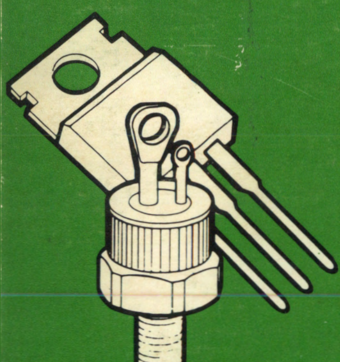
RCA **Solid State**

DATABOOK Series

SSD-206A

Thyristors, Rectifiers, and Diacs

Selection Guide
Data
Application Notes



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1973 Edition

RCA Solid State
DATABOOK Series

Thyristors, Rectifiers and Diacs

This DATABOOK contains complete data and related application notes on thyristors, rectifiers, and diacs presently available from RCA Solid State Division as standard products. For ease of type selection, product matrix charts for triacs and silicon controlled rectifiers are given on pages 11–20. Data sheets are then grouped in the following categories: (a) triacs, (b) silicon controlled rectifiers; (c) rectifiers; (d) diacs. Application notes are included in numerical order following the data sheets.

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

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

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

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B ☐ Purchasing/Procurement
C ☐ Research/Development
D ☐ Design Engineer
E ☐ Application/Components Engineer
F ☐ Production/Manufacturing
G ☐ Documentation/Library
H ☐ Reliability/QA
I ☐ Education/Training
J ☐ Program/Project Management
K ☐ Marketing

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A ☐ Broadcast
B ☐ Communication
C ☐ Instrumentation/Control
D ☐ Computer/Data Processing
E ☐ Computer, Peripheral
F ☐ Automotive
G ☐ Industrial
H ☐ Medical
I ☐ Research
J ☐ Transportation
K ☐ Consumer, Electronic
L ☐ Consumer, Appliance
M ☐ Space
N ☐ Ordnance
O ☐ Avionics
P ☐ Electronic Warfare

Product Interest: (Indicate order of interest if more than one is marked)

A ☐ Linear IC's
B ☐ Digital IC's, COS/MOS
C ☐ Digital IC's, Bipolar
D ☐ Thyristors/Rectifiers
E ☐ Liquid Crystals
F ☐ Semiconductor Diodes
G ☐ RF Power Semiconductors
H ☐ MOSFETS
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J ☐ Power Hybrid Circuits

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2N5444	Triac	40	200	593	127
2N5445	Triac	40	400	593	127
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2N5569	Triac	10	200	457	83
2N5570	Triac	10	400	457	83
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2N5756	Triac	2.5	400	414	22
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40114	Rectifier	10	600	48	319
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40431	Triac	6	200	477	48
40432	Triac	6	400	477	48
40485	Triac	6	200	352	54
40486	Triac	6	400	352	54
40502	Triac	3.3	200	351	41
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40505	SCR	1.7	400	266	168
40506	SCR	1.7	600	266	168
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40510	Triac	2.2	400	352	54
40511	Triac	2.2	200	477	48
40512	Triac	2.2	400	477	48
40525	Triac	2.5	100	470	27
40526	Triac	2.5	200	470	27
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40529	Triac	2.5	200	470	27
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40531	Triac	1.6	100	470	27
40532	Triac	1.6	200	470	27
40533	Triac	1.6	400	470	27
40534	Triac	1.9	100	470	27
40535	Triac	1.9	200	470	27
40536	Triac	1.9	400	470	27
40553	SCR	5	200	306	175
40554	SCR	5	400	306	175
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40575	Triac	15	200	300	105
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40656	SCR	7	200	496	191
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40658	SCR	3.3	200	496	191
40659	SCR	3.3	400	496	191
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40661	Triac	30	400	459	112
40662	Triac	30	200	459	112
40663	Triac	30	400	459	112
40664	Triac	6	450	375	61
40667	Triac	6	450	375	61
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40669	Triac	8	400	364	73
40671	Triac	30	600	459	112
40672	Triac	30	600	459	112
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40681	SCR	35	200	578	242
40682	SCR	35	400	578	242
40683	SCR	35	600	578	242
40684	Triac	1.9	100	414	22
40685	Triac	1.9	200	414	22
40686	Triac	1.9	400	414	22
40687	Triac	1.9	600	414	22
40688	Triac	40	200	593	127
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40692	Triac	2.5	400	431	34
40693	Triac	2.5	100	406	141
40694	Triac	2.5	200	406	141
40695	Triac	2.5	400	406	141
40696	Triac	2.5	100	406	141
40697	Triac	2.5	200	406	141
40698	Triac	2.5	400	406	141
40699	Triac	40	200	406	141
40700	Triac	40	400	406	141
40701	Triac	40	600	406	141
40702	Triac	40	200	406	141
40703	Triac	40	400	406	141
40704	Triac	40	600	406	141
40705	Triac	30	200	406	141
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40717	Triac	10	200	406	141
40718	Triac	10	400	406	141
40719	Triac	10	200	406	141
40720	Triac	10	400	406	141
40721	Triac	8	200	406	141
40722	Triac	8	400	406	141
40723	Triac	6	450	406	141
40724	Triac	6	450	406	141
40725	Triac	6	200	406	141
40726	Triac	6	400	406	141
40727	Triac	6	200	406	141
40728	Triac	6	400	406	141
40729	Triac	3.3	200	406	141
40730	Triac	3.3	400	406	141
40731	Triac	2.3	200	406	141
40732	Triac	2.3	400	406	141
40733	Triac	4.2	200	406	141
40734	Triac	4.2	400	406	141
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40738	SCR	10	200	417	206
40739	SCR	10	400	417	206
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40756	SCR	20	600	418	225
40757	SCR	20	100	418	225
40758	SCR	20	200	418	225
40759	SCR	20	400	418	225
40760	SCR	20	600	418	225
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40766	Triac	2.5	100	431	34
40767	Triac	1.6	100	431	34
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40769	Triac	0.5	200	441	35
40770	Triac	0.5	400	441	35
40771	Triac	0.5	200	441	35
40772	Triac	0.5	400	441	35
40773	Triac	2.5	200	442	67
40774	Triac	2.5	400	442	67
40775	Triac	6	200	443	90
40776	Triac	6	400	443	90
40777	Triac	6	200	443	90
40778	Triac	6	400	443	90
40779	Triac	10	200	443	90
40780	Triac	10	400	443	90
40781	Triac	10	200	443	90
40782	Triac	10	400	443	90
40783	Triac	15	200	443	90
40784	Triac	15	400	443	90
40785	Triac	15	200	443	90
40786	Triac	15	400	443	90
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40788	Triac	25	400	487	119
40789	Triac	25	200	487	119
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40791	Triac	40	200	487	119
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40793	Triac	40	200	487	119
40794	Triac	40	400	487	119
40795	Triac	10	600	457	83
40796	Triac	10	600	457	83
40797	Triac	15	600	458	98
40798	Triac	15	600	458	98
40799	Triac	10	200	457	83
40800	Triac	10	400	457	83
40801	Triac	10	600	457	83
40802	Triac	15	200	458	98
40803	Triac	15	400	458	98
40804	Triac	15	600	458	98
40805	Triac	30	200	459	112
40806	Triac	30	400	459	112
40807	Triac	30	600	459	112
40808	Rectifier	0.5	600	449	311
40809	Rectifier	0.5	800	449	311
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40834	SCR	7	600	496	192
40835	SCR	3.3	600	496	192
40842	Triac	6	450	493	79
40867	SCR	8	100	501	200
40868	SCR	8	200	501	200
40869	SCR	8	400	501	200
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40891	Rectifier	3	700	522	304
40892	Rectifier	1	700	522	304
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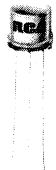
40901	Triac	8	200	540	143
40902	Triac	8	400	540	143
40916	Triac	80	200	549	134
40917	Triac	80	400	549	134
40918	Triac	80	600	549	134
40919	Triac	80	200	549	134
40920	Triac	80	400	549	134
40921	Triac	80	600	549	134
40922	Triac	80	200	549	134
40923	Triac	80	400	549	134
40924	Triac		600	549	134
40925	Triac	40	800	593	127
40926	Triac	40	800	593	127
40927	Triac	40	800	593	127
40937	SCR	35	800	578	243
40938	SCR	35	800	578	243
40942	SCR	4.5	100	567	161
40943	SCR	4.5	200	567	161
40944	SCR	4.5	400	567	161
40945	SCR	4.5	600	567	161
40946	Triac	6	600	351	41
40947	Triac	3.3	600	351	41
40948	Triac	6	600	352	54
40949	Triac	2.2	600	352	54
40950	Triac	6	600	352	54
40952	SCR	35	800	578	243
40956	Rectifier	40	50	580	333
40957	Rectifier	40	100	580	333
40958	Rectifier	40	200	580	333
40959	Rectifier	40	400	580	333
40960	Rectifier	40	600	580	333
44001	Rectifier	1	50	495	296
44002	Rectifier	1	100	495	296
44003	Rectifier	1	200	495	296
44004	Rectifier	1	400	495	296
44005	Rectifier	1	600	495	296
44006	Rectifier	1	800	495	296
44007	Rectifier	1	1000	495	296
45411	Diac	2	29-35	577	354
45412	Diac	2	25-40	577	354
CR101	Rectifier	1	1265	84	337
CR102	Rectifier	0.925	2530	84	337
CR103	Rectifier	0.825	4430	84	337
CR105	Rectifier	0.7	5065	84	337
CR106	Rectifier	0.65	6330	84	337
CR107	Rectifier	0.6	7595	84	337
CR108	Rectifier	0.6	8230	84	337
CR109	Rectifier	0.6	9495	84	337
CR110	Rectifier	0.6	10130	84	337
CR201	Rectifier	0.615	1900	86	341
CR203	Rectifier	0.615	3165	86	341
CR204	Rectifier	0.615	4800	86	341
CR206	Rectifier	0.615	6330	86	341
CR208	Rectifier	0.615	8000	86	341
CR210	Rectifier	0.615	10000	86	341
CR212	Rectifier	0.615	12000	86	341
CR273/8008	Rectifier	Replaces type 8008		100	350
CR247/872A	Rectifier	Replaces type 872, 872A		100	350
CR275/866A/ 3B25/3B28	Rectifier	Replaces types 866A, 3B25, 3B28		100	350
CR280	Rectifier	0.615	24000	86	350
CR301	Rectifier	5	2400	60	344
CR302	Rectifier	5	3600	60	344
CR303	Rectifier	5	4800	60	344
CR304	Rectifier	5	6000	60	344
CR305	Rectifier	5	7200	60	344
CR306	Rectifier	5	8400	60	344
CR307	Rectifier	5	9600	60	344
CR311	Rectifier	9	2400	60	344
CR312	Rectifier	9	3600	60	344
CR313	Rectifier	9	4800	60	344
CR314	Rectifier	9	6000	60	344
CR315	Rectifier	9	7200	60	344
CR316	Rectifier	9	8400	60	344
CR317	Rectifier	9	9600	60	344
CR321	Rectifier	12	2400	60	344
CR322	Rectifier	12	3600	60	344

Index to Thyristors, Rectifiers and Diacs (cont'd)

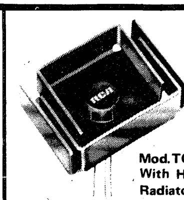
Application Notes for Thyristors, Rectifiers and Diacs

Triac Product Matrix

RCA Triacs



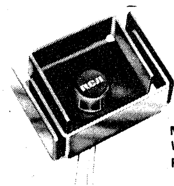
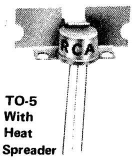
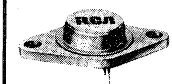
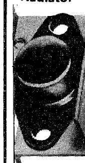
Modified TO-5



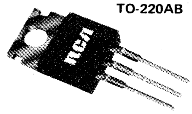
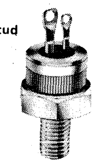
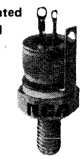
Mod. TO-5 With Heat Radiator

	$I_{T(RMS)}$	2.5A	2.5A	2.5A	2.5A	2-Lead 6.0A	2-Lead 6.0A	2-Lead 6.0A	2.5A	2.5A
STANDARD	I_{TSM}	25A	25A	25A	25A	100A	100A	100A	25A	25A
STANDARD	V_{DROM} (V) 100	40525	40766	40528	2N5754				40684	40531
STANDARD	200	40526	40691	40529	2N5755	40485		40431	40685	40532
STANDARD	400	40527	40692	40530	2N5756	40486		40432	40686	40533
STANDARD	450						40664			
STANDARD	600				2N5757				40687	
STANDARD	800									
STANDARD	I_{GT} (mA) I+, III-	3	4	10	25	25	50	INT.	25	3
	I–, III+	3	4	10	40	40	--	TRIG.	40	3
	V_{GT} (V) All Modes	2.2	2.2	2.2	2.2	2.2	4.0	–	2.2	2.2
	File No.	470	431	470	414	352	375	477	414	470
	Page No.	27	34	27	22	54	61	48	22	27
ZERO VOLTAGE SWITCH	V_{DROM} (V) 100				40696				40693	
ZERO VOLTAGE SWITCH	200				49697	40725			40694	
ZERO VOLTAGE SWITCH	400				40698	40726			40695	
ZERO VOLTAGE SWITCH	450					40723				
ZERO VOLTAGE SWITCH	600									
ZERO VOLTAGE SWITCH	I_{GT} (mA) I+, III+				45	45			45	
ZERO VOLTAGE SWITCH	V_{GT} (V) I+, III+				1.5	1.5			1.5	
	File No.				406	406			406	
	Page No.				135	135			135	
	$I_{T(RMS)}$			0.5A	0.5A	2.5A				
400-HZ OPERATION	V_{DROM} (V) 200			40769	40771	40773				
400-HZ OPERATION	400			40770	40772	40774				
400-HZ OPERATION	I_{GT} (mA) I+, III–			10	25	25				
400-HZ OPERATION	I–, III+			10	40	40				
400-HZ OPERATION	V_{GT} (V) All Modes			2.2	2.2	2.2				
	File No.			441	441	442				
	Page No.			35	35	67				

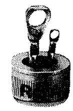
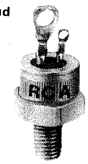
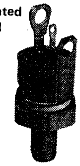
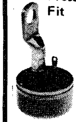
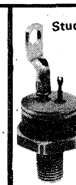
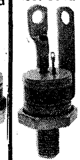
Triac Product Matrix (cont'd)

RCA Triacs										
		 Mod.TO-5 With Heat Radiator				 TO-5 With Heat Spreader		TO-66 		TO-66 With Heat Radiator 
	$I_{T(RMS)}$	2.5A	2.5A	6.0A	6.0A	6.0A	6.0A	6.0A	15.0A	6.0A
	I_{TSM}	25A	25A	100A	100A	100A	100A	100A	100A	100A
STANDARD	V_{DROM} (V) 100	40534	40767							
	200	40535	40761	40511	40509	40638		40429	40575	40502
	400	40536	40762	40512	40510	40639		40430	40576	40503
	450						40667			
	600									
	800									
	I_{GT} (mA) I+, III-	10	4	INT.	25	25	50	25	30	25
	I−, III+	10	4	TRIG.	40	40	–	40	80	40
	V_{GT} (V) All Modes	2.2	2.2	–	2.2	2.2	4.0	2.2	2.5	2.2
	File No.	470	431	477	352	352	375	351	300	351
	Page No.	27	34	42	54	54	61	41	106	41
ZERO VOLTAGE SWITCH	V_{DROM} (V) 100									
	200				40731	40733		40727	40715	40729
	400				40732	40734		40728	40716	40730
	450				40724					
	600									
	I_{GT} (mA) I+, III+				45	45		45	45	45
	V_{GT} (V) I+, III+				1.5	1.5		1.5	1.5	1.5
	File No.				406	406		406	406	406
	Page No.				141	141		141	141	141

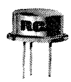
Triac Product Matrix (cont'd)

RCA Triacs		TO-220AB VERSAWATT 			Press Fit 		Stud 		Isolated Stud 	
	$I_{T(RMS)}$	8.0A	8.0A	ISOWATT 8.0A	10.0A	15.0A	10.0A	15.0A	10.0A	15.0A
	I_{TSM}	100A	100A	100A	100A	100A	100A	100A	100A	100A
STANDARD	V_{DROM} (V) 100			40900						
	200	40668		40901	2N5567	2N5571	2N5569	2N5573	40799	40802
	400	40669		40902	2N5568	2N5572	2N5570	2N5574	40800	40803
	450		40842							
	600				40795	40797	40796	40798	40801	40804
	800									
	I_{GT} (mA) I+, III-	25	25/30	25	25	50	25	50	25	50
	I–, III+	60	80	60	40	80	40	80	40	80
	V_{GT} (V) All Modes	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	V_{DROM} (V) 100									
	File No.	364	493	540	457	458	457	458	457	458
	Page No.	73	79	143	83	98	83	98	83	98
ZERO VOLTAGE SWITCH	200	40721			40717	40711	40719	40713		
	400	40722			40718	40712	40720	40714		
	450									
	600									
	I_{GT} (mA) I+, III+	45			45	45	45	45		
	V_{GT} (V) I+, III+	1.5			1.5	1.5	1.5	1.5		
	File No.	406			406	406	406	406		
	Page No.	141			141	141	141	141		
	$I_{T(RMS)}$				10.0A	15.0A	10.0A	15.0A		
400-HZ OPERATION	V_{DROM} (V) 200				40779	40783	40781	40785		
	400				40780	40784	40782	40786		
	I_{GT} (mA) I+, III–				50	50	50	50		
	I–, III+				80	80	80	80		
	V_{GT} (V) All Modes				2.5	2.5	2.5	2.5		
	File No.				443	443	443	443		
	Page No.				90	90	90	90		

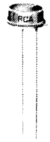
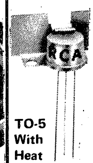
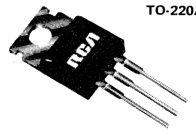
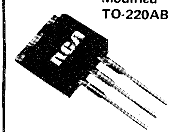
Triac Product Matrix (cont'd)

RCA Triacs		Press Fit 		Stud 		Isolated Stud 		Press Fit 	Stud 	Iso. Stud 
	$I_{T(RMS)}$	30.0A	40.0A	30.0A	40.0A	30.0A	40.0A	80.0A	80.0A	80.0A
	I_{TSM}	300A	300A	300A	300A	300A	300A	850A	850A	850A
STANDARD	V_{DROM} (V) 100									
	200	40660	2N5441	40662	2N5444	40805	40688	40916	40919	40922
	400	40661	2N5442	40663	2N5445	40806	40689	40917	40920	40923
	450									
	600	40671	2N5443	40672	2N5446	40807	40690	40918	40921	40924
	800		40925		40926		40927			
	I_{GT} (mA) I+, III-	50	50	50	50	50	50	75	75	75
	I–, III+	80	80	80	80	80	80	150	150	150
	V_{GT} (V) All Modes	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	V_{DROM} (V) 100									
	File No.	459	593	459	593	459	593	549	549	549
	Page No.	112	127	112	127	112	127	134	134	134
ZERO VOLTAGE SWITCH	200	40705	40699	40707	40702					
	400	40706	40700	40708	40703					
	450									
	600	40709	40701	40710	40704					
	I_{GT} (mA) I+, III+	45	45	45	45					
	V_{GT} (V) I+, III+	1.5	1.5	1.5	1.5					
	File No.	406	406	406	406					
	Page No.	141	141	141	141					
	$I_{T(RMS)}$	25.0A	40.0A	25.0A	40.0A					
400-HZ OPERATION	V_{DROM} (V) 200	40787	40791	40789	40793					
	400	40788	40792	40790	40794					
	I_{GT} (mA) I+, III–	80	80	80	80					
	I–, III+	120	120	120	120					
	V_{GT} (V) All Modes	3.0	3.0	3.0	3.0					
	File No.	487	487	487	487					
	Page No.	119	119	119	119					

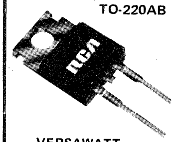
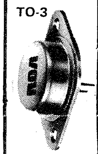
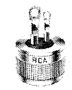
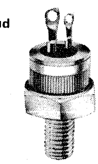
SCR Product Matrix

RCA SCR's	TO-8 	TO-66 					TO-66 With Heat Rad. 
$I_{T(RMS)}$	2.0A	5.0A	FTO 5.0A	5.0A	5.0A	5.0A	5.0A
I_{TSM}	60A	60A	80A	–	50A	50A	60A
V_{DROM} 15							
V_{RROM} (V) 25							
30							
50							
100							
150							
200	2N3528	2N3228	40553				40504
250							
300							
400	2N3529	2N3525	40554				40505
500							
600	2N4102	2N4101	40555	40768			40506
700					40889		
750						40888	
800							
I_{GT} (mA)	15	15	40	35	45	40	15
V_{GT} (V)	2	2	3.5	4	4	4	2
File No.	114	114	306	476	522	522	266
Page No.	166	166	175	190	192	193	173

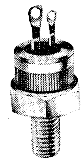
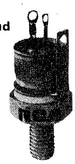
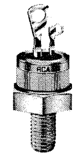
SCR Product Matrix (cont'd)

RCA SCR's	Low Profile Mod. TO-5 	TO-5, With Heat Rad. 	TO-5 With Heat Spreader 	TO-220AB VERSAWATT 			Modified TO-220AB VERSAWATT 	
$I_{T(RMS)}$	7.0A	7.0A	7.0A	4.0A	4.0A	8.0A	4.0A	4.0A
I_{TSM}	100A	100A	100A	35A	35A	100A	35A	35A
V_{DROM} V_{RROM} (V) 15				106Q1	107Q1		106Q2	107Q2
25								
30				106Y1	107Y1		106Y2	107Y2
50				106F1	107F1		106F2	107F2
100				106A1	107A1	40867	106A2	107A2
150								
200	40378	40658	40656	106B1	107B1	40868	106B2	107B2
250								
300				106C1	107C1		106C2	107C2
400	40379	40659	40657	106D1	107D1	40869	106D2	107D2
500				106E1	107E1		106E2	107E2
600		40835	40834	106M1	107M1		106M2	107M2
700								
750								
800								
I_{GT} (mA)	15	15	15	0.2	0.5	15	0.2	0.5
V_{GT} (V)	2	1.5	1.5	0.8	0.8	1.5	0.8	0.8
File No.	496	496	496	555	555	501	555	555
Page No.	197	197	197	155	155	205	155	155

SCR Product Matrix (cont'd)

RCA SCR's		Modified TO-220AB  VERSAWATT		TO-3 	Press Fit 			Stud 	
$I_{T(RMS)}$		**4.0A**	**4.0A**	**12.5A**	**10.0A**	**20.0A**	**35.0A**	**10.0A**	**20.0A**
I_{TSM}		35A	35A	200A	100A	200A	350A	100A	200A
V_{DROM}	**15**	106Q3	107Q3						
V_{RROM} (V)	**25**								
	30	106Y3	107Y3						
	50	106F3	107F3						
	100	106A3	107A3	2N3668	40737	40749	2N3870	40741	40753
	150								
	200	106B3	107B3	2N3669	40738	40750	2N3871	40742	40754
	250								
	300	106C3	107C3						
	400	106D3	107D3	2N3670	40739	40751	2N3872	40743	40755
	500	106E3	107E3						
	600	106M3	107M3	2N4103	40740	40752	2N3873	40744	40756
	700								
	750								
	800						40937		
I_{GT} (mA)		0.2	0.5	40	15	15	40	15	15
V_{GT} (V)		0.8	0.8	2	2	2	2	2	2
File No.		555	555	116	417	418	578	417	418
Page No.		155	155	219	211	248	211	230	155

SCR Product Matrix (cont'd)

RCA SCR's	Stud 	Isolated Stud 			TO-48 			
$I_{T(RMS)}$	**35.0A**	**10.0A**	**20.0A**	**35.0A**	**16.0A**	**25.0A**	**FTO 35.0A**	**FTO 40.0A**
I_{TSM}	350A	100A	200A	350A	125A	150A	180A	250A
V_{DROM} V_{RROM} (V) 15								
25					2N1842A	2N681		
30								
50					2N1843A	2N682		
100	2N3896	40745	40757	40680	2N1844A	2N683	2N3650	
150					2N1845A	2N684		
200	2N3897	40746	40758	40681	2N1846A	2N685	2N3651	TA7393
250					2N1847A	2N686		
300					2N1848A	2N687	2N3652	
400	2N3898	40747	40759	40682	2N1849A	2N688	2N3653	TA7394
500					2N1850A	2N689		
600	2N3899	40748	40760	40683		2N690	40735	TA7395
700								
750								
800	40938			40952				
I_{GT} (mA)	40	15	15	40	45	25	180	80
V_{GT} (V)	2	2	2	2	3.5	3	3	3
File No.	578	417	418	578	28	96	408	–
Page No.	248	211	230	248	226	238	241	–

* Data sheets on developmental (TA) types available on request.

Rectifier Product Matrix

RCA Rectifiers

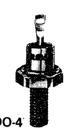
DO-1

DO-26

I_O	0.125A	0.75A	0.75A	1A	1A	2A	0.5A Aval-anche	0.75A	0.75A Insulated	1A	1A Insulated
I_{FSM}	30A	15A	15A	35A	35A	35A	35A	–	–	–	–
$V_{RRM}(V)$ 50			1N536		1N2858A						
100	1N3754	1N440B	1N537		1N2859A	40266					
200	1N3755	1N441B	1N538		1N2860A	40267		1N3193	1N3253	1N5211	1N5215
300		1N442B	1N539		1N2861A						
400	1N3756	1N443B	1N540	1N1763A	1N2862A			1N3194	1N3254	1N5212	1N5216
500		1N444B	1N1095	1N1764A	1N2863A						
600		1N445B	1N547		1N2864A		40808	1N3195	1N3255	1N5213	1N5217
800							40809	1N3196	1N3256	1N5214	1N5218
1000									1N3563		
File No.	39	5	3	89	91	75	449	41	41	245	245
Page	264	268	271	278	286	315	317	274	274	292	292

RCA Rectifiers

DO-15



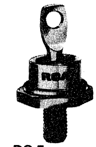
DO-4

DO-5

I_O	1A	1.5A	5A	6A	10A	12A	18A	20A	40A
I_{FSM}	30A	50A	–	160A	140A	240A	250A	350A	800A
$V_{RRM}(V)$ 50	44001	1N5391	1N1612	1N1341B	40108	1N1199A	40208	1N248C	1N1183A
100	44002	1N5392	1N1613	1N1342B	40109	1N1200A	40209	1N249C	1N1184A
200	44003	1N5393	1N1614	1N1344B	40110	1N1202A	40210	1N250C	1N1186A
300		1N5394		1N1345B	40111	1N1203A	40211	1N1195A	1N1187A
400	44004	1N5395	1N1615	1N1346B	40112	1N1204A	40212	1N1196A	1N1188A
500		1N5396		1N1347B	40113	1N1205A	40213	1N1197A	1N1189A
600	44005	1N5397	1N1616	1N1348B	40114	1N1206A	40214	1N1198A	1N1190A
800	44006	1N5398			40115				
1000	44007	1N5399							
File No.	495	478	18	58	48	20	120	6	38
Page	302	306	321	323	325	326	330	332	336

Rectifier Product Matrix (cont'd)

Fast Recovery Types*

RCA Rectifiers	 DO-26		 DO-4		 DO-5	
I_O	1A	3A	6A	12A	20A	40A
I_{FSM}	35A	75A	125A	250A	300A	700A
V_{RRM}(V) 50						
100			TA8411	TA8415	TA8419	TA7984
200	TA7892	TA7898	TA8412	TA8416	TA8420	TA7985
300						
400	TA7893	TA7899	TA8413	TA8417	TA8421	TA7986
500						
600	TA7894	TA7900	TA8414	TA8418	TA8422	TA7987
800	TA7895	TA7901				
1000						
Reverse Recovery Time trr						
Typ.	200 ns	200 ns	200 ns	200 ns	200 ns	200 ns
Max.	500 ns	500 ns	350 ns	350 ns	350 ns	350 ns

*Data sheets on developmental (TA) types available on request.

For Horizontal Deflection Circuits

RCA Rectifiers	 DO-26			 DO-1		 DO-15
I_O	1A	1A	1A	–	–	–
I_{FSM}	70A	10A	20A	70A	30A	
Trace	40642			40890		TA8215*
Commutating		40643		40891		TA8216*
Linearity			40644			TA8217*
Regulator						TA8218*
Clamp					40892	
File No.	354	354	354	522	522	—
Page	296	296	296	310	310	—

*Data sheets on developmental (TA) types available on request.

Triacs

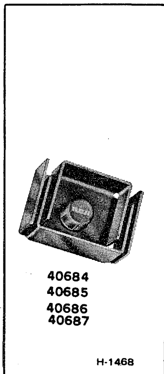
RCA

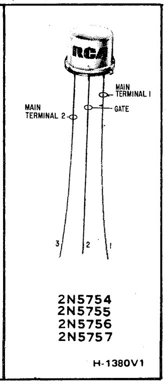
Solid State
Division

Thyristors

2N5754 2N5756 40685
2N5755 2N5757 40686
40684 40687

2.5-Ampere Silicon Triacs





For Low-Power Phase-Control and Load-Switching Applications

For Low-Voltage Operation – 2N5754, 40684
For 120-V Line Operation – 2N5755, 40685
For 240-V Line Operation – 2N5756, 40686
For High-Voltage Operation – 2N5757, 40687

Features:

- **25/40 mA I_{GT}**
- **Shorted Emitter Design**
- **3-Lead Package for Printed Circuit Board Applications**
- **Small Size . . . Suitable for Remote Switching Applications**

These RCA triacs are gate-controlled, full-wave silicon ac switches.

These devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

The gate sensitivity of these triacs permits the use of economical transistorized control circuits and enhances their use in low-power phase control and load-switching applications.

Types **2N5754, 2N5755, 2N5756, 2N5757**★ utilize a compact package (similar to JEDEC TO-5) and have an RMS on-state current rating of 2.5 A and repetitive peak off-state voltage ratings of 100, 200, 400, and 600 volts, respecitively.

Types **40684, 40685, 40686, 40687**▲ are the same as the 2N5754, 2N5755, 2N5756, 2N5757, respectively but have factory-attached heat-radiators and are intended for printed-circuit board applications.

★ Formerly RCA Dev. types TA7500, TA7501, TA7502, and TA7503, respectively.

▲ Formerly RCA Dev. types TA7579, TA7580, TA7581, and TA7582, respectively.

MAXIMUM RATINGS, ***Absolute-Maximum Values:***
For Operation with 50/60-Hz, Sinuosidal Supply Voltage and Resistive or Inductive Load

* REPETITIVE PEAK OFF-STATE VOLTAGE♦	V_{DROM}		
Gate Open, T_J = 65° to 100°C			
2N5754, 40684		100	V
2N5755, 40685		200	V
2N5756, 40686		400	V
2N5757, 40687		600	V
RMS ON-STATE CURRENT	$I_{T(RMS)}$		
Conduction angle = 360°:			
* Case temperature (T_C) = 70°C			
2N5754, 2N5755, 2N5756, 2N5757		2.5	A
Ambient temperature (T_A) = 25°C			
40684, 40685, 40686, 40687		1.9	A
For other conditions		See Figs. 2,3,4, & 5.	
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT	I_{TSM}		
* For one full cycle of applied principal voltage (60-Hz, sinusoidal)		25	A
For one full cycle of applied principal voltage (50-Hz, sinusoidal)		21	A
For more than one full cycle of applied voltage		See Fig.6.	
* PEAK GATE-TRIGGER CURRENT	I_{GTM}		
For 1 μs 1 max		1	A
GATE POWER DISSIPATION:			
* PEAK†	P_{GM}		
For 1 μs max		10	W
AVERAGE	$P_{G(AV)}$		
* For case temperature (T_C) = 60°C		0.15	W
* For ambient temperature (T_A) = 25°C		0.05	W
* TEMPERATURE RANGE‡:			
Storage		-65 to 150	°C
Operating (case)		-65 to 100	°C
* LEAD TEMPERATURE:			
During soldering, terminal temperature at a distance ≥ 1/16 in. (1.58 mm) from the case for 10 s		225	°C

♦ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

‡ For information on the reference point of temperature measurement, see *Dimensional Outlines.*

* In accordance with JEDEC registration data format (JS-14, RDF-2).

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS ALL TYPES Min.	Typ.	Max.	UNITS
* **Peak Off-State Current:** ♦ Gate Open, T_J = 100°C and V_{DROM} = Max. rated value	I_{DROM}	-	0.2	0.75	mA
Maximum On-State Voltage: ♦	V_{TM}				V
For i_T = 10 A (peak) and T_C = 25°C		-	2.2	2.6	
* For i_T = 3.5 A (peak) and T_C = 25°C		-	-	1.8	
DC Holding Current: ♦ Gate Open, Initial principal current = 150 mA (DC), V_D = 12 V	I_{HO}				mA
At T_C = 25°C		-	6	35	
At T_C = -65°C		-	20	82*	
For other case temperatures		← See Fig.8. →			
* **Critical Rate-of-Rise of Off-State Voltage:** ♦ For V_D = V_{DROM}, exponential voltage rise, and gate open, T_C = 100°C	dv/dt	10	100	-	V/μs
DC Gate-Trigger Current: ♦ † For V_D = 12 V (DC), R_L = 30Ω, and T_C = 25°C (Mode / V_{MT2} / V_G)	I_{GT}				mA
I⁺ positive positive		-	5	25	
III⁻ negative negative		-	5	25	
I⁻ positive negative		-	10	40	
III⁺ negative positive		-	10	40	
T_C = -65°C: I⁺ positive positive		-	30	60*	
III⁻ negative negative		-	30	60*	
I⁻ positive negative		-	40	100*	
III⁺ negative positive		-	40	100*	
For other case temperatures		← See Fig.11. →			
DC Gate-Trigger Voltage: ♦ † For V_D = 12 V (DC) and R_L = 30 Ω	V_{GT}				V
At T_C = 25°C		-	0.9	2.2	
At T_C = -65°C		-	1.5	3*	
For other case temperatures		← See Fig.12. →			
* For v_D = V_{DROM} and R_L = 125Ω At T_C = 100°C		0.2	-	-	
* **Thermal Resistance, Junction-to-Case:** Steady-State	$\theta_{J\text{-}C}$	-	-	8.5	°C/W

♦ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

* In accordance with JEDEC registration data format (JS-14, RDF-2).

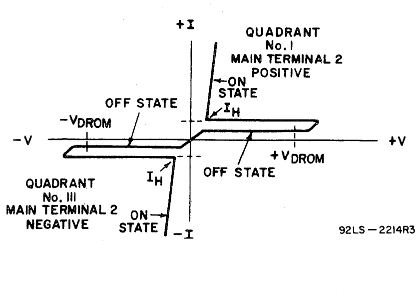


Fig.1 - Principal voltage-current characteristic.

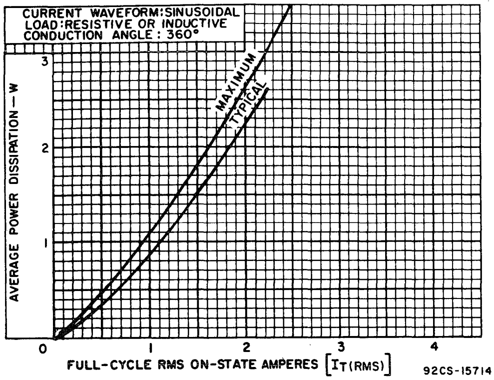


Fig.2 - Power dissipation vs. on-state current.

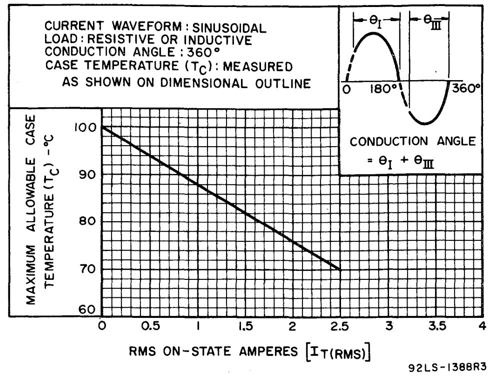


Fig.3 - Maximum allowable case temperature vs. on-state current.

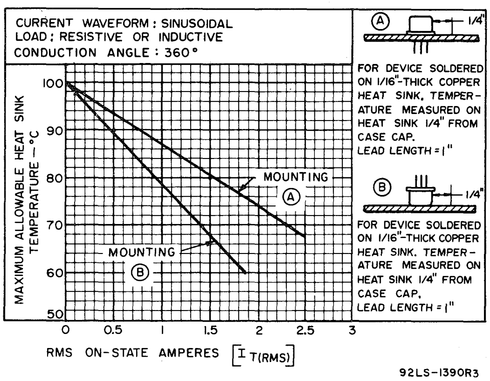


Fig.4 - Maximum allowable heat-sink temperature vs. on-state current.

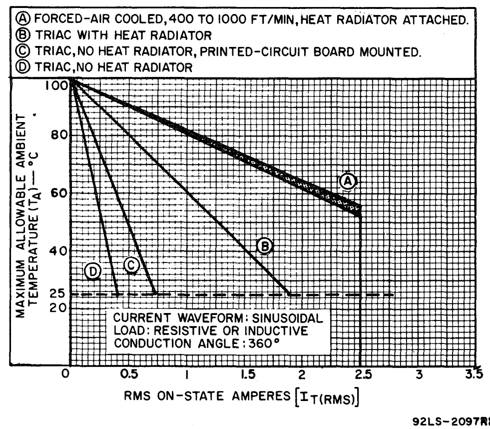


Fig.5 - Maximum allowable ambient temperature vs. on-state current.

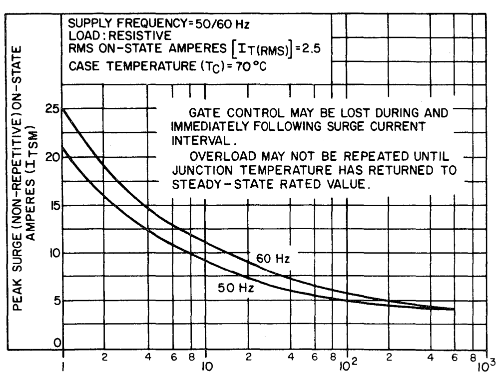


Fig.6 - Peak surge on-state current vs. surge-current duration.

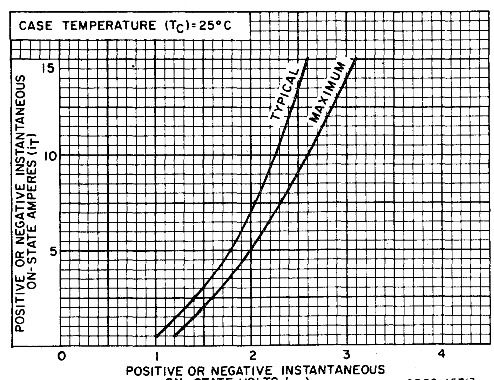


Fig.7 - On-state current vs. on-state voltage.

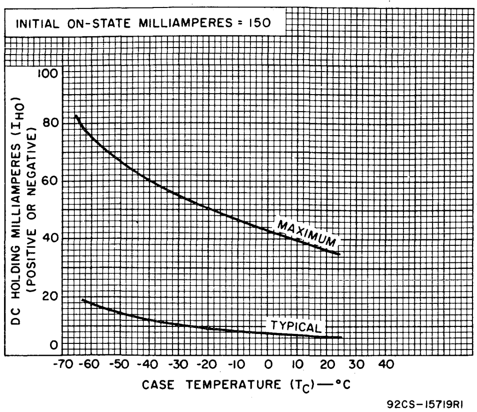


Fig.8 - DC holding current (positive or negative) vs. case temperature.

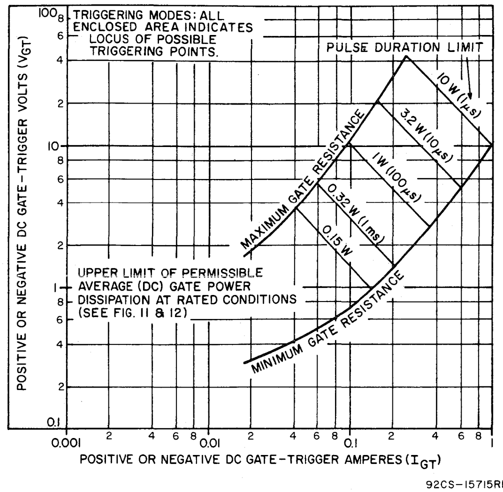
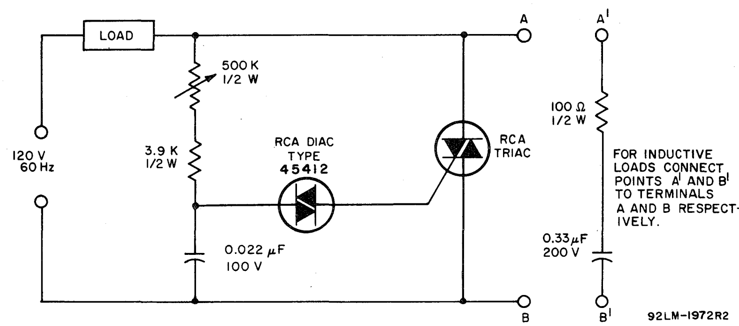


Fig.9 - Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.



NOTE: For incandescent lamp loads which produce burnout current surges with I^2t values greater than 2.5 ampere^2 seconds, connect a 10-ohm resistor of appropriate power rating in series with the load. This rating can be determined as follows:

Power Rating of 10-ohm Resistor = 10(rms load current)^2

Fig.10 - Typical phase-control circuit.

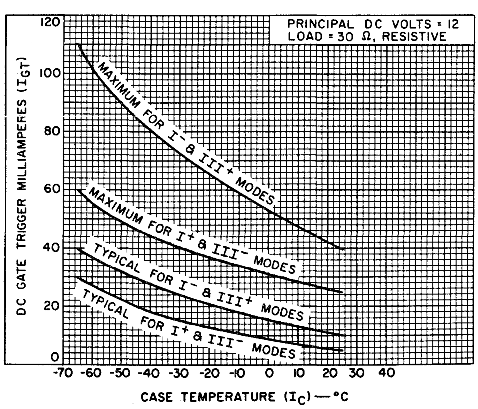


Fig.11 - DC gate-trigger current vs. case temperature.

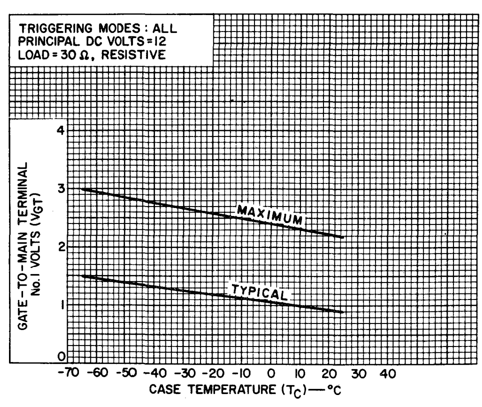
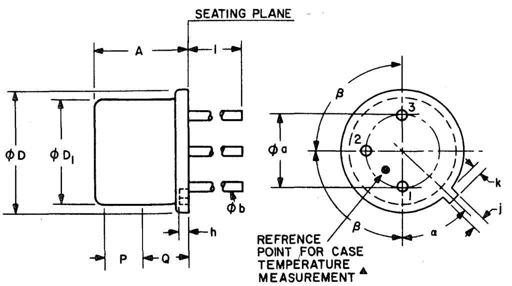


Fig.12 - DC gate-trigger voltage vs. case temperature.

DIMENSIONAL OUTLINE FOR TYPES 2N5754, 2N5755, 2N5756, 2N5757



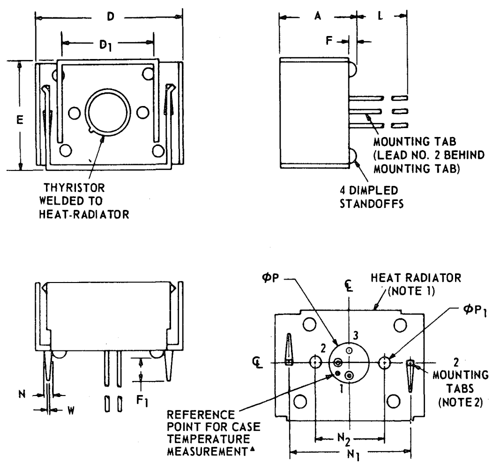
▲The temperature reference point specified should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 16 should be attached at the temperature reference point.

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕa	.190	.210	4.83	5.33	
A	.240	.260	6.10	6.60	
ϕb	.017	.021	.44	.53	
ϕD	.335	.366	8.51	9.30	
ϕD1		.330	8.13	8.38	
h	.015	.035	.38	.89	
i	.028	.035	.71	.89	
k	.029	.045	.74	1.14	
l	.975	1.025	24.76	26.03	
P	.100	-	2.54	-	
Q	-	-	-	-	1
α	45° NOMINAL				
β	50° NOMINAL				

Note 1: Details of outline in this zone optional.

92LM-2048R2

DIMENSIONAL OUTLINE FOR TYPES 40684, 40685, 40686, 40687



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D1	.745	.755	18.923	19.177	
E	.875	.905	22.22	22.99	
F	.040	.055	1.02	1.40	
F1	.170	.225	4.32	5.72	
L	.920	–	23.37	–	
ΦP	.295	.305	7.493	7.747	
ΦP1	.093	.095	2.362	2.413	
N	.048	.062	1.21	1.57	
N1	.998	1.002	25.349	25.450	3
N2	.687	.689	17.45	17.50	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 in. (1.78 mm) dia.
3. Measured at bottom of heat radiator

▲The specified temperature-reference point should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 26 should be attached at the temperature reference point.

92LM-2109R1

TERMINAL CONNECTIONS

For Types 2N5754, 2N5755, 2N5756, 2N5657

Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Case, Lead No. 3 – Main terminal 2

For Types 40684, 40685, 40686, 40687

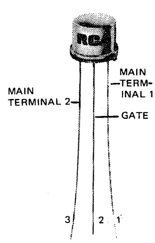
Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Heat Rad., Lead No. 3 – Main terminal 2

RCA Solid State Division

Thyristors

40525 40528 40531 40534
40526 40529 40532 40535
40527 40530 40533 40536

40531 40534
40532 40535
40533 40536
H-1468



40525 40528
40526 40529
40527 40530
H-1380V1

2.5-Ampere Sensitive-Gate Silicon Triacs

For Low-Power Phase-Control and Load-Switching Applications

For Low-Voltage Operation — 40525, 40528, 40531, 40534
For 120-V Line Operation — 40526, 40529, 40532, 40535
For 240-V Line Operation — 40527, 40530, 40533, 40536

Features:

- **Very High Gate Sensitivity**
  3 mA max. for types 40525, 40526, 40527, 40531, 40532, 40533
  10 mA max. for types 40528, 40529, 40530, 40534, 40535, 40536
- **3-Lead Package for Printed Circuit Board Applications**
- **Shorted Emitter Design**

RCA 40525 through 40530 are gate-controlled full-wave ac silicon switches. They are designed to switch from a blocking state to a conducting state for either polarity of applied voltage with positive or negative gate triggering.

The 40528, 40529, and 40530 differ from types 40525, 40526, and 40527 in that they have higher dv/dt capability and higher gate trigger current requirements. The gate sensitivity of these triacs permits the use of economical transistorized and IC control circuits and enhances their use in low-power phase control and load-switching applications.

The 40525, 40526, and 40527 have rms on-state current ratings of 2.5 amperes at a case temperature of +60° C while the 40528, 40529, and 40530 have the same ratings at a case temperature of +70° C.

The repetitive peak off-state voltage rating for the 40525 and 40528 is 100 volts; for the 40526 and 40529, 200 volts; and for the 40527 and 40530, 400 volts.

Types 40531–40536 (inclusive) are the same as the 40525–40530, respectively but have factory-attached heat-radiators and are intended for printed-circuit board applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with 50/60-Hz, Sinuosidal Supply Voltage and Resistive or Inductive Load

REPETITIVE PEAK OFF-STATE VOLTAGE♦ (Gate Open):	V_{DROM}		
T_J = -40° C to +90° C: 40525, 40531		100	V
40526, 40532		200	V
40527, 40533		400	V
T_J = -40° C to +100°C: 40528, 40534		100	V
40529, 40535		200	V
40530, 40536		400	V
RMS ON-STATE CURRENT (Conduction Angle = 360°):	$I_{T(RMS)}$		
T_C = 60° C: 40525, 40526, 40527		2.5	A
T_C = 70° C: 40528, 40529, 40530		2.5	A
T_A = 25° C: 40525, 40526, 40527		0.35	A
40528, 40529, 40530		0.40	A
For other conditions		**See Figs. 2, 3, 4 & 5**	
For heat-radiator types		**See Figs. 6 & 7**	
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}		
For one full cycle of applied principal voltage			
60 Hz sinusoidal		25	A
50 Hz sinusoidal		21	A
For more than on full cycle of applied voltage		**See Fig. 8**	
PEAK GATE-TRIGGER CURRENT+:	I_{GTM}		
For 1 μs max		0.5	A

MAXIMUM RATINGS (Cont'd)

GATE POWER DISSIPATION†:			
Peak (For 1 μs max.)	P_{GM}	10	W
Average: T_C = 60° C	$P_{G\ (AV)}$	0.15	W
T_A = 25° C		0.05	W
TEMPERATURE RANGE‡:			
Storage		-40 to +150	°C
Operating (case): 40525, 40526, 40527		-40 to +90	°C
40528, 40529, 40530		-40 to +100	°C
Heat-radiator types (From -40° C) Upper limits		**See Figs. 6 & 7**	
LEAD TEMPERATURE:			
During soldering, terminal temperature at a distance ≥ 1/16 in. (1.58 mm) from the case for 10 s		225	°C

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

‡ For information on the reference point of temperature measurement see *Dimensional Outlines.*

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS 40525 40531 / 40526 40532 / 40527 40533			LIMITS 40528 40534 / 40529 40535 / 40530 40536			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX	
Peak Off-State Current: ♠ Gate Open and V_{DROM} = Max. rated value	I_{DROM}							mA
At T_j = +100° C		–	–	–	–	0.2	0.75	
At T_j = +90° C		–	0.2	0.75	–	–	–	
Maximum On-State Voltage: ♠ For i_T = 10 A (peak) and T_C = 25° C	V_{TM}	–	1.7	2.2	–	1.7	2.2	V
DC Holding Current: ♠ Gate Open, Initial principal current = 150 mA (DC), V_D =12	I_{HO}							mA
At T_C = 25° C		–	2	5	–	6.5	15	
For other case temperatures		See Fig. 14			See Fig. 15			
Critical Rate-of-Rise of Off-State Voltage: ♠ For V_D = V_{DROM}, exponential voltage rise, and gate open	dv/dt							V/μs
At T_C = +100° C		–	–	–	–	10	–	
At T_C = +90° C		–	5	–	–	–	–	
DC Gate-Trigger Current: ♠† For V_D = 12 V (DC), R_L = 30 Ω, and T_C = 25° C	I_{GT}							mA
Mode 1^+: V_{MT2} positive, V_G positive		–	1	3	–	3.5	10	
Mode 111^-: V_{MT2} negative, V_G negative		–	1	3	–	3.5	10	
Mode 1^-: V_{MT2} positive, V_G negative		–	2	3	–	7	10	
Mode 111^+: V_{MT2} negative, V_G positive		–	2	3	–	7	10	
For other case temperatures		See Fig. 12			See Fig. 13			
DC Gate-Trigger Voltage: ♠† For V_D = 12 V (DC) and R_L = 30 Ω	V_{GT}							V
At T_C = 25° C		–	1	2.2	–	1	2.2	
For other case temperatures		See Fig. 11			See Fig. 11			
For v_D = V_{DROM} and R_L = 125 Ω								
At T_C = 100° C		–	–	–	0.15	–	–	
At T_C = +90° C		0.15	–	–	–	–	–	
Thermal Resistance, Junction-to-Case: Steady-State	$\theta_{J\text{-}C}$	40525, 40526, 40527: 8.5 (max.)			40528, 40529, 40530: 8.5 (max.)			°C/W

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

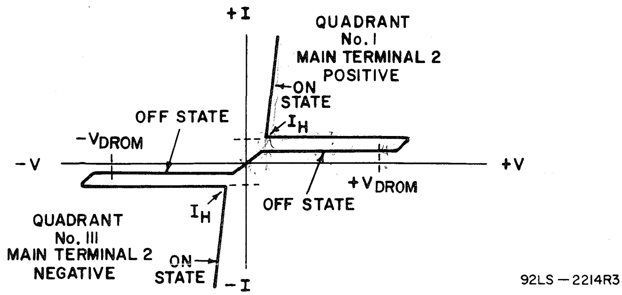


Fig. 1 - Principal voltage-current characteristics.

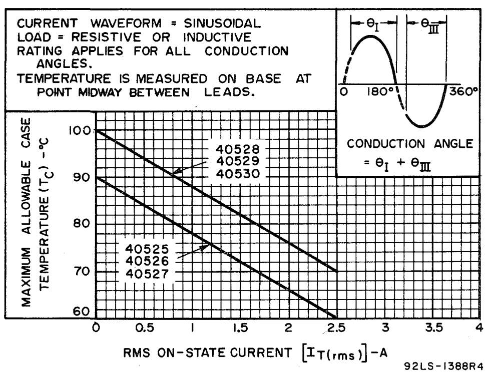


Fig. 2 - Conduction rating chart (case temperature) for types 40525–30.

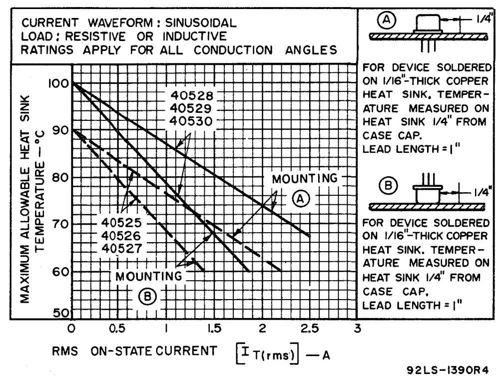


Fig. 3 - Conduction characteristics as a function of mounting method for types 40525–30.

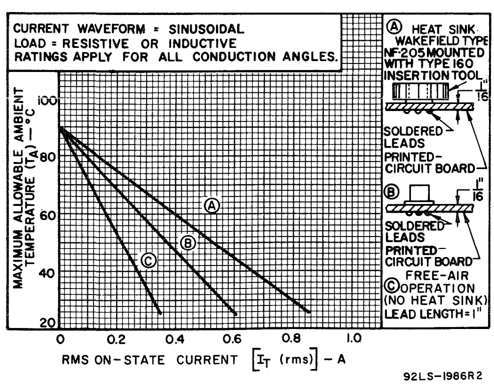


Fig. 4 - Conduction rating chart (ambient temperature) for types 40525, 40526, and 40527.

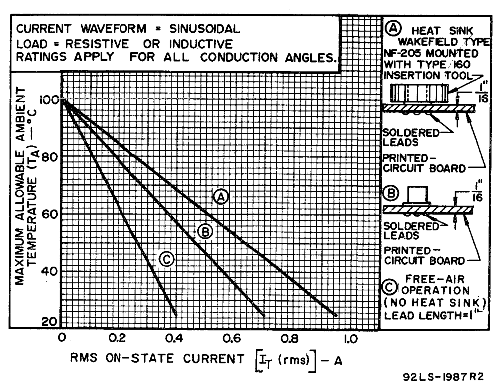


Fig. 5 - Conduction rating chart (ambient temperature) for types 40528, 40529, and 40530.

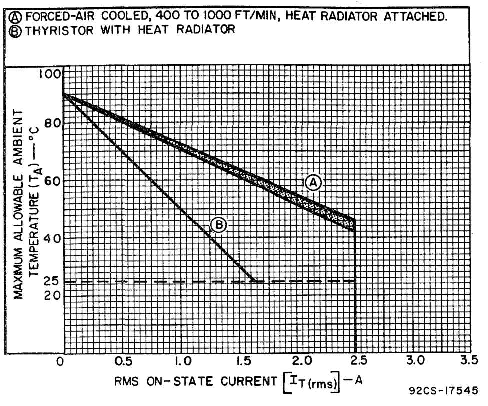


Fig. 6 - Conduction rating chart (ambient temperature) for types 40531, 40532, and 40533.

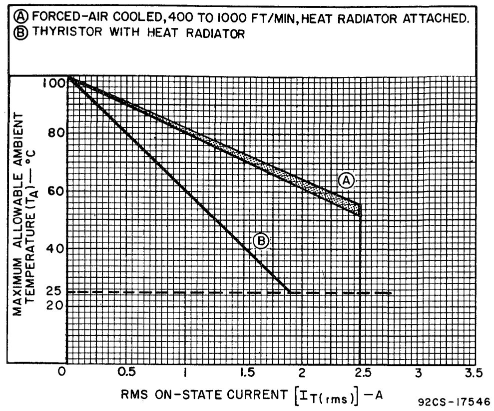


Fig. 7 - Conduction rating chart (ambient temperature) for types 40534, 40535, and 40536.

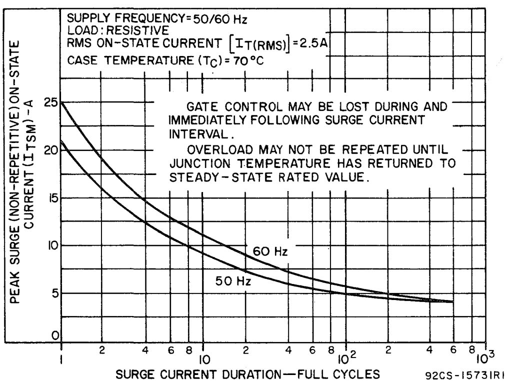


Fig. 8 - Peak surge on-state current vs. surge-current duration for all types.

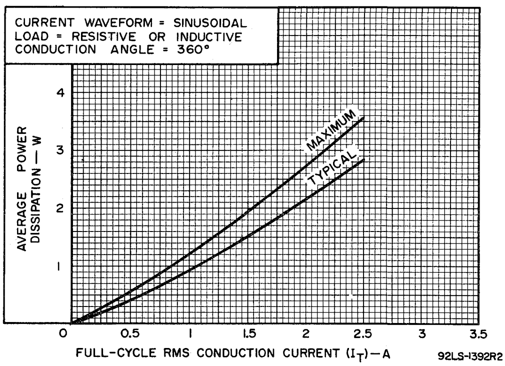


Fig. 9 - Power dissipation curves for all types.

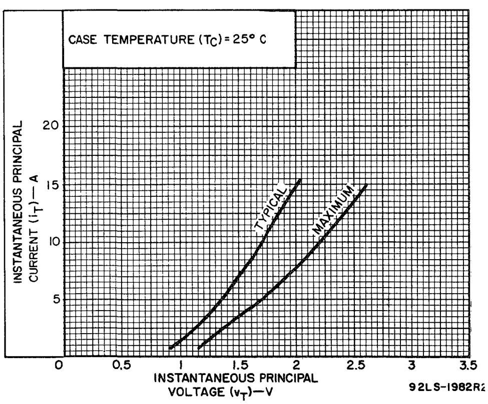


Fig. 10 - On-state characteristics for either direction of principal current for all types.

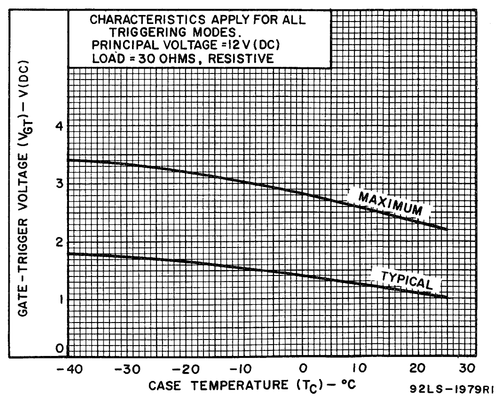


Fig. 11 - DC Gate-trigger voltage characteristics for all types.

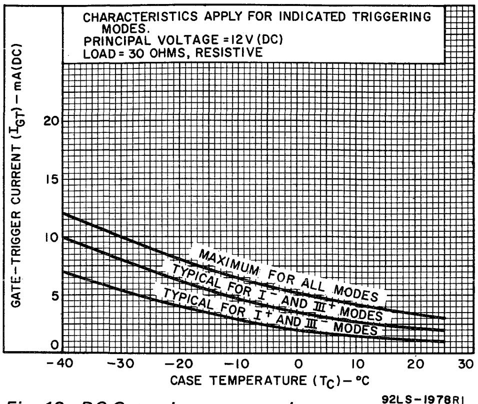


Fig. 12 - DC Gate-trigger current characteristics for types 40525, 40526, 40527, 40531, 40532 and 40533.

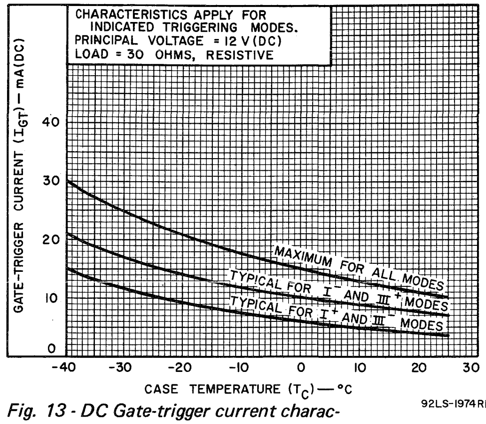


Fig. 13 - DC Gate-trigger current characteristics for types 40528, 40529, 40530, 40534, 40535 and 40536.

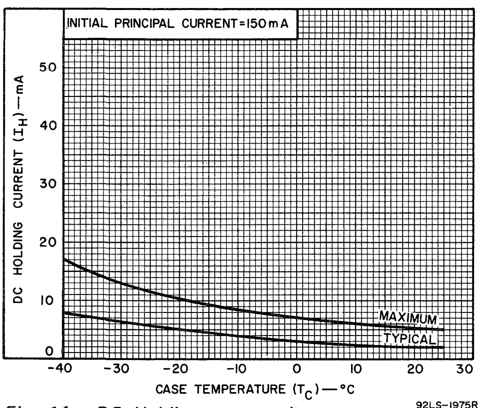


Fig. 14 - DC Holding current characteristics for either direction of principal current for types 40525, 40526, 40527, 40531, 40532 and 40533.

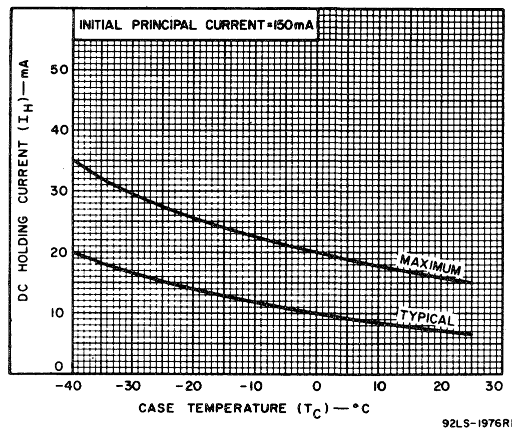


Fig. 15 - DC Holding current characteristics for either direction of principal current for types 40528, 40529, 40530, 40534, 40535 and 40536.

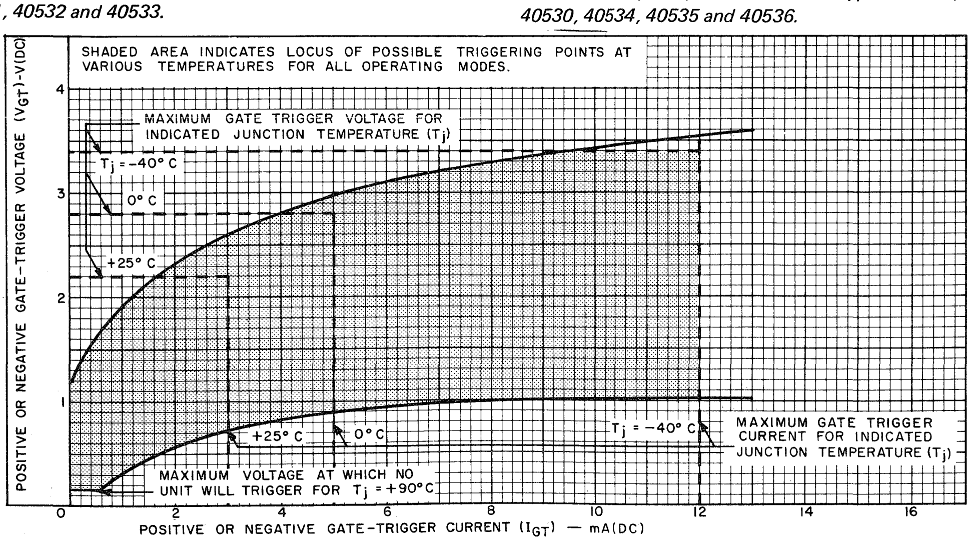


Fig. 16 - Gate characteristics for types 40525, 40526, 40527, 40531, 40532 and 40533.

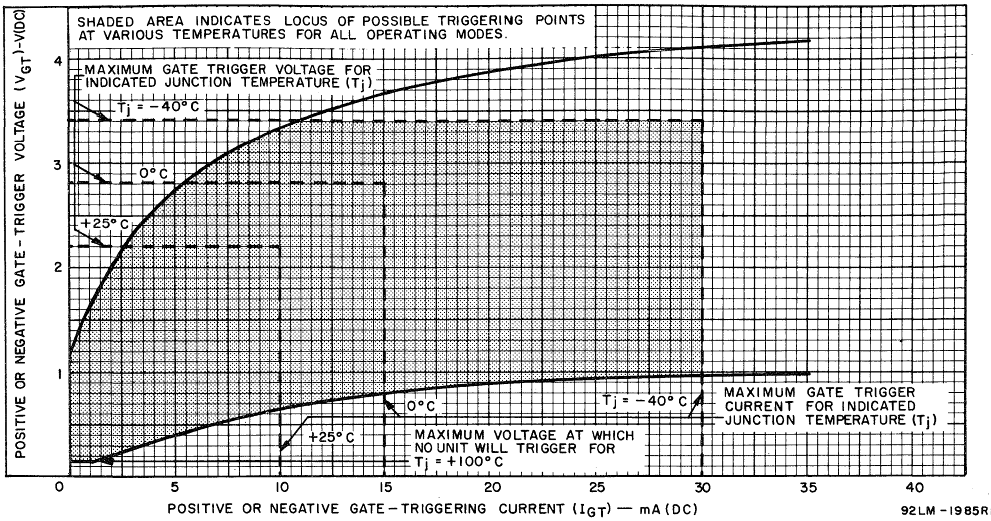
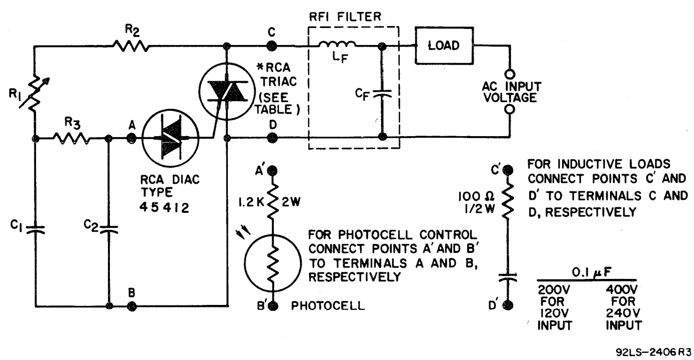


Fig. 17 - Gate characteristics for types 40528, 40529, 40530, 40534, 40535 and 40536.



NOTE: For incandescent lamp loads which produce burnout current surges with I^2t values greater than 2.5 ampere^2 seconds, connect a 10-ohm resistor of appropriate wattage rating in series with the load. The appropriate wattage rating can be determined as follows:

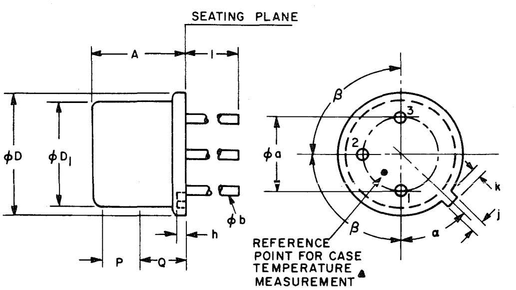
Wattage Rating of 10-ohm Resistor = 10 x (rms load current)^2

AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER		RCA TYPES
						L_F* (typ.)	C_F* (typ.)	
120V 60Hz	0.1μF 200V	0.1μF 100V	100KΩ 1/2W	2.2KΩ 1/2W	15KΩ 1/2W	100μH	0.1μF 200V	40526,40532 40529,40535
240V 50Hz	0.1μF 400V	0.1μF 100V	250KΩ 1W	3.3KΩ 1/2W	15KΩ 1/2W	200μH	0.1μF 400V	40527,40530 40533,40536

*Typical values for lamp dimming circuits.

Fig. 18 - Typical phase-control circuit for lamp dimming, heat controls, and universal motor speed controls.

DIMENSIONAL OUTLINE FOR TYPES 40525 – 40530, INCLUSIVE



▲The temperature reference point specified should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 16 should be attached at the temperature reference point.

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕa	0.190	0.210	4.83	5.33	
A	0.240	0.260	6.10	6.60	
ϕb	0.017	0.021	0.44	0.53	
ϕD	0.335	0.366	8.51	9.30	
ϕD_1	-	0.330	8.13	8.38	
h	0.015	0.035	0.38	0.89	
i	0.028	0.035	0.71	0.89	
k	0.029	0.045	0.74	1.14	
I	0.975	1.025	24.76	26.03	
P	0.100	-	2.54	-	
Q	-	-	-	-	1
α	45° NOMINAL				
β	50° NOMINAL				

Note 1: Details of outline in this zone optional.

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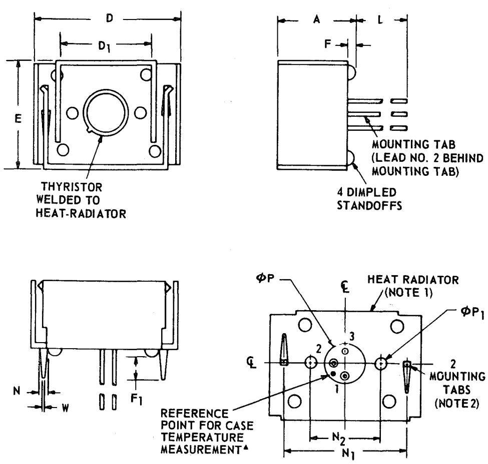
DIMENSIONAL OUTLINE FOR TYPES 40531 – 40536, INCLUSIVE



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	4.94	
L	0.920	–	23.37	–	
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
N_2	0.687	0.689	17.45	17.50	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 in. (1.78 mm) dia.
3. Measured at bottom of heat-radiator

92LM-2109R1

▲The specified temperature-reference point should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 26 should be attached at the temperature reference point.

TERMINAL CONNECTIONS

For Types 40525 – 40530 Inclusive

Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Case, Lead No. 3 – Main terminal 2

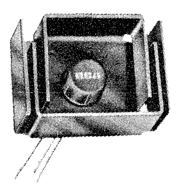
For Types 40531 – 40536, Inclusive

Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Heat Rad., Lead No. 3 – Main terminal 2

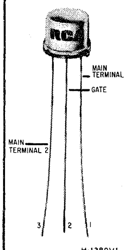
RCA
Solid State
Division

Thyristors

40691 40761
40692 40762
40766 40767



40761
40762
40767



40691
40692
40766

2.5-Ampere Sensitive-Gate Silicon Triacs

For Low-Power Phase-Control and Load Switching Applications

For Low-Voltage Operation – 40766, 40767
For 120-V Line Operation – 40691, 40761
For 240-V Line Operation – 40692, 40762

FEATURES

- **Very High Gate Sensitivity – 4 mA**
- **Shorted Emitter Design**
- **Heat-Radiator Package for Printed Circuit Board Applications**
- **Small Size – Suitable for Remote Switching Applications**

These RCA triacs are gate-controlled, full-wave ac switches.

These devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

The high gate sensitivity of these triacs permits the use of economical transistorized or integrated control circuits and enhances their use in low-power phase control and load-switching applications.

Types 40766, 40691, and 40692 utilize a compact package (similar to JEDEC TO-5) and have an RMS on-state current rating of 2.5 A and repetitive peak off-state voltage ratings of 100, 200, and 400 volts, respectively.

Types 40767, 40761, and 40762 are the same as the 40766, 40691, and 40692, respectively, but have factory-attached heat-radiators and are intended for printed-circuit board applications.

With the exception shown below, data appearing in bulletin File No. 261 for RCA-40525, 40526, and 40527 are applicable to the RCA-40766, 40691, and 40692, respectively.

ELECTRICAL CHARACTERISTICS:

Characteristic				Limits			Units
DC Gate-Trigger Current, I_{GT}	Mode	V_{MT2}	V_G	Min.	Typ.	Max.	
For v_D = 12 V (DC), R_L = 30Ω, and T_C = 25° C	I+	positive	positive	–	1	4	mA
	III-	negative	negative	–	1	4	
	I-	positive	negative	–	2	4	
	III+	negative	positive	–	2	4	

Data appearing in bulletin File No. 470 for RCA-40531, 40532, and 40533 are applicable to the RCA- 40767, 40761, and 40762, respectively

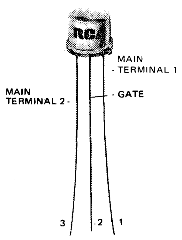
For data on additional RCA sensitive-gate triacs, refer to bulletin File number 470.

RCA

Solid State
Division

Thyristors

40769-40770
40771-40772



Modified JEDEC TO-5

H-1380V1

400-Hz, 0.5-A
Sensitive-Gate Silicon Triacs

For Control-Systems Application in Airborne and Ground-Support Type Equipment

For 115-V Line Operation – 40769, 40771
For 208-V Line Operation – 40770, 40772

Features:

- **High Gate Sensitivity, I_{GT} = 10/40 mA max.**
- **di/dt Capability = 100 A/μs**
- **Commutating dv/dt Capability Characterized at 400 Hz**
- **Shorted-Emitter Design**

These RCA triacs are gate-controlled, full-wave silicon ac switches.

The devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

They are intended for operation up to 400 Hz with resistive or inductive loads and nominal line voltages of 115 and 208 V RMS sine wave and repetitive peak off-stage voltages of 200 V and 400 V.

The high gate sensitivity of these triacs permits the use of economical transistorized or integrated control circuits and enhances their use in low-power phase control and load-switching applications.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 400 Hz and with Resistive or Inductive Load.

		40769 40771	40770 40772	
REPETITIVE PEAK OFF-STATE VOLTAGE:*				
Gate open, T_J = -50 to 100°C	V_{DROM}	200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°):	$I_{T(RMS)}$			
Case temperature (T_C) = 90°C		0.5		A
Ambient temperature (T_A) = 25°C, without heat sink		0.4		A
For other conditions		*See Figs. 3 & 4*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}			
For one cycle of applied principal voltage				
400 Hz (sinusoidal)		50		A
60 Hz (sinusoidal)		25		A
For more than one cycle of applied principal voltage		*See Fig. 5*		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt			
V_{DM} = V_{DROM}, I_{GT} = 60 mA, t_r = 0.1 μs (*See Fig. 14*)		100		A/μs
PEAK GATE-TRIGGER CURRENT:■	I_{GTM}			
For 1 μs (max.) (*See Fig. 10*)		1		A
GATE POWER DISSIPATION:				
PEAK (For 1 μs max., (*See Fig. 10*)	P_{GM}	10		W
AVERAGE (At T_C = 60°C)	$P_{G(AV)}$	0.15		W
(At T_A = 25°C, without heat sink)	$P_{G(AV)}$	0.05		W
TEMPERATURE RANGE:▲				
Storage	T_{stg}	-50 to 150		°C
Operating (Case)	T_C	-50 to 100		°C
LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/16 in. (1.58 mm) from the case for 10 s max.	T_L	225		°C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS 40769 40770 Min.	Typ.	Max.	40771 40772 Min.	Typ.	Max.	UNITS
Peak Off-State Current:♣ Gate open, T_J = 100°C, V_{DROM} = Max. rated value	I_{DROM}	-	0.2	0.75	-	0.2	0.75	mA
Maximum On-State Voltage:♣ For i_T = 10 A (peak), T_C = 25°C	V_{TM}	-	1.7	2.2	-	1.7	2.2	V
DC Holding Current:♣ Gate open, Initial principal current = 150 mA (DC), v_D = 12 V, T_C = 25°C	I_{HO}	-	7	15	-	15	30	mA
For other case temperatures		← See Figs. 8 & 9 →						
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 0.5 A, commutating di/dt = 1.8 A/ms, gate unenergized, T_C = 90°C (See Fig. 15)	dv/dt	1	4	-	1	4	-	V/µs
Critical Rate-of-Rise of Off-Stage Voltage:♣ For v_D = V_{DROM}, exponentail voltage rise, gate open, T_C = 100°C	dv/dt	10	100	-	10	100	-	V/µs
DC Gate-Trigger Current:♣ For v_D = 12 V (DC), R_L = 30 Ω, T_C = 25°C — Mode I⁺, V_{MT2} positive, V_G positive	I_{GT}	-	3.5	10	-	5	25	mA
Mode III⁻, V_{MT2} negative, V_G negative		-	3.5	10	-	5	25	
Mode I⁻, V_{MT2} positive, V_G negative		-	7	10	-	10	40	
Mode III⁺, V_{MT2} negative, V_G positive		-	7	10	-	10	40	
For other case temperatures		← See Figs. 11 & 12 →						
DC Gate-Trigger Voltage:♣† For v_D = 12 V (DC), R_L = 30Ω, T_C = 25°C	V_{GT}	-	1	2.2	-	1	2.2	V
For other case temperatures		← See Fig. 13 →						
For v_D = V_{DROM}, R_L = 125Ω, T_C = 100°C		0.15	-	-	0.15	-	-	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 60 mA, t_r = 0.1 µs, i_T = 10 A (peak), T_C = 25°C (See Fig. 16)	t_{gt}	-	1.8	-	2.5	1.8	2.5	µs
Thermal Resistance, Junction-to-Case:	θ_{J-C}	-	-	8.5	-	-	8.5	°C/W

♣ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

The following data are applicable to all triacs except as noted.

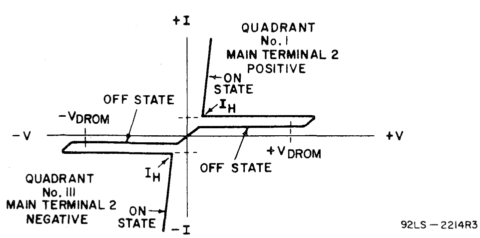


Fig. 1 - Principal voltage-current characteristic.

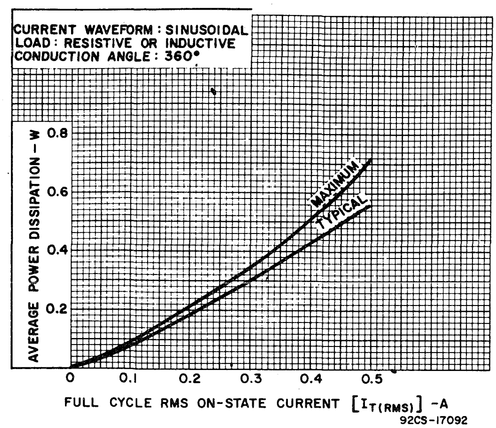


Fig. 2 - Power dissipation vs. on-state current.

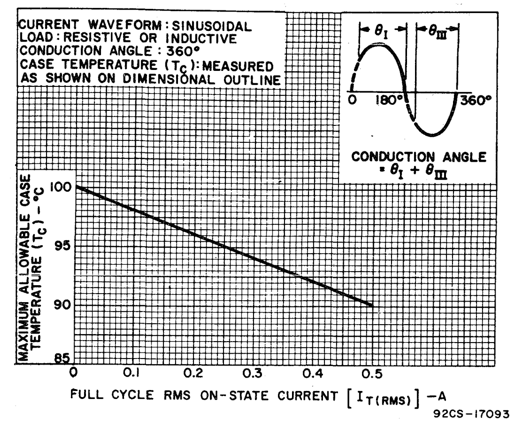


Fig. 3 - Maximum allowable case temperature vs. on-state current.

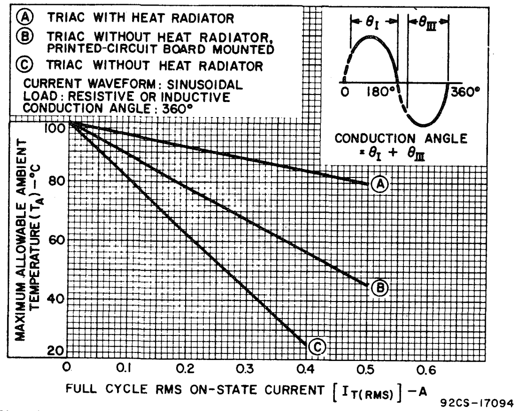


Fig. 4 - Maximum allowable ambient temperature vs. on-state current for the package/mounting options of these triacs.

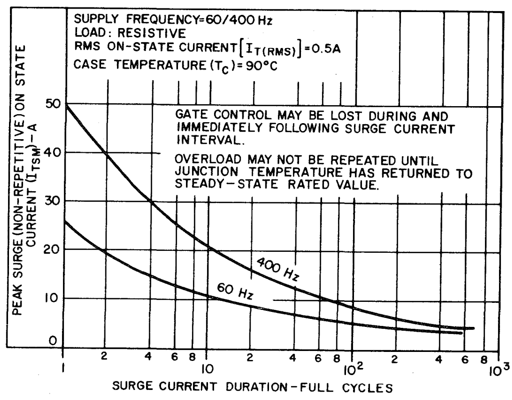


Fig. 5 - Peak surge on-stage current vs. surge-current duration.

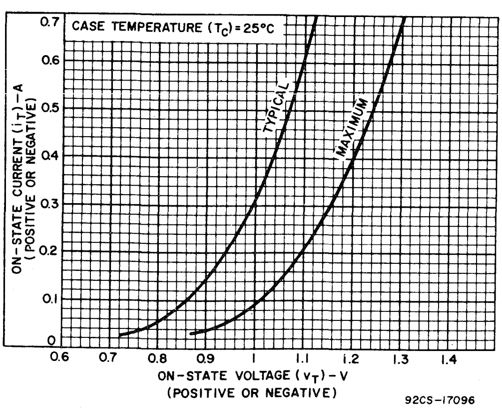


Fig. 6 - On-state current vs. on-state voltage (Steady-state condition).

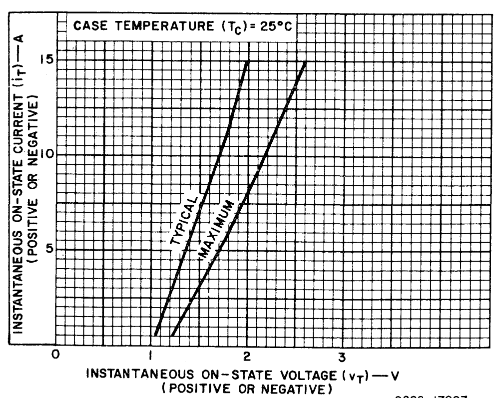


Fig. 7 - On-state current vs. on-state voltage (Surge condition).

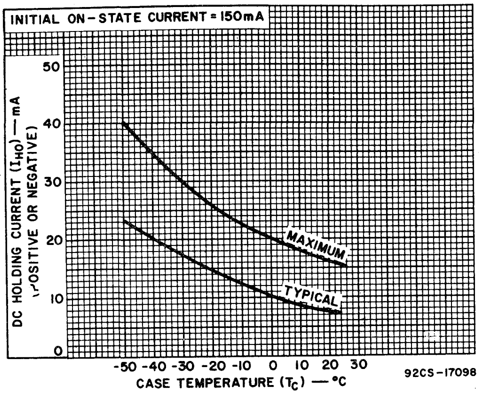


Fig. 8 - DC holding current vs. case temperature for 40769 & 40770.

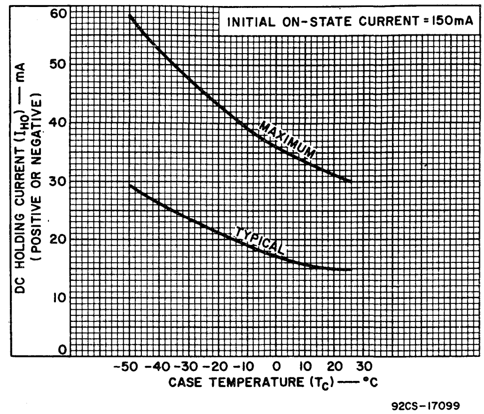


Fig. 9 - DC holding current vs. case temperature for 40771 & 40772.

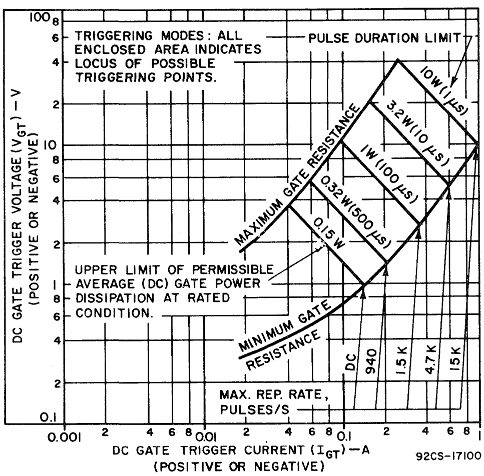


Fig. 10 - Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

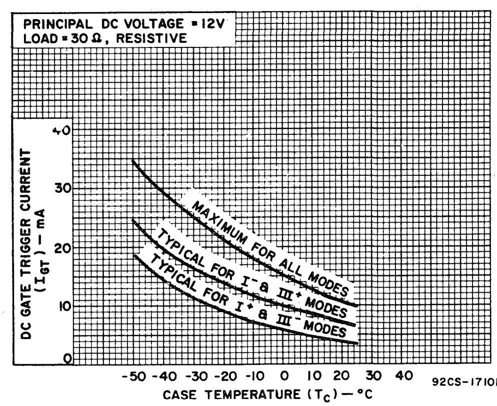


Fig. 11 - DC gate-trigger current vs. case temperature for 40769 & 40770.

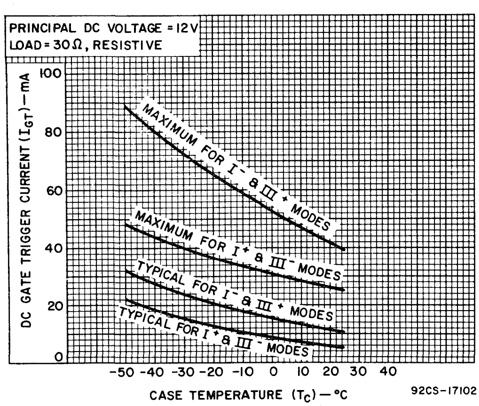


Fig. 12 - DC gate-trigger current vs. case temperature for 40771 & 40772.

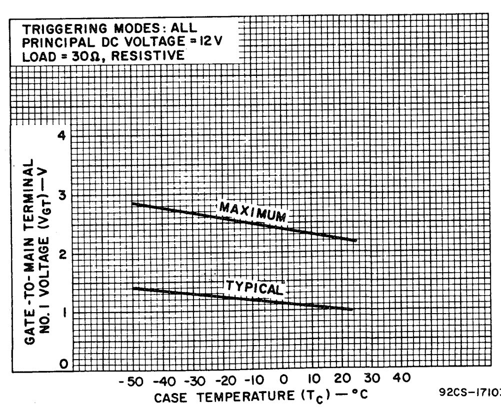


Fig. 13 - DC gate-trigger voltage vs. case temperature.

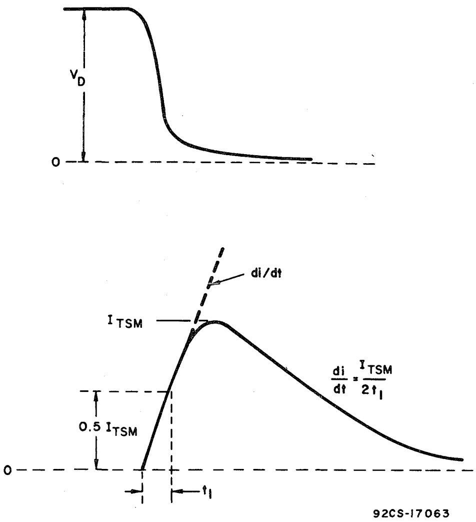


Fig. 14 - Rate-of-change of on-state current with time (defining di/dt).

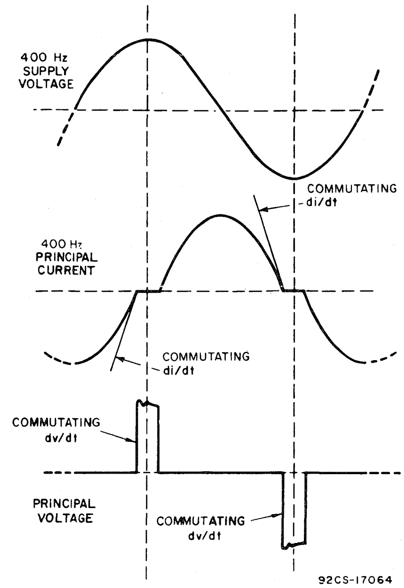


Fig. 15 - Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

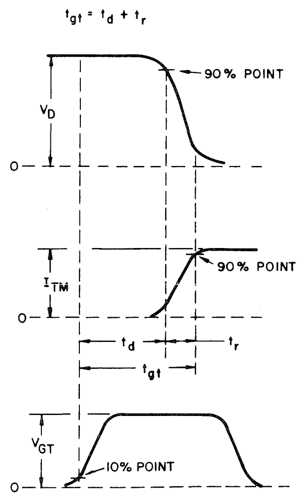
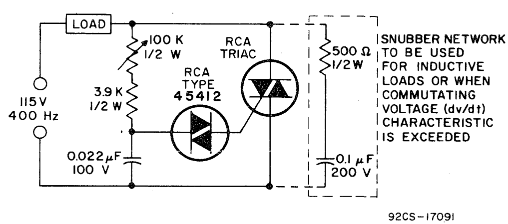


Fig. 16 - Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

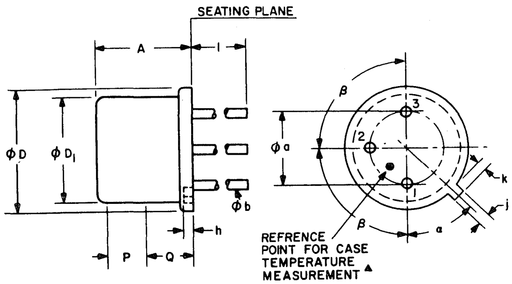


NOTE: For incandescent lamp loads which produce burnout current surges with I^2t values greater than 2.5 ampere^2 seconds, connect a 10 – ohm resistor of appropriate power rating in series with the load. This rating can be determined as follows:

$$\text{Power Rating of 10-ohm Resistor} = 10\ (\text{rms load current})^2$$

Fig. 17 - Typical phase-control circuit for operation at 400 Hz.

DIMENSIONAL OUTLINE



▲The temperature reference point specified should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 16 should be attached at the temperature reference point.

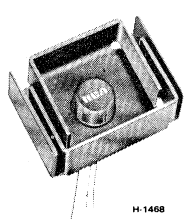
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕa	.190	.210	4.83	5.33	
A	.240	.260	6.10	6.60	
ϕb	.017	.021	.44	.53	
ϕD	.335	.366	8.51	9.30	
$ϕD_1$		.330	8.13	8.38	
h	.015	.035	.38	.89	
i	.028	.035	.71	.89	
k	.029	.045	.74	1.14	
l	.975	1.025	24.76	26.03	
P	.100	-	2.54	-	
Q·	-	-	-	-	1
α	45° NOMINAL				
β	50° NOMINAL				

Note 1: Details of outline in this zone optional.

92LM-2048R2

TERMINAL CONNECTIONS

Lead No. 1 - Main terminal 1
Lead No. 2 - Gate
Case, Lead No. 3 - Main terminal 2



H-1468

On special request, these triacs are also available with a factory-attached heat-radiator intended for printed-circuit board applications.

RCA

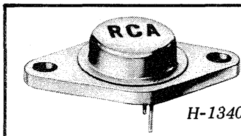
Solid State Division

Thyristors

40429 40502
40430 40503

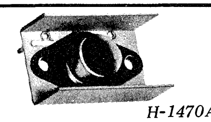
6-AMPERE SILICON TRIAC's

Medium-Power, Gate-Controlled, Full-Wave Types



H-1340

JEDEC TO-66
40429
40430



H-1470A

JEDEC TO-66
With Integral Heat Radiator
40502
40503

RCA-40429, 40430, 40502, and 40503 are gate-controlled, full-wave, silicon triacs. They are intended for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems.

These triacs are designed to switch from an off-state to an on-state condition for either polarity of applied voltage with positive or negative triggering voltages to the gate.

Types 40429 and 40430 are hermetically sealed types having an on-state current rating of 6 amperes at a case temperature of +75° C and repetitive off-state voltage ratings of 200 volts and 400 volts, respectively.

The 40429 and 40430 are also available with integral heat radiators — types 40502 and 40503, respectively.

Maximum Ratings, *Absolute-Maximum Values:*

For Operation with Sinusoidal Supply Voltage at Frequencies of 50/60 Hz, and with Resistive or Inductive Load

	40429 40502	40430 40503	
REPETITIVE PEAK OFF-STATE VOLTAGE♦, V_{DROM}:			
Gate Open, For T_J = −65 to +100 °C	200	400	V
RMS ON-STATE CURRENT, $I_{t(rms)}$:			
For case temperature (T_C) of +75 °C and a conduction angle of 360°	6 (40429)	6 (40430)	A
For ambient temperatures (T_A) up to +100 °C and a conduction angle of 360°	See Fig. 16.		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT, I_{TSM}:			
For one cycle of applied principal voltage	100	100	A
For more than one full cycle of applied voltage	See Fig. 4.		
PEAK GATE-TRIGGER CURRENT ■, I_{GTM}:			
For 1 μs max.	4	4	A
GATE POWER DISSIPATION:■			
PEAK, P_{GM} For 1 μs max. and $I_{GTM} \leq 4$ A (peak)	16	16	W
AVERAGE, $P_{G(AV)}$	0.2	0.2	W
TEMPERATURE RANGE⧫:			
Storage	−65 to +150		°C
Operating (case)	−65 to +100		°C

♦For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

■For either polarity of gate voltage (V_{GT}) with reference to main terminal 1.

Features

- 720-Watt Control, 120-Volt Line Operation — 40429
- 1,440-Watt Control, 240-Volt Line Operation — 40430
- 6-A (rms) On-State Current Ratings
- 100-A Peak Surge Full-Cycle Current Ratings
- Shorted-Emitter Design
  -- contains internally diffused resistor from gate to Main Terminal No. 1.
- Center Gate Construction
  -- provides rapid uniform gate current spreading for faster turn-on with substantially reduced heating effects
- Low Switching Losses
- Low Thermal Resistance

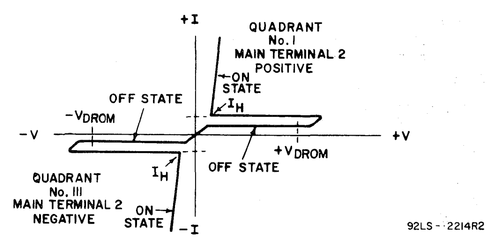


Fig. 1 - Principal Voltage-Current Characteristic

⧫For information on the reference point of temperature measurement, see *Dimensional Outline,* page 8.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified
(For Definitions of Terms and Symbols, See Page 6)

CHARACTERISTIC	SYMBOL	LIMITS 40429 Min.	40429 Typ.	40429 Max.	40502 Min.	40502 Typ.	40502 Max.	40430 Min.	40430 Typ.	40430 Max.	40503 Min.	40503 Typ.	40503 Max.	UNITS
Peak Off-State Current:* Gate Open At T_J = + 100 °C and V_{DROM} = Max. rated value	I_{DROM}	–	0.1	4	–	0.1	1.2	–	0.2	4	–	0.2	1.2	mA
Maximum On-State Voltage:* For i_T = 30A (peak) and T_C = +25 °C	v_{TM}	–	1.8	2.25	–	1.8	2.25	–	1.8	2.25	–	1.8	2.25	V
DC Holding Current:* Gate Open Initial principal current = 150 mA (DC) At T_C = +25 °C	I_{HO}	–	15	30	–	15	30	–	15	30	–	15	30	mA
For other case temperatures		See Fig. 8.												
Critical Rate of Rise of Commutation Voltage:*♦ For V_D = V_{DROM}, $I_{t(rms)}$ = 6 A, commutating di/dt = 3.2 A/ms, and gate unenergized At T_C = +75 °C	dv/dt	3	10	–	–	–	–	3	10	–	–	–	–	V/µs
$I_{t(rms)}$ and T_A specified by curve A of Fig. 16.		–	–	–	3	10	–	–	–	–	3	10	–	
$I_{t(rms)}$ and T_A specified by curve B of Fig. 16		–	–	–	4	12	–	–	–	–	4	12	–	
Critical Rate of Rise of Off-State Voltage:* For V_D = V_{DROM}, exponential voltage rise, and gate open At T_C = + 100 °C	dv/dt	30	150	–	30	150	–	20	100	–	20	100	–	V/µs
DC Gate-Trigger Current:*† For V_D = 12 volts (DC), R_L = 12 Ω T_C = +25 °C, and specified triggering mode: I+ Mode: positive V_{MT2}, positive V_{GT}	I_{GT}	–	15	25	–	15	25	–	15	25	–	15	25	mA
III– Mode: negative V_{MT2}, negative V_{GT}		–	15	25	–	15	25	–	15	25	–	15	25	
I– Mode: positive V_{MT2}, negative V_{GT}		–	25	40	–	25	40	–	25	40	–	25	40	
III+ Mode: negative V_{MT2}, positive V_{GT}		–	25	40	–	25	40	–	25	40	–	25	40	
For other case temperatures		See Fig. 12 & 13.												
DC Gate-Trigger Voltage:*† For V_D = 12 volts (DC) and R_L = 12 Ω At T_C = +25 °C	V_{GT}	–	1	2.2	–	1	2.2	–	1	2.2	–	1	2.2	V
For other case temperatures		See Fig. 14.												
For V_D = V_{DROM} and R_L = 125 Ω At T_C = + 100 °C		0.2	–	–	0.2	–	–	0.2	–	–	0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For V_D = V_{DROM} and I_{GT} = 80 mA, 0.1 µs rise time, and i_T = 10 A (peak) At T_C = +25 °C	t_{gt}	–	2.2	–	–	2.2	–	–	2.2	–	–	2.2	–	µs
Thermal Resistance: Junction-to-Case (Steady-State)	θ_{J-C}	–	–	4	–	–	–	–	–	4	–	–	–	°C/W
Junction-to-Case (Transient)	θ_{J-C}	See Fig. 15.												
Junction-to-Ambient	θ_{J-A}	–	–	–	See Fig. 16.			–	–	–	See Fig. 16.			

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
†For either polarity of gate voltage (V_{GT}) with reference to main terminal 1.
♦Variants of these devices having dv/dt characteristics selected specifically for inductive loads are available on special order; for additional information, contact your RCA Representative or your RCA Distributor.

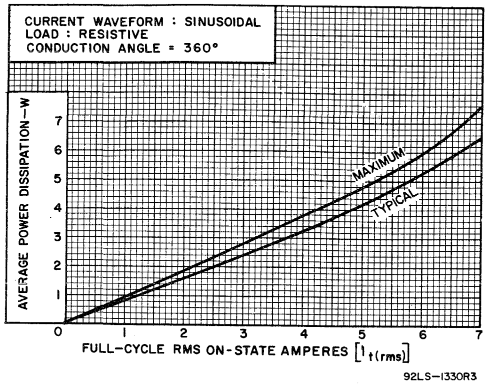


Fig. 2 - Power Dissipation vs. On-State Current

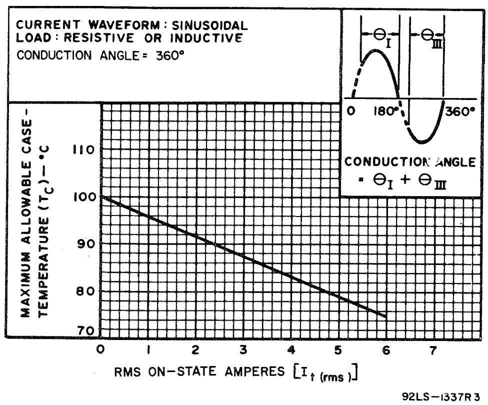


Fig. 3 - Allowable Case Temperature vs. On-State Current

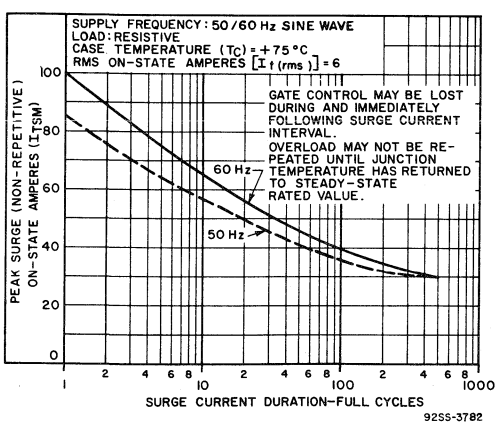


Fig. 4 - Peak Surge On-State Current vs. Surge Current Duration

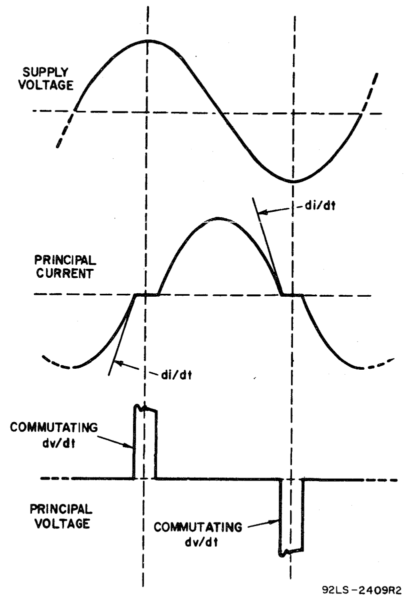


Fig. 5 - Oscilloscope Display of Commutating dv/dt

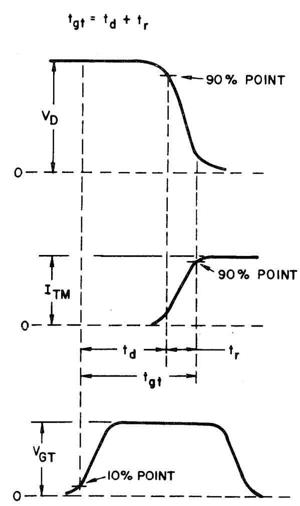


Fig. 6 - Oscilloscope Display for Measurement of Gate-Controlled Turn-On Time (t_{gt})

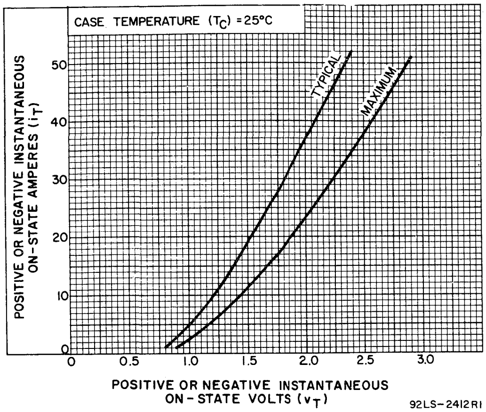


Fig. 7 - On-State Current vs. On-State Voltage

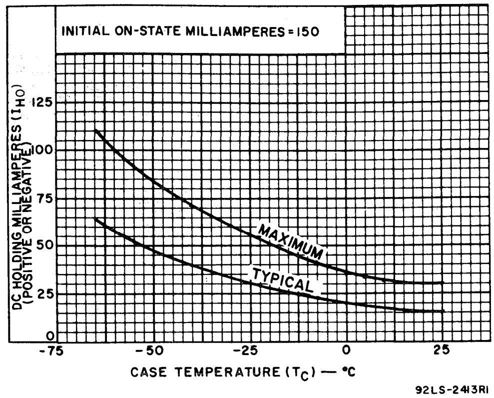


Fig. 8 - DC Holding Current for Either Direction of On-State Current vs. Case Temperature

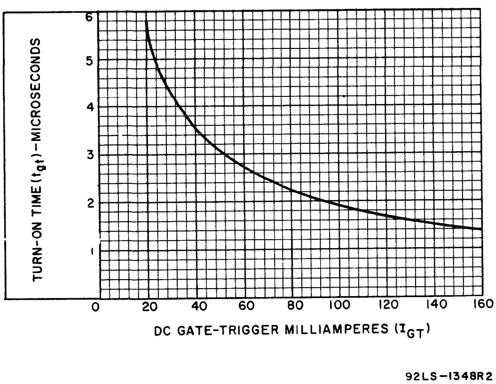


Fig. 9 - Typical Turn-On Time vs. Gate-Trigger Current

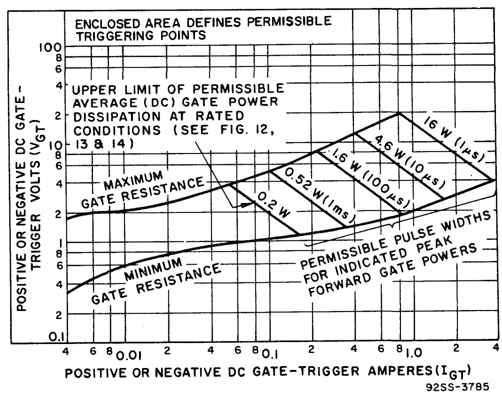
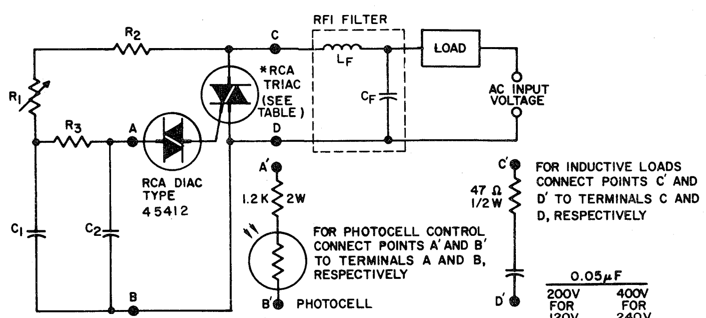


Fig. 10 - Gate Pulse Characteristics for All Triggering Modes



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	RFI FILTER C_F* (typ.)	RCA TYPES
120V 60Hz	0.1μF 200V	0.1μF 100V	100KΩ 1/2W	1KΩ 1/2W	15KΩ 1/2W	100μH	0.1μF 200V	40429 40502
240V 50/60Hz	0.05μF 400V	0.1μF 100V	200KΩ 1/2W	7.5KΩ 2W	7.5KΩ 2W	100μH	0.1μF 400V	40430 40503

*Typical values for lamp dimming circuits.

Fig. 11 - Typical Phase-Control Circuit for Lamp Dimming, Heat Controls, and Universal Motor Speed Controls

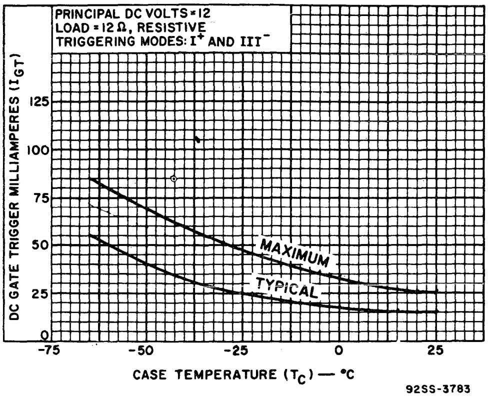


Fig. 12 - DC Gate-Trigger Current (for I^+ and III^- Triggering Modes) vs. Case Temperature

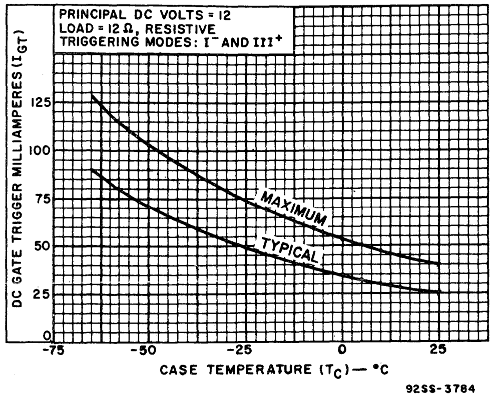


Fig. 13 - DC Gate-Trigger Current (for I^- and III^+ Triggering Modes) vs. Case Temperature

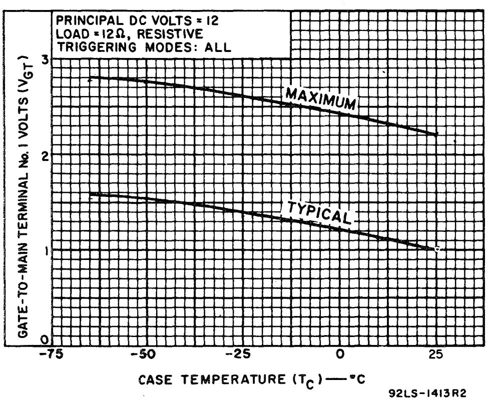


Fig. 14 - DC Gate-Trigger Voltage vs. Case Temperature

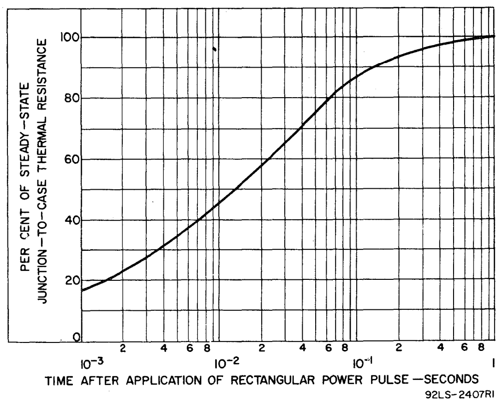


Fig. 15 - Transient Thermal Resistance (Junction-to-Case vs. Time

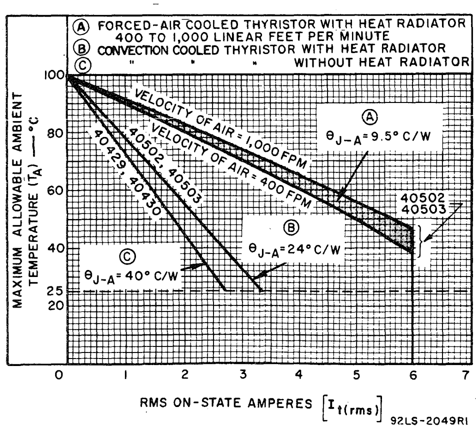
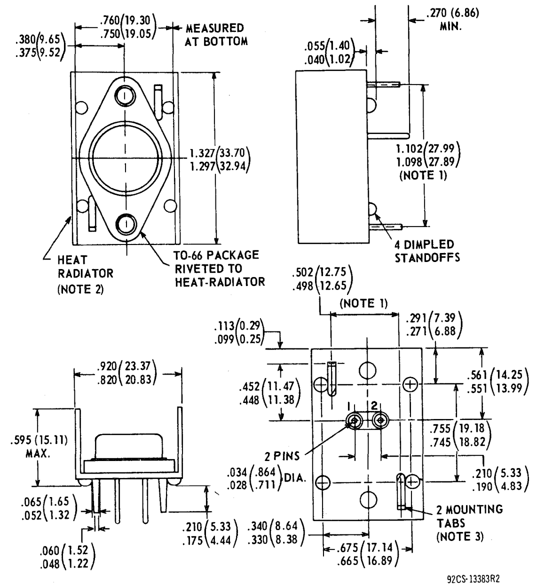


Fig. 16 - Maximum Allowable Ambient Temperature vs. On-State Current

DIMENSIONAL OUTLINE
FOR TYPES 40502 & 40503
JEDEC TO-66 WITH HEAT-RADIATOR



Dimensions in Inches and Millimeters

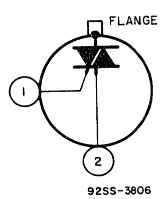
NOTE: *Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.*

Note 1: Measured at bottom of heat-radiator.

Note 2: 0.035 in. (.889) C.R.S., tin plated.

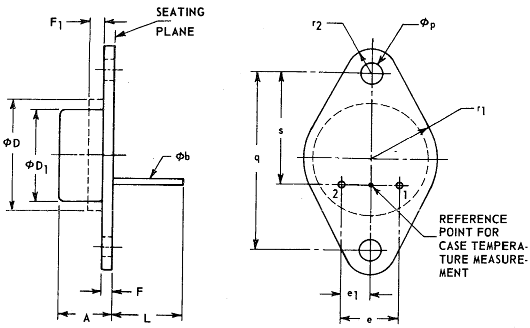
Note 3: Recommended hole size for printed-circuit board is 0.070 in. (1.778) dia.

TERMINAL DIAGRAM
FOR TYPES 40429, 40430, 40502 & 40503



Pin 1 - Gate
Pin 2 - Main Terminal 1
Flange, Case - Main Terminal 2
Case, Flange (40429, 40430)
Case, Flange, Heat Radiator (40502, 40503) - Main Terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40429 & 40430 JEDEC TO-66



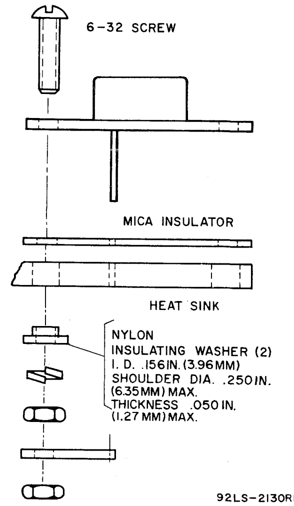
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.250	.340	6.35	8.64	
ϕb	.028	.034	.711	.863	
ϕD		.620		15.75	
ϕD_1	.470	.500	11.94	12.70	
e	.190	.210	4.83	5.33	
e_1	.093	.107	2.36	2.72	
F	.050	.075	1.27	1.91	2
F_1		.050		1.27	1
L	.360		9.14		
ϕp	.142	.152	3.61	3.86	
q	.958	.962	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 SEALING FLANGES.

92SS-3738

SUGGESTED MOUNTING ARRANGEMENT FOR TYPES 40429 & 40430

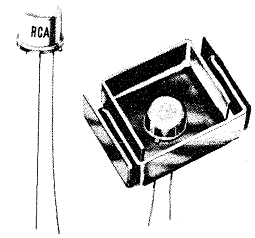


RCA

Solid State
Division

Thyristors

40431 40432
40511 40512



40431 H-1380 40511 H-1538
40432 40512

Modified
JEDEC TO-5

6-A Silicon Triacs with Integral Diac

For Phase-Control and Load-Switching Applications

For 120-V Line Operation – 40431, 40511
For 240-V Line Operation – 40432, 40512

Features

- **Integral triggering**
- **Symmetrical breakover**
- **Shorted-emitter, center-gate design**
- **Diffused construction for uniformity and stability**
- **Direct soldered internal construction – assures exceptional resistance to fatigue**

These RCA triacs are gate-controlled, full-wave silicon ac switches with integral triggers. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

They are intended primarily for the phase control of ac loads in applications such as light dimming, universal and induction motor control, and heater control. Types 40431 and 40432 utilize a compact package (similar to JEDEC TO-5). This package is especially suitable where space requirements are of prime importance. The hermetic, tin-plated package may be soldered directly to a heat sink to minimize mounting and heat sinking problems.

The 40431 is intended for applications requiring a repetitive peak off-state voltage up to 200 volts and an rms on-state current capability of 6 amperes at a case temperature of +75°C. The 40432 is intended for applications requiring a repetitive peak off-state voltage up to 400 volts and an rms on-state current capability of 6 amperes at a case temperature of +75°C. Types 40511 and 40512 are the same as 40431 and 40432, respectively, but are supplied with factory-attached heat radiators.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies of 50/60 Hz and with Resistive or Inductive Load.

		40431 40511	40432 40512	
REPETITIVE PEAK OFF-STATE VOLTAGE:*	V_{DROM}			
Gate open, T_J = –40 to 100°C		200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°):	$I_{T(RMS)}$			
Case temperature (T_C) = 75°C		6		A
Ambient temperature (T_A) = 25°C, without heat sink		See *Fig. 5*		
For other conditions		See *Fig. 4*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}			
For one cycle of applied principal voltage				
60 Hz (sinusoidal)		100		A
50 Hz (sinusoidal)		85		A
For more than one cycle of applied principal voltage		See *Fig. 6*		
PEAK GATE-TRIGGER CURRENT:■	I_{GTM}			
For 2 μs max.		1		A
GATE POWER DISSIPATION:				
PEAK (For 2 μs max., $I_{GTM} \leq$ 1 A)	P_{GM}	20		W
AVERAGE	$P_{G(AV)}$	0.2		W
TEMPERATURE RANGE:▲				
Storage	T_{stg}	–40 to 150		°C
Operating (Case)	T_C	–40 to 100		°C
LEAD TEMPERATURE (During soldering):				
At distances $\geq$ 1/16 in. (1.58 mm) from the case for 10 s max.	T_L	225		°C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For termperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS 40431, 40511 Min.	Typ.	Max.	40432, 40512 Min.	Typ.	Max.	UNITS
Peak Off-State Current:♣ Gate open, T_J = 100°C, V_{DROM} = Max. rated value	I_{DROM}	–	0.1	2	–	0.2	4	mA
Maximum On-State Voltage:♣ For i_T = 30 A (peak), T_C = 25°C	V_{TM}	–	1.6	2.25	–	1.6	2.25	V
DC Holding Current:♣ Gate open, Initial principal current = 150mA (DC), T_C = 25°C	I_{HO}	–	10	30	–	10	30	mA
For other case temperatures		See Fig. 8			See Fig. 8			
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 6A, commutating di/dt = 4 A/ms, gate unenergized, T_C = 75°C *(See Fig. 12.)*	dv/dt	2	10	–	2	10	–	V/μs
Critical Rate-of-Rise of Off-State Voltage:♣ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100°C	dv/dt	20	100	–	20	75	–	V/μs
Peak Gate Off-State Current: T_C = 25°C	I_{BR}	–	40	200	–	40	200	μA
For other case temperatures		See Fig. 9			See Fig. 9			
Gate Trigger Capacity: v_D = 12V, R_L = 30Ω, T_C = 100°C		0.1	–	2	0.1	–	2	μF
Gate Symmetry, Peak Voltage	$\|V_{GTM}{+}\|-\|V_{GTM}{-}\|$	–	± 1	± 3	–	± 1	± 3	V
Peak Gate Firing Voltage: For v_D = 12V(DC), R_L = 30 Ω, T_C = 25°C	V_{GM}	20	35	40	20	35	40	V
For other case temperatures		See Fig. 10			See Fig. 10			
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 160mA, t_r = 0.1 μs, i_T = 10 A (peak), T_C = 25°C *(See Fig. 11.)*	t_{gt}	–	1.6	2.5	–	1.6	2.5	μs
Thermal Resistance: Junction-to-case (40431, 40432)	$\theta_{J\text{-}C}$	–	–	4	–	–	4	°C/W
Junction-to-ambient (40511, 40512)	$\theta_{J\text{-}A}$	–	–	3.5	–	–	3.5	

♣For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

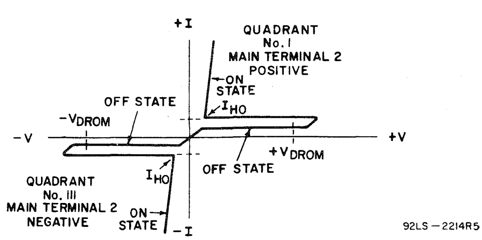


Fig. 1—Principal voltage-current characteristic

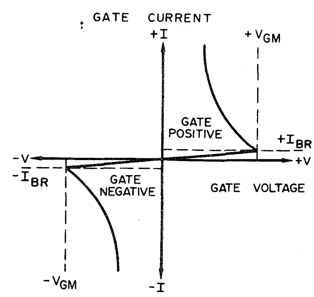


Fig. 2—Gate-to-Main Terminal 1 current-voltage characteristic

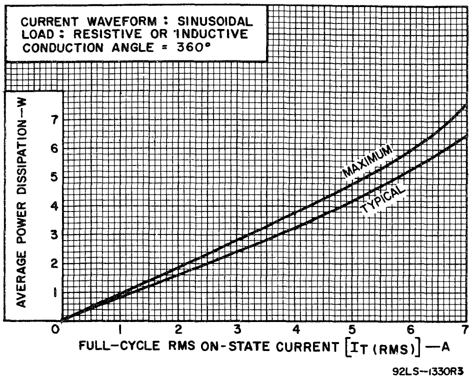


Fig. 3—Power dissipation vs. on-state current

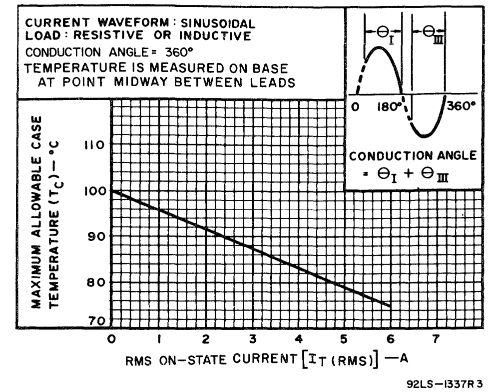


Fig. 4—Maximum allowable case temperature vs. on-state current

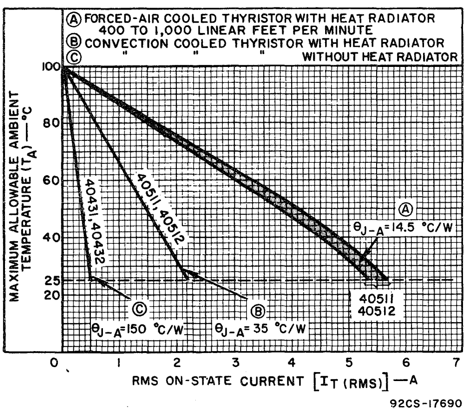


Fig. 5—Maximum allowable ambient temperature vs. on-state current for all types

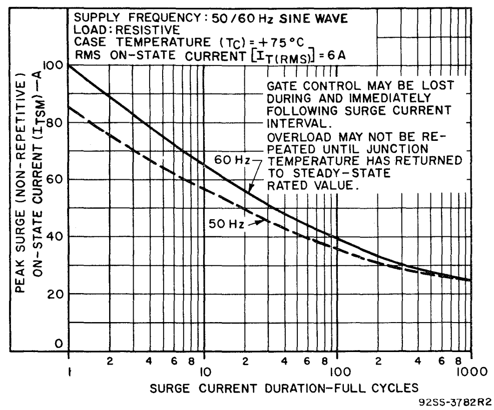


Fig. 6—Peak surge on-state current vs. surge current duration

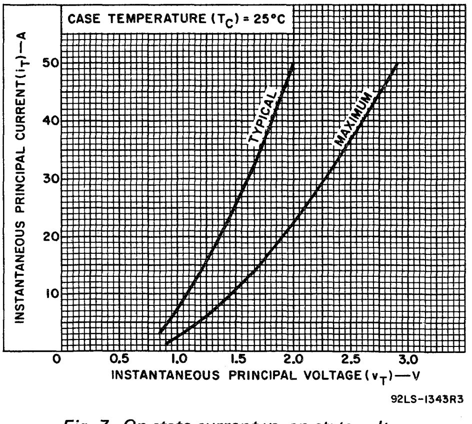


Fig. 7—On-state current vs. on-state voltage

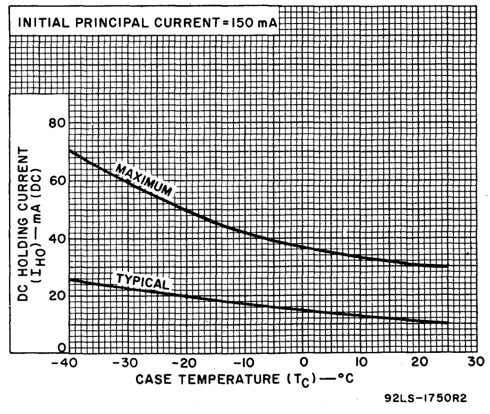


Fig. 8—DC holding current vs. case temperature

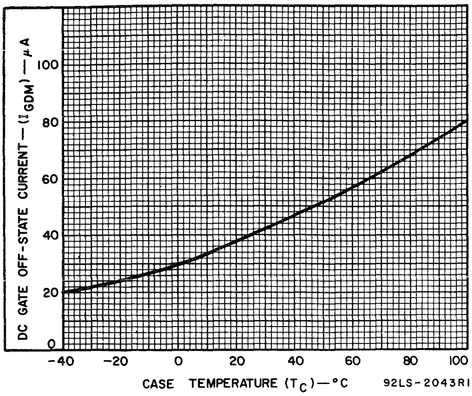


Fig. 9—Peak gate off-state current vs. case temperature

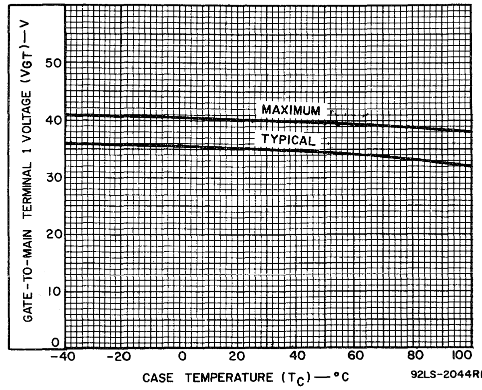


Fig. 10—Peak gate firing voltage vs. case temperature

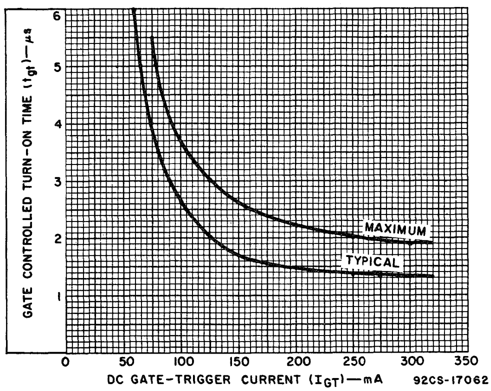


Fig. 11—Turn-on time vs. gate trigger current

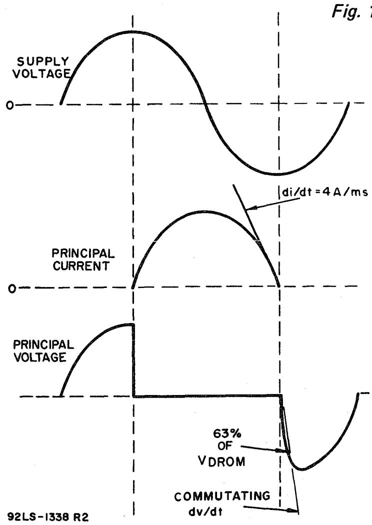


Fig. 12—Relationship between supply voltage and principal current (inductive load), showing reference points for definition of commutating voltage (dv/dt).

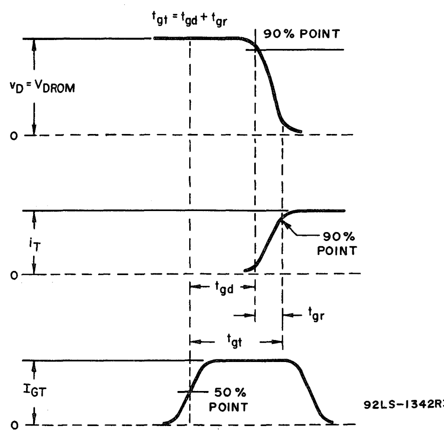
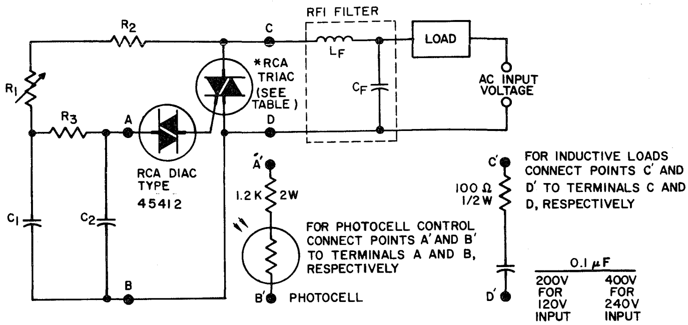


Fig. 13—Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).



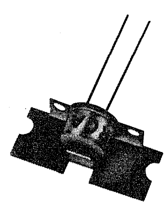
NOTE: For incandescent lamp loads which produce burnout current surges with I^2t values greater than 2.5 ampere^2 seconds, connect a 10-ohm resistor of appropriate wattage rating in series with the load. The appropriate wattage rating can be determined as follows:

$$\text{Wattage Rating of 10-ohm Resistor} = 10 \times (\text{rms load current})^2$$

AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	C_F* (typ.)	RCA TYPES
120 V 60 Hz	0.1 μF 200 V	0.1 μF 100 V	100 KΩ ½ W	2.2 KΩ ½ W	15 KΩ ½ W	100 μH	0.1 μF 200 V	40431 40511
240 V 50 Hz	0.1 μF 400 V	0.1 μF 100 V	250 KΩ 1 W	3.3 KΩ ½ W	15 KΩ ½ W	200 μH	0.1 μF 400 V	40432 40512

* Typical values for lamp dimming circuits.

Fig. 14—Typical phase-control circuit for lamp dimming, heat controls, and universal motor speed controls.



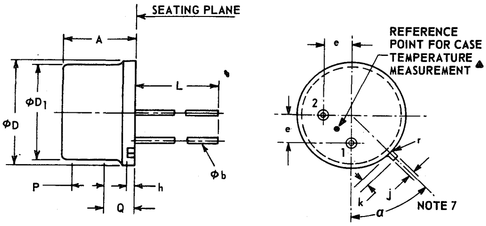
Triac with heat-spreader—

H-1539

On special request, these triacs are also available with a factory-attached heat spreader. This version provides efficient heat transfer to an external heat sink.

Please submit your requirements to your RCA Technical Sales Representative, or write to RCA Thyristor Marketing, Somerville, New Jersey 08876.

DIMENSIONAL OUTLINE FOR TYPES 40431 & 40432



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
ϕb	0.017	0.021	0.432	0.533	2
ϕD	0.355	0.366	9.017	9.296	
ϕD_1	0.323	0.335	8.204	8.51	
e	0.100 TRUE POSITION		2.45 TRUE POSITION		4,5
h	0.015	0.035	0.381	0.889	
j	0.028	0.035	0.711	0.889	5
k	0.029	0.045	0.737	1.14	3,5
L	0.975	1.025	24.76	26.04	2
P	0.100		2.54		1
Q					6
r		0.007		0.179	
α	42°	48°			5,7

NOTES:

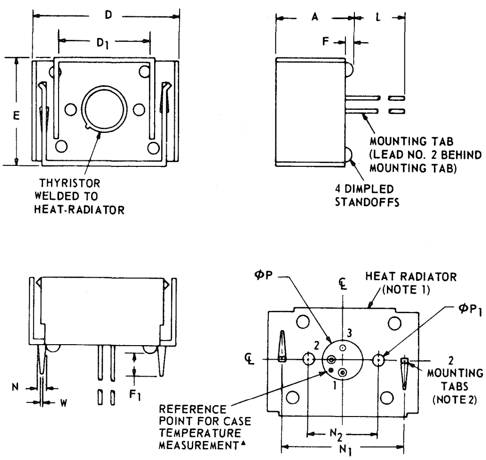
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.012 in. (0.279 mm).
2. (Two Leads) ϕb applies between seating plane and 1.025 in. (26.04 mm).
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.021 in. (0.533 mm) measured at 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 of JEDEC publication 12E, May 1964.
6. Details of outline in this zone optical.
7. Tab centerline.

92SS-3788R1

TERMINAL CONNECTIONS

Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Case – Main terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40511 & 40512



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	4.94	
L	0.885	–	22.47	–	
ϕP	0.295	0.310	7.493	7.87	
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
N_2	0.687	0.689	17.45	17.50	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 in. (1.78 mm) dia.
3. Measured at bottom of heat-radiator

92CM-17691

TERMINAL CONNECTIONS

Lead No. 1 – Main terminal 1
Lead No. 2 – Gate
Heat Rad., Lead No. 3 – Main terminal 2

▲The specified temperature-reference point should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 26 should be attached at the temperature reference point.

RCA

Solid State Division

Thyristors

40485 40510
40486 40638
40509 40639

6-AMPERE SILICON TRIAC's

Medium-Power, Gate-Controlled, Full-Wave Types

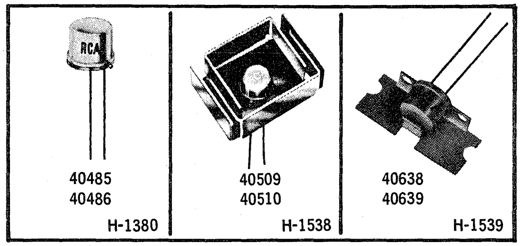
RCA-40485, 40486, 40509, 40510, 40638, and 40639 are gate-controlled, full-wave, silicon triacs. These devices are intended for the control of ac loads in applications such as heating controls, motor controls, light dimmers, and power switching systems.

These devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative triggering voltages to the gate.

Types 40485 and 40486 are hermetically sealed types having an on-state current rating of 6 amperes at a case temperature of +75 C and repetitive off-state voltage ratings of 200 volts and 400 volts, respectively.

Where space restrictions are of prime importance, the small size of this triac package (similar to the JEDEC TO-5 package) is especially suitable. Since this all-welded, tin-plated package may be soldered directly to a heat sink, mounting and heat-sinking problems are minimized--batch soldering and mass-production techniques may be fully utilized.

The 40485 and 40486 are also available with integral heat radiators or heat spreaders. Types 40509 and 40510 have the integral heat radiators for use in printed circuit board applications when the operating current is less than 6 amperes. Types 40638 and 40639 have integral heat spreaders to provide efficient heat transfer to an external heat sink.



Features

- 720-Watt Control, 120-Volt Line Operation — 40485, 40638
- 1,440-Watt Control, 240-Volt Line Operation — 40486, 40639
- 6-A (rms) On-State Current Ratings
- 100-A Peak Surge Full-Cycle Current Ratings
- Shorted-Emitter Design
  -- contains internal diffused resistor from gate to Main Terminal No. 1.
- Center Gate Construction
  -- provides rapid uniform gate current spreading for faster turn-on with substantially reduced heating effects
- Low Switching Losses
- Low Thermal Resistance

Maximum Ratings, *Absolute-Maximum Values:*

For Operation with Sinusoidal Supply Voltage at Frequencies of 50/60 Hz, and with Resistive or Inductive Load

	40485 40509 40638	40486 40510 40639	
REPETITIVE PEAK OFF-STATE VOLTAGE♦, V_{DROM}:			
Gate Open, for T_J = −65 to +100 °C	200	400	V
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT, I_{TSM}:			
For one cycle of applied principal voltage	100	100	A
For more than one full cycle of applied voltage	See Fig. 4.		
PEAK GATE-TRIGGER CURRENT■, I_{GTM}:			
For 1 μs max.	4	4	A
GATE POWER DISSIPATION■:			
PEAK, P_{GM} For 1 μs max. and $I_{GTM} \leq$ 4 A (peak)	16	16	W
AVERAGE, $P_{G(AV)}$	0.2	0.2	W
TEMPERATURE RANGE●*:			
Storage	−65 to +150		°C
Operating (case)	−65 to +100		°C
Soldering (case)	225		°C

RMS ON-STATE CURRENT, $I_{t(rms)}$:	40485 40486	40509 40510	40638 40639
For T_C of +75 °C and Cond. Angle of 360 °C	6 A	–	See Fig.16.
For T_A up to +100 °C and Cond. Angle of 360 °C	See Fig.17.	See Fig.17.	–

♦For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

■For either polarity of gate voltage (V_G) with reference to main terminal 1.

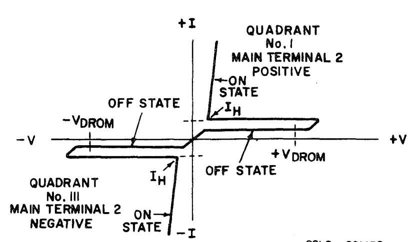


Fig. 1 - Principal Voltage-Current Characteristic

●For information on the reference point of temperature measurement, see Dimensional Outline, page 8.

*When these devices are soldered directly to the heat sink, a 60/40 solder should be used. Case heating time should be a minimum. . .sufficient to allow the solder to flow freely.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C), Unless Otherwise Specified

(For Definitions of Terms and Symbols, See Page 6.)

CHARACTERISTICS	SYMBOL	LIMITS												UNITS
		40485 40638			40509			40486 40639			40510			
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max	Min.	Typ.	Max.	
Peak Off-State Current:* Gate Open At T_J = +100 °C and V_{DROM} = Max. rated value	I_{DROM}	–	0.1	4	–	0.1	1.2	–	0.2	4	–	0.2	1.2	mA
Maximum On-State Voltage:* For i_T = 30A (peak) and T_C = +25 °C	v_{TM}	–	1.6	2.25	–	1.6	2.25	–	1.6	2.25	–	1.6	2.25	V
DC Holding Current:* Gate Open Initial principal current = 150 mA (DC) At T_C = +25 °C	I_{HO}	–	15	30	–	15	30	–	15	30	–	15	30	mA
For other case temperatures		See Fig. 8.												
Critical Rate of Rise of Commutation Voltage:*♦ For V_D = V_{DROM}, I_t(rms) = 6 A, commutating di/dt = 3.2 A/ms, and gate unenergized At T_C = +75 °C	dv/dt	3	10 (40485)	–	–	–	–	3	10 (40486)	–	–	–	–	V/µs
$I_{t(rms)}$ and T_{HS} specified by Fig. 16		3	10 (40638)	–	–	–	–	3	10 (40639)	–	–	–	–	
$I_{t(rms)}$ and T_A specified by Fig. 17: Curve A		–	–	–	3	10	–	–	–	–	3	10	–	
Curve B		–	–	–	4	12	–	–	–	–	4	12	–	
Critical Rate of Rise of Off-State Voltage:* For V_D = V_{DROM}, exponential voltage rise, and gate open, At T_C = +100 °C	dv/dt	30	150	–	30	150	–	20	100	–	20	100	–	V/µs
DC Gate-Trigger Current:*† For V_D = 12 volts (DC), R_L = 12 Ω T_C = + 25 °C, and specified triggering mode: I+Mode: positive V_{MT2}, positive V_{GT}	I_{GT}	–	15	25	–	15	25	–	15	25	–	15	25	mA
III–Mode: negative V_{MT2}, negative V_{GT}		–	15	25	–	15	25	–	15	25	–	15	25	
I–Mode: positive V_{MT2}, negative V_{GT}		–	25	40	–	25	40	–	25	40	–	25	40	
III+Mode: negative V_{MT2}, positive V_{GT}		–	25	40	–	25	40	–	25	40	–	25	40	
For other case temperatures		See Fig. 12 & 13.												
DC Gate-Trigger Voltage:*† For V_D = 12 volts (DC) and R_L = 12 Ω At T_C = +25 °C	V_{GT}	–	1	2.2	–	1	2.2	–	1	2.2	–	1	2.2	V
For other case temperatures		See Fig. 14.												
For V_D = V_{DROM} and R_L = 125 Ω At T_C = + 100 °C		0.2	–	–	0.2	–	–	0.2	–	–	0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For V_D = V_{DROM} and I_{GT} = 80 mA, 0.1 µs rise time, and i_T = 10 A (peak) At T_C = + 25 °C	t_{gt}	–	2.2	–	–	2.2	–	–	2.2	–	–	2.2	–	µs
Thermal Resistance: Junction-to-Case (Steady-State)	θ_{J-C}	–	–	4 (40485)	–	–	–	–	–	4 (40486)	–	–	–	°C/W
Junction-to-Case (Transient)		See Fig. 15.												
Junction-to-Heat Sink (Insulated mounting, page 7.)	θ_{J-HS}	–	–	7 (40638)	–	–	–	–	–	7 (40639)	–	–	–	
Junction-to-Ambient	θ_{J-A}	–	–	–	See Fig. 17.			–	–	–	See Fig. 17.			

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

†For either polarity of gate voltage (V_{GT}) with reference to main terminal 1.

♦Variants of these devices having dv/dt characteristics selected specifically for inductive loads are available on special order; for additional information, contact your RCA Representative or your RCA Distributor.

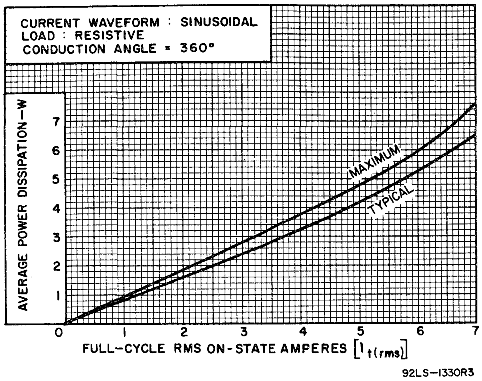


Fig. 2 - Power Dissipation vs. On-State Current

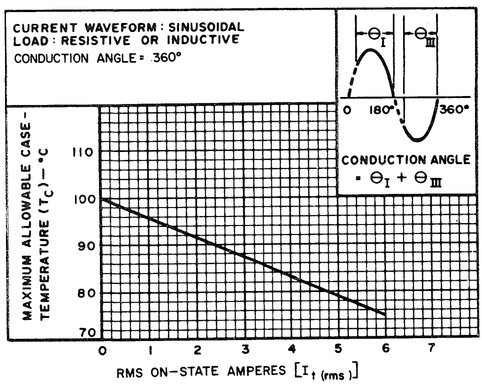


Fig. 3 - Allowable Case Temperature vs. On-State Current

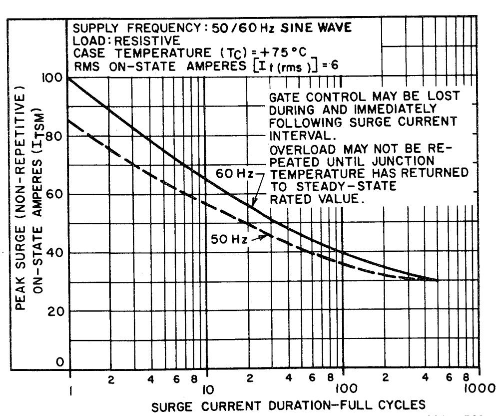


Fig. 4 - Peak Surge On-State Current vs. Surge Current Duration

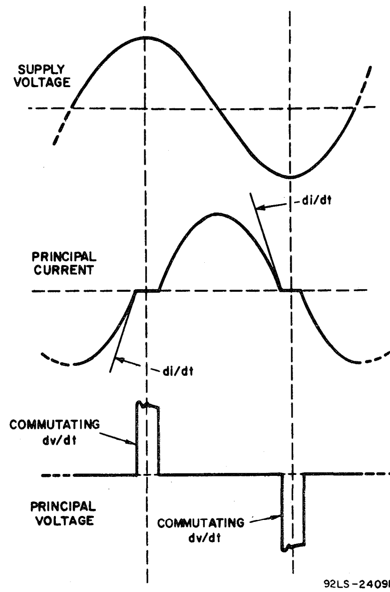


Fig. 5 - Oscilloscope Display of commutating dv/dt

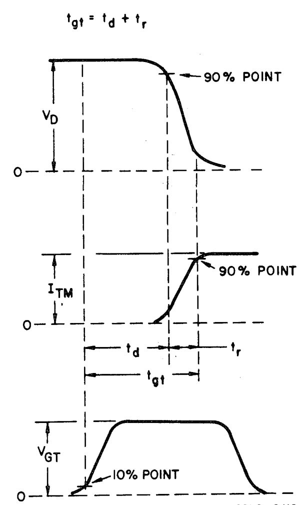


Fig. 6 - Oscilloscope Display for Measurement of Gate-Controlled Turn-On Time (t_{gt})

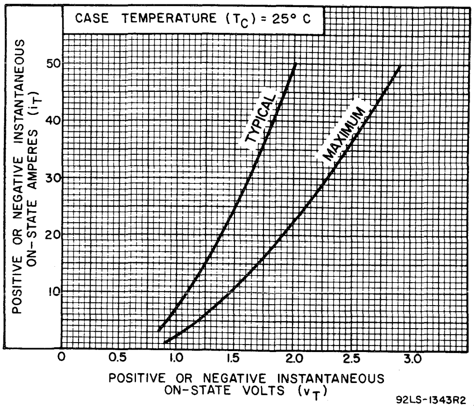


Fig. 7 - On-State Current vs. On-State Voltage

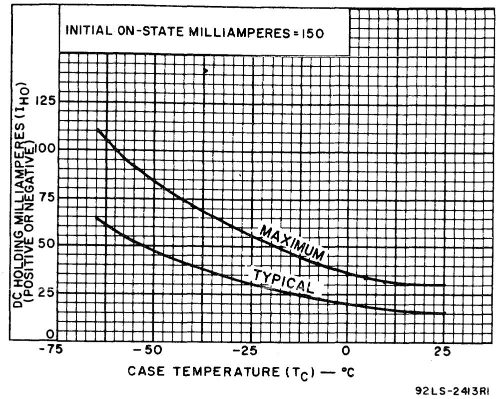


Fig. 8 - DC Holding Current for Either Direction of On-State Current vs. Case Temperature

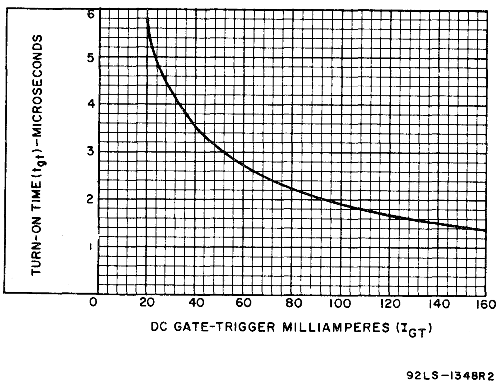


Fig. 9 - Typical Turn-On Time vs. Gate-Trigger Current

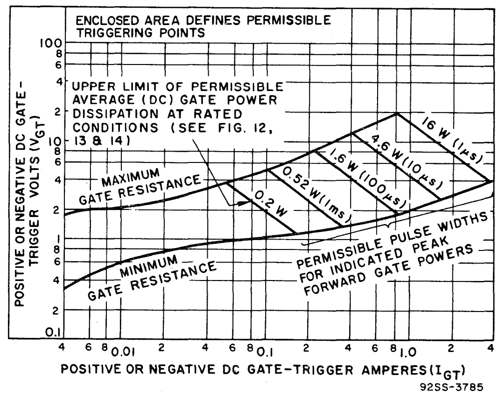
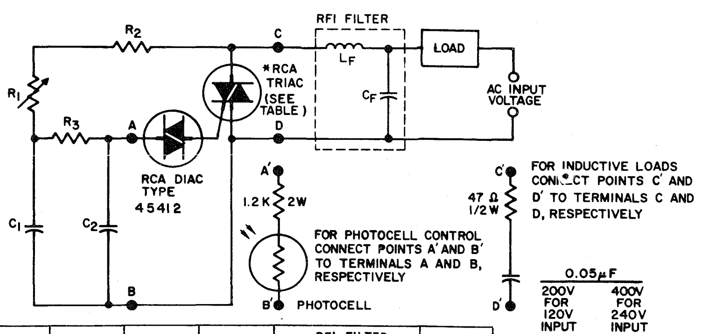


Fig. 10 - Gate Pulse Characteristics for All Triggering Modes



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	RFI FILTER C_F* (typ.)	RCA TYPES
120V 60Hz	0.1μF 200V	0.1μF 100V	100KΩ 1/2W	1KΩ 1/2W	15KΩ 1/2W	100μH	0.1μF 200V	40485 40509 40638
240V 50/60Hz	0.05μF 400V	0.1μF 100V	200KΩ 1/2W	7.5KΩ 2W	7.5KΩ 2W	100μH	0.1μF 400V	40486 40510 40639

*Typical values for lamp dimming circuits.

Fig. 11 - Typical Phase-Control Circuit for Lamp Dimming, Heat Controls, and Universal Motor Speed Controls

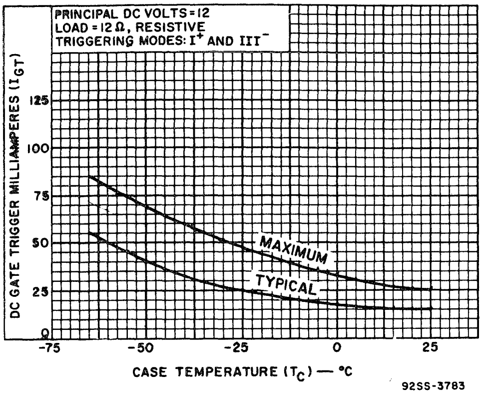


Fig. 12 - DC Gate-Trigger Current (for I+ and III− Triggering Modes) vs. Case Temperature

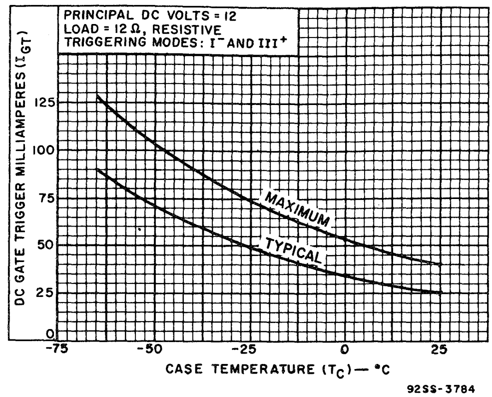


Fig. 13 - DC Gate-Trigger Current (for I− and III+ Triggering Modes) vs. Case Temperature

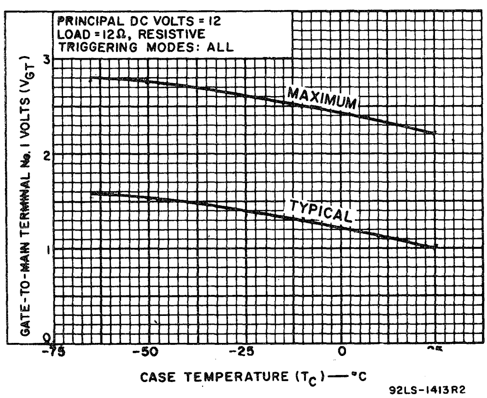


Fig. 14 - DC Gate-Trigger Voltage vs. Case Temperature

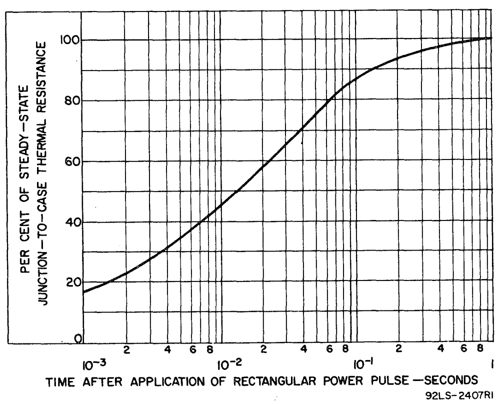


Fig. 15 - Transient Thermal Resistance (Junction-to-Case) vs. Time

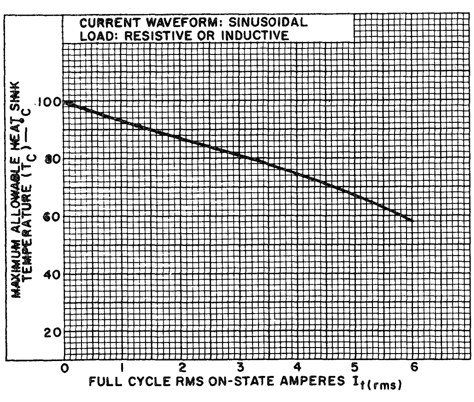


Fig. 16 - Maximum Allowable Heat Sink Temperature vs. On-State Current for Types 40638 & 40639

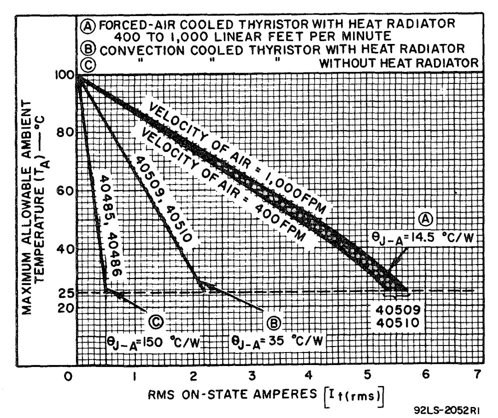
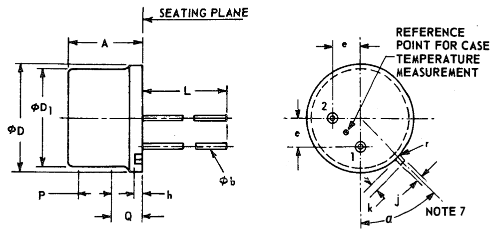


Fig. 17 - Maximum Allowable Ambient Temperature vs. On-State Current for Types 40485, 40486, 40509, & 40510

DIMENSIONAL OUTLINE FOR TYPES 40485 & 40486

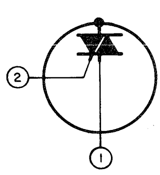


SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.017	.021	.432	.533	2
ΦD	.355	.366	9.017	9.296	
ΦD1	.323	.335	8.204	8.51	
e	.100 T.P.		2.54 T.P.		4,5
h	.015	.035	.381	.889	
j	.028	.035	.711	.889	5
k	.029	.045	.737	1.14	3,5
L	.975	1.025	24.76	26.04	2
P	.100		2.54		1
Q					6
r		.007		.179	
α	42°	48°			5,7

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed .012 in. (.279 mm).
2. (Two Leads) Φb applies between seating plane and 1.025 in. (26.04 mm).
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter .021 in. (.533 mm) measured at the seating plane of the device shall be within .007 in. (.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 of JEDEC publication 12E, May 1964.
6. Details of outline in this zone optional.
7. Tab centerline.

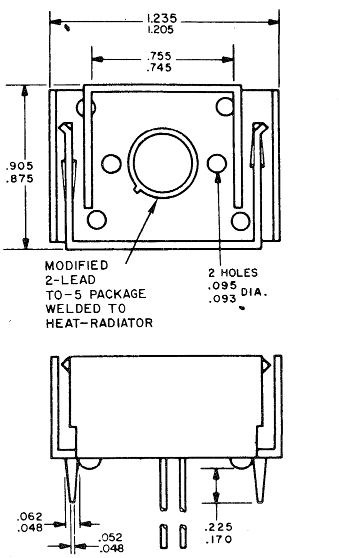
TERMINAL DIAGRAM FOR TYPES 40485, 40486 40509, 40510, 40638, & 40639

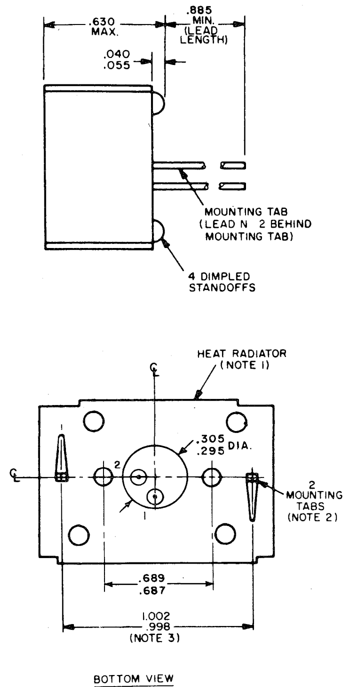


92SS-3805

Lead 1 - Main Terminal 1
Lead 2 - Gate
Case (40485, 40486)
Case, Heat Spreader (40638, 40639)
Case, Heat Radiator (40509, 40510)
} Main Terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40509 & 40510





NOTE 1: 0.035 C.R.S., FINISH—ELECTROLESS NICKEL PLATE

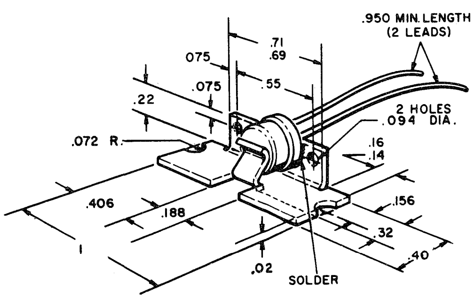
NOTE 2: RECOMMENDED HOLE SIZE FOR PRINTED-CIRCUIT BOARD IS 0.070 DIA.

NOTE 3: MEASURED AT BOTTOM OF HEAT-RADIATOR

DIMENSIONS IN INCHES

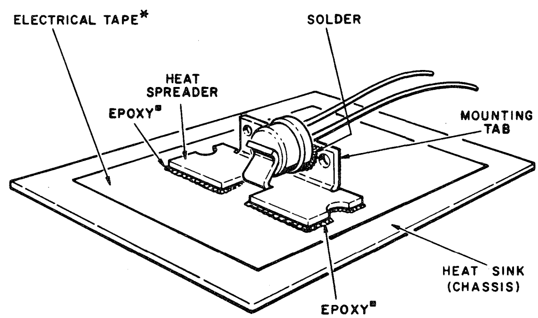
92LM-2054R1

DIMENSIONAL OUTLINE FOR TYPES 40638 & 40639



92LS-1423R2

SUGGESTED MOUNTING ARRANGEMENT FOR TYPES 40638 & 40639 (CASE INSULATED FROM HEAT SINK)



92LS-1422R2

NOTES:

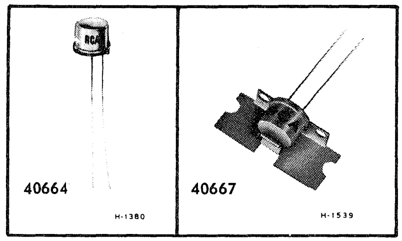
*Scotch brand electrical tape No. 27 (thermo-setting one side), Minnesota Mining & Mfg. Co., St. Paul, Minnesota, or equivalent.

■An epoxy such as Hysol-Epoxy Patch Kit 6C, Hysol Corporation, Olean, N.Y. 14761, or equivalent.

RCA
Solid State
Division

Thyristors
40664
40667

6-AMPERE SILICON TRIACS
For 240-V Line Light-Dimmer and Resistive Load-Control Applications



RCA-40664 and 40667 triacs are gate-controlled, full-wave, silicon ac switches designed to switch from an off-state to an on-state for either polarity of applied voltage. These devices are intended for light-dimmer and resistive load-control applications.

Type 40664 is a hermetically sealed type that has an on-state current rating of 6 amperes (rms) at a case temperature of +75°C and a repetitive peak off-state voltage rating of 450 volts.

Type 40664 with its small package (similar to the JEDEC TO-5 package) is especially suitable for those applications where space restrictions are of prime importance. Since this all-welded, tin-plated package may be soldered directly to a heat sink, mounting and heat-sinking problems are minimized—batch soldering and mass-production techniques may be fully utilized.

Type 40667 employs an integral heat spreader to provide efficient heat transfer to an external heat sink.

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

For Operation with 50/60 Hz, Sinusoidal Supply Voltage and Resistive Load

		40664 40667	
REPETITIVE PEAK OFF-STATE VOLTAGE*	V_{DROM}		
Gate Open, For T_J = −65 to +100°C		450	V
RMS ON-STATE CURRENT	$I_{T(RMS)}$		
For case temperature (T_C) of +75°C and a conduction angle of 360°		6	A
For other temperatures and a conduction angle of 360°		See Figs. 3, 4, 5, & 6.	
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT	I_{TSM}		
For one full cycle of applied principal voltage (60 Hz, sinusoidal)		100	A
For one full cycle of applied principal voltage (50 Hz, sinusoidal)		84	A
For more than one full cycle of applied voltage		See Fig. 7.	
PEAK GATE-TRIGGER CURRENT†	I_{GTM}		
For 1 μs max.		4	A
GATE POWER DISSIPATION: PEAK†	P_{GM}		
For 1 μs max. and $I_{GTM} \leq$ 4 A (peak)		16	W
AVERAGE	$P_{G(AV)}$	0.2	W
TEMPERATURE RANGE‡●:			
Storage		−65 to +150	°C
Operating (case)		−65 to +100	°C
Soldering (case)		225	°C

Features

- 300 to 1,440 Watt Dimmer Control 240-Volt Line Operation
- 6-A (rms) On-State Current Rating
- 100-A Peak Surge Full-Cycle Current Rating at 60 Hz
- 84-A Peak Surge Full-Cycle Current Rating at 50 Hz
- Shorted-Emitter Design--contains internal diffused resistor from gate to Main Terminal No. 1.
- Center Gate Construction--provides rapid uniform gate current spreading for faster turn-on with substantially reduced heating effects
- Low Switching Losses
- Low Thermal Resistance

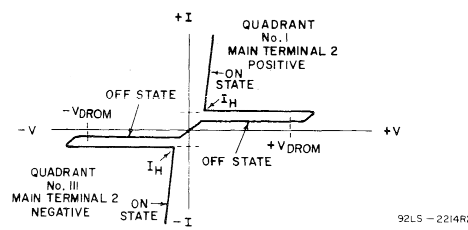


Fig. 1 - Principal voltage-current characteristic.

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

†For either polarity of gate voltage (V_G) with reference to main terminal 1.

‡For information on the reference point for temperature measurement, see *Dimensional Outlines.*

●When these devices are soldered directly to the heat sink, a 60/40 solder should be used. Case heating time should be a minimum. . . sufficient to allow the solder to flow freely.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C), Unless Otherwise Specified
(For Definitions of Terms and Symbols, See Page 7.)

CHARACTERISTIC	SYMBOL	LIMITS 40664, 40667 MIN.	TYP.	MAX.	UNITS
Peak Off-State Current:* Gate Open At T_J = + 100° C and V_{DROM} = Max. rated value	I_{DROM}	–	0.2	4	mA
Maximum On-State Voltage:* For i_T = 10 A (peak) and T_C = + 25° C	v_{TM}	–	1.1	2.25	V
Critical Rate of Rise of Off-State Voltage:* For V_D = V_{DROM}, exponential voltage rise, and gate open, At T_C = + 100° C	dv/dt	10	100	–	V/μs
DC Gate-Trigger Current:* For V_D = 12 volts (DC), R_L = 30 Ω T_C = + 25° C, and specified triggering mode:	I_{GT}				mA
I + Mode: positive V_{MT2}, positive V_{GT}		–	15	50	
III – Mode: negative V_{MT2}, negative V_{GT}		–	15	50	
For other case temperatures			See Fig. 10.		
DC Gate-Trigger Voltage:* For V_D = 12 volts (DC) and R_L = 30 Ω	V_{GT}				V
At T_C = + 25° C		–	1	4	
For other case temperatures			See Fig. 11.		
Thermal Resistance:					°C/W
Junction-to-Case, Steady-State (See Fig. 3.)	θ_{J-C}	–	–	4 (40664)	
Junction-to-Case, Transient	–		See Fig. 12.		
Junction-to-Heat Spreader, Steady State (See Fig. 5.)	–	–	–	5.5 (40667)	

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

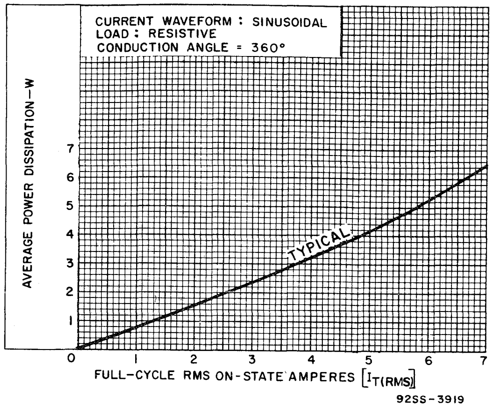


Fig. 2 - Power dissipation vs. on-state current.

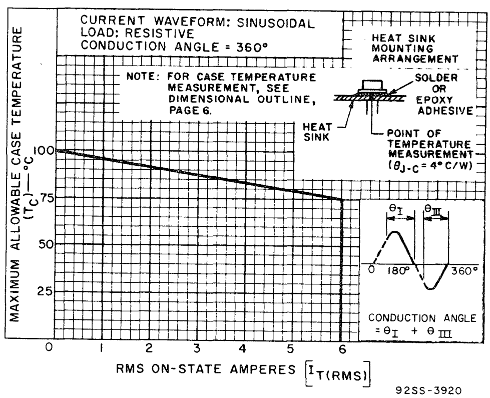


Fig. 3 - Maximum allowable case temperature vs. on-state current for type 40664 (bottom of thyristor case attached to heat sink)

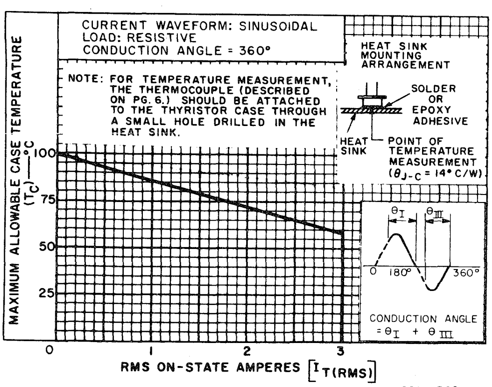


Fig. 4 - Maximum allowable case temperature vs. on-state current for type 40664 (top of case attached to copper heat sink)

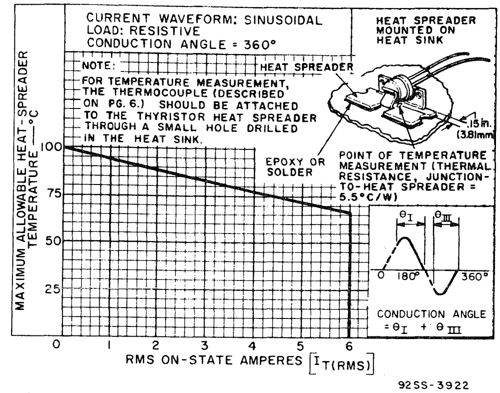


Fig. 5 - Maximum allowable heat-spreader temperature vs. on-state current for type 40667 (heat spreader mounted on heat sink).

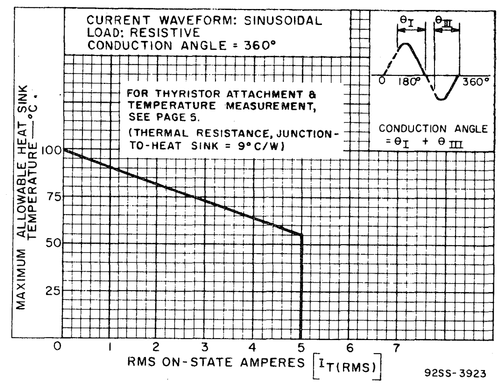


Fig. 6 - Maximum allowable heat-sink temperature vs. on-state current for type 40667 (heat spreader insulated from heat sink)

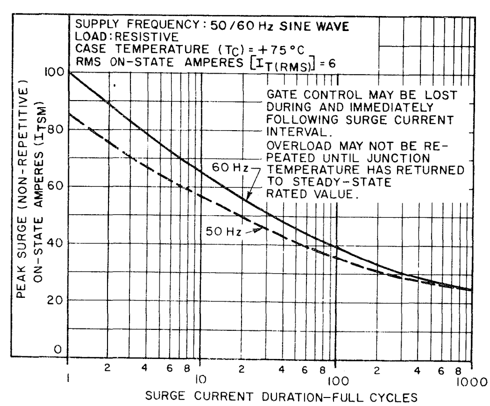
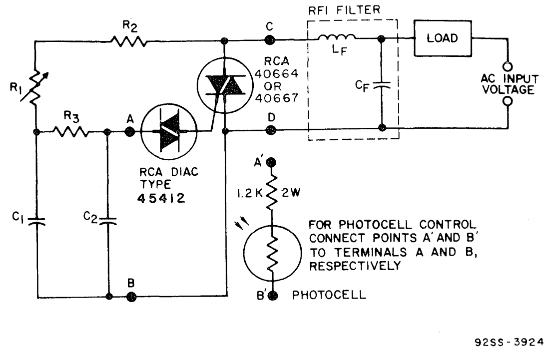


Fig. 7 - Peak surge on-state current vs. surge current duration



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F (typ.)	RFI FILTER C_F (typ.)
240V 60Hz	0.1μF 400V	0.1μF 100V	200kΩ 1W	3.3kΩ ½W	15kΩ ½W	200μH	0.1μF 400V
240V 50Hz	0.1μF 400V	0.1μF 100V	250kΩ 1W	3.3kΩ ½W	15kΩ ½W	200μH	0.1μF 400V

Fig. 8 - Typical phase-control circuit for lamp dimming

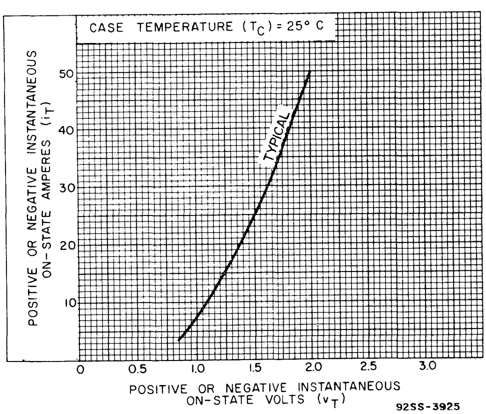


Fig. 9 - On-state current vs. on-state voltage

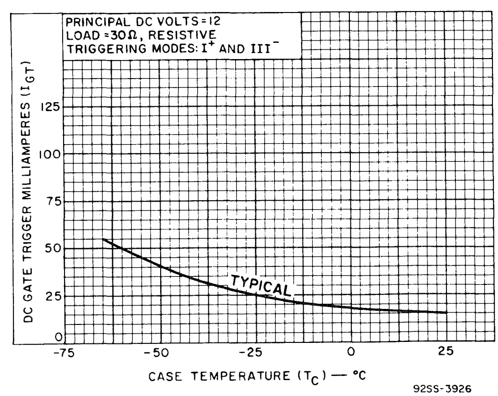


Fig. 10 - DC gate-trigger current (for I^+ and III^- triggering modes) vs. case temperature.

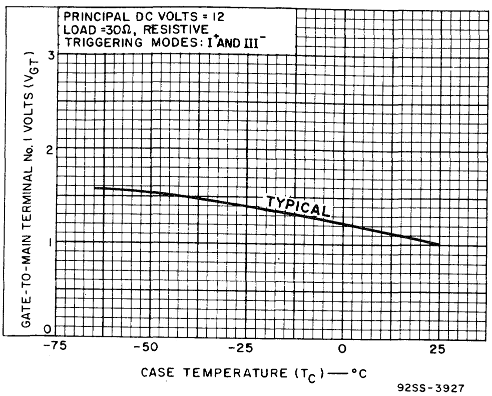


Fig. 11 - DC gate-trigger voltage vs. case temperature.

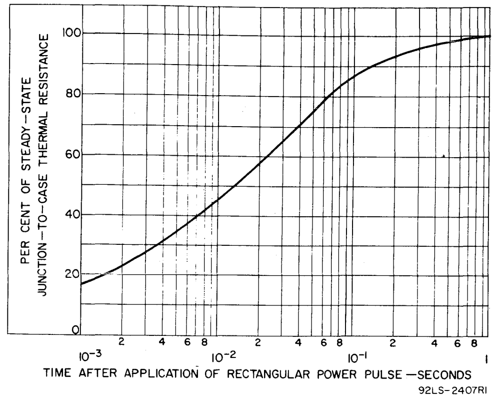
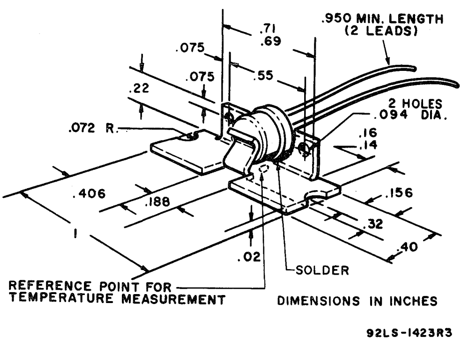
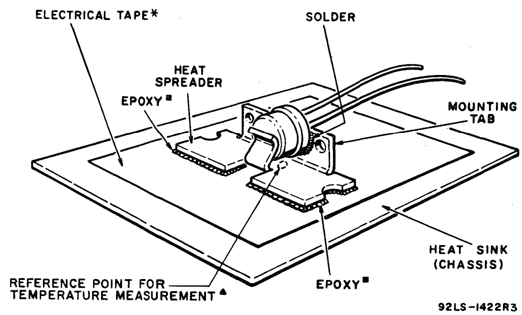


Fig. 12 - Transient thermal resistance (junction-to-case) vs. time.

DIMENSIONAL OUTLINE FOR HEAT-SPREADER TYPE 40667



SUGGESTED MOUNTING ARRANGEMENT FOR HEAT SPREADER TYPE 40667 (CASE INSULATED FROM HEAT SINK)



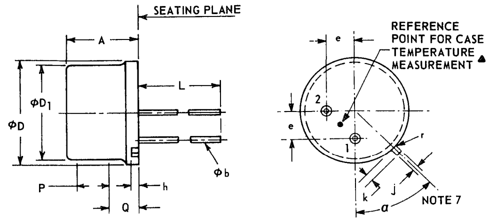
NOTES:

*Scotch brand electrical tape No. 27 (thermo-setting one side), Minnesota Mining & Mfg. Co., St. Paul, Minnesota, or equivalent.

■An epoxy such as Hysol-Epoxy Patch Kit 6C, Hysol Corporation, Olean, N.Y. 14761, or equivalent.

▲For heat sink temperature measurement, the thermocouple (of wire no larger than AWG No. 26) should be inserted into a small, shallow hole drilled in (but not through) the heat sink at the indicated temperature reference point.

*DIMENSIONAL OUTLINE FOR TYPES 40664 & 40667**



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.017	.021	.432	.533	2
ΦD	.355	.366	9.017	9.296	
$ΦD_1$	.323	.335	8.204	8.51	
e	.100 TRUE POSITION		2.45 TRUE POSITION		4,5
h	.015	.035	.381	.889	
j	.028	.035	.711	.889	5
k	.029	.045	.737	1.14	3,5
L	.975	1.025	24.76	26.04	2
P	.100		2.54		1
Q					6
r		.007		.179	
α	42°	48°			5,7

NOTES:

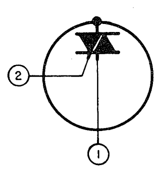
1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed .012 in. (.279 mm).
2. (Two Leads) Φb applies between seating plane and 1.025 in. (26.04 mm).
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter .021 in. (.533 mm) measured at the seating plane of the device shall be within .007 in. (.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 of JEDEC publication 12E, May 1964.
6. Details of outline in this zone optional.
7. Tab centerline.

*Dimensions of Heat Spreader are shown in Outline Drawing on Page 5.

▲CASE TEMPERATURE MEASUREMENT
The temperature reference point specified should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 26 should be attached at the temperature reference point.

92SS-3788R1

TERMINAL DIAGRAM FOR TYPES 40664 & 40667



92SS-3805

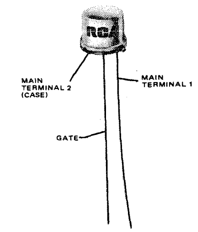
Lead 1-Main Terminal 1
Lead 2-Gate

Case (40664)
Case, Heat Spreader (40667)
} Main Terminal 2

RCA
Solid State
Division

Thyristors

40773
40774



Modified JEDEC TO-5

H-1380V2

400-Hz 2.5-A Silicon Triacs

For Control-Systems Application in Airborne and Ground-Support Type Equipment

For 115-V Line Operation – 40773
For 208-V Line Operation – 40774

Features

- **di/dt Capability = 150 A/μs**
- **Commutating dv/dt Capability Characterized at 400 Hz**
- **Shorted-Emitter, Center-gate Design**
- **Low Switching Losses**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled, full-wave silicon ac switches.

The devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

They are intended for operation up to 400 Hz with resistive or inductive loads and nominal line voltages of 115 and 208 V RMS sine wave and repetitive peak off-state voltages of 200 V and 400 V. These triacs are intended for control systems application for both commercial and military airborne and ground-support type equipment.

All types utilize a compact package(similar to JEDEC TO-5). This package is especially suitable where space requirements are of prime importance. The hermetic, tin-plated package may be soldered directly to a heat sink, minimizing mounting and heat sinking problems.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 400 Hz and with Resistive or Inductive Load.

		40773	40774	
REPETITIVE PEAK OFF-STATE VOLTAGE:*	V_{DROM}			
Gate open, T_J=-50 to 100°C		200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°):	$I_{T(RMS)}$			
Case temperature (T_C) = 90°C		2.5		A
Ambient temperature (T_A) = 25°C, without heat sink		0.5		A
For other conditions		*See Figs.3,4,&5.*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}			
For one cycle of applied principal voltage				
400 Hz (sinusoidal)		200		A
60 Hz (sinusoidal)		100		A
For more than one cycle of applied principal voltage		*See Fig.5.*		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt			
V_{DM} = V_{DROM}, I_{GT} = 80 mA, t_r = 0.1 μs *(See Fig. 15.)*		150		A/μs
PEAK GATE-TRIGGER CURRENT:■	I_{GTM}			
For 1 μs max., *See Fig. 9*		4		A
GATE POWER DISSIPATION:				
PEAK (For 1 μs max., $I_{GTM} < 4$ A, (See Fig. 9)	P_{GM}	16		W
AVERAGE	$P_{G(AV)}$	0.2		W
TEMPERATURE RANGE:				
Storage	T_{stg}	-50 to 150		°C
Operating (Case)	T_C	-50 to 100		°C
LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/16 in. (1.58 mm) from the case for 10 s max.	T_L	225		°C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

■ For either polarity of gate voltage (V_G) with reference to main terminal 1.

▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS 40773 40774 Min.	Typ.	Max.	UNITS
Peak Off-State Current:♠ Gate open, T_J = 100°C, V_{DROM} = Max. rated value	I_{DROM}	–	0.2	4	mA
Maximum On-State Voltage:♠ For i_T = 30 A (peak), T_C = 25°C	V_{TM}	–	1.6	2.25	V
DC Holding Current:♠ Gate open, Initial principal current = 150 mA(DC), v_D = 12 V, T_C = 25°C For other case temperatures	I_{HO}	–	15 See Fig. 8	30	mA
Critical Rate-of-Rise of Commutation Voltage:♠ For v_D = V_{DROM}, $I_{T(RMS)}$ = 2.5 A, commutating di/dt = 8.9 A/ms, gate unenergized, T_C = 90°C (See Fig. 16)	dv/dt	3	10	–	V/μs
Critical Rate-of-Rise of Off-State Voltage:♠ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100°C	dv/dt	30	150	–	V/μs
DC Gate-Trigger Current:♠† For v_D = 12 V(DC), R_L = 30 Ω, T_C = 25°C — Mode / V_{MT2} / V_G: I^+ positive positive III^- negative negative I^- positive negative III^+ negative positive For other case temperatures	I_{GT}	–	15 15 25 25 See Figs. 10 & 11	25 25 40 40	mA
DC Gate-Trigger Voltage:♠† For v_D = 12 V(DC), R_L = 30 Ω, T_C = 25°C For other case temperatures For v_D = V_{DROM}, R_L = 125 Ω, T_C = 100°C	V_{GT}	– 0.2	1 See Fig. 12 –	2.2 –	V
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 80 mA, t_r = 0.1 μs, i_T = 10 A (peak), T_C = 25°C (See Fig. 13 & 17)	t_{gt}	–	1.8	2.5	μs
Thermal Resistance, Junction-to-case: Steady State Transient	$\theta_{J\text{-}C}$	–	– See Fig. 14.	4	°C/W

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

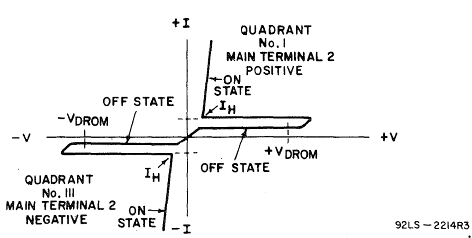


Fig. 1 - Principal voltage-current characteristic.

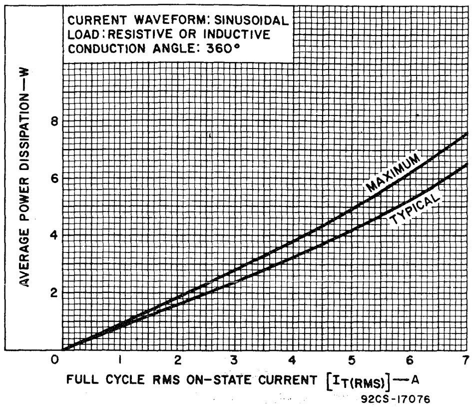


Fig. 2 - Power dissipation vs. on-state current.

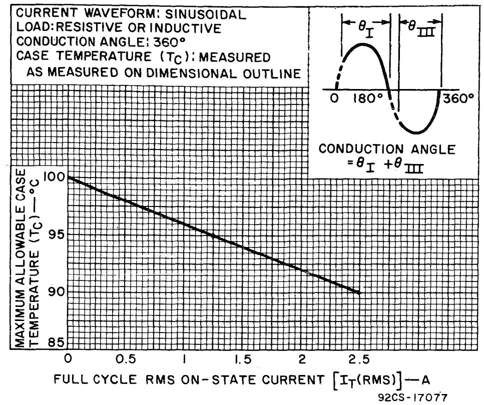


Fig. 3 - Maximum allowable case temperature vs. on-state current.

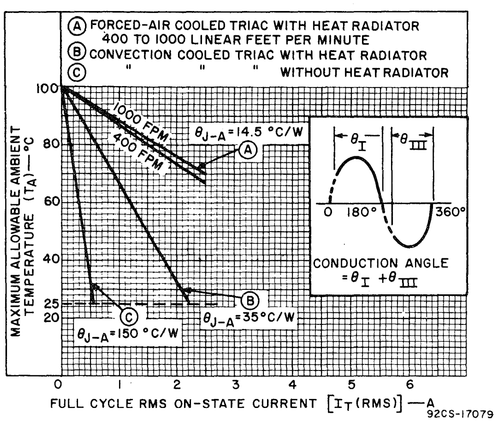


Fig. 4 - Maximum allowable ambient temperature vs. on-state current for the package/mounting option of these triacs. (See photo, page 6.)

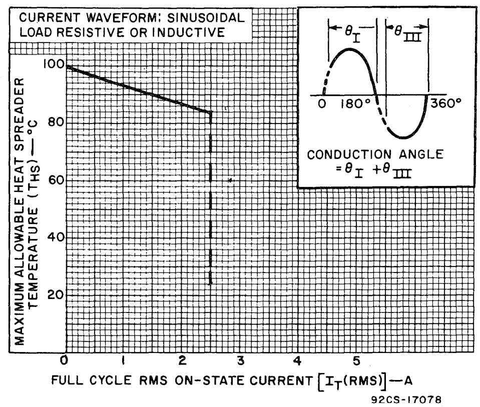


Fig. 5 - Maximum allowable heat-spreader temperature vs. on-state current for the heat-spreader package option of these triacs. (See photo, page 6.)

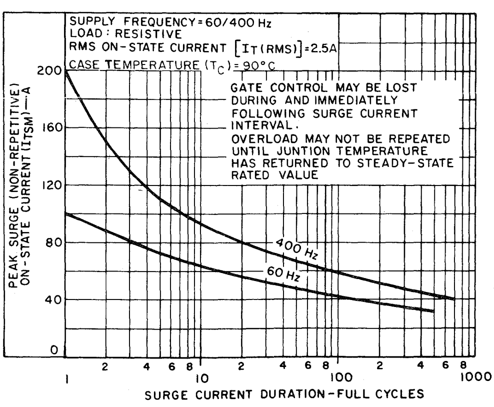


Fig. 6 - Peak surge on-state current vs. surge current duration.

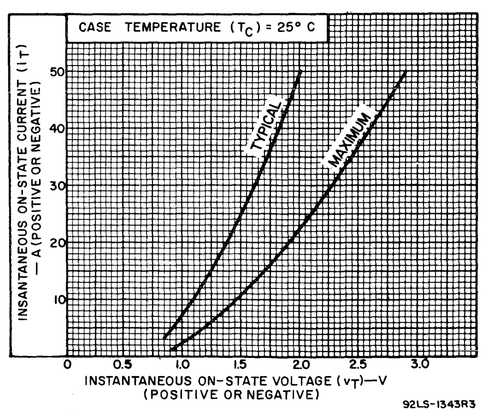


Fig. 7 - On state current vs on-state voltage.

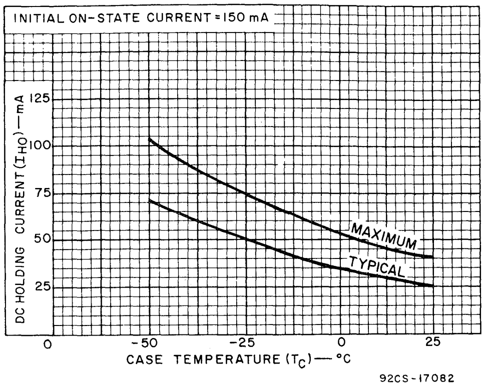


Fig. 8 - DC holding current vs. case temperature.

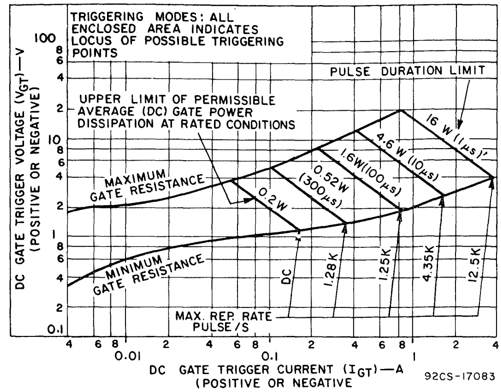


Fig. 9 - Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

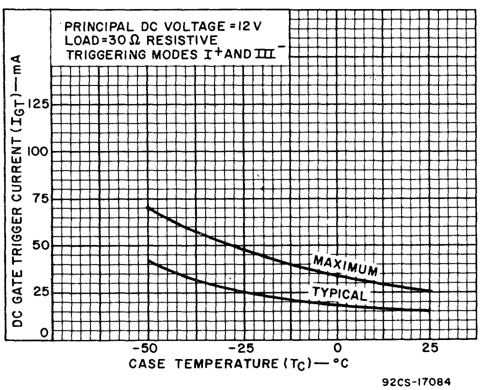


Fig. 10 - DC gate-trigger current vs. case temperature (I^+ & III^- modes).

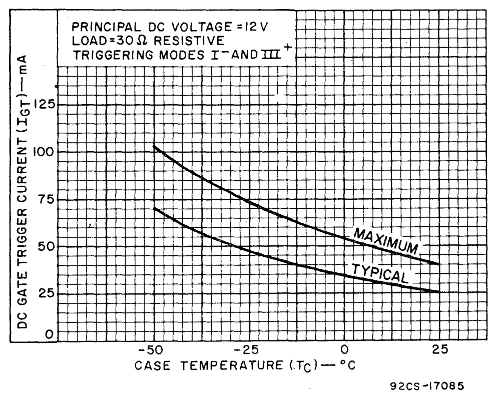


Fig. 11 - DC gate-trigger current vs. case temperature (I^- & III^+ modes).

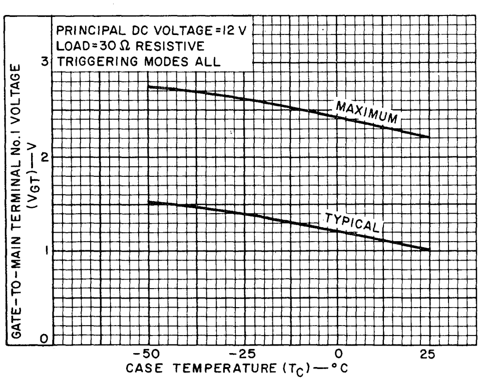


Fig. 12 - DC gate-trigger voltage vs. case temperature.

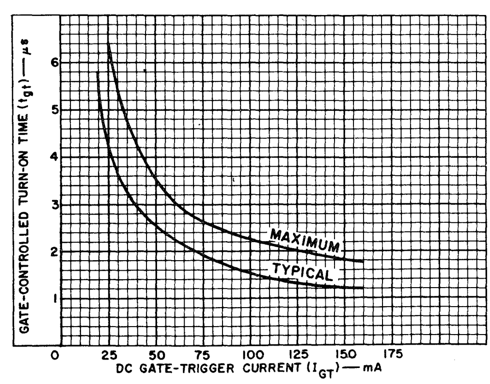


Fig. 13 - Turn-on time vs. gate trigger current.

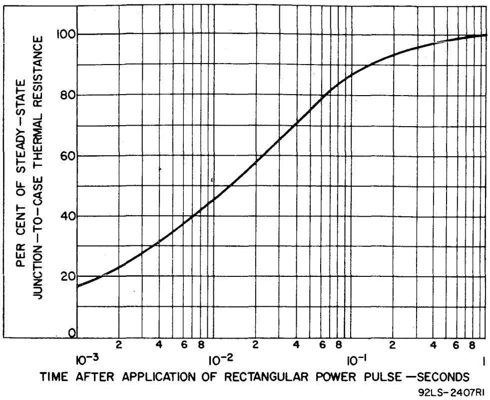


Fig. 14 - Transient thermal resistance vs. time (junction-to-case).

