected for a $V_{CER(sus)}$ at 200 ohms greater than 500 volts.

T_1 = 2 x Arnold AH-108 (or equiv.) with 0.054" air gap 17:1.7:1 turns ratio

L_1 = 120 turns of No.22 wire

L_2 = 12 turns of No.32 wire

L_3 = 7 turns of No.32 wire

Fig.13 - 175-watt, 200-to-300-volt switching-regulator ballasting circuit.

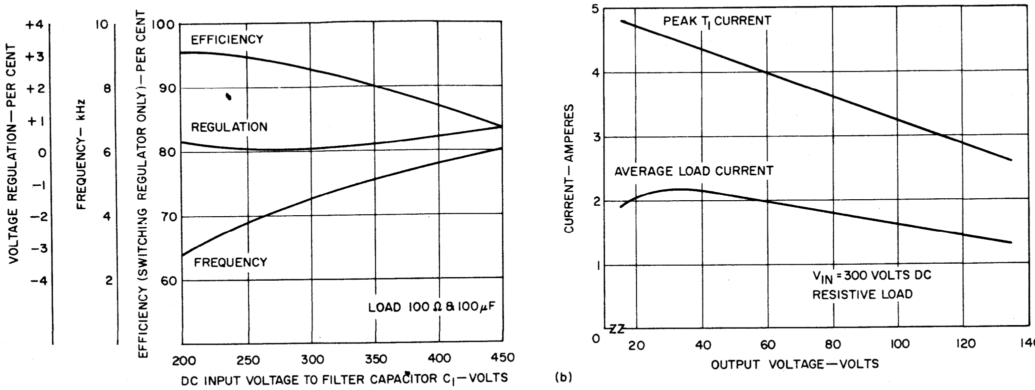
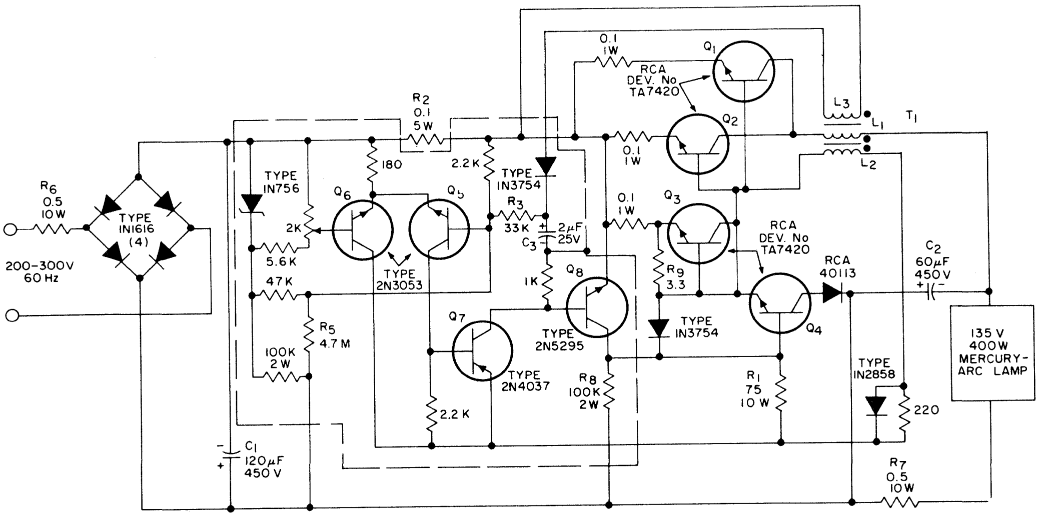


Fig.14 - Performance characteristics of the 175-watt, 200-to-300-volt ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.



Notes:
1. Maximum transient voltage = 450 V.
2. Control circuit shown within dotted line may be printed circuit.
3. Transistors Q_1 through Q_4 are selected to have a $V_{CER(sus)}$ at 20 ohms greater than 500 volts.
4. Transistors Q_5 and Q_6 are thermally connected.

T_1 = Arnold AH-223 (or equiv.) with 0.125 inch air gap, 17:1.7:1 turns ratio
L_1 = 98T turns of No.18 wire
L_2 = 10T turns of No.32 wire
L_3 = 6T turns of No.32 wire

Fig.15 - 400 watt, 200-to-300 volt switching-regulator ballasting circuit.

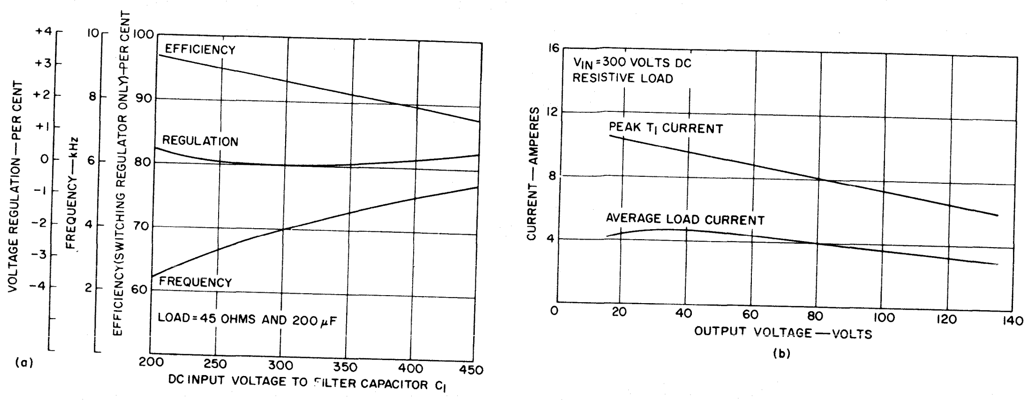


Fig.16 - Performance characteristics of the 400-watt, 200-to-300-volt switching-regulator ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.

and 16, respectively. Performance data are shown as a function of the dc input voltage to filter capacitor C_1. Excellent regulation is obtained for dc input voltages from 200 to 450 volts. Fig.17 shows a photograph of the two ballasting circuits.

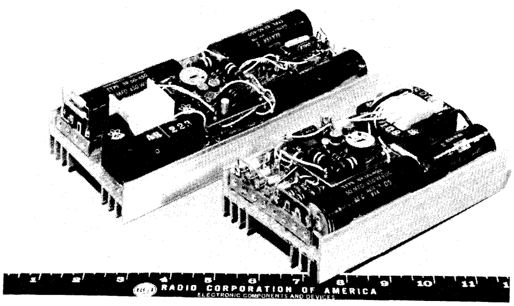


Fig.17 - Photograph of 175-watt and 400-watt 240-volt switching-regulator ballasts for mercury-arc lamps.

DESIGN PROCEDURE

The design of solid-state switching-regulator ballasts for mercury-arc lamps involves three critical operations: (1) selection of the mercury-arc lamp and the peak starting current, (2) selection of the reactor element, and (3) selection of the switching transistor and other circuit components.

Mercury-Arc Lamp and Peak Starting Current

The type of mercury-arc lamp used and the peak starting current that must be supplied to this lamp by the ballast circuit are dictated by the value of the ac source voltage, the amount of lamp power (P_L) required, and the warm-up time of the lamp. For operation from a 120-volt ac line at lamp power levels up to 200 watts, the special low-voltage (90-to-100-volt) type of mercury-arc lamp should be used. The peak starting current is then determined from the following relationship:

$$I_{peak} = 4\left(\frac{P_L}{100V}\right) \quad (6)$$

For operation from ac source voltages in the range of 200 to 300 volts, the more conventional 135-volt type of mercury-arc lamp is used. The peak starting current, for a specified bulb power rating P_L, is then determined as follows:

$$I_{peak} = 4\left(\frac{P_L}{135V}\right) \quad (7)$$

Switching-Regulator Reactor Element

The series inductor selected for the switching-regulator ballasting circuit should have a maximum core cross-sectional area and minimum air gap, consistent with the required inductance value, so that the minimum physical size is obtained. The circuit shown in Fig.18 permits simple di/dt measurements that eliminate the

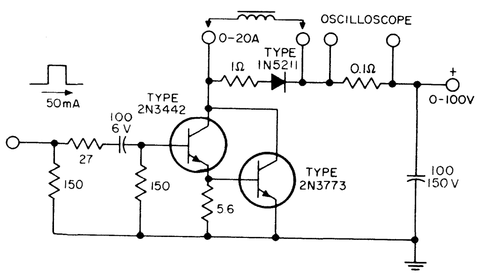


Fig.18 - Inductor tester.

need for repetitive calculations in determination of the required inductances. In this test circuit, the inductor is connected in series with a switching transistor and a dc voltage. The switching transistor is maintained in the "on" state until the inductor saturates. The following equation then becomes the basis for the determination of the inductor parameters:

$$V_{in} = L_1 \left(\frac{Isat}{t_{on}} \right) \quad (8)$$

The desired flux density for the inductor is some fraction of that producted by the saturation current. The air gap, number of turns, and the core are selected as required to obtain the desired value. The turns ratio from the series inductor winding (primary) to the secondary windings is as indicated in the circuit schematics (Fig.9, 13, or 15) of the type of switching-regulator ballast being designed.

If an iron core is used for the inductor, the core laminations should be 4 mils thick (only a negligible increase in efficiency results from the use of thinner laminations). For stabilized operation and to avoid overheating of the inductor, the switching frequency of the ballasting circuit should be less than 5 kHz and the flux density in the inductor should be less than 6 kilogauss. For an inductor that uses a ferrite core, the flux density (determined for worst-case conditions) is usually 3 kilogauss, and the frequency is limited by only the transistor switching losses.

Switching Transistor and Other Circuit Components

A switching transistor used as the switching element in a switching-regulator ballast must have a collector-to-emitter voltage-breakdown capability $V_{CER(sus)}$ high enough so that the device can withstand the total input dc voltage together with the maximum transient input voltage that may be developed in the circuit. In all the ballasting circuits described in this paper, the transistor used as the high-current switching element is the RCA Dev. No. TA7420. The specifications of the TA7420 are given in Table III.

The Darlington transistor circuit in shunt with the emitter-base junction must drive the switching transistor well into the saturation region for the particular I_{peak}.

1. For the 120-volt ballast-circuit design,

   I_B (max) < 10 mA

2. For the 200-to-300-volt ballast-circuit design,

   I_B (max) < 300 mA

Approximately 20 per cent of the base drive to the switching transistor is diverted by resistor R_9 (in Figs.9, 13, and 15) to achieve rapid turn-off of the transistor.

The power dissipated by the transistor selected for use as the switching element should not exceed 10 per cent of the power rating (P_L) of the mercury-arc bulb. The transistor power dissipation (P_D) is calculated for

TABLE III – SPECIFICATIONS FOR THE RCA DEV. NO. TA7420 TRANSISTOR

Parameter	TEST CONDITIONS AT 25°C ± 3°C						Unit	Limit	
	I_C	R_{BE}	V_{BE}	V_{CE}	I_B	L		Min.	Max.
	A	OHMS	V	V	A	μH			
$V_{CER(sus)}$	0.2	50					V	375	
$V_{CEO(sus)}$	0.2						V	300	
I_B	0.5			5.0			A	0.005	
$V_{CE(sat)}$	3.0				0.375		V		1.0
θ_{J-C}							°C/W		1.75
$I_{S/b}$ (1 second)				40			A	2.5	
$E_{S/b}$		20	-4			500	A	4.0	
$t_{f(1)}$	3.0			200	0.375		μS		0.5

NOTES: 1. $I_{B1} = I_{B2} = 0.375$ A; ($h_{FE} = 8$)

2. The RCA Dev. No. TA7420 is an epitaxial-overlay switching transistor in a JEDEC TO-3 case.

a hot, stabilized bulb ($I_{Cmax} = I_{STAB} = 2\ I_{avg}$) as follows:

P_D = saturation loss + turn-off loss

$$= \frac{t_{on}}{t_{on} + t_{off}} \int_0^{I_{STAB}} i\, R_{(sat)}\, di + \frac{f_{(STAB)} V_{IN}\, t_f}{2}$$

$$\left(\frac{I_{STAB}\, f}{2}\right) \left[t_{on} \left(I_{STAB}\right) \left(R_{sat}\right) + V_{IN}\, t_f\right] \quad (8)$$

In Eq.8, $R_{(sat)}$ is the saturation resistance of the switching transistor, and t_f is its turn-off time for the particular circuit conditions. [It should be noted that the turn-off time is not directly related to the gain-bandwidth product (f_T).]

The total base drive resistance of the switching-regulator ballasting circuits can be estimated on the basis of the current and voltage relationships for peak-current conditions.

1. For the 120-volt design, the voltage drop across the total of the resistors in the base drive circuit is the dc input voltage less the voltage (8.2 volts) across the 1N756 Zener diode. The maximum value for the drive-circuit resistance I_{peak}, therefore, can be calculated by use of following equation:

$$R_{IN} = \frac{V_{IN\ (min)} - 8.2\ V}{I_{B(max)}} = \frac{100}{I_{B(max)}} \quad (9)$$

Eq.(9) indicates that the drive-circuit resistance for the 120-volt ballast design must be greater than 9000 ohms for a permissible $I_{B(max)}$ of 10 milliamperes.

2. For the 200-to-300-volt design, the total drive-circuit resistance is estimated as follows:

$$R_{in} = \frac{V_{in(min.)} - V_{out(min.)}\ \frac{L_2}{L_1} - 2\ V}{I_{B(max.)}} \quad (10)$$

In this case, the drive-circuit resistance must be greater than 60 ohms for the 300 milliamperes of maximum permissible drive in the circuits presented.

The values of capacitors C_1 and C_2 and of resistors R_2, R_7, and R_{10} are determined on the basis of the type of circuit being designed and the power rating of the mercury-arc lamp with which this circuit is to be used. When the lamp power rating (P_L) differs from that shown in the circuit diagrams of Figs.12 and 14, the values of C_1, C_2, $1/R_2$, $1/R_7$, and $1/R_{10}$ should be increased or decreased in direct proportion to the change in the lamp power rating, i.e.,

$$\frac{C_1}{C_1'} = \frac{C_2}{C_2'} = \frac{R_2'}{R_2} = \frac{R_7'}{R_7} = \frac{R_{10}'}{R_{10}} = \frac{P_L}{P_L} \quad (11)$$

where the prime (') indicates the new circuit values.

The bridge-rectifier diodes and the commutation diode are selected on the basis of the maximum voltage and current requirements of the ballasting circuit.

The value of resistor R_3 is determined from the desired voltage-current slope of the ballast circuit.

$$VI_{(slope)} = - \frac{I_{bulb\ (hot)}}{V_{bulb\ (hot)}} \quad (12)$$

An increase in the warm-up time for a given bulb and ballasting circuit arrangement can be achieved by the use of a larger resistor R_3 in both the 120-volt and 200-to-300-volt designs. This larger resistor would result in a smaller voltage-current slope, as shown in Fig.19, and the collector current during starting (I_{PEAK}) would then be reduced.

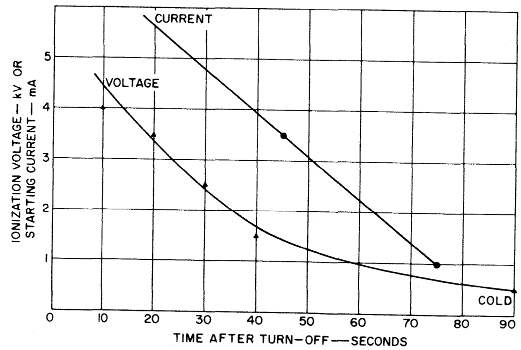


Fig.19 - Typical warm-up characteristics for a 100-watt mercury-arc lamp.

The value of R_5 is selected to provide the best voltage regulation.

ADVANTAGES OF SOLID-STATE MERCURY-ARC-LAMP BALLASTING

The circuit configuration and design procedure for the solid-state ballasts present several noted advantages over conventional ballasts.

1. Because no strobe effect is associated with the solid-state ballasts, it is possible to use long-life, efficient mercury-arc lamps in studios and

in similar critical lighting areas. In such applications, the low lighting cost and the advantage of more light with less heat are decisive factors in favor of mercury-arc lamps.

2. Solid-state ballasts provide unmatched power regulation for line voltage fluctuations.
3. The new ballasts offer the physical advantages of reduced weight and bulk in comparison to conventional ballasts. For example, the weight of a 400-watt conventional ballast is approximately 13 pounds, while the weight of an equivalent solid-state ballast is only 2.4 pounds. It is anticipated that the weight and bulk of solid-state ballasts will be further reduced by the use of hybrid circuit techniques and ultrasonic operating frequencies.
4. A solid-state photocell control is required to switch only milliwatts of power to actuate a solid-state ballast, rather than the kilowatts that would be required for a conventional ballast.
5. The circuits permit adjustment of 70 to 150 per cent of rated bulb wattage. Outside this range, the negative-impedance characteristics of the bulb cause the arc to be extinguished. However, one basic ballast circuit may be used for bulbs of various power ratings.
6. The solid-state ballast supplies dc power to the bulb so that there are no RFI radiation problems.

In a comparison of solid-state and conventional ballasts, the initial cost factor must be considered. In regard to the initial cost, the simple magnetic ballast has a decided advantage. In general, however, initial cost is only 10 per cent of the total costs of the lighting system, and this advantage is clearly outweighed when a less efficient lighting means is displaced.

From the standpoint of reliability, proper design should result in solid-state ballasts that match the performance of conventional ballasts.

In the ballast circuit described in this paper, only transistors were used. Thyristors (SCR's and triacs) are also suited for use in ballasting circuits for arc-discharge lighting systems, particularly at high power levels.

Significant future growth in mercury-arc lighting for both home and office should favor the transistor ballast at voltage and power levels below 120 volts and 100 watts.

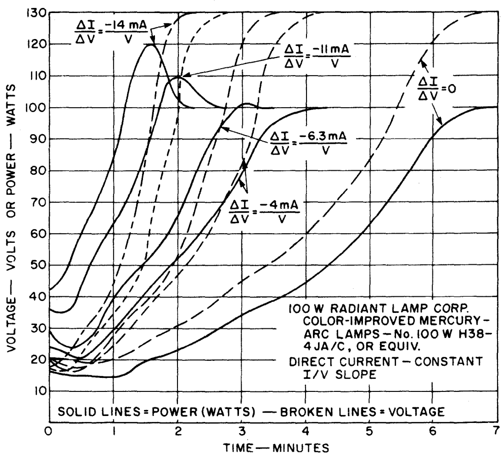


Fig.20 - Hot restart characteristics for a 100-watt mercury-arc lamp.

ADDITIONAL DEVELOPMENTS

A major disadvantage of mercury-arc lamps is the cooling-off period (approximately 5 minutes) required before a lamp previously in use can be restarted. Fig.20 shows the measured hot restart characteristics of a 100-watt mercury-arc lamp. These curves were obtained by use of only the main electrodes of the quartz burner. This technique effectively halved the cooling time. Work is currently underway to solve the problem through the development of new circuits that permit instant hot restarts of mercury-arc lamps.

REFERENCES

1. Cobin, J.D., GASEOUS CONDUCTORS, Dover Publications.

2. Dorgelo, E.G., "Alternating Current Circuits for Discharge Lamps", PHILIPS TECHNICAL REVIEW, April, 1937.

3. "Mercury Lamps", Westinghouse Corporation Publication A-7264.

4. "Mercury Lamps", General Electric Company Publication TP-109.

RCA
Solid State
Division

Power Transistors
Application Note
AN-4124

Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors

by W.J. Hepp, J.S. Vara, and J. Gaylord

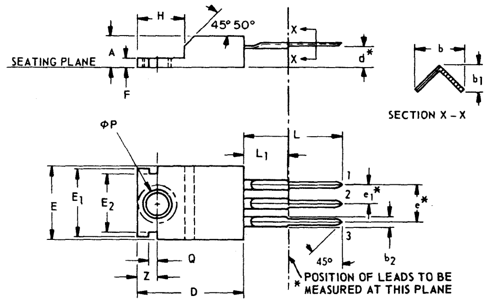
RCA power transistors and thyristors (SCR's and triacs) in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations. This Note provides detailed guidelines for handling and mounting of these plastic-package devices, and shows different types of packages and suggested mounting hardware to accommodate various mounting arrangements. Recommendations are made for handling of the packages during the forming of leads to meet specific mounting requirements. Various mounting arrangements, thermal considerations, and cleaning methods are described. This information is intended to augment the data on electrical characteristics, safe operating area, and performance capabilities in the technical bulletin for each type of plastic-package transistor or thyristor. (Data on mechanical and environmental capabilities of RCA plastic-package transistors are also available in a periodically updated **Reliability Report**, RCA Publication No. HBT-600.)

TYPES OF PACKAGES

Two basic types of molded-plastic packages are used for RCA solid-state power devices. These types include the RCA Versawatt packages for medium-power applications and the RCA high-power plastic packages, both of which are specifically designed for ease of use in many applications. Each basic type offers several different package options, and the user can select the configuration best suited to his particular application.

Figs. 1 through 3 show the options currently available for devices in RCA Versawatt packages. The JEDEC Type TO-220AB in-line-lead version, shown in Fig. 1, represents the basic style. This configuration features leads that can be formed to meet a variety of specific mounting requirements. Fig. 2 shows a package configuration that allows a Versawatt package to be mounted on a printed-circuit board with a 0.100-inch grid and a minimum lead spacing of 0.200 inch. Fig. 3 shows a JEDEC Type TO-220AA version of the Versawatt package. The dimensions of this type of transistor package are such that it can replace the JEDEC TO-66 transistor package in a commercial socket or printed-circuit board without retooling. The pin-connection arrangement of thyristors supplied in TO-220AA packages, however, differs from that of thyristors supplied in conventional TO-66 packages so that some hardware changes are required to effect a replacement. The TO-220AA Versawatt package is also supplied with an integral heat sink. Fig. 4 shows the dimensional outline for this heat sink. The use of the integral heat sink reduces the junction-to-air thermal resistance of the package from 70°C per watt to 35°C per watt.

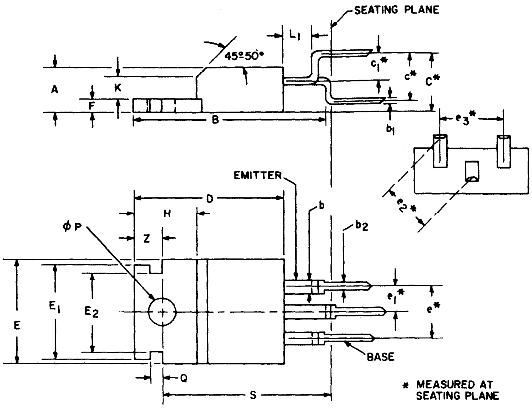
The RCA molded-plastic high-power packages are also supplied in several configurations for flexibility of application. The JEDEC Type TO-219AB, shown in Fig. 5, is the basic high-power plastic package. Fig. 6 shows a JEDEC Type TO-219AA version of the high-power plastic package. With the addition of an NR193B top clamp, the TO-219AA



SYMBOL	INCHES MIN.	INCHES MAX.
A	.140	.190
b	.020	.038
b_1	.012	.045
b_2	.045	.070
D	.560	.625
d	.080	.115
E	.330	.420
E_1	.365	.385
E_2	.300	.320

SYMBOL	INCHES MIN.	INCHES MAX.
e	.190	.210
e_1	.090	.110
F	.045	.055
H	.230	.270
L	.500	.562
L_1		.250
ΦP	.139	.147
Q	.040	.060
Z	.100	.120

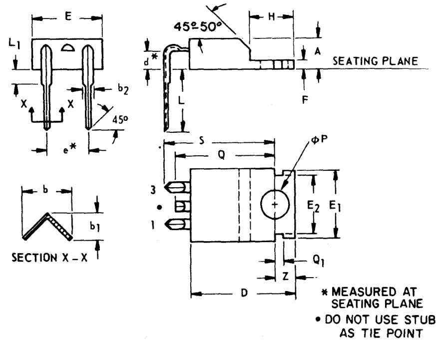
Fig. 1 - Dimensional outline of the JEDEC TO-220AB in-line-lead Versawatt transistor package.



SYMBOL	INCHES	
	MIN.	MAX
A	.140	.190
B		.850
b	.045	.070
b_1	.015	.030
b_2	.020	.038
C	.230	.270
c	.180	.220
c_1	.130	.170
D	.560	.625
E	.330	.410
E_1	.365	.385
E_2	.300	.320

SYMBOL	INCHES	
	MIN.	MAX
e	.190	.210
e_1	.090	.110
e_2	.203	.243
e_3	.190	.200
F	.045	.070
H	.230	.270
K	.080	.085
L_1	.070	.090
ϕP	.139	.147
Q	.040	.060
S	.655	.685
Z	.100	.120

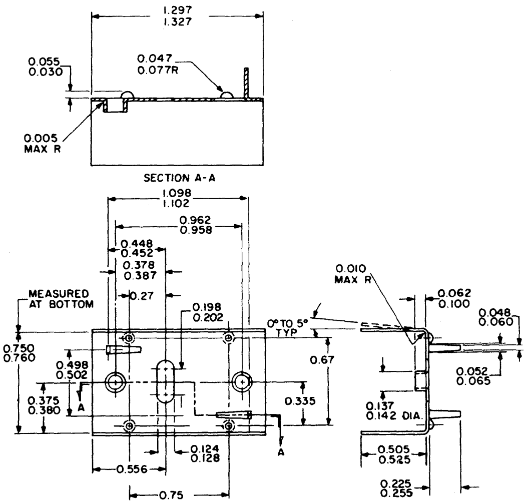
Fig. 2 - Dimensional outline of Versawatt transistor package designed for mounting on printed-circuit boards.



SYMBOL	INCHES	
	MIN.	MAX.
A	.140	.190
b	.020	.038
b_1	.012	.045
b_2	.045	.070
D	.560	.625
d	.080	.115
E	.330	.420
E_1	.365	.385
E_2	.300	.320
e	.190	.210

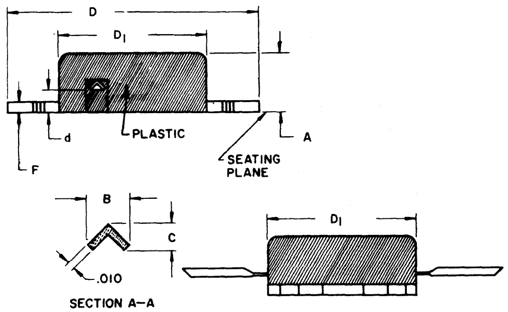
SYMBOL	INCHES	
	MIN.	MAX.
F	.045	.055
H	.230	.270
L	.360	.422
L_1		.050
ϕP	.139	.147
Q		.610
Q_1	.040	.060
S	.580	.610
Z	.100	.120

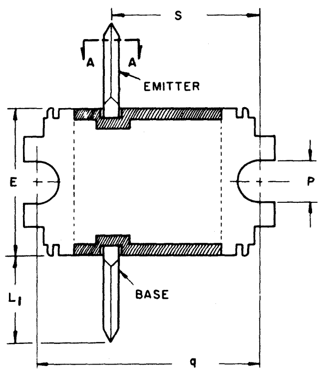
Fig. 3 - JEDEC TO-220AA Versawatt transistor package designed for direct replacement of the JEDEC TO-66 package.



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SHOWN. TOLERANCES ARE: ±0.02 FOR 2ND PLACE; ±0.005 FOR 3RD PLACE AND ±1/2° FOR ANGULAR DIMENSION.

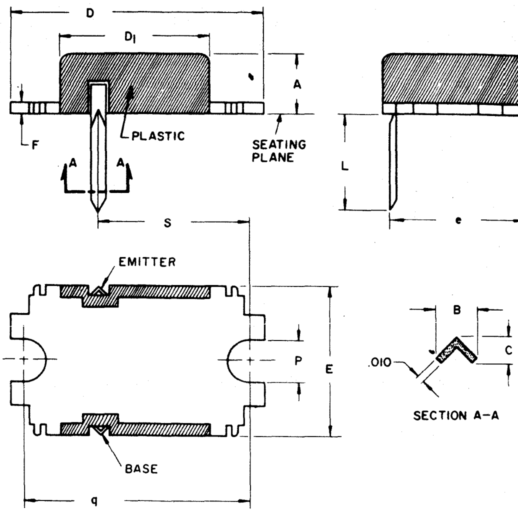
Fig. 4 - Integral heat sink used with the TO-220AA Versawatt package shown in Fig. 3.





SYMBOL	INCHES	
	MIN.	MAX.
A	.160	.200
B	.045	.060
C	.025	.045
D	.890	.910
D_1	.480	.515
d	.100	.120
E	.480	.520
F	.055	.070
L_1	.415	.560
p	.128	.150
q	.740	.760
S	.500	.520

Fig. 5 - JEDEC TO-219AB high-power molded-plastic transistor package.



SYMBOL	INCHES	
	MIN.	MAX.
A	.160	.200
B	.045	.060
C	.025	.045
D	.890	.910
D1	.480	.515
E	.480	.520

SYMBOL	INCHES	
	MIN.	MAX
e	.460	.505
F	.055	.070
L	.370	.450
p	.128	.150
q	.740	.760
S	.500	.520

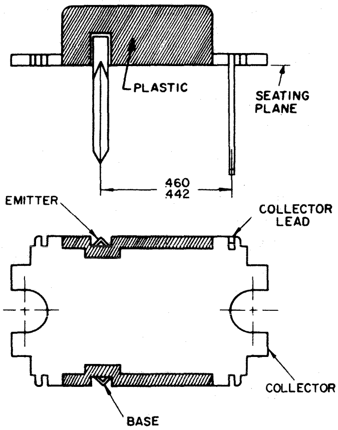
Fig. 6 - JEDEC TO-219AA plastic package designed for use (with the addition of an NR193B clamp) as a direct replacement for the hermetically sealed JEDEC TO-3 transistor package.

package can be used as a direct replacement for the hermetically sealed JEDEC TO-3 package. [The NR193B clamp is shown in the section on Mounting, Fig. 11(c), later in this Note.] The RCA high-power plastic package is also available with an attached header-case lead, as shown in Fig. 7. This three-lead package is designed for mounting on a printed-circuit board.

LEAD-FORMING TECHNIQUES

RCA Versawatt plastic packages are both rugged and versatile within the confines of commonly accepted standards for such devices. Although these versatile packages lend themselves to numerous arrangements, provision of a wide variety of lead configurations to conform to the specific requirements of many different mounting arrangements is highly impractical. However, the leads of the Versawatt in-line package can be formed to a custom shape, provided that they are not indiscriminately twisted or bent. Although these leads can be formed, they are not flexible in the general sense, nor are they sufficiently rigid for unrestrained wire wrapping.

Before an attempt is made to form the leads of an in-line package to meet the requirements of a specific application, the desired lead configuration should be determined, and a lead-bending fixture should be designed and constructed. The



ALL DIMENSIONS IN INCHES

Fig. 7 - TO-219AA plastic transistor package designed for mounting on printed-circuit boards.

use of a properly designed fixture for this operation eliminates the need for repeated lead bending. When the use of a special bending fixture is not practical, a pair of long-nosed pliers may be used. The pliers should hold the lead firmly between the bending point and the case, but should not touch the case. Fig. 8 illustrates the use of long-nosed pliers for lead bending. Fig. 8(a) shows techniques that should be avoided; Fig. 8(b) shows the correct method.

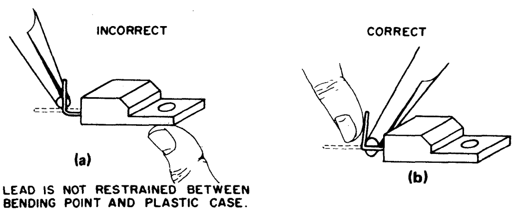


Fig. 8 - Use of long-nosed pliers for lead bending: (a) incorrect method; (b) correct method.

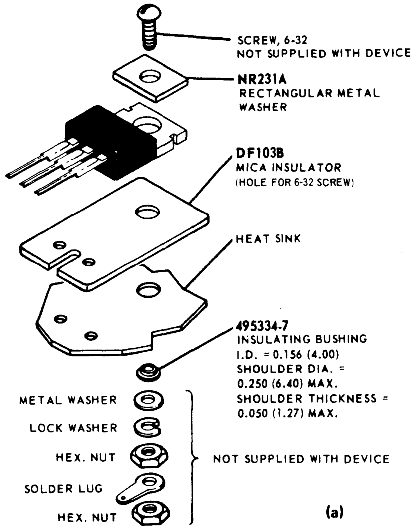
When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

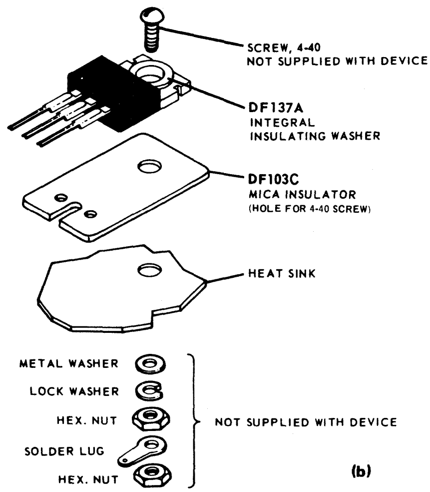
1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, make the bend at least 1/8 inch from the plastic case.
4. Do not use a lead-bend radius of less than 1/16 inch.
5. Avoid repeated bending of leads.

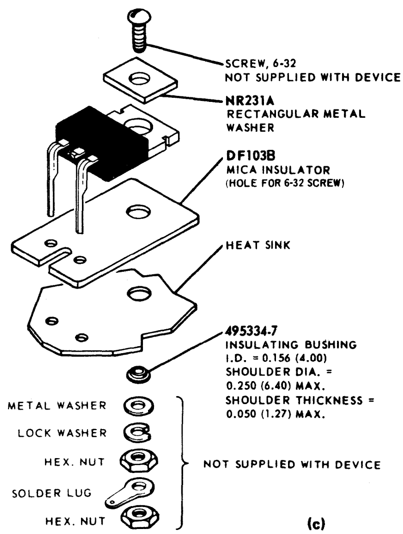
The leads of the TO-220AB Versawatt in-line package are not designed to withstand. excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised. Fig. 2 illustrates an acceptable lead-forming method that provides this relief.

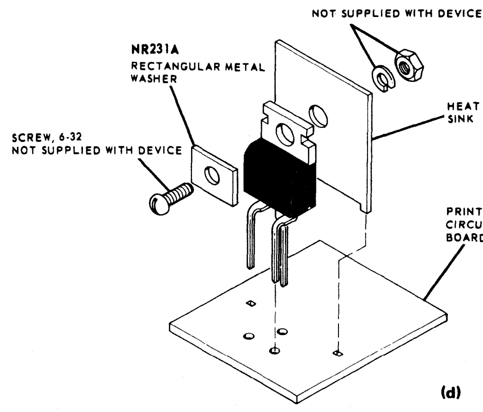
Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed; the maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance greater than 1/8 inch from the plastic case. When wires are used for connections, care should be exercised to assure that movement of the wire does not cause movement of the lead at the lead-to-plastic junctions.

The leads of the RCA molded-plastic high-power packages are not designed to be reshaped. Simple bending of the leads, however, is permitted to change them from a standard vertical to a standard horizontal configuration, or conversely. Bending of the leads in this manner is restricted to three 90-degree bends; repeated bendings, therefore, should be avoided.









Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 9 - Mounting arrangements for Versawatt transistors: (a) and (b) methods of mounting in-line-lead types; (c) chassis mounting; (d) mounting on printed-circuit boards.

MOUNTING

Fig. 9 shows recommended mounting arrangements and suggested hardware for the Versawatt transistors. The rectangular washer (NR231A) shown in Fig. 9(a) is designed to minimize distortion of the mounting flange when the transistor is fastened to a heat sink. Excessive distortion of the flange could cause damage to the transistor. The washer is particularly important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings; however, the holes should not be larger than necessary to provide hardware clearance and, in any case, should not exceed a diameter of 0.250 inch. Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8 inch-pounds is specified. Care should be exercised to assure that the tool used to drive the mounting screw never comes in contact with the plastic body during the driving operation. Such contact can result in damage to the plastic body and internal device connections. An excellent method of avoiding this problem is to use a spacer or combination spacer-isolating bushing which raises the screw head or nut above the top surface of the plastic body, as shown in Fig. 10. The material used for such a spacer or spacer-isolating bushing should, of course, be carefully selected to avoid "cold flow" and consequent reduction in mounting force. Suggested materials for these bushings are diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate. Unfilled nylon should be avoided.

Modification of the flange can also result in flange distortion and should not be attempted. The transistor should not be soldered to the heat sink by use of lead-tin solder because the heat required with this type of solder will cause the junction temperature of the transistor to become excessive.

The TO-220AA plastic transistor can be mounted in commercially available TO-66 sockets, such as UID Electronics Corp. Socket No. PTS-4 or equivalent. For testing purposes, the TO-220AB in-line package can be mounted in a Jetron Socket No. CD74-104 or equivalent. Regardless of the mounting method, the following precautions should be taken:

1. Use appropriate hardware.
2. Always fasten the transistor to the heat sink before the leads are soldered to fixed terminals.
3. Never allow the mounting tool to come in contact with the plastic case.
4. Never exceed a torque of 8 inch-pounds.
5. Avoid oversize mounting holes.
6. Provide strain relief if there is any probability that axial stress will be applied to the leads.
7. Use insulating bushings to prevent hot-creep problems. Such bushings should be made of diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate.

Fig. 11 shows the recommended hardware and mounting arrangements for RCA high-power molded-plastic transistors. These types can be mounted directly in a socket similar to that shown in Fig. 11(b) or they can be mounted in a standard TO-3 socket with the NR193B clamp. The precautions listed for the Versawatt packages should also be followed in the mounting of the high-power molded-plastic packages.

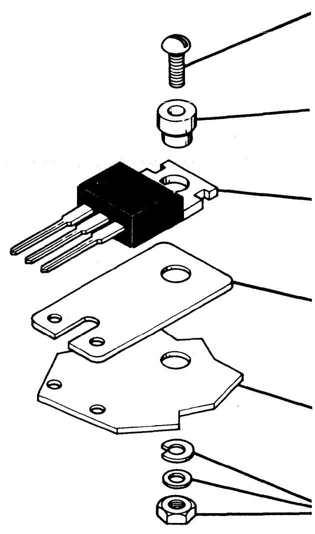
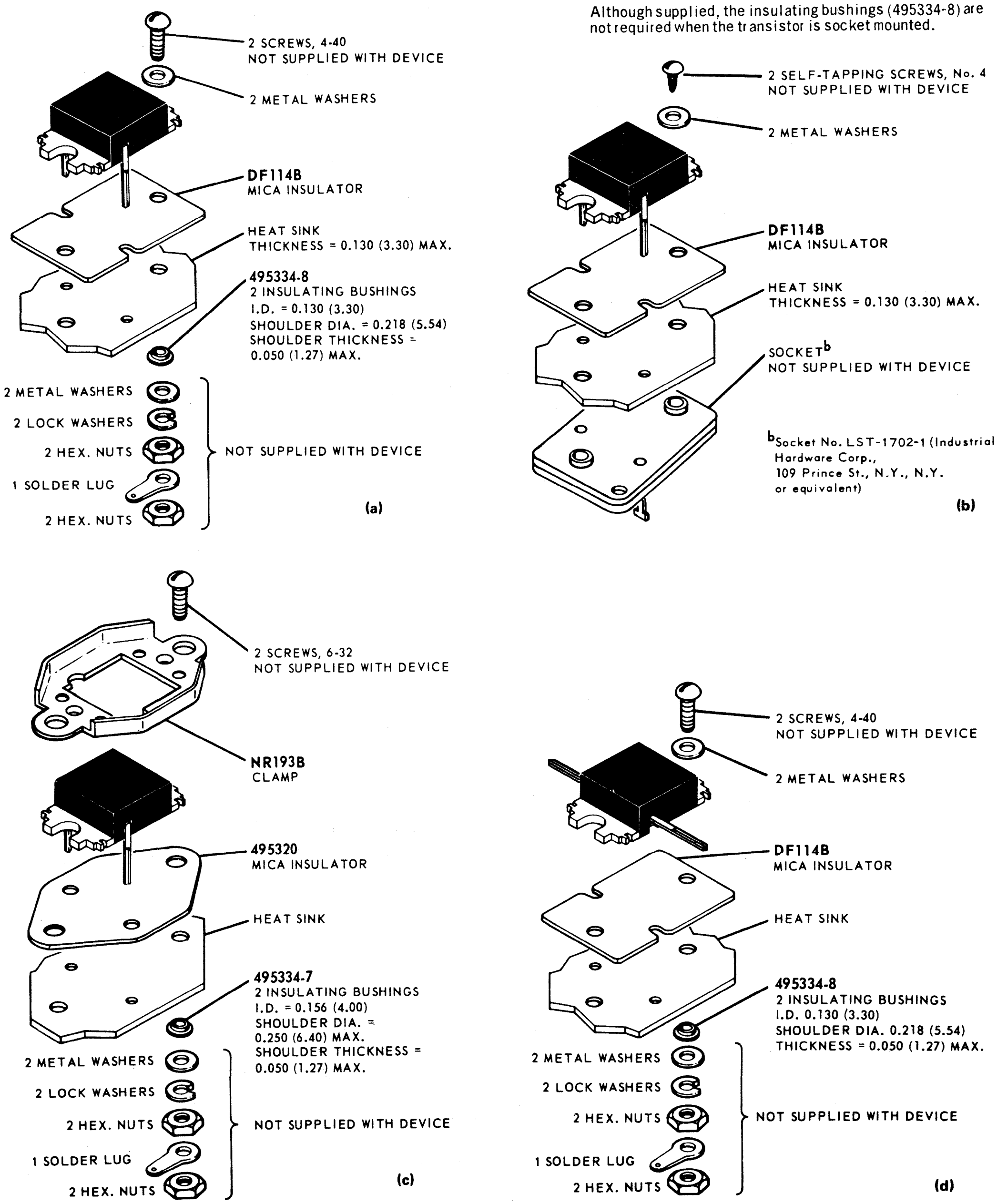


Fig. 10 - Mounting arrangements in which an isolating bushing is used to raise the head of the mounting screw above the plastic body of the Versawatt transistor.

THERMAL-RESISTANCE CONSIDERATIONS

The maximum allowable power dissipation in a solid-state device is limited by its junction temperature. An important factor to assure that the junction temperature remains below the specified maximum value is the ability of the associated thermal circuit to conduct heat away from the device.

When a solid-state device is operated in free air, without a heat sink, the steady-state thermal circuit is defined by the junction-to-free-air thermal resistance given in the published data on the device. Thermal considerations require that there be a free flow of air around the device and that the power dissipation be maintained below that which would cause the junction temperature to rise above the maximum rating. When the device is mounted on a heat sink, however, care must be taken to assure that all portions of the thermal circuit are considered.



Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 11 - Mounting arrangements for high-power plastic-package transistors: (a) chassis mounting; (b) socket mounting; (c) chassis mounting with top clamp; (d) printed-circuit-board mounting.

Fig. 12 shows the thermal circuit for a heat-sink-mounted transistor. This figure shows that the junction-to-ambient thermal circuit includes three series thermal-resistance components, i.e., junction-to-case, $\theta_{J\text{-}C}$; case-to-heat-sink, $\theta_{C\text{-}S}$; and heat-sink-to-ambient, $\theta_{S\text{-}A}$. The junction-to-case thermal resistance of the various transistor types is given in the individual technical bulletins on specific types. The heat-sink-to-ambient thermal resistance can be determined from the technical data provided by the heat-sink manufacturer, or from published heat-sink nomographs. The case-to-heat-sink thermal resistance depends on several factors, which include the condition of the heat-sink surface, the type of material and thickness of the insulator, the type of thermal compound, the mounting torque, and the diameter of the mounting hole in the heat-sink.

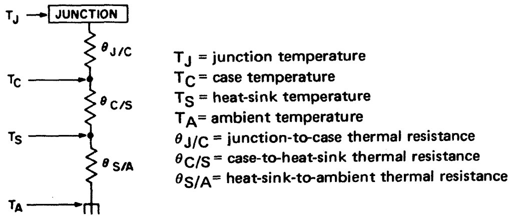


Fig. 12 - Thermal equivalent circuit for a transistor mounted on a heat sink.

Fig. 13 shows a set of curves of typical case-to-heat-sink thermal resistance of the Versawatt transistor as a function of mounting torque for several mounting arrangements. Curves A through D show typical case-to-heat-sink thermal resistance for the mounting arrangements shown in Figs. 9(a) through 9(d). Curves E and F are representative of a Versawatt transistor mounted over a heat-sink mounting hole that has a diameter of 0.140 inch (No. 6 screw clearance). Curve E shows the wide variation in thermal resistance with torque when the transistor is mounted dry. Curve F shows the effect on contact thermal resistance of a thin layer of Dow Corning No. 340 silicone grease applied between transistor and heat sink. For torques within the recommended range of 4 to 8 inch-pounds, contact thermal resistance is reduced to between 18 and 25 per cent of the dry values.

The curves shown in Fig. 14 represent typical case-to-heat-sink thermal resistance of the high-power molded-plastic transistor package as a function of mounting torque. The thermal resistances shown by curves A and C are representative of the mounting arrangements shown in Fig. 11(a) through 11(d). Curves B and D are typical for mounting without mica over heat-sink mounting holes that have a diameter of 0.113 inch (No. 4 screw clearance). The effect of a thin layer of silicone grease on contact thermal resistance is illustrated by a comparison of curves B and D.

Operation of the transistor with heat-sink temperatures of 100°C or greater results in some shrinkage of the insulating bushing normally used to mount power transistors. The degradation of contact thermal resistance (refer to Figs. 13 and 14) is usually less than 25 per cent if a good thermal compound is used. (A more detailed discussion of thermal resistance, including nomographs, can be found in the **RCA Power Circuits** Manual, Technical Series SP-51.)

During the mounting of RCA molded-plastic solid-state power devices, the following special precautions should be taken to assure efficient heat transfer from case to heat sink:

1. Mounting torque should be between 4 and 8 inch-pounds.

2. The mounting holes should be kept as small as possible.

3. Holes should be drilled or punched clean with no burrs or ridges, and chamfered to a maximum radius of 0.010 inch.

4. The mounting surface should be flat within 0.002 inch/inch.

5. Thermal grease (Dow Corning 340 or equivalent) should always be used (on both sides of the insulating washer if one is employed).

6. Thin insulating washers should be used (thickness of factory-supplied mica washers ranges from 2 to 4 mils).

7. A lock washer or torque washer should be used, together with materials that have sufficient creep strength to prevent degradation of heat-sink efficiency during life.

A wide variety of solvents is available for degreasing and flux removal. The usual practice is to submerge components in a solvent bath for a specified time. From a reliability standpoint, however, it is extremely important that the solvent, together with other chemicals in the solder-cleaning system (such as flux and solder covers), not adversely affect the life of the component. This consideration applies to all non-hermetic and molded-plastic components.

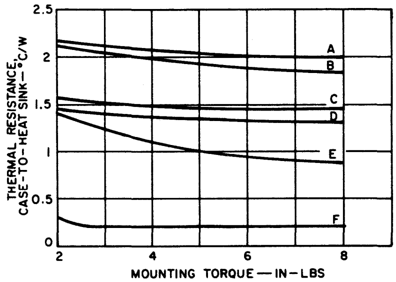
It is, of course, impractical to evaluate the effect on long-term transistor life of all cleaning solvents, which are marketed under a variety of brand names with numerous additives. These solvents can, however, be classified with respect to their component parts, as either acceptable or unacceptable. Chlorinated solvents tend to dissolve the outer package and, therefore, make operation in a humid atmosphere unreliable. Gasoline and other hydrocarbons cause the inner encapsulant to swell and damage the transistor. Alcohol and unchlorinated freons are acceptable solvents. Examples of such solvents are:

1. Freon TE
2. Freon TE-35
3. Freon TP-35 (Freon PC)
4. Alcohol (isopropanol, methanol, and special denatured alcohols, such as SDA1, SDA30, SDA34, and SDA44)

Care must also be used in the selection of fluxes in the soldering of leads. Rosin or activated rosin fluxes are recommended, while organic or acid fluxes are not. Examples of acceptable fluxes are:

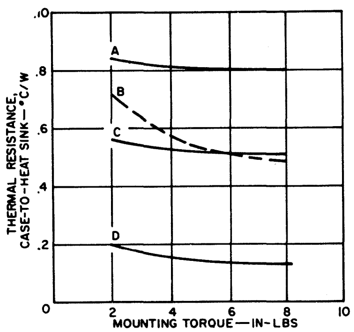
1. Alpha Reliaros No. 320-33
2. Alpha Reliaros No. 346
3. Alpha Reliaros No. 711
4. Alpha Reliafoam No. 807
5. Alpha Reliafoam No. 809
6. Alpha Reliafoam No. 811-13
7. Alpha Reliafoam No. 815-35
8. Kester No. 44

If the completed assembly is to be encapsulated, the effect on the molded-plastic transistor must be studied from both a chemical and a physical standpoint.



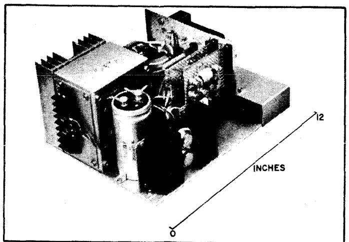
CURVE	MOUNTING ARRANGEMENT FIGURE	HEAT SINK HOLE DIA. (IN.)	MICA THICKNESS (MILS)	THERMAL COMPOUND
A	9(a)	.250	4	Dow Corning No.340
B	9(b)	.113	4	Dow Corning No.340
C	9(a)	.250	2	Dow Corning No.340
D	9(b)	.113	2	Dow Corning No.340
E	—	.140	None	None
F	—	.140	None	Dow Corning No.340

Fig. 13 - Typical case-to-heat-sink thermal resistance as a function of mounting torque for an RCA Versawatt transistor.



CURVE	MOUNTING ARRANGEMENT FIGURE	MICA THICKNESS (MILS)	THERMAL COMPOUND
A	10(a) thru 10(d)	4	Dow Corning No.340
B	—	None	None
C	10(a) thru 10(d)	2	Dow Corning No.340
D	—	None	Dow Corning No.340

Fig. 14 - Typical case-to-heat thermal resistance as a function of mounting torque for an RCA high-power plastic-package transistor.



Compact 5-Volt Power Supplies Using High-Voltage Power Transistors

By R.S.Myers

This Note discusses the use of low-cost, industrial-type, high-voltage power transistors and fast-recovery rectifiers to achieve size and weight reductions and efficiency improvements in 5-volt dc power supplies with output currents of 50 amperes or more. The power supplies described, like those used in high-reliability aerospace applications, use switching rather than dissipating regulators to eliminate the need for a 60-Hz power transformer and heat sinks for the transistors. As a result, these supplies achieve three important advantages over conventional power supplies:

- Size – Volume is reduced by a factor of four. This size reduction does not cause any cooling problems, because these supplies dissipate very little power (approximately 0.33 W/in.^{3}).
- Efficiency – Power dissipation in the regulator is virtually eliminated; only the power rectifiers require cooling. The reduction of heat dissipation in a 250-watt supply can be 200 to 300 watts, which represents a substantial economic saving.
- Weight – Weight is reduced by a factor of five. Portability is improved, mounting is simplified, and chassis cost is decreased.

A complete switching-regulator power supply that uses high-voltage transistors is described in detail. This unit produces 250 watts at 5 volts with an efficiency of 70 per cent. The performance of this supply is compared with that of a conventional supply in Table I. The design can be modified for more or less power, multiple outputs, or higher output voltages.

THE POWER-SUPPLY CONCEPT

In a switching-regulator type of power supply, the output voltage is regulated by a technique referred to as "pulse-width modulation", in which pulses of variable duty cycle are averaged with an inductor-capacitor filter. Regulation is accomplished by the variation of the duty cycle. The pulses constitute a two-state signal (power on and power off) that is supplied to the filter, as shown in Fig. 1. However, to permit use of a smaller isolation transformer, the "power-on" state is operated in a push-pull mode that is then rectified by full-wave power rectifiers. The time ratios of the push, pull, and off conditions are controlled by a modulator circuit.

Table I – Comparison of Power Supplies

	CONVENTIONAL SUPPLY	NEW SUPPLY	
Output Current at 5 volts	25	50	A
Power Losses (Max)	300	100	W
Size	1600	470	in.^{3}
Weight	50	10	lb.
Recovery Time	50	500	μs
Regulation (Half load to full load)	>0.25	0.5	%
Line Regulation	>0.25	0.5	%

The on-state voltage is unregulated and is always greater than the required output voltage from the filter. It is supplied by a low-impedance source that consists of a transformer with closely coupled windings, the main supply, and a saturated transistor. The on-state voltage is decreased to the specified output value by an inductor that forms part of the filter. Thus the filter, which converts the ac signals to a dc output, is a "choke-input" type.

The switching-regulator supply operates at a frequency above the audio range to permit use of a small isolation transformer, and also to prevent sound generation.

POWER-SUPPLY ELEMENTS

The design of a switching-regulator power supply involves the six major elements shown in Figs. 1 and 2: (1)

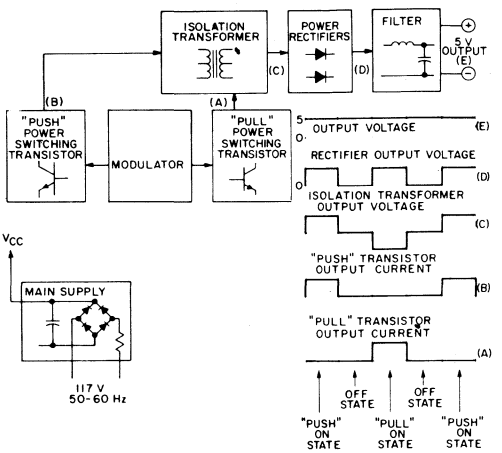


Fig. 1 - Block diagram of switching-regulator power supply, showing voltage waveforms at various points.

the main power supply, (2) the power-switching transistors, (3) the isolation transformer, (4) the modulator circuits, (5) the power rectifiers, and (6) the filter. The important parameters of these elements are discussed below.

Main Power Supply. The main supply provides the power that ultimately becomes the output power. It rectifies and filters the line voltage without use of a 60-Hz transformer. The design of such a supply is well covered in available literature[1-3]. In the case of a switching-regulator type of power supply, the main supply may be designed for high ripple without increased regulator losses (such as would occur in a conventional series regulator). Therefore, smaller capacitors and lower-cost rectifiers can be used. Some resistance must be added in series with the power line to prevent damage to the rectifiers during turn-on.[1, 2] The voltage delivered by the main power supply varies with line-voltage and load variations. The peak output voltage of the main supply at the maximum line conditions (with transients) determines both the collector-voltage rating required for the power-switching transistors and the turns ratio of the isolation transformer. Table II shows the relationship between line voltage and transistor collector voltage rating.

Power-Switching Transistors. The power-switching transistors are the most important components in the switching-regulator power supply. In the past, the high cost of these devices limited their use to aerospace applications; however, recent developments have made them economically competitive with other devices. The performance capabilities of the power supply are determined by the switching transistors, because they are the parts least able to withstand overloads such as those caused by load faults or misuse. Therefore, the switching transistors must have the following characteristics (listed in order of importance):

- High forward-bias second-breakdown capability. The transistors must carry high currents at high voltage, as shown in the switching load line of Fig. 3.[2]
- Ability to withstand the collector voltages specified in Table II in the cut-off condition. A leakage current (I_{CEV}) specification guarantees this capability.
- Short rise and fall times (t_r and t_f), for low power dissipation in the transistors and thus high efficiency of the power supply.
- Reasonably low V_{CE}(sat), for low dissipation and economical transistor heat sinks.
- Stable leakage current (I_{CEV}). The magnitude of the leakage is not important (even 20 milliamperes at 500 volts contributes less than 5 watts to the average dissipation per transistor), but it should be stable.

Table III lists the recommended specifications for the switching transistors.

Isolation Transformer. The isolation transformer is a ferrite-core transformer that operates at 20 kHz. Its design formulas are the same as those for conventional 60-Hz transformers, but the results are significantly different. The number of turns is never greater than 200, and may be as low as one. These turns always fit in the large "windows" in the ferrite core. Leakage inductance is reduced in the primary turns by sectioning the primary winding.[4] Leakage in the secondary is less important because the secondary is loaded by a filter choke. The copper losses can easily be made negligible, and the copper wire costs are small. The size of the transformer core is determined by the need to dissipate the heat generated in the core material; the Indiana General Co. recommends that dissipation be kept below 0.25 W/in.^{2}[5,6] The 20-kHz ferrite core is much smaller than a 60-Hz core (3 in.^{3} vs. 140 in.^{3}), and is much lighter (1 lb. vs. 33 lbs.).

The design of a 20-kHz power transformer involves three basic problems: core material selection, windings to keep peak flux below saturation, and compensation for unbalanced direct currents.

If a core has too much loss, it will overheat. If it has too many turns, the flux density will be below saturation, but the copper losses will be greater than necessary. The number of turns is kept low to avoid unnecessary copper loses, but must be great enough to keep the peak flux in the core below saturation.

The core will saturate if its cross section is too small, if there are not enough turns in the primary winding, or if the primary direct current is unbalanced. Core saturation causes the power-switching transistors to draw excessive currents

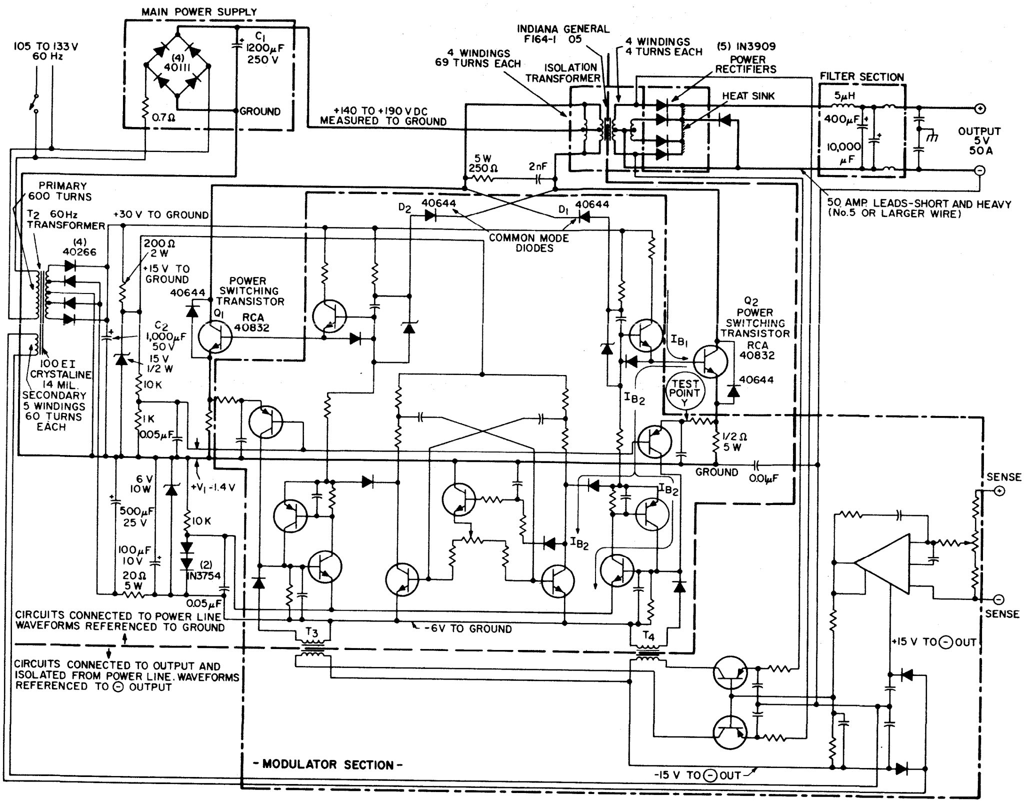


Fig. 2 - Circuit diagram of switching-regulator power supply, with major elements indicated.

that can increase collector dissipation to destructive levels. To prevent these high currents, the power supply includes a monitor circuit that cuts off the base drive to the switching transistors when emitter current reaches the maximum safe value.

Fig. 4 shows the emitter-current waveform of a power-switching transistor, monitored at point Y in Fig. 2, for different numbers of primary turns. If the emitter current is excessive, the circuit reduces the duty cycle to protect the power-switching transistor. Fig. 5 shows the waveforms for unbalanced dc drive. These unbalanced currents result from unequal duty cycles, caused by oscillator unbalance or by unbalance or faults in the modulator. Because such unbalances occur in normal operation, the protective circuits must be included in the power supply design.

Modulator Circuit (Oscillator, drivers, modulators, and latches). These circuits, which are indicated in the circuit diagram of Fig. 6 and are described in Table IV, deliver the base drive to the power-switching transistors. The forward drive must be sufficient to keep the transistors saturated under all conditions, and must have a short rise time to provide fast transistor turn-on and low dissipation. The reverse drive must have short rise time and a magnitude equal to or greater than the forward base drive. The circuits also sense excessive emitter current in the power-switching transistors, and compensate by adjustment of the duty cycle, as noted above.

These circuits eliminate common-mode conduction in the power-switching transistors. This conduction occurs in a driven inverter when the transistor that has been "off" is

Table II – Relationship Between Line Voltage and the Required Collector Voltage Rating for the Switching Transistors.

RMS LINE VOLTAGE (V)	PEAK LINE VOLTAGE (V)	NOMINAL COLLECTOR VOLTAGE (V)	SAFE (15% ADDED) COLLECTOR VOLTAGE RATING (V)	
90	127.3	254.5	292	
95	134.3	268.7	309	
100	141,4	282.8	325	
105	148.5	296.9	341	↑
110	155.5	311.1	357	
115	162.6	325.2	374	Operating
120	169.7	339.4	390	Range
125	176.7	353.5	406	
130	183.8	367.6	422	↓
135	190.0	381.8	439	
140	198.0	395.9	455	
145	205.0	410.1	471	
150	212.1	424.2	487	

turned "on"; the other transistor continues to conduct because of its storage time. For several microseconds both transistors conduct, and the current is not limited by the collector circuit. The transistor that has just been switched on has high current and voltage simultaneously, and therefore high dissipation (perhaps 50 per cent of the rated power-supply output). This power dissipation is wasteful and may even damage the transistor.

The oscillator frequency should be stable to minimize rectifier losses, and should be greater than 20 kHz to eliminate sound. All of the circuits should be insensitive to component-value variations, component drift, and random or stray interference.

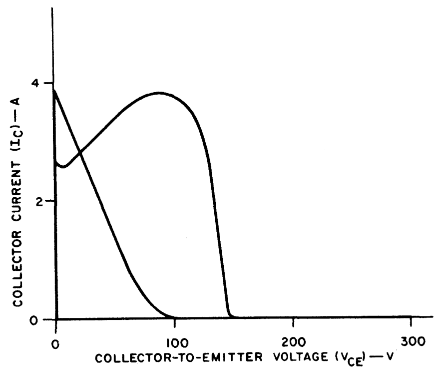


Fig. 3 - Typical load line for a switching transistor in the switching-regulator power supply.

