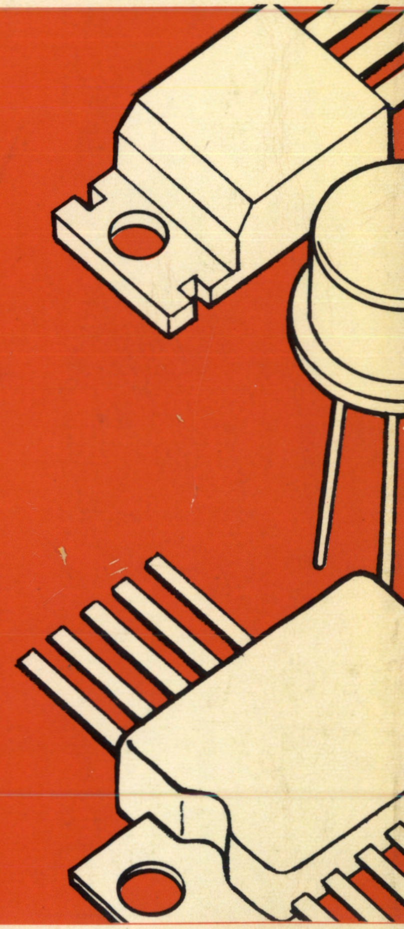
SSD-204

Solid State Europe

DATABOOK Series

Power Transistors

and Power Hybrid Circuits



Selection Guide
Data
Application Notes

'72

Optional Price
£0.85 $2.00 Bf.100 Lira.1260 Ff.11.20
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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 reference, the data sheets are 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) diffused-junction n-p-n silicon transistors, (g) special audio power transistors, (h) germanium power transistors, (i) power-transistor chips, (j) power hybrid circuits.

A feature of this DATABOOK is a Selection Guide to the complete line of RCA solid-state devices (including linear integrated circuits, MOS field-effect devices, COS/MOS integrated circuits, rf power devices, thyristors, rectifiers, and other diodes, as well as power transistors and power hybrid circuits). The complete Index to Devices at the back of the book identifies the volume of the DATABOOK series in which each type appears. The Key to Power Transistors and Power Hybrid Circuits following the Selection Guide gives page numbers in this DATABOOK for individual types.

New solid-state devices and related publications announced during the year are described in a monthly newsletter entitled "What's New in Solid State". Copies of data sheets on new devices and other publications can be obtained by request to RCA Solid State Division, Box 3200, Somerville, N.J. 08876; RCA Limited, Lincoln Way, Windmill Road, Sunbury-on-Thames, Middlesex, England; or RCA S/A Parc-Industriel des Hauts-Sarts, Herstal, Liege, Belgium. If you wish to receive the monthly announcement newsletter, please fill out the form bound into the back of the book and return it to RCA.

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SOLID-STATE SELECTION GUIDE

This Selection Guide classifies RCA solid-state devices by category, by function, by material, and by performance level. This guide is particularly useful for an initial selection of suitable devices for a specific application. Complete data on these devices are given in the technical data sheets included in the respective DATABOOKS (see Index to RCA Solid-State Devices at back of book).

Transistors

AUDIO-FREQUENCY APPLICATIONS

Small Signal—Class A
Silicon n-p-n

Dissipations up to 5 W

2N697	2N1711	2N2895
2N699	2N1893	2N2896
2N718A	2N2102	2N2897
2N720A	2N2270	2N3053
2N1613	2N2405	40084

Power—Class A, AB, B
Silicon n-p-n

Dissipations up to 5 W

2N697	2N2896	40360
2N699	2N2897	40361
2N1479	2N3053	40366
2N1480	40084	40367
2N1481	40309	40385
2N1482	40311	40407
2N1613	40314	40408
2N1700	40315	40539
2N1711	40317	40611
2N1893	40320	40616
2N2102	40321	40625
2N2270	40323	40628
2N2405	40326	40635
2N2895	40327	

Dissipations from 5 W to 29 W

2N1483	40250	40349V1
2N1484	40250V1	40349V2
2N1485	40310	40368
2N1486	40312	40372
2N1701	40316	40373
2N3054	40324	40374
2N3439	40346	40375
2N3440	40346V1	40389
2N3441	40346V2	40390
2N4063	40347	40392
2N4064	40347V1	40409
2N5320	40347V2	40412
2N5321	40348	40544
2N5784	40348V1	40594
2N5785	40348V2	
2N5786	40349	

Dissipations from 29 W to 100 W

2N1487	2N1490	2N3264
2N1488	2N1702	2N3583
2N1489	2N3263	2N3584
2N3585	2N5495	40322
2N3878	2N5496	40328
2N3879	2N5497	40364
2N4240	2N6098	40369
2N4347	2N6099	40513
2N5034	2N6100	40514
2N5035	2N6101	40542
2N5036	2N6102	40543
2N5037	2N6103	40613
2N5239	2N6260	40618
2N5240	2N6261	40621
2N5293	2N6263	40622
2N5294	2N6264	40624
2N5295	201	40627
2N5296	202	40629
2N5297	203	40630
2N5298	204	40631
2N5490	205	40632
2N5491	520	40633
2N5492	521	45190
2N5493	40313	45191
2N5494	40318	45192

Dissipations from 100 W to 300 W

2N2015	2N4348	2N6257
2N2016	2N5575	2N6258
2N2338	2N5576	2N6259
2N3055	2N5577	2N6262
2N3265	2N5578	40251
2N3266	2N5579	40325
2N3442	2N5580	40363
2N3771	2N6253	40411
2N3772	2N6254	40636
2N3773		

Silicon p-n-p

Dissipations up to 10 W

2N4036	2N5416	40410
2N4037	40319	40537
2N4314	40362	40538
2N5322	40391	40595
2N5323	40394	40634
2N5415	40406	

Dissipations from 10 W to 65 W

2N5781	2N6109	103
2N5782	2N6110	104
2N5783	2N6111	105
2N5954	2N6211	370
2N5955	2N6212	371
2N5956	2N6213	45193
2N6106	101	45194
2N6107	102	45195
2N6108		

Germanium p-n-p

Dissipations up to 30 W

2N1183	2N2147	40051
2N1183A	2N2148	40254
2N1183B	2N2869/	40421
2N1184	2N301	40462
2N1184A	2N2870/	40612
2N1184B	2N301A	40623
2N1905	40022	40626
2N1906	40050	

High-Voltage

Germanium p-n-p

2N3730	2N3732	40439
2N3731	2N4346	40440

Silicon n-p-n

2N2016	2N3584	2N5240
2N2102	2N3585	40346
2N2405	2N3773	40349
2N3263	2N3878	40349V1
2N3264	2N3879	40349V2
2N3265	2N4063	40366
2N3266	2N4064	40373
2N3439	2N4240	40374
2N3440	2N4347	40375
2N3441	2N4348	40385
2N3442	2N5239	40390
2N3583		

RADIO-FREQUENCY APPLICATIONS

Small Signal
MOS/FET Silicon N-Channel Single-Gate

3N128	3N143	40467A
3N138	3N152	40468A
3N139	3N153	40559A
3N142	3N154	

MOS/FET Silicon N-Channel Dual-Gate

3N140	40601	40820
3N141	40602	40821
3N159	40603	40822
3N187	40604	40823
3N200	40673	40841
40600	40819	

Silicon n-p-n
f_T to 700 MHz (Typ.)

2N2102	2N2895	2N3053
2N2270	2N2896	40084
2N2405	2N2897	

f_T to 1200 MHz (Min.)

2N918	2N3839	40894
2N2857	2N5109	40895
2N3478	2N5179	40896
2N3600	40294	40897

Power

Silicon n-p-n

2N1491	2N5917	40294
2N1492	2N5918	40305
2N1493	2N5919	40306
2N2631	2N5919A	40307
2N2876	2N5920	40340
2N3118	2N5921	40341
2N3229	2N5992	40446
2N3375	2N5993	40577
2N3553	2N5994	40578
2N3632	2N5995	40581
2N3733	2N5996	40582
2N3866	2N6093	40605
2N4012	2N6105	40608
2N4427	2N6265	40665
2N4440	2N6266	40666
2N4932	2N6267	40836
2N4933	2N6268	40837
2N5016	2N6269	40893
2N5070	40080	40898
2N5071	40081	40899
2N5090	40082	40909
2N5102	40279	40934
2N5108	40280	40935
2N5470	40281	40936
2N5913	40282	40939
2N5914	40290	40940
2N5915	40291	40941
2N5916	40292	

COMPUTER SWITCHING APPLICATIONS

Low Level, Medium-Speed Logic Switching

Silicon n-p-n

f_T to 175 MHz (Min.)

2N697	2N2895	2N3878
2N699	2N2896	2N3879
2N718A	2N2897	2N5202
2N720A	2N3053	2N5320
2N1613	2N3262	2N5321
2N1711	2N3263	40084
2N1893	2N3264	40375
2N2102	2N3265	40389
2N2270	2N3266	40392
2N2405		

Silicon p-n-p

f_T to 60 MHz (Min.)

2N4036	2N5322	40391
2N4037	2N5323	40394
2N4314		

High-Speed Logic Switching

Silicon n-p-n

f_T to 600 MHz (Min.)

2N3119

High-Voltage Switching

Silicon p-n-p

f_T to 600 MHz (Min.)

2N5189	2N5262

Chopper and Multiplex Service

MOS/FET Silicon N-Channel Single-Gate

3N138	3N153

POWER SWITCHING

Low Speed Switching

Silicon n-p-n

Dissipations up to 8.75 W

2N697	2N3053	40349
2N699	2N3262	40349V1
2N718A	40250V1	40360
2N720A	40309	40361
2N1479	40311	40366
2N1480	40314	40367
2N1481	40315	40372
2N1482	40317	40374
2N1613	40320	40375
2N1700	40321	40385
2N1711	40323	40389
2N1893	40326	40390
2N2102	40327	40392
2N2270	40346V1	40407
2N2405	40347	40408
2N2895	40347V1	40409
2N2896	40348	40412V1
2N2897	40348V1	

Dissipations from 8.75 W to 50 W

2N1483	2N5297	2N6292
2N1484	2N5298	2N6293
2N1485	2N5490	40250
2N1486	2N5491	40310
2N1701	2N5492	40312
2N3054	2N5493	40313
2N3439	2N5494	40316
2N3440	2N5495	40318
2N3441	2N5496	40322
2N3583	2N5497	40324
2N3584	2N6098	40328
2N3585	2N6099	40346
2N3878	2N6100	40346V2
2N3879	2N6101	40347V2
2N4063	2N6102	40348V2
2N4064	2N6103	40349V2
2N4240	2N6288	40364
2N5293	2N6289	40368
2N5294	2N6290	40412
2N5295	2N6291	40412V2
2N5296		

Dissipations from 50 W to 150 W

2N1487	2N3442	2N5575
2N1488	2N3771	2N5576
2N1489	2N3772	2N5577
2N1490	2N3773	2N5578
2N1702	2N4347	2N5579
2N2015	2N4348	2N5580
2N2016	2N5034	2N5671
2N2338	2N5035	2N5672
2N3055	2N5036	2N6032
2N3263	2N5037	2N6033
2N3264	2N5038	2N6246
2N3265	2N5039	2N6247
2N3266	2N5240	2N6248
40251	40363	40411
40325	40369	

Silicon p-n-p

Dissipations up to 40 W

40319	40391	40406
40362	40394	40410

Germanium p-n-p

Dissipations up to 30 W

2N1183	2N1184	2N1905
2N1183A	2N1184A	2N1906
2N1183B	2N1184B	

High-Voltage Switching

Silicon n-p-n

Collector-to-Emitter Voltage to 350 V (max.)

2N3439	2N5840	40349V1
2N3440	2N6077	40349V2
2N3441	2N6078	40354
2N3442	2N6079	40373
2N3583	2N6175	40374
2N3584	2N6176	40385
2N3585	2N6177	40390
2N3773	2N6249	40412
2N4063	2N6250	40412V1
2N4064	2N6251	40412V2
2N4240	410	40850
2N4347	411	40851
2N4348	413	40852
2N5239	423	40853
2N5240	431	40854
2N5804	40346	40885
2N5805	40346V1	40886
2N5838	40346V2	40887
2N5839	40349	

Silicon p-n-p

Collector-to-Emitter Sustaining Voltage to −300 V (max.)

2N5415	2N5416

POWER HYBRID CIRCUITS

Linear Amplifier

HC1000

Operational Amplifier

HC2000

Thyristors

TRIACS

Low-Voltage Operation, 50 & 60 Hz

2N5754	40534	40766
40525	40684	40767
40528	40693	40900
40531	40696	

120-V Line Operation, 50 & 60 Hz

2N5441	40575	40717
2N5444	40638	40719
2N5567	40660	40721
2N5569	40662	40725
2N5571	40668	40727
2N5573	40685	40729
2N5755	40688	40731
40429	40691	40733
40431	40694	40761
40485	40697	40799
40502	40699	40802
40509	40702	40805
40511	40705	40901
40526	40707	40916
40529	40711	40919
40532	40713	40922
40535	40715	

240-V Line Operation, 50 & 60 Hz

2N5442	40661	40720
2N5445	40663	40722
2N5568	40664	40723
2N5570	40667	40724
2N5572	40669	40726
2N5574	40686	40728
2N5756	40689	40730
40430	40692	40732
40432	40695	40734
40486	40698	40762
40503	40700	40800
40510	40703	40803
40512	40706	40806
40527	40708	40842
40530	40712	40902
40533	40714	40917
40536	40716	40920
40576	40718	40923
40639		

High-Voltage Operation, 50 & 60 Hz

2N5443	40704	40804
2N5446	40709	40807
2N5757	40710	40918
40671	40795	40921
40672	40796	40924
40687	40797	40925
40690	40798	40926
40701	40801	40927

400-Hz Service, V_{DROM} = 200 V

40769	40779	40787
40771	40781	40789
40773	40783	40791
40775	40785	40793
40777		

400-Hz Service, V_{DROM} = 400 V

40770	40780	40788
40772	40782	40790
40774	40784	40792
40776	40786	40794
40778		

Silicon Controlled Rectifiers

Low-Voltage Operation, 50 & 60 Hz

2N681	2N3870	40680
2N682	2N3897	40737
2N683	106A	40741
2N684	106F	40745
2N1842A	106Q	40749
2N1843A	106Y	40753
2N1844A	107A	40757
2N1845A	107F	40810
2N3650	107Q	40867
2N3668	107Y	

120-V Line Operation 50 & 60 Hz

2N685	107B	40738
2N1846A	40378	40742
2N3228	40504	40746
2N3528	40507	40750
2N3651	40553	40754
2N3669	40654	40758
2N3871	40656	40811
2N3897	40658	40868
106B	40681	

240-V Line Operation, 50 & 60 Hz

2N688	107C	40739
2N1849A	40379	40743
2N3525	40505	40747
2N3529	40508	40751
2N3653	40554	40755
2N3670	40655	40759
2N3872	40657	40812
2N3898	40659	40869
106C	40682	

High-Voltage Operation 50 & 60 Hz

2N686	106E	40744
2N687	106M	40748
2N689	107D	40752
2N690	107E	40756
2N1847A	107M	40760
2N1848A	40216	40768
2N1850A	40506	40813
2N3652	40555	40833
2N3873	40640	40834
2N4101	40641	40835
2N4102	40683	40937
2N4103	40735	40938
106D	40740	

TV Deflection Circuits

40888	40889

Rectifiers

Silicon Rectifiers—Low Power

$I_{F(AV)}$ to 2A

1N440B	1N444B	1N538
1N441B	1N445B	1N539
1N442B	1N536	1N540
1N443B	1N537	1N547

$I_{F(AV)}$ to 2A (cont'd)

1N1095	1N3256	1N5395
1N1763A	1N3563	1N5396
1N1764A	1N3754	1N5397
1N2858A	1N3755	1N5398
1N2859A	1N3756	1N5399
1N2860A	1N5211	40266
1N2861A	1N5212	40267
1N2862A	1N5213	40642
1N2863A	1N5214	40643
1N2864A	1N5215	40644
1N3193	1N5216	44001
1N3194	1N5217	44002
1N3195	1N5218	44003
1N3196	1N5391	44004
1N3253	1N5392	44005
1N3254	1N5393	44006
1N3255	1N5394	44007

Silicon Rectifiers—High Power

$I_{F(AV)}$ 12 A to 40 A

1N248C	1N1203A	40109
1N249C	1N1204A	40110
1N250C	1N1205A	40111
1N1183A	1N1206A	40112
1N1184A	1N1341B	40113
1N1186A	1N1342B	40114
1N1187A	1N1344B	40115
1N1188A	1N1345B	40208
1N1189A	1N1346B	40209
1N1190A	1N1347B	40210
1N1195A	1N1348B	40211
1N1196A	1N1612	40212
1N1197A	1N1613	40213
1N1198A	1N1614	40214
1N1199A	1N1615	
1N1200A	1N1616	
1N1202A	40108	

High-Voltage Rectifier Assemblies

CR101	CR280	CR323
CR102	CR301	CR324
CR103	CR302	CR325
CR104	CR303	CR331
CR105	CR304	CR332
CR106	CR305	CR333
CR107	CR306	CR334
CR108	CR307	CR335
CR109	CR311	CR341
CR110	CR312	CR342
CR201	CR313	CR343
CR203	CR314	CR344
CR204	CR315	CR351
CR206	CR316	CR352
CR208	CR317	CR353
CR210	CR321	CR354
CR212	CR322	

High-Voltage Replacement Types

CR273/ 8008	CR274/ 872A	CR275/ 866A/ 3B28

Controlled-Avalanche Types

40808 40809

TV Types

40890 40891 40892

DIACS

For Triggering Triacs

1N5411 40583

Diodes

Compensating

40428

RCA Military-Specification Types

TYPE	MIL-S-19500/	TYPE	MIL-S-19500/
Transistors			
JAN-2N384	27	JAN-2N1488	208
JAN-2N388	65	JAN-2N1489	208
JAN-2N398	174	JAN-2N1490	208
JAN-2N398A	174	JAN-2N1493	247
JAN-2N404	20	JAN-2N2015	248
JAN-2N404A	20	JAN-2N2016	248
JAN-2N918	301	JAN-2N2857	343
JAN-2N1183	143	JAN-TX2N2857	343
JAN-2N1183A	143	JAN-2N3055	407
JAN-2N1183B	143	JAN-TX2N3055	407
JAN-2N1184	143	JAN-2N3375	341
JAN-2N1184A	143	JAN-TX2N3375	341
JAN-2N1184B	143	JAN-2N3439	368
JAN-2N1224	189	JAN-TX2N3439	368
JAN-2N1225	189	JAN-2N3440	368
JAN-2N1302	126	JAN-TX2N3440	368
JAN-2N1303	126	JAN-2N3441	369
JAN-2N1304	126	JAN-2N3442	370
JAN-2N2305	126	JAN-2N3553	341
JAN-2N1306	126	JAN-TX2N3553	341
JAN-2N1307	126	JAN-2N3584	384
JAN-2N1308	126	JAN-TX2N3584	384
JAN-2N1309	126	JAN-2N3585	384
JAN-2N1479	207	JAN-TX2N3585	384
JAN-2N1480	207	JAN-2N3771	413
JAN-2N1481	207	JAN-TX2N3771	413
JAN-2N1482	207	JAN-2N3772	413
JAN-2N1483	180	JAN-TX2N3772	413
JAN-TX2N1483	180	JAN-2N3866	398
JAN-2N1484	180	JAN-TX2N3866	398
JAN-TX2N1484	180	JAN-2N4440	341
JAN-2N1485	180	JAN-TX2N4440	341
JAN-TX2N1485	180	JAN-2N5038	439
JAN-2N1486	180	JAN-TX2N5038	439
JAN-TX2N1486	180	JAN-2N5039	439
JAN-2N1487	208	JAN-TX2N5039	439

Copies of specification sheets may be obtained by directing requests to Department of the Navy, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120

COS/MOS Digital Integrated Circuits

GATES

NOR (Positive-Logic)

Dual 3-Input Plus Inverter

CD4000AD CD4000AE CD4000AK

Quad 2-Input

CD4001AD CD4001AE CD4001AK

Dual 4-Input

CD4002AD CD4002AE CD4002AK

Triple 3-Input

CD4025AD CD4025AE CD4025AK

NAND (Positive Logic)

Quad 2-Input

CD4011AD CD4011AE CD4011AK

Dual 4-Input

CD4012AD CD4012AE CD4012AK

Triple 3-Input

CD4023AD CD4023AE CD4023AK

GATE ARRAYS

AND-OR Select Quad

CD4019AD CD4019AE CD4019AK

Exclusive-OR Quad

CD4030AD CD4030AE CD4030AK

GENERAL PURPOSE

Complementary Pair Dual Plus Inverter

CD4007AD CD4007AE CD4007AK

HEX BUFFERS LOGIC-LEVEL CONVERTERS

Inverting

CD4009AD CD4009AE CD4009AK

Non-Inverting

CD4010AD CD4010AE CD4010AK

DECODERS

BDC-to Decimal

CD4028AD CD4028AE CD4028AK

MULTIPLEXERS

Quad Bilateral Switch

CD4016AD CD4016AE CD4016AK

ARITHMETIC DEVICES

Four-Bit Full Adder

CD4008AD CD4008AE CD4008AK

Triple Serial Adder
Positive Logic

CD4032AD CD4032AE CD4032AK

Negative Logic

CD4038AD CD4038AE CD4038AK

FLIP FLOPS

Dual 'D' Type with Set-Reset

CD4013AD CD4013AE CD4013AK

Dual J–K Master-Slave

CD4027AD CD4027AE CD4027AK

COUNTER/DIVIDERS

7-Stage Binary Ripple Carry

CD4004AD CD4004AT CD4024AK
CD4004AE CD4024AD CD4024AT
CD4004AK CD4024AE

14-Stage Binary Ripple Carry

CD4020AD CD4020AE CD4020AK

Decade-10 Decoded Decimal Outputs

CD4017AD CD4017AE CD4017AK

Decade-7-Segment Display Outputs

CD4026AD CD4026AK CD4033AE
CD4026AE CD4033AD CD4033AK

Octal-8-Decoded Outputs

CD4022AD CD4022AE CD4022AK

Divide-by-'N' Fixed or Programmable

CD4018AD CD4018AE CD4018AK

Pre-Settable Up/Down

CD4029AD CD4029AE CD4029AK

STATIC SHIFT REGISTERS

18 Stage

CD4006AD CD4006AE CD4006AK

8-Stage Synchronous

CD4014AD CD4014AE CD4014AK

8-Stage Asynchronous

CD4021AD CD4021AE CD4021AK

Dual 4-Stage

CD4015AD CD4015AE CD4015AK

Linear Integrated Circuits

FM, AM, AND AUDIO CIRCUITS

Stereo Preamplifier

CA3048 CA3052

Stereo Multiplex Decoder

CA3090Q

IF Amplifier

AM

CA3088E CA3089E

FM

CA3011 CA3043 CA3076
CA3012 CA3075

Wide-Band Amplifier

CA3013 CA3041 CA3042
CA3014

Limiter

CA3013 CA3042 CA3075
CA3014 CA3043 CA3076
CA3041

Detector

AM

CA3088E CA3089E

FM

CA3013 CA3041 CA3043
CA3014 CA3042 CA3075

AF Pre Amplifier

CA3043 CA3088E CA3089E
CA3075

Driver

CA3041 CA3042 CA3043

TELEVISION CIRCUITS

Video IF System

CA3068

Automatic Fine Tuning

CA3044 CA3044V1 CA3064

Remote Control

CA3035 CA3035V1

Chroma Demodulator

CA3067 CA3072

Chroma Signal Processors

CA3066 CA3070

Chroma Amplifier

CA3066 CA3071

Detector

CA3044 CA3044V1 CA3064

Zener Diode Voltage Regulator

CA3064

DC Amplifier

CA3064

Output Amplifier

CA3044 CA3044V1

IF Amplifier/Limiter, FM Detector, Electronic Attenuator, and Audio Driver

CA3065

OPERATIONAL AMPLIFIERS

Micropower

Single OTA

CA3080 CA3080A

Triple OTA Array

CA3060AD CA3060D CA3060E
CA3060BD

Single Op Amp.

CA3078AT CA3078T

High Current

CA3033 CA3047 CA3047A
CA3033A

General Purpose

CA3458T CA3747CE CA3747T
CA3558T CA3747CT CA3748CT
CA3741CT CA3747E CA3748T
CA3741T

Wide-Band

CA3008 CA3016 CA3030A
CA3008A CA3016A CA3037
CA3010 CA3029 CA3037A
CA3010A CA3029A CA3038
CA3015 CA3030 CA3038A
CA3015A

Premium Low Noise

CA6741T

HIGH-GAIN WIDE-BAND AMPLIFIERS

Video (DC to 200 MHz)

CA3040

Low Power Video (DC to 40 MHz)

CA3021 CA3022 CA3023

Multi Purpose Power (DC to 8 MHz)

CA3020 CA3020A

DIFFERENTIAL AMPLIFIERS

DC
(to 30 MHz)

CA3000 CA3000/2 CA3000/4
CA3000/1 CA3000/3

AF
(to 3 kHz)

CA30007 CA3008

IF
(to 15 MHz)

CA3002

RF
(to 100 MHz)

CA3004 CA3005 CA3006

Video & Wide-Band
(to 55 MHz)

CA3001 CA3001/2 CA3001/4
CA3001/1 CA3001/3

Dual Darlington Connected
(to 20 MHz)

CA3050 CA3051

Dual Independ.
(to 500 MHz)

CA3026 CA3049 CA3054

Cascade
(to 500 MHz)

CA3028A CA3028B/2 CA3053
CA3028B CA3028B/3
CA3028B/1 CA3028B/4

POWER CONTROL CIRCUITS

Thyristor Control

CA3058 CA3059 CA3079

Voltage Regulator

CA3055 CA3085A CA3085B
CA3085

Optoelectronic

CA3062

ARRAYS

2 Zener Diodes, 1 Diode, 3 Transistors

CA3093E

Matched Diode Types

Individual

CA3019

Quad plus Two

CA3039

Transistor Types

General Purpose N-P-N

CA3081 CA3083 CA3183AE
CA3082 CA3086 CA3183E

General Purpose P-N-P

CA3084

Dual Darlington Connected

CA3036 CA3050 CA3051

Darlington Connected Pair plus Two Individual

CA3018 CA3118AT CA3118T
CA3018A

Differentially Connected Pair plus Three Individual

CA3045 CA3146AE CA3146E
CA3046

Amplifier Types

Dual Independent (Differential)

CA3026 CA3049 CA3054

Three-Ampl.

CA3035 CA3035V1

Four-Ampl.

CA3048

SPECIAL PURPOSE

Sense Amplifier

CA3541D

Four-Quadrant Multiplier

CA3091D

Key to Power Transistors and Power Hybrid Circuits

Key to Power Transistors and Power Hybrid Circuits

Symbols for Power Transistors and Power Hybrid Circuits

General

d_b — duty factor
η — efficiency
NF — noise figure
T — temperature
$T_A [T_{FA}]$ — ambient temperature
T_C — case temperature
T_J — junction temperature
T_{MF} — mounting-flange temperature
T_{STG} — storage temperature
Θ — thermal resistance
$\Theta_{J\text{-}A}$ — thermal resistance, junction-to-ambient
$\Theta_{J\text{-}C}$ — thermal resistance, junction-to-case
$\Theta_{J\text{-}MF}$ — thermal resistance, junction-to-mounting-range
t — time
t_d — delay time
t_f — fall time
$t_{on}(t_d+t_r)$ — turn-on time
$t_{off}(t_s+t_f)$ — turn-off time
t_p — pulse time
t_r — rise time
t_s — storage time
τ — time constant
τ_s — saturation stored-change time constant

Transistors

$C_{b'c}$ — collector-to-base feedback capacitance
C_c — collector-to-case capacitance
C_{cb} — collector-to-base capacitance
C_{ibo} — input capacitance, open-circuit (common base)
C_{ieo} — input capacitance, open-circuit (common emitter)
C_{obo} — output capacitance, open-circuit (common base)
C_{oeo} — output capacitance, open-circuit (common emitter)
$E_{s/b}$ — second-breakdown energy
f_c — cutoff frequency
f_{hfb} — small-signal forward-current transfer-ratio cutoff frequency, short-circuit (common base)
f_{hfe} — small-signal forward-current transfer-ratio cutoff frequency, short circuit (common emitter)
f_T — gain-bandwidth product (frequency at which small-signal forward-current transfer-ratio, common emitter, extrapolates to unity)
g_{me} — small-signal transconductance (common emitter)
G_{PB} — large-signal average power gain (common base)
G_{pb} — small-signal average power gain (common base)
G_{PE} — large-signal average power gain (common emitter)
G_{pe} — small-signal average power gain (common emitter)
h_{FB} — static forward-current transfer ratio (common base)
h_{fb} — small-signal forward-current transfer ratio, short-circuit (common base)
h_{FE} — static forward-current transfer ratio (common emitter)
h_{fe} — small-signal forward-current transfer ratio, short-circuit (common emitter)
h_{ib} — small-signal input impedance, short-circuit (common base)
h_{IE} — static input resistance (common emitter)
h_{ie} — small-signal input impedance, short-circuit (common emitter)
h_{ob} — small-signal output impedance, open-circuit (common base)
h_{oe} — small-signal output impedance, open-circuit (common emitter)
h_{rb} — small-signal reverse-voltage transfer ratio, open-circuit (common base)
h_{re} — small-signal reverse-voltage transfer ratio, open-circuit (common emitter)
I_B — base current
I_{B1} — turn-on current
I_{B2} — turn-off current
I_C — collector current
I_c — collector current, instantaneous value
I_{CB} — collector-cutoff current
I_{CBO} — collector-cutoff current, emitter open
I_{CEO} — collector-cutoff current, base open
I_{CER} — collector-cutoff current, specified resistance between base and emitter
I_{CES} — collector-cutoff current, base short-circuited to emitter
I_{CEV} — collector-cutoff current, specified voltage between base and emitter
I_{CEX} — collector-cutoff current, specified circuit between base and emitter
I_{CS} — switching current (at minimum h_{FE} per specification)

Symbols for Power Transistors and Power Hybrid Circuits

Transistors

I_E – emitter current
I_{EBO} – emitter-cutoff current, collector open
$I_{s/b}$ – second-breakdown collector current
MAG – maximum available amplifier gain
MAG_c – maximum available conversion gain
MUG – maximum usable amplifier gain
P_{BE} – total dc or average power input to base (common emitter)
P_{BE} – total instantaneous power input to base (common emitter)
P_{CB} – total dc or average power input to collector (common base)
P_{CB} – total instantaneous power input to collector (common base)
P_{CE} – total dc or average power input to collector (common emitter)
P_{CE} – total instantaneous power input to collector (common emitter)
P_{EB} – total instantaneous power input to emitter (common base)
P_{IB} – large-signal input power (common base)
P_{ib} – small-signal input power (common base)
P_{IE} – large-signal input power (common emitter)
P_{ie} – small-signal input power (common emitter)
P_{OB} – large-signal output power (common base)
P_{ob} – small-signal output power (common base)
P_{OE} – large-signal output power (common emitter)
P_{oe} – small-signal output power (common emitter)
P_T – total non-reactive power input, dc, to all terminals (transistor dissipation)
Q_s – stored base charged
$r_{bb'}$ – intrinsic base spreading resistance
$r_{CE(sat)}$ – collector-to-emitter saturation resistance
$R_e[h_{ie}]$ – real part of small-signal input impedance, short-circuit (common emitter)
R_G – generator resistance
R_{ie} – input resistance (common emitter)
R_L – load resistance
R_{oe} – output resistance (common emitter)
R_S – source resistance
V_{BB} – base-supply voltage
V_{BC} – base-to-collector voltage
V_{BE} – base-to-emitter voltage
$V_{BE(sat)}$ – base-to-emitter saturation voltage
$V_{(BR)CBO}$ – collector-to-base breakdown voltage, emitter open
$V_{(BR)CEO}$ – collector-to-emitter breakdown voltage, base open
$V_{(BR)CER}$ – collector-to-emitter breakdown voltage, specified resistance between base and emitter
$V_{(BR)CES}$ – collector-to-emitter breakdown voltage, base short-circuited to emitter
$V_{(BR)CEV}$ – collector-to-emitter breakdown voltage, specified voltage between base and emitter
$V_{(BR)EBO}$ – emitter-to-base breakdown voltage, collector open
V_{CB} – collector-to-base voltage
$V_{CB(fl)}$ – dc open-circuit voltage between collector and base (floating potential), emitter biased with respect to base
V_{CBO} – collector-to-base voltage (emitter open)
V_{CBV} – collector-to-base voltage, specified voltage between emitter and base
V_{CC} – collector-supply voltage
V_{CE} – collector-to-emitter voltage
$V_{CE(fl)}$ – dc open-circuit voltage between collector and emitter (floating potential), base biased with respect to emitter
$V_{CE(sat)}$ – collector-to-emitter saturation voltage
V_{CEO} – collector-to-emitter voltage, base open
$V_{CEO(sus)}$ – collector-to-emitter sustaining voltage, base open
V_{CER} – collector-to-emitter voltage, specified resistance between base and emitter
$V_{CER(sus)}$ – collector-to-emitter sustaining voltage, specified resistor between base and emitter
V_{CES} – collector-to-emitter voltage, base short-circuited to emitter
V_{CEV} – collector-to-emitter voltage, specified voltage between base and emitter
$V_{CEV(sus)}$ – collector-to-emitter sustaining voltage, specified voltage between base and emitter
V_{CEX} – collector-to-emitter voltage, specified circuit between base and emitter
$V_{CEX(sus)}$ – collector-to-emitter sustaining voltage, specified circuit between base and emitter
V_{EB} – emitter-to-base voltage
$V_{EB(fl)}$ – dc open-circuit voltage between emitter and base (floating potential), collector biased with respect to base
V_{EBO} – emitter-to-base voltage, collector open
V_{EE} – emitter-supply voltage
V_{RT} – reach-through voltage
Y_{fe} – forward transconductance
Y_{ie} – input admittance
Y_{oe} – output admittance
Y_{re} – reverse transconductance

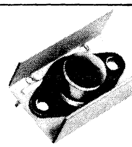
Hometaxial-Base n-p-n Power Transistors

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						UNITS
							2N6260 40910		2N3054 40372		2N6261 40911		
		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	–	–	–	–	
		80		−1.5			–	–	–	–	–	0.5	mA
		90		−1.5			–	–	–	1.0	–	–	
At T_C = 150°C	I_{CEX}	40		−1.5			–	5	–	–	–	–	
		80		−1.5			–	–	–	–	–	0.5	mA
		90		−1.5			–	–	–	6.0	–	–	
*Emitter-Cutoff Current	I_{EBO}		7			0	–	5	–	1.0	–	0.2	mA
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	
		4			1.5		–	2.2	–	–	–	–	V
		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			0.775		1	–	–	–	–	–	
		80			0.625		–	–	–	–	1	–	s
		55			0.460		–	–	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)

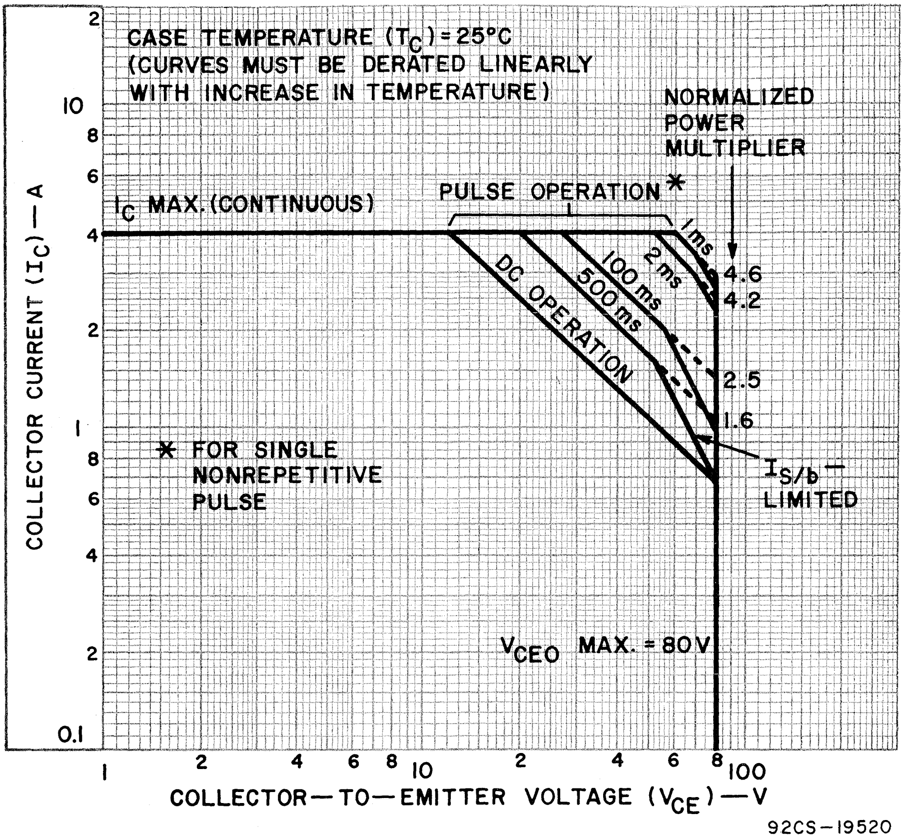


Fig. 1—Maximum operating areas for type 2N6261.

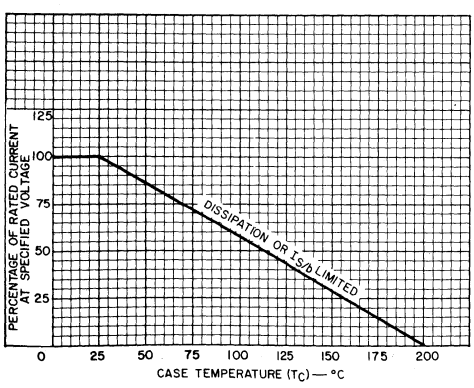


Fig. 2—Current derating curve for all types.

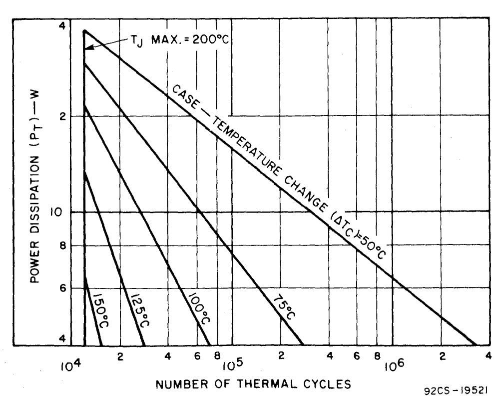


Fig. 3—Thermal-cycle rating chart for type 2N6261.

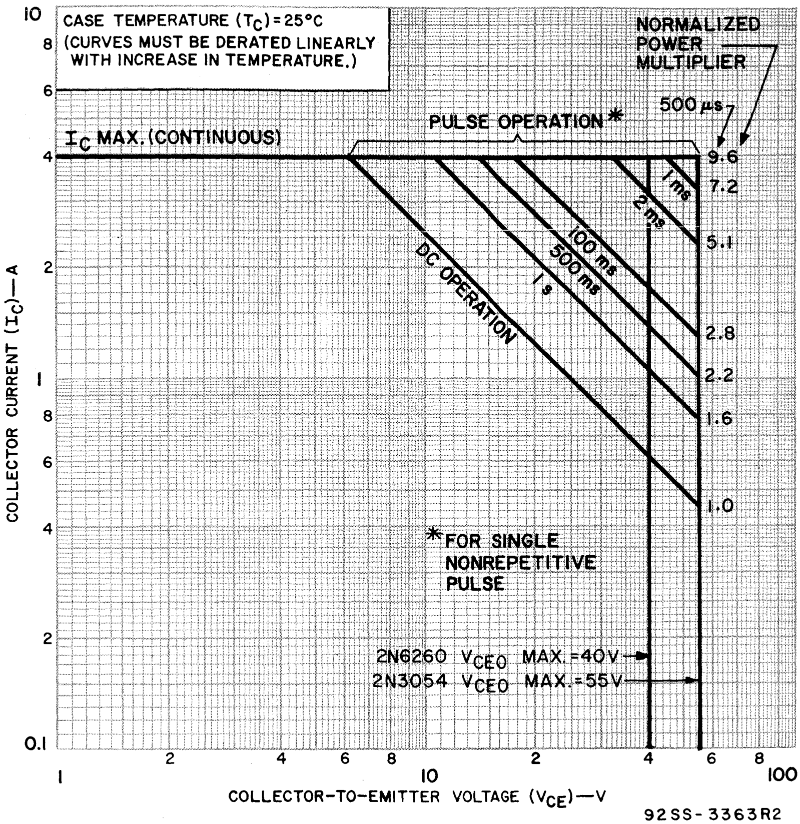


Fig.4—Maximum operating areas for types 2N3054 and 2N6260.

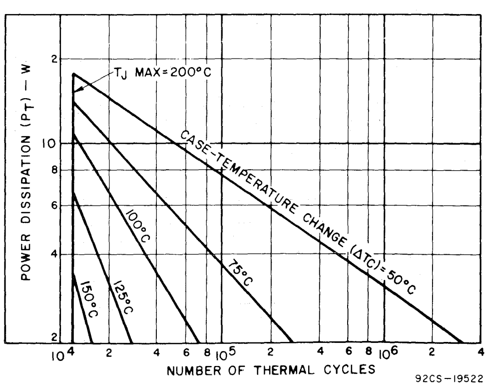


Fig.5— Thermal-cycle rating chart for type 2N3054.

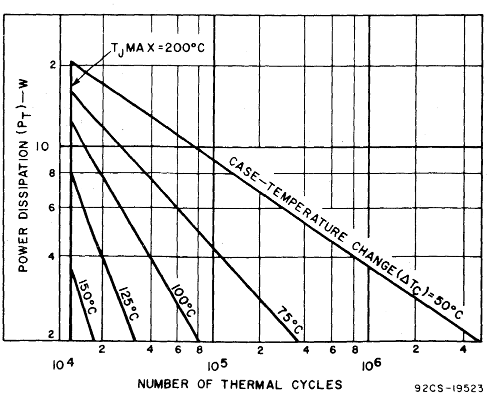


Fig.6— Thermal-cycle rating chart for type 2N6260.

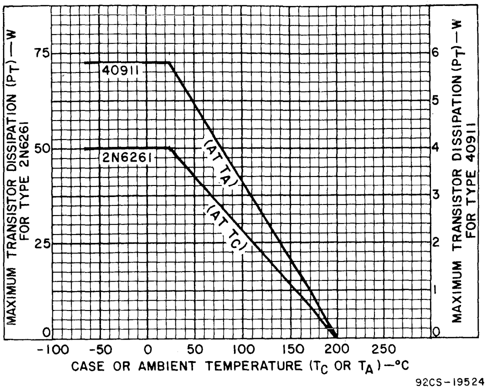


Fig.7—Dissipation derating curve for types 2N6261 and 40911.

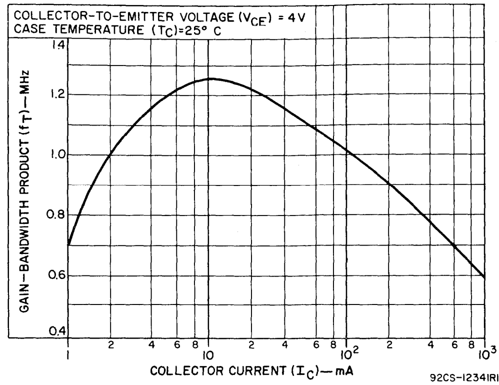


Fig.8—Typical gain-bandwidth product for all types.

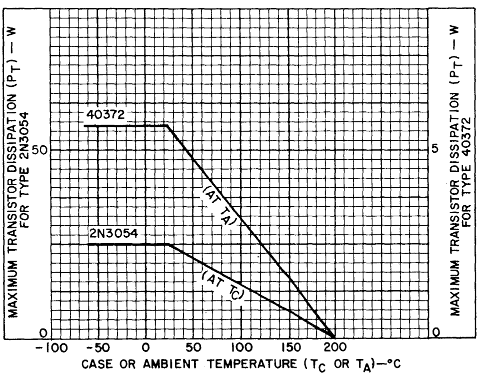


Fig.9—Dissipation derating curve for types 2N3054 and 40372.

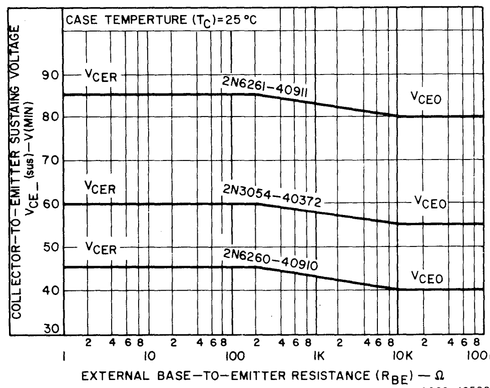


Fig.10—Sustaining voltage vs. base-to-emitter resistance for all types.

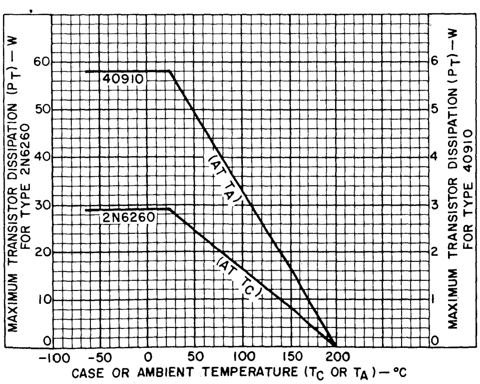


Fig.11—Dissipation derating curve for types 2N6260 and 40910.

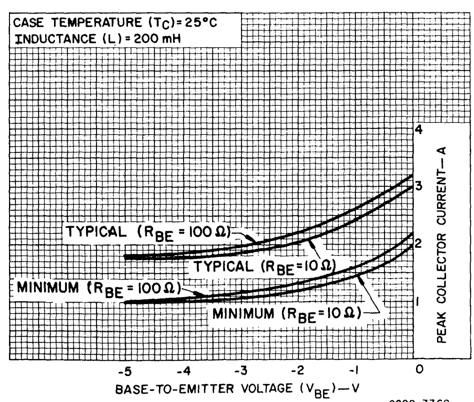


Fig.12—Reverse-bias second-breakdown characteristics for all types.

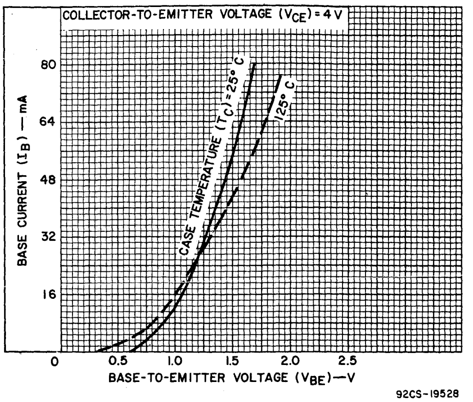


Fig. 13–Typical input characteristics for types 2N6261 and 40911.

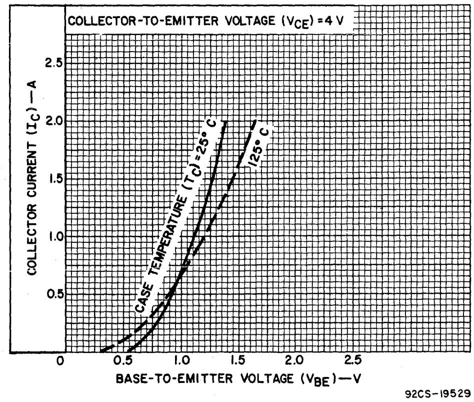


Fig. 14–Typical transfer characteristics for types 2N6261 and 40911.

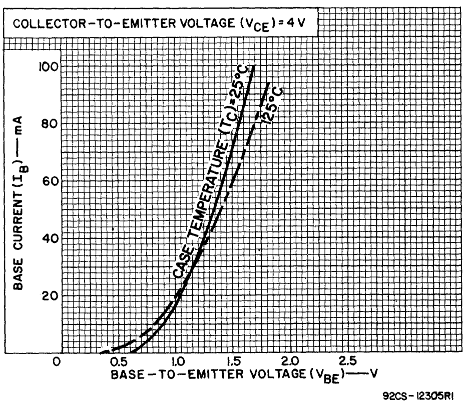


Fig. 15–Typical input characteristics for types 2N3054 and 40372.

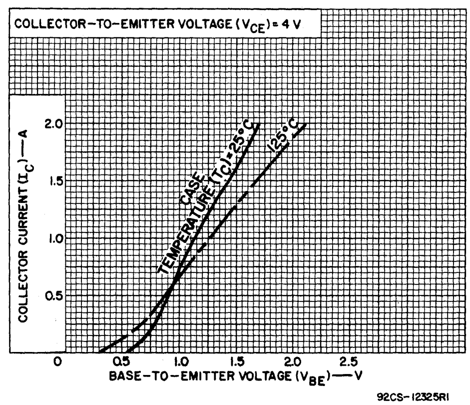


Fig. 16–Typical transfer characteristics for types 2N3054 and 40372.

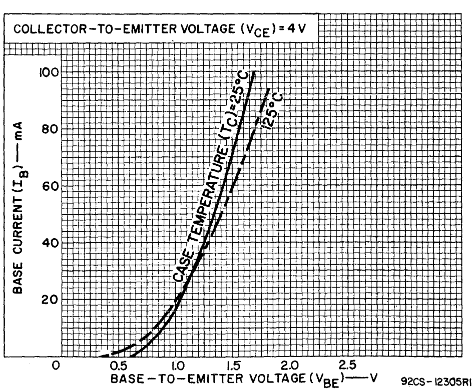


Fig. 17–Typical input characteristics for types 2N6260 and 40910.

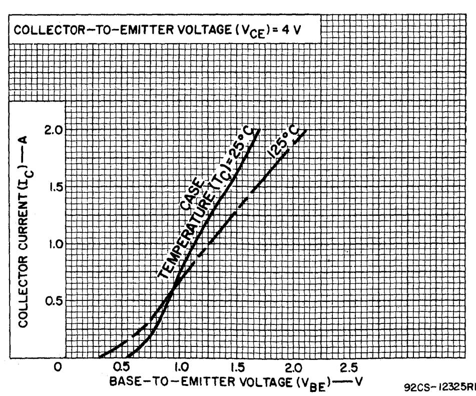


Fig. 18–Typical transfer characteristics for types 2N6260 and 40910.

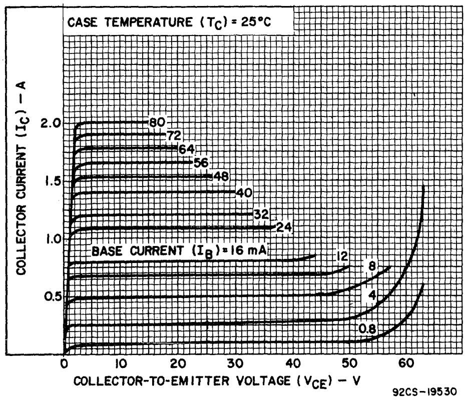


Fig.19—Typical output characteristics for types 2N6261 and 40911.

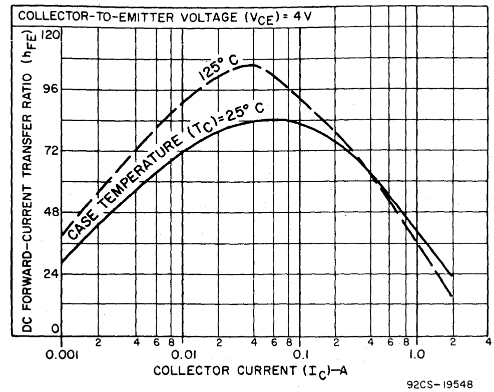


Fig.20—Typical dc beta characteristics for types 2N6261 and 40911.

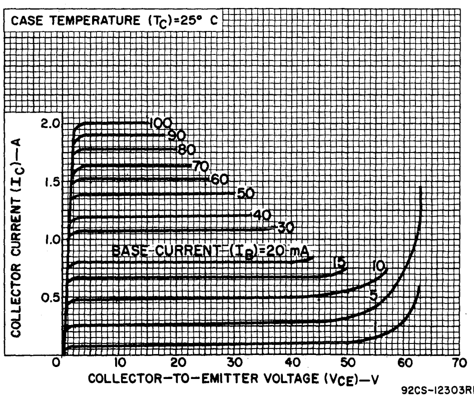


Fig.21—Typical output characteristics for types 2N3054 and 40372.

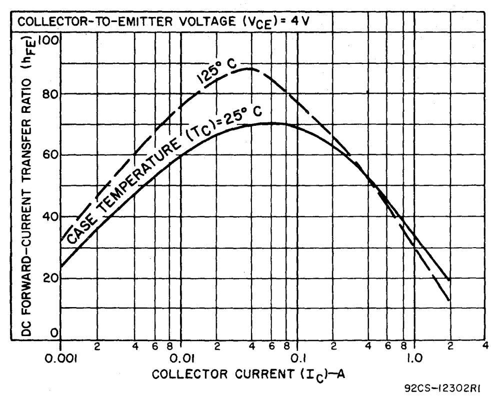


Fig.22—Typical dc beta characteristics for types 2N3054 and 40372.

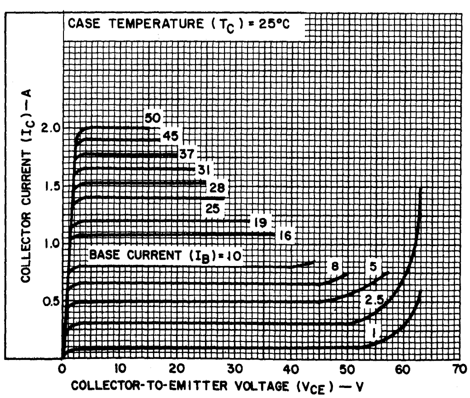


Fig.23—Typical output characteristics for types 2N6260 and 40910.

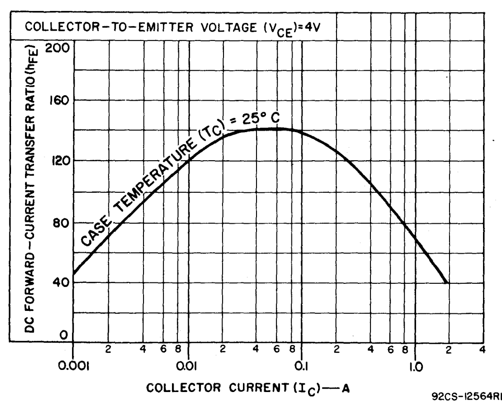


Fig.24—Typical dc beta characteristics for types 2N6260 and 40910.

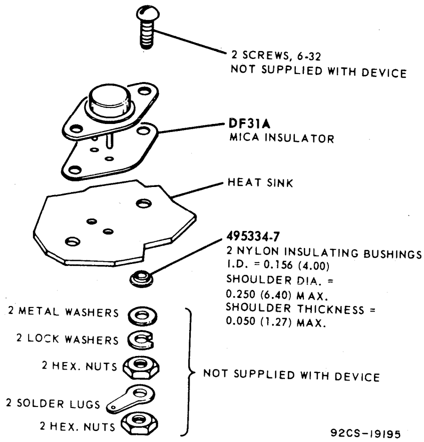
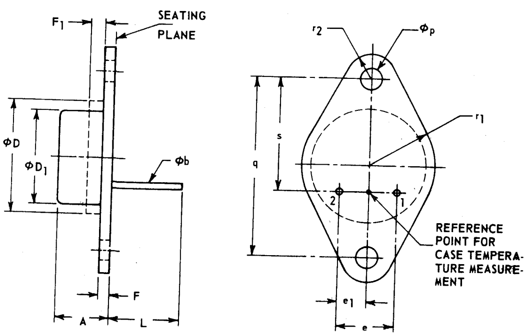


Fig.25–Suggested mounting hardware for 2N3054, 2N6260, and 2N6261.

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	
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:

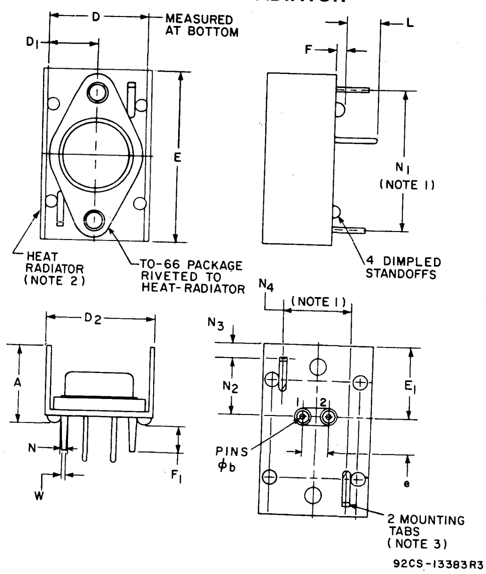
1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimensions does not include seating flanges.

92SS-3738

TERMINAL CONNECTIONS FOR 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	
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 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.

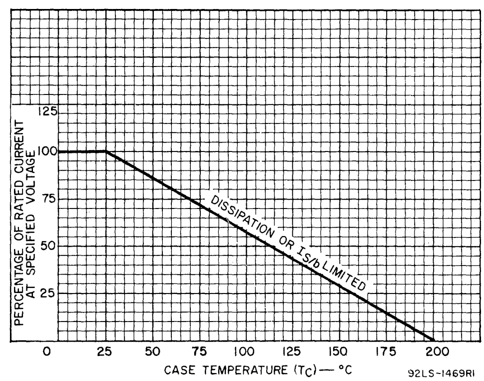


Fig. 1—Current derating curve.

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	–	–	–	–	
		30				0	–	–	–	0.7	–	–	
		60				0	–	–	–	–	–	1	
With base-emitter junction reverse-biased	I_{CEX}	55		-1.5			–	2	–	–	–	–	mA
		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	–	
* With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$				0.2[a]		55	–	70	–	85	–	V
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	–	–	–	–	
		4			4[a]		–	–	–	1.8	–	–	V
		2			5[a]		–	–	–	–	–	1.5	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				4[a]	0.4[a]	–	–	–	1.1	–	–	
					5[a]	0.5[a]	–	–	–	0.5	–	–	
					10[a]	3.3[a]	–	–	–	8	–	–	V
					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			1.29		–	–	–	–	1	–	
		60			1.95		–	–	1	–	–	–	s
		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).

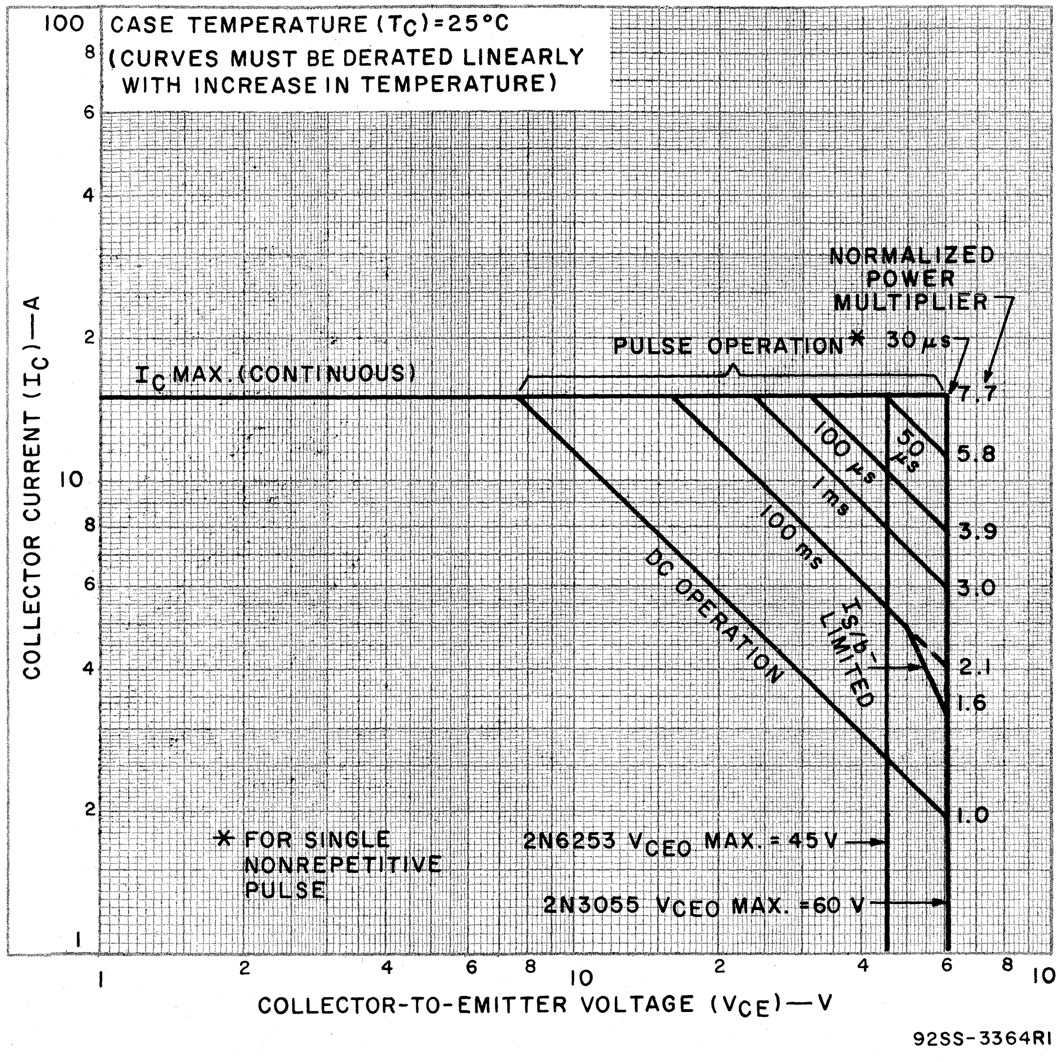


Fig.2–Maximum operating areas for types 2N6253 and 2N3055.

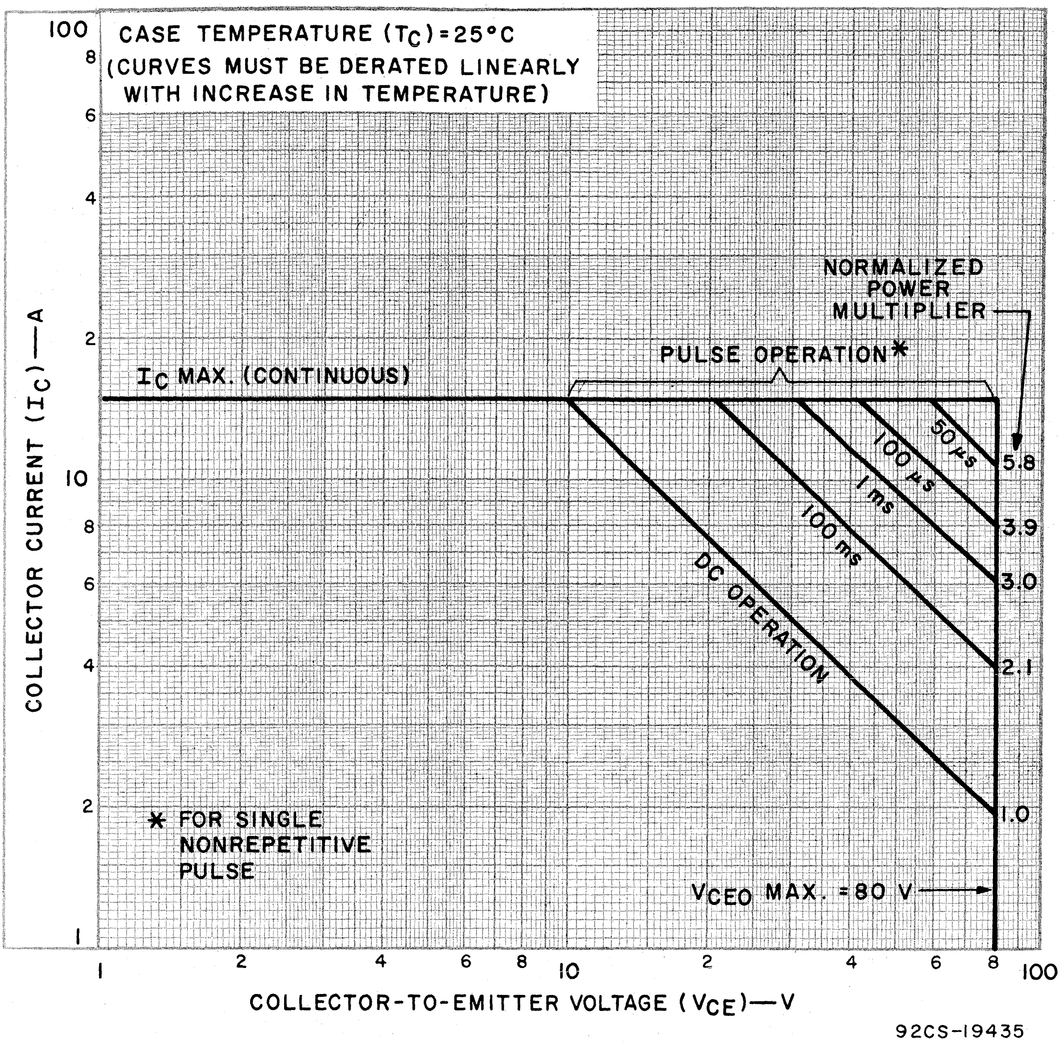


Fig.3—Maximum operating areas for 2N6254.

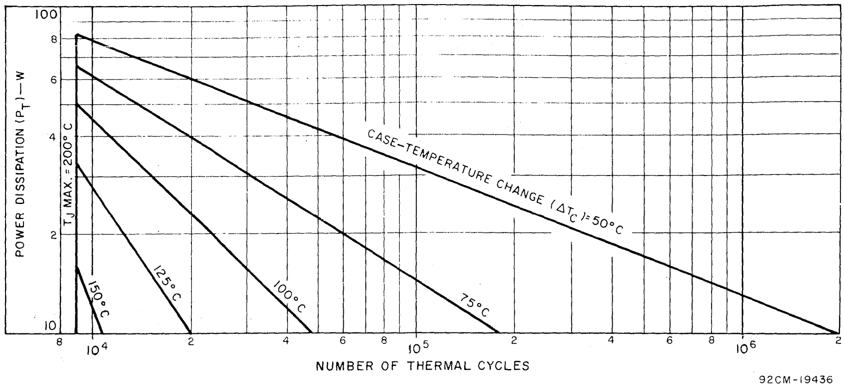


Fig.4—Thermal-cycle rating chart for types 2N3055 and 2N6253.

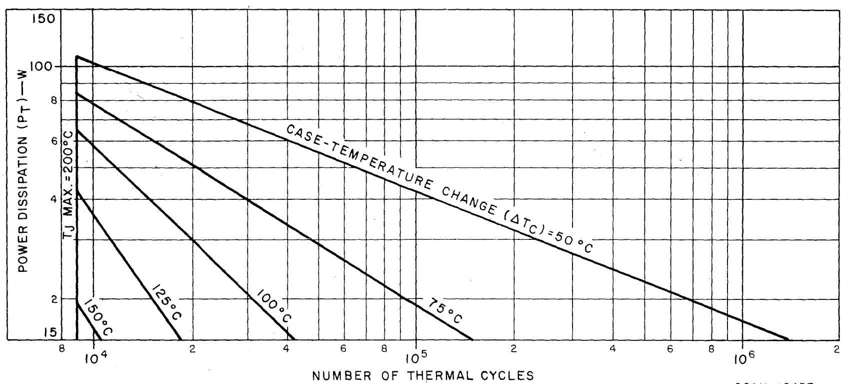


Fig.5—Thermal-cycle rating chart for type 2N6254.

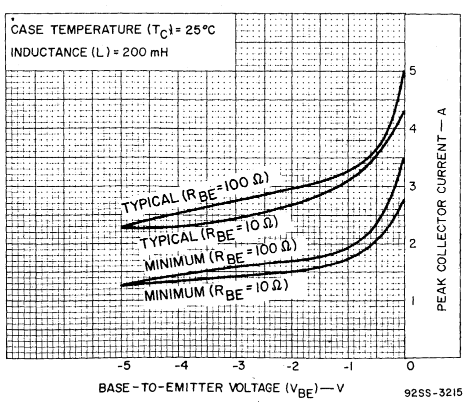


Fig.6—Reverse-bias, second-breakdown characteristics for all types.

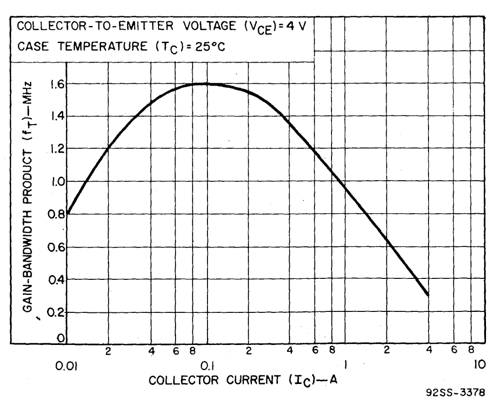


Fig.7—Typical gain-bandwidth product for all types.

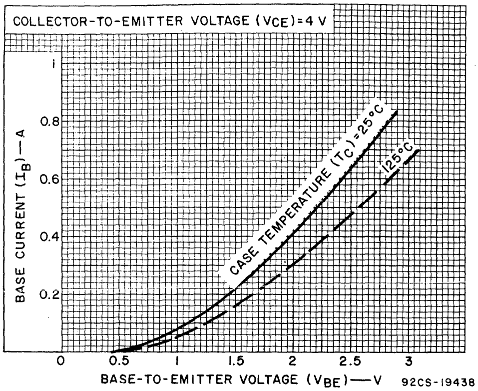


Fig.8—Typical input characteristics for type 2N6254.

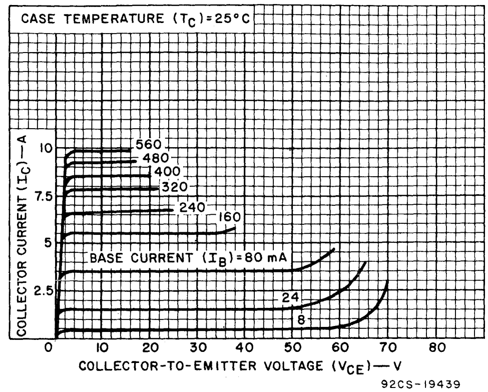


Fig.9—Typical output characteristics for type 2N6254.

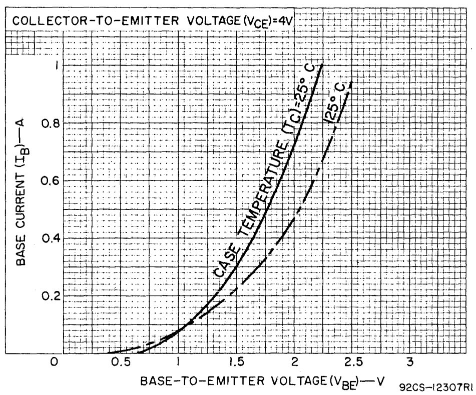


Fig.10—Typical input characteristics for type 2N3055.

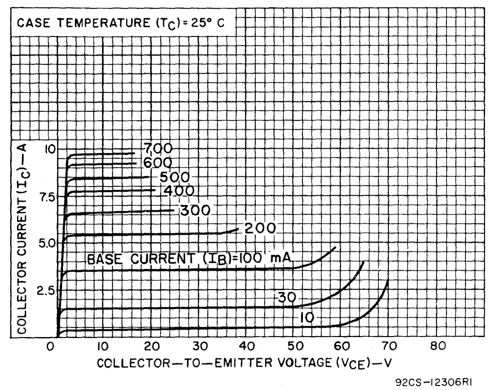


Fig.11—Typical output characteristics for type 2N3055.

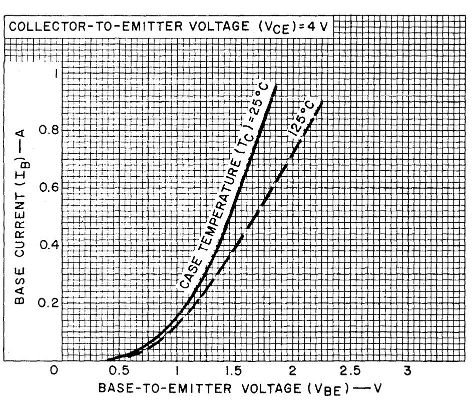


Fig.12—Typical input characteristics for type 2N6253.

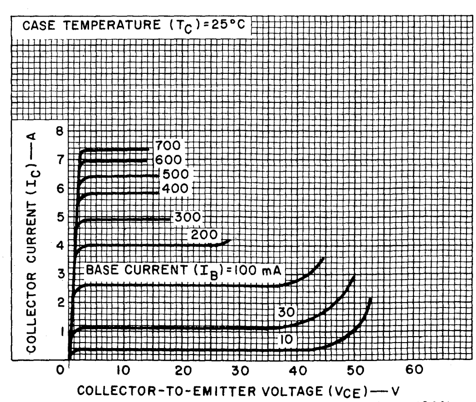


Fig.13—Typical output characteristics for type 2N6253.

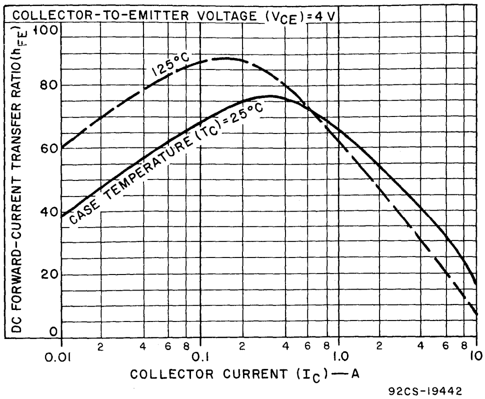


Fig.14—Typical dc-beta characteristics for type 2N6254.

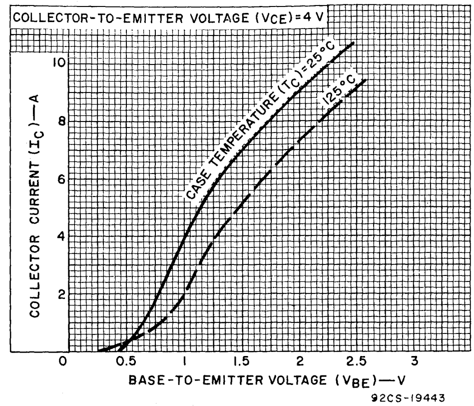


Fig.15—Typical transfer characteristics for type 2N6254.

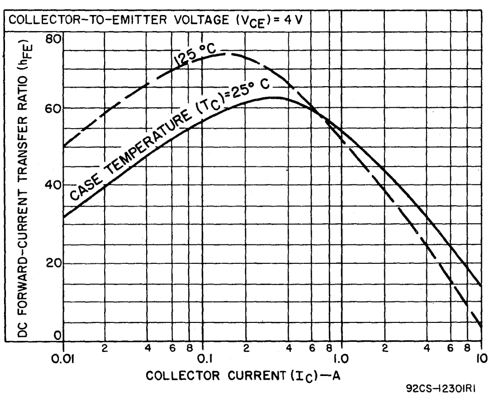


Fig.16—Typical dc-beta characteristics for type 2N3055.

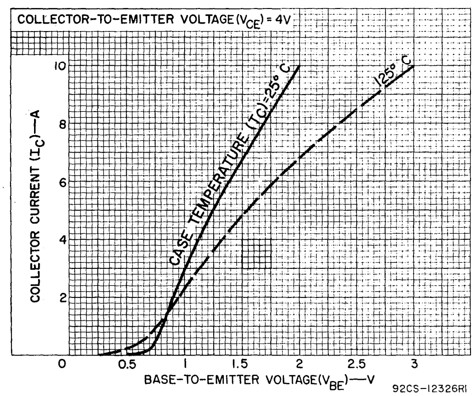


Fig.17—Typical transfer characteristics for types 2N6253 and 2N3055.

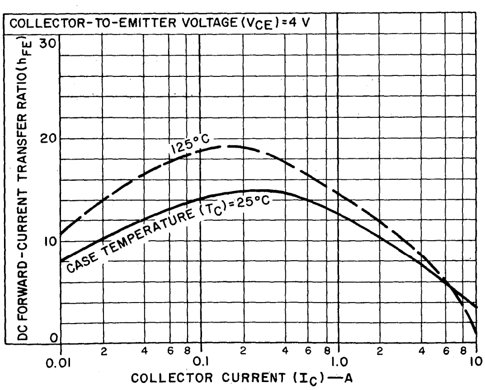


Fig.18—Typical dc-beta characteristics for type 2N6253.

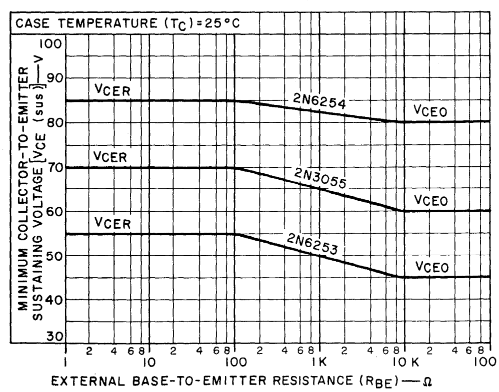


Fig.19—Sustaining voltage vs. base-to-emitter resistance for all types.

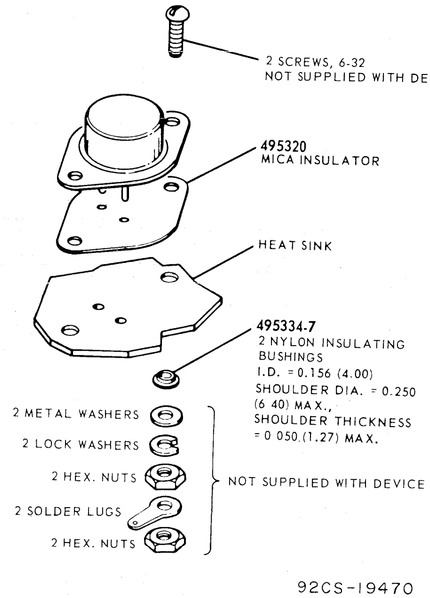
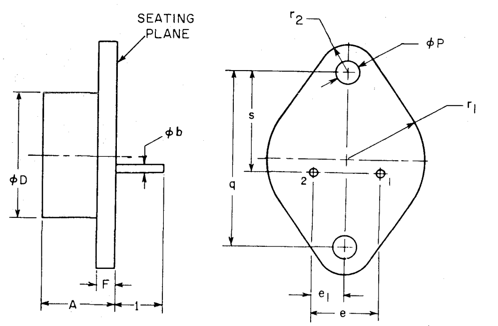


Fig.20–Suggested mounting hardware.

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

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

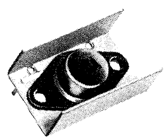
RCA

Solid State
Division

Power Transistors

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.

● "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).

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

"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 2N6263 40912		2N3441 40373		2N6264 40913		UNITS
		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}	140		–1.5			–	–	–	6*	–	–	
	(T_C = 150°C)	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]	V_{CEO}(sus)												
* With base open					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	$I_{S/b}$	100					0.2	–	–	–	–	–	
		100					–	–	–	–	0.5	–	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.

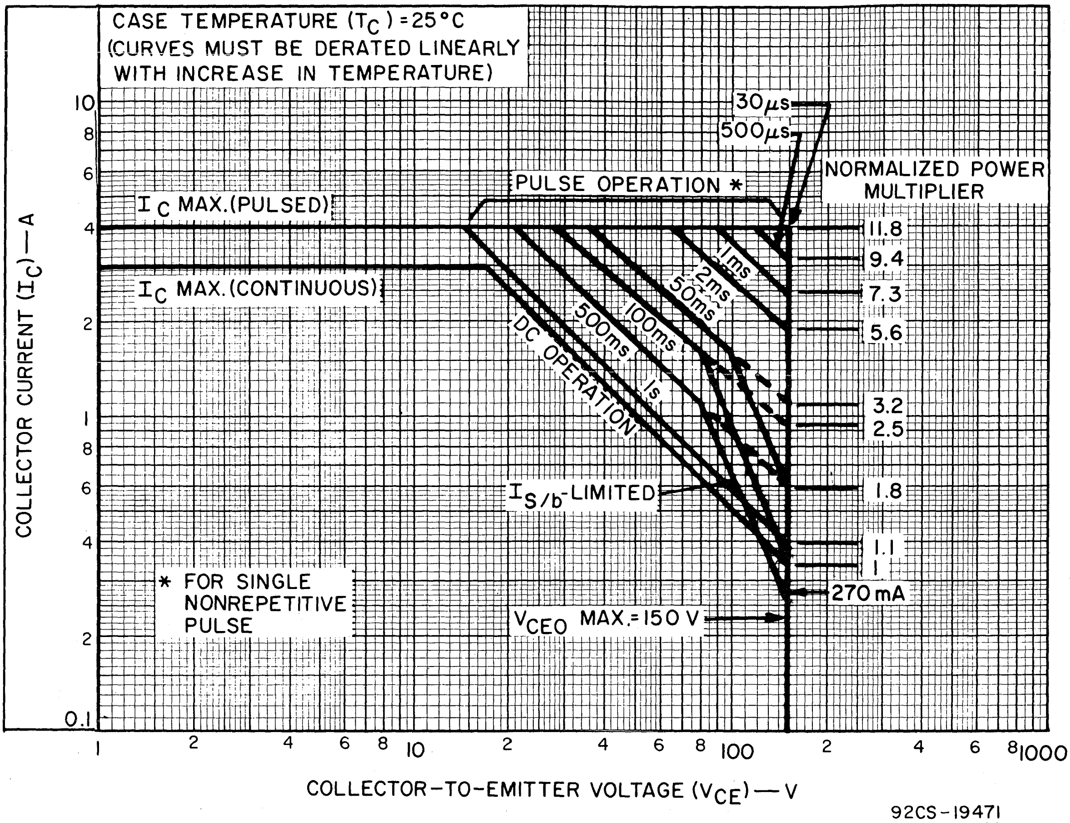


Fig. 1—Maximum operating areas for type 2N6264.

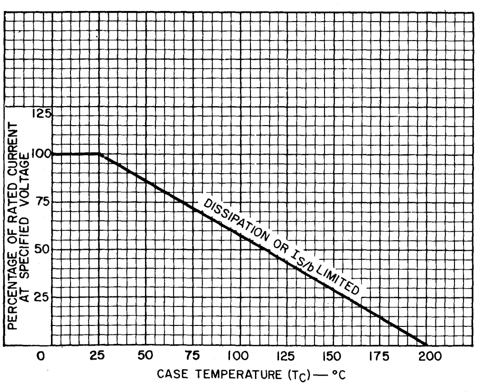


Fig.2—Current derating curve for all types.

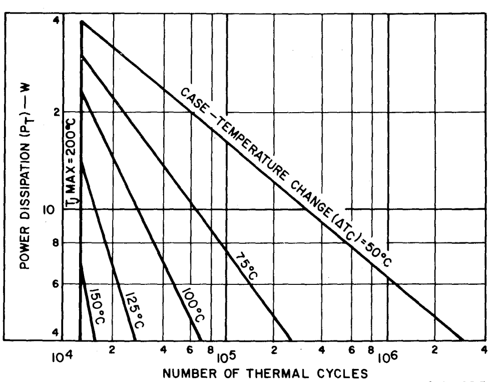


Fig.3—Thermal-cycle rating chart for type 2N6264.

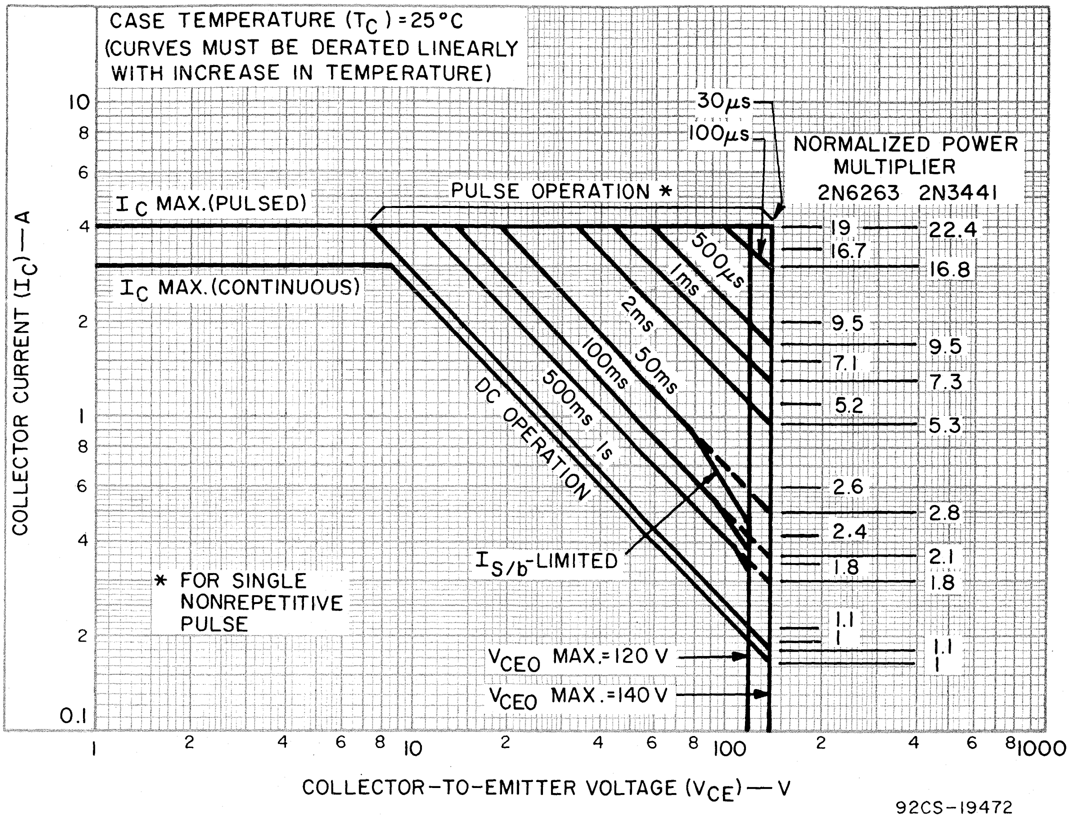


Fig.4—Maximum operating areas for type 2N6263 and 2N3441.

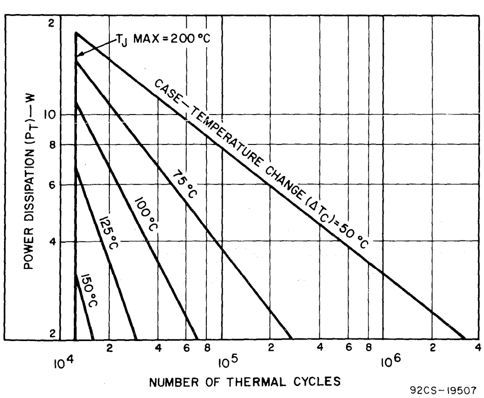


Fig.5—Thermal-cycle rating chart for type 2N3441.

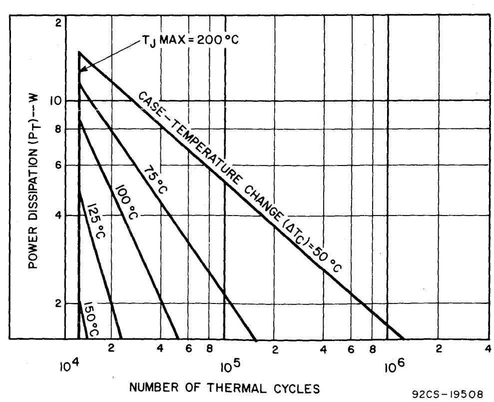


Fig.6—Thermal-cycle rating chart for type 2N6263.

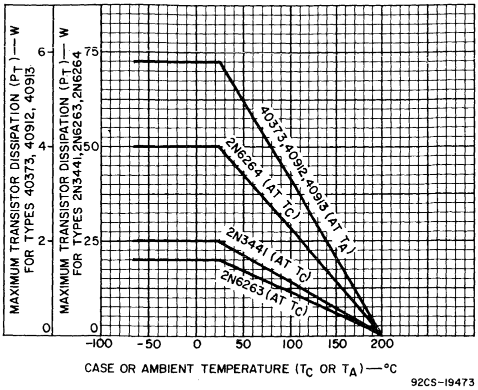


Fig.7—Dissipation derating curves for all types.

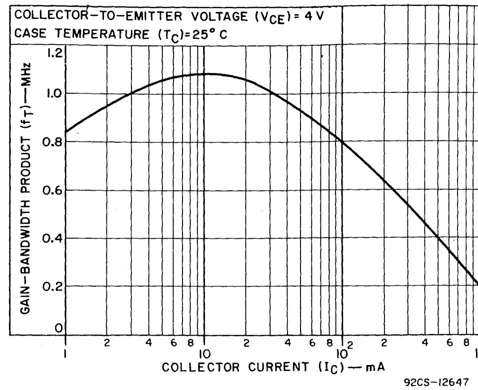


Fig.8—Typical gain-bandwidth product for all types.

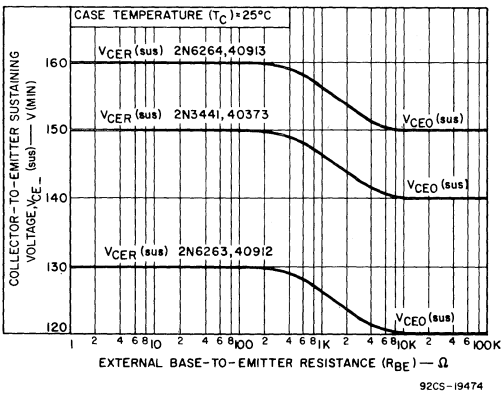


Fig.9—Sustaining voltage vs. base-to-emitter resistance for all types.

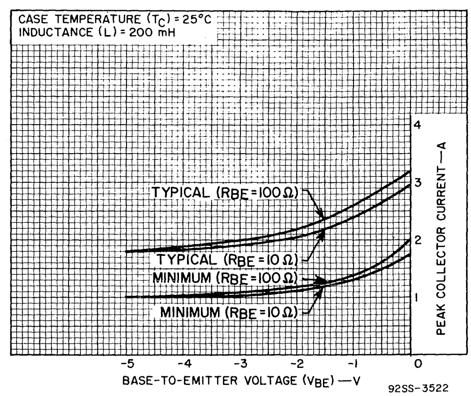


Fig.10—Reverse-bias second-breakdown characteristics for all types.

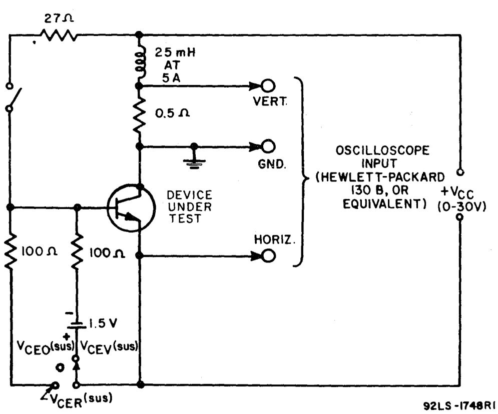
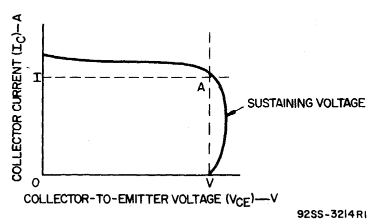


Fig.11—Circuit used to measure sustaining voltages, $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ for all types.



Note: The sustaining voltage, $V_{CEO}(sus)$, $V_{CER}(sus)$, or 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).

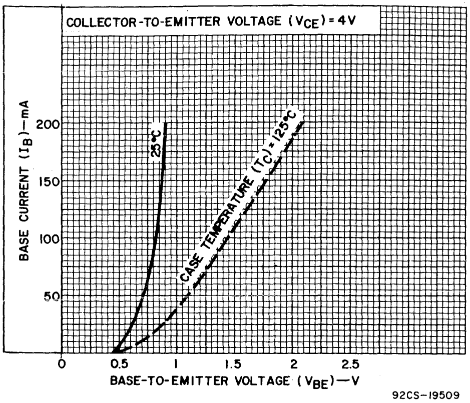


Fig. 13—Typical input characteristics for types 2N6264 and 40913.

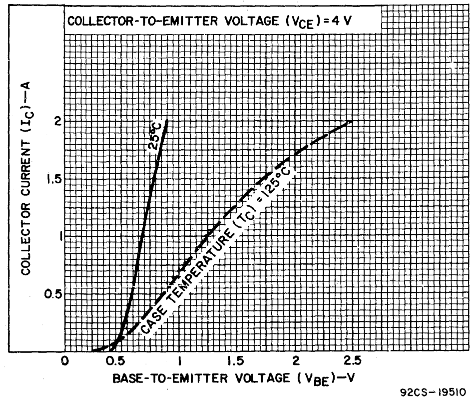


Fig. 14—Typical transfer characteristics for types 2N6264 and 40913.

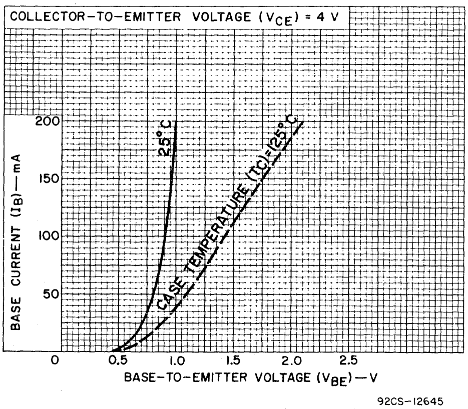


Fig. 15—Typical input characteristics for types 2N3441 and 40373.

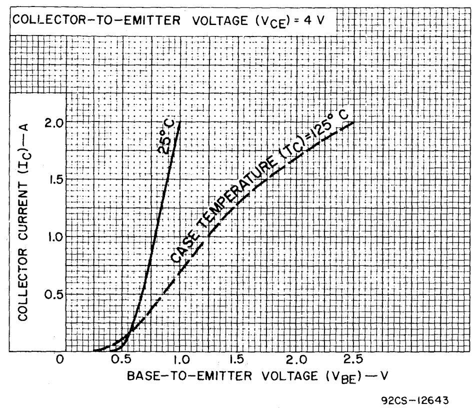


Fig. 16—Typical transfer characteristics for types 2N3441 and 40373.

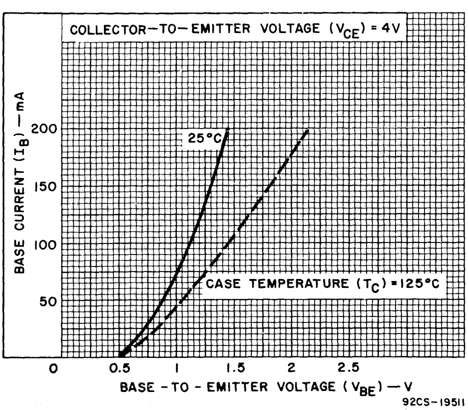


Fig. 17—Typical input characteristics for types 2N6263 and 40912.

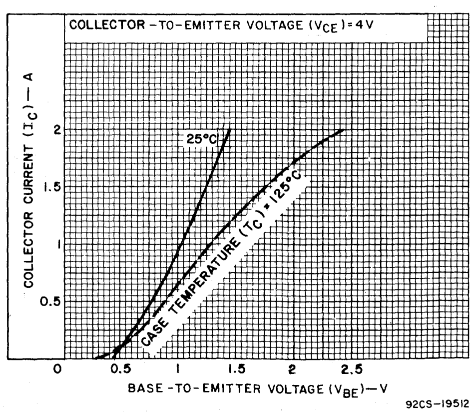


Fig. 18—Typical transfer characteristics for types 2N6263 and 40912.

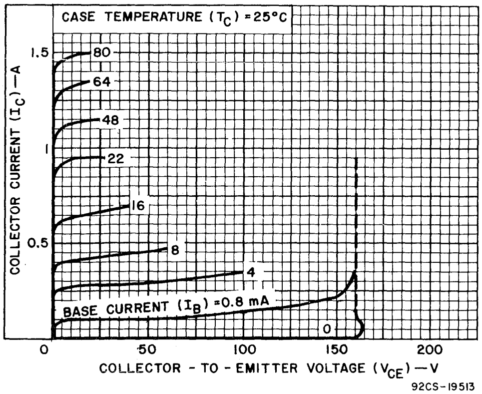


Fig.19—Typical output characteristics for types 2N6264 and 40913.

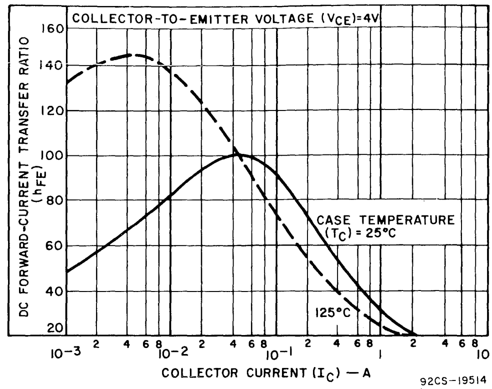


Fig.20—Typical dc-beta characteristics for types 2N6264 and 40913.

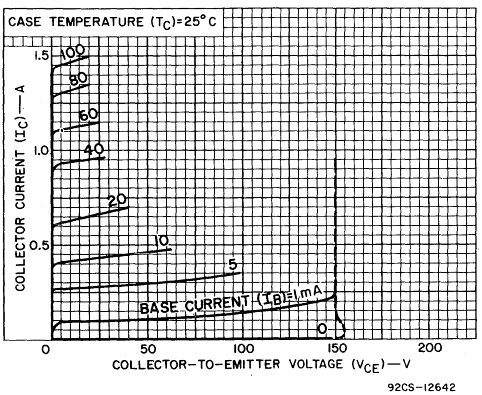


Fig.21—Typical output characteristics for types 2N3441 and 40373.

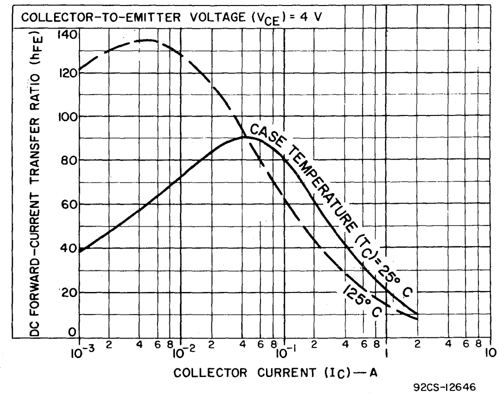


Fig.22—Typical dc-beta characteristics for types 2N3441 and 40373.

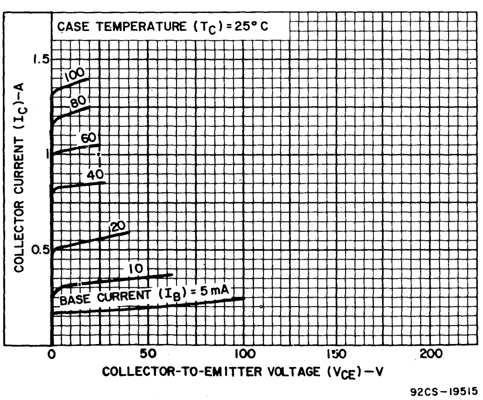


Fig.23—Typical output characteristics for types 2N6263 and 40912.

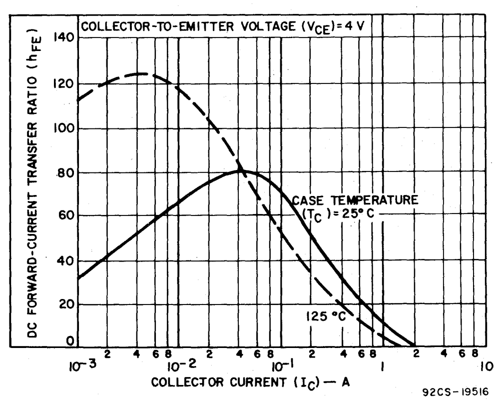


Fig.24—Typical dc-beta characteristics for types 2N6263 and 40912.

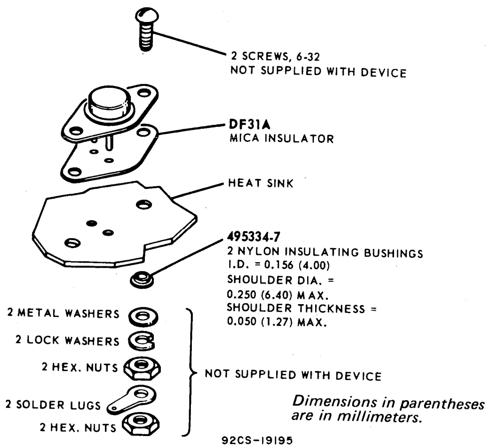
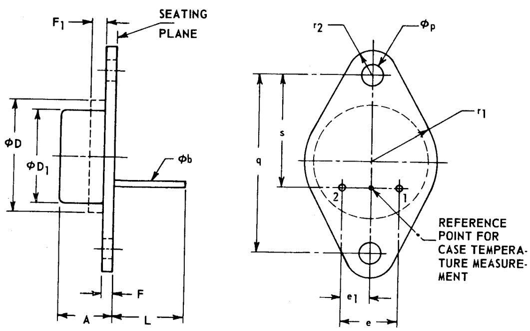


Fig.25–Suggested hardware for 2N3441, 2N6263, and 2N6264.

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



SYMBOL	INCHES 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:

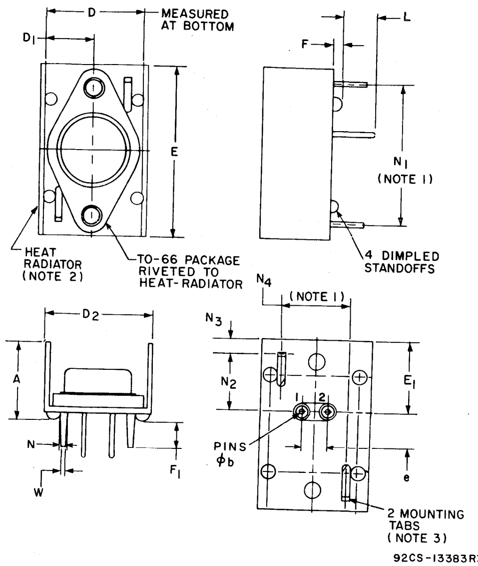
1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimensions does not include seating flanges.

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 MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
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 40373, 40912, & 40913

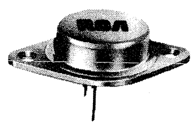
Pin 1 - Base
Pin 2 - Emitter
Heat-Radiator - Collector

RCA
Solid State
Division

Power Transistors 2N6262 2N4347 2N3442

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

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



JEDEC TO-3 H-1570

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: DC Collector Voltage (V)		DC Emitter or Base Voltage (V)		DC Current (A)			LIMITS: Type 2N4347		Type 2N3442		Type 2N6262		UNITS
		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}		125		−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
						0.8[a]		0	–	–	–	–	150	–	
* Base-to-Emitter Voltage	V_{BE}		2			3[a]			–	–	–	–	–	1	
			4			2[a]			–	2	–	–	–	–	V
			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	–	0.2	–	–	–	–	
						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

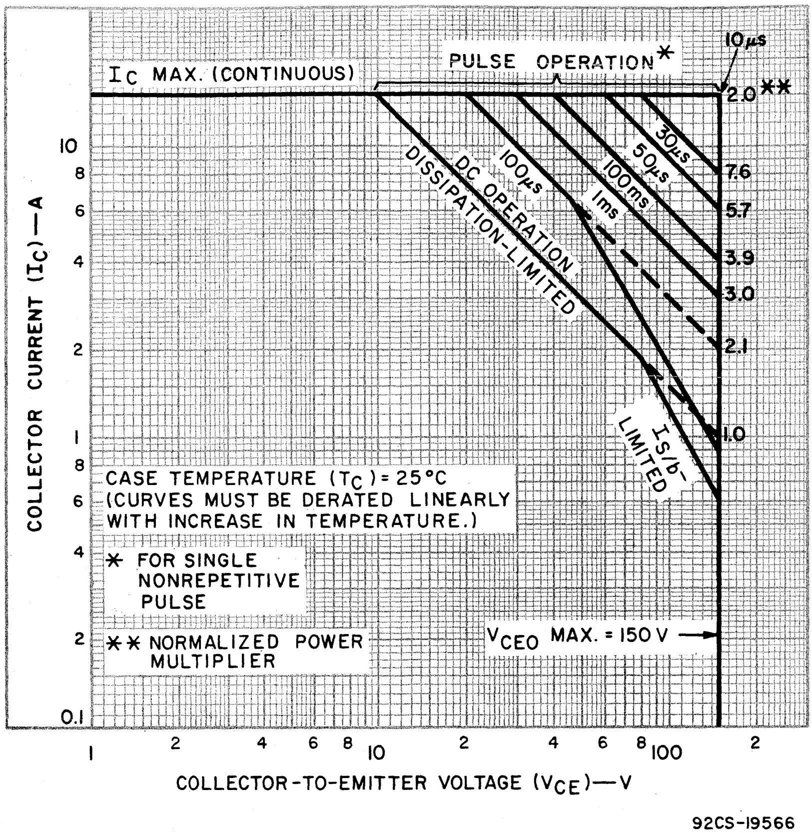


Fig. 1—Maximum operating areas for type 2N6262.

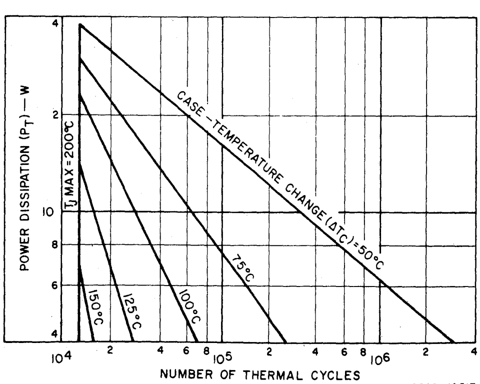


Fig.2—Thermal-cycle rating chart for type 2N6262.

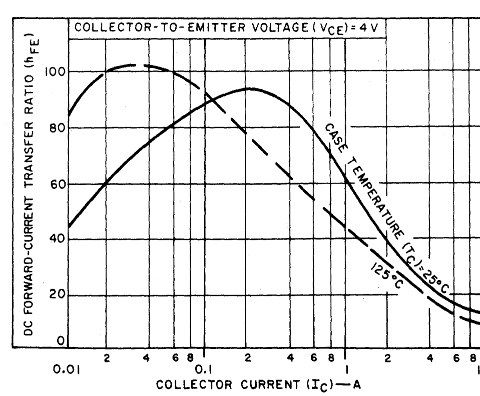


Fig.3—Typical dc beta characteristics for type 2N6262.

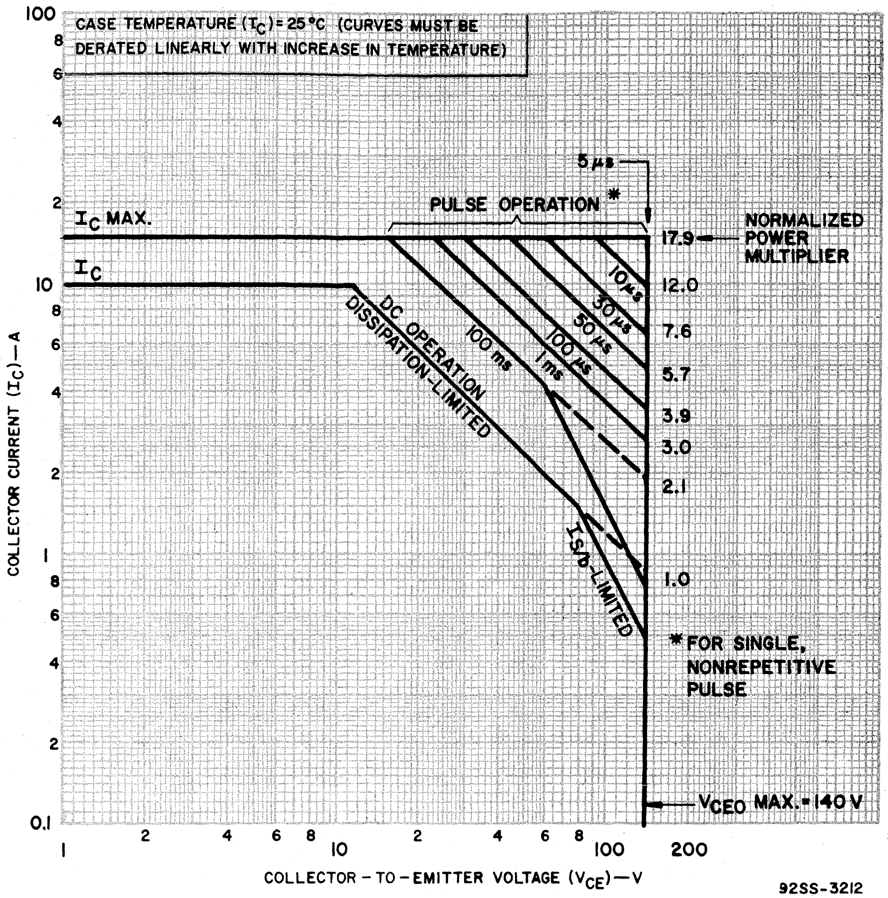


Fig.4— Maximum operating areas for type 2N3442.

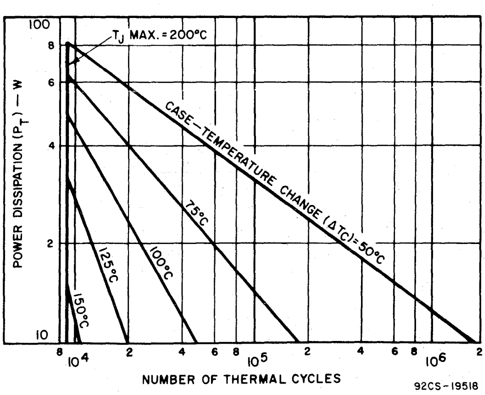


Fig.5— Thermal-cycle rating chart for type 2N3442.

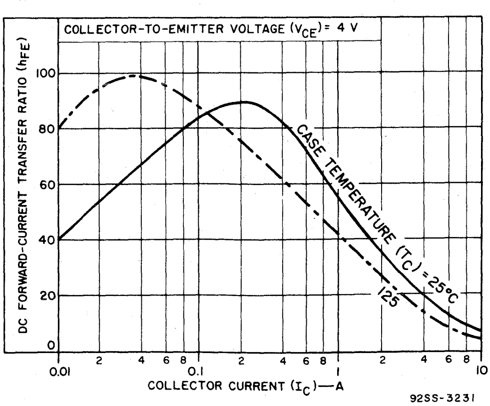


Fig.6— Typical dc beta characteristics for type 2N3442.

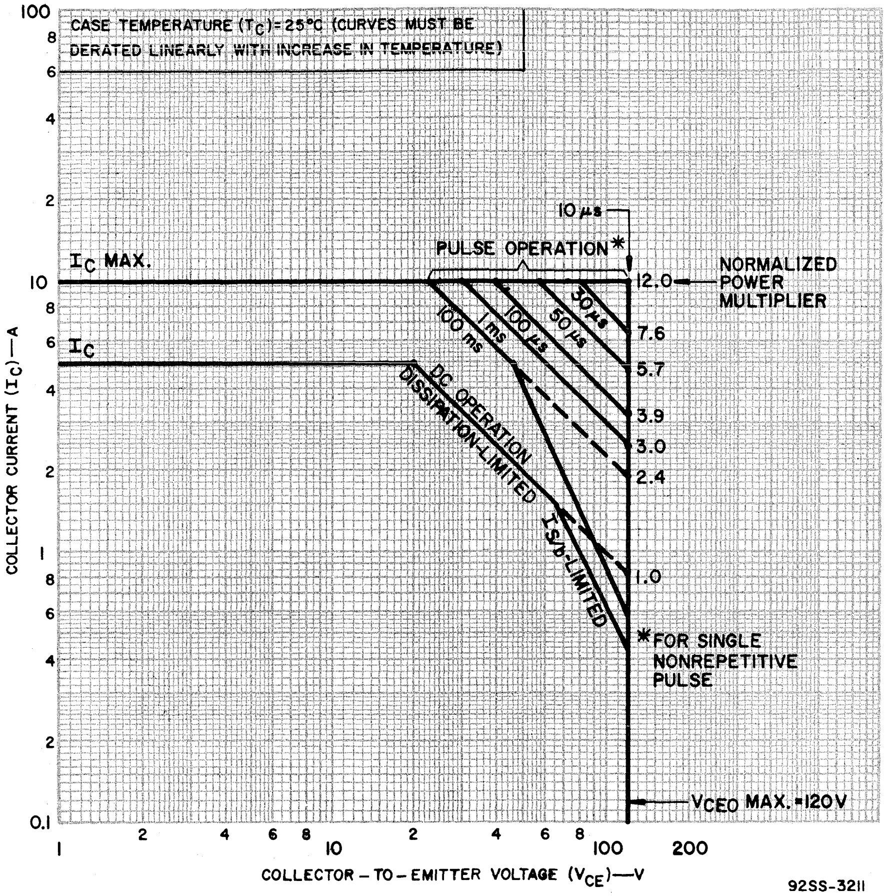


Fig.7—Maximum operating areas for type 2N4347.

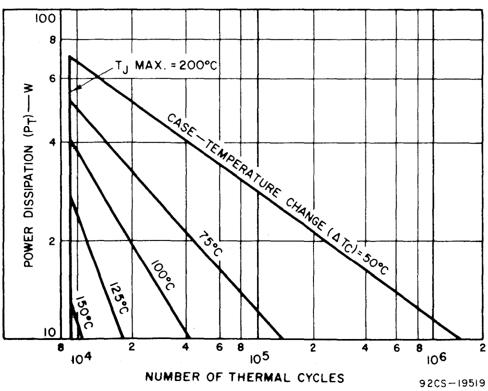


Fig.8—Thermal-cycle rating chart for type 2N4347.

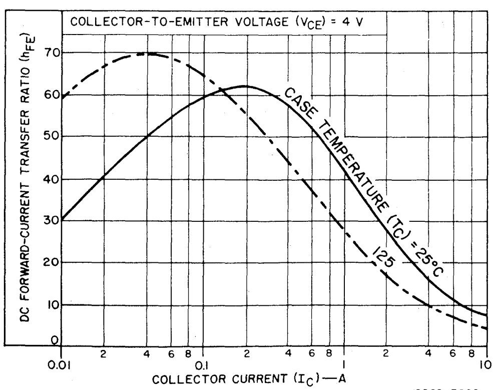


Fig.9—Typical dc beta characteristics for type 2N4347.

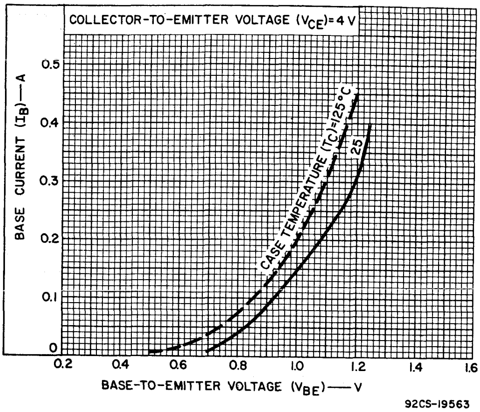


Fig. 10—Typical input characteristics for type 2N6262.

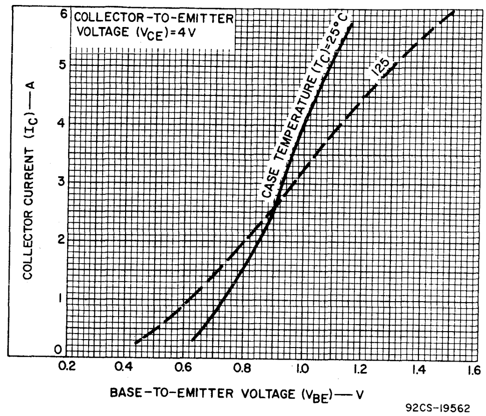


Fig. 11—Typical transfer characteristics for type 2N6262.

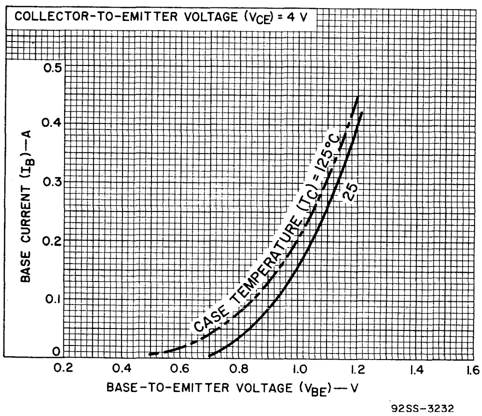


Fig. 12—Typical input characteristics for type 2N3442.

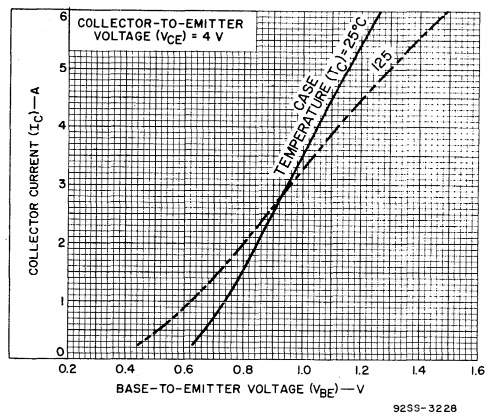


Fig. 13—Typical transfer characteristics for types 2N3442 and 2N4347.

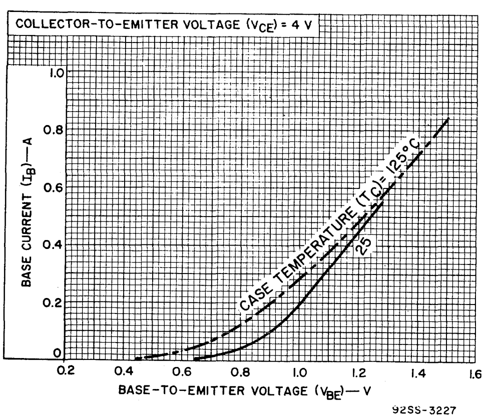


Fig. 14—Typical input characteristics for type 2N4347.

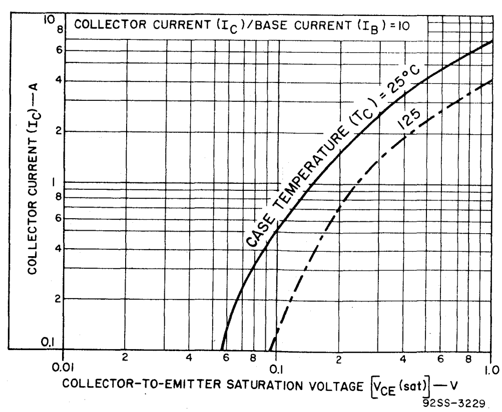


Fig. 15—Typical saturation-voltage characteristics for all types.

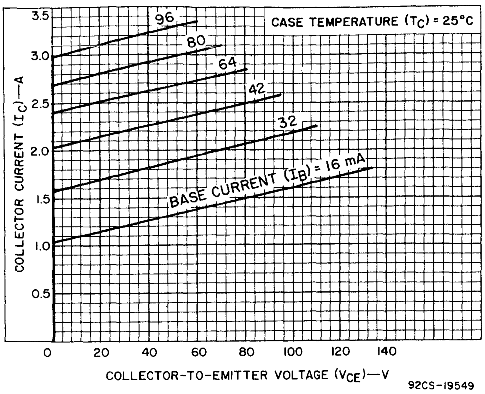


Fig.16—Typical large-signal output characteristics for type 2N6262.

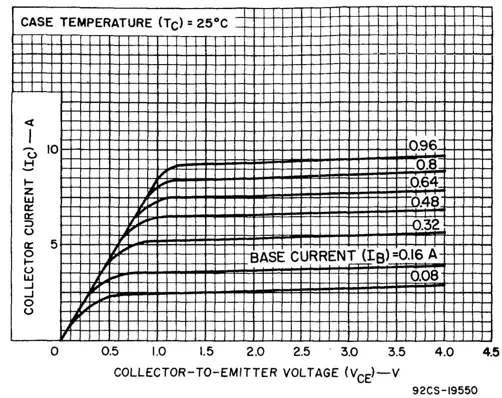


Fig.17—Typical small-signal output characteristics for type 2N6262.

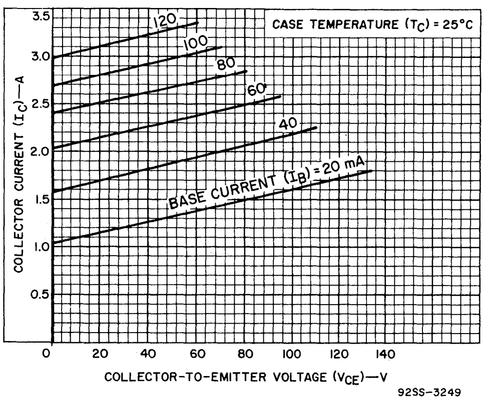


Fig.18—Typical large-signal output characteristics for type 2N3442.

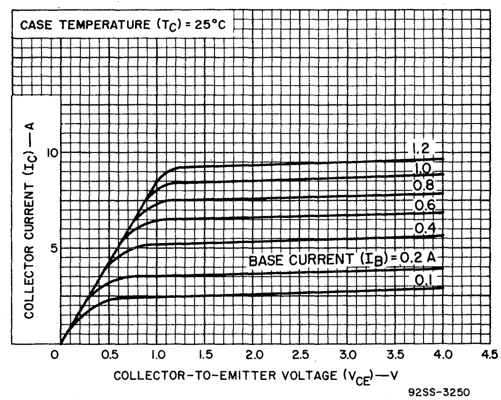


Fig.19—Typical small-signal output characteristics for type 2N3442.

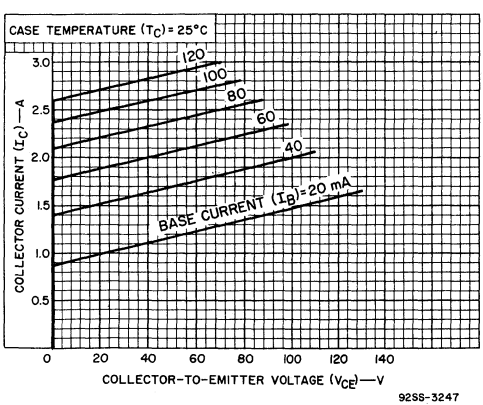


Fig.20—Typical large-signal output characteristics for type 2N4347.

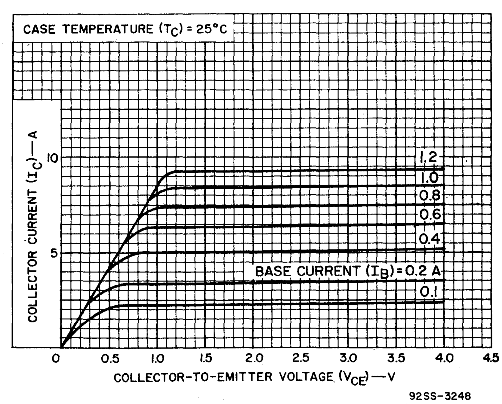


Fig.21—Typical small-signal output characteristics for type 2N4347.

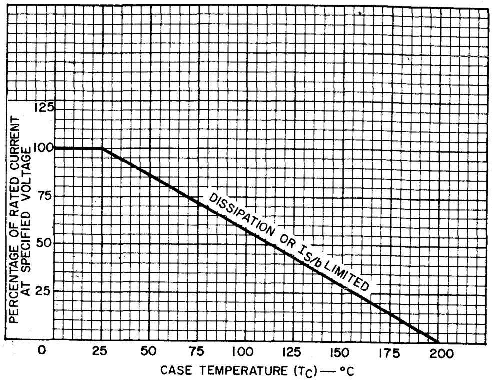


Fig.22—Current derating curve for all types.

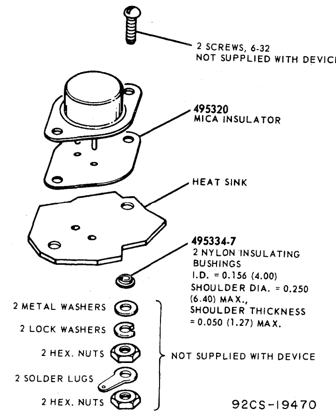


Fig.25—Suggested mounting hardware.

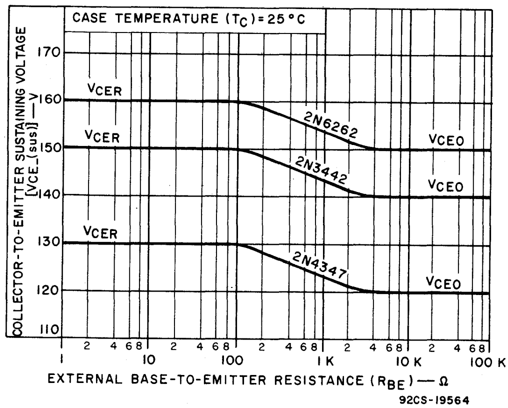


Fig.23—Sustaining voltage vs. base-to-emitter resistance for all types.

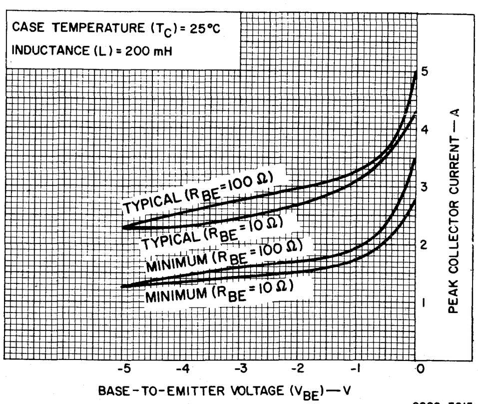
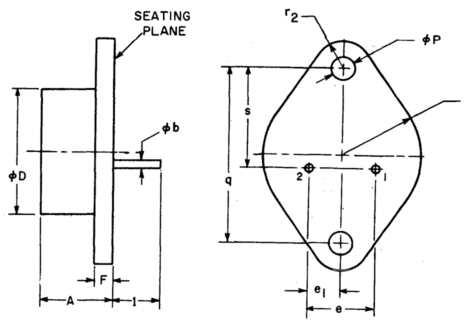


Fig.24—Reverse-bias, second-breakdown characteristics for all types.

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

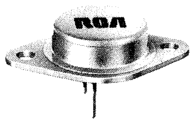
TERMINAL CONNECTIONS

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

RCA Solid State Division

Power Transistors

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)		DC Emitter or Base Voltage (V)		DC Current (A)			LIMITS: Type 2N3771		Type 2N3772		Type 2N6257		Type 2N6258		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 emitter open	I_{CBO}	50 100					0 0		– –	2* –	– –	– 5*	– –	4 –	– –	– 1	mA
With base-emitter junction reverse-biased	I_{CEX}		45 50 100		−1.5 −1.5 −1.5				– – –	– 2 –	– – –	– – 5	– – –	4 – –	– – –	– – 1	mA
With base-emitter junction reverse-biased & T_C = 150°C	I_{CEX}		30 45 100		−1.5 −1.5 −1.5				– – –	10 – –	– – –	10 – –	– – –	– 20 –	– – –	– – 10	mA
With base open	I_{CEO}		25 30 50 60					0 0 0 0	– – – –	– 10 – –	– – – –	– – 10 –	– – – –	10 – – –	– – – –	– – – 2	mA
* Emitter-Cutoff Current	I_{EBO}			5 7		0 0			– –	5 –	– –	– 5	– –	10 –	– –	– 2	mA
* DC Forward Current Transfer Ratio	h_{FE}		4 4 2 4 4 4			30[a] 20[a] 15[a] 15[a] 10[a] 8[a]			5 – – 15 – –	– – – 60 – –	– 5 – – 15 –	– – – – 60 –	– 5 – – – 15	– – – – – 75	5 – 20 – – –	– – 60 – – –	
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 4 4 4			20[a] 15[a] 10[a] 8[a]			– – – –	– 2.7 – –	– – – –	– – 2.2 –	– – – –	– – – 2.2	– – – –	2 – – –	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					30[a] 20[a] 15[a] 10[a] 8[a]		6 4 1.5 1 0.8	– – – – –	4 – 2 – –	– – – – –	– 4 – 1.4 –	– – – – –	– 4 – – 1.5	– – – – –	3 – 0.75 – –	V
Second-Breakdown Collector Current With base forward-biased & 1–s, nonrepetitive pulse	$I_{S/b}$[b]		80 60 40						– – –	– – 3.75	– 2.5 –	– – –	– – 3.75	– – –	3.1 – –	– – –	A
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. $E_{S/b} = ½LI^2$, where L is a series load or leakage inductance and I is the peak collector current.

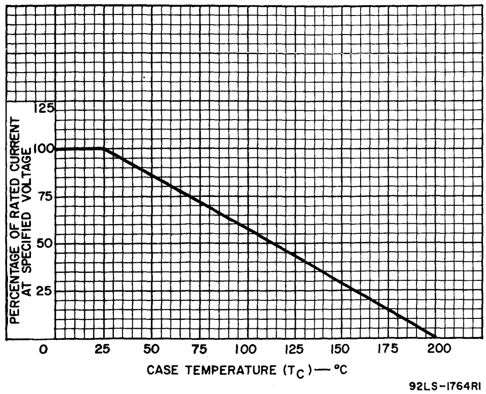


Fig. 1—Derating curve for all types.

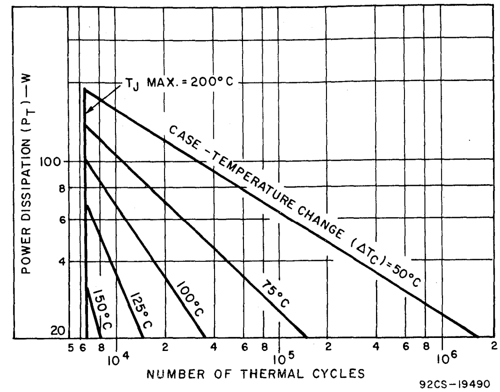


Fig.2—Thermal-cycle rating chart for type 2N6258.

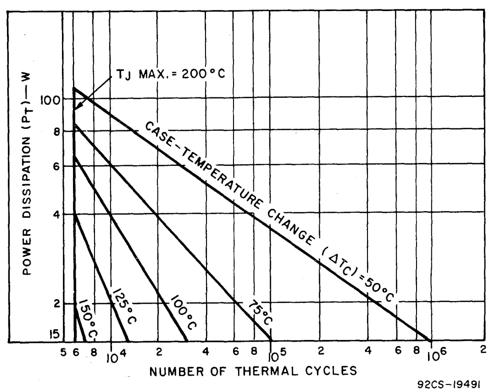


Fig.3—Thermal-cycle rating chart for types 2N3771, 2N3772, and 2N6257.

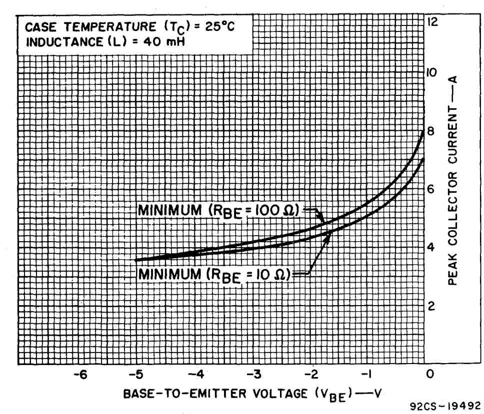


Fig.4—Reverse-bias second-breakdown characteristics for all types.

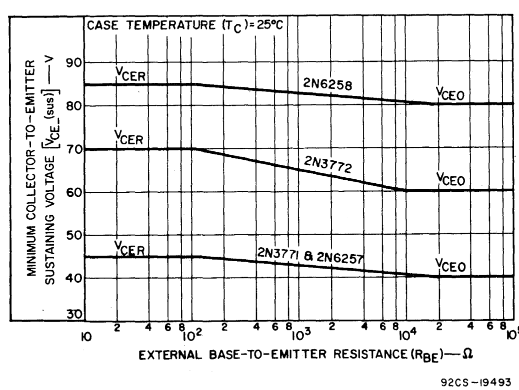


Fig.5—Sustaining voltage vs. base-to-emitter resistance for all types.

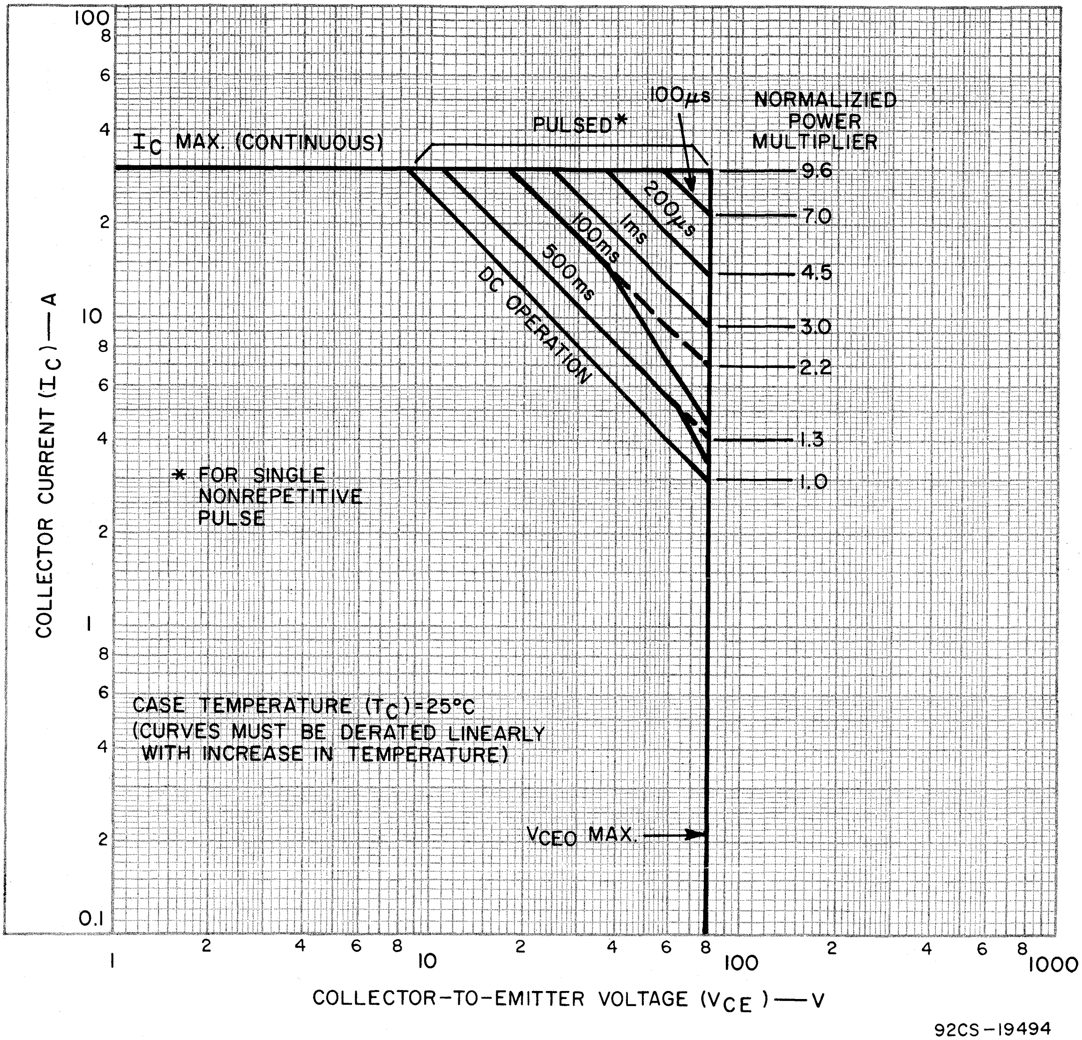


Fig.6—Maximum operating areas for types 2N6258.

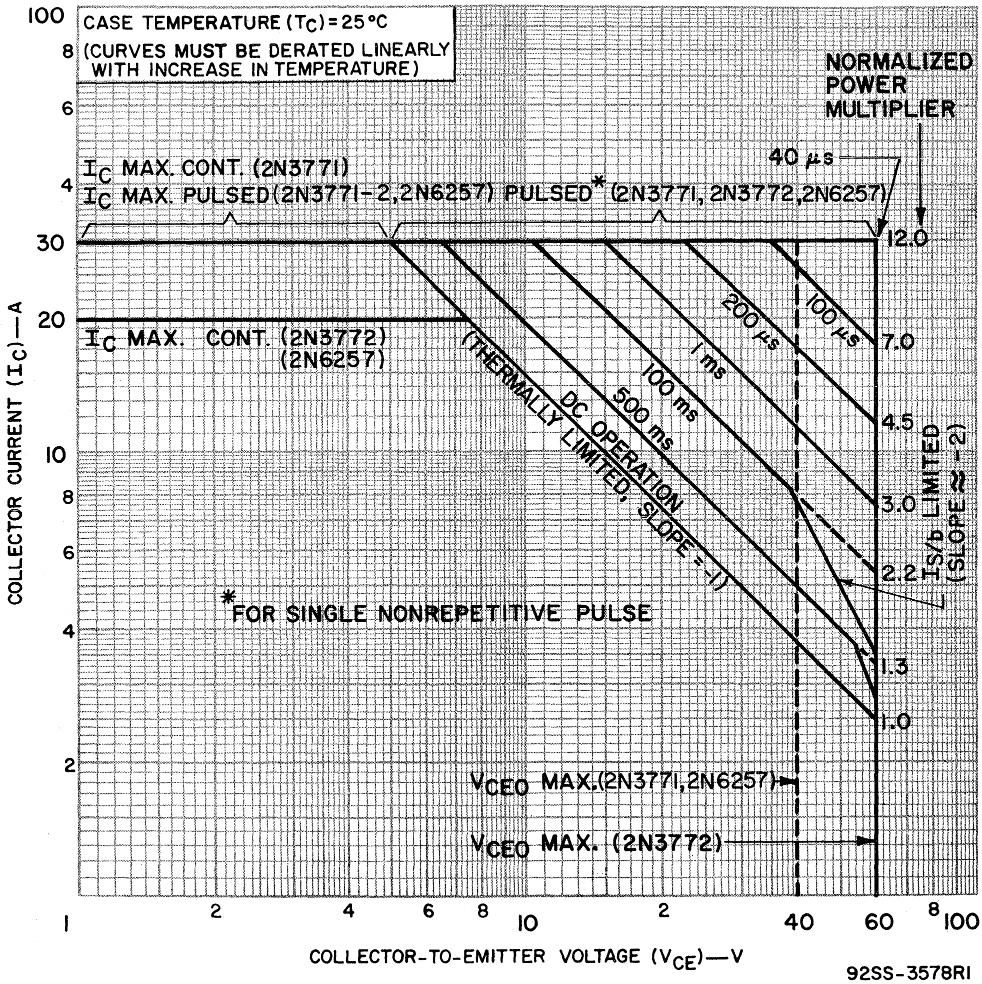


Fig.7—Maximum operating areas for types 2N3771, 2N3772, and 2N6257.

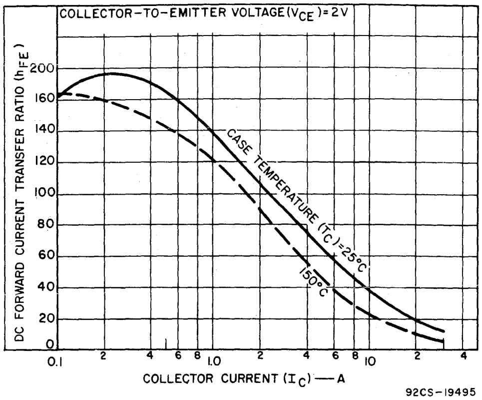


Fig.8—Typical dc beta characteristics for type 2N6258.

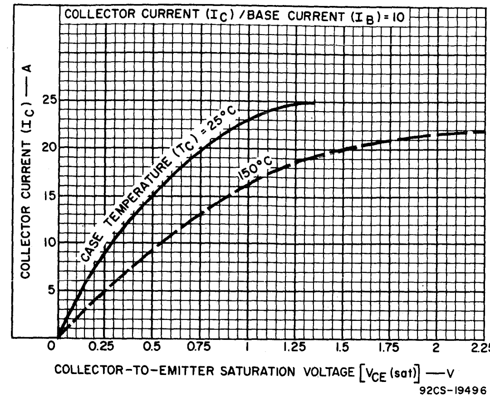


Fig.9—Typical saturation-voltage characteristics for type 2N6258.

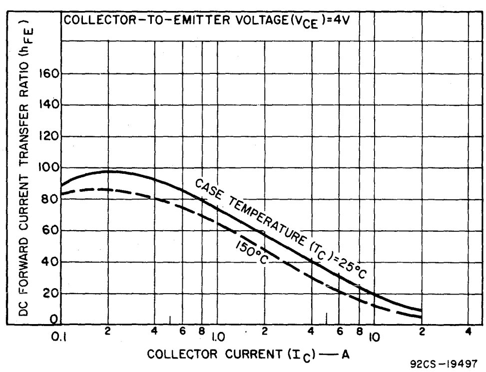


Fig.10—Typical dc beta characteristics for type 2N3772 and 2N6257.

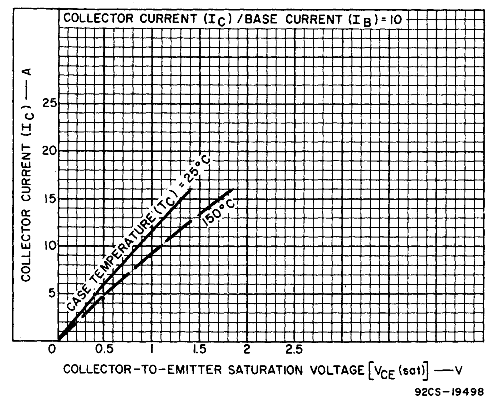


Fig.11—Typical saturation-voltage characteristics for types 2N3772 and 2N6257.

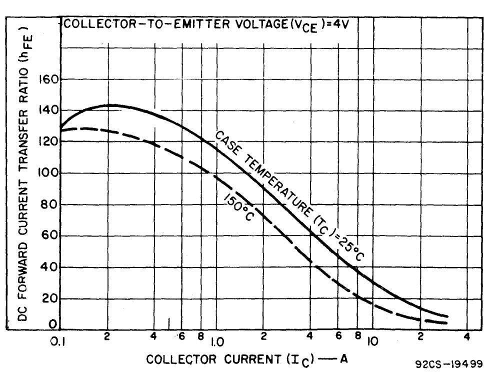


Fig.12—Typical dc beta characteristics for type 2N3771.

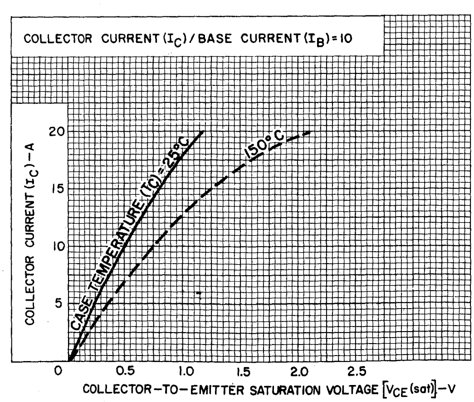


Fig.13—Typical saturation-voltage characteristics for type 2N3771.

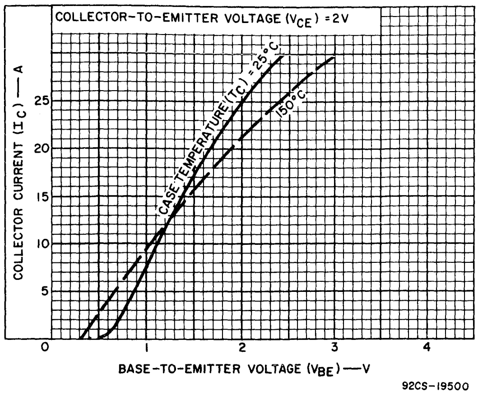


Fig.14—Typical transfer characteristics for type 2N6258.

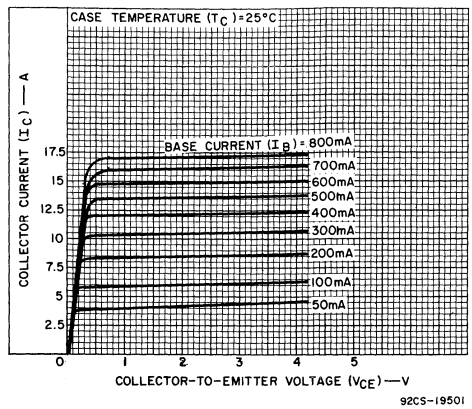


Fig.15—Typical output characteristics for type 2N6258.

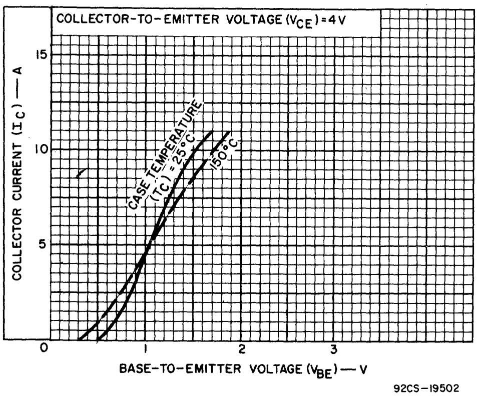


Fig.16—Typical transfer characteristics for types 2N3772 and 2N6257.

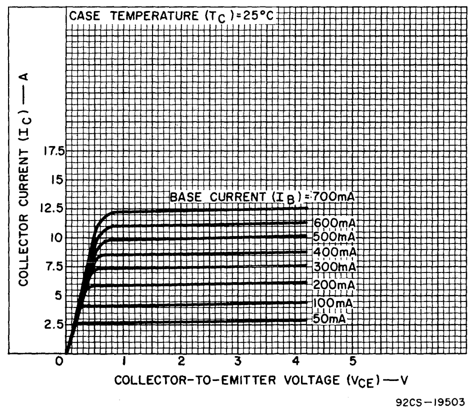


Fig.17—Typical output characteristics for types 2N3772 and 2N6257.

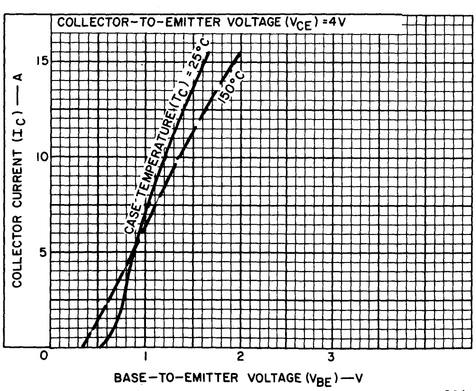


Fig.18—Typical transfer characteristics for type 2N3771.

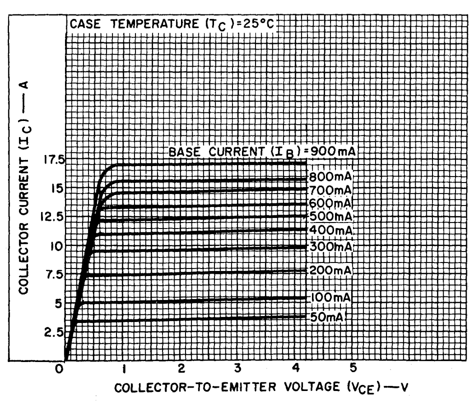


Fig.19—Typical output characteristics for type 2N3771.

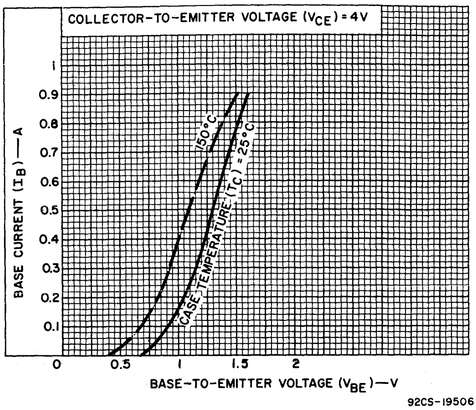


Fig.20—Typical input characteristics for type 2N6258.

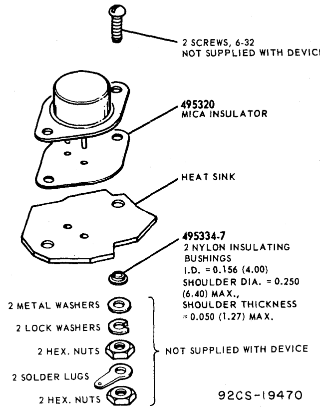


Fig.23—Suggested mounting hardware.

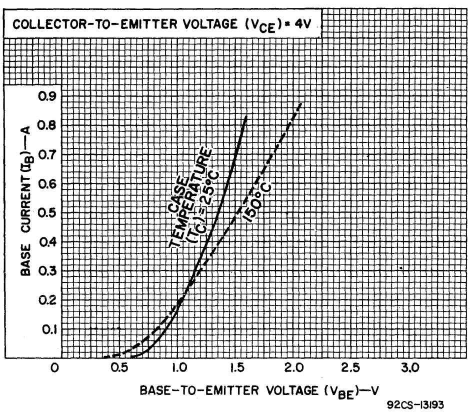


Fig.21—Typical input characteristics for types 2N3771 and 2N6257.

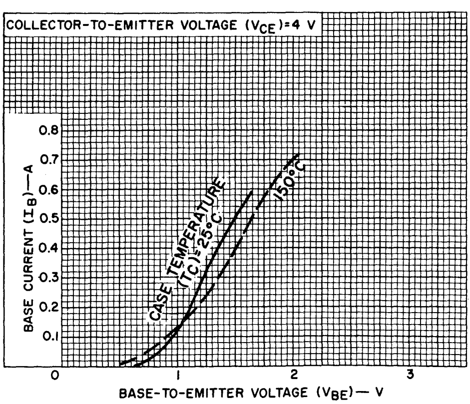
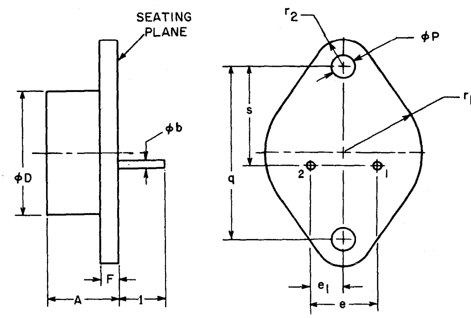


Fig.22—Typical input characteristics for type 2N3772.

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

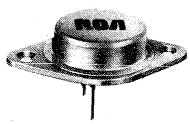
Pin 1 – Base
Pin 2 – Emitter
Case – Collector
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors
2N6259
2N4348
2N3773

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

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



JEDEC TO-3

H-1570

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	–	160	–	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]				–4	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.

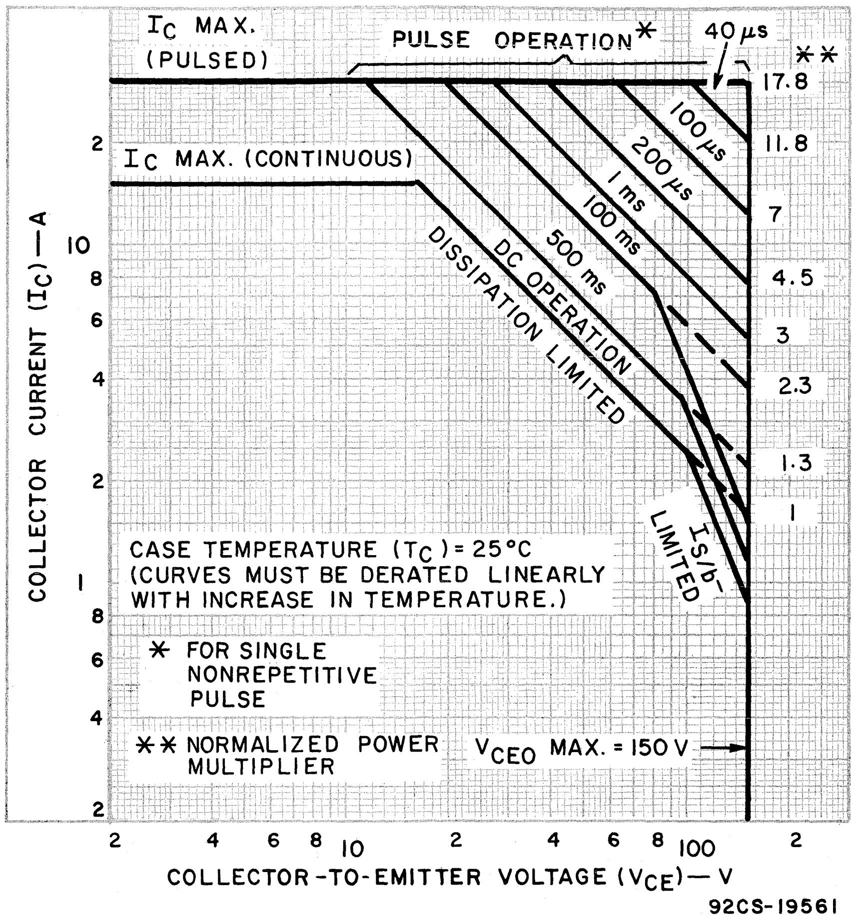


Fig.1—Maximum operating areas for type 2N6259.

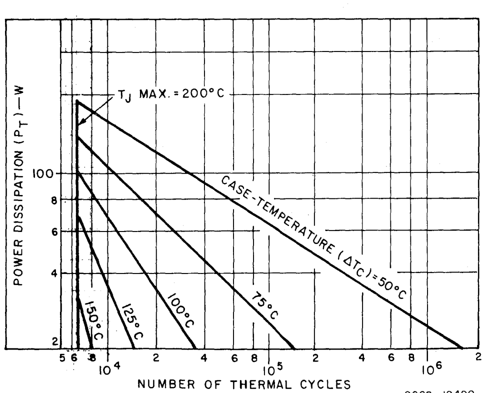


Fig.2—Thermal-cycle rating chart for type 2N6259.

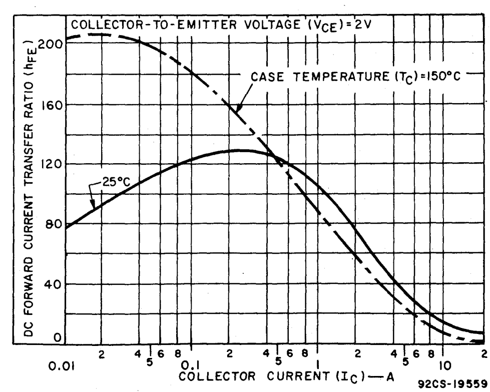


Fig.3—Typical dc beta characteristics for type 2N6259.

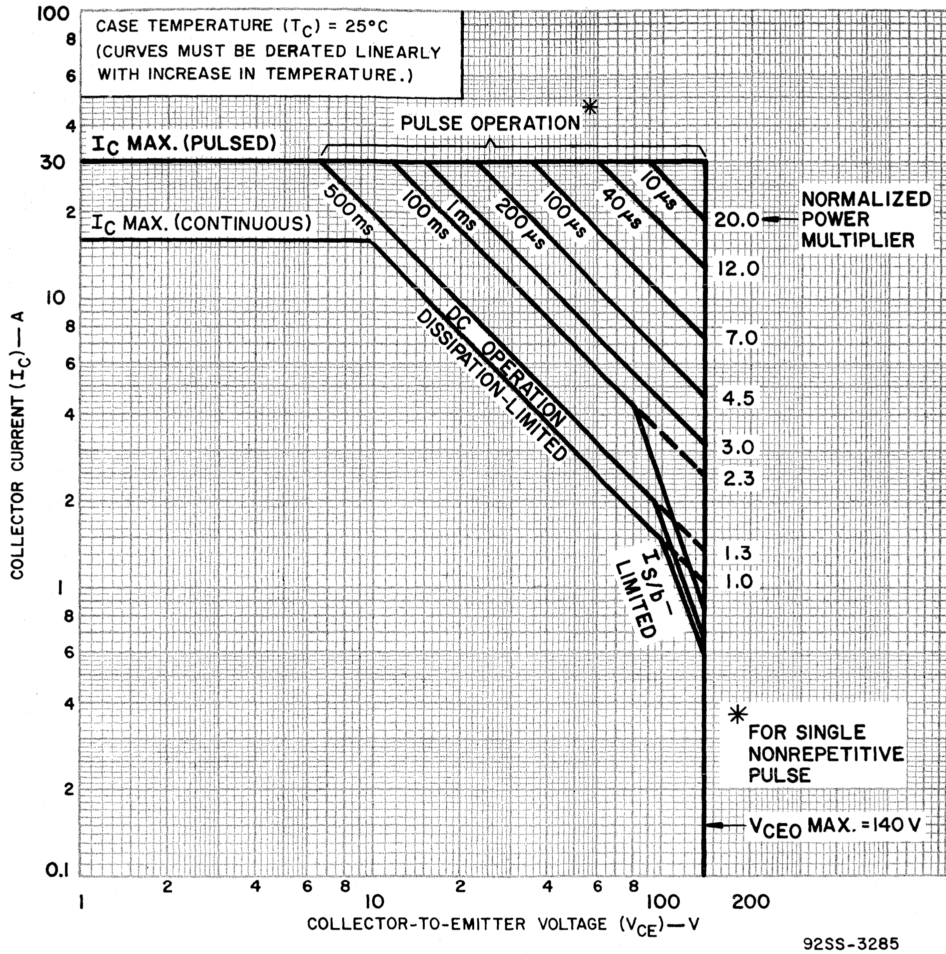


Fig.4—Maximum operating areas for type 2N3773.

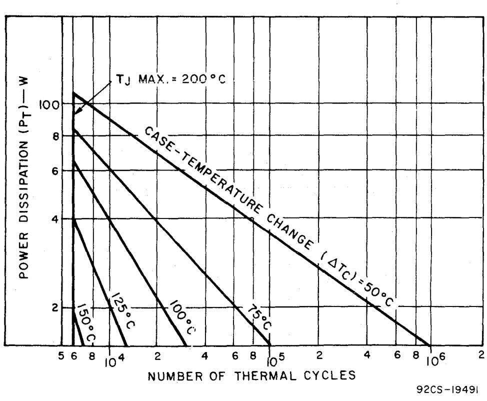


Fig.5—Thermal-cycle rating chart for type 2N3773.

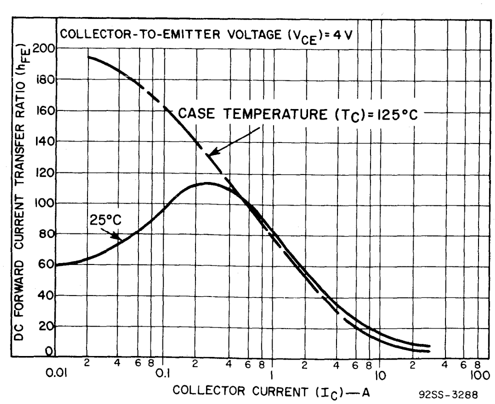


Fig.6—Typical dc beta characteristics for type 2N3773.

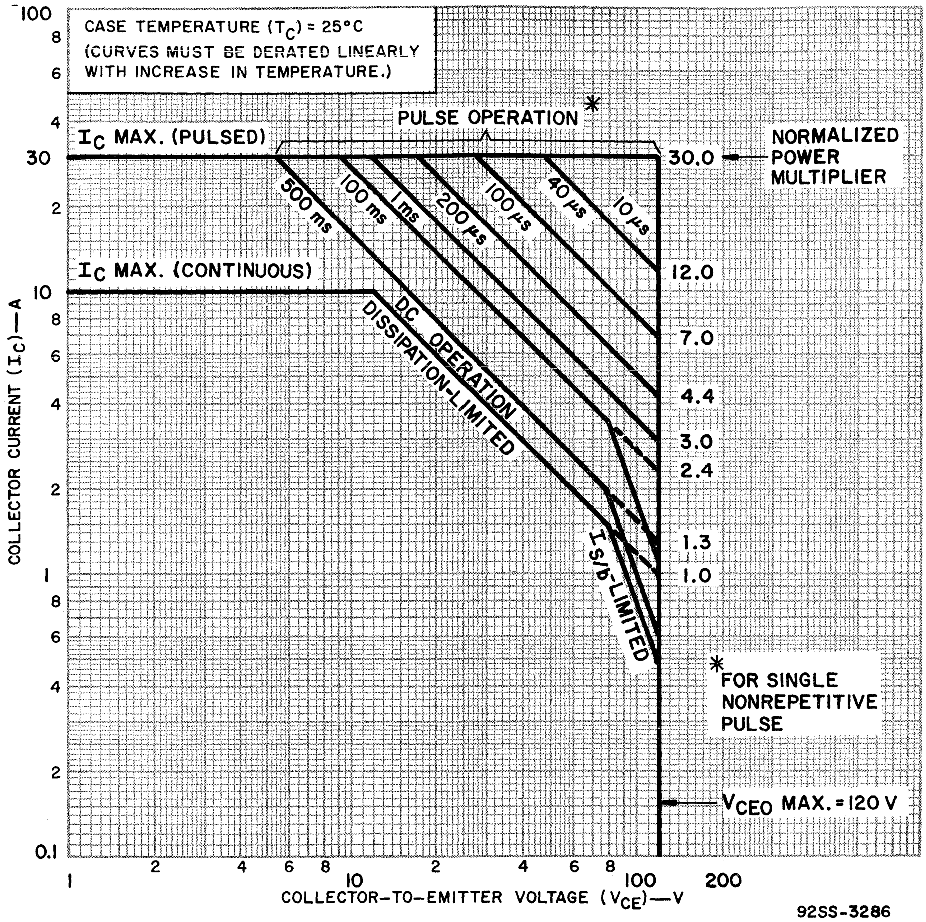


Fig.7—Maximum operating areas for type 2N4348.

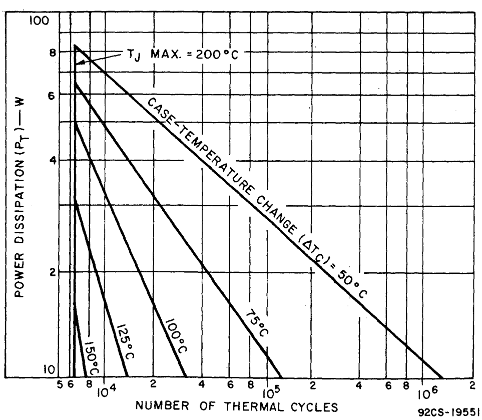


Fig.8—Thermal-cycle rating chart for type 2N4348.

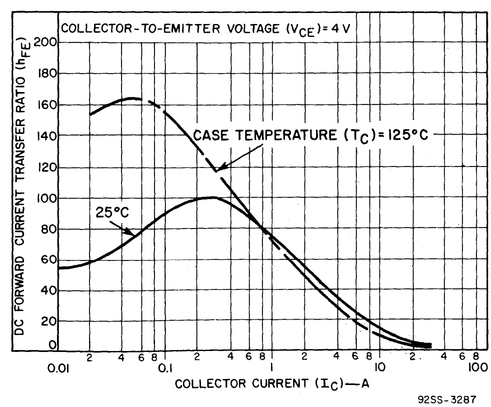


Fig.9—Typical dc beta characteristics for type 2N4348.

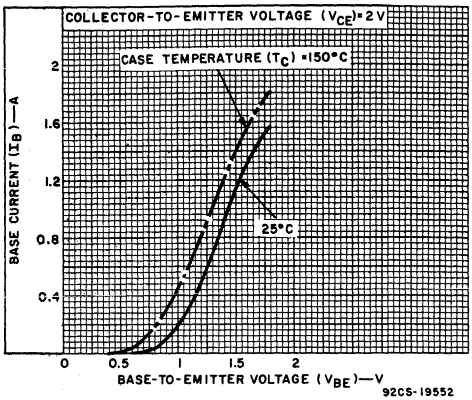


Fig.10—Typical input characteristics for type 2N6259.

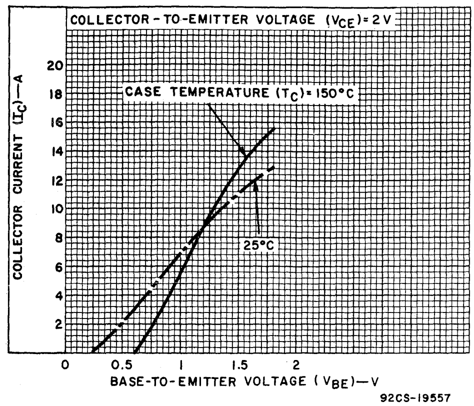


Fig.11—Typical transfer characteristics for type 2N6259.

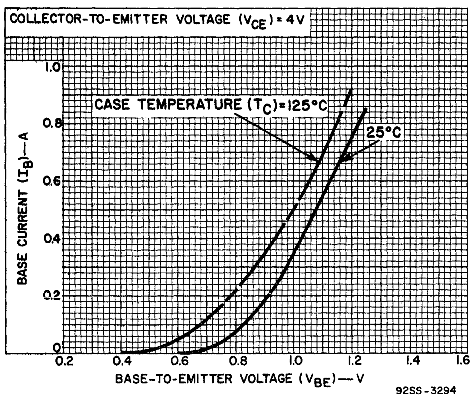


Fig.12—Typical input characteristics for type 2N3773.

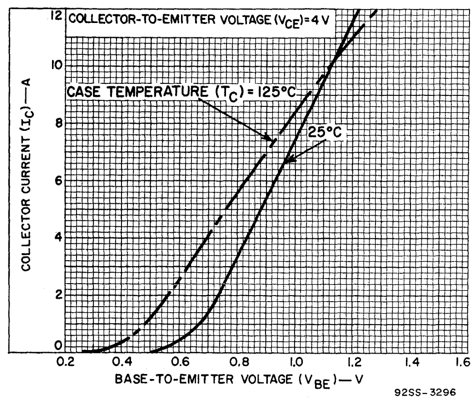


Fig.13—Typical transfer characteristics for type 2N3773.

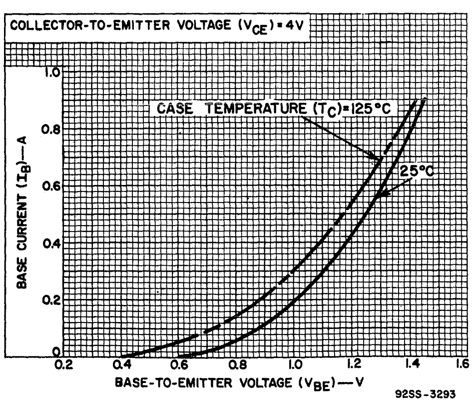


Fig.14—Typical input characteristics for type 2N4348.

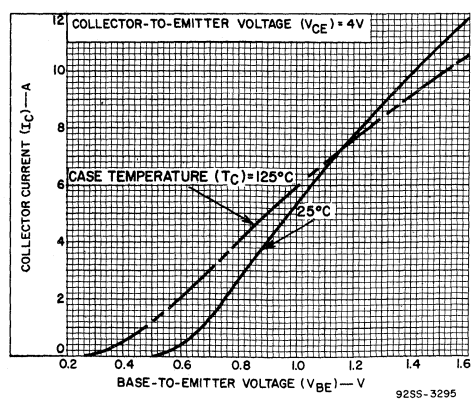


Fig.15—Typical transfer characteristics for type 2N4348.

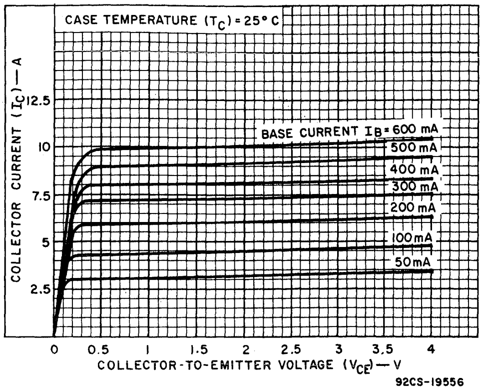


Fig.16—Typical output characteristics for type 2N6259.

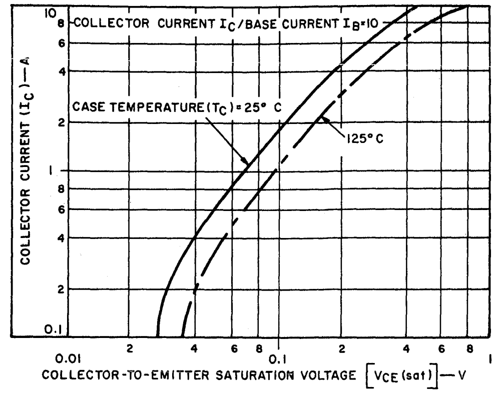


Fig.17—Typical saturation-voltage characteristics for type 2N6259.

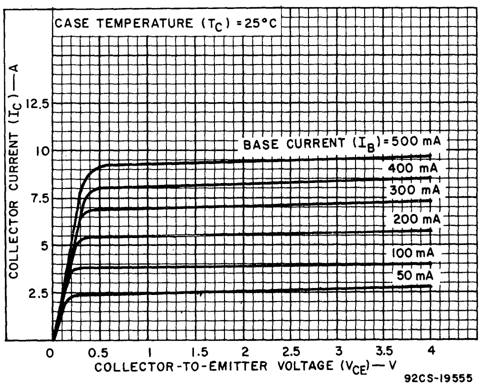


Fig.18—Typical output characteristics for type 2N3773.

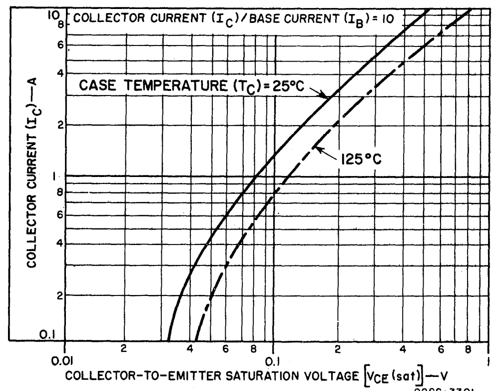


Fig.19—Typical saturation-voltage characteristics for type 2N3773.

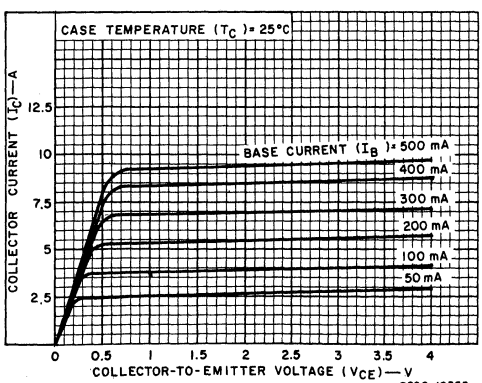


Fig.20—Typical output characteristics for type 2N4348.

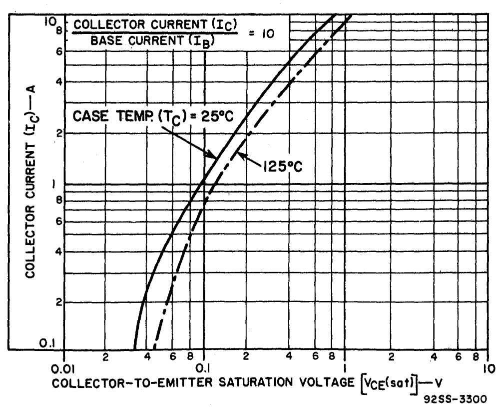


Fig.21—Typical saturation-voltage characteristics for type 2N4348.

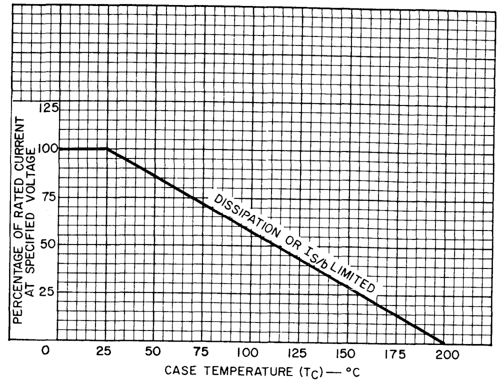


Fig.22—Dissipation derating curve for all types.

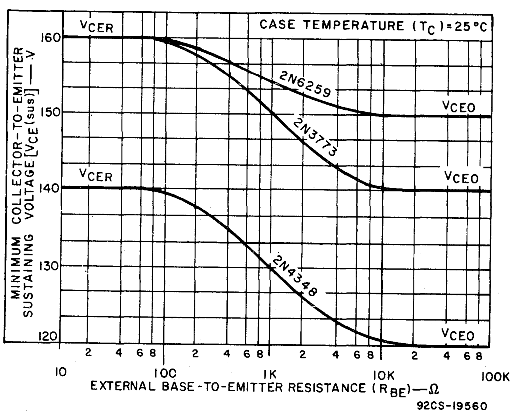


Fig.23—Sustaining voltage vs. base-to-emitter resistance for all types.

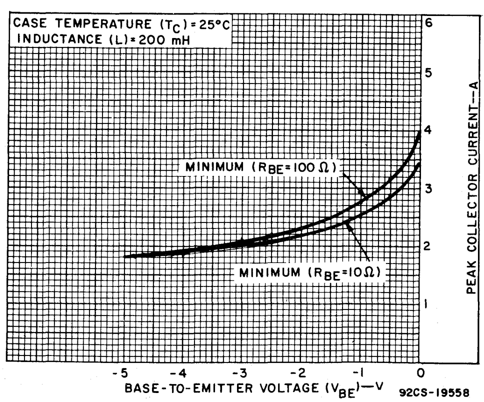


Fig.24—Reverse-bias, second-breakdown characteristics for all types.

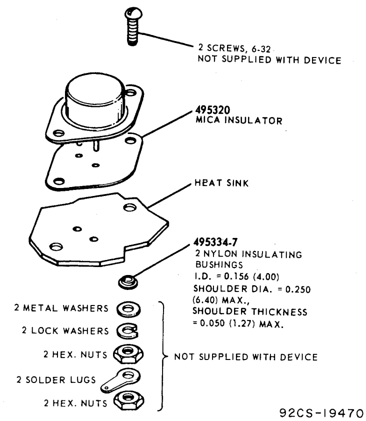
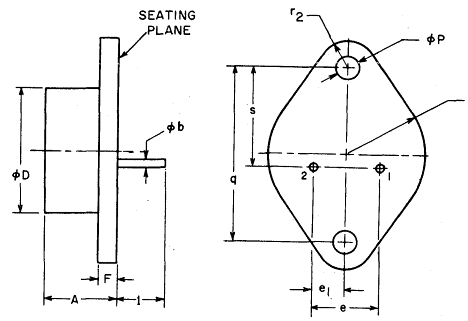


Fig.25—Suggested mounting hardware.

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	
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

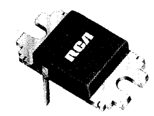
Pin 1 – Base
Pin 2 – Emitter
Case – Collector
Mounting Flange – Collector

RCA
Solid State
Division

Power Transistors

2N5034 2N5037
2N5035 40513
2N5036 40514

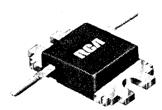
2N5034
2N5036
40514



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}	V_{BE}	DC Current (A) I_C	I_B	LIMITS: Types 40514, 40513 Min.	Max.	Types 2N5034, 2N5035 Min.	Max.	Types 2N5036, 2N5037 Min.	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)	$\lvert h_{fe} \rvert$	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.

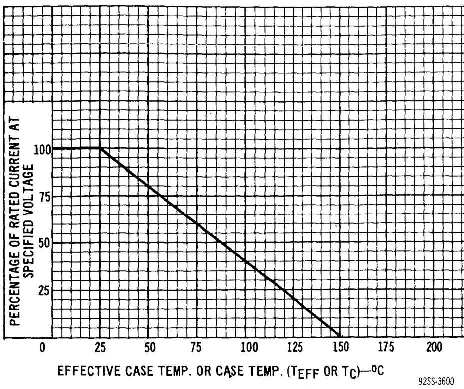


Fig.1—Dissipation derating curve for all types.

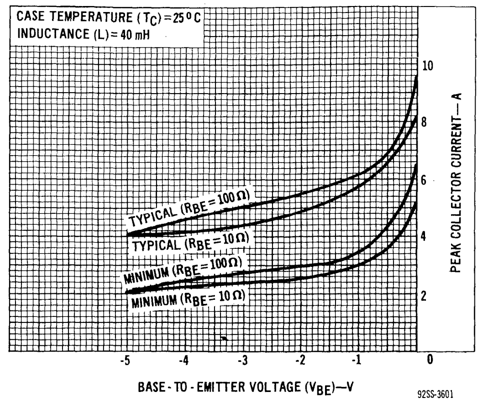


Fig.2—Reverse-bias, second breakdown characteristics for all types.

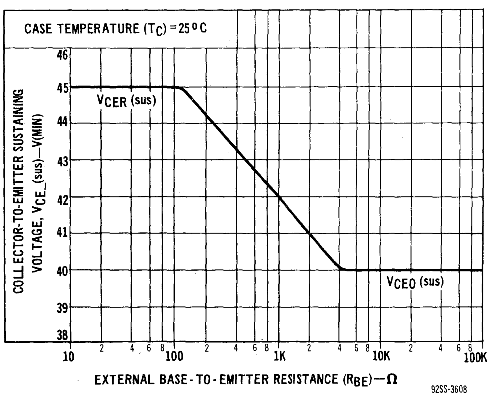


Fig.3—Sustaining voltage vs. base-to-emitter resistance for types 2N5034 & 2N5035.

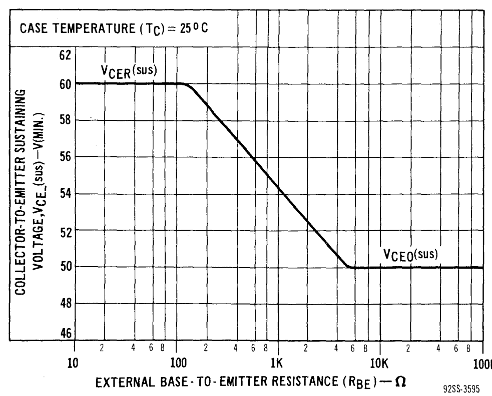


Fig.4—Sustaining voltage vs. base-to-emitter resistance for types 2N5036 & 2N5037.

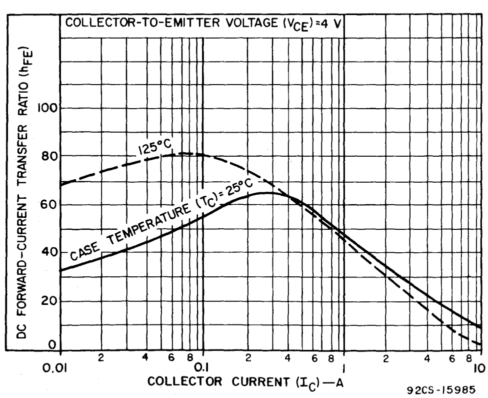


Fig.5—Typical dc beta characteristics for types 2N5034, 2N5035, 40513, & 40514.

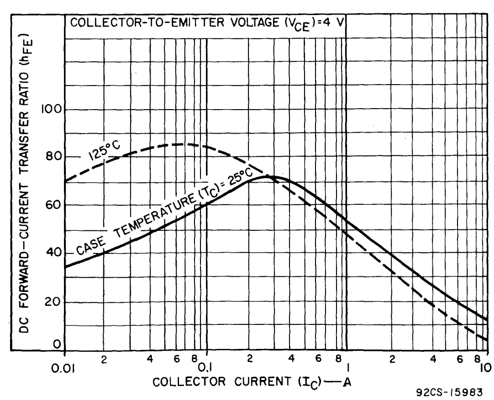


Fig.6—Typical dc beta characteristics for types 2N5036 & 2N5037.

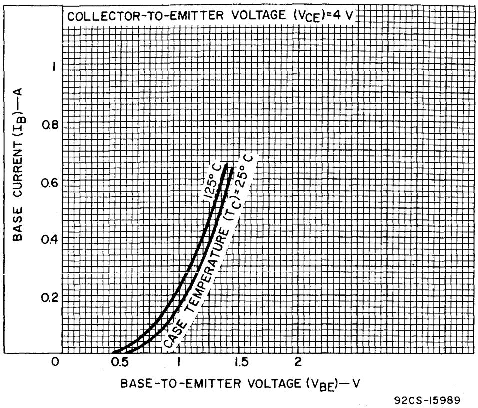


Fig.7—Typical input characteristics for types 2N5034, 2N5035, 40513, & 40514.

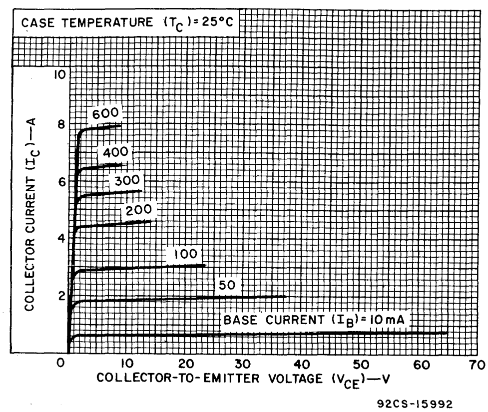


Fig.8—Typical output characteristics for types 2N5034, 2N5035, 40513, & 40514.

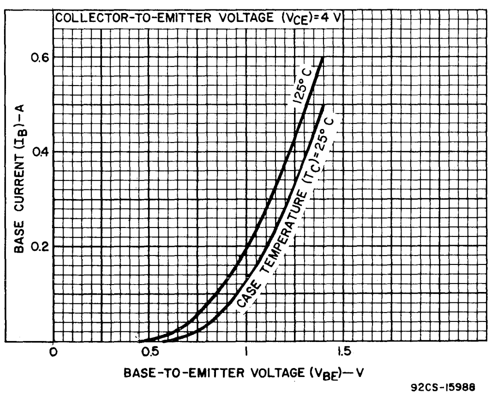


Fig.9—Typical input characteristics for types 2N5036 & 2N5037.

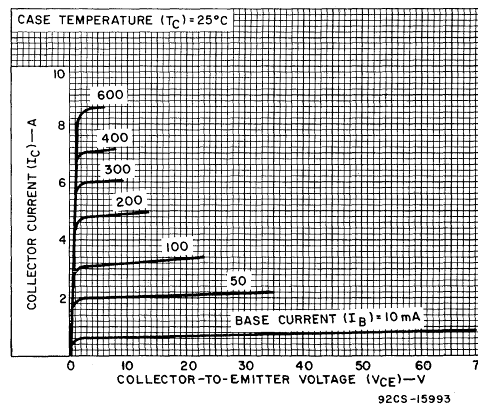


Fig.10—Typical output characteristics for types 2N5036 & 2N5037.

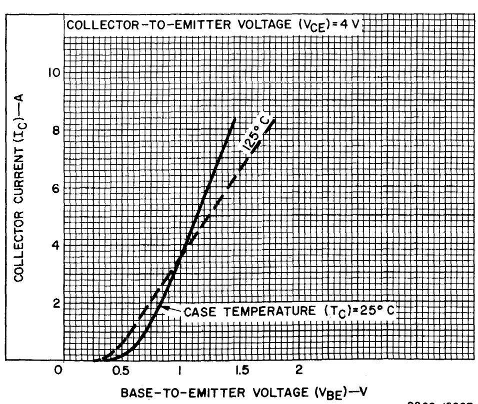


Fig.11—Typical transfer characteristics for all types.

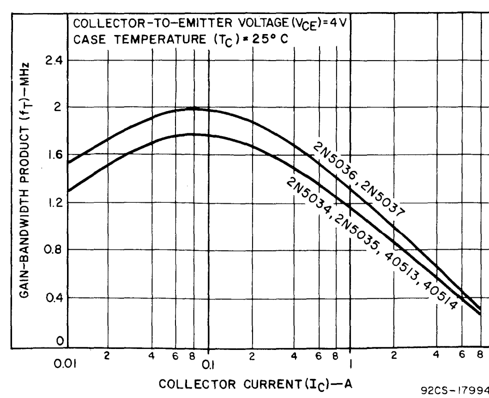


Fig.12—Typical gain-bandwidth product for all types.

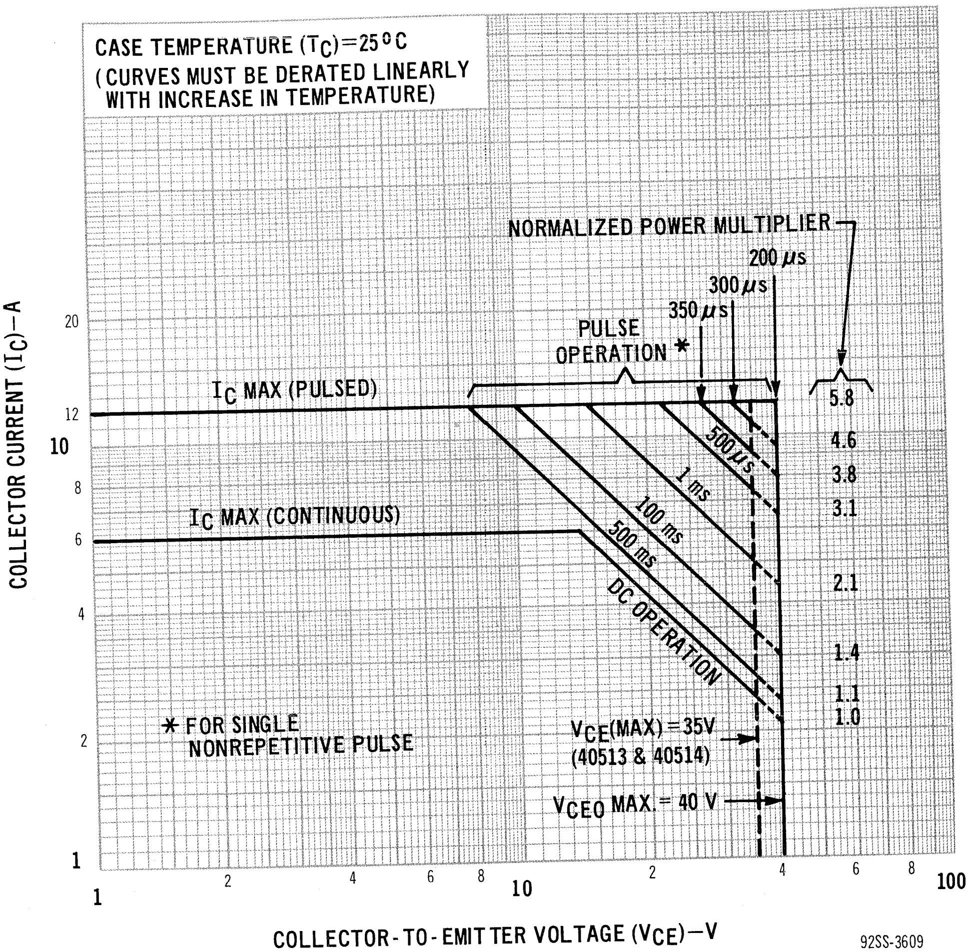


Fig. 13—Maximum operating areas for types 2N5034, 2N5035, 40513, & 40514.

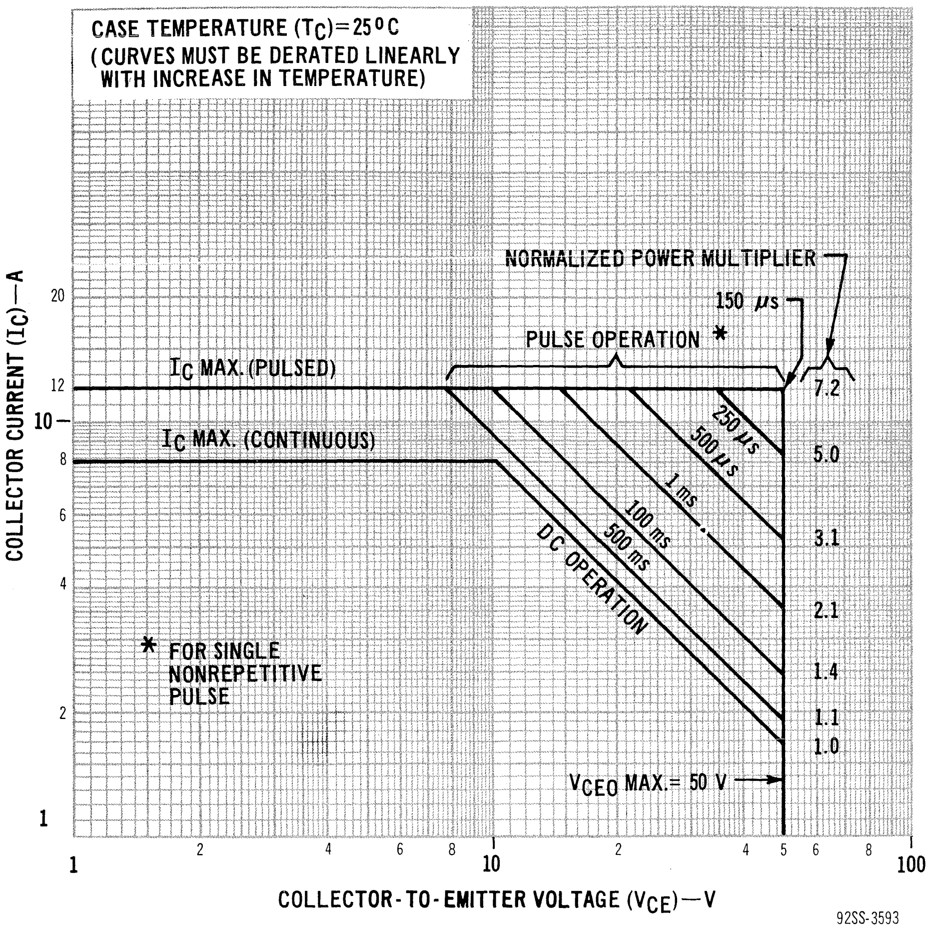


Fig. 14—Maximum operating areas for types 2N5036 & 2N5037.

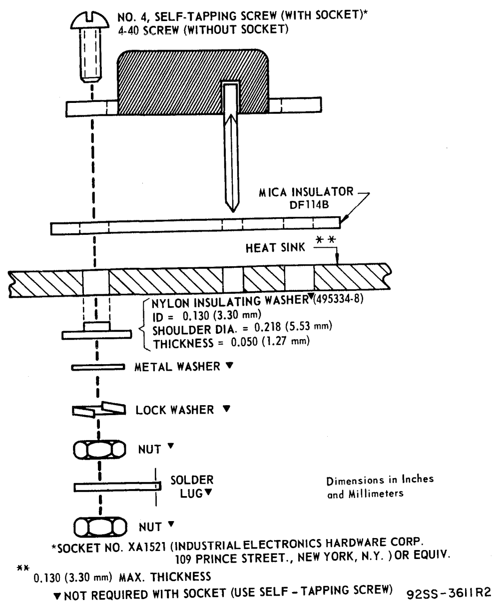


Fig.15—Suggested hardware for mounting types 2N5034, 2N5036, and 40514.

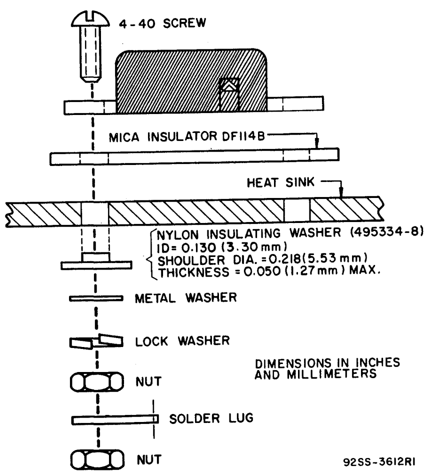


Fig.16—Suggested hardware for mounting types 2N5035, 2N5037, and 40513.