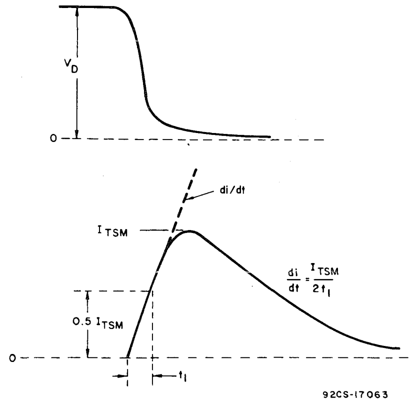


Fig. 15 - Rate-of-change of on-state current with time (defining di/dt).

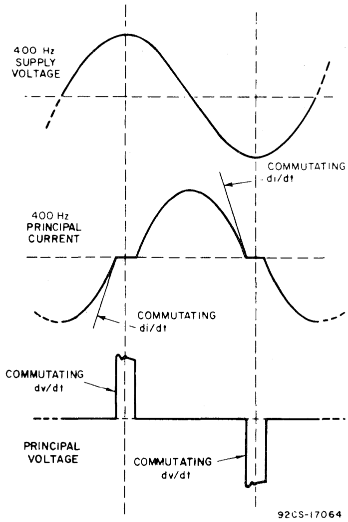


Fig. 16 - Relationship between supply voltage and principal current (inductive load), showing reference points for definition of commutating voltage (dv/dt).

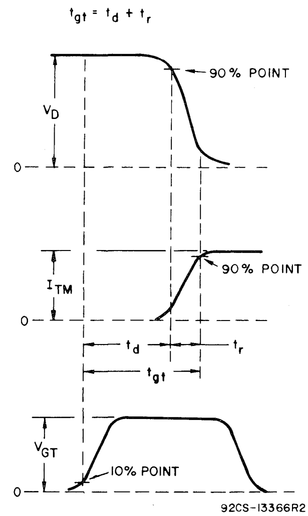


Fig. 17 - Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

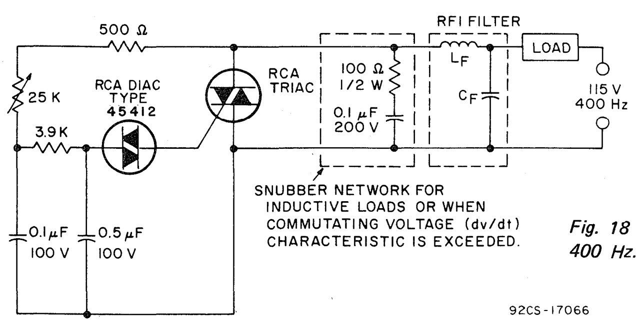
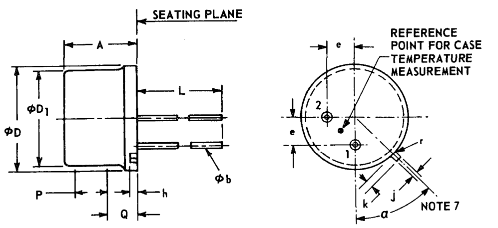


Fig. 18 - Typical phase-control circuit for operation at 400 Hz.

DIMENSIONAL OUTLINE



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	.240	.260	6.10	6.60	
Φb	.017	.021	.432	.533	2
ΦD	.355	.366	9.017	9.296	
$ΦD_1$	.323	.335	8.204	8.51	
e	.100 TRUE POSITION		2.45 TRUE POSITION		4,5
h	.015	.035	.381	.889	
j	.028	.035	.711	.889	5
k	.029	.045	.737	1.14	3,5
L	.975	1.025	24.76	26.04	2
P	.100		2.54		1
Q					6
r		.007		.179	
α	42°	48°			5,7

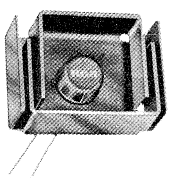
NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed .012 in. (.279 mm).
2. (Two Leads) Φb applies between seating plane and 1.025 in. (26.04 mm).
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter .021 in. (.533 mm) measured at the seating plane of the device shall be within .007 in. (.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 of JEDEC publication 12E, May 1964.
6. Details of outline in this zone optional.
7. Tab centerline.

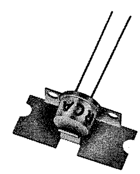
92SS-3788R1

TERMINAL CONNECTIONS

Lead No. 1 — Main terminal 1
Lead No. 2 — Gate
Case — Main terminal 2



Triac with factory-attached heat radiator —

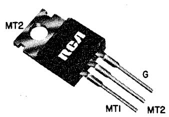


Triac with heat-spreader —

On special request, these triacs are also available with a factory attached heat radiator or heat spreader. The heat radiator version is intended for printed circuit board applications, and heat spreader version provides efficient heat transfer to an external heat sink.

RCA Solid State Division

Thyristors
40668
40669



JEDEC TO-220AB H-1535

8-A Silicon Triacs

Three-Lead Plastic Types for
Power-Control and Power-Switching Applications

For 120-V Line Operation 40668
For 240-V Line Operation 40669

Features

- **100-A Peak Surge Full-Cycle Current Ratings**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low Thermal Resistance**
- **Package Design Facilitates Mounting on a Printed-Circuit Board**

RCA-40668 and 40669* are gate-controlled, full-wave, silicon triacs utilizing a plastic case with three leads to facilitate mounting on printed-circuit boards. They are intended for the control of ac loads in such applications as motor controls, light dimmers, heating controls, and power-switching systems.

These devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. They have an on-state current rating of 8 amperes at a T_C of 80°C and repetitive off-state voltage ratings of 200 volts and 400 volts, respectively.

The unique plastic package design provides not only ease of mounting but also low thermal impedance, which allows operation at high case temperatures and permits reduced heat-sink size.

MAXIMUM RATINGS, ***Absolute-Maximum Values:***
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40668	40669	
REPETITIVE PEAK OFF-STATE VOLTAGE:●				
Gate open, T_J = −65 to 100°C	V_{DROM}	200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°):				
Case temperature	$I_{T(RMS)}$			
T_C = 80°C		8		A
For other conditions		See *Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:				
For one cycle of applied principal voltage	I_{TSM}			
60 Hz (sinusoidal)		100		A
50 Hz (sinusoidal)		85		A
For more than one cycle of applied principal voltage		See *Fig. 4*		
PEAK GATE-TRIGGER CURRENT:■				
For 10 μs max., See *Fig. 11*	I_{GTM}	4		A
GATE POWER DISSIPATION:				
Peak (For 1 μs max., $I_{GTM} \leq 4$ A, See *Fig. 11*	P_{GM}	16		W
AVERAGE	$P_{G(AV)}$	0.2		W
TEMPERATURE RANGE:▲				
Storage	T_{stg}	−65 to 150		°C
Operating (Case)	T_C	−65 to 100		°C
TERMINAL TEMPERATURE (During soldering):				
For 10 s max. (terminals and case)	T_T	225		°C

● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see *Dimensional Outline.*

ELECTRICAL CHARACTERISTICS, *At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified*

CHARACTERISTIC	SYMBOL	LIMITS 40668 MIN.	TYP.	MAX.	LIMITS 40669 MIN.	TYP.	MAX.	UNITS
Peak Off-State Current:* Gate Open At T_J = +100°C and V_{DROM} = Max. rated value	I_{DROM}	–	0.1	2	–	0.1	2	mA
Maximum On-State Voltage:* For i_T = 30 A (peak) and T_C = +25 °C	v_{TM}	–	1.7	2	–	1.7	2	V
DC Holding Current:* Gate Open Initial principal current = 150 mA (DC) At T_C = +25 °C	I_{HO}	–	15	30	–	15	30	mA
For other case temperatures		See Fig. 8.						
Critical Rate of Rise of Commutation Voltage:*♦ For v_D = V_{DROM}, $I_{T(RMS)}$ = 8 A, Commutating di/dt = 4.3 A/ms, and gate unenergized At T_C = +80 °C	dv/dt	4	10	–	4	10	–	V/μs
Critical Rate-of-Rise of Off-State Voltage:* For v_D = V_{DROM}, exponential voltage rise, and gate open At T_C = +100°C	dv/dt	100	300	–	75	250	–	V/μs
For other case temperatures		See Fig. 10						
DC Gate-Trigger Current:*† For v_D = 12 V (DC), R_L = 12 Ω T_C = +25 °C, and specified triggering mode: I+ Mode: V_{MT2} is positive, V_G is positive	I_{GT}	–	10	25	–	10	25	mA
III– Mode: V_{MT2} is negative, V_G is negative		–	15	25	–	15	25	
I– Mode: V_{MT2} is positive, V_G is negative		–	20	60	–	20	60	
III+ Mode: V_{MT2} is negative, V_G is positive		–	30	60	–	30	60	
For other case temperatures		See Fig. 12. & 13.						
DC Gate-Trigger Voltage:*† For v_D = 12 V (DC) and R_L = 12 Ω At T_C = +25 °C	V_{GT}	–	1.25	2.5	–	1.25	2.5	V
For other case temperatures		See Fig. 14.						
For v_D = V_{DROM} and R_L = 125 Ω At T_C = +100 °C		0.2	–	–	0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) 160 mA For v_D = V_{DROM} and I_{GT} = 80 mA 0.1μs rise time, and i_T = 10 A (peak) At T_C = +25 °C *(See Fig. 15).*	t_{gt}	–	1.6	2.5	–	1.6	2.5	μs
Thermal Resistance: Junction-to-Case	$\theta_{J\text{-}C}$	–	–	2.2	–	–	2.2	°C/W
Junction-to-Ambient	$\theta_{J\text{-}A}$	–	–	60	–	–	60	°C/W

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

†For either polarity of gate voltage (V_G) with reference to main terminal 1.

♦Variants of these devices having dv/dt characteristics selected specifically for inductive loads are available on special order; for additional information, contact your RCA Representative or your RCA Distributor.

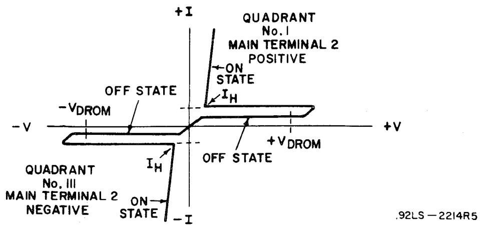


Fig. 1—Principal voltage-current characteristic

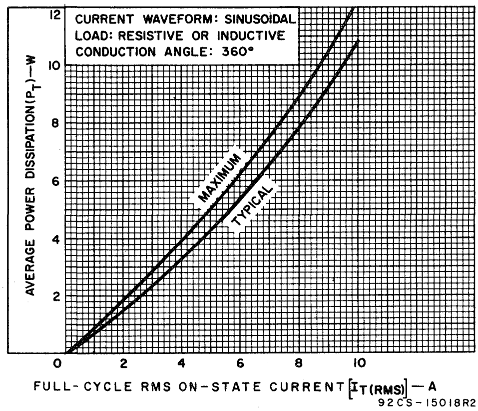


Fig. 2—Power dissipation vs. on-state current

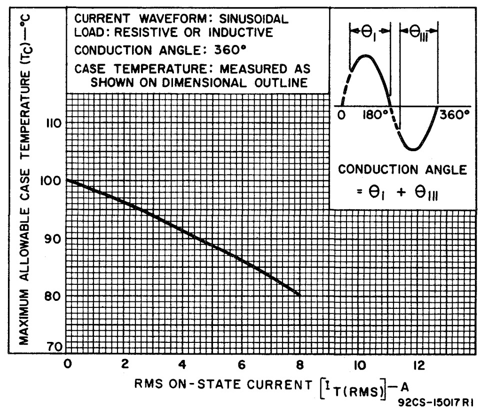


Fig. 3 —Allowable case temperature vs. on-state current

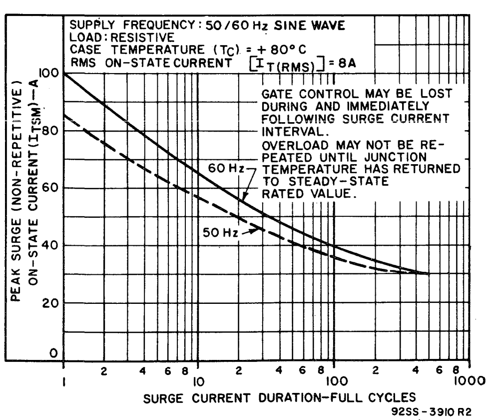


Fig. 4—Peak surge on-state current vs. surge current duration

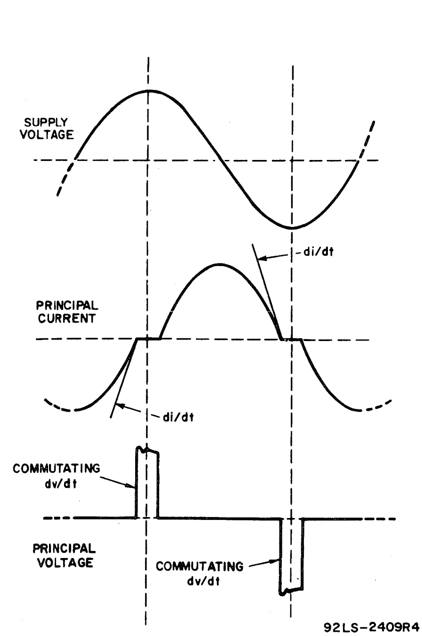


Fig. 5—Oscilloscope display of commutating dv/dt

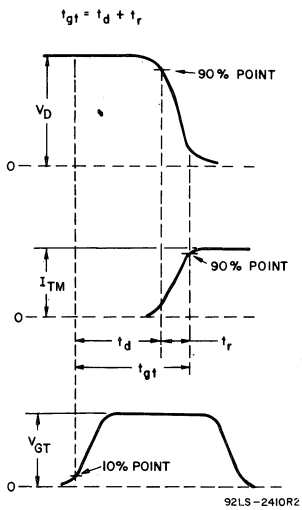


Fig. 6—Oscilloscope display for measurement of gate-controlled turn-on time (tgt)

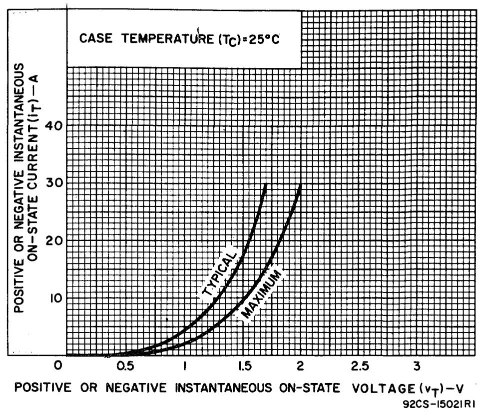


Fig. 7—On-state current vs. on-state voltage

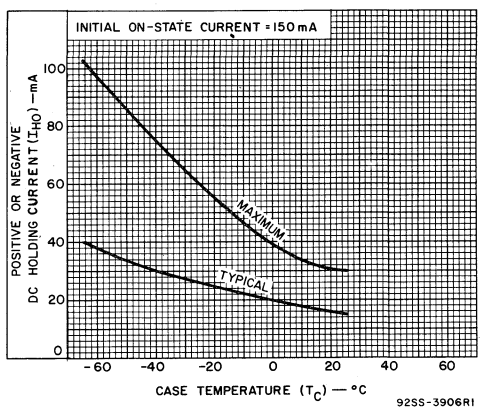
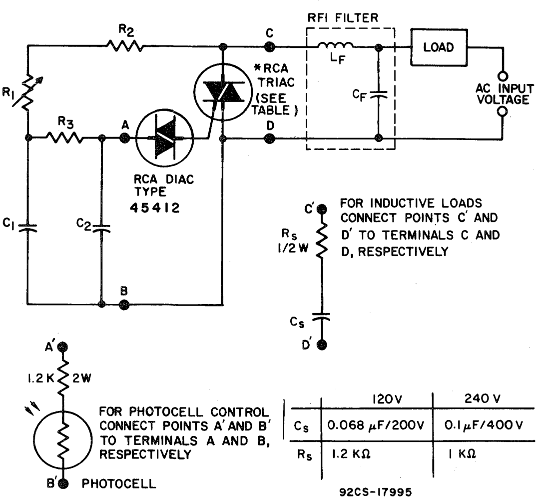


Fig. 8—DC holding current for either direction of on-state current vs. case temperature



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	RFI FILTER C_F* (typ.)	RCA TYPES
120 V 60 Hz	0.1 μF 200 V	0.1 μF 100 V	100 KΩ ½ W	2.2 KΩ ½ W	15 KΩ ½ W	100 μH	0.1 μF 200 V	40668
240 V 50 Hz	0.1 μF 400 V	0.1 μF 100 V	250 KΩ 1 W	3.3 KΩ ½ W	15 KΩ ½ W	200 μH	0.1 μF 400 V	40669
240 V 60 Hz	0.1 μF 400 V	0.1 μF 100 V	200 KΩ 1 W	3.3 KΩ ½ W	15 KΩ ½ W	200 μH	0.1 μF 400 V	40669

* Typical values for lamp dimming circuits.

Fig. 9—Typical phase-control circuit for lamp dimming, heat controls, and universal motor speed controls

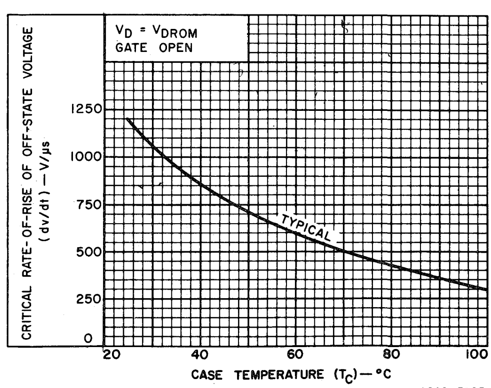


Fig. 10—Critical rate-of-rise of off-state voltage vs. case temperature

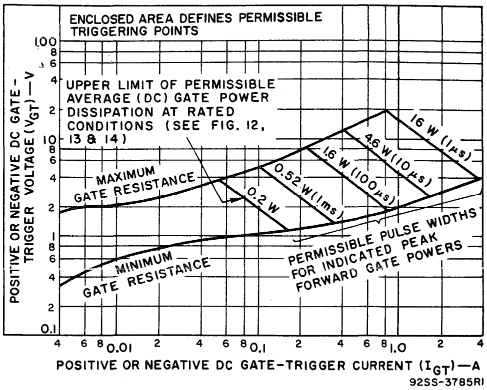


Fig. 11—Gate pulse characteristics for all triggering modes

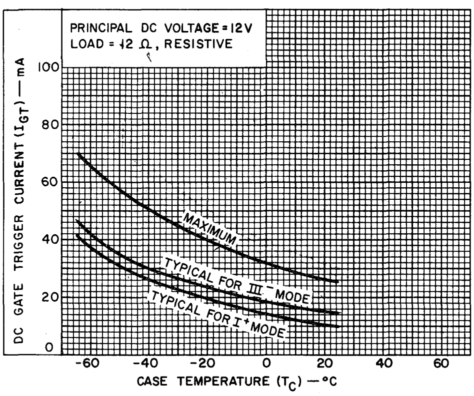


Fig. 12—DC gate-trigger current (for I^+ and III^- triggering modes) vs. case temperature

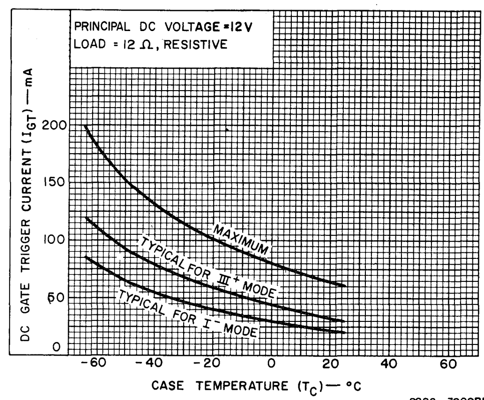


Fig. 13—DC gate-trigger current (for I^- and III^+ triggering modes) vs. case temperature

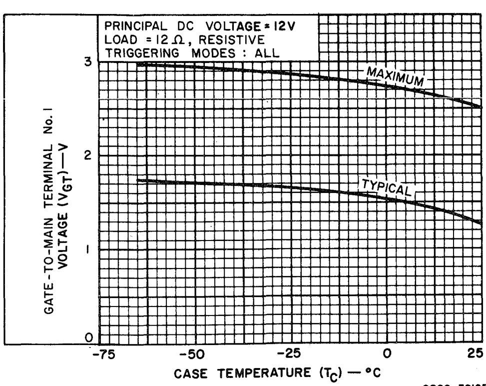


Fig. 14—DC gate-trigger voltage vs. case temperature

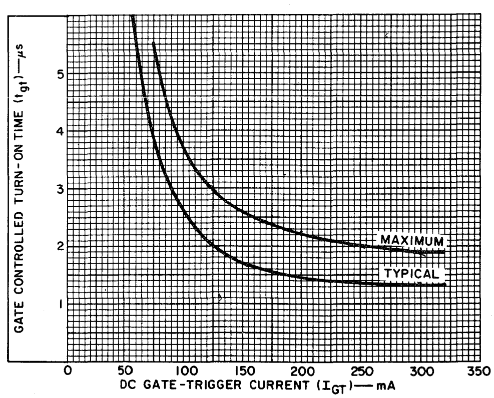
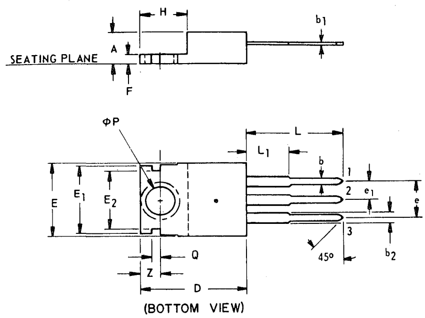


Fig. 15—Typical turn-on time vs. gate-trigger current

DIMENSIONAL OUTLINE



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.190	4.07	4.82
b	0.025	0.040	0.64	1.02
b_1	0.012	0.030	0.31	0.76
b_2	0.045	0.055	1.143	1.397
D	0.575	0.625	14.61	15.87
E	0.395	0.410	10.04	10.41
E_1	0.365	0.385	9.28	9.77
E_2	0.300	0.320	7.62	8.12
e	0.180	0.220	4.57	5.58
e_1	0.080	0.120	2.03	3.04
F	0.020	0.055	0.51	1.39
H	0.235	0.265	5.97	6.73
L	0.500	–	12.70	–
L_1	–	0.250	–	6.35
ϕP	0.141	0.145	3.582	3.683
Q	0.040	0.060	1.02	1.52
Z	0.100	0.120	2.54	3.04

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

92CM-15015R1

TERMINAL CONNECTIONS

Lead No. 1 - Main Terminal 1
Lead No. 2 - Main Terminal 2
Lead No. 3 - Gate
Mounting Flange - Main Terminal 2

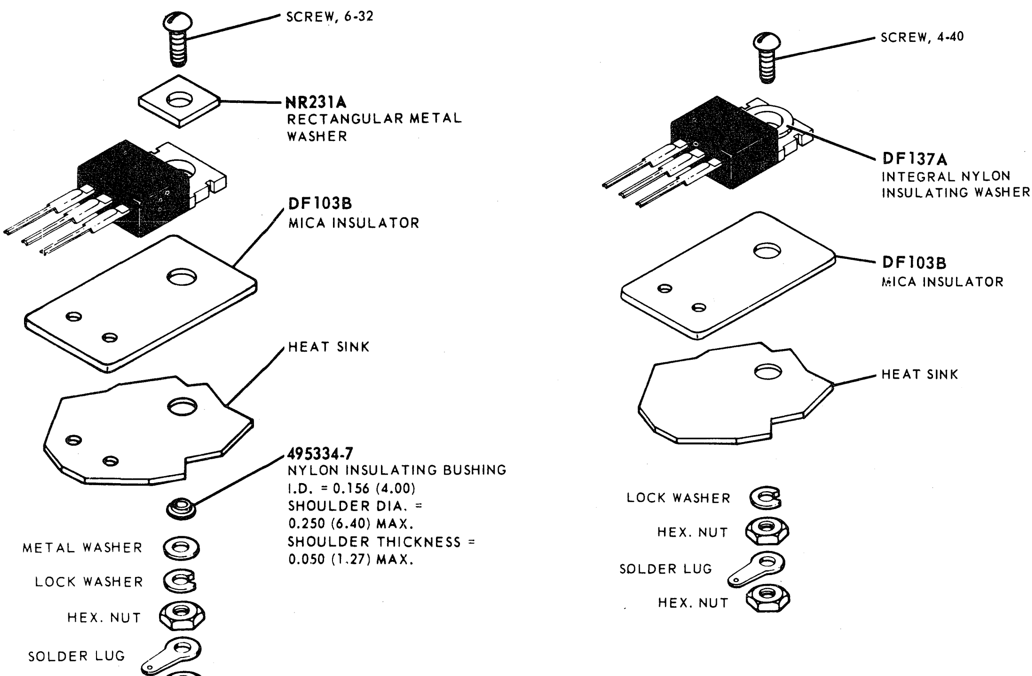
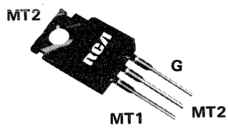


Fig. 16—Suggested mounting hardware

RCA Solid State Division

Thyristors

40842



JEDEC TO-220AB

H-1535

6-Ampere Silicon Triac

For Power-Control and Power-Switching Applications

Features:

- **6-A (rms) on-state current rating**
- **100-A peak surge full-cycle current rating at 60 Hz**
  85-A peak surge full-cycle current rating at 50 Hz
- **Shorted-emitter design — contains internal diffused resistor from gate to main terminal 1**
- **Center gate construction — provides rapid uniform gate-current spreading for faster turn-on with substantially reduced heating effects**
- **Low switching losses**
- **Low thermal resistance**
- **Package suitable for mounting on printed-circuit boards**

RCA-40842 is a gate-controlled, full-wave ac switch. It is intended for the control of ac loads in such applications as motor controls, light dimmers (300 to 1440 W), heating controls, and power-switching systems.

This device is designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. It has an on-state current rating of 6 amperes at a case temperature of 80°C and a repetitive off-state voltage rating of 450 volts.

The unique plastic package design provides not only ease of mounting but also low thermal impedance, which allows operation at high case temperatures and permits reduced heat-sink size.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For operation with 50/60 Hz, Sinusoidal Supply Voltage and Resistive or Inductive Load

REPETITIVE PEAK OFF-STATE VOLTAGE*	V_{DROM}		
Gate open, for T_J = -40 to +100 °C		450	V
RMS ON-STATE CURRENT	$I_{T(RMS)}$		
For case temperature (T_C) of +80°C and a conduction angle of 360°		6	A
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT	I_{TSM}		
For one full cycle of applied principal voltage (60-Hz, sinusoidal)		100	A
For one full cycle of applied principal voltage (50-Hz, sinusoidal)		85	A
For more than one full cycle of applied voltage		See Fig.4	
PEAK GATE-TRIGGER CURRENT†	I_{GTM}		
For 10μs max.		4	A
GATE POWER DISSIPATION:			
PEAK†	P_{GM}		
For 10μs max. and $I_{GTM} \leq 4$ A (peak)		16	W
AVERAGE	$P_{G(AV)}$	0.2	W

TEMPERATURE RANGE‡

Storage	-40 to +150 °C
Operating (case)	-40 to +100 °C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

‡ For information on the reference point of temperature measurement, *see Dimensional Outline.*

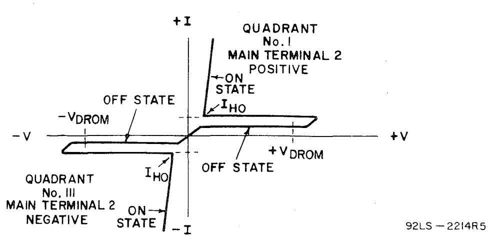


Fig.1—Principal voltage-current characteristic.

ELECTRICAL CHARACTERISTICS, *At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	LIMITS MIN.	TYP.	MAX.	UNITS
Peak Off-State Current:* Gate Open At T_J = +100°C and V_{DROM} = Max. rated value	I_{DROM}	–	0.1	2	mA
Maximum On-State Voltage:* For i_T = 10 A (peak) and T_C = +25°C	v_{TM}	–	1.5	2.25	V
Critical Rate of Rise of Commutation Voltage:*♦ For v_D = V_{DROM}, $I_{T(RMS)}$ = 6 A, Commutating di/dt = 3.2 A/ms, and gate unenergized	dv/dt				V/µs
At T_C = +80°C		2	10	–	
Critical Rate of Rise of Off-State Voltage.* For v_D = V_{DROM}, exponential voltage rise, and gate open	dv/dt				V/µs
At T_C = +100°C		20	250	–	
For other case temperatures			See Fig. 6.		
DC Gate-Trigger Current:† For v_D = 12 V (DC), R_L = 12Ω T_C = +25°C, and specified triggering mode:	I_{GT}				mA
I+ Mode: V_{MT2} is positive, V_G is positive		–	25	80	
III- Mode: V_{MT2} is negative, V_G is negative		–	30	80	
DC Gate-Trigger Voltage:*† For v_D = 12 V (DC) and R_L = 12Ω	V_{GT}				V
At T_C = +25°C		–	1.5	4.0	
For other case temperatures			See Fig. 10.		
For v_D = V_{DROM} and R_L = 125Ω At T_C = +100°C		0.2	–	–	
Gate-Controlled, Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM} and I_{GT} = 80 mA 0.1µs rise time, and i_T = 10 A (peak) at T_C = +25°C	t_{gt}	–	2.2	–	µs
Thermal Resistance: Junction-to-Case	θ_{J-C}	–	–	2.2	°C/W
Junction-to-Ambient	θ_{J-A}	–	–	60	°C/W

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

♦ Variants of these devices having dv/dt characteristics selected specifically for inductive loads are available on special order; for additional information, contact your RCA Representative or your RCA Distributor.

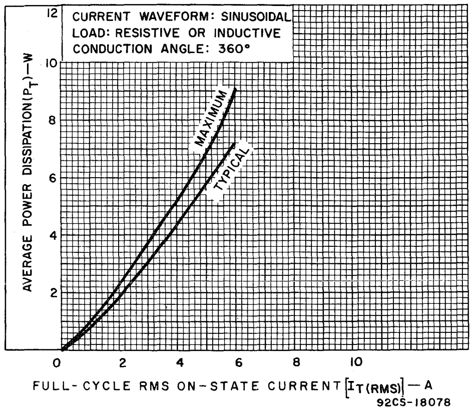


Fig.2—Power dissipation vs. on-state current.

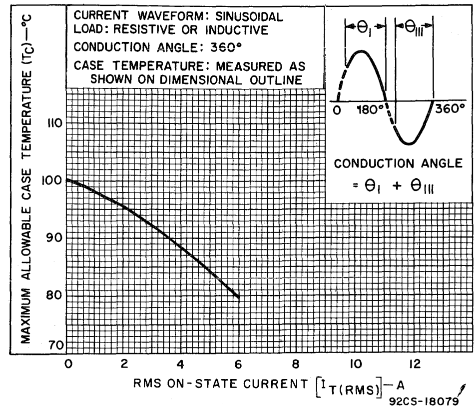


Fig.3—Allowable case temperature vs. on-state current.

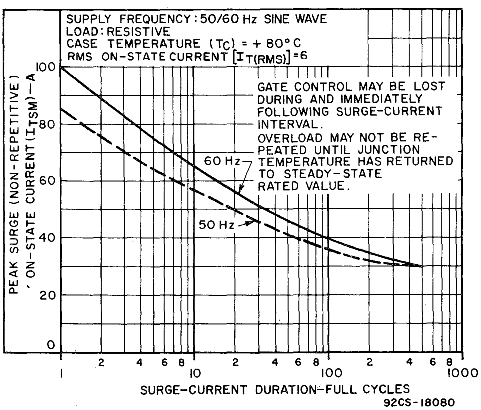


Fig.4—Peak surge on-state current vs. surge-current duration.

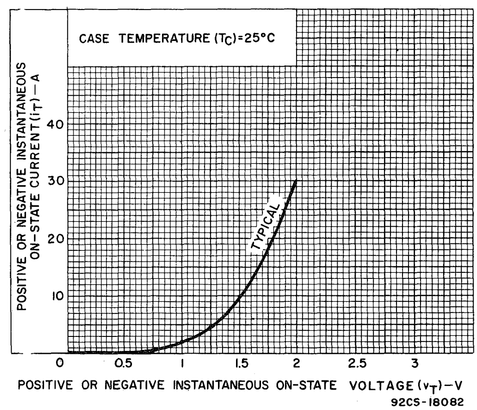


Fig.5—On-state current vs. on-state voltage.

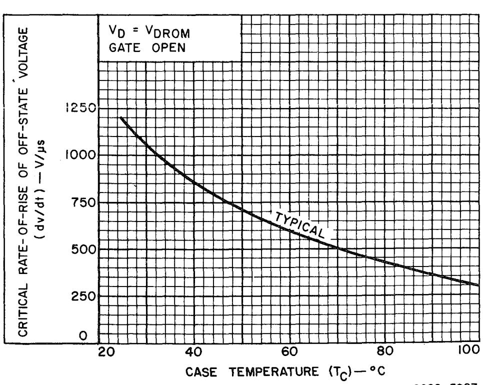


Fig.6—Critical rate-of-rise of off-state voltage vs. case temperature.

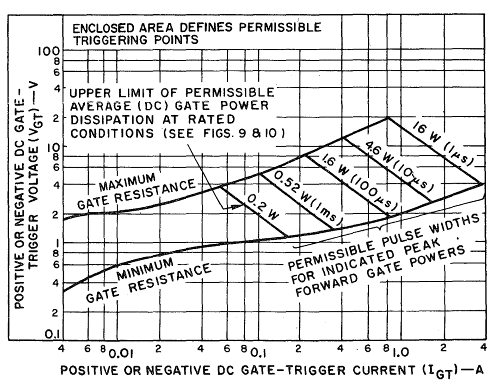
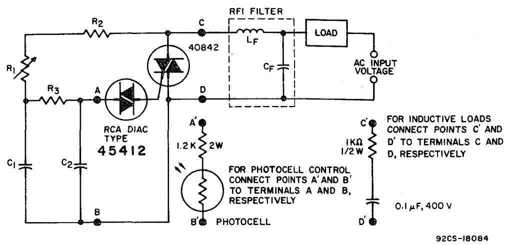


Fig.7—Gate pulse characteristics for all triggering modes.



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	RFI FILTER C_F* (typ.)
240V 50Hz	0.1µF 400V	0.1µF 100V	250KΩ 1W	3.3KΩ ½W	15KΩ ½W	200µH	0.1µF 400V
240V 60Hz	0.1µF 400V	0.1µF 100V	200KΩ 1W	3.3KΩ ½W	15KΩ ½W	200µH	0.1µF 400V

*Typical values for lamp-dimming circuits.

Fig.8—Typical phase-control circuit for lamp dimming, heat controls, and universal-motor speed controls.

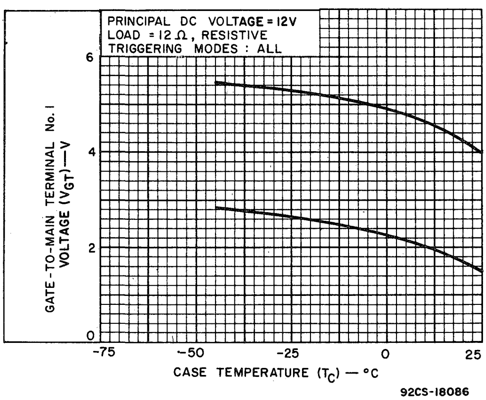


Fig.10—DC gate-trigger voltage vs. case temperature.

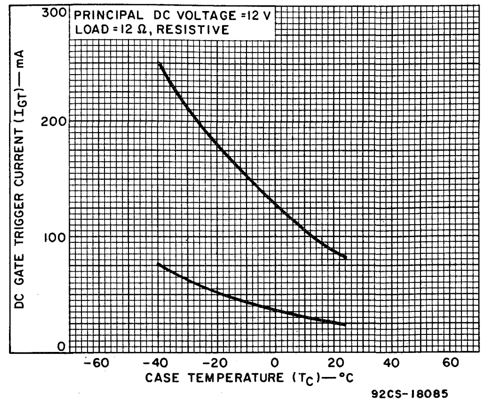
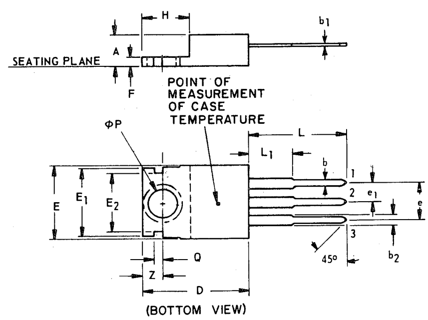


Fig.9—DC gatee-trigger current (for I+ and III⁻ triggering modes) vs. case temperature.



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.160	0.190	4.07	4.82
b	0.025	0.040	0.64	1.02
b_1	0.012	0.020	0.31	0.51
b_2	0.045	0.055	1.143	1.397
D	0.575	0.600	14.61	15.24
E	0.395	0.410	10.04	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	0.095	0.105	2.42	2.66
F	0.020	0.055	0.51	1,39
H	0.235	0.265	5.97	6.73
L	0.500		12.70	
L_1		0.250		6.35
φP	0.141	0.145	3.582	3.683
Q	0.040	0.060	1.02	1.52
Z	0.100	0.120	2.54	3.04

Dimensions in inches and millimeters. Millimeter values in parentheses.

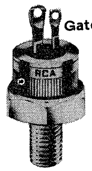
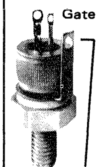
92CS-18087

RCA

Solid State
Division

Thyristors

2N5567 2N5569 40799
2N5568 2N5570 40800
40795 40796 40801

H-1611	H-1612	H-1658
Main Terminal 1, Gate, Main Terminal 2 	Main Terminal 1, Gate, Main Terminal 2 	Main Terminal 1, Gate, Main Terminal 2 
2N5567 2N5568 40795 Press-fit	2N5569 2N5570 40796 Stud	40799 40800 40801 Isolated-stud

10-A Silicon Triacs

Press-Fit, Stud, & Isolated-Stud Type Packages

For 120-V Line Operation . . . 2N5567, 2N5569, 40799
For 240-V Line Operation . . . 2N5568, 2N5570, 40800
For High-Voltage Operation . . . 40795, 40796, 40801

Features:

- **di/dt Capability = 150 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled, full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

These triacs are intended for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		2N5567 2N5569 40799	2N5568 2N5570 40800	40795 40796 40801	
***REPETITIVE PEAK OFF-STATE VOLTAGE:●**					
Gate open, T_J = −65 to 100° C	V_{DROM}	200	400	600	V
***RMS ON-STATE CURRENT (Conduction angle = 360°):**					
Case temperature (T_C) = 85° C	$I_{T(RMS)}$		10		A
For other conditions			See *Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of applied principal voltage					
* 60 Hz (sinusoidal)			100		A
50 Hz (sinusoidal)			85		A
For more than one cycle of applied principal voltage			See *Fig. 4*		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt				
$V_{DM} = V_{DROM}$, I_{GT} = 160 mA, t_r = 0.1 μs (See *Fig. 13*)			150		A/μs
PEAK GATE-TRIGGER CURRENT:■					
For 1 μs max., See *Fig. 7*	I_{GTM}		4		A
***GATE POWER DISSIPATION:**					
PEAK (For 1 μs max., $I_{GTM} \leq 4$ A, See *Fig. 7*)	P_{GM}		16		W
AVERAGE	$P_{G(AV)}$		0.5		W
***TEMPERATURE RANGE:▲**					
Storage	T_{stg}		−65 to 150		°C
Operating (Case)	T_C		−65 to 100		°C
***TERMINAL TEMPERATURE (During soldering):**	T_T				
For 10 s max. (terminals and case)			225		°C

* In accordance with JEDEC registration data format (JS-14, RDF 2) filed for the JEDEC (2N-Series) types.
● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS For All Types Unless Otherwise Specified Min.	Typ.	Max.	UNITS
Peak Off-State Current:♣ Gate open, T_J = 100° C, V_{DROM} = Max. rated value	I_{DROM}	–	0.1	2*	mA
Maximum On-State Voltage:♣ For i_T = 14 A (peak), T_C = 25° C	V_{TM}	–	1.35	1.65*	V
DC Holding Current:♣ Gate open, Initial principal current = 500 mA (DC), v_D = 12V: T_C = 25° C T_C = –65° C For other case temperatures	I_{HO}	 – –	 15 75 See *Fig. 6*	 30 200*	mA
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 10 A, commutating di/dt = 5.4 A/ms, gate unenergized, T_C = 85° C (See *Fig. 14*)	dv/dt	2*	5	–	V/µs
Critical Rate-of-Rise of Off-State Voltage:♣ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100° C: 2N5567, 2N5569, 40799 2N5568, 2N5570, 40800 40795, 40796, 40801	dv/dt	 30* 20* 10	 150 100 75	 – – –	V/µs
DC Gate-Trigger Current:♣♦ Mode V_{MT2} V_G For v_D = 12 V (DC), R_L = 30 Ω, T_C = 25° C I+ positive positive III- negative negative I- positive negative III+ negative positive	I_{GT}	 – – – –	 10 10 20 20	 25 25 40 40	mA
Mode V_{MT2} V_G For v_D = 12 V (DC), R_L = 30 Ω, T_C = –65° C I+ positive positive III- negative negative I- positive negative III+ negative positive For other case temperatures	I_{GT}	 – – – –	 45 45 80 80 See *Figs. 8 & 9*	 100* 100* 150* 150*	mA
DC Gate-Trigger Voltage:♣♦ For v_D = 12 V(DC), R_L = 30 Ω T_C = 25° C T_C = –65° C For other case temperatures For v_D = V_{DROM}, R_L = 125 Ω, T_C = 100° C	V_{GT}	 0.2	 1 2 See *Fig. 10* –	 2.5 4* –	V
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 160 mA, t_r = 0.1 µs, i_T = 15 A (peak), T_C = 25° C (See *Figs. 11 & 15*)	t_{gt}	–	1.6	2.5	µs
Thermal Resistance: **Junction-to-Case:** Steady-State Transient	$\theta_{J\text{-}C}$	 –	 – See *Fig. 12*	 1*	°C/W
Junction-to-Isolated Hex (Stud, see Dim. Outline): Steady-State	$\theta_{J\text{-}IH}$	–	–	1.1	°C/W

* In accordance with JEDEC registration data format (JS-14, RDF 2) filed for the JEDEC (2N-Series) types.

♣ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

♦ For either polarity of gate voltage (V_G) with reference to main terminal 1.

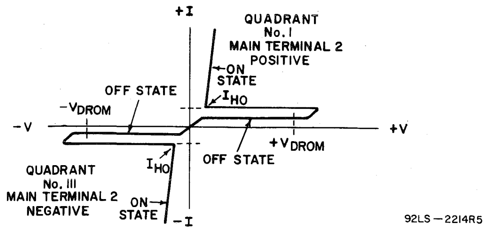


Fig. 1 – Principal voltage-current characteristic.

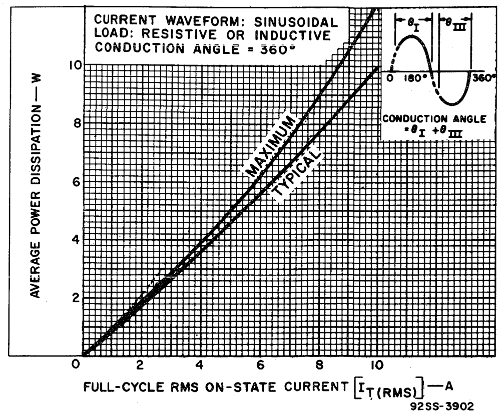


Fig. 2 – Power dissipation vs. on-state current.

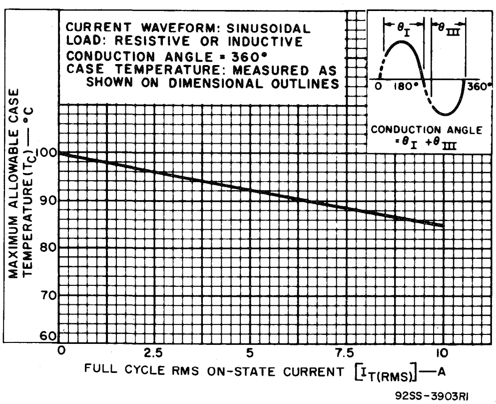


Fig. 3 – Maximum allowable case temperature vs. on-state current.

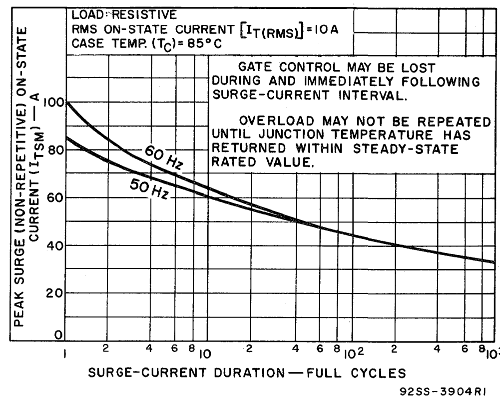


Fig. 4 – Peak surge on-state current vs. surge current duration.

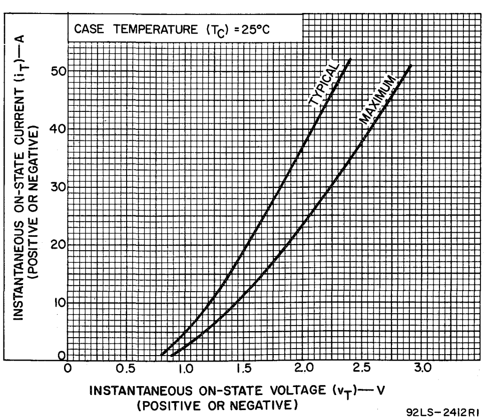


Fig. 5 – On-state current vs. on-state voltage.

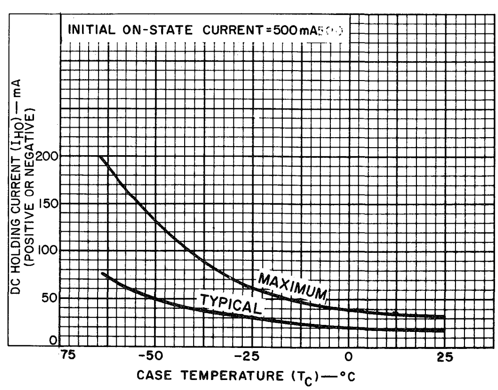


Fig. 6 – DC holding current vs. case temperature.

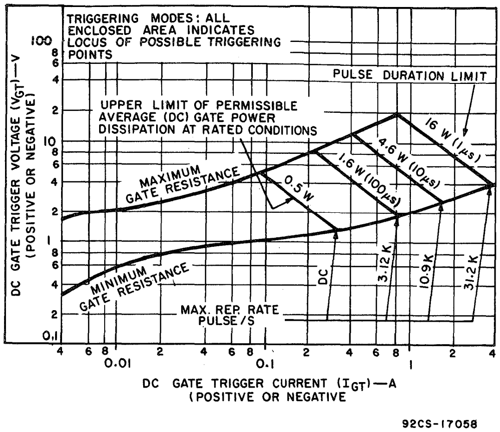


Fig. 7 – Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

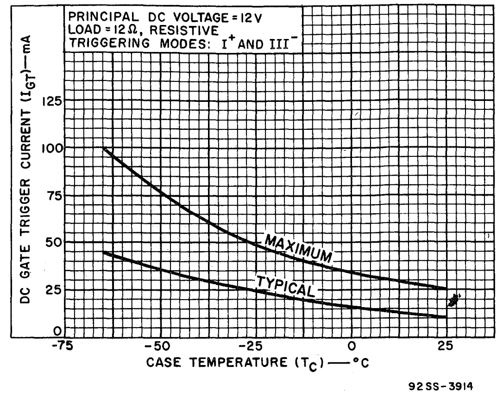


Fig. 8 – DC gate-trigger current vs. case temperature (I^+ & III^- modes).

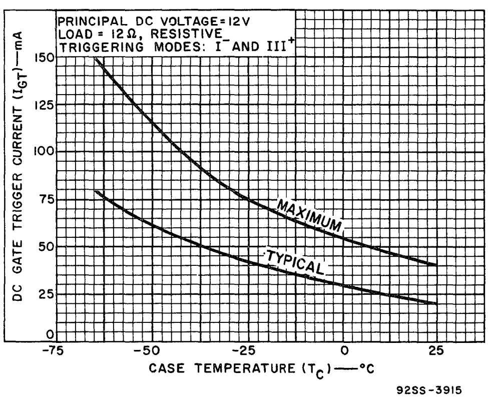


Fig. 9 – DC gate-trigger current vs. case temperature (I^- & III^+ modes).

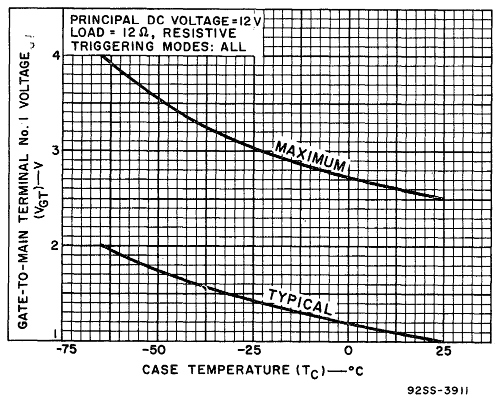


Fig. 10 – DC gate-trigger voltage vs. case temperature.

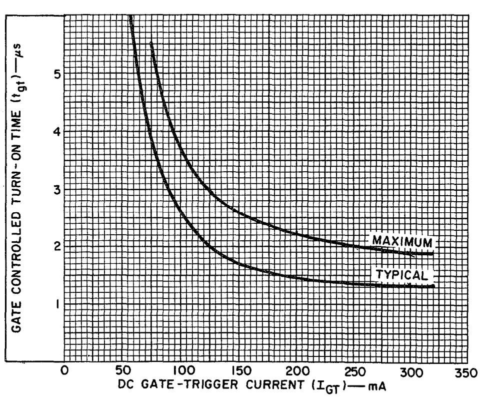


Fig. 11 – Turn-on time vs. gate trigger current.

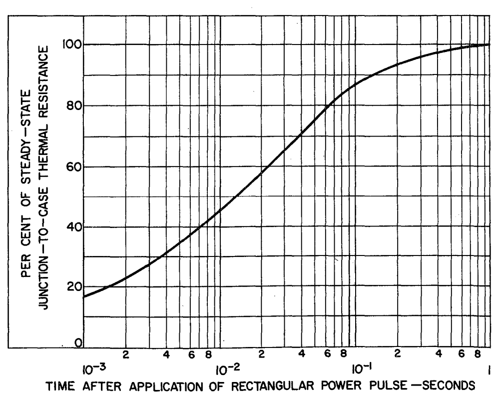


Fig. 12 – Transient junction-to-case thermal resistance vs. time.

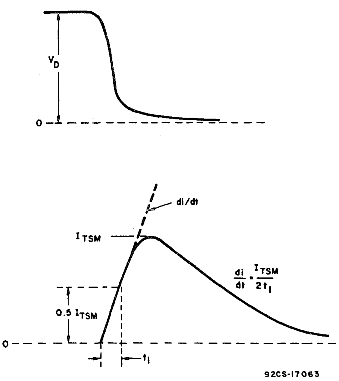


Fig. 13 — Rate-of-change of on-state current with time (defining di/dt).

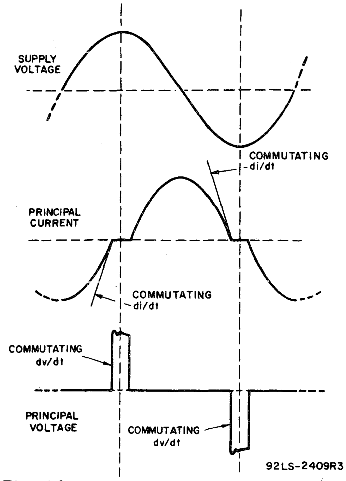


Fig. 14 — Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

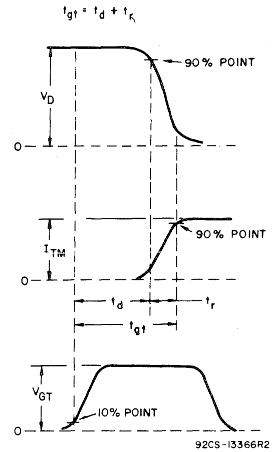


Fig. 15 — Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

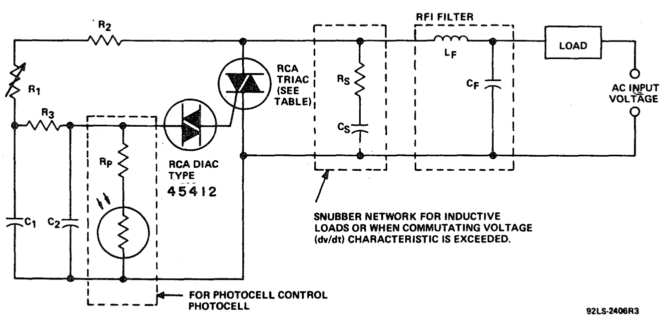


Fig. 16 — Typical phase-control circuit for lamp dimming, heat control, and universal-motor speed control.

AC INPUT VOLTAGE		120V 60Hz	240V 60Hz	240V 50Hz
C_1		0.1μF 200V	0.1μF 400V	0.1μF 400V
C_2		0.1μF 100V	0.1μF 100V	0.1μF 100V
R_1		100KΩ 1/2W	200KΩ 1W	250KΩ 1W
R_2		2.2KΩ 1/2W	3.3KΩ 1/2W	3.3KΩ 1/2W
R_3		15KΩ 1/2W	15KΩ 1/2W	15KΩ 1/2W
PHOTOCELL CONTROL	R_P	1.2KΩ 2W	1.2KΩ 2W	1.2KΩ 2W
SNUBBER NETWORK	C_S	0.1μF 200V	0.1μF 400V	0.1μF 400V
	R_S	100Ω 1/2W	100Ω 1/2W	100Ω 1/2W
RFI FILTER	C_F*	0.1μF 200V	0.1μF 400V	0.1μF 400V
	L_F*	100μH	200μH	200μH
RCA TRIACS		2N5567 2N5569 40799	2N5568 2N5570 40800	2N5568 2N5570 40800

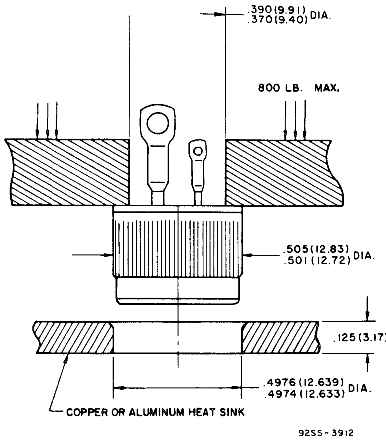
*Typical values for lamp dimming circuits.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in *Fig. 17,* shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



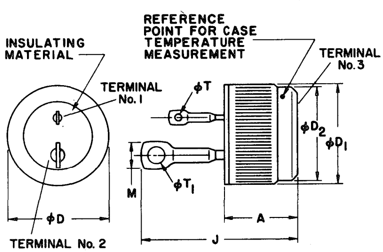
NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 17 – Suggested mounting method for press-fit package types.

Table I – Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud & Isolated-Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6
Stud	Mounted on heat sink with a 0.004 to 0.006 in. (0.102 to 0.152 mm) thick mica insulating washer used between unit and heat sink.	
	Without heat sink compound	2.5
	With heat sink compound	1.5

DIMENSIONAL OUTLINE FOR TYPES 2N5567, 2N5568, 40795

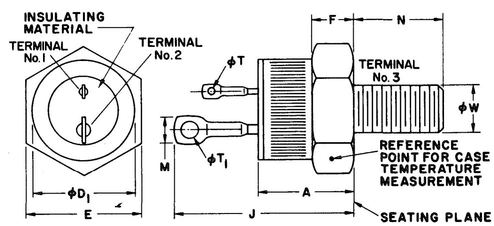


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.380	–	9.65	
ϕD	.501	.510	12.73	12.95	
ϕD_1	–	.505	–	12.83	2
ϕD_2	.465	.475	11.81	12.07	
J	–	.750	–	19.05	
M	–	.155	–	3.94	1
ϕT	.058	.068	1.47	1.73	
ϕT_1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Outer diameter of knurled surface. 92SS-3816

DIMENSIONAL OUTLINE FOR TYPES 2N5569, 2N5570, 40796

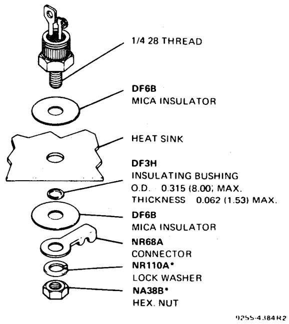


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	–
ϕD_1	–	.544	–	13.81	–
E	.544	.562	13.82	14.28	–
F	.113	.200	2.87	5.08	3
J	–	.950	–	24.13	–
M	–	.155	–	3.94	1
N	.422	.453	10.72	11.50	–
ϕT	.058	.068	1.47	1.73	–
ϕT_1	.080	.090	2.03	2.29	–
ϕW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional. 92SS-3817



*Only hardware required for isolated-stud package.

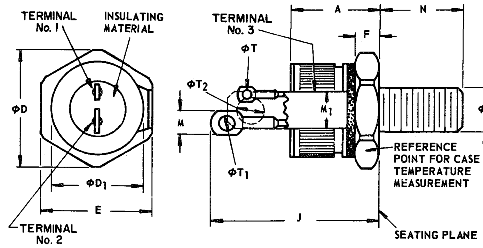
NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 18 – Suggested mounting arrangement for stud and isolated-stud package types.

WARNING:
The RCA isolated-stud package thyristors should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled.

TERMINAL CONNECTIONS
Terminal No.1–Gate
Terminal No.2–Main Terminal 1
Case, Terminal No.3–Main Terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40799, 40800, 40801



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.673	–	17.09	
ϕD	.604	.614	15.34	15.59	
$ϕD_1$	.501	.505	12.72	12.82	
E	.551	.557	13.99	14.14	
F	.175	.185	4.44	4.69	
J	–	1.055	–	26.79	
M	–	.155	–	3.94	
M_1	.200	.210	5.08	5.33	
N	.422	.452	10.72	11.48	
ϕT	.058	.068	1.47	1.73	2
$ϕT_1$	.080	.090	2.03	2.29	2
$ϕT_2$	.138	.148	3.50	3.75	2
ϕW	.225	.2268	5.652	5.760	3

NOTE 1: Ceramic between hex (stud) and terminal No.3 is beryllium oxide.

NOTE 2: Contour and angular orientation of these terminals is optional.

NOTE 3: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

92SS-4413

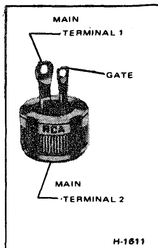
File No. 443

RCA

Solid State Division

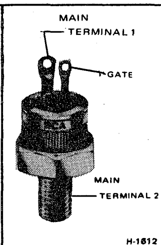
Thyristors

40775–40778 40779–40782 40783–40786



40775	40776
40779	40780
40783	40784

PRESS-FIT



40777	40778
40781	40782
40785	40786

STUD

400-Hz, 6,10, & 15-A Silicon Triacs

For Control-Systems Application in Airborne and Ground-Support Type Equipment

For 115-V Line Operation—40775, 40777, 40779, 40781, 40783, 40785

For 208-V Line Operation—40776, 40778, 40780, 40782, 40784, 40786

Features:

- **RMS On-State Current —**
  $I_{T(RMS)}$ = 6 A (40775, 40776, 40777, 40778)
  = 10 A (40779, 40780, 40781, 40782)
  = 15 A (40783, 40784, 40785, 40786)
- **di/dt Capability = 150 A/μs**
- **Commutating dv/dt Capability Characterized at 400 Hz**
- **Shorted-Emitter, Center-Gate Design**

These RCA triacs are gate-controlled, full wave silicon ac switches.

The devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

They are intended for operation up to 400 Hz with resistive or inductive loads and nominal line voltages of 115 and 208 V RMS sine wave and repetitive peak off-state voltages of 200 V and 400 V.

These triacs exhibit commutating voltage (dv/dt) capability at high commutating current (di/dt). They can also be used in 60-Hz applications where high commutating capability is required.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 400 Hz and with Resistive or Inductive Load.

Rating	Symbol	40775 40781 40777 40783 40779 40785	40776 40782 40778 40784 40780 40786	Unit
REPETITIVE PEAK OFF-STATE VOLTAGE:* Gate open, T_J = 50 to 100°C	V_{DROM}	200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°): Case temperature	$I_{T(RMS)}$			
T_C = 90°C (40775, 40776, 40777, 40778)		6		A
= 85°C (40779, 40780, 40781, 40782)		10		A
= 80°C (40783, 40784, 40785, 40786)		15		A
For other conditions		*See Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT: For one cycle of applied principal voltage	I_{TSM}			
400 Hz (sinusoidal)		200		A
60 Hz (sinusoidal)		100		A
For more than one cycle of applied principal voltage		*See Fig. 4*		
RATE-OF-CHANGE OF ON-STATE CURRENT: V_{DM} = V_{DROM}, I_{GT} = 160 mA, t_r = 0.1 μs *(See Fig. 13)*	di/dt	150		A/μs
PEAK GATE-TRIGGER CURRENT:■ For 1 μs max., *(See Fig. 7)*	I_{GTM}	4		A
GATE POWER DISSIPATION: PEAK (For 1 μs max., $I_{GTM} \leq 4$ A, *See Fig. 7)*	P_{GM}	16		W
AVERAGE	$P_{G(AV)}$	0.2		W
TEMPERATURE RANGE: Storage	T_{stg}	-50 to 150		°C
Operating (Case)	T_C	-50 to 100		°C
TERMINAL TEMPERATURE (During soldering): For 10 s max. (terminals and case)	T_T	225		°C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS ALL TYPES Min.	Typ.	Max.	UNITS
Peak Off-State Current:♠ Gate open, T_J = 100°C V_{DROM} = Max. rated value	I_{DROM}	–	0.1	2	mA
Maximum On-State Voltage:♠ For i_T = 21 A (peak), T_C = 25 °C.	V_{TM}	–	1.4	1.8	V
DC Holding Current:♠ Gate open, Initial principal current = 500 mA (DC), v_D = 12 V, T_C = 25° C.	I_{HO}	–	20	75	mA
For other case temperatures		See Fig. 6			
Critical Rate-of-Rise of Commutation Voltage:♠ For v_D = V_{DROM}, $I_{T(RMS)}$ = rated value, gate unenergized, (See Fig. 14): Commutating di/dt = 21.4 A/ms, T_C = 90° C 40775, 40776, 40777, 40778.	dv/dt	5	10	–	V/µs
Commutating di/dt = 36 A/ms, T_C = 85° C 40779, 40780, 40781, 40782.	dv/dt	5	10	–	V/µs
Commutating di/dt = 53.3 A/ms, T_C = 80° C 40783, 40784, 40785, 40786.	dv/dt	5	10	–	V/µs
Critical Rate-of-Rise of Off-State Voltage:♠ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100° C.	dv/dt	30	150	–	V/µs
DC Gate-Trigger Current:♠† For v_D = 12 V (DC), R_L = 30 Ω, and T_C = 25 °C — Mode I+, V_{MT2} positive, V_G positive	I_{GT}	–	20	50	mA
Mode III-, V_{MT2} negative, V_G negative	I_{GT}	–	20	50	mA
Mode I-, V_{MT2} positive, V_G negative	I_{GT}	–	35	80	mA
Mode III+, V_{MT2} negative, V_G positive	I_{GT}	–	35	80	mA
For other case temperatures.		See Figs. 8 & 9			
DC Gate-Trigger Voltage:♠† For v_D = 12 V(DC), R_L = 30Ω, T_C = 25°C.	V_{GT}	–	1	2.5	V
For other case temperatures.		See Fig. 10			
For v_D = V_{DROM}, R_L = 125Ω, T_C = 100°C	V_{GT}	0.2	–	–	V
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 160mA, t_r = 0.1 µs, i_T = 25A (peak), T_C = 25°C, (See Figs. 11 & 15)	t_{gt}	–	1.6	2.5	µs
Thermal Resistance Steady-State (Junction-to-Case)	$\theta_{J\text{-}C}$	–	–	1	°C/W
Transient (Junction-to-Case).		See Fig. 12			
Steady-State (Junction-to-Ambient).	$\theta_{J\text{-}A}$	–	–	33	°C/W

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

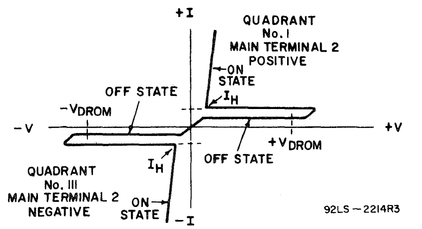


Fig. 1 - Principal voltage-current characteristic.

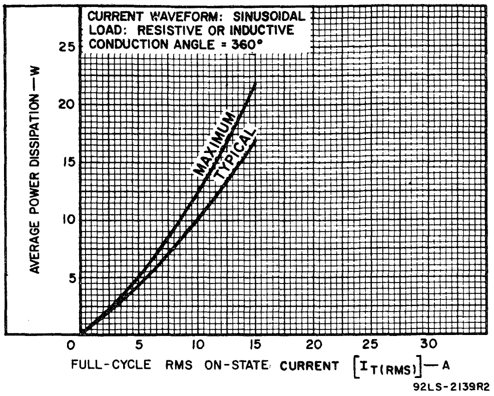


Fig. 2 - Power dissipation vs. on-state current.

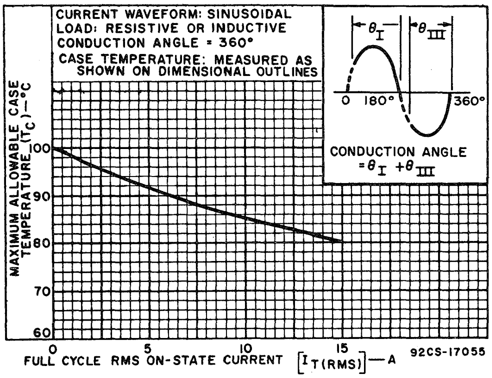


Fig. 3 - Maximum allowable case temperature vs. on-state current.

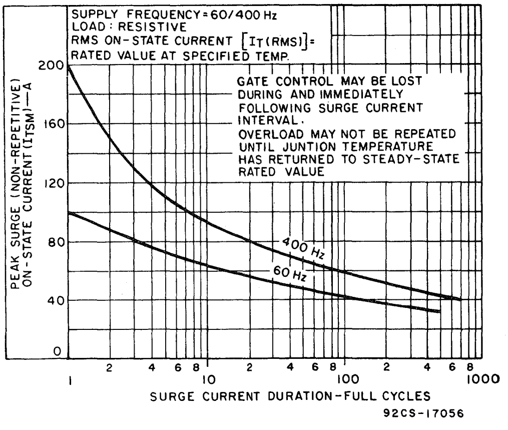


Fig. 4 - Peak surge on-state current vs. surge-current duration.

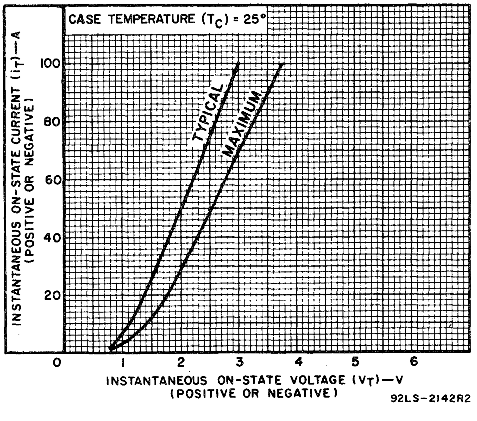


Fig. 5 - On-state current vs. on-state voltage.

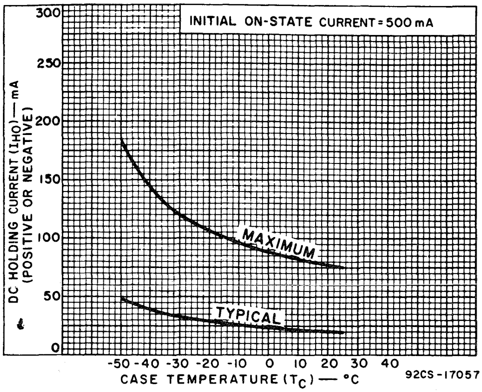


Fig. 6 - DC holding current vs. case temperature.

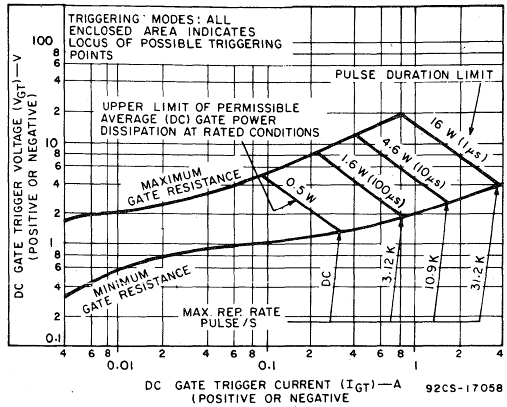


Fig. 7 - Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

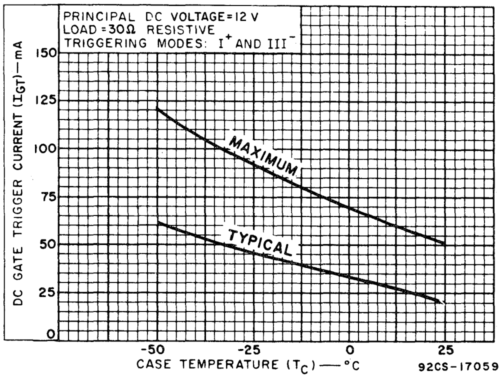


Fig. 8 - DC gate-trigger current vs. case temperature. (I^+ & III^- modes)

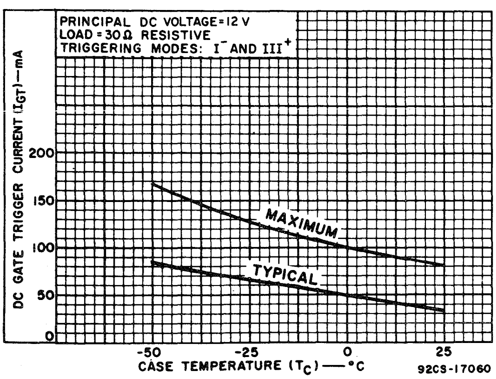


Fig. 9 - DC gate-trigger current vs. case temperature. (I^- & III^+ modes)

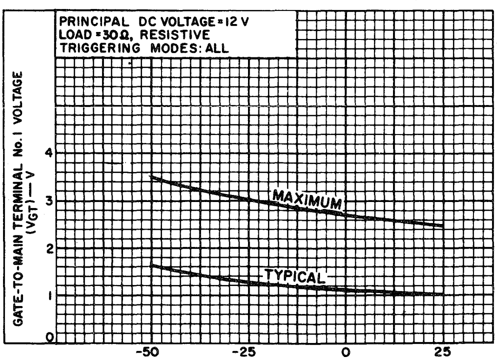


Fig. 10 - DC gate-trigger voltage vs. case temperature.

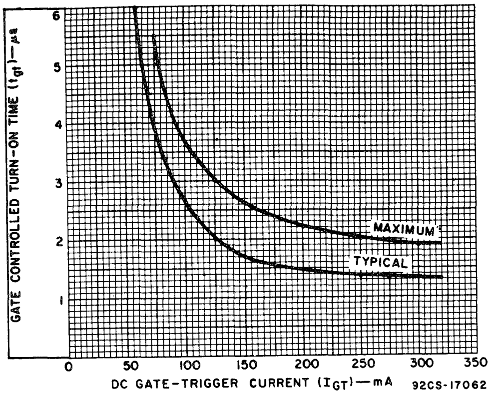


Fig. 11 - Turn-on time vs. gate trigger current.

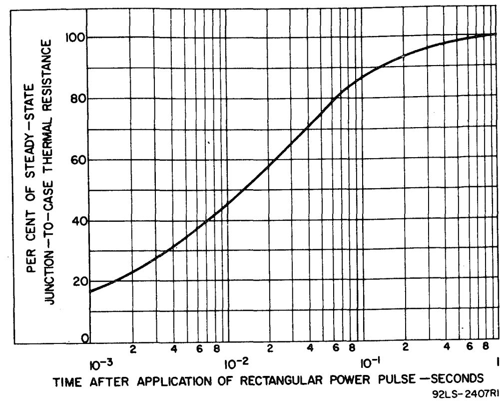


Fig. 12 - Transient thermal resistance vs. time (Junction-to-case).

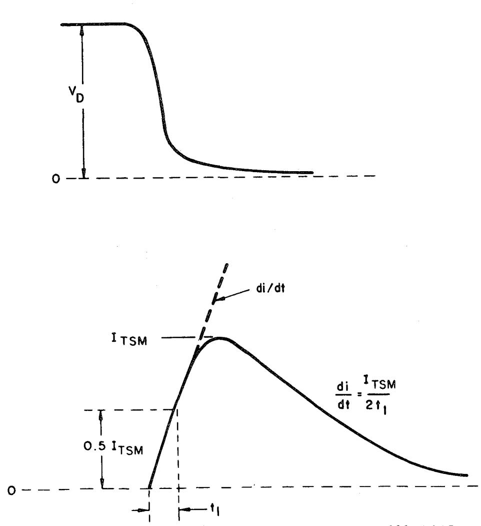


Fig. 13 - Rate-of-change of on-state current with time (defining di/dt).

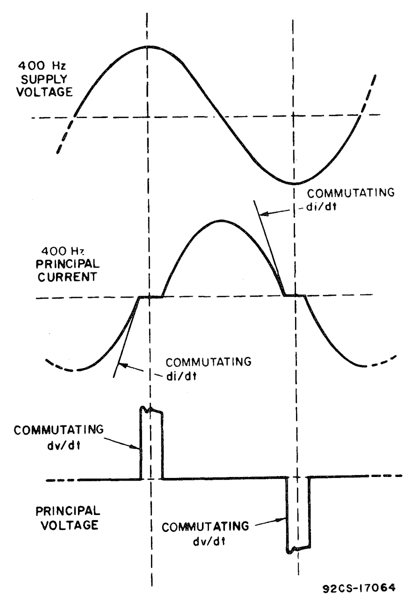


Fig. 14 - Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

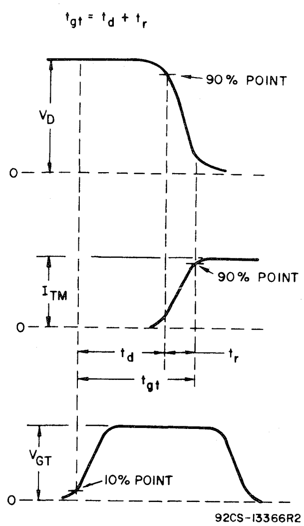


Fig. 15 - Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

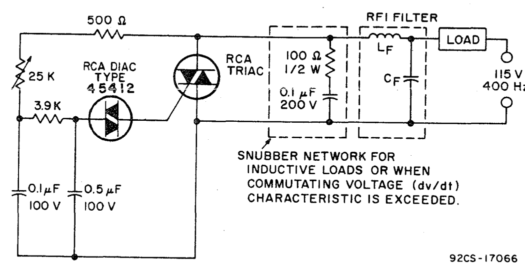


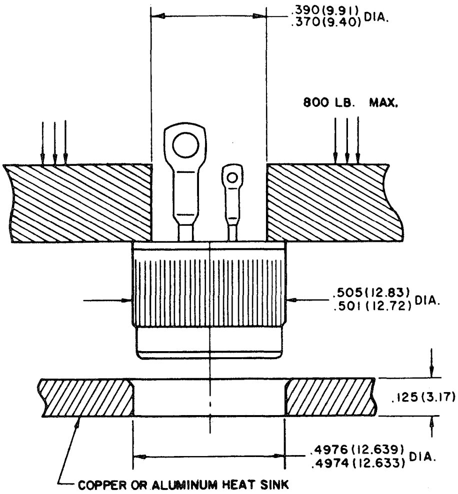
Fig. 16 - Typical phase-control circuit for operation at 400 Hz.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

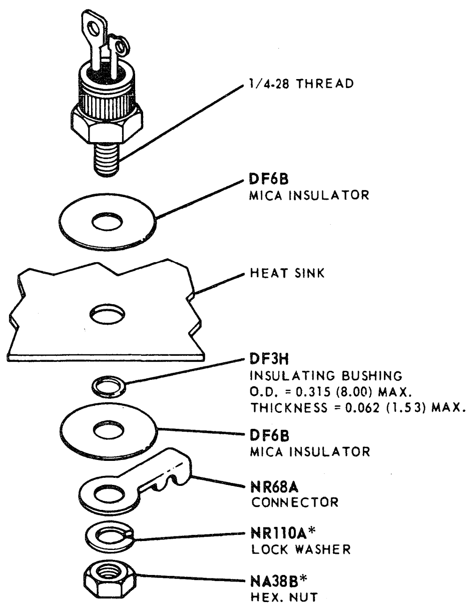
A recommended mounting method, shown in Fig. 17, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in. (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



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

Fig. 17 - Suggested mounting method for press-fit package types.



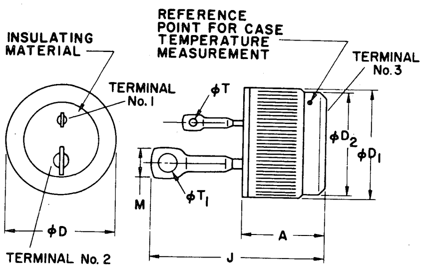
*Only hardware required for isolated-stud package.

Fig. 18 - Suggested mounting arrangement for stud and isolated-stud package types.

Table 1 - Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. (Minimum Required thickness of heat sink = 1/8 in.	0.5
	Soldered directly to heat sink. (60÷40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6
	Mounted on heat sink with a 0.004 to 0.006 in. thick mica insulating washer used between unit and heat sink.	
	Without heat sink compound	2.5
	With heat sink compound	1.5

DIMENSIONAL OUTLINE FOR TYPES 40775, 40776, 40779, 40780, 40783, 40784



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	—	.380	—	9.65	
φD	.501	.510	12.73	12.95	
φD1	—	.505	—	12.83	2
φD2	.465	.475	11.81	12.07	
J	—	.750	—	19.05	
M	—	.155	—	3.94	1
φT	.058	.068	1.47	1.73	
φT1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Outer diameter of knurled surface.

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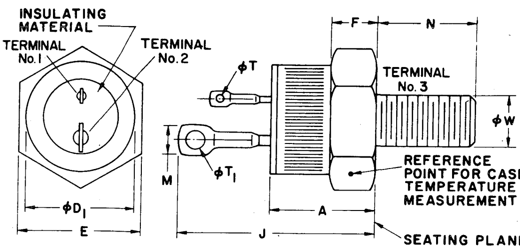
DIMENSIONAL OUTLINE FOR TYPES 40777, 40778, 40781, 40782, 40785, 40786



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	—
φD1	—	.544	—	13.81	—
E	.544	.562	13.82	14.28	—
F	.113	.200	2.87	5.08	3
J	—	.950	—	24.13	—
M	—	.155	—	3.94	1
N	.422	.453	10.72	11.50	—
φT	.058	.068	1.47	1.73	—
φT1	.080	.090	2.03	2.29	—
φW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).
NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

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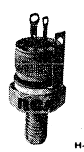
TERMINAL CONNECTIONS

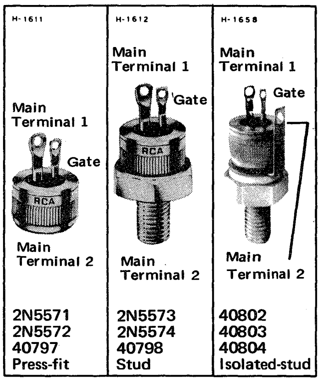
Terminal No. 1—Gate
Terminal No. 2—Main Terminal 1
Case, Terminal No. 3—Main Terminal 2


H-1658

On special request, isolated-stud package triacs are also available.

RCA Solid State Division

Thyristors
2N5571 2N5573 40802 2N5572 2N5574 40803 40797 40798 40804



15-A Silicon Triacs

Press-Fit, Stud, & Isolated-Stud Type Packages

For 120-V Line Operation . . . 2N5571, 2N5573, 40802
For 240-V Line Operation . . . 2N5572, 2N5574, 40803
For High-Voltage Operation . . . 40797, 40798, 40804

Features:

- **di/dt Capability = 150 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled, full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

These triacs are intended for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		2N5571 2N5573 40802	2N5572 2N5574 40803	40797 40798 40804	
***REPETITIVE PEAK OFF-STATE VOLTAGE:●**					
Gate open, T_J = −65 to 100° C	V_{DROM}	200	400	600	V
***RMS ON-STATE CURRENT (Conduction angle = 360°):**	$I_{T(RMS)}$				
Case temperature T_C = 80° C (Press-fit & stud types)			15		A
= 75° C (Isolated-stud types)			15		A
For other conditions			See *Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of applied principal voltage					
* 60 Hz (sinusoidal)			100		A
50 Hz (sinusoidal)			85		A
For more than one cycle of applied principal voltage			See *Fig. 4*		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt				
$V_{DM} = V_{DROM}$, I_{GT} = 160 mA, t_r = 0.1 μs (See *Fig. 13*)			150		A/μs
PEAK GATE-TRIGGER CURRENT:■	I_{GTM}				
For 1 μs max., See *Fig. 7*			4		A
***GATE POWER DISSIPATION:**					
PEAK (For 1 μs max., $I_{GTM} \leq$ 4 A; See *Fig. 7*)	P_{GM}		16		W
AVERAGE	$P_{G(AV)}$		0.5		W
***TEMPERATURE RANGE:▲**					
Storage	T_{stg}		−65 to 150		°C
Operating (Case)	T_C		−65 to 100		°C
***TERMINAL TEMPERATURE (During soldering):**	T_T				
For 10 s max. (terminals and case)			225		°C

* In accordance with JEDEC registration data format (JS-14, RDF 2) filed for the JEDEC 2N-Series) types.
● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS For All Types Unless Otherwise Specified Min.	Typ.	Max.	UNITS
Peak Off-State Current:♣ Gate open, T_J = 100° C, V_{DROM} = Max. rated value	I_{DROM}	–	0.2	2*	mA
Maximum On-State Voltage:♣ For i_T = 21 A (peak), T_C = 25° C	V_{TM}	–	1.4	1.8*	V
DC Holding Current:♣ Gate open, Initial principal current = 500 mA (DC), v_D = 12V: T_C = 25° C	I_{HO}	–	20	75	mA
T_C = –65° C		–	75	300*	
For other case temperatures			See *Fig. 6*		
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 15 A, commutating di/dt = 8 A/ms, gate unenergized, (See *Fig. 14*): T_C = 80° C (Press-fit & stud types)	dv/dt	2*	10	–	V/μs
= 75° C (Isolated-stud)		2	10	–	
Critical Rate-of-Rise of Off-State Voltage:♣ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100° C: 2N5571, 2N5573, 40802	dv/dt	30*	150	–	V/μs
2N5572, 2N5574, 40803		20*	100	–	
40797, 40798, 40804		10	75	–	
DC Gate-Trigger Current:♣♦ For v_D = 12 V (DC), R_L = 30 Ω, T_C = 25° C; Mode I+, V_{MT2} positive, V_G positive	I_{GT}	–	20	50	mA
Mode III-, V_{MT2} negative, V_G negative		–	20	50	
Mode I-, V_{MT2} positive, V_G negative		–	35	80	
Mode III+, V_{MT2} negative, V_G positive		–	35	80	
For v_D = 12 V (DC), R_L = 30 Ω, T_C = –65° C; Mode I+, V_{MT2} positive, V_G positive		–	75	150*	
Mode III-, V_{MT2} negative, V_G negative		–	75	150*	
Mode I-, V_{MT2} positive, V_G negative		–	100	200*	
Mode III+, V_{MT2} negative, V_G positive		–	100	200*	
For other case temperatures			See *Figs. 8 & 9*		
DC Gate-Trigger Voltage:♣♦ For v_D = 12 V(DC), R_L = 30 Ω, T_C = 25° C	V_{GT}	–	1	2.5	V
T_C = –65° C		–	2	4*	
For other case temperatures			See *Fig. 10*		
For v_D = V_{DROM}, R_L = 125 Ω, T_C = 100° C		0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 160 mA, t_r = 0.1 μs, i_T = 25 A (peak), T_C = 25° C (See *Figs. 11 & 15*)	t_{gt}	–	1.6	2.5	μs
Thermal Resistance: **Junction-to-Case:** Steady-State	$\theta_{J\text{-}C}$	–	–	1*	°C/W
Transient			See *Fig. 12*		
Junction-to-Isolated Hex (Stud, see Dim. Outline): Steady-State	$\theta_{J\text{-}IH}$	–	–	1.1	

* In accordance with JEDEC registration data format (JS-14, RDF 2) filed for the JEDEC (2N-Series) types.

♣ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

♦ For either polarity of gate voltage (V_G) with reference to main terminal 1.

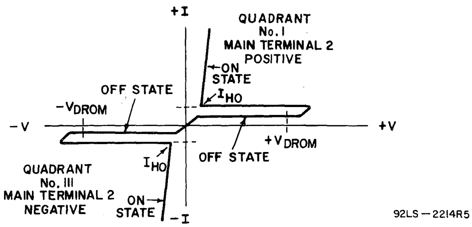


Fig. 1 – Principal voltage-current characteristic.

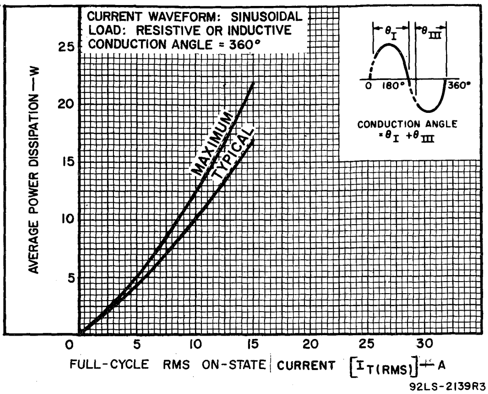


Fig. 2 – Power dissipation vs. on-state current.

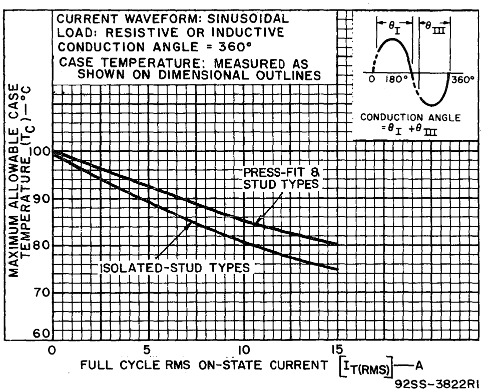


Fig. 3 – Maximum allowable case temperature vs. on-state current.

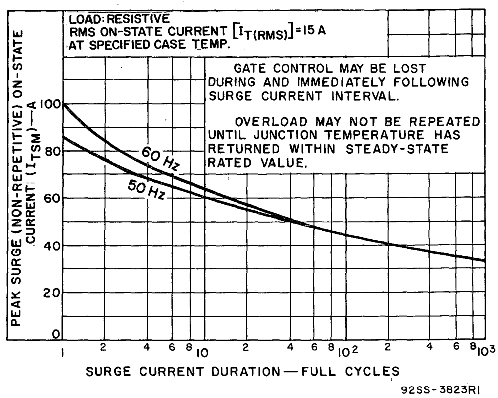


Fig. 4 – Peak surge on-state current vs. surge current duration.

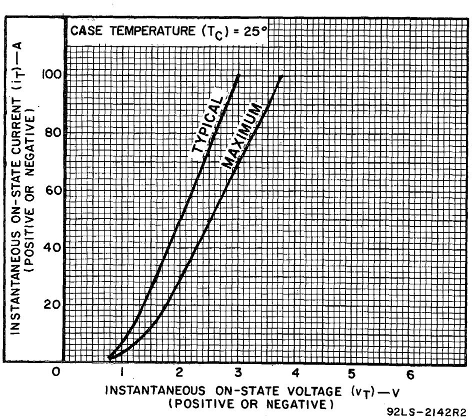


Fig. 5 – On-state current vs. on-state voltage.

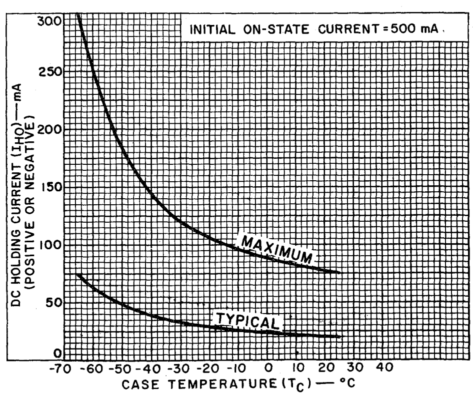


Fig. 6 – DC holding current vs. case temperature.

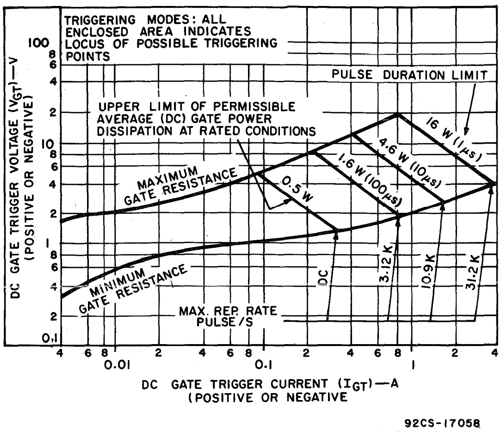


Fig. 7 – Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

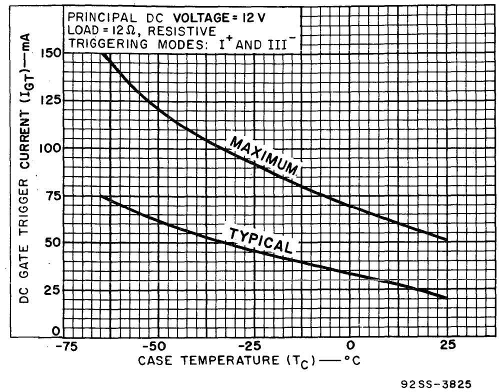


Fig. 8 – DC gate-trigger current vs. case temperature (1^+ & III^- modes).

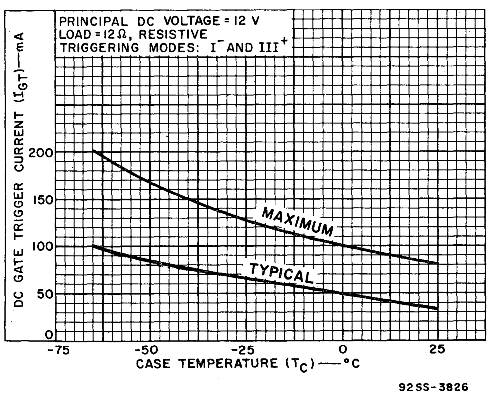


Fig. 10 – DC gate-trigger voltage vs. case temperature.

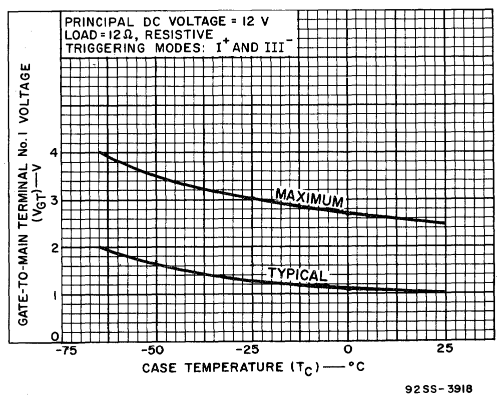


Fig. 9 – DC gate-trigger current vs. case temperature (1^- & III^+ modes).

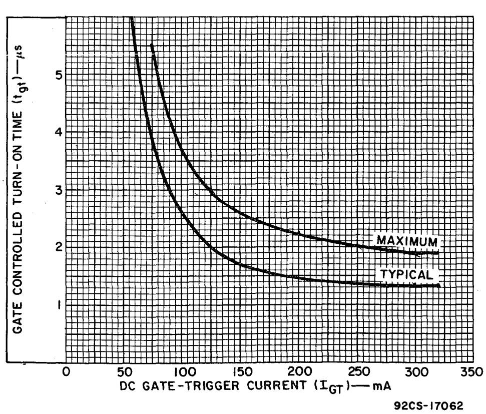


Fig. 11 – Turn-on time vs. gate trigger current.

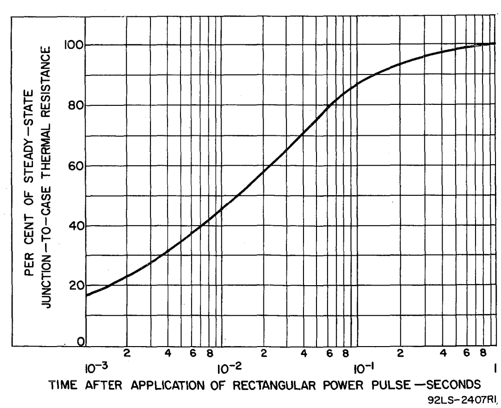


Fig. 12 – Transient junction-to-case thermal resistance vs. time.

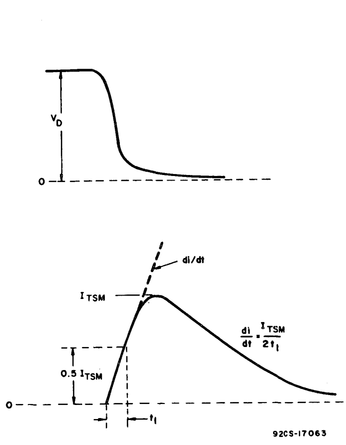


Fig. 13 – Rate-of-change of on-state current with time (defining di/dt).

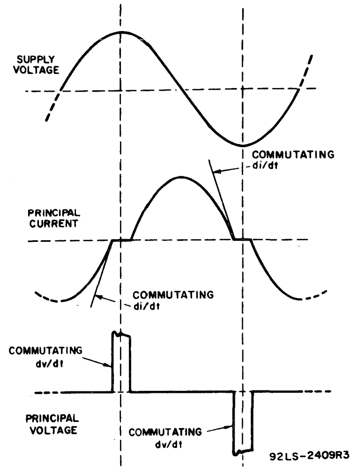


Fig. 14 – Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

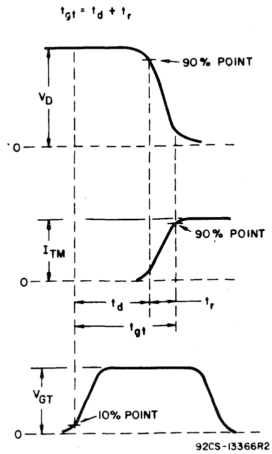


Fig. 15 – Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

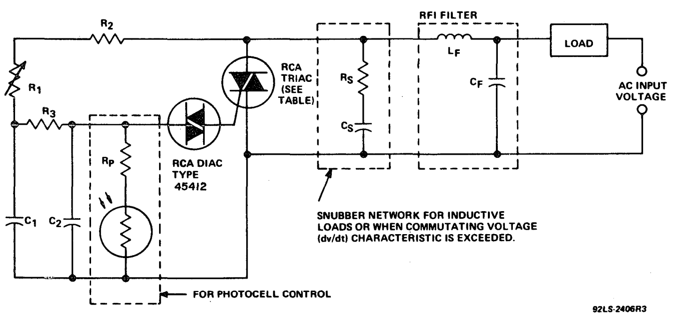


Fig. 16 – Typical phase-control circuit for lamp dimming, heat control, and universal-motor speed control.

AC INPUT VOLTAGE		120V 60Hz	240V 60Hz	240V 50Hz
C_1		0.1µF 200V	0.1µF 400V	0.1µF 400V
C_2		0.1µF 100V	0.1µF 100V	0.1µF 100V
R_1		100KΩ 1/2W	200KΩ 1W	250KΩ 1W
R_2		2.2KΩ 1/2W	3.3KΩ 1/2W	3.3KΩ 1/2W
R_3		15KΩ 1/2W	15KΩ 1/2W	15KΩ 1/2W
PHOTOCELL CONTROL	R_P	1.2KΩ 2W	1.2KΩ 2W	1.2KΩ 2W
SNUBBER NETWORK	C_S	0.1µF 200V	0.1µF 400V	0.1µF 400V
	R_S	100Ω 1/2W	100Ω 1/2W	100Ω 1/2W
RFI FILTER	C_F*	0.1µF 200V	0.1µF 400V	0.1µF 400V
	L_F*	100µH	200µH	200µH
RCA TRIACS		2N5571 2N5573 40802	2N5572 2N5574 40803	2N5572 2N5574 40803

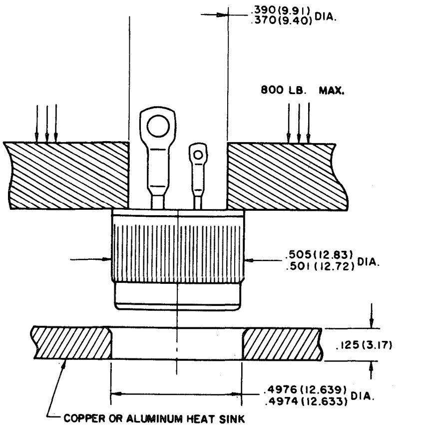
*Typical values for lamp dimming circuits.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in *Fig. 17,* shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



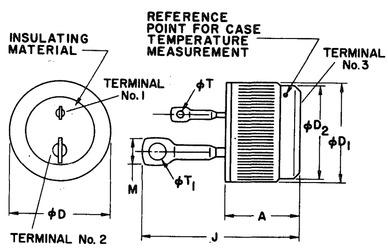
NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 17 – Suggested mounting method for press-fit package types.

Table I – Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud & Isolated-Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6
Stud	Mounted on heat sink with a 0.004 to 0.006 in. (0.102 to 0.152 mm) thick mica insulating washer used between unit and heat sink. Without heat sink compound	2.5
	With heat sink compound	1.5

DIMENSIONAL OUTLINE FOR TYPES 2N5571, 2N5572, 40797



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.380	–	9.65	
ϕD	.501	.510	12.73	12.95	
ϕD1	–	.505	–	12.83	2
ϕD2	.465	.475	11.81	12.07	
J	–	.750	–	19.05	
M	–	.155	–	3.94	1
ϕT	.058	.068	1.47	1.73	
ϕT1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Outer diameter of knurled surface.

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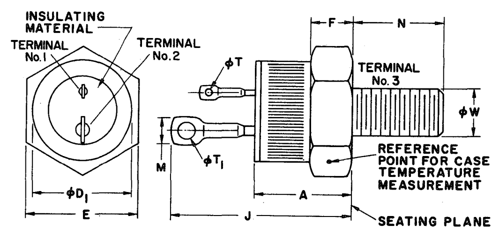
DIMENSIONAL OUTLINE FOR TYPES 2N5573, 2N5574, 40798



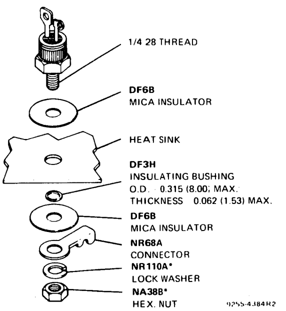
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	–
ϕD1	–	.544	–	13.81	–
E	.544	.562	13.82	14.28	–
F	.113	.200	2.87	5.08	3
J	–	.950	–	24.13	–
M	–	.155	–	3.94	1
N	.422	.453	10.72	11.50	–
ϕT	.058	.068	1.47	1.73	–
ϕT1	.080	.090	2.03	2.29	1
ϕW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

92SS-3817



*Only hardware required for isolated-stud package.

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

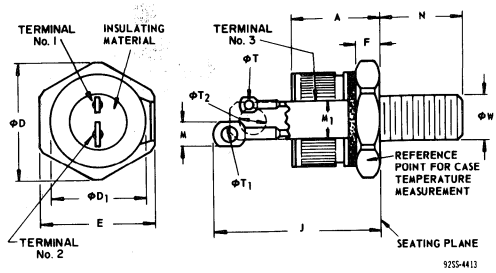
Fig. 18 – Suggested mounting arrangement for stud and isolated-stud package types.

WARNING:
The RCA isolated-stud package thyristors should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled.

TERMINAL CONNECTIONS

Terminal No.1–Gate
Terminal No.2–Main Terminal 1
Case, Terminal No.3–Main Terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40802, 40803, 40804



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.673	–	17.09	
ϕD	.604	.614	15.34	15.59	
ϕD_1	.501	.505	12.72	12.82	
E	.551	.557	13.99	14.14	
F	.175	.185	4.44	4.69	
J	–	1.055	–	26.79	
M	–	.155	–	3.94	
M_1	.200	.210	5.08	5.33	
N	.422	.452	10.72	11.48	
ϕT	.058	.068	1.47	1.73	2
ϕT_1	.080	.090	2.03	2.29	2
ϕT_2	.138	.148	3.50	3.75	2
ϕW	.225	.2268	5.652	5.760	3

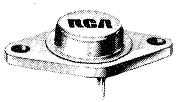
NOTE 1: Ceramic between hex (stud) and terminal No.3 is beryllium oxide.

NOTE 2: Contour and angular orientation of these terminals is optional.

NOTE 3: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

Solid State Division

Thyristors
40575
40576



JEDEC TO-66

H-1340

15-Ampere Silicon Triacs

For Low-Power Phase-Control and Load-Switching Applications

For 120-V Line Operation — 40575
For 240-V Line Operation — 40576

Features:

- **di/dt Capability = 150 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

RCA 40575* and 40576* are gate-controlled full-wave ac silicon switches. They are designed to switch from an off-state to a conducting state for either polarity of applied voltage with positive or negative gate triggering.

These devices are intended for the control of ac loads in applications such as space heater, oven and furnace controls, motor controls, and lamp loads.

The 40575 and 40576 are hermetically sealed in a JEDEC TO-66 package. They have an rms on-state current capability of 15 amperes at a case temperature of +70° C. The 40575 has a repetitive peak off-state voltage rating of 200 volts and the 40576, 400 volts.

*Formerly Dev. Types TA2834 and TA2835, respectively.

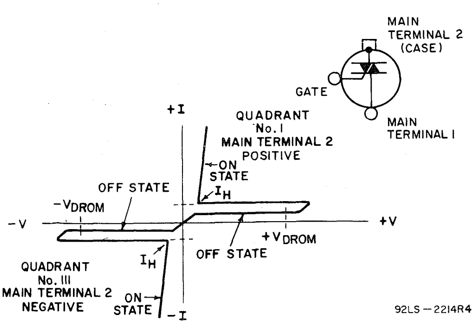


Fig. 1 - Principal voltage-current characteristic.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with 50/60-Hz, Sinusoidal Supply Voltage and Resistive or Inductive Load

REPETITIVE PEAK OFF-STATE VOLTAGE♠	V_{DROM}		
Gate Open, T_J = -40° C to +100° C			
40575		200	V
40576		400	V
RMS ON-STATE CURRENT	$I_{T(RMS)}$		
Conduction angle = 360°:			
Case temperature (T_C) = 70° C		15	A
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT	I_{TSM}		
For one full cycle of applied principal voltage (60-Hz, sinusoidal)		100	A
For one full cycle of applied principal voltage (50-Hz, sinusoidal)		85	A
For more than one full cycle of applied voltage		See Fig. 6.	
PEAK GATE-TRIGGER CURRENT	I_{GTM}		
For 1 μs max.		4	A
GATE POWER DISSIPATION:	P_{GM}		
PEAK†			
For 1 μs max. and I_{GTM} = ≤4 A (peak)		16	W
AVERAGE	$P_{G(AV)}$	0.45	W
TEMPERATURE RANGE‡			
Storage, T_{stg}		-40 to 150°C	
Operating (case), T_C		-40 to 100°C	

♠For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

†For either polarity of gate voltage (V_G) with reference to main terminal 1.

‡For information on the reference point of temperature measurement, see *Dimensional Outlines.*

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C).

CHARACTERISTICS	TRIAC TYPES						UNITS
	40575			40576			
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Peak Off-State Current♦, I_{DROM}							
Gate open							
At T_j = +100° C and V_{DROM} = Max. rated value	–	0.2	4	–	0.2	4	mA
Instantaneous On-State Voltage♦, v_T							
For i_T = 30 A (peak) and T_C = +25° C.	–	1.6	2.0	–	1.6	2.0	V(peak)
DC Holding Current♦, I_{HO}:							
Gate Open							
Initial principal current = 150 mA (dc)							
At T_C = +25° C.	–	15	60	–	15	60	mA(dc)
For other case temperatures.		See Fig. 8			See Fig. 8		
Critical Rate of Applied Commutating Voltage♦,							
Commutating dv/dt:							
For v_D = V_{DROM}, $I_{T(RMS)}$ = 15 A, commutating di/dt = 8 A/ms, and gate unenergized							
At T_C = +70° C.	2	10	–	2	10	–	V/μs
Critical Rate of Rise of Off-State Voltage♦,							
Critical dv/dt:							
For v_D = V_{DROM}, exponential voltage rise, gate open							
At T_C = +100° C.	30	150	–	20	100	–	V/μs
DC Gate-Trigger Current♦ ■, I_{GT}							
For v_D = 6 volts (dc), R_L = 12 ohms, T_C = +25° C, and Specified Triggering Mode:							
I^+ Mode: V_{T2} is positive, V_G is positive. . .	–	15	30	–	15	30	mA(dc)
I^- Mode: V_{T2} is positive, V_G is negative. . .	–	35	80	–	35	80	mA(dc)
III^+ Mode: V_{T2} is negative, V_G is positive. . .	–	35	80	–	35	80	mA(dc)
III^- Mode: V_{T2} is negative, V_G is negative. . .	–	15	30	–	15	30	mA(dc)
For other case temperatures.		See Figs. 12 & 13			See Figs. 12 & 13		
DC Gate-Trigger Voltage♦ ■, V_{GT}:							
For v_D = 6 volts (dc) and R_L = 12 ohms							
At T_C = +25° C.	–	1	2.5	–	1	2.5	V(dc)
For other case temperatures.		See Fig. 14			See Fig. 14		
For v_D = V_{DROM} and R_L = 125 ohms							
At T_C = +100° C.	0.2	–	–	0.2	–	–	V(dc)
Gate-Controlled Turn-On Time, t_{gt}							
(Delay Time + Rise Time)							
For v_D = V_{DROM}, I_{GT} = 160 mA, 0.1 μs rise time, and i_T = 25 A (peak)							
At T_C = +25° C.	–	1.6	2.5	–	1.6	2.5	μs
Thermal Resistance, Junction to case,							
$\theta_{J\text{-}C}$.	–	–	1.3	–	–	1.3	°C/W

♦For either polarity of main terminal 2 voltage (V_{T2}) with reference to main terminal 1.

■For either polarity of gate voltage (V_G) with reference to main terminal 1.

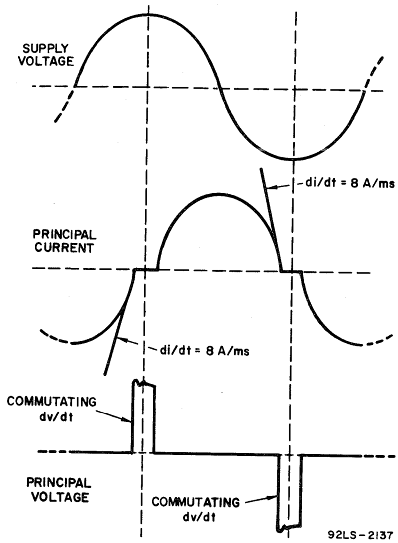


Fig. 2 - Waveshapes of commutating dv/dt characteristics.

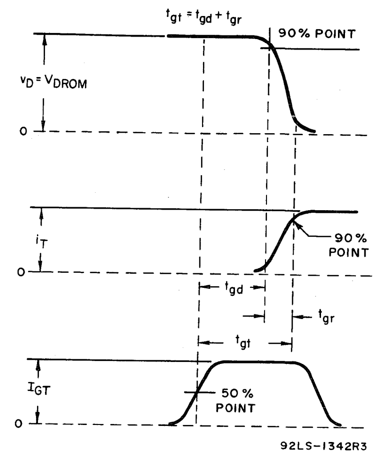


Fig. 3 - Waveshapes of t_{gt} characteristics test.

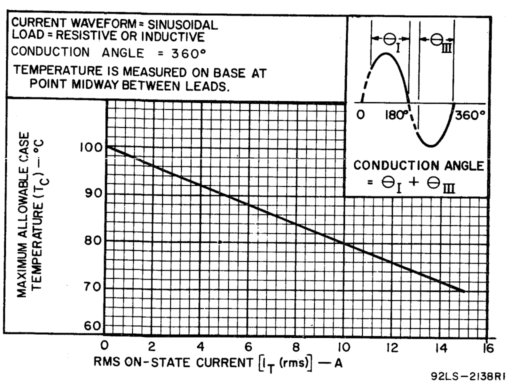


Fig. 4 - Conduction rating chart (case temperature).

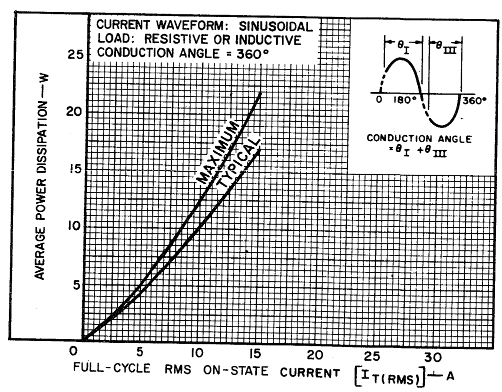


Fig. 5 - Power dissipation curve.

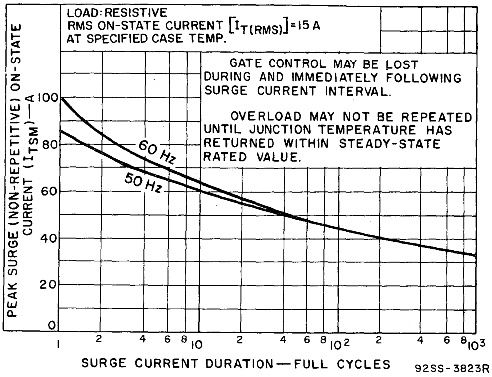


Fig. 6 - Surge current rating chart.

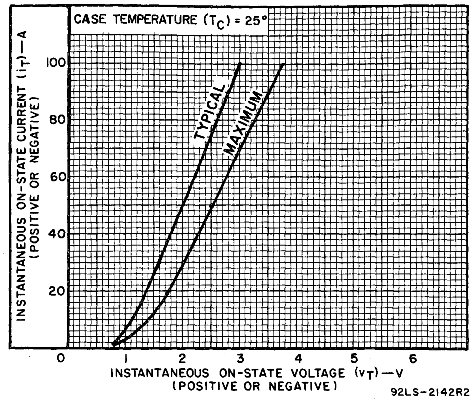


Fig. 7 - On-state characteristics for either direction of principal current.

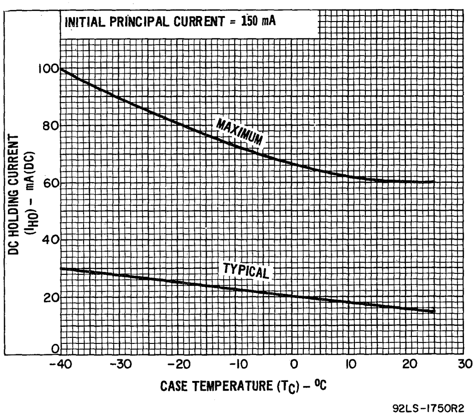


Fig. 8 - DC holding current characteristics for either direction of principal current.

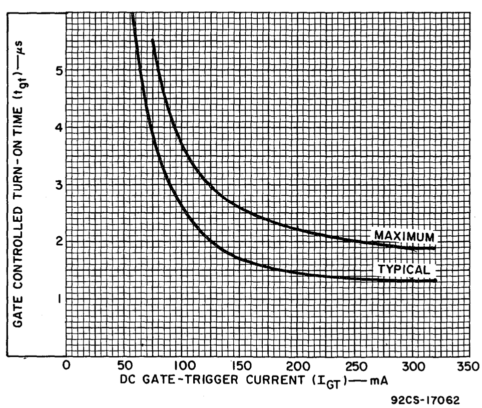


Fig. 9 - Turn-on time vs. gate trigger current.

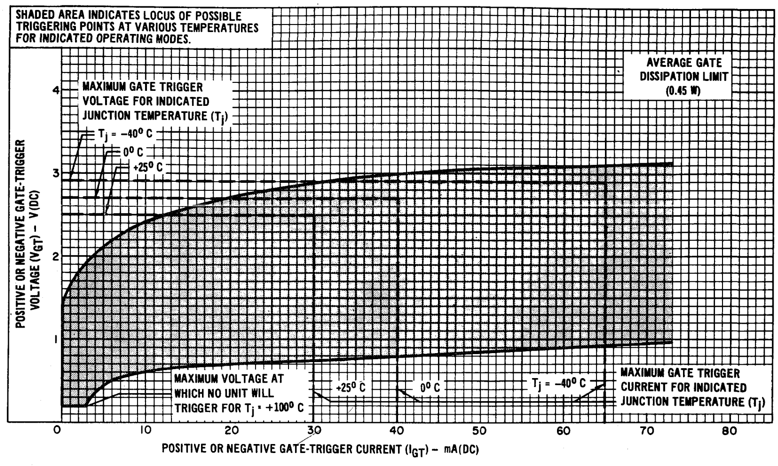


Fig. 10 - Gate characteristics for I^+ and III^+ triggering modes.

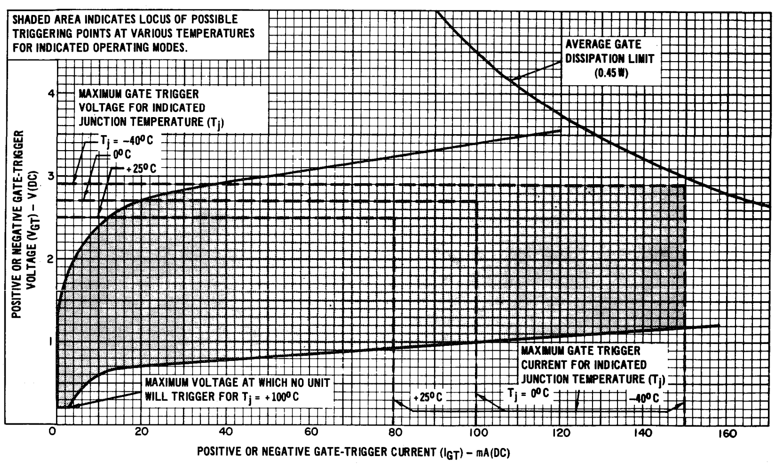


Fig. 11 - Gate characteristics for I^- and III^+ triggering modes.

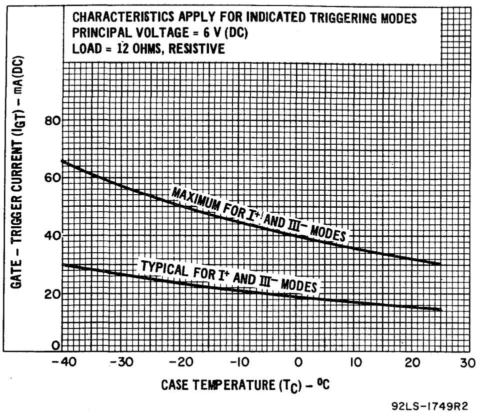


Fig. 12 - DC gate-trigger current characteristics for I^+ and III^- modes.

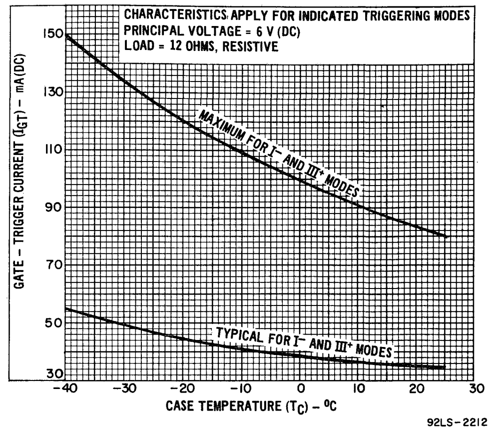


Fig. 13 - DC gate-trigger current characteristics for I^- and III^+ modes.

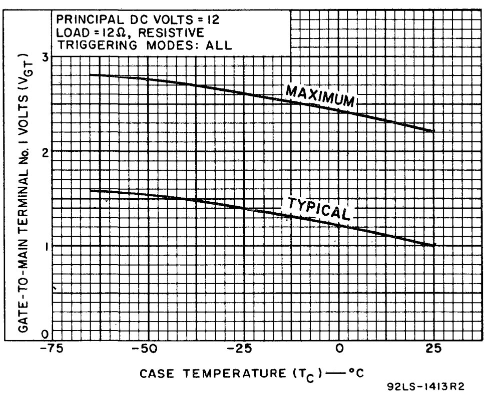
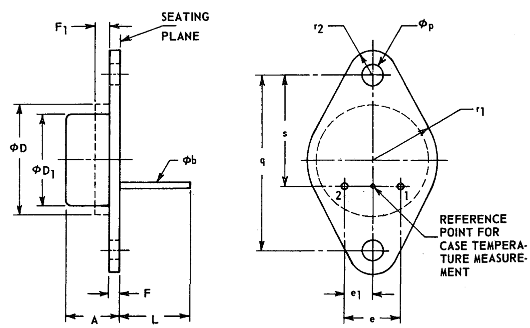


Fig. 14 - DC gate-trigger voltage characteristics.

DIMENSIONAL OUTLINE FOR BOTH TYPES
JEDEC TO-66



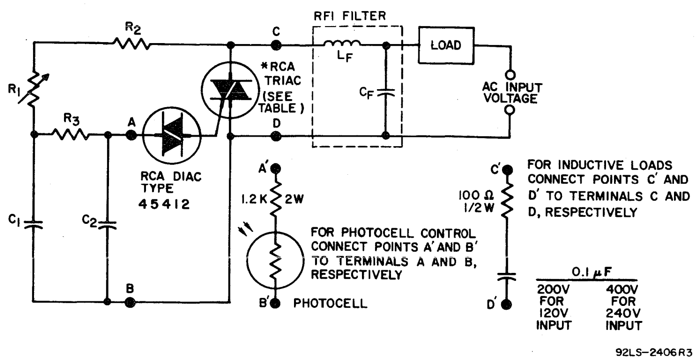
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.250	0.340	6.35	8.64	
ϕb	0.028	0.034	0.711	0.863	
ϕD		0.620		15.75	
ϕD_1	0.470	0.500	11.94	12.70	
e	0.190	0.210	4.83	5.33	
e_1	0.093	0.107	2.36	2.72	
F	0.050	0.075	1.27	1.91	2
F_1		0.050		1.27	1
L	0.360		9.14		
ϕp	0.142	0.152	3.61	3.86	
q	0.958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

TERMINAL CONNECTIONS

Pin 1: Gate
Pin 2: Main Terminal 1
Case: Main Terminal 2



AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER		RCA TYPES
						L_F* (typ.)	C_F* (typ.)	
120V 60Hz	0.1μF 200V	0.1μF 100V	100KΩ 1/2W	1KΩ 1/2W	15KΩ 1/2W	100μH	0.1μF 200V	40575
240V 50/60Hz	0.05μF 400V	0.1μF 100V	200KΩ 1/2W	7.5KΩ 2W	7.5KΩ 2W	100μH	0.1μF 400V	40576

*Typical values for lamp dimming circuits.

Fig. 15 - Typical phase-control circuit for lamp dimming, heat controls, and universal motor speed controls.

RCA Application Notes on Thyristors

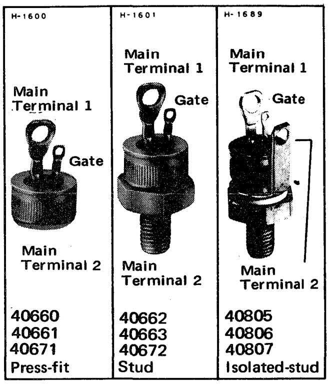
AN-3697 "Triac Power Control Applications"
AN-3778 "Light Dimmers Using Triacs"
AN-3822 "Thermal Considerations in Mounting of RCA Thyristors"
AN-4242 "A Review of Thyristor Characteristics and Applications"

For basic thyristor theory, circuits, and application information on Triacs, refer to "RCA Power Circuits" manual, SP-51.

RCA Solid State Division

Thyristors

40660 40662 40805 40661 40663 40806 40671 40672 40807



30-A Silicon Triacs

Press-Fit, Stud, & Isolated-Stud Type Packages

For 120-V Line Operation . . . 40660, 40662, 40805
For 240-V Line Operation . . . 40661, 40663, 40806
For High-Voltage Operation . . . 40671, 40672, 40807

Features:

- **di/dt Capability = 100 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled, full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

These triacs are intended for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. They can also be used in air-conditioning and photocopying equipment.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40660 40662 40805	40661 40663 40806	40671 40672 40807	
REPETITIVE PEAK OFF-STATE VOLTAGE:●					
Gate open, T_J = −50 to 100° C	V_{DROM}	200	400	600	V
RMS ON-STATE CURRENT (Conduction angle = 360°):	$I_{T(RMS)}$				
Case temperature					
T_C = 65° C (Press-fit types)			30		A
= 60° C (Stud types)			30		A
= 55° C (Isolated-stud types)			30		A
For other conditions			*See Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of applied principal voltage					
60 Hz (sinusoidal)			300		A
50 Hz (sinusoidal)			265		A
For more than one cycle of applied principal voltage			See *Fig. 4*		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt				
$V_{DM} = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.1 μs (See *Fig. 13)*			100		A/μs
PEAK GATE-TRIGGER CURRENT:■	I_{GTM}				
For 1 μs max.,See *Fig. 7*			12		A
GATE POWER DISSIPATION:					
PEAK (For 1 μs max., $I_{GTM} \leq$ 4 A, See *Fig. 7)*	P_{GM}		40		W
AVERAGE	$P_{G(AV)}$		0.75		W
TEMPERATURE RANGE:▲					
Storage	T_{stg}		−65 to 150		°C
Operating (Case)	T_C		−65 to 100		°C
TERMINAL TEMPERATURE (During soldering):	T_T				
For 10 s max. (terminals and case)			225		°C

● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS For All Types Unless Otherwise Specified			UNITS
		Min.	Typ.	Max.	
Peak Off-State Current:♣ Gate open, T_J = 100° C, V_{DROM} = Max. rated value	I_{DROM}	–	0.2	4	mA
Maximum On-State Voltage:♣ For i_T = 100 A (peak), T_C = 25° C	V_{TM}	–	2.1	2.5	V
DC Holding Current:♣ Gate open, Initial principal current = 150 mA (DC), v_D = 12V:					
T_C = 25° C	I_{HO}	–	25	60	mA
For other case temperatures			See *Fig. 6*		
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 30 A, commutating di/dt = 16 A/ms, gate unenergized, (See *Fig. 14*):					
T_C = 65° C (Press-fit types)	dv/dt	3	20	–	V/μs
= 60° C (Stud types)		3	20	–	
= 55° C (Isolated-stud types)		3	20	–	
Critical Rate-of-Rise of Off-State Voltage:♣ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 100° C:					
40660, 40662, 40805	dv/dt	40	200	–	V/μs
40661, 40663, 40806		25	150	–	
40671, 40672, 40807		20	100	–	
DC Gate-Trigger Current:♣♦ For v_D = 12 V (DC), R_L = 30 Ω, T_C = 25° C — Mode I^+, V_{MT2} positive, V_G positive	I_{GT}	–	15	50	mA
Mode III^-, V_{MT2} negative, V_G negative		–	20	50	
Mode I^-, V_{MT2} positive, V_G negative		–	30	80	
Mode III^+, V_{MT2} negative, V_G positive		–	40	80	
For other case temperatures			See *Figs. 8 & 9*		
DC Gate-Trigger Voltage:♣♦ For v_D = 12 V(DC), R_L = 30 Ω, T_C = 25° C	V_{GT}	–	1.35	2.5	V
For other case temperatures			See *Fig. 10*		
For v_D = V_{DROM}, R_L = 125 Ω, T_C = 100° C		0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 200 mA, t_r = 0.1 μs, i_T = 45 A (peak), T_C = 25° C (See *Figs. 11 & 15*)	t_{gt}	–	1.7	3	μs
Thermal Resistance, Junction-to-Case: Steady-State					
Press-fit types	$\theta_{J\text{-}C}$	–	–	0.8	°C/W
Stud		–	–	0.9	
Transient (Press-fit & stud types)			See *Fig. 12*		
Thermal Resistance, Junction-to-Hex (Stud, See Dim. Outline): Steady-State (Isolated-stud types)	$\theta_{J\text{-}IH}$	–	–	1	

♣ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

♦ For either polarity of gate voltage (V_G) with reference to main terminal 1.

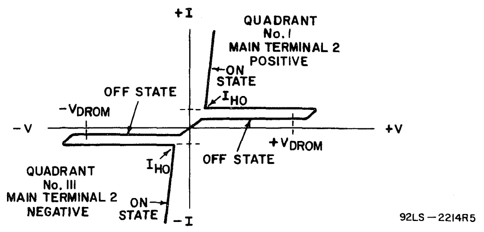


Fig. 1 – Principal voltage-current characteristic.

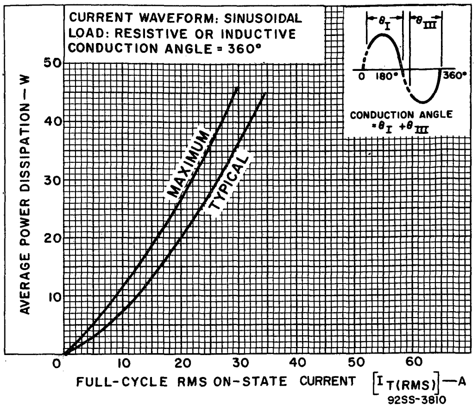


Fig. 2 – Power dissipation vs. on-state current.

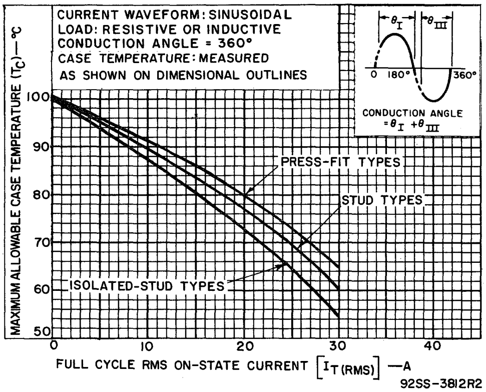


Fig. 3 – Maximum allowable case temperature vs. on-state current.

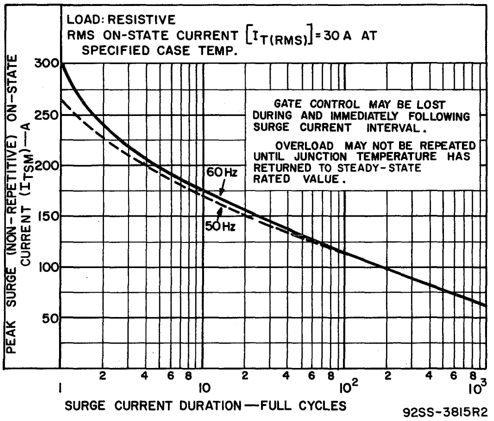


Fig. 4 – Peak surge on-state current vs. surge current duration.

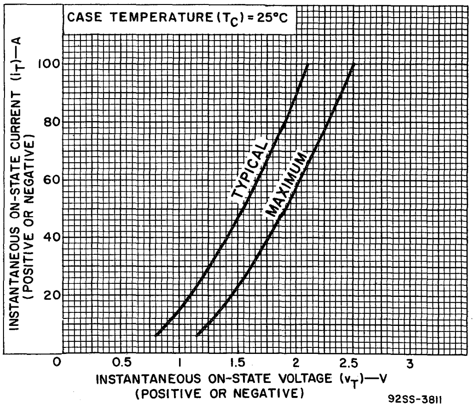


Fig. 5 – On-state current vs. on-state voltage.

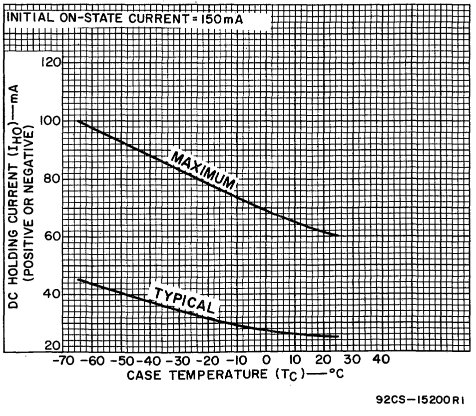


Fig. 6 – DC holding current vs. case temperature.

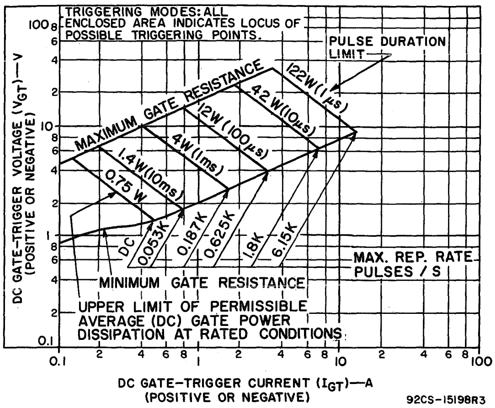


Fig. 7 — Gate trigger characteristics and limiting conditions for determination of permissible gate trigger pulses.

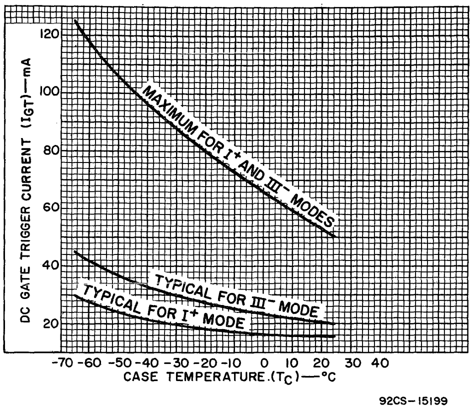


Fig. 8 — DC gate-trigger current vs. case temperature (I+ & III- modes).

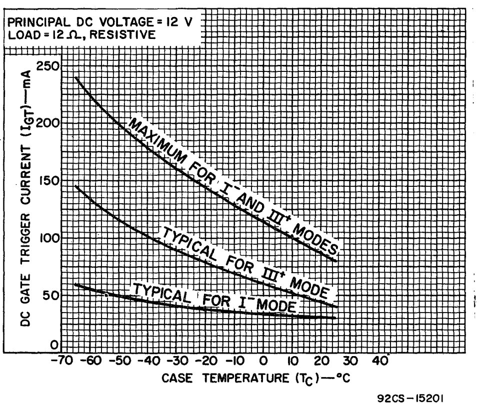


Fig. 9 — DC gate-trigger current vs. case temperature (I- & III+ modes).

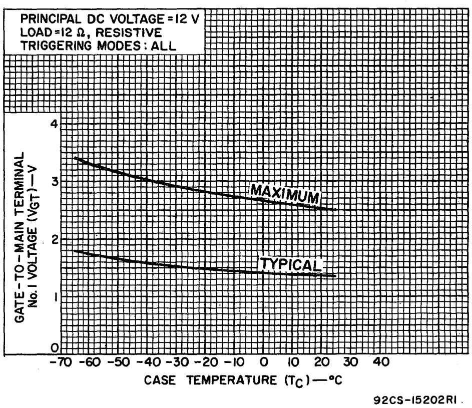


Fig. 10 — DC gate-trigger voltage vs. case temperature.

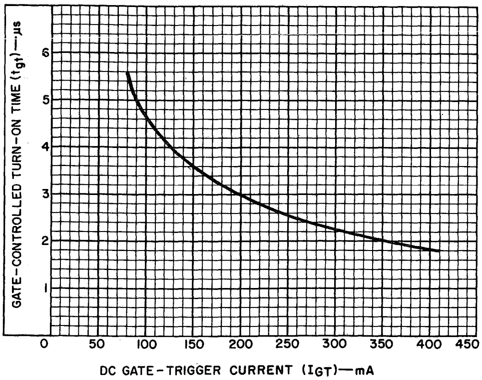


Fig. 11 — Turn-on time vs. gate trigger current.

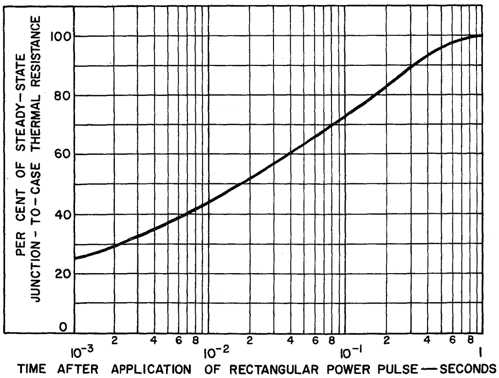


Fig. 12 — Transient junction-to-case thermal resistance vs. time.

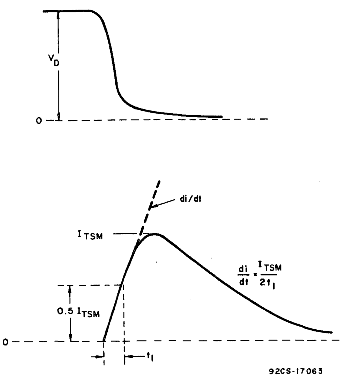


Fig. 13 – Rate-of-change of on-state current with time (defining di/dt).

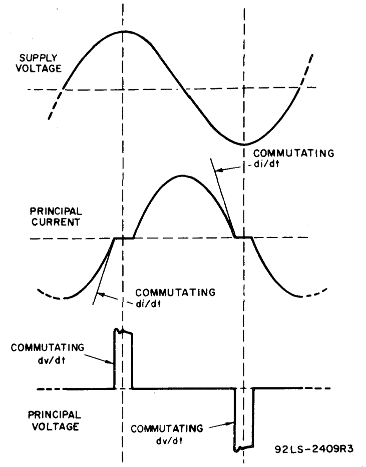


Fig. 14 – Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

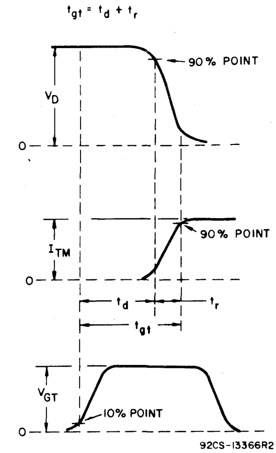


Fig. 15 – Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

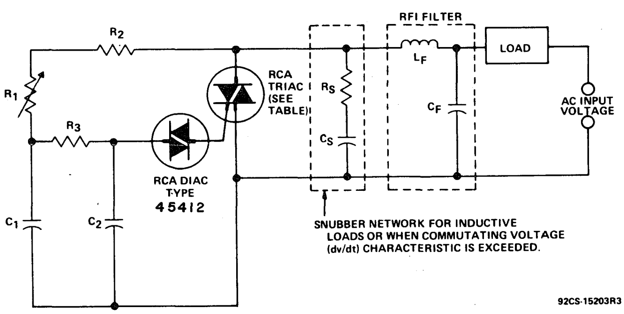


Fig. 16 – Typical phase-control circuit for lamp dimming, heat control, and universal-motor speed control.

AC INPUT VOLTAGE		120V 60Hz	240V 60Hz	240V 50Hz
C_1		0.1μF 200V	0.1μF 400V	0.1μF 400V
C_2		0.1μF 100V	0.1μF 100V	0.1μF 100V
R_1		100KΩ 1/2W	200KΩ 1W	250KΩ 1W
R_2		2.2KΩ 1/2W	3.3KΩ 1/2W	3.3KΩ 1/2W
R_3		15KΩ 1/2W	15KΩ 1/2W	15KΩ 1/2W
SNUBBER NETWORK	C_S	0.1μF 200V	0.1μF 400V	0.1μF 400V
	R_S	100Ω 1/2W	100Ω 1/2W	100Ω 1/2W
RFI FILTER	C_F*	0.1μF 200V	0.1μF 400V	0.1μF 400V
	L_F*	100μH	200μH	200μH
RCA TRIACS		40660 40662 40805	40661 40663 40806	40661 40663 40806

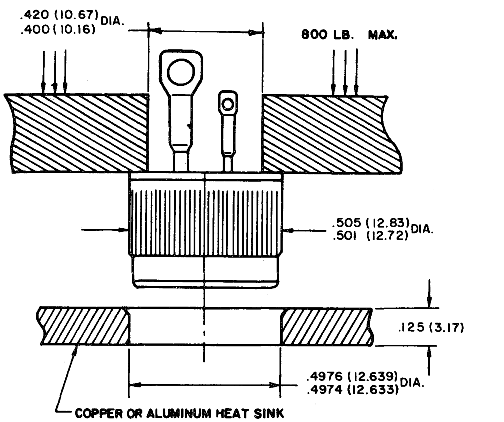
*Typical values for lamp dimming circuits.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in *Fig. 17,* shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



92LS-2264R3

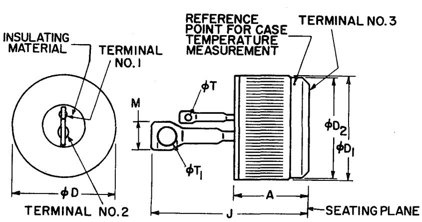
NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 17 – Suggested mounting method for press-fit package types.

Table I – Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6

DIMENSIONAL OUTLINE FOR TYPES 40660, 40661, 40671



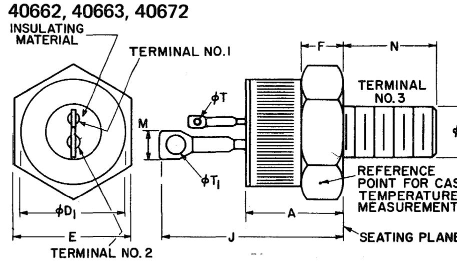
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.380	–	9.65	
ϕD	.501	.510	12.73	12.95	
ϕD_1	–	.505	–	12.83	2
ϕD_2	.465	.475	11.81	12.07	
J	–	.750	–	19.05	
M	–	.155	–	3.94	1
ϕT	.058	.068	1.47	1.73	
ϕT_1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Outer diameter of knurled surface.

92CS-15207R2

DIMENSIONAL OUTLINE FOR TYPES 40662, 40663, 40672



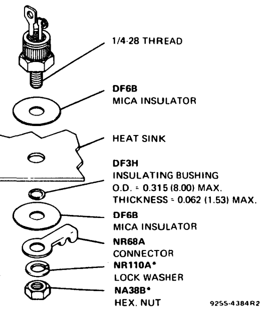
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	–
ϕD_1	–	.544	–	13.81	–
E	.544	.562	13.82	14.28	–
F	.113	.200	2.87	5.08	3
J	–	.950	–	24.13	–
M	–	.155	–	3.94	1
N	.422	.453	10.72	11.50	–
ϕT	.058	.068	1.47	1.73	–
ϕT_1	.080	.090	2.03	2.29	–
ϕW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

92CS-15208R2



*Only hardware required for isolated-stud package.

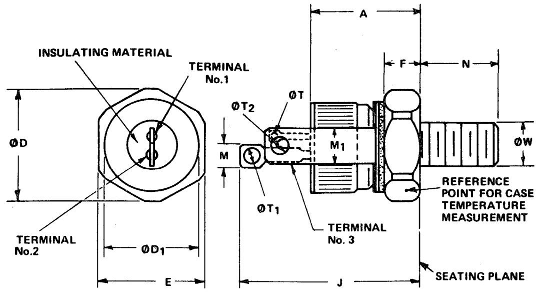
NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 18 – Suggested mounting arrangement for stud and isolated-stud package types.

WARNING:
The RCA isolated-stud package thyristors should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled.

TERMINAL CONNECTIONS
Terminal No.1—Gate
Terminal No.2—Main Terminal 1
Case, Terminal No.3—Main Terminal 2

DIMENSIONAL OUTLINE FOR TYPES 40805, 40806, 40807



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.673	–	17.09	
φD	.604	.614	15.34	15.59	
φD1	.501	.505	12.72	12.82	
E	.551	.557	13.99	14.14	
F	.175	.185	4.44	4.69	
J	–	1.298	–	32.96	
M	.210	.230	5.33	5.84	
M1	.200	.210	5.08	5.33	
N	.422	.452	10.72	11.48	
φT	.058	.068	1.47	1.73	2
φT1	.125	.165	3.18	4.19	2
φT2	.138	.148	3.50	3.75	2
φW	.2225	.2268	5.652	5.760	3

NOTE 1: Ceramic between hex (stud) and terminal No.3 is beryllium oxide.

NOTE 2: Contour and angular orientation of these terminals is optional.

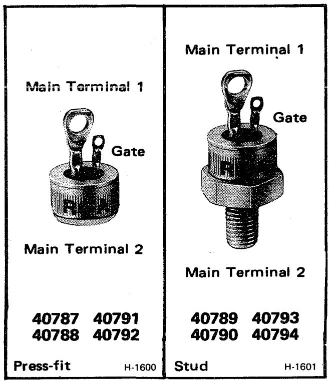
NOTE 3: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

92LS-3653

RCA
Solid State
Division

Thyristors

40787 – 40790
40791 – 40794



400-Hz, 25 & 40-A Silicon Triacs

For Control-Systems Application in Airborne and Ground-Support Type Equipment

For 115-V Line Operation—40787, 40789, 40791, 40793
For 208-V Line Operation—40788, 40790, 40792, 40794

Features:

- **RMS On-State Current —**
  $I_{T(RMS)}$ = 25 A (40787, 40788, 40789, 40790)
  = 40 A (40791, 40792, 40793, 40794)
- **di/dt Capability = 100 A/μs**
- **Commutating dv/dt Capability Characterized at 400 Hz**
- **Shorted-Emitter, Center-Gate Design**

These RCA triacs are gate-controlled, full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

They are intended for operation at 400 Hz with resistive or inductive loads and nominal line voltages of 115 and 208 V RMS sine wave and repetitive peak off-state voltages of 200 V and 400 V.

These triacs exhibit commutating voltage (dv/dt) capability at high commutating current (di/dt). They can also be used in 60-Hz applications where high commutating capability is required.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at 400 Hz and with Resistive or Inductive Load.

Rating	Symbol	40787 40789 40791 40793	40788 40790 40792 40794	Unit
REPETITIVE PEAK OFF-STATE VOLTAGE:* Gate open, T_J = –50 to 110° C	V_{DROM}	200	400	V
RMS ON-STATE CURRENT (Conduction Angle = 360°): Case temperature	$I_{T(RMS)}$			
T_C = 85° C (40787, 40788)		25		A
80° C (40789, 40790)		25		A
70° C (40791, 40792)		40		A
65° C (40793, 40794)		40		A
For other conditions		*See Fig.3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT: For one cycle of applied principal voltage	I_{TSM}			
400 Hz (sinusoidal)		600		A
60 Hz (sinusoidal)		300		A
For more than one cycle of applied principal voltage		*See Fig.4*		
RATE-OF-CHANGE OF ON-STATE CURRENT: $V_{DM} = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.1 μs *(See Fig. 15)*	di/dt	100		A/μs
FUSING CURRENT (for Triac Protection): T_J = –50 to 110° C, t = 1.25 to 10 ms	I^2t	350		A^2s
PEAK GATE-TRIGGER CURRENT:■ For 1 μs max. *(See Fig. 7)*	I_{GTM}	12		A
GATE POWER DISSIPATION: Peak (For 10 μs max., $I_{GTM} \leq$ 4 A (peak), *(See Fig. 7)*	P_{GM}	42		W
Average	$P_{G(AV)}$	0.75		W
TEMPERATURE RANGE:▲ Storage	T_{stg}	–50 to 150		°C
Operating (Case)	T_C	–50 to 110		°C
TERMINAL TEMPERATURE (During soldering): For 10 s max. (terminals and case)	T_T	225		°C

* For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS
At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS For All Types Unless Otherwise Specified Min.	Typ.	Max.	UNITS
Peak Off-State Current:♠					
Gate open, T_J = 110° C, V_{DROM} = Max. rated value	I_{DROM}	–	0.2	4	mA
Maximum On-State Voltage:♠					
For i_T = 100 A (peak), T_C = 25° C:	V_{TM}				V
40787, 40788, 40789, 40790		–	1.7	2.5	
40791, 40792, 40793, 40794		–	1.7	2	
DC Holding Current:♠					
Gate open, Initial principal current = 500 mA (DC), v_D = 12 V, T_C = 25° C	I_{HO}	–	30	90	mA
For other case temperatures			See Fig.6		
Critical Rate-of-Rise of Commutation Voltage:♠					
For v_D = V_{DROM}, $I_{T(RMS)}$ = rated value, gate unenergized, (See Figs.13 & 14):	dv/dt				V/µs
Commutating di/dt = 88 A/ms					
T_C = 85° C (40787, 40788)		2	–	–	
= 80° C (40789, 40790)		2	–	–	
Commutating di/dt = 141 A/ms					
T_C = 70° C (40791, 40792)		2	–	–	
= 65° C (40793, 40794)		2	–	–	
Critical Rate-of-Rise of Off-State Voltage:♠					
For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 110° C:	dv/dt				V/µs
40787, 40788, 40789, 40790		30	150	–	
40791, 40792, 40793, 40794		50	200	–	
DC Gate-Trigger Current:♠† (Mode / V_{MT2} / V_G)					
For v_D = 12 V (DC), R_L = 30 Ω, T_C = 25° C — I+ / positive / positive	I_{GT}	–	20	80	mA
III− / negative / negative		–	50	80	
I− / positive / negative		–	80	120	
III+ / negative / positive		–	80	120	
For other case temperatures			See Figs.8 & 9		
DC Gate-Trigger Voltage:♠†					
For v_D = 12 V(DC), R_L = 30 Ω, T_C = 25° C	V_{GT}	–	2	3	V
For other case temperatures			See Fig. 10		
For v_D = V_{DROM}, R_L = 125 Ω, T_C = 110° C		0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time)					
For v_D = V_{DROM}, I_{GT} = 150 mA, t_r = 0.1 µs, i_T = 60 A (peak), T_C = 25° C (See Figs. 11 & 12)	t_{gt}	–	1.6	2.5	µs
Thermal Resistance, Junction-to-Case:					
Steady-State	θ_{J-C}				°C/W
Press-fit types		–	–	0.8	
Stud		–	–	0.9	
Transient (Press-fit & stud types)			See Fig. 16		

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

† For either polarity of gate voltage (V_G) with reference to main terminal 1.

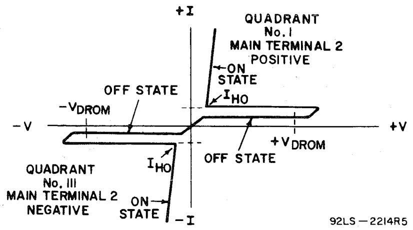


Fig.1—Principal voltage-current characteristic.

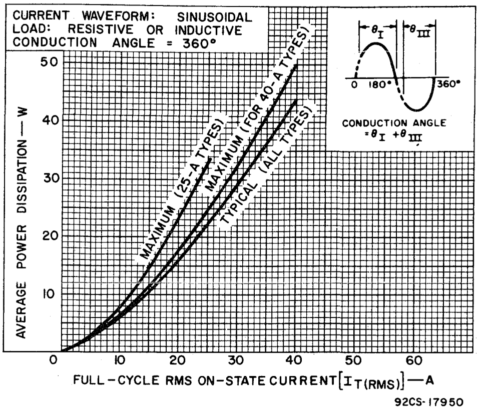


Fig.2—Power dissipation vs. on-state current.

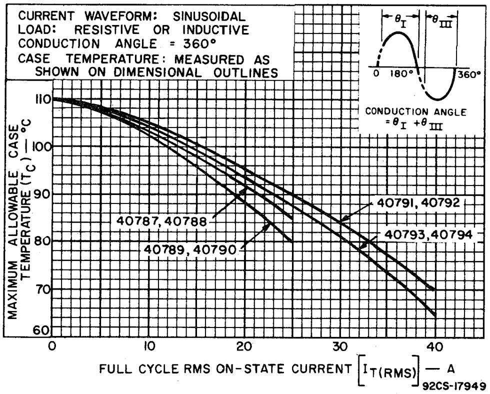


Fig.3—Maximum allowable case temperature vs. on-state current.

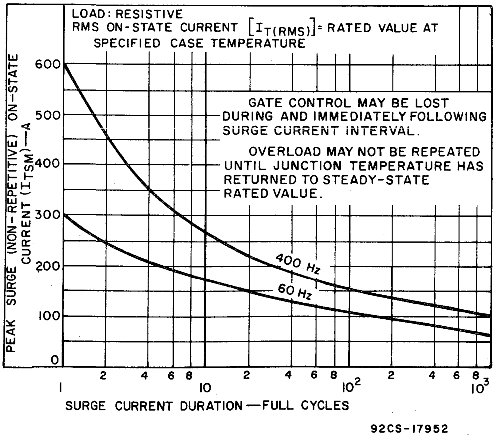


Fig.4—Peak surge on-state current vs. surge current duration.

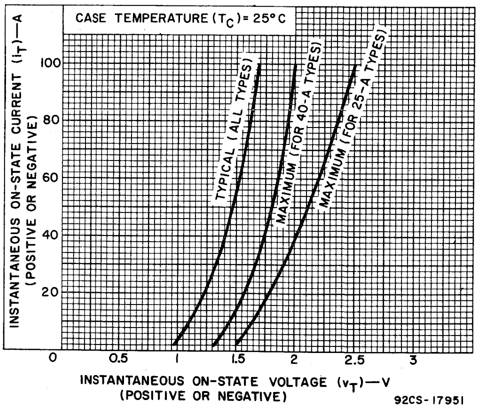


Fig.5—On-state current vs. on-state voltage.

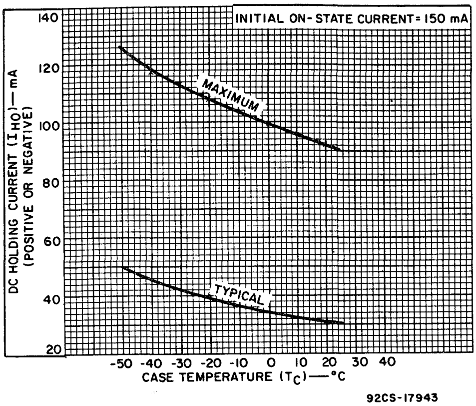


Fig.6—DC holding current vs. case temperature.

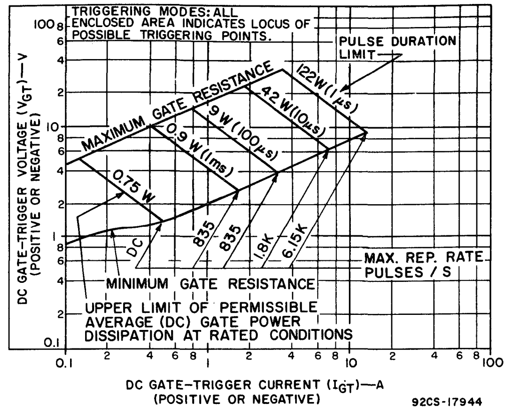


Fig.7—Gate-trigger characteristics and limiting conditions for determination of permissible gate-trigger pulses.

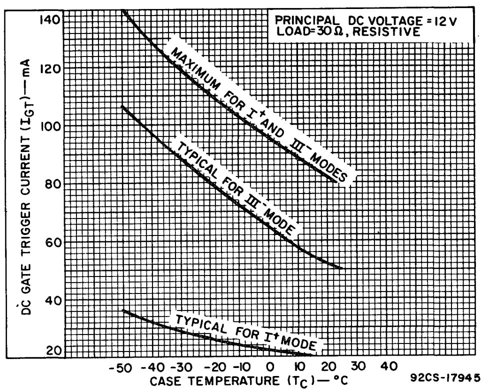


Fig.8—DC gate-trigger current vs. case temperature (I^+ & III^- modes).

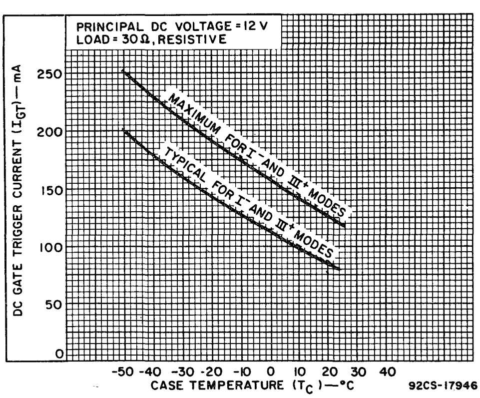


Fig.9—DC gate-trigger current vs. case temperature (I^+ & III^- modes).

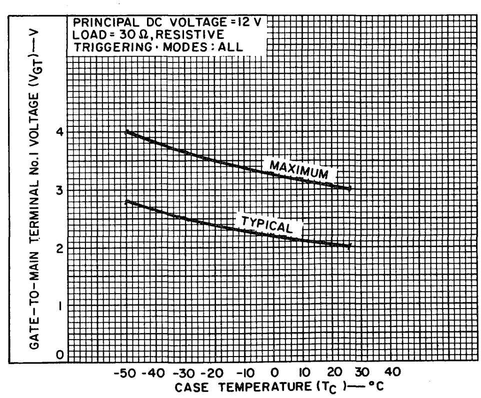


Fig.10—DC gate-trigger voltage vs. case temperature.

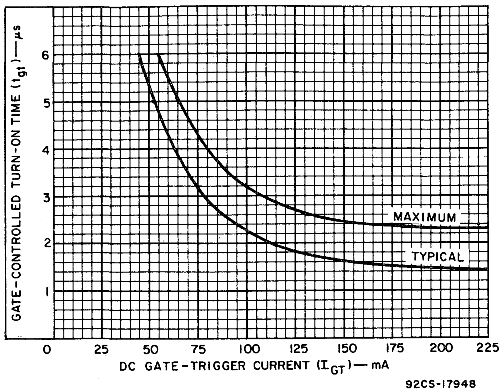


Fig.11—Turn-on time vs. gate trigger current.

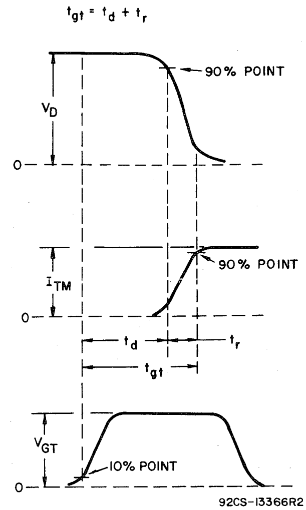


Fig.12—Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

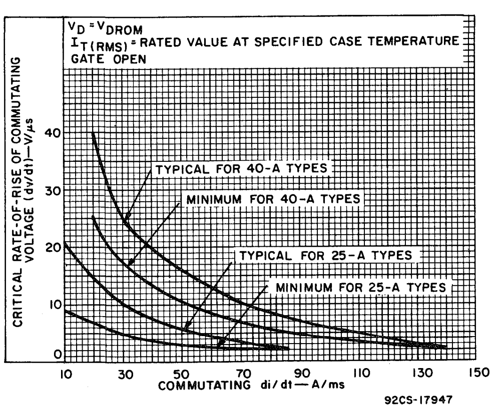


Fig.13—Commutating voltage vs. commutating current.

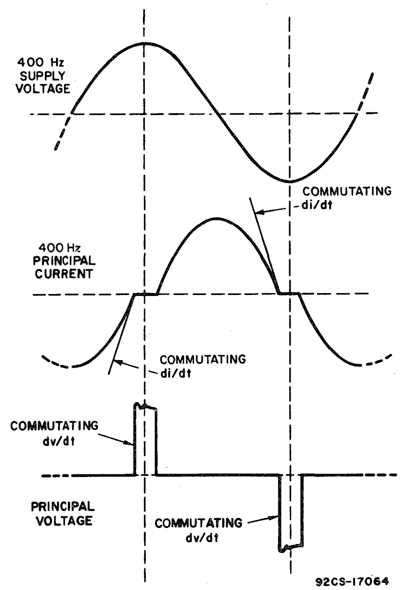


Fig.14—Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt) and commutating (di/dt).

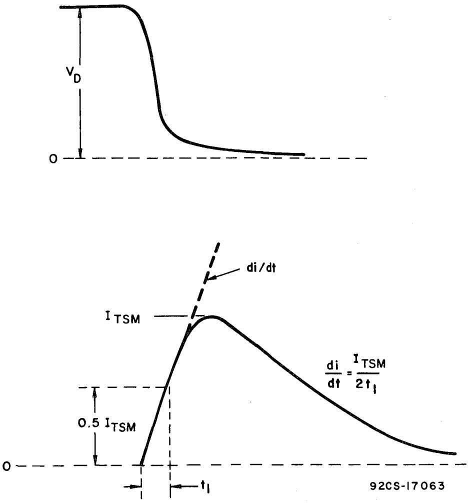


Fig. 15—Rate-of-change of on-state current with time (defining di/dt).

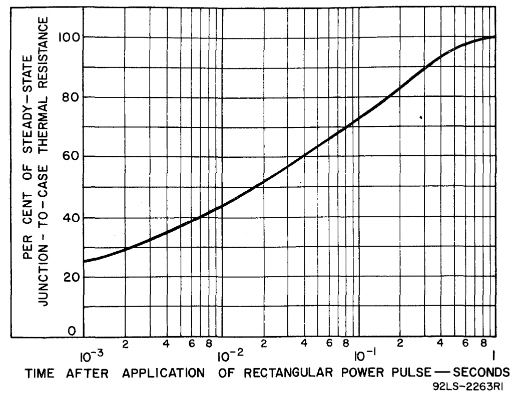


Fig. 16—Transient junction-to-case thermal resistance vs. time.

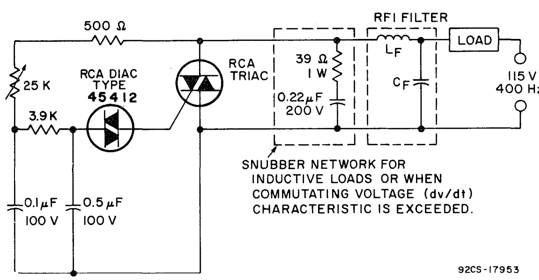


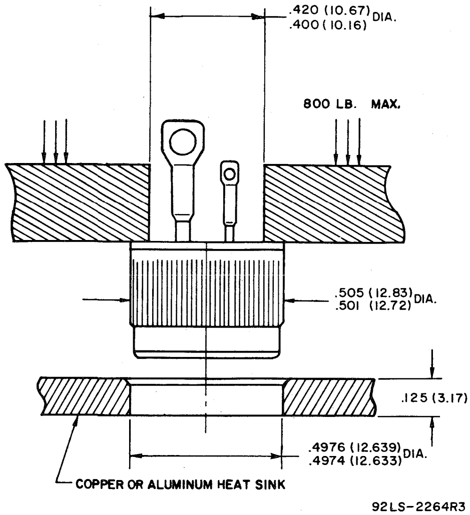
Fig. 17—Typical phase-control circuit for operation at 400 Hz.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in Fig. 18, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in. (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.

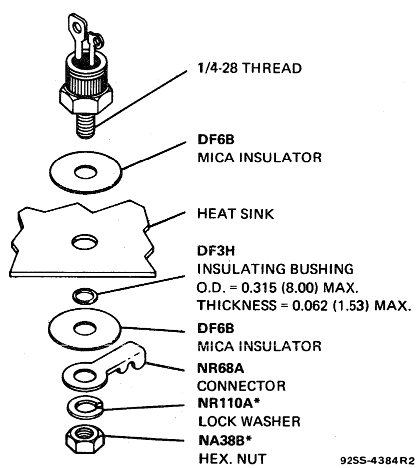


NOTE: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 18—Suggested mounting method for press-fit package types.

Table I — Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6

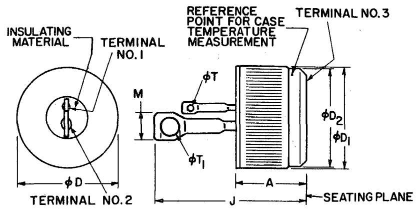


*Only hardware required for isolated-stud package.

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

Fig. 19—Suggested mounting arrangement for stud and isolated-stud package types.

DIMENSIONAL OUTLINE FOR TYPES 40787, 40788, 40791, 40792



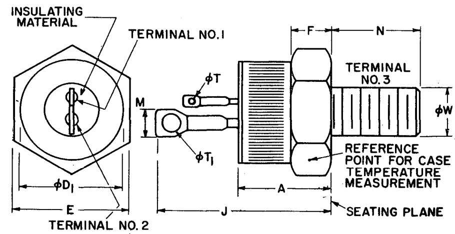
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.380	–	9.65	–
ϕD	0.501	0.510	12.73	12.95	–
ϕD1	–	0.505	–	12.83	2
ϕD2	0.465	0.475	11.81	12.07	–
J	0.825	1.000	20.95	25.40	–
M	0.215	0.225	5.46	5.71	1
ϕT	0.058	0.068	1.47	1.73	–
ϕT1	0.138	0.148	3.51	3.75	–

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Outer diameter of knurled surface.

92CS-15207R2

DIMENSIONAL OUTLINE FOR TYPES 40789, 40790, 40793, 40794



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.330	0.505	8.4	12.8	–
ϕD1	–	0.544	–	13.81	–
E	0.544	0.562	13.82	14.28	–
F	0.113	0.200	2.87	5.08	3
J	0.950	1.100	24.13	27.94	–
M	0.215	0.225	5.46	5.71	1
N	0.422	0.453	10.72	11.50	–
ϕT	0.058	0.068	1.47	1.73	–
ϕT1	0.138	0.148	3.51	3.75	–
ϕW	0.2225	0.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.

NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).

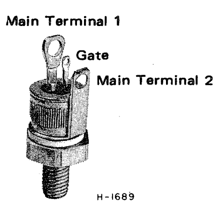
NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

92CS-15208R2

TERMINAL CONNECTIONS

No.1–Gate
No.2–Main Terminal 1
Case, No.3–Main Terminal 2

On special request, isolated-stud package triacs are also available.



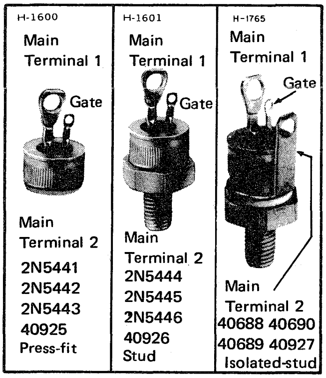
WARNING:
The RCA isolated-stud package thyristors should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled.

RCA

Solid State Division

Thyristors

2N5441 2N5444 40688 40925
2N5442 2N5445 40689 40926
2N5443 2N5446 40690 40927



40-A Silicon Triacs

Press-Fit, Stud, and Isolated-Stud Packages

For 120-V Line Operation ... 2N5441, 2N5444, 40688
For 240-V Line Operation ... 2N5442, 2N5445, 40689
For High-Voltage Operation .. 2N5443, 2N5446, 40690
40925, 40926, 40927

Features:

- **di/dt Capability = 100 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled, full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate-triggering voltages.

These triacs are intended for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. They can also be used in air-conditioning and photocopying equipment.

MAXIMUM RATINGS, *Absolute-Maximum Values: For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.*

		2N5441 2N5444 40688	2N5442 2N5445 40689	2N5443 2N5446 40690	40925 40926 40927	
***REPETITIVE PEAK OFF-STATE VOLTAGE:**● Gate open, T_J = −65 to 110°C	V_{DROM}	200	400	600	800	V
RMS ON-STATE CURRENT (Conduction angle = 360°): Case temperature	$I_{T(RMS)}$					
* T_C = 70°C (Press-fit types)		40				A
* = 65°C (Stud types)		40				A
= 60°C (Isolated-stud types)		40				A
For other conditions		See *Fig. 3*				
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT: For one cycle of applied principal voltage	I_{TSM}					
* 60 Hz (sinusoidal)		300				A
50 Hz (sinusoidal)		265				A
For more than one cycle of applied principal voltage		See *Fig. 4*				
RATE OF CHANGE OF ON-STATE CURRENT: $V_{DM} = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.1 μs (See *Fig. 13*)	di/dt	100				A/μs
FUSING CURRENT (for Triac Protection): T_J = −65 to 110°C, t = 1.25 to 10 ms	I^2t	350				A^2s
***PEAK GATE-TRIGGER CURRENT:**■ For 1 μs max., See *Fig. 7*	I_{GTM}	12				A
***GATE POWER DISSIPATION:**						
PEAK (For 10 μs max., $I_{GTM} \leq$ 4 A, See *Fig. 7*)	P_{GM}	40				W
AVERAGE	$P_{G(AV)}$	0.75				W
***TEMPERATURE RANGE:**▲						
Storage	T_{stg}	−65 to 150				°C
Operating (Case)	T_C	−65 to 110				°C
***TERMINAL TEMPERATURE** (During soldering): For 10 s max. (terminals and case)	T_T	225				°C

* In accordance with JEDEC registration data format (JS-14, RDF2) filed for the JEDEC (2N-Series) types.
● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings Unless Otherwise Specified and at Indicated Case Temperature (T_C)

CHARACTERISTIC	SYMBOL	LIMITS – FOR ALL TYPES UNLESS OTHERWISE SPECIFIED MIN.	TYP.	MAX.	UNITS
Peak Off-State Current:♠					
Gate open, T_J = 110°C, V_{DROM} = Max. rated value	I_{DROM}	–	0.2	4*	mA
Maximum On-State Voltage:♠					
For i_T = 100 A (peak), T_C = 25°C	V_{TM}	–	1.7	2	V
For i_T = 56 A (peak), T_C = 25°C		–	1.5	1.85*	
DC Holding Current:♠					
Gate open, Initial principal current = 500 mA (dc), v_D = 12V:					
T_C = 25°C		–	25	60	
T_C = -65°C	I_{HO}	–	–	100*	mA
For other case temperatures			See *Fig. 6*		
Critical Rate of Rise of Commutation Voltage:♠					
For v_D = V_{DROM}, $I_{T(RMS)}$ = 40 A, commutating di/dt = 22 A/ms, gate unenergized, (See *Fig. 14*):					
T_C = 70°C (Press-fit types)		5*	30	–	
= 65°C (Stud types)	dv/dt	5*	30	–	v/μs
= 60°C (Isolated-stud types)		5	30	–	
Critical Rate of Rise of Off-State Voltage:♠					
For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 110°C:					
2N5441, 2N5444, 40688		50*	200	–	
2N5442, 2N5445, 40689	dv/dt	30*	150	–	V/μs
2N5443, 2N5446, 40690		20*	100	–	
40925, 40926, 40927		10	75	–	
DC Gate-Trigger Current:♠♦ — Mode / V_{MT2} / V_G					
For v_D = 12 V (dc) — I+ positive positive		–	15	50	
R_L = 30 Ω — III− negative negative		–	20	50	
T_C = 25°C — I− positive negative		–	30	80	
III+ negative positive		–	40	80	
Mode / V_{MT2} / V_G	I_{GT}				mA
For v_D = 12 V (dc) — I+ positive positive		–	–	125*	
R_L = 30 Ω — III− negative negative		–	–	125*	
T_C = -65°C — I− positive negative		–	–	240*	
III+ negative positive		–	–	240*	
For other case temperatures			See *Figs. 8 & 9*		
DC Gate-Trigger Voltage:♠♦					
For v_D = 12 V (dc), R_L = 30 Ω,					
T_C = 25°C		–	1.35	2.5	
= -65°C	V_{GT}	–	1.8	3.4*	V
For other case temperatures			See *Fig. 10*		
For v_D = V_{DROM}, R_L = 125 Ω, T_C = 110°C		0.2	–	–	
Gate-Controlled Turn-On Time: (Delay Time + Rise Time)					
For v_D = V_{DROM}, I_{GT} = 200 mA, t_r = 0.1 μs, i_T = 60 A (peak), T_C = 25°C (See *Figs. 11 & 15*)	t_{gt}	–	1.7	3	μs
Thermal Resistance, Junction-to-Case:					
Steady-State					
Press-fit types		–	–	0.8*	
Stud types	$R_{\theta JC}$	–	–	0.9*	°C/W
Isolated-stud types		–	–	1	
Transient (Press-fit & stud types)			See *Fig. 12*		

* In accordance with JEDEC registration data format (JS-14, RDF 2) filed for the JEDEC (2N-Series) types.

♠ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

♦ For either polarity of gate voltage (V_G) with reference to main terminal 1.

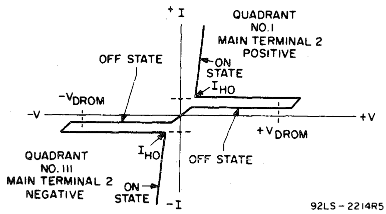


Fig. 1—Principal voltage-current characteristic.

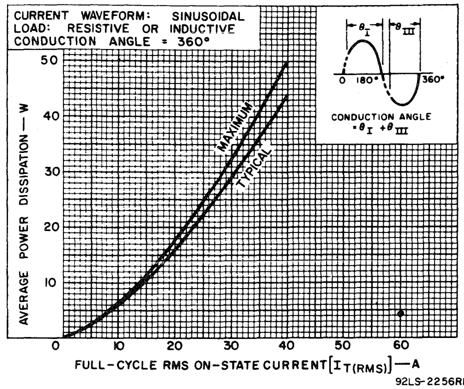


Fig.2—Power dissipation vs. on-state current.

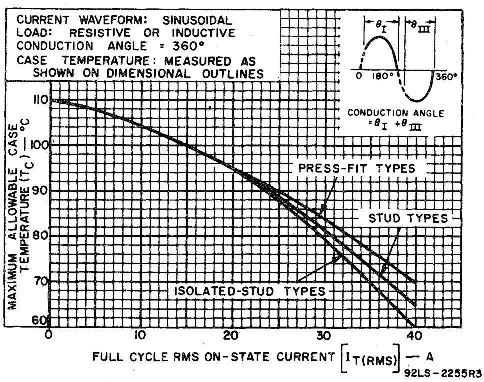


Fig.3—Maximum allowable case temperature vs. on-state current.

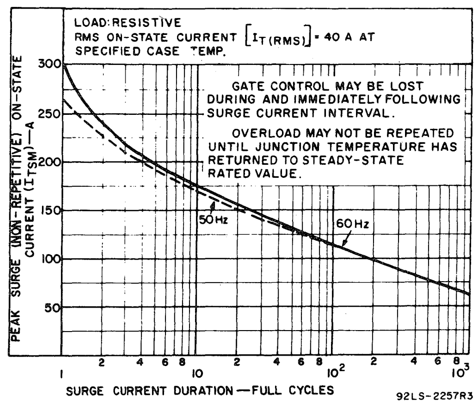


Fig.4—Peak surge on-state current vs. surge current duration.

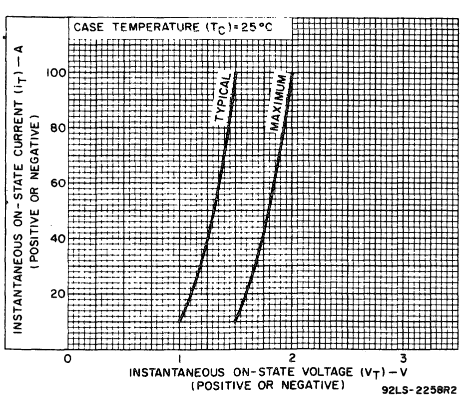


Fig.5—On-state current vs. on-state voltage.

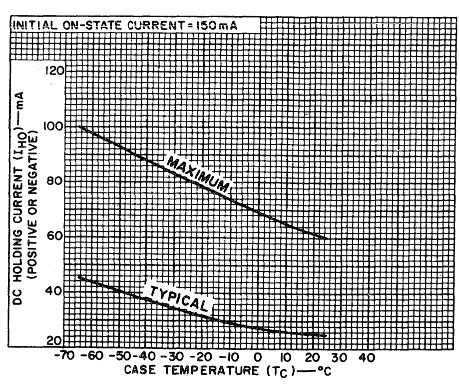


Fig.6—DC holding current vs. case temperature.

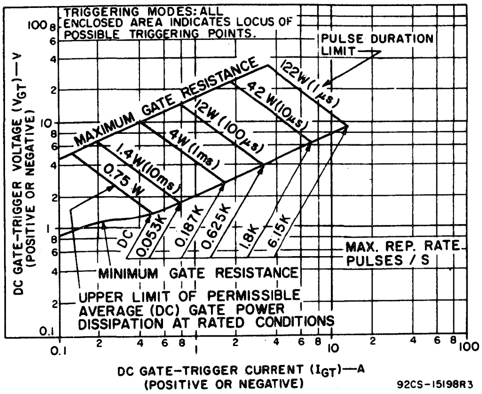


Fig.7—Gate-trigger characteristics and limiting conditions for determination of permissable gate-trigger pulses.

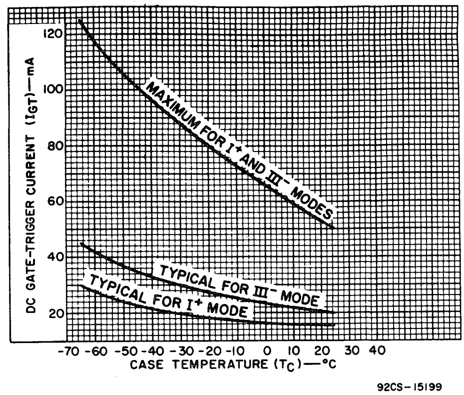


Fig.8—DC gate-trigger current vs. case temperature (I^+ & III^- modes).

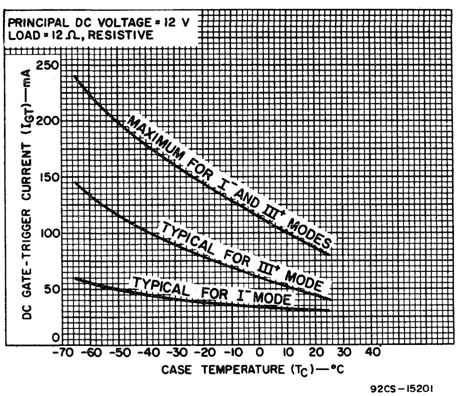


Fig.9—DC gate-trigger current vs. case temperature (I^- & III^+ modes).

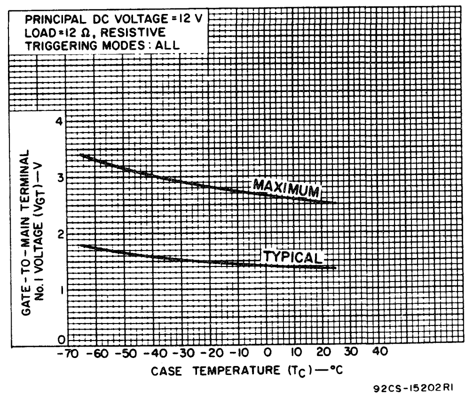


Fig.10—DC gate-trigger voltage vs. case temperature.

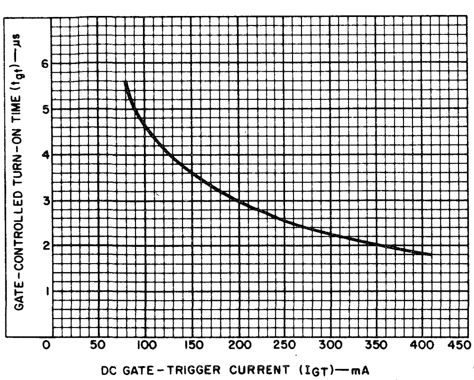


Fig.11—Turn-on time vs. gate-trigger current.

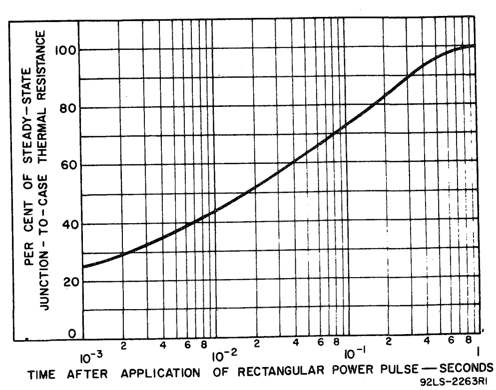


Fig.12—Transient junction-to-case thermal resistance vs. time for press-fit and stud types.

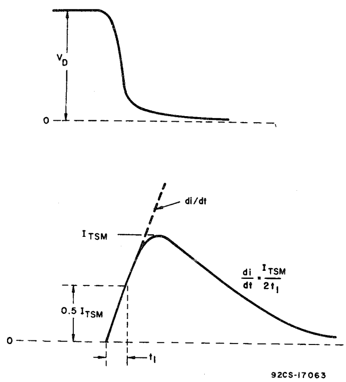


Fig.13—Rate of change of on-state current with time (defining di/dt).

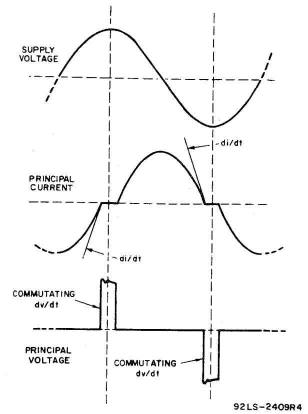


Fig.14—Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

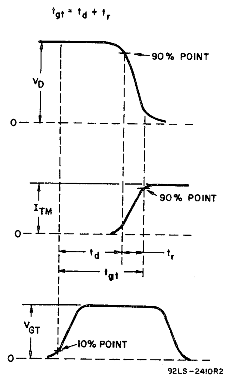


Fig.15—Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

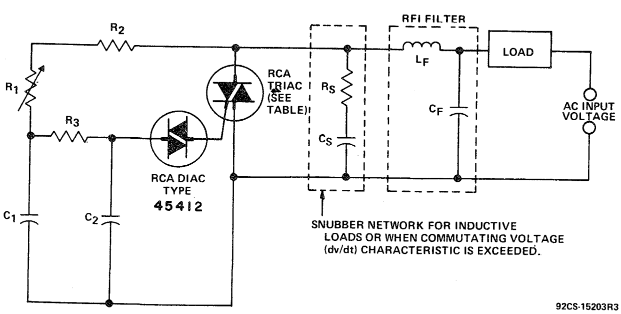


Fig.16—Typical phase-control circuit for lamp dimming, heat control, and universal-motor speed control.

AC INPUT VOLTAGE		120V 60Hz	240V 60Hz	240V 50Hz
C_1		0.1μF 200V	0.1μF 400V	0.1μF 400V
C_2		0.1μF 100V	0.1μF 100V	0.1μF 100V
R_1		100KΩ 1/2W	200KΩ 1W	250KΩ 1W
R_2		2.2KΩ 1/2W	3.3KΩ 1/2W	3.3KΩ 1/2W
R_3		15KΩ 1/2W	15KΩ 1/2W	15KΩ 1/2W
SNUBBER NETWORK FOR 40-A (RMS)• INDUCTIVE LOAD	C_S	0.18-0.22μF 200V	0.18-0.22μF 400V	0.18-0.22μF 400V
	R_S	330-390Ω 1/2W	330-390Ω 1/2W	330-390Ω 1/2W
RFI FILTER	C_F*	0.1μF 200V	0.1μF 400V	0.1μF 400V
	L_F*	100μH	200μH	200μH
RCA TRIACS		2N5441 2N5444 40688	2N5442 2N5445 40689	2N5442 2N5445 40689

• For other RMS-current values refer to RCA Application Note AN-4745.
* Typical values for lamp dimming circuits.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in *Fig. 17,* shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.

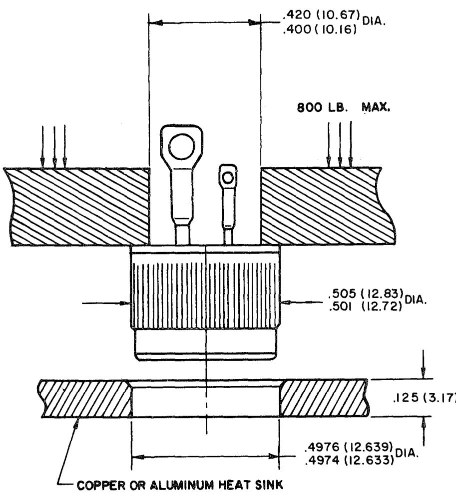
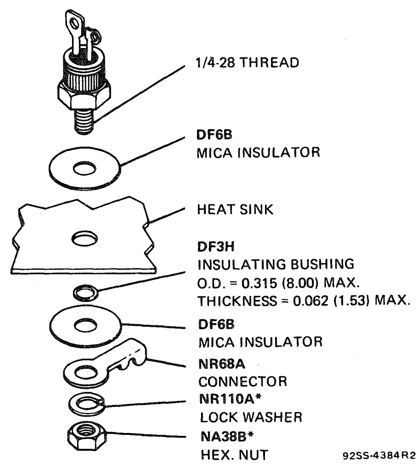


Fig. 17—Suggested mounting method for press-fit package types.

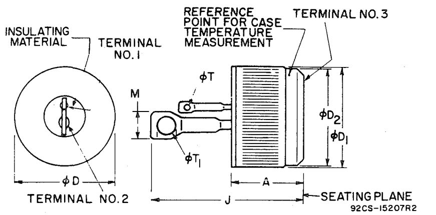


*Only hardware required for isolated-stud package.
NOTE: Dimensions in parentheses are in millimeters.

Fig. 18—Suggested mounting arrangement for stud and isolated-stud package types .

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6

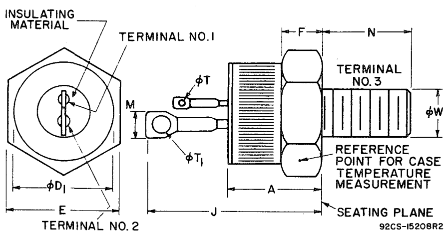
DIMENSIONAL OUTLINE FOR TYPES
2N5441, 2N5442, 2N5443, 40925
PRESS-FIT



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.380	–	9.65	
ϕD	0.501	0.510	12.73	12.95	
ϕD_1	–	0.505	–	12.83	2
ϕD_2	0.465	0.475	11.81	12.07	
J	0.825	1.000	20.95	25.40	
M	0.215	0.225	5.46	5.71	1
ϕT	0.058	0.068	1.47	1.73	
ϕT_1	0.138	0.148	3.51	3.75	

NOTES:
1. Contour and angular orientation of these terminals is optional.
2. Outer diameter of knurled surface.

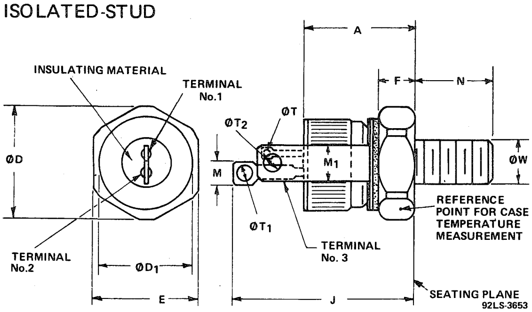
DIMENSIONAL OUTLINE FOR TYPES
2N5444, 2N5445, 2N5446, 40926
STUD



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.330	0.505	8.4	12.8	–
ϕD_1	–	0.544	–	13.81	–
E	0.544	0.562	13.82	14.28	–
F	0.113	0.200	2.87	5.08	3
J	0.950	1.100	24.13	27.94	–
M	0.215	0.225	5.46	5.71	1
N	0.422	0.453	10.72	11.50	–
ϕT	0.058	0.068	1.47	1.73	–
ϕT_1	0.138	0.148	3.51	3.75	–
ϕW	¼-28	UNF-2A	¼-28	UNF-2A	2

NOTES:
1. Contour and angular orientation of these terminals is optional.
2. Pitch diameter of ¼-28 UNF-2A (coated) threads (ASA B1. 1-1960).
3. A chamfer or undercut on one or both ends of hexagonal portion is optional.

DIMENSIONAL OUTLINE FOR TYPES
40688, 40689, 40690, 40927
ISOLATED-STUD



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.673	–	17.09	
ϕD	0.604	0.614	15.34	15.59	
ϕD_1	0.501	0.505	12.72	12.82	
E	0.551	0.557	13.99	14.14	
F	0.100	0.110	2.54	2.79	
J	–	1.298	–	32.96	
M	0.210	0.230	5.33	5.84	
M_1	0.200	0.210	5.08	5.33	
N	0.422	0.452	10.72	11.48	
ϕT	0.058	0.068	1.47	1.73	2
ϕT_1	0.138	0.148	3.51	3.75	2
ϕT_2	0.138	0.148	3.51	3.75	2
ϕW	¼-28	UNF-2A	¼-28	UNF-2A	3

NOTES:
1. Ceramic between hex (stud) and terminal No. 3 is beryllium oxide.
2. Contour and angular orientation of these terminals is optional.
3. Pitch diameter of ¼-28 UNF-2A (coated) threads (ASA B1. 1-1960).

TERMINAL CONNECTIONS

No. 1—Gate
No. 2—Main Terminal 1
Case, No. 3—Main Terminal 2

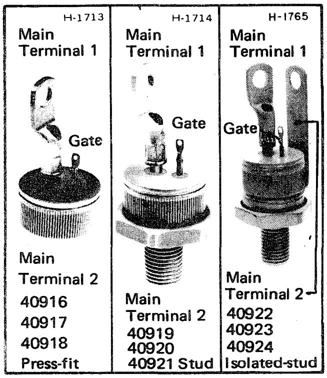
WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State
Division

Thyristors

40916 40919 40922
40917 40920 40923
40918 40921 40924



80-A Silicon Triacs

Press-Fit, Stud, and Isolated-Stud Packages

For 120-V Line Operation ... 40916, 40919, 40922
For 240-V Line Operation ... 40917, 40920, 40923
For High-Voltage Operation ... 40918, 40921, 40924

Features:

- **di/dt Capability = 300 A/μs**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low On-State Voltage at High Current Levels**
- **Low Thermal Resistance**

These RCA triacs are gate-controlled full-wave silicon ac switches. They are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages.

These triacs are intended for control of ac loads in applications such as heating controls, motor controls, arc-welding equipment, light dimmers, and power switching systems. They can also be used in air-conditioning and photocopying equipment.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40916 40919 40922	40917 40920 40923	40918 40921 40924	
REPETITIVE PEAK OFF-STATE VOLTAGE:*					
Gate open, T_J = −40 to 110°C	V_{DROM}	200	400	600	V
RMS ON-STATE CURRENT (Conduction Angle = 360°):	$I_{T(RMS)}$				
Case temperature					
T_C = 75°C (Press-Fit types)			80		A
65°C (Stud types)			80		A
55°C (Isolated-Stud types)			80		A
For other conditions			See Fig. 3		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of applied principal voltage					
60 Hz (sinusoidal)			850		A
50 Hz (sinusoidal)			720		A
For more than one cycle of applied principal voltage			See Fig. 4		
RATE-OF-CHANGE OF ON-STATE CURRENT:	di/dt				
$V_{DM} = V_{DROM}$, I_{GT} = 300 mA, t_r = 0.1μs *(See Fig. 13)*			300		A/μs
FUSING CURRENT (for Triac Protection):	I^2t				
T_J = −40 to 110°C, t = 1.25 to 10 ms			3600		A^2s
PEAK GATE-TRIGGER CURRENT: ■	I_{GTM}				
For 10μs max. *(See Fig. 7)*			7		A
GATE POWER DISSIPATION:					
Peak (For 10μs max., $I_{GTM} \leq$ 7A (peak), *(See Fig. 7)*	P_{GM}		40		W
Average	$P_{G(AV)}$		0.75		W
TEMPERATURE RANGE:▲					
Storage	T_{stg}		−40 to 150		°C
Operating (Case)	T_C		−40 to 110		°C
TERMINAL TEMPERATURE (During soldering):	T_T				
For 10 s max. (terminals and case)			225		°C

Formerly RCA Dev. Nos. TA7752—TA7757, and TA7937—TA7939, respectively.
*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲For temperature measurement reference point, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS at Maximum Ratings Unless Otherwise Specified and at Indicated Case Temperature (T_C)

CHARACTERISTIC	SYMBOL	LIMITS FOR ALL TYPES UNLESS OTHERWISE SPECIFIED MIN.	 TYP.	 MAX.	UNITS
Peak Off-State Current:♣ Gate open, T_J = 110°C, V_{DROM} = Max rated value. .	I_{DROM}	–	0.4	4	mA
Maximum On-State Voltage:♣ For i_T = 200 A (peak), T_C = 25°C	V_{TM}	–	1.7	2	V
DC Holding Current:♣ Gate open, Initial principal current = 500 mA (dc), v_D = 12V: T_C = 25°C . . . . = -40°C . . . . For other case temperatures	I_{HO}	 – – See *Fig. 6*	 20 –	 60 85	mA
Critical Rate-of-Rise of Commutation Voltage:♣ For v_D = V_{DROM}, $I_{T(RMS)}$ = 80 A, commutating di/dt = 42 A/ms, gate unenergized, (See *Fig. 14*): T_C = 75°C (Press-fit types) . . . . = 65°C (Stud types) . . . . = 55°C (Isolated-stud types)	dv/dt	 3 3 3	 10 10 10	 – – –	V/μs
Critical Rate-of-Rise of Off-State Voltage:♣ For v_D = V_{DROM}, exponential voltage rise, gate open, T_C = 110°C: 40916, 40919, 40922 . . . . 40917, 40920, 40923 . . . . 40918, 40921, 40924	dv/dt	 50 30 20	 200 150 100	 – – –	V/μs
DC Gate-Trigger Current:♣♦ Mode V_{MT2} V_G For v_D = 12 V (dc) I+ positive positive R_L = 30 Ω III- negative negative T_C = 25°C I- positive negative III+ negative negative	I_{GT}	 – – – –	 20 40 40 100	 75 75 150 150	mA
Mode V_{MT2} V_G For v_D = 12 V (dc) I+ positive positive R_L = 30Ω III- negative negative T_C = -40°C I- positive negative III+ negative positive For other case temperatures		 – – – – See *Figs. 8 & 9*	 35 80 100 280	 150 150 400 400	
DC Gate-Trigger Voltage:♣♦ For v_D = 12 V (dc), R_L = 30 Ω, T_C = 25°C . . . . For other case temperatures	V_{GT}	 – See *Fig. 10*	 1.35	 2.5	V
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) For v_D = V_{DROM}, I_{GT} = 300 mA, t_r = 0.1 μs, i_T = 112 A (peak), T_C = 25°C (See *Figs. 11 & 15*) . . .	t_{gt}	–	1.2	2.5	μs
Thermal Resistance, Junction-to-Case: Steady-State Press-fit types . . . . Stud types. . . . . Isolated-stud types . . . . Transient (Press-fit & Stud types)	$R_{\theta JC}$	 – – – See *Fig. 12*	 – – –	 0.3 0.4 0.5	°C/W

♣ For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
♦ For either polarity of gate voltage (V_G) with reference to main terminal 1.