Table III – Recommended Specifications for Switching Transistor

PARAMETER	MEASUREMENT CONDITIONS: GENERAL	MEASUREMENT CONDITIONS: FOR TRANSISTORS USED IN DESIGN EXAMPLE	VALUE
I_{CEV}	V_{CE} from Table II	V_{CE} = 450 V	5 mA max.
	$V_{BE} \leqslant V_{EE}$(1)	V_{BE} = 1.5 V	
I_{EBO}	$V_{EB} = V_{EE}$(1)	V_{EB} = 6 V	5 mA max.
$I_{S/b}$	$I_C = I_C$ (max.)	I_C = 4 A	(must pass test)
	$V_{CE} = V_{CC}$ (max.)	V_{CE} = 200 V	
	t ⩾ 50 μs	t = 100 μs	
V_{CE} (sat)	$I_C = I_C$ (max.) I_B as provided by driver circuit	I_C = 4 A I_B = 0.8 A	< 3 V
V_{BE}(sat)	"	"	< 2 V(2)
t_r	$I_C = I_C$ (max.) I_{B1} and I_{B2} as provided by driver circuits	conditions(3)	< 1 μs
t_f	"	"	< 1 μs

(1) V_{EE} is negative voltage source applied to the base.

(2) Importance depends upon drive-circuit design. For the design shown, V_{BE}(sat) is not critical.

(3) Because of the great variations in parameters and waveforms, some standard test condition is used for control. The manufacturers standard conditions are usually adequate control.

Power Recifiers. Most of the losses in the power supply occur in the power rectifiers. In a 5-volt, 50-ampere supply, for example, each of the four 1N3909 rectifier diodes carries a nominal peak current of 25 amperes at 50-per-cent duty cycle. The forward power loss in the rectifier can be calculated from the current and voltage values. The voltage

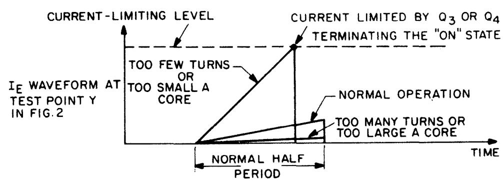


Fig. 4 - Waveform of emitter current in power-switching transistor showing effects of core-size and number of primary turns, with regulation defeated (see note on Fig. 6).

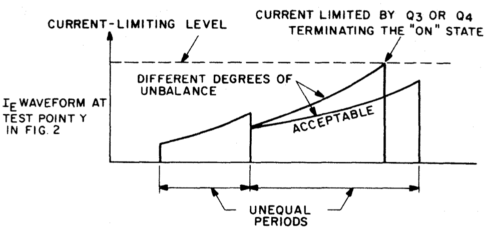


Fig. 5 - Waveform of emitter current in power-switching transistor showing effect of unbalanced direct current, with regulation defeated and load current of 25 amperes.

drop is not specified for 25-ampere operation, but the rectifier has a maximum voltage drop of 1.4 volts at a current of 30 amperes. Because this 30-ampere data is close to 25-ampere operation (and unbalance could cause the current to exceed 25 amperes), the maximum forward-drop rectifier losses can be estimated from the 30-ampere specifications: 1/2 x 1.4 V x 30 A x 4 = 84 watts at maximum rated output.

Reverse recovery losses in the diodes add to the total dissipation; these losses, which are significant at 20 kHz, depend on the rectifiers used, the leakage inductances in the wiring and the isolation transformer, the transistor switching times, and the operating frequency. Because of the many variables (and unknowns) involved, the rectifier losses should

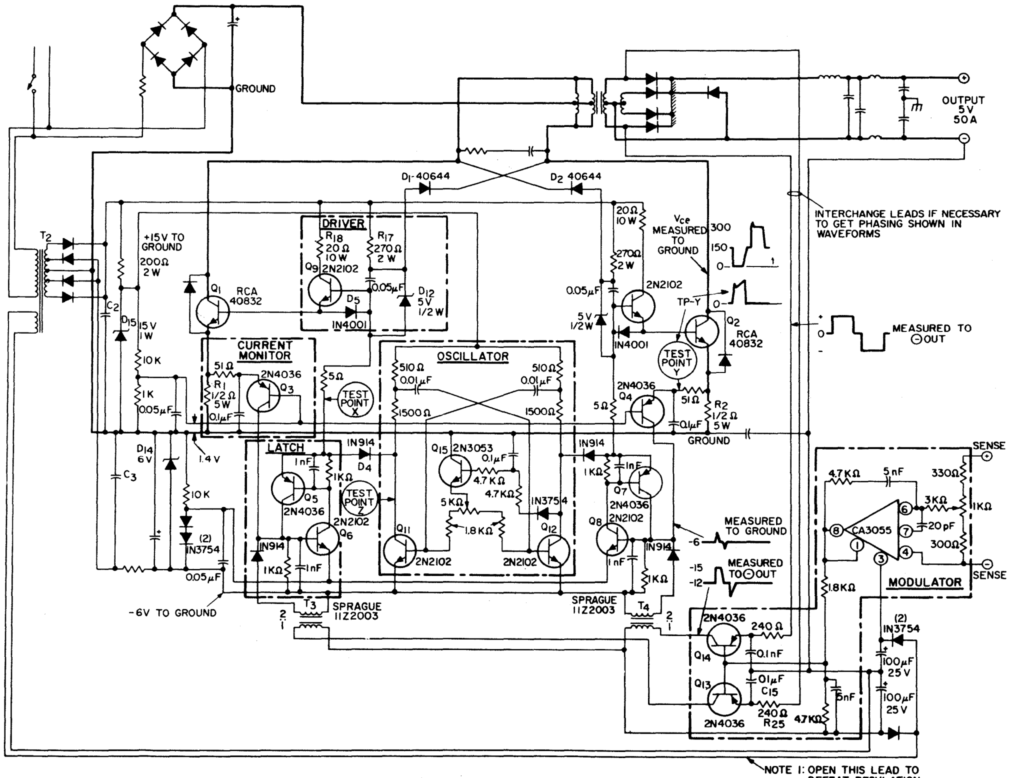


Fig. 6 - Diagram of switching-regulator power supply, with modulator circuits emphasized.

Table IV – Functional Description of Modulator Circuits

MODULATOR CIRCUIT SECTIONS	MAIN PARTS IN SECTION	FUNCTION OF SECTION
Oscillator	Q_{11}	Provides basic operating frequency. Holds off driver Q_9 through D_4 to keep Q_1 off for half the period. Provides reverse base drive for Q_1 at 100% duty cycle through D_4 and D_5. Resets the latch circuits.
	Q_{15}	Insures oscillator starts, by removing base drive if Q_{12} saturates too long.
Latch	Q_5	Terminates power-on cycle by latching and causing reverse base to Q_1.
	Q_6	Is triggered on by either the current monitor Q_3 or the modulator Q_{13} through T_3, and is held on by regenerative action. Is turned off by the oscillator.
Modulator	Q_{13} CA3055 R_{25} C_{15}	Compares the voltage developed by the CA3055 with a triangular waveform developed by R_{25} C_{15}. When the triangular voltage exceeds the other, Q_{13} conducts and triggers on the latch through T_3.
Driver	Q_9 D_{12} D_5 D_1 D_4 R_{18}	Supplies the forward base drive to Q_1, which is set by R_{18}. Prevents common-mode conduction. Diode D_1 senses V_{CE} of Q_2 and prevents base drive to Q_9 and thus to Q_1. Zener D_{12} causes Q_1 to be held off until V_{CE} of Q_2 exceeds the zener voltage (5V).
Current Monitor	Q_3 R_1	Limits the emitter current through Q_1. That current produces a voltage across R_1 which is filtered; if it exceeds 2.0 V, Q_3 conducts and triggers the latch to terminate the power-on cycle.
Low-Voltage Supplies	T_2 C_2 C_3 D_{14} D_{15}	A 30-volt unregulated supply is used to supply the base drive for Q_1 and Q_2. It is regulated to 15 volts by D_{15} to supply the oscillator. A -12-volt unregulated supply is regulated to -6 V by D_{14}. It supplies reverse base drive to Q_1 and Q_2, and operates the oscillator circuit. An isolated supply operating from T_2 supplies bias to the modulator circuit.

be determined by measurement of circuit efficiency or heat-sink temperature. A total rectifier loss of 45 per cent of the rated output power of the regulator is to be expected.

Filter. The use of ac power to generate dc outputs that are free of ac signals requires a good filter. Moreover, in a power supply that delivers high current, the filter components must be of high quality: the inductor must have high Q, and the capacitor must have both low resistance and low inductance.

The inductor carries a current equal to the dc output. It can have small size and low resistance because it has a low inductance (3 to 8 microhenries). The inductance value used is a compromise between the need for a high value to limit peak currents and thus permit good transistor utilization, and the need for a low value to permit fast response to sudden current demands. Fig. 7 shows how the inductor controls the ratio of peak collector current to average collector current in the power-switching transistors under steady-state operation. Smaller inductors cause higher peak currents, which require larger transistors and result in poor utilization of the transistor capabilities. The minimum value of inductance is determined by the peak collector current allowed, as follows:

$$L_{min} = \frac{t_{off}(max)\ E_{out}}{n_T\ I_c(peak) - I_{load}}$$

where n_T is the turns ratio of the isolation transformer. However, as shown in Fig. 8, the inductor also establishes the maximum rate of rise of current to the capacitor, and thus determines the ability of the power supply to respond to sudden demands for load current. For quick response, a low value of inductance is desirable.

The filter capacitors for this application must be selected for 20-kHz operation. Ceramic and paper types are best, but tantalum or high-quality aluminum electrolytics can be used for large values of capacitance. The capacitance must be sufficient to prevent the output voltage from decreasing excessively when the load is suddenly increased and the

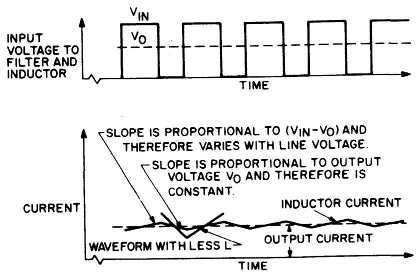


Fig. 7 - Waveforms for filter inductor under steady-state operation at 60-per-cent duty cycle.

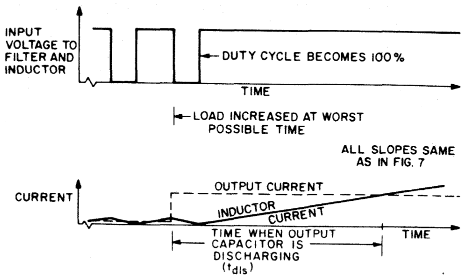


Fig. 8 - Waveforms for filter inductor under sudden increase of load current.

inductor supplies less than the load current. The minimum capacitance is given by

$$C_{min} = \frac{I_{load}(t_{dis} + 2t_{off}(max))}{2(\triangle V) \text{ allowed}}$$

where

$$t_{dis} = \frac{L\ I_{load}}{\frac{V_{CC}(min)}{n_T} - V_o - 1.0}$$

and $t_{off}(max)$ is 12.5 microseconds for this design.

A SPECIFIC DESIGN EXAMPLE

A power supply that uses the circuits shown in Figs. 1, 2, and 6 can deliver a load current of 50 amperes at 5 volts. All of the pulse-width modulation circuits, drivers, and latches are duplicated for each power-switching transistor. This duplication uses more than the minimum number of components, but it provides wide design margins and more reliable operation.

Voltage regulation and overload regulation are accomplished by reducing the duty cycle of the power-switching transistors. The duty cycle is reduced by triggering the latches on (see Fig. 6 and Table IV), either from pulse transformers T3 and T4 to regulate the output voltage, or from transistors Q3 and Q4 to prevent excessive emitter currents in the power-switching transistors. The excessive currents could be caused by overloads at the output or by transformer core saturation resulting from unbalanced duty cycles.

Input-to-output isolation is maintained through the main isolation transformer (T1), the 60-Hz transformer (T2), and the pulse transformers (T3 and T4). This circuit isolation is indicated in Fig. 2.

This power supply is capable of operating into any load impedance, including short circuits, without damage. It can operate at duty cycles from less than 10 per cent to 100 per cent. With a duty cycle of 100 per cent, the supply operates as a straight inverter at the full capacity of the transistors, transformers, and rectifiers.

The base drive for the power-switching transistors is direct-coupled, and is supplied by an unregulated low-voltage power supply that operates from a 60-Hz transformer. Direct coupling of the base drive provides positive control over transistor bias. The reverse base drive is supplied by the two-transistor latch circuits Q5 and Q6 or Q7 and Q8, or by the oscillator transistors (Q11 and Q12) if the duty cycle is 100 per cent. The reverse base voltage is obtained from a 6-volt regulated supply.

The frequency is controlled by the astable transistor oscillator that operates from 15-volt and −6-volt regulated sources. A potentiometer for equalization of the duty cycle is shown, but is not normally required. Transistor Q15 insures that the oscillator does not "hang up."

Common-mode conduction is reduced by cross-coupled diodes D1 and D2. These diodes conduct when V_{CE} of the power-switching transistor is less than 5 volts (breakdown of the zener diode), and prevent conduction of the opposite power-switching transistor; this operation is illustrated in the waveforms of Fig. 9. These diodes are of critical importance because the storage time of the power-switching transistors is several microseconds at light load conditions ($I_{B_1} > 0.5$ amperes and $I_C < 0.5$ amperes).

A major consideration in the design of this power supply is the protection of the switching transistors and the load circuit from damage caused by transients or faults in the modulator. The faults most likely to occur are lock-up in the oscillator, transient turn-on of the latching transistors caused by dv/dt at point X in Fig. 6, and magnetic pickup in the pulse transformers. The circuit is designed so that any of these faults will cause the power-switching transistors to turn off; this design protects the transistors and keeps the output voltage low. The overcurrent protection circuit is made independent of the proper functioning of the output regulator or its associated circuits, and is dc-coupled to minimize the possibility of failure. Finally, if the low-voltage supplies fail, the output voltage merely falls to zero without any harmful surges.

Table IV gives a full description of the modulator circuits. For simplicity, the discussion is limited to the components on the left side of the symmetrical circuit layout shown in Fig. 6.

VARIATIONS ON THE DESIGN

The design discussed above and shown in Figs. 2 and 6 can be modified for different performance.

More Output. Larger transistors, such as the 2N5805, can be used as the power switches to increase the output by as much as 100 per cent. These transistors would require more base drive, which can be supplied by the circuit shown

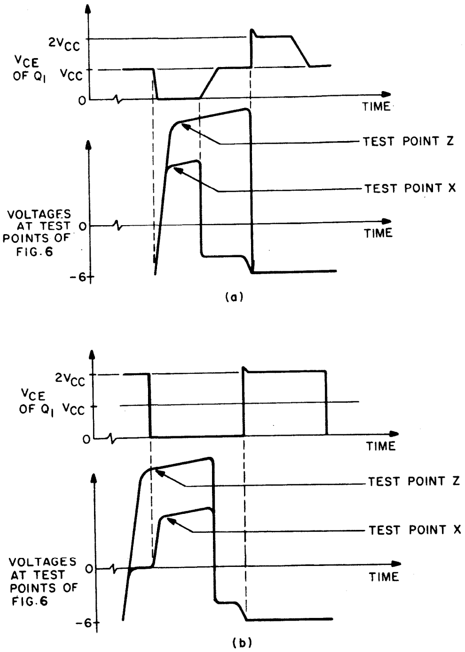


Fig. 9 - Suppression of common-mode conduction: (a) 50-per-cent duty cycle; (b) 100-per-cent duty cycle.

in Fig. 10 if the capacity of the 30-volt supply is increased.

Simpler Construction. Custom integrated circuits can reduce the number of parts in this unit.

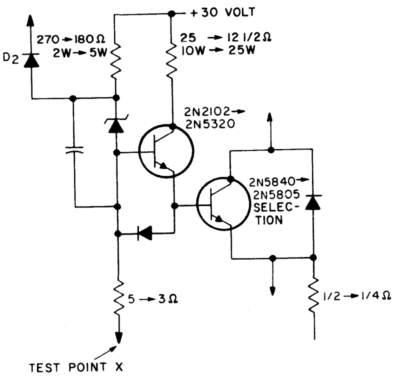


Fig. 10 - Changes in power-switching transistor drive circuit to produce increased output from larger power-switching transistors.

Smaller Package. A 20-kHz "off-the-line" inverter can be used in place of the 60-Hz transformer to reduce the size of the supply further. The smaller transformers, capacitors, and resistors for 20-kHz operation would, however, increase the cost.

Sensing. The output-voltage sensing can be improved, and output-current sensing can be added if required. The short-circuit protection in the circuit can be improved by adding an IC regulator that senses the output current by means of a current-sampling resistor.

Low-Voltage Supplies. Different voltages and different types of regulation can be used in the low-voltage supplies. One alternative, shown in Fig. 11, is the use of an extra winding on the isolation transformer to supply the base-drive transistors. This circuit reduces the cost of smoothing capacitor C2 in Fig. 2, and reduces the size of the 60-Hz transformer.

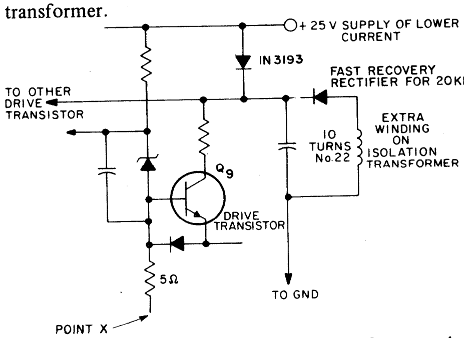


Fig. 11 - Use of a separate isolation-transformer winding to supply the base-drive transistors.

DESIGN NOTES

The switching-regulator type of power supply is more complex than a conventional dc series regulator. Because tests must be made with regard to waveforms, an oscilloscope is a required diagnostic tool. A special problem is that most of the components in these supplies are not isolated from the power line. Although the test equipment can be used "floating", the safest practice is to use an isolation transformer during tests of the power supply.

Finally, the design and construction of the filter are important to reduce spikes on the output. The filter unit should be sealed to prevent radiation.

References

1. *RCA Transistor, Thyristor, & Diode Manual (SC-14);* RCA Commercial Engineering, Harrison, N.J.
2. *RCA Silicon Power Circuits Manual (SP-51);* RCA Commercial Engineering, Harrison, N.J.
3. *RCA Silicon Rectifiers (SRS-300A);* RCA Commercial Engineering, Harrison, N. J.
4. F. E. Terman, *Radio Engineers' Handbook;* McGraw-Hill Book Co., 1943, pg. 100.
5. *Indiana General Ferramic Components,* Indiana General Corp.; Keasbey, N.J. 1970
6. "Applying Ferroxcube Ferrite Cores to the Design of Power Magnetics", Bulletin No. 330; Ferroxcube Corp., Saugerties, N.J. 1966

RCA
Solid State
Division

Power Transistors
Application Note
AN-4558

A 60-Watt, 20-Volt Regulated Power Supply Using a Single Pass Transistor

by D. Morris and R. H. Smith

This Note discusses a regulated constant-voltage power supply that uses RCA integrated circuits and a rugged RCA hometaxial transistor to attain high output-power capability. A 20-volt, 3-ampere supply that uses a single RCA-2N3055 pass transistor is described in detail; the discussion includes circuit descriptions, operating characteristics, component specifications, and suggestions for layout and construction. Thermal-fatigue effects and safe operating conditions for power transistors are considered. Finally, guidance is provided for those who may want to develop a similar circuit for their own needs.

DESCRIPTION OF CIRCUIT

Specifications for the 60-watt, 20-volt supply are listed in Table I, and a block diagram is shown in Fig. 1. The circuit uses an external pass transistor and driver to extend the current capability of the RCA-CA3055 integrated-circuit voltage regulator; the overload protection provided by a foldback current-limiting circuit permits operation of the transistor at a dissipation level close to its limit. This foldback circuit achieves high efficiency by use of an RCA-CA3030 integrated-circuit operational amplifier.

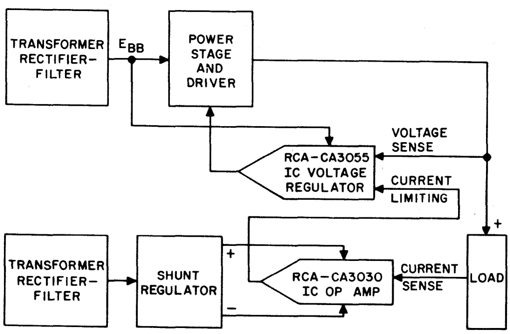
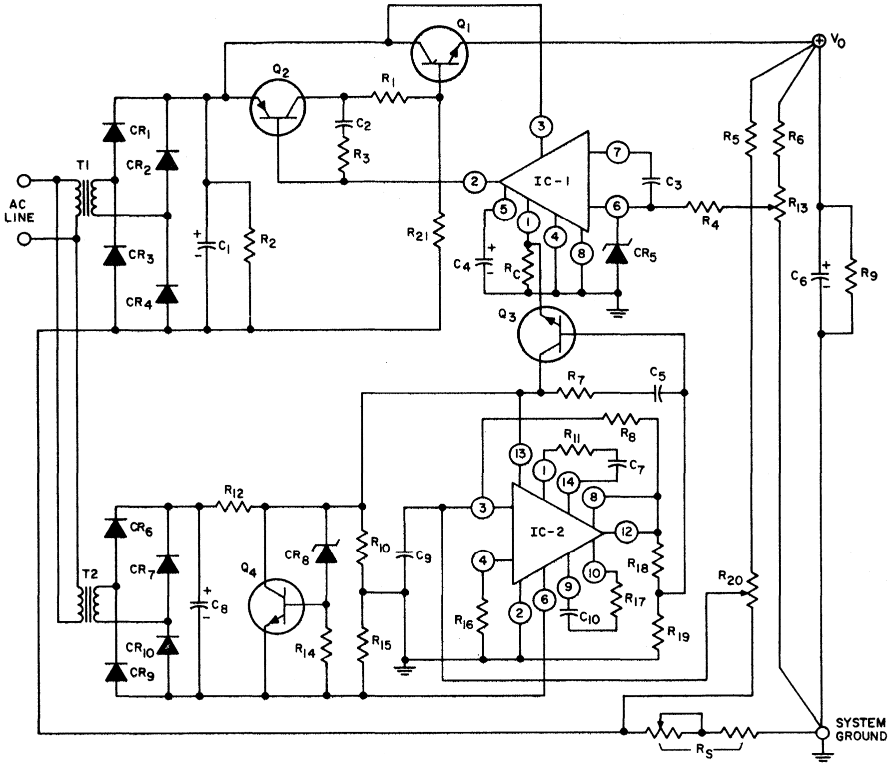


Fig. 1– Block diagram of regulated power supply with foldback current limiting.

Table I - Power-Supply Specifications

V_{input}	105-130 V, Single Phase 55-420 cps
V_{output}	20 V ±0.5 V
I_{load}(max)	3 A
Ambient Temperature	0 to +55°C
Voltage spikes	None at turn on or turn off
Regulation	Line: ±0.25%
	Load: ±0.25%
Ripple	33 mV pp; 9.5 mV rms
Transients:	
No load to full load:	100 mV, recovery within 50 μs
Full load to no load:	100 mV, recovery within 50 μs
Drift	20 mV in 8 hours of operation at constant ambient temperature
Short Circuit and overcurrent protection	Foldback technique

The over-all operation of the circuit can be understood with the aid of the schematic diagram shown in Fig. 2. Transformer T1 and its rectifiers supply the raw dc power that is regulated by pass transistor Q1; this pass transistor is driven by driver Q2, which is driven by the control circuit IC1. Transformer T2, with its rectifiers and shunt regulator Q4, provides positive and negative supplies for operational amplifier IC2; this operational amplifier drives the current-limiting control Q3. Output voltage is sensed at resistance string (R6 + R13), and load current is sensed by R_S.



T1	Signal Transformer Co., Part No. 24-4 or equivalent
T2	Signal Transformer Co., Part No. 12.8-0.25 or equivalent
CR1-CR4	RCA-1N1614
CR5	Zener Diode, 1N5225 (3.3 V)
CR6, CR7, CR9, CR10	Power Rectifier, RCA-1N3193
CR8	Zener Diode, 1N5242 (12 V)
C1	5900 µF, 75 V, Sprague Type 36D592F075BC or equivalent
C2	0.005 µF, ceramic disc, Sprague TGD50 or equivalent
C3, C7, C10	50pF, ceramic disc, Sprague 30GA-Q50 or equivalent
C4	2µF, 25 V, electrolytic, Sprague 500D G025BA7 or equivalent
C5	0.01 µF, ceramic disc, Sprague TG510 or equivalent
C6	500 µF, 50 V, Cornell-Dubilier No. BR500-50 or equivalent
C8	250 µF, 25 V, Cornell-Dubilier BR 250-25 or equivalent
C9	0.47 µF, film type, Sprague Type 220P or equivalent
R1	5 ohms, 1 watt, IRC type BWH or equivalent
R2	1000 ohms, 5 watts, Ohmite type 200-5 1/4 or equivalent
R3	1200 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent

R4	100 ohms, 1/2 watt, carbon, IRC Type RC 1/2 or equivalent
R5	430 ohms, 2 watts, wire wound, IRC Type BWH or equivalent
R6	9100 ohms, 2 watts, wire wound, IRC Type BWH or equivalent
R7	470 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent
R8	5100 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent
R9, R14	1000 ohms, 2 watts, wire wound, IRC type BWH or equivalent
R10, R15	250 ohms, 2 watts, 1% wire wound, IRC type AS-2 or equivalent
R11, R17	1000 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent
R12	82 ohms, 2 watts, IRC type BWH or equivalent
R13	1000 ohms, potentiometer, Clarostat Series U39 or equivalent
R16	1200 ohms, 2 watts, wire wound, IRC type BWH or equivalent
R18	510 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent
R19	10,000 ohms, 1/2 watt, carbon, IRC type RC 1/2 or equivalent

Fig. 2– Schematic diagram of 60-watt, 20-volt regulated power supply with foldback current limiting.

R20	300 ohms, potentiometer, Clarostat Series U39 or equivalent
R21	510 ohms, 3 watts, wire wound, Ohmite type 200-3 or equivalent
R_C	240 ohms, 1%, wire wound, IRC type AS-2 or equivalent
R_S	(See text for fixed portion); 1 ohm, 25 watts, Ohmite type H or equivalent
IC1	RCA-CA3055
IC2	RCA-CA3030
Q1	RCA-2N3055
Q2	RCA-2N5781
Q3, Q4	RCA-40347

Miscellaneous

(1 Req'd)	Heat Sink, Delta Division Wakefield Engineering NC-423 or equivalent
(3 Req'd)	Heat Sink, Thermalloy #2207 PR-10 or equivalent
(1 Req'd)	8-pin socket Cinch #8-ICS or equivalent
(1 Req'd)	14-pin DIL socket, T.I., #IC 014ST-7528 or equivalent
(2 Req'd)	TO-5 socket ELCO #05-3304 or equivalent
	Vector Board #838AWE-1 or equivalent
	Vector Receptacle R644 or equivalent
	Chassis – As required
	Cabinet – As required
	Dow Corning DC340 filled grease

Fig. 2– Schematic diagram of 60-watt, 20-volt regulated power supply with foldback current limiting. (cont.)

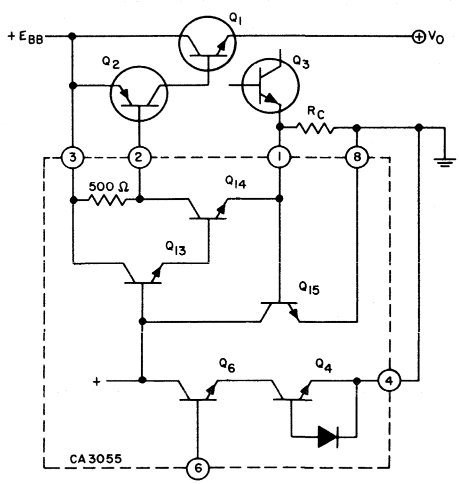


Fig. 3– CA3055 control of the power transistors.

Voltage Regulation

The power-supply output voltage is sampled by the voltage divider (R6 + R13), and a portion is fed to terminal No. 6 (the inverting input) of the CA3055. (This portion is less than the 3.3-volt breakdown voltage of zener diode CR5; the zener is present only to protect the integrated circuit from accidental overvoltages.) If the output voltage decreases, the base-to-emitter voltage of Q2 increases, as explained in the next paragraph. Therefore the pass transistor Q1 is driven harder, and as a result the output voltage increases to its original value (minus the error dictated by the system gain).

The process by which a voltage decrease at terminal No. 6 of the CA3055 produces an increase of Q2 base-to-emitter voltage can be understood with the aid of Fig. 3, which shows some of the internal circuitry of the CA3055.[1] The drop of voltage at terminal No. 6 causes a higher base-to-emitter voltage at the Darlington combination Q13-Q14. Therefore the collector current of Q14 increases, and thus increases the voltage drop across the 500-ohm resistor, which is the base-to-emitter voltage of Q2.

Foldback Current Limiting

The purpose of the current-limiting circuit is to prevent the power supply from passing a load current that could damage the pass transistor if a very low impedance (or a short circuit) is placed across the output terminals. Fig. 4 shows the effect of this circuit. The supply voltage remains constant until the load current reaches the threshold for activation of the limiting circuit; any further decrease of load impedance causes output voltage V_O and load current I_O to decrease, so that the V_O-I_O characteristic folds back to limit the power dissipation in the pass transistor. Activation of foldback disables the voltage-regulation circuit.

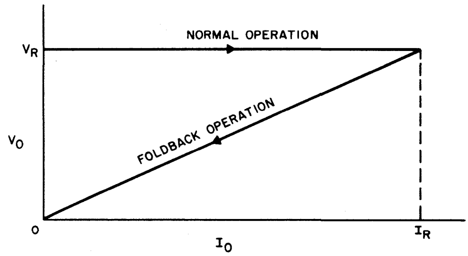


Fig. 4– Foldback current-limiting characteristic.

The circuitry for foldback current limiting, shown in Fig. 5, uses the CA3030 integrated circuit as a differential amplifier.[2-5] A signal from the voltage divider RR1 and RR2*, which is across V_O and the E_{BB} return, is applied to

*RR1 actually consists of R5 and the upper portion of R20 in the schematic diagram of Fig. 2; RR2 is the lower portion of R20.

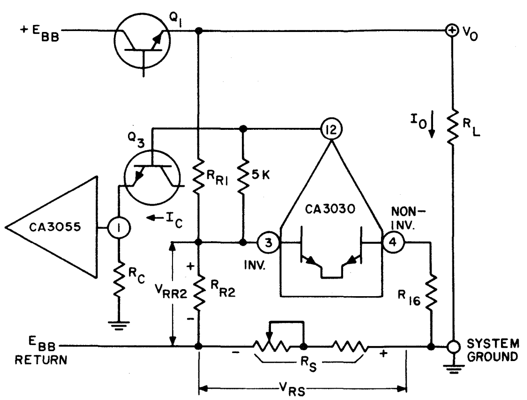


Fig. 5— Circuitry for foldback current limiting.

the inverting input (terminal No. 3) of the differential amplifier. The non-inverting input is tied to system ground through R16. Thus the base-to-base signal that actuates the differential amplifier is the difference between V_{RS} ($=I_O R_S$) and V_{RR2}. The CA3030 output, which is the voltage at terminal No. 12, varies linearly with the actuating voltage, as shown in Fig. 6. When the load current is zero* , V_{RS} is zero; therefore (V_{RS} - V_{RR2}) is negative, terminal 12 is negative with respect to ground, and Q3 is back-biased (i.e., cut off). Therefore Q3 does not interfere with the normal voltage-regulated operation of the supply. As the load current increases, V_{RS} increases and the voltage at terminal 12 increases.

The value of resistor R_S is adjusted so that when the load current reaches the foldback-activation value (about 3 amperes in the power supply shown), the voltage at terminal No. 12 of the CA3030 becomes positive. At about 0.7 volt, transistor Q3 begins to conduct; current flows through the current-limiting resistor R_C, with the result that terminal No. 1 of the CA3055 control circuit is driven positive. Q15 of Fig. 3 turns on, and the base-to-emitter voltage of Q13-Q14 is therefore reduced; the base-to-emitter voltage of Q2 is reduced, and the output voltage of the power supply decreases. This decrease of V_O tends to reduce the load current; however, V_{RR2} also decreases with V_O, so that $(V_{RS} - V_{RR2})$ remains fixed and Q3 continues to conduct at the same emitter current. If the load impedance is reduced, Q3 will be driven even harder, and therefore the output voltage and the load current will decrease even further. Fig. 4 shows the foldback as R_L decreases.

This process is reversible. If the load impedance R_L is increased, I_O and V_O will increase. When I_O reaches the foldback-activation level, Q3 will cut off again and the power supply will return to regulated operation.

The CA3030 must be operated as a linear voltage amplifier in the foldback circuit, so that the gain is as shown in Fig. 6. If the CA3030 is adjusted otherwise, a Schmitt trigger action can occur. Such operation may be desirable in latching-type current protection, e.g., in circuits that switch off at overload. However, those circuits introduce other problems such as lack of automatic turn-on, hysteresis effects on varying loads during the shutdown process, and capacitive and nonlinear loads; therefore, latching protection is not considered in this Note.

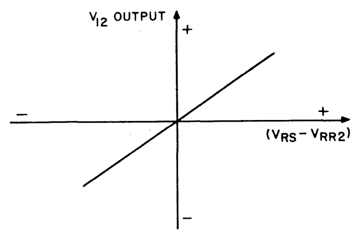


Fig. 6— Output voltage from the CA3030 operational amplifier as a function of actuating voltage.

DESIGN CONSIDERATIONS

For maximum performance from this power-supply circuit, several design features must be analyzed. These features include the equivalent source resistance of the rectifier filter circuit, the foldback-circuit parameters, and the maximum power dissipation in the pass transistor. In addition, safe-operation and thermal-fatigue ratings for the transistors are important.

Equivalent Resistance of the Raw DC Source

A full-wave bridge rectifier[6] provides the raw dc power for this supply; the rectifier and its filter are shown in Fig. 7(a). The output current and power capability would be improved by use of a custom-wound transformer, and even greater capability would be attained by use of a full-wave center-tapped rectifier circuit with a custom transformer. However, a custom transformer would increase the unit cost, particularly if no winding facilities were available; therefore, a commercially available transformer is used in this supply.

The load regulation of the transformer is approximately 10 per cent. This value is used as the approximate R_g/R_L parameter in Schade's curves[7] to select input capacitor C1. The value of C1 that will keep peak-to-peak ripple below 2.4 volts is found to be 5900 microfarads. With this capacitance, the measured value of equivalent source (generator) resistance R_g is 2 ohms. Fig. 7(b) shows the equivalent circuit of the rectifier and filter.

* The currents in the 1-kilohm bleeder resistor and the 10-kilohm sensing string are neglected in this discussion.

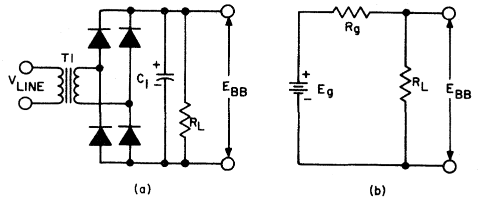


Fig. 7— Full-wave bridge rectifier and filter that provide raw dc for power supply: (a) circuit diagram; (b) equivalent circuit.

At high line voltage (130 volts ac) the cold-temperature, no-load dc voltage of the rectifier filter is 39.4 volts; this value is just below the 40-volt maximum rated voltage of the CA3055. At low line voltage (105 volts ac) the hot full-load dc voltage of the rectifier filter is 25.4 volts; the theoretical minimum necessary voltage for the supply is shown in Appendix A to be 25.4 volts.

Foldback-Circuit Parameters

A simple conventional foldback circuit, in which a single-ended amplifier is used instead of the differential amplifier described above, is shown in Fig. 8(a). The equivalent circuit is shown in Fig. 8(b). Analysis of this circuit (see Appendix B) shows that the ratio of maximum load current just before foldback activation, I_X, to the rated load current I_R, is approximately given by

$$\frac{I_X}{I_R} = \frac{V_D + V_{BE} + V_{RR}}{V_D + V_{RR}} \qquad (1)$$

in which V_D is the voltage drop across the diode (= 0.7 volt for a silicon diode). I_R is the zero-bias level for Q_X; when I_O exceeds I_R, Q_X becomes forward-biased and causes loss of regulation.

The ratio of the short-circuit current, I_{SC}, to the rated load current is approximately given by

$$\frac{I_{SC}}{I_R} = \frac{V_D + V_{BE}}{V_D + V_{RR}} \qquad (2)$$

When the values of the circuit components are inserted into these equations, these ratios have the following values:

$$\frac{I_X}{I_R} = 1.23 \qquad (3)$$

$$\frac{I_{SC}}{I_R} = 0.47 \qquad (4)$$

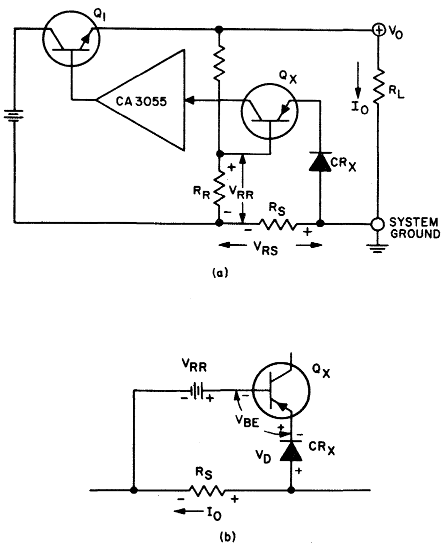


Fig. 8— A simple conventional foldback circuit that uses a single-ended amplifier instead of a differential amplifier: (a) circuit diagram; (b) equivalent circuit.

Eq. (3) shows that the pass transistor must have a current capability 23 per cent greater than the rated current value of the supply, or, equivalently, that the pass transistor is utilized at only 77 per cent of its current and power-dissipation capabilities at rated supply current. This utilization is reduced even further by the source resistance of the generator, as discussed below.

Another disadvantage of the simple foldback circuit is indicated in Appendix A: the minimum voltage across filter capacitor C1 is increased by at least ($V_D + V_{BE} + V_{RR}$).

The foldback circuit used in the supply shown, which uses a differential amplifier and a low actuating signal, is free of the drawbacks encountered in the simple conventional circuit. Actual values measured on the differential-amplifier foldback circuit, set for a 0.2-volt actuating signal and a rated load current of 3 amperes, are as follows:

$I_{SC} = 0.125$ A

$I_X = 3.15$ A

$$\frac{I_X}{I_R} = \frac{3.15}{3} = 1.05$$

$$\frac{I_{SC}}{I_R} = \frac{0.125}{3.00} = 0.042$$

The maximum load current to actuate foldback is 5 per cent greater than the rated current, and the short-circuit current is 4 per cent of the rated current.

Maximum Power Dissipation in the Pass Transistor

Power dissipation in the pass transistor reaches maximum during foldback. This worst-case value can be calculated by the analysis given in Appendix C, which uses the equivalent circuit shown in Fig. 9. (The use of a power-sharing resistor in parallel with the pass transistor is neglected in this discussion because transformer T1 operates at its maximum capacity.) Because the maximum-dissipation situation might occur during operation, the power supply must be designed to withstand this worst-case condition.

Maximum power dissipation occurs when the output voltage is given by

$$V_{OX} = \frac{E_g}{2(1 + \sigma R_g)} \qquad (5)$$

where E_g is the generator voltage, σ is the load conductance ($\sigma = I_R/V_R = 1/R_L$, I_R is the rated current, V_R is the rated voltage, and R_g is the generator resistance. The value of the maximum power, P_X, is given by

$$P_X = \frac{\sigma E_g{}^2}{4(1 + \sigma R_g)} \qquad (6)$$

The rated current is determined as a function of rated voltage, maximum power, generator voltage, and generator resistance, as follows:

$$I_R = V_R \frac{4P_X}{E_g{}^2 - 4 P_X R_g} \qquad (7)$$

The maximum power limit for the pass transistor, P_X, depends on the heat sink. Appendix D shows that for the particular case under discussion the maximum power is 47 watts. Therefore, I_R is given by

$$I_R = 20 \frac{4 \times 47}{(40)^2 - 4 \times 47 \times 2} = 3.07 \text{ A}$$

The value of V_{OX} is then determined as follows:

$$V_{OX} = \frac{E_g}{2(1 + I_R/V_R\, R_g)} = \frac{40}{2(1 + \frac{3.07}{20} \times 2)} = 15.4 \text{ V} \qquad (8)$$

Idealized curves of various power-supply parameters in regulated operation and in foldback are shown in Fig. 10. Maximum dissipation is 46 watts, at V_{OX} = 15.4 volts. This condition can occur if the supply is turned on with a load that causes worst-case foldback operation. As the transformer heats up, the capacitor voltage decreases (i.e., R_g increases), and dissipation is slightly reduced. Even at maximum dissipation in the transistor, however, the power supply can provide continuous trouble-free operation.

Safe Operation of Power Transistors

The current capability of the circuit can be increased almost indefinitely by use of drivers and output transistors with higher current and dissipation capability, by paralleling transistors, or by providing one or more additional stages in a Darlington configuration, along with increased heat sinking, transformer and rectifier capability, and filter capacitance. Information on the proper operation of transistors can be

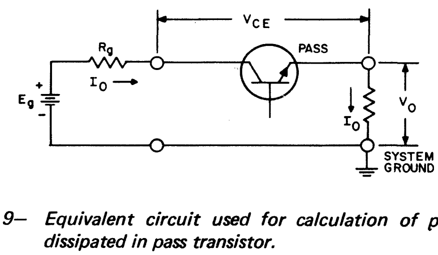


Fig. 9– Equivalent circuit used for calculation of power dissipated in pass transistor.

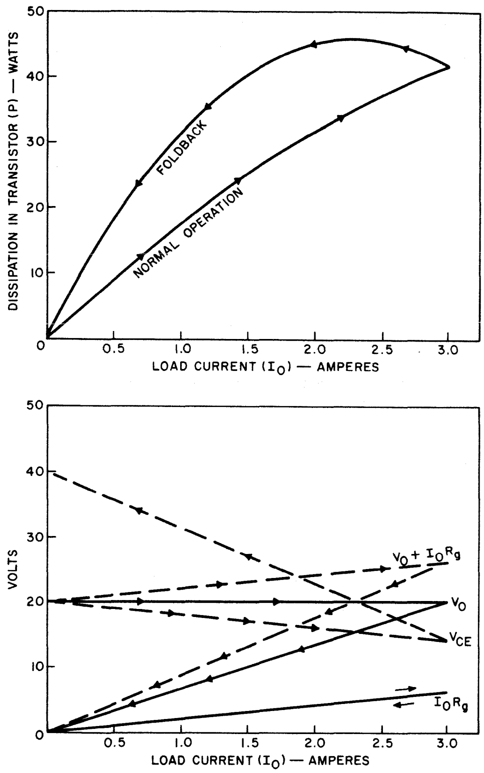


Fig. 10– Idealized operating characteristics of foldback current-limiting circuit.

found in published data sheets.[8,9] Safe-area charts, derating curves, thermal resistance, and maximum junction-temperature specifications are given in the data sheets. Worst-case-operation conditions for the transistors can be determined for a number of possible values of rated voltage and current, and these values can be checked against the specified ratings.

The current capability of linear series regulators is usually limited by the safe dissipation levels of the pass devices, rather than by maximum current ratings or available gain, especially if simple (not foldback) current limiting is used, as for an adjustable voltage supply. Safe operating area encompasses the limitations of power dissipation and second breakdown.[10] RCA hometaxial-base transistors, such as the 2N3055, show little or no second-breakdown limitation in the safe area. Because the published safe area is guaranteed by 100-per-cent factory testing, the user is sure of reliable service even in such severe applications as linear regulators.

Thermal-Fatigue Considerations

A transistor is constructed of materials that have various thermal-expansion coefficients. When the transistor is subjected to a range of internal temperatures in the course of normal operation, the different coefficients of expansion result in stresses on various parts of the internal transistor structure. These stresses are proportional to the change in temperature, the difference in expansion coefficients between two materials in contact, and the pellet size. When the stresses are severe enough and are repeated enough times, they can cause the transistor to fail, usually by rupture of the solder bonds between the pellet and the top contacts or between the pellet and the mounting base. Large power transistors that operate at high power levels, such as the pass devices in linear series regulators (e.g., the RCA-2N3055 family of transistors in the circuit described in this Note), operate in a mode of high thermal-fatigue stress.

RCA has recognized the thermal-fatigue problem and has developed transistors that are extremely resistant to thermal-fatigue failure. This resistance to thermal-fatigue failure is the result of a proprietary Controlled Solder Process (CSP), by which impurities and voids are reduced or eliminated from the solder system. Impurities enhance the propagation of cracks induced by thermal-fatigue stresses, and thus contribute to early failure of the solder bonds. Voids under the pellet act as insulation, and can lead to hot spots that cause high thermal-fatigue stresses. CSP is now employed on all RCA hermetic power transistors.

RCA has developed power-transistor thermal-cycling ratings that indicate expected life, in number of thermal cycles, as a function of power dissipation and case-temperature change. These ratings are calculated from theoretical models based on actual measurements.[11,12] This rating system shows that the RCA-2N3055 pass transistor, used as described in this Note (maximum power dissipation of 46 watts, case-temperature change of 43°C), can survive more than 50,000 thermal cycles without failure. The RCA-2N5781 and the smaller devices in the circuit should last even longer.

The combination of homotaxial construction for ruggedness and CSP for long thermal-fatigue life makes these power transistors the best choice for power-supply applications.

OPERATIONAL PERFORMANCE

Adjustment of Current-Sensing Resistor R_S

The fixed portion of current-sensing resistor R_S is simply a short length of resistance wire; its resistance is about 0.064 ohm. This resistor must be adjusted on each power supply, because both the over-all loop system gain and the current-limiting voltage across terminals 1 and 8 of the CA3055 can vary from unit to unit. The two-step procedure for adjusting the fixed portion of the R_S is as follows:

(a) Set the reference voltage by adjusting the 250-ohm potentiometer (R20) until the voltage from the arm of the potentiometer to ground is 200 millivolts (with the load current zero, and total sensing resistor $R_S = 0$).

(b) Use a variable resistor across the output terminals to set the load current at 3.15 amperes. Then insert the fixed portion of the sensing resistance and increase it until current foldback is just initiated. Initiation of foldback is evidenced by sudden reduction in output voltage.

This fixed resistor should be made of resistance wire such as Driver Harris Manganin #18 (0.176 ohms per foot) or equivalent. Copper wire can be used provided I^2R heating does not change its resistance, and effects of ambient-temperature change are taken into consideration. (The temperature coefficient of copper wire is 3.9 x 10^{-3} per ^oC. If the copper resistor were adjusted at 20^{o}C, and the ambient temperature then changed to 55^{o}C, the current required to activate foldback would be reduced from 3.15 amperes to 2.7 amperes).

The variable portion of current-sensing resistor R_S is a 1-ohm potentiometer. It is used to set the current-limitation threshold at levels below 3 amperes, if such operation is desired.

Adjustment of Current-Limiting Resistor R_C

The CA3055 voltage regulator would function most effectively if current-limiting resistor R_C were zero, but R_C is necessary for foldback operation. Therefore, as a compromise between regulation and protection sensitivity, R_C is adjusted to provide an over-all regulation of ± 0.25 per cent for all load currents from 0 to 3 amperes. This value of R_C results in a reasonable short-circuit current (0.125 amperes). If R_C is made smaller (to permit better regulation), the ratio R8/R16 must be increased to provide more gain in the current-limiting circuit. This change may require restabilization of the circuit.

Power-Supply Performance

With the circuit adjusted as described above, the power supply performs as shown in Table II.

CONSTRUCTION

Fig. 11 shows the assembled power supply; it is 8 inches long, 8 inches wide, and 5 3/4 inches high (these dimensions can be reduced if necessary). The chassis is made of 0.052-inch aluminum, perforated on top and sides for ventilation; a commercial chassis such as the BUD CA1751 or equivalent could also be used.

The control circuit is built on a pre-punched fiber board. Good wiring techniques are observed, all leads to the integrated circuits are kept as short as possible, and heat sinks are attached where required.

The positive and negative supplies for the operational amplifier are also constructed on pre-punched fiber board. The board is attached with an L-bracket to the diode support, as shown in the diagram.

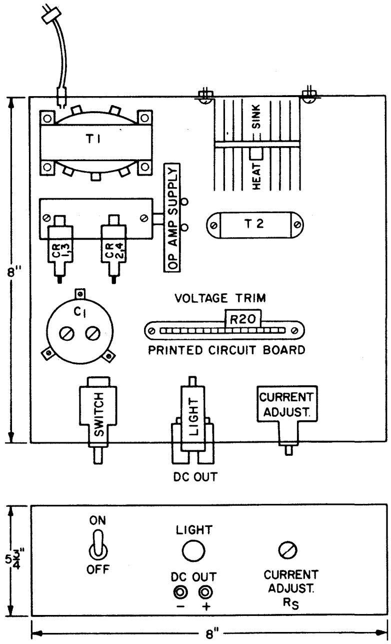


Fig. 11– Layout of power supply.

The pass-transistor heat sink is mounted vertically, with 1/4-inch clearance from the bottom of the chassis to provide adequate convection. The circuit board is mounted as far as possible from the pass-transistor heat sink to achieve maximum thermal isolation.

Construction of this supply is flexible. Wiring is not critical, but heavy wire should be used for the leads that carry high current. The total allowable IR drop in the wiring is 0.1 volt; at a current of 3 amperes, therefore, the total allowable resistance (including contact resistance) is 33 milliohms.

As in all error-detecting systems, the sampling should be accomplished at the terminals of the power supply, i.e., at the +20-volt and ground terminals. Therefore all of the system ground points indicated in Fig. 2 are connected with heavy wire to avoid ground loops. Output capacitor C6 is wired directly to the output terminals.

APPENDIX A. Minimum Voltage Across Filter Capacitor

The minimum voltage across filter capacitor C1 is obtained as follows:

$$V_{Cap}\ (min) = V_O + V_{O\text{-}PK} + V_{BE}\ 2N3055$$

$$+ V_{CE}\ 2N5781 + V_{R1} + V_{TOL} + V_{RS} + V_{LD}$$

Table II - Performance of Regulated Power Supply

Normal Operation: V_O set at 20.000 VDC with I_O = 3 A @ V_{line} = 115 VAC.

PARAMETER	CONDITIONS	VALUE	
Load regulation	$I_O = 0 \rightleftarrows 3A$, V_{Line} = 105 VAC	±0.25%	
Load regulation	$I_O = 0 \rightleftarrows 3A$, V_{Line} = 115 VAC	±0.25%	
Load regulation	$I_O = 0 \rightleftarrows 3A$, V_{Line} = 130 VAC	±0.25%	
Line regulation	$I_O = 0$, $V_{Line} = 105 \rightleftarrows 130$ VAC	±0.25%	
Line regulation	$I_O = 3A$, $V_{Line} = 105 \rightleftarrows 130$ VAC	±0.25%	
Total regulation spread	$0 \leqslant I_O \leqslant 3A$, $105 \leqslant V_{Line} \leqslant 130$ VAC	0.77%	
Ripple (peak-to-peak)	I_O = 3 A	33 mV	
Ripple (rms)	I_O = 3 A	9.5 mV	
Transients	Full load (3 A) to no load (0 A)	$\leqslant$ 100 mV, $t_{recovery} \leqslant 50\ \mu s$	
Transients	No load (0 A) to full load (3 A)	$\leqslant$ 100 mV, $t_{recovery} \leqslant 50\ \mu s$	
Transients	Turn on (105 or 130 VAC)	0	
Transients	Turn off (105 or 130 VAC)	0	
Drift	I_O = 3 A	$\leqslant$ 15 mV/8 hours	
Case Temperature Rise:	After 8 hours @ I_O = 3 A and V_{Line} = 130 VAC		
2N3055		43°C	
2N5781		49°C	
CA3055		15°C	
I_{SC}	V_{Line} = 105 or 130 VAC	0.125 A	
Abnormal Operation: Circuit in fold back operation at worst-case condition (V_O = 15.4 VDC)			
PARAMETER	CONDITIONS	VALUE	
Case Temperature Rise:	After 8 hours in foldback @ V_{Line} = 130 VAC	Measured	Calculated
2N3055		50°C	60°C
2N5781		63°C	85°C
CA3055		17°C	–

where

V_O = output voltage = 20 V
$V_{O\text{-}PK}$ = ripple voltage (zero to peak = 1/2 peak to peak) = 1.2 V
V_{BE} 2N3055 = worst case V_{BE} of pass transistor = 1.4 V
V_{CE} 2N5781 = worst case V_{CE} of driver transistor = 1 V
V_{R1} = Voltage across collector resistor R1 = 1 V
V_{TOL} = 0.5-volt tolerance on output = 0.5 V
V_{RS} = voltage of current-sensing resistor = 0.2 V
V_{LD} = voltage drop in wiring = 0.1 V

Therefore

$V_{Cap\,(min)}$ = 20 + 1.2 + 1.4 + 1 + 1 + 0.5 + 0.2 + 0.1 = 25.4 volts

APPENDIX B. Foldback Parameters

As a first approximation, the following equations describe the three conditions of load current in the circuit of Fig. 8(b):

General equation: $I_O R_S = V_D + V_{BE} + V_{RR}$

At rated current I_R, it is desirable that $V_{BE} = 0$.

$$\therefore I_R R_S = V_D + V_{RR}$$

At maximum load current, just before foldback is initiated,

$$I_X R_S = V_D + V_{BE} + V_{RR}$$

At short-circuit current, $V_O = 0$, and therefore $V_{RR} = 0$.

$$I_{SC} R_S = V_D + V_{BE}$$

By dividing appropriate equations,

$$\frac{I_X}{I_R} = \frac{V_D + V_{BE} + V_R}{V_D + V_R}$$

and

$$\frac{I_R}{I_{SC}} = \frac{V_D + V_R}{V_D + V_{BE}}$$

To make the maximum current close to rated current,

$$V_D + V_{BE} + V_R \approx V_D + V_R$$

$$\therefore (V_D + V_R) \gg V_{BE}$$

However, if V_D is large, the initiating voltage must also be large. Therefore, the minimum voltage across C1 must also be increased.

If V_D is one diode drop (0.7 volt) and if $(V_D + V_R)$ is 3 volts as a compromise, then V_R = 2.3 volts, and

$$\frac{I_X}{I_R} = \frac{0.7 + 2.3 + 0.7}{0.7 + 2.3} = 1.23$$

and

$$\frac{I_R}{I_{SC}} = \frac{0.7 + 2.3}{0.7 + 0.7} = 2.14$$

$$\therefore I_{SC} = \frac{I_R}{2.14} = 0.468\, I_R$$

APPENDIX C. Maximum Power Dissipation in the Pass Transistor

The equivalent circuit used to calculate the power dissipation in the pass transistor is shown in Fig. 9. R_g includes the 64-milliohm resistance used for sensing the 3.15-ampere actuating current. The additional current supplied for I_{CO} of Q1 and the current supplied to the CA3055 regulator are neglected.

The voltage across the transistor is given by

$$V_{CE} = E_g - V_O - I_O R_g = E_g - (V_O + I_O R_g)$$

The power dissipated in the transistor is given by

$$P = [E_g - (V_O + I_O R_g)]\, I_O$$

The ideal foldback characteristic is shown in Figs. 4 and 10. The measured values are within 5 per cent of the ideal values. Therefore a small error is introduced if the ideal characteristic is used for the analysis.

Equations that describe operation during foldback are derived as follows:

$$y = mx + b = mx + 0$$

$$m = \frac{V_R}{I_R}$$

$$V_O = \frac{V_R}{I_R} I_O$$

$$I_O = V_O \frac{I_R}{V_R} = V_O \sigma$$

$$P = E_g I_O - V_O I_O - I_O^2 R_g$$

$$= E_g V_O \sigma - V_O^2 \sigma - V_O^2 \sigma^2 R_g$$

$$P + V_O^2 [\sigma + \sigma^2 R_g] - V_O [\sigma E_g] = 0$$

or

$$P + V_O^2 A - V_O B = 0$$

$$P = BV_O - AV_O^2$$

$$\frac{dP}{dV_O} = B - 2AV_O$$

For maximum power, $\frac{dP}{dV_O} = 0$; therefore,

$$B - 2AV_O = 0$$

$$2AV_O = B$$

$$V_O = \frac{B}{2A} = \frac{1}{2} \left[\frac{\sigma E_g}{\sigma + \sigma^2 R_g} \right] = \frac{1}{2} \left[\frac{E_g}{1 + \sigma R_g} \right]$$

Thus maximum power occurs when

$$\acute{V}_O = \frac{E_g}{2(1 + \sigma R_g)}$$

Substitution of this solution into the power equation yields

$$P = BV_O - AV_O^2$$

$$= \sigma E_g V_O - (\sigma + \sigma^2 R_g) V_O^2$$

$$= \sigma E_g \left[\frac{\frac{E_g}{2}}{1 + \sigma R_g} \right] - (\sigma + \sigma^2 R_g) \left[\frac{\left(\frac{E_g}{2}\right)^2}{(1 + \sigma R_g)^2} \right]$$

However,

$$\sigma + \sigma^2 R_g = \sigma (1 + \sigma R_g)$$

$$\therefore P = \frac{\sigma \frac{E_g^2}{2}}{1 + \sigma R_g} - \frac{\sigma (1 + \sigma R_g) \left(\frac{E_g}{2}\right)^2}{(1 + \sigma R_g)^2}$$

$$P = \frac{\sigma \frac{E_g^2}{2}}{1 + \sigma R_g} - \frac{\sigma \frac{E_g^2}{4}}{1 + \sigma R_g} = \frac{\sigma \frac{E_g^2}{4}}{1 + \sigma R_g}$$

$$\frac{4P}{E_g^2} = \frac{\sigma}{1 + \sigma R_g}$$

Let

$$\frac{4P}{E_g^2} = G$$

Solving for σ,

$$\sigma = G(1 + \sigma R_g)$$

$$\sigma = G + \sigma G R_g$$

$$\sigma (1 - GR_g) = G$$

$$\sigma = \frac{G}{1 - GR_g}$$

Because $\sigma = \frac{I_R}{V_R}$

then

$$I_R = V_R \left[\frac{G}{1 - GR_g} \right] = \frac{V_R 4P}{E_g^2 - 4PR_g}$$

APPENDIX D. Maximum Power Dissipation Allowable for a Given Thermal Resistance

The heat sink selected is a Wakefield (Delta Division #NC-423) type. This heat sink has a thermal resistance to air in convection cooling of 0.8°C/watt. Any heat sink with similar or lower thermal resistance is suitable.

The case-to-junction thermal resistance of the 2N3055 is rated at 1.5°C/watt, and the heat-sink-to-case thermal resistance is 0.5°C/watt maximum if a mica washer and DC340 filled grease or equivalent are used.

The total junction-to-air thermal resistance is:

Ambient to Heat Sink	0.8°C/watt
Heat Sink to Case	0.5
Case to Junction	1.5
TOTAL	2.8°C/watt

If it is assumed that the ambient temperature is 55°C and the junction temperature is 200°C,

$$200^{\circ}C - 55^{\circ}C = 145^{\circ}C$$
$$145^{\circ}C / 2.8^{\circ}C/W = 52 \text{ watts}$$

If a 10-per-cent safety factor is allowed, the maximum allowable power dissipation by the pass transistor is 52 - 5 = 47 watts.

ACKNOWLEDGMENT

The authors wish to thank W. Williams and A. Cole for their helpful suggestions and comments.

REFERENCES

(1) Data bulletin for RCA-CA3055 Voltage Regulator, RCA File No. 395.

(2) Data bulletin for RCA-CA3030 Monolithic Operational Amplifier, RCA File No. 316.

(3) "Application of the RCA CA3008, CA3010 Integrated Circuit Operational Amplifiers", RCA Application Note ICAN-5015.

(4) "Application of the RCA CA3015 and CA3016 Integrated Circuit Operational Amplifiers", RCA Application Note ICAN-5213.

(5) "Integrated-Circuit Operational Amplifiers", RCA Application Note ICAN-5290.

(6) "Application of RCA Silicon Rectifiers to Capacitive Loads", RCA Application Note AN-3659.

(7) O.H. Schade, "Analysis of Rectifier Operation", *Proc. IRE*, vol. 31, pp. 341-361, July 1943.

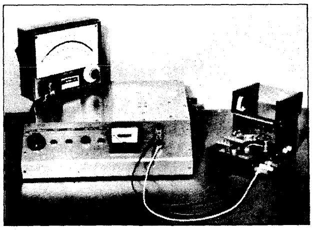
(8) Data bulletin for RCA-2N3055 Transistor, RCA File No. 434.

(9) Data bulletin for RCA Power Transistors, File No. 413.

(10) C. R. Turner, "Selection of Second-Breakdown-Resistant Transistors", *EEE*, vol. 15, no. 7, pp. 82-95, July 1967.

(11) G.A. Lang, B.J. Fehder, W.D. Williams, "Thermal Fatigue in Silicon Power Transistors", *IEEE Trans. on Electron Devices*, vol. ED-17, pp. 787-793, September 1970.

(12) "Thermal-Cycling Rating System for Silicon Power Transistors", RCA Application Note AN-4612.



Testing for Forward-Bias Second Breakdown in Power Transistors

by D. A. Moe

The addition of "safe-operating-area" curves to power-switching transistor data for JEDEC registration and to manufacturers' data sheets has made necessary the development of non-destructive forward-bias second-breakdown test facilities. This Note describes the design of a test facility which determines the forward-bias second-breakdown safe operating locus for power transistors and shows detailed schematic diagrams of test circuits which can be used for devices with collector-current ratings up to 2.5 amperes and sustaining collector-to-emitter voltage V_{CEO}(sus) ratings up to 300 volts, or with ratings to 5 amperes and 100 volts.

Causes of Second Breakdown

The safe operating area of a power transistor is bounded by a locus divided into four discrete segments, each representing a particular limiting condition. As shown in Fig. 1, the limiting factors are the maximum continuous-collector-current rating of the transistor, the maximum power-dissipation rating, second breakdown, and the sustaining voltage V_{CEO}(sus) of the device.

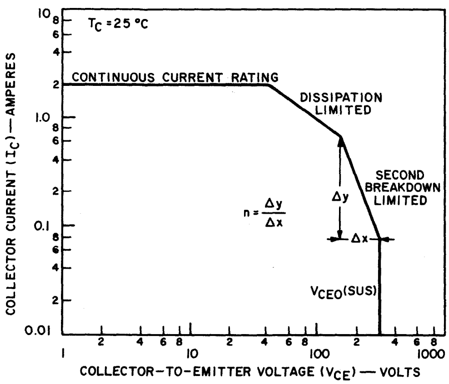


Fig. 1— A typical safe-operating-area curve.