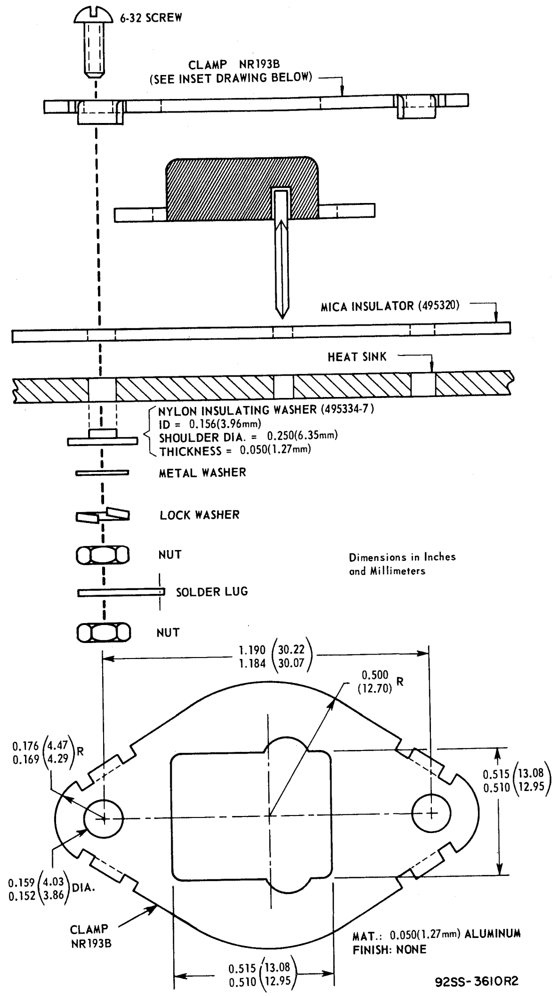
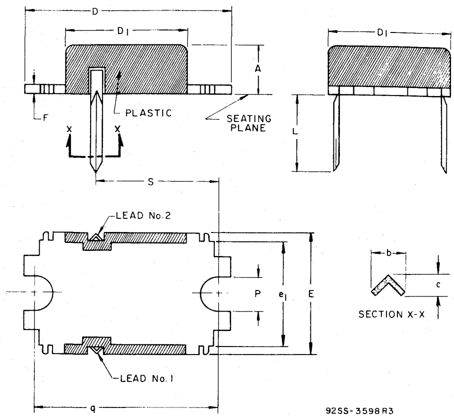
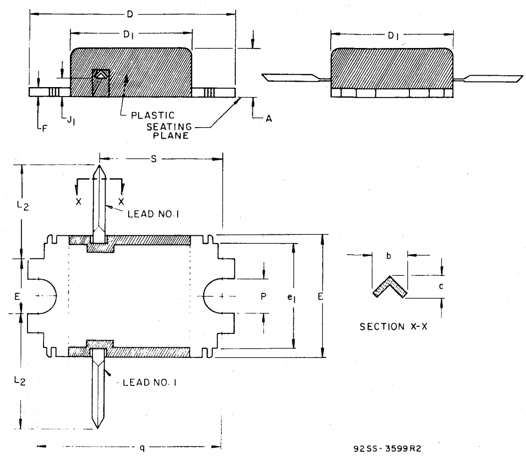


Fig.17—Suggested hardware for mounting types 2N5034, 2N5036, and 40514 in place of TO—3 types.

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.

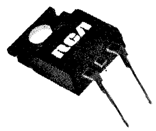
SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.200	4.07	5.08
b	0.045	0.060	1.15	1.52
c	0.025	0.045	0.64	1.14
D	0.890	0.910	22.61	23.11
D_1	0.480	0.515	12.20	13.03
E	0.480	0.520	12.20	13.20
F	0.055	0.070	1.40	1.77
J_1	0.100	0.120	2.54	3.04
L_2	0.415	0.560	10.54	14.22
P	0.128	0.150	3.26	3.81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

NOTE: Terminal end configurations are optional.

Solid State Division

Power Transistors

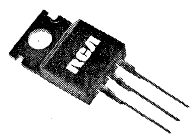
2N5293 2N5296
2N5294 2N5297
2N5295 2N5298



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.

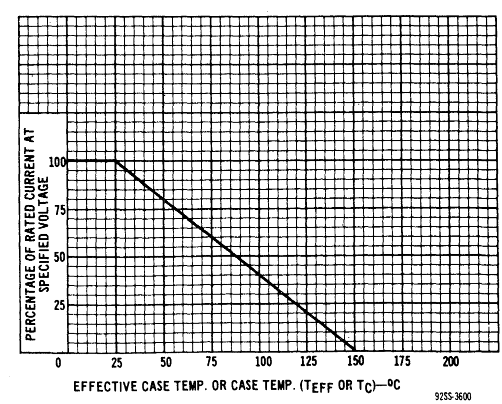


Fig. 1 - Derating curve for all types.

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

Characteristic	Symbol	TEST CONDITIONS					LIMITS						Units
		DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)		2N5293 2N5294		2N5295 2N5296		2N5297 2N5298		
		V_{CE}	V_{EB}	V_{BE}	I_C	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current With base-emitter junction reverse biased	I_{CEV}	65 35		-1.5 -1.5			– –	0.5 –	– –	– 2	– –	0.5 –	mA
	I_{CEV} (T_C = 150°C)	65 35		-1.5 -1.5			– –	3 –	– –	– 5	– –	3 –	mA
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 5				– –	1 –	– –	– 1	– –	– 1	mA
DC Forward-Current Transfer Ratio	h_{FE}[c]	4 4 4			0.5 1 1.5		30 – –	120 – –	– 30 –	– 120 –	– – 20	– – 80	
Collector-to-Emitter Sustaining Voltage With base open	$V_{CEO}(sus)$[c]				0.1 0.1 0.1	0 0 0	70 – –	– – –	– 40 –	– – –	– – 60	– – –	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$[c]				0.1 0.1 0.1		75 – –	– – –	– 50 –	– – –	– – 70	– – –	V
With base-emitter junction reverse biased	$V_{CEV}(sus)$[c]			-1.5 -1.5 -1.5	0.1 0.1 0.1		80 – –	– – –	– 60 –	– – –	– – 80	– – –	V
Base-to-Emitter Voltage	V_{BE}[c]	4 4 4			0.5 1 1.5		– – –	1.1 – –	– – –	– 1.3 –	– – –	– – 1.5	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[c]				0.5 1 1.5	0.05 0.1 0.15	– – –	1 – –	– – –	– 1 –	– – –	– – 1	V
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 1 1.5	0.05[a] 0.1[a] 0.15[a]	– – –	5 – –	– – –	– 5 –	– – –	– – 5	μs
Turn-Off (See Figs. 21-23)	t_{off}	V_{CC} = 30			0.5 1 1.5	-0.05[a] -0.1[b] -0.15[b]	– – –	15 – –	– – –	– 15 –	– – –	– – 15	μs
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_{B_2} value (turn-off base current).

[c] Pulsed, pulse duration = 300 μs, duty factor = .018.

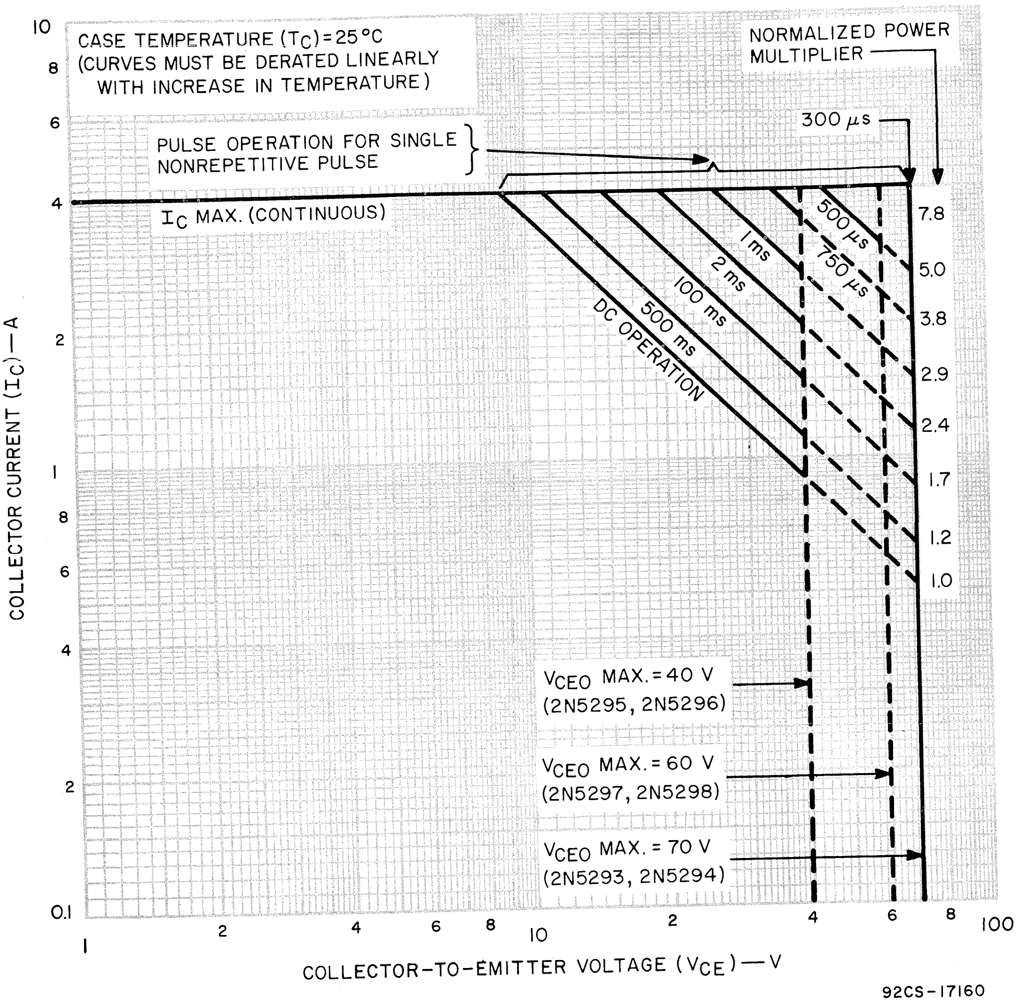


Fig. 2 - Maximum operating areas for all types.

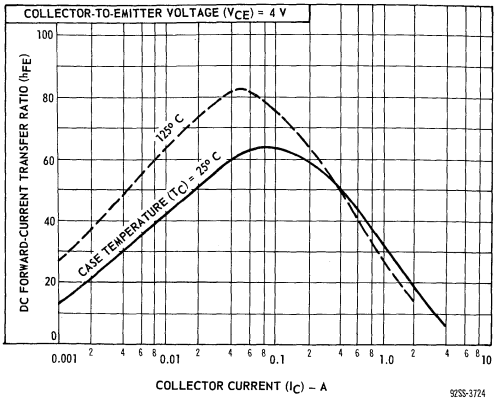


Fig. 3 - Typical DC beta for types 2N5293 & 2N5294.

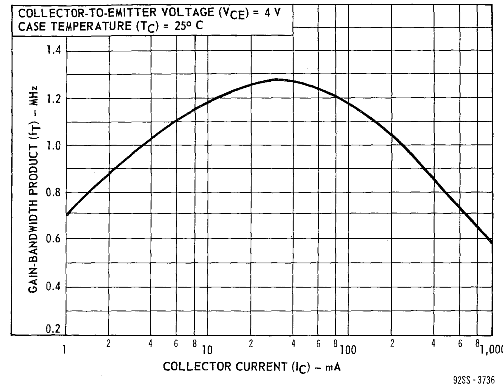


Fig. 4 - Typical gain-bandwidth product for types 2N5293 & 2N5294.

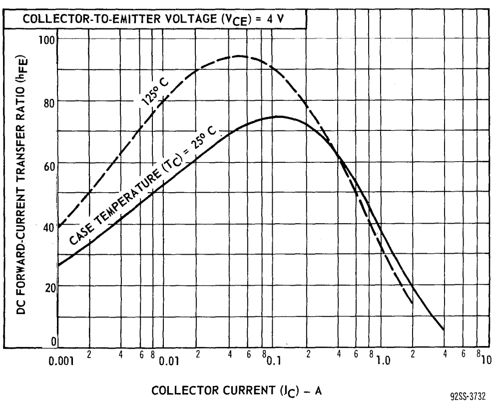


Fig. 5 - Typical DC beta for types 2N5295 & 2N5296.

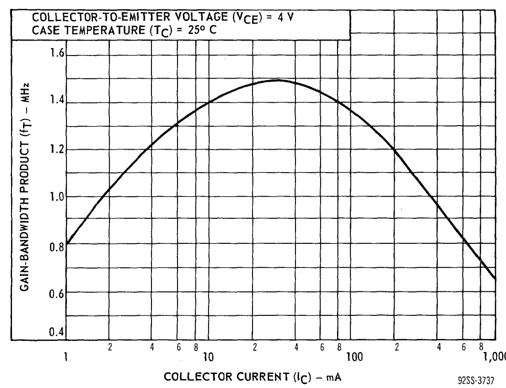


Fig. 6 - Typical gain-bandwidth product for types 2N5295 & 2N5296.

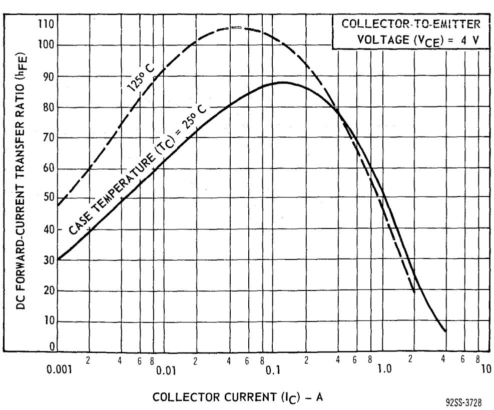


Fig. 7 - Typical DC beta for types 2N5297 & 2N5298.

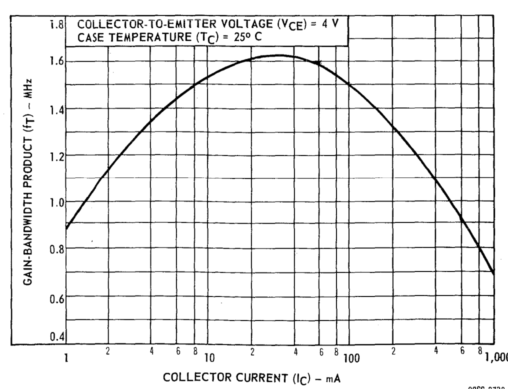


Fig. 8 - Typical gain-bandwidth product for types 2N5297 & 2N5298.

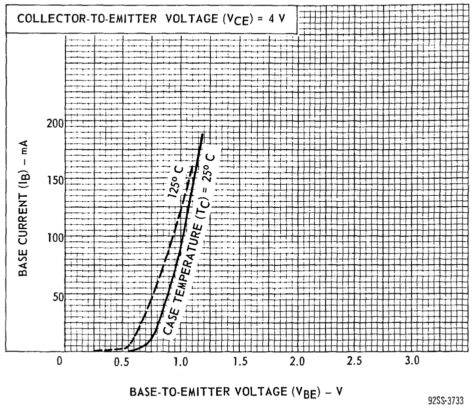


Fig. 9 - Typical input characteristics for types 2N5293 & 2N5294.

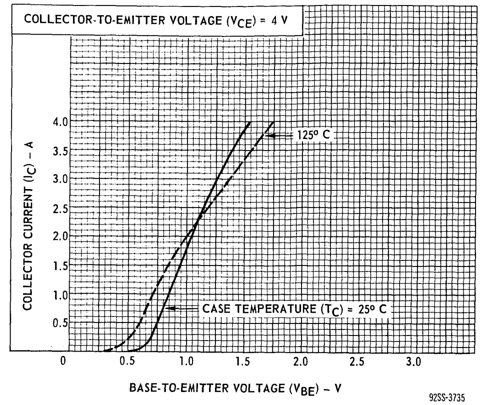


Fig. 10 - Typical transfer characteristics for types 2N5293 & 2N5294.

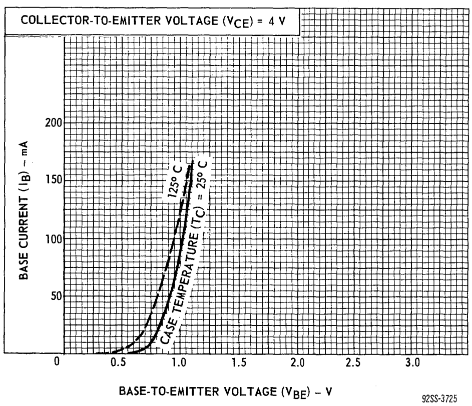


Fig. 11 - Typical input characteristics for types 2N5295 & 2N5296.

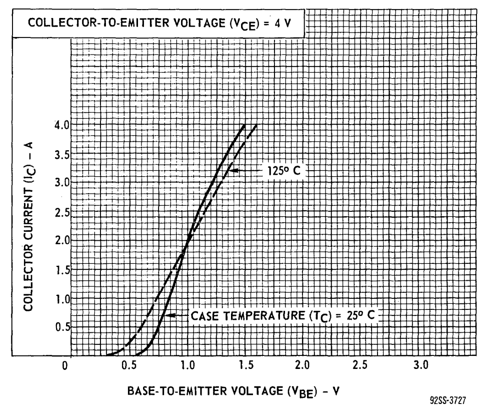


Fig. 12 - Typical transfer characteristics for types 2N5295 & 2N5296.

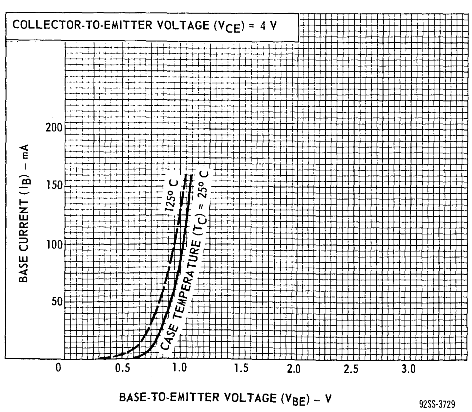


Fig. 13 - Typical input characteristics for types 2N5297 & 2N5298.

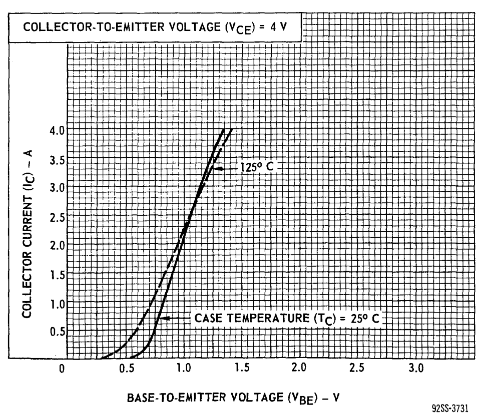


Fig. 14 - Typical transfer characteristics for types 2N5297 & 2N5298.

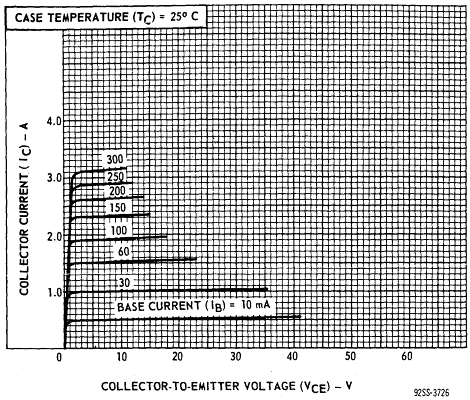


Fig. 15 - Typical output characteristics for types 2N5293 & 2N5294.

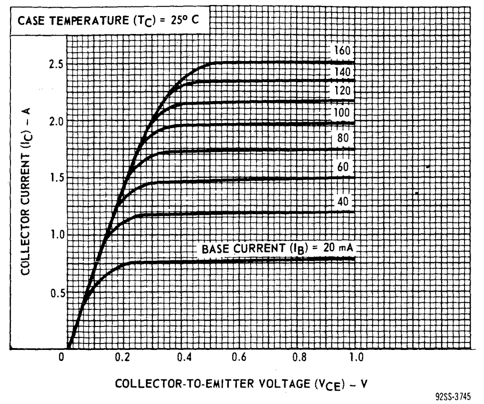


Fig. 16 - Typical output characteristics for types 2N5295 & 2N5296.

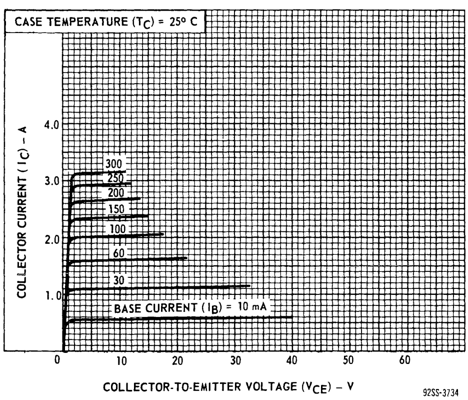


Fig. 17 - Typical output characteristics for types 2N5295 & 2N5296.

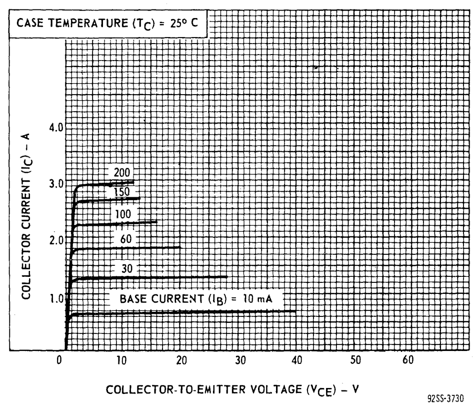


Fig. 18 - Typical output characteristics for types 2N5297 & 2N5298.

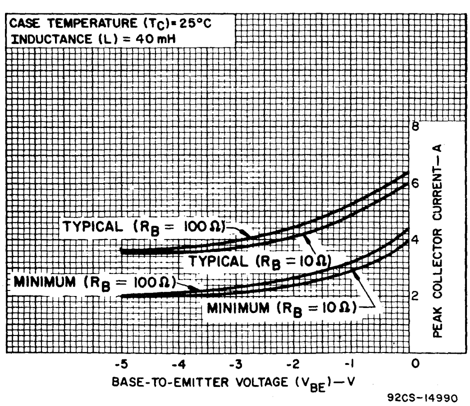


Fig. 19 - Reverse-bias, second-breakdown characteristics for all types.

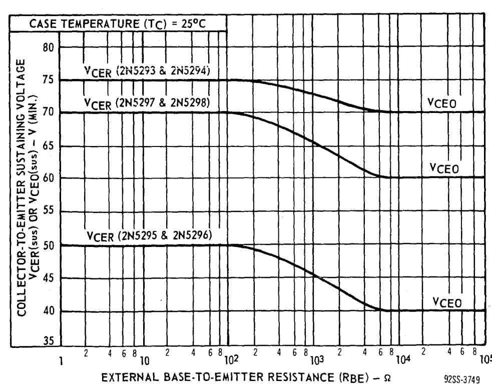


Fig. 20 - Sustaining voltage vs. base-to-emitter resistance for all types.

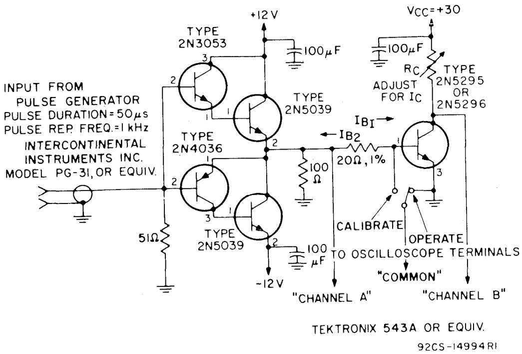


Fig. 21 - Circuit used to measure switching times for types 2N5295 & 2N5296.

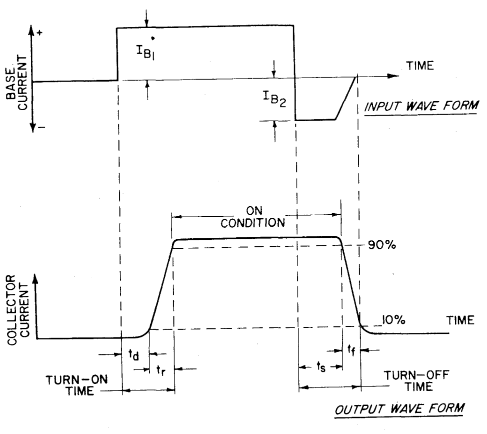


Fig. 22 - Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 21.)

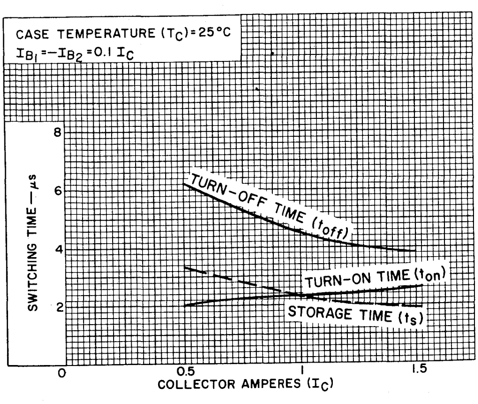


Fig. 23 - Typical saturated switching characteristics for types 2N5295 & 2N5296.

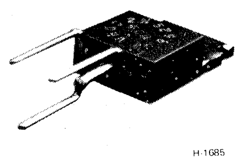
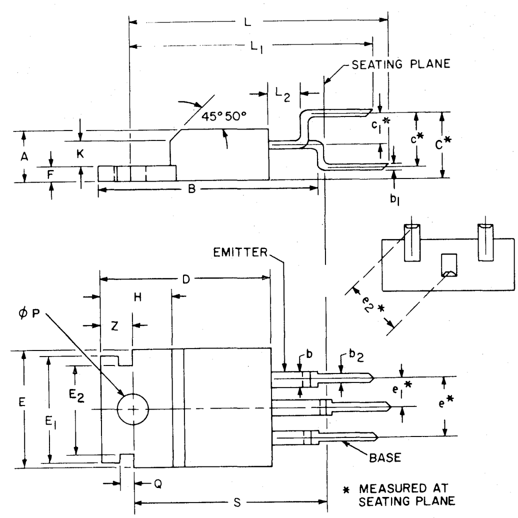


Fig. 24 - VERSAWATT package with optional lead configuration for printed-circiut-board mounting.



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS 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

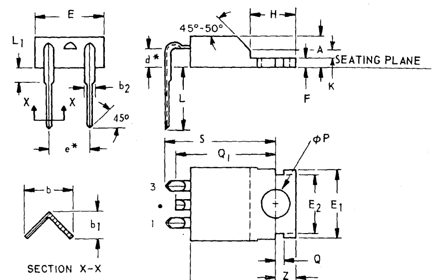
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
e_2	.203	.243	5.16	6.17
F	.045	.055	1.15	1.39
H	.230	.270	5.85	6.85
K	.080	.085	2.032	2.159
L	.993	1.033	25.22	26.23
L_1	.895	.935	22.73	23.74
L_2	.070	.090	1.78	2.28
ϕP	.139	.147	3.531	3.734
Q	.040	.060	1.02	1.52
S	.655	.685	16.64	17.39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

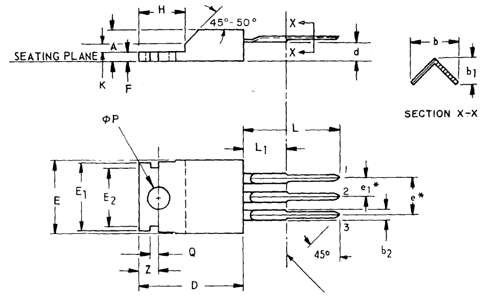
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured .050-.055 (1.27-1.40 mm) below seating plane.**

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	

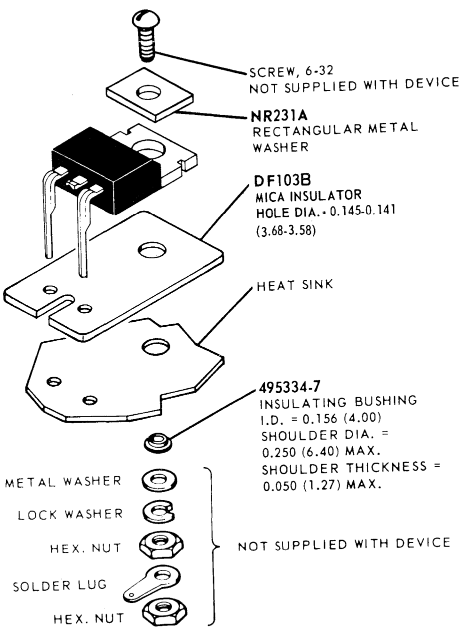
NOTES:

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

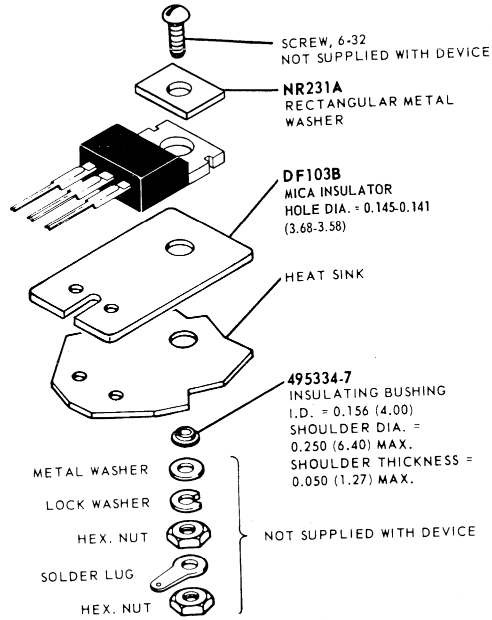
Lead No.1 - Base
Lead No.2 - Collector
Lead No.3 - Emitter
Mounting Flange - Collector



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 2N5492 2N5495
2N5491 2N5493 2N5496
2N5494 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.

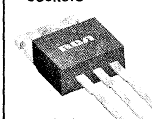
* Formerly RCA Dev. Nos. TA7317, TA7318, TA7315, TA7316, TA7313, TA7314, TA7311, TA7312, respectively.

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^o C Unless Otherwise Specified*

Characteristics	Symbols	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: Types 2N5496 2N5497 Min.	Max.	Types 2N5494 2N5495 Min.	Max.	Types 2N5492 2N5493 Min.	Max.	Types 2N5490 2N5491 Min.	Max.	Units
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^oC)	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^oC)	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	$^oC/W$
Junction-to-Ambient	θ_{J-A}						-	70	-	70	-	70	-	70	$^oC/W$

[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.

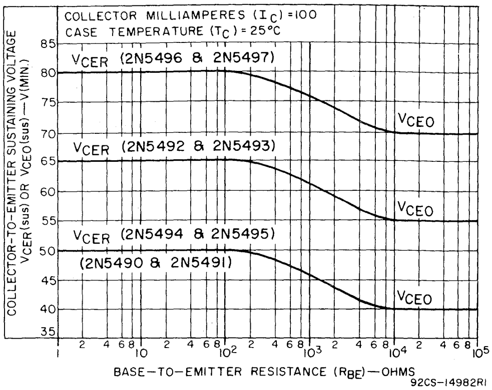


Fig.1 - Collector-to-emitter sustaining voltage characteristics for types 2N5490 through 2N5497 inclusive.

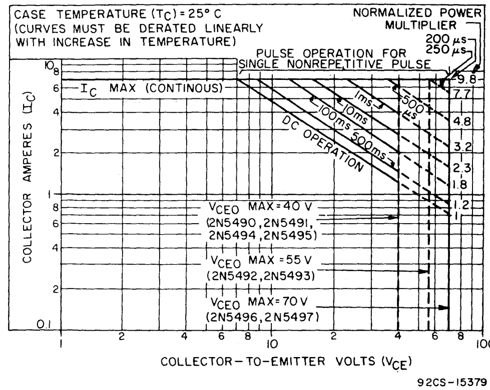


Fig.2 - Maximum operating areas for types 2N5490 through 2N5497 inclusive.

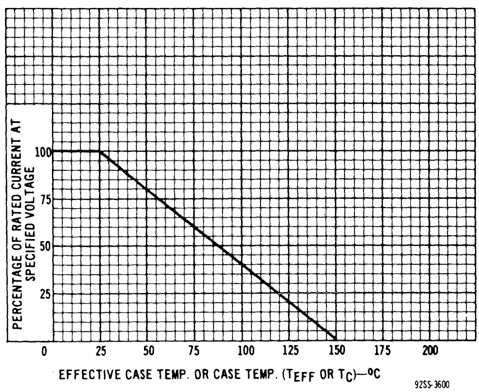


Fig.3 - Dissipation derating curve for types 2N5490 through 2N5497 inclusive.

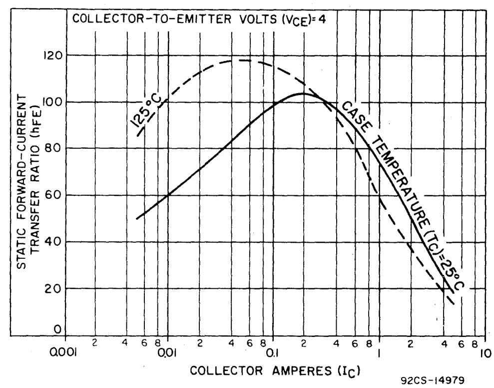


Fig.4 - Typical static beta characteristics for types 2N5496 and 2N5497.

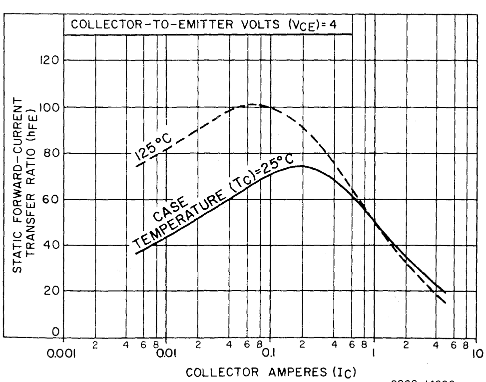


Fig.5 - Typical static beta characteristics for types 2N5494 and 2N5495.

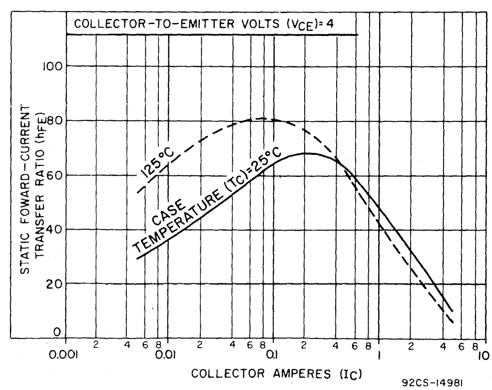


Fig.6 - Typical static beta characteristics for types 2N5490 through 2N5493 inclusive.

FORWARD-BIAS OPERATION

All transistors are power-dissipation limited and possibly second-breakdown limited. For a complete discussion of maximum operating area, refer to "RCA Silicon Power Circuits Manual" (SP-50) under sections: "MAXIMUM RATINGS" (page 68); "THERMAL CONSIDERATIONS" (page 70); "SECOND-BREAKDOWN" (page 84); and "SAFE-AREA RATINGS" (page 91).

When the emitter-base junction is forward-biased for transistor operation in the active region, the operating collector-to-emitter voltage, duration of the applied voltage, and transistor temperature determine whether the device is second-breakdown limited.

The maximum-area-of-operation curves, Fig.2, show the dc and pulse current derating curves applicable to these transistors at a case temperature of 25°C. The portions of the curves in which the slope is equal to -1 on these logarithmic plots indicate the regions where the devices are thermally limited (i.e., maximum allowable power dissipation does not vary with voltage). The curves shown in Fig.2 must be derated linearly with increasing case temperature as shown in Fig.3.

Steady State. The maximum steady-state dissipation capability P_{SS} depends on the total thermal resistance from the transistor junction to the thermal ambient $\theta_{J\text{-}A}$, the maximum junction temperature $T_J(max)$, and the ambient temperature T_A. These factors may be combined in the following equation:

$$P_{SS} = \frac{T_J(max) - T_A}{\theta_{J\text{-}A}} \quad (1)$$

where $\theta_{J\text{-}A}$, the thermal resistance from junction to ambient, is the sum of the thermal resistances from junction to case $\theta_{J\text{-}C}$, case to heat sink $\theta_{C\text{-}S}$, and heat sink to ambient $\theta_{S\text{-}A}$. When the case temperature, T_C, is known, Eq.(1) may be written in the following form:

$$P_{SS} = \frac{T_J(max) - T_C}{\theta_{J\text{-}C}} \quad (2)$$

The maximum specified junction temperature for these transistors is 150°C, and the maximum specified thermal resistance $\theta_{J\text{-}C}$ is 2.5°C/W. For these conditions, the maximum steady-state dissipation is 50 watts at a case temperature of 25°C. This value must be derated linearly with increasing case temperature.

Non-Repetitive Pulse. Reference to Figs.2 and 3 can facilitate direct calculation of the maximum dissipation limits when only a single non-repetitive pulse condition occurs. The recommended procedure for establishing the maximum dissipation is as follows: First, the temperature derating factor (TDF) is determined from the dissipating derating curve in Fig.3 for the case temperature T_C. The normalized power multiplier M is then obtained from Fig.2 for the pulse duration employed. The maximum power for single-pulse operation (P_{SP}) may then be calculated from the following equation:

$$P_{SP} = M\,(TDF)\,P_T \quad (3)$$

where P_T is the maximum power dissipation capability at 25°C case temperature. This equation may also be written in the following form:

$$P_{SP} = M\left[\frac{T_J(max) - T_C}{\theta_{J\text{-}C}}\right] \quad (4)$$

Repetitive-Pulse Operation. The collector-current limits shown in the maximum-operating-area curves of Fig.2 must be reduced when repetitive pulses are applied because of the rise in case temperature (caused by average power dissipation) and the heat energy stored in the thermal capacitance of the transistor pellet and header. The amount of current derating is determined by the slope of the dissipation derating curve, Fig.3, where T_{EFF} is the effective case temperature produced by the pulses.

For repetitive-pulse operation, the average power dissipation (P_{AVG}) in the transistor may be determined from the following relationship:

$$P_{AVG} = P_{PK}\,(\text{duty factor}) \quad (5)$$

where P_{PK} is the peak power.

The recommended procedure for establishing the maximum dissipation for repetitive-pulse operation is as follows: The normalized power multiplier (M) is determined from Fig.2 for the pulse duration employed. The peak power for repetitive pulses $(P_{RP})_{PK}$ may then be calculated from the following equation:

$$(P_{RP})_{PK} = \frac{M\,[T_J(max) - T_A]}{(\theta_{J\text{-}C} + M)\,(\text{duty factor})\,\theta_{J\text{-}A}} \quad (6)$$

In many applications, the heat sink may be held at a fixed temperature independent of the power dissipated in the device under consideration. In this instance, the effective case temperature may be calculated from the following equation:

$$T_{EFF} = T_C + P_{PK}\,(\text{duty factor})\,\theta_{J\text{-}C} \quad (7)$$

The recommended procedure for establishing the maximum dissipation for repetitive-pulse operation under these conditions is as follows: First, the temperature derating factor (TDF) is determined from the dissipating derating curve in Fig.3 for the case temperature T_C. The normalized power multiplier M is then obtained from Fig.2 for the pulse duration employed. The peak power may then be calculated from the following equation:

$$(P_{RP})_{PK} = M\,(TDF)\,P_T \quad (8)$$

where P_T is the maximum power dissipation capability at 25°C case temperature.

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.

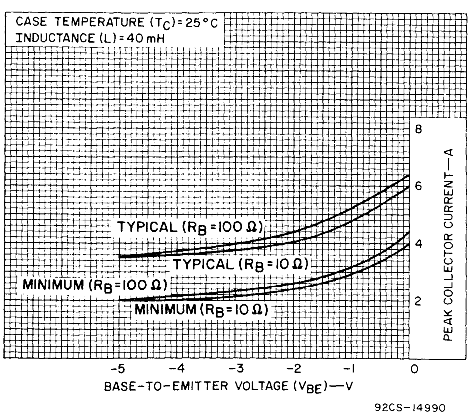


Fig.7 - Reverse-Bias, Second-Breakdown Characteristics for Types 2N5490 through 2N5497 inclusive.

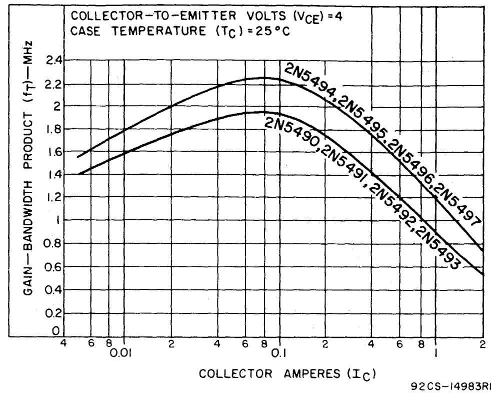


Fig.8 - Typical gain-bandwidth product for types 2N5490 through 2N5497 inclusive.

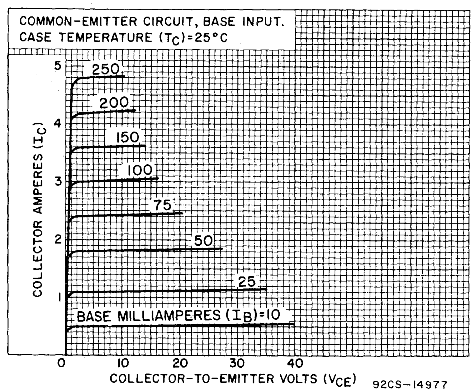


Fig.9 - Typical output characteristics for types 2N5494 through 2N5497 inclusive.

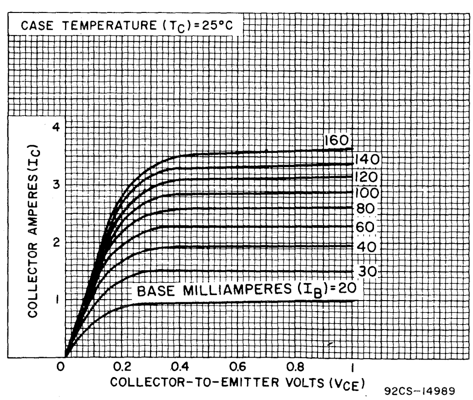


Fig.10 - Typical output characteristics for types 2N5494 and 2N5495.

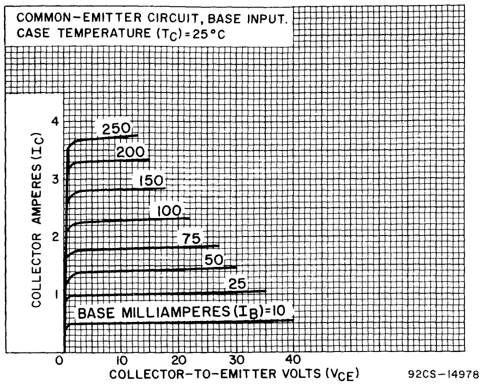


Fig.11 - *Typical output characteristics for types 2N5490 through 2N5493 inclusive.*

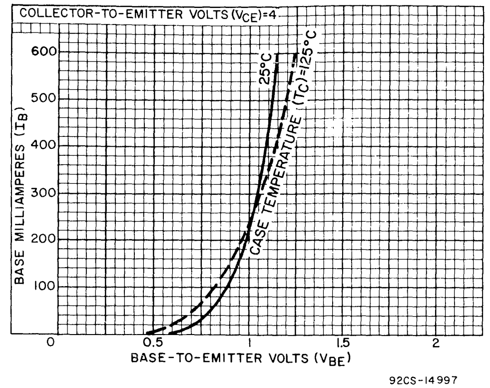


Fig.12 - *Typical input characteristics for types 2N5494 through 2N5497 inclusive.*

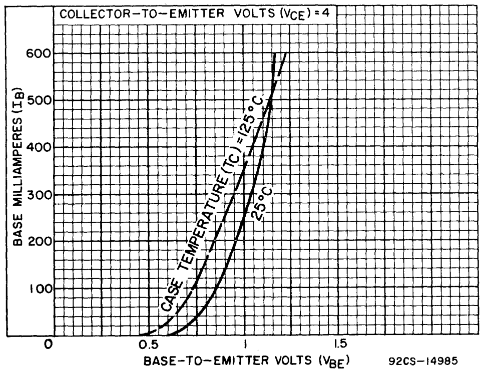


Fig.13 - *Typical input characteristics for types 2N5490 through 2N5493 inclusive.*

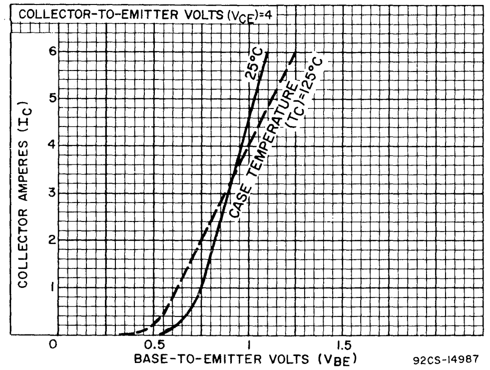


Fig.14 - *Typical transfer characteristics for types 2N5494 through 2N5497 inclusive.*

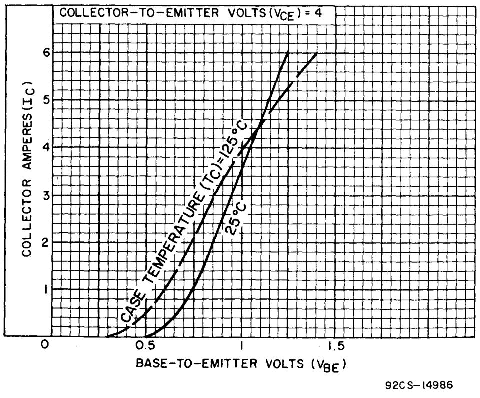


Fig.15 - *Typical transfer characteristics for types 2N5490 through 2N5493 inclusive.*

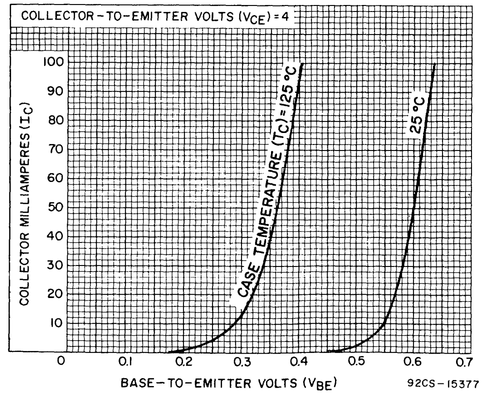


Fig.16 - *Typical transfer characteristics for types 2N5490 through 2N5497 inclusive.*

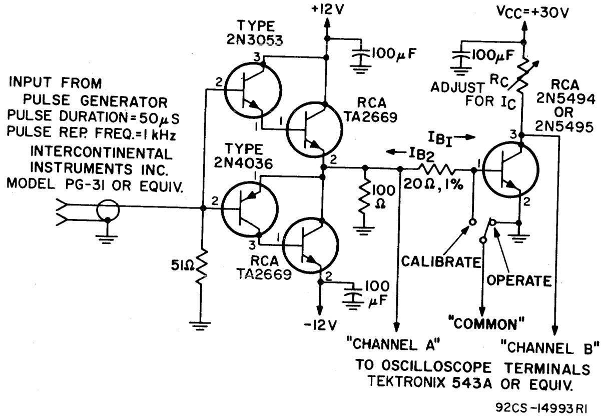


Fig.17 - Circuit used to measure switching times for types 2N5494 and 2N5495.

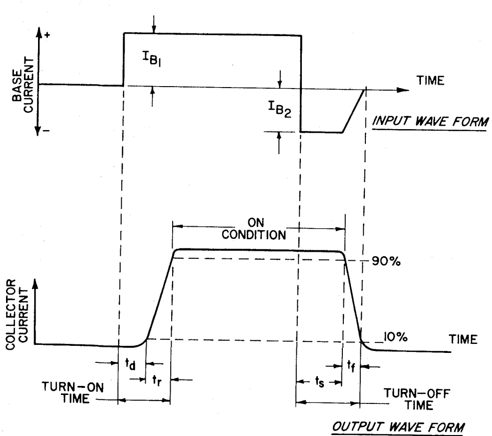


Fig.18 - Oscilloscope display for measurement of switching times (test circuit shown in Fig.17).

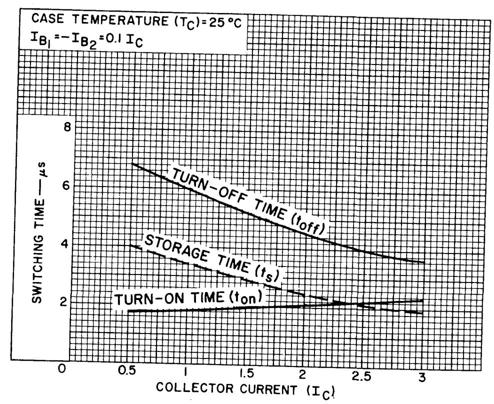


Fig.19 - Typical saturated switching characteristics for types 2N5494 and 2N5495.

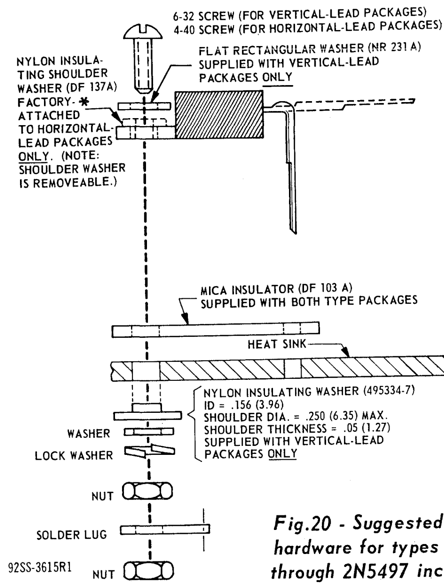


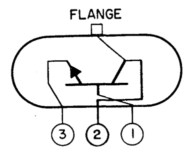
Fig.20 - Suggested mounting hardware for types 2N5490 through 2N5497 inclusive.

* Supplied on request.

TERMINAL CONNECTIONS

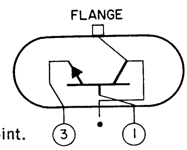
For Types 2N5490, 2N5492, 2N5494, 2N5496

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

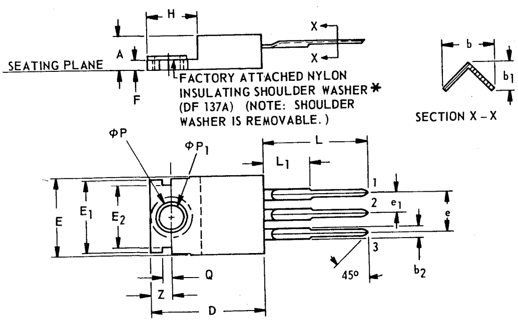


For Types 2N5491, 2N5493, 2N5495, 2N5497

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



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

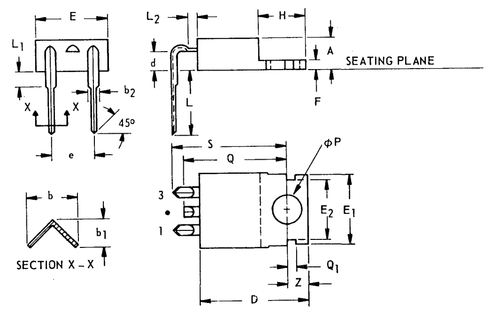


* Supplied on request.

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
2N5576 2N5579
2N5577 2N5580

RCA-2N5575, 2N5576, 2N5577, 2N5578, 2N5579 and 2N5580* are high-current, high-power, Hometaxial-base silicon n-p-n transistors. They differ in maximum voltage and current ratings and in terminal arrangement.

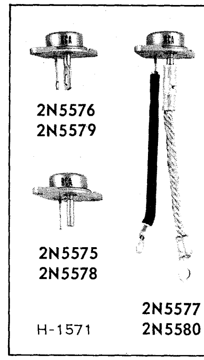
These power transistors are intended for a wide variety of high-current, high-power linear and switching applications such as low-to-medium-frequency amplifiers, switching and linear regulators, power-switching circuits, series- or shunt-regulator driver and output stages, dc-to-dc converters, inverters, 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, TA7415, TA7413, TA7017, TA7414, & TA7412, respectively.

Silicon N-P-N Power Transistors

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



Modified JEDEC TO-3

MAXIMUM RATINGS,
Absolute-Maximum Values:

		2N5575 2N5576 2N5577	2N5578 2N5579 2N5580	
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, 2N5576, & 2N5577)
  60 A continuous, 80 A peak (2N5578, 2N5579, & 2N5580)
- 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, 2N5576, & 2N5577
  40 A for 2N5578, 2N5579, & 2N5580
- Low Saturation Voltage at High Beta –
  V_{CE}(sat) = 2 V max. at h_{FE} = 10 (2N5575, 2N5576, & 2N5577)
  1.5 V max. at h_{FE} = 10 (2N5578, 2N5579, & 2N5580)
- 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: DC Collector Voltage (V) V_{CE}	V_{CB}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_B	I_E	Limits: Types 2N5575 2N5576 2N5577 Min.	Max.	Types 2N5578 2N5579 2N5580 Min.	Max.	Units
Collector-Cutoff Current:													
J 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)	θ_{J-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.

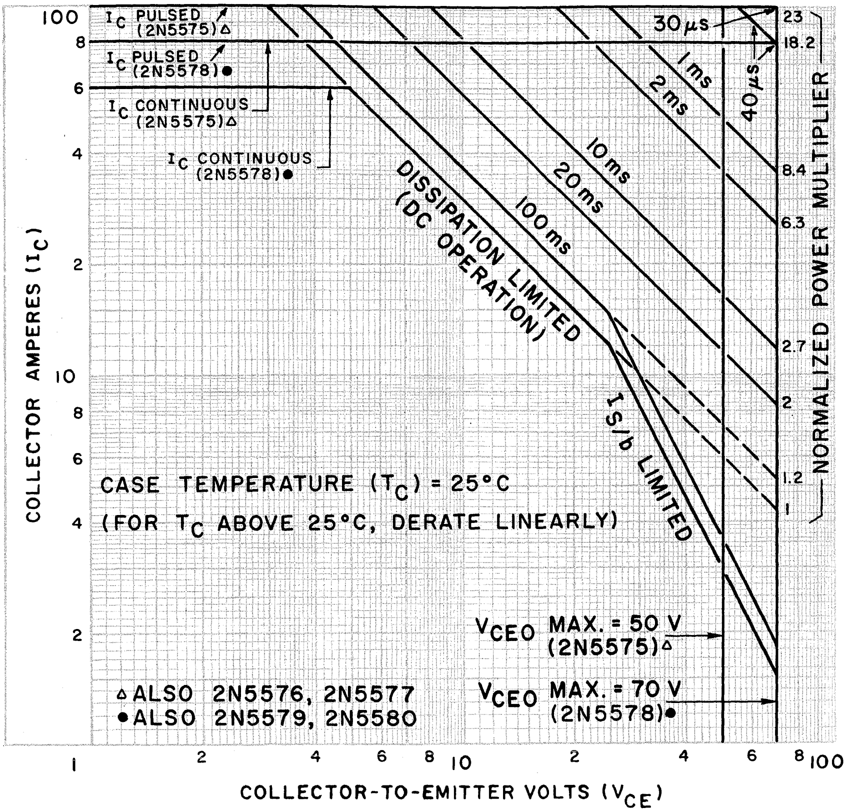


Fig. 1 - Maximum operating areas for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.

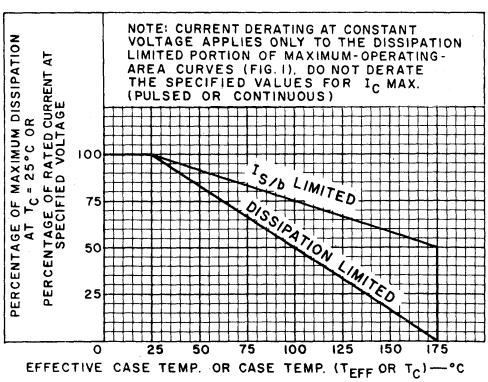


Fig. 2 - Dissipation derating curves for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.

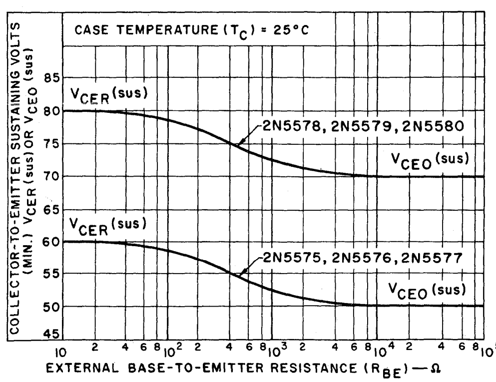


Fig. 3 - Collector-to-emitter sustaining voltage characteristics for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.

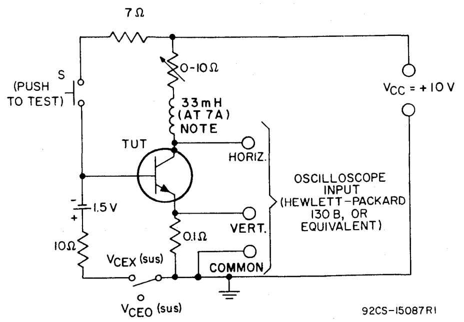
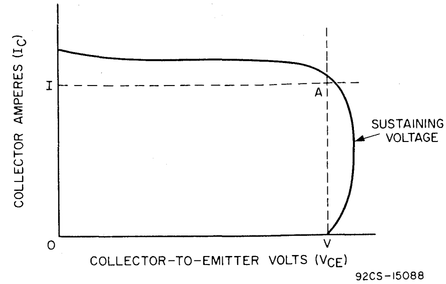


Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ & $V_{CEX}(sus)$ for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.



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).

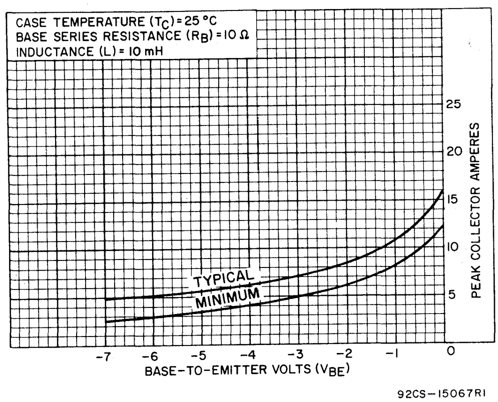


Fig. 6 - Reverse-bias, second-breakdown characteristics for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.

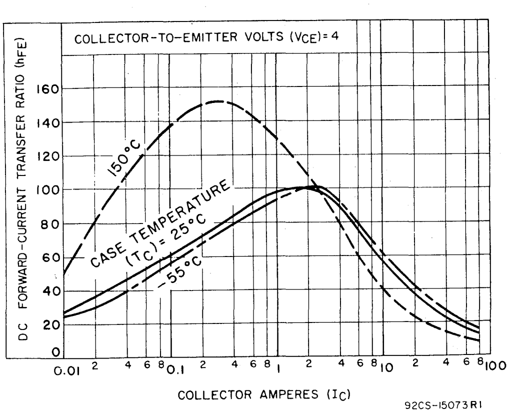


Fig. 7 - Typical dc beta characteristics for types 2N5575, 2N5576, & 2N5577.

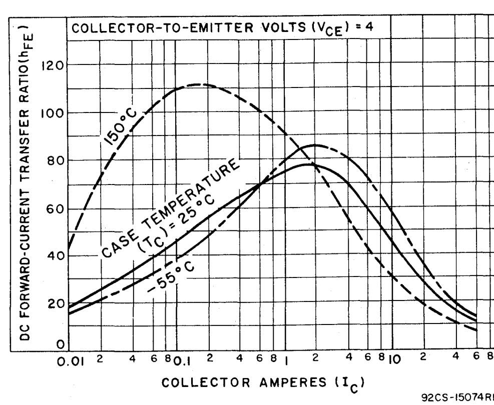


Fig. 8 - Typical dc beta characteristics for types 2N5578, 2N5579, & 2N5580.

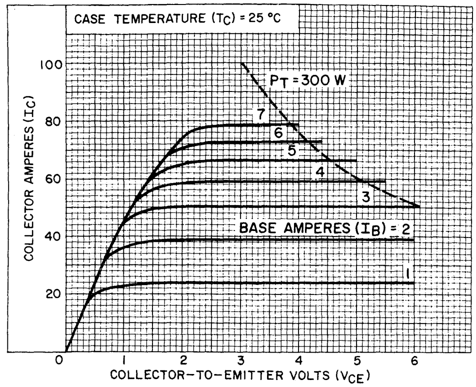


Fig. 9 - Typical output characteristics for types 2N5575, 2N5576, & 2N5577.

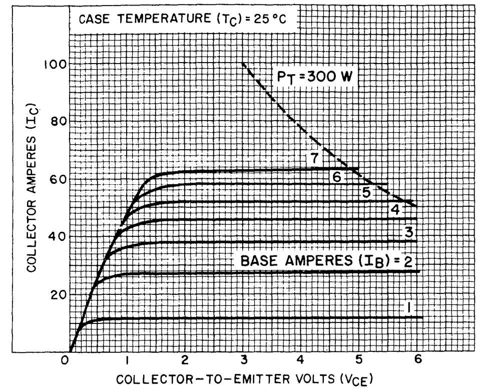


Fig. 10 - Typical output characteristics for types 2N5578, 2N5579, & 2N5580.

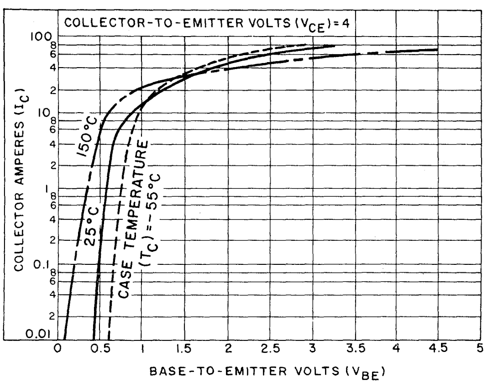


Fig. 11 - Typical transfer characteristics for types 2N5575, 2N5576, & 2N5577.

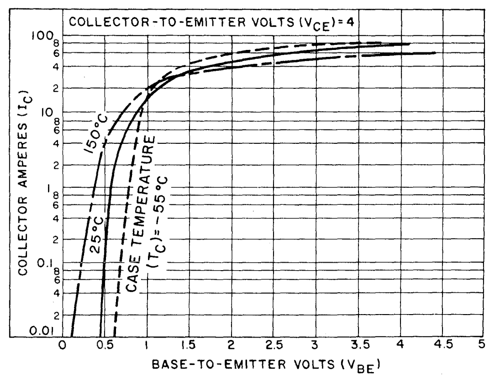


Fig. 12 - Typical transfer characteristics for types 2N5578, 2N5579, & 2N5580.

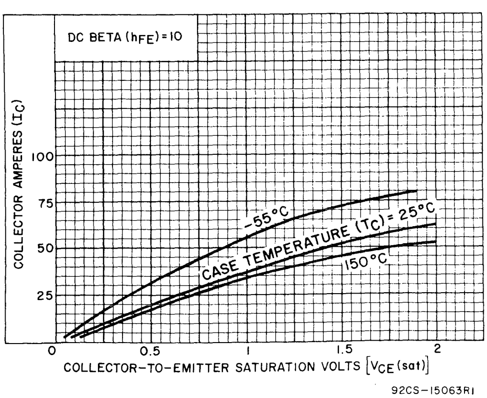


Fig. 13 - Typical saturation voltage characteristics for types 2N5575, 2N5576, & 2N5577.

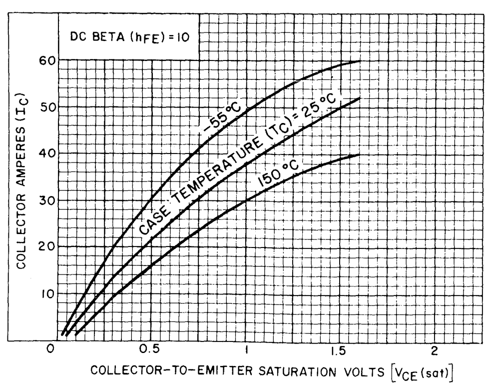


Fig. 14 - Typical saturation voltage characteristics for types 2N5578, 2N5579, & 2N5580.

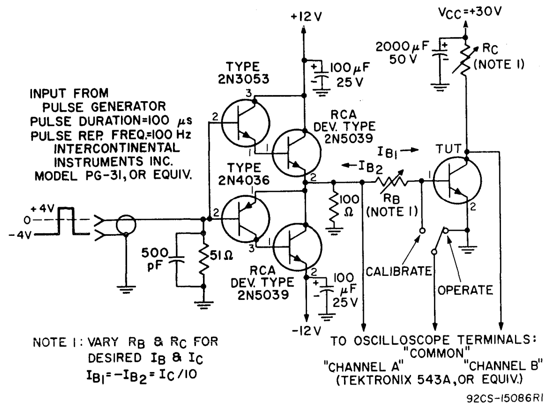


Fig. 15 - Circuit used to measure switching times for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.

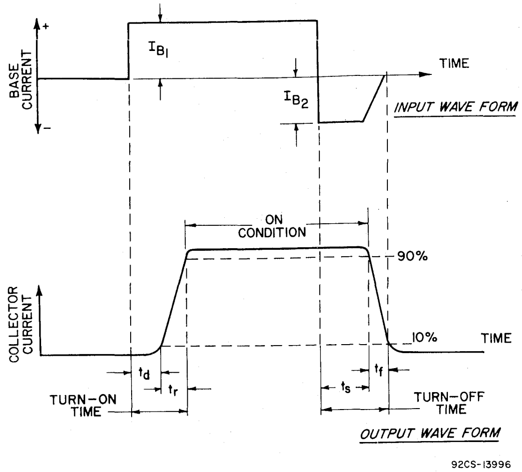


Fig. 16 - Oscilloscope display for measurement of switching times (Test circuit shown in Fig. 15).

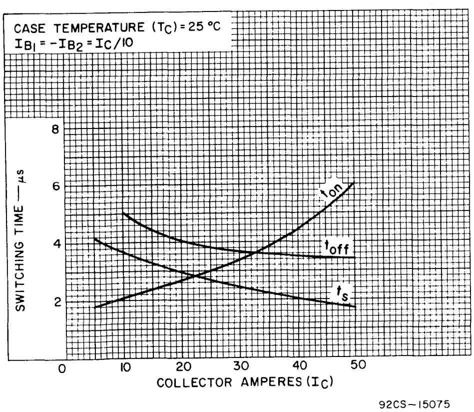
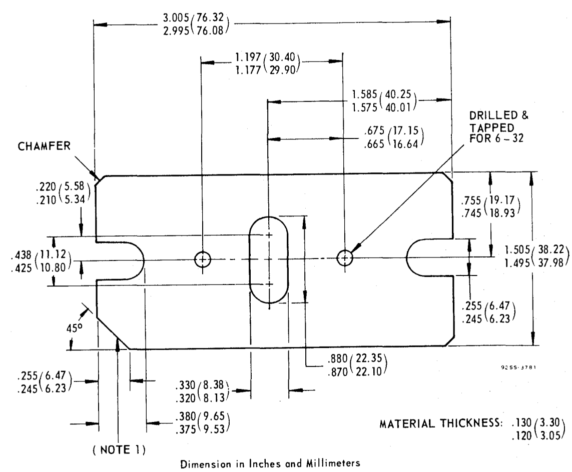


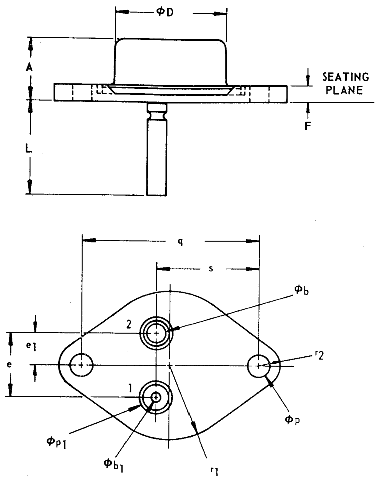
Fig. 17 - Typical saturated switching characteristics for types 2N5575, 2N5576, 2N5577, 2N5578, 2N5579, & 2N5580.



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.

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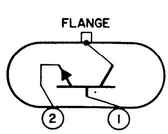
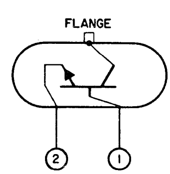
TERMINAL CONNECTIONS

FOR TYPES 2N5575, 2N5576 2N5578, & 2N5579



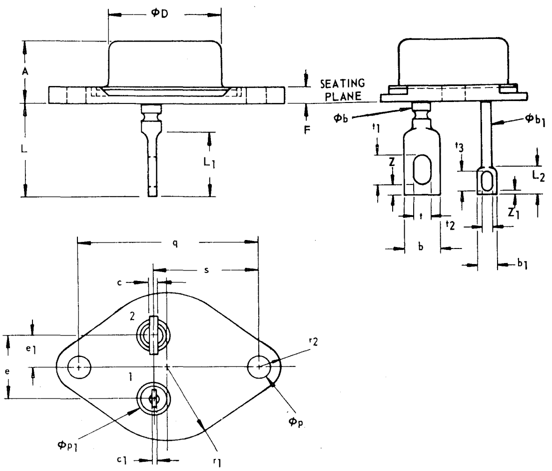
Pin (or Lug) 1 — Base
Pin (or Lug) 2 — Emitter
Mounting Flange — Collector

FOR TYPES 2N5577 & 2N5580



Lead 1 — Base
Lead 2 — Emitter
Mounting Flange — Collector

DIMENSIONAL OUTLINE FOR TYPES 2N5576 & 2N5579



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.416	.450	10.57	11.43	
b	.255	.270	6.48	6.85	
b_1	.105	.115	2.67	2.92	
Φb	.147	.153	3.734	3.886	
$Φb_1$	.059	.061	1.499	1.549	
c	.055	.065	1.40	1.65	
c_1	.025	.030	.635	.762	
ΦD	.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	—	.700	—	17.78	
L_1	.395	.405	10.04	10.28	1
L_2	.155	.165	3.94	4.19	1
Φp	.151	.161	3.84	4.09	
$Φp_1$	.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	
t	.110	.115	2.794	2.921	
t_1	.220	.230	5.59	5.84	
t_2	.057	.063	1.448	1.600	
t_3	.110	.120	2.80	3.04	
Z	.069	.094	1.76	2.38	
Z_1	.020	.030	.51	.76	

NOTES:
1. FLAT OF LUG.
2. CLEARANCE HOLE FOR BOTH LUGS SHOULD BE 0.285 in. (7.24 mm) **MIN. DIA.**

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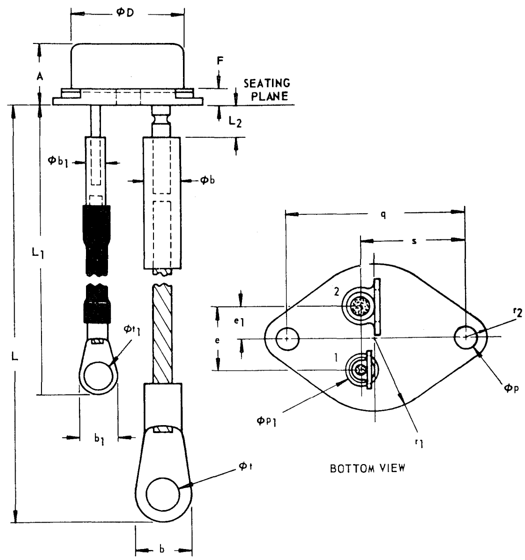
DIMENSIONAL OUTLINE FOR TYPES 2N5577 & 2N5580



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.416	.450	10.57	11.43	
b	.375	.500	9.53	12.70	1
b_1	.250	.375	6.35	9.52	1
Φb	.280	.290	7.12	7.36	2
$Φb_1$	.150	.160	3.81	4.06	2
ΦD	.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	3.75	4.25	95.25	107.95	3
L_1	3.25	3.75	82.55	95.25	4
L_2	.195	—	4.96	—	
Φp	.151	.161	3.84	4.09	
$Φp_1$	.280	.285	7.112	7.239	
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	
Φt	—	—	—	—	5
$Φt_1$	—	—	—	—	6

NOTES:
1. CLEARANCE HOLE THROUGH HEAT-SINK FOR BOTH FLEXIBLE LEADS SHOULD BE A SLOT MEASURING: 0.875 in. (22.22 mm) LONG BY 0.325 in. (8.25 mm) WIDE.
2. SOLDERLESS BUTT CONNECTOR.
3. FLEXIBLE LEAD.
4. FLEXIBLE LEAD WITH INSULATING TUBING.
5. SOLDERLESS LUG FOR NO. 10 SCREW.
6. SOLDERLESS LUG FOR NO. 6 SCREW.

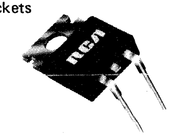
92SS-3773

RCA

Solid State
Division

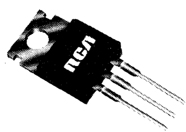
Power Transistors
2N6098 2N6099 2N6100 2N6101 2N6102 2N6103

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	-	
* 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	$\theta_{J\text{-}C}$					-	1.67	-		-	1.67	°C/W
Junction-to-Ambient	$\theta_{J\text{-}A}$					-	70	-		-	70	

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

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

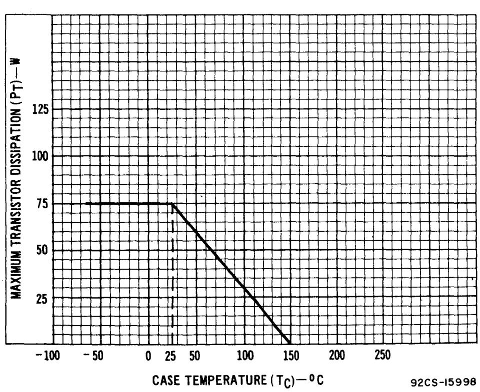


Fig. 1—Derating curve for all types.

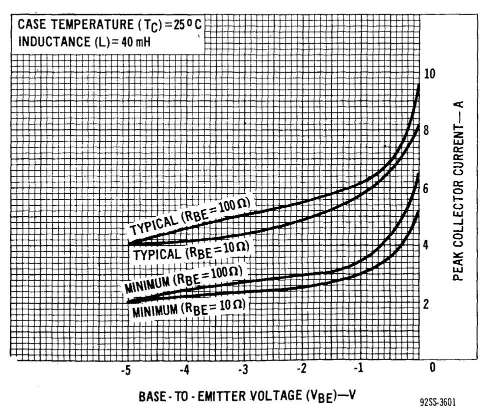


Fig. 2—Reverse-bias, second-breakdown characteristics for all types.

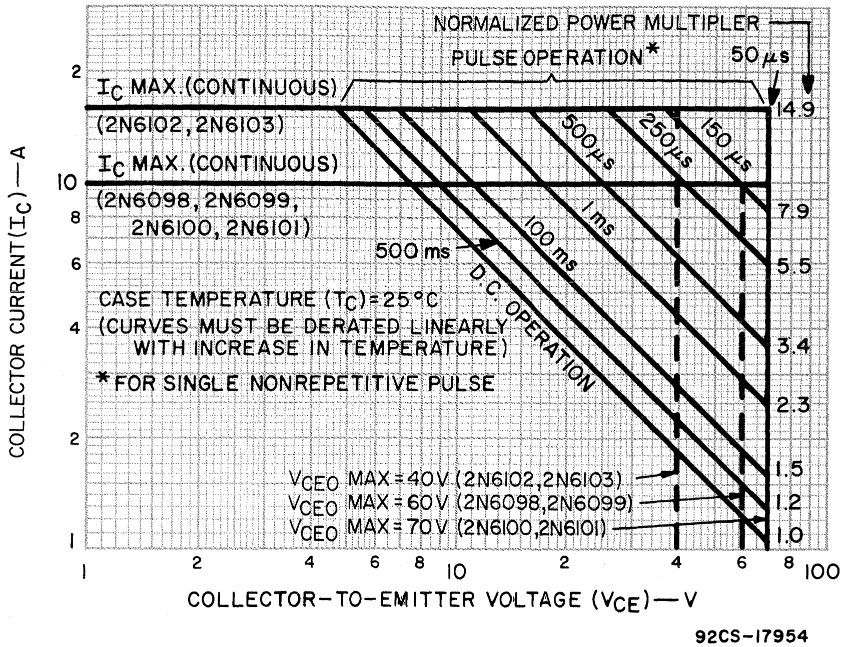


Fig.3—Maximum safe operating areas for all types.

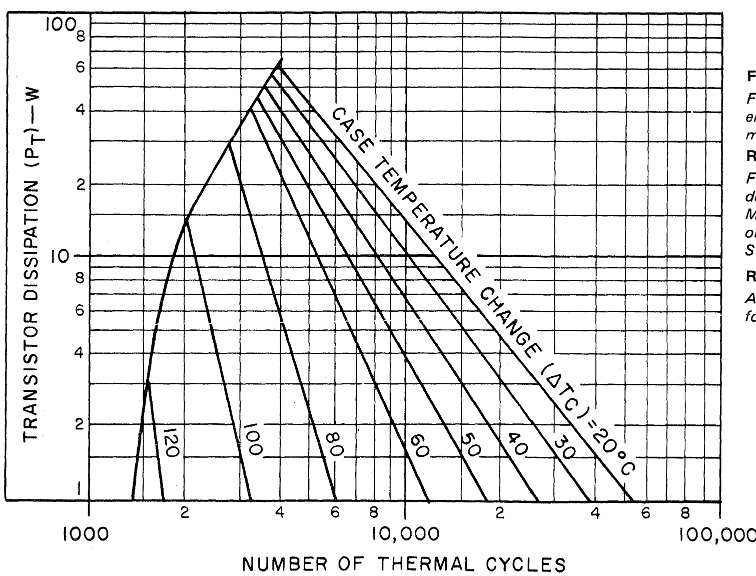


Fig.4—Thermal-cycling rating for all types.

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".

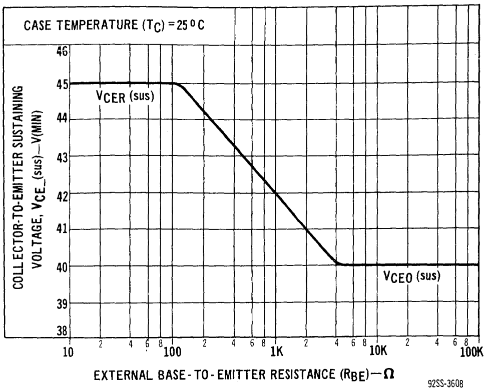


Fig.5—Sustaining voltage vs. base-to-emitter resistance for types 2N6102 & 2N6103.

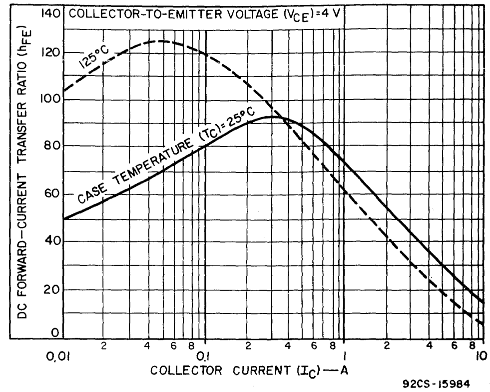


Fig.6—Typical dc beta characteristics for types 2N6102 & 2N6103.

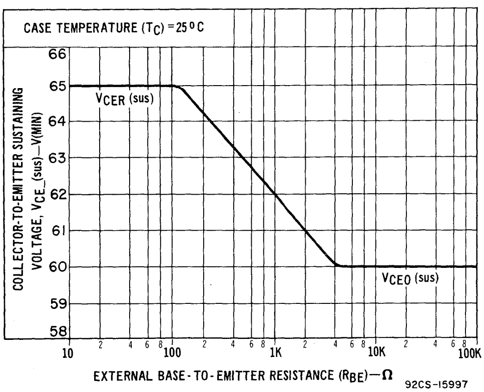


Fig.7—Sustaining voltage vs. base-to-emitter resistance for types 2N6098 & 2N6099.

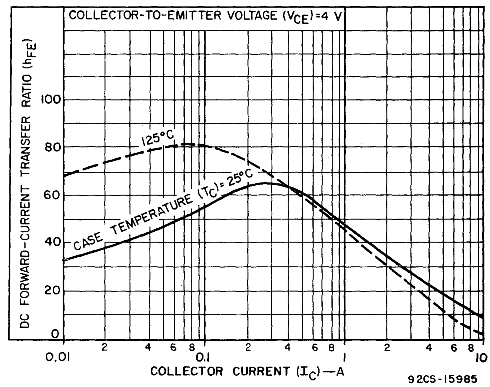


Fig.8—Typical dc-beta characteristics for types 2N6098 & 2N6099.

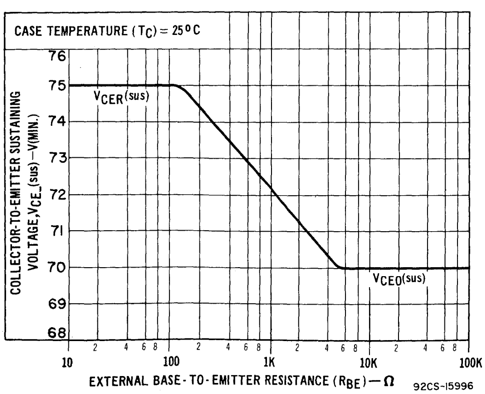


Fig.9—Sustaining voltage vs. base-to-emitter resistance for types 2N6100 & 2N6101.

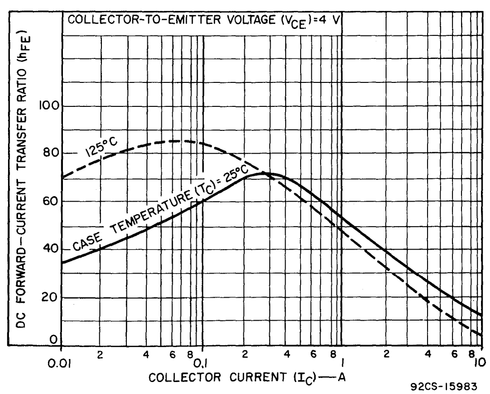


Fig.10—Typical dc beta characteristics for types 2N6100 & 6101.

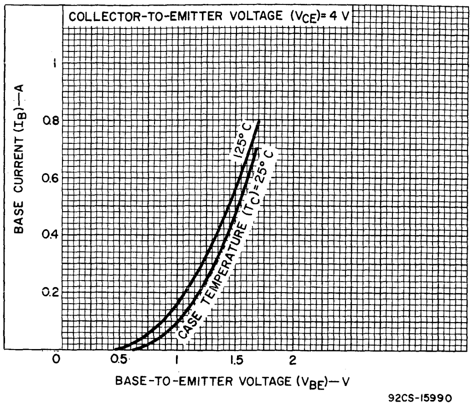


Fig. 11—Typical input characteristics for types 2N6102 & 2N6103.

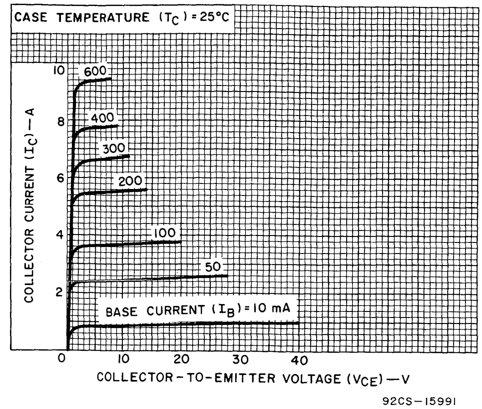


Fig. 12—Typical output characteristics for types 2N6102 & 2N6103.

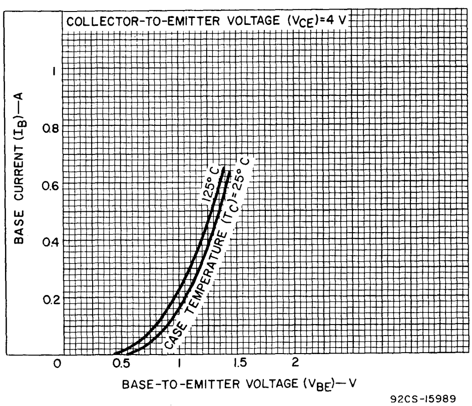


Fig. 13—Typical input characteristics for types 2N6098 & 2N6099.

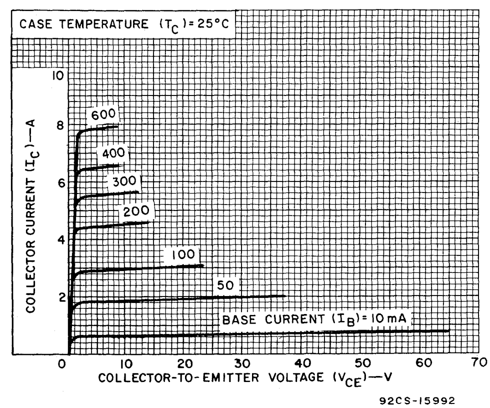


Fig. 14—Typical output characteristics for types 2N6098 & 2N6099.

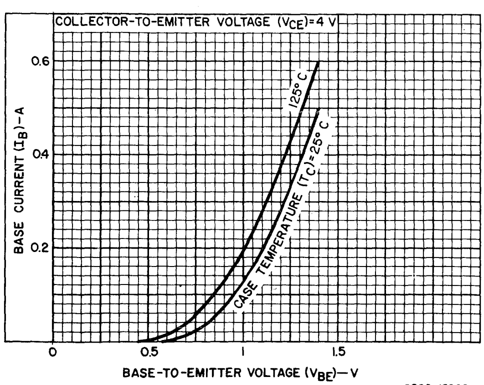


Fig. 15—Typical input characteristics for types 2N6100 & 2N6101.

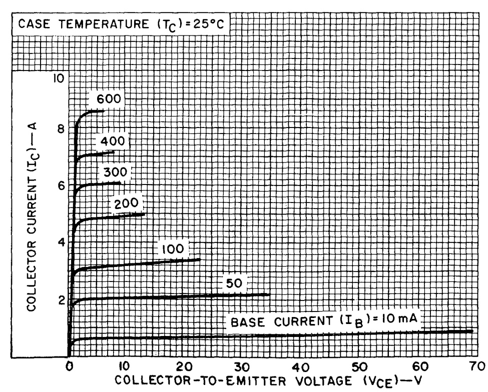


Fig. 16—Typical output characteristics for types 2N6100 & 2N6101.

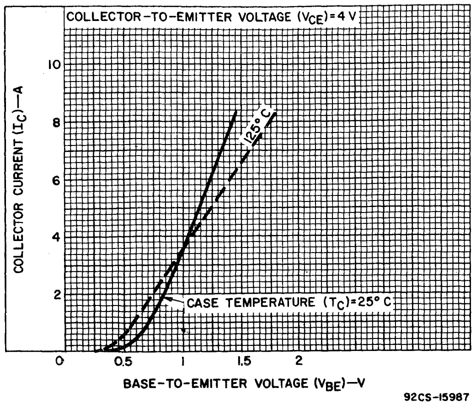


Fig. 17—Typical transfer characteristics for all types.

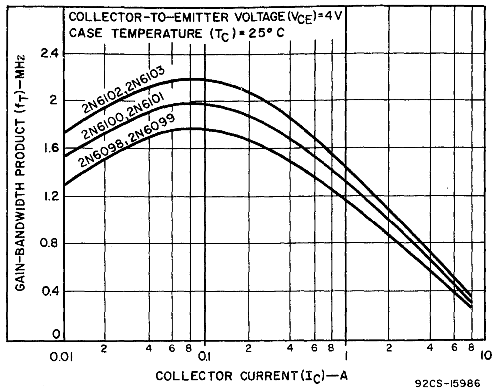


Fig. 18—Typical gain-bandwidth product for all types.

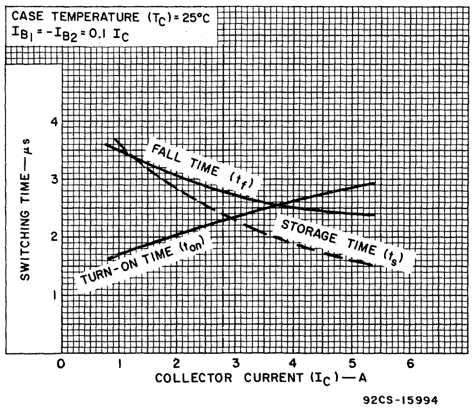
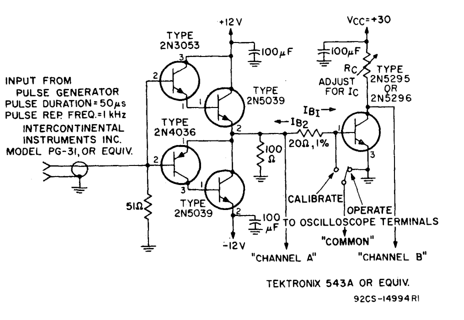


Fig. 19—Typical saturated switching characteristics for all types.



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.

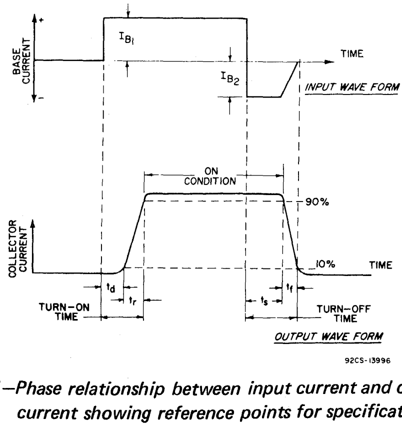
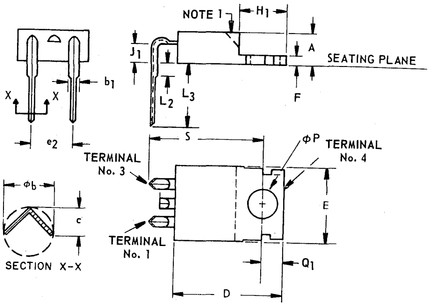


Fig. 21—Phase relationship between input current and output current showing reference points for specification of switching times. (Test circuit shown in Fig. 20).

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

JEDEC TO-220AA



SYMBOL	INCHES		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_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	

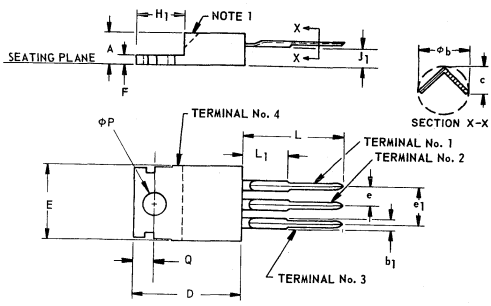
92CS-17990

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		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:

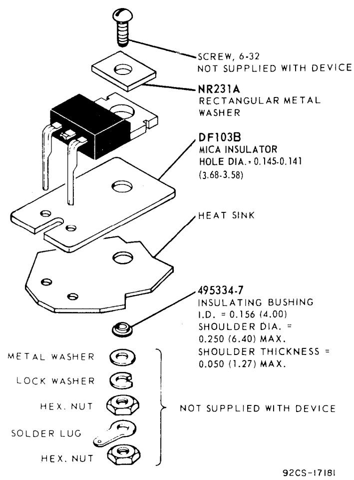
1. **Chamfer optional.**
2. **Tab contour optional within H and E.**
3. **Position of lead to be measured 0.250–0.255 (6.35–6.48 mm) from bottom of dimension D.**

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

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

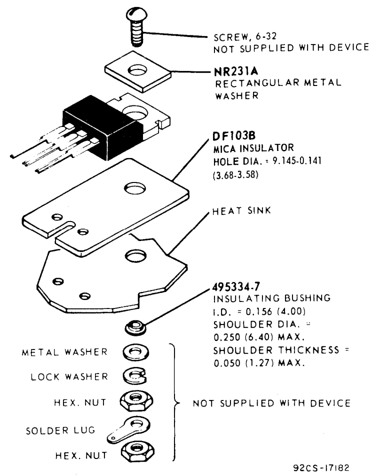
TERMINAL CONNECTIONS FOR TYPES 2N6099, 2N6101, 2N6103

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



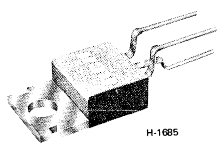
Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

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.



H-1685

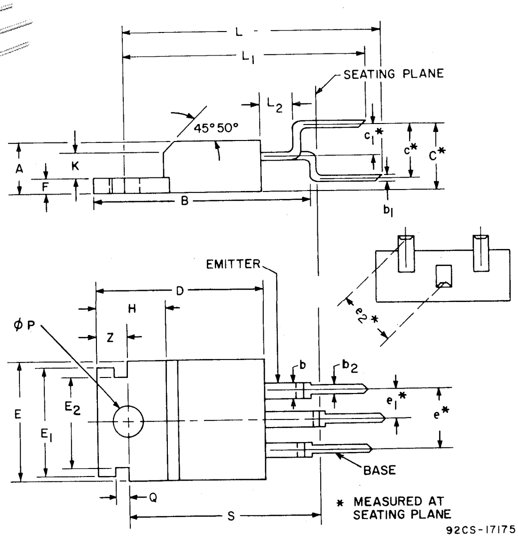


Fig.24–Dimensional outline of VERSAWATT transistor package designed for mounting on printed-circuit boards.

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

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.**

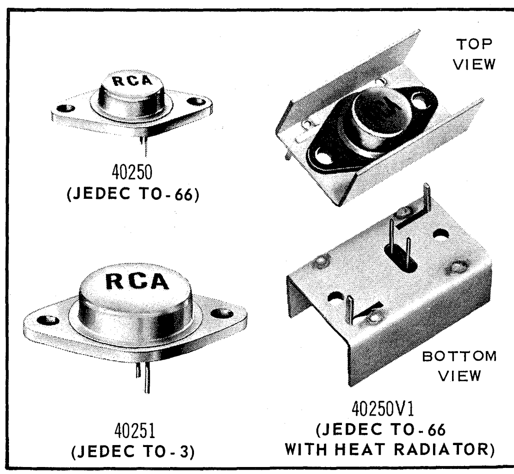
40251

- **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.



40250 (JEDEC TO-66)

40251 (JEDEC TO-3)

40250V1 (JEDEC TO-66 WITH HEAT RADIATOR)

MAXIMUM RATINGS

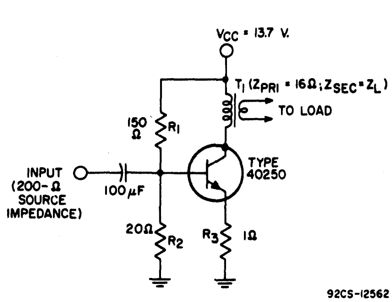
Absolute-Maximum Values:	*40250*	*40250V1*	*40251*	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	50	50	50	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With 1.5 volts of reverse bias, V_{CEV}	50	50	50	V
With base open, V_{CEO}	40	40	40	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5	5	5	V
COLLECTOR CURRENT, I_C	4	4	15	A
BASE CURRENT, 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

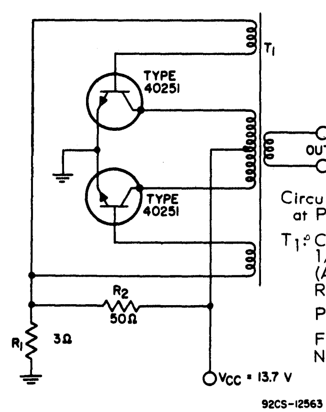
TYPICAL AUDIO-AMPLIFIER CIRCUIT FOR TYPE 40250



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

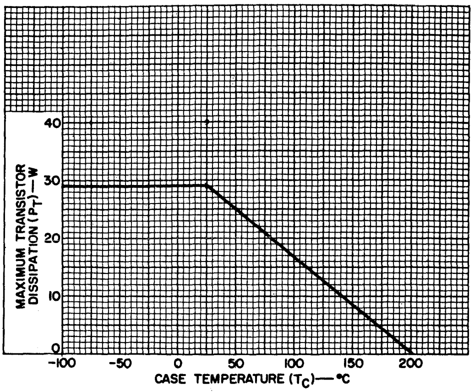


Fig.3 92CS-13005RI

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 40250 & 40250V1

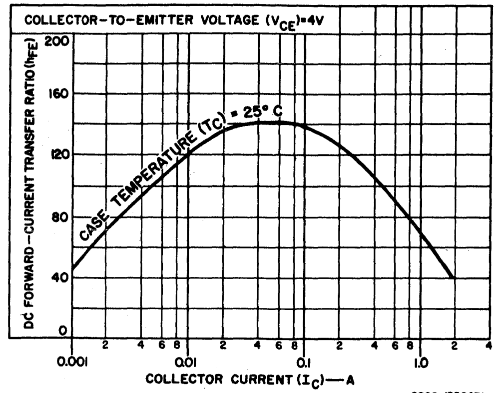


Fig.6 92CS-12564RI

DISSIPATION DERATING CURVE FOR TYPE 40250V1

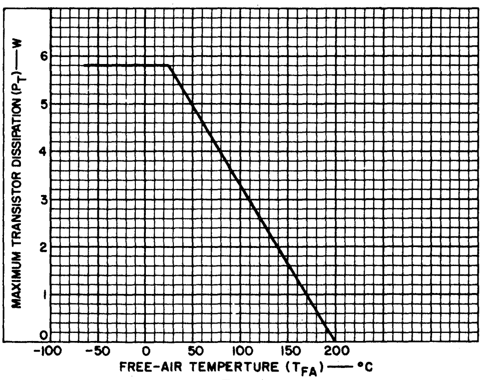


Fig.4 92CS-13373

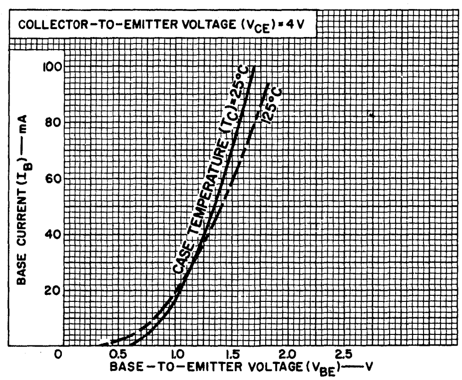


Fig.7 92CS-12305RI

DISSIPATION DERATING CURVE FOR TYPE 40251

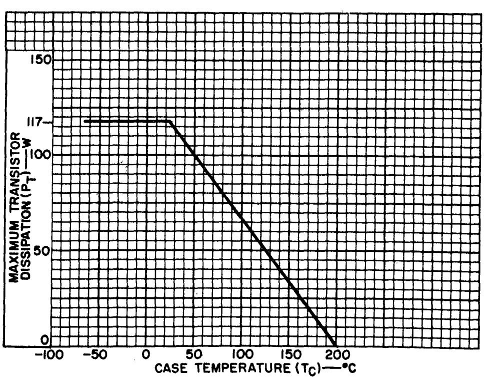


Fig.5 92CS-1303IRI

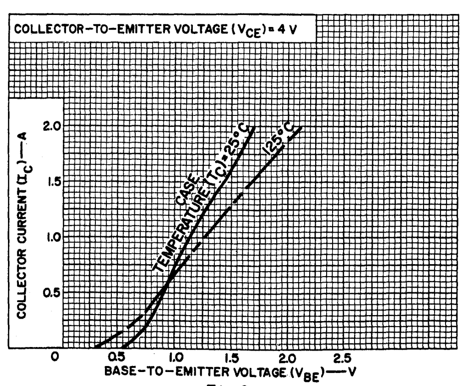


Fig.8 92CS-12325RI

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 40251

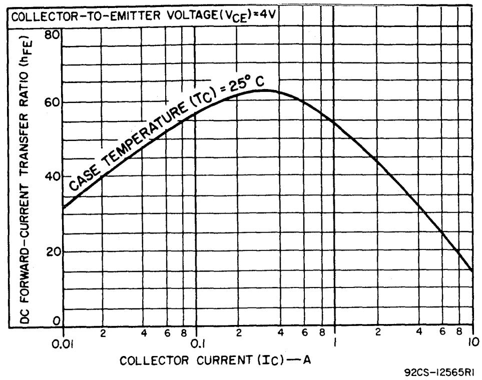


Fig.9

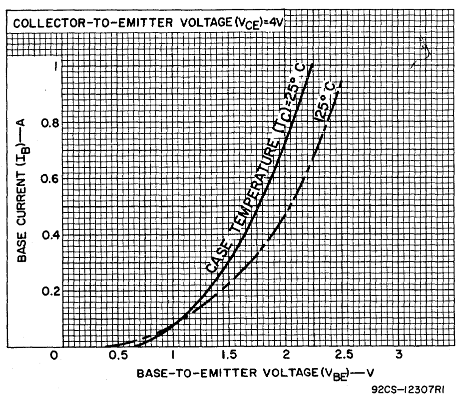


Fig.10

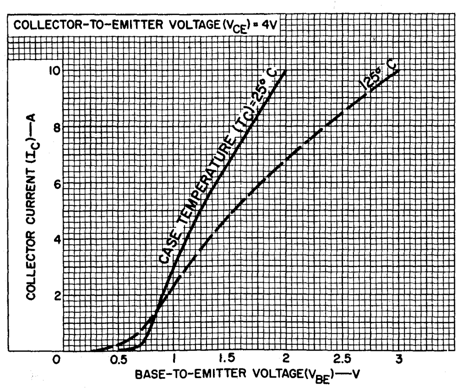
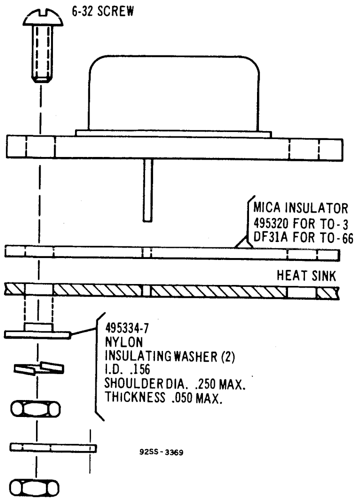


Fig.11

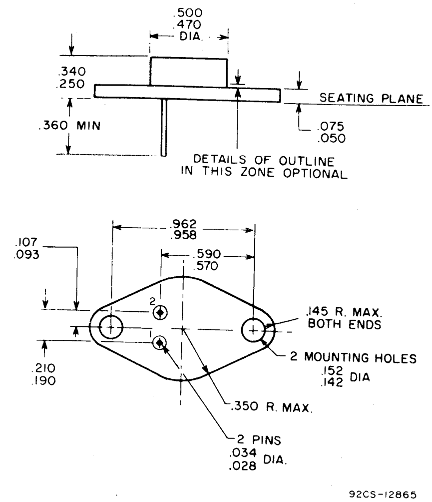
SUGGESTED MOUNTING ARRANGEMENT FOR TYPES 40250 & 40251



NOTE: Hardware With Part Numbers Supplied.

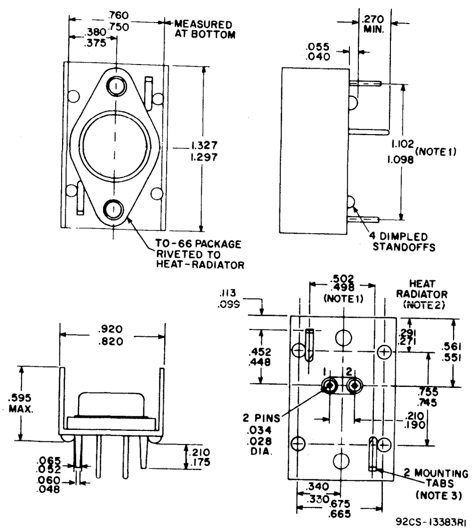
Fig.12

DIMENSIONAL OUTLINE FOR TYPE 40250 JEDEC No.TO-66



Dimensions in Inches

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



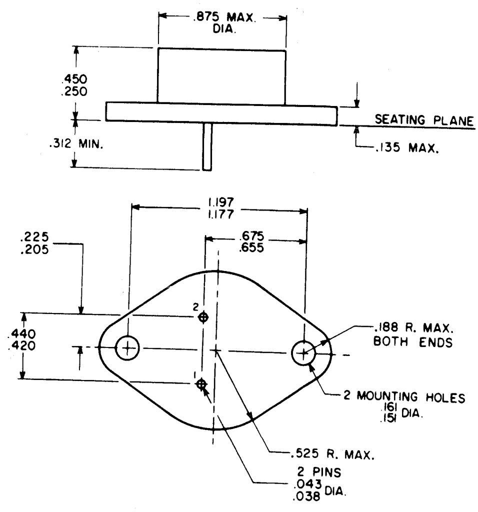
NOTE 1: Measured at bottom of heat-radiator.

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



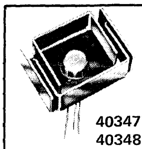
Dimensions in Inches

TERMINAL CONNECTIONS FOR TYPES 40250, 40250V1, & 40251

Pin 1 - Base
Pin 2 - Emitter
Flange, Case - Collector (For 40250 & 40251)
Heat Radiator - Collector (For 40250V1)

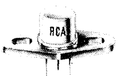
RCA
Solid State
Division

Power Transistors
40347
40348
40349



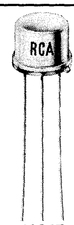
40347V1
40348V1
40349V1

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.	Type 40347 Max.	Type 40348 Min.	Type 40348 Max.	Type 40349 Min.	Type 40349 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		20(max.) 40348		20(max.) 40349		°C/W
							15(max.) 40347V2		15(max.) 40348V2		15(max.) 40349V2		
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%.

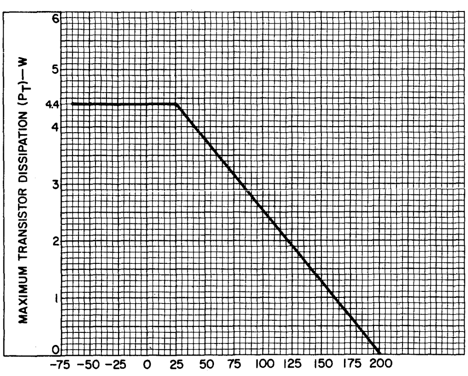


Fig. 1 - Dissipation derating curve for types 40347V1, 40348V1, and 40349V1.

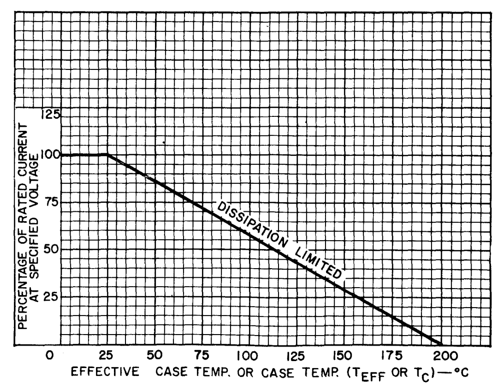


Fig. 2 - Dissipation derating curve for types 40347, 40348, and 40349.

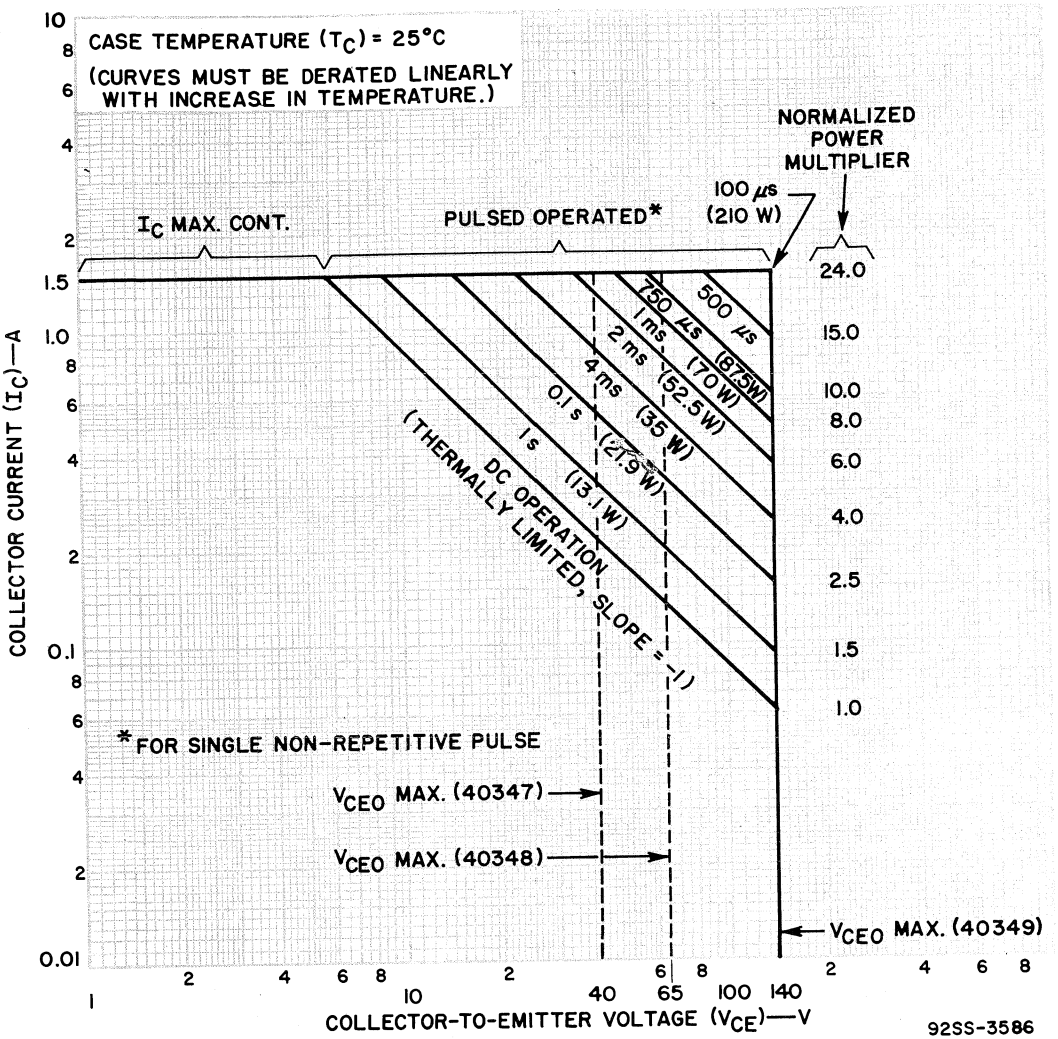


Fig. 3 - Maximum operating areas for types 40347, 40348 and 40349.

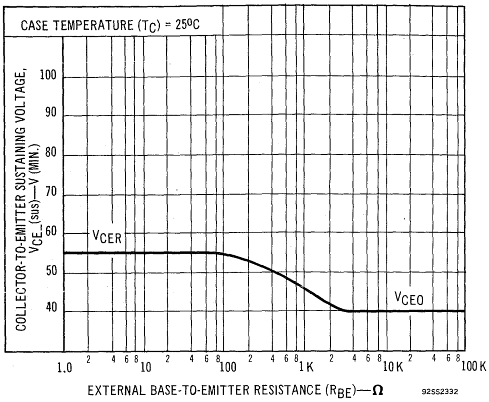


Fig. 4 - Sustaining voltage vs. base-to-emitter resistance for types 40347, 40347V1 and 40347V2.

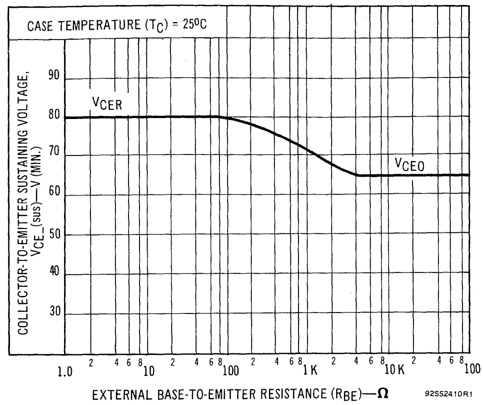


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for types 40348, 40348V1 and 40348V2.

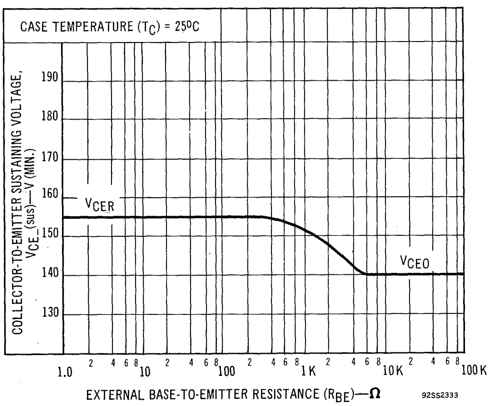


Fig. 6 - Sustaining voltage vs. base-to-emitter resistance for types 40349, 40349V1 and 40349V2.

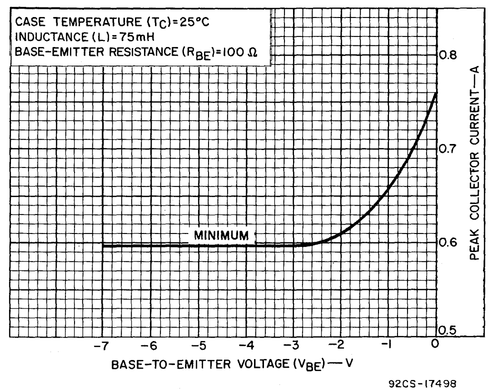


Fig. 7 - Reverse-bias second-breakdown characteristics for types 40347, 40348 and 40349.

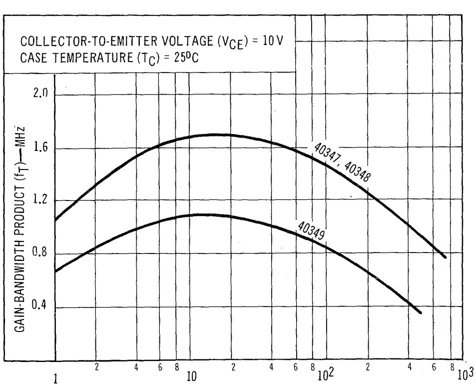


Fig. 8 - Typical gain-bandwidth product vs. collector current for types 40347, 40348 and 40349.

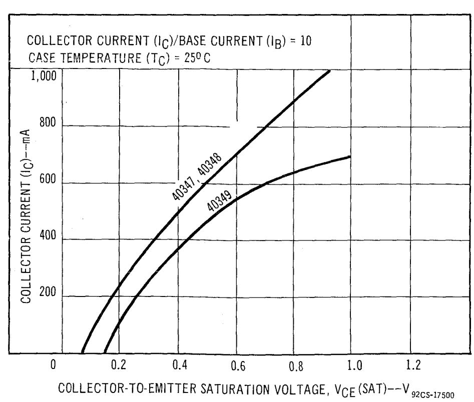


Fig. 9 - Typical saturation characteristic for types 40347, 40348 and 40349.

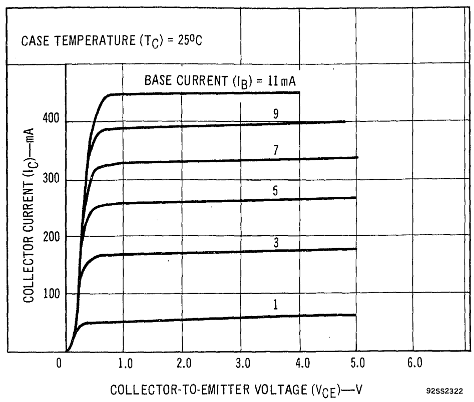


Fig. 10 - Typical output characteristics for type 40347.

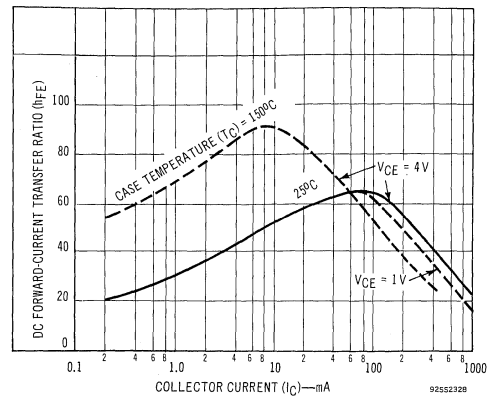


Fig. 11 - Typical dc beta characteristics for type 40347.

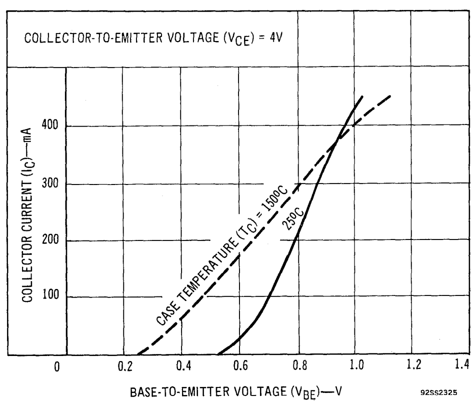


Fig. 12 - Typical transfer characteristics for type 40347.

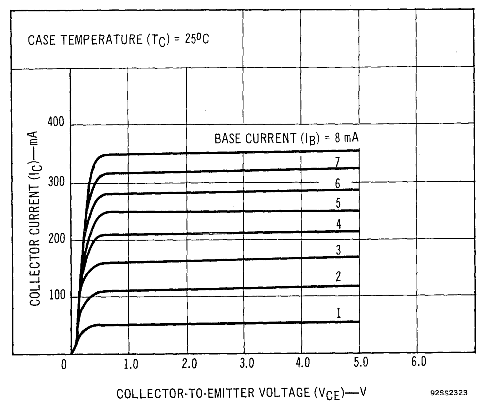


Fig. 13 - Typical output characteristics for type 40348.

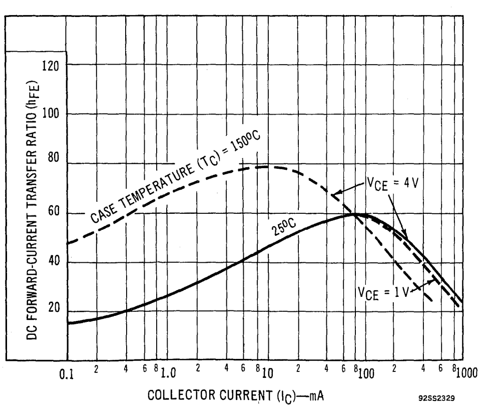


Fig. 14 - Typical dc beta characteristics for type 40348.

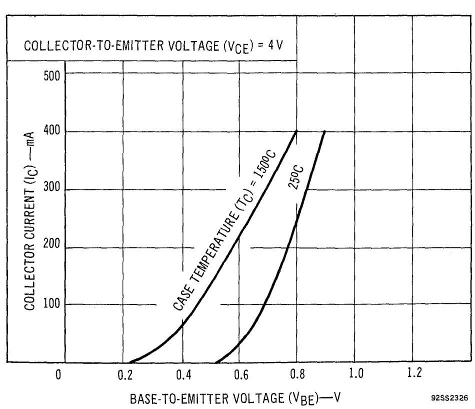


Fig. 15 - Typical transfer characteristics for type 40348.

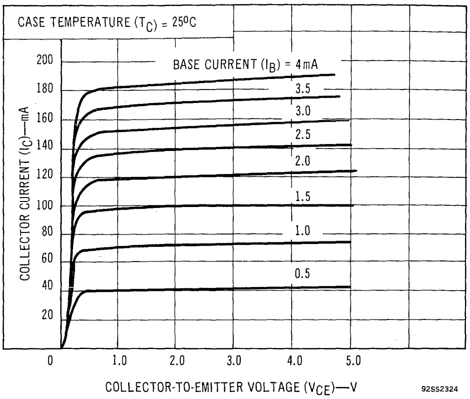


Fig. 16 - Typical output characteristics for type 40349.

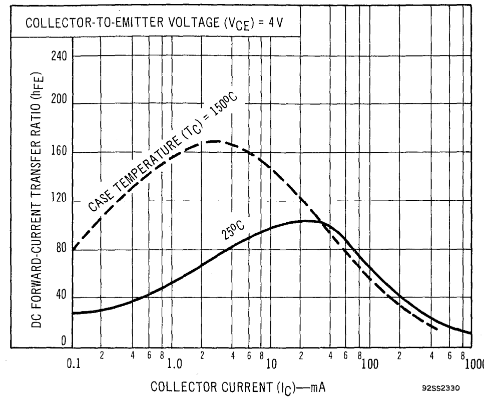


Fig. 17 - Typical dc beta characteristics for type 40349.

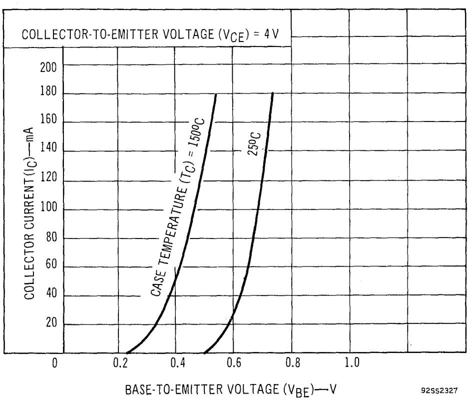


Fig. 18 - Typical transfer characteristics for type 40349.

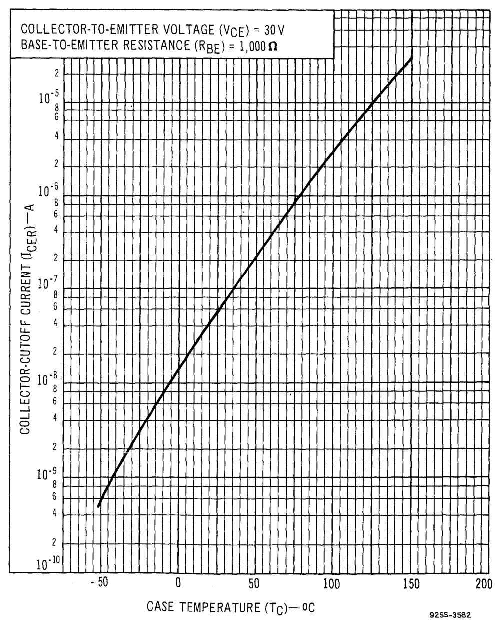


Fig. 19 - Collector-cutoff-current characteristic for type 40347.

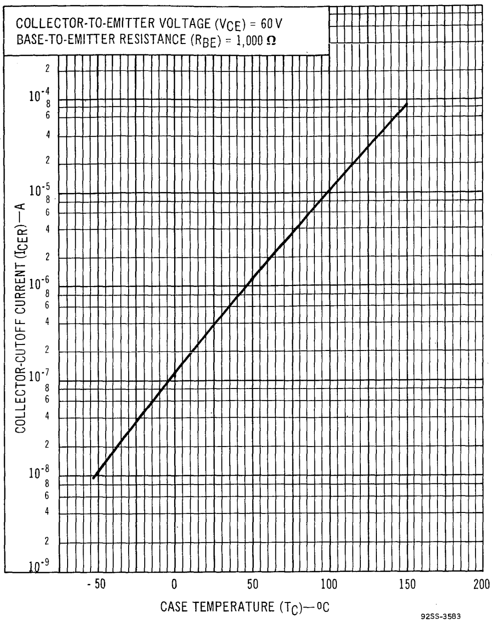


Fig. 20 - Collector-cutoff-current characteristic for type 40348.

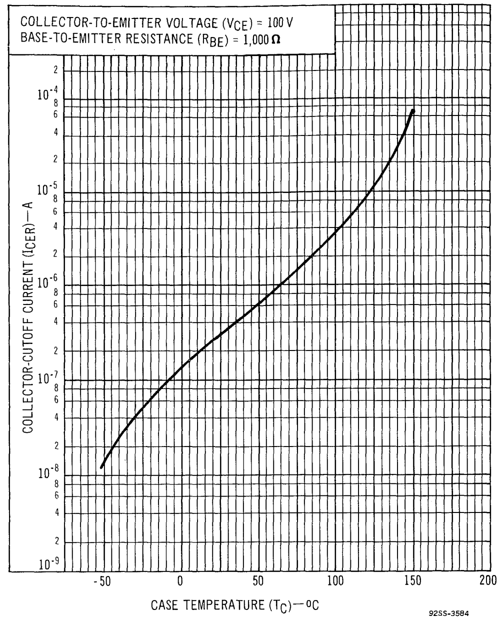
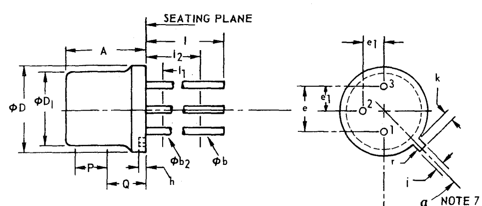


Fig. 21 - Collector-cutoff-current characteristic for type 40349.

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.

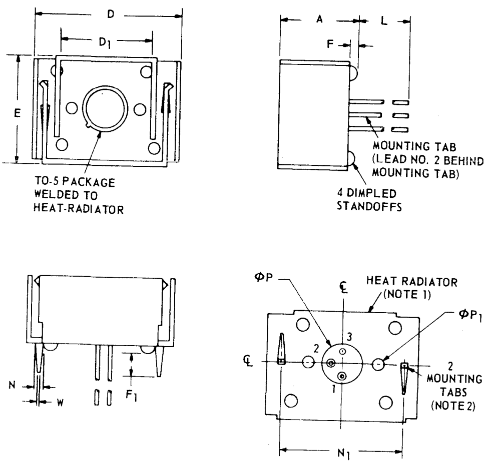
92SS-3821

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



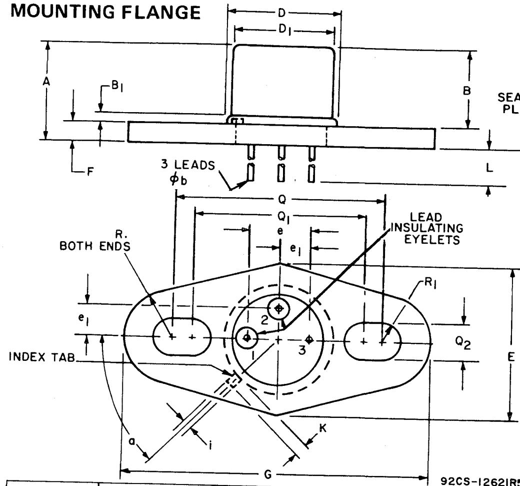
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	0.775	0.785	19.69	19.93	
E	0.875	0.905	22.22	22.99	
F	0.040	0.055	1.02	1.40	
F_1	0.160	0.195	4.06	4.95	
L	1.410	–	35.81	–	
φP	0.295	0.305	7.493	7.747	
$φP_1$	0.093	0.095	2.362	2.413	
N	0.048	0.062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

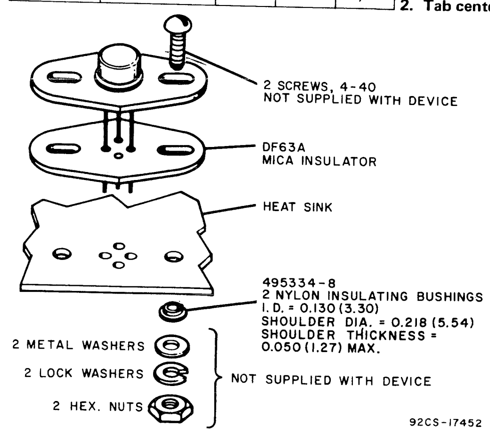


Fig. 22 - Suggested mounting hardware for types 40347V2. 40348V2 and 40349V2 (JEDEC TO-5 with mounting flange).

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

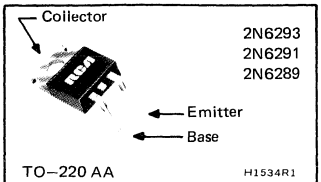
Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

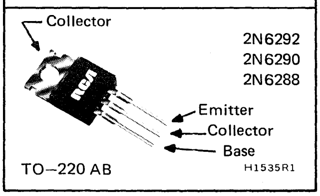
Epitaxial-Base n-p-n and p-n-p Power Transistors

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}	V_{BE}	DC CURRENT (A) I_C	I_B	LIMITS 2N6292 2N6293 MIN.	MAX.	2N6290 2N6291 MIN.	MAX.	2N6288 2N6289 MIN.	MAX.	UNITS
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)	70		-1.5			–	2	–	–	–	–	mA
		50		-1.5			–	–	–	2	–	–	
		30		-1.5			–	–	–	–	–	2	
* Emitter-Cutoff Current	I_{EBO}		5		0		–	1	–	1	–	1	mA
* Collector-Cutoff Current	I_{CEO}	60				0	–	1	–	–	–	–	mA
		40				0	–	–	–	1	–	–	
		20				0	–	–	–	–	–	1	
* 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			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	
		4			6.5[a]		–	3	–	3	–	3	
* 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		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	$R_{\theta JC}$						–	3.125	–	3.125	–	3.125	°C/W
Junction-to-Ambient	$R_{\theta JA}$							70		70		70	

[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).

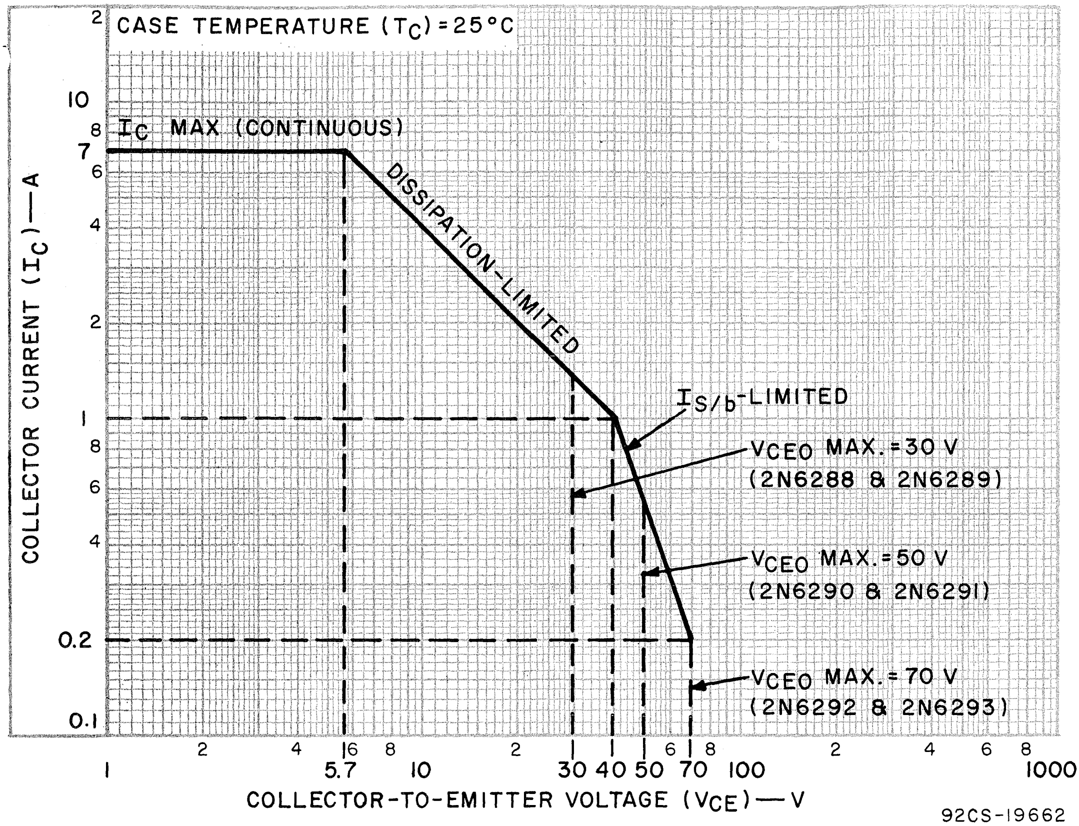


Fig. 1—Maximum operating areas for types 2N6288—2N6293.

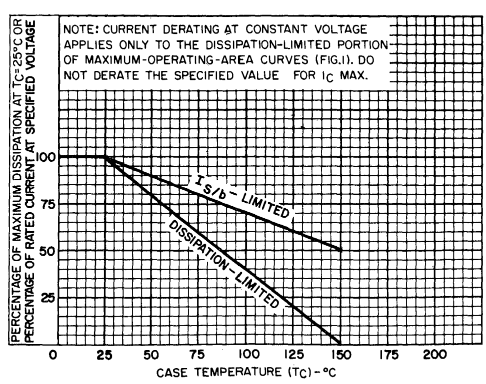


Fig. 2—Derating curves for types 2N6288—2N6293.

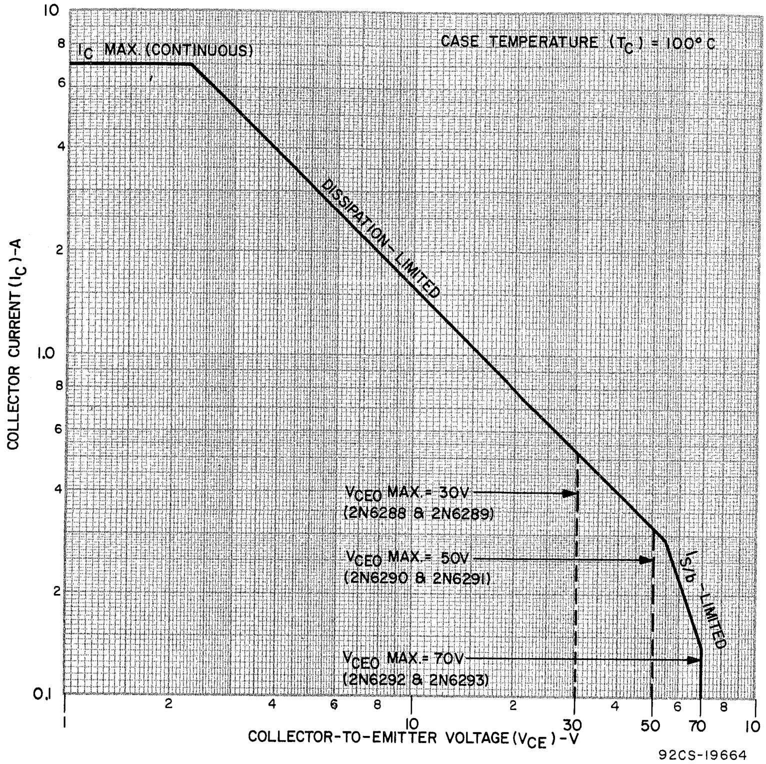


Fig.3—Maximum operating areas for types 2N6288—2N6293.

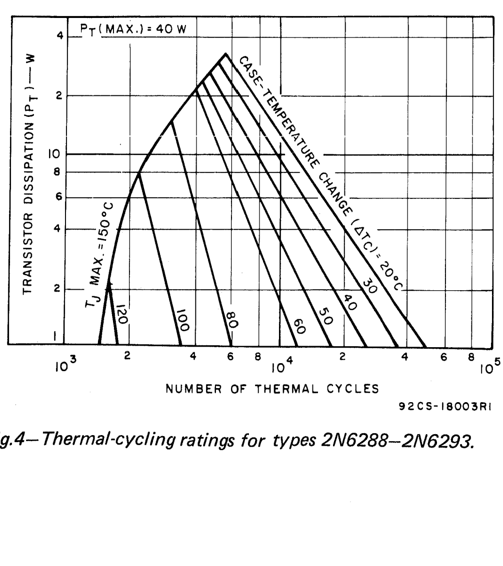


Fig.4—Thermal-cycling ratings for types 2N6288—2N6293.

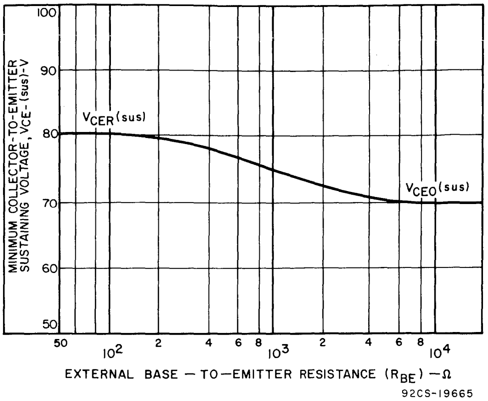


Fig. 5—Collector-to-emitter sustaining-voltage characteristic for types 2N6292 and 2N6293.

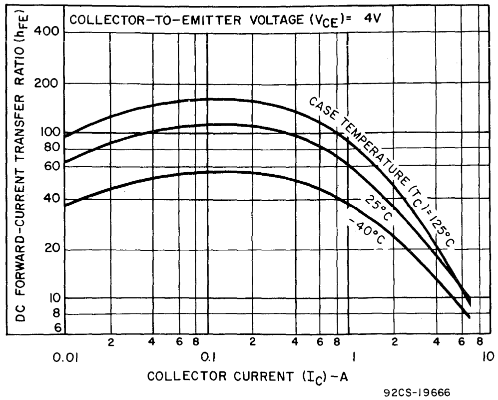


Fig. 6—Typical dc beta characteristics for types 2N6292 and 2N6293.

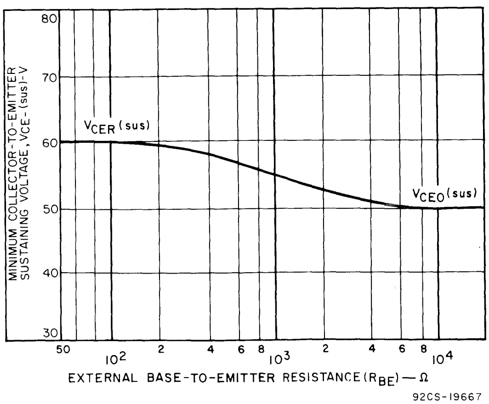


Fig. 7—Collector-to-emitter sustaining-voltage characteristic for types 2N6290 and2N6291.

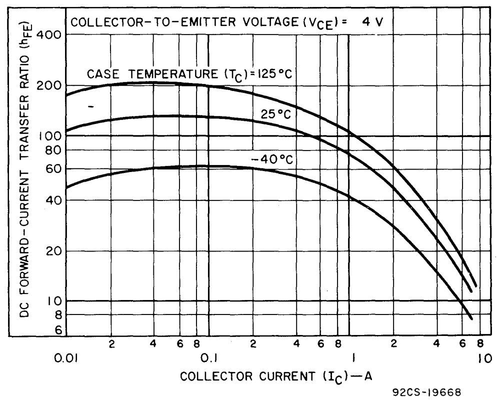


Fig. 8—Typical dc beta characteristics for types 2N6290 and 2N6291.

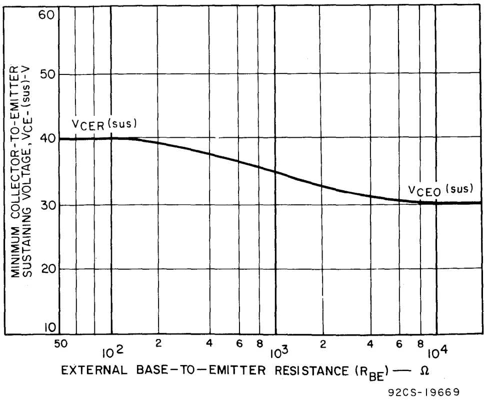


Fig. 9—Collector-to-emitter sustaining-voltage characteristic for types 2N6288 and 2N6289.

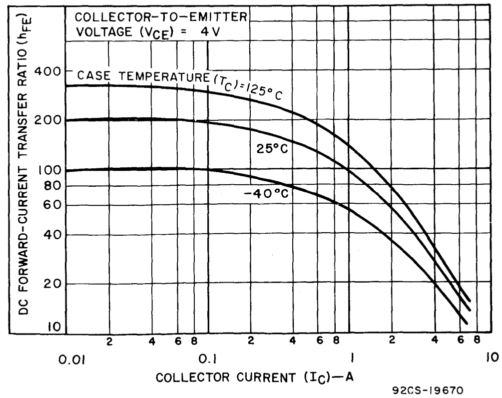


Fig. 10—Typical dc beta characteristics for types 2N6288 and 2N6289.

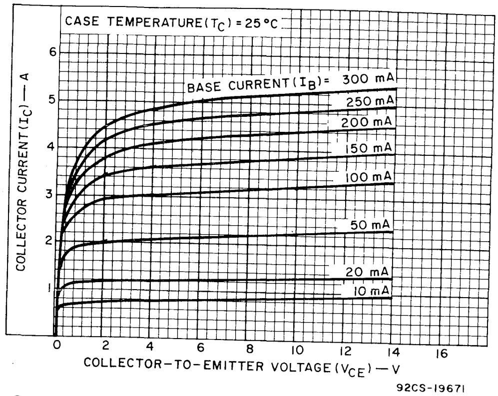


Fig. 11—Typical output characteristics for types 2N6292 and 2N6293.

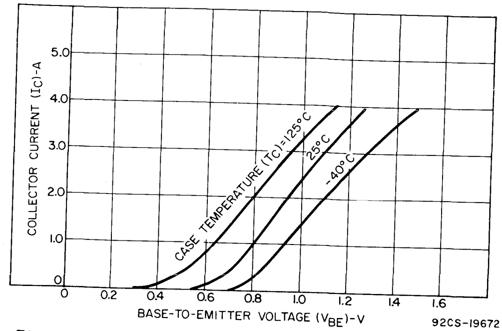


Fig. 12—Typical transfer characteristics of types 2N6288—2N6293.

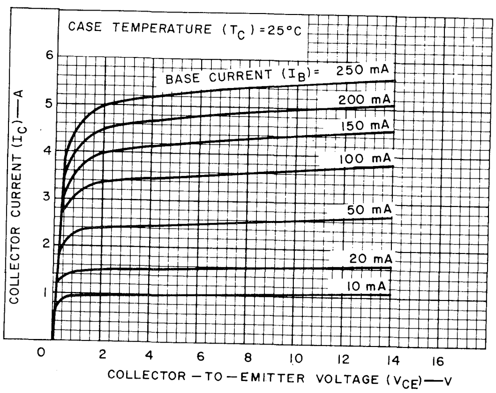


Fig. 13—Typical output characteristics for types 2N6290 and 2N6291.

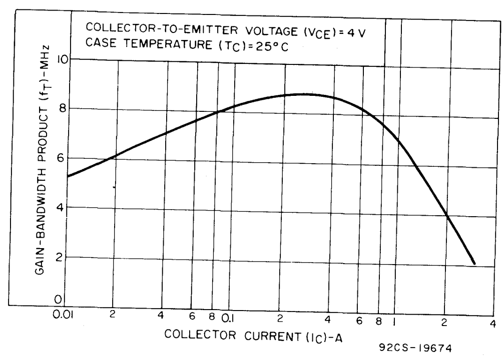


Fig. 14—Typical gain-bandwidth product for types 2N6288—2N6293.

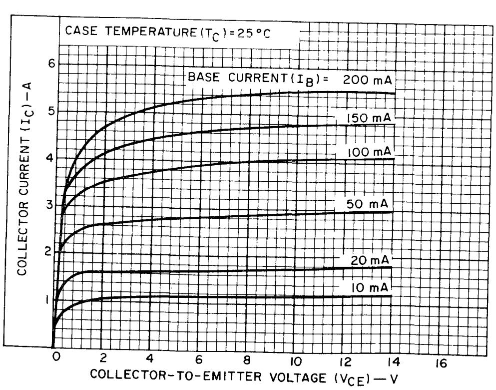


Fig. 15—Typical output characteristics for types 2N6288 and 2N6289.

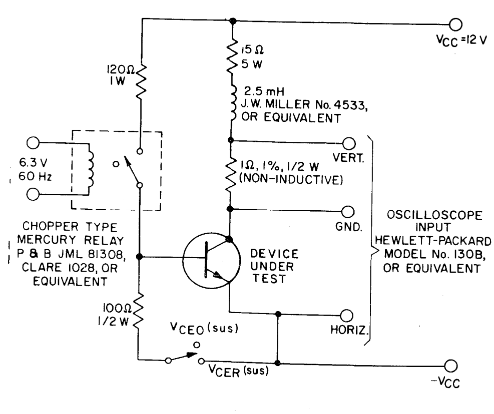
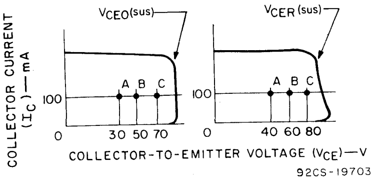


Fig. 16—Circuit used to measure sustaining voltages V_{CEO}(sus) and V_{CER}(sus) for types 2N6288—2N6293.



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).

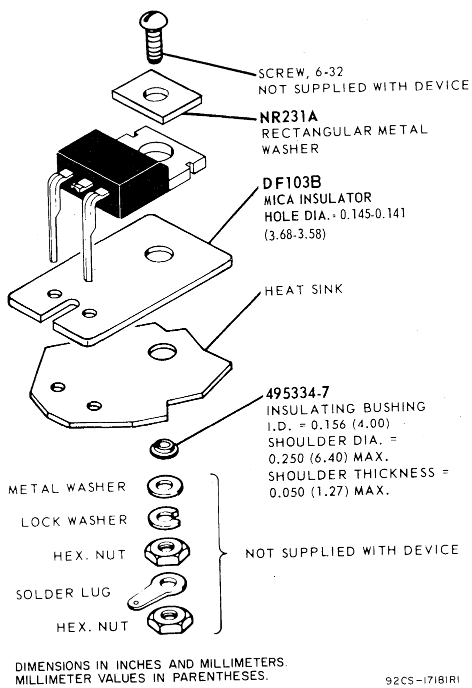


Fig. 18–Suggested mounting hardware for types 2N6293, 2N6291, and 2N6289.

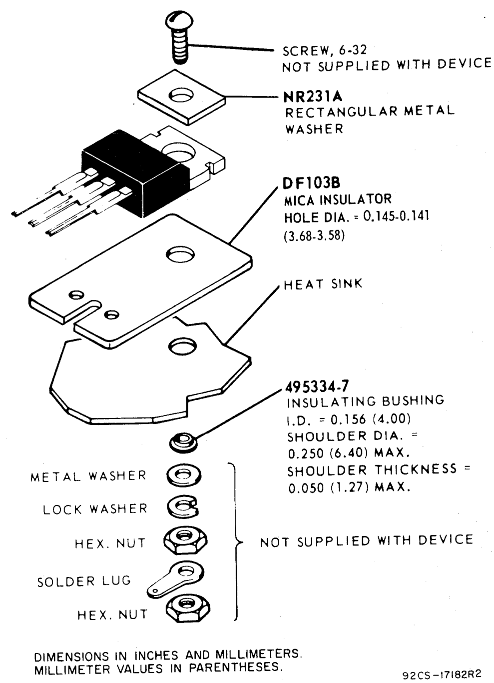
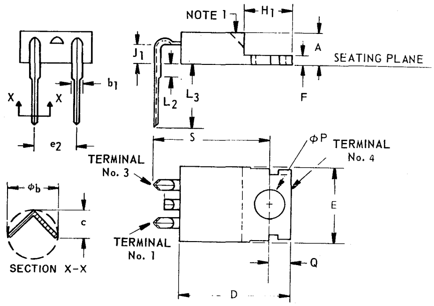


Fig. 19–Suggested mounting hardware for types 2N6292, 2N6290 and 2N6288.

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

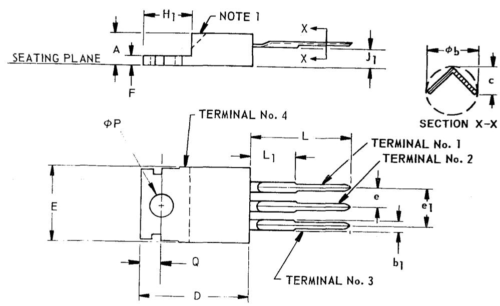


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.02	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	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

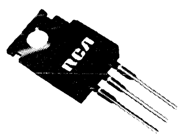
*Types are available with base and emitter leads interchanged. Additional information is available from the nearest RCA Solid State Sales Office.

RCA

Solid State
Division

Power Transistors

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%.

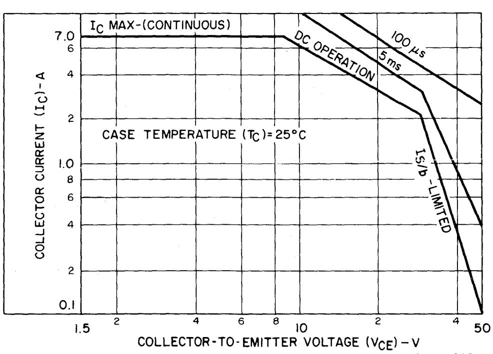


Fig. 1—Maximum operating areas for types 105 and 205.

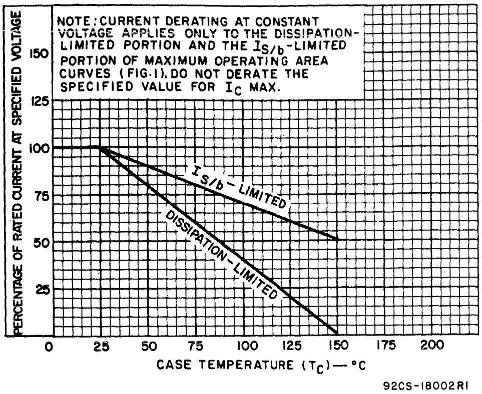


Fig. 2—Derating curves for types 105 and 205.

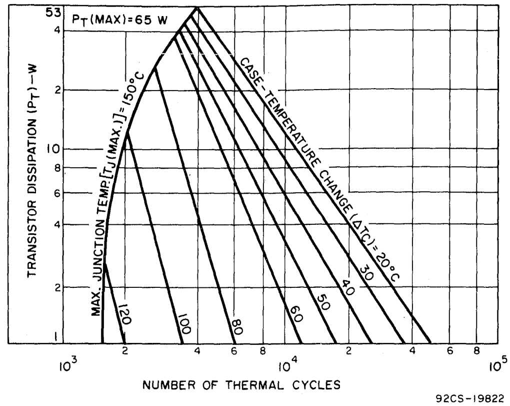


Fig. 3—Thermal-cycling ratings for types 105 and 205.

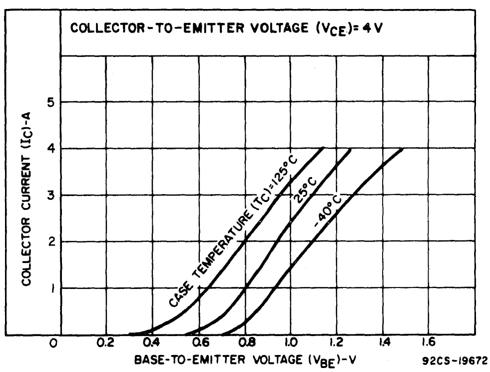


Fig. 4—Typical transfer characteristics for type 205.

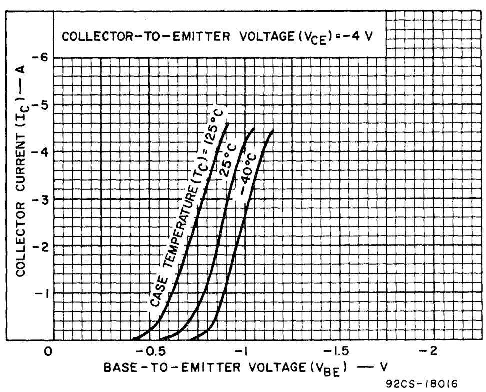


Fig. 5—Typical transfer characteristics for type 105.

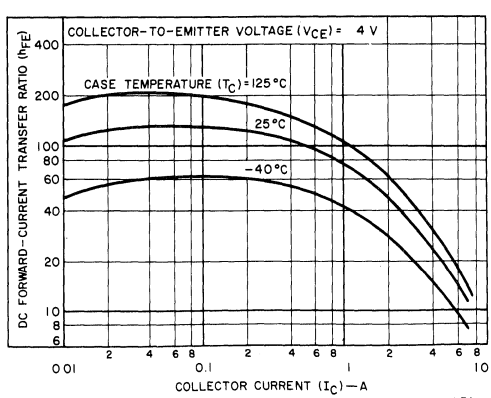


Fig. 6—Typical dc beta characteristics for types 105 and 205.

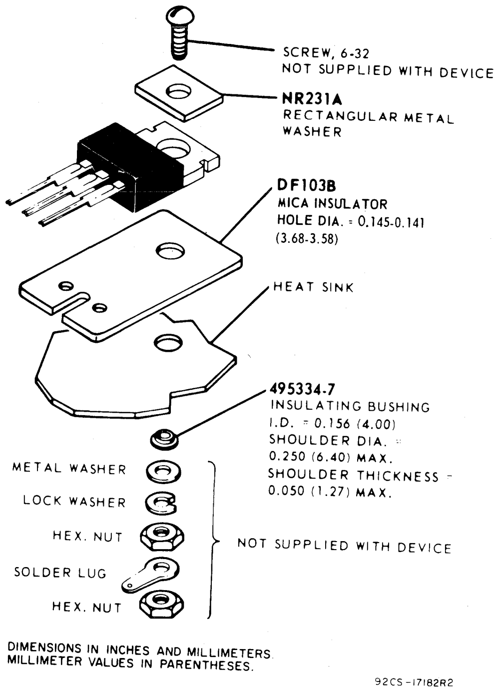
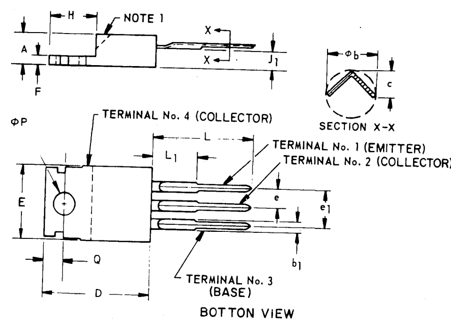


Fig. 7—Suggested mounting hardware for types 105 and 205.

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	–
b1	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
e1	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
J1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L1	–	0.250	–	6.35	–
φP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776R1

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.

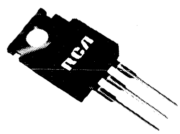
TERMINAL CONNECTIONS

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

RCA

Solid State
Division

Power Transistors
RCA-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 P-N-P TYPES 101 / N-P-N TYPES 201		102 / 202		103 / 203		104 / 204		UNITS
		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%.

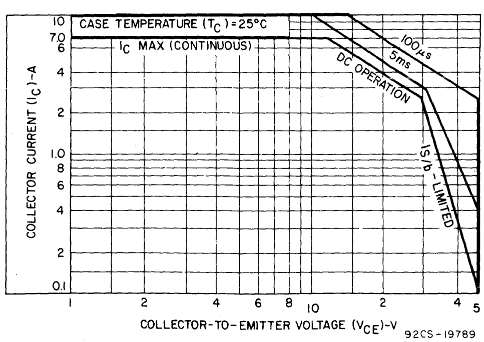


Fig. 1—Maximum operating areas for types 101–104 and 201–204.

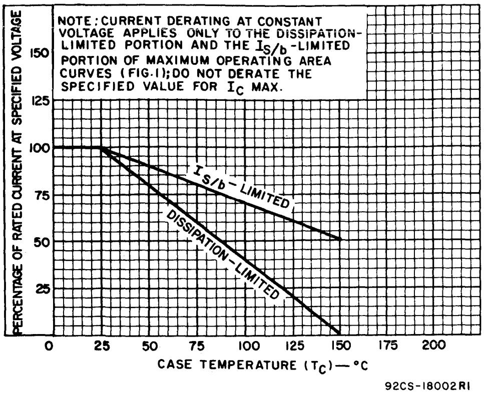


Fig. 2—Derating curves for all types.

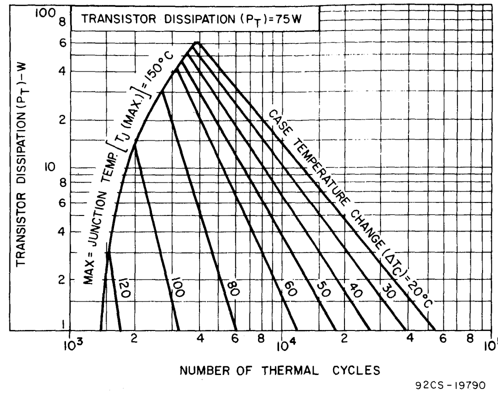


Fig. 3—Thermal-cycling ratings for all types.

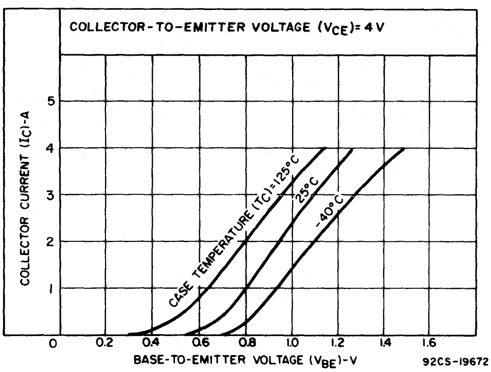


Fig. 4—Typical transfer characteristics for types 201–204.

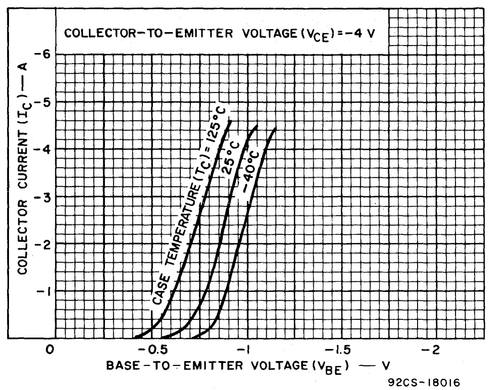


Fig. 5—Typical transfer characteristics for types 101–104.

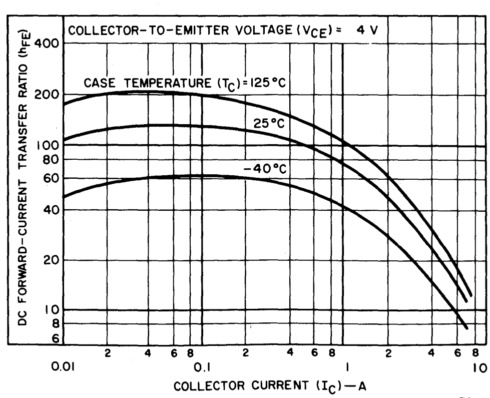
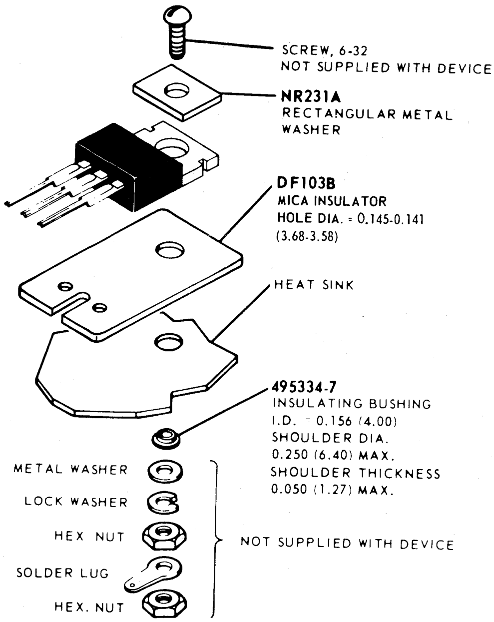


Fig. 6—Typical dc beta characteristics for types 101–104 and 201–204.

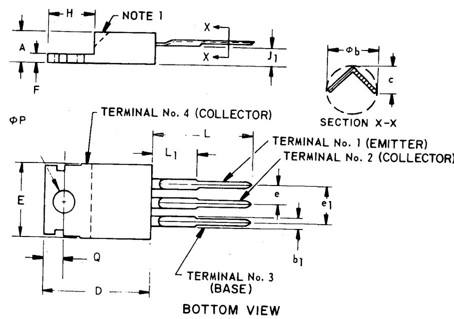


DIMENSIONS IN INCHES AND MILLIMETERS
MILLIMETER VALUES IN PARENTHESES.

92CS-17182R2

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	–
b1	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
e1	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
J1	0.080	0.115	2.04	2.92	–
L	0.500	0.562	12.70	14.27	–
L1	–	0.250	–	6.35	–
ϕP	0.139	0.147	3.531	3.733	–
Q	0.100	0.120	2.54	3.04	–

92CS-19776R1

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

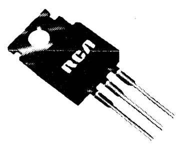
Lead No. 1 – Emitter
Lead No. 2 – Collector
Lead No. 3 – Base
Mounting Flange – Collector

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%.

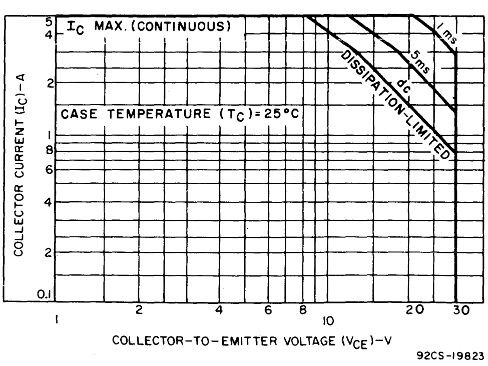


Fig. 1—Maximum operating areas for types 370 and 520.

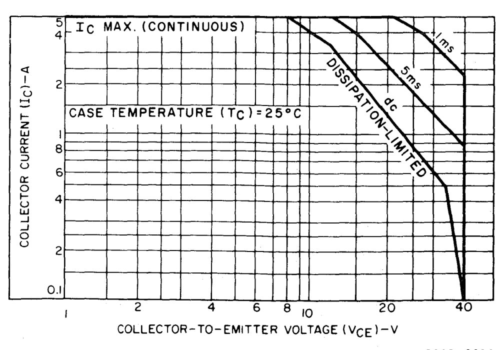


Fig. 2—Maximum operating areas for types 371 and 521.

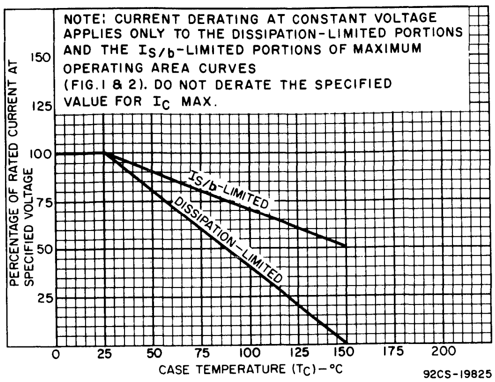


Fig. 3—Derating curves for all types.

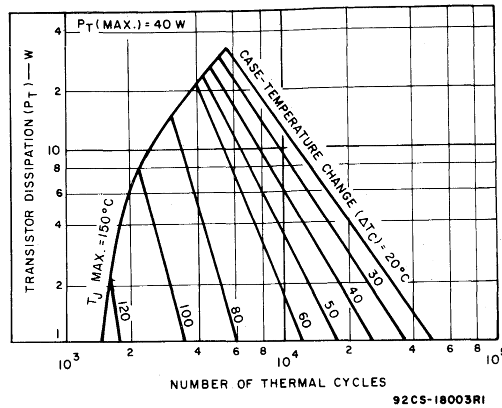


Fig. 4—Thermal-cycling ratings for all types.

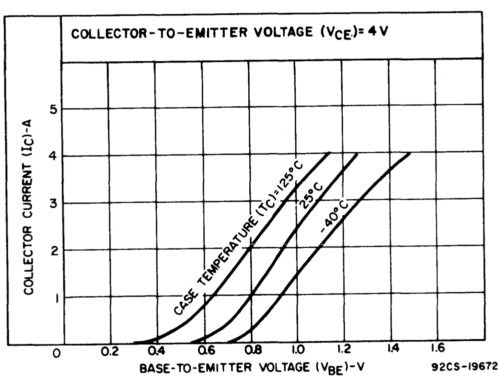


Fig. 5—Typical transfer characteristics for types 520 and 521.

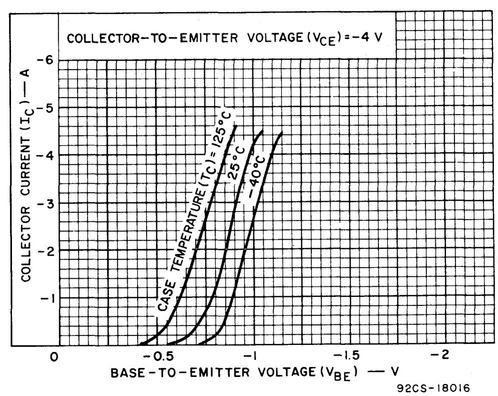


Fig. 6—Typical transfer characteristics for types 370 and 371.

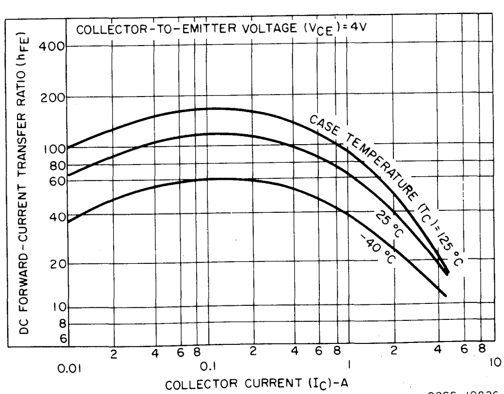
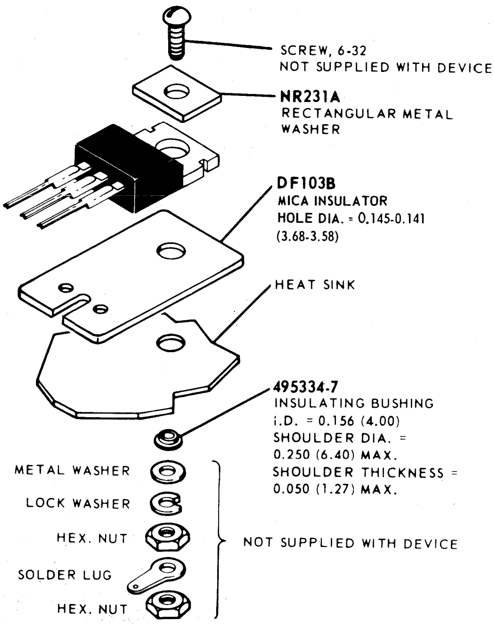


Fig. 7—Typical dc beta characteristics for all types.

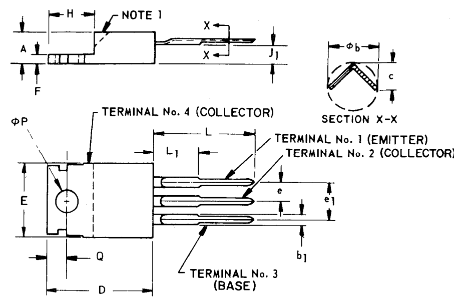


DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

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

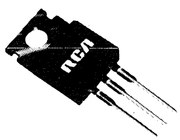
Terminal No. 1 – Emitter
Terminal No. 2 – Collector
Terminal No. 3 – Base
Mounting Flange, Terminal No. 4 – Collector

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						UNITS
								45190 (n-p-n) 45193 (p-n-p)		45191 (n-p-n) 45194 (p-n-p)		45192 (n-p-n) 45195 (p-n-p)		
		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 60 80					0 0 0	– – –	100 – –	– – –	– 100 –	– – –	– – 100	µA
Collector-Cutoff Current: With base open	I_{CEO}	40 60 80				0 0 0		– – –	1 – –	– – –	– 1 –	– – –	– – 1	mA
Collector-Cutoff Current: With base-emitter junction reverse-biased	I_{CEX}		40 60 80	1.5 1.5 1.5				– – –	0.1 – –	– – –	– 0.1 –	– – –	– – 0.1	mA
T_C = 125°C	I_{CEX} (T_C = 125°C)		40 60 80	1.5 1.5 1.5				– – –	2 – –	– – –	– 2 –	– – –	– – 2	mA
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 4	0.15 1		– –	0.6 1.4	– –	0.6 1.4	– –	0.6 1.4	V
Gain-Bandwidth Product (At f = 1 MHz)	f_T		10		1			2	–	2	–	2	–	MHz
DC Forward-Current Transfer Ratio	h_{FE}^a		2 2		1.5 4			25 10	100 –	25 10	100 –	20 7	80 –	
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%.

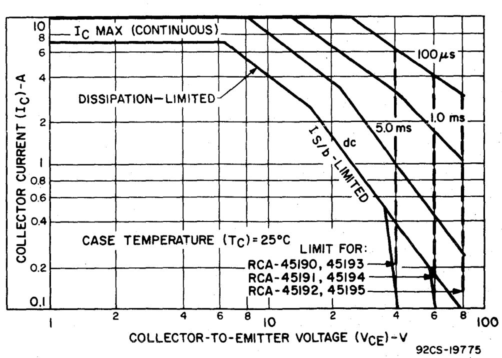


Fig. 1—Maximum operating areas for types 45190-5.

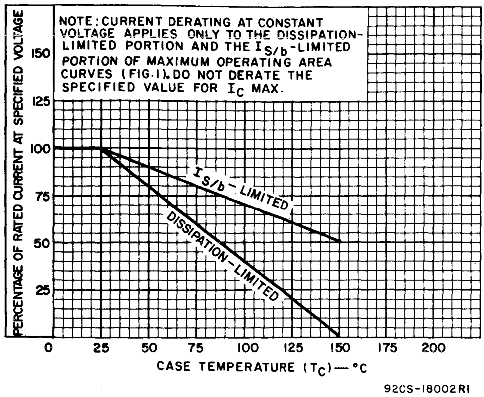


Fig. 2—Derating curves for types 45190-5.

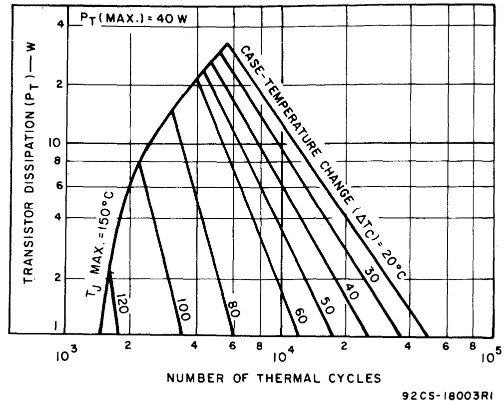


Fig. 3—Thermal-cycling ratings for types 45190-5.

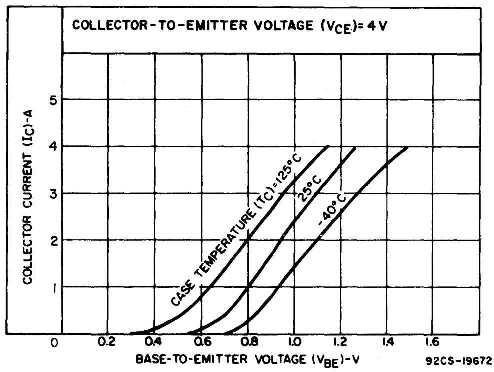


Fig. 4—Typical transfer characteristics for types 45190-2.

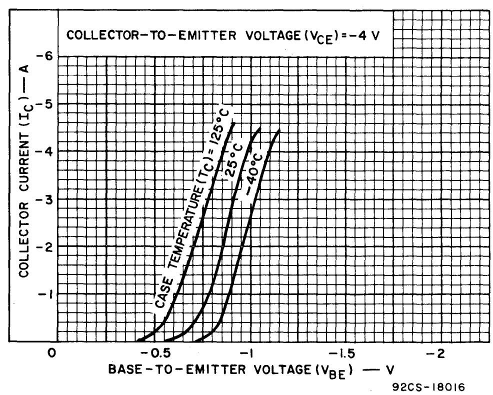


Fig. 5—Typical transfer characteristics for types 45193-5.

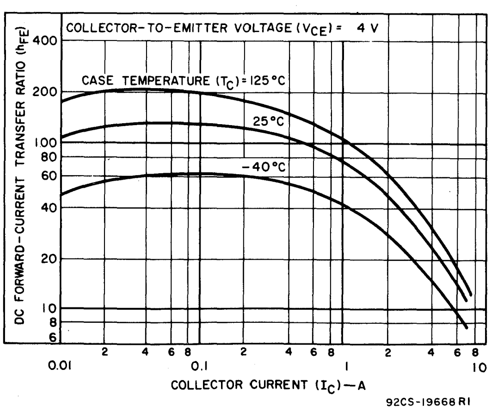
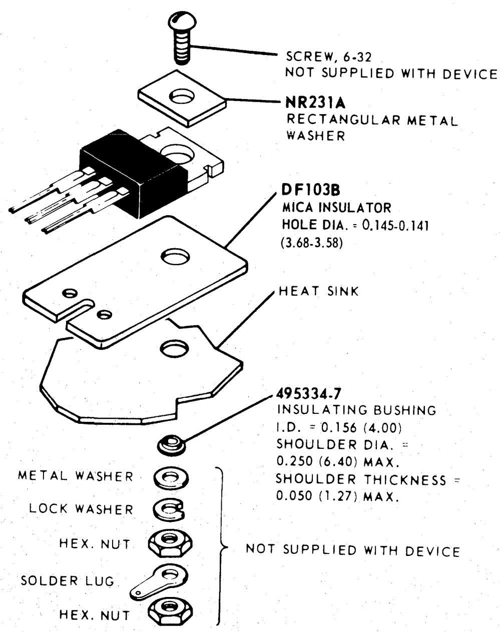


Fig. 6—Typical dc beta characteristics for types 45190-5.

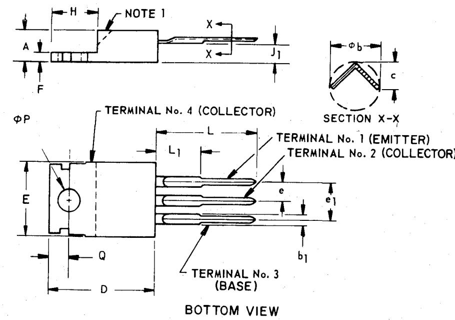


DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-17182R2

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

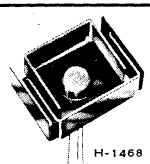
Power Transistors

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.



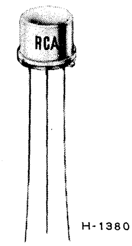
40390

ALSO AVAILABLE. . .

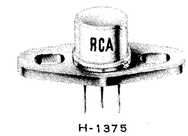
Type 40390 is a 2N3440 with a factory-attached heat radiator; it is intended for printed circuit-board applications.

- **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	θ_{J-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

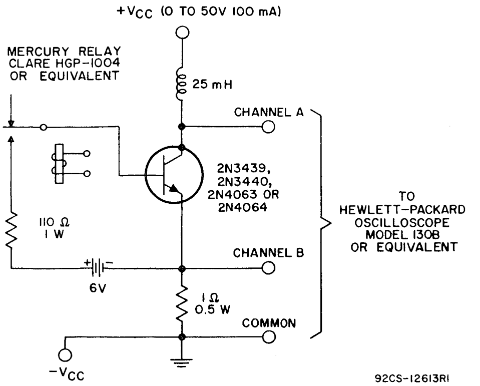
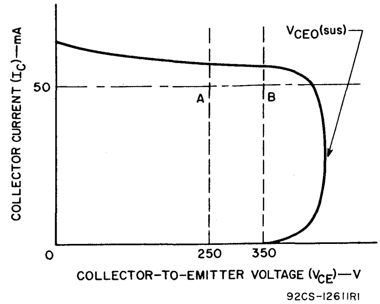


Fig. 1

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

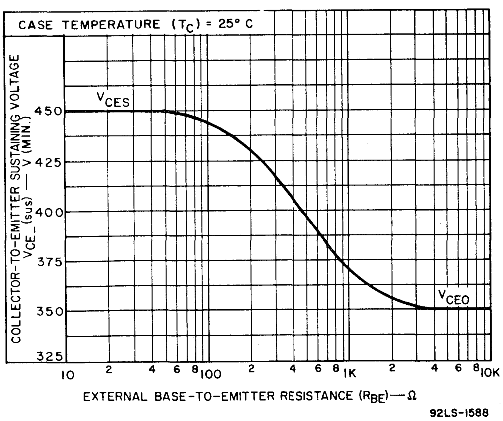


Fig. 3

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPES 2N3440, & 2N4064

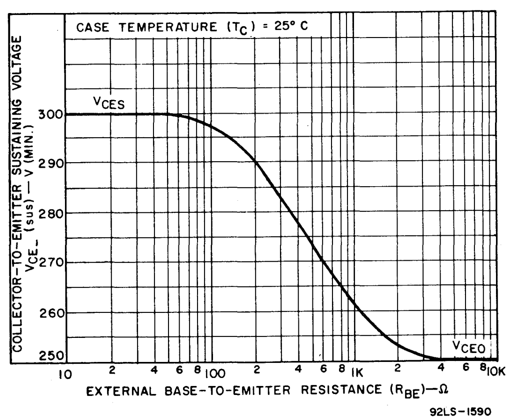


Fig. 4

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

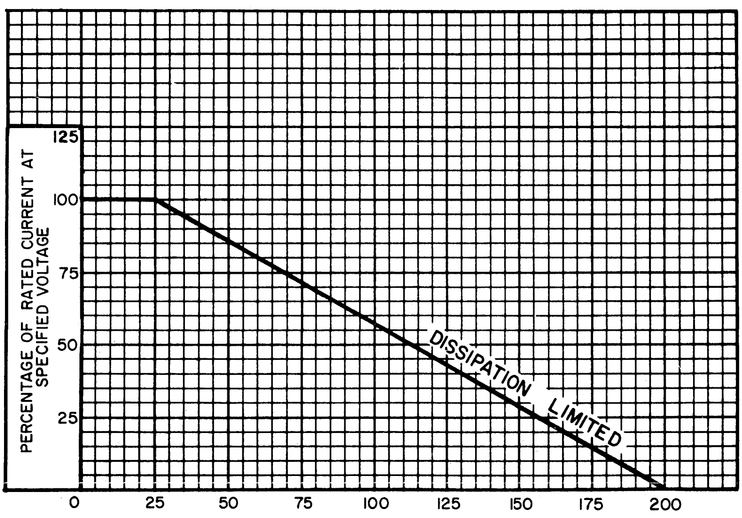
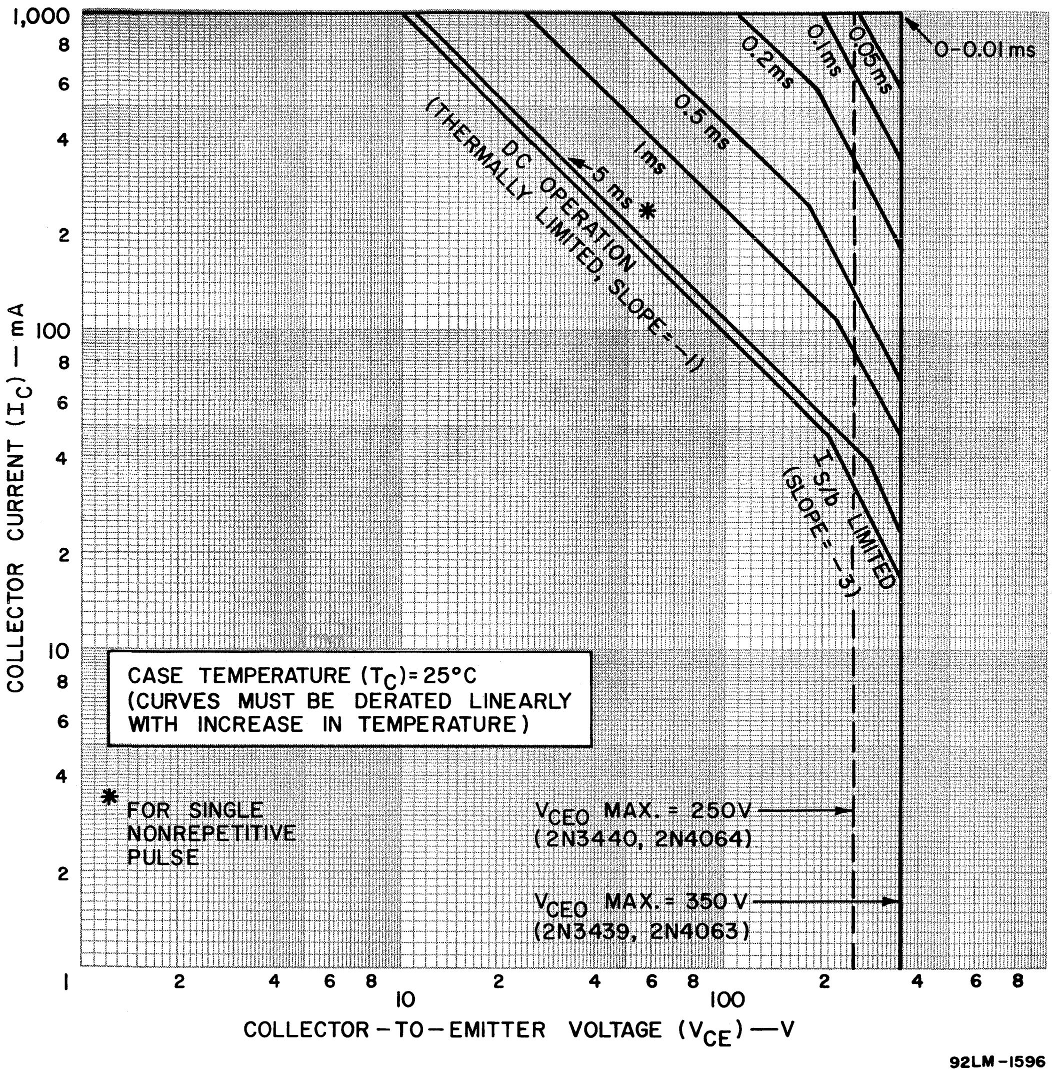


Fig. 5

MAXIMUM OPERATING AREAS FOR TYPES
2N3439, 2N3440, 2N4063, & 2N4064



92LM-1596

DISSIPATION DERATING CURVES FOR TYPES
2N3439, 2N3440, & 40390

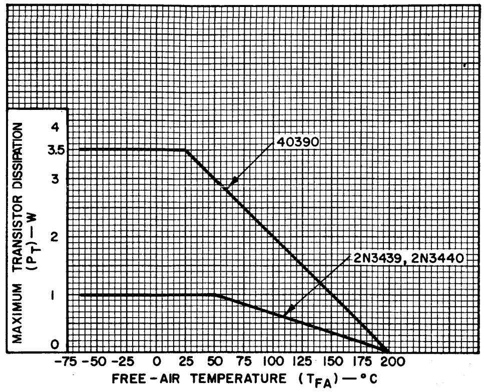


Fig. 7

SECOND BREAKDOWN

Second breakdown (S/b) is a potentially destructive phenomenon which occurs in bipolar transistors (n-p-n and p-n-p) and results from the transistor absorbing a critical amount of energy. The initiation of second breakdown is characterized by an abrupt decrease in collector-to-emitter voltage, V_{CE}, with a small positive dynamic resistance in the second-breakdown region. In general, transistors with higher-frequency response or faster switching speed characteristics, and higher collector-to-emitter voltage-breakdown capabilities are more susceptible to failure from second breakdown. The critical energy required to produce second breakdown is a variable which depends on operating conditions.

With the emitter-base junction forward biased for transistor operation in the active region, the severity of second breakdown depends on the operating collector-to-emitter voltage, duration of the applied voltage, and transistor temperature.

Figure 6 shows the DC and pulse current derating curves applicable to the 2N3439, 2N3440, 2N4063 & 2N4064, respectively. The portion of the curves with slope equal to −1 on these logarithmic plots indicates the regions where the device is thermally limited (i.e., maximum allowable power dissipation is constant at 10 watts). That portion where the slope is approximately −3 shows the region where the device is second breakdown limited, and applies for one-second pulse duration (essentially equal to DC operation). For shorter pulses, the transistor's second breakdown capability improves.

The 40390 is not limited by second breakdown. Fig. 7 shows the derating curve applicable for this type.

TYPICAL DC-BETA CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

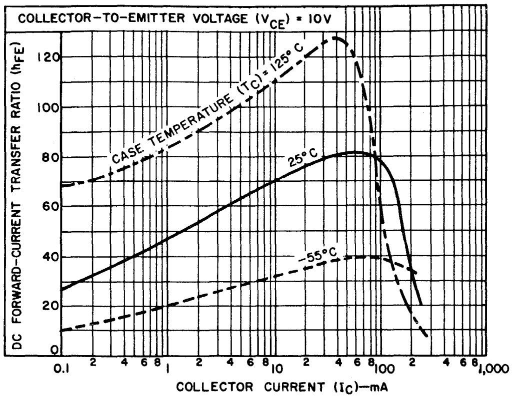


Fig. 8

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

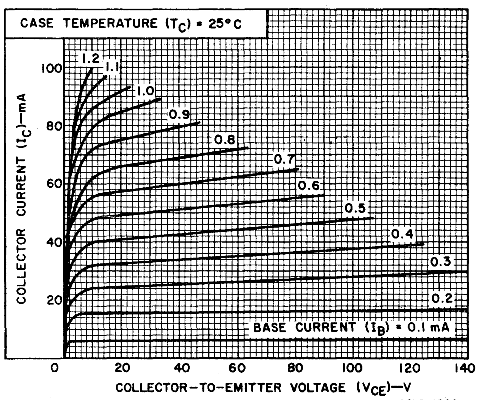


Fig. 9

TYPICAL INPUT CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

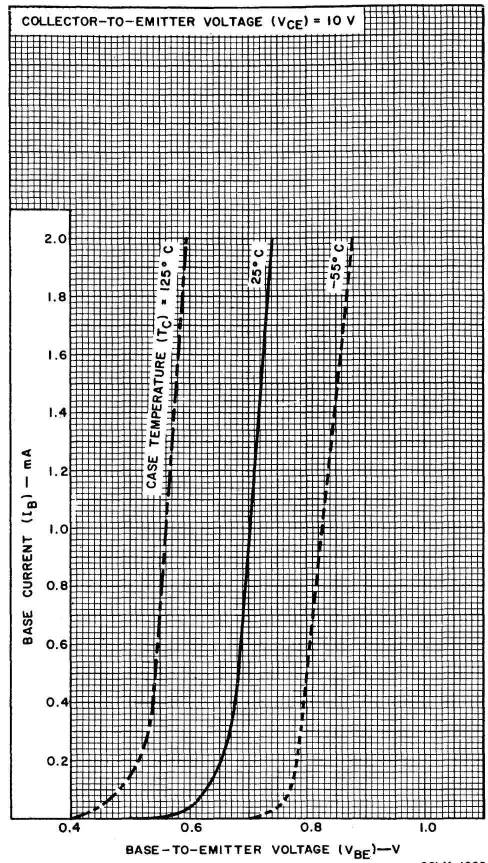


Fig. 10

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

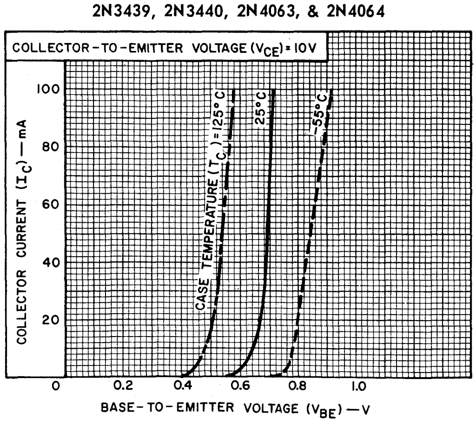


Fig. 11

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPES 2N3439, 2N3440, 2N4063, & 2N4064

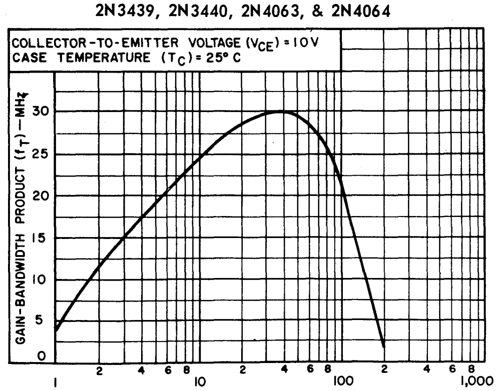
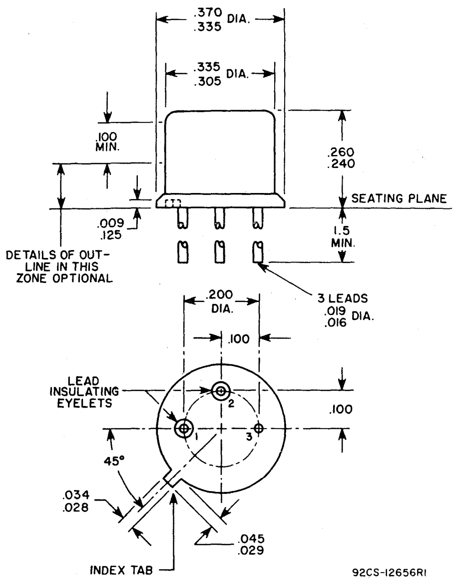


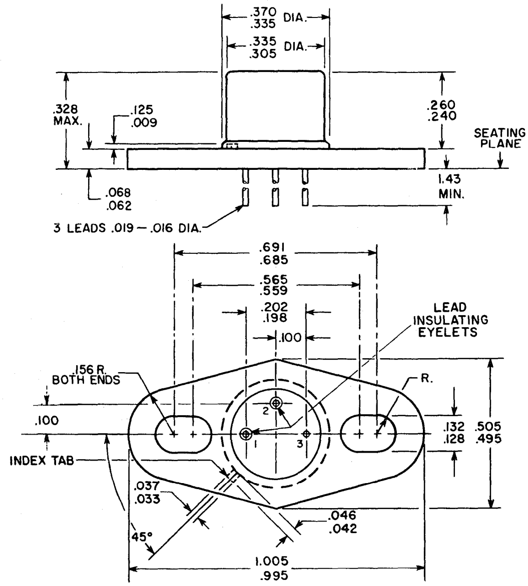
Fig. 12

DIMENSIONAL OUTLINE FOR TYPES 2N3439 & 2N3440 JEDEC No. TO-5



DIMENSIONS IN INCHES

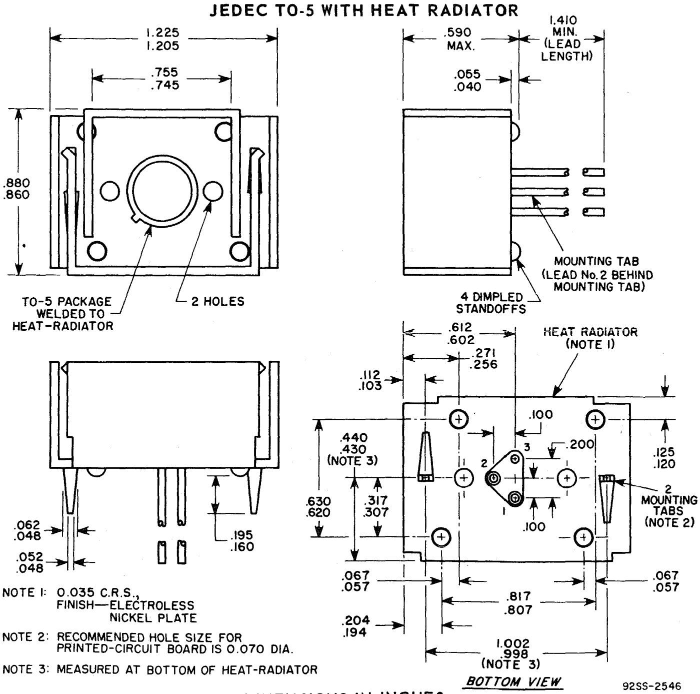
DIMENSIONAL OUTLINE FOR TYPES 2N4063 & 2N4064 JEDEC TO-5 WITH FLANGE



NOTE: SOME DEVICES MAY HAVE A FLANGE WITH A TRIANGULAR CUTOUT FOR LEADS.

DIMENSIONS IN INCHES

DIMENSIONAL OUTLINE FOR TYPE 40390 JEDEC TO-5 WITH HEAT RADIATOR



NOTE I: 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 2N3584 2N4240 2N3585 40374

RCA-2N3583,* 2N3584,* 2N3585,* 2N4240,* and 40374 are triple-diffused, 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 permit increasing 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. Type Nos. TA2510, TA2511, TA2512, and TA2871, respectively.

NEW!

Maximum area-of-operation curves for DC & pulse operation.

Derating curves for $I_{S/b}$-limited and dissipation-limited operation.

Now possible to determine maximum operating conditions for operation free from second breakdown.