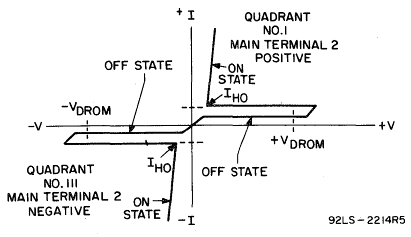


Fig.1—Principal voltage-current characteristic.

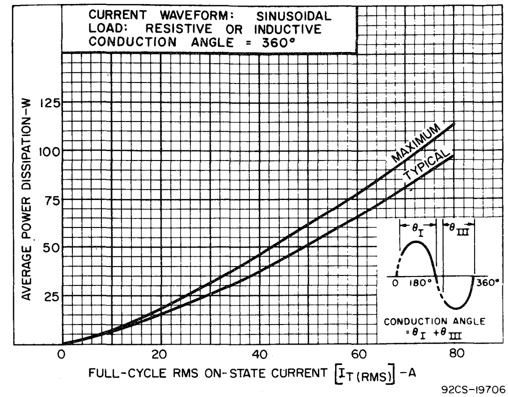


Fig.2—Power dissipation vs. on-state current.

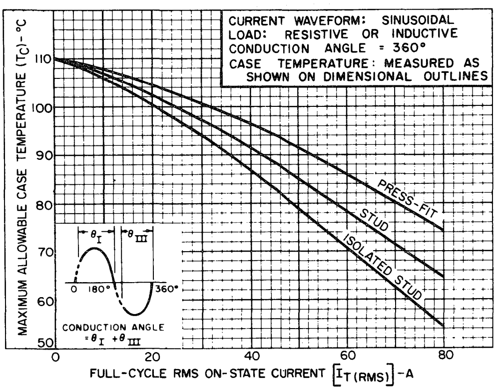


Fig.3—Maximum allowable case temperature vs. on-state current.

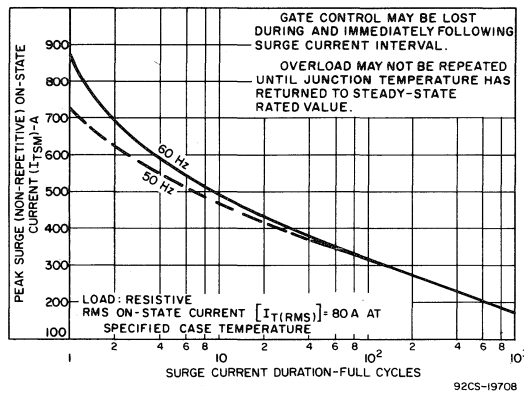


Fig.4—Peak surge on-state current vs. surge current duration.

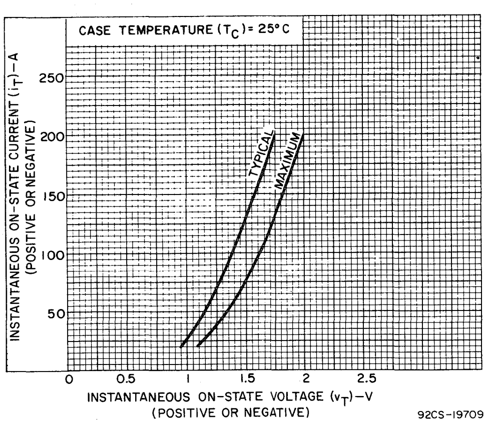


Fig.5—On-state current vs. on-state voltage.

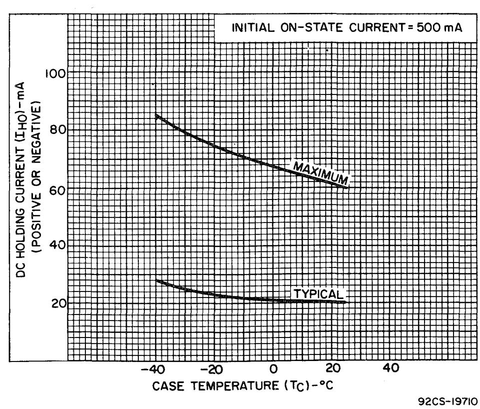


Fig.6—DC holding current vs. case temperature.

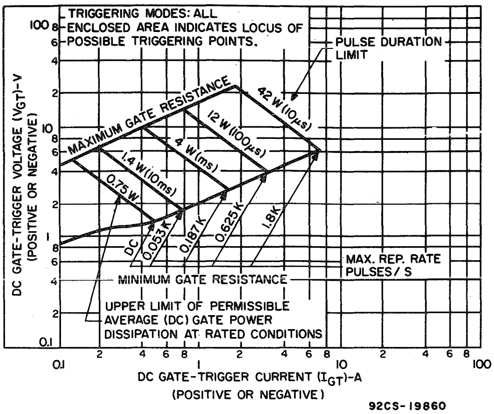


Fig.7—Gate-trigger characteristics and limiting conditions for determination of permissible gate-trigger pulses.

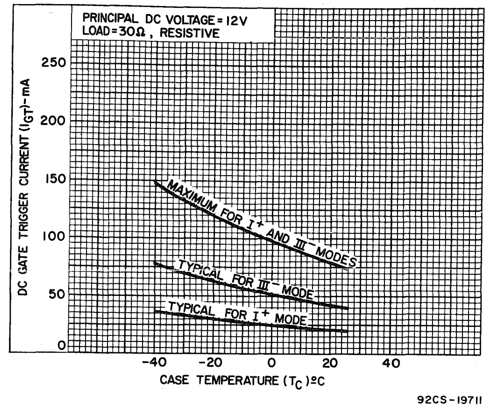


Fig.8—DC gate-trigger current vs. case temperature (I^+ & III^- modes).

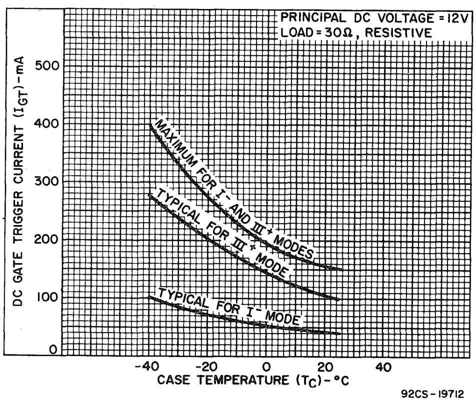


Fig.9—DC gate-trigger current vs. case temperature (I^- & III^+ modes).

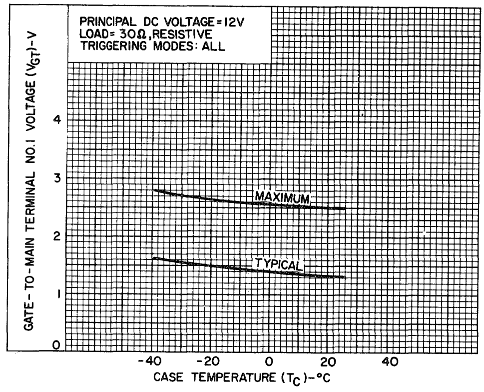


Fig.10—DC gate-trigger voltage vs. case temperature.

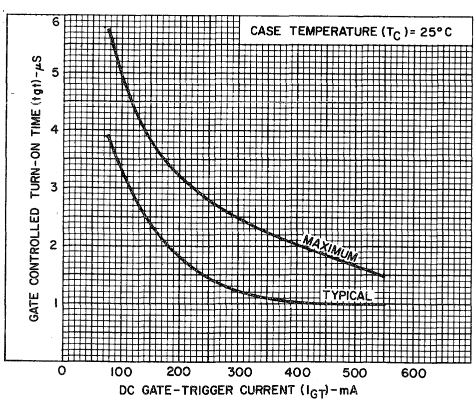


Fig.11—Turn-on time vs. gate-trigger current.

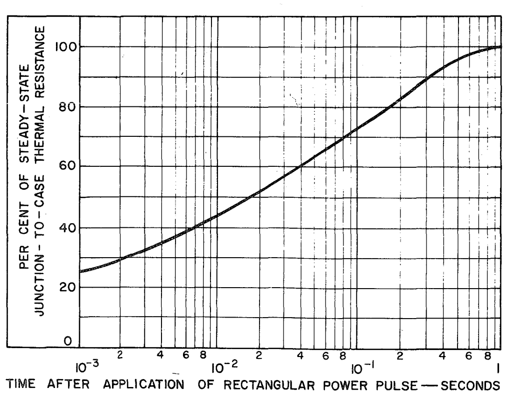


Fig.12—Transient junction-to-case thermal resistance vs. time.

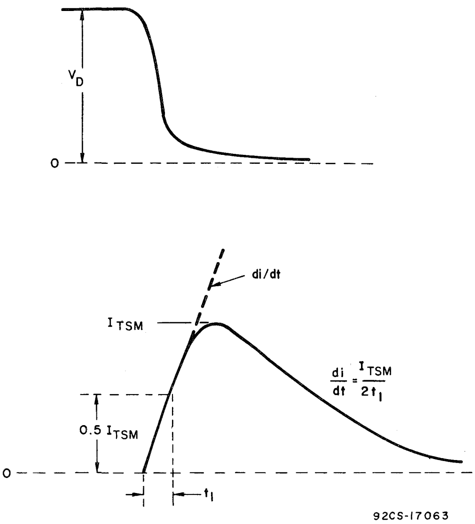


Fig. 13—Rate-of-change of on-state current with time (defining di/dt).

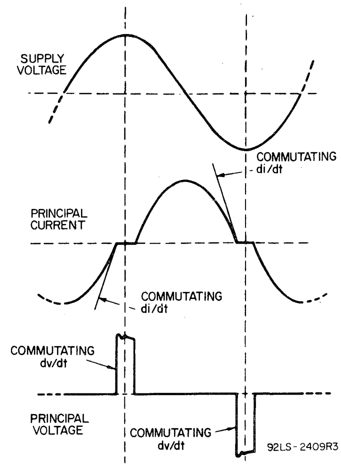


Fig. 14—Relationship between supply voltage and principal current (inductive load) showing reference points for definition of commutating voltage (dv/dt).

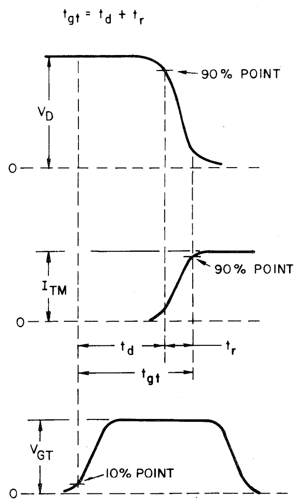
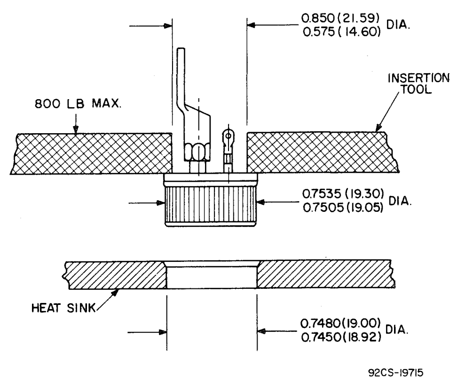


Fig. 15—Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).



NOTE: Dimensions in parentheses are in millimeters

Fig. 16—Suggested mounting method for press-fit package types.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

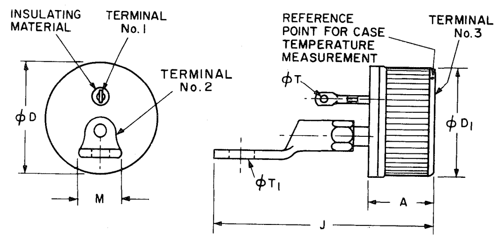
A recommended mounting method, shown in Fig. 16, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.575 in (14.60 mm) and an outer diameter of 0.850 in (21.59 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering has been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.

Table I – Case-to-Heat-Sink Thermal Resistance for Different Mounting Arrangements.

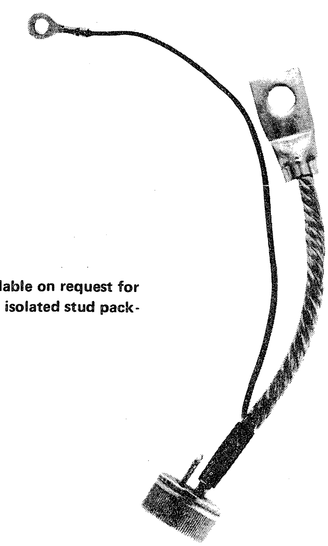
Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 0.25 in (6.35 mm)	0.4
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188°C should be used. Heating time should be sufficient to cause solder to flow freely).	0.15 to 0.3
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.2 to 0.4

DIMENSIONAL OUTLINE FOR TYPES 40916, 40917, 40918
PRESS-FIT



SYMBOL	INCHES MIN.	INCHES MAX	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	–	0.454	–	11.53	
φD	0.751	0.760	19.08	19.30	
ϕD_1	–	0.7585	–	19.13	2
J	–	1.53	–	38.86	
M	0.375	0.385	9.52	9.78	1
φT	0.060	0.065	1.52	1.65	
ϕT_1	–	0.193	–	4.90	

NOTES
1. Contour and angular orientation of these terminals is optional.
2. Outer diameter of knurled surface.



Flexible leads available on request for press-fit, stud, and isolated stud packages.

RCA APPLICATION NOTES ON THYRISTORS

AN-3469 "Application of RCA Silicon Controlled Rectifiers to the control of Universal Motors".

AN-3551 "Circuit Factor Charts for use in Applications with RCA Thyristors (SCR's and Triacs)."

AN-3822 "Thermal Considerations in Mounting RCA Thyristors".

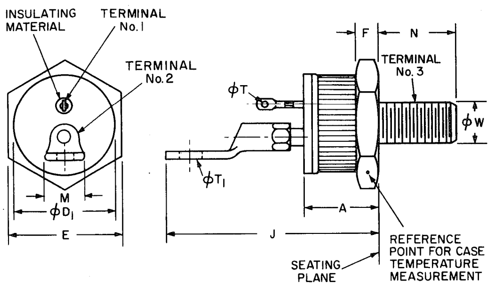
AN-3886 "AC Voltage Regulators Using Thyristors".

AN-4124 "Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors".

AN-4242 "A Review of Thyristor Characteristics and Applications".

AN-4537 "Thyristor Control of Incandescent Traffic-Signal Lamps".

DIMENSIONAL OUTLINE FOR TYPES 40919, 40920, 40921
STUD



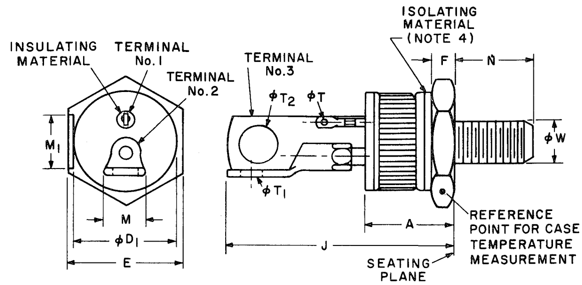
92CS-17667R1

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.591	–	15.01	
ϕD_1	0.751	0.760	19.08	19.30	
E	0.866	0.872	21.99	22.14	
F	0.182	0.192	4.62	4.87	3
J	–	1.63	–	41.40	
M	0.375	0.385	9.52	9.78	1
N	0.740	0.760	18.79	19.30	
ϕT	0.060	0.065	1.52	1.65	
ϕT_1	–	0.193	–	4.90	
ϕW	½–20	NF–2A	½–20	NF–2A	2

NOTES

1. Contour and angular orientation of these terminals is optional.
2. ϕW is pitch diameter of coated threads. Ref: ASA B_1, 1-1960. Recommended torque: 125 inch-pounds.
3. A chamfer or undercut on one or both ends of hexagonal portion is optional.

DIMENSIONAL OUTLINE FOR TYPES 40922, 40923, 40924
ISOLATED-STUD



92CS-19705

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.789	–	20.04	
ϕD_1	0.751	0.760	19.08	19.30	
E	0.866	0.872	21.99	22.14	
F	0.182	0.192	4.62	4.87	3
J	–	1.85	–	46.99	
M	0.375	0.385	9.52	9.78	1
M_1	0.375	0.385	9.52	9.78	1
N	0.740	0.760	18.79	19.30	
ϕT	0.060	0.065	1.52	1.65	
ϕT_1	–	0.193	–	4.90	
ϕT_2	0.195	0.205	4.95	5.20	
ϕW	½–20	NF–2A	½–20	NF–2A	2

NOTES

1. Contour and angular orientation of these terminals is optional.
2. ϕW is pitch diameter of coated threads, REF: ASA B1, 1-1960. Recommended torque: 125 inch-pounds.
3. A chamfer or undercut on one or both ends of hexagonal portion is optional.
4. Isolating material (ceramic) between hex (stud) and terminal No. 3 is beryllium oxide.

TERMINAL CONNECTIONS FOR ALL TYPES

No. 1 – Gate
No. 2 – Main Terminal 1
Case, No. 3 – Main Terminal 2

WARNING: The ceramic of the isolated stud package contains beryllium oxide. Do not crush, grind, or abrade this part because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State Division

Thyristors

40693 – 40734

RCA 40693–40734 triacs are gate-controlled full-wave ac switches. They are intended for ac load-control applications such as heating controls (proportional and on & off); lamp switching, motor switching, and a wide variety of power-control applications.

RCA CA3059 is a monolithic silicon IC zero-voltage switch designed for direct operation from the ac line. This integrated circuit drives the triac gate directly and provides the gating signal at zero-voltage crossings for minimum radio-frequency interference.

Types 40693–40734 have gate characteristics which insure that the CA3059 will supply sufficient drive current to trigger these triacs over the operating-temperature range from -40°C to +85°C. Ratings within this group of triacs range from 2.5 to 40 amperes rms on-state current, with repetitive off-state voltages available from 100 to 600 volts; and they employ a wide variety of packages.

2.5–40-A, 100–600-V SILICON TRIACS DESIGNED FOR USE WITH IC ZERO-VOLTAGE SWITCH RCA-CA3059 AS TRIGGERING CIRCUIT

For Power-Control and Switching Applications at Frequencies of 50 to 60 Hz

Ratings & Characteristics

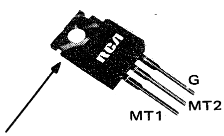
RCA Type No.	Rep. Peak Off-State Voltage V_{DROM} (V)	RMS On-State Current $I_{T(RMS)}$ (A)	at Case Temp. (°C)	Typ. DC Holding Current at 25°C, I_{HO} (mA)	Max. DC Gate Trigger Current & Voltage at 25°C ▲ I+ I_{GT} (mA)	I+ V_{GT} (V)	III+ I_{GT} (mA)	III+ V_{GT} (V)	Package	Family Type	Bulletin File No. for Family Type
40693	100	2.5	70	6	45	1.5	45	1.5	Mod. TO-5 on Heat Radiator	40684	414
40694	200	2.5	70	6	45	1.5	45	1.5	"	40685	414
40695	400	2.5	70	6	45	1.5	45	1.5	"	40686	414
40696	100	2.5	70	6	45	1.5	45	1.5	Mod. TO-5	2N5754	414
40697	200	2.5	70	6	45	1.5	45	1.5	"	2N5755	414
40698	400	2.5	70	6	45	1.5	45	1.5	Mod. TO-5	2N5756	414
40699	200	40	70	25	45	1.5	45	1.5	Press-fit	2N5441	593
40700	400	40	70	25	45	1.5	45	1.5	"	2N5442	593
40701	600	40	70	25	45	1.5	45	1.5	"	2N5443	593
40702	200	40	65	25	45	1.5	45	1.5	Stud	2N5444	593
40703	400	40	65	25	45	1.5	45	1.5	Stud	2N5445	593
40704	600	40	65	25	45	1.5	45	1.5	"	2N5446	593
40705	200	30	65	25	45	1.5	45	1.5	Press-fit	40660	459
40706	400	30	65	25	45	1.5	45	1.5	"	40661	459
40707	200	30	60	25	45	1.5	45	1.5	Stud	40662	459
40708	400	30	60	25	45	1.5	45	1.5	Stud	40663	459
40709	600	30	65	25	45	1.5	45	1.5	Press-fit	40671	459
40710	600	30	60	25	45	1.5	45	1.5	Stud	40672	459
40711	200	15	80	20	45	1.5	45	1.5	Press-fit	2N5571	458
40712	400	15	80	20	45	1.5	45	1.5	"	2N5572	458

RCA Type No.	Rep. Peak Off-State Voltage V_{DROM} (V)	RMS On-State Current $I_{T(RMS)}$ at Case Temp. (A)	(°C)	Typ. DC Holding Current at 25°C, I_{HO} (mA)	Max. DC Gate Trigger Current & Voltage at 25°C ▲ I+ I_{GT} (mA)	I+ V_{GT} (V)	III+ I_{GT} (mA)	III+ V_{GT} (V)	Package	Family Type	Bulletin File No. for Family Type
40713	200	15	80	20	45	1.5	45	1.5	Stud	2N5573	458
40714	400	15	80	20	45	1.5	45	1.5	"	2N5574	458
40715	200	15	70	15	45	1.5	45	1.5	TO-66	40575	300
40716	400	15	70	15	45	1.5	45	1.5	"	40576	300
40717	200	10	85	15	45	1.5	45	1.5	Press-fit	2N5567	457
40718	400	10	85	15	45	1.5	45	1.5	Press-fit	2N5568	457
40719	200	10	85	15	45	1.5	45	1.5	Stud	2N5569	457
40720	400	10	85	15	45	1.5	45	1.5	"	2N5570	457
40721	200	8	80	15	45	1.5	45	1.5	Plastic	40668	364
40722	400	8	80	15	45	1.5	45	1.5	"	40669	364
40723	450	6	75	–	45	1.5	45	1.5	Mod. TO-5	40664	375
40724	450	6	75	–	45	1.5	45	1.5	Mod. TO-5 on Heat Radiator	40667	375
40725	200	6	75	15	45	1.5	45	1.5	Mod. TO-5	40485	352
40726	400	6	75	15	45	1.5	45	1.5	"	40486	352
40727	200	6	75	15	45	1.5	45	1.5	TO-66	40429	351
40728	400	6	75	15	45	1.5	45	1.5	TO-66	40430	351
40729	200	6	75	15	45	1.5	45	1.5	TO-66 with Heat Radiator	40502	351
40730	400	6	75	15	45	1.5	45	1.5	"	40503	351
40731	200	2.3	75*	15	45	1.5	45	1.5	Mod. TO-5 on Heat Radiator	40509	352
40732	400	2.3	75*	15	45	1.5	45	1.5	"	40510	352
40733	200	4.2	75**	15	45	1.5	45	1.5	Mod. TO-5 on Heat Spreader	40638	352
40734	400	4.2	75**	15	45	1.5	45	1.5	"	40639	352

* Forced-air cooling
**Heat-sink temperature
▲ A triac driven directly from the output terminal of the CA3059 should be characterized for operation in the I^+ or III^+ triggering modes, i.e., with positive gate current (current flows into the gate for both polarities of the applied ac voltage).

RCA Solid State Division

Thyristors 40900 40901 40902



JEDEC TO-220AB H-1535

8-A Isolated-Tab Silicon Triacs

Three-Lead Plastic Types for
Power-Control and Power-Switching Applications

For Low-Voltage Operation 40900
For 120-V Line Operation 40901
For 240-V Line Operation 40902

Features

- **Internal Isolation**
- **Glass Passivated Junctions**
- **100-A Peak Surge Full-Cycle Current Ratings**
- **Shorted-Emitter, Center-Gate Design**
- **Low Switching Losses**
- **Low Thermal Resistance**
- **Package Suitable for Direct Mounting on Heat Sink**

RCA-40900, 40901,[a] and 40902[b] are gate-controlled full-wave ac switches utilizing a plastic case with three leads to facilitate mounting on printed-circuit boards. They are intended for the control of ac loads in such applications as motor controls, light dimmers, heating controls, and power-switching systems.

These devices are designed to switch from an off-state to an on-state for either polarity of applied voltage with positive or negative gate triggering voltages. They have an on-state current rating of 8 amperes at a T_C of 75°C and repetitive off-state voltage ratings of 100, 200, and 400 volts, respectively.

The ISOWATT package uses a plastic case with three leads that are electrically isolated from the mounting flange. Because of this internal isolation, the triac can be mounted directly on a heat sink, without any insulating hardware; therefore heat transfer is improved and heat-sink size can be reduced.

[a]Formerly RCA Dev. No. TA8357
[b]Formerly RCA Dev. No. TA8358

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40900	40901	40902	
REPETITIVE PEAK OFF-STATE VOLTAGE:●					
Gate open, T_J = −65 to 100°C	V_{DROM}	100	200	400	V
RMS ON-STATE CURRENT (Conduction angle = 360°):					
Case temperature	$I_{T(RMS)}$				
T_C = 75°C			8		A
For other conditions			See *Fig. 3*		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:					
For one cycle of applied principal voltage	I_{TSM}				
60 Hz (sinusoidal)			100		A
50 Hz (sinusoidal)			85		A
For more than one cycle of applied principal voltage			See *Fig. 4*		
PEAK GATE-TRIGGER CURRENT: ■					
For 1 μs max.; see *Fig. 11*	I_{GTM}		4		A
GATE POWER DISSIPATION:					
Peak (For 1 μs max., I_{GTM} ≤ 4 A; see *Fig. 11*)	P_{GM}		16		W
AVERAGE	$P_{G(AV)}$		0.2		W
TEMPERATURE RANGE: ▲					
Storage	T_{stg}		−65 to 150		°C
Operating (Case)	T_C		−65 to 100		°C
TERMINAL TEMPERATURE (During soldering):					
For 10 s max. (terminals and case)	T_T		225		°C

● For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.
■ For either polarity of gate voltage (V_G) with reference to main terminal 1.
▲ For temperature measurement reference point, see *Dimensional Outline.*

ELECTRICAL CHARACTERISTICS *At Maximum Ratings Unless Otherwise Specified, and at Indicated Case Temperature (T_C)*

CHARACTERISTIC	SYMBOL	LIMITS 40900 MIN.	40900 TYP.	40900 MAX.	40901 MIN.	40901 TYP.	40901 MAX.	40902 MIN.	40902 TYP.	40902 MAX.	UNITS
Peak Off-State Current:* Gate Open, V_{DROM} = Max. rated value At T_J = 100°C	I_{DROM}	–	0.1	2	–	0.1	2	–	0.1	2	mA
Maximum On-State Voltage:* For i_T = 30 A (peak) and T_C = 25°C	v_{TM}	–	1.7	2	–	1.7	2	–	1.7	2	V
DC Holding Current:* Gate Open Initial principal current = 150 mA (dc) At T_C = 25°C	I_{HO}	–	15	30	–	15	30	–	15	30	mA
For other case temperatures		See Fig. 8									
Critical Rate of Rise of Commutation Voltage:*♦ For v_D = V_{DROM}, $I_{T(RMS)}$ = 8 A, Commutating di/dt = 4.3 A/ms, and gate unenergized At T_C = 75°C	dv/dt	4	10	–	4	10	–	4	10	–	V/μs
Critical Rate of Rise of Off-State Voltage:* For v_D = V_{DROM}, exponential voltage rise, and gate open At T_C = 100°C	dv/dt	125	350	–	100	300	–	75	250	–	V/μs
For other case temperatures		See Fig. 10									
DC Gate-Trigger Current:*† For v_D = 12 V (dc), R_L = 12Ω T_C = 25°C, and specified triggering mode:											
I^+ Mode: V_{MT2} is positive, V_G is positive	I_{GT}	–	10	25	–	10	25	–	10	25	mA
III^- Mode: V_{MT2} is negative, V_G is negative		–	15	25	–	15	25	–	15	25	
I^- Mode: V_{MT2} is positive, V_G is negative		–	20	60	–	20	60	–	20	60	
III^+ Mode: V_{MT2} is negative, V_G is positive		–	30	60	–	30	60	–	30	60	
For other case temperatures		See Figs. 12 & 13									
DC Gate-Trigger Voltage:*† For v_D = 12 V (dc) and R_L = 12Ω At T_C = 25°C	V_{GT}	–	1.25	2.5	–	1.25	2.5	–	1.25	2.5	V
For other case temperatures		See Fig. 14									
For v_D = V_{DROM} and R_L = 125Ω At T_C = 100°C		0.2	–	–	0.2	–	–	0.2	–	–	
Gate-Controlled Turn-On Time (Delay Time + Rise Time): For v_D = V_{DROM} and I_{GT} = 160 mA rise time = 0.1 μs, and i_T = 10 A (peak) At T_C = 25°C *(See Fig. 15)*	t_{gt}	–	1.6	2.5	–	1.6	2.5	–	1.6	2.5	μs
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$	–	–	3.1	–	–	3.1	–	–	3.1	°C/W
Junction-to-Ambient	$R_{\theta JA}$	–	–	60	–	–	60	–	–	60	°C/W

*For either polarity of main terminal 2 voltage (V_{MT2}) with reference to main terminal 1.

†For either polarity of gate voltage (V_G) with reference to main terminal 1.

♦Variants of these devices having dv/dt characteristics selected specifically for inductive loads are available on special order; for additional information, contact your RCA Representative or your RCA Distributor.

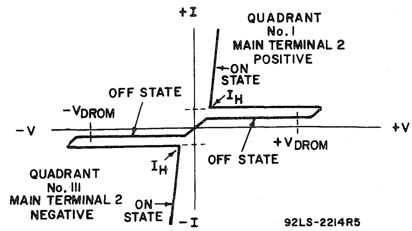


Fig. 1—Principal voltage-current characteristic.

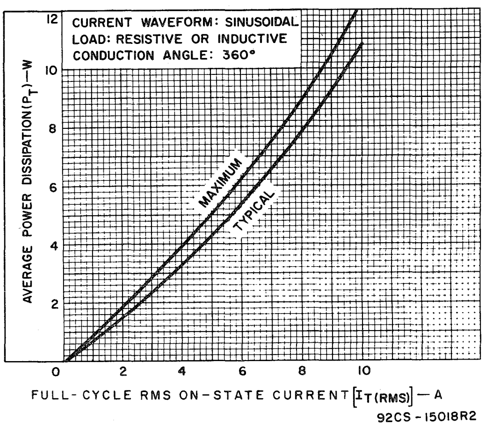


Fig. 2—Power dissipation vs. on-state current.

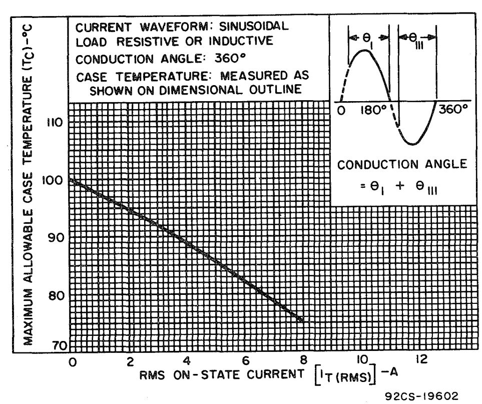


Fig. 3—Allowable case temperature vs. on-state current.

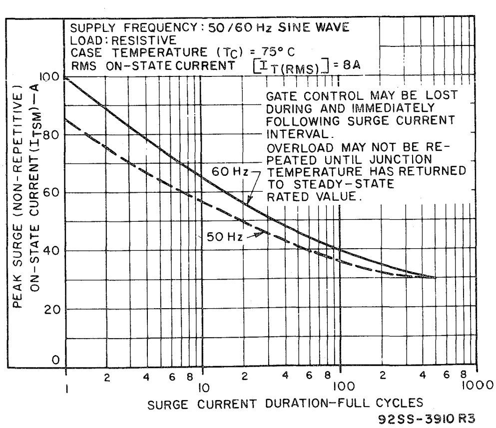


Fig. 4—Peak surge on-state current vs. surge current duration.

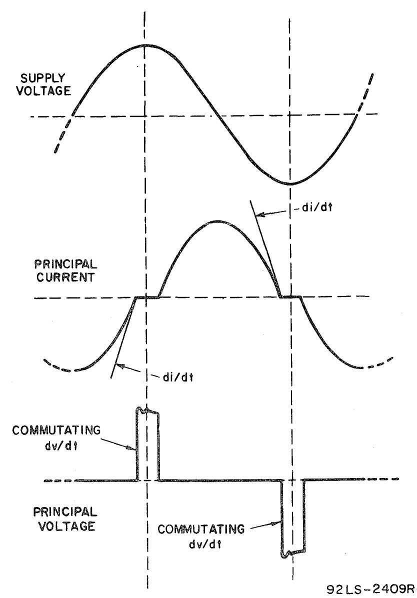


Fig. 5—Oscilloscope display of commutating dv/dt.

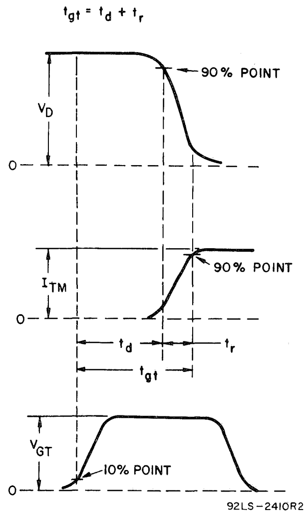


Fig. 6—Oscilloscope display for measurement of gate-controlled turn-on time (t_{gt}).

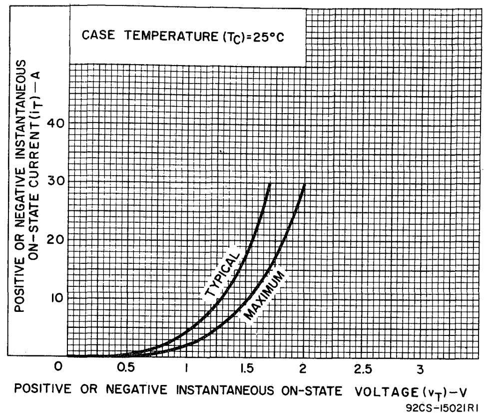


Fig. 7—On-state current vs. on-state voltage.

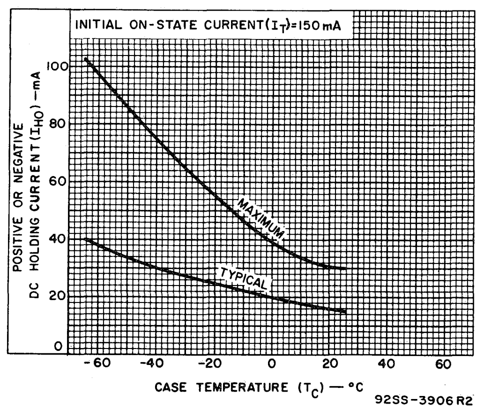
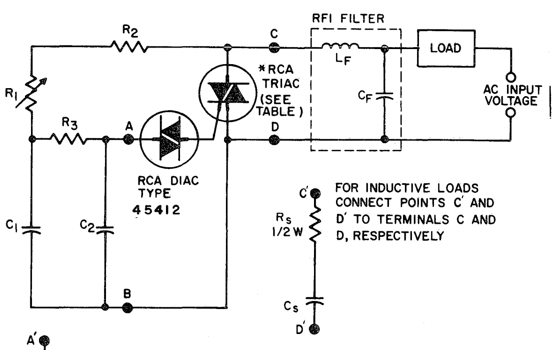


Fig. 8—DC holding current for either direction of on-state current vs. case temperature.



	120 V	240 V
Cs	0.068 μF/200V	0.1 μF/400 V
Rs	1.2 KΩ	1 KΩ

AC INPUT VOLTAGE	C_1	C_2	R_1	R_2	R_3	RFI FILTER L_F* (typ.)	RFI FILTER C_F* (typ.)	RCA TYPES
120 V 60 Hz	0.1 μF 200 V	0.1 μF 100 V	100 KΩ ½ W	2.2 KΩ ½ W	15 KΩ ½ W	100 μH	0.1 μF 200V	40901
240 V 50 Hz	0.1 μF 400 V	0.1 μF 100 V	250 KΩ 1 W	3.3 KΩ ½ W	15 KΩ ½ W	200 μH	0.1 μF 400 V	40902
240 V 60 Hz	0.1 μF 400 V	0.1 μF 100 V	200 KΩ 1 W	3.3 KΩ ½ W	15 KΩ ½ W	200 μH	0.1 μF 400 V	40902

*Typical values for lamp-dimming circuits.

Fig. 9—Typical phase-control circuit for lamp dimming, heat controls, and universal motor speed controls.

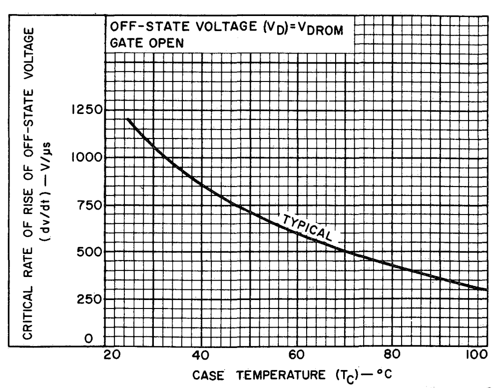


Fig. 10—Critical rate-of-rise of off-state voltage vs. case temperature.

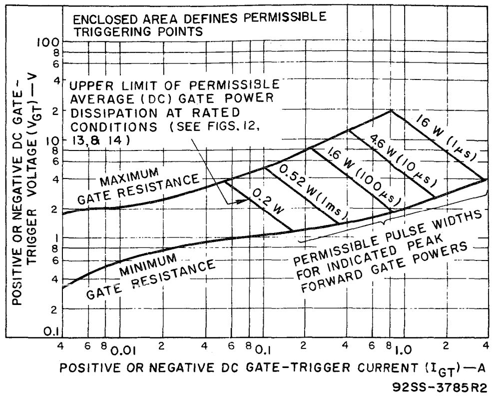


Fig. 11—Gate-pulse characteristics for all triggering modes.

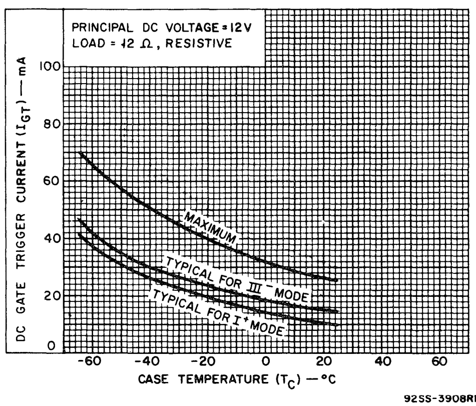


Fig. 12—DC gate-trigger current (for I^+ and III^- triggering modes) vs. case temperature.

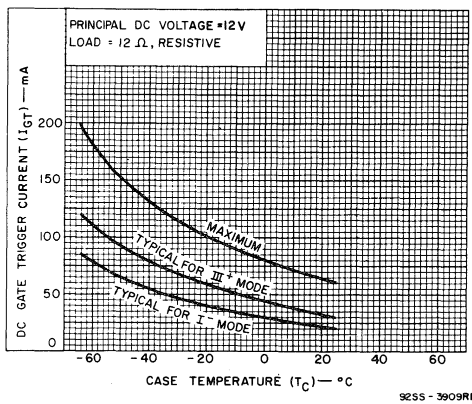


Fig. 13—DC gate-trigger current (for I^- and III^+ triggering modes) vs. case temperature.

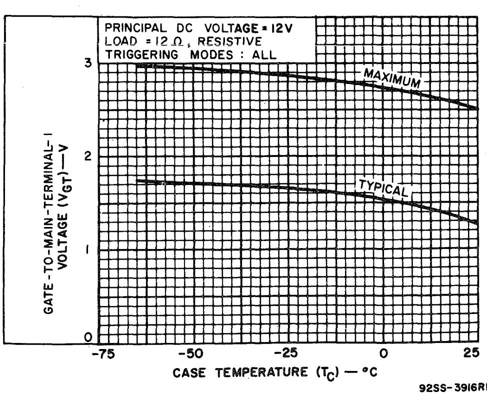


Fig. 14—DC gate-trigger voltage vs. case temperature.

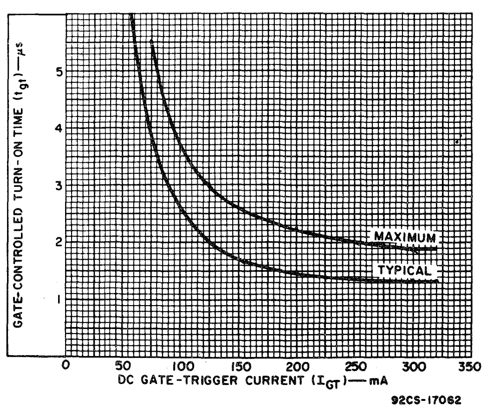
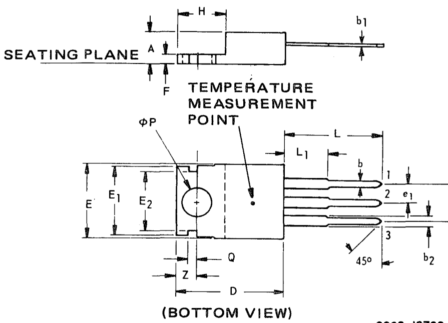


Fig. 15—Typical turn-on time vs. gate-trigger current.

DIMENSIONAL OUTLINE



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.190	4.07	4.82
b	0.025	0.040	0.64	1.02
b_1	0.012	0.030	0.31	0.76
b_2	0.045	0.055	1.143	1.397
D	0.575	0.625	14.61	15.87
E	0.395	0.410	10.04	10.41
E_1	0.365	0.385	9.28	9.77
E_2	0.300	0.320	7.62	8.12
e	0.180	0.220	4.57	5.58
e_1	0.080	0.120	2.03	3.04
F	0.020	0.055	0.51	1.39
H	0.235	0.265	5.97	6.73
L	0.500	–	12.70	–
L_1	–	0.250	–	6.35
ϕP	0.141	0.145	3.582	3.683
Q	0.040	0.060	1.02	1.52
Z	0.100	0.120	2.54	3.04

TERMINAL CONNECTIONS

Lead No. 1 - Main Terminal 1
Lead No. 2 - Main Terminal 2
Lead No. 3 - Gate
Mounting Tab - Isolated

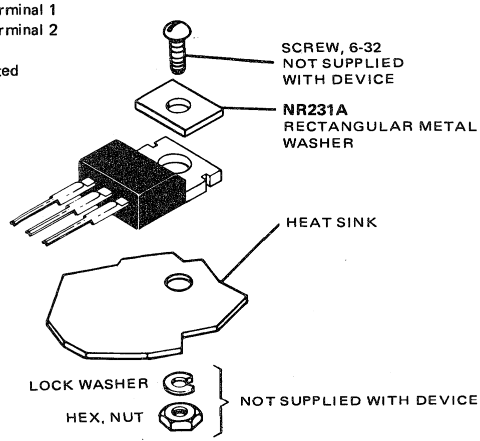


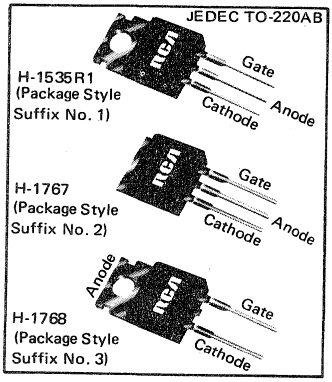
Fig. 16—Suggested mounting hardware.

Silicon Controlled Rectifiers (SCR's)

RCA
Solid State
Division

Thyristors

106, 107 Series



4-Ampere Sensitive-Gate Silicon Controlled Rectifiers

For Power Switching and Control Applications

Features:

- **Microampere gate sensitivity**
- **600-V capability**
- **4-A (rms) on-state current ratings**
- **35-A peak surge capability**
- **Glass-passivated chip for stability**
- **Low thermal resistances**
- **Surge capability curve**
- **Three package configurations for heat-sink and PC board mounting**

RCA–106 and 107 series are sensitive-gate silicon controlled rectifiers designed for switching ac and dc currents.

These SCR's are divided into the 106 series and the 107 series according to gate sensitivity. The types within each series differ in their voltage ratings; the voltage ratings are identified by suffix letters in the type designations. (Cont'd: pg. 2)

MAXIMUM RATINGS, *Absolute-Maximum Values:*

Rating	Symbol	106Q, 107Q	106Y, 107Y	106F, 107F	106A, 107A	106B, 107B	106C, 107C	106D, 107D	106E, 107E	106M, 107M	Unit
NON-REPETITIVE PEAK REVERSE VOLTAGE R_{GK} = 1000 Ω, T_C = -40 to 110°C	V_{RSOM}	25	50	75	125	250	400	500	600	700	V
NON-REPETITIVE PEAK FORWARD VOLTAGE R_{GK} = 1000 Ω, T_C = -40 to 110°C	V_{DSOM}										
REPETITIVE PEAK REVERSE VOLTAGE R_{GK} = 1000 Ω, T_C = -40 to 110°C	V_{RROM}	15	30	50	100	200	300	400	500	600	V
REPETITIVE PEAK OFF-STATE VOLTAGE R_{GK} = 1000 Ω, T_C = -40 to 110°C	V_{DROM}										

The V_{RSOM} and V_{DSOM} ratings share one row of values, as do the V_{RROM} and V_{DROM} ratings.

ON-STATE CURRENT: Conduction angle = 180°, T_C = 85°C			
Average ac value	$I_{T(AV)}$	2.5	A
RMS value	$I_{T(RMS)}$	4	A
DC operation	$I_{T(DC)}$	2.75	A
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT: For one cycle of applied principal voltage 60 Hz (sinusoidal)	I_{TSM}	35	A
For more than one cycle of applied principal voltage		See Fig. 6.	
PEAK GATE CURRENT	I_{GFM}	0.2	A
PEAK GATE REVERSE VOLTAGE	V_{GRM}	6	V
RATE OF CHANGE OF ON-STATE CURRENT: V_{DM} = V_{DROM}, I_{GT} = 1 mA, t_r = 0.5 μs, T_C = 110°C	di/dt	100	A/μs
GATE POWER DISSIPATION:			
PEAK FORWARD (for 10 μs max.)	P_{GM}	0.5	W
AVERAGE (averaging time = 10 ms, max.)	$P_{G(AV)}$	0.1	W
TEMPERATURE RANGE:			
Storage	T_{stg}	-40 to +150	°C
Operating (case)*	T_C	-40 to +110	°C
LEAD TEMPERATURE (During soldering): For 10 s max.		250	°C

*Temperature measuring points are shown in the dimensional outlines on page 6..

Three package designs are available: the JEDEC TO-220AB, which is RCA's popular plastic VERSAWATT package; the TO-220AB without a mounting flange; and a straight-lead variant of the TO-220AA package. These packages are identified as styles 1, 2, 3, respectively and are identified by suffix numbers following the suffix letters in the type designations e.g., RCA-106A1 is a 100-volt type in a VERSAWATT package.

These thyristors feature microampere gate-current requirements which permit operation in conjunction with low-level logic circuits. They can be used for lighting-, power-switching, and motor-speed controls, and for gate-current amplification for driving larger SCR's.

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	LIMITS: 106Q-, 106Y-, 106F-, 106A-, 106M-, 106B-, 106C-, 106D-, 106E-			LIMITS: 107Q-, 107Y-, 107F-, 107A-, 107M-, 107B-, 107C-, 107D-, 107E-			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
PEAK OFF-STATE CURRENT: Forward, $V_D = V_{DROM}$, $R_{GK} = 1000\ \Omega$, $T_C = 25°C$	I_{DROM}		0.1	10		0.1	10	
$T_C = 110°C$			10	100		10	100	
Reverse, $V_R = V_{RROM}$, $R_{GK} = 1000\ \Omega$, $T_C = 25°C$	I_{RROM}	–	0.1	10	–	0.1	10	μA
= 110°C		–	10	100	–	10	100	
INSTANTANEOUS ON-STATE VOLTAGE: For i_T = 4A and T_C = 25°C	v_T	–	1.25	2.2	–	1.25	2.2	V
DC GATE TRIGGER CURRENT: V_D = 12 V (DC), $R_L = 30\ \Omega$, T_C = 25°C	I_{GT}		30	200	–	325	500	μA
For other case temperatures		See Fig. 8			See Fig. 9			
DC GATE TRIGGER VOLTAGE: V_D = 12 V (DC), $R_L = 30\ \Omega$, T_C = 25°C; For other case temperatures, see Fig. 13	V_{GT}	–	0.5	0.8	–	0.5	0.8	V
INSTANTANEOUS HOLDING CURRENT: $R_{GK} = 1000\ \Omega$, T_C = 25°C	i_{HO}	–	1.7	3.0	–	1.9	3.0	mA
CRITICAL RATE OF RISE OF OFF-STATE VOLTAGE: $V_D = V_{DROM}$, $R_{GK} = 1000\ \Omega$, Exponential rise, T_C = 110°C	dv/dt	5	8	–	5	8	–	V/μs
GATE-CONTROLLED TURN-ON TIME: $V_D = V_{DROM}$, i_T = 1 A, I_{GT} = 1 mA, rise time = 0.1 μs, T_C = 25°C	t_{gt}	–	1.7	2.5	–	1.7	2.5	μs
CIRCUIT COMMUTATED TURN-OFF TIME: $V_D = V_{DROM}$, i_T = 1A, Pulse Duration = 50 μs, dv/dt = -5 V/μs, di/dt = -10 A/μs, I_{GT} = 1 mA at turn on, T_C = 110°C	t_q	–	30	100	–	30	100	μs
THERMAL RESISTANCE: Junction-to-Case*	$R_{\theta JC}$	–	–	3.5	–	–	3.5	°C/W
Junction-to-Ambient	$R_{\theta JA}$	–	–	60	–	–	60	
LATCHING CURRENT: $R_{GK} = 1000\ \Omega$, T_C = 25°C	i_L	–	1.8	4.0	–	2.5	4.0	mA

*Temperature measuring points are shown in the dimensional outlines on page 6.

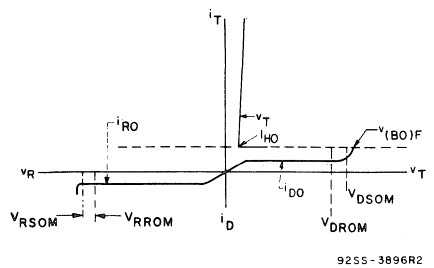


Fig. 1—Typical volt-ampere characteristic of 106/107 series of silicon controlled rectifiers.

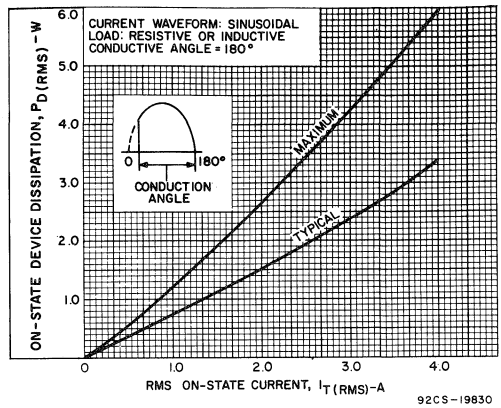


Fig. 4—Power dissipation vs. rms on-state current.

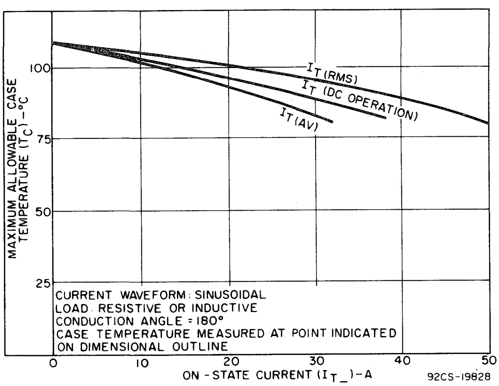


Fig. 2—Maximum allowable case temperature vs. on-state current.

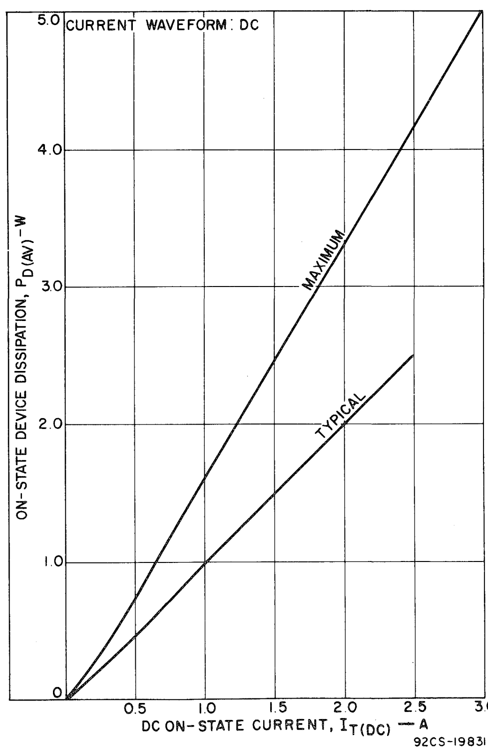


Fig. 5—Power dissipation vs. dc on-state current.

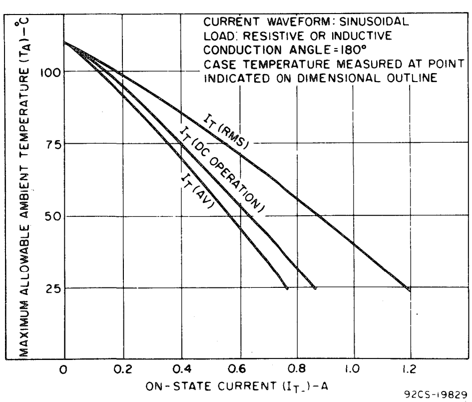


Fig. 3—Maximum allowable ambient temperature vs. on-state current.

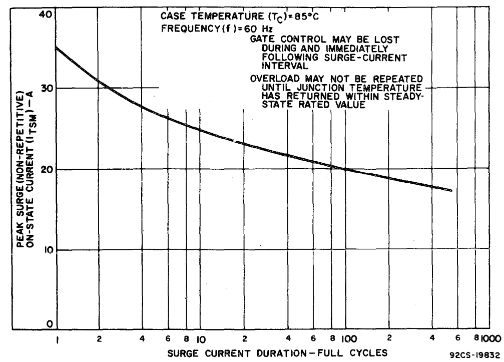


Fig. 6—Peak surge on-state current vs. surge-current duration.

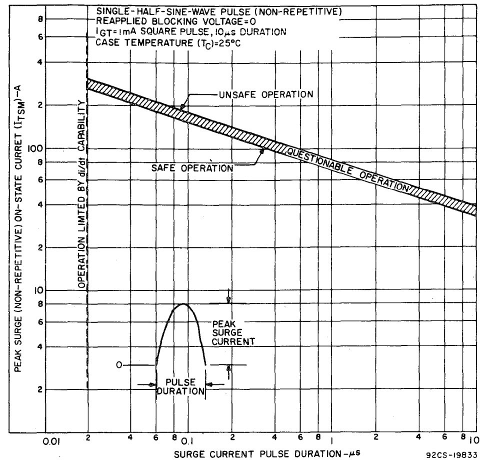


Fig. 7—Surge capability without reapplied blocking voltage.

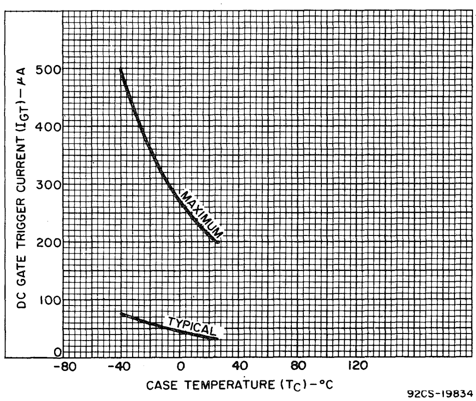


Fig. 8—DC gate trigger current vs. case temperature for 106 series.

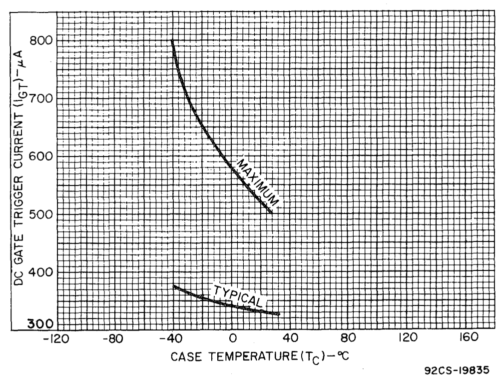


Fig. 9—DC gate trigger current vs. case temperature for 107 series.

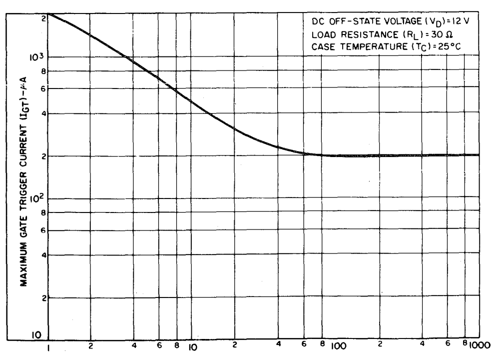


Fig. 10—Maximum gate trigger current vs. gate pulse duration for types in the 106 series.

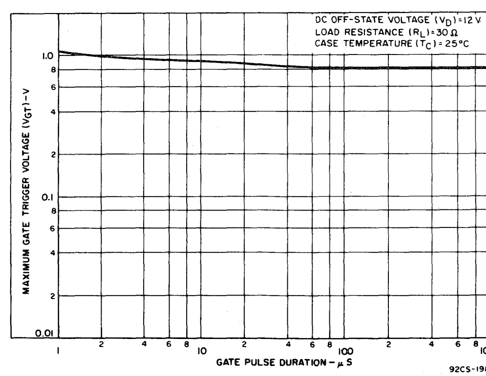


Fig. 11—Maximum gate trigger voltage vs. gate pulse duration for types in the 106 series.

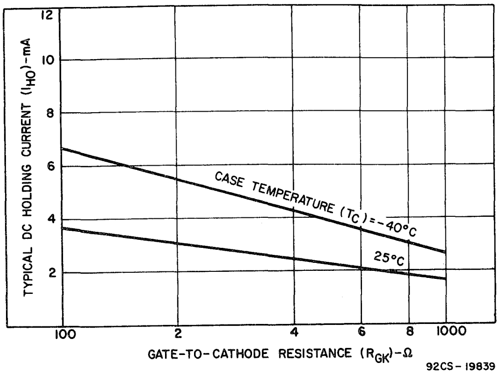


Fig. 12—DC holding current vs. gate-cathode resistance.

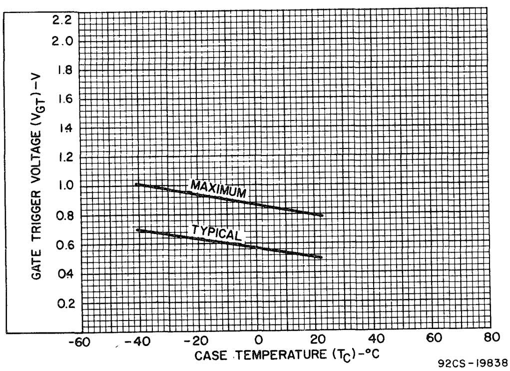


Fig. 13—Gate trigger voltage vs. case temperature.

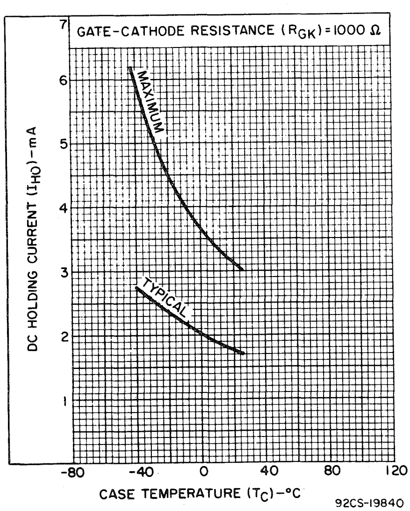


Fig. 14—DC holding current vs. case temperature for types in the 106 series.

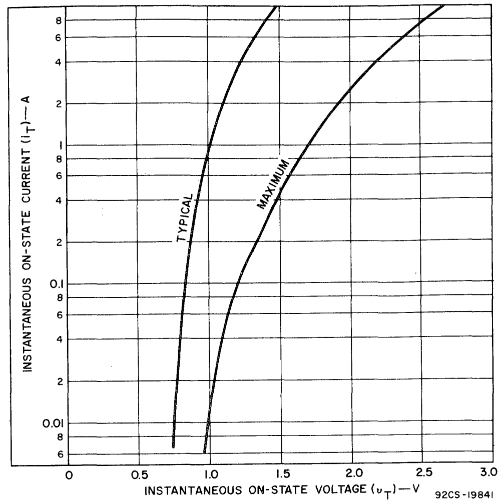


Fig. 15—Instantaneous on-state current vs. on-state voltage.

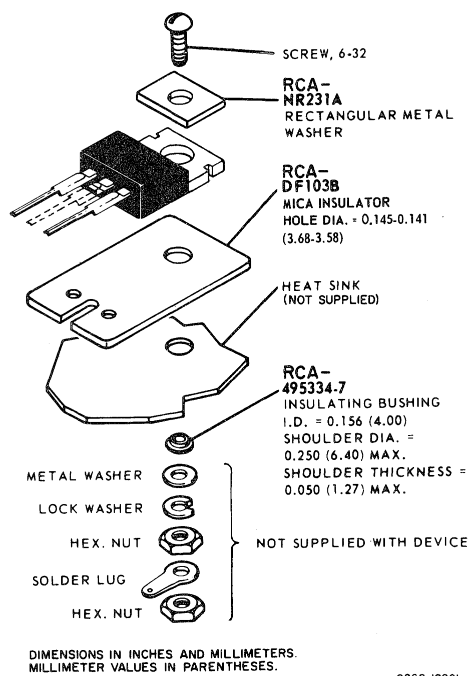


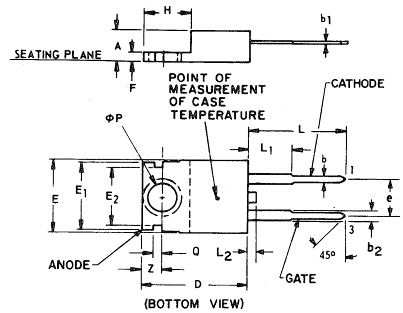
Fig. 16—Suggested mounting arrangement.

RCA APPLICATION NOTES ON THYRISTORS

- AN-3469 "Application of RCA Silicon Controlled Rectifiers to the Control of Universal Motors."
- AN-3822 "Thermal Considerations in Mounting RCA Thyristors."
- AN-4242 "A Review of Thyristor Characteristics and Applications."
- AN-3551 "Circuit Factor Charts for Use in Applications with RCA Thyristors (SCR's and Triacs)."
- AN-3886 "AC Voltage Regulators Using Thyristors."
- AN-4124 "Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors."

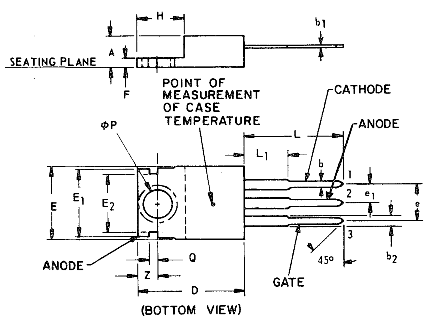
Single copies of these publications are available on request from RCA Solid State Division, Box 3200, Somerville, N.J. 08876

DIMENSIONAL OUTLINE (SUFFIX No. 3)



92CM-19863-3

DIMENSIONAL OUTLINE (JEDEC TO-220AB) (SUFFIX No. 1)

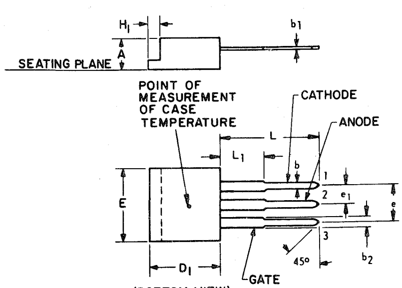


92CM-19863-1

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.190	4.07	4.82
b	0.025	0.040	0.64	1.02
b_1	0.012	0.020	0.31	0.51
b_2	0.045	0.055	1.143	1.397
D	0.575	0.625	14.6	15.9
D_1	0.32	0.42	8.13	10.7
E	0.395	0.410	10.04	10.41
E_1	0.365	0.385	9.28	9.77
E_2	0.300	0.320	7.62	8.12
e	0.180	0.220	4.57	5.58
e_1	0.080	0.120	2.03	3.04
F	0.020	0.055	0.51	1.39
H	0.235	0.265	5.97	6.73
H_1	0.03	0.05	0.762	1.27
L	0.500	–	12.70	–
L_1	–	0.250	–	6.35
L_2	0.02	0.05	0.51	1.27
ϕP	0.141	0.145	3.582	3.683
Q	0.040	0.060	1.02	1.52
Z	0.100	0.120	2.54	3.04

92CM-19863

DIMENSIONAL OUTLINE (SUFFIX No. 2)



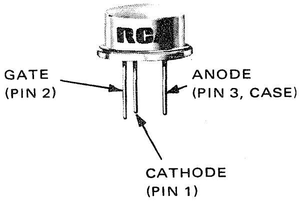
92CM-19863-2

RCA

Solid State Division

Thyristors

40942 40944 40943 40945



JEDEC TO-8 H-1015

4.5-Ampere Silicon Controlled Rectifiers For Capacitive-Discharge Systems

For Low-Voltage Operation.... 40942
For 120-V Line Operation..... 40943
For 240-V Line Operation..... 40944
For High-Voltage Operation.... 40945

Features:

- **200-A surge current capability**
- **Low switching losses**
- **High di/dt and dv/dt capabilities**
- **Shorted-emitter gate-cathode construction**
- **Forward and reverse gate-dissipation ratings**
- **Low forward voltage drop at high current levels**

These RCA types are all-diffused silicon controlled rectifiers (reverse-blocking triode thyristors) designed for high-peak-current low-average-current applications. Typical applications are ignition service, crowbars, and other capacitive-discharge systems.

These SCR's have an rms on-state current rating ($I_{T[RMS]}$) of 4.5 amperes and have voltage ratings (V_{DROM}) of 100, 200, 400, and 600 volts.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

<table>
<tr><th></th><th></th><th>40942</th><th>40943</th><th>40944</th><th>40945</th><th></th></tr>
<tr><td>Non-repetitive peak reverse voltage▲
Gate open</td><td>V_{RSOM}</td><td>100</td><td>200</td><td>400</td><td>600</td><td>V</td></tr>
<tr><td>Non-repetitive peak forward voltage▲
Gate open</td><td>V_{DSOM}</td><td>150</td><td>250</td><td>500</td><td>700</td><td>V</td></tr>
<tr><td>Repetitive peak reverse voltage▲
Gate open</td><td>V_{RROM}</td><td>100</td><td>200</td><td>400</td><td>600</td><td>V</td></tr>
<tr><td>Repetitive peak off-state voltage▲
Gate open</td><td>V_{DROM}</td><td>100</td><td>200</td><td>400</td><td>600</td><td>V</td></tr>
<tr><td>On-state current:
T_C = 75°C, conduction angle = 180°
RMS</td><td>$I_{T(RMS)}$</td><td colspan="4">4.5</td><td>A</td></tr>
<tr><td>Average</td><td>$I_{T(AV)}$</td><td colspan="4">3.3</td><td>A</td></tr>
<tr><td>For other conditions</td><td></td><td colspan="4">See Fig.3</td><td></td></tr>
<tr><td>Peak surge (non-repetitive) on-state current:
For one cycle of applied principal voltage
50-Hz, sinusoidal</td><td>I_{TSM}</td><td colspan="4">170</td><td>A</td></tr>
<tr><td>60-Hz, sinusoidal</td><td></td><td colspan="4">200</td><td>A</td></tr>
<tr><td>For more than one full cycle of applied principal voltage</td><td></td><td colspan="4">See Fig.4</td><td></td></tr>
<tr><td>Rate of change of on-state current
$V_D = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.5 μs (See Fig.12)</td><td>di/dt</td><td colspan="4">200</td><td>A/μs</td></tr>
<tr><td>Fusing current (for SCR protection):
T_J = −40 to 100°C, t = 1.5 to 10 ms</td><td>I^2t</td><td colspan="4">150</td><td>A^2s</td></tr>
<tr><td>Gate power dissipation:●
Peak forward (for 1 μs max.)</td><td>P_{GM}</td><td colspan="4">40</td><td>W</td></tr>
<tr><td>Peak reverse</td><td>P_{RGM}</td><td colspan="4">See Fig.8</td><td></td></tr>
<tr><td>Average (averaging time = 10 ms, max.)</td><td>$P_{G(AV)}$</td><td colspan="4">0.5</td><td>W</td></tr>
<tr><td>Temperature range:■
Storage</td><td>T_{stg}</td><td colspan="4">−40 to 150</td><td>°C</td></tr>
<tr><td>Operating (case)</td><td>T_C</td><td colspan="4">−40 to 100</td><td>°C</td></tr>
<tr><td>Pin temperature (during soldering):
For 10 s max. (pins and case)</td><td>T_P</td><td colspan="4">225</td><td>°C</td></tr>
</table>

See footnotes on page 2.

▲ These values do not apply if there is a positive gate signal. Gate must be open or negatively biased.
● Any product of gate current and gate voltage which results in a gate power less than the maximum is permitted.
■ Temperature measurement point is shown on the DIMENSIONAL OUTLINE.

ELECTRICAL CHARACTERISTICS, At Maximum Ratings Unless Otherwise Specified and at Indicated Case Temperature (T_C)

CHARACTERISTIC	SYMBOL	LIMITS For All Types Min.	Typ.	Max.	UNITS
Peak Off-State Current: (Gate open, T_C = 100°C) Forward at $V_D = V_{DROM}$	I_{DOM}	–	0.2	3	mA
Reverse at $V_R = V_{RROM}$	I_{ROM}	–	0.1	2	mA
Instantaneous On-State Voltage: i_T = 100 A, T_C = 25°C, See Fig.5	v_T	–	2.5	3	V
DC Gate Trigger Voltage: V_D = 12 V (dc), R_L = 30 Ω, T_C = 25°C	V_{GT}	–	1.1	2	V
For other conditions			See Fig.10		
DC Gate Trigger Current: V_D = 12 V (dc), R_L = 30 Ω, T_C = 25°C	I_{GT}	–	8	15	mA
For other conditions			See Fig.9		
DC Holding Current: Gate open, initial principal current = 150 mA, T_C = 25°C	I_{HO}	–	9	20	mA
For other conditions			See Fig.6		
Gate-Controlled Turn-On Time: (Delay Time + Rise Time) $V_D = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.1 μs, i_T = 30 A (peak), T_C = 25°C (See Fig.11)	t_{gt}	–	1.6	2.5	μs
Circuit-Commutated Turn-Off Time: $V_D = V_{DROM}$, i_T = 18 A, pulse duration = 50 μs, dv/dt = 20 V/μs, di/dt = –30 A/μs, I_{GT} = 200 mA, T_C = 75°C See Fig.14	t_q	–	20	40	μs
Critical Rate of Rise of Off-State Voltage: $V_D = V_{DROM}$, exponential voltage rise, gate open, T_C = 100°C, See Fig.15	dv/dt	10	100	–	V/μs
Thermal Resistance: Steady-state Junction-to-case	$R_{\theta JC}$	–	–	5	°C/W
Junction-to-ambient	$R_{\theta JA}$	–	–	40	°C/W

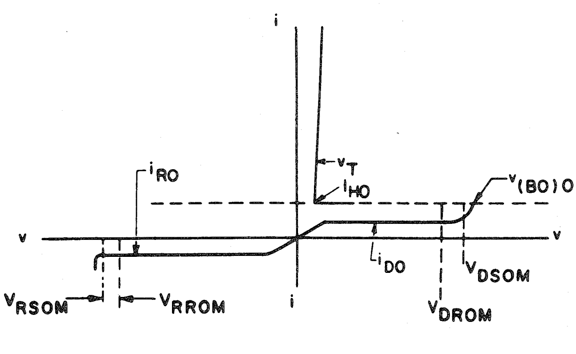


Fig.1–Principal voltage-current characteristics.

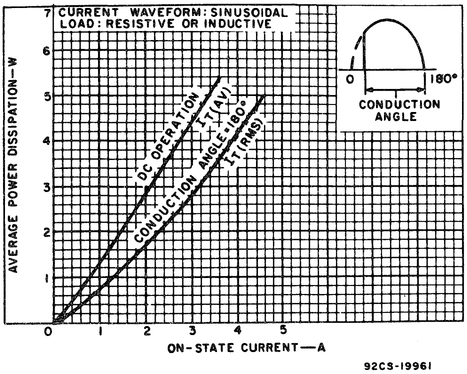


Fig. 2—Power dissipation vs. on-state current.

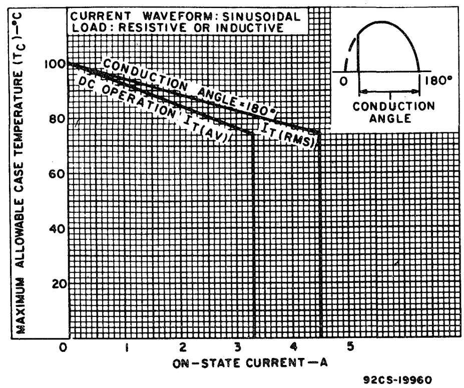


Fig. 3—Maximum allowable case temperature vs. on-state current.

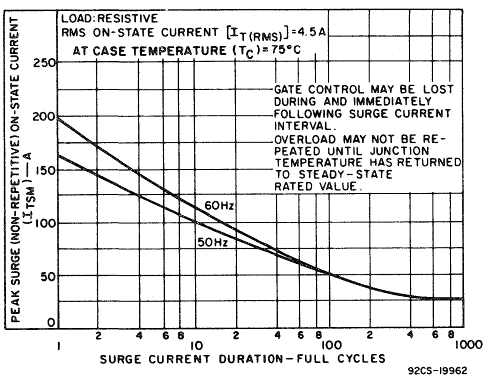


Fig. 4—Peak surge on-state current vs. surge current duration.

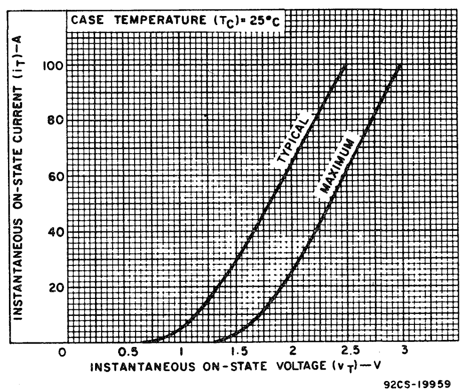


Fig. 5—Instantaneous on-state current vs. on-state voltage.

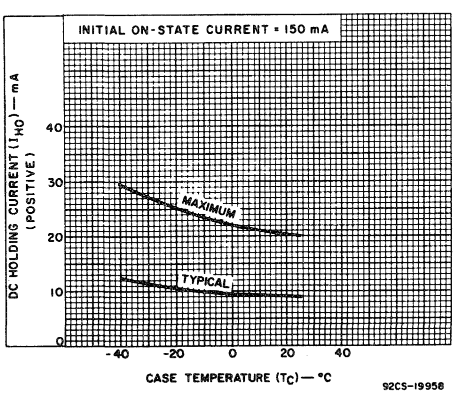


Fig. 6—DC holding current vs. case temperature.

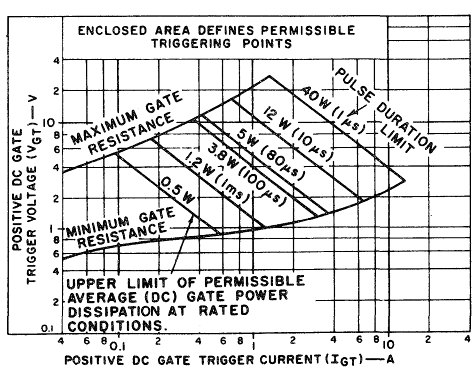


Fig. 7—Gate pulse characteristics for forward triggering mode.

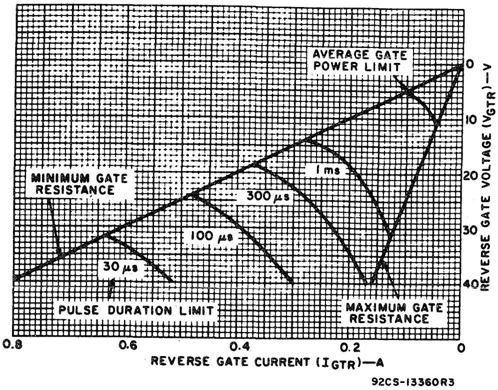


Fig.8—Reverse gate voltage vs. reverse gate current.

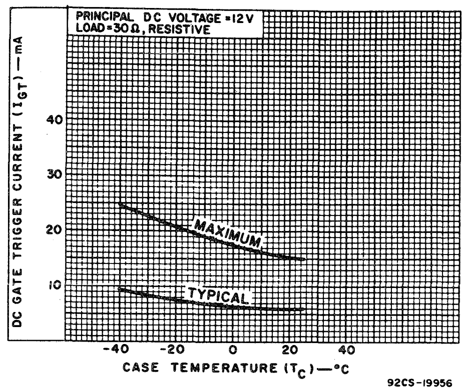


Fig.9—DC gate-trigger current (forward) vs. case temperature.

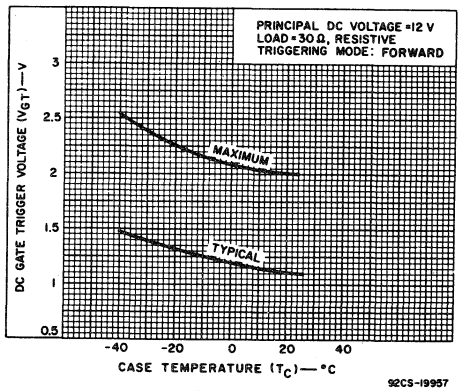


Fig.10—DC gate-trigger voltage (forward) vs. case temperature.

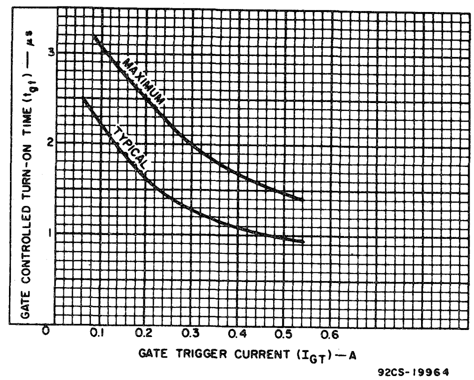


Fig.11—Gate-controlled turn-on time vs. gate-trigger current.

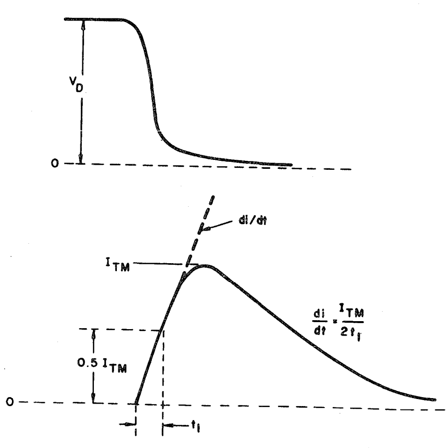


Fig.12—Rate of change of on-state current with time (defining di/dt).

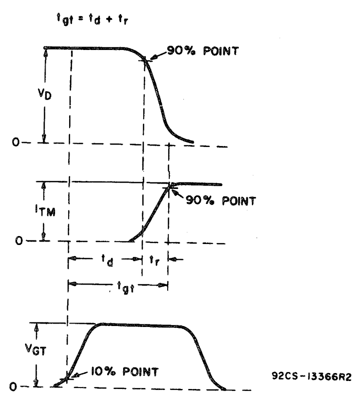


Fig.13—Relationship between off-state voltage, on-state current, and gate-trigger voltage showing reference points for definition of turn-on time (t_{gt}).

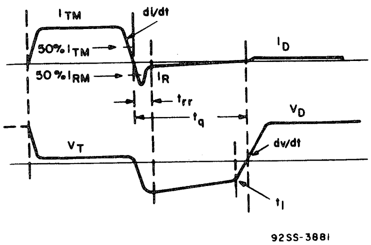


Fig. 14—Relationship between instantaneous on-state current and voltage showing reference points for definition of circuit-commutated turn-off time (t_q).

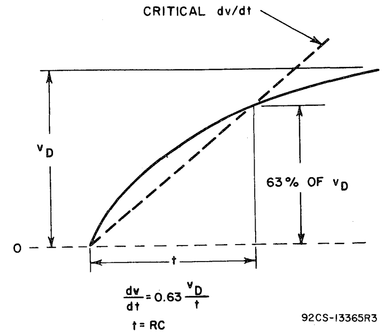


Fig.15—Rate of rise of off-state voltage with time (defining critical dv/dt).

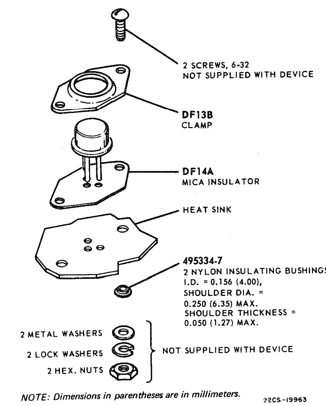
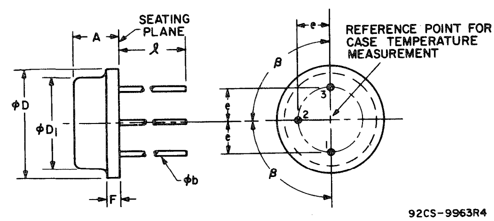


Fig.16—Suggested mounting arrangement.

DIMENSIONAL OUTLINE FOR TYPES 40942, 40943, 40944, 40945 JEDEC TO-8



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.270	0.330	6.86	8.38	–
φb	0.027	0.033	0.686	0.838	1
φD	0.550	0.650	13.97	16.51	–
φD1	0.444	0.524	11.28	13.31	–
e	0.136	0.146	3.45	3.71	–
F	–	0.115	–	2.92	–
ℓ	0.360	0.440	9.14	11.18	1
β	90° NOMINAL		–	–	–

NOTE:
1. THREE LEADS.

TERMINAL CONNECTIONS

Pin 1 — Cathode
Pin 2 — Gate
Case, Pin 3 — Anode

RCA
Solid State
Division

Thyristors
2N3228 2N3529
2N3525 2N4101
2N3528 2N4102

All-Diffused SCR's for Low-Cost Power-Control and Power-Switching Applications

RCA 2N3228*, 2N3525*, 2N4101*, and 2N3528●, 2N3529●, and 2N4102● are all-diffused, three-junction, silicon controlled-rectifiers (SCR's▲) intended for use in power-control and power-switching applications.

Types 2N3228, 2N3525, and 2N4101 use the JEDEC TO-66 package and have a blocking voltage capability of up to 600 volts and a forward current rating of 5 amperes (rms value) at a case temperature of 75°C.

Types 2N3528, 2N3529, and 2N4102 use the JEDEC TO-8 package and have a blocking voltage capability of up to 600 volts and a forward current rating of 2 amperes (rms value) at an ambient temperature of 25°C.

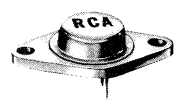
* Formerly Dev. Types TA1222, TA1225, and TA2773, respectively.

● Formerly Dev. Types TA2597, TA2617, and TA2774, respectively.

▲ The silicon controlled-rectifier is also known as a reverse-blocking triode thyristor.

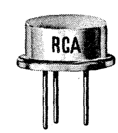
FEATURES

- Designed especially for high-volume systems
- Readily adaptable for printed-circuit boards and metal heat sinks
- Low switching losses
- High di/dt and dv/dt capabilities
- Shorted emitter gate-cathode construction
- Forward and reverse gate dissipation ratings
- All-diffused construction – assures exceptional uniformity and stability of characteristics
- Direct-soldered internal construction – assures exceptional resistance to fatigue
- Symmetrical gate-cathode construction – provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- All-welded construction and hermetic sealing
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance



2N3228
2N3525
2N4101

JEDEC TO-66

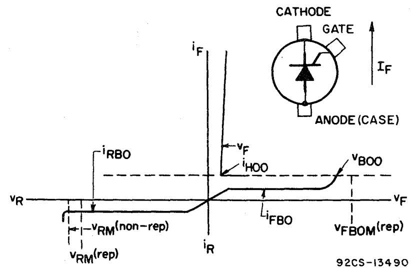


2N3528
2N3529
2N4102

JEDEC TO-8

Current → Voltage ↓	Average Forward Amperes 3.2	Average Forward Amperes 1.3
For 120-Volt Line Operation	2N3228	2N3528
For 240-Volt Line Operation	2N3525	2N3529
For High-Voltage Power Supplies	2N4101	2N4102

TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER



Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage at a Frequency between 50 and 400 Hz, and with Resistive or Inductive Load

RATINGS	CONTROLLED-RECTIFIER TYPES						UNITS
	2N3228	2N3525	2N4101	2N3528	2N3529	2N4102	
Transient Peak Reverse Voltage (Non-Repetitive), v_{RM}(non-rep)[a]	330	660	700	330	660	700	volts
Peak Reverse Voltage (Repetitive), v_{RM}(rep)[b]	200	400	600	200	400	600	volts
Peak Forward Blocking Voltage (Repetitive), v_{FBOM}(rep)[c]	600	600	700	600	600	700	volts
Forward Current:							
For case temperature (T_C) of + 75°C, and unit mounted on heat sink–							
Average DC value at a conduction angle of 180°, I_{FAV}[d]	3.2	3.2	3.2	—	—	—	amperes
RMS value, I_{FRMS}[e]	5.0	5.0	5.0	—	—	—	amperes
For other conditions, See Fig. 8							
For free-air temperature (T_{FA}) of 25°C, and with no heat sink employed–							
Average DC value at a conduction angle of 180°, I_{FAV}[d]	—	—	—	1.3	1.3	1.3	amperes
RMS value, I_{FRMS}[e]	—	—	—	2.0	2.0	2.0	amperes
For other conditions, See Fig. 9.							
Peak Surge Current, i_{FM}(surge)[f]:							
For one cycle of applied voltage		60			60		amperes
For more than one cycle of applied voltage		See Fig. 13			See Fig. 13		
Sub-Cycle Surge (Non-Repetitive) I^2t[g] For a period of 1ms to 8.3ms		15			15		ampere² second
Rate of Change of Forward Current, di/dt[h]		200			200		amperes/ microsecond
V_{FB} = v_{BOO}(min. value)							
I_{GT} = 200mA, 0.5 μs rise time (See waveshapes of Fig. 1)							
Gate Power*:							
Peak, Forward or Reverse, for 10 μs duration, P_{GM}[j] (See Figs. 5 and 6)		13			13		watts
Average, P_{GAV}[k]		0.5			0.5		watt
Temperature:							
Storage, T_{stg}		-40 to +125			-40 to +125		°C
Operating (Case), T_C		-40 to +100			-40 to +100		°C

*Any values of peak gate current or peak gate voltage to give the maximum gate power is permissible.

WAVESHAPE OF di/dt RATING TEST

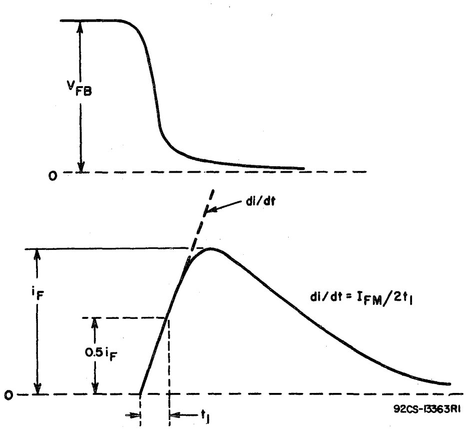


Fig. 1

WAVESHAPE OF CRITICAL dv/dt RATING TEST

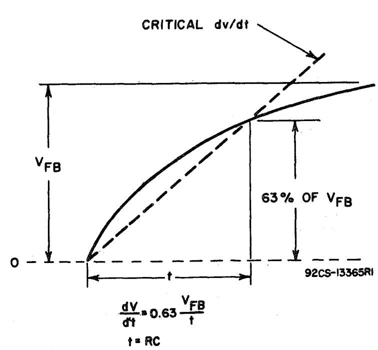


Fig. 2

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)

CHARACTERISTICS	CONTROLLED-RECTIFIER TYPES									UNITS
	2N3228, 2N3528			2N3525, 2N3529			2N4101, 2N4102			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Forward Breakover Voltage, v_{BOO}^{m}: At T_C = +100°C	200	—	—	400	—	—	600	—	—	volts
Peak Blocking Current, at T_C = +100°C: Forward, I_{FBOM}^{n}	—	0.10	1.5	—	0.20	3.0	—	0.40	4.0	mA
V_{FBO}^{p} = v_{BOO} (min. value)										
Reverse, I_{RBOM}^{q}	—	0.05	0.75	—	0.10	1.5	—	0.20	2.0	mA
V_{RBO}^{p} = v_{RM}(rep) value										
Forward Voltage Drop, v_{FT} At a Forward Current of 30 amperes and a T_C = +25°C (See Fig. 11)	—	2.15	2.8	—	2.15	2.8	—	2.15	2.8	volts
DC Gate-Trigger Current, I_{GT}^{s} At T_C = +25°C (See Fig. 5)	—	8	15	—	8	15	—	8	15	mA(dc)
Gate-Trigger Voltage, V_{GT}^{t} At T_C = +25°C (See Fig. 5)	—	1.2	2.0	—	1.2	2.0	—	1.2	2.0	volts(dc)
Holding Current, i_{HOO}^{u} At T_C = +25°C	—	10	20	—	10	20	—	10	20	mA
Critical Rate of Applied Forward Voltage, Critical dv/dt^{v}	10	200	—	10	200	—	10	200	—	volts/ microsecond
V_{FB} = v_{BOO} (min. value), exponential rise, T_C = +100°C (See waveshape of Fig. 2)										
Turn-On Time, t_{on}^{w}, (Delay Time + Rise Time)	0.75	1.5	—	0.75	1.5	—	0.75	1.5	—	microseconds
V_{FB} = v_{BOO} (min. value), i_F = 4.5 amperes, I_{GT} = 200mA, 0.1 μs rise time, T_C = +25°C (See waveshapes of Fig. 3)										
Turn-Off Time, t_{off}^{x}, (Reverse Recovery Time + Gate Recovery Time)	—	15	50	—	15	50	—	15	50	microseconds
i_F = 2 amperes, 50 μs pulse width, dv_{FB}/dt = 20 v/μs, di_r/dt = 30 A/μs, I_{GT} = 200mA, T_C = +75°C (See waveshapes of Fig. 4)										

CHARACTERISTICS	2N3228, 2N3525, 2N4101			2N3528, 2N3529, 2N4102			UNITS
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Thermal Resistance: Junction-to-case	—	—	4	—	—	—	°C/W
Junction-to-ambient	—	—	—	—	—	40	°C/W

WAVESHAPE OF t_{on} RATING TEST

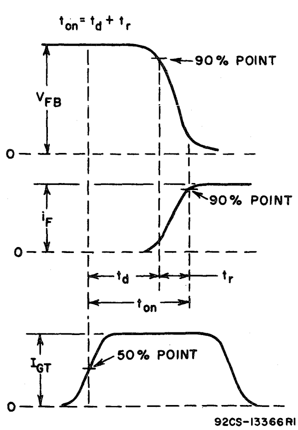


Fig. 3

WAVESHAPE OF t_{off} RATING TEST

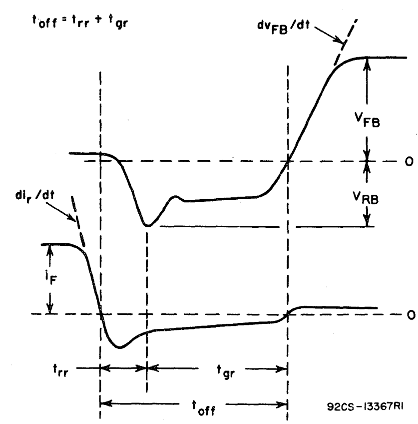


Fig. 4

FORWARD GATE CHARACTERISTICS

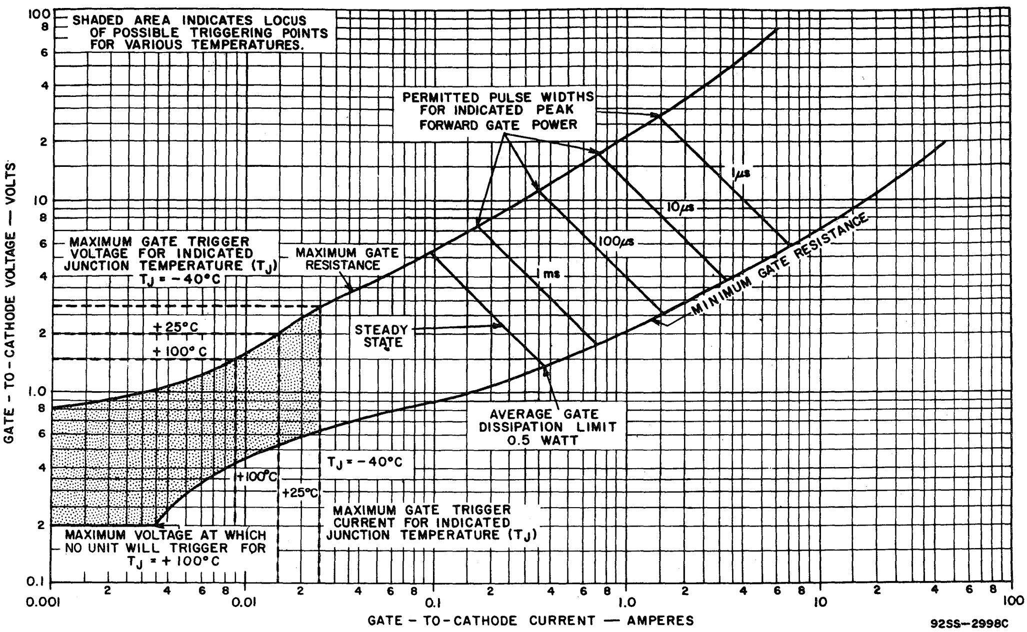


Fig. 5

REVERSE GATE CHARACTERISTICS

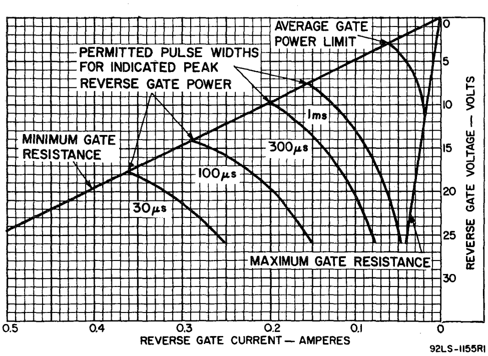


Fig. 6

TRIGGERING CONSIDERATIONS

The construction of the gate-cathode junction used in these devices provides a large periphery center gate. These devices also employ shorted-emitter construction which removes restrictions on both forward and reverse peak gate voltage and peak gate current. Limiting values of volt-ampere products for different gate pulse widths are shown in Fig. 5. These limits should be adhered to when designing pulse trigger circuits for maximum trigger pulse widths and peak power dissipation. The volt-ampere products in the reverse direction shown in Fig. 6 should be used to determine limitations for reverse gate transients or reverse gate pulses if present. In all cases, total average gate dissipation, both forward and reverse, should not exceed the average gate dissipation rating (P_{GAV}) of 0.5 watt.

Turn-on times for different gate currents are shown in Fig. 7. These curves may be used to determine the required width of the gate trigger pulses. It is only necessary to maintain the gate trigger pulse until the magnitude of the forward anode current has reached the latching current value. However, conservative design requires that the gate trigger pulse width be at least equal to or somewhat greater than the device turn-on time. Some applications may require wider gate pulse widths for proper circuit operation. Additional information on gate characteristics and triggering requirements for use in pulse applications are contained in RCA Application Note, SMA-39, "Gate Parameters of RCA SCR's for Trigger Circuit Design".

TURN-ON TIME CHARACTERISTICS

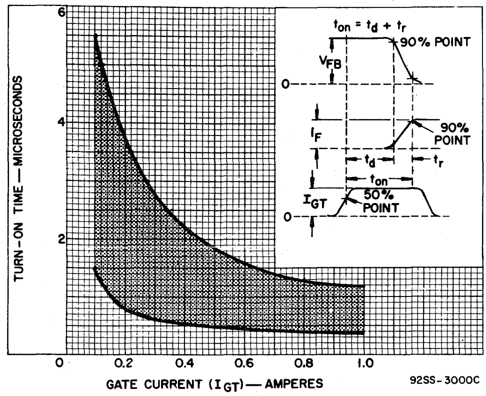


Fig. 7

RATING CHART (CASE TEMPERATURE) FOR TYPES 2N3228, 2N3525, AND 2N4101

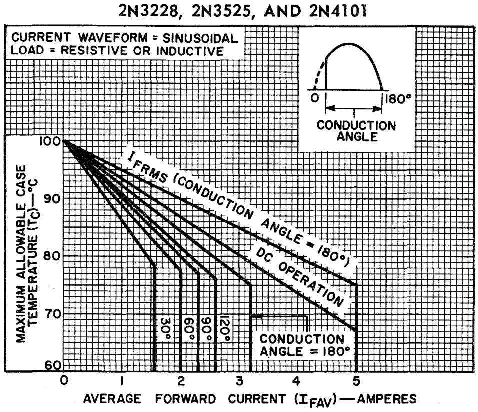


Fig. 8

RATING CHART (FREE-AIR TEMPERATURE) FOR TYPES 2N3528, 2N3529, AND 2N4102

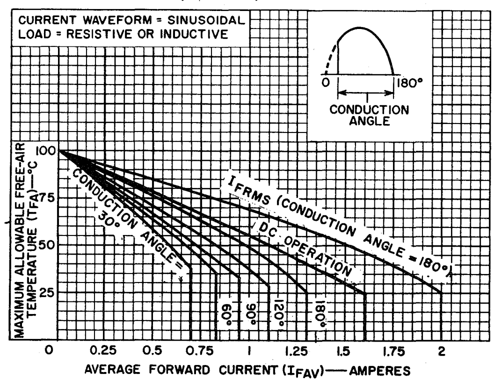


Fig. 9

POWER DISSIPATION CHART FOR ALL TYPES

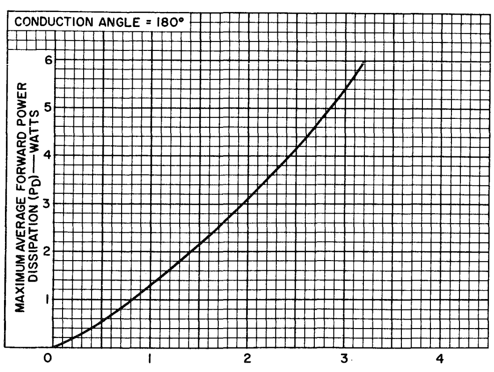


Fig. 10

FORWARD CHARACTERISTICS FOR ALL TYPES

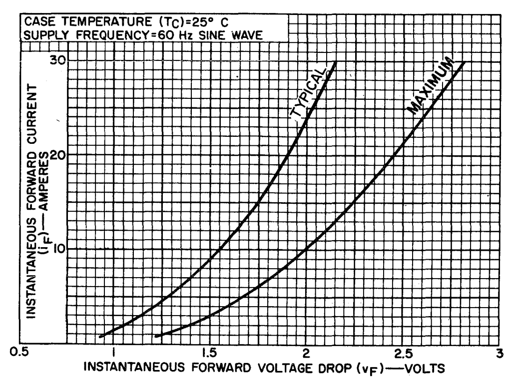


Fig. 11

OPERATION GUIDANCE CHART FOR TYPES 2N3228, 2N3525, AND 2N4101

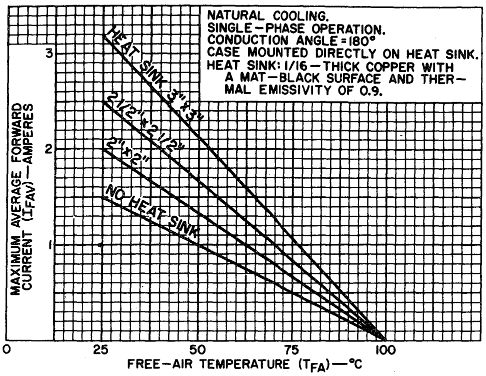


Fig. 12

SURGE CURRENT RATING CHART

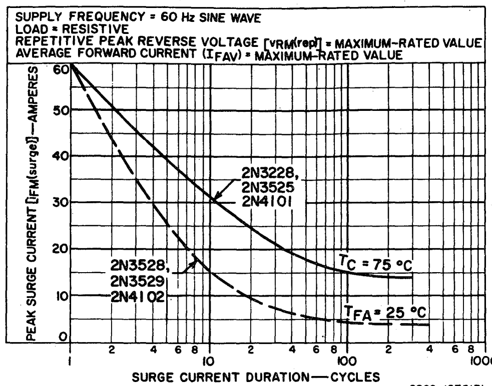
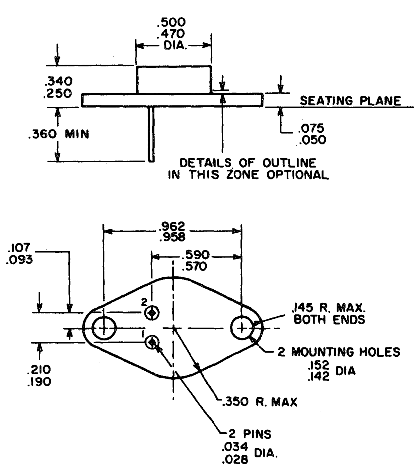


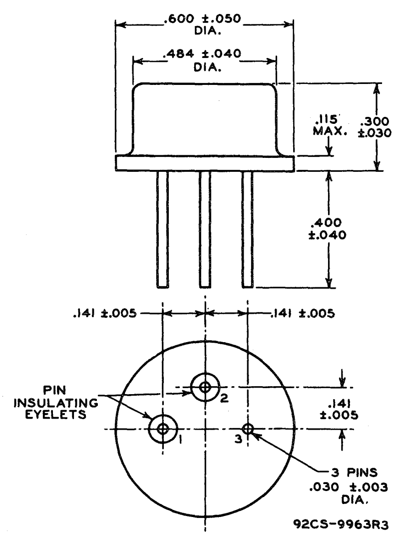
Fig. 13

DIMENSIONAL OUTLINE FOR TYPES 2N3228, 2N3525, AND 2N4101 JEDEC No. TO-66



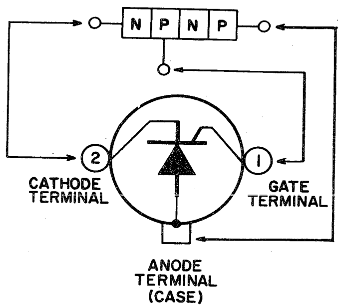
DIMENSIONS IN INCHES

DIMENSIONAL OUTLINE FOR TYPES 2N3528, 2N3529, AND 2N4102 JEDEC No. TO-8



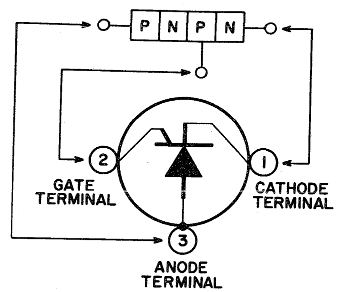
DIMENSIONS IN INCHES

TERMINAL DIAGRAM FOR TYPES
2N3228, 2N3525, AND 2N4101



PIN 1: GATE
PIN 2: CATHODE
CASE: ANODE

TERMINAL DIAGRAM FOR TYPES
2N3528, 2N3529, AND 2N4102



PIN 1: CATHODE
PIN 2: GATE
PIN 3: ANODE
(CONNECTED
TO CASE)

RCA

Solid State Division

Thyristors

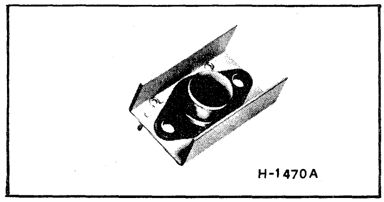
40504 40505 40506

This bulletin sheet is to be used in conjunction with the data sheet for types 2N3228, 2N3525, and 2N4101 dated 5/66.

RCA 40504, 40505, and 40506 are all-diffused, three-junction silicon controlled-rectifiers having integral heat radiators. They are variants of the 2N3228, 2N3525, and 2N4101, respectively.

The 40504, 40505, and 40506 are designed to meet the needs of many power-control and power-switching applications in which heat sinking is required but where the design of special cooling systems to achieve the full current rating of the thyristor is not warranted.

The radiator design of these devices has tabs to allow printed-circuit board mounting and holes to allow chassis mounting if desired.



Thyristor with Heat Radiator	Thyristor without Heat Radiator
40504	2N3228
40505	2N3525
40506	2N4101

CONDUCTION RATING CHART (FREE-AIR TEMPERATURE)

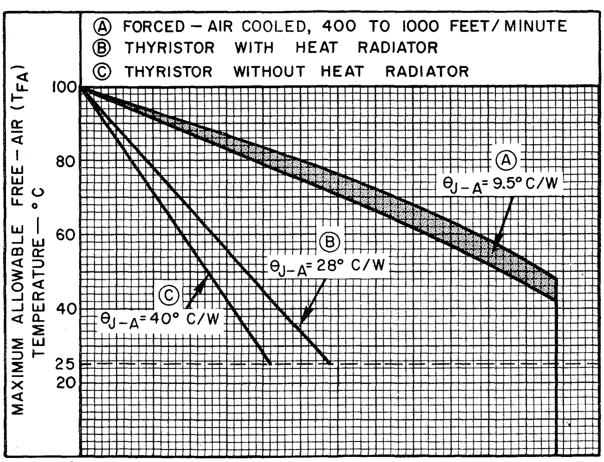
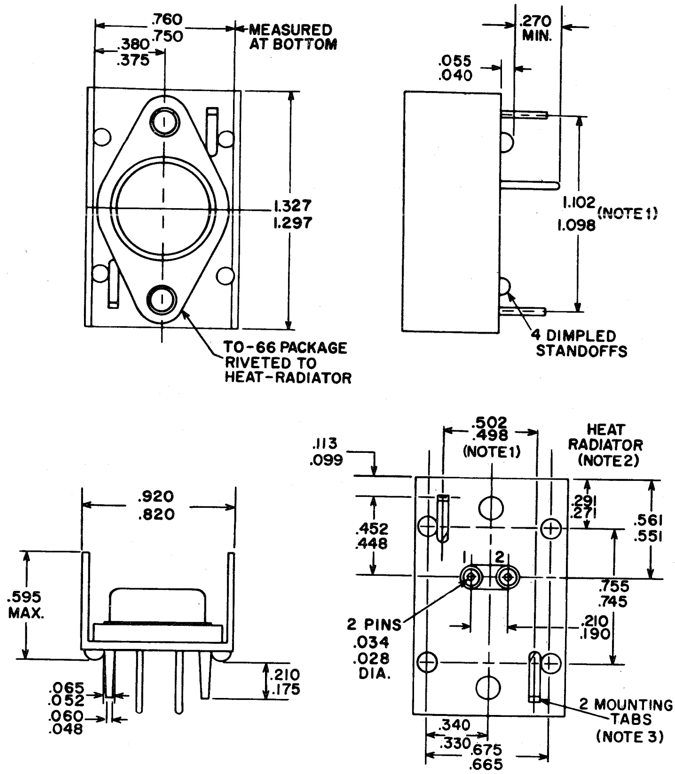


Fig. 1

DIMENSIONAL OUTLINE



92CS-13383R1

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.

TERMINAL CONNECTIONS

Pin 1: Gate
Pin 2: Cathode
Radiator, Case: Anode

RCA

Solid State
Division

Thyristors
40553
40554
40555

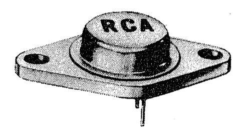
All-Diffused Silicon SCR's for Inverter Applications

RCA 40553*, 40554*, and 40555* are all-diffused, three-junction silicon controlled-rectifiers intended for use in inverter applications such as ultrasonics and fluorescent lighting. They feature fast turn-off time, high dv/dt, high di/dt characteristics and may be used at frequencies up to 25 kHz.

Each of these devices has an rms on-state current rating of 5 amperes at a case temperature of +60° C. The 40553, 40554, and 40555 have forward and reverse off-state voltage ratings of 200, 400, and 600 volts, respectively.

*Formerly Developmental Types TA2653, TA2654, and TA2655, respectively.

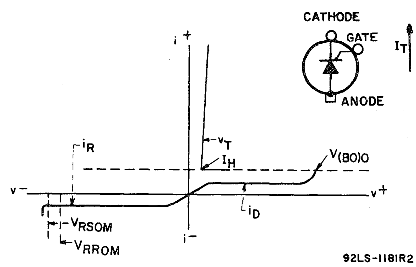
- **RMS On-State Current –**
  5 Amperes at T_C = + 60° C
- **Fast Turn-Off Time –**
  6 μs maximum
- **High dv/dt Capability –**
  100 V/μs minimum
- **High di/dt Capability –**
  200 A/μs
- **Shorted-Emitter and Center-Gate Design –**
  Removes restrictions on forward and reverse gate voltage and peak gate current



JEDEC TO-66

Type	Forward and Reverse Voltage V	$I_{T(RMS)}$ @ T_C = +60° C A
40553	200	5
40554	400	5
40555	600	5

ANODE-TO-CATHODE VOLTAGE-CURRENT CHARACTERISTIC



Principal voltage is the voltage between the main terminals. Principal voltage is called positive, or forward, when the anode potential is higher than the cathode potential, and called negative when the anode potential is lower than the cathode potential.

Principal current is the current flowing between anode and cathode.

Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage At Low to Ultrasonic Frequencies, and with Resistive or Inductive Load
For Definitions of Terms and Symbols, See Page 10

RATINGS	CONTROLLED-RECTIFIER TYPES			UNITS
	40553	40554	40555	
Non-Repetitive Peak Reverse Voltage, V_{RSOM}				
Gate Open	330	660	700	V
Repetitive Peak Reverse Voltage, V_{RROM}				
Gate Open	200	400	600	V
Repetitive Peak Off-State Voltage, V_{DROM}				
Gate Open	700	700	700	V
On-State Current:				
For case temperature of +60° C and 60 Hz				
Average DC value at a conduction angle of 180°, $I_{T(AV)}$	3.2	3.2	3.2	A
RMS value, $I_{T(RMS)}$	5	5	5	A
For other conditions		See *Fig.9*		
Peak Surge (Non-Repetitive) On-State Current, I_{TSM}				
For one cycle of applied voltage	80	80	80	A
For more than one cycle of applied voltage		See *Fig.11*		
Sub-Cycle for Fusing, I^2t				
For a period of 8.3 ms	25	25	25	A^2s
Critical Rate of Rise of On-State Current, Critical di/dt				
$V_{DX} = V_{(BO)O}$ rated value, I_{GT} = 50 mA, 0.1 μs rise time	200	200	200	A/μs
Gate Power Dissipation*				
Peak, Forward or Reverse, for 10 μs duration, P_{GM}	13	13	13	W
Average, $P_{G(AV)}$	0.5	0.5	0.5	W
Temperature:■				
Storage, T_{stg}	-40 to +150	-40 to +150	-40 to +150	°C
Operating (Case), T_C	-40 to +100	-40 to +100	-40 to +100	°C

*Any values of peak gate current or peak gate voltage to give the maximum gate power are permissible.

■For information on the reference point of temperature measurement, see *Dimensional Outline.*

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)
For Definitions of Terms and Symbols, See Page 10

CHARACTERISTICS	40553 Min.	40553 Typ.	40553 Max.	40554 Min.	40554 Typ.	40554 Max.	40555 Min.	40555 Typ.	40555 Max.	UNITS
Breakover Voltage, $V_{(BO)O}$ Gate Open At T_C = +100° C	200	–	–	400	–	–	600	–	–	V
Peak Off-State Current: Gate Open At T_C = +100° C **Forward, I_{DOM}** $V_{DO} = V_{(BO)O}$ rated value	–	0.5	3	–	0.5	3	–	0.5	3	mA
Reverse, I_{RROM} $V_{RO} = V_{RROM}$	–	0.3	1.5	–	0.3	1.5	–	0.3	1.5	mA
Instantaneous On-State Voltage, v_T For an on-state current of 30 A and T_C = +25° C (See *Fig.13*)	–	2.2	3	–	2.2	3	–	2.2	3	V
DC Gate Trigger Current, I_{GT} At T_C = +25° C (See *Fig.5*)	–	15	40	–	15	40	–	15	40	mA(dc)
DC Gate Trigger Voltage, V_{GT} At T_C = +25° C (See *Fig.5*)	–	1.8	3.5	–	1.8	3.5	–	1.8	3.5	V(dc)
Holding Current, I_H At T_C = +25° C	–	20	50	–	20	50	–	20	50	mA
Critical Rate of Rise of Off-State Voltage, Critical dv/dt $V_{DO} = V_{(BO)O}$ (rated value), linear rise, and T_C = +80° C (See waveshapes of *Fig.2*)	100	250	–	100	250	–	100	250	–	V/μs
Gate-Controlled Turn-On Time, t_{gt} (Delay Time + Rise Time) $V_{DX} = V_{(BO)O}$ rated value, I_{TM} = 2 A, I_{GT} = 300 mA, 0.1 μs rise time, and T_C = +25° C (See waveshapes of *Fig.3*)	–	0.7	–	–	0.7	–	–	0.7	–	μs
Circuit-Commutated Turn-Off Time, t_q (Reverse Recovery Time + Gate Recovery Time) $V_{DX} = V_{(BO)O}$ rated value, I_{TM} = 2 A, 50 μs min. pulse width, V_{RX} = 80 V min., rise time = 0.1 μs, dv/dt = 100 V/μs, di_R/dt = 10 A/μs, I_{GT} = 100 mA at turn-on, V_{GT} = 0 V at turn-off, and T_C = +80° C (See waveshapes of *Fig.4*)	–	4	6	–	4	6	–	4	6	μs

WAVESHAPE OF di/dt RATING TEST

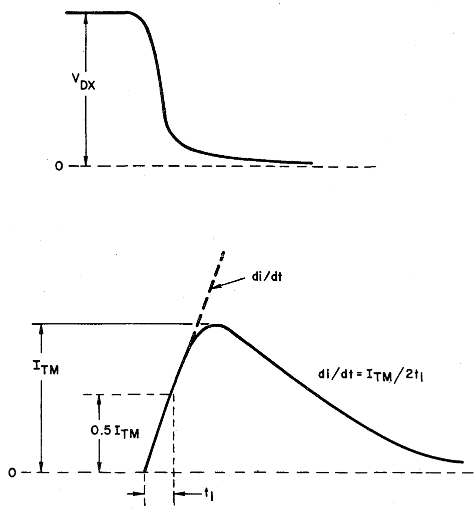


Fig. 1

WAVESHAPE OF CRITICAL dv/dt RATING TEST (LINEAR RISE)

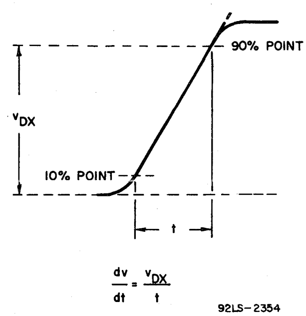


Fig. 2

WAVESHAPE OF t_{gt} RATING TEST

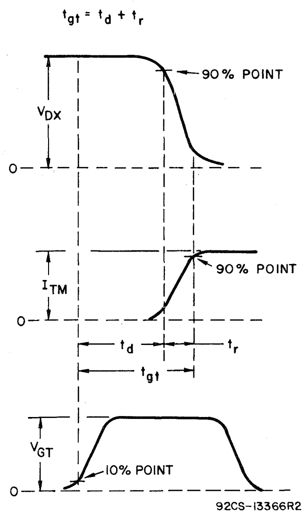


Fig. 3

WAVESHAPE OF t_q RATING TEST

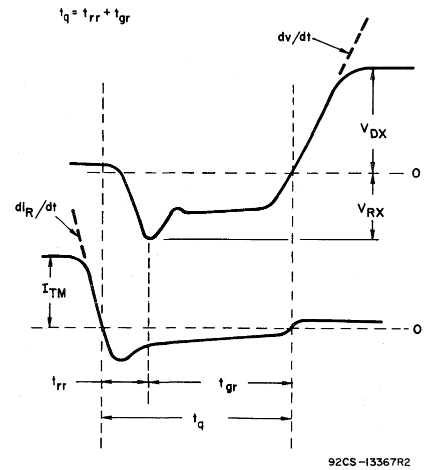


Fig. 4

FORWARD GATE CHARACTERISTICS

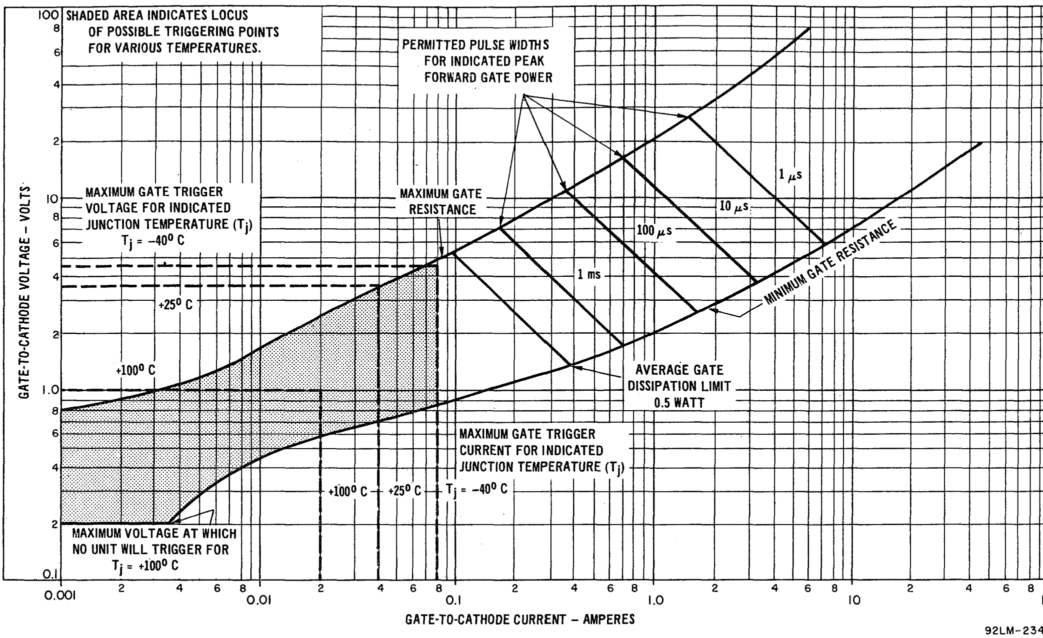


Fig. 5

TRIGGERING CONSIDERATIONS

The construction of the gate-cathode junction used in these devices provides a large periphery center gate and employs shorted-emitter design which remove restrictions on both forward and reverse peak gate voltage and peak gate current. Limiting values of volt-ampere products for different gate pulse widths are shown in *Fig.5*. These limits should be adhered to when designing pulse trigger circuits for maximum trigger pulse widths and peak power dissipation. The volt-ampere products in the reverse direction shown in *Fig.6* should be used to determine limitations for reverse gate transients or reverse gate pulses if present. In all cases, total average gate dissipation, both forward and reverse, should not exceed the average gate dissipation rating $[P_{G(AV)}]$ of 0.5 watt.

REVERSE GATE CHARACTERISTICS

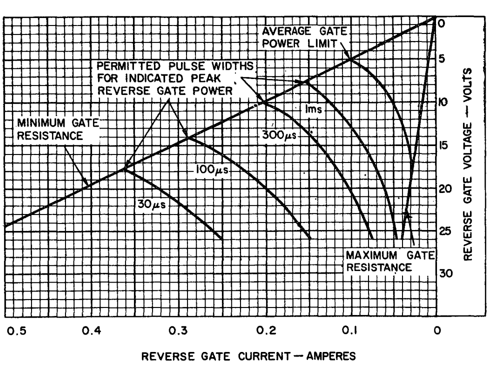


Fig. 6

Turn-on times for different gate currents are shown in *Fig.7*. These curves may be used to determine the required width of the gate trigger pulses. It is only necessary to maintain the gate trigger pulse until the magnitude of the forward anode current has reached the latching current value. However, conservative design requires that the gate trigger pulse width be at least equal to or somewhat greater than the device turn-on time. Some applications may require wider gate pulse widths for proper circuit operation. Additional information on gate characteristics and triggering requirements for use in pulse applications are contained in the RCA Reprint ST-2984 "Design Parameters for SCR Trigger Circuits".

TURN-ON TIME CHARACTERISTICS

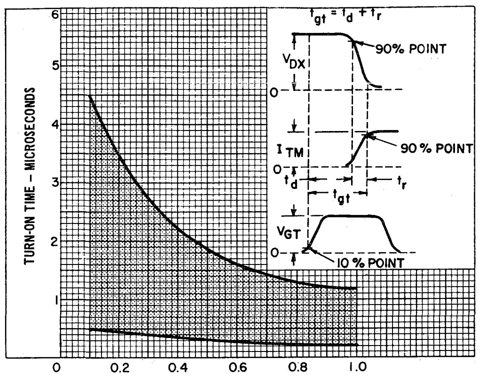


Fig. 7

In testing for turn-off time, stresses on the device similar to those shown in *Fig.4* are produced by the test set shown in *Fig.8*.

The factors affecting turn-off time are: on-state current prior to turn-off, rate of change of current going from forward to reverse, the reverse current that is available, reverse voltage, rate of change of reapplied off-state voltage, gate-trigger level, gate bias, and junction temperature. Of these effects, temperature and current are the most significant.

Because temperature has a critical effect on turn-off time, hot spots produced by fast di/dt immediately after turn-on will increase the required turn-off time. The conventional turn-off measurement is made following a long forward conduction period to allow even and predictable junction temperatures.

CONVENTIONAL TURN-OFF TIME TEST CIRCUIT

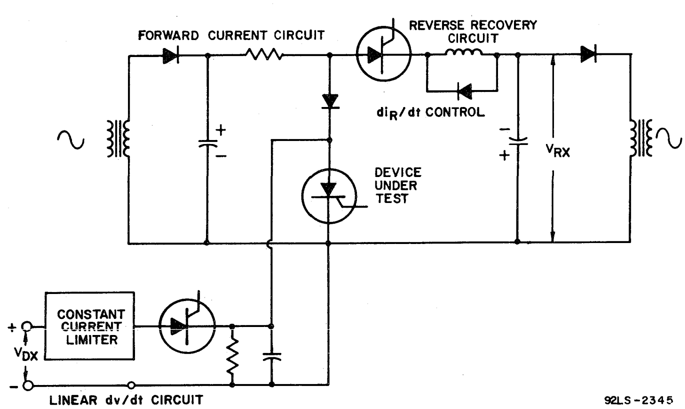


Fig. 8

RATING CHART (CASE TEMPERATURE)

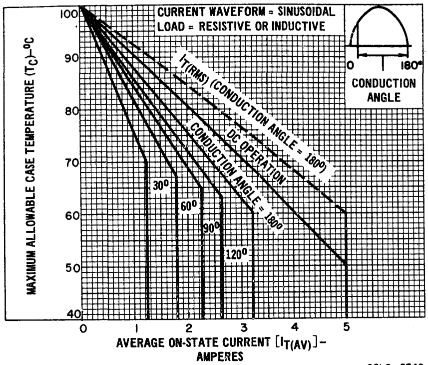


Fig. 9

POWER DISSIPATION VERSUS FREQUENCY

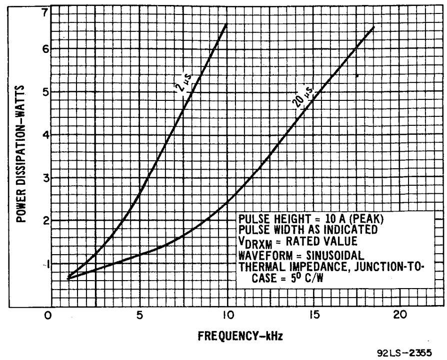


Fig. 10

SURGE CURRENT RATING

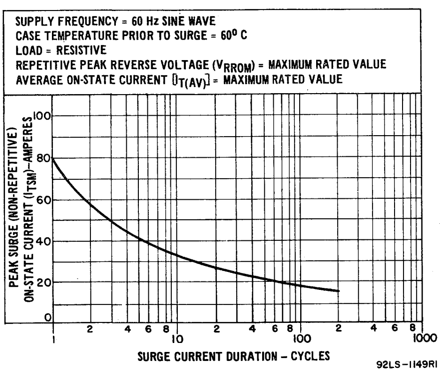


Fig. 11

POWER DISSIPATION VERSUS AVERAGE ON-STATE CURRENT

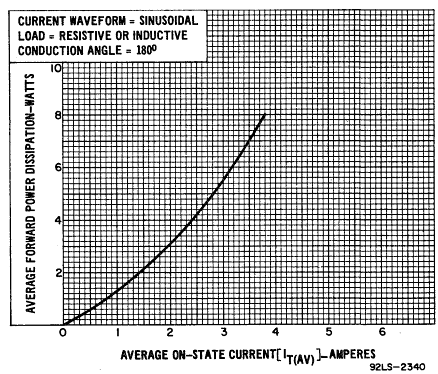


Fig. 12

ON-STATE CHARACTERISTICS

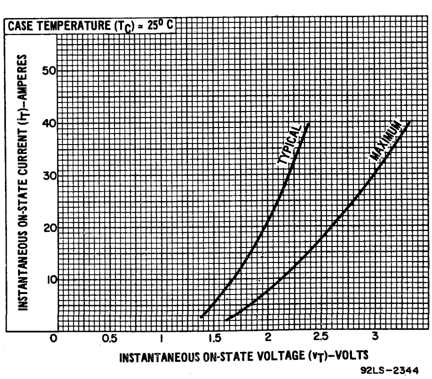
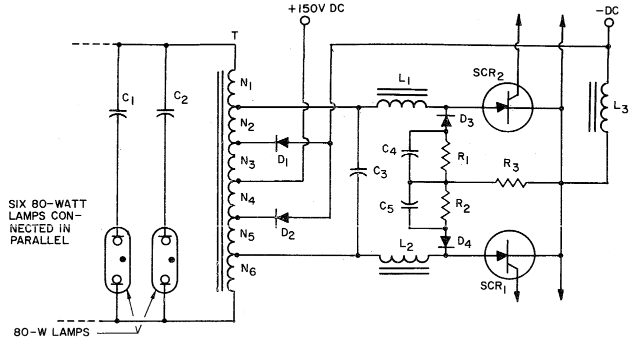


Fig. 13

TYPICAL INVERTER CIRCUIT FOR 500-WATT, 8 kHz FLUORESCENT-LIGHT CONTROL

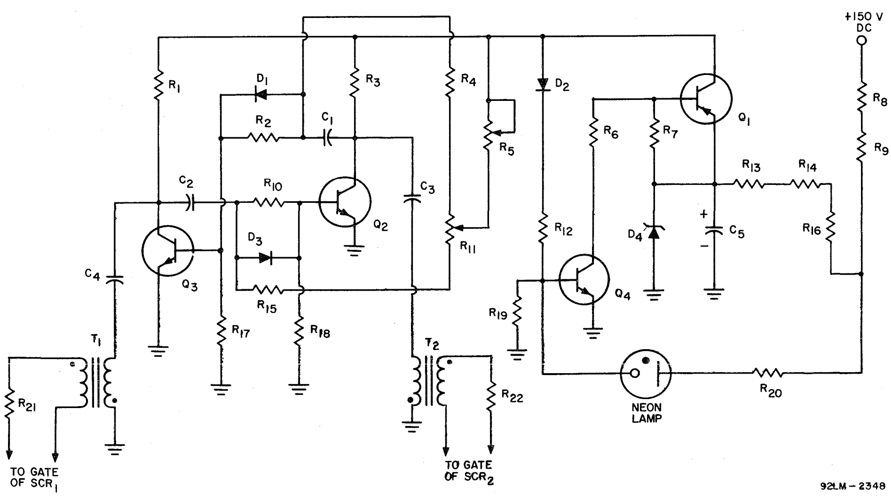


92LS-2353

C_1, C_2: 0.01 µF, 1200 V (Ballast Capacitors)
C_3: 0.01 µF, 600 V
C_4, C_5: 0.02 µF, 600 V
D_1, D_2: Fast-Recovery Diodes, 6 A, 600 V
D_3, D_4: 1N574
L_1, L_2: 32 µH
L_3: 131 Turns of No.15 Magnet Wire on Arnold Engineering Core No.A4-04117, or equivalent

R_1, R_2: 1.2 kΩ, 5 W
R_3: 200 Ω, 10 W
T: Core, 8 pieces of Indiana General No. CF-602 Material 05, or equivalent. Cross Section, 8 cm^2
N_1, N_6 – 30 Turns of No.18 Magnet Wire
N_2, N_5 – 13 Turns of No.18 Magnet Wire, 2 Strands
N_3, N_4 – 52 Turns of No.18 Magnet Wire, 2 Strands

TYPICAL TRIGGER PULSE GENERATOR FOR 500-WATT, 8 kHZ FLUORESCENT-LIGHT CONTROL INVERTER CIRCUIT

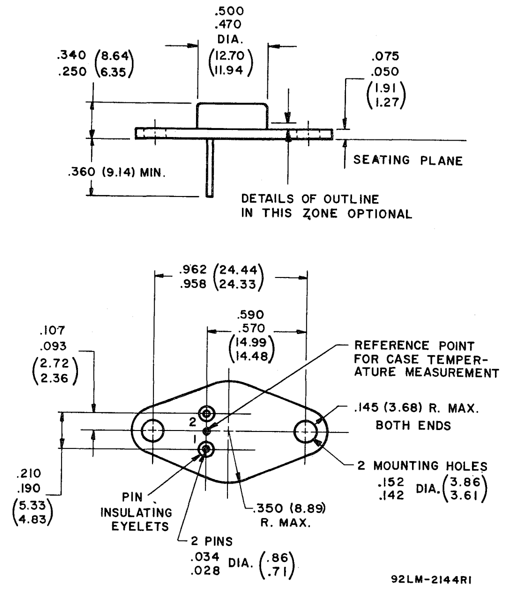


92LM-2348

Q_1: RCA-40438
Q_2, Q_3, Q_4: RCA-2N3053
C_1, C_2: 0.003 µF, 100 V
C_3, C_4: 0.02 µF, 100 V
C_5: 25 µF, 25 V, electrolytic
D_1, D_2, D_3: Transitron type T1G, or equivalent
D_4: Motorola type, 1M20Z10, or equivalent
Neon Lamp: GE type NE-83, or equivalent
R_1, R_3: 1 kΩ, 1/4 watt
R_2, R_{10}: 180 kΩ, 1/4 watt

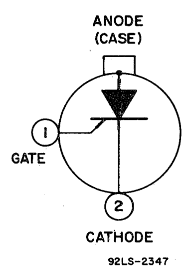
R_4, R_{12}, R_{15}, R_{17}, R_{18}: 22 kΩ, 1/4 watt
R_5, R_{11}: 10 kΩ potentiometer
R_6: 10 kΩ, 1/4 watt
R_7: 1.5 kΩ, 1/4 watt
R_8, R_9, R_{13}, R_{14}, R_{16}: 680 Ω, 2 watts
R_{19}: 5.6 kΩ, 1/4 watt
R_{20}: 33 kΩ, 1/4 watt
R_{21}, R_{22}: 10 Ω, 1/4 watt
T_1, T_2: Sprague Pulse Transformer type 42Z109, or equivalent

DIMENSIONAL OUTLINE



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

TERMINAL DIAGRAM



Pin 1: Gate
Pin 2: Cathode
Case : Anode

RCA

Solid State
Division

Thyristors

40640 40642
40641 40643
40644

SILICON CONTROLLED-RECTIFIER AND SILICON RECTIFIER COMPLEMENT

For Horizontal Deflection Circuits of Large-Screen Color-TV Receivers

RCA-40640, 40641, 40642, 40643, and 40644 are a group of silicon controlled-rectifiers and silicon rectifiers intended for use in horizontal-deflection circuits of large-screen color-television receivers.

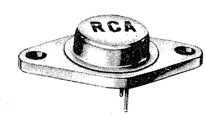
A simplified schematic diagram for the utilization of these SCR's and silicon rectifiers is shown below. For detailed information on the operation of this new deflection circuit, see Application Note AN-3780.

The 40640 silicon controlled-rectifier and the 40642 silicon rectifier are the trace circuit components. They provide bipolar switching action for controlling the horizontal yoke current during the picture tube beam-trace interval.

The 40641 silicon controlled-rectifier and the 40643 silicon rectifier are the commutating (retrace) circuit components. They control the yoke current during the retrace interval.

The 40644 silicon rectifier is used as a clamp in the trace circuit to protect the circuit components from excessively high voltages which may result from possible arcing in the picture tube or high-voltage rectifier.

40640, 40641



JEDEC TO-66

H-1340

40642
40643
40644

JEDEC
DO-26

H-1157

FEATURES

- **Designed for off-the-line operation: B+ = 155V**
- **Supply voltages: 108 to 129V ac**
- **Outstanding performance and reliability**
- **High picture-tube beam current capability: to 1.5mA dc average (max.)**
- **Can fully deflect picture tubes having deflection angles to 90°, 1-7/16" neck diameters, and 25-kV ultor voltages (nom. value)**

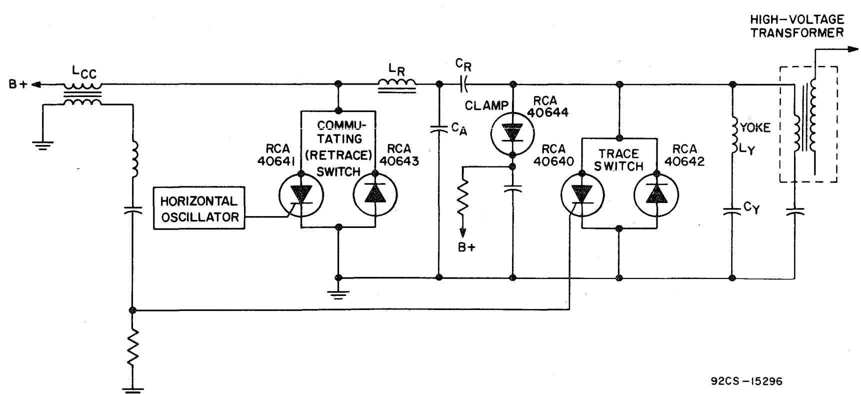


Fig.1 - Simplified schematic-diagram of horizontal output circuit.

SILICON CONTROLLED-RECTIFIERS

Maximum Ratings, *Absolute-Maximum Values:*

		40640 *Trace SCR* / 40641 *Commutating SCR*	
Repetitive Peak Off-State Voltage			
With gate open	V_{DROM}	600	V
Repetitive Peak Reverse Voltage			
With gate open	V_{RROM}	5	V
On-State Current:			
For case temperature of +60°C and 60 Hz			
Average DC at 180° conduction angle	$I_{T(AV)}$	3.2	A
RMS	$I_{T(RMS)}$	5	A
Peak Surge (Non-Repetitive) On-State Current:			
For one cycle of 60 Hz voltage	I_{TSM}	80	A
Critical Rate of Rise of On-State Current:			
For V_{DX} = $V_{(BO)O}$ rated value, I_{GT} = 50 mA, 0.1 µs rise time	di/dt	200	A/µs
Gate Power Dissipation[a]**:**			
Peak (forward or reverse) for 10 µs duration	P_{GM}	25	W
Temperature Range[b]**:**			
Storage	T_{stg}	-40 to +150	°C
Operating (case)	T_C	-40 to +100	°C

[a] Any values of peak gate current or peak gate voltage to give the maximum gate power are permissible.
[b] For information on the reference point of temperature measurement, see *Dimensional Outline*.

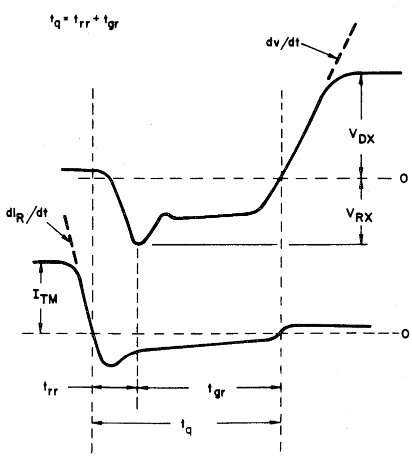


Fig.2 - Waveshape of t_q characteristic for types 40640, 40641.

SILICON CONTROLLED-RECTIFIERS

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)
For Definitions of Terms and Symbols, See Page 5

CHARACTERISTIC:		40640 Trace SCR Min.	Typ.	Max.	40641 Commutating SCR Min.	Typ.	Max.	UNIT
Breakover Voltage:								
With gate open								
At T_C = +100°C	$V_{(BO)O}$	–	–	–	400	–	–	V
At T_C = +80°C	$V_{(BO)O}$	550	–	–	–	–	–	V
Peak Forward Off-State Current:								
With gate open,								
V_{DO} = $V_{(BO)O}$ rated value								
At T_C = +100°C	I_{DOM}	–	–	–	–	0.5	1.5	mA
At T_C = +80°C	I_{DOM}	–	0.5	1.5	–	–	–	mA
Instantaneous On-State Voltage:								
For an on-state current of 30 A, T_C = +25°C	v_T	–	2.2	3	–	2.2	3	V
DC Gate Trigger Current:								
At T_C = +25°C	I_{GT}	–	15	30	–	15	30	mA(dc)
DC Gate Trigger Voltage:								
At T_C = +25°C	V_{GT}	–	1.8	4	–	1.8	4	V(dc)
Thermal Resistance:								
Junction-to-Case	θ_{J-C}	–	–	4	–	–	4	°C/W
Circuit-Commutated Turn-Off Time: (Reverse recovery time + gate recovery time)								
Trace SCR— At I_{TM} = 6 A (t_r = 25 µs, di/dt = 2.5 A/µs), V_D = 0 V (prior to turn on), V_D = 400 V (reapplied at 175 V/µs), V_R = 0.8 V (min.), I_{GT} = 100 mA, V_{GK}(bias) = -30 V (68 Ω source), f = 15.75 kHz, T_C = 70°C	t_q	–	–	2.5	–	–	–	µs
Commutating SCR— At I_{TM} = 13 A (½ sine wave 7 µs base, initial di/dt = 20 A/µs to 3 A), V_D = 350 V (prior to turn on), dV/dt = 400 V/µs (to 100 V), V_R = 0.8 V (min.) I_{GT} = 100 mA (t_p = 3 µs, t_r = 0.2 µs), V_{GK}(bias) = -2.5 V (47 Ω source during turn off), f = 15.75 kHz, T_C = 70°C	t_q	–	–	–	–	–	4.5	µs

SILICON RECTIFIERS

MAXIMUM RATINGS:

		40642 *Trace*	40643 *Commutating* *Silicon Rectifiers*	40644 *Clamp*		
Non-Repetitive Peak Reverse Voltage[c]	$V_{RM}(nonrep)$	700	800	700		V
Repetitive Peak Reverse Voltage[d]	$V_{RM}(rep)$	550	450	550		V
Forward Current:[d]						
DC	I_F	1	1	1		A
RMS	$I_{F(RMS)}$	1.9	1.6	0.2		A
Peak Repetitive	$I_{FM}(rep)$	6.5	6	0.3		A
Peak Surge[e]	$I_{FM}(surge)$	70	10	20		A
Ambient Temperature Range:						
Operating	T_A	← -40 to +150 →				°C
Storage	T_{stg}	← -40 to +175 →				°C
Lead Temperature:						
For 10 seconds maximum		← 255 →				°C

CHARACTERISTICS:

		40642	40643	40644		
Max. Instantaneous Forward Voltage Drop:						
At I_F = 4 A, $T_A \leq 75°C$	v_{FM}	1.3	1.3	2		V
Max. Reverse Current (Static):[f]						
At T_C = 100°C	I_{RM}	0.25	0.25	0.25		mA
At T_A = 25°C	I_{RM}	10	10	10		µA
Reverse Recovery Time:						
At I_F = 20 mA, I_R = 1 mA, T_C = 25°C	t_{rr}	1.1	1.1	1.6	max	µs
Turn-On Time:						
At I_F = 20 mA, T_C = 25°C	t_{on}	0.3	0.3	0.3	max	µs
Peak Turn-On Voltage:						
At I_F = 20 mA, T_C = 25°C		5	6	7	max	V

[c] Pulse width = 10 µs, pulse repetition rate = 15.7 kHz, 3 pulses.

[d] For ambient temperatures up to 45°C and maximum thermal resistance from reference point to ambient of 45°C/W, with devices operating in circuit of Fig.1.

[e] Pulse width = 3 ms.

[f] At max. peak reverse voltage and zero forward current.

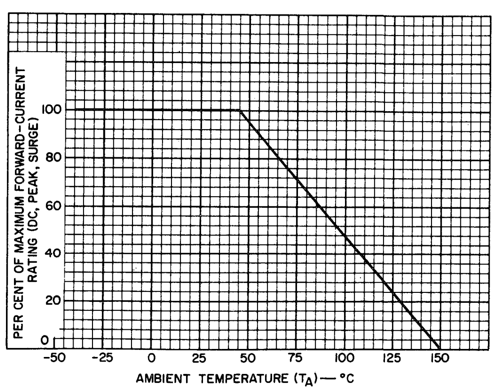


Fig.3 - Rating chart for types 40642, 40643, 40644.

OPERATING CONSIDERATIONS

The flexible leads of the silicon rectifiers are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in the leads 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 rectifiers. To absorb some of the heat, grip the flexible lead of the rectifier between the case and the soldering point with a pair of pliers.

When dip soldering is employed in the assembly of printed circuits using these rectifiers, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. Furthermore, the leads should not be dip soldered within 0.25" of the metal case.

Because the cases of these rectifiers may operate at potentials which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the devices. It is recommended that these rectifiers be mounted on the underside of the chassis.

DEFINITIONS OF TERMS AND SYMBOLS FOR SILICON CONTROLLED-RECTIFIERS

These terms and symbols follow the latest recommended standards of JEDEC. "JEDEC Suggested Standard No.7 on Thyristors, April 1967." This standard may be purchased from EIA, Engineering Department, 2001 Eye St., N.W., Washington, D.C. 20006. For convenience, formerly used symbols have been cross-referenced to the new standards.

PRINCIPAL VOLTAGE DEFINITIONS

Repetitive Peak Reverse Voltage -- V_{RROM} [Formerly v_{RM} (rep)] -- The maximum instantaneous value of reverse voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all non-repetitive transient voltages with the gate open.

Repetitive Peak Off-State Voltage -- V_{DROM} [Formerly V_{FBOM} (rep)] -- The maximum instantaneous value of off-state voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all non-repetitive transient voltages which will not cause switching from the off-state to the on-state with the gate open.

Breakover Voltage -- $V_{(BO)O}$ (Formerly v_{BOO}) -- The value of positive principal voltage at the breakover point with the gate open and at specified conditions of junction temperature.

Forward Off-State Voltage -- V_{DO} (Formerly V_{FBO}) -- The value of positive off-state voltage applied between anode and cathode with the gate open.

Reverse Voltage -- V_{RO} (Formerly V_{RBO}) -- The value of negative voltage applied between anode and cathode with the gate open.

Instantaneous On-State Voltage -- v_T (Formerly v_F) -- The instantaneous value of positive principal voltage when the thyristor is in the on-state at a given instantaneous current.

Critical Rate of Rise of Off-State Voltage -- Critical dv/dt -- The maximum value of the rate of the rise of positive principal voltage which will not cause switching from the off-state to the on-state under specified conditions.

PRINCIPAL CURRENT DEFINITIONS

Average On-State Current -- $I_{T(AV)}$ (Formerly I_{FAV}) -- The average value of the principal current when the thyristor is in the on-state.

RMS On-State Current -- $I_{T(RMS)}$ (Formerly I_{FRMS}) -- The RMS value of the principal current when the thyristor is in the on-state.

Peak Surge (Non-Repetitive) On-State Current -- I_{TSM} [Formerly $i_{FM(surge)}$] -- An overload on-state current of specific time duration and peak value which may be conducted through the thyristor for one half-cycle from a 60-Hz supply in a single-phase circuit with a resistive load. The thyristor shall be operating within its specified operating voltage, average on-state current, gate power, and temperature ratings prior to the surge current. The surge current may be repeated after sufficient time has elapsed for the device to return to pre-surge thermal equilibrium conditions.

Critical Rate of Rise of On-State Current -- Critical di/dt -- The maximum value of the rate of rise of on-state current which a thyristor can withstand under specified conditions.

Peak Forward Off-State Current -- I_{DOM} (Formerly I_{FBOM}) -- The peak value of the forward principal current when the thyristor is in the off-state with the gate open.

Peak Reverse Blocking Current -- I_{RROM} (Formerly I_{RBOM}) -- The peak value of the principal current when the thyristor is in the reverse blocking state with the gate open.

GATE DEFINITIONS

DC Gate-Trigger Voltage -- V_{GT} -- The value of gate voltage required to produce the gate trigger current under specified conditions.

DC Gate-Trigger Current -- I_{GT} -- The minimum value of gate current required to switch a thyristor from the off-state to the on-state under specified conditions.

Peak Gate Power Dissipation -- P_{GM} -- The maximum instantaneous value of gate power which may be dissipated between the gate and cathode for a specified time duration.

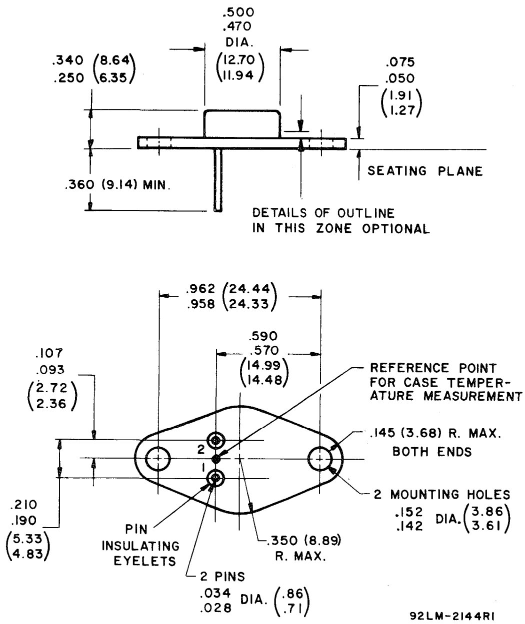
MISCELLANEOUS DEFINITIONS

Gate-Controlled Turn-On Time -- t_{gt} (Formerly t_{on}) -- The time interval between the 10 per-cent point at the beginning of the gate-trigger voltage pulse and the instant when the principal current has risen to the 90 per-cent point of its peak value during switching of the thyristor from the off-state to the on-state by a gate pulse.

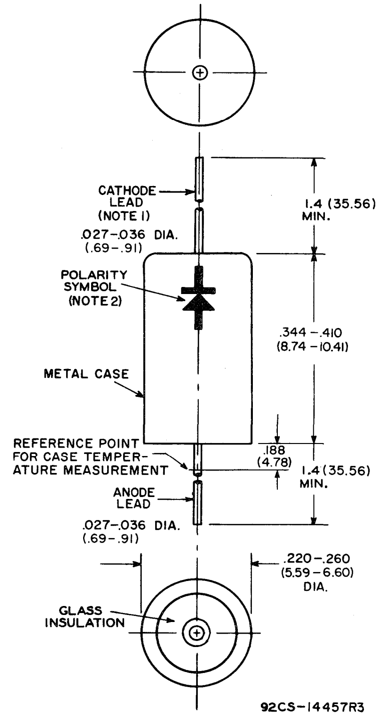
Circuit-Commutated Turn-Off Time -- t_q (Formerly t_{off}) -- The time interval between the instant when the principal current has decreased to zero after external switching of the principal voltage circuit, and the instant when the thyristor is capable of supporting a given principal voltage without turning on under specified conditions.

DIMENSIONAL OUTLINES

40640, 40641
JEDEC TO-66



40642, 40643, 40644
JEDEC DO-26



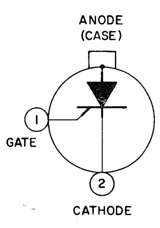
Note 1: Connected to metal case.

Note 2: Arrow indicates direction of forward (easy) current flow as indicated by dc ammeter.

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

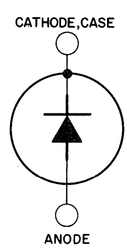
TERMINAL DIAGRAMS

40640, 40641



Pin 1: Gate
Pin 2: Cathode
Case: Anode

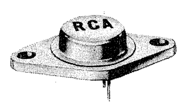
40642, 40643, 40644



RCA
Solid State
Division

Thyristors

40768



JEDEC TO-66 H-1340

5-Ampere Silicon Controlled Rectifier

For Applications in Pulse Power Supplies To Drive GaAs Laser Diodes

Features

- **High peak-current capability**
- **Good current-spreading attributes**
- **Symmetrical gate-cathode construction for uniform current density, rapid electrical conduction, and efficient heat dissipation**
- **Controlled minimum holding current**
- **Hermetic construction**
- **Low thermal resistance**

RCA-40768 is a silicon controlled rectifier intended for use in circuits which generate pulses to drive injection laser diodes. A simplified circuit of a laser pulser is shown in Fig. 1. Detailed information on circuits of this type is given in RCA Application Note AN-4469, "Solid-State Pulse Power Supplies for RCA GaAs Injection Lasers."

The conventional SCR turn-on time, turn-off time, and on-state voltage do not correlate with circuit performance in a laser pulser operating with extremely short, high-current pulses. Therefore, a functional test in a simulated pulser circuit is used to control the 40768 for laser pulser applications.

The 40768 SCR is designed for the good current-spreading and delay-time characteristics necessary to provide high-peak-current pulses to drive the laser diode. An additional significant characteristic of this device is its well controlled holding current, which assures operation only at currents sufficiently high to meet the circuit requirements.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
Case temperature (T_C) = 25°C, unless otherwise specified

REPETITIVE PEAK OFF-STATE VOLTAGE:			
Gate open	V_{DROM}	600	V
RMS ON-STATE CURRENT (Conduction angle = 180°)	$I_{T(RMS)}$	5	A
REPETITIVE PEAK ON-STATE CURRENT (0.2 μs Pulse Width):	I_{PM}		
Free-air cooling, f = 500 Hz		75	A
Free-air cooling, f = 5000 Hz		40	A
Infinite heat sink, f = 10,000 Hz		40	A
Infinite heat sink, f = 1,000 Hz		75	A
GATE POWER DISSIPATION:			
PEAK (For 10 μs pulse)	P_{GM}	25	W
TEMPERATURE RANGE:			
Storage	T_{stg}	-40 to 125	°C
Operating (Case)	T_C	-40 to 100	°C
TERMINAL TEMPERATURE (During soldering):	T_T		
For 10 s max. (terminals and case)		225	°C

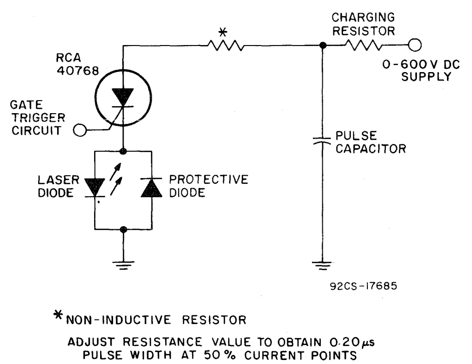
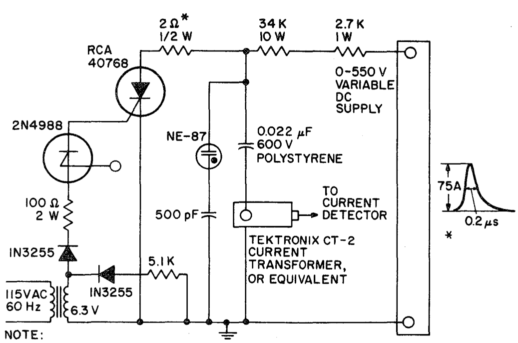


Fig. 1—Simplified laser pulser circuit. (See AN—4469 for specific circuits.)

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS Min.	LIMITS Max.	UNITS
Peak Off-State Current: Gate open, $v_D = V_{DROM}$, $T_C = 25^oC$	I_{DROM}	–	0.65	mA
$T_C = 75^oC$		–	1.2	
DC Gate-Trigger Current: $T_C = 25^oC$	I_{GT}	–	35	mA
DC Gate-Trigger Voltage: $T_C = 25^oC$	V_{GT}	–	4	V
DC Holding Current: Gate open, $T_C = 25^oC$	I_{HO}	15	–	mA
$T_C = 75^oC$		10	–	
Critical Rate-of-Rise of Off-State Voltage: For $v_D = V_{DROM}$, exponential voltage rise, gate open, $T_C = 75^oC$	dv/dt	200	–	V/μs
Source Voltage for Functional Test (See Fig. 2): $I_p = 75A$, $C = 0.022\mu F$, $R_s = 2\Omega$, f = 60Hz, pulse duration = 0.2μs, $T_C = 25^oC$	V_s	–	550	V
Thermal Resistance: Junction-to-Case	θ_{J-C}	–	7	$^oC/W$
Junction-to-Ambient	θ_{J-A}	–	40	



NOTE:
* NON-INDUCTIVE RESISTOR
ADJUST RESISTANCE VALUE TO OBTAIN 0.20μs PULSE WIDTH AT 50% CURRENT POINTS

92CS-17686

Fig. 2–Functional test circuit.

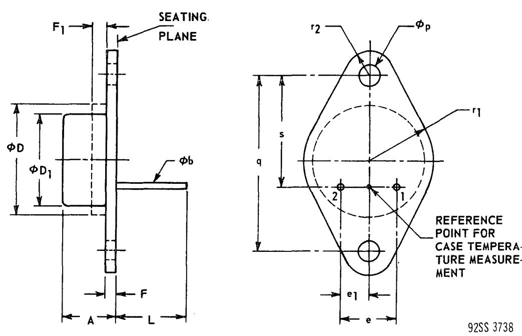
TERMINAL CONNECTIONS

Pin 1 – Gate

Pin 2 – Cathode

Mounting Flange, Case – Anode

DIMENSIONAL OUTLINE (JEDEC TO-66)



92SS 3738

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	

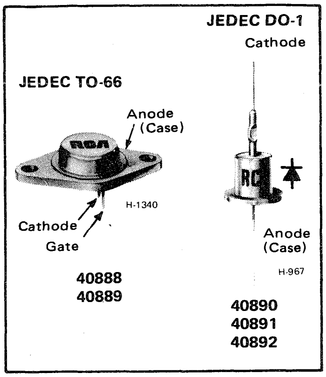
NOTES:
1. The outline contour is optional within zone defined by ϕ D and F_1.
2. Dimension does not include seating flanges.

RCA

Solid State
Division

Thyristors/Rectifiers

40888, 40889
40890, 40891, 40892



Horizontial - Deflection SCR's and Rectifiers

For 110° Large-Screen Color TV

Features:

- **Operation from supply voltages between 150 and 270 V (nominal).**
- **Ability to handle high beam current; average 1.6 mA dc.**
- **Ability to supply as much as 7 mJ of stored energy to the deflection yoke, which is sufficient for 29 mm-neck picture tubes, as well as 36.5 mm-neck tubes, both operated at 25 kV (nominal value).**
- **Highly reliable circuit which can also be used as a low-voltage power supply.**

These RCA types are designed for use in a horizontal output circuit such as that shown in Fig. 1.

The silicon controlled rectifier 40888 and the silicon rectifier 40890 are designed to act as a bipolar switch that controls horizontal yoke current during the beam trace interval. To initiate trace-retrace switching and control yoke current during retrace, the silicon controlled rectifier 40889 and the silicon recitifier 40891 act as the commutating switch.

RCA types 40888-40892, inclusive, were formerly RCA Dev. Nos. TA8158-TA8162, respectively.

The silicon rectifier 40892 may be used as a clamp to protect the circuit components from excessively high transient voltages which may be generated as a result of arcing in the picture tube or in a high-voltage rectifier tube.

To facilitate direct connection across each silicon controlled rectifier, 40888 and 40889, the anode connection of the silicon rectifiers 40890 and 40891, is reversed as compared to that of a normal power-supply rectifier diode.

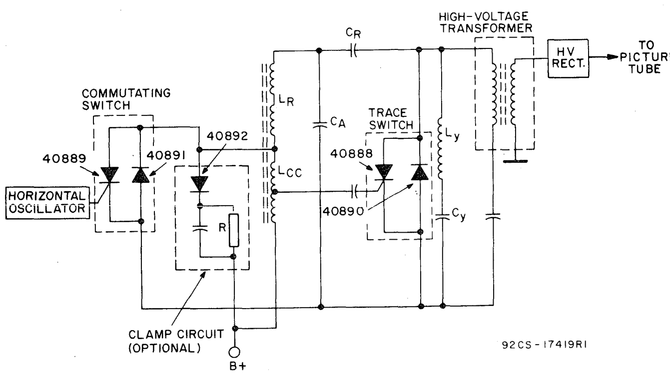


Fig. 1—Simplified schematic diagram of horizontal output circuit.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

SILICON CONTROLLED RECTIFIERS

		TRACE SCR 40888	COMMUTATING SCR 40889	
Non-Repetitive Peak Off-State Voltage:				
Gate open	V_{DSOM}	800*	750*	V
Repetitive Peak Off-State Voltage:				
Gate open	V_{DROM}			
$T_C = 80^oC$		750	700	V
Repetitive Peak Reverse Voltage:				
Gate open	V_{RROM}	25	25	V
On-State Current:				
$T_C = 60^oC$, 50 Hz sine wave, conduction angle = 180^o:				
Average DC	$I_{T(AV)}$	3.2	3.2	A
RMS	$I_{T(RMS)}$	5	5	A
Peak Surge (Non-Repetitive):				
For one cycle of applied voltage, 50 Hz	I_{TSM}	50	50	A
Critical Rate of Rise of On-State Current:				
For $V_D = V_{DROM}$ rated value, I_{GT} = 50 mA, 0.1 µs rise time	di/dt	200	200	A/µs
Gate Power Dissipation●:				
Peak (forward or reverse) for 10 µs duration, max. reverse gate bias = –35 V	P_{GM}	25	25	W
Temperature Range■:				
Storage	T_{stg}	–40 to 150		^oC
Operating (case)	T_C	–40 to 80		^oC

*Protection against transients above this value must be provided. Transients generated by arcing may persist for as long as 10 cycles.

●Any product of gate current and gate voltage which results in a gate power less than the maximum is permitted.

■Temperature measurement point is shown on the DIMENSIONAL OUTLINE.

ELECTRICAL CHARACTERISTICS, *At Maximum Ratings and at Indicated Case Temperature (T_C)*

SILICON CONTROLLED RECTIFIERS

CHARACTERISTIC	SYMBOL	LIMITS 40888 TYP.	40888 MAX.	40889 TYP.	40889 MAX.	UNITS
Peak Forward Off-State Current: Gate open, V_{DO} = Rated V_{DROM}, $T_C = 85^oC$	I_{DOM}	0.5	1.5	0.5	1.5	mA
Instantaneous On-State Voltage: i_T = 20 A, $T_C = 25^oC$	v_T	2.2	3	2.2	3	V
DC Gate Trigger Current: $T_C = 25^oC$	I_{GT}	15	40	15	45	mA
DC Gate Trigger Voltage: $T_C = 25^oC$	V_{GT}	1.8	4	1.8	4	V
Critical Rate-of Rise of Off-State Voltage: $T_C = 70^oC$	dv/dt	700 (MIN.)▲		700 (MIN.)▲		V/µs
Circuit-Commutated Turn-Off Time†: $T_C = 70^oC$, Minimum negative bias during turn-off time = –20 V (40888) and –2.5 V (40889)						
Rate of Reapplied Voltage (dv/dt) = 175 V/µs	t_q	–	2.4	–	–	µs
Rate of Reapplied Voltage (dv/dt) = 400 V/µs		–	–	–	4.2	µs
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$	–	4	–	4	$^oC/W$

▲ Up to 500 V max. See Fig. 3.

† This parameter, the sum of reverse recovery time and gate recovery time, is measured from the zero crossing of current to the start of the reapplied voltage. Knowledge of the current, the reapplied voltage, and the case temperature is necessary when measuring t_q. In the worst conditions (high line, zero-beam, off-frequency, minimum auxiliary load, etc.), turn-off time must not fall below the given values. Turn-off time increases with temperature; therefore, case temperature must not exceed 70^oC. See Figs. 2 & 3.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

SILICON RECTIFIERS

		TRACE 40890	COMMUTATING 40891	CLAMP 40892	
REVERSE VOLTAGE**:					
Non-repetitive peak●●	V_{RSM}	750	700	700	V
Repetitive peak	V_{RRM}	800	800	800	V
FORWARD CURRENT:					
RMS	$I_{F(RMS)}$	3■■	3■■	1**	A
Peak-surge (non-repetitive)●●	I_{FSM}	70	70	30	A
Peak (repetitive)	I_{FRM}	7	12	0.5	A
TEMPERATURE RANGE:					
Storage	T_{stg}		–30 to 150		°C
Operating (Case)	T_C		–30 to 80		°C
LEAD TEMPERATURE▲▲:					
For 10 s maximum	T_L		225		°C

** For ambient temperatures up to 45°C.
●● For a maximum of 3 pulses, 10 μs in duration, during any 64 μs period.
■■ Maximum current rating applies only if the rectifier is properly mounted to maintain junction temperature below 150°C. See Fig. 4.
▲▲ At distances no closer to rectifier body than points A and B on outline drawing.

ELECTRICAL CHARACTERISTICS

SILICON RECTIFIERS

CHARACTERISTIC	SYMBOL	MAXIMUM LIMITS 40890 40891	MAXIMUM LIMITS 40842	UNITS
Reverse Current: Static For V_{RRM} = max. rated value, I_F = 0, T_C = 25°C For V_R = 500 V, T_C = 100 °C	I_{RM}	10 250	– –	μA
Instantaneous Forward Voltage Drop: At I_F = 4 A, T_A = 75°C	v_F	1.4	1.5	V
Reverse-Recovery Time: I_{FM} = 3.14 A, ½ sinewave, –di/dt = – 10 A/μs, pulse duration = 0.94 μs, T_C = 25°C	t_{rr}	0.5	0.7	μs

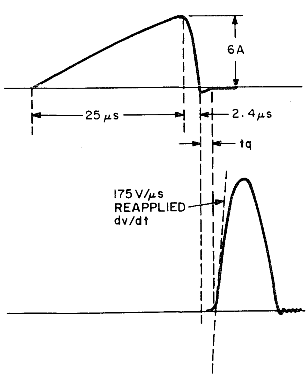


Fig.2—Circuit-commutated turn-off in the trace SCR 40888.

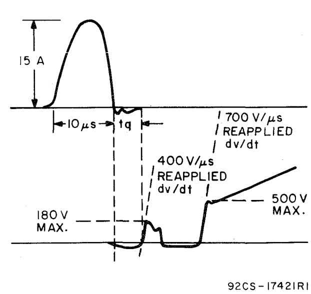
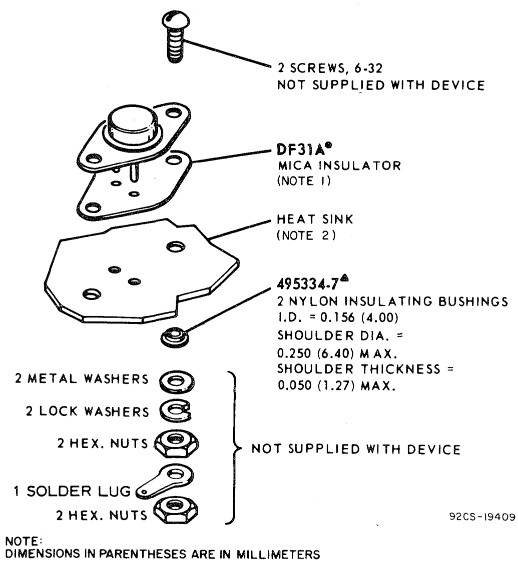


Fig.3—Circuit-commutated turn-off time in the commutating SCR 40889.

MOUNTING SCR's AND RECTIFIERS

The SCR's and rectifiers can be operated at full current only if they have adequate heat sinking. The procedure illustrated in Fig. 4 should be used when mounting the SCR's. A single aluminum plate made as shown in Fig. 5 will provide adequate heat sinking for trace and commutating rectifiers. Lip punching of the chassis at one end of the clamp plate, makes it possible to mount the rectifier using only one screw.

RCA 40888, 40889 fit socket PTS-4 (United International Dynamics Corp., 2029 Taft St., Hollywood, Fla.), or equivalent.



NOTE 1: 0.002 inch (0.51 mm) thick mica or anodized aluminum insulator drilled or punched with burrs removed.

NOTE 2: Remove burrs from chassis holes.

● Available from RCA Distributors as Part No. DF31A. 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.

▲ Available from RCA Distributors as Part No. 495334-7. Also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Fig.4—Suggested hardware and mounting arrangement for SCR's 40888 & 40889.

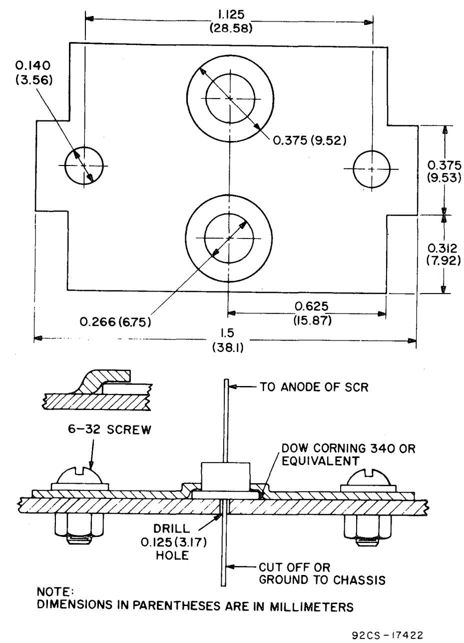
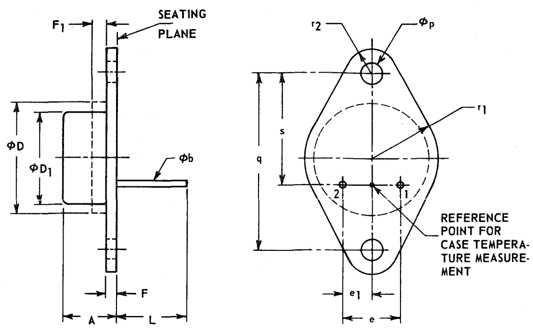


Fig.5—Suggested clamp plate and mounting arrangement for rectifiers 40890 & 40891.

DIMENSIONAL OUTLINE (JEDEC TO-66)
40888, 40889



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

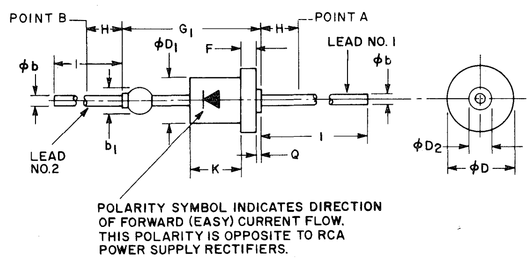
NOTES:
1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimensions does not include seating flanges.

92SS-3738

TERMINAL CONNECTIONS

Pin 1 - Gate
Pin 2 - Cathode
Mounting Flange, Case - Anode

DIMENSIONAL OUTLINE (JEDEC DO-1)
40890, 40891, 40892



92CS-17423

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕb	0.027	0.035	0.69	0.89	2
b_1		0.125		3.18	1
ϕD	0.360	0.400	9.14	10.16	
ϕD_1	0.245	0.280	6.22	7.11	
ϕD_2		0.200		5.08	
F		0.075		1.91	
G_1		0.725		18.42	
K	0.220	0.260	5.59	6.60	
1	1.000	1.625	25.40	41.28	
Q		0.025		0.64	
H	0.5		12.7		

NOTES:
1. Dimension to allow for pinch or seal deformation anywhere along tubulation (optional).
2. Diameter to be controlled from free end of lead to within 0.188 inch (4.78 mm) from the point of attachment to the body. Within the 0.188 inch (4.78 mm) dimension, the diameter may vary to allow for lead finishes and irregularities.

TERMINAL CONNECTIONS

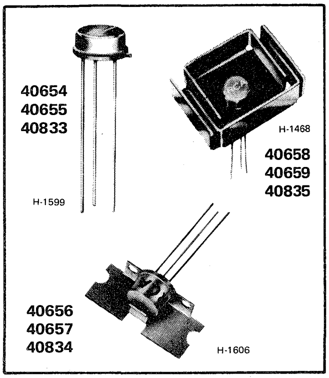
Lead No. 1 & Case – Anode
Lead No. 2 – Cathode

RCA

Solid State Division

Thyristors

40654 40657 40833
40655 40658 40834
40656 40659 40835



7-Ampere "Low-Profile" Silicon Controlled Rectifiers

For Power Switching, Power Control, Power Crowbar, and Ignition Applications

Features:

- **Forward and reverse gate ratings**
- **All-diffused center gate construction**
- **Low leakage currents, both forward and reverse**
- **Low forward voltage drop at high current levels**
- **High pulse-current capability for capacitor-discharge ignition circuits**
- **Sub-cycle surge capability curve**
- **High dv/dt capability**
- **Low switching losses**
- **Low thermal resistance**

RCA-40654–40659 and 40833–40835, inclusive, are all-diffused, three-junction, silicon controlled rectifiers (reverse-blocking triode thyristors) for capacitor-discharge ignition systems, high-voltage generators, and power-switching and control applications.

Types 40654, 40655, and 40833 use the 3-lead, low-profile package (similar to the JEDEC TO-5). They may be used in capacitor-discharge ignition systems (battery or magneto types) for internal combustion engines, electronic igniters, and high-voltage generators. Other uses are power-control and power-switching circuits.

Types 40656, 40657, and 40834 employ integral heat spreaders; types 40658, 40659, and 40835 have integral heat radiators.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40654 40656 40658	40655 40657 40659	40833 40834 40835	
NON-REPETITIVE PEAK REVERSE VOLTAGE•					
Gate open	V_{RSOM}	250	500	700	V
NON-REPETITIVE PEAK FORWARD VOLTAGE•					
Gate open	V_{DSOM}	250	500	700	V
REPETITIVE PEAK REVERSE VOLTAGE•					
Gate open	V_{RROM}	200	400	600	V
REPETITIVE PEAK OFF-STATE VOLTAGE•					
Gate open	V_{DROM}	200	400	600	V
RMS ON-STATE CURRENT (Conduction angle = 180°):	$I_{T(RMS)}$				
Case temperature (T_C) = 60°C		7 (40654–5, 40833)	See Fig. 10 (40656–7, 40834)		A
Ambient temperature (T_A) ≤ 100°C		See Fig. 9 (40654–5, 40833)	See Fig. 11 (40658–9, 40835)		
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of applied principal voltage					
60 Hz (sinusoidal)		100	100	100	A
50 Hz (sinusoidal)		85	85	85	A
For more than one cycle of applied principal voltage		See Fig. 12			
PEAK REPETITIVE ON-STATE CURRENT† (See Fig. 21):	I_{TRM}				
Duty factor = 0.1%, T_C = 75°C					
Pulse duration = 5 μs (min.), 20 μs (max.)		100	100	100	A
RATE OF CHANGE OF ON-STATE CURRENT:					
$V_{DM} = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.5 μs (See Fig. 1)	di/dt		200		A/μs

Continued on next page.

MAXIMUM RATINGS, (Cont'd).

For Operation with Sinusoidal Supply Voltage at Frequencies up to 50/60 Hz and with Resistive or Inductive Load.

		40654 40656 40658	40655 40657 40659	40833 40834 40835	
NON-REPETITIVE SUB-CYCLE SURGE CURRENT:					
T_C = 25°C, single pulse, I_{GT} = 50 mA, 10 μs square pulse			See Fig. 20		
GATE POWER DISSIPATION▲:					
PEAK FORWARD (for 1 μs max.)	P_{GM}	40	40	40	W
PEAK REVERSE	P_{RGM}		See Fig. 14		
AVERAGE (averaging time = 10 ms, max.)	$P_{G(AV)}$	0.5	0.5	0.5	W
TEMPERATURE RANGE♦:					
Storage	T_{stg}		-65 to +150		°C
Operating (case)	T_C		-65 to +100		°C
LEAD TEMPERATURE (During soldering)■:					
For 10 s max. for case or leads			225		°C

† When rms current exceeds 4 amperes (maximum rating for the anode lead), connection must be made to the case.

●These values do not apply if there is a positive gate signal. Gate must be open, terminated, or have negative bias.

▲Any values of peak gate current or peak gate voltage that yield the maximum gate power are permissible.

♦For information on the reference point of temperature measurement, see dimensional outlines.

■When these devices are soldered directly to the heat sink, a 60/40 solder should be used. Case heating time should be a minimum . . . sufficient to allow the solder to flow freely.

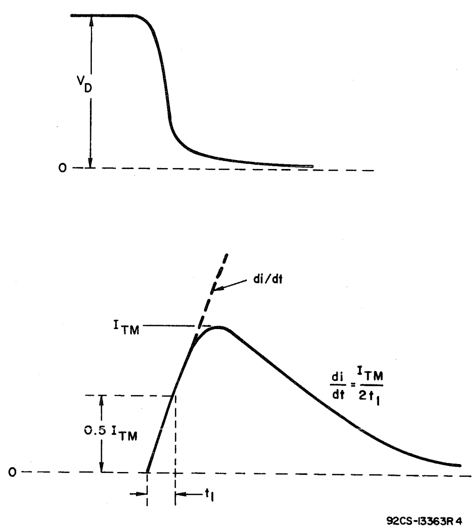


Fig. 1—Rate-of-change of on-state current with time (defining di/dt).

ELECTRICAL CHARACTERISTICS, *At maximum ratings and at indicated case temperature (T_C) unless otherwise specified*

CHARACTERISTIC	SYMBOL	LIMITS 40654, 40655, 40833 MIN.	TYP.	MAX.	LIMITS 40656, 40657, 40658, 40659, 40834, 40835 MIN.	TYP.	MAX.	UNITS
PEAK OFF-STATE CURRENT: (Gate Open, T_C = +100°C) FORWARD, $V_D = V_{DROM}$	I_{DOM}	–	0.1	0.5	–	0.2	1.5	mA
REVERSE, $V_R = V_{RROM}$	I_{ROM}	–	0.05	0.5	–	0.1	1.5	mA
INSTANTANEOUS ON-STATE VOLTAGE: For i_T = 30 A and T_C = +25°C	v_T	–	1.9	2.6	–	1.9	2.6	V
DC GATE TRIGGER CURRENT: V_D = 12 V (DC), R_L = 30 Ω, T_C = +25°C	I_{GT}	–	6	15	–	6	15	mA
For other case temperatures		See Fig. 16						
DC GATE TRIGGER VOLTAGE: V_D = 12 V (DC), R_L = 30 Ω, T_C = +25°C	V_{GT}	–	0.65	1.5	–	0.65	1.5	V
For other case temperatures		See Fig. 17						
INSTANTANEOUS HOLDING CURRENT: Gate Open and T_C = +25°C	i_{HO}	–	9	20	–	9	20	mA
For other case temperatures		See Fig. 18						
CRITICAL RATE-OF-RISE OF OFF-STATE VOLTAGE: $V_D = V_{DROM}$, Exponential rise, T_C = +100°C (See Fig. 3)	dv/dt	20	200	–	20	200	–	V/μs
GATE CONTROLLED TURN-ON TIME: $V_D = V_{DROM}$, i_T = 4.5 A, I_{GT} = 200 mA, 0.1 μs rise time, T_C = +25°C (See Fig. 4)	t_{gt}	–	1	2	1	2	–	μs
CIRCUIT COMMUTATED TURN-OFF TIME: $V_D = V_{DROM}$, i_T = 2 A, Pulse Duration = 50 μs, dv/dt = 20V/μs, di/dt = -30A/μs, I_{GT} = 200 mA at turn on, T_C = +75°C (See Fig. 5)	t_q	–	15	50	–	15	50	μs
THERMAL RESISTANCE: Junction-to-Case	$R_{\theta JC}$	–	–	5	–	–	5	°C/W
Junction-to-Ambient (See dimensional outlines)	$R_{\theta JA}$	–	–	120	–	–	30 (40658–9, 40835)	°C/W
Junction-to-Heat Spreader (See dimensional outline)	–	–	–	–	–	–	7 (40656–7, 40834)	°C/W

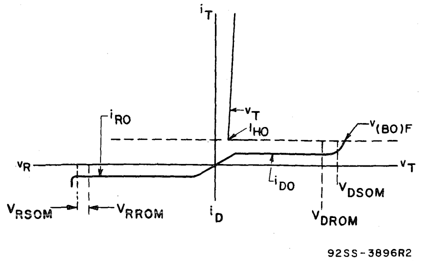


Fig.2—Principal voltage-current characteristics.

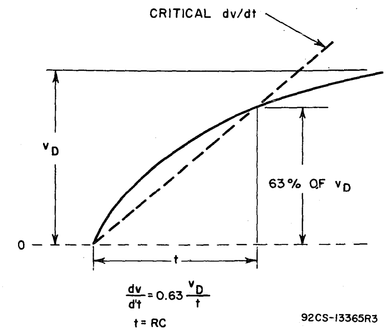


Fig.3—Oscilloscope display of critical rate-of-rise of off-state voltage (critical dv/dt).

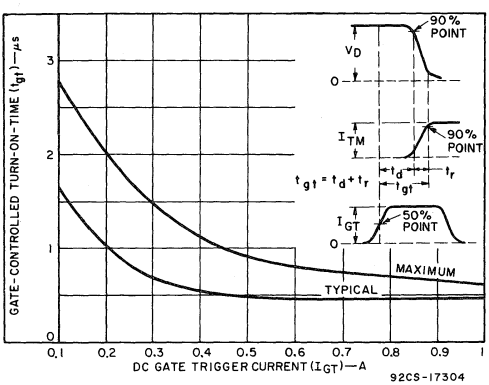


Fig.4—Gate controlled turn-on time (t_{gt}) vs. gate trigger current.

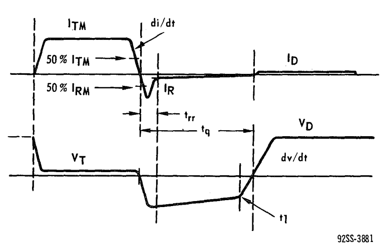


Fig.5—Oscilloscope display for measurement of circuit commutated turn-off time (tq).

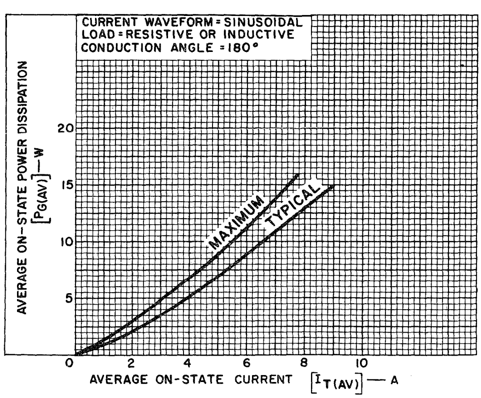


Fig.6—Power dissipation vs. on-state current.

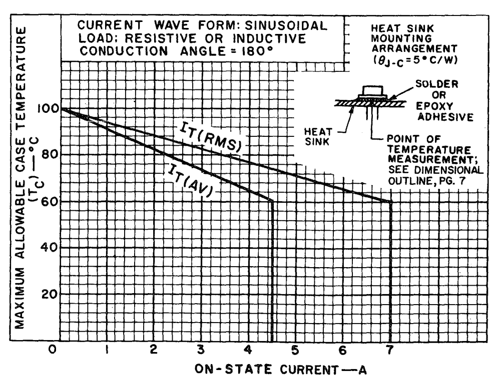


Fig.7—Maximum allowable case temperature vs. on-state current for types 40654, 40655 and 40833.

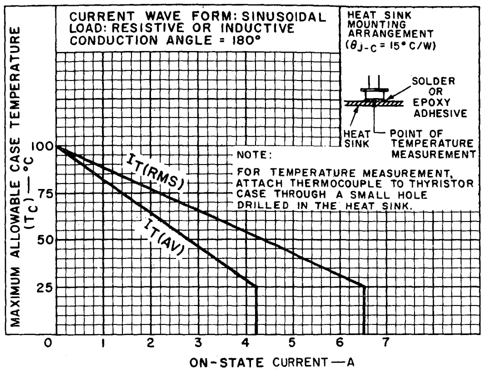


Fig.8—Maximum allowable case temperature vs. on-state current for types 40654, 40655 and 40833.

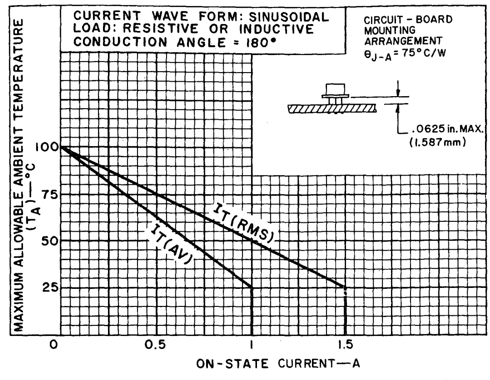


Fig.9—Maximum allowable ambient temperature vs. on-state current for types 40654, 40655 and 40833.

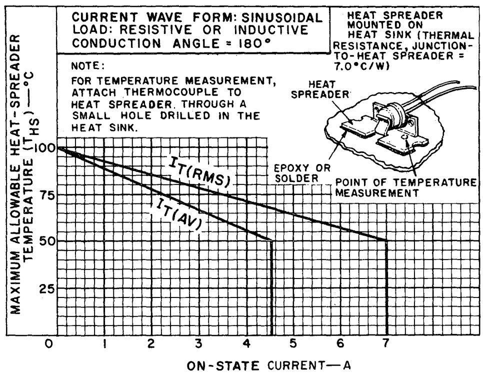


Fig.10—Maximum allowable heat-speader temperature vs. on-state current for types 40656, 40657 and 40834.

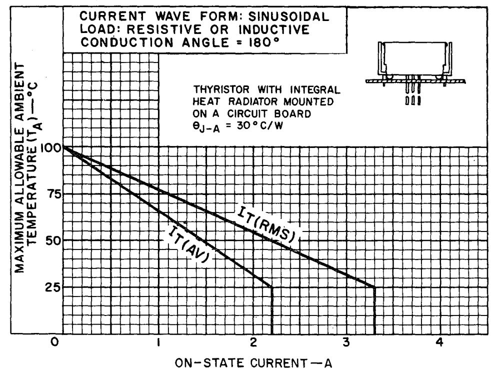


Fig.11—Maximum allowable ambient temperature vs. on-state current for types 40658, 40659 and 40835.

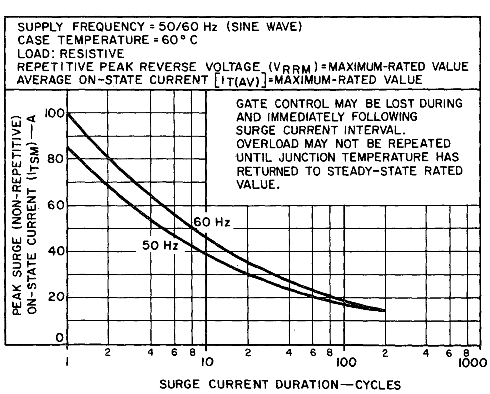


Fig.12—Peak surge on-state current vs. surge current duration for all types.

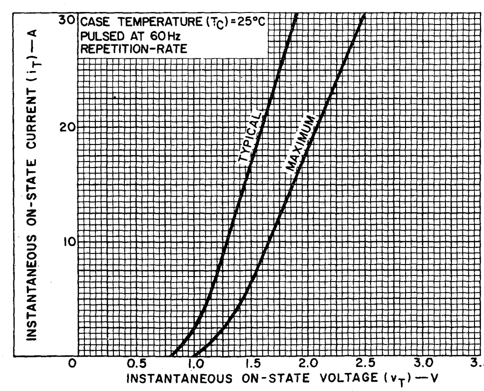


Fig.13—Instantaneous on-state current vs. on-state voltage for all types.

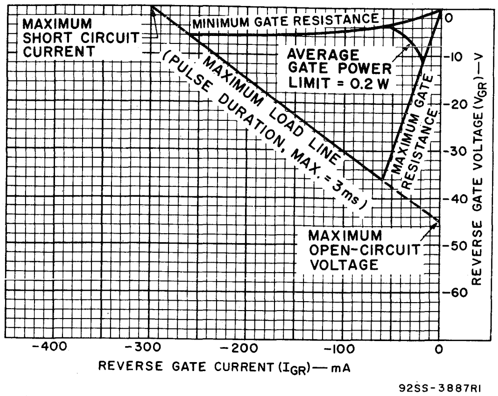


Fig. 14—Reverse gate voltage vs. reverse gate current.

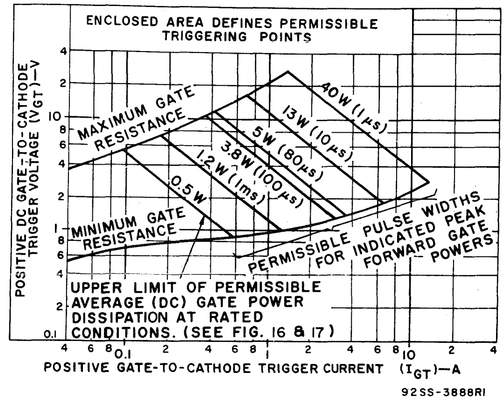


Fig. 15—Gate pulse characteristics for forward triggering mode.

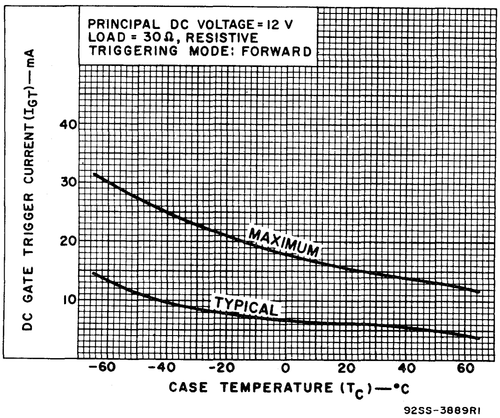


Fig. 16—DC gate-trigger current (forward) vs. case temperature.

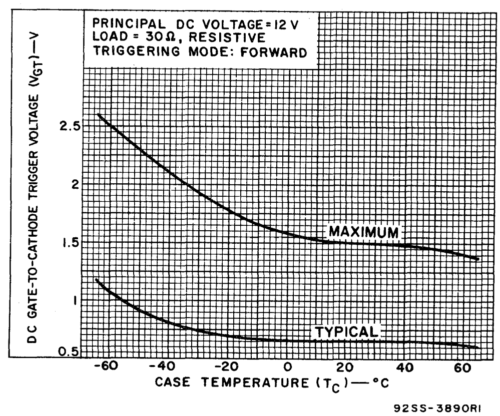


Fig. 17—DC gate-trigger voltage vs. case temperature.