Forward-bias second breakdown ($I_{S/b}$) in a power device is manifested by localized heating of the transistor pellet, as shown in Fig. 2. The average collector-junction temperature, T_J, of a power transistor may be calculated as follows:

$$T_J = T_C + P_{avg}\theta_{J\text{-}C}$$

where T_C is the case temperature in °C, P_{avg} is the average power dissipation in watts, and $\theta_{J\text{-}C}$ is the junction-to-case thermal resistance in °C per watt. However, the actual junction temperature can vary from point to point on the chip as a result of current-crowding that causes higher isolated dissipation. As a result, a localized thermal runaway may occur. In the forward-biased mode, such local heating is most likely to occur at the emitter edge because, under forward-bias conditions, lateral base current creates an electric field or voltage gradient in the base, as shown in Fig. 2. The direction of this voltage gradient causes greater forward bias at the emitter periphery than at the center. Therefore most injection occurs at the periphery, and the current density is greater. As the concentrated current flows across the depletion region, local power dissipation occurs and causes local heating. If the current density exceeds a

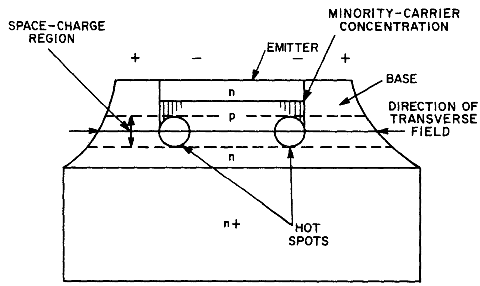


Fig. 2— Cross-section of a power transistor showing development of hot spots under forward bias.

critical level, the heat that is generated causes the local base-to-emitter voltage to decrease to a level that causes further injection, and collector-to-emitter current flow becomes regenerative. If this regenerative process is allowed to continue, device destruction follows. The current crowding may be aggravated by a non-homogeneous collector-base junction or by mounting-system imperfections such as solder voids.

A Second-Breakdown Test Facility

Fig. 3 shows a simplified schematic of a test set designed to determine the forward-bias second-breakdown safe operating locus for power transistors. This test facility is capable of determining this locus non-destructively, and therefore can be used to perform 100-per-cent tests of transistor capability in production without destroying transistors. This type of production test is usually made at one point of the second-breakdown locus shown on the published data. Determination of the second-breakdown limit for registration of a new device of a particular structure and geometry previously required the destructive finding of the $I_{S/b}$ limit of many individual transistors. Although each device would yield one data point, the points would not necessarily be on the same second-breakdown locus because the relative second-breakdown capability would vary from device to device. This procedure would therefore not yield accurate information about the actual shape of the $I_{S/b}$ locus. It has been found that the slope, n, of the forward-bias second-breakdown locus ($I = KV^{-n}$) plotted on log-log coordinates is essentially constant for a particular device structure and geometry.

The second-breakdown test set shown in Fig. 3 operates in either of two modes: "normal" operation or "shut-down" operation. There are two feedback drive amplifiers in the circuit. One drives the transistor under test to the magnitude of collector current programmed by adjustment of a potentiometer. The current-sensing feedback loop is arranged so that only actual collector current flows through the sensing resistor; no base current flows in the mesh common to that resistor. The second amplifier compares the collector-to-emitter voltage of a transistor in series with the one being tested to a reference voltage and maintains the pass-transistor voltage constant at six volts, independent of test-current magnitude.

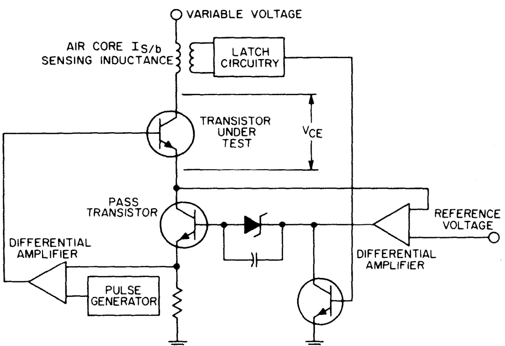


Fig. 3– Simplified schematic of test set for second-breakdown current ($I_{S/b}$).

The test voltage, V_{CE}, is varied by adjustment of the power-supply voltage across the transistor under test, the series pass transistor, and a one-ohm sensing resistor. During a normal test, the pulse generator applies an essentially square pulse of current through the transistor under test; the relatively short rise and fall times can be neglected. The current through the pass transistor tracks the current through the transistor under test. If the device being tested is operating within its safe area, no anomalies in transistor current or voltage occur and no degradation results during the test.

If the transistor is operated beyond its safe operating area, distinct changes occur in current and voltage at the initiation of second breakdown. The collector-to-emitter voltage of the transistor suddenly drops to a low value, while the current rises sharply. The second-breakdown test method shown in Fig. 3 takes advantage of this rapid rise in collector current.

For detection of second breakdown, an air-core inductor is placed in series with collector of the transistor under test. During normal operation of the test set, the voltage developed across this inductor is small because of the relatively long test-current-pulse rise time. During second breakdown, however, the rapidly rising collector current creates a high voltage across the inductor. A secondary winding then ac couples this voltage to a detection circuit which reverse-biases the series pass transistor. The inductive-detection approach is independent of test-current magnitude and reacts instead to the magnitude of its first derivative.

The 2.5-Ampere/300-Volt and 5-Ampere/100-Volt Test Circuits

Two forward-bias second-breakdown facilities are shown in Fig. 4. The first is capable of making second-breakdown tests at collector-current levels to 2.5 amperes and collector-to-emitter voltage levels to 300 volts; the second makes similar tests to 5 amperes and 100 volts.

In both facilities a voltmeter V is placed across the Current-Level-Adjust potentiometer during setting of the test conditions. The drive amplifier is disconnected so that no current flows through the transistor under test. The test transistor must not be preheated before the actual test voltage is applied because the second-breakdown limit decreases with increasing temperature. While the test is being performed, the voltmeter V is switched across the one-ohm sensing resistor and monitors actual test current.

A test is initiated by application of a pulse to the gate of a 2N3228 SCR, Q1, which begins to conduct and closes a mercury relay. A unijunction transistor fires to end the test. The pulse-width potentiometer can be varied to obtain test conditions varying from dc (2 seconds) to a short pulse (100 milliseconds). The setting of the Current-Level-Adjust potentiometer determines the amplitude of the test current during the pulse. The capacitor connected across this potentiometer maintains the rise time of the pulse applied to the differential-drive amplifier at approximately 25 milliseconds, as shown in Fig. 5. If the rise time were too short, the inductive detector would trigger the latch circuitry at the beginning of a pulse and would incorrectly indicate second breakdown.

The pass-transistor regulator maintains a constant voltage across the transistor under test. The series pass transistor is always operated in the active region so that it can turn off the transistor under test within one microsecond if second breakdown occurs.

The two differential amplifiers are stabilized by means of capacitors located at several points. Stabilization of these test facilities is difficult because they are required to perform tests on devices having gain-bandwidth products f_T up to 100 MHz and at all test currents and voltages within the test-set ratings. The problem is compounded by the fact that f_T is a function of collector voltage and current and may vary for individual devices at different test conditions.

Particular care is necessary in the physical layout of a second-breakdown test facility to avoid oscillation. High-frequency oscillations may then incorrectly appear to the inductive detector as second-breakdown failures and cause the protection circuitry to be triggered. Leads should be as short as possible.

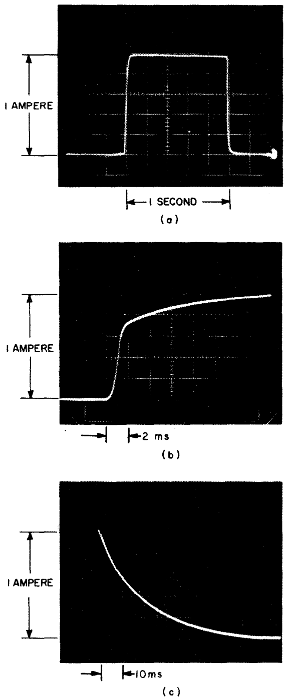


Fig. 5— Waveforms for $I_{S/b}$ test circuits of Fig. 4: (a) applied pulse; (b) turn-on time; (c) turn-off time.

In the event of second breakdown, the large current change di/dt causes a voltage to be coupled to the second-breakdown latch circuitry, Q24 and Q25. This regenerative circuitry drives the pass-transistor regulator, Q16, which then applies instantaneous negative voltage at the base of the pass transistor to interrupt the test current. A light on the front panel of the test set indicates second breakdown. The coupling capacitor in the reset circuitry for the latch is selected so that it cannot override a pulse from the second-breakdown-sensing transformer. If a shorted transistor is placed in the test socket and the reset button is depressed, the resulting instantaneous rise in primary current triggers the latch. Therefore, it is impossible to reset the facility with a shorted transistor in the socket. Although the primary inductance of the sensing transformer is very small, it helps to keep collector current from rising instantly during second breakdown. A diode clamp is employed to damp ringing voltages that might otherwise exceed the avalanche breakdown voltage of the transistor under test.

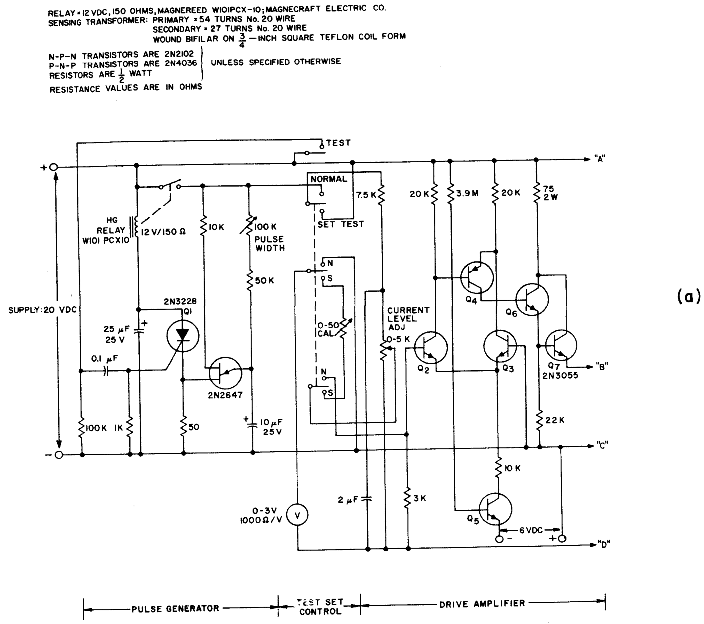
If the transistor under test has large leakage current, or if a slow thermal runaway occurs, the collector current does not rise fast enough to trigger Q24 and Q25. The latch is then triggered by back-up circuitry. The back-up circuit, which consists of Q21, Q22, and Q23, is a Schmitt trigger set to switch at a collector test current ten per cent higher than the rated value of the test facility. In this case, a relatively long time may be needed to exceed this rating.

Transistor Characterization for Forward-Bias Second Breakdown

Actual second-breakdown measurements for the RCA-2N5240 are shown in Fig. 6. The three curves indicate differences in second-breakdown capability at different case temperatures, but show that the second-breakdown loci have essentially identical slopes. The 2N5240 is a double-diffused triple epitaxial silicon power transistor having eight separate emitter sites. A small ballast is provided in series with each emitter to extend second-breakdown limits.

Characterization of a transistor for second breakdown and power handling is performed in two steps. First, the dc and pulsed power-dissipation capability of the device are calculated on the basis of its steady-state and transient thermal resistance. These curves are then checked empirically to determine at what value of collector-to-emitter voltage second breakdown begins to dominate.

To obtain a single point on the curve, the desired collector-to-emitter voltage V_{CE} is applied to the transistor under test, and a test is performed at a test-current magnitude below the expected capability of the device. If failure does not occur, the test-current magnitude is increased in steps until failure does occur. This procedure is repeated at several values of V_{CE}. During each trial, the transistor case must be at the temperature for which second-breakdown capability is being determined. Usually a



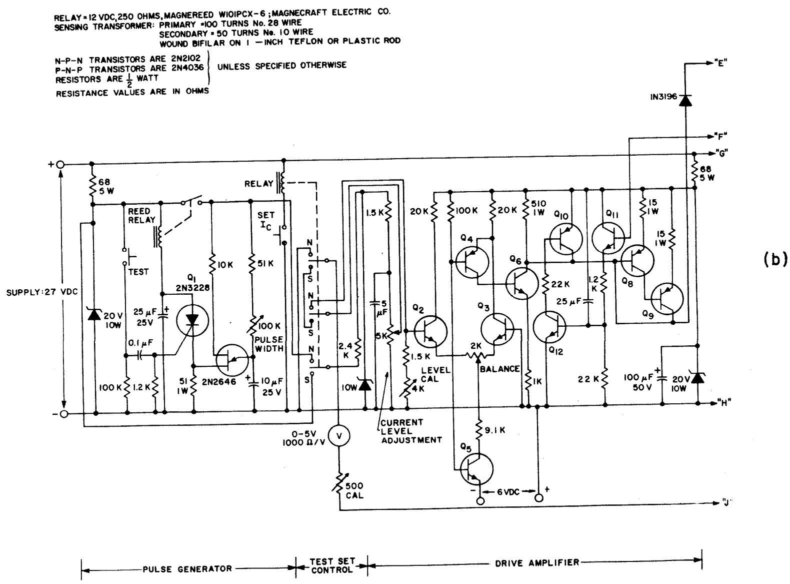
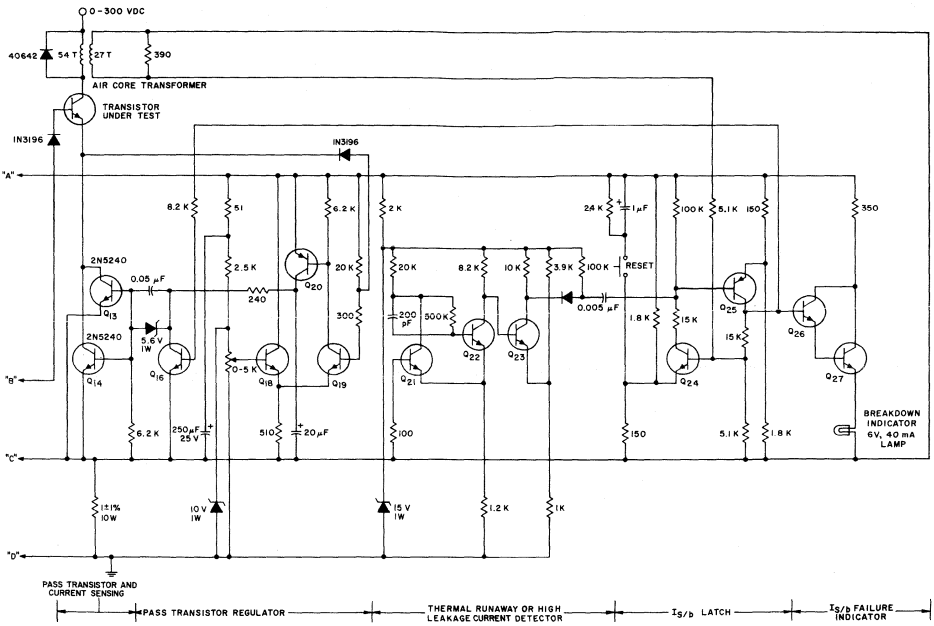


Fig. 4— Schematic diagram of $I_{S/b}$ test facilities for (a) currents to 2.5 amperes and voltages to 300 volts, and (b) currents to 5 amperes and voltages to 100 volts.

(a)



(b)

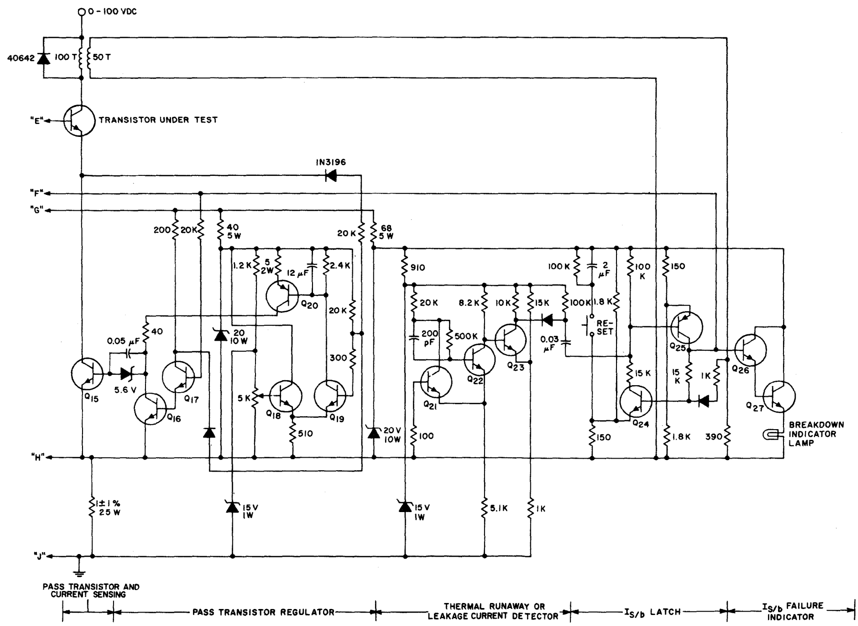


Fig. 4— Schematic diagram of $I_{S/b}$ test facilities for (a) currents to 2.5 amperes and voltages to 300 volts, and (b) currents to 5 amperes and voltages to 100 volts.

heat sink having a large thermal capacity is used. An approximate test for degradation may be made by repeating the second-breakdown test at the current level just preceding device failure; the device should pass this test. Another method is to measure changes in collector cutoff current I_{CBO} after second-breakdown failure.

The final second-breakdown curve plotted to characterize the device for registration, which is shown in the table of device characteristics on the data sheet, has a slope greater than that of the family of devices represented. To guarantee this published curve, a 100-per-cent test is performed in production at the $I_{S/b}$ specification point.

It should be noted that there is not an abrupt change in power-handling capability along the safe-area locus, but rather a gradual change in the slope of the curve. The slope becomes less at lower collector-to-emitter voltages because the electrical base width in the transistor varies as a function of voltage. As V_{CE} decreases, the depletion-region width decreases and the electrical base width increases. These changes have the effect of decreasing current density because the minority carriers in the base have a greater distance over which to diffuse outward laterally, as shown in Fig. 2.

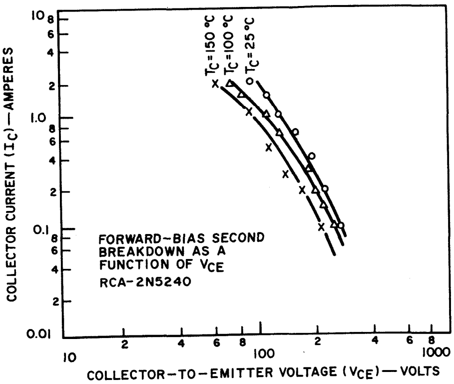


Fig. 6– Forward-bias second breakdown of RCA-2N5240 as a function of collector-to-emitter voltage for different case temperatures.

Thermal-Cycling Rating System for Silicon Power Transistors

by W. D. Williams

Thermal fatigue is a wear-out type of failure that may occur in silicon power transistors as a result of the thermal cycling produced by changes in power dissipation or in the ambient temperature. When a transistor is alternately heated and allowed to cool, cyclic mechanical stresses are produced within the device because of differences in the thermal expansion of the silicon pellet and the metallic materials to which the pellet is attached. In the past, the effect of such stresses has been almost completely ignored in the design of power-transistor circuits. The circuit designer should realize, however, that, just as a wire that is continuously flexed at one point will eventually break because of metal fatigue, cyclic thermal stresses can similarly lead to fatigue failures in power transistors.

This Note briefly analyzes the basic causes of thermal fatigue in silicon power transistors and describes a rating chart that makes it possible for a circuit designer to avoid such failures during the operating life of his equipment. Examples are provided on the use of this chart to determine the transistor operating conditions required to assure a desired thermal-cycling capability and to determine whether the thermal-cycling capability of a transistor is adequate for the requirements of a given application.

Analysis of Thermal Fatigue in Silicon Power Transistors

Power transistors are subjected to some thermal stresses in all practical circuits in which they may be employed. In many common applications, these stresses are very severe, as indicated by the examples of the thermal-cycling requirements of several typical applications listed in Table I. The cyclic stresses may eventually result in physical damage to the semiconductor pellet or the mounting interface.

In most silicon power transistors, the small silicon pellet is bonded to a copper header. The coefficient of thermal expansion for silicon (3×10^{-6}) is much less than that of copper (17.5×10^{-6}). Temperature variations within the transistor, therefore, result in cyclic stresses at the mounting interface of the silicon pellet and the copper header because of the difference in the thermal expansions of these parts. If a hard solder, such as silicon gold, is used to bond the pellet to the header, these stresses are transmitted to the silicon pellet. Silicon is relatively weak in tensile strength and is highly "notch sensitive." Such stresses therefore, often result in pellet fractures. In general, however, lead solder is used to bond the silicon pellet to the copper header. The cyclic thermal stresses then are absorbed by non-elastic deformation of the soft lead solder, and very little stress is transmitted to the pellet.

The continuous flexing that results from cyclic temperature changes in the transistor may eventually cause fatigue failures in the lead solder. Such failures are a function of the amount of change in temperature at the mounting interface, the difference in the thermal-expansion coefficients of the silicon pellet and the material to which the pellet is attached, and the maximum dimensions of the mounting interface.[1] Fatigue failures occur whenever the cyclic stresses damage the solder to the point at which the transfer of heat between the pellet and the surface to which it is mounted becomes impaired. This condition may exist in only a small portion of the pellet. This portion, however, overheats, and transistor failure results because of conditions that very closely approximate those encountered during second breakdown.[2]

Thermal-fatigue failures in power transistors are accelerated because of dislocation "pile-ups" that result from impurities in the lead solder.[3] RCA has developed a process that substantially reduces the amount of impurities introduced into the solder. Use of this proprietary "controlled solder process" (CSP) makes it possible to avoid the microcracks that propagate to cause fatigue failure in power transistors and, therefore, greatly increases the thermal-cycling capability of these devices.[4]

Thermal-Cycling Rating Chart

The mathematical relationship among the factors that affect fatigue failure in silicon power transistors can be expressed, in terms of the number of thermal cycles to failure N, as follows:[1]

$$N = Ae^{\psi_o / [\Delta T(\alpha_A - \alpha_B) L]}$$

Table I - Thermal-Cycling Requirements for Typical Applications of Power Transistors

Application	Circuit	P_T (W)	ΔT_C (°C)	Minimum Equipment Life Required (years)	Typical Thermal-Cycling Rating Required (cycles)
Auto radio audio output	Class A	8	75	5	5,000
	Class AB	2	45	5	5,000
Power supply	Series regulator	50	65	5	5,000
	Switching regulator	15	65	5	5,000
Hi-Fi audio amplifier	Class AB	35	50	5	5,000
Computer power supply	Series regulator	50	65	10	10,000
Computer peripheral equip.	Solenoid driver	5	5	10	1.3×10^8
Television	Vertical output	10	75	5	5,000
	Audio output	8	75	5	5,000
Sonar modulator	Linear amplifier	100	55	10	144×10^3

where A is a constant determined by the mounting system, ΔT is the change in temperature at the mounting interface, a_A and a_B are the thermal-expansion coefficients of the silicon and the metal under the solder joint, ψ_o is a material constant proportional to the change in temperature ΔT and the difference in the thermal-expansion coefficients a_A and a_B, and L is the maximum length of the solder joint under the pellet.

For a given transistor, the only variable in the thermal-cycling equation that can be controlled by the circuit designer is the change in temperature at the interface of the silicon pellet and the material to which the pellet is mounted. This change in temperature ΔT is, of course, less than the change in transistor junction temperature ΔT_J, but is greater than the change in case temperature ΔT_C.

RCA has devised a rating chart that relates the thermal-cycling capability of a silicon power transistor to total device dissipation and the change in case temperature. This chart is presented in the form of a log-log presentation in which power dissipation is shown on the vertical axis and the number of thermal cycles is shown on the horizontal axis. Rating curves are shown for various magnitudes of case-temperature swings. Fig. 1 shows an example of a typical rating chart of this type.

A circuit designer may use the rating chart to define the limiting value to which the change in case temperature must be restricted to assure that a power transistor is capable of operation at a specified power dissipation over the number of thermal cycles required in a given application. Conversely, if the power dissipation and the change in case temperature are known, the designer may use the rating chart to determine whether the thermal-cycling capability of the transistor is adequate for the application. These uses of the rating chart are illustrated by examples on the chart shown in Fig. 1.

The chart shows the thermal-cycling ratings for an experimental silicon power transistor that has a thermal

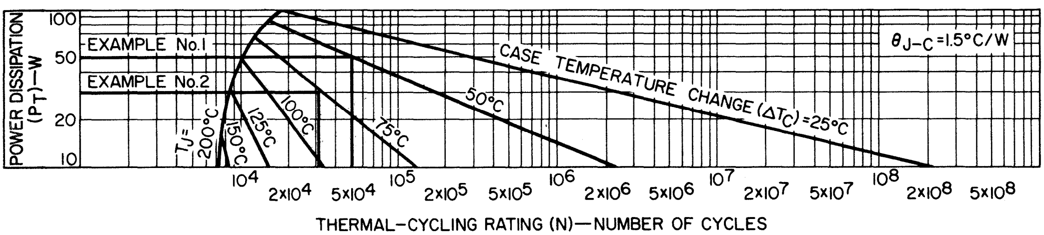


Fig. 1— Thermal cycling rating chart

resistance from junction to case of 1.5°C per watt. If a designer wishes to determine the maximum allowable change in the case temperature of this transistor for the thermal-cycling requirements of a given application, he simply plots the point of intersection of a horizontal projection of the total device dissipation with a vertical projection of the total number of thermal cycles required in the application. If this point lies exactly on one of the power-dissipation curves, the maximum allowable change in case temperature can be read directly from the chart; if not, the allowable temperature change can be approximated by linear interpolation. This use of the rating chart is illustrated by example No. 1 in Fig. 1.

For this example, it is assumed that the transistor is to be operated intermittently at a power dissipation level of 50 watts and that a thermal-cycling capability of 5.0×10^4 cycles is required to assure that the life of the transistor exceeds that of the equipment in which it is to be used. The point of intersection of line projections of the power dissipation and the required number of thermal cycles indicates that the change in case temperature must be restricted to a maximum value of 50°C per thermal cycle. This value determines the requirements of the transistor heat sink. If the thermal cycles are long in comparison to the thermal time constant of the heat sink, the total thermal resistance from case to ambient should not exceed 1°C per watt. If the thermal cycles are short relative to the thermal time constant, a higher thermal resistance is permissible provided that the thermal capacitance of the heat sink is sufficient to assure that the change in case temperature does not exceed 50°C during the thermal cycle.

Example No. 2 in Fig. 1 illustrates the use of the rating chart to determine whether the thermal-cycling capability of a transistor is adequate for a given application. In this example, a transistor dissipation of 30 watts and a case-temperature swing (measured) of 75°C are assumed. A vertical projection of the 30-watt point on the $\Delta T_C = 75°C$ power-dissipation curve indicates that, for these operating conditions, the transistor has a thermal-cycling rating of 3.2×10^4 cycles. If this rating is not adequate for the intended application, either the power dissipation must be reduced or a larger heat sink must be used so that a smaller change in case temperature will result during a thermal cycle.

In many applications, a power transistor may be subjected to thermal cycles that differ in both duration and magnitude. In such instances, the fractional amount of the thermal-cycling life of the transistor used by the total number of thermal cycles of each type during the required life of the equipment must be separately determined and then added together to ascertain whether the thermal-cycling rating of the transistor will be exceeded in the application. The ratio of the total number of cycles of each type to which the transistor will be subjected during the life of the equipment to the total number of cycles of the same type that the transistor is rated to withstand before fatigue failure is obtained for all the dissimilar thermal cycles. If the sum of these ratios is less than unity, the transistor is obviously operated within ratings in the application. If the sum is greater than unity, the thermal-cycling rating of the transistor is exceeded in the application, and device failure may occur during the operating life of the equipment.

The technique used to determine whether the thermal-cycling ratings of a transistor are exceeded in a specific application in which the transistor is subjected to different types of thermal cycles can be illustrated by use of the examples of different operating conditions shown in Fig. 1. If the transistor is assumed to be subjected to the conditions specified for examplele No. 1 for 2.5×10^4 thermal cycles and to the conditions specified for example No. 2 for 1.6×10^4 thermal cycles, the following summation is made to determine whether the transistor will be operated within its thermal-cycling ratings:

$$\frac{2.5 \times 10^4}{5.0 \times 10^4} + \frac{1.6 \times 10^4}{3.2 \times 10^4} = 1$$

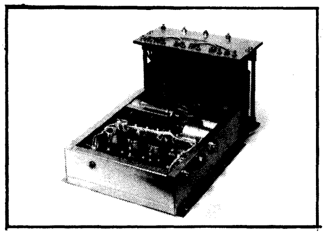
This summation indicates that, for the conditions assumed, the transistor is operated exactly to the limit of its thermal-cycling rating.

The RCA thermal-cycling ratings allow a circuit designer to use silicon power transistors with assurance that no fatigue failures of these devices will occur during the operating life of his equipment. These ratings provide valid indications of the thermal-cycling capability of silicon power transistors for all types of operating conditions and, therefore, enable the circuit designer to "design out" the possibility of transistor thermal-fatigue failures.

Obviously, all power transistors cannot be tested to determine their thermal-cycling capability because such tests are expensive, time consuming, and destructive. The validity of the thermal-cycling ratings results from the application of stringent process controls at each step in the manufacture of the transistors and from the testings of a statistically significant number of samples. Thermal-cycling ratings for silicon power transistors provide the same type of assurance that a device will not fail when operated within ratings as that provided by the more familiar voltage, current, and second-breakdown ratings.

Bibliography

1. G.A. Lang, et al, "Thermal Fatigue in Silicon Power Transistors," *IEEE Transactions on Electron Devices*, pp. 787-793, Sept. 1970.
2. C.R. Turner, "Carl Turner of RCA Speaks Out on Second Breakdown," *EEE*, Vol. 15, No. 7, July 1967.
3. J.J. Gilman, "Dislocation Mobility in Crystals," *J. Appl. Phys.*, Vol. 36, pp. 3195-3206, October 1965.
4. *RCA High-Speed, High-Voltage, High Current Power Transistors*, Technical Series PM-80, RCA Solid State Division, Somerville, N.J., May 1970.



A 750-Watt Three-Phase Frequency Converter

by W. J. Beiswinger

Military equipment frequently uses three-phase 400-Hz power, and industrial plants and laboratories often require power at a variety of low frequencies. Ac-to-ac converters, driven from standard power lines, can be used to meet these requirements. This Note describes a frequency converter with output frequency from 380 Hz to 1250 Hz that delivers up to 750 watts of three-phase power at 120/208 volts rms. The circuit uses a three-phase bridge inverter supplied from a rectified ac line; the input can be single-phase or three-phase, 120 volts or 208 volts, at any frequency from 47 Hz to 1250 Hz. The RCA-2N5805 power transistor used in this converter is especially suited for power-switching circuits.

CIRCUIT DESCRIPTION

As shown in the block diagram of Fig. 1, the converter has four basic components:

- a power supply, which consists of a rectifier and a filter, to change the ac line power to dc power for the three-phase bridge inverter;
- the three-phase bridge inverter;
- three-phase logic and driver circuits to switch the transistors of the inverter in the proper sequence; and
- an output transformer.

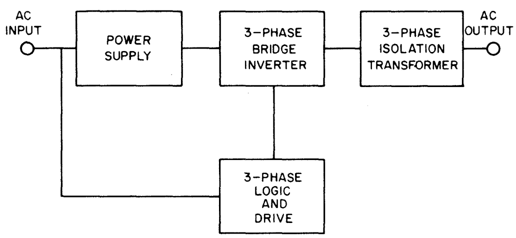


Fig. 1— Block diagram of 750-watt three-phase converter.

Fig. 2 is a schematic diagram that shows the power supply, inverter, and output transformer. The logic and driver circuits are shown in Figs. 3 and 4.

The Power Supply

The bridge rectifier will operate from either a single-phase or three-phase line; the circuit shown in Fig. 2, which uses 1N1204A rectifiers, is designed for either a 120-volt or a 208-volt line. The 11,000-microfarad filter capacitor keeps ripple below 50 millivolts even when a single-phase input line is used.

The Inverter

The three-phase bridge inverter uses pairs of RCA-2N5805 switching transistors that are transformer-driven from the logic circuit. The switching transistors in turn control the flow of current through the delta-connected primary of the output transformer.

The Logic and Driver Circuits

The logic and driver circuits include a low-voltage dc supply, which operates from a single phase of the ac line. A stepdown transformer reduces the line voltage to 12 volts, and provides isolation from the power line. This transformer, T4, has a frequency range from 47 Hz to 1250 Hz; its parameters are shown in Table I. The supply voltage is regulated by a pass transistor and a 12-volt zener diode.

The logic sequence begins with a tunable unijunction oscillator that delivers timing pulses to a six-stage ring counter, as shown in Fig. 3. The timing of these pulses is determined by the oscillator frequency; adjustment of the 75-kilohm potentiometer can set the frequency of the pulse sequence from 380 Hz to 1250 Hz. The output pulses from the ring counter are coupled to a diode matrix, shown in Fig. 4, to activate the inverter drive transistors.

The drive transistors provide drive to the inverter through transformers T1, T2, and T3. The first timing pulse produces a positive voltage across one half of the primary of T1, a negative voltage across one half of the primary of T2, and a

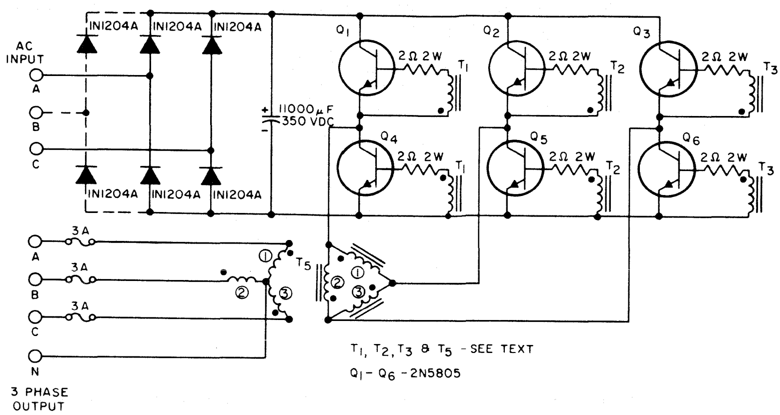


Fig. 2— Schematic diagram of three-phase frequency converter, showing the dc supply, the inverter, and the output transformer.

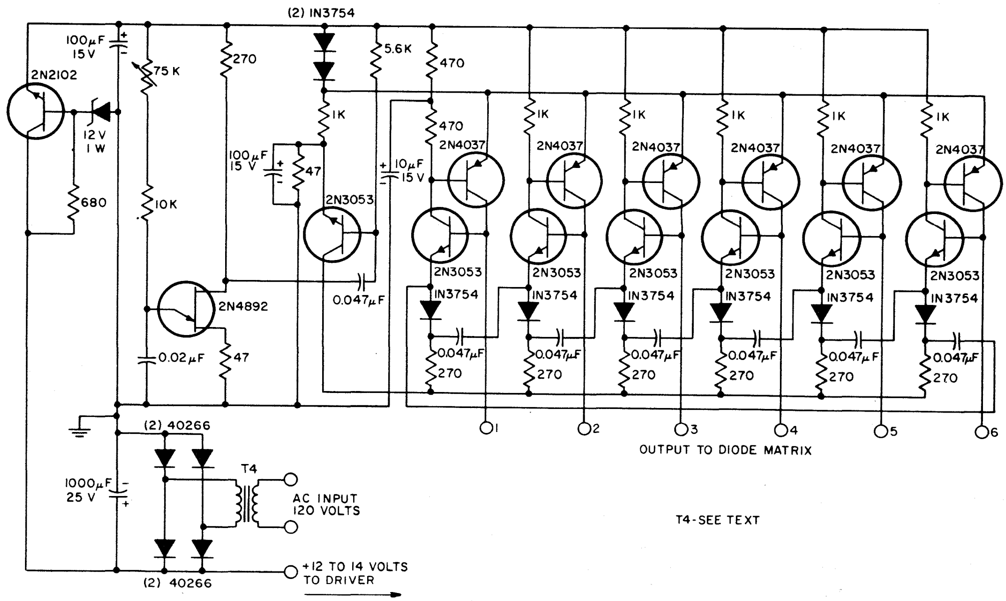


Fig. 3— Oscillator and six-stage ring counter for the logic circuit of the three-phase frequency converter.

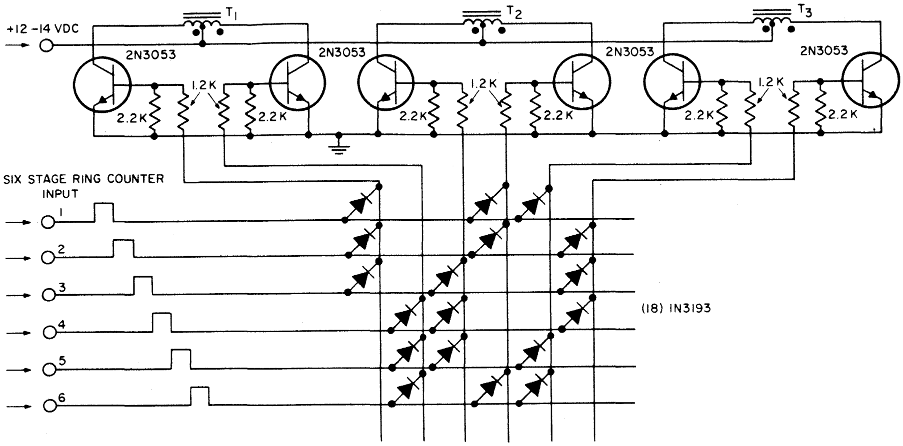


Fig. 4— Diode matrix and driver for output devices of three-phase frequency converter.

Table I — Stepdown Isolation Transformer for Logic Circuit Supply

CORE	– Square Stack 75EI Microsil (0.006) Magnetic Metals Co. 75EI3306
PRIMARY	– 120 Volts 1200 Turns #32 Wire 100 Turns Per Layer 12 Layers
SECONDARY	– 12 Volts 128 Turns #22 Wire 32 Turns Per Layer 4 Layers

Table II — Pulse Polarities at Primary Coils of T1, T2, and T3

Pulse	V_{T1}	V_{T2}	V_{T3}
1	+	–	+
2	+	–	–
3	+	+	–
4	–	+	–
5	–	+	+
6	–	–	+

positive voltage across one half of the primary of T3; the second timing pulse produces a positive voltage across one half of the primary of T1, and a negative voltage across halves of the primaries of T2 and T3; and so forth. The sequence of these voltages is tabulated in Table II and displayed graphically in Fig. 5 to show that the periodic voltages across the three transformers are offset by 120-degree intervals.

Design information on transformers T1, T2, and T3 is shown in Table III.

The Output Transformer

The output transformer, T5, isolates the output circuit from the power line, transforms the voltage up or down to produce a 120/208-volt output, and reduces harmonic distortion. The primary is delta-connected, and the secondary is wye-connected to provide three-phase, four-wire service.

The primary coils carry the full supply voltage. The waveshapes in the primary and secondary coils are the same, and are shown in Fig. 6; the polarities of these pulses are

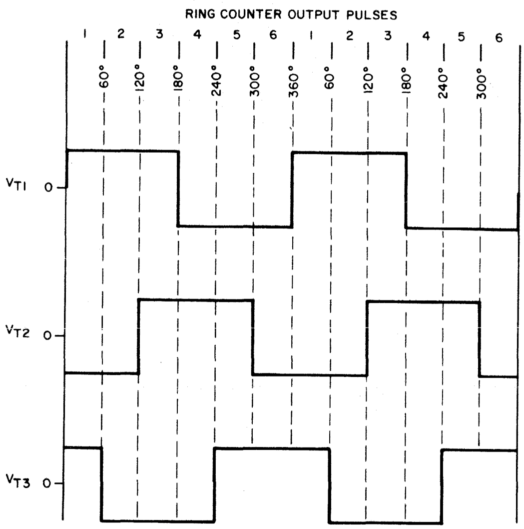
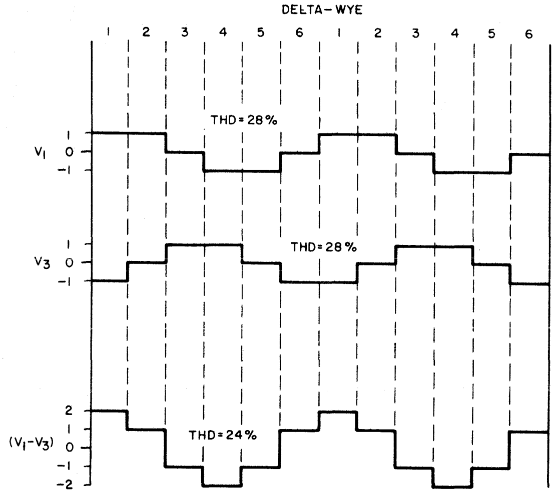


Fig. 5— Sequence of voltages across drive transformers T1, T2, and T3.



1	$V_1 - V_3 = 1-(-1) = 2$
2	$V_1 - V_3 = 1 - 0 = 1$
3	$V_1 - V_3 = 0-(1) = -1$
4	$V_1 - V_3 = -1-(1) = -2$
5	$V_1 - V_3 = -1 - 0 = -1$
6	$V_1 - V_3 = 0-(-1) = 1$

Fig. 6— Phase-to-neutral and phase-to-phase voltages in the delta-wye output transformer.

shown in Fig. 7. The manner in which the secondary coil voltages add to reduce distortion is also shown in Fig. 6. The voltage across secondary terminals A and C is equal to the difference of the voltages in secondary coils 1 and 3. Subtraction of waveform V3 from waveform V1 results in the output waveform (V1 - V3), which is more sinusoidal than V1 or V3. The measured value of total harmonic distortion (THD) in each coil is 28 per cent; the THD across the output terminals is 24 per cent.

Table III — Driver Transformer Design Information

CORE	— Square Stack 21EI Microsil (0.006) Magnetic Metals Co. 21EI3306
PRIMARY	— 14 Volts 140 Turns Bifilar #29 Wire (in Series) 20 Turns Per Layer 7 Layers
SECONDARY	— 4 Volts 52 Turns Bifilar #29 Wire 13 Turns Per Layer 4 Layers

Design information for the output transformer to operate from a 120-volt line or a 208-volt line is given in Table IV.

Table IV — Output Transformer Design Information

CORE	— Square Stack 1.2EI3φ Microsil (0.006) Magnetic Metals Co. 1.2EI3φ3306
PRIMARY (DELTA)	— 120 Volts 188 Turns #17 Wire 47 Turns Per Layer 4 Layers
	OR
	— 208 Volts 325 Turns #19 Wire 55 Turns Per Layer 6 Layers
SECONDARY (WYE)	— 120/208 Volts 200 Turns #17 Wire 50 Turns Per Layer 4 Layers

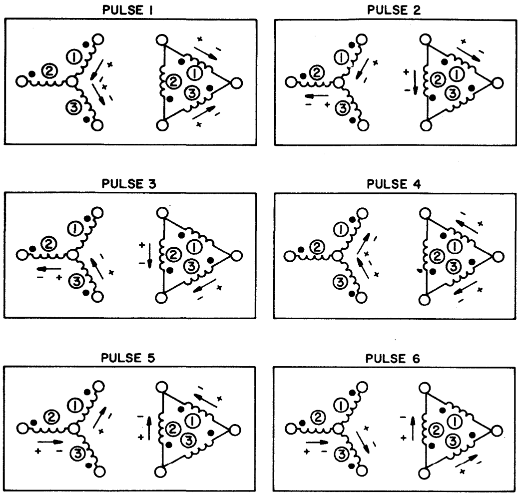


Fig. 7— Pulse polarities in output transformer T5.

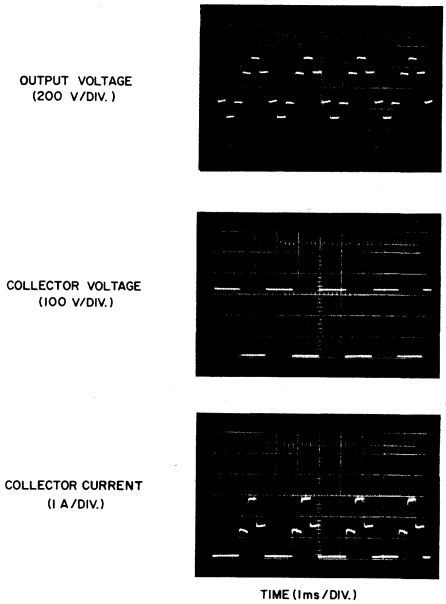


Fig. 8— Waveforms of transformer output voltage, collector voltage, and collector current.

CONVERTER PERFORMANCE

A photograph of the output waveform from the 400-Hz converter is shown in Fig. 8. Waveforms of the collector voltage and current in one of the switching transistors (Q1) are also shown in Fig. 8.

Fig. 9 shows the output performance of the converter. Both the efficiency and the regulation are good. Efficiency rises from 50 per cent at low load current to 75 per cent at the rated load current of 2.1 amperes. The rms output voltage varies by only 10 volts between low- and high-current loading.

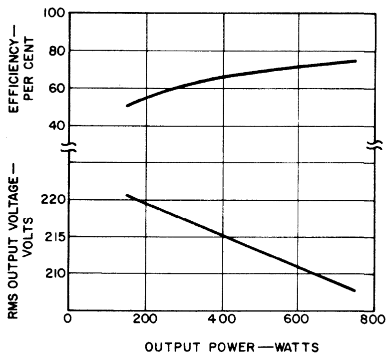


Fig. 9— Performance characteristics of the three-phase converter.

Thermal-Cycling Ratings of Power Transistors

by V. J. Lukach, L. J. Gallace, and W. D. Williams

SUMMARY

This Application Note discusses a testing program used to determine the capability of a particular power transistor design for withstanding thermal cycling over a wide range of operating conditions. A sufficient number of tests were performed to verify a rating chart which can be applied by an equipment designer to any practical operating condition. The discussion covers a brief description of thermal fatigue, a method of "scaling the environment" to determine the proper test conditions, specialized test equipment and techniques to insure that the proper stresses were applied to the transistor, and the test results and the transistor predicted capability chart.

INTRODUCTION

Thermal fatigue is a wearout failure mechanism in silicon power transistors caused by repeated temperature cycling from either changes in power dissipation or ambient temperature differences. In a transistor where the silicon die is mounted with lead-tin or other "soft" solder, a failure normally occurs because of a degradation of the joint between the silicon die and the surface to which it is mounted. This degradation results in localized overheating and eventual localized thermal runaway. The failure mode is very similar to that encountered in forward-biased second breakdown[1]. In many cases where the current is not limited during the resulting short circuit, the transistor chip is destroyed and it is impossible to determine what caused the failure.

In a transistor mounted with a gold-silicon eutectic or other "hard" solder, the failure due to thermal fatigue usually occurs from fracturing of the silicon die, which often also results in a shorted transistor and destruction of the silicon die.

The causative factors in thermal fatigue and device design methods of alleviating it have been covered in the literature[2]. A system of rating a power transistor to clearly delineate thermal-cycling capability was described in an earlier Application Note[3]. This Note describes a testing program to determine whether the rating chart computed by use of the theory suggested in the above references truly represents the capability of a silicon power transistor over a wide range of stress levels.

THERMAL-FATIGUE BACKGROUND

In almost any application, a silicon power transistor is subjected to some cyclical thermal stress. Often this stress is quite severe and frequent. Table I shows some typical applications of power transistors and the expected thermal-cycling-life requirements. The number N of cycles to failure in terms of the device characteristics and operating conditions has been expressed as[2]

$$N = Ae^{\frac{\psi_o}{\Delta T\,(a_1 - a_2)L}}$$

where A and ψ_o are constants for a given power transistor structure, $(a_1 - a_2)$ is the difference in thermal coefficient of expansion between the silicon die and the material on which it is mounted, L is the maximum dimension of the silicon chip, and ΔT is the change in temperature at the interface between the silicon chip and the material to which it is mounted. In practical applications, the temperature swing at this interface is the sum of the case-temperature change and the temperature rise equal to the thermal resistance between the interface and the case multiplied by the power dissipation.

By use of these relationships, and a small amount of empirical data, a thermal-cycling rating chart was drawn for the RCA-2N3055 power transistor, as shown as Fig. 1. Verification and/or correction of this rating chart was one purpose of the testing program described in this Note.

TEST PROGRAM

Objectives

There were multiple objectives in this program. First was the determination of thermal-fatigue capability for the RCA-2N3055. Second was the mathematical representation

Table I – Thermal-Cycling Requirements for Typical Applications of Power Transistors

Application	Circuit	P_T (W)	ΔT_C (°C)	Minimum Equipment Life Required (years)	Typical Thermal-Cycling Rating Required (cycles)
Auto radio audio output	Class A	8	75	5	5,000
	Class AB	2	45	5	5,000
Power supply	Series regulator	50	65	5	5,000
	Switching regulator	15	65	5	5,000
Hi-Fi audio amplifier	Class AB	35	50	5	5,000
Computer power supply	Series regulator	50	65	10	10,000
Computer peri-pheral equip.	Solenoid driver	5	5	10	1.3×10^8
Television	Vertical output	10	75	5	5,000
	Audio output	8	75	5	5,000
Sonar Modulator	Linear amplifier	100	55	10	144×10^3

of this capability in various tables and on appropriate charts. Finally, since thermal-fatigue rating charts were theoretically generated, independent appraisal and statistical approaches were used to compare the predicted response with the actual response.

Experimental Design

Because of the interrelationships among variables, this study requires a nonclassical approach. A thermal-fatigue test is basically a cyclical operating-life test. Fig. 2 shows one of the life-test racks used in this program. It accommodates 40 transistors and allows as many as four different thermal-fatigue tests simultaneously. Eight fans cool the units quickly during the "off" cycle. The photograph shows a free-air test; however, the plug-in sockets can be removed and devices on heat sinks or devices of another configuration substituted. Monitoring jacks are available on the front panel. The connections to the power supplies are not shown. Timers and relays are manually set for a variety of on/off conditions. The test circuit, shown in Fig. 3, is a common-emitter circuit that permits a smaller-current base power supply to be used. A common-base circuit could also be used. For room-

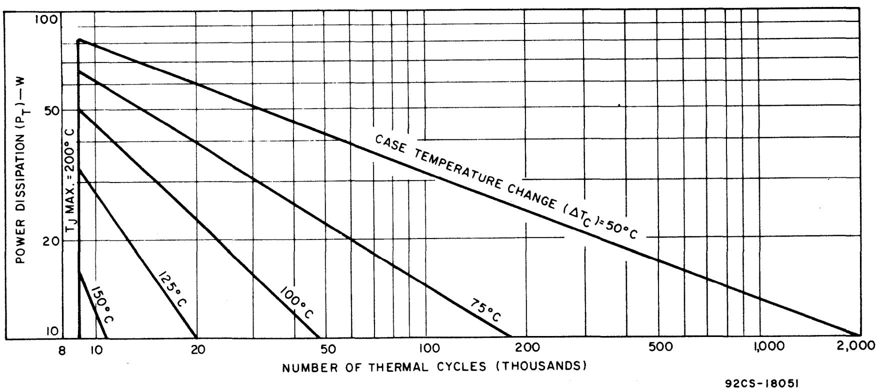


Fig. 1— Thermal-cycling rating chart for the RCA-2N3055 power transistor.

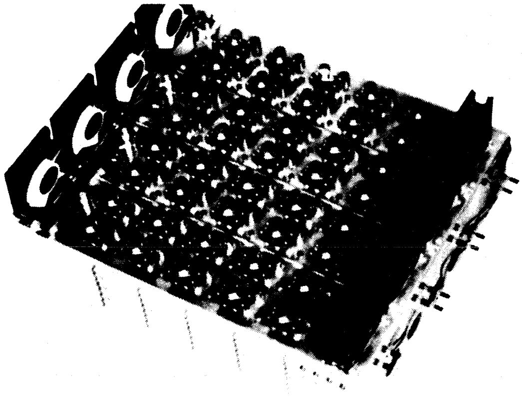


Fig. 2— Thermal-fatigue test rack.

ambient testing, the input variables include the heat-sink size, on/off cycle time, and power dissipation (collector-emitter voltage and collector current, V_{CE} and I_C). The response variables are the change in case temperature ΔT_c, and maximum junction temperature $T_{j(max)}$. The final response, of course, is the effect on the device, whether it be an open, short, or a change in an electrical parameter. Some of these variables are independent and some dependent. For example, with a given heat sink and cycle time, a change in power dissipation P_T will change both ΔT_c and $T_{j(max)}$. It is impossible to preset levels of these variables and achieve these conditions. This key point prevents utilization of a factorial design in a classical statistical approach.

The interdependency of some of the variables requires a complex preliminary set of experiments *before* the performance of a thermal-fatigue test on product capability. This preliminary work is called "scaling the environment". In the case of the 2N3055 transistor, it was necessary to determine 150 practical test (sampling) points that naturally exist when the bounds of the above-mentioned variables are considered. Table II shows parameter values for some of the 150 empirically derived test cells. From this data, test cells were selected to give sizable spread to the primary variables, P_T ($V_{CE} \cdot I_C$) and ΔT_c. The points chosen are shown on the theoretical rating chart of Fig. 4. Many of the points are outside of the projected safe area. This fact illustrates another consideration in the total study, time. To minimize testing time and still generate meaningful data, a form of accelerated testing was built into the program. The usual precautions were employed in utilizing accelerated testing; i.e., failure analysis and data analysis were used to verify the existence of a true acceleration and to assure that failures had not been created that had no correlation with a bearing on the more typical lower stress levels.

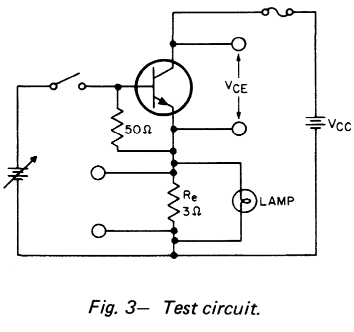


Fig. 3— Test circuit.

Table II – Scaling the Environment

V_{CE} (V)	I_C (A)	P_D (W)	On/Off Time (Sec.)	Heat Sink	$T_{j(max.)}$ (°C)	ΔT_{case} (°C)
17	1	17	100/200	H_0	188	150
17	1	17	180/180	H_0	230	190
30	1	30	50/130	H_0	190	145
27	1	27	50/130	H_0	178	125
30	1	30	50/130	H_0	235	170
30	1.4	41	100/200	H_1	200	145
30	1	30	100/200	H_1	165	120
27	1	27	150/300	H_2	150	100
28	2	56	15/25	H_1	150	50
33.3	3	100	50/100	H_3	170	80
33.3	3	100	100/150	H_3	185	100
5	1	5	50/100	H_0	70	32
10	1	10	100/200	H_1	80	58
35	2	70	180/180	H_3	155	86
7.5	1	7.5	180/180	H_1	154	113
10	1	10	300/300	H_2	92	63
45	2	90	50/100	H_3	150	93
30	1	30	600/600	H_3	103	61
10	1	10	300/300	H_0	223	130
5	1	5	150/300	H_2	54	43

H_0 = Free air
H_1 = 11°C/W thermal resistance
H_2 = 6.3°C/W thermal resistance
H_3 = 1.3°C/W thermal resistance
Thermal resistances of heat sinks are steady-state values
$T_{j(max)} = T_{c(max)} + \theta_{j\text{-}c} P_D$
($\theta_{j\text{-}c} \approx .5$°C/W)

Data

Table III is a tabulation of the data obtained from the 2N3055 thermal-fatigue rating program. Fig. 5 is a graphical representation of the cycles-to-failure for each test group. A visual examination of the data indicates that devices tend to fail sooner on tests with large ΔT_C and high junction temperatures, as expected.

Table III – 2N3055 Thermal-Fatigue Ratings

No. of Devices	Power (W)	Heat Sink	T_c (°C)	ΔT_c (°C)	$T_{j(max.)}$ (°C)	Cycle Time (sec.) On	Cycle Time (sec.) Off	Cycles @ Down Period	Cumulative Cycles	Catastrophic Failures
20	17	H_0	30 to 180	150	188.5	100	200	35,952	43,032	1 @ 2000 hrs. 2 @ 40,207 hrs.
20	17	H_0	30 to 220	190	228.5	180	180	30,525	36,442	1 @ 20,719 hrs. 1 @ 22,185 hrs. 1 @ 28,266 hrs. 1 @ 34,672 hrs.
20	30	H_0	35 to 180	145	195	50	130	52,851	72,061	1 @ 50,989 hrs. 1 @ 60,138 hrs. 1 @ 68,701 hrs. 1 @ 69,185 hrs.
20	27	H_0	40 to 165	125	178.5	50	130	53,402	72,479	1 @ 11,520 hrs. 1 @ 40,003 hrs.
20	30	H_0	50 to 220	170	235	50	130	18,698	70,564	1 @ 6036 hrs. 2 @ 11,808 hrs. 1 @ 18,703 hrs. 1 @ 36,846 hrs. 1 @ 62,616 hrs.
20	30	H_1	35 to 150	120	165	100	200	14,702	70,901	1 @ 65,200 hrs.
20	41	H_1	35 to 180	145	200.5	100	200	14,702	41,668	1 @ 449 hrs. 1 @ 1400 hrs. 1 @ 19,917 hrs. 1 @ 25,157 hrs. 1 @ 32,334 hrs. 1 @ 32, 642 hrs.
20	27	H_2	30 to 135	105	148.5	150	300	12,274	62,395	1 @ 50,100 hrs.
20	56	H_2	70 to 120	50	148	15	25	231,202	264,675	1 @ 8500 hrs. 1 @ 10,480 hrs. 1 @ 144,632 hrs. 1 @ 241,379 hrs.

H_0 = Free air (30°C/W)
H_1 = 11°C/W
H_2 = 6.3°C/W

Failure Analysis

The basic failure analysis procedure for all failing devices was as follows:

1. Electrical test
2. Leak test (Helium and freon bubble)
3. Gas Analysis (Mass spectrometer)
4. Decap unit
5. Electrical test
6. Visual inspection
7. Remove silicone conformal coating
8. Retest electrically
9. Remove solder
10. Cross section
11. Check pellet-to-header bond
12. Photograph results

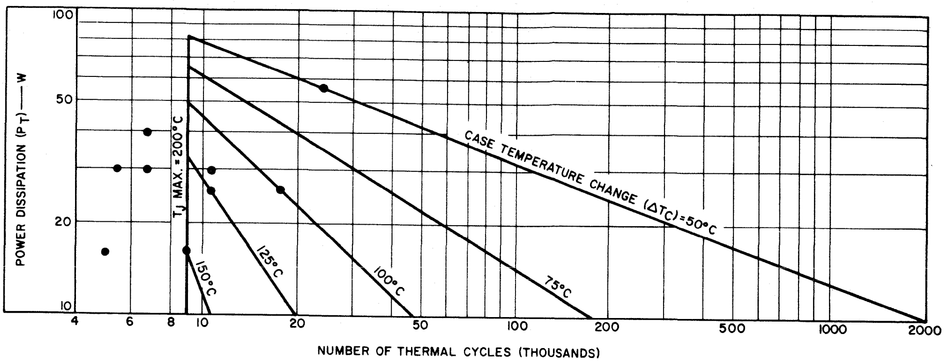


Fig. 4— Theoretical rating chart.

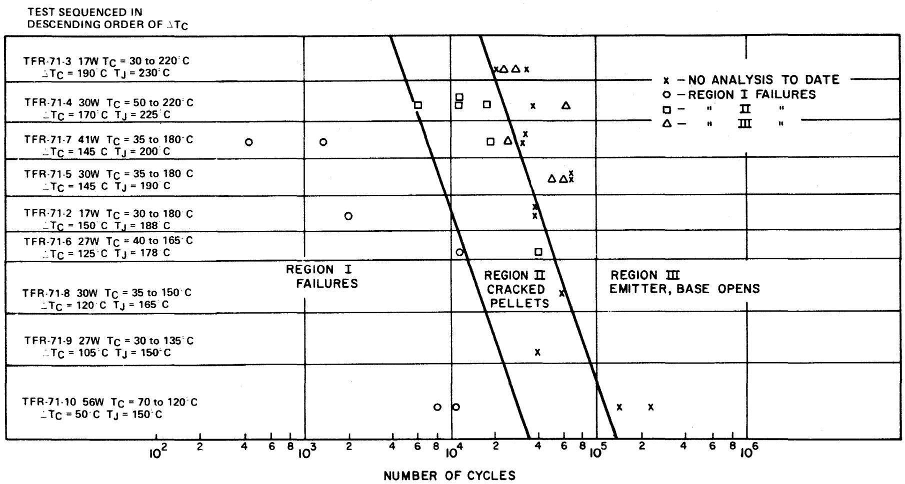


Fig. 5— Graphical representation of the cycles-to-failure number for various test groups.

Three basic types of failures were found in the analysis of failing devices using this procedure. These types were categorized as follows:

1. Non-controlled-solder-process* failures, Region I
2. Cracked pellets in Region II
3. Open emitter and base contacts (solder fracture) and nickel delamination on both collector and emitter-base side of pellet, Region III

*The controlled solder process is a proprietary process developed by RCA.

Corrective action has eliminated failures in Region I; such failures will not be discussed further. Figs. 6 and 7 illustrate the types of failures encountered in Regions II and III.

The cracked-pellet failures presented the problem of determining whether the silicon chip was cracked during assembly or as the result of thermal stresses. Analysis indicated that the cracks occur at points where high pressure is applied during assembly or where pellets are located over a solder void. Such failures are not expected to occur in devices using the controlled-solder-process solder system where the total strain of the system is taken up by the solder.

The third category of failures, open emitter and base contacts and pellet lifting, occurs very late in the cycle life of the device and is probably the only real wearout mechanism encountered in the test program. The interfaces between the emitter, base, and collector contacts consisting of nickel-lead/tin materials expand and contract at different rates during thermal cycling, and, consequently, strain occurs. Because of the difference in the coefficients of expansion of these materials, an appreciable amount of shearing takes place and causes fatigue failure at the contact point.

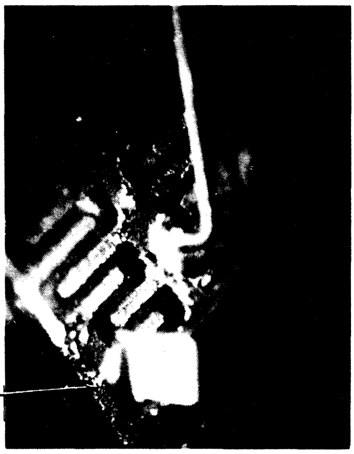
Curve Fitting – Predictive Model

In determining the number N(y) of cycles to first failure, it is assumed that a function exists and that the form of the function depends upon the measurable variables, as follows:

$$N(y) = f(\Delta T_C, \text{Power}, T_{j(max.)}, \text{Cycle Time } \theta_{h\text{-}s})$$

CRACK

Fig. 6– Pellet showing failure as the result of a crack.



OPEN BASE

Fig. 7– Pellet showing failure as the result of an open base.

Regression analysis techniques are used to minimize the estimation error; the method of least squares is employed for multiple regression, i.e.

$$S = \sum_{i=1}^{n} (N_i - \hat{N}_i)^2$$

is minimized; N_i is the actual value of failing cycles and $\hat{N}_i$ is the calculated value of cycles.

Because a functional exponential model exists from the previous theory and because the experimental data imply that an exponential model should be fitted by the regression equation, the following relation is postulated:

$$N(y) = \exp.^{(C_1 \Delta T_c + C_2 \Delta T_{j(max.)} + C_3 P_D + C_4 \theta_{h\text{-}s} t_r + \text{error})}$$

where ΔT_C is the case-temperature swing, $T_{j(max.)}$ is the maximum junction temperature, t_r is the ratio of "on" time t_{on} to "off" time t_{off}, P_D is the applied power, $\theta_{h\text{-}s}$ is the thermal resistance of the heat sink, and error is approximately normal $(0, \sigma^2)$

The coefficients of this equation should be highly correlated so that prediction will be restricted to the space from which the data were derived. The correlation matrix, Table IV, shows that the "independent" variables are highly correlated. This correlation illustrates the problem of designing the experiment in the classical manner, as mentioned in an earlier section.