N-P-N Types for High-Speed Switching and Linear-Amplifier Applications

2N3583, 2N3584, 2N3585, 2N4240 (JEDEC TO-66) — 40374 (JEDEC TO-66 WITH HEAT RADIATOR)

- High Voltage Ratings:

	2N3583 40374	2N3584	2N3585 2N4240	
V_{CBO}	250	375	500	V
$V_{CEO}(sus)$	175	250	300	V

- Low collector-to-emitter saturation voltage — — $V_{CE}(sat)$ = 0.75 V max. at I_C = 1 A (2N3584 & 2N3585)
- 100 percent tested to assure freedom from second breakdown in both forward- and reverse-bias conditions when operated within specified limits
- JEDEC No. TO-66 package for 2N3583, 2N3584, 2N3585, and 2N4240
  JEDEC No. TO-66 package with heat radiator for 40374
- Economy types for AC/DC circuits
- Fast turn-on time at high collector current — — 3 μs max. at 1 A (2N3584 & 2N3585)

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	$V_{CEO}(sus)$	175	250	300	175	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	6	6	6	6	V
CONTINUOUS COLLECTOR CURRENT	I_C	2	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	See Figs. 4,5,6,7,8,& 9.				
TEMPERATURE RANGE:						
Storage & Operating (Junction)		← -65 to 200 →				°C
PIN TEMPERATURE:						
1/16" ± 1/32" from seating plane for 10 s max.		255	255	255	255	°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 (Milliamperes) I_C	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	LIMITS: Types 2N3583 & 40374 Min.	Types 2N3583 & 40374 Max.	Type 2N3584 Min.	Type 2N3584 Max.	Type 2N3585 Min.	Type 2N3585 Max.	Type 2N4240 Min.	Type 2N4240 Max.	Units
Collector-Cutoff Current	I_{CEO}		150					0	–	10	–	5	–	5	–	5	mA
Collector-Cutoff Current	I_{CEV}		225 300 400		- 1.5 - 1.5 - 1.5				– – –	1.0 – –	– – –	– 1.0 –	– – –	– – 1.0	– – –	– – 2.0	mA
Collector-Cutoff Current (At T_C = 150°C)	I_{CEV}		225 300		- 1.5 - 1.5				– –	3 –	– –	– 3	– –	– 3	– –	– 5.0	mA
Emitter-Cutoff Current	I_{EBO}			6		0			–	5.0	–	0.5	–	0.5	–	0.5	mA
DC Forward-Current Transfer Ratio	h_{FE}		10 10 10			100 750 1 amp			40 – 10	– – –	40 – 25	– – 100	40 – 25	– – 100	40 30 –	– 150 –	
Collector-to-Emitter Sustaining Voltage: (*See Figs.* 10,11,12,& 13) With base open	$V_{CEO}(sus)$					200		0	175●	–	250●	–	300●	–	300●	–	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$					200			250●	–	300●	–	400●	–	400●	–	V
Base-to-Emitter Voltage	V_{BE}		10			1 amp			–	1.4	–	1.4	–	1.4	–	1.4	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					750 1 amp		75 125	– –	– –	– –	– 0.75	– –	– 0.75	– –	1.0 –	V
Small-Signal, Forward-Current Transfer Ratio (At 5 Mc/s)	h_{fe}		10			200			3	–	3	–	3	–	3	–	
Output Capacitance (At 1 Mc/s)	C_{ob}	10					0		–	120	–	120	–	120	–	120	pF
Second-Breakdown▲ Collector Current With base forward biased** (*See Figs.* 5 & 6)	$I_{S/b}$*		100						350	–	350	–	350	–	350	–	mA
Second-Breakdown▲ Energy With base reverse biased R_{BE} = 20 Ω, L = 100 μH	$E_{S/b}$†				-4				50	–	200	–	200	–	50	–	μJ
Sat. Switch Turn-On Time (Delay time + rise time (*See Figs.* 19,20,21,23,& 26)	t_{on}		30 V_{CC}			1 amp		100	–	–	–	3	–	2	–	–	μs
Storage Time (*See Figs.* 19,20,22,24,& 26)	t_s		30 V_{CC}			1 amp		100	–	–	–	4	–	4	–	–	μs
Fall Time (*See Figs.* 19,20,21,25,& 26)	t_f		30 V_{CC}			1 amp		100	–	–	–	3	–	3	–	–	μs
Thermal Resistance: Junction-to-Case	$\theta_{J\text{-}C}$					500			5 (Max.) 2N3583		–	5	–	5	–	5	°C/W
Junction-to-Free Air	$\theta_{J\text{-}FA}$					500			70 (Max.) 2N3583		–	70	–	70	–	70	°C/W
						500			30 (Max.) 40374		–	–	–	–	–	–	°C/W

● **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.12.

▲ Safe-operating region for second breakdown is explained under "SECOND BREAKDOWN" on page 3.

* $I_{S/b}$ 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. 1,2, and 3.

SECOND BREAKDOWN

Second breakdown (S/b) is a potentially destructive phenomenon which occurs in bipolar transistors (n-p-n and p-n-p) and results from the transistor absorbing a critical amount of energy. The initiation of second breakdown is characterized by an abrupt decrease in collector-to-emitter voltage, V_{CE}, with a small positive dynamic resistance in the second-breakdown region. In general, transistors with higher-frequency response or faster switching speed characteristics, and higher collector-to-emitter voltage-breakdown capabilities are more susceptible to failure from second breakdown. The critical energy required to produce second breakdown is a variable which depends on operating conditions.

With the emitter-base junction forward biased for transistor operation in the active region, the severity of second breakdown depends on the operating collector-to-emitter voltage, duration of the applied voltage, and transistor temperature.

Figure 5 shows the DC current derating curves applicable to the 2N3583, 2N3584, 2N3585, and 2N4240, respectively, at different temperatures. The portion of the curves with slope equal to -1 on these logarithmic plots indicates the regions where the device is thermally limited (i.e., maximum allowable power dissipation is constant at 35 watts). That portion where the slope is approximately -2.5 shows the region where the device is second breakdown limited, and applies for one-second pulse duration (essentially equal to DC operation). For shorter pulses, the transistor's second breakdown capability improves (See Figures 4 and 6).

The 40374 is not limited by second breakdown. Figure 7 shows the collector current derating curves applicable for this type.

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. It is much lower than that required in the forward-bias mode. The curves shown in Figures 1, 2, and 3 are recommended when designing circuits having inductive loads (such as solenoid- or relay-control circuits, magnetic-deflection circuits, and switching regulators) without protective zener diodes across the collector-to-emitter terminals; also, Figures 1, 2, and 3 can be used when designing circuits where some leakage inductance is present (such as in inverters, converters, and transformer-coupled power amplifiers). For further information on second breakdown, consult RCA Application Notes SMA-21, "Characterization of Second Breakdown in Silicon Power Transistors," and SMA-30, "Second Breakdown in Transistors Under Conditions of Cutoff."

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPES 2N3584 & 2N3585

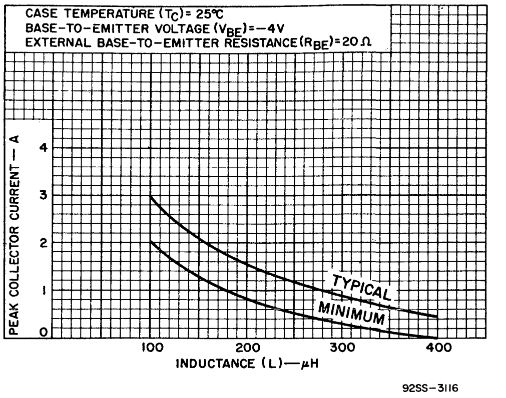


Fig. 1

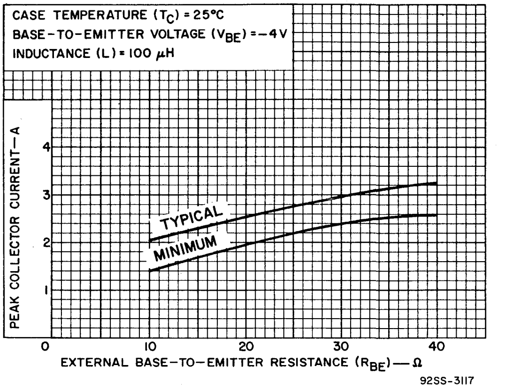


Fig. 2

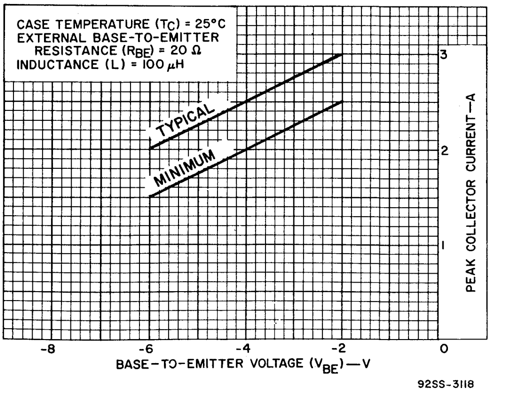


Fig. 3

MAXIMUM AREA-OF-OPERATION

Second breakdown is much less sensitive to temperature variations than normal power-dissipation limitations. Therefore, separate temperature derating curves are required for these two limiting factors as shown in Fig. 4. Figs. 4 & 5 may be used directly for DC operation. For pulse operation at a temperature greater than 25°C, Fig. 6 is used together with Fig. 4 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 "DISSIPATION LIMITED" (or its dashed-line extension);

(2) Refer to Fig. 4 and from the dissipation-limited curve 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 dissipation-limited operation.

(3) If the specified value of V_{CE} required the use of a dashed-line extension of a dissipation-limited curve in step (1), then repeat step (1), using the curve marked "$I_{S/b}$ LIMITED";

(4) Repeat step 2 using the $I_{S/b}$-LIMITED curve in Fig. 4;

(5) The maximum allowable current is the smaller of the two values obtained in steps (2) and (4).

For repetitive-pulse operation, the actual case temperature to be used in Fig. 4 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 CURVES FOR
FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240

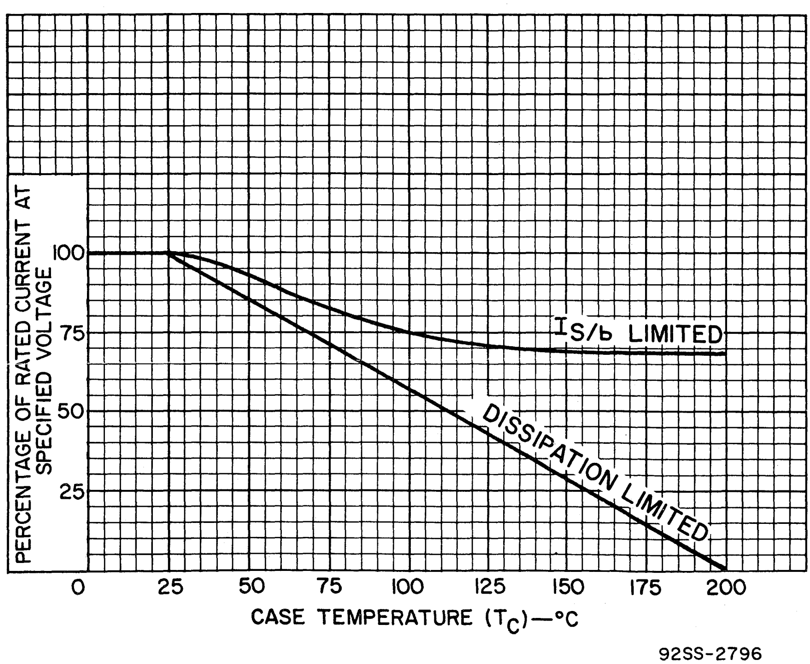


Fig. 4

MAXIMUM OPERATING AREAS FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240
DC CONDITIONS

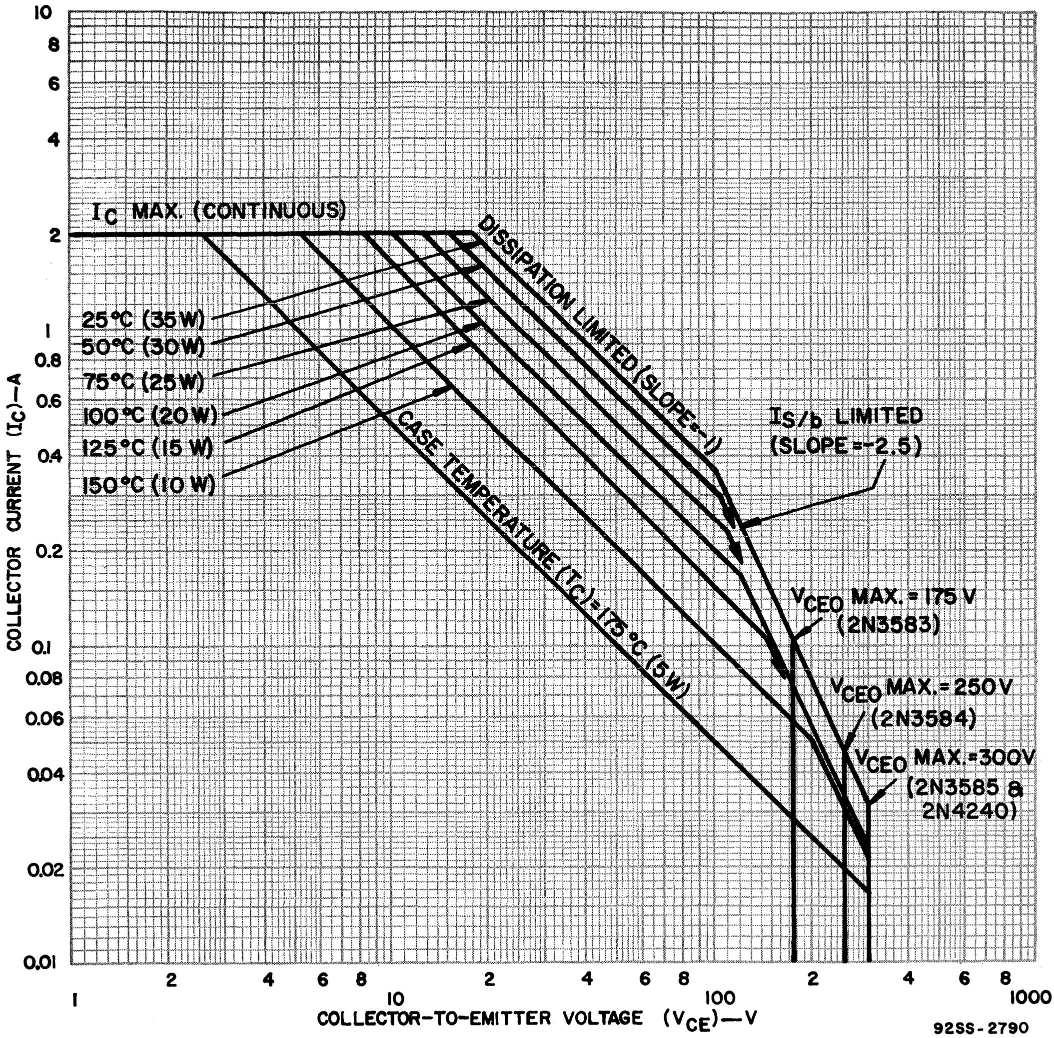


Fig. 5

MAXIMUM OPERATING AREAS FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240

PULSE CONDITIONS

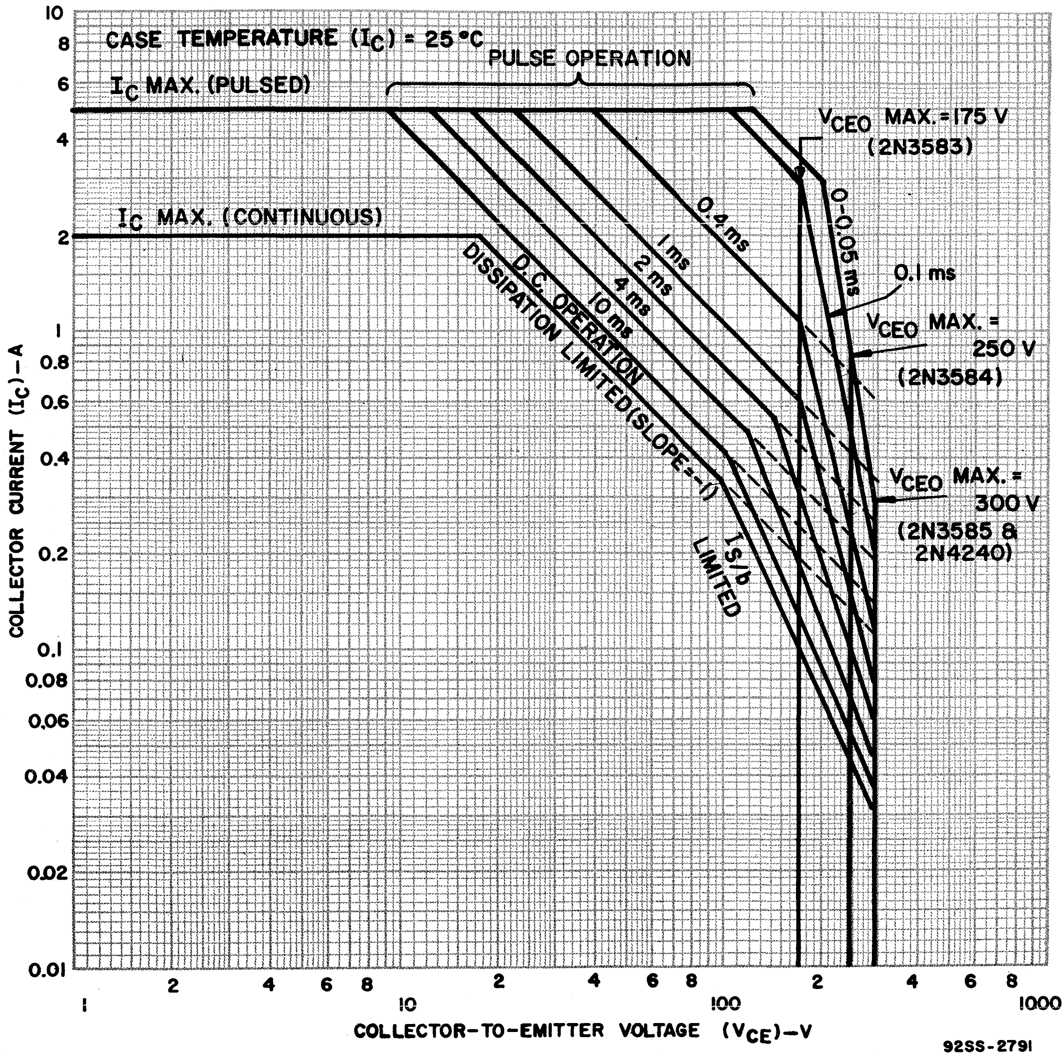


Fig. 6

MAXIMUM OPERATING AREAS FOR TYPE 40374

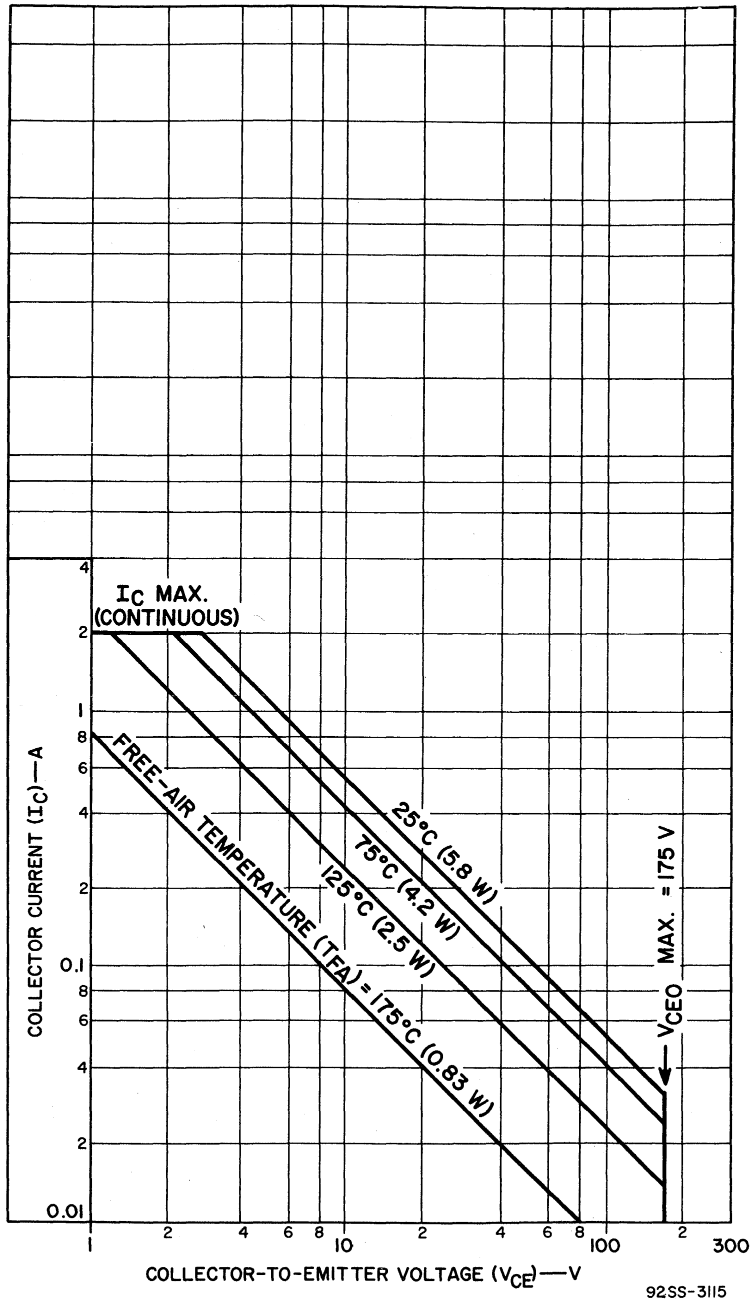


Fig. 7

DISSIPATION DERATING CURVE FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240

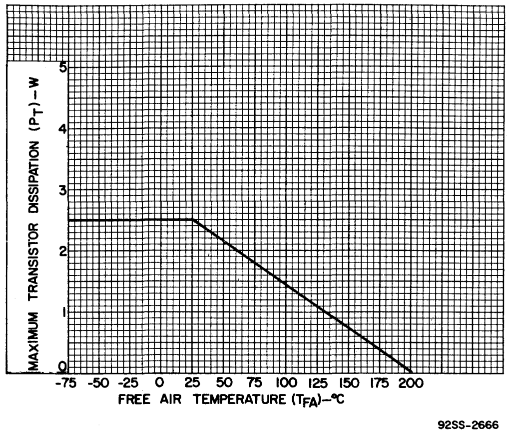


Fig. 8

DISSIPATION DERATING CURVE FOR TYPE 40374

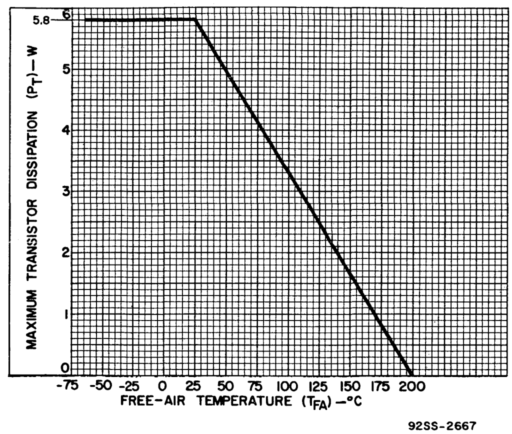


Fig. 9

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N3584

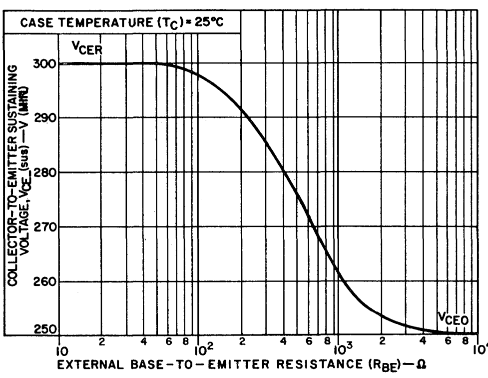


Fig. 10

SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N3585 & 2N4240

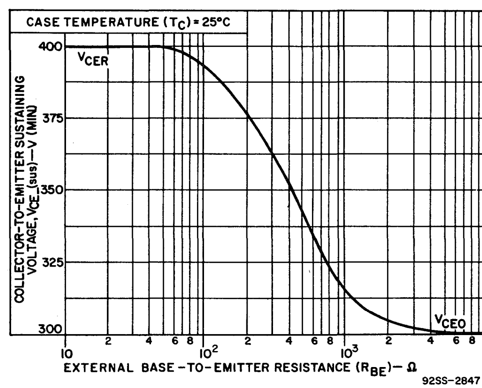
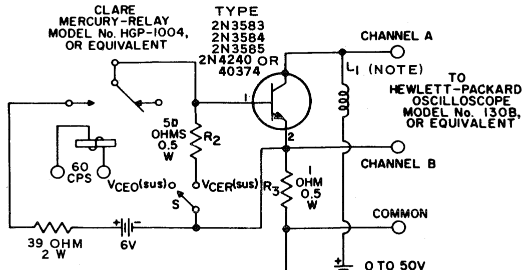


Fig. 11

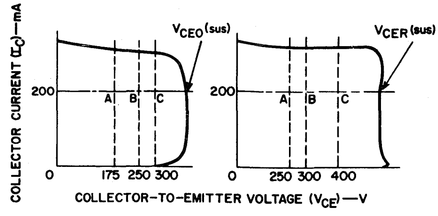
CIRCUIT USED TO MEASURE SUSTAINING VOLTAGES V_{CEO}(sus) & V_{CER}(sus) FOR TYPES 2N3583, 2N3584, 2N3585, 2N4240, & 40374



NOTE: L_1 = 20 mH for V_{CEO}(sus)
= 5 mH for V_{CER}(sus)

Fig. 12

OSCILLOSCOPE DISPLAY FOR MEASUREMENT OF SUSTAINING VOLTAGES (TEST CIRCUIT SHOWN IN FIG. 12)



NOTE: The sustaining voltages V_{CEO}(sus) and V_{CER}(sus) are acceptable when the trace falls to the right and above point "A" for types 2N3583 and 40374, point "B" for type 2N3584, and point "C" for types 2N3585 and 2N4240.

Fig. 13

TYPICAL DC BETA vs. COLLECTOR CURRENT FOR TYPES 2N3583, **2N4240**, & **40374**

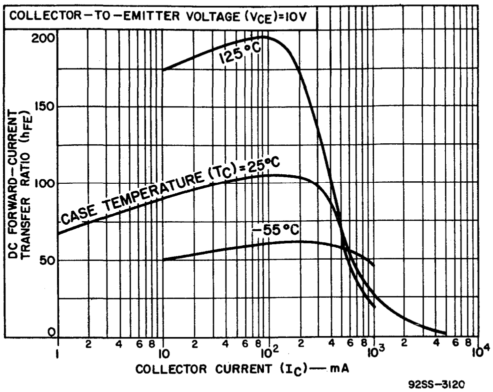


Fig. 14

TYPICAL DC BETA vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

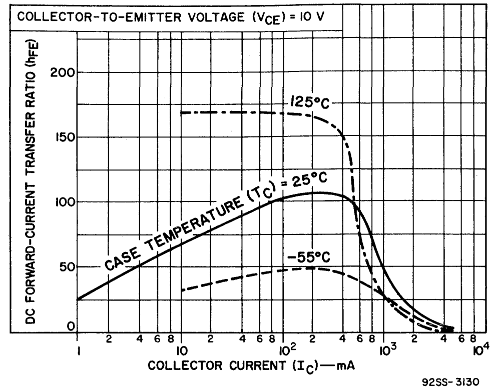


Fig. 15

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 2N3583 & **40374**

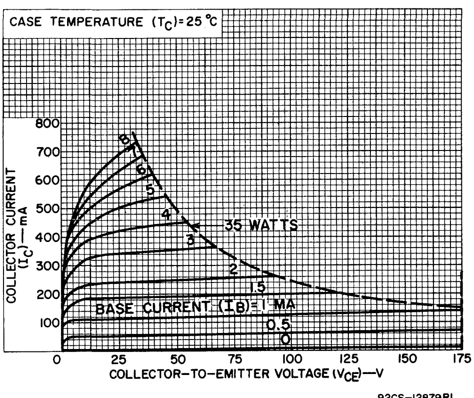


Fig. 16

TYPICAL INPUT CHARACTERISTICS FOR TYPES 2N3583, 2N3584, 2N3585, **2N4240**, & **40374**

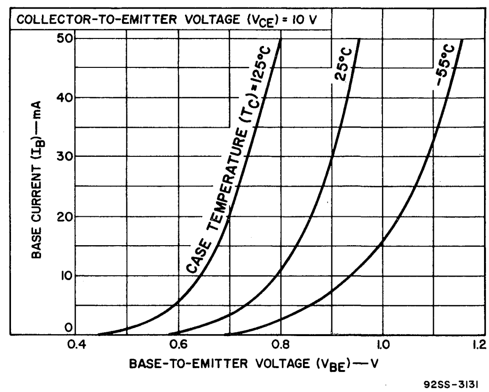


Fig. 17

TYPICAL COLLECTOR-TO-EMITTER SATURATION VOLTAGE vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

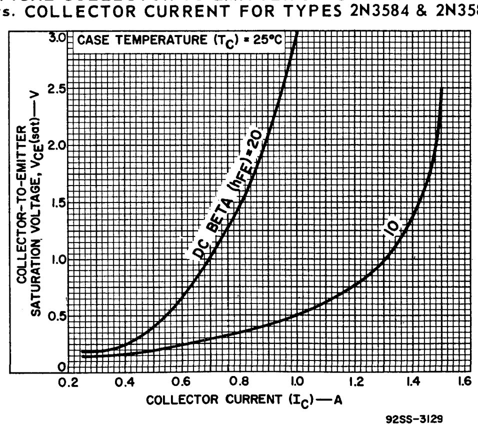
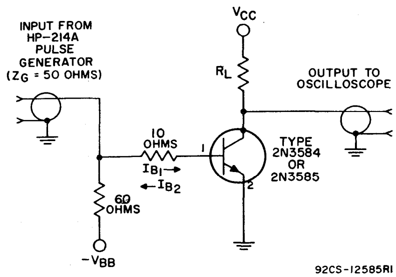


Fig. 18

CIRCUIT USED TO MEASURE SWITCHING TIMES FOR TYPES 2N3584 & 2N3585



INPUT PULSE:

Pulse Width = 20 μs

Fig. 19

OSCILLOSCOPE DISPLAY FOR MEASUREMENT OF SWITCHING TIMES (TEST CIRCUIT SHOWN IN FIG.19)

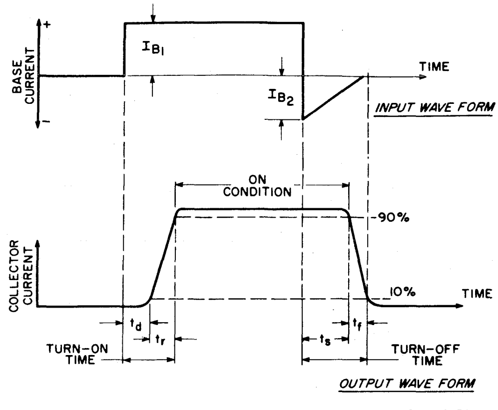


Fig. 20

TYPICAL TURN-ON TIME & FALL TIME vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

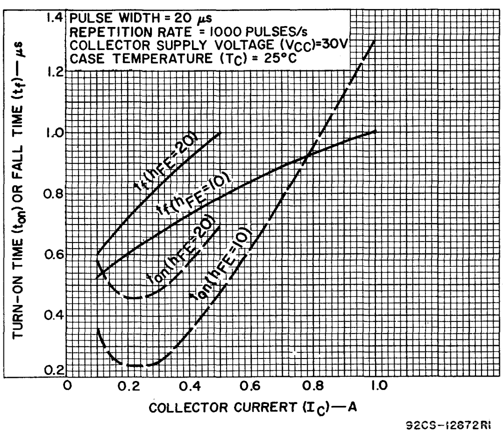


Fig. 21

TYPICAL STORAGE TIME vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

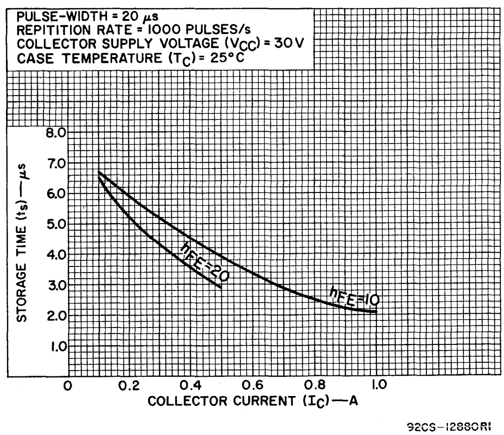


Fig. 22

TYPICAL TURN-ON TIME vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

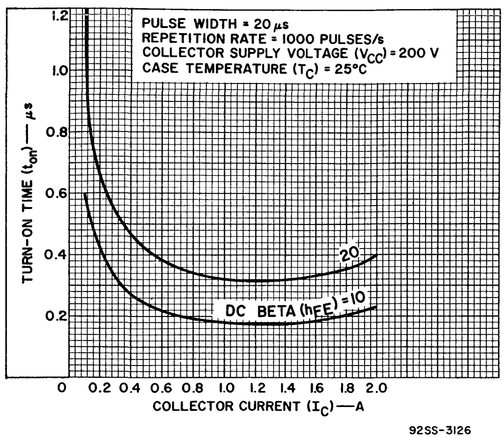


Fig. 23

TYPICAL STORAGE TIME vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

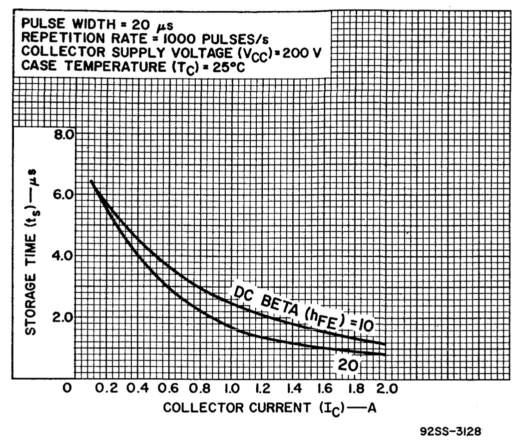


Fig. 24

TYPICAL FALL TIME vs. COLLECTOR CURRENT FOR TYPES 2N3584 & 2N3585

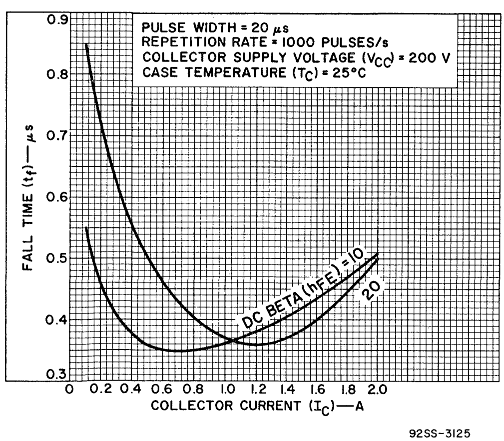


Fig. 25

TYPICAL TURN-ON TIME, FALL TIME, & STORAGE TIME vs. COLLECTOR SUPPLY VOLTAGE FOR TYPES 2N3584 & 2N3585

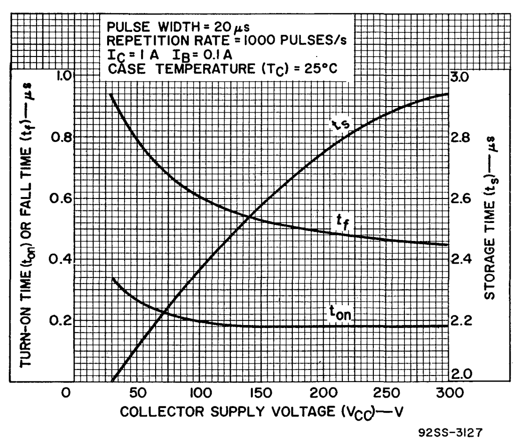
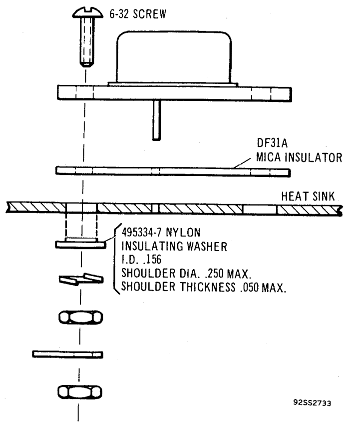


Fig. 26

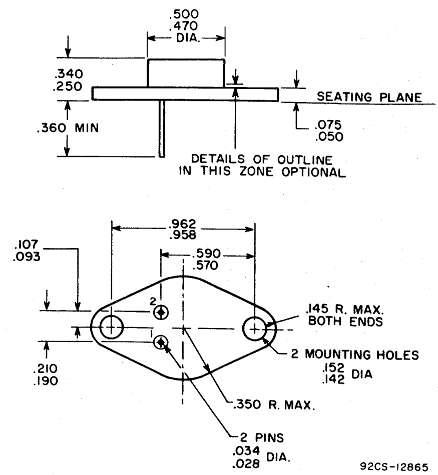
SUGGESTED HARDWARE FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240



NOTE: Hardware with part numbers are supplied

DIMENSIONAL OUTLINE FOR TYPES 2N3583, 2N3584, 2N3585, & 2N4240

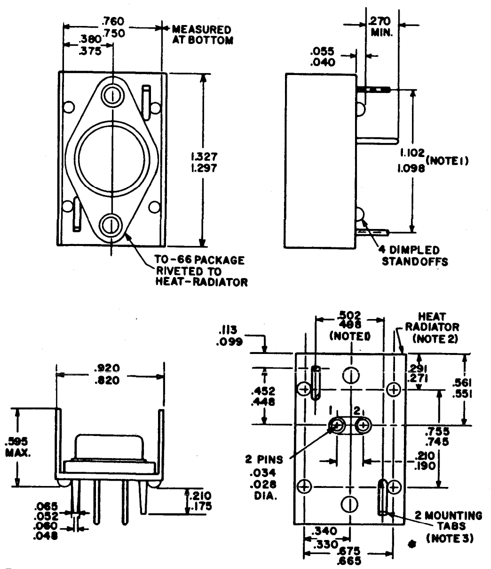
JEDEC NO. TO-66



Dimensions in Inches

DIMENSIONAL OUTLINE FOR TYPE 40374

JEDEC TO-66 WITH HEAT-RADIATOR



Dimensions in Inches

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 2N3583, 2N3584, 2N3585, 2N4240, & 40374

Pin 1 - Base

Pin 2 - Emitter

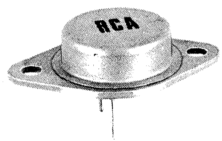
Flange, Case-Collector (For 2N3583, 2N3584, 2N3585, & 2N4240)

Heat Radiator-Collector (For 40374)

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)

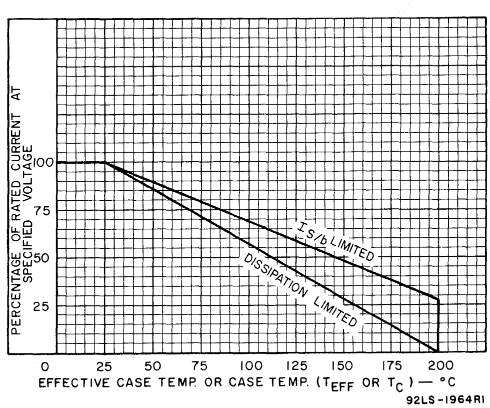


Fig. 1 - Dissipation derating curves for types 2N5239 & 2N5240

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.	
	I_{CEO}	—	200	—	—	—	—	0	—	5.0	—	2.0	mA
*	I_{CEV}	—	300	—	-1.5	—	—	—	—	4.0	—	—	mA
* Collector-Cutoff Current	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)

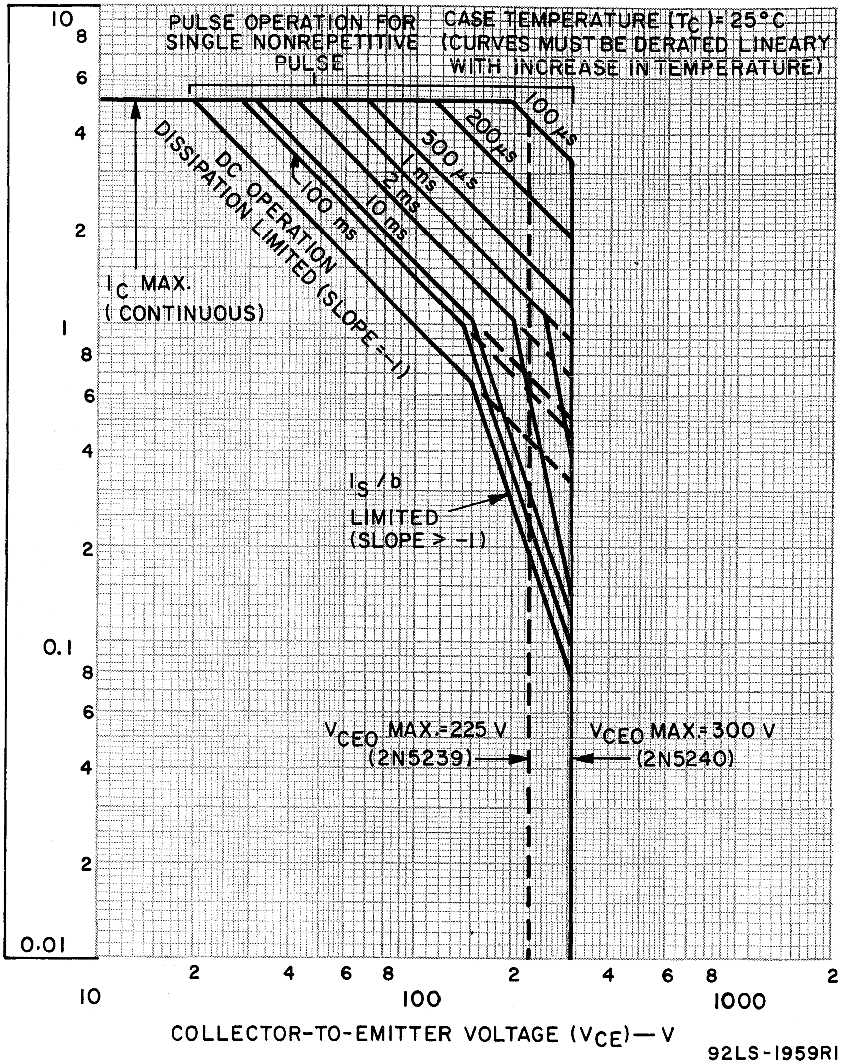


Fig. 2 - Maximum operating area for types 2N5239 & 2N5240

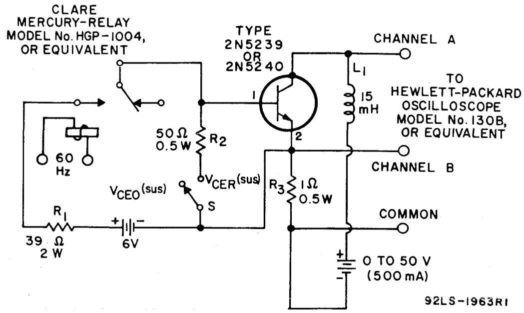
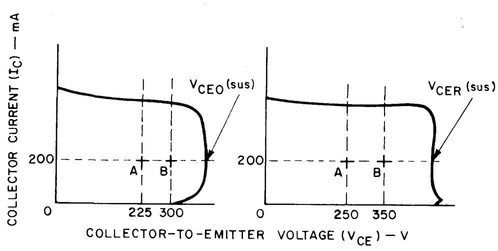


Fig. 3 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ for types 2N5239 & 2N5240



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.)

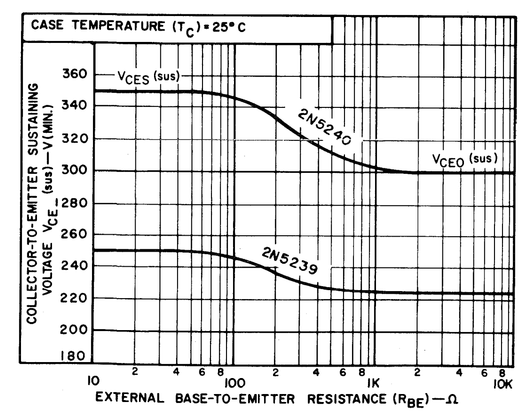


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for types 2N5239 & 2N5240

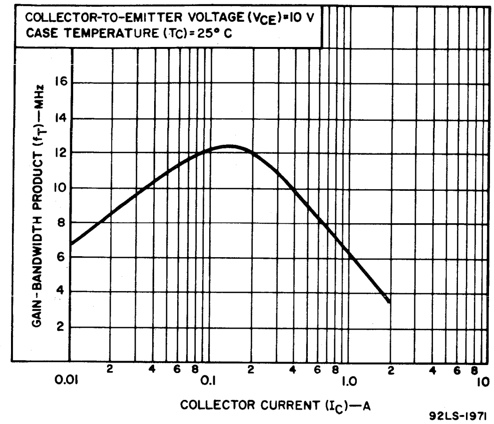


Fig. 6 - Typical gain-bandwidth product for types 2N5239 & 2N5240

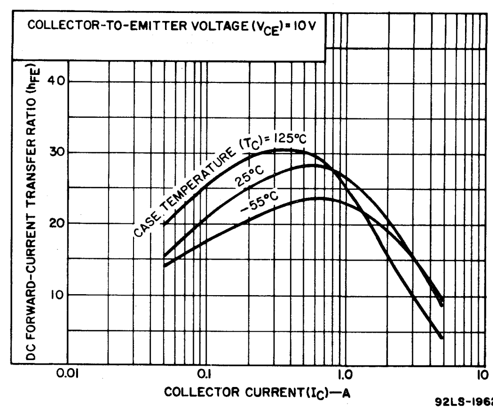


Fig. 7 - Typical DC beta for types 2N5239 & 2N5240

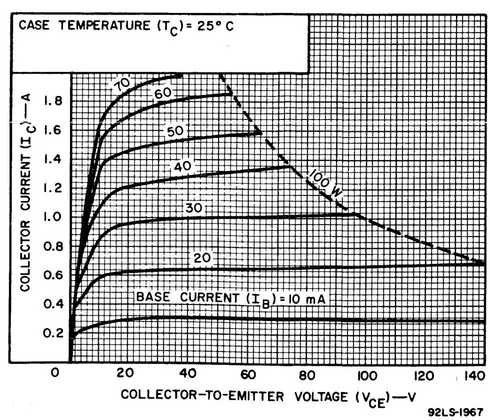


Fig. 8 - Typical output characteristics for types 2N5239 & 2N5240

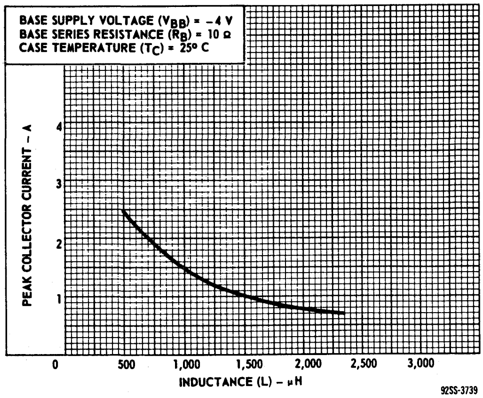


Fig. 9 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

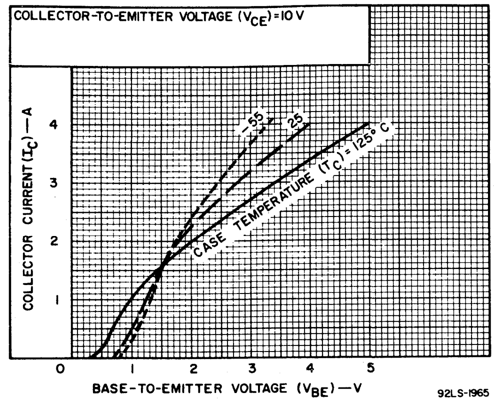


Fig. 12 - Typical transfer characteristics for types 2N5239 & 2N5240

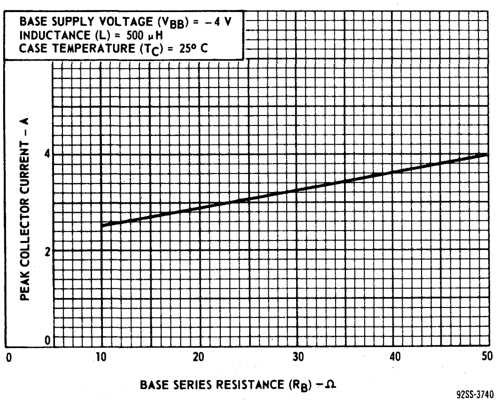


Fig. 10 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

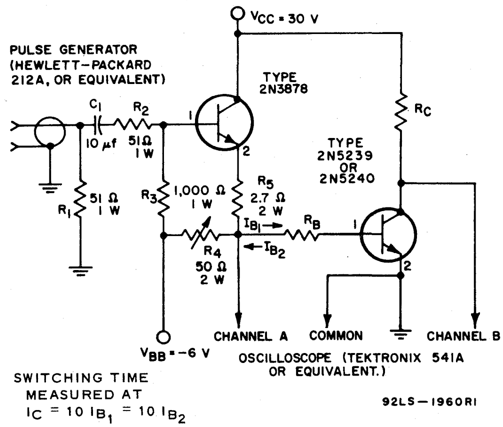


Fig. 13 - Circuit used to measure switching times for types 2N5239 & 2N5240

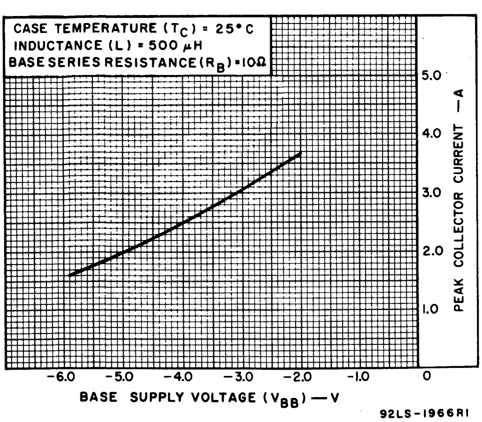


Fig. 11 - Typical reverse-bias, second breakdown characteristic for types 2N5239 & 2N5240

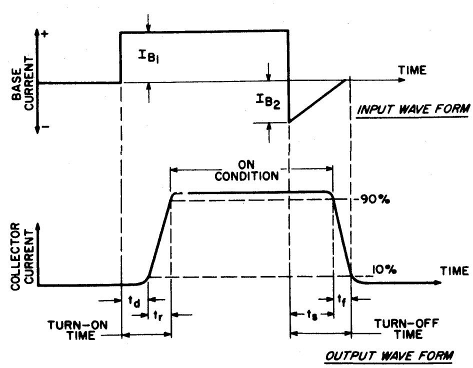


Fig. 14 - Oscilloscope display of switching times. (Test circuit shown in Fig. 13.)

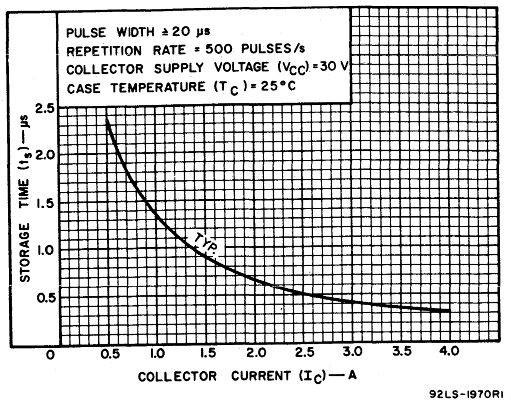


Fig. 15 - Saturated switching time (storage) vs. collector current for types 2N5239 & 2N5240

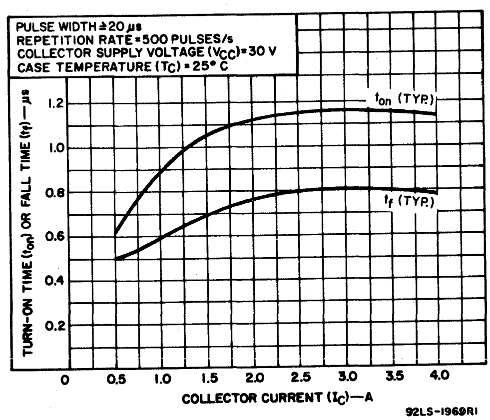


Fig. 16 - Saturated switching times (turn-on and fall) vs. collector current for types 2N5239 & 2N5240

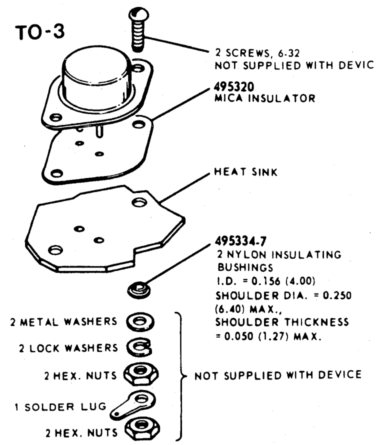
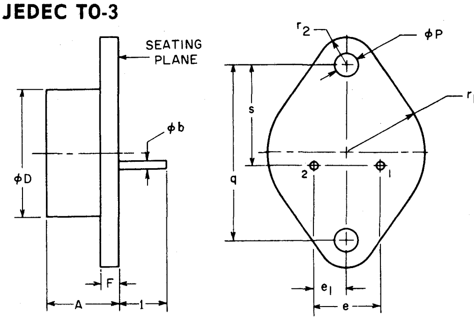


Fig. 17 - Suggested hardware for types 2N5239 & 2N5240

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	
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. (1.27mm) to 0.055 in. (1.40mm) 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

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.

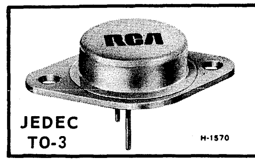
**Formerly RCA Dev. Types TA7130 & TA7130A respectively.

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 & external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CEX}(sus)$	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	5.0	5.0	A
*CONTINUOUS BASE CURRENT	I_B	2.0	2.0	A
TRANSISTOR DISSIPATION:	P_T			
* At case temperature 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. 2.		
At case temperatures above 25°C and V_{CE} above 50 V		See Fig. 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 RDF-1).

SILICON N-P-N POWER TRANSISTORS



High-Voltage High-Power Types

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

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.**

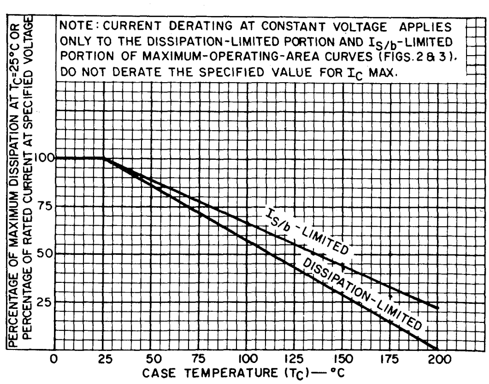


Fig. 1 - Dissipation derating curves for types 2N5804 & 2N5805.

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 2N5804 Min.	Max.	Type 2N5805 Min.	Max.	Units
Collector-Cutoff Current: With base open	I_{CEO}		150					0	–	15	–	5	mA
* With base-emitter junction reverse biased	I_{CEV}		270 340		– 1.5 – 1.5				– –	5 –	– –	– 5	mA
($T_C = 100^oC$)			270 340		– 1.5 – 1.5				– –	15 –	– –	– 15	mA
With external base-emitter resistance (R_{BE}) = 50 Ω	I_{CER}		300 375						–	15	–	– 15	mA
* Emitter-Cutoff Current	I_{EBO}			6 5		0 0			–	30 5	–	30 5	mA
* DC Forward-Current Transfer Ratio	h_{FE}		10 4			0.5[a] 5.0			25 10	250 100	25 10	250 100	
* Collector-to-Emitter Sustaining Voltage: *(See Fig. 4, 5,& 6.)* With base open	$V_{CEO}(sus)^b$					0.2		0	225	–	300	–	V
* With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CEX}(sus)^b$		–		-1.5	0.2		0	300[g]	–	375[g]	–	V
Emitter-to-Base Voltage	V_{EBO}							0.03	6	–	6	–	V
* Base-to-Emitter Sat. Voltage	$V_{BE}(sat)$		10			5.0[a]		0.5	–	2	–	2	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					5.0[a]		0.5	–	2	–	2	V
Output Capacitance (At 1 MHz)	C_{obo}	10					0		–	450	–	450	pF
* Second-Breakdown[c] Collector Current[e] (With base forward biased)	$I_{S/b}^d$		50		d				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 Fig. 13, 14 & 15.)*	t_s		200			5.0		0.5	–	3.5	–	3.5	μs
Fall *(See Fig. 14 & 15.)*	t_f		200			5.0		0.5	–	2.0	–	2.0	μs
** Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$		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. 4.
[c]Safe-operating region for forward- and reverse-bias operation is explained on page 3.
[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.

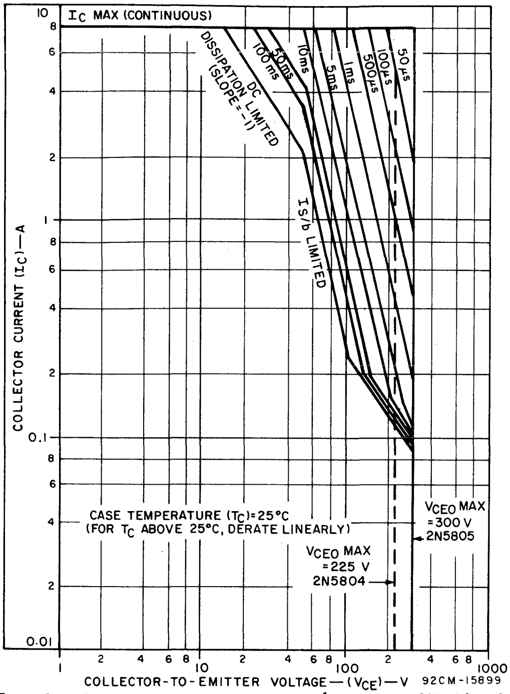


Fig. 2 - Maximum operating areas for types 2N5804 & 2N5805.

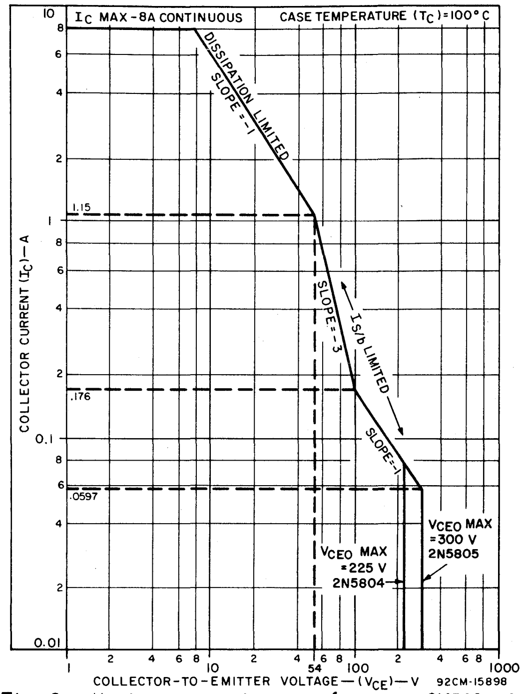


Fig. 3 - Maximum operating areas for types 2N5804 & 2N5805.

FORWARD-BIAS OPERATION

All transistors are power-dissipation limited and possibly second-breakdown limited. For a complete discussion of maximum operating area, refer to "RCA Power Circuits Manual" (Pub. No. SP-51.) See sections: "MAXIMUM RATINGS" (page 71); "THERMAL CONSIDERATIONS" (page 73); "SECOND-BREAKDOWN" (page 87); and "SAFE-AREA RATINGS" (page 94).

With the emitter-base junction forward biased for transistor operation in the active region, the operating collector-to-emitter voltage, duration of the collector current flow, and transistor temperature will determine whether the device is second-breakdown limited.

For types 2N5804 and 2N5805 the maximum operating area is defined by five straight lines on a log-log plot of V_{CE} vs. I_C. As shown in Fig. 2, a horizontal line defines the maximum current, a line with a slope of - 1(corresponding to values of V_{CE} between 14 and 50 volts) defines the maximum power dissipation allowable.

As can be seen in Fig. 2, these transistors are free from second-breakdown out to 50 volts and 2.2 amperes. The boundary, out to this point, is made up of the maximum current and maximum power curves. Beyond the boundary, second-breakdown effect becomes the controlling factor. The second-breakdown boundary is made up of two successive straight lines – one with a slope of -3, and another with a slope of -1(corresponding to values of V_{CE} between 100 and 300 volts). The final limiting factors are the maximum voltage ratings for the devices.

Second breakdown is less sensitive to temperature variations than normal power-dissipation limitations. Therefore, separate temperature derating curves are required for these two limiting factors as shown in Fig. 1. For operation at temperatures greater than 25°C, Figs. 1 and 2 are used to obtain the maximum allowable power. This is done as follows:

(1) For a specified value of collector-to-emitter voltage, V_{CE}, determine (from Fig.2) the maximum collector current at 25°C.

(2) Refer to Fig.1 and, from the appropriate curve, 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.

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 incuctance in series with the collector.

For further information on second-breakdown, consult "RCA Power Circuits Manual" (Pub. No. SP-51) and RCA Application Note SMA-30, "Second-Breakdown in Transistors Under Conditions of Cutoff."

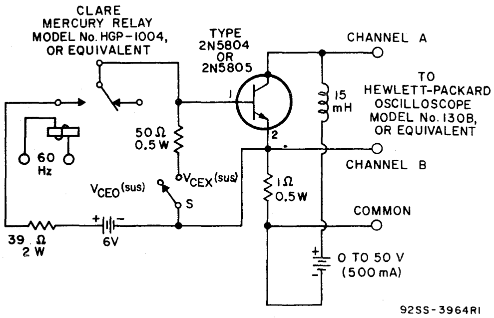


Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ & $V_{CEX}(sus)$ for types 2N5804 & 2N5805.

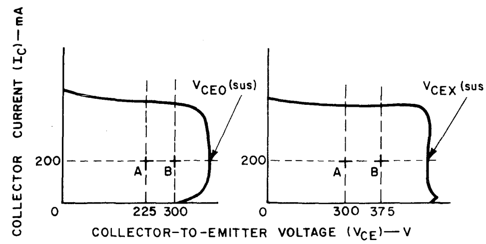


Fig. 5 - Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 4).

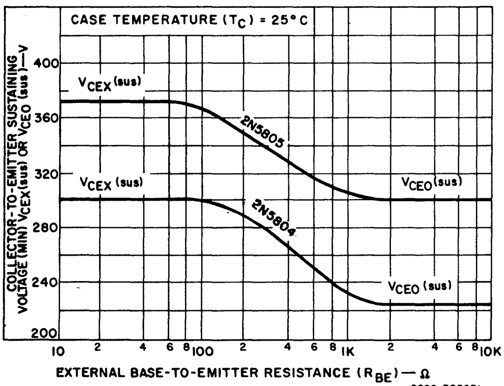


Fig. 6 - Collector-to-emitter sustaining-voltage characteristics for types 2N5804 & 2N5805.

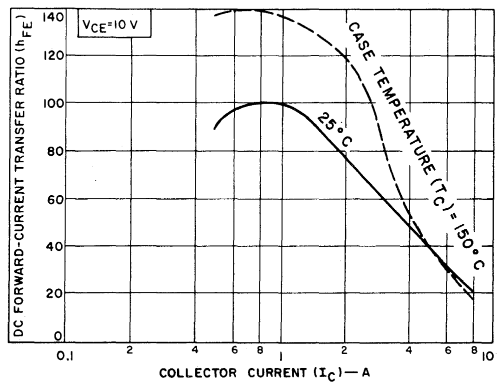


Fig. 7 - Typical dc-beta characteristics for types 2N5804 & 2N5805.

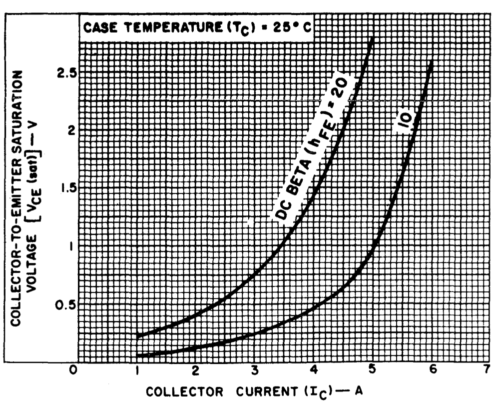


Fig. 8 - Typical saturation-voltage characteristics for types 2N5804 & 2N5805.

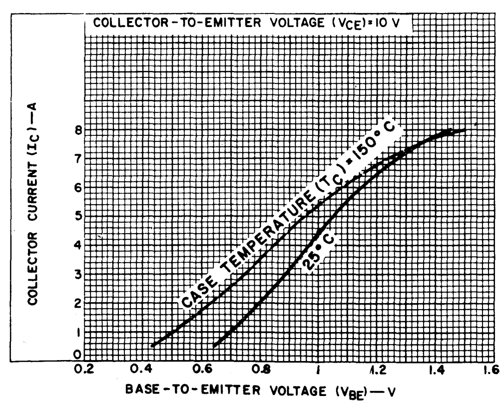


Fig. 9 - Typical transfer characteristics for types 2N5804 & 2N5805.

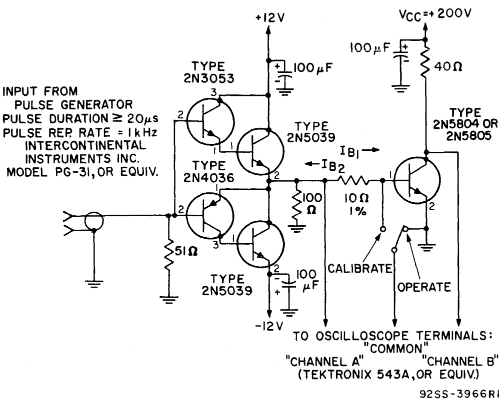


Fig. 10 - Circuit used to measure switching times for types 2N5804 & 2N5805.

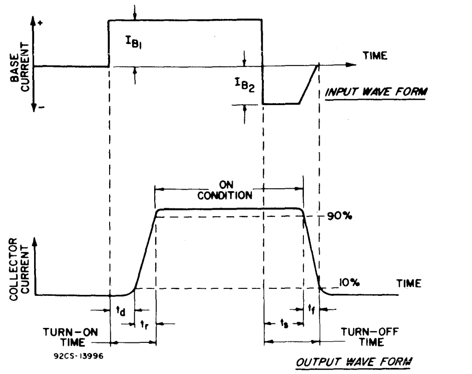


Fig. 11 - Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 10.)

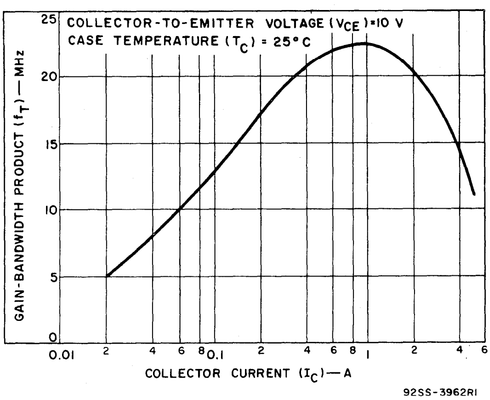


Fig. 12 - Typical gain-bandwidth product for types 2N5804 & 2N5805.

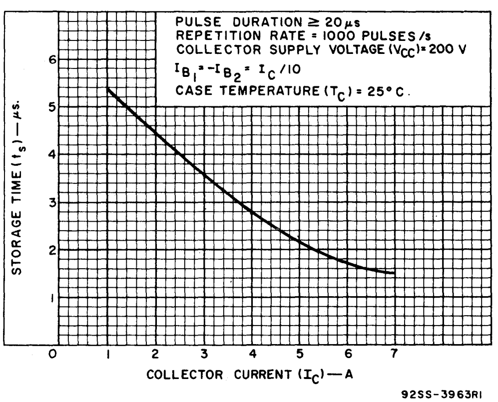


Fig. 13 - Typical storage-time characteristic for types 2N5804 & 2N5805.

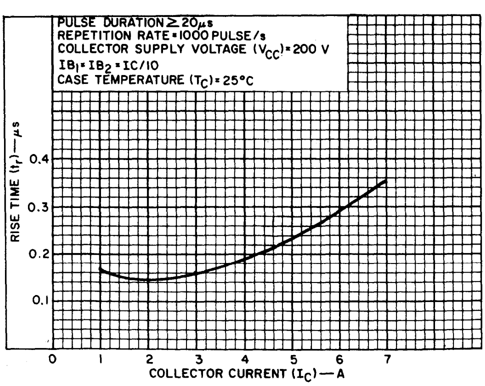


Fig. 14 - Typical rise-time characteristic for types 2N5804 & 2N5805.

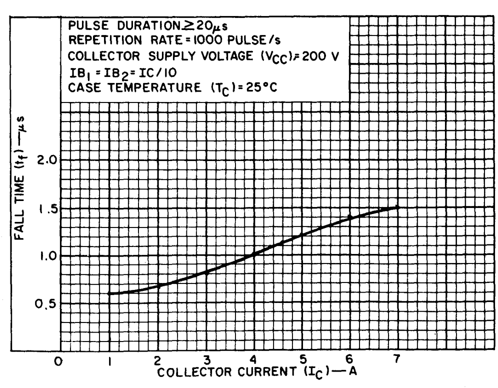


Fig. 15 - Typical fall-time characteristic for types 2N5804 & 2N5805.

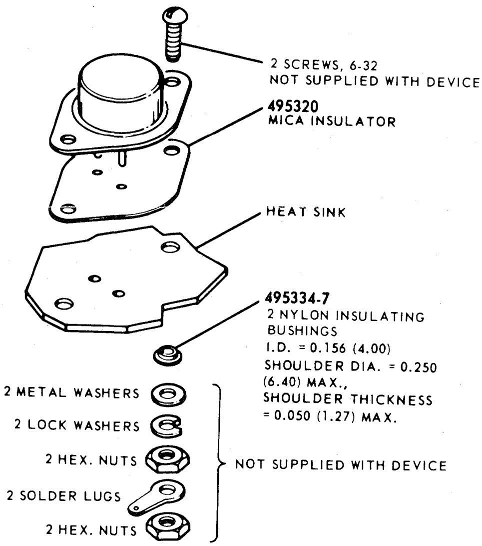
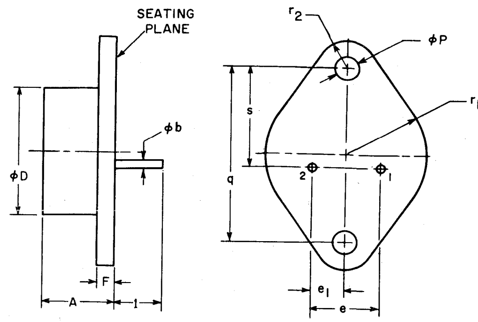


Fig. 16 - Suggested hardware for mounting types 2N5804 & 2N5805.

DIMENSIONAL OUTLINE (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

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

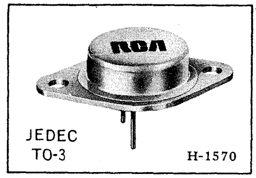
Power Transistors
2N5838
2N5839
2N5840

SILICON N-P-N POWER TRANSISTORS

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.



High-Voltage High-Power Types For Switching and Linear Applications in Military, Industrial, and Commercial Equipment

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}) $\leq 50\ \Omega$, 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 ≥ 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

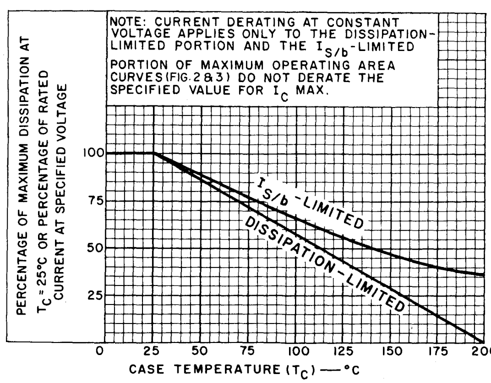


Fig. 1 - Derating curves for all types.

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

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 2N5838 Min.	Max.	Typ.	Type 2N5839 Min.	Max.	Typ.	Type 2N5840 Min.	Max.	Typ.	Units
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)	θ_{J-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).

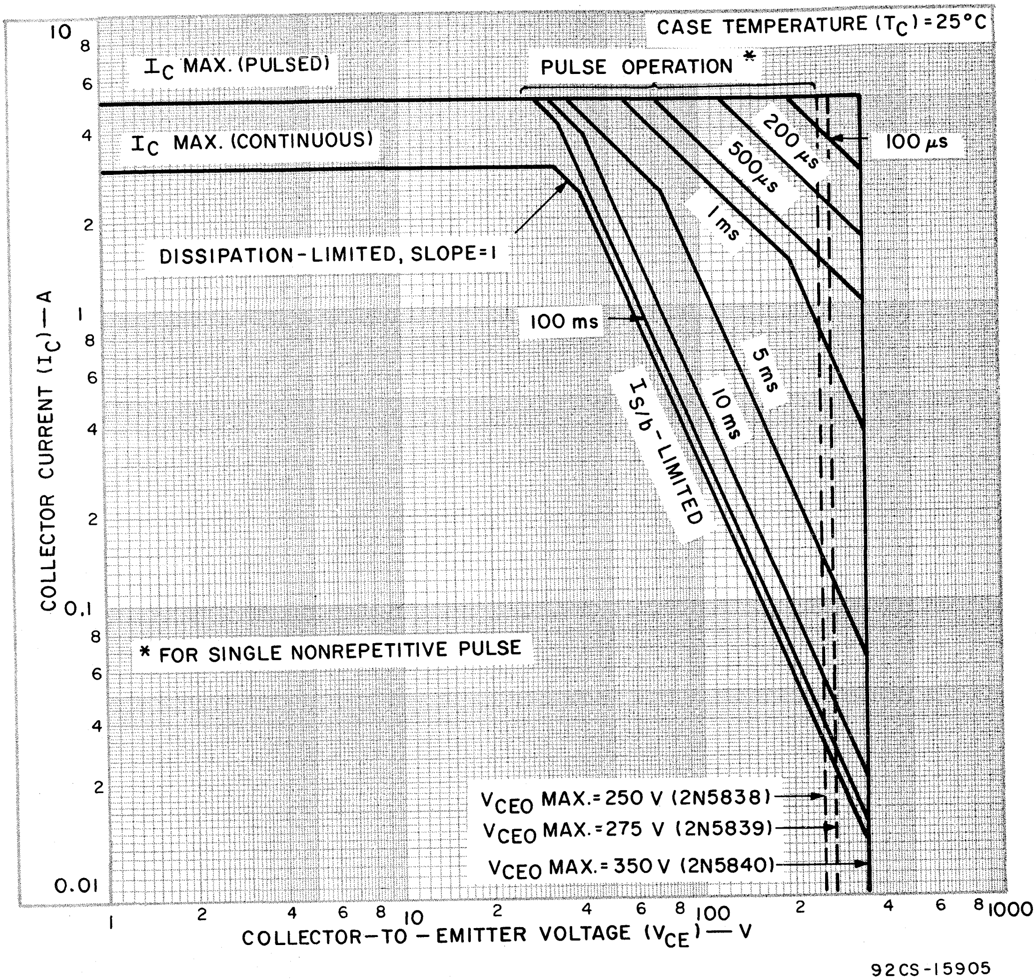


Fig. 2 - Maximum operating areas for all types.

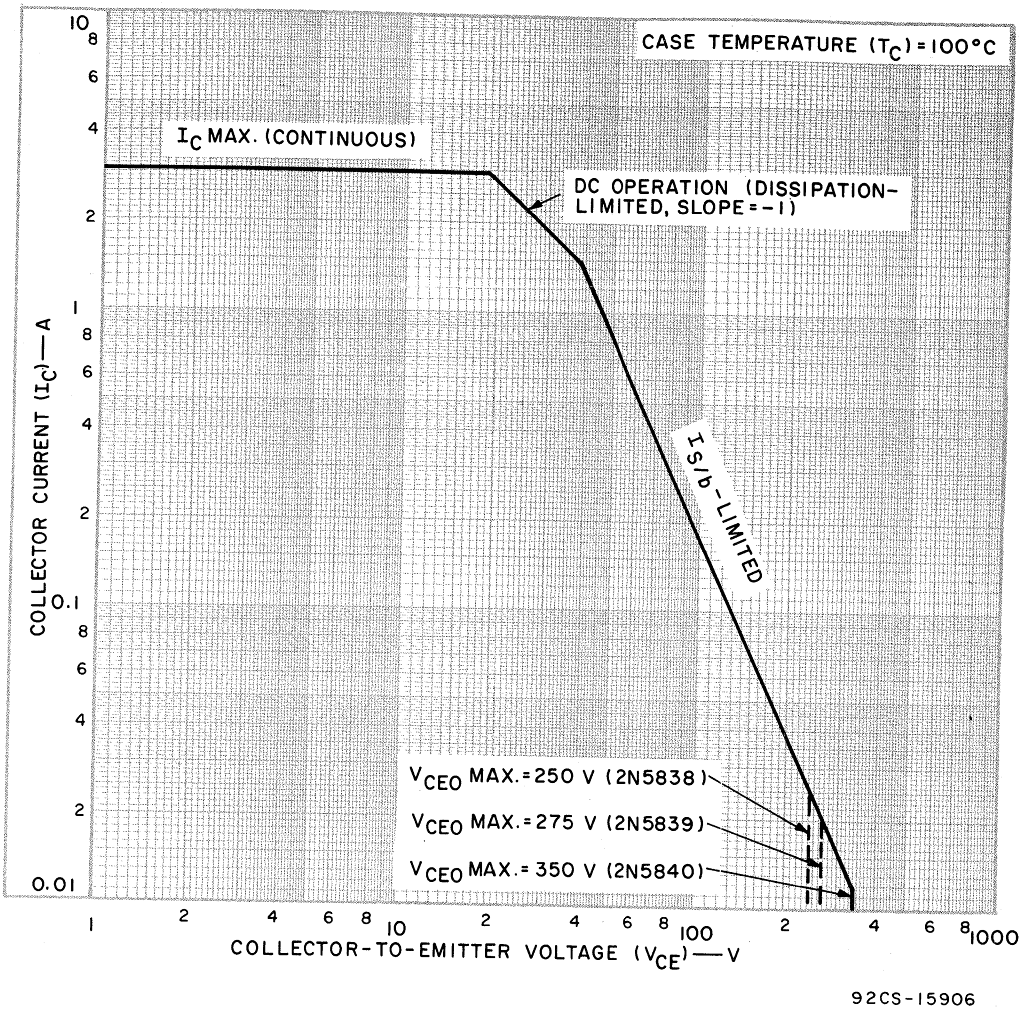


Fig. 3 - Maximum operating areas for all types.

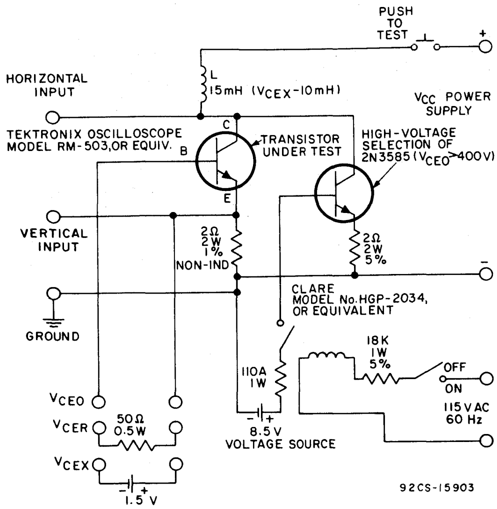


Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ for all types.

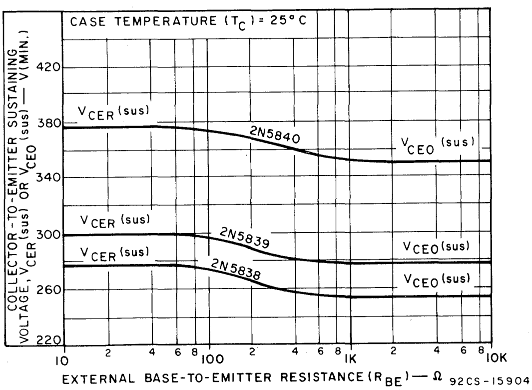


Fig. 6 - Collector-to-emitter sustaining voltage characteristics for all types.

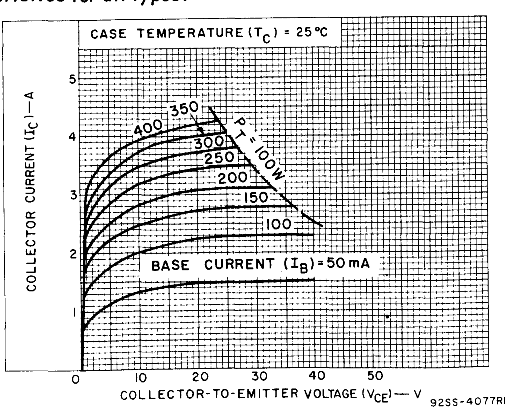
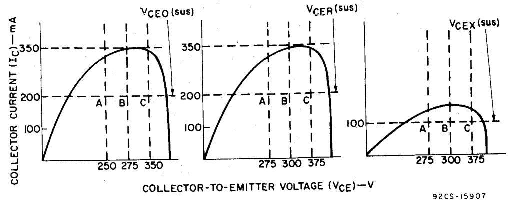


Fig. 8 - Typical output characteristics for all types.



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).

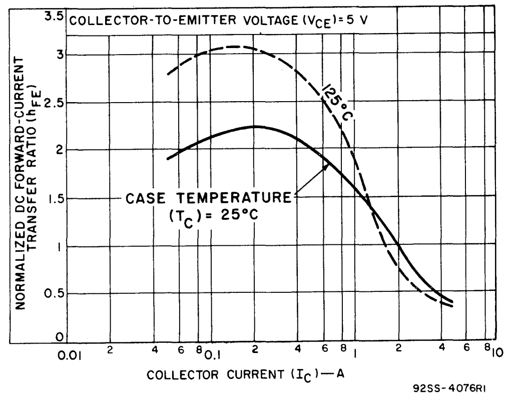


Fig. 7 - Typical normalized dc beta characteristics for all types.

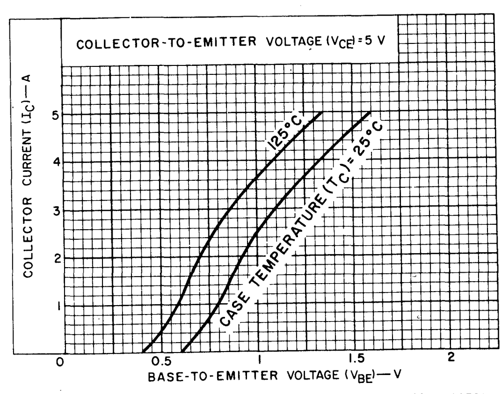


Fig. 9 - Typical transfer characteristics for all types.

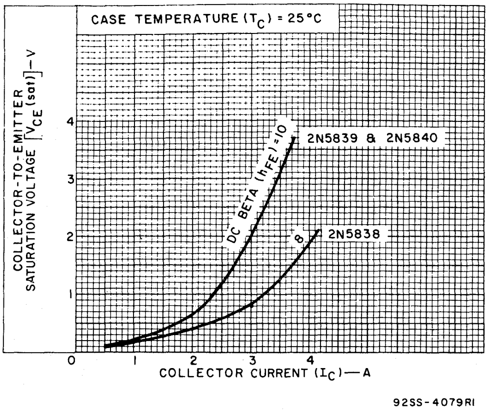


Fig. 10 - Typical saturation voltage characteristics for all types.

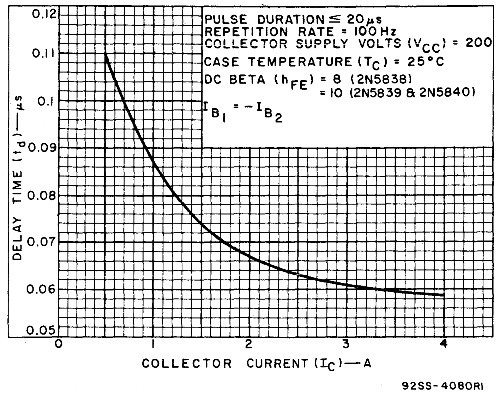


Fig. 11 - Typical delay-time characteristic for all types.

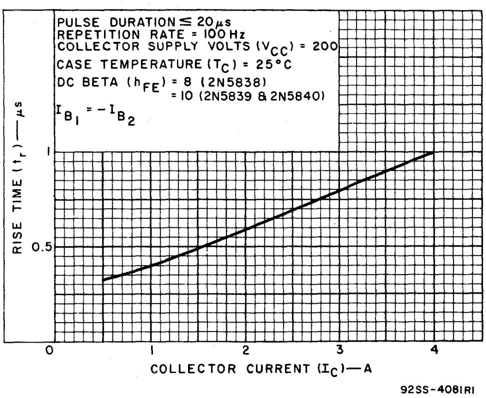


Fig. 12 - Typical rise-time characteristic for all types.

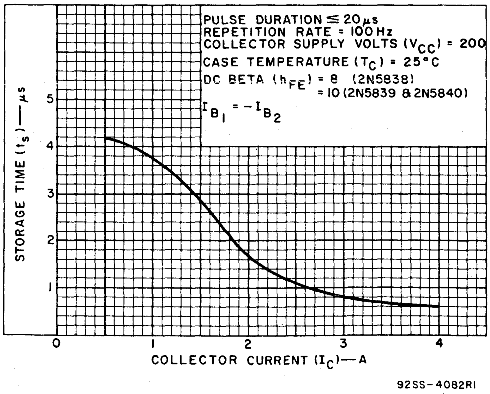


Fig. 13 - Typical storage-time characteristic for all types.

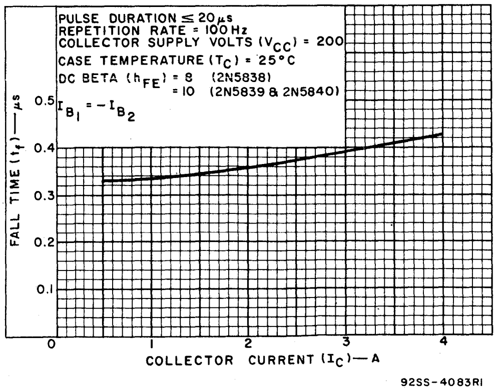
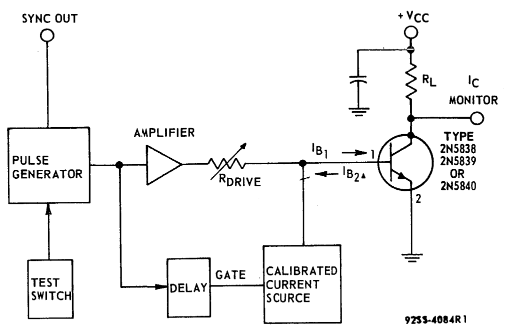


Fig. 14 - Typical fall-time characteristic for all types.



*I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig. 15 - Circuit used to measure switching times for all types.

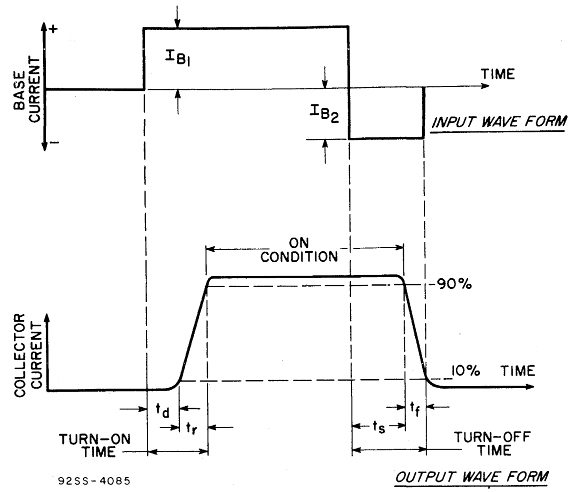


Fig. 16 - Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 15).

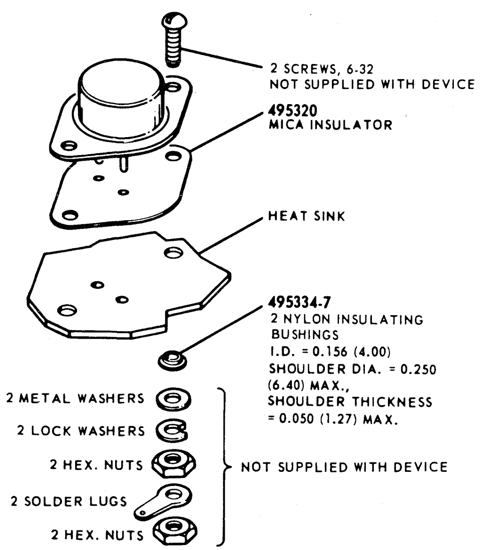
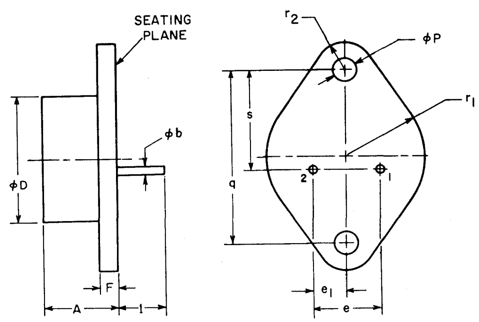


Fig. 17 - Suggested mounting hardware for all types.

TERMINAL CONNECTIONS

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

DIMENSIONAL OUTLINE FOR TYPES 2N5838, 2N5839, 2N5840 JEDEC TO-3



SYMBOL	INCHES 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

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: DC Collector Voltage (V) V_{CE}	DC Emitter Voltage (V) V_{CB}	DC Emitter Voltage (V) V_{BE}	DC Current (A) I_C	DC Current (A) I_B	DC Current (A) I_E	Limits: Type 2N6077 Min.	2N6077 Typ.	2N6077 Max.	Type 2N6078 Min.	2N6078 Typ.	2N6078 Max.	Type 2N6079 Min.	2N6079 Typ.	2N6079 Max.	Units
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]	–	–	V
* 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	μs
* 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	μs
* *(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	μs
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).

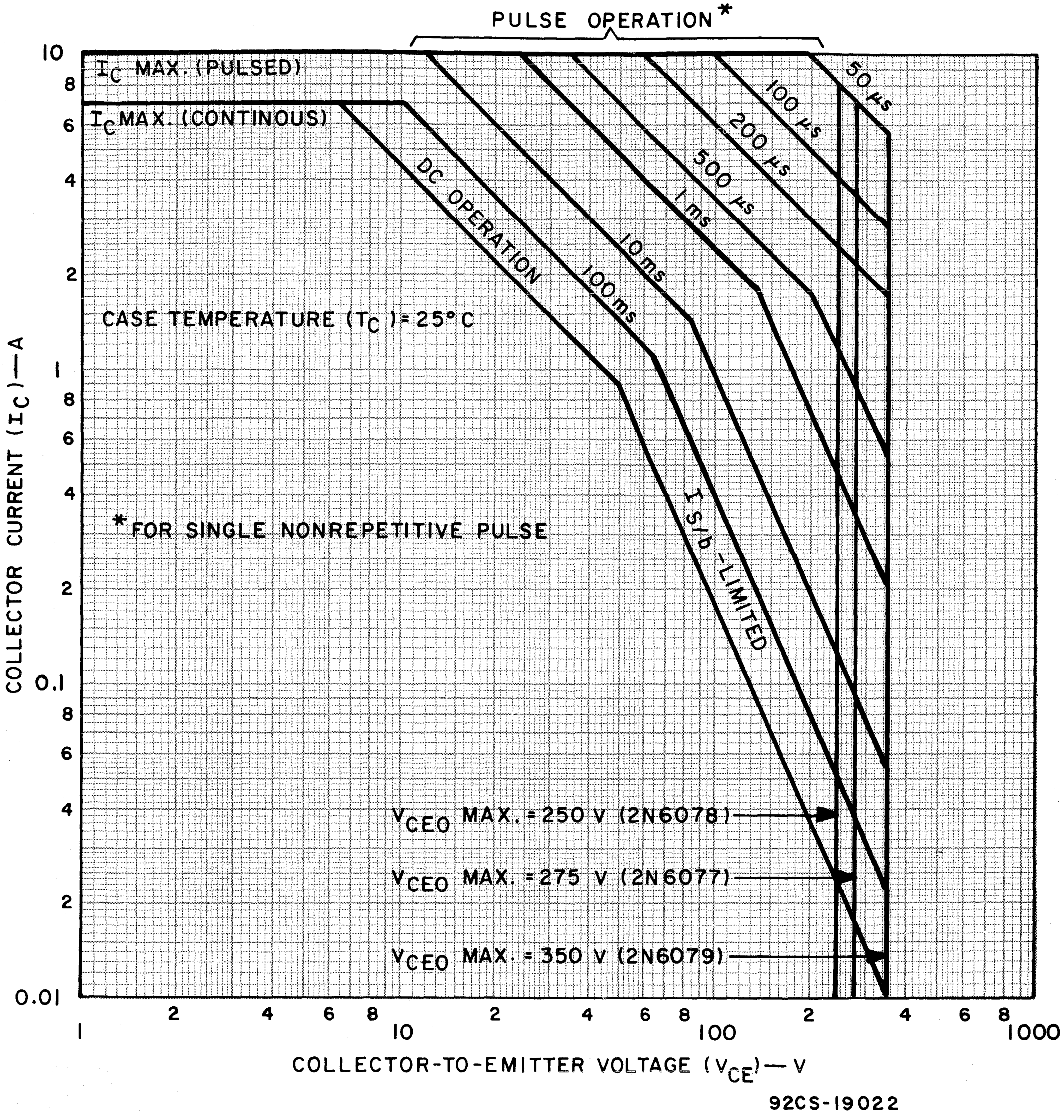


Fig. 1—Maximum operating areas for all types.

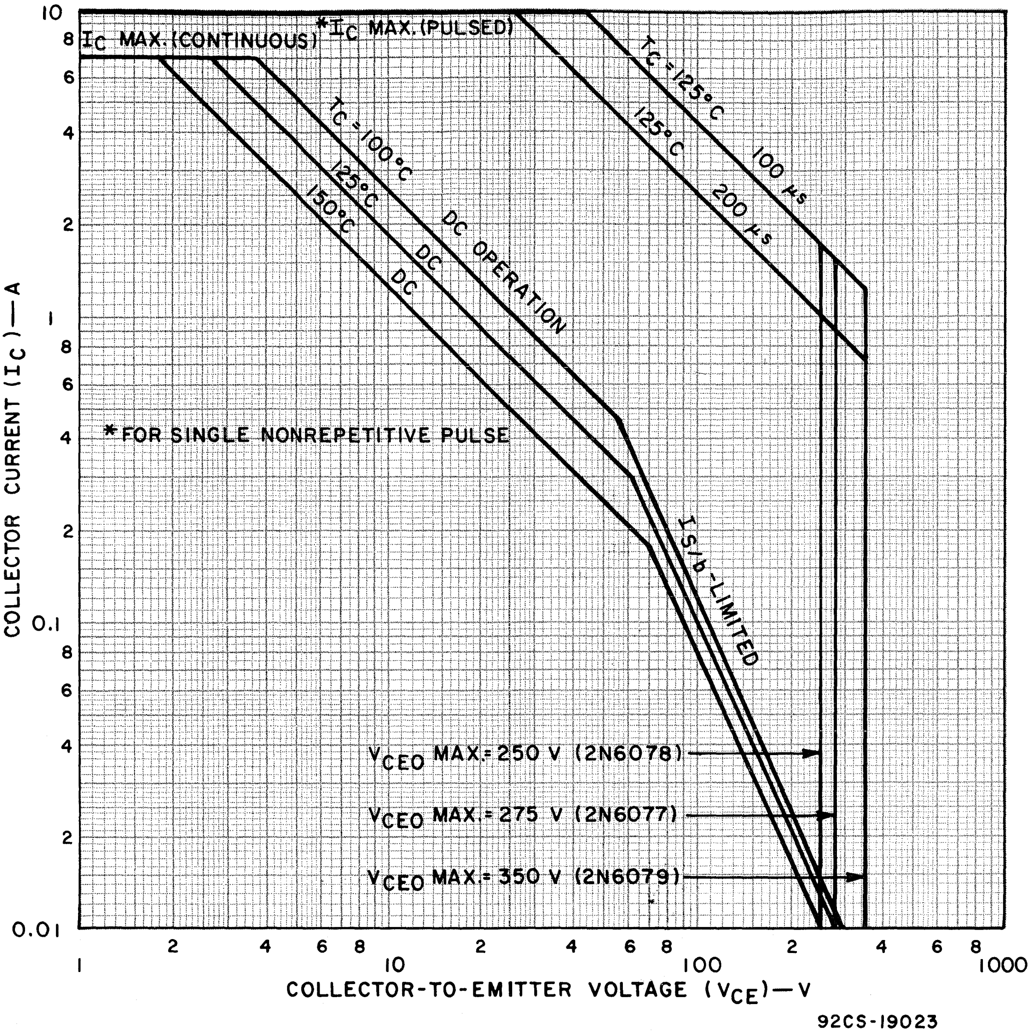


Fig.2—Maximum operating areas for all types.

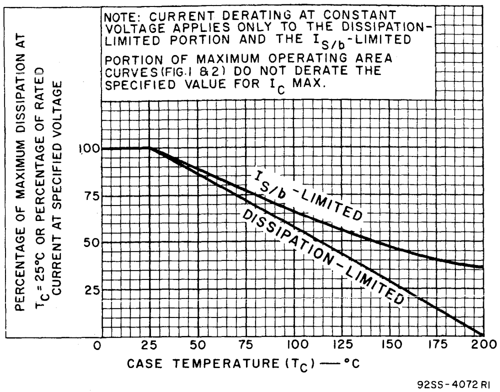


Fig.3—Derating curve for all types.

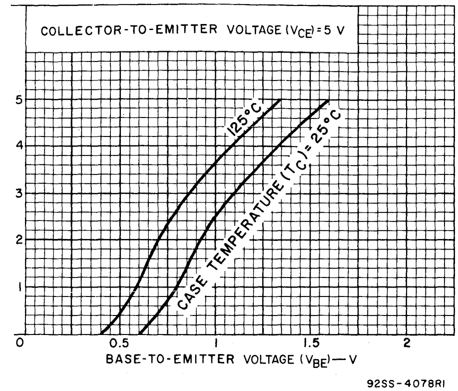


Fig.4—Typical transfer characteristics for all types.

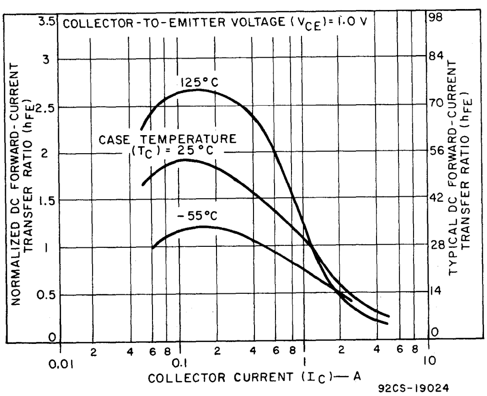


Fig.5—Typical normalized dc beta characteristics for all types.

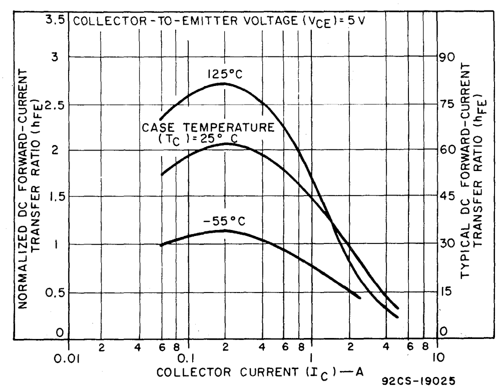


Fig.6—Typical normalized dc beta characteristics for all types.

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).

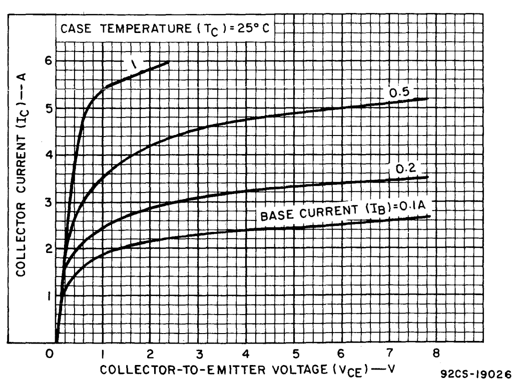


Fig.7—Typical output characteristics for all types.

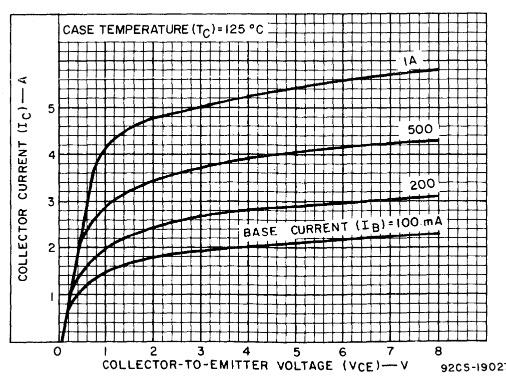


Fig.8—Typical output characteristics for all types.

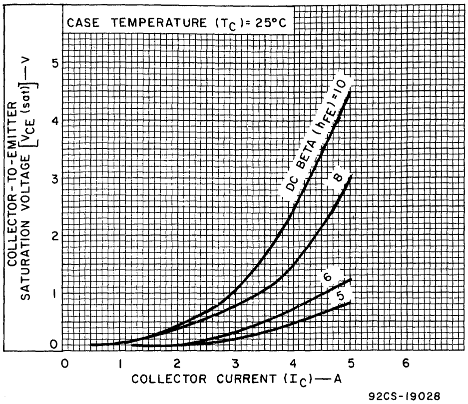


Fig.9—Typical saturation voltage characteristics for all types.

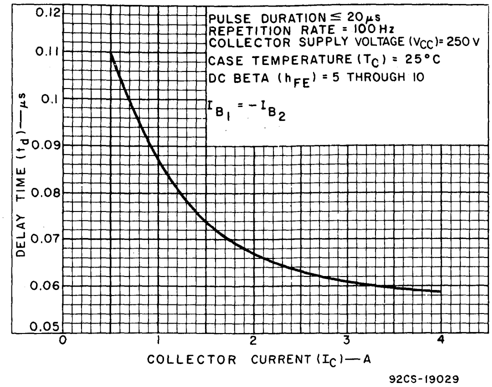


Fig.10—Typical delay-time characteristic for all types.

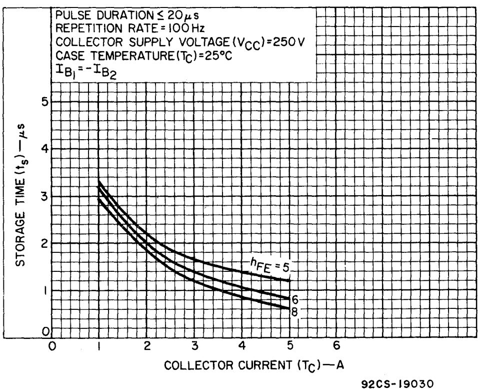


Fig.11—Typical storage-time characteristic for all types (with constant forced gain).

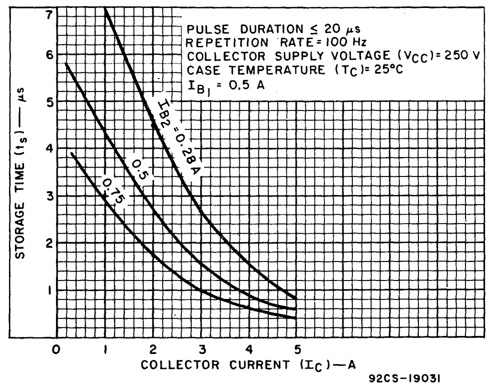


Fig.12—Typical storage-time characteristic for all types (with constant-base drives).

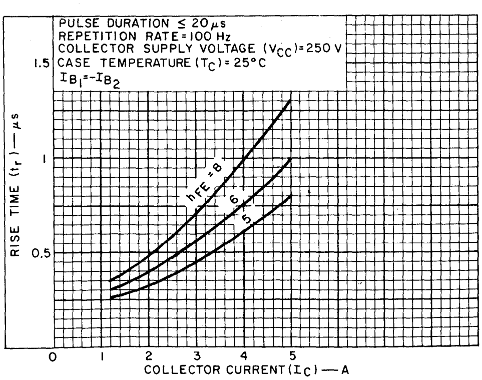


Fig.13—Typical rise-time characteristic for all types.

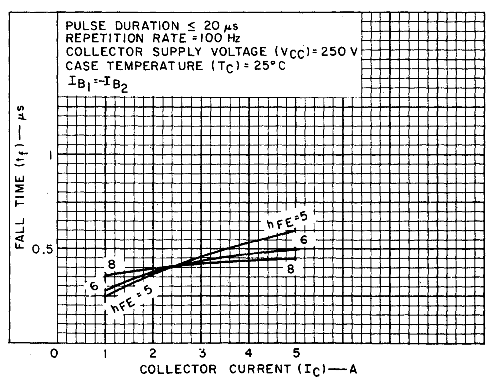


Fig.14—Typical fall-time characteristic for all types.

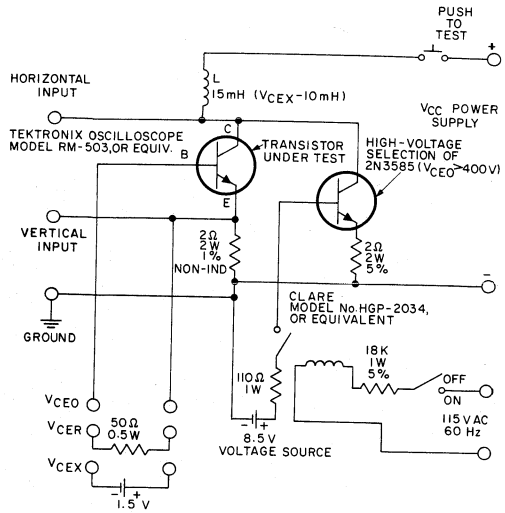
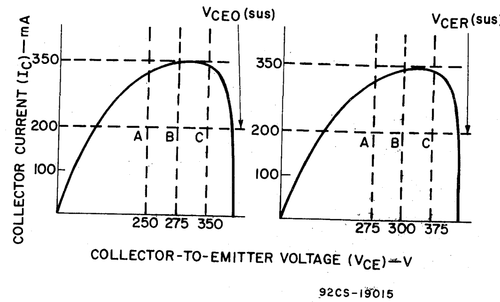
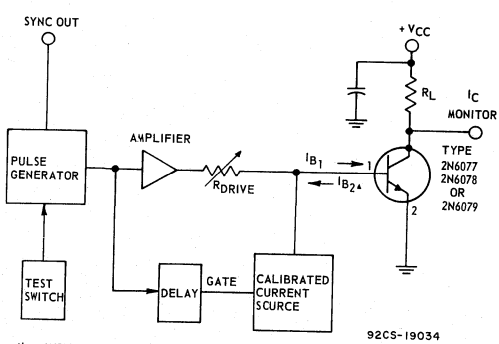


Fig.15—Circuit used to measure sustaining voltages V_{CEO}(sus), V_{CER}(sus) for all types.



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).



*I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig.17—Circuit used to measure switching times for all types.

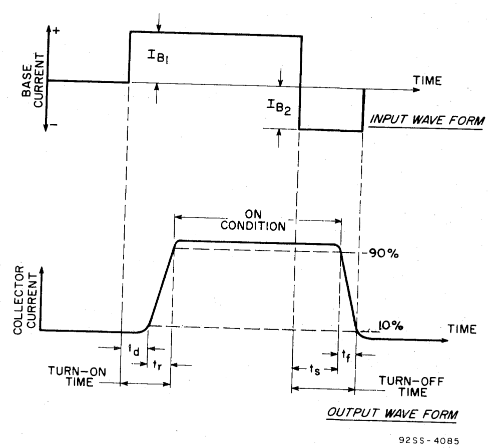


Fig.18—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 17).

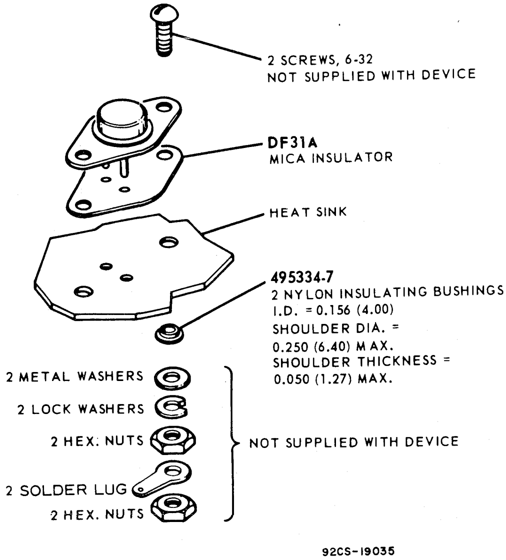
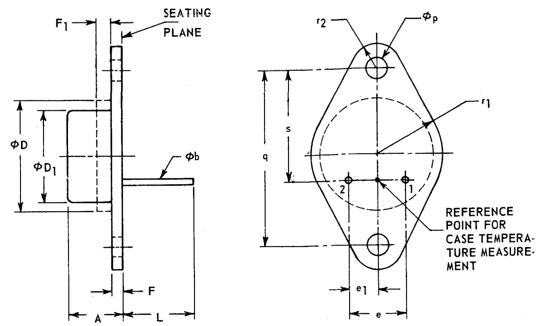


Fig.19– Suggested hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES		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. Dimension does not include sealing flanges.

92SS-3738

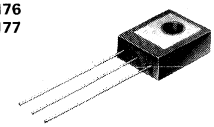
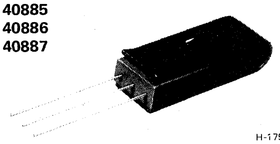
TERMINAL CONNECTIONS

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}	DC COLLECTOR VOLTAGE (V) V_{CE}	DC EMITTER OR BASE VOLTAGE (V) V_{EB}	DC EMITTER OR BASE VOLTAGE (V) V_{BE}	DC CURRENT (mA) I_C	DC CURRENT (mA) I_E	DC CURRENT (mA) I_B	LIMITS: 2N6175 40885 MIN.	2N6175 40885 MAX.	2N6176 40886 MIN.	2N6176 40886 MAX.	2N6177 40887 MIN.	2N6177 40887 MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}		300 200					0 0	– –	– 50	– –	– 50	– –	20 –	µA
* With emitter open	I_{CBO}	360 280 240							– – –	– – 50	– – –	– 50 –	– – –	20 – –	µA
With base-emitter junction reverse-biased	I_{CEV}		450 300		-1.5 -1.5				– –	– 500	– –	– 500	– –	500 –	µA
* Emitter-Cutoff Current	I_{EBO}			6					–	20	–	20	–	20	µA
DC Forward-Current Transfer Ratio	h_{FE}		10 10 10 10			50[d] 20[d] 5[d] 1[d]			– 30* – 15	– 190 – –	– 30* 15 –	– 150 – –	30* – 15 –	150 – – –	
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[d]		4	–	1.3	–	1.3	–	1.3	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					50[d]		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 10			20 5			– –	300 –	– –	– 300	– –	– 300	Ω
* 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	°C/W
Junction-to-Ambient	$R_{\theta JA}$								– (2N6175) – (40885)	138 78.6	– (2N6176) – (40886)	138 78.6	– (2N6177) – (40887)	138 78.6	°C/W

* 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.

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

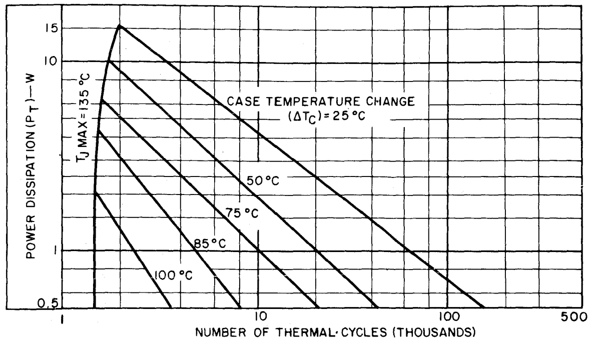


Fig. 1—Thermal-cycling rating chart.

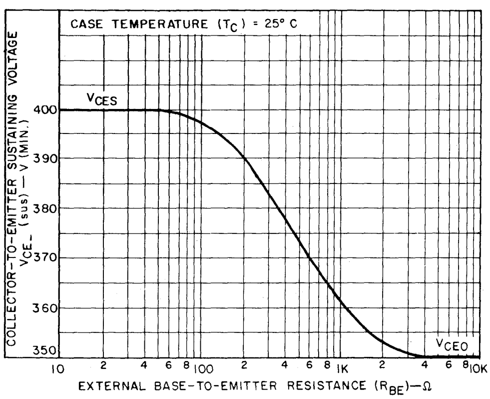


Fig.2—Sustaining voltage vs. base-to-emitter resistance for types 2N6177 and 40877.

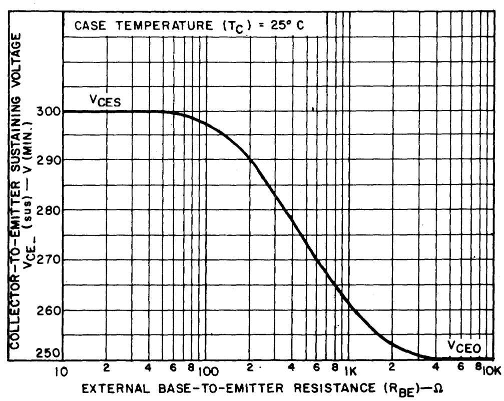


Fig.3—Sustaining voltage vs. base-to-emitter resistance for types 2N6175 and 40885.

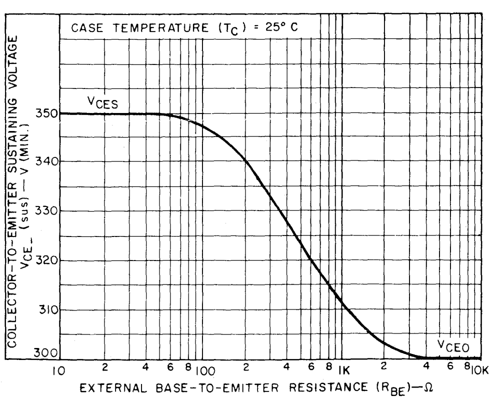


Fig.4—Sustaining voltage vs. base-to-emitter resistance for types 2N6176 and 40886.

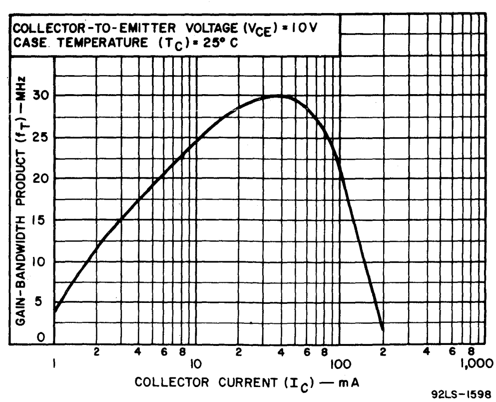


Fig.5—Typical gain-bandwidth product for all types.

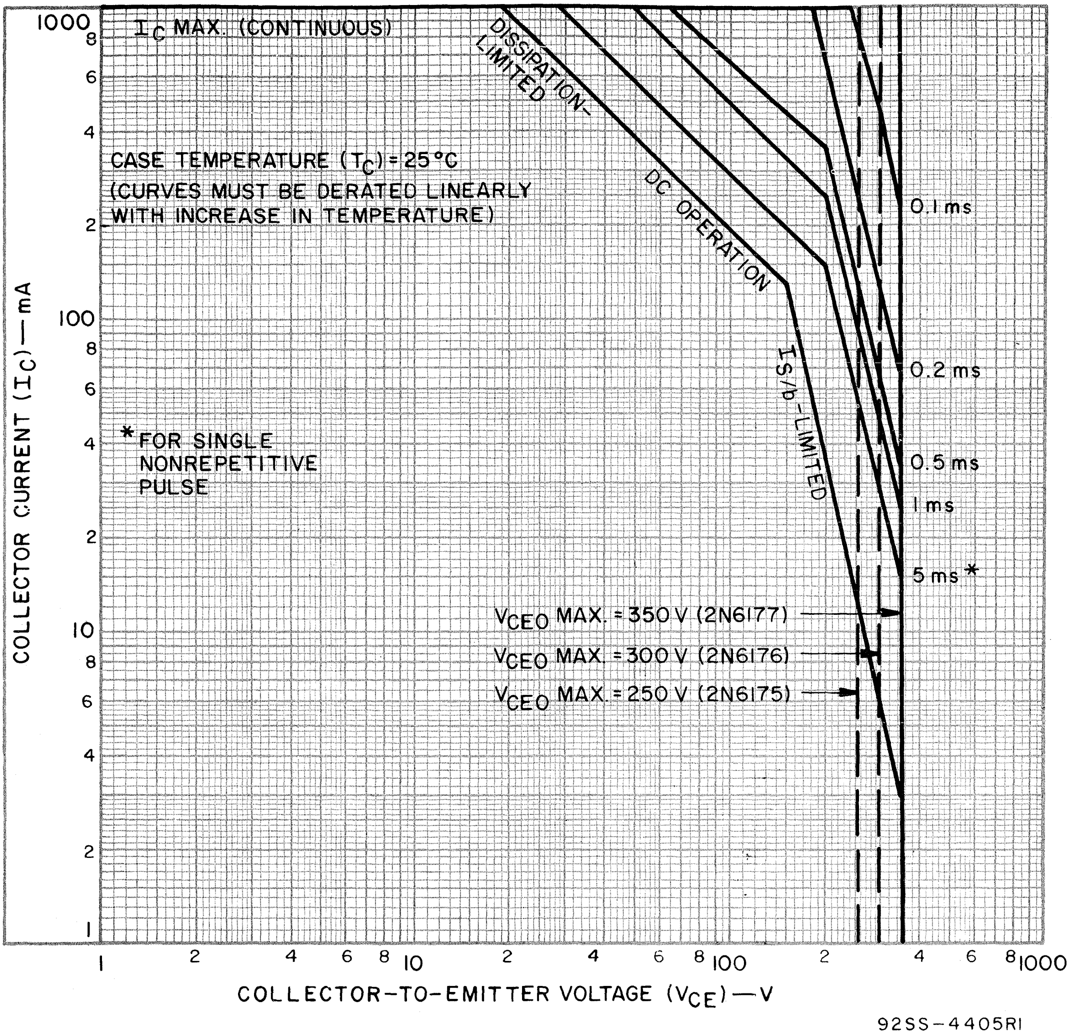


Fig.6—Maximum safe-operating-areas for types 2N6175, 2N6176, and 2N6177.

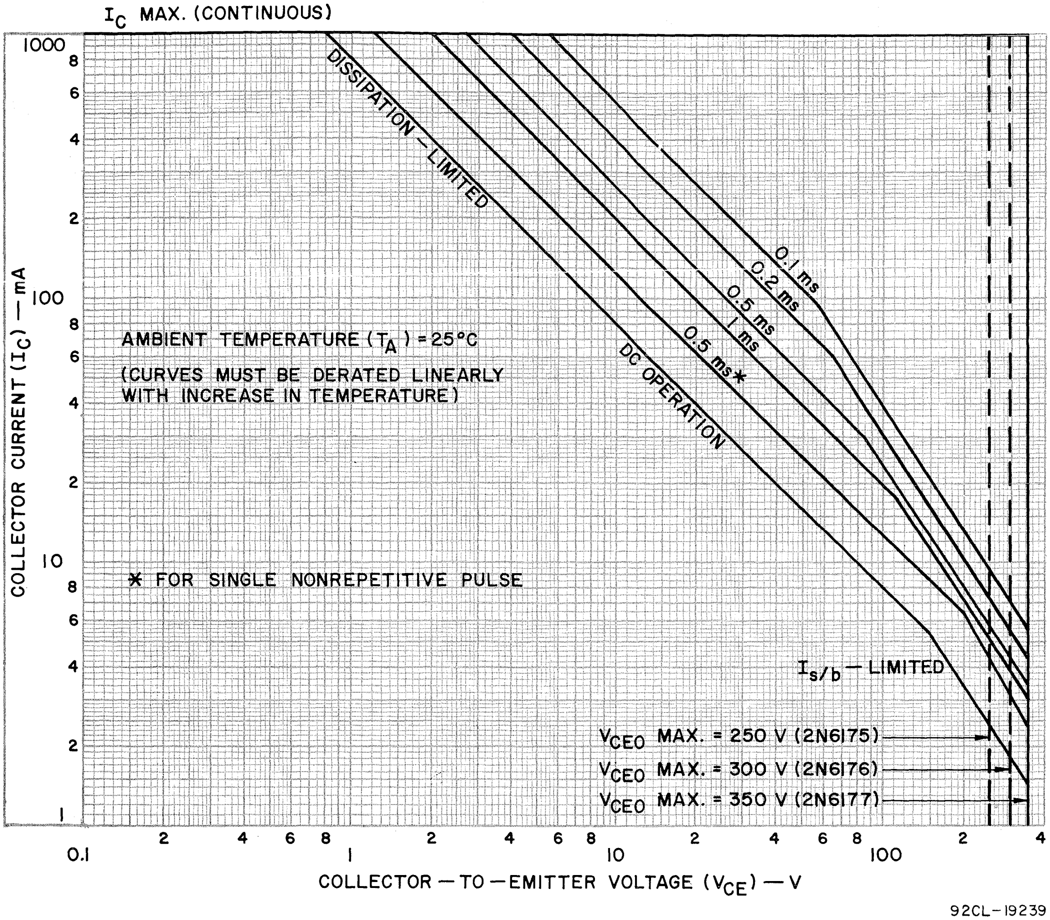


Fig.7—Maximum safe area-of-operation at ambient temperature for types 2N6175, 2N6176, and 2N6177.

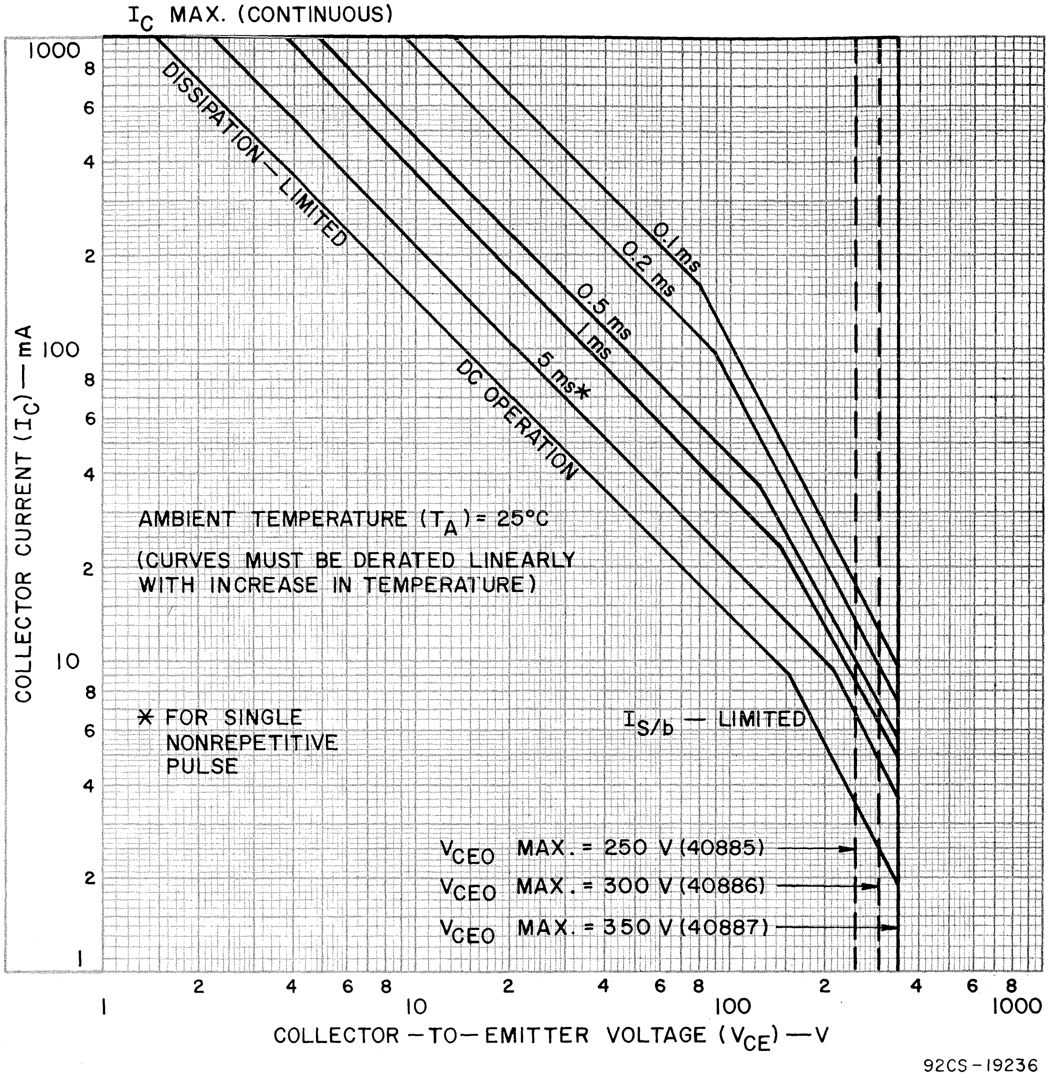


Fig.8—Maximum safe area-of-operation for types 40885, 40886, and 40887.

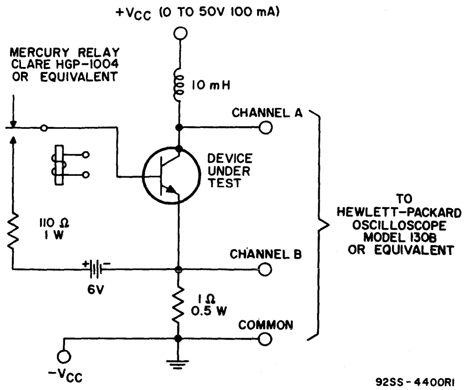
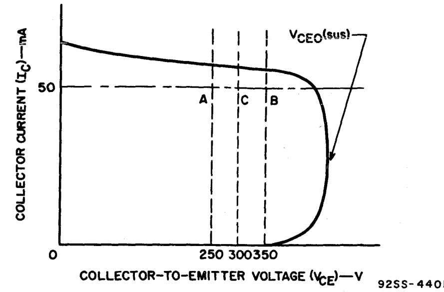


Fig.9—Circuit used to measure sustaining voltage, $V_{CEO}(sus)$.



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).

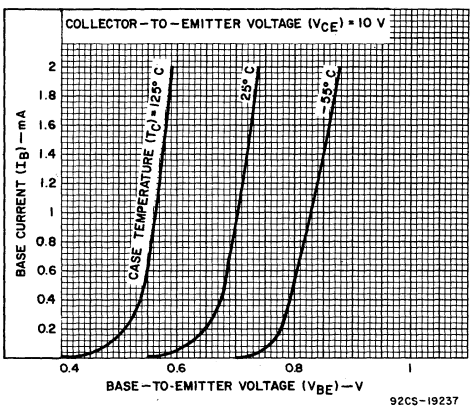


Fig.11—Typical input characteristics for all types.

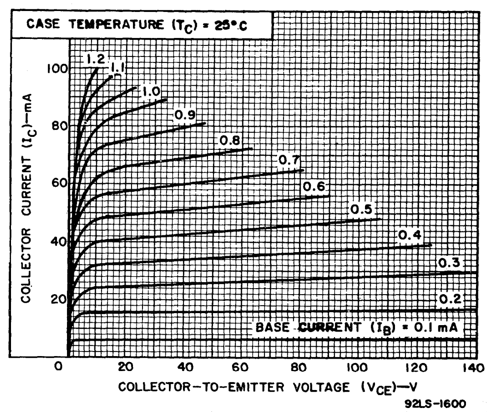


Fig.12—Typical output characteristics for all types.

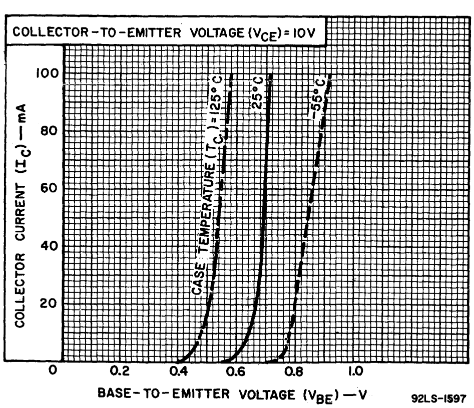


Fig.13—Typical transfer characteristics for all types.

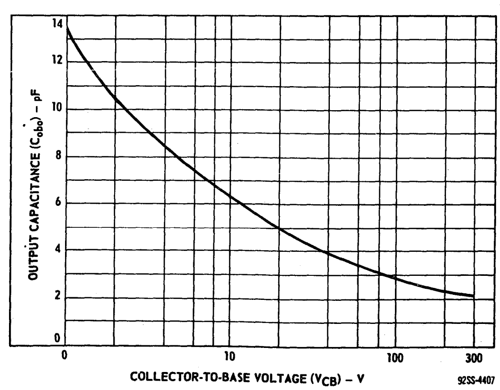


Fig.14—Typical output capacitance vs collector-to-base voltage for all types.

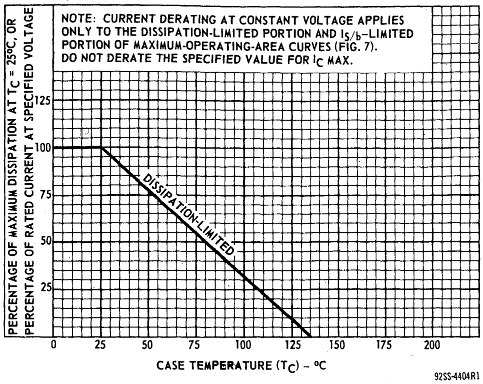


Fig. 15—Dissipation derating curve for all types.

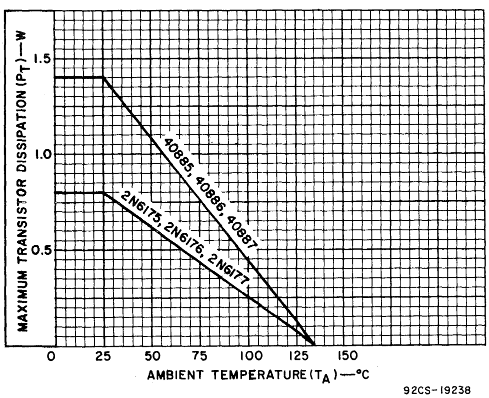


Fig. 16—Dissipation derating curves for all types.

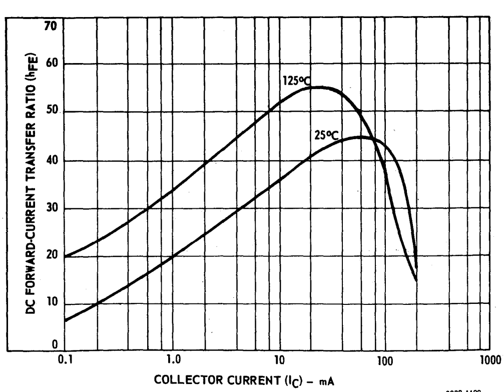
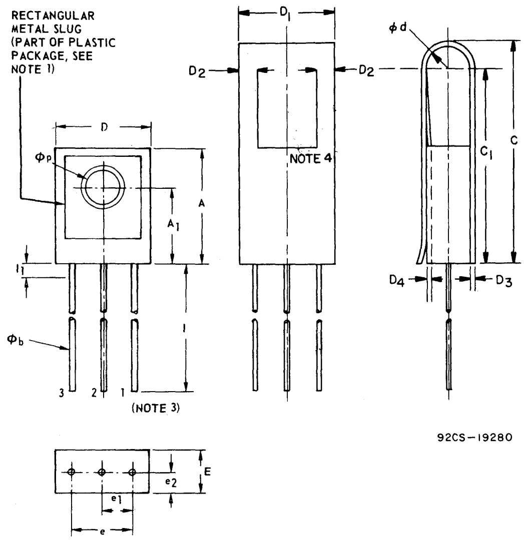


Fig. 17—Typical DC-beta characteristics for all types.

DIMENSIONAL OUTLINE

"Plastic TO-5"



TERMINAL CONNECTIONS FOR (all types)

Lead No. 1 – Emitter
Lead No. 2 – Base
Lead No. 3 – Collector

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.

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	400	V
With external base-to-emitter resistance (R_{BE}) $\leq$ 50 Ω	V_{CER}(sus)	225	300	400	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, & 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, *At Case Temperature (T_C) = 25°C unless otherwise specified*

Characteristic	Symbol	Test Conditions: DC Collector or Emitter Voltage (V) V_{CE}	V_{BE}	DC Current (A) I_C	I_B	I_E	Limits: Type 2N6249 Min.	Typ.	Max.	Type 2N6250 Min.	Typ.	Max.	Type 2N6251 Min.	Typ.	Max.	Units
Collector-Cutoff Current: With base open	I_{CEO}	175			0		–	–	5	–	–	–	–	–	–	
		250			0		–	–	–	–	–	5	–	–	–	
		325			0		–	–	–	–	–	–	–	–	5	
* With base-emitter junction reverse-biased	I_{CEV}	300	−1.5				–	–	1.2	–	–	–	–	–	–	
		375	−1.5				–	–	–	–	–	1.2	–	–	–	mA
		450	−1.5				–	–	–	–	–	–	–	–	1.2	
* With base-emitter junction reverse-biased	I_{CEV} T_C = 125°C	300	−1.5				–	–	10	–	–	–	–	–	–	
		375	−1.5				–	–	–	–	–	10	–	–	–	
		450	−1.5				–	–	–	–	–	–	–	–	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]	–	–	400[b]	–	–	V
* Emitter-to-Base Voltage	V_{EBO}					0.001	6	–	–	6	–	–	6	–	–	V
* DC Forward-Current Transfer Ratio	h_{FE}	2		10			12	–	50	–	–	–	–	–	–	
		3		10			–	–	–	10	–	50	–	–	–	
		3		10			–	–	–	–	–	–	8	–	50	
		5		3.5			20	–	100	20	–	100	20	–	100	
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$[a]			10	1		–	–	2	–	–	–	–	–	–	
				10	1		–	–	–	–	–	2	–	–	–	V
				10	1.25		–	–	–	–	–	–	–	–	2	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$[a]			15	3		–	–	2.5	–	–	2.5	–	–	2.5	
				10	1		–	–	1	–	–	–	–	–	–	V
				10	1		–	–	–	–	–	1.5	–	–	–	
				10	1.25		–	–	–	–	–	–	–	–	1.5	
* 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 = 310 μH	$E_{S/b}$[d]		−4	15			35	–	–	35	–	–	35	–	–	mJ
* Switching Times: Rise *(See Figs. 13, 17, & 18)*	t_r	V_{CC} = 200 V		10	1[e]		–	0.6	1.5	–	–	–	–	–	–	
				10	1[e]		–	–	–	–	0.8	2	–	–	–	
				10	1.25[e]		–	–	–	–	–	–	–	0.8	2	
Storage *(See Figs. 11, 12, 17, & 18)*	t_s	V_{CC} = 200 V		10	1[e]		–	2	3	–	–	–	–	–	–	
				10	1[e]		–	–	–	–	1.8	2.5	–	–	–	μs
				10	1.25[e]		–	–	–	–	–	–	–	1.8	2.5	
Fall *(See Figs. 14, 17, & 18)*	t_f	V_{CC} = 200 V		10	1[e]		–	0.5	1	–	–	–	–	–	–	
				10	1[e]		–	–	–	–	0.5	1	–	–	–	
				10	1.25[e]		–	–	–	–	–	–	–	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).

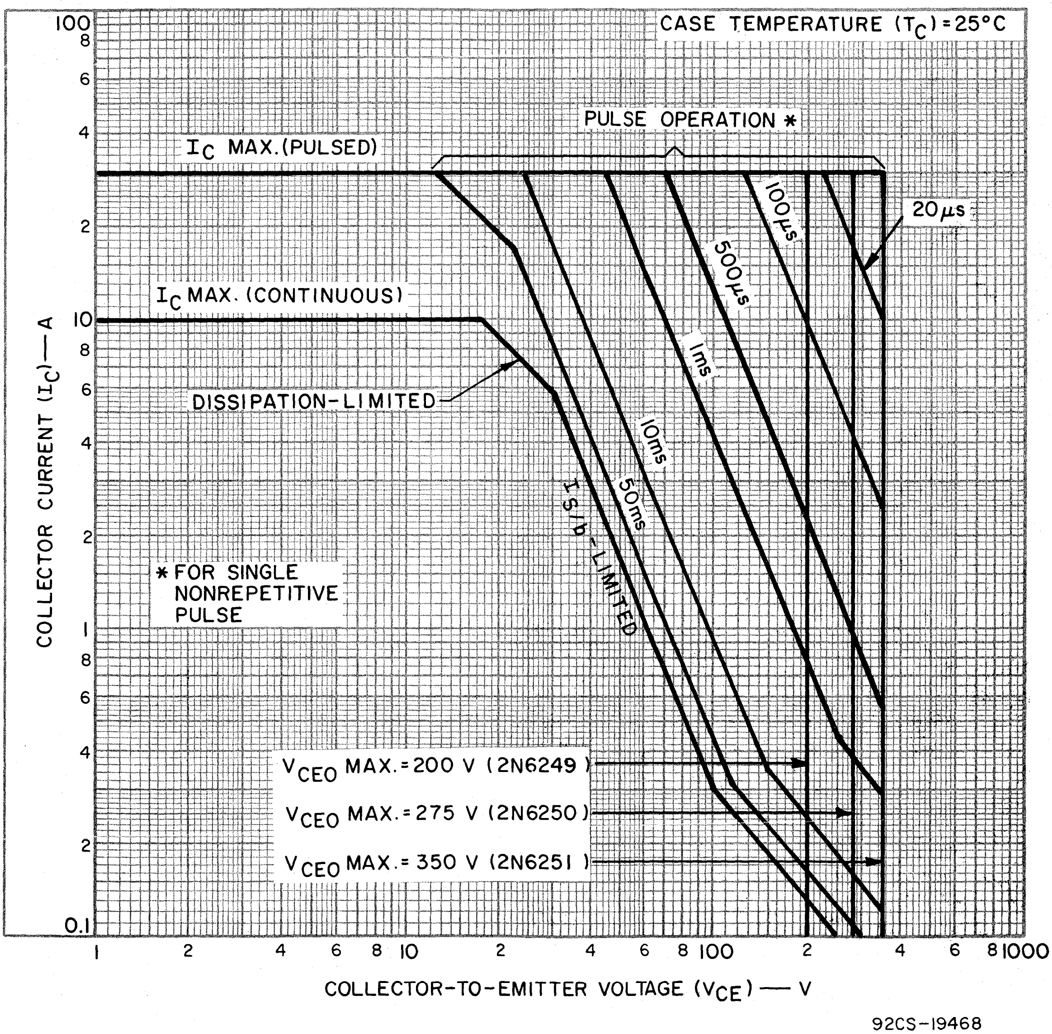


Fig. 1—Maximum operating areas for all types.

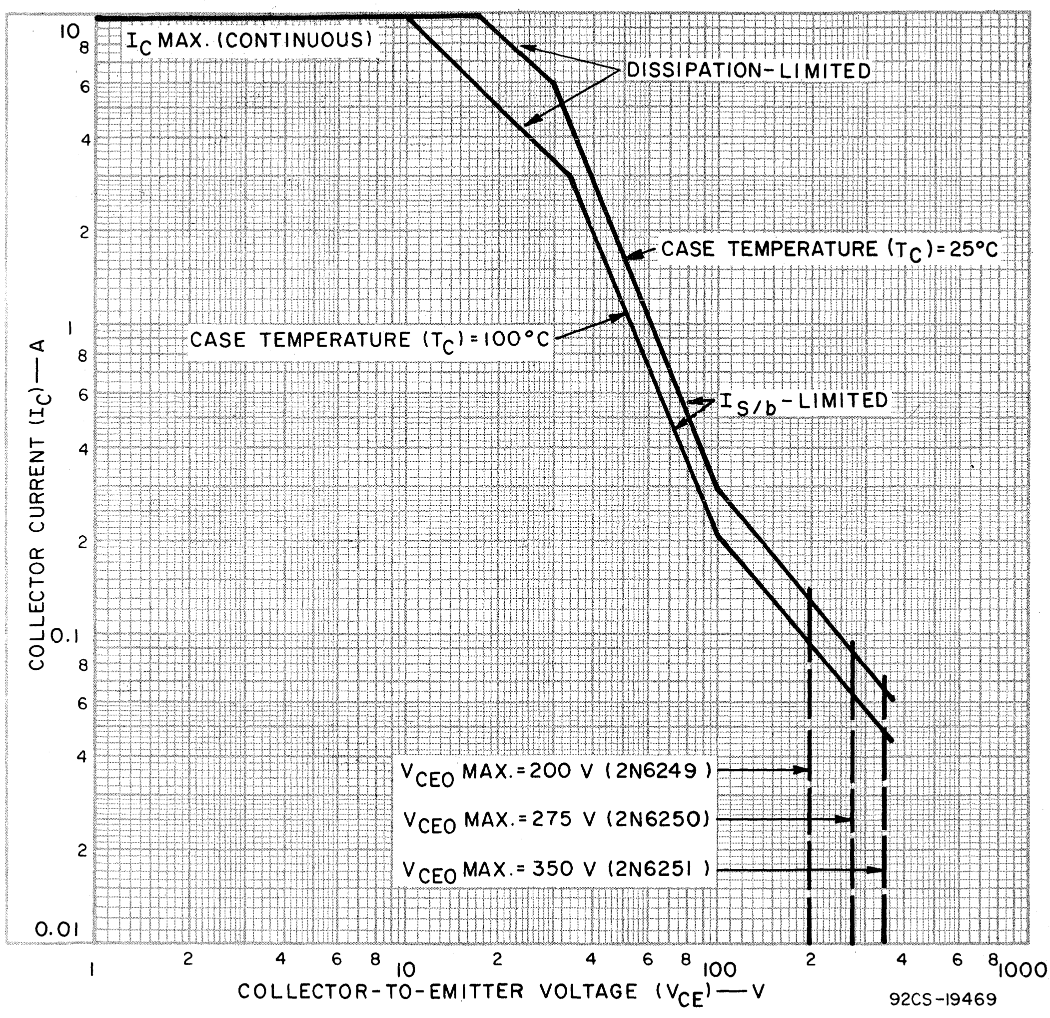


Fig.2–Maximum operating areas for all types.

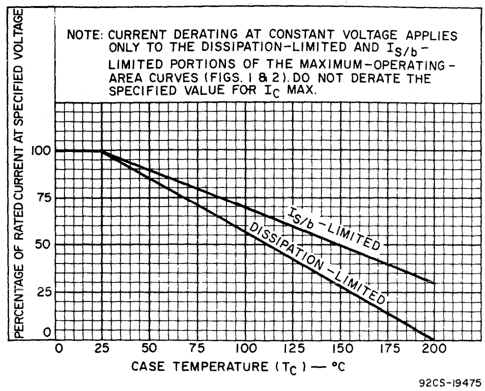


Fig.3—Dissipation derating and $I_{S/b}$ derating for all types.

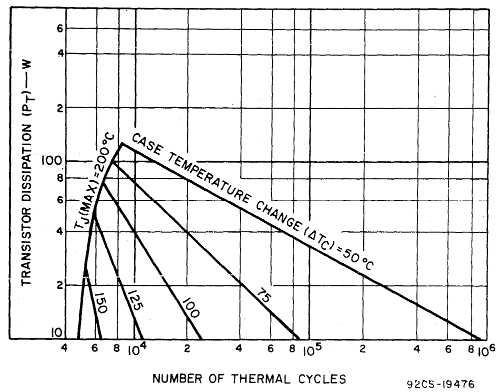


Fig.4—Thermal-cycle rating chart for all types.

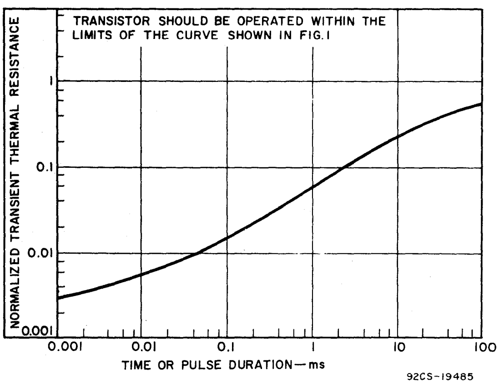


Fig.5—Typical thermal response characteristic for all types.

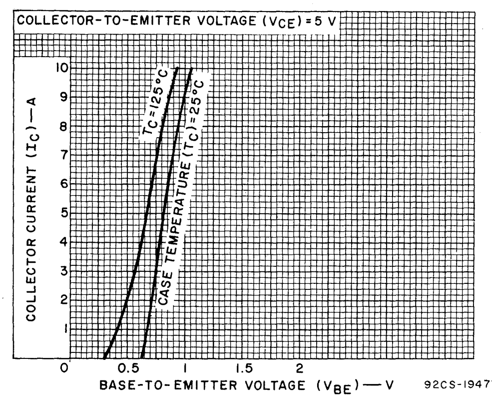


Fig.6—Typical transfer characteristics for all types.

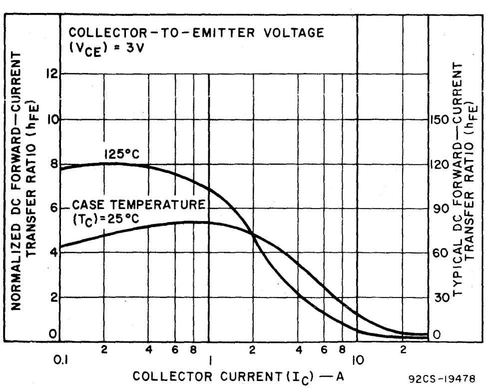


Fig.7—Typical normalized dc beta characteristics for all types.

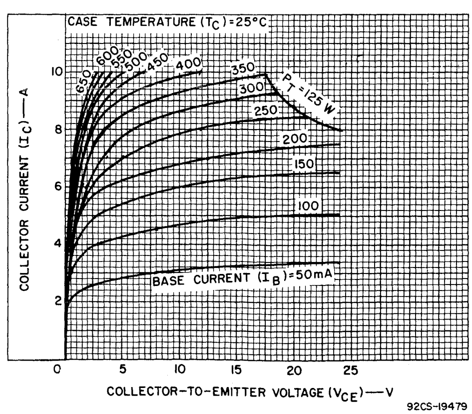


Fig.8—Typical output characteristics for all types.

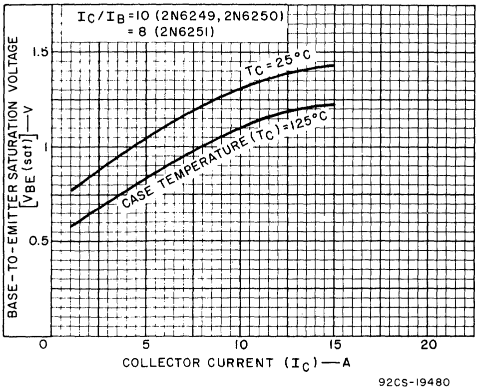


Fig.9—Typical base-to-emitter saturation voltage characteristics for all types.

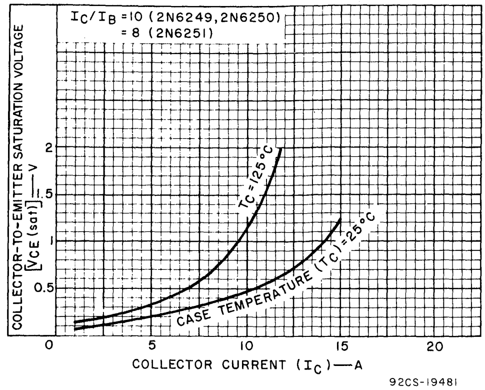


Fig.10—Typical collector-to-emitter saturation voltage characteristics for all types.

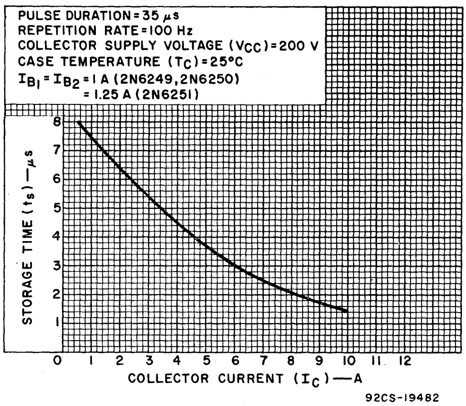


Fig.11—Typical storage-time characteristics for all types (with constant forced gain).

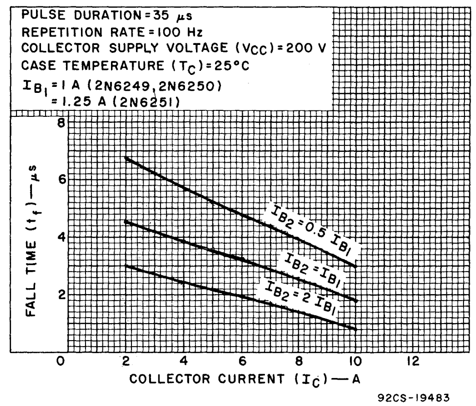


Fig.12—Typical storage-time characteristics for all types (with constant base drive).

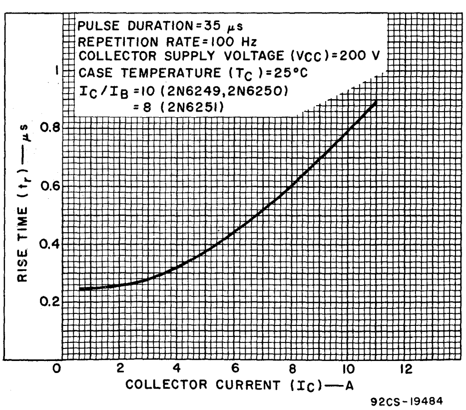


Fig.13—Typical rise-time characteristic for all types.

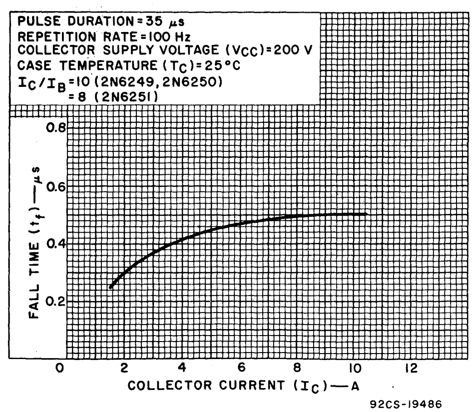


Fig.14—Typical fall-time characteristic for all types.

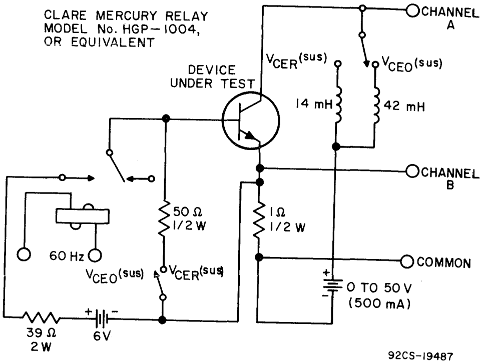
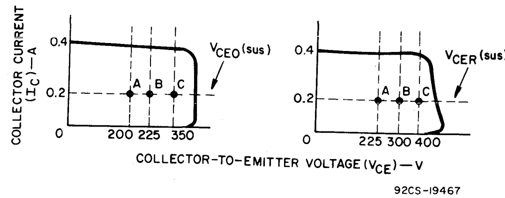


Fig. 15–Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ for all types.



The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ are acceptable when the traces fall to the right and above point "A" for type 2N6249 point "B" for type 2N6250 and point "C" for type 2N6251.

Fig.16–Oscilloscope display for measurement of sustaining voltages. (Test circuit shown in Fig. 15).

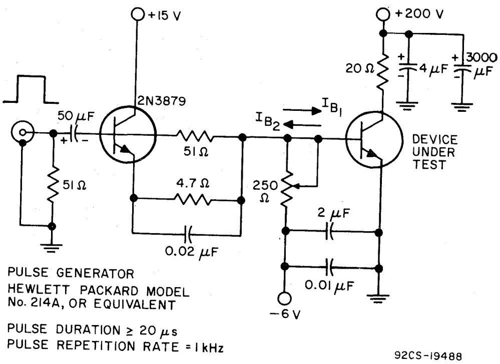


Fig.17–Circuit used to measure switching times for all types.

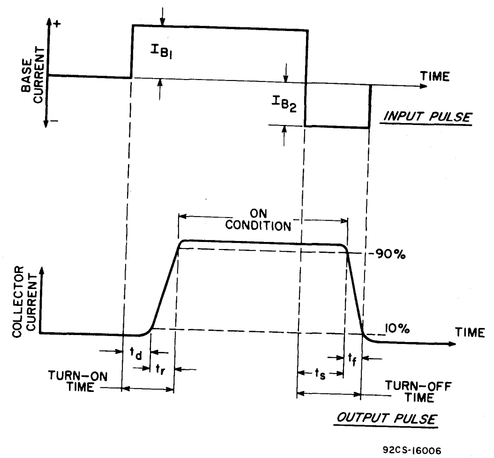
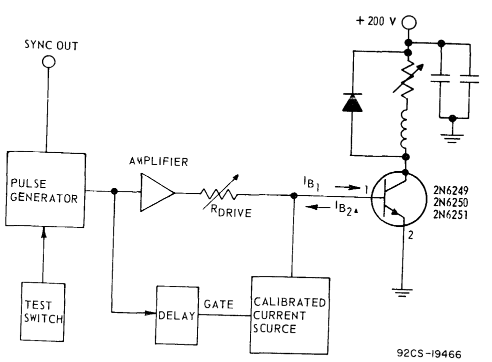


Fig.18–Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 17).



*I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig.19–Circuit used to measure inductive-load switching times for all types.

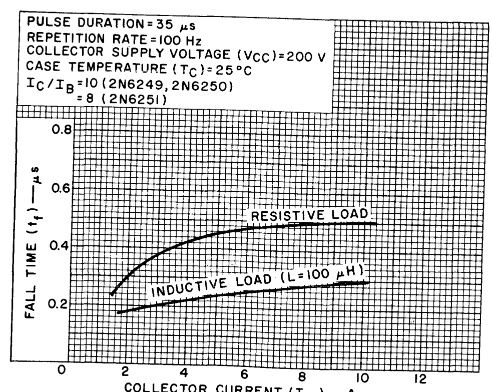


Fig.20– Typical inductive- and resistive-load fall-time characteristics for all types.

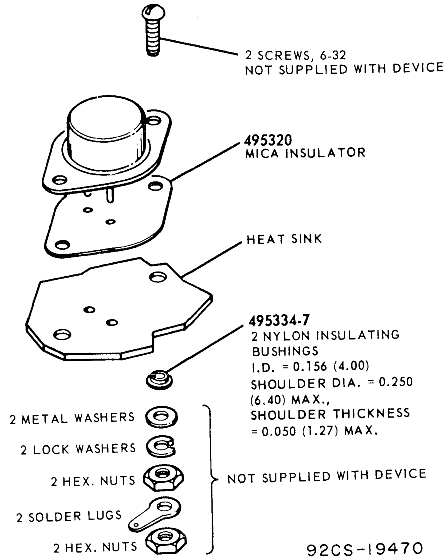
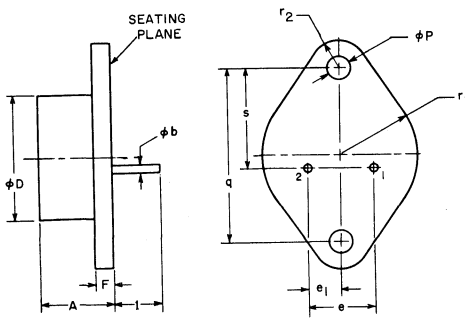


Fig.21—Suggested mounting hardware.

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	
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

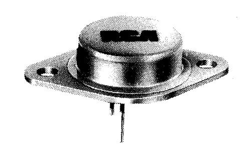
TERMINAL CONNECTIONS

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

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

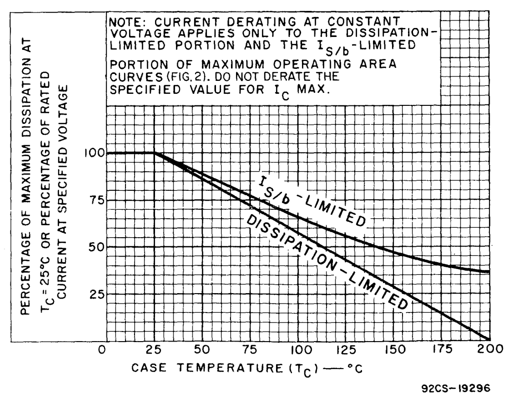


Fig. 1—Dissipation and current derating curves.

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

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	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}	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			1.0[a]		30	–	90	
		5			2.5[a]		10	–	–	
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.

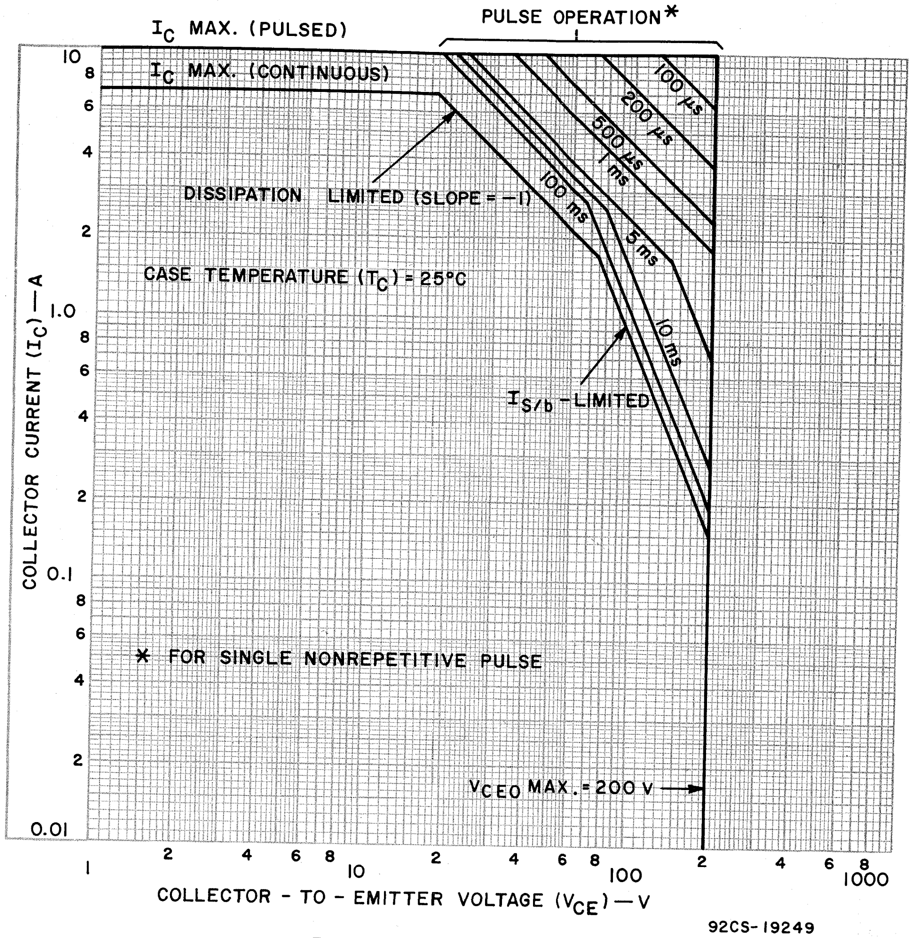


Fig.2—Maximum operating areas.

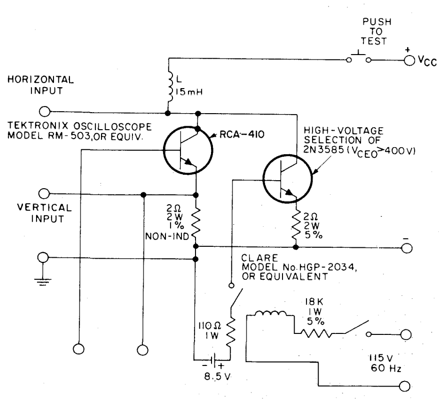


Fig.3—Circuit used to measure sustaining voltage, $V_{CEO}(sus)$.

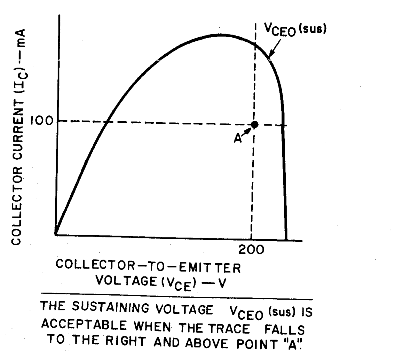


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

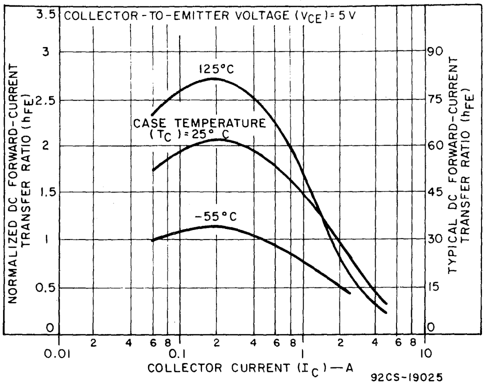


Fig.5—Typical dc beta characteristics.

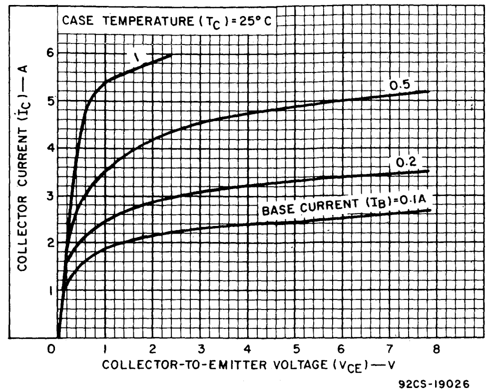


Fig.6—Typical output characteristics.

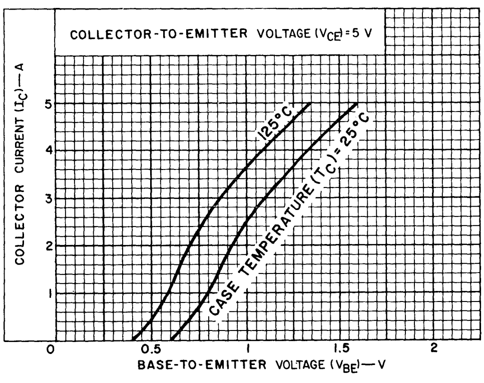


Fig.7—Typical transfer characteristics.

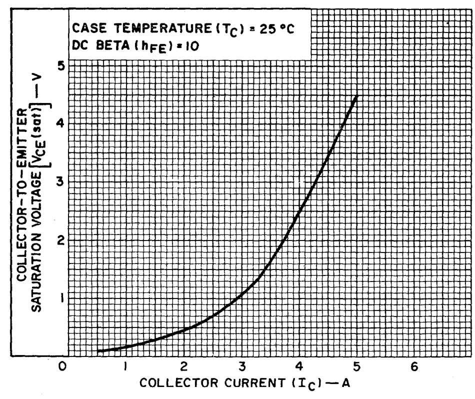


Fig.8—Typical saturation voltage characteristic.

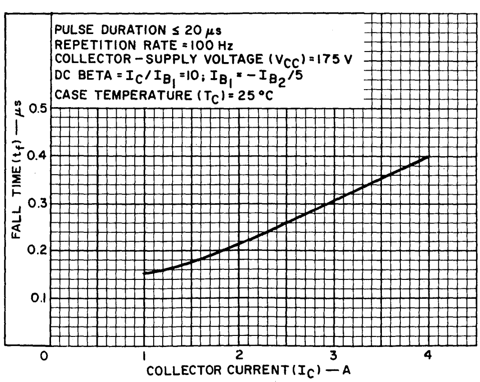


Fig.9—Typical fall time vs. collector current.

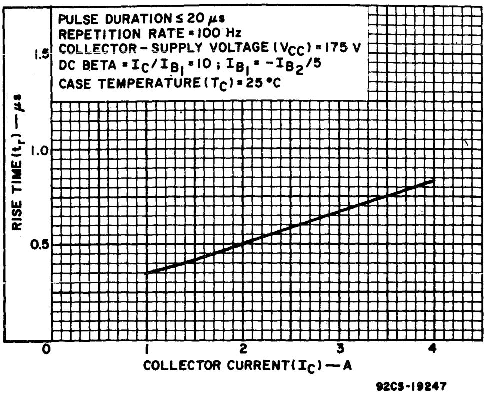


Fig. 10—Typical rise time vs. collector current.

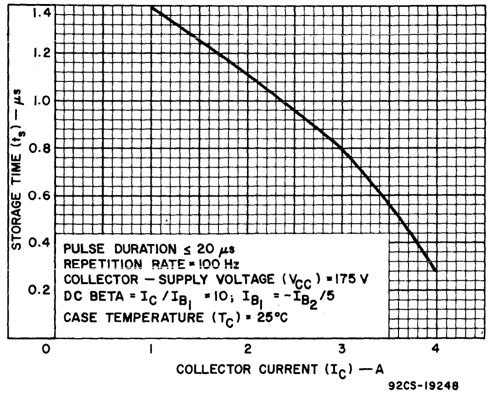
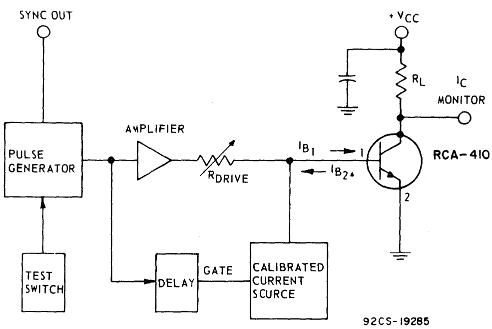


Fig. 11—Typical storage time vs. collector current.



*IB1 AND IB2 MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig. 12—Circuit used to measure switching times.

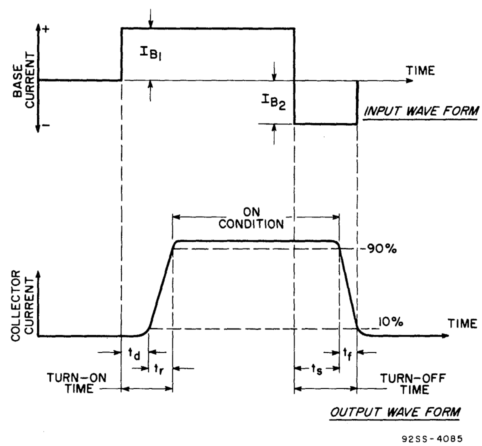


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times. Test circuit shown in Fig. 12).

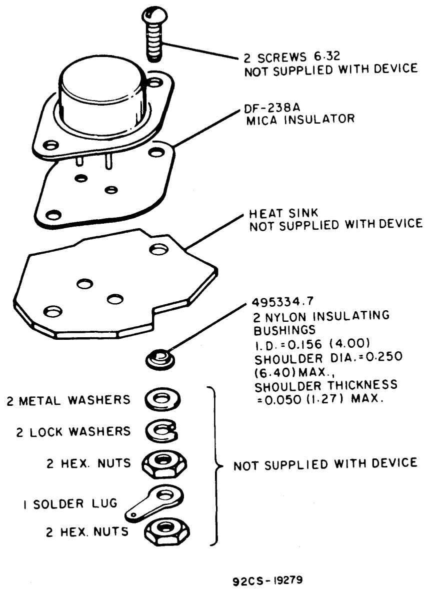
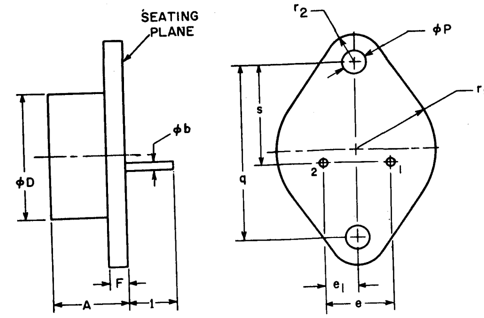


Fig.14—Suggested mounting hardware.

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

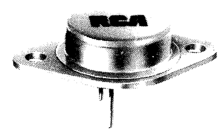
Solid State
Division

Power Transistors

411

High-Voltage, High-Power Silicon N-P-N Power Transistor

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



JEDEC
TO-3

H-1570

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

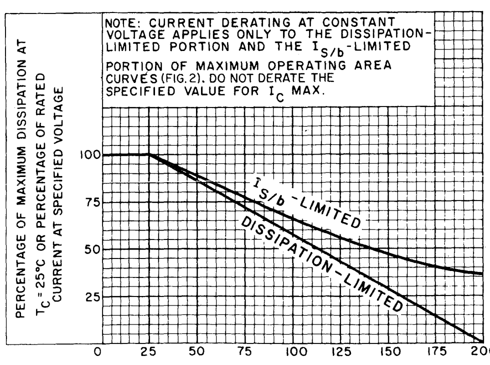


Fig. 1—Dissipation and current derating curves.

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

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V) 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 Min.	Limits Typ.	Limits Max.	Units
Collector-Cutoff Current: With base open	I_{CEO}	300					–	–	0.25	mA
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	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		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	–	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.

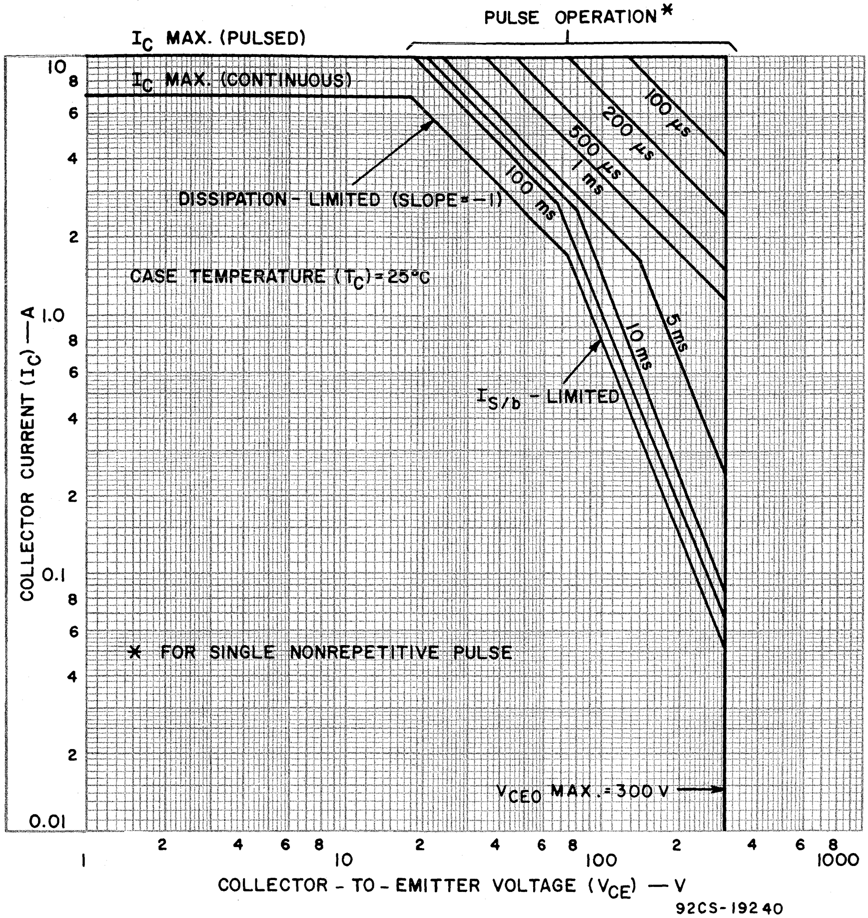


Fig.2—Maximum operating areas.

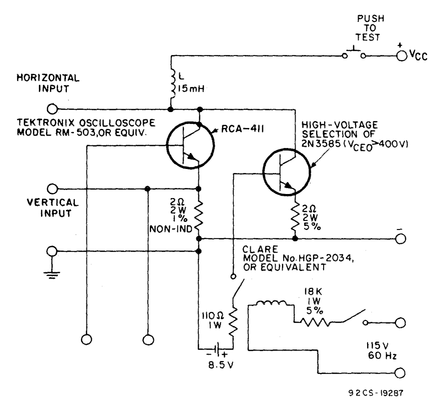


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

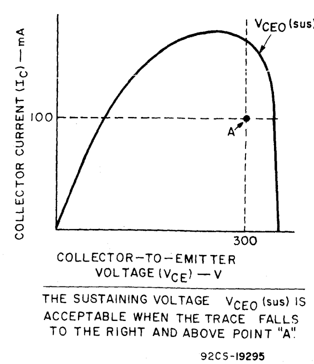


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig.3).

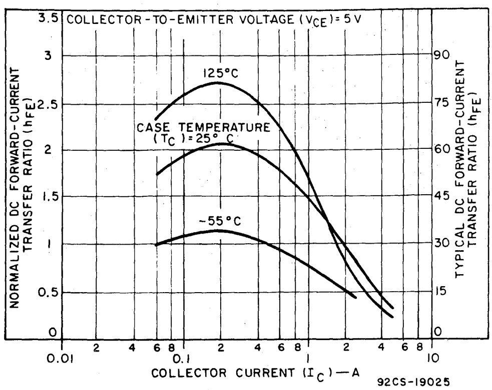


Fig.5—Typical dc beta characteristics.

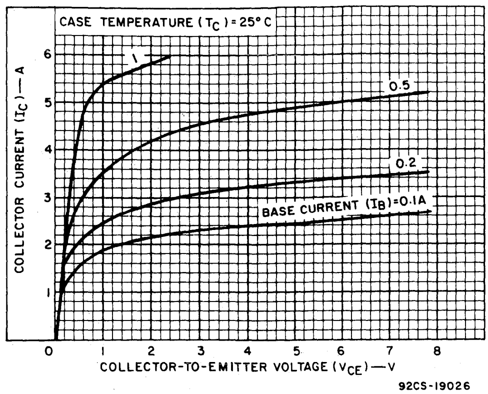


Fig.6—Typical output characteristics.

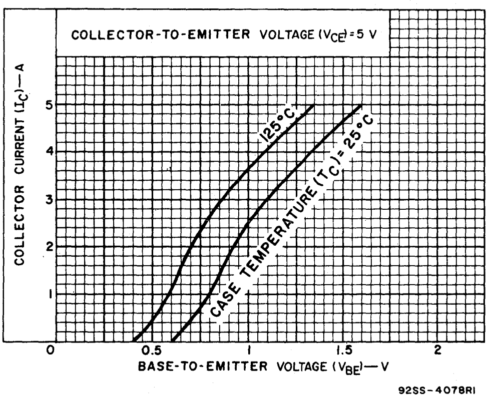


Fig.7—Typical transfer characteristics.

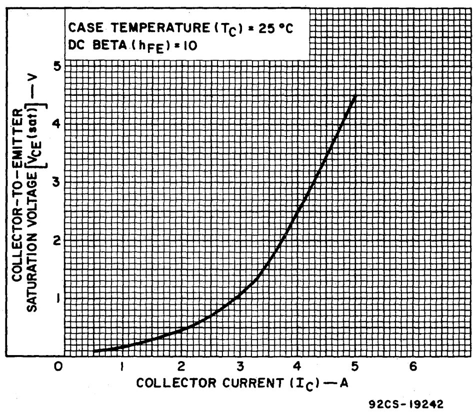


Fig.8—Typical saturation voltage characteristic.

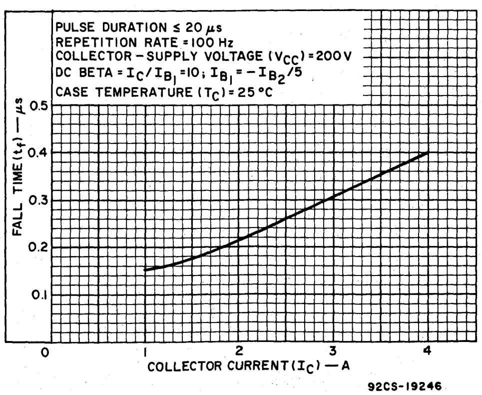


Fig.9—Typical fall time vs. collector current.

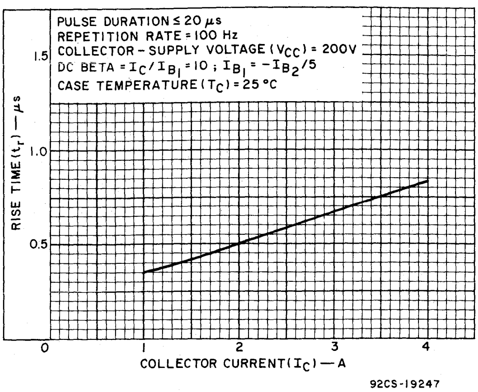


Fig.10—Typical rise time vs. collector current.

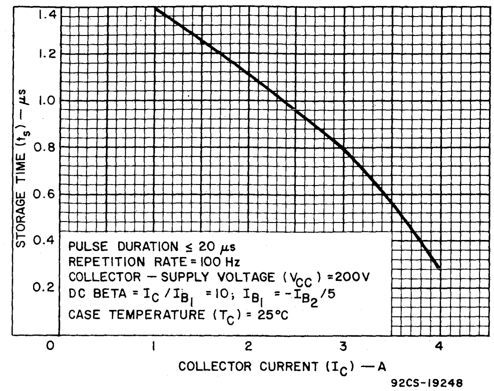


Fig.11—Typical storage time vs. collector current.

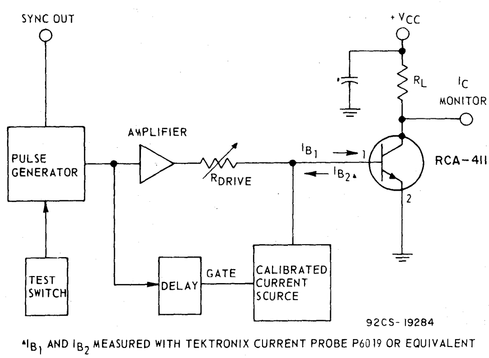


Fig.12—Circuit used to measure switching times.

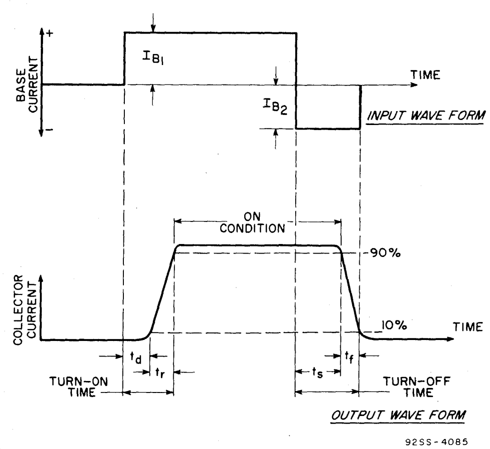


Fig.13—Phase relationship between input and output currents showing reference points for specification of switching times. Test circuit shown in Fig.12).

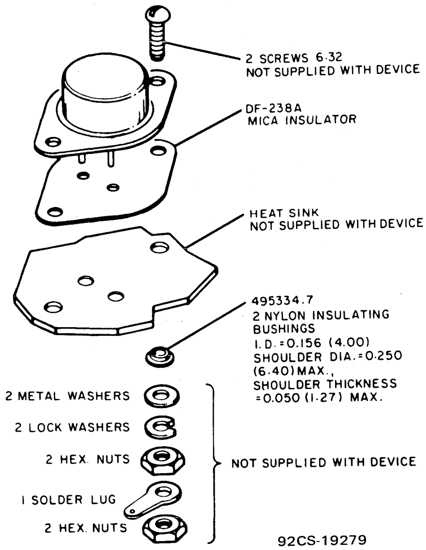
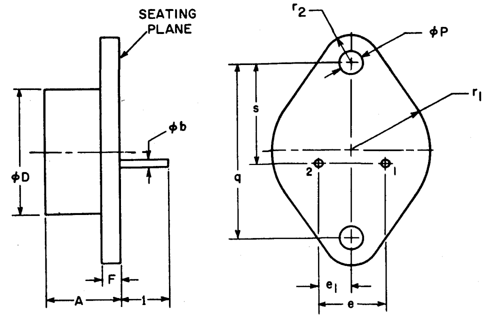


Fig. 14—Suggested mounting hardware.

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

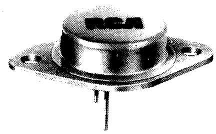
TERMINAL CONNECTIONS

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

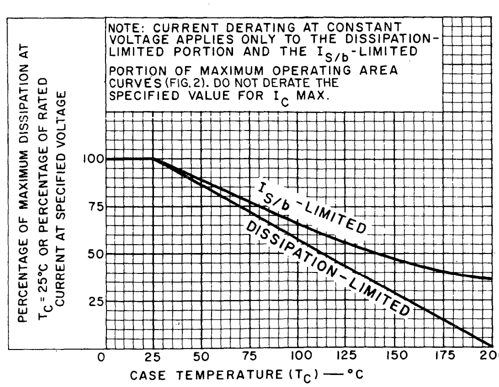


Fig. 1—Dissipation and current derating curves.

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

Characteristic	Symbol	Test Conditions					Limits			Units
		DC Collector Voltage (V)	DC Emitter or Base Voltage (V)		DC Current (A)					
		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	
With base-emitter junction reverse-biased & T_C = 125°C	I_{CEV}	400		−1.5			–	–	0.5	
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	–	
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.

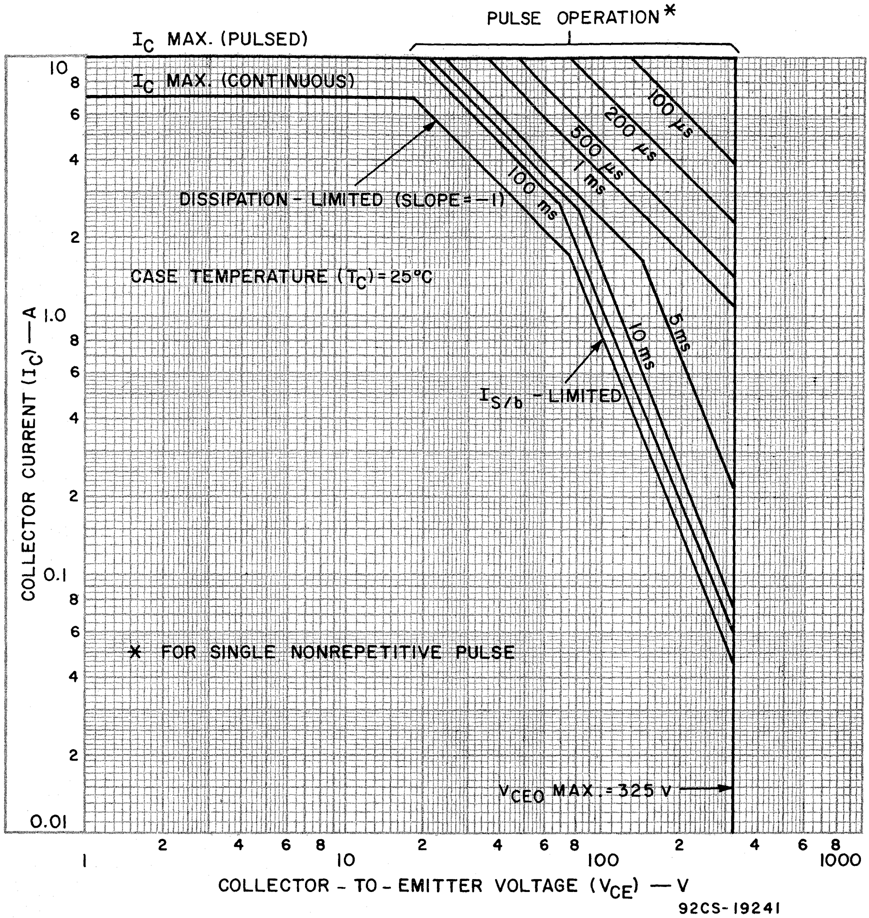


Fig.2—Maximum operating areas.

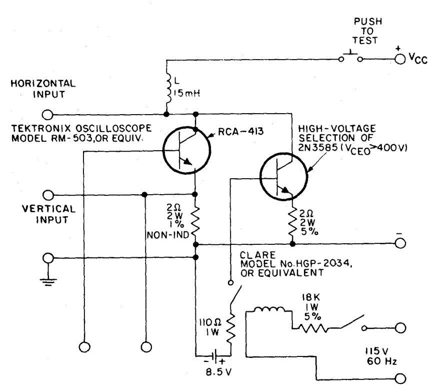


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

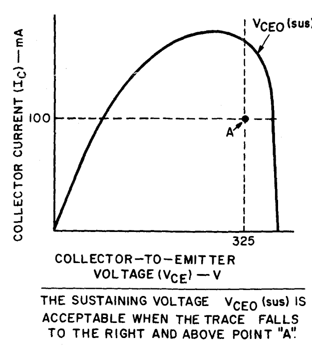


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

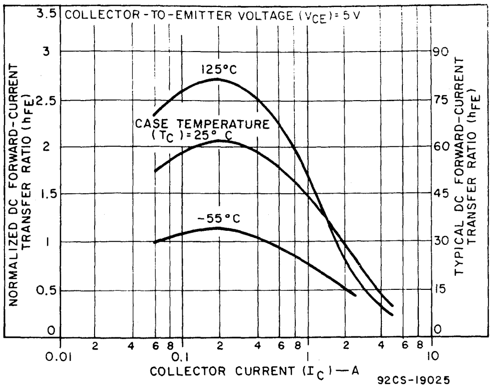


Fig.5—Typical dc beta characteristics.

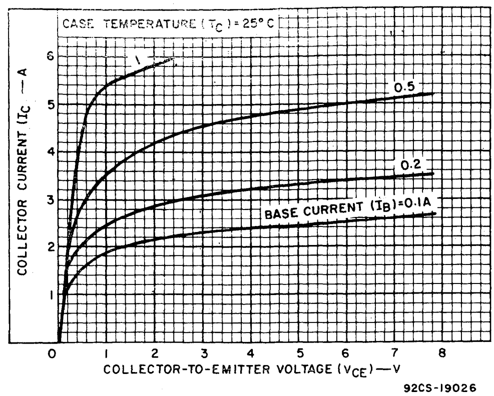


Fig.6—Typical output characteristics.

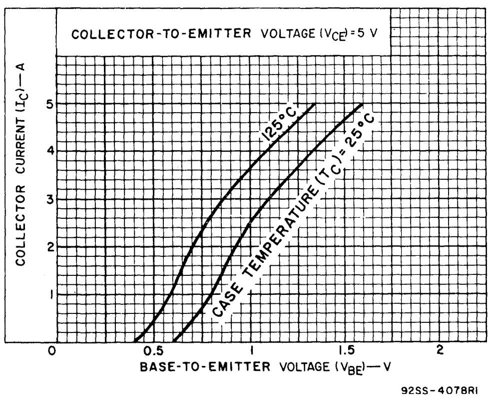


Fig.7—Typical transfer characteristics.

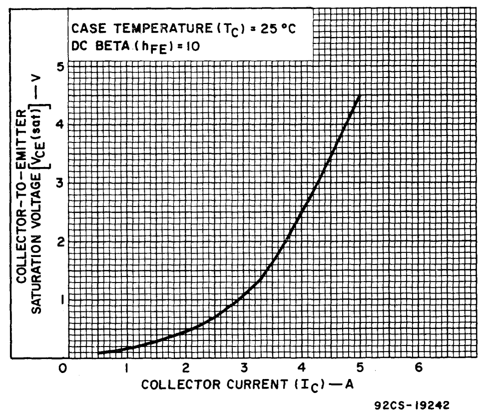


Fig.8—Typical saturation voltage characteristic.

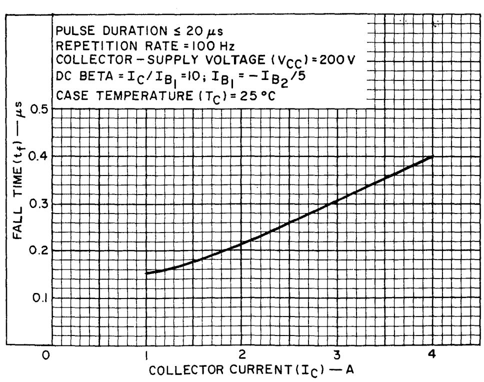


Fig.9—Typical fall time vs. collector current.

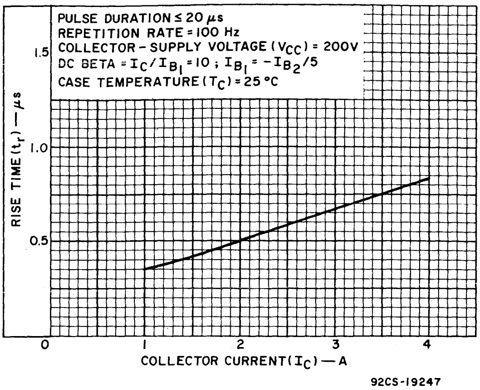


Fig.10—Typical rise time vs. collector current.

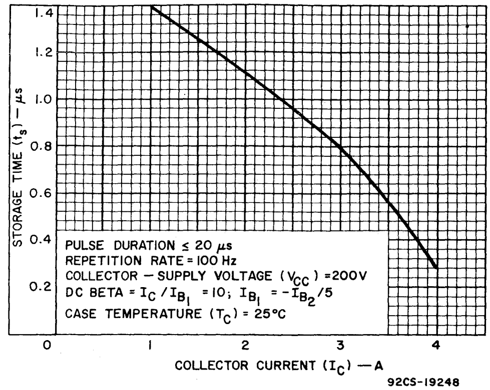


Fig.11—Typical storage time vs. collector current.

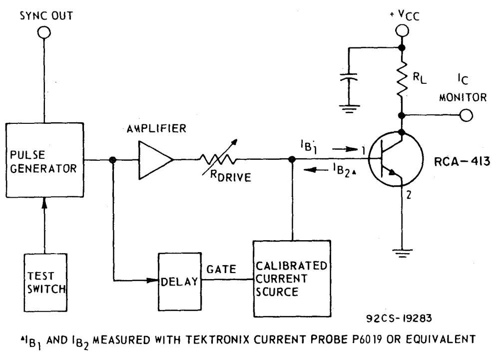


Fig.12—Circuit used to measure switching times.

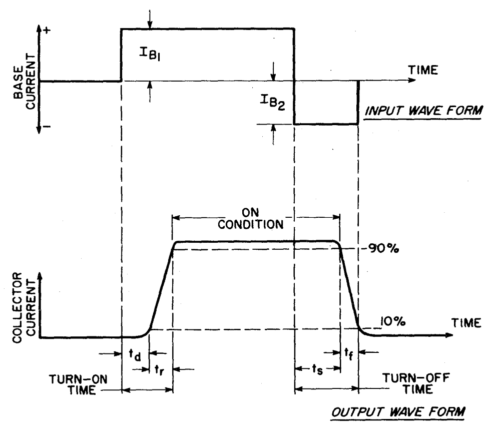


Fig.13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig.12).

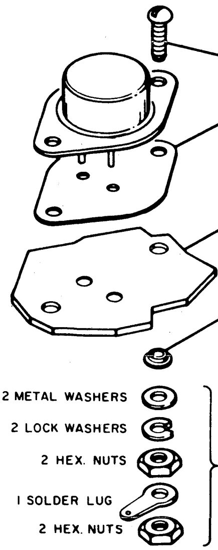
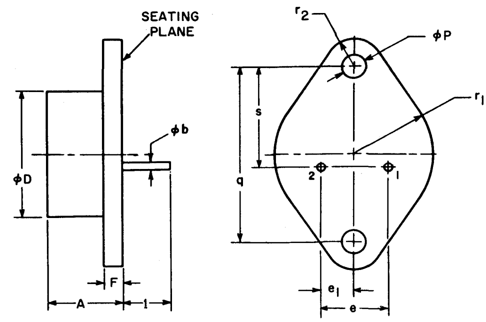


Fig. 14—Suggested mounting hardware.

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	
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.

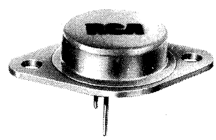
92CS-15222

TERMINAL CONNECTIONS

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

RCA
Solid State
Division

Power Transistors



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-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

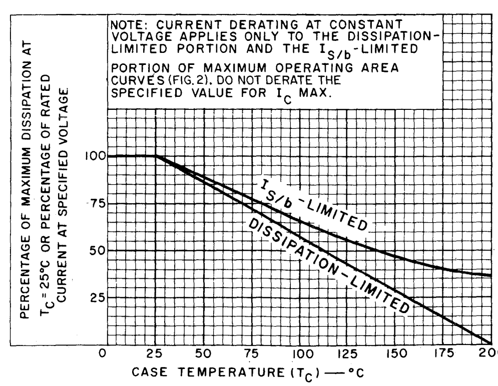


Fig. 1—Dissipation and current derating curves.

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

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V)	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					–	–	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}			−1.5			–	–	0.5	mA
Emitter-Cutoff Current	I_{EBO}		5				–	–	5.0	mA
DC Forward-Current Transfer Ratio	h_{FE}	5			1.0[a]		30	–	90	
		5			2.5[a]		10	–	–	
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	–	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.