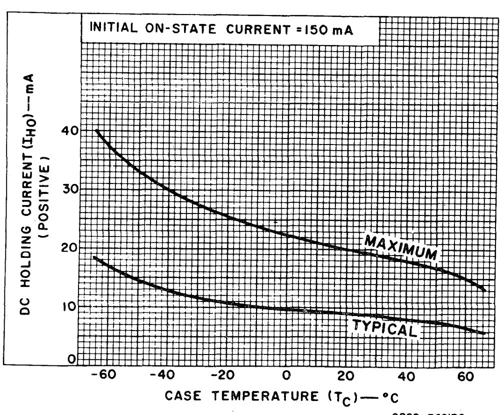


Fig. 18—DC holding current (positive) vs. case temperature.

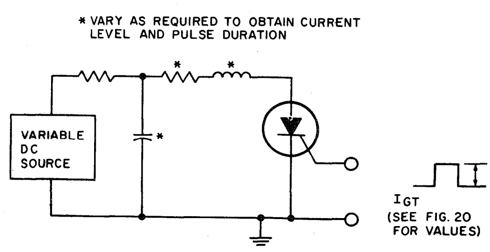


Fig. 19—Sub-cycle surge capability test circuit.

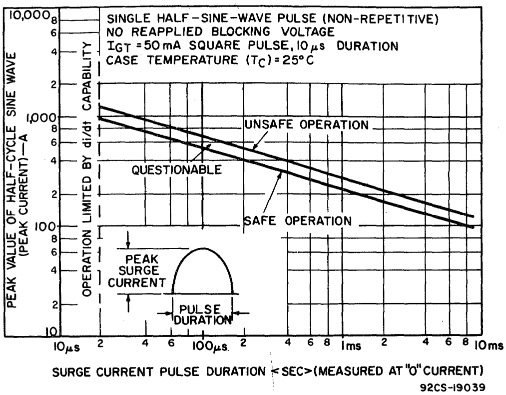


Fig.20—Sub-cycle surge capability.

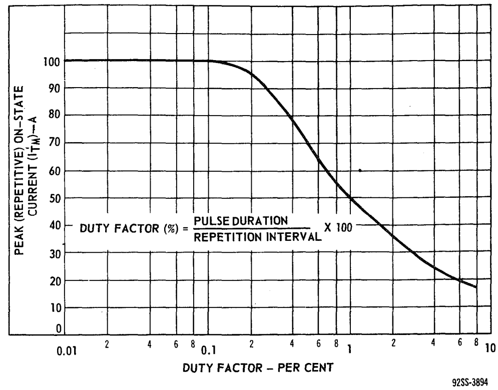
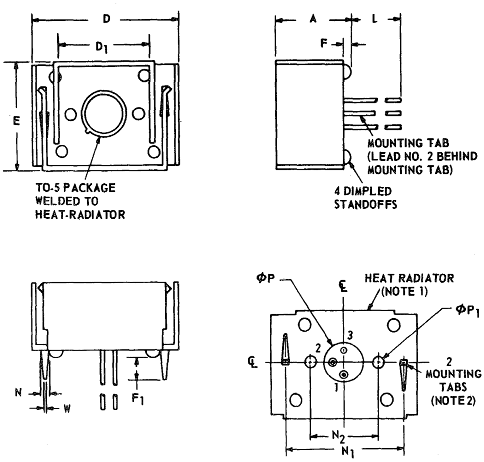


Fig.21—Derating curve for peak pulse current (repetitive) vs. duty factor for the ignition circuit.

DIMENSIONAL OUTLINE FOR TYPES 40658, 40659, & 40835



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.630	–	16.00	
D	1.205	1.235	30.61	31.37	
D_1	0.745	0.755	18.923	19.177	
E	0.875	0.905	22.22	22.99	
F	0.040	0.055	1.02	1.40	
F_1	0.170	0.225	4.32	5.72	
L	0.885	–	22.48	–	
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
N_2	0.687	0.689	17.45	17.50	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 in. (1.78 mm) dia.
3. Measured at bottom of heat radiator

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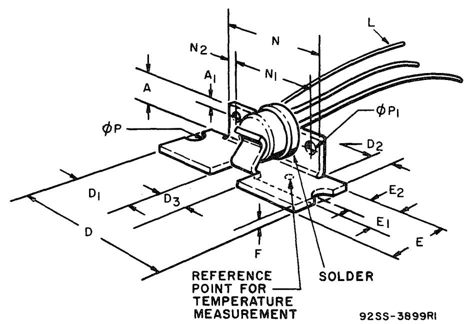
DIMENSIONAL OUTLINE FOR TYPES 40656, 40657, & 40834

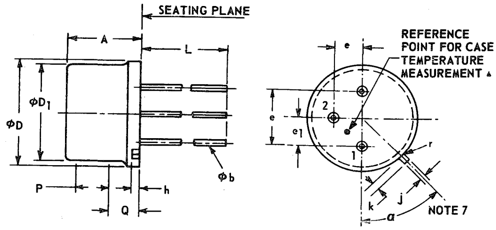


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.22		5.58		
A_1	0.75		19.05		
D	1.0		25.4		
D_1	0.406		10.31		
D_2	0.14	0.16	3.55	4.06	
D_3	0.188		4.77		
E	0.40		10.16		
E_1	0.32		8.12		
E_2	0.156		3.96		
F	0.02		0.05		
L	0.95	—	24.13	–	1
N	0.69	0.71	17.52	18.03	
N_1	0.55		13.97		
N_2	0.75		19.05		
φP	0.072 Rad.		1.83 Rad.		
$φP_1$	0.094 Dia.		2.39 Dia.		2

NOTES:

1. Min. length, 3 leads.
2. Two holes.

DIMENSIONAL OUTLINE FOR TYPES 40654, 40655, & 40833



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.160	0.180	4.06	4.57	
φb	0.017	0.021	0.432	0.533	2
φD	0.355	0.366	9.017	9.296	
$φD_1$	0.323	0.335	8.204	8.51	
e	0.190	0.210	4.83	5.33	
e_1	0.100 TRUE POSITION		2.54 TRUE POSITION		4, 5
he	0.15	0.035	0.381	0.889	
j	0.028	0.035	0.711	0.889	5
k	0.029	0.045	0.737	1.14	3, 5
L	0.985	1.015	25.02	25.78	2
P	0.100		2.54		1
Q					6
r		0.007		0.179	
α	42°	48°			5, 7

92SS 3901R1

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.012 in. (0.279mm).
2. (Three Leads) φb applies between seating plane and 1.015in. (25.78mm).
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.021in. (0.533mm) measured at the seating plane of the device shall be within 0.007in. (0.178mm) 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 of JEDEC publication 12E, May 1964.
6. Details of outline in this zone optional.
7. Tab centerline.

▲CASE TEMPERATURE MEASUREMENT

The specified temperature-reference point should be used when making temperature measurements. A low-mass temperature probe or thermocouple having wire no larger than AWG No. 26 should be attached at the temperature reference point.

TERMINAL CONNECTIONS

TYPES 40654, 40655, 40833

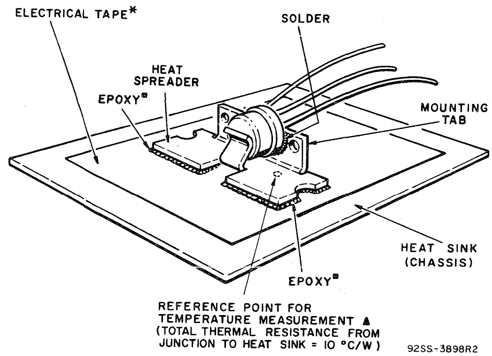
Lead 1 – Cathode
Lead 2 – Gate
Case, Lead 3 – Anode

TYPES 40656, 40657, 40834

Lead 1 – Cathode
Lead 2 – Gate
Case, Lead 3, Heat Spreader – Anode

TYPES 40658, 40659, 40835

Lead 1 – Cathode
Lead 2 – Gate
Case, Lead 3, Heat Radiator – Anode



* Scotch brand electrical tape No. 27 (thermo setting one side), Minnesota Mining & Mfg. Co., St Paul, Minnesota, or equivalent.

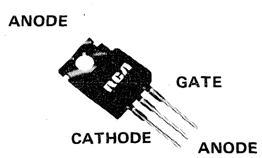
■ An epoxy such as Hysol Epoxy Patch Kit 6C, Hysol Corporation, Olean, N.Y. 14761, or equivalent.

▲ For heat sink temperature measurement, the thermocouple (wire no lagrer than AWG No. 26) should be inserted in a small, shallow hole drilled in (but not through) the heat sink at the indicated tempera ture reference point.

Fig.22–Suggested mounting arrangement for types 40656, 40657, & 40834 (case insulated from heat sink).

RCA
Solid State
Division

Thyristors
40867
40868 40869



JEDEC TO-220 AB H-1535

8-Ampere
Silicon Controlled Rectifiers

For Power Switching, Power Control, and Ignition Applications

Features:

- **Glass passivated chip**
- **High dv/dt capability**
- **8-A (RMS) on-state current ratings**
- **Low on-state voltage at high current levels**
- **100-A peak surge capability**
- **Low thermal resistance**
- **Shorted-emitter gate-cathode construction . . . contains an internally diffused resisto between gate and cathode**
- **Center gate construction . . . provides rapid uniform gate-current spreading for faster turn-on with substantially reduced heating effects**
- **Package design suitable for mounting on a printed-circuit board**

RCA types 40867, 40868,■ and 40869■ are medium-power silicon controlled rectifiers designed for switching ac and dc currents. These reverse-blocking thyristors switch from the off-state to the on-state when both the anode and gate voltages are positive. Negative anode voltages make these devices revert to the blocking state regardless of gate-voltage polarity.

The unique plastic package design provides easy package mounting and low thermal resistance, allowing operation at high case temperatures and permitting reduced heat-sink size. These SCRs can be used in lighting and motor-speed control, capacitor-discharge ignition circuits, high-voltage generators, automotive applications, and power-switching systems.

■Formerly RCA Dev.–types TA7404 and TA7405, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40867	40868	40869	
NON-REPETITIVE PEAK REVERSE VOLTAGE* Gate Open	V_{RSOM}	125	250	500	V
NON-REPETITIVE PEAK FORWARD VOLTAGE* Gate Open	V_{DSOM}	125	250	500	V
REPETITIVE PEAK REVERSE VOLTAGE* Gate Open	V_{RROM}	100	200	400	V
REPETITIVE PEAK OFF-STATE VOLTAGE* Gate Open	V_{DROM}	100	200	400	V
RMS ON-STATE CURRENT For T_C of +80°C and Conduction Angle of 180°	$I_{T(RMS)}$	8	8	8	A
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}				
For one cycle of 400-Hz applied principal voltage		200	200	200	A
For one cycle of 60-Hz applied principal voltage		100	100	100	A
For one cycle of 50-Hz applied principal voltage		85	85	85	A
For more than one full cycle of applied principal voltage			See Fig. 7.		
RATE OF CHANGE OF ON-STATE CURRENT $V_D = V_{DROM}$, I_{GT} = 80 mA, t_r = 0.5 μs (See Fig. 3)	di/dt	100	100	100	A/μs
GATE POWER DISSIPATION▲:					
PEAK FORWARD (for 10 μs max.)	P_{GM}	16	16	16	W
PEAK REVERSE	P_{RGM}		See Fig. 13.		
AVERAGE (averaging time = 10 ms max.)	$P_{G(AV)}$	0.5	0.5	0.5	W
TEMPERATURE RANGE♦:					
Storage			-65 to +150		°C
Operating (Case)			-65 to +100		°C
Soldering (10 sec. max.)			250		°C

*These values do not apply if there is a positive gate signal. Gate must be open or negatively biased.

▲Any values of peak gate current or peak gate voltage which result in an equal or lower power are permissible.

♦For information on the reference point of temperature measurement, see Dimensional Outline.

ELECTRICAL CHARACTERISTICS, *At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified.*

CHARACTERISTIC	SYMBOL	LIMITS 40867 MIN.	40867 TYP.	40867 MAX.	40868 MIN.	40868 TYP.	40868 MAX.	40869 MIN.	40869 TYP.	40869 MAX.	UNITS
PEAK OFF-STATE CURRENT: (Gate Open, T_C = +100°C) FORWARD, $V_D = V_{DROM}$	I_{DOM}	–	0.1	2	–	0.1	2	–	0.1	2	mA
REVERSE (REPETITIVE), $V_R = V_{RROM}$	I_{ROM}	–	0.1	3	–	0.1	3	–	0.1	3	mA
INSTANTANEOUS ON-STATE VOLTAGE: For i_T = 30 A and T_C = +25°C	v_T	–	1.7	2.0	–	1.7	2.0	–	1.7	2.0	V
DC GATE TRIGGER CURRENT: V_D = 12 V (DC) R_L = 30 Ω T_C = +25°C	I_{GT}	–	8	15	–	8	15	–	8	15	mA
For other case temperatures		See Fig. 9.									
DC GATE TRIGGER VOLTAGE: V_D = 12 V (DC) R_L = 30 Ω T_C = +25°C	V_{GT}	–	0.9	1.5	–	0.9	1.5	–	0.9	1.5	V
For other case temperatures		See Fig. 10.									
INSTANTANEOUS HOLDING CURRENT: Gate Open and T_C = +25°C	i_{HO}	–	10	20	–	10	20	–	10	20	mA
For other case temperatures		See Fig. 11.									
CRITICAL RATE-OF-RISE OF OFF-STATE VOLTAGE: $V_D = V_{DROM}$ Exponential rise, T_C = +100°C (See Fig. 2.)	dv/dt	75	300	–	50	300	–	30	200	–	V/μs
For other case temperatures		See Fig. 14.									
GATE CONTROLLED TURN-ON TIME: $V_D = V_{DROM}$, i_T = 4.5 A, i_T = 2 A I_{GT} = 80 mA, 0.1 μs rise time T_C = +25°C (See Fig. 5.)	t_{gt}	–	1.6	2.5	–	1.6	2.5	–	1.6	2.5	μs
CIRCUIT COMMUTATED TURN-OFF TIME: $V_D = V_{DROM}$, i_T = 2 A Pulse Duration = 50 μs dv/dt = 200 V/μs, di/dt = –10 A/μs I_{GT} = 200 mA at turn on, T_C = +75°C (See Fig. 4.)	t_q	–	10	35	–	10	35	–	10	35	μs
THERMAL RESISTANCE: Junction-to-Case	$R_{\theta J\text{-}C}$	–	–	2.2	–	–	2.2	–	–	2.2	°C/W
Junction-to-Ambient	$R_{\theta J\text{-}A}$	–	–	60	–	–	60	–	–	60	°C/W

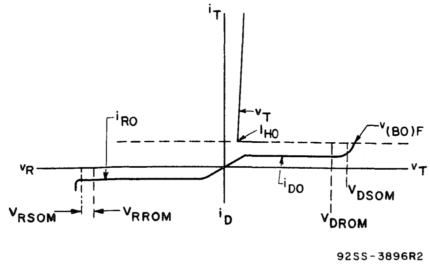


Fig. 1—Principal voltage-current characteristic.

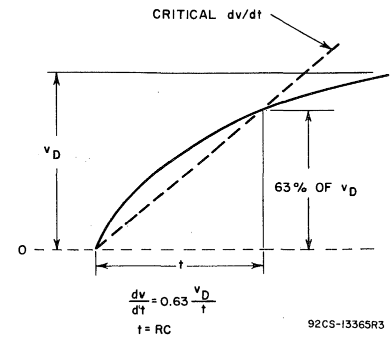


Fig.2—Rate-of-rise of off-state voltage with time (defining critical dv/dt).

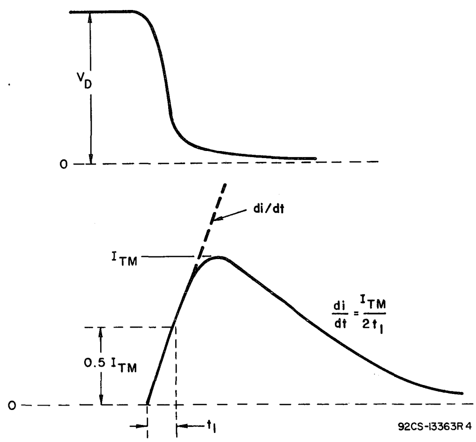


Fig.3—Rate-of-change of on-state current with time (defining di/dt).

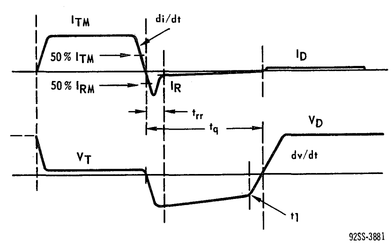


Fig.4—Relationship between instantaneous on-state current and voltage showing reference points for definition of circuit-commutated turn-off time (t_q).

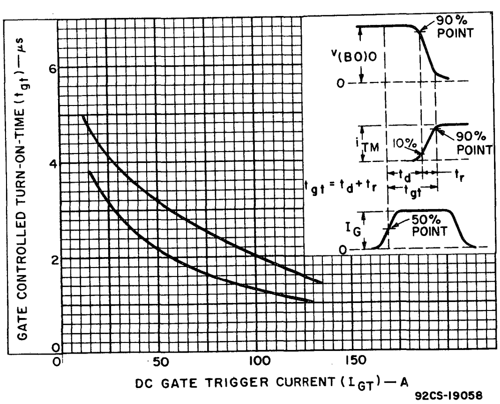


Fig.5—Typical gate-controlled turn-on time vs. gate trigger current.

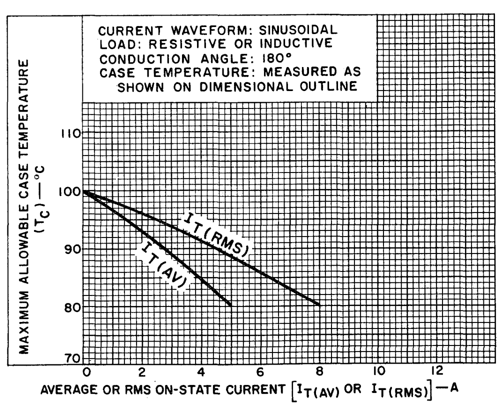


Fig.6—Maximum allowable case temperature vs. on-state current.

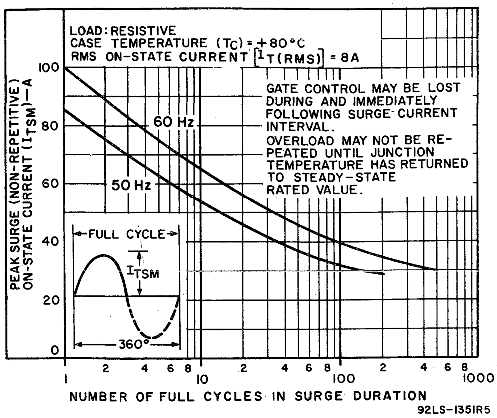


Fig.7—Allowable peak surge on-state current vs. surge duration.

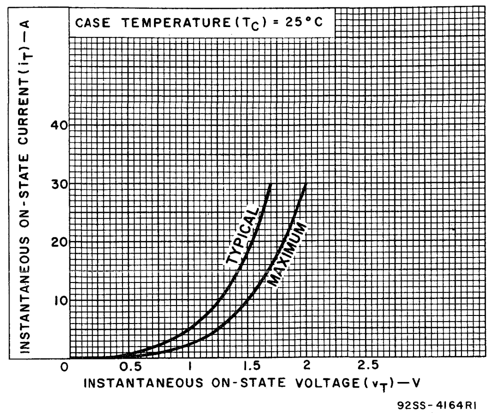


Fig.8—Instantaneous on-state current vs. on-state voltage.

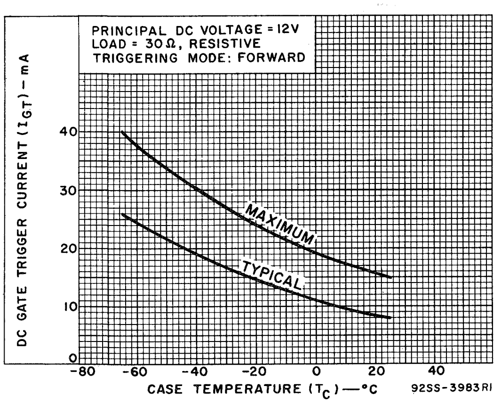


Fig.9—DC gate-trigger current (forward) vs. case temperature.

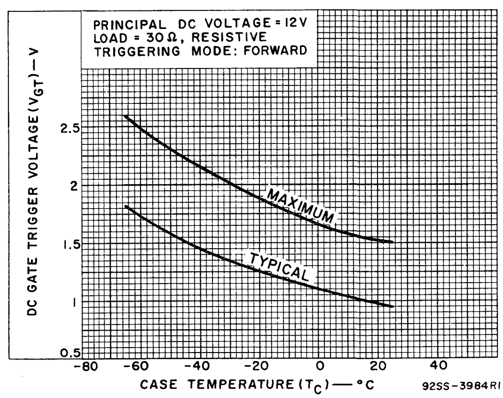


Fig.10—DC gate-trigger voltage (forward) vs. case temperature.

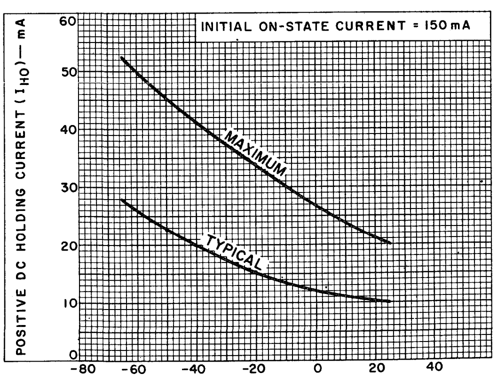


Fig.11—Holding current (positive) vs. case temperature.

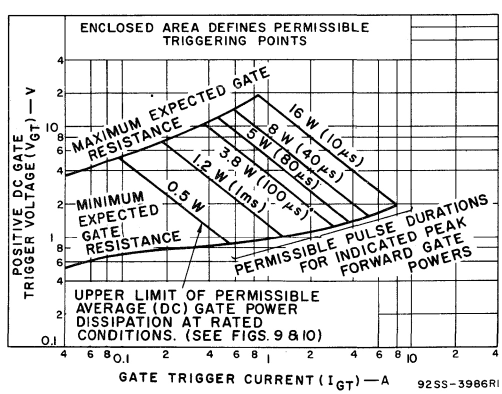


Fig.12—Typical forward-biased gate characteristics.

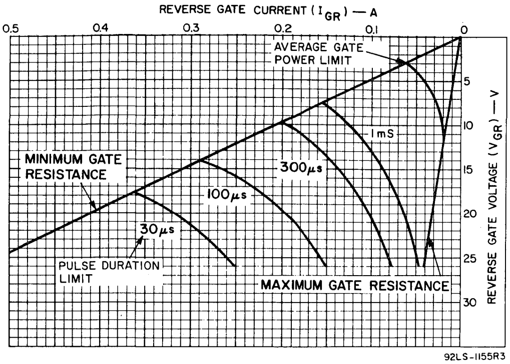


Fig. 13—Reverse gate voltage vs. reverse gate current.

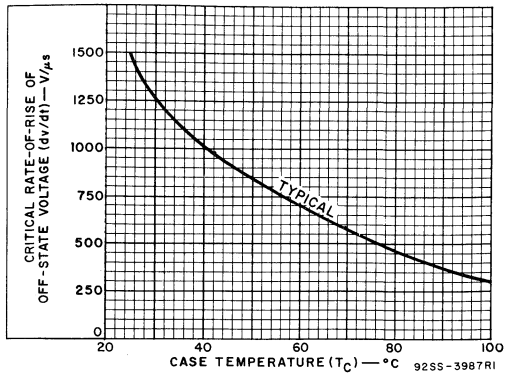


Fig. 14—Critical rate-of-rise of off-state voltage vs. case temperature.

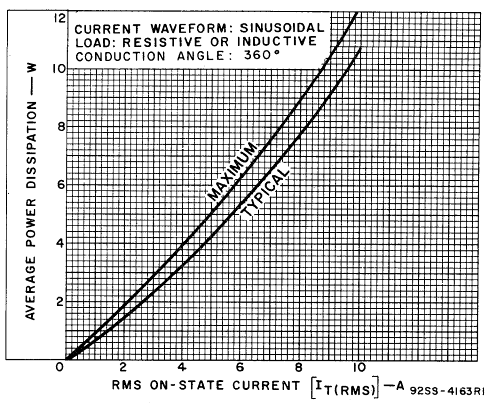
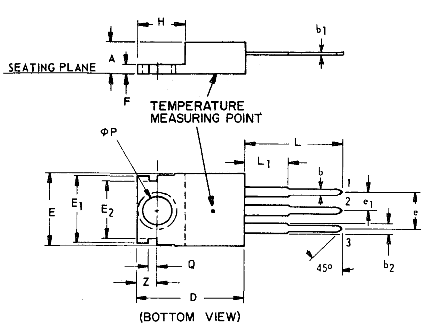


Fig. 15—Power dissipation vs. on-state current.

DIMENSIONAL OUTLINE (JEDEC TO-220 AB)

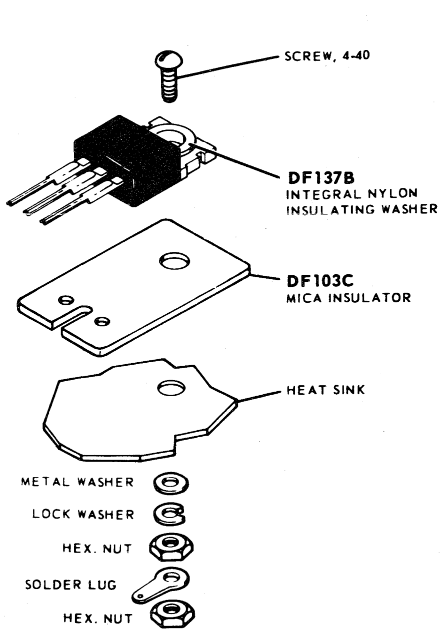


SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.160	0.190	4.07	4.82
b	0.025	0.040	0.64	1.02
b_1	0.012	0.020	0.31	0.51
b_2	0.045	0.055	1.143	1.397
D	0.575	0.600	14.61	15.24
E	0.395	0.410	10.04	10.41
E_1	0.365	0.385	9.28	9.77
E_2	0.300	0.320	7.62	8.12
e	0.180	0.220	4.57	5.58
e_1	0.080	0.120	2.03	3.04
F	0.020	0.055	0.51	1.39
H	0.235	0.265	5.97	6.73
L	0.500		12.70	
L_1		0.250		6.35
φP	0.141	0.145	3.582	3.683
Q	0.040	0.060	1.02	1.52
Z	0.100	0.120	2.54	3.04

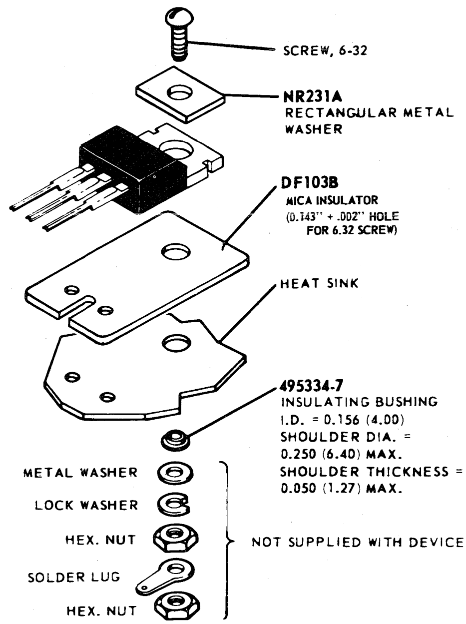
Dimensions in millimeters were derived from the basic inch dimensions as indicated.

92CM-15015R1

SUGGESTED MOUNTING ARRANGEMENTS
(All Parts Numbers Are RCA Part Numbers)



92CS-19060



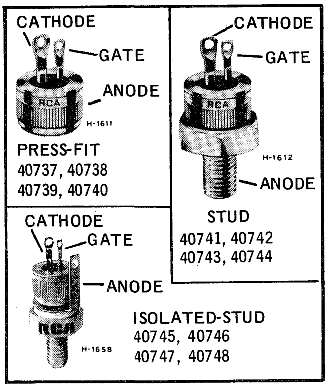
DIMENSIONS IN INCHES AND MILLIMETERS.
MILLIMETER VALUES IN PARENTHESES.

92CS-19059

RCA
Solid State
Division

Thyristors

40737 40741 40745
40738 40742 40746
40739 40743 40747
40740 40744 40748



10-Ampere Silicon Controlled Rectifiers

Press-Fit, Stud, & Isolated-Stud Type Packages

For Low-Voltage Operation. . .40737, 40741, 40745
For 120-V Line Operation. . .40738, 40742, 40746
For 240-V Line Operation. . .40739, 40743, 40747
For High-Voltage Operation. . .40740, 40744, 40748

These RCA types are all-diffused, silicon controlled rectifiers (reverse-blocking triode thyristors) designed for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits.

These SCRs have an RMS on-state current rating ($I_{T[RMS]}$) of 10-A and have voltage ratings (V_{DROM}) of 100, 200, 400, and 600 volts.

FEATURES

- Low switching losses
- High di/dt and dv/dt capabilities
- Shorted-emitter gate-cathode construction
- Forward and reverse gate dissipation ratings
- All-diffused construction–assures exceptional uniformity and stability of characteristics
- Symmetrical gate-cathode construction–provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40737 40741 40745	40738 40742 40746	40739 40743 40747	40740 40744 40748	
NON-REPETITIVE PEAK REVERSE VOLTAGE						
Gate Open	V_{RSOM}	100	200	400	600	V
NON-REPETITIVE PEAK FORWARD VOLTAGE						
Gate Open	V_{DSOM}	150	250	500	700	V
REPETITIVE PEAK REVERSE VOLTAGE						
Gate Open	V_{RROM}	100	200	400	600	V
REPETITIVE PEAK OFF-STATE VOLTAGE						
Gate Open	V_{DROM}	100	200	400	600	V
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:						
For one cycle of applied principal voltage	I_{TSM}					
50-Hz, sinusoidal		85				A
60-Hz, sinusoidal		100				A
For more than one full cycle of applied principal voltage		See Fig. 10				
ON-STATE CURRENT:						
For case temperature (T_C) = 85 °C, conduction angle of 180 °						
Average DC value	$I_{T(AV)}$	6.3				A
RMS value	$I_{T(RMS)}$	10				A
RATE-OF-CHANGE OF ON-STATE CURRENT:						
$V_{DM} = v_{(BO)O}$, I_{GT} = 200 mA, t_r = 0.5 μs (See Fig. 2.)	di/dt	200				A/μs
GATE POWER DISSIPATION:						
PEAK FORWARD (for 10 μs max.)	P_{GM}	40				W
AVERAGE (averaging time = 10 ms max.)	$P_{G(AV)}$	0.5				W
PEAK REVERSE	P_{RGM}	See Fig. 5				
TEMPERATURE RANGE:						
Storage		−65 to 150				°C
Operating (Case)		−65 to 100				°C
Soldering (10 s max. for terminals)		225				°C

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS – ALL TYPES			UNITS
		Min.	Typ.	Max.	
Instantaneous Forward Breakover Voltage: (Gate open, T_C = 100 °C)					
40737, 40741, 40745	$V_{(BO)O}$	100	–	–	V
40738, 40742, 40746		200	–	–	
40739, 40743, 40747		400	–	–	
40740, 40744, 40748		600	–	–	
Peak Off-State Current: (Gate open, T_C = 100 °C)					
Forward, V_{DO} = V_{DROM}	I_{DOM}	–	0.2	3	mA
Reverse, V_{RO} = V_{RROM}	I_{RROM}	–	0.1	3	
Instantaneous On-State Voltage: For i_T = 100 A, T_C = 25 °C	v_T	–	1.7	2.5	V
DC Gate Trigger Current: V_D = 12 V (DC), R_L = 30 Ω, T_C = 25 °C	I_{GT}	–	6	15	mA
At other case temperatures		See Fig. 11			
DC Gate Trigger Voltage: V_D = 12 V (DC), R_L = 30 Ω, T_C = 25 °C	V_{GT}		0.9	2	V
At other case temperatures		See Fig. 12			
Instantaneous Holding Current: Gate open, T_C = 25 °C	I_{HO}		9	20	mA
Critical Rate-of-Rise of Off-State Voltage: (V_D = V_{DROM}, Exponential Rise, T_C = 100 °C, See Fig. 3)					
40737, 40741, 40745	dv/dt	10	200	–	V/μs
40738, 40742, 40746		10	200	–	
40739, 40743, 40747		10	150	–	
40740, 40744, 40748		10	75	–	
Gate Controlled Turn-On Time: V_D = V_{DROM}, i_T = 30 A, I_{GT} = 200 mA, t_r = 0.1 μs, T_C = 25 °C, See Fig. 8	t_{gt}	–	1.6		μs
Circuit Commutated Turn-Off Time: V_{DX} = V_{DROM}, i_T = 18 A (pulse duration = 50 μs), I_{GT} = 200 mA at turn-on time, –di/dt = –30 A/μs, dv/dt = 20 V/μs, T_C = 75 °C, See Fig. 4	t_q	–	15	50	μs
Thermal Resistance:					
Junction-to-Case	θ_{J-C}	–	–	1.5	°C/W
Junction-to-Isolated Stud	θ_{J-IS}	–	–	1.7	

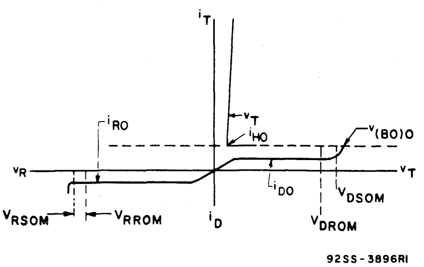


Fig. 1 - Principal voltage-current characteristic.

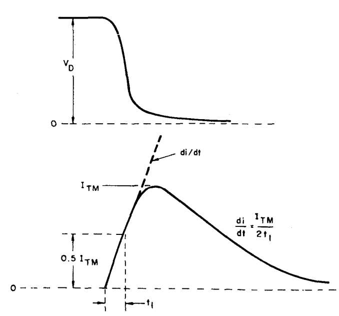


Fig. 2 - Rate-of-change of on-state current with time (defining di/dt).

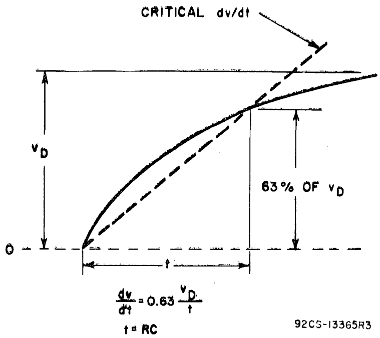


Fig. 3 - Rate-of-rise of off-state voltage with time (defining dv/dt).

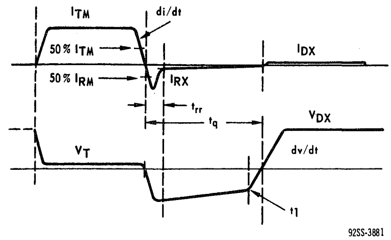


Fig. 4 - Relationship between on-state current, reverse current, on-state voltage and off-state voltage showing reference points for definition of turn-off time (tq).

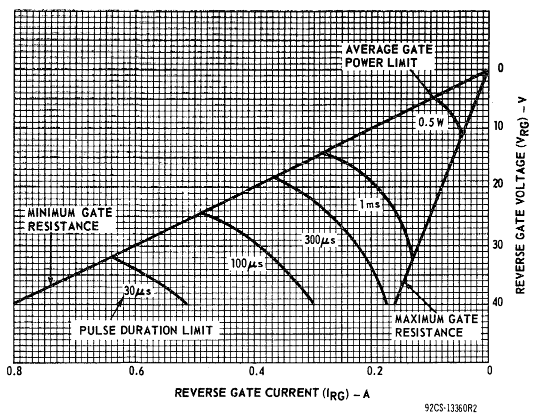


Fig. 5 - Reverse gate voltage vs. reverse gate current.

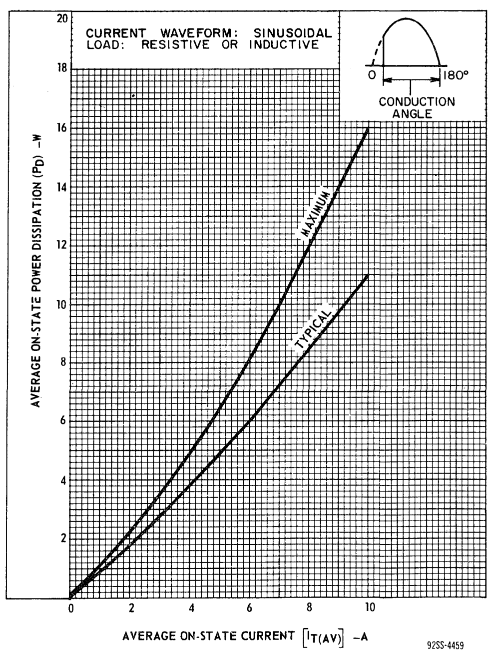


Fig. 6 - Power dissipation vs. on-state current.

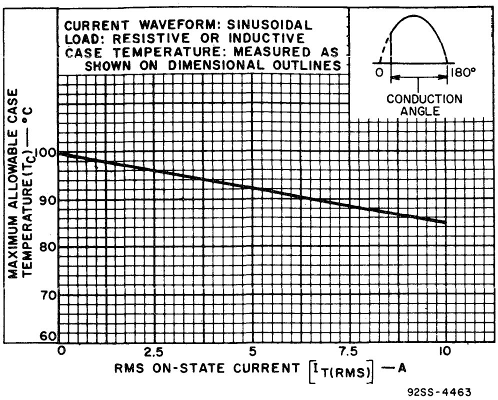


Fig. 7 - Maximum allowable case temperature vs. on-state current.

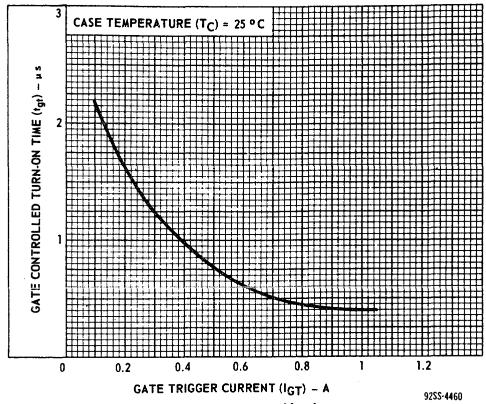


Fig. 8 - Typical gate controlled turn-on time vs. gate-trigger current.

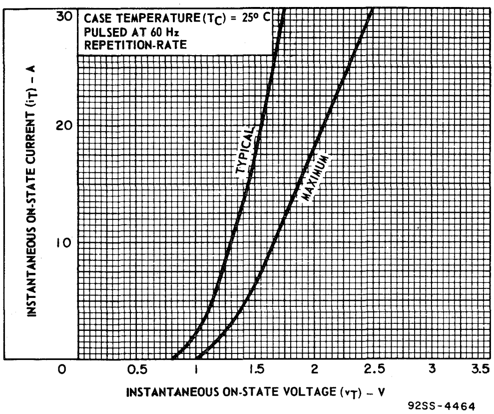


Fig. 9 - Instantaneous on-state current vs. on-state voltage.

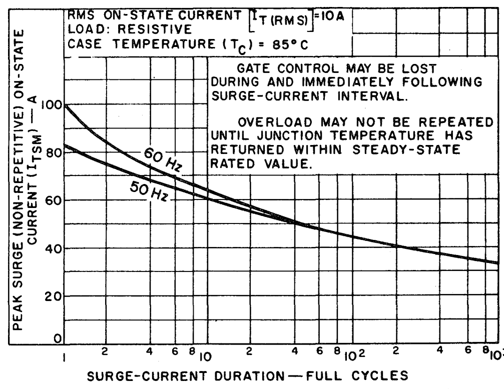


Fig. 10 - Peak surge on-state current vs. surge current duration.

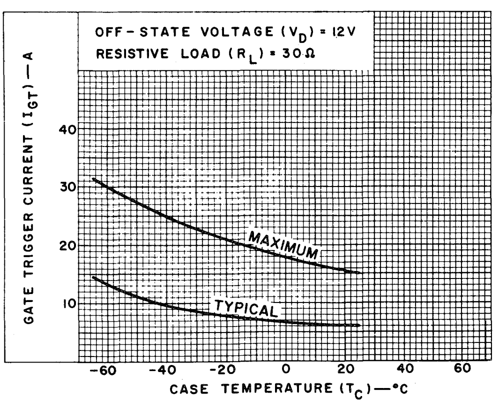


Fig. 11 - DC gate-trigger current vs. case temperature.

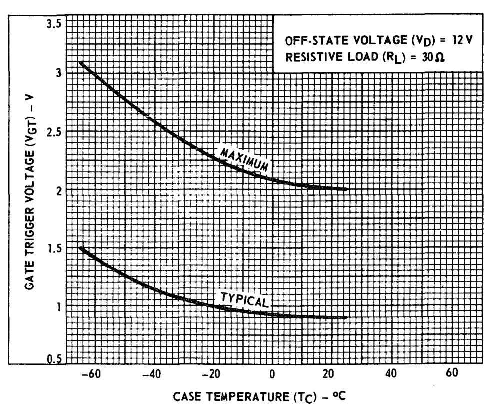


Fig. 12 - DC gate-trigger voltage vs. case temperature.

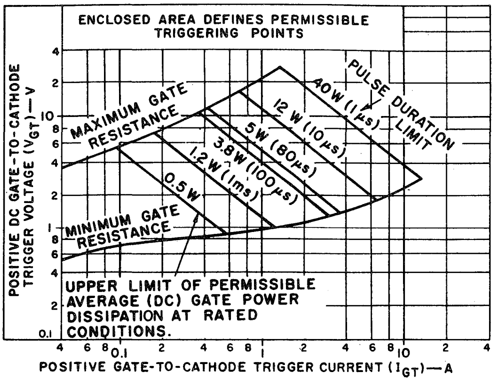


Fig. 13 - Typical forward-biased gate trigger characteristics.

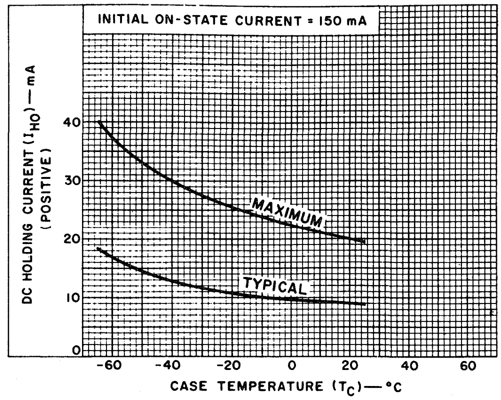


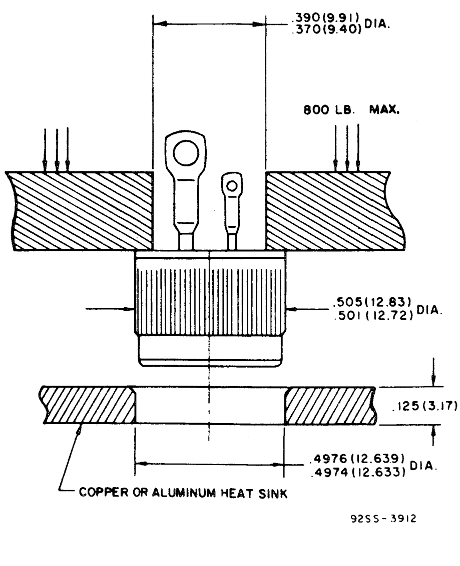
Fig. 14 - DC holding current vs. case temperature.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

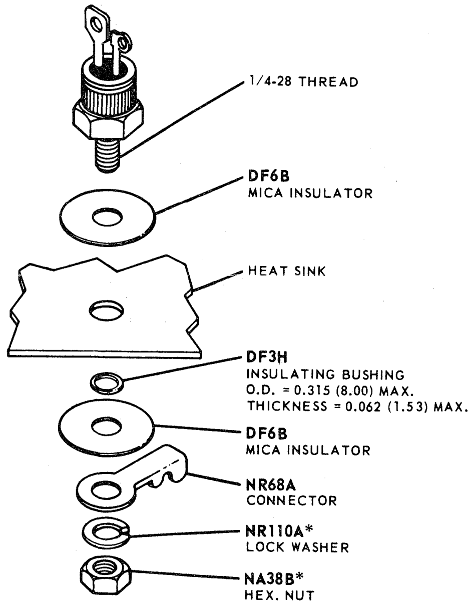
A recommended mounting method, shown in Fig. 15, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in. (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force is applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



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

Fig. 15 - Suggested mounting method of press-fit package types.



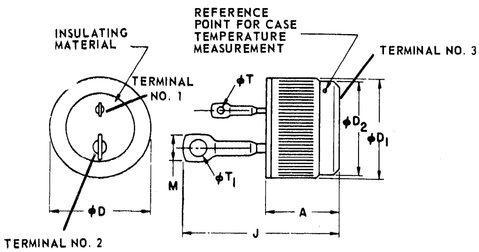
*Only hardware required for isolated-stud package.

Fig. 16 - Suggested mounting arrangement for stud and isolated-stud package types.

Table I – Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. (Minimum Required thickness of heat sink = 1/8 in.	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6
	Mounted on heat sink with a 0.004 to 0.006 in. thick mica insulating washer used between unit and heat sink.	
	Without heat sink compound	2.5
	With heat sink compound	1.5

DIMENSIONAL OUTLINE FOR TYPES 40737, 40738, 40739, 40740

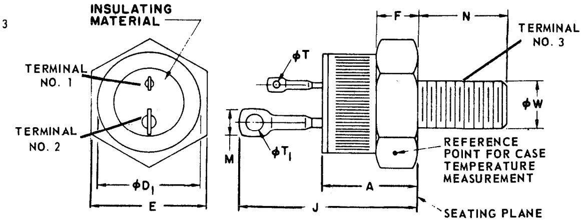


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	—	.380	—	9.65	
ϕD	.501	.510	12.73	12.95	
ϕD_1	—	.505	—	12.83	2
ϕD_2	.465	.475	11.81	12.07	
J	—	.750	—	19.05	
M	—	.155	—	3.94	1
ϕT	.058	.068	1.47	1.73	
ϕT_1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Outer diameter of knurled surface.

92SS-3816

DIMENSIONAL OUTLINE FOR TYPES 40741, 40742, 40743, 40744



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	—
ϕD_1	—	.544	—	13.81	—
E	.544	.562	13.82	14.28	—
F	.113	.200	2.87	5.08	3
J	—	.950	—	24.13	—
M	—	.155	—	3.94	1
N	.422	.453	10.72	11.50	—
ϕT	.058	.068	1.47	1.73	—
ϕT_1	.080	.090	2.03	2.29	—
ϕW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Pitch diameter of 1/4-28 UNF-2A (coated) threads (ASA B1. 1-1960).
NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

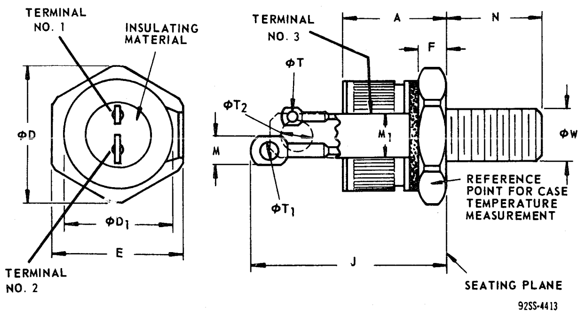
92SS-3817

TERMINAL CONNECTIONS

For Types 40737, 40738, 40739, 40740
40741, 40742, 40743, 40744

Terminal No. 1—Gate
Terminal No. 2—Cathode
Case, Terminal No. 3—Anode

DIMENSIONAL OUTLINE FOR TYPES 40745, 40746, 40747, 40748



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.673	–	17.09	
ΦD	.604	.614	15.34	15.59	
$ΦD_1$	.501	.505	12.72	12.82	
E	.551	.557	13.99	14.14	
F	.175	.185	4.44	4.69	
J	–	1.055	–	26.79	
M	–	.155	–	3.94	
M_1	.200	.210	5.08	5.33	
N	.422	.452	10.72	11.48	
ΦT	.058	.068	1.47	1.73	2
$ΦT_1$	.080	.090	2.03	2.29	2
$ΦT_2$	.138	.148	3.50	3.75	2
ΦW	.2225	.2268	5.652	5.760	3

NOTE 1: Ceramic between hex (stud) and terminal No. 3 is beryllium oxide.

NOTE 2: Contour and angular orientation of these terminals is optional.

NOTE 3: Pitch diameter of ¼-28 UNF-2A (coated) threads (ASA B1. 1-1960).

"**WARNING:** RCA-40745, 40746, 40747, 40748 should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled."

TERMINAL CONNECTIONS

For Types 40745, 40746
40747, 40748

Terminal No. 1 – Gate
Terminal No. 2 – Cathode
Terminal No. 3 – Anode

RCA
Solid State
Division

Thyristors

2N3668 2N3670 2N3669 2N4103

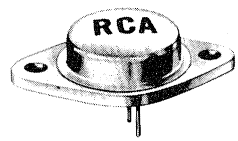
All-Diffused SCR's for Low-Cost Power-Control and Power-Switching Applications

RCA 2N3668*, 2N3669*, 2N3670*, and 2N4103* are all-diffused, three-junction, silicon controlled-rectifiers (SCR's▲). They are intended for use in power-control and power-switching applications requiring a blocking voltage capability of up to 600 volts and a forward-current capability of 12.5 amperes (rms value) or 8 amperes (average value) at a case temperature of 80°C.

The 2N3668 is designed for low-voltage power supplies, the 2N3669 for direct operation from 120-volt line supplies, the 2N3670 for direct operation from 240-volt line supplies, and the 2N4103 for high-voltage power supplies.

* Formerly Dev. Types TA2621, TA2598, TA2618, and TA2775, respectively.

▲ The silicon controlled-rectifier is also known as a reverse-blocking triode thyristor.



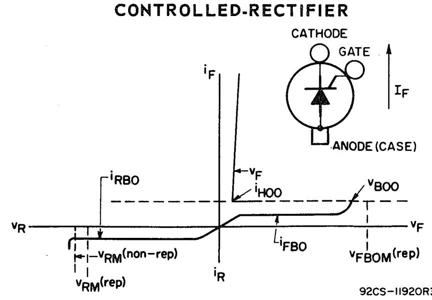
JEDEC TO-3

2N3668	For Low-Voltage Power Supplies
2N3669	For 120-Volt Line Operation
2N3670	For 240-Volt Line Operation
2N4103	For High-Voltage Power Supplies

FEATURES

- Low switching losses
- High di/dt and dv/dt capabilities
- Shorted emitter gate-cathode construction
- Forward and reverse gate dissipation ratings
- Designed especially for high-volume systems
- All-diffused construction – assures exceptional uniformity and stability of characteristics
- Direct-soldered internal construction – assures exceptional resistance to fatigue
- Symmetrical gate-cathode construction – provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- All-welded construction and hermetic sealing
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance

TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER



Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage at a Frequency between 50 and 400 Hz, and with Resistive or Inductive Load

RATINGS	CONTROLLED-RECTIFIER TYPES				UNITS
	2N3668	2N3669	2N3670	2N4103	
Transient Peak Reverse Voltage (Non-Repetitive), v_{RM}(non-rep)[a]	150	330	660	700	volts
Peak Reverse Voltage (Repetitive), v_{RM}(rep)[b]	100	200	400	600	volts
Peak Forward Blocking Voltage (Repetitive), v_{FBOM}(rep)[c]	600	600	600	700	volts
Forward Current:					
For case temperature (T_C) of +80° C					
Average DC value at a conduction angle of 180°, I_{FAV}[d]	8	8	8	8	amperes
RMS value, I_{FRMS}[e]	12.5	12.5	12.5	12.5	amperes
For other conditions, see Fig. 8					
Peak Surge Current, i_{FM}(surge)[f]:					
For one cycle of applied voltage	200	200	200	200	amperes
For more than one cycle of applied voltage	See Fig. 10	See Fig. 10	See Fig. 10	See Fig. 10	
Sub-Cycle Surge (Non-Repetitive), I^2t[g] For a period of 1ms to 8.3ms	165	165	165	165	ampere² second
Rate of Change of Forward Current, di/dt[h] $V_{FB} = v_{BOO}$ (min. value) I_{GT} = 200mA, 0.5 μs rise time (See waveshapes of Fig. 1)	200	200	200	200	amperes/ microsecond
Gate Power*:					
Peak, Forward or Reverse, for 10 μs duration, P_{GM}[i] (See Figs. 5 and 6)	40	40	40	40	watts
Average, P_{GAV}[k]	0.5	0.5	0.5	0.5	watt
Temperature:					
Storage, T_{stg}●	-40 to +125	-40 to +125	-40 to +125	-40 to +125	°C
Operating (Case), T_C	-40 to +100	-40 to +100	-40 to +100	-40 to +100	°C

* Any values of peak gate current or peak gate voltage to give the maximum gate power is permissible.
● Temperature reference point is within 1/8" of the center of the underside of unit.

WAVESHAPE OF di/dt RATING TEST

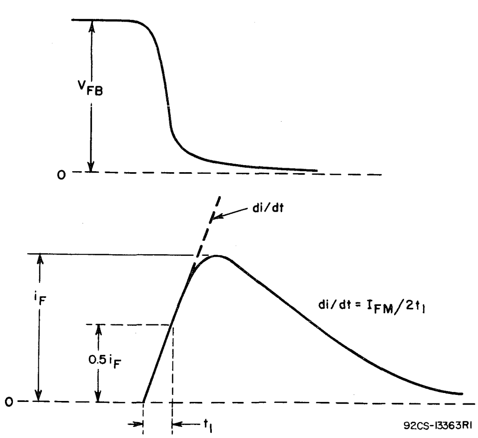


Fig. 1

WAVESHAPE OF CRITICAL dv/dt RATING TEST

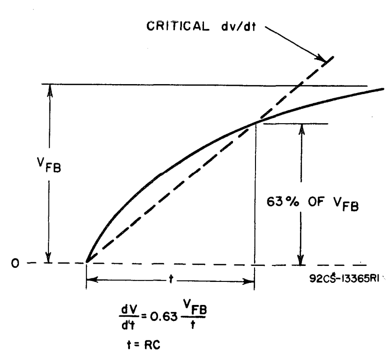


Fig. 2

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)

CHARACTERISTICS	CONTROLLED-RECTIFIER TYPES												UNITS
	2N3668			2N3669			2N3670			2N4103			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Forward Breakover Voltage, v_{BOO}[m] At T_C = +100°C	100	–	–	200	–	–	400	–	–	600	–	–	volts
Peak Blocking Current, at T_C = +100°C: Forward, I_{FBOM}[n]	–	0.2	2	–	0.25	2.5	–	0.3	3	–	0.35	4	mA
V_{FBO}[p] = v_{BOO}(min. value) Reverse, I_{RBOM}[q]	–	0.05	1	–	0.1	1.25	–	0.2	1.5	–	0.3	3	mA
V_{RBO}[p] = v_{RM}(rep) value													
Forward Voltage Drop, v_F[r] At a Forward Current of 25 amperes and a T_C = +25°C (See Fig. 11)	–	**1.5**	1.8	–	**1.5**	1.8	–	**1.5**	1.8	–	**1.5**	1.8	volts
DC Gate-Trigger Current, I_{GT}[s]: At T_C = +25°C (See Fig. 5)	1	20	40	1	20	40	1	20	40	1	20	40	mA(dc)
Gate-Trigger Voltage, V_{GT}[t]: At T_C = +25°C (See Fig. 5)	–	1.5	2	–	1.5	2	–	1.5	2	–	1.5	2	volts (dc)
Holding Current, i_{HOO}[u]: At T_C = +25°C	0.5	25	50	0.5	25	50	0.5	25	50	0.5	25	50	mA
Critical Rate of Applied Forward Voltage, Critical dv/dt[v] V_{FB} = v_{BOO}(min.value), exponential rise, T_C = +100°C (See waveshape of Fig. 2)	10	100	–	10	100	–	10	100	–	10	100	–	volts/ microsecond
Turn-On Time, t_{on}[w], (Delay Time + Rise Time) V_{FB} = v_{BOO}(min. value), i_F = 8 amperes, I_{GT} = 200mA, 0.1 µs rise time, T_C = +25°C (See waveshapes of Fig. 3)	0.75	1.25	–	0.75	1.25	–	0.75	1.25	–	0.75	1.25	–	microseconds
Turn-Off Time, t_{off}[x], (Reverse Recovery Time + Gate Recovery Time) i_F = 8 amperes, 50 µs pulse width, dv_{FB}/dt = 20 v/µs, di_r/dt = 30 A/µs, I_{GT} = 200mA, T_C = +80°C (See waveshapes of Fig. 4)	–	20	50	–	20	50	–	20	50	–	20	50	microseconds
Thermal Resistance, Junction-to-Case	–	–	1.7	–	–	1.7	–	–	1.7	–	–	1.7	°C/W

WAVESHAPE OF t_{on} RATING TEST

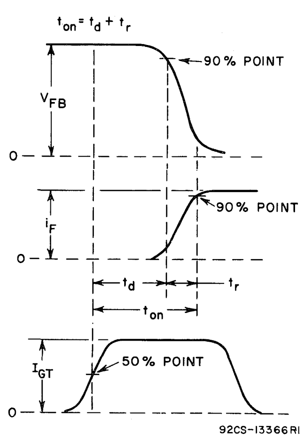


Fig. 3

WAVESHAPE OF t_{off} RATING TEST

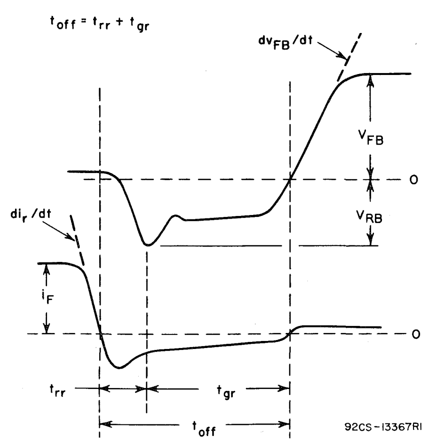


Fig. 4

FORWARD GATE CHARACTERISTICS

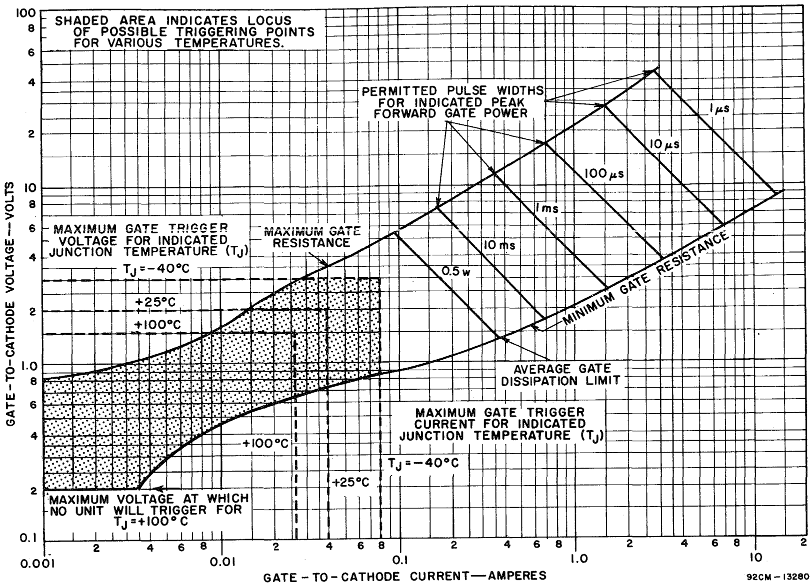


Fig. 5

REVERSE GATE CHARACTERISTICS

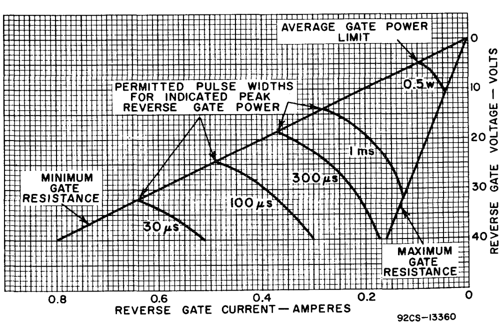


Fig. 6

TRIGGERING CONSIDERATIONS

The construction of the gate-cathode junction used in these devices provides a large periphery center gate. These devices also employ shorted-emitter construction which removes restrictions on both forward and reverse peak gate voltage and peak gate current. Limiting values of volt-ampere products for different gate pulse widths are shown in Fig. 5. These limits should be adhered to when designing pulse trigger circuits for maximum trigger pulse widths and peak power dissipation. The volt-ampere products in the reverse direction shown in Fig. 6 should be used to determine limitations for reverse gate transients or reverse gate pulses if present. In all cases, total average gate dissipation, both forward and reverse, should not exceed the average gate dissipation rating (P_{GAV}) of 0.5 watt.

Turn-on times for different gate currents are shown in Fig. 7. These curves may be used to determine the required width of the gate trigger pulses. It is only necessary to maintain the gate trigger pulse until the magnitude of the forward anode current has reached the latching current value. However, conservative design requires that the gate trigger pulse width be at least equal to or somewhat greater than the device turn-on time. Some applications may require wider gate pulse widths for proper circuit operation. Additional information on gate characteristics and triggering requirements for use in pulse applications are contained in RCA Application Note, SMA-39, "Gate Parameters of RCA SCR's for Trigger Circuit Design".

TURN-ON TIME CHARACTERISTICS

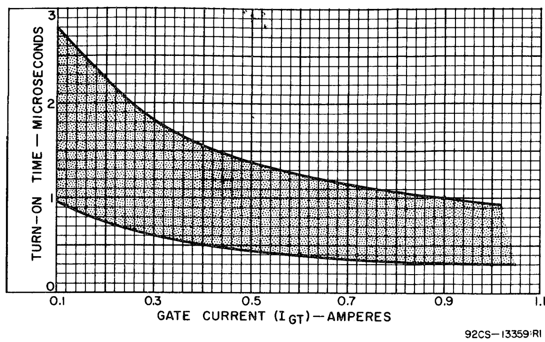


Fig. 7

RATING CHART (CASE TEMPERATURE)

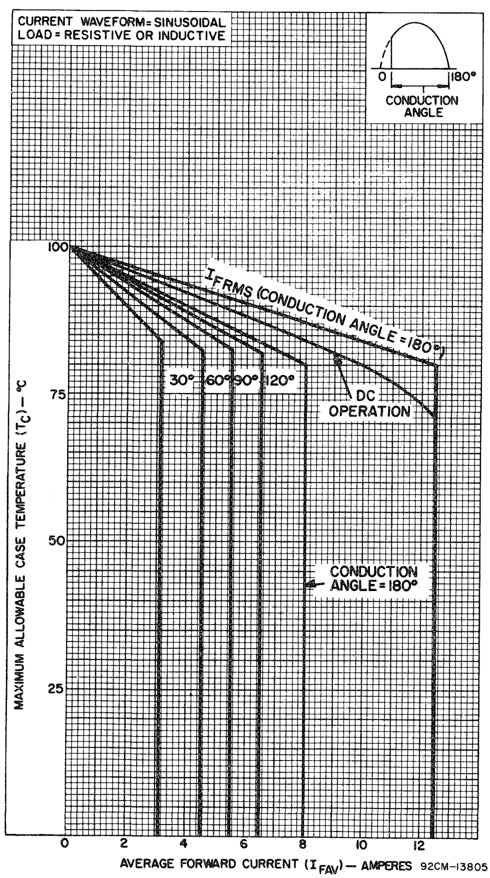


Fig. 8

POWER DISSIPATION

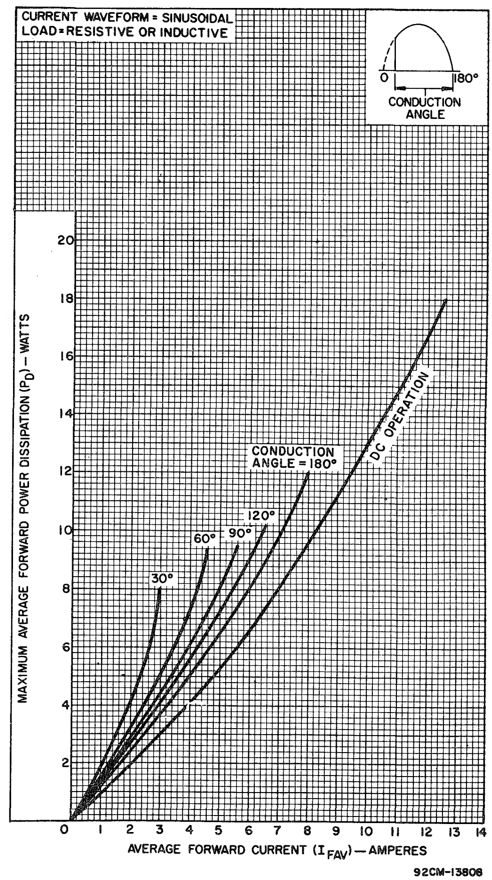


Fig. 9

SURGE CURRENT RATING

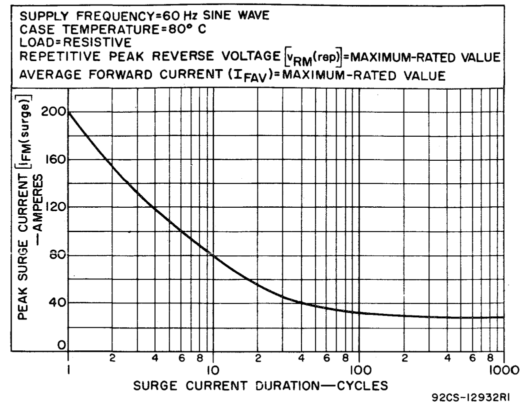


Fig. 10

FORWARD CHARACTERISTICS

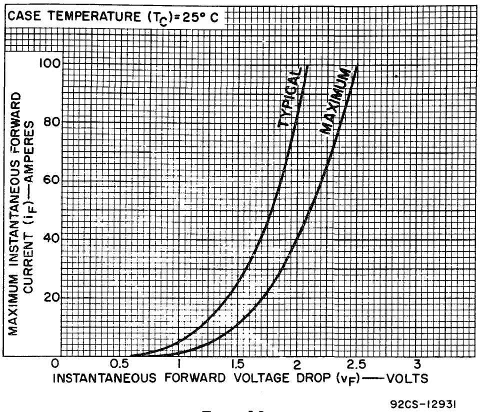


Fig. 11

NATURAL-AIR COOLING OPERATION GUIDANCE CHART

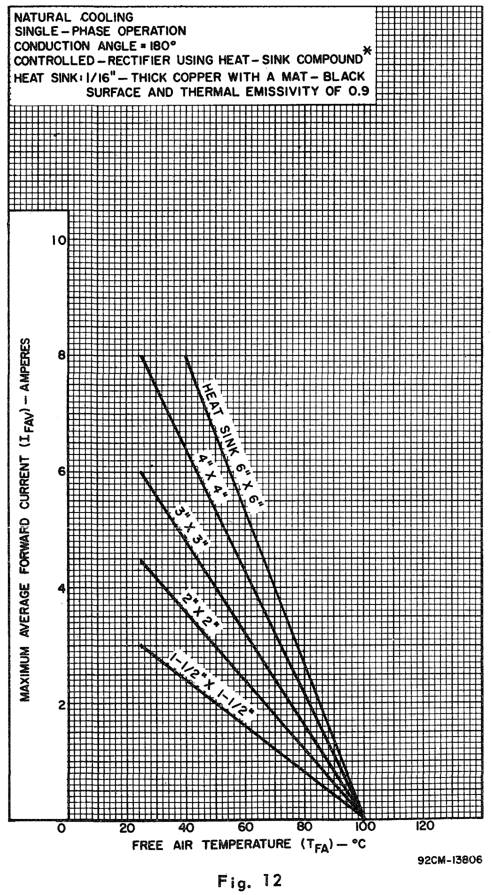


Fig. 12

FORCED-AIR COOLING OPERATION GUIDANCE CHART

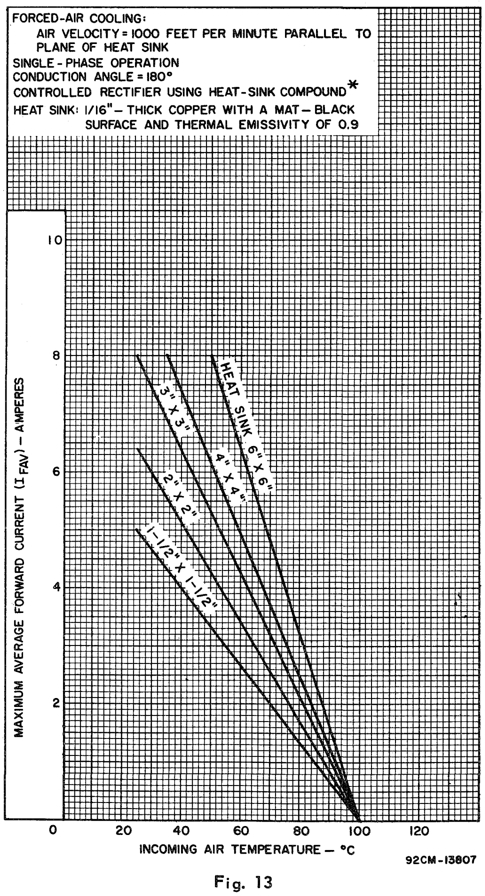
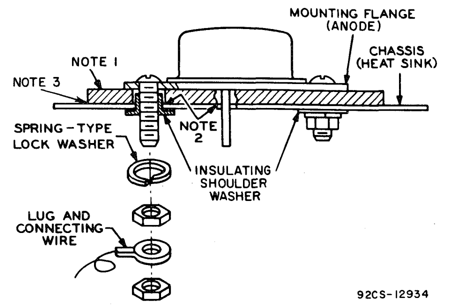


Fig. 13

*Dow Corning 340 Silicon Heat Sink Compound, or Equivalent.

SUGGESTED INSULATED MOUNTING ARRANGEMENT

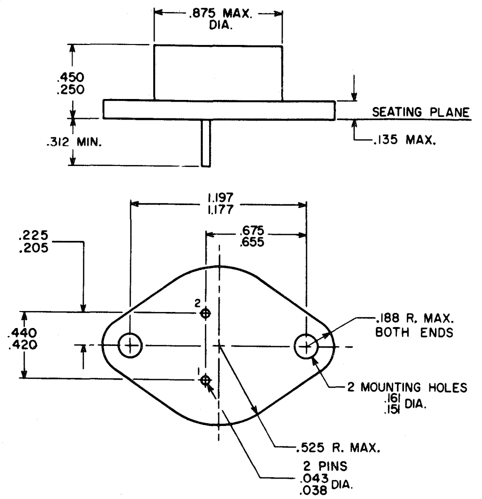


NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

NOTE 3: DOW CORNING 340 SILICON HEAT SINK COMPOUND, OR EQUIVALENT.

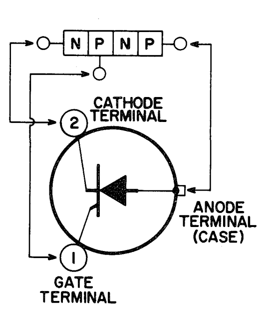
DIMENSIONAL OUTLINE JEDEC No. TO-3



Dimensions in Inches

NOTE: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050 TO .055 BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

TERMINAL DIAGRAM



PIN 1: GATE
PIN 2: CATHODE
CASE: ANODE

File No. 28

RCA

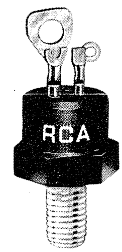
Solid State
Division

Thyristors

2N1842A 2N1845A 2N1848A
2N1843A 2N1846A 2N1849A
2N1844A 2N1847A 2N1850A

RCA—2N1842A-2N1850A controlled-rectifiers are all-diffused, three-junction silicon devices for use in power-control and power-switching applications requiring blocking-voltage capabilities to 500 volts and forward-current capability of 10 amperes (average value) or 16 amperes (rms value).

All-Diffused Types for Power-Control and Power-Switching Applications

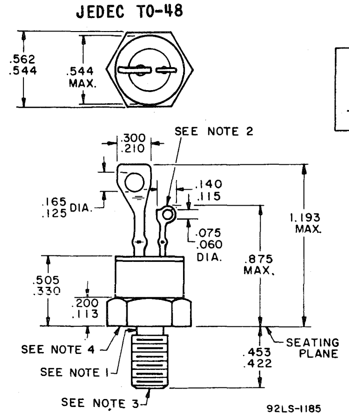


JEDEC TO-48

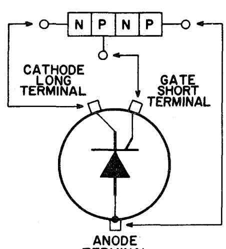
FEATURES—

- all-diffused construction—assures exceptional uniformity and stability of characteristics
- multi-diffusion process—permits precise control of individual junction parameters
- direct-soldered internal construction—assures exceptional resistance to fatigue
- shorted emitter gate-cathode construction
- each unit aged at maximum ratings to assure dependable performance
- symmetrical gate-cathode construction—provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- designed to meet stringent military environmental and mechanical specifications
- exceptionally rugged terminals
- hermetic seals
- low leakage currents, both forward and reverse
- welded construction
- low forward voltage drop at high current levels
- low thermal resistance
- exceptionally high stud-torque capability through use of high-strength copper-alloy stud

DIMENSIONAL OUTLINE
JEDEC TO-48



TERMINAL DIAGRAM



NOTE 1: COMPLETE THREADS TO EXTEND TO WITHIN 2 1/2 THREADS OF HEAD. DIA. OF UNTHREADED PORTION 0.249" MAXIMUM, 0.220" MINIMUM.

NOTE 2: ANGULAR ORIENTATION OF THESE TERMINALS IS UNDEFINED. SQUARE OR RADIUS ON END OF TERMINAL IS OPTIONAL.

NOTE 3: 1/4-28 UNF-2A. MAXIMUM PITCH DIA. OF PLATED THREADS SHALL BE BASIC PITCH DIA. 0.2268", MINIMUM PITCH DIA. 0.2225". REF. (SCREW THREAD STANDARDS FOR FEDERAL SERVICES 1957) HANDBOOK H28 1957 P1.

NOTE 4: A CHAMFER (OR UNDERCUT) ON ONE OR BOTH ENDS OF HEXAGONAL PORTION IS OPTIONAL.

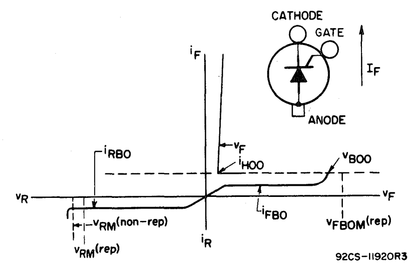
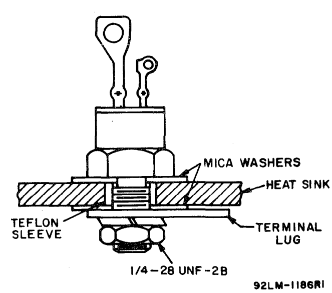


Fig. 1 - Typical E-I Characteristic of Silicon Controlled-Rectifier.



■ *Suggested Mounting Arrangement for Insulating Types 2N1842A-2N1850A from Heat Sink. Components Shown (Except Heat Sink) are Furnished with Each Device.*

Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage at a Frequency between 50 and 400 cps, and with Resistive or Inductive Load

RATINGS	SYMBOLS	* REF.	CONTROLLED-RECTIFIER TYPE 2N1842A	2N1843A	2N1844A	2N1845A	2N1846A	2N1847A	2N1848A	2N1849A	2N1850A	UNITS
TRANSIENT PEAK REVERSE VOLTAGE (NON-REPETITIVE)	v_{RM} (non-rep)	1	35	75	150	225	300	350	400	500	600	volts
PEAK REVERSE VOLTAGE (REPETITIVE)	v_{RM} (rep)	2	25	50	100	150	200	250	300	400	500	volts
PEAK FORWARD BLOCKING VOLTAGE (REPETITIVE)	v_{FBOM} (rep)	3	← 600 →									volts
AVERAGE FORWARD CURRENT:	I_{FAV}	4										
For a case temperature# of +80° C and a conduction angle of 180°			← 10 →									amp
For other case temperatures and conduction angles			← See *Fig. 2* →									
PEAK SURGE CURRENT:	i_{FM}(surge)	5										
For one cycle of applied voltage			← 125 →									amp
For more than one cycle of applied voltage			← See *Fig. 3* →									
PEAK GATE POWER	P_{GM}	6	← 5 →									watts
AVERAGE GATE POWER	P_{GAV}	7	← 0.5 →									watt
PEAK FORWARD GATE CURRENT	i_{GKM}	8	← 2 →									amp
PEAK FORWARD GATE VOLTAGE:	v_{KGM}	9										
Forward			← 10 →									volts
Reverse			← 5 →									volts
TEMPERATURE:												
Storage	T_{stg}	-	← -65 to +125 →									°C
Operating (Case)#	T_C	-	← -65 to +125 →									°C
Operating (Free-air)	T_{FA}	-	← See *Fig. 4* →									

#Measured at the center of any of the six major faces on the perimeter of the hexagonal flange.

Electrical and Thermal Characteristics at Maximum Electrical Ratings (unless otherwise specified), and at Indicated Case Temperature, T_C

CHARACTERISTICS	SYMBOLS	* REF.	T_C °C	CONTROLLED-RECTIFIER TYPE 2N1842A	2N1843A	2N1844A	2N1845A	2N1846A	2N1847A	2N1848A	2N1849A	2N1850A	UNITS
Minimum Forward Breakover Voltage	v_{BOO}	10	+125	25	50	100	150	200	250	300	400	500	volts
Maximum Average Forward Blocking Current	I_{FBOAV}	11	+125	22.5	19	12.5	6.5	6	5.5	5	4	3	ma
Maximum Average Reverse Blocking Current	I_{RBOAV}	12	+125	22.5	19	12.5	6.5	6	5.5	5	4	3	ma
Maximum Average Forward Voltage Drop	V_{FAV}	13	+80	← 1.2 →									volts
Maximum DC Gate Trigger Current	I_{GT}	14	+125	← 45 →									ma
DC Gate-Trigger Voltage:	V_{GT}	15											
Maximum			-40	← 3.5 →									volts
			-65	← 3.7 →									volts
Minimum			+125	← 0.25 →									volt
			+100	← 0.3 →									volt
Holding Current (Typical)	i_{HOO}	16	+125	← 8 →									ma
Maximum Thermal Resistance, Junction-to-Case	θ_{JC}	17	-	← 2 →									°C/watt

* Numerical References are to Table of Terms, Symbols, and Definitions on page 4.

Measured at the center of any of the six major faces on the perimeter of the hexagonal flange.

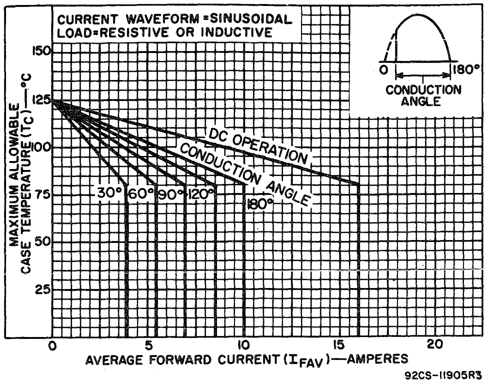


Fig. 2 - Rating Chart for Types 2N1842A through 2N1850A.

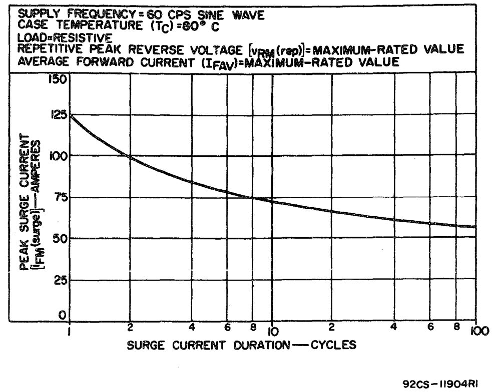


Fig. 3 - Surge Current Rating Chart for Types 2N1842A through 2N1850A.

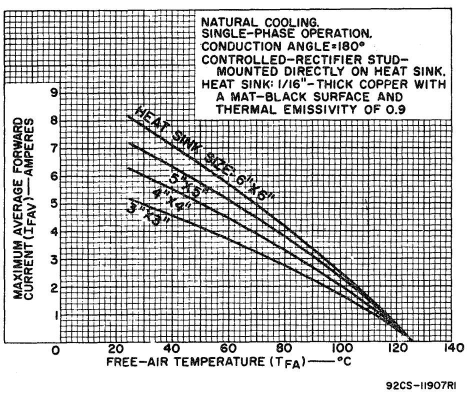


Fig. 4 - Operation Guidance Chart for Types 2N1842A through 2N1850A.

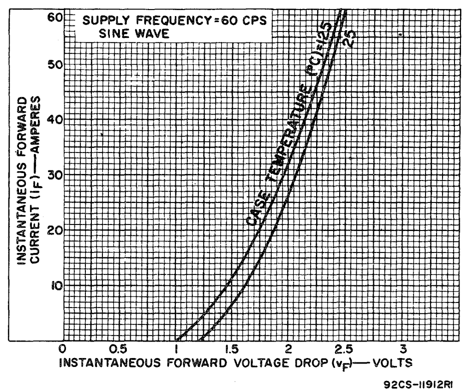


Fig. 5 - Maximum Forward Characteristics for Types 2N1842A through 2N1850A.

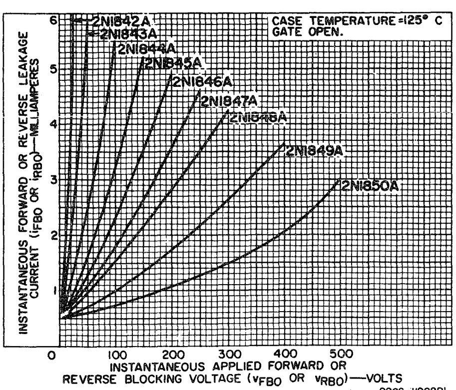


Fig. 6 - Typical Forward and Reverse Leakage Characteristics for Types 2N1842A through 2N1850A.

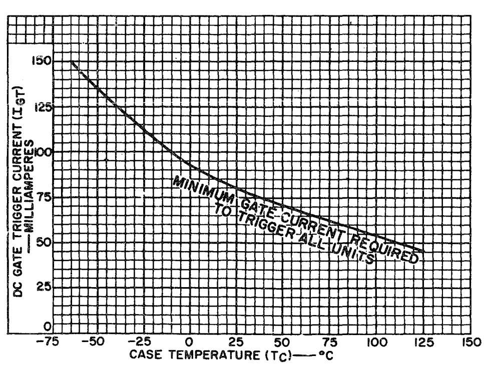


Fig. 7 - Gate Trigger-Current Characteristic for Types 2N1842A through 2N1850A.

CONTROLLED-RECTIFIER TERMS, SYMBOLS, AND DEFINITIONS
(as used in this bulletin)

1. **Transient Peak Reverse Voltage (Non-repetitive)** - v_{RM}(non-rep) - The maximum value of negative (reverse-blocking) voltage which may be applied to the anode for not more than 5 milliseconds when the gate is open.
2. **Peak Reverse Voltage (Repetitive)** - v_{RM}(rep) - The maximum instantaneous value of negative (reverse-blocking) voltage which may be applied repetitively to the anode when the gate is open.
3. **Peak Forward Blocking Voltage** - v_{FBOM}(rep) - The maximum instantaneous value of positive (forward-blocking) voltage which may be applied repetitively to the anode when the gate is open.
4. **Average Forward Current** - I_{FAV} - The average (dc) value of the current flowing from anode to cathode in the device.
5. **Peak Surge Current** - i_{FM}(surge) - The maximum instantaneous value of forward current which may be superimposed on the average forward current during one forward half-cycle when the device is operating within its specified maximum voltage, average-forward-current, gate-power, and temperature ratings in a single-phase circuit with 60-cps supply and resistive load. The peak surge current may be repeated after sufficient time has elapsed for the device to return to pre-surge thermal equilibrium conditions.
6. **Peak Gate Power** - p_{GM} - The maximum instantaneous power dissipated between gate and cathode.
7. **Average Gate Power** - P_{GAV} - The average power dissipated between gate and cathode.
8. **Peak Forward Gate Current** - i_{GKM} - The maximum instantaneous value of the current which may flow between gate and cathode.
9. **Peak Gate Voltage** - v_{GKM} or v_{KGM} - The maximum instantaneous value of voltage which may be applied between gate and cathode when the anode is open.
10. **Forward Breakover Voltage** - v_{BOO} - The value of positive anode voltage at which a controlled rectifier switches into the conducting state when the gate is open.
11. **Maximum Average Forward Blocking Current** - I_{FBOAV} - The maximum full-cycle average value of forward blocking current through a controlled rectifier when the gate is open.
12. **Maximum Average Reverse Blocking Current** - I_{RBOAV} - The maximum full-cycle average value of reverse blocking current through a controlled rectifier when the gate is open.
13. **Maximum Average Forward Voltage Drop** - V_{FAV} - The average value over one complete cycle of the forward voltage drop across a controlled rectifier operating at its maximum-average-forward-current rating in a single-phase circuit with 60-cps supply and resistive load.
14. **Maximum DC Gate Current** - I_{GT} - The gate current required to trigger a controlled rectifier operating at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.
15. **Gate-Trigger Voltage** - V_{GT} - The gate-to-cathode voltage required to trigger a controlled-rectifier at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.
16. **Holding Current** - i_{HOO} - The instantaneous value of forward current i_F below which a controlled rectifier with its gate open returns to its forward blocking state.
17. **Thermal Resistance, Junction-to-case** - θ_{JC} - The thermal resistance in °C per watt, between the junction and any of the six major surfaces on the perimeter of the hexagonal flange.
18. **Instantaneous Forward Current** - i_F - The instantaneous value of the current flowing from anode to cathode in the device.
19. **Instantaneous Forward Voltage Drop** - v_F - The instantaneous voltage drop across a controlled rectifier at a given instantaneous forward current i_F.
20. **Instantaneous Forward Blocking Voltage** - v_{FBOM} - Instantaneous forward blocking voltage of a controlled rectifier when the gate is open.
21. **Instantaneous Reverse Blocking Voltage** - v_{RBOM} - Instantaneous reverse blocking voltage of a controlled rectifier when the gate is open.
22. **Instantaneous Reverse Leakage Current** - i_{RBO} - Instantaneous reverse leakage current with the gate open.
23. **Instantaneous Forward Leakage Current** - i_{FBO} - Instantaneous forward leakage current with the gate open.

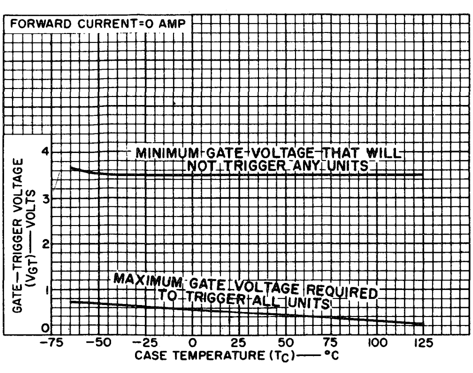


Fig.8 - Gate Trigger-Voltage Characteristics for Types 2N1842A through 2N1850A.

OPERATING CONSIDERATIONS

Because these controlled rectifiers may operate at voltages which are dangerous, care should be taken in the design of equipment to prevent personnel from coming in contact with the rectifier.

The recommended torque is 26 to 36 inch-pounds applied to 1/4-28 UNF-2B hex nut assembled on thread.

The applied torque during installation should not exceed 50 inch-pounds.

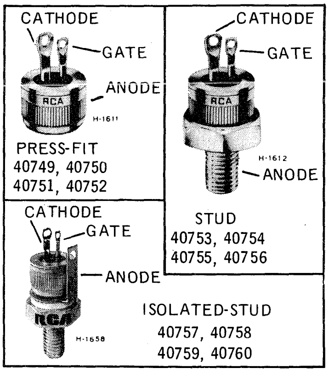
File No. 418

RCA

Solid State
Division

Thyristors

40749 40753 40757
40750 40754 40758
40751 40755 40759
40752 40756 40760



20-Ampere Silicon Controlled Rectifiers

Press-Fit, Stud, & Isolated-Stud Type Packages

For Low-Voltage Operation. . .40749, 40753, 40757
For 120-V Line Operation. . .40750, 40754, 40758
For 240-V Line Operation. . .40751, 40755, 40759
For High-Voltage Operation. . .40752, 40756, 40760

These RCA types are all-diffused, silicon controlled rectifiers (reverse-blocking triode thyristors) designed for power switching and voltage regulator applications and for heating, lighting and motor speed-control circuits.

These SCRs have an RMS on-state current rating ($I_{T\ [RMS]}$) of 20 A and have voltage ratings (V_{DROM}) of 100, 200, 400, and 600 volts.

FEATURES

- Low switching losses
- High di/dt and dv/dt capabilities
- Shorted-emitter gate-cathode construction
- Forward and reverse gate dissipation ratings
- All-diffused construction–assures exceptional uniformity and stability of characteristics
- Symmetrical gate-cathode construction–provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance

MAXIMUM RATINGS, *Absolute-Maximum Values:*		40749 40753 40757	40750 40754 40758	40751 40755 40759	40752 40756 40760	
NON-REPETITIVE PEAK REVERSE VOLTAGE						
Gate Open	V_{RSOM}	100	200	400	600	V
NON-REPETITIVE PEAK FORWARD VOLTAGE						
Gate Open	V_{DSOM}	150	250	500	700	V
REPETITIVE PEAK REVERSE VOLTAGE						
Gate Open	V_{RROM}	100	200	400	600	V
REPETITIVE PEAK OFF-STATE VOLTAGE						
Gate Open	V_{DROM}	100	200	400	600	V
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:						
For one cycle of applied principal voltage	I_{TSM}					
50-Hz, sinusoidal		170				A
60-Hz, sinusoidal		200				A
For more than one full cycle of applied principal voltage		See Fig. 10				
ON-STATE CURRENT:						
For case temperature (T_C) = 75° C, conduction angle of 180°						
Average DC value	$I_{T(AV)}$	12.5				A
RMS value	$I_{T(RMS)}$	20				A
RATE-OF-CHANGE OF ON-STATE CURRENT:						
$V_{DM} = V_{(BO)O}$, I_{GT} = 200 mA, t_r = 0.5 μs (See Fig. 2.)	di/dt	200				A/μs
GATE POWER DISSIPATION:						
PEAK FORWARD (for 10 μs max.)	P_{GM}	40				W
AVERAGE (averaging time = 10 ms, max.)	$P_{G(AV)}$	0.5				W
PEAK REVERSE	P_{RGM}	See Fig. 5				
TEMPERATURE RANGE:						
Storage		-65 to 150				°C
Operating (Case)		-65 to 100				°C
Soldering (10 s max. for terminals)		225				°C

ELECTRICAL CHARACTERISTICS

At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	LIMITS – ALL TYPES Min.	Typ.	Max.	UNITS
Instantaneous Forward Breakover Voltage: (Gate open, T_C = 100 °C)					
40749, 40753, 40757	$v_{(BO)O}$	100	–	–	V
40750, 40754, 40758		200	–	–	
40751, 40755, 40759		400	–	–	
40752, 40756, 40760		600	–	–	
Peak Off-State Current: (Gate open, T_C = 100 °C)					
Forward, $V_{DO} = V_{DROM}$	I_{DOM}	–	0.2	3	mA
Reverse, $V_{RO} = V_{RROM}$	I_{RROM}	–	0.1	2	
Instantaneous On-State Voltage: For i_T = 100 A, T_C = 25 °C	v_T	–	1.9	2.4	V
DC Gate Trigger Current: V_D = 12 V (DC), R_L = 30Ω, T_C = 25 °C	I_{GT}	–	8	15	mA
At other case temperatures			See Fig. 11		
DC Gate Trigger Voltage: V_D = 12 V (DC), R_L = 30Ω, T_C = 25 °C	V_{GT}		1.1	2	V
At other case temperatures			See Fig. 12		
Instantaneous Holding Current: Gate open, T_C = 25 °C	i_{HO}		9	20	mA
At other case temperatures			See Fig. 15		
Critical Rate-of-Rise of Off-State Voltage: ($V_{DO} = v_{(BO)O}$ Min. value, Exponential rise, T_C = 100°C, See Fig 5)					
40749, 40751, 40753, 40755, 40757, 40759	dv/dt	10	100	–	V/μs
40750, 40754, 40758		10	150	–	
40752, 40756, 40760		10	75	–	
Gate Controlled Turn-On Time: $V_D = v_{(BO)O}$ Min. value, i_T = 30 A, I_{GT} = 200 mA, 0.1 μs rise time, T_C = 25°C See Fig. 9	t_{gt}	–	2	–	μs
Circuit Commutated Turn-Off Time: $V_D = V_{F(BO)O}$ Min. value, i_T = 18 A, Pulse Duration = 50 μs, dv/dt = 20 V/μs, di/dt = −30 A/μs, I_{GT} = 200 mA at turn on, T_C = 75° C See Fig. 4	t_q	–	20	40	μs
Thermal Resistance: Junction-to-Case	θ_{J-C}	–	–	1.2	°C/W
Junction-to-Isolated Stud	θ_{J-IS}	–	–	1.4	

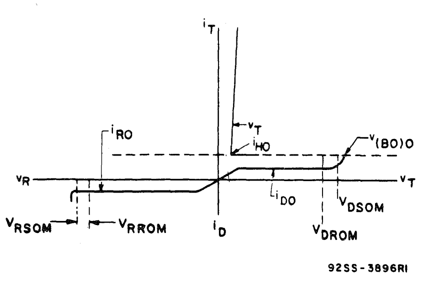


Fig. 1 - Principal voltage-current characteristic.

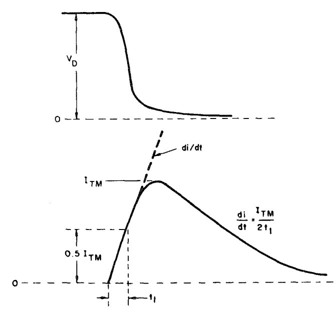


Fig. 2 - Rate-of-change of on-state current with time (defining di/dt).

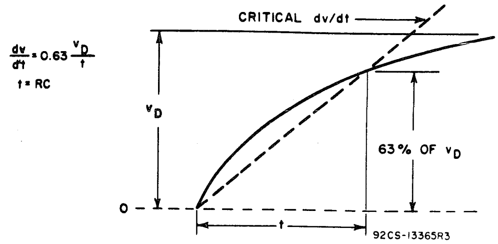


Fig. 3 - Rate-of-rise of off-state voltage with time (defining dv/dt).

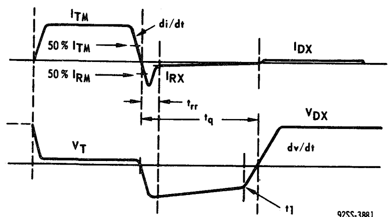


Fig. 4 - Relationship between on-state current, reverse current, on-state voltage and off-state voltage showing reference points for definition of turn-off time (tq).

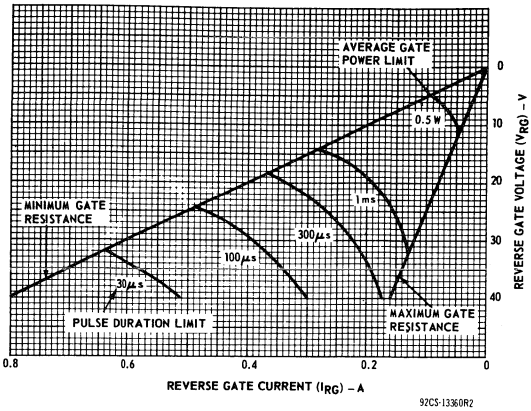


Fig. 5 - Reverse gate voltage vs. reverse gate current.

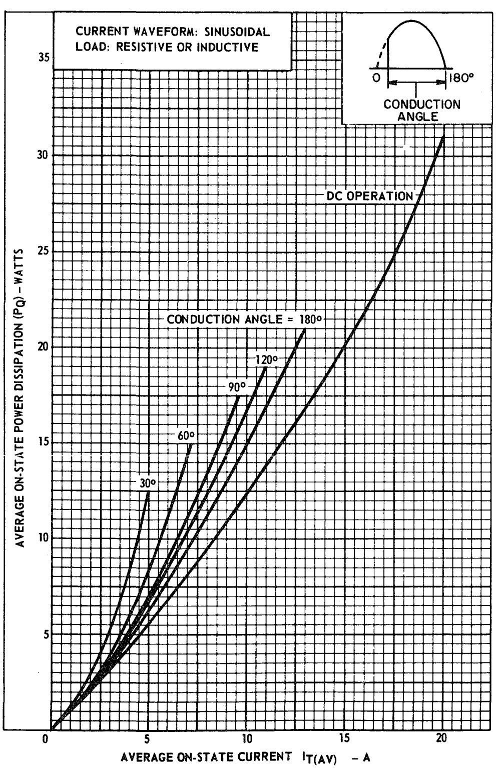


Fig. 6 - Power dissipation vs. on-state current.

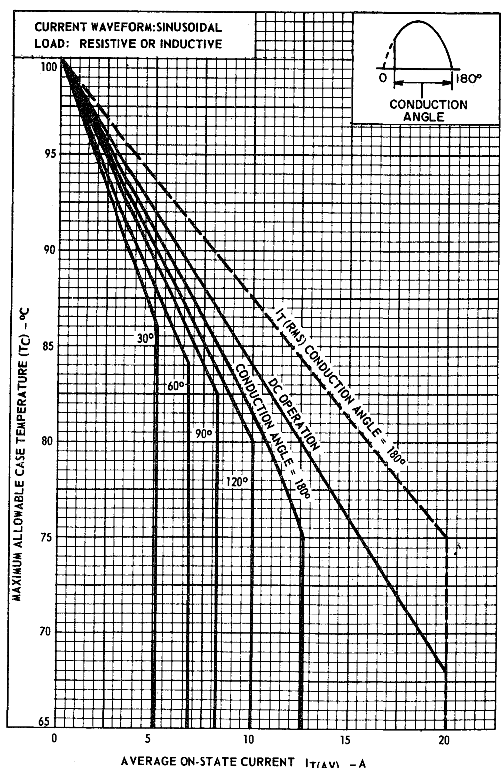


Fig. 7 - Maximum allowable case temperature vs. average forward current for stud and press-fit.

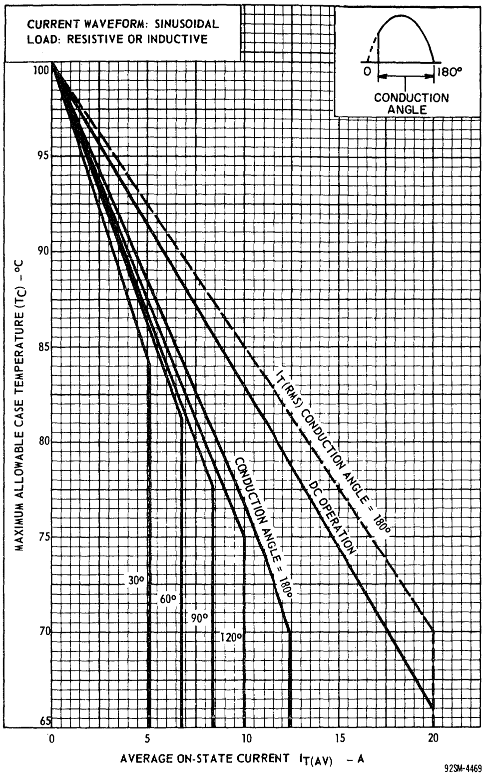


Fig. 8 - Maximum allowable case temperature vs. average forward current for isolated stud.

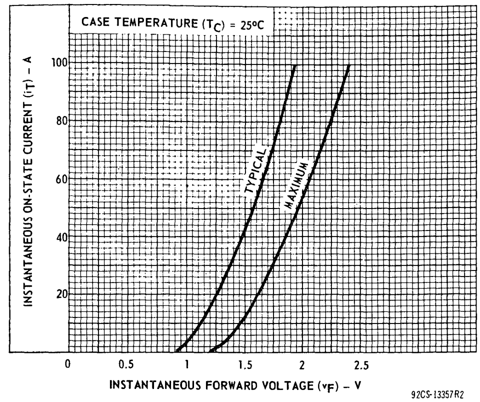


Fig. 10 - Instantaneous on-state current vs. on-state voltage.

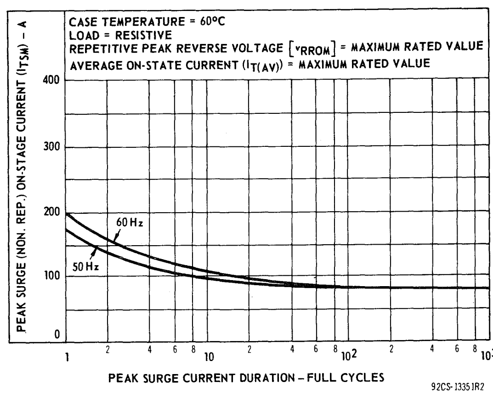


Fig. 11 - Peak surge on-state current vs. surge current duration.

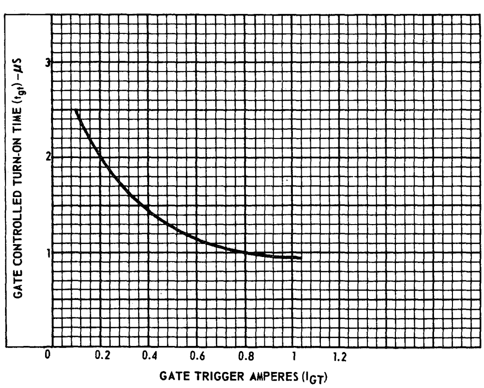


Fig. 9 - Gate controlled turn-on time (t_{gt}) vs. gate-trigger current.

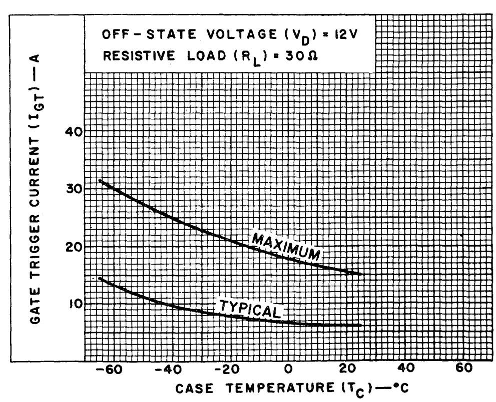


Fig 12 - DC gate-trigger current (FORWARD) vs. case temperature.

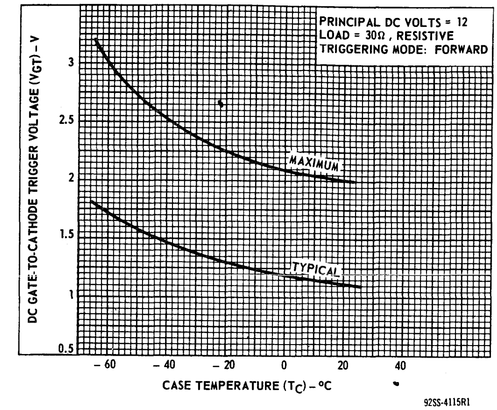


Fig. 13 - DC gate-trigger voltage vs. case temperatures.

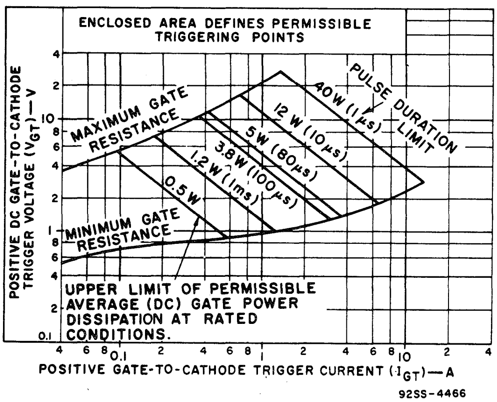


Fig. 14 - Typical forward-biased gate trigger characteristics.

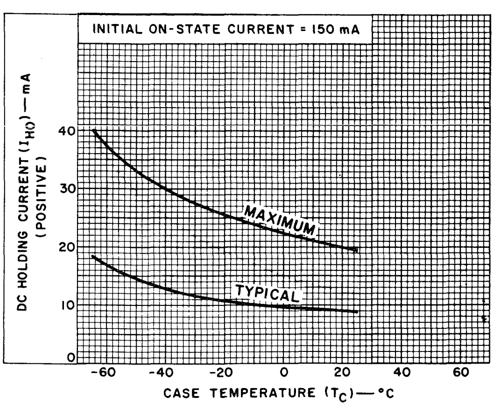


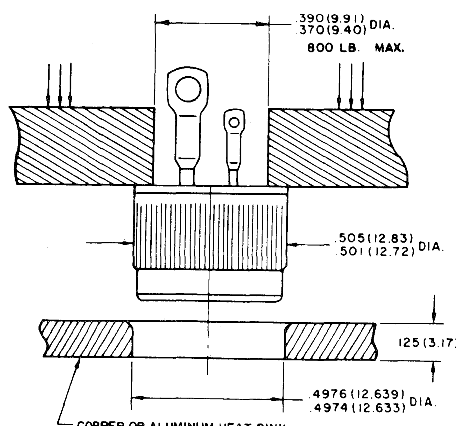
Fig. 15 - DC holding current vs. case temperature.

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

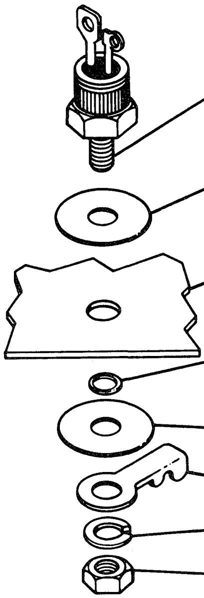
A recommended mounting method, shown in Fig. 15, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in. (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ±.0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force is applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.



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

Fig. 16 - Suggested mounting method of press-fit package types.



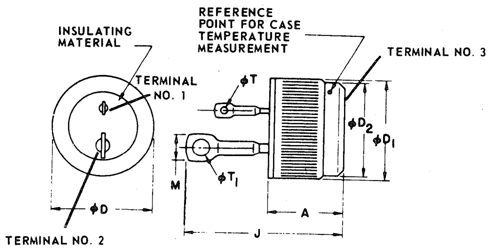
*Only hardware required for isolated-stud package.

Fig. 17 - Suggested mounting arrangement for stud and isolated-stud package types.

Table I – Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

Package	Type of Mounting Employed	Thermal Resistance-°C/W
Press-Fit	Press-fitted into heat sink. (Minimum Required thickness of heat sink = 1/8 in.	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188° C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6
	Mounted on heat sink with a 0.004 to 0.006 in. thick mica insulating washer used between unit and heat sink.	
	Without heat sink compound	2.5
	With heat sink compound	1.5

DIMENSIONAL OUTLINE FOR TYPES 40749, 40750, 40751, 40752

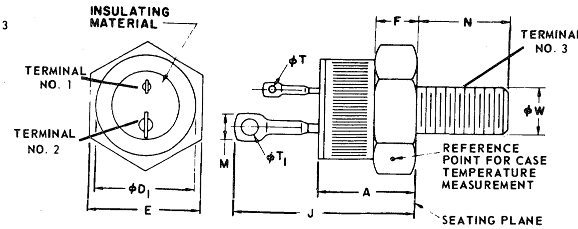


SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	—	.380	—	9.65	
ϕD	.501	.510	12.73	12.95	
ϕD_1	—	.505	—	12.83	2
ϕD_2	.465	.475	11.81	12.07	
J	—	.750	—	19.05	
M	—	.155	—	3.94	1
ϕT	.058	.068	1.47	1.73	
ϕT_1	.080	.090	2.03	2.29	

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Outer diameter of knurled surface.

92SS-3816

DIMENSIONAL OUTLINE FOR TYPES 40753, 40754, 40755, 40756



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	—
ϕD_1	—	.544	—	13.81	—
E	.544	.562	13.82	14.28	—
F	.113	.200	2.87	5.08	3
J	—	.950	—	24.13	—
M	—	.155	—	3.94	1
N	.422	.453	10.72	11.50	—
ϕT	.058	.068	1.47	1.73	—
ϕT_1	.080	.090	2.03	2.29	—
ϕW	.2225	.2268	5.652	5.760	2

NOTE 1: Contour and angular orientation of these terminals is optional.
NOTE 2: Pitch diameter of ¼-28 UNF-2A (coated) threads (ASA B1. 1-1960).
NOTE 3: A chamfer or undercut on one or both ends of hexagonal portion is optional.

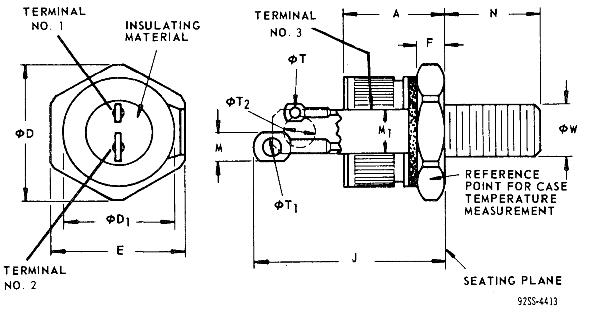
92SS-3817

TERMINAL CONNECTIONS

For Types 40749, 40750, 40751, 40752
40753, 40754, 40755, 40756

Terminal No. 1 – Gate
Terminal No. 2 – Cathode
Case, Terminal No. 3 – Anode

DIMENSIONAL OUTLINE FOR TYPES 40757, 40758, 40759, 40760



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	.673	–	17.09	
ΦD	.604	.614	15.34	15.59	
$ΦD_1$	.501	.505	12.72	12.82	
E	.551	.557	13.99	14.14	
F	.175	.185	4.44	4.69	
J	–	1.055	–	26.79	
M	–	.155	–	3.94	
M_1	.200	.210	5.08	5.33	
N	.422	.452	10.72	11.48	
ΦT	.058	.068	1.47	1.73	2
$ΦT_1$	.080	.090	2.03	2.29	2
$ΦT_2$	.138	.148	3.50	3.75	2
ΦW	.2225	.2268	5.652	5.760	3

NOTE 1: Ceramic between hex (stud) and terminal No. 3 is beryllium oxide.

NOTE 2: Contour and angular orientation of these terminals is optional.

NOTE 3: Pitch diameter of ¼-28 UNF-2A (coated) threads (ASA B1. 1-1960).

"**WARNING:** RCA-40757, 40758, 40759, 40760 should be handled with care. The ceramic portion of these thyristors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the thyristors because the dust resulting from such action may be hazardous if inhaled."

TERMINAL CONNECTIONS

For Types 40757, 40758
40759, 40760

Terminal No. 1 – Gate
Terminal No. 2 – Cathode
Terminal No. 3 – Anode

RCA
Solid State
Division

Thyristors
2N681
2N690

All-Diffused Types for Power-Control and Power-Switching Applications

JEDEC TO-48

RCA-2N681 through 2N690 controlled-rectifiers are all-diffused, three-junction, silicon devices for use in power-control and power-switching applications requiring blocking-voltage capabilities to 600 volts and forward-current capability of 16 amperes (average value) or 25 amperes (rms value).

FEATURES

- All-diffused construction — assures exceptional uniformity and stability of characteristics
- Multi-diffusion process — permits precise control of individual junction parameters
- Symmetrical gate-cathode construction — provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- Direct-soldered internal construction — assures exceptional resistance to fatigue
- Each unit aged at maximum ratings to assure dependable performance
- All-welded construction and hermetic sealing
- Shorted emitter gate-cathode construction
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance
- Exceptionally high stud-torque capability through use of high-strength copper-alloy stud

Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage at a Frequency between 50 and 400 cps, and with Resistive or Inductive Load

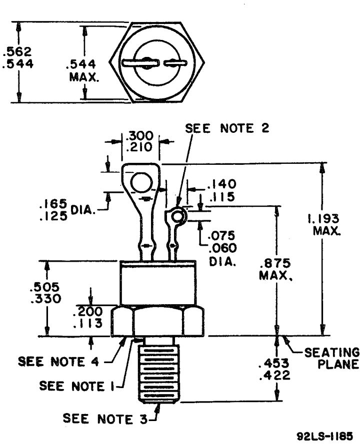
RATINGS	CONTROLLED-RECTIFIER TYPES										UNITS
	2N681	2N682	2N683	2N684	2N685	2N686	2N687	2N688	2N689	2N690	
Transient Peak Reverse Voltage (Non-Repetitive), v_{RM} (non-rep)[a]	35	75	150	225	300	350	400	500	600	720	volts
Peak Reverse Voltage (Repetitive), v_{RM} (rep)[b]	25	50	100	150	200	250	300	400	500	600	volts
Peak Forward Blocking Voltage (Repetitive), v_{FBOM} (rep)[c]	←				600					→	volts
Forward Current:											
For case temperature (T_C) of +65° C, and a conduction angle of 180°, I_{FAV}[d]	←				16					→	amp
RMS value, I_{FRMS}[e]	←				25					→	amp
For other case temperatures and conduction angles	←				See *Fig.2*					→	
Peak Surge Current, i_{FM} (surge)[f]:											
For one cycle of applied voltage	←				150					→	amp
For more than one cycle of applied voltage	←				See *Fig.3*					→	
Peak Gate Power, P_{GM}[g]	←				5					→	watts
Average Forward Gate Power, P_{GAV}[h]	←				0.5					→	watt
Peak Forward Gate Current, i_{GKM}[i]	←				2					→	amp
Peak Gate Voltage:											
Forward, v_{GKM}[k]	←				10					→	volts
Reverse, v_{KGM}[k]	←				5					→	volts
Temperature:											
Storage, T_{stg}	←				-65 to +150					→	°C
Operating, Case#, T_C	←				-65 to +125					→	°C
Free Air, T_{FA}	←				See *Fig.4*					→	

Electrical and Thermal Characteristics at Maximum Electrical Ratings (unless otherwise specified), and at Indicated Case Temperature, T_C.

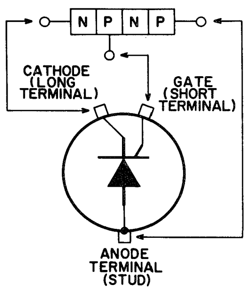
CHARACTERISTICS	CONTROLLED-RECTIFIER TYPES 2N681	2N682	2N683	2N684	2N685	2N686	2N687	2N688	2N689	2N690	UNITS
Minimum Forward Breakover Voltage, v_{BOO} [m]:											
At T_C = +125° C	25	50	100	150	200	250	300	400	500	600	volts
Maximum Average (DC) Forward Blocking Current, I_{FBOAV} [n]:											
At T_C = +125° C	6.5	6.5	6.5	6.5	6	5.5	5	4	3	2.5	ma
Maximum Average (DC) Reverse Blocking Current, I_{RBOAV} [p]:											
At T_C = +125° C	6.5	6.5	6.5	6.5	6	5.5	5	4	3	2.5	ma
Maximum Average Forward Voltage Drop, V_{FAV} [q]:											
At a Forward Current of 25 amperes and a T_C = +65° C	← 0.86 →										volt
Maximum DC Gate-Trigger Current, I_{GT} [r]:											
At T_C = +125° C	← 25 →										ma
DC Gate-Trigger Voltage, V_{GT} [s]:											
Maximum at T_C = -65° to +125° C	← 3 →										volts
Minimum at T_C = +125° C	← 0.25 →										volt
Holding Current, i_{HOO} [t]:											
Typical at T_C = +125° C	← 15 →										ma
Maximum Thermal Resistance, Junction-to-Case, $\theta_{J\text{-}C}$ [u]	← 2 →										°C/watt

\# Measured at the center of any of the six major faces on the perimeter of the hexagonal flange.

DIMENSIONAL OUTLINE JEDEC TO-48



TERMINAL DIAGRAM



TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER

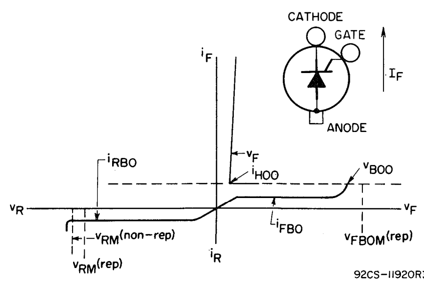
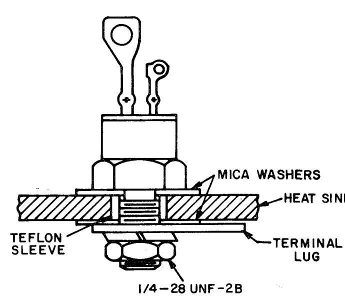


Fig. 1



Suggested Mounting Arrangement for Insulating Types 2N681 - 2N690 from Heat Sink. Components Shown (Except Heat Sink) are Furnished with Each Device.

Note 1: Complete threads to extend to within 2-1/2 threads of head. Dia. of unthreaded portion 0.249" maximum, 0.220" minimum.

Note 2: Angular orientation of these terminals is undefined. Square or radius on end of terminal is optional.

Note 3: 1/4-28 UNF-2A. Maximum pitch dia. of plated threads shall be basic pitch dia. 0.2268", minimum pitch dia. 0.2225". Ref. (Screw Thread Standards for Federal Services 1957) Handbook H28 1957 P1.

Note 4: A chamfer (or undercut) on one or both ends of hexagonal portion is optional.

RATING CHART

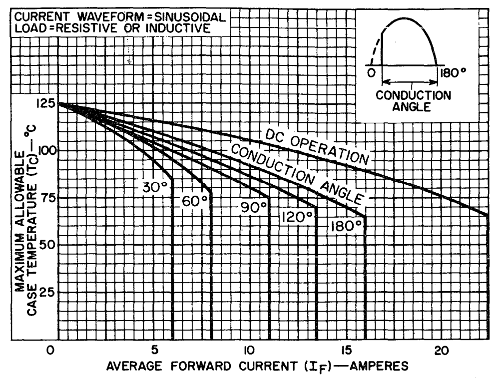


Fig.2 92CS-11928R3

SURGE CURRENT RATING CHART

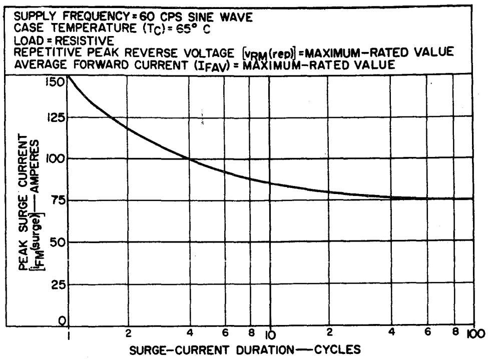


Fig.3 92CS-11918R1

OPERATION GUIDANCE CHART

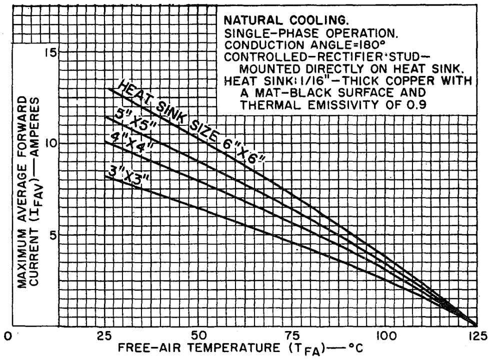


Fig.4 92CS-11916R1

FORWARD CHARACTERISTICS

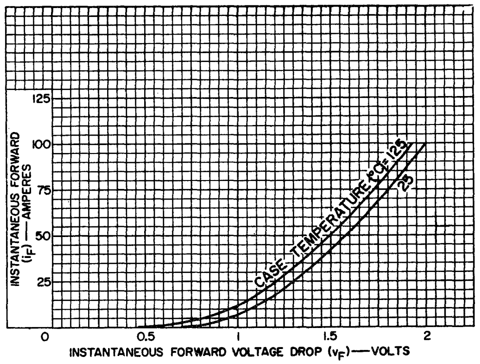


Fig.5 92CS-11917

FORWARD AND REVERSE LEAKAGE CHARACTERISTICS

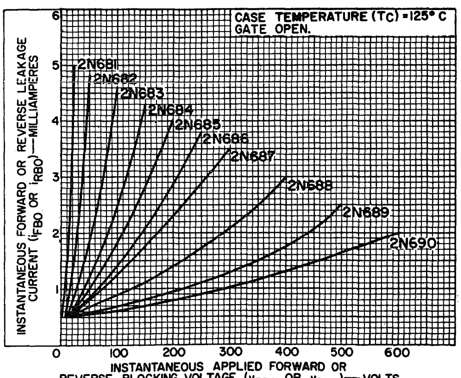


Fig.6 92CS-11915R2

RCA

Solid State Division

Thyristors

2N3650 2N3652 2N3651 2N3653 40735

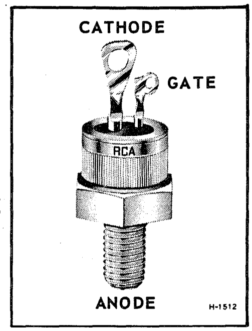
RCA-2N3650 to 2N3653, inclusive, and the RCA-40735* are all diffused, silicon controlled rectifiers (reverse-blocking triode thyristors) intended for high-speed switching applications such as power inverters, switching regulators, and high-current pulse applications. They feature fast turn-off, high dv/dt, and high di/dt characteristics and may be used at frequencies up to 25 kHz.

The 2N3650 to 2N3653 have forward and reverse off-state voltage ratings of 100, 200, 300, and 400 volts, respectively. Type 40735 has a forward and reverse off-state voltage rating of 600 volts.

*Formerly RCA Dev. Type No. TA7553.

35-AMPERE SILICON CONTROLLED RECTIFIERS

Fast Turn-Off Types for Inverter and Pulse Applications



JEDEC TO-48

FEATURES

- Fast turn-off time – 15 μs max.
- High di/dt and dv/dt capabilities
- High peak-current capability
- Shorted-emitter gate-cathode construction
- Forward and reverse gate dissipation ratings
- All-diffused construction – assures exceptional uniformity and stability of characteristics
- Symmetrical gate-cathode construction – provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- Hermetic construction
- Low thermal resistance

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N3650	2N3651	2N3652	2N3653	40735	
*NON-REPETITIVE PEAK REVERSE VOLTAGE Gate Open	V_{RSOM}	150	300	400	500	700	V
NON-REPETITIVE PEAK FORWARD VOLTAGE Gate Open	V_{DSOM}	150	300	400	500	700	V
*REPETITIVE PEAK REVERSE VOLTAGE Gate Open	V_{RROM}	100	200	300	400	600	V
*REPETITIVE PEAK OFF-STATE VOLTAGE Gate Open	V_{DROM}	100	200	300	400	600	V
*PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT: For one cycle of applied principal voltage (60 Hz, sinusoidal)	I_{TSM}	←		180		→	A
ON-STATE CURRENT: For case temperature (T_C) = 25 °C							
* Average DC value, conduction angle of 180°	$I_{T(AV)}$	←		25		→	A
RMS value	$I_{T(RMS)}$	←		35		→	A
*RATE-OF-CHANGE OF ON-STATE CURRENT: $V_{DM} = V_{(BO)O}$, I_{GT} = 200 mA, t_r = 0.1 μs (See Fig. 2)	di/dt	←		400		→	A/μs
*GATE POWER DISSIPATION							
PEAK FORWARD (for 10 μs max.)	P_{GM}	←		40		→	W
AVERAGE (averaging time = 10 ms, max.)	$P_{G(AV)}$	←		1		→	W
*TEMPERATURE RANGE							
Storage		←		-65 to 150		→	°C
Operating (Case)		←		-65 to 120		→	°C
Soldering (10 s max. for case)		←		225		→	°C

*In accordance with JEDEC registration data format (JS-14, RDF1)-- applies to the JEDEC (2N-Series) types only.

ELECTRICAL CHARACTERISTICS, ***At Maximum Ratings and at Indicated Case Temperature (T_C) Unless Otherwise Specified***

CHARACTERISTIC	SYMBOL	LIMITS Type 2N3650 MIN.	TYP.	MAX.	Type 2N3651 MIN.	TYP.	MAX.	Type 2N3652 MIN.	TYP.	MAX.	Type 2N3653 MIN.	TYP.	MAX.	Type 40735 MIN.	TYP.	MAX.	UNITS
INSTANTANEOUS FORWARD BREAKOVER VOLTAGE: Gate Open, T_C = 120 °C	$v_{(BO)O}$	100	–	–	200	–	–	300	–	–	400	–	–	600	–	–	V
* PEAK OFF-STATE CURRENT: (Gate Open, T_C = 120 °C) FORWARD, $V_{DO} = V_{DROM}$	I_{DOM}	–	–	6	–	–	6	–	–	5.5	–	–	4	–	–	3	mA
REVERSE, $V_{RO} = V_{RROM}$	I_{RROM}	–	–	6	–	–	6	–	–	5.5	–	–	4	–	–	3	mA
* INSTANTANEOUS ON-STATE VOLTAGE: For i_T = 25 A, T_C = 25 °C	v_T	–	–	2.05	–	–	2.05	–	–	2.05	–	–	2.05	–	–	2.05	V
DC GATE TRIGGER CURRENT: V_D = 6 V (DC), R_L = 4 Ω, T_C = 25 °C	I_{GT}	–	80	180	–	80	180	–	80	180	–	80	180	–	80	180	mA
V_D = 6 V (DC), R_L = 2 Ω, T_C = -65 °C	I_{GT}	–	150	500*	–	150	500*	–	150	500*	–	150	500*	–	150	500	mA
DC GATE TRIGGER VOLTAGE: V_D = 6 V (DC), R_L = 4 Ω, T_C = 25 °C	V_{GT}	–	1.5	3	–	1.5	3	–	1.5	3	–	1.5	3	–	1.5	3	V
$V_D = V_{DROM}$, R_L = 200 Ω, T_C = 120 °C	V_{GT}	0.25*	–	–	0.25*	–	–	0.25*	–	–	0.25*	–	–	0.25	–	–	V
V_D = 6 V (DC), R_L = 2 Ω, T_C = -65 °C	V_{GT}	–	2	4.5*	–	2	4.5*	–	2	4.5*	–	2	4.5*	–	2	4.5	V
INSTANTANEOUS HOLDING CURRENT: Gate Open At T_C = 25 °C	i_{HO}	–	75	150	–	75	150	–	75	150	–	75	150	–	75	150	mA
* At T_C = -65 °C	i_{HO}	–	150	350	–	150	350	–	150	350	–	150	350	–	150	350	mA
* CRITICAL RATE-OF-RISE OF OFF-STATE VOLTAGE: $V_{DO} = V_{DROM}$ Exponential rise, T_C = 120 °C, (See Fig. 4.)	dv/dt	200	–	–	200	–	–	200	–	–	200	–	–	200	–	–	V/μs
CIRCUIT COMMUTATED TURN-OFF TIME (Rectangular Pulse): $V_{DX} = V_{DROM}$, i_T = 10 A (pulse duration = 50 μs), I_{GT} = 200 mA at turn-on, -di/dt = 5 A/μs, dv/dt = 200 V/μs, V_{RX} = 15 min., V_{GK} = 0 V (at turn-off), T_C = 120 °C (See Fig. 4 & 5)	t_q	–	11	15	–	11	15	–	11	15	–	11	15	–	11	15	μs
CIRCUIT COMMUTATED TURN-OFF TIME (Half-Sinusoidal Waveform): $V_{DX} = V_{DROM}$, i_T = 100 A (pulse duration = 1.5 μs), I_{GT} = 200 mA dv/dt = 200 V/μs, V_{RX} = 30 V min., V_{GK} = 0 V (at turn-off), T_C = 115 °C (See Fig. 6 & 7)	t_q	–	12	15*	–	12	15*	–	12	15*	–	12	15*	–	12	15	μs
* THERMAL RESISTANCE: Junction-to-Case	θ_{J-C}	–	–	1.7	–	–	1.7	–	–	1.7	–	–	1.7	–	–	1.7	°C/W

*In accordance with JEDEC registration data format (JS-14, RD 1)--applies to the JEDEC (2N-Series) types only.

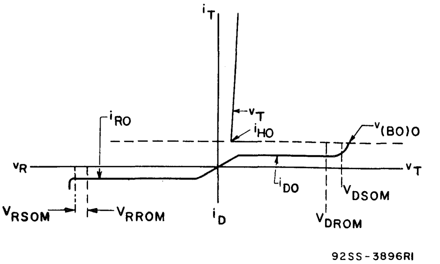


Fig. 1 - Principal voltage-current characteristic.

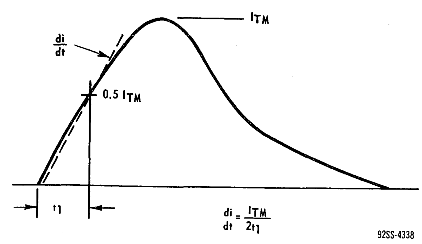


Fig. 2 - Rate-of-change of on-state current with time (defining di/dt).

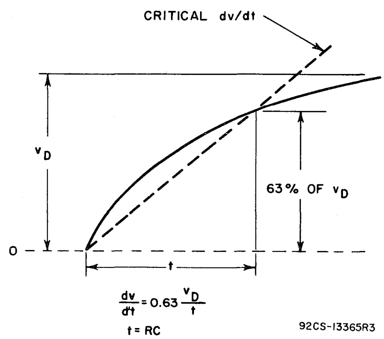


Fig. 3 - Rate-of-rise of off-state voltage with time (defining dv/dt).

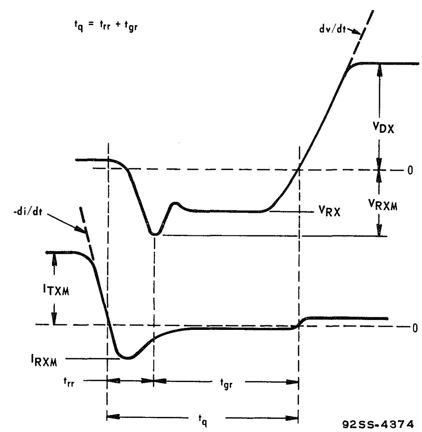


Fig. 4 - Relationship between off-state voltage, reverse voltage, on-state current, and reverse current showing reference points defining turn-off time (t_q), rectangular pulse.

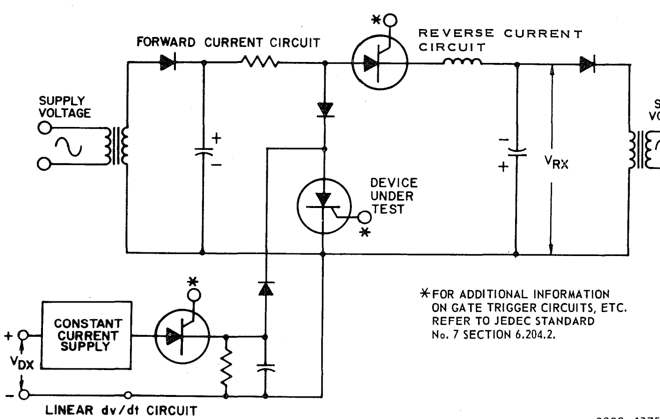


Fig. 5 - Circuit used to measure turn-off time (t_q), rectangular pulse.

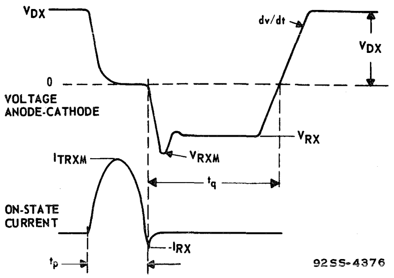


Fig. 6 - Relationship between off-state voltage, reverse voltage, on-state current, and reverse current showing reference points for specification of turn-off time (t_q), half sine wave pulse.

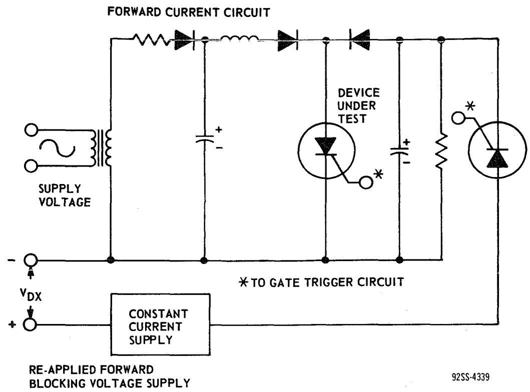


Fig. 7 - Circuit used to measure turn-off time (t_q), half sine wave pulse.

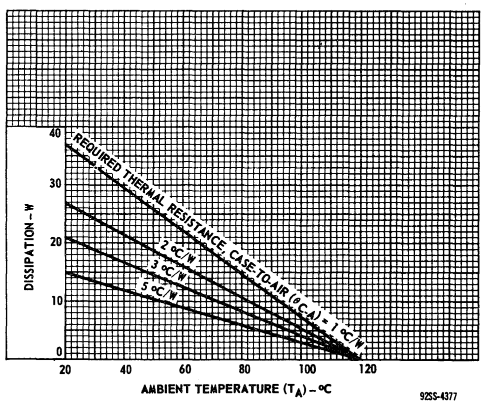


Fig. 8 - Heat sink guidance.

COOLING CONSIDERATIONS

The overall thermal resistance, case to air, needed to operate these devices at a given current and a specific ambient air temperature is shown in Fig. 8. For example: dissipation of 20 watts and an ambient air temperature of 43 °C (110 °F), the required thermal resistance, case to air, is 2 °C/W. This required case-to-air thermal resistance included both case-to-heat sink and heat sink-to-air thermal resistances.

Typical values of case-to-heat sink thermal resistances for different mounting arrangements are shown in Table 1. Thermal resistance characteristics of commercial heat sinks are contained in various manufacturers' data sheets.

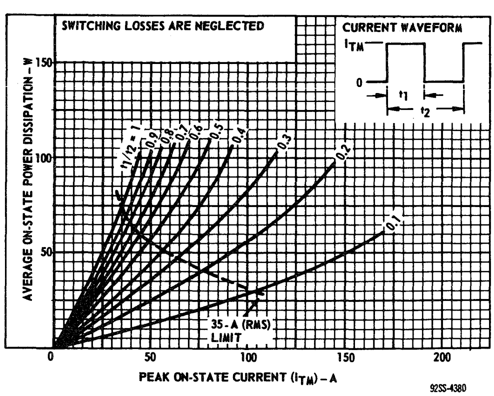


Fig. 9 - Power dissipation vs. on-state current.

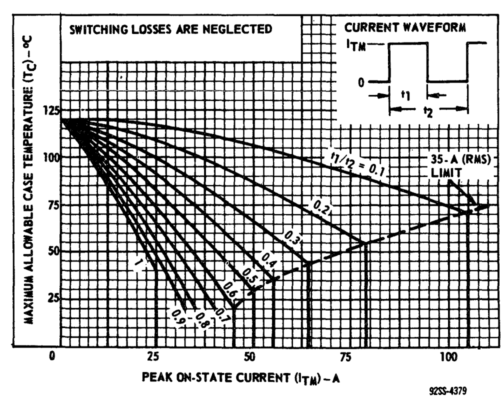


Fig. 10 - Maximum allowable case-temperature vs. on-state current.

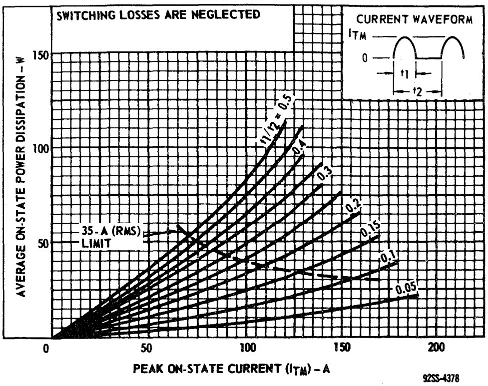


Fig. 11 - Power dissipation vs. on-state current.

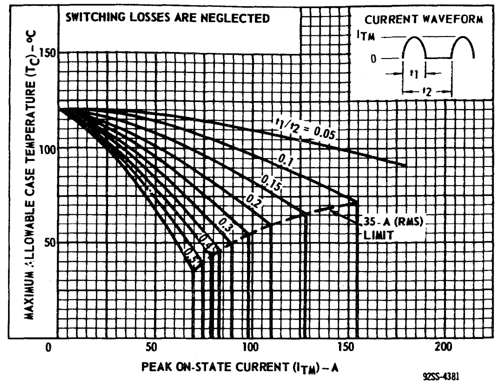


Fig. 12 - Maximum allowable case-temperature vs. on-state current

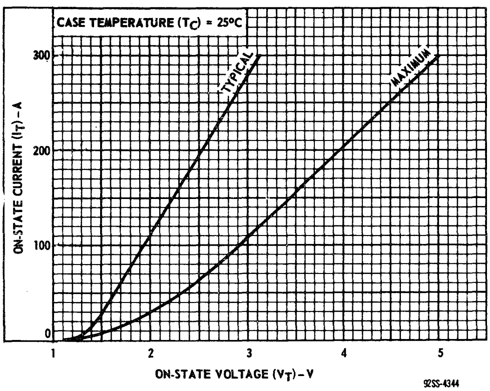


Fig. 13 - Variation of on-state current with on-state voltage.

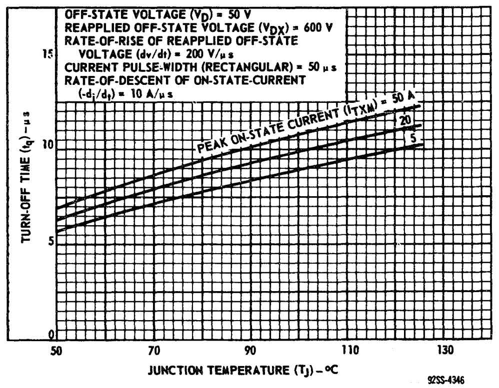


Fig. 14 - Typical variation of turn-off time with junction temperature (rectangular pulse).

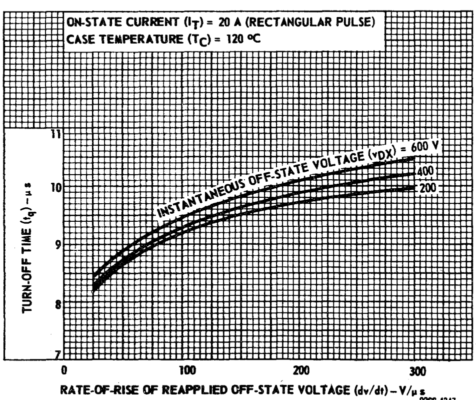


Fig. 15 - Typical variation of turn-off time with rate-of-rise of reapplied off-state voltage (rectangular pulse).

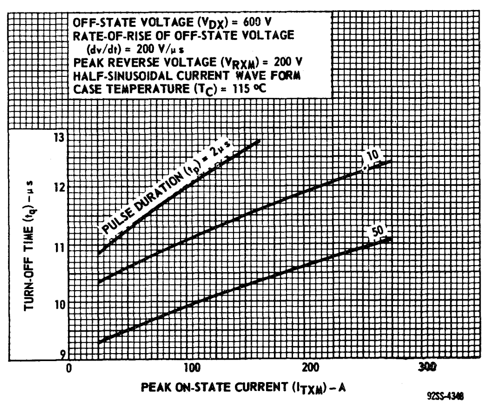


Fig. 16 – Typical variation of turn-off time with peak on-state current (half-sinusoidal pulse).

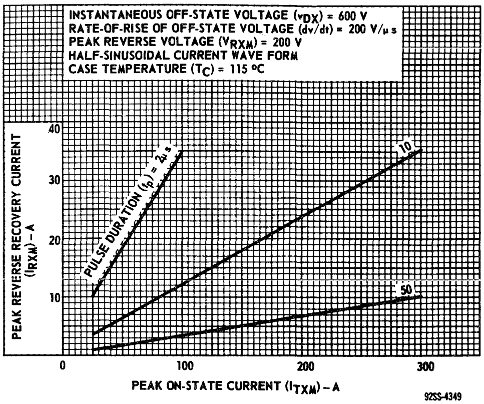


Fig. 17 - Typical variation of peak reverse recovery current with peak on-state current (half sinusoidal pulse).

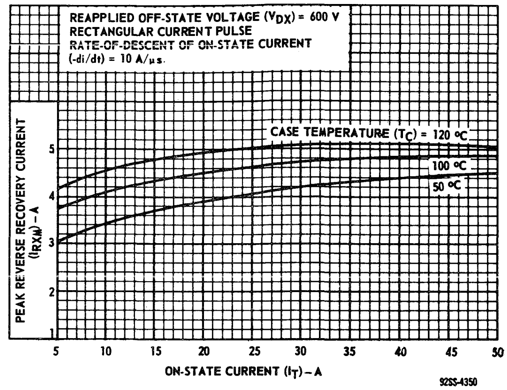


Fig. 18 - Typical variation of peak reverse-recovery current with on-state current.

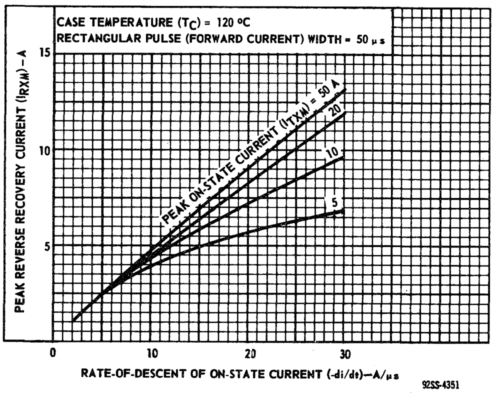


Fig. 19 - Typical variation of peak reverse recovery current with rate-of-descent of on-state current.

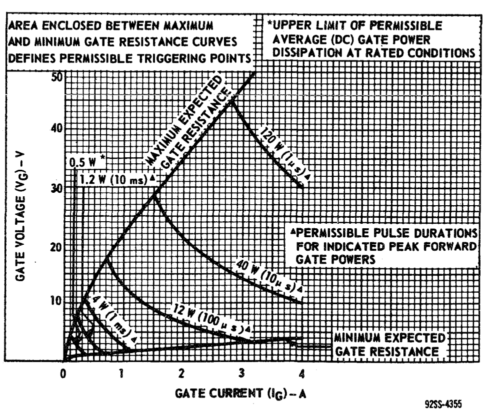


Fig. 20 - Typical forward-biased gate characteristics.

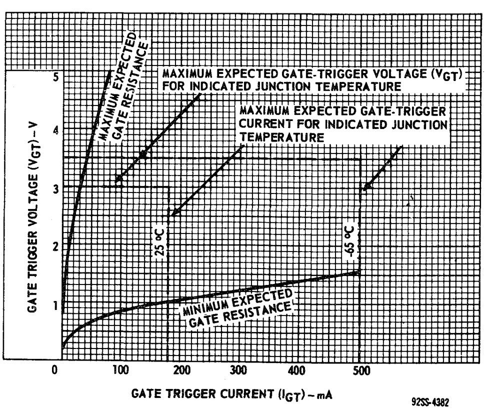
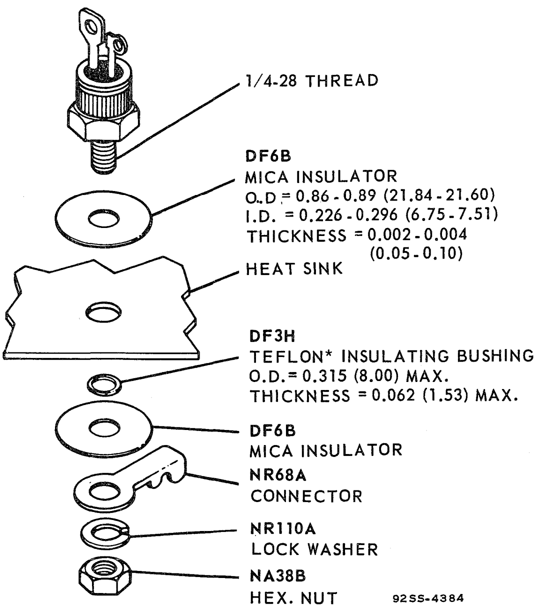


Fig. 21 - Typical gate trigger characteristics.



*REGISTERED TRADEMARK OF E.I. DUPONT DE NEMOURS & CO.

TABLE 1

TYPE	MOUNTING ARRANGEMENT	THERMAL RESISTANCE* (Case-to-Heat Sink)
2N3650-53 40735	Directly mounted on heat sink (Heat-Sink Compound: Dow Corning 340 silicone heat-sink compound, or equivalent.)	0.9 °C/W
	Mounted on heat sink with a 0.004 to 0.006-in. (0.10 to 0.15-mm) thick mica insulating washer (between unit and heat sink). Without heat-sink compound	2.8 °C/W
	With heat-sink compound Heat-Sink Compound: Dow Corning 340 silicone heat-sink compound, or equivalent.)	1.8 °C/W

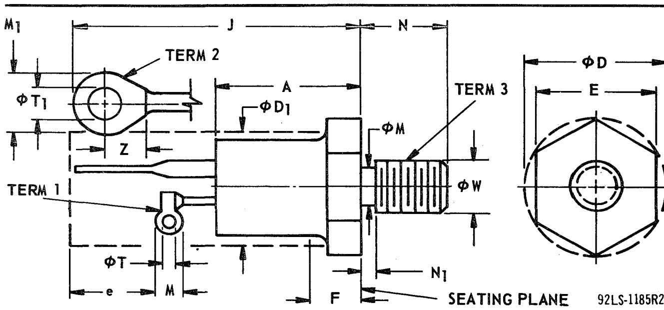
*Normal value. Actual value will vary slightly depending on use of heat sink compound, mounting surface, insulator thickness, mounting torque, and etc.

NOTE 1: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

NOTE 2: The recommended torque is 26 to 36 in. – lb. applied to a ¼-28 UNF-2B hex nut assembled on thread. The applied torque during installation should not exceed 50 in. – lb.

Fig. 22 - Suggested mounting arrangement.

DIMENSIONAL OUTLINE JEDEC TO-48



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	.330	.505	8.4	12.8	–
ΦD	–	.650	–	16.51	–
ΦD1	–	.544	–	13.81	5
e	.125	–	3.18	–	4
E	.544	.562	13.82	14.27	–
F	.113	.200	2.88	5.08	3
J	–	1.193	–	30.30	5
ΦM	.220	.249	5.59	6.32	6
M	.115	.140	2.93	3.55	1
M1	.210	.300	5.34	7.62	1
N	.422	.453	10.72	11.50	–
N1	–	.090	–	2.28	6
ΦT	.060	.075	1.53	1.90	–
ΦT1	.125	.165	3.18	4.19	–
ΦW	.2225	.2268	5.652	5.760	2
Z	.120	–	3.05	–	7

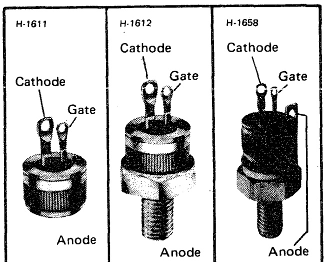
NOTES:
1. CONTOUR & ANGULAR ORIENTATION OF THESE TERMINALS IS OPTIONAL.
2. PITCH DIAMETER OF 1/4-28 UNF-2A (COATED) THREADS (ASA B1. 1-1969).
3. A CHAMFER OR UNDERCUT ON ONE OR BOTH ENDS OF HEXAGONAL PORTION IS OPTIONAL.
4. MINIMUM DIFFERENCE IN TERMINAL LENGTHS TO ESTABLISH DATUM LINE FOR NUMBERING TERMINALS.
5. THE DEVICE WITH EXCEPTION OF THE HEXAGON AND THREAD LIES WITHIN THE CYLINDER DEFINED BY D1 AND LENGTH J.
6. LENGTH OF INCOMPLETE OR UNDERCUT THREAD OF ΦM.
7. MINIMUM FLAT.

TERMINAL CONNECTIONS
Terminal 1 (Small Lug) – Gate
Terminal 2 (Large Lug) – Cathode
Terminal 3 (Stud) – Anode

RCA
Solid State
Division

Thyristors

2N3870-2N3873 & 40937
2N3896-2N3899 & 40938
40680-40683 & 40952



Press-fit	Stud	Isolated-stud
2N3870	2N3896	40680
2N3871	2N3897	40681
2N3872	2N3898	40682
2N3873	2N3899	40683
40937	40938	40952

35-A Silicon Controlled Rectifiers

Press-Fit, Stud, and Isolated-Stud Packages

For Low-Voltage Operation 2N3870, 2N3896, 40680
For 120-V Line Operation 2N3871, 2N3897, 40681
For 240-V Line Operation 2N3872, 2N3898, 40682
For High-Voltage Operation 2N3873, 2N3899, 40683, 40937, 40938, 40952

Features:

- **High di/dt and dv/dt capabilities**
- **Low on-state voltage at high current levels**
- **Low thermal resistance**
- **Shorted-emitter gate-cathode construction ... contains an internally diffused resistor between gate and cathode**
- **Center gate construction ... provides rapid uniform gate-current spreading for faster turn-on with substantially reduced heating effects**

These RCA types are all-diffused, silicon controlled rectifiers (reverse-blocking triode thyristors) designed for power switching, power control, and voltage regulator applications and for heating, lighting, and motor speed-control circuits.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		2N3870 2N3896 40680	2N3871 2N3897 40681	2N3872 2N3898 40682	2N3873 2N3899 40683	40937 40938 40952	
*NON-REPETITIVE PEAK REVERSE VOLTAGE▲ Gate Open	V_{RSOM}	150	330	660	700	900	V
NON-REPETITIVE PEAK OFF-STATE VOLTAGE▲ Gate Open	V_{DSOM}	150	330	660	700	900	V
*REPETITIVE PEAK REVERSE VOLTAGE▲ Gate Open	V_{RROM}	100	200	400	600	800	V
*REPETITIVE PEAK OFF-STATE VOLTAGE▲ Gate Open	V_{DROM}	100	200	400	600	800	V
ON-STATE CURRENT: T_C = 65°C◆, conduction angle = 180°:							
RMS	$I_{T(RMS)}$			35			A
* Average	$I_{T(AV)}$			22			A
For other conditions				See Figs. 3 & 5			
PEAK SURGE (NON-REPETITIVE) ON-STATE CURRENT:	I_{TSM}						
For one full cycle of applied principal voltage							
* 60 Hz (sinusoidal)				350			A
50 Hz (sinusoidal)				300			A
For more than one full cycle of applied principal voltage				See Fig. 4			
RATE OF CHANGE OF ON-STATE CURRENT $V_D = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.5 μs (See Fig. 13)	di/dt			200			A/μs
FUSING CURRENT (for SCR protection): T_J = -40 to 100°C, t = 1 to 8.3 ms	I^2t			300			A^2s
GATE POWER DISSIPATION●:							
Peak Forward (for 10 μs max., See Fig. 8)	P_{GM}			40			W
Peak Reverse	P_{RGM}			See Fig. 9			
Average (averaging time = 10 ms max.)	$P_{G(AV)}$			0.5			W
*TEMPERATURE RANGE■:							
Storage				-40 to 125			°C
Operating (Case)				-40 to 100			°C
TERMINAL TEMPERATURE (During soldering): For 10 s max. (terminals and case)	T_T			225			°C

* In accordance with JEDEC registration data filed for the JEDEC (2N-series) types.
▲ These values do not apply if there is a positive gate signal. Gate must be open or negatively biased.
◆ T_C = 60° for isolated-stud package types.
● Any product of gate current and gate voltage which results in a gate power less than the maximum is permitted.
■ Temperature measurement point is shown on the DIMENSIONAL OUTLINE.

ELECTRICAL CHARACTERISTICS

At Maximum Ratings Unless Otherwise Specified and at Indicated Case Temperature (T_C)

CHARACTERISTIC	SYMBOL	LIMITS FOR ALL TYPES Unless Otherwise Specified			UNITS
		MIN.	TYP.	MAX.	
Peak Off-State Current: (Gate open, T_C = 100°C) Forward Current (I_{DOM}) at $V_D = V_{DROM}$ Reverse Current (I_{ROM}) at $V_R = V_{RROM}$	I_{DOM} or I_{ROM}				mA
2N3870, 2N3896, 40680		–	0.2	2*	
2N3871, 2N3897, 40681		–	0.25	2.5*	
2N3872, 2N3898, 40682		–	0.3	3*	
2N3873, 2N3899, 40683, 40937, 40938, 40952		–	0.35	4*	
Instantaneous On-State Voltage:	v_T				V
i_T = 69 A (peak), T_C = 25°C		–	–	1.85*	
i_T = 100 A (peak), T_C = 25°C		–	1.7	2.1	
DC Gate Trigger Voltage:	V_{GT}				V
V_D = 12 V (dc), R_L = 30 Ω, T_C = -40°C		–	1.5	3*	
V_D = 12 V (dc), R_L = 30 Ω, T_C = 25°C		–	1.1	2	
For other case temperatures			See Fig. 11		
DC Gate Trigger Current:	I_{GT}				mA
V_D = 12 V (dc), R_L = 30 Ω, T_C = -40°C		–	46	80*	
V_D = 12 V (dc), R_L = 30 Ω, T_C = 25°C		1	25	40	
For other case temperatures			See Fig. 10		
Instantaneous Holding Current: Gate open, T_C = 25°C	i_{HO}	0.5	30	70	mA
For other case temperatures			See Fig. 7		
Gate Controlled Turn-On Time: (Delay Time + Rise Time) For $V_D = V_{DROM}$, I_{GT} = 200 mA, t_r = 0.1 μs, I_T = 30 A (peak), T_C = 25°C (See Fig. 12 & 14.)	t_{gt}	–	1.25	2	μs
Circuit Commutated Turn-Off Time: $V_D = V_{DROM}$, i_T = 18 A, pulse duration = 50 μs, dv/dt = 20 V/μs, -di/dt = -30 A/μs, I_{GT} = 200 mA, T_C = 80°C (See Fig. 15.)	t_q	–	20	40	μs
Critical Rate of Rise of Off-State Voltage: $V_D = V_{DROM}$, exponential voltage rise, Gate open, T_C = 100°C (See Fig. 16.)	dv/dt	10	100	–	V/μs
Thermal Resistance, Junction-to-Case: Steady-State	$R_{\theta JC}$				°C/W
Press-fit & stud types		–	–	0.9*	
Isolated-stud types		–	–	1	

*In accordance with JEDEC registration data filed for the JEDEC (2N-series) types.

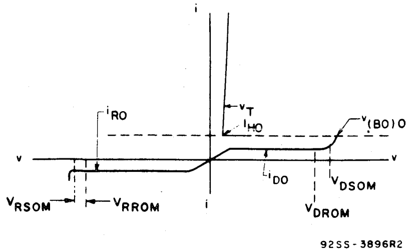


Fig.1—Principal voltage-current characteristic.

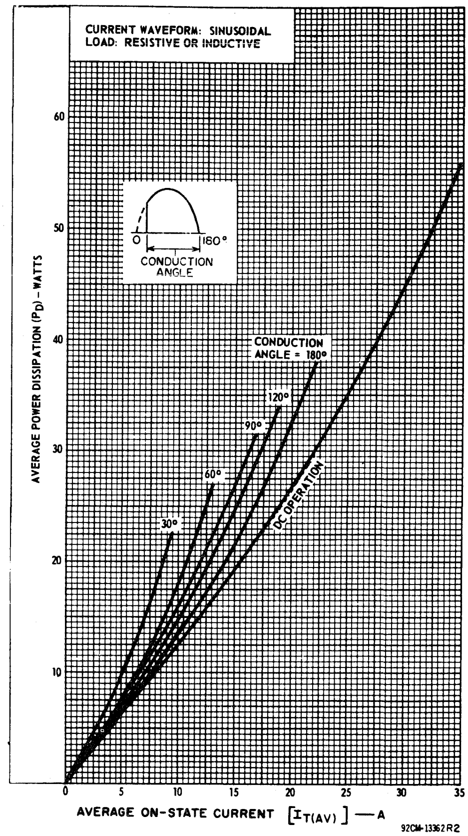


Fig.2—Power dissipation vs. on-state current.

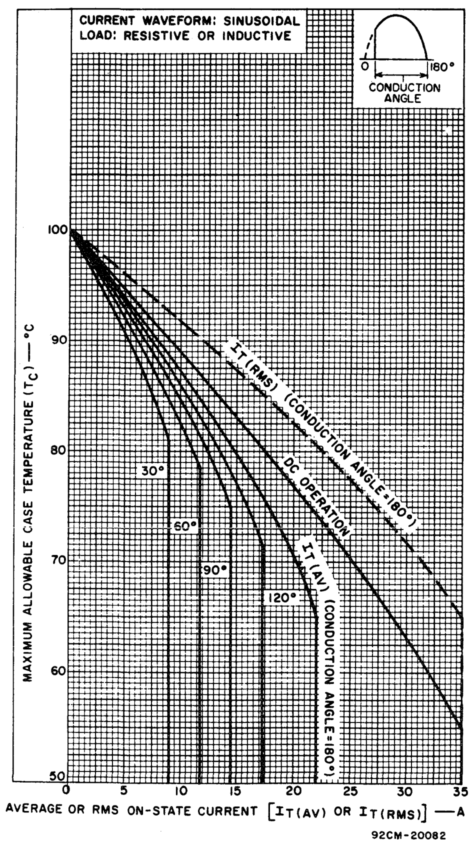


Fig.3—Maximum allowable case temperature vs. on-state current for press-fit and stud types.

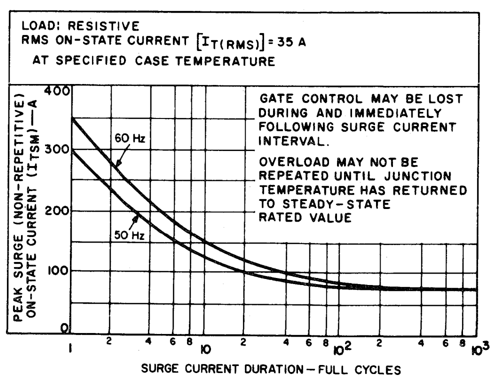


Fig.4—Peak surge on-state current vs. surge current duration.

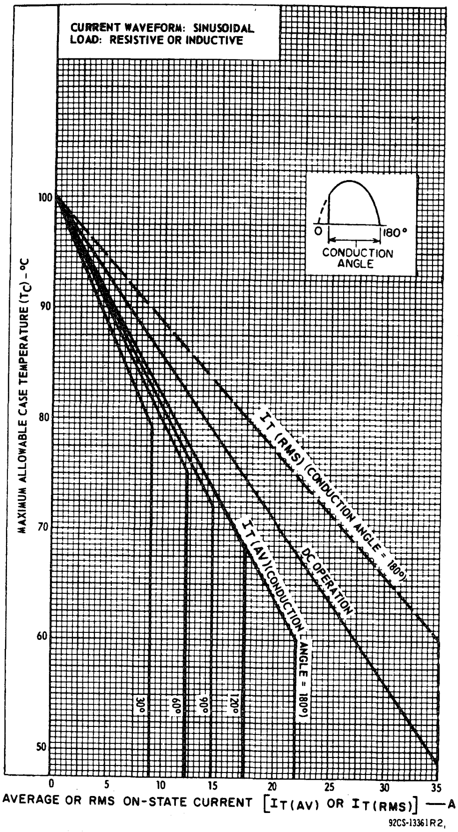


Fig.5—Maximum allowable case temperature vs. on-state current for isolated-stud types.

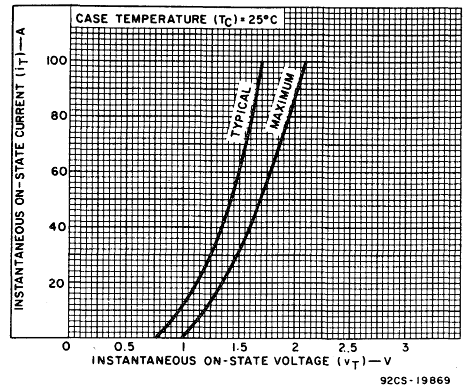


Fig.6—Instantaneous on-state current vs. on-state voltage.

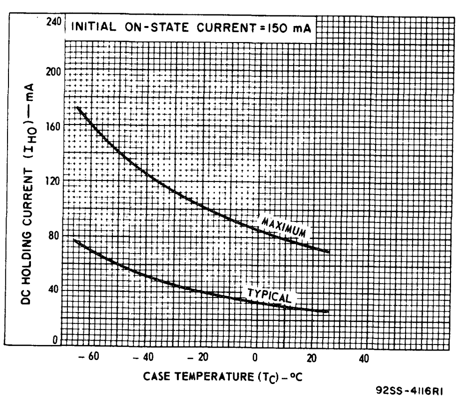


Fig.7—DC holding current vs. case temperature.

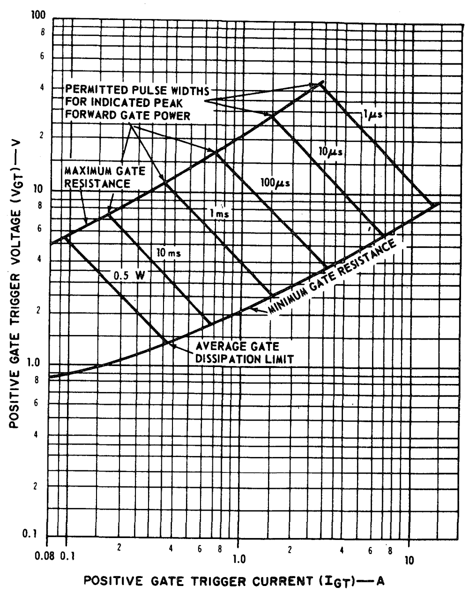


Fig.8—Gate pulse characteristics for forward triggering mode.

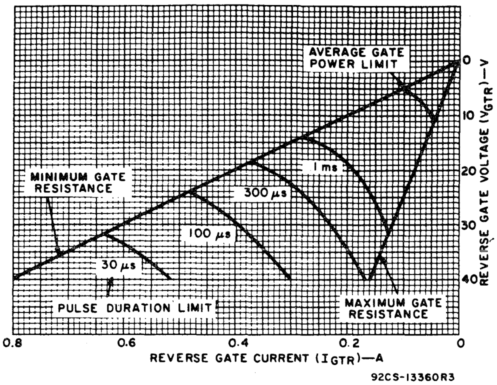


Fig.9—Reverse gate voltage vs. reverse gate current.

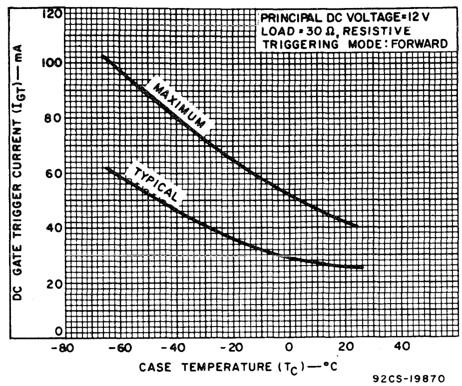


Fig.10—DC gate trigger current (forward) vs. case temperature.

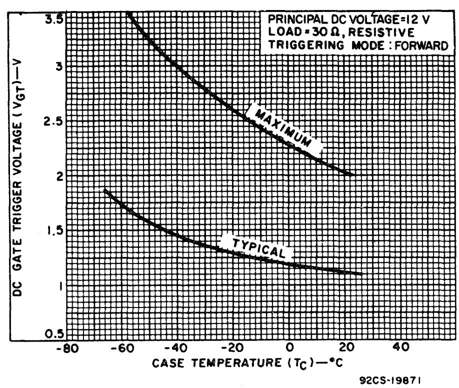


Fig.11—DC gate trigger voltage (forward) vs. case temperature.

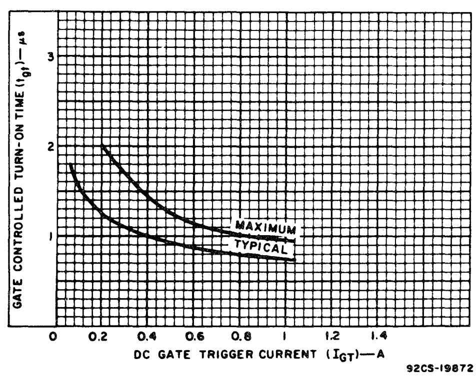


Fig.12—Gate-controlled turn-on time vs. gate trigger current.

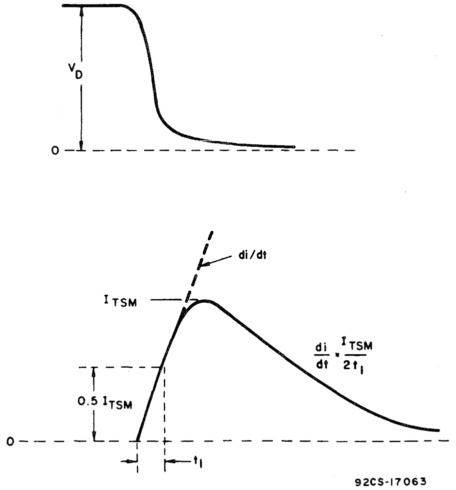


Fig.13—Rate of change of on-state current with time (defining di/dt).

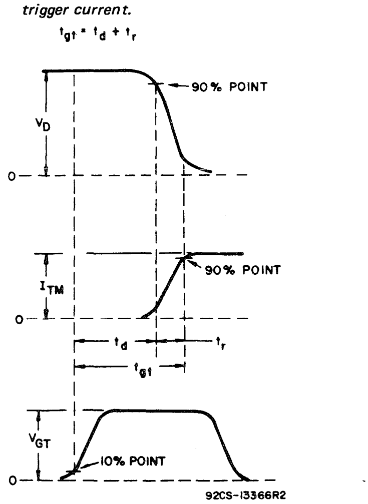


Fig.14—Relationship between off-state voltage, on-state current, and gate trigger voltage showing reference points for definition of turn-on time (t_{gt}).

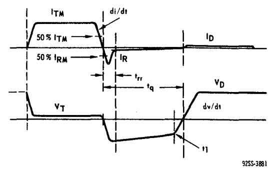


Fig.15—Relationship between instantaneous on-state current and voltage showing reference points for definition of circuit commutated turn-off time (t_q).

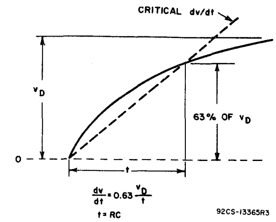


Fig.16—Rate of rise of off-stage voltage with time (defining critical dv/dt).

MOUNTING CONSIDERATIONS

Mounting of press-fit package types depends upon an interference fit between the thyristor case and the heat sink. As the thyristor is forced into the heat-sink hole, metal from the heat sink flows into the knurl voids of the thyristor case. The resulting close contact between the heat sink and the thyristor case assures low thermal and electrical resistances.

A recommended mounting method, shown in Fig. 17, shows press-fit knurl and heat-sink hole dimensions. If these dimensions are maintained, a "worst-case" condition of 0.0085 in. (0.2159 mm) interference fit will allow press-fit insertion below the maximum allowable insertion force of 800 pounds. A slight chamfer in the heat-sink hole will help center and guide the press-fit package properly into the heat sink. The insertion tool should be a hollow shaft having an inner diameter of 0.380 ± 0.010 in. (9.65 ± 0.254 mm) and an outer diameter of 0.500 in. (12.70 mm). These dimensions provide sufficient clearance for the leads and assure that no direct force will be applied to the glass seal of the thyristor.

The press-fit package is not restricted to a single mounting arrangement; direct soldering and the use of epoxy adhesives have been successfully employed. The press-fit case is tin-plated to facilitate direct soldering to the heat sink. A 60-40 solder should be used and heat should be applied only long enough to allow the solder to flow freely.

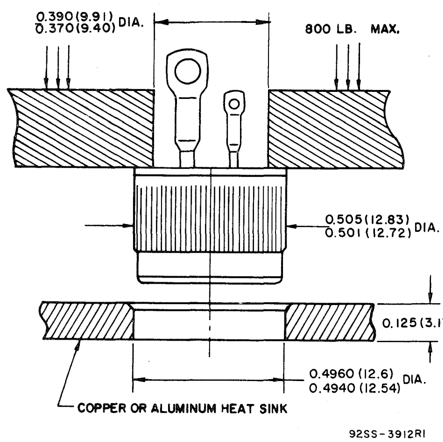
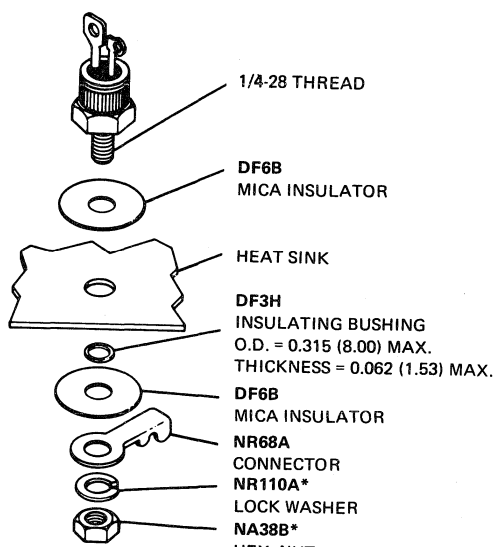


Fig.17—Suggested mounting method for press-fit package types.



*Only hardware required for isolated-stud package.

Note: Dimensions in parentheses are in millimeters.

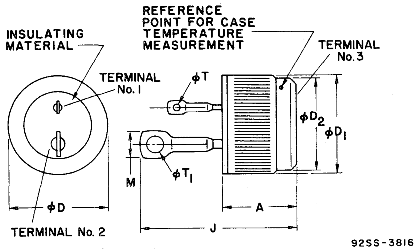
Fig.18—Suggested mounting arrangement for stud and isolated-stud package types.

Table I—Case-to-Heat Sink Thermal Resistance for Different Mounting Arrangements.

PACKAGE	TYPE OF MOUNTING EMPLOYED	THERMAL RESISTANCE-°C/W
Press-Fit	Press-fitted into heat sink. Minimum required thickness of heat sink = 1/8 in. (3.17 mm)	0.5
	Soldered directly to heat sink. (60-40 solder which has a melting point of 188°C should be used. Heating time should be sufficient to cause solder to flow freely).	0.1 to 0.35
Stud	Directly mounted on heat sink with or without the use of heat-sink compound.	0.6

When incorporating RCA Solid State Devices in equipment, it is recommended that the designer refer to "Operating Considerations for RCA Solid State Devices", Form No. 1CE-402, available on request from RCA Solid State Division, Box 3200, Somerville, N.J. 08876.

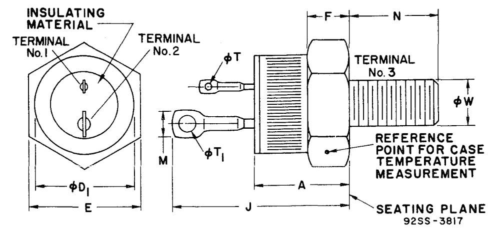
DIMENSIONAL OUTLINE FOR TYPES 2N3870, 2N3871, 2N3872, 2N3873, 40937 PRESS-FIT



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.380	–	9.65	
φD	0.501	0.510	12.73	12.95	
φD1	–	0.505	–	12.83	2
φD2	0.465	0.475	11.81	12.07	
J	–	0.750	–	19.05	
M	–	0.155	–	3.94	1
φT	0.058	0.068	1.47	1.73	
φT1	0.080	0.090	2.03	2.29	

NOTES:
1. Countour and angular orientation of these terminals is optional.
2. Outer diameter of knurled surface.

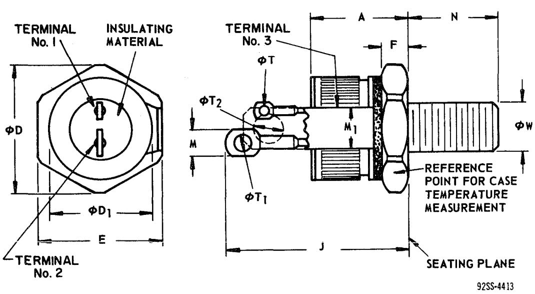
DIMENSIONAL OUTLINE FOR TYPES 2N3896, 2N3897, 2N3898, 2N3899, 40938 STUD



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.330	0.505	8.4	12.8	
φD1	–	0.544	–	13.81	
E	0.544	0.562	13.82	14.28	
F	0.113	0.200	2.87	5.08	3
J	–	0.950	–	24.13	
M	–	0.155	–	3.94	1
N	0.422	0.453	10.72	11.50	
φT	0.058	0.068	1.47	1.73	
φT1	0.080	0.090	2.03	2.29	
φW	1/4-28 UNF-2A		1/4-28 UNF-2A		2

NOTES:
1. Contour and angular orientation of these terminals is optional.
2. φW is pitch diameter of coated threads, Ref: ASA B_1, 1-1960. Recommended torque: 50 inch-pounds.
3. A chamfer or undercut on one or both ends of hexagonal portion is optional.

DIMENSIONAL OUTLINE FOR TYPES 40680, 40681, 40682, 40683, 40952 ISOLATED-STUD



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.673	–	17.09	
φD	0.604	0.614	15.34	15.59	
φD1	0.501	0.505	12.72	12.82	
E	0.551	0.557	13.99	14.14	
F	0.175	0.185	4.44	4.69	3
J	–	1.055	–	26.79	
M	–	0.155	–	3.94	1
M1	0.200	0.210	5.08	5.33	1
N	0.422	0.452	10.72	11.48	
φT	0.058	0.068	1.47	1.73	
φT1	0.080	0.090	2.03	2.29	
φT2	0.138	0.148	3.50	3.75	
φW	1/4-28 UNF-2A		1/4-28 UNF-2A		2

NOTES:
1. Contour and angular orientation of these terminals is optional.
2. φW is pitch diameter of coated threads, Ref: ASA B_1, 1-1960. Recommended torque: 50 inch-pounds.
3. A chamfer or undercut on one or both ends of hexagonal portion is optional.
4. Isolating material (ceramic) between hex (stud) and terminal No.3 is beryllium oxide.

WARNING: The ceramic of the isolated-stud package contains beryllium oxide. Do not crush, grind, or abrade this part because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

TERMINAL CONNECTIONS FOR ALL TYPES

No. 1 – Gate
No. 2 – Cathode
Case, No. 3 – Anode

RCA

Solid State Division

Thyristors

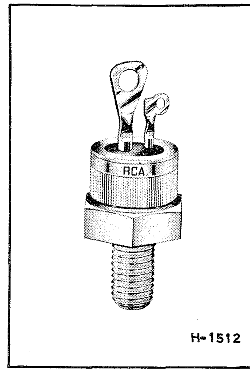
40216

RCA-40216 is an all-diffused, three-junction silicon controlled-rectifier (SCR▲) designed especially for use in radar pulse modulators, inverters, switching regulators, and other applications requiring a large ratio of peak to average current.

It is especially constructed for rapid spread of forward current over the full junction area to achieve a high rate of change of forward current (di/dt) capability and low switching dissipation.

▲The silicon controlled-rectifier is also known as a reverse-blocking triode thyristor.

All-Diffused SCR for High-Current Pulse Applications

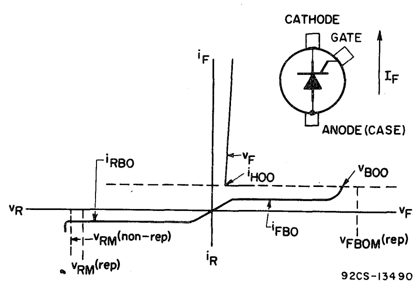


JEDEC TO-48

FEATURES

- Up to 900 Amperes Peak Forward Current Pulses
- 30 Watts Maximum Average Dissipation
- Forward Current of 35 Amperes (rms value)
- Shorted-Emitter Design
- All-Diffused Construction – Assures Exceptional Uniformity and Stability
- Direct Soldered Internal Construction – Assures Exceptional Resistance to Fatigue

TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER



Absolute-Maximum Ratings

RATINGS	CONTROLLED-RECTIFIER TYPE 40216	UNITS
Transient Peak Reverse Voltage (Non-Repetitive), v_{RM} (non-rep)	720	volts
Peak Reverse Voltage (Repetitive), v_{RM} (rep)	600	volts
Peak Forward Blocking Voltage (Repetitive), v_{FBOM} (rep)	600	volts
Forward Current:		
For case temperature of +65°C, RMS value, I_{FRMS}	35	amperes
Peak Pulse Current (See *Fig.7*)	900	amperes
Rate of Change of Forward Current, di/dt	See *Fig.7*	
Dynamic Dissipation:		
For case temperature of +65° C	30	watts
For other case temperatures	See *Fig.4*	
Gate Power*:		
Peak, Forward or Reverse, for 10 μs duration, P_{GM} (See *Figs.10 and 11*)	40	watts
Average, P_{GAV}	0.5	watt
Temperature:		
Storage, T_{stg}	–65 to +150	°C
Operating (Case), T_C	–65 to +125	°C

*Any values of peak gate current or peak gate voltage to give the maximum gate power is permissible.

WAVESHAPE OF CRITICAL dv/dt RATING TEST

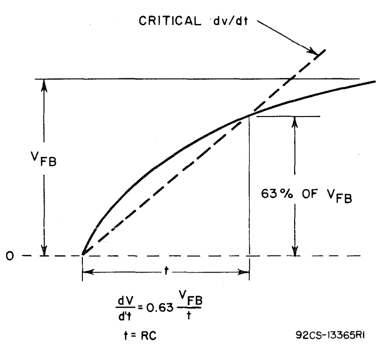


Fig. 1

WAVESHAPE OF t_{on} RATING TEST

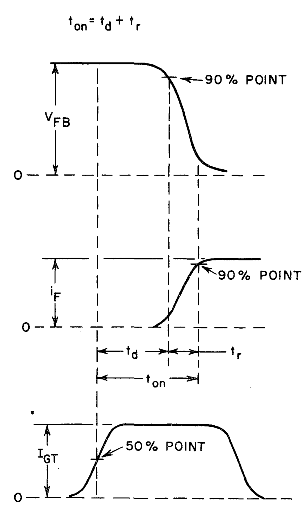


Fig. 2

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)

CHARACTERISTICS	CONTROLLED-RECTIFIER TYPE 40216 Min.	Typ.	Max.	UNITS
Forward Breakover Voltage, v_{BOO} At T_C = +125° C	600	–	–	volts
Instantaneous Blocking Current, At T_C = +125° C Forward, i_{FBO}	–	–	10	mA
Reverse, i_{RBO}	–	–	10	mA
Forward Voltage Drop, v_F		See *Fig.5*		
DC Gate-Trigger Current, I_{GT} At T_C = +25° C (See *Fig.10*)	1	25	80	mA(dc)
DC Gate-Trigger Voltage, V_{GT} At T_C = +25° C (See *Fig.10*)	–	1.1	2	volts(dc)
Holding Current, i_{HOO} At T_C = +25° C	0.5	20	70	mA
Critical Rate of Applied Forward Voltage, Critical dv/dt; V_{FB} = v_{BOO} (min. value), exponential rise, and T_C = +125° C (See waveshape of *Fig.1*)	20	50	–	volts/ microsecond
Turn-On Time, t_{on}, (Delay Time + Rise Time); V_{FB} = v_{BOO} (min. value), i_F = 30 A, I_{GT} = 200 mA, 0.1 µs min. rise time, and T_C = +25° C (See waveshapes of *Fig.2*)	–	1.25	–	microsecond
Turn-Off Time, t_{off}, (Reverse Recovery Time + Gate Recovery Time); i_F = 18 A, 50 µs pulse width, dv_{FB}/dt = 20 V/µs, di_r/dt = 30 A/µs, I_{GT} = 200 mA, and T_C = +80° C (See waveshapes of *Fig.3*)	15	20	40	microseconds
Thermal Resistance, Junction-to-Case	–	–	2	°C/W

WAVESHAPE OF t_{off} RATING TEST

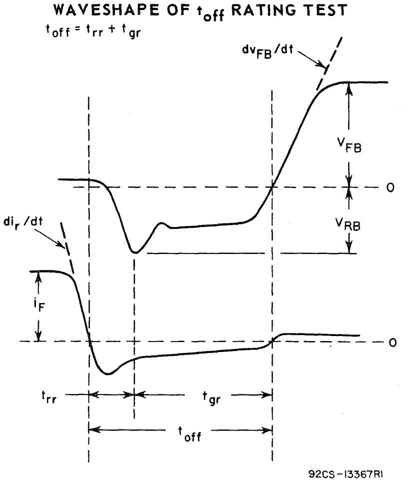


Fig. 3

MAXIMUM AVERAGE TOTAL POWER DISSIPATION AS A FUNCTION OF CASE TEMPERATURE

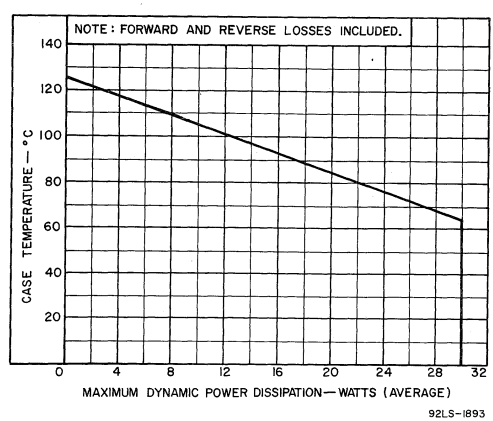


Fig. 4

FORWARD VOLTAGE-CURRENT CHARACTERISTICS AS A FUNCTION OF TIME

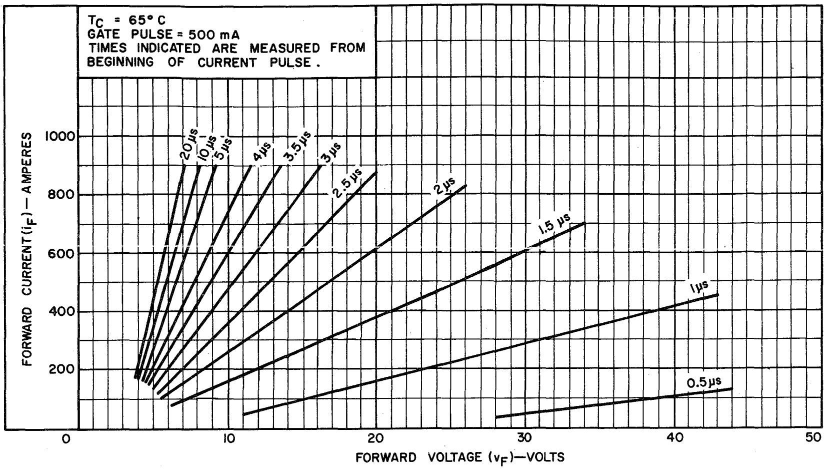


Fig. 5

INSTANTANEOUS FORWARD DISSIPATION-FORWARD CURRENT CHARACTERISTICS AS A FUNCTION OF TIME

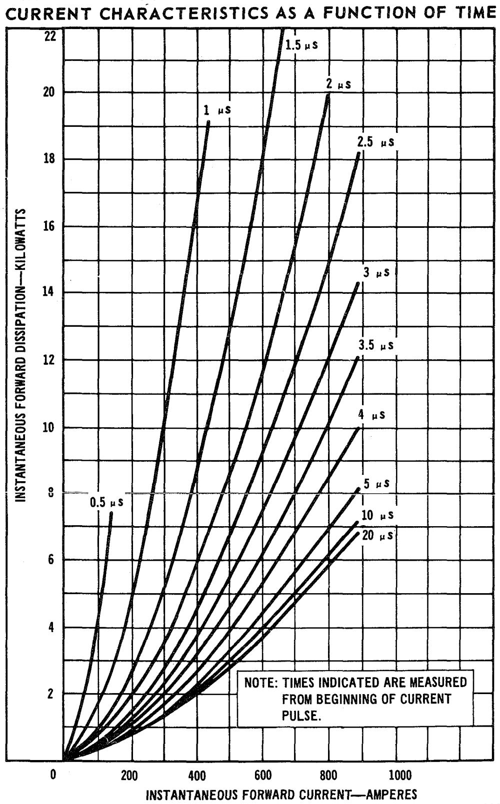


Fig. 6

MAXIMUM CURRENT AS A FUNCTION OF TIME

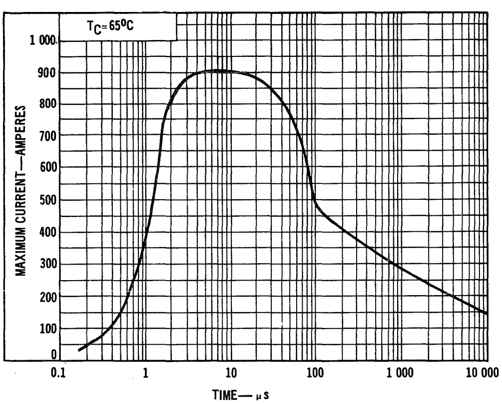


Fig. 7

PEAK CURRENT AS A FUNCTION OF MAXIMUM REPETITION RATE FOR SINE-WAVE PULSE SHAPES

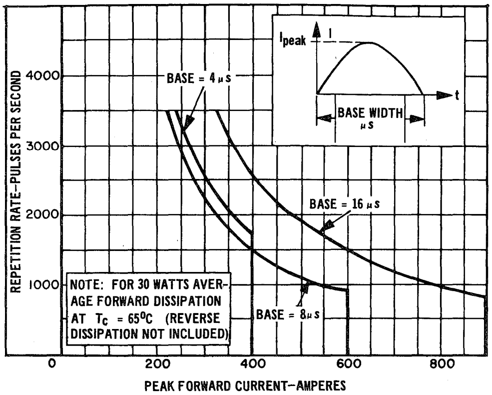


Fig. 8

PEAK CURRENT AS A FUNCTION OF MAXIMUM REPETITION RATE FOR SQUARE-WAVE PULSE SHAPES

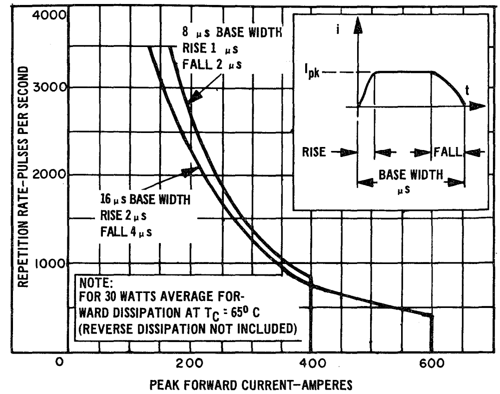


Fig. 9

FORWARD GATE CHARACTERISTICS

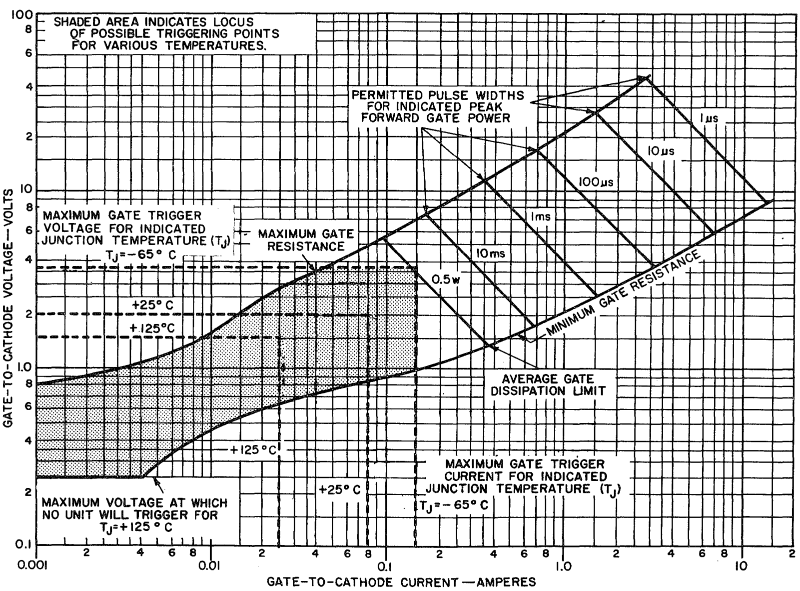


Fig. 10

TRIGGERING CONSIDERATIONS

The construction of the gate-cathode junction used in this device provides a large periphery center gate and employs shorted-emitter design which removes restrictions on both forward and reverse peak gate voltage and peak gate current. Limiting values of volt-ampere products for different gate pulse widths are shown in *Fig.10.* These limits should be adhered to when designing pulse trigger circuits for maximum trigger pulse widths and peak power dissipation. The volt-ampere products in the reverse direction shown in *Fig.11* should be used to determine limitations for reverse gate transients or reverse gate pulses if present. In all cases, total average gate dissipation, both forward and reverse, should not exceed the average gate dissipation rating (P_{GAV}) of 0.5 watt.

Turn-on times for different gate currents are shown in *Fig.12.* These curves may be used to determine the required width of the gate trigger pulses. It is only necessary to maintain the gate trigger pulse until the magnitude of the forward anode current has reached the latching current value. However, conservative design requires that the gate trigger pulse width be at least equal to or somewhat greater than the device turn-on time. Some applications may require wider gate pulse widths for proper circuit operation. Additional information on gate characteristics and triggering requirements for use in pulse applications are contained in RCA Application Note, SMA-39, "Gate Parameters of RCA SCR's for Trigger Circuit Design".