Table IV – Correlation Matrix

	N	ΔT_J	$T_{j(max.)}$	P	$\theta_{h\text{-}s} \times t_r$
N	1	-0.89	-0.74	0.688	-0.52
ΔT_J		1	-0.928	-0.66	0.724
$T_{j(max.)}$			1	-0.42	0.702
P				1	-0.72
$\theta_{h\text{-}s} \times t_r$					1

Table V shows the data used in the regression analysis. No Region I failures are used in the regression analysis since they have been eliminated on future product through corrective action.

Following modified step-wise regression procedures, the equation that best fits the data is $Y = 724e^{-.02\Delta T_j}$, where $\Delta T_j = \Delta T_C + P_D(\theta_{j\text{-}c})$. Because the present data are limited, especially between the ΔT_C range of 50 and 125°C, further data and more analyses may result in slight modifications of this equation. Fig. 8 is a plot of the data and equation.

Table V – Data Used in the Regression Analysis

Power (W)	ΔT_j (°C)	ΔT_c (°C)	$T_{jmax.}$ (°C)	t_r	$\theta_{h-s} \times t_r$ (°C/W)	Y (First Failure Kc)
17	158.5	150	188	$\frac{100}{200} = 0.5$	15	40,207
17	198.5	190	230	$\frac{180}{180} = 1$	15	20,719
30	160	145	195	$\frac{50}{130} = 0.375$	11.2	50,989
27	138.5	125	178	$\frac{50}{130} = 0.375$	11.2	40,003
30	185	170	235	$\frac{50}{130} = 0.375$	11.2	6,036
30	135	120	165	$\frac{100}{200} = 0.5$	5.5	65,200
41	165.5	145	200	$\frac{100}{200} = 0.5$	5.5	19,917
27	118.5	105	150	$\frac{150}{300} = 0.5$	3.15	50,100
56	78.0	50	150	$\frac{15}{25} = 0.6$	3.8	144,632

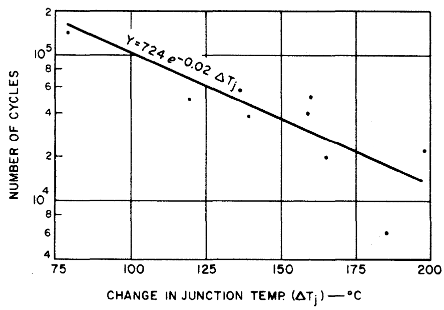


Fig. 8– Plot of change in junction temperature as a function of number of cycles.

CONCLUSIONS

There are a variety of causes for thermal-fatigue failures. Region I failures were completely corrected by the controlled solder process. Region II cracked-pellet failures are a function of mounting techniques and process control. Region III failures represent a wearout mechanism which occurs well beyond the normal use of the device.

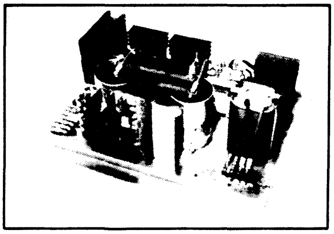
Empirical determination of thermal-cycling capability is a long and difficult process requiring specialized equipment and techniques. At present, the prime factor affecting thermal-cycling capability is change in junction temperature, $\Delta T_j = \Delta T_c + (P_D \times \theta_{j-c})$. The RCA-2N3055 power transistor has demonstrated a thermal-fatigue capability far in excess of theoretically postulated values published in the thermal-fatigue rating chart.

ACKNOWLEDGMENT

The authors acknowledge the contributions made in "scaling the environment" by F. Wehrfritz.

REFERENCES

1. "C.R. Turner Speaks Out on Second Breakdown", EEE, Vol. 15, No. 7, July, 1967.
2. G.A. Lang, et al, "Thermal Fatigue in Silicon Power Transistors", IEEE Transactions on Electron Devices, September, 1970.
3. W.D. Williams, "Thermal-Cycling Rating System for Silicon Power Transistors", RCA Application Note AN-4612.
4. Draper and Smith "Applied Regression Analysis", John Wiley and Sons, Inc., 1966.



Off-Line 1-Kilowatt Driven Converter

by P. A. Bothner

In recent years, the off-line inverter approach to power conversion has penetrated deep into the industrial, military, and consumer market places because of the size, weight, and cost advantages it offers over conventional methods of power conversion.[1,2] The off-line approach became feasible with the availability of power transistors that are low in cost and that have high voltage breakdown, low saturation voltage, and high-speed switching characteristics

The high voltage-breakdown characteristics of the power transistors allow operation directly from a rectified ac line without the use of the bulky power transformer required by conventional power sources. Elimination of this transformer reduces the power lost by the system due to wire resistance and core losses, and also results in a substantial reduction of the overall size and weight of the system. The low saturation voltage and high-speed switching capability of the power transistors yields maximum power transfer to the load. The maximum power transfer reduces the heat-sinking requirements and permits further reduction in the system's size.

This Note describes an off-line, 1-kilowatt driven converter that operates from a 117-volt ac line. The converter is designed to provide a dc output of 100 volts and deliver 1 kilowatt of continuous output power to the load with an overall system efficiency exceeding 85 percent; this performance is achieved through the use of type 40854 transistors selected from the 2N6250 power-transistor family.

CONVERTER CHARACTERISTICS

Driven converters, such as the one described in this note, offer certain advantages over free-running converter systems which depend on the magnetic properties of a transformer to control switching. The main advantages are: 1) stable operating frequency independent of load (the degree of stability is dependent on the clock circuit chosen); 2) a simplified transformer design because feedback windings are not required; and 3), lower cost of the ferrite material employed (the cost of linear ferrite cores is often less than half that of square-loop cores of comparable size). One major disadvantage of this converter-circuit approach, however, is a tendency for common-mode conduction. Common-mode conduction refers to a mode of circuit operation during which both devices of a push-pull pair conduct simultaneously. During this period, the net flux density within the transformer core is virtually nulled out, presenting, for all practical purposes, short-circuit load conditions to the transistors. Although the high currents which prevail during this mode tend to turn off the transistor which has completed its normal conduction period, the opposite device starting its on period experiences high voltage and high current at the same time. This could lead to second breakdown.[3] Therefore, considerable care must be taken when designing the drive circuitry to prevent or at least minimize common-mode conduction during light- or no-load conditions.

The inverter employed for this application uses a small high-frequency output transformer to isolate the load from the ac line and from the system ground of the converter itself. Because of the high operating frequency of the inverter, low ripple dc can be obtained by using low-valued capacitor-filter components. To achieve the same low level of ripple, a linear power supply would require the use of a regulator circuit and a series pass transistor (or transistors) with high energy-handling capability.

Since the transistors in an inverter are operated in the switching mode, their required energy-handling capability is considerably less than those employed in a linear power supply of comparable power output.

For simplicity, this Application Note is limited to a discussion of the design and construction of the converter circuit only. In a complete system, overload sensing and some form of latching circuit must be added to protect the transistors and other vital components from an overload or short circuit at the output terminals.

CIRCUIT DESCRIPTION

The converter consists of four major sections as illustrated by the block diagram shown in Fig. 1:

- Oscillator
- Buffer
- Driver
- Output

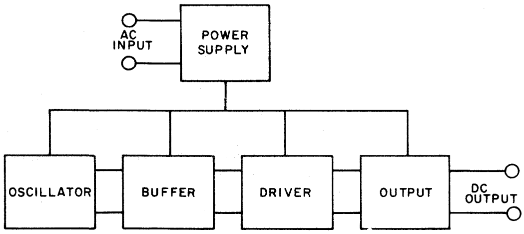


Fig. 1—The four major converter sections.

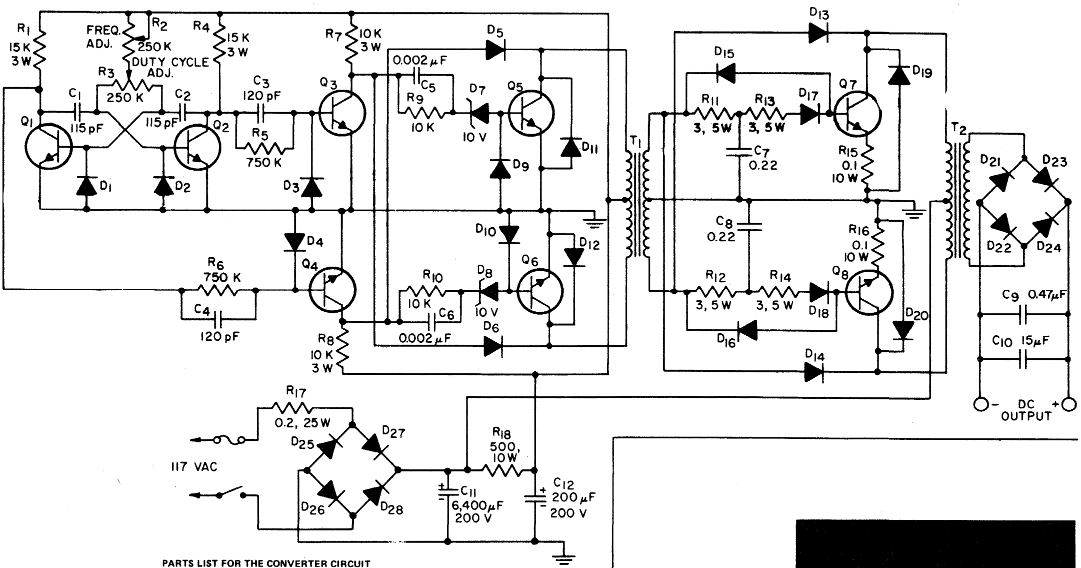
A complete schematic diagram of the converter circuit is shown in Fig. 2. All circuits are operated from a single high-voltage source and are stable over ac line-voltage variations between 105 and 130 volts. The oscillator, buffer, and driver circuits easily fit on a single 4-1/2-inch by 5-1/2-inch circuit board. Additional filtering of the supply voltage for these stages keeps the ripple voltage below 500 millivolts during normal load conditions. Because all circuitry operates from a high dc potential, and because the speed-up capacitors employed in the base drive circuits for wave shaping charge up to this potential, diodes must be connected from base to ground of every transistor (with the exception of output transistors Q_7 and Q_8) to clamp the bases and prevent base-emitter junction breakdown during each transistor's respective off period. The affect of the clamping diode can be seen in the bottom waveform of Fig. 3.

Oscillator

The clock signal is provided by a simple two transistor (Q_1 and Q_2) multivibrator. The desired frequency of 20 kHz is stable to within ± 2-percent drift with dc supply voltage varying between ·125 and 175 volts. Trimmer resistor R_2 and R_3 are used to adjust the oscillator frequency and duty cycle. Resistor R_3 is included to eliminate the need for matching circuit components.

Buffer

A buffer stage (Q_3, Q_4) between the oscillator and driver circuits provides the isolation required by the oscillator for



PARTS LIST FOR THE CONVERTER CIRCUIT

PART No.	MFG TYPE No.	DATA SHEET FILE No.	DESCRIPTION
$Q_{1, 2, 3, 4}$	RCA 2N3440	64	300V, 1A, 10W, TO-5
$Q_{5, 6}$	RCA 2N6176	508	350V, 1A, 20W, TO-5 Plastic
$Q_{7, 8}$	RCA 40854	498 (prototype File 523)	450V, 30A, 175W, TO-3
$D_{1, 2, 3, 4, 9, 10, 11, 12, 19, 20}$	RCA 1N3195	41	600V, 750 mA, DO-26
$D_{5, 6, 13, 14, 15, 16}$	RCA TA7894	*	600V, 1A, DO-26, fast recovery rectifier
$D_{7, 8}$	TRW 1N4740		10V, 1W, zener diode
$D_{17, 18}$	RCA TA7900	*	600V, 3A, modified DO-4, fast recovery rectifier
$D_{21, 22, 23, 24}$	RCA TA7985	*	300V, 40A, DO-5, fast recovery rectifier
$D_{25, 26, 27, 28}$	RCA 1N1195A	6	300V, 20A, DO-5

* – developmental data sheet

Fig.2—Complete schematic diagram of the converter circuit.

TOP: COLLECTOR VOLTAGE OF Q_1 (V-50V/DIV, H-10µs/DIV), BOTTOM= BASE VOLTAGE OF Q_4 (V-1V/DIV, H-10 µs/DIV)

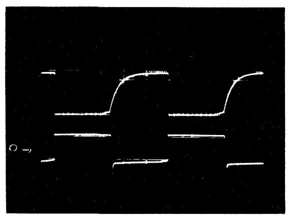


Fig.3—The effect of the clamping diodes and the wave shaping resulting from the presence of the buffer stage.

stable operation independent of the load. The wave shaping resulting from this stage is evident in the waveforms shown in Fig. 3. The top waveform is the collector voltage of Q_1 (or Q_2). The bottom waveform is the voltage present at the base of the respective drive transistor Q_6 (or Q_5).

Driver

Common-mode conduction in the push-pull driver stage is minimized by delaying the base drive to transistors Q_5 and Q_6. The desired delay is obtained through the use of cross-coupling diodes D_5 and D_6. These diodes prevent the base drive from reaching the non-conducting driver while the other is still in the conducting state. The base drive is held back until the V_{CE} of the conducting driver, during its transition to the off state, exceeds the breakdown voltage of the zener diode (D_7 or D_8) connected to the base of the non-conducting driver. This technique provides a delay that varies proportionately with the storage time of the devices in the sockets, and thus eliminates the need for matching transistors.

Output

The severity of common-mode conduction in the output stage is several orders of magnitude greater than that encountered in the driver stage if no steps are taken to delay the base drive. During the time when common-mode conduction occurs, the current flowing through each device is limited only by the transistor's gain and the impedance of the collector-emitter circuit. As these currents and their conduction times increase, the possibility of the occurrence of secondary breakdown also increases. Even if the safe-operating-area of the transistors is not exceeded, the resulting high volt-ampere pulses can substantially increase the power dissipation and affect the overall efficiency of the system.

The waveforms shown in Fig. 4 illustrate what the base current to output transistors Q_7 and Q_8 would look like if no delay circuit were employed. If this drawing represented the actual operating condition of the output stage, common-mode conduction would occur during the storage time interval t_s. The amount of storage time is dependent on how hard the transistor is driven into saturation. Fig. 5 shows the reverse base-current waveform of one of the output devices under different load conditions with constant forward base drive. Comparison of the two waveforms shows almost a two to one increase in storage time when the converter is switched from a normal load state (1 kilowatt output) to an unloaded state.

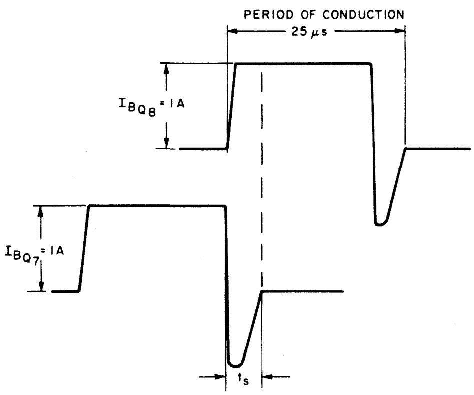


Fig.4—Form of base current to output transistors Q7 and Q8 without delay circuit.

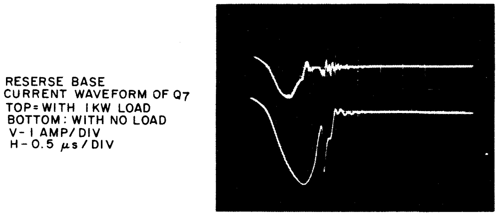


Fig.5—The reverse base-current waveform of one of the output devices under different load conditions with constant forward base drive.

A number of methods for obtaining the proper variable delay are available to the designer. The circuit approach shown in Fig. 2 has been chosen because it is economical in that it requires a minimum of parts. The same design philosophy used in the driver stage has been applied to the output stage. Cross-coupling diodes D_{13} and D_{14} are used to shunt drive current through the conducting transistor during the needed delay period. When the conducting transistor turns off, its collector-to-emitter voltage rises to twice the supply voltage. As soon as this voltage increases beyond the base threshold voltage, the conducting shunt diode becomes back biased, turns off, and permits current flow to the base of the non-conducting output transistor. The base threshold voltage is determined by the series base diode (D_{17}, D_{18}), the transistor base-emitter diode, and the voltage dropped across the emitter resistor (R_{15}, R_{16}). The end result is a base current pulse whose width varies according to the delay dictated by the load and the switching characteristics of the output transistors being used. For any given load and supply voltage, higher peak collector currents are required to maintain a constant average current if the forward drive portion of the base pulse width becomes narrower. Therefore, it is highly desirable to keep the needed delay to a minimum. Diodes D_{15} and D_{16} minimize delay by providing a low-impedance base return to ground during the reverse-bias portion of each cycle. This low-impedance return reduces transistor-switching storage time.

Although the emitter resistors account for only a small part of the base threshold voltage (voltage drop results from collector-to-emitter leakage current), the degeneration they provide contributes to the reliability of the output stage by suppressing transient current spikes and enhancing the thermal stability of the device.

TRANSFORMER DESIGN CONSIDERATIONS

A description of the transformers employed in the converter is given in Table I. Because of the high operating frequency, ferrite was chosen as the core material for both transformers to minimize core losses.[4] Each transformer is designed for non-saturated operation at core temperatures up to 100°C and supply voltages as high as 185 volts. The primaries of both transformers are wound bifilar to assure symmetrical coupling to the secondaries. The number of primary turns was determined through the use of the following formula:

TABLE I – FERRITE TRANSFORMER DESCRIPTION

TRANSFORMER	PRIMARY	SECONDARY	REMARKS
T_1	300 turns C.T. bifilar AWG No.30	10 turns C.T. bifilar AWG No.22	Ferroxcube pot core, No. 36/22, 3B7
T_2	60 turns C.T bifilar AWG No.18	20 turns bifilar AWG No.16	Allen Bradley C core, (4 pieces) No.U2625C133A, WO-3, paralleled sets of primary and secondary windings

$$N_p = \frac{2 V_{cc} \times 10^8}{4 f A_c B}$$

where V_{CC} is dc supply voltage, f is frequency, A_c is core cross-sectional area, and B is flux density.

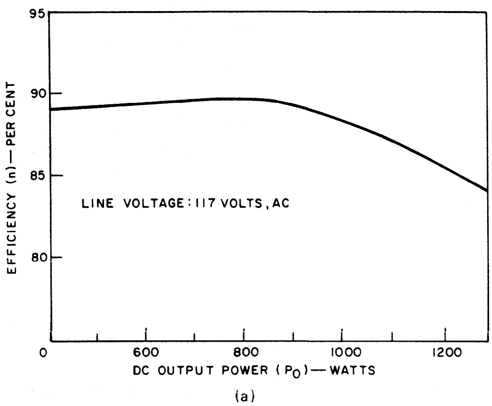
Utilization of No. 12 wire (based on 800 to 1000 cir. mils/amp. rms) for the output transformer was found to be impractical. Not only was it extremely difficult to wind, but several layers were required to obtain the needed number of turns called for in the design. The parasitic winding capacitance and leakage inductance resulting from this poor physical design caused severe ringing and large voltage turn-off spikes at the collectors of Q_7 and Q_8. The ringing and voltage spikes were reduced considerably by paralleling duplicate pairs of the primary and the secondary windings from each set of C cores. This arrangement permitted the use of smaller-gauge wire to reduce the total number of layers and to get the windings closer to the core for better coupling. As a result, the transformer efficiency was improved, and a corresponding decrease in its operating temperature was obtained.

PERFORMANCE CHARACTERISTICS

The output performance characteristics of the converter are shown in Fig. 6. Fig. 6(a) shows the converter efficiency versus dc output power at the nominal ac line voltage. Fig. 6(b) shows the dc output power as a function of the ac input line voltage. The efficiency is computed by the use of the following formula:

$$\eta = \frac{\text{DC output power}}{\text{AC input power}} \times 100 \text{ percent efficiency}$$

The losses in efficiency are primarily attributed to power consumption within the semiconductor components. The bulk of this dissipation is due to switching and saturation voltage losses. Since saturated switching techniques are employed, the dominant dissipation factor results from the switching losses. To optimize efficiency, the designer should therefore select devices that offer the best switching characteristics without sacrificing so much safe-operating-area capability that the system becomes unreliable. Because this trade-off exists, the care that should be exercised in device selection cannot be overemphasized.



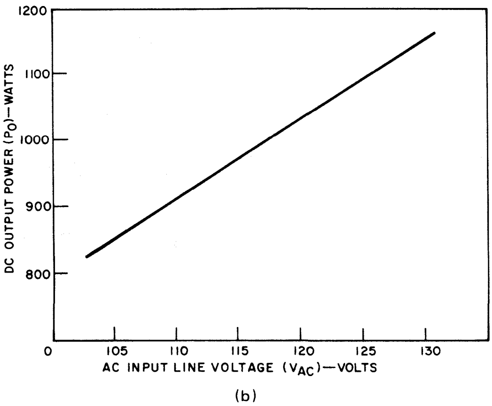


Fig.6—Output performance characteristics of the converter: (a) efficiency as a function of dc output power at the nominal ac line voltage; (b) dc output power as a function of the ac input line voltage.

Fig. 7 shows typical output collector voltage, collector current, and load-line waveforms for a 1-kilowatt load at the nominal ac line voltage. By using these waveforms together with the published safe-operating-area curves and temperature-derating curves found in the transistor data sheet, the designer can determine if the transistor will operate safely and reliably in the circuit.[5]

The bottom waveform in Fig. 8 shows a magnified view of the intensified portion of the fall-time region of the collector-voltage waveform shown in Fig. 7. The inflection

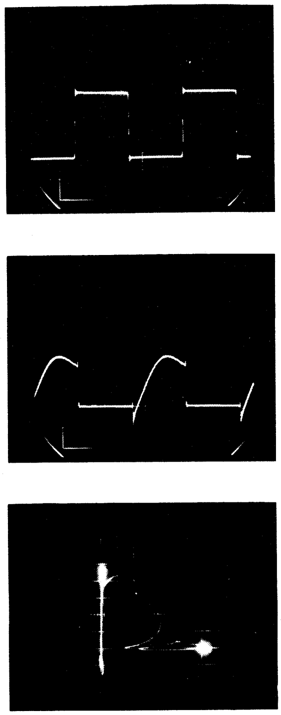


Fig.7—Typical output collector voltage, collector current, and load-line waveforms for a 1-kilowatt load at the nominal ac line voltage.

seen in Fig. 8 results when simultaneous conduction of both halves of the output-diode bridge reflects an instantaneous short back to the primary side of T_2 and causes a momentary collapse of the collector voltage. This condition occurs during the diode reverse-recovery time and persists until all stored charge is depleted from the junction and the diode ceases conduction. The condition becomes readily apparent in a comparison of the two waveforms in Fig. 8 where the top waveform is the output diode current of one half of the bridge.

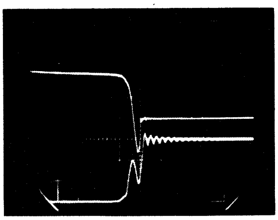


Fig.8—Waveforms showing current through diode D21 and collector voltage of Q8.

EFFICIENCY/COST CONSIDERATIONS

Some improvement in converter efficiency can be obtained by using two diodes instead of four for full-wave rectification of the output. This change can be readily accomplished by doubling the present number of secondary turns on T_2 and including a center tap for the ground return point. The elimination of a diode drop in the system described in this Note would represent a saving of 10 to 15 watts of power dissipation when the converter is delivering 1000 watts into a 10-ohm load. Since the forward diode voltage increases with current, the power dissipated by the rectifiers increases as the load-current demand increases. Although the number of secondary turns is doubled, dissipation within the transformer remains essentially unchanged because each half of the secondary conducts for only 50 percent of the time. The size constraints imposed on a system may make it impossible for a designer to use this approach even though it could offer increased reliability and, possibly, lower system cost. Implementation of this change in the present design would require the use of a larger core and a redesign of the transformer.

Another point to be considered when attempting to optimize efficiency is wire lead length. Because the residual inductance of the leads has an adverse effect on transistor switching speeds, lead lengths should be kept as short as possible. The turn-on times of transistors Q_7 and Q_8 were improved by approximately 0.3 microseconds when the converter breadboard circuit was reassembled into the final form.

Acknowledgments

The author thanks R. Kumbatovic, D. Moe, and A. Ott for their assistance in the preparation of this Note.

References*

1. Myers, R.S., "Compact 5-Volt Power Supplies Using High Voltage Power Transistors," 1971, RCA Application Note AN-4509.
2. Beiswinger, W.J., "A 750-Watt Three-Phase Frequency Converter," 1971, RCA Application Note AN-4673.
3. RCA Solid-State Power-Circuits Designer's Handbook (Technical Series SP-52).
4. "Applying Ferroxcube Ferrite Cores to the Design of Power Magnetics," Bulletin No. 330-B; Ferroxcube Corp., Saugerties, N.J. 1968.
5. A detailed description of safe-area analysis computation is given by C. R. Turner in E.E.E. magazine, July 1967, Vol. 15, No. 7.

* RCA publications are available through RCA Solid State Division Box 3200, Somerville, N.J., 08876

Audio Applications of the RCA-HC1000 Hybrid Linear Power Amplifier

By W. R. Peterson

Hybrid power circuits such as the RCA-HC1000 linear amplifier represent a new concept in power component design. The HC1000 is a complete amplifier system with high power-dissipation capabilities, complex circuitry, built-in protection devices to maintain reliability, and a small easy-to-handle package. These features, combined with the versatility of the circuit, make the amplifier suitable for a wide variety of applications.

The HC1000 is capable of delivering an rms power output of 100 watts into a 4-ohm load with peak current of 7 amperes, of operating from a total supply voltage of 75 volts, and of delivering 60 watts at a frequency of 30 kHz. The features described above are achieved through the use of hybrid construction techniques coupled with several design innovations which take advantage of previously incompatible processes and extend present technological capabilities. This Note briefly describes the circuit design and structure of the HC1000, and discusses its use in three types of audio amplifier configurations.

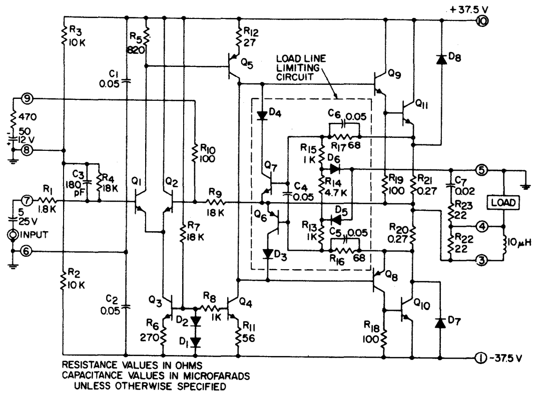


Fig. 1 — Schematic diagram of HC1000 hybrid linear amplifier using split power supply.

Circuit Features

The schematic diagram of the HC1000 is shown in **Fig. 1.** The quasi-complementary-symmetry output stage uses rugged n-p-n hometaxial transistors with excellent forward- and reverse-bias second-breakdown capability. The output stage composed of Q8, Q9, Q10, and Q11 is operated in the class B mode; diodes D7 and D8 protect the amplifier from excessive voltages when fault conditions occur with transformer-coupled and motor loads. Transistor Q4 operates as a constant-current source.

The input stage composed of transistors Q1 and Q2 is a difference amplifier which uses another constant-current source, Q3, in the emitter circuit. The circuit may be operated from a split power supply, as shown in **Fig. 1,** or from a single-ended supply. The load-line limiting network protects the amplifier against load conditions that would stress it beyond its design capability.

Basic Structure

The amplifier consists of two separate sections mounted directly on an integral common base plate, as shown in **Fig. 2.** One section contains the complete driver circuit, including 23 thick-film resistors, 7 chip capacitors, 6 diode chips, and 9 transistor chips on an alumina substrate. All active components are tested in chip form prior to mounting. The chips are then mounted on the driver circuit by means of an electrically and thermally conductive epoxy.

The second section contains the two output power-transistor chips and two diode chips. The output chips include a high-lead-content solder metallization which is reflow-soldered to the ceramic substrate in a hydrogen atmosphere to obtain a good solder bond. The use of soldered connections, plus the spreading of the heat flux within the metal pedestal, results in a very low thermal impedance for the output structure (typically less than 2° C per watt).

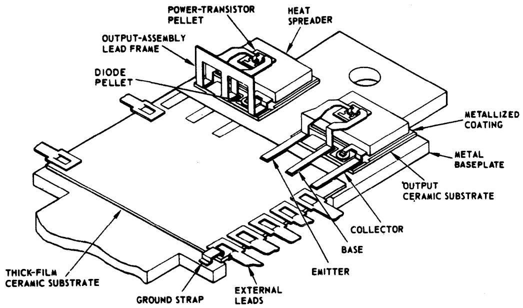


Fig. 2 — Internal structure of the HC1000 hybrid amplifier.

Prior to encapsulation, the amplifier is coated with a resilient resin which serves as a buffer for stresses induced by differences in thermal-expansion coefficients of the various materials used. Plastic is used for the final molded encapsulation because of its excellent bonding characteristics and low cost. The metal base plate of the completed amplifier can be either electrically floating or at electrical ground, and thus can be bolted directly to a heat sink.

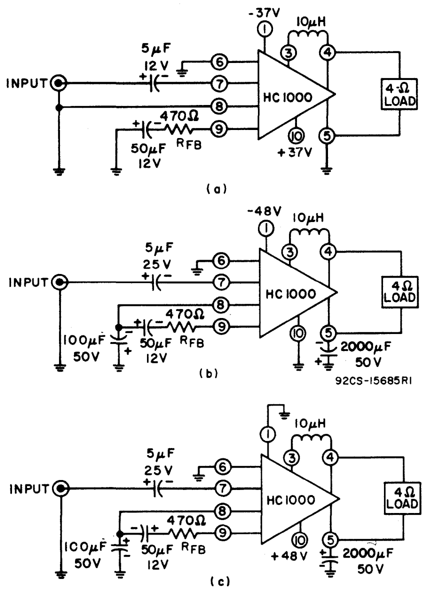


Fig. 3 — Typical connections for the HC1000 for use as an audio amplifier: (a) with split power supply and direct-coupled load; (b and c) with single-ended supply and capacitive-coupled load.

Audio Amplifier

Typical connections for the HC1000 for use as an audio amplifier are shown in **Fig. 3. Fig. 3(a)** illustrates the method for using a split supply with a direct-coupled load, and **Figs. 3(b)** and **(c)** show a single-ended supply with a capacitive-coupled load. Gain can be adjusted by varying R_{FB}. The input impedance is nominally 18000 ohms; the output impedance varies with frequency, as shown in **Fig. 4**, and can be varied by adjusting R_{FB}, as shown in **Fig. 5.**

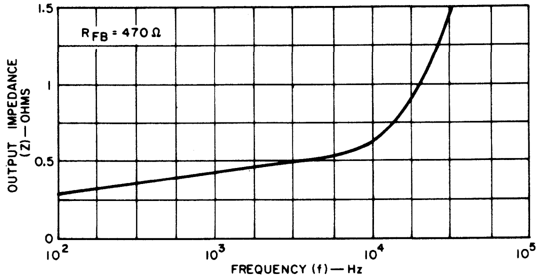


Fig. 4 — Output impedance as a function of frequency for the circuits of Fig. 3.

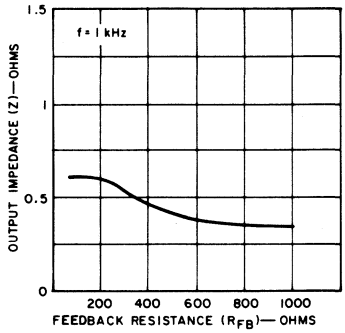


Fig. 5 — Output impedance as a function of feedback resistance R_{FB}.

When the HC1000 is connected as shown in **Fig. 3** and operated at 1 kHz, total harmonic distortion is less than 0.5 per cent at an output of 60 watts and drops to below 0.15 per cent at 1 watt. Low-frequency capability can be improved by increasing the value of the coupling capacitors at the input and in series with the feedback resistor. Roll-off at high frequencies depends on power dissipation to a small degree; at a particular power level, however, the frequency must be limited if power dissipation becomes excessive.

Transformer-Coupled Audio Amplifier

In some applications, it is necessary to deliver considerable power to a high-impedance load, and a transformer must be used, as shown in **Fig. 6.** When this configuration is used, however, several precautions must be taken.

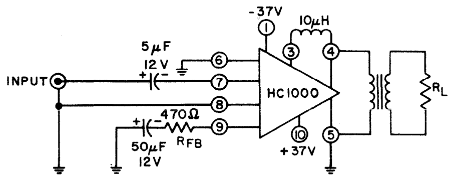


Fig. 6 — Typical connections for the HC1000 with a split power supply and a transformer-coupled load.

When the amplifier is in a quiescent mode, the offset voltage (quiescent load voltage) can be as high as 250 millivolts while the dc resistance of the transistor primary is several milliohms. The resulting offset current may be sufficient to activate the short-circuit protection network and cause considerable power dissipation in one output device. The following methods can be used to correct this condition:

1. Use a transformer with a high-resistance primary winding.
2. Add resistance in series with the primary.
3. Add a suitable electrolytic capacitor in series with the primary.
4. Balance out the offset voltage by use of the balancing network shown in **Fig. 7.** The typical temperature coefficient of offset voltage is 0.4 millivolt per °C up to case temperatures of 100° C.

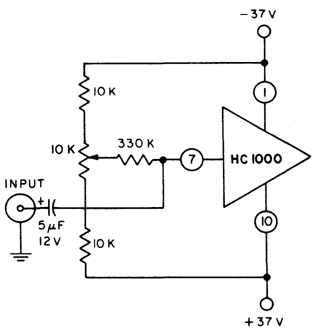


Fig. 7 — Balancing network for use in the circuit of Fig. 6.

Another problem may be encountered when the amplifier is operated below the low-frequency capability of the transformer. At such frequencies, the transformer presents an inductive load which may activate the protection circuit. The resulting transient condition can distort the waveform, as shown in **Fig. 8.** The solution to this probelm is to design the transformer to be compatible with the lowest frequency at which the amplifier will be used.

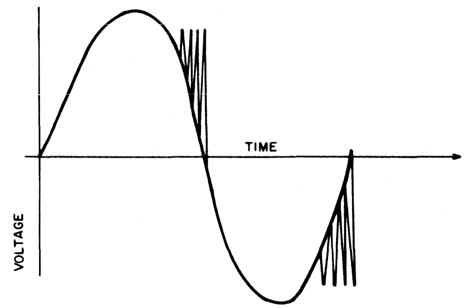


Fig. 8 — Waveform distortion caused by low-frequency limitations of transformer.

Bridge Amplifier

Two HC1000 amplifiers can be used in the configuration shown in **Fig. 9** to provide amplified outputs in excess of 100 watts. Maximum power output is 200 watts because the effective load voltage is doubled while the maximum load current remains the same. In this circuit, the protection-network terminals are connected to opposite sides of the load instead of to ground to increase the slope of the protection-network characteristic. However, the characteristic lies within the safe operating area of the protection-network transistors for voltages up to ± 23 volts, and the short-circuit protection remains the same as for a single amplifier.

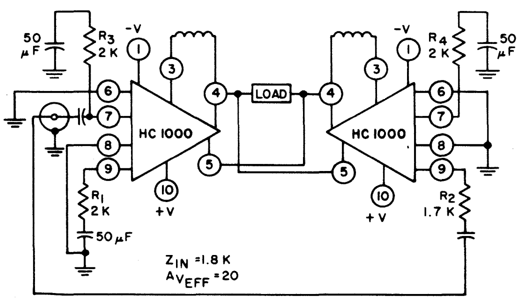


Fig. 9 — Bridge amplifier using two HC1000 hybrid modules to provide more than 100 watts.

Because the amplifiers must be driven 180 degrees out of phase, one amplifier receives its input signal at the inverting input. Resistances R_1 through R_4 are selected to provide the proper input impedance of each amplifier for the same voltage gain into a fixed load.

The bridge amplifier shown in **Fig. 10** is similar to that of **Fig. 9**. However, because both amplifiers are driven from the non-inverting terminal with a phase inverter, the circuit of **Fig.10** provides higher input impedance and higher gain than the circuit of **Fig. 9**.

Distortion is not appreciably greater in the bridge configurations of **Figs. 9** and **10** than in a single amplifier. Measurements with a direct-coupled load yielded total-harmonic-distortion levels below 0.2 per cent at 1 kHz and an output of 40 watts. Power dissipation levels are calculated by use of an apparent load resistance which is half the actual load resistance.

References

1. L. Balents, R. Gold and F. Kamp, "A Hybrid Linear Power Amplifier", **Proceedings of Electronic Components Conference,** May 1969.

2. F. Kamp and J. Sondermeyer, "A Hybrid 100-Watt Linear Audio Amplifier", **IEEE Transactions on Boardcast and TV Receivers,** July 1969.

3. W. Peterson, "Operation and Construction of a Hybrid 5-Ampere 75-Volt Linear Amplifier", **WESCON Reprint,** August 1969.

4. L. Balents, R. Gold, A. Kaiser, and W. Peterson, "Design Consideration for Power Hybrid Circuits", **Proceedings of 1969 Hybrid Microelectronics Symposium,** September, 1969.

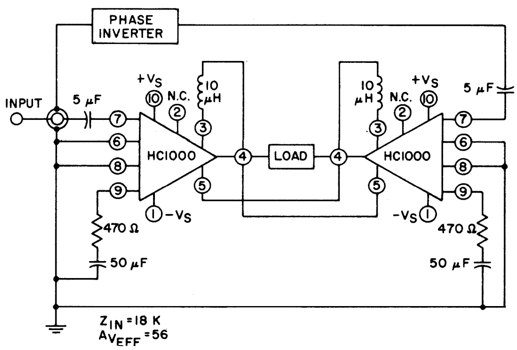


Fig. 10 — Bridge amplifier using a phase inverter.

General Application Considerations for the RCA-HC1000 Hybrid Linear Power Amplifier

By W. R. Peterson

Because hybrid power circuits consist of combinations of different types of devices which may be fabricated by different technologies, the effect of a changing environment is not as simple as in the case of discrete devices. This Note briefly describes the RCA-HC1000 hybrid linear amplifier, and discusses such operating considerations as dc and ac power dissipation, efficiency as a function of frequency, protection against excessive load variations and reactive loads, and heat-sink requirements.

Circuit Description

The schematic diagram of the HC1000 hybrid linear power amplifier is shown in **Fig. 1.** The circuit consists of a differential-amplifier input stage (Q1–Q3) followed by a bidirectional current source (Q4, Q5) which drives the class B output stages (Q8–Q11). The bias resistor R4 shunts the input to ground and sets the input impedance at 18000 ohms. The capacitor C3 causes no significant reduction of input impedance at frequencies below 50 kHz. Resistors R2, R3, and R4 provide dc bias for transistor Q1.

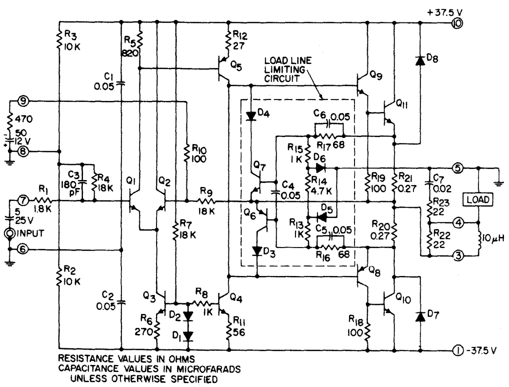


Fig. 1 — Schematic diagram of type HC1000 hybrid power module.

The input differential amplifier consists of transistors Q1 and Q2. The input signal is delivered to the base of Q1 (i.e., to the non-inverting input terminal of the amplifier). The base of Q2 receives a feedback signal from the output through resistor R9. The constant-current source in the emitter circuit, Q3, permits operation of the differential amplifier to be independent of supply voltage.

The bidirectional current source consists of a current-source transistor, Q4, and a class A amplifier, Q5. Because both the differential amplifier and the bidirectional current source are independent of supply-voltage variations, the complete amplifier can be operated over a supply-voltage range of 30 to 75 volts without bias adjustments. The high output impedance of Q4 and Q5 causes the output transistors to operate on their current-gain characteristics and allows class B operation with minimal crossover distortion.

The output stages use emitter-follower Darlington configurations of the quasi-complementary-symmetry form. The power transistors Q10 and Q11 are rugged single-diffused hometaxial devices with excellent second-breakdown capabilities. Resistors R20 and R21 provide stability and sensing points for the short-circuit protection network. Diodes D7 and D8 protect the output transistors from reverse potentials that occur during switching of a transformer-coupled load.

Power Dissipation

DC Operation. Maximum allowable power dissipation P_d(max.) for steady-state operation of the HC1000 is calculated as follows:

$$P_d(\text{max.}) = \frac{T_J(\text{max.}) - T_C}{\theta_{J-C}}$$

where the maximum junction temperature T_J(max.) is 150° C, the case temperature T_C is 25° C, and the junction-to-case thermal resistance $\theta_{J\text{-}C}$ is 2° C per watt. For each output transistor, therefore, $P_d(max)$ equals 62.5 watts. Actual dc power dissipation P_d is given by

$$P_d = V_{CE} I_C$$

where V_{CE} is the operating collector-to-emitter voltage and I_C is the average collector current. The limit value occurs at $V_S^2/4R_L$, where V_S is the supply voltage and R_L is the load impedance.

If the input signal consists of pulses or waveforms of short duration (10 milliseconds or less) with a maximum duty cycle of 50 per cent and a peak-to-average power-dissipation ratio of at least 2.5, the maximum allowable peak power dissipation can be increased to 88 watts for each output transistor. Both this value and the steady-state maximum of 62.5 watts calculated above are linearly derated to zero at a case temperature of 150° C.

AC Operation. The maximum allowable room-temperature peak power dissipation of 88 watts per output device mentioned above takes into account the thermal resistance, thermal capacitance, and junction temperature of each output transistor of the HC1000. This limitation is indicated in the curve of maximum allowable supply voltage as a function of load resistance shown in **Fig. 2.** This curve cannot be used for frequencies below 40 Hz, however, because the thermal capacitances of the output transistors become charged and cause the peak junction temperature to exceed the maximum limit.

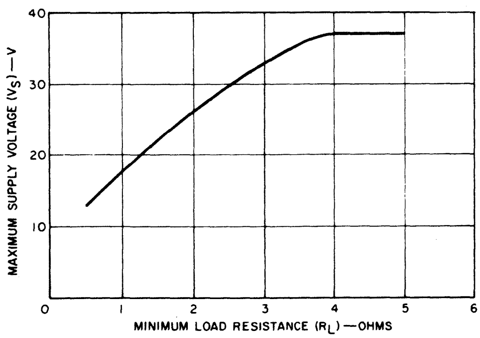


Fig. 2 — Maximum allowable supply voltage vs. load resistance for type HC1000.

The peak power of 88 watts per output device corresponds to an average power of 35 watts when the output waveform is a sine wave. For temperature derating, the maximum average power $P_d(avg)$ dissipated in each output transistor is calculated as follows:

$$P_d(avg) = V_S^2/10R_L$$

This equation is obtained from the following relationships:

$$2\,P_d(avg) = 0.4\,V_p^2/2\,R_L$$

$$V_p(max) = V_S$$

Regardless of waveform, therefore, the maximum possible peak power dissipation $P_d(peak)$ in one output transistor is given by

$$P_d(peak) = V_S^2/4\,R_L$$

For a sine-wave output, the maximum average power dissipation $P_d(avg)$ in one output transistor is given by

$$P_d(avg) = V_S^2/10\,R_L$$

Average power dissipation can be greater for other symmetrical waveforms. The worst case is an ac square wave, for which the dissipation is given by

$$P_d(avg) = V_S^2/8\,R_L$$

Regardless of waveform, however, the maximum allowable average dissipation per output device is 35 watts at a case temperature of 25° C.

Frequency Effect on Efficiency

Each output transistor has a frequency capability which is significantly lower than that of the remaining transistors in the amplifier. This limitation results in a common-mode conduction (both output transistors conducting simultaneously for a short period) as a result of excessive turn-off times. Common-mode conduction causes additional power to be dissipated in each transistor and reduces efficiency at high frequencies.

The turn-off time is affected by increases in storage time which are caused by increased temperature and collector current in the area of concern. **Fig. 3** shows maximum efficiency levels that can be expected over the frequency range under consideration, together with the effect of collector current. Each curve ends at the frequency at which the amplifier begins to dissipate excessive power at a case temperature of 25° C.

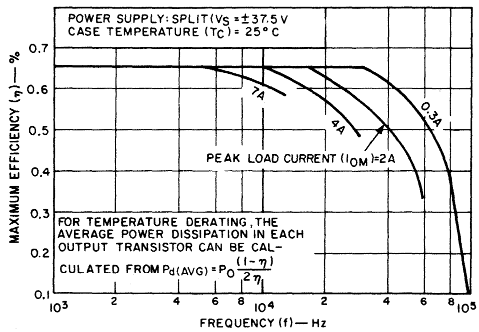


Fig. 3 — Maximum efficiency vs. frequency for type HC1000 with several values of peak load current.

Fig. 3 can be used to determine the power-handling capability of the amplifier at high frequencies. For example, the following operating conditions may be assumed:

V_S =	± 32 volts	f =	30 kHz
R_L =	8 ohms	T_C =	25° C

1. The maximum total average power dissipation, P_{d1} (avg) or P_o, at 1 kHz occurs when the efficiency is 50 per cent, and is equal to

   $P_{d1}(avg) = V_S^2/5\ R_L = (32)^2/40 = 25.6$ W

2. The peak load current under these conditions is given by

   $I_{om} = V_S/2\ R_L = 32/16 = 2$ A

3. The efficiency used in step 1 must be derated with frequency. From **Fig. 3**, average efficiency $\bar{\eta}$ is 65 per cent at 1 kHz and 57 per cent at 30 kHz for a peak load current of 2 amperes and a supply voltage of 37.5 volts. Therefore, the value for the conditions given above is calculated as follows:

   η (30 kHz) = 0.50 x (0.57/0.65) = 0.44

4. The efficiency can also be expressed in terms of power as follows:

$$\eta = \frac{P_o}{P_o + P_{d1} + P_{d2}}$$

where P_{d2} is the additional dissipation resulting from common-mode conduction and P_o and P_{d1} are known. P_{d2} can then be calculated as follows:

$$P_{d2} = \frac{P_o(1-\eta)}{\eta} - P_{d1} = \frac{25.6\,(1-0.44)}{0.44} - 25.6 = 7 \text{ W}$$

5. The total power dissipation is the sum of P_{d1} and P_{d2},

   $P_{d1} + P_{d2} = 25.6 + 7 = 32.6$ W

   or 16.3 watts per output transistor.

6. Because the output waveform is basically a sine wave with a frequency greater than 40 Hz, the curve shown in **Fig. 4** is used for temperature derating; the maximum allowable case temperature is found to be 92° C.

Protection Circuit

The HC1000 linear amplifier incorporates a network comprised of fourteen components (six active and eight passive) which provides protection against certain excessive load variations. Although it is primarily intended for short-circuit protection, this network also protects against resistive loads that are lower than the minimum rated load and capacitive loads which would cause excessive peak power dissipation. Both conditions are restricted to supply voltages of ±26 volts or less. For supply voltages between ±26 volts and the limit of ±37.5 volts, portions of the characteristic lie outside the safe operating area of the driver and output transistors. However, the short-circuit protection always operates in the safe area. The characteristic is shown in **Fig. 5**. This characteristic can readily be displayed on an oscilloscope by use of the setup shown in **Fig. 6**. Once the power supply is increased to approximately ±25 volts, the drive can be turned up until the waveform is observed.

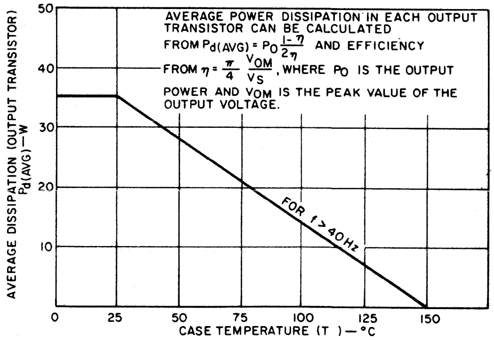


Fig. 4 — Dissipation (average) derating curve for each output transistor in type HC1000 (for symmetrical waveforms with f > 40 Hz).

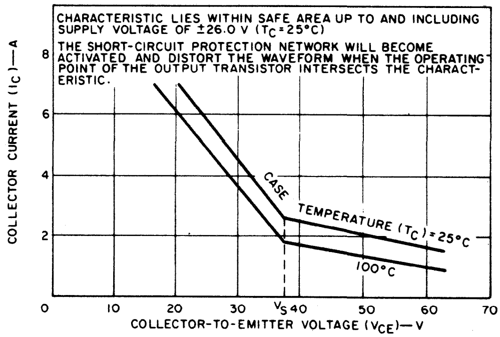


Fig. 5 — Characteristics of built-in load-line limiting circuit for type HC1000.

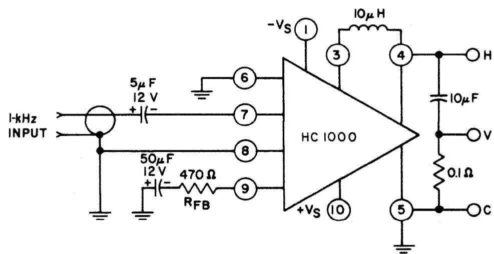


Figure 6 — Test set-up used to determine characteristics of built-in load-line limiting circuit for type HC-1000.

Reactive Loads

Almost all of the loads driven by the HC1000 linear amplifier vary with frequency; therefore, some part of the load is capable of storing energy. The load line for this type of load is a curve with a distinct point where peak power dissipation occurs.

As the magnitude of the impedance decreases or the phase angle of the load increases, the load line changes shape and approaches the protection-network characteristic, as shown by curve A in **Fig. 7.** When the lines intersect (i.e., when the protection circuit becomes activated), the output waveform becomes distorted. To avoid this type of distortion, a designer should be aware of the shape of the load line under conditions of extreme frequency and tolerance variations.

If the protection network were not used, the load line for a reactive load could appear as shown by curve B in **Fig. 7.** Because of the presence of the protection network, a capacitive load follows the protection characteristic, but an inductive load is diverted as shown in curve C for a short time period. This diversion appears as a spike or series of spikes on the voltage waveform. This condition can be prevented only by restricting the inductive load line to an area in which the protection circuit is not activated.

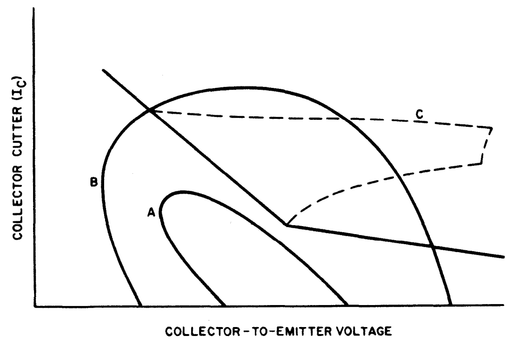


Figure 7 — Effect of protection circuit on the load-line characteristics of type HC1000 as the magnitude of the impedance decreases.

Heat Removal

For dc operation with one output device of the HC1000 conducting, the thermal resistance of the heat sink (θ_{HS}) can be determined from the following equation:

$$T_J = T_A + (\theta_{HS} + \theta_{JC})\, P_d$$

or

$$\theta_{HS} = \frac{T_J - T_A}{P_d} - \theta_{J-C}$$

where $T_J = 150^\circ$ C, $\theta_{J\text{-}C} = 2^\circ$ C/W, and P_d is the maximum power dissipation in the output device.

During ac operation, each output device dissipates power in a pulsed mode. Because the junction temperature must be limited to 150° C, it is necessary to consider both the average power dissipated, which charges the thermal capacitance of the output device assembly, and the peak power dissipation. However, for ac operation the frequency is greater than 40 Hz and each power pulse dissipated in the output device has a duration less than 10 milliseconds. Therefore, the thermal resistance can be reduced to 32 per cent during the pulse. The final equation for junction temperature is

$$T_J = T_C + \theta_{J\text{-}C} \times P_d + 0.32\, \theta_{J\text{-}C}\, P_{d(peak)}$$

In the case of a sine wave, the peak power $P_{d(peak)}$ is 2.5 times the steady-state power P_d; therefore

$$T_J = T_C + 1.8\, \theta_{J\text{-}C}\, P_d$$

Because the heat sink conducts the same average power from each transistor, the following equation is used to determine the heat-sink characteristics:

$$T_C = T_A + \theta_{HS} \times 2\, P_d$$

By substitution of known values, this equation can be solved for thermal resistance of the heat sink as follows:

$$\theta_{HS} = \frac{150 - T_A}{2\, P_d} - 1.8$$

This relationship is shown in **Fig. 8** with ambient temperature T_A as a parameter.

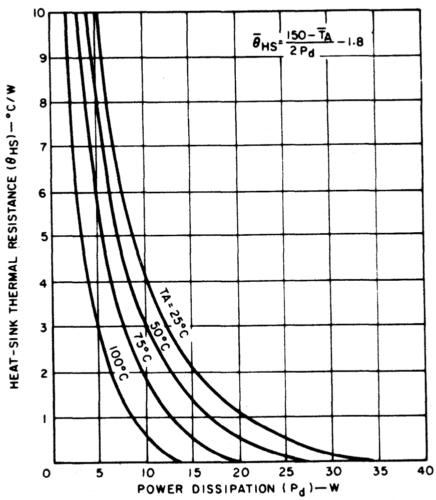


Figure 8 — Heat-sink thermal resistance as a function of power dissipation at various ambient temperatures.

Assembly

Because of the physical size and shape of the HC1000, a flat-back type of heat sink is the simplest type for assembly purposes. Two recommended types are the Thermalloy Model 6157 and the Wakefield A-1527. Improved thermal conduction can be achieved by positioning the module so that the center line of the mounting holes is parallel to the heat-sink fins. Recommended torque with 1/4-20 mounting bolts is 24 inch-pounds.

The simplest form of connection is to solder wires to the tinned ribbon leads of the module and then insulate each connection with a sleeve. **Fig. 9** shows a connection method which utilizes standard AMP receptacles. For cleaning purposes, the recommended type of agent is Freon TF or Freon TP35 Isopropynol blend.

The 10-microhenry coil shown in **Fig. 1** is a Miller 4622 for 1.5-ampere-rms loads or a Miller 5220 for 5-ampere-rms loads. This coil can also be assembled on a 20,000-ohm-or-larger 2-watt carbon composition resistor with 40 turns of copper wire of a suitable gauge.

In mounting the HC1000 to a heat sink, it is advisable to use a silicone grease or silicone heat-sink compound such as Dow Corning 340.

In some instances, long wire lengths and extraneous feedback signals may cause the amplifier to oscillate. This condition can be corrected by connecting 0.05-microfarad, 50-volt ceramic bypass capacitors from the amplifier supply terminals 1 and 10 and from output terminal 4 to ground.

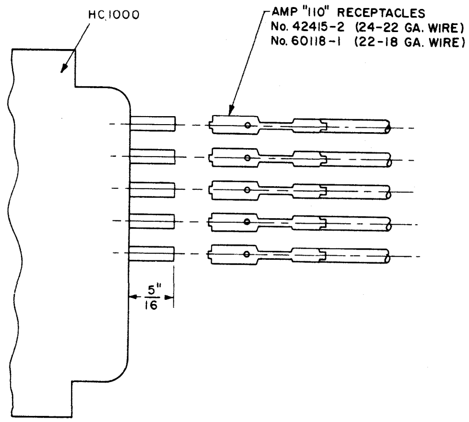
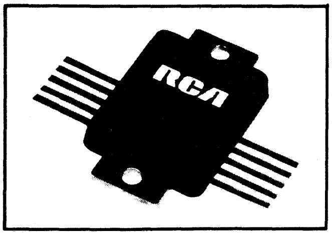


Figure 9 — Connection method for type HC1000 using standard AMP Receptacles

RCA
Solid State
Division

Power Hybrid Circuits

Application Note
AN-4782



General Application Considerations for the RCA-HC2000 Power Hybrid Operational Amplifier

by J. Nappe

The RCA-HC2000 is a power hybrid operational amplifier that can deliver 100 watts rms to a 4-ohm load at a maximum peak current of 7 amperes. It operates from a maximum power-supply voltage of ±75 volts (single ended) or ±37.5 volts (split). The low-profile package is light in weight and can be used with either printed-circuit-board connections or commercially available 0.110-inch quick-disconnect push-on terminals. The HC2000 is similar in construction and performance to the RCA-HC1000 hybrid linear amplifier. This Application Note briefly describes the major differences between the amplifiers and discusses some general application considerations for the HC2000; some of these considerations apply to the HC1000 as well.

CIRCUIT DESCRIPTION

A schematic diagram of the HC2000 circuit is shown in Fig. 1. The circuit consists of an input differential amplifier (Q1, Q2, and Q3), a class A amplifier stage (Q4 and Q5), and a class B quasi-complementary output section (Q8 through Q11). A detailed functional description of the basic circuit is given in RCA Application Notes AN-4474 and AN-4483.

Fig. 2 is a schematic diagram of the HC1000; it is included here to illustrate the subtle but significant differences between the HC1000 and the HC2000. The circuit for the HC1000 was modified as follows to produce the HC2000 circuit:

1. The internal feedback resistor R9 was brought out to terminal 2, and R10 was eliminated to permit the base of Q2 to be connected directly to terminal 9. These changes converted the HC1000 circuit from a fixed-voltage-feedback amplifier into the general-purpose HC2000 operational amplifier. Fig. 3 is a symbolic comparison of the two devices.
2. R24 was added to reduce crossover distortion at low output power levels.

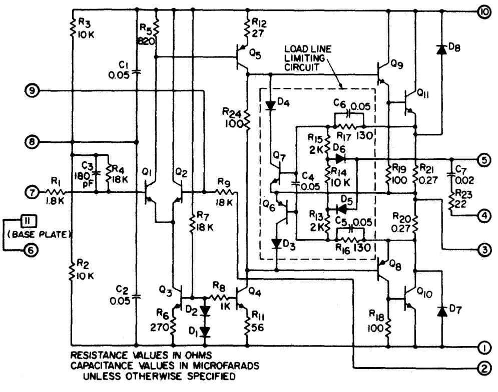
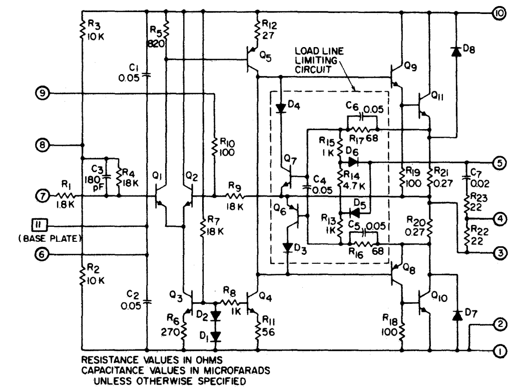


Fig. 1— Schematic diagram of the RCA-HC2000 power hybrid circuit operational amplifier.



**CAUTION: THE EXTERNAL DC RESISTANCE BETWEEN LEADS 3 AND 4 MUST BE MAINTAINED AT 0.5Ω OR LESS IN ORDER TO PROTECT R_{22} FROM EXCESSIVE DISSIPATION AND POSSIBLE DAMAGE. CARE SHOULD BE TAKEN TO INSURE GOOD ELECTRICAL CONNECTIONS TO LEADS 3 AND 4

Fig. 2— Schematic diagram of the RCA-HC1000 power hybrid circuit amplifier.

3. The base plate (terminal 11) was isolated from the circuit. This change was made by disconnecting terminal 6 from the center point of C1 and C2; in the HC2000, terminal 6 is connected to the base plate, and the C1-C2 center point is connected to terminal 8.
4. R22 was removed, allowing some circuit flexibility in the stability network.

These changes allow the HC2000 to be used in a wider range of applications than the HC1000. The HC2000 can perform all of the functions possible with the HC1000, but a direct replacement is not possible (without some minor modifications) because the two circuits have different terminal configurations.

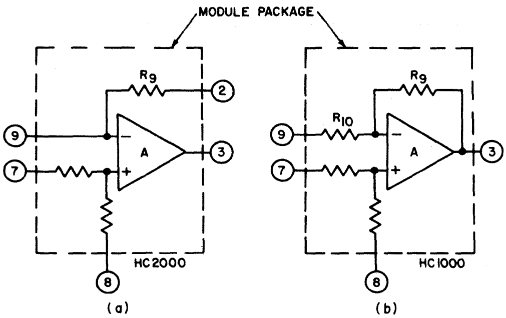


Fig. 3— Symbolic comparison of (a) the HC2000 and (b) the HC1000.

ELECTRICAL CHARACTERISTICS

Frequency Response

The HC2000 has an open-loop voltage gain (20 log V_{out}/V_{in}) of approximately 75 dB, and provides good performance in most high-power applications. The typical open-loop frequency response curve for the HC2000 is shown in Fig. 4. Phase compensation is provided by both internal and external elements. The internal elements are C3 at the input, and C7 and R23 at the output, as shown in Fig. 1. The external phase-compensation elements are an 8-microhenry choke and a 22-ohm resistor at the output, shown between terminals 3 and 4 of the audio amplifier in Fig. 5. The closed-loop phase response of the circuits in Fig. 5 is shown in Fig. 6.

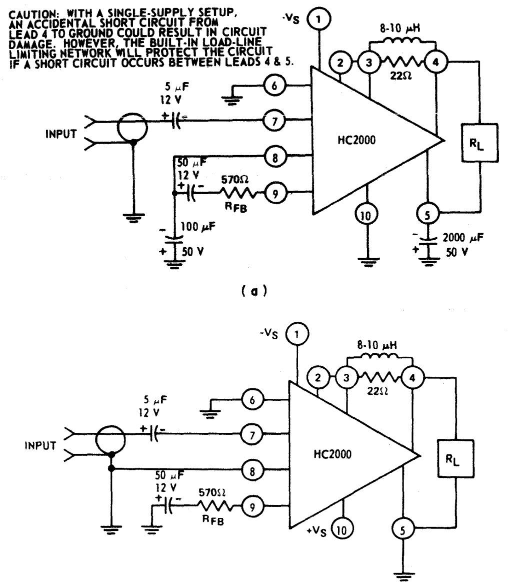


Fig. 5— Audio amplifier circuits that use the HC2000 with (a) a single power supply, and (b) a split power supply.

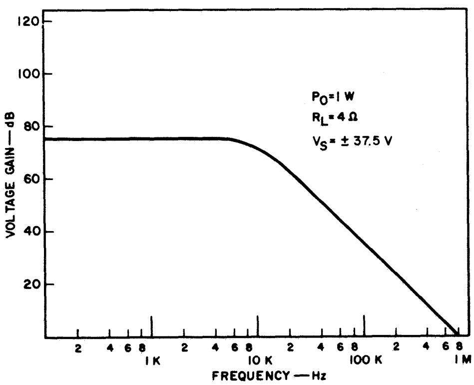


Fig. 4— Open-loop voltage gain as a function of frequency for the HC2000.