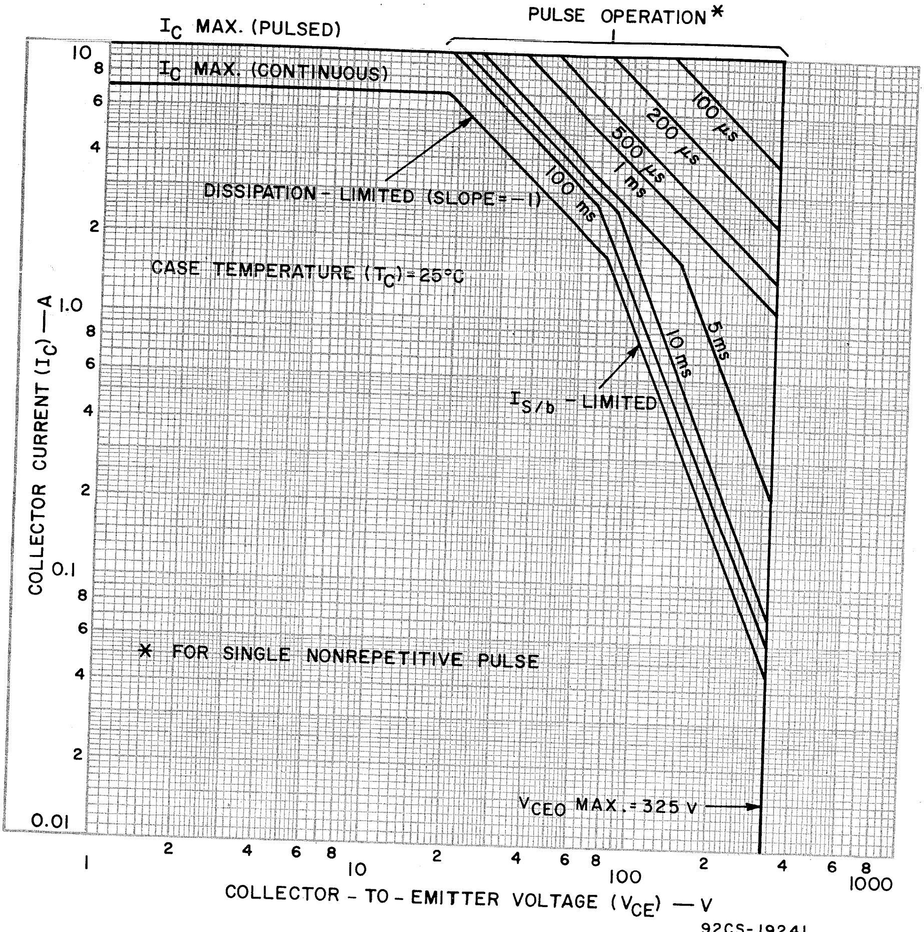


Fig.2—Maximum operating areas.

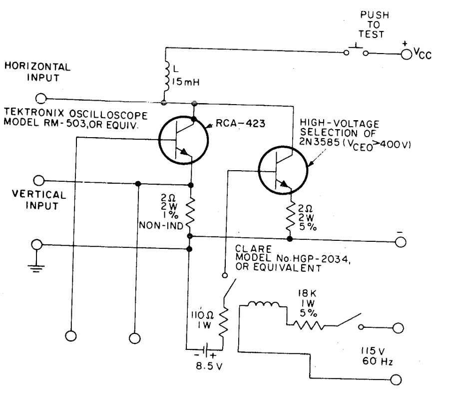


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

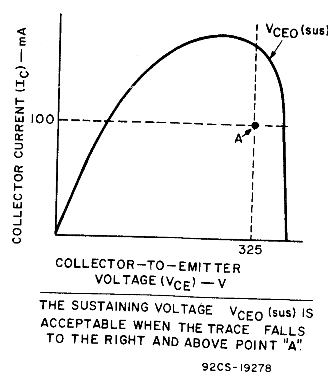


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig.3).

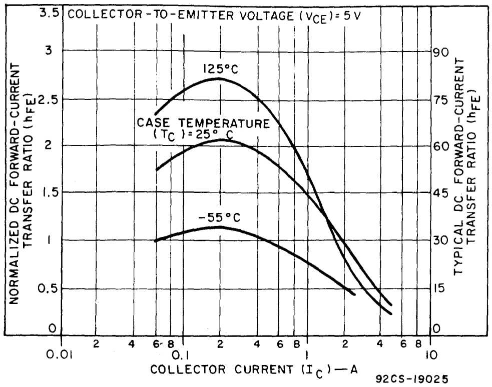


Fig.5—Typical dc beta characteristics.

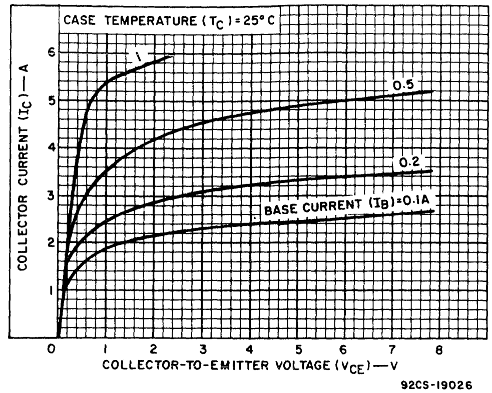


Fig.6—Typical output characteristics.

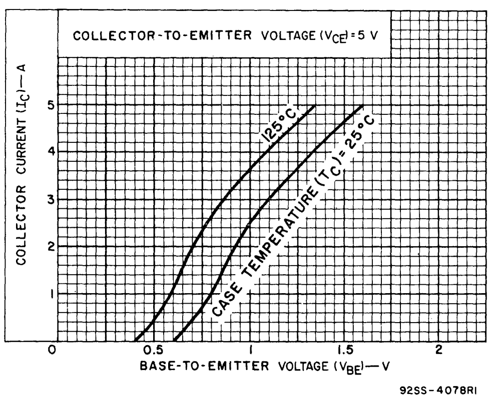


Fig.7—Typical transfer characteristics.

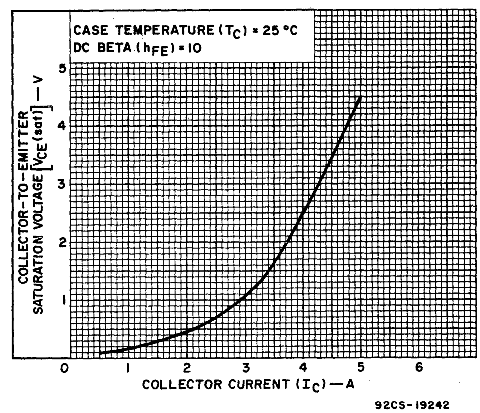


Fig.8—Typical saturation voltage characteristic.

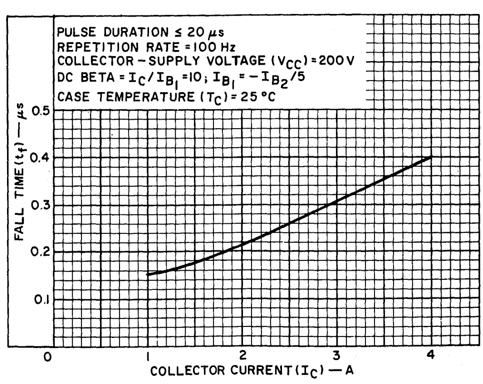


Fig.9—Typical fall time vs. collector current.

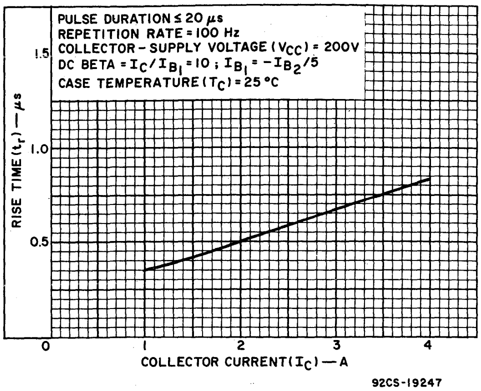


Fig. 10—Typical rise time vs. collector current.

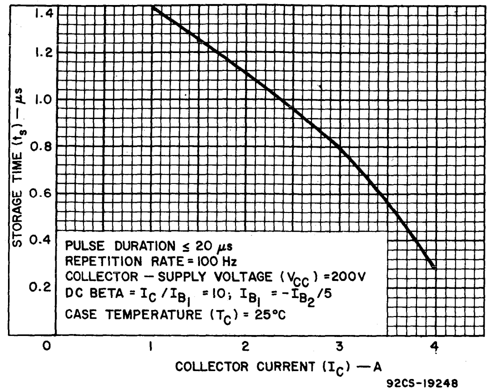
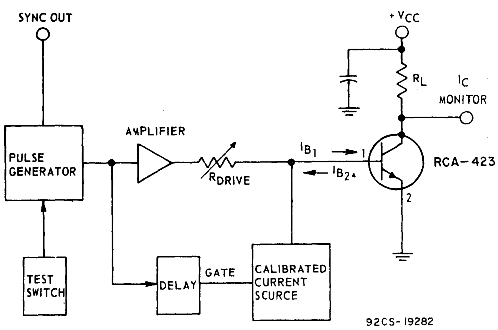


Fig. 11—Typical storage time vs. collector current.



*I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig. 12—Circuit used to measure switching times.

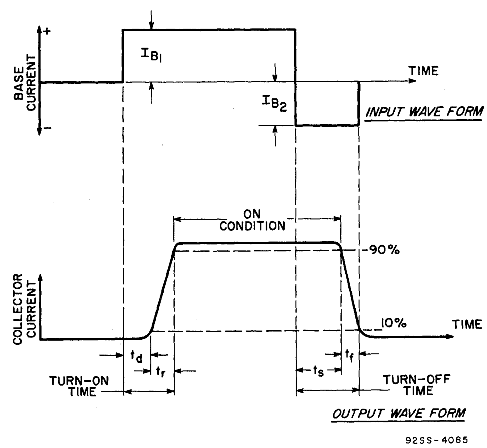


Fig. 13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig. 12).

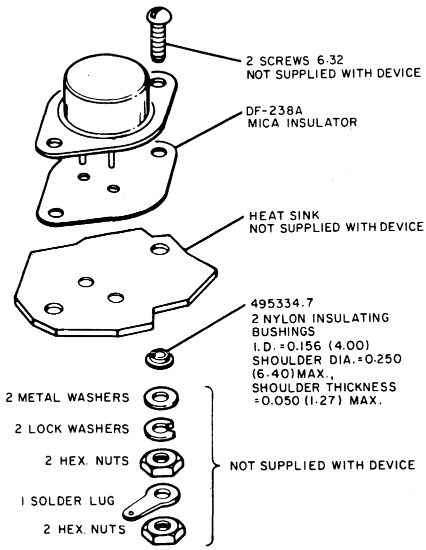
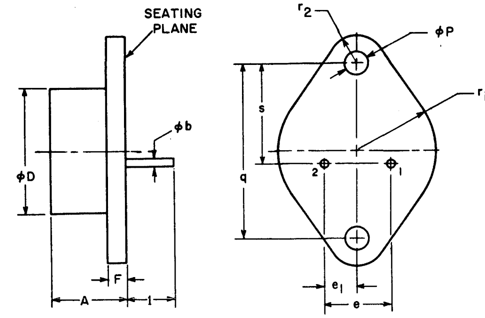


Fig.14—Suggested mounting hardware.

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

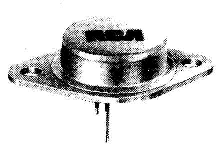
TERMINAL CONNECTIONS

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

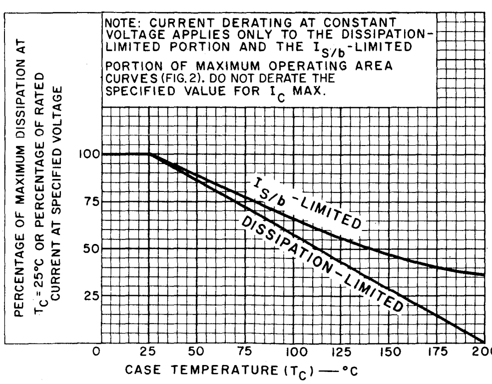


Fig. 1—Dissipation and current derating curves.

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

Characteristic	Symbol	Test Conditions: DC Collector Voltage (V) V_{CE}	DC Emitter or Base Voltage (V) V_{EB}	V_{BE}	DC Current (A) I_C	I_B	Limits Min.	Typ.	Max.	Units
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.

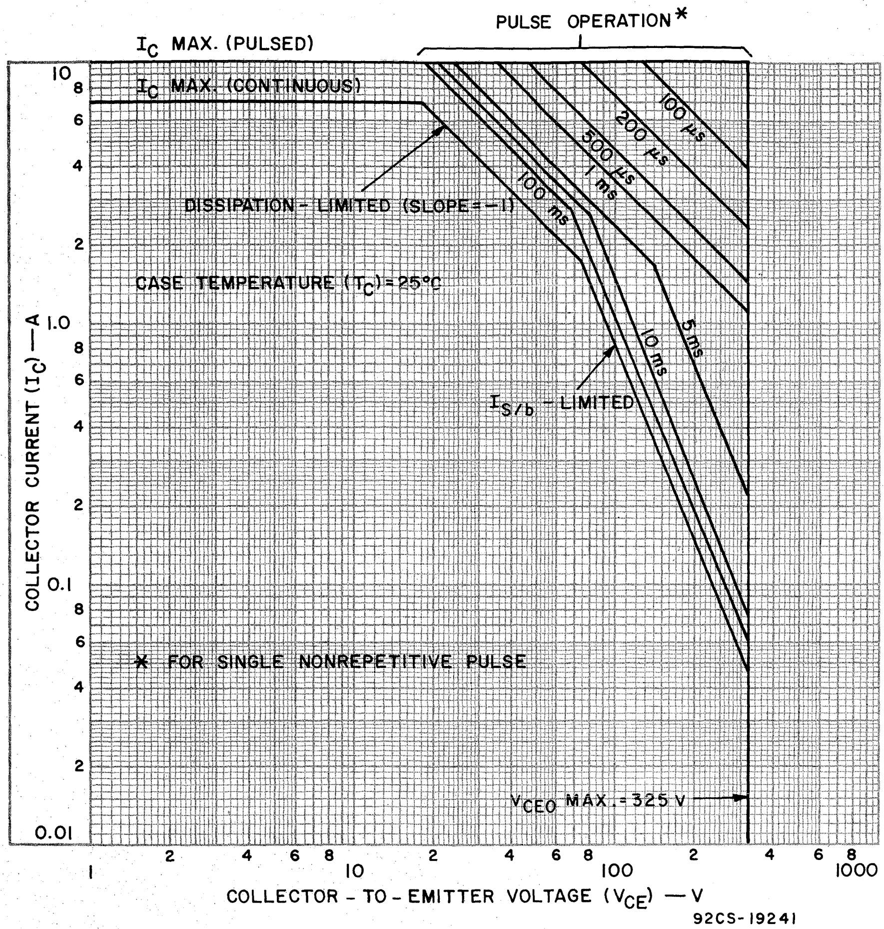


Fig.2—Maximum operating areas.

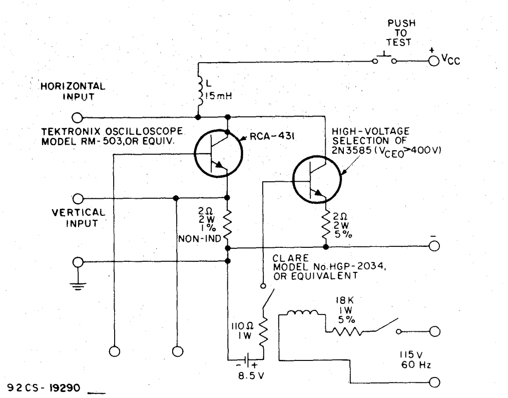


Fig.3—Circuit used to measure sustaining voltage, V_{CEO}(sus).

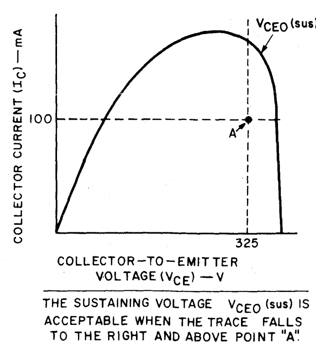


Fig.4—Oscilloscope display for measurement of sustaining voltage (test circuit shown in Fig. 3).

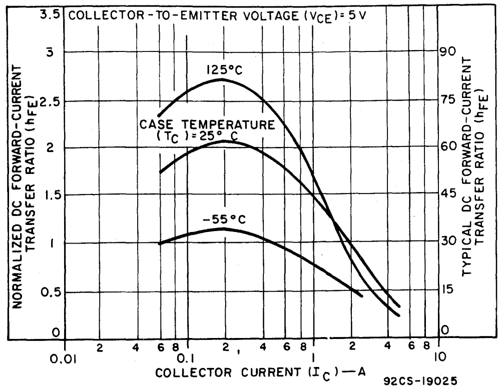


Fig.5—Typical dc beta characteristics.

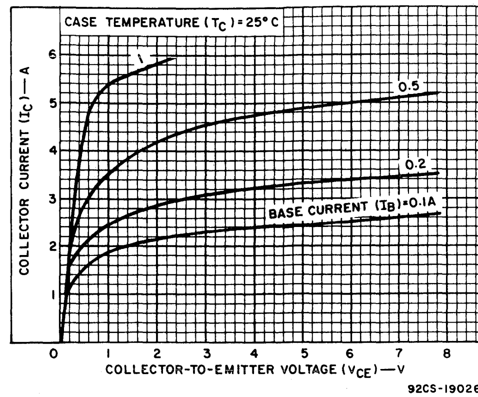


Fig.6—Typical output characteristics.

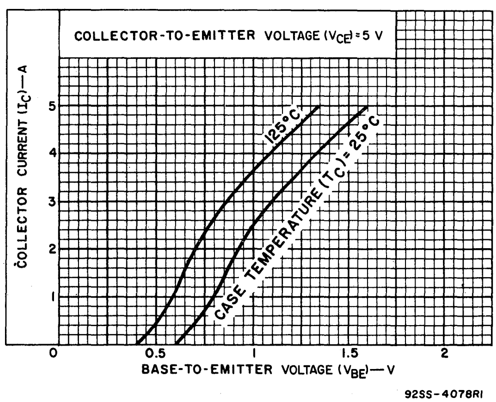


Fig.7—Typical transfer characteristics.

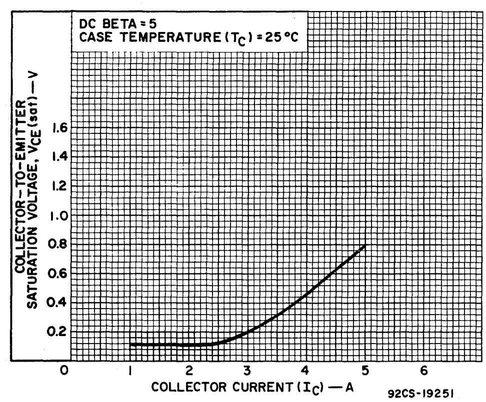


Fig.8—Saturation voltage vs. collector current.

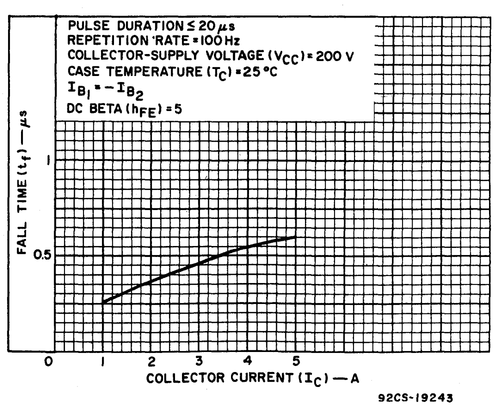


Fig.9—Typical fall-time characteristic.

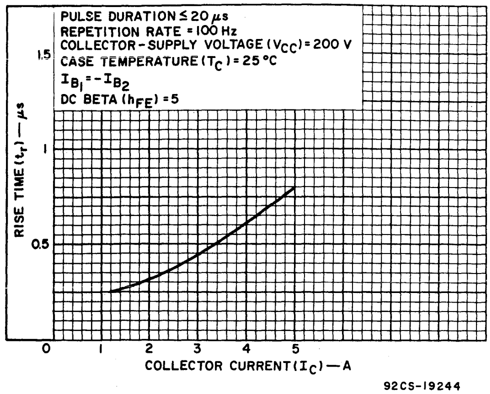


Fig.10—Typical rise-time characteristic.

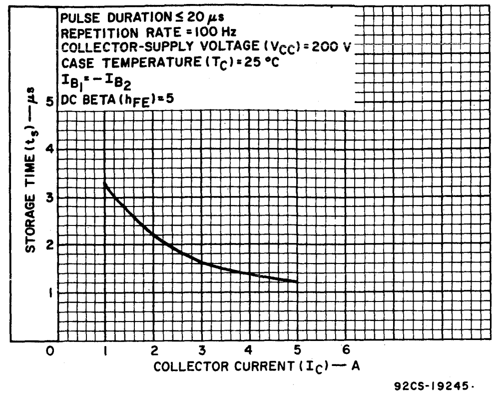
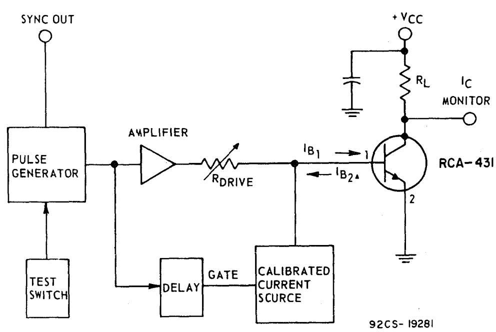


Fig.11—Typical storage-time characteristic (with constant forced gain).



*I_{B1} AND I_{B2} MEASURED WITH TEKTRONIX CURRENT PROBE P6019 OR EQUIVALENT

Fig.12—Circuit used to measure switching times.

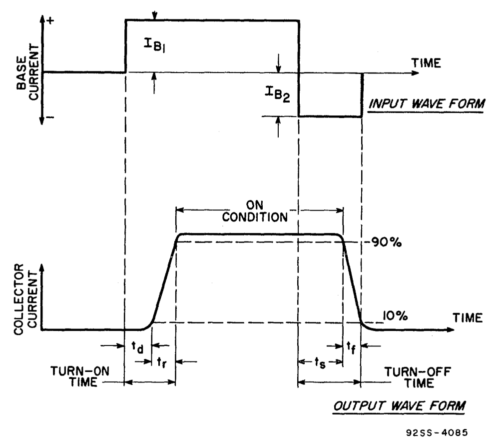


Fig.13—Phase relationship between input and output currents showing reference points for specification of switching times. (Test circuit shown in Fig.12).

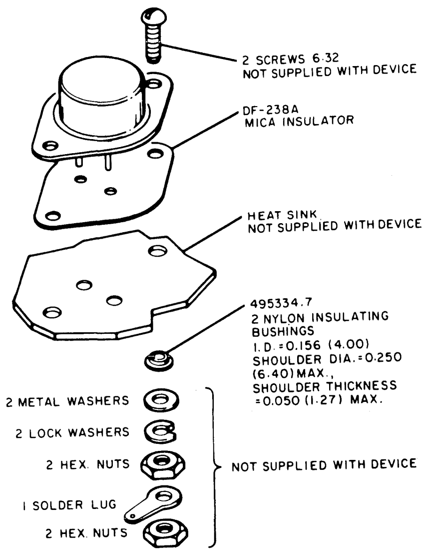
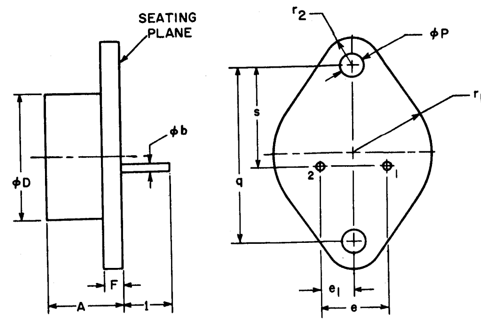


Fig. 14—Suggested mounting hardware.

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
2N3773
2N4348

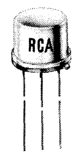
RCA-40346, -40346V1, -40346V2, -40412, -40412V1, and -40412V2 are triple-diffused silicon n-p-n transistors having high breakdown voltages, high frequency-response capability, and fast switching speeds.

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.

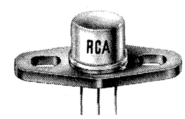
Types 40346 and 40412 are supplied in a JEDEC TO-5 package; types 40346V1 and 40412V1 in a JEDEC TO-5 package with a factory-attached heat radiator for greater free-air dissipation capability; and types 40346V2 and 40412V2 are supplied in a TO-5 package with an attached flange for increased power dissipation and mounting convenience.

*Nixie is a Registered Trademark of Burroughs Corporation, Electronic Components Division, Plainfield, N. J.

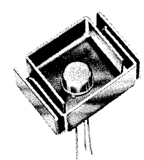
For High-Voltage Switching and Linear-Amplifier Applications in Military, Industrial, and Commercial Applications



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

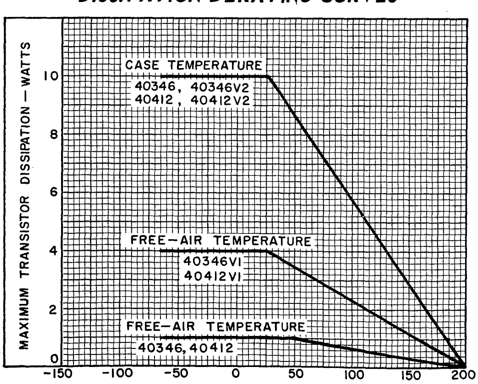


Fig. 1

TYPICAL DC-BETA CHARACTERISTICS FOR ALL TYPES

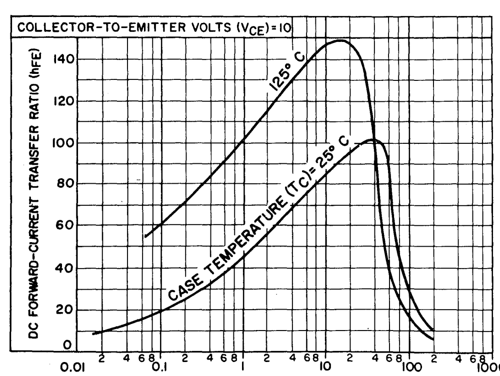


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS FOR ALL TYPES

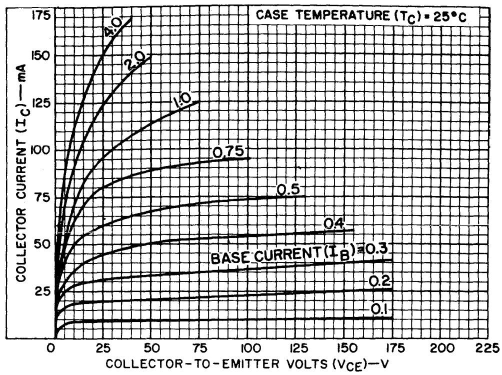


Fig. 3

TYPICAL OPERATION CHARACTERISTICS FOR ALL TYPES

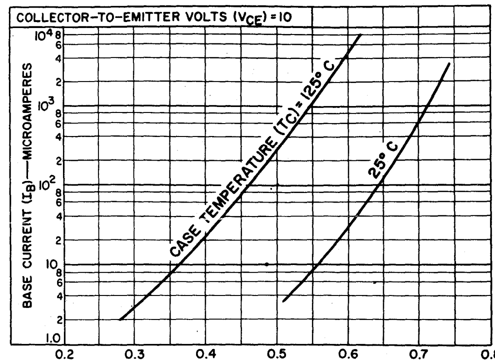


Fig. 4

TYPICAL OPERATION CHARACTERISTICS FOR ALL TYPES

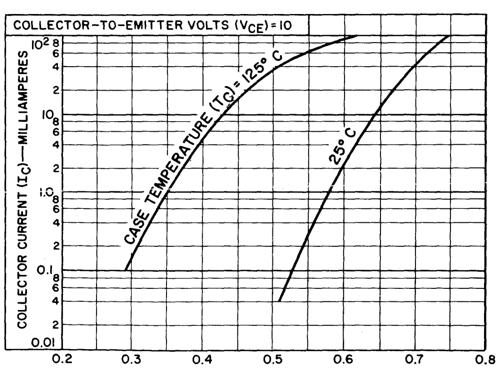
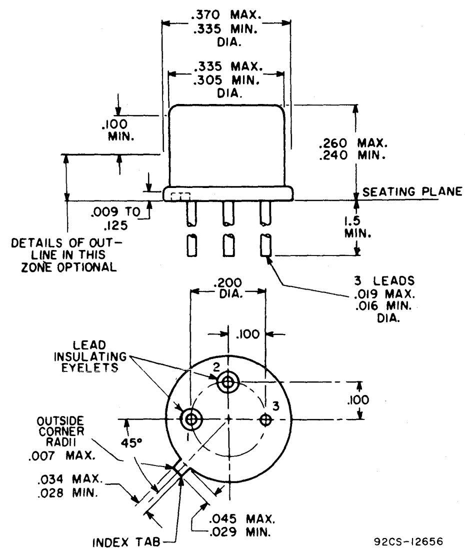


Fig. 5

DIMENSIONAL OUTLINE FOR TYPES 40346 & 40412 JEDEC TO-5

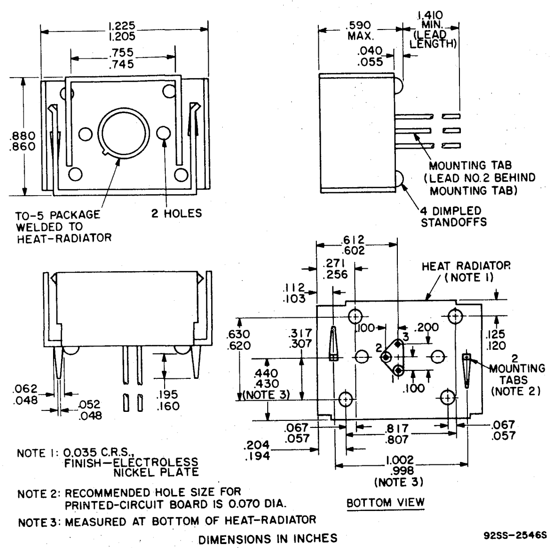


DIMENSIONS IN INCHES

TERMINAL CONNECTIONS

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

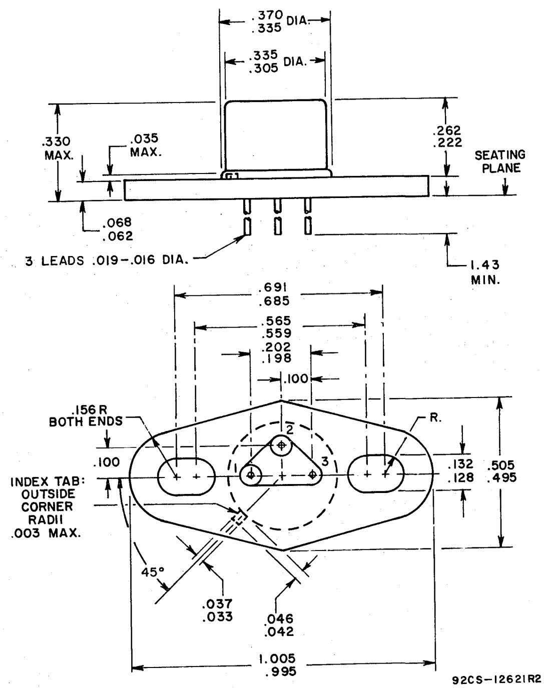
DIMENSIONAL OUTLINE FOR TYPES 40346V1, 40412V1 JEDEC TO-5 WITH HEAT RADIATOR



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

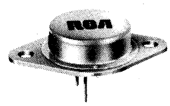
Power Transistors

40850 40851
40852 40853
40854

40850
40851

JEDEC TO-66 H 1340

40852
40853
40854



JEDEC TO-3 H 1570

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	20	A
CONTINUOUS BASE CURRENT, I_B	1	4	4	5	7	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^oC	35	45	100	100	110	W
At case temperaures above 25^oC and in the $I_{S/b}$-Limited Region*	See derating curves in prototype bulletins.					
TEMPERATURE RANGE:						
Storage & Operating (Junction)	← -65 to +200 ^oC →					
PIN TEMPERATURE (During Soldering):						
At distances ≥1/32 in. (0.8 mm) from case for 10 s max.	← 230^oC →					

* 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^oC 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	–	0.2	mA
With base reverse biased	I_{CEV}	V_{CE} = 450 V, V_{BE} = -1.5 V, T_C = 125^oC	–	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		UNITS
			MIN.	MAX.	
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).

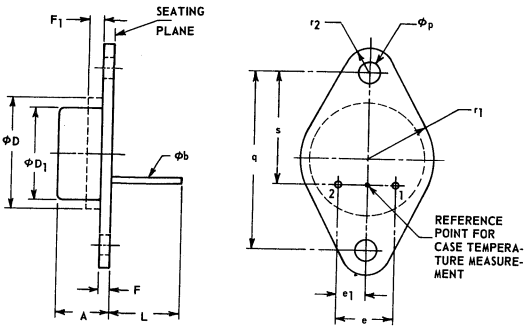
Type 40854 (For 5-V, 200-A & 30-V, 40-A Power Supplies)
Package: JEDEC TO-3
Construction: Silicon N-P-N, multiple-epitaxial, multiple-emitter-site mesa
Applications Information: See "RCA Power Circuits" manual SP-51

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

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS		UNITS
			MIN.	MAX.	
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} = 3 V	10	–	
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	–	2.0	V
Second-Breakdown Collector Current: With base forward biased	$I_{S/b}$[a]	V_{CE} = 20 V	5.0	–	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 TA7007.

DIMENSIONAL OUTLINE (JEDEC TO-66)



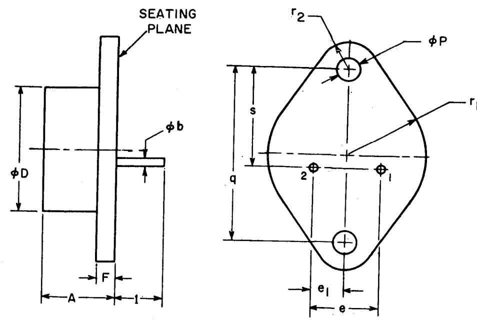
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD		0.620		15.75	
ϕD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1		0.050		1.27	1
L	0.360		9.14		
ϕp	0.142	0.152	3.61	3.86	
q	0.958	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 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	
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 (All Types)

Pin 1 - Base

Pin 2 - Emitter

Mounting Flange, Case - Collector

High-Speed Switching Power Transistors

RCA

Solid State
Division

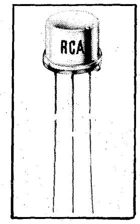
Power Transistors

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 $R_{BE} \leq$ 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

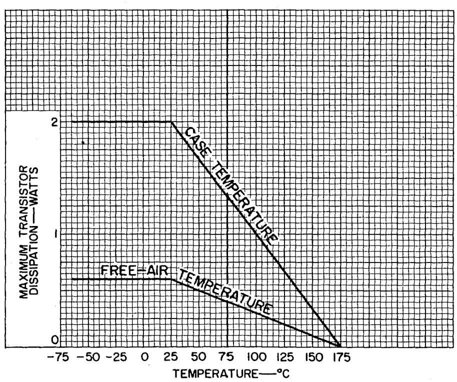


Fig. 1—Rating Chart for Type 2N699.

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	 θ_{J-C} θ_{J-FA}	 - -								 - -	 75 250	 °C/watt °C/watt

* Pulse width ≤ 300 µsec, duty factor ≤ 2%.

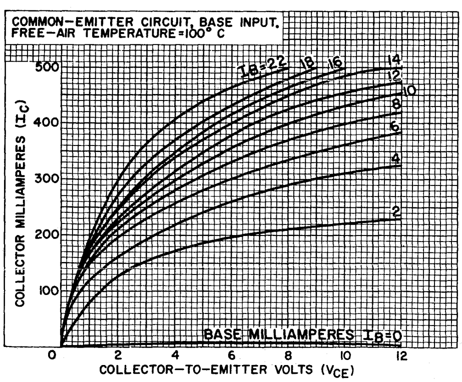


Fig.2 – Typical Collector Characteristics at 100° C for Type 2N699.

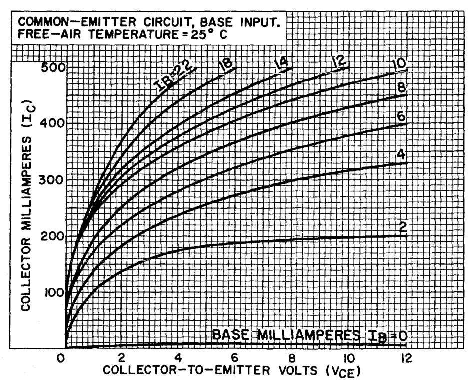


Fig.3 – Typical Collector Characteristics at 25° C for Type 2N699.

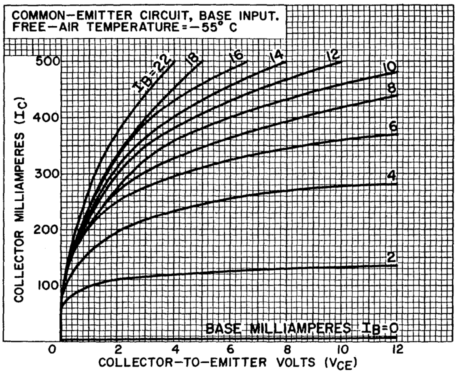


Fig.4 – Typical Collector Characteristics at -55° C for Type 2N699.

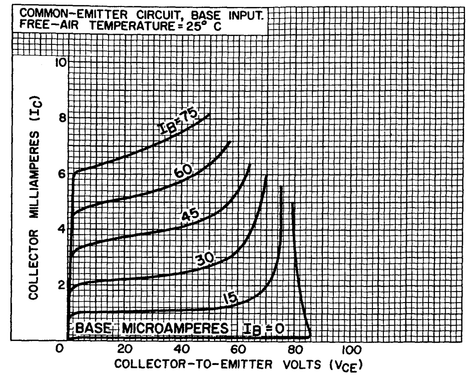


Fig.5 – Typical Collector Characteristics at 25° C for Type 2N699.

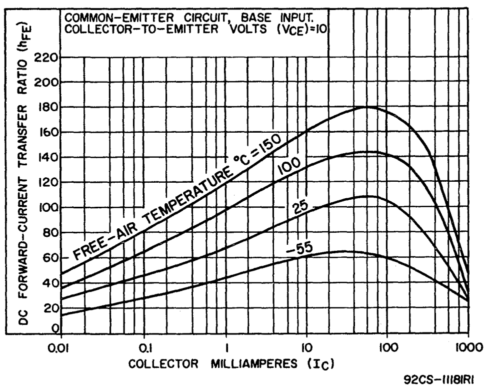


Fig.6 – Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N699.

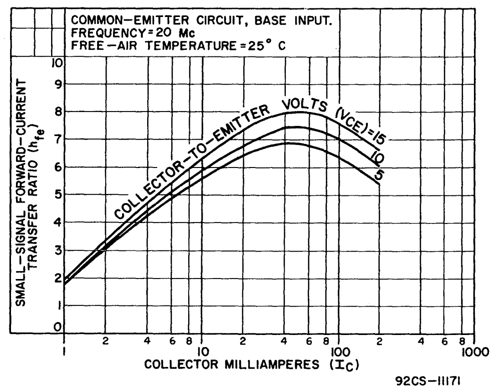


Fig.7 – Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N699.

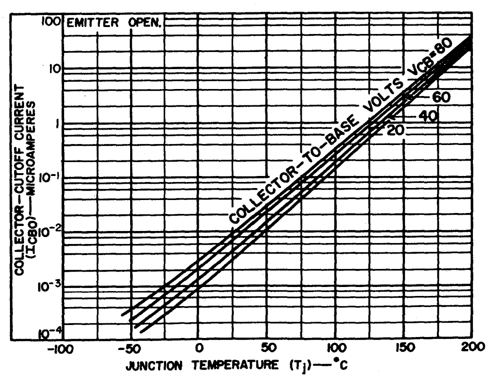
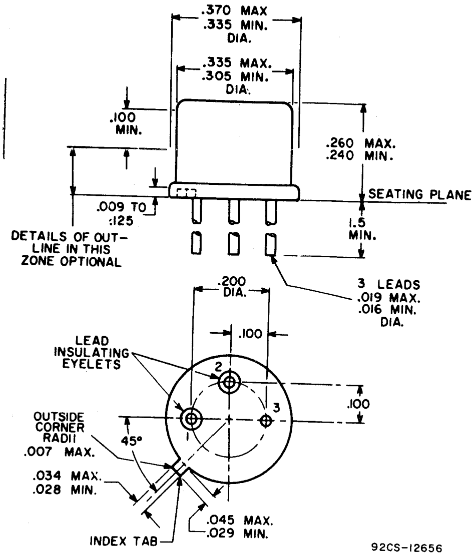


Fig.8 – Typical Collector-Cutoff-Current Characteristics for Type 2N699.

DIMENSIONAL OUTLINE for Type 2N699

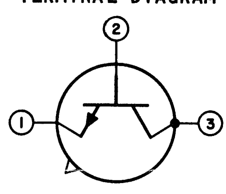
JEDEC No. TO-5



TERMINAL DIAGRAM

LEAD 1 – EMITTER

LEAD 2 – BASE



LEAD 3 – COLLECTOR, CASE

RCA
Solid State
Division

Power Transistors

2N1613
2N2102

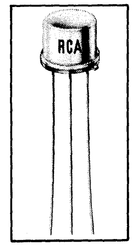
RCA-2N2102 is a triple-diffused, silicon n-p-n planar transistor intended for a wide variety of small-signal and medium-power applications in military and industrial equipment. It features exceptionally low noise, low leakage characteristics, high switching speed, and high pulse beta.

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

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

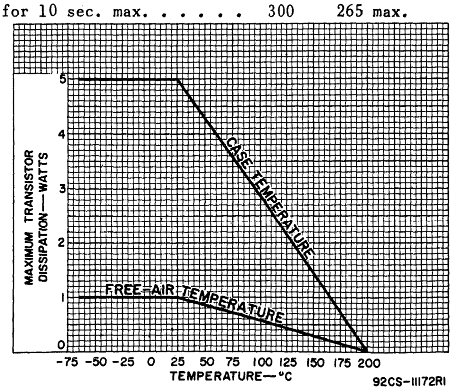


Fig. 1 RATING CHART FOR TYPE 2N2102

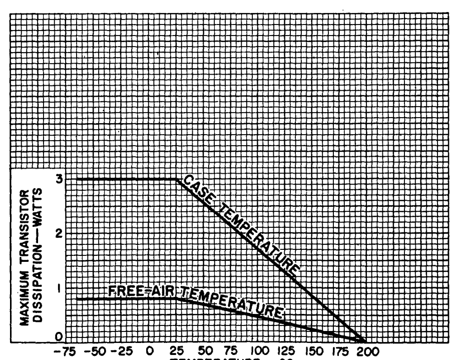


Fig. 2 RATING CHART FOR TYPE 2N1613

ELECTRICAL CHARACTERISTICS

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

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	TEST CONDITIONS: DC Collector Volts V_{CE}	DC Emitter Volts V_{EB}	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	DC Current (Milliamperes) 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

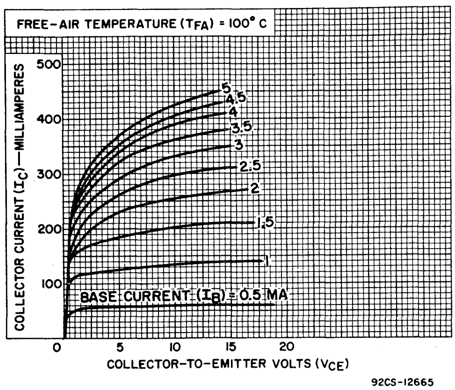


Fig.3

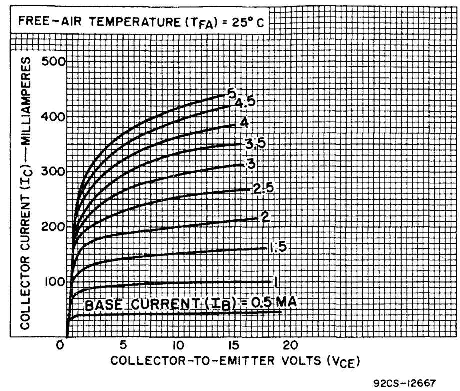


Fig.4

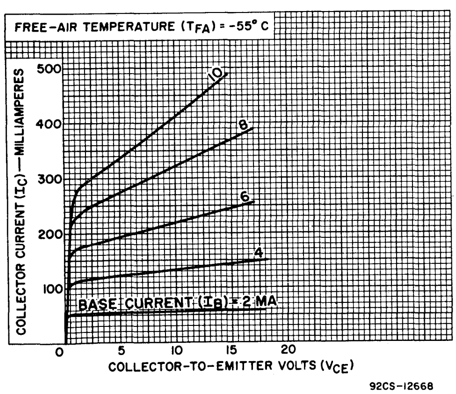


Fig.5

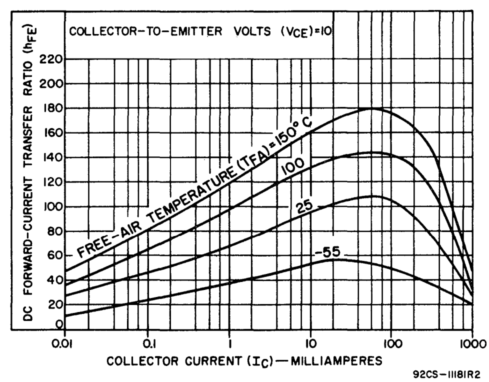


Fig.6

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 2N2102 & 2N1613

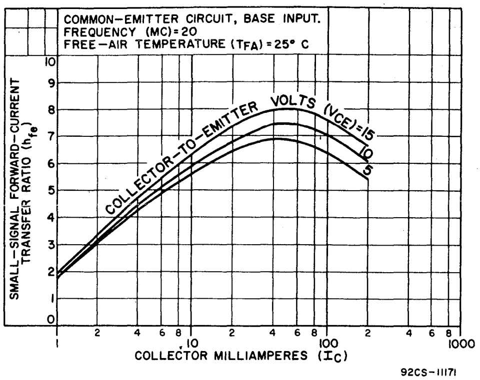


Fig.7

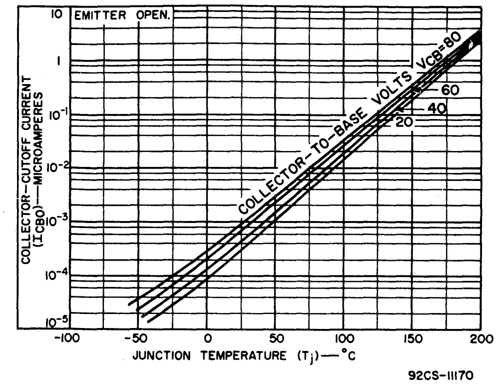


Fig.8

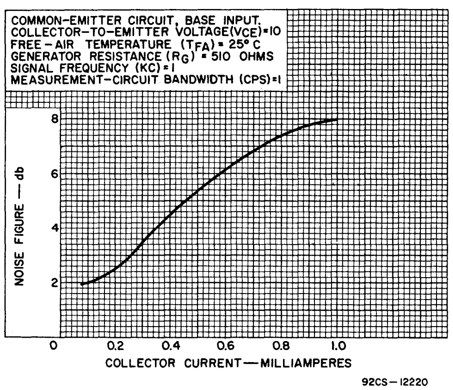


Fig.9

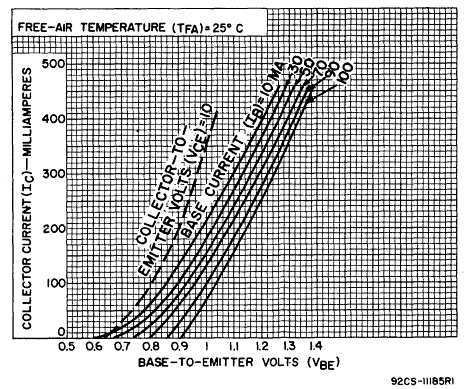


Fig.10

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 2N2102 & 2N1613

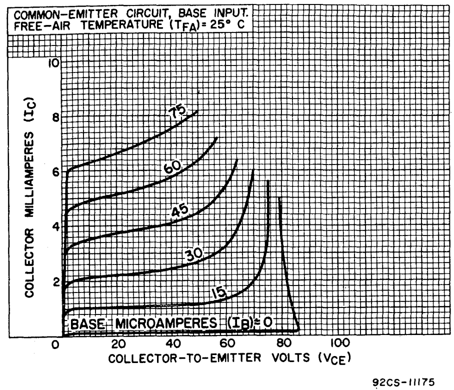


Fig.11

TYPICAL SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N1613

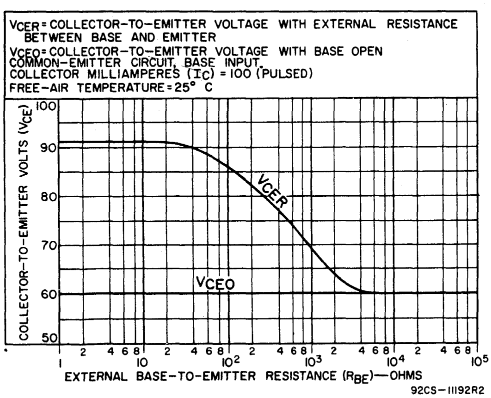


Fig.12

TYPICAL SUSTAINING VOLTAGE vs. BASE-TO-EMITTER RESISTANCE FOR TYPE 2N2102

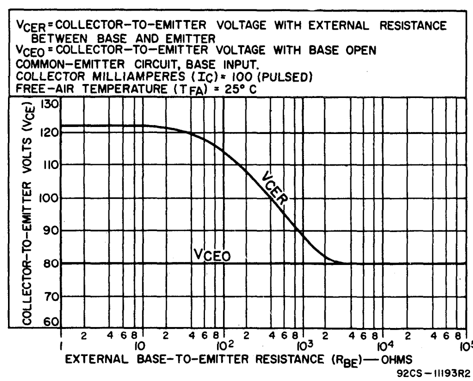
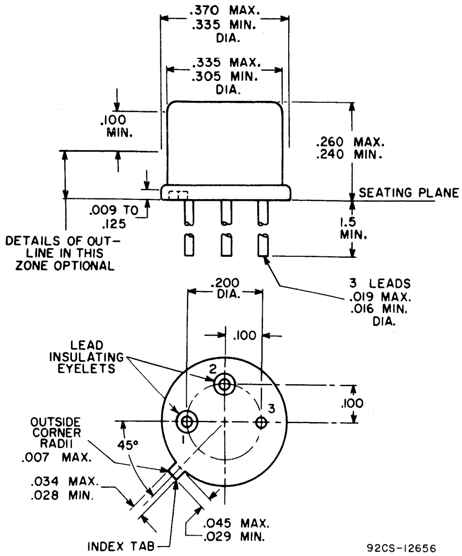


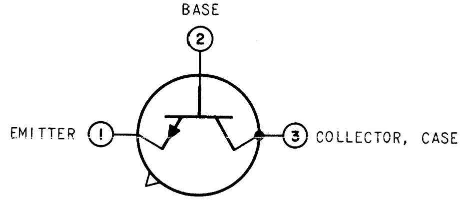
Fig.13

DIMENSIONAL OUTLINE FOR TYPES 2N2102 & 2N1613

JEDEC TO-5



TERMINAL DIAGRAM FOR TYPES 2N2102 & 2N1613



(Bottom View)

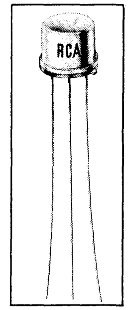
RCA
Solid State
Division

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.

For Small-Signal and Medium-Power Applications



JEDEC TO-5

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

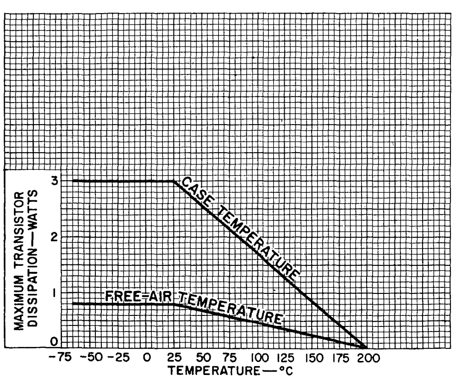


Fig. 1 - Rating Chart for Type 2N1711.

- 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: 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.	Max.	Units
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_{EBF} = Emitter-to-base floating potential.

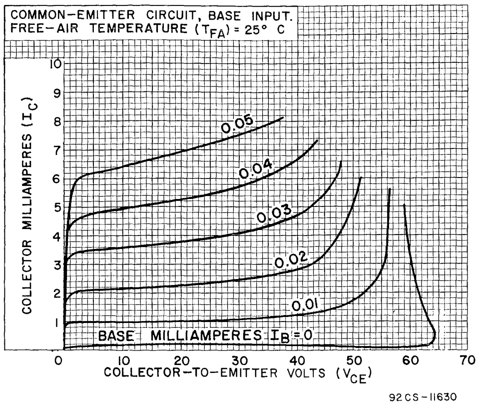


Fig. 2 - Typical Collector Characteristics at 25^0 C for Type 2N1711.

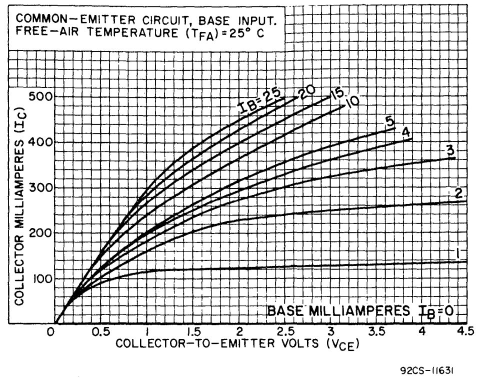


Fig. 5 - Typical Collector Characteristics at 25^0 C for Type 2N1711.

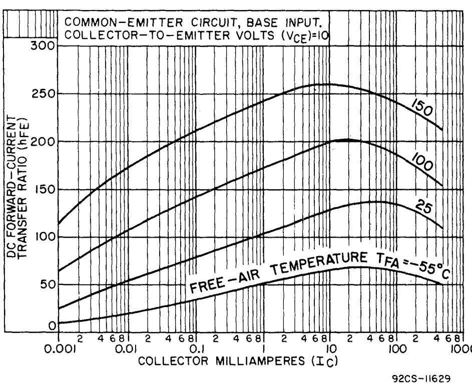


Fig. 3 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N1711.

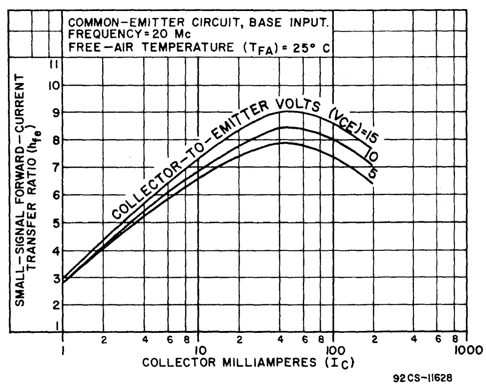


Fig. 6 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N1711.

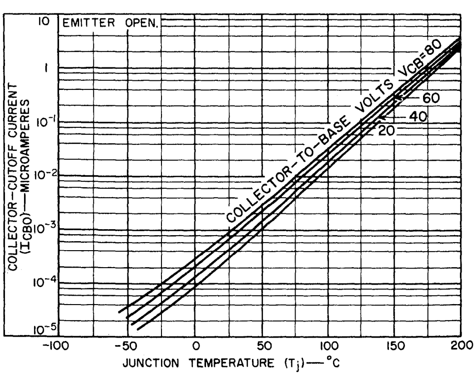


Fig. 4 - Typical Collector-Cutoff-Current Characteristics for Type 2N1711.

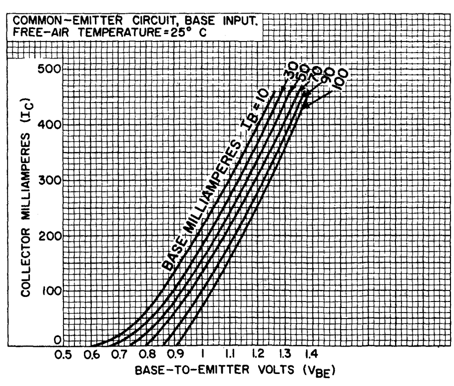


Fig. 7 - Typical Transfer Characteristics for Type 2N1711.

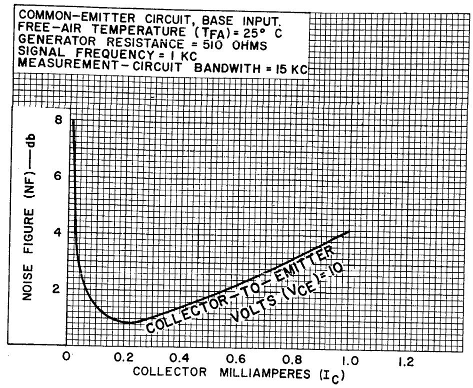
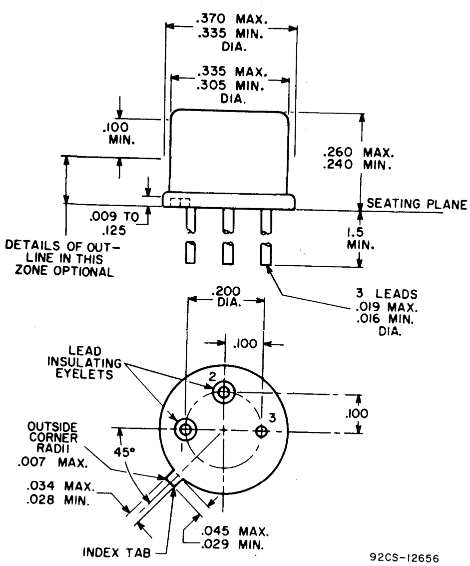
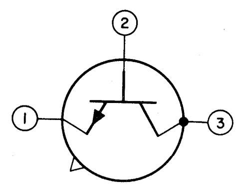


Fig. 8 - Typical AF-Noise-Figure Characteristic for Type 2N1711.

DIMENSIONAL OUTLINE
JEDEC No. TO-5



TERMINAL DIAGRAM



LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

RCA Solid State Division

Power Transistors
2N2405
2N1893

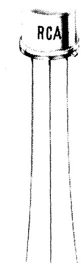
RCA 2N2405▲ and 2N1893 are triple-diffused planar transistors of the silicon n-p-n type intended for a variety of small-signal and medium-power applications. They feature exceptionally high collector-to-emitter sustaining voltage, low leakage characteristics, high switching speeds, and high pulse beta (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.

SILICON N-P-N POWER TRANSISTORS

For Small-Signal and Medium-Power Applications in Military and Industrial Equipment



JEDEC TO-5

H-1380

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}) $\leq$ 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 $\geq$ 1/32 in. (0.8 mm) from seating plane for 10s max	255	-	°C
At distances $\geq$ 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

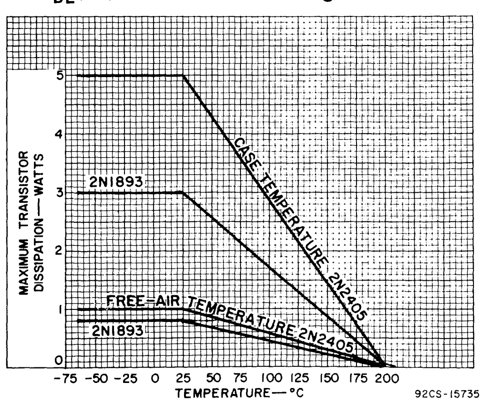


Fig.1 - Dissipation derating curves for types 2N2405 and 2N1893.

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

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Emitter Voltage (V) V_{EB}	DC Current (mA) I_C	I_E	I_B	LIMITS: Type 2N2405 Min.	Max.	Type 2N1893 Min.	Max.	UNITS
* Collector-Cutoff Current: T_C = 150°C	I_{CBO}	90 90				0 0		- -	0.01 10	- -	0.01 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] 30[a]		0 0	90 90	- -	- 80	- -	V
* With external base-to-emitter resistance (R_{BE}) = 10 Ω (R_{BE}) = 500 Ω	$V_{CER}(sus)$				100[a] 100[a]			140 120	- -	100 -	- -	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] 50[a]		15 5	- -	0.5 0.2	- -	5 1.2	V
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$				150[a] 50[a]		15 5	- -	1.1 0.9	- -	1.3 0.9	V
* * DC Forward-Current * Transfer Ratio	h_{FE}		10 10 10		150[a] 10[a] 0.1			60 35 -	200 - -	40 35 20	120 - -	
* T_C = -55°C	h_{FE}		10 10		10 10			20 -	- -	- 20	- -	
Small-Signal Forward-Current Transfer Ratio: * f = 1 kHz * 1 kHz * 1 kHz * 20 MHz 20 MHz	h_{fe}		5 5 10 10 10		1 5 5 50 50			- 50 - - 6	- 275 - - -	30 - 45 2.5 -	100 - - - -	
* Input Resistance (at f = 1 kHz)	h_{ib}	5 10			1 5			24 4	34 8	20 4	30 8	Ω
* Voltage-Feedback Ratio (at f = 1 kHz)	h_{rb}	5 10			1 5			- -	3×10^{-4} 3×10^{-4}	- -	1.25×10^{-4} 1.5×10^{-4}	
* Output Conductance (at f = 1 kHz)	h_{ob}	5 10			1 5			- -	0.5 0.5	- -	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 Junction-to-ambient	θ_{J-C} θ_{J-A}							- -	35 175	- -	58.3 219	°C/W

a Pulsed. Pulse duration = 300 μsec max.; duty factor ≤ 2%.

* In accordance with JEDEC registration data format (JS-9 RDF-2).

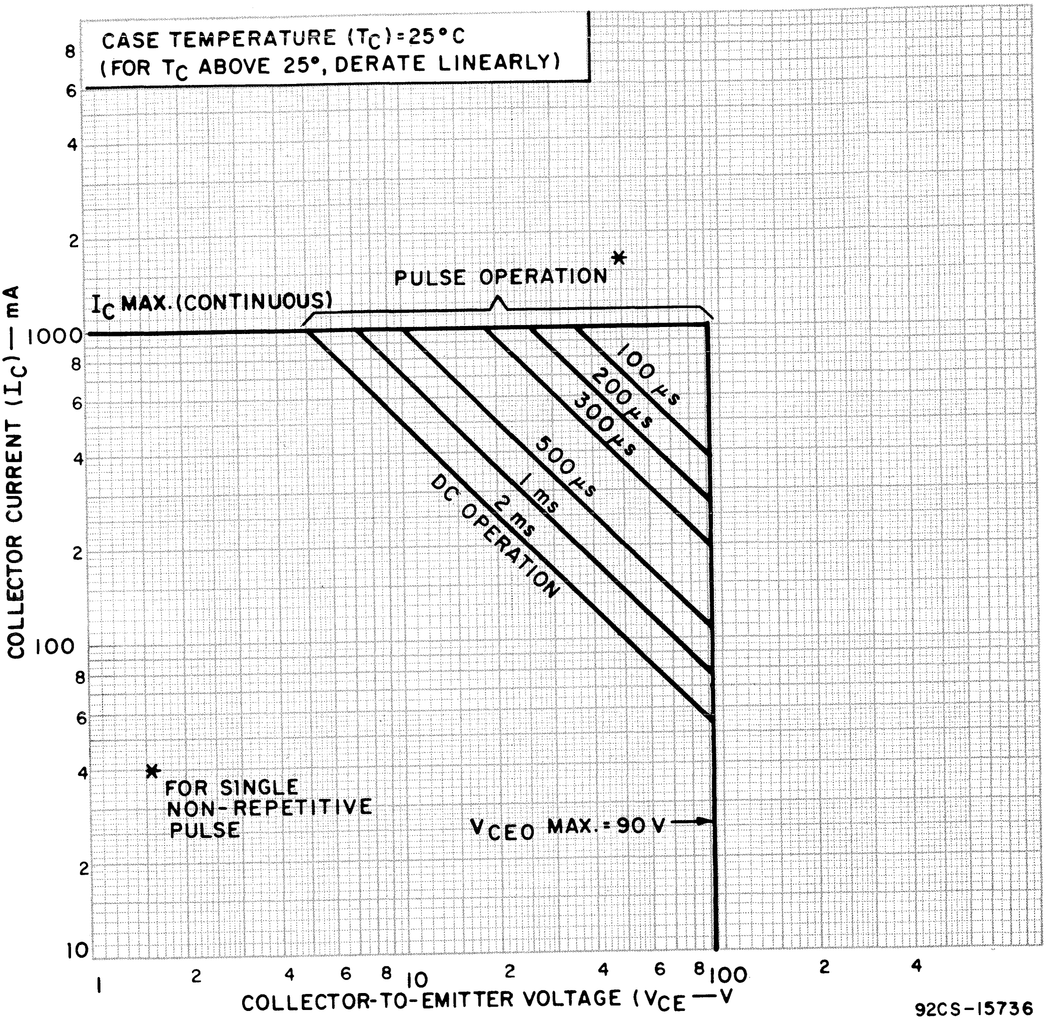


Fig.2 - Maximum operating areas for type 2N2405.

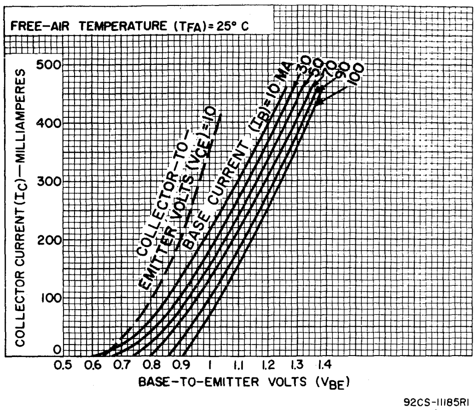


Fig.3 - Typical transfer characteristics for types 2N2405 and 2N1893.

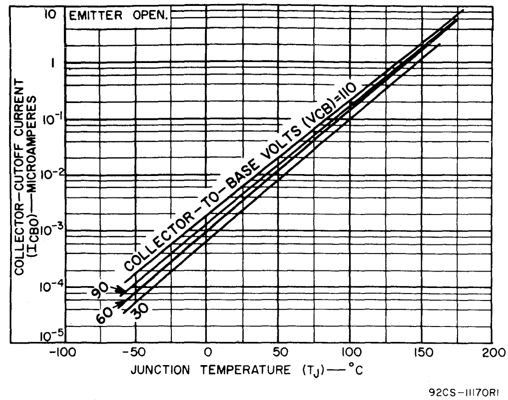


Fig.4 - Typical cutoff characteristics for types 2N2405 and 2N1893.

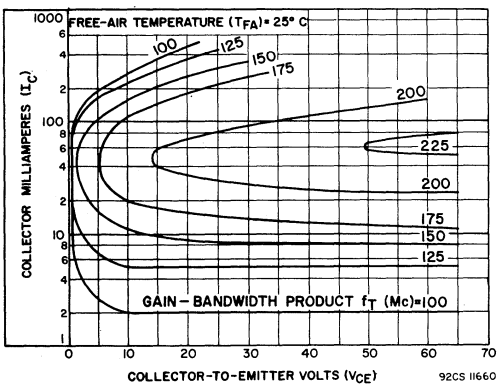


Fig.5 - Typical gain bandwidth product characteristics for types 2N2405 and 2N1893.

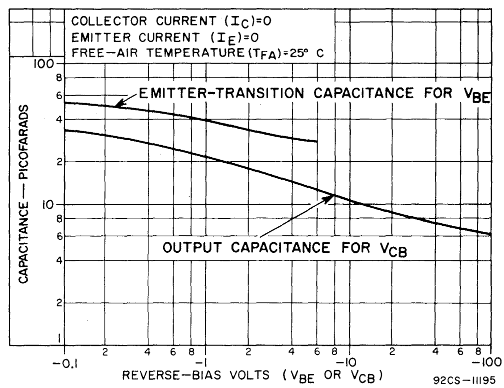


Fig.6 - Typical capacitance characteristics for types 2N2405 and 2N1893.

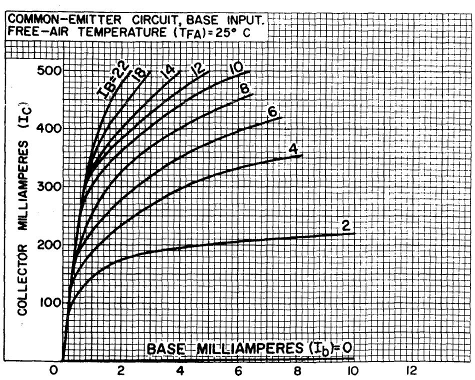


Fig.7 - Typical collector characteristics at 25°C for type 2N2405.

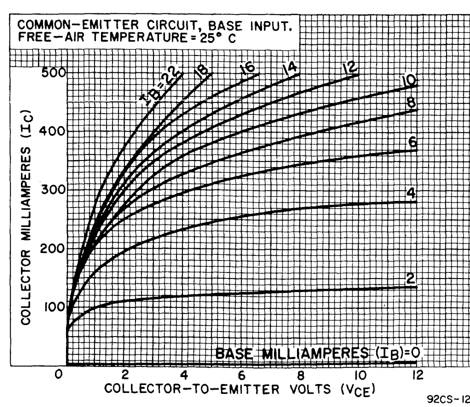


Fig.8 - Typical collector characteristics at 25°C for type 2N1893.

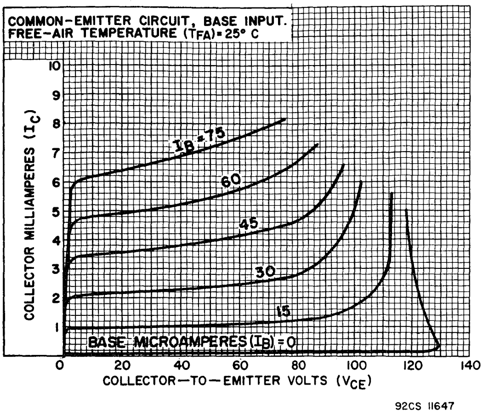


Fig.9 - Typical collector characteristics at 25°C for type 2N2405.

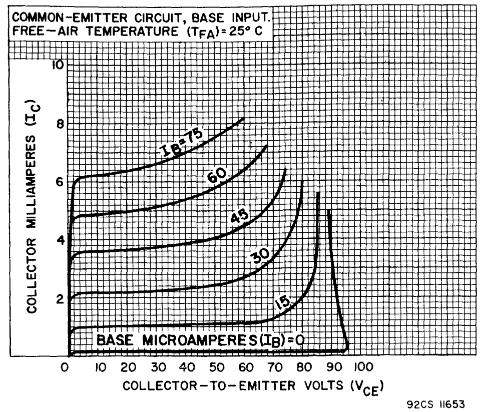


Fig.10 - Typical collector characteristics at 25°C for type 2N1893.

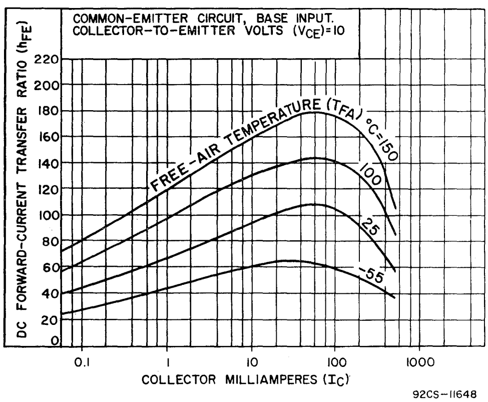


Fig.11 - Typical dc-beta characteristics for types 2N2405 and 2N1893.

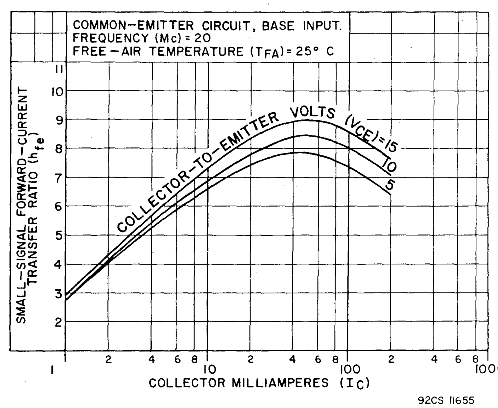


Fig.12 - Typical small-signal beta characteristics for types 2N2405 and 2N1893.

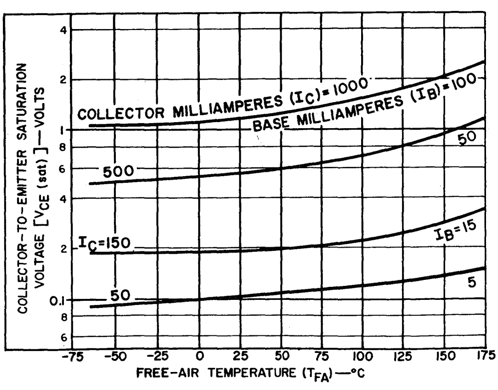


Fig.13 - Typical saturation characteristics for types 2N2405 and 2N1893.

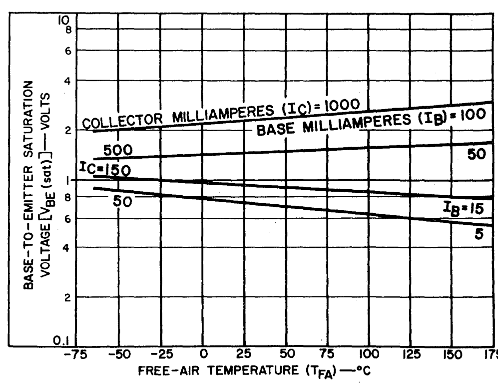


Fig.14 - Typical saturation characteristics for types 2N2405 and 2N1893.

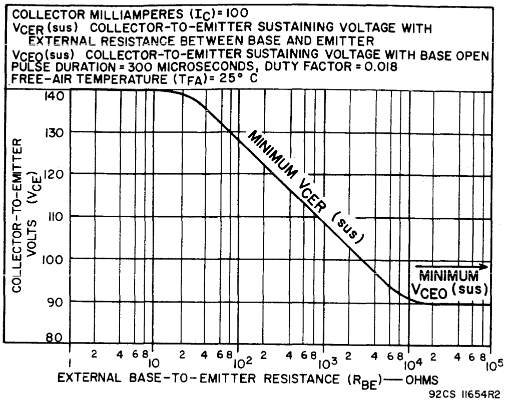


Fig.15 - Sustaining voltage characteristic for type 2N2405.

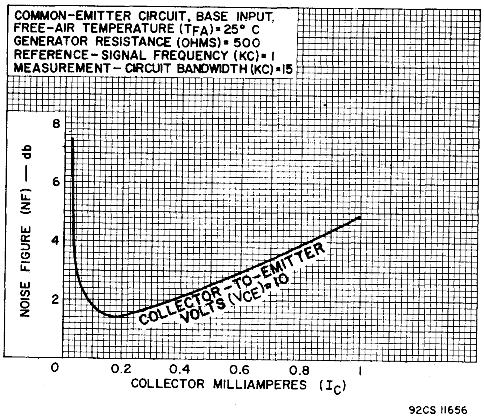


Fig.16 - Typical wide-band noise characteristic for type 2N2405.

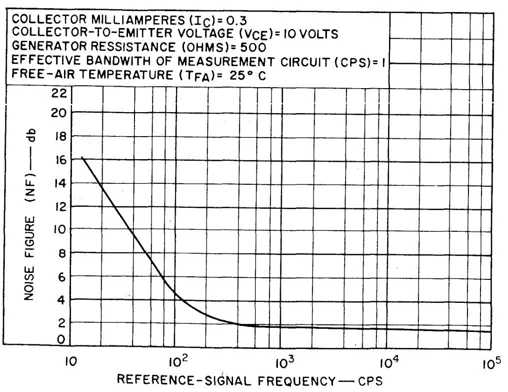
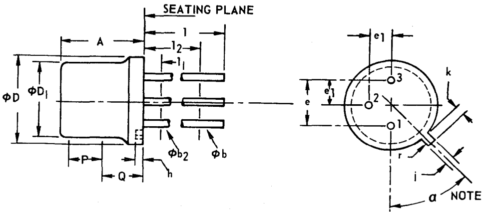


Fig.17 - Typical narrow-band noise characteristic for type 2N2405.

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

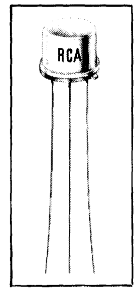
2N2270

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

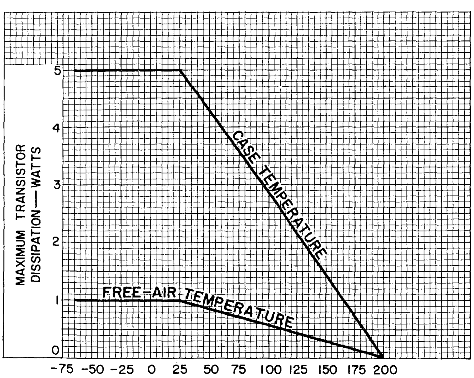


Fig. 1 Rating Chart for Type 2N2270.

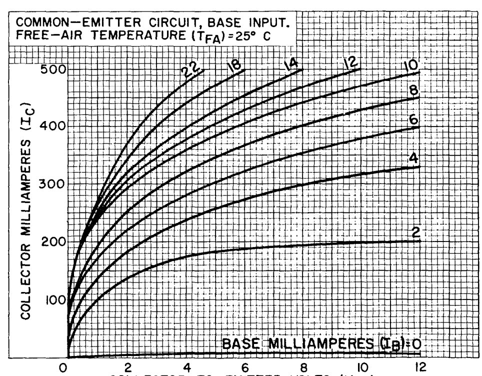


Fig. 2 - Typical Collector Characteristics at 25° C for Type 2N2270.

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 = 150° C	I_{CBO}	 60 60				 0 0		 - -	 0.1 50	 μa μa
Emitter-Cutoff Current	I_{EBO}			5	0			-	0.1	μa
DC Forward-Current Transfer Ratio	h_{FE}		10 10		150* 1			50 35	200 -	
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 20 Mc	h_{fe}		 10 10		 5 50			 30 3	 180 -	
Noise Figure: Generator resistance (R_G) = 1000 ohms, circuit bandwidth (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 Junction-to-free air	 θ_{J-C} θ_{J-FA}							 - -	 35 175	 °C/W °C/W

* Pulse Test: Pulse duration, 300 μsec; duty factor, 1.8%.

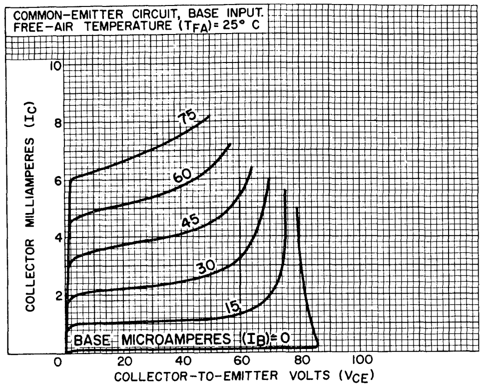


Fig. 3 - Typical Collector Characteristics at 25° C for Type 2N2270.

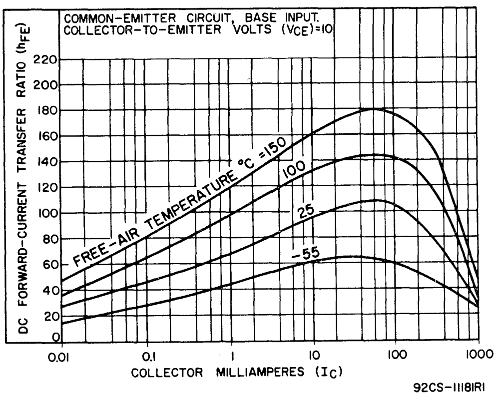


Fig. 4 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N2270.

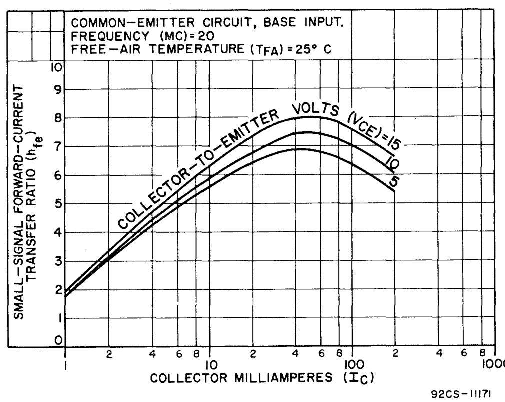


Fig. 5 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Type 2N2270.

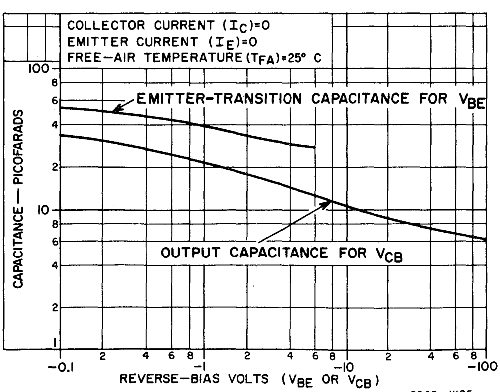


Fig. 6 - Typical Emitter-Transition-Capacitance and Output-Capacitance Characteristics for Type 2N2270.

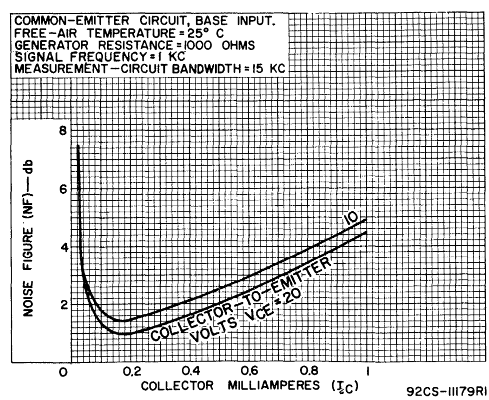
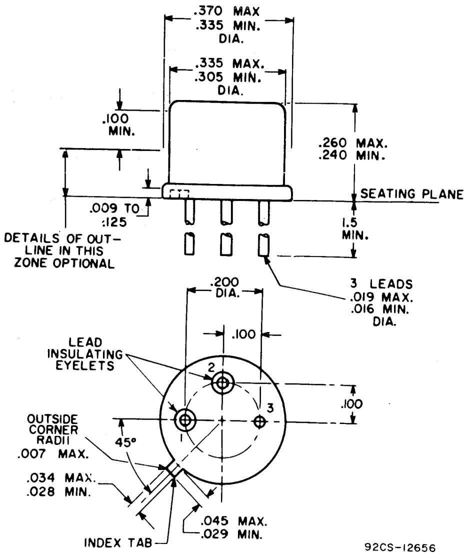
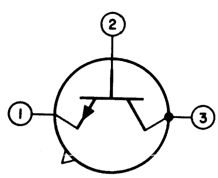


Fig. 7 - Typical AF-Noise-Figure Characteristics for Type 2N2270.

DIMENSIONAL OUTLINE
for Type 2N2270
JEDEC No. TO-5



TERMINAL DIAGRAM



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.

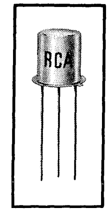
Like the 2N2102, the 2N2895 offers five levels of beta control from 0.1 ma to 0.5 ampere.

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}	25 150 25 150		90 90 60 60				0 0 0 0		- - - -	- - 0.002 2	- - - -	0.01 10 - -	- - - -	- - 0.05 50	µa µa µa µa
Emitter-Cutoff Current	I_{EBO}	25				5	0			-	0.002	-	0.01	-	0.05	µa
DC Forward-Current Transfer Ratio	h_{FE}	25 25 25 25 25 -55			10 10 10 10 10 10		150[b] 500[b] 0.1 1 10 10			40 25 20 - 35 20	120 - - - - -	60 - - 35 - 20	200 - - - - -	50 - - 35 - -	200 - - - - -	
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 25	1 20 Mc		5 10		5 50			50 6	200 -	50 6	275 -	50 5	275 -	
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 Junction-to-Free Air	θ_{J-C} θ_{J-FA}	- -								- -	97 350	- -	97 350	- -	97 350	°C/watt °C/watt

[b] Pulse test: Pulse duration = 300 µsec; duty factor = 1.8%.

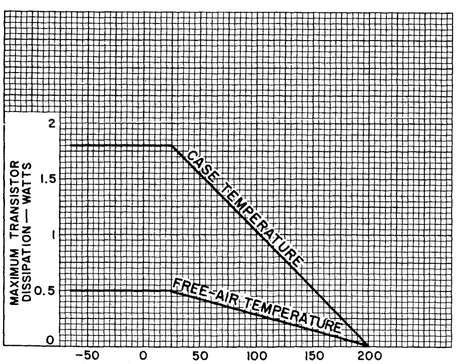


Fig. 1 - Rating Chart for Types 2N2895 2N2896, and 2N2897

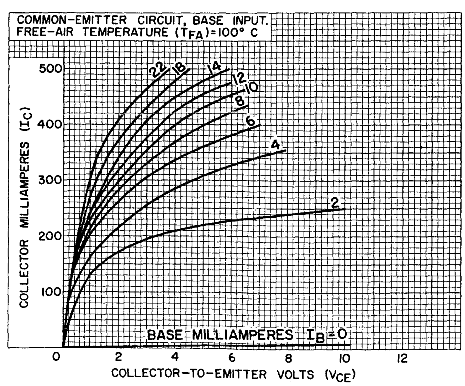


Fig. 2 - Typical Collector Characteristics at 100° C for Type 2N2895

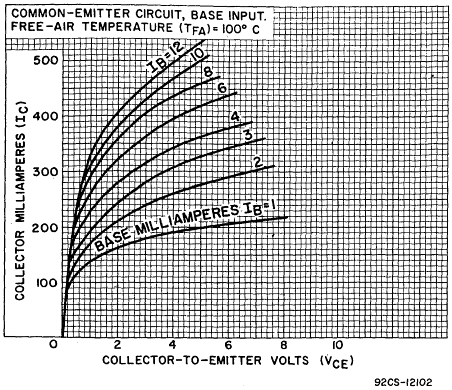


Fig. 3 - Typical Collector Characteristics at 100° C for Types 2N2896 and 2N2897.

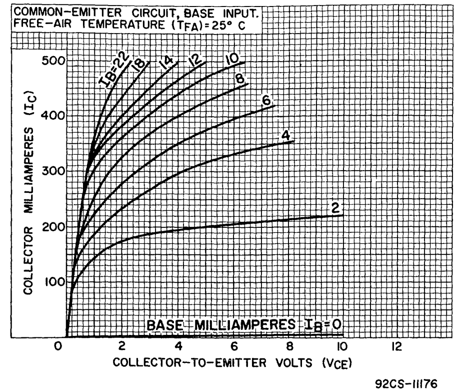


Fig. 4 - Typical Collector Characteristics at 25° C for Type 2N2895.

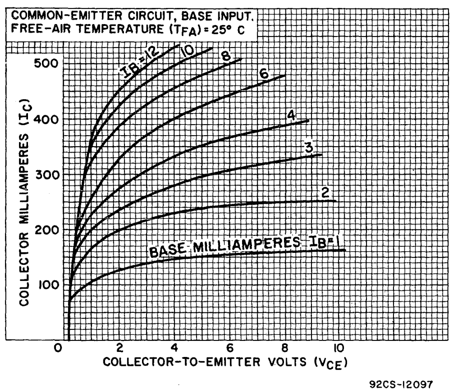


Fig. 5 - Typical Collector Characteristics at 25° C for Types 2N2896 and 2N2897.

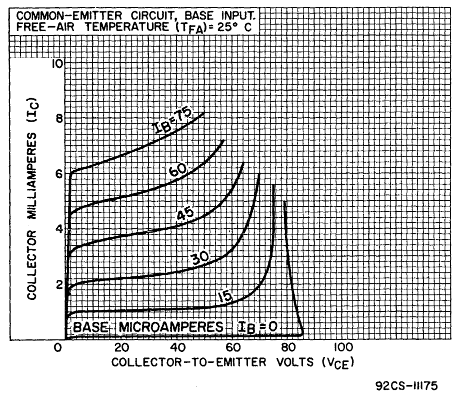


Fig. 6 - Typical Collector Characteristics at 25° C for Type 2N2895.

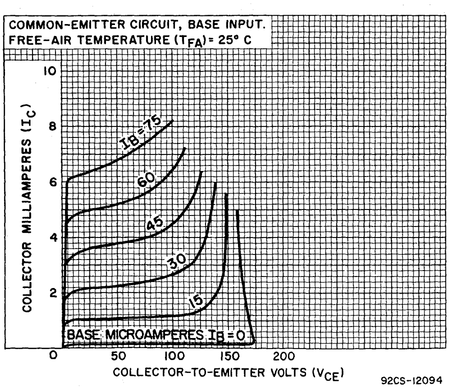


Fig. 7 - Typical Collector Characteristics at 25° C for Type 2N2896.

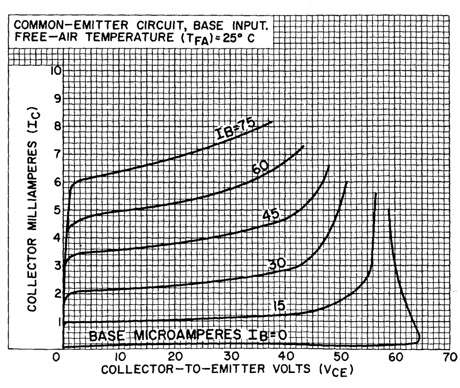
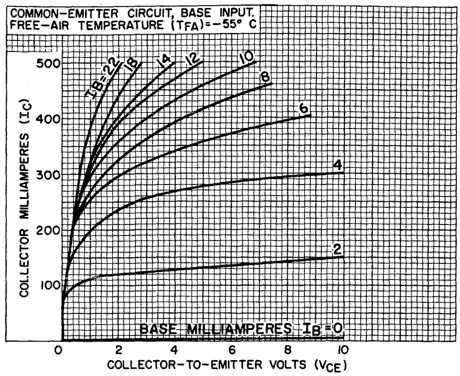
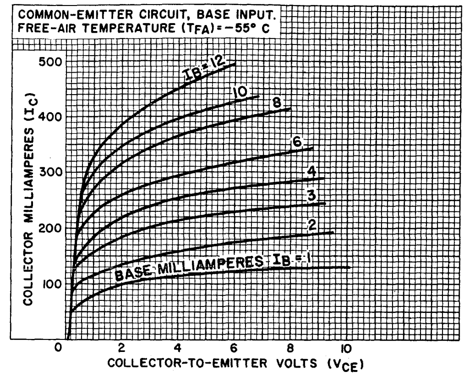


Fig. 8 - Typical Collector Characteristics at 25° C for Type 2N2897.



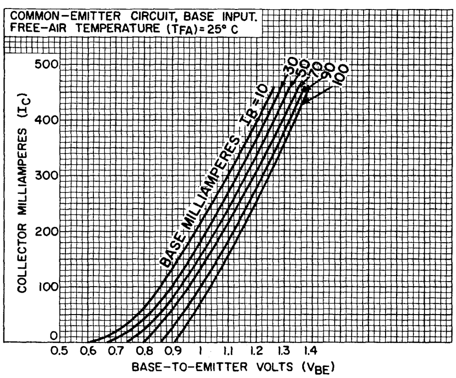
92CS-11190

Fig. 9 - Typical Collector Characteristics at -55° C for Type 2N2895.



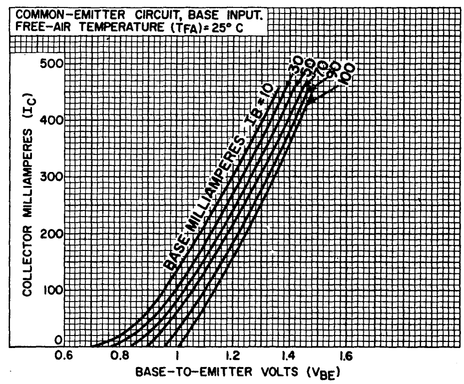
92CS-12099

Fig. 10 - Typical Collector Characteristics at -55° C for Types 2N2896 and 2N2897.



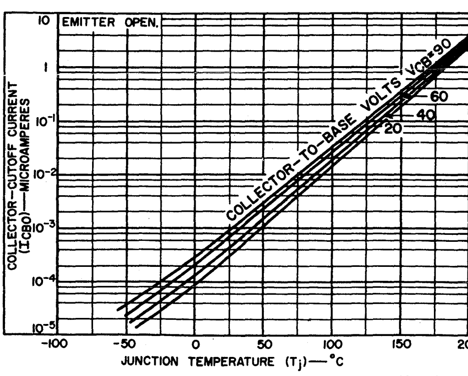
92CS-11185

Fig. 11 - Typical Transfer Characteristics for Types 2N2895 and 2N2896.



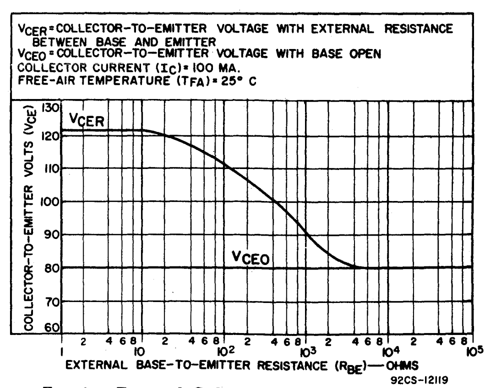
92CS-12104

Fig. 12 - Typical Transfer Characteristics for Type 2N2897.



92CS-12124

Fig. 13 - Typical Collector-Cutoff-Current Characteristics for Types 2N2895 and 2N2896.



92CS-12119

Fig. 14 - Typical Collector-to-Emitter-Voltage Characteristic for Type 2N2895.

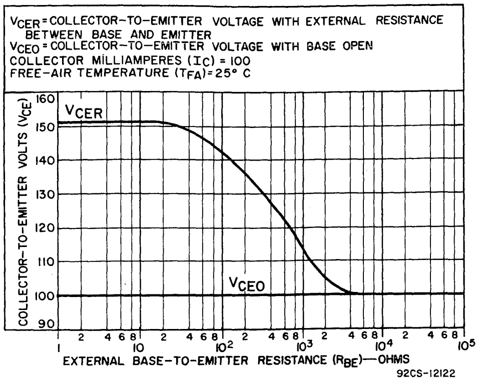


Fig. 15 - Typical Collector-to-Emitter-Voltage Characteristic for Type 2N2896.

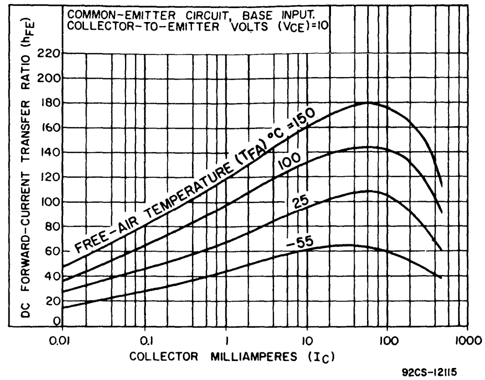


Fig. 16 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Type 2N2895.

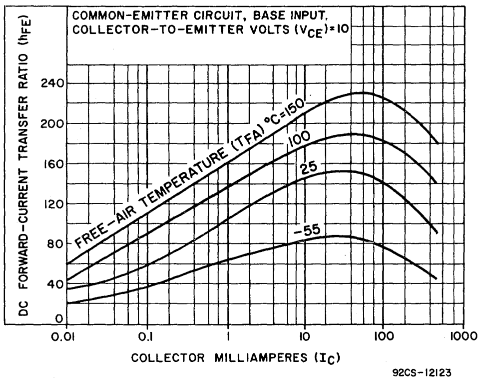


Fig. 17 - Typical DC-Forward-Current Transfer-Ratio Characteristics for Types 2N2896 and 2N2897.

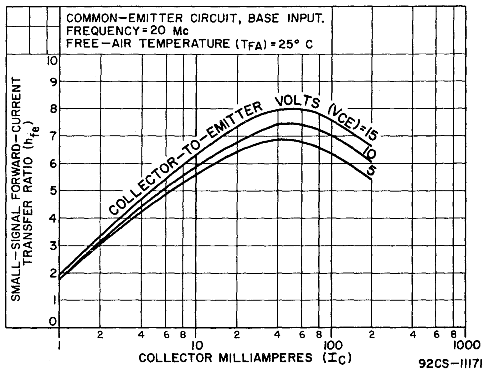


Fig. 18 - Typical Small-Signal Forward-Current Transfer-Ratio Characteristics for Types 2N2895, 2N2896 and 2N2897 .

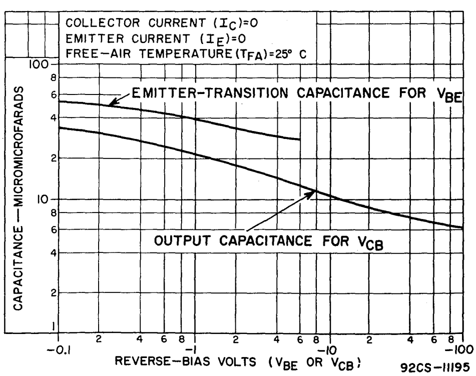


Fig. 19 - Typical Emitter-Transition-Capacitance and Output-Capacitance Characteristics for Types 2N2895, 2N2896 and 2N2897.

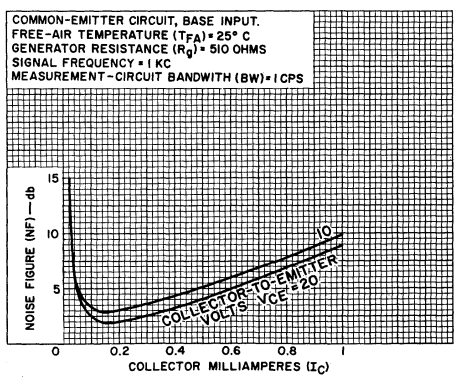
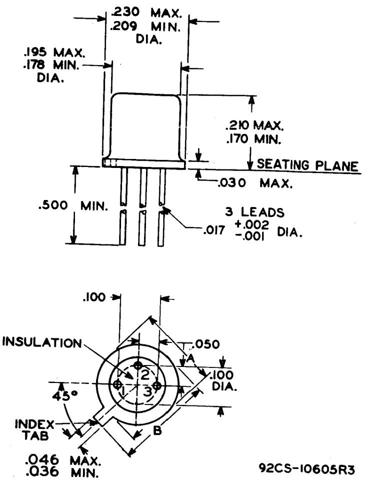
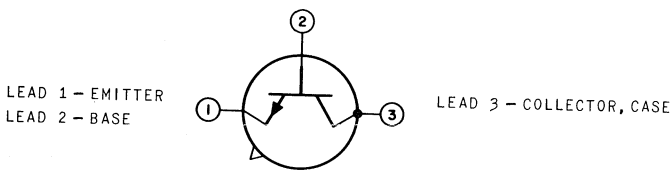


Fig. 20 - Typical AF-Noise-Figure Characteristics for Type 2N2895.

2N2895, 2N2896, and 2N2897
DIMENSIONAL OUTLINE
JEDEC No. TO-18

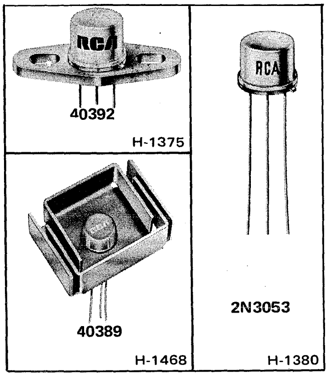


TERMINAL DIAGRAM
(Bottom View)
For All Types



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.

Applications

- **Audio amplifiers**
- **Controlled amplifiers**
- **Power supplies**
- **Power oscillators**

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

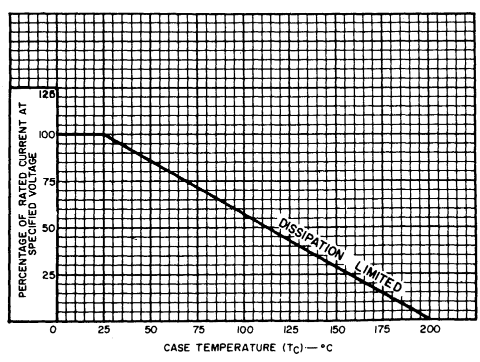


Fig. 1 - Derating curve for type 2N3053.

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 %.

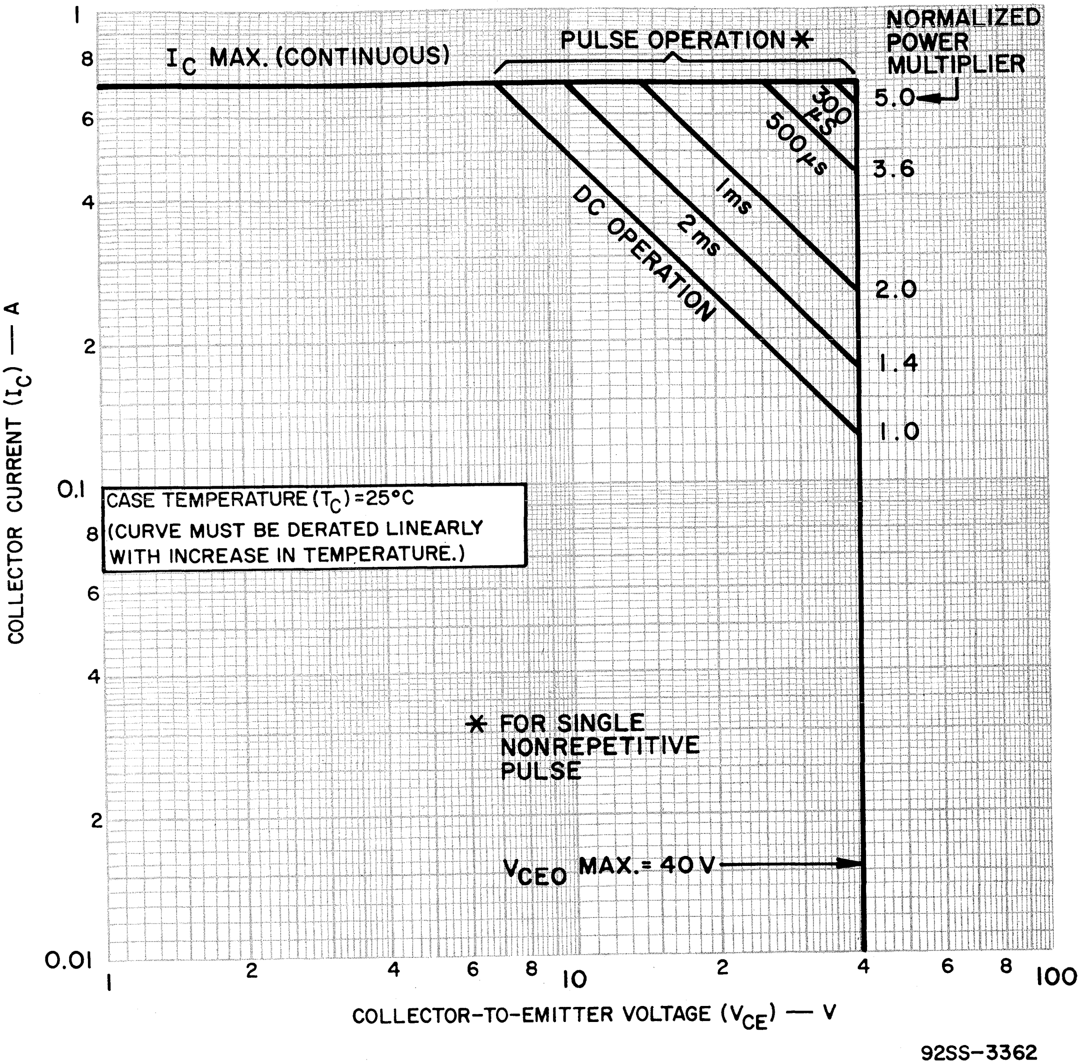


Fig. 2 - Maximum operating areas for type 2N3053.

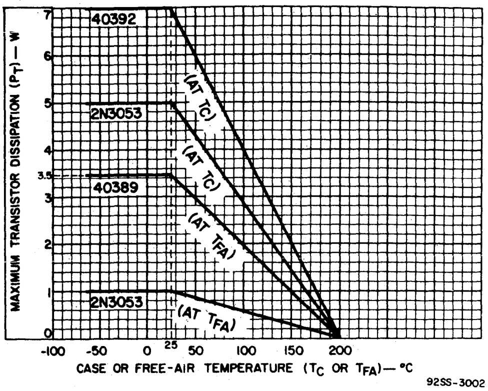


Fig. 3 - Dissipation derating curves for all types.

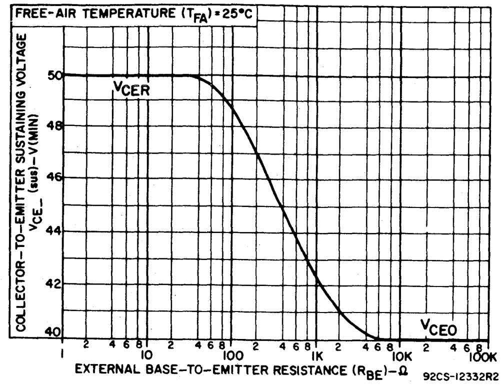


Fig. 4 - Sustaining voltage vs. base-to-emitter resistance for all types.

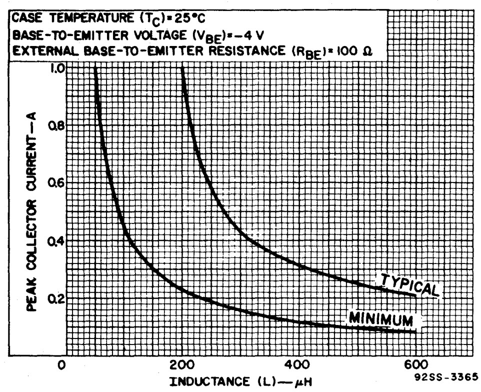


Fig. 5 - Reverse-bias, second-breakdown characteristics for all types.

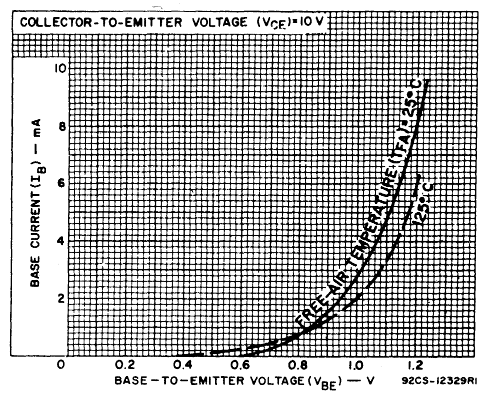


Fig. 6 - Typical dc-beta characteristics for all types.

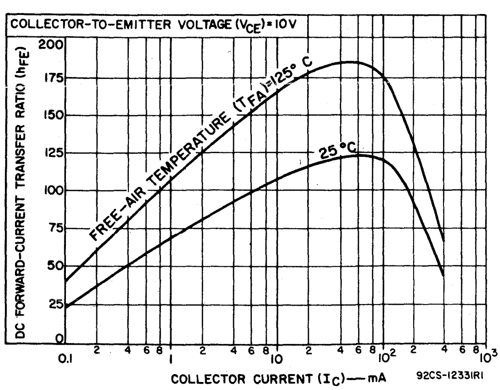


Fig. 7 - Typical input characteristics for all types.

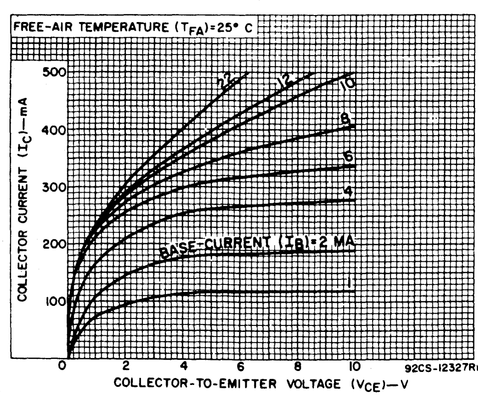


Fig. 8 - Typical output characteristics for all types.

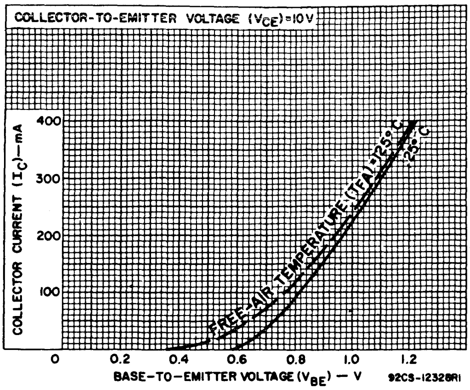


Fig. 9 - Typical transfer characteristics for all types.

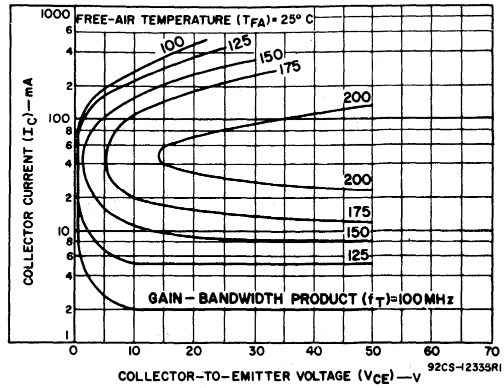


Fig. 10 - Typical variation of gain-bandwidth product with I_C and V_{CE} for all types.

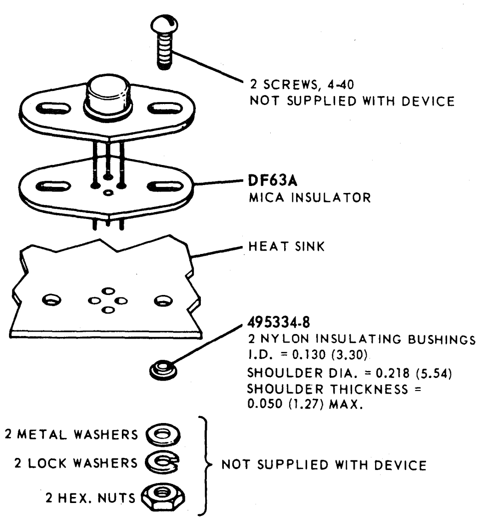


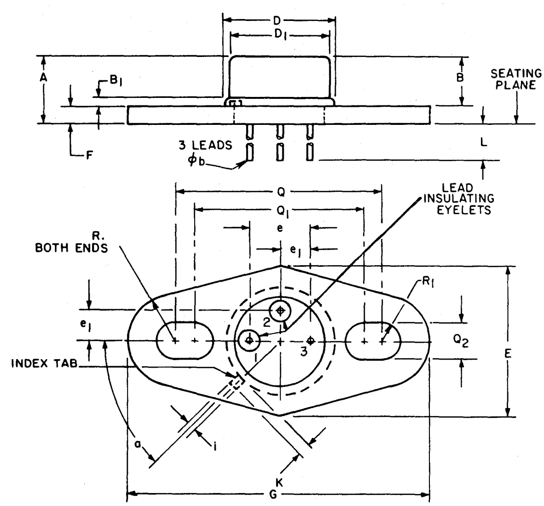
Fig. 11 - Suggested mounting hardware for type 40392 (JEDEC TO-5 with mounting flange).

TERMINAL CONNECTIONS

FOR TYPE 40392

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

DIMENSIONAL OUTLINE FOR TYPE 40392 JEDEC TO-5 WITH MOUNTING FLANGE

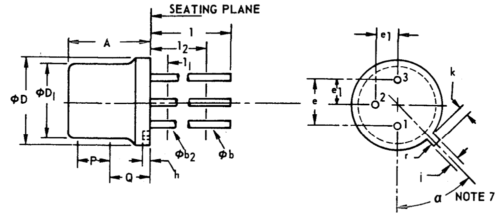


SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	-	.328	-	8.33	
B	.240	.260	6.10	6.60	
B_1	.009	.125	.229	3.18	
ϕb	.016	.019	.406	.483	
D	.335	.370	8.51	9.40	
D_1	.305	.335	7.75	8.51	
E	.495	.505	12.57	12.83	
e	.200 T.P.		5.08 T.P.		1
e_1	.100 T.P.		2.54 T.P.		1
F	.062	.068	1.57	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

DIMENSIONAL OUTLINE FOR TYPE 2N3053
JEDEC TO-5



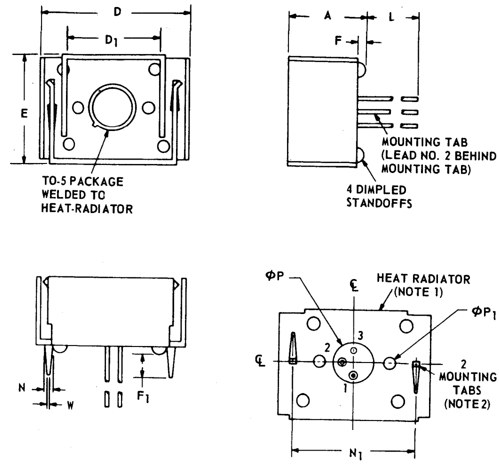
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.016	.021	.406	.533	2
$Φb_2$	.016	.019	.406	.483	2
ΦD	.335	.370	8.51	9.40	
$ΦD_1$	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
i	.028	.034	.711	.864	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_l and l_2. Φb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_l 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	FOR TYPE 40389
Lead 1 - Emitter	Lead 1 - Emitter
Lead 2 - Base	Lead 2 - Base
Case, Lead 3 - Collector	Heat-Radiator, Lead 3 - Collector

RCA

Solid State
Division

Power Transistors

2N3263 2N3265
2N3264 2N3266

RCA-2N3263, 2N3264, 2N3265, and 2N3266* are epitaxial silicon power transistors of the n-p-n type designed for aerospace, military, and industrial equipment where high reliability is required. The high current-handling capability of these transistors in conjunction with fast switching speed make them especially suitable in applications where optimum circuit efficiency is desired.

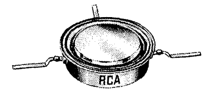
The 2N3263 and the 2N3264 are sealed in flat 3/4-inch diameter packages having radial leads. Types 2N3265 and 2N3266 are sealed in 7/8-inch hexagonal double-ended-stud copper packages.

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 Dev. Type Nos. TA2492, TA2493, TA2494, and TA2495, respectively.

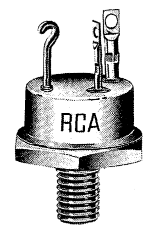
SILICON N-P-N HIGH-POWER HIGH-SPEED HIGH-CURRENT TRANSISTORS

Epitaxial Types for Aerospace, Military, and Industrial Applications



2N3263, 2N3264

H-1354



2N3265, 2N3266
(JEDEC TO-63)

H-1355

Maximum Ratings, *Absolute-Maximum Values:*

	2N3264 2N3266	2N3263 2N3265		
Collector-to-Base Voltage, V_{CBO}	120	150	max.	volts
Collector-to-Emitter Voltage:				
With base open (sustaining voltage), $V_{CEO}(sus)$	60	90	max.	volts
With 50 ohms or less between base and emitter (sustaining voltage), $V_{CER}(sus)$	80	110	max.	volts
With 1.5 volts of reverse voltage, V_{CEX}	120	150	max.	volts
Emitter-to-Base Voltage, V_{EBO}	7	7	max.	volts
Collector Current, I_C	25	25	max.	amperes
Base Current, I_B	10	10	max.	amperes
Transistor Dissipation	See *Fig.1* and *Fig.2*			
Temperature Range:				
Storage	-65 to +200			°C
Operating (Junction)	-65 to +200			°C
	2N3263 2N3264	2N3265 2N3266		
Thermal Resistance (Junction-to-case), θ_{J-C}	1.5	1.0	max.	°C/w

- High Reliability and Uniformity of Characteristics
- Operation at High-Junction Temperatures – Up to 200° C (max.)
- High Power Dissipation
- Fast Rise Time at High Collector Current – 0.2 μsec at 10 amp (typical)
- Low Saturation Voltages –
  - 2N3263 and 2N3265
    - $V_{CE}(sat)$ = 0.75 volt (max.) at I_C = 15 amp
    - $V_{BE}(sat)$ = 1.60 volts(max.) at I_C = 15 amp
  - 2N3264 and 2N3266
    - $V_{CE}(sat)$ = 1.20 volts(max.) at I_C = 15 amp
    - $V_{BE}(sat)$ = 1.80 volts(max.) at I_C = 15 amp

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 (Amperes) I_E	DC Current (Amperes) I_B	DC Current (Amperes) I_C	LIMITS 2N3264 2N3266 Min.	2N3264 2N3266 Max.	2N3263 2N3265 Min.	2N3263 2N3265 Max.	Units
Collector-Cutoff Current	I_{CBO}											
at T_C = 25° C		60				0			10			ma
		80				0					4	ma
T_C = 125° C		60				0			10			ma
		80				0					4	ma
Emitter-Cutoff Current	I_{EBO}											
at T_C = 25° C				5			0		15		5	ma
T_C = 125° C				5			0		15		5	ma
Collector Current (with base reverse biased)	I_{CEX}		120	1.5					20			ma
			150	1.5							20	ma
Emitter-to-Base Voltage	V_{EBO}				I_{EB}=0.02		0	7		7		volts
Collector-to-Emitter Sustaining Voltage: **Caution: See Note 1**												
With base open	$V_{CEO}(sus)$					0	0.2	60		90		volts
With external base-to-emitter resistance R_{BE} ≦ 50 ohms	$V_{CER}(sus)$					0	0.2	80		110		volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					1.2	15▲		1.20		0.75	volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					1.2	15▲		1.80		1.60	volts
DC Forward Current Transfer Ratio	h_{FE}		3				5▲	35		40		
			3				15▲	20	80	25	75	
			4				20▲	15		20		
Safe-Operating Region for Second Breakdown: See Note 2 —												
DC Forward Biased (See *Fig.5*)	$I_{S/b}$*		50					700				ma
			75							350		ma
Reverse Biased, R_{BE} = 20 ohms, L = 40 µh	$E_{S/b}$**			6			10	2		2		mjoules
Sat. Switch Turn-On Time (delay time + rise time) (See *Figs.3 & 4*)	$t_d + t_r$		V_{CC}=30			$I_{B1} = I_{B2}$ = 1.2	15		0.5		0.5	µsec
Sat. Switch Storage Time	t_s		V_{CC}=30			$I_{B1} = I_{B2}$ = 1.2	15		1.5		1.5	µsec
Sat. Switch Fall Time	t_f		V_{CC}=30			$I_{B1} = I_{B2}$ = 1.2	15		0.5		0.5	µsec
Gain-Bandwidth Product (at 5 Mc)	f_T		10				3	20		20		Mc
Collector-to-Base Feedback Capacitance (at 1 Mc)	C_{ob}	10			0				900		900	pf
								2N3263 2N3264		2N3265 2N3266		
Thermal Resistance Junction-to-Case T_J = 100° C	θ_{J-C}		40				0.5		1.5		1.0	°C/w

▲ Pulsed; pulse duration ≦ 350 µsec; duty factor ≦ 2%.

* $I_{S/b}$ 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.

Note 1: 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.10.

Note 2: Second breakdown (S/b) occurs in all high-frequency power transistors within the linear power-derating curves. This breakdown phenomenon occurs when the output impedance changes instantaneously from a large positive value to a negative value and then to a final small positive value. In general, the severity of S/b increases with both an increase in frequency response of the transistor and with an increase in the operating collector-to-emitter voltage. Repeated operation of the transistor in the S/b region will degrade and damage the transistor.

The curves in Fig.1 and Fig.2 show maximum dc dissipation as a function of collector-to-emitter voltage for the useful case-temperature range. The temperature derating factor is also shown on these curves and is applicable for average as well as dc dissipation values. The ratings shown in Fig.1 and Fig.2 are controlled by one-hundred per-cent testing. A safe region of operation in the forward bias mode which extends the useful range for different time durations of voltage and current is shown in Fig.5. Within this safe-operating region, these transistors may be operated with high reliability over their entire voltage and current ranges in medium-and-high-frequency amplifiers and in switching applications.

The energy required to induce S/b when the emitter-to-base junction is open, shorted, or reverse biased is much lower than that required in the forward-bias mode. The curves shown in Fig.7, Fig.8, and Fig.9 show collector current as a function of inductance. Use of these curves is recommended when designing circuits having inductive loads (such as solenoids, relays, deflecting yokes, and switching regulators) where protective zener diodes are not employed across the collector junction, and in circuits where some leakage induction is present (such as in inverters, converters, and in power amplifiers). For further information on S/b consult RCA Application Note SMA-30 "Second Breakdown in Transistors Under Conditions of Cutoff."

RATING CHARTS

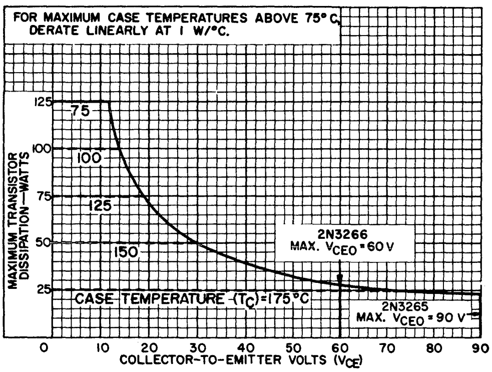


Fig. 1

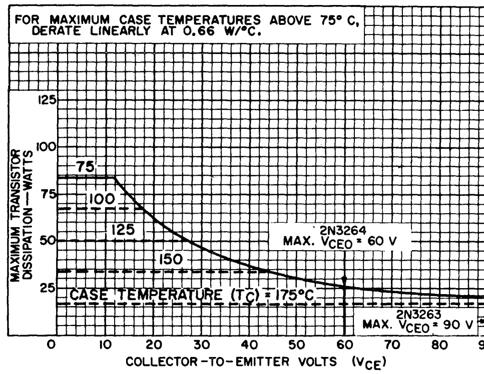
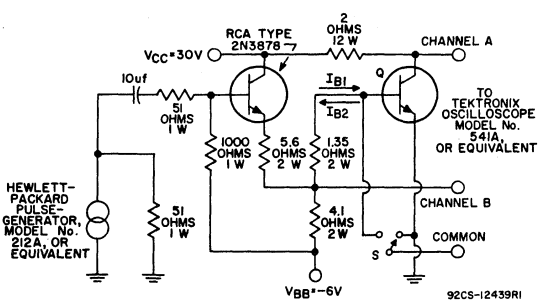


Fig. 2

CIRCUIT USED TO MEASURE t_{on} AND t_{off} FOR OPERATION AS A SATURATED SWITCH



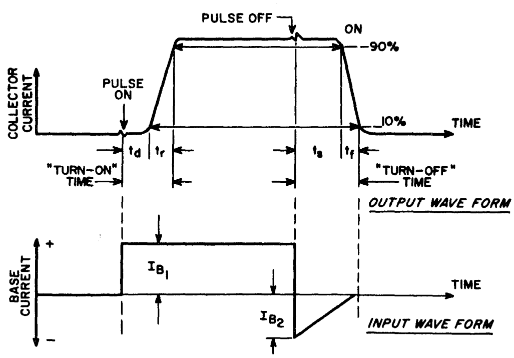
INPUT PULSE:

t_r < 20 nsec
t_f < 20 nsec
REP. RATE = 400 cps
PULSE WIDTH = 5 μsec

Q = 2N3263, 2N3264, 2N3265, 2N3266

Fig. 3

WAVE FORMS FOR SATURATED SWITCH CIRCUIT SHOWN IN FIG.3



I_{B1} = 1.2 a
I_{B2} = -1.2 a
I_C = 15 a

t_{on} = 0.5 μsec
t_{off} = 2.0 μsec

Fig. 4

SAFE OPERATING REGION AS A FUNCTION OF PULSE WIDTH

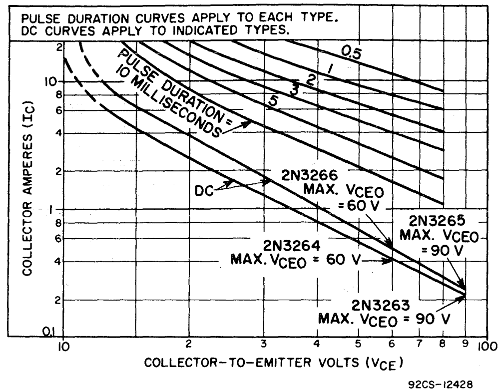


Fig. 5

TYPICAL CHANGE IN $I_{S/b}$ AS A FUNCTION OF BASE-TO-EMITTER RESISTANCE

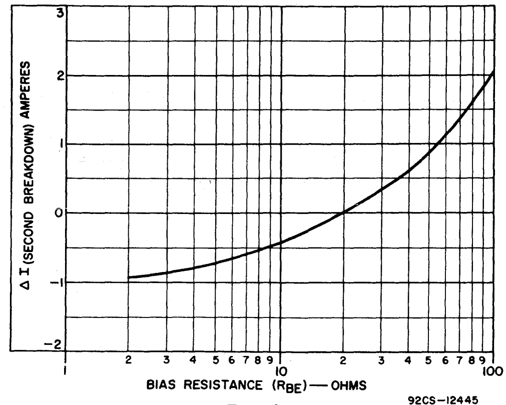


Fig. 6

COLLECTOR CURRENT AS A FUNCTION OF INDUCTANCE

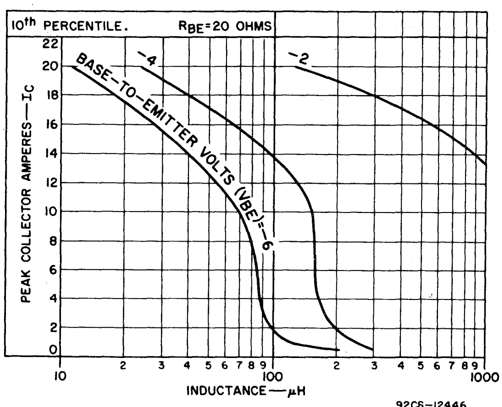


Fig. 7

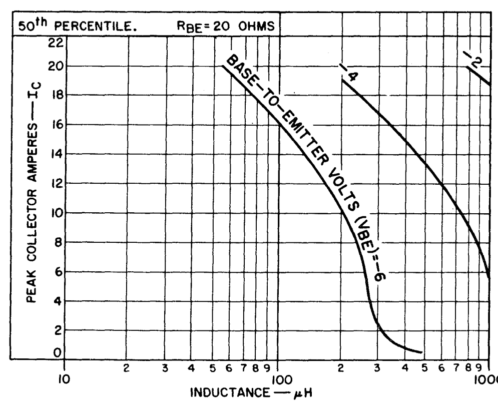


Fig. 8

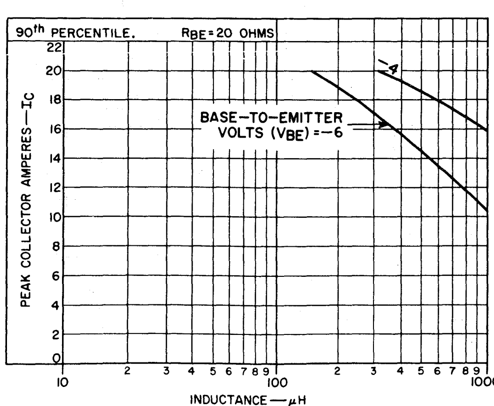


Fig. 9

CIRCUIT USED TO MEASURE SUSTAINING VOLTAGES $V_{CEO}(sus)$ AND $V_{CER}(sus)$

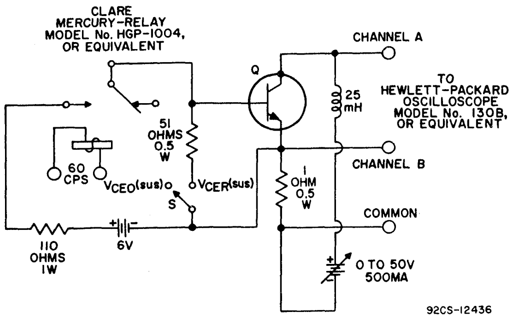
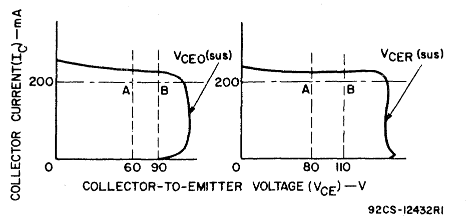


Fig. 10

COLLECTOR CHARACTERISTICS CHARTS



The sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$ are acceptable when the traces fall to the right and above points "A" for types 2N3264 and 2N3266. The traces must fall to the right and above points "B" for types 2N3263 and 2N3265.

Fig. 11

TYPICAL SATURATED-SWITCHING CHARACTERISTICS

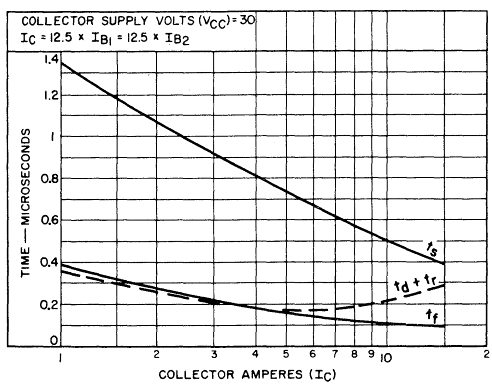


Fig. 12

TYPICAL INPUT CHARACTERISTICS

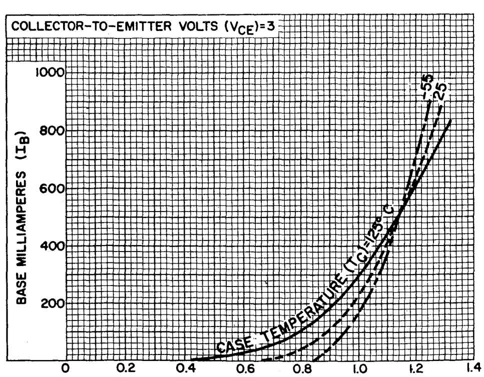


Fig. 13 92CS-12438

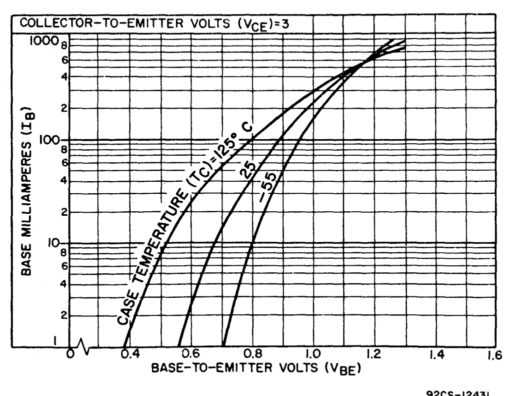


Fig. 14

DC BETA CHARACTERISTICS

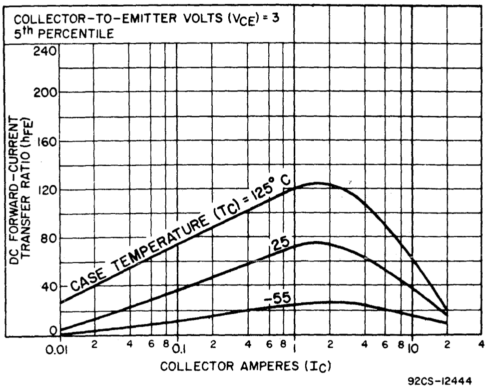


Fig. 15

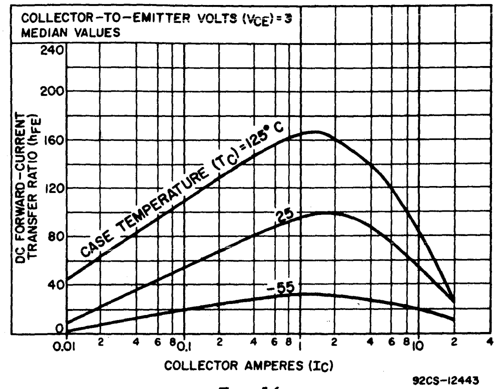


Fig. 16

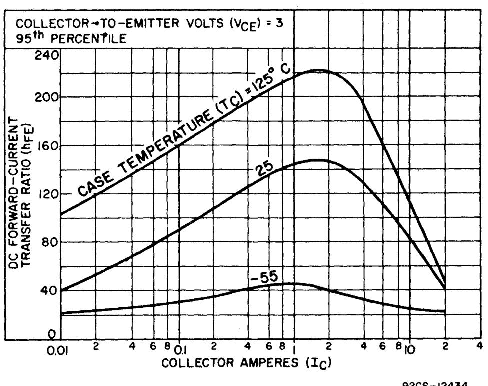


Fig. 17

TYPICAL TRANSFER CHARACTERISTICS

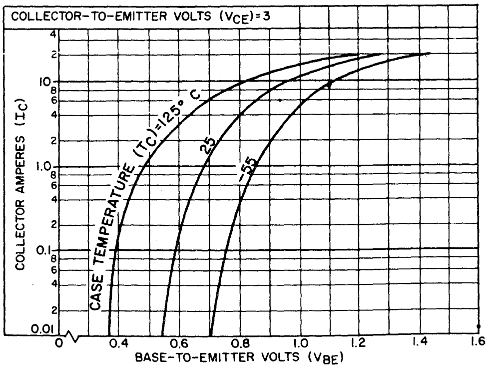


Fig. 18

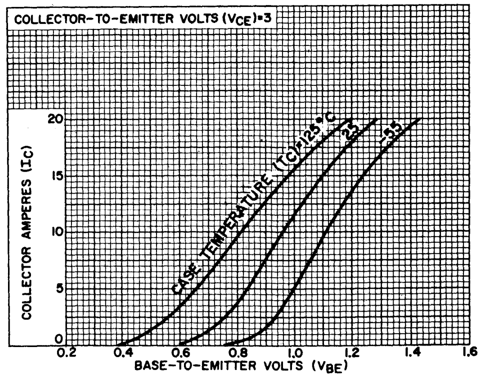


Fig. 19

TYPICAL CHARACTERISTICS

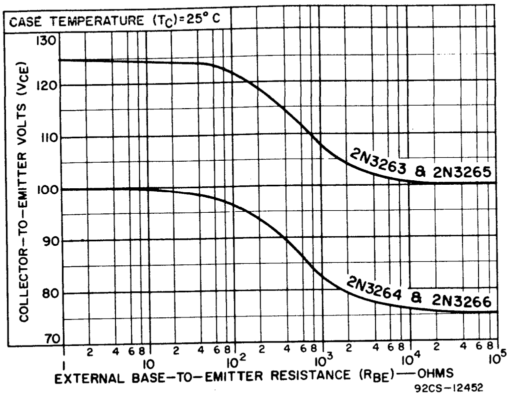
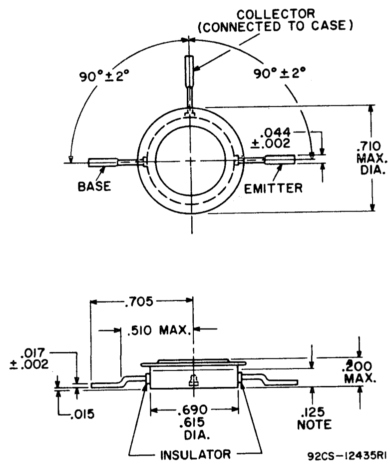


Fig. 20

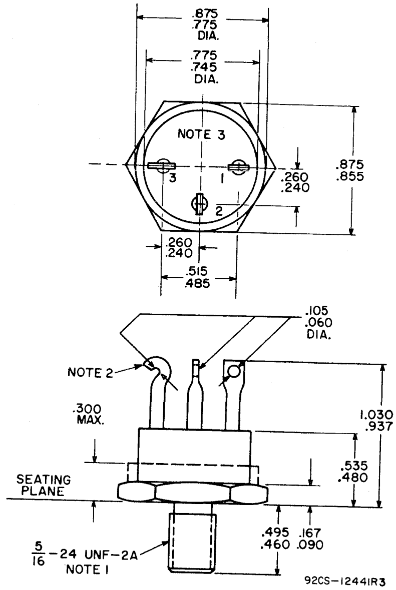
DIMENSIONAL OUTLINE for Types 2N3263 and 2N3264



DIMENSIONS IN INCHES

NOTE: THE CONTROLLED AREA OF THE 0.690 MAX. – 0.615 MIN. DIAMETER DOES NOT INCLUDE THE BRAZED AREA AROUND THE CERAMIC AND COLLECTOR TERMINAL.

DIMENSIONAL OUTLINE FOR TYPES 2N3265 & 2N3266 JEDEC No. TO-63



DIMENSIONS IN INCHES

NOTE 1: COMPLETE THREADS EXTEND TO WITHIN 2-1/2 THREADS OF SEATING PLANE.

NOTE 2: THIS TERMINAL MAY BE HOOK TYPE OR FLATTENED AND PIERCED.

NOTE 3: POSITION OF TERMINALS WITH RESPECT TO THE HEXAGON IS NOT CONTROLLED.

RCA
Solid State
Division

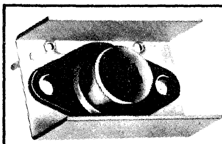
Power Transistors

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.*



H-1470A

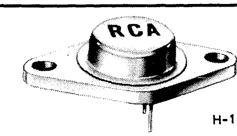
40375

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



H-1340

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							LIMITS						Units
		DC Collector Volts		DC Emitter or Base Volts		DC Current (Amperes)			Types 2N3878 40375		Type 2N3879		Type 2N5202		
		V_{CB}	V_{CE}	V_{EB}	V_{BE}	I_C	I_E	I_B	Min.	Max.	Min.	Max.	Min.	Max.	
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	–	–	
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					4		0.4	–	–	–	1.2	–	1.2	V
						4		0.5	–	2.0	–	–	–	–	
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	–	–	–	
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					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

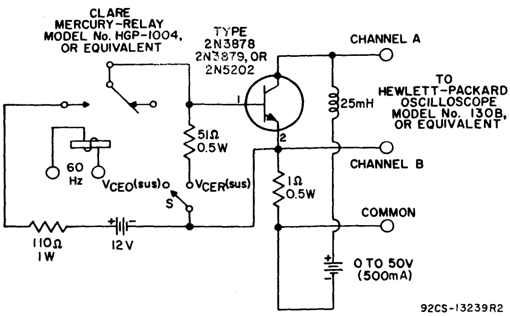
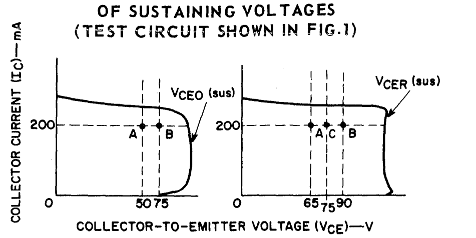


Fig. 1

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

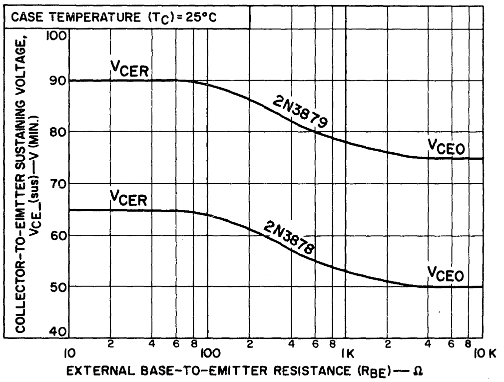


Fig. 3

DISSIPATION DERATING CURVE FOR TYPES 2N3878, 2N3879, & 2N5202

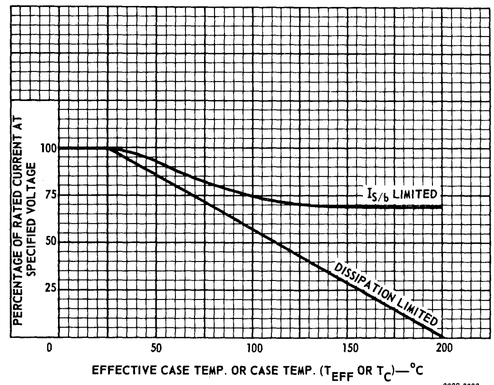


Fig. 4

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).

FORWARD-BIAS OPERATION

All transistors are power-dissipation limited and possibly second-breakdown limited. For a complete discussion of maximum operating area, refer to "RCA Silicon Power Circuits Manual" Form No. (SP-50) under sections: "MAXIMUM RATINGS" (page 68); "THERMAL CONSIDERATIONS" (page 70); "SECOND-BREAKDOWN" (page 84); and "SAFE-AREA RATINGS" (page 91).

With the emitter-base junction forward biased for transistor operation in the active region, the operating collector-to-emitter voltage, duration of the applied voltage and transistor temperature, will determine whether the device is second-breakdown limited.

For most transistors the maximum operating area is defined by four straight lines on a log-log plot of V_{CE} vs I_C. As shown in *Fig.5* and *6* a horizontal line defines the maximum current, a line with a slope of −1 defines the maximum power dissipation allowable; a line with a slope greater than −1 defines the forward-bias second breakdown limit; finally, a vertical line indicates the maximum voltage rating of the device.

As can be seen in *Fig.5* and *6* these transistors are free from second breakdown out to 36 V, 28 V, and 23 V for 2N3878, 2N3879, and 2N5202, respectively. Out to these points, the boundary is made up of the maximum current and maximum power curves. Then, the second breakdown effect becomes the controlling factor. This curve is made up of a line having a slope greater than −1.

Second breakdown is much less sensitive to temperature variations than normal power-dissipation limitations. Therefore, separate temperature derating curves are required for these two limiting factors as shown in *Fig.4*. For operation at temperatures greater than 25°C, *Fig.4* and *5* (2N3878) or *Fig.4* and *6* (2N3879, 2N5202) are used 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 either *Fig. 5 or 6*) the maximum collector current at 25°C, using the curve marked "DISSIPATION LIMITED" (or its dashed-line extension).

(2) Refer to *Fig.4* and from the "DISSIPATION LIMITED" curve 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 dissipation-limited operation.

(3) If the specified value of V_{CE} required the use of a dashed-line extension of a dissipation-limited curve in step (1), then repeat step (1), using the curve marked "$I_{S/b}$ LIMITED".

(4) Repeat step (2) using the $I_{S/b}$-LIMITED curve in *Fig.4*.

(5) The maximum allowable current is the smaller of the two values obtained in steps (2) and (4).

For repetitive-pulse operation, the effective case temperature (T_{EFF}) to be used in *Fig.4* is the sum of the maximum ambient temperature, the rise in case temperature, and the rise in junction temperature resulting from the average transistor power dissipation.

The effective case temperature (T_{EFF}) may be calculated by using the following equations:

$$T_{EFF} = T_A + (P_{AVG})(\theta_{C\text{-}FA}) + (P_{AVG})(\theta_{J\text{-}C})$$

$$T_{EFF} = T_C + (P_{AVG})(\theta_{J\text{-}C})$$

Where:

P_{AVG} = Average power, W, of applied repetitive pulses

T_A = Ambient temperature, °C

T_C = Case temperature, °C

$\theta_{C\text{-}FA}$ = Thermal resistance, °C/W, case (heat-sink) to free-air

$\theta_{J\text{-}C}$ = Thermal resistance, °C/W, junction-to-case

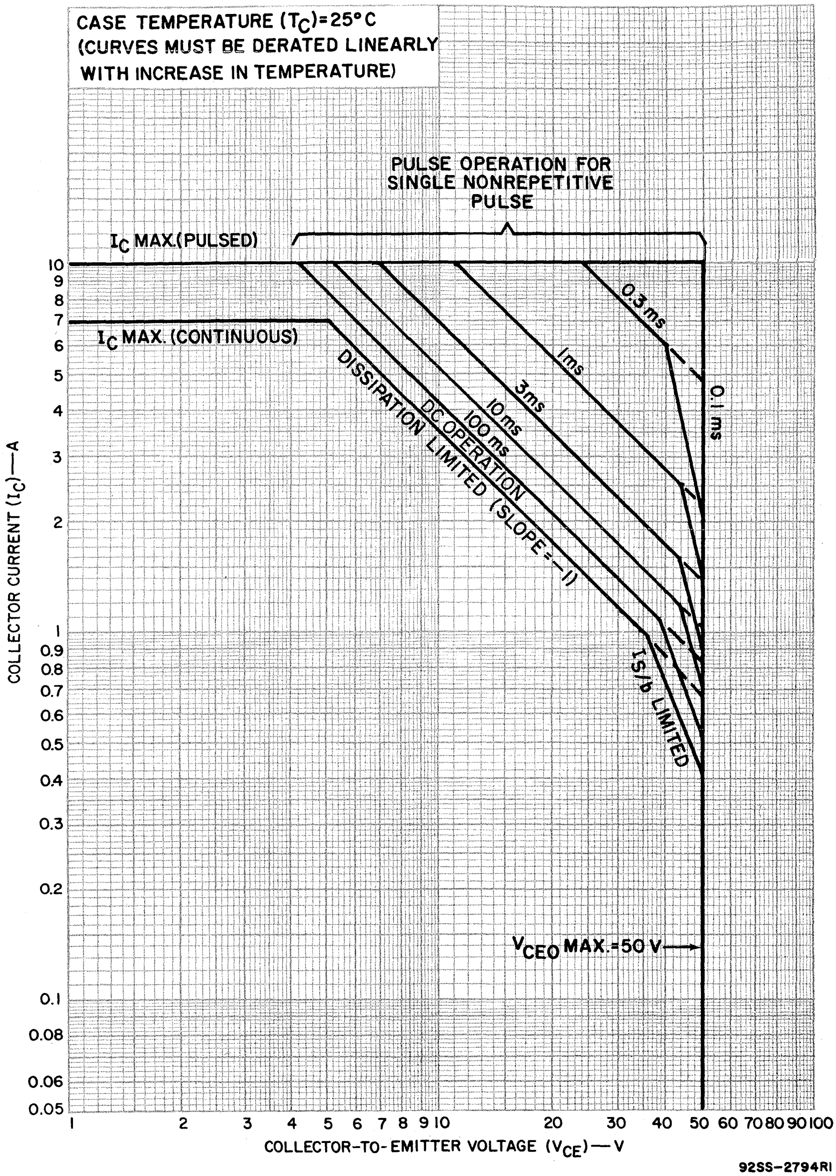

CASE TEMPERATURE (T_C)=25°C
(CURVES MUST BE DERATED LINEARLY
WITH INCREASE IN TEMPERATURE)
PULSE OPERATION FOR SINGLE NONREPETITIVE PULSE
I_C MAX.(PULSED)
I_C MAX. (CONTINUOUS)
0.3 ms
1ms
3ms
10 ms
100 ms
DC OPERATION
DISSIPATION LIMITED (SLOPE=−1)
0.1 ms
IS/b LIMITED
V_{CEO} MAX.=50 V
COLLECTOR CURRENT (I_C)—A
COLLECTOR-TO-EMITTER VOLTAGE (V_{CE})—V
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
92SS-2794R1

Fig. 5

MAXIMUM OPERATING AREAS FOR TYPES 2N3879 & 2N5202

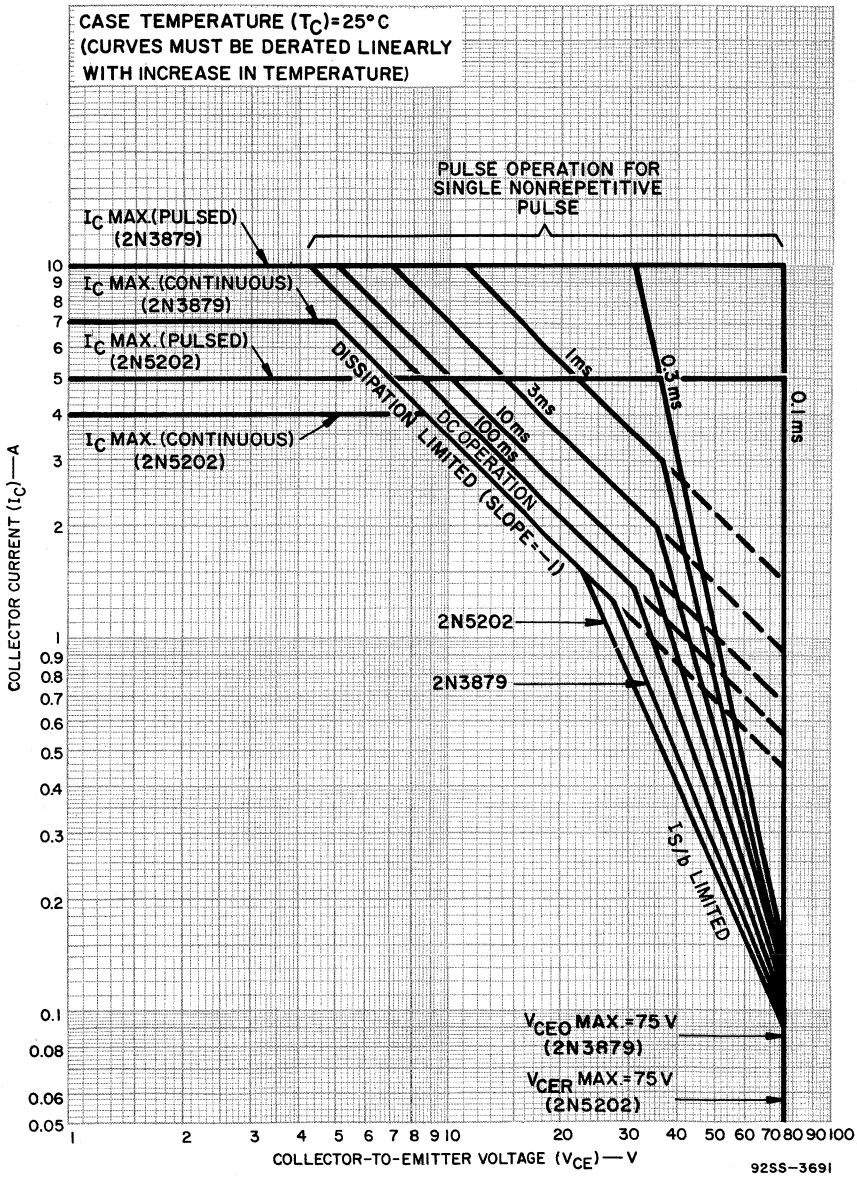


Fig. 6

MAXIMUM OPERATING AREAS FOR TYPE 40375

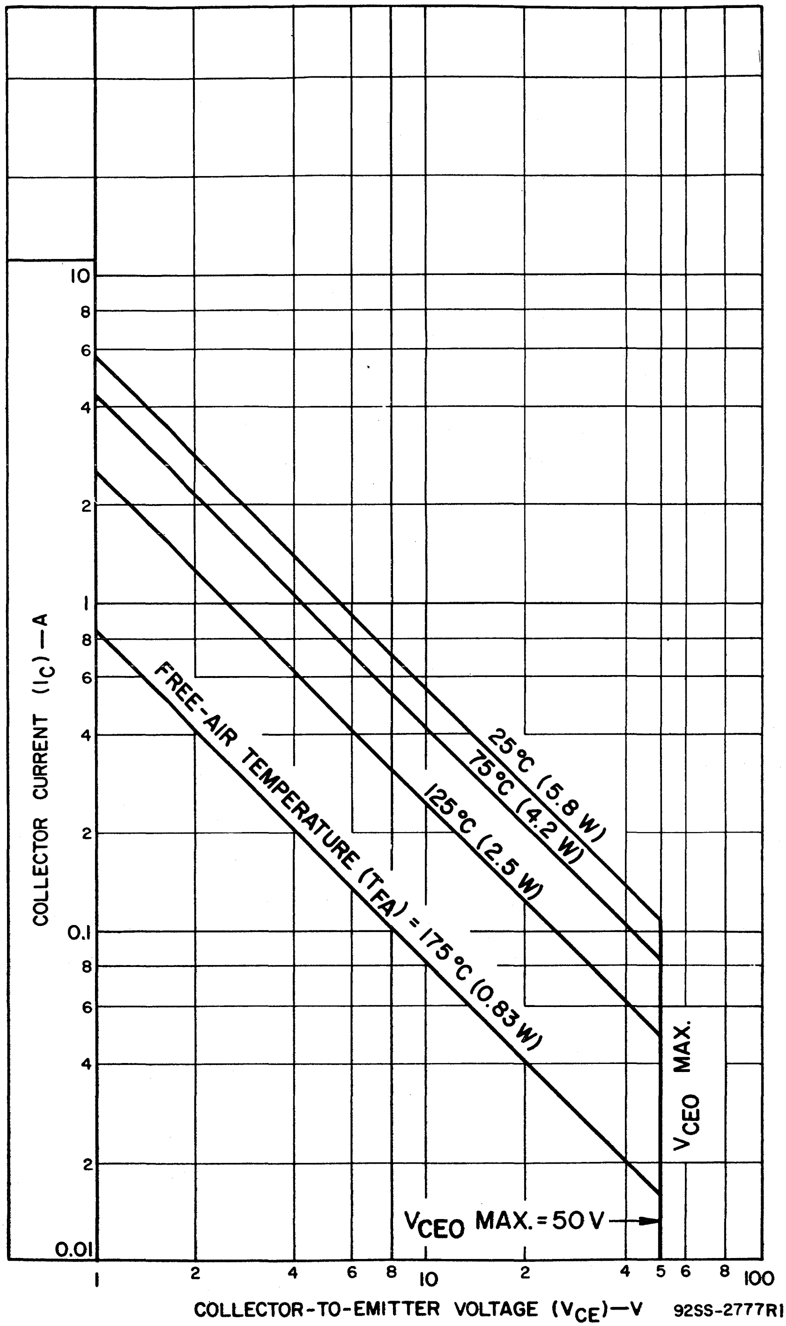


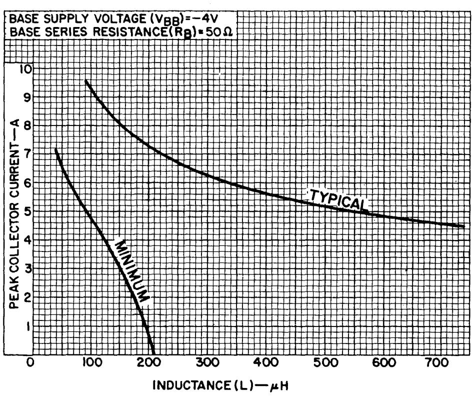
Fig. 7

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.)

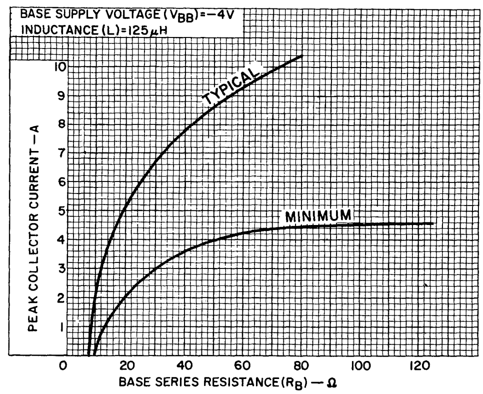
In general, reverse-bias, second breakdown energy ($E_{S/b}$) capability increases with a decrease in inductance. Therefore, the allowable energy shown in the above-mentioned curves (calculated from $E_{S/b} = 1/2LI^2$, where L is a series load or leakage inductance and I is the peak collector current 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



92CS-13230R2

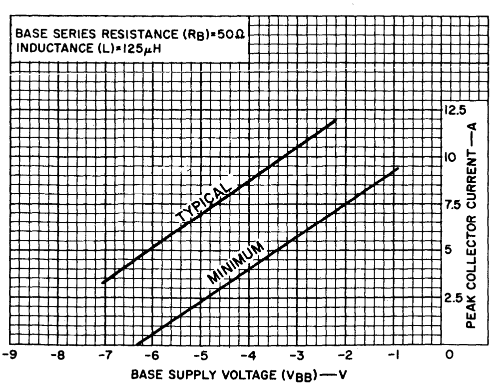
Fig. 8



92CS-13233R2

Fig. 9

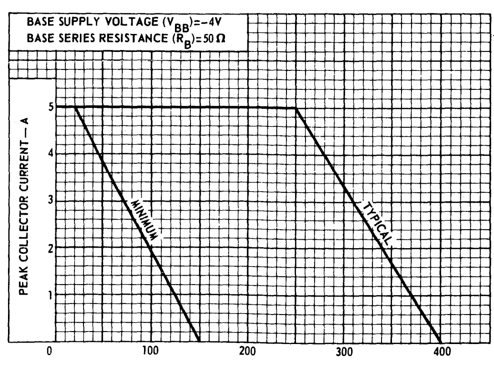
REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPES 2N3878 & 2N3879



92CS-13232R2

Fig. 10

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPE 2N5202



92SS-3692

Fig. 11

REVERSE-BIAS, SECOND-BREAKDOWN CHARACTERISTICS FOR TYPE 2N5202

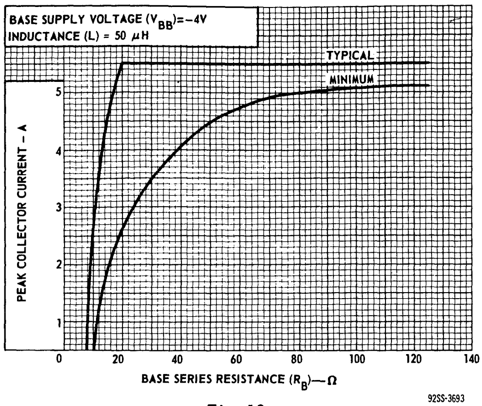


Fig. 12

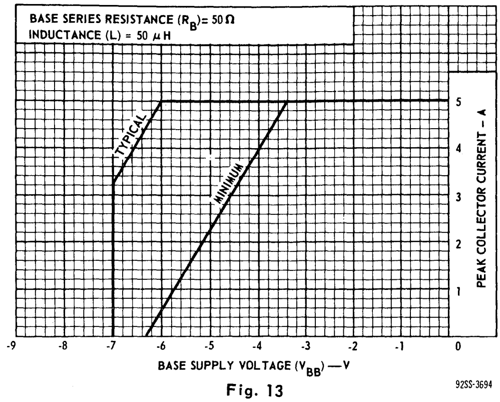


Fig. 13

TYPICAL DC BETA FOR TYPES 2N3878 & 2N3879

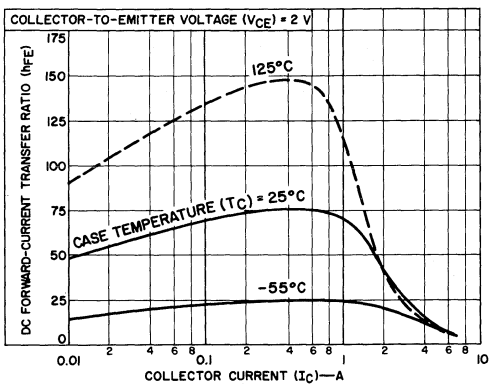


Fig. 14

TYPICAL DC BETA FOR TYPES 2N3878 & 2N3879

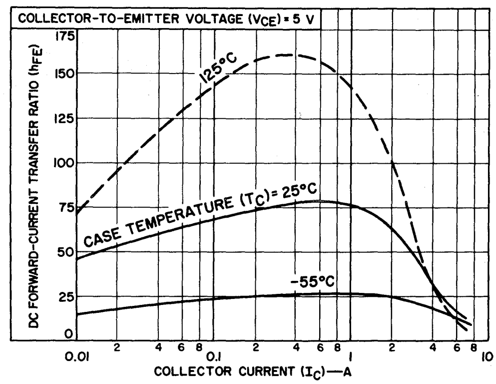


Fig. 15

TYPICAL DC BETA FOR TYPE 2N5202

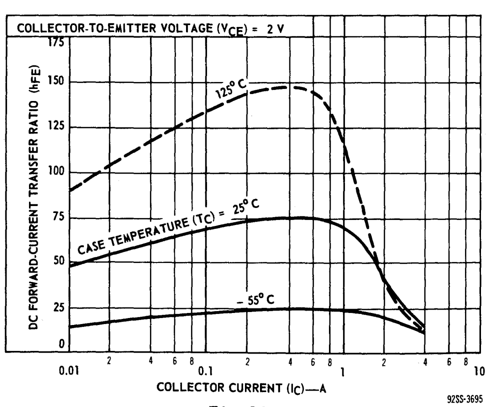


Fig. 16

TYPICAL DC BETA FOR TYPE 2N5202

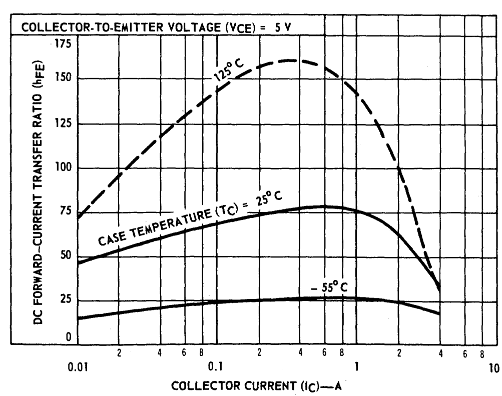


Fig. 17

TYPICAL INPUT CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

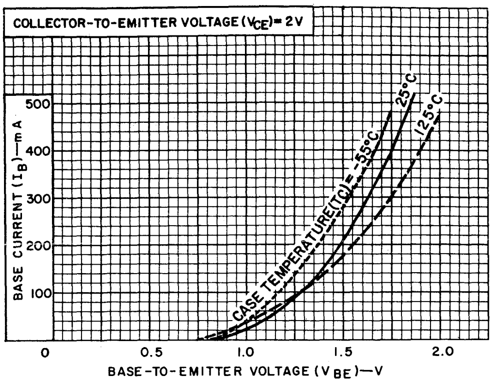


Fig. 18

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

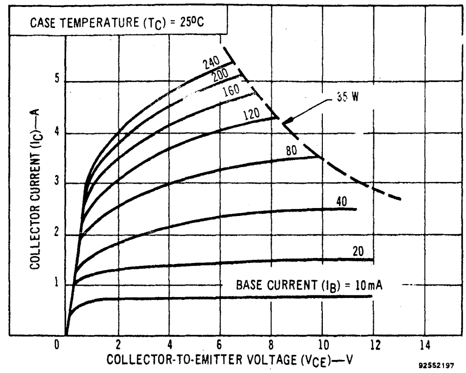


Fig. 19

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 2N3878, 2N3879, & 2N5202

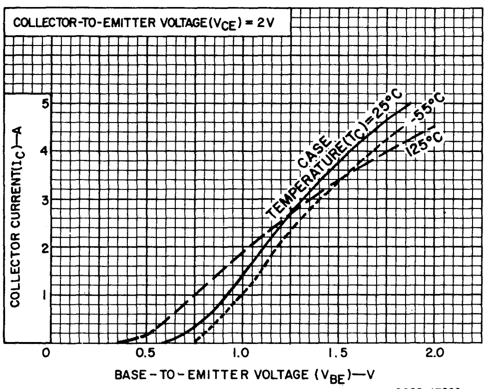


Fig. 20

TYPICAL GAIN-BANDWIDTH PRODUCT FOR TYPES 2N3878, 2N3879, & 2N5202

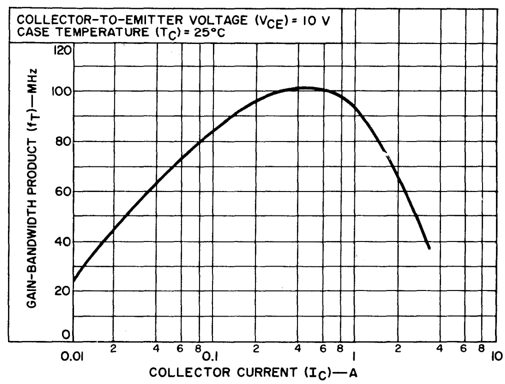


Fig. 21

TYPICAL SATURATION VOLTAGE CHARACTERISTICS FOR TYPES 2N3878 & 2N3879

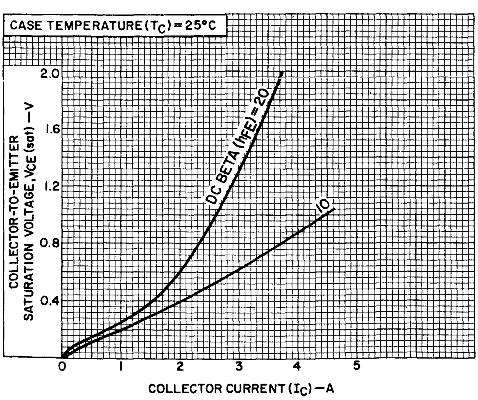


Fig. 22

TYPICAL SATURATION VOLTAGE CHARACTERISTICS FOR TYPE 2N5202

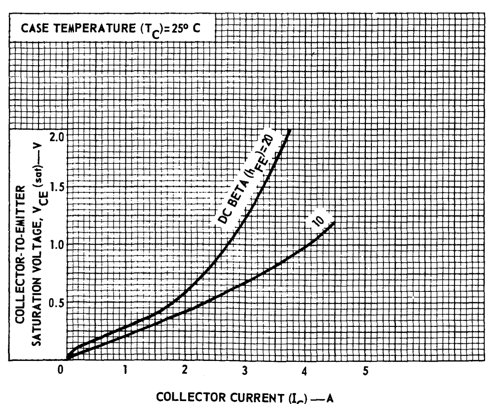
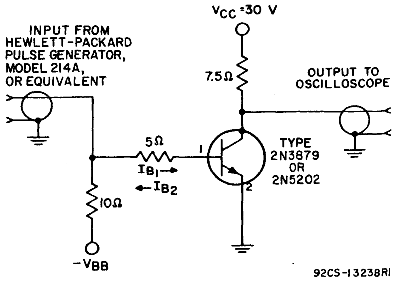


Fig. 23

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)

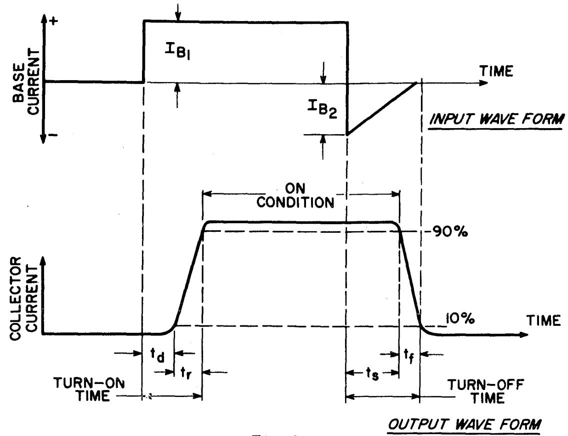


Fig. 25

TYPICAL TURN-ON TIME FOR TYPES 2N3879 & 2N5202

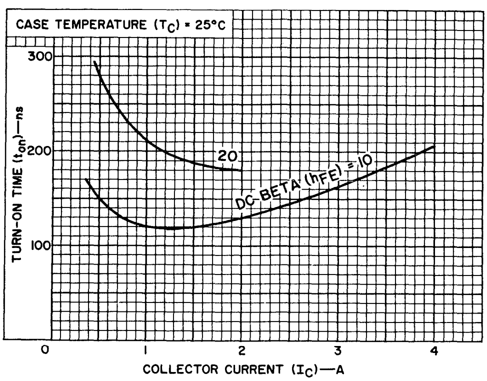


Fig. 26

TYPICAL STORAGE-TIME FOR TYPES 2N3879 & 2N5202

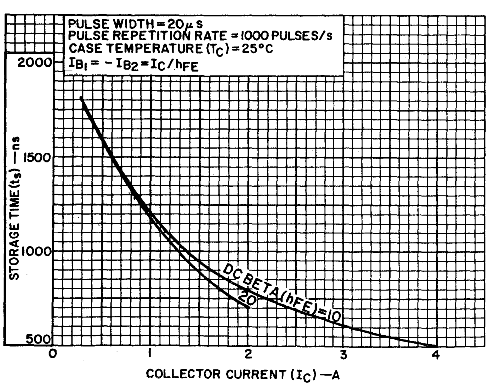


Fig. 27

TYPICAL FALL-TIME FOR TYPES 2N3879 & 2N5202

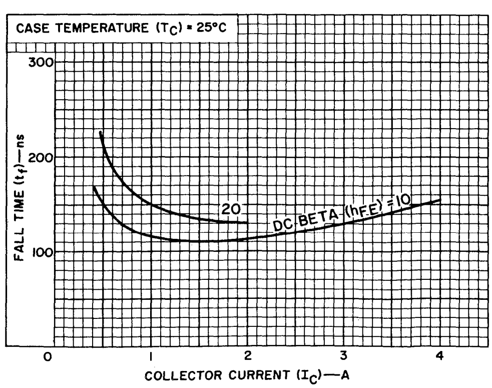


Fig. 28

SUGGESTED HARDWARE FOR MOUNTING TYPES 2N3878, 2N3879, & 2N5202

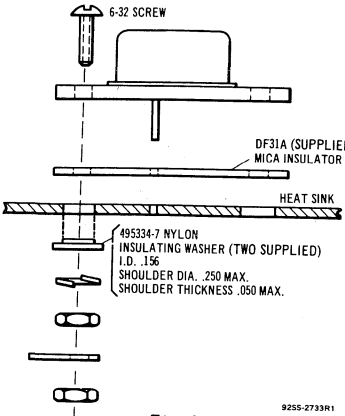
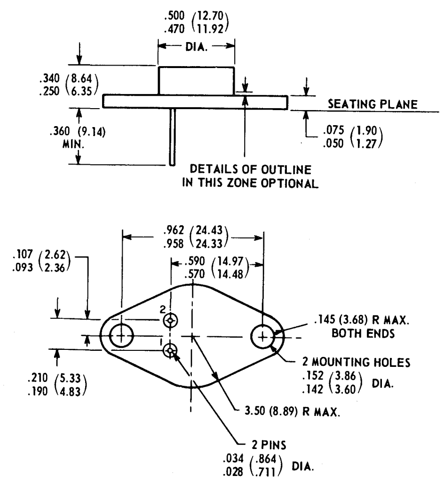


Fig. 29

DIMENSIONAL OUTLINE FOR TYPES 2N3878, 2N3879, & 2N5202

JEDEC TO-66



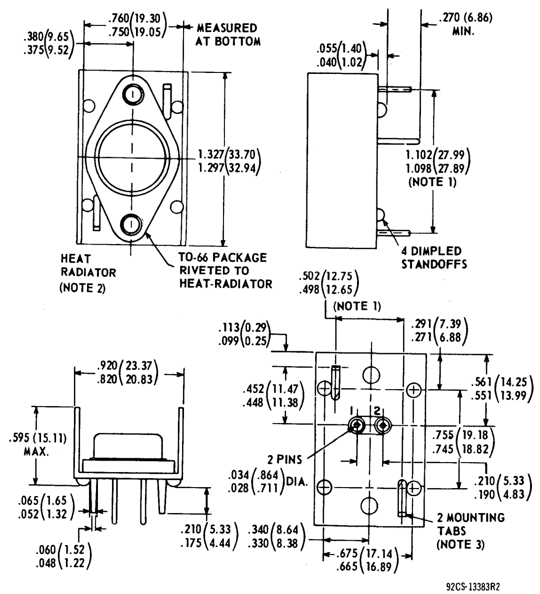
92CS-12865R1

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

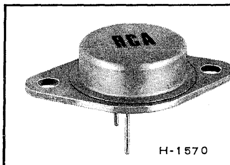
RCA-2N5038 and 2N5039* are epitaxial silicon n-p-n power transistors utilizing a multiple-emitter-site structure. They differ in breakdown-voltage ratings, leakage-current, and DC beta values.

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.

SILICON N-P-N POWER TRANSISTORS

High-Current, High-Power, High-Speed Types for Switching and Amplifier Circuits in Industrial and Commercial Applications



H-1570

- Maximum operating area curves for DC and pulse operation.
- $I_{S/b}$-limit line begining at 28 V.
- High collector current ratings . . .
  30 A (peak) 20 A (continuous)
- High-dissipation capability . . .
  $P_T = 140$ W max. at $T_C = 25^\circ$ 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

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, *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 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 Type 2N5038 Min.	Type 2N5038 Max.	Type 2N5039 Min.	Type 2N5039 Max.	Units
	Collector-Cutoff Current	I_{CEO}		55					0	–	–	–	20	mA
				70					0	–	20	–	–	
*		I_{CEV}		110		-1.5				–	–	–	50	mA
*				140		-1.5				–	50	–	–	
				85		-1.5				–	–	–	10	
				100		-1.5				–	10	–	–	
*		I_{CEV} (T_C = 150°C)		85		-1.5				–	–	–	10	mA
*				100		-1.5				–	10	–	–	
*	Emitter-Cutoff Current	I_{EBO}			5 7		0 0			– –	5 50	– –	15 50	mA
* *	DC Forward-Current Transfer Ratio	h_{FE}		5 5 5			2a 10a 12a			50 – 20	200 – 100	30 20 –	150 100 –	
*	Magnitude of Small-Signal Forward Current Transfer Ratio (At f = 5 MHz)	$\|h_{fe}\|$		10			2			12	–	12	–	
*	Collector-to-Emitter Sustaining Voltage: *(See Fig.5 & 6.)* With base open	V_{CEO}(sus)					0.2		0	90b	–	75b	–	V
	With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CEX}(sus)				-1.5	0.2		0	150b	–	120b	–	V
	With $R_{BE} \leq 50\ \Omega$	V_{CER}(sus)					0.2		0	110b	–	95b	–	V
*	Emitter-to-Base Voltage	V_{EBO}					0	0.05		7	–	7	–	V
	Base-to-Emitter Voltage	V_{BE}		5 5			10a 12a			– –	– 1.8	– –	1.8 –	V
*	Collector-to-Emitter Saturation Voltage	V_{CE}(sat)					10a 12a 20		1.0 1.2 5	– – –	– 1.0 2.5	– – –	1.0 – 2.5	V
*	Base-to-Emitter Saturation Voltage	V_{BE}(sat)		5			20		5	–	3.3	–	3.3	V
	Output Capacitance (At 1 MHz)	C_{ob}	10					0		–	500	–	500	pF
	Second-Breakdown[c] Collector Current[e] (With base forward biased)	$I_{S/b}$[d]		28 45						5.0 0.9	– –	5.0 0.9	– –	A
	Second-Breakdown[c] 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 Turn-On Time (Delay Time + Rise Time) *(See Fig.17, 18, & 19.)*	t_{on}	V_{CC} = 30 V				10 12		1.0g 1.2g	– –	– 0.5	– –	0.5 –	µs
*	Sat. Switching Storage Time *(See Fig.17, 18, & 20.)*	t_s	V_{CC} = 30 V				10 12		1.0g 1.2g	– –	– 1.5	– –	1.5 –	µs
*	Sat. Switching Fall Time *(See Fig. 17, 18, & 19.)*	t_f	V_{CC} = 30 V				10 12		1.0g 1.2g	– –	– 0.5	– –	0.5 –	µs
	Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$		40			0.5			–	1.25	–	1.25	°C/W

[a] Pulsed; pulse duration ≤ 350µs, 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.5*.

[c] Safe-operating region for forward- and reverse-bias operation is explained on page 4.

[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.

[g] $I_{B_1} = I_{B_2}$ = value shown.

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

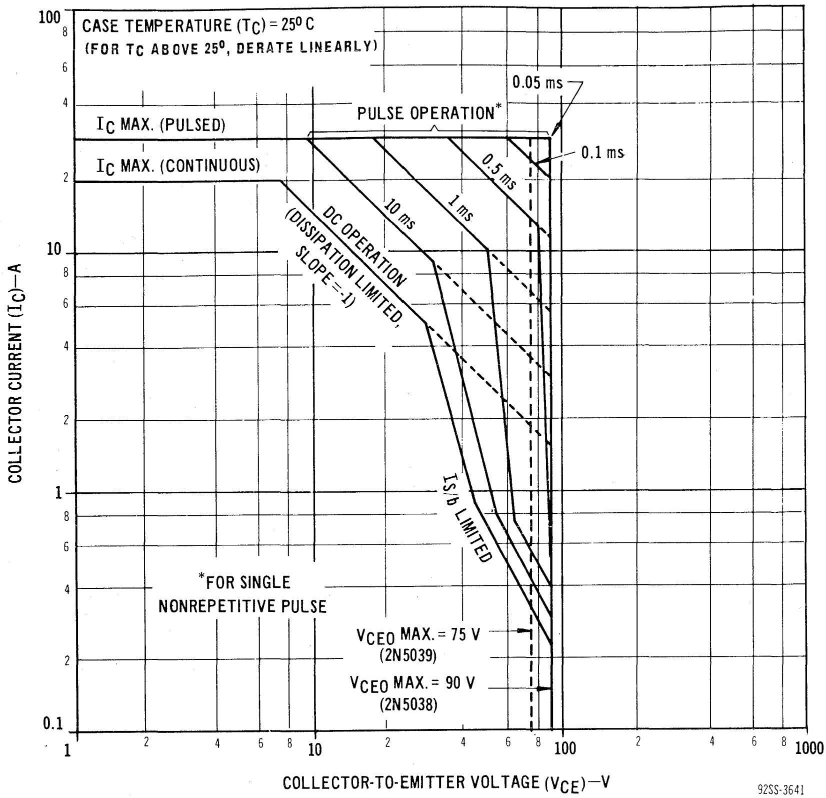


Fig.1 - Maximum operating areas for types 2N5038 and 2N5039.

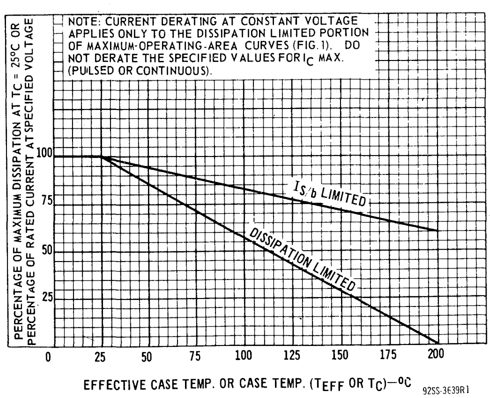


Fig.2 - Dissipation derating curves for types 2N5038 and 2N5039.

FORWARD-BIAS OPERATION

All transistors are power-dissipation limited and possibly second-breakdown limited. For a complete discussion of maximum operating area, refer to "RCA Silicon Power Circuits Manual" (Form No. SP-50). See sections: "MAXIMUM RATINGS" (page 68); "THERMAL CONSIDERATIONS" (page 70); "SECOND-BREAKDOWN" (page 84); and "SAFE-AREA RATINGS" (page 91).

With the emitter-base junction forward biased for transistor operation in the active region, the operating collector-to-emitter voltage, duration of the collector current flow, and transistor temperature will determine whether the device is second-breakdown limited.

For most transistors the maximum operating area is defined by four straight lines on a log-log plot of V_{CE} vs I_C. As shown in Fig.1 a horizontal line defines the maximum current, a line with a slope of-1 defines the maximum power dissipation allowable; a line with a slope greater than–1 defines the forward-bias second breakdown limit; finally, a vertical line indicates the maximum voltage rating of the device.

The RCA-2N5038 and 2N5039 transistors utilize the multiple-emitter site structure which provides a greater safe operating area than other similar devices. As can be seen in Fig.1, these transistors are free from second-breakdown out to 28 volts and 5 amperes. The boundary, out to this point is made up of the maximum current and maximum power curves. Beyond the boundary, second-breakdown effect becomes the controlling factor. Second-breakdown is made up of two successive straight lines—one with a slope of -4 and one with a slope of -2. The final limiting factor is the maximum voltage rating for the devices.

Second breakdown is less sensitive to temperature variations than normal power-dissipation limitations. Therefore, separate temperature derating curves are required for these two limiting factors as shown in Fig.2. For operation at temperatures greater than 25°C, Fig.1 and 2 are used to obtain the maximum allowable power. This is done as follows:

(1) For a specified pulse duration and collector-to-emitter voltage, V_{CE}, determine (from Fig.1) the maximum collector current at 25°C, using the curve marked "DISSIPATION LIMITED" (or its dashed-line extension).

(2) Refer to Fig.2 and, from the "DISSIPATION-LIMITED" curve, 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 dissipation-limited operation.

(3) If the specified value of V_{CE} required the use of a dashed-line extension of a dissipation-limited curve in step (1), then repeat step (1), using the curve marked "$I_{S/b}$ LIMITED".

(4) Repeat step (2) using the $I_{S/b}$-LIMITED curve in Fig.2.

(5) The maximum allowable current is the smaller of the two values obtained in steps (2) and (4).

For repetitive-pulse operation, the effective case temperature (T_{EFF}) to be used in Fig.2 is the sum of the maximum ambient temperature, the rise in case temperature, and the rise in junction temperature resulting from the average transistor power dissipation.

The effective case temperature (T_{EFF}) may be calculated by using the following equations:

$$T_{EFF} = T_A + (P_{AVG})(\theta_{C\text{-}FA}) + (P_{AVG})(\theta_{J\text{-}C})$$

$$T_{EFF} = T_C + (P_{AVG})(\theta_{J\text{-}C})$$

Where:

P_{AVG} = Average power, W, of applied repetitive pulses

T_A = Ambient temperature, °C

T_C = Case temperature, °C

$\theta_{C\text{-}FA}$ = Thermal resistance, °C/W, case (heat-sink) to free-air

$\theta_{J\text{-}C}$ = Thermal resistance, °C/W, junction-to-case

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 and 8 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 $E_{S/b} = ½LI^2$, 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 RCA Application Note SMA-30, "Second Breakdown in Transistors Under Conditions of Cutoff."

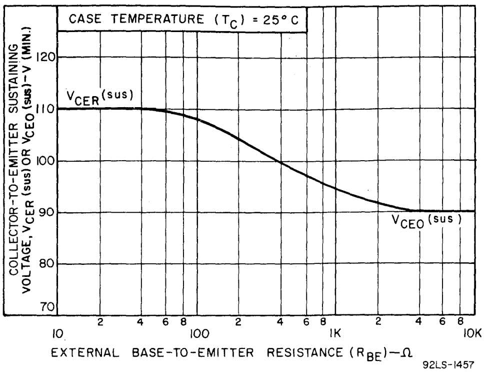


Fig.3 - Collector-to-emitter sustaining voltage characteristic for type 2N5038.

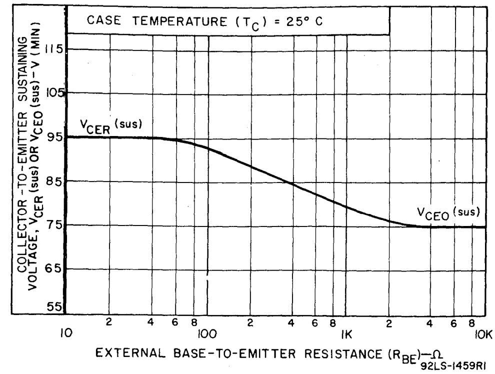
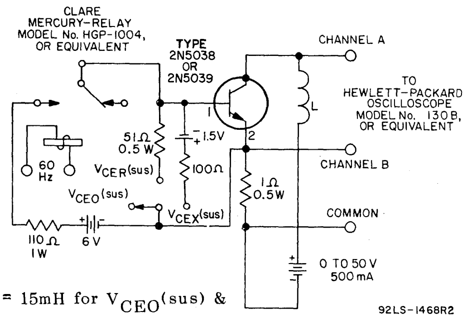


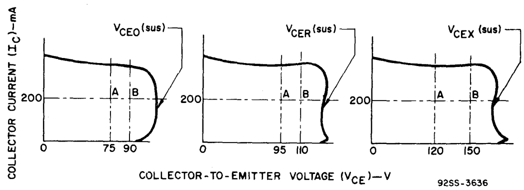
Fig.4 - Collector-to-emitter sustaining voltage characteristic for type 2N5039.



L = 15mH for V_{CEO}(sus) & V_{CER}(sus) measurements

L = 2mH for V_{CEX}(sus) measurements.

Fig.5 - 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 and above point "A" for type 2N5039; and point "B" for type 2N5038.

Fig.6 - Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig.5).

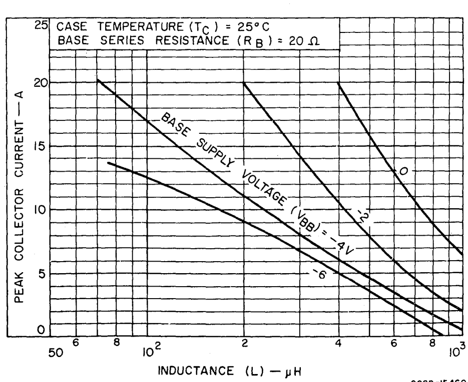


Fig.7 - Maximum reverse-bias, second-breakdown characteristics for types 2N5038 and 2N5039.

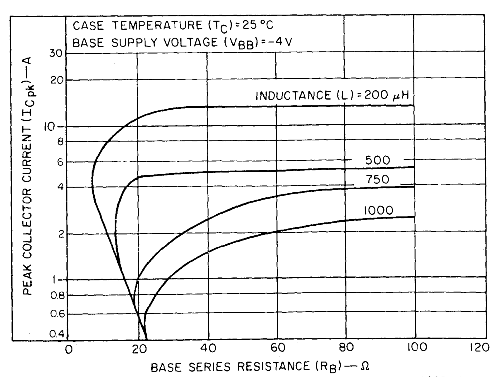


Fig.8 - Maximum reverse-bias, second-breakdown characteristics for types 2N5038 and 2N5039.

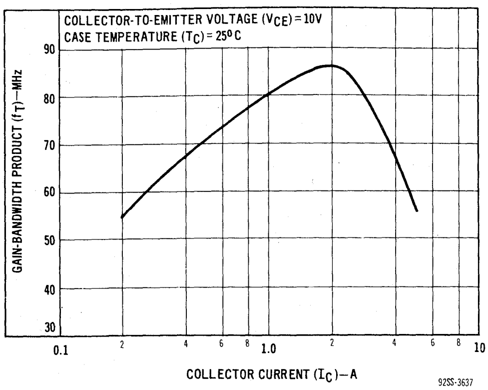


Fig.9 - Typical gain-bandwidth product for types 2N5038 and 2N5039.

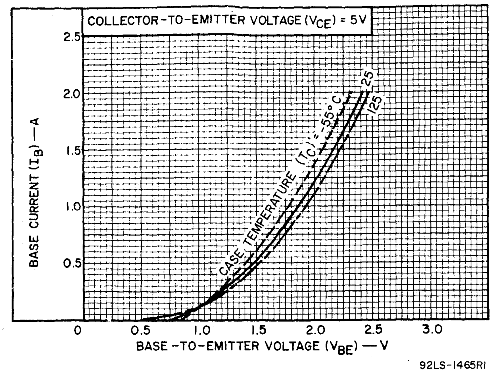


Fig.10 - Typical input characteristics for types 2N5038 and 2N5039.

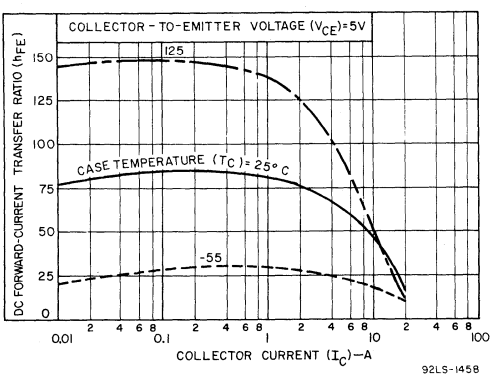


Fig.11 - Typical dc beta characteristics for type 2N5038.

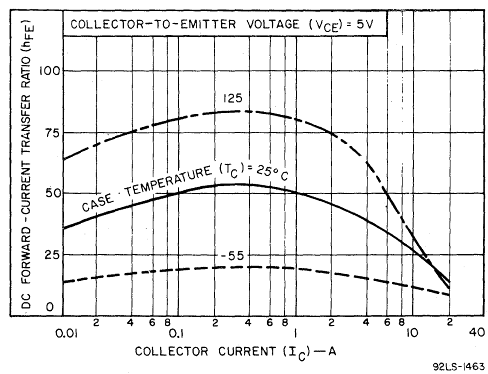


Fig.12 - Typical dc beta characteristics for type 2N5039.

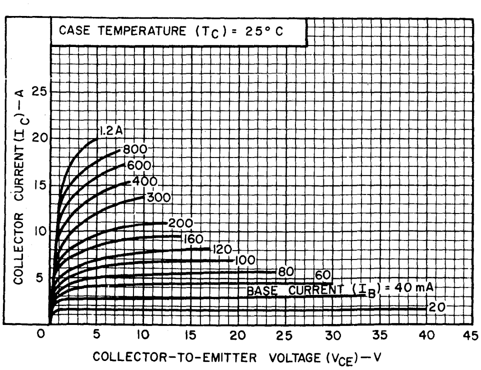


Fig.13 - Typical output characteristics for type 2N5038.

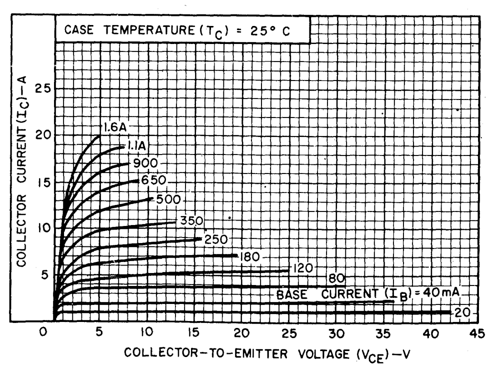


Fig.14 - Typical output characteristics for type 2N5039.

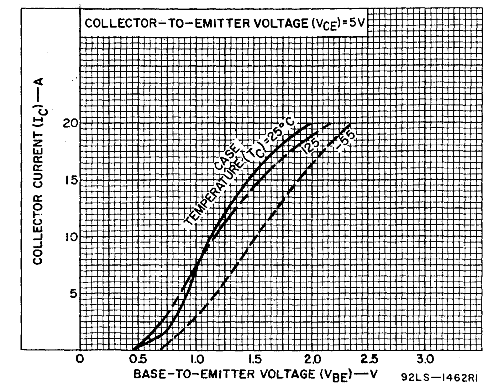


Fig.15 - Typical transfer characteristics for type 2N5038.

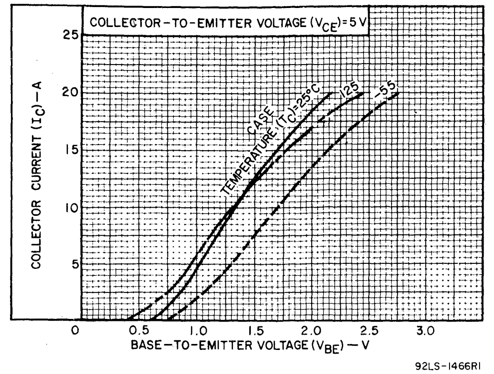


Fig.16 - Typical transfer characteristics for type 2N5039.

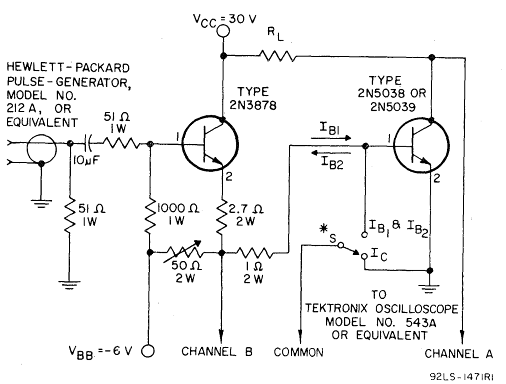


Fig.17 - Circuit used to measure switching times for types 2N5038 and 2N5039.

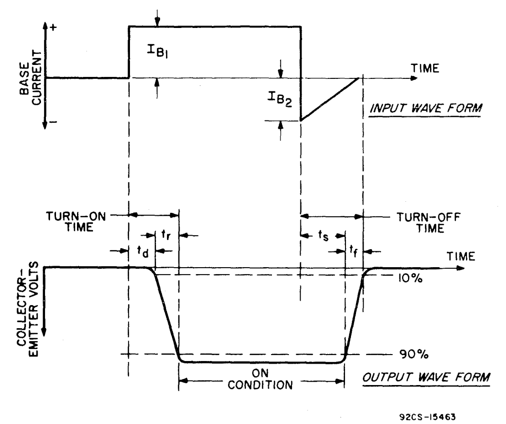


Fig.18 - Oscilloscope display for measurement of switching times. (Test circuit shown in Fig.17.)

Input Pulse:

t_r< 20 ns R_L = 3 Ω, 12 W (non-inductive) for 10-A test

t_f<20 ns R_L = 2.5 Ω, 12 W (non inductive) for 12-A test

Rep. Rate = 500 Hz

Pulse Duration = 20 μs

*Switch "S" determines connection of oscilloscope ground for observation of either base current or collector-to-emitter voltage.

t_{on}	t_{off}	Type	Test Conditions
0.5μs	2.0μs	2N5039	I_{B_1} = 1.0A, I_{B_2} = −1.0A, I_C = 10A
0.5μs	2.0μs	2N5038	I_{B_1} = 1.2A, I_{B_2} = −1.2A, I_C = 12A

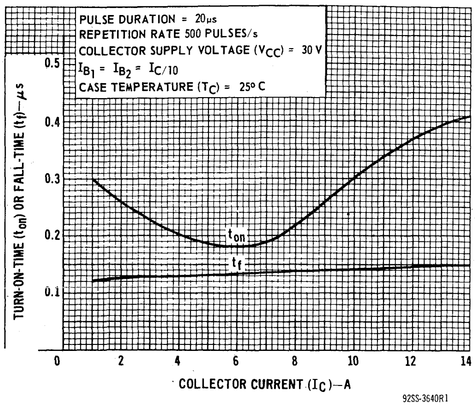


Fig.19 - Typical turn-on time and fall-time characteristics for types 2N5038 and 2N5039.