REVERSE GATE CHARACTERISTICS

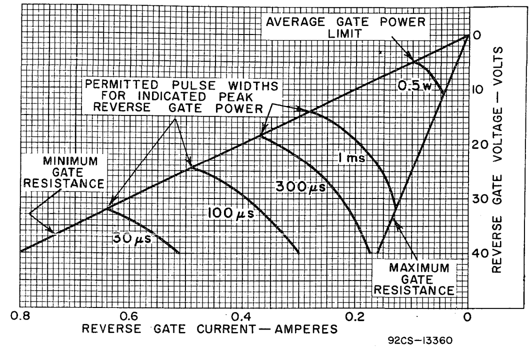


Fig. 11

TURN-ON TIME CHARACTERISTICS

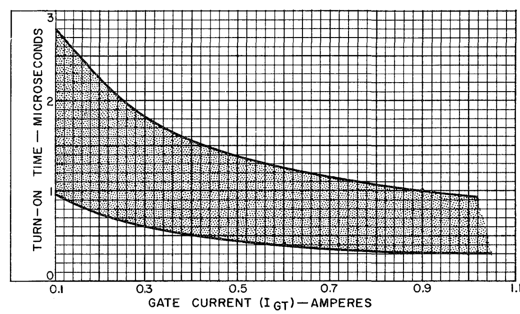
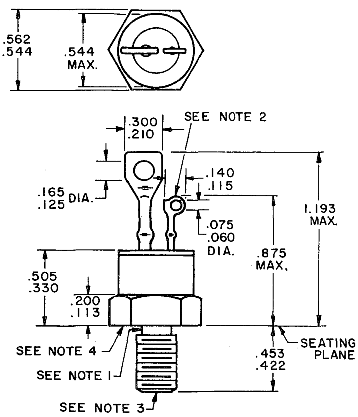


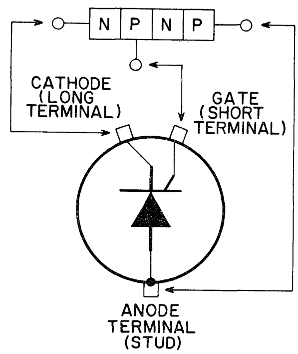
Fig. 12

DIMENSIONAL OUTLINE
JEDEC TO-48



DIMENSIONS IN INCHES

TERMINAL DIAGRAM

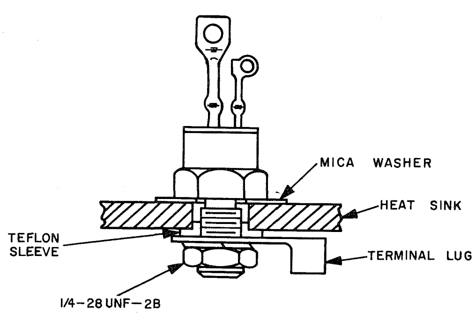


Note 1: Complete threads to extend to within 2-1/2 threads of head. Dia. of unthreaded portion 0.249" maximum, 0.220" minimum.

Note 2: Angular orientation of these terminals is undefined. Square or radius on end of terminal is optional.

Note 3: 1/4-28 UNF-2A. Maximum pitch dia. of plated threads shall be basic pitch dia. 0.2268", minimum pitch dia. 0.2225". Ref. (Screw Thread Standards for Federal Services 1957) Handbook H28 1957 P1.

Note 4: A chamfer (or undercut) on one or both ends of hexagonal portion is optional.



Suggested Mounting Arrangement for Insulating Type 40216 from Heat Sink. Components Shown (Except Heat Sink) are Furnished with Each Device.

Rectifiers

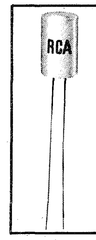
RCA

Solid State
Division

Rectifiers
1N3754
1N3755
1N3756

DIFFUSED-JUNCTION SILICON RECTIFIERS

For Industrial and Consumer-Product Applications



1N3754
1N3755
1N3756

RCA-1N3754, 1N3755, and 1N3756 are hermetically sealed diffused-junction silicon rectifiers of single-ended design, utilizing the same small case used in the standard JEDEC TO-1 transistor package.

These rectifiers are intended for use in industrial and consumer-product applications.

RECTIFIER SERVICE

For power-supply frequency of 60 cps

Maximum Ratings, *Absolute-Maximum Values:*

	For capacitor-input filter			
	1N3754	*1N3755*	*1N3756*	
PEAK REVERSE VOLTAGE	100	200	400	volts
RMS SUPPLY VOLTAGE	35	70	140	volts
FORWARD CURRENT:				
For free-air temperatures up to 65° C. (For free-air temperatures above 65° C, see *Rating Chart, Fig.1.)*				
DC	125	125	125	ma
PEAK RECURRENT	1.3	1.3	1.3	amp
SURGE - for "turn-on" time of 2 milliseconds at free-air temperature = 25° C.	30	30	30	amp
FREE-AIR-TEMPERATURE RANGE:				
Operating		-65 to +100		°C
Storage		-65 to +175		°C
LEAD TEMPERATURE:				
For 10 seconds maximum	255	255	255	°C

Characteristics, *At a Free-Air Temperature (T_{FA}) of 25° C*

	1N3754	*1N3755*	*1N3756*	
Maximum Instantaneous Forward Voltage Drop (at dc forward current of 125 milliamperes)	1	1	1	volt
Maximum Reverse Current:				
Dynamic[a], at free-air temperature = 65° C.	0.3	0.3	0.3	ma
Static[b], at free-air temperature = 25° C.	0.005	0.005	0.005	ma

[a] At maximum peak reverse voltage and maximum dc forward current.

[b] At maximum peak reverse voltage and zero forward current.

FEATURES:

- rated to cover a wide range of low-power rectifier and diode applications — up to 400 peak reverse volts at 125 milliamperes
- cylindrical case with flexible leads — features single-ended design for ease of handling and installation
- compact, hermetically sealed metal TO-1 transistor case (0.410" max. length; 0.240" max. dia.) completely insulated from rectifier unit
- designed to meet stringent temperature-cycling and humidity requirements of critical industrial and comsumer-product applications
- maximum free-air operating temperature — 100° C

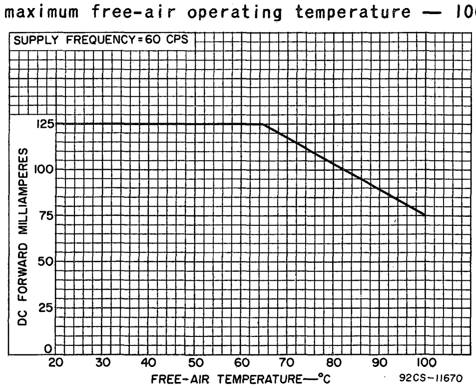


Fig. 1 - Rating Chart for Types 1N3754, 1N3755, 1N3756

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.

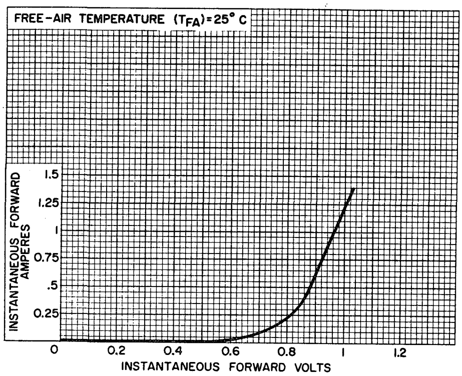


Fig. 2 - Typical Forward Characteristic for Types 1N3754, 1N3755, and 1N3756.

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.

A *surge-limiting impedance* should always be used in series with the rectifier. 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 windings, or by an external resistor or choke.

The *flexible leads* of these rectifiers are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in the leads to prevent excessive tension on the leads. It is important during the soldering operation to avoid

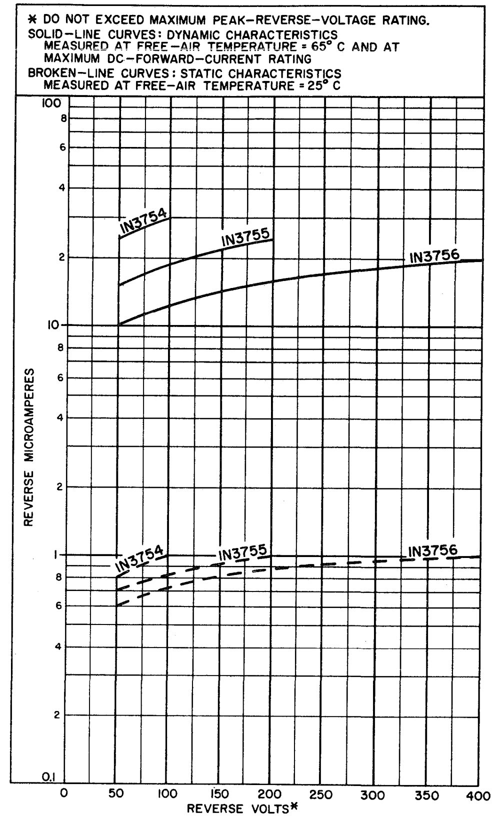


Fig. 3 - Typical Reverse Characteristics for Types 1N3754, 1N3755, and 1N3756.

excessive heat in order to prevent possible damage to the rectifiers. To absorb some of the heat, grip the flexible lead of the rectifier between the case and the soldering point with a pair of pliers.

When dip soldering is employed in the assembly of printed circuits using these rectifiers, the temperature of the solder should not exceed 255° C for a maximum immersion period of 10 seconds. Furthermore, the leads should not be dip soldered within 0.25" of the metal case.

The 1N3754, 1N3755, and 1N3756 are designed to provide reliable performance when operated within the maximum ratings shown in this bulletin. For measurement of the reverse characteristics of these devices, peak reverse voltages as high as 30 per cent above the maximum rated values may be applied for a period not exceeding 10 seconds. *Under no circumstances should peak reverse voltages greater than 30% above the maximum rated values be applied to these devices even momentarily.*

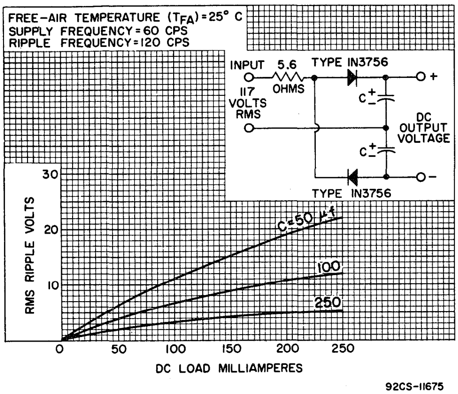


Fig. 4 - Typical Operation Characteristics for Types 1N3754, 1N3755, and 1N3756 in Full-Wave Voltage-Doubler Service.

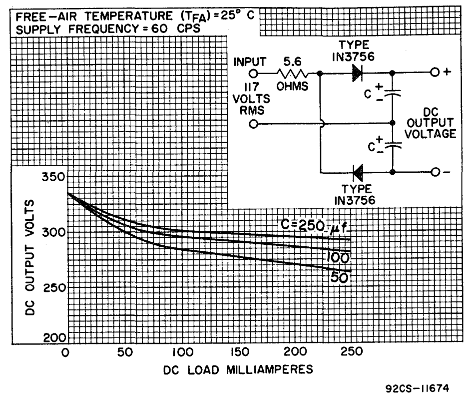


Fig. 5 - Typical Operation Characteristics for Types 1N3754, 1N3755, and 1N3756 in Full-Wave Voltage-Doubler Service.

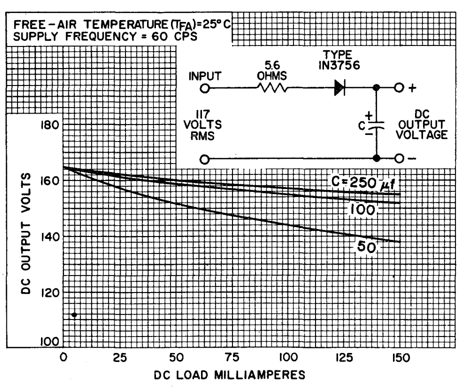


Fig. 6 - Typical Operation Characteristics for Types 1N3754, 1N3755, and 1N3756 in Half-Wave Rectifier Service.

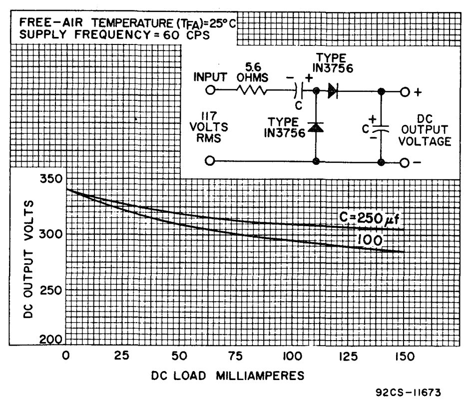
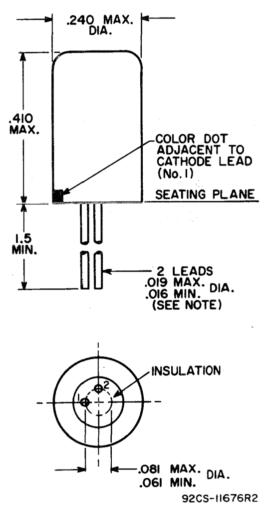


Fig. 7 - Typical Operation Characteristics for Types 1N3754, 1N3755, and 1N3756 in Half-Wave Voltage-Doubler Service.

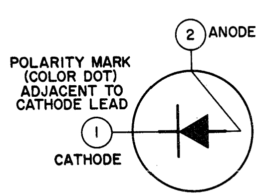
DIMENSIONAL OUTLINE



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

Solid State Division

1N440B 1N443B 1N441B 1N444B 1N442B 1N445B

RCA-1N440B, 1N441B, 1N442B, 1N443B, 1N444B, and 1N445B are hermetically sealed silicon rectifiers of the diffused-junction type, designed for use in power supplies of magnetic amplifiers, radio receivers, dc blocking circuits, power supplies, and other military and industrial applications.

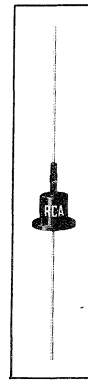
These devices have dc forward-current ratings to 0.75 ampere at an ambient temperature of 25°C, and peak reverse voltage ratings of 100, 200, 300, 400, 500 and 600 volts, respectively.

The 1N440B through 1N445B feature (1) sturdy and compact mount structure, (2) axial leads for flexibility of circuit connections, (3) welded hermetic seals—every unit is pressure-tested to assure protection against moisture and contamination, (4) superior junction formation made possible by a diffusion process with very precise controls. In addition, these devices are designed to meet the following stringent environmental, mechanical and life requirements of prime importance in military applications: (a) special temperature-cycling tests to assure stable performance over the entire operating temperature range, (b) special coating to provide protection against the effects of severe environmental conditions,

DIFFUSED-JUNCTION SILICON RECTIFIERS

FLANGED-CASE AXIAL-LEAD TYPES

For Power-Supply Applications In Industrial and Military Electronic Equipment



FEATURES:

- stringent environmental and mechanical tests to insure dependable performance in industrial and military applications
- hermetically sealed JEDEC DO-1 package
- wide operating-temperature range:
  1N440B, 1N441B, 1N442B, 1N443B: -65 to +165°C
  1N444B, 1N445B: -65 to +150°C

RECTIFIER SERVICE

Absolute-Maximum Ratings, for a Supply Frequency of 60 Hz:

	1N440B	1N441B	1N442B	1N443B	1N444B	1N445B	UNITS
PEAK REVERSE VOLTAGE	100	200	300	400	500	600	V
RMS SUPPLY VOLTAGE							
For resistive or inductive loads	70	140	210	280	350	420	V
DC REVERSE (BLOCKING) VOLTAGE	100	200	300	400	500	600	V
FORWARD CURRENT:[a]							
DC:							
at T_A = 50°C	750	750	750	750	650	650	mA
at T_A = 100°C	500	500	500	500	425	400	mA
at T_A = 150°C	250	250	250	250	0	0	mA
Peak, Repetitive	3.5	3.5	3.5	3.5	3.5	3.5	A
Surge, One-Cycle	15	15	15	15	15	15	A
TEMPERATURE RANGE (Ambient):							
Operating	165	165	165	165	150	150	°C
Storage	-65 to +175						°C

[a] For maximum dc forward current values at ambient temperatures other than those specified, See Rating Chart Fig. 1.

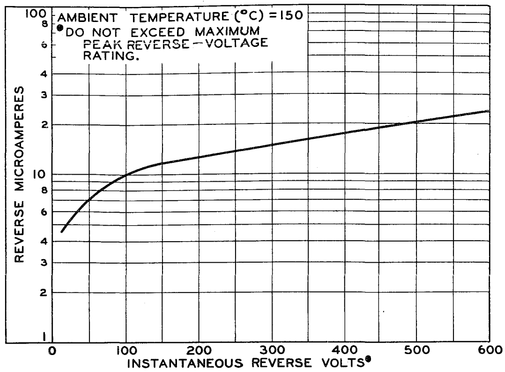


Fig.3 - Typical Dynamic Reverse Characteristic for RCA-1N440B through 1N445B.

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.

The *flexible leads* of these rectifiers are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in the leads 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 rectifiers. To absorb some of the heat, grip the flexible lead of the rectifier between the case and the soldering point with a pair of pliers.

When dip soldering is employed in the assembly of printed circuitry using these rectifiers, the temperature of the solder should not exceed 255° C for a maximum immersion period of 10 seconds. Furthermore, the leads should not be dip soldered beyond points A and B indicated on the Dimensional Outline Drawing.

Because the metal cases of these rectifiers may operate at voltages which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the rectifier. It is recommended that these rectifiers be mounted on the underside of the chassis.

Characteristics, at Ambient Temperature (T_A) = 25°C:

CHARACTERISTICS	1N440B	1N441B	1N442B	1N443B	1N444B	1N445B	UNITS
Maximum Forward Voltage Drop (DC) at full load current.	1.5	1.5	1.5	1.5	1.5	1.5	V
Maximum Reverse Current (DC) at maximum peak reverse voltage	0.3	0.75	1	1.5	1.75	2	μA
Maximum Reverse Current (averaged over 1 complete cycle of supply voltage): at maximum rated PRV, T_A = 150°C	100	100	200	200	200	200	μA

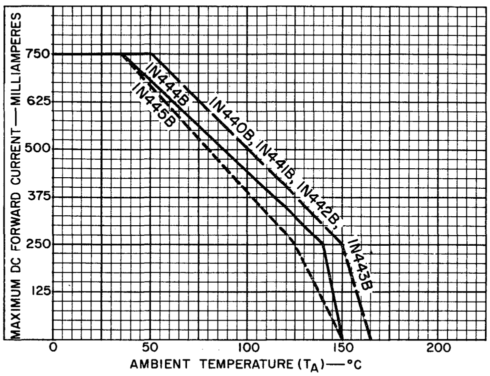


Fig.1 - Rating Chart for RCA-1N440B through 1N445B.

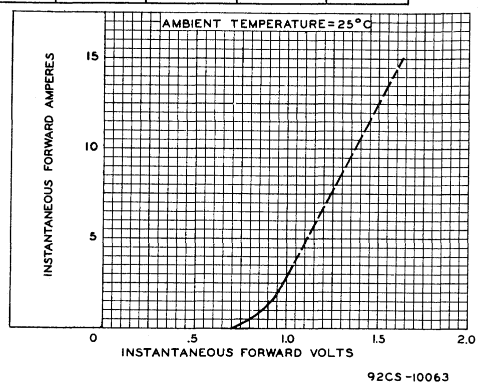
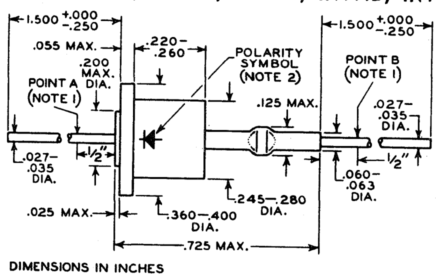


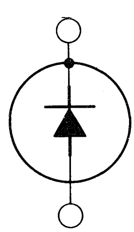
Fig.2 - Typical Forward Voltage and Current Characteristic for RCA-1N440B through 1N445B.

DIMENSIONAL OUTLINE
for Types
1N440B, 1N441B, 1N442B, 1N443B, 1N444B, 1N445B



NOTE 1: DO NOT DIP SOLDER BEYOND POINTS A AND B.
NOTE 2: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

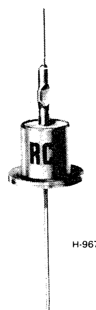
TERMINAL DIAGRAM
for Types
1N440B, 1N441B, 1N442B, 1N443B, 1N444B, 1N445B



RCA
Solid State
Division

Rectifiers

1N536 1N538 1N540
1N537 1N539 1N547 1N1095



JEDEC DO-1

Diffused-Junction Silicon Rectifiers

Flanged-Case, Axial-Lead Types
For Power-Supply Applications

Features:

- Wide operating-temperature range : -65 to +65°C.
- Stringent environmental and mechanical tests to insure dependable performance in industrial and military applications.
- Peak reverse voltages from 50 to 600 V.
- Max. dc forward current = 250 mA at T_A = 150°C.
- Hermetically sealed JEDEC DO-1 package.

RCA-1N536, 1N537, 1N538, 1N539, 1N540, 1N547, and 1N1095 are hermetically sealed silicon rectifiers of the diffused-junction type. They are specifically designed for use in power supplies of industrial and military equipment capable of operating at dc forward currents up to 750 milliamperes and temperatures ranging from -65° to +165°C.

These silicon rectifiers have peak reverse voltage ratings from 50 to 600 volts, and a maximum reverse current of 5 microamperes at rated peak reverse voltage and ambient temperature of 25°C.

These silicon rectifiers are designed to meet such stringent environmental, mechanical, and life requirements of prime importance in military applications as: (1) sturdy and compact mount structure, (2) axial leads for flexibility of circuit connections, (3) welded hermetic seals, and (4) special temperature cycling tests to assure stable performance over the entire operating temperature range.

RECTIFIER SERVICE, ABSOLUTE-MAXIMUM RATINGS, *for a Supply Frequency of 60 Hz:*

	1N536	1N537	1N538	1N539	1N540	1N1095	1N547	
PEAK REVERSE VOLTAGE	50	100	200	300	400	500	600	V
RMS SUPPLY VOLTAGE For resistive or inductive loads	35	70	140	210	280	350	420	V
DC REVERSE – (BLOCKING) VOLTAGE	50	100	200	300	400	500	400	V
FORWARD CURRENT*: DC, for resistive or inductive loads: T_A = 50°C	750	750	750	750	750	750	750	mA
SURGE, one cycle	15	15	15	15	15	15	15	A
OPERATING FREQUENCY	100	100	100	100	100	100	100	kHz
TEMPERATURE RANGE (Ambient): Operating	←			-65 to +165			→	°C
Storage	←			-65 to +175			→	°C

*For maximum dc forward current values at ambient temperatures other than those specified, see Rating Chart, Fig. 1.

CHARACTERISTICS, at Ambient Temperature (T_A) = 25°C:

	1N536	1N537	1N538	1N539	1N540	1N547	1N1095	
Maximum Forward Voltage Drop (DC) at a load current of 500 mA	1.1	1.1	1.1	1.1	1.1	1.2	1.2	V
Maximum Reverse Current (DC) at maximum peak reverse voltage	5	5	5	5	5	5	5	μA
Maximum Reverse Current (Averaged over 1 complete cycle of supply voltage): at maximum rated PRV, T_A = 150°C	0.4	0.4	0.3	0.3	0.3	0.35	0.3	mA

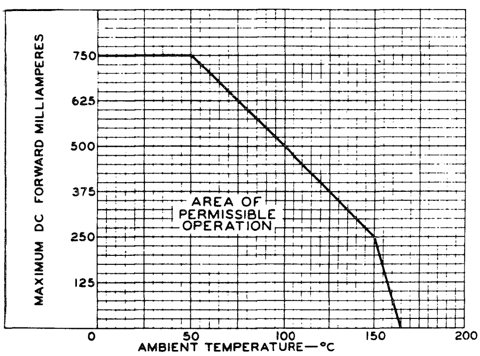


Fig.1— Rating chart.

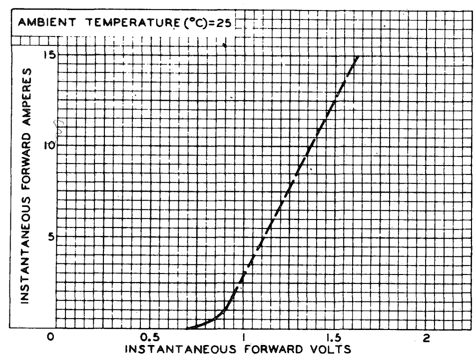


Fig.2— Typical forward voltage and current characteristic.

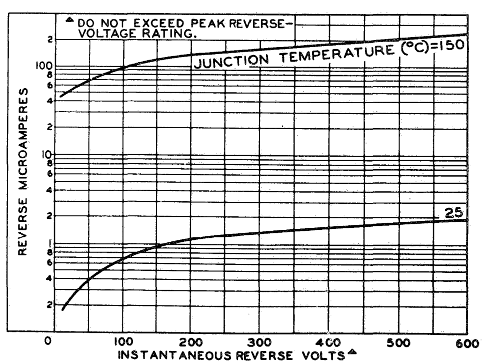
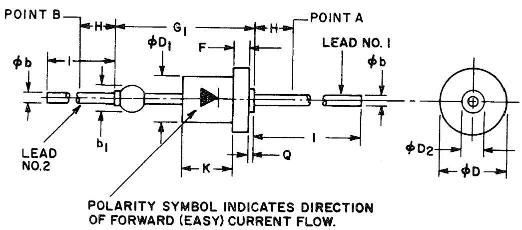


Fig.3— Typical dynamic reverse characteristics.

DIMENSIONAL OUTLINE

JEDEC DO-1



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
φb	0.027	0.035	0.69	0.89	2
b_1		0.125		3.18	1
φD	0.360	0.400	9.14	10.16	
$φD_1$	0.245	0.280	6.22	7.11	
$φD_2$		0.200		5.08	
F		0.075		1.91	
G_1		0.725		18.42	
K	0.220	0.260	5.59	6.60	
1	1.000	1.625	25.40	41.28	
Q		0.025		0.64	
H	0.5		12.7		

NOTES:

1. Dimension to allow for pinch or seal deformation anywhere along tubulation (optional).
2. Diameter to be controlled from free end of lead to within 0.188 inch (4.78 mm) from the point of attachment to the body. Within the 0.188 inch (4.78 mm) dimension, the diameter may vary to allow for lead finishes and irregularities.

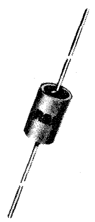
TERMINAL CONNECTIONS

Lead No. 1 & Case — Cathode
Lead No. 2 — Anode

RCA Solid State Division

Rectifiers

1N3255
1N3193 1N3195 1N3253 1N3256
1N3194 1N3196 1N3254 1N3563



L-391

JEDEC DO-26

Diffused-Junction Silicon Rectifiers

For Industrial and Consumer-Product Applications

Features:

- **Cylindrical design with axial leads for simple handling and installation**
- **Compact, hermetically sealed metal case (0.405" max. length; 0.240" max. dia.)**
- **Insulated types 1N3253, 1N3254, 1N3255, 1N3256, and 1N3563 have transparent, high-dielectric-strength plastic sleeve over metal case**
- **High maximum forward-current ratings – up to 750 milliamperes at 75 °C**
- **Peak-reverse-voltage ratings – 200 to 1000 volts**
- **Maximum free-air operating temperature – 100 °C**
- **Designed to meet stringent temperature-cycling and humidity requirements of critical industrial and consumer-product applications**

RCA-1N3193, 1N3194, 1N3195, 1N3196, 1N3253, 1N3254, 1N3255, 1N3256, and 1N3563 are hermetically sealed silicon rectifiers of the diffused-junction type utilizing small cylindrical metal cases and axial leads. Types 1N3253, 1N3254, 1N3255, and 1N3256 are insulated versions of types 1N3193, 1N3194, and 1N3196, respectively. Type 1N3563 is an insulated rectifier which does not have an uninsulated equivalent.

RECTIFIER SERVICE (For a supply-line frequency of 60 cps)

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	For resistive or inductive load					*For capacitor-input filter*					
	1N3193 1N3253	**1N3194 1N3254**	**1N3195 1N3255**	**1N3196 1N3256**	**1N3563**	**1N3193 1N3253**	**1N3194 1N3254**	**1N3195 1N3255**	**1N3196 1N3256**	**1N3563**	
PEAK REVERSE VOLTAGE	200	400	600	800	1000	200	400	600	800	1000	volts
RMS SUPPLY VOLTAGE	140	280	420	560	700	70	140	210	280	350	volts
FORWARD CURRENT: For free-air temperatures up to 75°C. For free-air temperatures above 75°C, see Rating Chart.											
DC	750	750	750	500	400	500	500	500	400	300	ma
PEAK RECURRENT	–	–	–	–	–	6	6	6	5	4	amp
SURGE – For "turn-on" time of 2 milliseconds	–	–	–	–	–	35	35	35	35	35	amp
FREE-AIR-TEMPERATURE RANGE:											
Operating	←				-65 to +100					→	°C
Storage	←				-65 to +175					→	°C
LEAD TEMPERATURE:											
For 10 seconds maximum	←				255					→	°C

Characteristics, *At a Free-Air Temperature of 25°C:*

	1N3193 1N3253	**1N3194 1N3254**	**1N3195 1N3255**	**1N3196 1N3256**	**1N3563**	
Maximum Instantaneous Forward Voltage Drop at dc forward current of 0.5 ampere	1.2	1.2	1.2	1.2	1.2	volts
Maximum Reverse Current:						
Dynamic, at T_{FA} = 75°C*	0.2	0.2	0.2	0.2	0.2	ma
Static, at T_{FA} = 25°C**	0.005	0.005	0.005	0.005	0.005	ma

*At max. peak reverse voltage and max. dc forward current. **At max. peak reverse voltage and zero forward current.

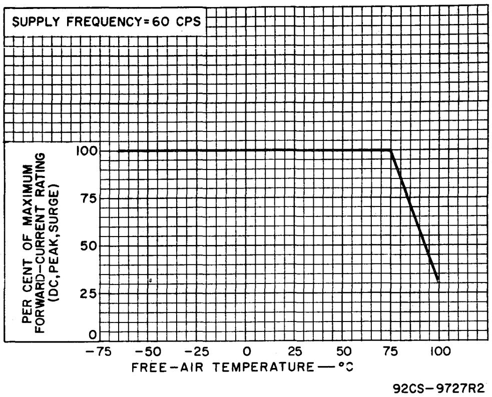


Fig.1— Rating chart for types 1N3193 to 1N3196, 1N3253 to 1N3256, and 1N3563.

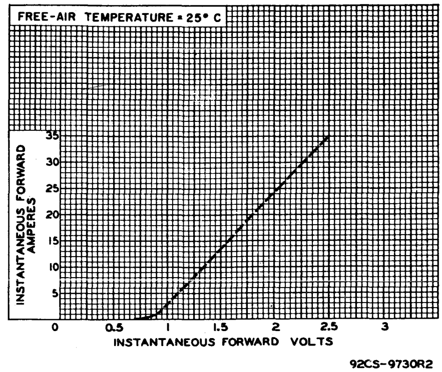


Fig.2— Typical forward characteristics for types 1N3193 to 1N3196, 1N3253 to 1N3256, and 1N3563.

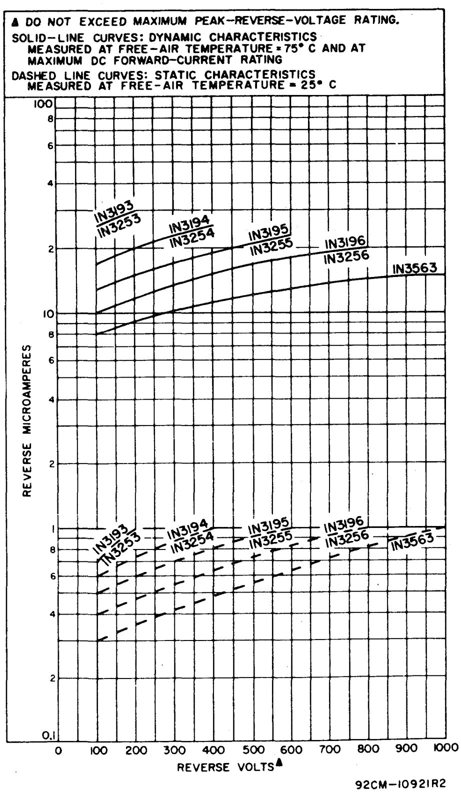


Fig.3— Typical reverse characteristics for types 1N3193 to 1N3196, 1N3253 to 1N3256, and 1N3563.

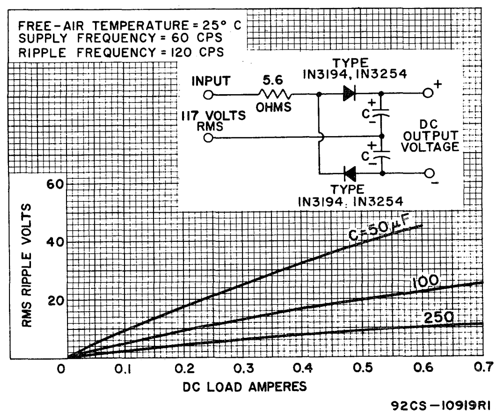


Fig.4— Typical operation characteristics of types 1N3194 and 1N3254 in full-wave voltage-doubler service.

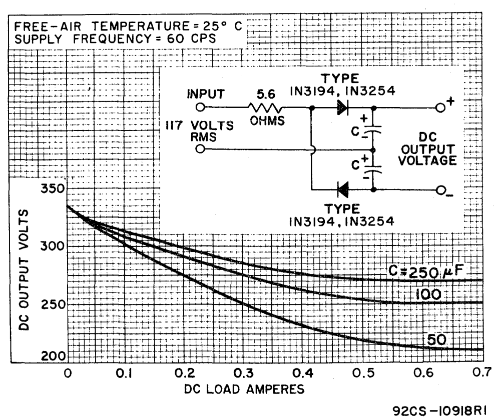


Fig.5— Typical operation characteristics of types 1N3194 and 1N3254 in full-wave voltage-doubler service.

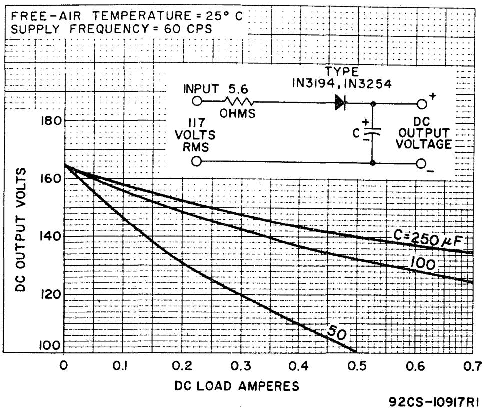


Fig.6— Typical operation characteristics of types 1N3194 and 1N3254 in half-wave rectifier service.

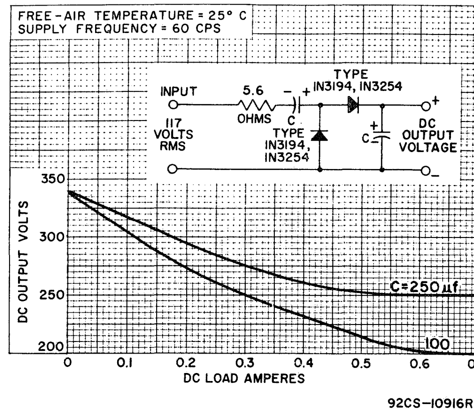


Fig.7— Typical operation characteristics of types 1N3194 and 1N3254 in half-wave voltage-doubler service.

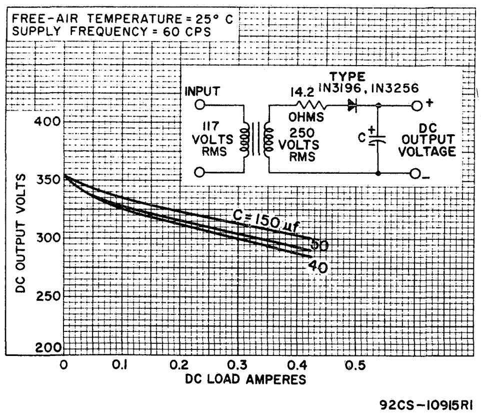


Fig.8— Typical operation characteristics of types 1N3196 and 1N3256 in half-wave rectifier service.

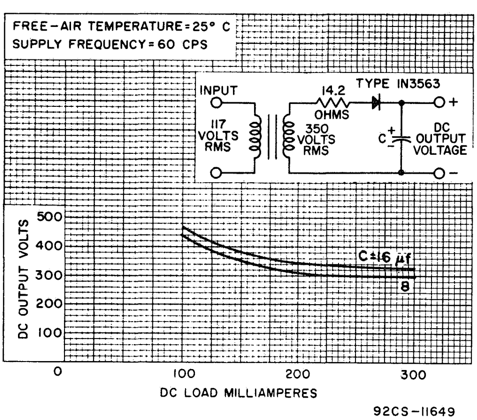


Fig.9— Typical operation characteristics of type 1N3563 in half-wave rectifier service.

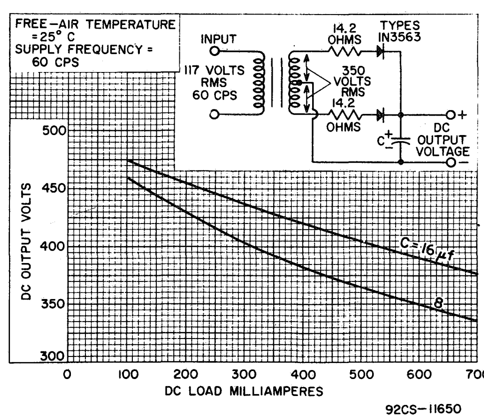
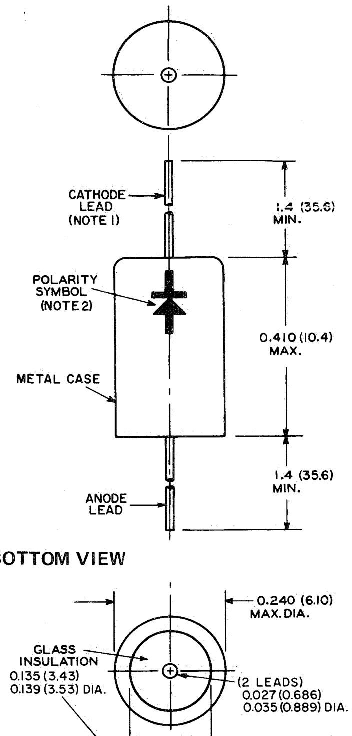


Fig.10—Typical operation characteristics of type 1N3563 in full-wave rectifier service.

DIMENSIONAL OUTLINE (JEDEC DO-26) for 1N3193, 1N3194, 1N3195, and 1N3196



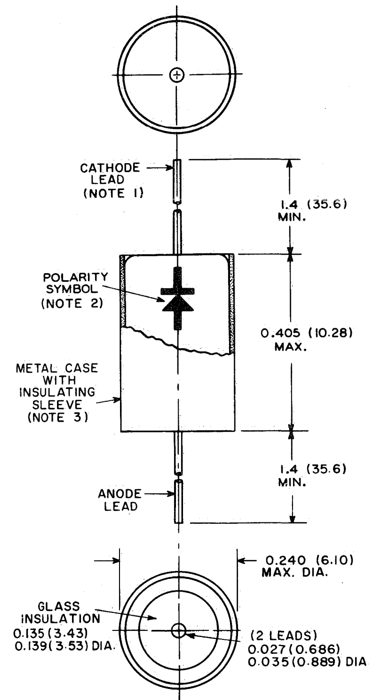
92CS-10920R5

NOTE 1: CONNECTED TO METAL CASE.

NOTE 2: ARROW INDICATED DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

Dimensions in inches and millimeters (values in parentheses).

DIMENSIONAL OUTLINE (JEDEC-DO-26 with insulating sleeve) for 1N3253, 1N3254, 1N3255, 1N3256, and 1N3563



92CS-11229R3

NOTE 1: CONNECTED TO METAL CASE.

NOTE 2: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

NOTE 3: INSULATOR SLEEVE MAY EXTEND 1/16" BEYOND ENDS OF CASE.

Dimensions in inches and millimeters (values in parentheses).

Specifications of Insulating Sleeve

Material: Plastic

Wall Thickness: 0.002"

Dielectric Strength: 4500 volts/mil at 25°C
3150 volts/mil at 150°C

Moisture Absorption: 0.3%
Surface resistivity is not affected by moisture.

Degree of Transparency: Optically clear

RCA
Solid State
Division

Rectifiers
1N1763A
1N1764A

RCA-1N1763A and 1N1764A are hermetically sealed silicon rectifiers of the diffused-junction type, designed for use in power supplies of color and black-and-white television receivers, radio receivers, phonographs, high-fidelity amplifier systems, and other electronic equipment for commercial and industrial applications.

RCA-1N1763A and 1N1764A supersede and are unilaterally interchangeable with RCA-1N1763 and 1N1764, respectively. The new rectifiers incorporate all of the superior performance and reliability features which have gained industry acceptance for their RCA prototypes, and, in addition, offer substantially higher dc-output-current capabilities, lower reverse (leakage) currents, lower forward voltage drop, and a wider operating-temperature range.

Both devices have dc forward-current ratings of 1 ampere — resistive or inductive load, and 0.75 ampere — capacitive load at free-air temperatures up to 75°C (natural convection cooling). They can provide dc output currents of up to 2 amperes to capacitive loads when attached to simple heat sinks (see OPERATING CONSIDERATIONS).

RCA-1N1763A has a peak-reverse-voltage rating of 400 volts, and is intended for applications in which the rectifier operates directly from an ac power line supplying up to 140 volts rms for capacitive loads, or up to 280 volts rms for resistive or inductive loads.

RCA-1N1764A has a peak-reverse-voltage rating of 500 volts, and is intended for applications in which the rectifier operates from an ac line through a step-up transformer supplying up to 175 volts rms for capacitive loads, or up to 350 volts rms for resistive or inductive loads.

RCA-1N1763A and 1N1764A have an operating-temperature range of -65°C to +135°C. They utilize the JEDEC DO-1 flanged-case, axial-lead package which provides flexibility of installation in both hand-wired and printed-circuit equipment designs. These new rectifiers, like their RCA prototypes, are conservatively rated and incorporate the following design features: (1) welded, hermetically sealed case for protection against moisture and contamination; (2) superior junction characteristics made possible by a precisely controlled diffusion process; (3) extensive and rigorous quality-control procedures.

DIFFUSED-JUNCTION SILICON RECTIFIERS

Flanged-Case Axial-Lead Types

For Power-Supply Applications In Commercial and Industrial Electronic Equipment

Features:

- high dc-output-current capability:
  - a) with natural convection cooling:
    - 1 ampere - resistive or inductive load; 3/4 ampere - capacitive load } to 75°C T_{FA}
  - b) with simple heat sinks:
    - 2 amperes - capacitive load } to 105°C T_C
    - up to 2 amperes - capacitive load } to 75°C T_{FA}
- low dc reverse (leakage) currents: 5 μa max. at 25°C; 100 μa max. at 75°C
- low forward voltage drop: 1.2 volts max. at a dc forward current of 1 ampere
- wide operating-temperature range: -65°C to +135°C
- hermetically sealed JEDEC DO-1 package
- unilaterally interchangeable with Types 1N1763 and 1N1764

RECTIFIER SERVICE

Absolute-Maximum Ratings, *for a Supply Frequency of 60 cps:*

	Type 1N1763A		Type 1N1764A			
PEAK REVERSE VOLTAGE	400		500		max.	volts
RMS SUPPLY VOLTAGE:						
For operation with resistive or inductive loads	280		350		max.	volts
For operation with capacitive loads	140		175		max.	volts
	At Free-Air Temperatures		*At Free-Air Temperatures*			
	Up to 75°C	*Above 75°C*	*Up to 75°C*	*Above 75°C*		
FORWARD CURRENT:						
For operation with resistive or inductive loads:						
AVERAGE (DC)	1	See *Fig.1*	1	See *Fig.1*	max.	amp
For operation with capacitive loads:						
AVERAGE (DC)	0.75	See *Fig.1*	0.75	See *Fig.1*	max.	amp
PEAK RECURRENT	5	See *Fig.1*	5	See *Fig.1*	max.	amp
SURGE, for "turn-on" transient of 2 milliseconds duration	35	See *Fig.1*	35	See *Fig.1*	max.	amp
TEMPERATURE RANGE (FREE-AIR):						
Operating	-65 to +135		-65 to +135			°C
Storage	-65 to +150		-65 to +150			°C

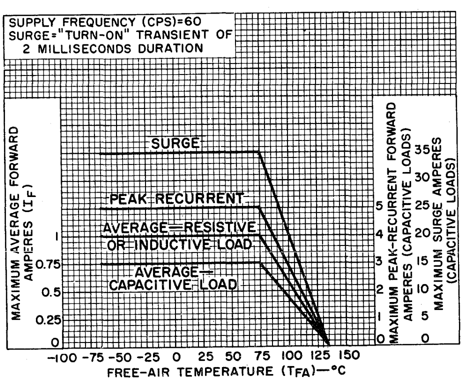


Fig.1 - Rating Chart for RCA-1N1763A and 1N1764A

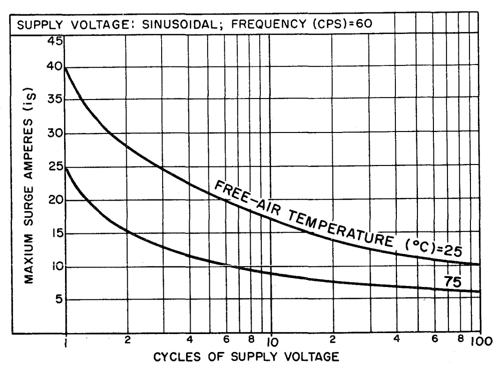


Fig.2 - Repetitive Surge Current Rating Chart for RCA-1N1763A and 1N1764A

Characteristics, *at a Free-Air Temperature of 25°C:*

	Type 1N1763A	Type 1N1764A	
Maximum Instantaneous Forward Voltage at an Instantaneous Forward Current of 1 ampere. . . .	1.2	1.2	volts
Maximum DC Reverse Current;			
At a Peak Reverse Voltage of 400 volts	5	-	μa
At a Peak Reverse Voltage of 500 volts	-	5	μa

Characteristics, *at a Free-Air Temperature of 75°C:*

	Type 1N1763A	Type 1N1764A	
Maximum DC Reverse Current:			
At a Peak Reverse Voltage of 400 volts	0.1	-	ma
At a Peak Reverse Voltage of 500 volts	-	0.1	ma

Typical Performance Characteristics, *at a Free-Air Temperature of 25°C:*

	Type 1N1763A			Type 1N1764A			
Half-Wave Rectifier Service:							
RMS Supply Voltage.	117	117	117	150	150	150	volts
Filter-Input Capacitor (C).	100	200	350	100	200	350	μF
Surge-Limiting Resistance#.	5.6	5.6	5.6	6.8	6.8	6.8	ohms
DC Output Voltage at Input to Filter (Approx.):							
At half-load current of 375 ma.	140	145	150	180	185	190	volts
At full-load current of 750 ma.	125	130	140	155	160	170	volts
Voltage Regulation (Approx.):							
Half-load current to full-load current. .	15	15	10	25	25	20	volts
Half-Wave Voltage-Doubler Service:							
RMS Supply Voltage.	117	117	117	150	150	150	volts
Filter-Input Capacitor (C).	100	200	350	100	200	350	μF
Surge-Limiting Resistance#.	5.6	5.6	5.6	6.8	6.8	6.8	ohms
DC Output Voltage at Input to Filter (Approx.):							
At half-load current of 375 ma.	255	265	275	325	340	350	volts
At full-load current of 750 ma.	225	240	255	285	305	325	volts
Voltage Regulation (Approx.):							
Half-load current to full-load current. .	30	25	20	40	35	25	volts
Full-Wave Voltage-Doubler Service:							
RMS Supply Voltage.	117	117	117	150	150	150	volts
Filter Input Capacitor (C).	100	200	350	100	200	350	μF
Surge-Limiting Resistance#.	5.6	5.6	5.6	6.8	6.8	6.8	ohms
DC Output Voltage at Input to Filter (Approx.):							
At half-load current of 375 ma.	275	280	290	350	355	365	volts
At full-load current of 750 ma.	250	260	275	320	330	345	volts
Voltage Regulation (Approx.):							
Half-load current to full-load current. .	25	20	15	30	25	20	volts

The transformer series resistance or other resistance in the rectifier supply circuit may be deducted from the value shown.

OPERATING CONSIDERATIONS

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.

Maximum ratings for these devices have been established with connections made to the extreme ends of the leads. For conservative equipment designs, the 1N1763A and 1N1764A should be operated with connections made as close as possible to the device case.

The Maximum Forward Current Ratings for RCA-1N1763A and 1N1764A given on page 1 and in Fig.1 apply specifically for operation of these rectifiers in free air (natural convection cooling). RCA-1N1763A and 1N1764A can, however, provide Average (DC) Forward Currents of **up to 2 amperes with capacitive load** if these rectifiers are attached to simple heat sinks. The Peak Recurrent Forward Current capabilities of these rectifiers are also substantially higher than those shown in the Maximum Ratings when the rectifiers are attached to heat sinks.

Fig.**5** shows the DC and Peak Recurrent Forward Current capabilities of RCA-1N1763A and 1N1764A for capacitive, resistive, or inductive loads, when operation is based on **case temperature** (measured at the intersection of the cathode lead and the case flange).

Figs.**6a**, **6b**, **6c**, **6d**, and **6e**, show the DC and Peak Recurrent Forward Current capabilities of RCA-1N1763A and 1N1764A for capacitive, resistive, or inductive loads when these rectifiers are mounted on simple, rectangular heat sinks of various sizes, and operation is based on free-air temperature.

Fig.**7** shows two suggested methods for attaching RCA-1N1763A or 1N1764A to a heat sink. The flange of the rectifier case may also be soldered directly to a heat sink, provided the flange temperature during soldering does not exceed 235°C for a maximum period of **10** seconds. **Permanent damage to the rectifier may result if these limits are exceeded.**

A **surge-limiting impedance** should always be used in series with either of the rectifiers described in this bulletin. The value of this impedance must be sufficient to limit the "turn-on" surge current to the value specified in the Maximum Ratings. This impedance may be provided by the power-transformer windings, or by an external resistor or choke.

The flexible leads of RCA-1N1763A and 1N1764A are usually soldered to the circuit elements. It is desirable in all installations to provide some slack or an expansion elbow in each lead to prevent excessive tension on the leads. Manual soldering should be done carefully and quickly to avoid damage to the rectifier by excessive heating. To minimize heating of the rectifier junction during manual soldering, grip the flexible lead being soldered between the case and the soldering point with a pair of pliers.

When dip soldering used in the assembly of printed circuits using RCA-1N1763A or 1N1764A, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. The leads should not be dip soldered beyond points "A" and "B" indicated on the DIMENSIONAL OUTLINE drawing.

Because the cases of these rectifiers may operate at potentials which are dangerous, care should be taken in the design of equipment to prevent personnel from coming in contact with the rectifiers. It is recommended that these rectifiers be mounted on the under side of the equipment chassis.

Figs.**8**, **9**, **10**, and **11**, show typical dc-output voltage characteristics of RCA-1N1763A and 1N1764A as functions of dc load current, for conventional half-wave, half-wave voltage-doubler, and full-wave voltage-doubler circuits. The solid portions of these curves extend to the maximum dc forward current values given in the maximum ratings on page 1. The dashed portions of the curves show typical performance at the higher current values permissible when the rectifiers are attached to heat sinks.

It is important to note that the amount of ac ripple present in the output of any of the rectifier circuits shown increases rapidly with increasing load currents. If operation is intended at the maximum current values shown on the dashed portions of the curves, it will generally be necessary to include additional filter circuits to achieve satisfactory hum levels.

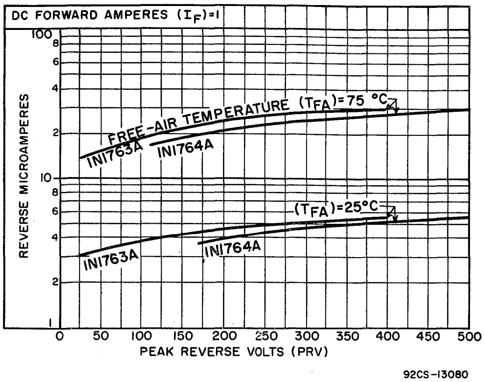


Fig.3 - Typical Dynamic Reverse Current Characteristics for RCA-1N1763A and 1N1764A.

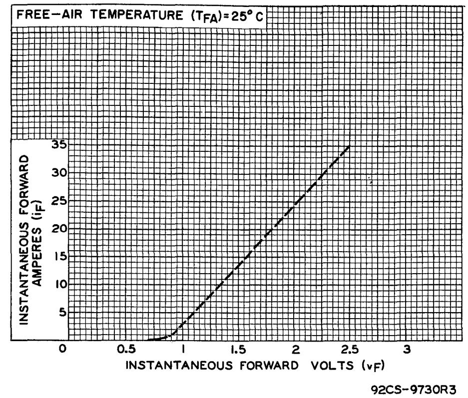


Fig.4 - Typical Forward Voltage and Current Characteristics for RCA-1N1763A and 1N1764A.

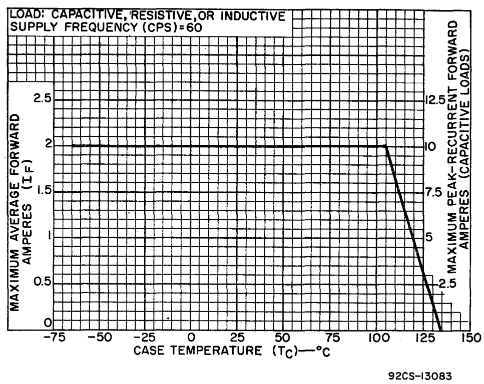
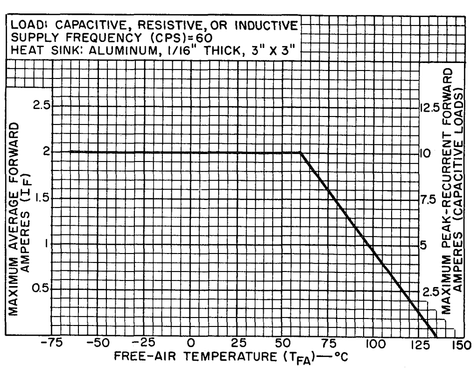
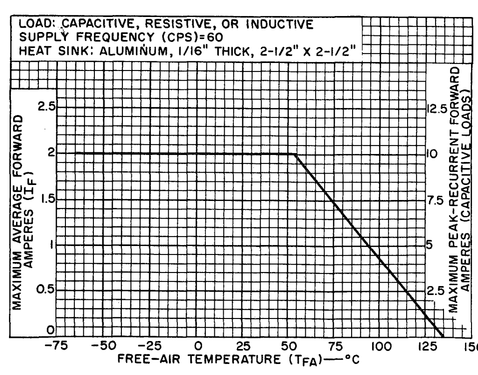


Fig.5 - Forward-Current Capabilities of RCA-1N1763A and 1N1764A for Operation with Heat Sink at Case Temperatures from -65°C to +135°C.

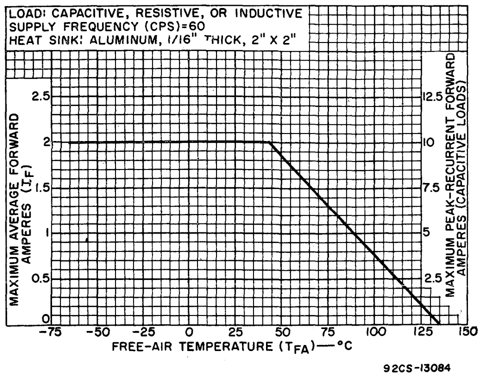


a) 3" x 3" Heat Sink.

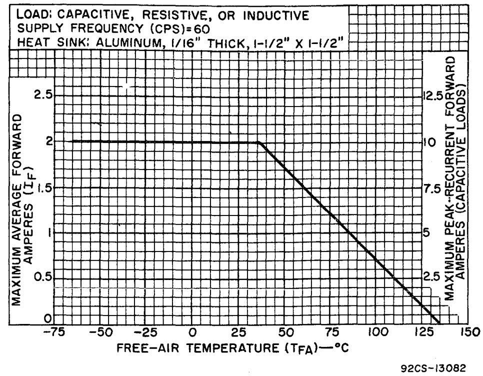


b) 2-1/2" x 2-1/2" Heat Sink.

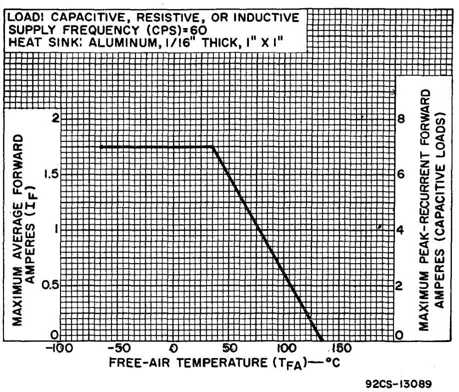
Figs.6a and 6b - Forward-Current Capabilities of RCA-1N1763A and 1N1764A for Operation with Heat Sinks.



c) 2" x 2" Heat Sink.

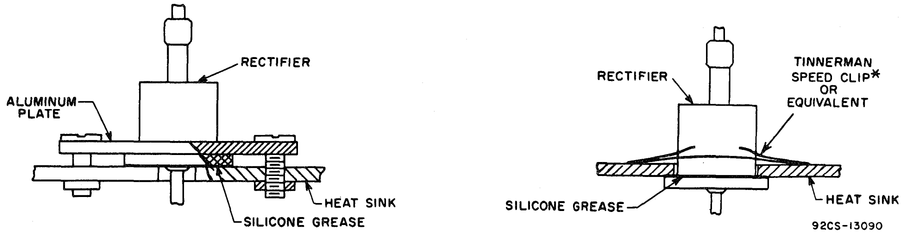


d) 1-1/2" x 1-1/2" Heat Sink.



e) 1" x 1" Heat Sink.

Figs.6c, 6d, and 6e - Forward-Current Capabilities of RCA-1N1763A and 1N1764A for Operation with Heat Sinks.



* Registered Trade Mark, Tinnerman Products, Inc., Cleveland 1, Ohio.

Fig.7 - Suggested Methods for Attaching RCA-1N1763A 1N1764A to Heat Sink

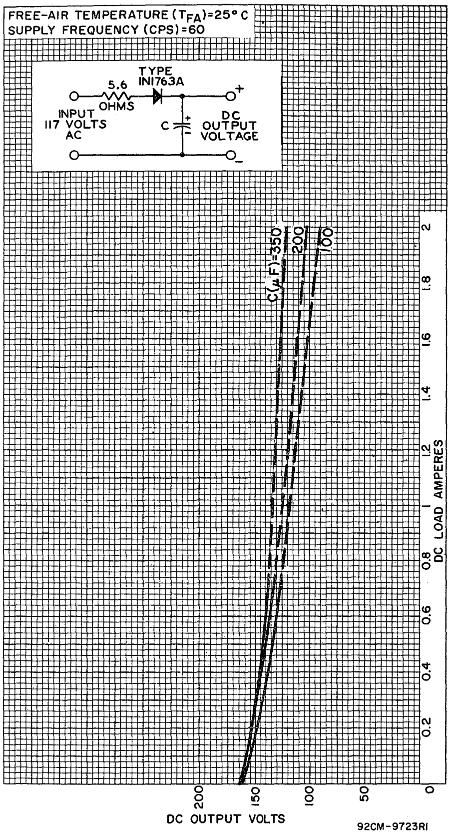


Fig.8 - Typical Operation Characteristics for RCA-1N1763A in Half-Wave Rectifier Service.

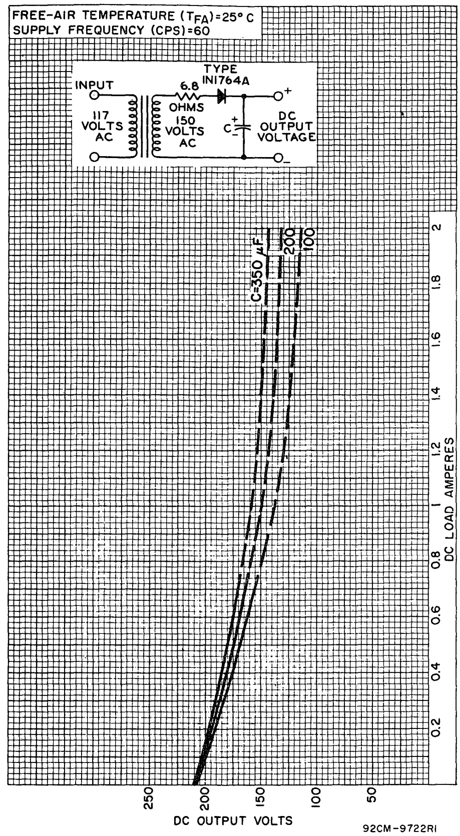


Fig.9 - Typical Operation Characteristics for RCA-1N1764A in Half-Wave Rectifier Service.

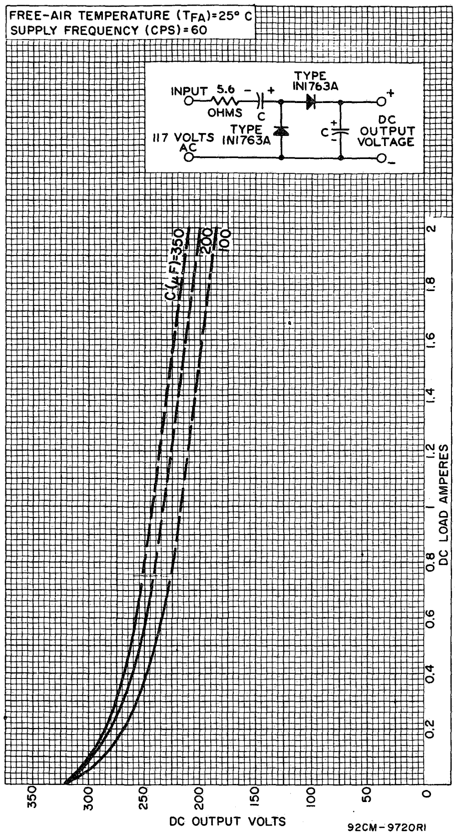


Fig.10 - Typical Operation Characteristics of RCA-1N1763A in Half-Wave Voltage-Doubler Service.

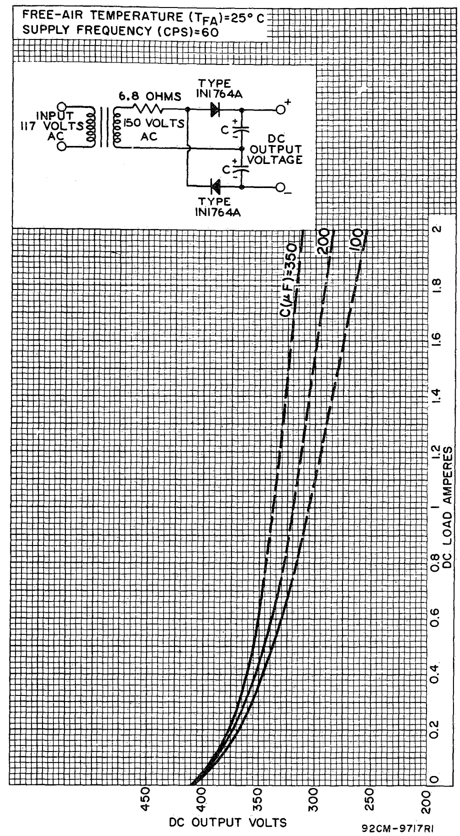
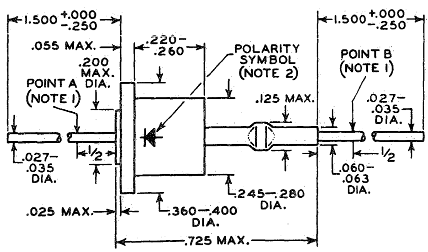


Fig.11 - Typical Operation Characteristics of RCA-1N1764A in Full-Wave Voltage-Doubler Service.

DIMENSIONAL OUTLINE (JEDEC-DO-1)
FOR RCA-1N1763A and 1N1764A



DIMENSIONS IN INCHES — 92CS-9728RI

NOTE 1: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

NOTE 2: DO NOT DIP SOLDER BEYOND POINTS "A" AND "B".

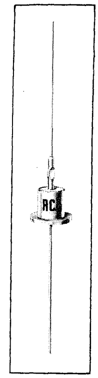
RCA Solid State Division

Rectifiers

1N2858A 1N2859A 1N2860A 1N2861A 1N2862A 1N2863A 1N2864A

DIFFUSED-JUNCTION SILICON RECTIFIERS

Flanged-Case Axial-Lead Types For General-Purpose Applications In Industrial And Commercial Electronic Equipment



RCA-1N2858A, 1N2859A, 1N2860A, 1N2861A, 1N2862A, 1N2863A, and 1N2864A are hermetically sealed silicon rectifiers of the diffused-junction type, designed for use in a variety of applications in industrial and commercial electronic equipment.

RCA-1N2858A through 1N2864A supersede and are unilaterally interchangeable with RCA-1N2858 through 1N2864, respectively. The new rectifiers incorporate all of the superior performance and reliability features which have gained industry acceptance for their RCA prototypes, and, in addition, offer substantially higher dc output-current capabilities, lower reverse (leakage) currents, and a wider operating-temperature range.

All seven of these new rectifier types have maximum dc-forward-current ratings of 1 ampere for resistive or inductive loads and 0.75 ampere for capacitive loads at free-air temperatures up to 75°C (natural convection cooling). They are also capable of providing dc output currents of up to 2 amperes with capacitive loads when attached to simple heat sinks (see OPERATING CONSIDERATIONS).

RCA-1N2858A through 1N2864A differ only in peak-reverse-voltage ratings (see Maximum Ratings chart). They are rated for operation at free-air temperatures from -65° to +135°C, and utilize the JEDEC DO-1 flange-type, axial-lead rectifier package which provides flexibility of installation in both hand-wired and printed-circuit equipment designs.

These new rectifiers, like their RCA prototypes, are conservatively rated, and incorporate the following design features and special tests which contribute to their outstanding performance and reliability: (1) junctions of extremely high uniformity produced by a special, precisely controlled diffusion process, (2) rugged internal mount structure, (3) hermetically sealed cases, (4) prolonged treatment at high temperatures to stabilize characteristics, (5) pressure tests of seals for protection against moisture and contamination, (6) tests for forward and reverse characteristics at 25°C, and (7) high-temperature dynamic tests under full-load conditions.

Features:

- high dc-output-current capability:
  - 1 ampere - resistive or inductive load; 3/4 ampere - capacitive load — to 75°C with natural convection cooling
  - up to 2 amperes - capacitive load — to 105°C with simple heat sinks
- low dynamic reverse current:
  0.1 ma max. at 50°C
  0.3 ma max. at 75°C
- low dc forward voltage drop:
  1.2 volts max. at 25°C with 1 ampere dc forward current
- wide operating-temperature range:
  -65° to +135°C
- hermetically sealed JEDEC DO-1 package
- unilaterally interchangeable with Types 1N2858 through 1N2864
- specially processed and tested for high reliability and stability of characteristics

RECTIFIER SERVICE

Absolute-Maximum Ratings, *for a Supply Frequency of 60 cps:*

	1N2858A	1N2859A	1N2860A	1N2861A	1N2862A	1N2863A	1N2864A	
PEAK REVERSE VOLTAGE	50	100	200	300	400	500	600	max. volts
RMS SUPPLY VOLTAGE:								
For resistive or inductive loads	35	70	140	210	280	350	420	max. volts
For capacitive loads	17	35	70	105	140	175	210	max. volts
DC REVERSE (BLOCKING) VOLTAGE	50	100	200	300	400	500	600	max. volts
FORWARD CURRENT:								
For resistive or inductive loads:								
AVERAGE (DC) At T_{FA} up to 75°C.	1	1	1	1	1	1	1	max. amp
AVERAGE (DC) At T_{FA} above 75°C.	See *Fig.1*							
For capacitive loads:								
AVERAGE (DC) At T_{FA} up to 75°C.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	max. amp
AVERAGE (DC) At T_{FA} above 75°C.	See *Fig.1*							
PEAK RECURRENT At T_{FA} up to 75°C.	5	5	5	5	5	5	5	max. amp
PEAK RECURRENT At T_{FA} above 75°C.	See *Fig.1*							
SURGE, for "turn-on" transient of 2 milliseconds duration:								
At T_{FA} up to 75°C.	35	35	35	35	35	35	35	max. amp
At T_{FA} above 75°C.	See *Fig.1*							
SURGE, repetitive, at T_{FA} = 25°C:								
For one cycle of supply voltage	40	40	40	40	40	40	40	max. amp
For more than one cycle of supply voltage	See *Fig.2*							
TEMPERATURE RANGE (FREE-AIR)								
Operating	-65 to +135							°C
Storage	-65 to +150							°C

Characteristics:

	1N2858A	1N2859A	1N2860A	1N2861A	1N2862A	1N2863A	1N2864A	
Maximum Forward Voltage Drop (DC) at I_F = 1 Ampere, T_{FA} = 25°C.	1.2	1.2	1.2	1.2	1.2	1.2	1.2	volts
Maximum Dynamic Reverse Current (Averaged over 1 Complete Cycle of Supply Voltage): at Maximum Rated PRV:								
T_{FA} = 50°C	0.1	0.1	0.1	0.1	0.1	0.1	0.1	ma
T_{FA} = 75°C	0.3	0.3	0.3	0.3	0.3	0.3	0.3	ma

OPERATING CONSIDERATIONS

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.

Maximum ratings for these devices have been established with connections made to the extreme ends of the leads. For conservative equipment designs, the 1N2858A through 1N2864A should be operated with connections made as close as possible to the device case.

The Maximum Forward Current Ratings for RCA-1N2858A through 1N2864A given on page 1 and in Fig.1 apply specifically for operation of these rectifiers in free air (natural convection cooling). RCA-1N2858A through 1N2864A can, however, provide Average (DC) Forward Currents of **up to 2 amperes with capacitive load** if these rectifiers are attached to simple heat sinks. The Peak Recurrent Forward Current capabilities of these rectifiers are also substantially higher than those shown in the Maximum Ratings when the rectifiers are attached to heat sinks.

Fig.**5** shows the DC and Peak Recurrent Forward Current capabilities of RCA-1N2858A through 1N2864A for capacitive, resistive, or inductive loads, when operation is based on **case temperature** (measured at the intersection of the cathode lead and the case flange).

Figs.**6a**, **6b**, **6c**, **6d**, and **6e** show the DC and Peak Recurrent Forward Current capabilities of RCA-1N2858A through 1N2864A for capacitive, resistive, or inductive loads when these rectifiers are mounted on simple, rectangular heat sinks of various sizes, and operation is based on **free-air temperature.**

Fig.**7** shows two suggested methods for attaching RCA-1N2858A, 1N2859A, 1N2860A, 1N2861A, 1N2862A, 1N2863A, or 1N2864A to a heat sink. The flanges of these rectifiers may also be soldered directly to heat sinks, provided the flange temperature during soldering does not exceed **235°C** for a maximum period of 10 seconds.●

A **surge-limiting impedance** should always be used in series with any of the rectifiers described in this bulletin. The value of this impedance must be sufficient to limit the "turn-on" surge current to the value specified in the Maximum Ratings. This impedance may be provided by the power-transformer windings, or by an external resistor or choke.

The flexible leads of the rectifiers described in this bulletin are usually soldered to the circuit elements. It is desirable in all installations to provide some slack or an expansion elbow in each lead to prevent excessive tension on the leads. Manual soldering should be done carefully and quickly to avoid damage to the rectifier by excessive heating. To minimize heating of the rectifier junction during manual soldering, grip the flexible lead being soldered between the case and the soldering point with a pair of pliers.

When dip soldering is used in the assembly of printed circuits using these rectifiers, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. The leads should not be dip soldered beyond points "A" and "B" indicated on the DIMENSIONAL OUTLINE drawing.

Because the cases of these rectifiers may operate at potentials which are dangerous, care should be taken in the design of equipment to prevent personnel from coming in contact with the rectifiers. It is recommended that these rectifiers be mounted on the under side of the equipment chassis.

● Permanent damage to the rectifier may result if these limits are exceeded.

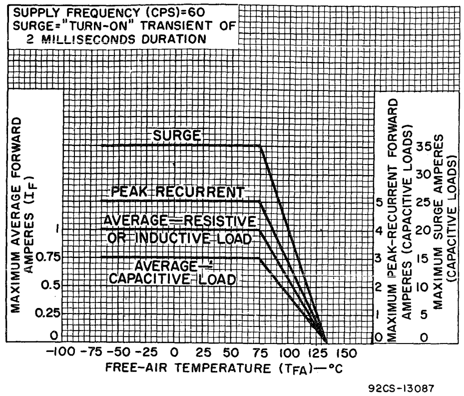


Fig. 1 - Rating Chart for RCA-1N2858A through 1N2864A.

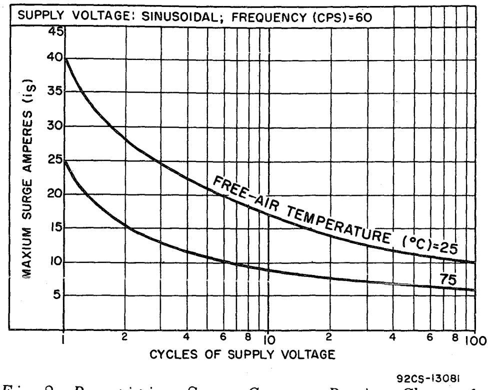


Fig. 2 - Repetitive Surge Current Rating Chart for RCA-1N2858A through 1N2864A.

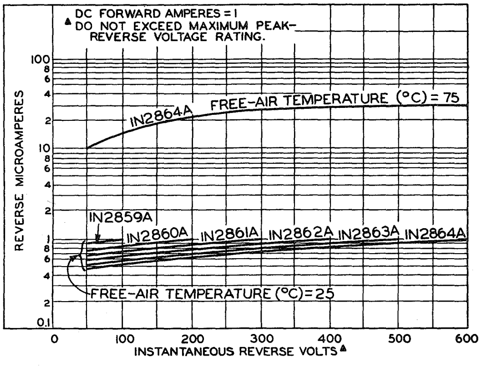


Fig. 3 - Typical Dynamic Reverse Characteristics for RCA-1N2858A through 1N2864A.

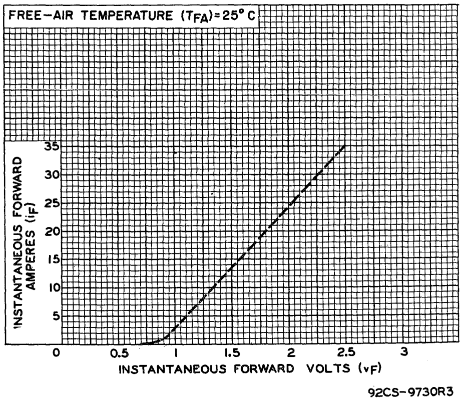


Fig. 4 - Typical Forward Voltage and Current Characteristic for RCA-1N2858A through 1N2864A.

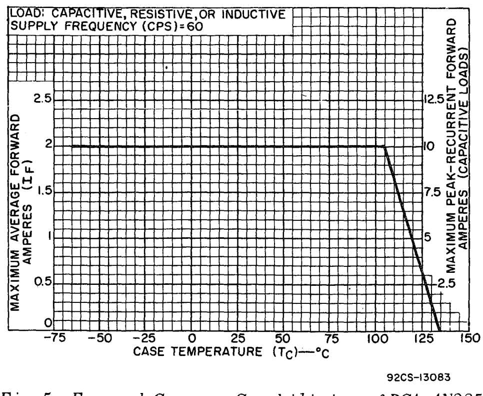
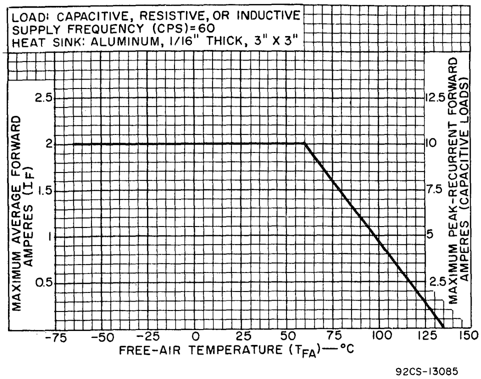
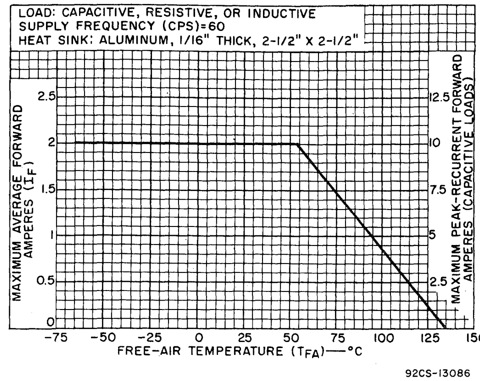


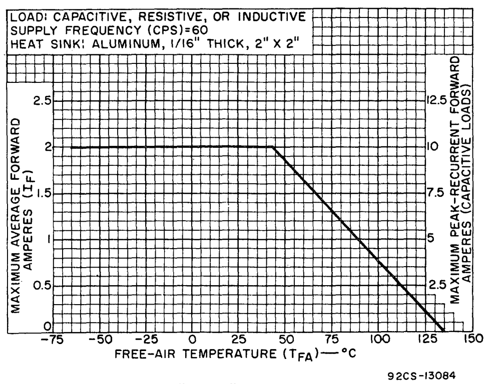
Fig. 5 - Forward-Current Capabilities of RCA-1N2858A through 1N2864A for Operation with Heat Sink at Case Temperatures from -65°C to +135°C.



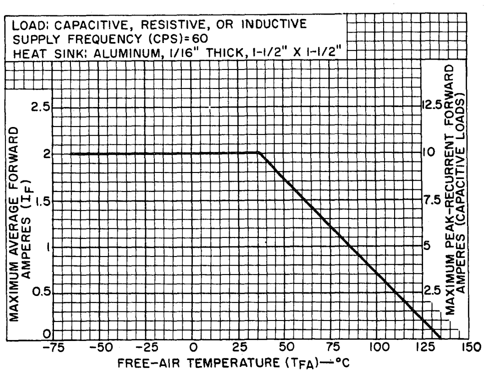
a) 3" x 3" Heat Sink.



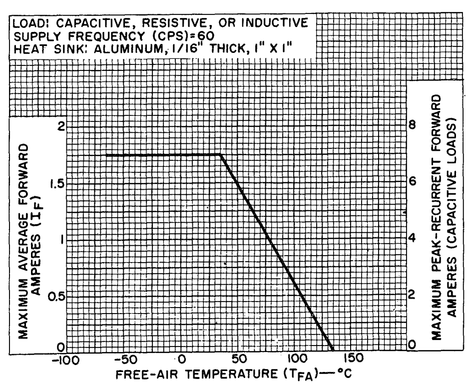
b) 2-1/2" x 2-1/2" Heat Sink.



c) 2" x 2" Heat Sink.

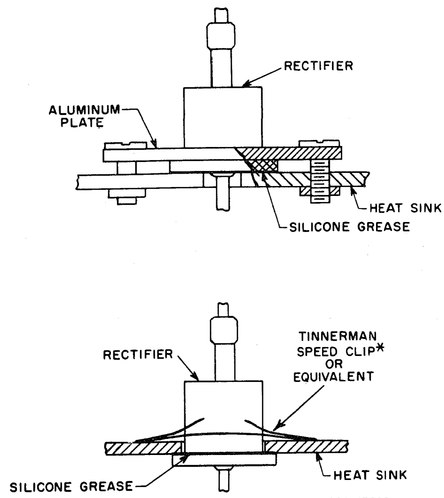


d) 1-1/2" x 1-1/2" Heat Sink.



e) 1" x 1" Heat Sink.

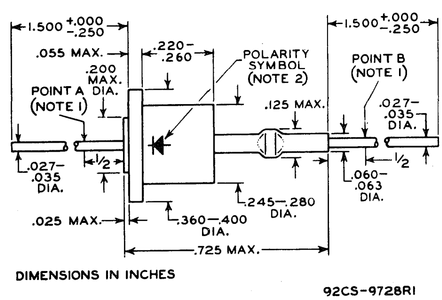
Figs. 6a, 6b, 6c, 6d, and 6e - Forward-Current Capabilities of RCA-1N2858A through 1N2864A for Operation with Heat Sinks.



* Registered Trade Mark, Tinnerman Products, Inc., Cleveland 1, Ohio.

Fig. 7 - Suggested Methods for Attaching RCA-1N2858A through 1N2864A to Heat Sink.

DIMENSIONAL OUTLINE (JEDEC-DO-1) FOR RCA-1N2858A through 1N2864A



NOTE 1: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

NOTE 2: DO NOT DIP SOLDER BEYOND POINTS "A" AND "B".

RCA Solid State Division

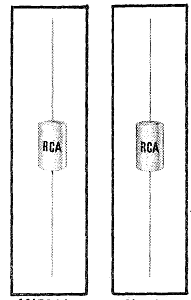
Rectifiers

1N5211 1N5212 1N5213 1N5214 1N5215 1N5216 1N5217 1N5218

SILICON RECTIFIERS

DIFFUSED-JUNCTION TYPES

For Industrial and Consumer-Product Applications



1N5211 through 1N5214 | 1N5215 through 1N5218

RCA-1N5211, 1N5212, 1N5213, 1N5214, 1N5215, 1N5216, 1N5217, and 1N5218* are hermetically sealed silicon rectifiers of the diffused-junction type utilizing small cylindrical metal cases and axial leads. Types 1N5215, 1N5216, 1N5217, and 1N5218 are insulated versions of types 1N5211, 1N5212, 1N5213, and 1N5214, respectively. These rectifiers feature dc forward current ratings of up to 1 A, a surge-current rating of 50A, low forward voltage drop, low leakage currents, and an operating-temperature range of -65°C to +175°C.

* Formerly Dev. Nos. TA2845C, TA2845B, TA2845A, TA2845, TA7048C, TA7048B, TA7048A, and TA7048, respectively.

- cylindrical design with axial leads for simple handling and installation
- compact, hermetically sealed metal case (0.405" max. length; 0.240" max. dia.)
- types 1N5215 through 1N5218 have transparent, high-dielectric-strength plastic sleeve over metal case
- high maximum forward-current ratings – up to 1 ampere DC at 75°C
- peak-reverse-voltage ratings from 200 to 800 volts
- operation at ambient temperatures to +175°C

RECTIFIER SERVICE (For a supply-line frequency of 60 Hz)

Maximum Ratings, *Absolute-Maximum Values:*

	For resistive or inductive load				*For capacitor-input filter*					
	1N5211 1N5215	1N5212 1N5216	1N5213 1N5217	1N5214 1N5218	1N5211 1N5215	1N5212 1N5216	1N5213 1N5217	1N5214 1N5218		
PEAK REVERSE VOLTAGE	200	400	600	800	200	400	600	800	max.	V
RMS SUPPLY VOLTAGE	140	280	420	560	70	140	210	280	max.	V
FORWARD CURRENT: For ambient temperatures up to 75°C. For ambient temperatures above 75°C, see Rating Chart.										
DC	1	1	1	0.75	0.75	0.75	0.75	0.6	max.	A
PEAK RECURRENT	-	-	-	-	6	6	6	5	max.	A
SURGE – For "turn-on" time of 2 milliseconds	-	-	-	-	50	50	50	50	max.	A
AMBIENT-TEMPERATURE RANGE:										
Operating	←			-65 to +175				→		°C
Storage	←			-65 to +175				→		°C
LEAD TEMPERATURE:										
For 10 seconds maximum	←			255				→	max.	°C

Characteristics:

	1N5211 1N5215	1N5212 1N5216	1N5213 1N5217	1N5214 1N5218		
Maximum Instantaneous Forward Voltage Drop at dc forward current of 1 ampere and $T_A \leq 75°C$	1.2	1.2	1.2	1.2	max.	V
Maximum Reverse Current:						
Dynamic, at T_A = 75°C**	0.2	0.2	0.2	0.2	max.	mA
Static, at T_A = 25°C***	0.005	0.005	0.005	0.005	max.	mA

**At max. peak reverse voltage and max. dc forward current.

***At max. peak reverse voltage and zero forward current.

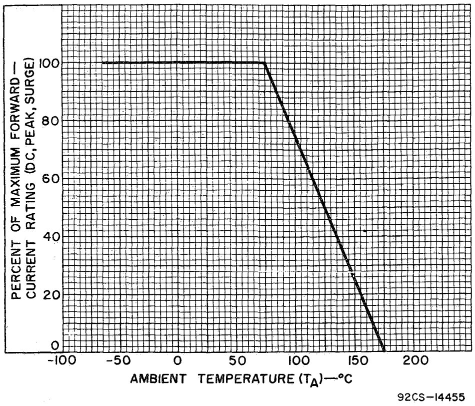


Fig.1 - Rating Chart for Types 1N5211 through 1N5218.

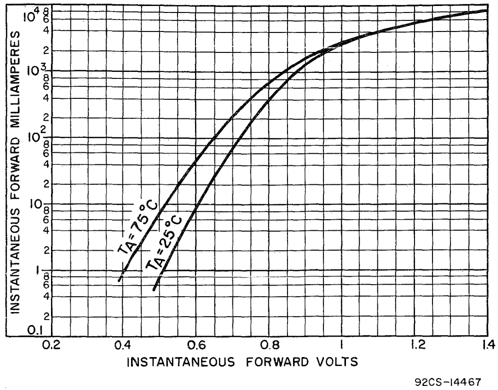


Fig.2 - Typical Forward Characteristics for Types 1N5211 through 1N5218.

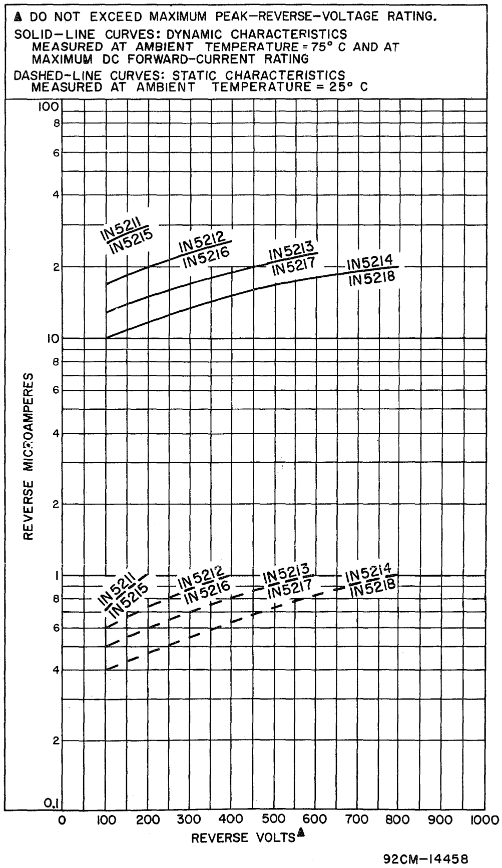


Fig.3 - Typical Reverse Characteristics for Types 1N5211 through 1N5218.

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.

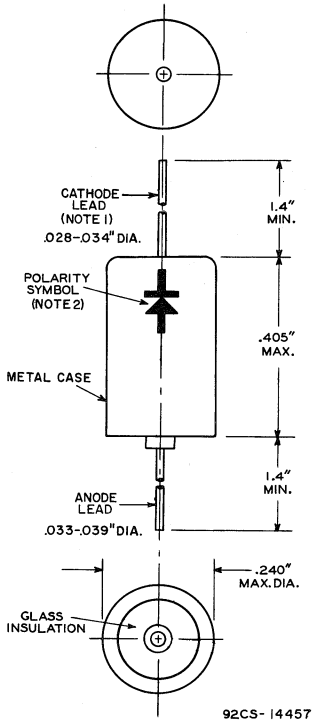
A *surge-limiting impedance* should always be used in series with the rectifier. The impedance value must be sufficient to limit the surge current to the value specified under the maximum ratings. This impedance may be provided by the power transformer windings, or by an external resistor or choke.

The flexible leads of these rectifiers are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in the leads 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 rectifiers. To absorb some of the heat, grip the flexible lead of the rectifier between the case and the soldering point with a pair of pliers.

When dip soldering is employed in the assembly of printed circuits using these rectifiers, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. Furthermore, the leads should not be dip soldered within 0.25" of the metal case. *Best thermal performance will be obtained when connections to the rectifier leads are made at points not more than 0.75" from the case.*

Because the cases of these rectifiers may operate at potentials which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the devices. It is recommended that these rectifiers be mounted on the underside of the chassis.

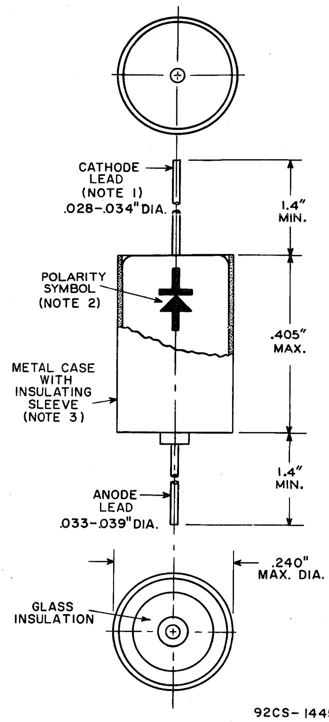
DIMENSIONAL OUTLINE
for Types 1N5211, 1N5212, 1N5213, 1N5214



NOTE 1: CONNECTED TO METAL CASE.

NOTE 2: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

DIMENSIONAL OUTLINE
for Types 1N5215, 1N5216, 1N5217, 1N5218



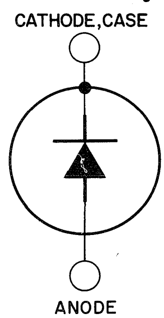
Insulating Sleeve Dielectric Strength: 2000 Volts Minimum

NOTE 1: CONNECTED TO METAL CASE.

NOTE 2: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

NOTE 3: INSULATING SLEEVE MAY EXTEND 1/16" BEYOND ENDS OF CASE.

TERMINAL DIAGRAM
for Types 1N5211 through 1N5218



File No. 354

RCA

Solid State Division

Rectifiers

40640 40641 40642 40643 40644

SILICON CONTROLLED-RECTIFIER AND SILICON RECTIFIER COMPLEMENT

For Horizontal Deflection Circuits of Large-Screen Color-TV Receivers

RCA-40640, 40641, 40642, 40643, and 40644 are a group of silicon controlled-rectifiers and silicon rectifiers intended for use in horizontal-deflection circuits of large-screen color-television receivers.

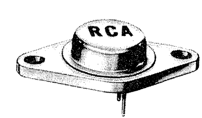
A simplified schematic diagram for the utilization of these SCR's and silicon rectifiers is shown below. For detailed information on the operation of this new deflection circuit, see Application Note AN-3780.

The 40640 silicon controlled-rectifier and the 40642 silicon rectifier are the trace circuit components. They provide bipolar switching action for controlling the horizontal yoke current during the picture tube beam-trace interval.

The 40641 silicon controlled-rectifier and the 40643 silicon rectifier are the commutating (retrace) circuit components. They control the yoke current during the retrace interval.

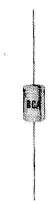
The 40644 silicon rectifier is used as a clamp in the trace circuit to protect the circuit components from excessively high voltages which may result from possible arcing in the picture tube or high-voltage rectifier.

40640, 40641



JEDEC TO-66

H-1340



40642
40643
40644

JEDEC DO-26

H-1157

FEATURES

- Designed for off-the-line operation: B+ = 155V
- Supply voltages: 108 to 129V ac
- Outstanding performance and reliability
- High picture-tube beam current capability: to 1.5mA dc average (max.)
- Can fully deflect picture tubes having deflection angles to 90°, 1-7/16" neck diameters, and 25-kV ultor voltages (nom. value)

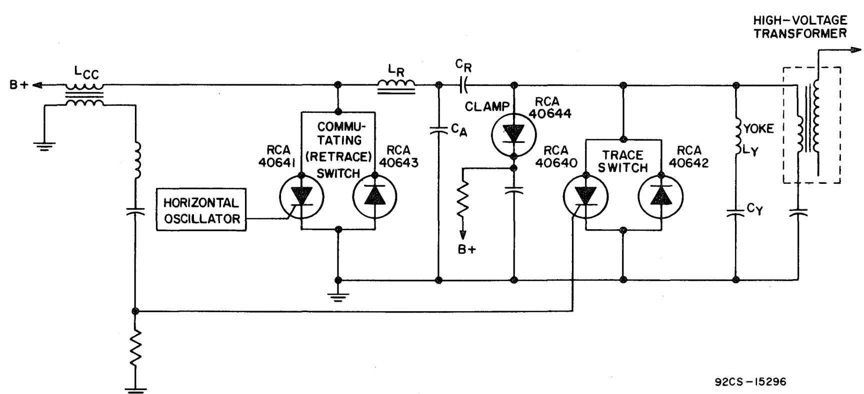


Fig.1 - Simplified schematic-diagram of horizontal output circuit.

SILICON CONTROLLED-RECTIFIERS

Maximum Ratings, *Absolute-Maximum Values:*

		40640 *Trace SCR*	40641 *Commutating SCR*	
Repetitive Peak Off-State Voltage				
With gate open	V_{DROM}	600		V
Repetitive Peak Reverse Voltage				
With gate open	V_{RROM}	5		V
On-State Current:				
For case temperature of +60°C and 60 Hz				
Average DC at 180° conduction angle	$I_{T(AV)}$	3.2		A
RMS	$I_{T(RMS)}$	5		A
Peak Surge (Non-Repetitive) On-State Current:				
For one cycle of 60 Hz voltage	I_{TSM}	80		A
Critical Rate of Rise of On-State Current:				
For $V_{DX} = V_{(BO)O}$ rated value, I_{GT} = 50 mA, 0.1 μs rise time	di/dt	200		A/μs
Gate Power Dissipation[a]:				
Peak (forward or reverse) for 10 μs duration	P_{GM}	25		W
Temperature Range[b]:				
Storage	T_{stg}	-40 to +150		°C
Operating (case)	T_C	-40 to +100		°C

[a] Any values of peak gate current or peak gate voltage to give the maximum gate power are permissible.
[b] For information on the reference point of temperature measurement, see *Dimensional Outline*.

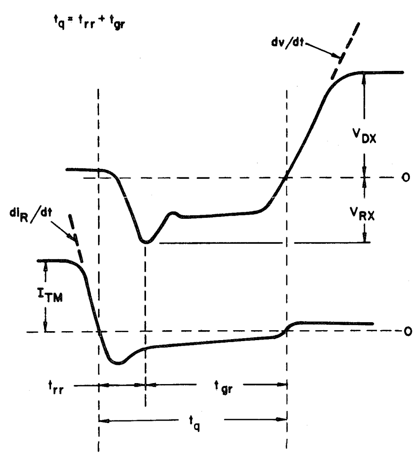


Fig.2 - Waveshape of t_q characteristic for types 40640, 40641.

SILICON CONTROLLED-RECTIFIERS

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)
For Definitions of Terms and Symbols, See Page 5

CHARACTERISTIC:		40640 Trace SCR			40641 Commutating SCR			UNIT
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Breakover Voltage: With gate open								
At T_C = +100°C	$V_{(BO)O}$	–	–	–	400	–	–	V
At T_C = +80°C	$V_{(BO)O}$	550	–	–	–	–	–	V
Peak Forward Off-State Current: With gate open, $V_{DO} = V_{(BO)O}$ rated value								
At T_C = +100°C	I_{DOM}	–	–	–	–	0.5	1.5	mA
At T_C = +80°C	I_{DOM}	–	0.5	1.5	–	–	–	mA
Instantaneous On-State Voltage: For an on-state current of 30 A, T_C = +25°C	v_T	–	2.2	3	–	2.2	3	V
DC Gate Trigger Current: At T_C = +25°C	I_{GT}	–	15	30	–	15	30	mA(dc)
DC Gate Trigger Voltage: At T_C = +25°C	V_{GT}	–	1.8	4	–	1.8	4	V(dc)
Thermal Resistance: Junction-to-Case	$\theta_{J\text{-}C}$	–	–	4	–	–	4	°C/W
Circuit-Commutated Turn-Off Time: (Reverse recovery time + gate recovery time)								
Trace SCR— At I_{TM} = 6 A (t_r = 25 µs, di/dt = 2.5 A/µs), V_D = 0 V (prior to turn on), V_D = 400 V (reapplied at 175 V/µs), V_R = 0.8 V (min.), I_{GT} = 100 mA, V_{GK}(bias) = -30 V (68 Ω source), f = 15.75 kHz, T_C = 70°C	t_q	–	–	2.5	–	–	–	µs
Commutating SCR— At I_{TM} = 13 A (½ sine wave 7 µs base, initial di/dt = 20 A/µs to 3 A), V_D = 350 V (prior to turn on), dV/dt = 400 V/µs (to 100 V), V_R = 0.8 V (min.) I_{GT} = 100 mA (t_p = 3 µs, t_r = 0.2 µs), V_{GK}(bias) = -2.5 V (47 Ω source during turn off), f = 15.75 kHz, T_C = 70°C	t_q	–	–	–	–	–	4.5	µs

SILICON RECTIFIERS

MAXIMUM RATINGS:

		40642 Trace	40643 Commutating Silicon Rectifiers	40644 Clamp		
Non-Repetitive Peak Reverse Voltage[c]	V_{RM}(nonrep)	700	800	700		V
Repetitive Peak Reverse Voltage[d]	V_{RM}(rep)	550	450	550		V
Forward Current:[d]						
DC	I_F	1	1	1		A
RMS	$I_{F(RMS)}$	1.9	1.6	0.2		A
Peak Repetitive	I_{FM}(rep)	6.5	6	0.3		A
Peak Surge[e]	I_{FM}(surge)	70	10	20		A
Ambient Temperature Range:						
Operating	T_A		-40 to +150			°C
Storage	T_{stg}		-40 to +175			°C
Lead Temperature:						
For 10 seconds maximum			255			°C

CHARACTERISTICS:

		40642	40643	40644		
Max. Instantaneous Forward Voltage Drop:						
At $I_F = 4$ A, $T_A \leq 75°C$	v_{FM}	1.3	1.3	2		V
Max. Reverse Current (Static):[f]						
At $T_C = 100°C$	I_{RM}	0.25	0.25	0.25		mA
At $T_A = 25°C$	I_{RM}	10	10	10		µA
Reverse Recovery Time:						
At $I_F = 20$ mA, $I_R = 1$ mA, $T_C = 25°C$	t_{rr}	1.1	1.1	1.6	max	µs
Turn-On Time:						
At $I_F = 20$ mA, $T_C = 25°C$	t_{on}	0.3	0.3	0.3	max	µs
Peak Turn-On Voltage:						
At $I_F = 20$ mA, $T_C = 25°C$		5	6	7	max	V

[c] Pulse width = 10 µs, pulse repetition rate = 15.7 kHz, 3 pulses.

[d] For ambient temperatures up to 45°C and maximum thermal resistance from reference point to ambient of 45°C/W, with devices operating in circuit of Fig.1.

[e] Pulse width = 3 ms.

[f] At max. peak reverse voltage and zero forward current.

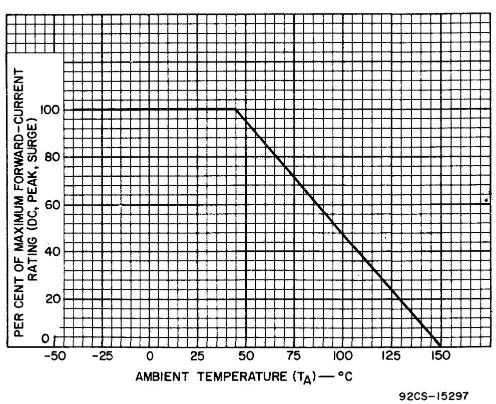


Fig.3 - Rating chart for types 40642, 40643, 40644.

OPERATING CONSIDERATIONS

The flexible leads of the silicon rectifiers are usually soldered to the circuit elements. It is desirable in all soldering operations to provide some slack or an expansion elbow in the leads 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 rectifiers. To absorb some of the heat, grip the flexible lead of the rectifier between the case and the soldering point with a pair of pliers.

When dip soldering is employed in the assembly of printed circuits using these rectifiers, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds. Furthermore, the leads should not be dip soldered within 0.25" of the metal case.

Because the cases of these rectifiers may operate at potentials which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the devices. It is recommended that these rectifiers be mounted on the underside of the chassis.

DEFINITIONS OF TERMS AND SYMBOLS FOR SILICON CONTROLLED-RECTIFIERS

These terms and symbols follow the latest recommended standards of JEDEC. "JEDEC Suggested Standard No.7 on Thyristors, April 1967." This standard may be purchased from EIA, Engineering Department, 2001 Eye St., N.W., Washington, D.C. 20006. For convenience, formerly used symbols have been cross-referenced to the new standards.

PRINCIPAL VOLTAGE DEFINITIONS

Repetitive Peak Reverse Voltage -- V_{RROM} [Formerly v_{RM} (rep)] -- The maximum instantaneous value of reverse voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all non-repetitive transient voltages with the gate open.

Repetitive Peak Off-State Voltage -- V_{DROM} [Formerly V_{FBOM} (rep)] -- The maximum instantaneous value of off-state voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all non-repetitive transient voltages which will not cause switching from the off-state to the on-state with the gate open.

Breakover Voltage -- $V_{(BO)O}$ (Formerly v_{BOO}) -- The value of positive principal voltage at the breakover point with the gate open and at specified conditions of junction temperature.

Forward Off-State Voltage -- V_{DO} (Formerly V_{FBO}) -- The value of positive off-state voltage applied between anode and cathode with the gate open.

Reverse Voltage -- V_{RO} (Formerly V_{RBO}) -- The value of negative voltage applied between anode and cathode with the gate open.

Instantaneous On-State Voltage -- v_T (Formerly v_F) -- The instantaneous value of positive principal voltage when the thyristor is in the on-state at a given instantaneous current.

Critical Rate of Rise of Off-State Voltage -- Critical dv/dt -- The maximum value of the rate of the rise of positive principal voltage which will not cause switching from the off-state to the on-state under specified conditions.

PRINCIPAL CURRENT DEFINITIONS

Average On-State Current -- $I_{T(AV)}$ (Formerly I_{FAV}) -- The average value of the principal current when the thyristor is in the on-state.

RMS On-State Current -- $I_{T(RMS)}$ (Formerly I_{FRMS}) -- The RMS value of the principal current when the thyristor is in the on-state.

Peak Surge (Non-Repetitive) On-State Current -- I_{TSM} [Formerly $i_{FM(surge)}$] -- An overload on-state current of specific time duration and peak value which may be conducted through the thyristor for one half-cycle from a 60-Hz supply in a single-phase circuit with a resistive load. The thyristor shall be operating within its specified operating voltage, average on-state current, gate power, and temperature ratings prior to the surge current. The surge current may be repeated after sufficient time has elapsed for the device to return to pre-surge thermal equilibrium conditions.

Critical Rate of Rise of On-State Current -- Critical di/dt -- The maximum value of the rate of rise of on-state current which a thyristor can withstand under specified conditions.

Peak Forward Off-State Current -- I_{DOM} (Formerly I_{FBOM}) -- The peak value of the forward principal current when the thyristor is in the off-state with the gate open.

Peak Reverse Blocking Current -- I_{RROM} (Formerly I_{RBOM}) -- The peak value of the principal current when the thyristor is in the reverse blocking state with the gate open.

GATE DEFINITIONS

DC Gate-Trigger Voltage -- V_{GT} -- The value of gate voltage required to produce the gate trigger current under specified conditions.

DC Gate-Trigger Current -- I_{GT} -- The minimum value of gate current required to switch a thyristor from the off-state to the on-state under specified conditions.

Peak Gate Power Dissipation -- P_{GM} -- The maximum instantaneous value of gate power which may be dissipated between the gate and cathode for a specified time duration.

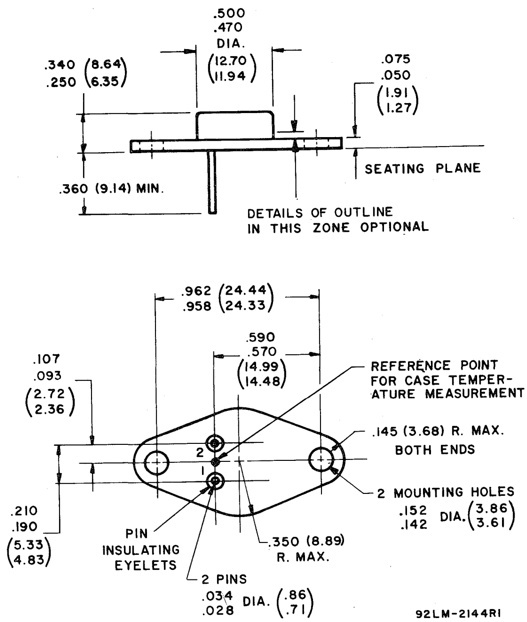
MISCELLANEOUS DEFINITIONS

Gate-Controlled Turn-On Time -- t_{gt} (Formerly t_{on}) -- The time interval between the 10 per-cent point at the beginning of the gate-trigger voltage pulse and the instant when the principal current has risen to the 90 per-cent point of its peak value during switching of the thyristor from the off-state to the on-state by a gate pulse.

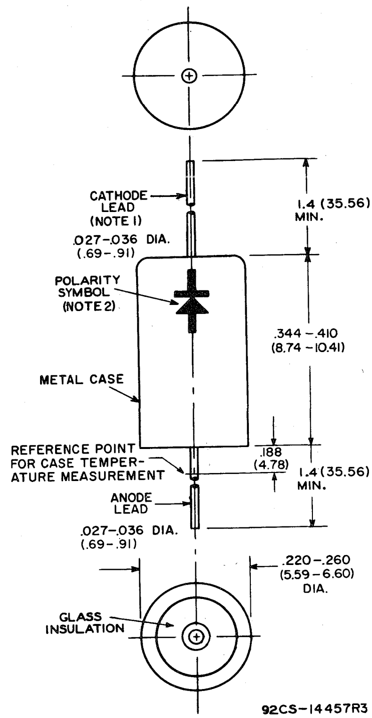
Circuit-Commutated Turn-Off Time -- t_q (Formerly t_{off}) -- The time interval between the instant when the principal current has decreased to zero after external switching of the principal voltage circuit, and the instant when the thyristor is capable of supporting a given principal voltage without turning on under specified conditions.

DIMENSIONAL OUTLINES

40640, 40641
JEDEC TO-66



40642, 40643, 40644
JEDEC DO-26



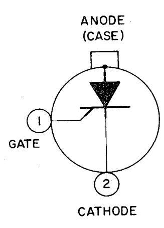
Note 1: Connected to metal case.

Note 2: Arrow indicates direction of forward (easy) current flow as indicated by dc ammeter.

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

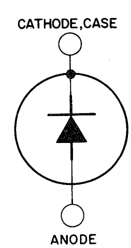
TERMINAL DIAGRAMS

40640, 40641



Pin 1: Gate
Pin 2: Cathode
Case : Anode

40642, 40643, 40644

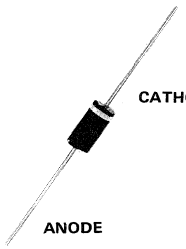


RCA

Solid State Division

Rectifiers

44001–44007



1-A, 50-to-1000-V Silicon Rectifiers

Plastic-Packaged, General-Purpose Types for Low-Power Applications

Features:

- **Electrically identical to JEDEC types 1N4001–1N4007**
- **High surge-current capability**
- **Low junction-to-lead thermal impedances**
- **–65 to +175°C operating temperature range**

RCA-44001–44007†, inclusive, are diffused-junction type silicon rectifiers in an axial-lead plastic package. These devices differ only in their voltage ratings.

Their small size and plastic package of high insulation resistance make these rectifiers especially suitable for those applications in which high packing densities are desirable.

†Types 44002–44007 were formerly RCA Dev. Nos. TA7996, TA7802–TA7806, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

REVERSE VOLTAGE:		44001	44002	44003	44004	44005	44006	44007	
REPETITIVE PEAK♠	V_{RRM}	50	100	200	400	600	800	1000	V
NON-REPETITIVE PEAK♦	V_{RSM}	100	150	300	525	800	1000	1200	V
WORKING PEAK▲	V_{RWM}	50	100	200	400	600	800	1000	V
DC BLOCKING	V_R	50	100	200	400	600	800	1000	V
RMS	$V_{R(RMS)}$	35	70	140	280	420	560	700	V

		All Types	
FORWARD CURRENT:			
AVERAGE-RECTIFIED:	I_O		A
Single-phase, half-wave operation with 60-Hz sinusoidal voltage and resistive load; with 1" leads. T_A = 75°C		1	
For other lead lengths		See Fig. 1	
PEAK-SURGE (NON-REPETITIVE):	I_{FSM}		
For one-half cycle of applied voltage, 50 Hz (10 ms)		28	A
60 Hz (8.3 ms)		30	A
400 Hz (1.25 ms)		60	A
For other durations		See Fig. 3	
TEMPERATURE RANGE:			
With 1-inch leads & infinite-heat-sink mounting (both leads):			
Storage & Operating		–65 to 175	°C
LEAD TEMPERATURE (During Soldering):	T_L		
Measured 3/8 in. (9.52 mm) from case for 10 s max.■		350	°C

♠ For single-phase, half-wave sinusoidal pulse of 100–μs duration and a repetition rate of 60 pulses per second.

♦ For one single-phase, half-wave, 60-Hz sinusoidal pulse with this peak value.

▲ Maximum input voltage that can be continuously applied (with the maximum current rating) over the normal operating-temperature range. For single-phase, half-wave operation with a 60-Hz sinusoidal supply and a resistive load.

■ Measured on anode or cathode lead.

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	LIMITS All Types Min.	Typ.	Max.	UNITS
Reverse Current:					
Static					
For V_R = rated value & T_J = 25°C	I_R	–	–	0.01	mA
For V_R = rated value & T_J = 100°C		–	–	0.05	
Dynamic					
Full-cycle average, for V_{RWM} = rated value, I_o = 1 A, T_A = 75°C	$I_{R(AV)}$	–	–	0.03	mA
Instantaneous Forward-Voltage Drop:					
At i_F = 1 A, T_J = 25°C, see Fig. 2	v_F	–	0.95	1.1	V
Reverse-Recovery Time:					
At I_{FSM} = 30 A, pulse duration = 3.1 μs, T_A = 25°C, see Fig. 6	t_{rr}	–	1.5	–	μs
For other conditions			See Fig. 7		
Thermal Impedance (Junction-to-Heat Sink):					
Steady-State					
Heat-sink mounting with 1-inch leads. For other mounting methods and other lead lengths, see Fig. 4	$\theta_{J\text{-}HS(t)}$	–	50	55	°C/W
Transient					
Heat-sink mounting with 0 to 1" leads, and with a pulse duration of 0.3 s. For other pulse durations, see Fig. 5	$\theta_{J\text{-}HS(t)}$	–	7.5	–	°C/W

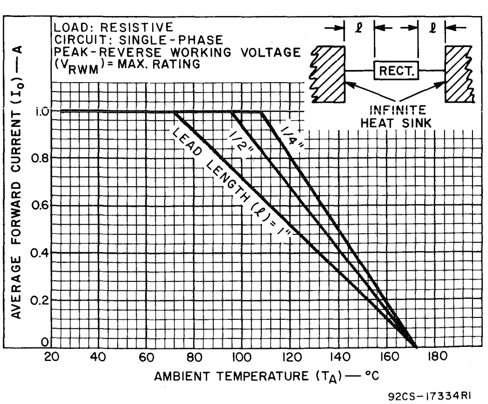


Fig.1—Average-forward-current derating curves for several lead lengths.

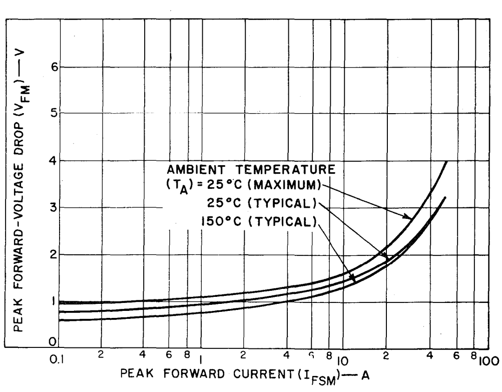


Fig.2—Peak forward-voltage drop vs. peak forward current.

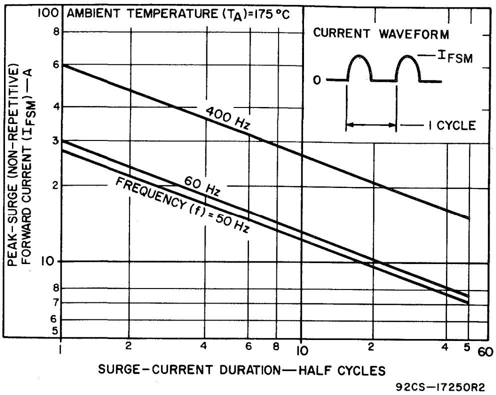


Fig.3—Peak-surge (non-repetitive) forward current vs. surge-current duration.

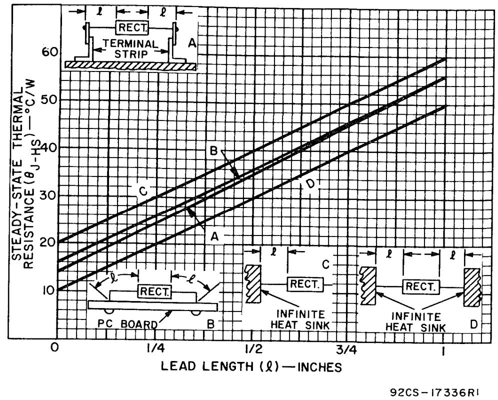


Fig.4—Typical steady-state thermal resistance with lead length (for different mounting methods).

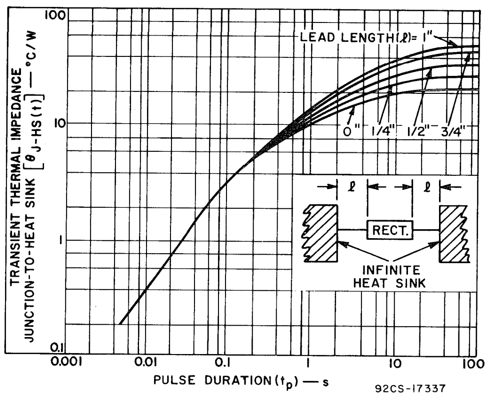


Fig.5—Typical variation of transient thermal impedance with pulse duration for several lead lengths.

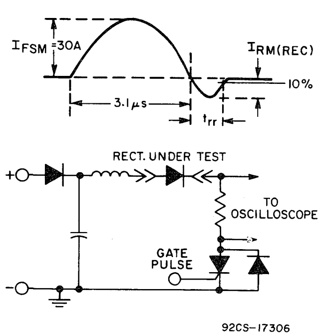


Fig.6—Oscilloscope display & test circuit for measurement of reverse-recovery time.

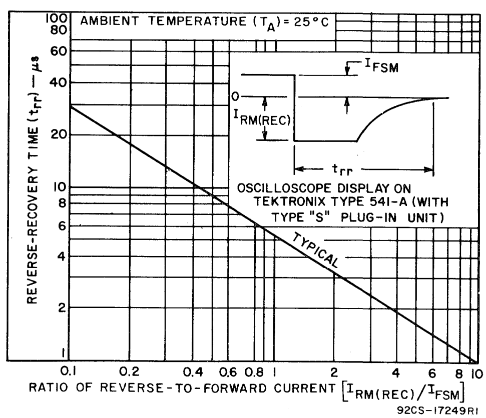
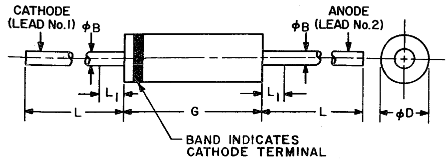


Fig.7—Typical reverse-recovery time with ratio of reverse-to-forward current.

DIMENSIONAL OUTLINE



92CS-17313R1

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
φB	0.030	0.034	0.762	0.863	–
φD	0.133	0.137	3.378	3.479	1
G	0.280	0.285	7.112	7.239	1
L	1.000	–	25.40	–	–
L_1	–	0.050	–	1.27	2

NOTES

1. Package contour optional within cylinder of diameter, φD, and length, G. Slugs, if any, shall be included within this cylinder but shall not be subject to the minimum limit of φD.
2. Lead diameter not controlled in this zone to allow for flash, lead-finish build-up, and minor irregularities other than slugs.

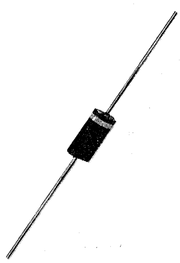
RCA

Solid State Division

Rectifiers

1N5391--1N5399

JEDEC DO-15



1N5391–1N5399 H-1695

1.5-A, 50–1000-V Silicon Rectifiers

Plastic-Packaged, General-Purpose Types for Low-Power Applications

Features:

- **High surge-current capability**
- **Low junction-to-lead thermal impedances**
- **−65 to +170° operating temperature range**

RCA-1N5391--1N5399, inclusive, are diffused-junction type silicon rectifiers in an axial-lead plastic package. These devices differ only in their voltage ratings. Their small size and plastic package of high insulation resistance make these rectifiers especially suitable for those applications in which high packaging densities are employed.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

REVERSE VOLTAGE:		1N5391	1N5392	1N5393	1N5394	1N5395	1N5396	1N5397	1N5398	1N5399	
* REPETITIVE PEAK■	V_{RRM}	50	100	200	300	400	500	600	800	1000	V
* NON-REPETITIVE PEAK▼	V_{RSM}	100	200	300	400	525	650	800	1000	1200	V
* WORKING PEAK▲	V_{RWM}	50	100	200	300	400	500	600	800	1000	V
* DC BLOCKING (At T_A = 150°C)	V_R	50	100	200	300	400	500	600	800	1000	V
RMS	$V_{R(RMS)}$	35	70	140	210	280	350	420	560	700	V

FORWARD CURRENT:		All Types	
* AVERAGE RECTIFIED	I_o	1.5	A
Single-phase, half-wave operation with 60-Hz sinusoidal voltage and resistive load, and 1/2-inch leads; for other lead lengths, see Fig. 1. T_A = 70°C			
* PEAK SURGE	I_{FSM}		
For one-half cycle of applied voltage, 50 Hz (10 ms)		45	A
*60 Hz (8.3 ms)		50	A
400 Hz (1.25 ms), T_A = 70°C		100	A
For other durations		See Fig. 4.	
TEMPERATURE RANGE:			
* Storage		−65 to +175	°C
* Operating		−65 to +170	°C
***LEAD TEMPERATURE (During Soldering):**			
Measured 1/8 inch from case for 10 s max.		240	°C

■ For single-phase, half-wave sinusoidal pulse of 100-μs duration with a repetition rate of 60 pulses per second.
▼ For one single-phase, half-wave, 60-Hz sinusoidal pulse with this peak value.
▲ Maximum input-voltage rating that can be continuously applied (with the maximum current rating) over the normal operating temperature range|. For single-phase, half-wave operation with a 60-Hz sinusoidal supply and a resistive load.
* In accordance with JEDEC registration format JS-1 RDF-3.

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	LIMITS All Types Min.	Typ.	Max.	UNITS
Reverse Current:					
**Static*					
For V_R = rated value & T_J = 25°C	I_R	–	0.001	0.01*	mA
For V_R = rated value & T_J = 150°C		–	0.100	0.3*	
**Dynamic*					
Full-cycle average, for V_{RWM} = rated value, I_o = 1.5A, T_A = 70°C	$I_{R(AV)}$	–	0.080	0.3*	mA
***Instantaneous Forward-Voltage Drop:**					
At i_F = 1.5A, T_A = 70°C, see Fig. 3.	v_F	–	1.1	1.4*	V
Reverse-Recovery Time:					
At I_{FM} = 30A, pulse duration = 3.1 μs, T_A = 25°C (See Fig. 7; for other conditions, see Fig. 8.)	t_{rr}	–	1.5	–	μs
***Thermal Impedance:**					
Steady-State					
Junction-to-anode-lead	$\theta_{J\text{-}L_a}$	–	–	100	°C/W
Junction-to-cathode-lead	$\theta_{J\text{-}L_k}$	–	–	100	
Anode-Lead } Free convection cooling	–	–	–	148	°C/W/in
Cathode-Lead } Free convection cooling	–	–	–	148	
Transient					
Heat-sink mounting with 0-to-1¼" leads, and with a pulse duration of 0.6 s. For other pulse durations, see Fig. 6.	$\theta_{J\text{-}HS(t)}$	–	10	–	°C/W

* In accordance with JEDEC registration data format JS-1 RDF-3

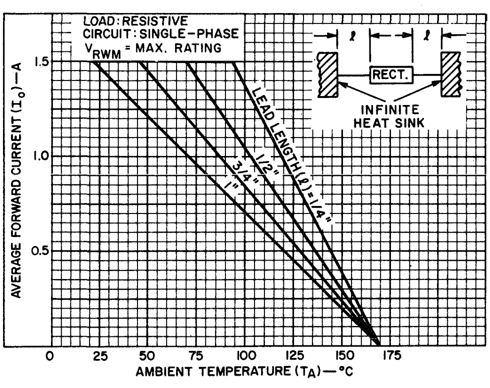


Fig. 1 - Average-forward-current derating curves for types 1N5391--1N5399 for several lead lengths.

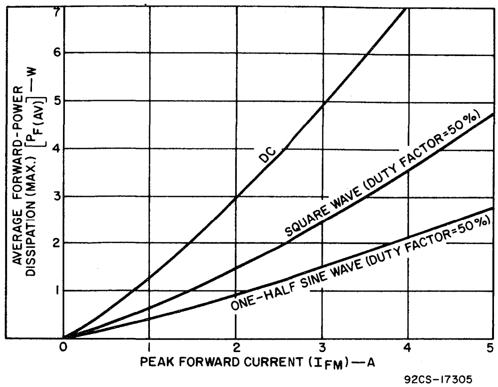


Fig. 2 - Variation of peak forward-power dissipation with peak forward current.

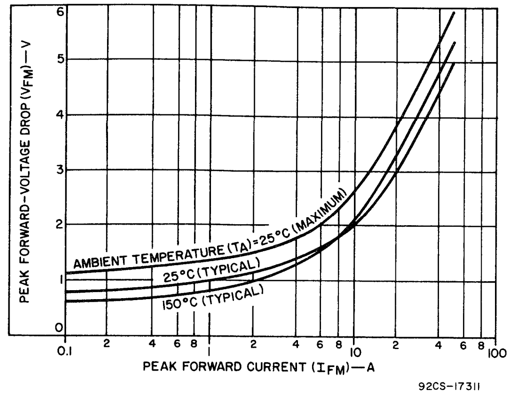


Fig. 3 - Peak forward-voltage drop vs. peak forward current for types 1N5391–1N5399.

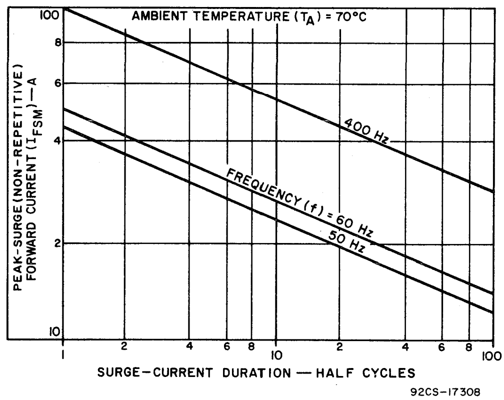


Fig. 4 - Peak-surge (non-repetitive) forward current vs. surge-current duration for types 1N5391–1N5399.

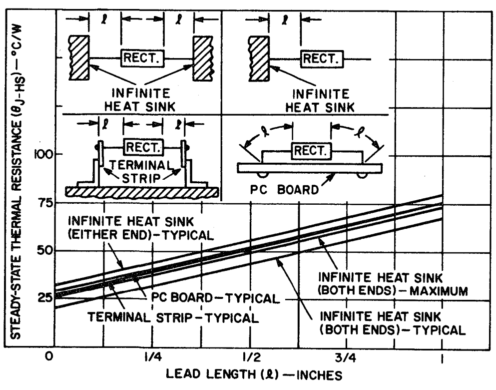


Fig. 5 - Variation of steady-state thermal resistance with lead length (for different mounting methods) for types 1N5391–1N5399.

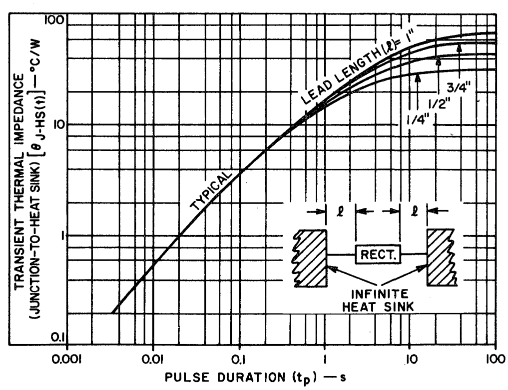


Fig. 6 - Variation of transient thermal impedance with pulse duration for several lead lengths for types 1N5391–1N5399.

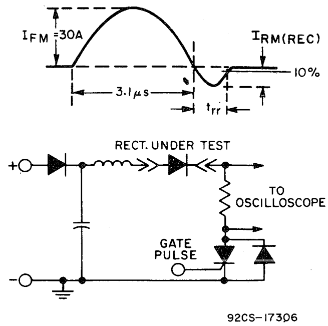


Fig. 7 - Oscilloscope display & test circuit for measurement of reverse-recovery time.

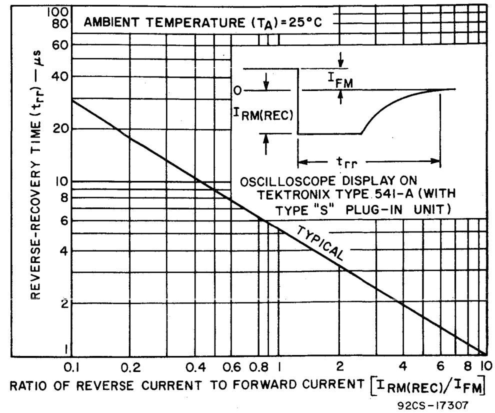
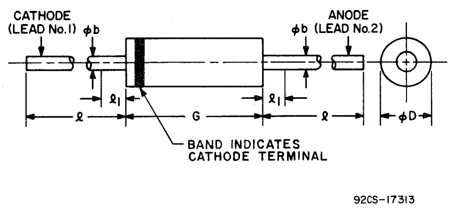


Fig. 8 - Variation of reverse-recovery time with ratio of reverse-to-forward current for types 1N5391--1N5399.

DIMENSIONAL OUTLINE
JEDEC DO-15



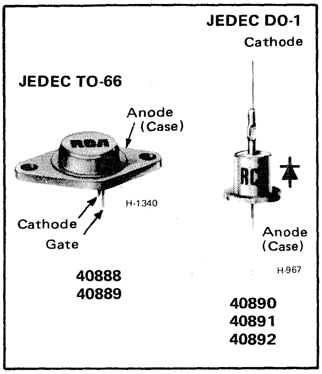
SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
φb	0.027	0.035	0.686	0.889
φD	0.104	0.140	2.64	3.56
G	0.230	0.300	5.84	7.62
ℓ	1.000	–	25.40	–
ℓ_1*	–	0.050	–	1.27

*Within this zone the diameter may vary to allow for lead finishes and irregularities.

RCA
Solid State
Division

Thyristors/Rectifiers

40888,40889
40890,40891,40892



Horizontial - Deflection SCR's and Rectifiers

For 110° Large-Screen Color TV

Features:

- **Operation from supply voltages between 150 and 270 V (nominal).**
- **Ability to handle high beam current; average 1.6 mA dc.**
- **Ability to supply as much as 7 mJ of stored energy to the deflection yoke, which is sufficient for 29 mm-neck picture tubes, as well as 36.5 mm-neck tubes, both operated at 25 kV (nominal value).**
- **Highly reliable circuit which can also be used as a low-voltage power supply.**

These RCA types are designed for use in a horizontal output circuit such as that shown in Fig. 1.

The silicon controlled rectifier 40888 and the silicon rectifier 40890 are designed to act as a bipolar switch that controls horizontal yoke current during the beam trace interval. To initiate trace-retrace switching and control yoke current during retrace, the silicon controlled rectifier 40889 and the silicon recitifier 40891 act as the commutating switch.

RCA types 40888-40892, inclusive, were formerly RCA Dev. Nos. TA8158-TA8162, respectively.

The silicon rectifier 40892 may be used as a clamp to protect the circuit components from excessively high transient voltages which may be generated as a result of arcing in the picture tube or in a high-voltage rectifier tube.

To facilitate direct connection across each silicon controlled rectifier, 40888 and 40889, the anode connection of the silicon rectifiers 40890 and 40891, is reversed as compared to that of a normal power-supply rectifier diode.

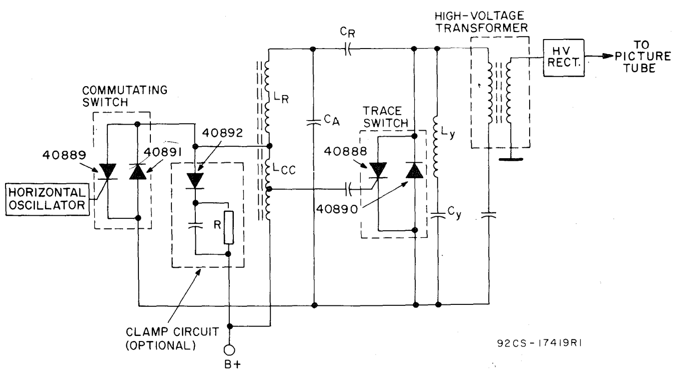


Fig.1—Simplified schematic diagram of horizontal output circuit.

For a description of the operation of SCR deflection systems see RCA Application Note AN-3780, "A New Horizontal Deflection System Using RCA-40640 and 40641 Silicon Controlled Rectifiers"; ST-3871; "An SCR Horizontal-Sawtooth-Current and High-Voltage Generator for Magnetically Deflected Picture Tubes"; ST-3835, "Switching-Device Requirements for a New Horizontal-Deflection System".

MAXIMUM RATINGS, *Absolute-Maximum Values:*

SILICON CONTROLLED RECTIFIERS

		TRACE SCR 40888	COMMUTATING SCR 40889	
Non-Repetitive Peak Off-State Voltage:				
Gate open	V_{DSOM}	800*	750*	V
Repetitive Peak Off-State Voltage:				
Gate open	V_{DROM}			
T_C = 80°C		750	700	V
Repetitive Peak Reverse Voltage:				
Gate open	V_{RROM}	25	25	V
On-State Current:				
T_C = 60°C, 50 Hz sine wave, conduction angle = 180°:				
Average DC	$I_{T(AV)}$	3.2	3.2	A
RMS	$I_{T(RMS)}$	5	5	A
Peak Surge (Non-Repetitive):				
For one cycle of applied voltage, 50 Hz	I_{TSM}	50	50	A
Critical Rate of Rise of On-State Current:				
For V_D = V_{DROM} rated value, I_{GT} = 50 mA, 0.1 μs rise time	di/dt	200	200	A/μs
Gate Power Dissipation●:				
Peak (forward or reverse) for 10 μs duration, max. reverse gate bias = –35 V	P_{GM}	25	25	W
Temperature Range■:				
Storage	T_{stg}	–40 to 150		°C
Operating (case)	T_C	–40 to 80		°C

*Protection against transients above this value must be provided. Transients generated by arcing may persist for as long as 10 cycles.

●Any product of gate current and gate voltage which results in a gate power less than the maximum is permitted.

■Temperature measurement point is shown on the DIMENSIONAL OUTLINE.

ELECTRICAL CHARACTERISTICS, *At Maximum Ratings and at Indicated Case Temperature (T_C)*

SILICON CONTROLLED RECTIFIERS

CHARACTERISTIC	SYMBOL	LIMITS 40888 TYP.	40888 MAX.	40889 TYP.	40889 MAX.	UNITS
Peak Forward Off-State Current: Gate open, V_{DO} = Rated V_{DROM}, T_C = 85°C	I_{DOM}	0.5	1.5	0.5	1.5	mA
Instantaneous On-State Voltage: i_T = 20 A, T_C = 25°C	v_T	2.2	3	2.2	3	V
DC Gate Trigger Current: T_C = 25°C	I_{GT}	15	40	15	45	mA
DC Gate Trigger Voltage: T_C = 25°C	V_{GT}	1.8	4	1.8	4	V
Critical Rate-of Rise of Off-State Voltage: T_C = 70°C	dv/dt	700 (MIN.)▲		700 (MIN.)▲		V/μs
Circuit-Commutated Turn-Off Time†: T_C = 70°C, Minimum negative bias during turn-off time = –20 V (40888) and –2.5 V (40889)						
Rate of Reapplied Voltage (dv/dt) = 175 V/μs	t_q	–	2.4	–	–	μs
Rate of Reapplied Voltage (dv/dt) = 400 V/μs		–	–	–	4.2	μs
Thermal Resistance: Junction-to-Case	$R_{\theta JC}$	–	4	–	4	°C/W

▲ Up to 500 V max. See Fig. 3.

† This parameter, the sum of reverse recovery time and gate recovery time, is measured from the zero crossing of current to the start of the reapplied voltage. Knowledge of the current, the reapplied voltage, and the case temperature is necessary when measuring t_q. In the worst conditions (high line, zero-beam, off-frequency, minimum auxiliary load, etc.), turn-off time must not fall below the given values. Turn-off time increases with temperature; therefore, case temperature must not exceed 70°C. See Figs. 2 & 3.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

SILICON RECTIFIERS

		TRACE 40890	COMMUTATING 40891	CLAMP 40892	
REVERSE VOLTAGE**:					
Non-repetitive peak●●	V_{RSM}	750	700	700	V
Repetitive peak	V_{RRM}	800	800	800	V
FORWARD CURRENT:					
RMS	$I_{F(RMS)}$	3■■	3■■	1**	A
Peak-surge (non-repetitive)●●	I_{FSM}	70	70	30	A
Peak (repetitive)	I_{FRM}	7	12	0.5	A
TEMPERATURE RANGE:					
Storage	T_{stg}		–30 to 150		°C
Operating (Case)	T_C		–30 to 80		°C
LEAD TEMPERATURE▲▲:					
For 10 s maximum	T_L		225		°C

** For ambient temperatures up to 45°C.
●● For a maximum of 3 pulses, 10 μs in duration, during any 64 μs period.
■■ Maximum current rating applies only if the rectifier is properly mounted to maintain junction temperature below 150°C. See Fig. 4.
▲▲ At distances no closer to rectifier body than points A and B on outline drawing.

ELECTRICAL CHARACTERISTICS
SILICON RECTIFIERS

CHARACTERISTIC	SYMBOL	MAXIMUM LIMITS 40890 40891	40842	UNITS
Reverse Current: Static For V_{RRM} = max. rated value, I_F = 0, T_C = 25°C For V_R = 500 V, T_C = 100 °C	I_{RM}	10 250	– –	μA
Instantaneous Forward Voltage Drop: At I_F = 4 A, T_A = 75°C	v_F	1.4	1.5	V
Reverse-Recovery Time: I_{FM} = 3.14 A, ½ sinewave, –di/dt = – 10 A/μs, pulse duration = 0.94 μs, T_C = 25°C	t_{rr}	0.5	0.7	μs

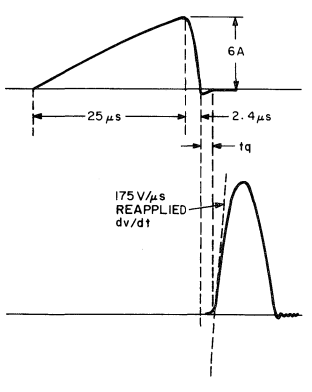


Fig.2—Circuit-commutated turn-off in the trace SCR 40888.

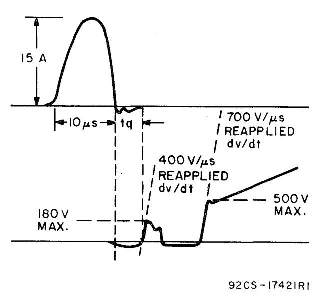
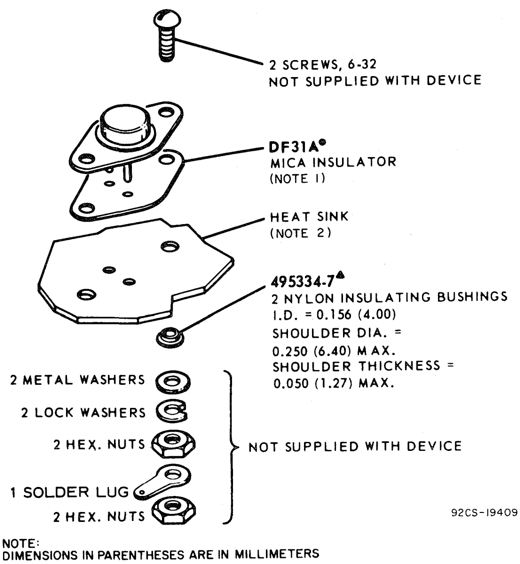


Fig.3—Circuit-commutated turn-off time in the commutating SCR 40889.

MOUNTING SCR's AND RECTIFIERS

The SCR's and rectifiers can be operated at full current only if they have adequate heat sinking. The procedure illustrated in Fig. 4 should be used when mounting the SCR's. A single aluminum plate made as shown in Fig. 5 will provide adequate heat sinking for trace and commutating rectifiers. Lip punching of the chassis at one end of the clamp plate, makes it possible to mount the rectifier using only one screw.

RCA 40888, 40889 fit socket PTS-4 (United International Dynamics Corp., 2029 Taft St., Hollywood, Fla.), or equivalent.



NOTE 1: 0.002 inch (0.51 mm) thick mica or anodized aluminum insulator drilled or punched with burrs removed.

NOTE 2: Remove burrs from chassis holes.

● Available from RCA Distributors as Part No. DF31A. 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.

▲ Available from RCA Distributors as Part No. 495334-7. Also available from Contour Plastics, Minneapolis, Minn. and other suppliers of similar components.

Fig.4—Suggested hardware and mounting arrangement for SCR's 40888 & 40889.

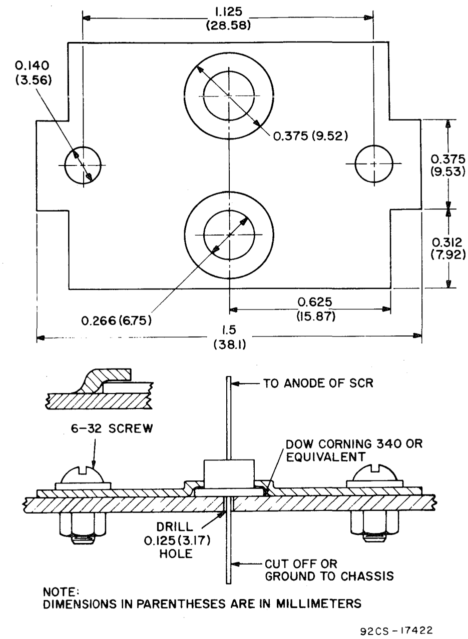
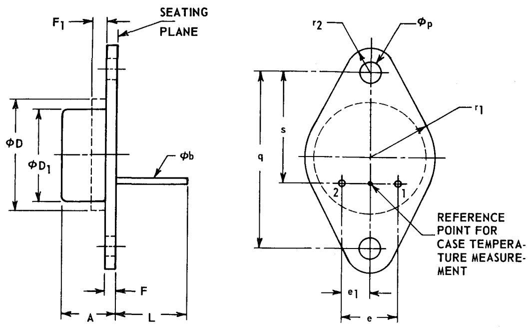


Fig.5—Suggested clamp plate and mounting arrangement for rectifiers 40890 & 40891.

DIMENSIONAL OUTLINE (JEDEC TO-66)
40888, 40889



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	

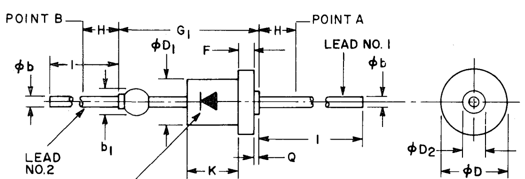
NOTES:
1. The outline contour is optional within zone defined by ϕD and F_1.
2. Dimensions does not include seating flanges.

92SS-3738

TERMINAL CONNECTIONS

Pin 1 - Gate
Pin 2 - Cathode
Mounting Flange, Case - Anode

DIMENSIONAL OUTLINE (JEDEC DO-1)
40890, 40891, 40892



POLARITY SYMBOL INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW. THIS POLARITY IS OPPOSITE TO RCA POWER SUPPLY RECTIFIERS.

92CS-17423

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
φb	0.027	0.035	0.69	0.89	2
b1		0.125		3.18	1
φD	0.360	0.400	9.14	10.16	
φD1	0.245	0.280	6.22	7.11	
φD2		0.200		5.08	
F		0.075		1.91	
G1		0.725		18.42	
K	0.220	0.260	5.59	6.60	
1	1.000	1.625	25.40	41.28	
Q		0.025		0.64	
H	0.5		12.7		

NOTES:
1. Dimension to allow for pinch or seal deformation anywhere along tubulation (optional).
2. Diameter to be controlled from free end of lead to within 0.188 inch (4.78 mm) from the point of attachment to the body. Within the 0.188 inch (4.78 mm) dimension, the diameter may vary to allow for lead finishes and irregularities.

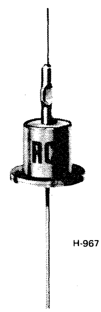
TERMINAL CONNECTIONS

Lead No. 1 & Case – Anode
Lead No. 2 – Cathode

RCA
Solid State
Division

Rectifiers

40266
40267



JEDEC DO-1

Diffused-Junction Silicon Rectifiers

For Industrial and Consumer-Product Applications

Features:

- **High output-current capabilities**
  2 amperes max. for heat-sink operation
  0.5 ampere max. for free-air operation
- **Superior junction characteristics**
- **Hermetically sealed JEDEC DO-1 package**

RCA-40266 and 40267 are hermetically sealed silicon rectifiers of the diffused junction type, intended principally for use in power supplies for transistor high-fidelity amplifiers. They are also useful in other applications requiring large dc supply currents at relatively low voltages.

These rectifiers are designed for use with capacitor-input filters, and have a dc forward current capability of 2 amperes at case temperatures up to 105°C, and of 500 milliamperes at free-air temperatures up to 75°C. They differ only in their Peak Reverse Voltage ratings (100 volts max. for RCA-40266; 200 volts max. for RCA-40267).

The 40266 and 40267 feature the same superior junction characteristics as the industry-proved, extensively-used RCA-1N1763 and 1N1764 — characteristics made possible by RCA's special, precisely-controlled diffusion technique. They also utilize the same welded, hermetically sealed, axial-lead package (JEDEC DO-1) for protection against moisture and contamination.

RECTIFIER SERVICE, MAXIMUM RATINGS, *absolute maximum values*
For supply frequency of 60 cps and with capacitor-input filter

		40266	40267	
PEAK REVERSE VOLTAGE	PRV	100	200	V
RMS SUPPLY VOLTAGE	V_{RMS}	35	70	V
FORWARD CURRENT:				
At case temperatures up to 105°C:				
DC	I_F	2	2	A
PEAK REPETITIVE	i_{PR}	10	10	A
SURGE*	i_S	35	35	A
At case temperatures above 105°C		See Fig. 1		
At free-air temperatures up to 75°C:				
DC	I_F	500	500	mA
PEAK REPETITIVE	i_{PR}	5	5	A
SURGE*	i_S	35	35	A
At free-air temperatures above 75°C		See Fig. 2		
TEMPERATURE RANGE:				
Storage		-65 to +150		°C
Operating:				
Free-air		-65 to +110		°C
Case		-65 to +135		°C
LEAD TEMPERATURE (During Soldering):				
At distances not closer to rectifier body than indicated by points A and B on outline drawing, for 10 seconds max.		225	225	°C
ELECTRICAL CHARACTERISTICS, at a free-air temperature of 25°C:				
Maximum instantaneous forward voltage at instantaneous forward current of 15 amperes		3	3	V
Maximum reverse current:				
At a peak reverse voltage of 100 volts		10	–	µs
At a peak reverse voltage of 200 volts		–	10	µs

*For a "turn-on" transient of 2 milliseconds duration

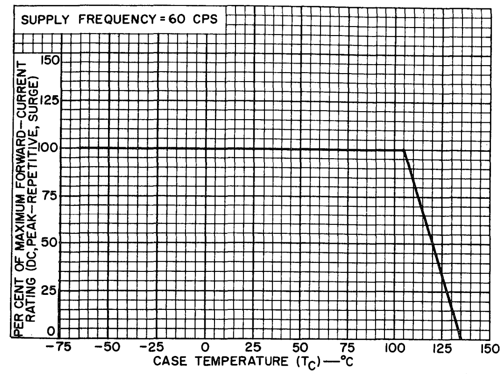


Fig.1— Rating chart for both types.

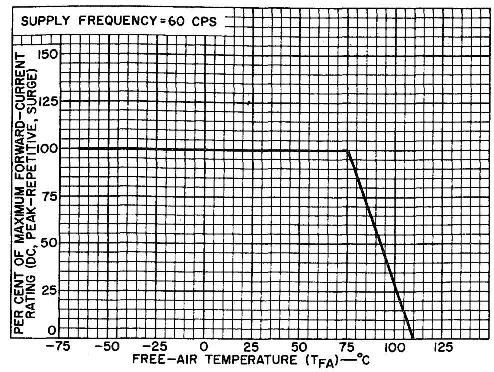


Fig.2— Rating chart for both types.

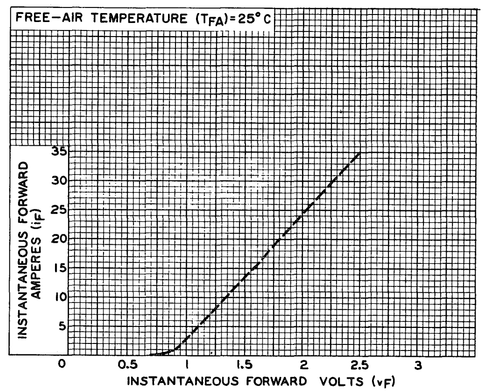


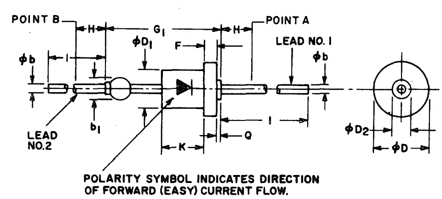
Fig.3— Typical forward voltage and current characteristic for both types.

TERMINAL CONNECTIONS

Lead No. 1 & Case – Cathode
Lead No. 2 – Anode

DIMENSIONAL OUTLINE

JEDEC DO-1



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕb	0.027	0.035	0.69	0.89	2
b_1		0.125		3.18	1
ϕD	0.360	0.400	9.14	10.16	
ϕD_1	0.245	0.280	6.22	7.11	
ϕD_2		0.200		5.08	
F		0.075		1.91	
G_1		0.725		18.42	
K	0.220	0.260	5.59	6.60	
1	1.000	1.625	25.40	41.28	
Q		0.025		0.64	
H	0.5		12.7		

NOTES:

1. Dimension to allow for pinch or seal deformation anywhere along tubulation (optional).
2. Diameter to be controlled from free end of lead to within 0.188 inch (4.78 mm) from the point of attachment to the body. Within the 0.188 inch (4.78 mm) dimension, the diameter may vary to allow for lead finishes and irregularities.

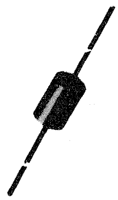
RCA

Solid State Division

Rectifiers

40808 40809

JEDEC DO-26



L-391

40808
40809

0.5-A Controlled-Avalanche Rectifiers

600–& 800–V Silicon Types for Industrial & Consumer-Product Applications

Features:

- **Continuous avalanche power dissipation of 0.5 W at 25°C.**
- **Specified range of avalanche breakdown voltage**
- **High peak-reverse voltage ratings**
- **For operation at ambient temperatures up to +175°C**

RCA-40808 and 40809* are controlled avalanche-type silicon rectifiers in the DO-26 axial-lead package. These hermetically-sealed devices differ only in their voltage ratings; both types are intended for general-purpose applications.

Their bulk-avalanche breakdown characteristics make the 40808 and 40809 particularly suitable for applications in which protection against reverse voltage transients is required.

* Formerly RCA developmental types TA7443 and TA7444, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40808	40809	
REVERSE VOLTAGE:				
REPETITIVE PEAK	V_{RM}(rep)	600	800	V
WORKING PEAK	V_{RM}(wkg)	600	800	V
DC BLOCKING	V_R	600	800	V
NON-REPETITIVE PEAK	V_{RM}(nonrep)	700	900	V
RMS	V_r	420	560	V
FORWARD CURRENT:				
AVERAGE RECTIFIED	I_O	0.5	0.5	A
Single-phase, resistive load, T_A = 75°C				
PEAK SURGE	I_{FM}(surge)			
For one-half cycle of applied voltage, 50 Hz (10 μs)		32	32	A
60 Hz (8.3 μs)		35	35	A
400 Hz (1.25 ms), T_J = 100°C		70	70	A
For other durations		See Fig. 6.		
REVERSE POWER DISSIPATION:				
CONTINUOUS	P_R	0.5	0.5	W
PULSE (Square), Avalanche	p_R			
For pulse duration of 10 μs		700	700	W
For other durations		See Fig. 10.		
TEMPERATURE RANGE:				
Storage & Operating		-65 to +175		°C
LEAD TEMPERATURE* (During Soldering):				
For 10 s Max.		255	255	°C

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	LIMITS 40808 MIN.	LIMITS 40808 TYP.	LIMITS 40808 MAX.	LIMITS 40809 MIN.	LIMITS 40809 TYP.	LIMITS 40809 MAX.	UNITS
Reverse Current:								
Static	I_R							mA
For V_R = rated value & T_J = 25°C		–	–	0.005	–	–	0.005	
For V_R = rated value & T_J = 150°C		–	–	0.2	–	–	0.2	
Dynamic Full-cycle average, for V_{RM}(rep) = rated value, I_o = 0.5 A, T_A = 75°C	$I_{R(AV)}$	–	–	0.15	–	–	0.15	mA
Instantaneous Forward-Voltage Drop: At i_F = 1 A, T_J = 25°C	v_F	–	1.0	1.2	–	1.0	1.2	V
Avalanche Voltage: At 10 μA [$i_{(BR)R}$] T_A = 25°C	$v_{(BR)R}$	700	–	–	900	–	–	V
At 500 μA (See Fig. 1.)		–	–	1100	–	–	1300	
Avalanche Voltage Shift: Between 10 and 500 μA (See Fig. 1 & 3.)		–	50	100	–	50	100	V
Reverse Recovery Time: At I_F = 20 A, pulse duration = 3.1 μs, T_A = 25°C (See Fig. 4; for other conditions, see Fig. 5.)	t_{rr}	–	1.4	–	–	1.4	–	μs
Thermal Impedance: (Junction-to-Heat Sink)								
Steady-State:	$R_{\theta JHS}$							°C/W
Heat-sink mounting with ½-inch leads		–	71	–	–	71	–	
For other mounting methods and other lead lengths		See Fig. 8.						
Transient:	$Z_{\theta JHS(t)}$							
Heat-sink mounting with 0 to 1-¼-inch leads, and with a pulse duration of 0.3 s		–	30	–	–	30	–	
For other pulse durations		See Fig. 7.						

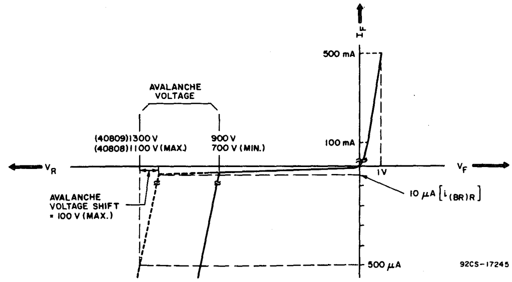


Fig. 1 - Characteristics for types 40808 and 40809 showing avalanche-breakdown regions.

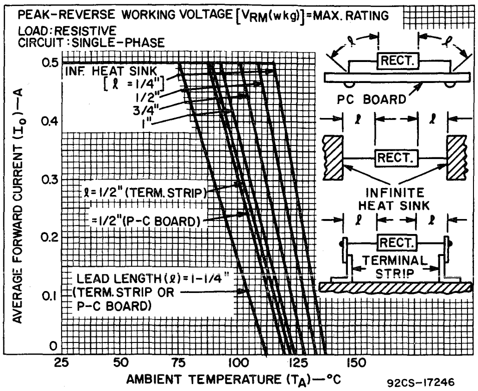


Fig. 2 - Average-forward-current derating curves for types 40808 & 40809 for three different mounting arrangements & several lead lengths.

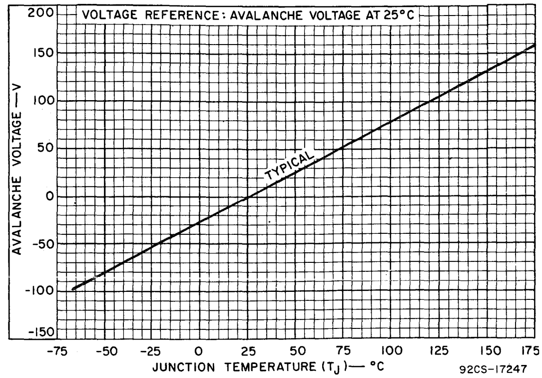


Fig. 3 - Avalanche-voltage shift with junction temperature for types 40808 & 40809.

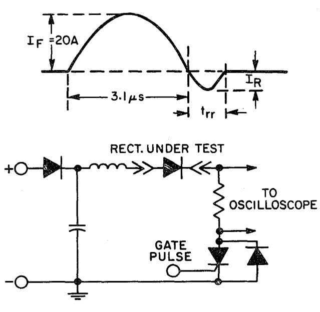


Fig. 4 - Oscilloscope display & test circuit for measurement of reverse-recovery time.

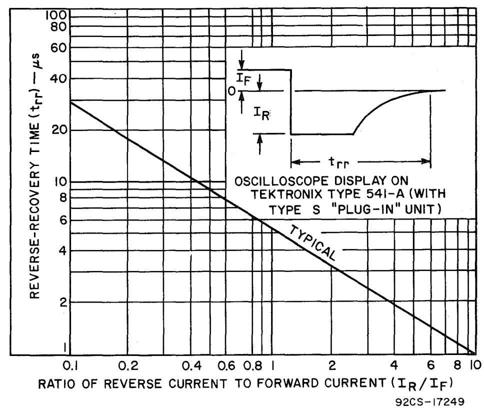


Fig. 5 - Variation of reverse-recovery time with ratio of reverse-to-forward current for types 40808 & 40809.

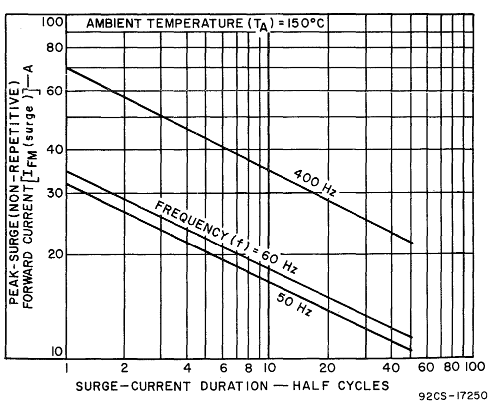


Fig. 6 - Peak-surge (non-repetitive) forward current vs. surge-current duration for types 40808 & 40809.

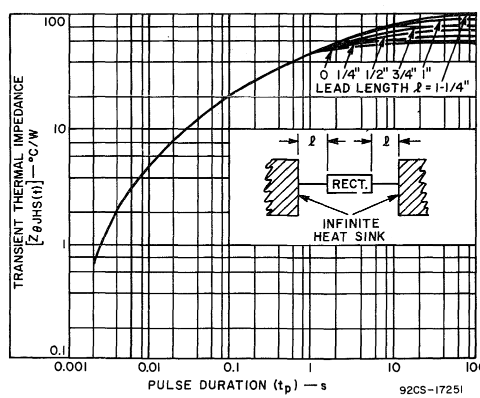


Fig. 7 - Variation of transient thermal impedance with pulse duration for several lead lengths for types 40808 & 40809.

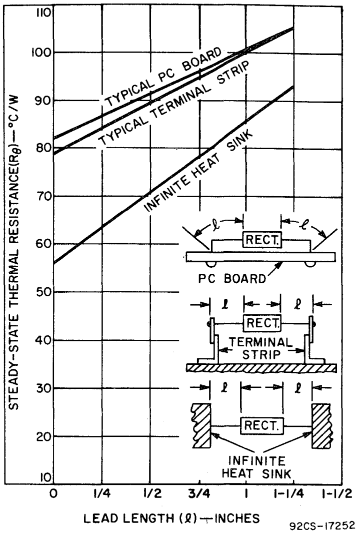


Fig. 8 - Variation of steady-state thermal resistance with lead length (for different mounting methods) for types 40808 & 40809.

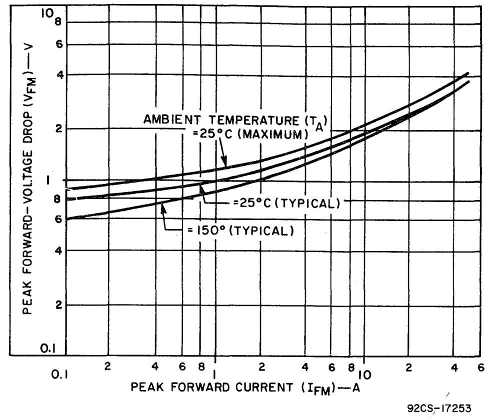


Fig. 9 - Peak forward-voltage drop vs. peak forward current for types 40808 & 40809.

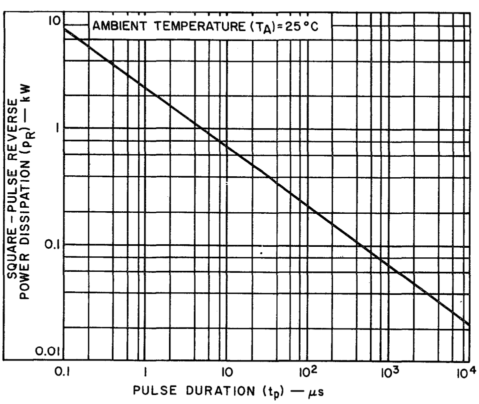
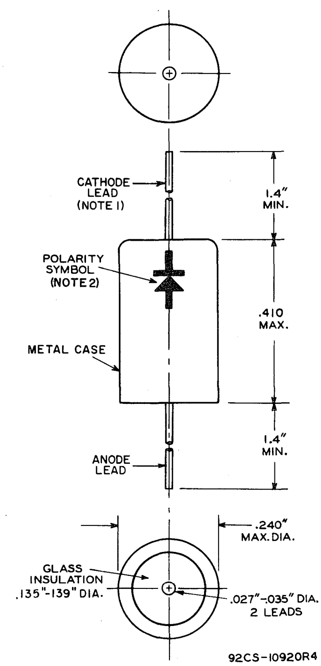


Fig. 10 - Reverse-power dissipation vs. pulse duration for types 40808 & 40809.

DIMENSIONAL OUTLINE FOR TYPES 40808 & 40809 (JEDEC DO-26)



NOTE 1: CONNECTED TO METAL CASE.
NOTE 2: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

RCA Solid State Division

Rectifiers

1N1612 1N1613 1N1614 1N1615 1N1616

Types 1N1612 through 1N1616 are intended for use in generator-type power supplies for mobile equipment; in dc-to-dc converters, battery chargers, and machine-tool controls; in power supplies for aircraft, marine, and missile equipment, for dc motors, transmitters, rf generators, welding equipment, and electroplating systems; in dc-blocking service, magnetic amplifiers, and in a wide variety of other applications in military and industrial equipment.

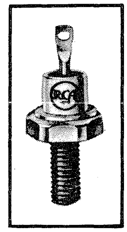
The 1N1612 through 1N1616 utilize a special copper-alloy mounting stud which can withstand an installation torque of 25-inch pounds — a feature of primary importance in applications critical as to shock and vibration. In addition, these rectifiers are conservatively rated to permit continuous operation at maximum ratings in applications requiring high reliability under severe operating conditions.

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings *for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load*

	1N1612	1N1613	1N1614	1N1615	1N1616
PEAK REVERSE VOLTS.	50	100	200	400	600
RMS SUPPLY VOLTS.	35	70	140	280	420
DC BLOCKING VOLTS.	50	100	200	400	600
AVERAGE FORWARD AMPERES:					
At 135° C case temperature .	5	5	5	5	5
At other case temperatures.	← See Rating Chart →				
PEAK RECURRENT AMPERES. . . .	15	15	15	15	15
CASE TEMPERATURE RANGE:					
Operating and Storage. . .	← -65 to +175° C →				

Stud-Mounted Types for Industrial and Military Power Supplies



JEDEC DO-4

- **available in reverse-polarity versions:** 1N1612-R, 1N1613-R, 1N1614-R, 1N1615-R, 1N1616-R
- extra-high-strength copper-alloy mounting stud — withstands installation torque of 25 inch-pounds
- designed to meet stringent military mechanical and environmental specifications
- diffused-junction process — exceptional uniformity and stability of characteristics
- low thermal resistance
- welded construction
- hermetic seals
- low leakage current
- low forward voltage drop
- JEDEC DO-4 outline
- high output current:
  up to 14 amperes — 6 rectifiers in 3-phase, full-wave bridge circuit
  up to 10 amperes — 4 rectifiers in single-phase full-wave bridge circuit

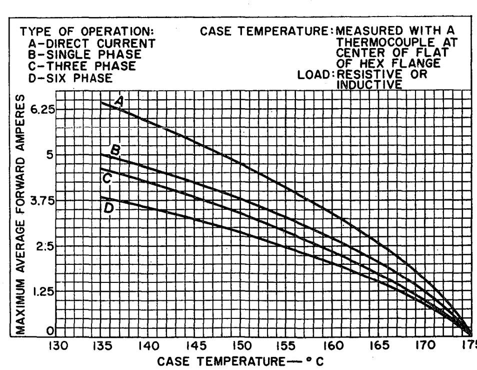
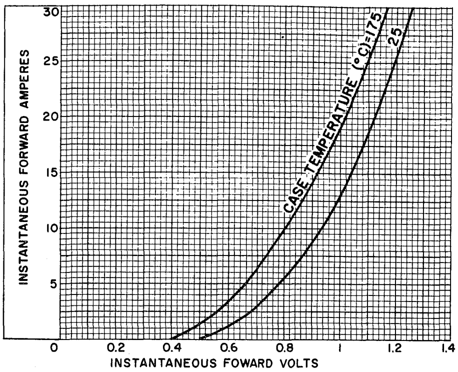
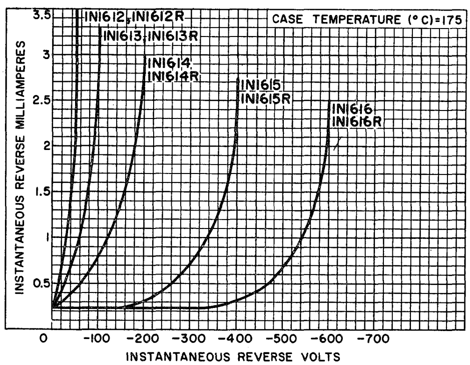


Fig.1 - Rating Chart for all Types and corresponding reverse-polarity versions.



92CS-11296

Fig. 2 - Typical Forward Characteristics for all Types and corresponding reverse-polarity versions.



92CS-11297

Fig. 3 - Typical Reverse Characteristics for all Types and corresponding reverse-polarity versions.

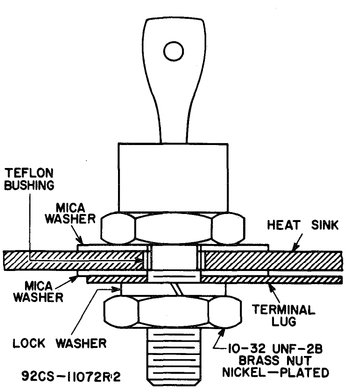


Fig. 4 - Suggested Mounting Arrangement.

Characteristics:	1N1612	1N1613	1N1614	1N1615	1N1616
Max. Forward Voltage Drop (Volts): At 25° C case temperature and dc forward current = 10 amperes.	1.5	1.5	1.5	1.5	1.5
Max. Reverse Current (Ma):					
Dynamic[a] . . .	1	1	1	1	1
Static[b]. . . .	0.01	0.01	0.01	0.01	0.01

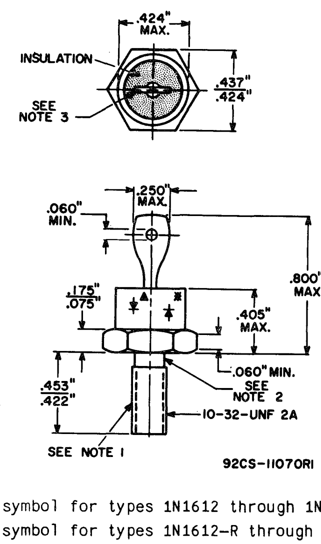
[a] Average value for one complete cycle, at maximum peak reverse voltage, forward amperes = 5, and case temperature (°C) = 150.

[b] DC value, at maximum peak reverse voltage, and case temperature (°C) = 25.

OPERATING CONSIDERATIONS

Because these rectifiers may operate at voltages which are dangerous, care should be taken in the design of equipment to prevent personnel from coming in contact with the rectifier.

DIMENSIONAL OUTLINE (JEDEC DO-4)



▲ Polarity symbol for types 1N1612 through 1N1616.

* Polarity symbol for types 1N1612-R through 1N1616-R.

Note 1: The recommended installation torque is 15 to 20 inch-pounds applied to a 10/32 UNF-2B hex nut assembled on stud thread. The applied torque during installation should not exceed 25 inch-pounds.

Note 2: Diameter of unthreaded portion: 0.189" max., 0.163" min.

Note 3: Angular orientation of this terminal is undefined.

Note 4: This device may be operated in any position.

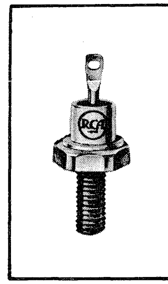
RCA
Solid State Division

Rectifiers

1N1341B 1N1342B 1N1344B 1N1345B 1N1346B 1N1347B 1N1348B

These silicon rectifiers are intended for use in generator-type power supplies for mobile equipment; in dc-to-dc converters, power supplies for dc motors, transmitters, rf generators, welding equipment, and electroplating systems; in dc-blocking service, magnetic amplifiers, and in a wide variety of other applications in industrial equipment.

Stud-Mounted Types for Industrial Power Supplies



JEDEC DO-4

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings *for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load*

	1N1341B	1N1342B	1N1344B	1N1345B	1N1346B	1N1347B	1N1348B
PEAK REVERSE VOLTS	50	100	200	300	400	500	600
TRANSIENT REVERSE VOLTS, NON-REPETITIVE (5-msec max. duration and case temperature range of 0 to 200° C.	100	200	350	450	600	700	800
RMS SUPPLY VOLTS	35	70	140	212	284	355	424
DC BLOCKING VOLTS	50	100	200	300	400	500	600
AVERAGE FORWARD AMPERES: At 150° C case temperature	6	6	6	6	6	6	6
At other case temperatures	← See Fig.1 →						
PEAK RECURRENT AMPERES	25	25	25	25	25	25	25
PEAK SURGE AMPERES:[a] One-half cycle, sine wave	160	160	160	160	160	160	160
CASE-TEMPERATURE RANGE: Operating and Storage	← -65 to +200° C →						
Characteristics:							
Max. Forward Voltage Drop[b] (Volts)	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Max. Reverse Current (Ma.): Dynamic[b]	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Static[c]	0.004	0.004	0.004	0.004	0.004	0.004	0.004

[a] Superimposed on device operating within the maximum voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Average value for one complete cycle at case temperature of 150° C and at maximum rated voltage and average forward current.

[c] DC value, at maximum peak reverse voltage, and case temperature (°C) = 25.

- Available in reverse-polarity versions: 1N1341RB, 1N1342RB, 1N1344RB, 1N1345RB, 1N1346RB, 1N1347RB, 1N1348RB
- Designed to meet stringent mechanical and environmental specifications
- Diffused-junction process — exceptional uniformity and stability of characteristics
- Hermetic seals
- Welded construction
- Low thermal resistance
- Low leakage current
- Low forward voltage drop
- JEDEC DO-4 outline
- High output current:
  up to 15 amperes — 6 rectifiers in 3-phase, full-wave bridge circuit
  up to 12 amperes — 4 rectifiers in single-phase full-wave bridge circuit

RATING CHART

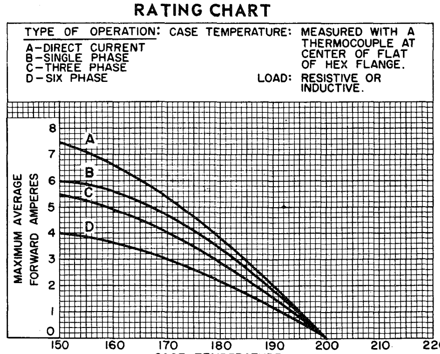
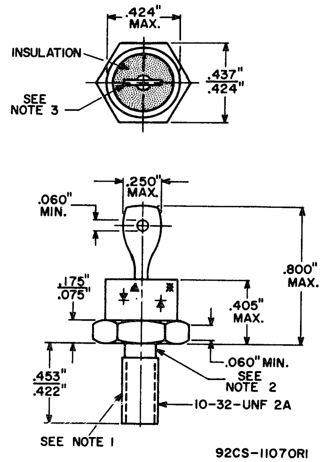


Fig.1

DIMENSIONAL OUTLINE
JEDEC DO-4

▲ Polarity symbol for types 1N1341B, 1N1342B, 1N1344B, 1N1345B, 1N1346B, 1N1347B, and 1N1348B



*Polarity symbol for types 1N1341RB, 1N1342RB, 1N1344RB, 1N1345RB, 1N1346RB, 1N1347RB, and 1N1348RB

Note 1: Normal installation torque is 15 to 20 inch-pounds applied to a 10/32 UNF-2B hex nut assembled on stud thread. The applied torque during installation should not exceed 25 inch-pounds.

Note 2: Diameter of unthreaded portion: 0.189" max., 0.163" min.

Note 3: Angular orientation of this terminal is undefined.

Note 4: The device may be operated in any position.

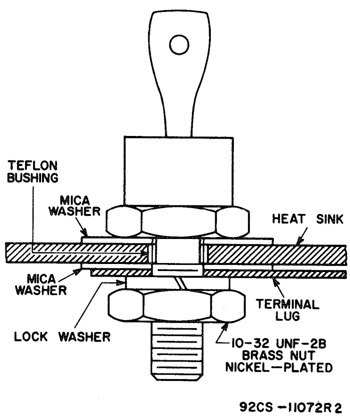


Fig. 2 - Suggested Mounting Arrangement. (Mounting components of the type shown are furnished with each rectifier cell. The increase in thermal resistance with these mounting components is approximately 3 °C/watt.)

RCA
Solid State
Division

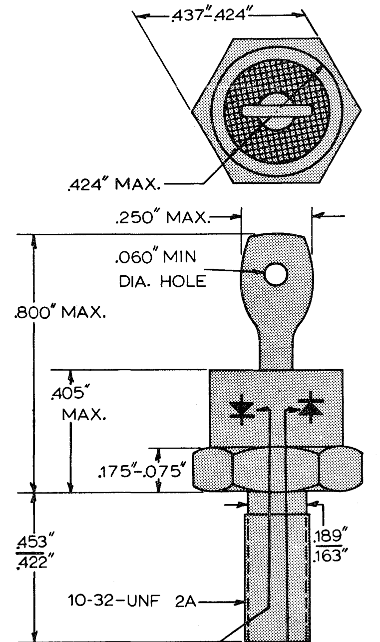
Rectifiers

40108 40109 40110 40111 40112 40113 40114 40115

Stud-Mounted

Types for Industrial

Power Supplies



* For reverse polarity versions, use the suffix—"R" after number.

DESCRIPTION

These RCA diffused junction silicon rectifiers are for use in industrial applications; the process and the construction provide exceptional uniformity and stability of characteristics. The closure is welded.

NOTE: Mounting nut, and lock-washer included with each unit. Insulating hardware and lug can be supplied if requested.

HALF-WAVE RECTIFIER SERVICE

60 cp/s supply, Single phase operation; with Resistive or Inductive Load.

	40108	40109	40110	40111	40112	40113	40114	40115	UNITS
Peak Reverse Volts - PRV	50	100	200	300	400	500	600	800	volts
DC Blocking - Volts	50	100	200	300	400	500	600	800	volts
Aver. Fwd. Current 150°T_C – I_F	← 10 →								amps.
Peak Recurrent Current	← 40 →								amps.
Peak Surge Current @ 150°C T_C	← 140 →								amps.

	40108	40109	40110	40111	40112	40113	40114	40115	UNITS
Max. Reverse Current									
Static @ ma 25°C T_C	← .075 →								ma
Dynamic @ ma 150°C T_C	2.0	2.0	1.5	1.5	1.0	.85	.75	.65	ma
Max. Voltage Drop Avg.	← .60 →								volt
Max. Operating Temperature	← 175 →								°C

RCA

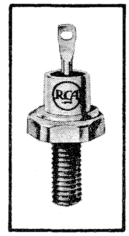
Solid State Division

Rectifiers

1N1199A 1N1200A 1N1202A 1N1203A 1N1204A 1N1205A 1N1206A

Used in generator-type power supplies for mobile equipment; in dc-to-dc converters, battery chargers, and machine-tool controls; in power supplies for aircraft, marine, and missile equipment, for dc motors, transmitters, rf generators, welding equipment, and electroplating systems; in dc-blocking service, and in a wide variety of other applications in military and industrial equipment.

Stud-Mounted Types for Industrial and Military Power Supplies



JEDEC DO-4

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings *for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load*

	1N1199-A	1N1200-A	1N1202-A	1N1203-A	1N1204-A	1N1205-A	1N1206-A
PEAK REVERSE VOLTS	50	100	200	300	400	500	600
TRANSIENT REVERSE VOLTS, NON-REPETITIVE (5-msec max. duration and case temperature range of 0 to 200° C)	100	200	350	450	600	700	800
RMS SUPPLY VOLTS	35	70	140	212	284	355	424
DC BLOCKING VOLTS	50	100	200	300	400	500	600
AVERAGE FORWARD AMPERES:							
At 150° C case temperature	12	12	12	12	12	12	12
At other case temperatures	← See Fig. 1 →						
PEAK RECURRENT AMPERES	50	50	50	50	50	50	50
PEAK SURGE AMPERES:♦							
One-half cycle, sine wave	240	240	240	240	240	240	240
For one or more than one cycle	← See Fig. 4 →						
CASE-TEMPERATURE RANGE: Operating and Storage	← -65 to +200° C →						
Characteristics:							
Max. Forward Voltage Drop▲ (Volts)	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Max. Reverse Current (Ma.):							
Dynamic▲	3	2.5	2	1.75	1.5	1.25	1
Static●	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Max. Thermal Resistance, Junction-to-Case	← 2°C/Watt →						

- available in reverse-polarity versions: 1N1199-RA, 1N1200-RA, 1N1202-RA, 1N1203-RA, 1N1204-RA, 1N1205-RA, 1N1206-RA
- designed to meet stringent military mechanical and environmental specifications
- diffused-junction process — exceptional uniformity and stability of characteristics
- hermetic seals
- welded construction
- low thermal resistance
- low leakage current
- low forward voltage drop
- JEDEC DO-4 outline
- high output current:
  - up to 30 amperes — 6 rectifiers in 3-phase, full-wave bridge circuit
  - up to 24 amperes — 4 rectifiers in single-phase full-wave bridge circuit

♦ Superimposed on device operating within the maximum voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

▲ Average value for one complete cycle at case temperature of 150° C and at maximum rated voltage and average forward current.

● DC value, at maximum peak reverse voltage, and case temperature (°C) = 25.

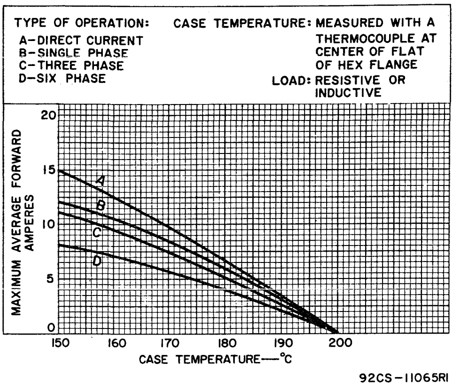


Fig. 1 - Rating Chart for all Types.

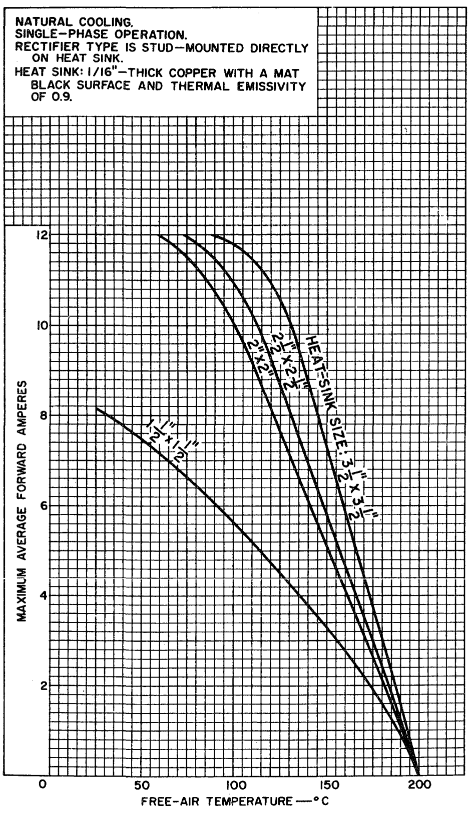


Fig. 2 - Operation Guidance Chart for all Types and corresponding reverse-polarity versions.

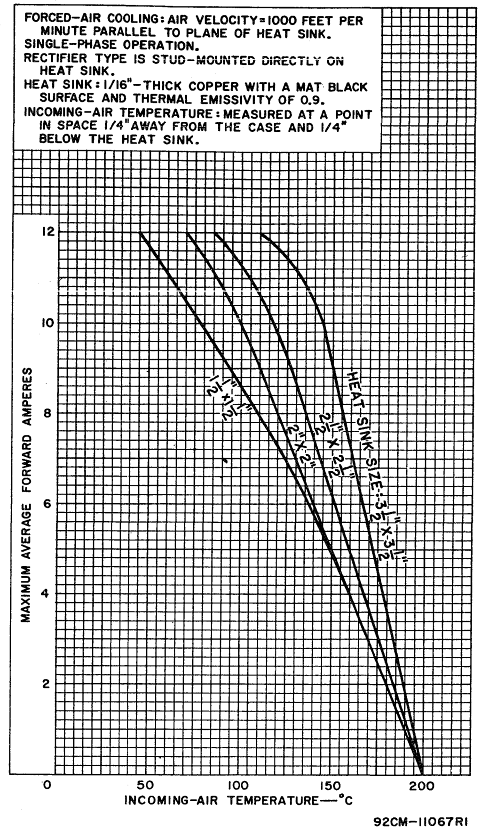


Fig. 3 - Operation Guidance Chart for all Types and corresponding reverse-polarity versions.

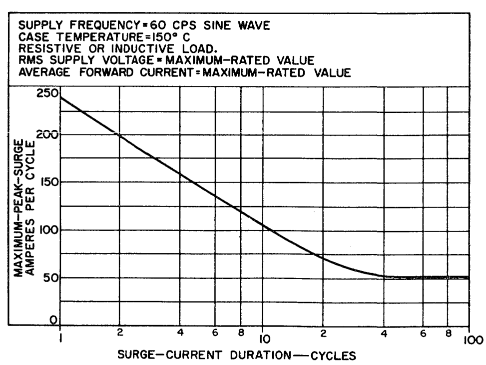


Fig. 4 - Peak-Surge-Current Rating Chart for all Types and corresponding reverse-polarity versions.

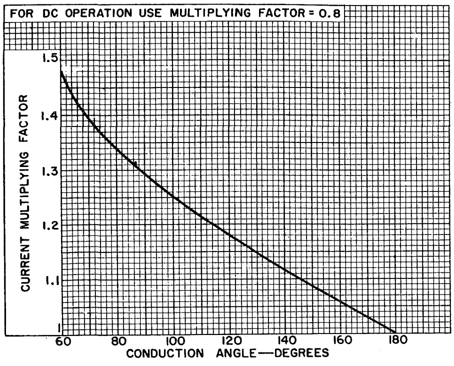


Fig.5 - Current-Multiplying-Factor Chart for Polyphase and DC operation for all Types and corresponding reverse-polarity versions.

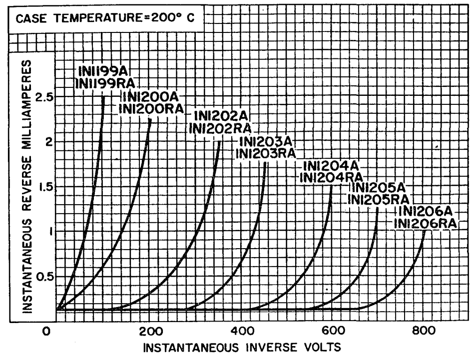


Fig.7 - Typical Reverse Characteristics for all Types and corresponding reverse-polarity versions.

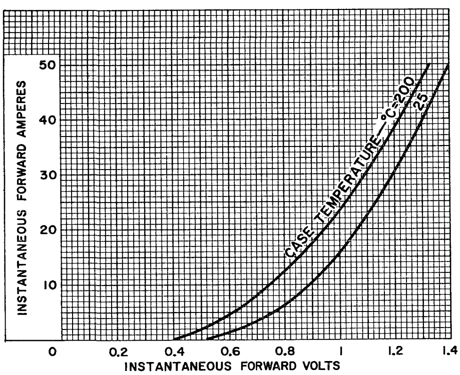


Fig.6 - Typical Forward Characteristics for all Types and corresponding reverse-polarity versions.

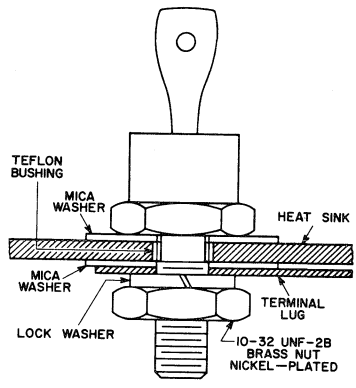


Fig.8 - Suggested Mounting Arrangement. (Mounting components of the type shown are furnished with each rectifier cell. The increase in thermal resistance with these mounting components is approximately 3 °C/watt.)

OPERATING CONSIDERATIONS

Because these rectifiers may operate at voltages which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the rectifier.

The recommended installation torque is 15 to 20 inch-pounds applied to a 10/32 UNF-2B hex nut assembled on stud thread.

The applied torque during installation should not exceed 25 inch-pounds.

Use of Rating Charts and Operation Guidance Chart.

Fig.5 is used in conjunction with Fig.2 and Fig.3 to determine maximum average forward amperes per rectifier cell for polyphase operation and dc operation. The procedure for the use of Fig.5 is as follows:

Step 1: From Fig.5 determine the current-multiplying factor for the applicable conduction angle. (For dc operation use current multiplying factor of 0.8.)

Step 2: Divide the required load current in amperes by the number of rectifier circuit branches — as shown in the following Table — to determine average forward amperes per rectifier cell.

Type of Operation	No. of Circuit Branches
Single-Phase, Full-Wave:	
Center-Tapped	2
Bridge	2
Three-Phase:	
Wye	3
Double Wye	6
Bridge	3
Six-Phase Star	6

Step 3: Multiply average forward amperes established in Step 2 by the current-multiplying factor established in Step 1 to determine adjusted average forward amperes per rectifier cell, for use with Fig.2 or Fig.3.

Step 4: Using the product obtained in Step 3, determine from Fig.2 or Fig.3 either (a) the maximum allowable incoming-air temperature or ambient temperature for a given heat-sink size, or (b) the minimum heat-sink size for a given incoming-air temperature or ambient temperature.

Example

Conditions:

(a) Three-phase, half-wave (wye) operation, conduction angle = 120°

(b) Desired output current = 30 amperes

(c) Forced-air cooling; incoming-air temperature = 90° C

Problem:

Determine minimum heat-sink size.

Procedure:

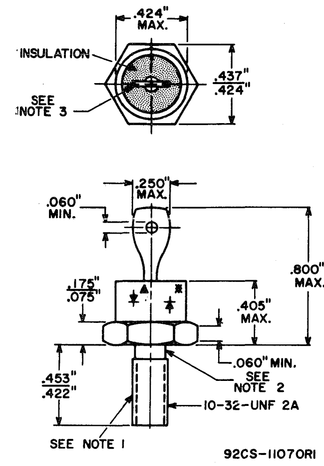
Step 1: From Fig.5, the current multiplying factor for a conduction angle of 120° is 1.18.

Step 2: For three-phase half-wave operation the number of rectifier circuit branches is three. The average forward current through each rectifier cell is, therefore, 30/3, or 10 amperes.

Step 3: Multiplying average forward amperes (10) obtained in Step 2 by the current-multiplying factor (1.18) obtained in Step 1 yields 11.8 adjusted forward amperes.

Step 4: From Fig.3, for forced-air cooling, the minimum heat-sink size for the conditions shown is 2-1/2" x 2-1/2".

DIMENSIONAL OUTLINE JEDEC DO-4



▲ Polarity symbol for types 1N1199-A, 1N1200-A, 1N1202-A, 1N1203-A, 1N1204-A, 1N1205-A, and 1N1206-A.

* Polarity symbol for types 1N1199-RA, 1N1200-RA, 1N1202-RA, 1N1203-RA, 1N1204-RA, 1N1205-RA, and 1N1206-RA.

Note 1: Normal installation torque is 15 to 20 inch-pounds applied to a 10/32 UNF-2B hex nut assembled on stud thread. The applied torque during installation should not exceed 25 inch-pounds.

Note 2: Diameter of unthreaded portion: 0.189" max., 0.163" min.

Note 3: Angular orientation of this terminal is undefined.

Note 4: The device may be operated in any position.

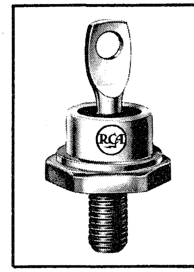
RCA
Solid State
Division

Rectifiers

40208 40209 40210 40211 40212 40213 40214

These RCA silicon rectifiers are designed for a wide variety of uses in heavy-duty power supplies. In industrial applications, they are well suited for use in battery chargers, ac-to-dc converters, welding equipment, power supplies for dc motors, and in generator-type power supplies for portable equipment.

Stud-Mounted Types for Industrial Power Supplies



JEDEC DO-5

FEATURES:

- Hermetic seals
- Low thermal resistance
- Low forward voltage drop
- High output current:
  up to 48 amperes – 6 rectifiers in 3-phase, full-wave bridge circuit
  up to 36 amperes – 4 rectifiers in single-phase, full-wave bridge circuit
- Welded construction
- Low leakage current
- JEDEC DO-5 outline
- Available in reverse-polarity versions: 40208R, 40209R, 40210R, 40211R, 40212R, 40213R, 40214R
- Diffused-junction process – exceptional uniformity and stability of characteristics

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings *for Supply Frequency of 60 Hz, Single-Phase Operation, and with Resistive or Inductive Load*

	40208	40209	40210	40211	40212	40213	40214
Peak reverse volts	50	100	200	300	400	500	600
DC blocking volts	50	100	200	300	400	500	600
Average forward amperes: At 150° C case temperature	18	18	18	18	18	18	18
Peak recurrent amperes	72	72	72	72	72	72	72
Peak surge amperes:[a] One-half cycle sine wave and case temperature = 150° C	250	250	250	250	250	250	250
Maximum operating temperature ($^{\circ}$C)	175	175	175	175	175	175	175

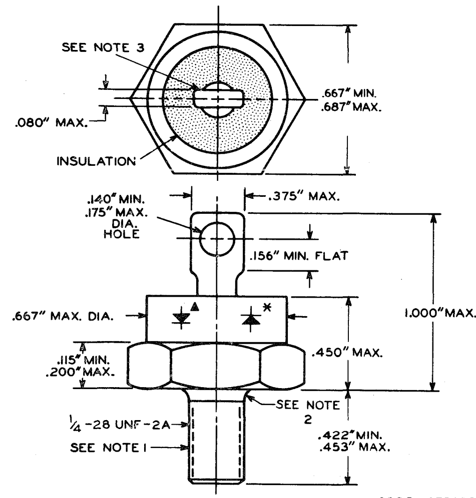
Characteristics							
Maximum forward voltage drop[b] (volts)	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Maximum reverse current (mA): Static[c]	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Dynamic[b]	3.0	3.0	2.5	2.5	2.0	1.75	1.5

[a] Superimposed on device operating within the maximum voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Average value for one complete cycle at case temperature of 150° C and at maximum rated voltage and average forward current.