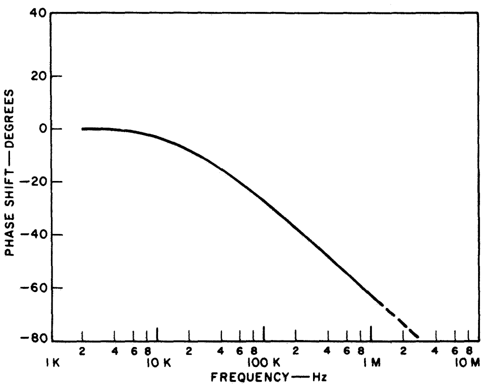


Fig. 6— Phase shift as a function of frequency for an audio amplifier using the HC2000 with phase compensation, as shown in Fig. 5.

Despite the phase compensation, some loads and methods of wiring external components can produce extraneous feedback signals that cause the amplifier to oscillate. In most cases, addition of 0.05-microfarad bypass capacitors from supply terminals 1 and 10 to ground and from output terminal 4 to ground will correct this condition.

Offset Voltage

The offset voltage of the HC2000 is typically ±30 millivolts; the maximum offset is ±250 millivolts. The offset-voltage drift is typically 0.5 millivolts per ^{o}C, with a maximum value of 0.7 millivolts per ^{o}C. In most high-power applications of the HC2000, the error introduced by offset voltage is not significant and can usually be neglected. The major problem with offset voltage is the high dc current that can be generated if a low dc impedance is connected to the output terminals. In many applications, transformer coupling is used to reduce the load impedance presented to the amplifier; under these circumstances, the dc resistance of the primary winding can be extremely low. Direct coupling of the primary to the amplifier can result in a dc current that saturates the output and prevents the circuit from functioning properly.

RCA Application Note AN-4474 discusses several methods that can be used to eliminate offset voltage. In many cases, the most practical way is to use the arrangement shown in Fig. 7 to zero the offset, with either the noninverting terminal as the input (as shown) or the inverting terminal (terminal 9) as the input. With this circuit, offset-voltage drift with temperature may still present some problems and should be analyzed for the specific application.

The value of offset drift is calculated from the offset voltages at each temperature extreme, assuming a linear relationship. With the circuit shown in Fig. 7, this linear drift is 0.5 millivolts per ^{o}C over the temperature range from -40^{o}C to +100^{o}C. The actual drift is less than this linearly-interpolated value at temperatures close to the zeroing temperature, so the approximation is conservative in that range.

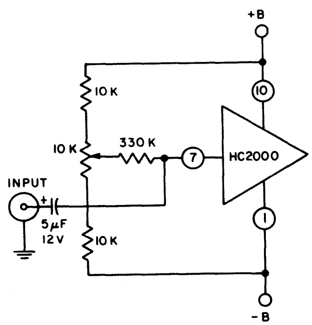


Fig. 7– Offset-voltage balancing network for use with HC2000.

Crossover Distortion

Crossover distortion at low output levels is a major concern in high-quality audio applications and deflection systems. In the HC2000 the small resistor R24 in the class A stage is in series with the current source Q4. The dc current through R24 provides a small bias voltage for the output section to reduce the crossover distortion. Some temperature compensation is provided by D2 and D1.

Output Power vs. Supply Voltage

In the output-section Darlington configuration, some losses can occur because of incomplete saturation of the output section. The voltage drops across Q11, Q9, Q5, R21, and R12 (considering just the positive half-cycle for illustration) can be significant, and will vary with the output current level. At low current levels the minimum drop can be between 2.5 and 3 volts; at higher levels, 4 to 5 volts can be dropped between the output and the supply. To optimize the performance of the HC2000, the load and the supply voltage should be selected to provide the required output with minimum loss in the output section. Fig. 8 shows the maximum output power as a function of supply voltage for various loads. These curves provide a good estimate of the optimum operating conditions.

RCA INTEGRATED CIRCUITS AND THE HC2000

A number of available RCA integrated circuits (IC's) can be used with the HC2000 to provide compact, cost-effective, reliable systems. In most cases, no special interfacing is required other than a coupling capacitor. RCA IC operational amplifiers such as the CA3015A, CA3033A, CA3060A, CA3056A/741, and CA3031/702A have been used to drive both the HC2000 and the HC1000. In the audio field, multiple-amplifier IC's such as the CA3048, CA3052, and CA3035 are useful for hybridizing a stereo system and can be combined with the HC2000 with a minimum amount of design time. A typical circuit arrangement for one channel is shown in Fig. 9.

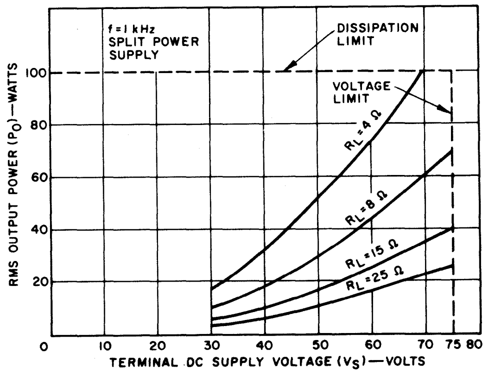


Fig. 8– Output power as a function of supply voltage, with various values of load resistance, for symmetrical sine-wave operation of the HC2000.

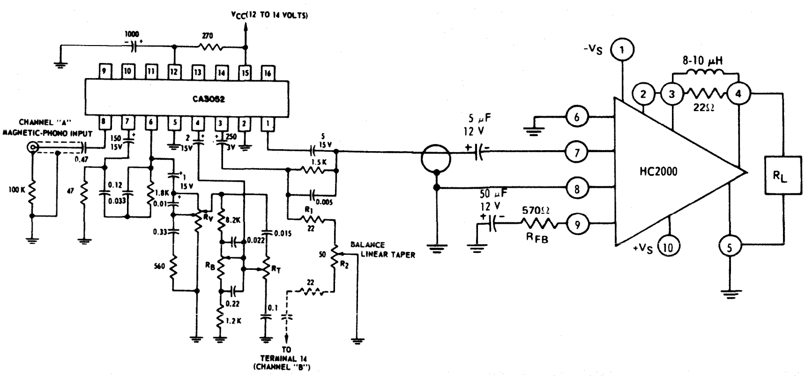


Fig. 9— One channel of a typical phonograph amplifier that uses the RCA-CA3052 for the preamplifier and the RCA-HC2000 for the power amplifier.

CONSTANT-CURRENT-SOURCE AMPLIFIER

Many motor-control and magnetic-deflection applications require constant programmable current of a fairly high value. The HC2000 can be used in this type of application at peak currents up to 7 amperes. For the basic operational-amplifier source configuration shown in Fig. 10, the load current is independent of the load impedance (as shown in the Appendix); the load voltage is a function of the load impedance and is bound only by the limits of the amplifier. Under these conditions, the extreme load variations should be clearly defined to prevent damage to the load and/or the operational amplifier.

In most cases, the HC2000 is protected by the load-line-limiting network when operated in the constant-current-source configuration. When the load impedance is low and has sufficient inductive reactance to activate the protection network, however, large voltage spikes can be generated in the load. For some values of spike duration and output current level at the time of spiking, these spikes can cause a catastrophic failure of the HC2000. Fig. 11 shows the safe area of operation for inductive load impedances and the phase angles associated with those impedances. Operation outside of this region is not recommended.

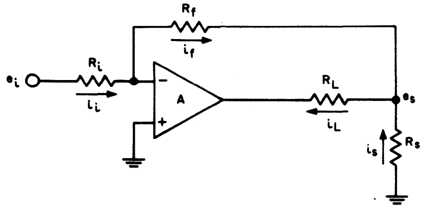


Fig. 10— The HC2000 used as a constant-current source.

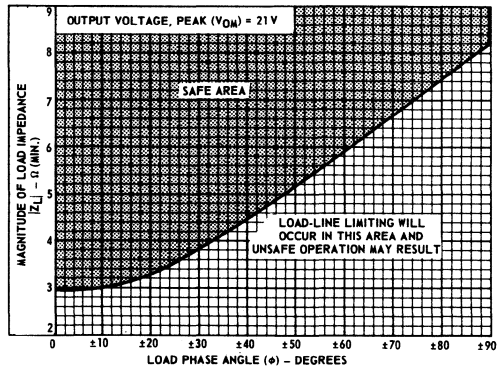


Fig. 11— Minimum load impedance as a function of load phase angle, and safe area of operation, for HC2000.

A typical circuit that uses an RCA-CA3030A in the voltage-gain mode and the HC2000 as a constant-current source is shown in Fig. 12. The over-all system provides a voltage gain of 34 dB, a current gain of 120 dB, and a transfer conductance ratio (I_{out}/V_{in}) of 0.1 ampere per millivolt. The current source has a dc output impedance of approximately 1300 ohms and can handle peak currents up to 7 amperes.

POWER-SUPPLY CONSIDERATIONS

Although the HC2000 can operate from an unregulated power supply without significant degradation in performance, a regulated supply should be used whenever possible. At fixed output level a decrease in supply voltage may cause clipping of the output, and a voltage increase raises the power dissipation in the module. In many applications, a compromise can be made between these two undesirable effects and a relatively inexpensive supply such as the one shown in Fig. 13 can be used.

TYPICAL APPLICATIONS

Typical applications of the RCA-HC2000 operational amplifier are illustrated in Fig. 5 and in Figs. 14-16. Figs. 14 and 15 show inverting unity-gain amplifiers with internal and external feedback, respectively. Fig. 16 shows a non-inverting unity-gain amplifier.

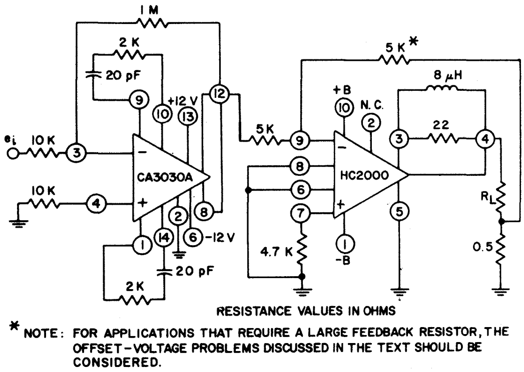


Fig. 12— The HC2000 connected as a constant-current source for servo motor control or deflection amplifier.

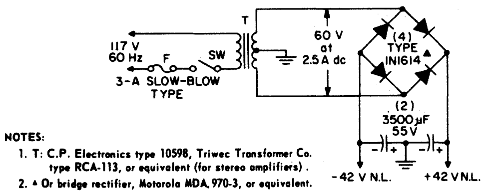


Fig. 13— A power supply for the HC2000.

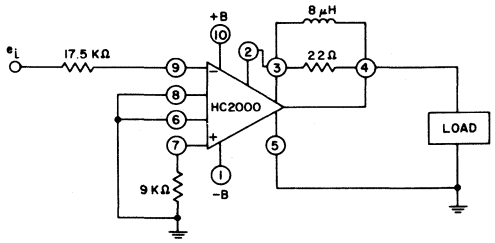


Fig. 14— Inverting unity-gain amplifier using internal feedback resistor.

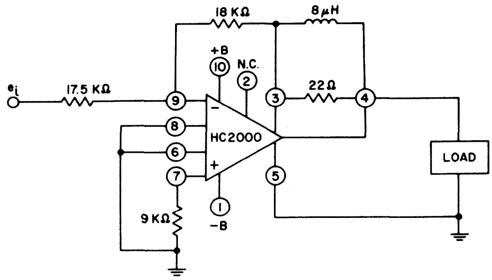


Fig. 15— Inverting unity-gain amplifier using external feedback resistor.

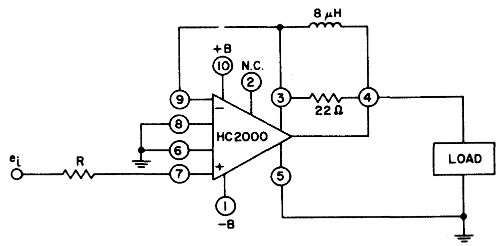


Fig. 16— Non-inverting unity-gain amplifier.

APPENDIX

To show that load current is independent of load impedance for the operational-amplifier current source, the following equations are written for the circuit shown in Fig. 10:

$$i_f = i_i \quad (1)$$

$$e_s = -i_f R_f = -i_i R_f \quad (2)$$

$$i_L = i_f + i_s = i_i + i_s \quad (3)$$

$$i_s = e_s / R_s \quad (4)$$

(In these equations the subscripts i, f, L, and s indicate input, feedback, load, and sensing quantities, respectively.) The term e_s can be eliminated by substitution of Eq. (2) into Eq. (4):

$$i_s = -\frac{i_i R_f}{R_s} \quad (5)$$

This expression for i_s can be used in Eq. (3) to find an expression for $\frac{i_L}{i_i}$:

$$i_L - i_i = -i_i \frac{R_f}{R_s} \quad (6)$$

$$i_L = i_i - i_i \frac{R_f}{R_s} \quad (7)$$

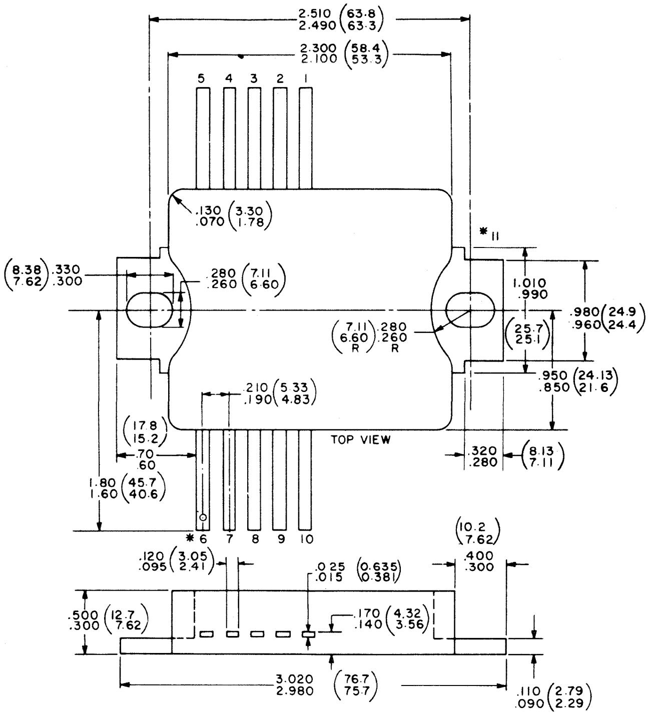
$$i_L = i_i \left(1 - \frac{R_f}{R_s}\right) \quad (8)$$

$$\frac{i_L}{i_i} = 1 - \frac{R_f}{R_s} \quad (9)$$

If $R_s << R_f$, then $\frac{R_f}{R_s} >> 1$ and

$$\frac{i_L}{i_i} = -\frac{R_f}{R_s} \quad (10)$$

The input current i_i is fixed by input voltage e_i and input impedance R_i; thus Eq. (10) shows that the load current i_L is independent of the load impedance R_L.



* TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY
DIMENSIONS IN INCHES AND MILLIMETERS
(MILLIMETER VALUES IN PARENTHESES)

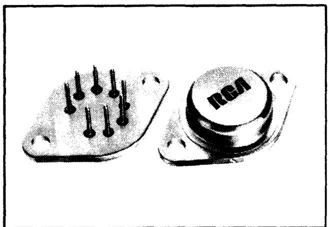
Fig. 17– Dimensional outline of RCA-HC2000.

RCA

Solid State Division

Power Hybrid Circuits

Application Note AN-6026



Application Considerations for Hybrid Series Voltage Regulators

by W. R. Peterson

This Note describes a series of hybrid voltage regulators that can supply 5, 12, or 15 volts while delivering up to 4 amperes. These circuits, the RCA-HC4000 family, use a series pass element for regulation, and include both self-protection (foldback) and load-protection (crowbar-trigger) networks. The foldback network protects the circuit against over-currents that would otherwise result from load-resistance decreases, either transient or steady state (catastrophic). The crowbar protection makes these circuits especially well suited for supplying a regulated voltage to loads that may be sensitive to over-voltage and expensive to repair or replace. Such loads include, for example, the logic circuits used in most computer and data-terminal applications.

CIRCUIT DESCRIPTION

The circuit of the RCA-HC4000 family, shown in Fig. 1, includes an integrated-circuit voltage regulator, ballast resistors for the internal pass transistor and for external pass transistors, the foldback circuit, and the crowbar trigger circuit.

Integrated-Circuit Voltage Regulator

Regulation, stability, and temperature compensation are achieved by use of the RCA-CA3085AH integrated-circuit voltage regulator chip. Because the CA3085AH is limited to a supply voltage of 40 volts and a feedback voltage to the inverting input of 1.6 volts, the regulated output voltage is limited to the range from 2 to 32 volts.

Resistors R2 and R3 set the output voltage because their junction provides the inverting input signal, which is approximately 1.6 volts. The regulator supplies current to the load so that the load (output) voltage is divided by resistors R2 and R3 to 1.6 volts at the inverting input. If the load resistance changes, the regulator changes the output current. The regulating action can be described as follows: because the regulator cannot change the load current instantaneously, an increase of load resistance causes an increase of output voltage. Consequently, transistor Q6 conducts more collector current. As a result, the base current of transistor Q13 decreases; the load current then decreases, and returns the output voltage to normal.

Ballast Resistors

The values of ballast resistors R4, R8, and R9 are selected to satisfy two conditions: (1) the voltage drop across each resistor at rated current must be approximately 450 millivolts; and (2) the current conducted by each external pass element must be 1.5 times the internal pass element current. Because the transconductance of the power transistors is nonlinear, the ratio of the internal to external ballast resistors is actually 1.8. With the ballast resistors set at R4 equal to 0.165 ohm and R8 and R9 equal to 0.09 ohm, respectively, current levels are within 15 per cent of design values.

Foldback Current Limiting

Foldback current limiting is included in the HC4000 circuit to keep power dissipation within safe limits when the load resistance falls below the rated level, as shown in Fig. 2. The main advantage of foldback limiting is that the ratio of maximum power dissipation in the pass transistor during normal regulation to the maximum power dissipated during the foldback mode is typically 0.9; a conventional current-limiting circuit would require the pass transistor to conduct the rated current for all excessive loads, including shorted loads.

As indicated in Fig. 1, the foldback circuit consists of transistor Q3 and resistors R1, R6, and R7. Transistor Q3 senses the voltage across the legs of a bridge formed by resistors R6 and R7 on one side and the base-to-emitter voltage V_{BE} of transistor Q4, resistor R4, and the load resistance on the other side. Voltage V_{BE} of Q4 is included because it increases with collector current, and thus increases the circuit sensitivity. When transistor Q3 senses an overload, it conducts current away from the base of transistor Q13. This effect reduces the base drive to transistor Q2 and subsequently the voltage drop across the undersize load resistor. The voltage feedback condition reaches a stable

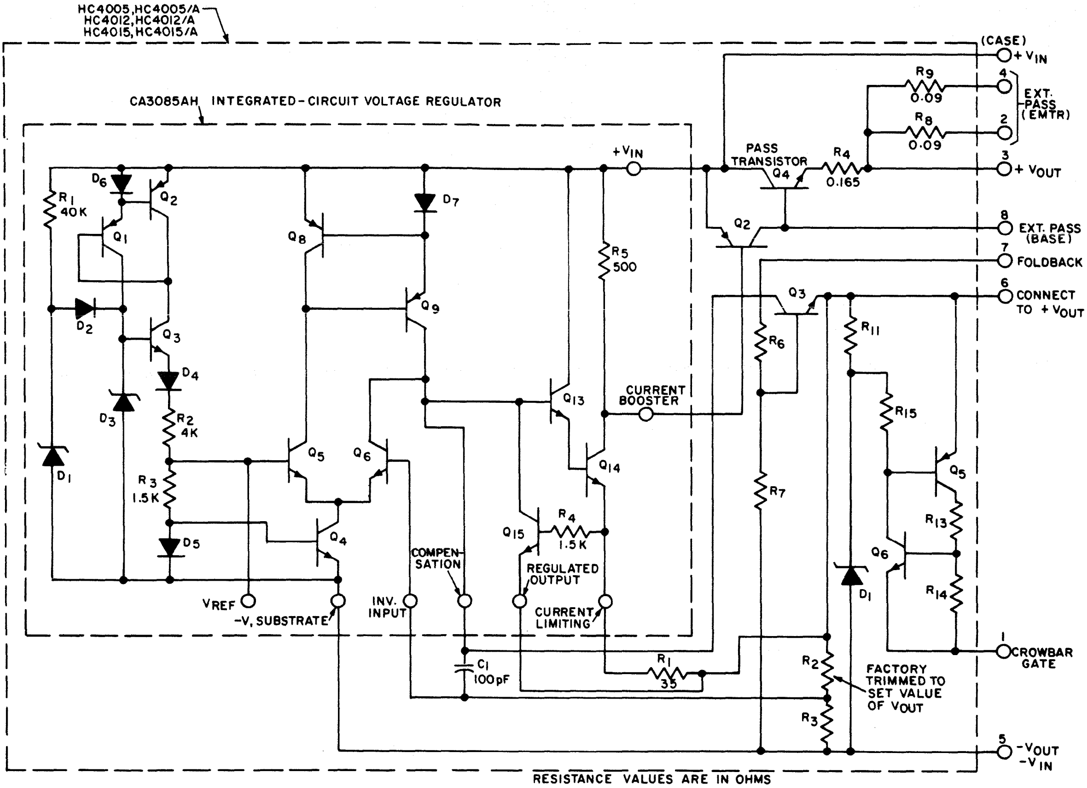


Fig. 1— Schematic diagram of the RCA-HC4000 family of series voltage regulators.

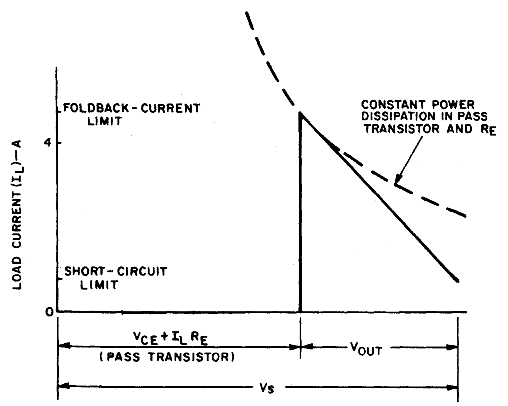


Fig. 2— Characteristic of the foldback protection circuit in RCA-HC4000 family of voltage regulators.

point on the foldback characteristic that corresponds to the load resistance. Additional protection of transistors Q13 and Q14 is achieved by activation of the current-limiting transistor Q15, which turns on when the current through R1 reaches 20 milliamperes.

Crowbar Trigger Circuits

The crowbar trigger circuit provides gate current to an external silicon controlled rectifier (SCR) in response to an over-voltage of 130 per cent of the output value. This over-voltage may result from a spike generated by the load, from the supply, or from a short-circuited pass element. Resistor R11 and zener diode D1 provide a stable reference voltage. The voltage at the junction of these components is compared to the output voltage by transistor Q5. If an over-voltage occurs, transistor Q5 turns on and provides base current to Q6, which also turns on. This condition is regenerative; the collector currents of Q5 and Q6 are limited only by resistor R13, which limits the base current to Q6 and therefore its collector current. Resistor R14 provides a leakage path for the collector-base junction of Q6. The crowbar output, terminal 1, is connected to the gate of an appropriate SCR. The output current always falls within the 100- to 500-milliampere range, with a typical rise time of 0.5 microsecond.

Once the SCR is turned on, the voltage across the trigger circuit is reduced to the forward voltage drop of the SCR. If the SCR fails to turn on (because of an open anode connection, for example), the crowbar trigger circuit dissipates a large amount of power P_d, determined by the following equation:

$$P_d = V_o I_G \qquad (1)$$

where V_o is the output voltage and I_G is the SCR gate current.

The trigger circuit is capable of dissipating 750 milliwatts at case temperatures up to 75°C. If it is anticipated that the power or the temperature will exceed these values, an external resistor should be connected in series with terminal 1 to limit the internal dissipation.

BASIC STRUCTURE

The basic regulator structure consists of three separate subassemblies mounted in an "eight-lead TO-3" package, as shown in Figs. 3, 4, and 5. The power pass element is mounted on a copper heat sink attached directly to the header base, and has a thermal resistance of approximately 2°C per watt. The drive circuit is mounted on the base or lower substrate and the crowbar is mounted on the upper substrate.

The base substrate is attached to the header by a thermally and electrically conductive epoxy. Electrical interconnection to the module is accomplished by reflow-soldering of solder-coated eyelets. The crowbar substrate is supported on these eyelets and electrically interconnected to the module by a reflow-soldering of solder-coated washers.

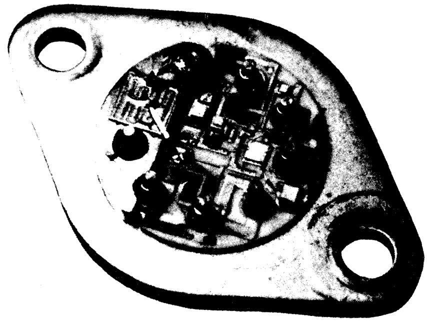


Fig. 4— The base substrate assembled to an output.

Additional interconnections among the three subassemblies are provided by three soldered clips and straps.

Two primary considerations determine the maximum allowable temperature of power hybrids: reliability, and material limitations. Usually, the most significant material limitation is a low-melting-point solder. However, extensive life studies have shown that the temperature of the thick-film substrate should not exceed 125°C; therefore the temperature limit of the HC4000 family of regulators is determined by reliability considerations.

The effect of lateral heat flow from the power transistor to the thick-film substrate is illustrated in Fig. 6. The junction temperature of pass transistor Q4 is 150°C (as a result of 30 watts dissipation and a heat-sink temperature of 85°C). The dissipation in Q4 causes the junction of Q2 to rise to 125°C, and also causes other components on the substrate to heat up. Because there is no source of appreciable thermal energy on the substrate, the tempera-

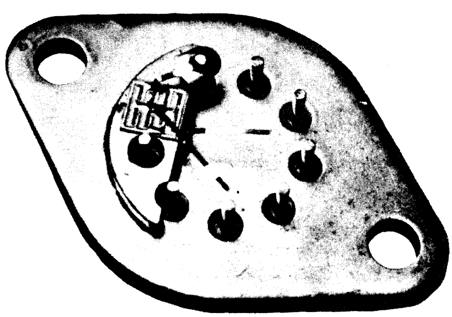


Fig. 3— Output assembly.

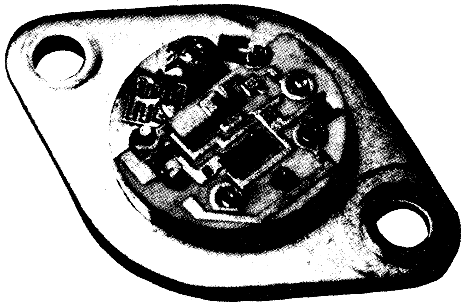


Fig. 5— Regulator module with the crowbar circuit in place just before sealing.

tures of the components on the substrate are determined by the temperature of the heat sink on which the regulator is mounted, and by the proximity of the components to the pass transistor. The integrated circuit (IC) is located in a cooler area of the substrate; this location minimizes output voltage drift during warm-up, because the temperature excursion of the IC is held to 75°C.

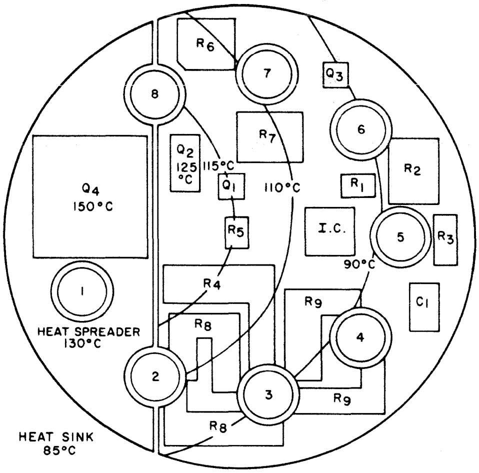


Fig. 6— Maximum operating temperature levels of the base-header assembly.

ANALYSIS OF FOLDBACK CIRCUIT

The cut-in, slope, and short-circuit levels of the foldback circuit can be derived from Fig. 7, which indicates the bridge concept of the circuit. The cut-in current can be determined from the following equation:

$$V_{BEQ3} = \frac{R_7}{R_6 + R_7} \left[V_{BEQ4} + I_L (R_4 + R_L)\right] - I_L R_L \quad (2)$$

where I_L is the cut-in current through R_L. Although the transconductance curve (Fig. 8) for the output pellet is nonlinear, the segment of interest is reasonably linear and can be expressed by

$$V_{BEQ4} = K_1 + K_2 I_L \quad (3)$$

Because the output voltage is still being regulated just before cut-in,

$$I_L R_L = V_o \quad (4)$$

Substitution of Eqs. (3) and (4) into Eq. (2) yields the following expression for I_L:

$$I_L = \frac{V_{BEQ3} + V_o - (K_1 + V_o)\dfrac{R_7}{R_6 + R_7}}{(K_2 + R_4)\dfrac{R_7}{R_6 + R_7}} \quad (5)$$

For a typical 5-volt regulator, the cut-in current is given by:

$$I_L = \frac{0.55 + 5.0 - (0.69 + 5.0)\dfrac{4.2K}{5.0K}}{(0.0525 + 0.165)\dfrac{4.2K}{5.0K}} = \frac{5.55 - 4.76}{0.183}$$

$$= 4.32 \text{ amperes}$$

The short-circuit current cannot be determined from Eq. (4) because the base-emitter junction of transistor Q3 clamps the voltage across R7. The expression for the short-circuit current can then be written as follows:

$$I_{LSC} = \frac{\left(\dfrac{V_{BEQ3}}{R_7} + I_{BQ3}\right) R_6 + V_{BEQ3} - K_1}{K_2 + R_4} \quad (6)$$

where I_{BQ3} has been determined empirically as 320 microamperes for a typical 5-volt regulator. Thus the short-circuit is given by:

$$I_{LSC} = \frac{\left(\dfrac{0.55}{5} + 0.32\right) \times 8 + 0.55 - 0.69}{0.2175} = 0.96 \text{ ampere.}$$

The slope of the foldback characteristic then is expressed as follows:

$$\frac{I_{LCI} - I_{LSC}}{V_o} = \frac{R_6}{R_7 (K_2 + R_4)} - \frac{I_{BQ3} R_6}{V_o (K_2 + R_4)} \quad (7)$$

The foldback cut-in current level can be set at values from 4.0 to 4.8 amperes, which is the upper limit for the practical range of use. However, in certain instances where the limits of temperature, power dissipation, and heat-sink thermal resistance are accurately known and where currents up to 6 amperes are necessary, the foldback sensitivity can be reduced. This reduction is achieved by inserting an external resistance in series with terminal 7. Effectively, R6 is increased and the amount by which the cut-in current is increased can be predicted from Eq. (5) or can be found experimentally.

The limit of 6 amperes is necessary because the h_{FE} of the pass transistor drops considerably as the current increases from 4 amperes to 6 amperes, creating a borderline current level on the driver. Resistor R1 limits the load current at 6.5 amperes, although its primary function is to protect the integrated circuit from excessive currents encountered during overload. Because current-limiting results in high power dissipation, the external resistor should be trimmed for cut-in at 6.1 amperes or less when the regulator is used to deliver currents between 4.0 and 6.0 amperes.

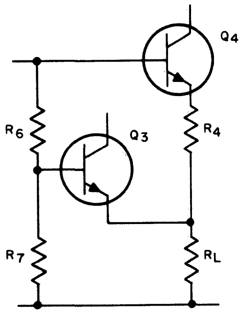


Fig. 7— Foldback bridge circuit.

POWER DISSIPATION

Maximum allowable power dissipation for steady-state operation of the HC4000 is calculated as follows:

$$P_d(max) = \frac{T_J(max) - T_C}{R_{\Theta JC}} \quad (8)$$

where the maximum junction temperature T_J (max) is 150°C, the case temperature T_C is 25°C, and the junction-to-case thermal resistance $R_{\Theta JC}$ is 2°C/W. P_d(max), therefore, is 62.5 watts.

Actual power dissipation, P_d, is given by

$$P_d = V_{CE} I_C \quad (9)$$

where V_{CE} is the operating collector-to-emitter voltage and I_C is the average collector current.

The p-n-p drive transistor Q2 can be used to provide drive current for external booster transistors; the additional power dissipation caused by this mode of operation must be limited to a safe value. Power dissipation in the drive transistor can be calculated as follows:

$$P_{dDR} = I_{DR} [V_S - (V_o + 0.165 I_{Q4} + 0.9)] \quad (10)$$

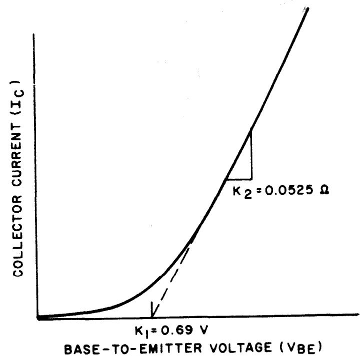


Fig. 8— Transconductance characteristic of pass transistor.

where I_{DR} is the base current supplied to the external boosters and V_S is the voltage supplied to the hybrid circuit. Fig. 9 shows the allowable power dissipation in Q2 as a function of its case temperature.

The worst-case power dissipation in the regulator occurs during foldback operation. Fig. 10 illustrates the foldback characteristic superimposed on the pass transistor characteristic. Power dissipation along the foldback characteristic can be determined from the following equation:

$$P_d = I_C V_{CE} = I_C [V_S - K_3 (I_C - I_{SC})] \quad (11)$$

where

$$K_3 = \frac{V_o}{I_{FB} - I_{SC}} \quad (12)$$

The maximum value of P_d can be found by equating its derivative to zero:

$$\frac{dP_d}{dI_C} = V_S - 2K_3 I_C + K_3 I_{SC} = 0 \quad (13)$$

$$I_C = \frac{V_S + K_3 I_{SC}}{2K_3} \quad (14)$$

$$P_{d(max)} = \frac{V_S^2}{4K_3} + \frac{V_S I_{SC}}{2} + \frac{K_3 I_{SC}^2}{4} \quad (15)$$

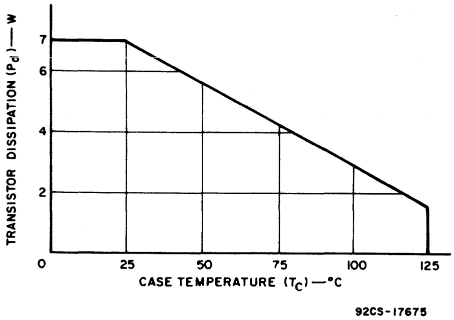


Fig. 9— Allowable power dissipation in driver transistor Q2 due to external drive current.

In a typical application, V_o is 12 volts, V_S is 16 volts, I_{FB} is 4.4 amperes, and I_{SC} is 1.0 ampere. Then

$$K_3 = \frac{12}{4.4 - 1.0} = 3.5$$

$$P_{d(max)} = \frac{16^2}{4 \times 3.5} + \frac{16 \times 1.0}{2} + \frac{3.5 \times 1.0^2}{4} = 27.2 \text{ watts}$$

$$I_C = \frac{16}{2 \times 3.5} + \frac{1.0}{2} = 2.8 \text{ amperes}$$

$$V_{CE} = V_S - K_3(I_C - I_{SC}) = 16 - 3.5\,(2.8 - 1.0) = 9.7 \text{ volts}$$

This operating condition is shown in Fig. 10. Obviously, $P_{d(max)}$ will occur at the foldback cut-in point for large values of V_S. The boundary condition for this value of $P_{d(max)}$ occurs at the level where I_C is equal to I_{FB}, which is 4.4 amperes in this example.

The thermal resistance from case to ambient, $R_{\Theta CA}$, can be determined from the following equation:

$$T_J = T_A + (R_{\Theta CA} + R_{\Theta JC})\, P_d \quad (16)$$

$$R_{\Theta CA} = \frac{T_J - T_A}{P_d} - R_{\Theta JC} \quad (17)$$

where T_J is 150°C, $R_{\Theta JC}$ is 2°C per watt, and P_d is the maximum power dissipation in the regulator for steady-state conditions that have a duration exceeding 4 seconds. This relationship is shown in Fig. 11 with ambient temperature T_A as a parameter. This chart can be utilized in determining the proper heat sink for each application. In some cases, the equipment chassis will be an adequate heat sink. However, lower thermal resistance can be achieved with a separate heat sink; the Thermalloy Model 6133B and Thermalloy Series 6001A-15 are recommended.

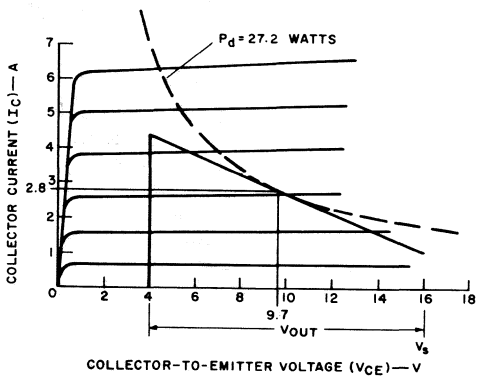


Fig. 10— Foldback and regulation load line.

OPERATING CONSIDERATIONS

Operation with External Pass Elements

The ballast resistors provide current sharing between external pass elements and the internal pass transistor. This function is shown in the 12-ampere regulator in Fig. 12, where the internal element conducts 3 amperes and each external element conducts 4.5 amperes. No serious compromise of regulator performance is caused by this method of boosting current. The external silicon controlled rectifier (SCR) for crowbar protection is also shown in Fig. 12.

Greater current capability can be achieved by utilizing the regulator in a Darlington configuration, as shown in Fig.

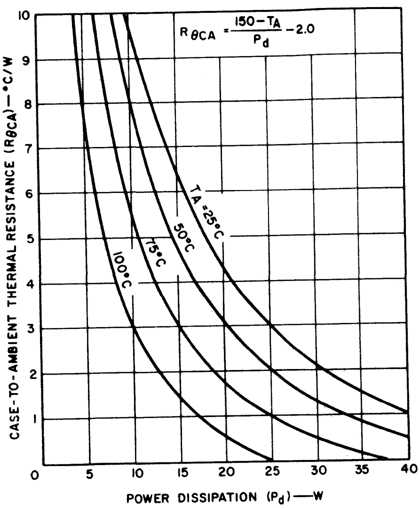


Fig. 11– Heat-sink thermal resistance as a function of power dissipation at various ambient temperatures.

13. In this design the internal pass transistor drives a group of parallel transistors, the number in the group being determined by the current- and power-handling capability of the particular type. Multiplication of the 2-ampere regulator current by a reasonable group beta of 20 yields a 40-ampere regulator. The base of the external pass transistor is connected to terminal 7, the foldback sensing terminal, instead of to terminal 8. For the foldback circuit to operate properly, the voltage from terminal 7 to terminal 6 must be 1.65 volts at cut-in. To satisfy this requirement the ballast resistors must have the correct values, determined by the transconductance of the pass transistors and the desired foldback cut-in current.

The current capability of the HC4000 family of regulators can be extended above 40 amperes by addition of the external elements that were used in the 12-ampere regulator. Fig. 14 shows this method. The number of parallel transistors must be increased to provide the necessary current- and power-handling capability.

Remote Sensing

If the regulator must be located at a distance from the load, the conductors carrying the load current may contribute a significant voltage drop. This drop can bring the voltage at the load to a level below the required regulated voltage and can increase the load regulation. To avoid this condition, the regulator can be connected for remote sensing as shown in Fig. 15. The sensing current that flows into

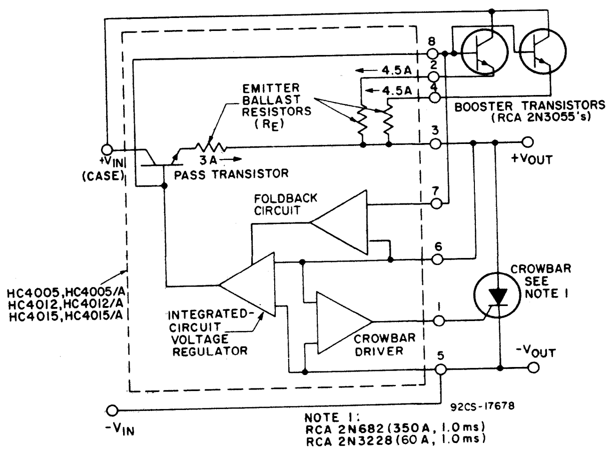


Fig. 12– RCA-HC4000 family of voltage regulator modules connected as a 12-ampere series regulator.

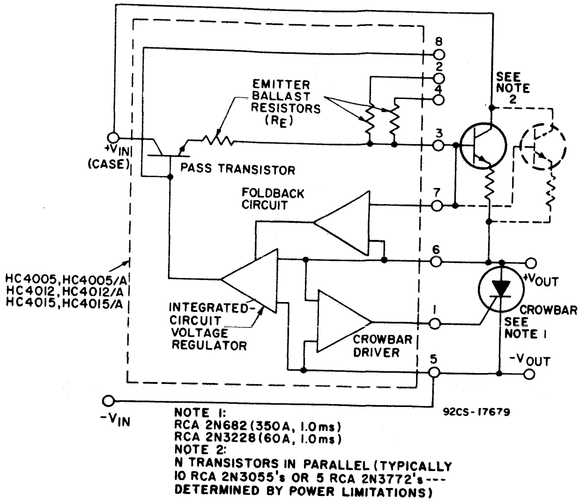


Fig. 13– RCA-HC4000 family of voltage regulator modules connected as a 40-ampere series regulator.

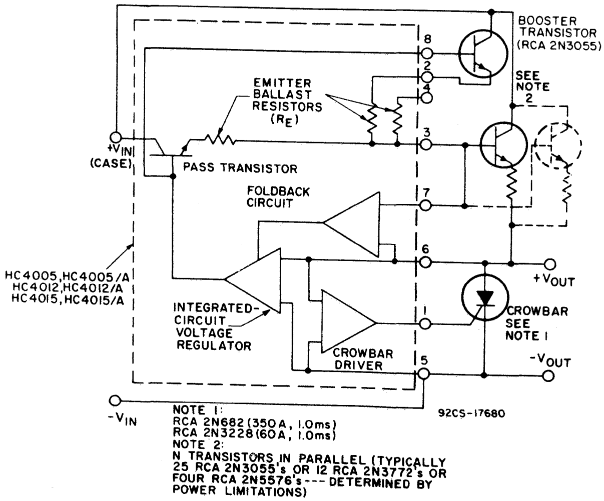


Fig. 14– RCA-HC4000 family of voltage regulator modules connected as a 100-ampere series regulator.

terminal 6 is approximately 1 milliampere, while the current flowing from terminal 5 to ground is approximately 15 milliamperes; therefore, the voltage drop in the sensing leads is small in comparison with the voltage drop in the load conductors. Effectively, the load conductor connected on the positive side of the load becomes a resistance internal to the regulator similar to the emitter ballast resistor. The load conductor on the negative side of the load becomes a small resistance in series with the supply.

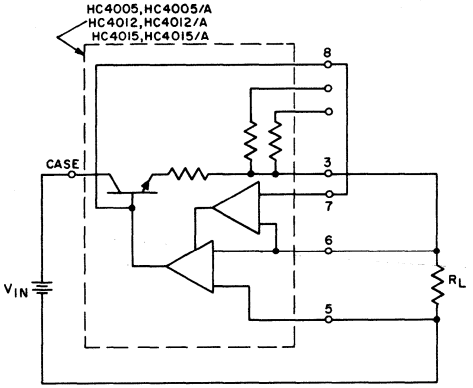


Fig. 15– Remote sensing circuit for the RCA-HC4000 family of voltage regulators.

Positive and Negative Voltage Regulation

A significant number of systems require both positive and negative voltages referenced to one particular ground. Regulated negative voltages can be provided by a negative regulator that is specially designed for that application; however the HC4000 devices, although they are positive regulators, can also provide regulated negative voltages when connected in the manner shown in Fig. 16. Regulator No. 1 provides an output voltage that is positive with respect to ground. Regulator No. 2, which is the same type of device (although any positive regulator could be used here), provides an output voltage that is negative with respect to ground. This technique requires a separate secondary winding on the power transformer to provide isolation between the two circuits.

Any number of positive regulators, regardless of output voltage, can be connected in this manner provided that there is only one common point such as ground. Use of a negative regulator eliminates the need for a separate secondary winding and full-wave bridge, but usually requires almost double current capability for the single secondary winding and full-wave bridge. For this reason, the cost of the system that uses positive and negative regulators has only a small advantage over the system that uses all positive regulators to obtain both positive and negative regulated voltages.

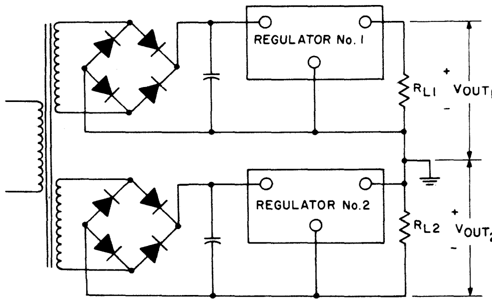


Fig. 16– Positive and negative regulation using the RCA-HC4000 family of voltage regulators.

Five-Volt Ten-Ampere Power Supply

A five-volt ten-ampere power supply is shown in Fig. 17. All of the external components were obtained from parts on hand, which explains the choice of a transformer with a 12-volt secondary. A better choice for the secondary voltage can be determined from the following equation:

$$V_{IN}(NOM) = 1.18(V_O + V_{pass}(min) + 0.5\ V_{RIPPLE}) \qquad (18)$$

This value allows a tolerance of ± 15 per cent on the average full-wave rectified secondary voltage that is identified as V_{IN}. The output voltage from this supply varies by only 2 millivolts from no-load to full-load, and by only 1 millivolt when the input voltage varies by ± 15 per cent.

Assembly and Handling

Because the collector of the power transistor in an HC4000 is connected directly to the case, some means of electrical isolation from the chassis must be provided during assembly. Isolation is usually achieved with a thin mica insulator made especially for the "8-lead TO-3" package. The resulting thermal impedance is typically 0.4°C/W.

Soldering to the terminal pins of the "8-lead TO-3" package, shown in Fig. 18, is not recommended except within the time and temperature limits specified on the data sheet. The reason for these limits is that the excellent thermal conductivity of the pins may transfer excessive heat to internal components and materials, causing immediate failure or compromising the life of the device. To avoid

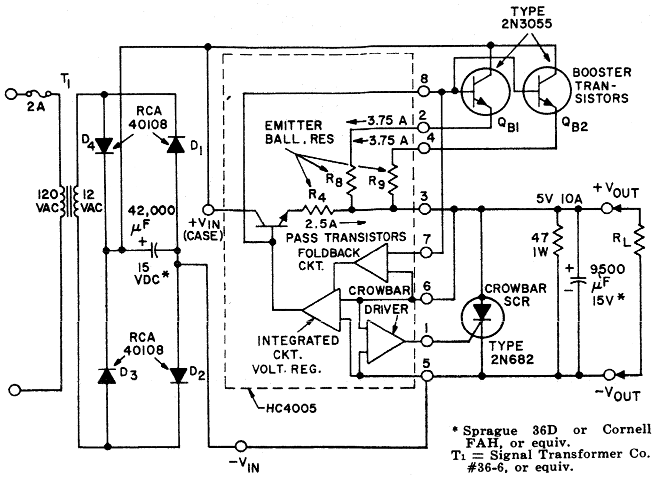


Fig. 17– A 5-volt 10-ampere supply that uses the RCA-HC4005 voltage regulator.

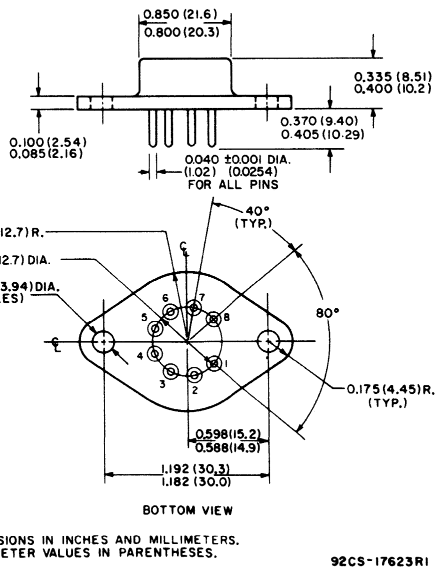


Fig. 18– The "eight-lead TO-3" package used for the RCA-HC4000 family of voltage regulators.

soldering to the pins, an "8-lead TO-3" socket* can be mounted on the heat sink or chassis, and solder connections made to the socket lugs.

For an HC4000 mounted on a heat sink, the thermal resistance can be reduced substantially by use of silicone grease or a silicone heat-sink compound such as Dow Corning 340.

*Socket RCA DF-263A.

Cutting or bending of the pins is not recommended because these operations may crack the glass seal and thus destroy the hermeticity of the package.

REFERENCES

1. R. Engler and W. Peterson, "Design Considerations for a Hybrid Power Series Regulator", Proceedings of the 21st Electronic Components Conference, May, 1971.
2. "A 60-Watt, 20-Volt Regulated Power Supply Using a Single Pass Transistor", RCA Application Note AN-4558.

Guide to RCA Solid-State Devices

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA144	RECT	1N536	3	SSD-206A	265
TA145	RECT	1N537	3	SSD-206A	265
TA146	RECT	1N538	3	SSD-206A	265
TA147	RECT	1N539	3	SSD-206A	265
TA148	RECT	1N540	3	SSD-206A	265
TA149	RECT	1N1095	3	SSD-106A	265
TA1000	RECT	1N547	3	SSD-206A	265
TA1003	RECT	1N440B	5	SSD-206A	262
TA1004	RECT	1N441B	5	SSD-206A	262
TA1005	RECT	1N442B	5	SSD-206A	262
TA1006	RECT	1N443B	5	SSD-206A	262
TA1007	RECT	1N444B	5	SSD-206A	262
TA1008	RECT	1N445B	5	SSD-206A	262
TA1011	RECT	1N2859A	91	SSD-206A	280
TA1012	RECT	1N2860A	91	SSD-206A	280
TA1013	RECT	1N2861A	91	SSD-206A	280
TA1014	RECT	1N2862A	91	SSD-206A	280
TA1015	RECT	1N2863A	91	SSD-206A	280
TA1016	RECT	1N2864A	91	SSD-206A	280
TA1049	RECT	1N248C	6	SSD-206A	326
TA1050	RECT	1N249C	6	SSD-206A	326
TA1051	RECT	1N250C	6	SSD-206A	326
TA1052	RECT	1N1195A	6	SSD-206A	326
TA1053	RECT	1N1196A	6	SSD-206A	326
TA1054	RECT	1N1197A	6	SSD-206A	326
TA1055	RECT	1N1198A	6	SSD-206A	326
TA1066	RECT	1N2858A	91	SSD-206A	280
TA1076	RECT	1N1199A	20	SSD-206A	320
TA1077	RECT	1N1200A	20	SSD-206A	320
TA1078	RECT	1N1202A	20	SSD-206A	320
TA1079	RECT	1N1203A	20	SSD-206A	320
TA1080	RECT	1N1204A	20	SSD-206A	320
TA1081	RECT	1N1205A	20	SSD-206A	320
TA1082	RECT	1N1206A	20	SSD-206A	320
TA1085	RECT	1N1183A	38	SSD-206A	332
TA1086	RECT	1N1184A	38	SSD-206A	332
TA1087	RECT	1N1186A	38	SSD-206A	332
TA1095	RECT	1N1197A	6	SSD-206A	326
TA1096	RECT	1N3194	41	SSD-206A	268
TA1111	RECT	1N3193	41	SSD-206A	268
TA1112	RECT	1N3195	41	SSD-206A	268
TA1113	RECT	1N3196	41	SSD-206A	268
TA1120	RECT	1N3253	41	SSD-206A	268
TA1121	RECT	1N3254	41	SSD-206A	268
TA1122	RECT	1N3255	41	SSD-206A	268
TA1123	RECT	1N3256	41	SSD-206	268
TA1133	RECT	1N1612	18	SSD-206A	315
TA1134	RECT	1N1613	18	SSD-206A	315
TA1135	RECT	1N1614	18	SSD-206A	315
TA1136	RECT	1N1615	18	SSD-206A	315
TA1137	RECT	1N1616	18	SSD-206A	315
TA1171	SCR	2N681	96	SSD-206A	233
TA1172	SCR	2N682	96	SSD-206A	233
TA1173	SCR	2N683	96	SSD-206A	233
TA1174	SCR	2N684	96	SSD-206A	233
TA1175	SCR	2N685	96	SSD-206A	233
TA1176	SCR	2N686	96	SSD-206A	233
TA1177	SCR	2N687	96	SSD-206A	233
TA1178	SCR	2N688	96	SSD-206A	233
TA1179	SCR	2N689	96	SSD-206A	233
TA1182	RECT	1N3563	41	SSD-206A	268
TA1195	RECT	1N3756	39	SSD-206A	258
TA1197	RECT	1N3754	39	SSD-206A	258
TA1198	RECT	1N3755	39	SSD-206A	258
TA1204	SCR	2N1842A	28	SSD-206A	221
TA1205	SCR	2N1843A	28	SSD-206A	221
TA1206	SCR	2N1844A	28	SSD-206A	221
TA1207	SCR	2N1845A	28	SSD-206A	221
TA1208	SCR	2N1846A	28	SSD-206A	221
TA1209	SCR	2N1847A	28	SSD-206A	221
TA1210	SCR	2N1848A	28	SSD-206A	221
TA1211	SCR	2N1849A	28	SSD-206A	221
TA1212	SCR	2N1850A	28	SSD-206A	221
TA1214	RECT	1N1187A	38	SSD-206A	332
TA1215	RECT	1N1188A	38	SSD-206A	332
TA1216	RECT	1N1189A	38	SSD-206A	332
TA1217	RECT	1N1190A	38	SSD-206A	332
TA1222	SCR	2N3228	114	SSD-206A	161
TA1225	SCR	2N3525	114	SSD-206A	161
TA1614	PWR	2N301	14	SSD-204A	572
TA1614A	PWR	2N301A	14	SSD-204A	572
TA1680G	PWR	40050	14	SSD-204A	572
TA1680G	PWR	40051	14	SSD-204A	572
TA1863	RF	2N1491	10	SSD-205A	22
TA1883	RF	2N1492	10	SSD-205A	22
TA1884	PWR	2N2015	12	SSD-204A	500
TA1844A	PWR	2N2016	12	SSD-204A	500
TA1910A	PWR	2N697	16	SSD-204A	472
TA1928A	PWR	2N3731	14	SSD-204A	572
TA1931	PWR	2N1183	14	SSD-204A	572
TA1931A	PWR	2N1183A	14	SSD-204A	572
TA1931B	PWR	2N1183B	14	SSD-204A	572
TA1932	PWR	2N1184	14	SSD-204A	572
TA1932A	PWR	2N1184A	14	SSD-204A	572
TA1932B	PWR	2N1184B	14	SSD-204A	572
TA1936	PWR	2N1066	14	SSD-204A	572
TA1936A	PWR	2N1397	14	SSD-204A	572
TA1945	PWR	2N1479	135	SSD-204A	474
TA1945A	PWR	2N1480	135	SSD-204A	474
TA1946	PWR	2N1481	135	SSD-204A	474
TA1946A	PWR	2N1482	135	SSD-204A	474
TA1947	PWR	2N1483	137	SSD-204A	479
TA1947A	PWR	2N1484	137	SSD-204A	479
TA1948	PWR	2N1485	137	SSD-204A	479
TA1948A	PWR	2N1486	137	SSD-204A	479
TA1949	PWR	2N1487	139	SSD-204A	484
TA1949A	PWR	2N1488	139	SSD-204A	484
TA1950	PWR	2N1489	139	SSD-204A	484
TA1950A	PWR	2N1490	139	SSD-204A	484
TA1951	RF	2N1493	10	SSD-205A	22
TA1986	PWR	2N699	22	SSD-204A	320
TA2045	PWR	2N1906	14	SSD-204A	572
TA2046	PWR	2N1905	14	SSD-204A	572
TA2047	PWR	2N2147	14	SSD-204A	572
TA2048	PWR	2N2148	14	SSD-204A	572
TA2049	PWR	2N1700	141	SSD-204A	489
TA2050	PWR	2N1701	141	SSD-204A	489
TA2051	PWR	2N1702	141	SSD-204A	489
TA2053	PWR	2N1613	106	SSD-204A	323
TA2053A	PWR	2N1711	26	SSD-204A	328
TA2053B	PWR	2N2102	106	SSD-204A	323
TA2083	PWR	2N3730	14	SSD-204A	572
TA2188	PWR	2N3732	14	SSD-204A	572
TA2192A	PWR	2N2270	24	SSD-204A	338
TA2199	PWR	2N2338	141	SSD-204A	489
TA2235	PWR	2N1893	34	SSD-204A	332
TA2235A	PWR	2N2405	34	SSD-204A	332
TA2267	RF	2N2631	32	SSD-205A	26
TA2275	PWR	2N2895	143	SSD-204A	342
TA2276	PWR	2N2896	143	SSD-204A	342
TA2277	PWR	2N2897	143	SSD-204A	342
TA2302	PWR	2N718A	14	SSD-204A	572
TA2303	PWR	2N720A	14	SSD-204A	572
TA2307	RF	2N3375	386	SSD-205A	50
TA2311	RF	2N2876	32	SSD-205A	26
TA2333	RF	2N2857	61	SSD-205A	31
TA2358	RF	2N918	83	SSD-205A	18
TA2358A	RF	2N3600	83	SSD-205A	18
TA2363	RF	2N3839	229	SSD-205A	67
TA2388	RF	2N3229	50	SSD-205A	43
TA2402A	PWR	2N3054	527	SSD-204A	20
TA2403A	PWR	2N3055	524	SSD-204A	28
TA2412	PWR	2N2869	14	SSD-204A	572
TA2412A	PWR	2N2870	14	SSD-204A	572
TA2442	SCR	2N3870	578	SSD-206A	243
TA2444	SCR	2N3871	578	SSD-206A	243
TA2447	SCR	2N3872	578	SSD-206A	243
TA2458	PWR	2N3439	64	SSD-204A	222
TA2462	RF	2N3118	42	SSD-205A	35
TA2463	RF	2N3119	44	SSD-205A	39

Developmental-Number-to-Commercial-Number Cross-Reference Index

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA2468A	PWR	2N3442	528	SSD-204A	44
TA2469A	PWR	2N3441	529	SSD-204A	36
TA2470	PWR	2N3440	64	SSD-204A	222
TA2492	PWR	2N3263	54	SSD-204A	354
TA2493	PWR	2N3264	54	SSD-204A	354
TA2494	PWR	2N3265	54	SSD-204A	354
TA2495	PWR	2N3266	54	SSD-204A	354
TA2501	RF	2N3262	56	SSD-205A	46
TA2509	PWR	2N3878	299	SSD-204A	360
TA2509A	PWR	2N3879	299	SSD-204A	360
TA2510	PWR	2N3583	138	SSD-204A	229
TA2511	PWR	2N3584	138	SSD-204A	229
TA2512	PWR	2N3585	138	SSD-204A	229
TA2515	SCR	2N690	96	SSD-206A	233
TA2544	PWR	2N3772	525	SSD-204A	52
TA2551	RF	2N3553	386	SSD-205A	50
TA2579	RECT	1N1341B	58	SSD-206A	317
TA2580	RECT	1N1342B	58	SSD-206A	317
TA2581	RECT	1N1344B	58	SSD-206A	317
TA2582	RECT	1N1345B	58	SSD-206A	317
TA2583	RECT	1N1346B	58	SSD-206A	317
TA2584	RECT	1N1347B	58	SSD-206A	317
TA2585	RECT	1N1348B	58	SSD-206A	317
TA2586	RECT	1N1341RB	58	SSD-206A	317
TA2587	RECT	1N1342RB	58	SSD-206A	317
TA2588	RECT	1N1344RB	58	SSD-206A	317
TA2589	RECT	1N1345RB	58	SSD-206A	317
TA2590	RECT	1N1346RB	58	SSD-206A	317
TA2591	RECT	1N1347RB	58	SSD-206A	317
TA2592	RECT	1N1348RB	58	SSD-206A	317
TA2597	SCR	2N3528	114	SSD-206A	161
TA2598	SCR	2N3669	116	SSD-206A	214
TA2600	RF	40282	68	SSD-205A	268
TA2606	RF	2N3478	77	SSD-205A	58
TA2616	RF	2N3632	386	SSD-205A	50
TA2617	SCR	2N3529	114	SSD-206A	161
TA2618	SCR	2N3670	116	SSD-206A	214
TA2620	RF	40281	68	SSD-205A	268
TA2621	SCR	2N3668	116	SSD-206A	214
TA2644	MOS/FET	3N140	285	SSD-201A	610
TA2645A	PWR	2N3773	526	SSD-204A	60
TA2650	PWR	2N3771	525	SSD-204A	52
TA2651	PWR	2N4036	216	SSD-204A	428
TA2653	SCR	40553	306	SSD-206A	175
TA2654	SCR	40554	306	SSD-206A	175
TA2655	SCR	40555	306	SSD-206A	175
TA2657	RF	40341	74	SSD-205A	295
TA2657A	RF	40340	74	SSD-205A	295
TA2658	RF	2N3866	80	SSD-205A	71
TA2669	PWR	2N5039	367	SSD-204A	371
TA2669A	PWR	2N5038	367	SSD-204A	371
TA2670	PWR	2N4037	216	SSD-204A	428
TA2670A	PWR	2N4314	216	SSD-204A	428
TA2672	PWR	40462	14	SSD-204A	572
TA2675	RF	2N5016	255	SSD-205A	94
TA2676	TRI	40429	351	SSD-206A	41
TA2685	TRI	40430	351	SSD-206A	41
TA2692	RF	2N3733	72	SSD-205A	62
TA2694	SCR	2N3896	578	SSD-206A	243
TA2695	SCR	2N3897	578	SSD-206A	243
TA2696	SCR	2N3898	578	SSD-206A	243
TA2703A	PWR	40349	88	SSD-204A	129
TA2705	SCR	2N3873	578	SSD-206A	243
TA2707	SCR	2N3899	578	SSD-206A	243
TA2710	RF	2N5108	280	SSD-205A	116
TA2714	RF	2N4012	90	SSD-205A	75
TA2728	TRI	40431	477	SSD-206A	48
TA2729	TRI	40432	477	SSD-206A	48
TA2733	PWR	40319	78	SSD-204A	510
TA2733A	PWR	40362	78	SSD-204A	510
TA2758	RF	2N6093	484	SSD-205A	219
TA2761	RF	40608	356	SSD-205A	332
TA2765	PWR	2N5239	321	SSD-204A	241
TA2765A	PWR	2N5240	321	SSD-204A	241
TA2773	SCR	2N4101	114	SSD-206A	161
TA2774	SCR	2N4102	114	SSD-206A	161
TA2775	SCR	2N4103	116	SSD-206A	214
TA2791	RF	2N5102	279	SSD-205A	111
TA2792	RF	2N4933	249	SSD-205A	90
TA2793	RF	2N5070	268	SSD-205A	98
TA2800	RF	2N5109	281	SSD-205A	120
TA2808	PWR	2N4348	526	SSD-204A	60
TA2809	PWR	2N4347	528	SSD-204A	44
TA2819	PWR	2N5415	336	SSD-204A	437
TA2819A	PWR	2N5416	336	SSD-204A	437
TA2827	RF	2N5071	269	SSD-205A	103
TA2828	RF	2N4932	249	SSD-205A	90
TA2834	TRI	40575	300	SSD-206A	105
TA2835	TRI	40576	300	SSD-206A	105
TA2836	TRI	2N5441	593	SSD-206A	127
TA2837	TRI	2N5442	593	SSD-206A	127
TA2838	TRI	2N5444	593	SSD-206A	127
TA2839	TRI	2N5445	593	SSD-206A	127
TA2840	MOS/FET	3N128	309	SSD-201A	568
TA2845	RECT	1N5214	245	SSD-206A	286
TA2845A	RECT	1N5213	245	SSD-206A	286
TA2845B	RECT	1N5212	245	SSD-206A	286
TA2845C	RECT	1N5211	245	SSD-206A	286
TA2862	PWR	40421	14	SSD-204A	572
TA2871	PWR	2N4240	138	SSD-204A	229
TA2875	RF	2N4440	217	SSD-205A	85
TA2892	TRI	40525	470	SSD-206A	27
TA2829A	TRI	40528	470	SSD-206A	27
TA2893	TRI	40526	470	SSD-206A	27
TA2893A	TRI	40529	470	SSD-206A	27
TA2894	TRI	40527	470	SSD-206A	27
TA2894A	TRI	40530	470	SSD-206A	27
TA2911	PWR	2N5294	332	SSD-204A	76
TA2918	TRI	40485	352	SSD-206A	54
TA2919	TRI	40486	352	SSD-206A	54
TA2920	PWR	2N4346	14	SSD-204A	572
TA2921	PWR	40440	14	SSD-204A	572
TA2928	PWR	40439	14	SSD-204A	572
TA5032	LIC	CA3000	121	SSD-201A	290
TA5033	LIC	CA3001	122	SSD-201A	304
TA5035	LIC	CA3002	123	SSD-201A	258
TA5037	LIC	CA3004	124	SSD-201A	318
TA5112	LIC	CA3005	125	SSD-201A	324
TA5112A	LIC	CA3006	125	SSD-201A	324
TA5115B	LIC	CA3007	126	SSD-201A	331
TA5124	LIC	CA3008	316	SSD-201A	507
TA5158	LIC	CA3015	316	SSD-201A	507
TA5164	LIC	CD2150	308	SSD-201A	443
TA5165	LIC	CD2151	308	SSD-201A	443
TA5166	LIC	CD2152	308	SSD-201A	443
TA5180	LIC	CA3010	316	SSD-201A	507
TA5183	LIC	CA3033	360	SSD-201A	488
TA5183A	LIC	CA3033A	360	SSD-201A	488
TA5213	LIC	CA3011	128	SSD-201A	264
TA5214	LIC	CA3012	128	SSD-201A	264
TA5218	LIC	CA3023	243	SSD-201A	278
TA5219	LIC	CA3021	243	SSD-201A	278
TA5220	LIC	CA3020	339	SSD-201A	270
TA5222	LIC	CA3018	338	SSD-201A	204
TA5222A	LIC	CA3018A	338	SSD-201A	204
TA5225	LIC	CA3019	236	SSD-201A	162
TA5234	LIC	CA3013	129	SSD-201A	62
TA5235	LIC	CA3014	129	SSD-201A	62
TA5236	LIC	CA3022	243	SSD-201A	278
TA5253	LIC	CA3016	316	SSD-201A	507
TA5254	LIC	CA3030	316	SSD-201A	507
TA5261	LIC	CD2153	308	SSD-201A	443
TA5277	LIC	CA3001	122	SSD-201A	304
TA5278	LIC	CA3029	316	SSD-201A	507
TA5282	LIC	CA3004	124	SSD-201A	318
TA5315	LIC	CA3043	331	SSD-201A	57
TA5316	LIC	CA3041	318	SSD-201A	90
TA5317A	LIC	CA3042	319	SSD-201A	98
TA5327C	LIC	CA3040	363	SSD-201A	284
TA5333	LIC	CA3036	275	SSD-201A	202