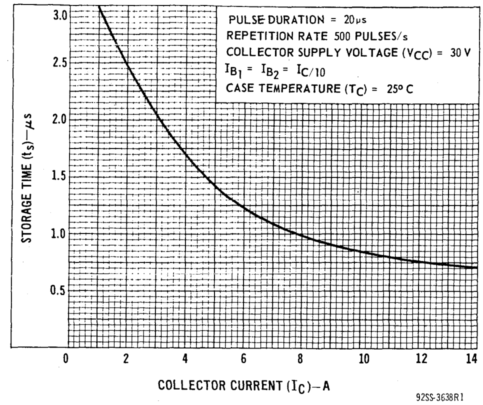
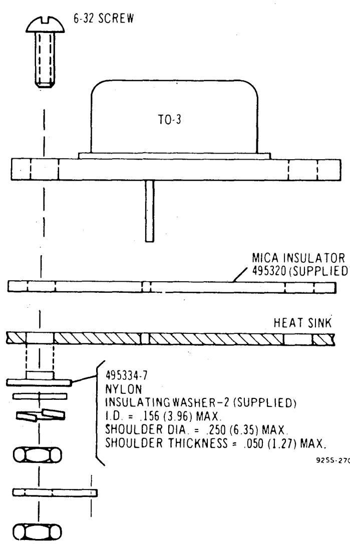


Fig.20 - Typical storage time characteristic for types 2N5038 and 2N5039.

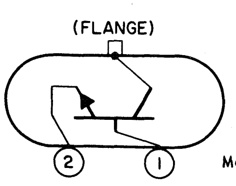


Dimensions in Inches and Millimeters

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

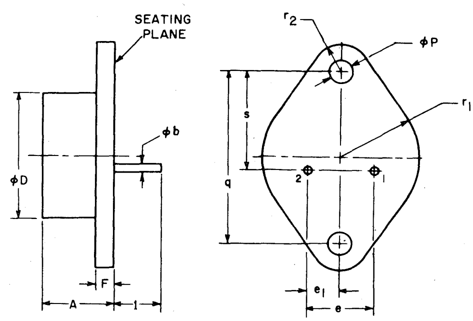
Fig.21-Suggested Hardware for types 2N5038 and 2N5039.

TERMINAL DIAGRAM



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

DIMENSIONAL OUTLINE
for Types 2N5038 & 2N5039
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	
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

92CS-15222

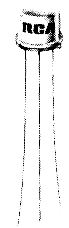
NOTES:

1. These dimensions should be measured at points .050 in. (1.27mm) to .055 in. (1.40mm) below seating plane. When gage is not used, measurement will be made at seating plane.
2. Two Leads.

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	-	-	-	-	µA
		-80					0		-	-	-	-	-	-0.5	-	-	µA
		-60					0		-	-	-	-	-	-	-	-5	µA
* With base-emitter Junction reverse biased	I_{CEX}		100		-1.5				-	0.1	-	-	-	-	-	-	mA
			75		-1.5				-	-	-	0.1	-	-	-	-	mA
			-100		1.5				-	-	-	-	-	-0.1	-	-	mA
			-75		1.5				-	-	-	-	-	-	-	-0.1	mA
T_C=150°C			70		-1.5				-	5	-	-	-	-	-	-	mA
			45		-1.5				-	-	-	5	-	-	-	-	mA
			-70		1.5				-	-	-	-	-	-5	-	-	mA
			-45		1.5				-	-	-	-	-	-	-	-5	mA
* Emitter-Cutoff Current	I_{EBO}			7		0			-	0.1	-	-	-	-	-	-	mA
				5		0			-	-	-	0.1	-	-	-	-	mA
				-7		0			-	-	-	-	-	-0.1	-	-	mA
				-5		0			-	-	-	-	-	-	-	-0.1	mA
				5		0			-	0.1	-		-	-	-	-	µA
				4		0			-	-	-	0.5	-	-	-	-	µA
				-5		0			-	-	-	-	-	-0.1	-	-	µA
				-4		0			-	-	-	-	-		-	-0.5	µA
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	-	V
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	-	V
* With base open	$V_{CEO}(sus)^a$					100		0	75	-	50	-	-	-	-	-	V
						-100		0	-	-	-	-	-75	-	-50	-	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					500		50	-	0.5	-	0.8	-	-	-	-	V
						-500		-50	-	-	-	-	-	-0.7	-	-1.2	V
* Base-to-Emitter Voltage	V_{BE}		4			500			-	1.1	-	1.4	-	-	-	-	V
			-4			-500			-	-	-	-	-	-1.1	-	-1.4	V
* 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	-	MHz
* 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		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.	
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	θ_{J-C}								-	17.5	-	17.5	-	17.5	-	17.5	°C/W
Junction-to-Ambient	θ_{J-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.

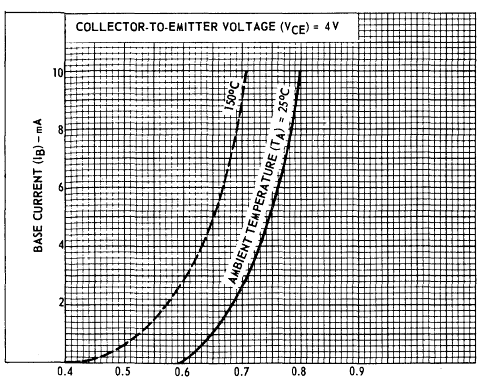


Fig. 1 - Typical input characteristics for types 2N5320 and 2N5321.

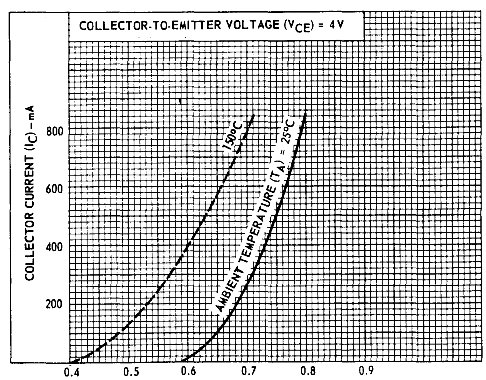


Fig. 2 - Typical transfer characteristics for types 2N5320 and 2N5321.

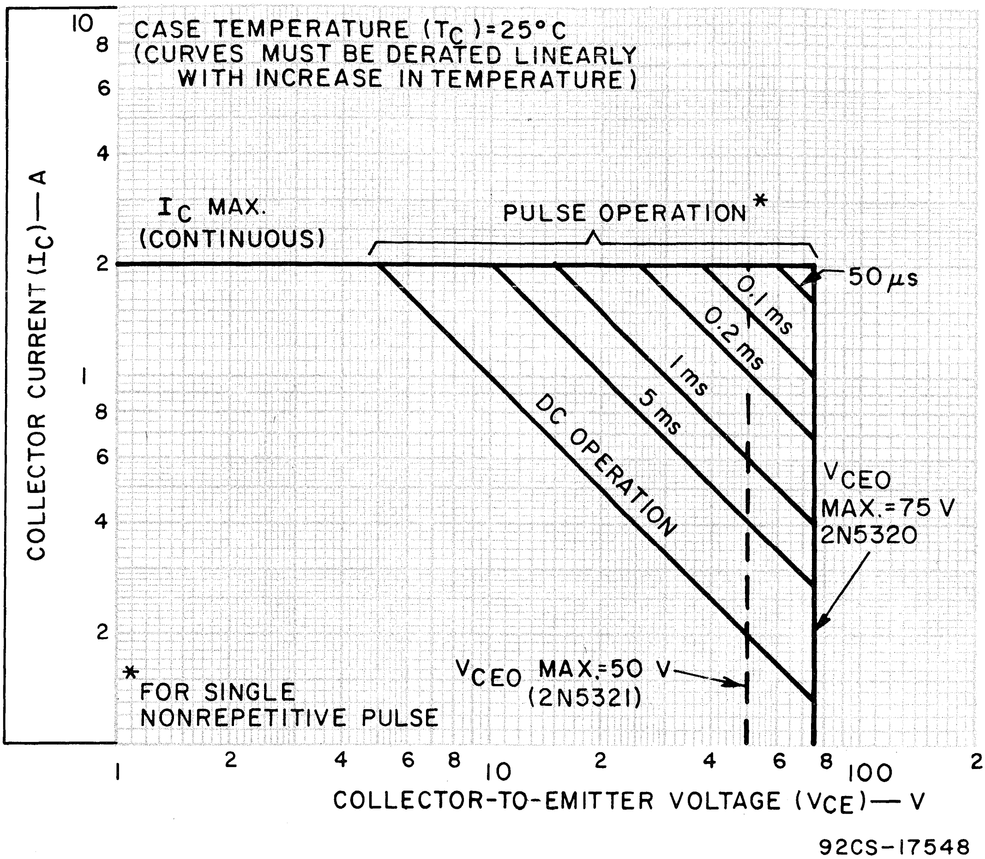


Fig. 3 - Maximum operating areas for types 2N5320 and 2N5321.

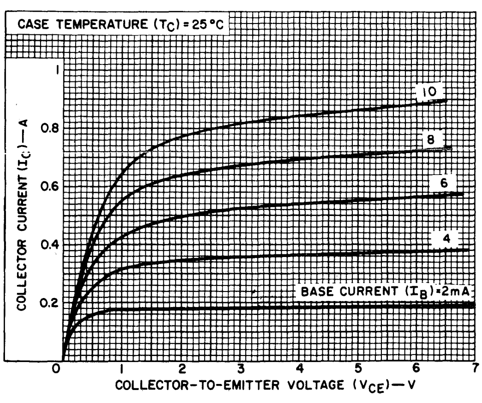


Fig. 4 - Typical output characteristics for types 2N5320 and 2N5321.

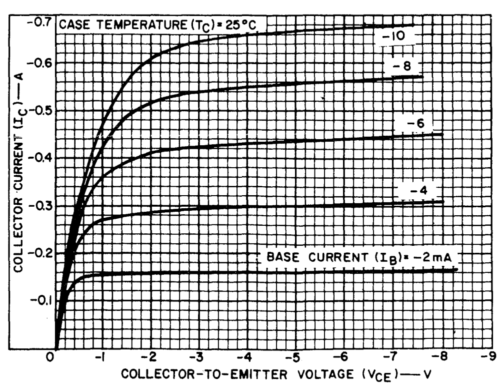


Fig. 5 - Typical output characteristics for types 2N5322 and 2N5323.

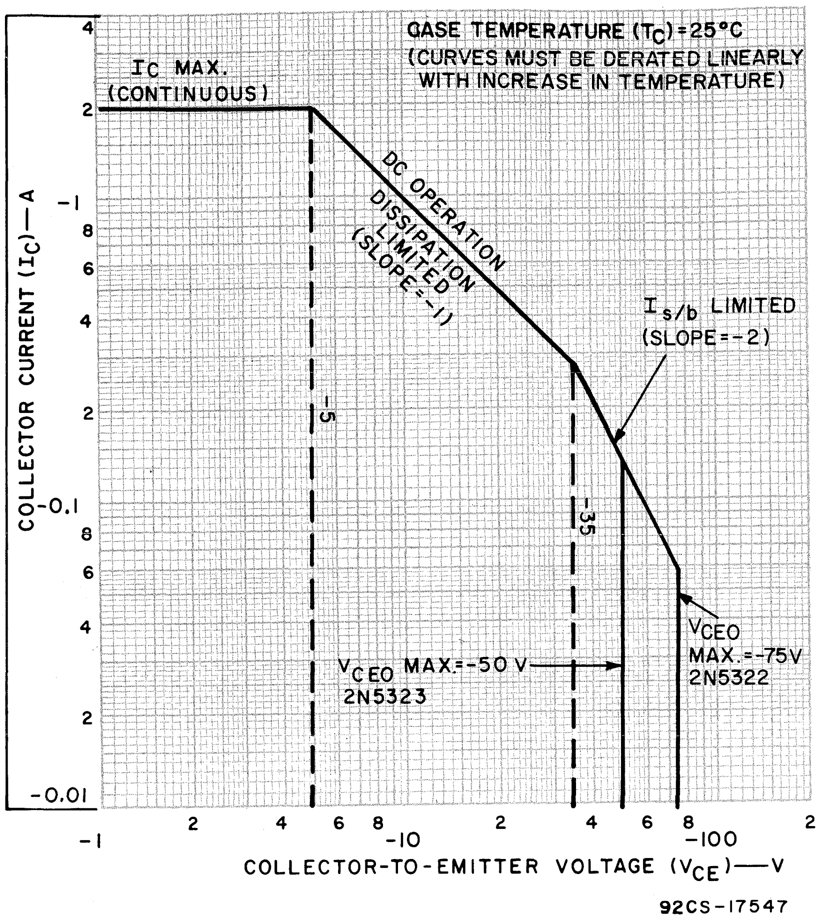


Fig. 6 - Maximum operating ***areas*** *for types 2N5322 and 2N5323.*

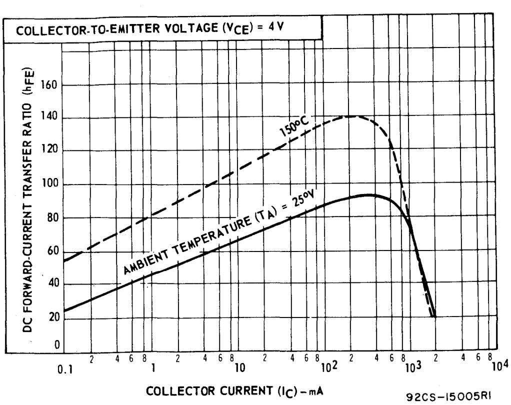


Fig. 7 - Typical static beta characteristics for types 2N5320 and 2N5321.

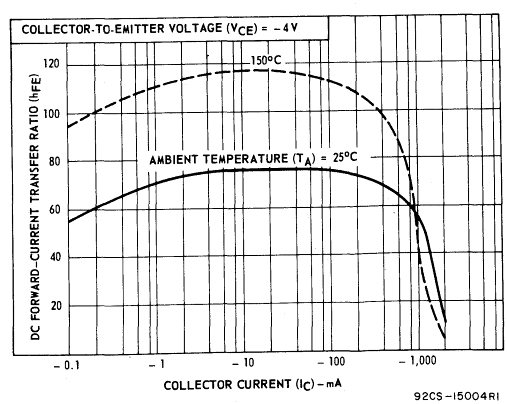


Fig. 8 - Typical static beta characteristics for types 2N5322 and 2N5323.

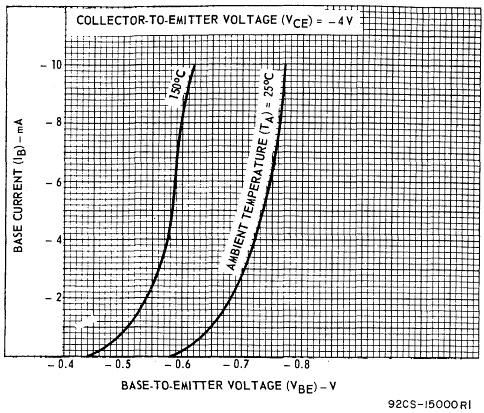


Fig. 9 - Typical input characteristics for types 2N5322 and 2N5323.

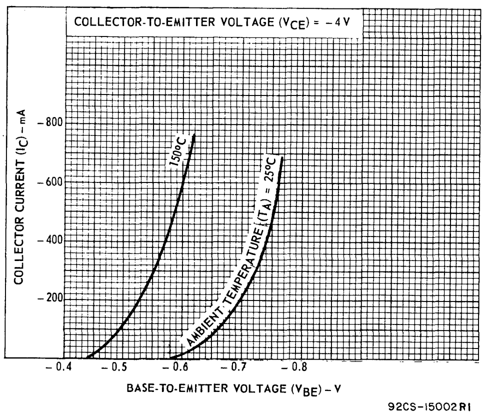


Fig. 10 - Typical transfer characteristics for types 2N5322 and 2N5323.

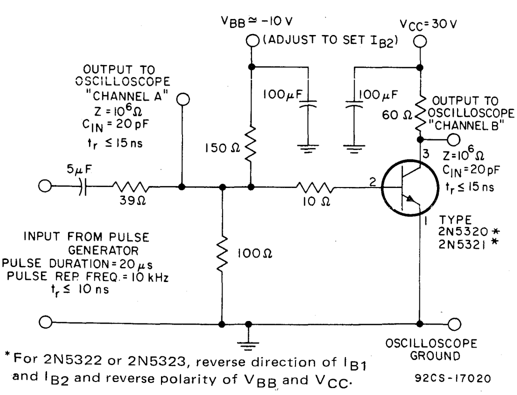


Fig. 11 - Circuit used to measure switching times for all types.

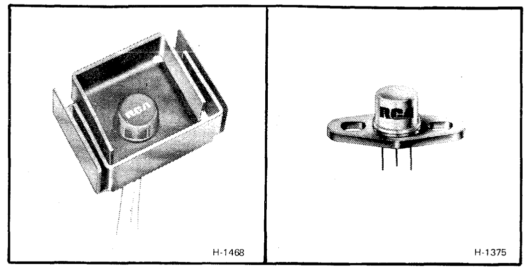
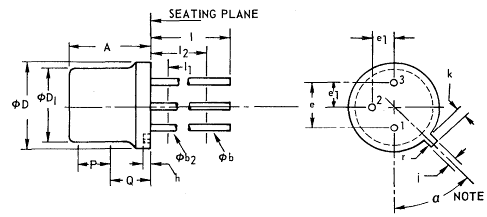


Fig. 12 -- 2N5320 — 23 in JEDEC TO-5 package with factory-attached heat radiator or mounting flange, available upon special request. (See page 1.).

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

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.

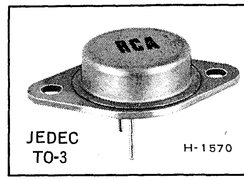
▲Formerly Dev. Types TA7323 and TA7323A, respectively

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)

SILICON N-P-N POWER TRANSISTORS



High-Current, High-Speed High-Power Types

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

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**

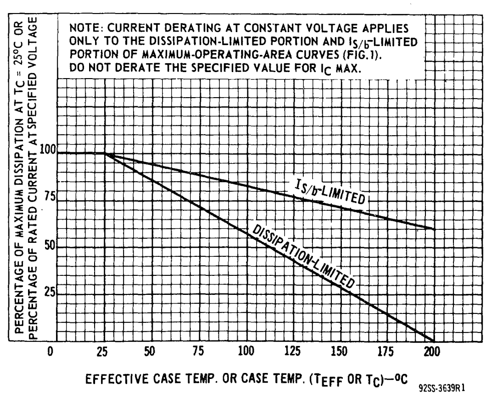


Fig. 1 - Dissipation derating curves for types 2N5671 & 2N5672

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

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) 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 2N5671 Min.	Max.	Type 2N5672 Min.	Max.	UNITS
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. $E_{S/b} = \frac{1}{2} LI^2$, 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, RFD-1)

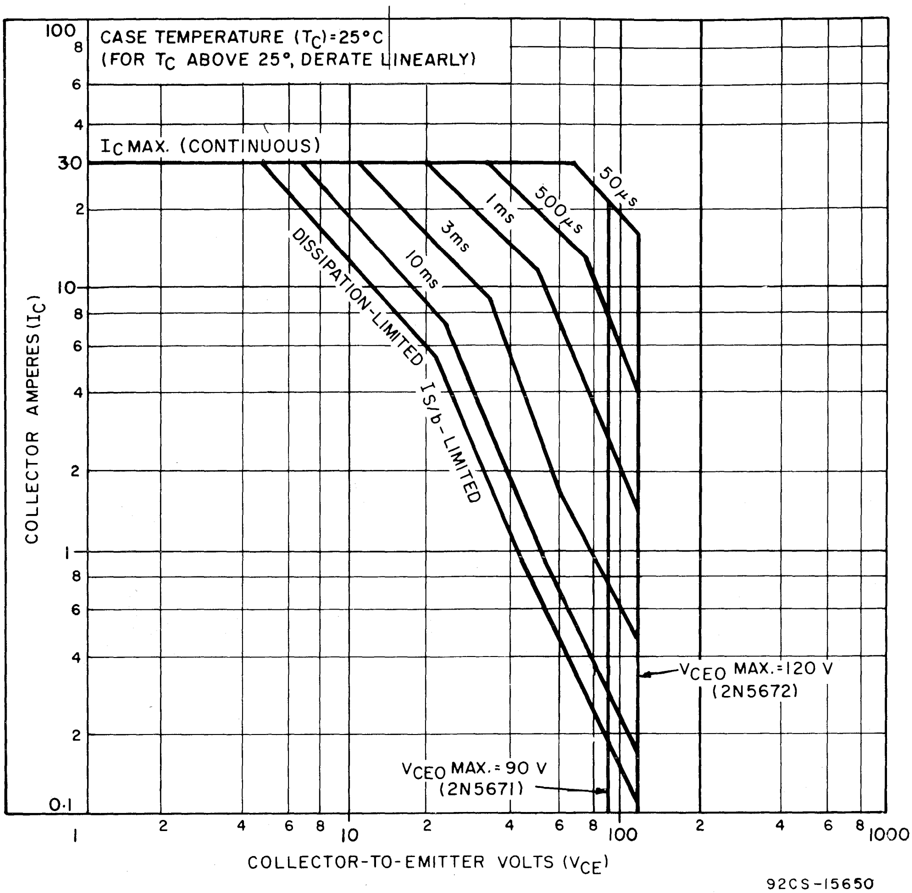


Fig.2 - Maximum operating areas for types 2N5671 & 2N5672

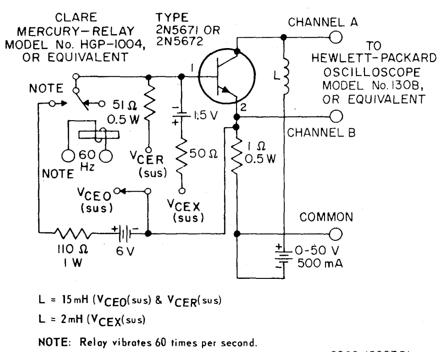
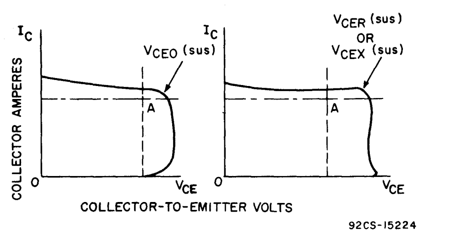


Fig. 3 - Circuit used to measure sustaining voltages V_{CEO}(sus), V_{CER}(sus), & V_{CEX}(sus) for types 2N5671 & 2N5672



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.)

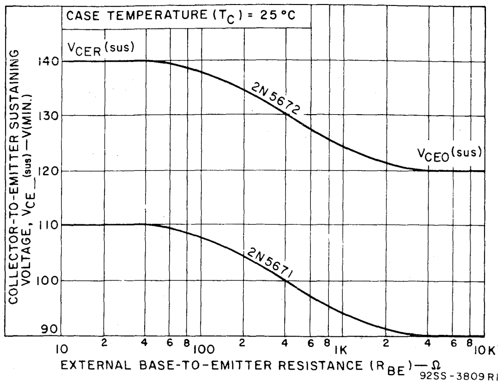


Fig. 5 - Collector-to-emitter sustaining voltage characteristics for types 2N5671 & 2N5672

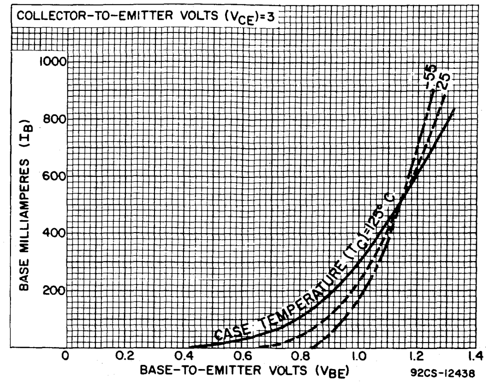


Fig. 6 - Typical input characteristics for types 2N5671 & 2N5672

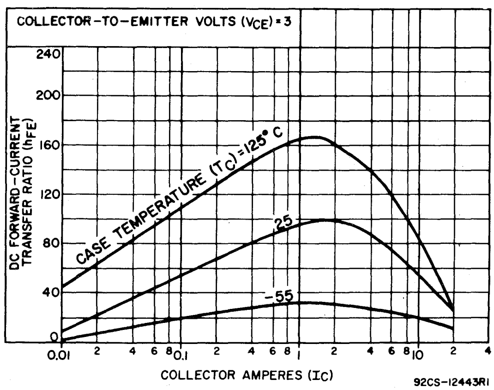


Fig. 7 - Typical DC beta characteristics for types 2N5671 & 2N5672

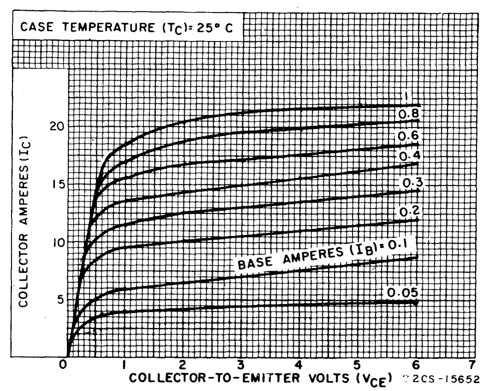


Fig. 8 - Typical output characteristics for types 2N5671 & 2N5672

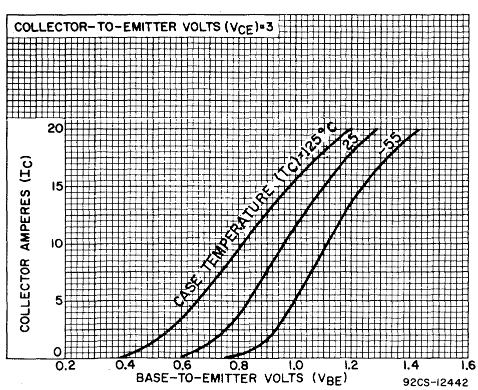


Fig. - 9 Typical transfer characteristics for types 2N5671 & 2N5672

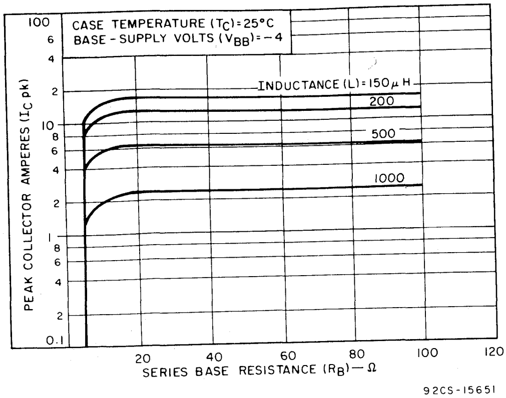


Fig. 10 - Maximum reverse-bias, second-breakdown characteristics for types 2N5671 & 2N5672

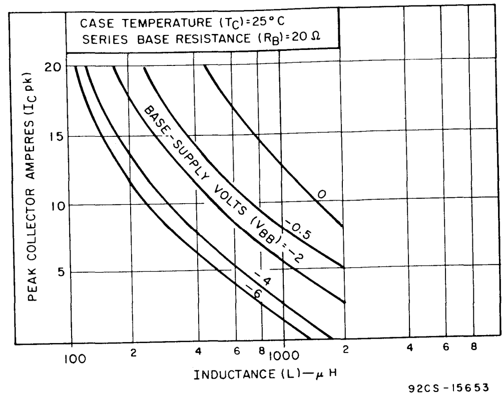


Fig. 11 - Maximum reverse-bias, second-breakdown characteristics for types 2N5671 & 2N5672

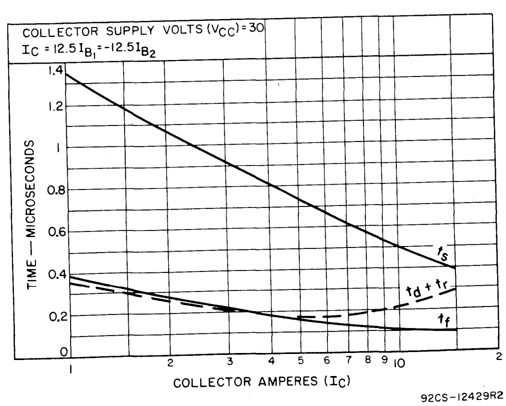
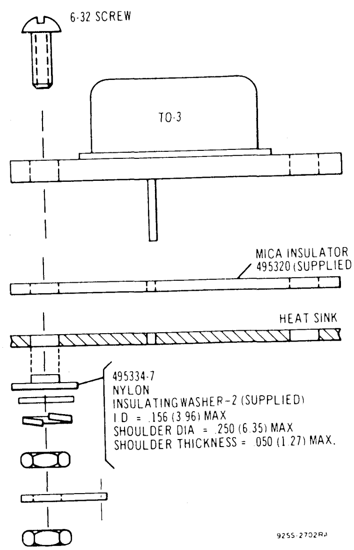


Fig. 12 - Typical saturated switching characteristics for types 2N5671 & 2N5672

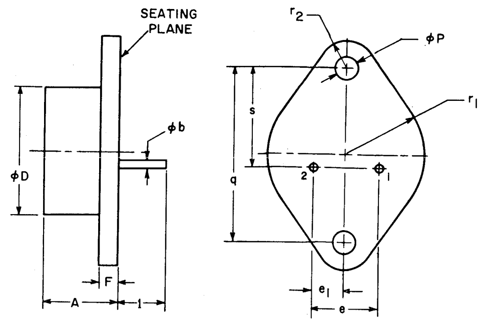


Dimensions in Inches and Millimeters

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



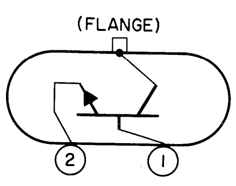
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.250	.450	6.35	11.43	
ϕb	.038	.043	.97	1.09	2
ϕD		.875		22.23	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F		.135		3.43	
1	.312		7.92		2
ϕP	.151	.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		.525		13.34	
r_2		.188		4.78	
s	.655	.675	16.64	17.15	1

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

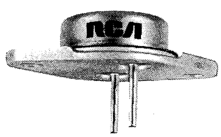


Pin 1 – Base
Pin 2 – Emitter
Mounting Flange, Case – Collector

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}) ≤ 50 Ω	V_{CER}(sus)	110	140	V
* With external base-to-emitter resistance (R_{BE}) ≤ 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 & 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.

Applications:

- **Switching-control amplifiers**
- **Power gates**
- **Switching regulators**
- **Power-switching circuits**
- **Power oscillators**
- **DC-RF amplifiers**
- **Converters**
- **Inverters**
- **Control circuits**

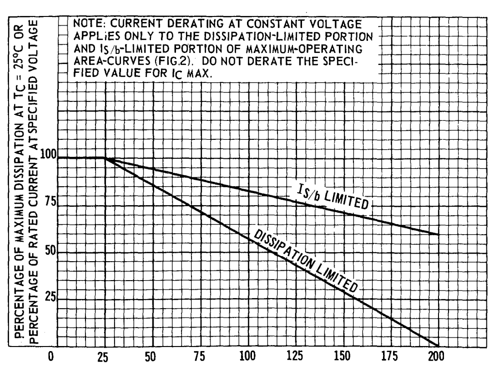


Fig. 1 – Derating curves for both types.

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)		–	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)	$\theta_{J\text{-}C}$	–	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] $I_{B_1} = I_{B_2}$ *In accordance with JEDEC registration format JS-6 RDF-1.

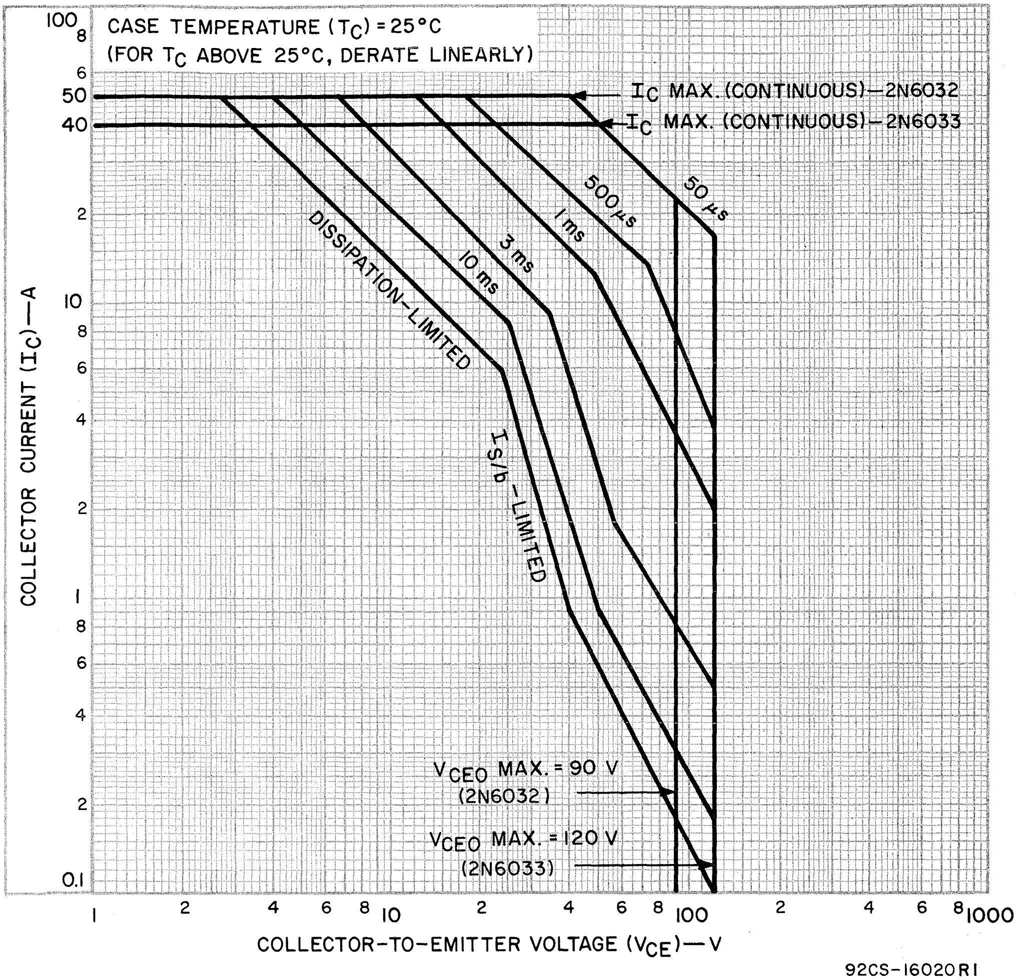


Fig. 2 — Maximum operating areas for both types.

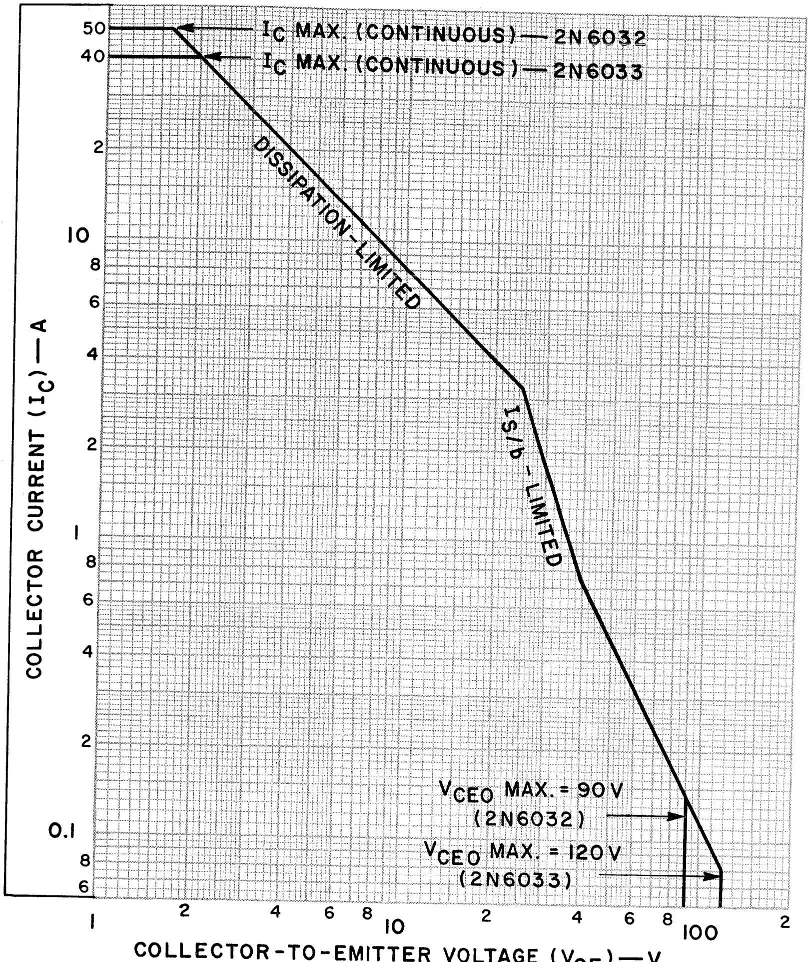


Fig. 3 – Maximum operating areas for both types at case temperature (T_C) = 100°C.

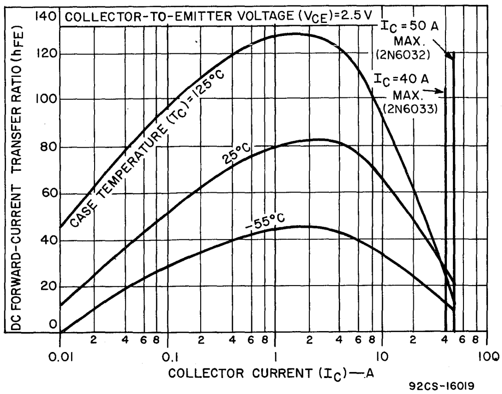


Fig. 4 — Typical dc-beta characteristic for both types.

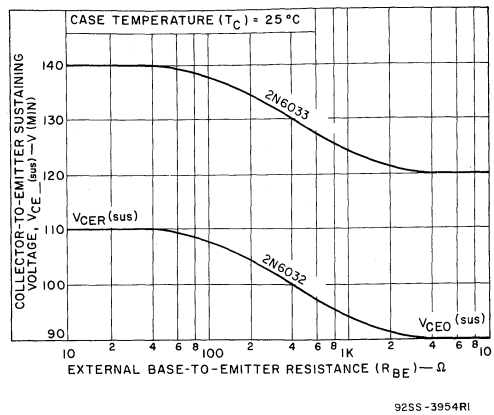


Fig. 5 — Collector-to-emitter sustaining voltage characteristics for both types.

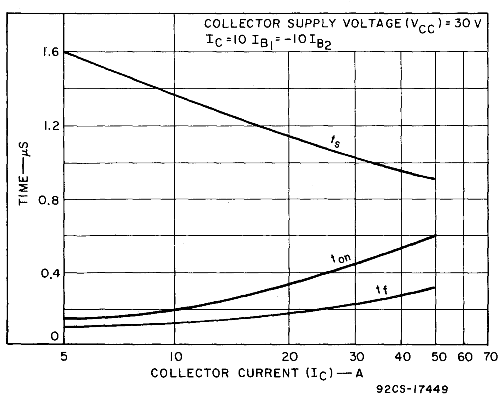


Fig. 6 — Typical saturated switching characteristics for both types.

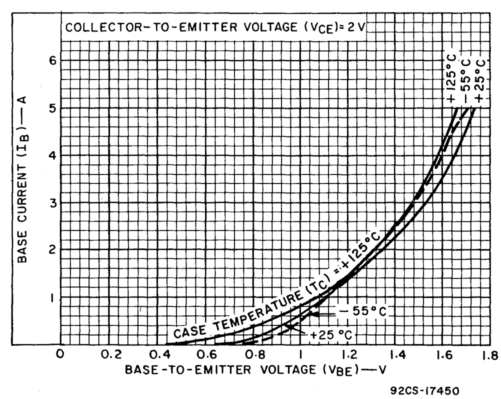


Fig. 7 — Typical input characteristics for both types.

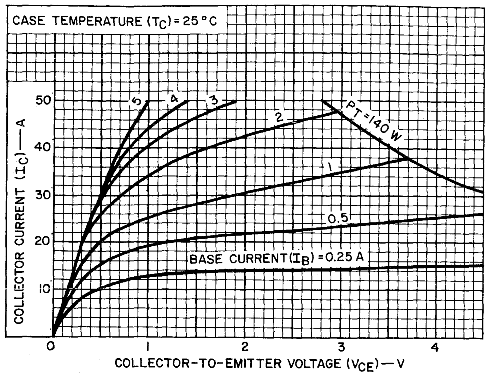


Fig. 8 – Typical collector characteristics for both types.

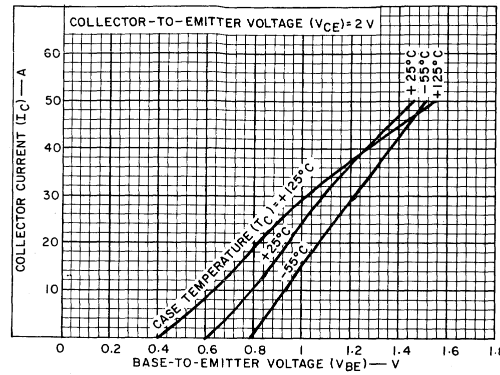


Fig. 9 – Typical transfer characteristics for both types.

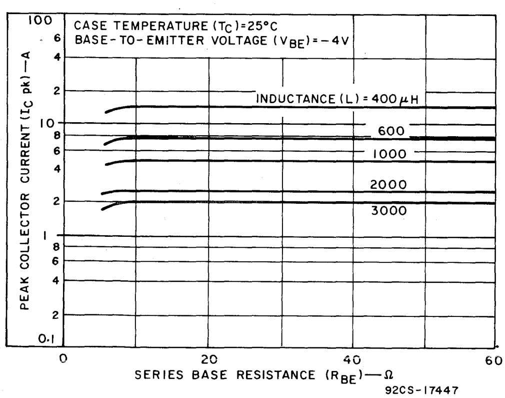


Fig. 10 – Maximum reverse-bias second-breakdown characteristics for both types.

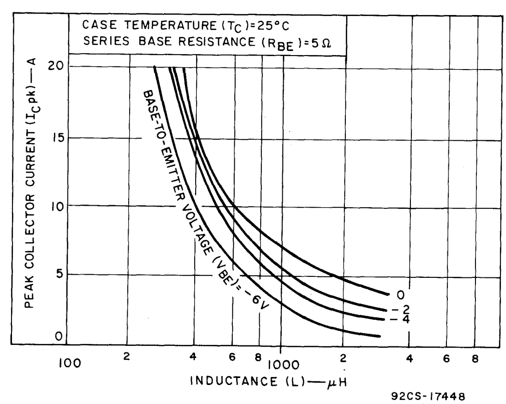


Fig. 11 – Maximum reverse-bias second-breakdown characteristics for both types.

RCA
Solid State
Division

Power Transistors

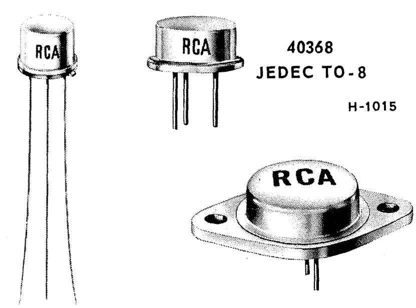
40346 40412
40346V1 40412V1
40346V2 40412V2

Silicon N-P-N Types for Power Switching and Amplifier Applications

FEATURES

- High reliability assured by five preconditioning steps
- Group-A test data included *
- Transistors utilize JEDEC "TO-"packages:
  TO–5 (40366, 40367 & 40385)
  TO–8 (40368)
  TO–3 (40369)
- 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.



40368
JEDEC TO-8
H-1015

40366 40367 40385
JEDEC TO-5
H-1380

40369
JEDEC TO-3
H-1339

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 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
Collector Current	I_C	1	1.5	3	6	1	A
Base Current	I_B	—	1	1.5	3	—	A
Transistor Dissipation:	P_T						
At case temperatures up to 25°C		5	5	25	75	5	W
At free-air temperatures 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: At distances $\geq$ 1/32" from seating plane, for 10 s max.		255	255	235	235	255	°C

ELECTRICAL CHARACTERISTICS Case Temperature (T_C) = 25° C

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	V_{CE}	DC Emitter Volts V_{EB}	DC Current (Milliamperes) I_C	I_E	I_B	LIMITS: Type 40366 Min.	Max.	Type 40367 Min.	Max.	Type 40368 Min.	Max.	Type 40369 Min.	Max.	Type 40385 Min.	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.	Max.	40367 Min.	Max.	40368 Min.	Max.	40369 Min.	Max.	40385 Min.	Max.	UNITS
	Subgroup 1		10												
2071	Visual and Mechanical Examination	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Subgroup 2														
3036D	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 = 100µA, V_{EB} = 1.5V	–	BV_{CBV}	120	–	–	–	–	–	–	–	–	–	V
3026D	Emitter-to-Base Breakdown Voltage	I_E = 100µA, I_C = 0	–	BV_{EBO}	7.0	–	–	–	–	–	–	–	–	–	V
3011A	Collector-to-Emitter Breakdown Voltage	I_C = 0.25mA, V_{EB} = 1.5V	–	BV_{CEV}	–	–	100	–	100	–	–	–	–	–	V
		I_C = 0.5mA, V_{EB} = 1.5V	–	BV_{CEV}	–	–	–	–	–	–	100	–	–	–	V
3011D	Collector-to-Emitter Sustaining Voltage	I_C = 50mA, I_B = 0	–	$V_{CEO}(sus)$	–	–	55	–	–	–	–	–	350	–	V
		I_C = 100mA●, I_B = 0	–	$V_{CEO}(sus)$	65	–	–	–	–	–	–	–	–	–	V
		I_C = 100mA, I_B = 0	–	$V_{CEO}(sus)$	–	–	–	–	55	–	55	–	–	–	V
3011B	Collector-to-Emitter Sustaining Voltage	I_C = 100mA●, R_{BE} = 10 Ω	–	$V_{CER}(sus)$	80	–	–	–	–	–	–	–	–	–	V
3071	**Subgroup 3**	I_C = 50mA, I_B = 4mA	–	$V_{CE}(sat)$	–	–	–	–	–	–	–	–	–	0.5	V
		I_C = 150mA●, I_B = 15mA	5	$V_{CE}(sat)$	–	0.5	–	–	–	–	–	–	–	–	V
	Collector-to-Emitter Saturation Voltage	I_C = 200mA, I_B = 10mA	–	$V_{CE}(sat)$	–	–	–	1.4	–	–	–	–	–	–	V
		I_C = 750mA, I_B = 40mA	–	$V_{CE}(sat)$	–	–	–	–	–	0.75	–	–	–	–	V
		I_C = 1.5A, I_B = 100mA	–	$V_{CE}(sat)$	–	–	–	–	–	–	–	1.0	–	–	V
3066A	Base-to-Emitter Saturation Voltage	I_C = 50mA, I_B = 4mA	–	$V_{BE}(sat)$	–	–	–	–	–	–	–	–	–	1.3	V
		I_C = 150mA●, I_B = 15mA	–	$V_{BE}(sat)$	–	1.1	–	–	–	–	–	–	–	–	V
3066A	Base-to-Emitter Voltage	I_C = 200mA, V_{CE} = 4V	–	V_{BE}	–	–	–	3.0	–	–	–	–	–	–	V
		I_C = 750mA, V_{CE} = 4V	–	V_{BE}	–	–	–	–	–	2.5	–	–	–	–	V
3076	DC Forward-Current Transfer Ratio	I_C = 0.01mA, V_{CE} = 10V	–	h_{FE}	10	–	–	–	–	–	–	–	–	–	
		I_C = 0.1mA, V_{CE} = 10V	–	h_{FE}	20	–	–	–	–	–	–	–	–	–	
		I_C = 2 mA, V_{CE} = 10V	–	h_{FE}	–	–	–	–	–	–	–	–	30	–	
		I_C = 20mA, V_{CE} = 10V	–	h_{FE}	–	–	–	–	–	–	–	–	40	160	
		I_C = 150mA●, V_{CE} = 10V	–	h_{FE}	40	120	–	–	–	–	–	–	–	–	
		I_C = 200mA, V_{CE} = 4V	–	h_{FE}	–	–	35	100	–	–	–	–	–	–	
		I_C = 500mA●, V_{CE} = 10V	–	h_{FE}	25	–	–	–	–	–	–	–	–	–	
		I_C = 750mA, V_{CE} = 4V	–	h_{FE}	–	–	–	–	35	100	–	–	–	–	
		I_C = 1A●, V_{CE} = 10V	–	h_{FE}	10	–	–	–	–	–	–	–	–	–	
		I_C = 1.5A, V_{CE} = 4V	–	h_{FE}	–	–	–	–	–	–	25	75	–	–	

●Pulsed; pulse duration = 300µs, duty factor = 1.8%. *Lot tolerance per cent defective.

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, high-beta at high currents, and are designed to assure freedom from forward-bias second breakdown when operated with specified limits.

The 40385, the high-reliability version of the 2N3439, features low saturation voltage, high collector-to-base and collector-to-emitter voltages, and high resistance to 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.

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* Complete data for types 2N1482, 2N1486, 2N1490, 2N2102 & 2N3439 are given in separate technical bulletins. Bulletins are available by writing to: Commercial Engineering, RCA Electronic Components and Devices, Harrison, N. J.

RELIABILITY TESTING

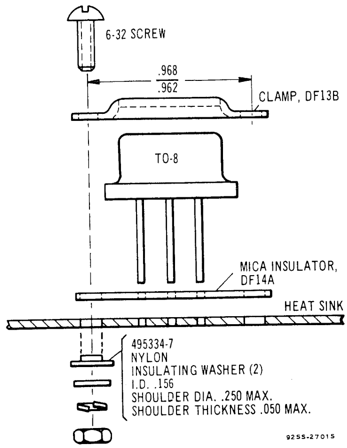
Each RCA-40366, 40367, 40368, 40369 and 40385 is subjected to the following preconditioning steps:

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° C, V_{CB} = 60 V, t = 168 hours, P_T = 1 W, free-air (For 40366 & 40367)
   (b) Power Age, T_C = 125° 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° 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.

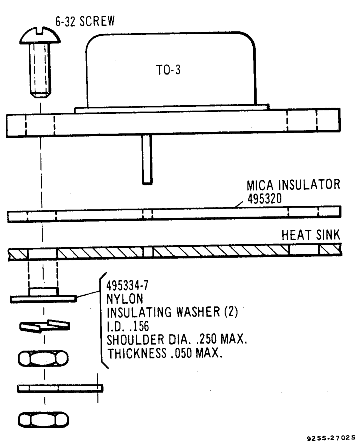
† Delta criteria after 168 hours Power Age:
Δh_{FE} ± 25% (For all types) ΔI_{CBO} + 1 μA (For 40367, 40368, & 40369)

SUGGESTED HARDWARE

FOR TYPE 40368

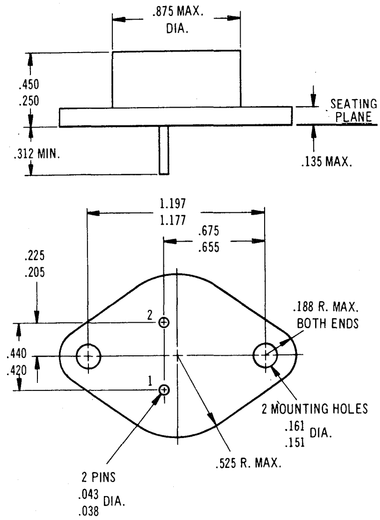


FOR TYPE 40369



NOTE: HARDWARE WITH PART NUMBERS ARE SUPPLIED.

DIMENSIONAL OUTLINE
FOR TYPE 40369
JEDEC TO-3

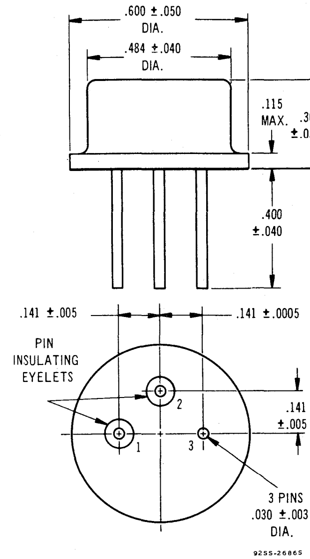


DIMENSIONS IN INCHES

TERMINAL CONNECTIONS
FOR TYPE 40369

PIN 1 - BASE
PIN 2 - EMITTER
FLANGE, CASE - COLLECTOR

DIMENSIONAL OUTLINE
FOR TYPE 40368
JEDEC TO-8

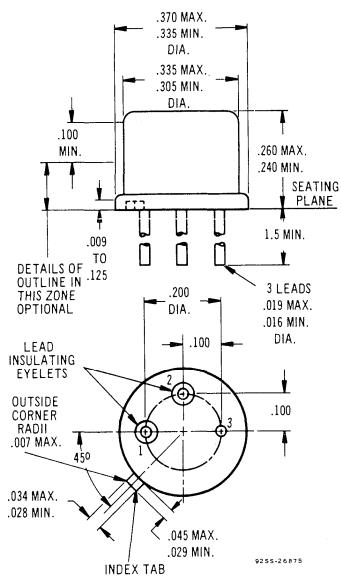


DIMENSIONS IN INCHES

TERMINAL CONNECTIONS
FOR TYPE 40368

PIN 1 - EMITTER
PIN 2 - BASE
CASE, PIN 3 - COLLECTOR

DIMENSIONAL OUTLINE FOR TYPES
40366, 40367 & 40385
JEDEC TO-5



DIMENSIONS IN INCHES

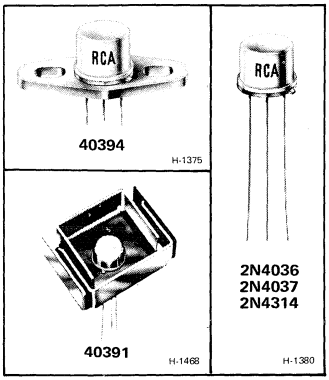
TERMINAL CONNECTIONS
FOR TYPES 40366, 40367 & 40385

LEAD NO. 1 - EMITTER
LEAD NO. 2 - BASE
CASE, LEAD NO. 3 - COLLECTOR

Other p-n-p Power Transistors

RCA
Solid State
Division

Power Transistors
2N4036 2N4314
2N4037 40391
40394



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		DC Emitter or Base Voltage-V		DC Current mA			LIMITS: Type 2N4036		Types 2N4037 40391 40394		Type 2N4314		Units
		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}	−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*	–	–	–	–	
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).

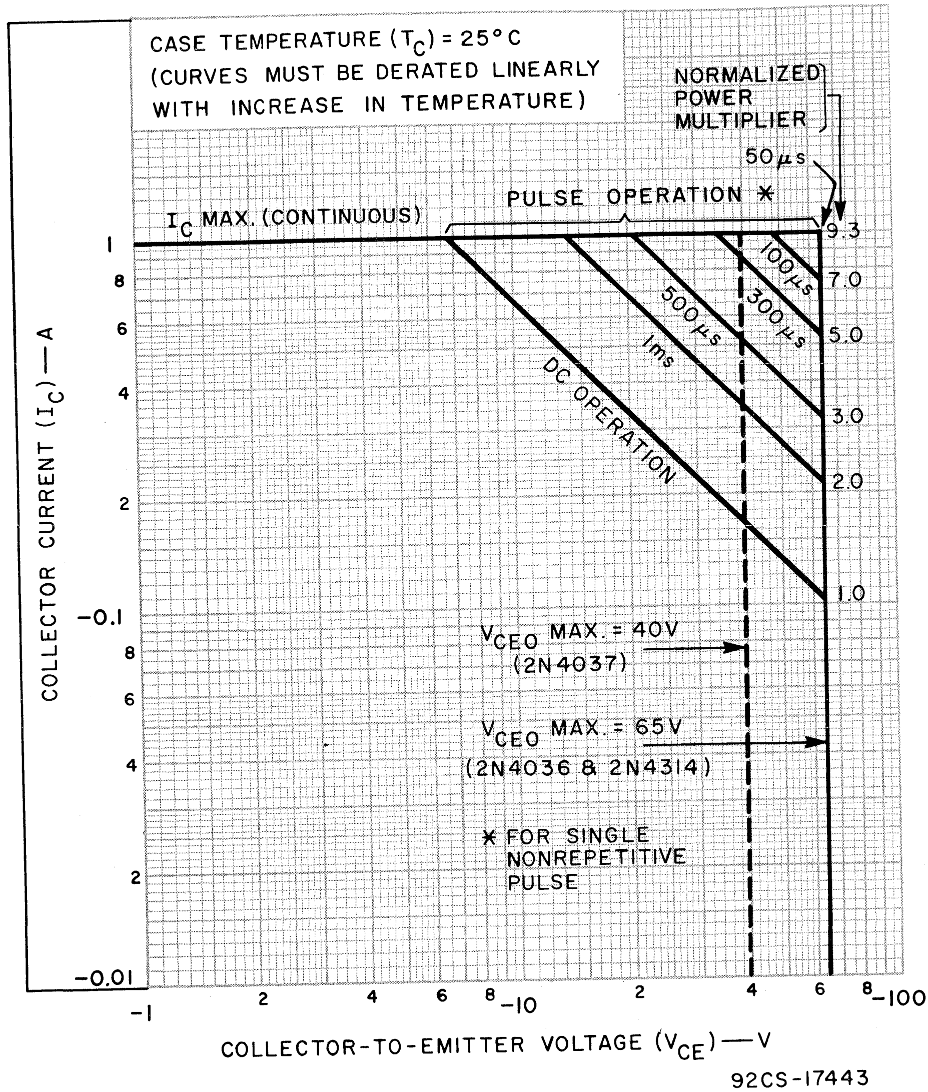
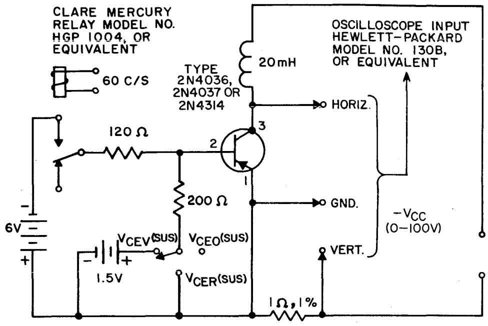
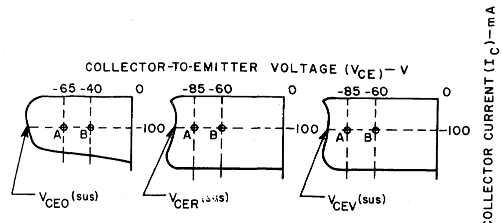


Fig. 1 – Maximum operating areas for types 2N4036, 2N4037 and 2N4314.



92LS-1255RI

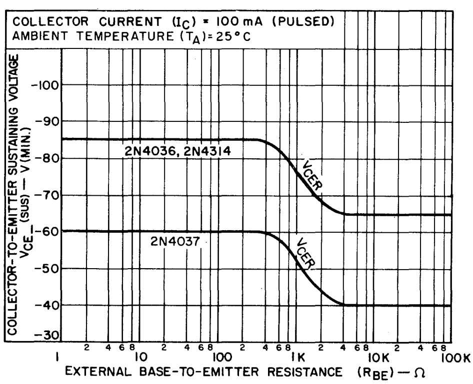
Fig. 2 – Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ for all types.



92LS-1263

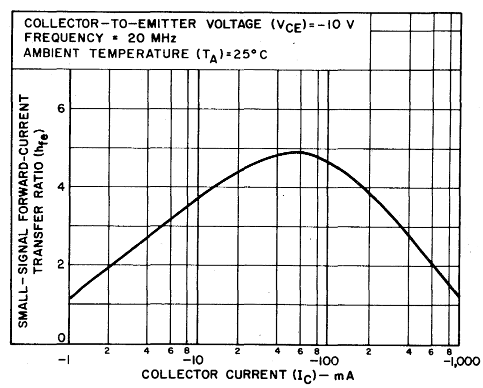
NOTE: The sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEV}(sus)$ are acceptable when the traces fall to the left and below point "A" for type 2N4036 and 2N4314, and point "B" for type 2N4037.

Fig. 3 – Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig. 2).



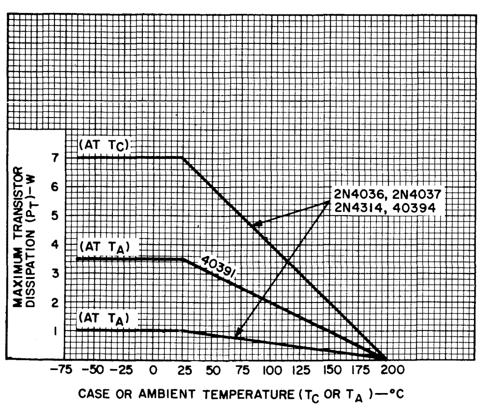
92LS-1256R2

Fig. 4 – Sustaining voltage vs. base-to-emitter resistance for all types.



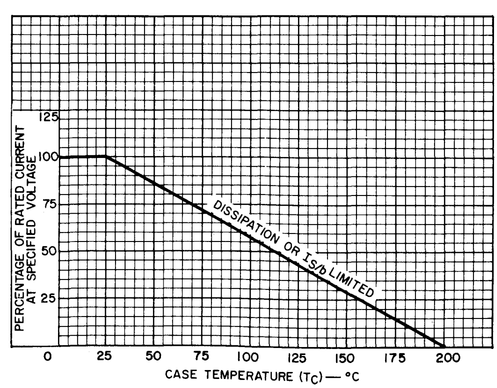
92LS-1257RI

Fig. 5 – Typical small-signal beta characteristic for all types.



92LS-1294R2

Fig. 6 – Dissipation derating curve for all types.



92LS-1469RI

Fig. 7 – Dissipation derating curve for types 2N4036, 2N4037 and 2N4314.

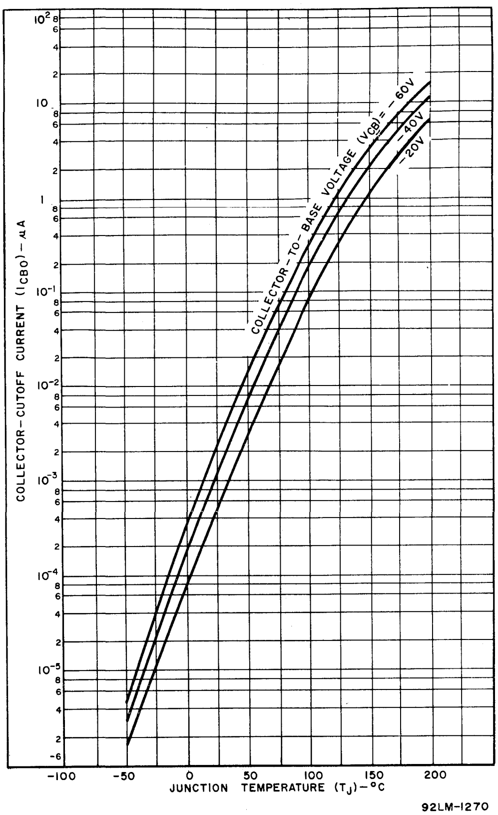


Fig. 8 – Typical collector-cutoff current vs. junction temperature for type 2N4036.

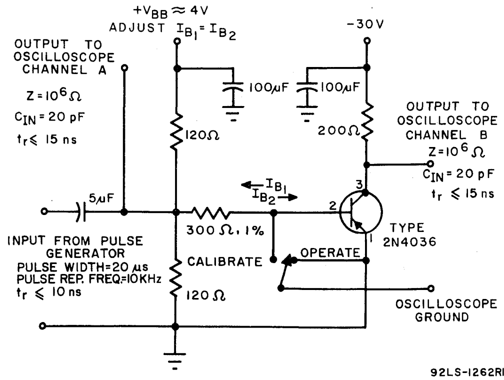


Fig. 9 – Circuit used to measure switching times for type 2N4036.

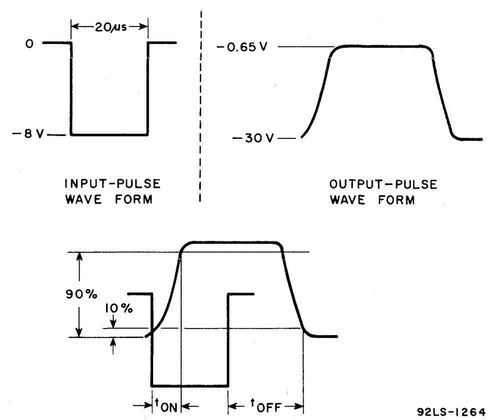


Fig. 10 – Oscilloscope display for measurement of switching times (test circuit shown in Fig. 9).

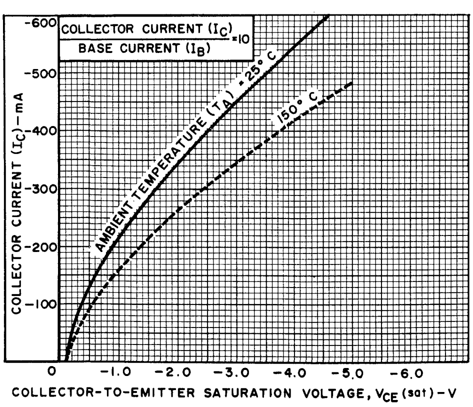


Fig. 11 – Typical saturation-voltage characteristics for type 2N4036.

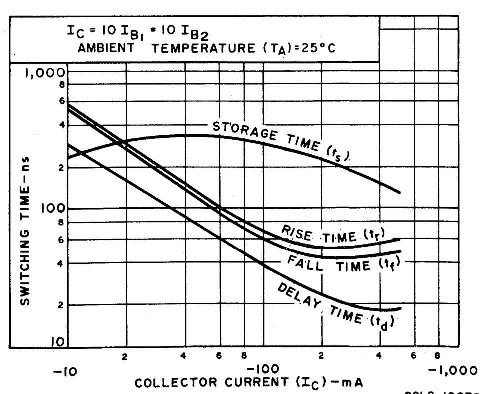


Fig. 12 – Typical saturated switching times for type 2N4036.

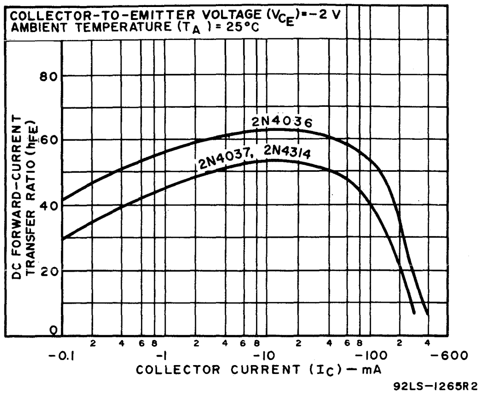


Fig. 13 — Typical dc beta characteristics for all types.

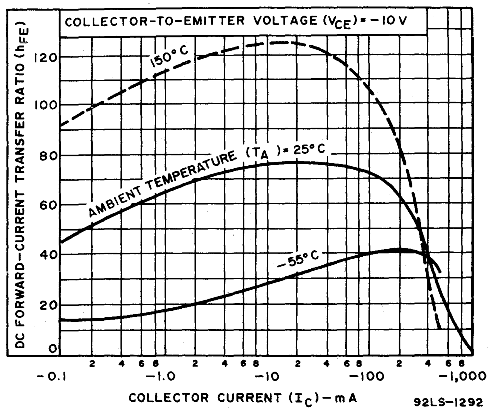


Fig. 14 — Typical dc beta characteristics for types 2N4037 and 2N4314.

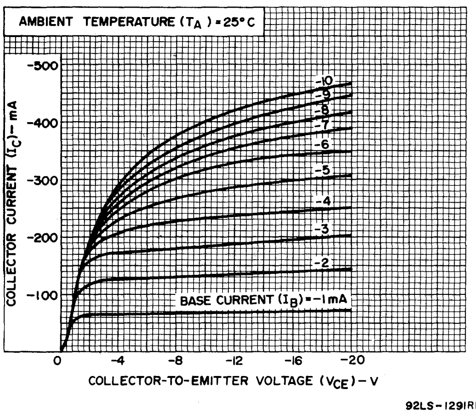


Fig. 15 — Typical output characteristics for types 2N4037 and 2N4314.

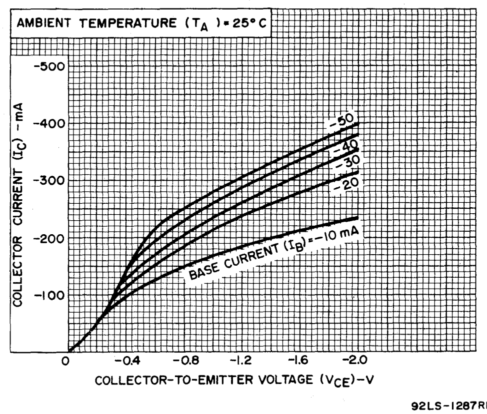


Fig. 16 — Typical output characteristics for types 2N4037 and 2N4314.

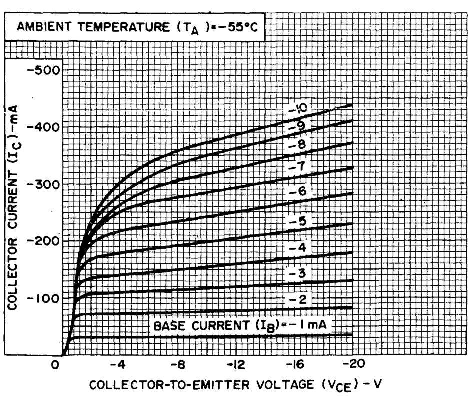


Fig. 17 — Typical output characteristics for types 2N4037 and 2N4314.

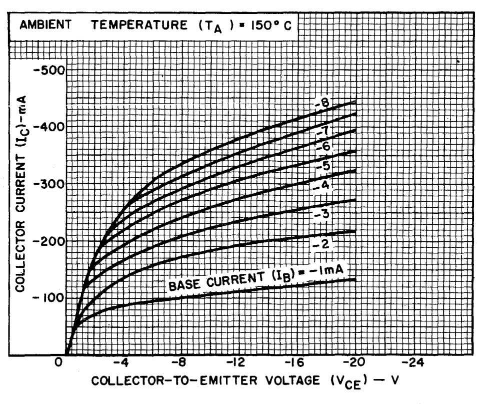


Fig. 18 — Typical output characteristics for types 2N4037 and 2N4314.

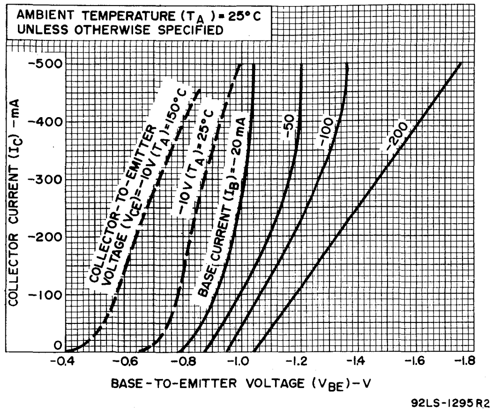


Fig. 19 – Typical transfer characteristics for types 2N4037 and 2N4314.

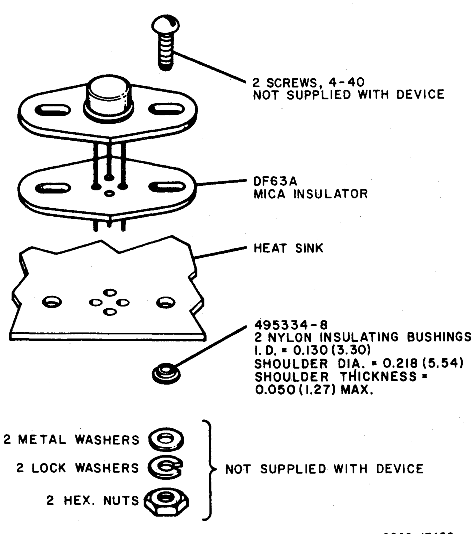
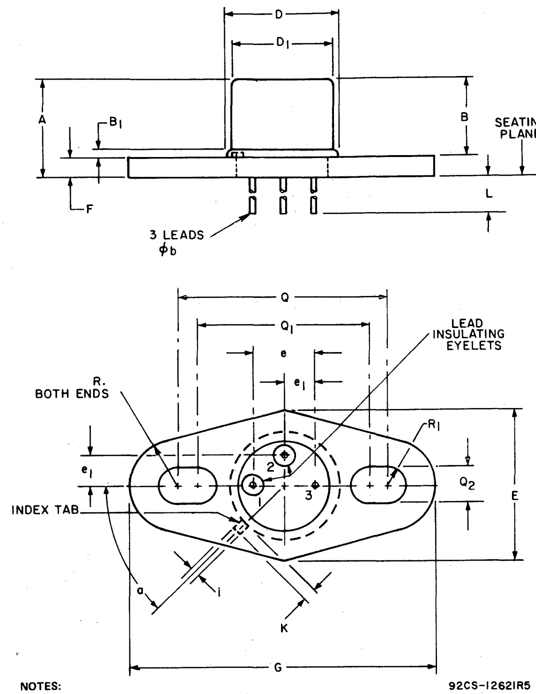


Fig. 20 – Suggested mounting hardware for type 40392 (JEDEC TO-5 with mounting flange).

DIMENSIONAL OUTLINE FOR TYPE 40394
JEDEC TO-5 WITH MOUNTING FLANGE



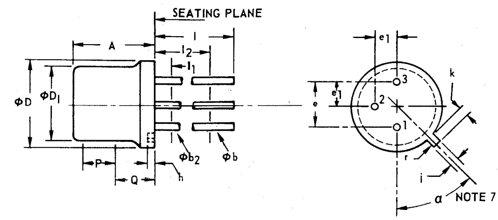
NOTES:
1. True position.
2. Tab centerline.

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	
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	
a	45° T.P.				1, 2

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
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:

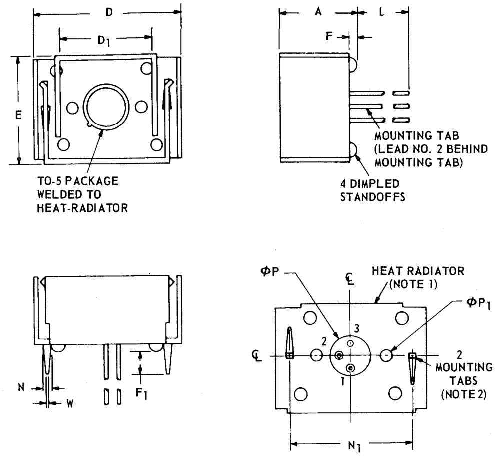
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) ϕb_2 applies between 1_1 and 1_2. ϕb applies between 1_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in 1_1 and beyond 1.5 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

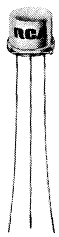
Lead 1 - Emitter
Lead 2 - Base
Heat-Radiator, Lead 3 - Collector

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**
- **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)

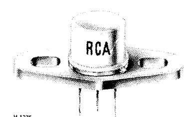
RCA-2N5415 and 2N5416* are triple-diffused silicon p–n–p transistors with high breakdown voltages, high frequency response, and fast switching speeds.

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)

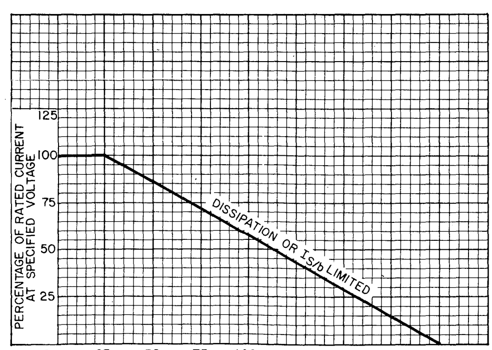


Fig. 1 - Dissipation derating curve

ELECTRICAL CHARACTERISTICS, *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 Type 2N5415 Min.	Max.	Type 2N5416 Min.	Max.	UNITS
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)

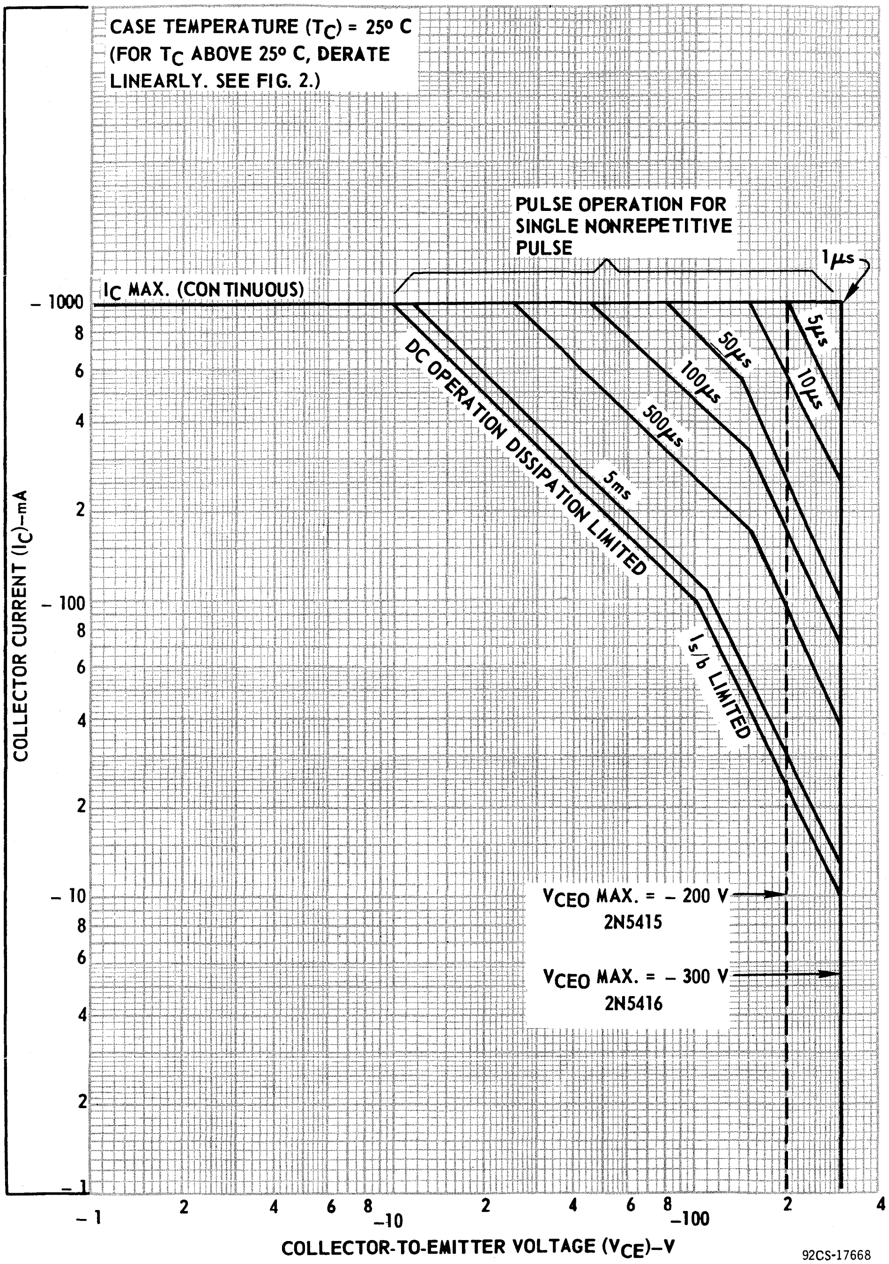


Fig. 2 - Maximum safe operating areas

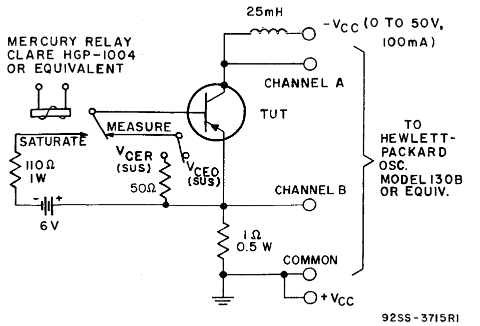
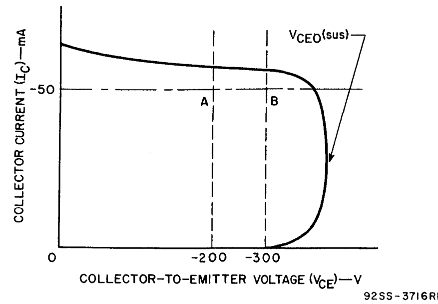


Fig. 3 - Circuit used to measure sustaining voltages, V_{CEO}(sus) and V_{CER}(sus) for both types



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)

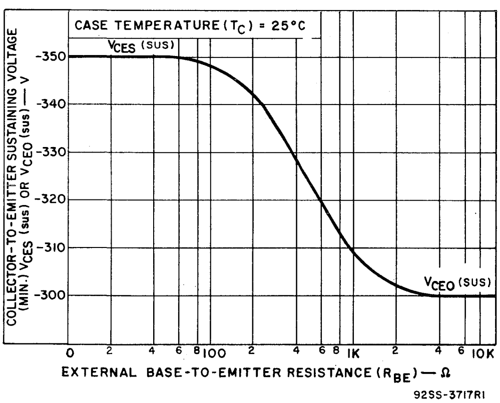


Fig. 5 - Sustaining voltage vs. base-to-emitter resistance for type 2N5416

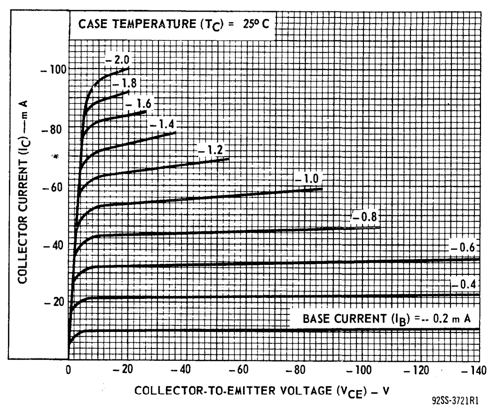


Fig. 6 - Typical output characteristics for both types

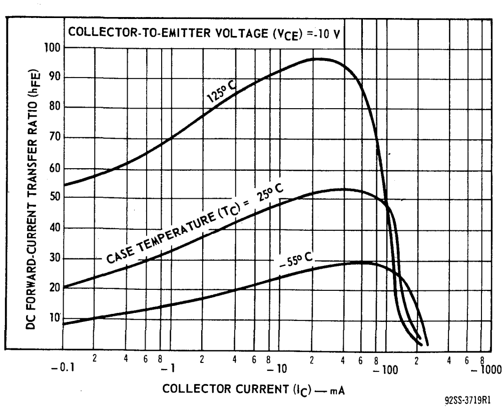


Fig. 7 - Typical dc beta for both types

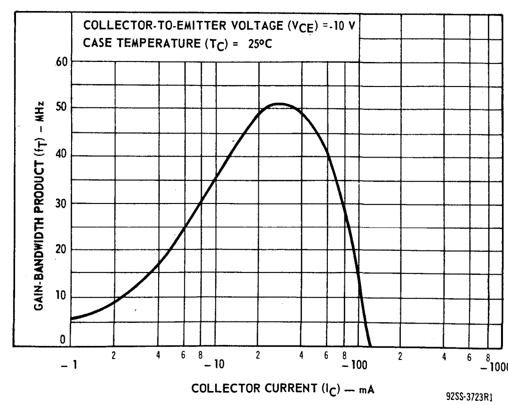


Fig. 8 - Typical gain-bandwidth product for both types

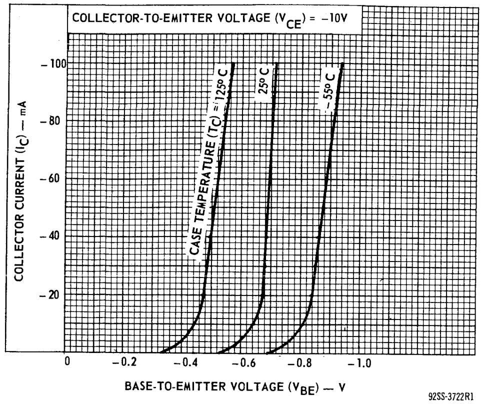


Fig. 9 - Typical transfer characteristics for both types

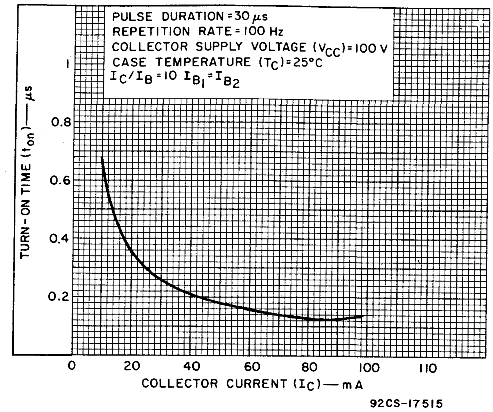


Fig. 11 - Typical turn-on time characteristic for both types

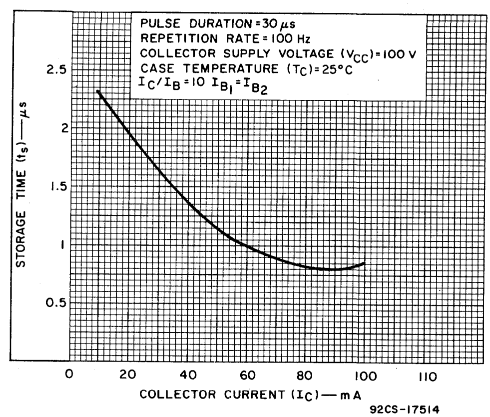


Fig. 12 - Typical storage-time characteristic for both types

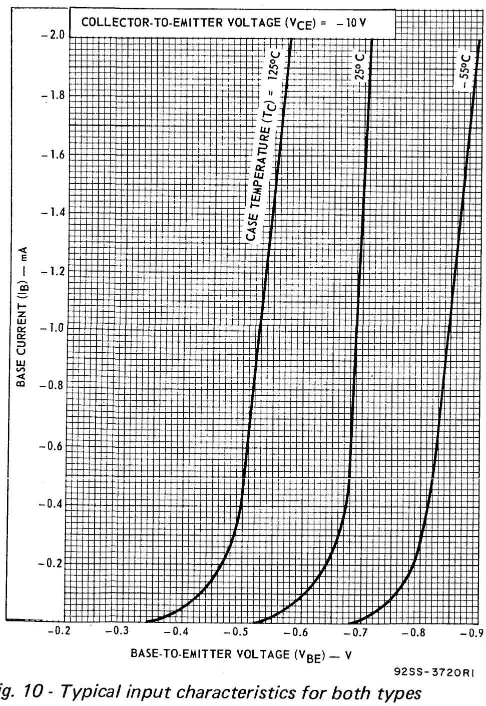


Fig. 10 - Typical input characteristics for both types

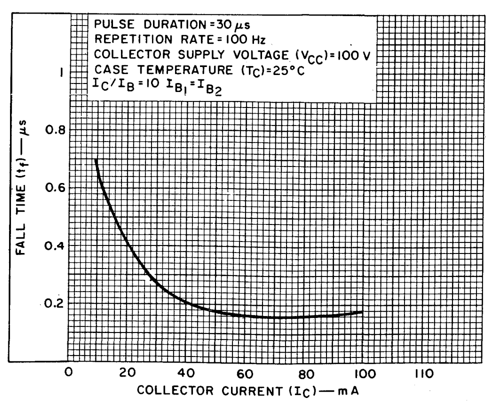


Fig. 13 - Typical fall-time characteristic for both types

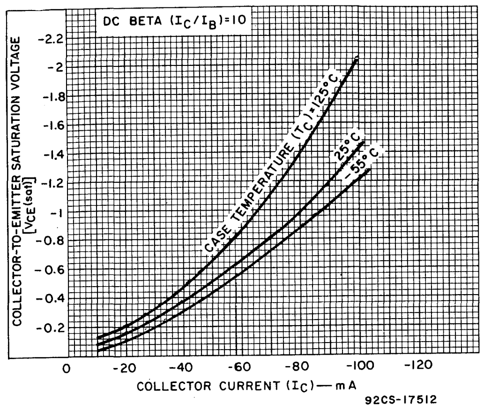
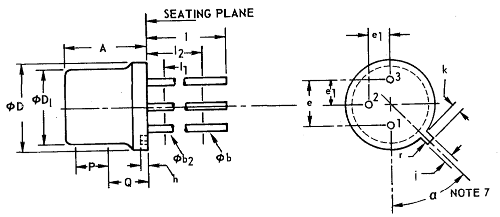


Fig. 14 - Typical collector-to-emitter saturation voltage for both types

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

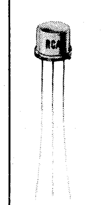
RCA Solid State Division

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

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

General-Purpose Complementary-Symmetry Types

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



JEDEC TO-5

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.

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				LIMITS												UNITS
		DC Collector Volts	DC Emitter Volts	DC Current (Amperes)		P-N-P TYPES						N-P-N TYPES						
						2N5781		2N5782		2N5783		2N5784		2N5785		2N5786		
		V_{CE}▲	V_{EB}▲	I_C▲	I_B▲	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
* 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	$V_{CE}(sat)$			-1, 1	-0.1, 0.1	–	-0.5	–	–	–	–	–	0.5	–	–	–	–	V
[Measured ¼ in.				-1.2, 1.2	-0.12, 0.12	–	–	–	-0.75	–	–	–	–	–	0.75	–	–	
(6.35 mm) from case][f]				-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	
Thermal Resistance: Junction-to-Case	$\theta_{J\text{-}C}$					–	17.5	–	17.5	–	17.5	–	17.5	–	17.5	–	17.5	°C/W
Junction-to-Ambient	$\theta_{J\text{-}A}$					–	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

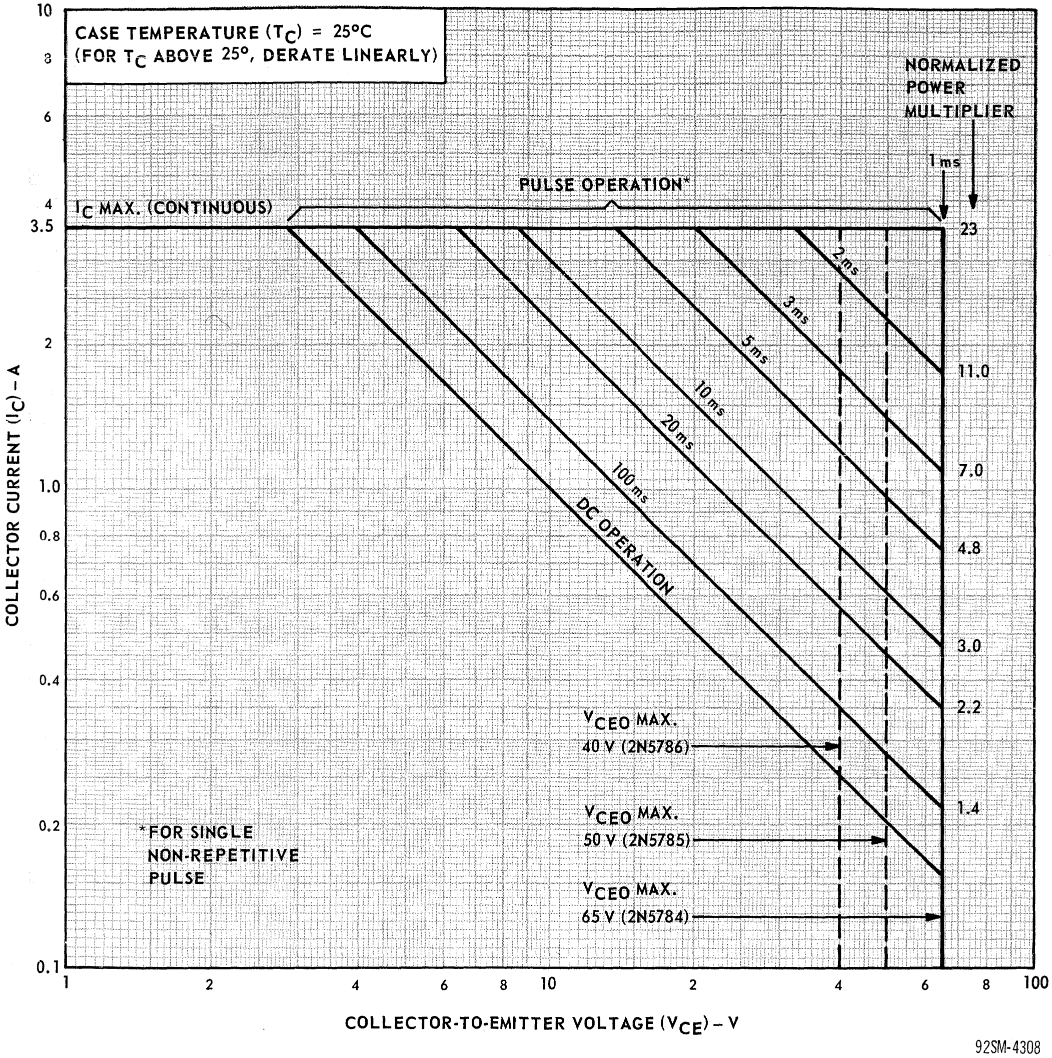


Fig. 1 - Maximum operating areas for types 2N5784, 2N5785, and 2N5786.

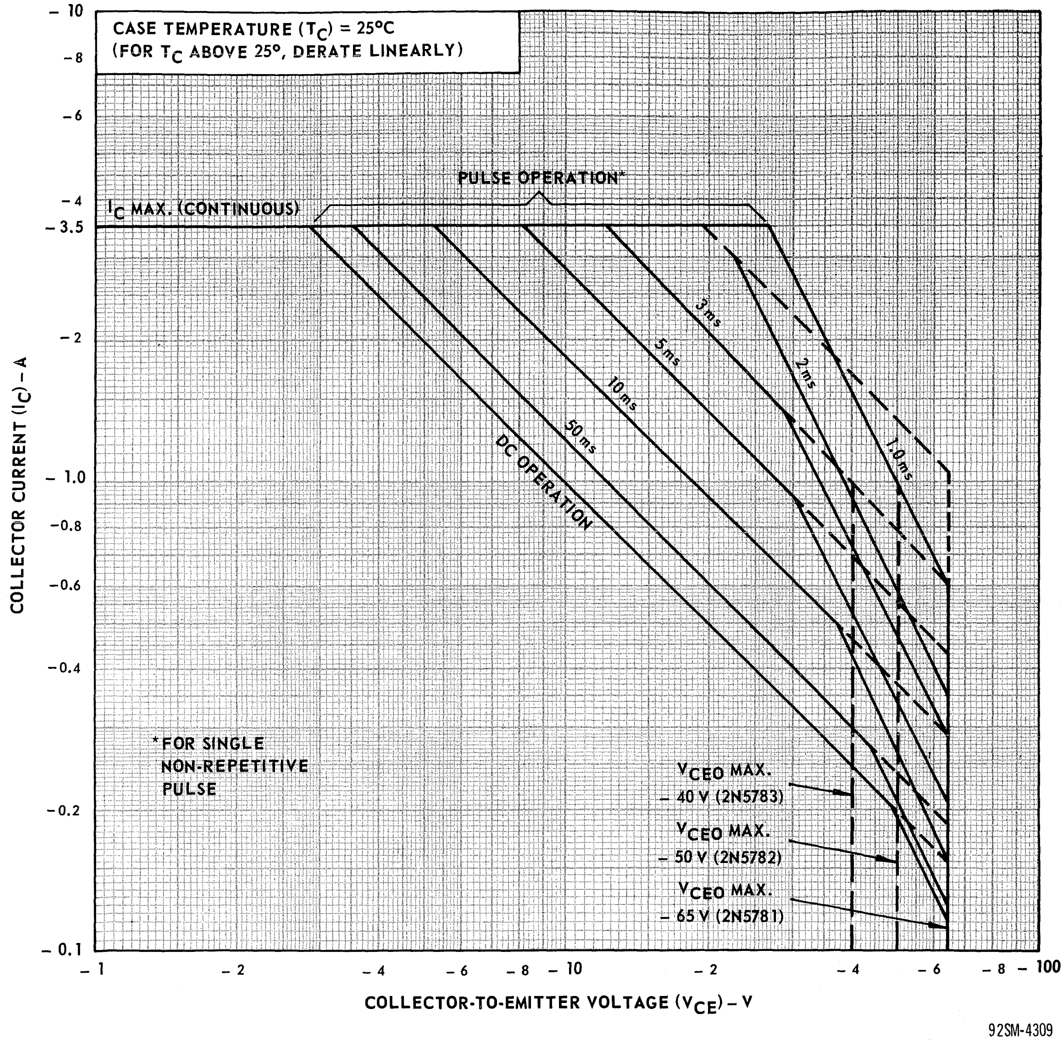


Fig. 2 - Maximum operating areas for types 2N5781, 2N5782, and 2N5783.

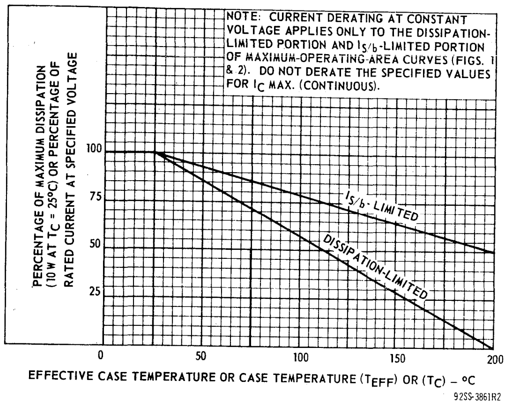
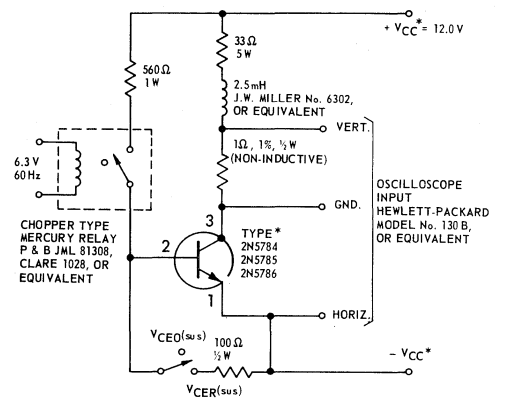
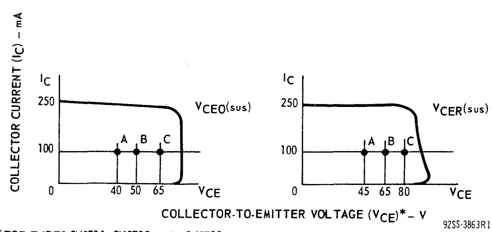


Fig. 3 - Dissipation derating curve for all types.



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

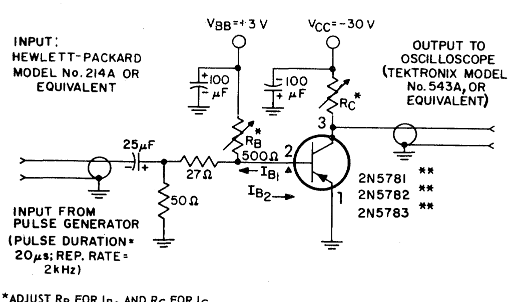
Fig. 4 - Circuit used to measure sustaining voltages $V_{CEO}(sus)$ and $V_{CER}(sus)$.



*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.

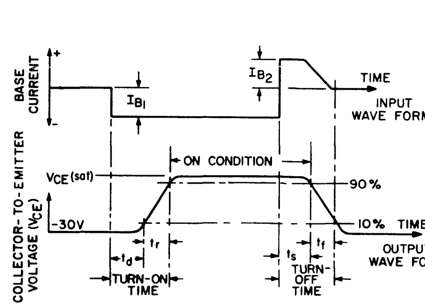


Fig. 7 - Oscilloscope display for measurement of switching times. (Test circuit shown in Fig. 6.)

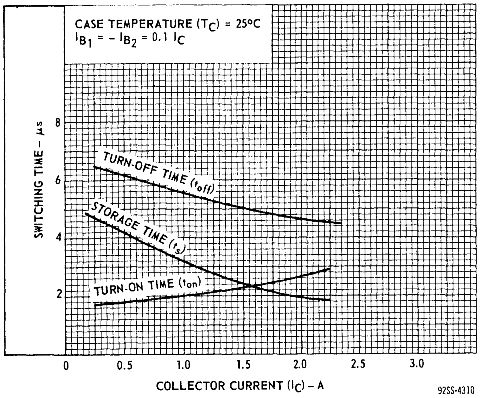


Fig. 8 - Typical saturated switching characteristics for types 2N5784, 2N5785, & 2N5786.

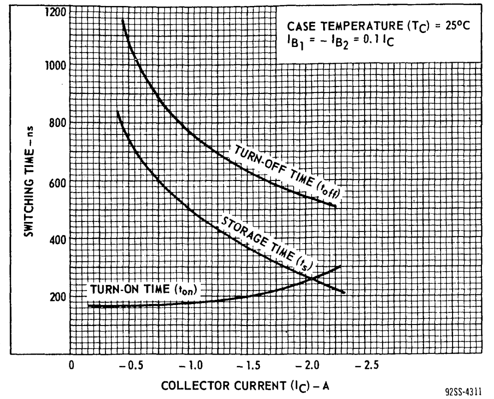


Fig. 9 - Typical saturated switching characteristics for types 2N5781, 2N5782, & 2N5783.

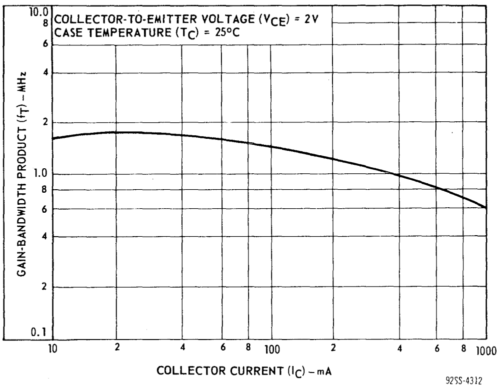


Fig. 10 - Typical gain-bandwidth product for types 2N5784, 2N5785, & 2N5786.

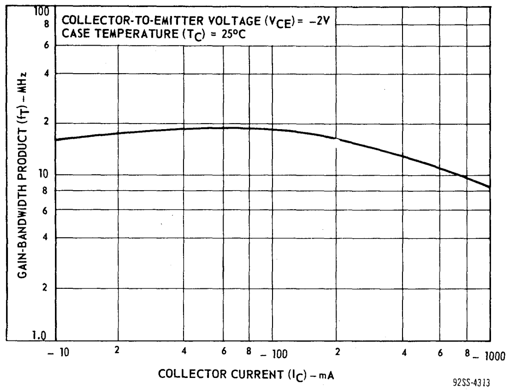


Fig. 11 - Typical gain-bandwidth product for types 2N5781, 2N5782, & 2N5783.

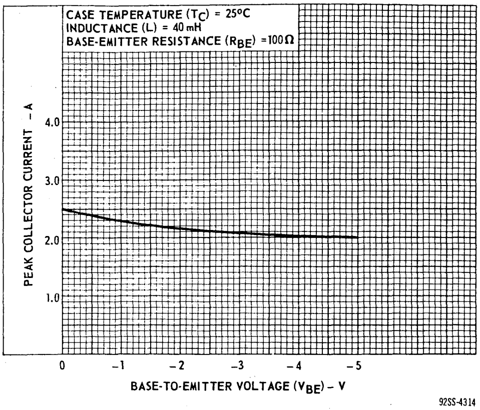


Fig. 12 - Reverse-bias second-breakdown characteristics for types 2N5784, 2N5785, & 2N5786.

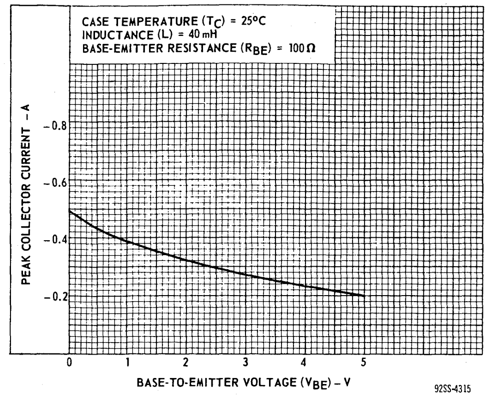


Fig. 13 - Reverse-bias second-breakdown characteristics for types 2N5781, 2N5782, & 2N5783.

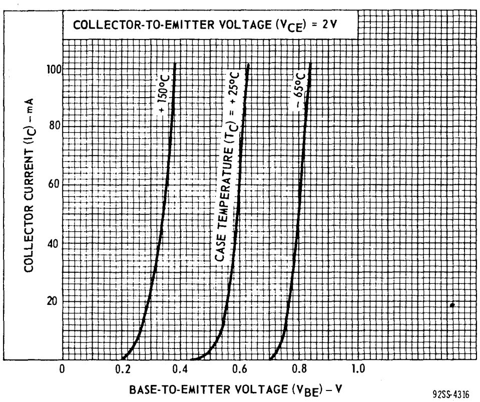


Fig. 14 - Typical transfer characteristics for types 2N5784, 2N5785, & 2N5786.

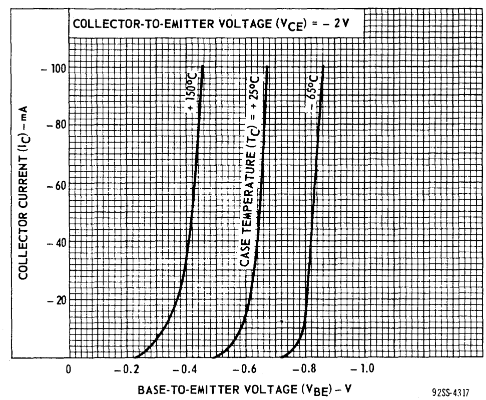


Fig. 15 - Typical transfer characteristics for types 2N5781, 2N5782, & 2N5783.

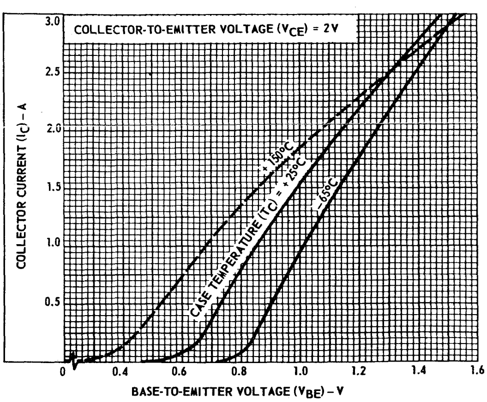


Fig. 16 - Typical transfer characteristics for types 2N5784, 2N5785, & 2N5786.

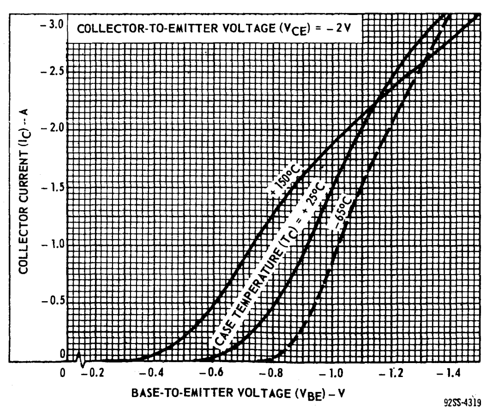


Fig. 17 - Typical transfer characteristics for types 2N5781, 2N5782, 2N5783.

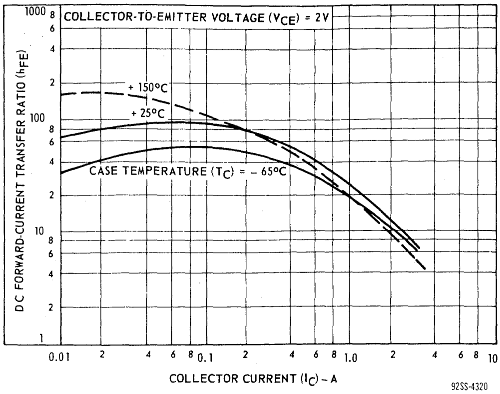


Fig. 18 - Typical DC-beta characteristics for type 2N5784.

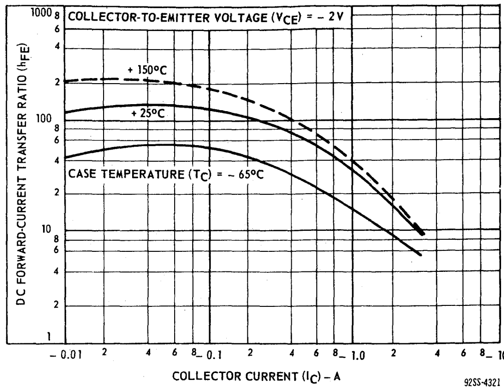


Fig. 19 - Typical DC-beta characteristics for type 2N5781.

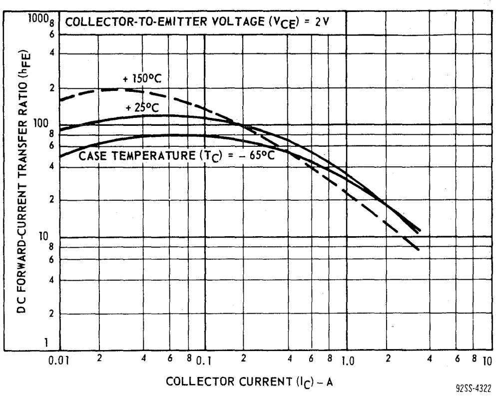


Fig. 20 - Typical DC-beta characteristics for type 2N5785.

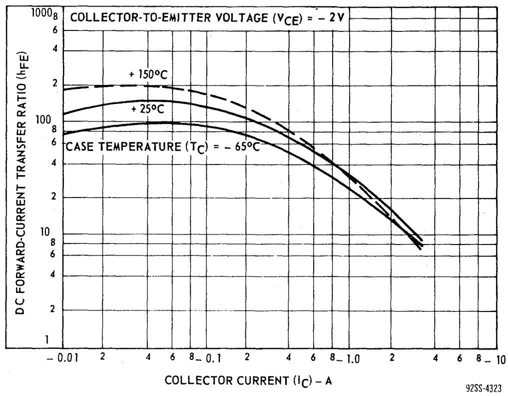


Fig. 21 - Typical DC-beta characteristics for type 2N5782.

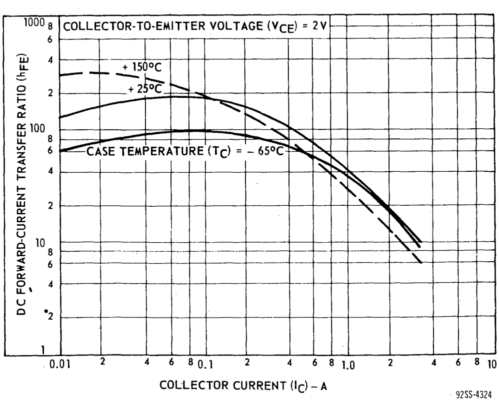


Fig. 22 - Typical DC-beta characteristics for type 2N5786.

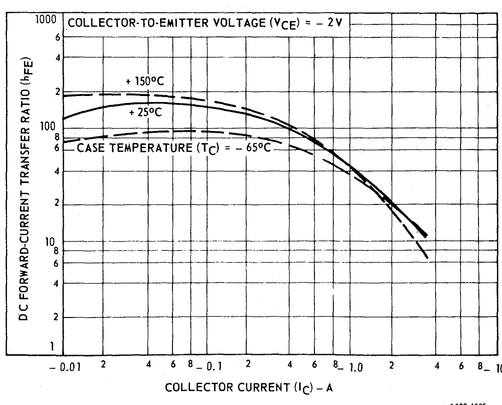


Fig. 23 - Typical DC-beta characteristics for type 2N5783.

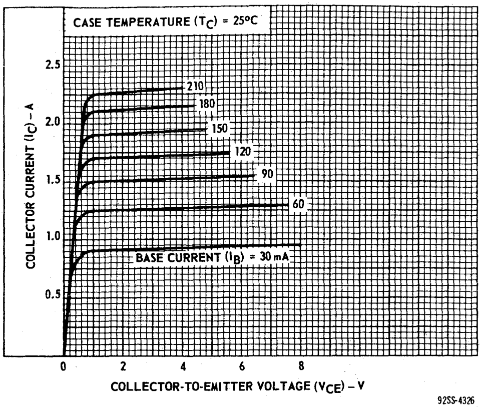


Fig. 24 - Typical output characteristics for type 2N5784.

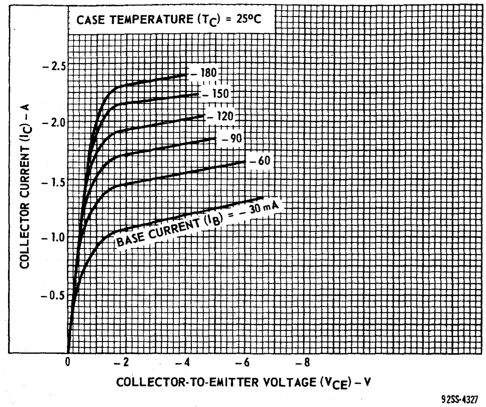


Fig. 25 - Typical output characteristics for type 2N5781.

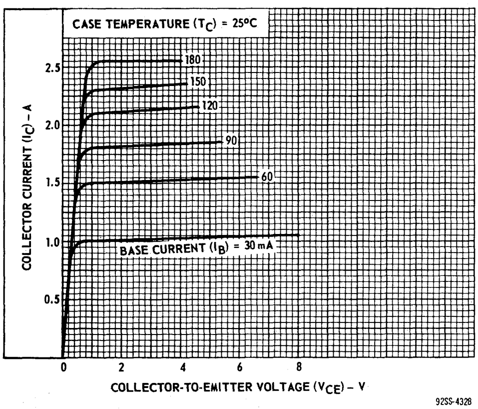


Fig. 26 - Typical output characteristics for type 2N5785.

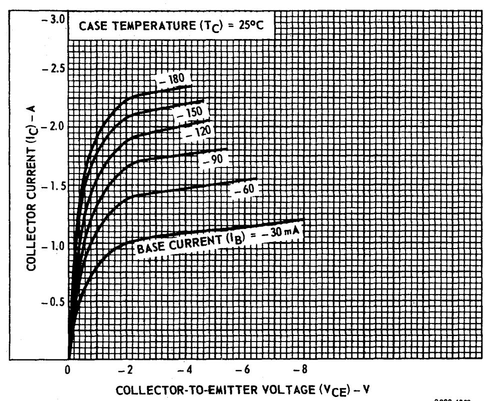


Fig. 27 - Typical output characteristics for type 2N5782.

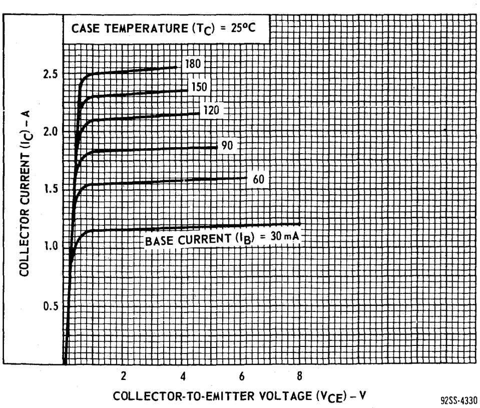


Fig. 28 - Typical output characteristics for type 2N5786.

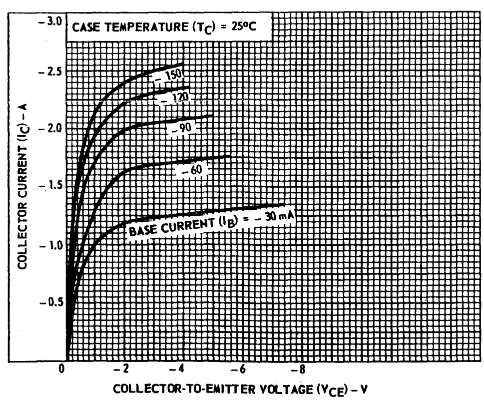


Fig. 29 - Typical output characteristics for type 2N5783.

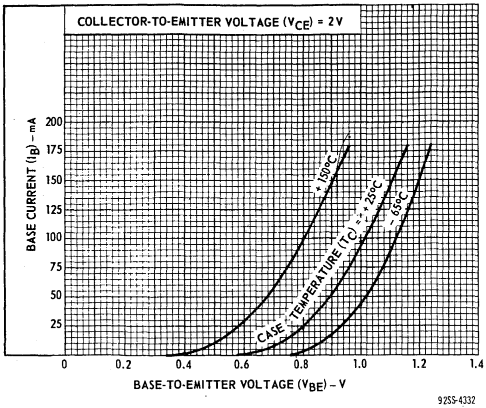


Fig. 30 - Typical input characteristics for type 2N5784.

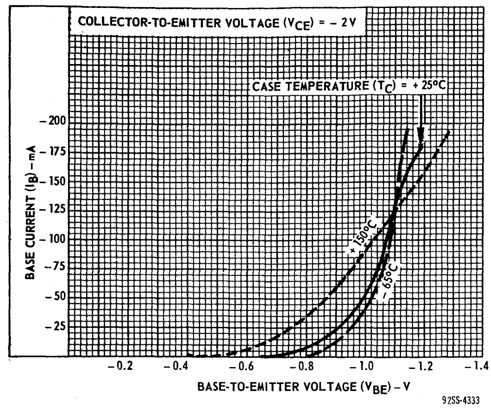


Fig. 31 - Typical input characteristics for type 2N5781.

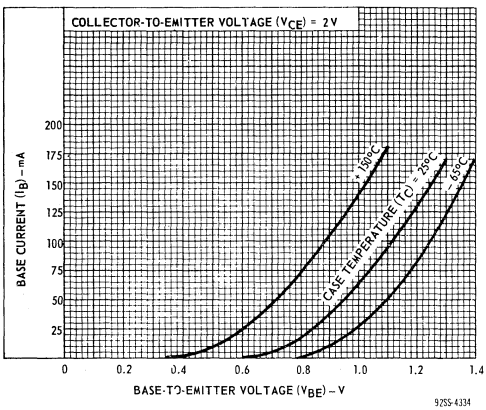


Fig. 32 - Typical input characteristics for type 2N5785.

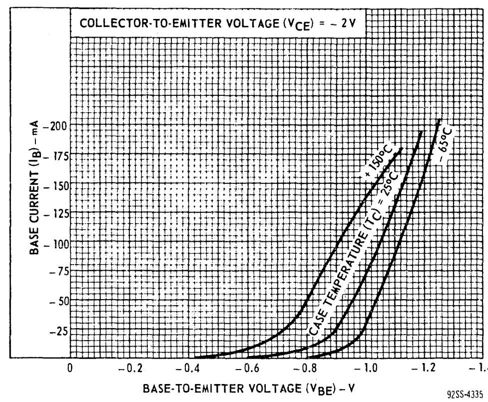


Fig. 33 - Typical input characteristics for type 2N5782.

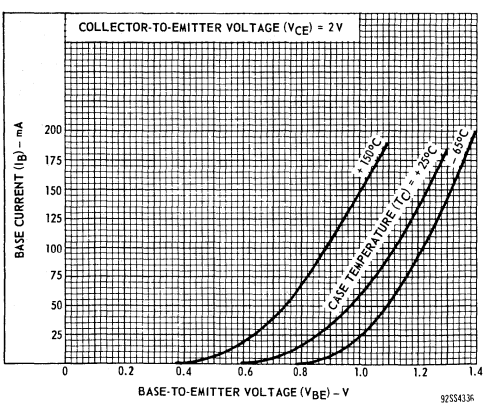


Fig. 34 - Typical input characteristics for type 2N5786.

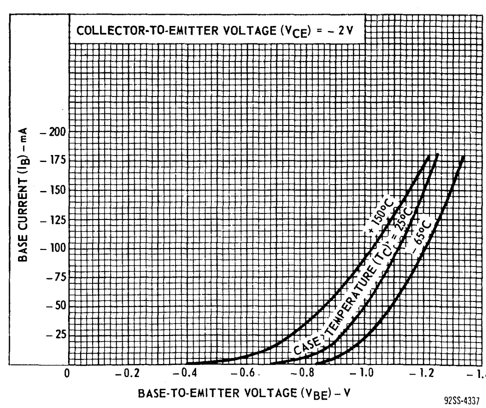
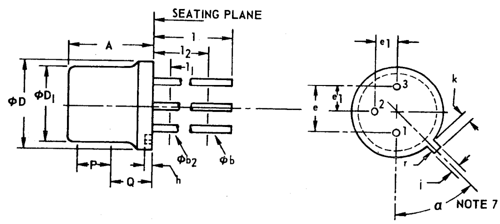


Fig. 35 - Typical input characteristics for type 2N5783.

DIMENSIONAL OUTLINE
(TO-5)



SYMBOL	INCHES		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_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_l and l_2. Φb applies between l_2 and 1.5 in. (38.10 mm) from seating plane. Diameter is uncontrolled in l_l 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

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 diffussed 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	-85	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	-85	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	V_{CER}	-45	-65	-80	V
With base open	V_{CEO}	-40	-60	-75	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

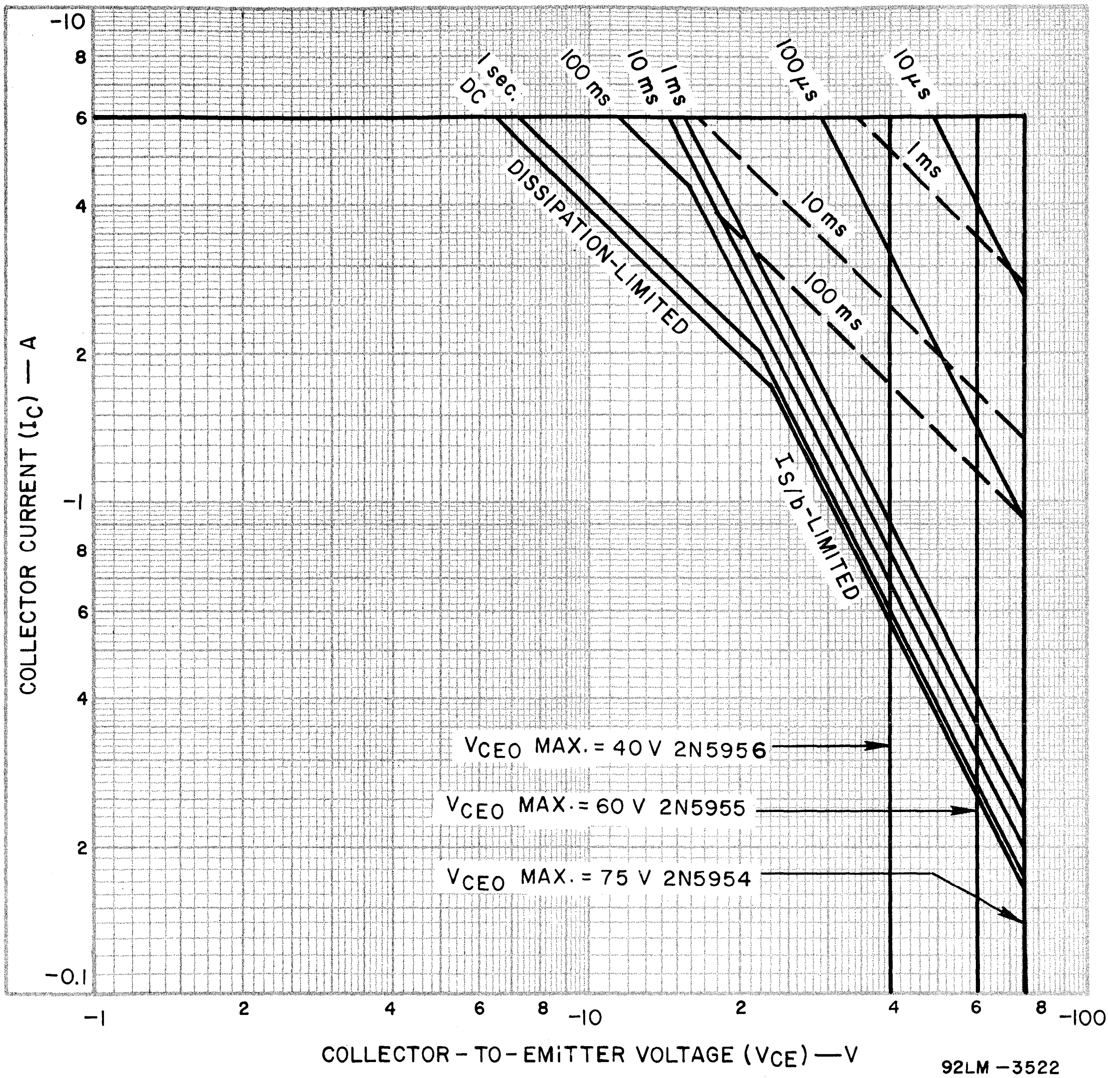
* In accordance with JEDEC registration data format (JS-6 RDF-2)

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	-	-	
		-70						-	-	-	-	-	-100	
	I_{CER} (T_C = 150°C)	-35						-	-2	-	-	-	-	mA
		-55						-	-	-	-2	-	-	
		-70						-	-	-	-	-	-2	
With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE})=100Ω	I_{CEX}	-45		1.5				-	-100	-	-	-	-	μA
		-65		1.5				-	-	-	-100	-	-	
		-80		1.5				-	-	-	-	-	-100	
	I_{CEX} (T_C = 150°C)	-45		1.5				-	-2	-	-	-	-	
		-65		1.5				-	-	-	-2	-	-	
		-80		1.5				-	-	-	-	-	-2	
* Collector-Cutoff Current, Base Open	I_{CEO}	-25						-	-1	-	-	-	-	mA
		-45						-	-	-	-1	-	-	
		-60						-	-	-	-	-	-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}	-	$-.75^{b}$	-	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}	-	-80^{b}	-	
With base-emitter junction reverse biased & external base-to-emitter resistance (R_{BE})=100Ω	$V_{CEX}(sus)$			1.5	-0.1			-50^{b}	-	-70^{b}	-	-85^{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)



COLLECTOR CURRENT (IC) — A
-10
8
6
4
2
-1
8
6
4
2
-0.1
-1
2
4
6
8
-10
2
4
6
8
-100
COLLECTOR-TO-EMITTER VOLTAGE (VCE) — V
DC
1 sec.
100 ms
10 ms
1 ms
100 μs
10 μs
1 ms
10 ms
100 ms
DISSIPATION-LIMITED
Is/b-LIMITED
VCEO MAX. = 40 V 2N5956
VCEO MAX. = 60 V 2N5955
VCEO MAX. = 75 V 2N5954
92LM-3522

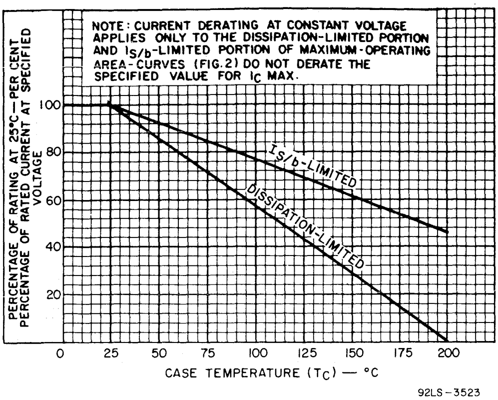


Fig. 2 Dissipation and $I_{s/b}$ derating of all types.

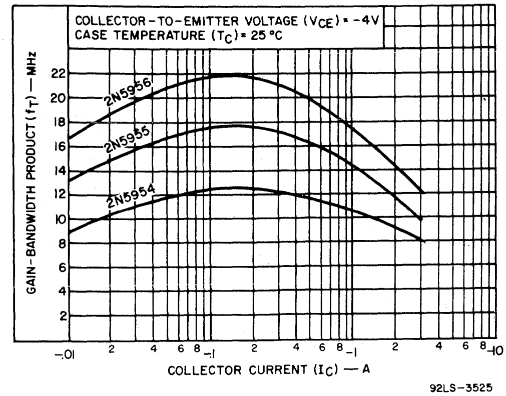


Fig. 3 Typical gain-bandwidth product vs. collector current in all types.

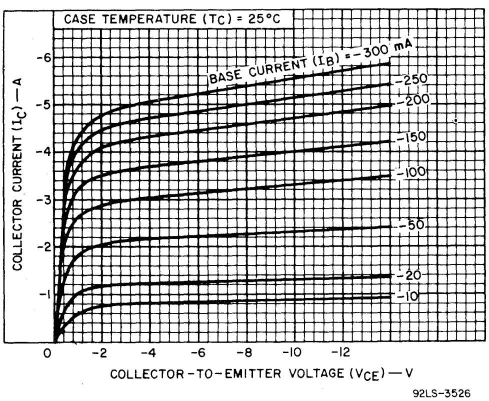


Fig. 4 Typical collector characteristics of 2N5954.

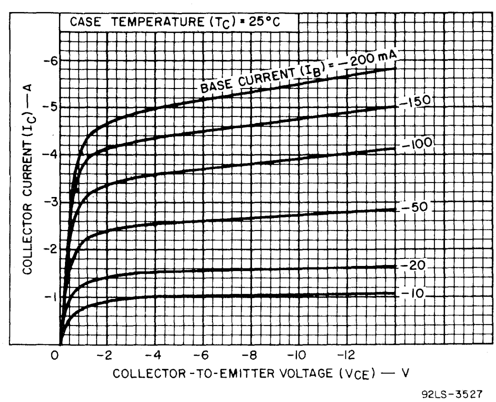


Fig. 5 Typical collector characteristics of 2N5955.

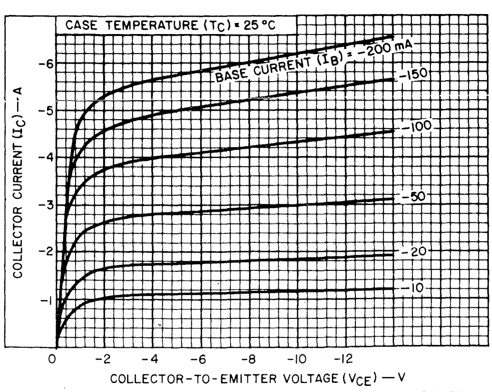


Fig. 6 Typical collector characteristics of 2N5956.

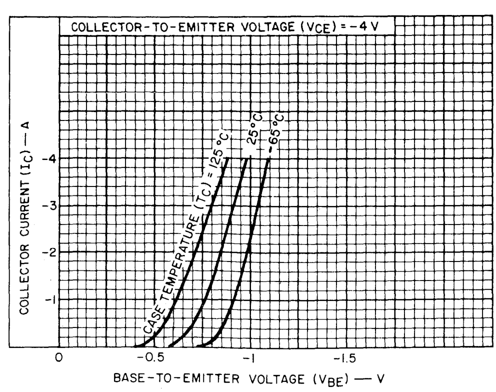
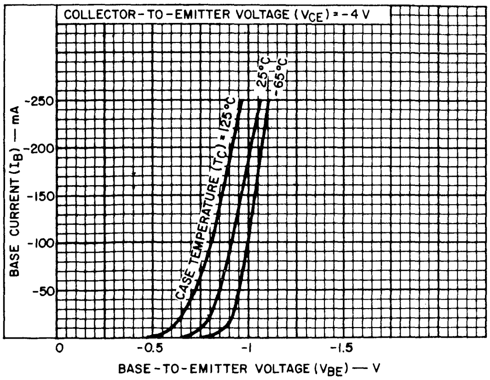
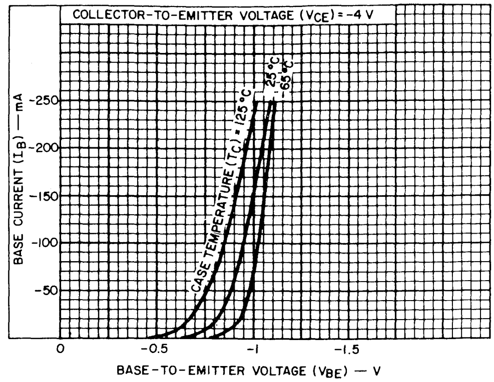


Fig. 7 Typical transfer characteristics of all types.



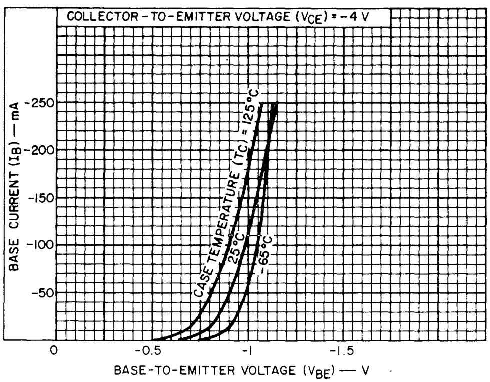
92LS-3530

Fig. 8 Typical input characteristics of 2N5954.



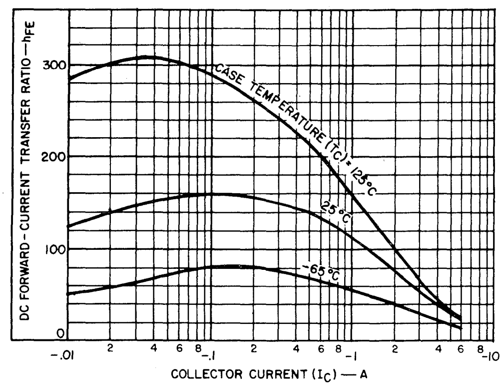
92LS-3531

Fig. 9 Typical input characteristics of 2N5955.



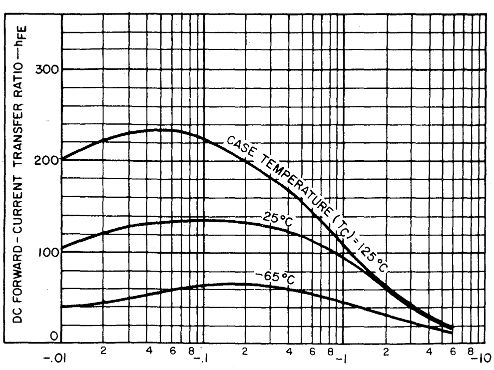
92LS-3532

Fig. 10 Typical input characteristics of 2N5956.



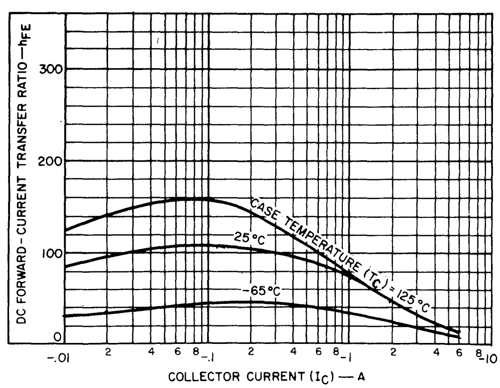
92LS-3533

Fig. 11 Typical dc beta characteristics of 2N5956.



92LS-3534

Fig. 12 Typical dc beta characteristics of 2N5955.



92LS-3535

Fig. 13 Typical dc beta characteristics of 2N5954.

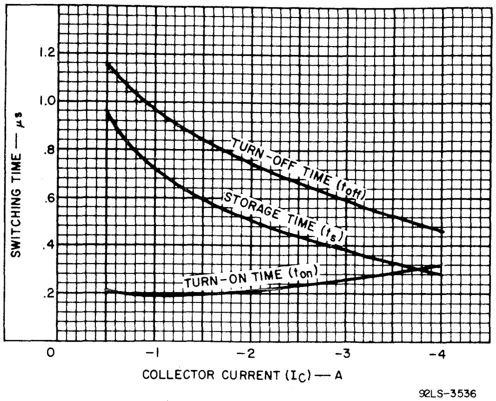


Fig. 14 Typical saturated switching characteristics for all types.

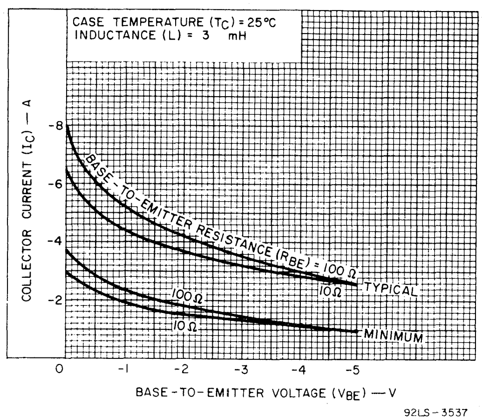


Fig. 15 Reverse bias second-breakdown characteristics for all types.

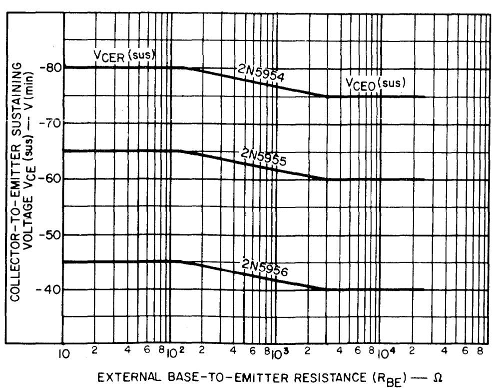


Fig. 16 Collector-to-emitter sustaining voltage characteristics for types 2N5954, 2N5955 and 2N5956.

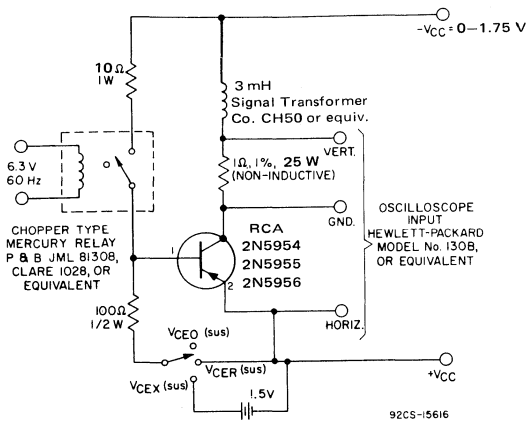
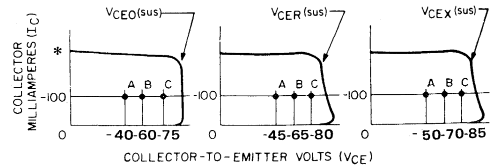


Fig. 17 Circuit used to measure sustaining voltages $V_{CEO}(sus)$ $V_{CER}(sus)$, & $V_{CEX}(sus)$ for all types.



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

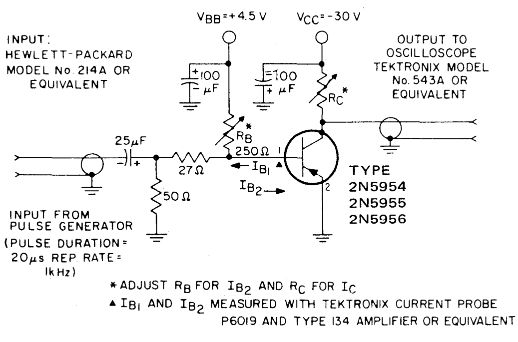


Fig. 19 - Circuit used to measure saturated switching times.

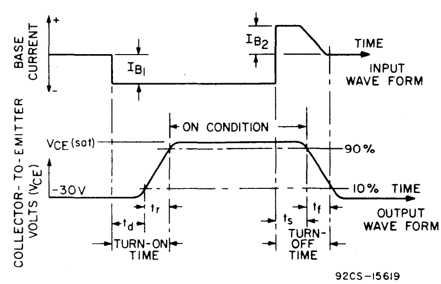


Fig. 20- Oscilloscope display for measurement of switching times.

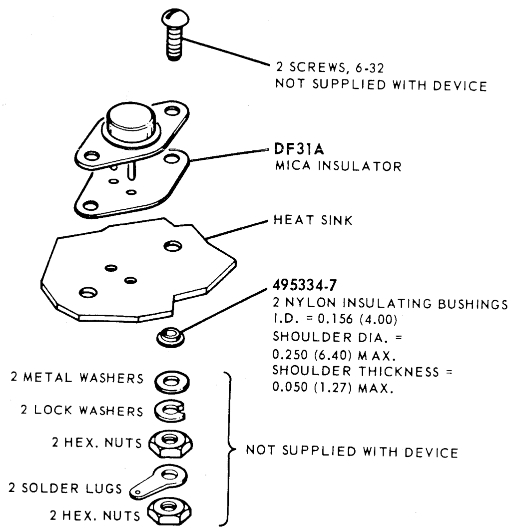
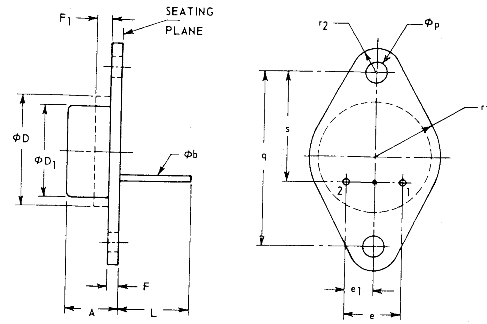


Fig. 21 Suggested hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.250	.340	6.35	8.64	
Φb	.028	.034	.711	.863	
ΦD		.620		15.75	
$ΦD_1$	.470	.500	11.94	12.70	
e	.190	.210	4.83	5.33	
e_1	.093	.107	2.36	2.72	
F	.050	.075	1.27	1.91	2
F_1		.050		1.27	1
L	.360		9.14		
Φp	.142	.152	3.61	3.86	
q	.958	.962	24.33	24.43	
r_1		.350		8.89	
r_2		.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

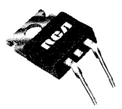
Pin 1 - Base
Pin 2 - Emitter
Mounting Flange, Case - Collector

RCA

Solid State
Division

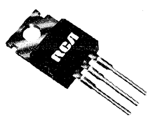
Power Transistors

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.

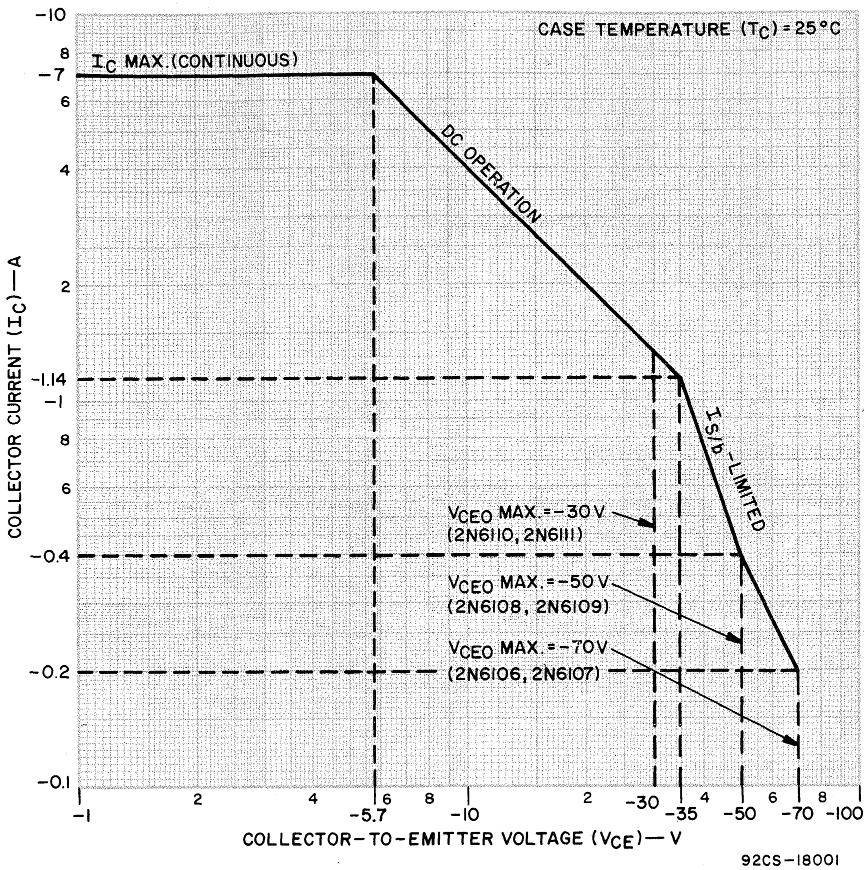


Fig.1—Maximum operating areas for types 2N6106—2N6111.

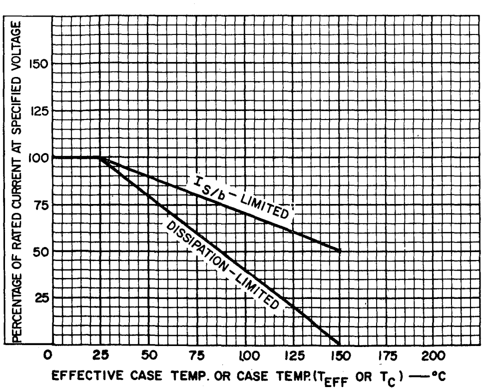


Fig.2—Derating curves for types 2N6106—2N6111.

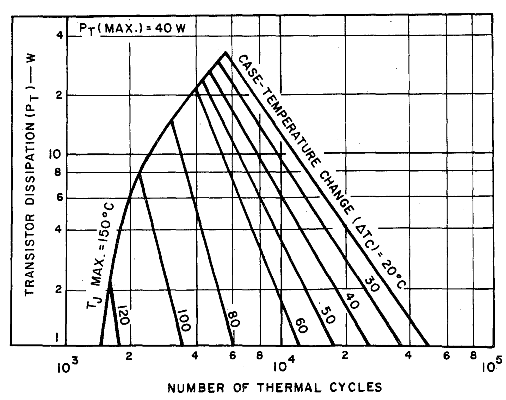


Fig.3—Thermal-cycling ratings for types 2N6106—2N6111.

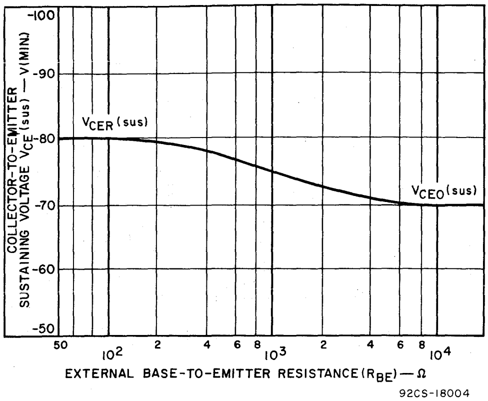


Fig.4—Collector-to-emitter sustaining-voltage characteristic for types 2N6106 & 2N6107.

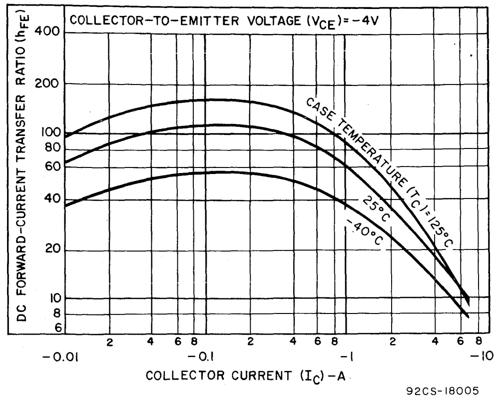


Fig.5—Typical dc beta characteristics for types 2N6106 & 2N6107.

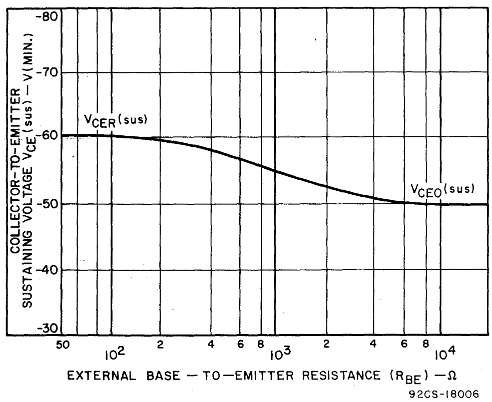


Fig.6—Collector-to-emitter sustaining-voltage characteristic for types 2N6108 & 2N6109.

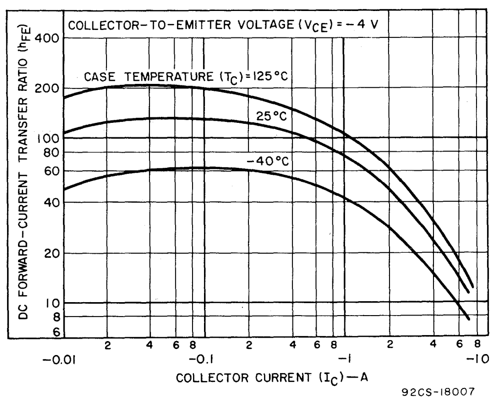


Fig.7—Typical dc beta characteristics for types 2N6108 & 2N6109.

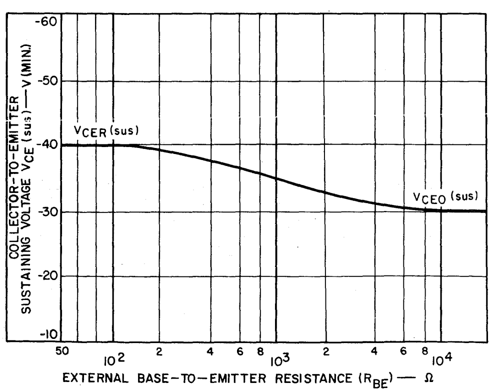


Fig.8—Collector-to-emitter sustaining-voltage characteristic for types 2N6110 & 2N6111.

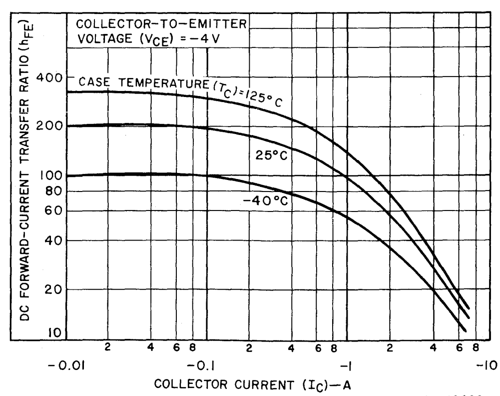


Fig.9—Typical dc beta characteristics for types 2N6110 & 2N6111.

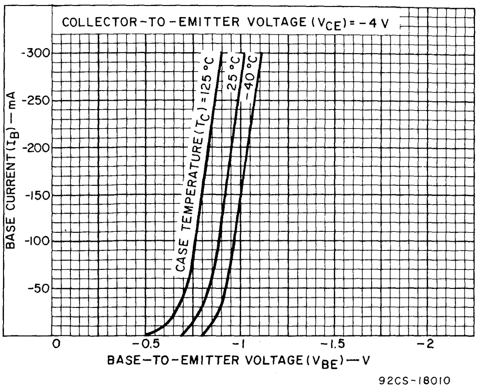


Fig.10—Typical input characteristics for types 2N6106 & 2N6107.

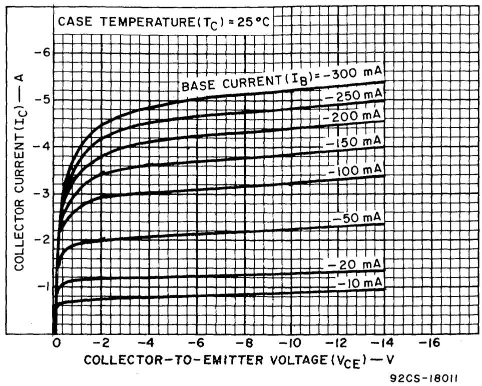


Fig.11—Typical output characteristics for types 2N6106 & 2N6107.

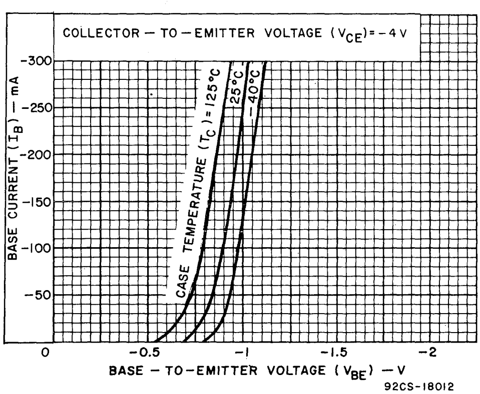


Fig.12—Typical input characteristics for types 2N6108 & 2N6109.

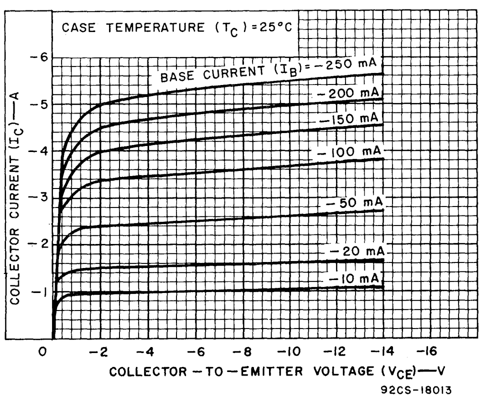


Fig.13—Typical output characteristics for types 2N6108 & 2N6109.

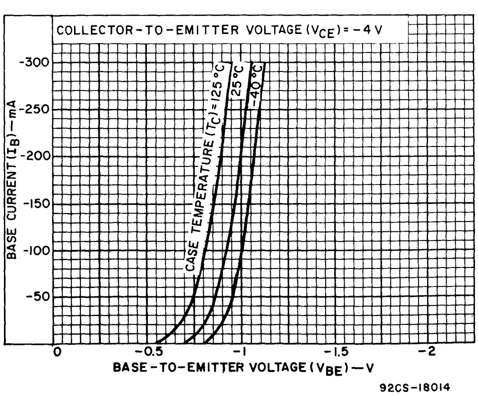


Fig.14—Typical input cnaracteristics for types 2N6110 & 2N6111.

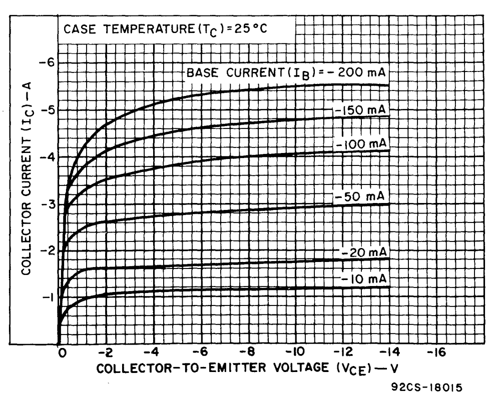


Fig.15—Typical output characteristics for types 2N6110 & 2N6111.

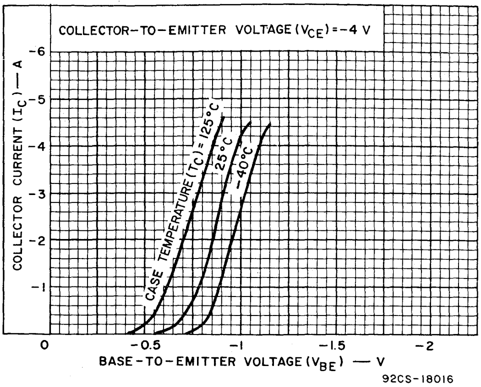


Fig.16—Typical transfer characteristics for types 2N6106—— 2N6111.

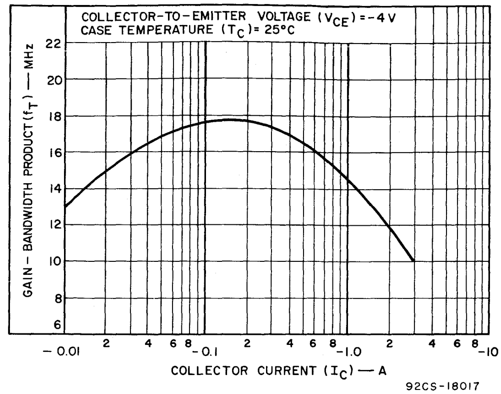


Fig.17—Typical gain-bandwidth product for types 2N6106—— 2N6111.

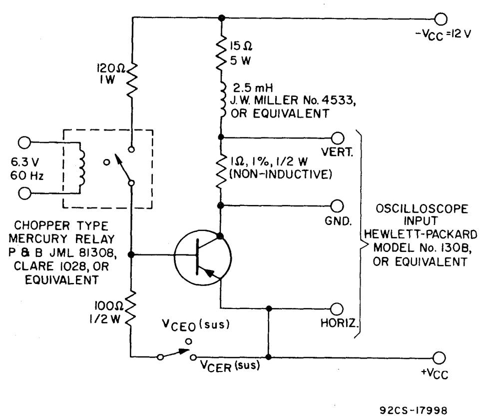
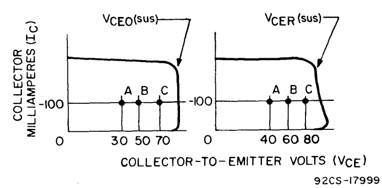


Fig.18—Circuit used to measure sustaining voltages V_{CEO}(sus) & V_{CER}(sus) for types 2N6106 —— 2N6111.



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).

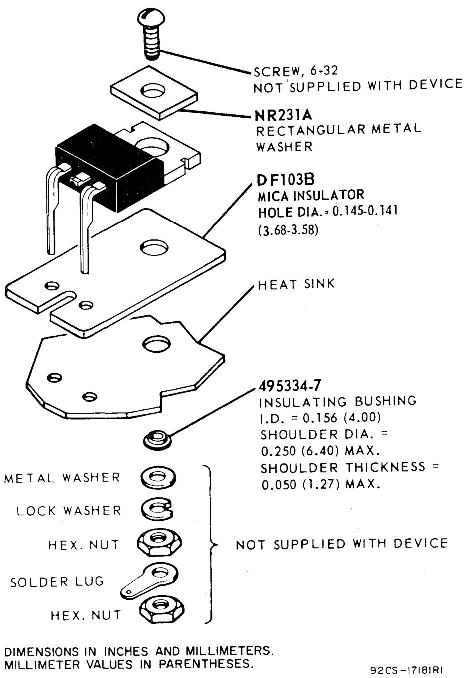


Fig.20–Suggested mounting hardware for types 2N6106, 2N6108, & 2N6110.

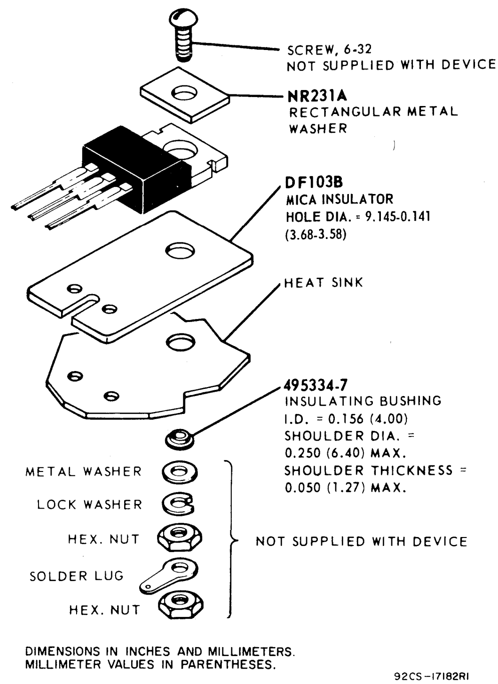
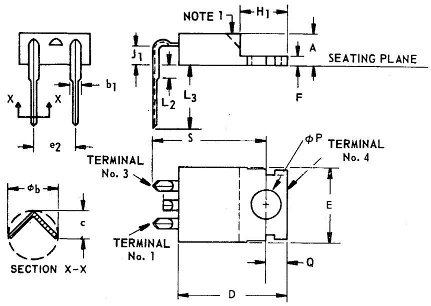


Fig.21–Suggested mounting hardware for types 2N6107, 2N6109, & 2N6111.

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

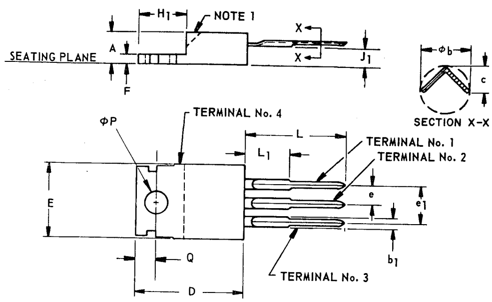


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.140	0.190	3.56	4.82	–
ϕb	0.02	0.045	0.51	1.14	–
b_1	0.045	0.070	1.15	1.77	–
c	0.015	0.030	0.38	0.762	–
D	0.560	0.625	14.23	15.87	–
E	0.380	0.420	9.66	10.66	2
e_2	0.190	0.210	4.83	5.33	3
F	0.045	0.055	1.15	1.39	–
H_1	0.230	0.270	5.85	6.85	2
J_1	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

2N6211
2N6212
2N6213

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) = –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 and 2N6213● 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 and TA8330, respectively.

Applications:

- **Power-Switching Circuits**
- **Switching Regulators**
- **Converters**
- **Inverters**
- **High-Fidelity Amplifiers**

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N6211	2N6212	2N6213	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	–275	–350	–400	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:					
With base open	V_{CEO}(sus)	–225	–300	–350	V
With external base-to-emitter resistance (R_{BE}) = 50 Ω	V_{CER}(sus)	–250	–325	–375	V
* With base-emitter junction reverse-biased (V_{BE} = 1.5 V)	V_{CEX}(sus)	–275	–350	–400	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	–6	–6	–6	V
*COLLECTOR CURRENT (Continuous)	I_C	–2	–2	–2	A
*BASE CURRENT (Continuous)	I_B	–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	W
At case temperatures up to 25°C and V_{CE} up to 40 V		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.	Typ.	Max.	2N6212 Min.	Typ.	Max.	2N6213 Min.	Typ.	Max.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}	−150				0	–	–	−5	–	–	−5	–	–	−5	
* With base-emitter junction reverse-biased	I_{CEV}	−250	1.5				–	–	−0.5	–	–	–	–	–	–	
		−315	1.5				–	–	–	–	–	−0.5	–	–	–	
		−360	1.5				–	–	–	–	–	–	–	–	−0.5	mA
* With base-emitter junction reverse biased and T_C = 100°C		−250	1.5				–	–	−5	–	–	–	–	–	–	
		−315	1.5				–	–	–	–	–	−5	–	–	–	
		−360	1.5				–	–	–	–	–	–	–	–	−5	
* Emitter-Cutoff Current	I_{EBO}		6	0			–	–	−1	–	–	−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			30	50	175	30	50	175	30	50	150	
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$			−0.2		0	−225	–	–	−300	–	–	−350	–	–	
With external base-to-emitter resistance (R_{BE}) = 50 Ω	$V_{CER}(sus)$			−0.2			−250	–	–	−325	–	–	−375	–	–	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	–	–	
Emitter-to-Base Voltage	V_{EBO}					0.5 mA	–	–	–	−6	–	–	−6	–	–	V
						1 mA	−6	–	–	–	–	–	–	–	–	
* Emitter-to-Base Saturation Voltage	$V_{BE}(sat)$			−1		−0.125	–	−0.9	−1.4	–	−0.9	−1.4	–	−0.9	−1.4	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			−1		−0.125	–	−0.7	−1.4	–	−0.9	−1.6	–	−1.2	−2	V
Output Capacitance (f = 1 MHz)	C_{obo}	−10 (V_{CB})			0		–	125	220	–	125	220	–	125	220	pF
Second-Breakdown Collector Current (Base forward-biased)	$I_{S/b}$	−40					−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	6	–	4	6	–	4	6	–	
* Saturated Switching Times: Rise time	t_r	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	0.17	0.6	–	0.17	0.6	–	0.17	0.6	
Storage time	t_s	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	1.2	2.5	–	1.2	2.5	–	1.2	2.5	μs
Fall time	t_f	V_{CC} = −200 V		−1		I_{B1} & I_{B2} −0.125	–	0.2	0.6	–	0.2	0.6	–	0.2	0.6	
Thermal Resistance (Junction-to-case)	$R_{\theta JC}$	−10		−1			–	2.5	5	–	2.5	5	–	2.5	5	°C/W

*In accordance with JEDEC registration data format JS-6 RDF-1.

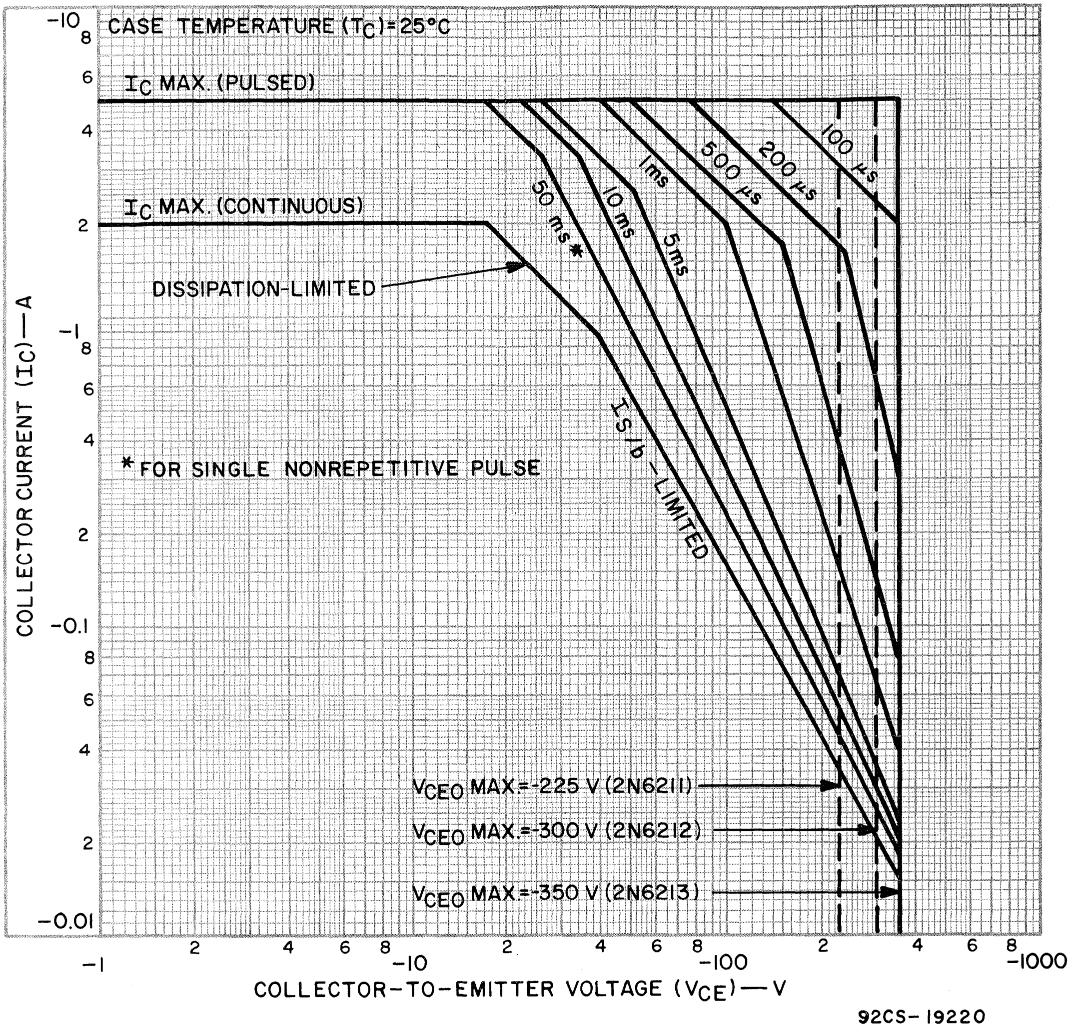


Fig.1—Maximum operating areas for all types.

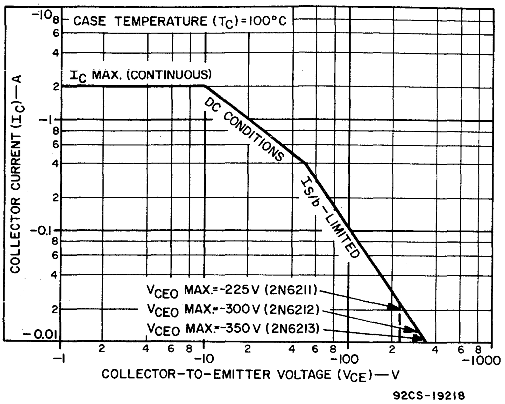


Fig.2—Maximum operating areas for all types.

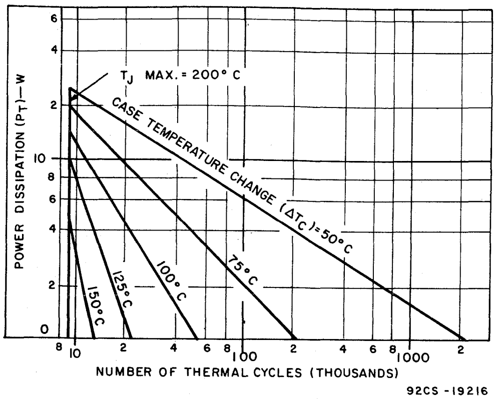


Fig.3—Thermal-cycling rating chart.

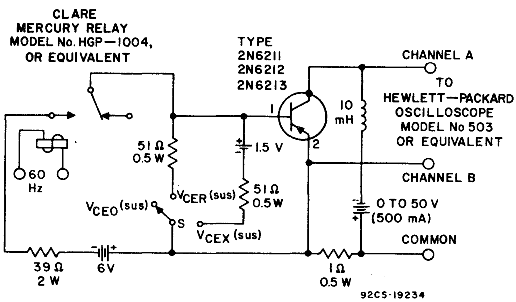
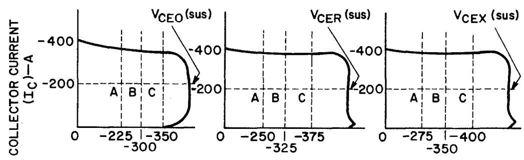


Fig.4—Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$ and $V_{CEX}(sus)$ for all types.



NOTE:
SUSTAINING VOLTAGES V_{CEO}(sus), V_{CER}(sus), AND V_{CEX}(sus) ARE ACCEPTABLE WHEN TRACES FALL TO THE RIGHT AND ABOVE POINTS "A" FOR TYPE 2N6211, POINTS "B" FOR TYPE 2N6212, AND POINTS "C" FOR TYPE 2N6213.

92CS-19235

Fig.5—Oscilloscope display for measurement of sustaining voltages (test circuit shown in Fig.3).

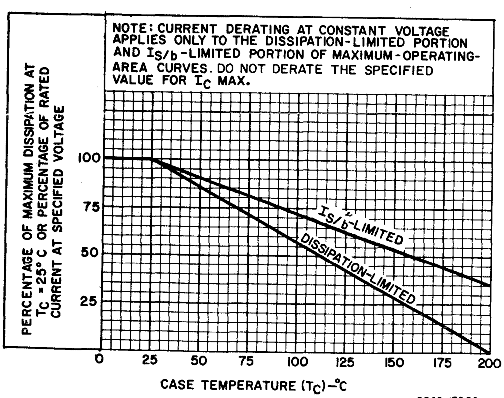


Fig.6—Derating curves for all types.

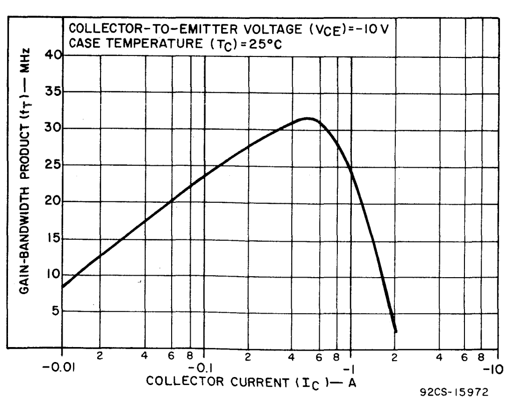


Fig.7—Typical gain-bandwidth product for all types.

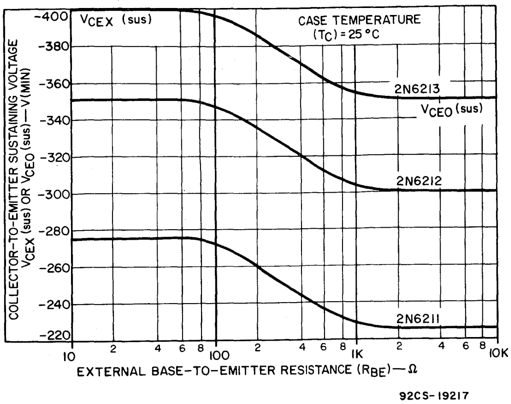


Fig.8—Collector-to-emitter sustaining-voltage characteristics for all types.

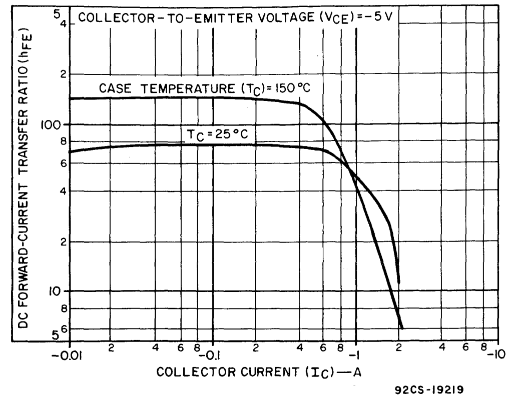


Fig.9—Typical dc beta characteristic for all types.

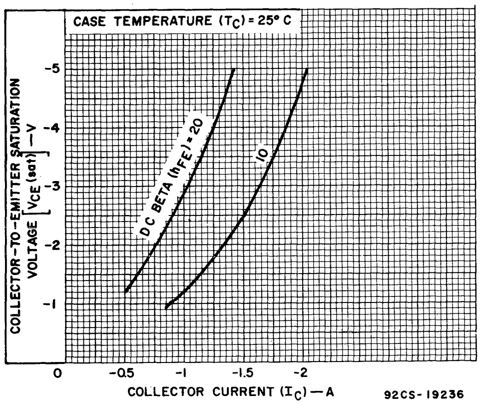


Fig.10—Typical saturation-voltage characteristics for all types.

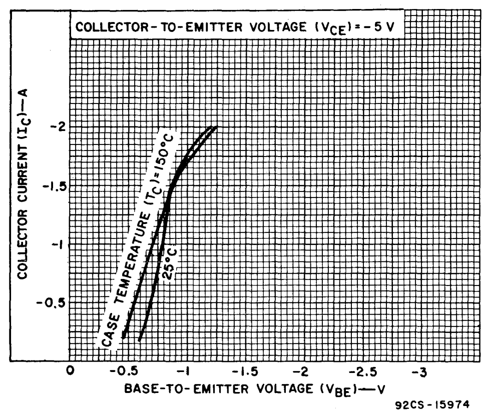


Fig.11—Typical transfer characteristics for all types.

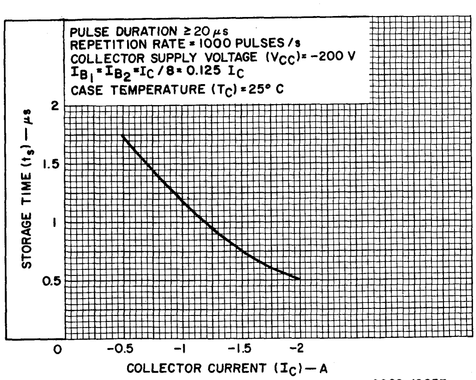


Fig.12—Typical storage-time characteristic for all types.

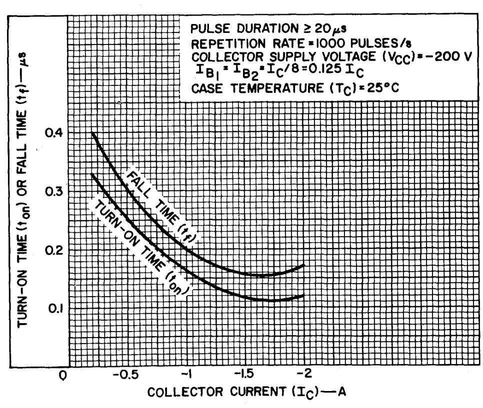


Fig.13—Typical turn-on time and fall-time characteristics for all types.

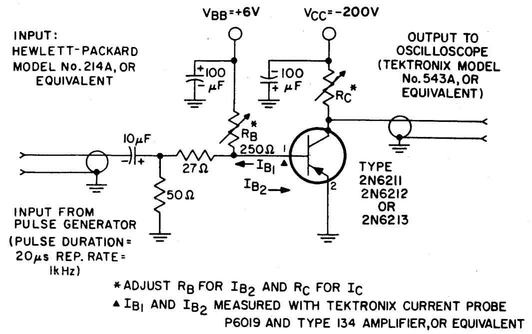


Fig.14—Circuit used to measure saturated switching times for all types.

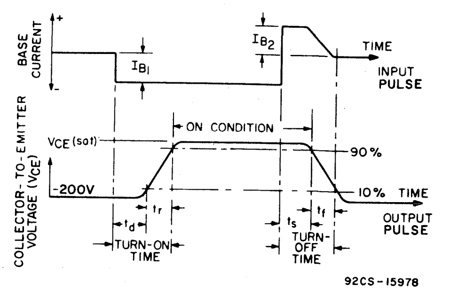


Fig.15—Phase relationship between input current and output voltage showing reference points for specification of switching times. (Test circuit shown in Fig.14).

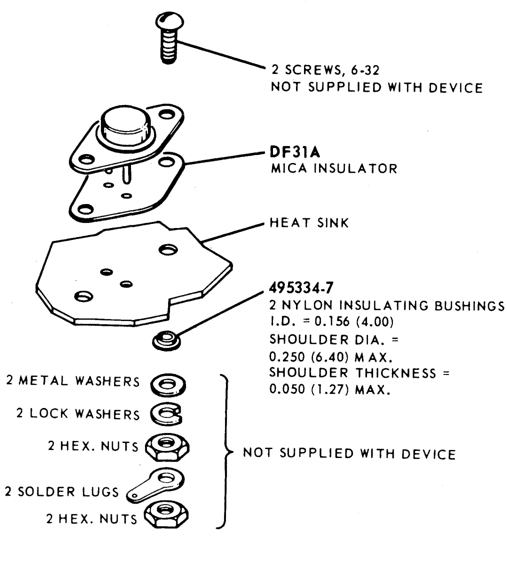
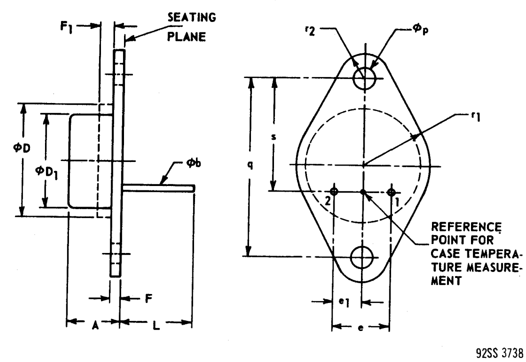


Fig.16—Suggested mounting hardware for all types.

DIMENSIONAL OUTLINE (JEDEC TO-66)



SYMBOL	INCHES 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	0.050	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

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}	V_{BE}	DC Current (A) I_C	I_B	LIMITS Type 2N6246 Min.	Max.	Type 2N6247 Min.	Max.	Type 2N6248 Min.	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
		[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.*											
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

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

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

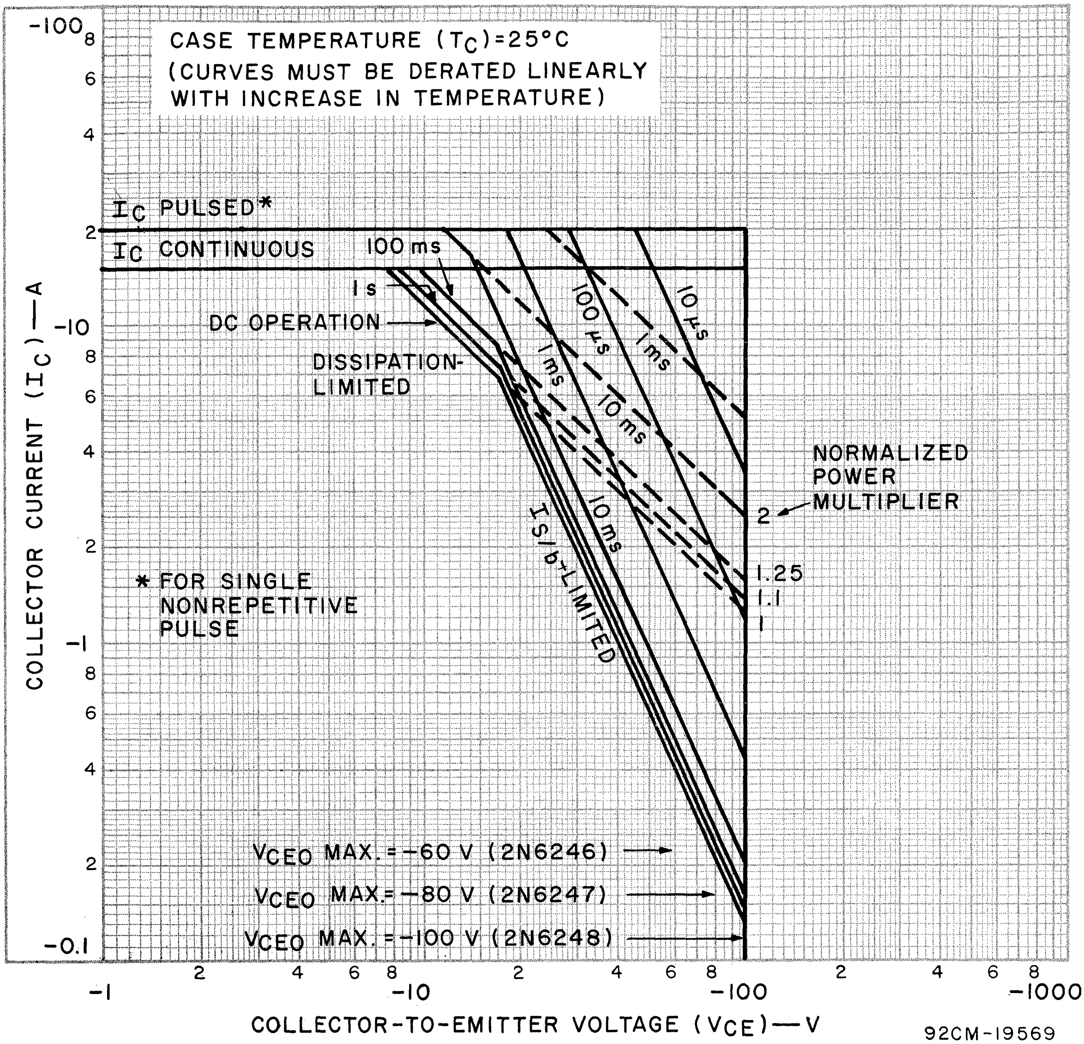


Fig. 1—Maximum operating area for all types.

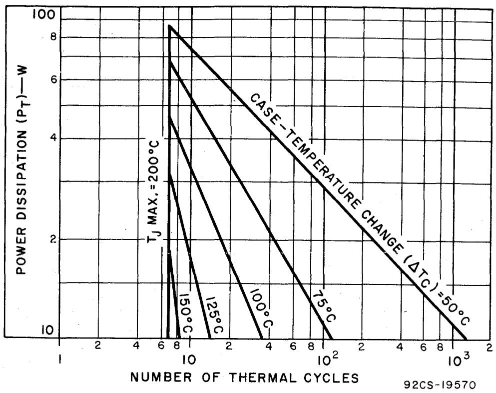


Fig.2—Thermal-cycle rating chart for all types.

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.

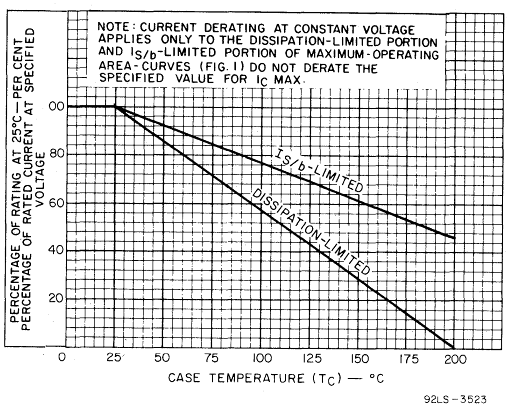


Fig.3—Dissipation and $I_{S/b}$ derating of all types.

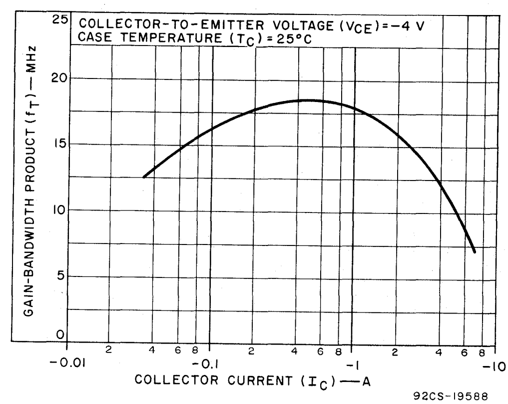


Fig.4—Typical gain-bandwidth product vs. collector current for all types.

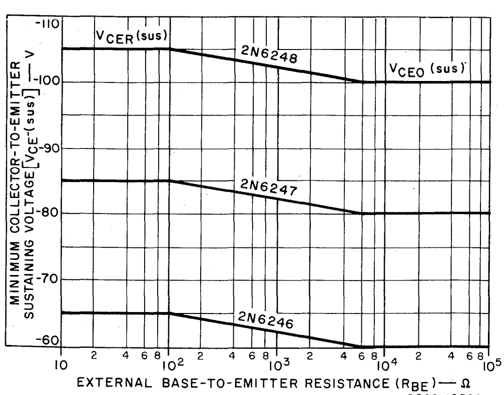


Fig.5—Collector-to-emitter sustaining voltage characteristics for all types.

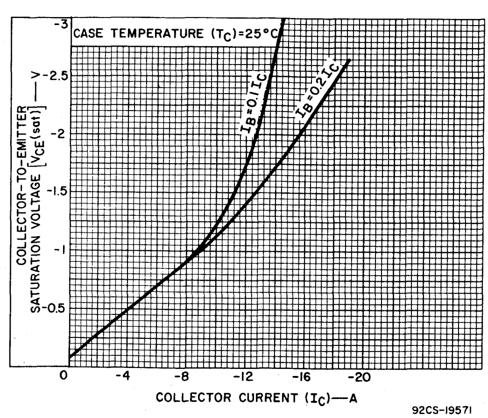


Fig.6—Typical collector-to-emitter saturation voltage vs. collector current for all types.

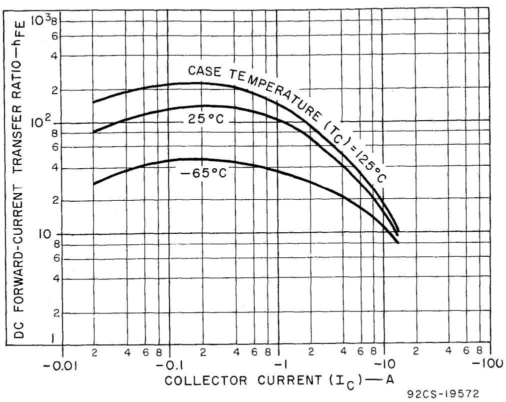


Fig.7—Typical dc beta characteristics of type 2N6248.

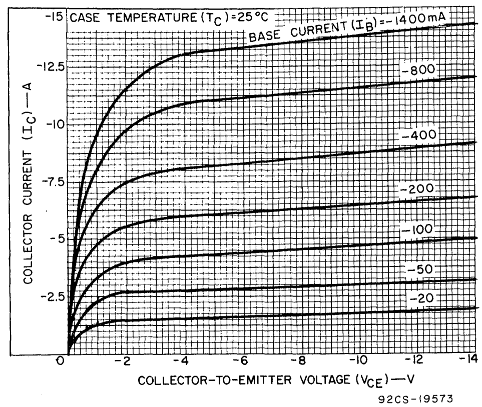


Fig.8—Typical collector characteristics of type 2N6248.

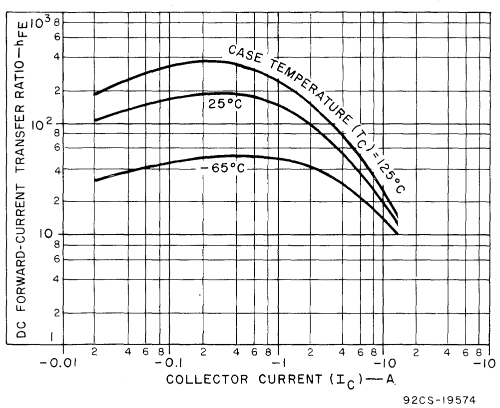


Fig.9—Typical dc beta characteristics of type 2N6247.

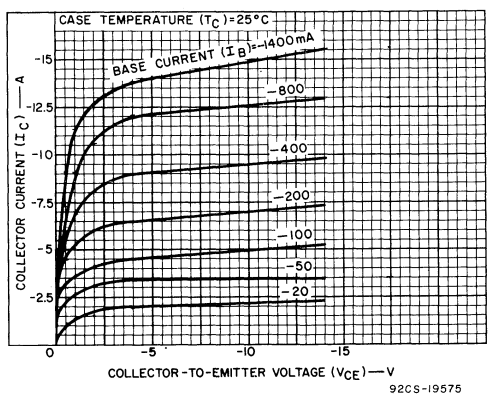


Fig.10—Typical collector characteristics of type 2N6247.

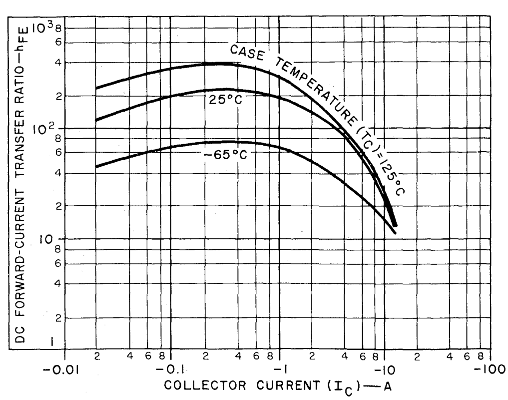


Fig.11—Typical dc beta characteristics of type 2N6246.

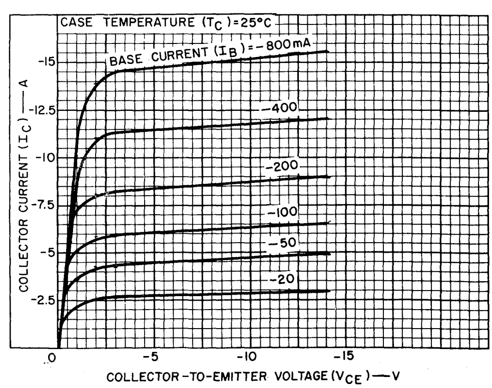


Fig.12—Typical collector characteristics of type 2N6246.

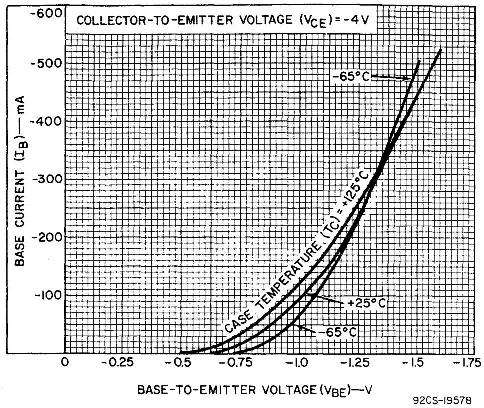


Fig. 13—Typical input characteristics of type 2N6248.

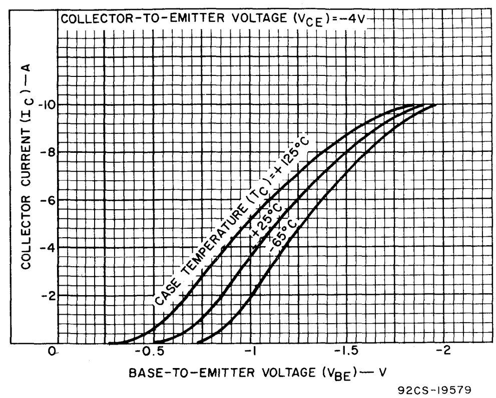


Fig. 14—Typical transfer characteristics for all types.

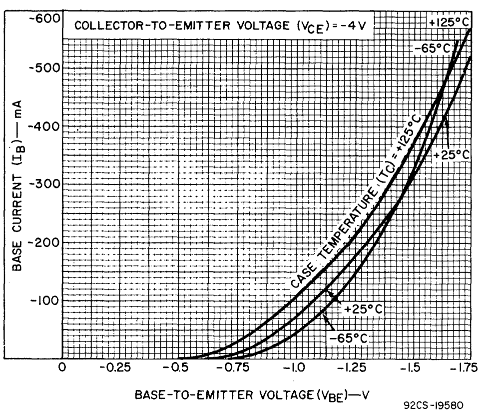


Fig. 15—Typical input characteristics of type 2N6247.