[c] DC value, at maximum peak reverse voltage, and case temperature ($^{\circ}$C) = 25.

DIMENSIONAL OUTLINE
JEDEC DO-5



Mounting nut and lock-washer included with each unit. Insulating hardware and lug can be supplied if requested.

▲Polarity symbol for types 40208, 40209, 40210, 40211, 40212, 40213, and 40214.

*Polarity symbol for types 40208R, 40209R, 40210R, 40211R, 40212R, 40213R, and 40214R.

Note 1: Must withstand torque of 30 inch-pounds applied to ¼-28 UNF-2B nut assembled on stud thread.

Note 2: Diameter of unthreaded portion: 0.249" maximum, 0.220" minimum.

Note 3: Angular orientation of this terminal undefined.

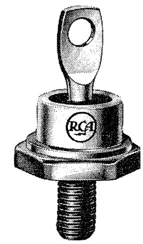
RCA
Solid State
Division

Rectifiers

1N248C 1N249C 1N1196A 1N250C 1N1197A 1N1195A 1N1198A

Applications:
In power supplies for mobile equipment, dc-to-dc converters, battery chargers, dynamic braking systems, aircraft and missile power supplies, high-power transmitter and rf-generator power supplies, machine-tool controls, dc-motor power supplies, and in other heavy-duty industrial and military equipment.

Stud-Mounted Types for Industrial and Military Power Supplies



JEDEC DO-5

- available in reverse-polarity versions: 1N248-RC, 1N249-RC, 1N250-RC, 1N1195-RA, 1N1196-RA, 1N1197-RA, 1N1198-RA
- designed to meet stringent military mechanical and environmental specifications
- diffused-junction process — exceptional uniformity of characteristics
- hermetic seals
- welded construction
- low thermal resistance
- low leakage current
- low forward voltage drop
- JEDEC DO-5 outline
- high output current: up to
  84 amperes — 6 rectifiers in 3-phase, full-wave bridge circuit
  60 amperes — 4 rectifiers in single-phase full-wave bridge circuit

HALF-WAVE RECTIFIER SERVICE

Maximum Ratings:

Absolute-Maximum Values for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load

	1N248-C	1N249-C	1N250-C	1N1195-A	1N1196-A	1N1197-A	1N1198-A
PEAK INVERSE VOLTS	55	110	220	300	400	500	600
RMS SUPPLY VOLTS	39	77	154	212	284	355	424
DC BLOCKING VOLTS	50	100	200	300	400	500	600
FORWARD AMPERES:							
Average DC: At 150° C case temperature	20	20	20	20	20	20	20
At other temperatures	See Rating Chart I						
PEAK RECURRENT AMPERES	90	90	90	90	90	90	90
PEAK SURGE AMPERES:♣ (One-half cycle, sine wave)	350	350	350	350	350	350	350
(For more than one cycle)	See Rating Chart IV						
CASE TEMPERATURE: Operating and Storage	-65 to +175° C						

Characteristics at 150° C Case Temperature

	1N248-C	1N249-C	1N250-C	1N1195-A	1N1196-A	1N1197-A	1N1198-A
Max. Forward Voltage Drop● (Volts)	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Max. Reverse Current● (Ma.)	3.8	3.6	3.4	3.2	2.5	2.2	1.5

♣ Superimposed on device operating within the maximum specified voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal equilibrium conditions.

● At maximum peak inverse voltage, average forward amperes = 20, and averaged over one complete cycle.

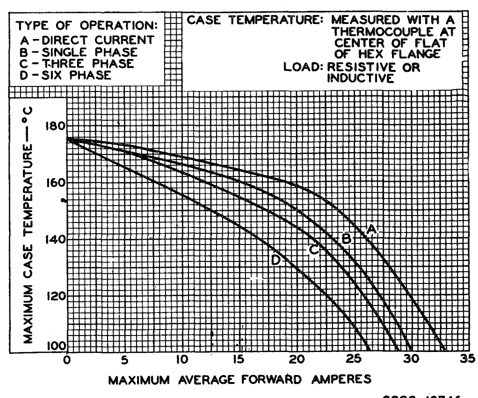
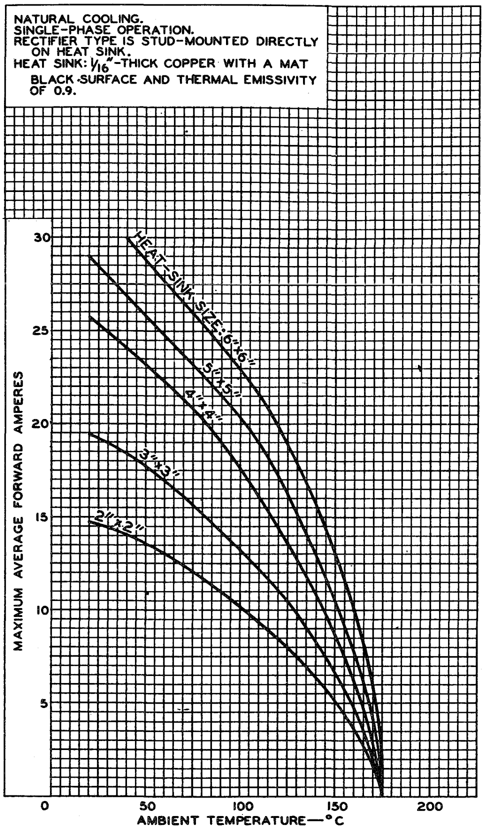
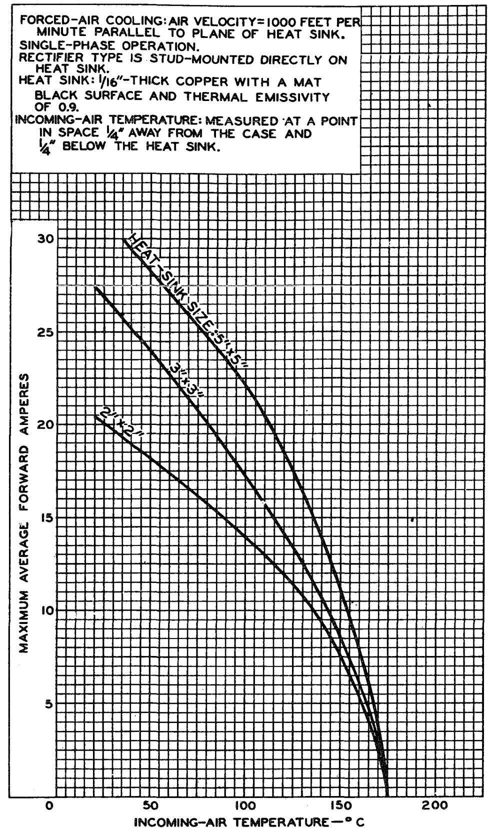


Fig. 1 - Rating Chart 1 for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.



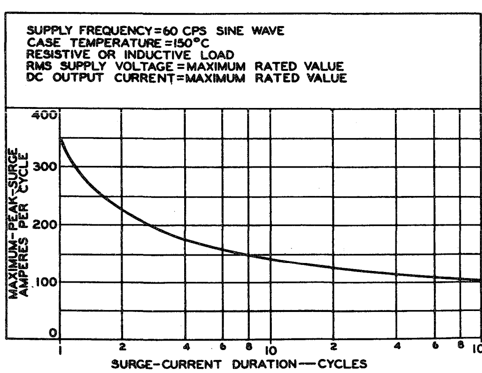
92CM-10741

Fig. 2 - Rating Chart II for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.



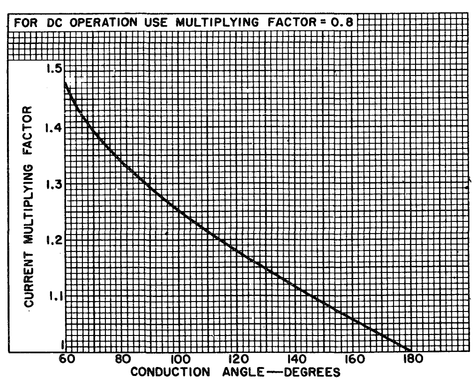
92CM-10745

Fig. 3 - Rating Chart III for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.



92CS-10909

Fig. 4 - Rating Chart IV for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.



92CS-10910

Fig. 5 - Chart V for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.

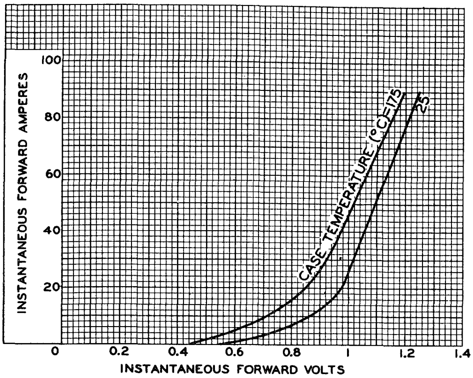


Fig.6 - Typical Forward Characteristics for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.

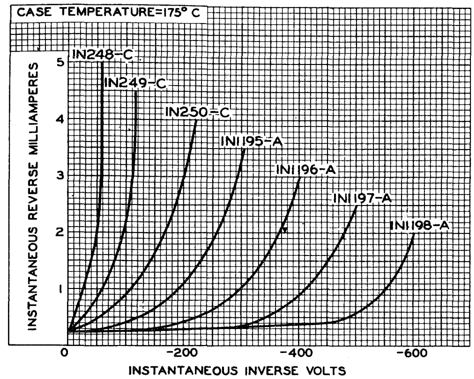


Fig.7 - Typical Reverse Characteristics for Types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, 1N1198-A, and corresponding reverse-polarity versions.

OPERATING CONSIDERATIONS

Because these rectifiers may operate at voltages which are dangerous, care should be taken in the design of equipment to prevent the operator from coming in contact with the rectifier.

The recommended installation torque is 26 to 36 inch-pounds applied to a 1/4-28 UNF-2A hex nut assembled on thread.

The applied torque during installation should not exceed 75 inch-pounds.

Use of Rating Charts

Chart V is used in conjunction with Rating Charts II and III to determine maximum average forward amperes per rectifier unit for polyphase operation and dc operation. The procedure for the use of Chart V is as follows:

Step 1: From Chart V determine the current-multiplying factor for the applicable conduction angle. (For dc operation use current multiplying factor of 0.8.)

Step 2: Divide the required load current in amperes by the number of rectifier circuit branches — as shown in the following Table — to determine average forward amperes per rectifier element.

Type of Operation	No. of Circuit Branches
Single-Phase, Full-Wave:	
Center-Tapped	2
Bridge	2
Three-Phase:	
Wye	3
Double Wye	6
Bridge	6
Six-Phase Star	6

Step 3: Multiply average forward amperes established in Step 2 by the current multiplying factor established in Step 1 to determine adjusted average forward amperes per rectifier element, for use with Rating Chart II or Rating Chart III.

Step 4: Using the product obtained in Step 3, determine from Rating Chart II or Rating Chart III either (a) the maximum allowable incoming-air temperature or ambient temperature for a given heat-sink size, or (b) the minimum heat-sink size for a given incoming-air temperature or ambient temperature.

Example

Conditions:

(a) Three-phase, half-wave operation; conduction angle = 120°
(b) Desired output current = 45 amperes
(c) Forced-air cooling; incoming-air temperature = 90° C

Problem:

Determine minimum heat-sink size.

Procedure:

Step 1: From Chart V, the current multiplying factor for a conduction angle of 120° is 1.18.

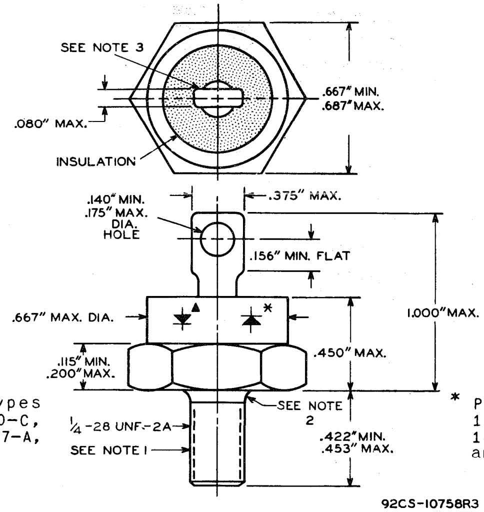
Step 2: For three-phase half-wave operation the number of rectifier circuit branches is three. The average forward current through each rectifier element is, therefore, 45/3, or 15 amperes.

Step 3: Multiplying average forward amperes (15) obtained in Step 2 by the current multiplying factor (1.18) obtained in Step 1 yields 17.7 adjusted average forward amperes.

Step 4: From Rating Chart III, for forced-air cooling, the minimum heat-sink size for the conditions shown in Step 3 is 3" x 3".

DIMENSIONAL OUTLINE

JEDEC DO-5



▲ Polarity symbol for types 1N248-C, 1N249-C, 1N250-C, 1N1195-A, 1N1196-A, 1N1197-A, and 1N1198-A.

* Polarity symbol for types 1N248-RC, 1N249-RC, 1N250-RC, 1N1195-RA, 1N1196-RA, 1N1197-RA, and 1N1198-RA.

NOTE 1: MUST WITHSTAND TORQUE OF 30 INCH-POUNDS APPLIED TO 1/4-28 UNF-2A NUT ASSEMBLED ON THREAD.

NOTE 2: ANGULAR ORIENTATION OF THIS TERMINAL UNDEFINED.

NOTE 3: DEVICE CAN BE USED IN ANY POSITION.

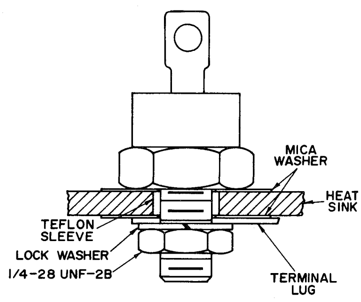


Fig. 8 – Suggested Mounting Arrangement.

RCA Solid State Division

Rectifiers

1N1183A 1N1184A 1N1186A-1N1190A

H-1113R2

JEDEC DO-5

40-Ampere Silicon Rectifiers

Stud-Mounted Types for Industrial and Military Power Supplies

Features:

- **Low thermal resistance**
- **Low forward voltage drop**
- **High output current:**
  up to 160 amperes — 6 rectifiers in 3-phase, full-wave bridge circuit
  up to 120 amperes — 4 rectifiers in single-phase, full-wave bridge circuit
- **Available in reverse-polarity versions:**
  1N1183RA, 1N1184RA, 1N1186RA, 1N1187RA, 1N1188RA, 1N1189RA, 1N1190RA
- **Extra-high-strength zirconium-alloy mounting stud — withstands installation torque of up to 50 inch-pounds**
- **Designed to meet stringent military mechanical and environmental specifications.**
- **Welded construction**
- **Low leakage current**
- **JEDEC DO-5 Outline**
- **Diffused-junction process — exceptional uniformity and stability of characteristics**
- **Hermetic seals**

RCA-1N1183A, 1N1184A, 1N1186A, 1N1187A, 1N1188A, 1N1189A, and 1N1190A are 40-ampere, diffused-junction silicon rectifiers suitable for use in generator-type power supplies for mobile electrical and electronic equipment, in dc-to-dc converters and battery chargers, and in power supplies for aircraft, marine, and missile equipment, transmitters, and rf generators. They are also extremely useful in power supplies for dc motors, in welding and electroplating equipment, in dc-blocking applications, in magnetic amplifiers, and in a wide variety of other applications in heavy-duty industrial and military equipment.

These rectifiers are conservatively rated to permit continuous operation at maximum ratings in applications requiring high reliability under severe operating conditions. In addition, they utilize a special zirconium-alloy mounting stud which can withstand installation torques of up to 50 inch-pounds — a feature of significant value in applications involving mechanical shock and vibration.

HALF-WAVE RECTIFIER SERVICE, ABSOLUTE-MAXIMUM RATINGS, *for Supply Frequency of 60 cps, Single-phase Operation, and with Resistive or Inductive Load*

	1N1183A	1N1184A	1N1186A	1N1187A	1N1188A	1N1189A	1N1190A
PEAK REVERSE VOLTS	50	100	200	300	400	500	600
RMS SUPPLY VOLTS	35	70	140	212	284	355	424
DC BLOCKING VOLTS	50	100	200	300	400	500	600
AVERAGE FORWARD AMPERES:							
At 150°C case temperature	← 40 →						
At other case temperatures	← See Fig. 1 →						
PEAK SURGE AMPERES:[a]							
One-half cycle, sine wave	← 800 →						
For more than one cycle	← See Fig. 5 →						
PEAK RECURRENT AMPERES	← 195 →						
CASE TEMPERATURE RANGE:							
Operating and storage	← -65 to +200°C →						
Characteristics:							
Max. Forward Voltage Drop (Volts)[b]	← 0.65 →						
Max. Reverse Current (mA):							
Dynamic[b]	2.5	2.5	2.5	2.5	2.2	2	1.8
Static[c]	← 0.015 →						
Max. Thermal Resistance, Junction-to-Case	← 1° C/W →						

[a] Superimposed on device operating within the maximum specified voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Average value for one complete cycle, at maximum peak reverse voltage, maximum average forward amperes = 40, and case temperature (°C) = 150.

[c] DC value, at maximum peak reverse voltage and case temperature (°C) = 25.

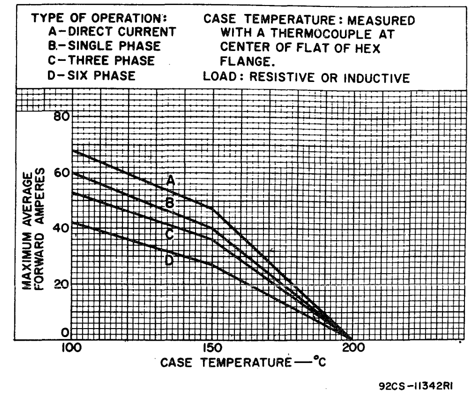


Fig.1— Rating chart for all types and corresponding reverse-polarity versions.

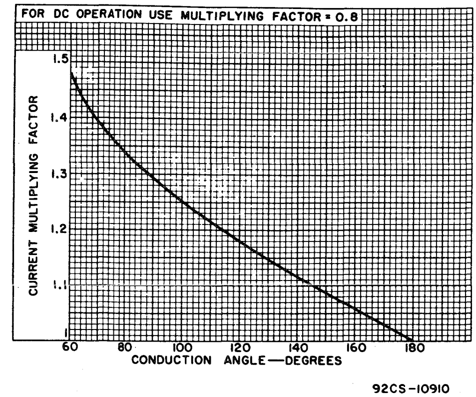


Fig.2— Current-multiplying-factor chart for polyphase and dc operation for all types and corresponding reverse-polarity versions.

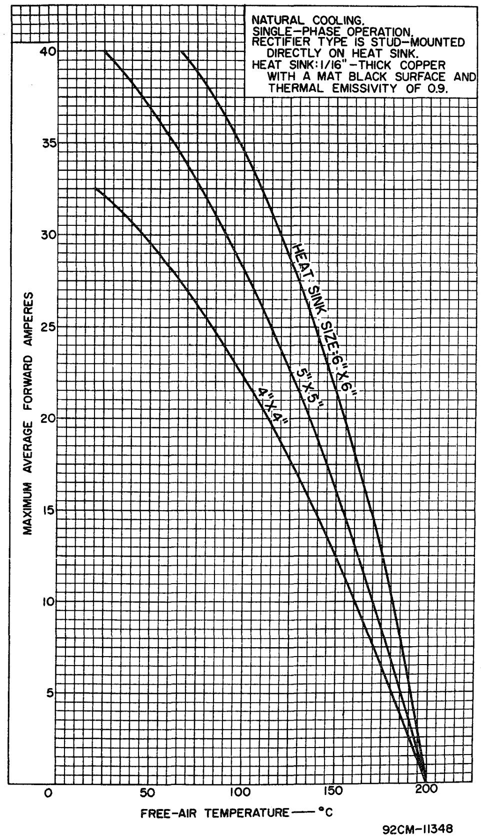


Fig.3— Operation guidance chart for all types and corresponding reverse-polarity versions.

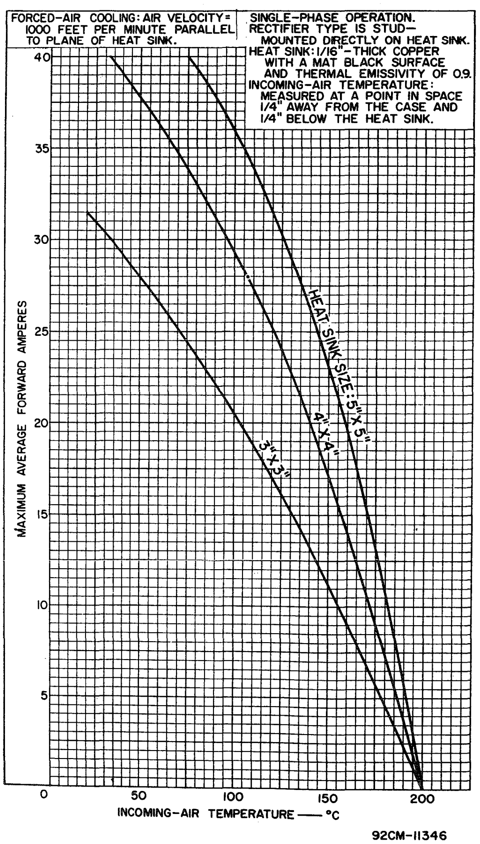


Fig.4— Operation guidance chart for all types and corresponding reverse-polarity versions.

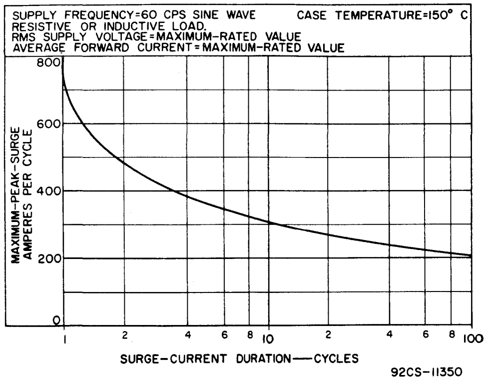


Fig.5— Surge-current rating chart for all types and corresponding reverse-polarity versions.

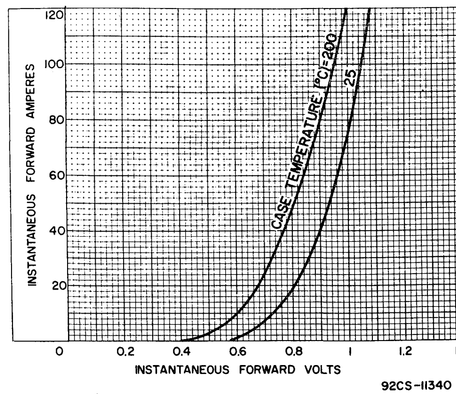


Fig.6— Typical forward characteristics for all types and corresponding reverse-polarity versions.

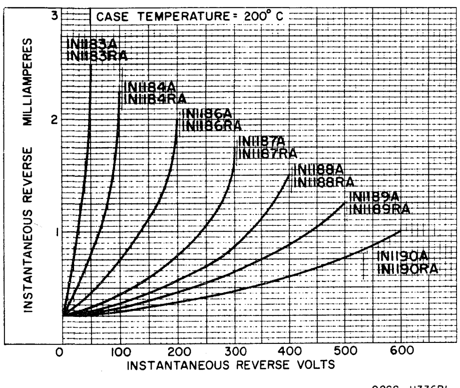


Fig.7— Typical reverse characteristics for all types and corresponding reverse-polarity versions.

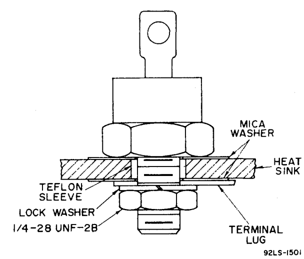
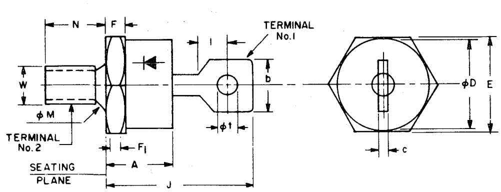


Fig.8— Suggested mounting arrangement for applications requiring that rectifier be electrically insulated from heat sink. For direct mounting omit mica and teflon washers. (Mounting components of the type shown are furnished with each rectifier. The increase in thermal resistance with these mounting components is approximately 1.5° C/watt.)

DIMENSIONAL OUTLINE

JEDEC DO-5



TERMINAL CONNECTIONS

No. 1 — Anode
No. 2 — Cathode

SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	–	0.450	–	11.43	
b	–	0.375	–	9.53	2
c	–	0.080	–	2.03	
ϕD	–	0.667	–	16.94	
E	0.667	0.687	16.94	17.45	
F	0.115	0.200	2.92	5.08	
F1	0.060	–	1.52	–	
J	–	1.000	–	25.40	
I	0.156	–	3.96	–	4
ϕM	0.220	0.249	5.59	6.32	1
N	0.422	0.453	10.72	11.51	
ϕt	0.140	0.175	3.56	4.45	
W	–	–	–	–	1, 3

92CS-20121

1. Complete threads to extend to within 2-1/2 threads of seating plane.
2. Angular orientation of the terminal is undefined.
3. 1/4-28 UNF-2A. Maximum pitch diameter of plated threads shall be basic pitch diameter (.2268 inch, 5.74 mm) ref. (screw thread standards for Federal Services 1957) Handbook H28 1957 Pl.
4. Minimum flat.

EIA-NEMA standard outline, NEMA SK-51 – EIA RS-241.

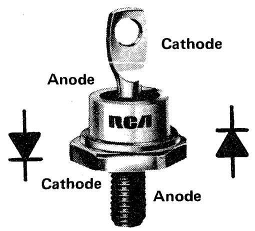
File No. 580

RCA

Solid State
Division

Rectifiers

40956 -40960
40956R-40960R



Forward-polarity (40956-40960) Reverse-polarity (40956R–40960R)

JEDEC DO-5

H-1113R1

40-A, 50- to- 600 V, Fast-Recovery Silicon Rectifiers

General Purpose Types for High-Current Applications

Features

- Available in reverse-polarity versions: 40956R, 40957R, 40958R, 40959R, 40960R‡
- Fast reverse-recovery time — 0.35 μs max. from 125 A peak
- Low reverse-recovery current
- Low forward-voltage drop
- Low-thermal-resistance hermetic package

RCA types 40956–40960 and 40956R–40960R inclusive, are diffused-junction-type silicon rectifiers in a stud-type hermetic package. These devices differ only in their voltage ratings.

All types feature fast reverse-recovery time (0.35 μs max. from 125 A peak) with "soft" recovery characteristics that reduce the generation of RFI and voltage transients.

These devices are intended for use in high-speed inverters, choppers, high-frequency rectifiers, "free-wheeling" diode circuits, and other high-frequency applications.

‡ Types 40957R–40960R were formerly RCA Dev. Nos. TA7984–TA7987, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40956 40956R	40957 40957R	40958 40958R	40959 40959R	40960 40960R	
REVERSE VOLTAGE							
Repetitive peak	V_{RRM}	50	100	200	400	600	V
Non-repetitive peak	V_{RSM}	100	200	300	600	800	V
FORWARD CURRENT (Conduction angle = 180°, half sine wave):							
RMS (T_C = 100°C)*	$I_{F(RMS)}$	←		60		→	A
Average (T_C = 100°C)*	I_o	←		40		→	A
Peak-surge (non-repetitive):							
At junction temperature (T_J) = 150°C							
For one-half cycle of applied voltage, 60 Hz (8.3 ms)	I_{FSM}	←		700		→	A
Peak (repetitive)	I_{FRM}	←		195		→	A
TEMPERATURE RANGE:							
Storage and Operating (Junction)		←		-40 to 150		→	°C

* Case temperature is measured at center of any flat surface on the heagonal head of the mounting stud.

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	LIMITS ALL TYPES MIN.	LIMITS ALL TYPES MAX.	UNITS
Reverse Current: *Static* For V_{RRM} = max. rated value, $I_F = 0$, $T_C = 25^oC$ $T_C = 100^oC$	I_{RM}	– –	100 2.5	µA mA
Instantaneous Forward Voltage Drop: At i_F = 100 A, $T_J = 25^oC$, See Figure 2.	v_F	–	1.8	V
Reverse-Recovery Time: For circuit shown in Figure 1: At I_{FRM} = 125 A, di/dt = 25 A/µs, pulse duration = 15 µs $T_C = 25^oC$	t_{rr}	–	0.35	µs
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$	–	0.9	$^oC/W$

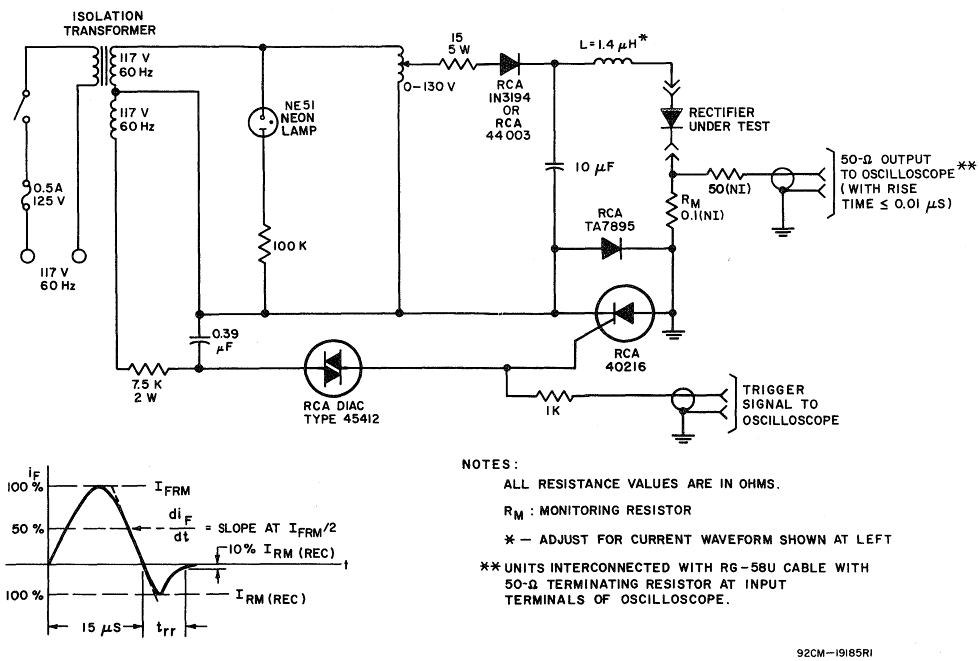


Fig. 1—Oscilloscope display and test circuit for measurement of reverse-recovery time.

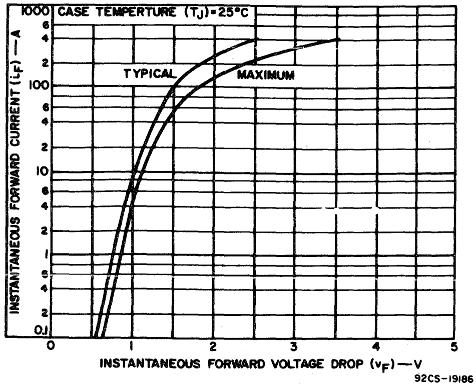


Fig.2—Forward current as a function of forward voltage drop.

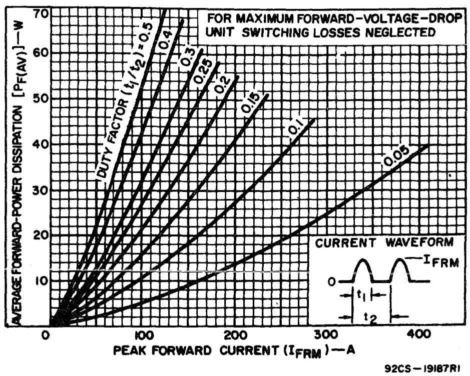


Fig.3—Average forward-power dissipation for maximum forward-voltage-drop unit.

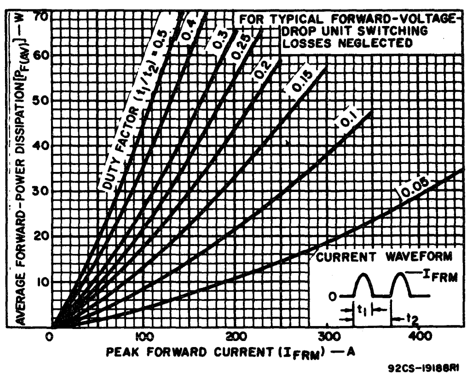


Fig.4—Average forward-power dissipation for typical forward-voltage-drop unit.

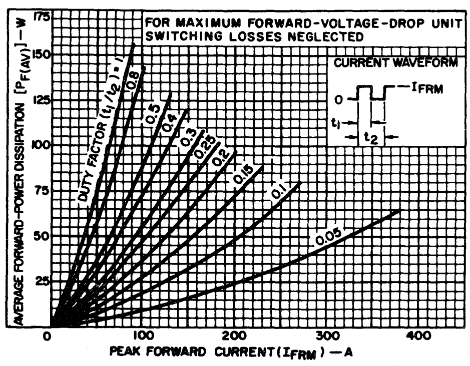


Fig.5—Average forward-power dissipation for maximum forward-voltage-drop unit.

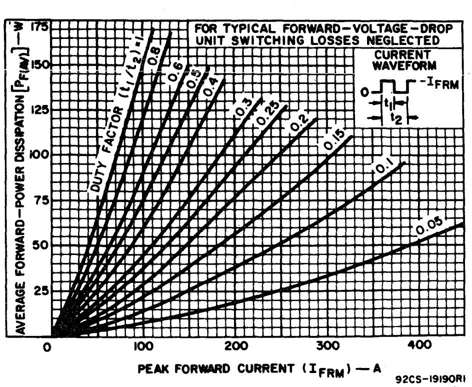


Fig.6—Average forward-power dissipation for typical forward-voltage-drop unit.

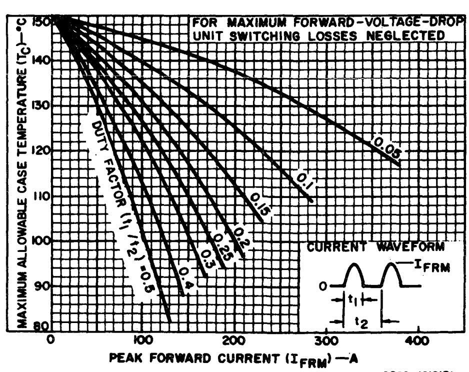


Fig.7—Maximum allowable case temperature for maximum forward-voltage-drop unit.

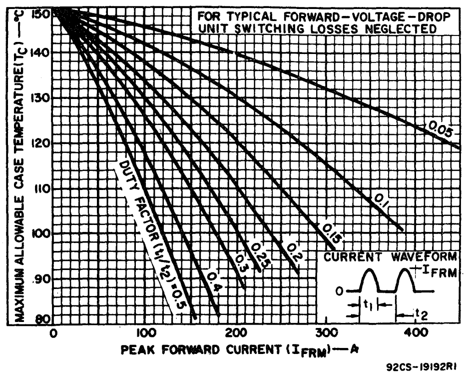


Fig.8—Maximum allowable case temperature for typical forward-voltage-drop unit.

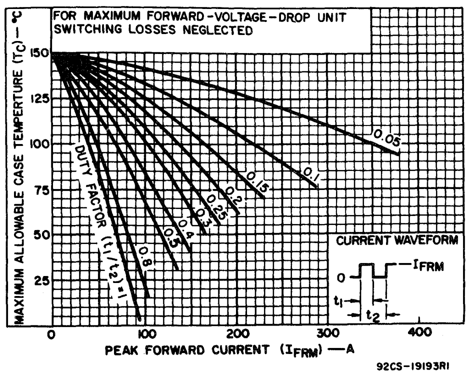


Fig.9—Maximum allowable case temperature for maximum forward-voltage-drop unit.

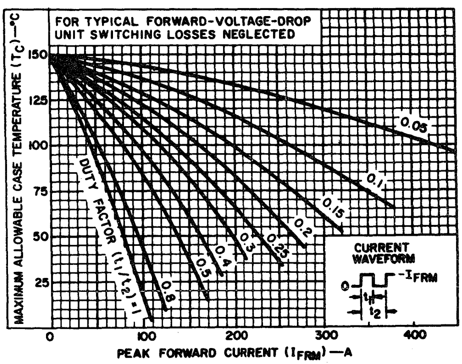


Fig.10—Maximum allowable case temperature for typical forward-voltage-drop unit.

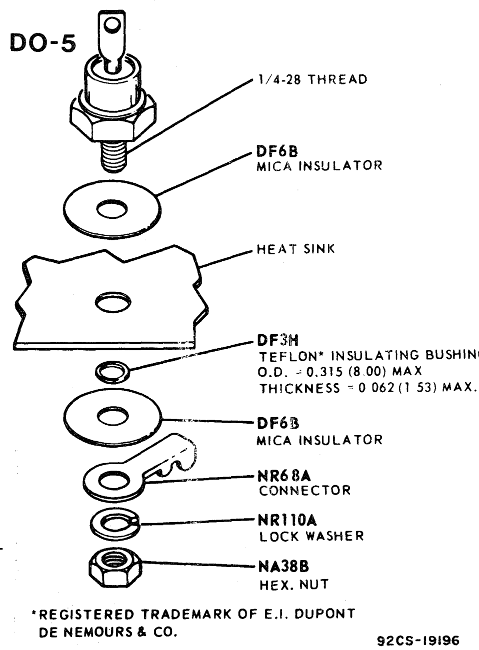
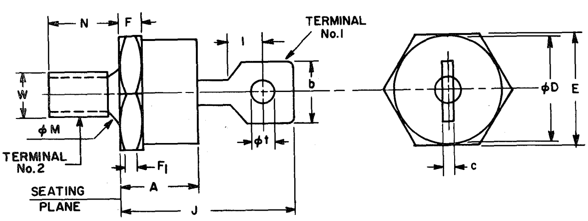


Fig.11—Suggested mounting hardware.

DIMENSIONAL OUTLINE JEDEC DO-5



SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	–	0.450	–	11.43	
b	–	0.375	–	9.53	2
c	–	0.080	–	2.03	
ϕD	–	0.667	–	16.94	
E	0.667	0.687	16.94	17.45	
F	0.115	0.200	2.92	5.08	
F_1	0.060	–	1.52	–	
J	–	1.000	–	25.40	
I	0.156	–	3.96	–	4
ϕM	0.220	0.249	5.59	6.32	1
N	0.422	0.453	10.72	11.51	
ϕt	0.140	0.175	3.56	4.45	
W	1/4-28 UNF 2A		1/4-28 UNF 2A		1, 3

92CS-10758R4

1. Complete threads to extend to within 2-1/2 threads of seating plane.
2. Angular orientation of the terminal is undefined.
3. 1/4-28 UNF-2A. Maximum pitch diameter of plated threads shall be basic pitch diameter (.2268 inch, 5.74 mm) ref. (screw thread standards for Federal Services 1957) Handbook H28 1957 Pl.
4. Minimum flat.

TERMINAL CONNECTIONS

Forward Polarity (40956–40960)	Reverse Polarity (40956R–40960R)
No.1 (Lug) — Anode	No.1 (Lug) — Cathode
No.2 (Stud) — Cathode	No.2 (Stud) — Anode

RCA

Solid State
Division

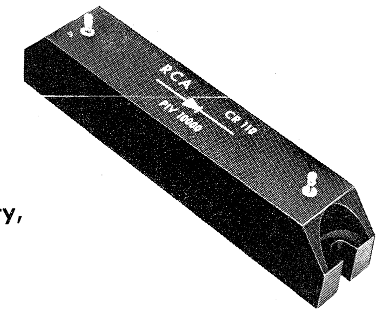
Rectifiers
CR101
CR110

RCA CR101 through CR110 high-voltage rectifiers consist of series-connected, hermetically-sealed, RCA diffused-junction silicon-rectifier cells molded into a compact, rugged case of insulating material.

These high-voltage rectifiers, which are intended for use in industrial and military equipment, contain integral R-C networks designed to equalize the reverse voltages across the rectifier cells under both steady-state and transient conditions.

With Integral R-C Voltage-Equalizing Networks

Designed to Meet Stringent Military, Mechanical, and Environmental Specifications



FEATURES

- 1265 to 10,130 PRV
- Up to 1000 ma output per rectifier
- Up to 2.0 amp output for 4 rectifiers in single-phase, full-wave bridge circuit
- Up to 2.67 amp output for 6 rectifiers in a 3-phase full-wave bridge circuit
- Low forward voltage drop
- Withstand transient reverse voltages 20% above PRV ratings
- -65° C to +125° C operating and storage temperature range
- All identification markings permanently molded in case
- Case material flammability: self-quenching

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load.

	CR101	CR102	CR103	CR104	CR105	CR106	CR107	CR108	CR109	CR110
PEAK REVERSE VOLTS:										
REPETITIVE	1265	2530	3165	4430	5065	6330	7595	8230	9495	10,130
NON-REPETITIVE (Transient, for max. duration of 5 msec):										
At free-air temperatures from 60° C to 125° C . . .	1520	3035	3800	5315	6080	7595	9115	9875	11,395	12,155 ←
At other free-air temperatures	← See *Fig. 1* →									
RMS SUPPLY VOLTS	895	1790	2240	3130	3580	4475	5370	5820	6710	7160
DC BLOCKING VOLTS.	1265	2530	3165	4430	5065	6330	7595	8230	9495	10,130
AVERAGE FORWARD MILLIAMPERES:										
At 60° C free-air temperature.	1000	925	825	700	700	650	600	600	600	600
At 100° C free-air temperature.	385	355	315	270	270	250	230	230	230	230
At other free-air temperatures.	← See *Fig. 2* →									
PEAK RECURRENT AMPERES	← 5 →									
PEAK SURGE AMPERES:[a]										
One-half cycle, sine wave . .	← 20 →									
For more than one cycle . . .	← See *Fig. 3* →									
FREE-AIR TEMPERATURE RANGE:										
Operating and storage.	← -65 to +125° C →									

For **Characteristics** and Footnotes see next page.

→ Indicates a change.

Characteristics	CR101	CR102	CR103	CR104	CR105	CR106	CR107	CR108	CR109	CR110
Max. Forward Voltage Drop (Volts)[b]	1.2	2.4	3.0	4.2	4.8	6.0	7.2	7.8	9.0	9.6
Instantaneous Forward Voltage Drop	← See *Fig.4* →									
Max. Reverse Milliamperes:										
Dynamic[c]	← 0.3 →									
Static[d]	← 0.6 →									
Shunt Capacitance (pf):										
Maximum	600	320	250	175	160	125	105	100	90	80
Minimum	350	175	140	100	85	70	60	55	45	40

[a] Superimposed on device operating within the maximum specified voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Maximum full-cycle average forward voltage drop at maximum rated operating conditions.

[c] Maximum reverse current averaged over one complete cycle and for operation at the maximum ratings. For example, for the CR101 at 60° C free-air temperature: average forward milliamperes = 1000; peak reverse volts = 1265.

[d] At maximum rated dc blocking voltage and any temperature within the operating temperature range.

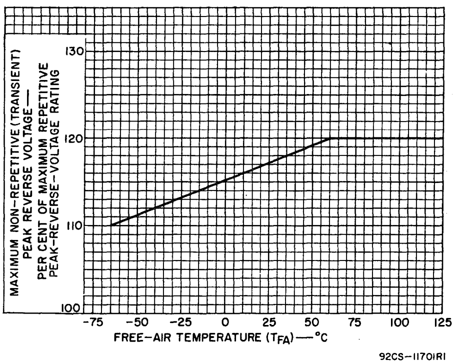


Fig.1 - Rating chart for RCA CR101 through CR110.

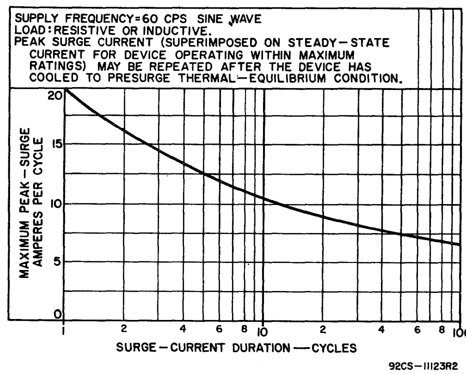


Fig.3 - Peak surge-current rating chart for types CR101 through CR110.

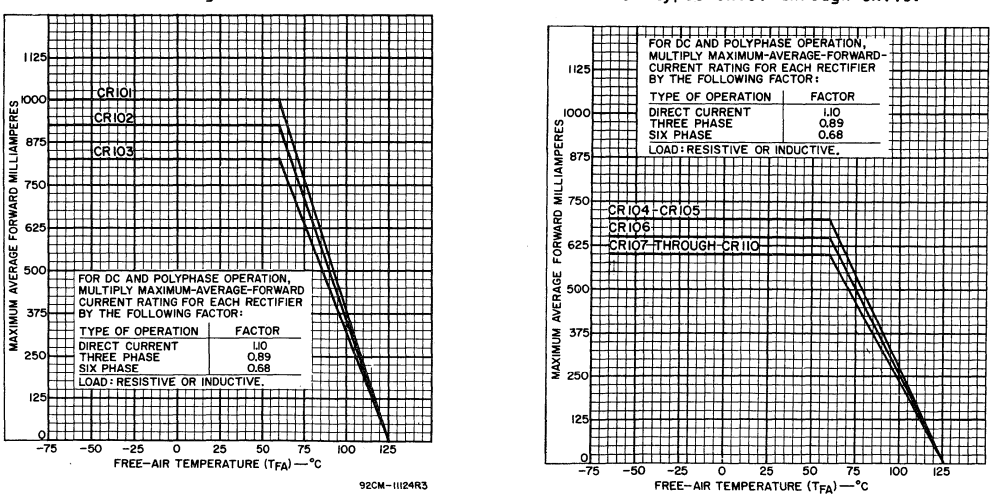


Fig.2 - Rating charts for types CR101 through CR110 for dc, and 60-cps single-phase and polyphase operation.

OPERATING CONSIDERATIONS

A *surge-limiting impedance* should always be used in series with an RCA CR-series rectifier. 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 windings, or by an external resistor or choke.

TO DETERMINE v_F FOR EACH RECTIFIER TYPE: MULTIPLY VALUE GIVEN AT INTERSECTION OF CURVE FOR THE APPROPRIATE TEMPERATURE WITH THE DESIRED VALUE i_F BY THE FOLLOWING FACTOR:

RCA TYPE	FACTOR	RCA TYPE	FACTOR
CR101	2	CR106	10
CR102	4	CR107	12
CR103	5	CR108	13
CR104	7	CR109	15
CR105	8	CR110	16

—— MAXIMUM — — — TYPICAL

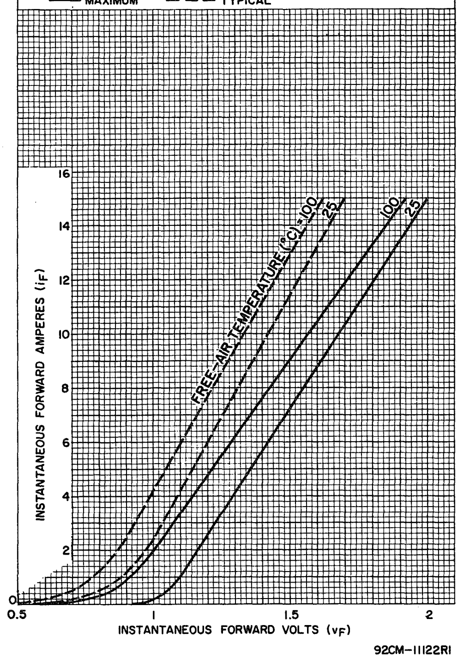


Fig.4 - Typical forward characteristics for types CR101 through CR110.

RCA CR101 through CR110 high-voltage silicon rectifiers can be mounted in any position. It is recommended, however, that wherever possible these rectifiers be mounted on vertical surfaces to prevent accumulation of dust on the surfaces between the rectifier terminals.

RCA CR101 through CR110 are designed to operate at full ratings at altitudes up to 30,000 feet. For operation at altitudes above 10,000 feet, it is recommended that sufficient spacing be provided between rectifiers and between rectifiers and other components (including the chassis and enclosure) to prevent corona. If the applied voltage exceeds 5500 volts peak, the rectifiers should be mounted on standoff insulators at least 1-1/2 inches high.

When several RCA CR-series rectifiers are to be operated in series across a supply voltage of 20,000 volts peak or more, the protection afforded by the integral voltage-equalizing networks may not be adequate, depending on the circuit arrangement and the physical layout of the components. Consequently, additional protection against high transient voltages may be required in the design of the equipment. For additional information on this subject, write to RCA, Commercial Engineering, Harrison, New Jersey.

Because these CR-series rectifiers operate at voltages which are dangerous, care should be taken in the design and operation of the equipment to prevent personnel from coming in contact with the rectifiers.

Connections to the solder terminals of these rectifiers should be made with No. 16AWG (or smaller diameter) wire. Care should be exercised during the soldering operation to prevent overheating of the rectifier terminals. A clean, well-tinned iron is recommended to keep soldering time to a minimum.

During a period of prolonged heating: for example, during lead unwrapping, a heat sink such as the jaws of a pair of long-nose pliers should be used between the tip of the soldering iron and the rectifier case.

RCA CR101 through CR110 rectifiers are designed to meet the following rigorous environmental tests:

Moisture Resistance:

MIL-STD-202B, method 106A
MIL-S-19500B, paragraph 40.6

Salt Spray (Corrosion):

MIL-STD-202B, method 101A, Condition A (Length of test—96 hours)
MIL-S-19500B, paragraph 40.9

Shock:

MIL-STD-202B, method 202A
MIL-S-19500B, paragraph 40.10
The device is subjected to 5 blows in each of the orientations X_1, Y_1, and Z_1 with an acceleration of 50 G and a duration of approximately 11 msec.

Vibration Fatigue:

MIL-S-19500B, paragraph 40.18
The device is subjected to a simple harmonic motion at any single frequency between 40 and 100 cps with a constant peak acceleration of 20 G. The vibration shall be applied for 32 hours minimum in each of the orientations X_1, Y_1, and Z_1 (a total of 96 hours minimum).

Vibration, Variable Frequency:

MIL-S-19500B, paragraph 40.20

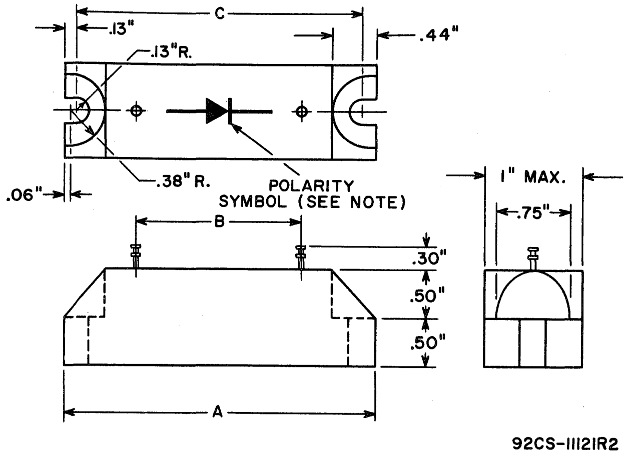
Temperature Cycling:

MIL-STD-202B, method 102A, Condition C
MIL-S-19500B, paragraph 40.14

Barometric Pressure:

MIL-STD-202B, method 105B, Condition A (Operation at altitude of 30,000 feet)
MIL-S-19500B, paragraph 40.1

DIMENSIONAL OUTLINE



NOTE: Arrow indicates direction of forward (easy) current flow as indicated by dc ammeter.

RCA Type	Maximum Overall Length (A) (inches)	Nominal Spacing Between Terminals (B) (inches)	Distance Between Centers of Mounting Holes* (C) (inches)	Weight (ounces)
CR101	2-3/8	1-1/8	2-1/8	2.0
CR102	2-3/8	1-1/8	2-1/8	2.0
CR103	2-3/8	1-1/8	2-1/8	2.1
CR104	3-1/4	1-3/4	3	3.0
CR105	3-1/4	1-3/4	3	3.1
CR106	4-1/2	3-1/4	4-1/4	4.2
CR107	4-1/2	3-1/4	4-1/4	4.4
CR108	4-1/2	3-1/4	4-1/4	4.5
CR109	5-1/2	4	5-1/4	5.4
CR110	5-1/2	4	5-1/4	5.5

*For 1/4-inch bolts.

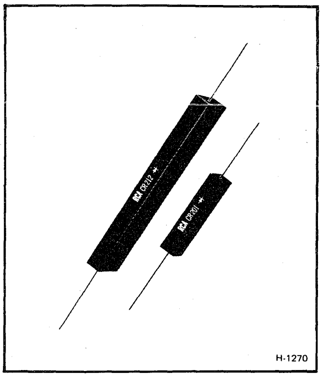
File No. 86

RCA

Solid State
Division

Rectifiers

CR201 CR203 CR208
CR204 CR210
CR206 CR212



High-Voltage Silicon Rectifiers

With Precisely Matched Cells for Internal Voltage Equalization

Features:

- Cells rigorously tested for dissipation capability under reverse voltage and current conditions
- 1900 to 12,000 V (V_{RM})
- Transient reverse voltage ratings 20% above V_{RM} ratings
- 615 mA output per rectifier
- Up to 1.23 A output for 4 rectifiers in single-phase, full-wave bridge circuit
- Up to 1.64 A output for 6 rectifiers in 3-phase full-wave bridge circuit
- Designed to meet stringent electrical, mechanical, and environmental specifications
- Diffused-junction construction for uniformity of characteristics
- Very small size, light weight—operable in any position
- Case material flammability: self-quenching
- No special heat sinks required
- Low forward voltage drop
- Low leakage

RCA CR201 through CR212 high-voltage rectifiers consist of series-connected, RCA difussed-junction silicon-rectifier cells molded into a compact rugged case of insulating material.

These devices are intended for use in industrial and military applications requiring small, light-weight rectifiers with very high reliability, a dc output capability of 615 mA per unit over a wide temperature range, and repetitive peak-reverse-voltage-ratings from 1900 to 12,000 volts.

These rectifiers also feature low forward voltage drop, low leakage, and axial wire leads for simplicity of installation. The rectifier cells comprising each unit are precisely matched to assure equalization of internal voltages under both steady-state and transient conditions.

RCA CR201 through CR212 rectifiers should not be used in series arrangements to obtain dc output voltages higher than those obtainable from single units. For information on special precision-matched units for use in such series arrangements, please submit your requirements to your RCA Technical Sales Representative, or write to RCA Rectifier Marketing, Somerville, N. J. 08876.

Type CR280

RCA-CR280 consists of two matched CR212s. Hence, the rated characteristics for this unit may be determined by doubling the corresponding voltage rating shown on page 2 for the CR212. As an example, $V_{RM(rep)}$ for CR280 = 24,000 V.

The CR280 is available as standard product without the necessity of custom-device order procedures through your RCA Technical Sales Representative or your RCA Solid State Distributor.

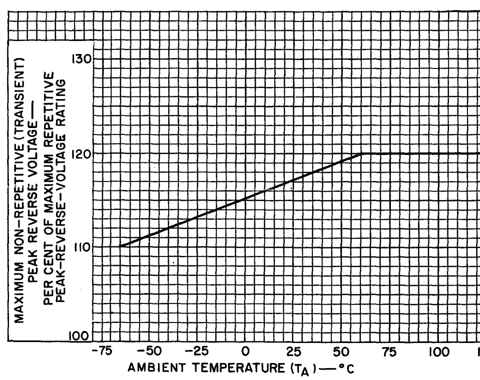


Fig. 1 — Rating chart for RCA CR200-series rectifiers.

MAXIMUM RATINGS, *Absolute-Maximum Values:*
Half-wave rectifier service for supply frequency of 50-to 400-Hz single-phase operation, and with resistive or inductive load.

		CR201	CR203	CR204	CR206	CR208	CR210	CR212	
REVERSE VOLTAGE:									
REPETITIVE PEAK	$V_{RM}(rep)$	1900	3165	4800	6330	8000	10,000	12,000	V
NON-REPETITIVE PEAK	$V_{RM}(nonrep)$								
Transient, for max. duration of 5 ms:									
At ambient temperatures from 60° C to 125° C		2280	3800	5760	7595	9600	12,000	14,000	V
At other ambient temperatures					← *See Fig. 1* →				
RMS	V_r	1345	2240	3395	4475	5655	7070	8485	V
DC BLOCKING	V_R	1900	3165	4800	6330	8000	10,000	12,000	V
FORWARD CURRENT:									
AVERAGE RECTIFIED	I_o								
Single-phase, resistive load									
At T_A = 25° C		615	615	615	615	615	615	615	A
At T_A = 100° C		155	155	155	155	155	155	155	A
At other ambient temperatures					← *See Fig. 2* →				
PEAK RECURRENT	I_{FRM}				← 3 →				A
PEAK SURGE[a]	$I_{FM}(surge)$								
One-half cycle, sine wave:									
At 60 Hz					← 12 →				A
At 50 Hz					← 10 →				A
At 400 Hz					← 24 →				A
For more than one cycle					← *See Fig. 3* →				
AMBIENT TEMPERATURE RANGE	T_A								
Storage & Operating					← -65 to +125 →				°C

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	SYMBOL	CR201	CR203	CR204	CR206	CR208	CR210	CR212	UNITS
Max. Forward Voltage Drop[b]	V_{FM}	1.8	3	3.6	6	6	7.2	9	V
Instantaneous Forward Voltage Drop	v_F				← *See Fig. 4* →				V
Max. Reverse Current	I_{RM}								
Dynamic[c] at T_A = 100° C					← 0.1 →				mA
Static at T_A = 25° C					← 0.01 →				mA
Static at T_A = 100°C					← 0.2 →				mA

[a] Superimposed on device operating within the maximum specified voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Maximum full-cycle average forward voltage drop at maximum rated operating conditions.

[c] Maximum reverse current averaged over one complete cycle and for operation at the maximum ratings. For example, for the CR201 at 60° C ambient temperature: average forward current = 400 mA; $V_{RM(rep)}$ = 1900 V.

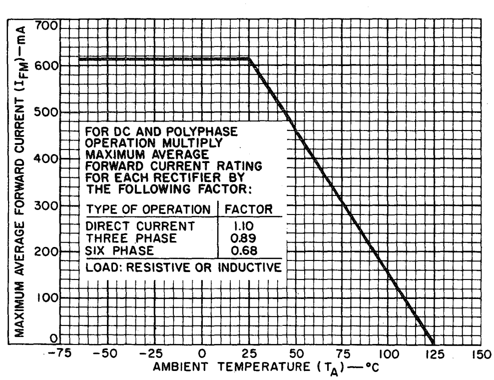


Fig. 2 — Rating chart for all types for dc, and 50-to 400-Hz single-phase and polyphase operation.

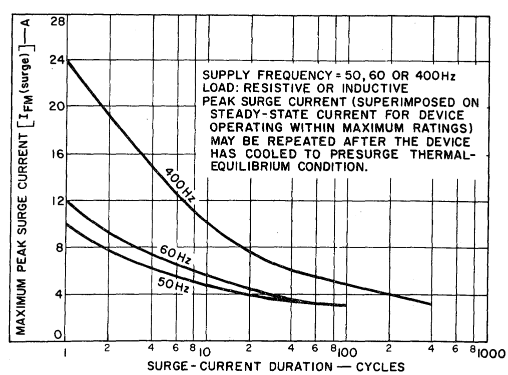


Fig. 3 — Peak surge-current rating chart for all types.

INSTALLATION AND 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.

A *surge-limiting impedance* should always be used in series with the rectifier. 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 windings, or by an external resistor or choke.

Because these rectifiers operate at voltages which are dangerous, care should be taken in the design and operation of the equipment to prevent personnel from coming in contact with the rectifiers.

Care should be exercised during soldering of the wire leads of these rectifiers to prevent overheating of the rectifier cells. A clean, well-tinned iron should be used to keep soldering time to a minimum.

During a period of prolonged heating—for example, during lead unwrapping—a heat sink such as the jaws of a pair of long-nose pliers should be used between the tip of the soldering iron and the rectifier case.

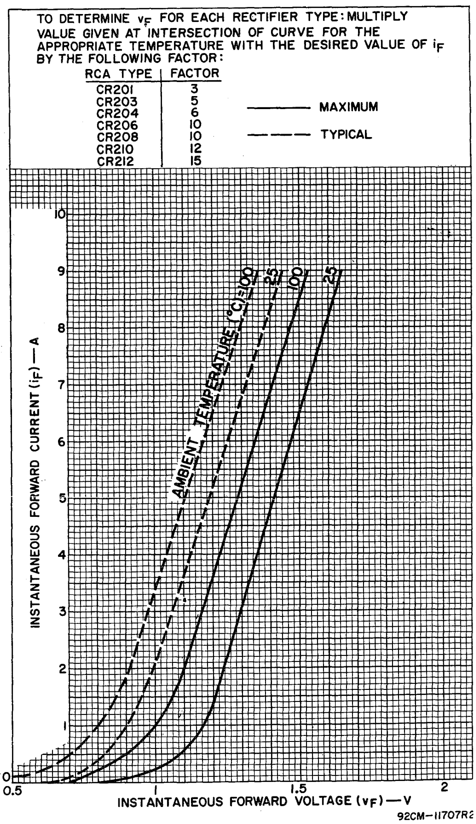
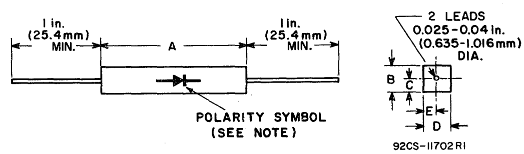


Fig. 4 — Typical forward characteristics for all types.

DIMENSIONAL OUTLINE



NOTE 1: ARROW INDICATES DIRECTION OF FORWARD (EASY) CURRENT FLOW AS INDICATED BY DC AMMETER.

TYPE	DIMENSIONS INCHES A	B	C	D	E	WEIGHT OUNCES
CR201	2	3/8	3/16	3/8	3/16	0.32
CR203	3-1/2	3/8	3/16	3/8	3/16	0.55
CR204	4-1/2	3/8	3/16	3/8	3/16	0.73
CR206	3-1/2	3/8	3/16	3/4	3/8	1.20
CR208	3-1/2	3/8	3/16	3/4	3/8	1.20
CR210	4-1/2	3/8	3/16	3/4	3/8	1.60
CR212	4-1/2	3/8	3/16	3/4	3/8	1.60

TYPE	MILLIMETERS A	B	C	D	E	GRAMS
CR201	50.8	9.5	4.8	9.5	4.8	9.07
CR203	88.9	9.5	4.8	9.5	4.8	15.59
CR204	114.3	9.5	4.8	9.5	4.8	20.79
CR206	88.9	9.5	4.8	19.1	9.5	34.02
CR208	88.9	9.5	4.8	19.1	9.5	34.02
CR210	114.3	9.5	4.8	19.1	9.5	45.36
CR212	114.3	9.5	4.8	19.1	9.5	45.36

RCA

Solid State Division

Rectifiers

CR301– CR354

RCA-CR301 through CR354 are high-voltage rectifiers consisting of series-connected, hermetically-sealed, RCA diffused-junction silicon-rectifier cells. The cells are specially selected, balanced dynamically under transient conditions to sustain reverse energy, processed to provide optimum performance and reliability, and fin-mounted to facilitate natural-air or forced-air cooling

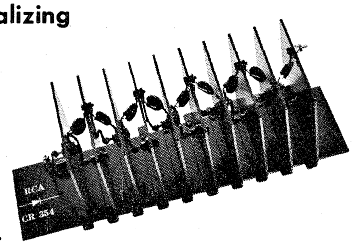
These high-voltage rectifiers, which are intended for use in industrial and military equipment, contain integral R-C networks designed to equalize the reverse voltages across the rectifier cells under both steady-state and transient conditions.

Fin-Mounted Types

Having Integral R-C

Voltage-Equalizing

Networks



Designed to Meet Stringent Military Mechanical and Environmental Specifications

FEATURES

- 2400 to 9600 PRV
- Up to 35 amperes output per rectifier (natural-air cooling)
- Up to 70 amperes output for 4 rectifiers in single-phase, full-wave bridge circuit (natural-air cooling)
- Up to 94 amperes output for 6 rectifiers in a 3-phase full-wave bridge circuit (natural-air cooling)
- Low forward voltage drop
- Ability to withstand transient reverse voltages 20% above PRV ratings
- Operating and storage temperature range of -55° C to +125° C
- Rectifiers may be series connected up to 20 KV*
- Extended current capability (up to 143%) with forced-air cooling
- Derating of these rectifier stacks from the Absolute-Maximum Rating values is not required.

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load

TABLE I

Peak Reverse Volts, Repetitive		2400	3600	4800	6000	7200	8400	9600
Average (DC) Forward Amperes: At 50° C free-air temperature	5	CR301	CR302	CR303	CR304	CR305	CR306	CR307
	9	CR311	CR312	CR313	CR314	CR315	CR316	CR317
	12	CR321	CR322	CR323	CR324	CR325	*	*
	17	CR331	CR332	CR333	CR334	CR335	*	*
	23	CR341	CR342	CR343	CR344	*	*	*
	35	CR351	CR352	CR353	CR354	*	*	*
Peak Reverse Volts, Non-Repetitive (Transient, for max. duration of 5 msec): At free-air temperatures from +50° C to +125° C		2880	4320	5760	7200	8640	10080	11520
At other free-air temperatures		← See *Fig.1* →						
RMS Supply Volts		1695	2545	3395	4240	5090	5935	6785
DC Blocking Volts		2400	3600	4800	6000	7200	8400	9600
Number of Cells Per Rectifier Stack		4	6	8	10	12	14	16

* Rectifier stacks having the same average (dc) forward ampere rating may be series connected to obtain these PRV ratings.

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load

TABLE II

	CR301 through CR307	CR311 through CR317	CR321 through CR325	CR331 through CR335	CR341 through CR344	CR351 through CR354
Average (DC) Forward Amperes:						
At 50° C free-air temperature	5	9	12	17	23	35
At 100° C free-air temperature	2.5	4.5	6	8.5	11.5	17.5
At other free-air temperatures and for forced-air cooling	See *Figs. 2, 3, and 4*					
RMS Forward Amperes at 50° C free-air temp.▲	7.85	14.1	18.85	26.6	36	55
Peak Surge Amperes:[a]						
Single cycle, sine wave, 60 cps	250	250	400	400	850	850
For more than one cycle	See *Fig.5*					
Temperature Range:						
Operating and storage	-55° C to +125° C					
Characteristics						
Instantaneous Forward Voltage Drop	See *Fig.6*					
Maximum Reverse Milliamperes:						
Dynamic[b]	1.5 ma					
Static[c]	2.0 ma					
Typical Cell Shunt Capacitance	0.01 μf					

[a] Superimposed on device operating within the maximum specified voltage, current, and temperature ratings and may be repeated after sufficient time has elapsed for the device to return to the presurge thermal-equilibrium conditions.

[b] Maximum reverse current averaged over one complete cycle and for operation at the maximum ratings.

[c] At maximum rated dc blocking voltage and any temperature within the operating temperature range.

▲ To obtain rms forward amperes at other operating temperatures, multiply the average (dc) forward amperes by 1.57.

OPERATING CONSIDERATIONS

A *surge-limiting impedance* should always be used in series with an RCA CR-series rectifier. 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 windings, or by an external resistor or choke.

For *capacitive loads and for sub-cycle surge considerations* consult RCA Application Notes SMA-4 and SMA-15.

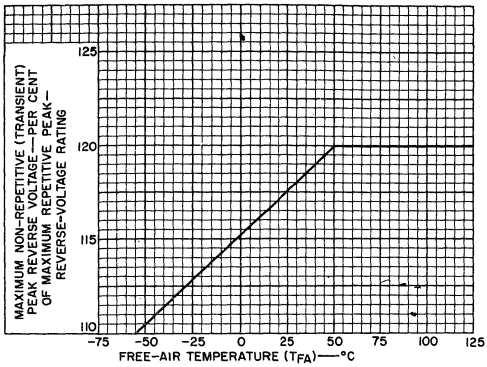
Each of the rectifier stacks in this CR-series has been coated with an epoxy phenolic resin to increase the rectifier's resistance to moisture and humidity, to increase thermal radiation and to improve voltage isolation.

RCA CR301 through CR354 high-voltage silicon rectifiers can be *mounted in* any position. It is recommended, however, that wherever possible these rectifiers be mounted on vertical surfaces to prevent accumulation of dust on the surfaces between the rectifier cells and to provide the maximum flow of cooling air.

When several RCA CR-series rectifiers are to be *operated in series* across a supply voltage of 20,000 volts peak or more, the protection afforded by the integral voltage-equalizing networks may not be adequate, depending on the circuit arrangement and the physical layout of the components. Consequently, additional protection against high transient voltages may be required in the design of the equipment. For additional information on this subject, write RCA, Commercial Engineering, Harrison, New Jersey.

Because these CR-series rectifiers operate at *voltages which are dangerous,* care should be taken in the design and operation of the equipment to prevent personnel from coming in contact with the rectifiers.

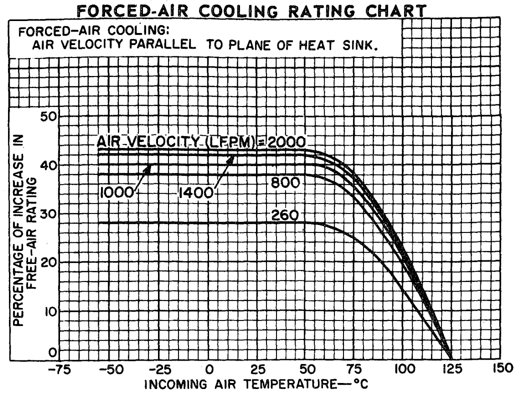
RATING CHART



92CS-12353

Fig.1

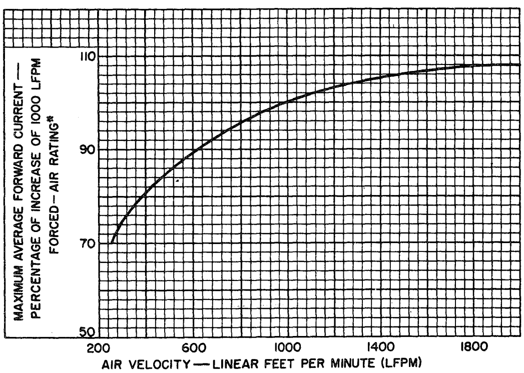
FORCED-AIR COOLING RATING CHART



92CS-12354R1

Fig.2

FORCED-AIR COOLING RATINGS AS A FUNCTION OF AIR VELOCITY

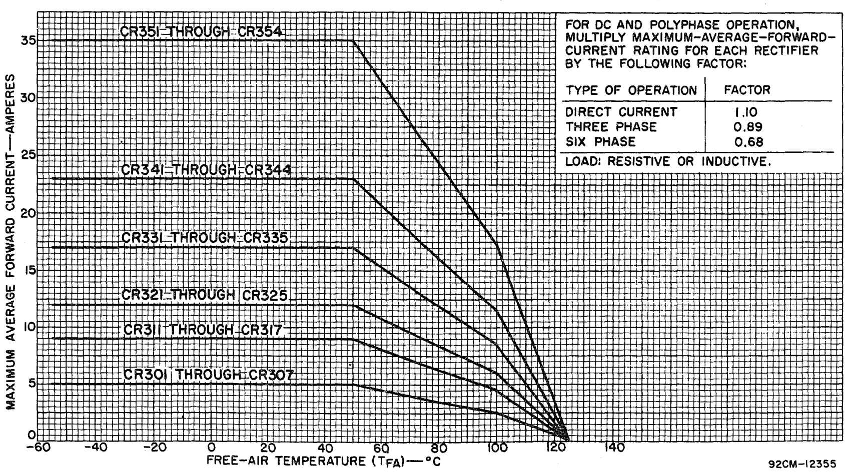


92CS-12578

* This curve may be used in conjunction with the 1000 LFPM curve shown in Fig.2 to determine any percentage of increase in the free-air rating between 260 and 2000 LFPM. For example, at -50° C and 260 LFPM, the percentage increase above the free-air rating is 0.7 x 0.4 = 28%, or a total of 128% of the free-air rating, and at +100° C and 260 LFPM is 0.7 x 0.21 = 14.7%, or 114.7% of the free-air rating.

Fig.3

NATURAL-AIR COOLING RATING CHART FOR 50-60 CPS SINGLE-PHASE AND POLYPHASE OPERATION



FOR DC AND POLYPHASE OPERATION, MULTIPLY MAXIMUM-AVERAGE-FORWARD-CURRENT RATING FOR EACH RECTIFIER BY THE FOLLOWING FACTOR:

TYPE OF OPERATION	FACTOR
DIRECT CURRENT	1.10
THREE PHASE	0.89
SIX PHASE	0.68

LOAD: RESISTIVE OR INDUCTIVE.

92CM-12355

Fig.4

PEAK SURGE-CURRENT RATING CHART

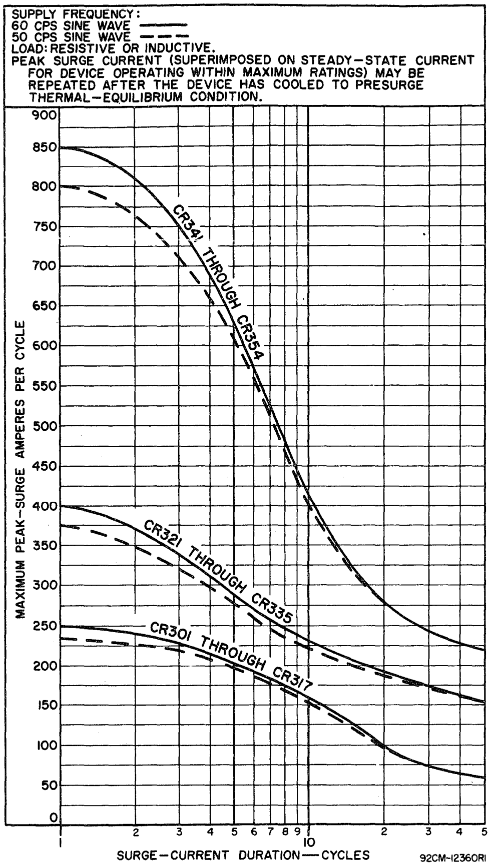


Fig.5

FORWARD CHARACTERISTICS

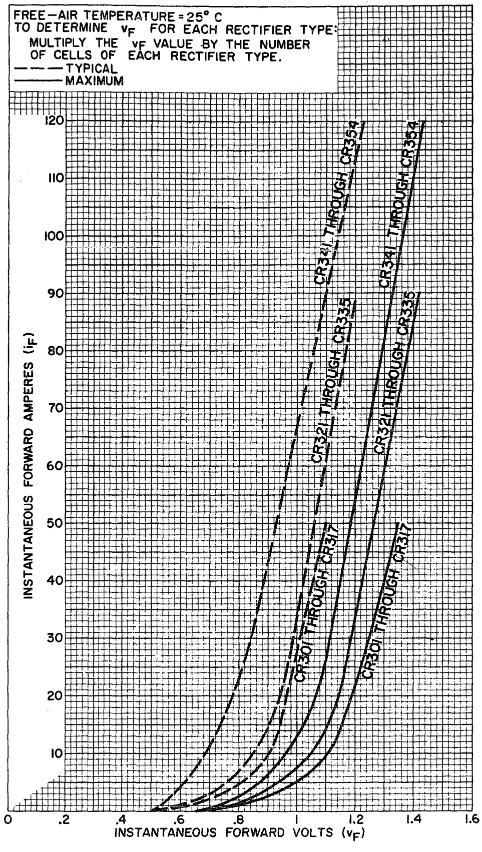
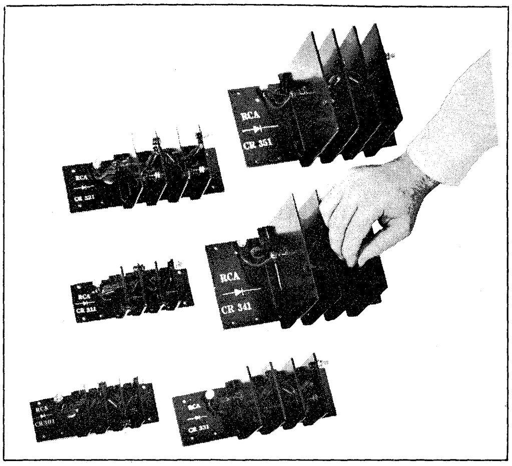
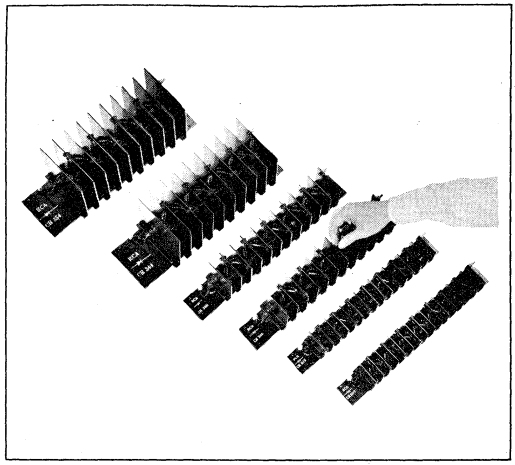


Fig.6

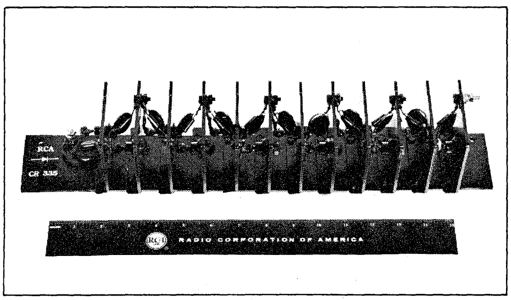
ILLUSTRATIONS SHOWING RELATIVE RECTIFIER SIZE



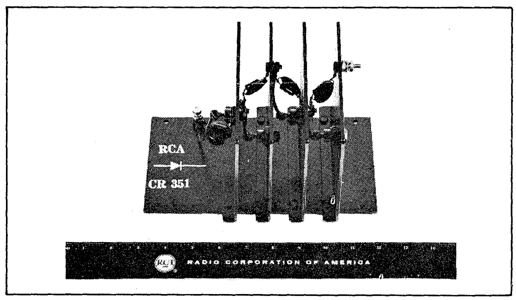
CR301, CR311, CR321, CR331, CR341, CR351



CR307, CR317, CR325, CR335, CR344, CR354



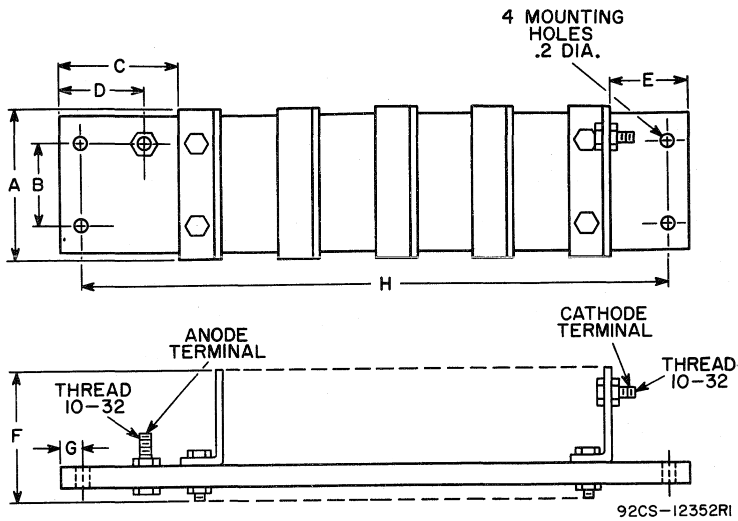
CR335



CR351

The modular design of the RCA CR301-series shown in the illustrations permits the rapid fabrication of stacked-rectifier units.

DIMENSIONAL OUTLINE



DIMENSIONS IN INCHES

	A	B	C	D	E	F	G
CR301 through CR307	2-1/4	1-5/8	2	1-9/32	15/16	2	13/32
CR311 through CR317	2-1/4	1-5/8	2	1-9/32	15/16	2	13/32
CR321 through CR325	3	1-7/8	2-3/4	1-23/32	1-3/8	3-3/8	9/16
CR331 through CR335	3	1-7/8	2-3/4	1-23/32	1-3/8	3-3/8	9/16
CR341 through CR344	5-1/2	4	3	1-29/32	1-1/2	5-3/8	5/8
CR351 through CR354	5-1/2	4	3	1-29/32	1-1/2	5-3/8	5/8

"H" Dimension

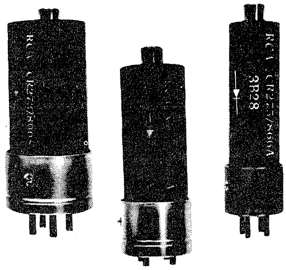
CR301 5-1/4	CR302 7	CR303 8-3/4	CR304 10-1/2	CR305 12-1/4	CR306 14	CR307 15-3/4
CR311 5-1/4	CR312 7	CR313 8-3/4	CR314 10-1/2	CR315 12-1/4	CR316 14	CR317 15-3/4
CR321 7-1/8	CR322 9-1/2	CR323 11-7/8	CR324 14-1/4	CR325 16-5/8		
CR331 7-1/8	CR332 9-1/2	CR333 11-7/8	CR334 14-1/4	CR335 16-5/8		
CR341 7-11/16	CR342 10-1/4	CR343 12-13/16	CR344 15-3/8			
CR351 7-11/16	CR352 10-1/4	CR353 12-13/16	CR354 15-3/8			

RCA
Solid State
Division

Rectifiers

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

Direct Plug-In Tube Replacement High-Voltage Rectifier Types



H-1379 H-1396
H-1398

Features:

- High reliability
- Long life
- Rugged, compact construction
- No required warm-up time

These devices are high-voltage rectifier units consisting of series-connected, hermetically sealed RCA diffused-junction silicon rectifier cells. They are intended specifically as direct replacements for the half-wave mercury-vapor rectifier tube types indicated below.

Because these units do not require filament power, care should be taken when utilizing these devices as direct replacements to assure that the filament circuits of any tubes employed are not affected. The filament transformer primaries for the tubes being replaced should be opened to prevent transformer core saturation and resultant high current flow through the primaries when separate filament supplies are used.

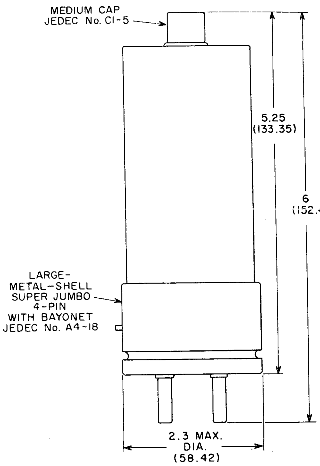
These replacement units are supplied in encapsulated plug-in packages with four-pin bayonet bases which fit the corresponding tube socket without need for special holders or adapters.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

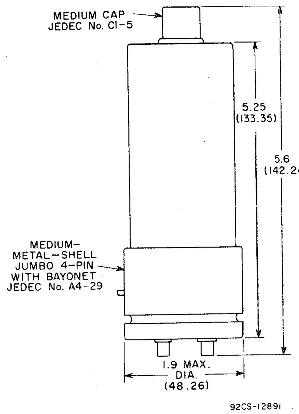
		CR273/ 8008	CR274/ 872A	CR275/ 866A/3B28	
REVERSE VOLTAGE:					
Repetitive peak	V_{RRM}	10	10	10	kV
FORWARD CURRENT:					
Average rectified	I_O	1.25	1.25	0.25	A
Peak surge	I_{FSM}	5	5	1	A
TEMPERATURE RANGE:					
Operating (at full ratings)			-50 to +60		°C
Storage			-50 to +110		°C
TUBE TYPE(S) REPLACED*		8008	872A	866, 866A 3B28	

*Each unit is branded to show both the type number of the solid-state plug-in rectifier and that of the tube or tubes which it replaces.

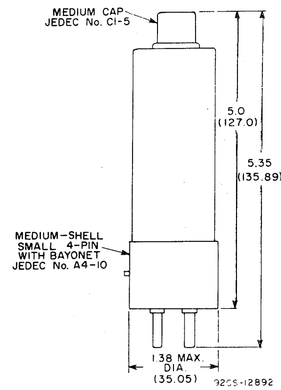
DIMENSIONAL OUTLINE CR273/8008



DIMENSIONAL OUTLINE CR274/872A



DIMENSIONAL OUTLINE CR275/866A/3B28



Dimensions in parentheses are in millimeters and are derived from the original inch dimensions as shown.

PIN CONNECTIONS CR273/8008

Pin 1: No connection
Pin 2: Cathode
Pin 3: No connection
Pin 4: No connection
Cap: Anode

PIN CONNECTIONS CR274/872A

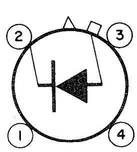
Pin 1: No connection
Pin 2: Cathode
Pin 3: No connection
Pin 4: No connection
Cap: Anode

PIN CONNECTIONS CR275/866A/3B28

Pin 1: Cathode
Pin 2: No connection
Pin 3: No connection
Pin 4: No connection
Cap: Anode

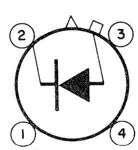
BASING DIAGRAM

Bottom View



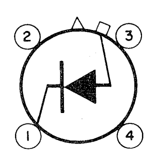
BASING DIAGRAM

Bottom View



BASING DIAGRAM

Bottom View



Diacs

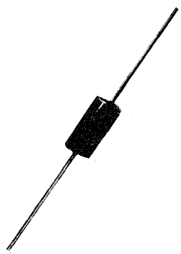
RCA
Solid State
Division

Thyristors

45411
45412

Silicon Bidirectional Diacs

Plastic-Packaged Two-Terminal Trigger Devices for Applications in Military, Industrial, and Commercial Equipment



JEDEC DO-15 H-1783

Features:

- **For critical triggering applications requiring narrow breakover voltage range (29-35V)—45411**
- **Typical breakover voltage: $V_{(BO)}$ = 32 V**
- **Low breakover current (at breakover voltage): $I_{(BO)}$ = 25 μA max.**
- **High peak pulse current capability**
- **Breakover voltage symmetry:**
  $|+V_{(BO)}| - |-V_{(BO)}| = \pm 3$ V max.

RCA-45411 and 45412 are all-diffused, three-layer, two-terminal devices in an axial-lead plastic package designed specifically for triggering thyristors. Both units exhibit bidirectional negative-resistance characteristics.

These diacs are intended for use in thyristor phase-control circuits for lamp-dimming, universal-motor speed control, and heat controls. Their small size and plastic package of high insulation resistance make these diacs especially suitable for applications in which high packing densities are employed.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

DEVICE DISSIPATION:

At case temperature up to 40°C	1 W
At case temperatures above 40°C	Derate 0.016 W/°C

TEMPERATURE RANGE:

Storage	−40 to +150 °C
Operating (Junction)	−40 to +100 °C

LEAD TEMPERATURE (During Soldering)

At distance ≥ 1/16 in. (1.59 mm) from case for 10 s max.	240 °C

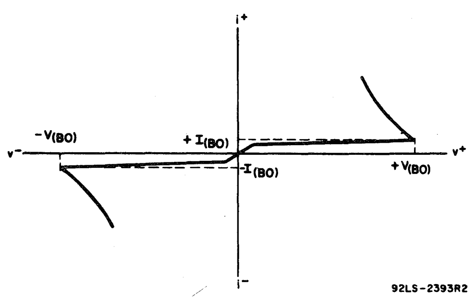


Fig.1—Voltage-current characteristic for both types.

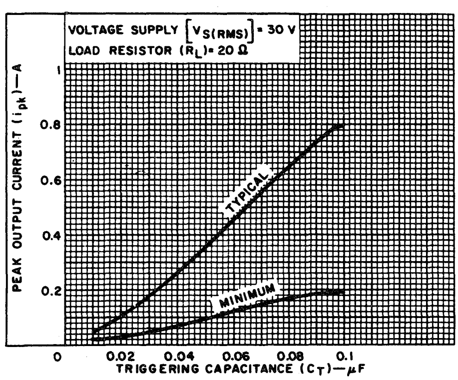


Fig.2—Peak output current vs. triggering capacitance.

ELECTRICAL CHARACTERISTICS: At Case Temperature (T_C) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS 45411 MIN.	LIMITS 45411 MAX.	LIMITS 45412 MIN.	LIMITS 45412 MAX.	UNITS
Breakover Voltage (Forward or Reverse)	$V_{(BO)}$		29	35	25	40	V
Breakover Voltage Symmetry	$\lvert +V_{(BO)}\rvert - \lvert -V_{(BO)}\rvert$		–	±3	–	±3	V
Peak Output Current (See Figs. 2, 3, & 5.)	i_{pk}	V_{SUPPLY} = 30 V_{RMS}, C_T = 0.1 μF, R_L = 20 Ω	190	–	190	–	mA
Peak Breakover Current	$I_{(BO)}$	At breakover voltage	–	25	–	25	μA
Dynamic Breakback Voltage	$\lvert \Delta V\pm \rvert$	V_{SUPPLY} = 30 V_{RMS}, C_T = 0.1 μF, R_L = 20 Ω	9	–	9	–	V
Thermal Impedance Junction-to-ambient	$I\theta_{JA}$		–	60	–	60	°C/W

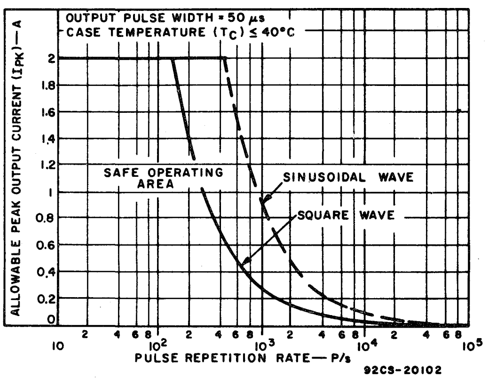


Fig.3—Peak output-current derating curves.

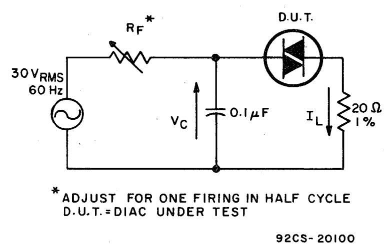


Fig.4—Circuit used to measure diac characteristics.

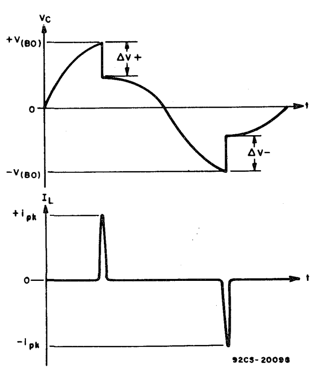
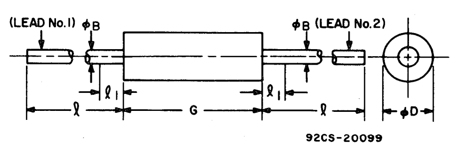


Fig.5—Test circuit waveforms (see Fig.4).

DIMENSIONAL OUTLINE FOR TYPES
45411 & 45412
JEDEC DO-15



Lead 1 or 2 — Positive or Negative Terminal

SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
φb	0.027	0.035	0.686	0.889
φD	0.104	0.140	2.64	3.56
G	0.230	0.300	5.84	7.62
ℓ	1.000	–	25.40	–
ℓ_1*	–	0.050	–	1.27

* Within this zone the diameter may vary to allow for lead finishes and irregularities.

Application Notes

Solid State Division

Thyristors/Rectifiers 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

Thyristors Application Note
AN-3418

Design Considerations for the RCA-40216 Silicon Controlled Rectifier In High-Current Pulse Applications

by

D. E. Burke and G. W. Albrecht

Silicon controlled rectifiers (SCR's) are often used in pulse circuits in which the ratio of peak to average current is large. Typical applications include radar pulse modulators, inverters, and switching regulators. The limiting parameter in such applications often is the time required for forward current to spread over the whole area of the junction. Losses in the SCR are high, and are concentrated in a small region until the entire junction area is in conduction. This concentration produces undesirable high temperatures.

The RCA-40216 SCR is specially designed to achieve rapid utilization of the full junction area. The rating curves and calculations presented in this Note allow the designer to make full use of the high switching capability of this device.

Circuits

A typical SCR pulse modulator circuit is shown in Fig.1. Basic waveforms for the circuit are shown in Fig.2. The capacitors of the energy-storage network are charged by the dc supply. The SCR is triggered by pulses from the gate-trigger generator No.1, and the energy-storage network discharges through an inductance and the load (transformer). Fig.2 shows that the discharge of the storage network (t_1-t_2) is oscillatory; the half-sine-wave shape is characteristic of a single LC-section energy-storage network.

For turn-off, the load is "mismatched" to the discharge-circuit impedance so that a negative voltage is developed on the capacitor at the end of the pulse. The negative voltage reverse-biases the SCR. This form of turn-off is indicated in Fig.2(b).

When the energy-storage network is recharged from the dc supply, the SCR returns to the forward-blocking condition and is ready for the next cycle. The recharge interval (t_3 - t_4) may be delayed by use of a charging SCR, as shown in Figs.1 and 2 (t_2 - t_3). This technique reduces the turn-off time requirements for the SCR. The rate of recharge influences the dv/dt requirements for the SCR.

Figs.1 and 2 illustrate only one of a great variety of pulse circuits, each of which would have particular requirements for the SCR. A common requirement would be to pass forward currents with particular emphasis on shape and magnitude.

Turn-On Time Definitions

In the idealized waveforms of Fig.2, the SCR is presented as a perfect switch. Actually, it exhibits a finite resistance prior to turn-on, a delay after the introduction of the trigger pulse, and appreciable resistance after turn-on.

The common definition of turn-on time adequately covers the delay and rise-time intervals of the turn-on process, but does not consider the rate of current spread over the junction area and its attendant dissipation. Because the dissipation after turn-on is an important consideration in pulse circuits, turn-on definitions in themselves provide no indication of the switching capability of the SCR.

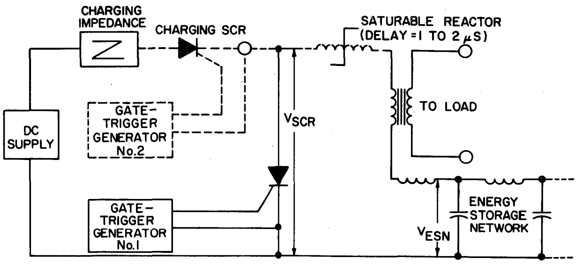


Fig.1 - Basic pulse modulator circuit.

As an example, the rise-time portion of turn-on is defined as the time interval between the 10-per-cent and 90-per-cent points on the current wave shape when the SCR is triggered on in a circuit that has rated forward voltage and sufficient resistance to limit the current to rated values. For a 600-volt device, the end of the turn-on interval occurs when the forward voltage drop across the SCR is 60 volts. This value contrasts with the steady-state forward voltage of only 1 or 2 volts under such conditions. An interval many times greater than the turn-on time may be required before the forward voltage drop reduces to the steady-state level.

Switching Capability

Because several different physical effects occur in the SCR during the complete turn-on interval, it is convenient to divide the total turn-on time into three discrete intervals: delay time t_1, fall time t_2, and equalizing time t_3. These intervals are shown in Fig.3. The solid lines represent device turn-on to low steady-state forward current, in which case equalization effects are not pronounced. The dashed lines represent SCR turn-on to high currents, in which case t_3 becomes a noticeable interval.

The first interval (t_1 or delay time) results from the initiation of forward conduction between the p-type base and the n-type emitter (i.e., injection of holes through the gate-cathode junction and injection of electrons through the cathode-gate junction). This interval depends to a large extent upon the level of gate current used to turn on the SCR. The use of a trigger pulse greater than the minimum gate-current requirement of the SCR minimizes delay time and reduces the range of the delay times encountered between individual SCR's, the variability of delay with temperature, and the variability of cycle-to-cycle delay or jitter.* There are no significant power losses in the SCR during delay. The delay interval is primarily of interest because of its effect on system performance.

* The technical bulletin for the 40216 contains information on maximum trigger-pulse magnitudes for various pulse widths for this device. This Note discusses gating characteristics of RCA SCR's in more detail.

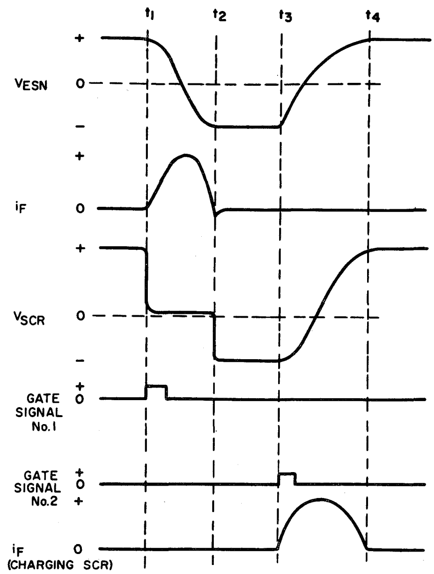


Fig.2 - Idealized waveforms for pulse-discharge circuit.

The second interval (t_2 or fall time) depends on the initiation of forward conduction between the p-type emitter and the n-type emitter (i.e., anode-to-cathode current). When this phenomenon is isolated from current effects, as described later, the duration of the voltage fall time measured from the 90-per-cent to the 10-per-cent point is less than 0.3 microsecond. Voltage fall time is illustrated in Fig.4 for a range of initial voltages.

The flow of forward current during the voltage fall time results in power loss in this interval. The magni-

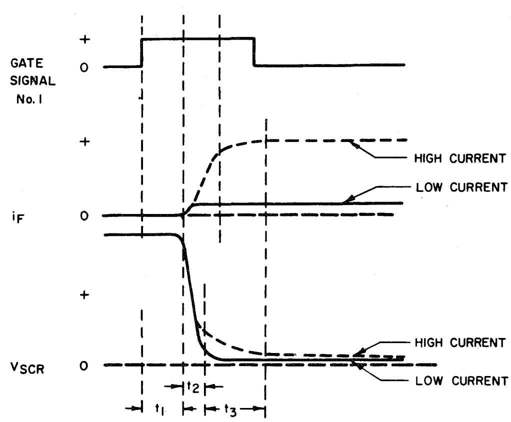


Fig.3 - Actual SCR wave shapes during turn-on.

tude of this loss is primarily determined by the response of the circuit to the voltage fall waveshape. If the rate of current rise desired by the circuit is faster than the fall time of voltage in the SCR, the device experiences high peak dissipation during the short turn-on interval.

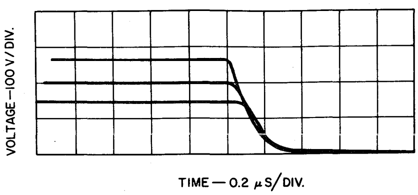


Fig.4 - Illustration of voltage fall time (low forward current).

The third discrete interval during turn-on, equalization time (t_3 of Fig.3), represents the time required for the current to spread over the junction area. The forward current resulting from the initial voltage fall is concentrated in a small area of the junction and spreads gradually over the entire area. The rate of increase in the active junction area depends on the geometry and the junction parameters, and is influenced by the levels of driving voltage and current. In general, the time required for full utilization of junction area represents a considerably longer interval than t_1 (delay) or t_2 (fall).

For given conditions of current rise time, current level, and gate drive, t_3 could be defined as the time required for forward voltage to decrease to a given multiple of the final steady-state value under a constant-current pulse. Such a definition would be more indicative of switching capability than the conventional definition of turn-on time as the time required for forward ON-state voltage to decrease to a percentage of the initial blocking voltage. At best, however, either type of definition has only limited usefulness to the user.

Characteristics and Ratings

Because the major factor in the rating of SCR's for pulse applications is the initial forward-voltage drop, the RCA-40216 is rated specifically for this characteristic. Figs.5 and 6 show two families of rating curves which make it possible to calculate the power loss per pulse and the average power loss for a particular current-pulse shape, magnitude, and repetition rate desired. Figs.7 and 8 show maximum allowable repetition rates and pulse amplitudes for several pulse shapes, and are useful as a quick estimating guide for the pulse-current switching capability of the 40216 SCR.

Limits must also be imposed upon the instantaneous temperature rise of the junction over the average case

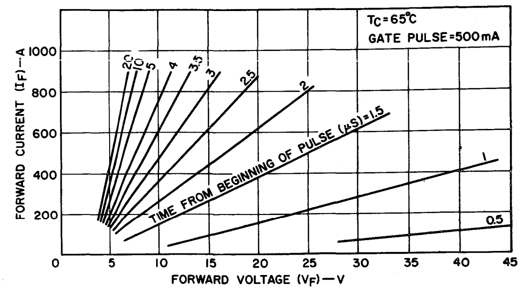


Fig.5 - Forward voltage as a function of forward voltage at various times after the initiation of turn-on.

temperature and upon the differential temperature stresses in the device. Fig.9 shows the allowable maximum current for the 40216 at any time after the initiation of the current pulse. This curve, together with those in Figs.7 and 8, gives an indication of the feasibility of using the 40216 in a high-current pulse application.

Fig.10 illustrates the calculation of device dissipation and pulse repetition rate for a particular pulse

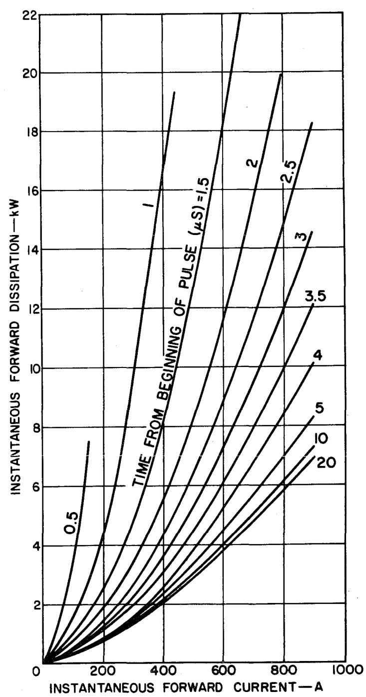


Fig.6 - Instantaneous forward dissipation as a function of current at various times after the initiation of turn-on.

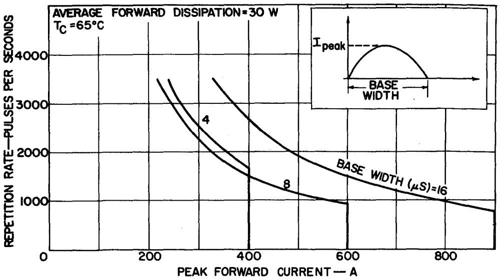


Fig.7 - Peak current as a function of maximum repetition rate for sine-wave pulse shapes.

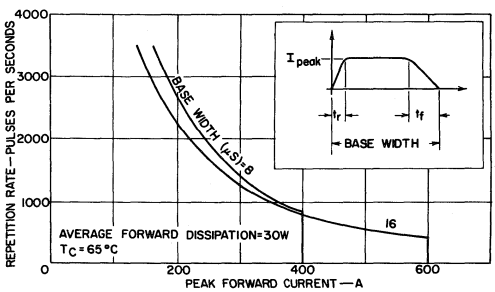


Fig.8 - Peak current as a function of maximum repetition rate for square-wave pulse shapes.

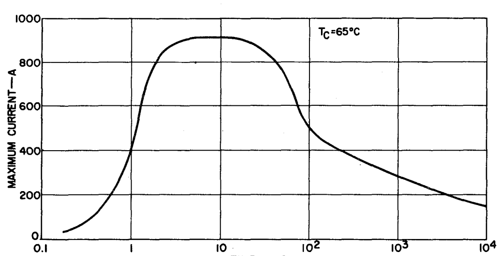
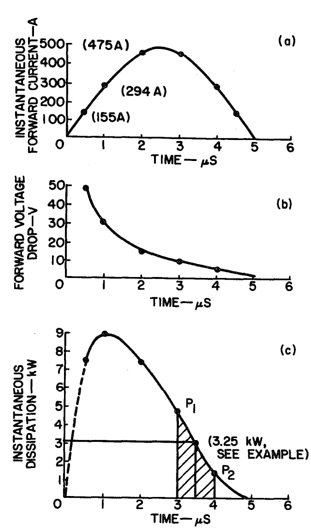


Fig.9 - Maximum permissible current as a function of time after the initiation of turn-on.

shape. In the example shown, the pulse has a peak magnitude of 500 amperes and a base width of 5 microseconds. The curves shown in Fig.10 are constructed from the curves of Figs.5 and 6 by means of a series of readings at different time intervals (delay and fall regions are neglected). A step-by-step approximate integral approach is then used to obtain the watt-seconds-per-pulse measurements shown in the table. For a repetition rate of 1000 pulses per second, the average forward dissipation is 24.37 watts for the current pulse specified. This value is within the rating of 30-watts for the 40216 at a case temperature



(d)

TIME INTERVAL (μS)	DISSIPATION FOR INTERVAL mW-S	TOTAL DISSIPATION FOR ONE PULSE mW-S	AVERAGE DISSIPATION AT 1000 C/S REP. RATE (W)	MAXIMUM REP. RATE FOR 30W DISSIPATION (C/S)
0–0.5	1.87	24.37	24.37	1225
0.5–1	4.12			
1–2	8.25			
2–3	6.18			
3–4	3.25			
4–5	0.70			

EXAMPLE: AVERAGE FORWARD WATT-SECOND DISSIPATION DURING 3μS TO 4μS INTERVAL:
$(4-3) \times 10^{-6}$ S $\times 3.25 \times 10^{3}$ W $=3.25$mW-S

Fig.10 - Sample calculation of forward dissipation.

of 65°C. At higher case temperatures the total dissipation must be decreased, as shown in Fig.11.

Because the interval of highest dissipation occurs at the beginning of the current pulse, reduction in the magnitude of current during this time increases the over-all switching capability of the SCR. The current may be reduced by use of a saturable reactor in the pulse-discharge circuit which has sufficient unsaturated volt-second capacity to present a high impedance for one to two microseconds. The current is then small, and dissipation is limited, until the junction area in conduction increases to include an appreciable percentage of the total cathode. By the time the reactor saturates and high pulse current results, the cathode area in conduction is adequate to handle the high current with low dissipation.

The rate of current spread over the cathode area depends upon several factors, one of which is the level of current. Therefore, the use of a delay reactor to keep forward current low also delays the spread of current to some extent and subtracts from its beneficial effects. The maximum benefit can be achieved by reduction of the inductance of the reactor prior to saturation, or by addition of another impedance in parallel with the reactor, to effect a compromise between the initial current level and dissipation and the rate of current-density equalization. The curves in this Note do not represent the use of a delay reactor.

In addition to the power loss in the SCR caused by forward current, the total dissipation in the device includes forward and reverse blocking losses and probably reverse recovery losses during the turn-off process. The reverse recovery losses depend upon several factors, such as forward-current amplitude, rate of decrease of forward current, reverse-current flow, rate of rise of reverse voltage, and reverse-voltage amplitude. Because reverse losses are circuit-dependent, they can best be evaluated in a working circuit.

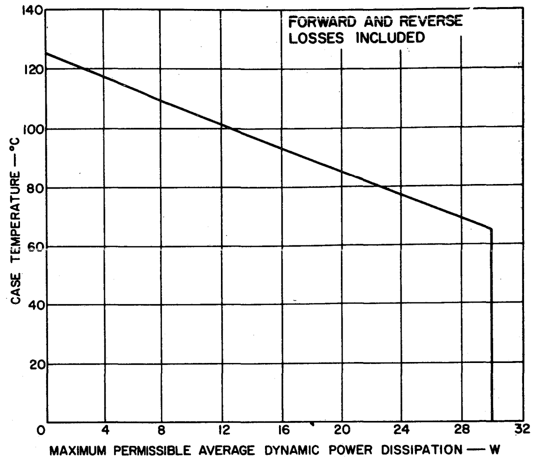


Fig.11 - Maximum average total power dissipation as a function of case temperature.

RCA

Solid State
Division

Thyristors
Application Note
AN-3469

Application of RCA Silicon Controlled Rectifiers to the Control of Universal Motors

by
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Silicon controlled rectifiers have been widely accepted in power-control applications in industrial systems where high-performance requirements justify the economics of the application. Historically, in the commercial high-volume market, economic considerations have precluded the use of the SCR. However, with the development of a family of SCR's by RCA designed specifically for mass-production economy and rated for 120- and 240-volt line operation, the use of these devices in controls for many types of small electric motors has been made economically feasible. The controls can be designed to provide good performance, maximum efficiency, and high reliability in compact packaging arrangements.

The control circuits discussed in the following text are typical of the many possible circuits applicable to electric motor control. A general description including the typical characteristics of universal motors is given. Speed control by use of phase-angle variations is discussed; schematic diagrams are given, and the advantages and limitations of each circuit are contrasted. A chart of available SCR's is shown at the end of the Note.

Universal Motors

Many fractional horsepower motors are series-wound "universal" motors, so named because of their ability to operate directly from either ac or dc power sources. Fig.1 is a schematic of this type of motor operated from an ac supply. Because most domestic applications today require 60-hertz power, universal motors are usually designed to have optimum performance characteristics at this frequency. Most universal motors run faster at a given dc voltage than at the same 60-hertz ac voltage.

The field winding of a universal motor, whether distributed or lumped (salient pole), is in series with the armature and external circuit, as shown in Fig.1.

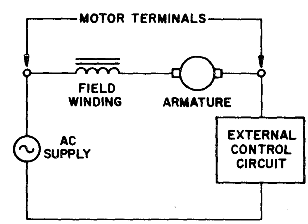


Fig.1 - Schematic diagram for a series-wound universal motor.

The current through the field winding produces a magnetic field which cuts across the armature conductors. The action of this field in opposition to the field set up by the armature current subjects the individual conductors to a lateral thrust which results in armature rotation.

AC operation of a universal motor is possible because of the nature of its electrical connections. As the ac source voltage reverses every half-cycle, the magnetic field produced by the field winding reverses its direction simultaneously. Because the armature windings are in series with the field windings through the brushes and commutating segments, the current through the armature winding also reverses. Because both the magnetic field and armature current are reversed, the direction of the lateral thrust on the armature windings remains constant.

As the armature rotates through the magnetic field, a voltage opposite to the impressed voltage is induced in the individual conductors. Counter emf produced in the armature conductors is therefore proportional to motor speed. In half-wave operation, during the non-conducting half-cycle of an SCR, the rotating armature still produces a counter emf because of the residual magnetism of the field poles. In some of the applications described, the counter emf of an operating motor is used as a means of providing speed regulation to compensate for changing shaft loads.

The current through an operating motor armature depends upon the difference between the impressed voltage (emf) and the counter emf. The current that flows through a universal motor when it is initially energized is large because there is no rotation to generate a counter emf in the armature windings. The starting current is limited only by the impedance of the armature and field windings. The ratio of peak starting current to peak running current can be as high as 10:1.

The speed of a series motor automatically adjusts itself so that the difference between the impressed voltage and the counter emf is sufficient to permit enough current to flow to develop the torque required by the load. At very light loads, or at no load, the current through a universal motor is small. To maintain a small current through the motor, the counter emf must be high enough so that only a small difference exists between the impressed voltage and the counter emf. The small current through the motor also results in a weak magnetic-field flux because it is the current through the field winding that produces the flux. The weakened magnetic-field flux tends to make the motor speed increase even further to produce the high counter emf required to maintain a small motor current. It would appear, then, that universal motors should tend to "run away" at no load. This run-away does not occur, however, because motors of this type usually offer enough friction and windage loss to limit the maximum attainable no-load speed to a safe value.

When a mechanical load is attached to a universal motor, the current through the motor must increase to provide the increased torque required by the load. An increase in the current through the motor requires an increase in the difference between the impressed voltage and the counter emf. This increased difference can only be brought about by a reduction in counter emf derived from a decrease in speed. For an uncompensated universal motor, the full-load speed is approximately 60 per cent or less of the no-load speed.

The torque developed by a universal motor is a direct result of the magnitude of magnetic-field flux and armature current. For fixed mechanical loads, the starting torque of a universal motor is high because the armature current at starting time is high; at "stall" conditions, because of the large armature current, the torque is again high. The stall torque of a series motor can be as high as 10 times the continuous rated torque.

Because torque and armature current influence the speed of a universal motor, it is possible under certain operating conditions to vary the impressed voltage and influence operating characteristics of the motor. For increased mechanical loads, an increase in the impressed voltage produces a larger armature current and tends to keep the speed constant. High starting torque, adjustable speed characteristics, and small size are distinct advantages of a universal motor over a comparably rated single-phase induction motor. Typical performance characteristic curves for a universal motor are shown in Fig.2.

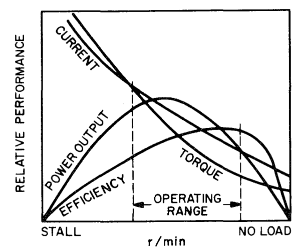


Fig.2 - Typical performance curves for a universal motor.

Use of Silicon Controlled Rectifiers for Motor Control

One of the simplest and most efficient means of varying the impressed voltage to a load on an ac power system is by control of the conduction angle of an SCR placed in series with the load. Typical curves showing the variation of motor speed with SCR conduction angle for both half-wave and full-wave impressed motor voltages are illustrated in Fig.3. If desired, a switch may be installed in the half-wave circuits so that the SCR and its related control circuit can be bypassed for full-power operation.

Half-Wave Control

There are many good circuits available for half-wave control of universal motors; their attributes and limitations are described in detail below. The circuits are divided into two classes; regulating and non-regulating. Regulation in this instance implies load sensing and compensation of the system to prevent changes in

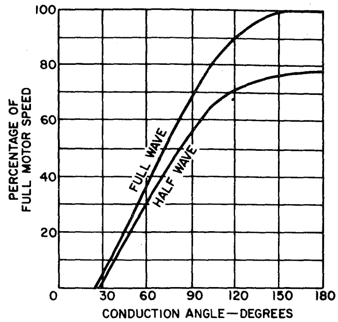


Fig.3 - Typical performance curves for a universal motor with phase-angle control.

motor speed. The type of regulation provided by each circuit is stated and compared to other circuits.

The half-wave proportional control circuit shown in Fig.4 is a non-regulating circuit whose function depends upon an RC delay network for gate phase-lag control. This circuit is better than simple resistance firing circuits because the phase-shifting characteristics of the RC network permit the firing of the SCR beyond the peak of the impressed voltage, resulting in small conduction angles and very slow speed.

The control circuit shown in Fig.4 uses the breakdown voltage of a neon lamp as a threshold setting for firing the SCR. The neon lamp is specifically designed for handling the high-current pulses required to trigger SCR's. When the voltage across capacitor C reaches the breakdown voltage of the neon lamp, the lamp fires, and C discharges through the lamp to its maintaining voltage. At this point, the lamp again reverts to its high-impedance state. The discharge of the capacitor from breakdown to maintaining voltage of the neon lamp provides a current pulse of sufficient magnitude to fire the SCR. Once the SCR has fired, the voltage across the phase-shift network reduces to the forward voltage drop of the SCR for the remainder of the half-cycle. The range of conduction angles of this circuit is approximately 30 to 150 degrees. The high breakdown voltage of the neon lamp improves noise rejection and prevents erratic firing of the SCR because of brush noises on the voltage supply lines. Table I shows components for the circuit of Fig.4.

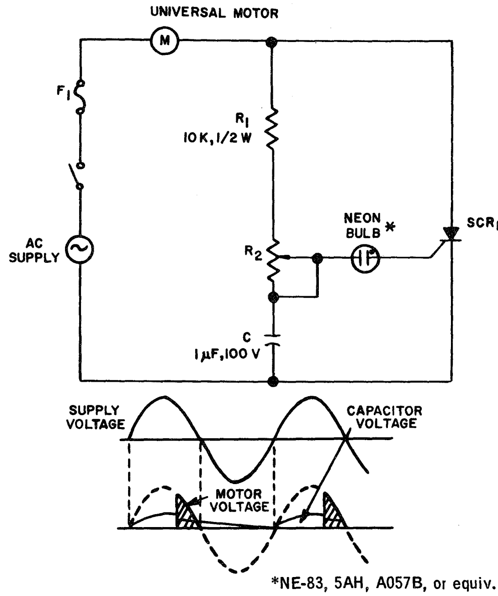


Fig.4 - Half-wave motor control with no regulation.

The circuit shown in Fig.5 reduces spread in gate turn-on characteristics. This circuit depends upon the fast switching characteristics of transistors such as those used in the two-transistor regenerative trigger network shown. The phase-shift characteristics are still retained to provide conduction angles less than 90 degrees through the RC network of R_1, R_2, and C_1. Resistor R_3 provides turn-on current to the base of Q_1 when the voltage across C_1 becomes large enough during the positive half-cycle. The base current in Q_1 turns on this transistor. Transistor Q_1 then supplies base

TABLE I - COMPONENTS FOR CIRCUIT SHOWN IN FIG.4.

AC SUPPLY	AC CURRENT	F_1	CR_1	R_2	SCR_1
120 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3755	100 K, 1/2 W	RCA-2N3528
120 V	3 A	3 AB, 3 A	RCA-1N3755	100 K, 1/2 W	RCA-2N3228
120 V	7 A	3 AB, 7 A	RCA-1N3755	100 K, 1/2 W	RCA-2N3669
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670

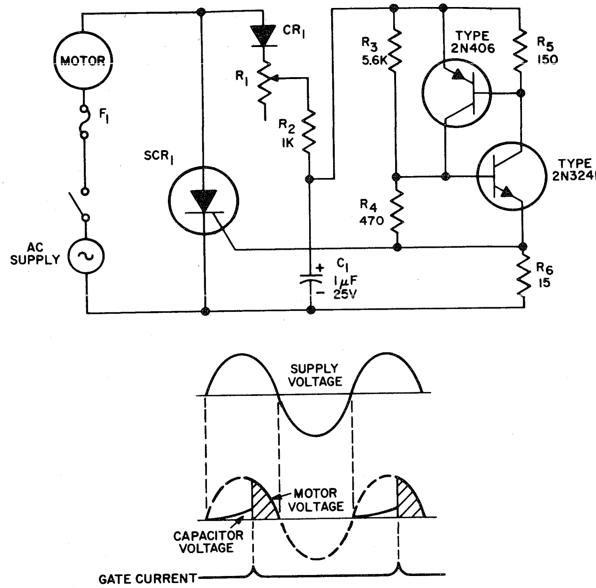


Fig.5 - Half-wave motor control with no regulation.

current to Q_2. When Q_2 turns on, it supplies more base current to Q_1. This regenerative action leads to the rapid saturation of transistors Q_1 and Q_2. Capacitor C_1 discharges through the saturated transistors into the gate of the SCR. When the SCR fires, the remaining portion of the positive half-cycle of ac power is applied to the motor. Speed control is accomplished by adjustment of potentiometer R_1. With component values as shown on the schematic diagram in Fig.5, the threshold voltage for firing the circuit is approximately 8 volts; the maximum conduction angle is approximately 170 degrees. Table II shows components for the circuit with various RCA SCR's.

Fig.6 shows a fundamental circuit of direct-coupled SCR control with voltage feedback. This circuit is highly effective for speed control of universal motors. The circuit makes use of the counter emf (cemf) induced

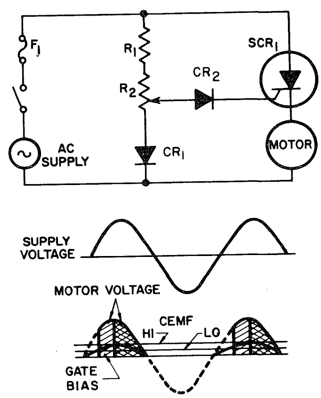


Fig.6 - Half-wave motor control with regulation.

TABLE II - COMPONENTS FOR CIRCUIT SHOWN IN FIG.5.

AC SUPPLY	AC CURRENT	F_1	CR_1	R_1	SCR_1
120 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3755	75 K, 1/2 W	RCA-2N3528
120 V	3 A	3 AB, 3 A	RCA-1N3755	75 K, 1/2 W	RCA-2N3228
120 V	7 A	3 AB, 7 A	RCA-1N3755	75 K, 1/2 W	RCA-2N3669
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670

in the rotating armature because ofthe residual magnetism in the motor on the half-cycle when the SCR is blocking.

The counter emf is a function of speed and, therefore, can be used as an indication of speed changes as mechanical load varies. The gate-firing circuit is a resistance network consisting of R_1 and R_2. During the positive half-cycle of the source voltage, a fraction of the voltage is developed at the center-tap of the potentiometer and is compared with the counter emf developed in the rotating armature of the motor. When the bias developed at the gate of the SCR from the potentiometer exceeds the counter emf of the motor, the SCR fires. AC power is then applied to the motor for the remaining portion of the positive half-cycle. Speed control is accomplished by adjustment of potentiometer R_1. If the SCR is fired early in the cycle, the motor operates at high speed because essentially the full rated line voltage is applied to the motor. If the SCR is fired later in the cycle, the average value of voltage applied to the motor is reduced, and a corresponding reduction in motor speed occurs. On the negative half-cycle, the SCR blocks voltage to the motor. The voltage applied to the gate of the SCR is a sine wave because it is derived from the sine-wave line voltage. The minimum conduction angle occurs at the peak of the sine wave and is restricted to 90 degrees. Increasing conduction angles occur when the gate bias to the SCR is increased to allow firing at voltage values which are less than the peak value.

At no load and at the low-speed control setting, "skip-cycling" operation occurs, and motor speeds are erratic. Because no counter emf is induced in the armature when the motor is standing still, the SCR fires at low bias settings. The motor is then accelerated to a point at which counter emf induced in the rotating armature exceeds the gate-firing bias of the SCR and prevents the SCR from firing. The SCR is not able to fire again until the speed of the motor is reduced (because of friction and windage losses) to a value for which the induced voltage in the rotating armature is less than the gate bias. At this time the SCR fires again. The motor deceleration occurs over a number of cycles when there is no voltage applied to the motor, (hence the term "skip cycling").

When a load is applied to the motor, the motor speed decreases and thus reduces the counter emf induced in the rotating armature. With a reduced counter emf, the SCR fires earlier in the cycle and provides increased motor torque to the load. Fig.6 also shows variations of conduction angle with changes in counter emf. The counter emf appears as a constant voltage at the motor terminals when the SCR is blocking. Because the counter emf is essentially a characteristic of the motor, different potentiometer settings are required for comparable operating conditions for different motors. Circuit values for use with various RCA SCR's are shown in Table III.

Fig.7 shows a variation of the circuit in Fig.5. The basic difference between the two circuits is that the circuit in Fig.7 provides feedback for changing load conditions to minimize changes in motor speed. The feedback is provided by R_7, which is in series with the motor. A voltage proportional to the peak current through the motor is developed across the resistor. This voltage is stored on capacitor C_2 through diode CR_2, and is of a polarity that causes the bias on the resistance network of R_3 and R_4 to change in accordance with the load on the motor. With an increasing motor load, the speed tends to decrease. This decrease in motor speed causes more current to flow through the motor armature and field windings. When the current flowing through R_7 increases, the voltage stored on capacitor C_2 increases in the positive direction. This increase in capacitor voltage causes the transistors to conduct earlier in the cycle, to fire the SCR, and to provide a greater portion of the power cycle to the motor. With a decreasing load, the motor current decreases and the voltage stored by capacitor C_2 decreases. The transistors and SCR then conduct later in the cycle. The resultant reduction in the average power supplied to the motor causes a reduced torque to the smaller load. Because motor current is a function of the motor itself, resistor R_7 has to be matched with the motor rating to provide optimum feedback for load compensation. Resistor R_7 may range from 0.1 ohm for

TABLE III - COMPONENTS FOR CIRCUIT SHOWN IN FIG.6.

AC SUPPLY	AC CURRENT	F_1	CR_1, CR_2	R_1	R_2	SCR_1
120 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3755	5.6 K, 2 W	1 K, 2 W	RCA-2N3528
120 V	3 A	3 AB, 3 A	RCA-1N3755	5.6 K, 2 W	1 K, 2 W	RCA-2N3228
120 V	7 A	3 AB, 7 A	RCA-1N3755	2.7 K, 4 W	500, 2 W	RCA-2N3669
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	10 K, 5 W	1 K, 2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	10 K, 5 W	1 K, 2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	5.6 K, 7.5 W	500, 2 W	RCA-2N3670

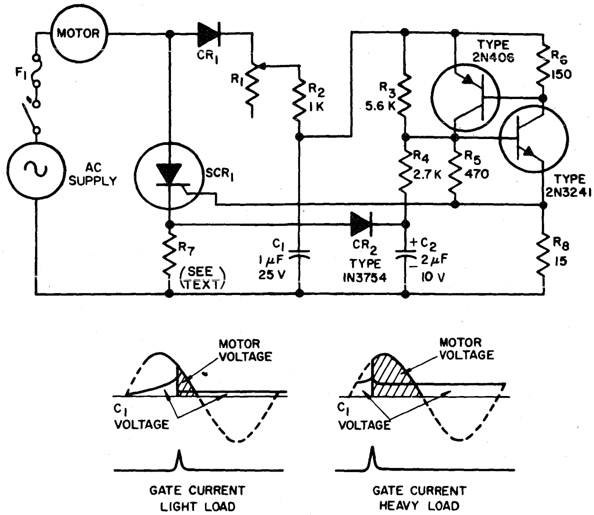


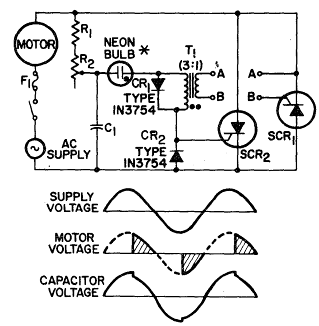
Fig.7 - Half-wave motor control using two-transistor regenerative triggering with regulation.

larger-size universal motors to 1.0 ohm for smaller types. Circuit values for use with various RCA SCR's are shown in Table IV.

Full-Wave Control

This section discusses the application of SCR's to full-wave motor control. Two SCR's are usually required to provide full-wave control.

A very simple SCR full-wave proportional control circuit is shown in Fig.8. Again, ac phase shifting and neon triggering are used to provide gate phase-angle control; a small pulse transformer is utilized for isolation. The circuit provides a symmetrical output for both halves of the ac input voltage because the same electrical components are used in the phasing network for both SCR gates. Because the SCR gate circuits are completely isolated from each other, the cross-talk problem usually associated with gate firing circuits using transformer coupling and bi-directional trigger devices is avoided. There is a hysteresis effect associated with this circuit because C_1 charges to alternate positive and negative values. As R_2 decreases from



*NE-83, 5AH, A057B, or equiv.
T_1 - Better Coil and Transformer Co. Type 99A16, or equiv.

Fig.8 - Full-wave motor control with no regulation.

TABLE IV - COMPONENTS FOR CIRCUIT SHOWN IN FIG.7.

AC SUPPLY	AC CURRENT	F_1	CR_1	R_1	SCR_1
120 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3755	75 K, 1/2 W	RCA-2N3528
120 V	3 A	3 AB, 3 A	RCA-1N3755	75 K, 1/2 W	RCA-2N3228
120 V	7 A	3 AB, 7 A	RCA-1N3755	75 K, 1/2 W	RCA-2N3669
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670

its maximum value, C_1 charges to a higher voltage on each half cycle. When the positive half-cycle voltage on C_1 reaches the breakdown potential of the neon lamp, the lamp fires, allowing C_1 to discharge to the maintaining voltage of the lamp through CR_1 and the lamp into the gate of SCR_2. When SCR_2 fires, the voltage across the control circuit drops to the forward voltage value of the SCR, allowing C_1 to discharge. On the next half-cycle, C_1 charges from a lower positive potential and allows the neon lamp to fire earlier in the cycle. If the potentiometer resistance R_2 is increased, the SCR's fire at a reduced conduction angle and the hysteresis effect is produced. On the negative half-cycle, when the charge on C_1 has reached the breakdown potential of the neon lamp, the capacitor discharges through CR_2, the lamp, and the primary of transformer T_1 to the maintaining voltage of the neon lamp. The current pulse formed by the discharge of C_1 is coupled by T_1 into the gate of SCR_1. For 60-hertz operation, the transformer characteristics are not critical because the magnitude and shape of the current firing pulse are determined primarily by the charge on the capacitor and the characteristics of the neon lamp. Circuit values for use with various RCA SCR's are shown in Table V. Conduction angles obtained with this circuit vary from 30 to 150 degrees; at the maximum conduction angle, the voltage impressed upon the load (universal motor) is approximately 95 per cent of the input rms voltage.

Fig.9 shows a full-wave control circuit that has increased conduction-angle capability. Table VI shows the component chart for use of the circuit with various SCR's. The threshold point of the transistor circuit can be changed by varying the value of R_3. The phase-shift network composed of R_1, R_2, and C_1 permits the variation of conduction angles from minimum to maximum. An ac potential impressed upon this phase-shifting network eliminates skip-cycling at low conduction angles. The bridge network of CR_1, CR_2, CR_3, and CR_4 rectifies the ac voltage developed across C_1 and provides the switching transistors with dc voltage. When the switching transistors are on and saturated, capacitor C_1 discharges through them into the primary of T_1. Because both SCR's receive the same gate polarity pulse, the pulse formed by C_1 and T_1 fires that SCR with a positive potential at the anode. When the SCR fires, the remaining portion of the half-cycle is applied to the load. On the alternate half-cycle, the other SCR turns on. With the component values shown in Fig.9, the threshold voltage required to fire the transistor circuit is approximately 8 volts. Variations in conduction angle are accomplished by changing the setting of R_2. In this circuit, the conduction angles may be varied from 5 to 170 degrees; this larger range is more desirable when higher power is to be controlled.

An SCR full-wave circuit designed for applications requiring feedback for compensation of load changes is shown in Fig.10. Operation is similar to that of the circuits discussed previously except that this circuit has full-wave conduction with proportional control. Again, as in the circuit of Fig.7, R_7 must be matched with the motor rating to provide optimum feedback for load compensation. Resistor R_7 may range from 0.1 ohm for larger-size universal motors to 1.0 ohm for smaller types. Table VII gives a component list for use of this circuit with various SCR's.

Ratings and Limitations

Package size and environment limit the voltage and current capabilities and, consequently, the power-dissipation abilities of an SCR. Maximum temperature ratings usually depend on the use of a heat sink of a particular size at a prescribed ambient or case temperature.

The main cause of heat within an SCR operating at 60 hertz is the forward current and voltage drop during conduction. Under steady-state conditions, the heat generated within the device must be balanced by the flow of heat to the heat sink and the ambient air. If more heat is generated within the SCR than can be dissipated by the case and the heat sink, the junction temperature increases and forward blocking capabilities are lost. Under these conditions the SCR may break down thermally in the reverse direction, causing damage to the SCR pellet. An increase in heat-sink size to maintain the balance between heat generated and heat dissipated assures reliable performance of the SCR.

TABLE V - COMPONENTS FOR CIRCUIT SHOWN IN FIG.8.

AC SUPPLY	AC CURRENT	F_1	R_1	R_2	C_1	SCR_1, SCR_2
120 V	1.5 A	3 AG, 2 A, Quick Act	1 K, 1/2 W	50 K, 1/2 W	0.22 μF, 100 V	RCA-2N3528
120 V	5 A	3 AB, 5 A	1 K, 1/2 W	50 K, 1/2 W	0.22 μF, 100 V	RCA-2N3228
120 V	10 A	3 AB, 10 A	1 K, 1/2 W	25 K, 2 W	0.47 μF, 100 V	RCA-2N3669
240 V	1.5 A	3 AG, 2 A, Quick Act	1 K, 1 W	50 K, 2 W	0.22 μF, 100 V	RCA-2N3529
240 V	5 A	3 AB, 5 A	1 K, 1 W	50 K, 2 W	0.22 μF, 100 V	RCA-2N3525
240 V	10 A	3 AB, 10 A	1 K, 1 W	25 K, 4 W	0.47 μF, 100 V	RCA-2N3670

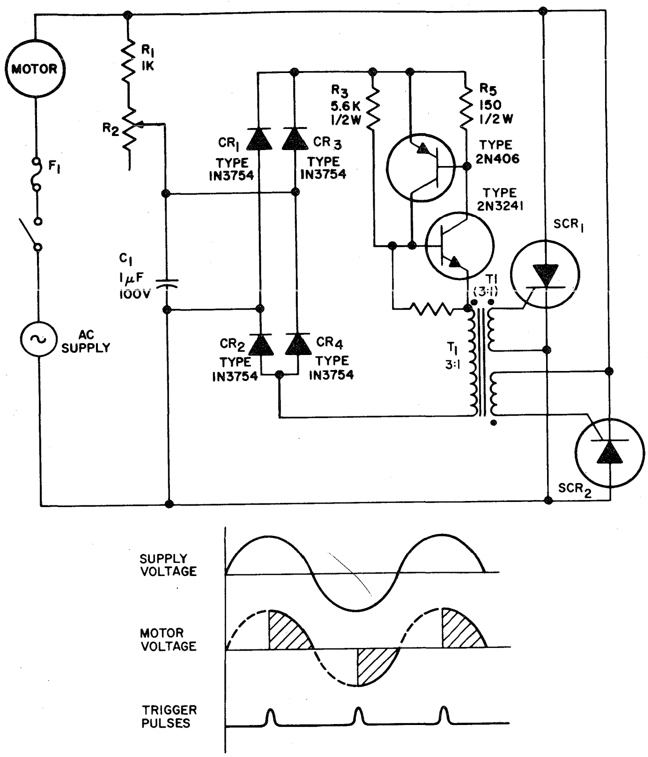


Fig.9 - Full-wave motor control with no regulation in which the conduction angle can be varied from 5 to 180 degrees.

The current ratings for the circuits using the 2N3528 and 2N3529 SCR's are based upon measurements made with these devices mounted by their electrical leads with the package in free air. The current ratings for the circuits using the other SCR types are based upon measurements made with the SCR's mounted on an aluminum heat sink having an equivalent dimension of 3 by 3 by 1/16 inches.

The SCR can be mounted on a single-plate heat sink or on a metal chassis. In chassis mounting the package housing and heat sink can be insulated from the chassis by a mica washer, as shown in Fig.11. The use of silicone grease or other similar material between the SCR housing and the heat sink provides a better thermal contact and more efficient heat dissipation. If heat dissipation is critical, a finned heat sink should

TABLE VI - COMPONENTS FOR CIRCUIT SHOWN IN FIG.9.

AC SUPPLY	AC CURRENT	F_1	R_2	SCR_1, SCR_2
120 V	1.5 A	3 AG, 2 A, Quick Act	75 K, 1/2 W	RCA-2N3528
120 V	5 A	3 AB, 5 A	75 K, 1/2 W	RCA-2N3228
120 V	10 A	3 AB, 10 A	75 K, 1/2 W	RCA-2N3669
240 V	1.5 A	3 AG, 2 A, Quick Act	150 K, 1/2 W	RCA-2N3529
240 V	5 A	3 AB, 5 A	150 K, 1/2 W	RCA-2N3525
240 V	10 A	3 AB, 10 A	150 K, 1/2 W	RCA-2N3670

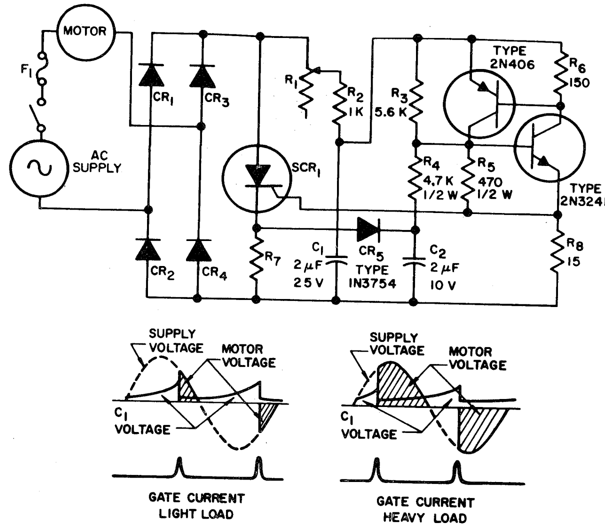


Fig.10 - Full-wave motor control with regulation.

TABLE VII - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 10.

AC SUPPLY	AC CURRENT	F_1	CR_1, CR_2, CR_3, CR_4	R_1	SCR_1
120 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N2860	50 K, 1/2 W	RCA-2N3528
120 V	3 A	3 AB, 3 A	RCA-40110	50 K, 1/2 W	RCA-2N3228
120 V	7 A	3 AB, 7 A	RCA-40110	50 K, 1/2 W	RCA-2N3669
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N2862	100 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-40112	100 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-40112	100 K, 1/2 W	RCA-2N3670

be used. Heat-sink size may be reduced in any application if moving air can be provided at the SCR mounting site.

If a universal motor is operated at low speed under a heavy mechanical load, it may stall and cause heavy current flow through the SCR. For this reason, low-speed heavy-load conditions should be allowed to exist for only a few seconds to prevent possible circuit damage. In any case, fuse ratings should be carefully observed and limited to the types and values indicated in the tables accompanying the circuits in this Note.

Practical heat sinks, packaging, available fuse characteristics, and motor overload and stall performance have been considered and are reflected in the current ratings shown for the circuits in this Note; these current values should not be exceeded.

Nameplate data for some universal motors are given in developed horsepower to the load. This mechanical designation can be converted into its electrical current equivalent through the following procedure.

Internal motor losses are taken into consideration by assigning a figure of merit. This figure, 0.5, represents motor operation at 50-per-cent efficiency, and indicates that the power input to the motor is twice the power delivered to the load. With this figure of merit and the input voltage V_{ac}, the rms input current to the motor can be calculated as follows:

$$\text{rms current} = \frac{\text{mechanical horsepower} \times 746}{0.5\ V_{ac}}$$

For an input voltage of 120 volts, the rms input current becomes:

$$\text{rms current} = \text{horsepower} \times 12.4$$

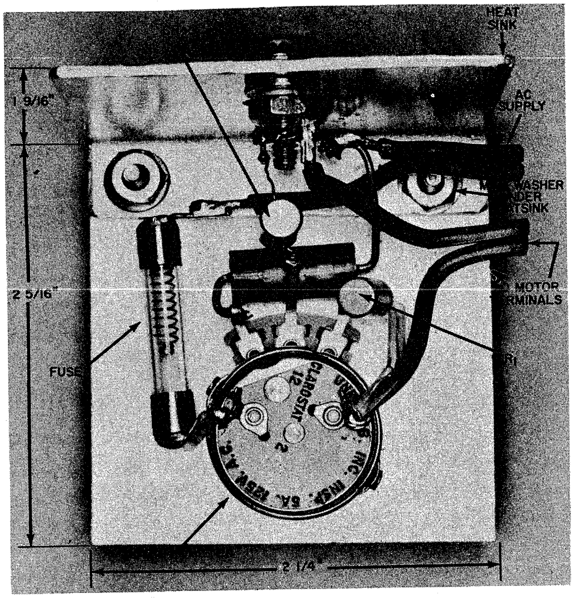


Fig. 11 - Photograph of half-wave motor speed control.

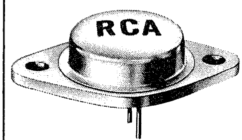
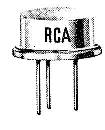
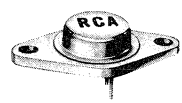
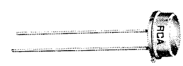
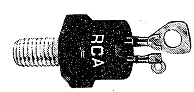
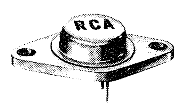
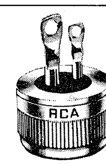
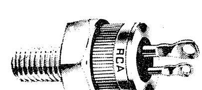
For an input voltage of 240 volts, the rms input current becomes:

rms current = horsepower x 6.2

The circuits in this Note should not be used with universal motors that have calculated rms current exceeding the values given in the tables. The circuits will accommodate universal motors with ratings up to 3/4 horsepower at 120 volts input and up to 1-1/2 horsepower at 240 volts input.

RCA SILICON CONTROLLED RECTIFIERS

(Technical data booklets that completely describe each SCR type shown may be obtained by request to RCA Electronic Components and Devices, Harrison, N.J.)

RCA TYPE NO.	CURRENT - A		CASE TEMP. - °C	VOLTAGE - V	JEDEC PACKAGE
	ave.	rms			
2N3668	8	12.5	80	100	 TO-3
2N3669	8	12.5	80	200§	
2N3670	8	12.5	80	400‡	
2N4103	8	12.5	80	600	
2N3528	1.3	2.0	25*	200§	 TO-8
2N3529	1.3	2.0	25*	400‡	
2N4102	1.3	2.0	25*	600	
2N3228	3.2	5.0	75	200§	 TO-66
2N3525	3.2	5.0	75	400‡	
2N4101	3.2	5.0	75	600	
40378	4.5	7.0	60	200§	 TO-5 Modified
40379	4.5	7.0	60	400‡	
2N681 - 2N690	16	25	65	25 - 600	 TO-48
2N1842A - 2N1850A	10	16	80	25 - 500	
TA2653	3.2	5.0	60	200	 TO-66
TA2654	3.2	5.0	60	400	
TA2655	3.2	5.0	60	600	
2N3870	22	35	65	100	 Press Fit
2N3871	22	35	65	200§	
2N3872	22	35	65	400‡	
2N3873	22	35	65	600	
2N3896	22	35	65	100	 Stud Mounted
2N3897	22	35	65	200§	
2N3898	22	35	65	400‡	
2N3899	22	35	65	600	

* Free-air temperature. § 120-volt line. ‡ 240-volt line.

Solid State Division

Thyristors
Application Note
AN-3551

Circuit Factor Charts for RCA Thyristor Applications (SCR's and Triacs)

by

B. J. Roman and J. M. Neilson

In the design of circuits using thyristors (SCR's and triacs), it is often necessary to determine the specific values of peak, average, and rms current flowing through the device. Although these values are readily determined for conventional rectifiers, the calculations are more difficult for thyristors because the current ratios become functions of both the conduction angle and the firing angle of the device.

This Note presents charts that show several current ratios as functions of conduction and firing angles for some of the basic SCR and triac circuits. Examples are given of the use of these charts in the design of half-wave, full-wave ac, full-wave dc, and three-phase half-wave circuits using RCA thyristors. Current and voltage waveforms for the various circuits are also included, as well as curves of per-cent ripple in load current and voltage.

Current-Ratio Curves

Figs. 1, 2, and 3 show current-ratio curves for a single-phase half-wave SCR circuit with resistive load, a single-phase SCR or triac full-wave circuit with resistive load, and a three-phase half-wave SCR circuit with resistive load, respectively. These curves relate average current I_{avg}, rms current I_{rms}, and peak current I_{pk} to a reference current I_o. This reference current I_o is a constant of the circuit equal to the peak source voltage V_{pk} divided by the load resistance R_L; it represents the maximum value that the current can obtain and corresponds to the peak of the sine wave. The peak current I_{pk} is the current which appears at the thyristor during its period of forward conduction. For conduction angles greater than 90 degrees, I_{pk} is equal to I_o; for conduction angles smaller than 90 degrees, I_{pk} is smaller than I_o.

The curves of Figs. 1, 2, and 3 can be used in a number of ways to calculate desired current values. For example, they can be used to determine the peak or rms current in a thyristor when a specified average current is to be delivered to a load during a given part of the conduction period. It is also possible to work backwards and determine the necessary period of conduction to maintain a specified peak-to-average current ratio in a particular application. Another use is the calculation of rms current at various conduction angles when it is necessary to determine the power delivered to a load, or power losses in transformers, motors, leads, or bus bars. Although the curves represent device currents, they are equally useful for calculation of load current and voltage ratios.

For use of these curves, it is first necessary to identify the unknown or desired parameter. The values of the parameters fixed by the circuit specifications are then determined, and the appropriate curve is used to obtain the unknown quantity as a function of two of the fixed parameters. Examples of the use of the curves are given to illustrate their versatility.

Half-Wave SCR Circuit

In the single-phase half-wave circuit shown in Fig. 4, an RCA-2N3897 is used to control power from a sinusoidal ac source of 120 volts rms (170 volts peak) into a 2.8-ohm load. This application requires a load

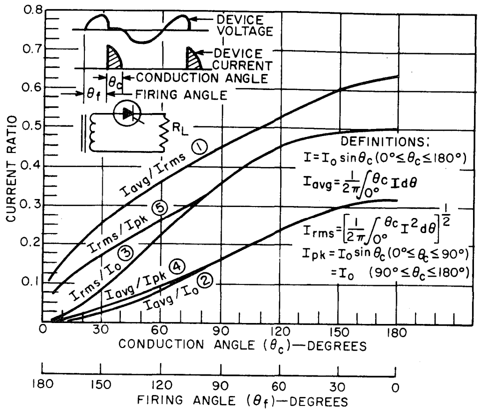


Fig. 1 - SCR current ratios for single-phase, half-wave conduction with resistive load.

current which can be varied from 2 to 25 amperes. It is necessary to determine the range of conduction angles required to obtain this range of load current.

The reference current I_o is first calculated, as follows:

$$I_o = \frac{V_{pk}}{R_L} = \frac{170}{2.8} = 61 \text{ amperes}$$

The ratio of rms current I_{rms} to I_o is then calculated for the maximum and minimum load-current requirements, as follows:

$$(I_{rms}/I_o)_{max} = (25/61) = 0.41$$

$$(I_{rms}/I_o)_{min} = (2/61) = 0.033$$

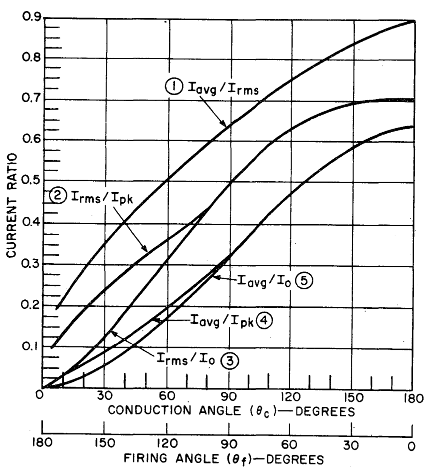


Fig. 2 - SCR or triac current ratios for single-phase, full-wave conduction with resistive load.

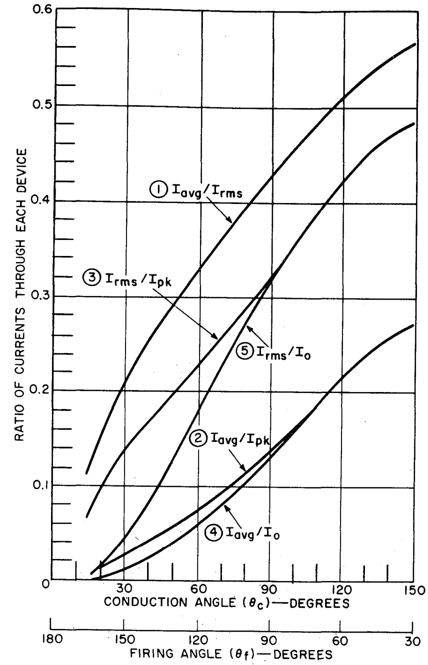


Fig. 3 - SCR current ratios for three-phase half-wave circuit with resistive load.

The conduction angles corresponding to the ratios can then be determined by use of curve 3 in Fig. 1:

$$\theta_c \text{ max} = 106^\circ$$

$$\theta_c \text{ min} = 15^\circ$$

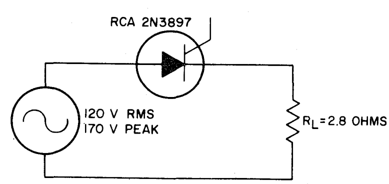


Fig. 4 - Half-wave SCR circuit.

Full-Wave AC Triac Circuit

Fig. 5 shows a circuit in which an RCA-40485 triac is used to control the power to a 20-ohm resistive load. It is desired to find the range of conduction angles the gate circuit must be capable of supplying to provide continuous variation in load power between 5 and 97 per cent of the full power which the load could draw.

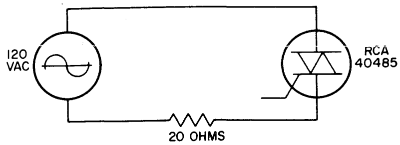


Fig. 5 - Full-wave triac control circuit.

Full power P is given by

$$P = \frac{V_{rms}^2}{R_L} = \frac{120^2}{20} = 720 \text{ watts}$$

Therefore, the 5- and 97-per-cent power points are as follows:

$$P_5 = 36 \text{ watts}$$

$$P_{97} = 698 \text{ watts}$$

The rms current corresponding to each point is given by

$$I_5 = \sqrt{P_5/R_L} = \sqrt{36/20} = 1.3 \text{ amperes rms}$$

$$I_{97} = \sqrt{P_{97}/R_L} = \sqrt{698/20} = 5.9 \text{ amperes rms}$$

The reference current I_o is determined as follows:

$$I_o = \frac{V_{peak}}{R_L} = \frac{120 \times \sqrt{2}}{20} = 8.5 \text{ amperes}$$

The current ratios for the 5- and 97-per-cent power levels then become

at 5%, I_{rms}/I_o = 1.3/8.5 (amperes) = 0.153

at 97%, I_{rms}/I_o = 5.9/8.5 (amperes) = 0.695

Because the circuit shown in Fig. 5 is a full-wave circuit, the calculated current ratios are used in curve 3 of Fig. 2 to determine the required conduction angles:

at 5% power, conduction angle = 35°

at 97% power, conduction angle = 150°

Thus, the load power is continuously variable from 5 to 97 per cent of full load if the gate circuit is constructed so that the conduction angle can be varied between 35 and 150 degrees. This variation is within the range which can be obtained with a simple trigger-diode type of gate circuit.

Full-Wave DC SCR or Triac Circuit

Fig. 6 shows several different SCR circuits and a triac circuit which can be used to supply a constant dc output to a variable load resistance with an ac input of 64 volts rms. It is desired to determine the variation in conduction angle required to maintain the average load current at a constant value of 30 amperes while the load resistance varies between 0.12 and 1.80 ohms.

The reference currents are calculated for maximum and minimum values of load resistance, as follows:

$$I_{o_{max}} = \frac{V_{peak}}{R_{L_{min}}} = \frac{64\sqrt{2}}{0.12} = 750 \text{ amperes}$$

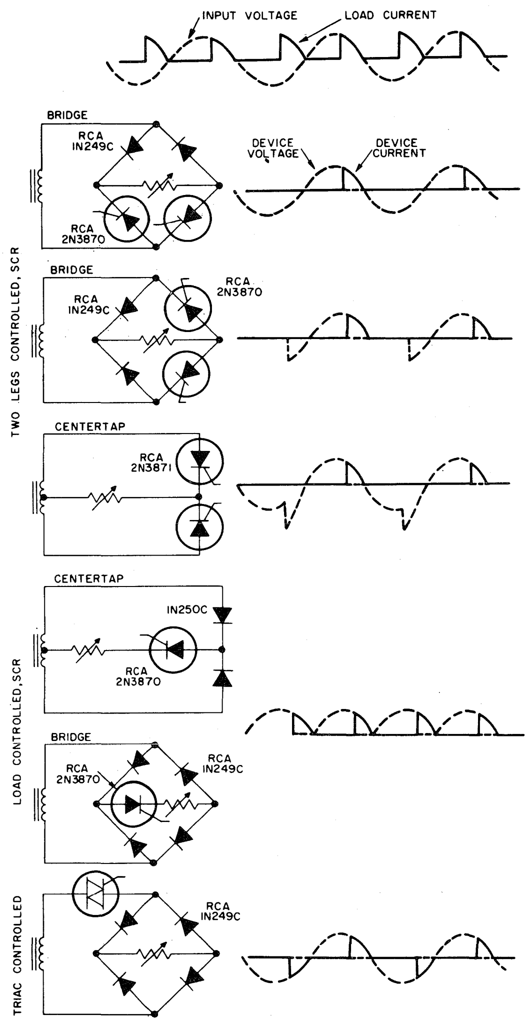


Fig. 6 - Typical current and voltage waveforms for single-phase, full-wave thyristor circuits with resistive load.

$$I_{o_{min}} = \frac{V_{peak}}{R_{L_{max}}} = \frac{64\sqrt{2}}{1.80} = 50 \text{ amperes}$$

The ratios of I_{avg} to I_o for an average load current of 30 amperes are then calculated as follows:

$$\frac{I_{avg}}{I_{o_{max}}} = \frac{30}{750} = 0.04$$

$$\frac{I_{avg}}{I_{o_{min}}} = \frac{30}{50} = 0.60$$

The conduction angles corresponding to these two ratios can then be obtained from curve 5 in Fig. 2:

$$\theta_{c_{min}} = 28^\circ$$

$$\theta_{c_{max}} = 153^\circ$$

Three-Phase Half-Wave SCR Circuit

Fig. 7 shows a three-phase, half-wave circuit that uses three RCA-2N3897 SCR's. In this application, the firing angle can be varied continuously from 30 to 145 degrees. It is desired to determine the resulting variation in the attainable load power. Current and voltage waveforms for SCR's in three-phase, half-wave circuits are shown in Fig. 8.

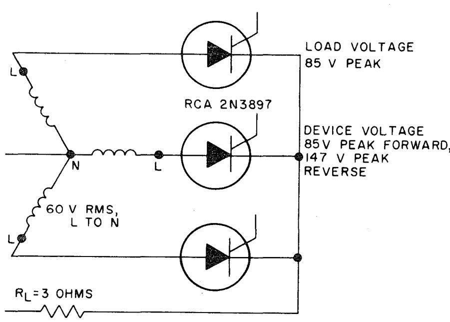


Fig. 7 - Three-phase, half-wave SCR circuit.

Again, the reference current I_o is calculated first, as follows:

$$I_o = \frac{V_L peak}{R_L} = \frac{85}{3} = 28 \text{ amperes}$$

Current ratios at the extremes of the firing range are determined from Fig. 3. For the specified firing angles, the current ratios are given by

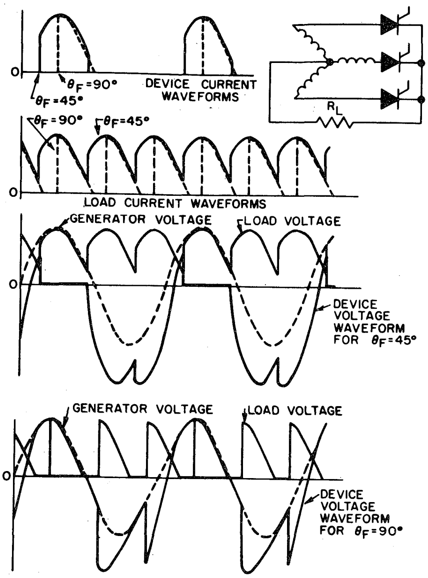


Fig. 8 - Typical current and voltage waveforms for three-phase, half-wave SCR circuit with resistive load.

$$\frac{I_{rms}}{I_o} = 0.49 \text{ for } \theta_f = 30^\circ$$

$$\frac{I_{rms}}{I_o} = 0.06 \text{ for } \theta_f = 145^\circ$$

These ratios, together with the reference current, are then used to determine the range of rms current in the SCR's, as follows:

$$I_{rms} \max = (0.49)(28) = 13.7 \text{ amperes}$$

$$I_{rms} \min = (0.06)(28) = 1.7 \text{ amperes}$$

In this type of circuit, the rms load current is equal to the rms SCR current multiplied by the square root of three. The load power P, therefore, is given by

$$P = (I_{rms}\sqrt{3})^2 (R)$$

The range of load power can then be determined as follows:

$$P_{max} = 1700 \text{ watts}$$

$$P_{min} = 27 \text{ watts}$$

In other words, the load power can be varied continuously from 27 to 1700 watts.

Per-Cent Ripple in Load

The choice of a rectifier circuit for a particular application often depends on the amount of rectifier "ripple" (undesired fluctuation in the dc output caused by an ac component) that can be tolerated in the application. Fig. 9 shows per-cent ripple in load current and voltage for single-phase half-wave, single-phase full-wave, and three-phase half-wave thyristor circuits.

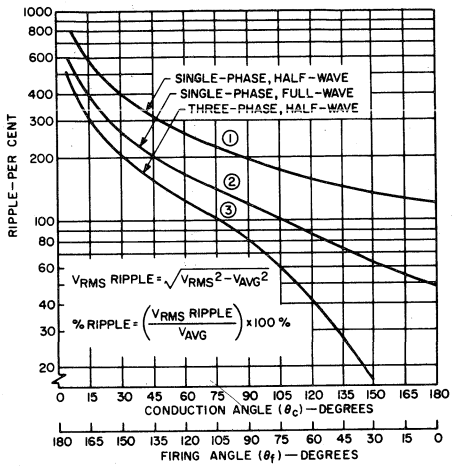


Fig. 9 - Output ripple in thyristor circuits as a function of conduction and firing angles.

Application of RCA Silicon Rectifiers To Capacitive Loads

by

B. J. Roman and J. M. S. Neilson

When rectifiers are used in capacitive-load circuits, the rectifier current waveforms may deviate considerably from their true sinusoidal shape. This deviation is most evident for the peak-to-average current ratio, which is somewhat higher than that for a resistive load. Because of the variation in current waveshapes, calculations of ratings for capacitive-load circuits are generally more complicated and time-consuming than those for resistive-load rectifier circuits.

This Note describes a simplified rating system which allows designers to calculate the characteristics of capacitive-load rectifier circuits quickly and accurately. The effect of the addition of a series limiting resistance to such circuits and the importance of the ratio of the limiting resistance to capacitive reactance are described, and curves of rectifier current ratios are presented as functions of the effective ratio. Typical design examples are given, and output-ripple considerations are discussed. Table I defines the symbols used in the equations and calculations.

Design of Capacitor-Input Circuits

In the design of a rectifier circuit, the output voltage and current, the input voltage, and the ripple and regulation requirements are usually specified. The transformer and the type of rectifier to be used are selected by the designer, and the load resistance is determined on the basis of the output voltage and current requirements. The ripple requirements are satisfied by use of a capacitor to shunt the load R_L, as shown in Fig. 1. The waveforms for this circuit indicate that the voltage across the capacitor E_C coincides with the supply voltage E when the rectifier is conducting in the forward direction. A high initial diode surge current I_S occurs because the capacitor acts as a short circuit when power is first applied. The diode turns off at the peak of the curve (point0), and remains off until E_C is again equal to E (point A). The turn on point t_{on} is determined by the time constant R_LC, and affects the average, peak, and rms currents through the device.

As stated above, the low forward voltage drop of silicon rectifiers may result in a very high surge of current when the capacitive load is first energized. Although the generator or source impedance may be high

Table I – Definition of Symbols

E	=	sinsusoidal input voltage ($E = E_o \sin \omega t$)
E_o	=	peak input voltage
E_{avg}	=	average output voltage
f	=	input frequency (Hz)
ω	=	angular frequency of input ($\omega = 2\pi f$ radians per second)
t	=	time counted from beginning of cycle
R_S	=	limiting resistance
R_L	=	load resistance
C	=	load capacitance
I_o	=	absolute peak current through rectifier
I_{pk}	=	actual peak current through rectifier
Irms	=	root-mean-squafe current through rectifier
I_{avg}	=	average current through rectifier
n	=	charge factor; 1 for half-wave circuit, ½ for doubler circuit, 2 for full-wave circuit

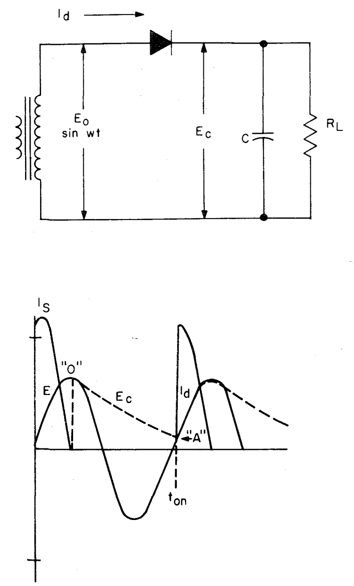


Fig.1 - Circuit showing use of capacitor to shunt the load, and resulting waveforms.

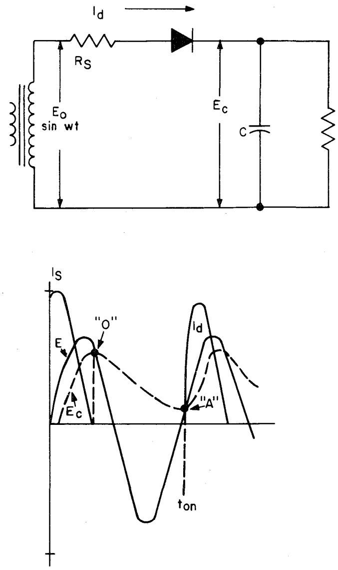


Fig.2 - Circuit showing addition of limiting resistance, and resulting waveforms.

enough to protect the rectifier, in some cases additional resistance must be added to the generator-rectifier-capacitor loop, as shown in Fig.2, to keep the surge within device ratings. The waveforms in Fig.2 show that the capacitor voltage E_C is no longer coincident with the steady state supply voltage E during any part of the cycle. The sum of the additional limiting resistance plus the source resistance is referred to as the total limiting resistance R_S. The ratio of R_S to capacitive reactance $1/\omega C$ is an important consideration in capacitor-input rectifier circuits; ideally, R_S should be much smaller than $1/\omega C$. The magnitude of R_S required in a particular circuit is calculated as described below.

Calculation of Limiting Resistance

The value of resistance required to protect the rectifier is calculated from the surge rating chart for the particular device used. Fig. 3 shows surge rating charts for the RCA CR100 and CR200 series of diffused junction stack rectifiers. Each point on the curves defines a surge rating by indicating the maximum time for which the device can safely carry a specific value of rms current.

With a capacitive load, maximum surge current occurs if the circuit is switched on when the input voltage is near its peak value. When the time constant R_SC of the surge loop is much smaller than the period of the

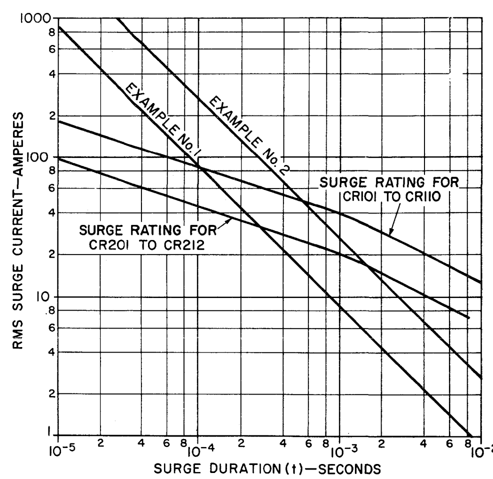


Fig.3 - Surge-rating chart used for calculation of limiting resistance.

input voltage, the peak current is equal to the peak input voltage E_o divided by the limiting resistance R_S, and the resulting surge I_S approximates an exponentially decaying current with the time constant R_SC, as follows:

$$I_S = (E_o/R_S)\ \exp\ (-1/R_SC) \qquad (1)$$

Surge-current ratings for rectifiers are often given in terms of the rms value of the surge current and the time duration t of the surge, as shown in Fig. 3. For rating purposes, the surge duration t is defined as the time constant R_SC. The rms surge current is then approximated by the following equations:

$$I_{rms} = 0.7\,(E_oC/R_SC) = 0.7\,(E_oC/t) \qquad (2)$$

and

$$I_{rms}\,t = 0.7\,E_oC \qquad (3)$$

The values for E_o and C specified by the circuit design are used in Eq.(3) to obtain an equation which relates the rms surge current I_{rms} to surge duration t. This equation may then be plotted on the surge rating chart. Because R_SC is equal to t, any given value of R_S defines a specific time t, and hence a specific point on the plot of Eq.(3). However, R_S must be large enough to make this point fall below the rating curve.

The following examples illustrate the procedure described for calculating the limiting resistance required in a particular circuit.

Example No. 1: Fig. 4 shows a half-wave rectifier circuit that has a 60-Hz frequency and a peak input voltage E_o of 4950 volts. The values of E_o and C are substituted in Eq.(3) to obtain the value of $I_{rms}t$, as follows:

$$I_{rms}t = 0.7\,(4950)\,(2.5 \times 10^{-6})$$

$$I_{rms}\,t = 0.0086$$

This value is then plotted on the surge-rating chart of Fig. 3 and is found to intersect the CR210 rating curve at 2.7 x 10^{-4} second. The minimum limiting resistance which affords adequate surge protection is then calculated as follows:

$$R_SC \geq 2.7 \times 10^{-4}$$

$$R_S \geq \frac{2.7 \times 10^{-4}}{2.5 \times 10^{-6}} = 108 \text{ ohms}$$

Because the value given for R_S is 150 ohms, the circuit has adequate surge-current protection for the rectifiers.

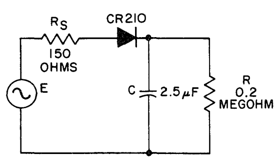


Fig.4 - Half-wave rectifier circuit (E = 3500 V rms, E_o = 3820 V, f = 60 Hz).

Example No. 2: The doubler circuit shown in Fig. 5 has a peak input voltage of 3800 volts and a load capacitance of 10 microfarads. These values are substituted into Eq. (3), as follows:

$$I_{rms}t = (0.7)\,(3800)\,(10^{-5})$$

$$I_{rms}\,t = 0.0266$$

This value is then plotted on Fig.3 and intersects the CR108 rating curve at 5.4 x 10^{-4} second. Therefore, the equation for the time constant is given by

$$R_SC \geq 5.4 \times 10^{-4}$$

$$R_S \geq \frac{5.4 \times 10^{-4}}{10^{-5}} = 54 \text{ ohms}$$

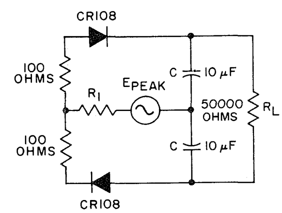


Fig.5 - Voltage-doubler rectifier circuit (E = 2700 V rms, E_o = 3820 V, f = 60 Hz).

Calculation of Rectifier Current

The design of rectifier circuits using capacitive loads often requires the determination of rectifier current waveforms in terms of average, rms, and peak currents. These waveforms are needed for calculations of circuit parameters, selection of components, and matching of circuit parameters with rectifier ratings. Actual calculation of rectifier current is a rather lengthy process. A much more direct process is to use the current-relationship charts shown in Figs. 6 and 7. These curves can be readily used to find peak or rms current if the average current is known, or vice versa.

The ratios of peak-to-average current and rms-to-average current are shown in Fig. 6 as functions of the circuit constants $n\omega CR_L$ and R_S/nR_L. The quantity ωCR_L is the ratio of resistive-to-capacitive reactance in the load, and the quantity R_S/R_L is the ratio of limiting resistance to load resistance. The factor n is referred to as the "charge factor" and is simply a multiplier which allows the chart to be used for various circuit configurations. It is equal to unity for half-wave circuits, ½ for doubler circuits, and 2 for full-wave circuits. (These values actually represent the relative quantity of charge delivered to the capacitor on each cycle).

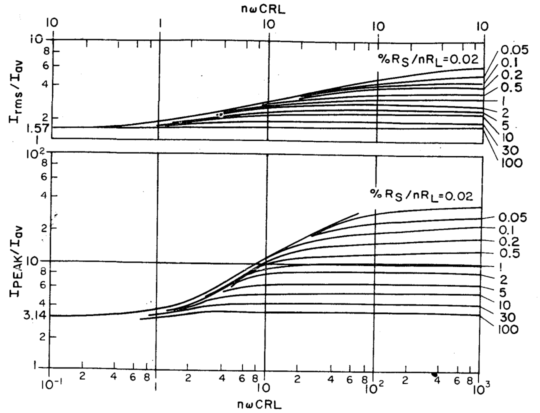


Fig.6 - Relation of peak, average, and rms rectifier currents in capacitor-input circuits.

In many silicon rectifier circuits, R_S may be completely neglected when compared with the magnitude of R_L. In such circuits, the calculation of rectifier current is even more simplified by the use of Fig. 7, which gives current ratios under the limitation that R_S/R_L approaches zero. Even if this condition is not fully satisfied, the use of Fig. 7 merely indicates a higher peak and higher rms current than will actually flow in the circuit; as a result, the rectifiers will operate more conservatively than calculated. This simplified solution can be used whenever a rough approximation or a quick check is needed on whether a rectifier will fit the application. When more exact information is needed, Fig.6 should be used.

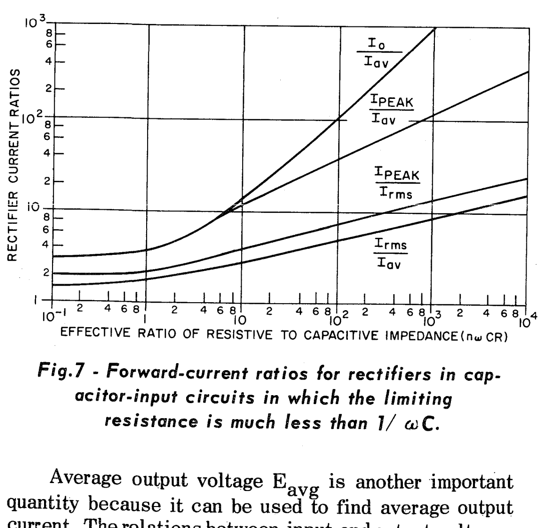


Fig.7 - Forward-current ratios for rectifiers in capacitor-input circuits in which the limiting resistance is much less than 1/ ωC.

Average output voltage E_{avg} is another important quantity because it can be used to find average output current. The relations between input and output voltages for half-wave, voltage-doubler, and full-wave circuits are given in Figs. 8,9, and 10, respectively. Output ripple is shown in Fig. 11 for all three circuits. Although these curves were originally calculated for vacuum-tube rectifiers, they are equally applicable to silicon rectifier circuits.

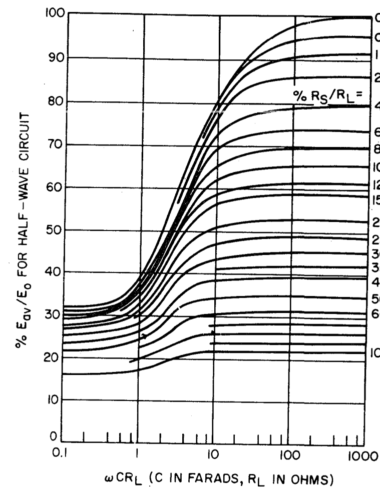


Fig.8 - Relation of applied alternating peak voltage to direct output voltage in half-wave capacitor-input circuits.

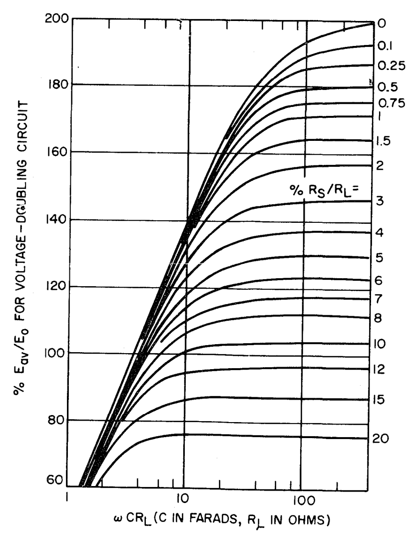


Fig.9 - Relation of applied alternating peak voltage to direct output voltage in capacitor-input voltage doubler circuits.

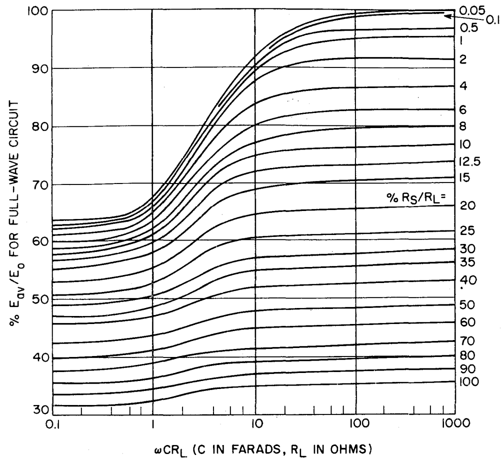


Fig. 10 - Relation of applied alternating peak voltage to direct output voltage in full-wave capacitor-input circuits.

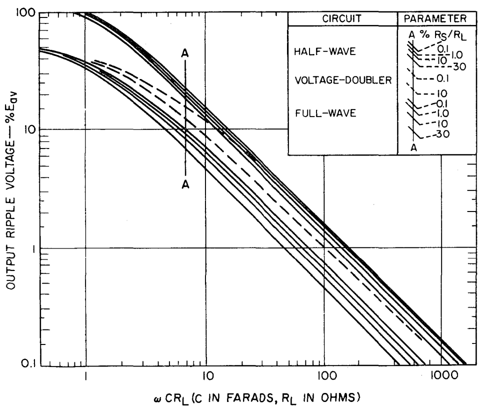


Fig. 11 - RMS ripple voltage of capacitor-input circuits.

The following examples illustrate the use of Figs. 8 through 11 in rectifier-current calculations. Both exact and approximate solutions are given for each example.

Example No. 3: For the half-wave circuit of Fig. 4, the resistive-to-capacitive reactance is found to be:

$$\omega CR_L = (2\pi)(60)\ (2.5 \times 10^{-6})\ (200{,}000)$$

$$\omega CR_L = 189$$

Exact solution using Fig. 6: The ratio of R_S to R_L must first be calculated as follows:

$$\%\ \frac{R_S}{R_L} = \frac{150 \times 100\%}{200{,}000} = 0.075\%$$

The values given above are then plotted in Fig. 8 to determine average output voltage and average output current, as follows:

$$E_{avg}/E_o = 98\%$$

$$E_{avg} = (0.98)\ (4950) = 4850 \text{ volts}$$

$$I_{avg} = E_{avg}/R_L$$

$$I_{avg} = 4850/200{,}000 = 24.2 \text{ milliamperes}$$

This value of I_{avg} is then substituted in the ratio of I_{rms}/I_{avg} obtained from Fig. 6, and the exact value of rms current in the rectifier is determined, as follows:

$$I_{rms}/I_{avg} = 4.4$$

$$I_{rms} = (4.4)\ (24.2) = 107 \text{ milliamperes}$$

Simplified solution using Fig. 7: Average output current is approximately equal to peak input voltage divided by load resistance, as given by

$$I_{avg} = E_o/R_L$$

$$I_{avg} = 4950/200{,}000 = 24.7 \text{ milliamperes}$$

This value of I_{avg} is then substituted in the ratio of I_{rms}/I_{avg} obtained from Fig. 7 and the approximate rms current is determined, as follows:

$$I_{rms}/I_{avg} = 5.7$$

$$I_{rms} = (5.7)\ (24.7) = 141 \text{ milliamperes}$$

Example No. 4: For the doubler circuit of Fig. 5, the resistive-to-capacitive reactance is determined as follows:

$$\omega CR_L = (2\pi)\ (60)\ (10^{-5})\ (50{,}000)$$

$$\omega CR_L = 189$$

$$n\,\omega CR_L = 94$$

Exact solution: The ratio of R_S to R_L is determined as follows:

$$\%\ \frac{R_S}{R_L} = \frac{100 \times 100\%}{50{,}000} = 0.2\%$$

This percentage is then used in conjunction with Fig. 9, and E_{avg} and I_{avg} are determined as follows:

$$E_{avg}/E_o = 186\%$$

$$E_{avg} = (1.86)\ (3820) = 7100 \text{ volts}$$

$$I_{avg} = E_{avg}/R_L$$

$$I_{avg} = 7100/50{,}000 = 142 \text{ milliamperes}$$

The values given above are then plotted in Fig. 6, and the rms current is calculated as follows:

$$I_{rms}/I_{avg} = 3.7$$

$$I_{rms} = (3.7)\ (142) = 525 \text{ milliamperes}$$

Simplified solution: The average output current is given by

$$I_{avg} = 2E_o/R_L$$

$$I_{avg} = (2 \times 3820)/50{,}000 = 153 \text{ milliamperes}$$

This value is then plotted in Fig. 7, and the rms cur- is determined as follows:

$$I_{rms}/I_{avg} = 4.8$$

$$I_{rms} = (4.8)\ (153) = 734 \text{ milliamperes}$$

As previously noted, the simplified solution in both examples predicted a higher rms current than the actual value: about 32 per cent higher in Example No. 3 and 40 per cent higher in Example No. 4. The amount of error involved depends on both ωCR_L and R_S/R_L.

Rating Curves for RMS Current Versus Temperature

In most technical data for rectifiers, the current-versus-temperature ratings are given in terms of average current for a resistive load with 60-Hz sinusoidal input voltage. However, when the ratio of peak-to-average current becomes higher (as with capacitive loads), junction heating effects become more and more dependent on rms current rather than average current. Therefore, the capacitive-load ratings should be obtained from a curve of rms current as a function of temperature. The average current-rating curves for a sinusoidal source and resistive load may be converted to rms-rating curves simply by multiplying the current axis by 1.57 because this value is the ratio of rms-to-average current for such service (as shown by I_{rms}/I_{avg} at low ωCR_L in Figs. 6 and 7). An example of this conversion is shown in Fig. 12 for the CR100- and CR200- series rating curves.

The following examples illustrate the use of the rms current ratings.

Example No. 5: For the half-wave circuit of Fig. 4, it was found in Example No. 3 that the actual rms current in the rectifier is 107 milliamperes. The rms rating curve in Fig. 12 shows that the CR210 may carry up to 107 milliamperes at ambient temperatures up to 115°C.

Example No. 6: For the doubler circuit of Fig. 5, the actual rms current was determined to be 525 milliamperes. The rms rating curve for the CR108 in Fig. 12 shows that the circuit may be operated up to 88° C ambient temperature.

Example No. 7: If the higher values of rms current given by the simplified solution are used instead of the actual currents, the rms rating curves of Fig. 12 also give more conservative ratings because they predict a lower value for the maximum permissible ambient temperature. For example, for the half-wave circuit the exact rms current was found to be 107 milliamperes, and the approximate value was 141 milliamperes. These current values correspond to a maximum ambient temperature rating of 115°C by the exact solution and 110°C by the approximate solution.

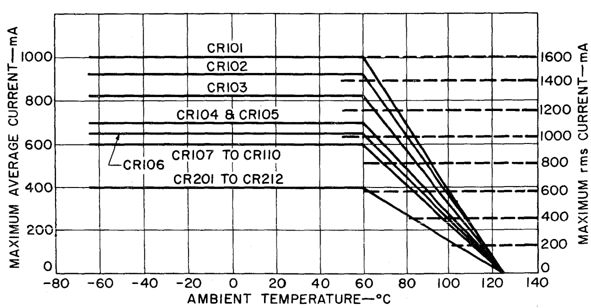


Fig. 12 - Current as a function of temperature for silicon rectifier stacks.

RCA
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Thyristors
Application Note
AN-3697

TRIAC POWER-CONTROL APPLICATIONS

by

J. V. YONUSHKA

In the control of ac power by means of semiconductor devices, emphasis has been placed upon limiting the complexity of the circuits involved, the cost of the system, and the over-all package size. With the development of the bidirectional triode thyristor, commonly known as the triac, all of these goals can be achieved. A triac can perform the functions of two SCR's for full-wave operation and can easily be triggered in either direction to simplify gate circuits. Because they are rated for 120-volt and 240-volt line operation, triacs are readily adaptable for the control of power to any equipment being operated directly from ac power lines. When used for ac power control, triacs add new functions to many designs, improve performance, and provide maximum efficiency and high reliability. This Note describes triac operating characteristics and provides guidance in the use of triacs for specific applications.

Principal Voltage-Current Characteristic Diagram

Fig. 1 shows the principal voltage-current characteristic of a triac. This curve shows the current through the triac as a function of the voltage applied between main terminals Nos. 1 and 2. In quadrant I, the voltage on main terminal No. 2 is positive with respect to main terminal No. 1; in quadrant III, the voltage on main terminal No. 2 is negative with respect to main terminal No. 1. When a positive voltage is applied to main terminal No. 2, as shown by the curve in quadrant I, a point is reached, called the breakover voltage V_{BO}, at which the device switches from a high-impedance state to a low-impedance state. The current can then be increased through the triac with only a small increase in voltage across the device. The triac remains in the ON state until the current through the main terminals drops below a value, called the holding current, which cannot maintain the breakover condition. The triac then reverts again to the high-impedance or OFF state. If the voltage across the main terminals of the triac is reversed, the same switching action occurs as shown by the curve in quadrant III. Thus, the triac is capable of switching from the OFF state to the ON state for either polarity of voltage applied to the main terminals.

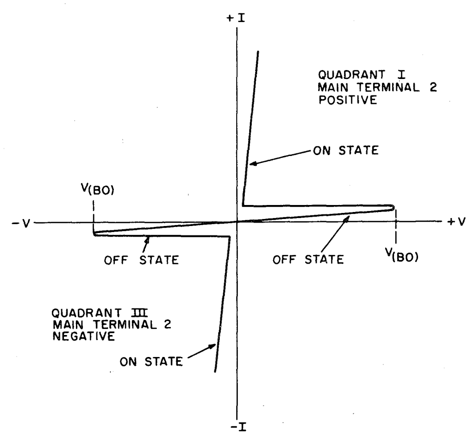


Fig. 1 — Triac principal voltage-current characteristics.

Gate Characteristics

When a trigger current is applied to the gate terminal of a triac, the breakover voltage is reduced. After the triac is triggered, the current flow through the main terminals is independent of the gate signal and the triac remains in the ON state until the principal current is reduced below the holding-current level. The triac has the unique capability of being triggered by either a positive or a negative gate signal regardless of the voltage polarity across the main terminals of the device. Fig. 2 illustrates the triggering mechanism and current flow within a triac. The gate trigger polarity is always referenced to main terminal No. 1. The potential difference between the two terminals is such that gate current flows in the direction indicated by the dotted arrow. The polarity symbol at main terminal No. 2 is also referenced to main terminal No. 1. The semiconductor materials between the various junctions within the pellet are labeled p and n to indicate the type of majority-carrier concentrations within the material.

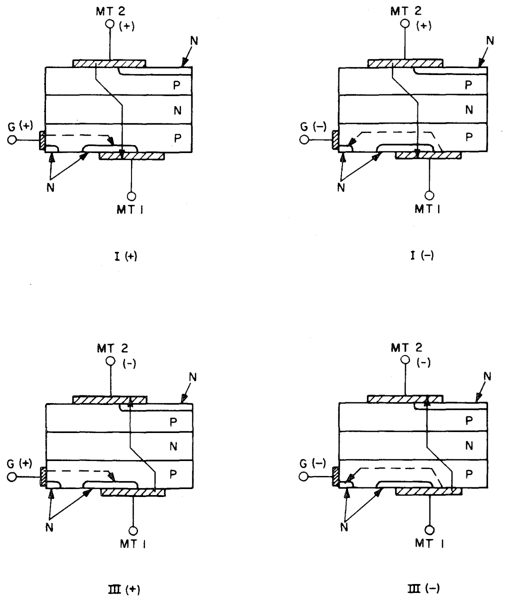


Fig. 2 – Current flow in a triac.

For the various operating modes, the polarity of the voltage on main terminal No. 2 with respect to main terminal No. 1 is given by the quadrant in which the triac operates, (either I or III) and the polarity of the gate signal used to trigger the device is given by the proper symbol next to the operating quadrant. For the I (+) operating mode, therefore, main terminal No. 2 and the gate are both positive with respect to main terminal No. 1. Initial gate current flows into the gate terminal, through the p-type layer, across the junction into the n-type layer, and out main terminal No. 1, as shown by the dotted arrow. As gate current flows, current multiplication occurs and the regenerative action within the pellet switches the triac to its ON state. Because of the polarities indicated between the main terminals, the principal current flows through the pnpn structure as shown by the solid arrow. Similarly, for the other three operating modes, the initial gate current flow is shown by the dotted arrow, and principal current flow through the main terminals is shown by the solid arrow.

Because the principal current influences the gate trigger current, the magnitude of the current required to trigger the triac differs for each mode. The operating modes in which the principal current is in the same direction as the gate current require less gate trigger current, while modes in which the principal current is in opposition to the gate current require more gate trigger current.

Like many other semiconductor parameters, the magnitude of the gate trigger current and voltage varies with the junction temperature. As the thermal excitation of carriers within the semiconductor increases, the increase in leakage current makes it easier for the device to be triggered by a gate signal. Therefore, the gate becomes more sensitive in all operating modes as the junction temperature increases. Conversely, if the triac is to be operated at low temperatures, sufficient gate trigger current must be provided to assure triggering of all devices at the lowest operating temperature expected in any particular application. Variations of gate trigger requirements are given in the data sheets for individual triacs.

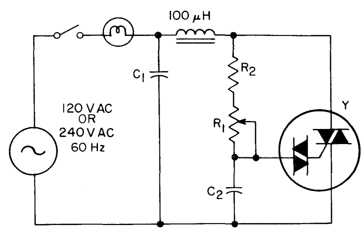
Light Control

Because the light output of an incandescent lamp depends upon the voltage impressed upon the lamp filament, changes in the lamp voltage vary the brightness of the lamp. When ac source voltages are used, a triac can be used in series with an incandescent lamp to vary the voltage to the lamp by changing its conduction angle; i.e., the portion of each half cycle of ac line voltage in which the triac conducts to provide voltage to the lamp filament. The triac, therefore, is very attractive as a switching element in light-dimming applications.

To switch incandescent-lamp loads reliably, a triac must be able to withstand the inrush current of the lamp load. The inrush current is a result of the difference between the cold and hot resistance of the tungsten filament. The cold resistance of the tungsten filament is much lower than the hot resistance. The resulting inrush current is approximately 12 times the normal operating current of the lamp.

The simplest circuit that can be used for light-dimming applications is shown in Fig. 3 and uses a trigger diode in series with the gate of a triac to minimize the variations in gate trigger characteristics. In applications where space is premium the RCA-40431 or RCA-40432 may be used because it combines both functions in a single package. Changes in the resistance in series with the capacitor change the conduction angle of the triac. Because of its simplicity, this circuit can be packaged in confined areas where space is at a premium.

The capacitor in the circuit of Fig. 3 is charged through the control potentiometer and the series resistance. The series resistance is used to protect the potentiometer by limiting the capacitor charging current when the control potentiometer is at its minimum resistance setting. This resistor may be eliminated if the potentiometer can withstand the peak charging current until the triac turns on. The trigger diode conducts when the voltage on the capacitor reaches the diode breakover voltage. The capacitor then discharges through the trigger diode to produce a current pulse of sufficient amplitude and width to trigger the triac. Because the triac can be triggered with either



	120VAC, 60Hz	240VAC, 60Hz
R1	200kΩ, ½W	250kΩ, 1W
R2	3.3kΩ, ½W	4.7kΩ, ½W
C1	0.1μF, 200V	0.1μF, 400V
C2	0.1μF, 100V	0.1μF, 100V
Y	RCA 40431	RCA 40432

Fig. 3 – Single-time-constant light-dimmer circuit.

polarity of gate signal, the same operation occurs on the opposite half-cycle of the applied voltage. The triac, therefore, is triggered and conducts on each half-cycle of the input supply voltage.

The interaction of the RC network and the trigger diode results in a hysteresis effect when the triac is initially triggered at small conduction angles. The hysteresis effect is characterized by a difference in the control potentiometer setting when the triac is first triggered and when the circuit turns off. Fig. 4 shows the interaction between the RC network and the trigger diode to produce the hysteresis effect. The capacitor voltage and the ac line voltage are shown as solid lines. As the resistance in the circuit is decreased from its maximum value, the capacitor voltage reaches a value which fires the trigger diode. This point is designated A on the capacitor-voltage wave-shape. When the trigger diode fires, the capacitor discharges and triggers the triac at an initial conduction angle θ_1. During the forming of the gate trigger pulse, the capacitor voltage drops suddenly. The charge on the capacitor is smaller than when the trigger diode did not conduct. As a result of the different voltage conditions on the capacitor, the breakover voltage of the trigger diode is reached earlier in the next half-cycle. This point is labeled point B on the capacitor-voltage waveform. The conduction angle θ_2 corresponding to point B is greater than θ_1. All succeeding conduction angles

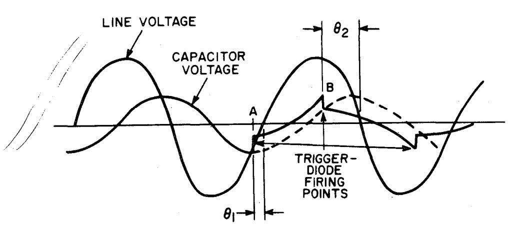
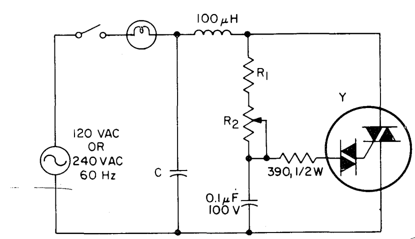


Fig. 4 – Waveforms showing interaction of control network and trigger diode.

are equal to θ_2 in magnitude. When the circuit resistance is increased by a change in the potentiometer setting the triac is still triggered, but at a smaller conduction angle. Eventually, the resistance in series with the capacitance becomes so great that the voltage on the capacitor does not reach the breakover voltage of the trigger diode. The circuit then turns off and does not turn on until the circuit resistance is again reduced to allow the trigger diode to be fired. The hysteresis effect makes the voltage load appear much greater than would normally be expected when the circuit is initially turned on.