Developmental-Number-to-Commercial-Number Cross-Reference Index

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA5334	LIC	CA3035	274	SSD-201A	74
TA5334	LIC	CA3035V1	274	SSD-201A	74
TA5345	LIC	CA3028A	382	SSD-201A	344
TA5345A	LIC	CA3028B	382	SSD-201A	344
TA5346	LIC	CA3015A	310	SSD-201A	516
TA5347	LIC	CA3010A	310	SSD-201A	516
TA5348	LIC	CA3030A	310	SSD-201A	516
TA5349	LIC	CA3029A	310	SSD-201A	516
TA5350	LIC	CA3016A	310	SSD-201A	516
TA5351	LIC	CA3008A	310	SSD-201A	516
TA5360	LIC	CA3044	340	SSD-201A	78
TA5369	LIC	CA3040	363	SSD-201A	284
TA5371B	LIC	CA3062	421	SSD-201A	401
TA5385CV	COS/MOS	CD4024AK	503	SSD-203A	114
TA5401	LIC	CA3038	316	SSD-301A	507
TA5401	LIC	CA3038A	310	SSD-201A	516
TA5402	LIC	CA3037	316	SSD-201A	507
TA5402	LIC	CA3037A	310	SSD-201A	516
TA5457	LIC	CA3045	341	SSD-201A	221
TA5458	LIC	CA3046	341	SSD-201A	221
TA5460AV	COS/MOS	CD4016AK	479	SSD-203A	78
TA5507	LIC	CA3050	361	SSD-201A	372
TA5513	LIC	CA3026	388	SSD-201A	336
TA5516	LIC	CA3039	343	SSD-201A	166
TA5517C	LIC	CA3064	396	SSD-201A	84
TA5519V	COS/MOS	CD4008AK	479	SSD-203A	43
TA5523A	LIC	CA3048	377	SSD-201A	250
TA5537	LIC	CA3049T	611	SSD-201A	363
TA5551	COS/MOS	CD4000AK	479	SSD-203A	24
TA5553	COS/MOS	CD4007AK	479	SSD-203A	24
TA5554	COS/MOS	CD4001AK	479	SSD-203A	24
TA5555	COS/MOS	CD4002AK	479	SSD-203A	24
TA5556B	COS/MOS	CD4006AK	479	SSD-203A	31
TA5561	LIC	CA3047A	360	SSD-201A	488
TA5562	LIC	CA3047	360	SSD-201A	488
TA5578V	COS/MOS	CD4014AK	479	SSD-203A	68
TA5579V	COS/MOS	CD4015AK	479	SSD-203A	73
TA5580V	COS/MOS	CD4018AK	479	SSD-203A	89
TA5615A	LIC	CA3059	490	SSD-201A	380
TA5625A	LIC	CA3066	466	SSD-201A	125
TA5628C	LIC	CA3089E	561	SSD-201A	46
TA5634	LIC	CD2154	402	SSD-201A	455
TA5645	LIC	CA3060E	537	SSD-201A	466
TA5649A	LIC	CA3070	468	SSD-201A	143
TA5652V	COS/MOS	CD4019AK	479	SSD-203A	94
TA5655	LIC	CA3051	361	SSD-201A	372
TA5660V	COS/MOS	CD4009AK	479	SSD-203A	48
TA5668V	COS/MOS	CD4010AK	479	SSD-203A	48
TA5672	LIC	CA3052	387	SSD-201A	28
TA5675V	COS/MOS	CD4013AK	479	SSD-203A	62
TA5677V	COS/MOS	CD4044AK	590	SSD-203A	214
TA5681V	COS/MOS	CD4011AK	479	SSD-203A	55
TA5682V	COS/MOS	CD4012AK	479	SSD-203A	55
TA5683V	COS/MOS	CD4021AK	479	SSD-203A	104
TA5684V	COS/MOS	CD4017AK	479	SSD-203A	84
TA5690X	LIC	CD2501E	392	SSD-201A	437
TA5702B	LIC	CA3071	468	SSD-201A	143
TA5716W	COS/MOS	CD4057AD	Prel.	SSD-203A	254
TA5718	LIC	CA3054	388	SSD-201A	336
TA5721X	LIC	CD2500E	392	SSD-201A	437
TA5733	LIC	CA3053	382	SSD-201A	344
TA5752	LIC	CA3067	466	SSD-201A	125
TA5757	LIC	CA3076	430	SSD-201A	70
TA5758B	LIC	CA3085	491	SSD-201A	409
TA5776V	COS/MOS	CD4020AK	479	SSD-203A	99
TA5785X	LIC	CD2503E	392	SSD-201A	437
TA5786X	LIC	CD2502E	392	SSD-201A	437
TA5790	LIC	CA3060D	537	SSD-201A	466
TA5795	LIC	CA3058	490	SSD-201A	380
TA5797	LIC	CA3741T	531	SSD-201A	501
TA5799A	LIC	CA3084	482	SSD-201A	178
TA5807	LIC	CA3078T	535	SSD-201A	479
TA5814	LIC	CA3065	412	SSD-201A	106
TA5816	LIC	CA3080	475	SSD-201A	458
TA5820	LIC	CA3541D	536	SSD-201A	429
TA5842	LIC	CA3088E	560	SSD-201A	42
TA5855A	LIC	CA3091D	534	SSD-201A	417
TA5858	LIC	CA3081	480	SSD-201A	170
TA5866	LIC	CA3075	429	SSD-201A	53
TA5867V	COS/MOS	CD4023AK	479	SSD-203A	55
TA5867W	COS/MOS	CD4023AD	479	SSD-203A	55
TA5867X	COS/MOS	CD4023AE	479	SSD-203A	55
TA5872V	COS/MOS	CD4027AK	503	SSD-203A	129
TA5873V	COS/MOS	CD4028AK	503	SSD-203A	135
TA5876W	COS/MOS	CD4035AD	568	SSD-203A	173
TA5878W	COS/MOS	CD4034AD	575	SSD-203A	164
TA5884AV	COS/MOS	CD4022AK	479	SSD-203A	109
TA5884W	COS/MOS	CD4022AD	479	SSD-203A	109
TA5884AX	COS/MOS	CD4022AE	479	SSD-203A	109
TA5897X	LIC	CD2501E	392	SSD-201A	437
TA5898X	LIC	CD2503E	392	SSD-201A	437
TA5899X	LIC	CD2500E	392	SSD-201A	437
TA5900X	LIC	CD2502E	392	SSD-201A	437
TA5912B	LIC	CA3072	468	SSD-201A	143
TA5914C	LIC	CA3068	467	SSD-201A	117
TA5920V	COS/MOS	CD4025AK	479	SSD-203A	24
TA5920W	COS/MOS	CD4025AD	479	SSD-203A	24
TA5920X	COS/MOS	CD4025AE	479	SSD-203A	24
TA5925V	COS/MOS	CD4029AK	503	SSD-203A	140
TA5925W	COS/MOS	CD4029AD	503	SSD-203A	140
TA5925X	COS/MOS	CD4029AE	503	SSD-203A	140
TA5926V	COS/MOS	CD4036AK	613	SSD-203A	181
TA5926W	COS/MOS	CD4036AD	613	SSD-203A	181
TA5932	LIC	CA3090Q	502	SSD-201A	36
TA5940V	COS/MOS	CD4030AK	503	SSD-203A	147
TA5940W	COS/MOS	CD4030AD	503	SSD-203A	147
TA5940X	COS/MOS	CD4030AE	503	SSD-203A	147
TA5951V	COS/MOS	CD4038AK	503	SSD-203A	159
TA5951W	COS/MOS	CD4038AD	503	SSD-203A	159
TA5951X	COS/MOS	CD4038AE	503	SSD-203A	159
TA5957	LIC	CA3018L	515	SSD-201A	545
TA5958	LIC	CA3039L	515	SSD-201A	545
TA5959	LIC	CA3045L	515	SSD-201A	545
TA5960	LIC	CA3054L	515	SSD-201A	545
TA5963V	COS/MOS	CD4032AK	503	SSD-203A	159
TA5963W	COS/MOS	CD4032AD	503	SSD-203A	159
TA5963X	COS/MOS	CD4032AE	503	SSD-203A	159
TA5964	LIC	CA3015L	515	SSD-201A	545
TA5975	LIC	CA3028AL	515	SSD-201A	545
TA5978	LIC	CA3084L	515	SSD-201A	545
TA5979	LIC	CA3741L	515	SSD-201A	545
TA5998	LIC	CA3083	481	SSD-201A	174
TA5999W	COS/MOS	CD4037AD	576	SSD-203A	188
TA6007W	COS/MOS	CD4051AD	Prel.	SSD-203A	245
TA6010V	COS/MOS	CD4047AK	Prel.	SSD-203A	228
TA6010W	COS/MOS	CD4047AD	Prel.	SSD-203A	228
TA6010X	COS/MOS	CD4047AE	Prel.	SSD-203A	228
TA6014	LIC	CA3068	467	SSD-201A	117
TA6018V	COS/MOS	CD4026AK	503	SSD-203A	120
TA6018W	COS/MOS	CD4026AD	503	SSD-203A	120
TA6018X	COS/MOS	CD4026AE	503	SSD-203A	120
TA6029	LIC	CA3741CT	531	SSD-201A	501
TA6031V	COS/MOS	CD4041AK	572	SSD-203A	199
TA6031W	COS/MOS	CD4041AD	572	SSD-203A	199
TA6031X	COS/MOS	CD4041AE	572	SSD-203A	199
TA6033	LIC	CA3082	480	SSD-201A	170
TA6037	LIC	CA3748CT	531	SSD-201A	501
TA5037A	LIC	CA3748T	531	SSD-201A	501
TA6044	LIC	CA3086	483	SSD-201A	234
TA6051	LIC	CA3079	490	SSD-201A	380
TA6062W	COS/MOS	CD4045AD	Prel.	SSD-203A	222
TA6062X	COS/MOS	CD4045AE	Prel.	SSD-203A	222
TA6065V	COS/MOS	CD4040AK	Prel.	SSD-203A	195
TA6065W	COS/MOS	CD4040AD	Prel.	SSD-203A	195
TA6065X	COS/MOS	CD4040AE	Prel.	SSD-203A	195
TA6080V	COS/MOS	CD4043AK	590	SSD-203A	214
TA6080W	COS/MOS	CD4043AD	590	SSD-203A	214
TA6080X	COS/MOS	CD4043AE	590	SSD-203A	214
TA6081V	COS/MOS	CD4044AK	590	SSD-203A	214
TA6081W	COS/MOS	CD4044AD	590	SSD-203A	214

Developmental-Number-to-Commercial-Number Cross-Reference Index

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA6081X	COS/MOS	CD4044AE	590	SSD-203A	214
TA6084	LIC	CA3146AE	532	SSD-201A	210
TA6091	LIC	CA3118AT	532	SSD-201A	210
TA6094	LIC	CA3183AE	532	SSD-201A	210
TA6111	LIC	CA3458T	531	SSD-201A	501
TA6111A	LIC	CA3558T	531	SSD-201A	501
TA6116V	COS/MOS	CD4046AK	Prel.	SSD-203A	224
TA6116W	COS/MOS	CD4046AD	Prel.	SSD-203A	224
TA6116X	COS/MOS	CD4046AE	Prel.	SSD-203A	224
TA6119	LIC	CA3093E	533	SSD-201A	196
TA6145V	COS/MOS	CD4039AK	613	SSD-203A	181
TA6145W	COS/MOS	CD4039AD	613	SSD-203A	181
TA6145X	COS/MOS	CD4039AE	613	SSD-203A	181
TA6153W	COS/MOS	CD4052AD	Prel.	SSD-203A	245
TA6154W	COS/MOS	CD4053AD	Prel.	SSD-203A	245
TA6157	LIC	CA3747CE	531	SSD-201A	501
TA6157A	LIC	CA3747E	531	SSD-201A	501
TA6164	LIC	CA3094T	598	SSD-201A	388
TA6165A	LIC	CA3094AT	598	SSD-201A	388
TA6181	LIC	CA3146E	532	SSD-201A	210
TA6182	LIC	CA3118T	532	SSD-201A	210
TA6183	LIC	CA3183E	532	SSD-201A	210
TA6220	LIC	CA2111AE	612	SSD-201A	112
TA6237V	COS/MOS	CD4054AK	Prel.	SSD-203A	249
TA6237W	COS/MOS	CD4054AD	Prel.	SSD-203A	249
TA6237X	COS/MOS	CD4054AE	Prel.	SSD-203A	249
TA6238V	COS/MOS	CD4055AK	Prel.	SSD-203A	249
TA6238W	COS/MOS	CD4055AD	Prel.	SSD-203A	249
TA6238X	COS/MOS	CD4055AE	Prel.	SSD-203A	249
TA6245V	COS/MOS	CD4058AK	Prel.	SSD-203A	262
TA6245W	COS/MOS	CD4058AD	Prel.	SSD-203A	262
TA6246V	COS/MOS	CD4049AK	599	SSD-203A	237
TA6246W	COS/MOS	CD4049AD	599	SSD-203A	237
TA6246X	COS/MOS	CD4049AE	599	SSD-203A	237
TA6250V	COS/MOS	CD4048AK	Prel.	SSD-203A	233
TA6250W	COS/MOS	CD4048AD	Prel.	SSD-203A	233
TA6250X	COS/MOS	CD4048AE	Prel.	SSD-203A	233
TA6251V	COS/MOS	CD4056AK	Prel.	SSD-203A	249
TA6251W	COS/MOS	CD4056AD	Prel.	SSD-203A	249
TA6251X	COS/MOS	CD4056AE	Prel.	SSD-203A	249
TA6265V	COS/MOS	CD4050AK	599	SSD-203A	237
TA6265W	COS/MOS	CD4050AD	599	SSD-203A	237
TA6265X	COS/MOS	CD4050AE	599	SSD-203A	237
TA6269X	LIC	CA3095E	591	SSD-201A	240
TA6270X	LIC	CA3096E	595	SSD-201A	185
TA6270AX	LIC	CA3096AE	595	SSD-201A	185
TA6289X	LIC	CA3747CE	531	SSD-201A	501
TA6289AX	LIC	CA3747E	531	SSD-201A	501
TA6309	LIC	CA3049L	515	SSD-201A	545
TA6330T	LIC	CA3094AT	598	SSD-201A	388
TA7003	RF	2N5470	350	SSD-205A	136
TA7005	PWR	2N6249	523	SSD-204A	276
TA7006	PWR	2N6250	523	SSD-204A	276
TA7007	PWR	2N6251	523	SSD-204A	276
TA7016	PWR	2N5575	359	SSD-204A	92
TA7017	PWR	2N5578	359	SSD-204A	92
TA7032	MOS/FET	3N138	283	SSD-201A	573
TA7047	RF	2N4427	228	SSD-205A	79
TA7048	RECT	1N5218	245	SSD-206A	286
TA7048A	RECT	1N5217	245	SSD-206A	286
TA7048B	RECT	1N5216	245	SSD-206A	286
TA7048C	RECT	1N5215	245	SSD-206A	286
TA7078	RF	40606	600	SSD-205A	325
TA7079	RF	40577	297	SSD-205A	305
TA7080	RF	40578	298	SSD-205A	312
TA7090	RF	JAN-2N3866	–	–	–
TA7121	PWR	2N5320	325	SSD-204A	389
TA7122	PWR	2N5321	325	SSD-204A	389
TA7124	PWR	2N5322	325	SSD-204A	389
TA7125	PWR	2N5323	325	SSD-204A	389
TA7130	PWR	2N5804	407	SSD-204A	247
TA7130A	PWR	2N5805	407	SSD-204A	247
TA7134	PWR	2N6177	508	SSD-204A	268
TA7137	PWR	2N5296	332	SSD-204A	76
TA7146	RF	2N5090	270	SSD-205A	107
TA7149	MOS/FET	40600	333	SSD-201A	624
TA7150	MOS/FET	40603	334	SSD-201A	632
TA7151	MOS/FET	40604	334	SSD-201A	632
TA7155	PWR	2N5293	332	SSD-204A	76
TA7156	PWR	2N5295	332	SSD-204A	76
TA7189	MOS/FET	40602	333	SSD-201A	624
TA7199	PWR	2N5036	244	SSD-204A	68
TA7200	PWR	2N5037	244	SSD-204A	68
TA7201	PWR	2N5034	244	SSD-204A	68
TA7202	PWR	2N5035	244	SSD-204A	68
TA7205	RF	2N5921	427	SSD-205A	184
TA7238	PWR	2N5262	313	SSD-204A	383
TA7244	MOS/FET	3N139	284	SSD-201A	577
TA7262	MOS/FET	40601	333	SSD-201A	624
TA7264	PWR	2N5954	435	SSD-204A	138
TA7265	PWR	2N5955	435	SSD-204A	138
TA7266	PWR	2N5956	435	SSD-204A	138
TA7270	PWR	2N5781	413	SSD-204A	100
TA7271	PWR	2N5782	413	SSD-204A	100
TA7272	PWR	2N5783	413	SSD-204A	100
TA7274	MOS/FET	3N141	285	SSD-201A	610
TA7275	MOS/FET	3N143	309	SSD-201A	568
TA7279	PWR	2N6248	541	SSD-204A	153
TA7280	PWR	2N6247	541	SSD-204A	153
TA7281	PWR	2N6246	541	SSD-204A	153
TA7285	PWR	2N5202	299	SSD-204A	360
TA7289	PWR	2N5784	413	SSD-204A	100
TA7290	PWR	2N5785	413	SSD-204A	100
TA7291	PWR	2N5786	413	SSD-204A	100
TA7303	RF	2N5180	289	SSD-205A	132
TA7306	MOS/FET	3N142	286	SSD-201A	582
TA7311	PWR	2N5496	353	SSD-204A	85
TA7312	PWR	2N5497	353	SSD-204A	85
TA7313	PWR	2N5494	353	SSD-204A	85
TA7314	PWR	2N5495	353	SSD-204A	85
TA7315	PWR	2N5492	353	SSD-204A	85
TA7316	PWR	2N5493	353	SSD-204A	85
TA7317	PWR	2N5490	353	SSD-204A	85
TA7318	PWR	2N5491	353	SSD-204A	85
TA7319	RF	2N5179	288	SSD-205A	126
TA7322	PWR	2N5189	296	SSD-204A	378
TA7323	PWR	2N5671	383	SSD-204A	395
TA7323A	PWR	2N5672	383	SSD-204A	395
TA7327	RF	JANTX-2N3866		–	–
TA7328	RF	JANTX-2N3553		–	–
TA7329	RF	JANTX-2N3375		–	–
TA7337	PWR	2N6032	462	SSD-204A	401
TA7337A	PWR	2N6033	462	SSD-204A	401
TA7344	RF	2N5919	426	SSD-205A	165
TA7352	MOS/FET	3N153	320	SSD-201A	593
TA7353	MOS/FET	3N152	314	SSD-201A	588
TA7354	RF	JAN-2N4440		–	–
TA7355	RF	JANTX-2N4440		–	–
TA7358	RF	JANTX-2N5071		–	–
TA7360	RF	JAN-2N5071		–	–
TA7361	RF	40605	389	SSD-205A	318
TA7362	PWR	2N5297	332	SSD-204A	76
TA7363	PWR	2N5298	332	SSD-204A	76
TA7364	TRI	40668	364	SSD-206A	73
TA7365	TRI	40669	364	SSD-206A	73
TA7367	RF	2N5918	448	SSD-205A	160
TA7374	MOS/FET	3N159	326	SSD-201A	618
TA7375	MOS/FET	3N154	335	SSD-201A	596
TA7381	PWR	2N6098	485	SSD-204A	111
TA7382	PWR	2N6099	485	SSD-204A	111
TA7383	PWR	2N6100	485	SSD-204A	111
TA7384	PWR	2N6101	485	SSD-204A	111
TA8385	PWR	2N6102	485	SSD-204A	111
TA7386	PWR	2N6103	485	SSD-204A	111
TA7399	MOS/FET	40673	381	SSD-201A	679
TA7401	DIAC	45412	577	SSD-206A	353
TA7403	RF	40836	497	SSD-205A	336
TA7404	SCR	40868	501	SSD-206A	200
TA7405	SCR	40869	501	SSD-206A	200
TA7408	RF	2N5914	424	SSD-205A	148

Developmental-Number-to-Commercial-Number Cross-Reference Index

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA7409	RF	2N5915	424	SSD-205A	148
TA7410	PWR	2N6212	507	SSD-204A	443
TA7411	RF	2N5916	425	SSD-205A	154
TA7420	PWR	2N5840	410	SSD-204A	253
TA7426	TRI	2N5443	593	SSD-206A	127
TA7427	TRI	2N5446	593	SSD-206A	127
TA7428	TRI	2N5567	457	SSD-206A	83
TA7429	TRI	2N5568	457	SSD-206A	83
TA7430	TRI	2N5571	458	SSD-206A	98
TA7431	TRI	2N5572	458	SSD-206A	98
TA7434	SCR	40654	496	SSD-206A	191
TA7435	SCR	40655	496	SSD-206A	191
TA7441	TRI	40660	459	SSD-206A	112
TA7442	TRI	40661	459	SSD-206A	112
TA7443	RECT	40808	449	SSD-206A	311
TA7444	RECT	40809	449	SSD-206A	311
TA7452	SCR	40640	354	SSD-206A	179
TA7453	SCR	40641	354	SSD-206A	179
TA7454	RECT	40642	354	SSD-206A	290
TA7455	RECT	40643	354	SSD-206A	290
TA7456	RECT	40644	354	SSD-206A	290
TA7461	TRI	40662	459	SSD-206A	112
TA7462	TRI	40663	459	SSD-206A	112
TA7463	SCR	40656	496	SSD-206A	191
TA7464	SCR	40657	496	SSD-206A	191
TA7465	SCR	40658	496	SSD-206A	191
TA7466	SCR	40659	496	SSD-206A	191
TA7467	TRI	40795	457	SSD-206A	83
TA7468	TRI	40797	458	SSD-206A	98
TA7477	RF	2N5913	423	SSD-205A	142
TA7479	TRI	2N5569	457	SSD-206A	83
TA7480	TRI	2N5570	457	SSD-206A	83
TA7481	TRI	40796	457	SSD-206A	83
TA7482	TRI	2N5573	458	SSD-206A	98
TA7483	TRI	2N5574	458	SSD-206A	98
TA7484	TRI	40798	458	SSD-206A	98
TA7487	RF	2N5920	440	SSD-205A	178
TA7500	TRI	2N5754	414	SSD-206A	22
TA7501	TRI	2N5755	414	SSD-206A	22
TA7502	TRI	2N5756	414	SSD-206A	22
TA7503	TRI	2N5757	414	SSD-206A	22
TA7504	TRI	40688	593	SSD-206A	127
TA7505	TRI	40689	593	SSD-206A	127
TA7506	TRI	40690	593	SSD-206A	127
TA7507	SCR	40681	578	SSD-206A	242
TA7508	SCR	40682	578	SSD-206A	242
TA7509	SCR	40683	578	SSD-206A	242
TA7513	PWR	2N5838	410	SSD-204A	253
TA7530	PWR	2N5839	410	SSD-204A	253
TA7532	RF	2N5919A	505	SSD-205A	172
TA7534	PWR	2N6354	582	SSD-204A	415
TA7543	SCR	RCA106Q	555	SSD-206A	150
TA7545	SCR	RCA106Y	555	SSD-206A	150
TA7546	SCR	RCA106F	555	SSD-206A	150
TA7547	TRI	40799	457	SSD-206A	83
TA7548	TRI	40800	457	SSD-206A	83
TA7549	TRI	40801	457	SSD-206A	98
TA7550	TRI	40802	458	SSD-206A	98
TA7551	TRI	40803	458	SSD-206A	98
TA7552	TRI	40804	458	SSD-206A	98
TA7553	SCR	40735	408	SSD-206A	236
TA7554	PWR	2N6178	562	SSD-204A	407
TA7555	PWR	2N6179	562	SSD-204A	407
TA7556	PWR	2N6180	562	SSD-204A	407
TA7557	PWR	2N6181	562	SSD-204A	407
TA7560	SCR	40738	417	SSD-206A	206
TA7561	SCR	40739	417	SSD-206A	206
TA7562	SCR	40740	417	SSD-206A	206
TA7563	SCR	40750	418	SSD-206A	225
TA7564	SCR	40751	418	SSD-206A	225
TA7565	SCR	40752	418	SSD-206A	225
TA7567	SCR	40742	417	SSD-206A	206
TA7568	SCR	40743	417	SSD-206A	206
TA7569	SCR	40744	417	SSD-206A	206
TA7570	SCR	40754	418	SSD-206A	225
TA7571	SCR	40755	418	SSD-206A	225
TA7579	TRI	40684	414	SSD-206A	22
TA7580	TRI	40685	414	SSD-206A	22
TA7581	TRI	40686	414	SSD-206A	22
TA7583	TRI	40671	459	SSD-206A	112
TA7584	TRI	40672	459	SSD-206A	112
TA7589	RF	2N5994	453	SSD-205A	202
TA7590	SCR	2N3650	408	SSD-206A	236
TA7591	SCR	2N3651	408	SSD-206A	236
TA7592	SCR	2N3652	408	SSD-206A	236
TA7593	SCR	2N3653	408	SSD-206A	236
TA7596	SCR	40746	417	SSD-206A	206
TA7597	SCR	40747	417	SSD-206A	206
TA7598	SCR	40748	417	SSD-206A	206
TA7599	SCR	40758	418	SSD-206A	225
TA7600	SCR	40759	418	SSD-206A	225
TA7601	SCR	40760	418	SSD-206A	225
TA7602	TRI	40805	459	SSD-206A	112
TA7603	TRI	40806	459	SSD-206A	112
TA7604	TRI	40807	459	SSD-206A	112
TA7614	TRI	40779	443	SSD-206A	90
TA7615	TRI	40780	443	SSD-206A	90
TA7616	TRI	40781	443	SSD-206A	90
TA7617	TRI	40782	443	SSD-206A	90
TA7618	TRI	40783	443	SSD-206A	90
TA7619	TRI	40784	443	SSD-206A	90
TA7620	TRI	40785	443	SSD-206A	90
TA7621	TRI	40786	443	SSD-206A	90
TA7625	HYB	HC1000	565	SSD-204A	550
TA7625A	HYB	HC2000	566	SSD-204A	555
TA7626	HYB	HC1000H	565	SSD-204A	550
TA7626A	HYB	HC2000H	566	SSD-204A	555
TA7642	TRI	40775	443	SSD-206A	90
TA7643	TRI	40776	443	SSD-206A	90
TA7644	TRI	40777	443	SSD-206A	90
TA7645	TRI	40778	443	SSD-206A	90
TA7646	TRI	40787	487	SSD-206A	119
TA7647	TRI	40788	487	SSD-206A	119
TA7648	TRI	40790	487	SSD-206A	119
TA7649	TRI	40790	487	SSD-206A	119
TA7650	TRI	40791	487	SSD-206A	119
TA7651	TRI	40792	487	SSD-206A	119
TA7652	TRI	40793	487	SSD-206A	119
TA7653	TRI	40794	487	SSD-206A	119
TA7654	TRI	40769	441	SSD-206A	35
TA7655	TRI	40770	441	SSD-206A	35
TA7656	TRI	40772	441	SSD-206A	35
TA7657	TRI	40772	441	SSD-206A	35
TA7669	MOS/FET	3N187	436	SSD-201A	636
TA7670	SCR	40680	578	SSD-206A	242
TA7671	TRI	40773	442	SSD-206A	67
TA7672	TRI	40774	442	SSD-206A	67
TA7673	PWR	2N6078	492	SSD-204A	260
TA7679	RF	40837	497	SSD-205A	336
TA7680	RF	40941	554	SSD-205A	380
TA7684	MOS/FET	3N200	437	SSD-201A	644
TA7686	RF	40893	514	SSD-205A	342
TA7706	RF	2N6105	504	SSD-205A	224
TA7707	RF	2N6104	504	SSD-205A	224
TA7719	PWR	2N6211	507	SSD-204A	443
TA7739	PWR	2N6175	508	SSD-204A	268
TA7740	PWR	2N6176	508	SSD-204A	268
TA7741	PWR	2N6107	488	SSD-204A	145
TA7742	PWR	2N6109	488	SSD-204A	145
TA7743	PWR	2N6111	488	SSD-204A	145
TA7752	TRI	40916	549	SSD-206A	134
TA7753	TRI	40917	549	SSD-206A	134
TA7754	TRI	40918	549	SSD-206A	134
TA7755	TRI	40919	459	SSD-206A	134
TA7756	TRI	40920	549	SSD-206A	134
TA7757	TRI	40921	549	SSD-206A	134
TA7782	PWR	2N6292	542	SSD-204A	161
TA7783	PWR	2N6290	542	SSD-204A	161
TA7784	PWR	2N6288	542	SSD-204A	161
TA7802	RECT	44003	495	SSD-206A	296

Developmental-Number-to-Commercial-Number Cross-Reference Index

Dev. No.	Product Line	Comm. No.	File No.	DATA-BOOK Vol. No.	Page
TA7803	RECT	44004	495	SSD-206A	296
TA7804	RECT	44005	495	SSD-206A	296
TA7805	RECT	44006	495	SSD-206A	296
TA7806	RECT	44007	495	SSD-206A	296
TA7821	SCR	40937	578	SSD-206A	243
TA7823	SCR	40938	578	SSD-206A	243
TA7825	SCR	40951	578	SSD-206A	243
TA7852	RF	2N5917	425	SSD-205A	154
TA7920	RF	2N5992	451	SSD-205A	192
TA7921	RF	2N5993	452	SSD-205A	197
TA7922	RF	2N5995	454	SSD-205A	208
TA7923	RF	2N5996	454	SSD-205A	213
TA7936	MOS/FET	40819	463	SSD-201A	650
TA7937	TRI	40922	549	SSD-206A	134
TA7938	TRI	40923	549	SSD-206A	134
TA7939	TRI	40924	549	SSD-206A	134
TA7941	RF	40934	550	SSD-205A	367
TA7943	RF	40909	547	SSD-205A	359
TA7955	HYB	HC4005A	571	SSD-204A	566
TA7957	HYB	HC4012A	571	SSD-204A	566
TA7982	RF	40940	553	SSD-205A	375
TA7985	RECT	40958R	580	SSD-206A	333
TA7986	RECT	40959R	580	SSD-206A	333
TA7987	RECT	40960R	580	SSD-206A	333
TA7988	SCR	106A	555	SSD-206A	150
TA7989	SCR	106B	555	SSD-206A	150
TA7990	SCR	106C	555	SSD-206A	150
TA7991	SCR	106D	555	SSD-206A	150
TA7993	RF	2N6265	543	SSD-205A	231
TA7994	RF	2N6266	544	SSD-205A	237
TA7995	RF	2N6267	545	SSD-205A	243
TA7995A	RF	2N6269	546	SSD-205A	249
TA7996	RECT	44001	495	SSD-206A	296
TA7999	MOS/FET	40820	464	SSD-201A	658
TA8000	MOS/FET	40821	464	SSD-201A	658
TA8001	MOS/FET	40822	465	SSD-201A	666
TA8002	MOS/FET	40823	465	SSD-201A	666
TA8004	PWR	2N6077	492	SSD-204A	260
TA8005	PWR	2N6079	492	SSD-204A	260
TA8104	RF	40915	574	SSD-205A	363
TA8141	HYB	HC3000	539	SSD-204A	560
TA8158	SCR	40888	522	SSD-206A	187
TA8159	SCR	40889	522	SSD-206A	187
TA8160	RECT	40890	522	SSD-206A	304
TA8161	RECT	40891	522	SSD-206A	304
TA8162	RECT	40892	522	SSD-206A	304
TA8197	TRI	40925	593	SSD-206A	127
TA8198	TRI	40926	593	SSD-206A	127
TA8199	TRI	40927	593	SSD-206A	127
TA8201	PWR	2N6388	610	SSD-204A	461
TA8202	PWR	2N6386	610	SSD-204A	461
TA8210	PWR	2N6106	488	SSD-204A	145
TA8211	PWR	2N6108	488	SSD-204A	145
TA8212	PWR	2N6110	488	SSD-204A	145
TA8231	PWR	2N6293	542	SSD-204A	161
TA8232	PWR	2N6291	542	SSD-204A	161
TA8236	RF	40936	551	SSD-205A	371
TA8241	HYB	HC3100	564	SSD-204A	563
TA8242	MOS/FET	40841	489	SSD-201A	673
TA8247	PWR	40887	508	SSD-204A	268
TA8248	PWR	40885	508	SSD-204A	268
TA8249	PWR	40886	508	SSD-204A	268
TA8330	PWR	2N6213	507	SSD-204A	443
TA8344	RF	40895	548	SSD-205A	347
TA8345	RF	40895	548	SSD-205A	347
TA8346	RF	40896	548	SSD-205A	347
TA8347	RF	40897	548	SSD-205A	347
TA8348	PWR	2N6385	609	SSD-204A	455
TA8349	PWR	2N6383	609	SSD-204A	455
TA8352	PWR	2N6372	608	SSD-204A	169
TA8353	PWR	2N6373	608	SSD-204A	169
TA8354	PWR	2N6374	608	SSD-204A	169
TA8357	TRI	40901	540	SSD-206A	143
TA8358	TRI	40902	540	SSD-206A	143
TA8397	PWR	HC4015A	571	SSD-204A	566
TA8407	RF	2N6268	546	SSD-205A	249
TA8425	RF	R47M15	605	SSD-205A	410
TA8428	PWR	2N6254	524	SSD-204A	28
TA8429	PWR	2N6253	524	SSD-204A	28
TA8430	PWR	2N6258	525	SSD-204A	52
TA8431	PWR	2N6257	525	SSD-204A	52
TA8432	PWR	2N6259	526	SSD-204A	60
TA8433	PWR	2N6261	527	SSD-204A	20
TA8434	PWR	2N6260	527	SSD-204A	20
TA8435	PWR	2N6262	528	SSD-204A	44
TA8436	PWR	2N6264	529	SSD-204A	36
TA8437	PWR	2N6263	529	SSD-204A	36
TA8439	RF	40898	538	SSD-205A	351
TA8440	RF	40899	538	SSD-205A	351
TA8485	PWR	2N6387	610	SSD-204A	461
TA8486	PWR	2N6384	609	SSD-204A	455
TA8559	RF	40954	579	SSD-205A	384
TA8561	RF	40955	579	SSD-205A	384
TA8562	RF	40967	596	SSD-205A	393
TA8563	RF	40968	596	SSD-205A	393
TA8591	PWR	HC4005	571	SSD-204A	566
TA8595	PWR	HC4012	571	SSD-204A	566
TA8599	PWR	HC4015	571	SSD-204A	566

Military-Specification (JAN and JANTX) Types

Type No.	MIL-Spec 19500/	Product Line	For data on basic type, see File No.	DATA-BOOK Vol. No.	Page
JAN-2N918	301	RF	83	SSD-205A	18
JAN-2N1184	143	PWR	14	SSD-204A	572
JAN-2N1184A	143	PWR	14	SSD-204A	572
JAN-2N1184B	143	PWR	14	SSD-204A	572
JAN-2N1224	189	PWR	14	SSD-204A	572
JAN-2N1479	207	PWR	135	SSD-204A	474
JAN-2N1480	207	PWR	135	SSD-204A	474
JAN-2N1481	207	PWR	135	SSD-204A	474
JAN-2N1482	207	PWR	135	SSD-204A	474
JAN-2N1483	180	PWR	137	SSD-204A	479
JANTX-2N1483	180	PWR	137	SSD-204A	479
JAN-2N1484	180	PWR	137	SSD-204A	479
JANTX-2N1484	180	PWR	137	SSD-204A	479
JAN-2N1485	180	PWR	137	SSD-204A	479
JANTX-2N1485	180	PWR	137	SSD-204A	479
JAN-2N1486	180	PWR	137	SSD-204A	479
JANTX-2N1486	180	PWR	137	SSD-204A	479
JAN-2N1487	208	PWR	139	SSD-204A	484
JAN-2N1488	208	PWR	139	SSD-204A	484
JAN-2N1489	208	PWR	139	SSD-204A	484
JAN-2N1490	208	PWR	139	SSD-204A	484
JAN-2N1493	247	RF	10	SSD-205A	22
JAN-2N2015	248	PWR	12	SSD-204A	500
JAN-2N2016	248	PWR	12	SSD-204A	500
JAN-2N2857	343	RF	61	SSD-205A	31
JANTX-2N2857	343	RF	61	SSD-205A	31
JAN-2N3055	407	PWR	524	SSD-204A	28
JANTX-2N3055	407	PWR	524	SSD-204A	28
JAN-2N3375	341	RF	386	SSD-205A	50
JANTX-2N3375	341	RF	386	SSD-205A	50
JAN-2N3439	368	PWR	64	SSD-204A	222
JANTX-2N3439	368	PWR	64	SSD-204A	222
JAN-2N3440	368	PWR	64	SSD-204A	222
JANTX-2N3440	368	PWR	64	SSD-204A	222
JAN-2N3441	369	PWR	529	SSD-204A	36
JAN-2N3442	370	PWR	528	SSD-204A	44
JAN-2N3553	341	RF	386	SSD-205A	50
JANTX-2N3553	341	RF	386	SSD-205A	50
JAN-2N3584	384	PWR	138	SSD-204A	229
JANTX-2N3584	384	PWR	138	SSD-204A	229
JAN-2N3585	384	PWR	138	SSD-204A	229
JANTX-2N3585	384	PWR	138	SSD-204A	229
JAN-2N3771	413	PWR	525	SSD-204A	52
JANTX-2N3771	413	PWR	525	SSD-204A	52
JAN-2N3772	413	PWR	525	SSD-204A	52
JANTX-2N3772	413	PWR	525	SSD-204A	52
JAN-2N3866	398	RF	80	SSD-205A	71
JANTX-2N3866	398	RF	80	SSD-205A	71
JAN-2N4440	341	RF	217	SSD-205A	85
JANTX-2N4440	341	RF	217	SSD-205A	85
JAN-2N5038	439	PWR	367	SSD-204A	371
JANTX-2N5038	439	PWR	367	SSD-204A	371
JAN-2N5039	439	PWR	367	SSD-204A	371
JANTX-2N5039	439	PWR	367	SSD-204A	371

	Databook	Page
AC-DC isolation	206A	453
Active filter, integrated-circuit	201A	475
AC voltage regulators, thyristors	206A	
Adders, scaling	202A	273
Admittance parameters, short-circuit	202A	93
AGC	202A	46,47
Alarm system, intrusion	202A	247
AM broadcast receivers	202A	43
AM modulator, integrated-circuit	201A	476
AM radio, integrated circuit for	202A	42
Applications	202A	43
Circuit description	202A	42
AND-OR bi-phase pairs, COS/MOS triple (technical data)	203A	188
Amplification, sound-carrier	202A	46
Amplifier array, general-purpose, integrated-circuit (technical data)	201A	42
Amplifier array, integrated-circuit,	202A	68
Circuit applications	202A	72
Circuit description	202A	68
Gain-frequency response	202A	70
Noise voltage and current	202A	72
Output swing vs. supply voltage	202A	72
Quick selection chart	201A	10
Stability requirements	202A	70
Amplifier array, integrated-circuit, ac (technical data)	201A	28,250
Amplifier array, ultra-high-gain, wide-band, integrated-circuit (technical data)	201A	74
Amplifier, broadband (118-to-136-MHz), 4-watt (PEP):		
Design considerations	205A	419
Load-mismatch test	205A	417
Output power and modulation	205A	417
Performance and adjustment	205A	421
Amplifier, broadband, rf, linear, push-pull, 150-watt PEP	205A	467
Amplifier circuit, broadband, uhf	205A	473
Amplifier, class B, circuit description	204A	599
Amplifier, class B, integrated-circuit	202A	79,189
Amplifier, control, and special-function integrated circuits:		
Application notes on	202A	88-260
Quick selection chart	201A	12
Technical data	201A	257-456
Amplifier, dc, integrated-circuit	202A	130
Applications	201A	136
Circuit description	201A	130
Operation	201A	130
Technical data	201A	290
Amplifier, differential detector, dc amplifier, and voltage regulator, integrated-circuit (technical data)	201A	84
Amplifier-discriminators, omtegrated-circuit (technical data)	201A	62
Amplifier economics	204A	596
Amplifier, feedback	202A	137
Amplifier fidelity	204A	596
Amplifier-filter, high-gain	202A	259
Amplifier, FM detector, af preamplifier integrated-circuit (technical data)	201A	90,98
Amplifier, gain-controlled, integrated-circuit	202A	75
Amplifier, if, integrated-circuit	202A	141
Applications	202A	146
Characteristics	202A	144
Circuit description	202A	141
Operating modes	202A	141
Technical data	201A	258
Amplifier, narrow-band, tuned, integrated-circuit	202A	138
Amplifier, rf, integrated-circuit	202A	78,80
Amplifier, servo, integrated-circuit	202A	194
Amplifiers, integrated-circuit:		
Audio	202A	150,190
Driver	202A	193
Frequency-shaping	202A	272
Operational	202A	261-334
Output	202A	58
Power	202A	187
RF	202A	163
Video	202A	268
Wide-band	202A	173,191, 195,201
Amplifier, tint-control, integrated-circuit	202A	62
Amplifier, twin-T, bandpass	202A	281
Amplifier, video, integrated-circuit	202A	153,182, 268
Amplitude modulation	205A	451
AM receiver subsystem, integrated-circuit (technical data)	201A	42,46
Analog or digital signals, transmission and multiplexing of	203A	379
AND-OR gates, COS/MOS, triple bi-phase pairs (technical data)	203A	188
AND-OR select gate COS/MOS quad	203A	373
AND-OR select gate, COS/MOS quad (technical data)	203A	94
Arcing	206A	460
Arithmetic unit, COS/MOS	203A	373
Circuit description	203A	373
Operation	203A	374
Performance data	203A	378
Arithmetic arrays, COS/MOS	203A	373
Arrays, integrated-circuit		
Application notes on	202A	67-86
Technical data	201A	161-256
Astable multivibrator, integrated-circuit	202A	73,307
Astable multivibrator, COS/MOS	203A	353
Audio amplifier, hybrid-circuit	204A	670
Audio amplifier, integrated-circuit	202A	150
Capacitor-coupled cascaded circuits	202A	153
Circuit description	202A	150
Direct-coupled cascaded circuits	202A	151
Technical data	201A	331
Audio amplifiers, integrated-circuit	202A	190
Audio amplifier, line-operated	204A	588
Audio amplifier, transformer-coupled	204A	671
Audio driver, integrated-circuit:		
Dual-supply circuit	202A	152
Single-supply circuit	202A	153
Autodyne converter, integrated-circuit	202A	163
Automatic-fine-tuning systems, integrated-circuit	202A	33
Automatic shut-off and alarm system	202A	258
Axial-lead silicon rectifiers (technical data)	206A	262-271, 280-289, 296-299
Audio power transistors, special (technical data)	204A	509-542

Subject Index

	Databook	Page
Balanced detector, integrated-circuit	202A	33
Balanced modulator, integrated-circuit	202A	82
Ballasting circuits, solid-state	204A	504
Ballast resistors	204A	684
Bandpass amplifiers	202A	281
Bandpass shaping	202A	46
Bass roll-off	202A	39
BCD data, conversion of	202A	244
Beam-lead (sealed-junction) IC's (technical data)	201A	545-566
Bidirectional thyristors, gated (technical data)	206A	105
Bilateral switch, COS/MOS quad	203A	379
Digital control of signal gain, frequency, and impedance	203A	384
Features	203A	379
Logic functions	203A	383
Multiplexing/demultiplexing	203A	384
Operation	203A	379
Sample-hold applications	203A	388
Switch and logic applications	203A	383
Technical data	203A	78
Binary counter	203A	328
Bi-phase pairs, AND-OR, COS/MOS (technical data)	203A	188
Bi-polarity comparator	202A	332
Bistable multivibrator	202A	309
Bridge circuits, SCR	206A	442
Bridge rectifier	204A	652
Broadband rf circuit design	205A	453
Broadband rf operation	205A	470
Broadband rf power amplifier	205A	427
Broadband transistor rf amplifier	205A	417
Broadband uhf amplifier	205A	477,481
Broadband uhf circuit, design approach	205A	475
Broadcast receivers, AM	202A	42
Buffer, converter-circuit	204A	666
Buffer, COS/MOS quad, true/complement (technical data)	203A	199
Buffers/converters, COS/MOS hex (technical data)	203A	48
Burst (popcorn) noise, meansurement of	202A	327
Pass-fail criteria	202A	330
Test conditions	202A	330
Test configuration	202A	327
Test-system circuits	202A	331
Bus register, COS/MOS MSI, 8-stage (technical data)	203A	164
Capacitor-input circuits, design of	206A	384
Capture ratio	202A	25
Case-temperature effects	205A	471
Characteristics of COS/MOS integrated circuits (chart)	203A	8
Charge transport during irradiation	203A	410
Chips (technical data):		
COS/MOS integrated-circuit	203A	268-276
Linear integrated-circuit	201A	534-544
Power-transistor	204A	543-547
Chroma amplifier, integrated-circuit (technical data)	201A	148
Chroma demodulator, integrated-circuit (technical data)	201A	129,151

	Databook	Page
Chroma signal processor, integrated-circuit (technical data)	201A	126,144
Chopper circuits, MOS-transistor	202A	347
Basic chopper circuits	202A	347
Basic MOS chopper circuits	202A	448
Equivalent circuit of MOS chopper	202A	350
Ideal chopper characteristics	202A	347
Relative merits of available devices	202A	347
Typical circuits	202A	352
Use of MOS transistors in choppers	202A	348
Circuit factor charts for thyristors (SCR's and Triacs)	206A	379
Current-Ratio curves	206A	379
Full-wave ac triac circuit	206A	380
Full-wave dc SCR or Triac circuit	206A	381
Full-wave SCR circuit	206A	379
Per cent ripple in load	206A	383
Three-phase half-wave SCR circuit	206A	382
Class B transistor amplifier	204A	594
Circuit description	204A	599
Complementar-symmetry type	204A	595
Economics of	204A	596
Effective power-supply series resistance	204A	596,600
Fidelity of	204A	596
Music-power rating	204A	596,600
Power dissipation, ideal	204A	597
Power-output	204A	595
Power-supply regulation	204A	594
Practical circuit	204A	595
Transistor dissipation	204A	595
Clocked D latch, COS/MOS quad (technical data)	203A	208
Clock/timer, battery-operated, Digital-display, COS/MOS:		
Applications	203A	444
Circuit operation	203A	434
Display-driver circuits	203A	436
Performance characteristics	203A	434
Coaxial-line rf power amplifier	205A	437
Coaxial-package transistors	205A	443
Color demodulator, integrated-circuit	202A	58
Application of	202A	65
Demodulation and matrix	202A	59
Demodulator preamplifier	202A	61
Filtering capactiors	202A	61
Output amplifiers	202A	58
Tint-control amplifier	202A	62
Color matrix, integrated-circuit	202A	59
Color system, RGB	202A	65
Color TV receivers, if system for, integrated-circuit	202A	51
Colpitts oscillator, integrated-circuit	202A	73
Common-base rf power amplifiers	205A	432
Common-mode gain	202A	266
Common-mode rejection	202A	157
Common-mode rejection ratio	202A	98.157, 266
Commutating dv/dt (of thyristors)	206A	455
Comparator:		
Bi-polarity	202A	332
DC	202A	309
Differential	202A	231
Micropower	202A	324
Phase	203A	427
Tri-level	203A	409

	Databook	Page
Controlled-avalanche rectifiers (technical data)	206A	311
Control systems, triac	202A	247
Conversion, digital-to-analog	203A	296
	202A	218
Converter-circuit driver stage	204A	666
Converter-circuit oscillator	204A	665
Converter-circuit output stage	204A	666
Converter, off-line, driven, 1-kilowatt	204A	664
Characteristics	204A	664
Circuit description	204A	665
Efficiency/cost considerations	204A	668
Performance characteristics	204A	667
Transformer design considerations	204A	667
Converter, ringing-choke	204A	605
COS/MOS chips (technical data)	203A	268-276
COS/MOS digital integrated circuits	203A	1
Applications information	203A	289-449
Functional diagrams	203A	10
General features	203A	23
Technical data	203A	24-276
COS/MOS IC's for low-voltage Applications (technical data)	203A	24,114
COS/MOS integrated circuits, functional diagrams	203A	10-19
COS/MOS integrated circuits, general features	203A	23
COS/MOS integrated circuits, typical characteristics chart	203A	8
COS/MOS logic gates, noise immunity of	203A	344
COS/MOS power-supply considerations	203A	368
COS/MOS switch	203A	302
Counter, COS/MOS binary/ripple, 12-stage (technical data)	203A	195
Counter, COS/MOS, 21-stage	203A	222
Counters, COS/MOS, applications of:		
Decade, 7-segment-output	203A	434
Divide-by-N	203A	422
Divide-by-R	203A	427
Divide-by-12	203A	445
Divide-by-60	203A	445
Fixed, single-stage, divide-by-N		
Programmable, multidecade, Divide-by-N	203A	363
Counter, COS/MOS, fixed and programmable, Design of	203A	361
Counters, COS/MOS MSI, design and applications of	203A	327
Counters, COS/MOS (technical data):		
Binary, 7-stage	203A	114
Decade	203A	120
Divide-by-N	203A	89
Up/down, presettable	203A	140
Counting circuit, COS/MOS, digital-display	203A	416
Counter/dividers, COS/MOS, applications of:		
Decade	203A	333
Divide-by-8	203A	334
Counter-latch-timer control circuit	202A	332
Counter/timers, digital	203A	
Cross-modulation distortion	202A	102
Crosstalk	203A	343
Crowbar trigger circuits	204A	685
Crystal oscillators:		
Bipolar integrated-circuit	202A	136
COS/MOS integrated-circuit	203A	431
Current-amplifier pair, hybrid-circuit (technical data)	204A	560,563
Current limiting, foldback	204A	633,684
Current mirrors	202A	325
Current-ratio curves (SCR's and triacs)	206A	
Current source, diode-transistor	202A	325
Curves, rf power-transistor power-		379
frequency	205	8-10
DC amplifier, integrated-circuit	202A	130
Applications	202A	136
Circuit description	202A	130
Operation	202A	130
Technical data	201A	290
DC power supply, ac voltage-regulated	206A	423
DC safe area (power transistors)	205A	469
Decade counters, COS/MOS, 7-segment output	203A	435
Decoder, COS/MOS, BCD-to-decimal (technical data)	203A	135
Decoder-Drivers, MSI, BCD-to-7-segment	202A	244
Fail-safe circuit	202A	252
Logic description	202A	244
Logic diagram	202A	246
Multiplex operation	202A	252
Operating characteristics	202A	247
Static-drive applications	202A	249
Technical data	201A	437
Decoder stero multiplex, integrated-circuit (technical data)	201A	36
Deflection circuit, magnetic	204A	586
Delayed agc	202A	46,47
Demodulation, color-signal	202A	59
Demodulator, color, integrated-circuit	202A	58
Demodulator preamplifier, integrated-circuit	202A	61
Detection, sound-carrier	202A	46
Diacs, silicon bidirectional:		
Technical data	206A	353-355
Use of for thyristor triggering	206A	441
Voltage-current characteristics	206A	442
Differential-amplifier array, dual independent, integrated-circuit (technical data)	201A	336,363
Differential amplifiers, integrated-circuit, Basic configuration for	202A	21
Differential amplifiers, integrated-circuit high-reliability types (technical data)	201A	299,310
Differential/cascode amplifiers, integrated-circuit (technical data)	201A	348,355
Differential comparator, integrated-circuit	202A	231
	206A	483
Differentiators, integrated-circuit	202A	273
Diffused-junction n-p-n power transistors (technical data)	204A	471-542
Digital-clock prototypes, COS/MOS	203A	446
Digital-display clock, COS/MOS	203A	434
Digital-display clock/watch configuration, COS/MOS	203A	445
Digital-display devices	203A	438
Digital-display metering application, COS/MOS	203A	434
Digital-display timer, COS/MOS	203A	434
Digital frequency synthesizer, COS/MOS	203A	419
Digital meter applications, COS/MOS	203A	449

Subject Index

	Databook	Page
Digital signals, transmission and multiplexing of	203A	379
Digital timer/clock/watch applications, COS/MOS	203A	439
Digital-to-analog conversion, general considerations	203A	297
Digital-to-analog converter, COS/MOS	203A	301
Digital-to-analog switch, COS/MOS	203A	297
Diode Array, integrated-circuit	202A	81
Applications	202A	82
Circuit configuration	202A	81
Operating characteristics	202A	81
Technical data	201A	162,169
Diodes, light-emitting	203A	438
Display-lamp turn-on characteristics	202A	248
Double-tuned interstage filter	202A	23
Down-conversion, heterodyne	203A	421,431
Down-converter, heterodyne, COS/MOS	203A	421
Driver amplifiers, integrated-circuit	202A	193
Driver, audio, integrated circuit	202A	152,153
Drivers circuits for digital displays, types of	203A	436
Driver for 600-ohm balanced-line	202A	75
Driver stage, converter-circuit	204A	666
D-type latch, clocked, COS/MOS quad (technical data)	203A	208
Dv/dt suppression (in thyristor circuits)	206A	462
Dual Darlington array, integrated-circuit (technical data)	201A	202
Dual differntial amplifiers (technical data)	201A	372
Dynamic performance of AFT system	202A	35
Economics, amplifier	204A	586
Electric-heat application	206A	492
Electron radiation	203A	405
Emitter ballasting	205A	470
Emitter ballast resistance	205A	461
Envelope detector	202A	147
Epitaxial-base power transistors (selection chart)	204A	18
Epitaxial-base power transistors, (technical data)	204A	137-220
Epitaxial-base, high-power, p-n-p transistors (technical data)	204A	153
External noise	203A	343
False turn-on (of thyristors)	206A	462
False turn-on (of thyristors)	206A	462
Fast-recovery silicon rectifiers	206A	333
Fast-turn-off silicon controlled rectifiers (technical data)	206A	236
Feedback amplifier, integrated-circuit, cascaded, RC-coupled	202A	137
Feedback factor	202A	38
Feedback-type volume-control circuit	202A	38
Ferrite cores	205A	464
Filament pre-heating circuit	206A	451
Filter, active, integrated-circuit	201A	475
Filters, interstage	202A	23

	Databook	Page
Flanged-case silicon rectifiers (technical data)	206A	262-271, 280
Flasher circuit, thyristor	206A	452
Flashover current	206A	448
Flip-flop, COS/MOS dual D-type:		
Technical data	203A	62
Use of in arithmetic unit	203A	373
Flip-flop, COS/MOS dual J-K master-slave (technical data)	203A	129
Flourescent readouts, low-voltage vacuum	203A	442
FM broadcast receivers, integrated circuits for	202A	14
FM front-end circuits (IC's)	202A	16,17, 170
FM if amplifier and detector, integrated-circuit	202A	19
FM if amplifier, limiter, and discriminator, integrated-circuit	202A	18
FM if amplifier-limiter, detector, and audio preamplifier, integrated-circuit (technical data)	201A	53
FM if strip integrated-circuit	202A	25
FM if system, integrated-circuit (technical data)	201A	46
FM receiver synthesizers, COS/MOS	203A	422
Prescaler system design	203A	422
System requirements	203A	422
FM subsystems, integrated-circuit	202A	28
FM synthesizer system, COS/MOS	203A	431
FM tuner, integrated-circuit	202A	15
FM tuner using MOS-transistor rf amplifier	202A	354
Circuit considerations	202A	354
Performance	202A	356
RF stage design	202A	356
FM tuner using MOS-transistor rf amplifier and mixer	202A	360
Conversion transconductance, calculation of	202A	364
Mixer-circuit considerations	202A	362
Oscillator-circuit considerations	202A	363
Over-all tuner performance	202A	363
Performance features of MOS transistors	202A	360
RF-circuit considerations	202A	362
Tuner design	202A	361
Foldback current limiting:		
Analysis of	204A	687
Basic circuit configuration	204A	635
Characteristics	204A	633
Circuit parameters	204A	635,640
Purpose and advantage	204A	684
Forward-bias second breakdown, testing for	204A	643
Four-quadrant multiplier, integrated-circuit	202A	317
Frequency converter, three-phase 750-watt:		
Circuit description	204A	652
Inverter	204A	652
Logic and driver circuits	204A	652
Output transformer	204A	654
Performance	204A	656
Power supply for	204A	652
Frequency-modulation if amplifiers, integrated-circuit	202A	21
Frequency multipliers, COS/MOS	203A	360
Frequency-shaping amplifiers, integrated-circuit	202A	272

	Databook	Page
Frequency synthesizer, COS/MOS low-power digital	203A	419
Full adder, COS/MOS four-bit:		
Technical data	203A	43
Use in arithmetic unit	203A	373
Full-wave motor controls	206A	373
Regulated	206A	374
Unregulated	206A	373
Gain controlled amplifier, integrated-circuit	202A	75
Gain control, rf-amplifier	202A	100
Gain equalizer (for uhf amplifier)	205A	479
Garage-door electronic control system	206A	395
Gate characteristics (of thyristors)	206A	436
Gate, COS/MOS dual complementary pair plus inverter (technical data)	203A	37
Gate, COS/MOS quad AND-OR select	203A	344
Gate, COS/MOS quad exclusive-OR (technical data)	203A	147
Gate-oxide field analysis	203A	409
Gate-oxide protection circuit	203A	351
Gates, COS/MOS quad, 2-input NAND	203A	374
Gates, COS/MOS quad 2-input NOR	203A	374
Gates, COS/MOS triple AND-OR bi-phase pairs (technical data)	203A	188
Gates, high-speed	202A	77
Series	202A	78
Shunt	202A	79
Series-shunt	202A	79
Ground-line noise	203A	419
Gyrator, integrated-circuit	201A	475
Half-wave motor controls	206A	368
Unregulated	206A	369
Regulated	206A	370
Half-wave SCR circuit	206A	379
Harmonic distortion	202A	152,158
Hartley oscillator, integrated-circuit	202A	73
Heat control	206A	397
Heat controllers	202A	227
Heater control, three-phase	206A	469
Heater regulation	206A	421
Heterodyne down-conversion	203A	421,431
Heterodyne down-converter	203A	292
High-current transistors (technical data)	204A	60
High-frequency power transistors (technical data)	205A	347
High-gain selective building blocks, evolution of	202A	22
High-power generation	205A	429
High-reliability transistor (technical data)	205A	305-317
High-speed gates	202A	77
High-speed switching power transistors (technical data)	204A	319-426
High-voltage application of silicon transistors	204A	591
High-voltage generation	206A	410,458
High-voltage n-p-n power transistors (technical data)	204A	221-318