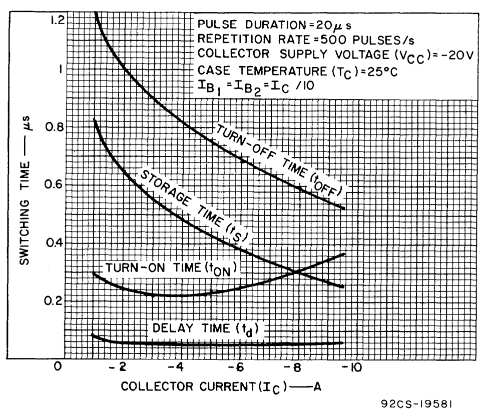


Fig. 16—Typical saturated switching characteristics for all types.

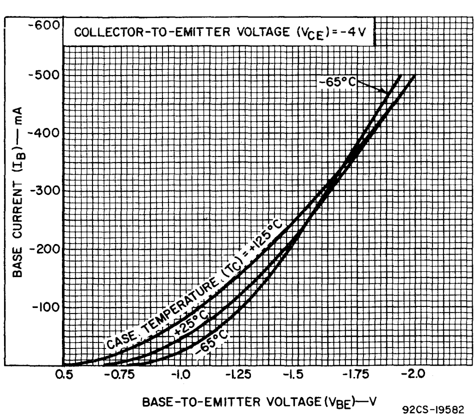


Fig. 17—Typical input characteristics of type 2N6246.

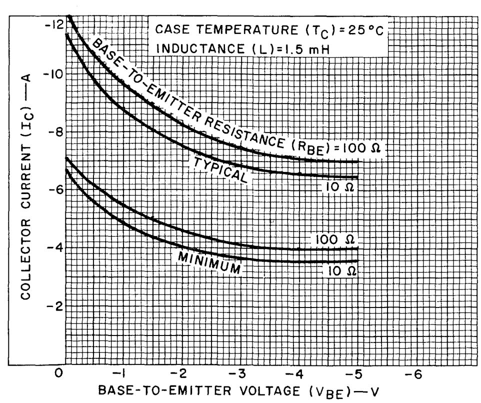


Fig. 18—Reverse-bias second-breakdown characteristics for all types.

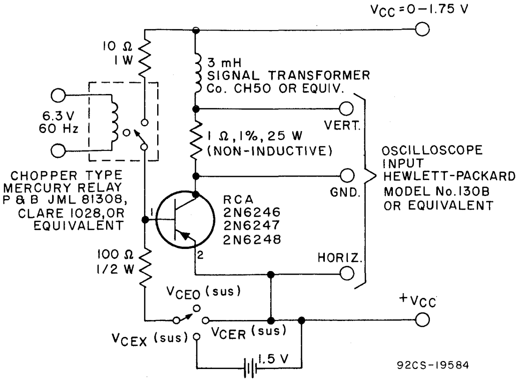
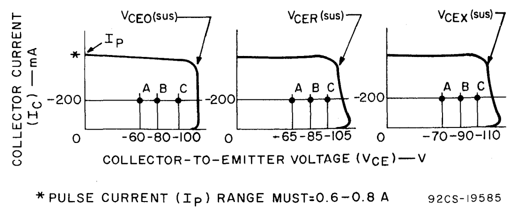


Fig.19—Circuit used to measure sustaining voltages $V_{CEO}(sus)$, $V_{CER}(sus)$, and $V_{CEX}(sus)$ for all types.



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).

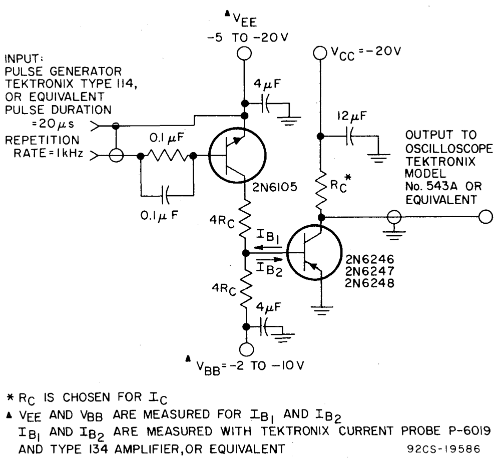


Fig.21—Circuit used to measure saturated switching times.

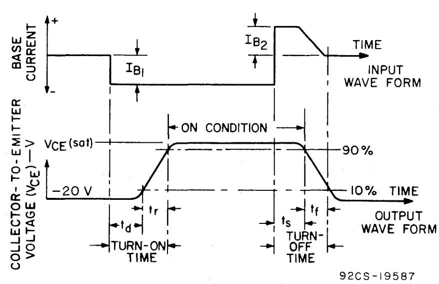


Fig.22—Oscilloscope display for measurement of switching times.

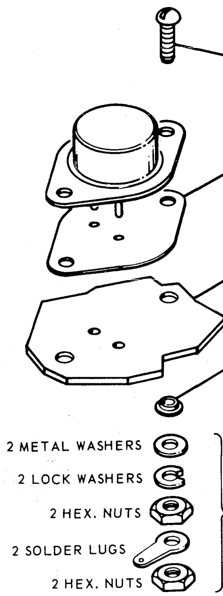
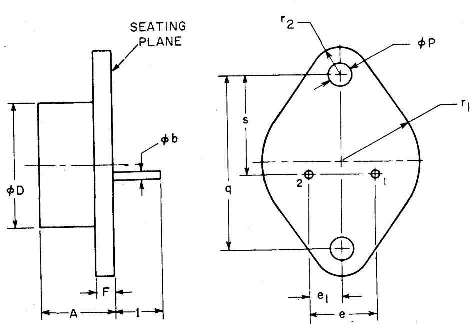


Fig.23—Suggested mounting hardware.

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

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

Diffused-Junction n-p-n Silicon Transistors

RCA

Solid State
Division

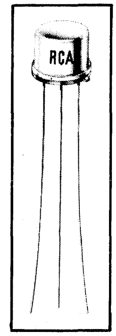
Power Transistors

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



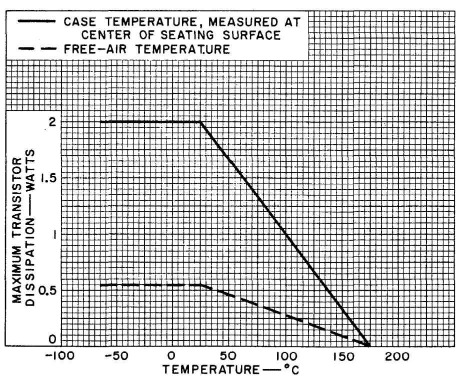
JEDEC TO-5

- 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.



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

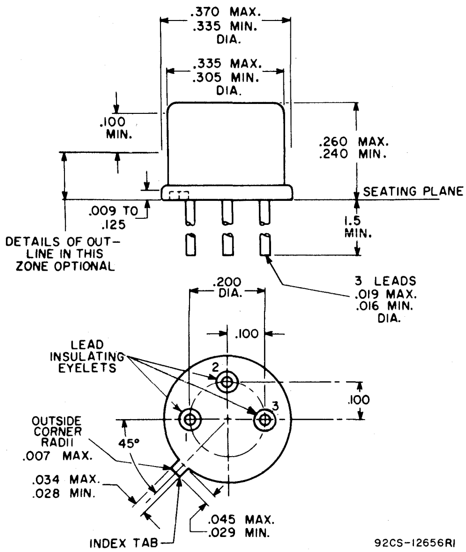
[a] Pulsed to prevent excessive heating of collector junction.

[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

RCA

Solid State
Division

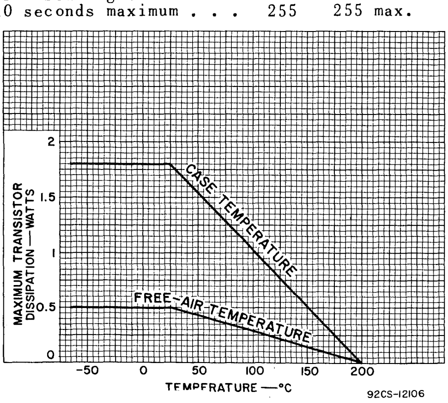
Power Transistors

2N718A
2N720A

RCA-2N718A and 2N720A are triple-diffused-junction planar transistors of the silicon n-p-n type intended for a wide variety of small-signal and switching applications in military and industrial equipment. These transistors feature low noise and leakage characteristics, high pulsed beta over a wide range of collector current, and high switching-speed capabilities.

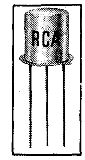
Maximum Ratings, *Absolute-Maximum Values:*

	2N720A	2N718A		
COLLECTOR-TO-BASE VOLTAGE WITH EMITTER OPEN, V_{CBO}.	120	75	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE WITH $R_{BE} \leq 10$ OHMS, V_{CER}	100	50	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE WITH BASE OPEN, V_{CEO}	80	32	max.	volts
EMITTER-TO-BASE VOLTAGE WITH COLLECTOR OPEN, V_{EBO}	7	7	max.	volts
TRANSISTOR DISSIPATION, P_T:				
At case temperatures				
up to 25° C.	1.8	1.8	max.	watts
above 25° C.	See Rating Chart			
At free-air temperatures				
up to 25° C.	0.5	0.5	max.	watt
above 25° C.	See Rating Chart			
TEMPERATURE RANGE:				
Storage.	-65 to +300			°C
Operating (Junction) . .	-65 to +200			°C
LEAD TEMPERATURE (DURING SOLDERING):				
At distances ≥ 1/32 inch from seating surface for 10 seconds maximum . . .	255	255	max.	°C



Rating Chart for Types 2N718A and 2N720A.

For Small-Signal and Switching Applications



JEDEC TO-18

- high minimum gain-bandwidth products:
  60 Mc min. (100 Mc typical) for 2N718A
  50 Mc min. (100 Mc typical) for 2N720A
  useful in applications from dc to 20 Mc
- operation at high junction temperatures—up to 200° C
- low collector-to-emitter saturation voltage — $V_{CE}(sat)$ = 0.3 volt typ. at I_C = 150 ma.
- planar construction — for low noise and low leakage characteristics
- Very low output capacitances:
  15 pf max. for 2N720A
  25 pf max. for 2N718A

RCA-2N718A FEATURES:

- high dc pulsed beta at high collector current — h_{FE} = 20 min. at I_C = 0.5 amp
- high switching speed (non-saturating mode) — 30 nanoseconds max.
- low narrow-band noise figure — 12 db max.

RCA-2N720A FEATURES:

- high voltage ratings:
  V_{CBO} = 120 volts
  V_{CER} = 100 volts for $R_{BE} \leq 10$ ohms
  V_{CEO} = 80 volts

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	TEST CONDITIONS: Free-Air Temperature T_{FA} (°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 2N720A Min.	Type 2N720A Max.	Type 2N718A Min.	Type 2N718A Max.	Units
Collector-Cutoff Current	I_{CBO}	25 150 25 150		90 90 60 60				0 0 0 0		- - - -	0.01 15 - -	- - - -	- - 0.01 10	μa μa μa μa
Emitter-Cutoff Current	I_{EBO}	25				5	0			-	0.01	-	0.01	μa
DC Forward-Current Transfer Ratio	h_{FE}	25 25 25 25 -55			10 10 10 10 10		150[a] 500[a] 10[a] 0.1 10[a]			40 - 35 20 20	120 - - - -	40 20 35 20 20	120 - - - -	
Collector-to-Base Breakdown Voltage	BV_{CBO}	25					0.1	0		120	-	75	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}	25					0	0.1		7	-	7	-	volts
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$	25					100[a]		0	80	-	-	-	volts
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance = 10 ohms	$V_{CER}(sus)$	25					100[a]			100	-	50	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25 25					150[a] 50		15[a] 5	- -	5 1.2	- -	1.5 -	volts volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25 25					150[a] 50		15[a] 15	- -	1.3 0.9	- -	1.3 -	volts volts
Small-Signal Forward-Current Transfer Ratio	h_{fe}	25 25 25	1 1 20 Mc		5 10 10		1 5 50			30 45 2.5	100 - -	30 35 3	100 150 -	
Noise Figure: Generator resistance (R_G) = 510 ohms, circuit bandwidth (BW) = 1 cps	NF	25	1		10		0.3			-	-	-	12	db
Total Switching Time (See *Fig.1*)	$t_d + t_r + t_f$	25								-	-	-	30	nsec
Output Capacitance	C_{ob}	25		10				0		-	15	-	25	pf
Input Capacitance	C_{ib}	25				0.5	0			-	85	-	80	pf
Input Resistance	h_{ib}	25 25	1 1		5 10		1 5			20 4	30 8	24 4	34 8	ohms ohms
Voltage-Feedback Ratio	h_{rb}	25 25	1 1		5 10		1 5			*Max.* 1.25x10-4 1.5x10-4		- -	3x10-4 3x10-4	
Output Conductance	h_{ob}	25 25	1 1		5 10		1 5			- -	0.5 0.5	0.1 0.1	0.5 1	μmho μmho
Thermal Resistance: Junction-to-case; Junction-to-free air	θ_{J-C} θ_{J-FA}	- -								- -	97 350	- -	97 350	°C/watt °C/watt

[a] Pulse Test: Pulse duration ≤ 300 μsec; duty factor ≤ 2%.

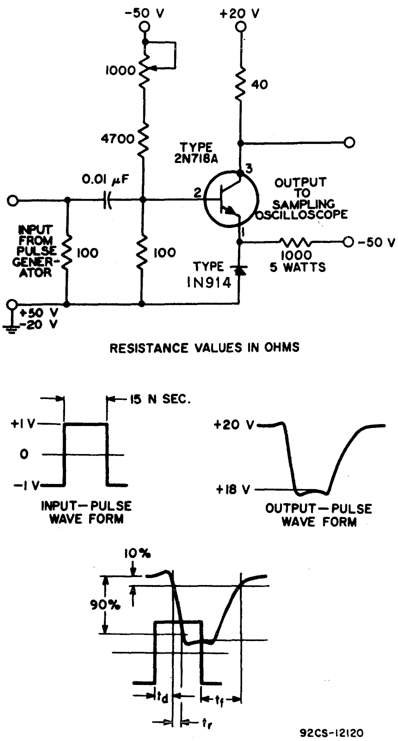


Fig. 1 - Circuit Used to Measure Total Switching Time for Type 2N718A.

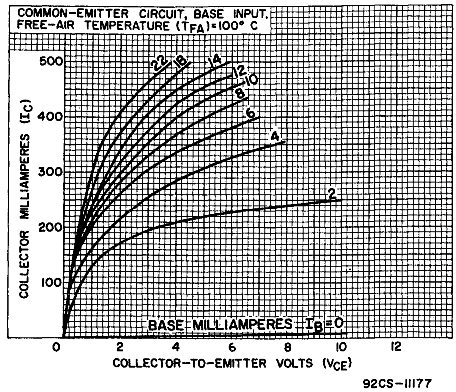


Fig. 2 - Typical Collector Characteristics at 100° C for Types 2N718A and 2N720A.

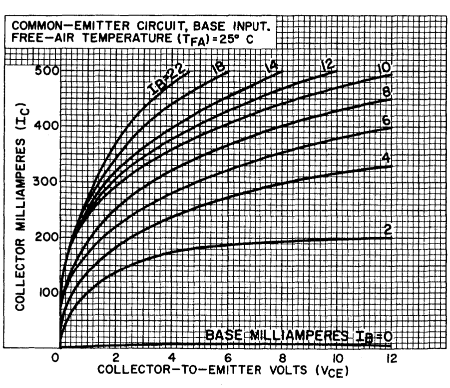


Fig. 3 - Typical Collector Characteristics at 25° C for Types 2N718A and 2N720A.

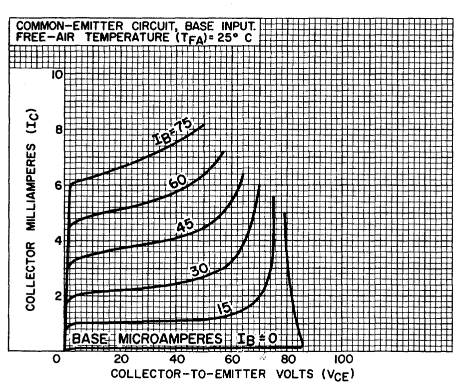


Fig. 4 - Typical Collector Characteristics at 25° C for Type 2N720A.

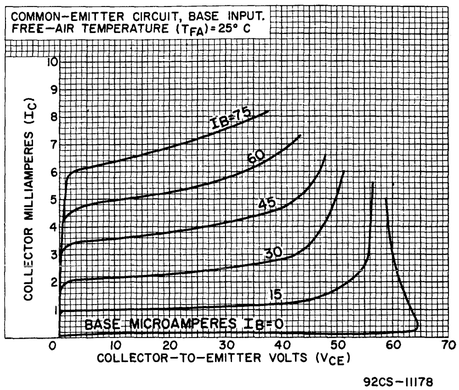


Fig. 5 - Typical Collector Characteristics at 25° C for Type 2N718A.

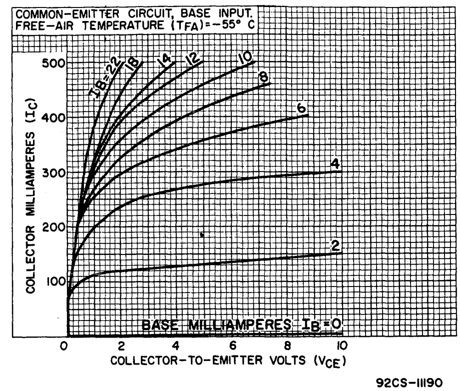


Fig. 6 - Typical Collector Characteristics at -55° C for Types 2N718A and 2N720A.

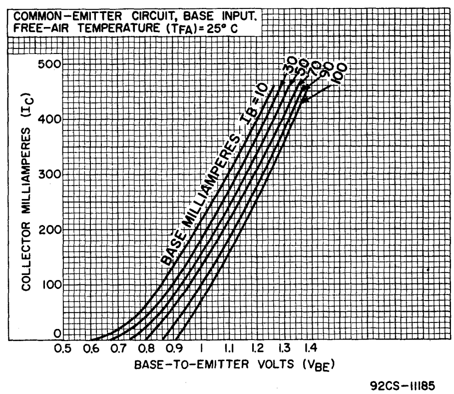


Fig. 7 - Typical Transfer Characteristics for Types 2N718A and 2N720A.

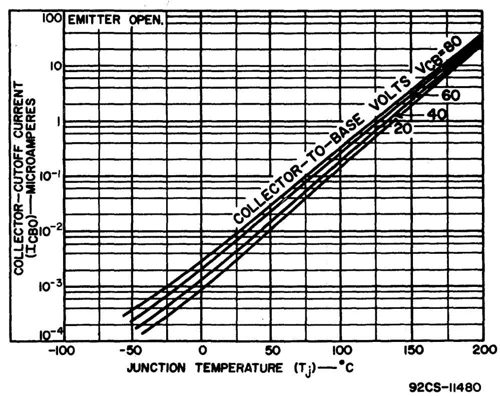


Fig. 8 - Typical Collector-Cutoff-Current Characteristics for Type 2N718A.

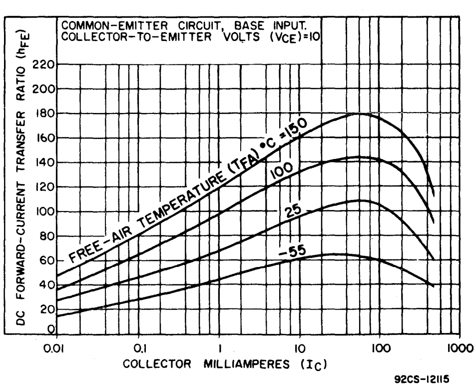


Fig. 9 - Typical DC-Beta Characteristics for Types 2N718A and 2N720A.

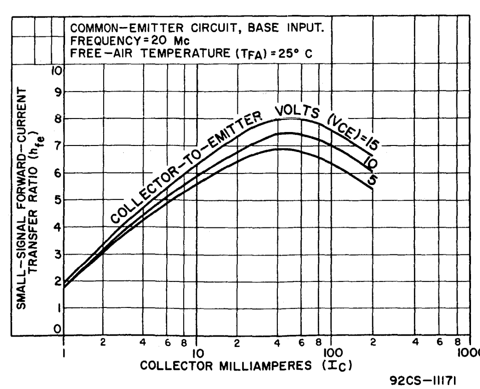


Fig. 10 - Typical Small-Signal-Beta Characteristics for Types 2N718A and 2N720A.

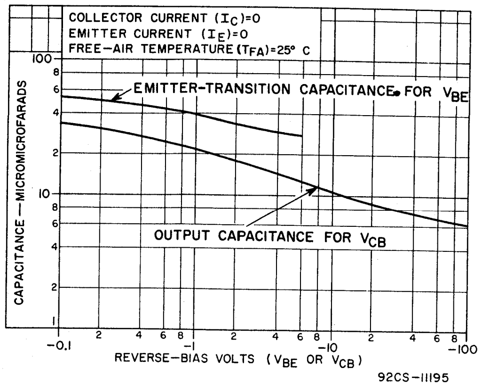
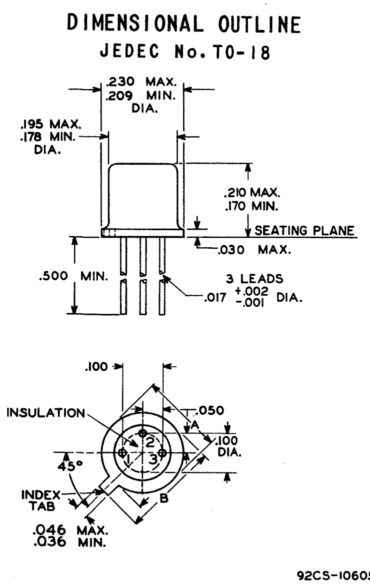
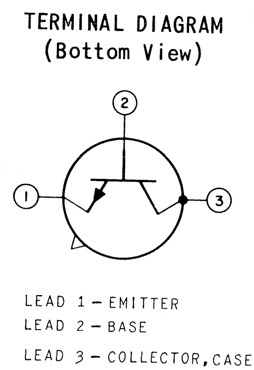


Fig. 11 - Typical Capacitance Characteristics for Types 2N718A and 2N720A.





RCA
Solid State
Division

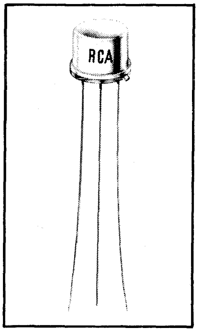
Power Transistors

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

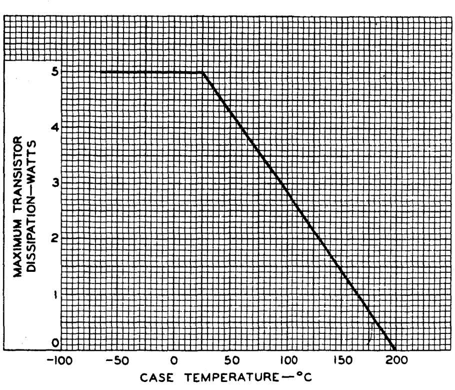


Fig. 1 - Rating Chart for Types 2N1479, 2N1480, 2N1481, and 2N1482.

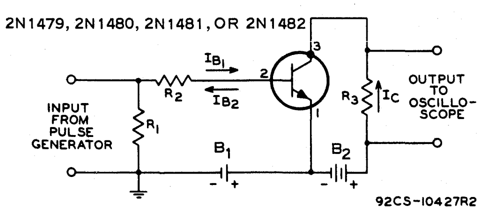
Typical Operation of the 2N1479, 2N1480, 2N1481, and 2N1482 in the Power–Switching Circuit of Fig. 2:

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 = 5 ma, V_{CE} = 4 volts)	50	
Collector-to-Base Capacitance: C_{ob} (V_{CB} = 40 volts)	150	μμf
Thermal Time Constant, τ_1	10	msec
Alpha-Cutoff Frequency: f_{a_b} (V_{CB} = 28 volts, I_C = 5 ma)	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

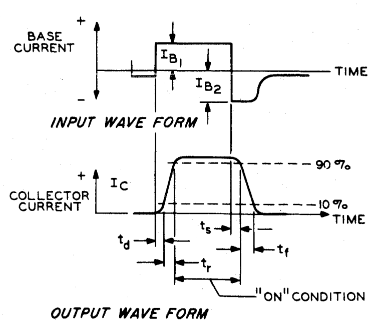


Fig. 2 - Typical Power-Switching Circuit.

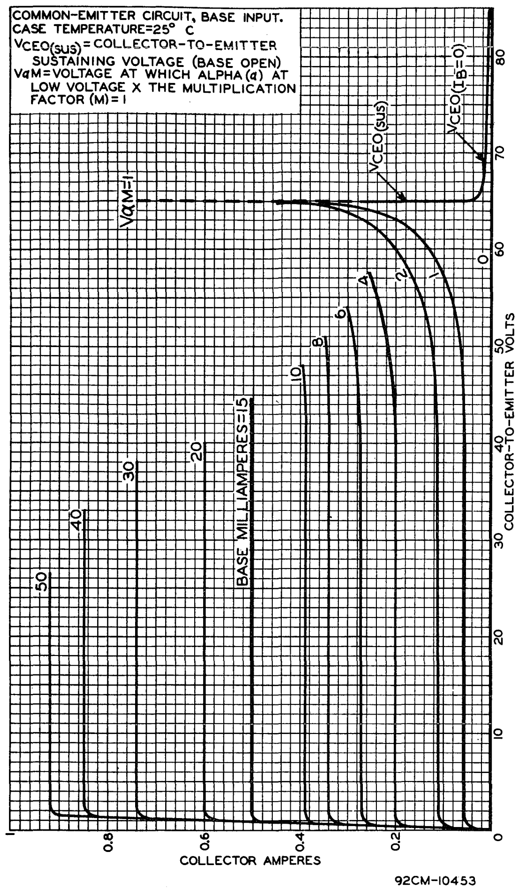


Fig. 3 - Typical Collector Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

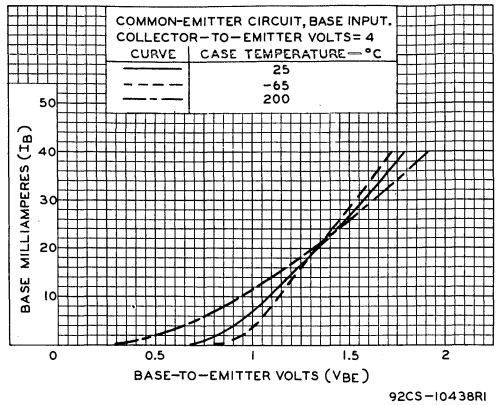


Fig. 4 - Typical Input Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

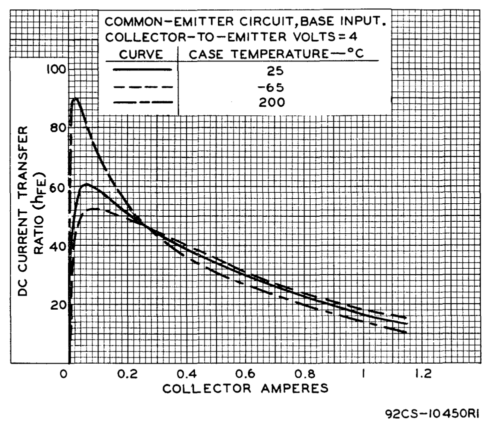


Fig. 5 - Typical Operation Characteristics for Types 2N1479, 2N1480, 2N1481, and 2N1482.

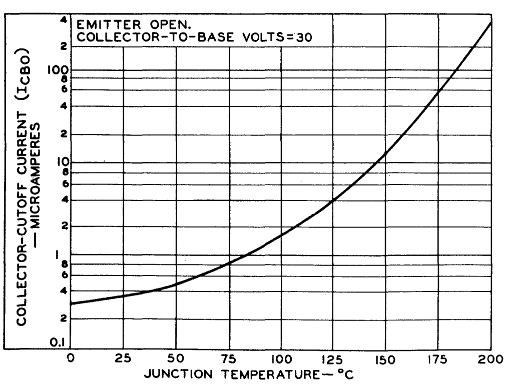
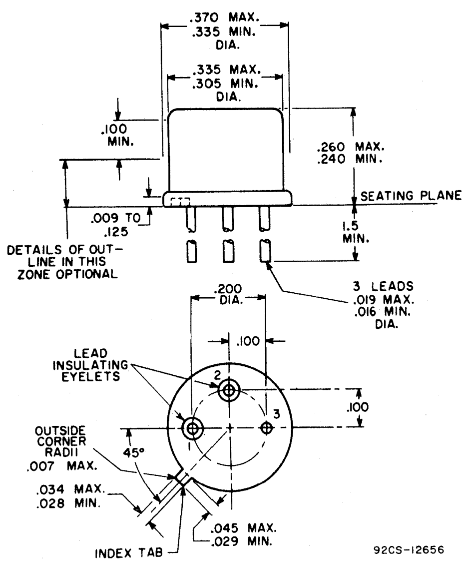


Fig. 6 - Typical Operation Characteristic for Types 2N1479, 2N1480, 2N1481, and 2N1482.

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

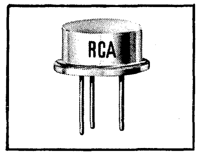
Power Transistors

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:	R_T														
Junction-to-case								7		7		7		7	°C/w
Junction-to-free air								100		100		100		100	°C/w

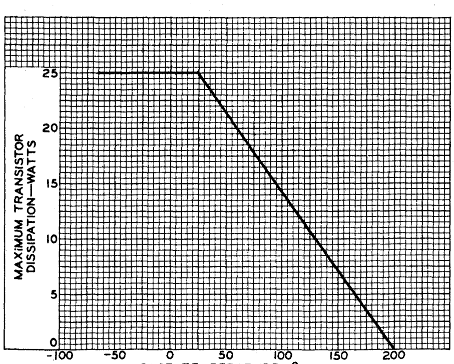


Fig. 1 - Rating Chart for Types 2N1483, 2N1484, 2N1485, and 2N1486.

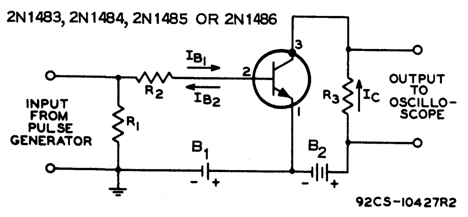
Typical Operation of the 2N1483, 2N1484, 2N1485, and 2N1486 in the Power–Switching Circuit of Fig. 2:

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



B_1 = 8.5 volts
B_2 = 12 volts

R_1 = 50 ohms, 1 watt
R_2 = 220 ohms, 1 watt
R_3 = 15.9 ohms, 2 watts

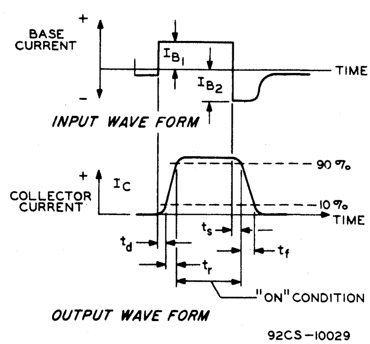


Fig. 2 - Typical Power-Switching Circuit.

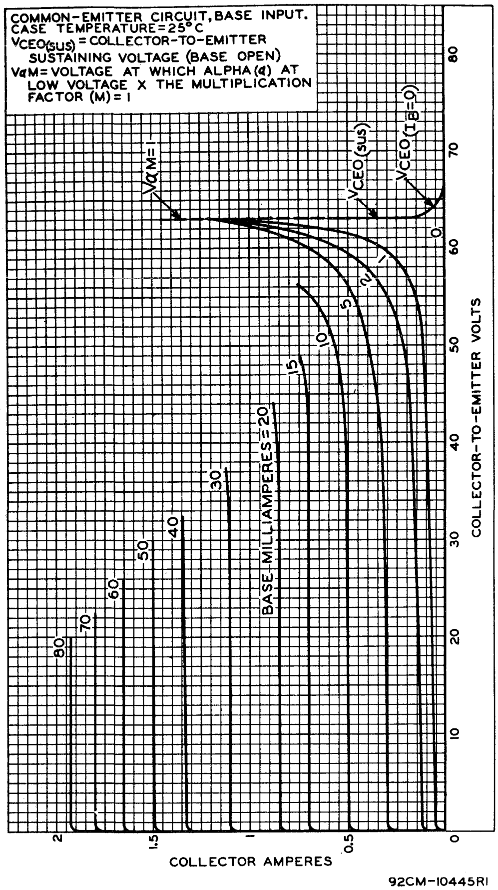


Fig. 3 - Typical Collector Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

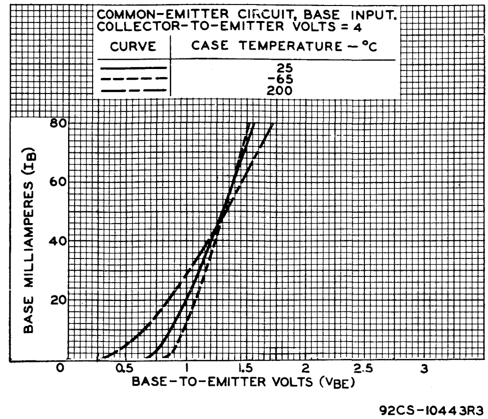


Fig. 4 - Typical Input Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

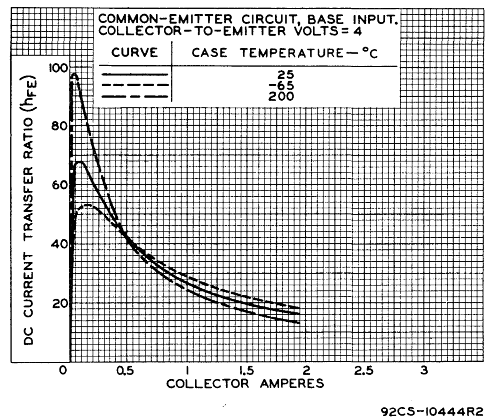


Fig. 5 - Typical Operation Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

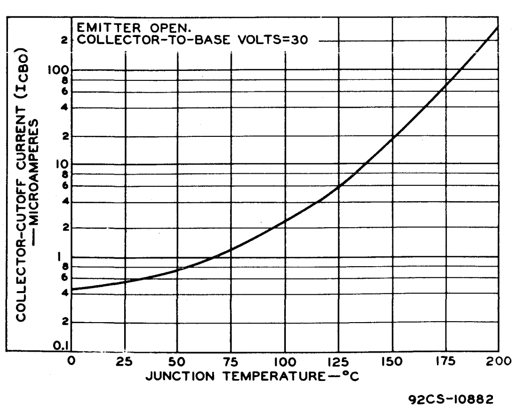


Fig. 6 - Typical Operation Characteristics for Types 2N1483, 2N1484, 2N1485, and 2N1486.

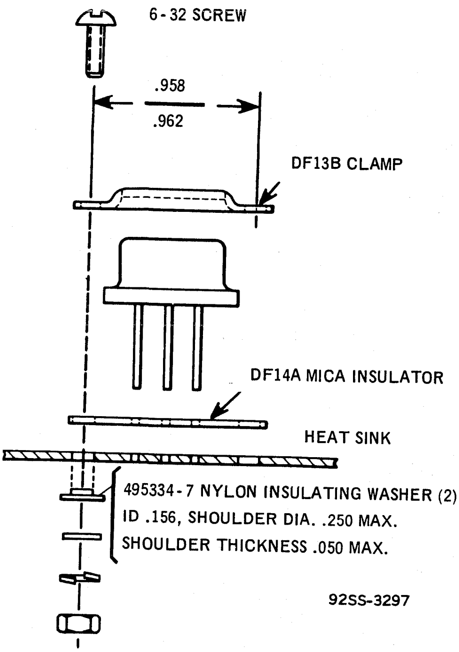
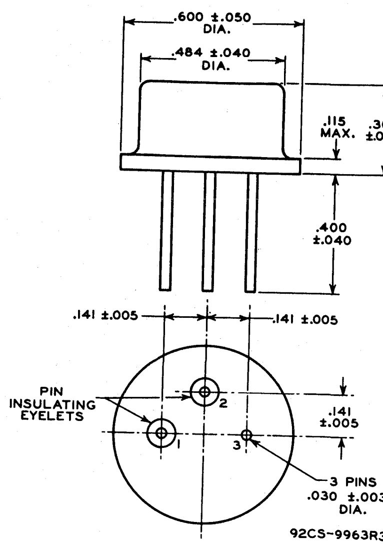


Fig. 7 - Suggested Mounting Arrangement for Types 2N1483, 2N1484, 2N1485, or 2N1486.

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

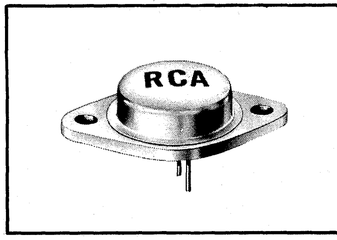
Power Transistors

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

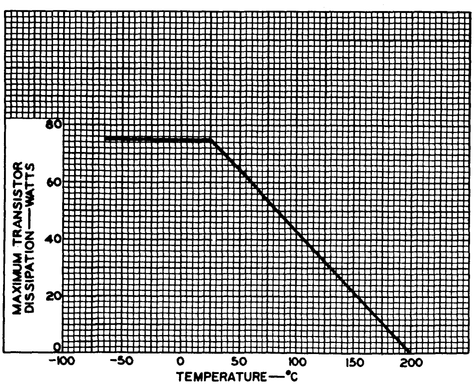


Fig. 1 - Rating Chart for Types 2N1487, 2N1488, 2N1489, and 2N1490.

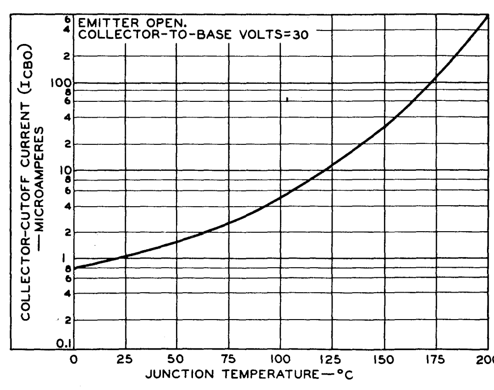


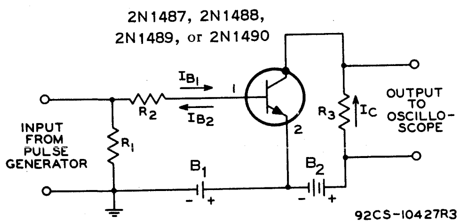
Fig. 2 - Typical Operation Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

Typical Operation of the 2N1487, 2N1488, 2N1489, and 2N1490 in the Power–Switching Circuit of Fig. 3:

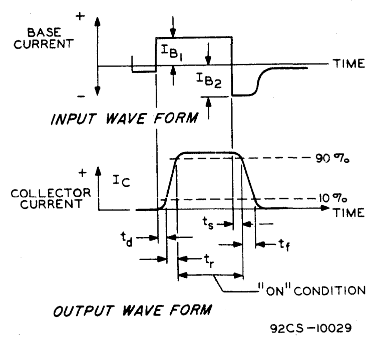
DC Supply Voltage (B_2)	12	volts
DC Base Bias Voltage (B_1)	-8.5	volts
Generator Resistance	50	ohms
"On" DC Collector Current	1.5	amp
"Turn-On" Base Current (I_{B_1})	300	ma
"Turn-Off" Base Current (I_{B_2})	-150	ma
Switching Time:		
Delay Time (t_d)	0.2	μsec
Rise Time (t_r)	1.0	μsec
Storage Time (t_s)	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



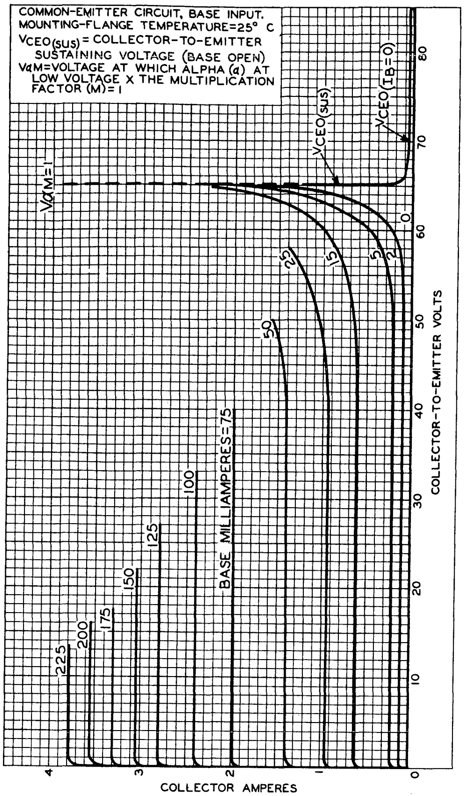


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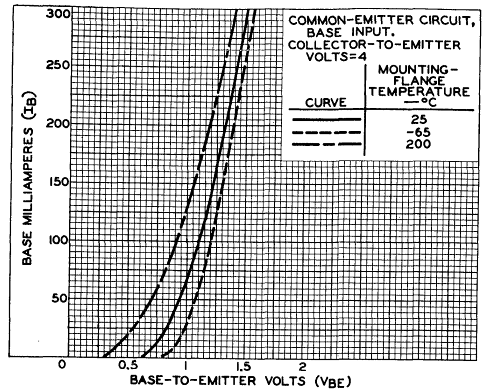
Fig. 4 - Typical Collector Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.



92CS-10451R2

Fig. 5 - Typical Input Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

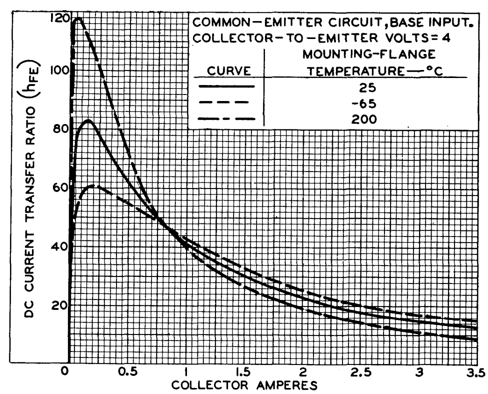


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Fig. 6 - Typical Operation Characteristics for Types 2N1487, 2N1488, 2N1489, and 2N1490.

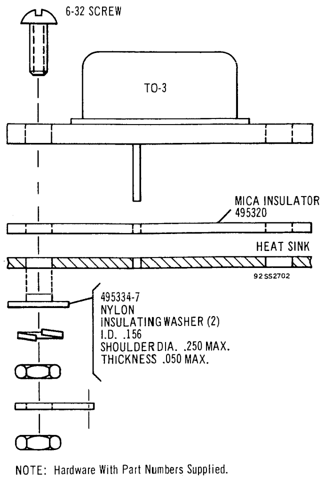
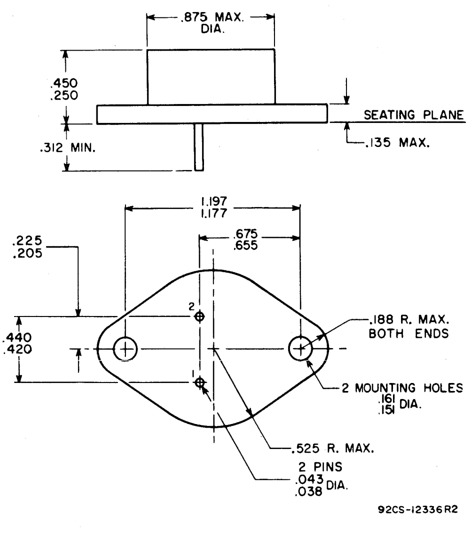


Fig. 7 - Suggested Mounting Arrangement for Types 2N1487, 2N1488, 2N1489, and 2N1490:

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

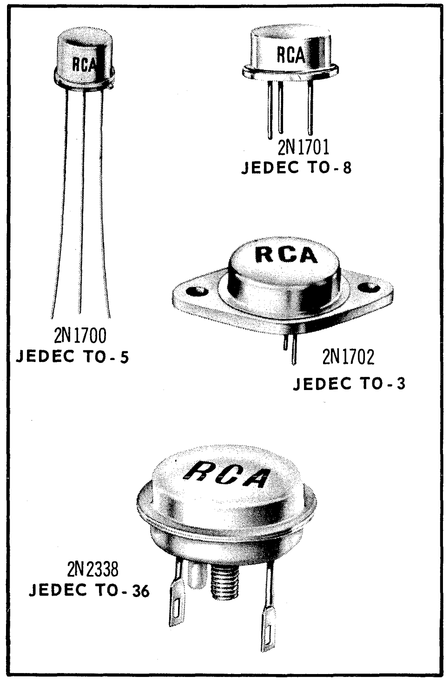
Power Transistors

2N1700 2N1702 2N1701 2N2338

For Industrial Applications

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".

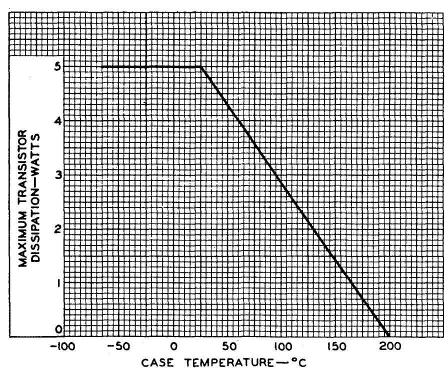


Fig. 1 - Rating Chart for Type 2N1700.

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

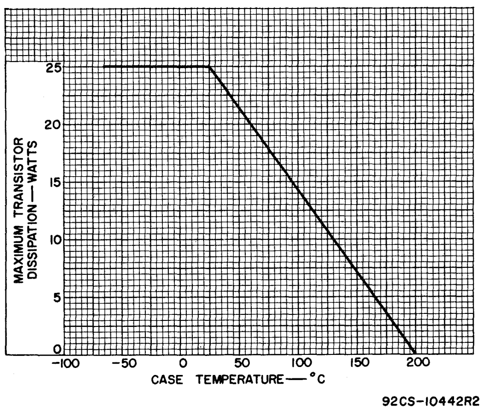


Fig. 2-Rating Chart for Type 2N1701.

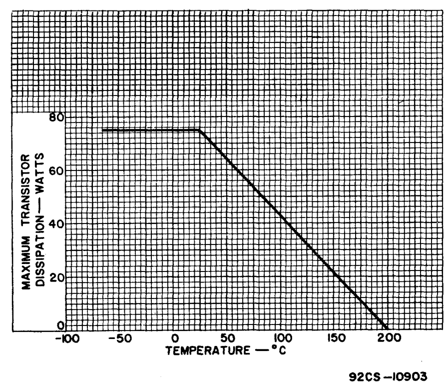


Fig. 3-Rating Chart for Type 2N1702.

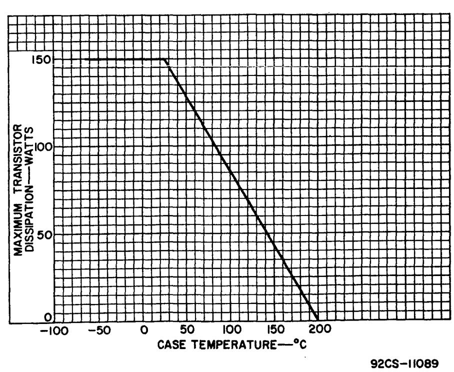


Fig. 4-Rating Chart for Type 2N2338.

ELECTRICAL CHARACTERISTICS

At case or mounting-flange temperature of 25° C, unless otherwise specified.

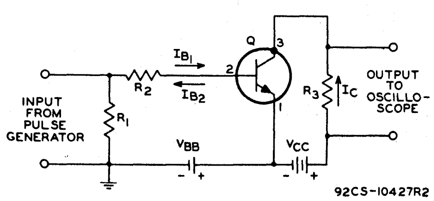
Characteristic	Symbol	TEST CONDITIONS: DC Collector-to-Base Voltage (V_{CB}) volts	DC Collector-to-Emitter Voltage (V_{CE}) volts	DC Emitter-to-Base Voltage (V_{EB}) volts	DC Base Current (I_B) ma	DC Collector Current (I_C) ma	LIMITS: Type 2N1700 Min.	Type 2N1700 Max.	Type 2N1701 Min.	Type 2N1701 Max.	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

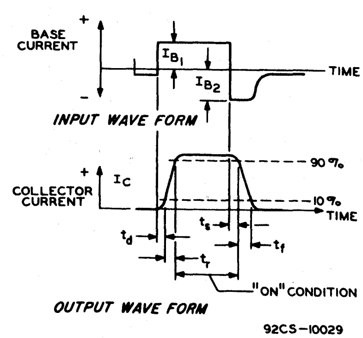


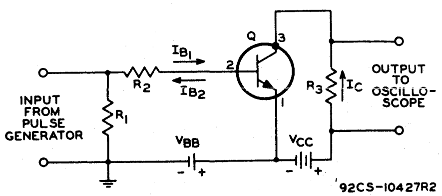
Fig. 5 - Typical Power-Switching Circuit for Type 2N1700.

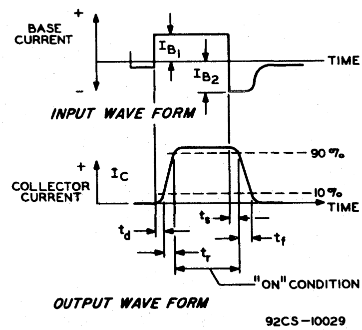
Typical Operation of Type 2N1701 in the Power-Switching Circuit of Fig. 6:

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

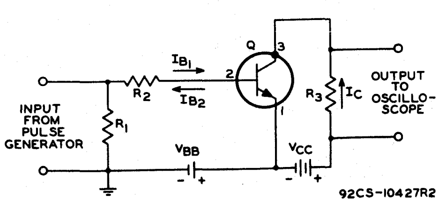
Fig. 6 - Typical Power-Switching Circuit for Type 2N1701.

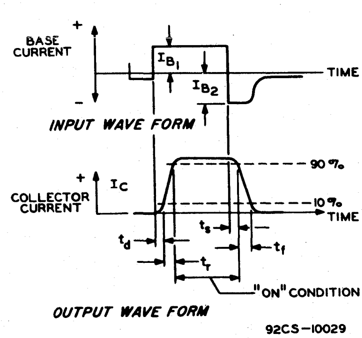
Typical Operation of Types 2N1702 and 2N1703 in the Power-Switching Circuit of Fig. 7:

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



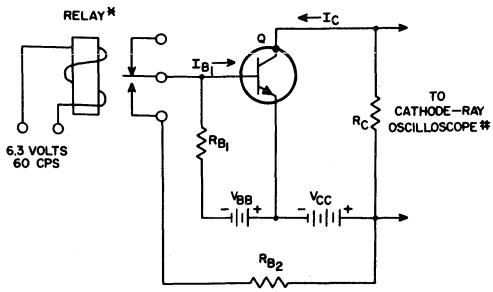


Q = Type 2N1702
V_{BB} = 8.5 volts
V_{CC} = 12 volts

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.



*C.P. CLARE TYPE HGP-1028 OR EQUIVALENT

#TEKTRONIX TYPE 545 OR EQUIVALENT

Q = Type 2N2338

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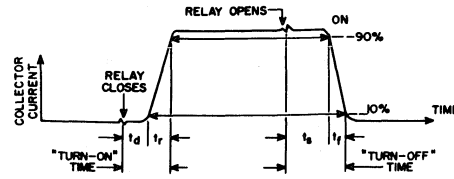
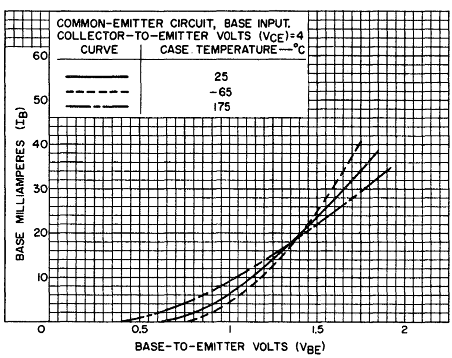
DC Collector Supply Voltage (V_{CC})	24	volts
DC Base Bias Voltage (V_{BB}).	6	volts
DC Collector Current ("On" condition) . .	10	amp



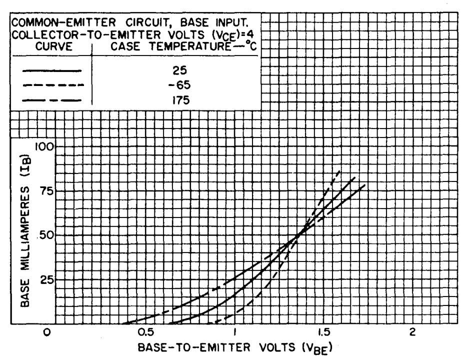
"Turn-On" Base Current (I_{B1}).	2	amp
Base Circuit Resistance (R_{B1})	10	ohms
Base Circuit Resistance (R_{B2})	10	ohms
Collector Circuit Resistance (R_C)	2	ohms
Switching Time:		
"On" Time		
[Delay time (t_d) + Rise time (t_r)]. .	4	μsec
"Off" Time		
[Storage time (t_s) + Fall time (t_f)].	7	μsec

Fig. 8 - Pulse-Response Test Circuit for Type 2N2338.



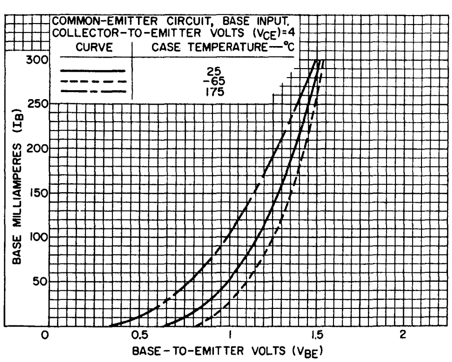
92CS-11569

Fig. 9 - Typical Input Characteristics for Type 2N1700.



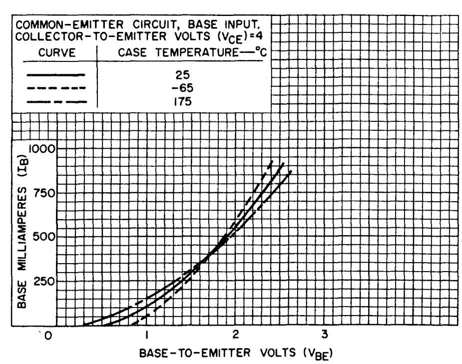
92CS-11571

Fig. 10 - Typical Input Characteristics for Type 2N1701.



92CS-11567

Fig. 11 - Typical Input Characteristics for Type 2N1702.



92CS-11568

Fig. 12 - Typical Input Characteristics for Type 2N2338.

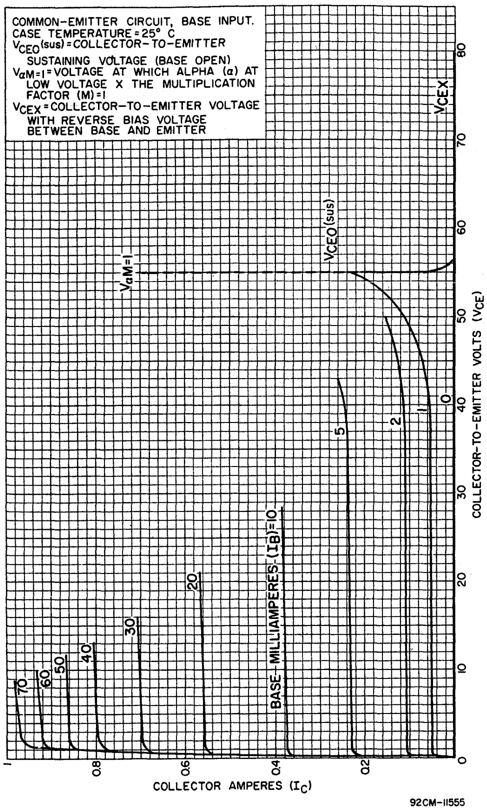


Fig. 13 - Typical Collector Characteristics for Type 2N1700.

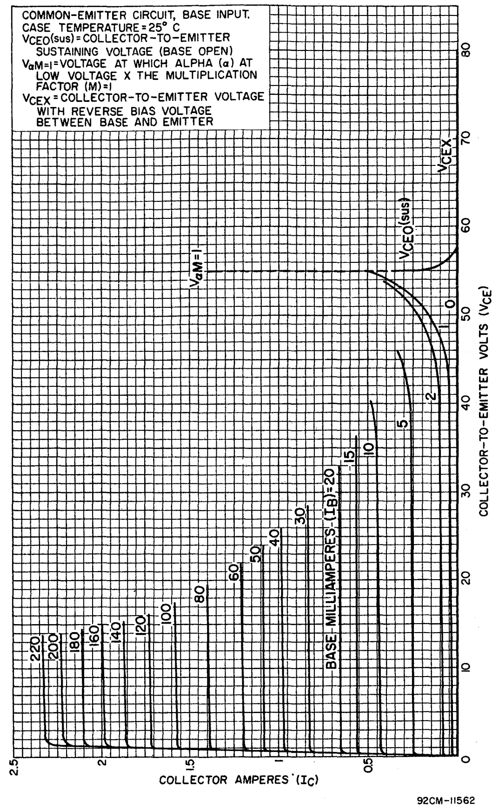


Fig. 14 - Typical Collector Characteristics for Type 2N1701.

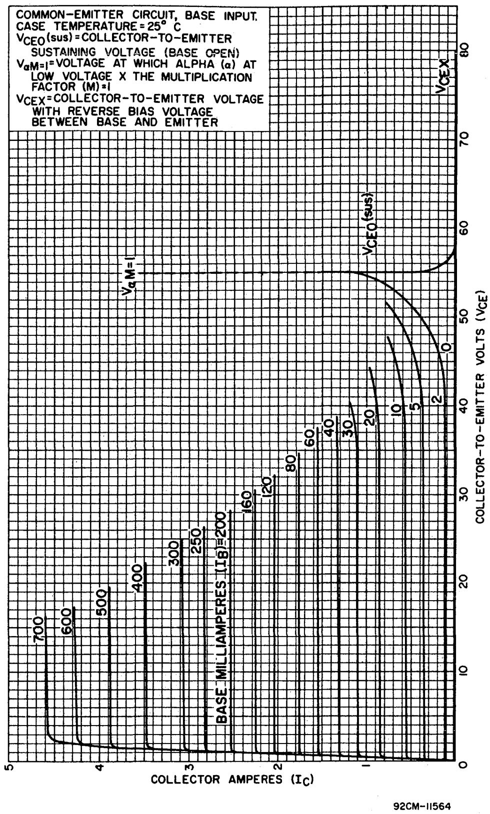


Fig. 15 - Typical Collector Characteristics for Type 2N1702.

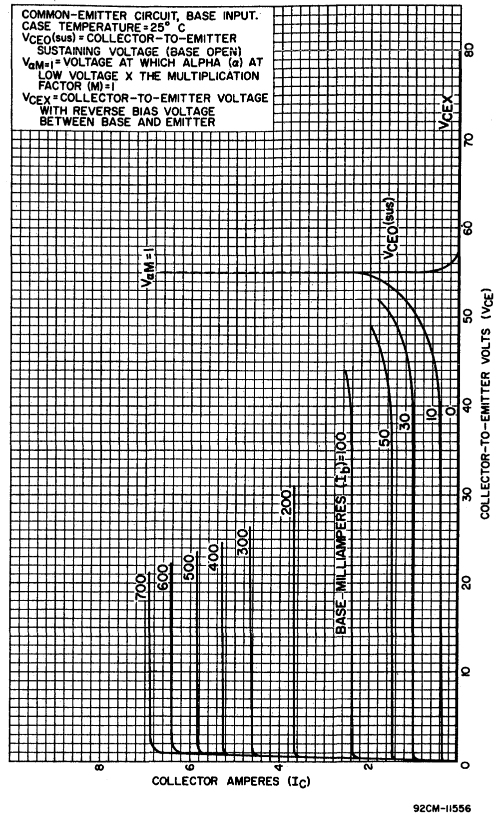


Fig. 16 - Typical Collector Characteristics for Type 2N2338.

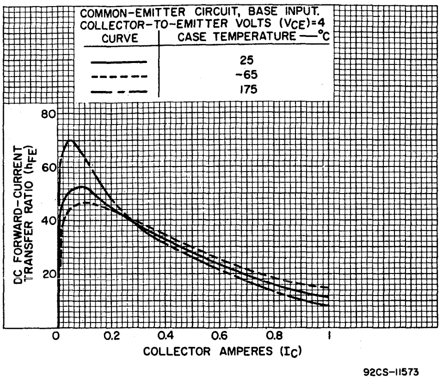


Fig. 17 - Typical Operation Characteristics for Type 2N1700.

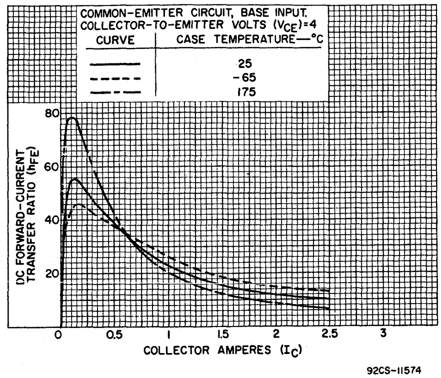


Fig. 18 - Typical Operation Characteristics for Type 2N1701.

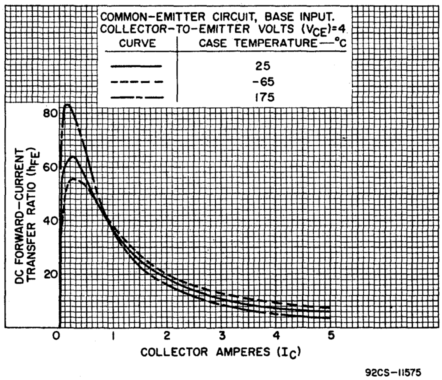


Fig. 19 - Typical Operation Characteristics for Type 2N1702.

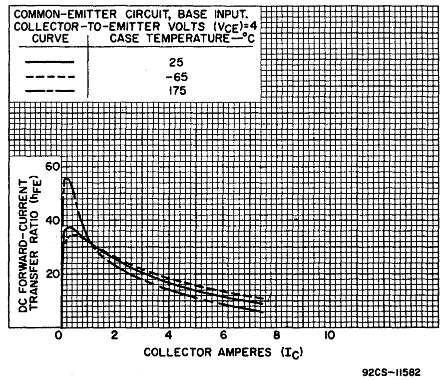


Fig. 20 - Typical Operation Characteristics for Type 2N2338.

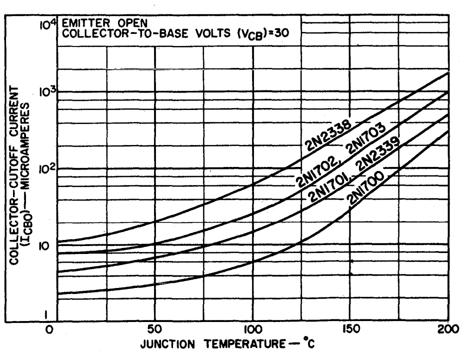
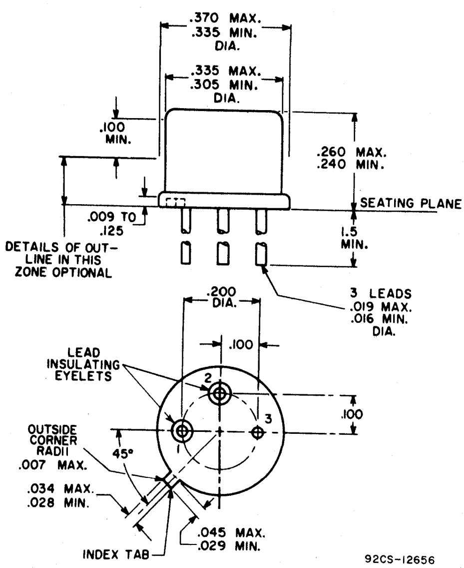


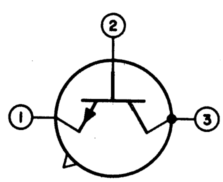
Fig. 21 - Typical Operation Characteristics for Types 2N1700, 2N1701, 2N1702 and 2N2338.

DIMENSIONAL OUTLINE for Type 2N1700

JEDEC No. TO-5



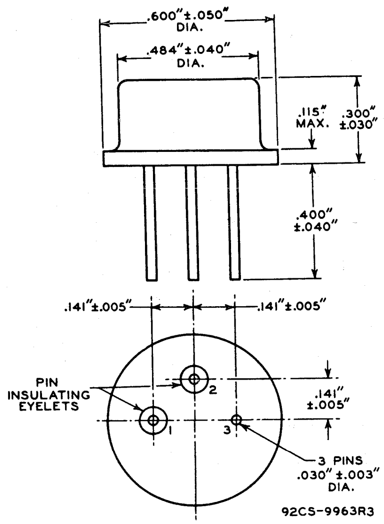
TERMINAL DIAGRAM (Bottom View) for Type 2N1700



LEAD 1 – EMITTER LEAD 3 – COLLECTOR, CASE

LEAD 2 – BASE

DIMENSIONAL OUTLINE
for Type 2N1701
JEDEC No. TO-8



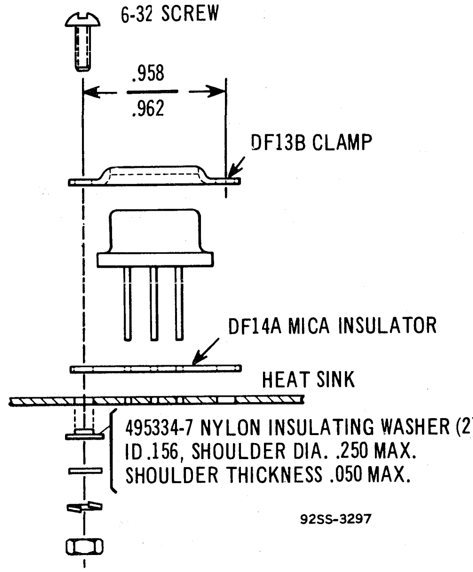
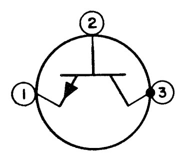


Fig. 22 - Suggested Mounting Arrangement for Type 2N1701.

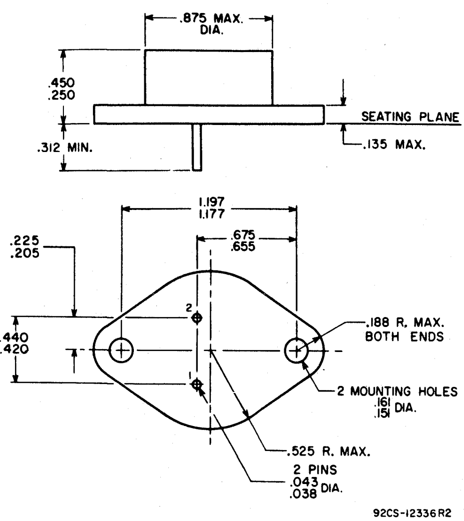
TERMINAL DIAGRAM (Bottom View)
for Type 2N1701



LEAD 1 – EMITTER   LEAD 3 – COLLECTOR, CASE

LEAD 2 – BASE

DIMENSIONAL OUTLINE for Type 2N1702



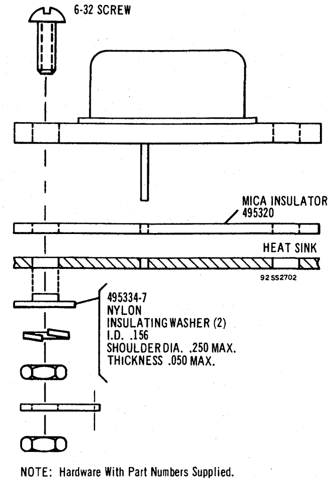
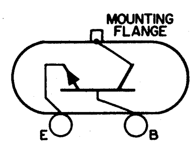


Fig. 23 - Suggested Mounting Arrangement for Type 2N1702.

TERMINAL DIAGRAM (Bottom View) for Type 2N1702



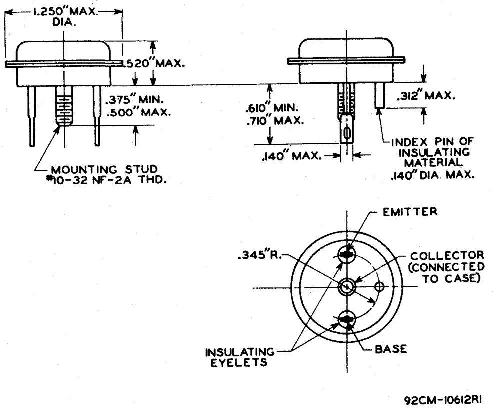
E – EMITTER

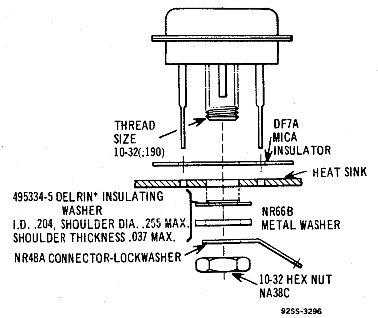
B – BASE

MOUNTING FLANGE – COLLECTOR, CASE

DIMENSIONAL OUTLINE for Type 2N2338

JEDEC No. TO-36

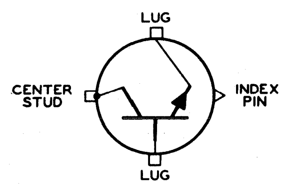




*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

Fig. 24 - Suggested Mounting Arrangement for Type 2N2338.

TERMINAL DIAGRAM (Bottom View) for Type 2N2338

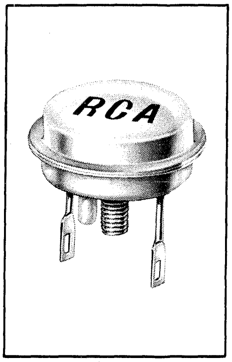


RCA
Solid State
Division

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".

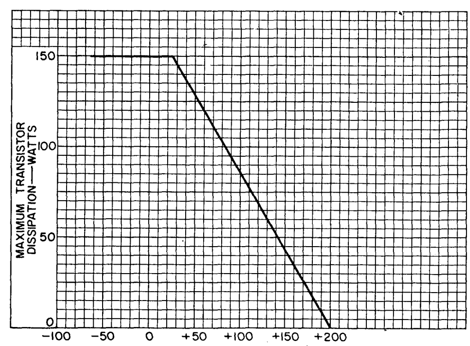
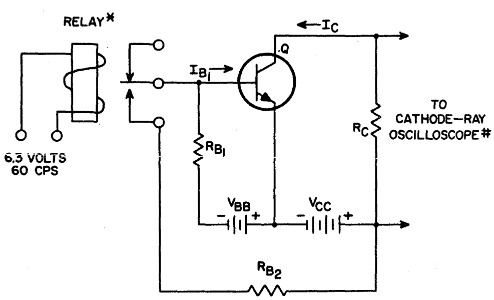


Fig. 1 - Rating Chart for Types 2N2015 and 2N2016.

ELECTRICAL CHARACTERISTICS

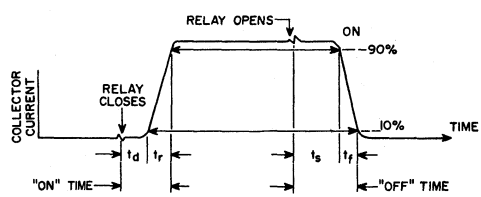
Case temperature = 25° C unless otherwise specified.

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: 25° C	I_{CBO}	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



"ON" TIME, DELAY TIME (t_d) + RISE TIME (t_r)........4µsec
"OFF" TIME, STORAGE TIME (t_s)+FALL TIME (t_f).....7µsec

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.

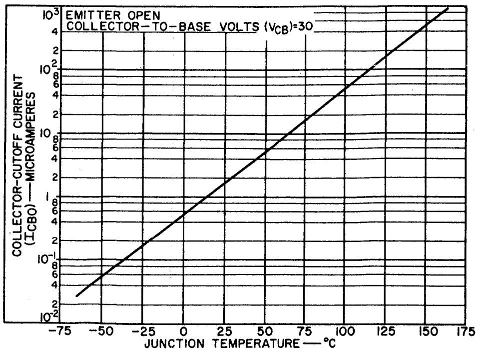


Fig.3 - Typical Operation Characteristic for Types 2N2015 and 2N2016.

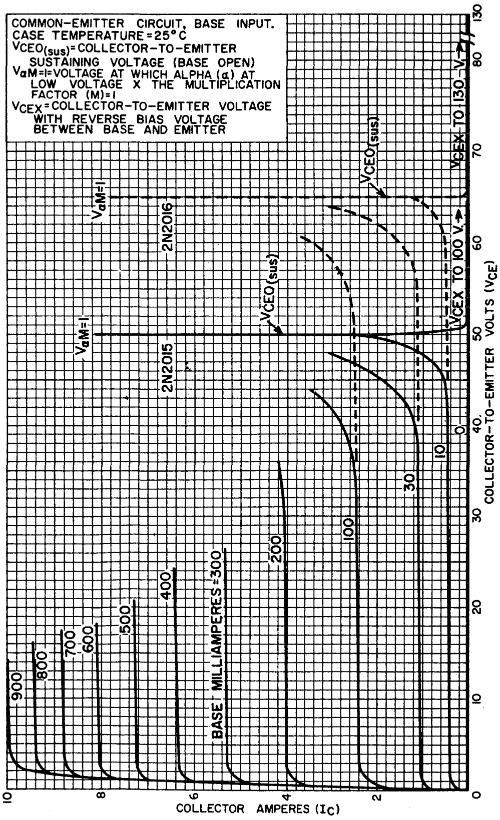


Fig.4 - Typical Collector Characteristics for Types 2N2015 and 2N2016.

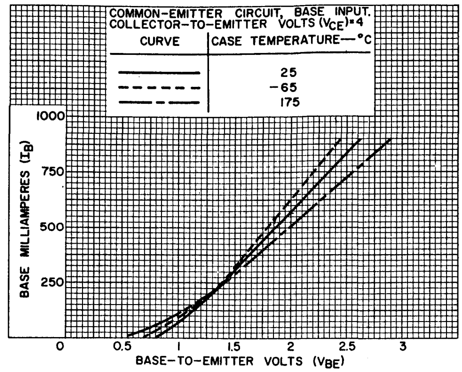


Fig.5 - Typical Input Characteristics for Types 2N2015 and 2N2016.

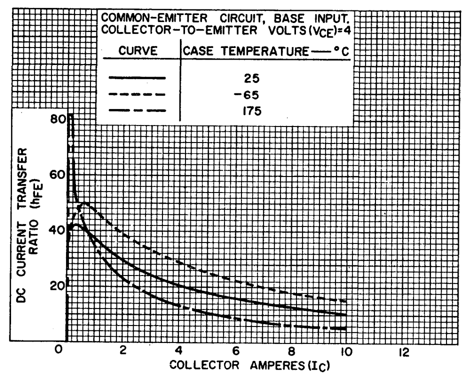


Fig.6 - Typical Operation Characteristics for Types 2N2015 and 2N2016.

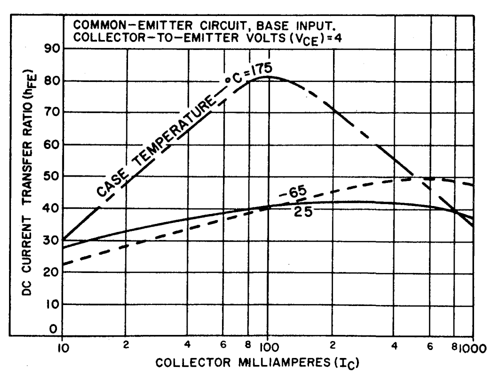
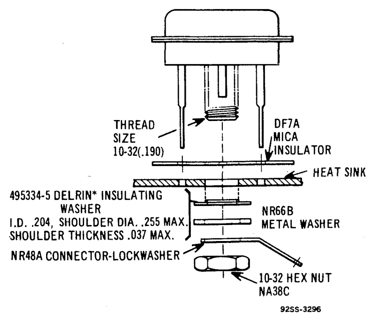


Fig.7 - Typical Operation Characteristics for Types 2N2015 and 2N2016.

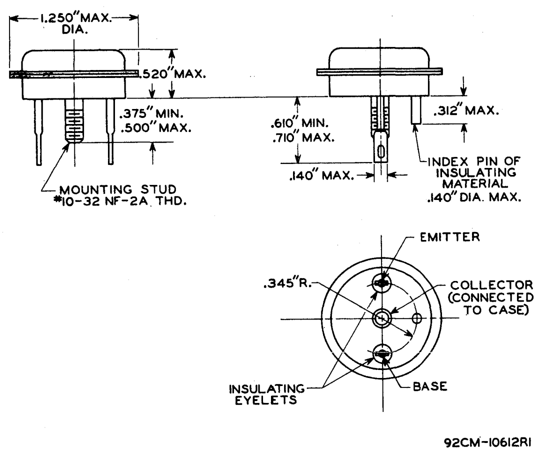


*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

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

2N5189

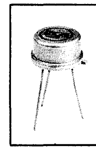
RCA-2N5189* is a double-diffused epitaxial planar transistor of the silicon n-p-n type featuring high breakdown voltages, low saturation voltages, and high switching speeds over a wide range of collector current.

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
For case temperatures[a] above 25°C	Derate at 28.5mW/°C	
For ambient temperatures up to 25°C	1 max.	W
For ambient temperatures above 25°C	Derate at 5.7mW/°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

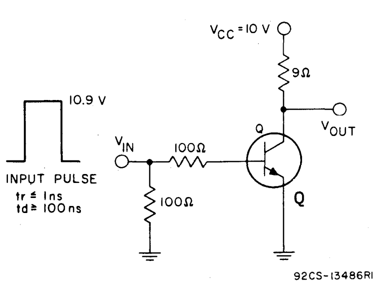
- **excellent power handling capability —**
  P_T = 5W max. at T_C = 25°C
  1W max. at T_A = 25°C
- **high switching speeds at high currents —**
  t_{on} = 40ns max. at I_C = 1A
  t_{off} = 70ns max. at I_C = 1A
- **high breakdown-voltage capabilities —**
  $V_{(BR)CBO}$ = 60V min.
  $V_{(BR)CEO}$ = 35V min.
- **high reliability —**
  production lots of RCA-2N5189 are subjected to and meet the minimum mechanical, environmental, and life-test requirements of the basic MILITARY specification MIL-S-19500. See Page 5 for a description of the Group A and Group B Tests.

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		-	12	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.

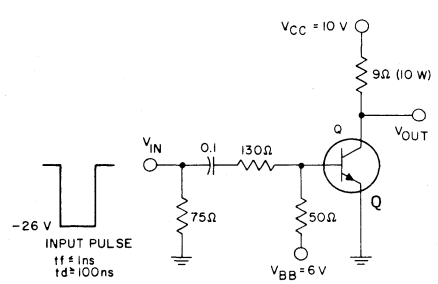
CIRCUIT USED TO MEASURE TURN-ON TIME (t_{on})



Q = Type 2N5189

Fig. 1

CIRCUIT USED TO MEASURE TURN-OFF TIME (t_{off})



Q = Type 2N5189

Fig. 2

TYPICAL CHARACTERISTICS

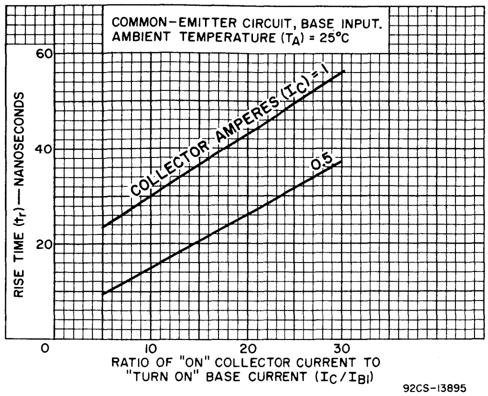


Fig. 3 – Rise Time vs I_C/I_{B1}

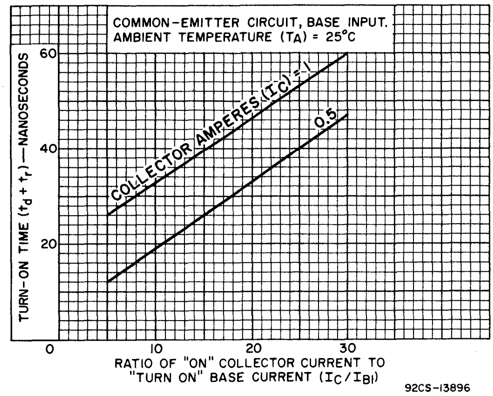


Fig. 4 – Turn-On Time vs I_C/I_{B1}

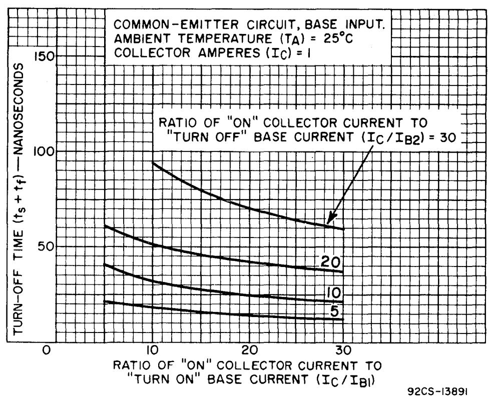


Fig. 5 – Turn-Off Time vs I_C/I_{B1}

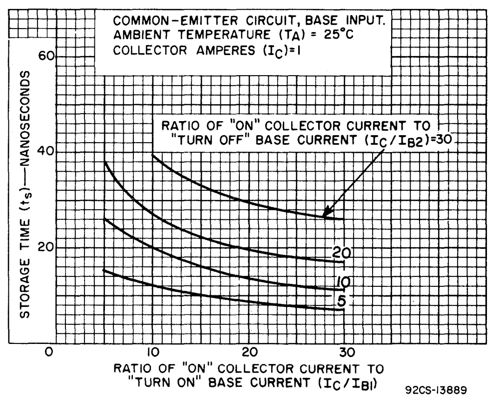


Fig. 6 – Storage Time vs I_C/I_{B1}

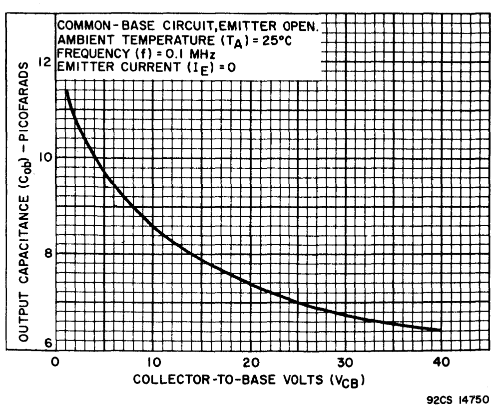


Fig. 7 – Output Capacitance vs Collector-to-Base Voltage

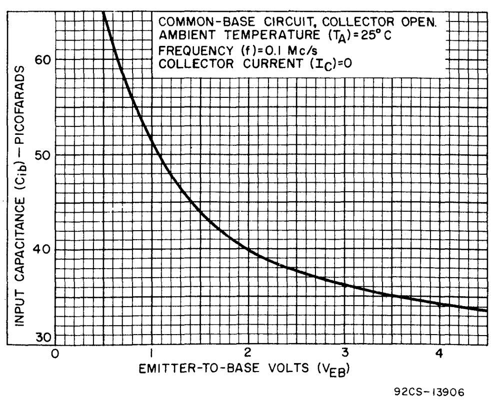


Fig. 8 – Input Capacitance vs Emitter-to-Base Voltage

TYPICAL CHARACTERISTICS

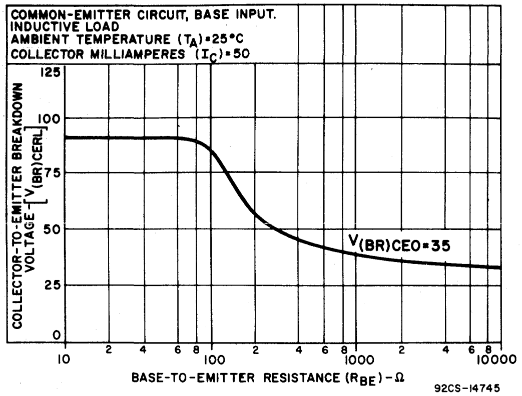


Fig. 9 – Collector-Cutoff Current vs Ambient Temperature

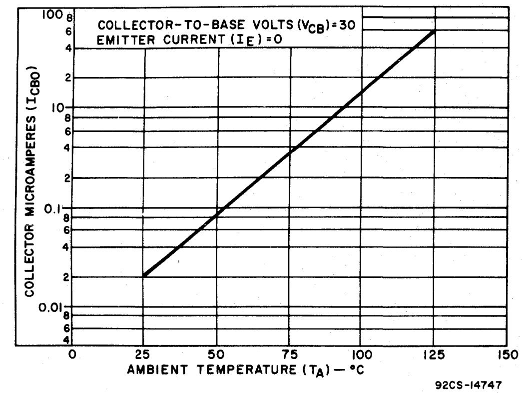


Fig. 10 – Collector-to-Emitter Breakdown Voltage vs Base-to-Emitter Resistance

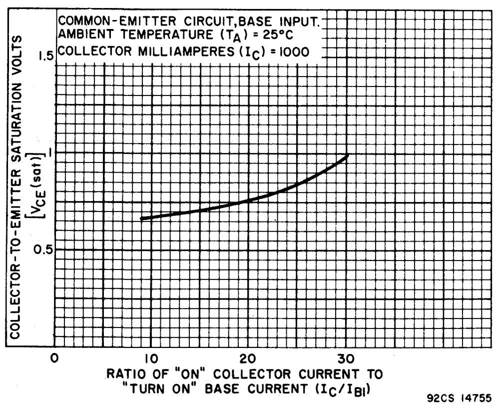


Fig. 11 – Collector-to-Emitter Saturation Voltage vs I_C/I_{B1}

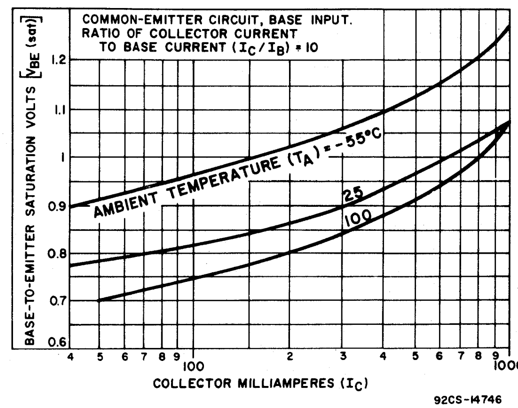


Fig. 12 – Base-to-Emitter Saturation Voltage vs I_C

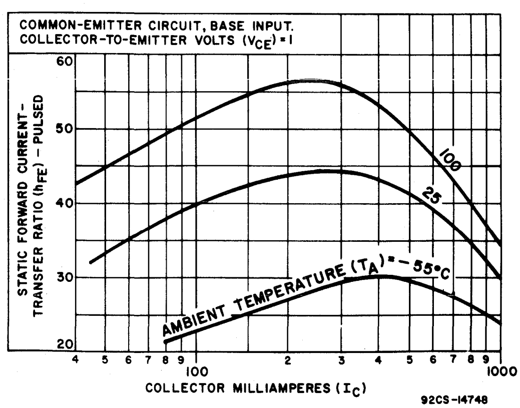


Fig. 13 – Static Forward Current-Transfer Ratio (Pulsed) vs I_C

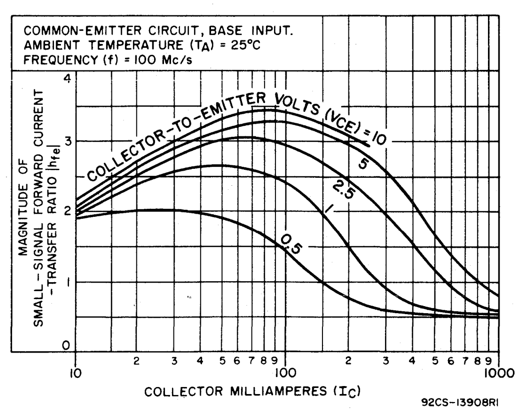
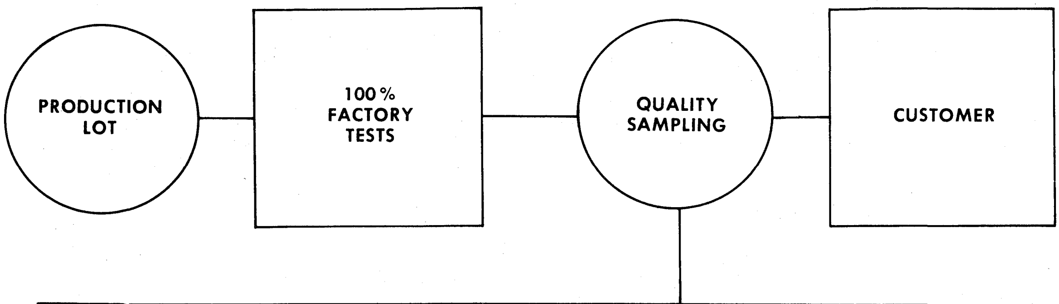


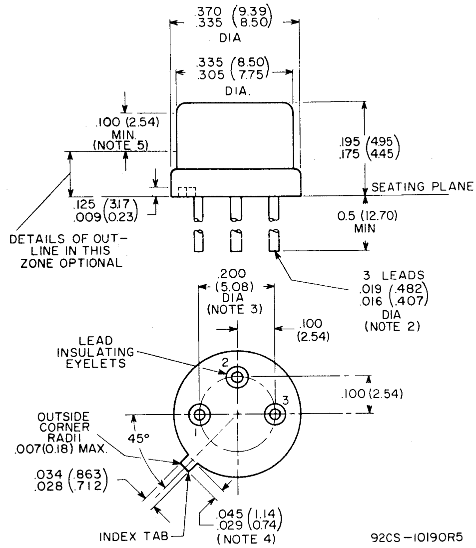
Fig. 14 – Small-Signal Forward Current-Transfer Ratio vs I_C

GROUP A AND GROUP B QUALITY SAMPLING TESTS



ITEM	TEST DESCRIPTION	LTPD
GROUP A TESTS		
Subgroup 1.	Visual and Mechanical Examination	10%
Subgroup 2.	Electrical	5%
GROUP B TESTS		
Subgroup 1.	Physical Dimensions	20%
Subgroup 2.	Solderability, Temperature Cycling, Thermal Shock, Moisture Resistance	20%
Subgroup 3.	Shock, Vibration Fatigue, Vibration Variable Frequency, Constant Acceleration	20%
Subgroup 4.	Terminal Strength	20%
Subgroup 5.	Salt Atmosphere	20%
Subgroup 6.	High-Temperature Life, Non-Operating ($T_A = 200°C$)	$\lambda = 10\%$
Subgroup 7.	Steady-State-Operation Life ($P_D = 300mW$, $T_A = 25°C$)	$\lambda = 10\%$

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.

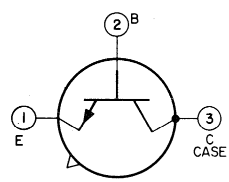
Note 3: Leads having a maximum diameter of 0.019" (0.482 mm) at a gauging plane of 0.054" (1.372 mm) + 0.001" (0.025 mm) - 0.000" (0.000 mm) below seating plane shall be within 0.007" (0.177 mm) of their true position (location) relative to a maximum width of tab.

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.

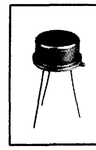
* Developmental number TA-7238 is a reduced-height version of the former developmental number TA-2626.

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					LIMITS			UNITS
		f	V_{CE}	I_C	I_E	I_B	2N5262			
		MHz	Volts	mA			Min.	Typ.	Max.	
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})

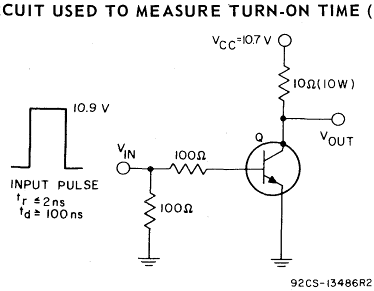


Fig.1

CIRCUIT USED TO MEASURE TURN-OFF TIME (t_{off})

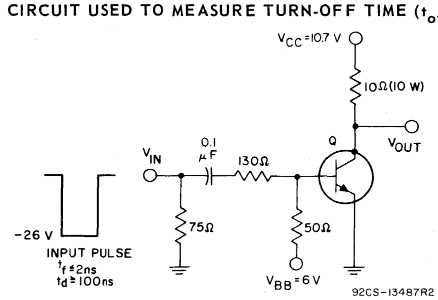


Fig.2

RATING CHART

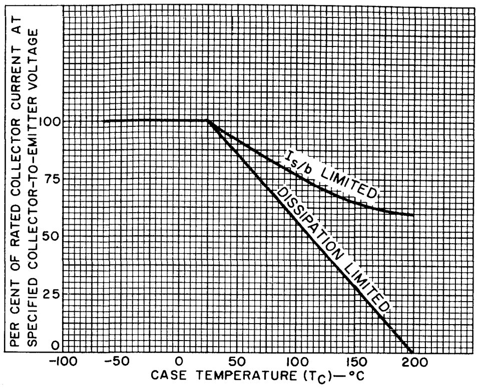


Fig.3

SECOND BREAKDOWN CHARACTERISTICS AND RATINGS

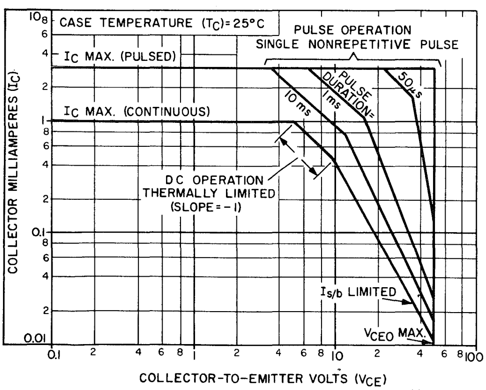


Fig.4

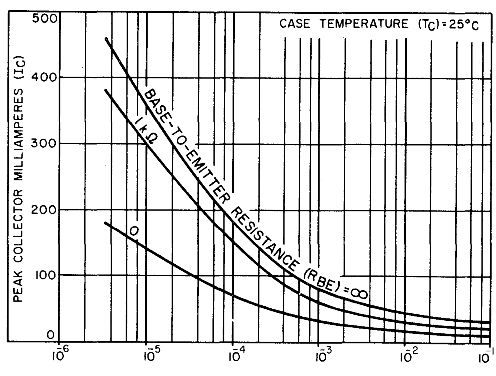


Fig.5

TYPICAL CHARACTERISTICS

h_{fe} vs I_C

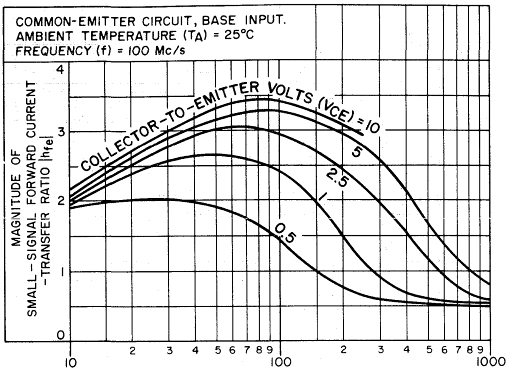


Fig.6

h_{FE} vs I_C

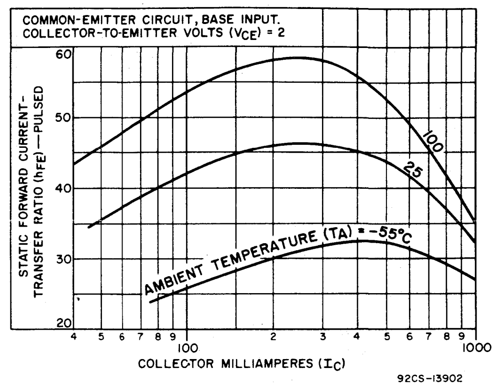


Fig.7

$V_{CE}(sat)$ vs I_C/I_B

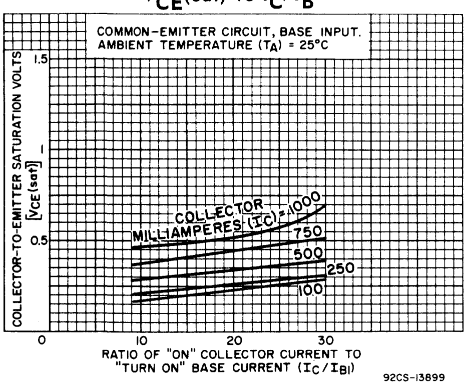


Fig.8

$V_{CE}(sat)$ vs β_T/β_C

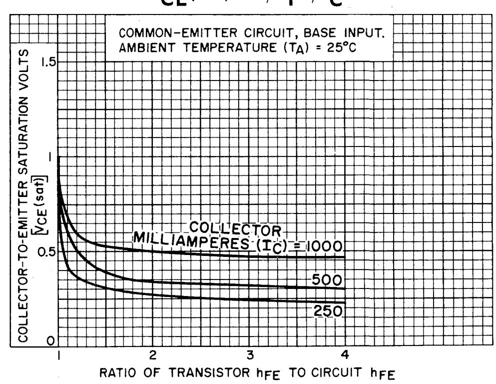


Fig.9

$V_{BE}(sat)$ vs I_C

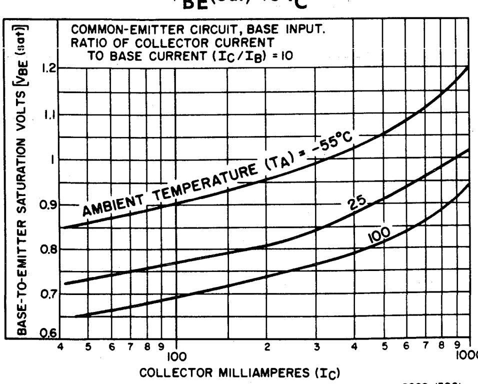


Fig.10

I_C & I_B vs V_{BE}

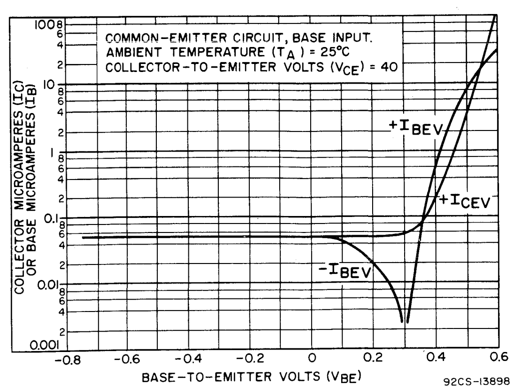


Fig.11

TYPICAL CHARACTERISTICS

t_r vs I_C/I_{B1}

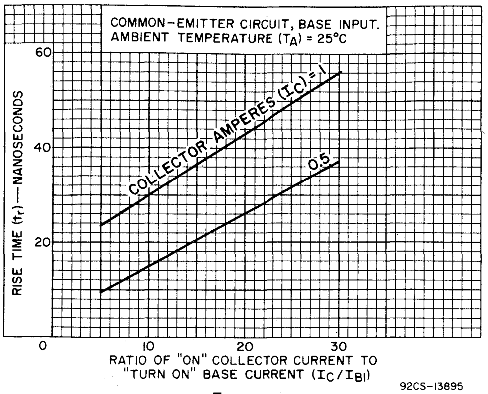


Fig.12

t_s vs I_C/I_{B1}

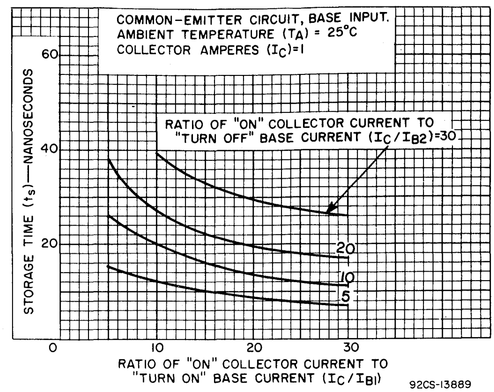


Fig.13

t_{on} vs I_C/I_{B1}

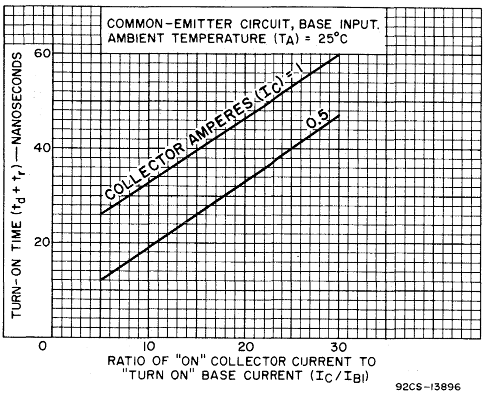


Fig.14

t_{off} vs I_C/I_{B1}

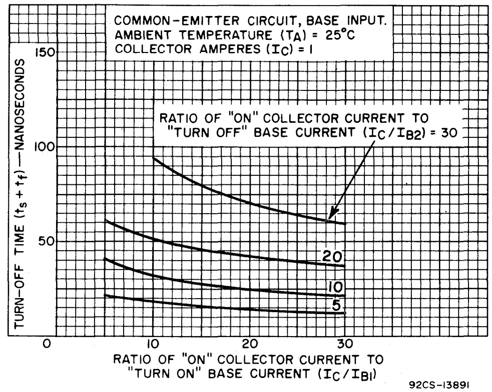


Fig.15

I_{CES} vs T_A

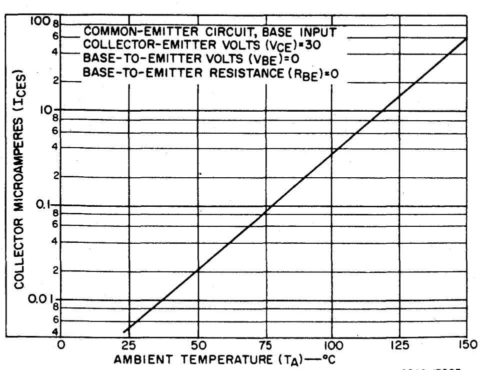


Fig.16

BV_{CERL} vs R_{BE}

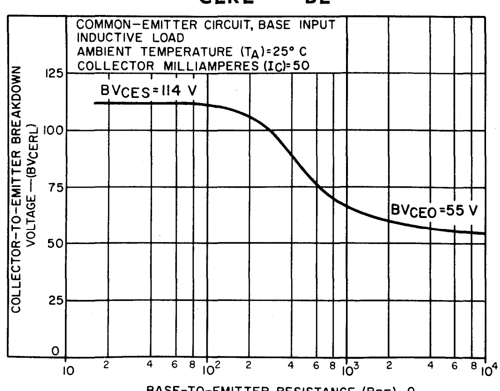


Fig.17

TYPICAL CHARACTERISTICS

C_{ob} vs V_{CB}

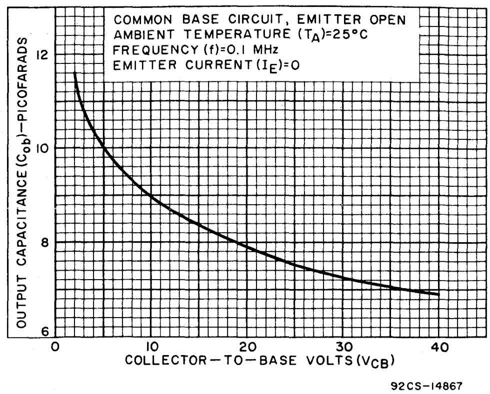


Fig. 18

C_{ib} vs V_{EB}

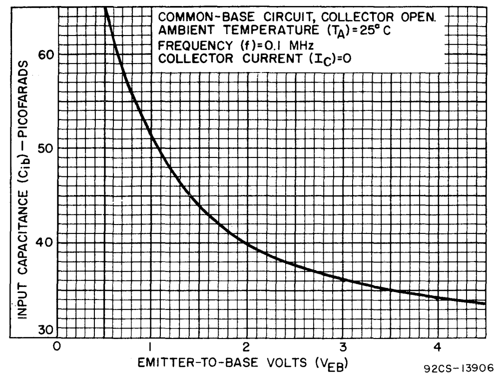
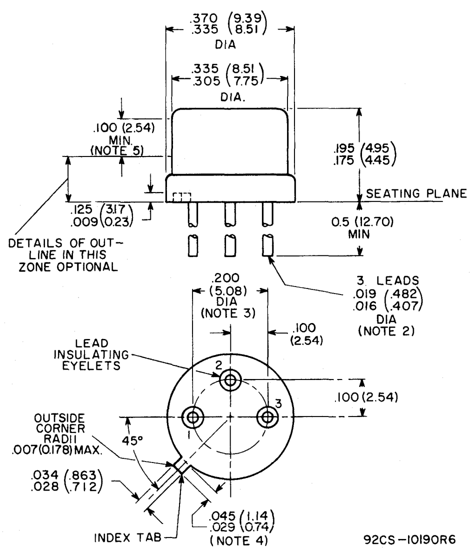


Fig. 19

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.

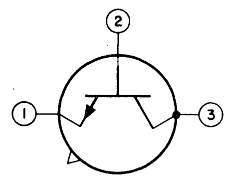
Note 3: Leads having a maximum diameter of 0.019" (0.482 mm) at a gauging plane of 0.054" (1.372 mm) + 0.001" (0.025 mm) - 0.000" (0.000 mm) below seating plane shall be within 0.007" (0.178 mm) of their true position (location) relative to a maximum width of tab.

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

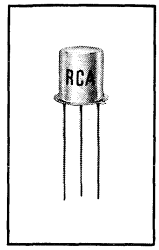
Solid State
Division

Power Transistors

40084

RCA-40084 is a general-purpose planar transistor of the silicon n-p-n type 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.

For Small-Signal and Medium-Power Applications



JEDEC TO-18

- minimum gain-bandwidth product = 100 Mc, useful in applications from dc to 20 Mc
- operation at high junction temperatures—up to 200°C
- low noise and low leakage characteristics
- high switching speed (non-saturating mode)—30 nanoseconds maximum
- very low output capacitance—15 pf maximum

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	60 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:		
With base open, V_{CEO}	40 max.	volts
With $R_{BE} \leq 10$ ohms, V_{CER}	50 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	5 max.	volts
COLLECTOR CURRENT, I_C	1 max.	amp
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25° C.	1.8 max.	watts
At case temperatures above 25° C.	See *Rating*	*Chart*
At free-air temperatures up to 25° C.	0.5 max.	watt
At free-air temperatures above 25° C.	See *Rating*	*Chart*
TEMPERATURE RANGE:		
Storage	-65 to +200	°C
Operating (Junction)	-65 to +200	°C
LEAD TEMPERATURE (During Soldering): At distances $\geq$ 1/32 inch from seating surface for 10 sec. max.	225 max.	°C

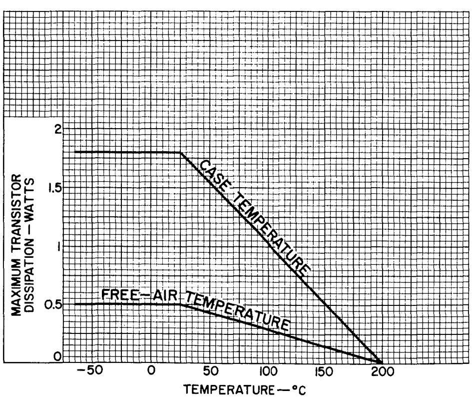


Fig.1 - Rating Chart for RCA-40084.

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.	LIMITS RCA 40084 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	θ_{J-C}							-	97	°C/W
Junction-to-free air	θ_{J-FA}							-	350	°C/W

** Pulse Test: Pulse duration, 300 μsec; duty factor, 1.8%.

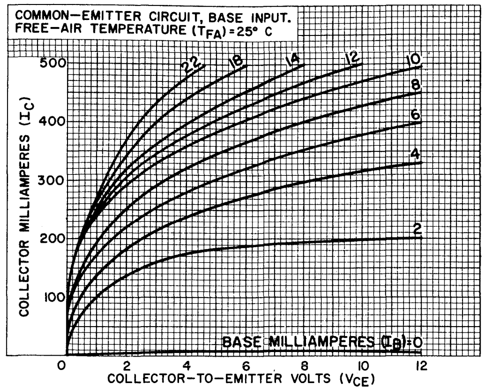


Fig. 2 - Typical Collector Characteristics at 25° C for RCA-40084.

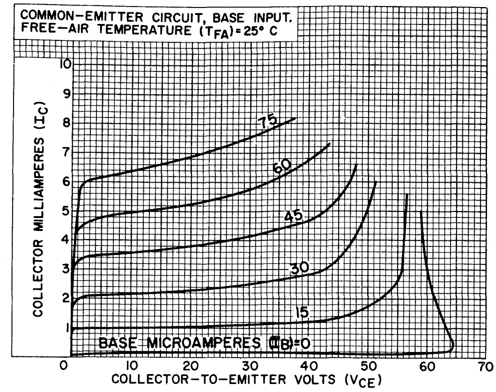


Fig. 3 - Typical Collector Characteristics at 25° C for RCA-40084.

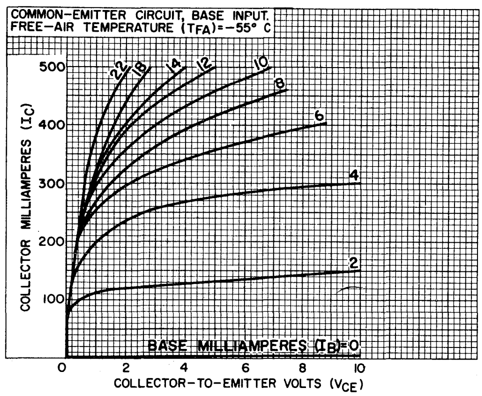


Fig. 4 - Typical Collector Characteristics at -55° C for RCA-40084.

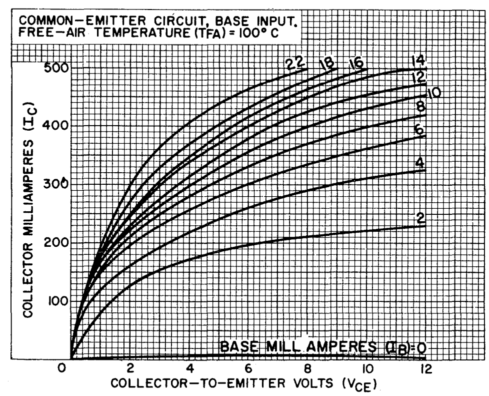


Fig. 5 - Typical Collector Characteristics at 100° C for RCA-40084.

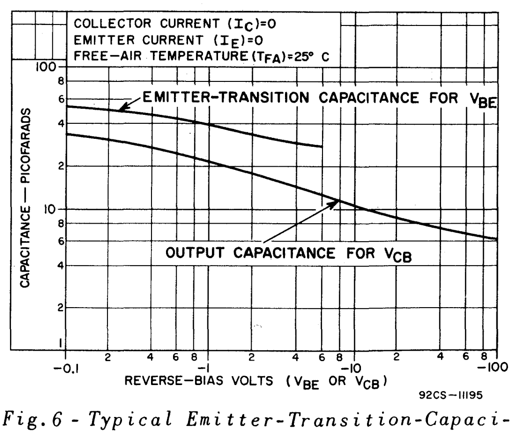
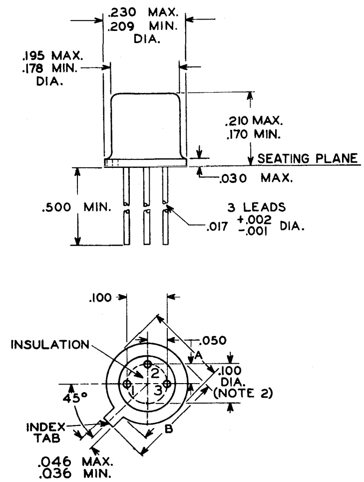


Fig. 6 - Typical Emitter-Transition-Capacitance and Output-Capacitance Characteristics for RCA-40084.

DIMENSIONAL OUTLINE

JEDEC NO. TO-18



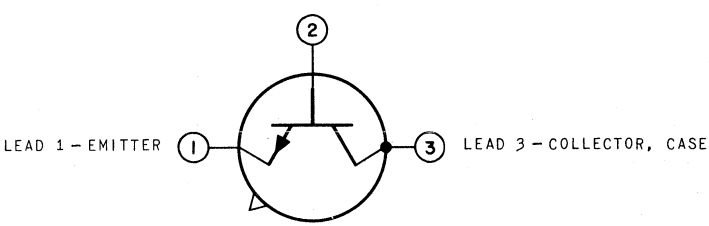
92CS-10605R3

NOTE: Tab length to be 0.028" min., 0.048" max. and will be determined by subtracting diameter "A" from dimension "B".

DIMENSIONS IN INCHES

TERMINAL DIAGRAM

Bottom View



Special Audio Power Transistors

RCA
Solid State
Division

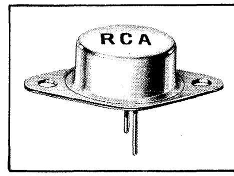
Power Transistors
2N2147
2N2148

RCA-2N2147 and 2N2148 are diffused-collector--graded-base power transistors of the germanium p-n-p type intended for use in high-fidelity amplifiers and other af amplifiers where wide frequency range and low distortion are required. These transistors utilize a combination of diffusion and alloying techniques to provide a built-in accelerating field in the base region. This accelerating field makes possible a wide frequency response and a linearity of characteristics not available in conventional power transistors.

RCA-2N2147 and 2N2148 are intended primarily for use in class B amplifier service, and have specially controlled breakdown-voltage and collector-saturation-current characteristics to provide dependable performance in this type of service. In a "single-ended push-pull" class B amplifier circuit of the type shown in Fig.1, using a 4-Ω speaker, a pair of 2N2147 transistors can deliver 25 watts rms power output with less than 5% total harmonic distortion, and provide a power gain of 33 dB; a pair of 2N2148 transistors can deliver 15 watts rms power output with less than 5% total harmonic distortion, and provide a power gain of 31 dB.

RCA-2N2148 is also extremely useful as a class A power amplifier in driver stages of high-power, high-quality af amplifiers, and in output stages of moderate-power amplifiers. In class A amplifier service a 2N2148 can deliver up to 5 watts output and provide a power gain of 36 dB.

GERMANIUM P-N-P DRIFT-FIELD POWER TRANSISTORS



For High-Fidelity Audio-Frequency-Amplifier Applications

- **High Power Sensitivity Over Entire AF Spectrum:**
  - high minimum betas at high currents —
    h_{FE} = 100 min. for 2N2147, 60 min. for 2N2148 at I_C = 1 A; 75 min. for 2N2147, 40 min. for 2N2148 at I_C = 4 A
  - high gain-bandwidth product provides full gain to 20 kHz — f_T = 4 MHz typ. for 2N2147, 3 MHz typ. for 2N2148
  - low base resistance minimizes driving-voltage requirements
- 100% pulse tested for freedom from second breakdown
- completely welded, hermetically sealed TO-3 package

AF-POWER-AMPLIFIER SERVICE

Maximum Ratings, *Absolute-Maximum Values:*

	2N2147	2N2148		
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-75	-60	max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	-50	-40	max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-1.5[a]	-1.5[a]	max.	V
COLLECTOR CURRENT, I_C	-5	-5	max.	A
BASE CURRENT, I_B	-1	-1	max.	A
EMITTER CURRENT, I_E	+5	+5	max.	A
TRANSISTOR DISSIPATION, P_T:				
Average: For mounting-flange temperatures[b] up to 81° C.	12.5	12.5	max.	W
Derate linearly:	0.66 W/°C			

Peak: Determined by operating conditions — See *Figs.4 and 5.*

TEMPERATURE RANGE:				
Storage	-65° C to +100° C			
Operating (Junction)	-65° C to +100° C			
PIN TEMPERATURE (During soldering):				
At distances of not less than 1/16" from seating surface for 10 seconds max.	255	255	max.	°C

[a] This rating may be exceeded provided the combined dissipation in the emitter and the collector does not exceed the maximum dissipation rating for the device, and provided the driver stage (transformer-coupled) is capable of providing the emitter-to-base current drawn by the transistors under the emitter-to-base voltage conditions (reverse-bias) shown.

[b] Measured at center of seating surface.

Electrical Characteristics, at a Mounting-Flange Temperature (T_{MF}) of 25° C

Characteristics: Common-Emitter Circuit, Base Input Unless Otherwise Specified	Symbols	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 Base Current I_B	DC Emitter Current I_E	Type 2N2147			Type 2N2148			
		volts	volts	volts	mA	mA	mA	Min.	Typical	Max.	Min.	Typical	Max.	
Collector-to-Base Breakdown Voltage*	BV_{CBO}				-10		0	-75	–	–	-60	–	–	V
Collector-to-Emitter Sustaining Voltage	V_{CEO} (sus)				-100	0		-50	–	–	-40	–	–	V
Collector-to-Emitter Saturation Voltage	V_{CE} (sat)				-5000	-250		–	–	-0.6	–	–	-0.75	V
Collector Cutoff Current	I_{CBO}	-40					0	–	–	-1	–	–	-1	mA
Collector Cutoff Saturation Current	I_{CBO} (sat)	-0.5					0	–	–	-70	–	–	-100	μA
EmitterCutoff Current	I_{EBO}			-1.5	0			–	–	-2.5	–	–	-10	mA
Static Forward-Current-Transfer Ratio	h_{FE}		-2 -2		-1000 -4000			100 75	150 –	300 –	60 40	100 –	– –	
Gain-Bandwidth Product	f_T		-5		-500			3	4	–	2	3	–	MHz
Thermal Resistance (Junction-to-Case)	θ_{JC}			–				–	–	1.5	–	–	1.5	°C/W
Base-to-Emitter Voltage	V_{BE}		-10 -2		-50 -1000			-0.2 –	-0.23 –	-0.27 -0.5	-0.21 –	-0.24 –	-0.28 -0.5	V

* Pulse Test: Pulse Duration = 300 μs; Duty Factor = 0.01

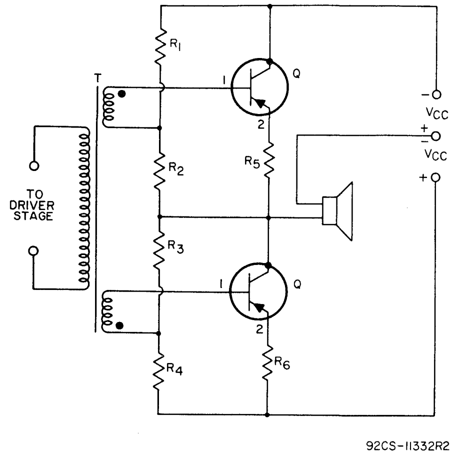
Typical Operation of Types 2N2147 and 2N2148 in "Single-Ended Push-Pull" Class B AF-Amplifier Circuit Shown in Fig. 1:

For a Mounting-Flange Temperature of 25° C

	2N2147	2N2148	
DC Collector Supply Voltages (V_{CC})[c]	22	16.5	V
Zero-Signal DC Collector Current	-0.035	-0.035	A
Zero-Signal Base-Bias Voltage	-0.24	-0.26	V
Peak Collector Current	-3.5	-2.7	A
Maximum-Signal DC Collector Current	-1.1	-0.85	A
Input Impedance of Stage (per base)	75	65	Ω
Load-Impedance (Speaker Voice-Coil)	4	4	Ω
Power Gain	33	31	dB
Maximum-Signal Power Output	25	15	W
Total Harmonic Distortion at Maximum-Signal Power Output	5	5	%
Maximum Collector Dissipation (per transistor) under worst-case conditions	12.5	7.5	W
EIA Music Power Output Rating[d]	45	25	W

[c] The data shown are for a dc collector supply having 10 per cent regulation.

[d] EIA Standard No.RS234, Section 2.1.2.1.



Q: Transistor Types 2N2147, 2N2148

	2N2147	2N2148	
R_1, R_3	330	270	Ω ± 10%, 2 W
R_2, R_4	3.9	3.9	Ω ± 10%, 0.5 W
R_5, R_6	0.47	0.47	Ω ± 10%, 0.5 W
Speaker: Voice-Coil Impedance	4	4	Ω

T: Driver Transformer. Primary-winding impedance, current-carrying capacity, and dc resistance determined by large-signal characteristics of driver stage; secondary windings bifilar wound, impedance of each winding = 100 Ω

Fig. 1 - "Single-Ended-Push-Pull" Class-B AF Amplifier Stage using RCA Types 2N2147 or 2N2148.

Typical Operation of Type 2N2148 in Class A AF-Amplifier Circuit Shown in Fig. 2

For a Mounting-Flange Temperature of 25° C

DC Collector Supply Voltage (V_{CC})	16	V
DC Collector-Emitter Voltage	-13.2	V
DC Collector Current	0.9	A
Peak Collector Current	1.8	A
Input Impedance	10	Ω
Collector Load Impedance	15	Ω
Maximum-Signal Power Output	5	W
Total Harmonic Distortion at 5 watts Output	5	%
Power Gain	36	dB
Maximum Collector Dissipation	12	W

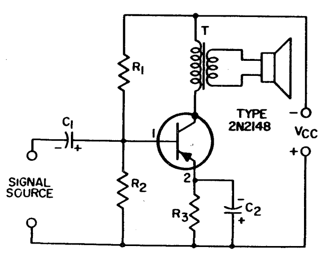


Fig. 2 - Class-A AF-Amplifier Stage using RCA Type 2N2148 Transistor.

C_1: Value determined by signal-source impedance

C_2: 5000 μF, electrolytic, 3 V

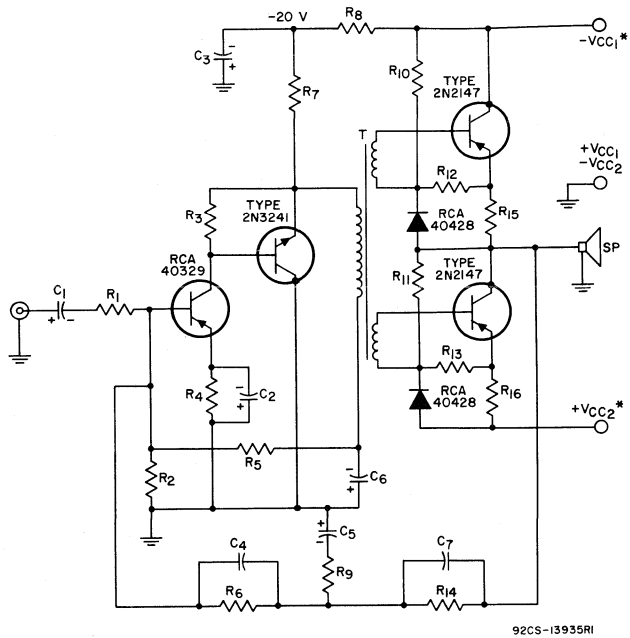
R_1: 120 Ω ± 10%, 2W

R_2: 22 Ω ± 10%, 0.5 W

R_3: 2.2 Ω ± 10%, 2 W

T: Output Transformer for matching impedance of speaker voice coil to 15-Ω collector load impedance for 2N2148; primary-winding current = 1 A; primary-winding dc resistance = 1 Ω max.

V_{CC}: 16 V



C_1 = 5 µF, 3 V, electrolytic
C_2 = 200 µF, 3 V, electrolytic
C_3 = 2500 µF, 35 V, electrolytic
C_4,C_7 = 39 pF, mica
C_5 = 10 µF, 3 V, electrolytic
C_6 = 250 µF, 15 V, electrolytic
R_1 = 1500 Ω, 0.5 W
R_2 = 22 KΩ, 0.5 W
R_3 = 270 Ω, 0.5 W

R_4,R_9 = 1 KΩ, 0.5 W
R_5 = 56 KΩ, 0.5 W
R_6 = 22 KΩ, 0.5 W
R_7 = 330 Ω, 1 W
R_8 = Selected to provide 20 V across C_3 under zero-signal conditions
R_{10},R_{11} = 270 Ω, 2 W
R_{12},R_{13} = 22 Ω, 5 W

R_{14},= 33 KΩ, 0.5 W
R_{15},R_{16} = 0.47 Ω, 0.5 W
SP = Speaker or speaker system: Impedance = 4 Ω
T = Driver Transformer:
Turns ratio, primary to each secondary: 3:1
Primary impedance: 400 Ω
Primary dc: 0 mA

* V_{CC_1}, V_{CC_2}: Zero-signal value = 22 V (I = 150 mA)
Maximum-signal value = 20 V (I = 1 A)

Performance Specifications for 4 Ω Speaker Load:

Continuous (Sine-Wave) Power Output = 25 W
EIA Music Power Output# = 40 W
Total Harmonic Distortion at 25 W output, f = 1 kHz = 0.5%
Sensitivity = 50 mV rms input for 25 W output at 1 kHz
Frequency Response = 1 dB down at 20 Hz and 20 kHz
3 dB down at 15 Hz and 35 kHz
Input Resistance = 1500 Ω
Hum and Noise = 80 dB below 25 W, input open or shorted

EIA Standard No.RS 234, Section 2.1.2.1

Fig.3 - Circuit of 25-Watt High-Quality Power Amplifier Using RCA-2N2147, 2N3241, and 40329 Transistors, and RCA-40428 Compensating Diode.

OPERATING CONSIDERATIONS

The *maximum ratings* in the tabulated data are established in accordance with the following definition of the *Absolute-Maximum Rating System* for rating electron devices.

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.

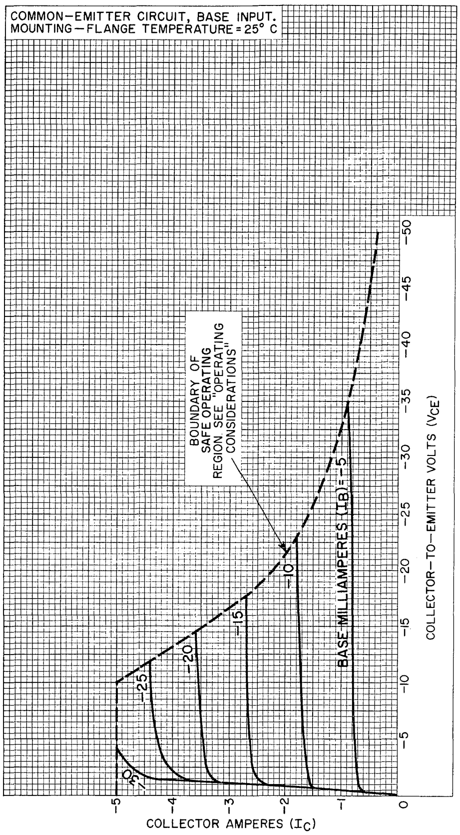


Fig.4 - Typical Collector Characteristics for Type 2N2147.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environment 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.

In the design of amplifier circuits using the 2N2147 and 2N2148, it is extremely important to assure that the operating characteristic for either type does not,

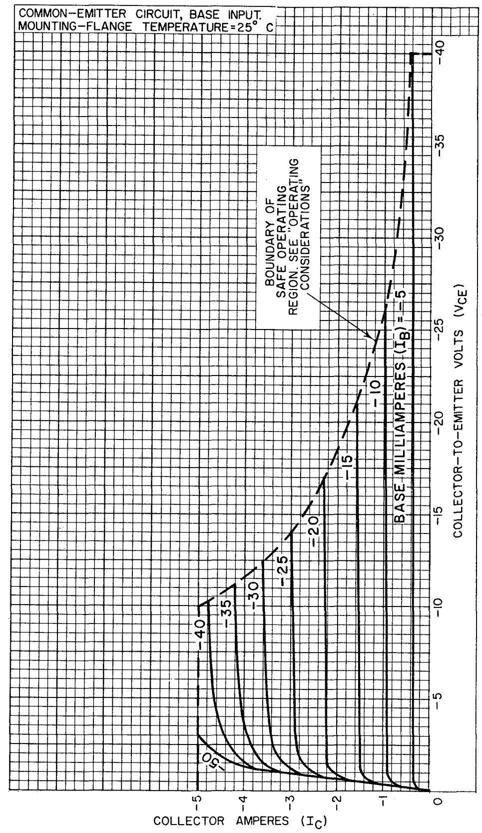


Fig.5 - Typical Collector Characteristics for Type 2N2148.

under any foreseeable combination of operating conditions, extend outside the safe operating region shown in Fig.4 or Fig.5. EVEN MOMENTARY EXCURSION OF THE TRANSISTOR OPERATING CHARACTERISTIC OUTSIDE THIS REGION, OR MOMENTARY OPERATION OF THE TRANSISTOR ABOVE ANY OF ITS MAXIMUM RATINGS CAN RESULT IN PERMANENT DAMAGE TO THE TRANSISTOR.

To assure that the 2N2147 and 2N2148 are operated at all times within the safe regions shown in Figs.4 and 5, the circuit designer should take into account the possible effects of the following factors:

(1) phase shift due to circuit capacitances and/or speaker resonance

(2) parasitic oscillations, such as "ringing" caused by excessive or improperly neutralized feedback

(3) high line voltage

(4) variations in speaker impedance

(5) overdriving of transistors

(6) non-sinusoidal signal waveforms

Any of these factors, or combination, can change the character and value of the transistor load sufficiently to cause operation outside the safe operating region shown in Fig.4 and Fig.5.

Because the metal shells of these transistors operate at the collector voltage, consideration should be given to the possibility of shock hazard if the shells are to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

The 2N2147 and 2N2148 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistors.

These transistors can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistor.

It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE TRANSISTOR.

The mounting-flange temperature of the 2N2147 or 2N2148 will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.

Depending on the application, the heat sink or chassis may be connected to either the positive or negative terminal of the voltage supply.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be necessary to use either an anodized aluminum insulator having high thermal conductivity, or a 0.002" thick mica insulator between the mounting flange and the chassis. If an aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the emitter and base pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that a insulating washer be used between each bolt and the chassis as shown in Fig.13

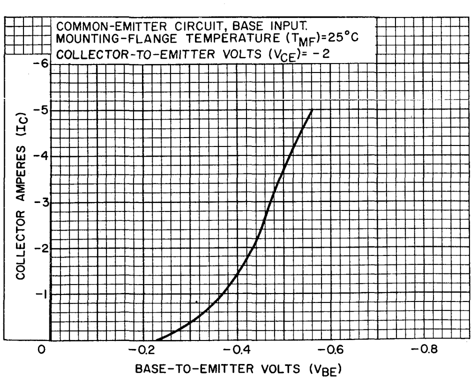


Fig.6 - Typical Transfer Characteristic for Type 2N2147.

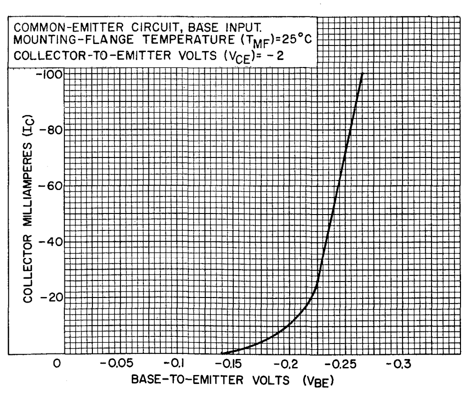


Fig.7 - Typical Transfer Characteristic for Type 2N2147.

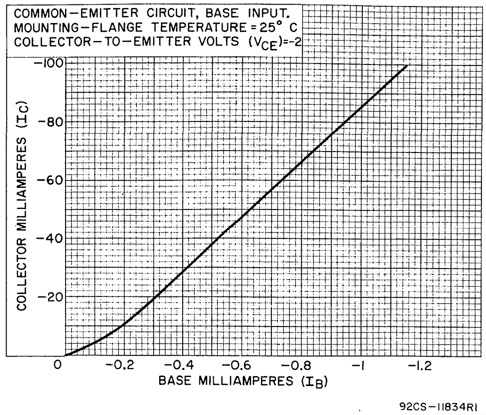


Fig.8 - Typical Current-Transfer Characteristic for Type 2N2147.

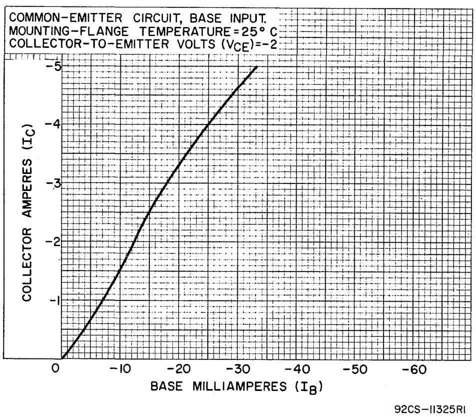


Fig.9 - Typical Current-Transfer Characteristic for Type 2N2147.

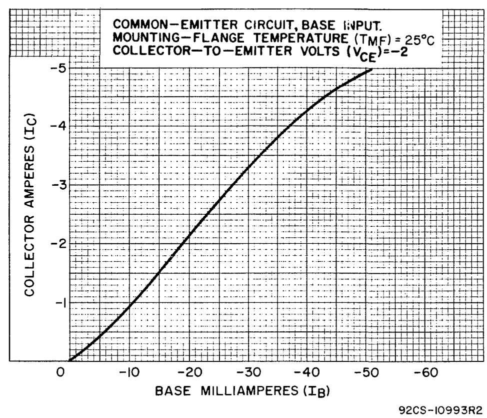


Fig.10 - Typical Current-Transfer Characteristic for Type 2N2148.

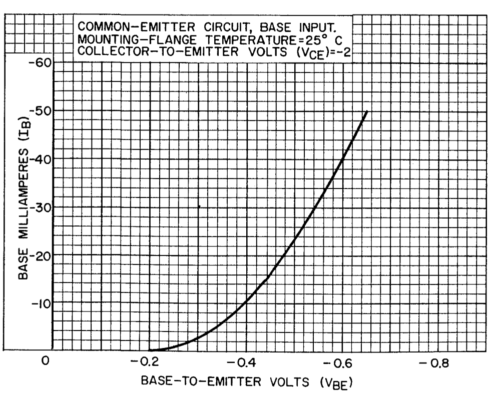


Fig.11 - Typical Input Characteristics for Type 2N2147.

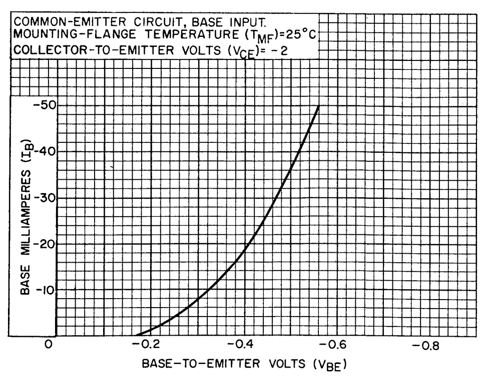
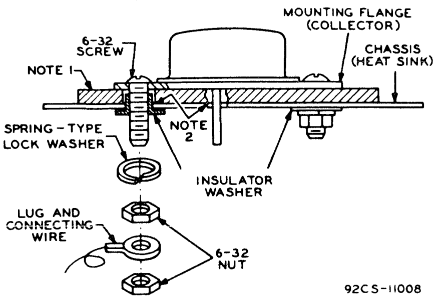


Fig.12 - Typical Input Characteristics for Type 2N2148.



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Mounting hardware items for RCA-2N2147 and 2N2148 are available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART NO.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

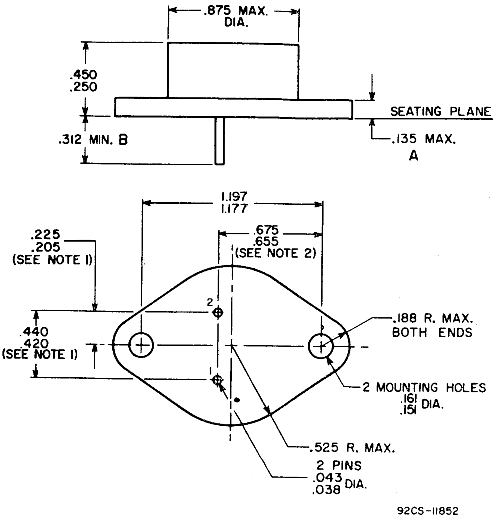
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-2N2147 and 2N2148 and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

Fig.13 - Suggested Mounting Arrangement for Types 2N2147, 2N2148.

DIMENSIONAL OUTLINE
For Types 2N2147, 2N2148
JEDEC No.TO-3



DIMENSIONS IN INCHES

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

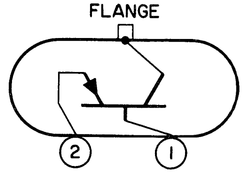
NOTE 2: TWO LEADS.

For RCA-2N2147 and 2N2148

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. / 0.480" max.

TERMINAL CONNECTIONS



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

RCA Solid State Division

Power Transistors

40309–40328 40360–40364

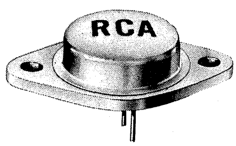
RCA transistors 40309–40328 and 40360–40364 are diffused-junction, silicon n-p-n and p-n-p transistors intended for specific applications in audio amplifiers, giving high-quality performance economically. These types cover applications from low-level input stages to high-power output stages of 5 to 50 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.

N-P-N and P-N-P Types for AF Amplifier Applications

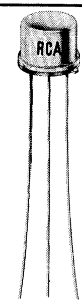
- JEDEC TO-3, TO-5 and TO-66, hermetically-sealed packages
- Operation at case temperatures up to 257°F
- Freedom from second breakdown in operating region
- Pellet bonded to header
  - for greater power-handling capability
  - for greater shock resistance

40325
40363



TO-3 **A●**

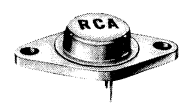
40309 40311 40314
40315 40317 40319



40320 40321 40323
40326 40327 40360 40361 40362

TO-5 **B●**

40310 40312
40313 40316
40318 40322
40324 40328 40364



TO-66 **C●**

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

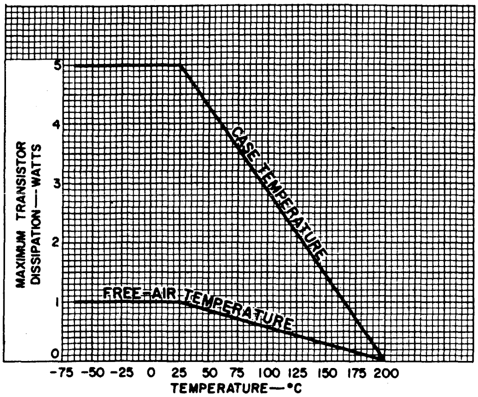
*R_{BE} = 500 Ω
R_{BE} = 1,000 Ω for 40327
R_{BE} = 200 Ω for 40361, 40362, & 40363
R_{BE} = 150 Ω for 40364

**V_{BE} = -1.5 V

*** At other temperatures see derating curves

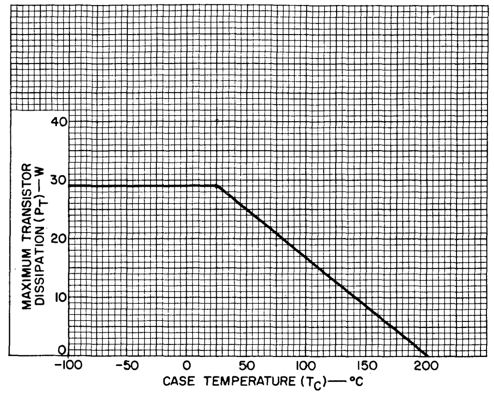
● See page 3, 4, or 5 for electrical characteristics for these types.

DISSIPATION RATING CURVES FOR TYPES 4309, 40311, 40314, 40315, 40317, 40319, 40320, 40323, 40326, 40360, 40361, AND 40362



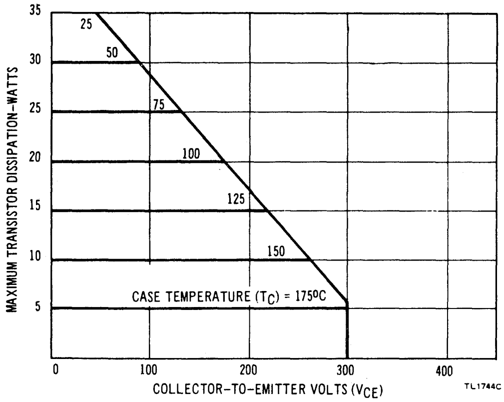
92CS-11172RI

DISSIPATION DERATING CURVE FOR TYPES 40310, 40312, 40316, AND 40324



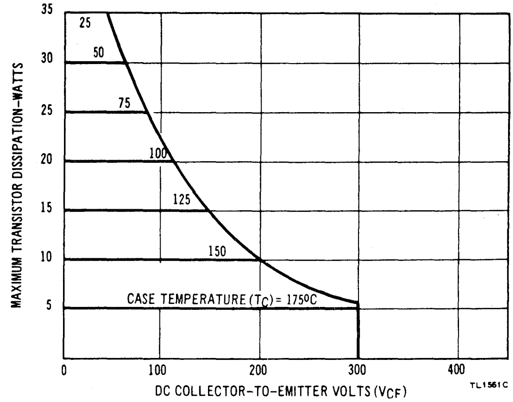
92CS-13005RI

DISSIPATION DERATING CURVE FOR TYPE 40313



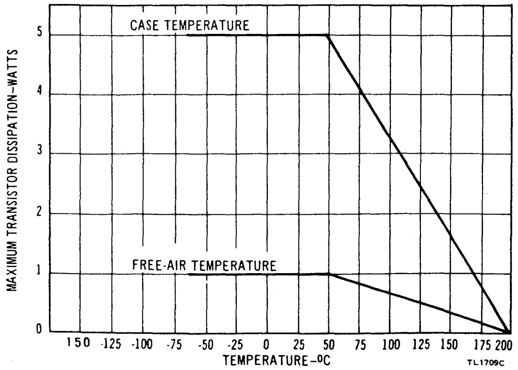
TL1744C

DISSIPATION DERATING CURVE FOR TYPES 40318, 40322, AND 40328



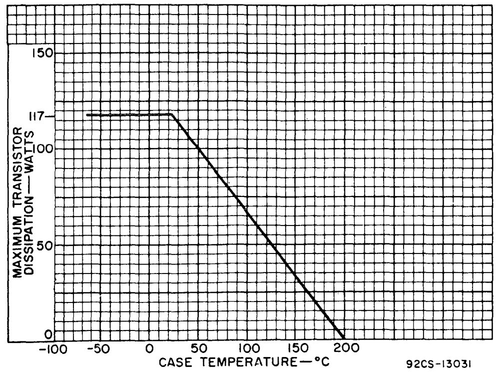
TL1561C

DISSIPATION DERATING CURVES FOR TYPES 40321 AND 40327



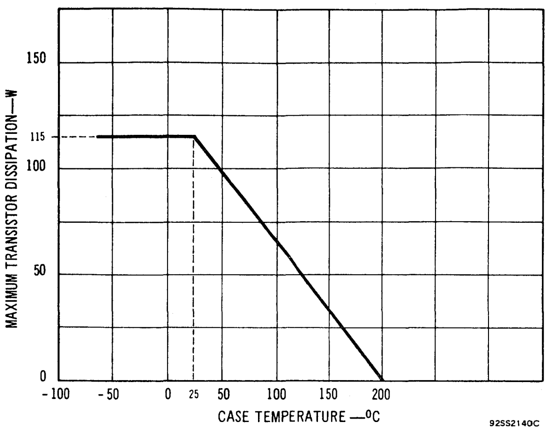
TL1709C

DISSIPATION DERATING CURVE FOR TYPE 40325

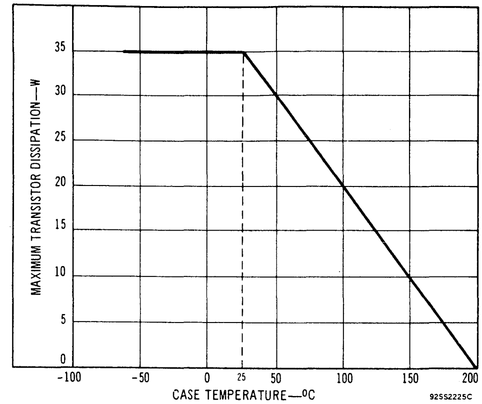


92CS-13031

DISSIPATION DERATING CURVE FOR TYPE 40363



DISSIPATION DERATING CURVE FOR TYPE 40364



ELECTRICAL CHARACTERISTICS (40325 and 40363)

CHARACTERISTIC	TEST CONDITIONS V_{CB} (Volts)	V_{CE} (Volts)	V_{EB} (Volts)	I_C (mA)	T_C (°C)	LIMITS 40325	40363
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

B ELECTRICAL CHARACTERISTICS (40309, 40311, 40314, 40315, 40317, 40319, 40320, 40321, 40323, 40326, 40327, 40360, 60361, and 40362)

CHARACTERISTIC	TEST CONDITIONS					LIMITS													
	V_{CB}	V_{CE}	V_{EB}	I_C	T_C	40309	40311	40314	40315	40317	40319	40320	40321	40323	40326	40327	40360	40361	40362
	Volts			mA	°C														
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			
θ_{J-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.)
θ_{J-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		100Mc/s (Typ.)	100Mc/s (Typ.)		100Mc/s (Typ.)					100Mc/s (Typ.)					
		-4		-50							100 Mc/s (Typ.)								100Mc/s (Typ.)
		4		50				100Mc/s (Typ.)									100Mc/s (Typ.)	100Mc/s (Typ.)	

* Pulsed; pulse duration = 300μsec, 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

C

ELECTRICAL CHARACTERISTICS (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.)

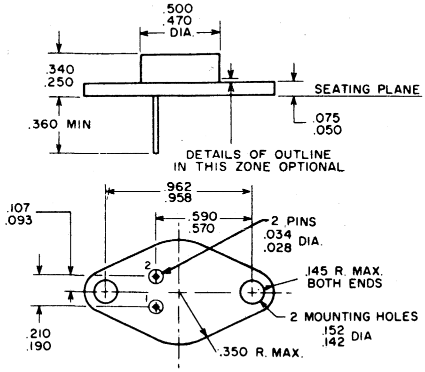
* Pulsed; Pulse duration = 300 μsec, duty factor < 2%. ⊡ R_{BE} value ■ R_{BE} = 20 ohms & L = 100 μh ♦ R_{BE} = 200 Ω, L = 5 mH

\# $I_{S/b}$ 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} = 150 Ω □ I_B = 0.25 A ● BV_{CEO} value.

DIMENSIONAL OUTLINE JEDEC No. TO-66



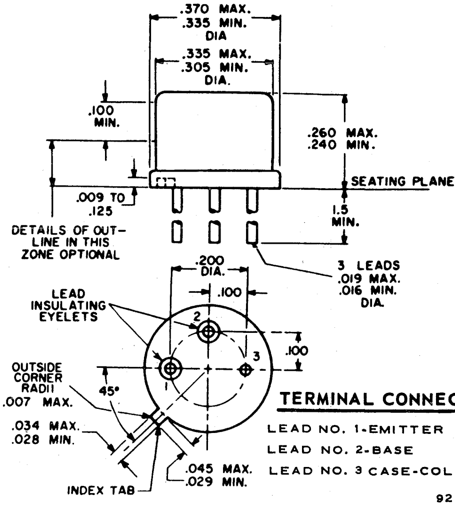
TERMINAL CONNECTIONS

PIN NO. 1-BASE
PIN NO. 2-EMITTER
FLANGE, CASE-COLLECTOR

92CS-12865

Dimensions in Inches

DIMENSIONAL OUTLINE JEDEC No. TO-5



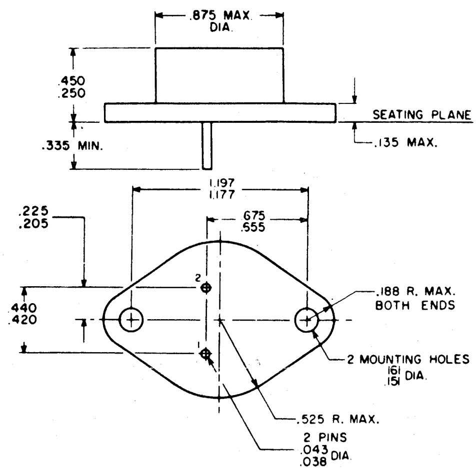
TERMINAL CONNECTIONS

LEAD NO. 1-EMITTER
LEAD NO. 2-BASE
LEAD NO. 3 CASE-COLLECTOR

92CS-12656

Dimensions in Inches

DIMENSIONAL OUTLINE JEDEC No. TO-3



TERMINAL CONNECTIONS

PIN NO. 1-BASE
PIN NO. 2-EMITTER
FLANGE, CASE-COLLECTOR

92CS-12336R2

Dimensions in Inches

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.

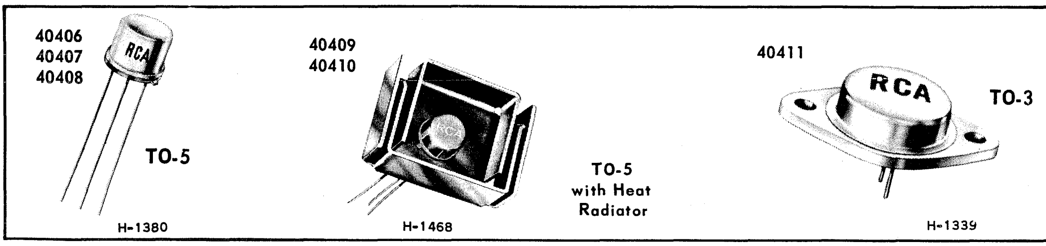
Silicon N-P-N & P-N-P Power Transistors for Audio Amplifier Applications

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] $R_{BE} = 100\ \Omega$

[c] F = 20 MHz

[d] F = 1 MHz, $I_E = 0$

[e] Power rating test at 200 watts

DISSIPATION DERATING CURVE FOR TYPES 40406, 40407, AND 40408

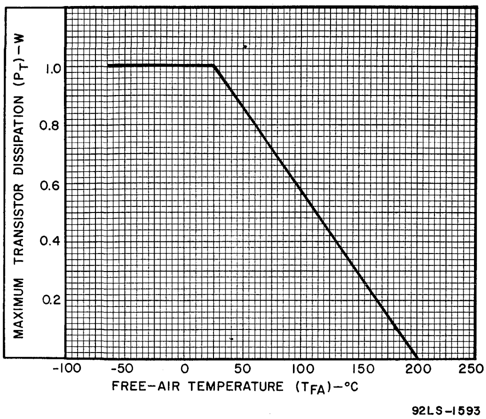


Fig. 1

DISSIPATION DERATING CURVE FOR TYPES 40409 AND 40410

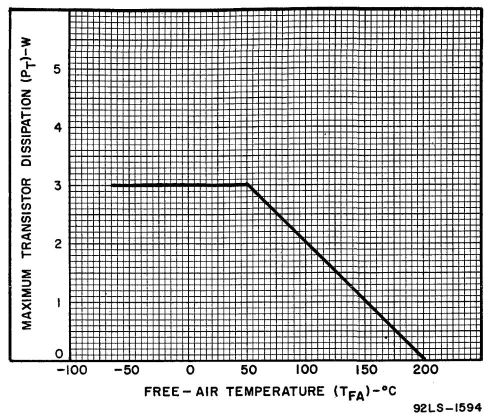


Fig. 2

DISSIPATION DERATING CURVE FOR TYPE 40411

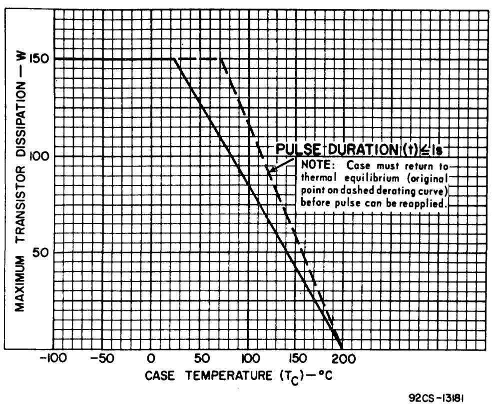


Fig. 3

TYPICAL OPERATION CHARACTERISTIC FOR TYPE 40411

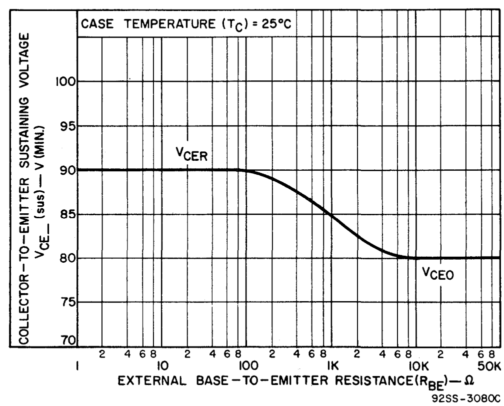


Fig. 4

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 40406 & 40410

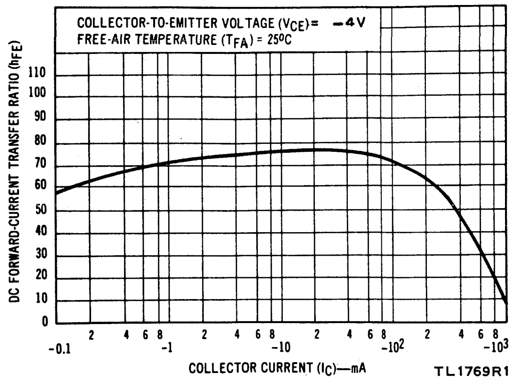


Fig. 5

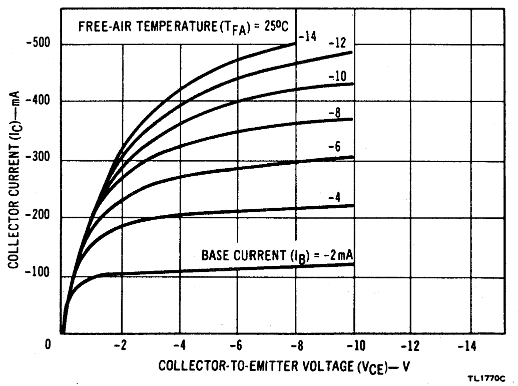


Fig. 6

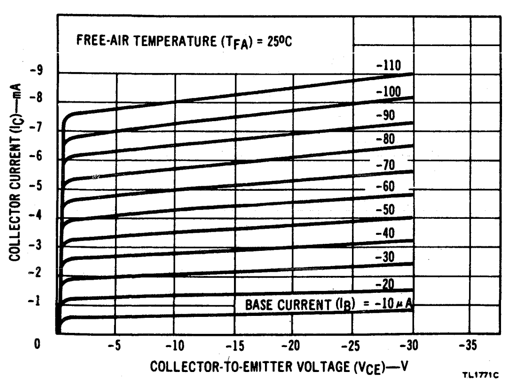


Fig. 7

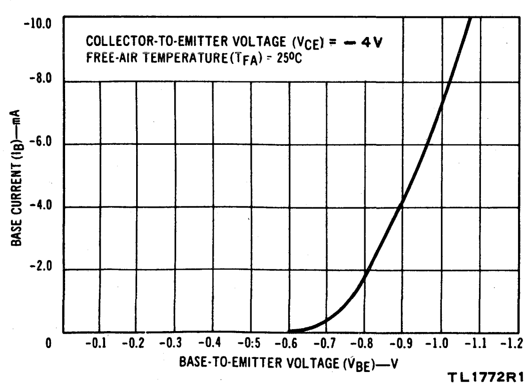


Fig. 8

TYPICAL OPERATION CHARACTERISTICS FOR TYPES 40407, 40408, & 40409

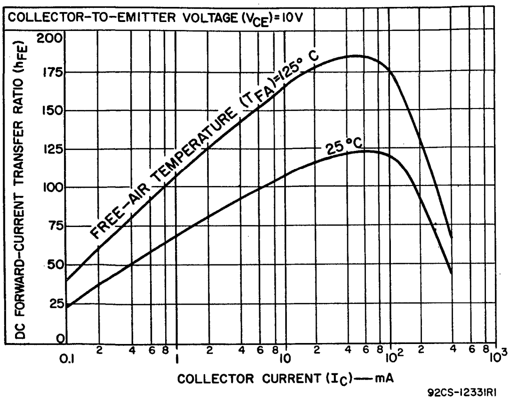


Fig. 9

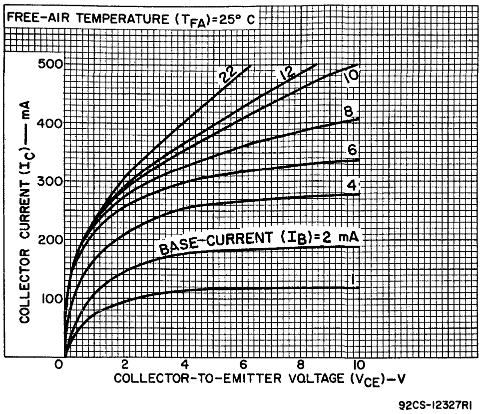


Fig. 10

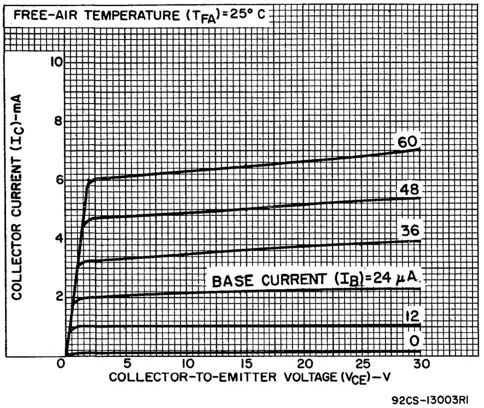


Fig. 11

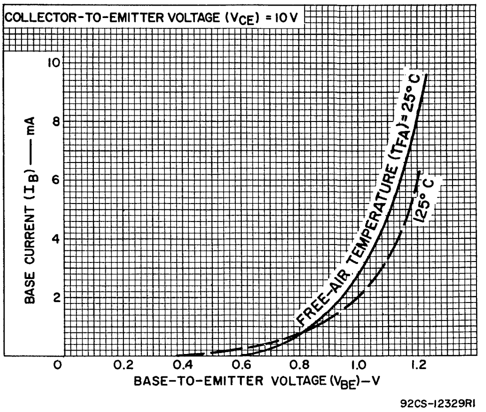


Fig. 12

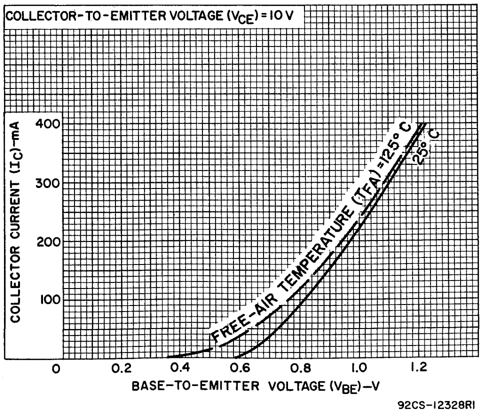


Fig. 13

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 40411

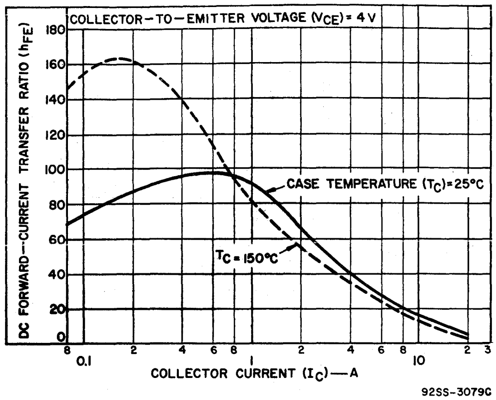


Fig. 14

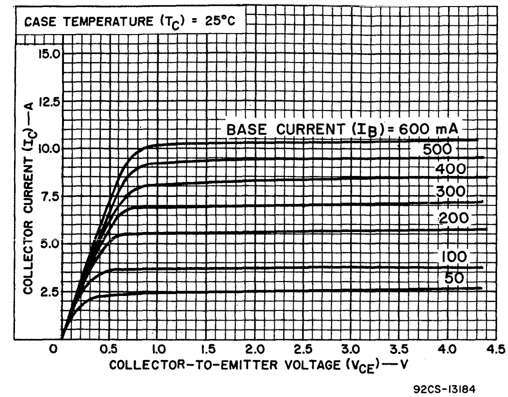


Fig. 15

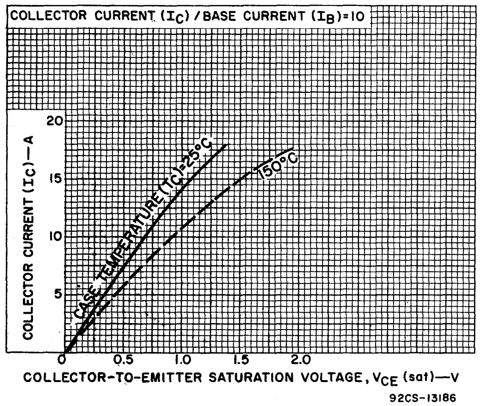


Fig. 16

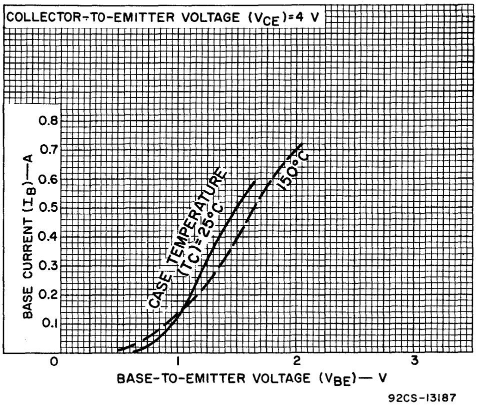


Fig. 17

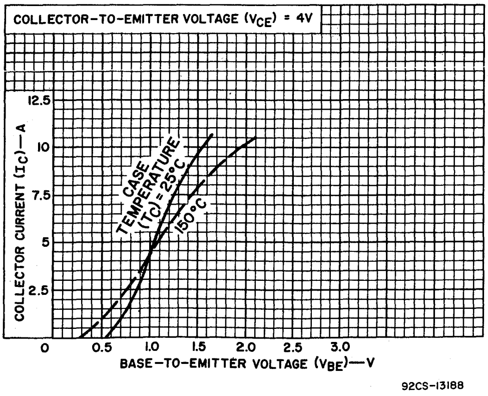
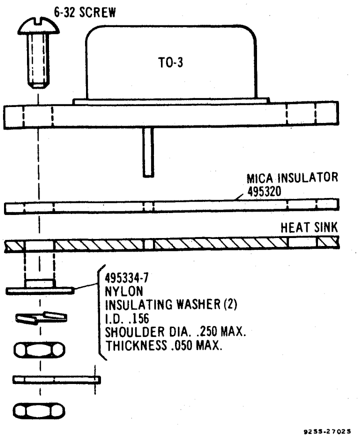


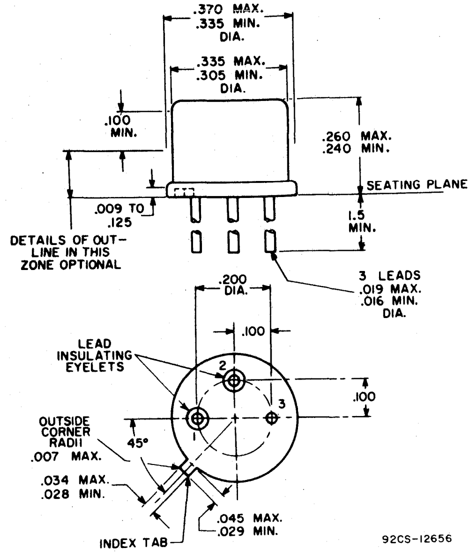
Fig. 18

SUGGESTED HARDWARE FOR TYPE 40411

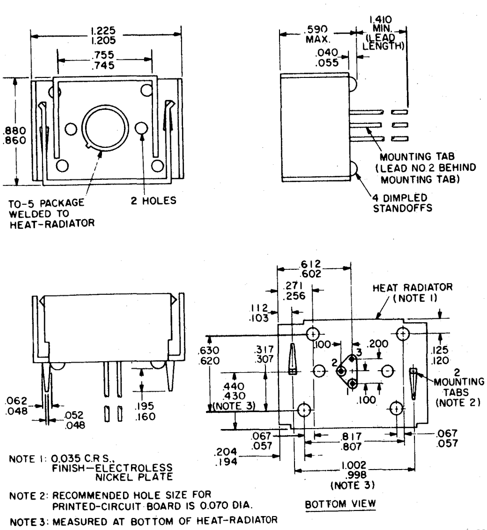


NOTE: Hardware with part numbers supplied.

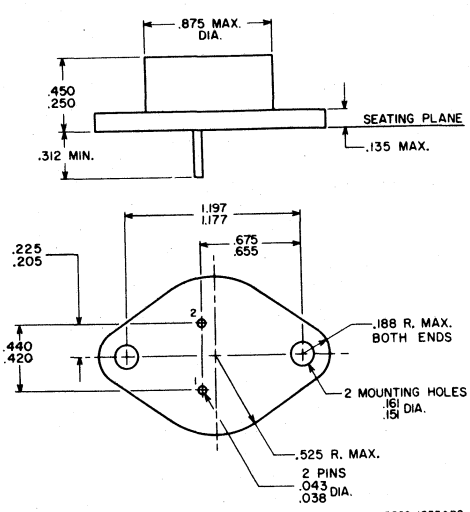
DIMENSIONAL OUTLINE FOR TYPES 40406, 40407, & 40408 JEDEC No. TO-5



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**.

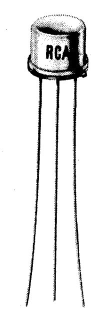
*Data for type 40539 appears in File No. 303.
**Typical audio-amplifier circuit using the 40537 and 40538 is shown as Circuit No. 4 in "RCA POWER TRANSISTORS, Typical Audio-Amplifier Circuits", publication No. ATC-500 (6/67).

- **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)	θ_{J-FA}					–	175	–	175	°C/W

[a]Pulsed; pulse duration = 300 μs, duty factor < 2%.

TYPICAL DC-BETA FOR TYPES 40537 & 40538

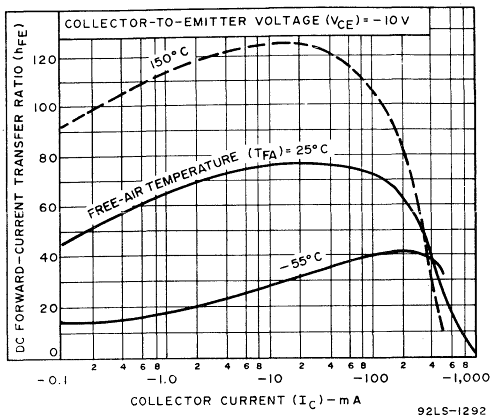


Fig. 1

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 40537 & 40538

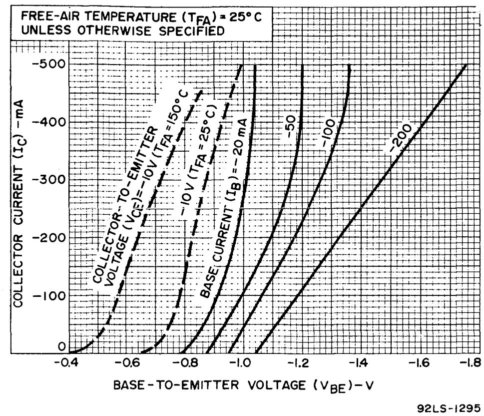


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 40537 & 40538

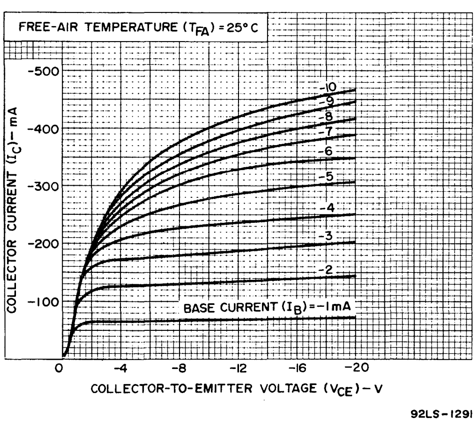


Fig. 3

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 40537 & 40538

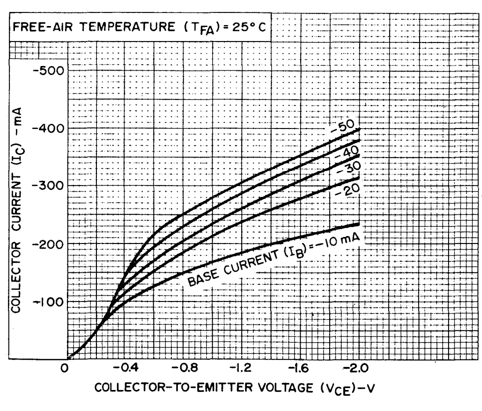
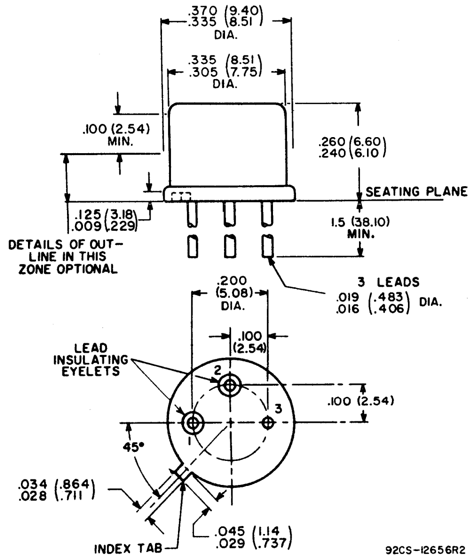


Fig. 4

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

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.

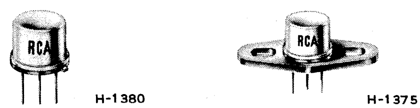
The 40539 is intended as a complement to p-n-p type 40538 in complementry-symmetry output stages. The 40544 was designed specifically as a driver in audio-amplifier circuits.

*Data for type 40538 appears in File No. 302.

SILICON N-P-N TRANSISTORS

For Driver and Output Stages in Audio-Amplifier Circuits

40539 – N-P-N Complement of 40538*



40539 (JEDEC TO-5)   40544 (TO-5 with Flange)

- **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				LIMITS				Units
		DC Voltage (V)		DC Current (mA)		Type 40539		Type 40544		
		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				–	–	–	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

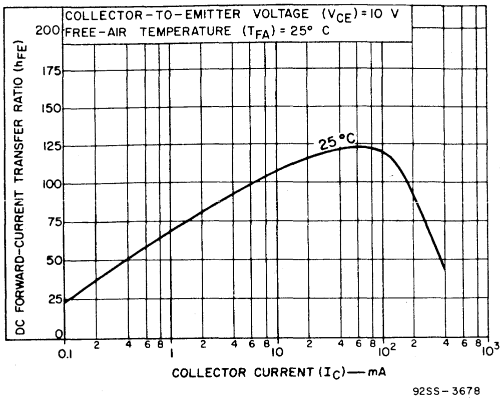


Fig. 1

TYPICAL INPUT CHARACTERISTICS FOR TYPES 40539 & 40544

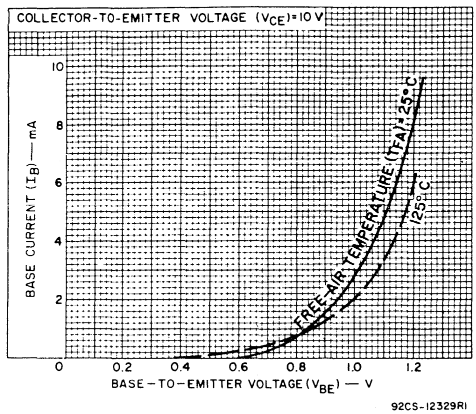


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS FOR TYPES 40539 & 40544

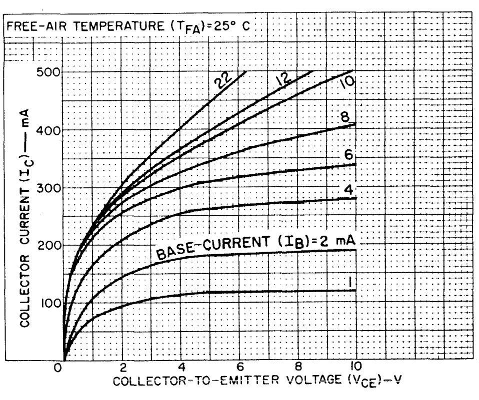


Fig. 3

TYPICAL TRANSFER CHARACTERISTICS FOR TYPES 40539 & 40544

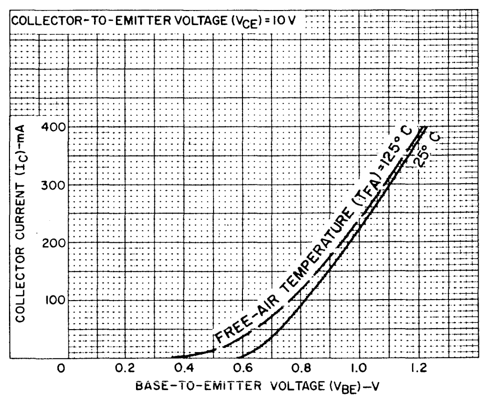
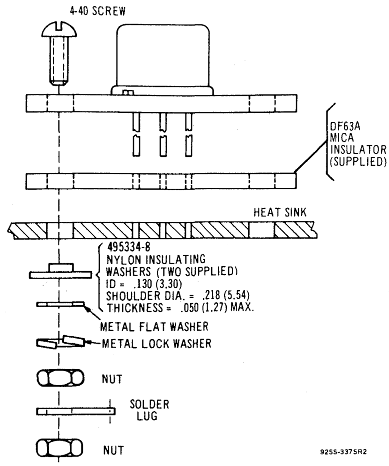


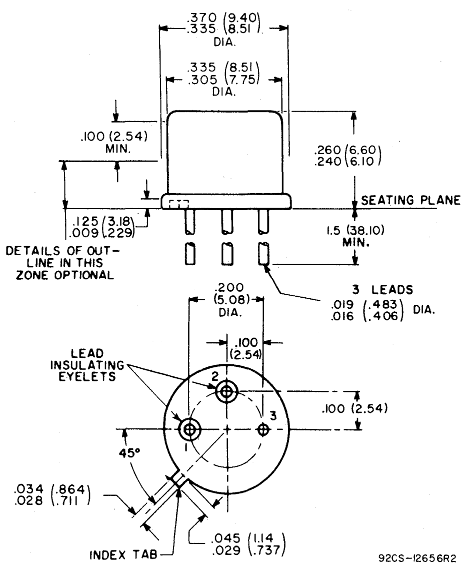
Fig. 4

SUGGESTED HARDWARE FOR MOUNTING TYPE 40544



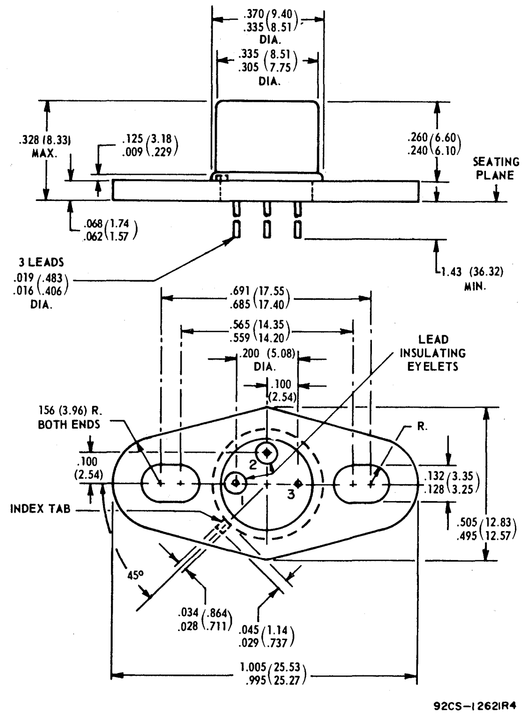
DIMENSIONAL OUTLINE FOR TYPE 40539

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

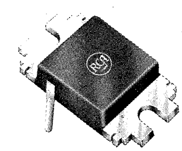
SILICON N-P-N, MOLDED SILICONE-PLASTIC HOMETAXIAL-BASE TRANSISTORS

FOR OUTPUT STAGES IN AUDIO-AMPLIFIER CIRCUITS

40542 -- N-P-N Complement of 40051*

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.



H-1532

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.

*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.

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: DC Voltage (V) V_{CE}	DC Voltage (V) V_{EB}	DC Current (A) I_C	DC Current (A) I_B	LIMITS: Type 40542 Min.	Type 40542 Max.	Type 40543 Min.	Type 40543 Max.	Units
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

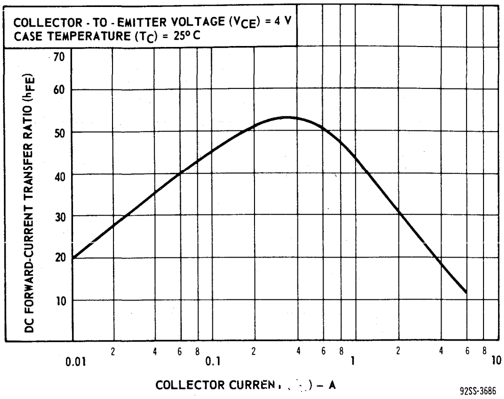


Fig. 1

TYPICAL INPUT CHARACTERISTICS
FOR TYPE 40542

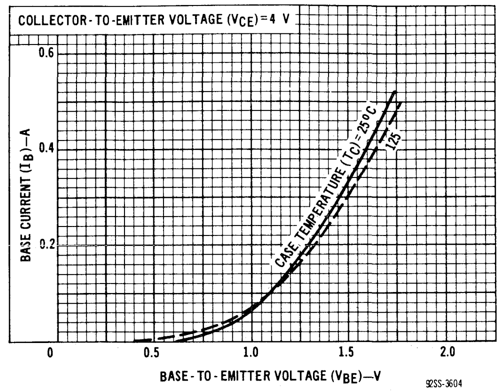


Fig. 2

TYPICAL OUTPUT CHARACTERISTICS
FOR TYPE 40542

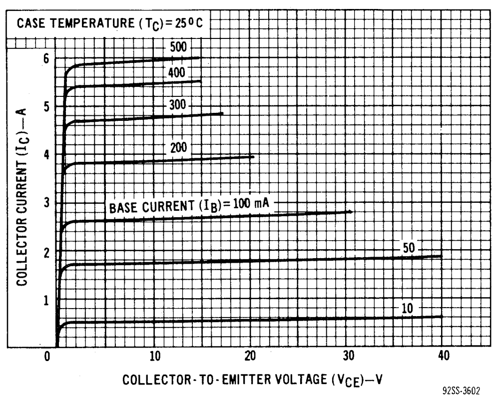


Fig. 3

TYPICAL TRANSFER CHARACTERISTICS
FOR TYPE 40542

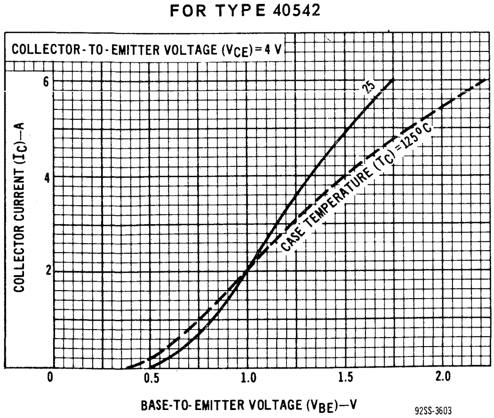


Fig. 4

TYPICAL GAIN-BANDWIDTH PRODUCT
FOR TYPE 40542

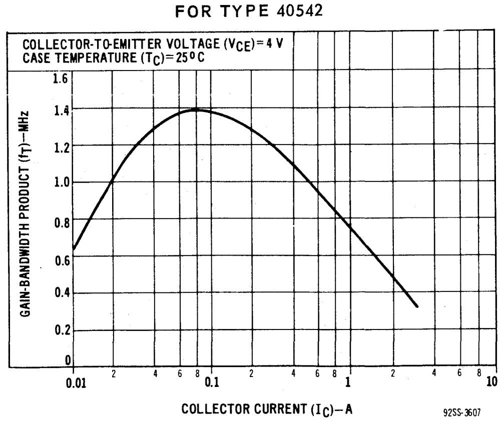


Fig. 5

TYPICAL DC BETA
FOR TYPE 40543

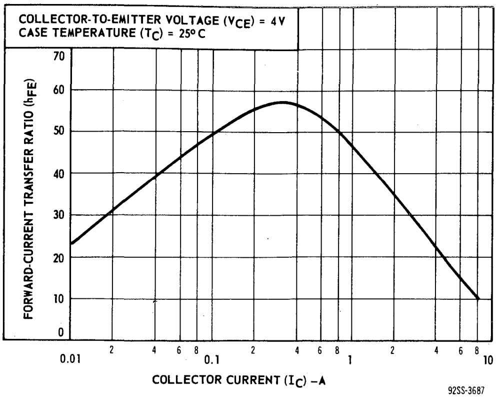


Fig. 6

TYPICAL INPUT CHARACTERISTICS
FOR TYPE 40543

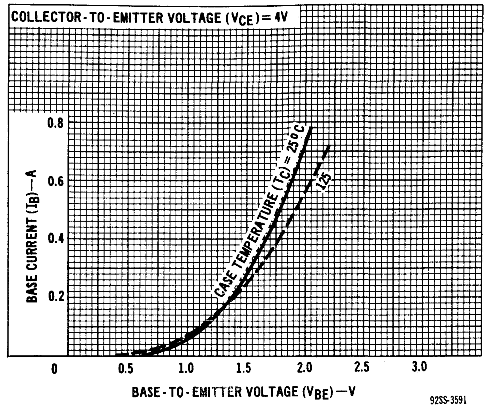


Fig. 7

TYPICAL OUTPUT CHARACTERISTICS
FOR TYPE 40543

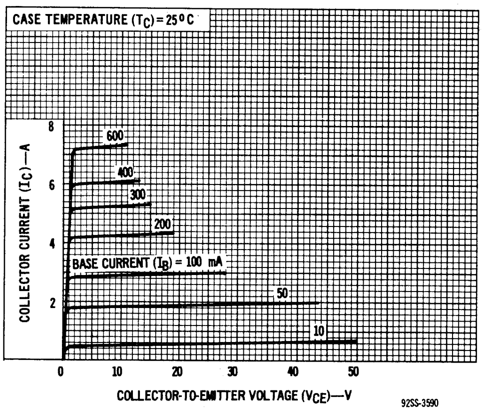


Fig. 8

TYPICAL TRANSFER CHARACTERISTICS
FOR TYPE 40543

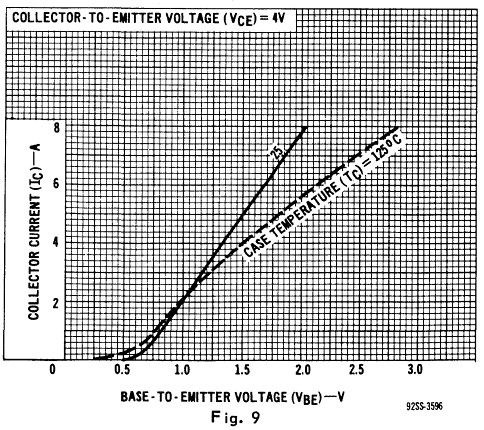


Fig. 9

TYPICAL GAIN-BANDWIDTH PRODUCT
FOR TYPE 40543

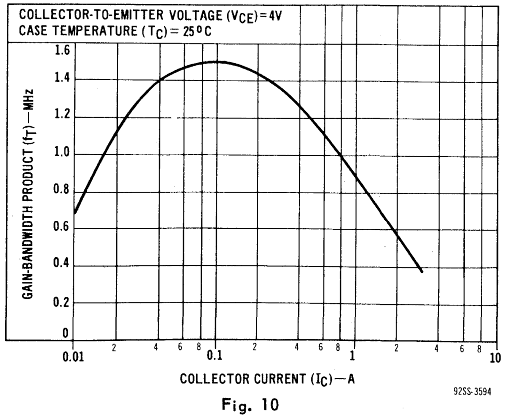
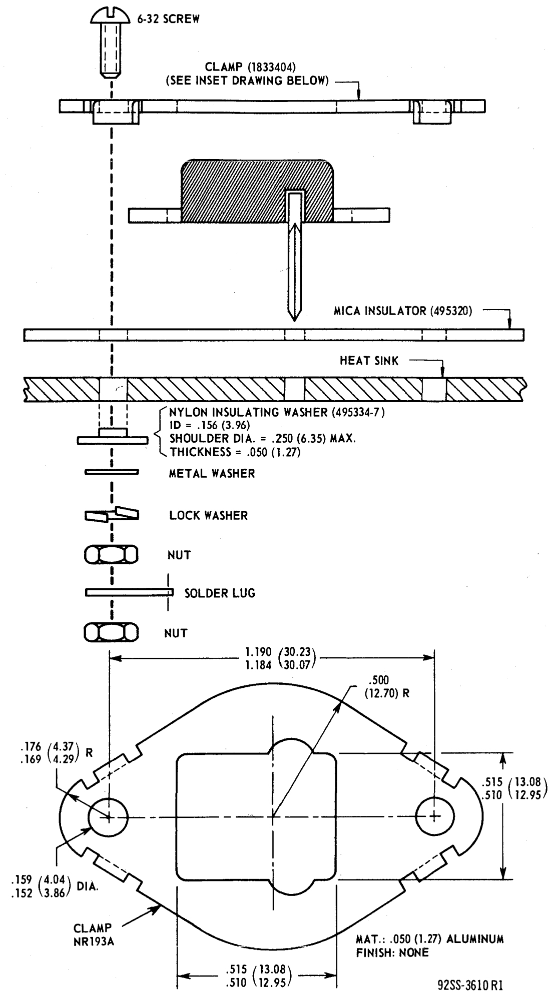


Fig. 10

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

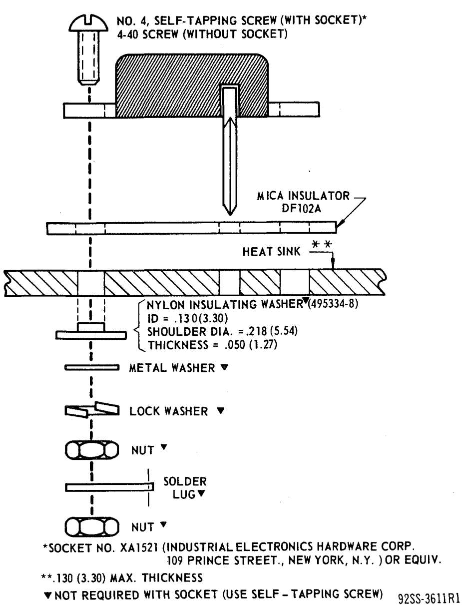
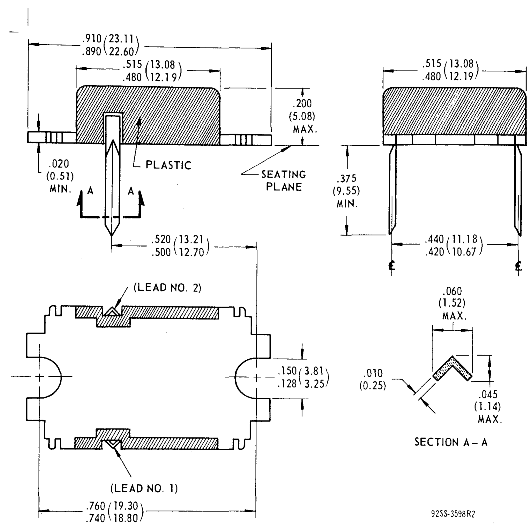


Fig. 12

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

Transistor Types for Driver Applications . . .

Type	Constr.
40594	Si N-P-N
40595	Si P-N-P
40611	Si N-P-N

Type	Constr.
40616	Si N-P-N
40625	Si N-P-N
40628	Si N-P-N

Type	Constr.
40634	Si P-N-P
40635	Si N-P-N

Transistor Types for Output Applications . . .

Type	Constr.
40612	Ge P-N-P
40613	Si N-P-N
40618	Si N-P-N
40621	Si N-P-N
40622	Si N-P-N

Type	Constr.
40623	Ge P-N-P
40624	Si N-P-N
40626	Ge P-N-P
40627	Si N-P-N
40629	Si N-P-N

Type	Constr.
40630	Si N-P-N
40631	Si N-P-N
40632	Si N-P-N
40633	Si N-P-N
40636	Si N-P-N

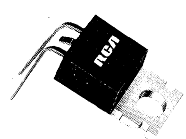
MAXIMUM RATINGS▲, Absolute-Maximum Values:

RCA Type	V_{CEO}(sus)	V_{CER}(sus)*	V_{EBO}	I_C	I_B	P_T – W●		Temp. Range (Storage & Operating) °C		
	V	V	V	A	A	T_C = 25°C	T_A = 25°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.

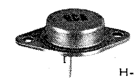
* R_{BE} = 68 Ω (40612, 40623, & 40626)
= 100 Ω (40594, 40595, 40629, 40630, 40631, 40632, 40633, 40634, 40635, & 40636)

● P_T at temperatures above 25°C, derate linearly to 0 watts at maximum temperature (e.g. + 100, + 150, or + 200°C).


H-1534

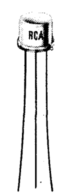
40613 40627
40618 40629
40621 40630
40622 40631
40624 40632

"Plastic TO-66"
(For TO-66 Sockets)


H-1570

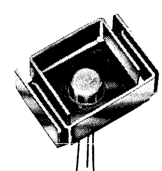
40612 40626
40623 40636

JEDEC TO-3


H-1380

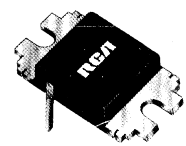
40594
40595
40611
40616
40634
40635

JEDEC TO-5


H-1468

40625
40628

TO-5
With Heat-Radiator


H-1532

40633

"Plastic TO-3"
(For TO-3 Sockets)

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

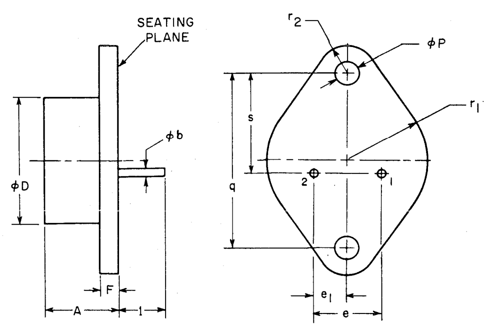
RCA Type	RCA Prototype	Publication and Issue Date
40022	–	Tech. Bull. File No. 69 (7-66)
40050	–	Tech. Bull. File No. 67 (7-66)
40389	–	Tech. Bull. File No. 145 (8-66)
40594	2N5320	Tech. Bull. File No. 325 (3-68)
40595	2N5322	Tech. Bull. File No. 325 (3-68)
40611	40311	Tech. Bull. File No. 78 (6-66)
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



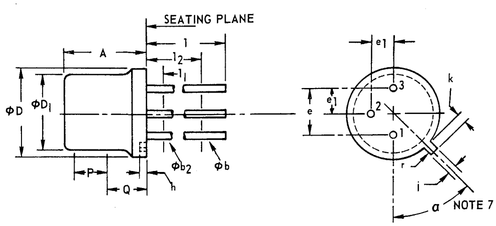
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.250	.450	6.35	11.43	
φb	.038	.043	.97	1.09	2
φD		.875		22.23	
e	.420	.440	10.67	11.18	
e_1	.205	.225	5.21	5.72	
F		.135		3.43	
l	.312		7.92		2
φP	.151	.161	3.84	4.09	
q	1.177	1.197	29.90	30.40	
r_1		.525		13.34	
r_2		.188		4.78	
s	.655	.675	16.64	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



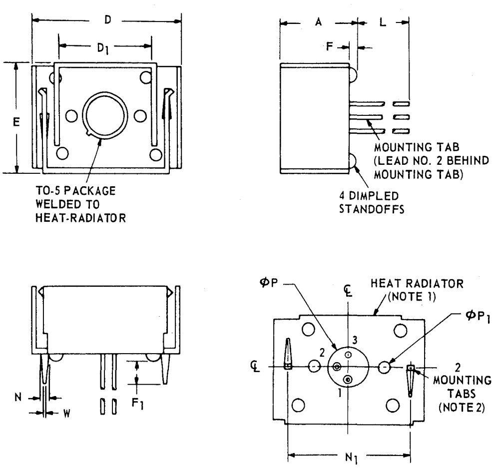
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.240	.260	6.10	6.60	
φb	.016	.021	.406	.533	2
$φb_2$	.016	.019	.406	.483	2
φD	.335	.370	8.51	9.40	
$φD_1$	.305	.335	7.75	8.51	
e	.200 T.P.		5.08 T.P.		4,5
e_1	.100 T.P.		2.54 T.P.		5
h	.009	.125	.229	3.18	
i	.028	.034	.711	.864	5
k	.029	.045	.737	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



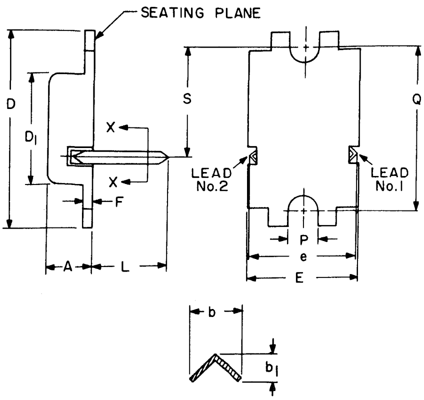
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	.745	.755	18.923	19.177	
E	.875	.905	22.22	22.99	
F	.040	.055	1.02	1.40	
F_1	.170	.225	4.32	5.72	
L	1.410	–	35.81	–	
φP	.295	.305	7.493	7.747	
$φP_1$	.093	.095	2.362	2.413	
N	.048	.062	1.21	1.57	
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"



SECTION X–X

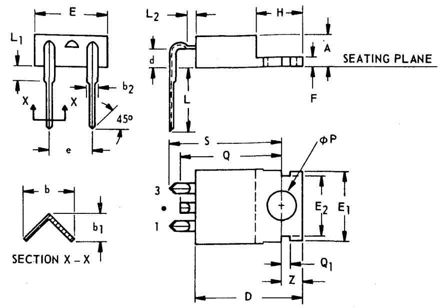
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.200	–	5.08	
b	.045	.060	1.15	1.52	
b_1	.025	.045	.64	1.14	
D	.890	.910	22.61	23.11	
D_1	.480	.515	12.20	13.08	
E	.480	.520	12.20	13.20	
e	.460	.505	11.69	12.82	1
F	.020	.065	.51	1.65	
L	.312	–	7.93	–	
P	.128	.150	3.26	3.81	
Q	.740	.760	18.80	19.30	
S	.500	.520	12.70	13.20	1

92CS-15191

NOTE:

1. Position of leads to be measured at the seating plane.

DIMENSIONAL OUTLINE FOR "PLASTIC TO-66"



SECTION X – X

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	

92CS-14995

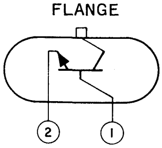
NOTE:

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

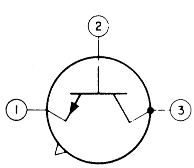
FLANGE



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

40612 (P-N-P)
40623 (P-N-P)
40626 (P-N-P)
40633
40636

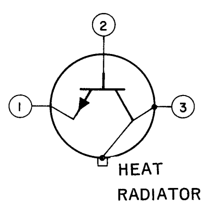
TO-5



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

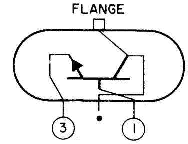


Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, Heat Radiator

40625
40628

TO-66

FLANGE



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

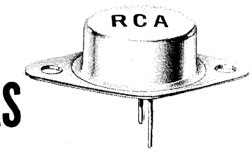
40613	40627
40618	40629
40621	40630
40622	40631
40624	40632

Germanium Power Transistors

RCA
Solid State
Division

Power Transistors
2N2869/2N301
2N2870/2N301A

GERMANIUM P-N-P POWER TRANSISTORS



Actual Size

For AF Power-Amplifier and other Large-Signal Applications in Commercial, Industrial, and Military Equipment

RCA-2N2869/2N301 and RCA-2N2870/2N301A are alloy-junction power transistors of the germanium p-n-p type, designed for use in a wide variety of applications in commercial, industrial, and military equipment. These transistors are similar to and unilaterally interchangeable with types 2N301 and 2N301A respectively, but have substantially higher voltage, current, and dissipation ratings, lower saturation voltages, and linearity of beta over a wider range of collector current.