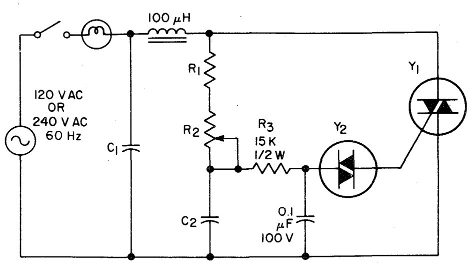
The hysteresis effect can be reduced by use of a resistor in series with the trigger diode and gate, as shown in Fig. 5. The series resistor slows down the discharge of the capacitor through the trigger diode. Consequently, the capacitor does not lose as much charge while triggering the triac, and produces a smaller hysteresis effect. As a result of the slower capacitor discharge through the trigger diode, however, the peak magnitude of the gate trigger current pulse is reduced. The size of the trigger capacitor may have to be increased to compensate for the reduction of the gate trigger current pulse.



	120VAC, 60Hz	240VAC, 60Hz
R1	3.3kΩ, ½W	4.7kΩ, ½W
R2	200kΩ, ½W	250kΩ, 1W
C	0.1μF, 200V	0.1μF, 400V
Y	RCA 40431	RCA 40432

Fig. 5 – Single-time-constant light-dimmer circuit with series gate resistor.

The double-time-constant circuit in Fig. 6 improves on the performance of the single-time-constant control circuit. This circuit uses an additional RC network to extend the phase angle so that the triac can be triggered at small conduction angles. The additional RC network also minimizes the hysteresis effect. Fig. 7 shows the voltage waveforms for the ac supply and the trigger capacitor of the circuit of Fig. 6. Because of the voltage drop across R_3, the input capacitor C_2 charges to a higher voltage than the trigger capacitor C_3. When the voltage on C_3 reaches the breakover voltage of the trigger diode, the diode conducts and causes the capacitor to discharge and produce the gate current pulse to trigger the triac. After the trigger diode turns off, the charge on C_3 is partially restored by



	120VAC, 60Hz	240VAC, 60Hz
R_1	2.2kΩ, ½W	3.3kΩ, ½W
R_2	100kΩ, ½W	200kΩ, 1W
C_1 C_2	0.1μF, 200V	0.1μF, 400V
Y_1	RCA 40485 } or 40431	RCA 40486 } or 40432
Y_2	RCA45412 }	RCA45412 }

Fig. 6 – Double-time-constant light-dimmer circuit.

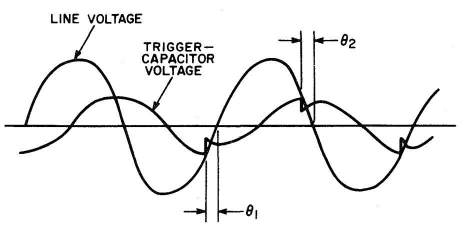
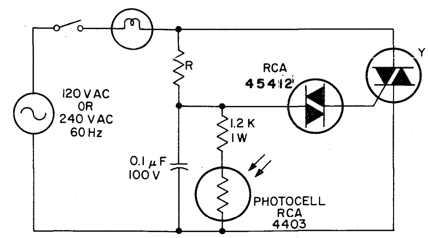


Fig. 7 – Voltage waveforms of double-time-constant control circuit.

the charge from the input capacitor C_2. The partial restoration of charge on C_3 results in better circuit performance with a minimum of hysteresis.

Light-Activated Control

For applications requiring a light-activated circuit, such as outdoor lights or indoor night lights, the circuit shown in Fig. 8 can be employed. Although this circuit functions in the same manner as the light-dimming circuit, the photocell controls its operation. When the light impinges on the surface of the photocell, the resistance of the photocell becomes low and prevents the voltage on the trigger capacitor from increasing to the breakover voltage of the trigger diode. The circuit is then inoperative. When the light source is removed, the photocell becomes a high resistance. The voltage on the trigger capacitor then increases to the breakover voltage of the trigger diode and causes the diode to fire. The trigger pulse formed by the capacitor discharge through the trigger diode makes the triac conduct and operates the circuit. The triac continues to be triggered on each half-cycle and supplies power to the load as long as the resistance of the photocell is high. When light again impinges on the surface of the photocell

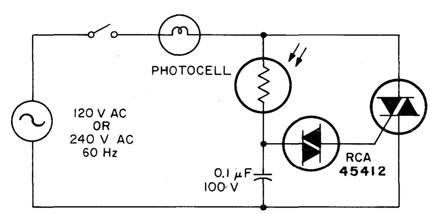


	120VAC, 60Hz	240VAC, 60Hz
R	15kΩ, 2W	30kΩ, 3W
Y	RCA 40485	RCA 40486

Fig. 8 – Light Controlled Turn-Off Circuit.

and reduces its resistance, the voltage on the capacitor can no longer reach the breakover voltage of the trigger diode, and the circuit turns off.

For applications requiring operation when light impinges on the surface of the photocell, the circuit of Fig. 9 is recommended. In this circuit, low resistance of the photocell allows the triac to be triggered on. When light is removed from the photocell the increased resistance of the photocell prevents the triac from being triggered and renders the circuit inoperative.



	120VAC, 60Hz	240VAC, 60Hz
Y	RCA 40485	RCA 40486

Fig. 9 – Light Controlled Turn-On Circuit.

Radio Frequency Interference

The fast switching action of triacs when they turn on into resistive loads causes the current to rise to the instantaneous value determined by the load in a very short period of time. This fast switching action produces a current step which is largely composed of higher-harmonic frequencies that have an amplitude varying inversely as the frequency. In phase-control applications, such as light dimming, this current step is produced on each half-cycle of the input voltage. Because the switching occurs many times a second, a noise pulse is generated into frequency-sensitive devices such as AM radios and causes annoying interference. The amplitude of the higher frequencies in the current step is of such low levels that they do not interfere with television or FM radio.

There are two basic types of radio-frequency interference (RFI) associated with the switching action of triacs. One form, radiated RFI, consists of the high-frequency energy radiated through the air from the equipment. In most cases, this radiated RFI is insignificant unless the radio is located very close to the source of the radiation.

Of more significance is conducted RFI which is carried through the power lines and affects equipment attached to the same power lines. Because the composition of the current waveshape consists of higher frequencies, a simple choke placed in series with the load slows down the current rise time and reduces the amplitude of the higher harmonics. To be effective, however, such a choke must be quite large. A more effective filter, and one that has been found adequate for most light-dimming applications is shown in Fig. 10. The LC filter provides adequate attenuation of the high-frequency harmonics and reduces the noise interference to a low level.

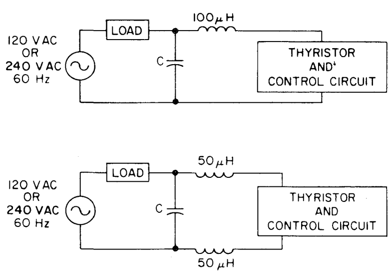


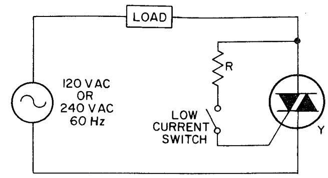
Fig. 10 – RFI-suppression networks: at 120 VAC, C = 0.1 μF, 200 V; at 240 VAC, C = 0.1 μF, 400 V.

Motor Control

Triacs can be used very effectively to apply power to motors and perform such functions as speed control, reversing, full power switching, or any other desired operating condition that can be obtained by a switching action. Because most motors are line-operated, the triac can be used as a direct replacement for electro-mechanical switches. In proper control circuits, triacs can change the operating characteristics of motors to obtain many different speed and torque curves.

A very simple triac static switch for control of ac motors is shown in Fig. 11. The low-current switch controlling the gate trigger current can be any type of transducer, such as a pressure switch, a thermal switch, a photocell, or a magnetic reed relay. This simple type of circuit allows the motor to be switched directly from the transducer switch without any intermediate power switch or relay.

For dc control, the circuit of Fig. 12 can be used. By use of the dc triggering modes, the triac can be directly triggered from transistor circuits by either a pulse or continuous signal.



	120VAC, 60Hz	240VAC, 60Hz
R	1kΩ, ½W	2kΩ, ½W
Y	RCA 40429	RCA 40430

Fig. 11 – Simple Triac Static Switch.

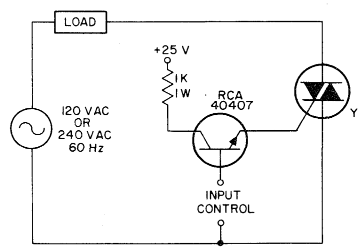
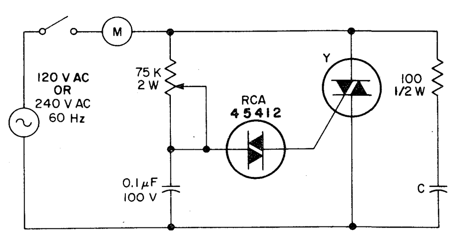


Fig. 12 – AC Triac Switch Control From DC Input: at 120 VAC, Y = RCA 40429; at 240 VAC, Y = RCA 40430.

Induction Motor Controls

Fig. 13 shows a single-time-constant circuit which can be used as a satisfactory proportional speed control for some applications and with certain types of induction motors, such as shaded pole or permanent split-capacitor motors, when the load is fixed. This type of circuit is best suited to applications which require speed control in the medium to full-power range. It is specifically useful in applications such as fans or blower-motor controls, where a small change in motor speed produces a large change in



	120VAC, 60Hz	240VAC, 60Hz
C	0.22μF, 200V	0.22μF, 400V
Y	RCA 40429	RCA 40430

Fig. 13 – Induction motor control.

air velocity. Caution must be exercised if this type of circuit is used with induction motors because the motor may stall suddenly if the speed of the motor is reduced below the drop-out speed for the specific operating condition determined by the conduction angle of the triac. Because the single-time-constant circuit cannot provide speed control of an induction motor load from maximum power to full off, but only down to some fraction of the full-power speed, the effects of hysteresis described previously are not present. Speed ratios as high as 3:1 can be obtained from the single-time-constant circuit used with certain types of induction motors.

Because motors are basically inductive loads and because the triac turns off when the current reduces to zero, the phase difference between the applied voltage and the device current causes the triac to turn off when the source voltage is at a value other than zero. When the triac turns off, the instantaneous value of input voltage is applied directly to the main terminals of the triac. This commutating voltage may have a rate of rise which can retrigger the triac. The commutating dv/dt can be limited to the capability of the triac by use of an RC network across the device, as shown in Fig. 13. The current and voltage waveshapes for the circuit are shown in Fig. 14 to illustrate the principle of commutating dv/dt.

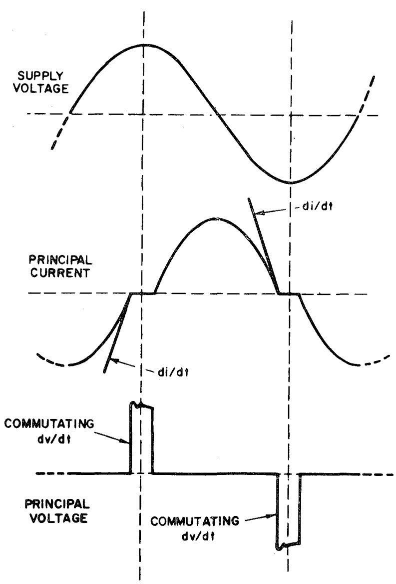
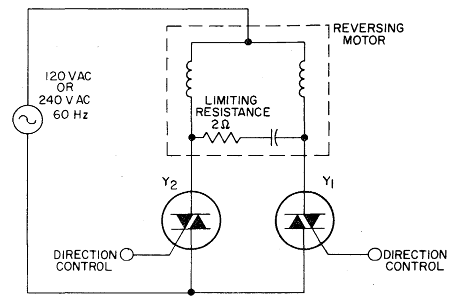


Fig. 14 – Waveshapes of commutating dv/dt characteristics.

Reversing Motor Control

In many industrial applications, it is necessary to reverse the direction of a motor, either manually or by means of an auxiliary circuit. Fig. 15 shows a circuit which uses two triacs to provide this type of reversing motor control. The reversing switch can be either a manual switch or an electronic switch used with some type of sensor to reverse the direction of the motor. A resistance is added in series with the capacitor to limit capacitor discharge current to a safe value whenever both triacs are conducting simultaneously. Simultaneous conduction can easily occur because the triggered triac remains in conduction after the gate is disconnected until the current reduces to zero. In the meantime, the nonconducting-triac gate circuit can be energized so that both triacs are ON and large loop currents are set up in the triacs by the discharge of the capacitor.

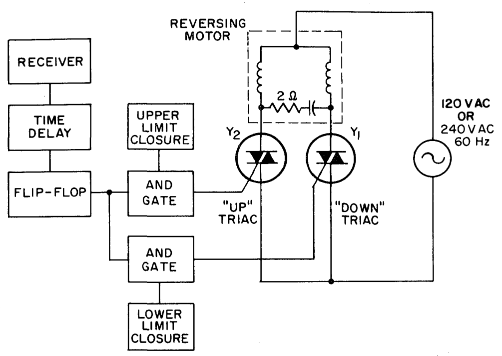


	120VAC, 60Hz	*240VAC, 60Hz*
Y_1	RCA 40485	RCA 40486
Y_2	RCA 40485	RCA 40486

Fig. 15 – Reversing motor control.

Electronic Garage-Door System

The triac motor-reversing circuit can be extended to electronic garage-door systems which use the principle of motor reversing for garage-door direction control. The system contains a transmitter, a receiver, and an operator to provide remote control for door opening and closing. The block diagram in Fig. 16 shows the functions required for a complete solid-state system. When the garage door is closed, the gate drive to the DOWN triac is disabled by the lower-limit closure and the gate drive to the UP triac is inactive because of the state of the flip-flop. If the transmitter is momentarily keyed, the receiver activates the time-delay monostable multivibrator so that it then changes the flip-flop state and provides continuous gate drive to the UP triac. The door then continues to travel in the UP direction until the upper-limit switch closure disables gate drive to the UP triac. A second keying of the transmitter provides the DOWN triac with gate drive and causes the door to travel in the DOWN direction until the gate drive is disabled by the lower limit closure. The time in which the monostable multivibrator is active should override normal transmitter keying for the purpose of eliminating erroneous firing. A feature of this system is that, during travel, transmitter keying provides motor reversing independent of the upper- or lower-limit closures. Additional features, such as obstacle obstructions, manual control, or time delay for overhead garage lights can be achieved very economically.

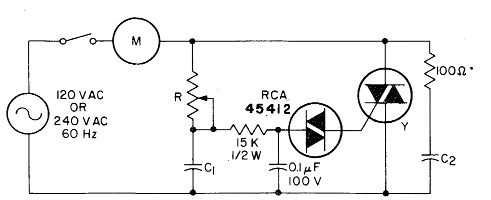


	120VAC, 60Hz	240VAC, 60Hz
Y_1	RCA 40485	RCA 40486
Y_2	RCA 40485	RCA 40486

Fig. 16 – Block diagram for remote-control solid-state garage-door systems.

Universal Motor Speed Controls

In applications in which the hysteresis effect can be tolerated or which require speed control primarily in the medium to full-power range, a single-time-constant circuit such as that shown in Fig. 13 for induction motors can also be used for universal motors. However, it is usually desirable to extend the range of speed control from full-power ON to very low conduction angles. The double-time-constant circuit shown in Fig. 17 provides the delay necessary to trigger the triac at very low conduction angles with a minimum of hysteresis, and also provides practically full power to the load at the minimum-resistance position of the control potentiometer. When this type of control circuit is used, an infinite range of motor speeds can be obtained from very low to full-power speeds.



	120VAC, 60Hz	240VAC, 60Hz
R	100kΩ, ½W	200kΩ, 1W
C_1	0.1μF, 200V	0.1μF, 400V
C_2	0.22μF, 200V	0.22μF, 400V
Y	RCA 40429	RCA 40430

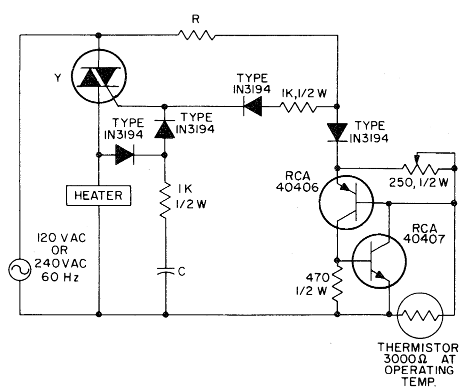
Fig. 17 – Universal Motor Speed Control.

Heat Control

There are three general categories of solid-state control circuits for electric heating elements: on-off control, phase control, and porportional control using integral-cycle synchronous switching. Phase-control circuits, such as those used for light dimming are very effective and efficient for electric heat control except for the problem of RFI. In higher-power applications, the RFI is of such magnitude that suppression circuits to minimize the interference become quite bulky and expensive.

An on-off circuit for the control of resistance-heating elements is shown in Fig. 18. The circuit also provides synchronous switching close to the beginning of the zero-voltage crossing of the input voltage to minimize RFI. The thermistor controls the operation of the two-transistor regenerative switch, which, in turn, controls the operation of the triac. When the temperature being controlled is low, the resistance of the thermistor is high and the regenerative switch is OFF. The triac is then triggered directly from the line on positive half-cycles of the input voltage. When the triac triggers and applies voltage to the load, the capacitor is charged to the peak value of the input voltage. The capacitor discharges through the triac gate to trigger the triac on the opposite half-cycle. The diode-resistor-capacitor "slaving" network triggers the triac on negative half-cycles of the ac input voltage after it is triggered on the positive half-cycle to provide integral cycles of ac power to the load.

When the temperature being controlled reaches the desired value as determined by the thermistor, the transistor regenerative switch conducts at the beginning of the positive input-voltage cycle to shunt the trigger current away from the triac gate. The triac does not conduct as long as the resistance of the thermistor is low enough to make the transistor regenerative switch turn on before the triac can be triggered.



	120VAC, 60Hz	240VAC, 60Hz
R	2.2kΩ, 5W	3.9kΩ, 5W
C	0.5μF, 200V	0.5μF, 400V
Y	RCA 40575	RCA 40576

Fig. 18 – Synchronous switching on-off heat controller.

Proportional Integral-Cycle Control

On-off controls have only two levels of power input to the load. The heating coils are either energized to full power or are at zero power. Because of thermal time constants, on-off controls produce a cyclic action which alternates between thermal overshoots and undershoots with poor resolution.

This disadvantage is overcome and RFI is minimized by use of the concept of integral-cycle proportional control with synchronous switching. In this system, a time base is selected and the on-time of the triac is varied within the time base. The ratio of the on-to-off time of the triac within this time interval depends upon the power required to the heating elements to maintain the desired temperature. Fig. 19 shows the on-off ratio of the triac. Within the time period, the on-time varies by an integral number of cycles from full ON to a single cycle of input voltage.

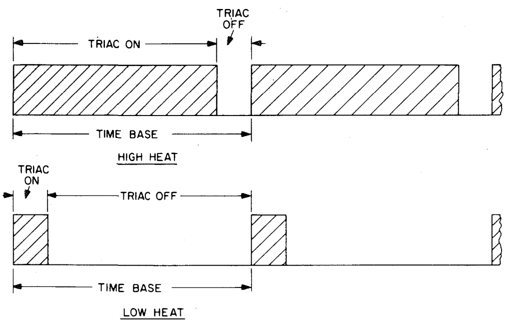


Fig. 19 – Triac duty cycle.

One method of achieving integral cycle proportional control is to use a fixed-frequency sawtooth generator signal which is summed with a dc control signal. The sawtooth generator establishes the period or time base of the system. The dc control signal is obtained from the output of the temperature-sensing network. The principle is illustrated in Fig. 20. As the sawtooth voltage increases, a level is reached which turns on power to the heating elements. As the temperature at the sensor changes, the dc level shifts accordingly and changes the length of time that the power is applied to the heating elements within the established time.

When the demand for heat is high, the dc control signal is high and little power is supplied continuously to the heating elements. When the demand for heat is completely satisfied, the dc control signal is low and no power is supplied to the heating elements. Usually a system using this principle operates continuously somewhere between full ON and full OFF to satisfy the demand for heat.

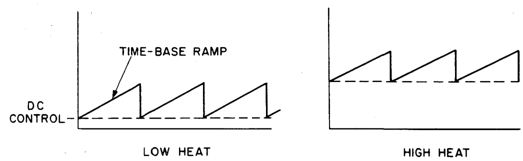
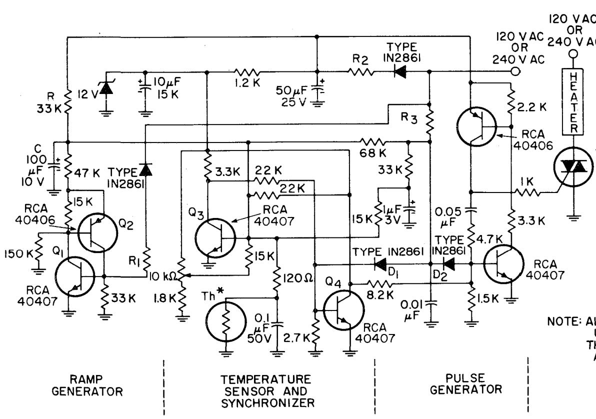


Fig. 20 – Proportional-controller waveshapes.

A proportional integral-cycle heat control system is shown in Fig. 21. The ramp voltage is generated by charging of capacitor C through resistor R for approximately 2 seconds for the values shown. The length of the ramp is determined by the voltage magnitude required to trigger the regenerative switch consisting of Q_1 and Q_2. The temperature sensor consisting of Q_3 and Q_4, together with the controlling thermistor Th, establishes a voltage level at the base of Q_3 which depends upon the resistance value of the thermistor. Q_3 and Q_4 form a bistable multivibrator. The state of the multivibrator depends upon the base bias of Q_3. When Q_3 is conducting, Q_4 is cut off. The pulse generator is energized and generates pulses to trigger the triac. The output of the pulse generator is synchronized to the line voltage on the negative half-cycle by D_2 and R_3 and on the positive half-cycle by D_1 and R_3. The pulses are, therefore, generated at the zero-voltage crossings and trigger the triacs into conduction at only these points.



	120VAC, 60Hz	240VAC, 60Hz
R_1	60kΩ, ½W	120kΩ, ½W
R_2	3.3kΩ, 2W	5.6kΩ, 2W
R_3	33kΩ, ½W	57kΩ, ½W
Y	2N5441 or 2N5444	2N5442 or 2N5445

NOTE: ALL RESISTORS 1/2 W, ±10% UNLESS OTHERWISE SPECIF.
THERMISTOR APPROX. 3000 Ω AT OPERATING TEMP.

Fig. 21 – Proportional integral-cycle heat controller.

RCA Solid State Division

Thyristors Application Note AN-3778

Light Dimmers Using Triacs

by J. M. Neilson

Introduction

A simple, inexpensive light-dimmer circuit contains a diac, triac and RC charge-control network. The diac is a two-terminal ac switch which is changed from the non-conducting state to the conducting state by an appropriate voltage of either polarity. The triac is a three-terminal ac switch which is changed from the non-conducting state to the conducting state when a positive or negative voltage is applied to the gate terminal. This Note describes the use of the diac to trigger the triac in light-dimming circuits. The basic light-control circuit is introduced and its operation described. In addition, the various components added to improve circuit performance are discussed. Three complete circuits are shown, with tables showing the component values to be used for 120-volt, 60-Hz operation and 240-volt, 50/60 Hz operation. Mechanical details involved in building the circuits are also discussed and a trouble-shooting chart is included.

Circuit Description

The triac or bidirectional triode thyristor is a three-terminal solid-state switch. The two power electrodes or main terminals are referred to as T_1 and T_2, and the control electrode is referred to as the gate. Fig. 1 shows the voltage-current characteristic observed between the power electrodes. For either polarity of applied voltage, the device is bistable: the triac exhibits either a high impedance (off state) or a low impedance (on state). The device normally assumes the off state when bias is applied, but can be triggered into the on state by a pulse of current, of either polarity, applied between gate and T_1. The device then remains in the on state until current is reduced close to zero by the external circuitry.

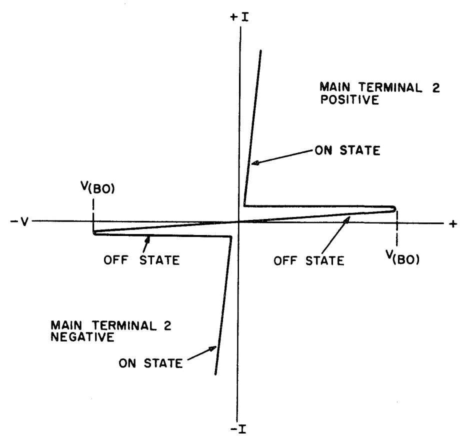


Fig.1 - Voltage-current characteristic of a triac.

The diac or symmetrical trigger diode is a two-terminal bidirectional switch with a voltage-current characteristic as shown in Fig. 2. The device exhibits a high-impedance, low-leakage-current characteristic until the applied voltage reaches the breakover voltage V_{BO}, of the order of 35 volts. Above this voltage the device exhibits a negative resistance, so that voltage decreases as current increases. In light-dimmer circuits a diac is used in conjunction with a capacitor to generate current pulses which trigger the triac into conduction. The voltage on the diac and capacitor increases until it reaches V_{BO}, at which point the diac voltage breaks back and a pulse of current flows as the capacitor discharges.

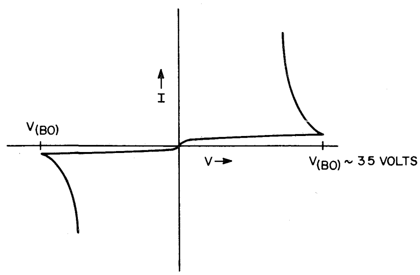


Fig.2 - Voltage-current characteristic of a diac.

Fig. 3 shows the basic triac-diac light control circuit with the triac connected in a series with the load. During the beginning of each half cycle the triac is in the off-state. As a result, the entire line voltage appears across the triac, and none appears across the load. Because the triac is in parallel with the potentiometer and capacitor, the voltage across the triac drives current through the potentiometer and charges the capacitor. When the capacitor voltage reaches the breakover voltage V_{BO} of the diac, the capacitor discharges through the triac gate, turning on the triac. At this point, the line voltage is transferred from the triac to the load for the remainder of that half cycle. This sequence of events is repeated for every half cycle of either polarity. If the potentiometer resistance is reduced, the capacitor charges more rapidly and V_{BO} is reached earlier in the cycle, increasing the power applied to the load and hence the intensity of light. If the potentiometer resistance is increased, triggering occurs later, load power is reduced, and the light intensity is decreased.

Although the basic light-control circuit operates with the component arrangement shown in Fig. 3, additional components and sections are usually added to reduce hysteresis effects, extend the effective range of the light-control potentiometer, and suppress radio-frequency interference.

Hysteresis

As applied to light controls, the term hysteresis refers to a difference in the control potentiometer setting at which the light initially turns-on and the setting at which it is extinguished. With high hysteresis, the control may have to be turned across 35 per cent of its range before the light turns on at all, after which the

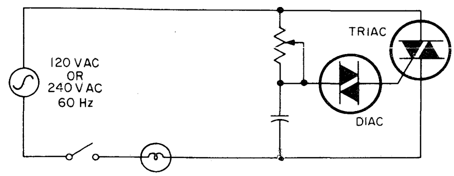


Fig.3 - Basic triac-diac light-control circuit.

control must be turned back to a much lower setting before the light goes completely out.

Besides poor control, hysteresis is undesirable because at low illumination levels, the light may be extinguished by a momentary drop in line voltage. At low illumination levels, the potentiometer is normally turned back beyond the setting at which it initially turned on. When triggering is missed on one half cycle as a result of a momentary drop in line voltage such as that caused by starting a heavy appliance, oil burner, etc., the light may go out and stay out until the control is again turned up to the starting point.

Hysteresis is caused by an abrupt decrease in capacitor voltage when triggering begins. Fig. 4 shows the charging cycle of the capacitor-diac circuit. The large ac sine wave represents the line voltage; the smaller ac sine wave represents the normal charging cycle of the capacitor. Gate triggering occurs at the first point of intersection of the two waves. At this point, however, there is an abrupt decrease in the capacitor voltage (dashed line). As a result, the capacitor begins to charge during the next half cycle at a lower voltage and reaches the trigger voltage in the opposite direction earlier in the cycle (2nd (Actual) Gate Trigger Point). Hysteresis is reduced by maintaining some voltage on the capacitor during gate triggering.

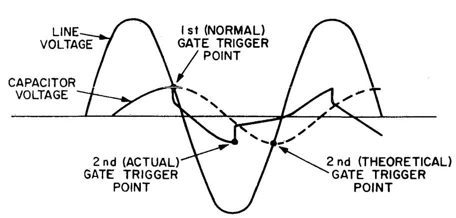


Fig.4 - Charging cycle of the capacitor-diac network in the circuit of Fig.3.

Some improvement is realized when a resistor is connected in series with the diac, as shown in Fig. 5. Although this positive resistance reduces the net amount of negative resistance so the capacitor voltage does not drop as much, it also decreases the magnitude

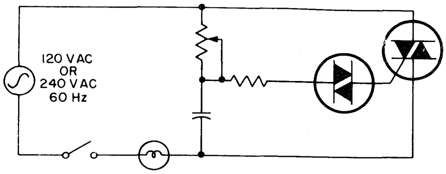


Fig.5 - Light-control circuit incorporating a resistor in series with the diac.

of the gate current pulse, and therefore, a larger-value capacitor may be required. More significant improvement is obtained when a second capacitor is added as shown in Fig. 6, forming a "double-time-constant" circuit.

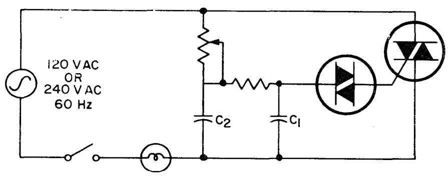


Fig.6 - "Double-time-constant" light-control circuit.

The added capacitor C_2 reduces hysteresis by charging to a higher voltage than C_1, and maintaining some voltage on C_1 after triggering. The effect is illustrated in Fig. 7. As gate triggering occurs C_1 discharges to form the gate current pulse. However, because of the longer C_2 R time constant, C_2 restores some of the charge removed from C_1 by the gate current pulse.

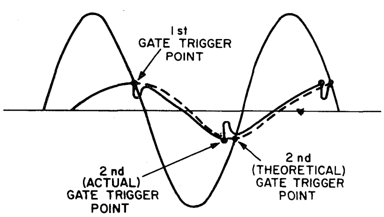


Fig.7 - Charging cycle of the diac network in the circuit of Fig.6.

Fig. 8 shows another double-time constant circuit in which a fixed resistor is added and the potentiometer is moved over to connect directly to the diac. Although the maximum attainable conduction angle is increased, the difference in power is less than one per cent.

Range Control

Maximum range of light control is obtained when the lamp begins to light as soon as the potentiometer is turned slightly from the zero-intensity end of the range.

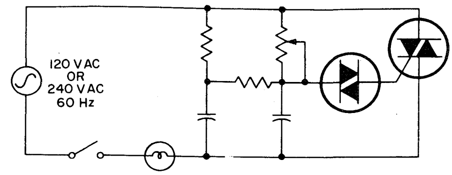


Fig.8 - Double-time-constant circuit in which the potentiometer is connected directly to the diac.

After the control circuit is assembled, the point of initial turn-on may be located at 40 per cent across the control range, leaving only 60 per cent effective to control the light intensity. This difference occurs because the point of initial turn-on is determined by the interaction of three components (potentiometer, capacitor, and diac) each of which may have values with a tolerance of plus or minus 20 per cent. A trimmer resistor connected across the potentiometer, as shown in Fig. 9, can be used to compensate for component variations and move the initial turn-on point back to the end of the control range. The trimmer can be a variable resistor which is set to the required value after the circuit is assembled, or a fixed resistor of the required value as determined by individually testing the assemblies with a resistor substitution box in place of the trimmer.

The double-time-constant circuit with trimmer resistor provides consistently good hysteresis correction as well as good range control. The use of a high-resistance potentiometer, possibly about twice the resistance of the trimmer, spreads out the low-intensity range for finer control.

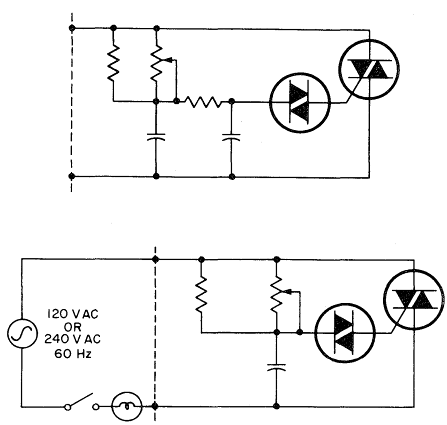


Fig.9 - Light-control circuits incorporating a trimmer resistor across the potentiometer.

RFI Suppression

Because the triac switches from the high-impedance state to the low-impedance state within 1 or 2 microseconds, the current must rise from essentially zero to whatever the load will permit within this period. This rapid rise in current produces radio frequency interference (RFI) extending up into the range of several megahertz. Although the resulting noise does not affect the television and FM radio frequencies, it does affect the short-wave and AM-radio bands. The level of RFI produced by the triac is well below that produced by most AC-DC brush-type electric motors, but because the light dimmer may be on for long periods of time, some type of RFI suppression network is usually added. A reasonably effective suppression network is obtained, as

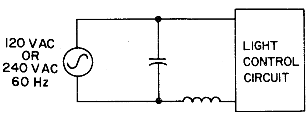


Fig.10 - RFI-suppression network.

shown in Fig. 10, by connection of an inductor in series with the light-control circuit to limit the rate of current rise. The capacitor is connected across the entire network to bypass high-frequency signals so that they are not connected to any external circuits through the power lines.

Overload Considerations

An important consideration in the choice of a triac is the transient load which results from the initially lower resistance of the cold filament when the lamp is first turned on. The transient load results in a surge or inrush current which can destroy the triac. The worst case occurs when the light is switched on at the peak of the line voltage. The ratio of initial peak current to steady-state current is usually about 10 to 1 and can be as high as 15 to 1 for high-wattage lamps. The triac chosen for a particular lamp, therefore, should have a subcycle surge capability sufficient to allow repeated passage of this peak current without degradation of the device.

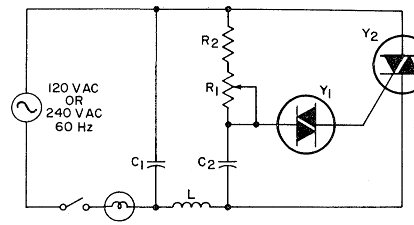
Flashover is another transient condition associated with incandescent loads, and may impose an even greater stress than inrush. Flashover refers to the arc developed between the broken ends of the filament when the light bulb burns out. Ionization within the bulb allows the arc to flow directly between the internal lead-in wires, and current is then limited only by line impedance. Because of the large currents associated with flashover, incandescent light bulbs have fuses built into the stem to open circuit at the bulb without opening the line circuit breaker. On low-wattage bulbs, the arc frequently self-extinguishes as line voltage goes through zero, so the surge duration is less than one half cycle. On higher-wattage bulbs, however, the arc often continues until the bulb fuse opens, and may last for somewhat more than one half cycle. Damage or degradation of the triac can be avoided by selection of a triac that has surge capability in excess of the flashover currents which can occur. A device capable of handling a one-cycle peak current of 100 amperes or more is adequate for most installations using up to 150-watt bulbs. When the triac has inadequate surge capability for a particular application, special high-speed fuses or circuit breakers, external resistors, or other current limiting devices such as chokes may be used.

Light-Dimmer Circuits

Fig. 11 shows a single-time-constant circuit; Fig. 12 shows a double-time-constant circuit. Both are complete circuits suitable for operation at 120 or 240 volts ac, 50 or 60 Hz. The chart with each circuit specifies the values of components which change with the line voltage. The resistor in series with the potentiometer in each circuit is used to protect the potentiometer by limiting the current when the potentiometer is at the low-resistance end of its range. Where space is limited, the diac and triac of each circuit may be replaced by a single integral diac-triac unit: the RCA 40431 for 120-volt operation, or the RCA 40432 for 240-volt operation.

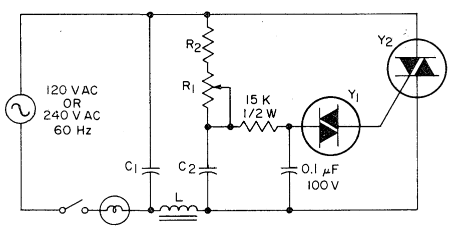
It is important to remember that a triac in these circuits dissipates power at the rate of about one watt per ampere. Therefore, some means of removing heat must be provided to keep the device within its safe operating-temperature range. On a small light-control circuit such as one built into a lamp socket, the lead-in wire serves as an effective heat sink. Attachment of the triac case directly to one of the lead-in wires provides sufficient heat dissipation for operating currents up to 2 amperes (rms). On wall-mounted controls operating up to 6 amperes, the combination of face plate and wallbox serves as an effective heat sink. For higher-power controls, however, the ordinary face plate and wallbox do not provide sufficient heat-sinking area. In this case, additional area may be obtained by use of a finned face plate that has a cover plate which stands out from the wall so air can circulate freely over the fins.

On wall-mounted controls, it is also important that the triac be electrically isolated from the face plate, but at the same time be in good thermal contact with it. Although the thermal conductivity of most electrical insulators is relatively low when compared with metals, a low-thermal-resistance, electrically isolated bond of triac to face plate can be obtained if the thickness of



	120 VAC, 60 Hz	240 VAC, 50/60 Hz
R_1	0.25 megohm, ½W	0.25 megohm, 1W
R_2	3300 ohms, ½W	4700 ohms, ½W
C_1	0.05 μF, 100V	0.1 μF, 100V
C_2	0.05 μF, 100V	0.10 μF, 100V (60 Hz) 0.12 μF, 100V (50 Hz)
L	100 μH	200 μH
Y_1	RCA 45412 } or RCA 40431	RCA 45412 } or RCA 40432
Y_2	RCA 40485 }	RCA 40486 }

Fig.11 - Single-time-constant light-dimmer circuit.



	120 VAC, 60 Hz	240 VAC, 50/60 Hz
R_1	0.1 megohm, ½W	3300 ohms, ½W
R_2	2200 ohms, ½W	0.2 megohm, 1W (60 Hz) 0.25 megohm, 1W (50 Hz)
C_1C_2	0.1 μF, 200V	0.1 μF, 400V
L	100 μH	200 μH
Y_1	RCA 45412 } or RCA 40431	RCA 45412 } or RCA 40432
Y_2	RCA 40485 }	RCA 40486 }

Fig.12 - Double-time-constant light-dimmer circuit.

the insulator is minimized, and the area for heat transfer through the insulator is maximized. Suitable insulating materials are fiber-glass tape, ceramic sheet, mica, and polyimide film. Fig. 13 shows two examples of isolated mounting for triacs: in Fig. 13(a), a TO-5 package; in Fig. 13(b), the new plastic package. Electrical insulating tape is first placed over the inside of the face plate. The triac is then mounted to the insulated face plate by use of epoxy-resin cement.

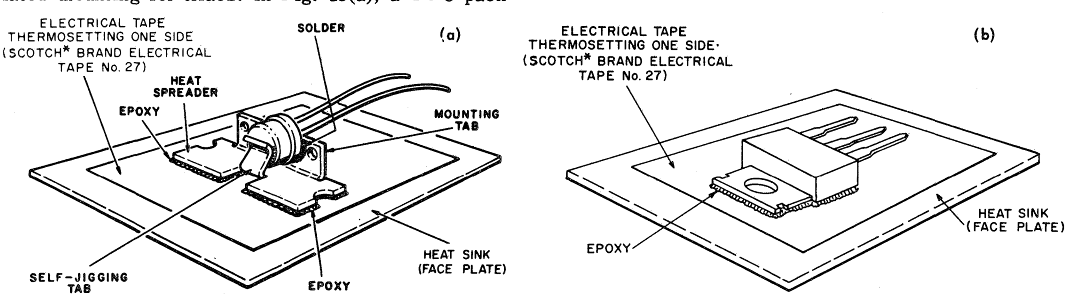


Fig.13 - Examples of isolated mounting of triacs.

Trouble Shooting

Some malfunctions which can occur in light-dimming circuits are listed with their possible causes, as follows:

	Component	Possible Cause
Light remains on full intensity and will not dim.	Triac	Shorted in both directions caused by flashover or high current surge.
	Wiring	Anode-cathode or anode-gate shorted.
Light intensity can be varied but fails to reach zero.	Triac	Breakover voltage reduced in one or both directions.
	Diac	Low breakover voltage.
	Triggering Capacitor	Capacitance too low.
	Potentiometer	Maximum resistance too low.
Discontinuity in brightness at about half intensity.	Triac	I_{GT} too high in one mode.
	Diac	Breakover not symmetrical.
Flickering exists at low intensity.	Triac	Low commutating $dv/_{dt}$ capability. Flickering stops when the inductor is shorted.
Light out over most of the control range; turns on full intensity near low resistance end of potentiometer.	Triac	I_{GT} too high.
	Diac	Voltage breakback too low.
	Wiring	Diac not included or shorted out.
Same effect as preceding, but accompanied by arcing in potentiometer.	Triac	Internal short gate to cathode (very unlikely because such devices are rejected by 100 per cent electrical test).
	Capacitor	Shorted (this condition destroys the potentiometer, but not the triac).
	Wiring	Open anode contact (this condition destroys both the potentiometer and the triac). Cathode to gate short (this condition destroys only the potentiometer).
Light fails to turn on at all.	Triac	Open gate contact (very unlikely due to the 100 per cent electrical test by manufacturer).
	Diac	Open
	Potentiometer	Open
	Wiring	Open circuit at potentiometer, diac, triac gate, or cathode.

RCA

Solid State
Division

Thyristors
Application Note
AN-3780

A New Horizontal-Deflection System Using RCA 40640 and 40641 Silicon Controlled Rectifiers

This Note describes a highly reliable horizontal-deflection system designed for use in the RCA CTC-40 solid-state color television receiver. This system illustrates a new approach in horizontal-circuit design that represents a complete departure from the approaches currently used in commercial television receivers. The switching action required to generate the scan current in the horizontal yoke windings and the high-voltage pulse used to derive the dc operating voltages for the picture tube is controlled by two silicon controlled rectifiers (SCR's) that are used in conjunction with associated fast-recovery diodes to form bipolar switches.

The RCA-40640 SCR used to control the trace current and the RCA-40641 SCR that provides the commutating action to initiate trace-retrace switching exhibit the high voltage- and current-handling capabilities, together with the the excellent switching characteristics, required for reliable operation in deflection-system applications. The switching diodes, RCA-40642 (trace) and 40643 (commutating), provide fast recovery times, high reverse-voltage blocking capabilities, and low turn-on voltage drops. These features and the fact that, with the exception of one non-critical triggering pulse, all control voltages, timing, and control polarities are supplied by passive elements within the system (rather than by external drive sources) contribute substantially to the excellent reliability of the SCR deflection system.

SYSTEM PERFORMANCE

Fig. 1 shows the circuit configuration of the over-all horizontal-deflection system. The system operates directly from a conventional, unregulated dc power supply of +155 volts, provides full-screen deflection at angles up to 90 degrees at full beam current (1.5 milliamperes average in the CTC-40 receiver). The current and voltage waveforms required for horizontal deflection and for generation of the high voltage are derived essentially from LC resonant circuits. As a result, fast and abrupt switching transients, which would impose strains on the solid-state devices, are avoided.

A regulator stage is included in the SCR horizontal-deflection circuit to maintain the scan and the high voltage within acceptable limits with variations in the ac line voltage or picture-tube beam current. The system also contains circuits that provide full protection against the effects of arcs in the picture tube or the high-voltage rectifier and linearity and pincushion correction circuits. Each individual part of the deflection system is designed to specifications that are compatible with achievement of the following system performance:

Picture Tube

25-inch, 90-degree color type; neck diameter = 1 7/16 inches (i.e., similar to RCA-Type 25XP22)

Ultor Voltage, Beam Current, and Regulation

26.5 kilovolts at zero beam current or 24.5 kilovolts at 1.5 milliamperes (average) of beam current for ac line voltages of 120 to 130 volts rms

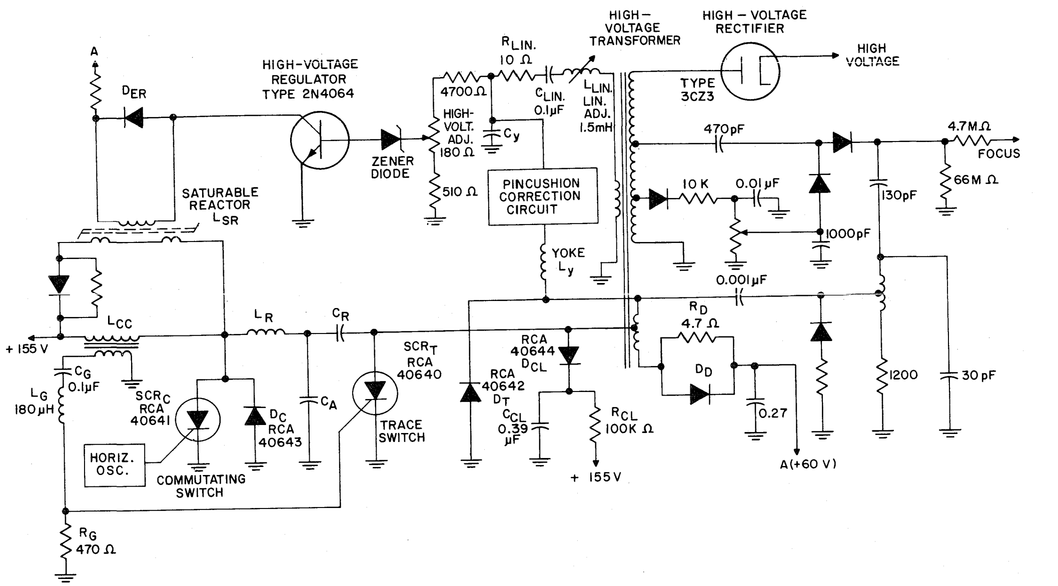


Fig. 1 — General circuit configuration of the over-all SCR horizontal-deflection system.

24.5 kilovolts at 1 milliampere of beam current for ac line voltages of 108 to 130 volts rms

22.5 kilovolts at 1.5 milliamperes of beam current for an ac line voltage of 105 volts rms

Input Current

420 milliamperes at zero beam current

670 milliamperes at 1.5 milliamperes of beam current

DC Input Voltage (Nominal)

155 volts at zero beam current

148 volts at 1.5 milliamperes of beam current

Scan Regulation*

¼-inch change for variation in ac line voltage from 105 to 130 volts rms

¼-inch change for beam-current variation of 0.3 to 1.5 milliamperes at a line voltage of 120 volts rms

Linearity*

Deviation in picture width is equal to or less than 5 per cent, left to right

Retrace Time

Flyback pulse width = 12.5 microseconds at zero crossing of yoke voltage

Total flyback pulse width = 14 microseconds at extremes of yoke voltage

Trigger Input

10-volt, 5-microsecond pulse (obtained directly from horizontal oscillator)

Pincushion Correction

Top and bottom pincushion correction provided for a minimum radius of 150 inches

REQUIREMENTS OF THE SWITCHING SCR's AND DIODES

The SCR horizontal-deflection circuit requires fast reverse recovery for both the switching SCR's and the diodes and fast turn-on for the SCR's. The 40640 and 40641 SCR's and the 40642 and 40643 diodes are well suited to provide this type of performance. (Detailed specifications for the SCR's and diodes are given in the published data on the devices). The exceptional capabilities of these devices are illustrated by the performance that they provide in the horizontal-deflection system. Fig. 2 shows the significant current and voltage waveforms that the SCR's and diodes are subjected to during operation of the deflection circuit.

The 40641 SCR used in the commutating switch is required to pass a pulse of current that has a peak amplitude of 13 amperes and an initial rate of rise of 20 amperes per microsecond. At the operating frequency of the horizontal-deflection circuit, achievement of this performance requires low turn-on dissipation in

* The deflection system is not subject to degradation of scan or linearity during component life.

the SCR. The turn-on dissipation in the 40640 SCR used in the trace switch is also low because of the waveform of the current that flows through the device.

An SCR is turned off by a reversal of its anode-to-cathode voltage; before the forward voltage can be reapplied, a short time is required to allow the device to regain its forward-blocking capability. Under worst-case conditions, the available turn-off time for the commutating switch requires the use of an SCR that can be completely turned off in 4.5 microseconds. The SCR must then be able to block a reapplied forward voltage of 100 volts applied at a rate of 400 volts per microsecond. The turn-off requirement for the trace-switch SCR, under worst-case circuit conditions, is 2.5 microseconds. This device is then required to block a reapplied forward voltage of 400 volts at a rate of 175 volts per microsecond. Negative gate bias is used with both SCR's to reduce turn-off time. The gate sensitivity of the commutating-switch SCR is high enough so that this device can be triggered directly from the horizontal oscillator.

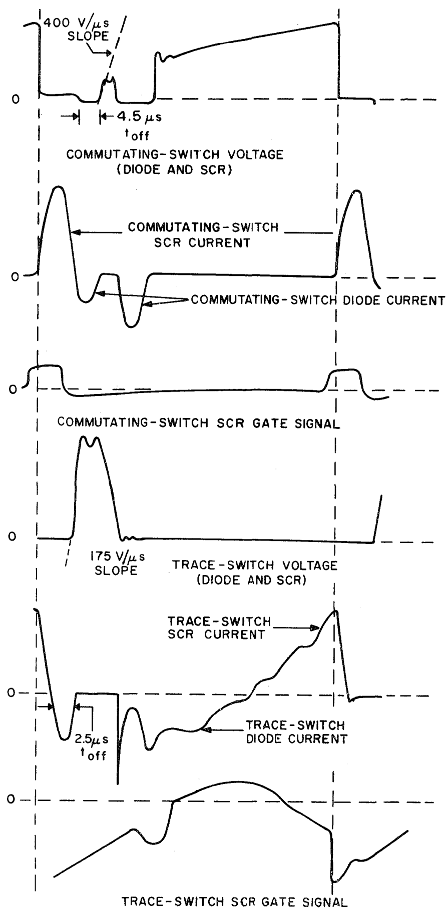


Fig. 2 — Voltage and current waveforms applied to the SCR's and diodes used to control the switching actions in the SCR horizontal-deflection system.

The exceptional switching performance provided by the 40640 and 40641 SCR's is made possible by use of all-diffused pellet structures that employ a centrally located gate having a large gate-cathode periphery to ensure low initial forward voltage drops and, therefore, low switching losses. The lifetime of minority charge carriers is substantially reduced to provide the fast turn-off-time capability. The "shorted-emitter" construction technique, in which a low-resistance path is provided around the gate-to-cathode junction, is used to obtain the high dv/dt capability required for the SCR's to withstand the high rates of reapplied forward voltage encountered in the horizontal-deflection system.

The 40642 and 40643 diodes used in the trace and commutating switches, respectively, are designed to provide fast reverse recovery (by means of minority-carrier lifetime control), to reduce rf interference in the circuit, and to decrease diode recovery losses. The slope and magnitude of the reverse-recovery current in the diodes have been optimized to ensure minimum reverse-recovery dissipation and to prevent rf interference because of overly abrupt recovery. The fast recovery characteristics have been achieved while maintaining a low turn-on voltage drop and a high reverse-voltage blocking capability.

OPERATION OF THE BASIC DEFLECTION CIRCUIT

The essential components in the SCR horizontal-deflection system required to develop the scan current in the yoke windings are shown in Fig. 3. Essentially

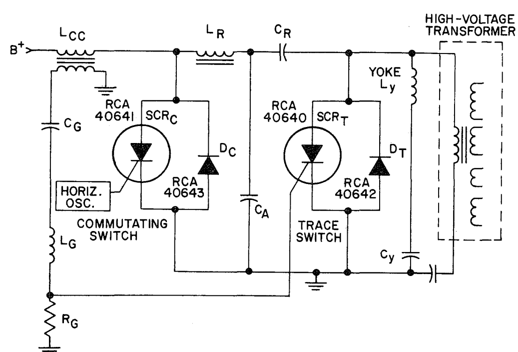


Fig. 3 — Basic circuit for generation of the deflection-current waveform in the horizontal yoke winding.

the trace-switch diode D_T and the trace-switch controlled rectifier SCR_T provide the switching action which controls the current in the horizontal yoke windings L_y during the picture-tube beam-trace interval. The commutating-switch diode D_C and the commutating-switch controlled rectifier SCR_C initiate retrace and control the yoke current during the retrace interval. Inductor L_R and capacitors, C_R, C_A, and C_y provide the necessary energy storage and timing cycles. Inductor L_{CC} supplies a charge path for capacitor C_R from the dc supply voltage (B+) so that the system can be recharged from the receiver power supply. The secondary of inductor L_{CC}, provides the gate trigger voltage for the trace-switch SCR. Capacitor C_R establishes the optimum retrace time by virtue of its resonant action with inductor L_R.

The complete horizontal-deflection cycle may best be described as a sequence of discrete intervals, each terminated by a change in the conduction state of a switching device. In the following discussion, the action of the auxiliary capacitor C_A and the flyback high-voltage transformer are initially neglected to simplify the explanation.

First Half of the Trace Interval

Fig. 4 shows the circuit elements involved and the voltage and current relationships during the first half of the trace deflection-current interval, the period from T_0 to T_2. At time T_0, the magnetic field has been established about the horizontal yoke windings L_y by the circuit action during the retrace period of the preceding cycle (explained in the subsequent discussion of retrace intervals). This magnetic field generates a decaying yoke current i_y that decreases to zero when the energy in the yoke winding is depleted (at time T_2). This current charges capacitor C_y to a positive voltage V_{C_y} through the trace-switch diode D_T.

During the first half of the trace interval (just prior to time T_2) the trace controlled rectifier SCR_T is made ready to conduct by application of an appropriate gate voltage pulse V_{GATE}. SCR_T does not conduct, however, until a forward bias is also applied between its anode and cathode. This voltage is applied during the second half of the trace interval.

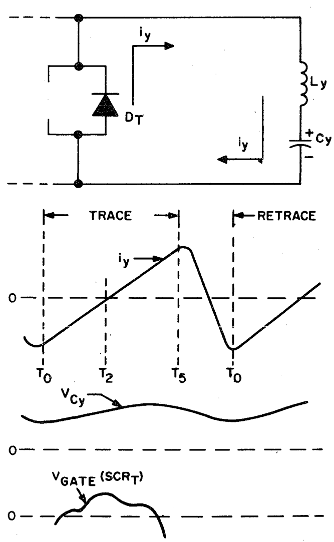


Fig. 4 — Effective configuration of the deflection circuit during the first half of the trace interval, time T_0 to T_2, and operating voltage and current waveforms for the complete trace-retrace cycle.

Second Half of the Trace Interval

At time T_2, current is no longer maintained by the yoke inductance, and capacitor C_y begins to discharge into this inductance. The direction of the current in the circuit is then reversed, and the trace-switch diode D_T becomes reverse-biased. The trace-switch controlled rectifier SCR_T, however, is then forward-biased by the voltage V_{C_y} across the capacitor, and the capacitor discharges into the yoke inductance through SCR_T, as indicated in Fig. 5. The capacitor C_y

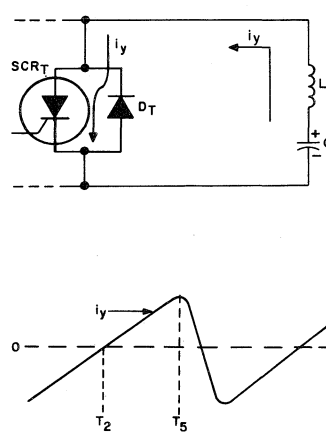


Fig. 5 — Effective configuration of the deflection circuit during the second half of the trace interval, time T_2 to T_5, and the complete scan-current waveform.

is sufficiently large so that the voltage V_{C_y} remains essentially constant during the entire trace and retrace cycle. This constant voltage results in a linear rise in current through the yoke inductance L_y over the entire scan interval from T_0 to T_5.

Start of the Retrace Interval

The circuit action to initiate retrace starts before the trace interval is completed. Fig. 6 shows the circuit elements and the voltage and current waveforms required for this action. At time T_3, prior to the end of

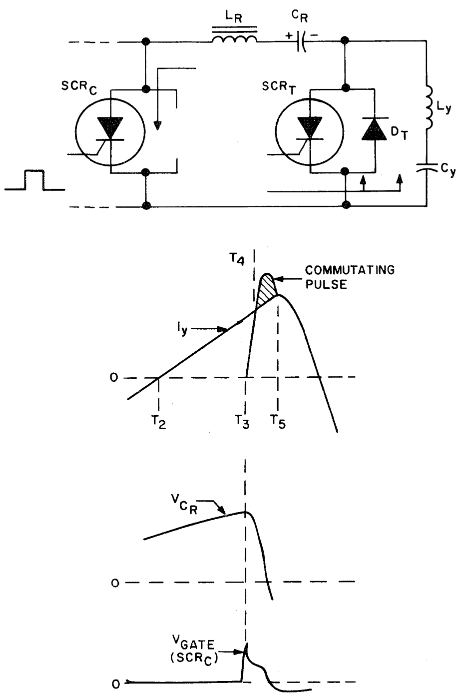


Fig. 6 — Effective configuration of the deflection circuit and significant voltage and current waveforms for initiation of retrace, time T_3 to T_5.

the trace period, the commutating-switch controlled rectifier SCR_C is turned on by application of a pulse from the horizontal oscillator to its gate. Capacitor C_R is then allowed to discharge through SCR_C and inductor L_R. The current in this loop, referred to as the commutating circuit, builds up in the form of a half-sine-wave pulse. At time T_4, when the magnitude of this current pulse exceeds the yoke current, the trace-switch diode D_T again becomes forward-biased. The excess current in the commutating pulse is then bypassed around the yoke winding by the shunting action of diode D_T. During the time from T_4 to T_5, the trace-switch controlled rectifier SCR_T is reverse-biased by the amount of the voltage drop across diode D_T. The trace-switch controlled rectifier, therefore, is turned off during this interval and is allowed to recover its ability to block the forward voltage that is subsequently applied.

First Half of the Retrace Interval

At time T_5, the commutating pulse is no longer greater than the yoke current, as shown in Fig. 7; trace-switch diode D_T then ceases to conduct. The yoke inductance maintains the yoke current but, with SCR_T in the OFF state, this current now flows in the commutating loop formed by L_R, C_R, and SCR_C. Time T_5 is the beginning of retrace.

As the current in the yoke windings decreases to zero, the energy supplied by this current charges capacitor C_R with an opposite-polarity voltage in a resonant oscillation. At time T_6, the yoke current is zero, and capacitor C_R is charged to its maximum negative voltage value. This action completes the first half of retrace.

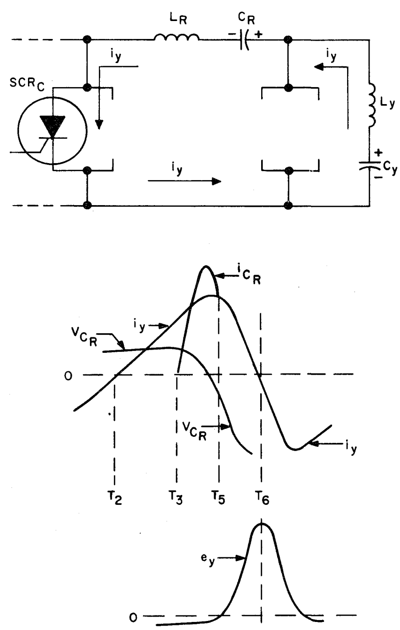


Fig. 7 — Effective configuration of the deflection circuit and operating voltage and current waveforms during the first half of retrace, time T_5 to T_6.

Second Half of the Retrace Interval

At time T_6, the energy in the yoke inductance is depleted, and the stored energy on the retrace capacitor C_R is then returned to the yoke inductance. This action reverses the direction of current flow in the yoke. During the reversal of yoke current, the commutating-switch diode D_C provides the return path for the loop current, as indicated in Fig. 8. The commutating-

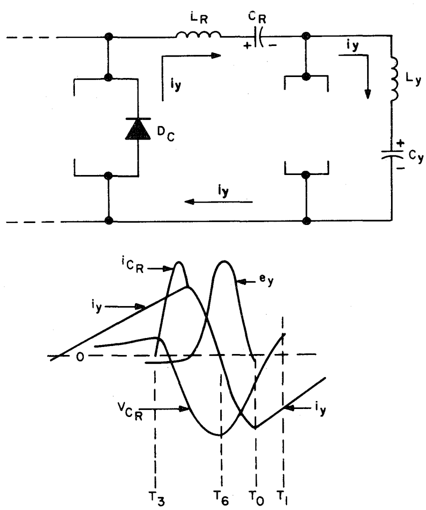


Fig. 8 — Effective configuration of the deflection circuit and operating voltage and current waveforms during the second half of retrace, time T_6 to T_0.

switch controlled rectifier SCR_C is reverse-biased by the amount of the voltage drop across diode D_C. The commutating-switch controlled rectifier, therefore, turns off and recovers its voltage-blocking capability. As the yoke current builds up in the negative direction, the voltage on the retrace capacitor C_R is decreased. At time T_0, the voltage across capacitor C_R no longer provides a driving voltage for the yoke current to flow in the loop formed by L_R, C_R, and L_v. The yoke current finds an easier path up through trace-switch diode D_T, as shown in Fig. 9. This action represents the beginning of the trace period for the yoke current (i.e., the start of a new cycle of operation), time T_0.

Once the negative yoke current is decoupled from the commutating loop by the trace-switch diode, the current in the commutating circuit decays to zero. The stored energy in the inductor L_R charges capacitor C_R to an initial value of positive voltage. Because the resonant frequency of L_R and C_R is high, this transfer is

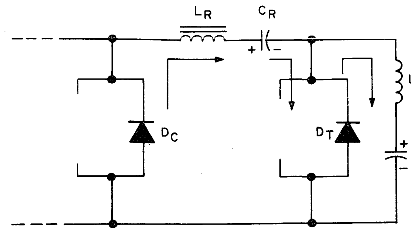


Fig. 9 — Effective configuration of the deflection circuit during the switchover from retrace to trace, time T_0.

accomplished in a relatively short period, T_0 to T_1, as shown in Fig. 8.

Recharging and Resetting Actions

The actions required to restore energy to the commutating circuit and to reset the trace SCR are also very important considerations in the operation of the basic deflection circuit. Both actions involve the inductor L_{CC}.

During the retrace period, inductor L_{CC} is connected between the dc supply voltage (B+) and ground by the conduction of either the commutating-switch SCR or diode (SCR_C or D_C), as indicated in Fig. 10. When the diode and the SCR cease to conduct, however, the path from L_{CC} to ground is opened. The energy stored in inductor L_{CC} during the retrace interval then charges capacitor C_R through the B+ supply, as shown in Fig. 11. This charging process continues through the trace period until retrace is again initiated. The resultant charge on capacitor C_R is used to resupply energy to the yoke circuit during the retrace interval.

The voltage developed across inductor L_{CC} during the charging of capacitor C_R is used to forward-bias the gate electrode of the trace SCR properly so that this

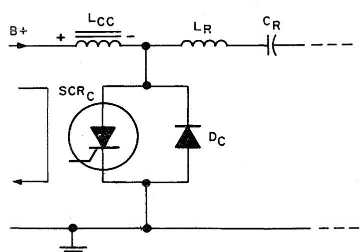


Fig. 10 — Circuit elements and current path used to supply energy to the charging choke Lcc during period from the start of retrace switching action to the end of the first half of the retrace interval, time T_3 to T_1.

device is made ready to conduct. This voltage is inductively coupled from L_{CC} and applied to the gate of SCR_T through to a wave-shaping network formed by inductor L_G, capacitor C_G, and resistor R_G. The resulting voltage signal applied to the gate of SCR_T has the desired shape and amplitude so that SCR_T conducts when a forward bias is applied from anode to cathode, approximately midway through the trace interval.

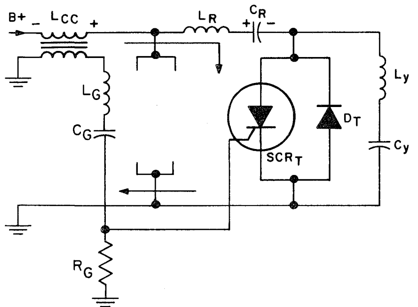


Fig. 11 — Effective configuration of the deflection circuit for resetting (application of forward bias to) the trace SCR and recharging the retrace capacitor C_R, during time interval from T_1 to T_3.

Effect of Auxiliary Capacitor C_A

In the preceding discussions of the operation of the deflection circuit, the effect of capacitor C_A was neglected. Inclusion of this capacitor affects some of the circuit waveforms, as shown in Fig. 12, aids in the turn-off of the trace SCR, reduces the retrace time, and provides additional energy-storage capability for the circuit.

During most of the trace interval (from T_0 to T_4), including the interval (T_3 to T_4) during which the commutating pulse occurs, the trace switch is closed, and capacitor C_A is in parallel with the retrace capacitor C_R. From the start of retrace at time T_4 to the beginning of the next trace interval at time T_0, the trace switch is open. For this condition, capacitor C_A is in series with the yoke L_y and the retrace capacitor C_R so that the capacitance in the retrace circuit is effectively decreased. As a result, the resonant frequency of the retrace is increased, and the retrace time is reduced.

The auxiliary capacitor C_A is also in parallel with the retrace inductor L_R. The waveshapes in the deflection circuit are also affected by the resultant higher-frequency resonant discharge around this loop. The voltage and current waveforms shown in Fig. 12 illustrate the effects of the capacitor C_A.

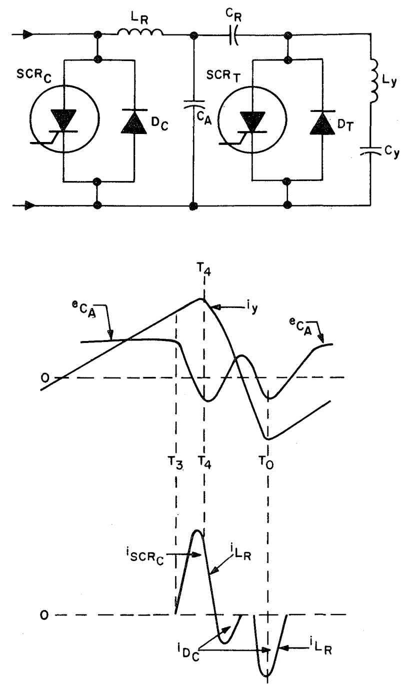


Fig. 12 — Circuit configuration showing the addition of auxiliary capacitor C_A and current and voltage waveforms showing the effect of this capacitor.

HIGH-VOLTAGE GENERATION

The SCR horizontal-deflection system in the RCA CTC-40 receiver generates the high voltage for the picture tube in essentially the same manner as has been used for many years in other commercial television receivers, i.e., by transformation of the horizontal-deflection retrace (flyback) pulse to a high voltage with a voltage step-up transformer and subsequent rectification of this stepped-up voltage. The RCA-3CZ3 electron tube is used as the high-voltage rectifier in the RCA CTC-40 television receiver.

Fig. 13 shows a schematic of the over-all high-voltage circuit, and Fig. 14 shows a simplified schematic of this circuit together with the significant voltage and current waveforms. The high-voltage transformer is connected across the yoke and retrace capacitor. The inductance and capacitance of this transformer are such that it presents a load tuned to about the third harmonic of the retrace resonant frequency. The presence of this load adds harmonic components to the waveforms previously described.

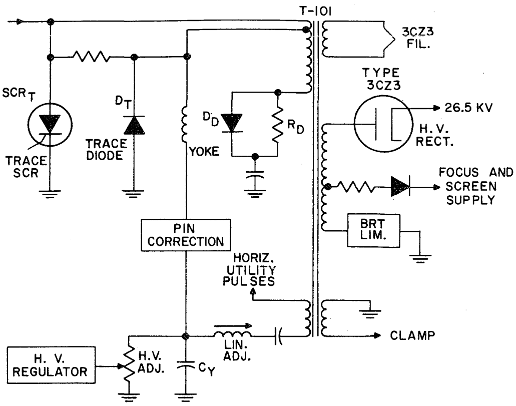


Fig. 13 — High-voltage circuit.

HIGH-VOLTAGE REGULATION

The high voltage is regulated by controlling the amount of energy made available to the horizontal-output trace circuit. As stated previously, the trace circuit is supplied by energy which is stored primarily on the commutating capacitor C_R. This capacitor is charged during the trace interval through inductance L_{CC}.

Control of the high-voltage energy on the commutating capacitor is made possible by the design of inductor L_{CC} so that it approaches resonance with capacitor C_R; the degree of this resonance can be varied by the high-voltage regulator circuit.

Fig. 15 illustrates the effect of this resonant action on the charge on the commutating capacitor. The waveshape that results from the resonant action determines the amount of charge that will be on the capacitor when its energy is released into the trace circuit.

The resonance of the inductor L_{CC} and the commutating capacitor C_R is varied by use of a saturable reactor L_{SR} to control the inductance across L_{CC}. The saturable-reactor load winding is placed in parallel with L_{CC}. Changes in the current through the reactor control windings varies the total inductance of the input circuit. The current in the reactor load winding is controlled by the pulse regulator circuit.

The control current for the reactor control winding is determined by the conduction of the high-voltage regulator transistor Q_X. The collector current of this transistor is in turn controlled by the voltage across the yoke-return capacitor C_y. This voltage, which is directly proportional to high voltage and which tracks any changes in the high voltage, is sampled by the high-voltage adjustment control and compared to a reference voltage determined by a Zener diode. The resulting difference voltage, which is indicative of changes in the high voltage, controls the conduction of the regulator transistor.

As the high-voltage load (beam current) decreases, the high voltage tends to increase. The voltage across the yoke-return capacitor then tends to increase. This action results in an instantaneously higher current pulse through the base-emitter junction of the regulator transistor. The reactor control current, therefore, tends to increase proportionally, so that the total inductance of the input circuit is decreased. The resulting change in resonance of L_{CC}, L_{SR}, and C_R reduces the charge on C_R and the energy made available to the trace circuit. In this way, the high voltage is stabilized. The reverse action, of course, occurs if the high voltage tends to decrease.

Diode D_{ER} acts as an energy-recovery diode which improves the efficiency of the control circuit. The regulator transistor actually conducts only for a very short time, and the majority of the control current is supplied by diode conduction. This high-voltage regulating system also maintains the high voltage within acceptable limits for variations in the ac line voltage over the range from 105 to 130 volts.

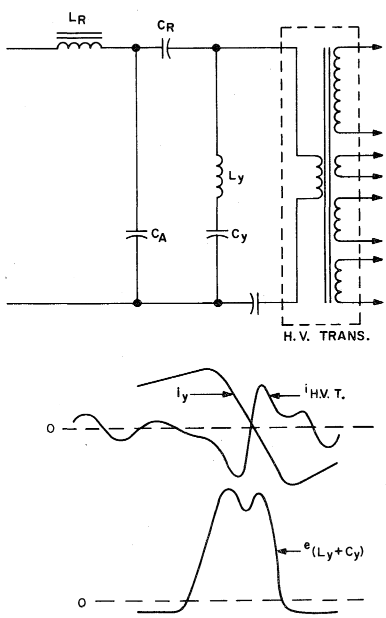


Fig. 14 — Simplified schematic and significant voltage and current waveforms for the high-voltage circuit.

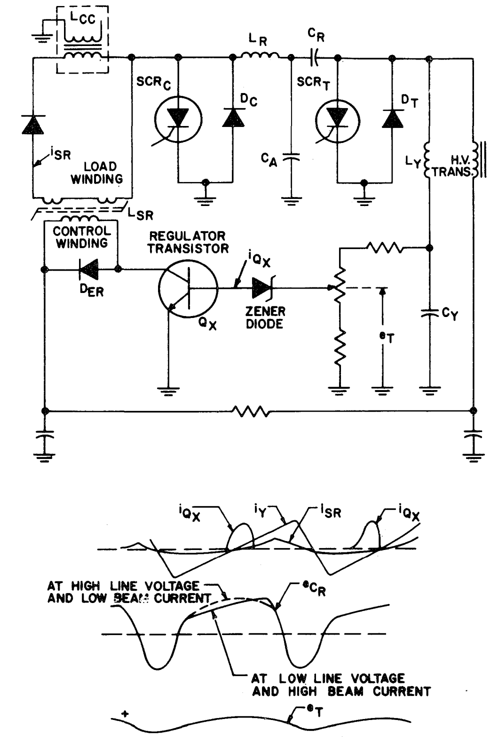


Fig. 15 — High-voltage regulator and operating voltage and current waveforms.

ARC PROTECTION

Two circuits are included in the SCR deflection system to protect the trace-switch SCR and diode from high voltages and currents that may result because of arcing from the high-voltage rectifier or the picture tube. These circuits are shown in Fig. 16.

One circuit includes the parallel combination of a diode (D_D) and a 4.7-ohm resistor (R_D) connected in series with the primary of the high-voltage transformer.

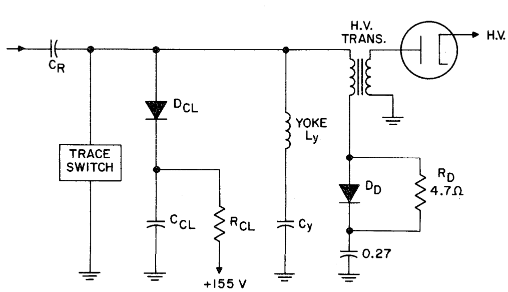


Fig. 16 — Arc-protection circuits.

These components dampen the high ringing current that may occur as a result of high-voltage arcing. This current is mainly dissipated in the resistor R_D; The principal purpose of the shunting diode is to allow the normal initial flyback current to flow unimpeded so that the high voltage is not decreased by the dampening action of the resistor.

The other protection circuit consists of a diode (D_{CL}), a capacitor (C_{CL}) connected between the diode cathode and ground, and a resistor R_{CL} from the diode cathode to the B+ supply voltage. The anode of the diode is connected to the ungrounded end of the primary of the high-voltage transformer. The diode conducts during the peak of the retrace voltage pulse that appears across the primary of the high-voltage transformer and charges the capacitor to this voltage. The resistor provides a high-resistance discharge path for the capacitor and allows the voltage across the capacitor to be reduced just enough to keep the diode reverse-biased during the retrace interval. When a sharp voltage pulse is produced because of high-voltage arcing, the diode conducts so that the trace switch is clamped to the voltage across the capacitor. The arc pulse voltage, therefore, is not allowed to exceed the breakdown voltage of the trace-switch components.

LINEARITY CORRECTION

Two means are provided in the SCR horizontal-deflection system to correct for nonlinearities in the horizontal scanning current that may result because of voltage drops across the inherent resistance in the trace circuit. Voltage drops across the resistance of the trace-switch SCR and diode are held to a minimum by operation of the trace diode at a more negative voltage than the trace SCR. This condition is achieved by connection of the trace diode one turn higher (more negative) on the high-voltage transformer than the SCR.

Fig. 17 illustrates another technique used to correct for nonlinearity in the scanning current. This technique

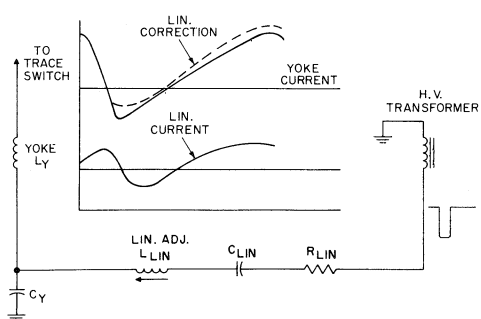


Fig. 17 — Linearity-correction circuit and correction-current waveforms.

uses a damped series resonant circuit (L_{LIN}, C_{LIN}, and R_{LIN}), connected between a winding on the high-voltage transformer and the ungrounded side of the yoke-return capacitor C_y, to produce a damped sine wave of current that effectively adds to and subtracts from the charge on the yoke-return capacitor C_y. The resulting alteration in yoke current corrects for any trace-current nonlinearities.

ADVANTAGES OF THE SCR HORIZONTAL-DEFLECTION SYSTEM

It is apparent from the preceding discussions that the SCR horizontal-deflection system offers a number of distinct advantages over the conventional types of systems currently used in commercial television receivers. The following list outlines some of the more significant circuit features of the SCR deflection system and points out the advantage derived from each of them:

1. Critical voltage and current waveforms, and timing cycles are determined by passive components in response to the action of two SCR-diode switches. The stability of the system, therefore, is determined primarily by the passive components. When the passive components are properly adjusted, the system exhibits highly predictable performance characteristics and exceptional operational dependability.

2. The only input drive signal required for the SCR deflection system is a low-power pulse which has no stringent accuracy specification in relation to either amplitude or time duration. The deflection system, therefore, can be driven directly from a pulse developed by the horizontal oscillator.

3. This deflection system is unique in that, although it operates from a conventional B+ supply of +155 volts, the flyback pulse is less than 500 volts. This level of voltage stress is substantially less than that in conventional line-operated systems, and this factor contributes to improved reliability of the switching devices.

4. Regulation in the SCR deflection system is accomplished by control of the energy stored by a reactive element. This technique avoids the use of resistive-load regulating elements required by many other types of systems and, therefore, makes possible higher over-all system efficiency and reduces input-power requirements.

5. All switching occurs at the zero current level through the reverse recovery of high-voltage p-n junctions in the deflection diodes. The diode junctions are not limited in volt-ampere switching capabilities for either normal or abnormal conditions in the circuit.

Thermal Considerations in Mounting of RCA Thyristors

by

J. M. S. Neilson

Consideration of thermal problems involved in the mounting of thyristors is synonymous with consideration of the best heat sink for a particular application. Most practical heat sinks used in modern, compact equipment are the result of experiments with heat transfer through convection, radiation, and conduction in a given application. Although there are no set design formulas that provide exact heat-sink specifications for a given application, there are a number of simple rules that reduce the time required to evolve the best design for the job. These simple rules are as follows:

1. The surface area of the heat sink should be as large as possible to provide the greatest possible heat transfer. The area of the surface is dictated by thyristor case-temperature requirements and the environment in which the thyristor is to be placed.
2. The heat-sink surface should have an emissivity value near unity for optimum heat transfer by radiation. A value approaching unity can be obtained if the heat-sink surface is painted flat black.
3. The thermal conductivity of the heat-sink material should be such that excessive thermal gradients are not established across the heat sink.

Although these rules are followed in conventional heat-sink systems, the size and cost of such systems often become restrictive in compact, mass-produced power-control and power-switching applications using thyristors. These restrictions are overcome in RCA thyristors because the JEDEC TO-5 and "modified TO-5" packages shown in Figs.1 and 2 are tin-plated and can be soldered directly to a heat sink. The use of mass-

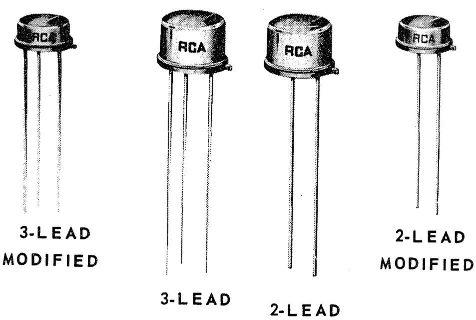


Fig.1 - RCA TO-5 thyristor packages.

produced prepunched parts, direct soldering, and batch-soldering techniques eliminates many of the difficulties associated with heat sinks by making possible the use of a variety of simple, efficient, readily fabricated heat-sink configurations that can be easily incorporated into the mechanical design of equipment.

Power Dissipation and Heat-Sink Area

The curves shown in Fig.3 are designed for use with the power-dissipation curves shown in the technical bulletins describing the various RCA thyristors. The curves of Fig.3 are conservative and can be used directly for thyristors having thermal-resistance ratings (θ_r), junction-to-case, of 5°C/W or less. The curves shown in Fig.4 represent the power-dissipation characteristics of a typical thyristor. As an example of the use of Figs.3 and 4, it is assumed that an appropriate heat sink must be

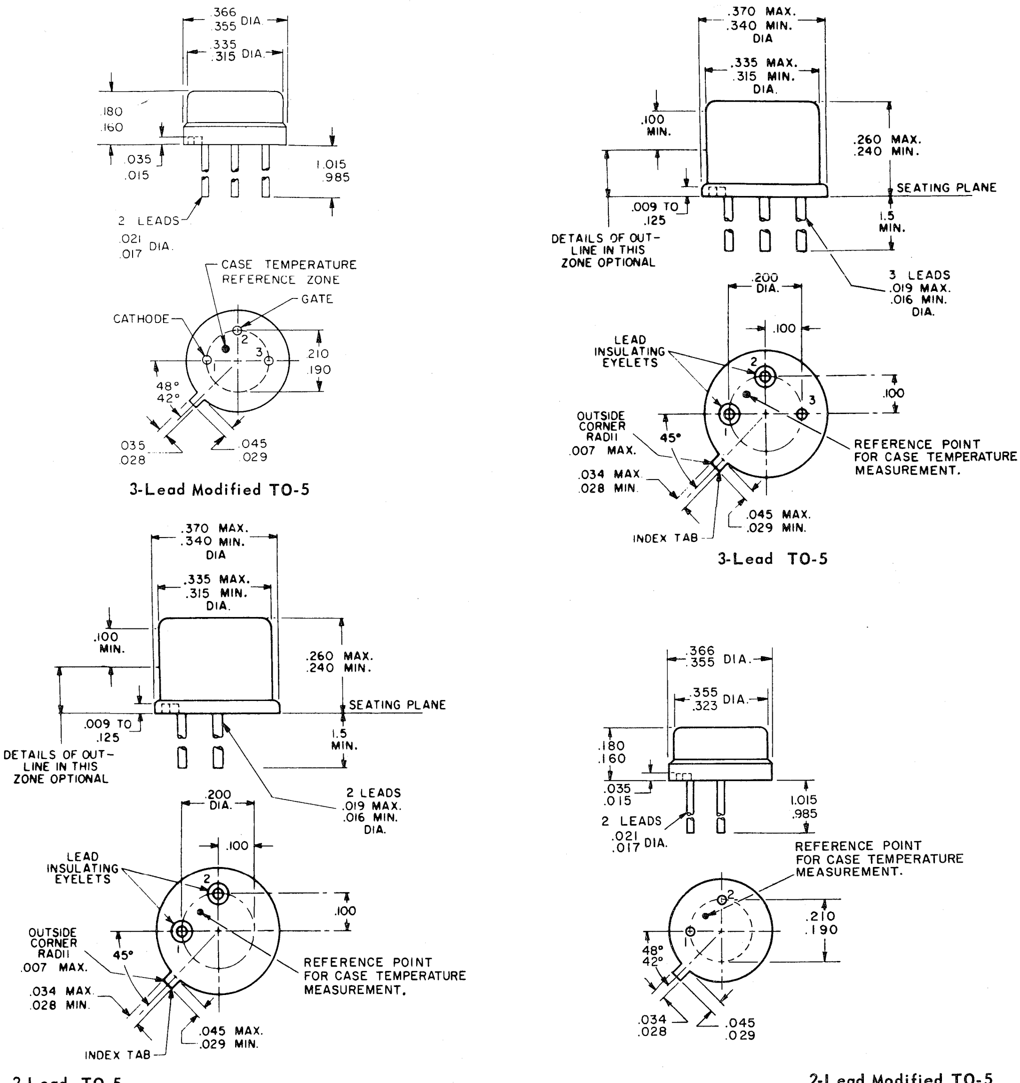


Fig.2 - Details of thyristor packages showing dimensions and reference point for case-temperature measurement.

found for a thyristor that is to conduct a current of 2 amperes, operate at an air temperature of 37°C, and be soldered to the heat sink at the base of the package. From Fig.4, the maximum power dissipation in the thyristor is found to be 3 watts. Fig.3 shows that the maximum allowable thermal resistance of the heat sink at this level of power dissipation is 15°C/W, and that a square, dull, 1/16-inch-thick copper or 1/8-inch-thick aluminum heat sink with an area of at least 1-3/4 by 1-1/4 inches is required.

The curves of Fig.3 can also be used with thyristors having junction-to-case thermal-resistance ratings of more than 5°C/W. However, the difference between the higher thermal-resistance value of the thyristor and the value of 5°C/W upon which the curves are based must be subtracted from the thermal-resistance values shown in Fig.3. For example, if it is assumed that the conditions are the same as those stated previously except that the thermal resistance, junction-to-case, of the device is 13°C/W, the difference in thermal-resistance

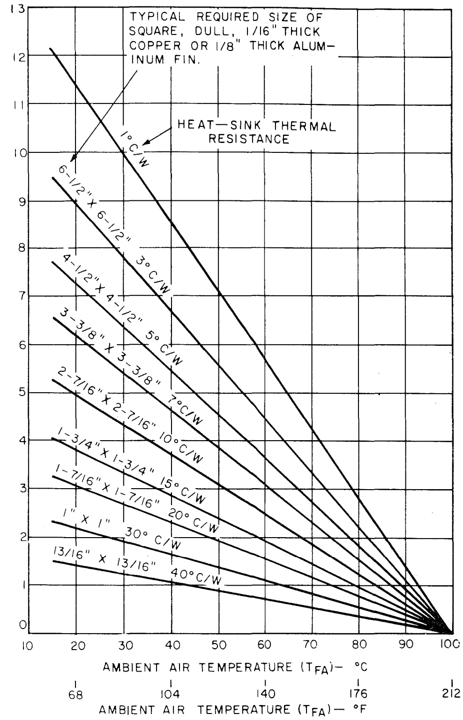


Fig.3 - Guide to heat-sink area determination.

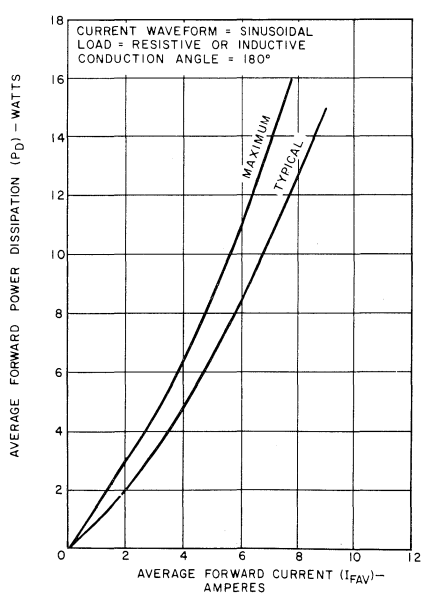


Fig.4 - Typical power-dissipation curves.

values is 8°C/W. The closest value of thermal resistance to 8°C/W in Fig.3 is 7°C/W; therefore, a 3-3/8-by-3-3/8-inch heat sink is required.

Commercial heat sinks are available for the thyristor packages described; however, because the thyristor package is usually attached to the heat sink at the cap, the additional thermal resistance from the base of the package to the cap must be considered. Although this resistance can be as high as 8°C/W, it can be neglected if it is only a small percentage of the over-all allowable thermal resistance. It should be noted that most thyristor thermal-resistance ratings are based on temperature measurements taken at the base of the package. The case-temperature reference point specified on the dimensional outlines shown in Fig.2 should be used when temperature measurements are made. A low-mass temperature probe or thermocouple equipped with wire leads no larger than AWG No. 26 should be employed for systems with thermal-resistance values less than 50°C/W. For systems with thermal-resistance values greater than 50°C/W, smaller wire (such as AWG No. 36) is preferred.

Mounting Thyristors on Heat Sinks

For most efficient heat sinks, intimate contact should exist between the heat sink and at least one-half of the package base. The package can be mounted on the heat sink mechanically, with glue or epoxy adhesive, or by soldering. If mechanical mounting is employed, silicone grease should be used between the device and the heat sink to eliminate surface voids, prevent insulation build-up due to oxidation, and help conduct heat across the interface. Although glue or epoxy adhesive provides good bonding, a significant amount of resistance may exist at the interface. To minimize this interface resistance, an adhesive material with low thermal resistance, such as Hysol* Epoxy Patch Material No. 6C or Wakefield* Delta Bond No. 152, or their equivalent, should be used.

Soldering of the thyristor to the heat sink is preferable because it is most efficient. Not only is the bond permanent, but interface resistance is easily kept below 1°C/W under normal soldering conditions. Oven or hot-plate batch-soldering techniques are recommended because of their low cost. The use of a self-jigging arrangement of the thyristor and the heat sink and a 60-40 solder preform is recommended. If each unit is soldered individually with a flame or electric soldering iron, 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. Because RCA thyristors are tin-plated, maximum solder wetting is easily obtainable without thyristor overheating.

* Products of Hysol Corporation, Olean, New York and Wakefield Engineering, Inc., Wakefield, Massachusetts, respectively.

The special high-conductivity leads on the two-lead TO-5 package permit operation of the thyristor at current levels that would be considered excessive for an ordinary TO-5 package. The special leads can be bent into almost any configuration to fit any mounting requirement; however, they are not intended to take repeated bending and unbending. In particular, repeated bending at the glass should be avoided. The leads are not especially brittle at this point, but the glass has a sharp edge which produces an excessively small radius of curvature in a bend made at the glass. Repeated bending with a small radius of curvature at a fixed point will cause fatigue and breakage in almost any material. For this reason, right-angle bends should be made at least 0.020 inch from the glass. This practice will avoid sharp bends and maintain sufficient electrical isolation between lead connections and header. A safe bend can be assured if the lead is gripped with pliers close to the glass seal and then bent the requisite amount with the fingers, as shown in Fig.5. When the leads of a number of devices are to be bent into a particular configuration, it may be advantageous to use a lead-bending fixture to assure that all leads are bent to the same shape and in the correct place the first time, so that there is no need for repeated bending.

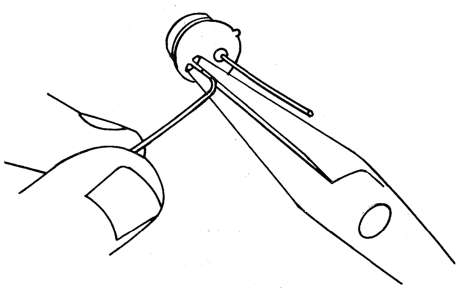


Fig.5 - Method of bending leads on thyristor package.

Typical Heat-Sink Configurations

Typical heat-sink designs that can be used with RCA thyristors are shown in Fig.6. The case-to-air thermal-resistance value for each of the easily fabricated sinks is given, along with approximate dimensions. The thyristors in the illustrations are soldered to the heat sink; if epoxy is used, an additional thermal resistance of $1^{o}C/W$ to $2^{o}C/W$ must be added to the thermal-resistance values shown. The junction-to-case thermal-resistance value for the particular thyristor being used should be added to the values shown to obtain the over-all junction-to-air thermal resistance of each configuration. In the designs shown, electrical insulation of the heat sink from the chassis or equipment housing may be required.

Chassis-Mounted Heat Sinks

In many applications, it is desirable and practical to use the chassis or equipment housing as the heat sink. In such cases, the thyristor must be electrically insulated from the heat sink, but must still permit heat generated by the device to be efficiently transferred to the chassis or housing. This heat transfer can be achieved by use of the heat-spreader mounting method. In this method, the thyristor is attached to a metal bracket (heat spreader) which is attached to, but electrically insulated from, the chassis. Examples of heat spreaders are shown in Figs.6 and 7. Electrical insulation may consist of material such as alumina ceramic, polyimide film or tape, fiberglass tape, or epoxy. The metal bracket itself has a low thermal resistance, and spreads the heat out over a larger area than could the thyristor case alone. The larger area in contact with the electrical insulation allows heat to transfer from bracket to chassis through the insulation with relatively low thermal resistance. Typical heat sinks, such as those shown in Fig.6, provide a much lower thermal resistance when used as heat spreaders than when used as heat sinks. Heat spreader dimensions can be varied over a wide range to suit particular applications. For example, area or diameter can be increased, or shape changed, as long as the heat-transfer area in contact with the electrical insulation is sufficient. An area of 0.2 square inch or more is usually desirable. The exact thermal resistance of any heat spreader depends on the heat-transfer area, type of metal used, type of insulation used, and whether the thyristor is fastened to the heat spreader with solder or epoxy. Soldered construction yields a thermal resistance about $1^{o}C/W$ less than that obtained with epoxy. Alumina or polyimide insulation provides a thermal resistance about 1 to $2^{o}C/W$ less than that obtained with thermosetting fiberglass-tape insulation. The heat spreader can be made of any material with suitable thermal conductivity, such as copper, brass, or aluminum. Solderable plating for aluminum is commercially available.

A self-jigging type of copper heat spreader is shown in Fig.7. Triacs soldered to this heat spreader are available from RCA as type numbers 40638 and 40639; SCR's on this spreader are available as type numbers 40656 and 40657.

Bibliography

J. Neilson and N. Smith, "Thermal Impedance of Silicon Rectifiers," RCA Publication No. ST-2055A.

Frank D. Gross, "Semiconductor Heat-Sink Design Chart," *Electronics World,* January, 1965.

A. D. Marquis, "How 'Hot' Are You On Thermal Ratings?," *Electronic Design,* November 8, 1967.

RCA Silicon Power Circuits Manual, Technical Series SP-50, RCA, Harrison, N. J.

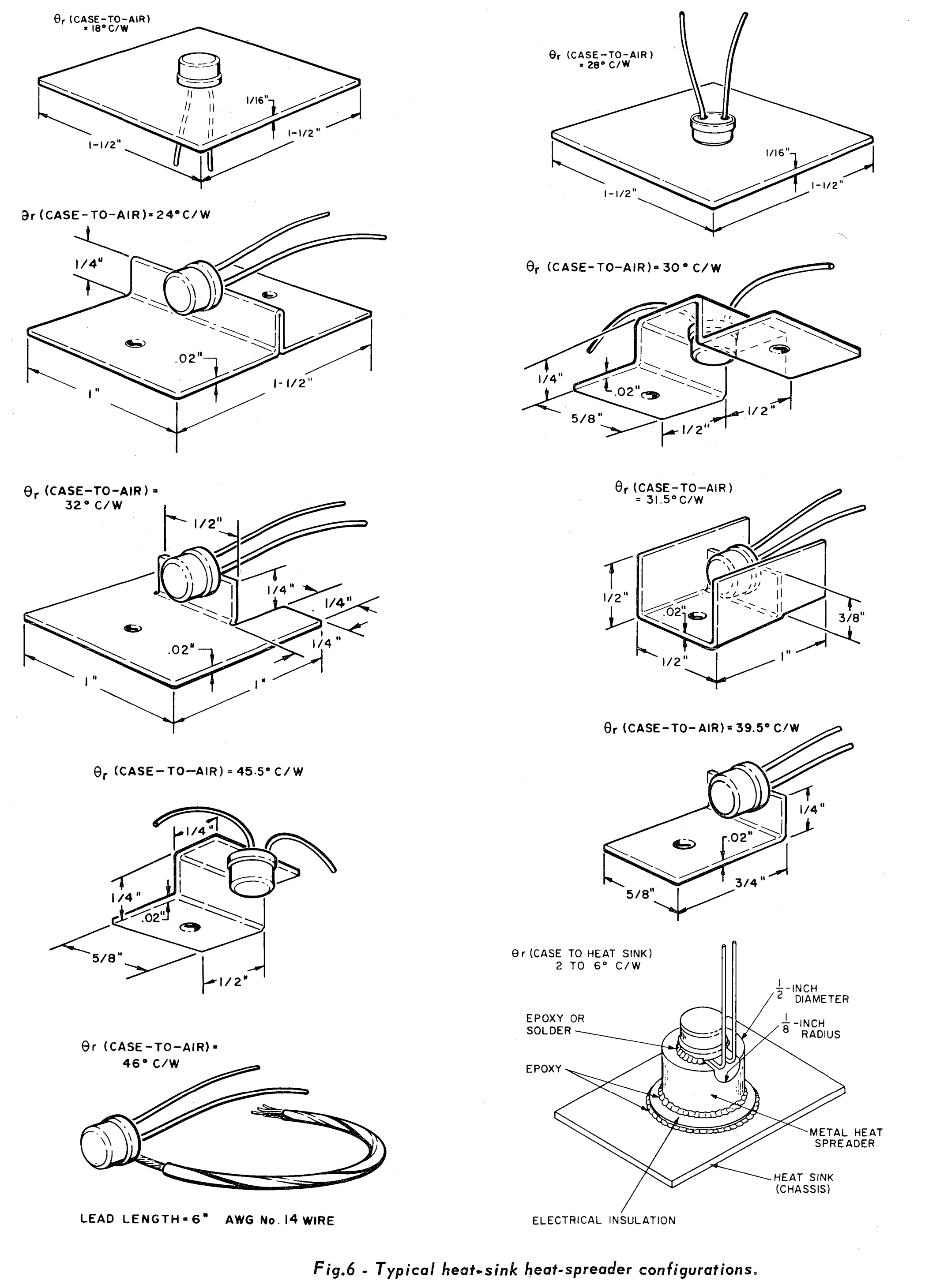


Fig.6 - Typical heat-sink heat-spreader configurations.

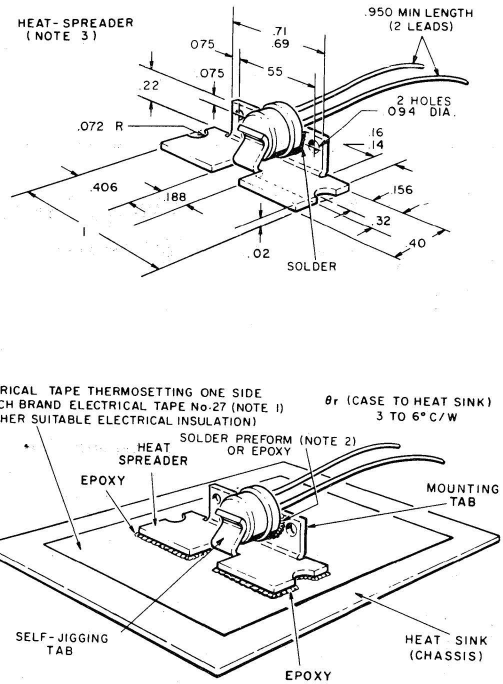


Fig.7 - Self-jigging heat spreader.

NOTES:

1. Products of Minnesota Mining & Mfg. Co., St. Paul, Minnesota.
2. Solder preforms are available from RCA as Part No.NR184A and from the Kester Solder Co., Newark, N.J. 07105 as Part No.KSFD-375005.
3. This heat spreader is available from RCA as Part No.NR166B and from the General Stamping Co., Inc. Denville, N.J. 07834 as Part No.14-110.

AC Voltage Regulators Using Thyristors

by G. J. Granieri

This Note describes a basic ac-voltage regulating technique using thyristors that prevents ac rms or dc voltage from fluctuating more than ± 3 per cent in spite of wide variations in input line voltage. Load voltage can also be held within ± 3 per cent of a desired value despite variations in load impedance through the use of a voltage-feedback technique. The voltage regulator described can be used in photocopying machines, light dimmers, dc power supplies, and motor controllers (to maintain fixed speed under fixed load conditions).

Circuit Operation

The schematic diagram of the ac regulator is shown in Fig.1. For simplicity, only a half-wave SCR configuration is shown; however, the explanation of circuit operation is easily extended to include a full-wave regulator that uses a triac.

The trigger device Q_1 used in Fig.1, a diac such as the RCA-40583, is an all-diffused three-layer trigger diode. This diac exhibits a high-impedance, low-leakage-current characteristic until the applied voltage reaches the breakover voltage V_{BO}, approximately 35 volts. Above this voltage, the device exhibits a negative resistance so that voltage decreases as current increases.

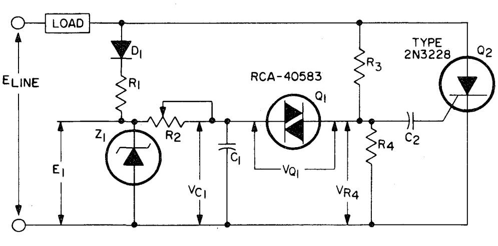


Fig.1 - A basic ac regulator.

Capacitor C_1 in Fig.1 is charged from a constant-voltage source established by zener diode Z_1. The capacitor is charged, therefore, at an exponential rate regardless of line-voltage fluctuations. A trigger pulse is delivered to the 2N3228 SCR, Q_2, when the voltage across capacitor C_1 is equal to the trigger voltage of diac Q_1 plus the instantaneous voltage drop developed across R_4 during the positive half-cycle of line voltage. When Q_1 is turned on, Q_2 is turned on for the remainder of the positive cycle of source voltage. Control of the conduction angle of the SCR regulates rms voltage to the load.

Regulation is achieved by the following means: When line voltage increases, the voltage across R_4 increases, but the charging rate of C_1 remains the same; as a result, the voltage across C_1 must attain a larger value than required without line-voltage increase before diac Q_1 can be triggered. The net effect is that the pulse that triggers Q_2 is delayed and the rms voltage to the load is reduced. In a similar manner, as line voltage is reduced, Q_2 turns on earlier in the cycle and increases the effective voltage across the load.

Fig.2 shows the voltage waveforms exhibited by the ac regulator at both high and low line voltage. The charging voltage for capacitor C_1, E_1, is equal to the zener voltage and remains constant up to the instant that the SCR is turned on. The capacitor voltage, V_{C1}, increases exponentially because the charging voltage E_1 is constant. The voltage across resistor R_4 conforms

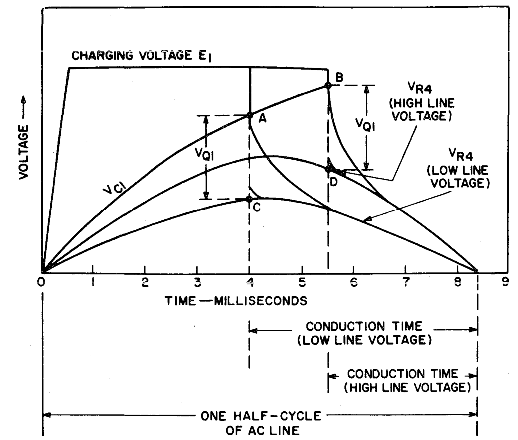


Fig.2 - Voltage waveforms exhibited by the ac regulator in Fig.1.

to the sinusoidal variations of the 60-Hz line voltage. At any given phase angle, the voltage across R_4 increases if line voltage increases and decreases if line voltage decreases.

The diac and SCR both trigger when the capacitor voltage, V_{C1}, equals the breakdown voltage of the diac plus the instantaneous value of voltage developed across R_4 during the positive half-cycle of line voltage. This capacitor voltage is represented by points A and B for the low and high line-voltage conditions, respectively. The instantaneous voltages across R_4 just before the SCR is triggered are represented by points C and D for the low and high line-voltage conditions, respectively. The voltage difference between points A and C and between points B and D is equal to the breakdown voltage of the diac.

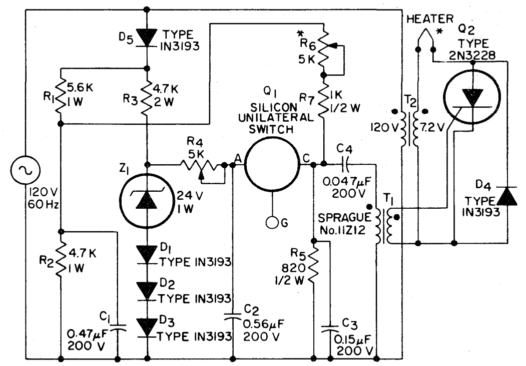
Fig.2 illustrates that the conduction time of the SCR is decreased as line voltage increases, and is increased when the line voltage decreases. By proper selection of the values of the voltage-divider-ratio resistors R_3 and R_4, it is possible to prevent the load voltage from varying more than 3 per cent with a 30-per-cent (approximate) change in line voltage.

It should be mentioned that during measurements of load voltage careful consideration must be given to the measuring instruments. Most of the circuits described in this Note produce a non-sinusoidal voltage across the load; the rms value of this voltage can be measured only with a true rms meter, such as a thermocouple meter. It is possible, however, that in certain applications the low input impedance of the thermocouple meter might load down the circuit being measured. In such cases, a high-input-impedance rms meter may be required.

HEATER REGULATION

Fig.3 shows a basic regulating technique for applications in which it is desired to maintain constant voltage across a load such as a receiving-tube heater, the filament of an incandescent lamp, or possibly a space heater. It should be noted that this configuration is actually a half-wave regulator. However, the circuit of Fig.3 differs from the circuit of Fig.1, in which one half-cycle is blocked from the load and the other half-cycle is phase-controlled to provide regulation. In Fig.3, essentially full voltage is applied to the load for one half-cycle by means of D4; the other half-cycle is phase-controlled by the SCR to provide regulation.

The circuit in Fig.3 is an open-loop regulator that features a high degree of safety; i.e., an open– or short-circuited component does not result in an excessive



* IN THE CLOSED-LOOP REGULATOR R_6 IS REPLACED BY A PHOTOCELL RCA SQ2520 AND A POTENTIOMETER IN SERIES WITH A 6-VOLT INCANDESCENT LAMP IS CONNECTED IN PARALLEL WITH THE HEATER TERMINALS

NOTE: ALL RESISTOR VALUES ARE IN OHMS

Fig.3 - A circuit using a regulator to maintain voltage constant across a load.

load voltage. Phase-controlled voltage regulation is provided by a silicon unilateral switch Q1* and a control circuit, as follows: Capacitor C_2 is charged from a voltage source that is maintained constant by zener diode Z_1; diodes D_1, D_2, and D_3 compensate for the change in zener voltage with temperature. The voltage across C_2 increases until the sum of the breakover voltage of Q_1 and the instantaneous voltage across R_5 is exceeded. At this point, a positive pulse is coupled into the gate of Q_2 by means of the pulse transformer T_1. The SCR Q_2 then switches on for the remainder of the positive cycle of line voltage. Control of the conduction angle of the SCR varies rms voltage to the heater.

* A silicon unilateral switch is a silicon, planar, monolithic integrated circuit that has thyristor electrical characteristics closely approximating those of an ideal four-layer diode. The device shown switches at approximately 8 volts.

As line voltage increases, the voltage across R_5 also increases; because C_2 charges along the same exponential curve, however, the voltage across C_2 must attain a larger value before Q_2 is turned on. The net effect is a delay in the trigger pulse and reduced rms voltage across the heater. In a similar manner, as line voltage is reduced, the SCR turns on earlier in the cycle and increases the effective voltage across the heater. By proper adjustment of potentiometer R_6 in conjunction with potentiometer R_4, it is possible to obtain excellent heater-voltage compensation over a range of line voltages. Fig.4 shows the waveforms associated with the heater-regulator circuit.

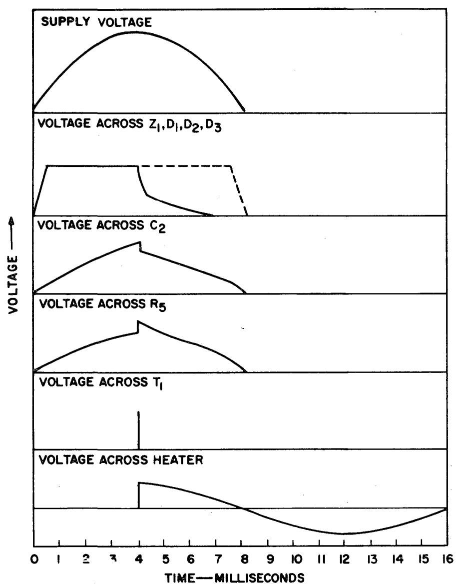


Fig.4 - Voltage waveforms exhibited by the circuit of Fig.3.

Curve A in Fig.5 shows heater voltage as a function of line voltage for the open-loop regulator circuit shown in Fig.3. Curve B in Fig.5 shows a similar curve for a closed-loop regulator using a lamp-photocell module. The lamp, in series with a limiting resistor, is connected across the heater terminals, and the photocell replaces R_6. The lamp unit senses the phase-controlled true rms heater voltage. Changes in lamp brightness produced by heater-voltage variations change the photocell resistance in reverse proportion to the lamp voltage. The remainder of the circuit functions as previously described except that regulation is obtained not only through the monitoring of the instantaneous magnitude of line voltage, but also through the sensing of the true rms voltage across the heater. This characteristic identifies the

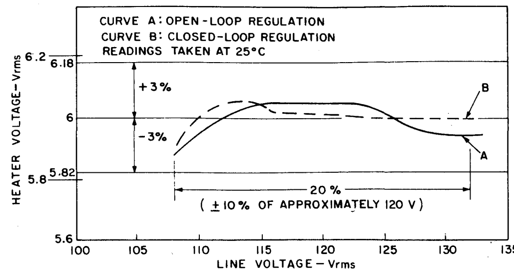


Fig.5 - Heater voltage as a function of line voltage of the open- and closed-loop regulators.

circuit as an ac voltage regulator with closed-loop feedback control. The closed-loop regulator produces less error, is more resistant to the drift effects of components, and is easier to adjust than the open-loop regulator.

The lamp used in the closed-loop regulator is rated at 6 volts, but the series resistor limits the voltage to approximately 2 volts so that extremely long lamp life can be expected. An additional advantage at low voltage is that the light intensity varies linearly with the voltage across the lamp so that a small increase in voltage increases brightness markedly; near rated voltage the intensity does not vary linearly and the variation in brightness is not very apparent. A loss in sensitivity would result if the lamp were operated at its rated voltage.

The open-loop regulator can regulate 6 volts to within ± 3 per cent within a temperature range from 10 to 40°C with an input-voltage swing of ± 10 per cent. The closed-loop regulator can regulate 6 volts to within ± 2 per cent within a temperature range from 0 to 60°C with an input-voltage swing of ± 10 per cent.

LIGHT DIMMER WITH OVER-VOLTAGE CLAMP

Light-dimmer circuits are becomingly increasingly popular for home use. Fig.6 shows a typical light-dimmer configuration. This circuit provides the advantages of low hysteresis and continuous control up to the maximum conduction angle. At low illumination

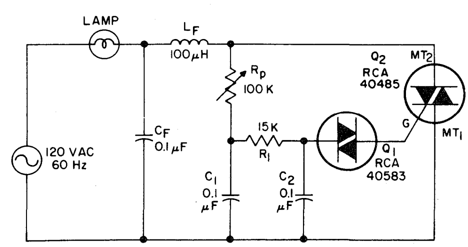
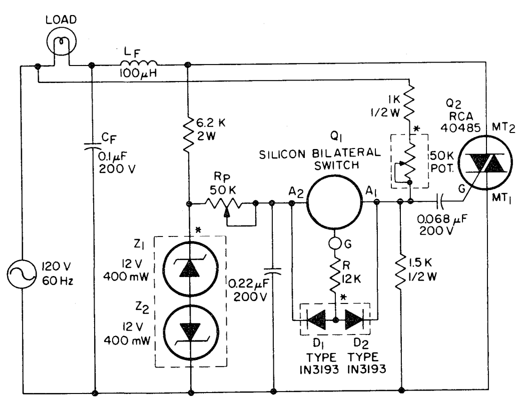


Fig.6 - A typical light-dimmer circuit.

levels, however, the variable resistor R_p is adjusted to a high resistance setting. If a momentary drop in line voltage occurs at this condition, the high breakover voltage of the diac in conjunction with the high resistance could result in a circuit misfire; i.e., the light could be extinguished and remain so until the circuit is reset by readjustment of the control to a high illumination setting.

A natural successor to the circuit of Fig.6 might consist of a configuration which not only provides the light-dimming function but also extends the life of the lamp being controlled. One of the major causes of reduced lamp life can be directly attributed to line-voltage fluctuations and in particular to periods of over-voltage. Nominal line voltage is approximately 120 volts ± 10 per cent; it is the + 10-per-cent variation that causes lamps to reach end-of-life prematurely.

A technique for limiting or clamping the lamp voltage, without sacrificing any of the desirable features of the dimmer of Fig.6, is shown in Fig.7; L_F and C_F suppress rf interference. Fig.7 employs the basic regulating circuit described earlier; however, in the configuration shown, the switching voltage of Q_1, a silicon bilateral switch,* is reduced by steering diodes D_1 and D_2 in conjunction with resistor R. This arrangement not



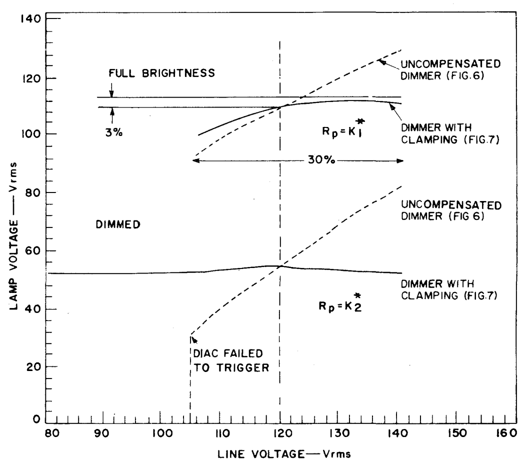
*DASHED LINES INDICATE MAJOR ADDITIONAL COMPONENTS REQUIRED TO ACHIEVE VOLTAGE CLAMP

NOTE: ALL RESISTOR VALUES ARE IN OHMS

Fig.7 - A light-dimmer circuit that includes clamping.

only makes it possible to achieve larger conduction angles, but also prevents the circuit from misfiring at low illumination levels when it is subjected to dips in line voltage. The light-dimmer circuit in Fig.7 is capable of clamping the high-line-voltage condition to within +3 per cent of its nominal value; as a result, the lamp is subjected to voltages of 120 volts plus 3 per cent and minus 10 per cent. The − 10-per-cent line dip has little effect on lamp-life reduction.

The circuit also regulates lamp voltage for various settings of potentiometer R_p. Fig.8 shows line voltage as a function of lamp voltage for two settings of R_p for the circuits of Figs.6 and 7. These curves illustrate the increased regulation achieved by the improved circuit.



*K_1 AND K_2 ARE ARBITRARY BUT DIFFERENT VALUES

Fig.8 - Lamp voltage as a function of line voltage for two values of R_p in the circuits of Figs.6 and 7.

The dimmer configuration of Fig.7 can also be used as a 120-volt full-wave heater regulator. In this application the light is replaced by a heater load. If the load can be operated at a nominal 100 volts with an input voltage of 120 volts, more symmetrical regulation can be realized; i.e., ±3 per cent regulation can be achieved with a line variation of ±10 per cent. In the full-wave heater-regulator application, diodes D_1, D_2, and resistor R in Fig.7 can be eliminated because a wide conduction angle is not required.

Such a control might also be used in colorimetry, an application in which it is necessary to match the color (and temperature) of a lamp with a standard; in this application line-voltage fluctuations can create a measurement error. Other areas of application, such as photography, heater control, and hot-plate and solder-pot control, can also make effective use of the dimmer circuit with over-voltage clamp.

VOLTAGE-REGULATED DC SUPPLY

A simple but stable dc power supply using thyristors is shown in Fig.9. The power-supply section consists of the well known full-wave bridge with RC filter.

* A silicon bilateral switch is a silicon, planar, monolithic integrated circuit that switches at approximately 8 volts in both directions.

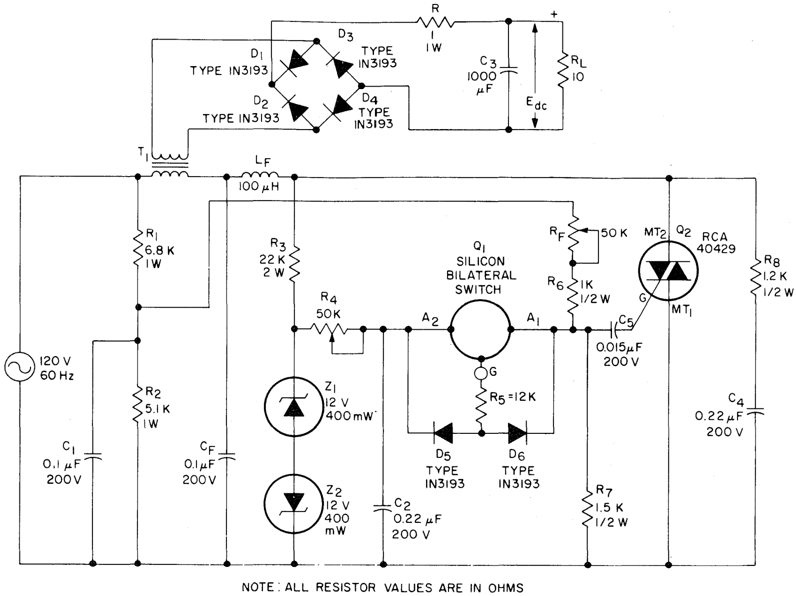


Fig.9 - A voltage-regulated dc supply.

A line-voltage transformer is employed to step-down the supply voltage of 120 volts rms to approximately 12.5 volts rms. If a dc output voltage greater than 10 volts is desired, a transformer with a lower primary-to-secondary turns ratio should be employed.

The heart of the regulator shown in Fig.9 is the phase-controlled triac on the primary side of the line transformer. Because the load presented to the triac is somewhat inductive, an RC network is used to assure proper commutation; L_F and C_F suppress rf interference. The circuit automatically compensates for wide variations in line voltage. Fig.10 shows a curve of line voltage as a function of load voltage, E_{dc}, for a constant load of 10 ohms. Fig.11 shows the voltage waveforms associated with the circuit of Fig.9.

If increased line, temperature, and load compensation is desired in the regulated dc supply of Fig.9, a closed-loop type of control can be obtained by use of a photocell in place of R_F and connection of a lamp across the output terminals of the supply in such a way that the light from the lamp can impinge on the photocell surface.

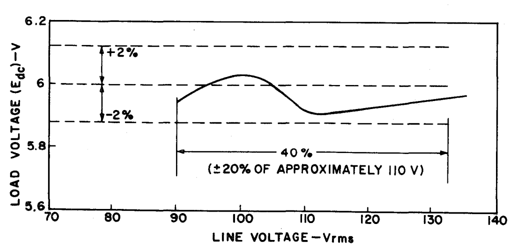


Fig.10 - Load voltage as a function of line voltage for the circuit of Fig.9; load resistance is constant at 10 ohms.

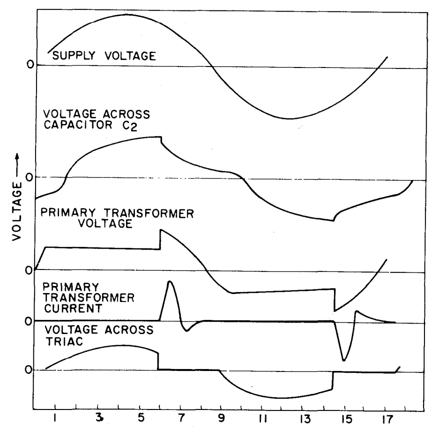


Fig.11 - Voltage waveforms exhibited by the circuit of Fig.9.

SELECTION OF CONTROL DEVICE

Other thyristors than those shown in this Note can also be used for voltage regulation. The selection of an SCR or triac for a particular regulating circuit depends on the voltage and current requirements of the application. The quick-selection charts shown below indicate the capabilities of RCA thyristors for this type of usage.

	Triac Quick-Selection Chart						SCR Quick-Selection Chart						
Line Operation	0.35A	6A	10A	15A	30A	40A	2A	5A	7A	12.5A	15A	25A	35A
120-Volt	40526	40429	2N5567	2N5571	40660	2N5441	2N3528	2N3228	40378	2N3669	2N1846A	2N685	2N3871
	40529	40431	2N5569	2N5573	40662	2N5441		40504	40507				2N3897
	40532	40485						40553					
	40535	40502											
		40509											
		40511											
		40638											
240-Volt	40527	40430	2N5568	2N5572	40661	2N5442	2N3529	2N3525	40379	2N3670	2N1849A	2N688	2N3872
	40530	40432	2N5570	2N5574	40663	2N5445		40505	40508				2N3898
	40533	40486		40576				40554					
	40536	40503											
		40510											
		40512											
		40639											

RCA
Solid State Division

Power Transistors and Thyristors
Application Note
AN-4124

Handling and Mounting of RCA Molded-Plastic Transistors and Thyristors

by W.J. Hepp, J.S. Vara, and J. Gaylord

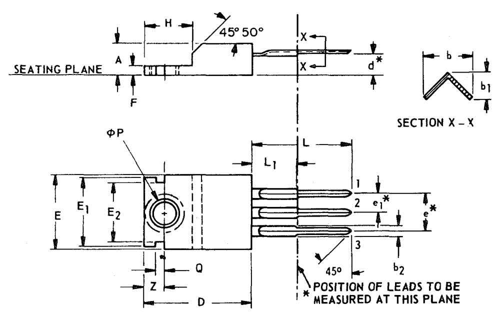
RCA power transistors and thyristors (SCR's and triacs) in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations. This Note provides detailed guidelines for handling and mounting of these plastic-package devices, and shows different types of packages and suggested mounting hardware to accommodate various mounting arrangements. Recommendations are made for handling of the packages during the forming of leads to meet specific mounting requirements. Various mounting arrangements, thermal considerations, and cleaning methods are described. This information is intended to augment the data on electrical characteristics, safe operating area, and performance capabilities in the technical bulletin for each type of plastic-package transistor or thyristor. (Data on mechanical and environmental capabilities of RCA plastic-package transistors are also available in a periodically updated **Reliability Report**, RCA Publication No. HBT-600.)

TYPES OF PACKAGES

Two basic types of molded-plastic packages are used for RCA solid-state power devices. These types include the RCA Versawatt packages for medium-power applications and the RCA high-power plastic packages, both of which are specifically designed for ease of use in many applications. Each basic type offers several different package options, and the user can select the configuration best suited to his particular application.

Figs. 1 through 3 show the options currently available for devices in RCA Versawatt packages. The JEDEC Type TO-220AB in-line-lead version, shown in Fig. 1, represents the basic style. This configuration features leads that can be formed to meet a variety of specific mounting requirements. Fig. 2 shows a package configuration that allows a Versawatt package to be mounted on a printed-circuit board with a 0.100-inch grid and a minimum lead spacing of 0.200 inch. Fig. 3 shows a JEDEC Type TO-220AA version of the Versawatt package. The dimensions of this type of transistor package are such that it can replace the JEDEC TO-66 transistor package in a commercial socket or printed-circuit board without retooling. The pin-connection arrangement of thyristors supplied in TO-220AA packages, however, differs from that of thyristors supplied in conventional TO-66 packages so that some hardware changes are required to effect a replacement. The TO-220AA Versawatt package is also supplied with an integral heat sink. Fig. 4 shows the dimensional outline for this heat sink. The use of the integral heat sink reduces the junction-to-air thermal resistance of the package from 70°C per watt to 35°C per watt.

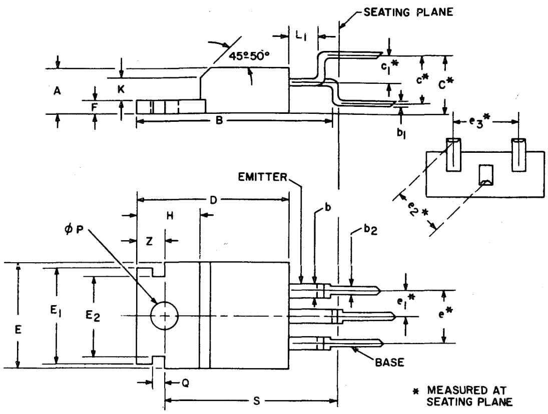
The RCA molded-plastic high-power packages are also supplied in several configurations for flexibility of application. The JEDEC Type TO-219AB, shown in Fig. 5, is the basic high-power plastic package. Fig. 6 shows a JEDEC Type TO-219AA version of the high-power plastic package. With the addition of an NR193B top clamp, the TO-219AA



SYMBOL	INCHES MIN.	INCHES MAX.
A	.140	.190
b	.020	.038
b_1	.012	.045
b_2	.045	.070
D	.560	.625
d	.080	.115
E	.330	.420
E_1	.365	.385
E_2	.300	.320

SYMBOL	INCHES MIN.	INCHES MAX.
e	.190	.210
e_1	.090	.110
F	.045	.055
H	.230	.270
L	.500	.562
L_1		.250
ΦP	.139	.147
Q	.040	.060
Z	.100	.120

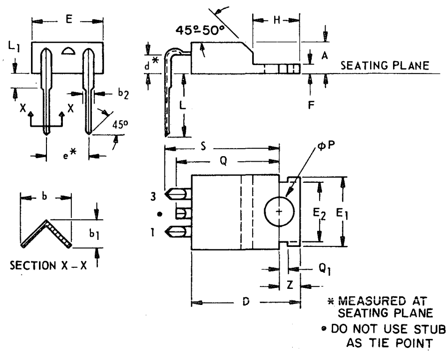
Fig. 1 - Dimensional outline of the JEDEC TO-220AB in-line-lead Versawatt transistor package.



SYMBOL	INCHES	
	MIN.	MAX
A	.140	.190
B		.850
b	.045	.070
b_1	.015	.030
b_2	.020	.038
C	.230	.270
c	.180	.220
c_1	.130	.170
D	.560	.625
E	.330	.410
E_1	.365	.385
E_2	.300	.320

SYMBOL	INCHES	
	MIN.	MAX
e	.190	.210
e_1	.090	.110
e_2	.203	.243
e_3	.190	.200
F	.045	.070
H	.230	.270
K	.080	.085
L_1	.070	.090
ΦP	.139	.147
Q	.040	.060
S	.655	.685
Z	.100	.120

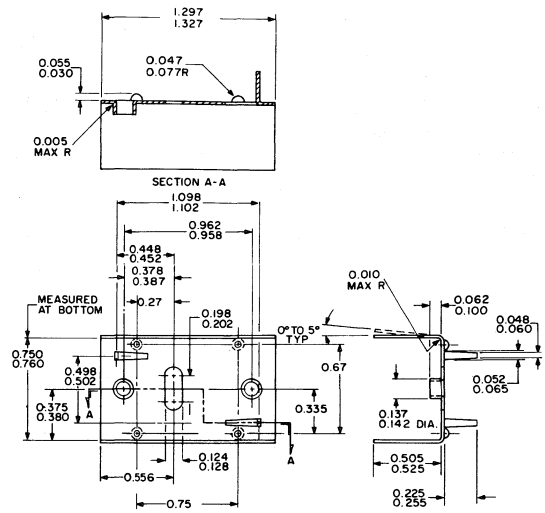
Fig. 2 - Dimensional outline of Versawatt transistor package designed for mounting on printed-circuit boards.



SYMBOL	INCHES	
	MIN.	MAX.
A	.140	.190
b	.020	.038
b_1	.012	.045
b_2	.045	.070
D	.560	.625
d	.080	.115
E	.330	.420
E_1	.365	.385
E_2	.300	.320
e	.190	.210

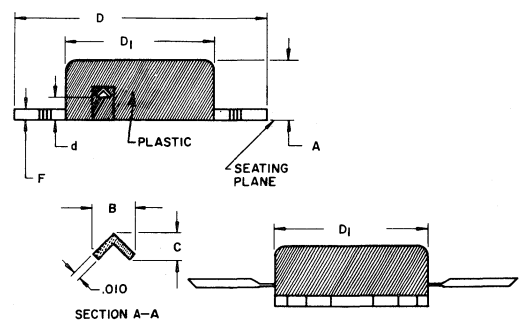
SYMBOL	INCHES	
	MIN.	MAX.
F	.045	.055
H	.230	.270
L	.360	.422
L_1		.050
ϕP	.139	.147
Q		.610
Q_1	.040	.060
S	.580	.610
Z	.100	.120

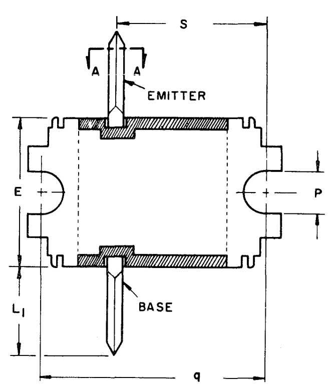
Fig. 3 - JEDEC TO-220AA Versawatt transistor package designed for direct replacement of the JEDEC TO-66 package.



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SHOWN. TOLERANCES ARE: ±0.02 FOR 2ND PLACE; ±0.005 FOR 3RD PLACE AND ±1/2° FOR ANGULAR DIMENSION.

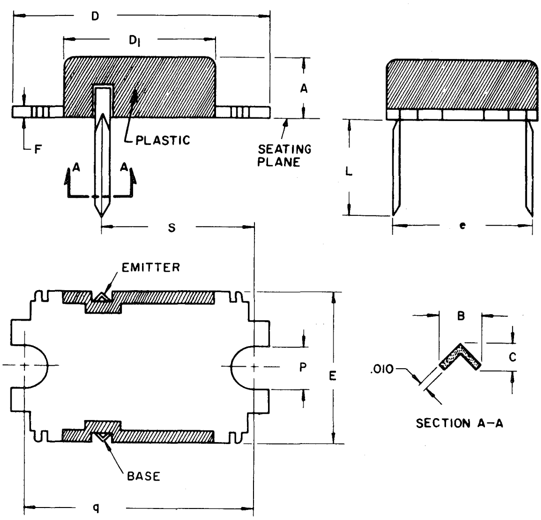
Fig. 4 - Integral heat sink used with the TO-220AA Versawatt package shown in Fig. 3.





SYMBOL	INCHES	
	MIN.	MAX.
A	.160	.200
B	.045	.060
C	.025	.045
D	.890	.910
D_1	.480	.515
d	.100	.120
E	.480	.520
F	.055	.070
L_1	.415	.560
p	.128	.150
q	.740	.760
S	.500	.520

Fig. 5 - JEDEC TO-219AB high-power molded-plastic transistor package.

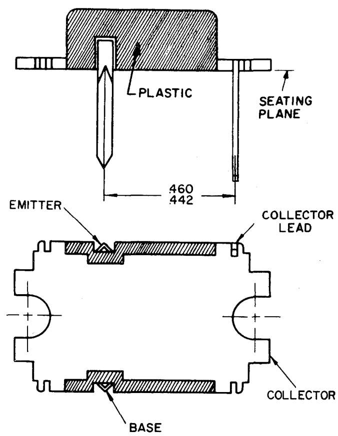


SYMBOL	INCHES	
	MIN.	MAX.
A	.160	.200
B	.045	.060
C	.025	.045
D	.890	.910
D_1	.480	.515
E	.480	.520

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.



ALL DIMENSIONS IN INCHES

Fig. 7 - TO-219AA plastic transistor package designed for mounting on printed-circuit boards.

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 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.

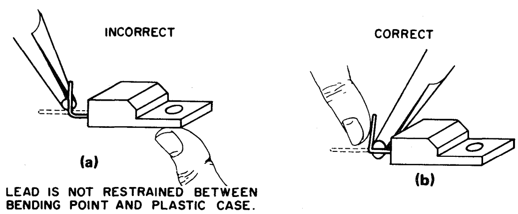


Fig. 8 - Use of long-nosed pliers for lead bending: (a) incorrect method; (b) correct method.

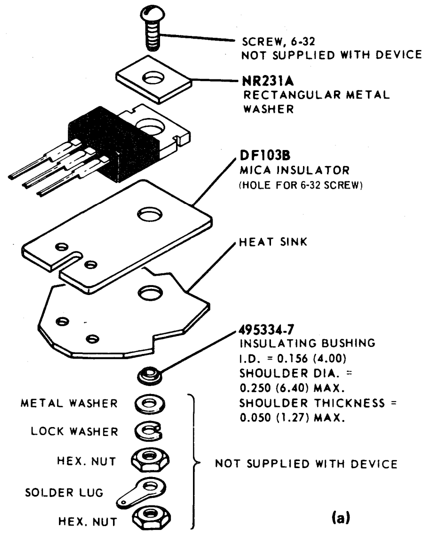
When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

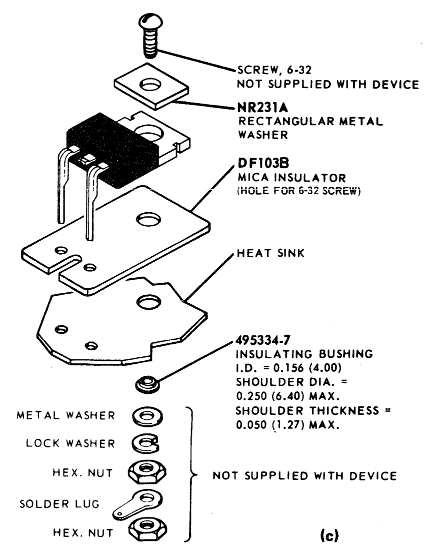
1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, 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.

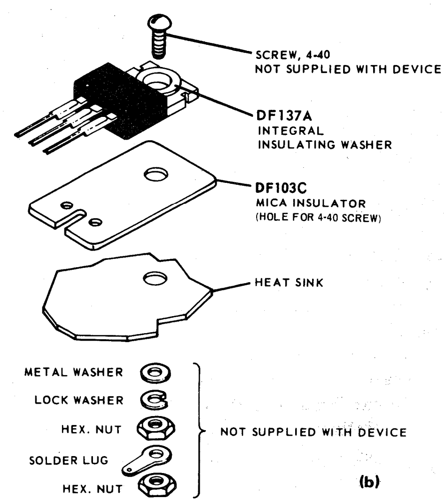
The leads of the TO-220AB Versawatt in-line package are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised. Fig. 2 illustrates an acceptable lead-forming method that provides this relief.

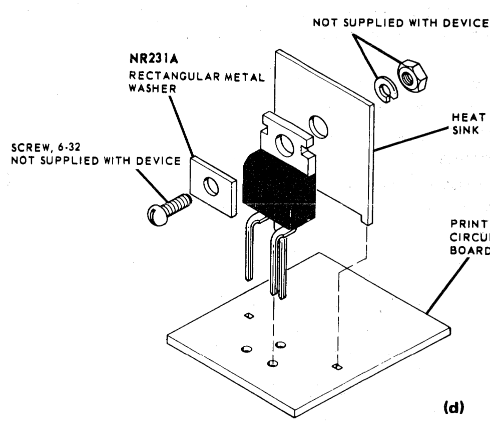
Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed; the maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance 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.

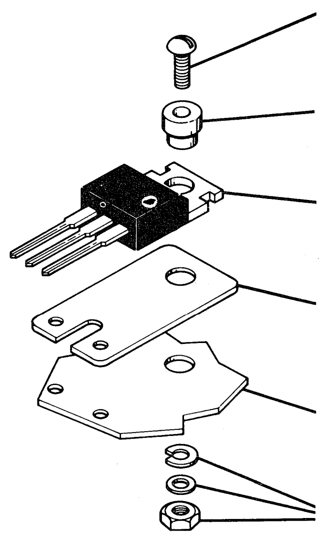
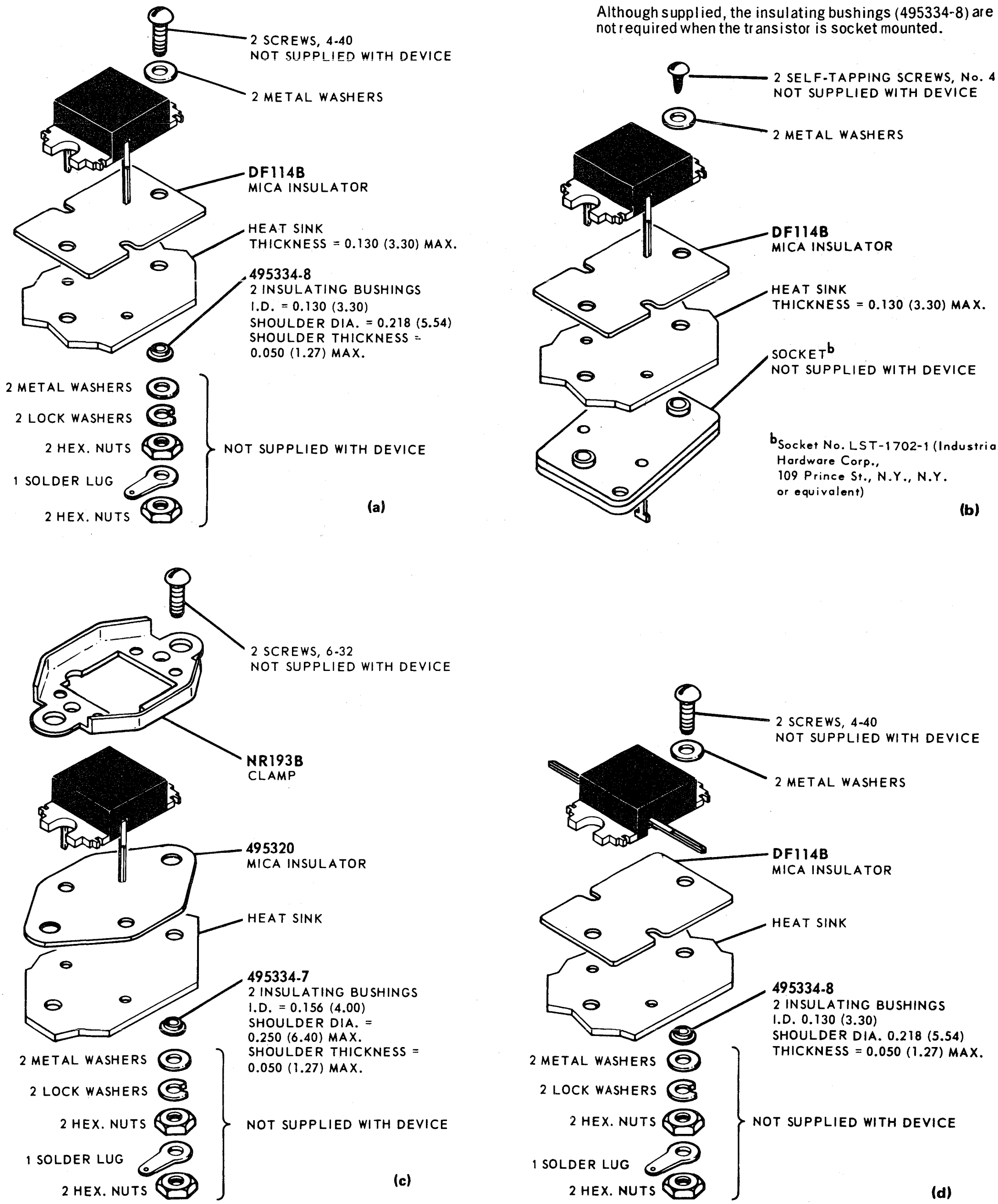


Fig. 10 - Mounting arrangements in which an isolating bushing is used to raise the head of the mounting screw above the plastic body of the Versawatt transistor.

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.

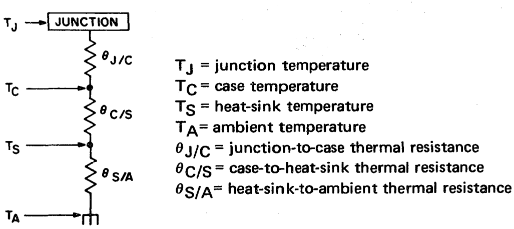


Fig. 12 - Thermal equivalent circuit for a transistor mounted on a heat sink.

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.

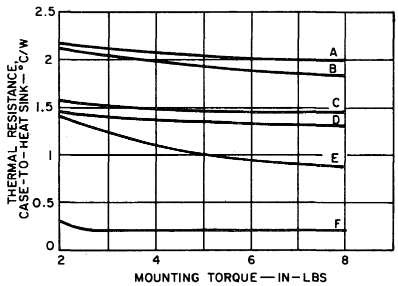
It is, of course, impractical to evaluate the effect on long-term transistor life of all cleaning solvents, which are marketed under a variety of brand names with numerous additives. These solvents can, however, be classified with respect to their component parts, as either acceptable or unacceptable. 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:

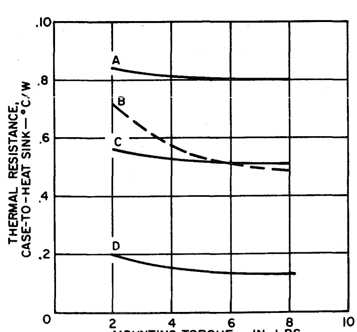
1. Alpha Reliaros No. 320-33
2. Alpha Reliaros No. 346
3. Alpha Reliaros No. 711
4. Alpha Reliafoam No. 807
5. Alpha Reliafoam No. 809
6. Alpha Reliafoam No. 811-13
7. Alpha Reliafoam No. 815-35
8. Kester No. 44

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.

A Review of Thyristor Characteristics and Applications

by T.C. McNulty

Thyristors, both SCR's and triacs, are now widely accepted in power-control applications. With the emphasis in such applications placed on low cost, small package size, and circuit simplicity, thyristors satisfy these requirements with reliability exceeding that of electromechanical counterparts. This Note describes the operation, ratings, characteristics, and typical applications of these devices.

Types of Thyristors

Thyristors are semiconductor devices that have characteristics similar to those of thyratron tubes; more specifically, they are semiconductor switches whose bistable state depends on the regenerative feedback associated with a p-n-p-n structure. Basically, this group includes any bistable semiconductor device that has three or more junctions (i.e., four or more semiconductor layers) and can be switched from a high-impedance (OFF) state to a conducting (ON) state, and from the conducting (ON) state to the high-impedance (OFF) state, within at least one quadrant of the principal-voltage characteristics.

There are several types of thyristors, which differ primarily in number of electrode terminals and operating characteristics associated with the third quadrant (negative) of the voltage-current characteristics. Reverse-blocking triode thyristors, commonly called silicon controlled rectifiers (SCR's), and bidirectional triode thyristors, referred to as triacs, are the most popular types. Silicon controlled rectifiers have satisfied the requirements of many power-switching applications with much greater reliability than electromechanical or tube counterparts. As the use of SCR's in power applications increased, the need for complete ac control became apparent. The new family of thyristor devices generated to provide bidirectional current properties is referred to as triacs. A triac can be considered as two parallel SCR's (p-n-p-n) oriented in opposite directions to provide symmetrical bidirectional characteristics.

Two-Transistor Analogy

The bistable action of thyristors can be explained by analysis of the structure of an SCR. This analysis can be related to either operating quadrant of a triac because a triac is essentially two parallel SCR's oriented in opposite directions. A two-transistor analogy of an SCR is illustrated in Fig. 1. Fig. 1(a) shows the schematic symbol for an SCR, and Fig. 1(b) shows the p-n-p-n structure the symbol represents. In the two-transistor model for the SCR shown in Fig. 1(c), the interconnections of the two transistors are such that regenerative action can occur when a proper gate signal is applied to the base of the lower n-p-n transistor.

In the diagram of Fig. 2, the emitter of the upper (p-n-p) transistor is returned to the positive terminal of a dc supply through a limiting resistor R_2, and the emitter of the lower (n-p-n) transistor is returned to the negative terminal of the dc supply to provide a complete electrical path. When the model is in the OFF state, the initial principal-current flow is zero. If a positive pulse is then applied to the base of the n-p-n transistor, the transistor turns on and forces the collector (which is also the base of the p-n-p transistor) to a low potential; as a result, current (I_a) begins to flow. Because the p-n-p transistor is then in the active state, collector current ($I_{c1} = I_{b2}$) flows into the base of the n-p-n transistor and sets up the conditions for regeneration. If the external gate drive is removed, the model remains in the ON state as a result of the division of currents associated with the two transistors, provided that sufficient principal current (I_a) is available.

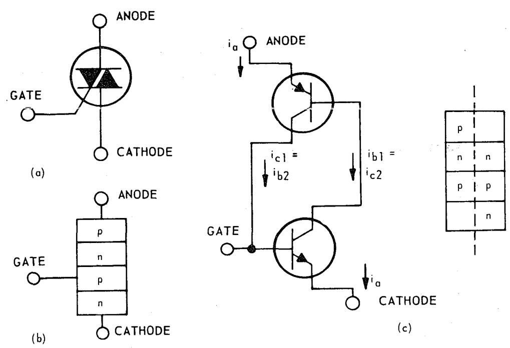


Fig. 1 - Two-transistor analogy of an SCR: (a) schematic symbol of SCR; (b) p-n-p-n structure represented by schematic symbol; (c) two-transistor model of SCR.

Theoretically, the model shown in Fig. 2 remains in the ON state until the principal current flow is reduced to zero. Actually, turn-off occurs at some value of current greater than zero. This effect can be explained by observation of the division of currents as the value of the limiting resistor is gradually increased. As the principal current is gradually reduced to the zero current level, the division of currents within the model can no longer sustain the required regeneration and the model reverts to the blocking state.

The two-transistor model illustrates three features of thyristors: (1) a gate trigger current is required to initiate regeneration, (2) a minimum principal current (referred to as "latching current") must be available to sustain regeneration, and (3) reduction of principal-current flow results in turn-off at some level of current flow (referred to as "holding current") slightly greater than zero.

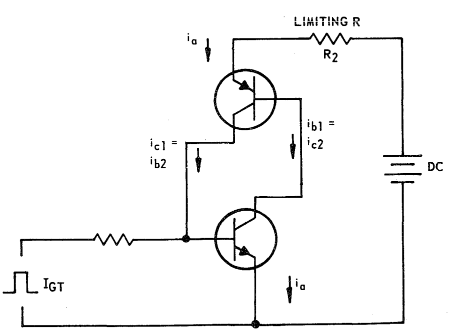


Fig.2 - Two-transistor model connected to show a complete electrical path.

Fig. 3 illustrates the effects on latching and holding current for resistive termination at the base of the n-p-n transistor. The collector current through the p-n-p transistor must be increased to supply both the base current for the n-p-n transistor and the shunt current through the terminating resistor. Because the principal-current flow must be increased to supply this increased collector current, latching and holding current requirements also increase. The use of the two-transistor model provides a more concise meaning to the mechanics of thyristors. In thyristor fabrication, it is generally good practice to use a low-beta p-n-p unit and to include internal resistance termination for the base of the n-p-n unit. Termination of the n-p-n unit provides immunity from "false" (non-gated) turn-on, and the use of the low-beta p-n-p units permits a wider base region to be used to support the high voltage encountered in thyristor applications.

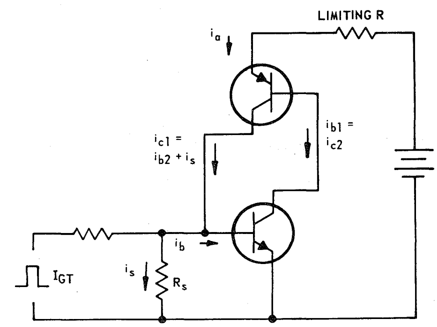


Fig.3 - Two-transistor model of SCR with resistive termination of the n-p-n transistor base.

Voltage and Temperature Ratings

The effects of temperature and voltage are important in thyristors because these devices possess regenerative action and are required to support high voltage in the OFF state. In the two-transistor model shown in Fig. 2, an increase in temperature causes a leakage current which, if allowed to migrate to the base of the n-p-n transistors, forces the transistor into the active region. Regenerative action then calls for additional leakage current, and causes the model to switch into the ON state and establish a principal-current flow. For reliable operation at high temperature, the base of the n-p-n transistor should be terminated with a low value of resistance to prevent turn-on as a result of high-temperature operation.

Because gate termination is required on all thyristors, RCA devices contain a diffused internal gate-cathode resistor (the so-called "shorted-emitter" design) and do not require external gate termination. Therefore, it is not necessary to specify an OFF-state rating under the conditions of external gate-resistance termination. The use of this internal shunt resistance improves the OFF-state blocking capability, provides increased immunity against false turn-on, and slightly increases gate-current requirements.

OFF-state voltage ratings of thyristors are specified for both steady-state and transient operation for both forward (positive) and reverse (negative) blocking conditions at the maximum junction temperature. For SCR's, voltages are considered to be forward (positive) when the anode is at a positive potential with reference to the cathode. Negative voltages are referred to as reverse-blocking voltages. For triacs, voltages are considered to be positive when main terminal 2 is at a positive potential with reference to main terminal 1; this condition is referred to as first-quadrant (I) operation. Third-quadrant (III) operation occurs when main terminal 2 is at a negative potential with reference to main terminal 1. Fig. 4 shows the principal voltage-current characteristics for both SCR's and triacs.

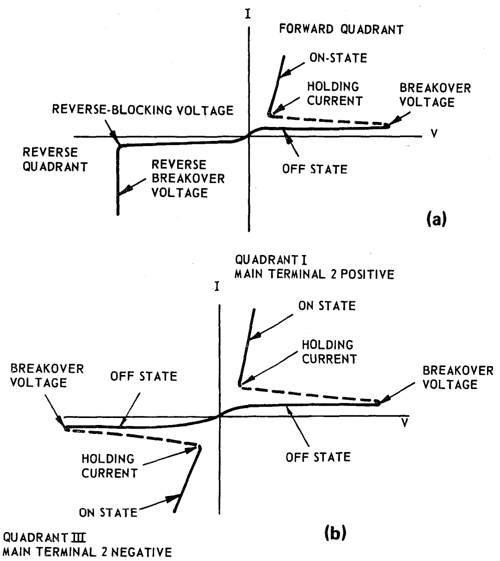


Fig.4 - Principal voltage-current characteristics of SCR's and triacs.

Operation of an SCR under reverse-blocking voltage is similar to that of a reverse-biased silicon rectifier or other semiconductor diodes. In this operating mode, the SCR exhibits a very high internal impedance, and a small reverse current flows through the p-n-p-n structure until the reverse breakdown voltage is reached, at which time the reverse current increases rapidly. For forward (positive) operation, the SCR is electrically bistable and exhibits either high impedance (forward-blocking or OFF state) or low impedance (forward-conducting or ON state). In the forward-blocking state, a small leakage current, considered to be of approximately the same value as that for reverse leakage, flows through the p-n-p-n structure. As the forward voltage is increased, a "breakdown" point is reached at which the forward current increases rapidly and the voltage across the SCR decreases abruptly to a very low voltage, referred to as the forward ON voltage. When the SCR is in the ON state, the forward current is limited primarily by the impedance of the external circuit. Increases in forward (principal) current are accompanied by only a slight change in ON-state voltage.

If the triac is considered as two parallel SCR's oriented in opposite directions to provide symmetrical current flow, the behavior of a triac under positive or reverse voltage operation is essentially the same as that of an SCR in the forward-blocking mode.

Gate Characteristics

The breakover voltage of a thyristor can be varied, or controlled, by injection of a signal at the gate terminal. Fig. 5

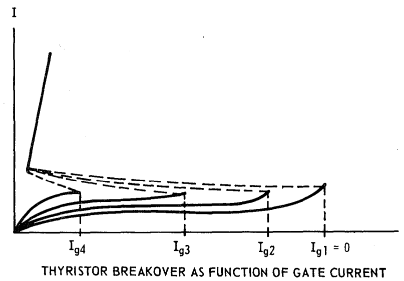


Fig.5 - Thyristor breakover as a function of gate current.

shows curves of breakover as a function of gate current for first-quadrant operation of an SCR. A similar set of curves can be drawn for both the first and the third quadrant to represent triac operation.

When the gate current I_g is zero, the applied voltage must reach the breakover voltage of the SCR or triac before switching occurs. As the value of gate current is increased, however, the ability of a thyristor to support applied voltage is reduced and there is a certain value of gate current at which the behavior of the thyristor closely resembles that of a rectifier. Because thyristor turn-on, as a result of exceeding the breakover voltage, can produce instantaneous power dissipation during the switching transition, an irreversible condition may exist unless the magnitude and rate of rise of principal current is restricted to tolerable levels. For normal operation, therefore, thyristors are operated at applied voltages lower than the breakover voltage, and are made to switch to the ON state by gate signals of sufficient amplitude to assure complete turn-on independent of the applied voltage. Once the thyristor is triggered to the ON state, the principal-current flow is independent of gate voltage or gate current, and the device remains in the ON state until the principal-current flow is reduced to a value below the holding current required to sustain regeneration.

The gate voltage and current required to switch a thyristor from its high-impedance (OFF) state to its low-impedance (ON) state at maximum rated forward anode current can be determined from the circuit shown in Fig. 6. Resistor R_2 is selected so that the anode current specified in the manufacturer's ratings flows when the device latches into its low-impedance or ON state. The value of R_1 is gradually decreased until the device under test is switched from its OFF state to its low-impedance or ON state. The values of gate current and gate voltage immediately prior to switching are the values required to trigger the thyristor. For an SCR, there is only one mode of gate firing capable of switching the device into the ON state, i.e., a positive gate signal for a positive anode voltage. If the gate polarity is reversed (negative voltage), the reverse current flow is limited by the value of R_2 and the gate-cathode internal shunt. The value of power dissipated for the reverse gate polarity is restricted to the maximum power-dissipation limit imposed by the manufacturer.

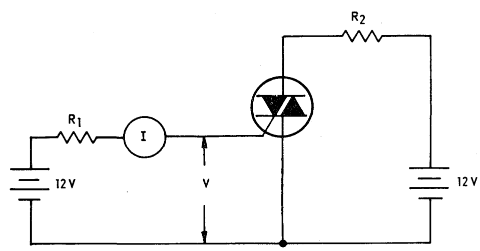


Fig.6 - Circuit used to measure thyristor gate voltage and current switching threshold.

Because of its complex structure, a triac can be triggered by either a positive or a negative gate signal regardless of the voltage polarity across the main terminals of the device. Fig. 7 illustrates the triggering mechanism and current flow within a triac. The gate trigger polarity is always referenced

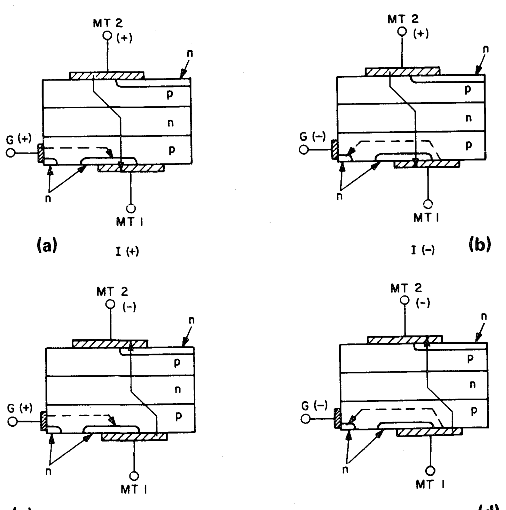


Fig.7 - Current flow in a triac.

to main terminal 1. The potential difference between the two terminals is such that gate current flows in the direction indicated by the dotted arrow. The polarity symbol at main terminal 2 is also referenced to main terminal 1. The semiconductor materials between the various junctions within the pellet are labeled "p" and "n" to indicate the type of majority-carrier concentrations within the material.

For the various operating modes, the polarity of the voltage on main terminal 2 with respect to main terminal 1 is given by the quadrant in which the triac operates (either I or III), and the polarity of the gate signal used to trigger the device is given by the proper symbol next to the operating quadrant. For the I(+) operating mode, main terminal 2 and the gate are both positive with respect to main terminal 1. Initial gate current flows into the gate terminal, through the p-type layer, across the junction into the n-type layer, and out main terminal 1, as shown by the dotted arrow. As gate current flows, current multiplication occurs and the regenerative action within the pellet switches the triac to its ON state. Because of the polarities indicated between the main terminals, the principal current flows through the p-n-p-n structure as shown by the solid arrow. Similarly, for the other three operating modes, the initial gate-current flow is shown by the dotted arrow, and principal-current flow through the main terminals is shown by the solid arrow.

Because the direction of principal current influences the gate trigger current, the magnitude of the current required to trigger the triac differs for each mode. The operating modes in which the principal current is in the same direction as the gate current require less gate trigger current; modes in which the principal current is in opposition to the gate current require more gate trigger current.

Because triacs are bidirectional, they can provide full-cycle (360-degree) control of ac power from either a positive or a negative gate-drive signal. This feature is an advantage when it is necessary to control ac power from low-level logic systems such as integrated-circuit logic. With gate-power requirements for turn-on in the milliwatt region, triacs are capable of controlling power levels up to 10 kilowatts. Thus, the power gain associated with these thyristors far exceeds that of transistor counterparts in the semiconductor switching field.

Like many other semiconductor-device parameters, the magnitude of gate trigger current and voltage varies with the junction temperature. As thermal excitation of carriers within the semiconductor material increases, the increase in leakage current makes it easier for the device to be triggered by a gate signal. Therefore, the gate becomes more sensitive in all operating modes as the junction temperature increases. Conversely, if a triac or SCR is to be operated at low temperatures, sufficient gate trigger current must be provided to assure triggering of all devices at the lowest operating temperature expected in any particular application. Variations of gate-trigger requirements are given in the published data for individual thyristors.

The gate current specified in published data for thyristors is the dc gate trigger current required to switch an SCR or triac into its low-impedance state. For practical purposes, this dc value can be considered equivalent to a pulse current that has a minimum pulse width of 50 microseconds. For gate-current pulse widths smaller than 50 microseconds, the pulse-current curves associated with a particular device should be used to assure turn-on.

When pulse triggering of a thyristor is required, it is always advantageous to provide a gate-current pulse that has a magnitude exceeding the dc value required to trigger the device. The use of large trigger currents reduces variations in turn-on time, increases di/dt capability, minimizes the effect of temperature variation on triggering characteristics, and makes possible very short switching times. When a thyristor is initially triggered into conduction, the current is confined to a small area which is usually the more sensitive part of the cathode. If the anode current magnitude is great, the localized instantaneous power dissipation may result in irreversible damage unless the rate of rise of principal current is restricted to tolerable levels to allow time for current spreading over a larger area. When a much larger gate signal is applied, a greater part of the cathode is turned on initially; as a result, turn-on time is reduced, and the thyristor can support a much larger peak anode inrush current.

Switching Characteristics

Ratings of thyristors are based upon the amount of heat generated within the device pellet and the ability of the device package to transfer the internal heat to the external case. For high-performance applications in which switching of high peak current values but narrow pulse widths is desired, the internal energy dissipated during the turn-on process must be determined to assure that power dissipation is within ratings.

When thyristors (either triacs or SCR's) are triggered by a gate signal, the turn-on time consists of two stages, a delay time t_d and a rise time t_r, as shown in Fig. 8. The total turn-on time t_{gt} is defined as the time interval between the initiation of the gate signal and the time for the principal anode current flow through the thyristor to reach 90 per cent of its maximum value for a resistive load. The delay time t_d is defined as the time interval between the 50-per-cent point of the leading edge of the gate trigger voltage and the 10-per-cent point of the principal current for a resistive load. The rise time t_r is the time interval required for the principal current to rise from 10 to 90 per cent of its maximum value. The total turn-on time t_{on} is the sum of both delay and rise time ($t_d + t_r$).

Although the thyristor is affected to some extent by the peak off-state voltage and the peak on-state current level, the turn-on time is influenced primarily by the magnitude of the gate-trigger pulse current, as shown in Fig. 9. Faster turn-on time for larger gate drive is a result of a decrease in delay

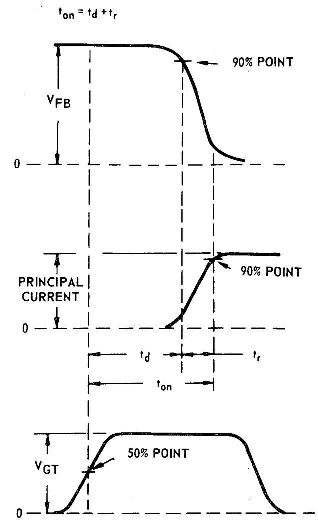


Fig.8 - Waveshapes illustrating thyristor turn-on time.

time associated with the thyristor because of the increased current density at the gate-cathode periphery. Of major importance in the turn-on time interval is the relationship between thyristor voltage and principal current flow through the thyristor. During the turn-on interval, the dynamic voltage drop is high and the current density can produce localized hot spots in the pellet area. Therefore, it is important that power dissipation during turn-on be restricted to levels within device specifications.

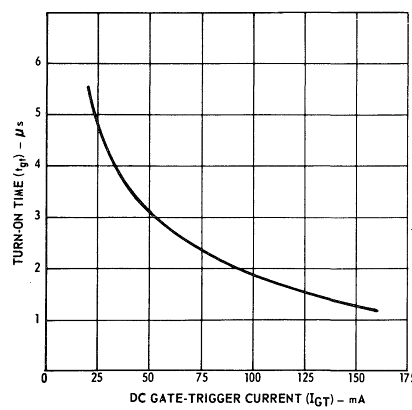


Fig.9 - Thyristor turn-on time as a function of gate trigger current.

Turn-off time of a thyristor can be associated only with SCR's. In triacs, a reverse voltage cannot be used to provide circuit-commutated turn-off voltage because a reverse voltage applied to one half of the triac structure would be a forward-bias voltage to the other half. For turn-off times in an SCR, the recovery period consists of two stages, a reverse recovery time and a gate recovery time, as shown in Fig. 10.

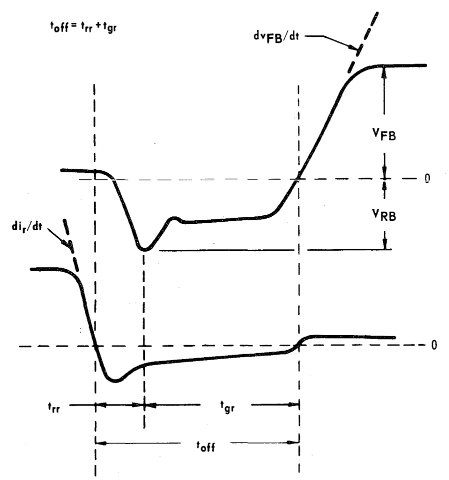


Fig. 10 - Waveshapes illustrating thyristor turn-off time.

When the forward current of an SCR is reduced to zero at the end of a conduction period, application of reverse voltage between the anode and cathode terminals causes reverse current to flow in the SCR until the time that the reverse current passes its peak value to a steady-state level called the reverse recovery time t_{rr}. A second recovery period, called the gate recovery time, t_{gr}, must then elapse for the forward-blocking junction to establish a depletion region so that forward-blocking voltage can be reapplied and successfully blocked by the SCR. The gate recovery time of an SCR is usually much longer than the reverse recovery time. The total time from the instant reverse recovery current begins to flow to the start of the forward- blocking voltage is referred to as circuit-commutated turn-off time t_q.

Turn-off time depends upon a number of circuit parameters, including on-state current prior to turn-off, rate of change of current during the forward-to-reverse transition, reverse-blocking voltage, rate of change of reapplied forward voltage, gate trigger level, the gate bias, and junction temperature. Junction temperature and on-state current have a more significant effect on turn-off than any of the other factors. With turn-off time specified on the manufacturer's data sheet and dependent upon the conditions as outlined above, turn-off time specification is only meaningful if all of the above critical parameters are available in the actual application.

For applications in which an SCR is used to control 60-Hz ac power, the entire negative half of the sine wave is a turn-off condition and more than adequate for complete turn-off. For applications in which the SCR is used to control the output of a full-wave rectifier bridge, however, there is no reverse voltage available for turn-off, and complete turn-off can be accomplished only if the bridge output is reduced to zero volts or the principal current is reduced to a value lower than the device holding current.

Because turn-off times are not associated with triacs due to the physical structure of the device, a new term is introduced called "critical rate of rise of commutation voltage", or the ability of a triac to commutate a fixed value of current under specified conditions. The rating can be explained by consideration of two SCR's in an inverse parallel mode, as shown in Fig. 11. SCR-1 is assumed to be in the conducting state

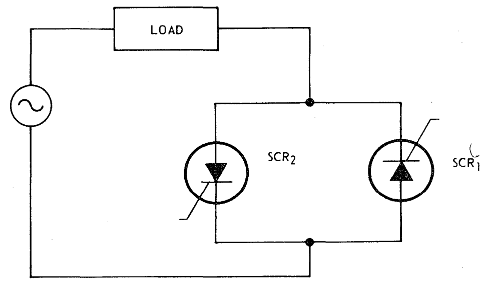


Fig. 11 - Circuit used to demonstrate critical rate of rise of commutation voltage.

with forward current established. As the principal current flow crosses the zero reference point, a small reverse current flows in SCR-1 until the time that the SCR reverts to the OFF state. The principal current is then diverted to SCR-2, provided that sufficient gate current is available to that device.

The structure of a triac shown in Fig. 12 indicates that the main blocking junctions are common to both halves of the

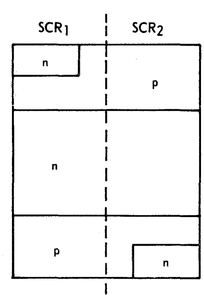


Fig. 12 - Structure of a triac.

device. When the first half of the triac structure (SCR-1) is in the conducting state, a quantity of charge accumulates in the n-type region as a result of the principal current flow. As the principal current crosses the zero reference point, a small reverse current is established as a result of the charge remaining in the n-type region. Because the n-type region is common to both halves of the devices, this reverse recovery current becomes a forward current to the second half of the triac. The current resulting from stored charge may cause the second half of the triac to go into the conducting state in the absence of a gate signal. Once current conduction has been established by application of a gate signal, therefore, complete loss in power control can occur as a result of interaction within the n-type base region of the triac unless sufficient time elapses to assure turn-off. It is imperative that triac manufacturers provide sufficient information regarding commutating capability under maximum current and case-temperature conditions so that triac control of ac power for resistive loading in a 60-Hz power source can be assured.

Commutation of triacs is more severe with inductive loads than with resistive loads because of the phase lag between voltage and current associated with inductive loads. Fig. 13 shows the waveforms for an inductive load with lagging

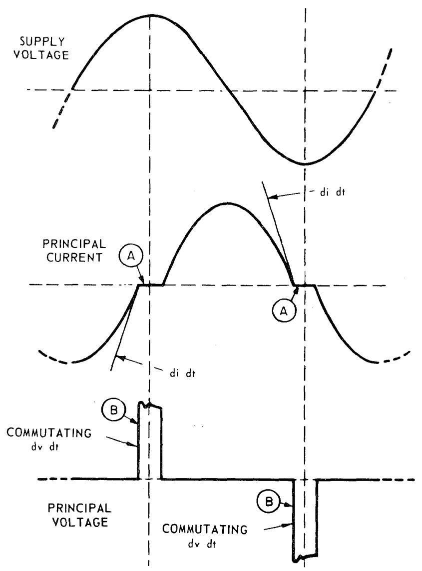


Fig. 13 - Waveshapes of commutating dv/dt characteristics.

current power factor. At the time the current reaches zero crossover (point A), the half of the triac in conduction begins to commutate when the principal current falls below the holding current required to sustain regeneration. Because the high-voltage junction is common to both halves of the triac, the stored charge can be neutralized only by recombination. At the instant the conducting half of the triac turns off, an applied voltage opposite to the current polarity is applied across the triac terminals (point B). Because this voltage is a forward bias to the second half of the triac, the sudden reapplied voltage in conjunction with the remaining stored charge in the high-voltage junction reduces the over-all device capability to support a fast rate of rise of applied voltage. The result is a loss of power control to the load, and the device remains in the conducting state in absence of a gate signal. Therefore, it is imperative that some means be provided to restrict the rate of rise of reapplied voltage to a value which will permit triac turn-off under the conditions of inductive load.

An accepted method for keeping the commutating dv/dt within tolerable levels during triac turn-off is to use an RC snubber network in parallel with the main terminals of the triac. Because the rate of rise of applied voltage at the triac terminal is a function of the load impedance and the RC snubber network, the circuit can be evaluated under worst-case conditions of operating case temperature, maximum principal current, and any value of conjunction angle. The values of resistance and capacitance in the snubber are then adjusted so that the rate of rise of commutating dv/dt stress is within the specified minimum limit under any of the conditions mentioned above. The value of snubber resistance should be high enough to limit the snubber capacitance discharge currents during turn-on and dampen the LC oscillation during commutation (turn-off). Any combination of snubber resistance and capacitance that provides the requirements outlined above is considered satisfactory.

Some of the factors affecting commutating dv/dt capability of triacs are temperature, current magnitude, rate of change of current during commutation, and frequency of the applied principal current. With frequency directly related to commutating di/dt, early triac use was restricted to 60-Hz applications. Continued technological advances in triac device structure has resulted in faster "turn-off" capability and made possible a new family of triacs having 400-Hz commutating capability that is now being offered to circuit designers who must work with 400-Hz source voltages.

Another important parameter for thyristors is the "critical rate of rise of off-state voltage". A source voltage can be suddenly applied to an SCR or a triac which is in the OFF state through either closure of an ac line switch or transient voltages as a result of an ac line disturbance. If the fast rate of rise of the transient voltage exceeds the device rating, the thyristor may switch from the OFF state to the conducting state in the absence of a gate signal. If the thyristor is controlling alternating voltage, "false" turn-on (non-gated) resulting from a transient imposed voltage is limited to no more than half the applied voltage because turn-off occurs during the zero current crossing. However, if the source voltage suddenly applied to the OFF thyristor is a dc voltage, the device may switch to the ON state and turn-off could then be achieved only by circuit interruptions. The switching from the OFF state is caused by the internal capacitance of the thyristor. A steep-rising voltage dv/dt impressed across the terminals of a thyristor causes a capacitance-charging current to flow through the device. This charging current (i=Cdv/dt) is a function of the rate of rise of applied off-state voltage. If the rate of rise of voltage exceeds a critical value, the capacitance-charging current exceeds the gate trigger current and causes device turn-on. Operation at elevated junction temperatures reduces the thyristor ability to support a steep rising voltage dv/dt because less gate current is required for turn-on. The effect of temperature on the critical rate of rise of off-state voltage is shown in Fig. 14.

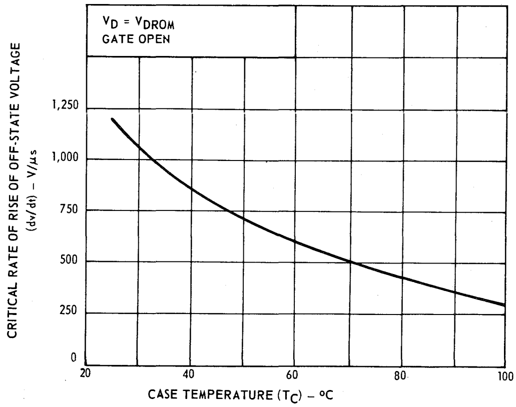


Fig. 14 - Critical rate of rise of off-state voltage as a function of case temperature.

Voltage transients which occur in electrical systems as a result of disturbance on the ac line caused by various sources such as energizing transformers, load switching, solenoid closure, contactors, and the like may generate voltages which are above the ratings of thyristors and result in spike voltages exceeding the critical rate of rise of off-state voltage capability. Thyristors, in general, switch from the OFF state to the ON state whenever the breakover voltage of the device is exceeded, and energy is then transferred to the load. Good practice in the use of thyristors exposed to a heavy transient environment is to provide some form of transient suppression.

For applications in which low-energy, long-duration transients may be encountered, it is advisable to use thyristors that have voltage ratings greater than the highest voltage transient expected in the system to provide protection against destructive transients. The use of voltage clipping cells is also effective. In either case, analysis of the circuit application will reveal the extent to which suppression should be employed. In an SCR application in which there is a possibility of exceeding the reverse-blocking voltage rating, it is advisable to add a clip cell or to use an SCR with a higher reverse-blocking voltage rating to minimize power dissipation in the reverse mode. Because triacs generally switch to a low conducting state, if the di/dt buildup of the principal current flow after turn-on is within device ratings it is safe to assume that reliable operation will be achieved under the specified conditions.

The use of an RC snubber is most effective in reducing the effects of the high-energy short-duration transients more frequently encountered in thyristor applications. When an RC snubber is added at the thyristor terminals, the rate of rise of voltage at the terminals is a function of the load impedance and the RC values used in the network. In some applications, "false" (non-gated) turn-on for even a portion of the applied voltage cannot be tolerated, and circuit response to voltage transients must be determined. An effective means of generating fast-rising transients and observing the circuit response to such transients is shown in Fig. 15. This circuit makes use of the "splash" effects of a mercury-wetted relay to transfer a capacitor charge to the input terminals of a control circuit. This approach permits generation of a transient of known magnitude whose rate of rise of voltage can easily be displayed on an oscilloscope. For a given load condition, the values in the RC snubber network can be adjusted so that the transient voltage at the device terminals is suppressed to a tolerable level. This approach affords the circuit designer with meaningful information as to how a control circuit will respond in a heavy transient environment. The circuit is capable of generating transient

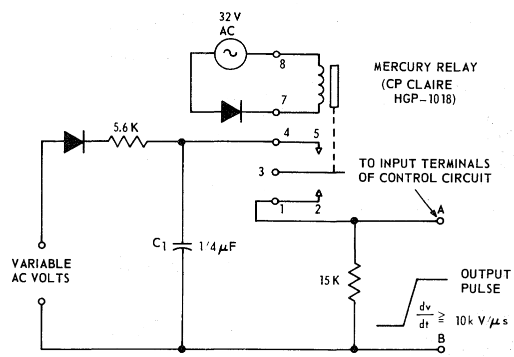


Fig. 15 - Circuit used to generate-fast rising transients.

voltages in excess of 10 kilovolts per microsecond, which exceeds industrial generated transients. The response of a 100-millihenry solenoid control circuit exposed to a fast-rising transient is shown in Fig. 16.

Use of Diacs For Control Triggering

Basically, thryristors are current-dependent devices, and the magnitude of gate current I_{GT} and voltage V_{GT} required to trigger a thyristor into the on-state varies. The point at which thyristor triggering occurs depends not only on the required gate current and voltage, but also on the trigger source impedance and voltage. Fig. 17 shows a family of curves representing the gate-circuit load line between the open-circuit source voltage and the short-circuit current for different time intervals. In a circuit which applies time-dependent variable voltage Vac to a load and the gate trigger current required to trigger the thyristor is derived from the same source Vac, devices that have a gate current I_{gl} are

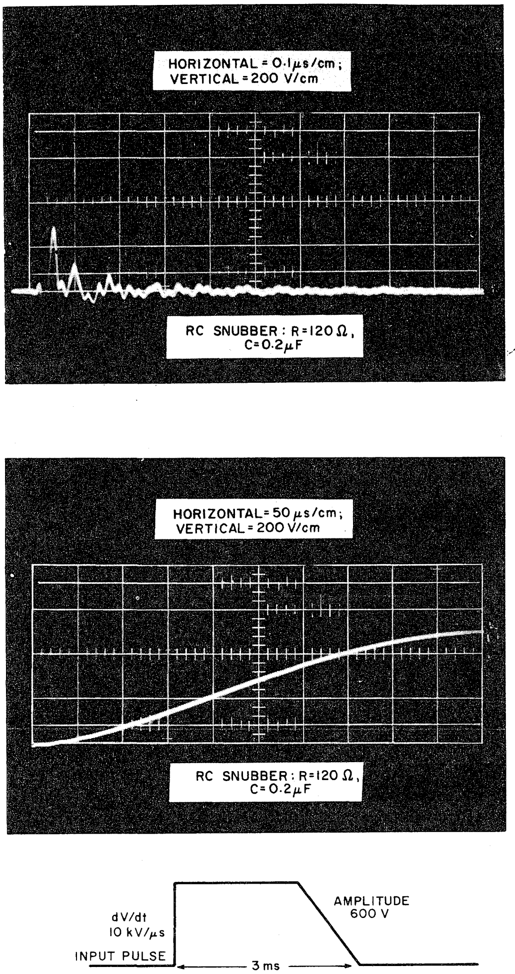


Fig. 16 - Waveforms showing response of a 100-millihenry solenoid control circuit to a fast-rising transient.

triggered earlier in the ac cycle than devices that have a higher gate trigger current Fig. 3. Although the circuit is capable of providing variable power to the load, it is heavily dependent on the gate current distribution, and results in uncontrolled conduction angles for a given value of gate series resistance. Furthermore, the circuit does not provide the recommended gate-current overdrive for switching of the fast-rising high-amplitude load currents present in resistive loading. A more efficient circuit for control of variable power to a load that eliminates the need for tight gate-current distribution uses a solid-state trigger device, called a diac, which is voltage dependent.

The diac, often referred to as a bidirectional trigger diode, is a two-terminal, three-layer, transistor-like structure that

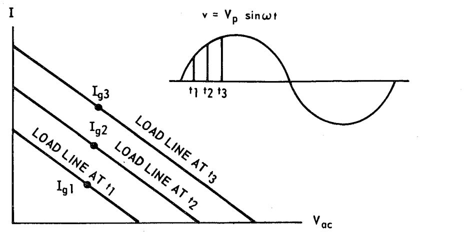


Fig. 17 - Thyristor gate-circuit load line for different time intervals.

exhibits a high-impedance blocking state up to a breakover voltage $V_{(BO)}$, above which the device enters a negative-resistance region. The characteristic curve in Fig. 18 shows

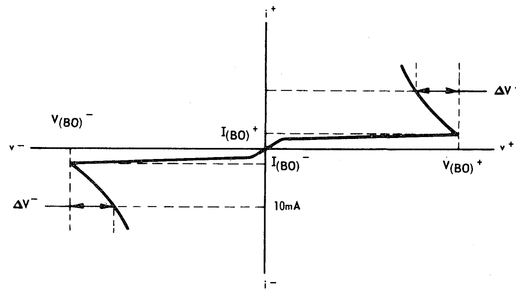


Fig. 18 - Diac voltage-current characteristic.

the negative characteristics associated with diacs when they are exposed to voltages in excess of the breakover voltage $V_{(BO)}$. Because of their bidirectional properties and breakover voltage level, diacs are useful in triac control circuits in which variable power is to be supplied to a load. Because of their negative characteristic slope, diacs can also be used with capacitors to provide the fast-rising high-magnitude trigger current pulses recommended in thyristor applications which require efficient gate turn-on for the purpose of switching high-level load currents.

In normal applications, diacs are used in conjunction with RC phase networks to trigger triacs, as shown in Fig. 19. The

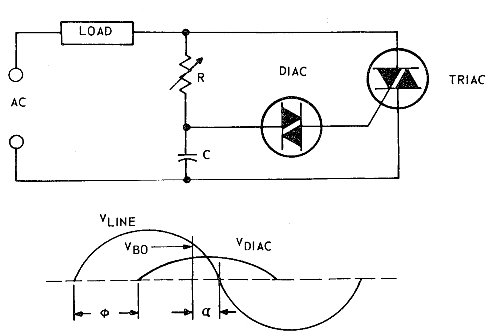


Fig. 19 - Use of diac with RC phase network to trigger triac.

RC phase network provides an initial phase-angle displacement ϕ so that conduction angles in excess of 90 degrees can be realized. As the voltage on the capacitor begins to build up in a sinusoidal manner, the breakover voltage $V_{(BO)}$ of the diac is reached, the triac is turned on, and a portion of the ac input voltage is provided to the load, as represented by the angle α. As previously mentioned, the diac offers a negative-resistance region and is capable of providing current pulses whose magnitude and pulse width are a function of the capacitor C and the combined impedance of the diac and the gate and main terminal of the triac. When the voltage on the capacitor C reaches the breakover voltage $V_{(BO)}$, the capacitor does not discharge completely, but is restricted to some finite level as a result of the diac negative-impedance characteristic at high values of pulse current. Fig. 20 shows the peak pulse current of a diac as a function of the capacitances of the phasing capacitor C.

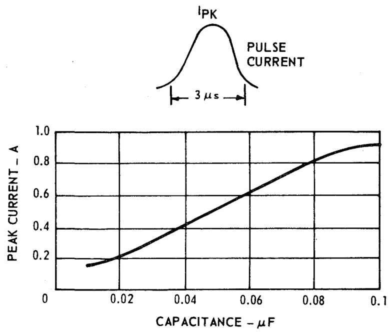


Fig.20 - Peak pulse current of a diac as a function of phasing capacitance.

Power Control Using Thyristors

In the control of ac power by means of semiconductor devices, emphasis has been placed on circuit simplicity, low cost, and small over-all package size. Thyristors meet these goals, and are also capable of providing either fixed or adjustable power to the load. Fixed power is achieved by use of the thyristor as an ON-OFF switch, and adjustable power through the use of an RC phase network which provides variable phase-gating operation. The following section discusses both SCR and triac circuit operations, and analysis of SCR and triac behavior for various circuit conditions.

Many fractional-horsepower motors are series-wound "universal" motors capable of operation from either an ac or a dc source. In the early stages of thyristor control, SCR's found wide acceptance in the control of universal motors, particularly in the portable power tools market. SCR's are capable of providing speed control over half of an ac sine wave, and, if full power is required, a simple shorting switch across the SCR provides the necessary function; such a switch is shown in Fig. 21. Turn-off parameters for this

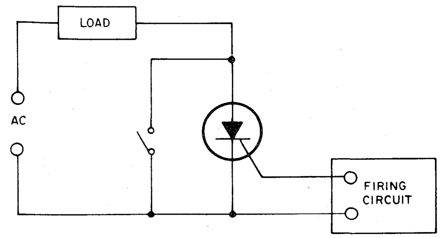


Fig.21 - Simple SCR half-wave control circuit.

circuit are not critical because the SCR has a half-cycle of applied negative voltage in which to recover. The SCR provides a reliable, highly efficient, long-life control for half-wave control circuits.

Fig. 22 shows a full-wave bridge that feeds a resistive load and uses an SCR as the control element for load current. Power control is accomplished by SCR turn-on at various conduction angles with respect to the applied voltage. The criteria for turn-off in this circuit is important because the SCR must recover its forward-blocking state during the time that the forward current stops flowing. Although this time interval may appear to be very small, close analysis of the voltage wave during the transition time in which the full-wave bridge reverses direction reveals that substantial time exists for turn-off.

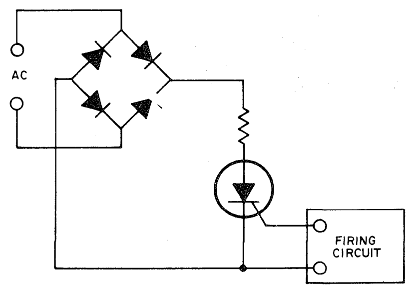


Fig.22 - Full-wave SCR bridge circuit.

Fig. 23 shows one-half of the bridge during the time that the forward current is approaching zero current. Two diodes are in series with the SCR; it is generally accepted that a diode

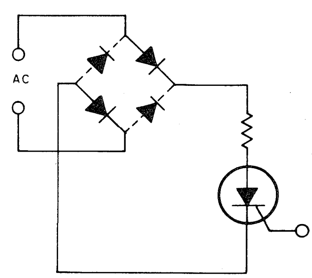


Fig.23 - Half of bridge circuit of Fig. 22 when forward current approaches zero for a resistive load.

voltage of approximately 0.6 volt is required to maintain each diode in conduction. If it is further assumed that a voltage of approximately 0.6 volt is required across the SCR to maintain conduction, the sum of the voltage drops over the circuit requires 1.8 volts; below this value, the SCR drops out of conduction. As the bridge reverses current direction, the same analysis holds true, i.e., forward conduction current is not resumed until the sum of the voltage drops exceeds 1.8 volts.

The waveform during the interval that the voltage wave goes from 1.8 volts to zero can be analyzed by reference to Fig. 24. A half-cycle (180 degrees) of conduction requires 8.3 milliseconds, one degree being equal to approximately 46 microseconds. Because a sine wave is linear for very small angles, a graph can be constructed to show the time interval during which the voltage is less than 1.8 volts for various magnitudes of applied voltage. Analysis of the voltage wave for an angle of one degree shows that an input voltage of 120 volts rms results in a voltage equal to 2.9 volts, which decays to zero in 46 microseconds. Because the SCR is non-conducting below a circuit threshold of 1.8 volts, a time of 28.5 microseconds then elapses while the voltage decays from 1.8 volts to zero. An equal time is required for the bridge to build up to the threshold voltage of 1.8 volts. Therefore, a total exposure time of 57 microseconds elapses in which the SCR is allowed to regain its forward-blocking state.

As shown in Fig. 24, increasing the magnitude of the applied voltage source to 240 volts rms cuts in half the time interval which the SCR is allowed for turn-off. Further increases in input voltage magnitude result in shorter turn-off periods.

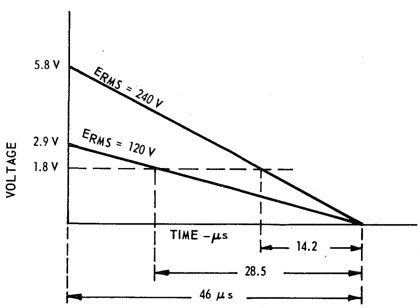


Fig.24 - Waveform of circuit in Fig. 22 as voltage wave goes from 1.8 volts to zero.

This analysis gives a clear, well-defined picture of the turn-off time available for a resistive load. However, for reactive loads, such as fractional-horsepower motors, the turn-off conditions, including turn-off time and dv/dt stress, are more difficult to define because they are affected by a number of variables, including the back EMF of the motor, the ratio of inductance to resistance, the motor loading, and the phase angle of motor current to source voltage. Normally, turn-off times for SCR's are industry-standardized to include peak forward current, rate of rise of reverse current, peak forward blocking voltage applied, and rate of rise of applied blocking voltage. The presence of the applied reverse current helps to shorten turn-off times because the reverse current sweeps out the charge in the blocking junction. For SCR operation from a full-wave bridge in which there is no appreciable reverse voltage available, turn-off is accomplished through recombination, and the effects of circuit loading on SCR operation must be clearly evaluated.

Full-wave ac switching can also be performed by use of two SCR's in an inverse parallel mode, often referred to as a "back-to-back" SCR pair, as shown in Fig. 25. This circuit can be used as a simple static switch or as a variable phase control circuit. It does not make use of a full-wave diode bridge, but simply uses the SCR's in an alternating mode. The circuit has the disadvantage of separate trigger logic, but possesses an inherent advantage in higher-frequency applications because advantage can be taken of the periods of the alternating voltage in which either device may recover to its blocking state. During the half-cycle of the applied voltage that SCR-1 is conducting, SCR-2 is reverse-biased and can recover its blocking state. Because of the applied reverse voltage and associated time of the half-cycle voltage, turn-off times are not critical.

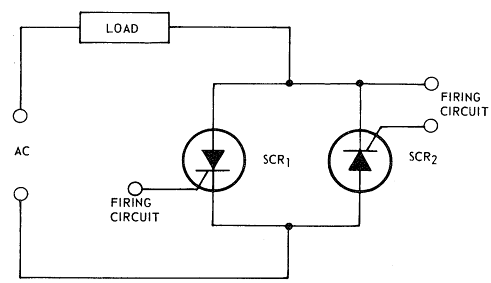


Fig.25 - Full-wave ac switching circuits using a "back-to-back" SCR pair.

This two-SCR circuit is often favored over a triac circuit, even though separate trigger sources are required, because it is supposed to have better commutating capability. Fig. 26 shows the waveforms of commutating dv/dt for the SCR circuit. If the load is inductive with lagging current power factor, the conducting SCR commutates at the time the principal current reaches zero crossover (point A) and reverts to the blocking state; a reapplied voltage of opposite polarity equal to the source voltage then appears across the non-conducting SCR. Because this voltage is a forward-bias voltage to the non-conducting SCR, device turn-on can occur if the rate of rise of applied forward voltage exceeds the device rating for critical rate of rise of off-state voltage. For inductive loading in an inverse-parallel-mode SCR application, power control to the load can be lost if the rate of rise of applied voltage is exceeded.

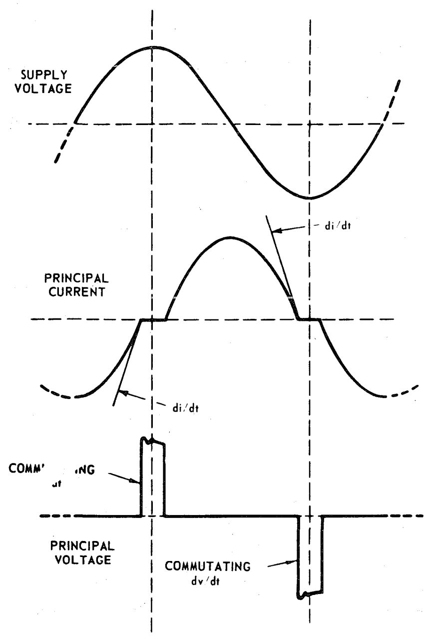


Fig.26 - Waveforms of commutating dv/dt for SCR circuit of Fig. 25.

Although it may appear that the rate of rise is extremely fast, closer circuit evaluation reveals that the dv/dt stress is restricted to some finite value which is a function of the load reactance L and the device capacitance C. Therefore, it is important that the rate of rise of applied voltage during commutation not exceed the device specification for critical rate of rise of off-state voltage under worst-case condition or unreliable operation may result. It is generally good practice in inverse-parallel operation to use an RC snubber network across the SCR pair to limit the rate of rise to some finite value below the minimum requirements, not only to limit the voltage rise during commutation, but also to suppress transient voltage that may occur as a result of ac line disturbances.