	Databook	Page
High-voltage p-n-p power transistors (technical data)	204A	437
High-voltage power transistors selection chart	204A	12
High-voltage rectifiers (technical data)	206A	337-351
With R-C voltage-equalizing networks	206A	337
With matched cells for voltage equalization	206A	341
Plug-in types for direct tube replacements	206A	350
Fin-mounted types	206A	344
High-voltage regulation	206A	411,458
Hometaxial-base n-p-n power transistors (selection chart)	204A	10
Hometaxial-base n-p-n power transistors (technical data)	204A	19-136
Hometaxial-base power transistors, molded-silicone-plastic types (technical data)	204A	68
Horizontal-deflection SCR's and rectifiers (technical data)	206A	290,304
Horizontal deflection system:		
For color TV receivers	206A	404,455
For monochrome TV receivers	206A	473
Hot-spot thermal resistance	205A	470,473
Hotspotting	205A	469
Hybrid-circuit current-amplifier pair (technical data)	204A	563
Hybrid-circuit operational amplifiers (technical data)	204A	555
Hybrid circuits, power (technical data)	204A	549-570
Hybrid combiners	205A	431
Hybrid combiner/dividers	205A	465
Hybrid linear power amplifier:		
Audio applications of	204A	669
General application considerations	204A	673
Hysteresis effect, lamp-dimmer	206A	399
IF-amplifier circuits, integrated types	202A	77,109, 146,163, 168,183
IF amplifier-limiter, FM detector, electronic attenuator, audio driver, integrated-circuit (technical data)	201A	106
IF amplifier, integrated-circuit	202A	141
Applications	202A	146
Characteristics	202A	144
Circuit description	202A	141
Operating modes	202A	141
IF amplifier-limiter, integrated-circuit high-gain, wide-band (technical data)	201A	70
IF strips, FM, integrated-circuit	202A	22,169, 170
IF system, FM, Integrated-circuit (technical data)	201A	46
IF system, integrated-circuit, black-and-white TV receiver	202A	54
IF system integrated- circuit, for for color TV receiver	202A	49
IHFM (Institute of High-Fidelity Manufacturers)	202A	169
Incandescents readouts	203A	442
Induction motor controls	206A	394

Subject Index

	Databook	Page
Inrush current	206A	449
Insertion loss	202A	25
Institute of High-Fidelity Manufacturers (IHFM)	202A	169
Integral-cycle heater control, proportional	206A	397
Integrated-circuit arrays:		
Application notes on	202A	67-86
Technical data	201A	161-256
Integrated-circuit chips, linear (technical data)	201A	534-544
Integrated-circuit FM, IF amplifiers, design approaches for	202A	22
Integrated circuits, COS/MOS digital	203A	1
Integrated circuits, linear (bipolar)	201A	1
Integrators	202A	273
Interfacing of COS/MOS devices	203A	391
Active pull-ups	203A	393
Bipolar driving COS/MOS	203A	393
COS/MOS-bipolar HTL interface	203A	396
COS/MOS driving bipolar	203A	394
COS/MOS-ECL/ECCSL interface	203A	400
COS/MOS-to-N-MOS interface	203A	402
COS/MOS-to-P-MOS interface	203A	401
COS/MOS-TTL/DTL interface	203A	391
Current sinking	203A	392,395
Current sourcing	203A	392,395
Level shifters	203A	400
Resistor, pull-up	203A	392
Intermodulation distortion	202A	152
Interstage filters	202A	23
Intrinsic transistor structure	205A	427
Intrusion alarm system, triac	202A	247
Inverters	204A	584,591
Push-pull types	204A	605
Three-phase bridge types	204A	652
Isolation, ac-dc	206A	453
Keyed AGC	202A	46,47
Ladder networks, resistance	203A	297
Lamp-dimmer circuits	206A	401
Double-time constant types	206A	402
Single-time-constant types	206A	401
With over-voltage clamp	206A	422
Latch, COS/MOS quad, clocked D (technical data)	203A	208
Latch COS/MOS quad, 3-state NAND R/S (technical data	203A	214
Latch, COS/MOS quad 3-state, NOR R/S (technical data)	203A	214
Latched memory circuit	202A	257
Level converters, COS/MOS	203A	436
Level detector, COS/MOS	203A	390
Light-activated control	202A	258
	206A	393
Light control	206A	391
Light-control circuits	206A	398,445
Basic triac-diac type	206A	399
Double-time-constant types	206A	400
Single-time-constant types	206A	399

	Databook	Page
Light dimmers, triac	206A	398
Circuits	206A	401
Circuit description	206A	398
Hysteresis effect	206A	399
Range control	206A	400
RFI suppression	206A	401
Trouble shooting	206A	401
Light-emitting diodes	203A	438
Light flasher, synchronous	202A	243
	206A	496
Lighting systems, relative merits of various types	204A	602
Limiter, integrated-circuit	202A	163
Limited-amplifier, integrated-circuit	202A	33,185
Limiter characteristics (of IC rf amplifiers)	202A	106
Limiting amplifier, integrated-circuit	202A	186
Linear amplifier, push-pull 150-watt, 2-to-30-MHz	205A	467
Linear applications of rf power transistors	205A	429
Linear IC arrays (technical data)	201A	161-256
Linear IC chips (technical data)	201A	534-544
Linear integrated circuits and MOS devices	201A	1
	202A	1
Index to	201A	6
Packages and ordering information	201A	20
Linearity	206A	405
Linearity circuit	206A	459
Linear mixer, four-channel, integrated-circuit	202A	73
Losser-type volume-control circuit	202A	38
Loudness contouring	202A	39
Lumped-constant rf power amplifiers	205A	442
Lumped-constant rf power oscillator	205A	441
Magnetic deflection circuit	204A	586
Matched diodes, ultra-fast, low-capacitance (technical data)	201A	166
Matrix:		
Rectifier products	206A	17
SCR products	206A	11
Triac products	206A	13
Maximum usable gain	202A	51
Medium-power p-n-p transistors (technical data)	204A	428
Medium-power transistors, hometaxial II types (technical data)	204A	20,36
Mercury-arc lamps:		
Advantages of	204A	603
Ballasting of	204A	602
Characteristics of	204A	602
Conventional ballasting methods	204A	604
Starting current for	204A	611
Solid-state ballasting circuits	204A	604
Memory, COS/MOS, preset-channel	203A	432
Memory, integrated-circuit, latched	202A	257
Memory sense amplifier, integrated-circuit, dual-input (technical data)	201A	429
Microstripline circuits	205A	443
Design of	205A	444
Mounting arrangement	205A	443
Performance of	205A	447
Microstripline oscillator	205A	440

	Databook	Page
Microwave power amplifiers	205A	436
Biasing arrangements	205A	441
Coaxial-line types	205A	437
Device and package construction	205A	434
Design of	205A	436
Large-signal amplifier operation	205A	436
Lumped-constant, common-base types	205A	442
Performance of practical circuits	205A	447
Power gain	205A	441
Pulse operation	205A	438
Reliability	205A	436
Stripline type	205A	438
Microwave power oscillators	205A	434
Basic configuration	205A	439
Design of	205A	439
Device and package construction	205A	434
Lumped-constant type	205A	440
Microstripline type	205A	440
Reliability	205A	436
Wide-band type	205A	440
Mixer capabilities (of integrated-circuit rf amplifiers)	202A	103
Mixers, integrated-circuit:		
Balanced	202A	103,109
Four-channel linear	202A	73
Low-frequency	202A	120
Mixers, MOS-transistor:		
FM-receiver	202A	360,362
VHF-receiver	202A	344
Molded-Plastic transistors and thyristors		
Lead forming techniques	206A	427
Mounting	206A	430
Thermal-resistance considerations	206A	427
Types of packages	206A	426
Monochrome TV receivers, thyristor horizontal deflection system for	206A	473
Monostable multivibrators, COS/MOS:		
Basic configuration	203A	356
Compensated circuit	203A	357
Low-power circuit	203A	358
Monolithic n-p-n Darlington power transistors (technical data)	204A	449-470
Monostable multivibrator, integrated-circuit	202A	309
MOS chopper circuits	202A	352
MOS/FET's (see MOS field-effect transistors)		
MOS field-effect devices (see MOS field-effect transistors)		
MOS field-effect transistors:		
Application notes on	202A	261-377
Technical data	201A	567-686
MOS field-effect transistors, dual-gate-protected types:		
Breakdown mechanism	202A	366
Cross-modulation considerations	202A	375
Current-handling capability	202A	369
Electrical requirements	202A	368
Gate-protection diodes	202A	368,371 375
Gate-protection methods	202A	367
Input capacitance and resistance	202A	369
Noise factor	202A	369
Operating conditions	202A	371
Power gain	202A	369

	Databook	Page
RF applications	202A	371
Stability considerations	202A	375
Static discharge, effect of	202A	366
MOS field-effect transistor, vhf applications:		
Biasing requirements	202A	336
Circuit configurations	202A	336
Operating-point selection	202A	338
AGC methods	202A	339
RF considerations	202A	339
Use of in vhf circuit design	202A	340
MOS-transistor vhf mixer, design of	202A	344
Motor controller, integrated-circuit	202A	194
Motor controls	206A	368,395
Circuit components	206A	370-377
Full-wave types	206A	373
Half-wave types	206A	367
Ratings and limitations	206A	374
Regulated	206A	371,374
Three-phase	206A	471
Unregulated	206A	370,373
Multiplex decoder, integrated-circuit, stereo (technical data)	201A	36
Multiplexer-decoder integrated-circuit, linear	202A	321
Multiplexer, integrated-circuit, three-channel	201A	476
Multiplexing of analog and digital signals	203A	379
Multiplex system, integrated-circuit, two-channel linear	202A	313
Multiplier, integrated-circuit, four-quadrant, analysis of	201A	477
	202A	317
Multiplier, integrated-circuit, four-quadrant (technical data)	201A	417
Multiplier, integrated-circuit, two-quadrant	201A	467
Multistable circuits, precision	202A	322
Multivibrators, COS/MOS		
Astable	203A	353
Monostable	203A	353,356
One-shot, basic circuit	203A	356
One-shot, compensated circuit	203A	357
Multivibrators, integrated-circuit:		
Astable	202A	73,307
Bistable	202A	309
Monostable	202A	309
Music power output	204A	600
NAND gates, COS/MOS quad 2-input	203A	316
NAND gates, (positive logic) COS/MOS (technical data)	203A	55
NAND R/S latch, 3-state COS/MOS quad (technical data)	203A	214
Noise immunity (of COS/MOS logic gates):	203A	343
Crosstalk noise immunity	203A	347
External noise immunity, signal-line	203A	344
Ground-line noise immunity	203A	347
Power-supply noise immunity	203A	345
Types of noise	203A	343
Noise performance (of integrated-circuit rf amplifiers)	202A	96
Noise-limited amplification	202A	46,49

Subject Index

	Databook	Page
NOR gates, COS/MOS quad 2-input	203A	374
NOR gates (positive logic), COS/MOS (technical data)	203A	26
NOR R/S latch, COS/MOS quad, 3-state (technical data)	203A	214
Numitron devices	202A	248
	203A	442
Oscillator, converter-circuit	204A	665
Oscillators, COS/MOS astable and monstable:		
Astable multivibrator circuits	203A	353
Applications	203A	359
Compensation for 50-per-cent duty duty cycle	203A	357
Monostable multivibrator circuits	203A	356
Oscillator, COS/MOS crystal-controlled	203A	430
Oscillator, COS/MOS phase-locked, voltage-controlled	203A	359
Oscillator, COS/MOS voltage-controlled	203A	359
Oscillators, integrated-circuit	202A	73
Crystal-controlled	202A	136
Modulated	202A	136
Oscillator, microstripline	205A	440
On-off switching circuits	206A	451
Operational amplifier	204A	590
Operational amplifiers, high-performance, integrated-circuit	202A	303
Circuit description	202A	303
Noise figure	202A	304
Phase compensation	202A	305
Slewing rate	202A	305
Applications	202A	306
Technical data	201A	448
Operational amplifiers, high-reliability integrated-circuit types (technical data)	201A	525
Operational amplifiers, integrated-circuit	202A	262,277, 283
Applications	202A	
Basic theory	202A	275
Bias current, input	202A	301
Characteristics and features chart	201A	16
Circuit description	202A	262
Common-mode gain	202A	289
Common-mode rejection	202A	266,278, 301
DC levels, input and output	202A	298
Design criteria	202A	298
Equivalent-circuit model	202A	290
External modifications	202A	275
Gain-frequency response	202A	265,278, 299
General considerations	202A	283
Input and output impedances	202A	266,278, 285,289, 300
Inverting configuration	202A	284
Load impedance, effect of finite	202A	290
Noninverting configuration	202A	287
Offset voltage and current	202A	301
Operating characteristics	202A	262,277
Output-power capability	202A	199
Output-power modifications	202A	268
Output swing	202A	266
Phase compensation	202A	267,278, 298
Phase shifts, feedback	202A	291
Power-supply stability	202A	302
Quick-selection chart	201A	14
Technical data	201A	457-532
Transfer characteristics	202A	266,278
Transfer function	202A	284,287
Operational amplifiers, integrated-circuit, application notes on	202A	261-334
Operational amplifiers, integrated-circuit, characteristics and features chart	201A	16
Operational amplifiers, integrated-circuit high-output-current (technical data)	201A	488
Operational amplifiers, integrated-circuit quick selection chart	201A	14
Operational amplifier, micropower integrated-circuit (technical data)	201A	479
Operational amplifiers, power-hybrid-circuit:		
Applications	204A	682
Circuit description	204A	678
Constant-source amplifier	204A	681
Electrical characteristics	204A	679
Power-supply considerations	204A	681
Technical data	204A	555
Use with monolithic integrated-circuits	204A	680
Operational transconductance amplifiers, integrated-circuit, high-performance:	202A	311
Amplitude modulation	202A	316
Applications	202A	313
Circuit description	202A	311
Gain control	202A	316
Multiplexing	202A	313
Technical data	201A	458,466
Output amplifiers, integrated-circuit	202A	58
Output stage, converter-circuit	204A	666
Output stages, integrated-circuit	202A	322
Overlay transistors (see rf power transistors)		
Pass elements,external	204A	689
Peak-envelope-power rating	205A	460
Phase comparator, COS/MOS	203A	327
Phase-locked loop, fundamentals of	203A	319
Phase-locked loops, practical digital types	203A	320
Phase-shift transformer, discriminator	202A	18
Photo-coupled isolators	206A	470
Photo detector and power amplifier (technical data)	201A	401
Photo-detector and power amplifier, integrated-circuit	202A	255
Circuit description	202A	255
Technical data	201A	401
Typical applications	202A	258
Pinlite	203A	413
Lumped-constant	205A	440
Microstripline	205A	440
Wideband	205A	440
Power output, noise	204A	595,600
Power hybrid circuits:		
Application notes on	204A	669-694
Technical data	204A	549-570
Power hybrid operational amplifier	204A	678
Power-hybrid-circuit series voltage regulators:		
Basic structure	204A	686

	Databook	Page
Circuit description	204A	684
Operating considerations	204A	689
Power dissipation	204A	688
Power supplies, auxiliary	206A	459
Power supplies, compact, high-current 5-volt, regulated		
Basic design concept	204A	623
Design example	204A	629
Major elements	204A	623
Power supply, bridge-rectifier	204A	652
Power supply considerations for COS/MOS devices:		
AC dissipation characteristics	203A	367
AC performance characteristics	203A	369
Filtering requirements	203A	371
High dc source	203A	372
Quiescent dissipation	203A	367
Regulation requirements	203A	371
System power calculation of	203A	370
Switching characteristics	203A	370
Power-supply consideration for integrated-circuit FM sound section subsystems:		
Dissipation derating curve	202A	30
General considerations	202A	28
Series dropping resistor, calculation of	202A	30
Voltage-current curves	202A	31
Power supply, regulated 60-watt 20-volt	204A	631
Circuit description	204A	631
Construction	204A	638
Design considerations	204A	635
Foldback current limiting	204A	633
Performance	204A	637
Voltage regulation	204A	631
Power supply, with hybrid-circuit regulator	204A	692
Power-transistor chips (technical data)	204A	544-547
Power transistors and power hybrid circuits	204A	1
Power transistors, selection charts	204A	10-19
Power transistors (technical data):		
Audio types, special	204A	509,542
Epitaxial-base n-p-n and p-n-p types	204A	137-220
High-speed switching n-p-n types	204A	319-426
High-voltage n-p-n types	204A	221-318
Hometaxial-base n-p-n types	204A	19-136
Monolithic n-p-n Darlington types	204A	449-470
Other p-n-p types	204A	427-448
Power transistors, thermal-cycling ratings for	204A	649,657
Power transistors, thermal-cycling requirements	204A	650,658
Power transistor, vhf/uhf, broadband power-amplifier applications of	205A	473
Pix-if system, integrated-circuit	202A	46
Planar transistor, rf power (technical data)	205A	39
Plastic-package transistor and thyristors	204A	615
Lead-forming techniques	204A	617
Mounting	204A	619
Thermal-resistance considerations	204A	619
Types of packages	204A	607
Plastic-package transistors and thyristors, types of	206A	477
Plug-in type high-voltage rectifiers (technical data)	206A	350
P-N-P power transistors, selection chart	204A	16
Popcorn noise	202A	327

	Databook	Page
Power amplifiers, broadband, uhf/microwave	205A	449
Amplitude modulation	205A	451
Cascade and parallel connections	205A	456
Circuit impedances	205A	453
Circuit performance	205A	456
Evaluation circuit	205A	449
Gain and VSWR control	205A	450
Hybrid combiners	205A	451
Input-circuit design	205A	453
Output-circuit design	205A	451
Package design	205A	449
Practical circuits	205A	456
Reduction of VSWR	205A	449
Power amplifier, hybrid-circuit multipurpose, 7-ampere (technical data)	204A	550
Power amplifiers, integrated-circuit multipurpose wideband	202A	187
Applications	202A	190
Circuit description	202A	187
Operating characteristics	202A	190
Operation	202A	187
Technical data	201A	270
Power amplifiers, linear, hybrid-circuit types:		
AC operation	204A	672
Assembly	204A	677
Audio-amplifier applications	204A	670
Basic structure	204A	669
Circuit description	204A	669,673
Frequency and efficiency	204A	672
Heat removal	204A	676
Power dissipation	204A	673
Protection circuit	204A	675
Reactive Loads	204A	672
Power control	206A	443
Power control, proportional	206A	492
Power controls, triac, for three-phase systems	206A	467
Basic design rules	206A	467
Circuits	206A	471,473
DC logic circuitry isolation of	206A	469
Inductive-load systems	206A	471
Resistive-load systems	206A	469
Trigger circuit	206A	467
Power dissipation, ideal (for class B amplifier)	204A	597
Power-frequency curves for rf power transistors	205A	8-10
Power-line noise	203A	343
Power one-shot control	202A	232
	206A	485
Power oscillators, microwave: Design of	205A	439
Preamplifier, demodulator, integrated-circuit	202A	62
Prescaler, COS/MOS	203A	420
Prescaling	203A	420
Preset-channel memory COS/MOS	203A	432
Product detector, integrated-circuit	202A	111,148
Program-switch ("N"-select) options	203A	366
Proportional power control	206A	492
Protection circuit COS/MOS gate-oxide	203A	351
Pull-up resistor	203A	392
Pulse applications, high-current	206A	363
Pulse-width circuit, COS/MOS voltage-controlled	203A	359
Push-pull inverter	204A	605

Subject Index

	Databook	Page
Quadruple-tuned interstage filter	202A	25
Quiescent dissipation (of COS/MOS devices)	203A	367
Radio frequency interference (RFI)	206A	393
Suppression network	206A	447
Suppression of	206A	401,446, 453
Radiation effects (on COS/MOS devices)	203A	403,404
Radiation, electron	203A	405
Radiation hardening, methods of	203A	415
Radiation-induced failure, types of	203A	413
Radiation, long-term effects of	203A	409
Radiation resistance	203A	404
Radiation tests	203A	408,417
RAM, COS/MOS, binary, 4-word, 8-bit (technical data)	203A	181
Ramp generator	202A	228
	206A	481
Raster correction circuit	206A	458
Rating chart, thermal-cycling	204A	649,657
Rating curves, rectifier	206A	389
RCB color system	202A	65
Reactor element, switching-regulator	204A	611
Read-only-memory, COS/MOS (technical data)	203A	181
Readouts, incandescent	203A	442
Receiver circuits, integrated		
Quick selection chart	201A	8
Technical data	201A	27-160
Receiver subsystem, AM, integrated-circuit (technical data)	201A	42
Receiver synthesizer, COS/MOS FM	203A	422
Receiver turn-on transient	206A	461
Recovered audio	202A	18
Rectifier current, calculation of	206A	386
Rectifier product matrix	206A	17
Rectifier rating curves	206A	389
Rectifiers controlled-avalanche types (technical data)	206A	311
Rectifiers, fast-recovery	206A	333
Rectifiers, high-voltage (technical data)	206A	337-351
Rectifiers, silicon		
Product matrix	206A	17
Technical data	206A	257-351
Rectifiers, stud-mounted types (technical data)	206A	315-332
Rectifier surge-protection resistance, calculation of	206A	385
Reed-relay thyristor gate control	206A	453
Registers, COS/MOS MSI, design and application	203A	327
Remote sensing	204A	690
Remote-sensing circuit	204A	692
Resistance ladder networks	203A	297
Resistance networks for DAC's	203A	297
Resistance, rectifier surge-protection calculation of	206A	385
Resistor, pull-up	203A	392
Reversawatt transistors, epitaxial base silicon n-p-n and p-n-p (technical data)	204A	205-220
Reversing motor control	206A	395
RF amplifiers, integrated circuit	202A	88,150
Applications	202A	93,155
Cascode type	202A	155
Characteristics	202A	88
Circuits	202A	78,80, 107
Circuit description	202A	88,151
Differential-amplifier type	202A	154
Operating modes	202A	88,152
Supply-voltage connections	202A	89
Technical data	201A	318,324
RF amplifier, MOS-transistor	202A	354,356, 360,362
RFI (see radio frequency interference)		
RF operation	205A	470
RF power amplifiers	205A	427,442, 456,457
RF power devices	205A	1
Application notes for	205A	411-509
Power-frequency curves	205A	8-10
Selection charts	205A	11-16
Technical data	205A	17-410
RF power transistors, power-frequency curves	205A	8-10
RF power transistors, selection charts for:		
Aircraft and marine-radio applications	205A	14
Microwave applications	205A	11
Military applications	205A	12
Military communications and CATV/MATV and small-signal applications	205A	16
Mobile-radio applications	205A	13
Single-sideband applications	205A	15
RF power transistors in linear applications	205A	459
RF power transistors, pulsed operation of	205A	425
RF power transistors, safe-area curves for	205A	425
RF power transistor, for single-sideband linear amplifier	205A	459
Ringing-choke converter	204A	605
Ring modulator, integrated-circuit	202A	85
Ripple blanking	202A	247
R/S latches, COS/MOS quad 3-state (technical data)	203A	214
Sample-and-hold circuits	202A	314
Sample-hold applications of COS/MOS bilateral switch	203A	388
Scaling adders	202A	263
Scan regulation	206A	405
Schmitt circuit	202A	259
Schmitt trigger	202A	170
Schmitt trigger	202A	148
Schmitt trigger	202A	139
SCR's and rectifiers, horizontal-deflection (technical data)	206A	290,304
SCR applications, circuit factor charts	206A	379
SCR bridge circuits	206A	442
SCR circuit, full-wave dc	206A	381
SCR circuit, half-wave	206A	379
SCR control circuit, full-wave	206A	442
SCR control circuit, half-wave	206A	442
SCR horizontal deflection system	206A	404
Advantages of	206A	413
Arc protection	206A	412
Basic operation	206A	406
High-voltage generation	206A	410
High-voltage regulation	206A	411
Linearity correction	206A	412

	Databook	Page
Performance requirements	206A	404
Switching-device requirements	206A	405
SCR product matrix	206A	11
SCR's (technical data)	206A	149-256
SCR turn-on time	206A	363
SCR, two-transistor analogy of	206A	434
SCR, two-transistor model of	206A	463
Second breakdown, forward-bias	204A	643
Causes of	204A	643
Test facility for	204A	644
Test circuits	204A	644
Transistor characterization for	204A	644
Second detector	202A	79
Selectivity curve:		
Double-tuned filter	202A	23
Quadruple-tuned filter	202A	24
Six double-tuned filters	202A	27
Triple-tuned filter	202A	24
Sensitive-gate silicon controlled rectifiers (technical data)	206A	150
Sensitive-gate triacs (technical data)	206A	27-40
Sensor isolation	206A	484
Sensor, low impedance	206A	496
Serial adder, COS/MOS triple (technical data)	203A	159
Serial adder, COS/MOS triple (technical data)	203A	164
Series dropping resistor	202A	30
Series resistance, class B-amplifier	204A	597,600
Series voltage regulators, hybrid	204A	684
Servo amplifier	202A	184
Shift register, COS/MOS dual 4-stage static (technical data)	203A	73
Shift register, static, COS/MOS MSI (technical data)	203A	164
Shift register, COS/MOS, parallel-in, parallel-out, 4-stage (technical data)	203A	208
Shift register, COS/MOS 4-stage serial-input/parallel-output, static	203A	338
Shift register, COS/MOS 8-stage, asynchronous, parallel-input/serial output static	203A	341
Shift register, COS/MOS 8-stage static (technical data)	203A	68,104
Shift register, COS/MOS, 18-stage static (technical data)	203A	338
Shift register, COS/MOS 18-stage (technical data)	203A	31
Shift register, static COS/MOS 64-stage (technical data)	203A	152,159
Silicon bidirectional diacs (technical data)	206A	353-355
Silicon controlled rectifiers and silicon rectifier complement (technical data)	206A	290,304
Silicon controlled rectifiers, high-current pulsed applications of	206A	363
Characteristics and ratings	206A	365
Circuits	206A	363
Design considerations for	206A	363
Switching capability	206A	364
Turn-on time	206A	363
Silicon controlled rectifiers, product matrix	206A	11
Silicon controlled rectifiers (technical data)	206A	149-256
Silicon rectifiers (technical data)	206A	257-351

	Databook	Page
Silicon rectifiers, fast-recovery (technical data)	206A	236
Silicon rectifiers, fast-recovery (technical data)	206A	333
Silicon rectifiers, capacitive-load applications of	206A	384
Capacitor-input circuits	206A	384
Limiting resistance	206A	385
Rating curves	206A	389
Rectifier current	206A	386
Silicon transistors for high-voltage application	204A	581
Silicon transistors, high-current, n-p-n, hometaxial II (technical data)	204A	60
Silicon transistors, high-voltage, n-p-n, hometaxial II (technical data)	204A	44
Silicon transistors, medium-power	204A	20,36
Silicon triacs (technical data)	206A	21-148
Single-sideband communications systems	205A	459
Single-sideband rf power transistor (technical data)	205A	98,371
Slewing rate	202A	305
Snubber networks	206A	462
Basic circuit analysis	206A	464
Design procedure	206A	465
Solid-state ballasting circuits	204A	604
Solid-state traffic flasher	206A	486
Sound carrier amplification	202A	46
Special-function sub-system, integrated-circuit (technical data)	201A	57,78
Speed controls, universal motors	206A	396
Spurious noise sources	202A	333
Spurious noise, suppression of	202A	333
Squelch control, COS/MOS	203A	391
Stability, conditions for	202A	70
Staircase generator, linear	202A	308
Static shift register, COS/MOS MSI, 8-stage (technical data)	203A	164
Static shift register, COS/MOS, 64-stage (technical data)	203A	152
Stereo multiplex decoder, integrated-circuit (technical data)	201A	36
Stereo preamplifier, integrated-circuit (technical data)	201A	28,250
Stripline-package microwave power transistors (technical data)	205A	332,338, 344
Stripline power amplifier	205A	438
Stud-mounted rectifiers (technical data)	206A	315-332
Surge-protection resistance (rectifier), calculation of	206A	385
Switch controller, transient-free	202A	234
	206A	487
Switching capability (SCR)	206A	364
Switching characteristics (of thyristors)	206A	438
Switching circuits, on-off	206A	451
Switch, COS/MOS	203A	299
Switching regulator	204A	583,605
Switching-regulator ballasts	204A	586,608
Switching-regulator circuit components	204A	612
Switching-regulator reactor element	204A	611
Switching-regulator transistor	204A	612
Switching SCR's and diodes	206A	405
Switching transistor, silicon n-p-n (technical data)	204A	415

Subject Index

	Databook	Page
Switching transistor, rf power, planar (technical data)	205A	39
Switches, zero-voltage, integrated-circuit	202A	224
Symmetrical limiting, load impedance for	202A	22
Synchronous light flasher	206A	496
Synchronous switching, zero-voltage	206A	469
Synthesizer system, FM	203A	431
System gain	202A	39
Tapers, -volume-control	202A	40
Temperature controllers	202A	227
Electric-heat application	202A	229
Transfer characteristics	202A	228
Integral-cycle	202A	230
On-off	202A	227
Temperature controllers	206A	490
Integral-cycle type	206A	493
On-off type	206A	490
Proportional type	206A	491
Temperature-sensing diode	205A	291
Television video if system, integrated-circuit (technical data)	201A	117
Television chroma system integrated-circuit (technical data)	201A	125,143
Thermal considerations in thyristor mounting	206A	414
Chassis mounted heat sinks	206A	417
Heat sink configurations	206A	416
Heat-sink mounting	206A	416
Power dissipation and heat-sink area	206A	414
Thermal-cycling rating system	204A	649,657
Rating chart	204A	449,657
Test program	204A	657
Thermal-fatigue background	204A	657
Thermal fatigue, power-transistor, analysis of	204A	649
Thermal resistance, hot-spot	205A	470,473
Three-phase heater control	206A	469
Three-phase motor control	206A	472
Three-phase system, triac power control for:		
Basic design rules	206A	467
Circuits	206A	473
Inductive-load systems	206A	471
Isolation of dc logic circuitry	206A	470
Resistive-load systems	206A	470
Trigger circuit	206A	467
Threshold voltage, COS/MOS, effect of electron radiation on	203A	405
Thyristor applications, circuit factors charts	206A	379
Thyristor circuits, snabber networks for	206A	462
Thyristor flasher	206A	452
Thyristor gate characteristics	206A	436
Thyristor horizontal deflection system for color TV receivers:		
Auxiliary power supplies	206A	459
Circuit descriptions	206A	456
Commutation and energy-transfer circuit	206A	456
General design considerations	206A	455
High-voltage section	206A	458
Linearity circuit	206A	459
Raster correction circuit	206A	458
Regulator section	206A	458
Transient conditions	206A	460
Thyristor horizontal deflection system for monochrome TV receivers:		
Auxiliary power supplies	206A	473
Circuit description	206A	473
Design considerations	206A	473
Thyristor power control	206A	453
Thyristors, characteristics and applications	206A	434
Thyristors, gated, bidirectional (technical data)	206A	105
Thyristors, rectifiers, and other diodes	206A	1
Thyristors, types of	206A	434
Thyristor switching characteristics	206A	438
Thyristor voltage and temperature ratings	206A	435
Thyristor voltage regulators, ac	206A	420
Timer, COS/MOS, battery-operated, digital-display	203A	434
Tint-control amplifier, integrated-circuit	202A	62
Traffic flasher, solid-state	202A	233
	206A	486
Traffic-signal lamp control, traic:		
Circuits	206A	450
Surge current effects	206A	448
Triac operation	206A	448
Transfer characteristic, differential amplifier	202A	22
Transformers, transmission-line	205A	463
Transient-free switch controller	206A	448
Transient radiation tests	203A	417
Transistor amplifiers, class B	204A	594
Economics	204A	594
Fidelity	204A	596
Ideal power dissipation	204A	597
Music power output	204A	600
Power output and dissipation	204A	595
Power-supply regulation	204A	594
Series resistance	204A	596
Transistor array, integrated-circuit:		
Circuit applications	202A	77
Circuit description	202A	76
Operating characteristics	202A	77
Technical data	201A	204
Transistor array, integrated-circuit high-current, n-p-n, display-driver applications of	203A	438
Transistor arrays, integrated-circuit, quick selection chart	201A	10
Transistor arrays, integrated-circuit (technical data)	201A	161-256
Transistor power supplies, compact, 5-volt	204A	623
Basic concept	204A	623
Circuit elements	204A	623
Design example	204A	628
Transistors, high-voltage, medium-power silicon n-p-n (technical data)	204A	268
Transistors, high-voltage, high-power, silicon n-p-n (technical data)	204A	260, 284-313
Transistor, rf power single-sideband (technical data)	205A	98,371
Transistors, high-power, silicon n-p-n types (technical data)	204A	28
Transistors, hometaxial-base, molded-silicon-plastic (technical data)	204A	68

	Databook	Page
Transistors, medium-power, silicon n-p-n types (technical data)	204A	20,36
Transistor structure, intrinsic	205A	427
Transistors, versawatt, silicon n-p-n (technical data)	204A	76,111, 145,161
Transistor-zener diode-diode array (technical data)	201A	196
Transmission of analog and digital signals	203A	319
Transmission-line reflections	203A	343
Transmission-line transformers	205A	463
Triac applications, circuit factors charts	206A	379
Triac circuit, full-wave:		
AC	206A	380
DC	206A	381
Triac controls for three-phase, power systems	206A	467
Triac gate characteristics	206A	390
Triac product matrix	206A	13
Triacs for use with IC zero-voltage switch	206A	141
Triacs, isolated-tab (technical data)	206A	143
Triacs with integral diac (technical data)	206A	48
Traics, 400-Hz types (technical data)	206A	67,119
Triacs (technical data)	206A	21-148
Triac voltage-current characteristic	206A	390
Trigger circuits, crowbar	204A	685
Tri-level comparator, COS/MOS	203A	409
Triple-tuned interstage filter	202A	23
True/complement buffer, COS/MOS quad (technical data)	203A	199
Tuned amplifier, integrated circuit	202A	138
Turn-on time definitions (SCR)	206A	363
TV circuits	206A	41
TV receiver	202A	46
Two-transistor analogy (of SCR)	206A	434
UHF amplifier, single-ended	205A	477
UHF power generation	205A	422
Package considerations	205A	422
Pulsed operation of rf power trans.	205A	425
Reliability considerations	105A	424
RF performance criteria	205A	422
Safe-area curves for rf power trans.	205A	425
UHF power transistors, broadband applications of	205A	473
Broadband amplifier chain	205A	481
Broadband circuit design approach	205A	475
Combined-transistor stage	205A	481
Gain equalizer	205A	479
Single-ended amplifier	205A	477
UHF power transistors, characteristics of	205A	473
Hot-spot thermal resistance	205A	473
Overdrive capability	205A	473
Pulsed operation	205A	473
Ultor voltage	206A	404
Universal motors	206A	368
Universal motor speed controls	206A	396
Variable-feedback volume-control circuits,	202A	38
VCO, phase-locked	203A	359
Versawatt transistors, epitaxial-base, silicon n-p-n (technical data)	204A	161

	Databook	Page
Versawatt transistors, high-current, silicon n-p-n (technical data)	204A	111
Versawatt transistors, hometaxial-base silicon n-p-n (technical data)	204A	76
Versawatt transistors, silicon p-n-p, (technical data)	204A	145
VHF mixer, MOS-transistor	202A	344
Design considerations	202A	344
Design example	202A	345
Maximum available gain	202A	346
Maximum usable gain	202A	346
Video amplifier, integrated-circuit	202A	153
Applications	202A	158
Biasing	202A	153
Characteristics	202A	155
Circuit description	202A	153
Common-mode rejection	202A	157
Gain control	202A	157
Harmonic distortion	202A	158
Input and output impedance	202A	156
Swing capability	202A	158
Video amplifiers, integrated-circuit	202A	77, 182,268
Video and wide-band amplifier, integrated-circuit (technical data)	201A	278, 284,304
Video detection, linear	202A	46
Video detector, integrated-circuit	202A	49
Video if amplification	202A	46
Voltage-controlled oscillators	203A	359
Voltage-current curves	202A	31
Voltage-follower amplifier, COS/MOS	203A	299
Voltage follower, integrated-circuit	202A	281
Voltage regulation	204A	633,692
Voltage-regulator modules	204A	690
Voltage regulators, ac	206A	420
Voltage regulators, integrated-circuit (technical data)	201A	409
Voltage regulators, power-hybrid circuit:		
Assembly and handling	204A	692
Basic structure	204A	686
Circuit description	204A	684
Foldback circuit, analysis of	204A	687
Operating considerations	204A	689
Power dissipation	204A	688
Voltage regulator, series type	204A	581
Volume-control circuit, conventional	202A	38
Volume-control circuit, feedback type	202A	38
Volume-control circuit, losser type	202A	38
Volume controls, types of	202A	38
Volume-control tapers	202A	40
Wideband multipurpose amplifier, integrated-circuit	202A	173
Applications	202A	182
Circuit description	202A	174
Gain-frequency response	202A	176
Limiting	202A	176,181
Noise performance	202A	181
Operating characteristics	202A	175
Wideband multipurpose power amplifiers, integrated circuit:		
Applications	202A	190
Circuit description and operation	202A	187

Subject Index

	Databook	Page
Operating characteristics	202A	190
Technical data	201A	270
Wideband video and if amplifier, integrated-circuit:		
Bias modes	202A	197
Characteristics	202A	198
Circuit	202A	201
Circuit description	202A	195
Construction techniques	202A	203
Ratings	202A	198
Stability considerations	202A	202
Technical data	201A	284
Y parameters	202A	93
Zero-voltage switches integrated-circuit	202A	224,236
Applications	202A	240
Circuit operation	202	224,270
Fail-safe feature	202A	226,240
Half-cycling effect	202A	226
Hysteresis characteristics	202A	226,239
Inductive-load switching	202A	240
Load characteristics	202A	226
Proportional control	202A	239
Sensing amplifier	202A	238
Sensor isolation	202A	231
Supplementary characteristics data	202A	240
Temperature-controller application	202A	227
Technical data	201A	380
Zero-voltage switches, integrated-circuit,	206A	477,489
Characteristics data	206A	493
Circuit operation	206A	477,489
Effect of thyristor load	206A	478
Fail-safe feature	206A	478,493
Half-cycling effect	206A	478
Hysteresis characteristics	206A	478,492
Inductive-load switching	206A	493
On-off sensing amplifier	206A	491
Proportional control	206A	492
Applications	206A	479,493
Zero-voltage switching	206A	450
Zero-voltage switches, integrated circuit (technical data)	201A	380
Zero-voltage switch, integrated-circuit	206A	467
Zero-voltage synchronous switching	206A	469

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
1N248C	RECT	THC-500B	6	SSD-206A	326
1N249C	RECT	THC-500B	6	SSD-206A	326
1N250C	RECT	THC-500B	6	SSD-206A	326
1N440B	RECT	THC-500B	5	SSD-206A	262
1N441B	RECT	THC-500B	5	SSD-206A	262
1N442B	RECT	THC-500B	5	SSD-206A	262
1N443B	RECT	THC-500B	5	SSD-206A	262
1N444B	RECT	THC-500B	5	SSD-206A	262
1N445B	RECT	THC-500B	5	SSD-206A	262
1N536	RECT	THC-500B	3	SSD-206A	265
1N537	RECT	THC-500B	3	SSD-206A	265
1N538	RECT	THC-500B	3	SSD-206A	265
1N539	RECT	THC-500B	3	SSD-206A	265
1N540	RECT	THC-500B	3	SSD-206A	265
1N547	RECT	THC-500B	3	SSD-206A	265
1N1095	RECT	THC-500B	3	SSD-206A	265
1N1183A	RECT	THC-500B	38	SSD-206A	332
1N1184A	RECT	THC-500B	38	SSD-206A	332
1N1186A	RECT	THC-500B	38	SSD-206A	332
1N1187A	RECT	THC-500B	38	SSD-206A	332
1N1188A	RECT	THC-500B	38	SSD-206A	332
1N1189A	RECT	THC-500B	38	SSD-206A	332
1N1190A	RECT	THC-500B	38	SSD-206A	332
1N1195A	RECT	THC-500B	6	SSD-206A	326
1N1196A	RECT	THC-500B	6	SSD-206A	326
1N1197A	RECT	THC-500B	6	SSD-206A	326
1N1198A	RECT	THC-500B	6	SSD-206A	326
1N1199A	RECT	THC-500B	20	SSD-206A	320
1N1200A	RECT	THC-500B	20	SSD-206A	320
1N1202A	RECT	THC-500B	20	SSD-206A	320
1N1203A	RECT	THC-500B	20	SSD-206A	320
1N1204A	RECT	THC-500B	20	SSD-206A	320
1N1205A	RECT	THC-500B	20	SSD-206A	320
1N1206A	RECT	THC-500B	20	SSD-206A	320
1N1341B	RECT	THC-500B	58	SSD-206A	317
1N1342B	RECT	THC-500B	58	SSD-206A	317
1N1344B	RECT	THC-500B	58	SSD-206A	317
1N1345B	RECT	THC-500B	58	SSD-206A	317
1N1346B	RECT	THC-500B	58	SSD-206A	317
1N1347B	RECT	THC-500B	58	SSD-206A	317
1N1348B	RECT	THC-500B	58	SSD-206A	317
1N1612	RECT	THC-500B	18	SSD-206A	315
1N1613	RECT	THC-500B	18	SSD-206A	315
1N1614	RECT	THC-500B	18	SSD-206A	315
1N1615	RECT	THC-500B	18	SSD-206A	315
1N1616	RECT	THC-500B	18	SSD-206A	315
1N1763A	RECT	THC-500B	89	SSD-206A	272
1N1764A	RECT	THC-500B	89	SSD-206A	272
1N2858A	RECT	THC-500B	91	SSD-206A	280
1N2859A	RECT	THC-500B	91	SSD-206A	280
1N2860A	RECT	THC-500B	91	SSD-206A	280
1N2861A	RECT	THC-500B	91	SSD-206A	280
1N2862A	RECT	THC-500B	91	SSD-206A	280
1N2863A	RECT	THC-500B	91	SSD-206A	280
1N2864A	RECT	THC-500B	91	SSD-206A	280
1N3193	RECT	THC-500B	41	SSD-206A	268
1N3194	RECT	THC-500B	41	SSD-206A	268
1N3195	RECT	THC-500B	41	SSD-206A	268
1N3196	RECT	THC-500B	41	SSD-206A	268
1N3253	RECT	THC-500B	41	SSD-206A	268
1N3254	RECT	THC-500B	41	SSD-206A	268
1N3255	RECT	THC-500B	41	SSD-206A	268
1N3256	RECT	THC-500B	41	SSD-206A	268
1N3563	RECT	THC-500B	41	SSD-206A	268
1N3754	RECT	THC-500B	39	SSD-206A	258
1N3755	RECT	THC-500B	39	SSD-206A	258
1N3756	RECT	THC-500B	39	SSD-206A	258
1N5211	RECT	THC-500B	245	SSD-206A	286
1N5212	RECT	THC-500B	245	SSD-206A	286
1N5213	RECT	THC-500B	245	SSD-206A	286
1N5214	RECT	THC-500B	245	SSD-206A	286
1N5215	RECT	THC-500B	245	SSD-206A	286
1N5216	RECT	THC-500B	245	SSD-206A	286
1N5217	RECT	THC-500B	245	SSD-206A	286
1N5218	RECT	THC-500B	245	SSD-206A	286
1N5391	RECT	THC-500B	478	SSD-206A	300
1N5392	RECT	THC-500B	478	SSD-206A	300
1N5393	RECT	THC-500B	478	SSD-206A	300
1N5394	RECT	THC-500B	478	SSD-206A	300
1N5395	RECT	THC-500B	478	SSD-206A	300
1N5396	RECT	THC-500B	478	SSD-206A	300
1N5397	RECT	THC-500B	478	SSD-206A	300
1N5398	RECT	THC-500B	478	SSD-206A	300
1N5399	RECT	THC-500B	478	SSD-206A	300
2N176	PWR	SPG-201J	14	SSD-204A	572
2N217	PWR	SPG-201J	14	SSD-204A	572
2N274	PWR	SPG-201J	14	SSD-204A	572
2N301	PWR	SPG-201J	14	SSD-204A	572
2N301A	PWR	SPG-201J	14	SSD-204A	572
2N351	PWR	SPG-201J	14	SSD-204A	572
2N376	PWR	SPG-201J	14	SSD-204A	572
2N404	PWR	SPG-201J	14	SSD-204A	572
2N414	PWR	SPG-201J	14	SSD-204A	572
2N681	SCR	THC-500B	96	SSD-206A	233
2N682	SCR	THC-500B	96	SSD-206A	233
2N683	SCR	THC-500B	96	SSD-206A	233
2N684	SCR	THC-500B	96	SSD-206A	233
2N685	SCR	THC-500B	96	SSD-206A	233
2N686	SCR	THC-500B	96	SSD-206A	233
2N687	SCR	THC-500B	96	SSD-206A	233
2N688	SCR	THC-500B	96	SSD-206A	233
2N689	SCR	THC-500B	96	SSD-206A	233
2N690	SCR	THC-500B	96	SSD-206A	233
2N697	PWR	PTD-187D	16	SSD-204A	472
2N699	PWR	PTD-187D	22	SSD-204A	320
2N718A	PWR	SPG-201J	14	SSD-204A	572
2N720A	PWR	SPG-201J	14	SSD-204A	572
2N918	RF	RFT-700K	83	SSD-205A	18
2N1066	PWR	SPG-201J	14	SSD-204A	572
2N1183	PWR	SPG-201J	14	SSD-204A	572
2N1183A	PWR	SPG-201J	14	SSD-204A	572
2N1183B	PWR	SPG-201J	14	SSD-204A	572
2N1184	PWR	SPG-201J	14	SSD-204A	572
2N1184A	PWR	SPG-201J	14	SSD-204A	572
2N1184B	PWR	SPG-201J	14	SSD-204A	572
2N1224	PWR	SPG-201J	14	SSD-204A	572
2N1225	PWR	SPG-201J	14	SSD-204A	572
2N1226	PWR	SPG-201J	14	SSD-204A	572
2N1285	PWR	SPG-201J	14	SSD-204A	572
2N1395	PWR	SPG-201J	14	SSD-204A	572
2N1396	PWR	SPG-201J	14	SSD-204A	572
2N1397	PWR	SPG-201J	14	SSD-204A	572
2N1479	PWR	PTD-187D	135	SSD-204A	474
2N1480	PWR	PTD-187D	135	SSD-204A	474
2N1481	PWR	PTD-187D	135	SSD-204A	474
2N1482	PWR	PTD-187D	135	SSD-204A	474
2N1483	PWR	PTD-187D	137	SSD-204A	479
2N1484	PWR	PTD-187D	137	SSD-204A	479
2N1485	PWR	PTD-187D	137	SSD-204A	479
2N1486	PWR	PTD-187D	137	SSD-204A	479
2N1487	PWR	PTD-187D	139	SSD-204A	484
2N1488	PWR	PTD-187D	139	SSD-204A	484
2N1489	PWR	PTD-187D	139	SSD-204A	484
2N1490	PWR	PTD-187D	139	SSD-204A	484
2N1491	RF	RFT-700K	10	SSD-205A	22
2N1492	RF	RFT-700K	10	SSD-205A	22
2N1493	RF	RFT-700K	10	SSD-205A	22
2N1613	PWR	PTD-187D	106	SSD-204A	323
2N1683	PWR	SPG-201J	14	SSD-204A	572
2N1700	PWR	PTD-187D	141	SSD-204A	489
2N1701	PWR	PTD-187D	141	SSD-204A	489
2N1702	PWR	PTD-187D	141	SSD-204A	489
2N1711	PWR	PTD-187D	26	SSD-204A	328
2N1842A	SCR	THC-500B	28	SSD-206A	221
2N1843A	SCR	THC-500B	28	SSD-206A	221
2N1844A	SCR	THC-500B	28	SSD-206A	221
2N1845A	SCR	THC-500B	28	SSD-206A	221
2N1846A	SCR	THC-500B	28	SSD-206A	221
2N1847A	SCR	THC-500B	28	SSD-206A	221
2N1848A	SCR	THC-500B	28	SSD-206A	221

Index to Devices

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
2N1849A	SCR	THC-500B	28	SSD-206A	221
2N1850A	SCR	THC-500B	28	SSD-206A	221
2N1893	PWR	PTD-187D	34	SSD-204A	332
2N1905	PWR	SPG-201J	14	SSD-204A	572
2N1906	PWR	SPG-201J	14	SSD-204A	572
2N2015	PWR	PTD-187D	12	SSD-204A	500
2N2016	PWR	PTD-187D	12	SSD-204A	500
2N2102	PWR	PTD-187D	106	SSD-204A	323
2N2147	PWR	SPG-201J	14	SSD-204A	572
2N2148	PWR	SPG-201J	14	SSD-204A	572
2N2270	PWR	PTD-187D	24	SSD-204A	338
2N2338	PWR	PTD-187D	141	SSD-204A	489
2N2405	PWR	PTD-187D	34	SSD-204A	332
2N2631	RF	RFT-700K	32	SSD-205A	26
2N2857	RF	RFT-700K	61	SSD-205A	31
2N2869/2N301	PWR	SPG-201J	14	SSD-204A	572
2N2870/2N301A	PWR	SPG-201J	14	SSD-204A	572
2N2876	RF	RFT-700K	32	SSD-205A	26
2N2895	PWR	PTD-187D	143	SSD-204A	342
2N2896	PWR	PTD-187D	143	SSD-204A	342
2N2897	PWR	SPG-201J	143	SSD-204A	442
2N3053	PWR	PTD-187D	432	SSD-204A	348
2N3054	PWR	PTD-187D	527	SSD-204A	20
2N3055	PWR	PTD-187D	524	SSD-204A	28
2N3118	RF	RFT-700K	42	SSD-205A	35
2N3119	RF	RFT-700K	44	SSD-205A	39
2N3228	SCR	THC-500B	114	SSD-206A	161
2N3229	RF	RFT-700K	50	SSD-205A	43
2N3262	RF	RFT-700K	56	SSD-205A	46
2N3263	PWR	PTD-187D	54	SSD-204A	354
2N3264	PWR	PTD-187D	54	SSD-204A	354
2N3265	PWR	PTD-187D	54	SSD-204A	354
2N3266	PWR	PTD-187D	54	SSD-204A	354
2N3375	RF	RFT-700K	386	SSD-205A	50
2N3439	PWR	PTD-187D	64	SSD-204A	222
2N3440	PWR	PTD-187D	64	SSD-204A	222
2N3441	PWR	PTD-187D	529	SSD-204A	36
2N3442	PWR	PTD-187D	528	SSD-204A	44
2N3478	RF	RFT-700K	77	SSD-205A	58
2N3528	SCR	THC-500B	114	SSD-206A	161
2N3529	SCR	THC-500B	114	SSD-206A	161
2N3553	RF	RFT-700K	386	SSD-205A	50
2N3583	PWR	PTD-187D	138	SSD-204A	229
2N3584	PWR	PTD-187D	138	SSD-204A	229
2N3585	PWR	PTD-187D	138	SSD-204A	229
2N3600	RF	RFT-700K	83	SSD-205A	18
2N3632	RF	RFT-700K	386	SSD-205A	50
2N3650	SCR	THC-500B	408	SSD-206A	236
2N3651	SCR	THC-500B	408	SSD-206A	236
2N3652	SCR	THC-500B	408	SSD-206A	236
2N3653	SCR	THC-500B	408	SSD-206A	236
2N3668	SCR	THC-500B	116	SSD-206A	214
2N3669	SCR	THC-500B	116	SSD-206A	214
2N3670	SCR	THC-500B	116	SSD-206A	214
2N3730	PWR	SPG-201J	14	SSD-204A	572
2N3731	PWR	SPG-201J	14	SSD-204A	572
2N3732	PWR	SPG-201J	14	SSD-204A	572
2N3733	RF	RFT-700K	72	SSD-205A	62
2N3771	PWR	PTD-187D	525	SSD-204A	52
2N3772	PWR	PTD-187D	525	SSD-204A	52
2N3773	PWR	PTD-187D	526	SSD-204A	60
2N3839	RF	RFT-700K	229	SSD-205A	67
2N3866	RF	RFT-700K	80	SSD-205A	71
2N3870	SCR	THC-500B	578	SSD-206A	243
2N3871	SCR	THC-500B	578	SSD-206A	243
2N3872	SCR	THC-500B	578	SSD-206A	243
2N3873	SCR	THC-500B	578	SSD-206A	243
2N3878	PWR	PTD-187D	299	SSD-204A	360
2N3879	PWR	PTD-187D	299	SSD-204A	360
2N3896	SCR	THC-500B	578	SSD-206A	243
2N3897	SCR	THC-500B	578	SSD-206A	243
2N3898	SCR	THC-500B	578	SSD-206A	243
2N3899	SCR	THC-500B	578	SSD-206A	243
2N4012	RF	RFT-700K	90	SSD-205A	75
2N4036	PWR	PTD-187D	216	SSD-204A	428

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
2N4037	PWR	PTD-187D	216	SSD-204A	428
2N4063	PWR	PTD-187D	64	SSD-204A	222
2N4064	PWR	PTD-187D	64	SSD-204A	222
2N4101	SCR	THC-500B	114	SSD-206A	161
2N4102	SCR	THC-500B	114	SSD-206A	161
2N4103	SCR	THC-500B	116	SSD-206A	214
2N4240	PWR	PTD-187D	135	SSD-204A	229
2N4314	PWR	PTD-187D	216	SSD-204A	428
2N4346	PWR	SPG-201J	14	SSD-204A	572
2N4347	PWR	PTD-187D	528	SSD-204A	44
2N4348	PWR	PTD-187D	526	SSD-204A	60
2N4427	RF	RFT-700K	228	SSD-205A	79
2N4440	RF	RFT-700K	217	SSD-205A	85
2N4932	RF	RFT-700K	249	SSD-205A	90
2N4933	RF	RFT-700K	249	SSD-205A	90
2N5016	RF	RFT-700K	255	SSD-205A	94
2N5034	PWR	PTD-187D	244	SSD-204A	68
2N5035	PWR	PTD-187D	244	SSD-204A	68
2N5036	PWR	PTD-187D	244	SSD-204A	68
2N5037	PWR	PTD-187D	244	SSD-204A	68
2N5038	PWR	PTD-187D	367	SSD-204A	371
2N5039	PWR	PTD-187D	367	SSD-204A	371
2N5070	RF	RFT-700K	268	SSD-205A	98
2N5071	RF	RFT-700K	269	SSD-205A	103
2N5090	RF	RFT-700K	270	SSD-205A	107
2N5102	RF	RFT-700K	279	SSD-205A	111
2N5108	RF	RFT-700K	280	SSD-205A	116
2N5109	RF	RFT-700K	281	SSD-205A	120
2N5179	RF	RFT-700K	288	SSD-205A	126
2N5180	RF	RFT-700K	289	SSD-205A	132
2N5189	PWR	PTD-187D	296	SSD-204A	378
2N5202	PWR	PTD-187D	299	SSD-204A	360
2N5239	PWR	PTD-187D	321	SSD-204A	241
2N5240	PWR	PTD-187D	321	SSD-204A	241
2N5262	PWR	PTD-187D	313	SSD-204A	383
2N5293	PWR	PTD-187D	332	SSD-204A	76
2N5294	PWR	PTD-187D	332	SSD-204A	76
2N5295	PWR	PTD-187D	332	SSD-204A	76
2N5296	PWR	PTD-187D	332	SSD-204A	76
2N5297	PWR	PTD-187D	332	SSD-204A	76
2N5298	PWR	PTD-187D	332	SSD-204A	76
2N5320	PWR	PTD-187D	325	SSD-204A	389
2N5321	PWR	PTD-187D	325	SSD-204A	389
2N5322	PWR	PTD-187D	325	SSD-204A	389
2N5323	PWR	PTD-187D	325	SSD-204A	389
2N5415	PWR	PTD-187D	336	SSD-204A	437
2N5416	PWR	PTD-187D	336	SSD-204A	437
2N5441	TRI	THC-500B	593	SSD-206A	127
2N5442	TRI	THC-500B	593	SSD-206A	127
2N5443	TRI	THC-500B	593	SSD-206A	127
2N5444	TRI	THC-500B	593	SSD-206A	127
2N5445	TRI	THC-500B	593	SSD-206A	127
2N5446	TRI	THC-500B	593	SSD-206A	127
2N5470	RF	RFT-700K	350	SSD-205A	136
2N5490	PWR	PTD-187D	353	SSD-204A	85
2N5491	PWR	PTD-187D	353	SSD-204A	85
2N5492	PWR	PTD-187D	353	SSD-204A	85
2N5493	PWR	PTD-187D	353	SSD-204A	85
2N5494	PWR	PTD-187D	353	SSD-204A	85
2N5495	PWR	PTD-187D	353	SSD-204A	85
2N5496	PWR	PTD-187D	353	SSD-204A	85
2N5497	PWR	PTD-187D	353	SSD-204A	85
2N5567	TRI	THC-500B	457	SSD-206A	83
2N5568	TRI	THC-500B	457	SSD-206A	83
2N5569	TRI	THC-500B	457	SSD-206A	83
2N5570	TRI	THC-500B	457	SSD-206A	83
2N5571	TRI	THC-500B	458	SSD-206A	98
2N5572	TRI	THC-500B	458	SSD-206A	98
2N5573	TRI	THC-500B	458	SSD-206A	98
2N5574	TRI	THC-500B	458	SSD-206A	98
2N5575	PWR	PTD-187D	359	SSD-204A	92
2N5578	PWR	PTD-187D	359	SSD-204A	92
2N5671	PWR	PTD-187D	383	SSD-204A	395
2N5672	PWR	PTD-187D	383	SSD-204A	395
2N5754	TRI	THC-500B	414	SSD-206A	22

Index to Devices

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
2N5755	TRI	THC-500B	414	SSD-206A	22
2N5756	TRI	THC-500B	414	SSD-206A	22
2N5757	TRI	THC-500B	414	SSD-206A	22
2N5781	PWR	PTD-187D	413	SSD-204A	100
2N5782	PWR	PTD-187D	413	SSD-204A	100
2N5783	PWR	PTD-187D	413	SSD-204A	100
2N5784	PWR	PTD-187D	413	SSD-204A	100
2N5785	PWR	PTD-187D	413	SSD-204A	100
2N5786	PWR	PTD-187D	413	SSD-204A	100
2N5804	PWR	PTD-187D	407	SSD-204A	247
2N5805	PWR	PTD-187D	407	SSD-204A	247
2N5838	PWR	PTD-187D	410	SSD-204A	253
2N5839	PWR	PTD-187D	410	SSD-204A	253
2N5840	PWR	PTD-187D	410	SSD-204A	253
2N5913	RF	RFT-700K	423	SSD-205A	142
2N5914	RF	RFT-700K	424	SSD-205A	148
2N5915	RF	RFT-700K	424	SSD-205A	148
2N5916	RF	RFT-700K	425	SSD-205A	154
2N5917	RF	RFT-700K	425	SSD-205A	154
2N5918	RF	RFT-700K	448	SSD-205A	160
2N5919	RF	RFT-700K	426	SSD-205A	165
2N5919A	RF	RFT-700K	505	SSD-205A	172
2N5920	RF	RFT-700K	440	SSD-205A	178
2N5921	RF	RFT-700K	427	SSD-205A	184
2N5954	PWR	PTD-187D	435	SSD-204A	138
2N5955	PWR	PTD-187D	435	SSD-204A	138
2N5956	PWR	PTD-187D	435	SSD-204A	138
2N5992	RF	RFT-700K	451	SSD-205A	192
2N5993	RF	RFT-700K	452	SSD-205A	197
2N5994	RF	RFT-700K	453	SSD-205A	202
2N5995	RF	RFT-700K	454	SSD-205A	208
2N5996	RF	RFT-700K	455	SSD-205A	213
2N6032	PWR	PTD-187D	462	SSD-204A	401
2N6033	PWR	PTD-187D	462	SSD-204A	401
2N6055	PWR	PTD-187D	563	SSD-204A	450
2N6056	PWR	PTD-187D	563	SSD-204A	450
2N6077	PWR	PTD-187D	492	SSD-204A	260
2N6078	PWR	PTD-187D	492	SSD-204A	260
2N6079	PWR	PTD-187D	492	SSD-204A	260
2N6093	RF	RFT-700K	484	SSD-205A	219
2N6098	PWR	PTD-187D	485	SSD-204A	111
2N6099	PWR	PTD-187D	485	SSD-204A	111
2N6100	PWR	PTD-187D	485	SSD-204A	111
2N6101	PWR	PTD-187D	485	SSD-204A	111
2N6102	PWR	PTD-187D	485	SSD-204A	111
2N6103	PWR	PTD-187D	485	SSD-204A	111
2N6104	RF	RFT-700K	504	SSD-205A	224
2N6105	RF	RFT-700K	504	SSD-205A	224
2N6106	PWR	PTD-187D	488	SSD-204A	145
2N6107	PWR	PTD-187D	488	SSD-204A	145
2N6108	PWR	PTD-187D	488	SSD-204A	145
2N6109	PWR	PTD-187D	488	SSD-204A	145
2N6110	PWR	PTD-187D	488	SSD-204A	145
2N6111	PWR	PTD-187D	488	SSD-204A	145
2N6175	PWR	PTD-187D	508	SSD-204A	268
2N6176	PWR	PTD-187D	508	SSD-204A	268
2N6177	PWR	PTD-187D	508	SSD-204A	268
2N6178	PWR	PTD-187D	562	SSD-204A	407
2N6179	PWR	PTD-187D	562	SSD-204A	407
2N6180	PWR	PTD-187D	562	SSD-204A	407
2N6181	PWR	PTD-187D	562	SSD-204A	407
2N6211	PWR	PTD-187D	507	SSD-204A	443
2N6212	PWR	PTD-187D	507	SSD-204A	443
2N6213	PWR	PTD-187D	507	SSD-204A	443
2N6214	PWR	PTD-187D	507	SSD-204A	443
2N6246	PWR	PTD-187D	541	SSD-204A	153
2N6247	PWR	PTD-187D	541	SSD-204A	153
2N6248	PWR	PTD-187D	541	SSD-204A	153
2N6249	PWR	PTD-187D	523	SSD-204A	276
2N6250	PWR	PTD-187D	523	SSD-204A	276
2N6251	PWR	PTD-187D	523	SSD-204A	276
2N6253	PWR	PTD-187D	524	SSD-204A	28
2N6254	PWR	PTD-187D	524	SSD-204A	28
2N6257	PWR	PTD-187D	525	SSD-204A	52
2N6258	PWR	PTD-187D	525	SSD-204A	52
2N6259	PWR	PTD-187D	526	SSD-204A	60
2N6260	PWR	PTD-187D	527	SSD-204A	20
2N6261	PWR	PTD-187D	527	SSD-204A	20
2N6262	PWR	PTD-187D	528	SSD-204A	44
2N6263	PWR	PTD-187D	529	SSD-204A	36
2N6264	PWR	PTD-187D	529	SSD-204A	36
2N6265	RF	RFT-700K	543	SSD-205A	231
2N6266	RF	RFT-700K	544	SSD-205A	237
2N6267	RF	RFT-700K	545	SSD-205A	243
2N6268	RF	RFT-700K	546	SSD-205A	249
2N6269	RF	RFT-700K	546	SSD-205A	249
2N6288	PWR	PTD-187D	542	SSD-204A	161
2N6289	PWR	PTD-187D	542	SSD-204A	161
2N6290	PWR	PTD-187D	542	SSD-204A	161
2N6291	PWR	PTD-187D	542	SSD-204A	161
2N6292	PWR	PTD-187D	542	SSD-204A	161
2N6293	PWR	PTD-187D	542	SSD-204A	161
2N6354	PWR	PTD-187D	582	SSD-204A	415
2N6371	PWR	PTD-187D	607	SSD-204A	119
2N6372	PWR	PTD-187D	608	SSD-204A	169
2N6373	PWR	PTD-187D	608	SSD-204A	169
2N6374	PWR	PTD-187D	608	SSD-204A	169
2N6383	PWR	PTD-187D	609	SSD-204A	455
2N6384	PWR	PTD-187D	609	SSD-204A	455
2N6385	PWR	PTD-187D	609	SSD-204A	455
2N6386	PWR	PTD-187D	610	SSD-204A	461
2N6387	PWR	PTD-187D	610	SSD-204A	461
2N6388	PWR	PTD-187D	610	SSD-204A	461
3N128	MOS/FET	MOS-160C	309	SSD-201A	568
3N138	MOS/FET	MOS-160C	283	SSD-201A	573
3N139	MOS/FET	MOS-160C	284	SSD-201A	577
3N140	MOS/FET	MOS-160C	285	SSD-201A	610
3N141	MOS/FET	MOS-160C	285	SSD-201A	610
3N142	MOS/FET	MOS-160C	286	SSD-201A	582
3N143	MOS/FET	MOS-160C	309	SSD-201A	568
3N152	MOS/FET	MOS-160C	314	SSD-201A	588
3N153	MOS/FET	MOS-160C	320	SSD-201A	593
3N154	MOS/FET	MOS-160C	335	SSD-201A	596
3N159	MOS/FET	MOS-160C	326	SSD-201A	618
3N187	MOS/FET	MOS-160C	436	SSD-201A	636
3N200	MOS/FET	MOS-160C	437	SSD-201A	644
29	PWR	PTD-187D	583	SSD-204A	175
29A	PWR	PTD-187D	583	SSD-204A	175
29B	PWR	PTD-187D	583	SSD-204A	175
29C	PWR	PTD-187D	583	SSD-204A	175
30	PWR	PTD-187D	584	SSD-204A	180
30A	PWR	PTD-187D	584	SSD-204A	180
30B	PWR	PTD-187D	584	SSD-204A	180
30C	PWR	PTD-187D	584	SSD-204A	180
31	PWR	PTD-187D	585	SSD-204A	185
31A	PWR	PTD-187D	585	SSD-204A	185
31B	PWR	PTD-187D	585	SSD-204A	185
31C	PWR	PTD-187D	585	SSD-204A	185
32	PWR	PTD-187D	586	SSD-204A	190
32A	PWR	PTD-187D	586	SSD-204A	190
32B	PWR	PTD-187D	586	SSD-204A	190
32C	PWR	PTD-187D	586	SSD-204A	190
41	PWR	PTD-187D	587	SSD-204A	195
41A	PWR	PTD-187D	587	SSD-204A	195
41B	PWR	PTD-187D	587	SSD-204A	195
41C	PWR	PTD-187D	587	SSD-204A	195
42	PWR	PTD-187D	588	SSD-204A	200
42A	PWR	PTD-187D	588	SSD-204A	200
42B	PWR	PTD-187D	588	SSD-204A	200
42C	PWR	PTD-187D	588	SSD-204A	200
101	PWR	PTD-187D	557	SSD-204A	205
102	PWR	PTD-187D	557	SSD-204A	205
103	PWR	PTD-187D	557	SSD-204A	205
104	PWR	PTD-187D	557	SSD-204A	205
105	PWR	PTD-187D	556	SSD-204A	209
106A	SCR	THC-500B	555	SSD-206A	150
106B	SCR	THC-500B	555	SSD-206A	150
106C	SCR	THC-500B	555	SSD-206A	150
106D	SCR	THC-500B	555	SSD-206A	150
106E	SCR	THC-500B	555	SSD-206A	150