RCA-2N2869/2N301 and RCA-2N2870/2N301A can be used as direct replacements for types 2N301 and 2N301A respectively in existing equipment. Because of their higher ratings and superior characteristics, these new transistors also can provide greater power output and better performance than the 2N301 and 2N301A in new equipment designs.

RCA-2N2869/2N301 and RCA-2N2870/2N301A supersede RCA types 2N301 and 2N301A.

RCA-2N2869/2N301 and RCA-2N2870/2N301A are particularly suitable for use in class A and class B af-output-amplifier stages of automobile radio receivers and mobile communications equipment. They are also capable of providing very efficient performance in dc-to-dc and dc-to-ac power-conversion circuits.

The 2N2870/2N301A has higher collector-to-base voltage rating (-80 volts) than the 2N2869/2N301 (-60 volts), and is intended for use in applications requiring this higher voltage capability. The 2N2870/2N301A also has a lower collector-to-emitter saturation voltage (-0.3 volt typ., -0.5 volt max.) than the 2N2869/2N301 (-0.4 volt typ., -0.75 volt max.).

- High Breakdown Voltages—
  BV_{CBO} for 2N2870/2N301A = -80 volts min.
  BV_{CBO} for 2N2869/2N301 = -60 volts min.
- Low Saturation Voltages—
  $V_{CE}(sat)$ for 2N2870/2N301A = -0.3 volt typ.
  $V_{CE}(sat)$ for 2N2869/2N301 = -0.4 volt typ.
- Very Low Collector Saturation Current $I_{CBO}(sat)$ = -100 μa max. at V_{CB} = -0.5 volt— Assures Excellent Operating Stability for Wide Temperature Variations
- High Dissipation Capability = 30 watts max.
- High Collector Current Capability = -10 amp. max.
- High Large-Signal (DC) Beta = 90 typ.
- Excellent Beta Linearity — Essentially linear up to 10 amp. I_C
- At V_{CC} = -14.4 volts:
  (a) 5 watts output (5% THD) with 38 db power gain in single-ended class A_I Service
  (b) 12 watts output (5% THD) with 30 db power gain in push-pull class B service
- Hermetically Sealed JEDEC TO-3 Package

Maximum Ratings, *Absolute-Maximum Values:*

	2N2869/ 2N301	2N2870/ 2N301A	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-60	-80 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	-50	-50 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-10	-10 max.	volts
COLLECTOR CURRENT, I_C	-10	-10 max.	amp
EMITTER CURRENT, I_E	+10	+10 max.	amp
BASE CURRENT, I_B	-3	-3 max.	amp
TRANSISTOR DISSIPATION: At Mounting-Flange Temperatures*—			
Up to +55° C	30	30 max.	watts
Above +55° C	See *Fig.1*		
TEMPERATURE RANGE: Storage and Operating (Junction)	-65 to +100		°C
PIN TEMPERATURE (During Soldering): At distance of not less than 1/32" from seating surface for 10 seconds max.	255	255	°C

* Measured at center of seating surface.

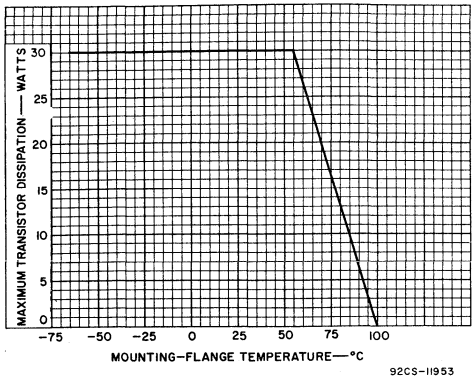


Fig.1 - Rating Chart for Types 2N2869/2N301 and 2N2870/2N301A.

Electrical Characteristics, *at a Mounting-Flange Temperature, T_{MF}*, of 25° C*

Characteristics	Symbols	TEST CONDITIONS					LIMITS						Units
		DC Collector-to-Base Voltage V_{CB}	DC Collector-to Emitter Voltage V_{CE}	DC Collector Current I_C	DC Emitter Current I_E	DC Base Current I_B	Type 2N2869/2N301			Type 2N2870/2N301A			
		volts	volts	amp	ma	amp	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-to-Base Breakdown Voltage	BV_{CBO}			-0.005	0		-60	-	-	-80	-	-	volts
Collector-to-Emitter Breakdown Voltage	BV_{CEO}			-0.6		0	-50	-	-	-50	-	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}			0	-2		-10	-	-	-10	-	-	volts
Collector-Cutoff Current	I_{CBO}	-30			0		-	-	-0.5	-	-	-0.5	ma
Saturation Collector-Cutoff Current	$I_{CBO}(sat)$	-0.5			0		-	-	-0.1	-	-	-0.1	ma
DC Forward-Current Transfer Ratio	h_{FE}		-2	-1			50	90	165	50	90	165	
Base-to-Emitter Voltage	V_{BE}		-2	-1			-	-0.3	-0.5	-	-0.3	-0.5	volt
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			-5		-0.5	-	-0.4	-0.75	-	-0.3	-0.5	volt
Gain-Bandwidth Product	f_T		-2	-1			200	450	-	200	450	-	Kc

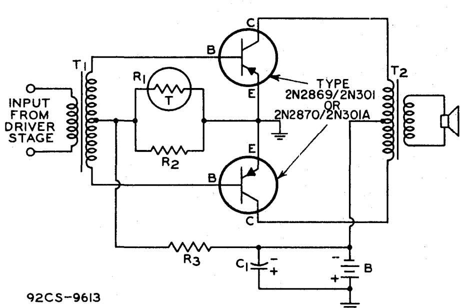
* Measured at center of seating surface.

Typical Operation for Types 2N2869/2N301 and 2N2870/2N301A in the Class B Push-Pull Audio Power-Amplifier Circuit of Fig.2:

At Mounting-Flange Temperature of 80° C and Signal Frequency of 400 cps
Unless otherwise specified, values are for two transistors

DC Supply Voltage.	−14.4	volts
Zero-Signal DC Collector Current□	−0.05	amp
Zero-Signal DC Base-to-Emitter Voltage.	−0.13	volt
Peak Collector Current□. . . .	−2	amp
Max.-Signal DC Collector Current□	−0.64	amp
Signal-Source Impedance (per base)	10	ohms
Load Impedance (Per collector)	6	ohms
Power Gain●.	30	db
Max.-Signal Power Output●. . .	12	watts
Total Harmonic Distortion (At Power Output of 12 watts)	5% max.	
Circuit Efficiency (At Power Output of 12 watts)●	67	%
Collector Dissipation (Per Transistor at Power Output of 12 watts)	3	watts

● Measured at the primary of the output transformer.
□ Per transistor.



B : 14.4-volt supply

C_1: 1000 μf, electrolytic, 25 volts

R_1: Thermistor, 28.25 ohms at 0° C, 10 ohms at 25° C, 4.06 ohms at 50° C

R_2: 5.6 ohms, 0.5 watt

R_3: 270 ohms, 1 watt

T_1: Driver Transformer: Primary Impedance determined by large-signal considerations of the driver unit. Secondary Impedance = 40 ohms center tapped.

T_2: Output Transformer: Primary Impedance = 24 ohms center tapped, Secondary Impedance = voice-coil impedance.

Fig.2 - Class B Push-Pull AF Power-Amplifier Circuit Utilizing Types 2N2869/2N301 and 2N2870/2N301A.

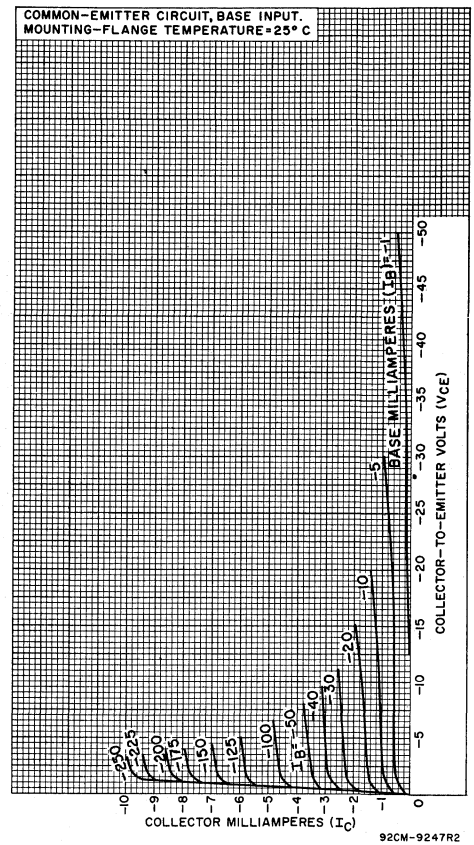


Fig.3 - Typical Collector Characteristics for Types 2N2869/2N301 and 2N2870/2N301A.

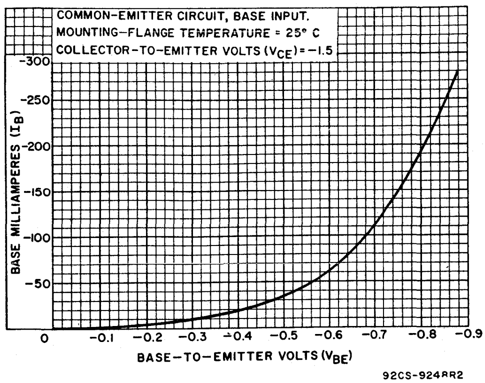


Fig.4 - Typical Input Characteristic for Types 2N2869/2N301 and 2N2870/2N301A

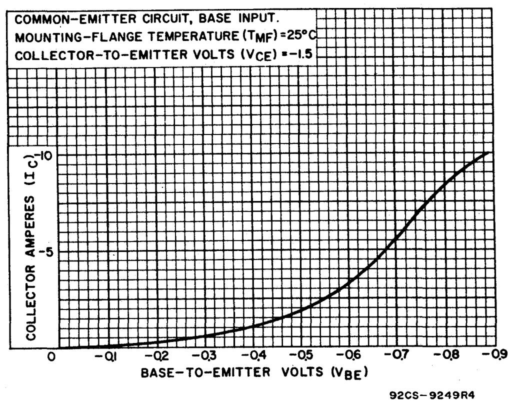


Fig.5 - Typical Transfer Characteristic for Types 2N2869/2N301 and 2N2870/2N301A

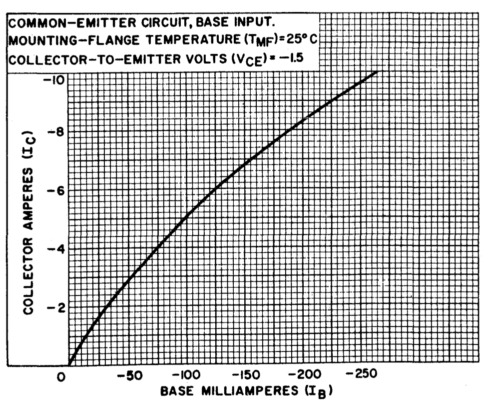


Fig.6 - Typical Current-Transfer Characteristic for Types 2N2869/2N301 and 2N2870/2N301A

OPERATING CONSIDERATIONS

The *maximum ratings* in the tabulated data are established in accordance with the following definition of the *Absolute-Maximum Rating System* for rating electron devices.

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, environment 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.

In class A service, to insure stable operation and low distortion, it will be necessary to provide some degeneration in the emitter circuit. This degeneration may be accomplished by using an unbypassed resistor in the emitter circuit.

In class B service, if the 2N2869/2N301 or 2N2870/2N301A is operated near its maximum collector voltage rating, it is important that circuit arrangements be made to prevent thermal runaway. A convenient method is to reduce the base-to-emitter forward voltage by an amount equal to approximately 0.002 volt for each degree centigrade that the mounting-flange temperature is above 25° C.

In the design of circuits using the RCA-2N2869/2N301 and 2N2870/2N301A it is extremely important to assure that the maximum junction-temperature rating of 100° C is not exceeded. This consideration is especially important in af-amplifier and other applications involving complex signal waveforms and other factors capable of producing high peak values of dissipation, such as

(a) oscillation or "ringing" due to excessive or improperly neutralized feedback
(b) phase shifts due to circuit capacitances and/or reactive loads
(c) variations in load impedance
(d) overdriving of transistors
(e) high line voltage

Because of the short thermal time constant of the RCA-2N2869/2N301 and 2N2870/2N301A (approximately 15 milliseconds), the rise in junction temperature produced when so-called "instantaneous" peak values of dissipation are sustained for longer than 15 milliseconds may be as great as 1.5° C per watt. The circuit designer, therefore, must select operating conditions such that no possible combination of the factors listed above, or any other operating condition will cause the junction temperature to rise above 100° C.

Because the metal shells of these transistors operate at the collector voltage, consideration should be given to the possibility of shock hazard if the shells are to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

The 2N2869/2N301 and 2N2870/2N301A should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistors.

These transistors can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistor.

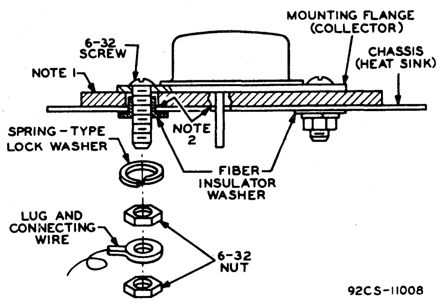
It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE TRANSISTOR.

The mounting-flange temperature of the 2N2869/2N301 or 2N2870/2N301A will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.

Depending on the application, the heat sink or chassis may be connected to either the positive or negative terminal of the voltage supply.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be necessary to use an anodized aluminum washer having high thermal conductivity, or a 0.002" thick mica insulator between the mounting flange and the chassis. If an aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the emitter and base pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that a fibre washer be used between each bolt and the chassis as shown in Fig.7.

An insulated mounting arrangement such as that described in the preceding paragraph and shown in Fig.7 is also necessary when Type 2N2869/2N301 or 2N2870/2N301A transistors are used in class B push-pull af-amplifier stages of the type shown in Fig.2. In such stages the mounting flanges of the two transistors must be insulated from the chassis or heat sink and from each other to avoid short-circuiting the primary winding of the output transformer.



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Mounting hardware items for RCA 2N2869/2N301 and 2N2870/2N301A are available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART No.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

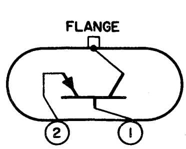
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-2N2869/2N301 and 2N2870/2N301A and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

Fig.7 - Suggested Mounting Arrangement for Types 2N2869/2N301 and 2N2870/2N301A.

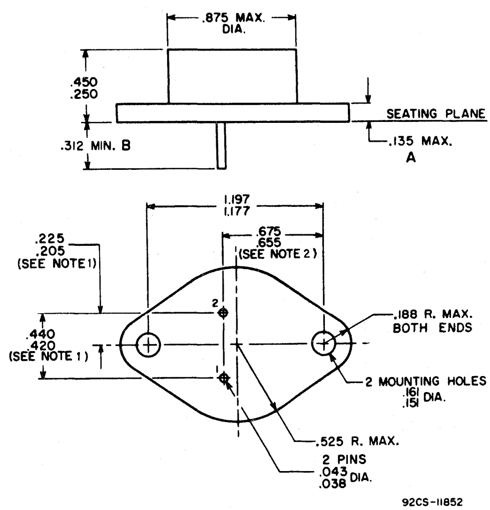
TERMINAL CONNECTIONS



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

DIMENSIONAL OUTLINE For Types 2N2869/2N301 and 2N2870/2N301A

JEDEC No. TO-3



ALL DIMENSIONS IN INCHES.

For RCA-2N2869/2N301 and 2N2870/2N301A

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. 0.480" max.

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

NOTE 2: TWO LEADS.

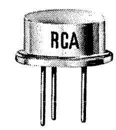
RCA
Solid State
Division

Power Transistors

2N1183 2N1184 2N1183A 2N1184A 2N1183B 2N1184B

The transistors in the 2N1183-2N1184 families are germanium p-n-p alloy-junction types for use in intermediate power-switching and low-frequency applications in military and industrial equipment. The transistors are especially useful in devices such as dc-to-dc converters, choppers, solenoid drivers, and relay controls; in oscillator, regulator, multivibrator, and pulse-amplifier circuits, and as class A and class B amplifiers for servo and linear amplifier applications.

For Power Switching and Amplifier Applications



2N1183 2N1184
2N1183A 2N1184A
2N1183B 2N1184B

JEDEC TO-8

These transistors which feature low saturation resistance and low leakage currents, provide the equipment designer with a choice of voltage ratings and beta ranges for flexibility of circuit design.

Maximum Ratings, *Absolute-Maximum Values:*

	2N1183 2N1184	*2N1183A 2N1184A*	*2N1183B 2N1184B*	
COLLECTOR-TO-BASE VOLTAGE	-45	-60	-80 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base connected to emitter	-35	-50	-60 max.	volts
With base open	-20	-30	-40 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE (V_{EB}) = -1.2 volts	-45	-60	-80 max.	volts
EMITTER-TO-BASE VOLTAGE	-20	-20	-20 max.	volts
COLLECTOR CURRENT	-3.0	-3.0	-3.0 max.	amp
EMITTER CURRENT	3.5	3.5	3.5 max.	amp
BASE CURRENT	-0.5	-0.5	-0.5 max.	amp
TRANSISTOR DISSIPATION: (See Rating Chart Fig. 1):				
With heat sink and case temperature = 25° C.	7.5	7.5	7.5 max.	watts
In free air at ambient temperature = 25° C.	1.0	1.0	1.0 max.	watt
AMBIENT TEMPERATURE:				
Storage	-65 to + 100	-65 to + 100	-65 to + 100	°C
Operating	-65 to + 100	-65 to + 100	-65 to + 100	°C

CHARACTERISTICS

At mounting-base temperature = 25^{o} C

Characteristic	Symbol	TEST CONDITIONS: DC Collector Voltage (volts) V_{CB}	V_{CE}	DC Collector Current (ma) I_C	DC Emitter Current (ma) I_E	RANGE VALUES: Type 2N1183 Min.	Max.	Type 2N1183A Min.	Max.	Type 2N1183B Min.	Max.	Type 2N1184 Min.	Max.	Type 2N1184A Min.	Max.	Type 2N1184B Min.	Max.	Units
Collector-Cutoff Current	I_{CBO}	-1.5			0		-30		-30		-30		-30		-30		-30	μa
		-45			0		-250						-250					μa
		-60			0				-250						-250			μa
		-80			0						-250						-250	μa
Emitter Cutoff Current For V_{EB} = -20 volts and collector open	I_{EBO}			0			-100		-100		-100		-100		-100		-100	μa
Emitter-to-Base Voltage	V_{EB}		-2	-400			1.5		1.5		1.5		1.5		1.5		1.5	volts
Collector-to-Emitter Voltage With V_{EB} = -1.2 volts	V_{CEX}			-250		-45		-60		-80		-45		-60		-80		volts
With base connected to emitter	V_{CES}			-50		-35		-50		-60		-35		-50		-60		volts
With base open	V_{CEO}			-50		-20		-30		-40		-20		-30		-40		volts
Collector Saturation Resistance With I_B = -40 ma	R_S			-400			1.25		1.25		1.25		1.25		1.25		1.25	ohms
Alpha-Cutoff Frequency	$f_{\alpha b}$	-6			1	500		500		500		500		500		500		Kc
DC Current Transfer Ratio	h_{FE}		-2	-400		20	60	20	60	20	60	40	120	40	120	40	120	
Thermal Resistance Junction-to-mounting base	R_T						10		10		10		10		10		10	°C/watt
Junction-to-free air							75		75		75		75		75		75	°C/watt

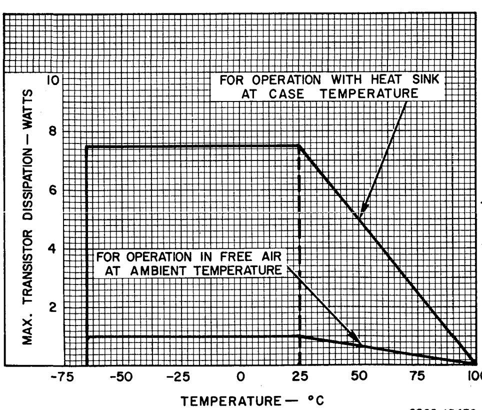


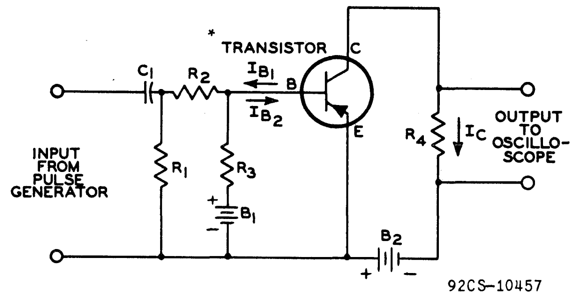
Fig.1 - Rating Chart for Types 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A and 2N1184B

Typical Operation of the 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A and 2N1184B in the Power-Switching Circuit of Fig.2:

At a Mounting-Base Temperature of 25° C

Generator Resistance	50	ohms
"On" DC Collector Current	-400	ma
"Turn-On" Base Current (I_{B1})	-40	ma
"Turn-Off" Base Current (I_{B2})	40	ma
Switching Time:		
Delay Time (t_d)	0.2	μsec
Rise Time (t_r)	2.0	μsec
Storage Time (t_s)	1.8	μsec
Fall Time (t_f)	1.4	μsec

B_1, B_2 = 12 volts
C_1 = 10 μf, electrolytic 25 volts
R_1 = 51 ohms, 2 watts
R_2 = 120 ohms, 2 watts
R_3 = 230 ohms, 1 watt
R_4 = 29.5 ohms. 5 watts



* Type 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A, or 2N1184B

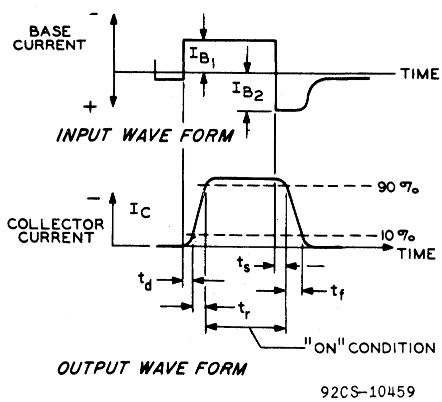


Fig. 2 - Typical Power-Switching Circuit Utilizing Types 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A and 2N1184B

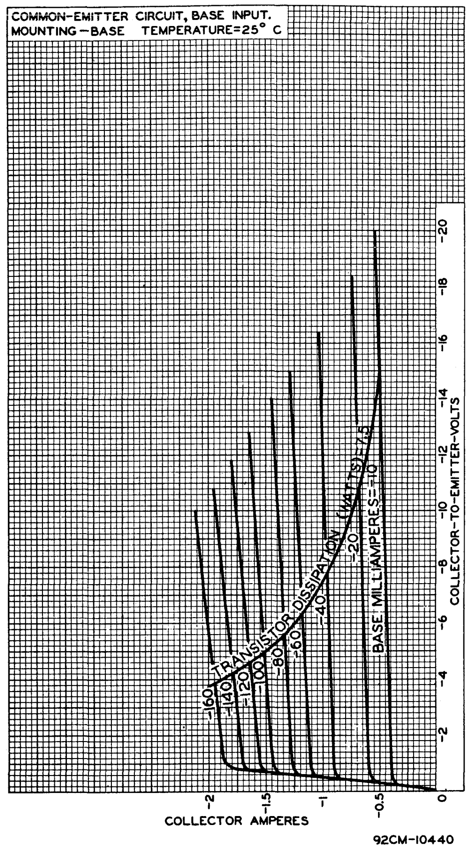


Fig. 3 - Typical Collector Characteristics for Types 2N1183, 2N1183A and 2N1183B.

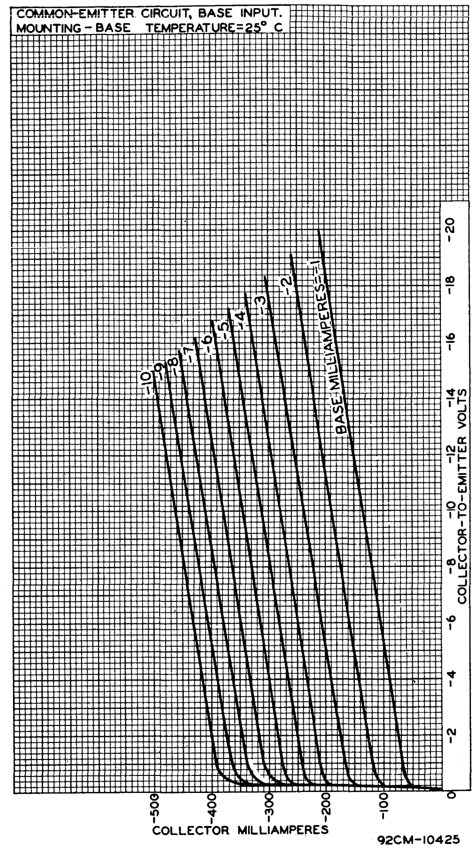


Fig. 4 - Typical Collector Characteristics for Types 2N1183, 2N1183A and 2N1183B.

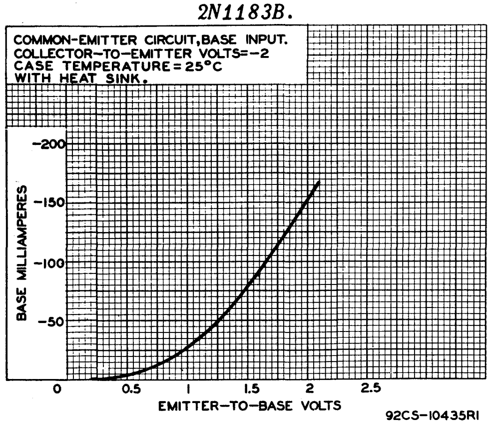


Fig. 5 - Typical Operation Characteristics for Types 2N1183, 2N1183A and 2N1183B.

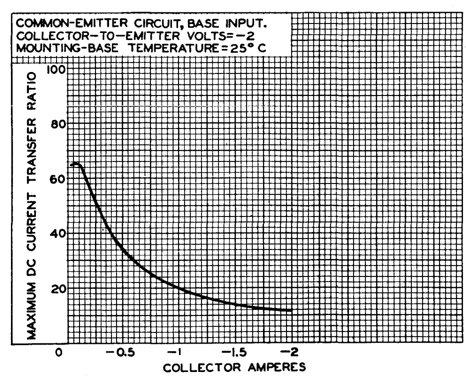


Fig. 6 - Typical Operation Characteristics for Types 2N1183, 2N1183A and 2N1183B.

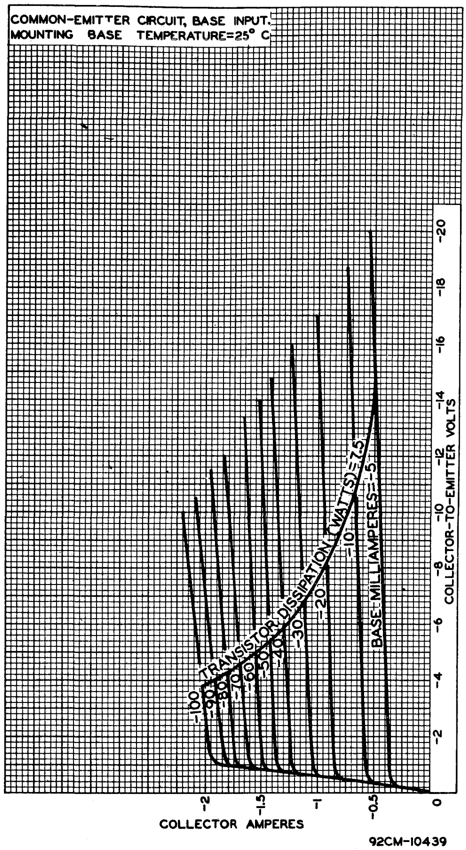


Fig. 7 - Typical Collector Characteristics for Types 2N1184, 2N1184A and 2N1184B.

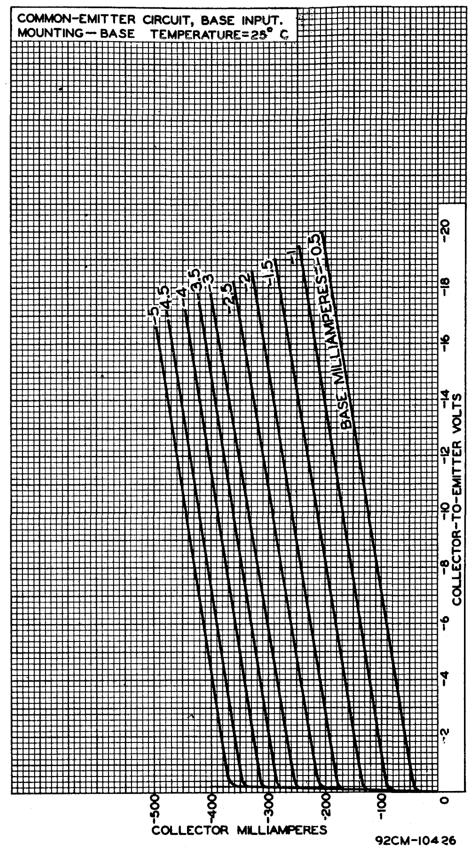


Fig. 8 - Typical Collector Characteristics for Types 2N1184, 2N1184A and 2N1184B.

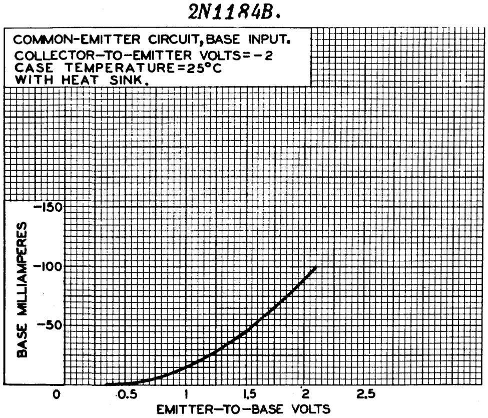


Fig. 9 - Typical Operation Characteristics for Types 2N1184, 2N1184A and 2N1184B.

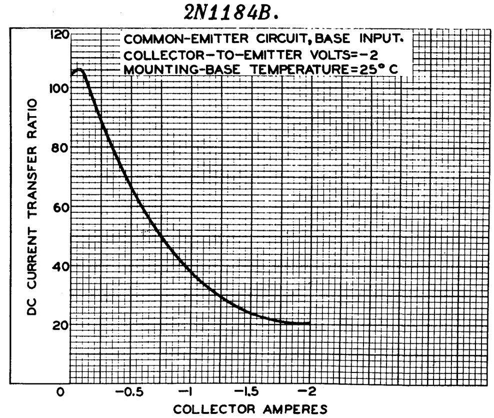


Fig. 10 - Typical Operation Characteristics for Types 2N1184, 2N1184A, and 2N1184B.

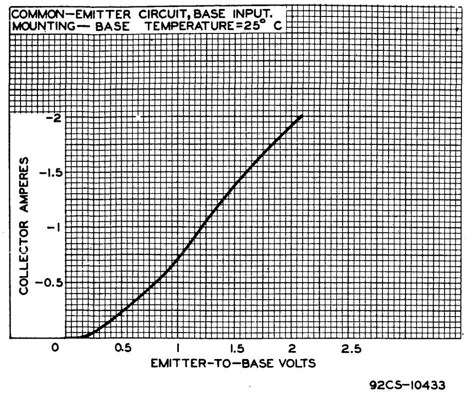
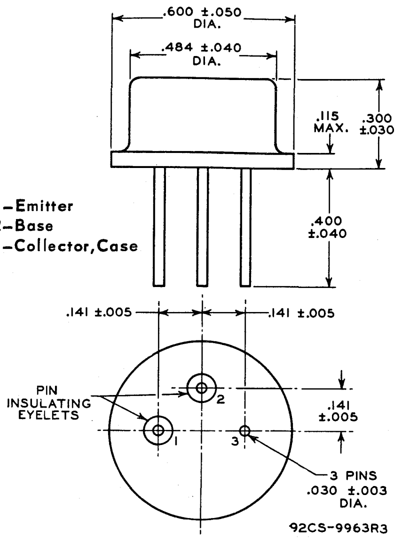


Fig. 11 - Typical Transfer Characteristic for Types 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A and 2N1184B.

DIMENSIONAL OUTLINE For 2N1183–2N1184 Families



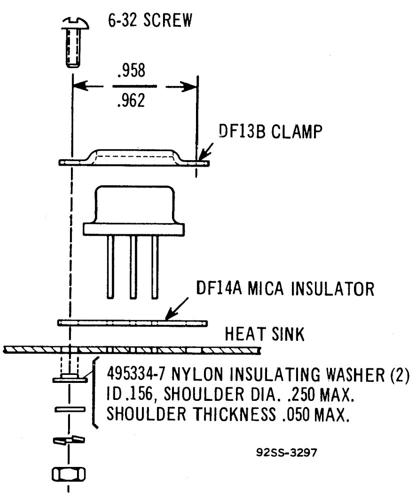


Fig. 12 - Suggested Mounting Arrangement for Types 2N1183, 2N1183A, 2N1183B, 2N1184, 2N1184A and 2N1184B.

RCA

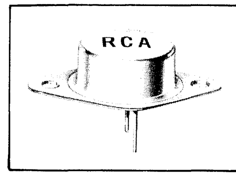
Solid State
Division

Power Transistors

2N1905
2N1906

GERMANIUM P-N-P DRIFT-FIELD POWER TRANSISTORS

For Industrial and Commercial Applications



JEDEC TO-3

RCA-2N1905 and 2N1906 are diffused-collector graded-base power transistors of the germanium p-n-p type intended for a wide variety of applications in industrial and consumer-type equipment. These transistors utilize a combination of diffusion and alloying techniques to provide a built-in accelerating field in the base region. This accelerating field makes possible a wide frequency response and a linearity of characteristics over the entire collector-current range not available in conventional power transistors. RCA-2N1905 and 2N1906 are particularly useful as high-power, high-speed switches in dc-to-dc converters, inverters, and computers for data-processing equipment, as ultrasonic oscillators, and as large-signal, wide-band linear amplifiers.

The 2N1906 differs from the 2N1905 in having a higher collector-to-base-voltage rating, controlled switching characteristics, and controlled saturation voltage and beta at high current levels.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	2N1905	2N1906	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-100	-130	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	-50	-60	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-1.5*	-1.5*	V
COLLECTOR CURRENT, I_C	-6	-6	A
BASE CURRENT, I_B	-1	-1	A
TRANSISTOR DISSIPATION, P_T:			
For Mounting-Flange Temperatures▲ up to 55°C	30	30	W
For other Mounting Flange Temperatures▲	See Rating Chart (Fig.1)		
TEMPERATURE RANGE:			
Storage	-65 to +100		°C
Operating (Junction)	-65 to +100		°C
LEAD TEMPERATURE:			
≥ 1/16" from Case for 10 Seconds max.	255	255	°C

* This value may be exceeded provided that the power dissipated in the Emitter under breakdown conditions is limited to 5 watts.

▲ Measured at center of seating surface.

FEATURES

- 30-watt dissipation at T_{MF} = 55°C
- high min. beta: 50 for 2N1905; 75 for 2N1906
- extremely short rise and fall times at high values of I_C – less than 1 μs
- high typical gain-bandwidth product –
  2N1905, f_T = 4 MHz
  2N1906, f_T = 5 MHz
- low base resistance for high power sensitivity
- linear current-transfer characteristic (h_{FE}) over wide collector-current range

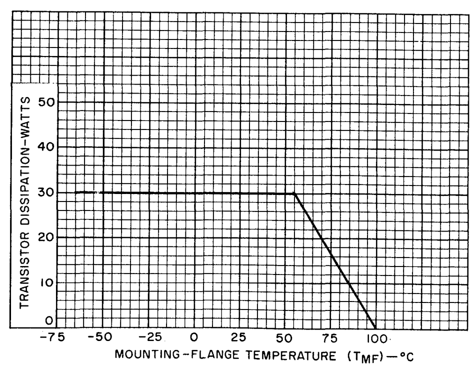


Fig.1 - Rating Chart for 2N1905 and 2N1906.

CHARACTERISTICS RANGE VALUES FOR EQUIPMENT DESIGN

At Mounting-Flange Temperature (T_{MF}) = 25°C, Measured at Center of Seating Surface

Characteristics Common-Emitter Circuit, Base Input Unless Otherwise Specified	Symbols	TEST CONDITIONS					LIMITS						Units
		DC Collector-to-Emitter Voltage V_{CE}	DC Emitter-to-Base Voltage V_{EB}	DC Collector Current I_C	DC Base Current I_B	DC Emitter Current I_E	Type 2N1905			Type 2N1906			
		V	V	A	A	A	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-to-Base Breakdown Voltage	BV_{CBO}			-0.01		0	-100	-	-	-130	-	-	V
Collector-to-Emitter Breakdown Voltage	BV_{CEO}			-0.1	0		-50	-	-	-60	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}			0		0.005	-1.5	-	-	-1.5	-	-	V
Collector Cutoff Current	I_{CBO}	V_{CB} = -40				0	-	-	-1	-	-	-1	mA
Collector Cutoff Saturation Current	I_{CBO}(sat)	V_{CB} = -0.5				0	-	-	-100	-	-	-100	μA
Emitter Cutoff Current	I_{EBO}		-0.5	0			-	-1	-	-	-1	-	mA
Static-Forward-Current Transfer Ratio	h_{FE}	-2 -2		-1 -5			50 30	90 -	150 -	75 75	125 -	250 -	
Base-to-Emitter Voltage	V_{BE}	-2 -2		-1 -5			- -	-0.38 -	-0.5 -	- -	- -0.6	-0.5 -0.9	V
Collector-to-Emitter Saturation Voltage	V_{CE}(sat)			-5	-0.25		-	-	-1	-	-	-0.5	V
Gain-Bandwidth Product	f_T	-5		-0.5			2	4	-	3	5	-	MHz
Thermal Resistance (Junction-to-Case)	θ_{J-C}						-	-	1.5	-	-	1.5	°C/W

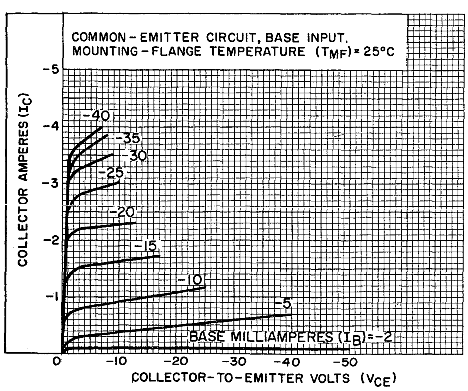


Fig.2 - Typical Collector Characteristics for Type 2N1905.

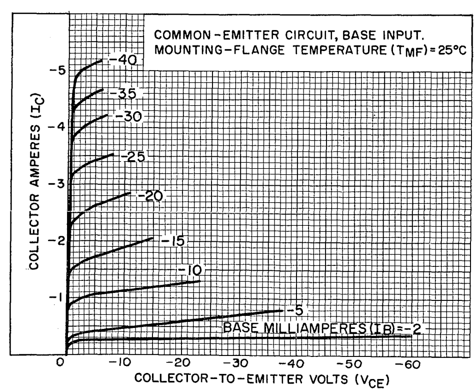


Fig.3 - Typical Collector Characteristics for Type 2N1906.

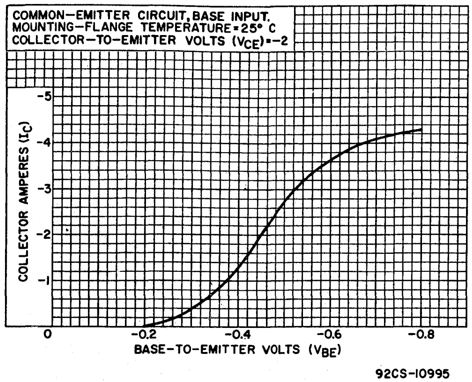


Fig.4 - Typical Characteristic for Type 2N1905.

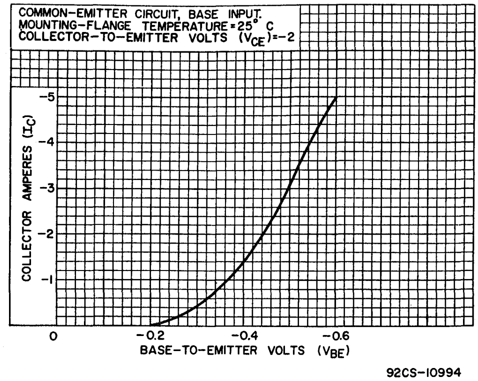


Fig.5 - Typical Characteristic for Type 2N1906.

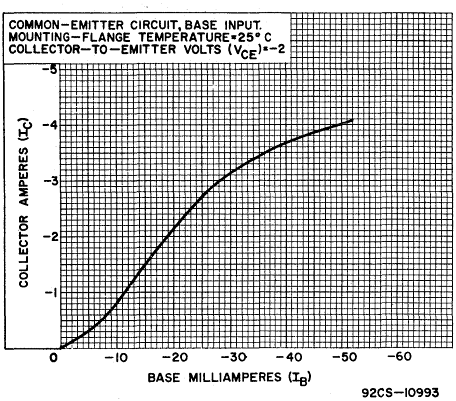


Fig.6 - Typical Current-Transfer Characteristic for Type 2N1905.

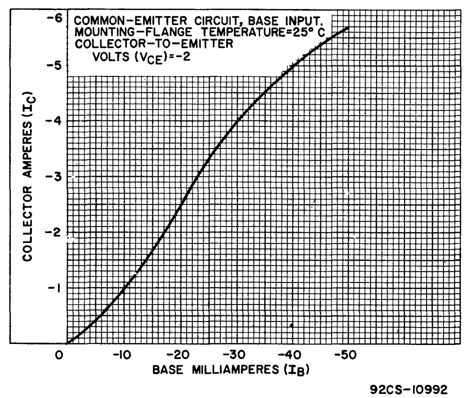


Fig.7 - Typical Current-Transfer Characteristic for Type 2N1906.

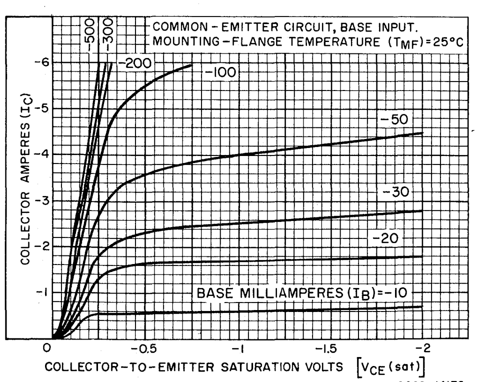


Fig.8 - Typical Collector-to-Emitter Saturation Voltage Characteristics for Type 2N1905.

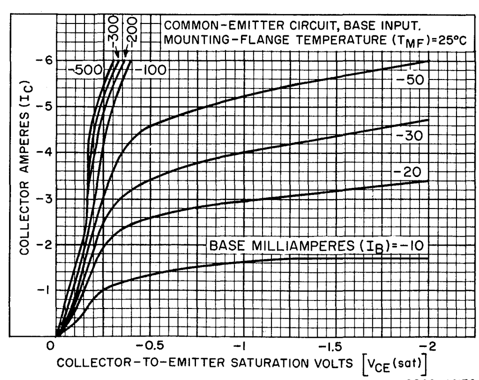


Fig.9 - Typical Collector-to-Emitter Saturation Voltage Characteristics for Type 2N1906.

OPERATING CONSIDERATIONS

The *maximum ratings* in the tabulated data are established in accordance with the following definition of the *Absolute-Maximum Rating System* for rating electron devices.

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, environment 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.

These transistors utilize the Loranger Mfg. Corp., Socket No.2149 or equivalent. Electrical connection can also be made to the base and emitter pins by soldering directly to the pins. Soldering of connections to the pins may be made close to the pin seals provided care is taken to conduct excessive heat away from the pin seals, otherwise the heat of the soldering operation will crack the glass seals of the pins and damage the transistor.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be necessary to use an anodized aluminum insulator having high thermal conductivity, or a 0.002" mica insulator between the mounting flange and the chassis. An aluminum washer should be drilled or punched to provide the two mounting holes, and the clearance holes for the emitter and base pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolt and the chassis, it is important that a fibre washer be used between the bolt and the chassis as shown in Fig.10.

It is important that the mounting flange which serves as the collector be securely fastened to a heat sink. Depending on the application, the chassis (heat sink) may be connected either to the positive or negative terminal of the voltage supply.

It is to be noted that the metal shells of these transistors operate at the collector voltage. Consideration, therefore, should be given to the possibility of shock hazard if the metal shells of these transistors are to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

Under no circumstances should the mounting flange be soldered to the heat sink because the heat of the soldering operation will permanently damage the transistor.

The 2N1905 or the 2N1906 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistors.

To prevent damage to the transistors by thermal runaway an external resistance may be placed in the emitter or collector circuit. The minimum value of this resistance may be obtained from the following equation:

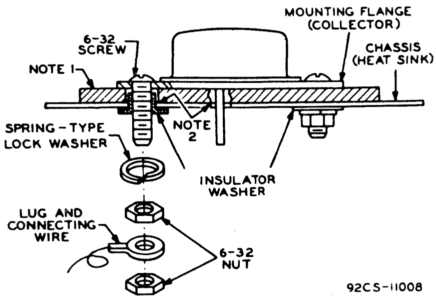
$$R_{min} = \frac{E^2}{4\left(P_o + \frac{25}{K}\right)}$$

where:

E = DC Collector Supply Voltage (volts)

P_o = Collector-to-Emitter Voltage x Collector Current at desired operating point (watts)

K = Thermal Resistance - Transistor and Heat Sink (^oC/watt)



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Mounting hardware items for RCA-2N1905 and 2N1906 are available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART NO.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

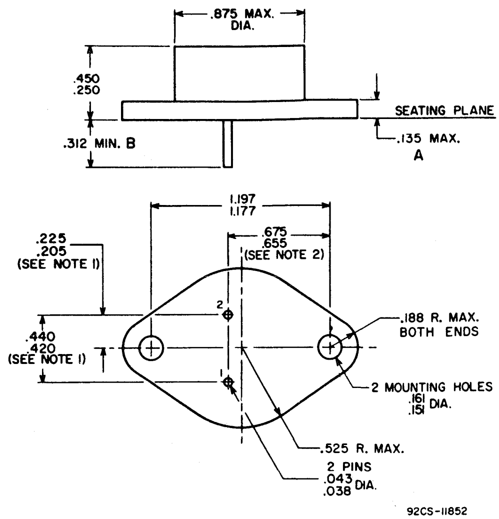
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-2N1905 and 2N1906 and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

Fig.10 - Suggested Mounting Arrangement for Types 2N1905 and 2N1906.

DIMENSIONAL OUTLINE
For Types 2N1905 and 2N1906
JEDEC No.TO-3



DIMENSIONS IN INCHES

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

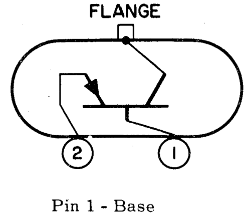
NOTE 2: TWO LEADS.

For RCA-2N1905 and 2N1906

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. / 0.480" max.

TERMINAL CONNECTIONS



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

RCA

Solid State
Division

Power Transistors

1N4785 2N3730 40439
2N3731 40440
2N3732 40442

RCA-2N3730, 2N3731, 2N3732, 40439[a], 40440[b], and 40442[c] are germanium solid-state devices specifically designed for use in the deflection systems of commercial television receivers.

Types 2N3730, 2N3731, 2N3732, 40439, and 40440, are diffused-collector, graded-base power transistors of the germanium pnp type. Type 2N3730 is intended for use as a vertical-deflection output amplifier; type 2N3732 as a horizontal driver, and types 2N3731, 40439, and 40440 as horizontal output amplifiers.

Types 1N4785 and 40442 are diffused-germanium diodes for use in damper service in transistorized horizontal-deflection systems.

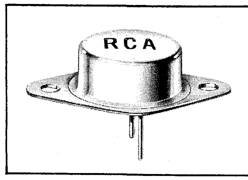
All seven devices are hermetically sealed in metal JEDEC TO-3 packages.

Horizontal-amplifier types 2N3731, 40439, and 40440, and damper-diode types 1N4785 and 40442 provide a choice of devices for use in deflection systems having different energy requirements and circuit configurations, and employing a wide range of dc supply voltages. Types 40439 and 1N4785, for example, are suitable for use in high-energy systems for picture tubes having deflection angles up to 114°, anode-voltage ratings up to 18 kV, and neck diameters up to 1-1/8 inches.

Types 2N3731, 40440, and 40442 are intended primarily for use in systems having lower energy requirements, particularly those for picture tubes having narrower deflection angles (up to 90°) and smaller neck diameters (20mm). Because of their high voltage ratings, types 2N3731 and 1N4785 can also be used in systems employing B+ boost arrangements.

[a] Formerly Dev. No.TA2928.
[b] Formerly Dev. No.TA2921.
[c] Formerly Dev. No.TA2929.

TRANSISTOR/DAMPER-DIODE COMPLEMENTS



For Television Deflection Systems

- for picture tubes with deflection angles to 114°, anode-voltage ratings to 18 kV, neck dia. to 1-1/8"
- high breakdown-voltage capabilities:
  BV_{CES} = -320 min. V for 40439, 2N3731 horizontal-output types
  -200 min. V for 40440 horizontal-output and 2N3730 vertical-output types
  -100 min. V for 2N3732 horizontal-driver type
- high collector-current capabilities:
  I_C = -10 max. A for 2N3731, 40439, 40440 horizontal-output types
  -3 max. A for 2N3730 vertical-output and 2N3732 horizontal-driver types
- low collector-saturation voltages:
  $V_{CE}(sat)$ = -0.75 max. V for 40440
  -1.5 max. V for 2N3731, 40439
  -2 max. V for 2N3730, 2N3732
- short turn-off time in typical horizontal-deflection output circuits:
  t_{off} = 0.75 max. μs for 40439
  1.2 max. μs for 2N3731, 40440
- high voltage and current capabilities for damper diodes:
  peak reverse voltage = 320 max. V for 1N4785; 200 max. V for 40442
  continuous reverse voltage = 60 max. V for 1N4785; 40 max. V for 40442
  peak forward current = 10 max. A for 1N4785 and 40442
  average forward current = 7 max. A for 1N4785 and 40442
- hermetically sealed JEDEC TO-3 package

TELEVISION DEFLECTION SERVICE

Absolute Maximum Ratings:	Vertical Output Amplifier Type 2N3730	Horizontal Output Amplifiers Type 2N3731	RCA 40439	RCA 40440	Horizontal Driver Type 2N3732	Damper Diodes Type 1N4785	RCA 40442	
COLLECTOR-TO-BASE VOLTAGE:								
PEAK, V_{CBO}	-200	-320	-320	-200	-100	-	-	max. V
CONTINUOUS, V_{CB}	-60	-60	-60	-40	-60	-	-	max. V
COLLECTOR CURRENT, I_C	-3	-10	-10	-10	-3	-	-	max. A
BASE CURRENT, I_B	±0.5	+4,-1	+4,-1	+4,-1	±0.5	-	-	max. A
TRANSISTOR DISSIPATION, P_T:								
For mounting-flange temperatures* up to 55°C	10	5	5	5	3	-	-	max. W
above 55°C	Derate linearly to zero watts at 85°C					-	-	
REVERSE VOLTAGE:								
PEAK, PRV	-	-	-	-	-	320	200	max. V
CONTINUOUS, RV	-	-	-	-	-	60	40	max. V
PEAK FORWARD CURRENT, I_{FM}	-	-	-	-	-	10	10	max. A
AVERAGE FORWARD CURRENT, I_{FA}	-	-	-	-	-	7	7	max. A
TEMPERATURE RANGE:								
Storage and operating (junction)	-65 to +85							°C
LEAD TEMPERATURE (During soldering): At distances not closer than 1/32 inch to seating surface for 10 seconds max.	230							max. °C

*Measured at center of seating surface.

ELECTRICAL CHARACTERISTICS, at T_A = 25°C

HORIZONTAL-OUTPUT-AMPLIFIER TYPES

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS V_{CB} (V)	V_{EB} (V)	I_B (A)	I_C (A)	I_E (mA)	LIMITS: RCA 40439 Min.	Typ.	Max.	Type 2N3731 Min.	Typ.	Max.	RCA 40440 Min.	Typ.	Max.	UNITS
Collector-Cutoff Current	I_{CBO}	-10					-	-	-200	-	-	-200	-	-	-200	μA
Collector-to-Emitter Breakdown Voltage	BV_{CES}		0		-0.025		-320	-	-	-320	-	-	-200	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}		*		0	-100	-2	-	-	-2	-	-	-2	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			-0.4	-6		-	-	-1.5	-	-	-1.5	-	-	-0.75	V
				-0.2	-3		-	-	-	-	-	-1.5	-	-	-0.75	V
Base-to-Emitter Voltage	V_{BE}			-0.4	-6		-	-	-0.8	-	-	-0.8	-	-	-1	V
Turn-Off Time▲	t_{off}	See Fig.1					-	-	0.75	-	-	1.2	-	-	1.2	μs
Thermal Resistance: Junction to Case	θ_{J-C}						-	-	1.5	-	-	1.5	-	-	1.5	°C/W

▲"Turn-Off Time" t_{off} as used in this bulletin is the time required for the Collector Current I_C to decrease to -100 milliamperes AFTER the Collector-to-Emitter voltage V_{CE} has risen 2 volts into its "flyback" excursion. In a circuit of the type shown in Fig.1 the collector current may be determined by measuring the base and emitter currents simultaneously with the aid of a current-transformer-type probe.

* Momentary operation in breakdown is permissible.

ELECTRICAL CHARACTERISTICS, at $T_A = 25°C$

VERTICAL-OUTPUT-AMPLIFIER AND HORIZONTAL-DRIVER TYPES

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS					LIMITS						UNITS
		V_{CB}	V_{EB}	I_B	I_C	I_E	VERTICAL OUTPUT AMPLIFIER TYPE 2N3730			HORIZONTAL DRIVER TYPE 2N3732			
		V	V	A	A	mA	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-Cutoff Current	I_{CBO}	-10					-	-	-200	-	-	-200	μA
Collector-to-Emitter Breakdown Voltage	BV_{CES}		0		-0.005		-200	-	-	-100	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					-100	-0.5	-	-	-0.5	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			-0.02 -0.005	-0.7 -0.05		- -	- -	-2 -1	- -	- -	-2 -	V V
Base-to-Emitter Voltage	V_{BE}			-0.02	-0.7		-	0.5	-	-	0.5	-	V
Thermal Resistance: Junction to Case	θ_{J-C}						-	-	1.5	-	-	1.5	°C/W

DAMPER-DIODE TYPES

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS	LIMITS				UNITS
			DAMPER DIODES				
			TYPE 1N4785		RCA 40442		
			Min.	Max.	Min.	Max.	
Peak Reverse Voltage	PRV	Peak Reverse Current (I_{RM}) = 1 mA	320	-	200	-	V
Static Reverse Current	I_R	Static Reverse Voltage (V_R) = 10 V	-	150	-	150	μA
Static Forward Voltage Drop	V_F	Average Forward Current (I_F) = 7 A	-	0.77	-	0.77	V

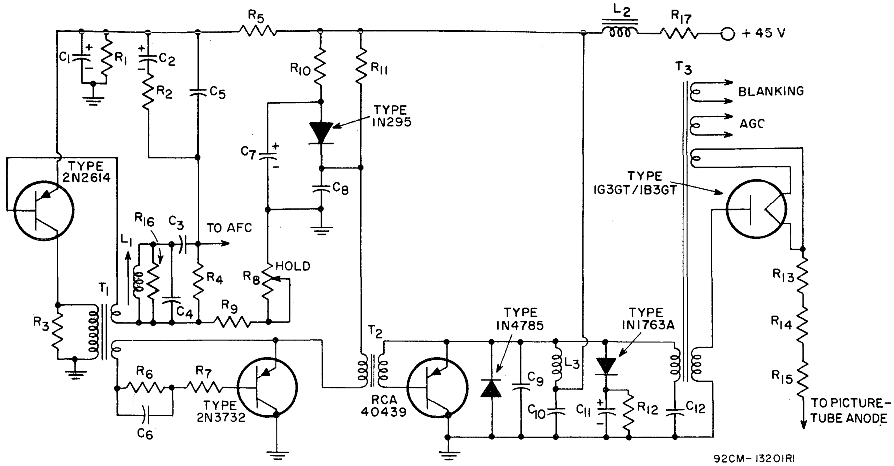


Fig.1 - Typical Horizontal Deflection and High-Voltage Circuit Using Types 40439, 2N3732, and 1N4785.

PARTS LIST FOR FIG.1

C_1 = 50 μF, 12 V, electrolytic
C_2 = 2 μF, 3 V, electrolytic
C_3 = 0.008 μF, mica
C_4 = 0.01 μF, mica
C_5 = 0.2 μF
C_6 = 0.1 μF, 3 V
C_7 = 10 μF, 15 V, electrolytic
C_8 = 0.05 μF, 50 V
C_9 = 0.05 μF, 300 V
C_{10} = 4 μF, 25 V
C_{11} = 10 μF, 300 V, electrolytic
C_{12} = 0.15 μF, 400 V
L_1 = Sine-wave coil (see below for design data)
L_2 = Choke, 2 mH at 2 A
L_3 = Horizontal-deflection windings of yoke – Inductance = 200 μH

R_1, R_{16} = 560 Ω
R_2 = 2.2 K Ω
R_3, R_5 = 1 K Ω
R_4 = 15 K Ω
R_6 = 4.7 Ω
R_7 = 10 Ω
R_8 = Hold control, potentiometer, 10 K Ω
R_9 = 22 K Ω
R_{10} = 2.7 K Ω
R_{11} = 560 Ω, 1W
R_{12} = 1 M Ω
R_{13}, R_{14}, R_{15} = 27 K Ω
R_{17} = 15 Ω, 10 W

T_1 = Blocking-oscillator transformer, Columbus Process Co., Columbus, Ind. Part No.CPX9372, or equivalent (see design data)
T_2 = Driver transformer, Columbus Process Co., Columbus, Ind. Part No.CPX9370 or equivalent (see design data)
T_3 = Horizontal-deflection output and high-voltage transformer, F.W. Sickles Co., Div. of General Instruments Corp., Chicopee, Mass. Part No.18428-4 or equivalent.

TYPICAL PERFORMANCE DATA FOR HORIZONTAL-DEFLECTION AND HIGH-VOLTAGE CIRCUIT SHOWN IN FIG.1

DC Supply Voltage.	+45	V
Average Supply Current	0.55	A
Input Power:		
Oscillator and driver circuits	1.5	W
Output circuit:		
at beam) = 0	18	W
current) = 200 μA.	22	W
Peak collector-to-emitter voltage for Type 40439	260	V
DC high-voltage output:		
at beam) = 0	18	kV
current) = 200 μA.	17	kV
Yoke current (peak-to-peak).	10	A
Peak yoke energy	2.5	mJ
Retrace time	11.5	μs

DESIGN DATA FOR TRANSFORMERS SHOWN IN FIG.1

L_1 — Sine-Wave Coil:

Form – Tapped or embossed to accommodate 1/4 – 28 threaded slug.
Slug – General Ceramics Type Q material or equivalent, 5/8 inch long.
Winding – 350 turns No.7/41 Litz wire (Cam = 0.5 inch).

DESIGN DATA FOR TRANSFORMERS SHOWN IN FIG.1 cont'd

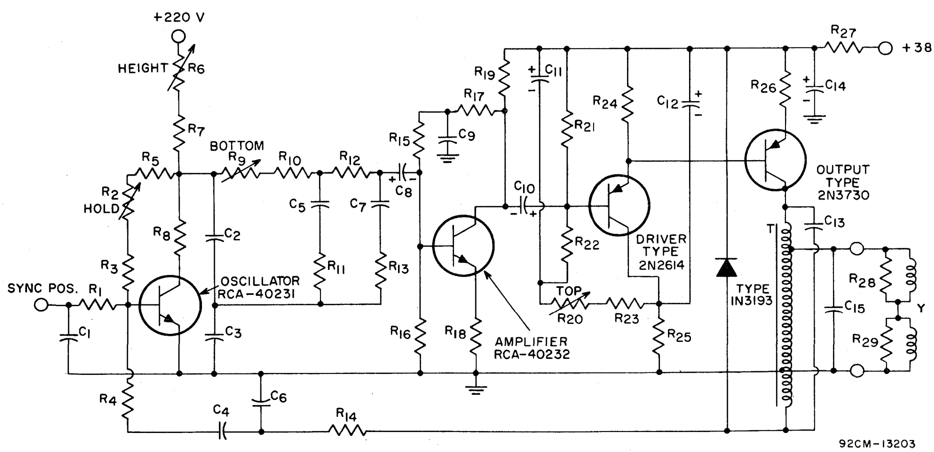
T_1 — Blocking-Oscillator Transformer:

Cup core: Indiana General Corp., Keasbey, N.J. Part No.F912-03 or equivalent.
Cup-core cover: Indiana General Corp., Keasbey, N.J., Part No. F913-03 or equivalent.
Nylon bobbin: American Molded Products, Chicago 22, Ill., Part No.5661 or equivalent.
Gap: 1.5-mil paper
Windings:
Primary - 135 turns No.34 FORMVAR* wire
Secondary - 35 turns No.30 FORMVAR wire
Feedback - 45 turns No.30 FORMVAR wire
Wind 45 turns of primary; then trifilar-wind secondary and feedback windings with remainder of primary to assure tight coupling.

T_2 — Driver Transformer:

Cup core, Cup-core cover, Nylon bobbin, Gap: Same as for T_1
Windings:
Primary - 80 turns No.30 FORMVAR wire
Secondary - 20 turns No.24 FORMVAR wire
Wind 30 turns of primary; then bifilar-wind secondary winding with remainder of primary to assure tight coupling.

* Trade Mark, Shawinidan Products Corp.



C_1, C_{13} = 0.005 μF
C_2 = 1 μF, paper
C_3 = 4 μF, paper
C_4 = 0.05 μF
C_5, C_7 = 0.25 μF, paper
C_6 = 0.02 μF
C_8 = 2 μF, 25 V, electrolytic
C_9 = 0.1 μF
C_{10}, C_{11}, C_{12} = 25 μF, 25 V, electrolytic
C_{14} = 500 μF, 50 V, electrolytic
C_{15} = 0.22 μF
R_1 = 15 KΩ

R_2 = Hold control, potentiometer, 250 KΩ
R_3, R_5 = 82 KΩ
R_4 = 18 KΩ
R_6 = Height control, potentiometer, 500 KΩ
R_7 = 270 KΩ
R_8 = 220 Ω
R_9, R_{20} = Linearity control, potentiometer, 25 KΩ
R_{10} = 22 KΩ
R_{11}, R_{13} = 4.7 KΩ
R_{12} = 10 KΩ
R_{14}, R_{23} = 3.3 KΩ

R_{15} = 150 KΩ
R_{16}, R_{17} = 100 KΩ
R_{18} = 470 Ω
R_{19} = 2.7 KΩ
R_{21} = 1.5 KΩ
R_{22} = 3.9 KΩ
R_{24} = 150 Ω
R_{25} = 680 Ω
R_{26} = 5.6 Ω
R_{27} = 50 Ω, 10W
R_{28}, R_{29} = 56 Ω

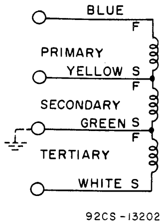
All capacitors are disc ceramic type, unless otherwise specified.

All resistors are 0.5-Watt, composition type, unless otherwise specified.

T = Vertical-deflection output transformer: Better Coil & Transformer Corp., Goodlands, Ind. Part NO.99A20, or equivalent. (See Fig.3 for design data)

Y = Vertical-deflection windings of yoke: Inductance = 5 mH, resistance = 5 Ω

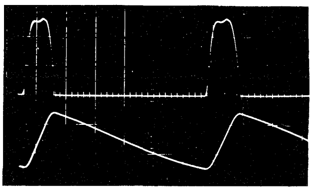
Fig.2 - Typical Vertical Deflection Circuit Using Type 2N3730.



Core: 3/4" square "E-I" stack, 25-mil laminations
Gap: 5-mil paper
Windings (in order of winding on bobbin):
1 – Tertiary = 115 turns No.34 Heavy FORMVAR* or equivalent
2 – Secondary = 160 turns No.22 Heavy FORMVAR or equivalent
3 – Primary = 350 turns No.30 Heavy FORMVAR or equivalent

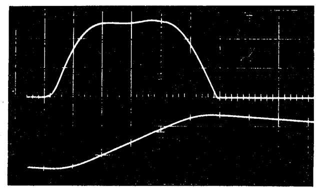
* Trade Mark, Shawinidan Products Corp.

Fig.3 - Design Data for Vertical Deflection Output Transformer Shown in Fig.2.



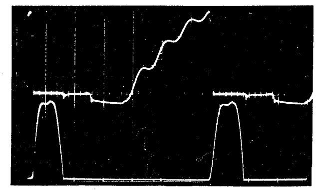
Upper Trace: Yoke Voltage, 100 V/div.
Lower Trace: Yoke Current, 5 A/div.
Time Base: 10 µs/div.

A - L_3 (Yoke) Voltage and Current



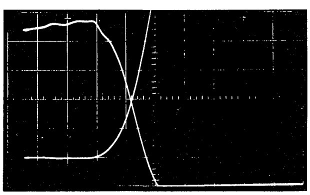
Upper Trace: Yoke Voltage, 100 V/div.
Lower Trace: Yoke Current, 5 A/div.
Time Base: 2 µs/div.

B - L_3 (Yoke) Voltage and Current (Expanded Trace)



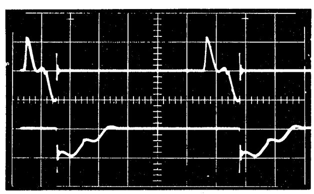
Upper Trace: I_C, 2 A/div.
Lower Trace: V_{CE}, 100 V/div.
Time Base: 10 µs/div.

C - 40439 Collector Voltage and Current



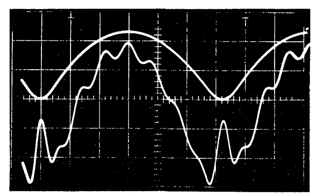
Upper Trace: I_C, 1 A/div.
Lower Trace: V_{CE}, 10 V/div.
Time Base: 0.5 µs/div.

D - 40439 Collector Voltage and Current (Expanded Trace)



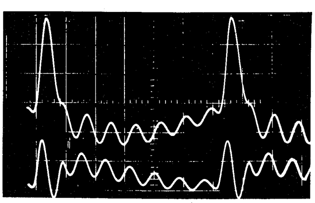
Upper Trace: C_9 Current, 5 A/div.
Lower Trace: 1N4785 Current, 5 A/div.
Time Base: 10 µs/div.

E - (C_9) Flyback-Capacitor Current 1N4785 Damper Diode Current



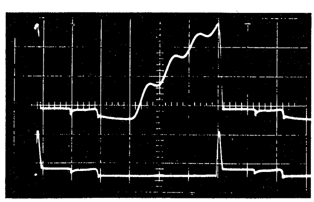
Upper Trace: C_{10} Voltage, 10 V/div.
Lower Trace: C_{12} Voltage, 20 V/div.
Time Base: 10 µs/div.

F - (C_{10}) "S"-Shaping Capacitor Voltage and (C_{12}) Flyback-Coupling Capacitor Voltage



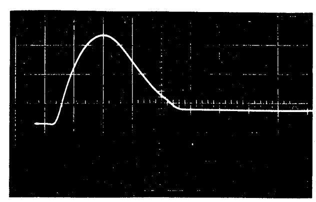
Upper Trace: Secondary Voltage, 5000 V/div.
Lower Trace: Primary Current, 2 A/div.
Time Base: 10 µs/div.

G - T_3 (Output Transformer) Secondary Voltage and Primary Current



Upper Trace: I_C, 2 A/div.
Lower Trace: I_B, 2 A/div.
Time Base: 10 µs/div.

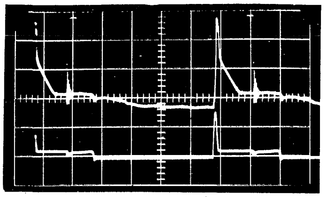
H - 40439 Output Transistor Collector and Base Currents



Amplitude Scale: 1 A/div.
Time Scale: 0.5 µs/div.

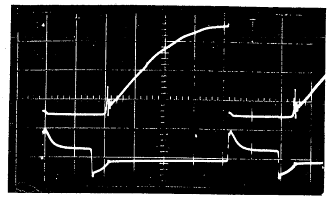
I - Expanded Trace of 40439 Output Transistor Base Current Pulse Shown in H

Fig.4 - Typical Waveforms for Horizontal-Deflection Circuit Shown in Fig.1.



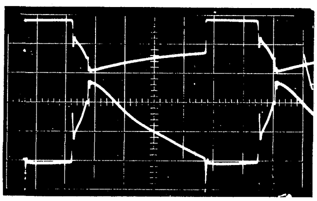
Upper Trace: V_{BE}, 2 V/div.
Lower Trace: I_B, 2 A/div.
Time Base: 10 μs/div.

J - 40439 Output Transistor Base-to-Emitter Voltage and Base Current



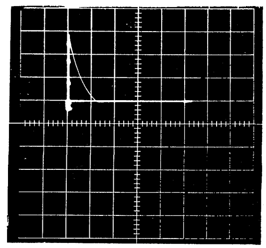
Upper Trace: V_{CE}, 10 V/div.
Lower Trace: I_B, 100 mA/div.
Time Base: 10 μs/div.

K - 2N3732 Driver Transistor Collector-to-Emitter Voltage and Base Current



Upper Trace: V_{CE}, 10 V/div.
Lower Trace: V_{BE}, 2 V/div.
Time Base: 10 μs/div.

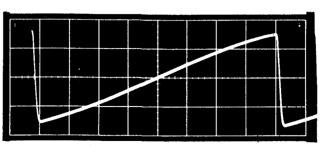
L - 2N2614 Oscillator Transistor Collector-to-Emitter Voltage and Base-to-Emitter Voltage



Ordinate: I_C, 2 A/div.
Abscissa: V_{CE}, 50 V/div.

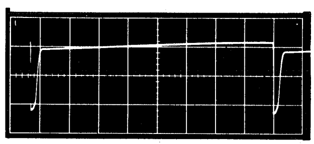
M - 40439 Output Transistor Load Line (Collector Current vs. Collector-to-Emitter Voltage)

Fig.4 - Typical Waveforms for Horizontal-Deflection Circuit Shown in Fig.1.



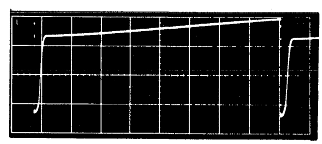
Ordinate: I, 400 mA/div.
Abscissa: Time, 2000 μs/div.

A - Y (Yoke) Current



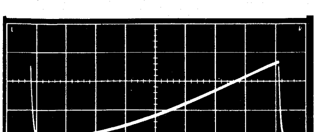
Ordinate: V, 20 V/div.
Abscissa: Time, 2000 μs/div.

B - Y (Yoke) Voltage



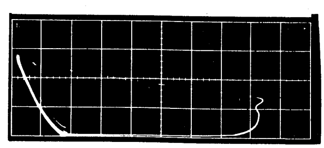
Ordinate: V_{CE}, 50 V/div.
Abscissa: Time, 2000 μs/div.

C - 2N3730 Vertical Output Transistor Collector-to-Emitter Voltage



Ordinate: I_C, 200 mA/div.
Abscissa: Time, 2000 μs/div.

D - 2N3730 Vertical Output Transistor Collector Current



Ordinate: I_C, 200 mA/div.
Abscissa: V_{CE}, 20 V/div.

E - 2N3730 Vertical Output Transistor Load Line (I_C vs. V_{CE})

Fig.5 - Typical Waveforms for Vertical-Deflection Circuit Shown in Fig.2

OPERATING CONSIDERATIONS

Because the metal shells of the 2N3730, 2N3731, 2N3732, 40439, and 40440 operate at the collector voltage, and those of the 1N4785 and 40442 at the anode voltage, 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 such cases, suitable precautionary measures should be taken.

These devices should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the devices.

These devices can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the device.

It is essential that the mounting flange which serves as the collector or anode terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE DEVICE.

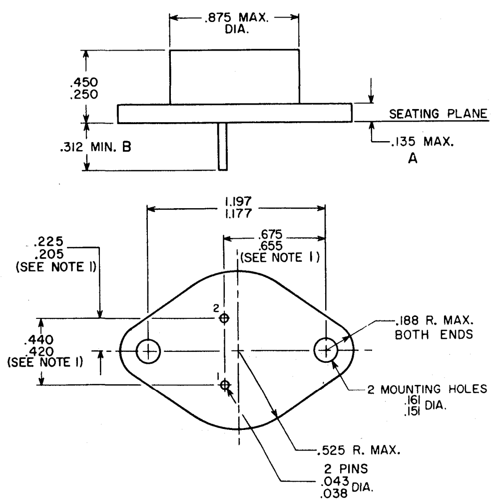
The mounting-flange temperatures of these devices will be higher than the ambient (free-air) temperature by an amount which depends on the heat sink used. The heat sink must have sufficient thermal capability to assure that the heat dissipated in the heat sink itself does not raise the device mounting-flange temperature above the design value.

Depending on the application, the heat sink or chassis may be connected to either the positive or negative terminal of the voltage supply.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be 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 aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the terminal pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that a fibre washer be used between each bolt and the chassis.

DIMENSIONAL OUTLINE

JEDEC No.TO-3



ALL DIMENSIONS IN INCHES. 92CS-11852

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

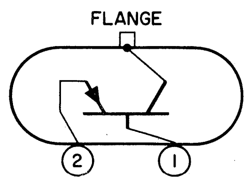
For RCA-2N3730, 2N3731, 2N3732, 1N4785, 40439, 40440, and 40442

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. / 0.480" max.

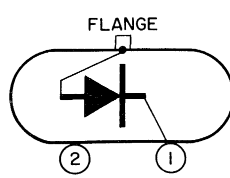
TERMINAL CONNECTIONS

2N3730, 2N3731, 2N3732
40439, 40440



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

1N4785
40442



Pin 1 - Cathode
Pin 2 - No Connection
Mounting Flange - Anode, Case

RCA

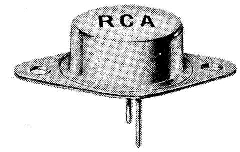
Solid State Division

Power Transistors

1N4785 2N3732 2N3730 2N4346

TRANSISTOR/DAMPER-DIODE COMPLEMENT

For High-Reliability High-Energy Deflection Systems



RCA-2N3730, 2N4346,▲ 2N3732, and 1N4785 are a complement of germanium solid-state devices specifically designed for use in high-energy deflection systems for television monitors and other equipment required to provide highly reliable performance.

Types 2N3730, 2N4346, and 2N3732 are diffused-collector, graded-base power transistors of the germanium pnp type. Type 2N3730 is intended for use as a vertical-deflection output amplifier; types 2N4346 and 2N3732 are for use respectively as a horizontal output amplifier and horizontal driver.

Type 1N4785 is a diffused-germanium diode for use in damper service in transistorized horizontal deflection systems.

All four devices are hermetically sealed in metal JEDEC TO-3 packages.

▲ Formerly Dev. No. TA2920.

- short turn-off time in typical horizontal deflection circuits: t_{off} = 0.75 max. μs for 2N4346
- high minimum beta at high collector current: h_{FE} = 25 min. at I_C = 6 A for 2N4346
- high breakdown-voltage capabilities: BV_{CES} = -320 min V for 2N4346 horizontal-output type; -200 min. V for 2N3730 vertical-output type; -100 min. V for 2N3732 horizontal-driver type

DEFLECTION SERVICE

Absolute Maximum Ratings:	2N3730	2N4346	2N3732	1N4785		
COLLECTOR-TO-BASE VOLTAGE:						
PEAK, V_{CBO}	-200	-320	-100	-	max.	V
CONTINUOUS, V_{CB}	-60	-60	-60	-	max.	V
COLLECTOR CURRENT, I_C	-3	-10	-3	-	max.	A
BASE CURRENT, I_B	±0.5	+4, -1	±0.5	-	max.	A
TRANSISTOR DISSIPATION, P_T:						
For mounting-flange temperatures* up to 55°C	10	5	3	-	max.	W
For mounting-flange temperatures* above 55°C	Derate linearly to zero watts at 85°C					
REVERSE VOLTAGE:						
PEAK, PRV	-	-	-	320	max.	V
CONTINUOUS, RV	-	-	-	60	max.	V
PEAK FORWARD CURRENT, i_{FM}	-	-	-	10	max.	A
AVERAGE FORWARD CURRENT, I_{FA}	-	-	-	7	max.	A
TEMPERATURE RANGE:						
Storage and operating (junction)	← -65 to +85 →					°C
LEAD TEMPERATURE (During soldering):						
At distances not closer than 1/32 inch to seating surface for 10 seconds max.	← 230 →				max.	°C

*Measured at center of seating surface.

ELECTRICAL CHARACTERISTICS, at an Ambient Temperature (T_A) of 25°C

Characteristics	Symbols and Units	LIMITS: Vertical Output Amplifier 2N3730 Min.	Typ.	Max.	Horizontal Output Amplifier 2N4346 Min.	Typ.	Max.	Horizontal Driver 2N3732 Min.	Typ.	Max.	Damper Diode 1N4785 Min.	Typ.	Max.	TEST CONDITIONS: V_{CB} V	V_{EB} V	I_C A	I_B A	I_E mA
Collector-Cutoff Current	I_{CBO} µA	-	-	-200	-	-	-200	-	-	-200	-	-	-	-10				0
Collector-to-Emitter Breakdown Voltage	BV_{CES} volts	-	-	-	-320	-	-	-	-	-	-	-	-		0	-0.025		
		-200	-	-	-	-	-	-100	-	-	-	-	-		0	-0.005		
Emitter-to-Base Breakdown Voltage	BV_{EBO} volts	0.5	-	-	-2	-	-	0.5	-	-	-	-	-			0		-100
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$ volts	-	-	-	-	-	-0.75	-	-	-	-	-	-			-6	-0.4	
		-	-	-2	-	-	-	-	-	-2	-	-	-			-0.7	-0.02	
		-	-	-1	-	-	-	-	-	-	-	-	-			-0.05	-0.005	
Base-to-Emitter Voltage	V_{BE} volts	-	-	-	-	0.8	-	-	-	-	-	-	-			-6	-0.4	
		-	0.5	-	-	-	-	-	0.5	-	-	-	-			-0.7	-0.02	
Turn-off Time△	t_{off} µs	-	-	-	-	-	0.75	-	-	-	-	-	-	See *Fig.1*				
Thermal Resistance Junction to Case	θ_{JC} °C/W	-	-	1.5	-	-	1.5	-	-	1.5	-	-	-					
Peak Reverse Voltage	PRV volts	-	-	-	-	-	-	-	-	-	320	-	-	Reverse Current I_R = 1 mA				
Static Reverse Current	I_R µA	-	-	-	-	-	-	-	-	-	-	-	150	DC Reverse Voltage V_R = 10 V				
Static Forward Voltage Drop	V_F volts	-	-	-	-	-	-	-	-	-	-	-	0.77	DC Forward Current I_F = 7 A				

△ "Turn-Off Time" t_{off} as used in this bulletin is the time required for the Collector Current I_C to decrease to -100 milliamperes **after** the Collector-to-Emitter voltage V_{CE} has risen 2 volts into its "flyback" excursion. In a circuit of the type shown in Fig.1 the collector current may be determined by measuring the base and emitter currents simultaneously with the aid of a current-transformer-type probe.

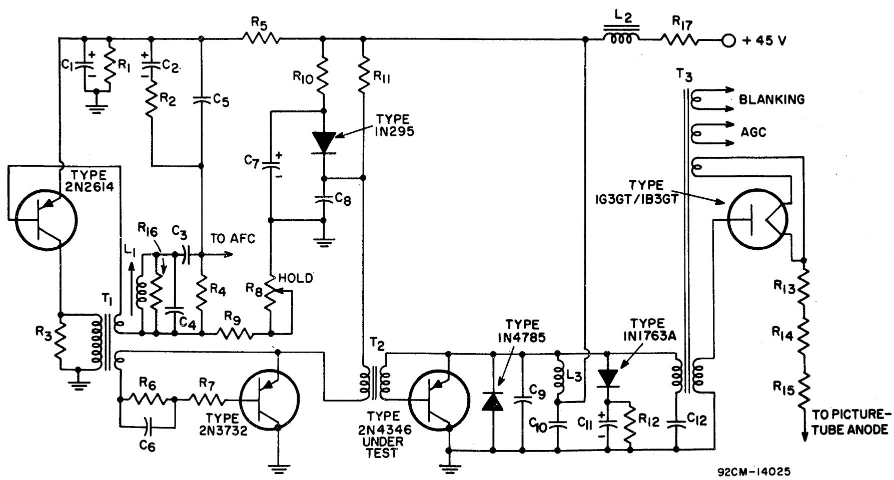


Fig.1 - Circuit of Turn-Off-Time Test-Set for RCA-2N4346.

PARTS LIST FOR FIG. I

C_1 = 50 µF, 12 V, electrolytic
C_2 = 2 µF, 3 V, electrolytic
C_3 = 0.008 µF, mica
C_4 = 0.01 µF, mica
C_5 = 0.2 µF
C_6 = 0.1 µF, 3 V
C_7 = 10 µF, 15 V, electrolytic
C_8 = 0.05 µF, 50 V
C_9 = 0.05 µF, 300 V
C_{10} = 4 µF, 25 V
C_{11} = 10 µF, 300 V, electrolytic
C_{12} = 0.15 µF, 400 V
L_1 = Sine-wave coil (see below for design data)
L_2 = Choke, 2 mH at 2 A
L_3 = Horizontal-deflection windings of yoke - Inductance = 200 µH
R_1, R_{16} = 560 Ω
R_2 = 2.2 KΩ
R_3, R_5 = 1 KΩ
R_4 = 15 KΩ
R_6 = 4.7 Ω
R_7 = 10 Ω
R_8 = Hold control, potentiometer, 10 KΩ
R_9 = 22 KΩ
R_{10} = 2.7 KΩ
R_{11} = 560 Ω, 1W
R_{12} = 1 MΩ
R_{13}, R_{14}, R_{15} = 27 KΩ
R_{17} = 15 Ω, 10 W
T_1 = Blocking-oscillator transformer, Columbus Process Co., Columbus, Ind. Part No.CPX9372, or equivalent (see design data)
T_2 = Driver transformer, Columbus Process Co., Columbus, Ind. Part No.CPX9370 or equivalent (see design data)
T_3 = Horizontal-deflection output and high-voltage transformer, F.W. Sickles Co., Div. of General Instruments Corp., Chicopee, Mass. Part No.18428-4 or equivalent.

TYPICAL PERFORMANCE DATA FOR TURN-OFF-TIME TEST-SET CIRCUIT SHOWN IN FIG. I

DC Supply Voltage	**+45**	**V**
Average Supply Current	**0.55**	**A**
Input Power:		
Oscillator and driver circuits	**1.5**	**W**
Output circuit:		
at beam) = 0	**18**	**W**
current) = 200 µA.	**22**	**W**
Peak collector-to-emitter voltage for Type 2N4346	**260**	**V**
DC high-voltage output:		
at beam) = 0	**18**	**kV**
current) = 200 µA.	**17**	**kV**
Yoke current (peak-to-peak)	**10**	**A**
Peak yoke energy	**2.5**	**mJ**
Retrace time	**11.5**	**µs**

DESIGN DATA FOR TRANSFORMERS SHOWN IN FIG. I

L_1 — Sine-Wave Coil:

Form - Tapped or embossed to accommodate 1/4 - 28 threaded slug.
Slug - General Ceramics Type Q material or equivalent, 5/8 inch long.
Winding - 350 turns No.7/41 Litz wire (Cam = 0.5 inch).

T_1 — Blocking-Oscillator Transformer:

Cup core: Indiana General Corp., Keasbey, N.J. Part No.F912-03 or equivalent.
Cup-core cover: Indiana General Corp., Keasbey, N.J., Part No. F913-03 or equivalent.
Nylon bobbin: American Molded Products, Chicago 22, Ill., Part No.5661 or equivalent.
Gap: 1.5-mil paper
Windings:
Primary - 135 turns No.34 FORMVAR* wire
Secondary - 35 turns No.30 FORMVAR wire
Feedback - 45 turns No.30 FORMVAR wire
Wind 45 turns of primary; then trifilar-wind secondary and feedback windings with remainder of primary to assure tight coupling.

T_2 — Driver Transformer:

Cup core, Cup-core cover, Nylon bobbin, Gap — Same as for T_1
Windings:
Primary - 80 turns No.30 FORMVAR wire
Secondary - 20 turns No.24 FORMVAR wire
Wind 30 turns of primary; then bifilar-wind secondary winding with remainder of primary to assure tight coupling.

* Trade Mark, Shawinidan Products Corp.

OPERATING CONSIDERATIONS

Because the metal shells of the 2N3730, 2N4346 and 2N3732 operate at the collector voltage, and that of the 1N4785 at the anode voltage, 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 such cases, suitable precautionary measures should be taken.

These devices should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the devices.

These devices can be installed in commercially available sockets. Electrical connection to the terminal pins may also be made by soldering directly to these 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 will crack the pin seals and damage the device.

It is essential that the mounting flange which serves as the collector or anode terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE DEVICE.

The mounting-flange temperature of the 2N3730, 2N4346, 2N3732, or 1N4785 will be higher than the ambient (free-air) temperature by an amount which depends on the heat sink used. The heat sink must have sufficient thermal capability to assure that the heat dissipated in the heat sink itself does not raise the device mounting-flange temperature above the design value.

Depending on the application, the heat sink or chassis may be connected to either the positive or negative terminal of the voltage supply.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be 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 aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the terminal pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that a fibre washer be used between each bolt and the chassis.

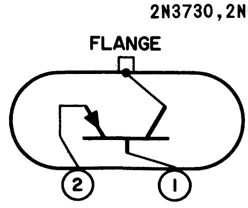
DIMENSIONAL OUTLINE
JEDEC No.TO-3

For RCA-2N3730, 2N4346, 2N3732, 1N4785

Mounting-Flange Thickness (A) = 0.050" max.

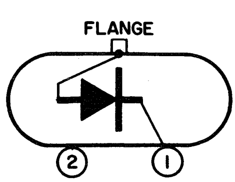
Pin Length (B) = 0.440" min. / 0.480" max.

TERMINAL CONNECTIONS
2N3730, 2N4346, 2N3732

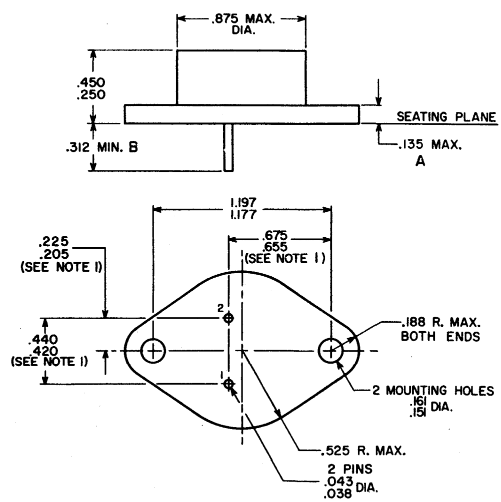


Pin 1 - Base
Pin 2 - Emitter
Mounting Flange - Collector, Case

1N4785



Pin 1 - Cathode
Pin 2 - No Connection
Mounting Flange - Anode, Case



ALL DIMENSIONS IN INCHES.

NOTE I: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

Solid State Division

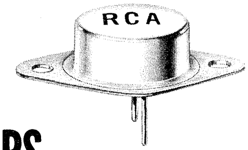
RCA types 40022 and 40254 are alloy-junction power transistors of the germanium p-n-p type, intended primarily for use in high-fidelity amplifiers and other af-amplifier applications. They feature high collector-current and dissipation capabilities, and exceptional linearity of characteristics over the full range of collector current. These transistors are hermetically sealed in the JEDEC TO-3 package and can be operated over the temperature range from -65 to +100° C.

The 40022 is particularly suitable for use in push-pull class B output stages of high-fidelity af-amplifier equipment. A pair of 40022 transistors in a "single-ended push-pull" class B amplifier circuit can deliver up to 10 watts rms power (18 watts EIA music power[a]) into a 4-ohm load with less than 5 per cent total harmonic distortion, and provide a power gain of 25 db (see Fig.3). When used with an RCA type 2N2613 low-noise transistor in the input stage and RCA type 2N2614 transistors in the intermediate and driver stages, the 40022 makes possible the design of economical high-fidelity-amplifier systems having high power output, low distortion, and wide frequency response.

The 40254 is intended primarily for use in class A af-power-amplifier service in driver and output-stage applications. In these applications the 40254 can deliver power outputs as high as 5 watts rms with less than 5 per cent total harmonic distortion, and provide power gains of up to 36 db.

[a] EIA Standard No.R234, Section 2.1.2.1.
[b] Measured at center of seating surface.

GERMANIUM P-N-P ALLOY-JUNCTION POWER TRANSISTORS



JEDEC TO-3

For High-Fidelity Audio-Frequency-Amplifier Applications

- Up to 18 watts EIA music power output in class B push-pull operation
- DC beta = 50 (typical)
- 5-amp collector-current capability
- exceptional linearity of characteristics over entire collector-current range

Maximum Ratings, *Absolute-Maximum Values:*

	40022 40254	
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-32 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CER} ($R_{BE} \leq$ 33 ohms)	-32 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-5 max.	volts
COLLECTOR CURRENT, I_C	-5 max.	amp
BASE CURRENT, I_B	-1 max.	amp
TRANSISTOR DISSIPATION, P_T:		
For mounting-flange temperatures[b] up to 81° C	12.5 max.	watts
For mounting-flange temperatures[b] above 81° C	Derate linearly at 0.66 watt/°C	
TEMPERATURE RANGE:		
Storage and operating (Junction)	-65 to +100	°C
PIN TEMPERATURE (During Soldering)		
At distances ≥ 1/32 inch from seating surface for 10 seconds max.	255 max.	°C

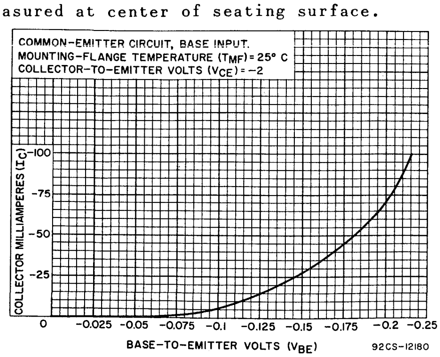


Fig.1 - Typical Transfer Characteristic For Types 40022 and 40254

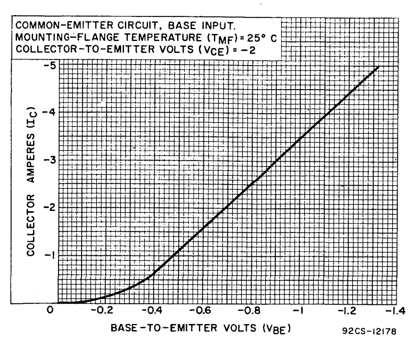
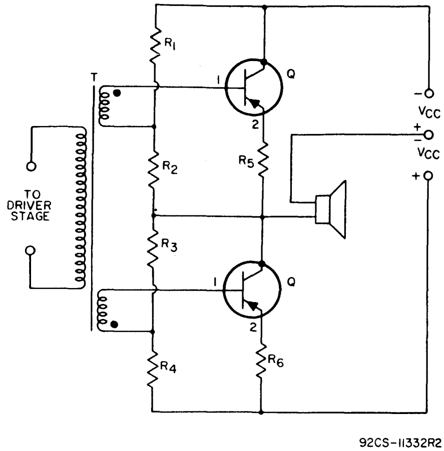


Fig.2 - Typical Transfer Characteristic For Types 40022 and 40254



Q = Transistor Type RCA-40022
R_1, R_3 = 270 ohms ± 10%, 1 watt
R_2, R_4 = 3.9 ohms ± 10%, C 5 watt
R_5, R_6 = 0.56 ohm ± 10%, 0.5 watt
Speaker Voice-Coil Impedance = 4 ohms
T = Driver Transformer. Primary-winding impedance, current-carrying capacity, and dc resistance determined by large-signal characteristics of driver stage; secondary windings bifilar wound impedance of each winding = 100 ohms.

Fig.3 - Circuit of "Single-Ended Push-Pull" Amplifier Stage Using RCA Type 40022 Power Transistors

TYPICAL OPERATION OF TYPE 40022 IN "SINGLE-ENDED PUSH-PULL" CLASS B AF-AMPLIFIER CIRCUIT SHOWN IN FIG.3

For a Mounting-Flange Temperature[b] of 25° C

DC Collector Supply Voltages (V_{CC})[c]	14	volts
Zero-Signal DC Collector Current	-0.025	amp
Zero-Signal Base-Bias Voltage. .	-0.16	volt
Peak Collector Current	-2.25	amp
Maximum-Signal DC Collector Current.	-0.716	amp
Input Impedance of Stage (per base)	60	ohms
Load Impedance (Speaker Voice-Coil).	4	ohms
Power Gain	25	db
Maximum-Signal Power Output. . .	10	watts
Total Harmonic Distortion at Maximum-Signal Power-Output. .	5	%
Maximum Collector Dissipation (per transistor) under worst-case conditions.	5	watts
EIA Music Power Output Rating[a] .	18	watts

[a] EIA Standard No.R234, Section 2.1.2.1.
[b] Measured at center of seating surface.
[c] The data shown are for a dc collector supply having 10 per cent regulation.

ELECTRICAL CHARACTERISTICS, *at a Mounting-Flange Temperature[b] of 25° C:*

Characteristic	Symbol	TEST CONDITIONS: DC Collector-to-Base Voltage V_{CB} (volts)	DC Collector-to-Emitter Voltage V_{CE} (volts)	External Base-to-Emitter Resistance R_{BE} (ohms)	DC Collector Current I_C (amp)	DC Emitter Current I_E (amp)	LIMITS: Type 40022 Min.	Typ.	Max.	Type 40254 Min.	Typ.	Max.	Units
Collector-to-Base Breakdown Voltage	BV_{CBO}				-0.005	0	-32	-	-	-32	-	-	volts
Collector-to-Emitter Breakdown Voltage	BV_{CER}			33	-0.2		-32	-	-	-32	-	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0	-0.002	-5	-	-	-5	-	-	volts
Collector-Cutoff Current	I_{CBO}	-30				0	-	-	-1	-	-	-3	ma
Collector-Cutoff Saturation Current	$I_{CBO}(sat)$	-0.5				0	-	-	-0.1	-	-	-0.16	ma
DC Forward-Current Transfer Ratio	h_{FE}		-2		-1		38	70	-	30	70	-	
Base-to-Emitter Voltage	V_{BE}		-10		-0.05		-	-0.18	-	-	-	-	volt
Gain-Bandwidth Product	f_T		-5		-0.5		-	300	-	-	300	-	kc
Thermal Resistance Junction-to-Case	θ_{J-C}						-	-	1.5	-	-	1.5	°C/watt

TYPICAL OPERATION OF TYPE 40254 IN CLASS A AF-AMPLIFIER CIRCUIT

For a Mounting-Flange Temperature of 25° C

DC Collector Supply Voltage (V_{CC})	-16	volts
DC Collector-to-Emitter Voltage.	-13.2	volts
DC Collector Current.	-0.9	amp
Peak Collector Current.	-1.8	amp
Input Impedance	15	ohms
Collector Load Impedance. . . .	15	ohms
Maximum-Signal Power Output . .	5	watts
Total Harmonic Distortion at 5 watts Output	5	%
Power Gain.	36	db
Maximum Collector Dissipation .	12	watts

OPERATING CONSIDERATIONS

Because the metal shells of RCA-40022 and RCA-40254 operate at the collector voltage, 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 such cases, suitable precautionary measures should be taken.

RCA-40022 and RCA-40254 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistors.

RCA-40022 and RCA-40254 can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistors.

It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE TRANSISTOR.

The mounting-flange temperature of RCA-40022 and RCA-40254 will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.

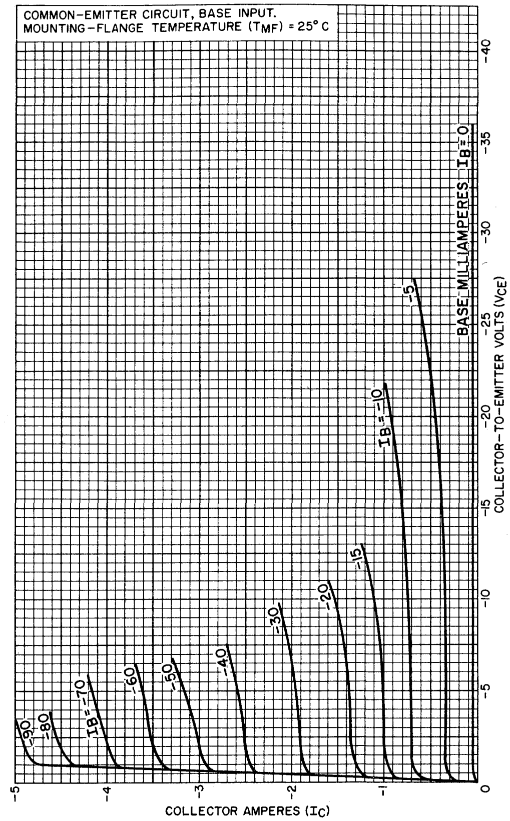


Fig.4 - Typical Collector Characteristics for Types 40022 and 40254

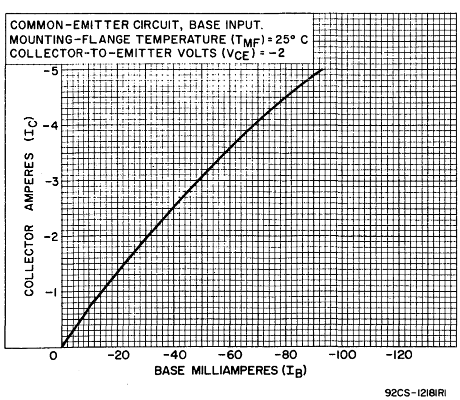


Fig.5 - Typical Current-Transfer Characteristic for Types 40022 and 40254

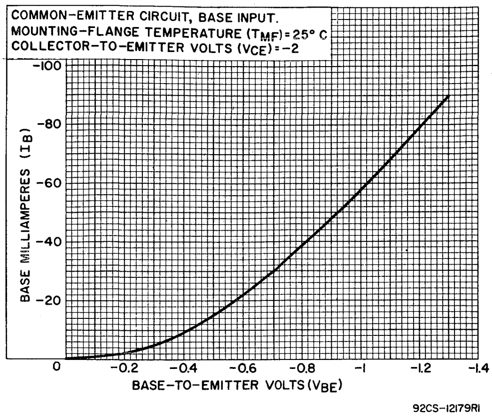
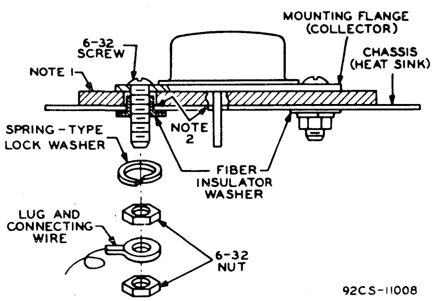


Fig.6 - Typical Input Characteristic for Types 40022 and 40254



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Mounting hardware items for RCA-40022 and 40254 are available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART NO.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

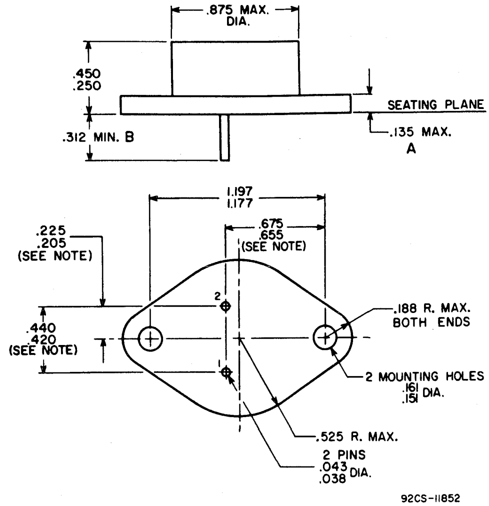
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-40022 and 40254 and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

Fig.7 - Suggested Mounting Arrangement for Types 40022 and 40254

DIMENSIONAL OUTLINE For Types 40022 and 40054 JEDEC No. TO-3



DIMENSIONS IN INCHES

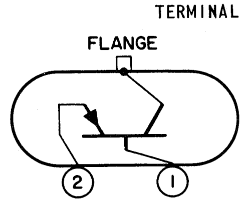
For Types 40022 and 40254:

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. 0.480" max.

NOTE: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

TERMINAL CONNECTIONS



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

RCA
Solid State
Division

Power Transistors
40050
40051

RCA-40050 and 40051 are alloy-junction power transistors of the germanium p-n-p type, intended primarily for use in high-fidelity amplifiers and other commercial af-amplifier applications. These transistors feature high collector-current and dissipation capabilities, and exceptional linearity of characteristics over their full ranges of collector current. When used with RCA-2N2613 low-noise transistors in low-level stages and RCA-2N2614 transistors in intermediate-level and driver stages, the 40050 and 40051 make possible the design of economical high-fidelity amplifier systems having high power output, low distortion, and wide frequency response.

The 40050 and 40051 are particularly desirable for use in class B amplifier service in push-pull circuit arrangements. In a "single-ended push-pull" amplifier circuit of the type shown in Fig.2, using direct coupling to a 4-ohm speaker load, a pair of RCA-40051 transistors can deliver up to 25 watts output with sine-wave-signal input or 45 watts music-power output[a], with less than 5 per cent total harmonic distortion and a power gain of 28 db. In the same type of circuit a pair of RCA-40050 transistors can deliver up to 15 watts output with sine-wave-signal input or 25 watts music-power output[a], also with less than 5 per cent total harmonic distortion and a power gain of 28 db.

RCA-40050 and 40051 are also useful as class A power amplifiers in driver and output-stage applications. In this type of service these transistors can provide power outputs as high as 5 watts with less than 5 per cent total harmonic distortion, and power gains as great as 38 db.

The 40051 has a higher collector-to-emitter voltage capability (-50 volts) than the 40050 (-40 volts), and consequently can provide greater power output in direct-coupled amplifier circuits and other applications requiring this capability.

Both the 40050 and the 40051 utilize a hermetically sealed JEDEC TO-3 package.

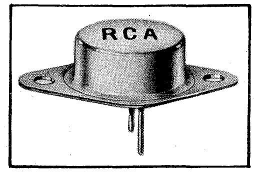
Maximum Ratings, *Absolute-Maximum Values:*

	40050	40051	
Collector-to-Base Voltage, V_{CBO}	-40	-50 max.	volts
Collector-to-Emitter Voltage, V_{CEO}	-40	-50 max.	volts
Emitter-to-Base Voltage, V_{EBO}	-5	-5 max.	volts
Collector Current, I_C	-5	-5 max.	amp
Base Current, I_B	-1	-1 max.	amp
Transistor Dissipation:			
At Mounting-Flange Temperatures*—			
Up to 81° C	12.5	12.5 max.	watts
Above 81° C		See *Fig.1*	
Temperature Range:			
Storage and Operating (Junction)	-65 to +100		°C
Pin Temperature (During Soldering):			
At distances of not less than 1/32" from seating surface for 10 seconds max.	255	255	°C

* Measured at center of seating surface.

GERMANIUM P-N-P POWER TRANSISTORS

For High-Fidelity, Audio-Frequency-Amplifier Applications



- High Large-Signal (DC) Beta = 90 typ.
- Excellent Beta Linearity — Essentially linear up to 5 amp. I_C
- 40051 Features in Push-Pull Class B Service
  - (a) 45 watts music power output[a]
  - (b) 25 watts sine-wave power output

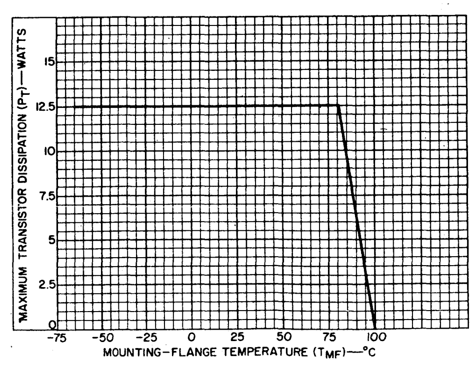
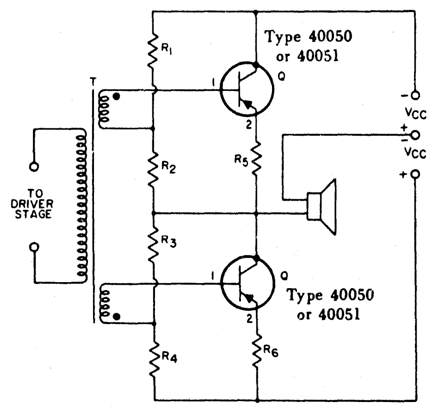


Fig.1 - Rating Chart for Types RCA-40050 and RCA-40051

Electrical Characteristics, *at a Mounting-Flange Temperature, T_{MF}*, of 25° C*

Characteristics	Symbols	TEST CONDITIONS: DC Collector-to-Base Voltage V_{CB} volts	DC Collector-to-Emitter Voltage V_{CE} volts	DC Collector Current I_C amp	DC Emitter Current I_E ma	External Base-to-Emitter Resistance RBE ohms	LIMITS: Type RCA-40050 Min.	Typ.	Max.	Type RCA-40051 Min.	Typ.	Max.	Units
Collector-to-Base Breakdown Voltage	BV_{CBO}			-0.005	0		-40	-	-	-50	-	-	volts
Collector-to-Emitter Breakdown Voltage	BV_{CER}			-0.6		68	-40	-	-	-50	-	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}			0	-2		-5	-	-	-5	-	-	volts
Collector-Cutoff Current	I_{CBO}	-30			0		-	-	-0.5	-	-	-0.5	ma
Saturation Collector-Cutoff Current	$I_{CBO}(sat)$	-0.5			0		-	-	-0.1	-	-	-0.1	ma
DC Forward-Current Transfer Ratio	h_{FE}		-2	-1			50	90	-	50	90	-	
Base-to-Emitter Voltage	V_{BE}		-10	0.5			-	-0.17	-	-	-0.17	-	volt
Thermal-Resistance (Junction-to-case)	θ_{JC}						-	-	1.5	-	-	1.5	°C/watt
Gain-Bandwidth Product	f_T		5	0.5			-	500	-	-	500	-	Kc

* Measured at center of seating surface.



92CS-11332R2

	40051	40050
R_1, R_3	470	390 ohms ± 10%, 1 watt
R_2, R_4	3.9	3.9 ohms ± 10%, 0.5 watt
R_5, R_6	0.33	0.33 ohm ± 10%, 0.5 watt
Speaker: Voice-Coil Impedance.......	4	4 ohms

T: Driver Transformer. Primary-winding impedance, current-carrying capacity, and dc resistance determined by large-signal characteristics of driver stage; secondary windings bifilar wound, impedance of each winding = 100 ohms.

Fig.2 - Single-Ended Push-Pull Class B AF Amplifier Circuit

Typical Operation of Types 40050 and 40051 in "Single-Ended Push-Pull" Class B AF-Amplifier Circuit Shown in Fig.2:

For a Mounting-Flange Temperature of 25°C

	40051	40050	
DC Collector Supply Voltages (V_{CC1}, V_{CC2})[b] . . .	22	18	volts
Zero-Signal DC Collector Current	-0.025	-0.025	amp
Zero-Signal Base-Bias Voltage	-0.16	-0.16	volt
Peak Collector Current. . . .	-3.5	-2.8	amp
Maximum-Signal DC Collector Current	-1.1	-0.8	amp
Input Impedance of Stage (per base).	31	32	ohms
Load Impedance (Speaker Voice Coil)	4	4	ohms
Power Gain.	28	28	db
Maximum-Signal Power Output. .	25	15	watts
Total Harmonic Distortion at Maximum-Signal Power Output.	5	5	%
Maximum Collector Dissipation (per transistor) under worst-case conditions . . .	12.5	7.5	watts
EIA Music Power Output Rating[a]	45	25	watts

[a] EIA Standard No.RS234, Section 2.1.2.1.

[b] The data shown are for a dc collector supply having 10 per cent regulation.

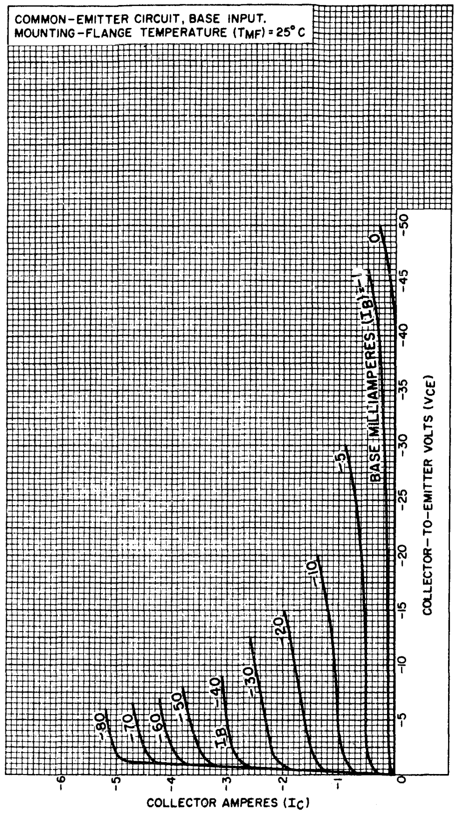


Fig. 3 - Typical Collector Characteristics for Types RCA-40050 and RCA-40051.

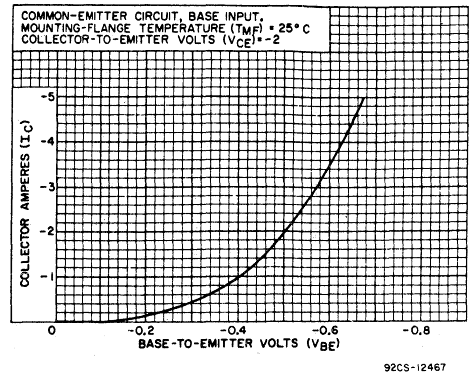


Fig. 5 - Typical Transfer Characteristic for Types RCA-40050 and RCA-40051.

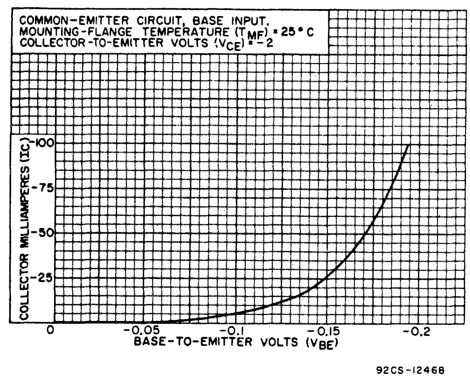


Fig. 6 - Typical Transfer Characteristic for Types RCA-40050 and RCA-40051.

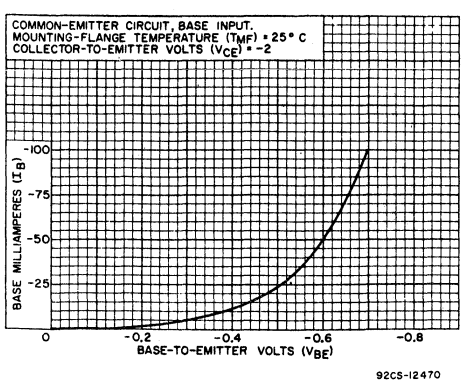


Fig. 4 - Typical Input Characteristic for Types RCA-40050 and RCA-40051.

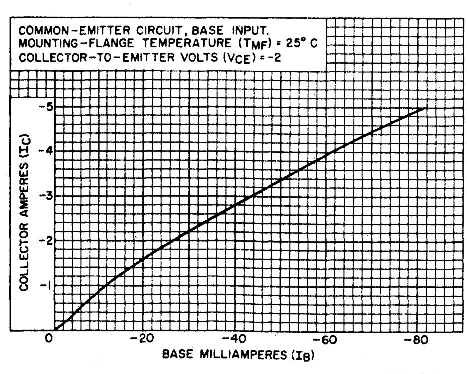


Fig. 7 - Typical Current-Transfer Characteristic for Types RCA-40050 and RCA-40051.

OPERATING CONSIDERATIONS

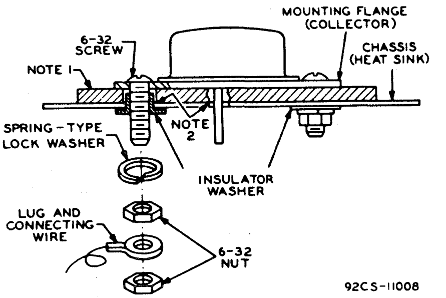
Because the metal shells of these transistors operate at the collector voltage, consideration should be given to the possibility of shock hazard if the shells are to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

The 40050 and 40051 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistors.

These transistors can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistor.

It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. *Under no circumstances, however, should the mounting flange be soldered to the heat sink or chassis because the heat of the soldering operation will permanently damage the transistor.*

The mounting-flange temperature of the 40050 or 40051 will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Mounting hardware items for RCA-40050 and 40051 are available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART NO.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

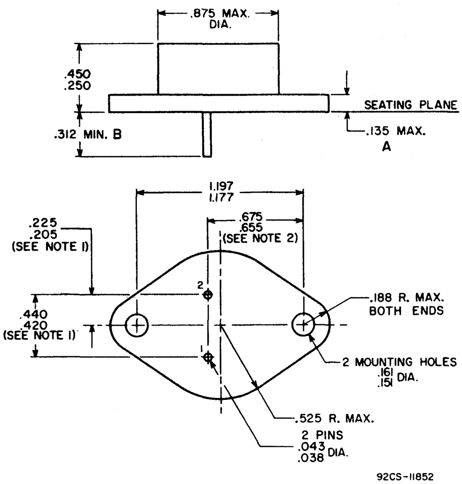
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-40050 and 40051 and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

Fig.8 - Suggested Mounting Arrangement for Types RCA-40050 and RCA-40051.

JEDEC No. TO-3



DIMENSIONS IN INCHES

For RCA-40050 and RCA-40051

Mounting-Flange Thickness (A) = 0.050" max.

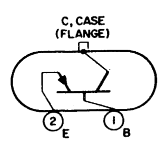
Pin Length (B) = 0.440" min. 0.480" max.

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

NOTE 2: TWO LEADS.

TERMINAL CONNECTIONS

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



Solid State
Division

Power Transistors

40421
40428

RCA-40421* is a diffused-collector, graded-base power transistor of the germanium pnp type intended for use in high-fidelity amplifiers and other af amplifiers which are required to provide relatively large power outputs over a wide frequency range with low distortion. This transistor utilizes a combination of diffusion and alloying techniques to provide a built-in accelerating field in the base region. This accelerating field makes possible a wide frequency response and a linearity of characteristics not available in conventional power transistors.

RCA-40421 is intended for use in class B amplifier service, and has specially controlled breakdown-voltage and collector-saturation-current characteristics to provide dependable performance in this type of service. A pair of 40421 transistors in a "single-ended push-pull" class B amplifier stage of the type shown in Fig.1 can deliver 25 watts output at less than 0.5% total harmonic distortion directly to a 4-ohm speaker, and provide a power gain of 25 dB.

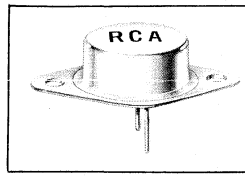
RCA-40428# is a germanium, alloy-junction diode. It is designed to compensate for the effects of temperature and supply-voltage changes on the operation of class B push-pull af power amplifier stages using drift-field power transistors such as RCA Types 40421, 2N2147, 2N2148, and similar types. When used in the type of circuit shown in Fig.1 the 40428 will stabilize the idling current of the output stage against variations of both supply voltage and ambient temperature.

Because of its low dynamic impedance, the 40428 reduces variations in idling current caused by variations in component values as well as by changes in dc supply voltage due to both line-voltage fluctuations and poor power-supply regulation. This feature reduces harmonic distortion in the class B amplifier stage and, in addition, reduces the power requirements for the driver stage.

Both RCA-40421 and RCA-40428 are hermetically sealed in metal cases. RCA-40421 utilizes the standard JEDEC TO-3 package; RCA-40428 utilizes a JEDEC TO-1-size case and has its electrical elements insulated from the case to permit use of a common heat sink for the 40428 and the associated power transistors (see OPERATING CONSIDERATIONS).

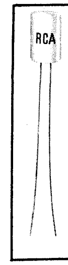
*Formerly Dev. No.TA2862.
#Formerly Dev. No.TA2870.

40421
GERMANIUM P-N-P DRIFT-FIELD POWER TRANSISTOR



For High-Fidelity Amplifier Applications

40428
GERMANIUM ALLOY-TYPE DIODE



For Temperature- and Voltage-Compensation Applications

RCA-40421

- excellent power sensitivity over entire audio-frequency spectrum
- high dc beta at high current levels:
  $h_{FE} = \begin{cases} 62 \text{ min. at } I_C = 1\text{ A} \\ 40 \text{ min. at } I_C = 4\text{ A} \end{cases}$
- high gain-bandwidth product provides exceptional high-frequency response (no loss of gain to over 20 KHz):
  f_T = 4 MHz typ.
- low base resistance — minimizes driving-voltage requirements
- linear transfer characteristics
- 100% pulse tested to prevent secondary breakdown
- completely welded, hermetically sealed JEDEC TO-3 package

RCA-40428

- compensates for effects of changes in temperature, supply voltage, and component values
- low dynamic impedance minimizes amplifier distortion and driving-power requirements
- hermetically sealed TO-1 size metal package — electrical elements insulated from case

Maximum Ratings, *Absolute-Maximum Values:*

RCA-40421

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-75	max. volts
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	-50	max. volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-1.5[a]	max. volts
COLLECTOR CURRENT, I_C	-5	max. amp
BASE CURRENT, I_B	-1	max. amp
EMITTER CURRENT, I_E	+5	max. amp
TRANSISTOR DISSIPATION, P_T:		
Average: For mounting-flange temperatures[b] up to 81°C	12.5	max. watts
Derate linearly: 0.66 watt/°C		
Peak: Determined by operating conditions — See *Fig.4*		
TEMPERATURE RANGE:		
Storage	-65°C to +100°C	
Operating (Junction)	-65°C to +100°C	
PIN TEMPERATURE (During soldering):		
At distances of not less than 1/16" from seating surface for 10 seconds max.	255	max. °C

[a] This rating may be exceeded provided the combined dissipation in the emitter and the collector does not exceed the maximum dissipation rating for the device, and provided the driver stage (transformer coupled) is capable of providing the emitter-to-base current drawn by the transistors under the emitter-to-base voltage conditions (reverse-bias) shown.

[b] Measured at center of seating surface.

RCA-40421

ELECTRICAL CHARACTERISTICS, at a Mounting-Flange Temperature (T_{MF}) of 25°C*

Characteristics	Symbols	TEST CONDITIONS: DC Base-to-Emitter Voltage V_{BE} (V)	DC Collector-to-Base Voltage V_{CB} (V)	DC Collector-to-Emitter Voltage V_{CE} (V)	DC Base Current I_B (mA)	DC Emitter Current I_E (mA)	DC Collector Current I_C (mA)	LIMITS: RCA 40421 Min.	Typ.	Max.	Units
Collector-Cutoff Current	I_{CBO}		-40			0		-	-	-1	mA
Collector-Cutoff Saturation Current	$I_{CBO}(sat)$		-0.5			0		-	-	-70	µA
Emitter-Cutoff Current	I_{EBO}	1.5					0	-	-	-2.5	mA
Collector-to-Base Breakdown Voltage**	BV_{CBO}					0	-10	-75	-	-	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$				0		-100	-50	-	-	V
Base-to-Emitter Voltage	V_{BE}			-10			-50	0.21	0.24	0.28	V
				-2			-1	-	-	0.5	V
Static Forward Current-Transfer Ratio	h_{FE}			-2			-1000	62	100	175	-
				-2			-4000	40	-	-	-
Gain-Bandwidth Product	f_T			-5			-500	2	4	-	MHz
Thermal Resistance: Junction-to-Mounting Flange*	$\theta_{J\text{-}MF}$							-	-	1.5	°C/W

* Measured at center of seating surface.

** Pulse Test: Pulse duration ≥ 300 µs; duty factor = 0.01.

RCA-40428
TEMPERATURE- AND VOLTAGE-COMPENSATION SERVICE

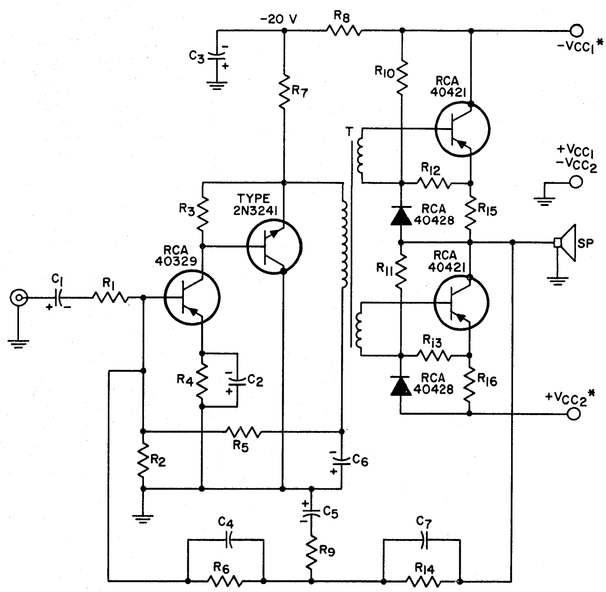
REVERSE VOLTAGE, V_R[c]	-0.5 max.	V
DC FORWARD CURRENT, I_F	100 max.	mA
PEAK FORWARD CURRENT, $i_F(max)$. . .	200 max.	mA
AMBIENT TEMPERATURE RANGE:		
Storage and operating.	-65 to +85	°C
LEAD TEMPERATURE (During soldering):		
At distances not closer than 1/32" to seating surface for 10 seconds max. .	255 max.	°C

ELECTRICAL CHARACTERISTICS, at a DC Forward Current (I_F) of 80 mA, and under conditions of thermal equilibrium

	Min.	Typ.	Max.	Units
Forward Voltage Drop V_F:				
At Case Temperature (T_C)* = 25°C. . .	235	260	285	mV
At Ambient Temperature (T_A) = 25°C .	225	250	275	mV

[c] RCA-40428 is not intended for operation with reverse voltages.

*Measured on case perimeter at junction with seating surface.



92CS-13935

C_1 = 5 μF, 3 V, electrolytic
C_2 = 200 μF, 3 V, electrolytic
C_3 = 2500 μF, 35 V, electrolytic
C_4,C_7 = 39 pF, mica
C_5 = 10 μF, 3 V, electrolytic
C_6 = 250 μF, 15 V, electrolytic
R_1 = 1500 Ω, 0.5 W
R_2 = 22 KΩ, 0.5 W
R_3 = 270 Ω, 0.5 W
R_4,R_9 = 1 KΩ, 0.5 W
R_5 = 56 KΩ, 0.5 W
R_6 = 22 KΩ, 0.5 W
R_7 = 330 Ω, 1 W
R_8 = Selected to provide 20 V across C_3 under zero-signal conditions
R_{10},R_{11} = 270 Ω, 2 W
R_{12},R_{13} = 22 Ω, 5 W
R_{14},= 33 KΩ, 0.5 W
R_{15},R_{16} = 0.47 Ω, 0.5 W
T = Driver Transformer:
Turns ratio, primary to each secondary: 3:1
Primary impedance: 400 Ω
Primary dc: 0 mA

* V_{CC_1}, V_{CC_2}: Zero-signal value = 22 V (I = 150 mA)
Maximum-signal value = 20 V (I = 1 A)

Performance Specifications for 4 Ω Speaker Load:

Continuous (Sine-Wave) Power Output = 25 W
EIA Music Power Output# = 40 W
Total Harmonic Distortion at 25 W output, F = 1 kHz = 0.5%
Sensitivity = 50 mV rms input for 25 W output at 1 kHz
Frequency Response = 1 - 1 dB down at 20 Hz and 20 kHz
2 - 3 dB down at 15 Hz and 35 kHz
Input Resistance = 1500 Ω
Hum and Noise - 80 dB below 25 W, input open or shorted

EIA Standard No.RS 234, Section 2.1.2.1

Fig.1 - Schematic Diagram of 25-Watt High-Quality Power Amplifier Using RCA-40421, 40329, and 2N3241 Transistors, and RCA-40428 Compensating Diodes.

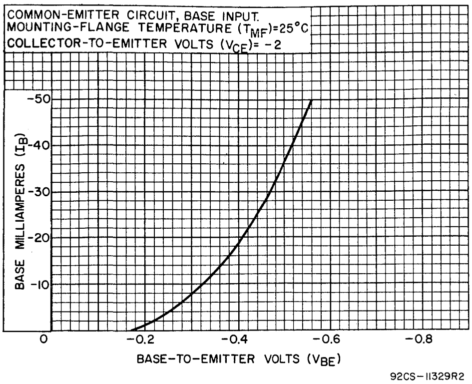


Fig.2 - Typical Input Characteristic for RCA-40421.

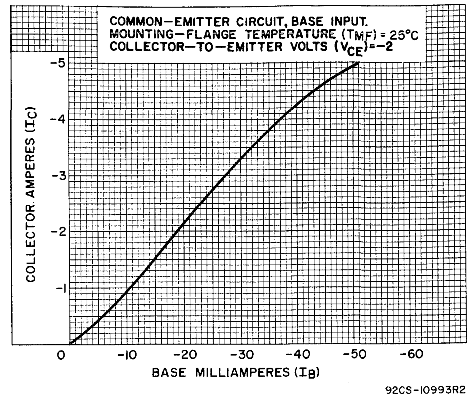


Fig.3 - Typical Current-Transfer Characteristic for RCA-40421.

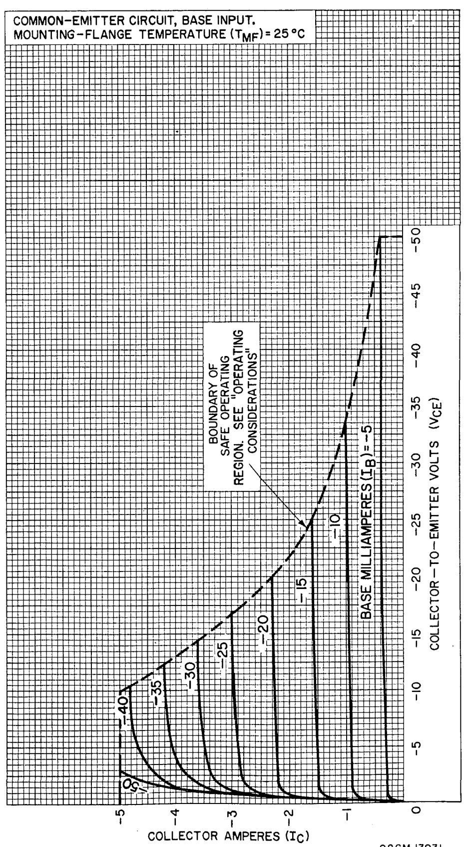


Fig.4 - Typical Collector Characteristics for RCA-40421.

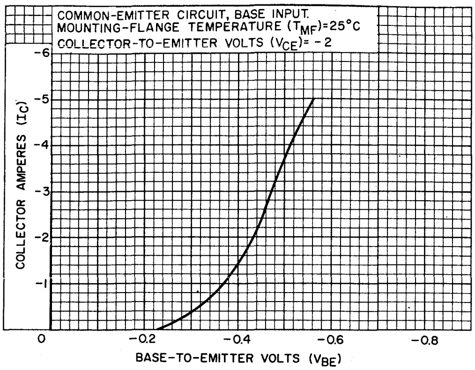


Fig.5 - Typical Transfer Characteristic for RCA-40421.

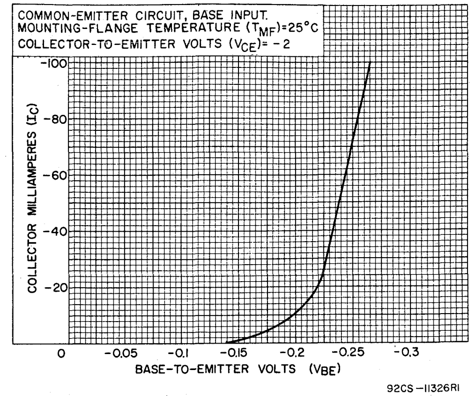


Fig.6 - Typical Transfer Characteristic for RCA-40421.

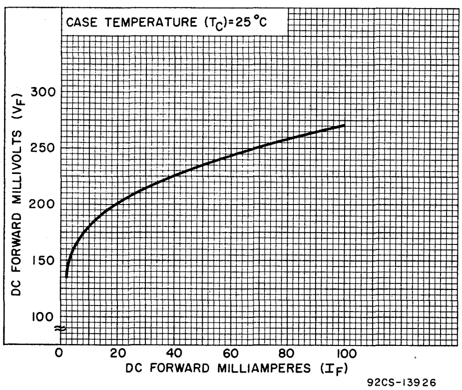


Fig.7 - Typical Forward Characteristic for RCA-40428.

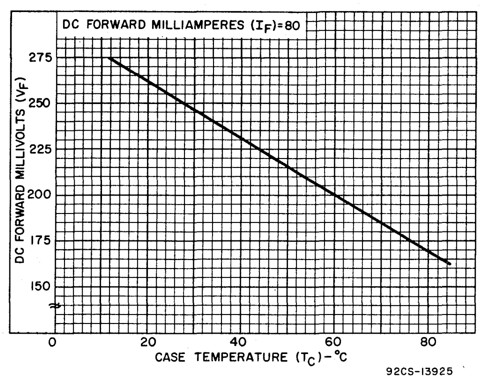


Fig.8 - Forward Voltage vs Temperature for RCA-40428.

OPERATING CONSIDERATIONS

The *maximum ratings* in the tabulated data are established in accordance with the following definition of the *Absolute-Maximum Rating System* for rating electron devices.

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, environment 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.

In the design of amplifier circuits using RCA-40421 it is extremely important to assure that the operating characteristic does not, under any foreseeable combination of operating conditions, extend outside the safe operating region shown in Fig.4. EVEN MOMENTARY EXCURSION OF THE TRANSISTOR OPERATING CHARACTERISTIC OUTSIDE THIS REGION, OR MOMENTARY OPERATION OF THE TRANSISTOR ABOVE ANY OF ITS MAXIMUM RATINGS CAN RESULT IN PERMANENT DAMAGE TO THE TRANSISTOR.

To assure that the 40421 is operated at all times within the safe region shown in Fig.4 the circuit designer should take into account the possible effects of the following factors:

(1) phase shift due to circuit capacitances and/or speaker resonance
(2) parasitic oscillations, such as "ringing" caused by excessive or improperly neutralized feedback
(3) high line voltage
(4) variations in speaker impedance
(5) overdriving of transistors
(6) non-sinusoidal signal waveforms

Any of these factors, or combination, can change the character and value of the transistor load sufficiently to cause operation outside the safe operating region shown in Fig.4.

Because the metal shell of RCA-40421 operates at the collector voltage, consideration should be given to the possibility of shock hazard if the shell is to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

The 40421 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistor.

RCA-40421 can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistor.

It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. UNDER NO CIRCUMSTANCES, HOWEVER, SHOULD THE MOUNTING FLANGE BE SOLDERED TO THE HEAT SINK OR CHASSIS BECAUSE THE HEAT OF THE SOLDERING OPERATION WILL PERMANENTLY DAMAGE THE TRANSISTOR.

The mounting-flange temperature of RCA-40421 will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.

Depending on the application, the heat sink or chassis may be connected to either the positive or negative terminal of the voltage supply.

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be necessary to use either an anodized aluminum insulator having high thermal conductivity, or a 0.002" thick mica insulator between the mounting flange and the chassis. If an aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the emitter and base pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that an insulating washer be used between each bolt and the chassis as shown in Fig. 9.

The forward current through RCA-40428 should be chosen so that at the reference ambient temperature the zero-signal collector current of the associated transistor or transistors has the desired value. The 40428 will then maintain the zero-signal collector current essentially constant with variations in temperature or supply voltage.

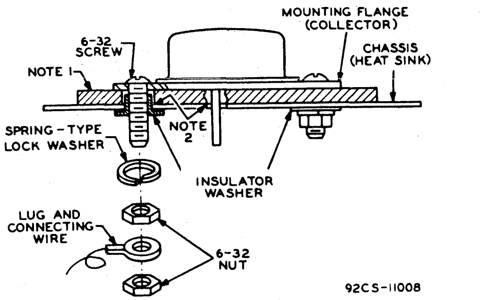
To provide most effective stabilization of transistor idling current, RCA-40428 should be attached to the same heat sink as that used for the associated output transistor or transistors. This arrangement will provide the best possible thermal tracking. The 40428 may be attached to the heat sink by means of a simple clip such as RCA-SA2100, see Fig.10.

To prevent premature clipping in an amplifier stage using RCA-40428, the circuit must be designed to assure that the 40428 is operated under forward-bias conditions at all times. This requirement may be met either by (a) making the dc forward current through the 40428 greater than the peak base current of the associated output transistor (or one of the associated output transistors), or (b) providing a separate source of driving current for the transistor. Such a source is provided in the circuit shown in Fig.1 by resistors R_{12} and R_{13}. These resistors provide driving current to the output transistors during intervals when the peak current through R_{10} or R_{11} is below the required value.

The *flexible leads* of RCA-40428 are usually soldered to the circuit elements. Soldering of the leads may be done to within 1/32 inch of the glass stem provided care is taken to conduct excessive heat away from the lead seals. Otherwise, the heat of the soldering operation may crack the glass seals of the leads and damage the diode.

The 40428 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the diode or the associated circuits.

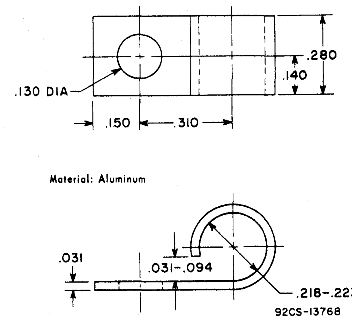
When dip soldering is employed in the assembly of printed circuits using the 40428 the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds.



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Fig. 9 - Suggested Mounting Arrangement for RCA-40421.



Dimensions in Inches

Fig.10 - Detail Drawing of RCA-SA2100 Heat-Sink Attachment Clip.

Mounting hardware for RCA-40421 is available from RCA Distributors under the following RCA Part Numbers:

ITEM	RCA PART NO.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

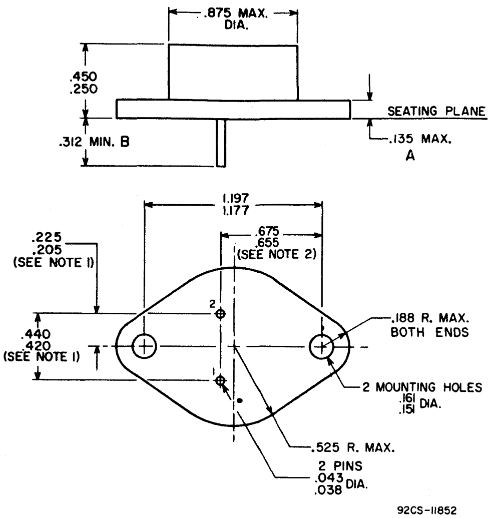
Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for RCA-40421 and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

DIMENSIONAL OUTLINE (JEDEC TO-3)

RCA-40421



DIMENSIONS IN INCHES

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

NOTE 2: TWO LEADS.

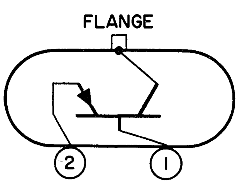
RCA-40421

Mounting-Flange Thickness (A) = 0.050" max.

(B) = 0.440" min. / 0.480" max.

TERMINAL CONNECTIONS

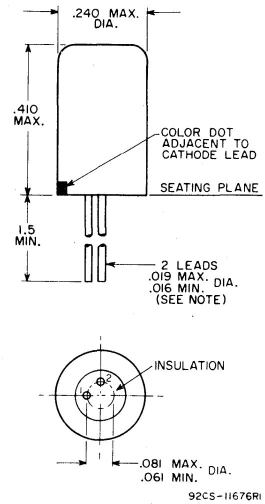
RCA-40421



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

DIMENSIONAL OUTLINE

RCA-40428



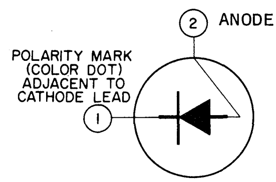
DIMENSIONS IN INCHES

NOTE 1: THE SPECIFIED LEAD DIAMETER APPLIES IN THE ZONE BETWEEN 0.050" AND 0.250" FROM THE BASE SEAT. BETWEEN 0.250" AND 1.50" A MAXIMUM OF 0.21" DIAMETER IS HELD.

NOTE 2: FORWARD (EASY) CURRENT FLOW THROUGH THE DEVICE IS IN THE DIRECTION TOWARD THE LEAD ADJACENT TO THE POLARITY MARK.

TERMINAL DIAGRAM

RCA-40428

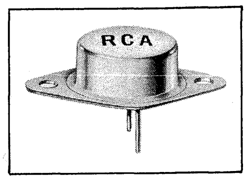


RCA Solid State Division

Power Transistors

40462

GERMANIUM P-N-P POWER TRANSISTOR



JEDEC TO-3

RCA-40462* is an alloy-junction power transistor of the germanium pnp type, intended primarily for use in high-fidelity amplifiers and other large-signal af-amplifier applications. The 40462 features high collector-current and dissipation capabilities, and exceptional linearity of characteristics over its full range of collector current. It is similar to RCA-2N2869/2N301, but has the advantages of a higher gain-bandwidth product (600 kHz typ.), and the ability to idle at lower currents with low cross-over distortion.

When used with RCA-2N2613 low-noise transistors in low-level stages and RCA-2N2614 transistors in intermediate-level and driver stages, the 40462 makes possible the design of economical high-fidelity amplifier systems having high power output, low distortion, and wide frequency response.

The 40462 is particularly desirable for use in class B amplifier service in push-pull circuit arrangements. In a "single-ended push-pull" amplifier circuit of the type shown in Fig. 2, using direct coupling to a 4-Ω speaker load, a pair of RCA-40462 transistors can deliver up to 15 W output with sine-wave signal input, or 25 W music-power output[a], with less than 5 per cent total harmonic distortion and a power gain of 25 dB.

The 40462 is hermetically sealed in a JEDEC TO-3 package.

* Formerly Dev. No. TA2672.
a EIA Standard No. RS234, Section 2.1.2.1.
b Measured at center of seating surface.

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	-40 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	-40 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	-5 max.	V
COLLECTOR CURRENT, I_C	-5 max.	A
BASE CURRENT, I_B	-1 max.	A
TRANSISTOR DISSIPATION, P_T:		
At Mounting-Flange Temperatures[b] up to 81° C	12.5 max.	W
At Mounting-Flange Temperatures[b] above 81° C	See Fig. 1	
TEMPERATURE RANGE:		
Storage and operating (Junction)	-65 to +100	°C
PIN TEMPERATURE (During soldering):		
At distances ≥ 1/32 inch from seating surface for 10 seconds max.	255 max.	°C

For AF Power-Amplifier and other Large-Signal Applications in Commercial, Industrial, and Military Equipment

FEATURES

- high collector-current capability— I_C = -5 A max.
- high gain-bandwidth product— f_T = 600 kHz typ.
- high dissipation capability— P_T = 12.5 W max. at mounting flange temperatures to 81° C
- exceptionally low idling current with low crossover distortion
- beta substantially constant over entire range of collector current
- hermetically sealed JEDEC TO-3 package

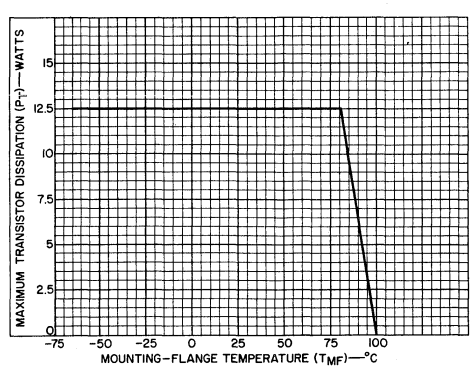


Fig. 1 - Rating chart

ELECTRICAL CHARACTERISTICS, *at a Mounting Flange Temperature, T_{MF}●, of 25°C*

Characteristics	Symbols	DC Collector-to-Base Voltage V_{CB} (V)	DC Collector-to-Emitter Voltage V_{CE} (V)	DC Collector Current I_C (A)	DC Emitter Current I_E (mA)	External Base-to-Emitter Resistance R_{BE} (Ω)	TYPE 40462 Min.	Typ.	Max.	Units
Collector-to-Base Breakdown Voltage	BV_{CBO}			-0.005	0		-40	-	-	V
Collector-to-Emitter Breakdown Voltage	BV_{CER}			-0.6		68	-40	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}			0	-2		-5	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			5		I_B = -0.5A	-	-	1	V
Collector-Cutoff Current	I_{CBO}	-30			0		-	-	-0.5	mA
Saturation Collector-Cutoff Current	$I_{CBO}(sat)$	-0.5			0		-	-	-0.1	mA
Static Forward-Current Transfer Ratio	h_{FE}		-2	-1			50	90	-	—
Base-to-Emitter Voltage	V_{BE}		-10	-0.05			-	-0.19	-	V
Thermal-Resistance (Junction-to-case)	θ_{JC}						-	-	1.5	°C/W
Gain-Bandwidth Product	f_T		5	-0.5			-	600	-	kHz

● Measured at center of seating surface.

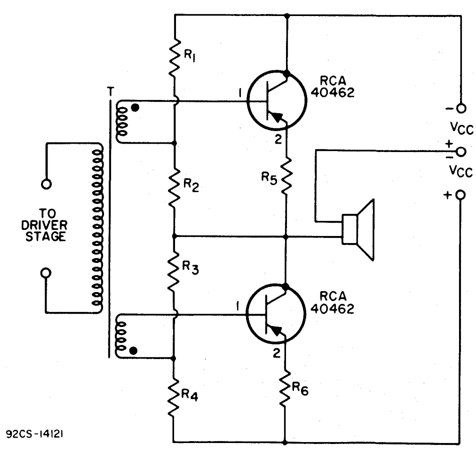
Typical Operation of RCA-40462 in the "Single-Ended Push-Pull" Class B AF-Amplifier Circuit Shown in Fig.2:

For a Mounting-Flange Temperature of 25°C

DC Collector Supply Voltages (V_{CC})[a]	18	V
Zero-Signal DC Collector Current	-12	mA
Zero-Signal Base-Bias Voltage	-0.15	V
Peak Collector Current	-2.8	A
Maximum-Signal DC Collector Current	-1	A
Input Impedance of Stage (per base)	32	Ω
Load Impedance (Speaker Voice Coil)	4	Ω
Power Gain	25	dB
Maximum-Signal Power Output	15	W
Total Harmonic Distortion at Maximum-Signal Power Output	5	%
Maximum Collector Dissipation (per transistor) under worst-case conditions	7.5	W
EIA Music Power Output Rating[b]	25	W

[a] The data shown are for a dc collector supply having 10 per cent regulation.

[b] EIA Standard No.RS234, Section 2.1.2.1.



R_1, R_3	470 Ω ± 10%, 1 W
R_2, R_4	3.9 Ω ± 10%, 0.5 W
R_5, R_6	0.33 Ω ± 10%, 0.5 W
Speaker: Voice Coil Impedance	4 Ω

T: Driver Transformer. Primary-winding impedance, current-carrying capacity, and dc resistance determined by large-signal characteristics of driver stage; secondary windings bifilar wound, impedance of each winding = 100 Ω.

Fig.2 - Single-ended push-pull class B AF amplifier circuit.

TYPICAL CHARACTERISTICS

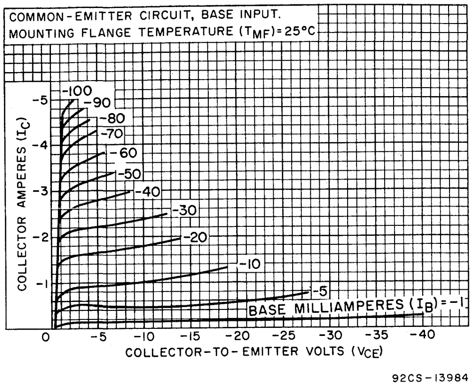


Fig.3 - Collector characteristics

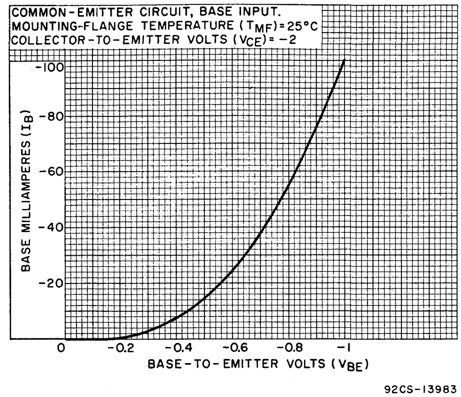


Fig.4 - Input characteristic

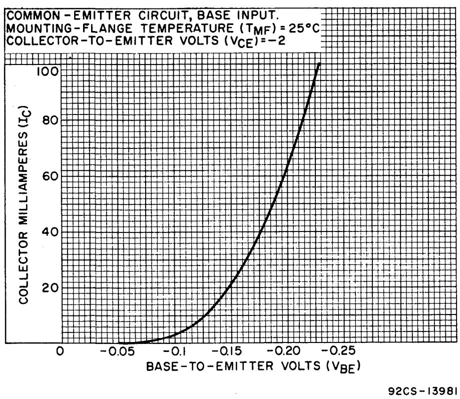


Fig.5 - Transfer characteristic

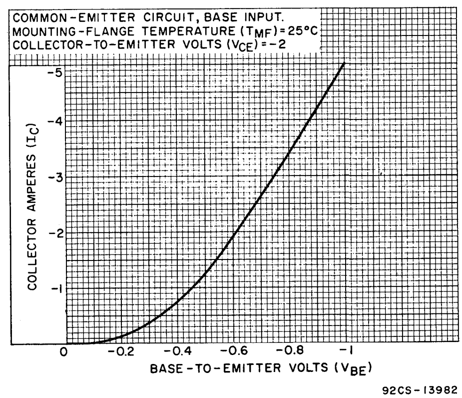


Fig.6 - Transfer characteristic

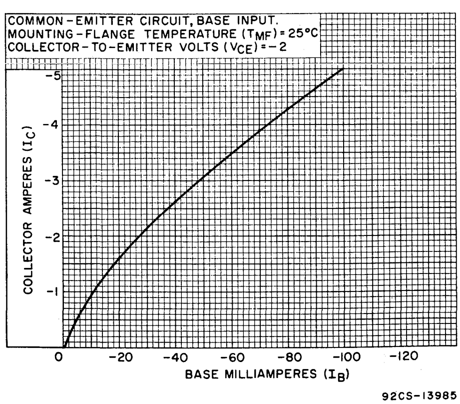


Fig.7 - Current-transfer characteristic

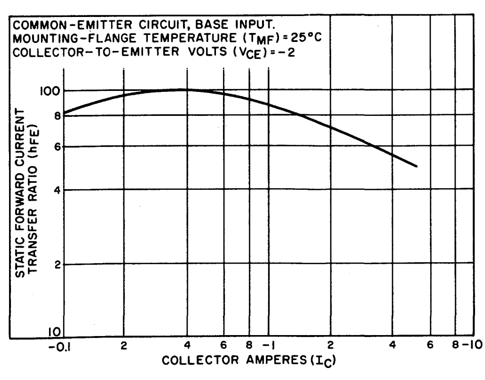


Fig.8 - Static forward current-transfer ratio characteristic

OPERATING CONSIDERATIONS

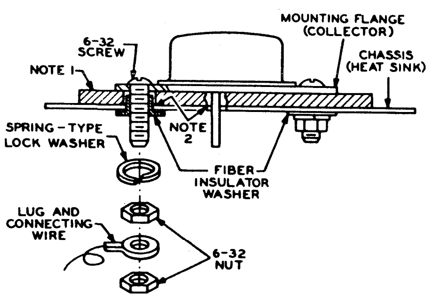
Because the metal shell of this transistor operates at the collector voltage, consideration should be given to the possibility of shock hazard if the shell is to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

The 40462 should not be connected into or disconnected from circuits with the power on because high transient currents may cause permanent damage to the transistor.

This transistor can be installed in commercially available sockets. Electrical connection to the base and emitter pins may also be made by soldering directly to these 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 will crack the pin seals and damage the transistor.

It is essential that the mounting flange which serves as the collector terminal be securely fastened to a heat sink, which may be the equipment chassis. *Under no circumstances, however, should the mounting flange be soldered to the heat sink or chassis because the heat of the soldering operation will permanently damage the transistor.*

The mounting-flange temperature of the 40462 will be higher than the ambient (free-air) 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 transistor-mounting-flange temperature above the design value.



NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).
NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Fig.9 - Suggested mounting arrangement

Mounting hardware for **RCA-40462** is available from RCA Distributors under the following RCA Part Numbers:

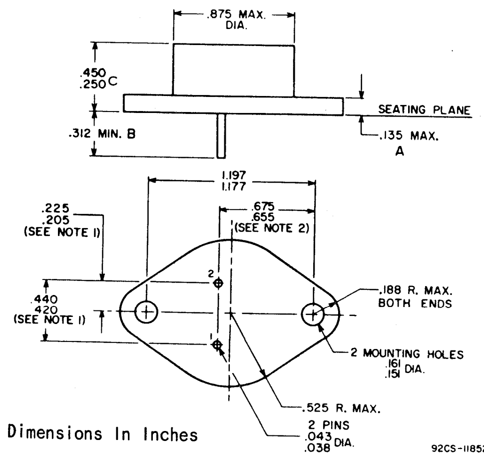
ITEM	RCA PART No.
Mica Insulator	495320
Nylon Insulating Washer (2)	495334-7

Mica insulators are also available from Reliance Mica Co., 341-351 39th St., Brooklyn, N.Y. 10032, United Mineral & Chemical Corp., 16 Hudson St., N.Y., N.Y. 10014, and other suppliers of similar components.

Insulating shoulder washers are also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Sockets for **RCA-40462** and other semiconductor devices utilizing the JEDEC TO-3 package are made by several manufacturers, and are generally available from electronic parts distributors.

DIMENSIONAL OUTLINE



NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270 MM) TO .055" (1.397 MM) BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.
NOTE 2: TWO LEADS.

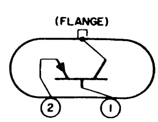
For RCA-40462

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = $\begin{cases} 0.440" \text{ min.} \\ 0.480" \text{ max.} \end{cases}$

Seated Height (C) = 0.325" max.

TERMINAL CONNECTIONS



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

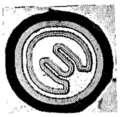
Power-Transistor Chips

RCA Solid State Division

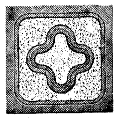
Power Transistors

CH3439 CH3440 CH3053 CH2270 CH2102 CH2405 CH4036 CH4037 CH5320 CH5321 CH5322 CH5323

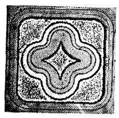
Unmounted and Unencapsulated N-P-N and P-N-P Power Transistor Chips



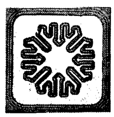
H-1700



H-1699



H-1698



H-1701

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.

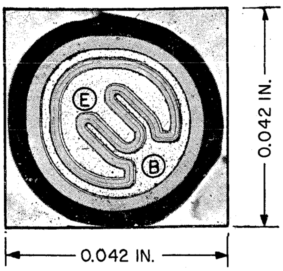
Aluminum has been deposited at the base and emitter electrodes of all the transistor chips for ease of bonding. The base and emitter bonding areas on each chip will accommodate up to a 0.003-inch-diameter wire bond. Either thermo-compression or ultrasonic bonding can be used to attach gold wires to these 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

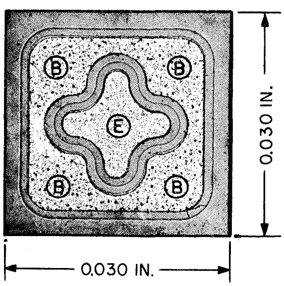
CH3440
CH3439

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

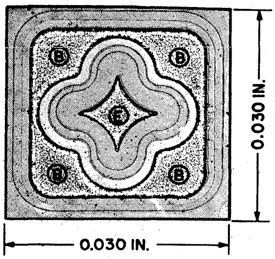
RCA–CH3053, CH2270, CH2102, and CH2405 are triple-diffused n-p-n planar transistor chips similar to RCA–2N3053, 2N2270, 2N2102, and 2N2405 transistors, respectively. They can be used either singly or in complementary-pair configurations with RCA p-n-p chips CH4037 and CH4036 for large-signal, medium-power 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

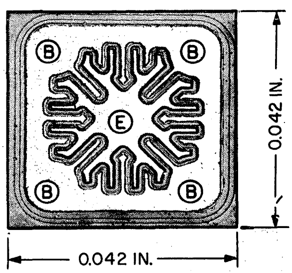
CH4037
CH4036

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

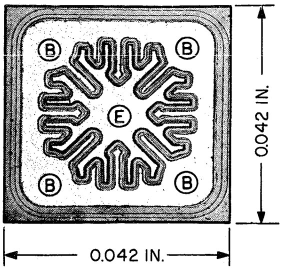
RCA–CH5321 and CH5320 are triple-diffused n-p-n planar transistor chips similar to RCA–2N5321 and 2N5320 transistors. They can be used singly or as complements of RCA p-n-p chips CH5323 and CH5322.

(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.

Ⓑ 4 Base Bonding Areas 0.008 in. diameter Ⓔ 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.

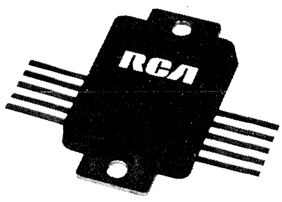
Oxide missing from the junction area.

Power Hybrid Circuits

RCA
Solid State
Division

Power Hybrid Circuits

HC1000



(Approx. 1/3 Actual Size)

H-1637

Multi-Purpose, All-Silicon 7-Ampere Power Amplifier

Linear Amplifier 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 amplifier 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 type HC1000* is a complete solid-state hybrid amplifier in a compact molded-epoxy plastic package.

The HC1000 employs a quasi-complementary-symmetry class B output circuit with built-in load-fault protection and hometaxial output transistors. This circuit may be operated from a single or split power supply.

Type HC1000 is recommended for the following applications: servo amplifiers (AC, DC, PWM); deflection amplifiers; power operational amplifiers; audio amplifiers; voltage regulators, and driven inverters.

* Formerly RCA Developmental Type TA7625.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

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

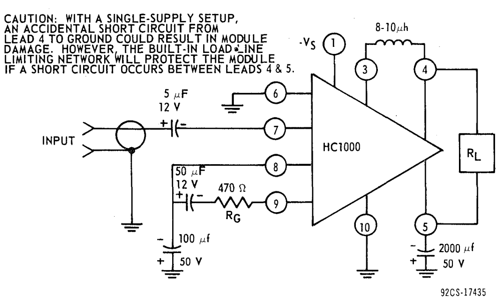


Fig.1 – Type HC1000 power circuit module with external connections for operation with a single power supply.

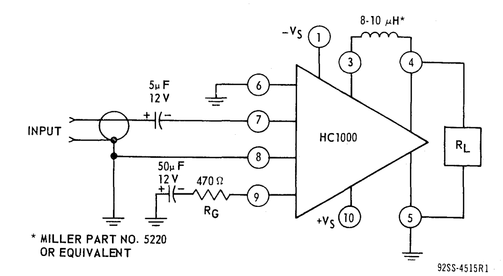
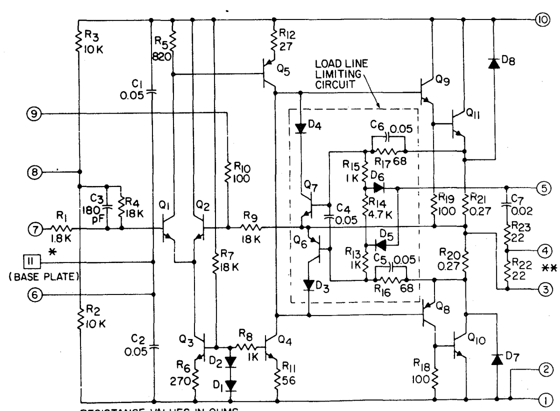


Fig. 2 – Type HC1000 power circuit module with external connections (& split power supply) for measuring relative response & distortion; see Fig.8 & 9.

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: SUPPLY VOLTAGE (V_S)–V	TEST CONDITIONS: FREQ. (f)–kHz	TEST CONDITIONS: OUTPUT POWER (P_O)–W	TEST CONDITIONS: LOAD RESIST. (R_L)–Ω	LIMITS: MIN.	LIMITS: TYP.	LIMITS: MAX.	UNITS
Voltage Gain (See Fig.2)	$\frac{V_{OUT}}{V_{IN}}$	±37.5	1	1	4	28	30	–	–
Input Impedance Measured between leads 7 & 8 (See Fig. 2)	Z_{IN}	–	–	–	0	16	18	–	kΩ
Quiescent Current	I_o	±37.5	–	–	–	15	–	30	mA
Offset Voltage Measured between leads 4 & 5 (See Fig. 2)	V_{offset}	±37.5	–	–	4	0	±75	±250	mV
Bandwidth (See Fig. 2 & 8)	f_H	±37.5	–	1	4	43	–	–	kHz
Total Harmonic Distortion (See Figs. 2 & 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)	$\theta_{J\text{-}C}$	–	–	–	–	–	–	2	°C/W



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 0.5 Ω 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-4514R1

Fig. 3 – Schematic diagram of type HC1000 power circuit module.

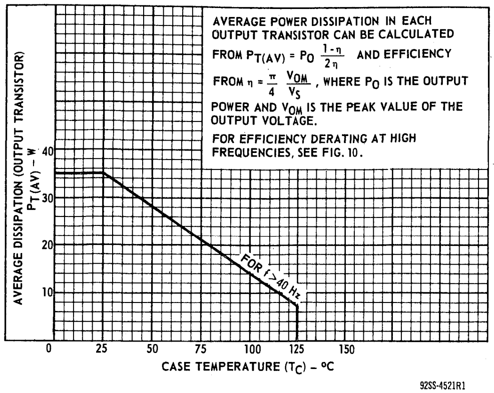


Fig. 4 – Dissipation (average) derating curve for each output transistor in type HC1000 (for symmetrical waveforms with f > 40 Hz).

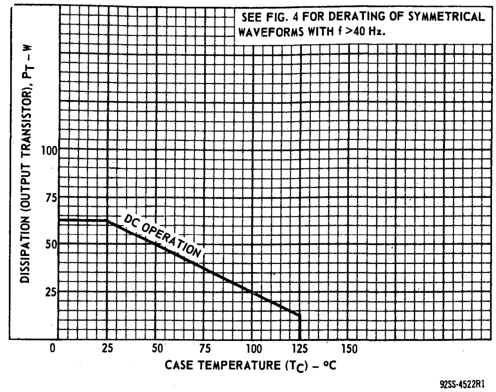


Fig. 5 – Dissipation (DC) derating curve for each output transistor in type HC1000.

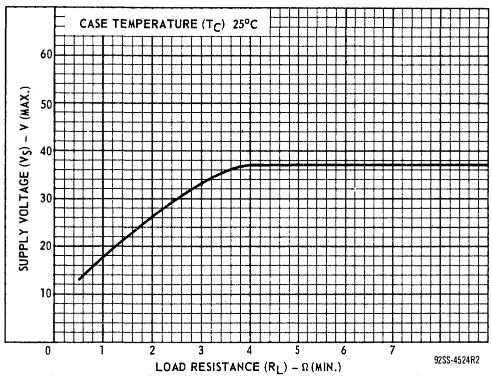


Fig. 6 – Maximum allowable supply voltage vs. load resistance for type HC1000.

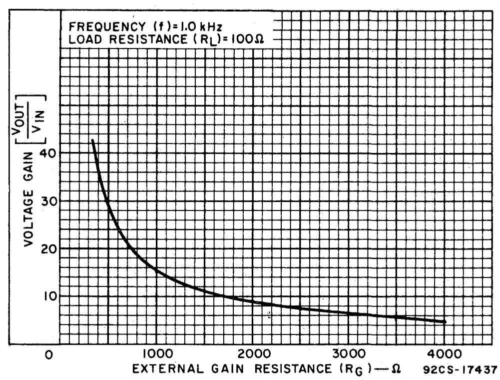


Fig. 7 – Voltage gain vs. external gain resistance for type HC1000.

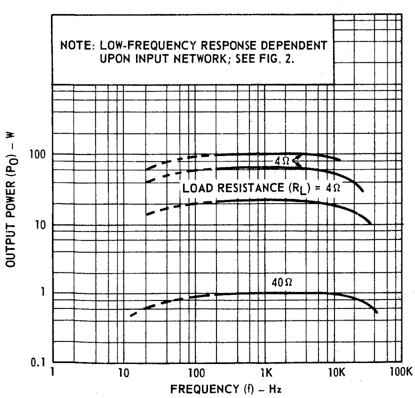


Fig. 8 – Output power vs. frequency for HC1000.

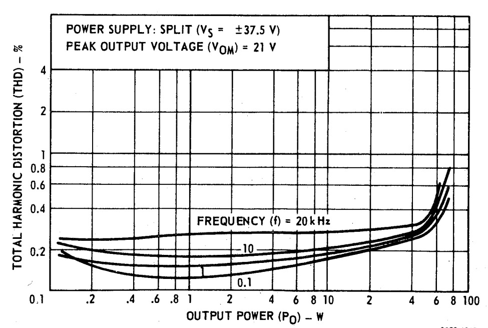


Fig. 9 – Total harmonic distortion for HC1000 with split supply.

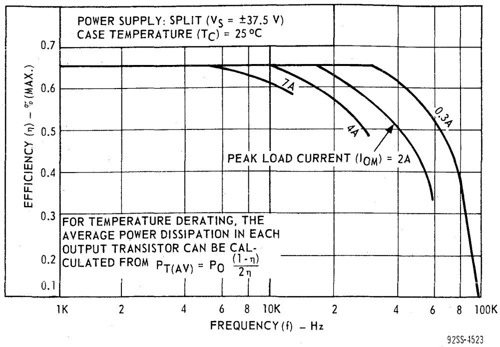


Fig. 10 – Maximum efficiency vs. frequency for type HC1000 for several values of peak load current.

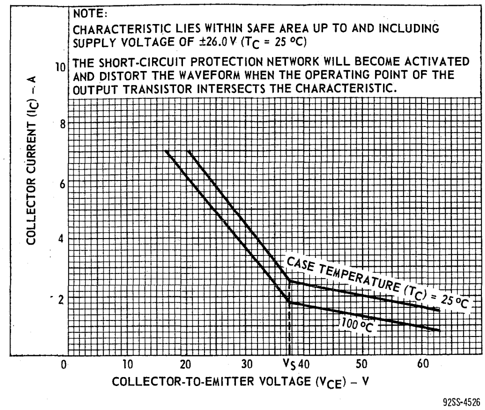


Fig. 11 – Characteristics of built-in load-line limiting circuit for type HC1000.

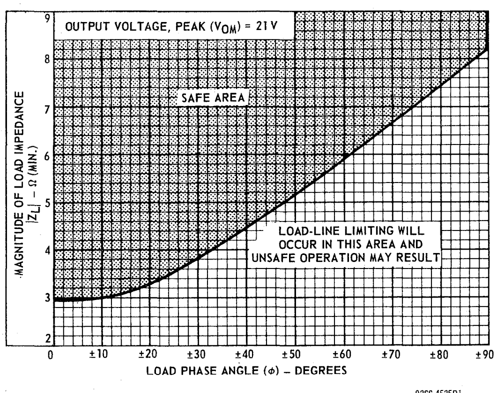


Fig. 12 – Minimum load impedance vs. load phase angle and safe area of operation for type HC1000.

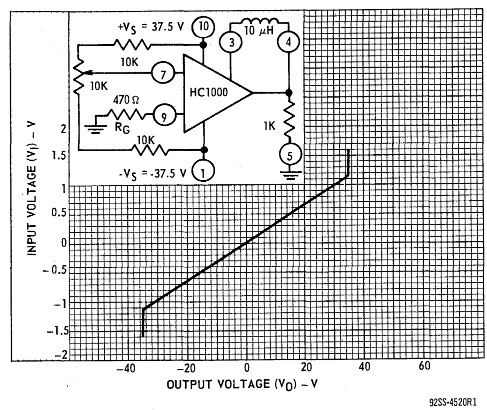


Fig. 13 – Gain linearity characteristic of type HC1000.

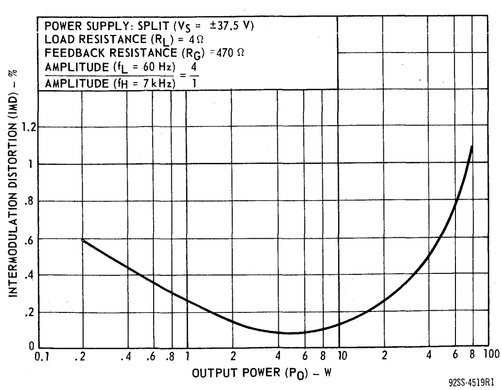
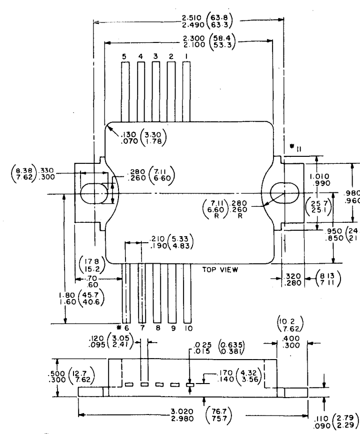


Fig. 14 – Intermodulation distortion for HC1000 with split supply & 4–Ω load.

DIMENSIONAL OUTLINE



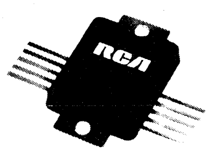
* TERMINALS 6 AND 11 ARE CONNECTED INTERNALLY

Dimensions in inches and millimeters (values in parentheses).

RCA
Solid State
Division

Power Hybrid Circuits

HC2000



(Approx. 1/3 Actual Size)

H-1637

Multi-Purpose, All-Silicon 7-Ampere Operational Amplifier

Linear Amplifier 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 amplifier 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 plastic package.

The device employs a quasi-complementary-symmetry class B output circuit with built-in load-fault protection and hometaxial output transistors. This circuit may be operated from a single or split power supply.

Type HC2000 is recommended for the following applications: servo amplifiers (AC, DC, PWM); deflection amplifiers; power operational amplifiers; audio amplifiers; voltage regulators; and driven inverters.

* Formerly RCA Dev. No. TA7625A.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

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)

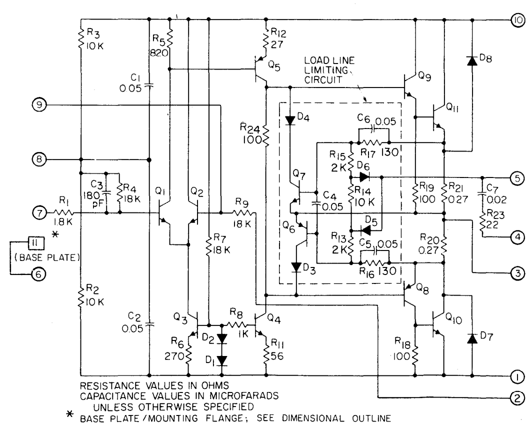


Fig.1—Schematic diagram of type HC2000 power hybrid circuit operational amplifier.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25^{o}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/^{o}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)	$R_{\theta JC}$	–	–	–	–	–	–	2	^{o}C/W

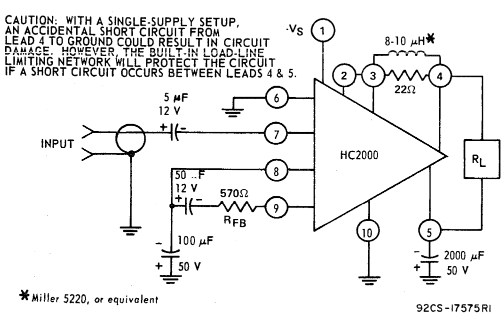


Fig.2–Type HC2000 power hybrid circuit with external connections for operation with a single power supply.

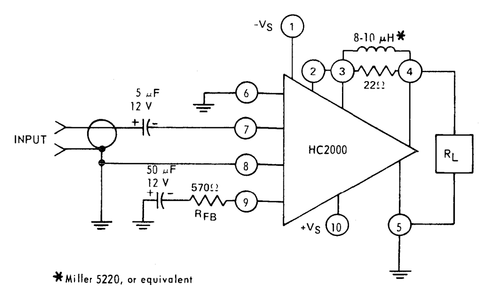


Fig.3–Type HC2000 power hybrid circuit with external connections (and split power supply) for measuring relative response and distortion; see Figs. 8 & 9.

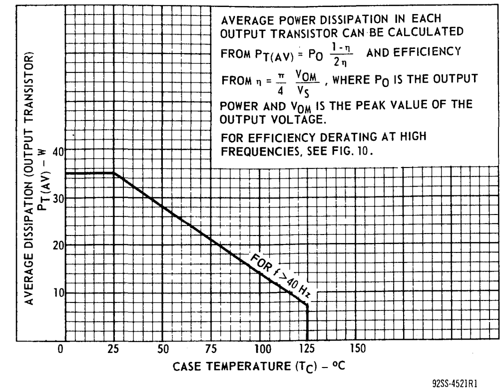


Fig.4—Dissipation (average) derating curve for each output transistor (for symmetrical waveforms with f>40Hz).

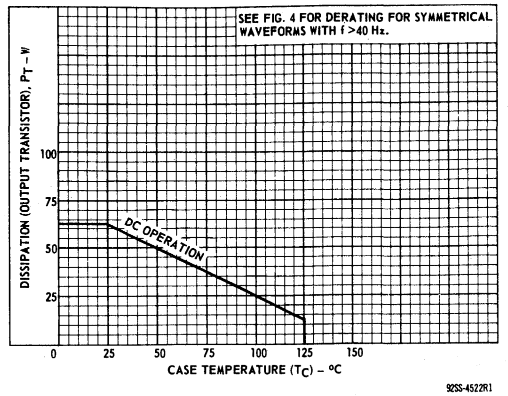


Fig.5—Dissipation (DC) derating curve for each output transistor.

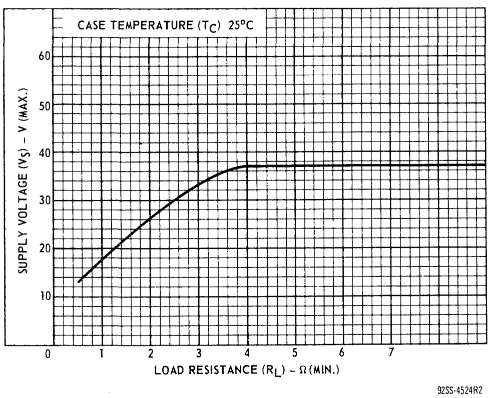


Fig. 6 — Maximum allowable supply voltage vs. load resistance.

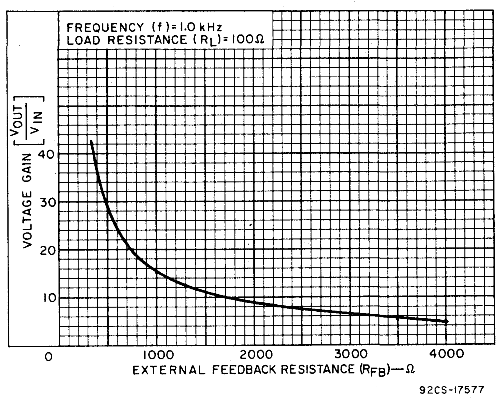


Fig.7—Closed-loop voltage gain vs. external feedback resistance.

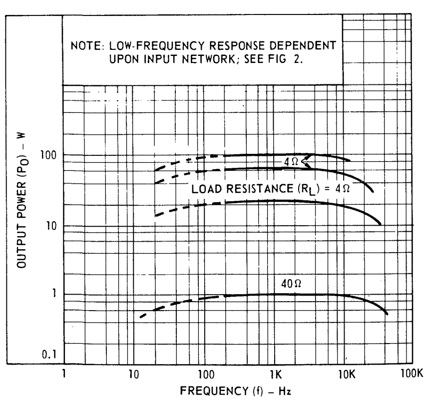


Fig. 8 — Output power vs. frequency.

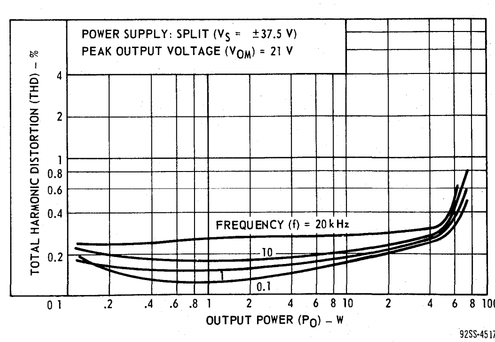


Fig. 9 — Total harmonic distortion with split power supply.

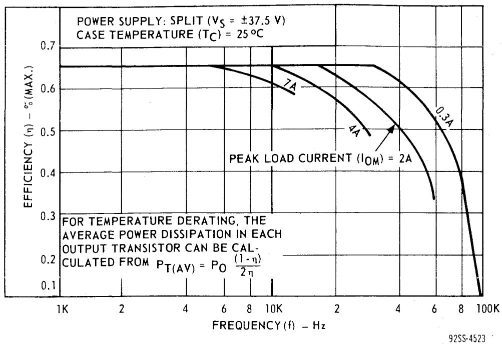


Fig.10—Maximum efficiency vs. frequency for several values of peak load current.

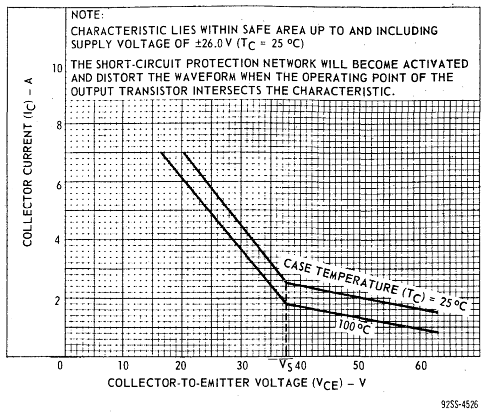


Fig.11—Characteristics of built-in load-line limiting circuit.

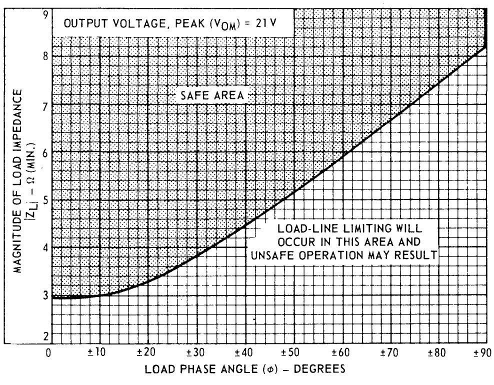


Fig.12—Minimum load impedance vs. load phase angle and safe area of operation.

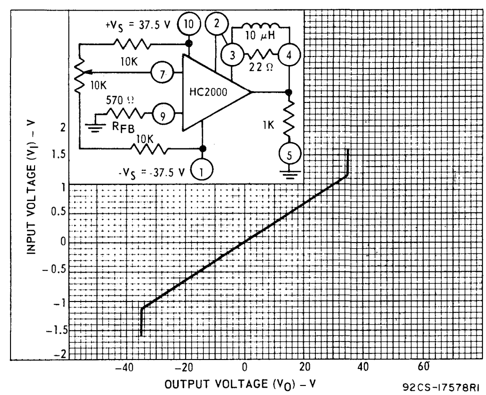
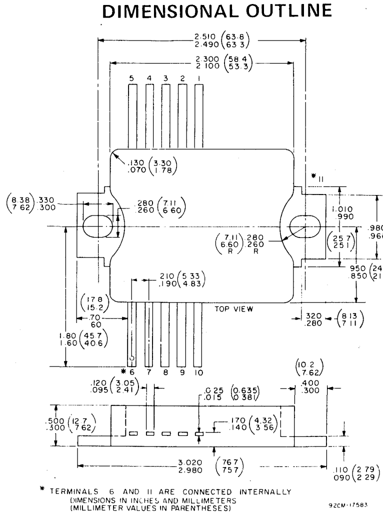


Fig.13—Gain linearity characteristic.

DIMENSIONAL OUTLINE



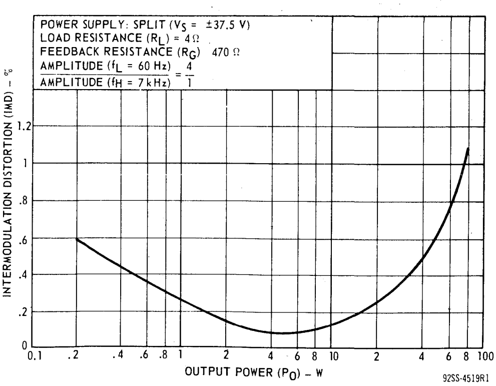


Fig.14—Intermodulation distortion with split supply and 4–Ω load.

RCA
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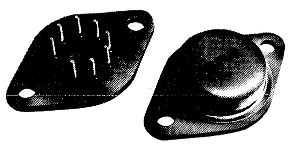
Power Hybrid Circuits

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

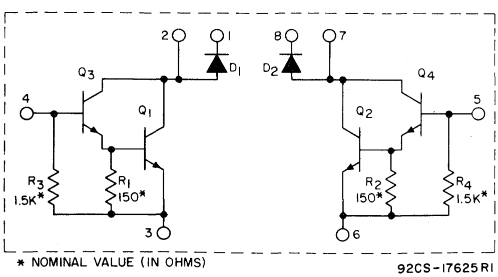


Fig. 1—Schematic diagram of type HC3000 power hybrid circuit.

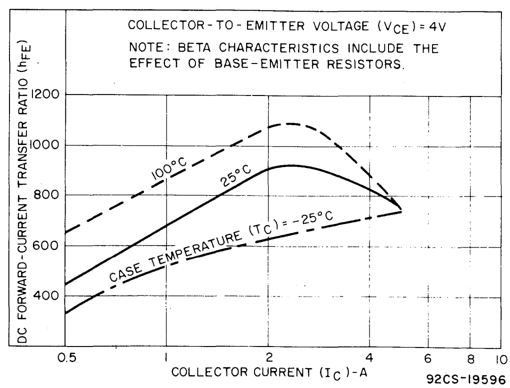


Fig. 2—Typical dc beta vs. collector current for each Darlington circuit.

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%.

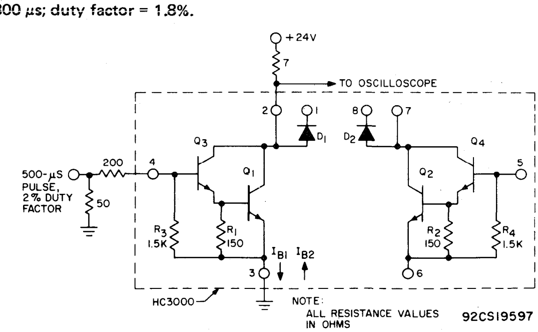


Fig. 3—Test circuit for measurement of switching times.

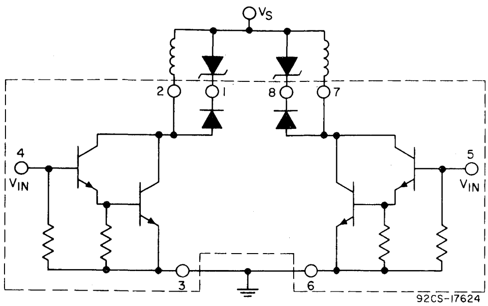


Fig. 4—Type HC3000 in a typical hammer-driver application.

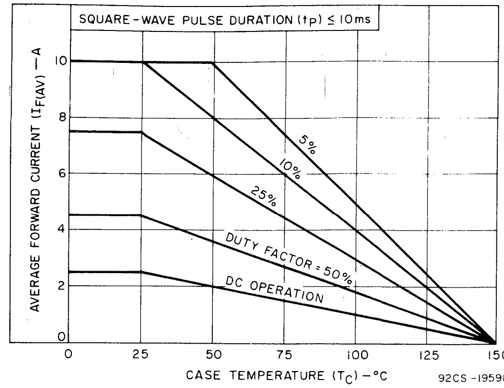


Fig. 5—Current derating curves for each commutating diode.

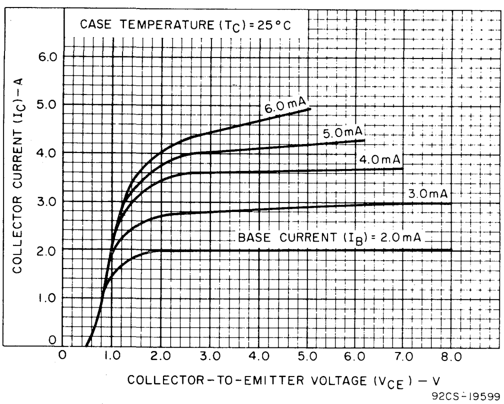


Fig. 6—Typical output characteristics of each Darlington circuit.

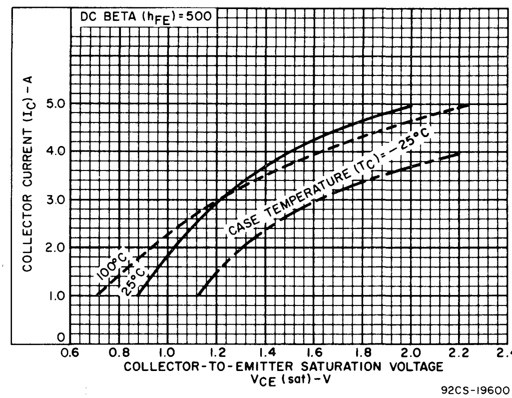


Fig. 7—Typical saturation-voltage characteristics of each Darlington circuit.

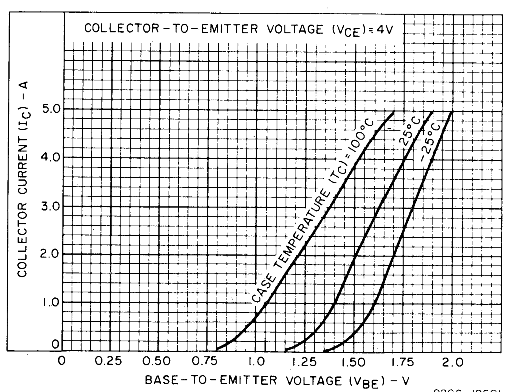
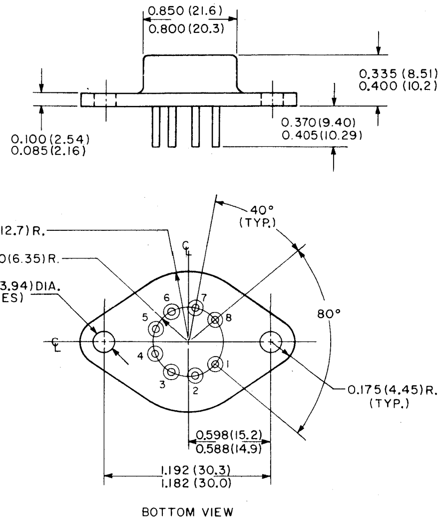


Fig. 8—Typical transfer characteristics of each Darlington circuit.

DIMENSIONAL OUTLINE



DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-17623R1

TERMINAL CONNECTIONS

See Fig. 1.

Socket:
RCA DF-263A

RCA
Solid State
Division

Solid State Devices

Discontinued Types

This bulletin gives basic data for RCA Solid State Devices not recommended for new equipment design. These devices are classified into two categories:

(1) Devices that are no longer being manufactured by RCA and are available only to the extent of limited inventory.

(2) Devices that have recently been discontinued and are not available from RCA.