Index to Devices

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
106F	SCR	THC-500B	555	SSD-206A	150
106M	SCR	THC-500B	555	SSD-206A	150
106Q	SCR	THC-500B	555	SSD-206A	150
106Y	SCR	THC-500B	555	SSD-206A	150
107A	SCR	THC-500B	555	SSD-206A	150
107B	SCR	THC-500B	555	SSD-206A	150
107C	SCR	THC-500B	555	SSD-206A	150
107D	SCR	THC-500B	555	SSD-206A	150
107E	SCR	THC-500B	555	SSD-206A	150
107F	SCR	THC-500B	555	SSD-206A	150
107M	SCR	THC-500B	555	SSD-206A	150
107Q	SCR	THC-500B	555	SSD-206A	150
107Y	SCR	THC-500B	555	SSD-206A	150
201	PWR	PTD-187D	557	SSD-204A	205
202	PWR	PTD-187D	557	SSD-204A	205
203	PWR	PTD-187D	557	SSD-204A	205
204	PWR	PTD-187D	557	SSD-204A	205
205	PWR	PTD-187D	556	SSD-204A	209
370	PWR	PTD-187D	558	SSD-204A	213
371	PWR	PTD-187D	558	SSD-204A	213
410	PWR	PTD-187D	509	SSD-204A	284
411	PWR	PTD-187D	510	SSD-204A	290
413	PWR	PTD-187D	511	SSD-204A	296
423	PWR	PTD-187D	512	SSD-204A	302
431	PWR	PTD-187D	513	SSD-204A	308
520	PWR	PTD-187D	558	SSD-204A	213
521	PWR	PTD-187D	558	SSD-204A	213
1000	PWR	PTD-187D	594	SSD-204A	468
1001	PWR	PTD-187D	594	SSD-204A	468
40022	PWR	SPG-201J	14	SSD-204A	572
40050	PWR	SPG-201J	14	SSD-204A	572
40051	PWR	PTD-187D	14	SSD-204A	572
40080	RF	RFT-700K	301	SSD-205A	260
40081	RF	RFT-700K	301	SSD-205A	260
40082	RF	RFT-700K	301	SSD-205A	260
40084	PWR	PTD-187D	40	SSD-204A	505
40108	RECT	THC-500B	48	SSD-206A	319
40109	RECT	THC-500B	48	SSD-206A	319
40110	RECT	THC-500B	48	SSD-206A	319
40111	RECT	THC-500B	48	SSD-206A	319
40112	RECT	THC-500B	48	SSD-206A	319
40113	RECT	THC-500B	48	SSD-206A	319
40114	RECT	THC-500B	48	SSD-206A	319
40115	RECT	THC-500B	48	SSD-206A	319
40208	RECT	THC-500B	120	SSD-206A	324
40209	RECT	THC-500B	120	SSD-206A	324
40210	RECT	THC-500B	120	SSD-206A	324
40211	RECT	THC-500B	120	SSD-206A	324
40212	RECT	THC-500B	120	SSD-206A	324
40213	RECT	THC-500B	120	SSD-206A	324
40214	RECT	THC-500B	120	SSD-206A	324
40216	SCR	THC-500B	247	SSD-206A	250
40250	PWR	PTD-187D	112	SSD-204A	124
40250V1	PWR	PTD-187D	112	SSD-204A	124
40251	PWR	PTD-187D	112	SSD-204A	124
40254	PWR	SPG-201J	14	SSD-204A	572
40266	RECT	THC-500B	75	SSD-206A	309
40267	RECT	THC-500B	75	SSD-206A	309
40279	RF	RFT-700K	46	SSD-205A	264
40280	RF	RFT-700K	68	SSD-205A	268
40281	RF	RFT-700K	68	SSD-205A	268
40282	RF	RFT-700K	68	SSD-205A	268
40290	RF	RFT-700K	70	SSD-205A	272
40291	RF	RFT-700K	70	SSD-205A	272
40292	RF	RFT-700K	70	SSD-205A	272
40294	RF	RFT-700K	202	SSD-205A	276
40296	RF	RFT-700K	603	SSD-205A	283
40305	RF	RFT-700K	144	SSD-205A	290
40306	RF	RFT-700K	144	SSD-205A	290
40307	RF	RFT-700K	144	SSD-205A	290
40309	PWR	PTD-187D	78	SSD-204A	510
40310	PWR	PTD-187D	78	SSD-204A	510
40311	PWR	PTD-187D	78	SSD-204A	510
40312	PWR	PTD-187D	78	SSD-204A	510
40313	PWR	PTD-187D	78	SSD-204A	510
40314	PWR	PTD-187D	78	SSD-204A	510
40315	PWR	PTD-187D	78	SSD-204A	510
40316	PWR	PTD-187D	78	SSD-204A	510
40317	PWR	PTD-187D	78	SSD-204A	510
40318	PWR	PTD-187D	78	SSD-204A	510
40319	PWR	PTD-187D	78	SSD-204A	510
40320	PWR	PTD-187D	78	SSD-204A	510
40321	PWR	PTD-187D	78	SSD-204A	510
40322	PWR	PTD-187D	78	SSD-204A	510
40323	PWR	PTD-187D	78	SSD-204A	510
40324	PWR	PTD-187D	78	SSD-204A	510
40325	PWR	PTD-187D	78	SSD-204A	510
40326	PWR	PTD-187D	78	SSD-204A	510
40327	PWR	PTD-187D	78	SSD-204A	510
40328	PWR	PTD-187D	78	SSD-204A	510
40340	RF	RFT-700K	74	SSD-205A	295
40341	RF	RFT-700K	74	SSD-205A	295
40346	PWR	PTD-187D	211	SSD-204A	237
40346V1	PWR	PTD-187D	211	SSD-204A	237
40346V2	PWR	PTD-187D	211	SSD-204A	237
40347	PWR	PTD-187D	88	SSD-204A	129
40347V1	PWR	PTD-187D	88	SSD-204A	129
40347V2	PWR	PTD-187D	88	SSD-204A	129
40348	PWR	PTD-187D	88	SSD-204A	129
40348V1	PWR	PTD-187D	88	SSD-204A	129
40348V2	PWR	PTD-187D	88	SSD-204A	129
40349	PWR	PTD-187D	88	SSD-204A	129
40349V1	PWR	PTD-187D	88	SSD-204A	129
40349V2	PWR	PTD-187D	88	SSD-204A	129
40360	PWR	PTD-187D	78	SSD-204A	510
40361	PWR	PTD-187D	78	SSD-204A	510
40362	PWR	PTD-187D	78	SSD-204A	510
40363	PWR	PTD-187D	78	SSD-204A	510
40364	PWR	PTD-187D	78	SSD-204A	510
40366	PWR	PTD-187D	215	SSD-204A	421
40367	PWR	PTD-187D	215	SSD-204A	421
40368	PWR	PTD-187D	215	SSD-204A	421
40369	PWR	PTD-187D	215	SSD-204A	421
40372	PWR	PTD-187D	527	SSD-204A	20
40373	PWR	PTD-187D	529	SSD-204A	36
40374	PWR	PTD-187D	128	SSD-204A	229
40375	PWR	PTD-187D	299	SSD-204A	360
40385	PWR	PTD-187D	215	SSD-204A	421
40389	PWR	PTD-187D	432	SSD-204A	348
40390	PWR	PTD-187D	64	SSD-204A	222
40391	PWR	PTD-187D	216	SSD-204A	428
40392	PWR	PTD-187D	432	SSD-204A	348
40394	PWR	PTD-187D	216	SSD-204A	428
40406	PWR	PTD-187D	219	SSD-204A	516
40407	PWR	PTD-187D	219	SSD-204A	516
40408	PWR	PTD-187D	219	SSD-204A	516
40409	PWR	PTD-187D	219	SSD-204A	516
40410	PWR	PTD-187D	219	SSD-204A	516
40411	PWR	PTD-187D	219	SSD-204A	516
40412	PWR	PTD-187D	211	SSD-204A	237
40412V1	PWR	PTD-187D	211	SSD-204A	237
40412V2	PWR	PTD-187D	211	SSD-204A	237
40414	RF	RFT-700K	259	SSD-205A	299
40421	PWR	SPG-201J	14	SSD-204A	572
40429	TRI	THC-500B	351	SSD-206A	41
40430	TRI	THC-500B	351	SSD-206A	41
40431	TRI	THC-500B	477	SSD-206A	48
40432	TRI	THC-500B	477	SSD-206A	48
40439	PWR	SPG-201J	14	SSD-204A	572
40440	PWR	SPG-201J	14	SSD-204A	572
40446	RF	RFT-700K	301	SSD-205A	260
40462	PWR	SPG-201J	14	SSD-204A	572
40467A	MOS/FET	MOS-160C	324	SSD-201A	601
40468A	MOS/FET	MOS-160C	323	SSD-201A	606
40484	PWR	SPG-201J	14	SSD-204A	572
40485	TRI	THC-500B	352	SSD-206A	54
40486	TRI	THC-500B	352	SSD-206A	54
40502	TRI	THC-500B	351	SSD-206A	41
40503	TRI	THC-500B	351	SSD-206A	41
40504	SCR	THC-500B	266	SSD-206A	168

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
40505	SCR	THC-500B	266	SSD-206A	168
40506	SCR	THC-500B	266	SSD-206A	168
40509	TRI	THC-500B	352	SSD-206A	54
40510	TRI	THC-500B	352	SSD-206A	54
40511	TRI	THC-500B	477	SSD-206A	48
40512	TRI	THC-500B	477	SSD-206A	48
40513	PWR	PTD-187D	244	SSD-204A	68
40514	PWR	PTD-187D	244	SSD-204A	68
40525	TRI	THC-500B	470	SSD-206A	27
40526	TRI	THC-500B	470	SSD-206A	27
40527	TRI	THC-500B	470	SSD-206A	27
40528	TRI	THC-500B	470	SSD-206A	27
40529	TRI	THC-500B	470	SSD-206A	27
40530	TRI	THC-500B	470	SSD-206A	27
40531	TRI	THC-500B	470	SSD-206A	27
40532	TRI	THC-500B	470	SSD-206A	27
40533	TRI	THC-500B	470	SSD-206A	27
40534	TRI	THC-500B	470	SSD-206A	27
40535	TRI	THC-500B	470	SSD-206A	27
40536	TRI	THC-500B	470	SSD-206A	27
40537	PWR	PTD-187D	320	SSD-204A	523
40538	PWR	PTD-187D	320	SSD-204A	523
40539	PWR	PTD-187D	303	SSD-204A	527
40542	PWR	PTD-187D	304	SSD-204A	531
40543	PWR	PTD-187D	304	SSD-204A	531
40544	PWR	PTD-187D	303	SSD-204A	527
40546	PWR	SPG-201J	14	SSD-204A	572
40553	SCR	THC-500B	306	SSD-206A	175
40554	SCR	THC-500B	306	SSD-206A	175
40555	SCR	THC-500B	306	SSD-206A	175
40559A	MOS/FET	MOS-160C	323	SSD-201A	606
40575	TRI	THC-500B	300	SSD-206A	105
40576	TRI	THC-500B	300	SSD-206A	105
40577	RF	RFT-700K	297	SSD-205A	305
40578	RF	RFT-700K	298	SSD-205A	312
40581	RF	RFT-700K	301	SSD-205A	260
40582	RF	RFT-700K	301	SSD-205A	260
40594	PWR	PTD-187D	358	SSD-204A	537
40595	PWR	PTD-187D	358	SSD-204A	537
40600	MOS/FET	MOS-160C	333	SSD-201A	624
40601	MOS/FET	MOS-160C	333	SSD-201A	624
40602	MOS/FET	MOS-160C	333	SSD-201A	624
40603	MOS/FET	MOS-160C	334	SSD-201A	632
40604	MOS/FET	MOS-160C	334	SSD-201A	632
40605	RF	RFT-700K	389	SSD-205A	318
40606	RF	RFT-700K	600	SSD-205A	325
40608	RF	RFT-700K	356	SSD-205A	332
40611	PWR	PTD-187D	358	SSD-204A	537
40612	PWR	SPG-201J	14	SSD-204A	572
40613	PWR	PTD-187D	358	SSD-204A	537
40616	PWR	PTD-187D	358	SSD-204A	537
40618	PWR	PTD-187D	358	SSD-204A	537
40621	PWR	PTD-187D	358	SSD-204A	537
40622	PWR	PTD-187D	358	SSD-204A	537
40623	PWR	SPG-201J	14	SSD-204A	572
40624	PWR	PTD-187D	358	SSD-204A	537
40625	PWR	PTD-187D	358	SSD-204A	537
40626	PWR	SPG-201J	14	SSD-204A	572
40627	PWR	PTD-187D	358	SSD-204A	537
40628	PWR	PTD-187D	358	SSD-204A	537
40629	PWR	PTD-187D	358	SSD-204A	537
40630	PWR	PTD-187D	358	SSD-204A	537
40631	PWR	PTD-187D	358	SSD-204A	537
40632	PWR	PTD-187D	358	SSD-204A	537
40633	PWR	PTD-187D	358	SSD-204A	537
40634	PWR	PTD-187D	358	SSD-204A	537
40635	PWR	PTD-187D	358	SSD-204A	537
40636	PWR	PTD-187D	358	SSD-204A	537
40637	PWR	SPG-201J	14	SSD-204A	572
40638	TRI	THC-500B	352	SSD-206A	54
40639	TRI	THC-500B	352	SSD-206A	54
40640	SCR	THC-500B	354	SSD-206A	179
40641	SCR	THC-500B	354	SSD-206A	179
40642	RECT	THC-500B	354	SSD-206A	290
40643	RECT	THC-500B	354	SSD-206A	290
40644	RECT	THC-500B	354	SSD-206A	290
40654	SCR	THC-500B	496	SSD-206A	191
40655	SCR	THC-500B	496	SSD-206A	191
40656	SCR	THC-500B	496	SSD-206A	191
40657	SCR	THC-500B	496	SSD-206A	191
40658	SCR	THC-500B	496	SSD-206A	191
40659	SCR	THC-500B	496	SSD-206A	191
40660	TRI	THC-500B	459	SSD-206A	112
40661	TRI	THC-500B	459	SSD-206A	112
40662	TRI	THC-500B	459	SSD-206A	112
40663	TRI	THC-500B	459	SSD-206A	112
40664	TRI	THC-500B	375	SSD-206A	61
40665	RF	RFT-700K	386	SSD-205A	50
40666	RF	RFT-700K	386	SSD-205A	50
40667	TRI	THC-500B	375	SSD-206A	61
40668	TRI	THC-500B	364	SSD-206A	73
40669	TRI	THC-500B	364	SSD-206A	73
40671	TRI	THC-500B	459	SSD-206A	112
40672	TRI	THC-500B	459	SSD-206A	112
40673	MOS/FET	MOS-160C	381	SSD-201A	679
40680	SCR	THC-500B	578	SSD-206A	242
40681	SCR	THC-500B	578	SSD-206A	242
40682	SCR	THC-500B	578	SSD-206A	242
40683	SCR	THC-500B	578	SSD-206A	242
40684	TRI	THC-500B	414	SSD-206A	22
40685	TRI	THC-500B	414	SSD-206A	22
40686	TRI	THC-500B	414	SSD-206A	22
40687	TRI	THC-500B	414	SSD-206A	22
40688	TRI	THC-500B	593	SSD-206A	127
40689	TRI	THC-500B	593	SSD-206A	127
40690	TRI	THC-500B	593	SSD-206A	127
40691	TRI	THC-500B	431	SSD-206A	34
40692	TRI	THC-500B	431	SSD-206A	34
40693	TRI	THC-500B	406	SSD-206A	141
40694	TRI	THC-500B	406	SSD-206A	141
40695	TRI	THC-500B	406	SSD-206A	141
40696	TRI	THC-500B	406	SSD-206A	141
40697	TRI	THC-500B	406	SSD-206A	141
40698	TRI	THC-500B	406	SSD-206A	141
40699	TRI	THC-500B	406	SSD-206A	141
40700	TRI	THC-500B	406	SSD-206A	141
40701	TRI	THC-500B	406	SSD-206A	141
40702	TRI	THC-500B	406	SSD-206A	141
40703	TRI	THC-500B	406	SSD-206A	141
40704	TRI	THC-500B	406	SSD-206A	141
40705	TRI	THC-500B	406	SSD-206A	141
40706	TRI	THC-500B	406	SSD-206A	141
40707	TRI	THC-500B	406	SSD-206A	141
40708	TRI	THC-500B	406	SSD-206A	141
40709	TRI	THC-500B	406	SSD-206A	141
40710	TRI	THC-500B	406	SSD-206A	141
40711	TRI	THC-500B	406	SSD-206A	141
40712	TRI	THC-500B	406	SSD-206A	141
40713	TRI	THC-500B	406	SSD-206A	141
40714	TRI	THC-500B	406	SSD-206A	141
40715	TRI	THC-500B	406	SSD-206A	141
40716	TRI	THC-500B	406	SSD-206A	141
40717	TRI	THC-500B	406	SSD-206A	141
40718	TRI	THC-500B	406	SSD-206A	141
40719	TRI	THC-500B	406	SSD-206A	141
40720	TRI	THC-500B	406	SSD-206A	141
40721	TRI	THC-500B	406	SSD-206A	141
40722	TRI	THC-500B	406	SSD-206A	141
40723	TRI	THC-500B	406	SSD-206A	141
40724	TRI	THC-500B	406	SSD-206A	141
40725	TRI	THC-500B	406	SSD-206A	141
40726	TRI	THC-500B	406	SSD-206A	141
40727	TRI	THC-500B	406	SSD-206A	141
40728	TRI	THC-500B	406	SSD-206A	141
40729	TRI	THC-500B	406	SSD-206A	141
40730	TRI	THC-500B	406	SSD-206A	141
40731	TRI	THC-500B	406	SSD-206A	141
40732	TRI	THC-500B	406	SSD-206A	141
40733	TRI	THC-500B	406	SSD-206A	141
40734	TRI	THC-500B	406	SSD-206A	141

Index to Devices

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
40735	SCR	THC-500B	408	SSD-206A	236
40737	SCR	THC-500B	417	SSD-206A	206
40738	SCR	THC-500B	417	SSD-206A	206
40739	SCR	THC-500B	417	SSD-206A	206
40740	SCR	THC-500B	417	SSD-206A	206
40741	SCR	THC-500B	417	SSD-206A	206
40742	SCR	THC-500B	417	SSD-206A	206
40743	SCR	THC-500B	417	SSD-206A	206
40744	SCR	THC-500B	417	SSD-206A	206
40745	SCR	THC-500B	417	SSD-206A	206
40746	SCR	THC-500B	417	SSD-206A	206
40747	SCR	THC-500B	417	SSD-206A	206
40748	SCR	THC-500B	417	SSD-206A	206
40749	SCR	THC-500B	418	SSD-206A	225
40750	SCR	THC-500B	418	SSD-206A	225
40751	SCR	THC-500B	418	SSD-206A	225
40752	SCR	THC-500B	418	SSD-206A	225
40753	SCR	THC-500B	418	SSD-206A	225
40754	SCR	THC-500B	418	SSD-206A	225
40755	SCR	THC-500B	418	SSD-206A	225
40756	SCR	THC-500B	418	SSD-206A	225
40757	SCR	THC-500B	418	SSD-206A	225
40758	SCR	THC-500B	418	SSD-206A	225
40759	SCR	THC-500B	418	SSD-206A	225
40760	SCR	THC-500B	418	SSD-206A	225
40761	TRI	THC-500B	431	SSD-206A	34
40762	TRI	THC-500B	431	SSD-206A	34
40766	TRI	THC-500B	431	SSD-206A	34
40767	TRI	THC-500B	431	SSD-206A	34
40768	SCR	THC-500B	476	SSD-206A	185
40769	TRI	THC-500B	441	SSD-206A	35
40770	TRI	THC-500B	441	SSD-206A	35
40771	TRI	THC-500B	441	SSD-206A	35
40772	TRI	THC-500B	441	SSD-206A	35
40773	TRI	THC-500B	442	SSD-206A	67
40774	TRI	THC-500B	442	SSD-206A	67
40775	TRI	THC-500B	443	SSD-206A	90
40776	TRI	THC-500B	443	SSD-206A	90
40777	TRI	THC-500B	443	SSD-206A	90
40778	TRI	THC-500B	443	SSD-206A	90
40779	TRI	THC-500B	443	SSD-206A	90
40780	TRI	THC-500B	443	SSD-206A	90
40781	TRI	THC-500B	443	SSD-206A	90
40782	TRI	THC-500B	443	SSD-206A	90
40783	TRI	THC-500B	443	SSD-206A	90
40784	TRI	THC-500B	443	SSD-206A	90
40785	TRI	THC-500B	443	SSD-206A	90
40786	TRI	THC-500B	443	SSD-206A	90
40787	TRI	THC-500B	487	SSD-206A	119
40788	TRI	THC-500B	487	SSD-206A	119
40789	TRI	THC-500B	487	SSD-206A	119
40790	TRI	THC-500B	487	SSD-206A	119
40791	TRI	THC-500B	487	SSD-206A	119
40792	TRI	THC-500B	487	SSD-206A	119
40793	TRI	THC-500B	487	SSD-206A	119
40794	TRI	THC-500B	487	SSD-206A	119
40795	TRI	THC-500B	457	SSD-206A	83
40796	TRI	THC-500B	457	SSD-206A	83
40797	TRI	THC-500B	458	SSD-206A	98
40798	TRI	THC-500B	458	SSD-206A	98
40799	TRI	THC-500B	457	SSD-206A	83
40800	TRI	THC-500B	457	SSD-206A	83
40801	TRI	THC-500B	457	SSD-206A	83
40802	TRI	THC-500B	458	SSD-206A	98
40803	TRI	THC-500B	458	SSD-206A	98
40804	TRI	THC-500B	458	SSD-206A	98
40805	TRI	THC-500B	459	SSD-206A	112
40806	TRI	THC-500B	459	SSD-206A	112
40807	TRI	THC-500B	459	SSD-206A	112
40808	RECT	THC-500B	449	SSD-206A	311
40809	RECT	THC-500B	449	SSD-206A	311
40819	MOS/FET	MOS-160C	463	SSD-201A	650
40820	MOS/FET	MOS-160C	464	SSD-201A	658
40821	MOS/FET	MOS-160C	464	SSD-201A	658
40822	MOS/FET	MOS-160C	465	SSD-201A	666
40823	MOS/FET	MOS-160C	465	SSD-201A	666
40833	SCR	THC-500B	496	SSD-206A	192
40834	SCR	THC-500B	496	SSD-206A	192
40835	SCR	THC-500B	496	SSD-206A	192
40836	RF	RFT-700K	497	SSD-205A	336
40837	RF	RFT-700K	497	SSD-205A	336
40841	MOS/FET	MOS-160C	489	SSD-201A	673
40842	TRI	THC-500B	493	SSD-206A	79
40850	PWR	PTD-187D	498	SSD-204A	314
40851	PWR	PTD-187D	498	SSD-204A	314
40852	PWR	PTD-187D	498	SSD-204A	314
40853	PWR	PTD-187D	498	SSD-204A	314
40854	PWR	PTD-187D	498	SSD-204A	314
40867	SCR	THC-500B	501	SSD-206A	200
40868	SCR	THC-500B	501	SSD-206A	200
40869	SCR	THC-500B	501	SSD-206A	200
40885	PWR	PTD-187D	508	SSD-204A	268
40886	PWR	PTD-187D	508	SSD-204A	268
40887	PWR	PTD-187D	508	SSD-204A	268
40888	SCR	THC-500B	522	SSD-206A	187
40889	SCR	THC-500B	522	SSD-206A	187
40890	RECT	THC-500B	522	SSD-206A	304
40891	RECT	THC-500B	522	SSD-206A	304
40892	RECT	THC-500B	522	SSD-206A	304
40893	RF	RFT-700K	514	SSD-205A	342
40894	RF	RFT-700K	514	SSD-205A	342
40895	RF	RFT-700K	514	SSD-205A	342
40896	RF	RFT-700K	514	SSD-205A	342
40897	RF	RFT-700K	514	SSD-205A	342
40898	RF	RFT-700K	538	SSD-205A	351
40899	RF	RFT-700K	538	SSD-205A	351
40900	TRI	THC-500B	540	SSD-206A	143
40901	TRI	THC-500B	540	SSD-206A	143
40902	TRI	THC-500B	540	SSD-206A	143
40909	RF	RFT-700K	547	SSD-205A	359
40910	PWR	PTD-187D	527	SSD-204A	20
40911	PWR	PTD-187D	527	SSD-204A	20
40912	PWR	PTD-187D	529	SSD-204A	36
40913	PWR	PTD-187D	529	SSD-204A	36
40915	RF	RFT-700K	574	SSD-205A	363
40916	TRI	THC-500B	549	SSD-206A	134
40917	TRI	THC-500B	549	SSD-206A	134
40918	TRI	THC-500B	549	SSD-206A	134
40919	TRI	THC-500B	549	SSD-206A	134
40920	TRI	THC-500B	549	SSD-206A	134
40921	TRI	THC-500B	549	SSD-206A	134
40922	TRI	THC-500B	549	SSD-206A	134
40923	TRI	THC-500B	549	SSD-206A	134
40924	TRI	THC-500B	549	SSD-206A	134
40925	TRI	THC-500B	593	SSD-206A	127
40926	TRI	THC-500B	593	SSD-206A	127
40927	TRI	THC-500B	593	SSD-206A	127
40934	RF	RFT-700K	550	SSD-205A	367
40936	RF	RFT-700K	551	SSD-205A	371
40937	SCR	THC-500B	578	SSD-206A	243
40938	SCR	THC-500B	578	SSD-206A	243
40940	RF	RFT-700K	553	SSD-205A	375
40941	RF	RFT-700K	554	SSD-205A	380
40942	SCR	THC-500B	567	SSD-206A	161
40943	SCR	THC-500B	567	SSD-206A	161
40944	SCR	THC-500B	567	SSD-206A	161
40945	SCR	THC-500B	567	SSD-206A	161
40946	TRI	THC-500B	351	SSD-206A	41
40947	TRI	THC-500B	351	SSD-206A	41
40948	TRI	THC-500B	352	SSD-206A	54
40949	TRI	THC-500B	352	SSD-206A	54
40950	TRI	THC-500B	352	SSD-206A	54
40952	SCR	THC-500B	578	SSD-206A	243
40953	RF	RFT-700K	579	SSD-205A	384
40954	RF	RFT-700K	579	SSD-205A	384
40955	RF	RFT-700K	579	SSD-205A	384
40956	RECT	THC-500B	580	SSD-206A	333
40957	RECT	THC-500B	580	SSD-206A	333
40958	RECT	THC-500B	580	SSD-206A	333
40959	RECT	THC-500B	580	SSD-206A	333

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
40960	RECT	THC-500B	580	SSD-206A	333
40964	RF	RFT-700K	581	SSD-205A	389
40965	RF	RFT-700K	581	SSD-205A	389
40967	RF	RFT-700K	596	SSD-205A	393
40968	RF	RFT-700K	596	SSD-205A	393
40970	RF	RFT-700K	604	SSD-205A	397
40972	RF	RFT-700K	597	SSD-205A	402
40973	RF	RFT-700K	597	SSD-205A	402
40974	RF	RFT-700K	597	SSD-205A	402
40975	RF	RFT-700K	606	SSD-205A	406
40976	RF	RFT-700K	606	SSD-205A	406
40977	RF	RFT-700K	606	SSD-205A	406
44001	RECT	THC-500B	495	SSD-206A	296
44002	RECT	THC-500B	495	SSD-206A	296
44003	RECT	THC-500B	495	SSD-206A	296
44004	RECT	THC-500B	495	SSD-206A	296
44005	RECT	THC-500B	495	SSD-206A	296
44006	RECT	THC-500B	495	SSD-206A	296
44007	RECT	THC-500B	495	SSD-206A	296
45190	PWR	PTD-187D	559	SSD-204A	217
45191	PWR	PTD-187D	559	SSD-204A	217
45192	PWR	PTD-187D	559	SSD-204A	217
45193	PWR	PTD-187D	559	SSD-204A	217
45194	PWR	PTD-187D	559	SSD-204A	217
45195	PWR	PTD-187D	559	SSD-204A	217
45411	DIAC	THC-500B	577	SSD-206A	354
45412	DIAC	THC-500B	577	SSD-206A	354
CA2111AE	LIC	CDL-820E	612	SSD-201A	112
CA2111AQ	LIC	CDL-820E	612	SSD-201A	112
CA3000	LIC	CDL-820E	121	SSD-201A	290
CA3000/1-4	LIC	CDL-820E	368	SSD-201A	296
CA3000H	LIC	CDL-820E	516	SSD-201A	534
CA3001	LIC	CDL-820E	122	SSD-201A	304
CA3001/1-4	LIC	CDL-820E	369	SSD-201A	310
CA3001H	LIC	CDL-820E	516	SSD-201A	534
CA3002	LIC	CDL-820E	123	SSD-201A	258
CA3002H	LIC	CDL-820E	516	SSD-201A	534
CA3004	LIC	CDL-820E	124	SSD-201A	318
CA3005	LIC	CDL-820E	125	SSD-201A	324
CA3005H	LIC	CDL-820E	516	SSD-201A	534
CA3006	LIC	CDL-820E	125	SSD-201A	324
CA3007	LIC	CDL-820E	126	SSD-201A	331
CA3008	LIC	CDL-820E	316	SSD-201A	507
CA3008A	LIC	CDL-820E	310	SSD-201A	516
CA3010	LIC	CDL-820E	316	SSD-201A	507
CA3010A	LIC	CDL-820E	310	SSD-201A	516
CA3011	LIC	CDL-820E	128	SSD-201A	264
CA3012	LIC	CDL-820E	128	SSD-201A	264
CA3012H	LIC	CDL-820E	516	SSD-201A	534
CA3013	LIC	CDL-820E	129	SSD-201A	62
CA3014	LIC	CDL-820E	129	SSD-201A	62
CA3015	LIC	CDL-820E	316	SSD-201A	507
CA3015A	LIC	CDL-820E	310	SSD-201A	516
CA3015A/1-4	LIC	CDL-820E	371	SSD-201A	525
CA3015H	LIC	CDL-820E	516	SSD-201A	534
CA3015L	LIC	CDL-820E	515	SSD-201A	545
CA3016	LIC	CDL-820E	316	SSD-201A	507
CA3016A	LIC	CDL-820E	310	SSD-201A	516
CA3018	LIC	CDL-820E	338	SSD-201A	204
CA3018A	LIC	CDL-820E	338	SSD-201A	204
CA3018H	LIC	CDL-820E	516	SSD-201A	534
CA3018L	LIC	CDL-820E	515	SSD-201A	545
CA3019	LIC	CDL-820E	236	SSD-201A	162
CA3019H	LIC	CDL-820E	516	SSD-201A	534
CA3020	LIC	CDL-820E	339	SSD-201A	270
CA3020A	LIC	CDL-820E	339	SSD-201A	270
CA3020H	LIC	CDL-820E	516	SSD-201A	534
CA3021	LIC	CDL-820E	243	SSD-201A	278
CA3022	LIC	CDL-820E	243	SSD-201A	278
CA3023	LIC	CDL-820E	243	SSD-201A	278
CA3023H	LIC	CDL-820E	516	SSD-201A	534
CA3026	LIC	CDL-820E	388	SSD-201A	336
CA3026H	LIC	CDL-820E	516	SSD-201A	534
CA3028A	LIC	CDL-820E	382	SSD-201A	344
CA3028AF	LIC	CDL-820E	382	SSD-201A	344
CA3028AH	LIC	CDL-820E	516	SSD-201A	534
CA3028AL	LIC	CDL-820E	515	SSD-201A	545
CA3028AS	LIC	CDL-820E	382	SSD-201A	344
CA3028B	LIC	CDL-820E	382	SSD-201A	344
CA3028B/1-4	LIC	CDL-820E	400	SSD-201A	355
CA3028BF	LIC	CDL-820E	382	SSD-201A	344
CA3028BS	LIC	CDL-820E	382	SSD-201A	344
CA3029	LIC	CDL-820E	316	SSD-201A	507
CA3029A	LIC	CDL-820E	310	SSD-201A	516
CA3030	LIC	CDL-820E	316	SSD-201A	507
CA3030A	LIC	CDL-820E	310	SSD-201A	516
CA3033	LIC	CDL-820E	360	SSD-201A	488
CA3033A	LIC	CDL-820E	360	SSD-201A	488
CA3033H	LIC	CDL-820E	516	SSD-201A	534
CA3035	LIC	CDL-820E	274	SSD-201A	74
CA3035H	LIC	CDL-820E	516	SSD-201A	534
CA3035V1	LIC	CDL-820E	274	SSD-201A	74
CA3036	LIC	CDL-820E	275	SSD-201A	202
CA3037	LIC	CDL-820E	316	SSD-201A	507
CA3037A	LIC	CDL-820E	310	SSD-201A	516
CA3038	LIC	CDL-820E	316	SSD-201A	507
CA3038A	LIC	CDL-820E	310	SSD-201A	516
CA3039	LIC	CDL-820E	343	SSD-201A	166
CA3039H	LIC	CDL-820E	516	SSD-201A	534
CA3039L	LIC	CDL-820E	515	SSD-201A	545
CA3040	LIC	CDL-820E	363	SSD-201A	284
CA3041	LIC	CDL-820E	318	SSD-201A	90
CA3042	LIC	CDL-820E	319	SSD-201A	98
CA3043	LIC	CDL-820E	331	SSD-201A	57
CA3043H	LIC	CDL-820E	516	SSD-201A	534
CA3044	LIC	CDL-820E	340	SSD-201A	78
CA3044V1	LIC	CDL-820E	340	SSD-201A	78
CA3045	LIC	CDL-820E	341	SSD-201A	221
CA3045/1-4	LIC	CDL-820E	401	SSD-201A	227
CA3045F	LIC	CDL-820E	341	SSD-201A	221
CA3045H	LIC	CDL-820E	516	SSD-201A	534
CA3045L	LIC	CDL-820E	515	SSD-201A	545
CA3046	LIC	CDL-820E	341	SSD-201A	221
CA3047	LIC	CDL-820E	360	SSD-201A	488
CA3047A	LIC	CDL-820E	360	SSD-201A	488
CA3048	LIC	CDL-820E	377	SSD-201A	250
CA3048H	LIC	CDL-820E	516	SSD-201A	534
CA3049H	LIC	CDL-820E	516	SSD-201A	534
CA3049L	LIC	CDL-820E	515	SSD-201A	545
CA3049T	LIC	CDL-820E	611	SSD-201A	363
CA3050	LIC	CDL-820E	361	SSD-201A	372
CA3051	LIC	CDL-820E	361	SSD-201A	372
CA3052	LIC	CDL-820E	387	SSD-201A	28
CA3053	LIC	CDL-820E	382	SSD-201A	344
CA3054	LIC	CDL-820E	388	SSD-201A	336
CA3054H	LIC	CDL-820E	516	SSD-201A	534
CA3054L	LIC	CDL-820E	515	SSD-201A	545
CA3058	LIC	CDL-820E	490	SSD-201A	380
CA3059	LIC	CDL-820E	490	SSD-201A	380
CA3059H	LIC	CDL-820E	516	SSD-201A	534
CA3060AD	LIC	CDL-820E	537	SSD-201A	466
CA3060BD	LIC	CDL-820E	537	SSD-201A	466
CA3060D	LIC	CDL-820E	537	SSD-201A	466
CA3060E	LIC	CDL-820E	537	SSD-201A	466
CA3060H	LIC	CDL-820E	516	SSD-201A	534
CA3062	LIC	CDL-820E	421	SSD-201A	401
CA3064	LIC	CDL-820E	396	SSD-201A	84
CA3065	LIC	CDL-820E	412	SSD-201A	106
CA3066	LIC	CDL-820E	466	SSD-201A	125
CA3067	LIC	CDL-820E	466	SSD-201A	125
CA3068	LIC	CDL-820E	467	SSD-201A	117
CA3070	LIC	CDL-820E	468	SSD-201A	143
CA3071	LIC	CDL-820E	468	SSD-201A	143
CA3072	LIC	CDL-820E	468	SSD-201A	143
CA3075	LIC	CDL-820E	429	SSD-201A	53
CA3075H	LIC	CDL-820E	516	SSD-201A	534
CA3076	LIC	CDL-820E	430	SSD-201A	70
CA3076H	LIC	CDL-820E	516	SSD-201A	534
CA3078AS	LIC	CDL-820E	535	SSD-201A	479
CA3078AT	LIC	CDL-820E	535	SSD-201A	479

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
CA3078H	LIC	CDL-820E	516	SSD-201A	534
CA3078S	LIC	CDL-820E	535	SSD-201A	479
CA3078T	LIC	CDL-820E	535	SSD-201A	479
CA3079	LIC	CDL-820E	490	SSD-201A	380
CA3080	LIC	CDL-820E	475	SSD-201A	458
CA3080A	LIC	CDL-820E	475	SSD-201A	458
CA3080AS	LIC	CDL-820E	475	SSD-201A	458
CA3080H	LIC	CDL-820E	516	SSD-201A	534
CA3080S	LIC	CDL-820E	475	SSD-201A	458
CA3081	LIC	CDL-820E	480	SSD-201A	170
CA3081H	LIC	CDL-820E	516	SSD-201A	534
CA3082	LIC	CDL-820E	480	SSD-201A	170
CA3082H	LIC	CDL-820E	516	SSD-201A	534
CA3083	LIC	CDL-820E	481	SSD-201A	174
CA3083F	LIC	CDL-820E	481	SSD-201A	174
CA3083H	LIC	CDL-820E	516	SSD-201A	534
CA3084	LIC	CDL-820E	482	SSD-201A	178
CA3084H	LIC	CDL-820E	516	SSD-201A	534
CA3084L	LIC	CDL-820E	515	SSD-201A	545
CA3085	LIC	CDL-820E	491	SSD-201A	409
CA3085A	LIC	CDL-820E	491	SSD-201A	409
CA3085AF	LIC	CDL-820E	491	SSD-201A	409
CA3085AS	LIC	CDL-820E	491	SSD-201A	409
CA3085B	LIC	CDL-820E	491	SSD-201A	409
CA3085BF	LIC	CDL-820E	491	SSD-201A	409
CA3085BS	LIC	CDL-820E	491	SSD-201A	409
CA3085H	LIC	CDL-820E	516	SSD-201A	534
CA3085F	LIC	CDL-820E	491	SSD-201A	409
CA3085S	LIC	CDL-820E	491	SSD-201A	409
CA3086	LIC	CDL-820E	483	SSD-201A	234
CA3088E	LIC	CDL-820E	560	SSD-201A	42
CA3089E	LIC	CDL-820E	561	SSD-201A	46
CA3090Q	LIC	CDL-820E	502	SSD-201A	36
CA3091D	LIC	CDL-820E	534	SSD-201A	417
CA3091H	LIC	CDL-820E	516	SSD-201A	534
CA3093E	LIC	CDL-820E	533	SSD-201A	196
CA3093H	LIC	CDL-820E	516	SSD-201A	534
CA3094AT	LIC	CDL-820E	598	SSD-201A	388
CA3094BT	LIC	CDL-820E	598	SSD-201A	388
CA3094T	LIC	CDL-820E	598	SSD-201A	388
CA3095E	LIC	CDL-820E	591	SSD-201A	240
CA3096AE	LIC	CDL-820E	595	SSD-201A	185
CA3096E	LIC	CDL-820E	595	SSD-201A	185
CA3102E	LIC	CDL-820E	611	SSD-201A	363
CA3118AT	LIC	CDL-820E	532	SSD-201A	210
CA3118H	LIC	CDL-820E	516	SSD-201A	534
CA3118T	LIC	CDL-820E	532	SSD-201A	210
CA3120E	LIC	CDL-820E	Prel.	SSD-201A	159
CA3121E	LIC	CDL-820E	Prel.	SSD-201A	141
CA3146AE	LIC	CDL-820E	532	SSD-201A	210
CA3146E	LIC	CDL-820E	532	SSD-201A	210
CA3146H	LIC	CDL-820E	516	SSD-201A	534
CA3183AE	LIC	CDL-820E	532	SSD-201A	210
CA3183E	LIC	CDL-820E	532	SSD-201A	210
CA3183H	LIC	CDL-820E	516	SSD-201A	534
CA3458S	LIC	CDL-820E	531	SSD-201A	501
CA3458T	LIC	CDL-820E	531	SSD-201A	501
CA3541D	LIC	CDL-820E	536	SSD-201A	429
CA3541H	LIC	CDL-820E	516	SSD-201A	534
CA3558S	LIC	CDL-820E	531	SSD-201A	501
CA3558T	LIC	CDL-820E	531	SSD-201A	501
CA3741CH	LIC	CDL-820E	516	SSD-201A	534
CA3741CS	LIC	CDL-820E	531	SSD-201A	501
CA3741CT	LIC	CDL-820E	531	SSD-201A	501
CA3741L	LIC	CDL-820E	515	SSD-201A	545
CA3741S	LIC	CDL-820E	531	SSD-201A	501
CA3741T	LIC	CDL-820E	531	SSD-201A	501
CA3747CE	LIC	CDL-820E	531	SSD-201A	501
CA3747CF	LIC	CDL-820E	531	SSD-201A	501
CA3747CH	LIC	CDL-820E	516	SSD-201A	534
CA3747CT	LIC	CDL-820E	531	SSD-201A	501
CA3747E	LIC	CDL-820E	531	SSD-201A	501
CA3747F	LIC	CDL-820E	531	SSD-201A	501
CA3747T	LIC	CDL-820E	531	SSD-201A	501
CA3748CH	LIC	CDL-820E	516	SSD-201A	534
CA3748CS	LIC	CDL-820E	531	SSD-201A	501
CA3748CT	LIC	CDL-820E	531	SSD-201A	501
CA3748S	LIC	CDL-820E	531	SSD-201A	501
CA3748T	LIC	CDL-820E	531	SSD-201A	501
CA6078AS	LIC	CDL-820E	592	SSD-201A	496
CA6078AT	LIC	CDL-820E	592	SSD-201A	496
CA6741S	LIC	CDL-820E	592	SSD-201A	496
CA6741T	LIC	CDL-820E	592	SSD-201A	496
CD2150	LIC	CDL-820E	308	SSD-201A	443
CD2151	LIC	CDL-820E	308	SSD-201A	443
CD2152	LIC	CDL-820E	308	SSD-201A	443
CD2153	LIC	CDL-820E	308	SSD-201A	443
CD2154	LIC	CDL-820E	402	SSD-201A	455
CD2500E	LIC	CDL-820E	392	SSD-201A	437
CD2501E	LIC	CDL-820E	392	SSD-201A	437
CD2502E	LIC	CDL-820E	392	SSD-201A	437
CD2503E	LIC	CDL-820E	392	SSD-201A	437
CD4000AD	COS/MOS	COS-278B	479	SSD-203A	24
CD4000AE	COS/MOS	COS-278B	479	SSD-203A	24
CD4000AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4000AK	COS/MOS	COS-278B	479	SSD-203A	24
CD4001AD	COS/MOS	COS-278B	479	SSD-203A	24
CD4001AE	COS/MOS	COS-278B	479	SSD-203A	24
CD4001AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4001AK	COS/MOS	COS-278B	479	SSD-203A	24
CD4002AD	COS/MOS	COS-278B	479	SSD-203A	24
CD4002AE	COS/MOS	COS-278B	479	SSD-203A	24
CD4002AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4002AK	COS/MOS	COS-278B	479	SSD-203A	24
CD4004A Series	Replaced by CD4024A Series				
CD4006AD	COS/MOS	COS-278B	479	SSD-203A	31
CD4006AE	COS/MOS	COS-278B	479	SSD-203A	31
CD4006AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4006AK	COS/MOS	COS-278B	479	SSD-203A	31
CD4007AD	COS/MOS	COS-278B	479	SSD-203A	37
CD4007AE	COS/MOS	COS-278B	479	SSD-203A	37
CD4007AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4007AK	COS/MOS	COS-278B	479	SSD-203A	37
CD4008AD	COS/MOS	COS-278B	479	SSD-203A	43
CD4008AE	COS/MOS	COS-278B	479	SSD-203A	43
CD4008AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4008AK	COS/MOS	COS-278B	479	SSD-203A	43
CD4009AD	COS/MOS	COS-278B	479	SSD-203A	48
CD4009AE	COS/MOS	COS-278B	479	SSD-203A	48
CD4009AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4009AK	COS/MOS	COS-278B	479	SSD-203A	48
CD4010AD	COS/MOS	COS-278B	479	SSD-203A	48
CD4010AE	COS/MOS	COS-278B	479	SSD-203A	48
CD4010AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4010AK	COS/MOS	COS-278B	479	SSD-203A	48
CD4011AD	COS/MOS	COS-278B	479	SSD-203A	55
CD4011AE	COS/MOS	COS-278B	479	SSD-203A	55
CD4011AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4011AK	COS/MOS	COS-278B	479	SSD-203A	55
CD4012AD	COS/MOS	COS-278B	479	SSD-203A	55
CD4012AE	COS/MOS	COS-278B	479	SSD-203A	55
CD4012AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4012AK	COS/MOS	COS-278B	479	SSD-203A	55
CD4013AD	COS/MOS	COS-278B	479	SSD-203A	62
CD4013AE	COS/MOS	COS-278B	479	SSD-203A	62
CD4013AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4013AK	COS/MOS	COS-278B	479	SSD-203A	62
CD4014AD	COS/MOS	COS-278B	479	SSD-203A	68
CD4014AE	COS/MOS	COS-278B	479	SSD-203A	68
CD4014AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4014AK	COS/MOS	COS-278B	479	SSD-203A	68
CD4015AD	COS/MOS	COS-278B	479	SSD-203A	73
CD4015AE	COS/MOS	COS-278B	479	SSD-203A	73
CD4015AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4015AK	COS/MOS	COS-278B	479	SSD-203A	73
CD4016AD	COS/MOS	COS-278B	479	SSD-203A	78
CD4016AE	COS/MOS	COS-278B	479	SSD-203A	78
CD4016AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4016AK	COS/MOS	COS-278B	479	SSD-203A	78
CD4017AD	COS/MOS	COS-278B	479	SSD-203A	84

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
CD4017AE	COS/MOS	COS-278B	479	SSD-203A	84
CD4017AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4017AK	COS/MOS	COS-278B	479	SSD-203A	84
CD4018AD	COS/MOS	COS-278B	479	SSD-203A	89
CD4018AE	COS/MOS	COS-278B	479	SSD-203A	89
CD4018AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4018AK	COS/MOS	COS-278B	479	SSD-203A	89
CD4019AD	COS/MOS	COS-278B	479	SSD-203A	94
CD4019AE	COS/MOS	COS-278B	479	SSD-203A	94
CD4019AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4019AK	COS/MOS	COS-278B	479	SSD-203A	94
CD4020AD	COS/MOS	COS-278B	479	SSD-203A	99
CD4020AE	COS/MOS	COS-278B	479	SSD-203A	99
CD4020AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4020AK	COS/MOS	COS-278B	479	SSD-203A	99
CD4021AD	COS/MOS	COS-278B	479	SSD-203A	104
CD4021AE	COS/MOS	COS-278B	479	SSD-203A	104
CD4021AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4021AK	COS/MOS	COS-278B	479	SSD-203A	104
CD4022AD	COS/MOS	COS-278B	479	SSD-203A	109
CD4022AE	COS/MOS	COS-278B	479	SSD-203A	109
CD4022AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4022AK	COS/MOS	COS-278B	479	SSD-203A	109
CD4023AD	COS/MOS	COS-278B	479	SSD-203A	55
CD4023AE	COS/MOS	COS-278B	479	SSD-203A	55
CD4023AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4023AK	COS/MOS	COS-278B	479	SSD-203A	55
CD4024AD	COS/MOS	COS-278B	503	SSD-203A	114
CD4024AE	COS/MOS	COS-278B	503	SSD-203A	114
CD4024AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4025AD	COS/MOS	COS-278B	479	SSD-203A	24
CD4025AE	COS/MOS	COS-278B	479	SSD-203A	24
CD4025AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4025AK	COS/MOS	COS-278B	479	SSD-203A	24
CD4026AD	COS/MOS	COS-278B	503	SSD-203A	120
CD4026AE	COS/MOS	COS-278B	503	SSD-203A	120
CD4026AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4026AK	COS/MOS	COS-278B	503	SSD-203A	120
CD4027AD	COS/MOS	COS-278B	503	SSD-203A	129
CD4027AE	COS/MOS	COS-278B	503	SSD-203A	129
CD4027AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4027AK	COS/MOS	COS-278B	503	SSD-203A	129
CD4028AD	COS/MOS	COS-278B	503	SSD-203A	135
CD4028AE	COS/MOS	COS-278B	503	SSD-203A	135
CD4028AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4028AK	COS/MOS	COS-278B	503	SSD-203A	135
CD4029AD	COS/MOS	COS-278B	503	SSD-203A	140
CD4029AE	COS/MOS	COS-278B	503	SSD-203A	140
CD4029AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4029AK	COS/MOS	COS-278B	503	SSD-203A	140
CD4030AD	COS/MOS	COS-278B	503	SSD-203A	147
CD4030AE	COS/MOS	COS-278B	503	SSD-203A	147
CD4030AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4030AK	COS/MOS	COS-278B	503	SSD-203A	147
CD4031AD	COS/MOS	COS-278B	569	SSD-203A	152
CD4031AE	COS/MOS	COS-278B	569	SSD-203A	152
CD4031AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4031AK	COS/MOS	COS-278B	569	SSD-203A	152
CD4032AD	COS/MOS	COS-278B	503	SSD-203A	159
CD4032AE	COS/MOS	COS-278B	503	SSD-203A	159
CD4032AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4032AK	COS/MOS	COS-278B	503	SSD-203A	159
CD4033AD	COS/MOS	COS-278B	503	SSD-203A	120
CD4033AE	COS/MOS	COS-278B	503	SSD-203A	120
CD4033AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4033AK	COS/MOS	COS-278B	503	SSD-203A	120
CD4034AD	COS/M(S	COS-278B	575	SSD-203A	164
CD4034AE	COS/MOS	COS-278B	575	SSD-203A	164
CD4034AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4034AK	COS/MOS	COS-278B	575	SSD-203A	164
CD4035AD	COS/MOS	COS-278B	568	SSD-203A	173
CD4035AE	COS/MOS	COS-278B	568	SSD-203A	173
CD4035AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4035AK	COS/MOS	COS-278B	568	SSD-203A	173
CD4036AD	COS/MOS	COS-278B	613	SSD-203A	181
CD4036AE	COS/MOS	COS-278B	613	SSD-203A	181
CD4036AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4036AK	COS/MOS	COS-278B	613	SSD-203A	181
CD4037AD	COS/MOS	COS-278B	576	SSD-203A	188
CD4037AE	COS/MOS	COS-278B	576	SSD-203A	188
CD4037AK	COS/MOS	COS-278B	576	SSD-203A	188
CD4038AD	COS/MOS	COS-278B	503	SSD-203A	159
CD4038AE	COS/MOS	COS-278B	503	SSD-203A	159
CD4038AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4038AK	COS/MOS	COS-278B	503	SSD-203A	159
CD4039AD	COS/MOS	COS-278B	613	SSD-203A	181
CD4039AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4039AK	COS/MOS	COS-278B	613	SSD-203A	181
CD4040AD	COS/MOS	COS-278B	Prel.	SSD-203A	195
CD4040AE	COS/MOS	COS-278B	Prel.	SSD-203A	195
CD4040AK	COS/MOS	COS-278B	Prel.	SSD-203A	195
CD4041AD	COS/MOS	COS-278B	572	SSD-203A	199
CD4041AE	COS/MOS	COS-278B	572	SSD-203A	199
CD4041AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4041AK	COS/MOS	COS-278B	572	SSD-203A	199
CD4042AD	COS/MOS	COS-278B	589	SSD-203A	208
CD4042AE	COS/MOS	COS-278B	589	SSD-203A	208
CD4042AK	COS/MOS	COS-278B	589	SSD-203A	208
CD4043AD	COS/MOS	COS-278B	590	SSD-203A	214
CD4043AE	COS/MOS	COS-278B	590	SSD-203A	214
CD4043AK	COS/MOS	COS-278B	590	SSD-203A	214
CD4044AD	COS/MOS	COS-278B	590	SSD-203A	214
CD4044AE	COS/MOS	COS-278B	590	SSD-203A	214
CD4044AK	COS/MOS	COS-278B	590	SSD-203A	214
CD4045AD	COS/MOS	COS-278B	Prel.	SSD-203A	222
CD4045AE	COS/MOS	COS-278B	Prel.	SSD-203A	222
CD4045AK	COS/MOS	COS-278B	Prel.	SSD-203A	222
CD4046AD	COS/MOS	COS-278B	Prel.	SSD-203A	224
CD4046AE	COS/MOS	COS-278B	Prel.	SSD-203A	224
CD4046AK	COS/MOS	COS-278B	Prel.	SSD-203A	224
CD4047AD	COS/MOS	COS-278B	Prel.	SSD-203A	228
CD4047AE	COS/MOS	COS-278B	Prel.	SSD-203A	228
CD4047AK	COS/MOS	COS-278B	Prel.	SSD-203A	228
CD4048AD	COS/MOS	COS-278B	Prel.	SSD-203A	233
CD4048AE	COS/MOS	COS-278B	Prel.	SSD-203A	233
CD4048AK	COS/MOS	COS-278B	Prel.	SSD-203A	233
CD4049AD	COS/MOS	COS-278B	599	SSD-203A	237
CD4049AE	COS/MOS	COS-278B	599	SSD-203A	237
CD4049AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4049AK	COS/MOS	COS-278B	599	SSD-203A	237
CD4050AD	COS/MOS	COS-278B	599	SSD-203A	237
CD4050AE	COS/MOS	COS-278B	599	SSD-203A	237
CD4050AH	COS/MOS	COS-278B	517	SSD-203A	268
CD4050AK	COS/MOS	COS-278B	599	SSD-203A	237
CD4051AD	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4051AE	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4051AK	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4052AD	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4052AE	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4052AK	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4053AD	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4053AE	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4053AK	COS/MOS	COS-278B	Prel.	SSD-203A	245
CD4054AD	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4054AE	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4054AK	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4055AD	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4055AE	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4055AK	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4056AD	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4056AE	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4056AK	COS/MOS	COS-278B	Prel.	SSD-203A	249
CD4057AD	COS/MOS	COS-278B	Prel.	SSD-203A	254
CD4058AD	COS/MOS	COS-278B	Prel.	SSD-203A	262
CD4058AK	COS/MOS	COS-278B	Prel.	SSD-203A	262
CH2102	PWR	SPG-201J	469	SSD-204A	544
CH2270	PWR	SPG-201J	469	SSD-204A	544
CH2405	PWR	SPG-201J	469	SSD-204A	544
CH3053	PWR	SPG-201J	469	SSD-204A	544
CH3439	PWR	SPG-201J	469	SSD-204A	544

Index to Devices

Type No.	Product Line	Catalog	File No.	DATA-BOOK Vol. No.	Page
CH3440	PWR	SPG-201J	469	SSD-204A	544
CH4036	PWR	SPG-201J	469	SSD-204A	544
CH4037	PWR	SPG-201J	469	SSD-204A	544
CH5320	PWR	SPG-201J	469	SSD-204A	544
CH5321	PWR	SPG-201J	469	SSD-204A	544
CH5322	PWR	SPG-201J	469	SSD-204A	544
CH5323	PWR	SPG-201J	469	SSD-204A	544
CR101	RECT	THC-500B	84	SSD-206A	337
CR102	RECT	THC-500B	84	SSD-206A	337
CR103	RECT	THC-500B	84	SSD-206A	337
CR105	RECT	THC-500B	84	SSD-206A	337
CR106	RECT	THC-500B	84	SSD-206A	337
CR107	RECT	THC-500B	84	SSD-206A	337
CR108	RECT	THC-500B	84	SSD-206A	337
CR109	RECT	THC-500B	84	SSD-206A	337
CR110	RECT	THC-500B	84	SSD-206A	337
CR201	RECT	THC-500B	86	SSD-206A	341
CR203	RECT	THC-500B	86	SSD-206A	341
CR204	RECT	THC-500B	86	SSD-206A	341
CR206	RECT	THC-500B	86	SSD-206A	341
CR208	RECT	THC-500B	86	SSD-206A	341
CR210	RECT	THC-500B	86	SSD-206A	341
CR212	RECT	THC-500B	86	SSD-206A	341
CR273/8008	RECT	THC-500B	100	SSD-206A	350
CR274/872A	RECT	THC-500B	100	SSD-206A	350
CR275/866A/ 3B25/3B28	RECT	THC-500B	100	SSD-206A	350
CR280	RECT	THC-500B	86	SSD-206A	341
CR301	RECT	THC-500B	60	SSD-206A	344
CR302	RECT	THC-500B	60	SSD-206A	344
CR303	RECT	THC-500B	60	SSD-206A	344
CR304	RECT	THC-500B	60	SSD-206A	344
CR305	RECT	THC-500B	60	SSD-206A	344
CR306	RECT	THC-500B	60	SSD-206A	344
CR307	RECT	THC-500B	60	SSD-206A	344
CR311	RECT	THC-500B	60	SSD-206A	344
CR312	RECT	THC-500B	60	SSD-206A	344
CR313	RECT	THC-500B	60	SSD-206A	344
CR314	RECT	THC-500B	60	SSD-206A	344
CR315	RECT	THC-500B	60	SSD-206A	344
CR316	RECT	THC-500B	60	SSD-206A	344
CR317	RECT	THC-500B	60	SSD-206A	344
CR321	RECT	THC-500B	60	SSD-206A	344
CR322	RECT	THC-500B	60	SSD-206A	344
CR323	RECT	THC-500B	60	SSD-206A	344
CR324	RECT	THC-500B	60	SSD-206A	344
CR325	RECT	THC-500B	60	SSD-206A	344
CR331	RECT	THC-500B	60	SSD-206A	344
CR332	RECT	THC-500B	60	SSD-206A	344
CR333	RECT	THC-500B	60	SSD-206A	344
CR334	RECT	THC-500B	60	SSD-206A	344
CR335	RECT	THC-500B	60	SSD-206A	344
CR341	RECT	THC-500B	60	SSD-206A	344
CR342	RECT	THC-500B	60	SSD-206A	344
CR343	RECT	THC-500B	60	SSD-206A	344
CR344	RECT	THC-500B	60	SSD-206A	344
CR351	RECT	THC-500B	60	SSD-206A	344
CR352	RECT	THC-500B	60	SSD-206A	344
CR353	RECT	THC-500B	60	SSD-206A	344
CR354	RECT	THC-500B	60	SSD-206A	344
HC1000	HYB	PHC-600A	565	SSD-204A	550
HC1000H	HYB	PHC-600A	565	SSD-204A	550
HC2000	HYB	PHC-600A	566	SSD-204A	555
HC2000H	HYB	PHC-600A	566	SSD-204A	555
HC3000	HYB	PHC-600A	539	SSD-204A	560
HC3100	HYB	PHC-600A	564	SSD-204A	563
HC4005	HYB	PHC-600A	571	SSD-204A	566
HC4005A	HYB	PHC-600A	571	SSD-204A	566
HC4012	HYB	PHC-600A	571	SSD-204A	566
HC4012A	HYB	PHC-600A	571	SSD-204A	566
HC4015	HYB	PHC-600A	571	SSD-204A	566
HC4015A	HYB	PHC-600A	571	SSD-204A	566
QR2900	RECT	THC-500B	–	SSD-206A	8
QR2901	RECT	THC-500B	–	SSD-206A	8
QR2902	RECT	THC-500B	–	SSD-206A	8
QR2903	RECT	THC-500B	–	SSD-206A	8
QR2904	RECT	THC-500B	–	SSD-206A	8
QR2905	RECT	THC-500B	–	SSD-206A	8
QR2906	RECT	THC-500B	–	SSD-206A	8
QR2907	RECT	THC-500B	–	SSD-206A	8
QR2908	RECT	THC-500B	–	SSD-206A	8
QR2909	RECT	THC-500B	–	SSD-206A	8
QR2910	RECT	THC-500B	–	SSD-206A	8
QR2911	RECT	THC-500B	–	SSD-206A	8
R47M10	RF	RFT-700K	605	SSD-205A	410
R47M13	RF	RFT-700K	605	SSD-205A	410
R47M15	RF	RFT-700K	605	SSD-205A	410