Transistors

RCA Type No.	Material	Pkg.	$V_{CE}(sat)$• or V_{CEO} max. V	P_T max. W	f_T min. MHz	h_{FE} or h_{fe}■ min.	Term. Diagrams Pg. 4
2N176	Ge	TO-3	−30	10	–	65	C
2N217	Ge	TO-1	−18	0.16	–	50	A
2N270□	Ge	TO-7	−25	0.25	–	70	N
2N351	Ge	TO-3	−30	10	–	65	C
2N370	Ge	TO-7	−15	0.08	30	60	H
2N372	Ge	TO-7	−15	0.08	30	60	H
2N376	Ge	TO-3	−50	10	–	78	C
2N388	Ge	TO-5	15	0.15	5	60	G
2N388A	Ge	TO-5	15	0.15	5	60	G
2N398	Ge	TO-5	–	0.05	50	20	F
2N398A	Ge	TO-5	–	0.15	150	20	F
2N398B	Ge	TO-5	–	0.25	250	20	F
2N404	Ge	TO-5	−0.15•	0.15	4	20	F
2N404A	Ge	TO-5	−0.15•	0.15	4	30	F
2N405	Ge	TO-40	−18	0.15	–	55	K
2N406	Ge	TO-1	−20	0.15	–	40	A
2N407	Ge	TO-40	−18	0.15	–	65	K
2N408	Ge	TO-1	−20	0.15	–	55	A
2N412□	Ge	TO-1	–	0.08	–	75	A
2N414	Ge	TO-5	−14	0.15	8	80■	F
2N585	Ge	TO-5	0.2•	0.12	3	20	F
2N591	Ge	TO-1	−32	0.09	–	40■	A
2N647□	Ge	TO-1	25	0.1	–	50	B
2N649□	Ge	TO-1	18	0.3	–	30	B
2N706	Si	TO-18	0.6•	0.3	200	20	I
2N706A	Si	TO-18	0.6•	0.3	200	20	I
2N709	Si	TO-18	0.3•	0.3	600	20	I
2N718	Si	TO-18	32	1.8	–	40	I
2N720A	Si	TO-18	80	1.8	–	40	I
2N834	Si	TO-18	0.25•	1	350	25	I
2N917□	Si	TO-72	–	0.3	600	30	N
2N1066	Ge	TO-33	–	0.12	–	20■	J

Transistors

RCA Type No.	Material	Pkg.	$V_{CE}(sat)$• or V_{CEO} max. V	P_T max. W	f_T min. MHz	h_{FE} or h_{fe}■ min.	Term. Diagrams Pg. 4
2N1090□	Ge	TO-5	0.2•	0.12	5	30	B
2N1091□	Ge	TO-5	0.2•	0.12	10	40	B
2N1177	Ge	TO-45	–	0.08	–	100■	L
2N1178	Ge	TO-45	–	0.08	–	40■	L
2N1179	Ge	TO-45	–	0.08	–	80■	L
2N1180	Ge	TO-45	–	0.08	–	80■	L
2N1224	Ge	TO-33	–	0.12	–	20■	J
2N1225	Ge	TO-33	–	0.12	–	20■	J
2N1226	Ge	TO-33	–	0.12	–	20■	J
2N1285	–	–	–	–	–	–	–
2N1300	Ge	TO-5	−12	0.15	25	30	F
2N1301	Ge	TO-5	−12	0.15	25	40	F
2N1302	Ge	TO-5	0.2•	0.15	3	20	G
2N1303	Ge	TO-5	−0.2•	0.15	3	20	E
2N1304	Ge	TO-5	0.2•	0.15	5	40	G
2N1305	Ge	TO-5	−0.2•	0.15	5	40	E
2N1306	Ge	TO-5	0.2•	0.15	10	60	G
2N1307	Ge	TO-5	−0.2•	0.15	10	60	E
2N1308	Ge	TO-5	0.2•	0.15	15	80	G
2N1309	Ge	TO-5	−0.2•	0.15	15	80	E
2N1395	Ge	TO-33	–	0.12	–	50■	J
2N1396	Ge	TO-33	–	0.12	–	50■	J
2N1397	Ge	TO-33	–	0.12	–	50■	J
2N1524□	Ge	TO-1	–	0.08	33	54	A
2N1526□	Ge	TO-1	–	0.08	33	49	A
2N1605	Ge	TO-5	0.15•	0.15	4	40	G
2N1605A	Ge	TO-5	0.15•	0.2	4	40	G
2N1631□	Ge	TO-40	–	0.08	–	80■	K
2N1632□	Ge	TO-1	–	0.08	45	48	A
2N1637□	Ge	TO-1	–	0.08	45	48	A
2N1638□	Ge	TO-1	–	0.08	40	61	A
2N1639□	Ge	TO-1	–	0.08	45	37	A

□ Not available from RCA

Transistors

RCA Type No.	Material	Pkg.	V_{CE}(sat)● or V_{CEO} max. V	P_T max. W	f_T min. MHz	h_{FE} or h_{fe}■ min.	Term. Diagrams Pg. 4
2N1683	Ge	TO-5	−12	0.15	50	50	F
2N2369A	Si	TO-18	0.2●	1.2	500	200	I
2N2475	Si	TO-18	0.4●	0.3	600	30	I
2N2476	Si	TO-5	0.75●	2	250	20	I
2N2477	Si	TO-5	0.65●	2	250	4	I
2N2613□	Ge	TO-1	–	0.12	–	120■	A
2N2614□	Ge	TO-1	−40	0.12	–	100■	A
2N2708□	Si	TO-72	20	0.3	700	30	N
2N2953□	Ge	TO-1	−30	0.12	–	200■	A
2N3241A□	Si	TO-104	25	0.5	175	100	O
2N3242A□	Si	TO-104	40	0.5	175	125	O
2N3261	Si	TO-52	0.35●	1	600	40	I
2N3512	Si	TO-5	0.4●	4	250	10	I
2N3932□	Si	TO-104	20	0.2	750	40	N
2N3933□	Si	TO-104	30	0.2	750	60	N
2N4068□	Si	TO-104	3●	0.5	50	30	I
2N4069□	Si	TO-104	3●	1	600	30	I
2N4074□	Si	TO-104	40	0.5	50	50	O
2N4259□	Si	TO-104	30	0.18	750	11.5	N
2N4390□	Si	TO-104	120	0.5	50	20	I
2N5180□	Si	TO-104	15	0.18	650	20	N
2N5183□	Si	TO-104	18	0.5	125	40	I
2N5184□	Si	TO-104	120	0.5	50	10	I
2N5185□	Si	TO-104	120	1	50	10	I
2N5186	Si	TO-52	0.3●	0.3	400	25	I
2N5187	Si	TO-52	0.25●	1	400	30	I
2N5188	Si	TO-39	0.5●	4	250	20	I
40231□	Si	TO-104	18	0.5	60	55■	O
40232□	Si	TO-104	18	0.5	60	90■	O
40233□	Si	TO-104	18	0.5	60	90■	O

□ Not available from RCA

Transistors

RCA Type No.	Material	Pkg.	V_{CE}(sat)● or V_{CEO} max. V	P_T max, W	f_T min. MHz	h_{FE} or h_{fe}■ min.	Term. Diagrams Pg. 4
40234□	Si	TO-104	40	0.5	50	75	O
40235□	Si	TO-104	45	0.18	1000	40	N
40236□	Si	TO-104	45	0.18	1000	40	N
40237□	Si	TO-104	45	0.18	1000	27	N
40238□	Si	TO-104	45	0.18	800	45	N
40239□	Si	TO-104	45	0.18	800	45	N
40240□	Si	TO-104	45	0.18	800	45	N
40242□	Si	TO-104	45	0.18	–	38	N
40243□	Si	TO-104	45	0.18	–	38	N
40244□	Si	TO-104	45	0.18	–	27	N
40245□	Si	TO-104	45	0.18	–	51	N
40246□	Si	TO-104	45	0.18	–	51	N
40295□	Si	TO-72	20	0.3	700	10	M
40329	Ge	TO-1	−0.25●	0.12	–	50	A
40354□	Si	TO-104	150	0.5	50	55	I
40355□	Si	TO-104	150	1	50	55	I
40359□	Ge	TO-1	−20	0.12	–	40■	A
40395□	Ge	TO-1	−20	0.12	60	170■	N
40396	Ge	TO-1	−18	0.3	—	50	B
40397□	Si	TO-104	25	0.5	50	100	I
40398□	Si	TO-104	25	0.5	50	50	I
40399□	Si	TO-104	18	0.5	50	100	I
40400□	Si	TO-104	18	0.5	50	50	I
40405□	Si	TO-52	16	1	300	20	I
40413□	Si	TO-72	20	0.3	700	10	N
40414	Si	TO-72	15	0.3	1000	30	N
40458□	Si	TO-104	40	0.5	150	100	I
40519	Si	TO-52	16	0.3	–	3■	I
40637	Si	TO-52	–	1	300	–	I

Linear Integrated Circuits – (Operational) Amplifiers

RCA Type No.	Pkg.	Typ. Characteristics @ V_{CC} = +12 V, V_{EE} = −6V, T_A = 25°C				
		A_{OL} dB	C_{MR} dB	R_{OUT} Ω	VIO mV	P_T mW
CA3031/702A	8L TO-5	70	85	130	2	85
CA3032/702C	8L TO-5	70	80	200	5	90

Diodes

RCA Type No.	Pkg.	Max. Ratings			Term. Diagrams Pg. 4
		i_{FM} (peak) A	$I_{F(AV)}$ A	V_{RM} V	
IN2326	–	0.2	0.1	−1	P
IN4785	TO-3	10	7	320	D

Digital Integrated Circuits

RCA Type No.	Pkg.	Funct-ion *	Output Voltage V_{OL} max. V	V_{OH} min. V	Propagation Delay Time t_{PHL} min. ns	t_{PLH} min. ns	t_{PHL}, t_{PLH} typ. ns
CD2200	14L FP	1	0.1	3.4	–	–	55
CD2200D	14L DIC	1	0.1	3.4	–	–	55
CD2201	14L FP	3	0.1	3.4	–	–	55
CD2201D	14L DIC	3	0.1	3.4	–	–	55
CD2202	14L FP	1	0.1	3.4	–	–	48
CD2202D	14L DIC	1	0.1	3.4	–	–	48
CD2203	14L FP	7	0.1	3.4	–	–	130
CD2203D	14L DIC	7	0.1	3.4	–	–	130
CD2204	14L FP	8	For input expansion of CD2200, CD2202, and CD2205 gates capable of expanding fan-in to more than 20.				
CD2204D	14L DIC	8					
CD2205	14L FP	9	0.1	3.4	–	–	71
CD2205D	14L DIC	9	0.1	3.4	–	–	71
CD2300/930	14L FP	1	0.4	2.6	10	25	–
CD2300D/930	14 L DIC	1	0.4	2.6	10	25	–
CD2300E/830	14L DIP	1	0.45	2.6	10	25	–
CD2301/961	14L FP	1	0.4	3.8	10	15	–
CD2301D/961	14L DIC	1	0.4	3.8	10	15	–
CD2301E/861	14L DIP	1	0.45	4.3	10	15	–
CD2302/946	14L FP	3	0.4	2.6	10	25	–
CD2302D/946	14L DIC	3	0.4	2.6	10	25	–
CD2302E/846	14L DIP	3	0.45	2.6	10	25	–
CD2303/949	14L FP	3	0.4	2.6	10	15	–
CD2303D/949	14L DIC	3	0.4	2.6	10	15	–
CD2303E/849	14L DIP	3	0.45	2.6	10	15	–
CD2304/945	14L FP	10	0.4	3.1	30	35	–
CD2304D/945	14L DIC	10	0.4	3.1	30	35	–
CD2304E/845	14L DIP	10	0.45	3.1	30	35	–
CD2305/948	14L FP	10	0.4	4	30	30	–
CD2305D/948	14L DIC	10	0.4	4	30	30	–
CD2305E/848	14L DIP	10	0.45	4.3	30	30	–
CD2306/932	14L FP	1	0.4	2.6	15	25	–
CD2306D/932	14L DIC	1	0.4	2.6	15	25	–
CD2306E/832	14L DIP	1	0.45	2.6	15	25	–
CD2307/944	14L FP	1	0.4	6	10	15	–
CD2307D/944	14L DIC	1	0.4	6	10	15	–
CD2307E/844	14L DIP	1	0.45	6	10	15	–

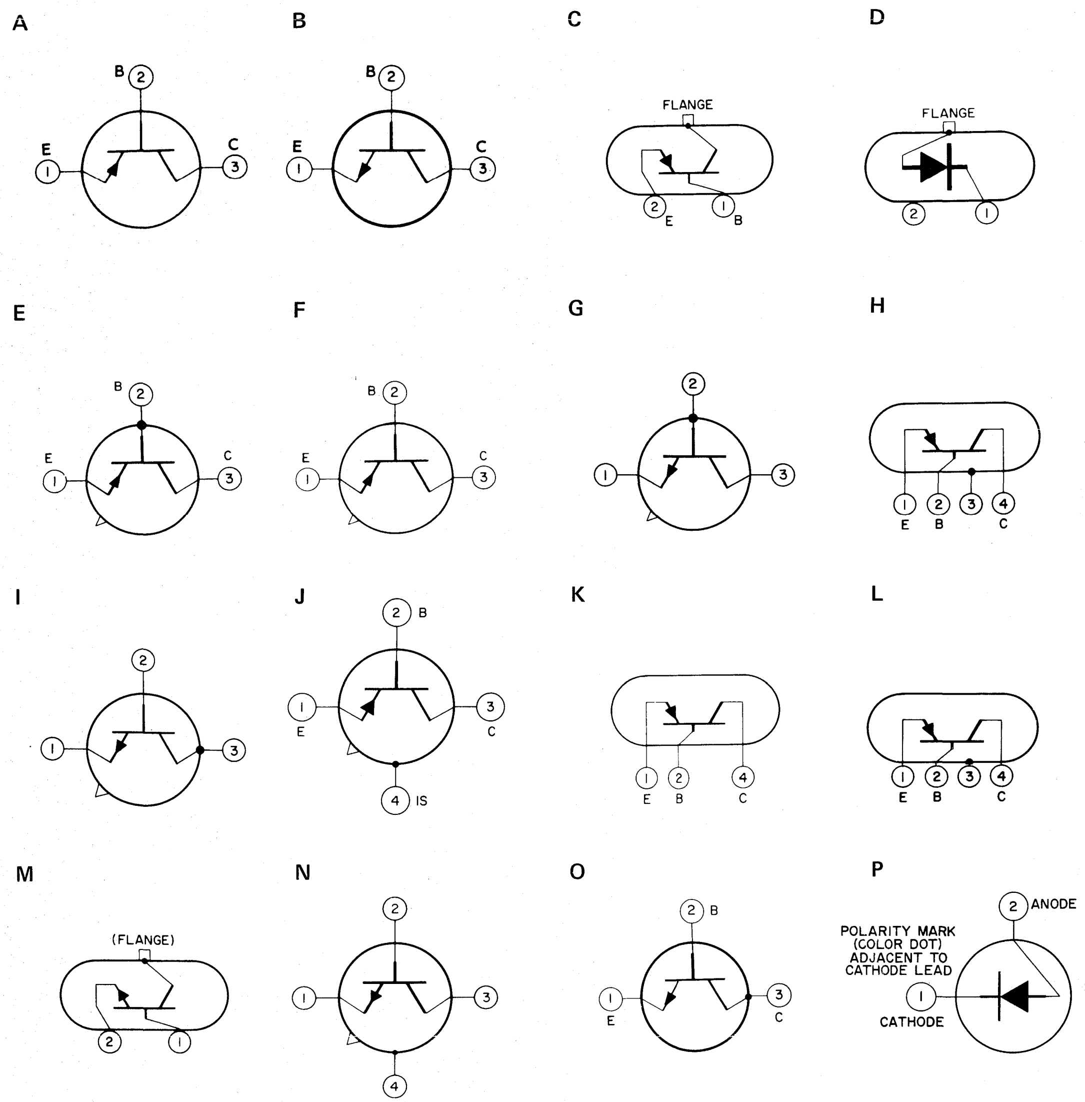
Digital Integrated Circuits

RCA Type No.	Pkg.	Funct-ion *	Output Voltage V_{OL} max. V	V_{OH} min. V	Propagation Delay Time t_{PHL} min. ns	t_{PLH} min. ns
CD2308/962	14L FP	2	0.4	2.6	10	30
CD2308D/962	14L DIC	2	0.4	2.6	10	30
CD2308E/862	14L DIP	2	0.45	2.6	10	30
CD2309/963	14L FP	2	0.4	3.8	10	15
CD2309D/963	14L DIC	2	0.4	3.8	10	15
CD2309E/863	14L DIP	2	0.45	4.3	10	15
CD2310/936	14L FP	4	0.4	2.6	10	25
CD2310D/936	14L DIC	4	0.4	2.6	10	25
CD2310E/836	14L DIP	4	0.45	2.6	10	25
CD2311/937	14L FP	4	0.4	3.8	10	15
CD2311D/937	14L DIC	4	0.4	3.8	10	15
CD2311E/837	14L DIP	4	0.5	4.3	10	15
CD2312	14L FP	4	0.4	2.6	10	25
CD2312D	14L DIC	4	0.4	2.6	10	25
CD2312E	14L DIP	4	0.45	2.6	10	25
CD2313	14L FP	4	0.4	3.8	10	15
CD2313D	14L DIC	4	0.4	3.8	10	15
CD2313E	14L DIP	4	0.5	4.3	10	15
CD2314/933	14L FP	5	Input Fwd Volt/Diode = 0.7V min.			
CD2314D/933	14L DIC	5	= 0.7V min.			
CD2314E/833	14L DIP	5	= 0.68V min.			
CD2315	14L FP	7	0.4	3.1	30	35
CD2315D	14L DIC	7	0.4	3.1	30	35
CD2315E	14L DIP	7	0.45	3.1	30	35
CD2316	14L FP	7	0.4	3.1	30	30
CD2316D	14L DIC	7	0.4	3.1	30	30
CD2316E	14L DIP	7	0.45	3.1	30	30
CD2317	14L FP	7	0.4	3.1	30	35
CD2317D	14L DIC	7	0.4	3.1	30	35
CD2317E	14L DIP	7	0.45	3.1	30	35
CD2318	14L FP	7	0.4	4	30	30
CD2318D	14L DIC	7	0.4	4	30	30
CD2318E	14L DIP	7	0.45	4.3	30	30

* FUNCTION

1. Dual 4-Input NAND Gates
2. Triple 3-Input NAND Gates
3. Quad 2-Input NAND Gates
4. Hex Inverters
5. Dual 4-Diode Input Expanders
6. Clocked R-S Flip Flops
7. Dual Clocked J-K Flip Flops
8. Dual 4-Input Gate Expander
9. Dual 3-Input Expandable AND/OR/NOT Gate
10. Clocked RS Flip Flop with J-K Capability

TRANSISTOR AND DIODE TERMINAL DIAGRAMS



SYMBOL DEFINITIONS

A_{OL}	voltage gain, open loop
CMR	common-made rejection ratio
f_T	gain-bandwidth product
h_{FE}	static forward current transfer ratio
h_{fe}	small-signal forward current transfer ratio
i_{FM}	peak forward current
P_T	transistor dissipation
R_{OUT}	output resistance
t_{PHL}	high-to-low level propagation delay time
t_{PLH}	low-to-high level propagation delay time
V_{CEO}	collector-to-emitter voltage
$V_{CE(sat)}$	collector-to-emitter saturation voltage
V_{IO}	input offset voltage
V_{OH}	high-level output voltage
V_{OL}	low-level output voltage
V_{RM}	peak reverse voltage

Application Notes for Power Transistors and Power Hybrid Circuits

Solid State Division

Power Transistors
Application Note 1CE-402

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.

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

*Trade Mark: Emerson and Cumming, Inc.

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"

RCA Solid State Division

Power Transistors Application Note AN-3065

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

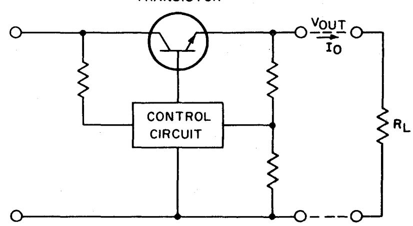


Fig. 1 - Basic form of a transistorized series voltage regulator.

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

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.

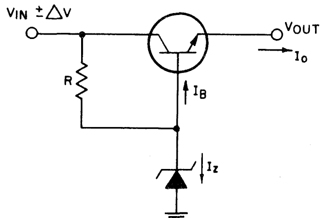


Fig.2 - Simplest circuit arrangement for a transistor voltage regulator.

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.

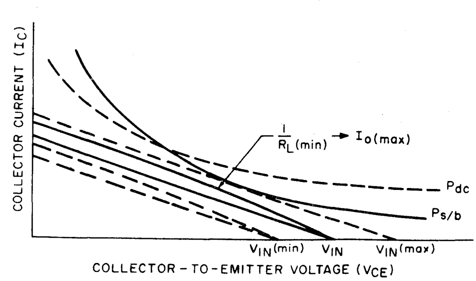


Fig.3 - Transistor load line.

Design Example

The following conditions are specified for a series voltage regulator:

$$V_{out} = 100\ V$$
$$I_o(max) = 400\ mA$$
$$V_{in} = 135 \pm 15\ V$$
$$h_{FE}(min) = 20$$

Circuit values are then determined as follows:

$$R = \frac{(135 - 15 - 100)\ 20}{0.4} = \frac{400}{0.4} = 1\ k\Omega \text{ at } 2.5\ W$$

$$I_B(max) = \frac{0.4}{20} = 20\ mA$$

$$I_Z = \frac{135 + 15 - 100}{1000} = \frac{50}{1000} = 50\ mA$$

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:

$$R = \frac{(135 - 15 - 100)\ 800}{0.4} = 40\ k\Omega \text{ at } 0.062\ W$$

$$I_Z = \frac{135 + 15 - 100}{40000} = \frac{50}{40000} = 1.25\ mA$$

$$P_Z = 125\ mW$$

The maximum power dissipated by the 2N3440 transistor in this circuit is (20 mA)(50 V) = 1 W.

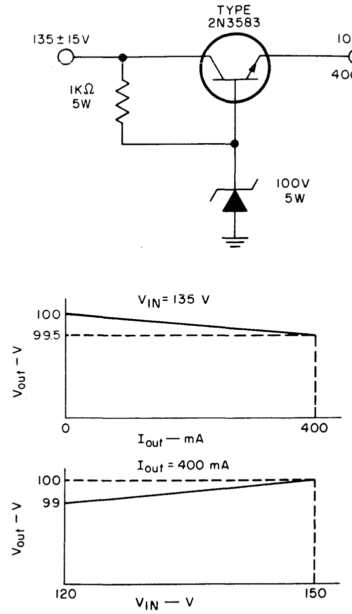


Fig.4 - Schematic diagram of a simple transistor voltage regulator.

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.

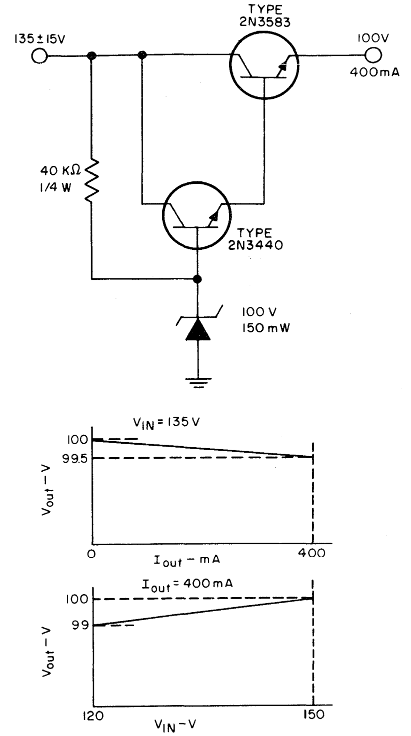


Fig.5 - Schematic diagram of a series voltage regulator using darlington driver.

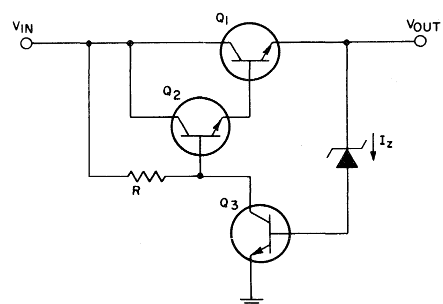


Fig.6 - Schematic diagram of a series voltage regulator employing feedback amplifier.

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.

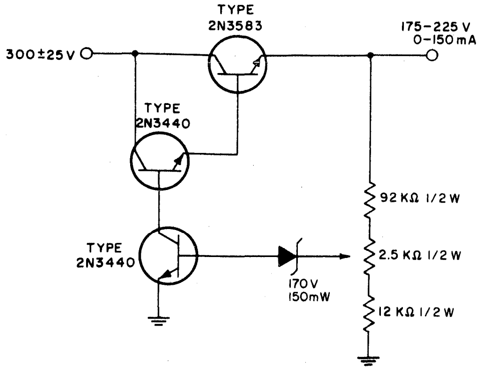


Fig.7 - Schematic diagram of a typical series high-voltage regulator.

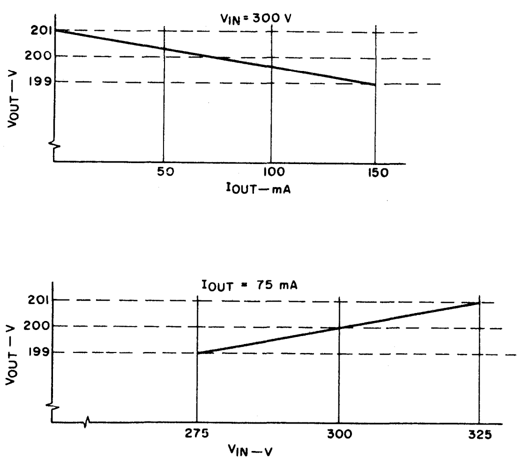


Fig.8 - Regulation characteristics for circuit shown in Fig.7.

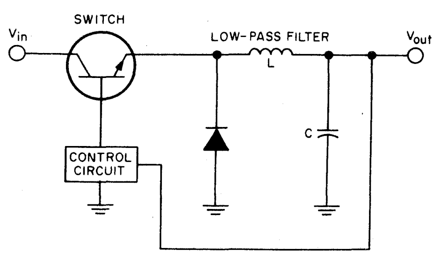


Fig.9 - Simplest form of a transistor switching regulator.

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

$$I_p = \frac{V_{in} - V_{out}}{L}(t_{on})$$

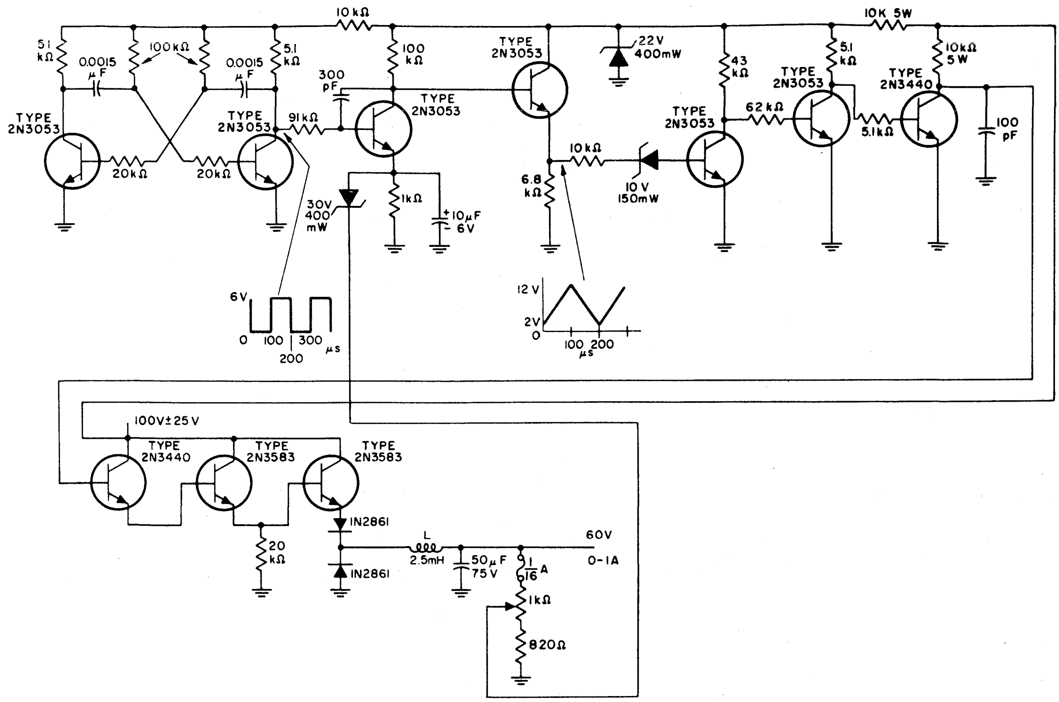
The transistor chosen for this application must provide sufficiently fast switching times, i.e., rise time t_r and fall time t_f. For good regulation over a wide range of input voltage and output current, the duty cycle must be variable from 10 to 90 per cent. Consequently, the minimum pulse width should 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.

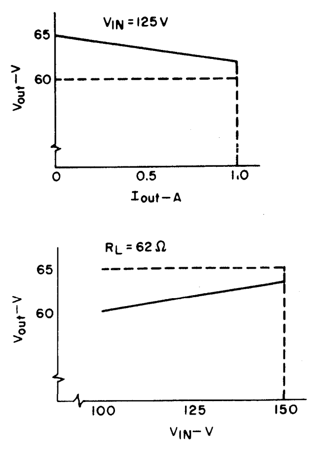


Fig.11 - Performance curves for circuit shown in Fig.10.

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

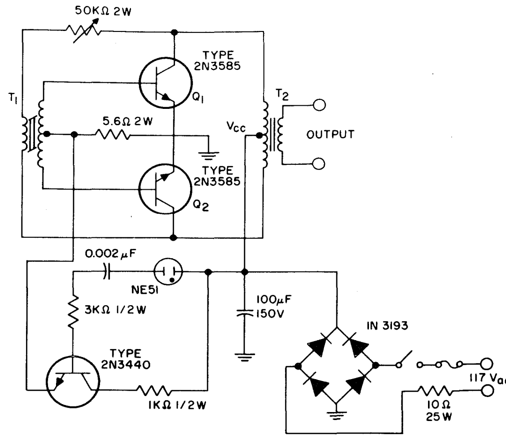
High gain (to reduce feedback power and increase efficiency)

$f_T \geq 10f$ (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:

$$\frac{\Delta I}{\Delta t} = \frac{V}{L} \quad \Delta I = \frac{V_{CC}}{L}\Delta t, \; I_p = \frac{V_{CC}}{L}\frac{t_s}{2}$$

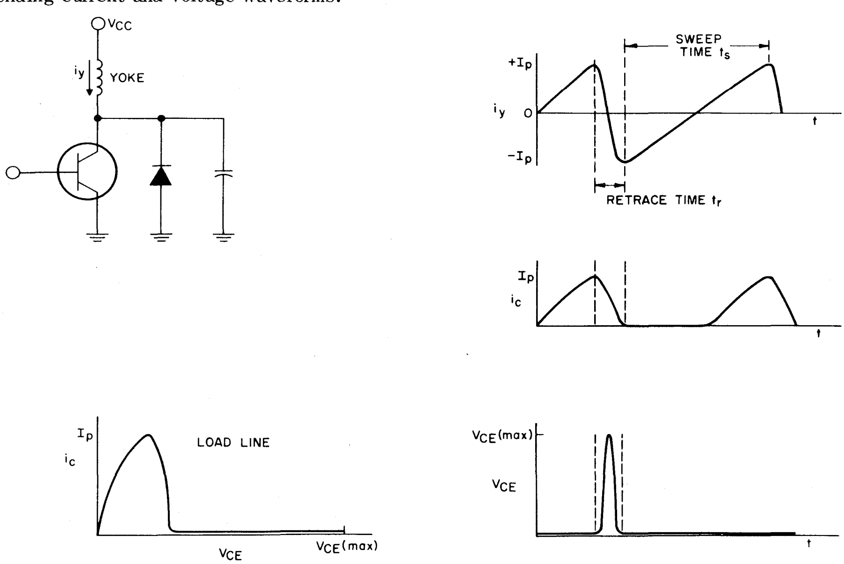


Fig.13 - Basic configuration for a transistor magnetic deflection circuit showing corresponding current and voltage waveforms.

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:

$$V_{CE}(sat) \text{ (at } I_C = I_p,\ I_B = \frac{I_p}{15}) = 1.5 \text{ V max.}$$

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:

$$I_p = \sqrt{\frac{2\,(225)\,10^{-6}}{250 \cdot 10^{-6}}} = 1.35 \text{ A}$$

The supply voltage V_{CC} required is given by

$$V_{CC} = \frac{2 L I_p}{t_s} = \frac{2\,(250 \cdot 10^{-6})\,(1.35)}{50 \cdot 10^{-6}} = 13.5 \text{ V}$$

The tuning-capacitor value C is given by

$$C = \left(\frac{t_r}{\pi}\right)^2 \left(\frac{1}{L}\right) = \frac{100 \cdot 10^{-12}}{(\pi)^2\, 250 \cdot 10^{-6}} = .040\ \mu F$$

Finally, the maximum collector voltage V_{CE} is given by

$$V_{CE} = 13.5 + (1.35) \frac{\pi}{(10) \cdot 10^{-6}} 250 \cdot 10^{-6} = 118 \text{ V}$$

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.

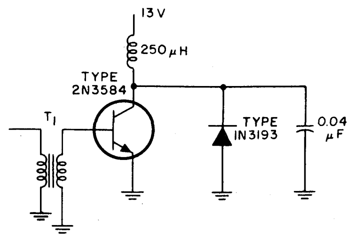


Fig.14 - Schematic diagram of a typical transistor magnetic deflection circuit.

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.

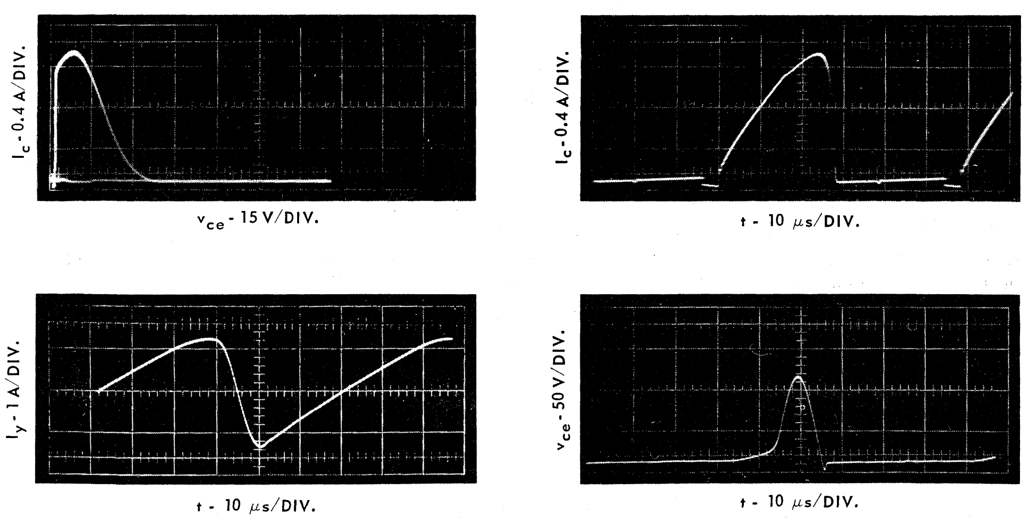


Fig.15 - Current and voltage waveforms produced by circuit shown in Fig.14.

* Additional information concerning this amplifier circuit is given in RCA publication ATC-402.

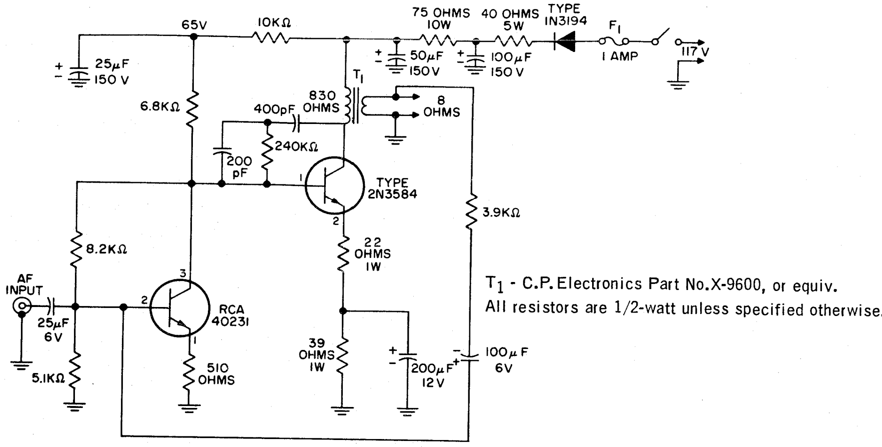


Fig.16 - Schematic diagram of a line-operated, class A, 5-watt audio amplifier.

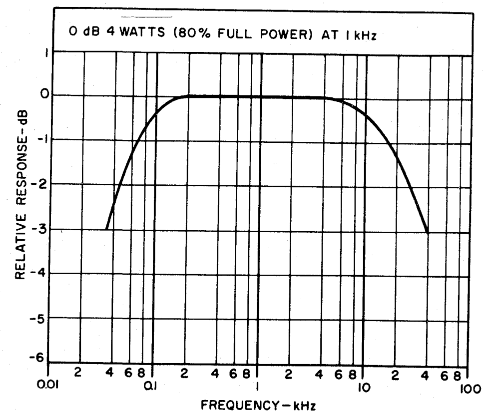


Fig.17 - Response curve for circuit shown in Fig.16.

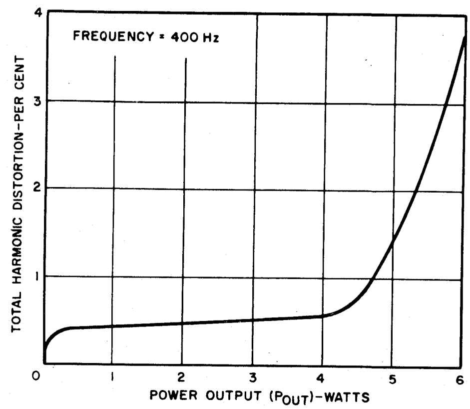


Fig.19 - Harmonic distortion as a function of power output for circuit shown in Fig.16.

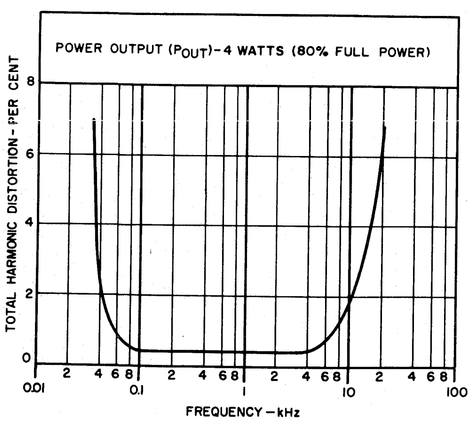


Fig.18 - Total harmonic distortion as a function of frequency for circuit shown in Fig.16.

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.

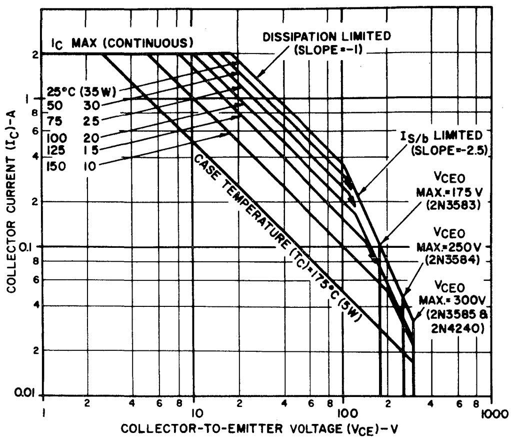


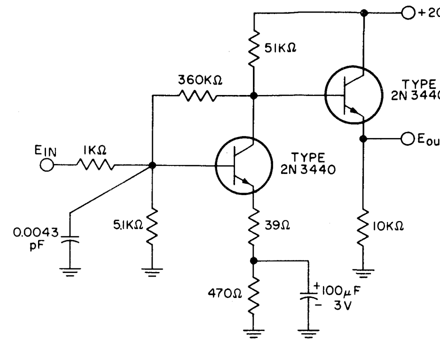
Fig.20 - Safe operating area for the 2N3584 transistor.

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.

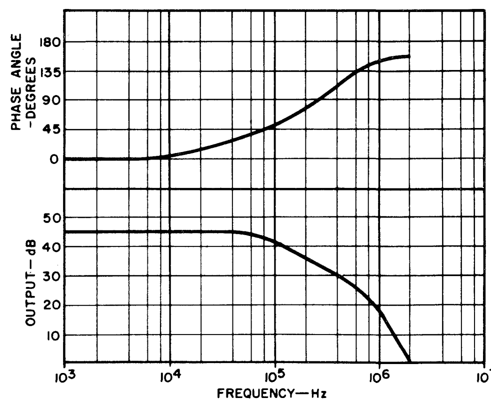


Fig.22 - Performance curves for circuit shown in Fig.21.

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.

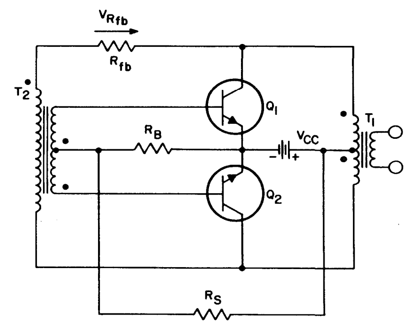


Fig.1 - Schematic diagram of two-transistor/two-transformer inverter.

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 $2 V_{CC} - V_{Rfb}$.

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.

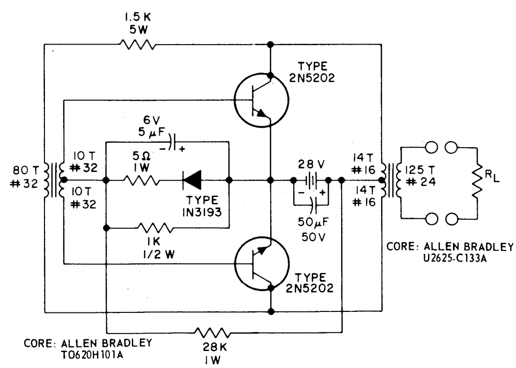


Fig.2 - Circuit diagram for 100-watt, 18-kHz inverter.

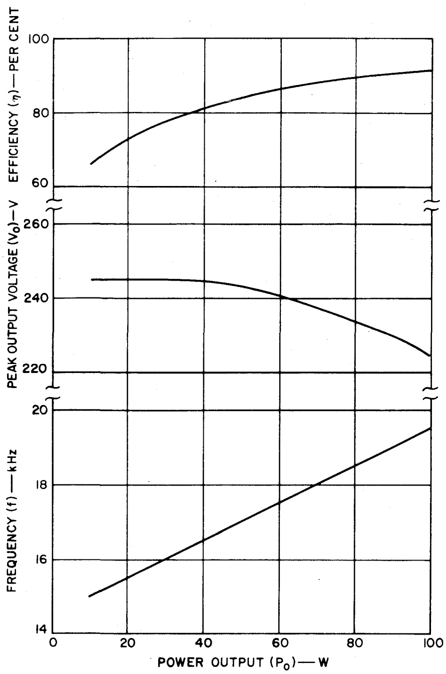


Fig.3 - Performance characteristics of inverter shown in Fig.2.

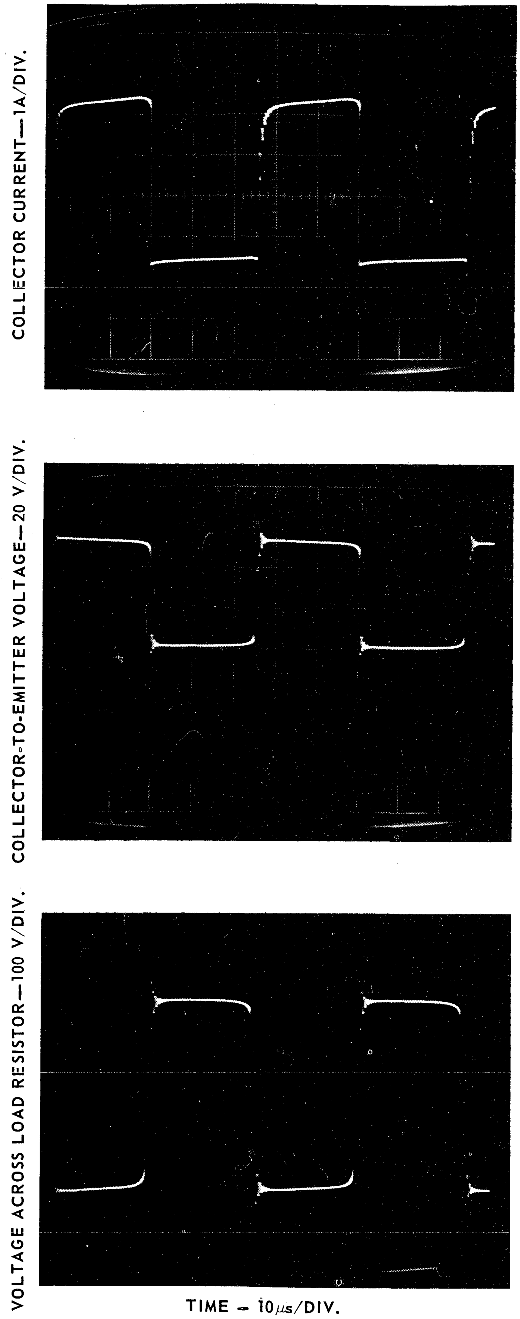


Fig.4 - Waveforms of output voltage, collector voltage, and collector current in inverter of Fig.2.

RCA
Solid State
Division

Power Transistors
Application Note
AN-3576

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:

$$E_S = E_o - R_S I_{dc} \qquad (1)$$

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

$$E_S = E_o - R_S (I_{pk}/\pi) \qquad (2)$$

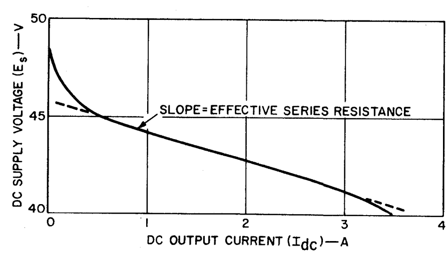


Fig.1 - Typical regulation curve for a transformer/rectifier power supply with a capacitive input filter.

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:

$$P_{T(max)} = E_o^2/(8R_S + 4\pi^2 R_L) \qquad (3)$$

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

$$\text{P.O.(music)} = E_o^2/8R_L \qquad (4)$$

Maximum average transistor dissipation is related to the music power output by the following expression:

$$\frac{P_{T(max)}}{\text{P.O.(music)}} = \left[\frac{\pi^2}{2} + \frac{R_S}{R_L}\right]^{-1} \qquad (5)$$

The power output at which maximum average transister dissipation occurs, P.O. (max diss), is related to the music power output as follows:

$$\frac{\text{P.O.(max diss)}}{\text{P.O.(music)}} = \left[\frac{\pi^2}{4} + \frac{R_S}{R_L} + \frac{R_S^2}{\pi^2 R_L^2}\right]^{-1} \qquad (6)$$

The continuous power output at the clipping level, P.O. (clipping), is related to the music power output by the following expression:

$$\frac{\text{P.O.(clipping)}}{\text{P.O.(music)}} = \left[1 + \frac{R_S}{\pi R_L} + \frac{R_S^2}{4\pi^2 R_L^2}\right]^{-1} \qquad (7)$$

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]

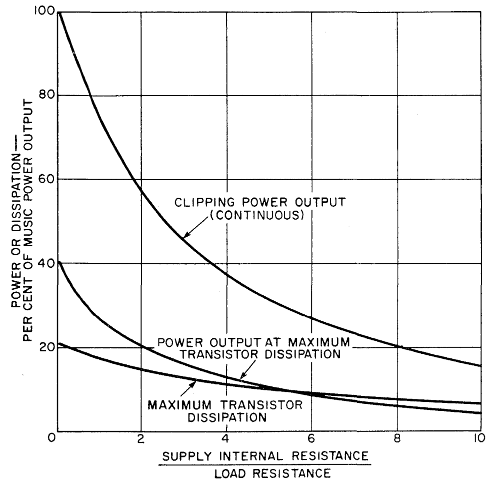


Fig.2 - Power output and dissipation as a function of the ratio of internal supply to load resistance.

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.

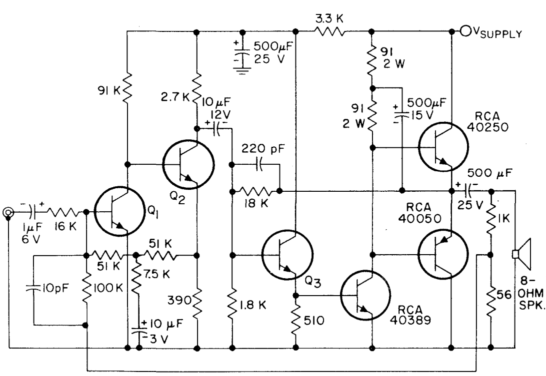


Fig.3 - A practical class B amplifier circuit.

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.

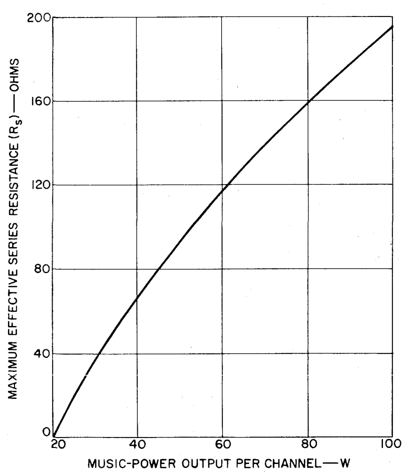


Fig.4 - Maximum effective series resistance as a function of music power.

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:

$$\frac{P_C(max)}{P.O.(max)} = \frac{2}{\pi^2} \quad (A7)$$

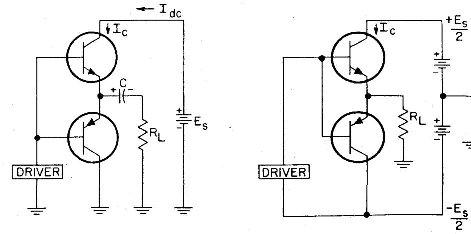


Fig.5 - Typical complementary-symmetry circuits.

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

$$\text{P.O.(max diss)} = \frac{E_S^{\,2}}{2\pi^2 R_L} \qquad \text{(A8)}$$

The ratio of the power output at maximum dissipation P.O. (max diss) to maximum power output P.O, (max) is then given by

$$\frac{\text{P.O.(max diss)}}{\text{P.O.(max)}} = \frac{4}{\pi^2} \qquad \text{(A9)}$$

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.

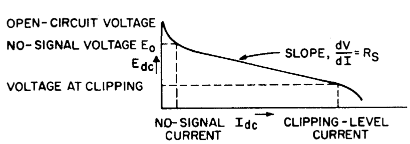


Fig.6 - Typical regulation curve for a rectifier power supply with a capacitive input filter.

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:

$$E_S = E_o - R_S I_{dc} \qquad \text{(A10)}$$

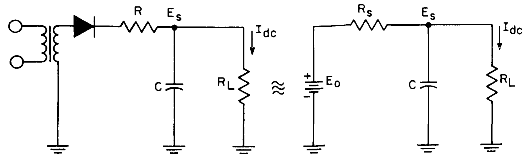


Fig.7 - Equivalent circuits for a single-ended capacitive-input rectifier power supply.

If this value is substituted for the supply voltage E_S in Eq. (A3), Eq. (A5) can be rewritten as follows:

$$P_C = \frac{I_{pk} E_o}{2\pi} - \frac{R_S I_{pk}^{\,2}}{2\pi^2} - \frac{I_{pk}^{\,2} R_L}{4} \qquad \text{(A11)}$$

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:

$$\frac{\partial P_C}{\partial I_{pk}} = \frac{E_o}{2\pi} - I_{pk}\frac{2R_S + \pi^2 R_L}{2\pi^2} \qquad \text{(A12)}$$

$$I_{pk} = \frac{E_o \pi}{2R_S + \pi^2 R_L} \qquad \text{(A13)}$$

$$P_C(\max) = \frac{E_o^{\,2}}{8R_S + 4\pi^2 R_L} \qquad \text{(A14)}$$

Clipping begins at the point where the peak collector current I_{pk} is given by

$$I_{pk} = \frac{E_o \pi}{R_S + 2\pi R_L} \qquad \text{(A15)}$$

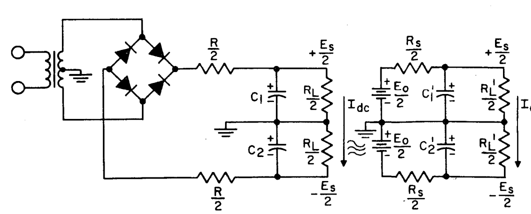


Fig.8 - Equivalent circuits for a split capacitive-input rectifier power supply.

Power output at clipping can then be expressed as follows:

$$\text{P.O.(clipping)} = \frac{E_o^2 \pi^2 R_L}{2(R_S + 2\pi R_L)^2} \qquad \text{(A16)}$$

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

$$\frac{\text{P.O.(clipping)}}{\text{P.O.(music)}} = \left[1 + \frac{R_S}{\pi R_L} + \frac{R_S^2}{4\pi^2 R_L^2}\right]^{-1} \qquad \text{(A17)}$$

Maximum transistor dissipation occurs at the peak-current level given in Eq. (A13). The power output at maximum dissipation is given by

$$\text{P.O.(max diss)} = \frac{E_o^2 \pi^2 R_L}{2(2R_S + \pi^2 R_L)^2} \qquad \text{(A18)}$$

The ratio of power output at maximum dissipation to music power can then be expressed as follows:

$$\frac{\text{P.O.(max diss)}}{\text{P.O.(music)}} = \left[\frac{\pi^2}{4} + \frac{R_S}{R_L} + \frac{R_S^2}{\pi^2 R_L^2}\right]^{-1} \qquad \text{(A19)}$$

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

$$I_{RMS} = \sqrt{\frac{P_{out}}{R_L}} = 0.5 \text{ ampere} \quad \text{(C1)}$$

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

$$\bar{I} = \frac{I_{RMS}\sqrt{2}}{\pi} = 0.225 \text{ ampere} \quad \text{(C2)}$$

The power-supply voltage at zero signal, E_o, can be determined from the following equation:

$$E_o = E_{S(min)} + \bar{I}R_S \quad \text{(C3)}$$

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

$$\text{P.O.(music)} = \frac{E_o^2}{8R_L} \quad \text{(C4)}$$

Combination of Eqs. (C3) and (C4) results in the following relation:

$$\text{P.O.(music)} = \frac{\left[E_{S(min)} + \bar{I}R_S\right]^2}{8R_L} \quad \text{(C5)}$$

The solution of Eq. (C5) for R_S is as follows:

$$R_S = \frac{\sqrt{8R_L\ \text{P.O.(music)}}}{\bar{I}} - \frac{E_{S(min)}}{\bar{I}} \quad \text{(C6)}$$

For a load resistance of 8 ohms, R_L is given by

$$R_S = \frac{8}{\bar{I}}\sqrt{\text{P.O.(music)}} - \frac{E_{S(min)}}{\bar{I}} \quad \text{(C7)}$$

The required $E_{S(min)}$ for a music-power output of 20 watts per channel is

$$E_{S(min)} = \sqrt{20(8R_L)} = 35.8 \text{ volts} \quad \text{(C8)}$$

Substitution of $\bar{I}$ and E_S then provides the following expression for R_S:

$$R_S = 35.6\sqrt{\text{P.O.(music)}} - 159 \quad \text{(C9)}$$

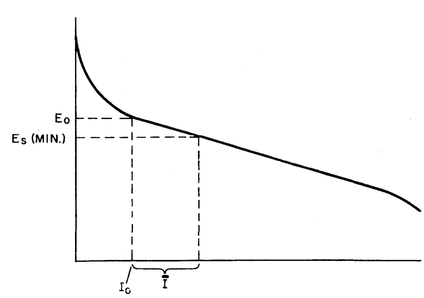


Fig.9 - A power-supply regulation curve.

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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.

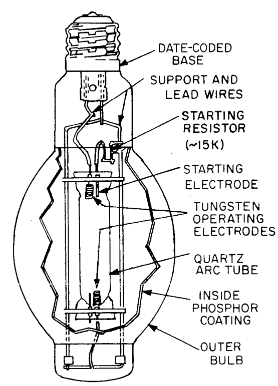


Fig.1 - Cutaway view of a mercury-arc lamp.

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.

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).

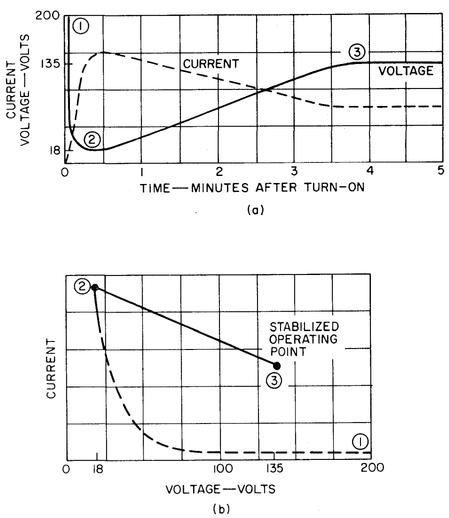


Fig.2 - Warm-up characteristics of a typical (135-volt) mercury-arc lamp: (a) current and voltage as a function time; (b) current as a function of voltage.

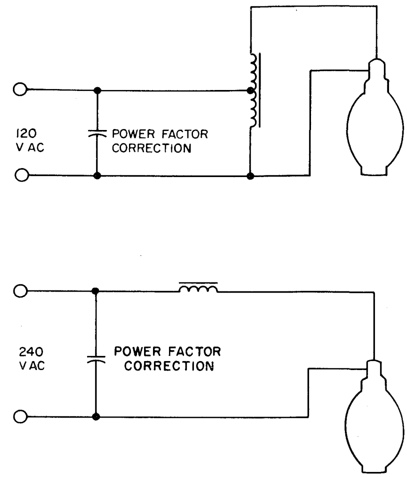


Fig.3 - Conventional ballasts for 120- and 240-volt ac mercury-arc lamps.

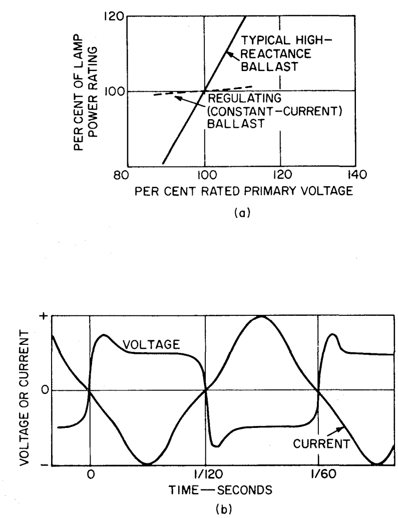


Fig.4 - Characteristics of conventional mercury-arc-lamp ballasts: (a) regulation characteristics; (b) voltage and current as a function of time.

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

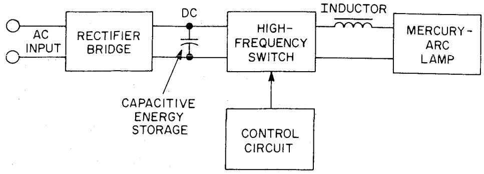


Fig.5 - Block diagram of an electronic ballasting system for mercury-arc lamps.

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.

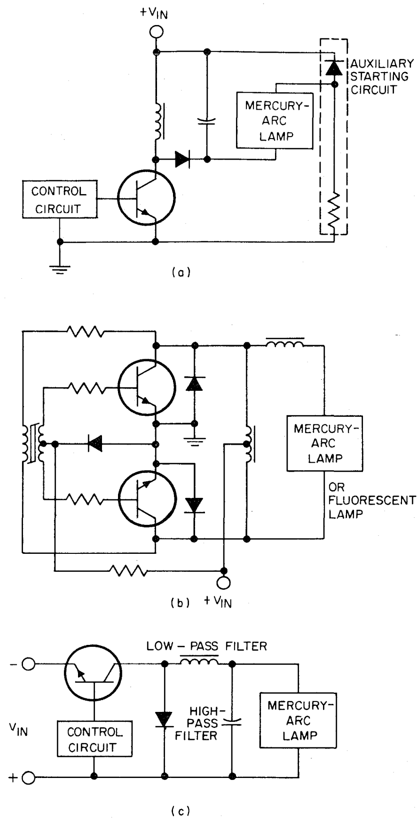


Fig.6 - Three basic circuit configurations that may be used in electronic ballasting systems: (a) ringing-choke converter; (b) push-pull inverter; (c) switching regulator.

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	V_{CE}	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 transistor 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.

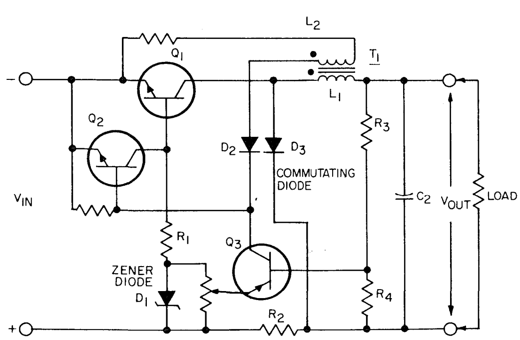


Fig.7 - 120-volt switching regulator.

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:

$$E_L = L \frac{di}{dt} \tag{1}$$

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:

$$V_{in} - V_{out} = L_1 \frac{(I_{peak})}{t_{on}} \tag{2}$$

If this equation is solved for t_{on}, the following result is obtained:

$$t_{on} = \frac{L_1 (I_{peak})}{V_{in} - V_{out}} \tag{3}$$

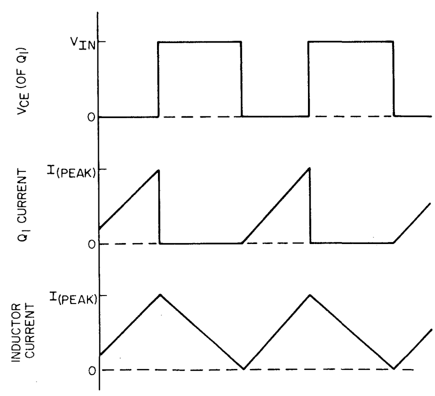


Fig.8 - Typical voltage and current waveforms for the switching regulator shown in Fig.7.

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:

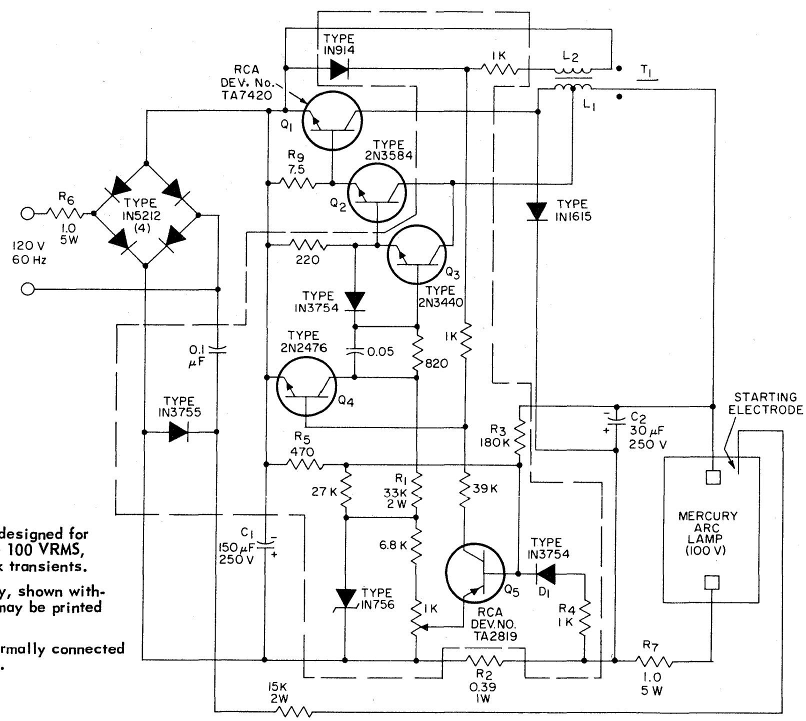
$$f = \frac{1}{t_{on} + t_{off}}$$

$$= \frac{V_{out} + (V_{in} - V_{out})}{L_1 (I_{peak}) (V_{in})} \qquad (5)$$

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.

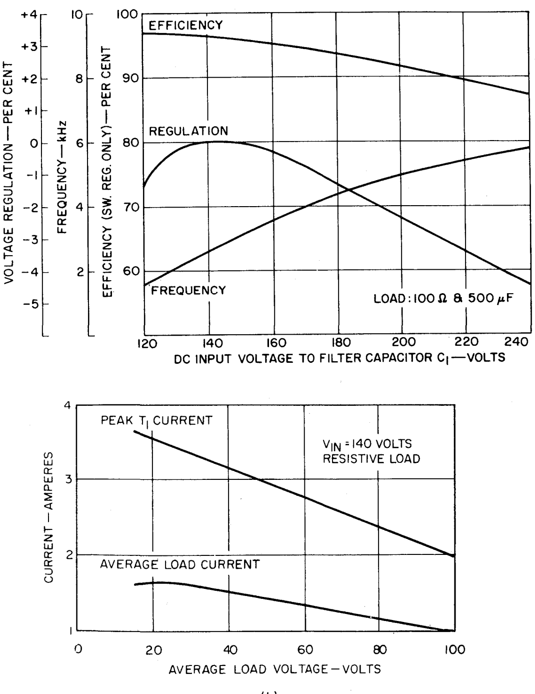


Fig.10 - Performance characteristics of the 100-watt, 100-volt switching-regulator ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.

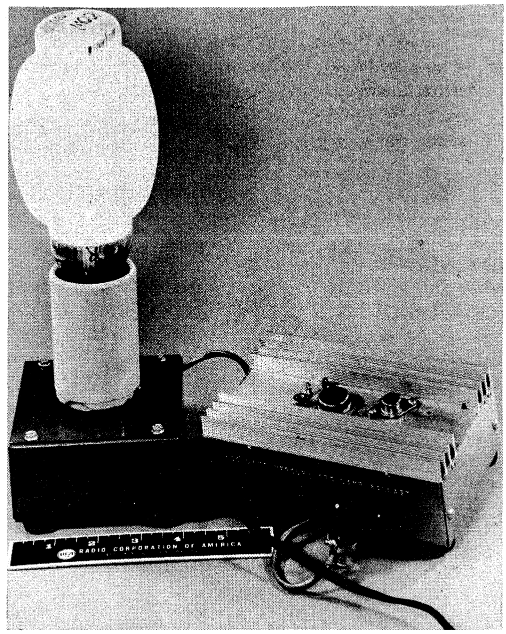


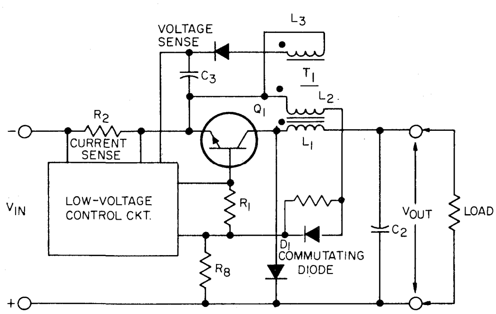
Fig.11 - Photograph of the 100-watt, 120-volt switching-regulator ballasting circuit.

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.

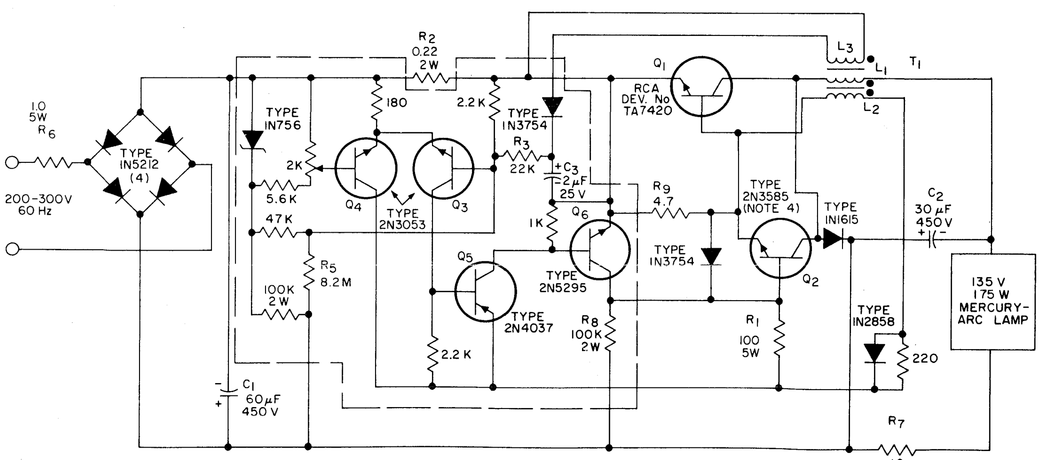


NOTE: This circuit needs only one high-voltage switching element.

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.

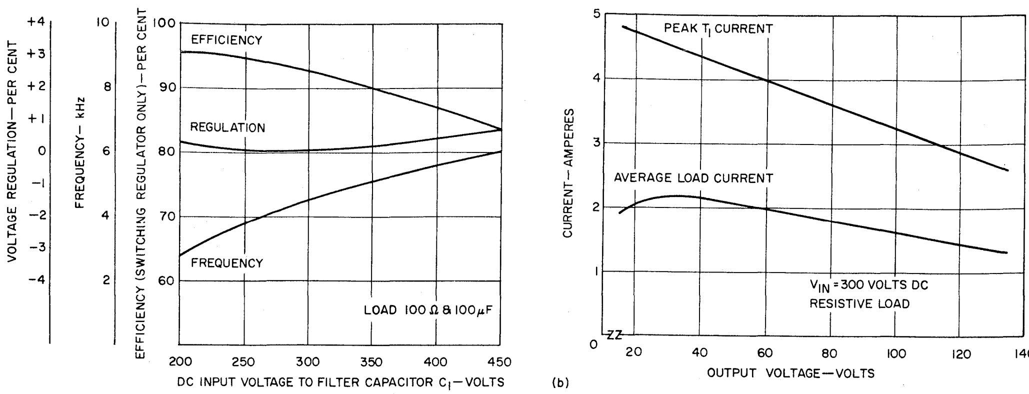
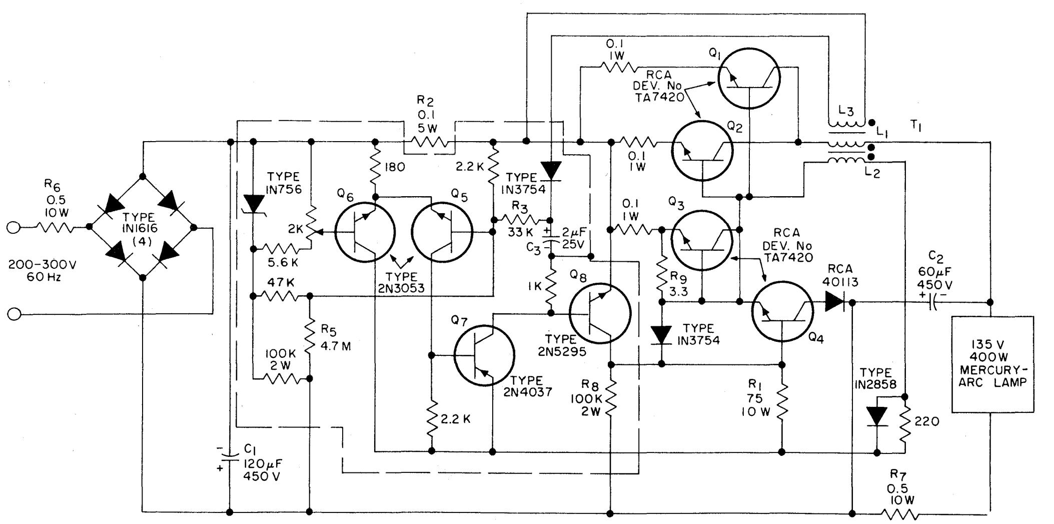


Fig.14 - Performance characteristics of the 175-watt, 200-to-300-volt ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.



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.

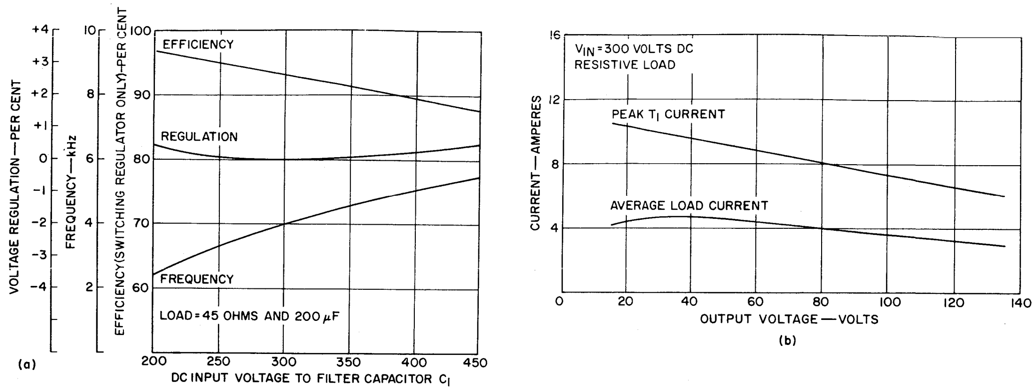


Fig.16 - Performance characteristics of the 400-watt, 200-to-300-volt switching-regulator ballasting circuit: (a) voltage regulation, frequency response, and efficiency; (b) output characteristics.

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.

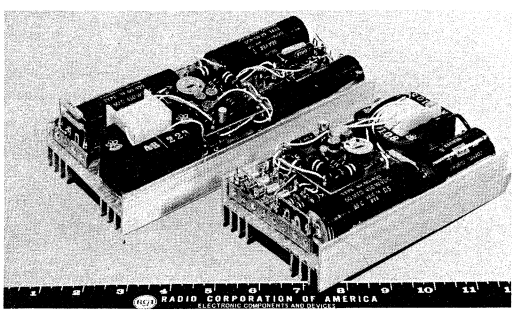


Fig.17 - Photograph of 175-watt and 400-watt 240-volt switching-regulator ballasts for mercury-arc lamps.

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

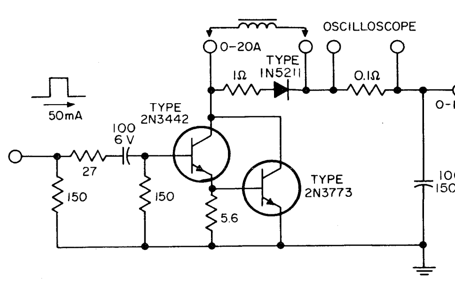


Fig.18 - Inductor tester.

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			
	A	OHMS	V	V	A	μH		Min.	Max.
$V_{CER(sus)}$	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:

$$R_{in} = \frac{V_{in(min.)} - V_{out(min.)}\ \dfrac{L_2}{L_1} - 2\ V}{I_{B(max.)}} \quad (10)$$

   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.

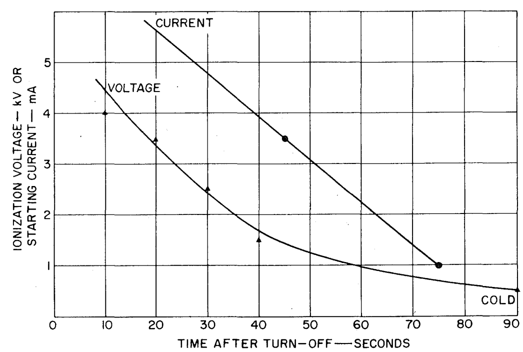


Fig.19 - Typical warm-up characteristics for a 100-watt mercury-arc lamp.

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.

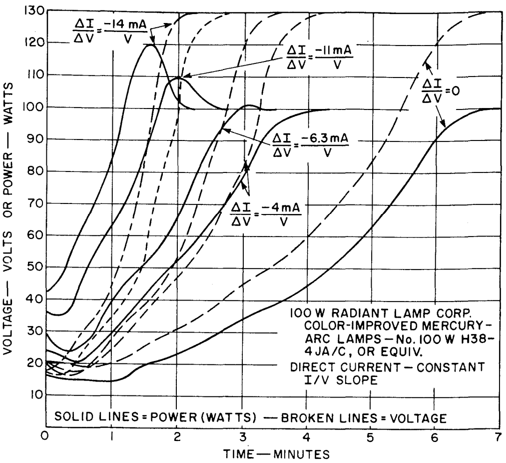


Fig.20 - Hot restart characteristics for a 100-watt mercury-arc lamp.

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.

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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

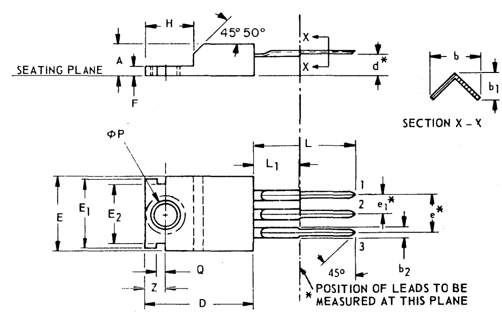
RCA power transistors and thyristors (SCR's and triacs) in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations. This Note provides detailed guidelines for handling and mounting of these plastic-package devices, and shows 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.

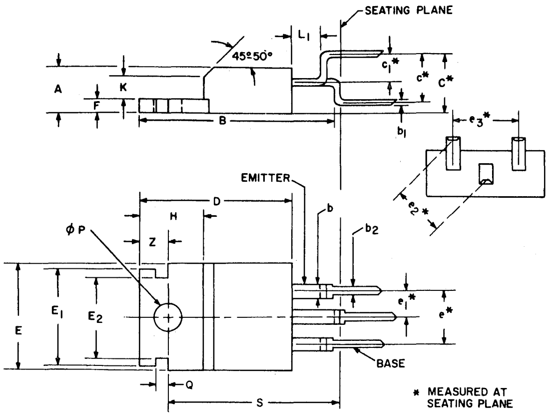
The RCA molded-plastic high-power packages are also supplied in several configurations for flexibility of application. The JEDEC Type TO-219AB, shown in Fig. 5, is the basic high-power plastic package. Fig. 6 shows a JEDEC Type TO-219AA version of the high-power plastic package. With the addition of 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

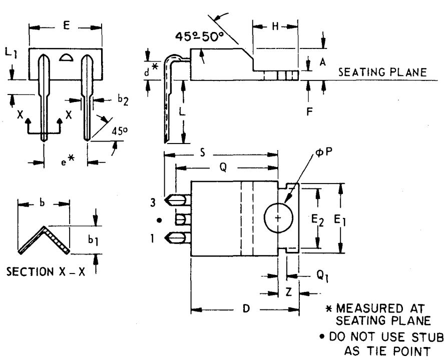
Fig. 1 - Dimensional outline of the JEDEC TO-220AB in-line-lead Versawatt transistor package.



SYMBOL	INCHES MIN.	INCHES 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.	INCHES 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

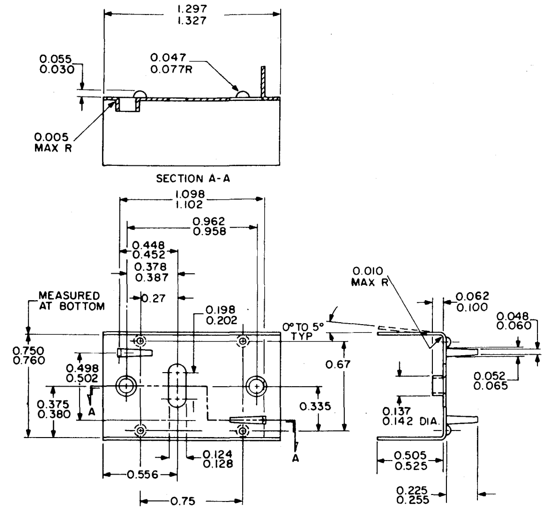
Fig. 2 - Dimensional outline of Versawatt transistor package designed for mounting on printed-circuit boards.



SYMBOL	INCHES MIN.	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
e	.190	.210

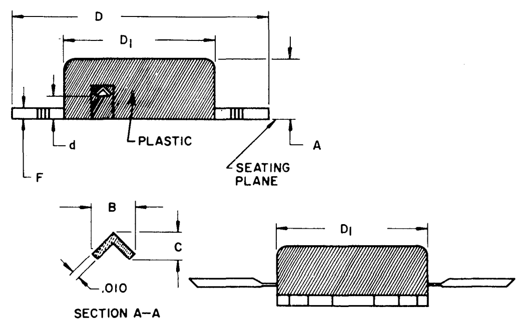
SYMBOL	INCHES MIN.	INCHES MAX.
F	.045	.055
H	.230	.270
L	.360	.422
L_1		.050
φP	.139	.147
Q		.610
Q_1	.040	.060
S	.580	.610
Z	.100	.120

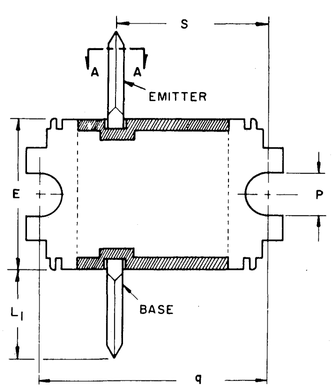
Fig. 3 - JEDEC TO-220AA Versawatt transistor package designed for direct replacement of the JEDEC TO-66 package.



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.

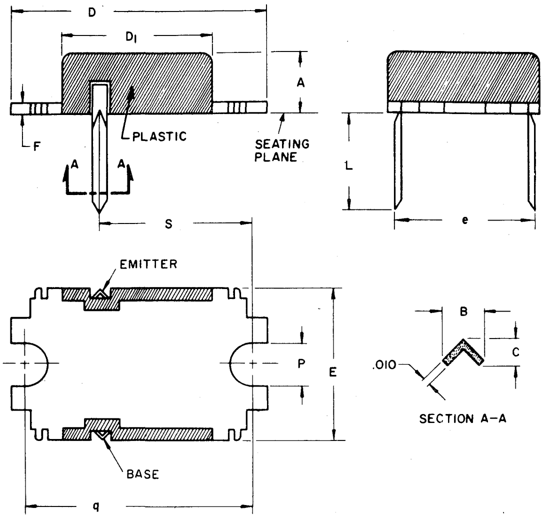
Fig. 4 - Integral heat sink used with the TO-220AA Versawatt package shown in Fig. 3.





SYMBOL	INCHES MIN.	INCHES 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
D_1	.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

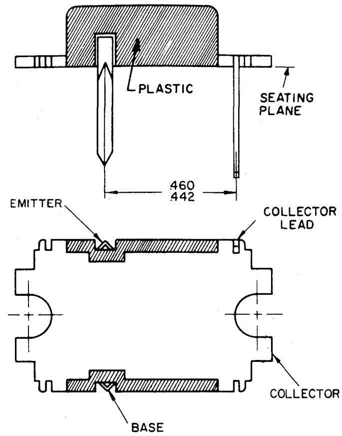
Fig. 6 - JEDEC TO-219AA plastic package designed for use (with the addition of an NR193B clamp) as a direct replacement for the hermetically sealed JEDEC TO-3 transistor package.

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.

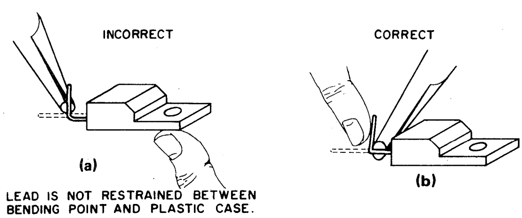


Fig. 8 - Use of long-nosed pliers for lead bending: (a) incorrect method; (b) correct method.

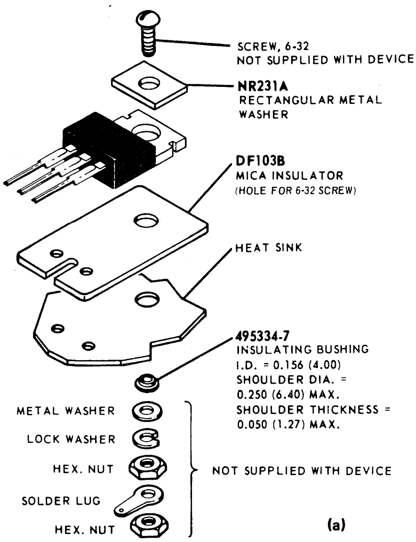
When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

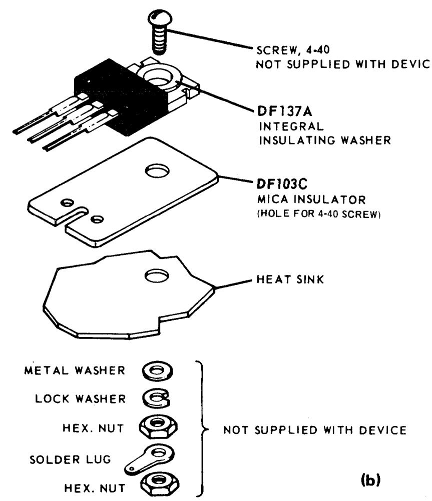
1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, 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.

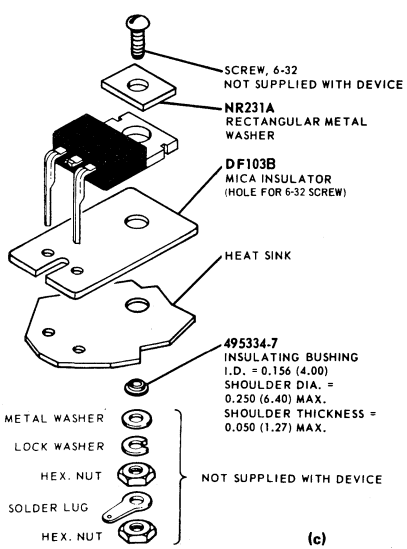
The leads of the TO-220AB Versawatt in-line package are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised. Fig. 2 illustrates an acceptable lead-forming method that provides this relief.

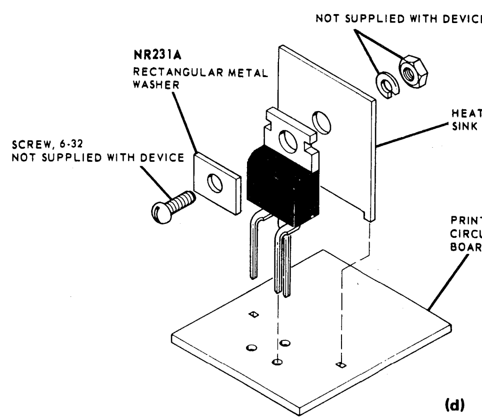
Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed; the maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance 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.

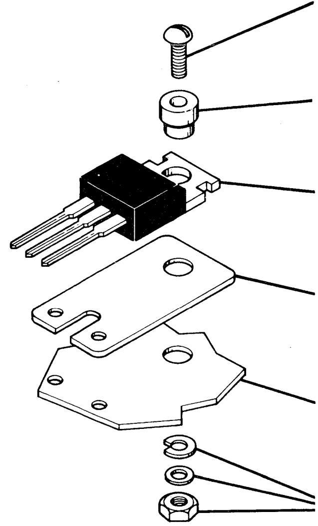
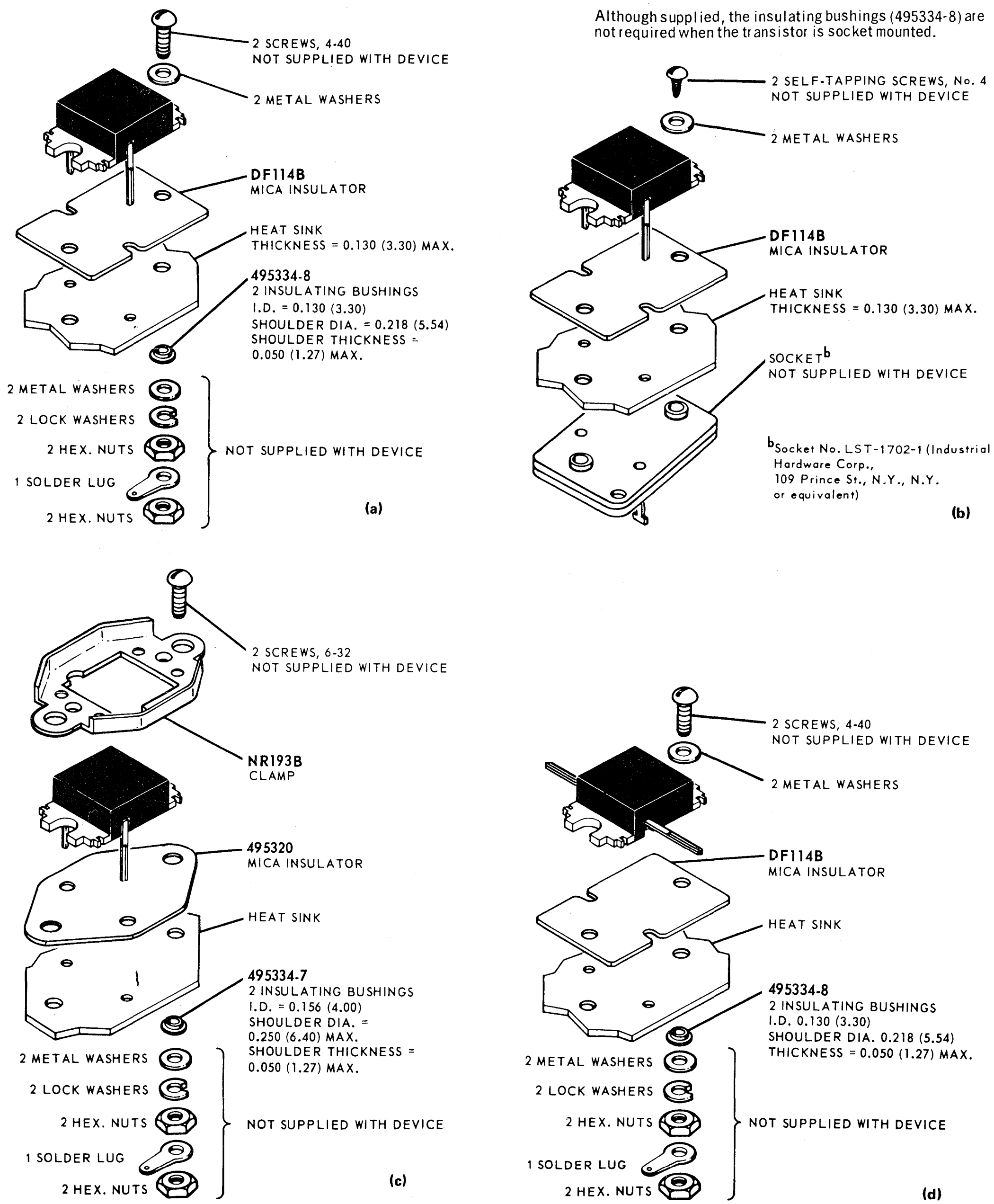


Fig. 10 - Mounting arrangements in which an isolating bushing is used to raise the head of the mounting screw above the plastic body of the Versawatt transistor.

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.

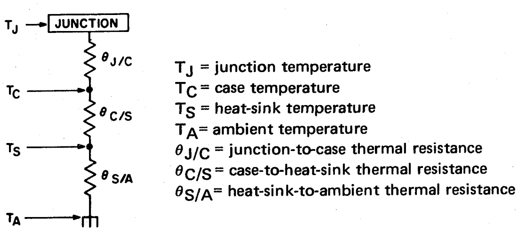


Fig. 12 - Thermal equivalent circuit for a transistor mounted on a heat sink.

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.

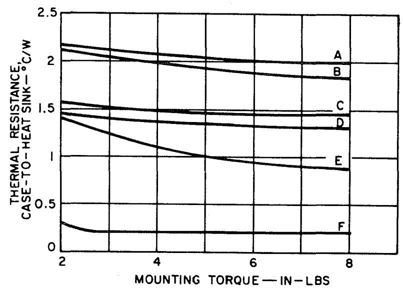
It is, of course, impractical to evaluate the effect on long-term transistor life of all cleaning solvents, which are marketed under a variety of brand names with numerous additives. These solvents can, however, be classified with respect to their component parts, as either acceptable or unacceptable. 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:

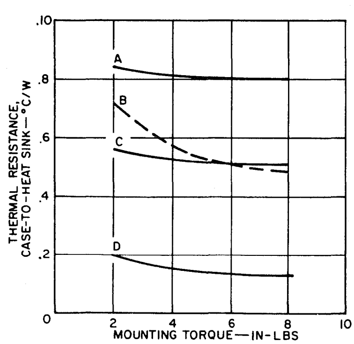
1. Alpha Reliaros No. 320-33
2. Alpha Reliaros No. 346
3. Alpha Reliaros No. 711
4. Alpha Reliafoam No. 807
5. Alpha Reliafoam No. 809
6. Alpha Reliafoam No. 811-13
7. Alpha Reliafoam No. 815-35
8. Kester No. 44

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.



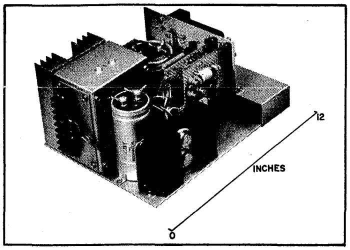
CURVE	MOUNTING ARRANGEMENT FIGURE	MICA THICKNESS (MILS)	THERMAL COMPOUND
A	10(a) thru 10(d)	4	Dow Corning No.340
B	—	None	None
C	10(a) thru 10(d)	2	Dow Corning No.340
D	—	None	Dow Corning No.340

Fig. 14 - Typical case-to-heat thermal resistance as a function of mounting torque for an RCA high-power plastic-package transistor.

Solid State
Division

Power Transistors
Application Note

AN-4509



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)

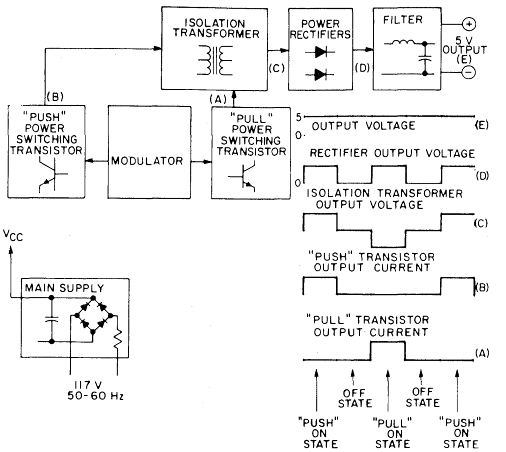


Fig. 1 - Block diagram of switching-regulator power supply, showing voltage waveforms at various points.

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

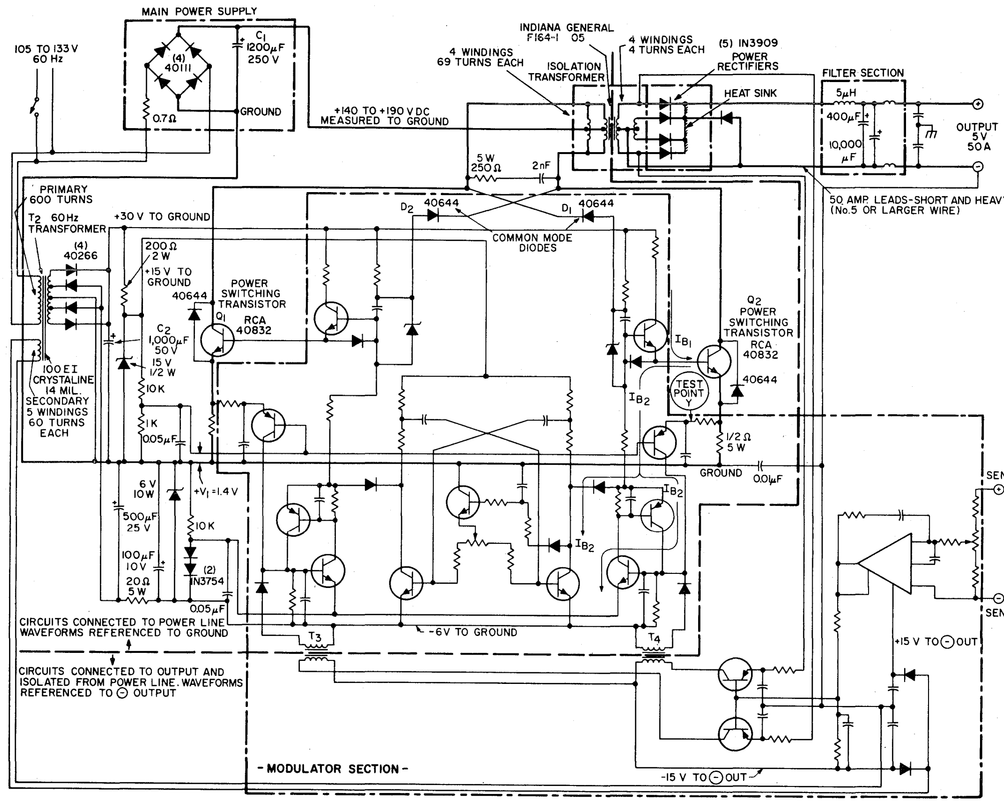


Fig. 2 - Circuit diagram of switching-regulator power supply, with major elements indicated.

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.

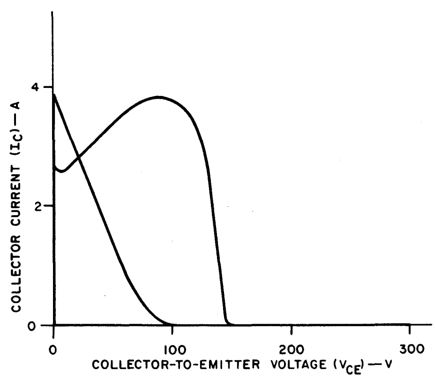


Fig. 3 - Typical load line for a switching transistor in the switching-regulator power supply.

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; $V_{BE} \leqslant V_{EE}$(1)	V_{CE} = 450 V; V_{BE} = 1.5 V	5 mA max.
I_{EBO}	$V_{EB} = V_{EE}$(1)	V_{EB} = 6 V	5 mA max.
$I_{S/b}$	$I_C = I_C$ (max.); $V_{CE} = V_{CC}$ (max.); $t \geqslant 50\ \mu s$	I_C = 4 A; V_{CE} = 200 V; $t = 100\ \mu s$	(must pass test)
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

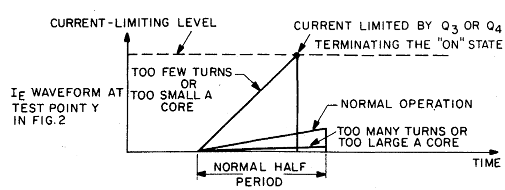


Fig. 4 - Waveform of emitter current in power-switching transistor showing effects of core-size and number of primary turns, with regulation defeated (see note on Fig. 6).

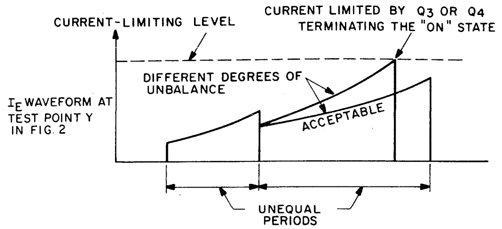


Fig. 5 - Waveform of emitter current in power-switching transistor showing effect of unbalanced direct current, with regulation defeated and load current of 25 amperes.

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

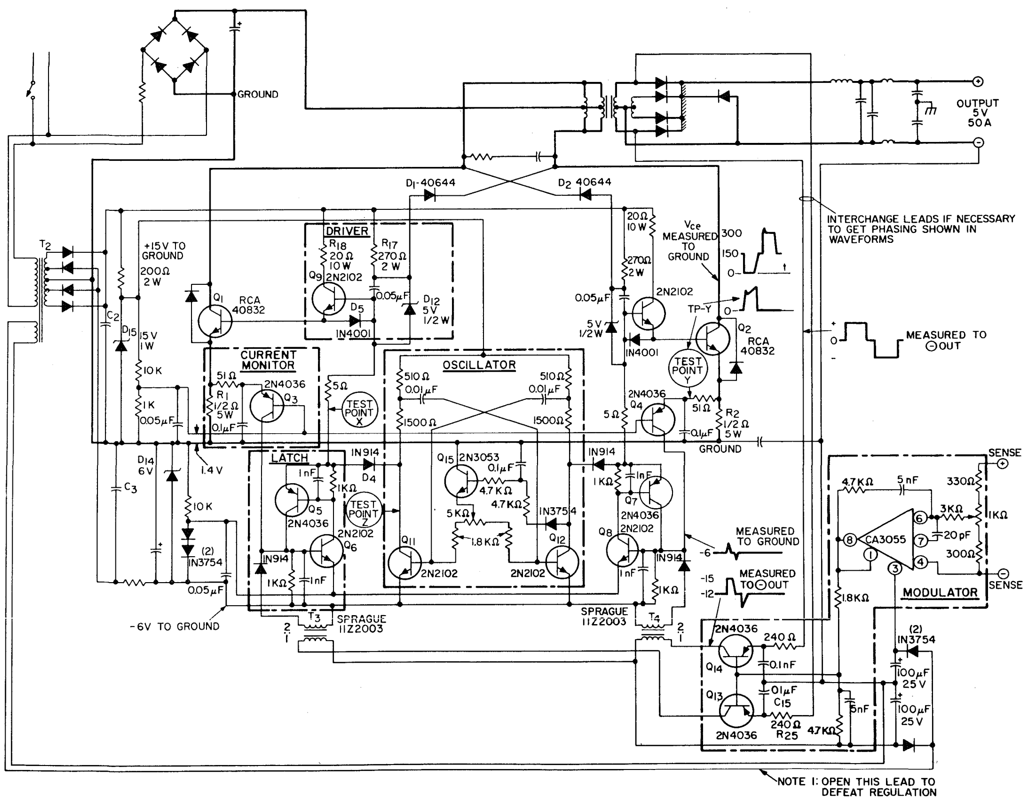


Fig. 6 - Diagram of switching-regulator power supply, with modulator circuits emphasized.

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

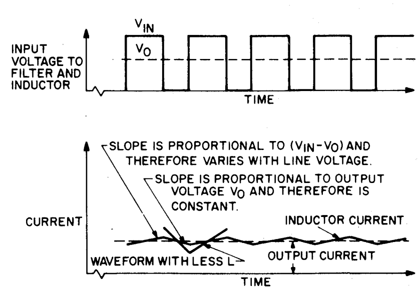


Fig. 7 - Waveforms for filter inductor under steady-state operation at 60-per-cent duty cycle.

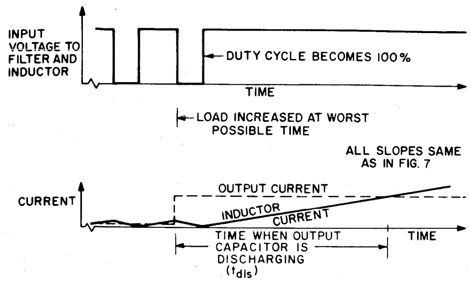


Fig. 8 - Waveforms for filter inductor under sudden increase of load current.

inductor supplies less than the load current. The minimum capacitance is given by

$$C_{min} = \frac{I_{load}(t_{dis} + 2t_{off}(max))}{2(\Delta V)\ allowed}$$

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

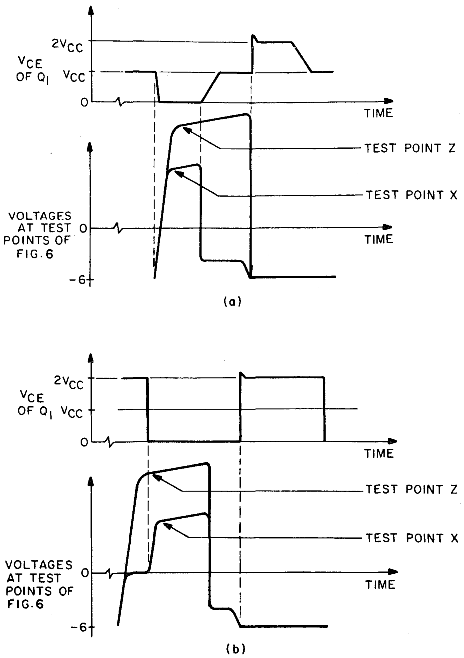


Fig. 9 - Suppression of common-mode conduction: (a) 50-per-cent duty cycle; (b) 100-per-cent duty cycle.

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.

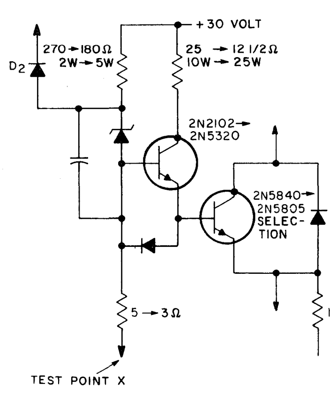


Fig. 10 - Changes in power-switching transistor drive circuit to produce increased output from larger power-switching transistors.

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.

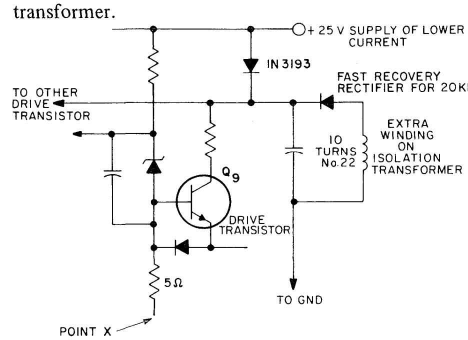


Fig. 11 - Use of a separate isolation-transformer winding to supply the base-drive transistors.

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.

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RCA
Solid State
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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 fold-back 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.

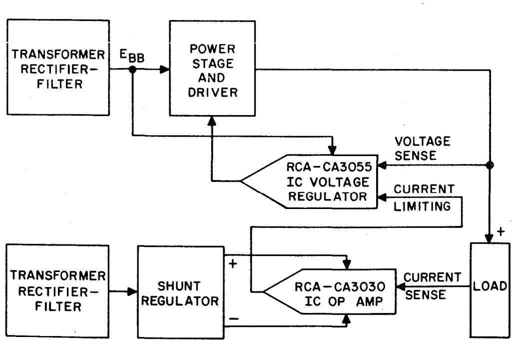
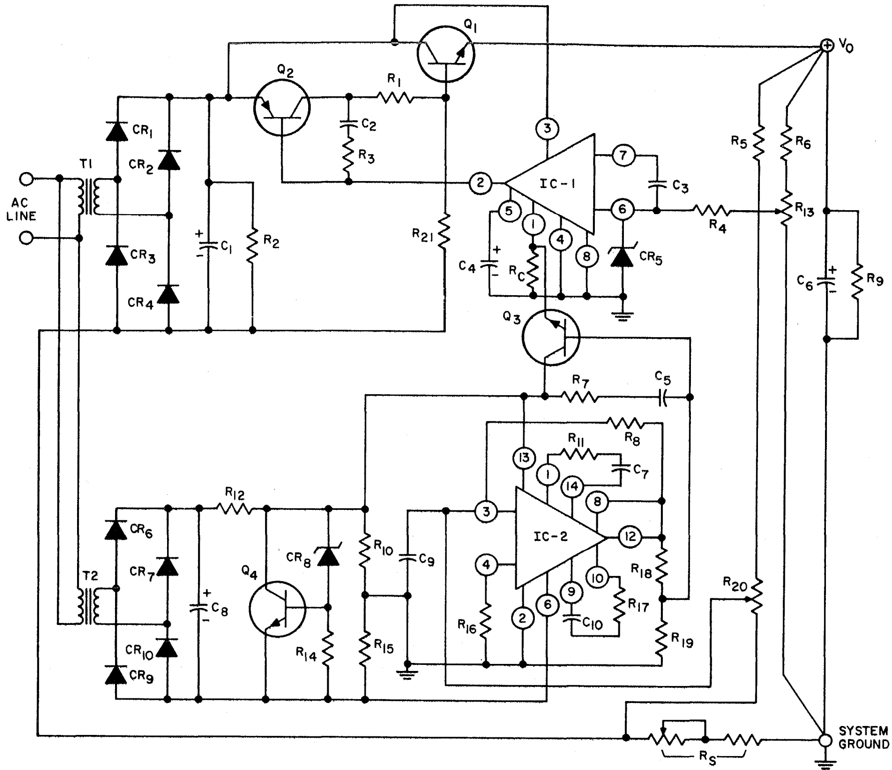


Fig. 1– Block diagram of regulated power supply with foldback current limiting.

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.)

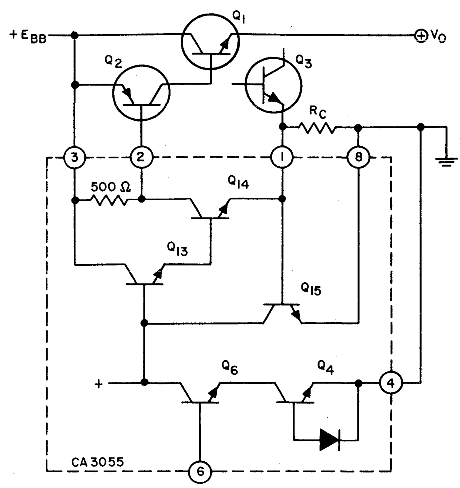


Fig. 3– CA3055 control of the power transistors.

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

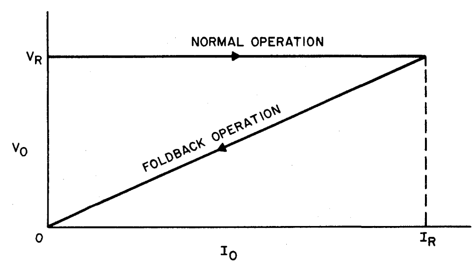


Fig. 4– Foldback current-limiting characteristic.

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.

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.

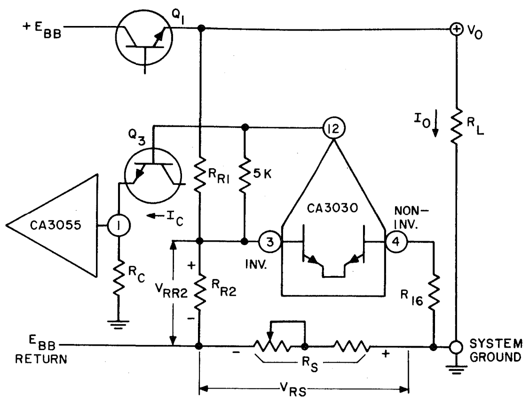


Fig. 5— Circuitry for foldback current limiting.

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 currents in the 1-kilohm bleeder resistor and the 10-kilohm sensing string are neglected in this discussion.

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.

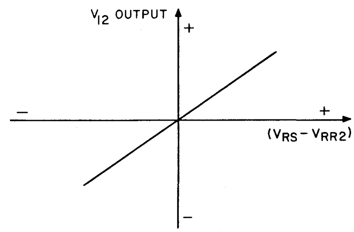


Fig. 6— Output voltage from the CA3030 operational amplifier as a function of actuating voltage.

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.

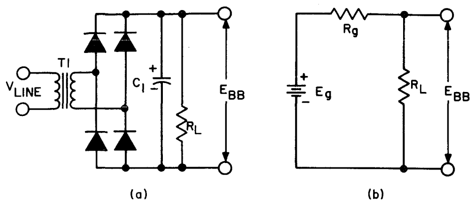


Fig. 7— Full-wave bridge rectifier and filter that provide raw dc for power supply: (a) circuit diagram; (b) equivalent circuit.

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:

$$\frac{I_X}{I_R} = 1.23 \qquad (3)$$

$$\frac{I_{SC}}{I_R} = 0.47 \qquad (4)$$

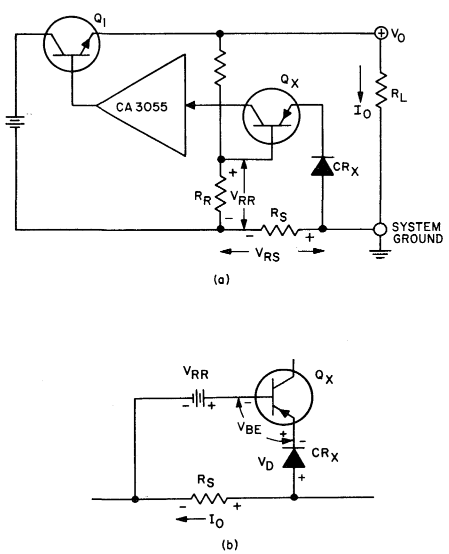


Fig. 8— A simple conventional foldback circuit that uses a single-ended amplifier instead of a differential amplifier: (a) circuit diagram; (b) equivalent circuit.

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:

$$I_{SC} = 0.125\text{ A}$$

$$I_X = 3.15\text{ A}$$

$$\frac{I_X}{I_R} = \frac{3.15}{3} = 1.05$$

$$\frac{I_{SC}}{I_R} = \frac{0.125}{3.00} = 0.042$$

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

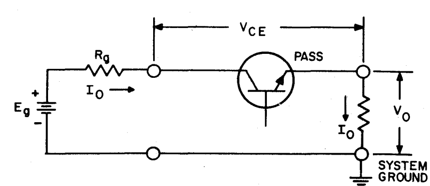


Fig. 9– Equivalent circuit used for calculation of power dissipated in pass transistor.

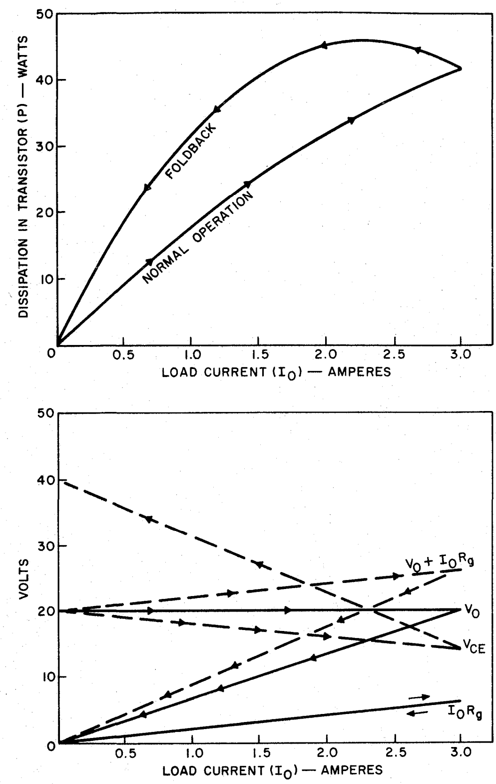


Fig. 10– Idealized operating characteristics of foldback current-limiting circuit.

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 3.9×10^{-3} per ^oC. If the copper resistor were adjusted at 20^oC, and the ambient temperature then changed to 55^oC, 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.

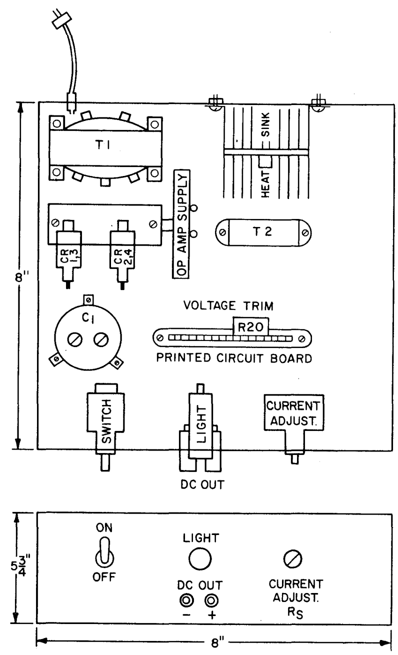


Fig. 11– Layout of power supply.

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

$$V_O = \frac{E_g}{2(1 + \sigma R_g)}$$

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°C - 55°C = 145°C
145°C/2.8°C/W = 52 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.

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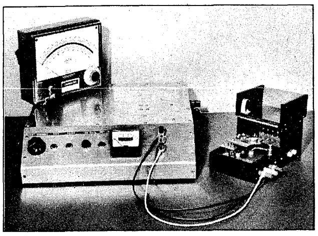
Power Transistors
Application Note
AN-4573



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.

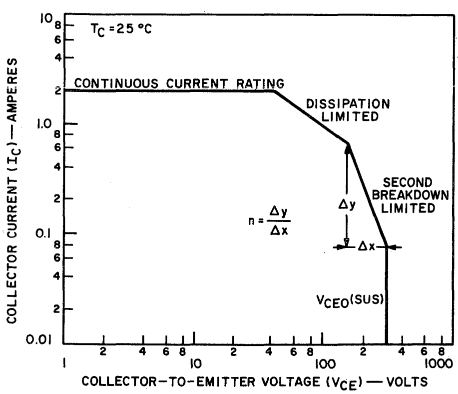


Fig. 1— A typical safe-operating-area curve.

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 ^oC, P_{avg} is the average power dissipation in watts, and $\theta_{J\text{-}C}$ is the junction-to-case thermal resistance in ^oC 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

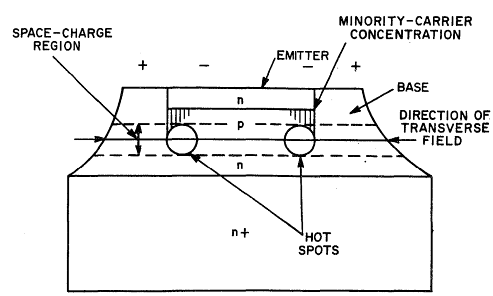


Fig. 2— Cross-section of a power transistor showing development of hot spots under forward bias.

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.

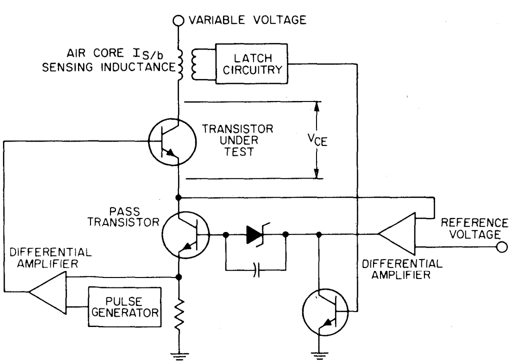


Fig. 3– Simplified schematic of test set for second-breakdown current ($I_{S/b}$).

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.

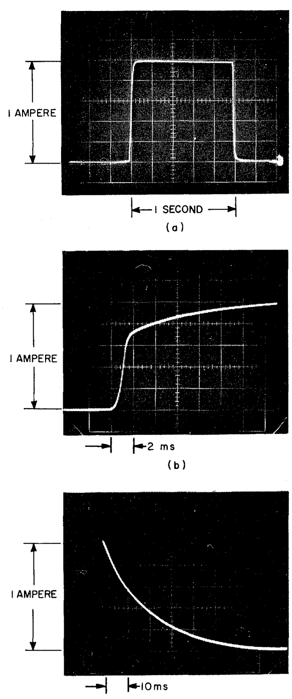


Fig. 5— Waveforms for $I_{S/b}$ test circuits of Fig. 4: (a) applied pulse; (b) turn-on time; (c) turn-off time.

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.

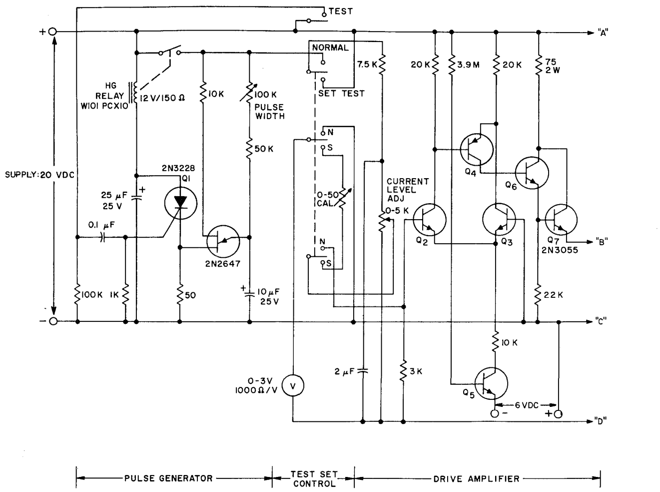
Transistor Characterization for Forward-Bias Second Breakdown

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.

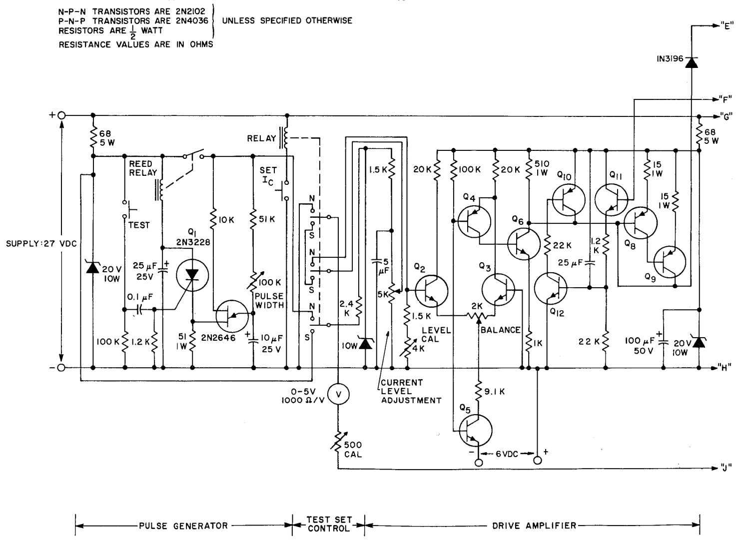
To obtain a single point on the curve, the desired collector-to-emitter voltage V_{CE} is applied to the transistor under test, and a test is performed at a test-current magnitude below the expected capability of the device. If failure does not occur, the test-current magnitude is increased in steps 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

RELAY = 12 VDC, 150 OHMS, MAGNEREED W101PCX-10; MAGNECRAFT ELECTRIC CO.
SENSING TRANSFORMER: PRIMARY = 54 TURNS No. 20 WIRE
SECONDARY = 27 TURNS No. 20 WIRE
WOUND BIFILAR ON $\frac{3}{4}$ – INCH SQUARE TEFLON COIL FORM
N-P-N TRANSISTORS ARE 2N2102
P-N-P TRANSISTORS ARE 2N4036 } UNLESS SPECIFIED OTHERWISE
RESISTORS ARE $\frac{1}{2}$ WATT
RESISTANCE VALUES ARE IN OHMS



(a)

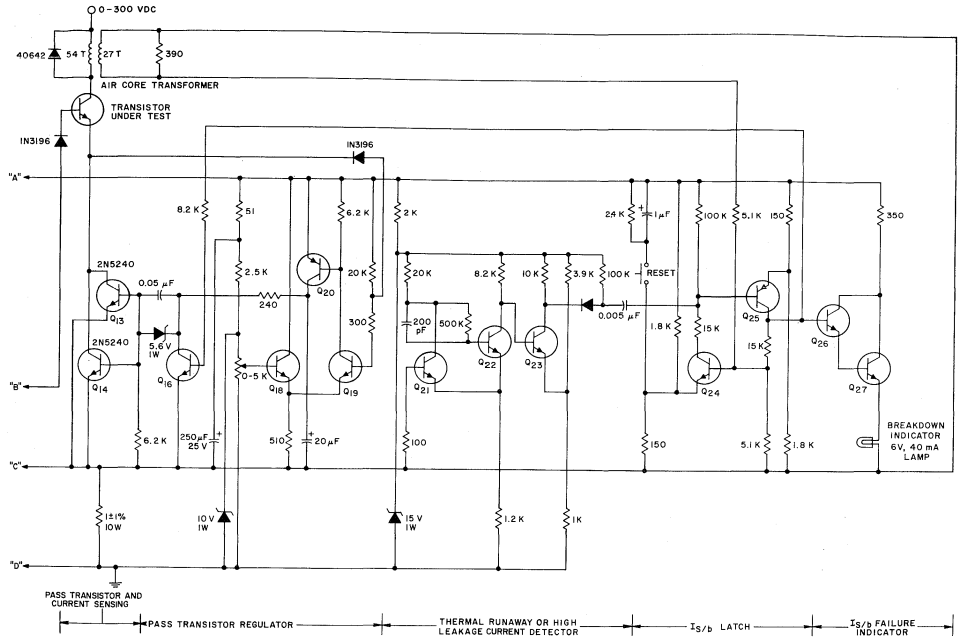
RELAY = 12 VDC, 250 OHMS, MAGNEREED W101PCX-6; MAGNECRAFT ELECTRIC CO.
SENSING TRANSFORMER: PRIMARY = 100 TURNS No. 28 WIRE
SECONDARY = 50 TURNS No. 10 WIRE
WOUND BIFILAR ON 1 – INCH TEFLON OR PLASTIC ROD
N-P-N TRANSISTORS ARE 2N2102
P-N-P TRANSISTORS ARE 2N4036 } UNLESS SPECIFIED OTHERWISE
RESISTORS ARE $\frac{1}{2}$ WATT
RESISTANCE VALUES ARE IN OHMS



(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.

(a)



(b)

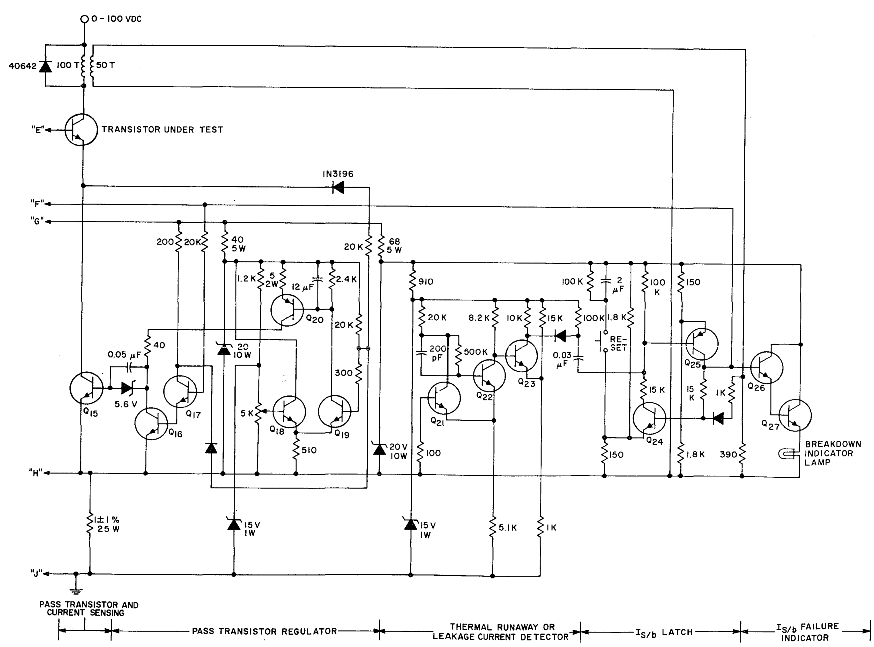


Fig. 4— Schematic diagram of $I_{S/b}$ test facilities for (a) currents to 2.5 amperes and voltages to 300 volts, and (b) currents to 5 amperes and voltages to 100 volts.

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.

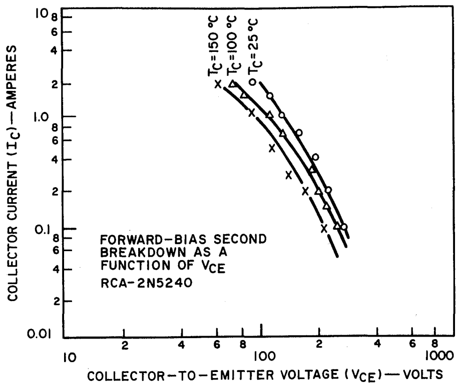


Fig. 6— Forward-bias second breakdown of RCA-2N5240 as a function of collector-to-emitter voltage for different case temperatures.

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.

RCA Solid State Division

Power Transistors Application Note

AN-4612

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]

$$N = Ae^{\psi_0 / [\Delta T(\alpha_A - \alpha_B) L]}$$

Table I - Thermal-Cycling Requirements for Typical Applications of Power Transistors

Application	Circuit	P_T (W)	ΔT_C (^oC)	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

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

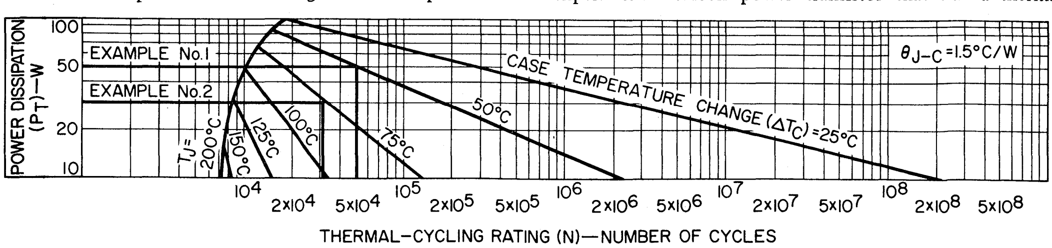


Fig. 1— Thermal cycling rating chart

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.

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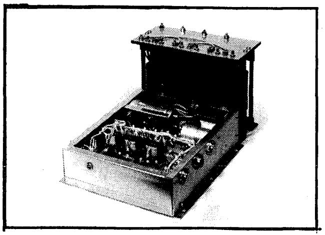
Power Transistors Application Note AN-4673



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.

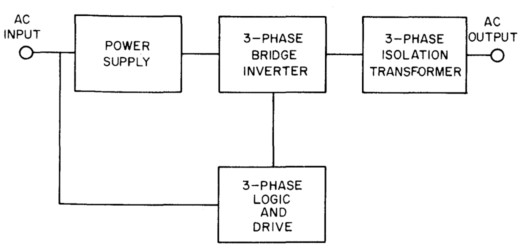


Fig. 1— Block diagram of 750-watt three-phase converter.

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

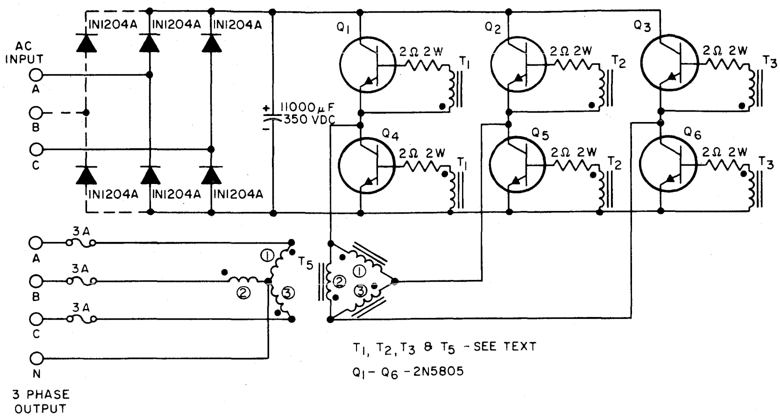


Fig. 2— Schematic diagram of three-phase frequency converter, showing the dc supply, the inverter, and the output transformer.

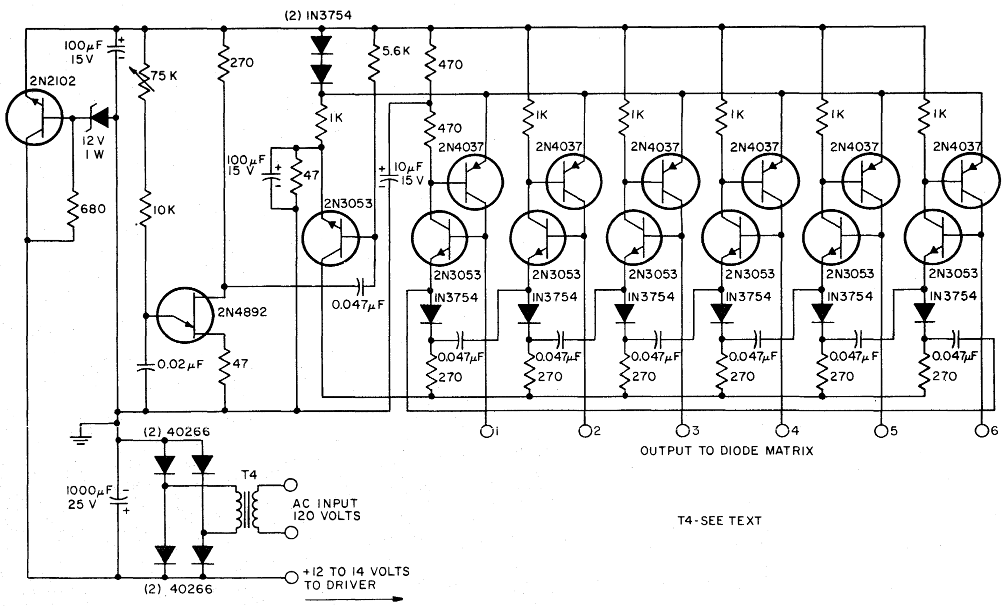


Fig. 3— Oscillator and six-stage ring counter for the logic circuit of the three-phase frequency converter.

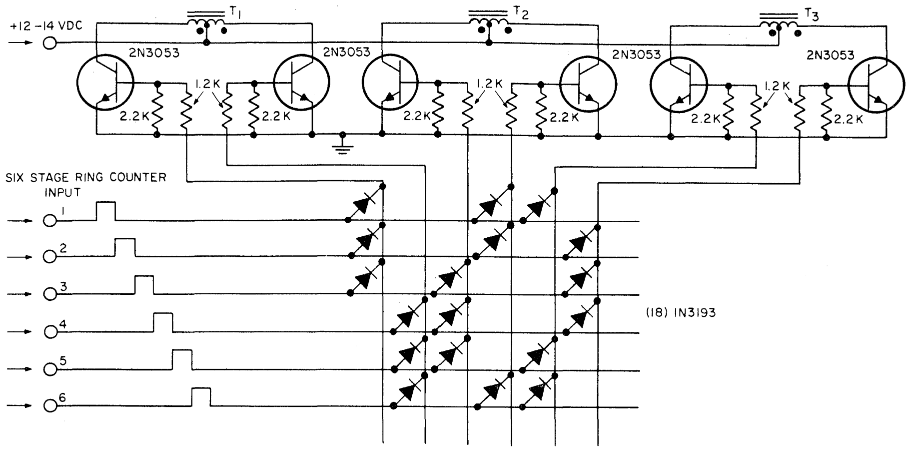


Fig. 4— Diode matrix and driver for output devices of three-phase frequency converter.

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

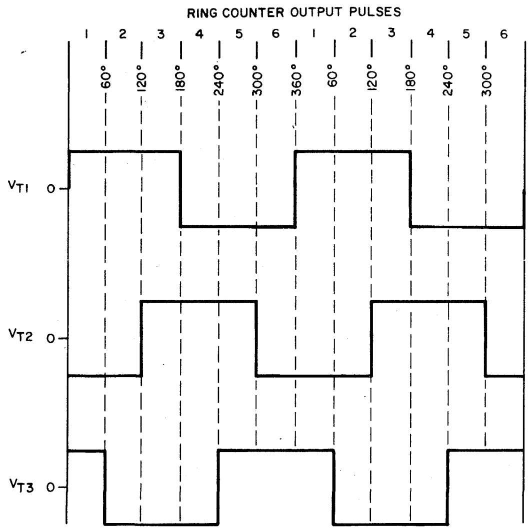
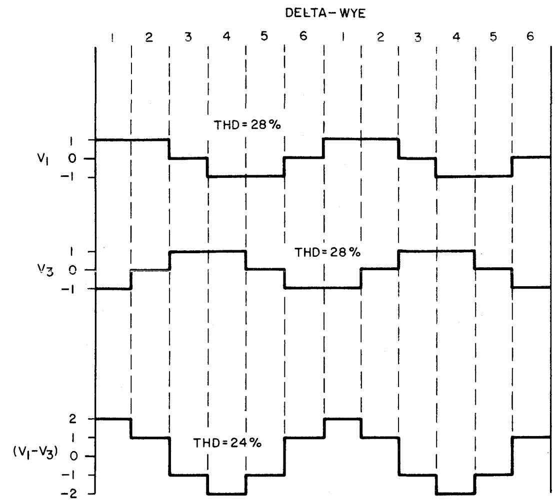


Fig. 5— Sequence of voltages across drive transformers T1, T2, and T3.



1	V1 − V3 = 1 − (−1) = 2
2	V1 − V3 = 1 − 0 = 1
3	V1 − V3 = 0 − (1) = −1
4	V1 − V3 = −1 − (1) = −2
5	V1 − V3 = −1 − 0 = −1
6	V1 − V3 = 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

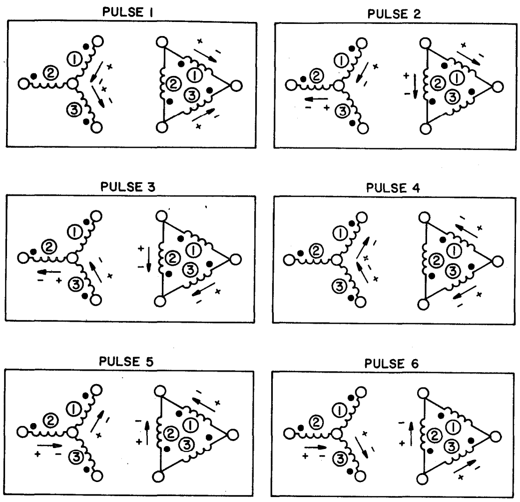


Fig. 7— Pulse polarities in output transformer T5.

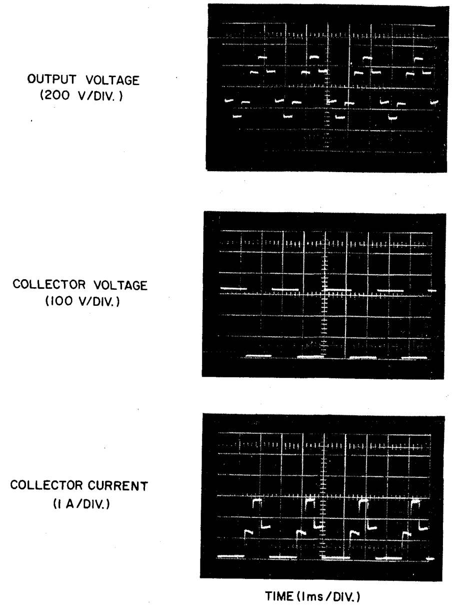


Fig. 8— Waveforms of transformer output voltage, collector voltage, and collector current.

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.

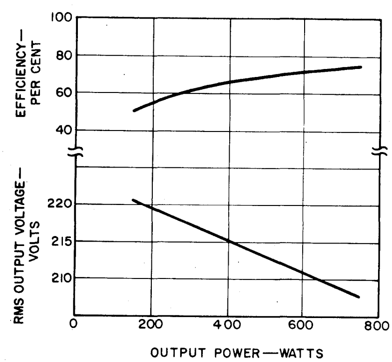


Fig. 9— Performance characteristics of the three-phase converter.

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Application Note
AN-4474

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.

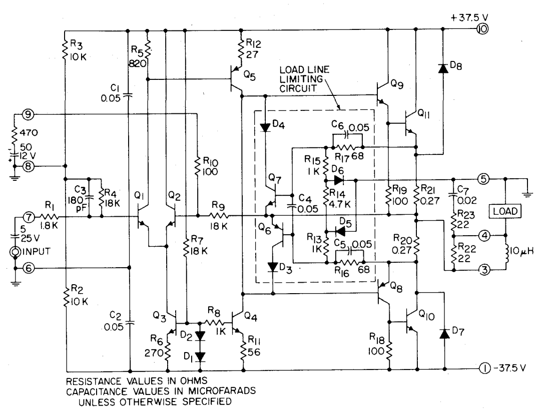

Fig. 1 — **Schematic diagram of HC1000 hybrid linear amplifier using split power supply.**

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).

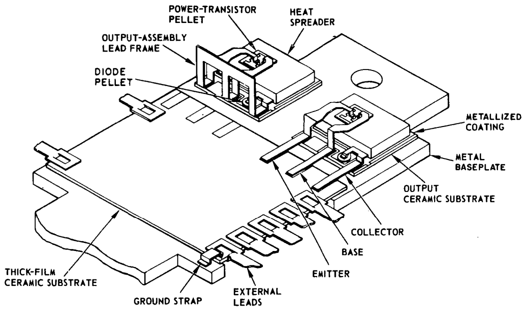

Fig. 2 — Internal structure of the HC1000 hybrid amplifier.

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.

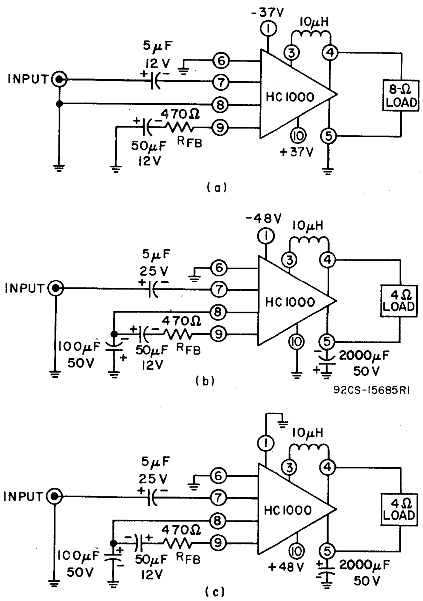

Fig. 3 — Typical connections for the HC1000 for use as an audio amplifier: (a) with split power supply and direct-coupled load; (b and c) with single-ended supply and capacitive-coupled load.

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.**

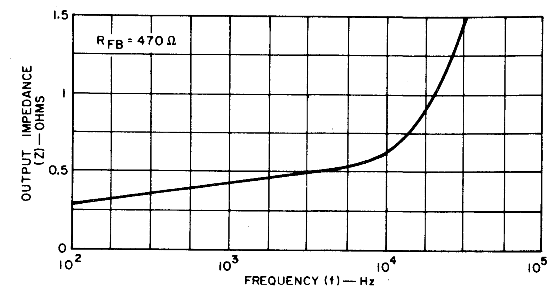

Fig. 4 — Output impedance as a function of frequency for the circuits of Fig. 3.

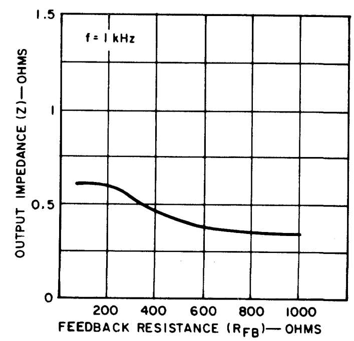

Fig. 5 — Output impedance as a function of feedback resistance R_{FB}.

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.

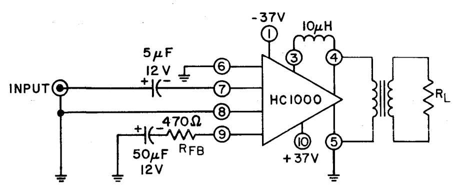

Fig. 6 — Typical connections for the HC1000 with a split power supply and a transformer-coupled load.

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 ^{o}C up to case temperatures of 100^{o} C.

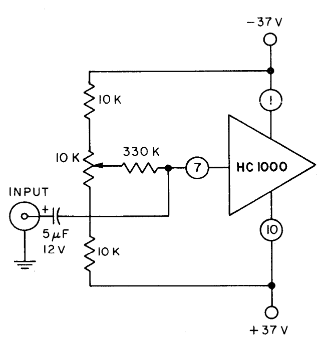

Fig. 7 — Balancing network for use in the circuit of Fig. 6.

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.

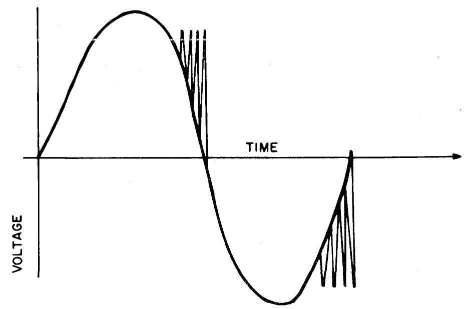

Fig. 8 — Waveform distortion caused by low-frequency limitations of transformer.

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.

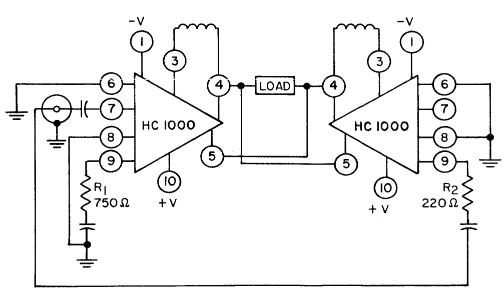

Fig. 9 — Bridge amplifier using two HC1000 hybrid modules to provide more than 100 watts.

Because the amplifiers must be driven 180 degrees out of phase, one amplifier receives its input signal at the inverting input. Resistances R_1 and R_2 are selected to provide the proper input impedance of each amplifier for the same voltage gain into a fixed load.

A bridge amplifier with a single-ended supply is shown in **Fig. 10.** In this configuration, the signal source must be separated from ground, as shown. If it is necessary to ground the generator, the supplies can be isolated. If a grounded load is required, a transformer must be utilized.

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.

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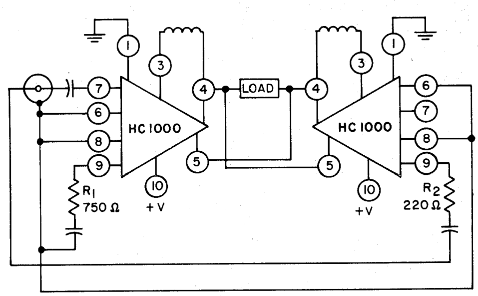

Fig. 10 — Bridge amplifier using a single-ended power supply.

RCA Solid State Division

Power Hybrid Circuits Application Note

AN-4483

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.

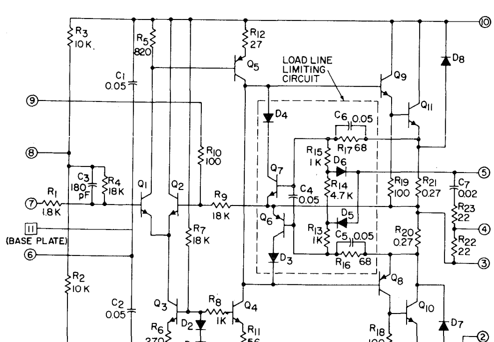

Fig. 1 — Schematic diagram of type HC1000 hybrid power module.

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:

$$P_d(max.) = \frac{T_J(max.) - T_C}{\theta_{J-C}}$$

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 θ_{J-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.

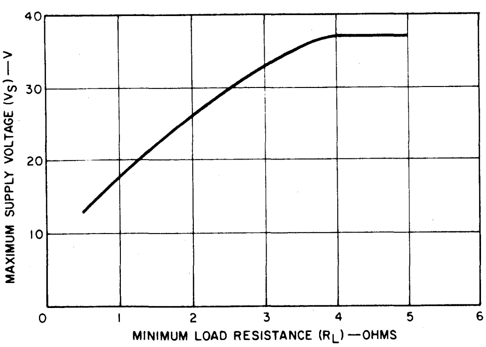

Fig. 2 — Maximum allowable supply voltage vs. load resistance for type HC1000.

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.

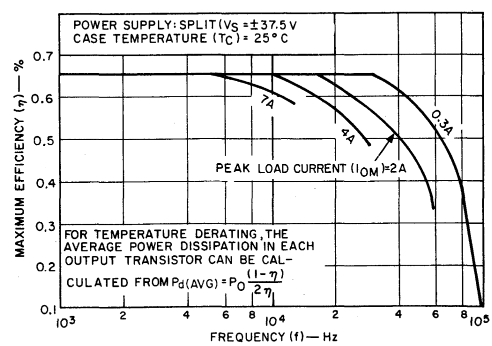

Fig. 3 — Maximum efficiency vs. frequency for type HC1000 with several values of peak load current.

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:

$V_S = \pm 32$ volts $f = 30$ kHz
$R_L = 8$ ohms $T_C = 25^o$ 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:

   $$\eta\,(30\ kHz) = 0.50 \times (0.57/0.65) = 0.44$$

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:

   $$P_{d2} = \frac{P_o\,(1 - \eta)}{\eta} - P_{d1} = \frac{25.6\,(1 - 0.44)}{0.44} - 25.6 = 7\ W$$

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^o 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.

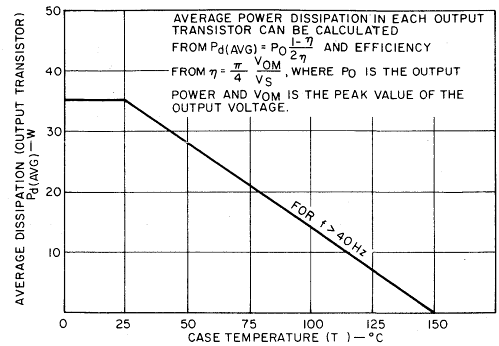

Fig. 4 — Dissipation (average) derating curve for each output transistor in type HC1000 (for symmetrical waveforms with f > 40 Hz).

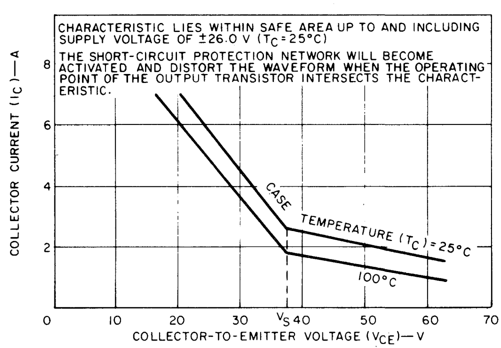

Fig. 5 — Characteristics of built-in load-line limiting circuit for type HC1000.

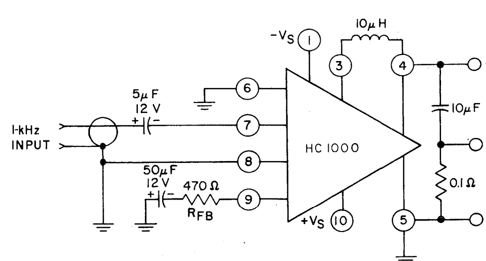

Figure 6 — Test set-up used to determine characteristics of built-in load-line limiting circuit for type HC-1000.

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.

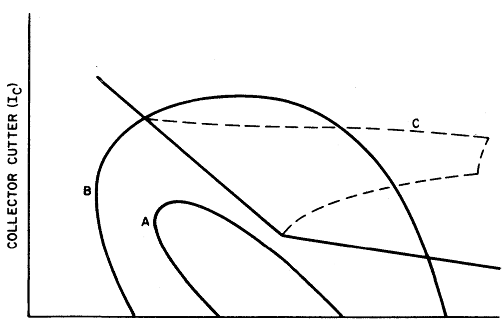

Figure 7 — Effect of protection circuit on the load-line characteristics of type HC1000 as the magnitude of the impedance decreases.

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:

$$T_J = T_A + \theta_{HS} P_d$$

or

$$\theta_{HS} = \frac{T_J - T_A}{P_d} - \theta_{J-C}$$

where $T_J = 150^o$ C, $\theta_{J\text{-}C} = 2^o$ 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.

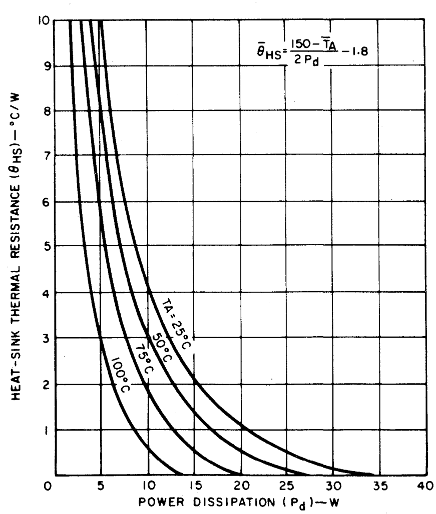

Figure 8 — Heat-sink thermal resistance as a function of power dissipation at various ambient temperatures.

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** of AN-4474 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.

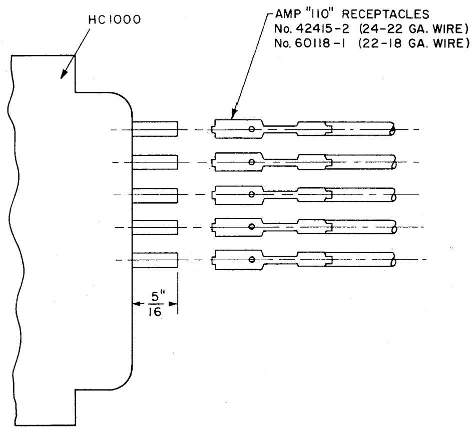

Figure 9 – Connection method for type HC1000 using standard AMP Receptacles

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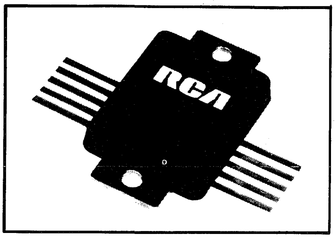
Power Hybrid Circuits

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.

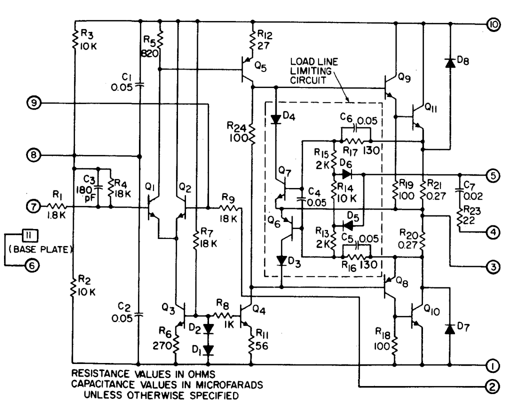
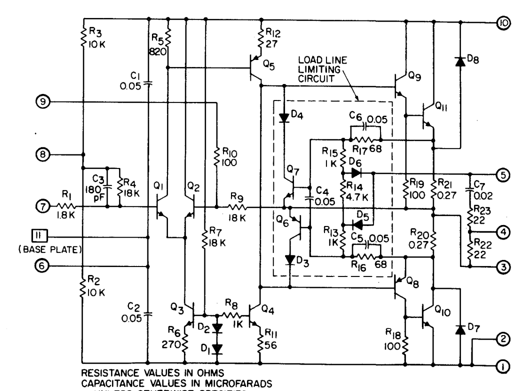


Fig. 1– Schematic diagram of the RCA-HC2000 power hybrid circuit operational amplifier.



**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.

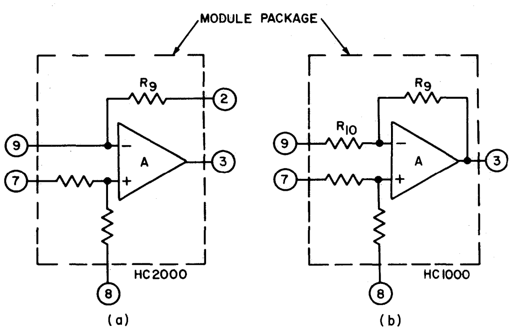


Fig. 3— Symbolic comparison of (a) the HC2000 and (b) the HC1000.

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.

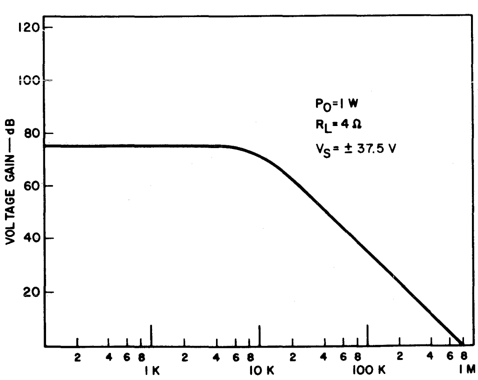


Fig. 4— Open-loop voltage gain as a function of frequency for the HC2000.

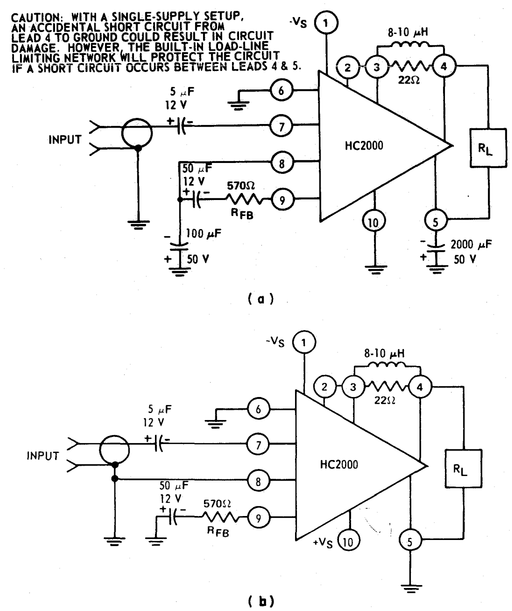


Fig. 5— Audio amplifier circuits that use the HC2000 with (a) a single power supply, and (b) a split power supply.

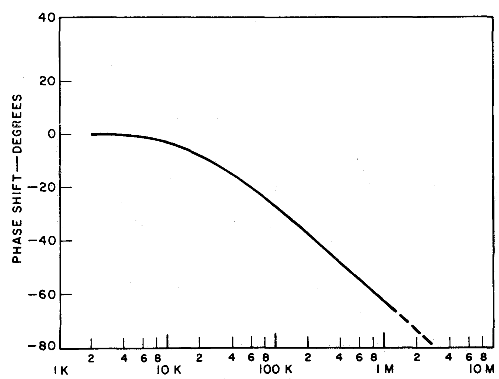


Fig. 6— Phase shift as a function of frequency for an audio amplifier using the HC2000 with phase compensation, as shown in Fig. 5.

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 °C, with a maximum value of 0.7 millivolts per °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 °C over the temperature range from -40°C to +100°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.

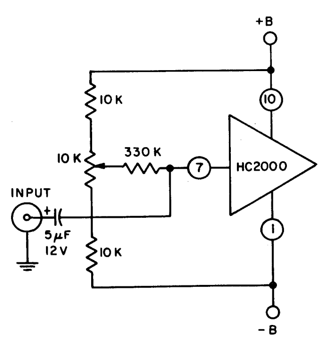


Fig. 7— Offset-voltage balancing network for use with HC2000.

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.

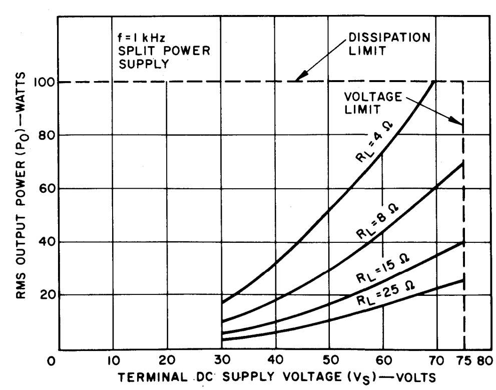


Fig. 8— Output power as a function of supply voltage, with various values of load resistance, for symmetrical sine-wave operation of the HC2000.

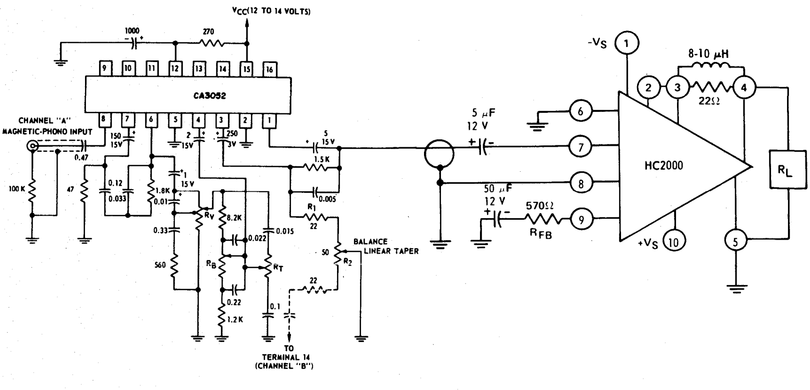


Fig. 9— One channel of a typical phonograph amplifier that uses the RCA-CA3052 for the preamplifier and the RCA-HC2000 for the power amplifier.

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.

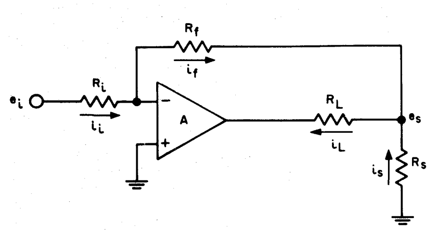


Fig. 10— The HC2000 used as a constant-current source.

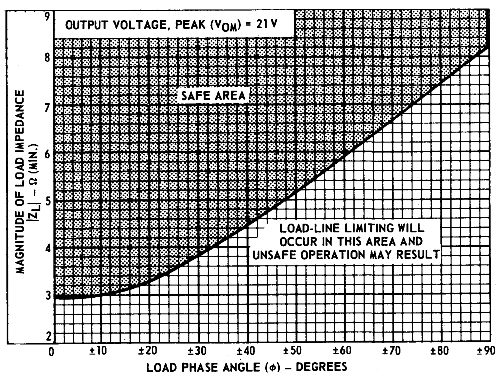


Fig. 11— Minimum load impedance as a function of load phase angle, and safe area of operation, for HC2000.

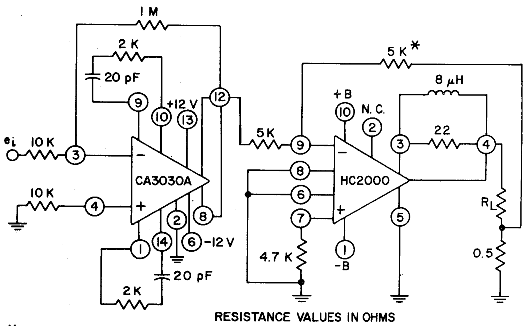
A typical circuit that uses an RCA-CA3030A in the voltage-gain mode and the HC2000 as a constant-current source is shown in Fig. 12. The over-all system provides a voltage gain of 34 dB, a current gain of 120 dB, and a transfer conductance ratio (I_{out}/V_{in}) of 0.1 ampere per millivolt. The current 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.



* NOTE: FOR APPLICATIONS THAT REQUIRE A LARGE FEEDBACK RESISTOR, THE OFFSET-VOLTAGE PROBLEMS DISCUSSED IN THE TEXT SHOULD BE CONSIDERED.

Fig. 12— The HC2000 connected as a constant-current source for servo motor control or deflection amplifier.

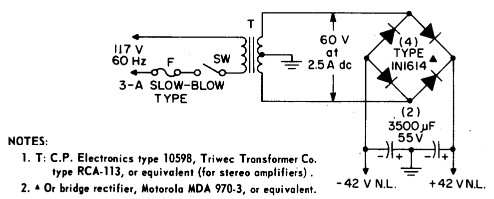


Fig. 13— A power supply for the HC2000.

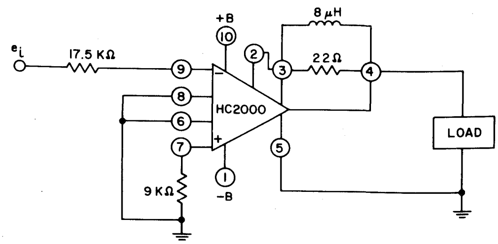


Fig. 14— Inverting unity-gain amplifier using internal feedback resistor.

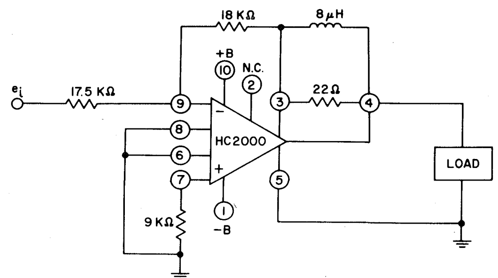


Fig. 15— Inverting unity-gain amplifier using external feedback resistor.

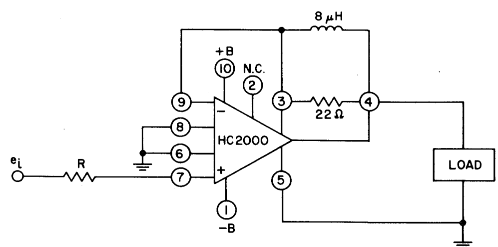


Fig. 16— Non-inverting unity-gain amplifier.

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 $\frac{i_L}{i_i}$:

$$i_L - i_i = -i_i\frac{R_f}{R_s} \quad (6)$$

$$i_L = i_i - i_i \frac{R_f}{R_s} \tag{7}$$

$$i_L = i_i \left(1 - \frac{R_f}{R_s}\right) \tag{8}$$

$$\frac{i_L}{i_i} = 1 - \frac{R_f}{R_s} \tag{9}$$

If $R_s << R_f$, then $\frac{R_f}{R_s} >> 1$ and

$$\frac{i_L}{i_i} = -\frac{R_f}{R_s} \tag{10}$$

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.

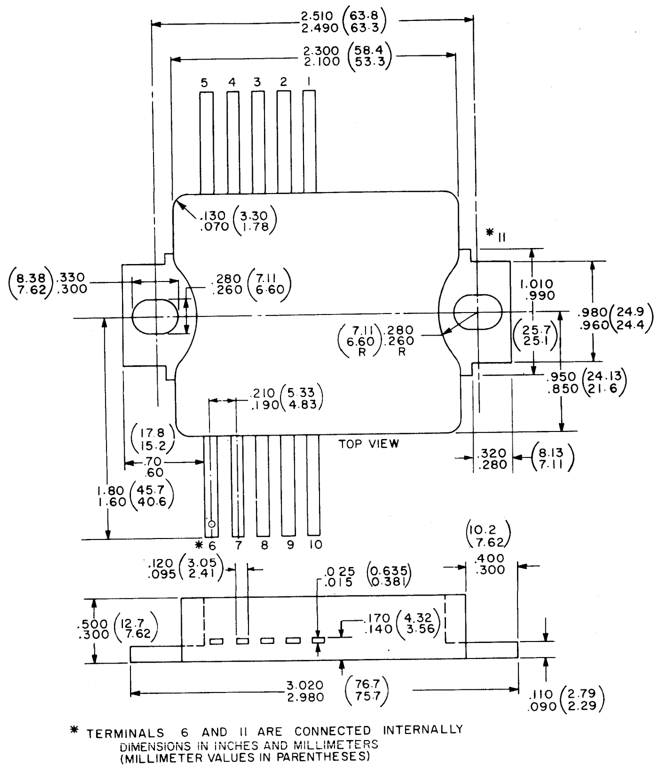


Fig. 17— Dimensional outline of RCA-HC2000.

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Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book
1N248C	6	206	1N3755	39	206	2N917	14	ALL	2N1847A	28	206	2N3668	116	206
1N249C	6	206	1N3756	39	206	2N918	83	205	2N1848A	28	206	2N3669	116	206
1N250C	6	206	1N4785	14	ALL	2N1066	14	ALL	2N1849A	28	206	2N3670	116	206
1N440B	5	206	1N5211	245	206	2N1090	14	ALL	2N1850A	28	206	2N3730	205	204
1N441B	5	206	1N5212	245	206	2N1091	14	ALL	2N1893	34	204	2N3731	205	204
1N442B	5	206	1N5213	245	206	2N1177	14	ALL	2N1905	17	204	2N3732	205	204
1N443B	5	206	1N5214	245	206	2N1178	14	ALL	2N1906	17	204	2N3733	72	205
1N444B	5	206	1N5215	245	206	2N1179	14	ALL	2N2015	12	204	2N3771	525	204
1N445B	5	206	1N5216	245	206	2N1180	14	ALL	2N2016	12	204	2N2772	525	204
1N536	3	206	1N5217	245	206	2N1183	4	204	2N2102	106	204	2N3773	526	204
1N537	3	206	1N5218	245	206	2N1183A	4	204	2N2147	204	204	2N3839	229	205
1N538	3	206	1N5391	478	206	2N1183B	4	204	2N2148	204	204	2N3866	80	205
1N539	3	206	1N5392	478	206	2N1184	4	204	2N2270	24	204	2N3870	94	206
1N540	3	206	1N5393	478	206	2N1184A	4	204	2N2338	141	204	2N3871	94	206
1N547	3	206	1N5394	478	206	2N1184B	4	204	2N2369A	14	ALL	2N3872	94	206
1N1095	3	206	1N5395	478	206	2N1224	14	ALL	2N2405	34	204	2N3873	94	206
1N1183A	38	206	1N5396	478	206	2N1225	14	ALL	2N2475	14	ALL	2N3878	299	204
1N1184A	38	206	1N5397	478	206	2N1226	14	ALL	2N2476	14	ALL	2N3879	299	204
1N1186A	38	206	1N5398	478	206	2N1300	14	ALL	2N2477	14	ALL	2N3896	94	206
1N1187A	38	206	1N5399	478	206	2N1301	14	ALL	2N2613	14	ALL	2N3897	94	206
1N1188A	38	206	1N5411	328	206	2N1302	14	ALL	2N2614	14	ALL	2N3898	94	206
1N1189A	38	206	2N176	14	ALL	2N1303	14	ALL	2N2631	32	205	2N3899	94	206
1N1190A	38	206	2N217	14	ALL	2N1304	14	ALL	2N2708	14	ALL	2N3932	14	ALL
1N1195A	6	206	2N270	14	ALL	2N1305	14	ALL	2N2857	61	205	2N3933	14	ALL
1N1196A	6	206	2N301	53	204	2N1306	14	ALL	2N2869	53	204	2N4012	90	205
1N1197A	6	206	2N301A	53	204	2N1307	14	ALL	2N2870	53	204	2N4036	216	204
1N1198A	6	206	2N351	14	ALL	2N1308	14	ALL	2N2876	32	205	2N4037	216	204
1N1199A	20	206	2N370	14	ALL	2N1309	14	ALL	2N2895	143	204	2N4063	64	204
1N1200A	20	206	2N372	14	ALL	2N1395	14	ALL	2N2896	143	204	2N4064	64	204
1N1202A	20	206	2N376	14	ALL	2N1396	14	ALL	2N2897	143	204	2N4068	14	ALL
1N1203A	20	206	2N388	14	ALL	2N1397	14	ALL	2N2953	14	ALL	2N4069	14	ALL
1N1204A	20	206	2N388A	14	ALL	2N1479	135	204	2N3053	432	204	2N4074	14	ALL
1N1205A	20	206	2N398	14	ALL	2N1480	135	204	2N3054	527	204	2N4101	114	206
1N1206A	20	206	2N398A	14	ALL	2N1481	135	204	2N3055	524	204	2N4102	114	206
1N1341B	58	206	2N398B	14	ALL	2N1482	135	204	2N3118	42	205	2N4103	116	206
1N1342B	58	206	2N404	14	ALL	2N1483	137	204	2N3119	44	205	2N4240	138	204
1N1344B	58	206	2N404A	14	ALL	2N1484	137	204	2N3228	114	206	2N4259	14	ALL
1N1345B	58	206	2N405	14	ALL	2N1485	137	204	2N3229	50	205	2N4314	216	204
1N1346B	58	206	2N406	14	ALL	2N1486	137	204	2N3241A	14	ALL	2N4346	206	204
1N1347B	58	206	2N407	14	ALL	2N1487	139	204	2N3242A	14	ALL	2N4347	528	204
1N1348B	58	206	2N408	14	ALL	2N1488	139	204	2N3261	14	ALL	2N4348	526	204
1N1612	18	206	2N412	14	ALL	2N1489	139	204	2N3262	56	204	2N4390	14	ALL
1N1613	18	206	2N414	14	ALL	2N1490	139	204	2N3263	54	204	2N4427	228	205
1N1614	18	206	2N585	14	ALL	2N1491	10	204	2N3264	54	204	2N4440	217	205
1N1615	18	206	2N591	14	ALL	2N1492	10	204	2N3265	54	204	2N4932	249	205
1N1616	18	206	2N647	14	ALL	2N1493	10	204	2N3266	54	204	2N4933	249	205
1N1763A	89	206	2N649	14	ALL	2N1524	14	ALL	2N3375	386	205	2N5016	255	205
1N1764A	89	206	2N681	96	206	2N1526	14	ALL	2N3439	64	204	2N5034	244	204
1N2326	14	ALL	2N682	96	206	2N1605	14	ALL	2N3440	64	204	2N5035	244	204
1N2858A	91	206	2N683	96	206	2N1605A	14	ALL	2N3441	529	204	2N5036	244	204
1N2859A	91	206	2N684	96	206	2N1613	106	204	2N3442	528	204	2N5037	244	204
1N2860A	91	206	2N685	96	206	2N1631	14	ALL	2N3478	77	205	2N5038	367	204
1N2861A	91	206	2N686	96	206	2N1632	14	ALL	2N3512	14	ALL	2N5039	367	204
1N2862A	91	206	2N687	96	206	2N1637	14	ALL	2N3525	114	206	2N5070	268	205
1N2863A	91	206	2N688	96	206	2N1638	14	ALL	2N3528	114	206	2N5071	269	205
1N2864A	91	206	2N689	96	206	2N1639	14	ALL	2N3529	114	206	2N5090	270	205
1N3193	41	206	2N690	96	206	2N1683	14	ALL	2N3553	386	205	2N5102	279	205
1N3194	41	206	2N697	16	204	2N1700	141	204	2N3583	138	204	2N5108	280	205
1N3195	41	206	2N699	22	204	2N1701	141	204	2N3584	138	204	2N5109	281	205
1N3196	41	206	2N706	14	ALL	2N1702	141	204	2N3585	138	204	2N5179	288	205
1N3253	41	206	2N706A	14	ALL	2N1711	26	204	2N3600	83	205	2N5180	14	ALL
1N3254	41	206	2N709	14	ALL	2N1842A	28	206	2N3632	386	205	2N5183	14	ALL
1N3255	41	206	2N718	14	ALL	2N1843A	28	206	2N3650	408	206	2N5184	14	ALL
1N3256	41	206	2N718A	36	204	2N1844A	28	206	2N3651	408	206	2N5185	14	ALL
1N3563	41	206	2N720A	36	204	2N1845A	28	206	2N3652	408	206	2N5186	14	ALL
1N3574	39	206	2N834	14	ALL	2N1846A	28	206	2N3653	408	206	2N5187	14	ALL

Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book
2N5188	14	ALL	2N5915	424	205	2N6292	542	204	40115	48	206	40346VI	211	204
2N5189	296	204	2N5916	425	205	2N6293	542	204	40208	120	206	40346V2	211	204
2N5202	299	204	2N5917	425	205	3N128	309	201	40209	120	206	40347	88	204
2N5239	321	204	2N5918	448	205	3N138	283	201	40210	120	206	40347VI	88	204
2N5240	321	204	2N5919	426	205	3N139	284	201	40211	120	206	40347V2	88	204
2N5262	313	204	2N5919A	505	205	3N140	285	201	40412	120	206	40348	88	204
2N5293	322	204	2N5920	440	205	3N141	285	201	40213	120	206	40348VI	88	204
2N5294	322	204	2N5921	427	205	3N142	286	201	40214	120	206	40348V2	88	204
2N5295	322	204	2N5954	435	204	3N143	309	201	40216	247	206	40349	88	204
2N5296	322	204	2N5955	435	204	3N152	314	201	40231	14	ALL	40349VI	88	204
2N5297	322	204	2N5956	435	204	3N153	320	201	40232	14	ALL	40349V2	88	204
2N5298	322	204	2N5992	451	205	3N154	335	201	40233	14	ALL	40354	14	ALL
2N5320	325	204	2N5993	452	205	3N159	326	201	40234	14	ALL	40355	14	ALL
2N5321	325	204	2N5994	453	205	3N187	436	201	40235	14	ALL	40359	14	ALL
2N5322	325	204	2N5995	454	205	3N200	437	201	40236	14	ALL	40360	78	204
2N5323	325	204	2N5996	455	205	101	557	204	40237	14	ALL	40361	78	204
2N5415	336	204	2N6032	462	204	102	557	204	40238	14	ALL	40362	78	204
2N5416	336	204	2N6033	462	204	103	557	204	40239	14	ALL	40363	78	204
2N5441	456	206	2N6077	492	204	104	557	204	40240	14	ALL	40364	78	204
2N5442	456	206	2N6078	492	204	105	556	204	40242	14	ALL	40366	215	204
2N5443	456	206	2N6079	492	204	106A	555	206	40243	14	ALL	40367	215	204
2N5444	456	206	2N6093	484	205	106B	555	206	40244	14	ALL	40368	215	204
2N5445	456	206	2N6098	485	204	106C	555	206	40245	14	ALL	40369	215	204
2N5446	456	206	2N6099	485	204	106D	555	206	40246	14	ALL	40372	527	204
2N5470	350	205	2N6100	485	204	106E	555	206	40250	112	204	40373	529	204
2N5490	353	204	2N6101	485	204	106F	555	206	40250VI	112	204	40374	138	204
2N5491	353	204	2N6102	485	204	106M	555	206	40251	112	204	40375	299	204
2N5492	353	204	2N6103	485	204	106Q	555	206	40254	69	204	40378	486	206
2N5493	353	204	2N6105	504	205	106Y	555	206	40266	75	206	40379	486	206
2N5494	353	204	2N6106	488	204	107A	555	206	40267	75	206	40385	215	204
2N5495	353	204	2N6107	488	204	107B	555	206	40279	46	205	40389	432	204
2N5496	353	204	2N6108	488	204	107C	555	206	40280	68	205	40390	64	204
2N5497	353	204	2N6109	488	204	107D	555	206	40281	68	205	40391	216	204
2N5567	457	206	2N6110	488	204	107E	555	206	40282	68	205	40392	432	204
2N5568	457	206	2N6111	488	204	107F	555	206	40290	70	205	40394	216	204
2N5569	457	206	2N6175	508	204	107M	555	206	40291	70	205	40395	14	ALL
2N5570	457	206	2N6176	508	204	107Q	555	206	40292	70	205	40396	14	ALL
2N5571	458	206	2N6177	508	204	107Y	555	206	40294	202	205	40397	14	ALL
2N5572	458	206	2N6211	507	204	201	557	204	40295	14	ALL	40398	14	ALL
2N5573	458	206	2N6212	507	204	202	557	204	40305	144	205	40399	14	ALL
2N5574	458	206	2N6213	507	204	203	557	204	40306	144	205	40400	14	ALL
2N5575	359	204	2N6246	541	204	204	557	204	40307	144	205	40405	14	ALL
2N5576	359	204	2N6247	541	204	205	556	204	40309	78	204	40406	219	204
2N5577	359	204	2N6248	541	204	370	558	204	40310	78	204	40407	219	204
2N5578	359	204	2N6249	523	204	371	558	204	40311	78	204	40408	219	204
2N5579	359	204	2N6250	523	204	410	509	204	40312	78	204	40409	219	204
2N5580	359	204	2N6251	523	204	411	510	204	40313	78	204	40410	219	204
2N5671	383	204	2N6253	524	204	413	511	204	40314	78	204	40411	219	204
2N5672	383	204	2N6254	524	204	423	512	204	40315	78	204	40412	211	204
2N5754	414	206	2N6257	525	204	431	513	204	40316	78	204	40412VI	211	204
2N5755	414	206	2N6258	525	204	520	558	204	40317	78	204	40412V2	211	204
2N5756	414	206	2N6259	526	204	521	558	204	40318	78	204	40413	14	ALL
2N5757	414	206	2N6260	527	204	40022	69	204	40319	78	204	40414	14	ALL
2N5781	413	204	2N6261	527	204	40050	67	204	40320	78	204	40421	115	204
2N5782	413	204	2N6262	528	204	40051	67	204	40321	78	204	40428	115	206
2N5783	413	204	2N6263	529	204	40080	301	205	40322	78	204	40429	351	206
2N5784	413	204	2N6264	529	204	40081	301	205	40323	78	204	40430	351	206
2N5785	413	204	2N6265	543	205	40082	301	205	40324	78	204	40431	477	206
2N5786	413	204	2N6266	544	205	40084	40	204	40325	78	204	40432	477	206
2N5804	407	204	2N6267	545	205	40108	48	206	40326	78	204	40439	205	204
2N5805	407	204	2N6268	546	205	40109	48	206	40327	78	204	40440	205	204
2N5838	410	204	2N6269	546	205	40110	48	206	40328	78	204	40446	301	205
2N5839	410	204	2N6288	542	204	40111	48	206	40329	14	ALL	40458	14	ALL
2N5840	410	204	2N6289	542	204	40112	48	206	40340	74	205	40462	220	204
2N5913	423	205	2N6290	542	204	40113	48	206	40341	74	205	40467A	324	201
2N5914	424	205	2N6291	542	204	40114	48	206	40346	211	204	40468A	323	201

Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book
40485	352	206	40628	358	204	40710	406	206	40780	443	206	40897	548	205
40486	352	206	40629	358	204	40711	406	206	40781	443	206	40898	538	205
40502	351	206	40630	358	204	40712	406	206	40782	443	206	40899	538	205
40503	351	206	40631	358	204	40713	406	206	40783	443	206	40900	540	206
40504	266	206	40632	358	204	40714	406	206	40784	443	206	40901	540	206
40505	266	206	40633	358	204	40715	406	206	40785	443	206	40902	540	206
40506	266	206	40634	358	204	40716	406	206	40786	443	206	40909	547	205
40507	265	206	40635	358	204	40717	406	206	40787	487	206	40910	527	204
40508	265	206	40636	358	204	40718	406	206	40788	487	206	40911	527	204
40509	352	206	40637	14	ALL	40719	406	206	40789	487	206	40912	529	204
40510	352	206	40638	352	206	40720	406	206	40790	487	206	40913	529	204
40511	477	206	40639	352	206	40721	406	206	40791	487	206	40916	549	206
40512	477	206	40640	354	206	40722	406	206	40792	487	206	40917	549	206
40513	244	204	40641	354	206	40723	406	206	40793	487	206	40918	549	206
40514	244	204	40642	354	206	40724	406	206	40794	487	206	40919	549	206
40519	14	ALL	40643	354	206	40725	406	206	40795	457	206	40920	549	206
40525	470	206	40644	354	206	40726	406	206	40796	457	206	40921	549	206
40526	470	206	40654	496	206	40727	406	206	40797	458	206	40922	549	206
40527	470	206	40655	496	206	40728	406	206	40798	458	206	40923	549	206
40528	470	206	40656	496	206	40729	406	206	40799	457	206	40924	549	206
40529	470	206	40657	496	206	40730	406	206	40800	457	206	40925	456	206
40530	470	206	40658	496	206	40731	406	206	40801	457	206	40926	456	206
40531	470	206	40659	496	206	40732	406	206	40802	458	206	40927	456	206
40532	470	206	40660	459	206	40733	406	206	40803	458	206	40934	550	205
40533	470	206	40661	459	206	40734	406	206	40804	458	206	40935	550	205
40534	470	206	40662	459	206	40735	408	206	40805	459	206	40936	551	205
40535	470	206	40663	459	206	40737	417	206	40806	459	206	40937	94	206
40536	470	206	40664	375	206	40738	417	206	40807	459	206	40938	94	206
40537	302	204	40665	386	205	40739	417	206	40808	449	206	40939	552	205
40538	302	204	40666	386	205	40740	417	206	40809	449	206	40940	553	205
40539	303	204	40667	375	206	40741	417	206	40810	473	206	40941	554	205
40542	304	204	40668	364	206	40742	417	206	40811	473	206	44001	495	206
40543	304	204	40669	364	206	40743	417	206	40812	473	206	44002	495	206
40544	303	204	40671	459	206	40744	417	206	40813	473	206	44003	495	206
40553	306	206	40672	459	206	40745	417	206	40819	463	201	44004	495	206
40554	306	206	40673	381	201	40746	417	206	40820	464	201	44005	495	206
40555	306	206	40680	409	206	40747	417	206	40821	464	201	44006	495	206
40559A	323	201	40681	409	206	40748	417	206	40822	465	201	44007	495	206
40575	300	206	40682	409	206	40749	418	206	40823	465	201	45190	559	204
40576	300	206	40683	409	206	40750	418	206	40833	496	206	45191	559	204
40577	297	205	40684	414	206	40751	418	206	40834	496	206	45192	559	204
40578	298	205	40685	414	206	40752	418	206	40835	496	206	45193	559	204
40581	301	205	40686	414	206	40753	418	206	40836	497	205	45194	559	204
40582	301	205	40687	414	206	40754	418	206	40837	497	205	45195	559	204
40583	329	206	40688	456	206	40755	418	206	40841	489	201	CA3000	121	201
40594	358	204	40689	456	206	40756	418	206	40842	493	206	CA3000/1	368	201
40595	358	204	40690	456	206	40757	418	206	40850	498	204	CA3000/2	368	201
40600	333	201	40691	431	206	40758	418	206	40851	498	204	CA3000/3	368	201
40601	333	201	40692	431	206	40759	418	206	40852	498	204	CA3000/4	368	201
40602	333	201	40693	406	206	40760	418	206	40853	498	204	CA3000H	516	201
40603	334	201	40694	406	206	40761	431	206	40854	498	204	CA3001	122	201
40604	334	201	40695	406	206	40762	431	206	40867	501	206	CA3001/1	369	201
40605	389	205	40696	406	206	40766	431	206	40868	501	206	CA3001/2	369	201
40608	356	205	40697	406	206	40767	431	206	40869	501	206	CA3001/3	369	201
40611	358	204	40698	406	206	40768	476	206	40885	508	204	CA3001/4	369	201
40612	358	204	40699	406	206	40769	441	206	40886	508	204	CA3001H	516	201
40613	358	204	40700	406	206	40770	441	206	40887	508	204	CA3002	123	201
40616	358	204	40701	406	206	40771	441	206	40888	522	206	CA3002/1	398	201
40618	358	204	40702	406	206	40772	441	206	40889	522	206	CA3002/2	398	201
40621	358	204	40703	406	206	40773	442	206	40890	522	206	CA3002/3	398	201
40622	358	204	40704	406	206	40774	442	206	40891	522	206	CA3002/4	398	201
40623	358	204	40705	406	206	40775	443	206	40892	522	206	CA3002H	516	201
40624	358	204	40706	406	206	40776	443	206	40893	514	205	CA3004	124	201
40625	358	204	40707	406	206	40777	443	206	40894	548	205	CA3005	125	201
40626	358	204	40708	406	206	40778	443	206	40895	548	205	CA3005H	516	201
40627	358	204	40709	406	206	40779	443	206	40896	548	205	CA3006	370	201

Type No.	File No.	Data-Book
CA3007	126	201
CA3008	316	201
CA3008A	310	201
CA3010	316	201
CA3010A	310	201
CA3011	128	201
CA3012	128	201
CA3012H	516	201
CA3013	129	201
CA3014	129	201
CA3015	316	201
CA3015A	310	201
CA3015A/1	371	201
CA3015A/2	371	201
CA3015A/3	371	201
CA3015A/4	371	201
CA3015H	516	201
CA3015L	515	201
CA3016	316	201
CA3016A	310	201
CA3018	338	201
CA3018A	338	201
CA3018H	516	201
CA3018L	515	201
CA3019	236	201
CA3020	339	201
CA3020A	339	201
CA3020H	516	201
CA3021	243	201
CA3022	243	201
CA3023	243	201
CA3023H	516	201
CA3026	388	201
CA3026H	516	201
CA3028A	382	201
CA3028AH	516	201
CA3028AL	515	201
CA3028B	382	201
CA3028B/1	400	201
CA3028B/2	400	201
CA3028B/3	400	201
CA3028B/4	400	201
CA3029	316	201
CA3029A	310	201
CA3030	316	201
CA3030A	310	201
CA3031/ 702A	14	ALL
CA3031/ 702C	14	ALL
CA3033	360	201
CA3033A	360	201
CA3033H	516	201
CA3035	274	201
CA3035H	516	201
CA3035VI	274	201
CA3036	275	201
CA3037	316	201
CA3037A	310	201
CA3038	316	201
CA3038A	310	201
CA3039	343	201
CA3039L	515	201
CA3040	363	201
CA3041	318	201
CA3042	319	201
CA3043	331	201
CA3043H	516	201
CA3044	340	201
CA3044Y1	340	201
CA3045	341	201
CA3045/1	401	201
CA3045/2	401	201
CA3045/3	401	201
CA3045/4	401	201
CA3045H	516	201
CA3045L	515	201
CA3046	341	201
CA3047	360	201
CA3047A	360	201
CA3048	377	201
CA3048H	516	201
CA3049	378	201
CA3049H	516	201
CA3050	361	201
CA3051	361	201
CA3052	387	201
CA3053	382	201
CA3054	388	201
CA3054H	516	201
CA3054L	515	201
CA3058	490	201
CA3059	490	201
CA3059H	516	201
CA3060AD	537	201
CA3060BD	537	201
CA3060D	537	201
CA3060E	537	201
CA3060H	516	201
CA3062	421	201
CA3064	396	201
CA3065	412	201
CA3066	466	201
CA3067	466	201
CA3068	467	201
CA3070	468	201
CA3071	468	201
CA3072	468	201
CA3075	429	201
CA3075H	516	201
CA3076	430	201
CA3078AT	535	201
CA3078H	516	201
CA3078T	535	201
CA3079	490	201
CA3080	475	201
CA3080A	475	201
CA3080H	516	201
CA3081	480	201
CA3081H	516	201
CA3082	480	201
CA3082H	516	201
CA3083	481	201
CA3083H	516	201
CA3084	482	201
CA3084H	516	201
CA3084L	515	201
CA3085	491	201
CA3085A	491	201
CA3085B	491	201
CA3085H	516	201
CA3086	483	201
CA3088E	560	201
CA3089E	561	201
CA3090Q	502	201
CA3091D	534	201
CA3093E	533	201
CA3118AT	532	201
CA3118T	532	201
CA3146AE	532	201
CA3146E	532	201
CA3183AE	532	201
CA3183E	532	201
CA3458T	531	201
CA3541D	536	201
CA3558T	531	201
CA3741CH	516	201
CA3741CT	531	201
CA3741L	515	201
CA3741T	531	201
CA3747CE	531	201
CA3747CT	531	201
CA3747E	531	201
CA3747T	531	201
CA3748CT	531	201
CA3748T	531	201
CA6741T	530	201
CD2150	308	—
CD2151	308	—
CD2152	308	—
CD2153	308	—
CD2154	402	—
CD2155D	403	—
CD2200	14	ALL
CD2200D	14	ALL
CD2201	14	ALL
CD2201D	14	ALL
CD2202	14	ALL
CD2202D	14	ALL
CD2203	14	ALL
CD2203D	14	ALL
CD2204	14	ALL
CD2204D	14	ALL
CD2205	14	ALL
CD2205D	14	ALL
CD2300/ 930	14	ALL
CD2300D/ 930	14	ALL
CD2300E/ 830	14	ALL
CD2301/ 961	14	ALL
CD2301D/ 961	14	ALL
CD2301E/ 861	14	ALL
CD2302/ 946	14	ALL
CD2302D/ 946	14	ALL
CD2302E/ 846	14	ALL
CD2303/ 949	14	ALL
CD2303D/ 949	14	ALL
CD2303E/ 849	14	ALL
CD2304/ 945	14	ALL
CD2304D/ 945	14	ALL
CD2304E/ 845	14	ALL
CD2305/ 948	14	ALL
CD2305D/ 948	14	ALL
CD2305E/ 848	14	ALL
CD2306/ 932	14	ALL
CD2306D/ 932	14	ALL
CD2306E/ 832	14	ALL
CD2307/ 944	14	ALL
CD2307D/ 944	14	ALL
CD2308D/ 962	14	ALL
CD2308E/ 862	14	ALL
CD2309/ 963	14	ALL
CD2309D/ 963	14	ALL
CD2309E/ 863	14	ALL
CD2310/ 936	14	ALL
CD2310D/ 936	14	ALL
CD2310E/ 836	14	ALL
CD2311/ 937	14	ALL
CD2311D/ 937	14	ALL
CD2311E/ 837	14	ALL
CD2312	14	ALL
CD2312D	14	ALL
CD2312E	14	ALL
CD2313	14	ALL
CD2313D	14	ALL
CD2313E	14	ALL
CD2314/ 933	14	ALL
CD2314D/ 933	14	ALL
CD2314E/ 833	14	ALL
CD2315	14	ALL
CD2315D	14	ALL
CD2315E	14	ALL
CD2316	14	ALL
CD2316D	14	ALL
CD2316E	14	ALL
CD2317	14	ALL
CD2317D	14	ALL
CD2317E	14	ALL
CD2318	14	ALL
CD2318D	14	ALL
CD2318E	14	ALL
CD2500E	392	—
CD2501E	392	—
CD2502E	392	—
CD2503E	392	—
CD4000AD	479	203
CD4000AE	479	203
CD4000AH	517	203
CD4000AK	479	203
CD4001AD	479	203
CD4001AE	479	203
CD4001AH	517	203
CD4001AK	479	203
CD4002AD	479	203
CD4002AE	479	203
CD4002AH	517	203
CD4002AK	479	203
CD4006AD	479	203
CD4006AE	479	203
CD4006AH	517	203
CD4006AK	479	203
CD4007AD	479	203
CD4007AE	479	203
CD4007AH	517	203
CD4007AK	479	203
CD4008AD	479	203
CD4008AE	479	203
CD4008AH	517	203
CD4008AK	479	203
CD4009AD	479	203
CD4009AE	479	203
CD4009AH	517	203
CD4009AK	479	203
CD4010AD	479	203
CD4010AE	479	203
CD4010AH	517	203
CD4010AK	479	203
CD4011AD	479	203
CD4011AE	479	203
CD4011AH	517	203
CD4011AK	479	203
CD4012AD	479	203
CD4012AE	479	203
CD4012AH	517	203
CD4012AK	479	203
CD4013AD	479	203
CD4013AE	479	203
CD4013AH	517	203
CD4013AK	479	203
CD4014AD	479	203
CD4014AE	479	203
CD4014AH	517	203
CD4014AK	479	203
CD4015AD	479	203
CD4015AE	479	203
CD4015AH	517	203
CD4015AK	479	203
CD4016AD	479	203
CD4016AE	479	203
CD4016AH	517	203
CD4016AK	479	203
CD4017AD	479	203
CD4017AE	479	203

Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book	Type No.	File No.	Data-Book
CD4017AH	517	203	CD4024AH	517	203	CD4032AE	503	203	CR106	84	206	CR313	60	206
CD4017AK	479	203	CD4024AK	503	203	CD4032AH	517	203	CR107	84	206	CR314	60	206
CD4018AD	479	203	CD4024AT	503	203	CD4032AK	503	203	CR108	84	206	CR315	60	206
CD4018AE	479	203	CD4025AD	479	203	CD4033AD	503	203	CR109	84	206	CR316	60	206
CD4018AH	517	203	CD4025AE	479	203	CD4033AE	503	203	CR110	84	206	CR317	60	206
CD4018AK	479	203	CD4025AH	517	203	CD4033AH	517	203	CR201	86	206	CR321	60	206
CD4019AD	479	203	CD4025AK	479	203	CD4033AK	503	203	CR203	86	206	CR322	60	206
CD4019AE	479	203	CD4026AD	503	203	CD4038AD	503	203	CR204	86	206	CR323	60	206
CD4019AH	517	203	CD4026AE	503	203	CD4038AE	503	203	CR206	86	206	CR324	60	206
CD4019AK	479	203	CD4026AH	517	203	CD4038AH	517	203	CR208	86	206	CR325	60	206
CD4020AD	479	203	CD4026AK	503	203	CD4038AK	503	203	CR210	86	206	CR331	60	206
CD4020AE	479	203	CD4027AD	503	203	CH2102	469	204	CR212	86	206	CR332	60	206
CD4020AH	517	203	CD4027AE	503	203	CH2270	469	204	CR273/			CR333	60	206
CD4020AK	479	203	CD4027AH	517	203	CH2405	469	204	8008	100	206	CR334	60	206
CD4021AD	479	203	CD4027AK	503	203	CH3053	469	204	CR274/			CR335	60	206
CD4021AE	479	203	CD4028AD	503	203	CH3439	469	204	872A	100	206	CR341	60	206
CD4021AH	517	203	CD4028AE	503	203	CH3440	469	204	CR275/			CR342	60	206
CD4021AK	479	203	CD4028AH	517	203	CH4036	469	204	866A/3B28	100	206	CR343	60	206
CD4022AD	479	203	CD4028AK	503	203	CH4037	469	204	CR280	86	206	CR344	60	206
CD4022AE	479	203	CD4029AD	503	203	CH5320	469	204	CR301	60	206	CR351	60	206
CD4022AH	517	203	CD4029AE	503	203	CH5321	469	204	CR302	60	206	CR352	60	206
CD4022AK	479	203	CD4029AH	517	203	CH5322	469	204	CR303	60	206	CR353	60	206
CD4023AD	479	203	CD4029AK	503	203	CH5323	469	204	CR304	60	206	CR354	60	206
CD4023AE	479	203	CD4030AD	503	203	CR101	84	206	CR305	60	206	HC1000	461	204
CD4023AH	517	203	CD4030AE	503	203	CR102	84	206	CR306	60	206	HC2000	506	204
CD4023AK	479	203	CD4030AH	517	203	CR103	84	206	CR307	60	206	HC3000	539	204
CD4024AD	503	203	CD4030AK	503	203	CR104	84	206	CR311	60	206			
CD4024AE	503	203	CD4032AD	503	203	CR105	84	206	CR312	60	206			

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If you are not presently receiving the newsletter and have obtained one or more DATABOOKS from a source other than RCA, please fill out just one copy of the following form, detach it, and mail to RCA:

(a) from North and South America and Far East, mail to RCA Solid State Division, Box 3200, Somerville, N.J. 08876.

(b) from United Kingdom, mail to RCA Limited, Lincoln Way, Windmill Road, Sunbury-on-Thames, Middlesex, England.

(c) from Europe, Middle East and Africa, mail to RCA S/A Parc-Industriel des Hauts-Sarts, Herstal, Liege, Belgium.

Name ☐☐☐☐☐☐ ☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐

(First) (Middle) (Last)

Company ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

(Number) (Street, RFD, P.O. Box)

Home ☐
Business ☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐ ☐☐☐☐☐☐☐☐

(City) (State or Prov.)

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(Country) (Zip or Pstl. Zone)

Job Function ____________________

Product Area of Interest ____________________

Company End Product ____________________