As previously mentioned, the use of semiconductor devices for ac power control has emphasized circuit simplicity, low cost, and small over-all package size. The development of the bidirectional triode thyristor, referred to as a triac, achieved all of these goals. Triacs can perform the same functions as two SCR's for full-wave operation, and also simplify gate logic requirements for triggering.

A simple, inexpensive triac circuit that can provide variable power to a load over a full cycle of applied voltage is the light-dimmer circuit. This circuit contains a diac, a triac, and an RC phase-control network. The basic light-dimmer circuit is described below because it provides a good example of triac behavior as related to load requirements and of the operation of a diac in an RC phase-control circuit.

Fig. 27 shows the basic triac-diac light-dimmer control circuit with the triac connected in series with the load. During the beginning of each half-cycle, the triac is in the off-state and the entire line voltage is across the triac; therefore, no voltage appears across the load. (Actually, there is some voltage across the load as a result of triac leakage currents, which are a function of applied voltage and junction temperature. However, these leakage currents are relatively small, at most in the milliampere range, and the resulting load voltages are generally ignored.)

The RC charge-control circuit is in parallel with the control triac, and the applied voltage serves to charge the timing capacitor C through the variable resistor R. When the voltage across C reaches the breakover voltage $V_{(BO)}$ of the diac, the capacitor discharges through the diac and the gate-to-main-terminal-1 impedance of the triac and turns on the control triac. At this point, the line voltage is transferred to the load for the remainder of the applied half-cycle voltage. As the load current reverses direction (zero crossing), the triac turns off and reverts to the blocking state. This sequence of events is repeated for every following half-cycle of applied voltage.

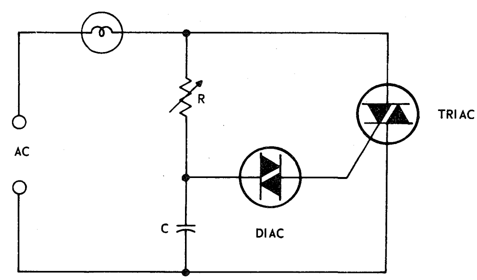


Fig.27 - Basic triac-diac light-dimmer control circuit.

If the value of resistance R is decreased, the capacitor charges to the breakover voltage $V_{(BO)}$ of the diac earlier in the ac cycle; the power supplied to the load is then increased and the lamp intensity is effectively increased. If the value of resistance R is increased, triac triggering occurs later in the ac cycle and applied voltage to the load is reduced; the result is decreased lamp intensity. Therefore, changes in the resistance value R effectively apply variable power to a load (which is a lamp load in the circuit of Fig. 27, but could also be a motor load or heating element).

Although the load is arbitrarily placed in series with main terminal 2, the circuit performs equally as well if the load is shifted to main terminal 1. (Actually, any commercial lamp dimmer available has two wires brought out for external connection, and the chance that the load will be connected to main terminal 1 is 50 per cent.) The only requirements for reliable operation are that the RC phase network be in parallel with the triac and that capacitor-discharge loop currents be directed from the diac to the triac gate and main terminal 1. Although the basic light-control circuit operates with the component arrangement shown in Fig. 27, additional components are often added to reduce hysteresis effects, extend the effective range of power control, and suppress radio-frequency interference.

Hysteresis in triac phase-control circuits is referred to as the ratio of applied load voltage when the triac initially turns on (as control potentiometer is slowly reduced from some high value) to the value of load voltage prior to "extinguishing" (as the control potentiometer is slowly increased to some higher value). If the circuit has high hysteresis, the control potentiometer travel may be as high as 25 per cent before triac turn-on occurs, after which the control potentiometer may be turned back 15 per cent before the triac "extinguishes". Hysteresis is an undesirable feature if the circuit application requires low-level lamp illumination because a momemtary drop in line voltage may result in the triac "extinguishing" or missing one half-cycle of applied voltage when the capacitor voltage is barely equal to the breakover voltage $V_{(BO)}$ of the diac. If this condition exists, the control potentiometer must be reduced to "start up" the triac again.

Hysteresis is a result of the capacitor discharging through the diac and not recovering the original voltage prior to triggering. Fig. 28 shows the waveforms of the charging

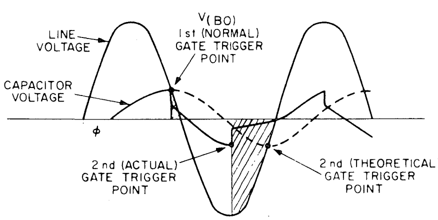


Fig.28 - Charging cycle of capacitor-diac network in Fig. 27 (high hysteresis).

capacitor C as related to the applied line voltage. The initial displacement angle ϕ is a result of the phase angle due to the value of the RC components used. As the value of the control potentiometer is slowly reduced, the value of charging voltage reaches the breakover voltage $V_{(BO)}$ of the diac, and the triac allows that portion of the ac wave remaining to appear at the load, as represented by the shaded area at the first trigger point. At this point, there is an abrupt change in capacitor voltage (Δ V). Therefore, as the capacitor charge reverses direction, the second trigger point is reached much earlier in the next half-cycle, and that portion of the ac wave remaining appears across the load, as represented by the shaded area at the second trigger point. The second trigger point and subsequent trigger points represent the steady-state level at which triggering occurs. Some reduction in hysteresis can be realized by inserting a resistor in series with the diac to reduce the effective diac negative resistance and minimize the change in capacitor voltage. However, this change reduces the gate current pulse and, if not carefully controlled, may result in di/dt failures because the triac switches high-magnitude current under minimum gate drive.

A more effective method of reducing hysteresis is to use a second RC time constant, or a "double-time-constant" circuit such as that shown in Fig. 29. As C_2 supplies the

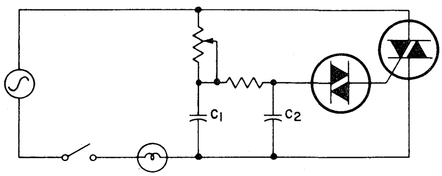


Fig.29 - "Double-time-constant" light-control circuit.

charging voltage for the diac breakover voltage $V_{(BO)}$, the abrupt change is capacitor voltage during diac turn-on is partially restored by capacitor C_1, as shown in Fig. 30. The restoring of the charge on C_2 maintains the original triggering point very closely and results in extended range of the control setting. This triac circuit can be turned on for very low levels of applied voltage and is not prone to "extinguishing" for line-voltage drops.

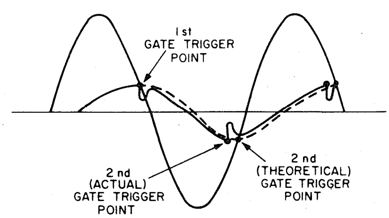


Fig.30 - Charging cycle of capacitor-diac network in Fig. 29 (reduced hysteresis).

Because triac switching from the high-impedance to the low-impedance state can occur in less than one microsecond, the current applied to the load increases from essentially zero to a magnitude limited by the load impedance within the triac switching time. This rapid rise of load current produces radio-frequency interference (RFI) extending into the range of several megahertz. Although this rapid rise does not affect television and FM radio frequencies, it does affect the short-wave and AM radio bands. The level of RFI generated is well below that caused by small ac/dc brush-type motors, but some means of RFI suppression is generally required if the triac phase-control circuit is to be used for any extended period of time in an environment in which RFI generation cannot be tolerated.

A reasonably effective suppression technique is shown in Fig. 31. An inductor is connected in series with the triac control circuit to restrict the current rate of rise, and a filter capacitor is used in parallel with the entire network to bypass high-frequency signals.

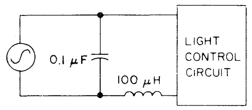


Fig.31 - RFI-suppression network.

The values shown in Fig. 31 are effective in reducing RFI noise for rms load currents up to 6 amperes to such an extent that the effects on short-wave and AM signals are either minimized or considered tolerable. For values above 6 amperes rms, additional suppression can be achieved by use of dual chokes in the ac lines to the triac network. Depending on the circuit performance required, such suppression may or may not be effective and other means of triac control may be required.

An alternate method of providing high-current heating controls is through use of a proportional control circuit using integral-cycle synchronous switching or zero-voltage switching. This approach varies the average power to the load through controlled bursts of full cycles of ac voltage to the load by turning on the triac at the beginning of the zero-voltage crossing. Because the triac turns on near zero current, the sudden current steps associated with phase-control circuits and the RFI generated are minimized. The RCA-CA3059 zero-voltage switch is a monolithic integrated circuit used primarily as a trigger-current generator for control of thyristor turn-on during the zero-voltage transition. This circuit has many features, one of which is a fail-safe circuit which inhibits output pulses in the event that the external sensor is opened or shorted.

Conclusions

This Note has reviewed thyristors from the viewpoints of temperature and voltage conditions, gate trigger characteristics, and effects of SCR's and triacs on circuit performance. The availability of power thyristors gives design engineers greater freedom in achieving circuit simplicity, low cost, and small package assembly than electromechanical or tube counterparts. Technological improvements are far from reaching the saturation level, but are opening new doors for circuit application. The impact of thyristor applications is being felt in normal everyday environments such as residential lamp dimming, TV deflection systems, home appliances, marine ignition, automotive applications, electric heating, comfort controls, and igniters for fuel-fired furnaces. Industrial applications for multiple-horsepower motors, lamp display boards, inverters, relay protection or replacement, radar, sonar, and emergency standby generating systems are now finding widespread acceptance in thyristor controls. The introduction of RCA triacs fully characterized for 400-Hz commutating capability opens the doors to many aircraft support applications which previously were devoid of the advantages offered in solid-state design. It appears that the answer to most power-control applications may be the thyristor.

Thyristor Control of Incandescent Traffic-Signal Lamps

by C.P. Knudsen

This Note discusses the use of thyristors in the control of traffic signals. The thyristor most applicable to this application is the triac, which can carry the electrical power required for incandescent traffic-light bulbs, yet can be gated by the low-power signals from electronic control timers or monitoring computers. In addition, the triac is able to handle the large transient currents that result from cold filament turn-on (inrush) and filament rupture (flashover). Triac operation, stresses on triacs in operation with incandescent lamps, and a number of triac circuits for control of incandescent lamps in traffic signal applications are discussed below.

TRIAC OPERATION

A triac, shown schematically in Fig. 1(a), is a bidirectional triode thyristor. In the absence of a gate signal, the triac blocks both portions of an ac sine wave, but a steady-state or pulsed gate signal will switch it on as in Fig. 1(b). The gate signal can be either positive or negative with respect to main terminal no. 1 (MT1), while MT2 can also be either positive or negative referenced to MT1; the four possible modes of switching are depicted in Table I. For example, when a triac is triggered by connecting a resistor between MT2 and the gate, as shown in Fig. 2, the triac operates in the I+ and III− modes in energizing the ac load. Other thyristor characteristics will be introduced below as needed, while an extensive review of thyristors is available in RCA Application Note AN-4242, "A Review of Thyristor Characteristics and Applications".

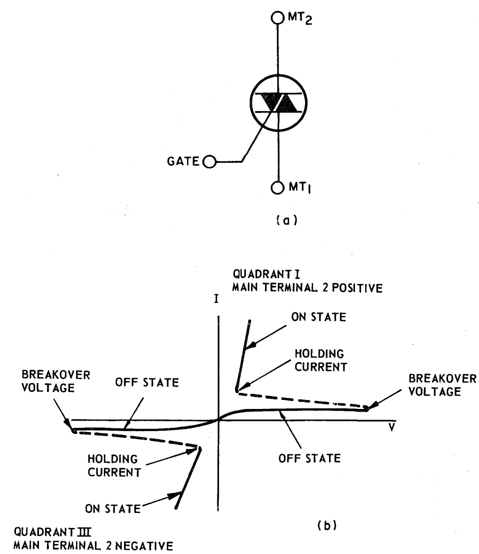


Fig. 1— (a) Schematic symbol, and (b) principal voltage-current characteristic for a triac.

Table I — Four Gate-Trigger Modes For Triac

MODE	MT2	G
I+	+	+
I−	+	-
III+	-	+
III−	-	-

Polarities are referenced to MT1.

SURGE CURRENT THROUGH TRIACS IN INCANDESCENT-BULB OPERATION

The traffic-control circuit designer must be aware of two characteristics of incandescent bulbs: end-of-life filament rupture and cold-filament inrush surge. Both these transient conditions impose a high surge stress on the controlling triac, which without proper circuit design can be destructive.

Flashover

Flashover is a short-duration, extremely high-current surge through the triac that is initiated when a lamp filament ruptures. The rupture is most likely to occur as a result of a termination in bulb life; however it can be caused by a mechanical shock. The mechanism of flashover is initiated by

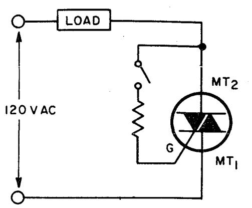


Fig. 2— Example of I+, III- gating of triac.

the gap formed when rupturing occurs. The instantaneous value of line voltage across the break sets up an electric field that ionizes the gases in close proximity to the gap. The ionized gases, usually argon and nitrogen, provide an electrical conduction path across the gap, and the resulting current heats and ionizes more gases until an arc is formed across the filament lead-in wires. The arc is maintained as long as the regenerative heating and ionization continue. Finally, because of either increasing arc length or decreasing ac line voltage, or both, the electric field becomes too weak to sustain the arc, and the arc is extinguished.

Fig. 3 shows a flashover current pulse. Its magnitude and duration depend on many factors. The actual peak magnitude of the source voltage, the voltage phase at the instant of filament rupture, and the impedance of the lead wires and other circuitry (including RFI filters) all affect the duration and magnitude of the surge. Typical values can be given for the stress of flashover at a load center point. For bulbs of less than 75 watts the duration of the surge can be typically less than 2 milliseconds. For bulbs of 100 to 150 watts the duration of the surge can be typically less than 4 milliseconds. The magnitude of surge can vary considerably, with typical peak values ranging from 80 to 200 amperes when the flashover occurs near the maximum voltage point. If the flashover occurs at a zero-voltage crossing, the current surge may be reduced as a result of the dependence of the magnitude on the voltage phase at rupture.

Because of the short duration of the flashover current, it is usually difficult to provide circuit fuse protection against flashover. Most incandescent bulbs are provided with a fuse built into one of the lead-in wires. This built-in fuse is not 100-per-cent effective against flashover and therefore cannot be depended upon to protect the triac. Fusing of triac circuits is described in more detail in the following discussion of inrush current.

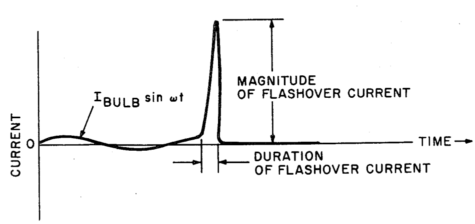


Fig. 3— Flashover current at peak voltage point.

Inrush

In tungsten-filament lamps, the cold filament resistance is approximately 1/18 to 1/12 of the hot filament resistance. The actual currents in a circuit under inrush and steady-state conditions do not vary in these ratios, however, because of the inductance and external limiting resistance of the circuitry, including the lead-in wires to the bulb. Furthermore, it is obvious that the highest inrush current will occur at the peak of the voltage sine wave in a lamp load circuit. If switching occurs at any other phase of the voltage sine wave, the peak current through the bulb is less than "worst case". Typically, the maximum inrush peak current can be ten times as great as the steady-state peak current, while the peak inrush current with zero-voltage switching can be approximately five times as great as the steady-state peak current, as shown in Fig. 4. Thus zero-voltage switching of a lamp effects a soft turn-on that reduces the initial peak of inrush current by half and greatly increases bulb life. This increase of bulb life by zero-voltage switching has been verified by test results; an increase in life of approximately ten times, with a 90 per cent confidence level, has been reported. Thus maintenance costs are reduced and system reliability increased.

Fig. 4 shows how the current in a lamp circuit decreases to the steady-state value. The rate of decrease depends upon the thermal time constant of the tunsten filament. A

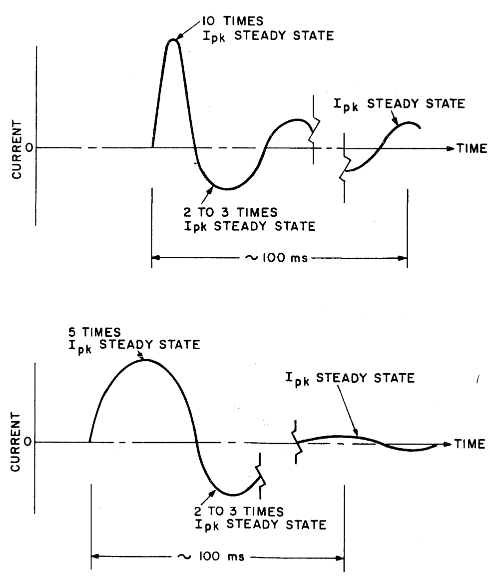


Fig. 4— (a) Inrush current at peak voltage point, and (b) inrush current at zero-voltage point.

100-watt bulb typically might reach steady-state current within 100 milliseconds after turn-on, while a 1000-watt bulb typically requires 200 milliseconds to reach its steady-state current condition.

Flashover and inrush can occur in combination. Because a bulb is exposed to its most severe normal operating stress during inrush, the weakest spot of the filament often ruptures and causes a flashover at turn-on. Most often, switching and flashover occur at some point other than the peak voltage; therefore the resulting peak current is usually within the handling capability of the triac.

Fuses in incandescent-lamp circuits must not blow under the stress of inrush current, yet must blow under flashover current. For low-power bulbs the flashover current is substantially greater than the peak inrush current, and fuse protection is simple. For example, a 100-watt bulb might have a typical flashover current of 100 to 200 amperes and a typical inrush current of 10 amperes. For large-wattage bulbs, however, fusing is difficult. For a 1000-watt bulb, the peak flashover current might still be between 100 and 200 amperes, while the peak inrush current is approximately 120 amperes. Fuses set to blow at 150 amperes peak flashover current of short duration may also blow under the long-duration, slightly-lower-amplitude stress of inrush. As a result, a fusing solution to the problem of triac protection would be marginally reliable. One solution is to use a 40-ampere triac (available in the RCA-2N5443 series), which has a single-cycle surge capability of 300 amperes, to control this 10-ampere load. Here again system reliability would be improved and maintenance costs reduced.

CIRCUITS

With the closely-related transient stresses imposed on a triac by an incandescent-light-bulb circuit having been noted, a number of circuits that help to reduce these stresses on the triac and increase lifetime of the bulb are discussed below.

Zero-Voltage Switching with an IC

An RCA-CA3059 integrated circuit (IC) can be used with a triac to accomplish zero-voltage switching of a load. A functional block diagram of this IC is shown in Fig. 5. The CA3059 is a monolithic, multistage, integrated circuit that incorporates a diode limiter, a threshold detector, a differential amplifier, a Darlington output driver, and other features. A more extensive description of this IC is given in RCA Application Note ICAN-4158, "Application of the RCA-CA3059 Zero-Voltage Switch in Thyristor Circuits". The CA3059-and-triac circuit for zero-voltage switching is shown in Fig. 6. When Q1 is off, the IC does not generate pulses to the gate of the triac. When Q1 is biased on, the IC generates gating pulses of approximately 40 milliamperes for 100 microseconds that straddle the zero-voltage crossing points. These pulses trigger the triac on in the I+ and III+ modes at the zero-voltage crossing for the resistive-tungsten-filament bulb and effect the desired result of decreasing inrush current.

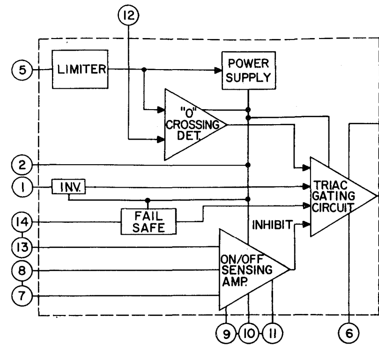


Fig. 5– Functional block diagram of the RCA-CA3059 integrated-circuit zero-voltage switch.

The circuit shown in Fig. 6 has one disadvantage for traffic controls, in which the bulb load is usually grounded and the power circuit ground and the logic ground are common. This arrangement presents a severe problem of interfacing between logic and power circuitry. If the load in Fig. 6 were grounded, terminal No. 4 of the CA3059 would be at line voltage above ground and the substrate (terminal No. 7) at ground potential when the bulb was energized. As a result, the IC would be destroyed. Similar problems are encountered whenever the logic circuitry is directly coupled with the triac power circuit and the load is grounded. However, this problem is eliminated in the discrete-component circuits described below.

Discrete-Component Zero-Voltage Switching

A discrete-component circuit that accomplishes zero-voltage switching of a grounded tungsten filament load is

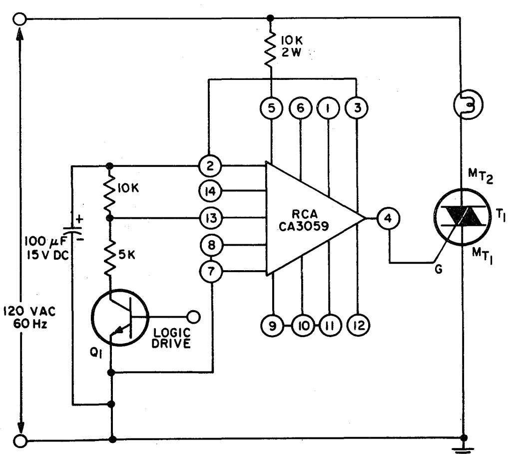


Fig. 6– Circuit that uses the CA3059 and a triac to switch a lamp at zero voltage.

shown in Fig. 7. With Q1 on, T1 is on and source voltage is shunted away from the load. With Q1 biased off, T1 is off and T2 is gated on through R1 and R3. When T2 conducts, it connects R4 from gate to MT2 of T3, and thus triggers T3 on in the I+ and III- modes. Because T2 is a sensitive-gate device, it turns on close to the zero-voltage point; therefore, the load is also zero-voltage switched after the initial turn-on. For a typical 40526 device, triggering in the I+ and III- modes results in firing at about 7 volts peak on the line. After T3 is turned on, the triggering circuitry is shorted; therefore, no triggering power is dissipated while the lamp is on.

Filament Pre-Heating

Another approach to reducing the inrush current is shown in Fig. 8, where a filament pre-heater function is included in the switching arrangement. In this circuit, when Q1 is off the logic interfacing triac T1 is off. R3, which can be a fixed resistor of approximately 98 kilohms, is set so that T2 is fired for only a small portion of the voltage cycle. This

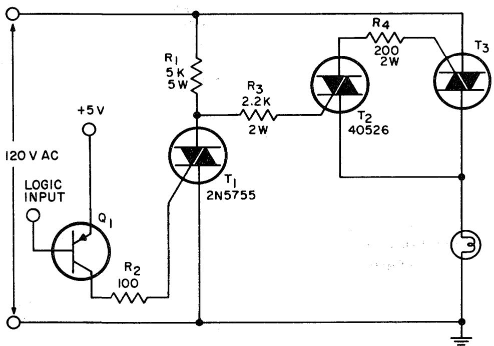


Fig. 7— Discrete-component circuit used to switch a grounded load at zero voltage.

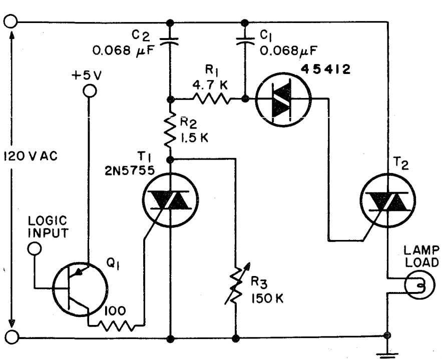


Fig. 8— A circuit including a filament pre-heat arrangement.

firing is accomplished by the standard double-time-constant lamp-dimmer gate circuitry of T2. The low-conduction-phase firing of the bulb keeps the tungsten filament warm but not hot enough to radiate any readily visible light. When Q1 is turned on, T1 is gated on and R3 is shorted, and the lamp load turns on.

The associated waveforms are shown in Fig. 9. For a 200-watt bulb in the circuit of Fig. 8, the first peak of current through the bulb was 7.5 amperes when the warm up circuit was used and 25 amperes with cold-filament inrush.

These circuits of Figs. 7 and 8 show that triacs can be used to switch power lamp loads and also interface with low-level logic systems. They also show how some of the stresses involved with the switching of incandescent lamps can be reduced. Other switching circuitry for use in traffic controls is discussed below.

OTHER APPLICABLE ON-OFF SWITCHING CIRCUITS

Two other circuits that can be used in the traffic control area are shown in Figs. 10 and 12. These circuits have the advantages of a common ground between logic and power circuitry, grounded bulbs, and isolation between the dc logic and the power circuitry afforded by use of the interfacing logic triacs.

In the positive-logic switching circuit of Fig. 10, logic triac T1 is used to interface between the low level logic and the load triac T2. With T1 gated on, C1 is charged through R1 to the breakover voltage of the diac, at which point T2 and the load are triggered on. The various circuit waveforms are shown in Fig. 11. As Fig. 11(d) shows, there is continuous gate power driving T2 whenever T1 is on and thus the light is on hard.

A variation of this circuit with opposite (negative) logic is shown in Fig. 12. In this circuit, when T1 is triggered on, T2 and the lamp are off. When T1 is off, C1 can charge through R1 and R2 to diac breakover, which discharges C1 into the gate of T2 and energizes the load. The waveforms of this circuit are shown in Fig. 13. Little gate power is dissipated in this circuit because T2 shorts across its gate circuitry when it is on.

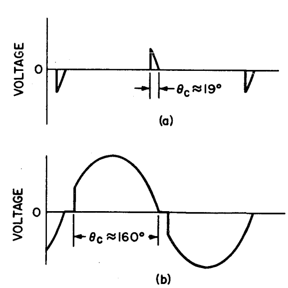


Fig. 9— Waveforms for circuit in Fig. 8: (a) voltage on bulb when Q1 is off; (b) voltage on bulb when Q1 is on.

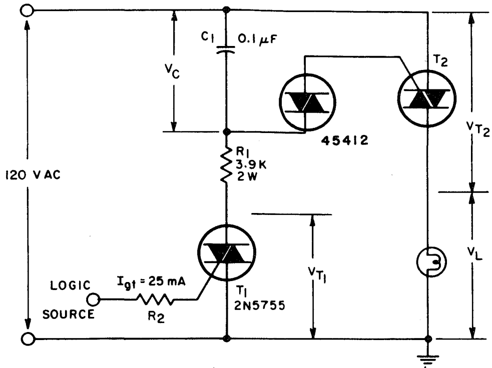


Fig. 10– Positive-logic bulb-switching circuit.

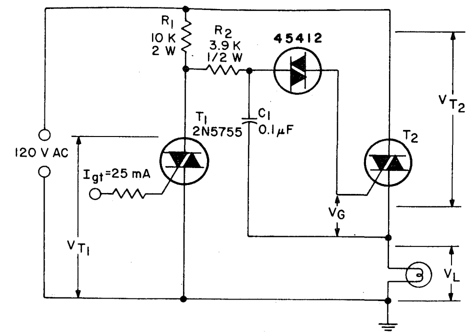


Fig. 12– Negative-logic bulb-switching circuit.

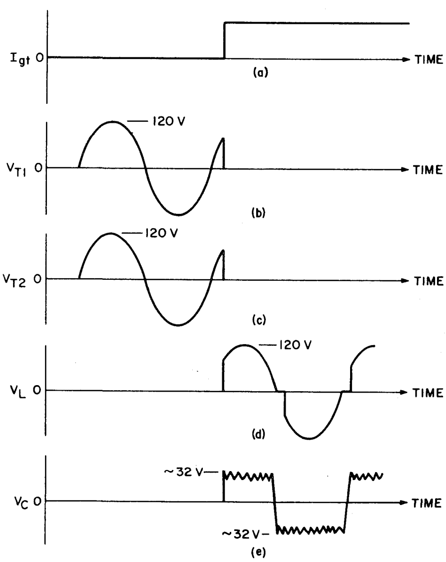


Fig. 11– Waveforms for positive-logic switching.

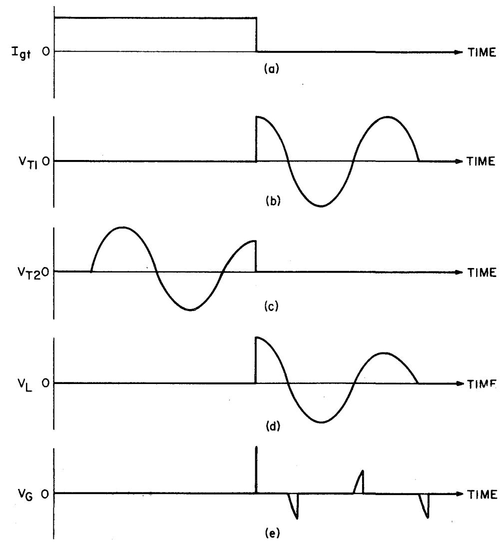


Fig. 13– Waveforms for negative-logic switching.

Both of these circuits are shown with continuous gate drive into triac T1. Logic power could be conserved by use of pulse drive, with no change of power stage operation; however, the logic circuitry would be more complex.

THYRISTOR FLASHER

Thyristors can also be used to advantage in flasher-type traffic-control systems. In these applications, two lights are usually flashed on and off as a warning display. Fig. 14 shows a thyristor circuit that accomplishes this flashing function. As shown, a silicon-controlled-rectifier (SCR) multivibrator functions as the timer and flasher-triggering driver. The drive to the control triac is dc and is alternated between T1 and T2 according to the timing set in the multivibrator. A waveform for the component values shown is displayed in Fig. 15. The timing can be modified by selecting different values for any of the following components: R1, R2, R3, R4, C1, C2. The important features of this circuit are the simple, rugged dc power supply used and the use of SCR's as both timing and memory devices to trigger the triacs. Alternative approaches to the traffic control flasher are given in Fig. 24 of ICAN-4158, "Application of the RCA-CA3059 Zero-Voltage Switch in Thyristor Circuits", and Fig. 17 of ICAN-6268, "Applications and Extended Operating Characteristics for the RCA-CA3059 IC Zero-Voltage Switch".

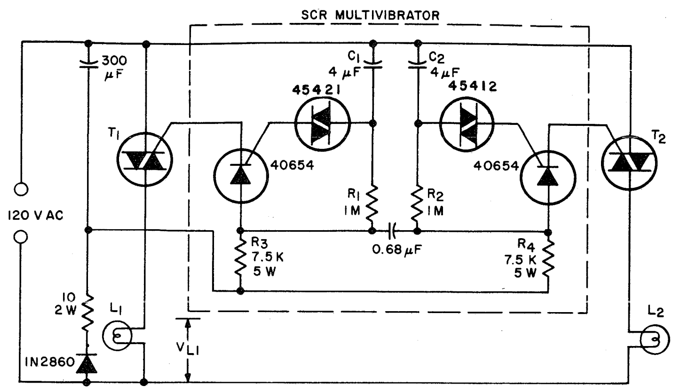


Fig. 14— Thyristor flasher.

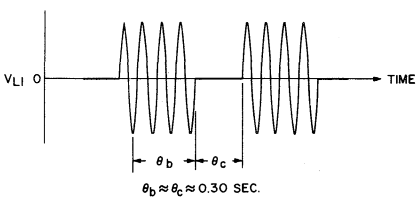


Fig. 15— Timing of thyristor flasher.

AC - DC ISOLATION

In the circuits shown thus far, either a triac or an IC is used to interface between the dc logic and the ac power circuitry. A number of other methods can be used to isolate these stages in a traffic controller. The circuit of Fig. 16 illustrates the use of a reed-type relay. When the relay is activated, the triac is gated in its I+ and III- modes and little power is dissipated in the gate circuit. Fig. 17 shows the use of a light source and photocell combination. Because the photocell is part of a single-time-constant circuit, it must have enough dark resistance to keep the voltage across C1 below 32 volts so that the diac does not switch and discharge the capacitor into the gate of the triac at all times. A pulse transformer can also be used for isolation, as shown in Fig. 18. A 5-kHz signal into the gate turns the triac on at initiation of the pulsing and keeps it on until the oscillator is stopped.

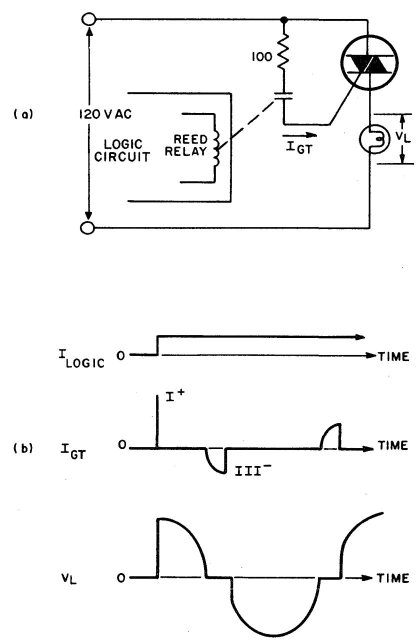


Fig. 16— (a) Circuit, and (b) waveforms of reed-relay gate control.

RFI SUPPRESSION

Radio-frequency interference (RFI) that can result from the fast triac switching of high power loads must be considered in traffic control circuits. When an ac load is switched on, as shown in Fig. 19, RFI is generated in the initial wavefront. This steep wavefront contains many harmonics that can be sustained by the circuit Q.

One method of reducing RFI is zero-voltage switching with resistive loads; thus, the circuits above that utilize the RCA-CA3059 IC inherently include RFI suppression. Circuits that do not use zero-voltage switching require external filters for RFI suppression. A typical filter used in conjunction with ac loads is portrayed in Fig. 20. The effect

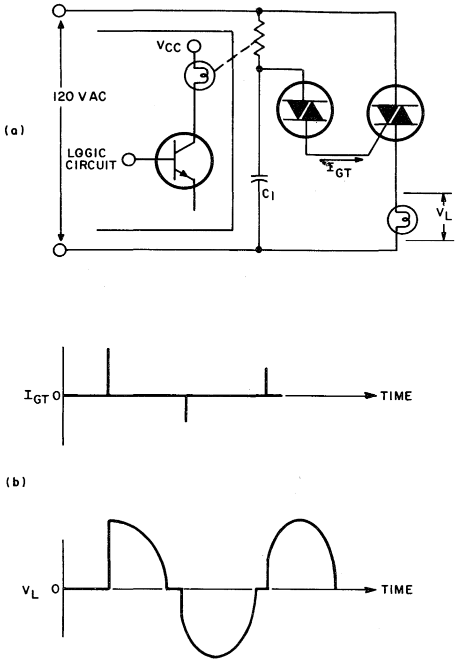


Fig. 17— Photocell gate control: (a) circuit; (b) waveforms.

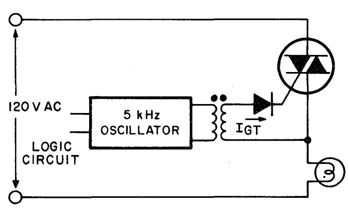


Fig. 18— Isolation transformer gate control.

of the LC filter is to slow down any fast-rising voltage or current wavefronts that might be propagated down the line and radiated. Other filters are available; each application should include its own filtering design.

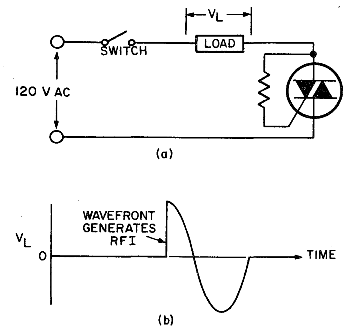


Fig. 19— RFI generation: (a) circuit; (b) waveform.

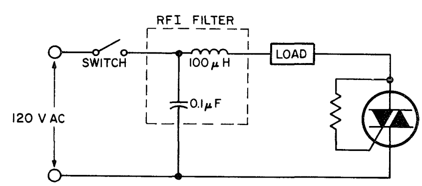


Fig. 20— RFI-suppression filter.

A Thyristor Horizontal Deflection, High-Voltage, and Power-Supply System for RCA 110° Color Picture Tubes

by W. Dietz

This Note describes a thyristor-circuit horizontal-deflection system for use with RCA 110° color picture tubes. The circuit generates the horizontal sweep, raster correction, and high voltage for the picture tube; it also provides low-voltage supplies for other portions of the TV receiver, and thus eliminates the costly 60-Hz line transformer. This system for 110° tubes contains the same number of components as a similar system for 90° tubes, and produces a raster of the same high quality.

The design and operation of the system and circuits are described in this Note, and the performance is illustrated by waveforms of currents and voltages.

GENERAL DESIGN CONSIDERATIONS

As shown in the block diagram of Fig. 1, the system operates from a 150-volt dc supply that can be obtained by half-wave rectification of a 120-volt ac line. The trace switch and the commutating switch each consist of a silicon controlled rectifier (SCR) and a fast-recovery diode; SCR switches are used because they have excellent reliability and the greatest power-handling capability of any active devices available. The regulator uses a saturable reactor in a closed-loop circuit to keep the high voltage and the scan rate nearly constant during line-voltage fluctuations. Side pincushion and top-and-bottom pincushion distortion are both corrected with one saturable transformer. A linearity correction circuit is used to maintain linearity within four per cent.

The high-voltage rectifier is a tripler in combination with a tightly coupled flyback transformer to achieve an internal impedance of less than 1.6 megohms.

A 25-volt supply for the signal-processing circuits in the TV receiver is derived from the input choke. This supply is not regulated because the individual circuits that it serves are

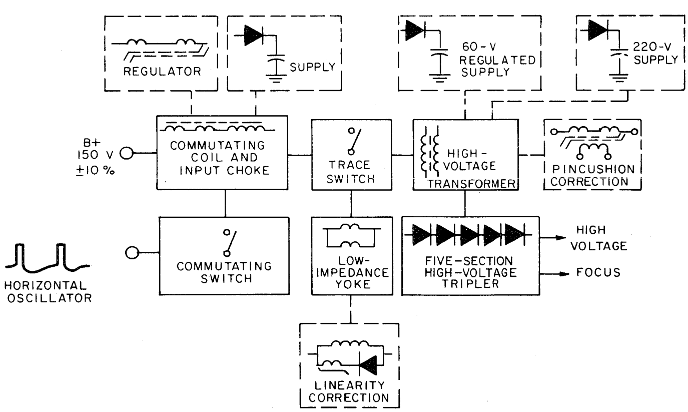


Fig. 1– Block diagram of thyristor horizontal-deflection, high-voltage, and power-supply system for RCA 110° color picture tubes.

usually regulated by zener diodes. The 60-volt supply for the vertical-deflection circuit is obtained from the high-voltage transformer. Because the vertical-deflection circuit presents a constant load to this supply, high-voltage regulation is not affected. The current drawn by the rectifier in the 60-volt supply is phased in such a way that raster size and pincushion correction are unaffected.

The 220-volt supply for the video circuit is obtained by adding to the B+ supply a 100 volts obtained by rectifying the retrace voltage at the high-voltage transformer. The variation in the load current on this supply is small enough that it does not affect the performance of the deflection circuit.

CIRCUIT DESCRIPTIONS

A schematic diagram of the complete deflection system is shown in Fig. 2. Operation of the system in terms of the individual circuit functions is described below.

Commutation and Energy-Transfer Circuit

The commutation and energy-transfer section of the deflection system consists of the input choke L_{cc}, the commutating switch SCR_c and D_c, the commutating coil L_c, and the commutating and auxiliary capacitors C_c and C_a, as shown in Fig. 3(a). The input choke and the commutating coil are magnetically isolated from each other. This isolation is accomplished by winding the input choke on the center leg of a pair of E cores and winding the commutating coil in two equal sections on the outer legs of the same E cores. The magnetic fields from the two halves of the commutating coil cancel in the center leg so that interaction between the commutating coil and the input choke is eliminated. Also, the stray fields in space from the two halves of the commutating coil cancel; therefore, no shielding is required.

The input choke stores energy from the B+ supply during the part of trace time when the commutating switch is closed. The commutating coil controls the rate of change of current when the charge previously stored in C_c and C_a transfers to the yoke and high-voltage transformer. This transfer occurs just before retrace when a pulse from the horizontal oscillator turns on the commutating SCR. Conduction of current through this SCR initiates an oscillation of current in the commutating coil and the commutating capacitors for one full cycle. During the first quarter-cycle, the peak current in C_c exceeds the yoke current. The difference between the commutating current and the yoke current is then carried by the trace diode for at least 2.5 microseconds, which is the time needed for the trace SCR to turn off (recover forward-blocking capability). This turn-off is assisted by a negative pulse of approximately 25 volts on the gate. When the current in C_c again becomes smaller than the yoke current, as shown in Fig. 3(b), the

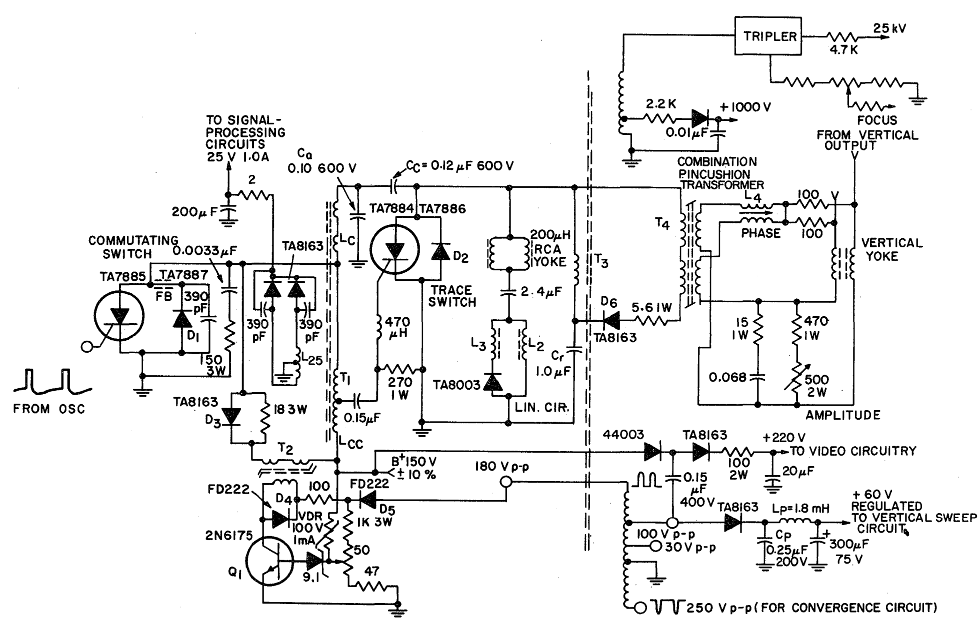


Fig. 2– Complete circuit diagram of horizontal-deflection, high-voltage, and power-supply system.

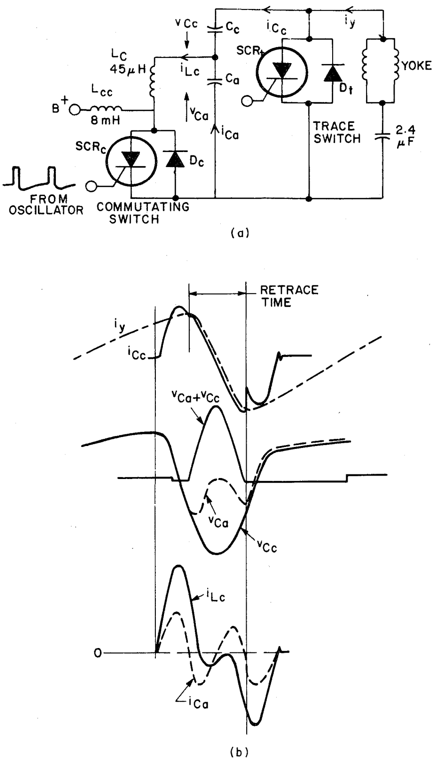


Fig. 3— Commutating and energy-transfer section of deflection system: (a) schematic diagram; (b) waveforms.

diode stops conducting and the trace SCR, which is in the off state (i.e., free of minority carriers), blocks the positive voltage appearing at that time.

With the trace switch open, the energy stored in the yoke and the commutating coil oscillates for one half-cycle through the commutating capacitor and auxiliary capacitor C_c and C_a, the commutating coil, and the commutating SCR and diode until the yoke current is reversed and has reached a maximum in the reverse direction (i.e., completion of retrace). Retrace ends when the sum of the voltages across the commutating and auxiliary capacitors (C_c and C_a) becomes negative and forward-biases the trace diode. The current still flowing in the commutating coil then decays to zero, charging C_c and C_a to a positive voltage during a short period at the beginning of trace. The charge in C_c and C_a when the commutating switch opens is reduced below that at the instant energy transfer started, by an amount that corresponds to the energy replaced in the yoke (to restore resistance and radiation losses) and in the high-voltage storage capacitors (to supply energy to the picture tube). .

During retrace the high-voltage rectifier is coupled through C_c to the parallel combination of C_a and L_c. This combination presents a low impedance to the high-voltage rectifier during retrace. C_a also reduces the rate of rise of the voltage across the trace SCR at the beginning of retrace. During retrace, while the trace switch is open, the energy in the commutating coil and auxiliary capacitor oscillates for slightly more than one full cycle. The amplitude of this oscillation depends upon the ratio of yoke impedance to the impedance made up of L_c and C_a.

The first step in design of the circuit is to determine the value of C_a from the chosen B+ voltage, the yoke impedance, and the amount of energy that is to be stored in the yoke. Commutating capacitor C_c is then chosen to provide sufficient turn-off time for the trace SCR. The internal impedance of the high-voltage supply is made as low as possible by use of the smallest L_c that will keep the commutating diode in conduction during the whole retrace interval.

If the internal impedance of the high-voltage supply is still too high, then the picture size may increase with beam current for this value of L_c. More change of yoke current with beam current can be obtained by decreasing L_c to a value such that the commutating diode ceases conduction for a short period during retrace. During this time the high-voltage supply recharges; therefore C_c discharges at a faster rate, causing greater decrease of yoke current with beam current.

To prevent changes in pincushion correction with beam-current variations, the commutating diode should remain open even when the beam current is large; however, the initial conduction period of the commutating diode for zero beam current should be long enough to provide turn-off for the commutating SCR.

As indicated in Fig. 3(b), the retrace time for the yoke current is the period during which the yoke current falls rapidly from its maximum positive value to its minimum value (maximum negative value). Measurement of the width of the retrace pulse across the trace switch indicates a time approximately one microsecond longer than the true retrace time. The retrace time of the circuit discussed in the Note, as indicated in Fig. 4, is about 12 microseconds.

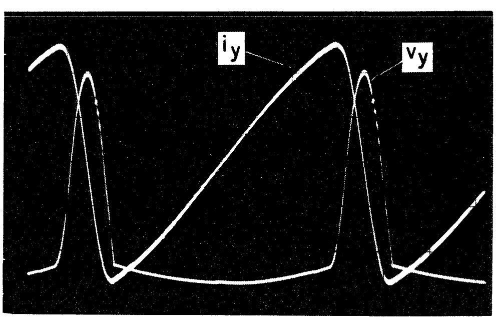


Fig. 4— Waveforms of yoke current (2.5 A/div) and yoke voltage (100 V/div). Time scale is 10 μs/div.

High-Voltage Section

A tightly coupled high-voltage transformer results in a low-impedance high-voltage supply, even with variations in leakage inductance, because the ringing amplitude is small in comparison with the main retrace pulse. Because the yoke is connected directly across the trace switch, the winding for the transformer needs less space, and the core need be no larger than that used for monochrome receivers. The leakage inductance is about 6 millihenries. The performance does not change even with fewer turns per layer as long as the leakage is not higher than 9 millihenries and the distributed capacitance decreases proportionally. The capacitor in series with the primary winding is small enough to be partially discharged during the second half of retrace. This discharge forms a parabolic waveform during trace which prevents the high-voltage multiplier from conducting on the ringing voltage after retrace. Such conduction would cause poor regulation at low beam currents.

Regulator Section

A reactive regulator is used to obtain good reliability at low cost. Because the transistor used to drive the control winding dissipates less than 200 milliwatts, an inexpensive device can be used. This regulator has a response time fast enough to regulate almost every horizontal line.

Because the high-voltage system has low impedance (less than 1.6 megohms), the regulator must regulate the high voltage and scan only against variations in line voltage. The line voltage could be sampled for use in the regulator; however, the gain of the transistor and saturable transformer are high enough so that a closed-loop system can be used without additional cost. The closed-loop system has the advantage of keeping the high voltage constant regardless of oscillator frequency or variations in component values. The sampled signal is the peak of the retrace voltage, which varies with supply voltage but very little with normal variations of beam current or the vertical component of side-pincushion correction. The peak retrace voltage varies only to the extent that line voltage fluctuations or beam current in the picture tube reduce the B+ voltage. The fast response time of the regulator reduces the effective ripple voltage on the deflection system by a factor of about five.

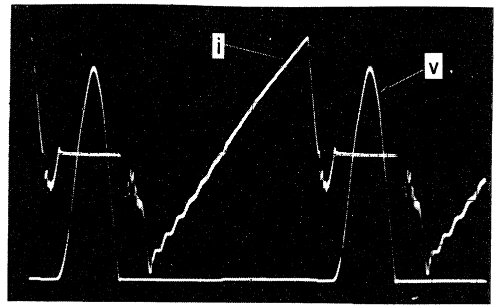


Fig. 6— Waveforms of trace-switch current (2 A/div) and trace-switch voltage (100 V/div). Time scale is 10 µs/div.

Transistor Q1 operates class C, conducting only during retrace. The diode D4 recovers the energy stored during this time in the control winding. D5 blocks the transistor from being forward-biased. D3 prevents the saturable transformer from saturating while the charge on C_a and C_c is increasing in the positive direction, and also improves the sensitivity of the regulator. A voltage-dependent resistor (VDR) from B+ to the regulator improves regulation by providing direct regulation against line-voltage changes.

Raster Correction Circuit

Side-pincushion correction can be accomplished by simple loading circuits during the second part of retrace, but top-and-bottom pincushion correction always requires some kind of transformer. The SCR circuit, because of its retrace-driven operation, can use a single transformer to correct both side-pincushion and top-and-bottom pincushion distortion. The horizontal windings are connected in parallel

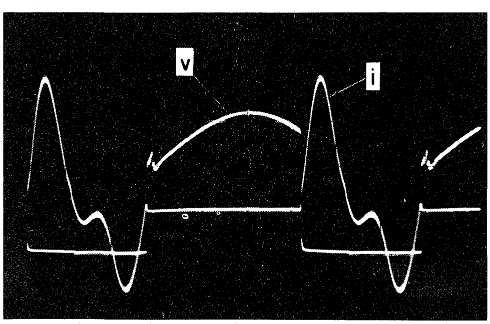


Fig. 5— Waveforms of commutating-switch current (5 A/div) and commutating-switch voltage (100 V/div). Time scale is 10 µs/div.

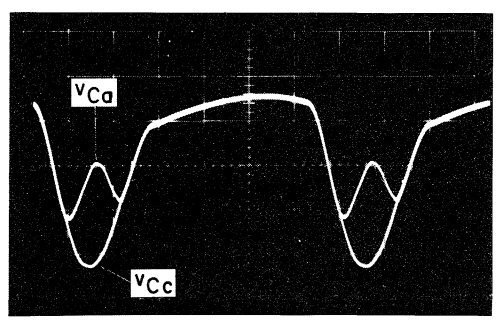


Fig. 7— Waveforms of voltage on C_a (200 V/div) and voltage on C_c (200 V/div). Time scale is 10 µs/div.

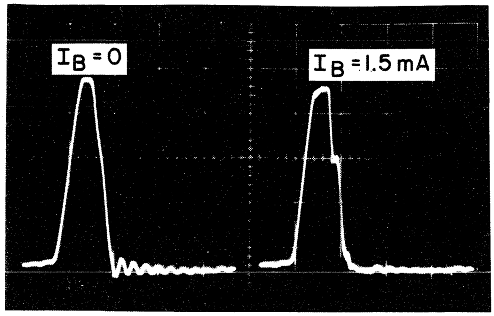


Fig. 8— Waveforms of tripler input voltage (2 kV/div), for beam currents of 0 and 1.5 mA. Time scale is 10 μs/div.

with the primary of the high-voltage transformer, with a diode and a resistor in series. The resistor adds losses that help to preserve the turn-off time of the trace SCR; the diode improves the efficiency of the raster correction and prevents current from flowing in the saturable transformer during the second half of trace. There is no vertical modulation of high voltage despite the modulation of the yoke current for side-pincushion correction, because only the second half of the retrace pulse is modulated in width, while the total amplitude of the pulse on the high-voltage transformer remains constant.

During retrace and the early part of trace, the core is saturated. The current that flows in the horizontal windings at this time charges capacitor C_r to a higher voltage and then C_r partially discharges to a lower voltage during the second part of the trace period. Thus the voltage on C_r is less during retrace. During the energy-transfer period, more current flows in the outside windings of the pincushion-correction transformer and less in the yoke; side pincushion correction is thus accomplished when the current in the horizontal windings is modulated by the vertical yoke current in the center winding. S-shaping is unaffected over one field, because the reactances of the yoke and the S-shaping capacitor are not changed (as they would be if the yoke and the high-voltage transformer shared the same storage capacitor.

The top-and-bottom correction functions in conventional fashion.

Linearity Circuit

The linearity circuit acts as a variable inductance in series with the yoke; the yoke current flows through L2 during the first part of trace, and then is gradually shunted through the self-saturable inductor L3. The diode is turned off for the last part of retrace. This circuit has an advantage over a ringing circuit in that it needs no adjustment after the nominal values for L2 and L3 are determined.

Auxiliary Power Supplies

Fig. 3 shows three auxiliary power supplies that are derived from the SCR deflection circuit. The 220-volt supply for the video output stages is obtained by rectifying a 100-volt pulse in the high-voltage transformer and adding it to the B+ supply.

The regulated 60-volt supply for the vertical sweep is obtained from the high-voltage transformer. Inductor L_p and capacitor C_p restrict the conduction of the rectifier to the first part of retrace, so that the load current drawn by the vertical circuit has no effect on the pincushion correction or the raster size. The filter choke can be adjusted to set the dc voltage to a predetermined value, which makes it possible to keep the dissipation in the vertical output stages to a minimum. The voltage and currents are shown in Fig. 10. This supply can deliver 18 watts without affecting the performance of the high voltage or scan.

An unregulated 25-volt supply is obtained by full-wave rectification of the voltage from an auxiliary winding on the input choke. This supply needs less filtering because its load variations do not affect the raster or high voltage except at low line voltage.

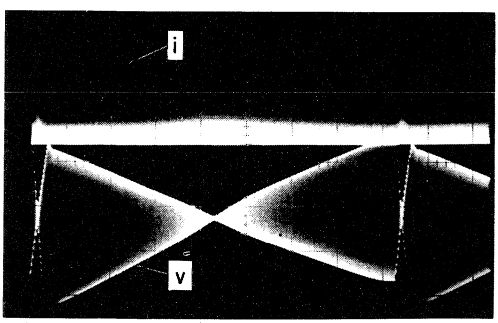


Fig. 9— Waveforms in pincushion-correction transformer: horizontal-winding current (0.5 A/div), and vertical-winding input voltage (50 V/div). Time scale is 2 ms/div.

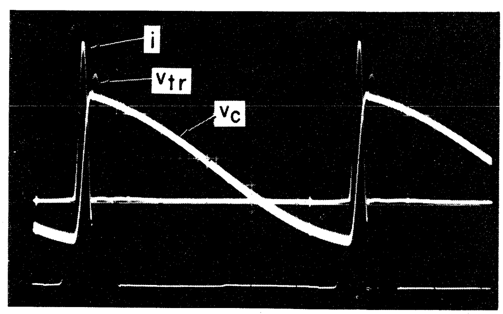


Fig. 10— Waveforms in 60-volt regulated supply for the vertical sweep circuit: trace-switch voltage (100 V/div), rectifier current (2 A/div), and charging-capacitor voltage (20 V/div). Time scale is 10 μs/div.

Table I shows the performance of the system with the vertical and video output circuits connected to the supplies of the deflection system and a 35-ohm resistor across the unregulated 25-volt supply (to simulate the loading of the signal-processing circuits).

TRANSIENT CONDITIONS

In the design of circuits and the rating of devices for this horizontal-deflection system, the transient conditions of picture-tube arcing and receiver turn-on must be considered.

Arcing

If the picture tube arcs to ground, currents of up to 60 amperes can flow through the trace SCR and the trace diode. These currents do not damage the devices, because the forward voltage drop is small and the duration is short. The peak voltage under arcing exceeds the repetitive voltage by not more than 50 volts if the usual surge resistor is used

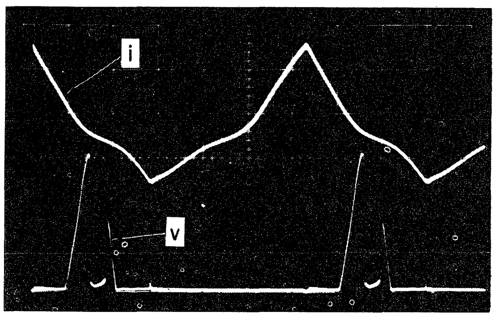


Fig. 11— Waveforms in regulator: load-winding current (1 A/div), and Q1 collector voltage (50 V/div). Time scale is 10 μs/div.

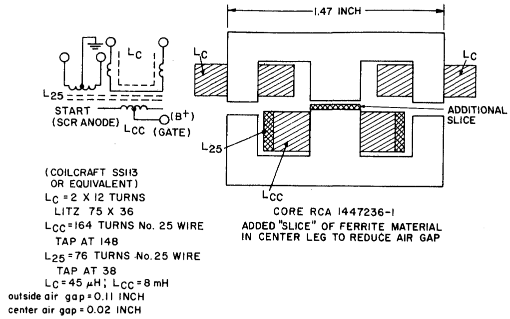


Fig. 12— Combined input choke (L_{CC}), commutating coil (L_C), and power-supply transformer for horizontal deflection system. This assembly is T1 in Fig. 2.

between tripler output and picture tube. The peak voltage on the commutating switch under normal arcing exceeds the repetitive voltage by 100 volts. However, "screwdriver-type" arcing can result in higher peak voltages. These voltages should be considered when the commutating SCR and diode are selected. The ratings of the devices used also depend on whether the auxiliary power supply from the input choke is used, because the rectifier for this supply also functions as a clamp and thus reduces the transient voltage. The oscillator should be designed so that the timing of the pulses that drive the SCR can not change. Higher repetition rates or lack of pulses could result in failure to commutate and cause the circuit breaker to open with no excessive stress on any devices or components.

Table I — Performance of Horizontal-Deflection System as a Function of AC Line Voltage and Beam Current.

PARAMETER	SYMBOL							UNITS
Line Voltage	V_{LINE}	108	108	120	120	132	132	VAC
Beam Current	I_{BEAM}	0	1.5	0	1.5	0	1.5	mA
B+ Voltage	V_{B+}	135	130	150	143	165	159	V
B+ Current	I_{B+}	750	1010	750	1060	765	1030	mA
Beam Voltage	V_{HI}	25.3	21.6	25.8	23.1	26.2	23.5	kV
Sig.-Process. Voltage	V_{25}	25.0	25.0	27.5	27.0	30.5	30.0	V
Sig.-Process. Current	I_{25}	720	710	800	780	880	855	mA
Vertical Voltage	V_{60}	54	55	55	60	56	60	V
Vertical Current	I_{60}	240	245	250	250	252	252	mA
Video Voltage	V_{220}	210	180	225	200	237	215	V
Video Current	I_{220}	12.0	22.0	12.5	24.0	15.0	26.5	mA

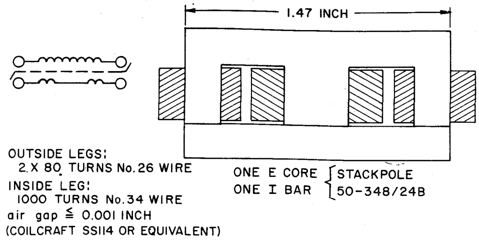


Fig. 13– Saturable reactor for regulator in horizontal-deflection system. This assembly is T2 in Fig. 2.

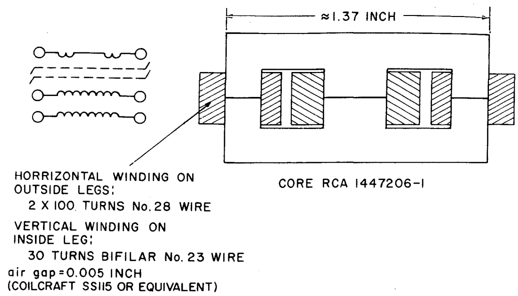


Fig. 15– Pincushion-correction transformer for horizontal-deflection system. This assembly is T4 in Fig. 2.

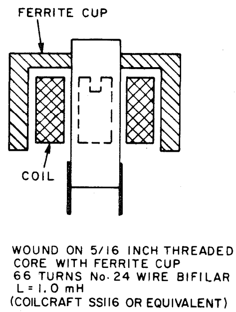


Fig. 16–Pincushion-correction phasing coil for horizontal-deflection systems. This assembly is L4 in Fig. 2.

Receiver Turn-On

When the receiver is switched on, the gate pulses derived from the horizontal oscillator for the commutating SCR should be of sufficient amplitude to trigger the SCR before the B+ supply reaches 30 per cent of nominal (i.e., about 45 volts). The horizontal-oscillator frequency should not exceed its nominal value by more than 10 per cent. Frequencies lower than nominal are not a problem because less energy is stored in the system at lower frequencies. However, higher frequencies produce higher peak voltages on both the trace and commutating switches and decrease the turn-off time for the commutating SCR.

The gate pulses must have sufficient amplitude to assure good turn-on over the whole cathode area, and during turnoff of the commutating SCR the gate voltage should be at least −3 volts under normal line-voltage operation. These requirements are easily satisfied if the gate circuit is designed to deliver 300 to 500 milliamperes for 4 to 5 microseconds at the nominal line voltage of 120 volts. With such a gate circuit, the gate current is approximately 100 milliamperes when line voltage drops to 20 per cent of nominal.

INVESTIGATION OF CIRCUIT MALFUNCTIONS

Interactions between the trace and commutating circuits often make it difficult to isolate circuit problems. Investigation of these problems can be expedited by isolating different portions of the circuit. For example, the trace switch can be shorted to allow investigation of the commutating circuit or the signal-processing portion of the receiver without generation of high voltage.

A short-circuit in the high-voltage transformer or in circuits connected to the transformer can be checked easily by disconnecting the primary from the SCR circuit or any of the circuits connected to the transformer. However, the yoke should *never* be disconnected, because the trace SCR would turn on during a time when C_c and C_a were positively charged, causing the SCR to fail because of di/dt stress.

For chassis removal the yoke should have an interlock with the B+ supply for the SCR system.

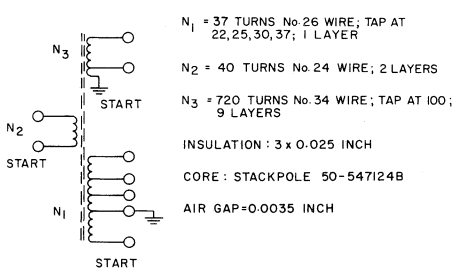


Fig. 14– High-voltage transformer for horizontal-deflection system. This assembly is T3 in Fig. 2.

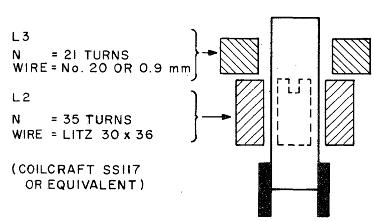


Fig. 17–Linearity coil. This assembly is L2 and L3 in Fig. 2.

Analysis and Design of Snubber Networks for dv/dt Suppression in Thyristor Circuits

by J. E. Wojslawowicz

When a triac is used to control an inductive load, voltages with high rates of change (dv/dt) can be generated that can cause a non-gated turn-on of the triac. This false turn-on can occur if the dv/dt exceeds the critical rate of rise of commutation voltage of the triac, or if voltage ringing occurs that exceeds the blocking capability of the triac (V_{DROM}). The false triggering caused by these mechanisms results in a loss of control of power to the load; to assure reliable operation, therefore, it is necessary to provide means to suppress this dv/dt stress as it is commonly called. The simplest method of dv/dt suppression is the use of a series RC network across the main terminals of the triac. The design of this network, commonly called a snubber network, must take into account the peak voltage that can be allowed in the circuit, and the maximum dv/dt stress that the device can withstand. This Note analyzes the RC network design and presents graphs that allow a designer to select a snubber to fulfill his requirements.

Commutating dv/dt And False Turn-On

Fig. 1 shows a control triac in a typical connection with an ac power source and a load. The triac is a regenerative device; once it has been turned on, it continues to conduct until the principal current drops below a value that just supports the regeneration. This current level is called the holding current of the device. If the gate signal is removed before the principal current decreases below the holding current, the device turns off and regains its blocking capability.

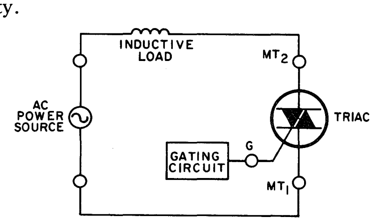


Fig. 1— Series connection of a triac, an inductive load, and an ac power source.

Fig. 2 shows the triac principal voltage and current waveforms when the load is resistive. If the gate signal is removed at time t_0, the device continues to conduct until the current attempts to reverse polarity. The device then undergoes a reverse recovery period, and thereafter must support a main terminal voltage of the reverse polarity that is equal to the source voltage. The rate of reapplication of this off-state voltage for a resistive load and a 120-volt 60-Hz source is typically 0.064 volt per microsecond if the stray inductance due to wiring is minimal. This rate of reapplication generally does not cause turn-on of the device.

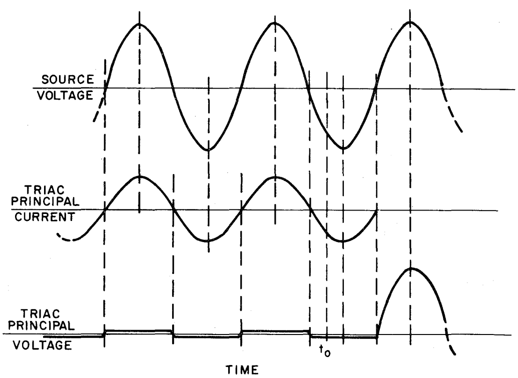


Fig. 2— Principal voltage and current for a triac in operation with a resistive load.

In a circuit with an inductive load the voltage leads the current by some phase angle ϕ as shown in Fig. 3. After the triac turns off it must block the reapplied instantaneous line voltage of the reverse polarity. Because the triac goes from the conducting state to the blocking state in a very short time, this voltage is reapplied very rapidly. The turn-off of the triac causes a rapid decay of current through the inductance, and thus produces an Ldi/dt voltage. This rapidly

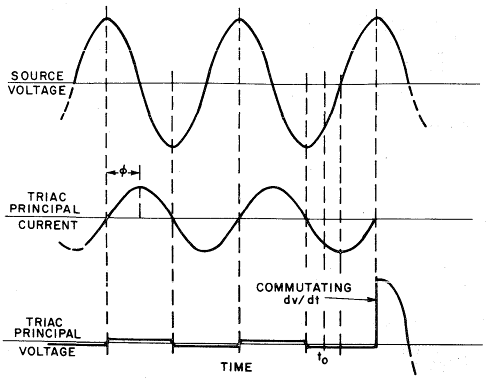


Fig. 3— Principal voltage and current for a triac in operation with an inductive load.

rising off-state voltage stress is impressed across the main terminals of the device and can cause it to turn on. Fig. 4 illustrates this false turn-on.

A triac analog that uses two silicon controlled rectifiers (SCR's) provides a simple understanding of how this dv/dt causes the device to turn on. The inverse parallel SCR analog of the triac is shown in Fig. 5(a), and a two-transistor analog of the SCR is shown in Fig. 5(b). At the end of the half cycle of on-state current conduction, some charge remains in the bases of the equivalent transistors that comprise the conducting SCR. Upon application of the opposite-quadrant off-state voltage, this charge flows as a recovery current. Part of this current flows through the equivalent transistor emitter of the adjacent SCR. In addition, some charge may already exist in the bases of the blocking SCR because of lateral transport of carriers from the previously conducting side. Finally, a capacitive displacement current flows to the reverse-biased middle junction of the blocking SCR; this displacement current, I_{DIS}, can be described by the following equation:

$$I_{DIS} = C_M \frac{dV}{dt} + V \frac{dC_M}{dt} \qquad (1)$$

where C_M is the capacitance of the reverse-biased junction and V is the voltage across that junction.

If the total of the three currents is sufficient to cause the sum of the transistor gains to become unity, the device switches on. The use of the shorted-emitter construction by RCA shunts some of the current away and thus permits a higher dv/dt stress to be placed across the device, but does not eliminate the current completely. The first two current flows are functions of device design and construction, but the displacement current flow can be controlled by use of an RC snubber network that limits the rate of reapplication of off-state voltage.

The snubber network, illustrated in Fig. 6, consists of a resistance R_S and a capacitance C_S placed in series across the main terminals of the device. For some snubber component values and some types of load, excessive ringing can occur in the circuit; this voltage ringing can exceed the blocking capability (V_{DROM}) of the device. Malfunction of the device is then caused by the inability of the triac to block the voltage even though it can withstand the dv/dt stress. An example of voltage ringing is shown in Fig. 7(a). Fig. 7(b) shows the same voltage on an expanded time scale.

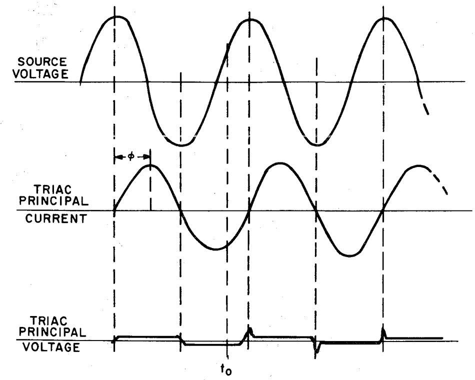


Fig. 4— Principal voltage and current curves showing triac malfunction that results from commutating dv/dt produced by inductive load.

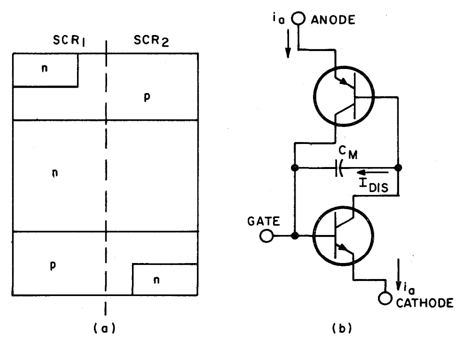


Fig. 5— (a) Two-SCR representation of a triac; (b) two-transistor model of an SCR, with junction capacitance shown.

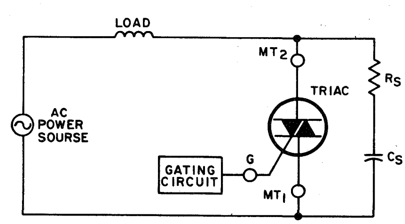


Fig. 6— Triac circuit using a snubber network of R_S and C_S connected across the triac.

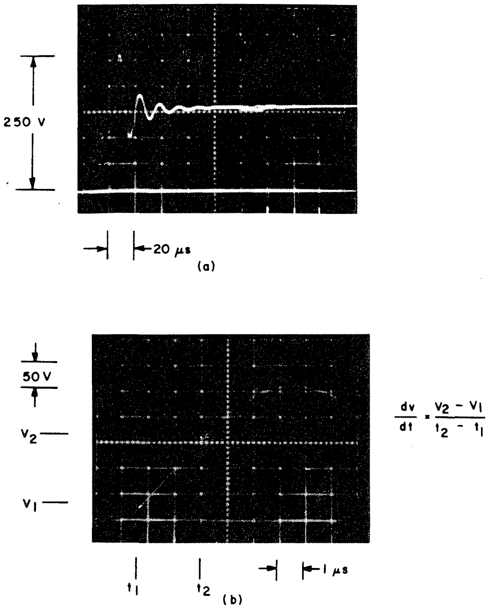


Fig. 7— (a) Ringing, caused by inductive load, in the principal voltage of triac; (b) principal voltage shown on an expanded scale.

Basic Circuit Analysis

The suppression network must be designed to limit the dv/dt stress and to have an acceptable voltage overshoot. Fig. 8 shows an equivalent circuit used for analysis, in which the triac has been replaced by an ideal switch. When the triac is in the blocking or non-conducting state, represented by the open switch, the circuit is a standard RLC series network driven by an ac voltage source. The following differential equation can be obtained by summing the voltage drops around the circuit:

$$(R_L + R_S)\, i(t) + L\frac{di(t)}{dt} + \frac{q_c(t)}{C_S} = V_M \sin(\omega t + \phi) \qquad (2)$$

in which i(t) is the instantaneous current after the switch opens, $q_c(t)$ is the instantaneous charge on the capacitor, V_M is the peak line voltage, and ϕ is the phase angle by which the voltage leads the current prior to opening of the switch. After differentiation and rearrangement, the equation becomes a standard second-order differential equation with constant coefficients. With the imposition of the boundary conditions that i(0)=0 and $q_c(0)=0$, the equation for the charge on the capacitor can be stated for the three circuit conditions as follows:

Condition I[1]: $(R_L + R_S)^2 < 4L/C$

$$q_c(t) = \frac{-|V_M|}{\omega |Z|} \cos(\omega t + \phi + \theta) + |Q_t|\, \epsilon^{-\alpha t} \sin(\beta t + \eta) \qquad (3)$$

Condition II[2]: $(R_L + R_S)^2 = 4L/C$

$$q_c(t) = \frac{-|V_M|}{\omega |Z|} \cos(\omega t + \phi + \theta) + \epsilon^{-\alpha t} [(1 + \alpha t)\, q_d + i_d t] \qquad (4)$$

Condition III[3]: $(R_L + R_S)^2 > 4L/C$

$$q_c(t) = \frac{-|V_M|}{\omega |Z|} \cos(\omega t + \phi + \theta) + \frac{\epsilon^{-\alpha t}}{\beta'} [(\alpha q_d + i_d t) \sinh \beta' t + \beta' q_d \cosh \beta' t] \qquad (5)$$

The symbols used in these equations are defined as follows:

$$\phi = \tan^{-1}(\omega L / R_L) \qquad (6)$$

$$\theta = -\tan^{-1} \left[\left(\omega L - \frac{1}{\omega C_S}\right) / (R_L + R_S)\right] \qquad (7)$$

$$\alpha = \frac{R_L + R_S}{2L} \qquad (8)$$

$$\beta' = \sqrt{\left(\frac{R_L + R_S}{2L}\right)^2 - \frac{1}{LC_S}} \qquad (9)$$

$$\beta = \sqrt{\frac{1}{LC_S} - \left(\frac{R_L + R_S}{2L}\right)^2} \qquad (10)$$

$$Z = (R_L + R_S) + j\left(\omega L - \frac{1}{\omega C_S}\right) \qquad (11)$$

$$q_d = \frac{|V_M|}{\omega |Z|} \cos(\phi + \theta) + q_c(0) \qquad (12)$$

$$i_d = i(0) - \frac{|V_M|}{|Z|} \sin(\phi + \theta) \qquad (13)$$

$$|Q_t| = \sqrt{\left[\frac{\alpha q_d + i_d}{\beta}\right]^2 + q_d^2} \qquad (14)$$

$$\eta = \tan^{-1} \left(\frac{\beta q_d}{\alpha q_d + i_d}\right) \qquad (15)$$

The voltage across the device is determined by calculating the voltages across the snubber capacitor and resistor from the following fundamental relations:

$$v_{C_S}(t) = \frac{q_c(t)}{C_S} \qquad (16)$$

$$v_{R_S}(t) = R_S \frac{dq_c(t)}{dt} \qquad (17)$$

The sum of these two voltages then represents the instantaneous voltage across the triac. The following equations give the instantaneous voltage for the three circuit conditions:

Condition I: $(R_L + R_S)^2 < 4L/C$

$$v(t) = \frac{-|V_M|}{|Z|}\left[\frac{1}{\omega C_S}\cos(\omega t + \phi + \theta) - R_S \sin(\omega t + \phi + \theta)\right] + |Q_t|\epsilon^{-\alpha t}\left[\frac{1}{C_S}\sin(\beta t + \eta) + \frac{R_S}{\sqrt{LC_S}}\sin(\beta t + \eta + \psi)\right] \quad (18)$$

where ψ is defined by the following expression:

$$\psi = \tan^{-1}\left(\frac{\beta}{-\alpha}\right) \quad (19)$$

Condition II: $(R_L + R_S)^2 = 4L/C$

$$v(t) = \frac{-|V_M|}{|Z|}\left[\frac{1}{\omega C_S}\cos(\omega t + \phi + \theta) - R_S \sin(\omega t + \phi + \theta)\right] + \frac{1}{C_S}\left[(1 + \alpha t)\, q_d + i_d t\right]\epsilon^{-\alpha t} + R_S\left[(1 - \alpha t)\, i_d - \alpha^2 t q_d\right]\epsilon^{-\alpha t} \quad (20)$$

Condition III: $(R_L + R_S)^2 > 4L/C$

$$v(t) = \frac{-|V_M|}{|Z|}\left[\frac{1}{\omega C_S}\cos(\omega t + \phi + \theta) - R_S \sin(\omega t + \phi + \theta)\right] + \frac{\epsilon^{-\alpha t}}{\beta' C_S}\left[(\alpha q_d + i_d)\sinh \beta' t + \beta' q_d \cosh \beta' t\right] + R_S \epsilon^{-\alpha t}\left[\frac{-\alpha i_d - \frac{1}{LC_S} q_d}{\beta'}\sinh \beta' t + i_d \cosh \beta' t\right] \quad (21)$$

A computer is used to calculate the voltage across the snubber because hand calculation is time-consuming. The magnitude and time of occurrence of the peak voltage are found by numerical analysis, and then the values and times of the voltages at 10 per cent and 63 per cent of peak are calculated. These values are used to compute the dv/dt stress as defined by the following equation:

$$dv/dt = \frac{V_2 - V_1}{t_2 - t_1} \quad (22)$$

where V_1 and t_1 are the voltage and time of the 10-per-cent point and V_2 and t_2 are the voltage and time of the 63-per-cent point. This program therefore allows evaluation of various load and snubber combinations in a matter of minutes.

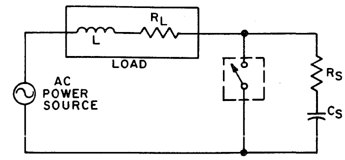


Fig. 8— Equivalent circuit used for analysis.

In general, it is most desirable from a cost standpoint to use a device with the lowest possible V_{DROM} capability. For applications involving the control of a load operating on a 120-volt ac line a device with a V_{DROM} of 200 volts would be desirable; a 400-volt device should be used for operation on a 220-volt line. The use of the lower-voltage device in any application is contingent on the ability of the circuit to limit any possible voltage ringing below the V_{DROM} rating of the device. The snubber can be designed to limit this voltage ringing during the post-commutation period to within this rating. Figs. 9 and 10 show the values of C_S and R_S that limit peak voltage across the triac to specific values. Fig. 9 allows the selection of snubber components that will limit the peak voltage of 200 volts for a zero-power-factor load at the desired dv/dt for an rms line voltage of 120 volts. Fig. 10 shows the components that limit the voltage to 400 volts when the rms line voltage is 220 volts.

Snubber Design Procedure

For use of the graphs, three things must be known: (1) the rms line voltage, (2) the rms load current, and (3) the allowable dv/dt. The following procedure is used to obtain the required snubber components:

(1) Draw a vertical line on the proper voltage graph at the load current.

(2) At the intersection of the vertical line and the dashed line that represents the allowable dv/dt, draw a horizontal line to the right vertical axis. Read the value of R_S from the right vertical axis.

(3) At the intersection of the vertical line and the solid line that represents the allowable dv/dt, draw a horizontal line to the left vertical axis. Read the value of C_S from the left vertical axis.

As an illustration of the above procedure. Fig. 9 is used to find snubber component values that limit the dv/dt stress to 5 volts per microsecond for a 40-ampere rms current in a 120-volt rms line. From Fig. 9, these values are R_s = 340 ohm and C_s = 0.18 microfarad.

As previously stated, these graphs were developed to limit the peak voltage for a zero-power-factor load. For the non-ideal load the graphs are used in the same fashion; a reduction in the peak voltage following commutation and a slight reduction in the dv/dt stress are the only effects introduced by the non-ideal load. The reduction in the peak voltage excursion is caused by the decrease in instantaneous voltage at the time of commutation. As the power factor increases, the phase angle between the voltage and current decreases toward 0^{o}. This decrease in the phase angle shifts the time of commutation in the half-cycle toward the zero-voltage crossing and thus reduces the instantaneous voltage. The reduction in the dv/dt stress is the result of both the reduction in the voltage at commutation and the increasing resistive impedance of the load.

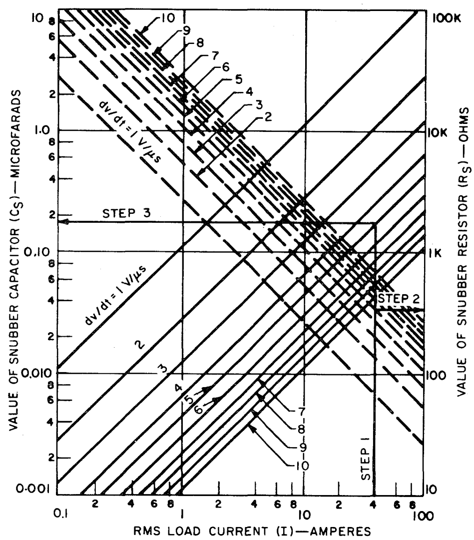


Fig. 9— Design curves for snubber that limits peak voltage to 200 volts for 120-volt ac line and zero power factor.

A numerical example shows how a load that is not purely inductive reduces the peak voltage after commutation. The snubber components for 8 volts per microsecond at an rms current of 22.7 amperes are found from Fig. 9 to be 960 ohms and 0.04 microfarad. If the load is purely inductive, the peak voltage is limited to 200 volts. If the load has the same current rating but a power factor of 0.7, this snubber network limits the peak voltage after commutation to 140 volts. The peak voltage is reduced because the instantaneous line voltage at the time of commutation is only 121 volts. The dv/dt stress is also slightly lower than the 8-volts-per-microsecond value. This example demonstrates that the design graphs of Figs. 9 and 10 can be used for loads having any power factor.

Because the selection of snubber components is dependent on circuit and device characteristics, values obtained may be impractical from a cost or size standpoint. In such a case, a triac with higher dv/dt capability or higher V_{DROM} rating should be used. A higher dv/dt capability allows selection of new snubber components to meet the size and/or cost requirements of the circuit. A higher V_{DROM} rating permits a higher peak voltage excursion that in general will allow selection of a smaller snubber capacitor and smaller resistor.

The circuit analysis described in this Note assumes the effects of the triac to be a minimum. Thus some error is introduced by neglect of the reverse recovery process and the displacement current. The additional current flow tends to increase the instantaneous dv/dt during the first few microseconds following commutation. The over-all effect is to increase slightly the average dv/dt stress across the device. This effect is most noticeable when the snubber capacitance is less than 0.001 microfarad. Selection of a snubber for a lower dv/dt stress limit will generally eliminate this problem.

Because the design of a snubber is contingent on the load, it is almost impossible to simulate and test every possible combination under actual operating conditions. It is advisable to measure the peak amplitude and rate of rise of voltage across the triac after a snubber has been selected.

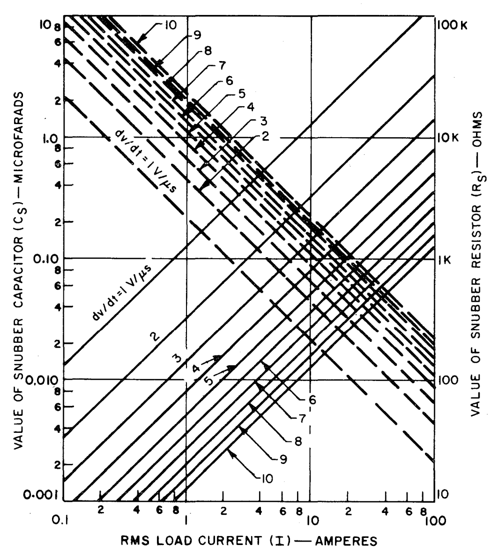


Fig. 10— Design curves for snubber that limits peak voltage to 400 volts for 220-volt ac line and zero power factor.

References

1. Myril B. Reed, Alternating Current Circuit Theory (New York: Harper & Brothers, 1948), pg. 276.
2. Ibid, pg. 284.
3. Ibid, pg. 284.

RCA

Solid State Division

Thyristors

Application Note AN-6054

Triac Power Controls for Three-Phase Systems

by J. Yellin

The growing demand for solid-state switching of ac power in heating controls and other industrial applications has resulted in the increasing use of triac circuits in the control of three-phase power. This Note explains a basic approach to the design of triac control circuits for use in the switching of three-phase power. The basic design rules employed in this approach are outlined, an integrated-circuit zero-voltage switch specifically intended for use in triac triggering is briefly described, and the necessity for and methods of isolation of the dc logic circuitry in power controls for three-phase systems are pointed out. Recommended configurations are then shown for power-control circuits intended for use with both inductive and resistive balanced three-phase loads, and the specific design requirements for each type of loading condition are discussed. (Unbalanced three-phase systems, which have different design requirements, are not covered in this Note.)

Basic Design Rules

In the power-control circuits described in this Note, the RCA-CA3059 integrated-circuit zero-voltage switch is used as the trigger circuit for the power triacs.* The following conditions are also imposed in the design of the triac control circuits:

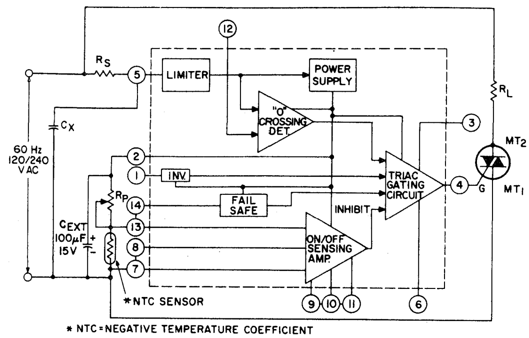
1. The load should be connected in a three-wire configuration with the triacs placed external to the load; either delta or wye arrangements may be used. Four-wire loads in wye configurations can be handled as three independent single-phase systems. Delta configurations in which a triac is connected within each phase rather than in the incoming lines can also be handled as three independent single-phase systems.
2. Only one logic command signal is available for the control circuits. This signal must be electrically isolated from the three-phase power system.
3. Three separate triac gating signals are required.
4. For operation with resistive loads, the zero-voltage-switching technique should be used to minimize any radio-frequency interference (RFI) that may be generated.

*In addition to the CA3059, the RCA-CA3058 and -CA3079 integrated-circuit zero-voltage switches may also be used for triac triggering in the power-control circuits. All information given on the CA3059 in this Note is, in general, equally applicable to the CA3058 and CA3079.

Integrated-Circuit Zero-Voltage Switch

The RCA-CA3059 integrated-circuit zero-voltage switch is intended primarily as a trigger circuit for the control of thyristors and is particularly suited for use in thyristor temperature-control applications. Fig. 1 shows a functional block diagram of the CA3059 integrated-circuit zero-voltage switch. This multistage circuit employs a diode limiter, a threshold detector, a differential amplifier, and a Darlington output driver to provide the basic switching action. The dc supply voltage for these stages is supplied by an internal zener-diode-regulated power supply that has sufficient current capability to drive external circuit elements, such as transistors and other integrated circuits. The trigger pulse developed by this circuit can be applied directly to the gate of an SCR or a triac. A built-in fail-safe circuit inhibits the application of these pulses to the thyristor gate circuit in the event that the external sensor for the integrated-circuit switch should be inadvertently opened or shorted. The CA3059 may be employed as either an on-off type of controller or a proportional controller, depending upon the degree of temperature regulation required.

Fig. 2 shows the schematic diagram for the CA3059 integrated circuit. Any triac that is driven directly from the output terminal of this circuit should be characterized for operation in the I(+) or III(+) triggering modes, i.e., with positive gate current (current flows into the gate for both polarities of the applied ac voltage). The circuit operates directly from a 50-, 60-, or 400-Hz ac line voltage of 120 to 277 volts.



AC Input Voltage (50/60 or 400 Hz) V AC	Input Series Resistor (R_S) kΩ	Dissipation Rating for R_S W
24	2	0.5
120	10	2
208/230	20	4
277	25	5

Fig. 1—Functional block diagram of the CA3059 integrated-circuit zero-voltage switch.

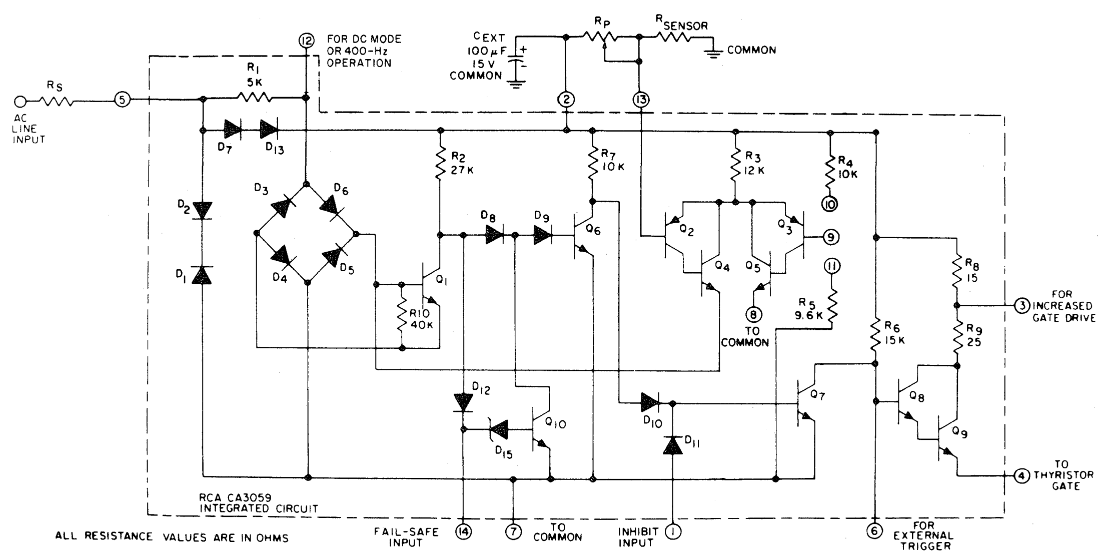


Fig. 2—Circuit diagram for the CA3059 zero-voltage switch.

The diodes D1 and D2 in the CA3059 form a limiter stage that clips the incoming ac line voltage to approximately plus and minus 8 volts. This signal is then applied to the zero-voltage-crossing detector (diodes D3 through D6 and transistor Q1), which generates an output pulse during each passage of the line voltage through zero. The limiter output is also applied to the rectifying diodes D7 and D13 and the external capacitor C_{EXT} that comprise the dc power supply. The power supply provides approximately 6 volts (at terminal 2) as the dc supply to the other stages of the CA3059. The on/off sensing amplifier (transistors Q2 through Q5) is basically a differential comparator. The triac gating circuit contains a driver (transistors Q8 and Q9) for direct triac triggering. The gating circuit is enabled when all the inputs are at a high voltage, i.e., the line voltage must be approximately zero volts, the sensing-amplifier output must be "high", the external voltage to terminal 1 must be a logical "1", and the output of the fail-safe circuit must be "high".

Fig. 3 shows the position and width of the pulses supplied to the gate of a thyristor with respect to the incoming ac line voltage. The CA3059 can supply sufficient gate voltage and current to trigger most RCA thyristors at ambient temperatures of 25°C. However, under worst-case conditions (i.e., at low ambient-temperature extremes and maximum trigger requirements), selection of the higher-current thyristors may be necessary for particular applications. (The RCA technical bulletin File No. 406 lists triacs designed for use with the integrated-circuit zero-voltage switch as the triggering circuit. Detailed information on the operating characteristics and capabilities of this integrated circuit are given in RCA technical bulletin File No. 490, RCA application notes ICAN-6158 and ICAN-6268, and the *RCA Linear Integrated Circuits* Manual, IC-42.)

As shown in Fig. 1, when terminal 13 is connected to terminal 14, the fail-safe circuit of the CA3059 is operable. If the sensor should then be accidentally opened or shorted, power is removed from the load (i.e., the triac is turned off). The internal fail-safe circuit functions properly, however, only when the ratio of the sensor impedance at 25°C, if a thermistor is the sensor, to the impedance of the potentiometer R_P is less than 4 to 1.

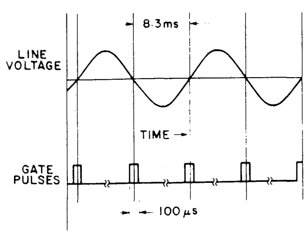


Fig. 3– Timing relationship between the output pulses of the CA3059 and the ac line voltage (pulse duration shown is a typical value for operation from a 120-volt 60-Hz line voltage).

Isolation of DC Logic Circuitry

Isolation of the dc logic circuitry* from the ac line, the triac, and the load circuit is often desirable even in many single-phase power-control applications. In control circuits for polyphase power systems, however, this type of isolation is essential, because the common point of the dc logic circuitry cannot be referenced to a common line in all phases.

In the three-phase circuits described in this Note, photo-optic techniques (i.e., photo-coupled isolators) are used to provide the electrical isolation of the dc logic command signal from the ac circuits and the load. The photo-coupled isolators consist of an infrared light-emitting diode aimed at a silicon photo transistor, coupled in a common package. The light-emitting diode is the input section, and the photo transistor is the output section. The two components provide a voltage isolation typically of 1500 volts. Other isolation techniques, such as pulse transformers, magnetoresistors, or reed relays, can also be used with some circuit modifications.

Resistive Loads

Fig. 4 illustrates the basic phase relationships of a balanced three-phase resistive load, such as may be used in heater applications, in which the application of load power is controlled by zero-voltage switching. The following conditions are inherent in this type of application:

1. The phases are 120 degrees apart; consequently, all three phases cannot be switched on simultaneously at zero voltage.
2. A single phase of a wye configuration type of three-wire system cannot be turned on.
3. Two phases must be turned on for initial starting of the system. These two phases form a single-phase circuit which is out of phase with both of its component phases. The single-phase circuit leads one phase by 30 degrees and lags the other phase by 30 degrees.

These conditions indicate that in order to maintain a system in which no appreciable RFI is generated by the switching action from initial starting through the steady-state operating condition, the system must first be turned on, by zero-voltage switching, as a single-phase circuit and then must revert to synchronous three-phase operation.

Fig. 5 shows a simplified circuit configuration of a three-phase heater control that employs zero-voltage synchronous switching in the steady-state operating condition, with random starting. In this system, the logic command to turn on the system is given when heat is required, and the command to turn off the system is given when heat is not required. Time proportioning heat control is also possible through the use of logic commands.

*The dc logic circuitry provides the low-level electrical signal that dictates the state of the load. For temperature controls, the dc logic circuitry includes a temperature sensor for feedback. The RCA integrated-circuit zero-voltage switch, when operated in the dc mode with some additional circuitry, can replace the dc logic circuitry for temperature controls.

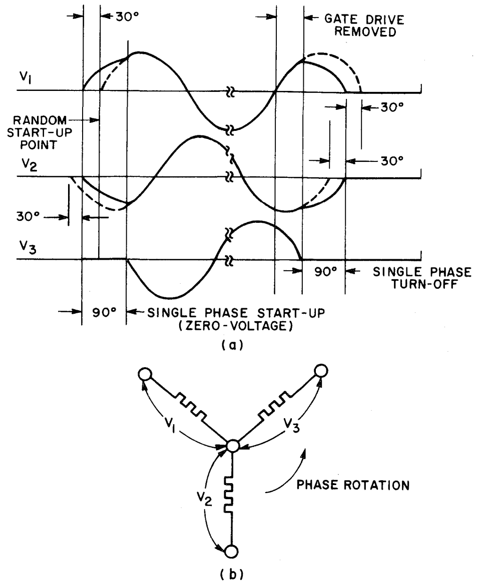


Fig. 4– Voltage phase relationship for a three-phase resistive load when the application of load power is controlled by zero-voltage switching: (a) voltage waveforms, (b) load-circuit orientation of voltages. (The dashed lines indicate the normal relationship of the phases under steady-state conditions. The deviation at start-up and turn-off should be noted.)

The three photo-coupled inputs to the three CA3059 circuits change state simultaneously in response to a "logic command". The CA3059 circuits then provide a positive pulse, approximately 100 microseconds in duration, only at a zero-voltage crossing relative to their particular phase. A balanced three-phase sensing circuit is set up with the three CA3059 circuits each connected to a particular phase on their common side (terminal 7) and referenced at their high side (terminal 5), through the current-limiting resistors R4, R5, and R6, to an established artificial neutral point. This artificial neutral point is electrically equivalent to the inaccessible neutral point of the wye type of three-wire load and, therefore, is used to establish the desired phase relationships. The same artificial neutral point is also used to establish the proper phase relationships for a delta type of three-wire load. Because only one triac is pulsed on at a time, the diodes (D1, D2, and D3) are necessary to trigger the opposite-polarity triac, and, in this way, to assure initial latching-on of the system. The three resistors (R1, R2, and R3) are used for current limiting of the gate drive when the opposite-polarity triac is triggered "on" by the line voltage.

In critical applications that require suppression of all generated RFI, the circuit shown in Fig. 6 may be used. In addition to synchronous steady-state operating conditions. this circuit also incorporates a zero-voltage starting circuit. The start-up condition is zero-voltage synchronized to a single-phase, 2-wire, line-to-line circuit, comprised of phases A and B. The logic command engages the single-phase "start-up" CA3059 and three-phase photo-coupled isolators OCI3, OCI4, OCI5 through the photo-coupled isolators OCI1 and OCI2. The single-phase CA3059, which is synchronized to phases A and B, starts the system at zero voltage. As soon

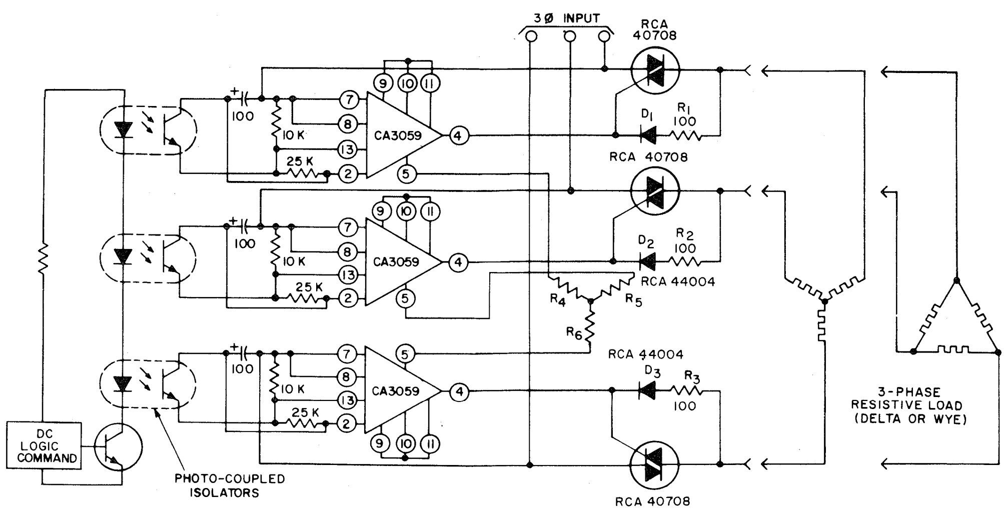


Fig. 5—Simplified diagram of a three-phase heater control that employs zero-voltage synchronous switching in the steady-state operating conditions.

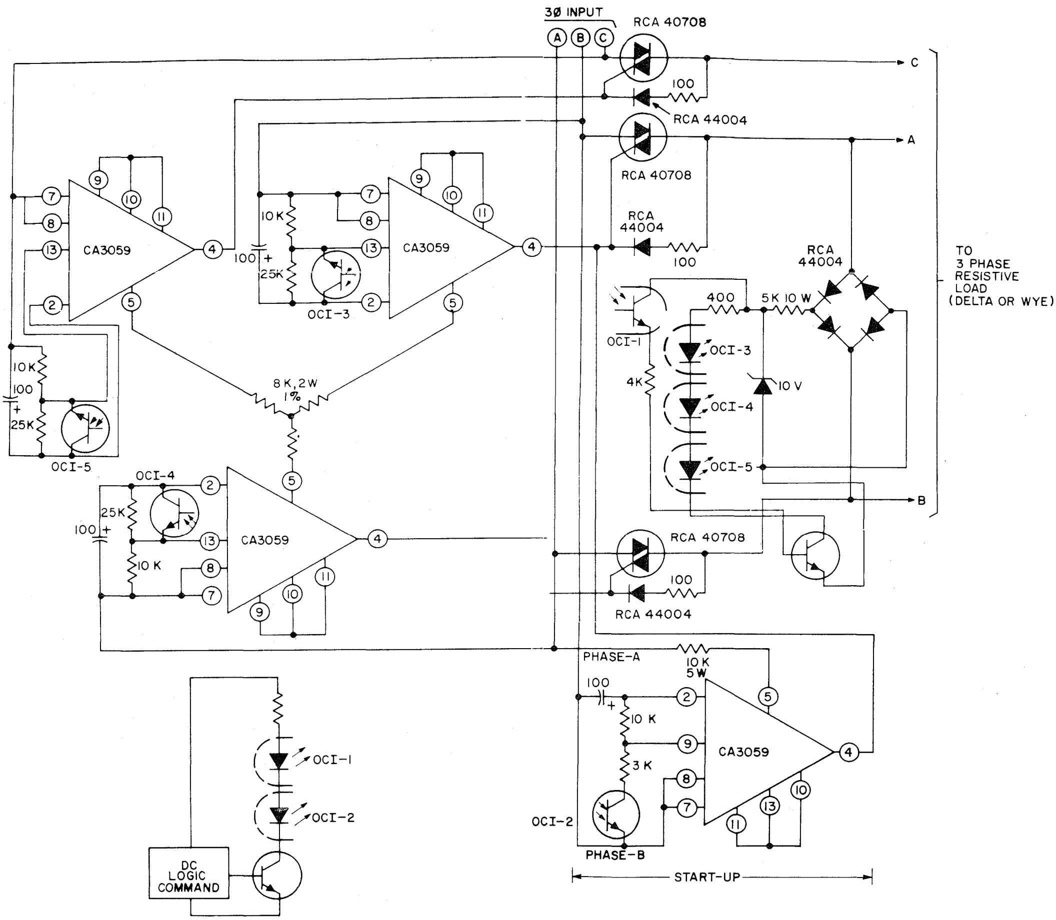


Fig. 6—Three-phase power control that employs zero-voltage synchronous switching both for steady-state operation and for starting.

as start-up is accomplished, the three photo-coupled isolators OCI3, OCI4, and OCI5 take control, and three-phase synchronization begins. When the "logic command" is turned off, all control is ended, and the triacs automatically turn off when the sine-wave current decreases to zero. Once the first phase turns off, the other two will turn off simultaneously, 90^o later, as a single-phase line-to-line circuit, as is apparent from Fig. 4.

Inductive Loads

For inductive loads, zero-voltage turn-on is not generally required because the inductive current cannot increase instantaneously; therefore, the amount of RFI generated is usually negligible. Also, because of the lagging nature of the inductive current, the triacs cannot be pulse-fired at zero voltage. There are several ways in which the CA3059 may be interfaced to a triac for inductive-load applications. The most direct approach is to use the CA3059 in the dc mode, i.e., to provide a continuous dc output instead of pulses at points of zero-voltage crossing. This mode of operation is accomplished by connection of terminal 12 to terminal 7, as shown in Fig. 7. The output of the CA3059 should also be limited to approximately 5 milliamperes in the dc mode by the 750-ohm series resistor. Use of a triac such as the RCA 40692 is recommended for this application. Terminal 3 is connected to terminal 2 to limit the steady-state power

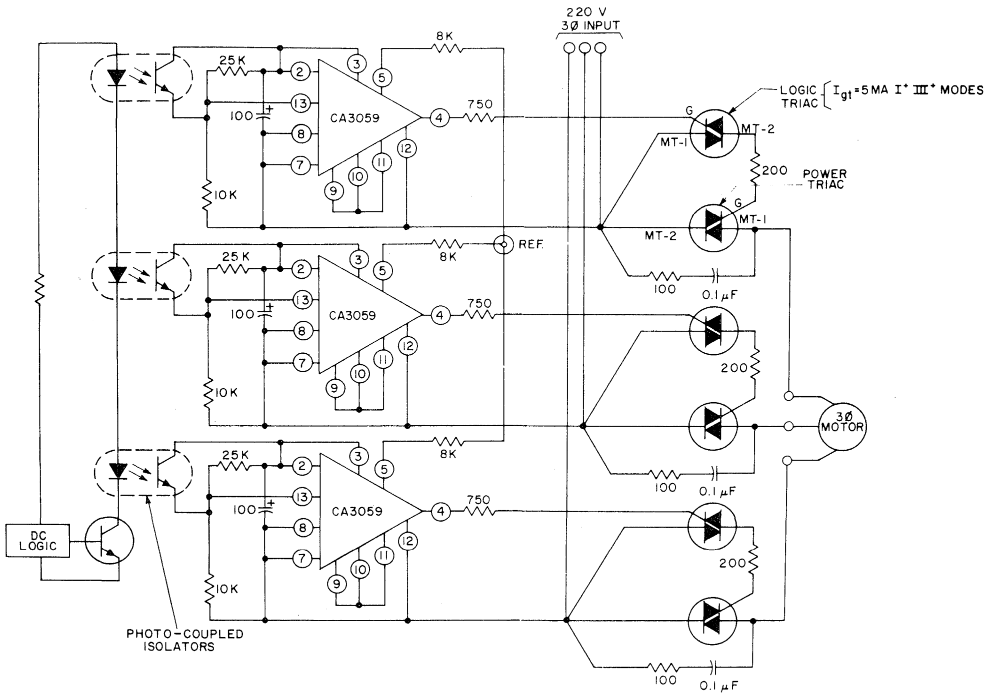


Fig. 7—Triac three-phase control circuit for an inductive load, i.e., three-phase motor.

dissipation within the CA3059. For most three-phase inductive load applications, the current-handling capability of the 40692 triac (2.5 amperes) is not sufficient. Therefore, the 40692 is used as a trigger triac to turn on any other currently available power triac that may be used. The trigger triac is used only to provide trigger pulses to the gate of the power triac (one pulse per half cycle); the power dissipation in this device, therefore, will be minimal.

Simplified circuits using pulse transformers and reed relays will also work quite satisfactorily in this type of application. The RC networks across the three power triacs are used for suppression of the commutating dv/dt when the circuit operates into inductive loads. (A detailed explanation of commutating dv/dt is provided in the basic discussion of thyristors in the *RCA Solid-State Power Circuits Designer's Handbook,* SP-52.)

RCA Solid State Division

Thyristors

Application Note AN-6076

A Thyristor Horizontal-Deflection System With Auxiliary Power Supplies For 110° Monochrome Receivers

by S. B. Alexander

This Note describes a thyristor horizontal-deflection system for 110° monochrome picture tubes. The system generates the horizontal-sweep and ultor voltages, the low voltages for the signal processing and audio section, and the power required to drive a transistorized vertical-sweep circuit. The picture-tube heater is driven from the system so that the need for an ac line-transformer is eliminated.

General Design Considerations

To minimize cost, the voltage regulator has been eliminated from the receiver.[1] The deflection system is designed to provide adequate scan and high voltage at low ac line voltage (108 volts) and is allowed to overscan at normal and high line voltages. The circuit is shown in Fig. 1 with a width-coil and a linearity control. The width-coil allows the scan to be controlled so that normal picture width can be achieved at high line voltages. A linearity control is required because the Q of the 110° monochrome yoke is not high enough to provide acceptable linearity without it.

The system is designed to operate from a B+ supply of +135 volts because this voltage can easily be obtained from half-wave rectification of the 60-Hz power. Because the vertical scan represents an unvarying load, its power is derived from the high-voltage transformer. Since no regulation of scan or high voltage is used, the dc supplied to the vertical-sweep system will track with the variations of horizontal scan resulting from line-voltage changes. The dc supplies for the signal processing and audio sections are derived from an auxiliary winding on the input reactor. These supplies can be regulated by a zener diode when necessary.

The picture-tube heater supply is taken from a second auxiliary winding on the input reactor. This arrangement provides picture turn-on at a speed between the relatively slow all-tube parallel-heater arrangement and the series-string "quick-on" feature in which the tube heaters are partially energized on a stand-by basis. Normally, with the picture-tube heater supplied from the input reactor, the picture appears in 10 to 15 seconds from turn-on. The "instant-on" feature is, of course, not attainable with this arrangement. If instant-on is considered a necessity, it can be obtained by the use of a 60-Hz filament transformer for the picture-tube heater. The ultor voltage is supplied by a single-stack rectifier rather than a multiplier to keep costs to a minimum.

Circuit Description

The thyristor horizontal-deflection system shown in Fig. 1 can best be described by examining its two basic parts, the commutator section and the trace section. The commutator section consists of commutating SCR 1 and diode D2, the input reactor L_{N1}, the commutating coil L_c, the commutating capacitor C_c, and the auxiliary capacitor C_A. The trace section consists of trace SCR 2 and diode D3, the yoke L_y, yoke capacitor C_y, and the high-voltage transformer T_1. The commutator section supplies the energy needed to overcome losses in the yoke L_Y and the high-voltage transformer T_1. Its action also provides the delay needed by trace SCR 2 to turn off (recover forward blocking capability) before the start of retrace.

The input-reactor and commutating coils are wound on a pair of ferrite E cores as shown in Fig. 2; this arrangement provides the isolation necessary without additional shielding. The input reactor and auxiliary windings are wound on the center leg of the E core; the commutating coil consists of two equal sections wound on the outside legs of the core. The flux of the commutating coil is cancelled in the center leg. This method of winding also reduces the stray flux in space to a minimum.

When the commutating SCR is turned on by a pulse from the horizontal oscillator, the anode is grounded and the input reactor L_{N1} is connected between B+ and ground. The input reactor then stores energy. This action continues until commutating SCR 1 and diode D2 are no longer conducting (at the end of the commutation period). When commutating SCR 1 is conducting, the charge previously stored on C_c and C_A sets up an oscillation with commutating inductor L_c. The peak current set up by the oscillation exceeds the yoke current during the first quarter-cycle as shown in Fig. 3. When this current reaches the magnitude of the yoke current which had been flowing through trace SCR2, yoke current

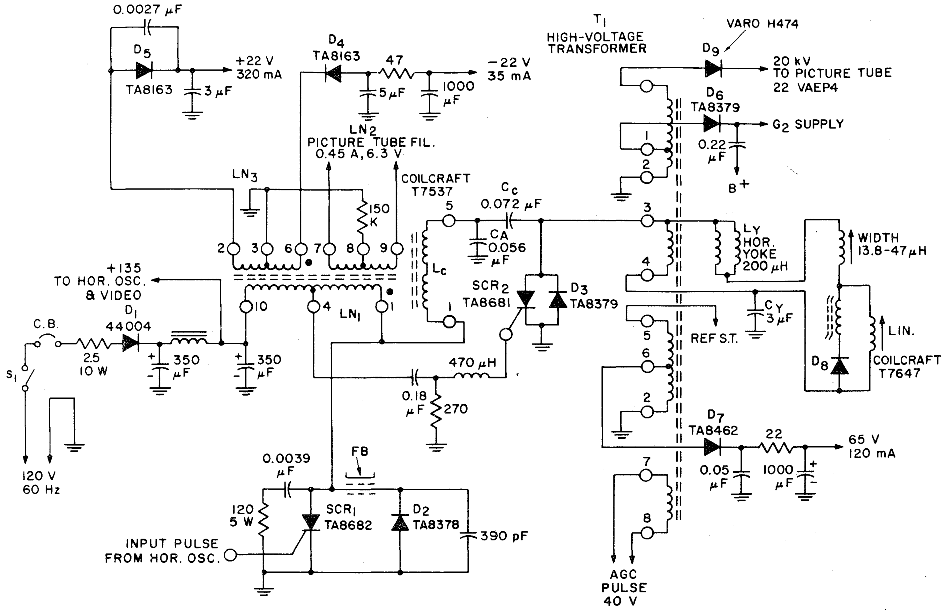


Fig. 1—Schematic diagram of the thyristor horizontal-deflection system for 110° receivers.

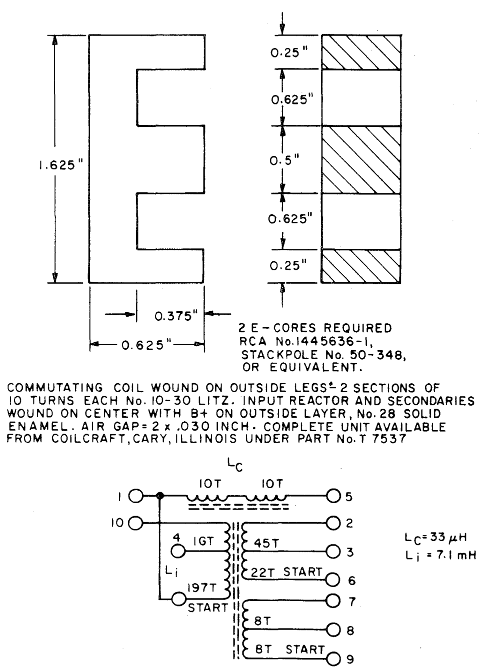


Fig. 2—Input-reactor and commutating-coil construction details.

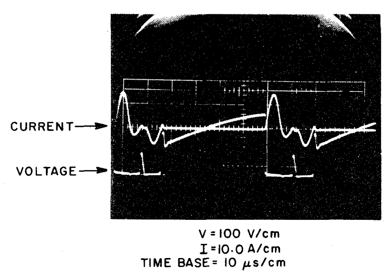


Fig. 3—Commutating-switch voltage and current.

flows into the commutating capacitor and allows the trace SCR to turn off (recover forward-blocking capability). Trace diode D3 carries the extra current at this time and allows the trace SCR to recover (in about 2.5 microseconds). This action supplies energy to the deflection system. When the current in the commutator section drops again to a level lower than the trace yoke current, the trace diode ceases to conduct and retrace begins, as shown in Fig. 4.

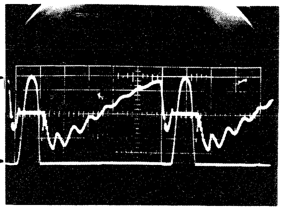


Fig.4—Trace-switch voltage and current.

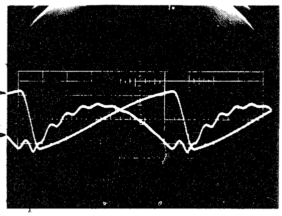


Fig.6—Yoke current and voltage across C_Y.

When the trace SCR and trace diode are open (during retrace), the energy stored in the yoke and commutating coil oscillates for one half-cycle in conjunction with commutating capacitor C_C and auxiliary capacitor C_A. When the voltage on commutating capacitor C_C drops below ground (becomes negative) the trace diode becomes forward-biased and retrace ends. Current in the commutating coil continues to flow in an oscillatory manner until the voltage on commutating diode D2 becomes positive. The commutator section then ceases to operate until it is turned on again by a pulse from the horizontal oscillator, as shown in Fig. 5.

When commutating-components SCR 1 and Diode D2 are not conducting, commutating capacitor C_C and auxiliary capacitor C_A are recharged through inductor L_C, and the energy the capacitors lost during the commutating period is replenished. The yoke inductance then continues to drive current through trace diode D3. This current charges yoke-capacitor C_Y until about the middle of the trace period, as shown in Fig. 6. At this mid-point of trace, yoke current is transferred from trace diode D3 to trace SCR 2. Trace SCR 2 is made ready to conduct prior to this period by the application of a positive signal to the gate. The yoke capacitor then continues to drive the yoke current through the trace SCR until current in the commutator section again equals yoke current near the end of the trace interval.

To minimize the change of picture width with beam current, the inductance chosen for the commutating inductor

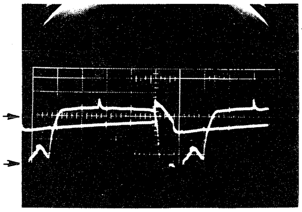


Fig.5—Commutating— and trace-gate drives.

is small enough so that the commutating diode actually opens during retrace. This small inductance causes the yoke current to change with ultor current in the amount required to keep the scan nearly constant. The yoke inductance of 200 microhenries and the yoke capacitance of 3 microfarads provide the correct amount of "S" shaping of horizontal scan. Retrace time by actual yoke-current measurement is 9 microseconds, approximately 1 microsecond less than the base width of the pulse measured at the trace SCR.

Auxiliary Power Supplies

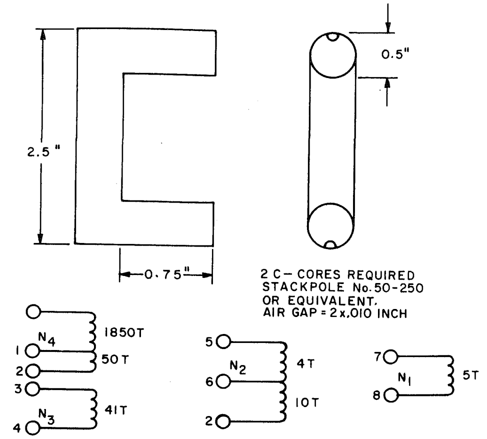
As mentioned previously, the power for the vertical scan is taken from the high-voltage transformer. The high-voltage transformer also provides the G2 voltage. The construction of the high-voltage transformer is shown in Fig. 7. The low-voltage supplies of +22 and −22 volts are derived from an auxiliary winding, L_{N3}, on the input reactor. The receiver used in the preliminary testing of this circuit required considerably more current on the +22−volt supply than on the −22−volt supply so that the winding, as shown in Fig. 1, is not center-tapped. The specific requirements of the receiver dictate just what this winding should deliver and where it should be tapped. The winding is phased so that the rectifiers conduct when the commutating SCR is conducting. This phasing is used for two reasons: first, the waveform developed at the commutator has a greater peak at this time, and, second, the rectifier load is removed when the oscillatory action is recharging the commutating capacitors. The number of turns is determined empirically because of the complex waveform involved.

The picture-tube heater voltage is taken from an additional winding balanced to ground to prevent harmonics of the 15-kHz sweep frequency from modulating the beam current through the heater-cathode capacitance. Since the picture-tube heater presents a constant load, this power could be derived from the high-voltage transformer; however, the voltage at the input reactor has a much smaller peak-to-rms value so that the harmonic content is less.

The performance of the SCR deflection system is described in Table I. The data were taken with the width-coil set for full scan at low line voltage. The width-coil, adjustable from 13.8 to 47 microhenries, allows the scan at high line voltage to be brought down to normal. A summary of the characteristics of devices used in the monochrome horizontal-deflection circuit is given in Table II.

Note

1. A voltage regulator similar to that shown in RCA Application Notes AN-3780, "A New Horizontal-Deflection System Using RCA 40640 and 40641 Silicon Controlled Rectifiers," or AN-4375, "A Thyristor Horizontal-Deflection, High-Voltage, and Power-Supply System for RCA 110° Color Picture Tubes," may be used if better width regulation with line-voltage changes is desired.



N_1 – 8 µH – 5T No. 22 SOLID ENAMEL

N_2 – 65 µH – 14T No. 22 SOLID ENAMEL TAPPED AS SHOWN

N_3 – 535 µH – 41T No. 24 SOLID ENAMEL

N_4 – 1.14H – 1900T No. 34 SOLID ENAMEL TAPPED AS SHOWN

LEAKAGE INDUCTANCE – N_3 WITH N_4 SHORTED = 40 µH

Fig. 7—Construction details of the high-voltage transformer.

TABLE I
SYSTEM PERFORMANCE DATA

PARAMETER	VALUE									UNITS
SUPPLY VOLTAGE	108			120			132			VOLTS AC
Beam Current	0	250	500	0	250	500	0	250	500	µA
B+ Voltage	124	123	122	140	138	135	154	152	150	volts
B+ Current	365	400	430	405	440	470	450	478	510	milliamperes
Picture Size	Full Width	1/8	1/4	1–1/8	1–1/4	1–5/8	2–3/8	2–1/2	2–5/8	total inches overscan on 21-inch tube
$I_{Y(PP)}$	8.9	8.6	8.4	9.0	8.9	8.8	10.8	10.8	10.4	amperes
High Voltage	19.6	18.2	17.2	21.8	20.5	19.5	24.3	22.9	21.7	kilovolts
Picture Tube Heater	5.96	6.03	6.07	6.65	6.70	6.75	7.6	7.7	7.8	volts
Low dc +	+21	+20.8	+20.6	+23.5	+23.1	+23.0	+26.0	+26.0	+25.5	volts
Low dc –	–17	–17	–17	–18.5	–18.5	–18.5	–20.0	–20.0	–20.0	volts
DC –Vertical Supply	+65	+62	+60	+73	+70	+68	+82	+79	+76	volts

TABLE II
SUMMARY OF CHARACTERISTICS OF DEVICES USED IN THE HORIZONTAL-DEFLECTION CIRCUIT

SCR'S

DEVICE	$I_{T(RMS)}$	V_{DROM}	V_{RROM}	V_{DSOM}	t_q (µs)	Case
TA8681 Trace SCR	5	450	15	500	2.5	TO–66
TA8682 Commutating SCR	5	350	15	400	4.5	TO–66

RECTIFIERS

DEVICE	$I_{F(RMS)}$	V_{RRM}	V_{RSM}	t_{rr} (µs)	Case
TA8379 Trace Rectifier & G-2 Rectifier	1.0	650	700	0.3	DO–15
TA8378 Commutating Rectifier	1.0	450	500	0.3	DO–15
TA8462 65-V Rectifier	1.0	400	500	0.5	DO–15
TA8163 22-V Rectifier	1.8	150	200	0.5	DO–15
44004 B+ Rectifier	1.0(Ave)	400	525	–	DO–15
TA8164 Linearity Rectifier	2.8(Ave)	150	150	1.5	DO–1

Application of the RCA-CA3058 and RCA-CA3059 Zero-Voltage Switches in Thyristor Circuits

by George J. Granieri

The RCA-CA3059 zero-voltage switch is a monolithic integrated circuit used primarily as a trigger circuit for the control of thyristors. This multistage circuit employs a diode limiter, a threshold detector, a differential amplifier, and a Darlington output driver to provide the basic switching action. The dc supply voltage for these stages is supplied by an internal zener-diode-regulated power supply that has sufficient current capability to drive external circuit elements, such as transistors and other integrated circuits. This built-in power supply provides unique solutions to many application problems. An important feature of the CA3059 is that the trigger pulses developed by this circuit can be applied directly to the gate of a silicon controlled rectifier (SCR) or a triac. A built-in fail-safe circuit inhibits the application of these pulses to the thyristor gate circuit in the event that the external sensor for the integrated-circuit switch should be inadvertently opened or shorted.

The RCA CA3058 is similar to the CA3059 but utilizes a dual-in-line ceramic package. For additional information on this device, see RCA data bulletin File No. 490.

The CA3059 is particularly suited for use in thyristor temperature-control applications. The integrated circuit may be employed as either an on-off type of controller or a proportional controller, depending upon the degree of temperature regulation required. The availability of numerous terminal connections to internal circuit points greatly increases the flexibility of the CA3059 and permits the circuit designer to exercise his creativity to employ the integrated switch in unique ways. This Note describes the operation of the CA3059 integrated-circuit switch and discusses its operation in thyristor power-switching and control circuits.

CIRCUIT OPERATION

Fig. 1 shows a functional block diagram of the CA3059 integrated-circuit zero-voltage switch. Any triac that is driven directly from the output terminal of this circuit should be characterized for operation in the I(+) or III(+) triggering modes, i.e., with positive gate current (current flows into the gate for both polarities of the applied ac voltage).

*See chart

AC Input Voltage (Volts) 50/60 or 400 Hz	Series Resistor R_S (kΩ)	Power Rating of R_S (Watts)
24	2	0.5
120	10	2
208/230	20	4
277	25	5

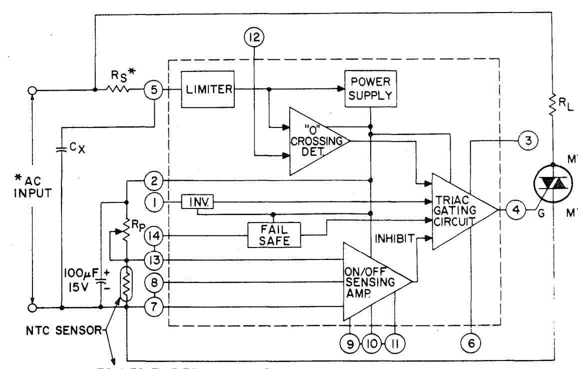


Fig. 1 - Functional block diagram of the integrated-circuit zero-voltage switch.

The limiter stage of the CA3059 clips the incoming ac line voltage to approximately plus and minus 8 volts. This signal is then applied to the zero-voltage-crossing detector, which generates an output pulse during each passage of the line voltage through zero. The limiter output is also applied to a rectifying diode and an external capacitor that comprise the dc power supply. The power supply provides approximately 6 volts as the V_{CC} supply to the other stages of the CA3059. The on/off sensing amplifier is basically a differential comparator. The triac gating circuit contains a driver for direct triac triggering. The gating circuit is enabled when all the inputs are at a high voltage, i.e., the line voltage must be approximately zero volts, the sensing-amplifier output must be "high," the external voltage to terminal 1 must be a logical "1," and the output of the fail-safe circuit must be "high."

Fig. 2 shows the circuit diagram of the CA3059. The zero-voltage threshold detector consists of diodes D_3, D_4, D_5, and D_6, and transistor Q_1. The differential amplifier consists of transistor pairs Q_2-Q_4 and Q_3-Q_5. Transistors Q_1, Q_6, Q_7, Q_8, and Q_9 comprise the triac gating circuit and driver stage. Diode D_{12}, zener diode D_{15}, and transistor Q_{10} constitute the fail-safe circuit. The power supply consists of diodes D_7 and D_{13}, and an external resistor and capacitor connected to terminals 5 and 2, respectively, and to ground through pin 7. If the transistor pair Q_2-Q_4 and transistor Q_1 are turned off, an output appears at terminal 4. Transistor Q_1 is in the OFF state if the incoming line voltage is less than approximately the voltage drops across three silicon diodes (2.1 volts) for either the positive or negative excursion of the line voltage. Transistor pair Q_2-Q_4 is OFF if the voltage across the sensor, connected from terminals 13 to 7, exceeds the reference voltage from 9 to 7. If either of these conditions is not satisfied, pulses are not supplied to terminal 4. Fail-safe operation requires that terminal 13 be connected to 14. The addition of hysteresis and elimination of half-cycling can be obtained by a resistive voltage divider connected from 13 to 8 and from 8 to 7.

Fig. 3 shows the position and width of the pulses supplied to the gate of a thyristor with respect to the incoming ac line voltage. The CA3059 can supply sufficient gate voltage and current to trigger most RCA thyristors at ambient temperatures of 25°C. *However, under worst-case conditions (i.e., at ambient-temperature extremes and maximum triggering requirements), selection of the higher-current thyristors may be necessary for particular applications.* RCA bulletin File No. 406 lists Triacs suitable for use with the CA3058 or CA3059. For example, the RCA-2N5444 40-ampere triac has a maximum gate trigger voltage $V_{GT}(max)$ of 2.5 volts and a maximum gate trigger current $I_{GT}(max)$ of 80 milliamperes in the III(+) quadrant

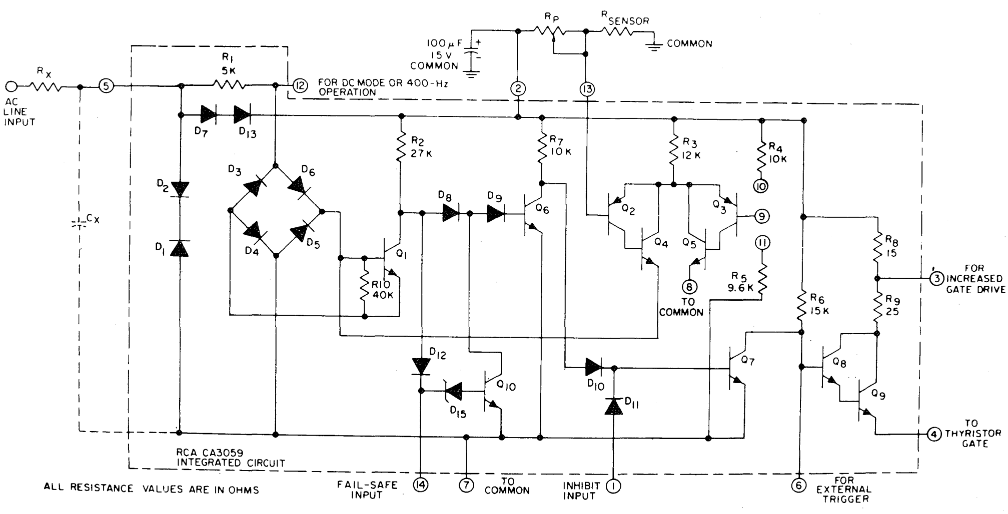


Fig.2 - Circuit diagram for the CA3059 zero-voltage switch.

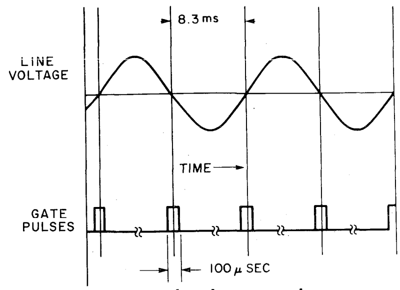


Fig.3 - Timing relationship between the output pulses of of the CA3059 and the ac line voltage.

at 25°C. Because the CA3059 cannot guarantee a drive of 80 milliamperes for a V_{GT} of 2.5 volts, triac selection will be required.

EFFECT OF CA3059 ON THYRISTOR LOAD CHARACTERISTICS

The CA3059 is designed primarily to gate a thyristor that switches a resistive load. Because the output pulse supplied by the CA3059 is of short duration, the latching current* of the triac becomes a significant factor in determining whether other types of loads can be switched. (The latching-current value determines whether the triac will remain in conduction after the gate pulse is removed.) Provisions are included in the CA3059 to accommodate inductive loads and low-power loads. For example, for loads that are less than approximately 4 amperes rms or that are slightly inductive, it is possible to retard the output pulse with respect to the zero-voltage crossing by insertion of the capacitor C_x from terminal 5 to terminal 7 as shown in Fig. 1. The insertion of capacitor C_x permits switching of triac loads that have a slight inductive component and that are greater than approximately 200 watts (for operation from an ac line voltage of 120 volts rms). However, for loads less than 200 watts (for example, 70 watts), it is recommended that the user employ the RCA-40526 sensitive-gate triac with the CA3059 because of the low latching-current requirement of this triac.

For loads that have a low power factor, such as a solenoid valve, the user may operate the CA3059 in the dc mode. In this mode, terminal 12 is connected to terminal 7, and the zero-crossing detector is inhibited. Whether a "high" or "low" voltage is produced at terminal 4 is then dependent only upon the state of the differential comparator within the CA3059 integrated circuit, and not upon the zero crossing of the incoming line voltage. Of course, in this mode of operation, the CA3059 no longer operates as a zero-voltage switch. However, for many applications that involve the switching of low-current inductive loads, the amount of RFI generated can frequently be tolerated.

For switching of high-current inductive loads, which must be turned on at zero line current, the triggering technique employed in the dual-output over-under temperature controller and the transient-free switch controller described later in this Note is recommended.

* The latching current is the minimum current required to sustain conduction immediately after the thyristor is switched from the OFF to the ON state and the gate signal is removed.

FAIL-SAFE FEATURE

As shown in Figs. 1 and 2, when terminal 13 is connected to terminal 14, the fail-safe circuit of the CA3059 is operable. If the sensor should then be accidentally opened or shorted, power is removed from the load (i.e., the triac is turned OFF). The internal fail-safe circuit functions properly, however, only when the ratio of the sensor impedance at 25°C, if a thermistor is the sensor, to the impedance of the potentiometer R_p is less than 4 to 1. It is readily apparent that, if the potentiometer is adjusted for 1000 ohms and the sensor is 100,000 ohms, the zener diode D_{15} (shown in Fig. 2) would conduct because virtually all the dc power-supply voltage (from terminal 2 to terminal 7) would appear across the sensor. The CA3059 would then detect this condition as an open sensor.

For ratios greater than 4 to 1, for example 100 to 1, the circuit shown in Fig. 4 may be employed to provide fail-safe operation. In this circuit, transistor Q_1 and diode D_1 are components external to the CA3059. Transistor Q_1 detects the sensor current which maintains this transistor in saturation so that terminal 1 is effectively shorted to terminal 7 through the collector-to-emitter junction of the transistor. Transistor Q_1 provides sufficient current gain to permit operation with a sensor impedance greater than 1 megohm. If the sensor becomes open-circuited, transistor Q_1 turns OFF, and current then flows into terminal 1, the inhibit terminal of the CA3059, and results in the removal of power to the load. For the shorted-sensor condition, the external diode D_1 conducts and causes triac Y_1 to turn OFF. Diode D_2 compensates for variations in the base-to-emitter voltage of transistor Q_1 with temperature. Terminals 13 and 14 on the CA3059 should not be connected when the external fail-safe circuit shown in this illustration is employed.

HALF-CYCLING AND HYSTERESIS CHARACTERISTICS

The method by which the CA3059 senses the zero crossing of the ac power results in a half-cycling phenomenon at the control

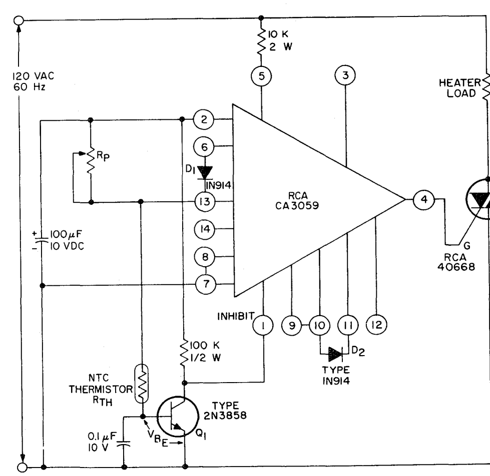


Fig.4 - CA3059 on-off controller that uses an external fail-safe circuit.

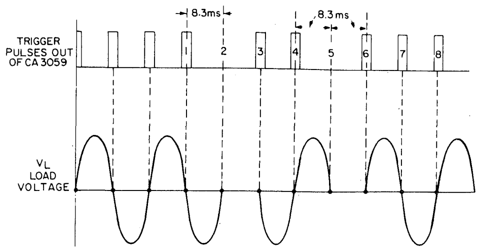
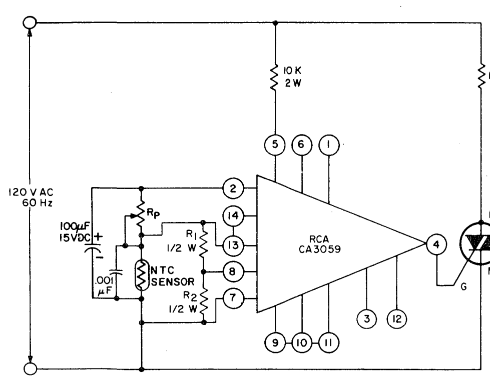


Fig.5 - Half-cycling phenomenon in the CA3059.

point. Fig. 5 illustrates this phenomenon. The CA3059 senses the zero-voltage crossing every half-cycle and an output, for example pulse No. 4, is produced to indicate the zero crossing. During the remaining 8.3 milliseconds, however, the differential amplifier in the CA3059 may change state and inhibit any further output pulses. The uncertainity region of the differential amplifier, therefore, prevents pulse No. 5 from triggering the triac during the negative excursion of the ac line voltage.

Several solutions exist for elimination of the half-cycling phenomenon. If the user can tolerate some hysteresis in the control, then positive feedback can be added around the differential amplifier. Fig. 6 illustrates this technique. The tabular data in the figure lists the recommended values of R_1 and R_2 for different sensor impedances at the control point.

If a significant amount (greater than ±10%) of controlled hysteresis is required, then the circuit shown in Fig. 7 may be employed. In this configuration, external transistor Q_1 provides a means for addition of positive feedback to the CA3059. It should be noted that the signal developed at the collector to Q_1 could perhaps be used to provide an auxiliary time-delay function.



THERMISTOR→ NTC	R1	R2
5 K	12 K	12 K
12 K	68 K	12 K
100 K	200 K	18 K

Fig.6 - CA3059 on-off controller with hysteresis.

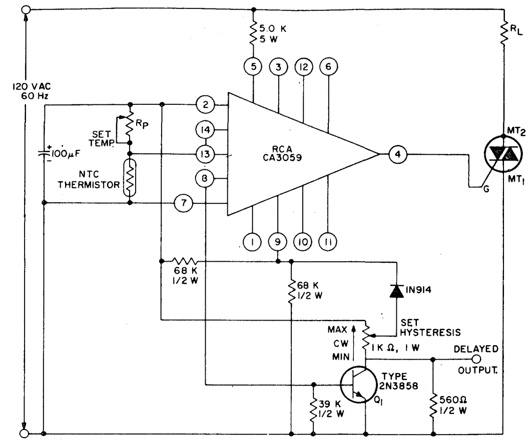


Fig.7 - CA3059 on-off controller with controlled hysteresis.

For applications which require complete elimination of half-cycling without the addition of hysteresis, the *integral-cycle* temperature controller described in a later section of this Note, which senses the zero-voltage crossing only once during the ac power cycle, can be used.

TEMPERATURE CONTROLLERS

Fig. 8 shows a triac used in an on-off temperature-controller configuration. The triac is turned on at zero voltage whenever the

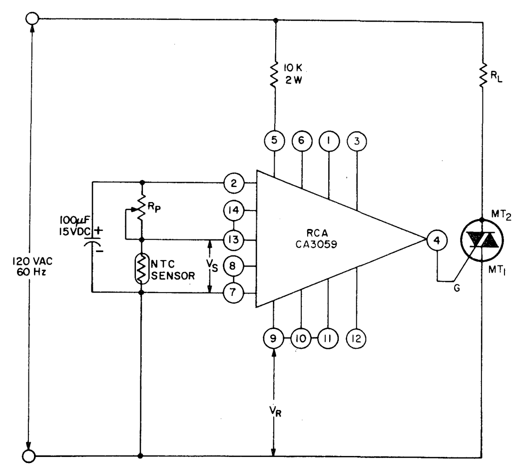
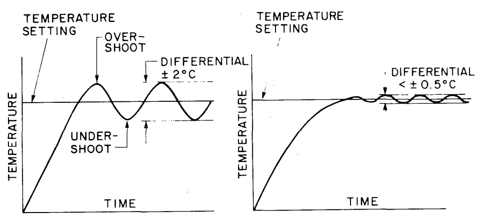


Fig.8 - CA3059 on-off temperature controller.

voltage V_s exceeds the reference voltage V_r. The transfer characteristic of this system, shown in Fig. 9(a), indicates significant thermal overshoots and undershoots, a well-known characteristic of such a system. The differential or hysteresis of this system, however, can be further increased, if desired, by the addition of positive feedback.

For precise temperature-control applications, the proportional-control technique with synchronous switching is employed. The transfer curve for this type of controller is shown in Fig. 9(b). In this case, the duty cycle of the power supplied to the load is varied with the demand for heat required and the thermal time constant (inertia) of the system. For example, when the temperature setting is increased in an "on-off" type of controller, full power (100 per cent duty cycle) is supplied to the system. This effect results in significant temperature excursions *because there is no anticipatory circuit* to reduce the power gradually before the actual set temperature is achieved. However, in a proportional control technique, less power is supplied to the load (reduced duty cycle) as the error signal is reduced (sensed temperature approaches the set temperature).



(a) (b)

Fig.9 - Transfer characteristics of (a) on-off and (b) proportional control systems.

Before such a system is implemented, a time base is chosen so that the ON-time of the triac is varied within this time base. The ratio of the ON-to-OFF time of the triac within this time interval depends on the thermal time constant of the system and the selected temperature setting. Fig. 10 illustrates the principle of proportional control. For this operation, power is supplied to the load until the ramp voltage reaches a value greater than the dc control signal supplied to the opposite side of the differential amplifier. The triac then remains OFF for the remainder of the time-base period. As a result, power is "proportioned" to the load in a direct relation to the heat demanded by the system.

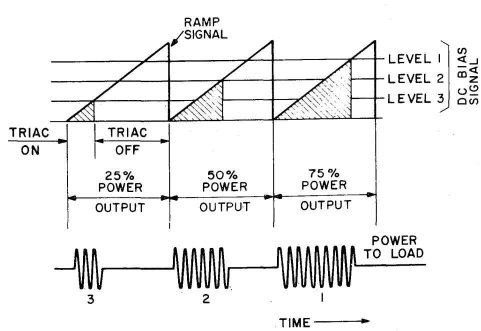


Fig.10 - Principles of proportional control.

For this application, a simple ramp generator can be realized with a minimum number of active and passive components. It is noted that a ramp having good linearity is not required for proportional operation because of the nonlinearity of the thermal system and the closed-loop type of control. In the circuit shown in Fig. 11, ramp voltage is generated when the capacitor C_1 charges through resistors R_0 and R_1. The time base of the ramp is determined by resistors R_2 and R_3, capacitor C_2, and the breakover voltage of the 1N5411 diac. When the voltage across C_2 reaches approximately 32 volts, the diac switches and turns on the 2N3241A transistor. The capacitor C_1 then discharges through the collector-to-emitter junction of the transistor. This discharge time is the retrace or flyback time of the ramp. The circuit shown can generate ramp times ranging from 0.3 to 2.0 seconds through

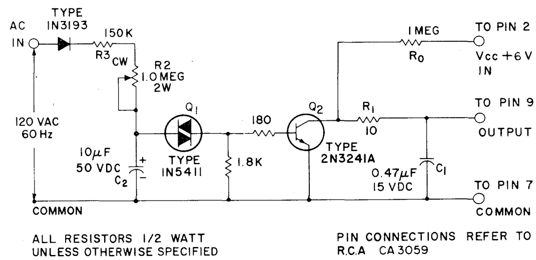


Fig.11 - Ramp generator.

adjustment of R_2. For precise temperature regulation, the time base of the ramp should be shorter than the thermal time constant of the system, but long with the respect to the period of the 60-Hz line voltage. Fig. 12 shows a triac connected for the proportional mode.

Fig. 13 shows a dual-output temperature controller that drives two triacs. When the voltage V_s developed across the temperature-sensing network exceeds the reference voltage V_{R1}, motor M_1

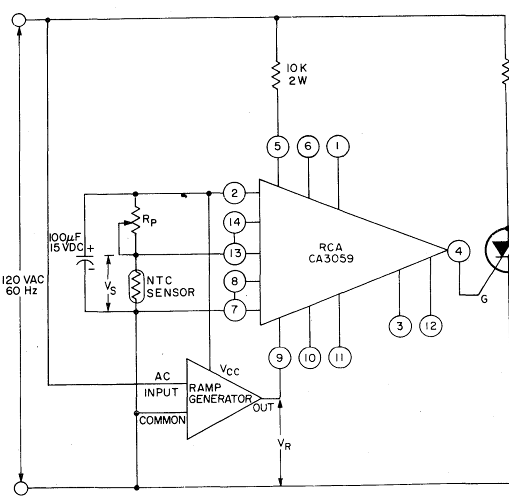


Fig.12 - CA3059 proportional temperature controller.

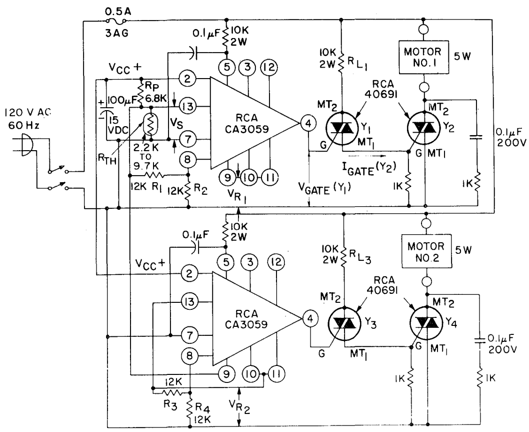


Fig.13 - Dual-output, over-under temperature controller using two CA3059 integrated circuits.

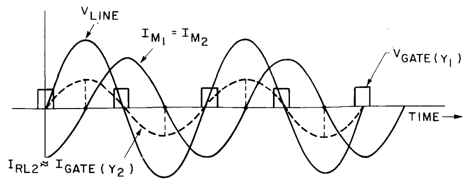


Fig.14 - Voltage and current waveforms for the dual-output temperature controller.

turns on. When the voltage across the network drops below the reference voltage V_{R2}, M_2 turns on. Because the motors are inductive, the currents I_{M1} and I_{M2} lag the incoming line voltage. The motors, however, are switched by the triacs at zero current, as shown in Fig. 14.

The problem of driving inductive loads such as these motors by the narrow pulses generated by the CA3059 circuit is solved by use of the sensitive-gate RCA-40526 triac. The high sensitivity of this device (3 milliamperes maximum) and low latching current (approximately 9 milliamperes) permit synchronous operation of the temperature-controller circuit. In Fig. 13, it is apparent that, though the gate pulse V_g of triac Y_1 has elapsed, triac Y_2 is switched on by the current through R_{L1}. The low latching current of the RCA-40526 triac results in dissipation of only 2 watts in R_{L1}, as opposed to 10 to 20 watts when devices that have high latching currents are used.

Electric-Heat Application

For electric-heating applications, the RCA-2N5444 40-ampere triac and the CA3059 circuit constitute an optimum pair. Such a combination provides synchronous switching and effectively replaces the heavy-duty contactors which easily degrade as a result of pitting and wearout from the switching transients. The salient features of the 2N5444 40-ampere triac are as follows:

(1) 300-ampere single-surge capability (for operation at 60-Hz),

(2) a typical gate sensitivity of 20 milliamperes in the I(+) and III(-) modes,

(3) low ON-state voltage of 1.5 volts maximum at 40 amperes, and

(4) available V_{DROM} equal to 600 volts.

Fig. 15 shows the circuit diagram of a synchronous-switching heat-staging controller that is used for electric heating systems. Loads

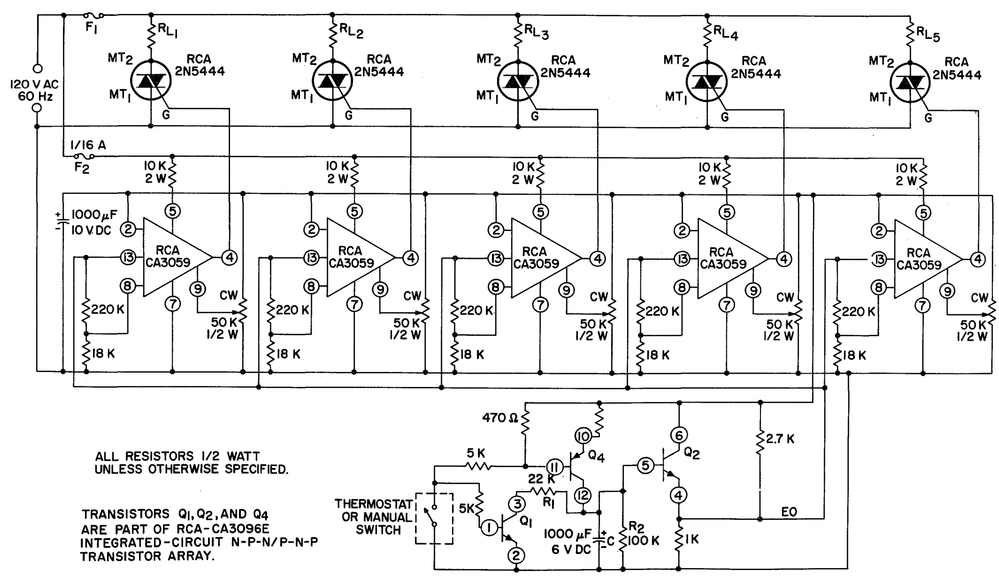


Fig.15 - Synchronous-switching heat-staging controller using a series of CA3059 integrated circuits.

as heavy as 5 kilowatts are switched sequentially at zero voltage to eliminate RFI and prevent a dip in line voltage that would occur if the full 25 kilowatts were to be switched simultaneously.

Transistor Q_1 is used as a constant-current source to charge capacitor C in a linear manner. Transistor Q_2 acts as a buffer stage. When the thermostat is closed, a ramp voltage is provided at output E_o. At approximately 3-second intervals, each 5-kilowatt heating element is switched onto the power system by its respective triac. When there is no further demand for heat, the thermostat opens, and capacitor C discharges through R_1 and R_2 to cause each triac to turn OFF in the reverse heating sequence. It should be noted that some half-cycling occurs before the heating element is switched fully ON. This condition can be attributed to the inherent dissymmetry of the CA3059 and is further aggravated by the slow-rising ramp voltage applied to one of the inputs. The timing diagram in Fig. 16 shows the turn-on and turn-off sequence of the heating system being controlled.

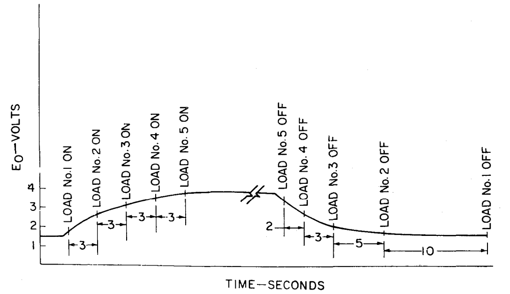


Fig.16 - Ramp-voltage waveform for the heat-staging controller.

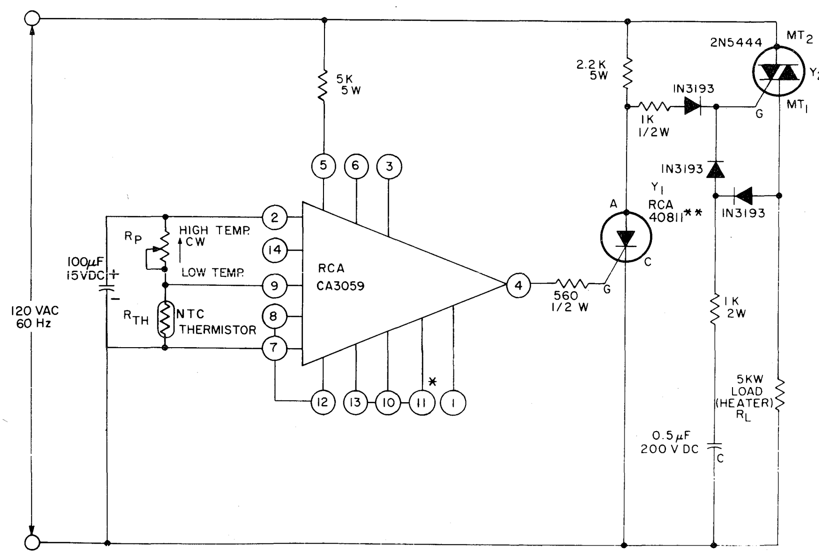
Seemingly, the basic method shown in Fig. 15 could be modified to provide proportional control in which the number of heating elements switched into the system, under any given thermal load, would be a function of the BTU's required by the system or the temperature differential between an indoor and outdoor sensor within the total system environment. That is, the closing of the thermostat would not switch in all the heating elements within a short time interval, which inevitably results in undesired temperature excursions, but would switch in only the number of heating elements required to satisfy the actual heat load.

Integral-Cycle Temperature Controller (No half-cycling)

If a temperature controller which is completely devoid of half-cycling and hysteresis is required, then the circuit shown in Fig. 17 may be used. This type of circuit is essential for applications in which half-cycling and the resultant dc component could cause overheating of a power transformer on the utility lines.

In the circuit shown in Fig. 17, the sensor is connected between terminals 7 and 9 of the CA3059. This arrangement is required because of the phase reversal introduced by SCR Y_1. With this configuration, terminal 12 is connected to terminal 7 for operation of the CA3059 in the dc mode (however, the load is switched at zero voltage). Because the position of the sensor has been changed for this configuration, the internal fail-safe circuit cannot be used (terminals 13 and 14 are not connected).

In the integral-cycle controller, when the temperature being controlled is low, the resistance of the thermistor is high and an



* FOR PROPORTIONAL OPERATION OPEN TERMINALS 10, 11, AND 13, AND CONNECT POSITIVE RAMP VOLTAGE TO TERMINAL 13

** SELECTED FOR I_{GT}=6 mA MAXIMUM.

Fig.17 - CA3059 integral-cycle temperature controller in which half-cycling effect is eliminated.

output signal at terminal 4 of zero volts is obtained. The SCR (Y_1), therefore, is turned off. The triac (Y_2) is then triggered directly from the line on positive cycles of the ac voltage. When Y_2 is triggered and supplies power to the load R_L, capacitor C is charged to the peak of the input voltage. When the ac line swings negative, capacitor C discharges through the triac gate to trigger the triac on the negative half-cycle. The diode-resistor-capacitor "slaving network" triggers the triac on negative half-cycles of the ac input voltage after it is triggered on the positive half-cycle to provide only *integral cycles* of ac power to the load.

When the temperature being controlled reaches the desired value, as determined by the thermistor, then a positive voltage level appears at terminal 4 of the CA3059. The SCR then starts to conduct at the beginning of the positive input cycle to shunt the trigger current away from the gate of the triac. The triac is then turned OFF. The cycle repeats when the SCR is again turned OFF by the CA3059.

The circuit shown in Fig. 18 is similar to the configuration in Fig. 17 except that the fail-safe circuit incorporated in the CA3059 can be used. In this new circuit, the NTC sensor is connected between terminals 7 and 13, and transistor Q_o inverts the signal output at terminal 4 to nullify the phase reversal introduced by the SCR (Y_1). The internal power supply of the CA3059 supplies bias current to transistor Q_o.

Of course, the circuit shown in Fig. 18 can readily be converted to a *true proportional integral-cycle temperature controller* simply by connection of a positive-going ramp voltage to terminal 9 (with terminals 10 and 11 open), as previously discussed in this Note.

SENSOR ISOLATION

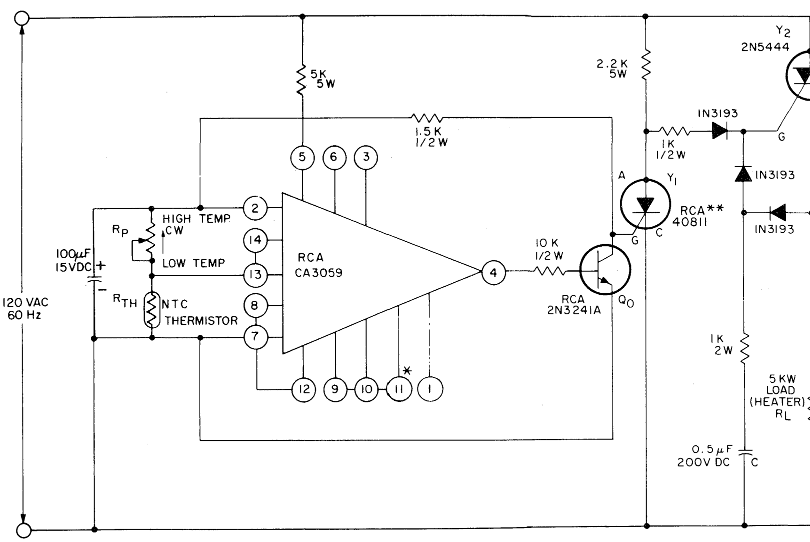
For some applications, electrical isolation of the sensor from the incoming ac power lines may be desired. Fig. 19 shows such a configuration. The pulse transformer T_1 isolates the sensor from main terminal No. 1 of the triac Y_1, and transformer T_2 isolates the CA3059 from the power lines. Capacitor C_1 shifts the phase of the output pulse at terminal 4 in order to retard the gate pulse delivered to triac Y_1 to compensate for the small phase shift introduced by transformer T_1.

DIFFERENTIAL COMPARATOR FOR INDUSTRIAL USE

Differential comparators have found widespread use as limit detectors which compare two analog input signals and provide a go/no-go, logic "one" or logic "zero" output, depending upon the relative magnitudes of these signals. Because the signals are often at very low voltage levels and very accurate discrimination is normally required between them, differential comparators in many cases employ differential amplifiers as a basic building block. However, in many industrial control applications, a high-performance differential comparator is not required. That is, high resolution, fast switching speed, and similar features are not essential. The CA3059 is ideally suited for use in such applications. Connection of terminal 12 to terminal 7 inhibits the zero-voltage threshold detector of the CA3059, and the circuit becomes a differential comparator.

Fig. 20 shows the circuit arrangement for use of the CA3059 as a differential comparator. In this application, no external dc supply is required, as is the case with most commercially available integrated-circuit comparators; of course, the output-current capability of the CA3059 is reduced because the circuit is operating in the dc mode. The 1000-ohm resistor R_G, connected between terminal 4 and the gate of the triac, limits the output current to approximately 3 milliamperes.

When the CA3059 is connected in the dc mode, the drive current for terminal 4 can be determined from a curve of the



* FOR PROPORTIONAL OPERATION OPEN TERMINALS 9,10 AND 11 AND CONNECT POSTIVE RAMP VOLTAGE TO TERMINAL 9
** SELECTED FOR I_{GT}=6 mA MAXIMUM

Fig.18 - CA3059 integral-cycle temperature controller that features fail-safe operation and no half-cycling effect.

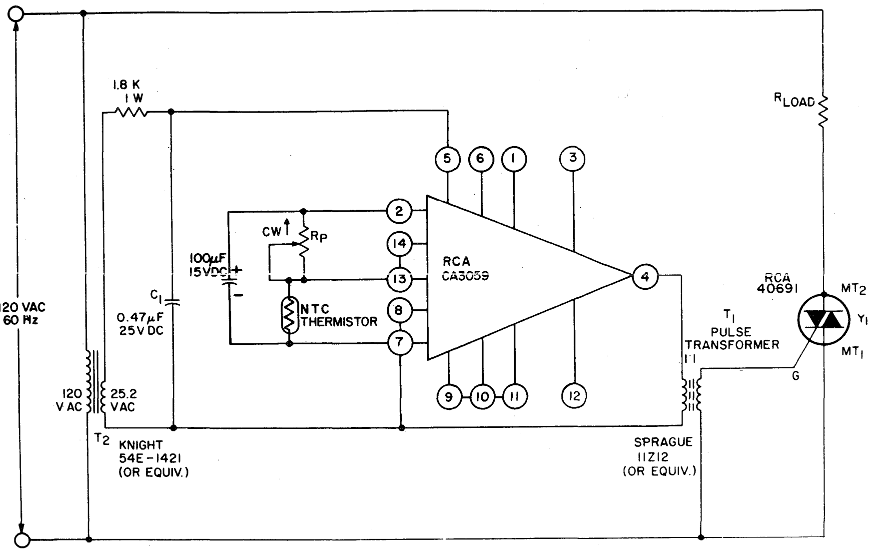


Fig.19 - CA3059 on-off controller with an isolated sensor.

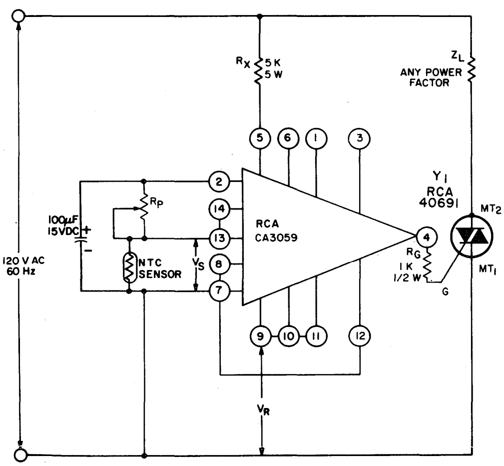


Fig.20 - Differential comparator using the CA3059 integrated circuit.

external load current as a function of dc voltage from terminals 2 and 7. This curve is shown in the technical bulletin for the CA3059 integrated circuit. Of course, if additional output current is required, an external dc supply may be connected between terminals 2 and 7, and resistor R_X (shown in Fig. 20)may be removed.

The chart below compares some of the operating characteristics of the CA3059, when used as a comparator, with a typical high-performance commercially available integrated-circuit differential comparator.

PARAMETERS	CA3059 (typical values)	Typical Integrated-Circuit Comparator (710)
1. Sensitivity	30 mV	2mV
2. Switching speed (rise time)	> 20 µs	90 ns
3. Output drive capability	*4.5V at ≤4mA	3.2V at ≤5.0mA

*Refer to Figure 20; R_X equals 5000 ohms.

POWER ONE-SHOT CONTROL

Fig. 21 shows a circuit which triggers a triac for one complete half-cycle of either the positive or negative alternation of the ac line

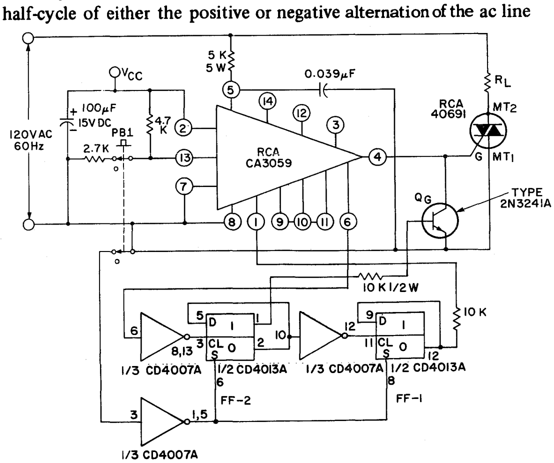


Fig.21 - Block diagram of a power one-shot control using the CA3059.

voltage. In this circuit, triggering is initiated by the push button PB-1, which produces triggering of the triac near zero voltage even though the button is randomly depressed during the ac cycle. The triac does not trigger again until the button is released and again depressed. This type of logic is required for the solenoid drive of electrically operated stapling guns, impulse hammers, and the like, where load-current flow is required for only one complete half-cycle. Such logic can also be adapted to keyboard consoles in which contact bounce produces transmission of erroneous information.

generated, but the state of Q_G determines the requirement for their supply to the triac gate. The first pulse generated serves as a "framing pulse" and does not trigger the triac but toggles FF-1. Transistor Q_G is then turned off. The second pulse triggers the triac and FF-1 which, in turn, toggles the second flip-flop FF-2. The output of FF-2 turns on transistor Q_7, as shown in Fig. 22, which inhibits all further output pulses. When the pushbutton is released, the circuit resets itself until the process is repeated with the button. Fig. 23 shows the timing diagram for the described operating sequence.

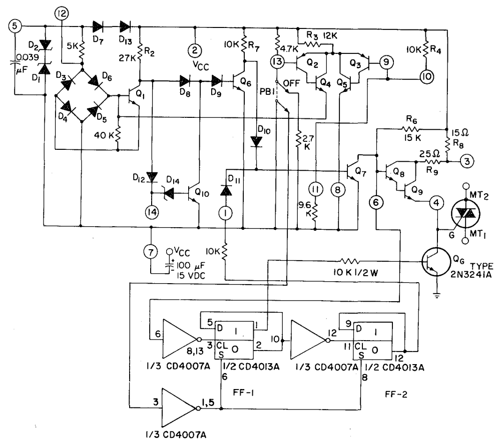


Fig.22 - Circuit diagram for the power one-shot control.

In the circuit of Fig. 21, before the button is depressed, both flip-flop outputs are in the "zero" state. Transistor Q_G is biased ON by the output of flip-flop FF-1. The differential comparator which is part of the CA3059 circuit is initially biased to inhibit output pulses. When the push button is depressed, pulses are

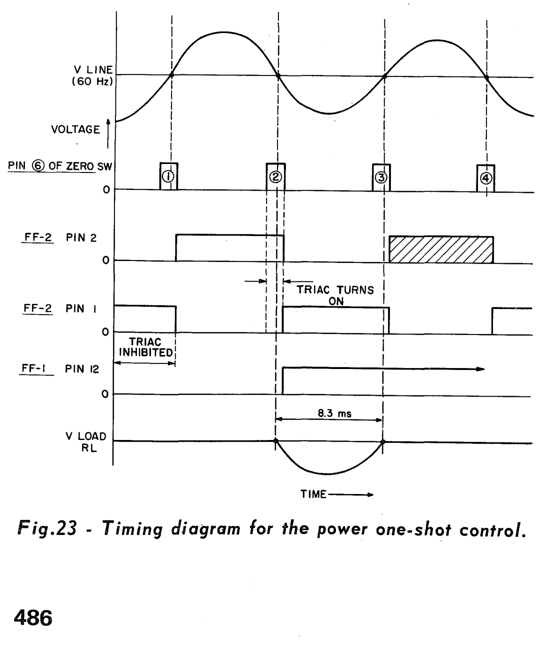


Fig.23 - Timing diagram for the power one-shot control.

SOLID-STATE TRAFFIC FLASHER

Another application which illustrates the versatility of the CA3059, when used with RCA thyristors, involves switching traffic-control lamps. In this type of application, it is essential that a triac withstand a current surge of the lamp load on a continuous basis. This surge results from the difference between the cold and hot resistance of the tungsten filament. If it is assumed that triac turn-on is at 90 degrees from the zero-voltage crossing, the first current-surge peak is approximately ten times the peak steady-state value or fifteen times the steady-state rms value. The second current-surge peak is approximately four times the steady-state rms value.

When the triac randomly switches the lamp, the rate of current rise di/dt is limited only by the source inductance. The triac di/dt rating may be exceeded in some power systems. In many cases, exceeding the rating results in excessive current concentrations in a small area of the device which may produce a hot spot and lead to device failure. Critical applications of this nature require adequate drive to the triac gate for fast turn-on. In this case, some inductance may be required in the load circuit to reduce the initial magnitude of the load current when the triac is passing through the active region. Another method may be used which involves the switching of the triac at zero line voltage. This method involves the supply of pulses to the triac gate only during the presence of zero voltage on the ac line.

Fig. 24 shows a circuit in which the lamp loads are switched at zero line voltage. This approach reduces the initial di/dt, decreases the required triac surge-current ratings, increases the operating lamp life, and eliminates RFI problems. This circuit consists of two triacs, a flip-flop (FF-1), the CA3059, and a diac pulse generator. The flashing rate in this circuit is controlled by potentiometer R, which provides between 10 and 120 flashes per minute. The state of FF-1 determines the triggering of triacs Y_1 or Y_2 by the output pulses at terminal 4 generated by the zero-crossing circuit. Transistors Q_1 and Q_2 inhibit these pulses to the gates of the triacs until the triacs turn on by the logical "1" (V_{CC} high) state of the flip-flop.

The arrangement described can also be used for a synchronous, sequential traffic-controller system by addition of one triac, one gating transistor, a "divide-by-three" logic circuit, and modification in the design of the diac pulse generator. Such a system can control the familiar red, amber, and green traffic signals that are found at many intersections.

TRANSIENT-FREE SWITCH CONTROLLER

The CA3059 can be used as a simple solid-state switching device that permits ac currents to be turned on or off with a minimum of electrical transients and circuit noise.

The circuit shown in Fig. 25 is connected so that, after the control terminals (14 and 7) are opened, electronic logic waits until the power-line voltage reaches a zero crossing before power is applied to the load Z_L. Conversely, when the control terminals are shorted, the load current continues until it reaches a zero crossing. This circuit can switch a load at zero current whether it is resistive or inductive.

The circuit shown in Fig. 26 is connected to provide the opposite control logic to that of the circuit shown in Fig. 25. That is, when the switch is closed, power is supplied to the load, and when the switch is opened, power is removed from the load.

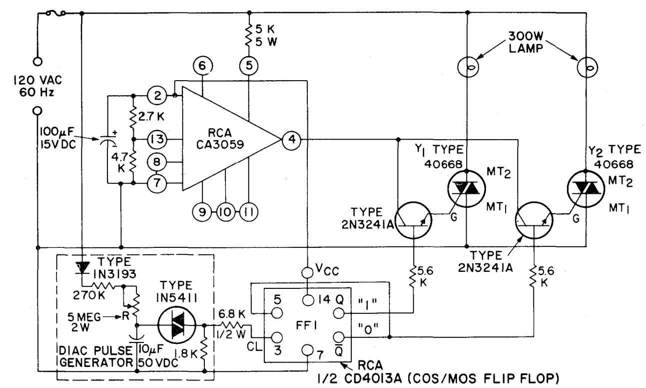
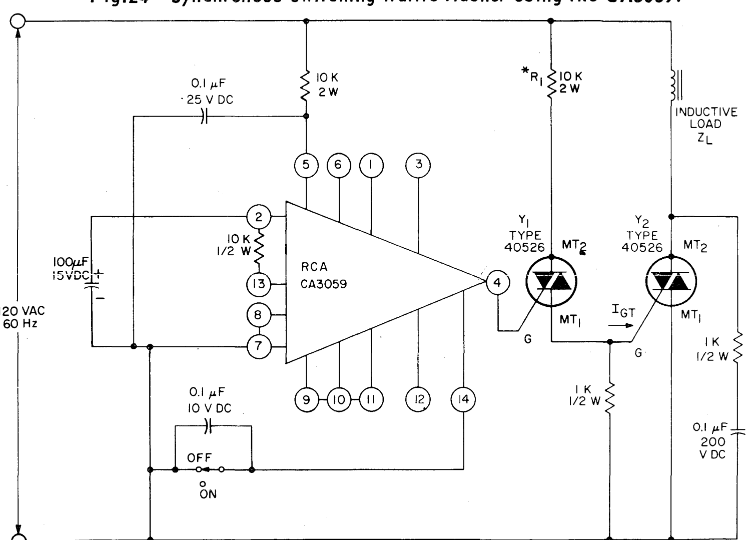


Fig.24 - Synchronous-switching traffic flasher using the CA3059.



*IF Y_2, FOR EXAMPLE, IS A 40-AMPERE TRIAC, THEN R_1 MUST BE DECREASED TO SUPPLY SUFFICIENT I_{GT} FOR Y_2.

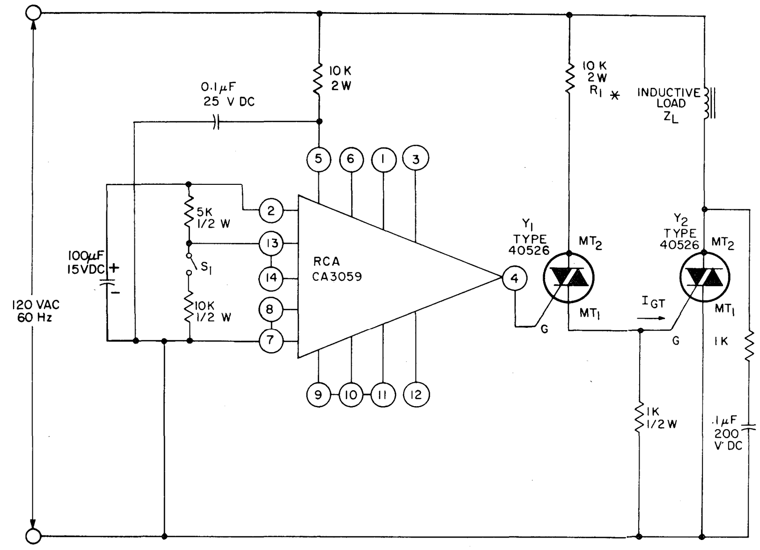
Fig.25 - CA3059 transient-free switch controller in which power is supplied to the load when the switch is open.

In both configurations, the maximum rms load current that can be switched depends on the rating of triac Y_2. If Y_2 is an RCA-2N5444 triac, an rms current of 40 amperes can be switched.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to P. Howard for his able assistance in development of many of the circuits described in this Note.

Ref. 1. RCA bulletin File No. 479, "COS/MOS IC's for Low-Voltage (3-15V) Applications.



* IF Y_2, FOR EXAMPLE, IS A 40-AMPERE TRIAC, R_1 MUST BE DECREASED TO SUPPLY SUFFICIENT I_{GT} FOR Y_2

Fig.26 - CA3059 transient-free switch controller in which power is applied to the load when the switch is closed.

RCA Solid State Division

Linear Integrated Circuits
Application Note
ICAN-6268

Applications and Extended Operating Characteristics for the RCA-CA3059 IC Zero-Voltage Switch

by H. M. Kleinman and A. Sheng

The RCA-CA3059 zero-voltage switch is a monolithic silicon integrated circuit designed to control a thyristor in a variety of ac power switching applications. A previous Application Note (ICAN-4158) described several useful control systems in which the CA3059 was used as a thyristor trigger. This Note briefly describes the CA3059 circuit, explains the circuit functions and basic system configurations, and gives supplemental data for extending operation to 220-volt, 50-to-60-Hz lines and temperatures from -40°C to +85°C. It also discusses additional applications including the switching of inductive loads, the provision of negative gate current, operation with low-impedance sensors, and synchronous light flashers.

CIRCUIT DESCRIPTION

Operation of the CA3059 can best be explained by reference to the functional block diagram shown in Fig. 1 and the schematic diagram shown in Fig. 2. In the following discussion, all voltages are referred to terminal 7.

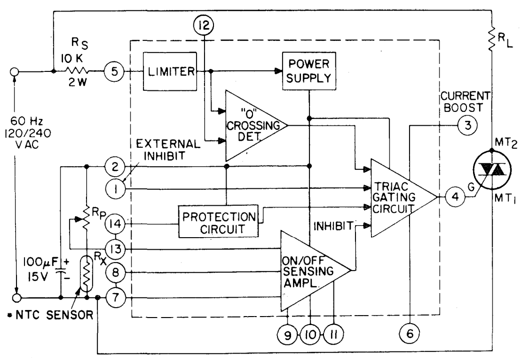


Fig. 1 - Functional block diagram of CA3059 integrated-circuit zero-voltage switch.

Power to the circuit may be derived directly from the ac line, as shown in Fig. 1, or from an external dc power supply connected between terminals 2 and 7, as shown in Fig. 3. In the normal mode of operation, a dropping resistor R_s of 5000 to 10,000 ohms is required to limit the current in the IC. The choice of resistor is a function of the average current drawn from the power supply, either by external circuits or by the thyristor trigger circuits, as shown in Fig. 4.

The diodes D_1 and D_2 in Fig. 2 form a symmetrical clamp that limits the voltages on the chip to ±8 volts; D_7 and D_{13} form a half-wave rectifier that develops a positive voltage on the external storage capacitor. When an external power supply is used to increase the current capability of the IC, care must be used to avoid exceeding the 14-volt breakdown voltage rating between terminals 2 and 5. This requirement is not a problem if the supply voltage is 6 volts or less. If higher supply voltages are required, terminal 5 must be shorted to terminal 7 and the line synchronizing voltage applied to terminal 12 through a resistor of 10,000 ohms or more, as shown in Fig. 3.

The functions of the other blocks in Fig. 1 can best be understood by consideration of the normal state of a thyristor gating circuit as its ON state, in which current is being delivered to the triac gate through terminal 4. The other circuit blocks inhibit the gating circuit unless certain conditions are met. In the ON state, Q_8 and Q_9 are conducting, Q_7 is off, and Q_6 is on. Any action that turns Q_7 on removes the drive from Q_8 and allows the thyristor to turn off. Q_7 may be turned on directly by application of a minimum of +1.2 volts at 10 microamperes to the EXTERNAL INHIBIT terminal 1. (If a voltage of more than 2 volts is available, external resistance must be added to limit the current to 10 milliamperes.) Diode D_{10} isolates the base of Q_7 from other signals when an external inhibit signal is applied so that this signal is the highest priority command for normal operation. (Although grounding of terminal 6 creates a higher-priority inhibit function, this level is not compatible with normal DTL or TTL logic levels.) Q_7 may

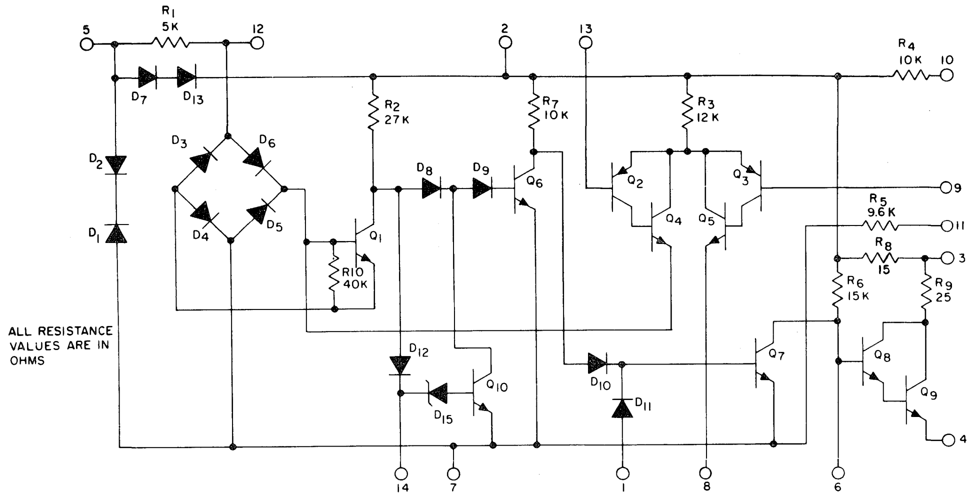


Fig. 2 - Schematic diagram of CA3059 zero-voltage switch.

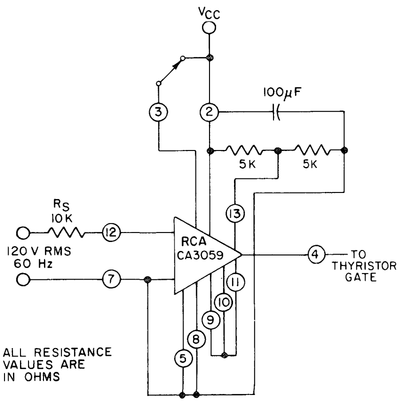


Fig. 3 - Operation of the CA3059 from an external dc power supply connected between terminals 2 and 7.

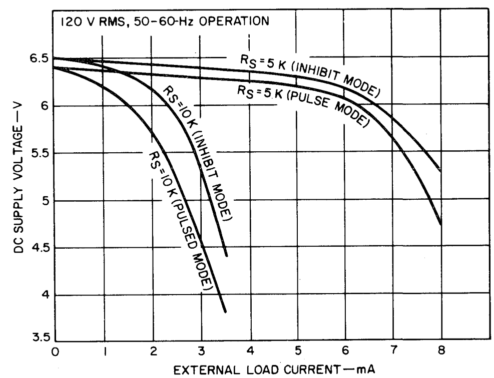


Fig. 4 - DC supply voltage as a function of external load current for several values of dropping resistance R_S.

also be activated by turning off Q_6 to allow current to flow from the power supply through R_7 and D_{10} into the base. Q_6 is normally held on by current flowing into its base through R_2, D_8, and D_9 when Q_1 is off.

Q_1 is a portion of the zero-crossing detector. When the voltage at terminal 5 is greater than +3 volts, current can flow through R_1, D_6, the base-to-emitter junction of Q_1, and D_4 to terminal 7 to turn on Q_1 and inhibit the pulse. For negative voltages with magnitudes greater than 3 volts, the current flows through D_5, the emitter-to-base junction of Q_1, D_3, and R_1, and again turns Q_1 on. Q_1 is off only when the voltage at terminal 5 is less than the threshold voltage of approximately 2 volts. When the CA3059 is connected as shown in Fig. 1, therefore, output occurs in a narrow pulse which is approximately centered about the zero-voltage time in the cycle, as shown in Fig. 5. In some applications, however, particularly those using either slightly inductive or low-power loads, the thyristor load current does not reach

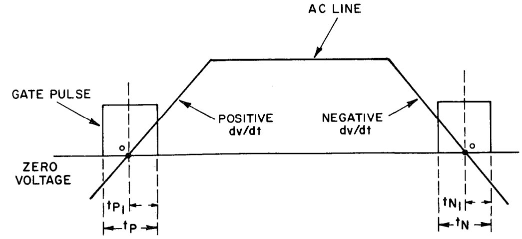


Fig. 5 - Waveform showing output-pulse duration of CA3059.

the holding current by the end of this pulse. Fig. 6 shows how an external capacitor between terminal 5 and 7 can be used to delay the pulse to accommodate such loads. The amount of pulse stretching and delay is shown in Figs. 7(a) and 7(b).

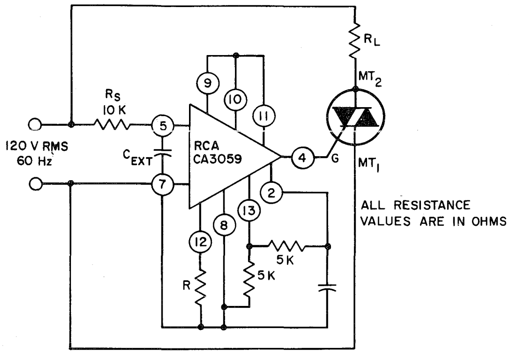


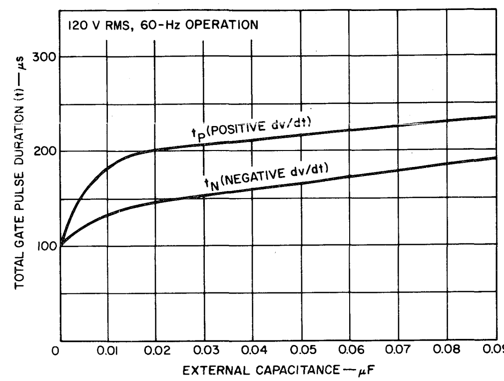
Fig. 6 - Use of a capacitor between terminals 5 and 7 to delay the output pulse of the CA3059.

Continuous gate current can be obtained if terminal 12 is connected to terminal 7 to disable the zero-crossing detector. In this mode, Q_1 is always off. This mode of operation is useful when comparator operation is desired or when inductive loads must be switched. (If the capacitance in the load circuit is low, most RFI is eliminated.) Care must be used to avoid overloading of the internal power supply in this mode. A sensitive-gate thyristor should be used and a resistor placed between terminal 4 and the gate of the thyristor to limit the current.

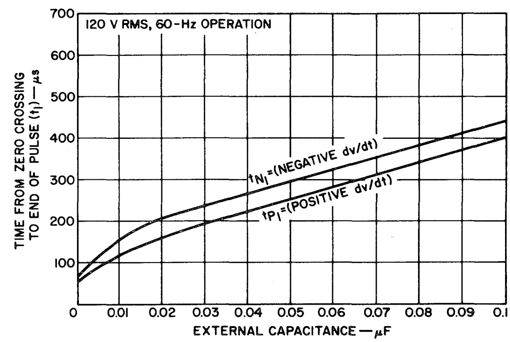
THE ON-OFF SENSING AMPLIFIER

The discussion thus far has considered only cases in which pulses are present all the time or not at all. The differential sense amplifier consisting of transistors Q_2, Q_3, Q_4, and Q_5 makes the CA3059 a flexible power-control circuit. The transistor pairs Q_2-Q_4 and Q_3-Q_5 form high-beta composite p-n-p transistors in which the emitters of Q_4 and Q_5 act as the collectors of the composite devices. These two composite transistors are connected as a differential amplifier with R_3 acting as a constant-current source. The relative current flow in the two "collectors" is a function of the difference in voltage between the bases of Q_2 and Q_3. Therefore, when terminal 13 is more positive than terminal 9, little or no current flows in the "collector" of Q_2-Q_4; when terminal 13 is negative with respect to terminal 9, most of the current flows through that path and none in terminal 8. When current flows in Q_2-Q_4, the path is from the supply through R_3, through Q_2-Q_4, through the base-emitter junction of Q_1, and finally through D_4 to terminal 7. Therefore, when V_{13} is equal to or more negative than V_9, Q_1 is on and output is inhibited.

In the circuit shown in Fig. 1, the voltage at terminal 9 is derived from the supply by connection of terminals 10 and 11 to form a precision voltage divider. This divider forms one side of a transducer bridge, with R_P and the NTC sensor forming the other. At low temperatures, the large value of the sensor causes terminal 13 to be positive with respect to terminal 9 so that the thyristor fires on every half-cycle and power is applied to the load. As the temperature increases, the sensor resistance decreases until a balance is reached and V_{13} approaches V_9. At this point, Q_2-Q_4 turns on and inhibits any further pulses. The controlled temperature is adjusted by variation of the value of R_P. For cooling service, either the positions of R_P and the sensor may be reversed or terminals 9 and 13 may be interchanged.



(a)



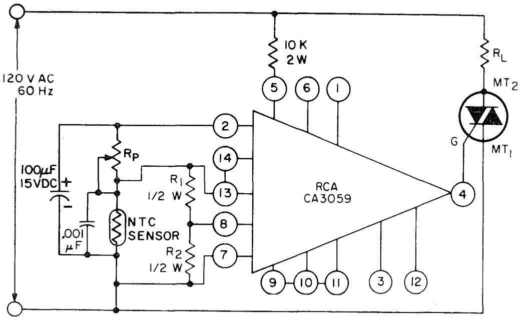
(b)

Fig. 7 - Curves showing effect of external capacitance on (a) the total output-pulse duration, and (b) the time from zero crossing to the end of the pulse.

The low bias current of the sensing amplifier permits operation with sensor impedances of up to 0.1 megohm at balance without introduction of substantial error (i.e., greater than 5 per cent). The error may be reduced if the internal bridge elements R_4 and R_5 are not used but are replaced with resistors which equal the sensor impedance. The minimum value of sensor impedance is restricted by the current drain on the internal power supply; the curves shown in Fig. 4 should be consulted when low-impedance sensors are used. Operation with sensors as low as 300 ohms may be obtained with a 5000-ohm series resistor. Slightly better sensitivity can be realized if R_S is reduced to 4000 ohms.

ADDING HYSTERESIS

Because the logic circuitry of the CA3059 causes a decision concerning power delivery to be made on each half-cycle, it is possible that power may be required for an odd number of half-cycles once equilibrium is reached. In systems with relatively fast response times (less than 1 second), a substantial dc component might be placed on the power line and cause heating of any isolation or distribution transformers. This problem may be reduced by introducing hysteresis into the system, as shown in Fig. 8. A "dead zone" of 10 per cent of the sensor impedance may be achieved by



THERMISTOR→	NTC	R_1	R_2	NTC	R_1	R_2	NTC	R_1	R_2
	5K	12K	12K	12K	68K	12K	100K	200K	18K

Fig. 8 - CA3059 on-off controller with hysteresis.

use of a sensor resistance R_a of 0.1 megohm, an R_1 value of 0.2 megohm, and an R_2 value of 18000 ohms. A decrease in the R_2 value reduces the effect. With a 5000-ohm sensor impedance, values of 12000 ohms for R_1 and R_2 yield a 5-per-cent dead zone. A more eleborate system (described in ICAN-4158) is required if the degree of hysteresis must be accurately controlled.

PROPORTIONAL CONTROL

The ON-OFF nature of the control shown in Fig. 1 causes some overshoot that leads to a definite steady-state error. The addition of hysteresis adds further to this error factor. However, the connections shown in Fig. 9(a) can be used to add proportional control to the system. In this circuit, the sense amplifier is connected as a free-running multivibrator. At balance, the voltage at terminal 13 is as shown in Fig. 9 (b). When this voltage is more positive than the threshold, power is applied to the load so that the duty cycle is approximately 50 per cent. With a 0.1-megohm sensor and

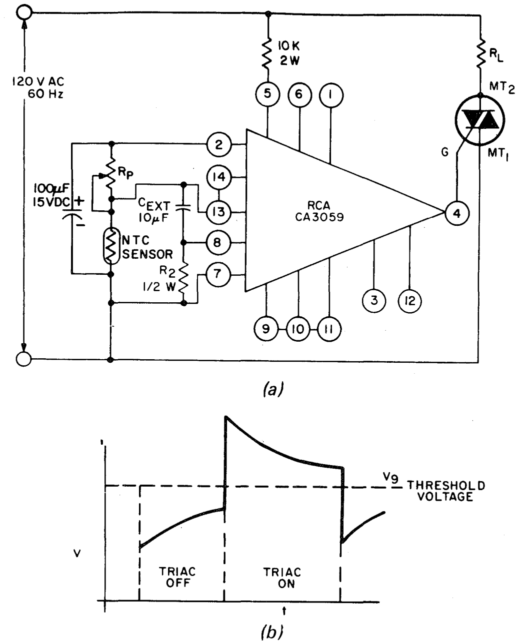


Fig. 9 - Typical heating control with proportional control: (a) schematic diagram, and (b) waveform of voltage at terminal 13.

values of R_p = 0.1 megohm, R_2 = 10,000 ohms, and $C_{ext.}$ = 10 microfarads, a period greater than 3 seconds is achieved. This period should be much shorter than the thermal time constant of the system. Changing the value of any of these elements changes the period, as shown in Fig. 10. As the resistance of the sensor changes, the voltage on terminal 13 moves relative to V_9. A cooling sensor moves V_{13} in a positive direction. The triac is ON for a larger portion of the pulse cycle and increases the average power to the load.

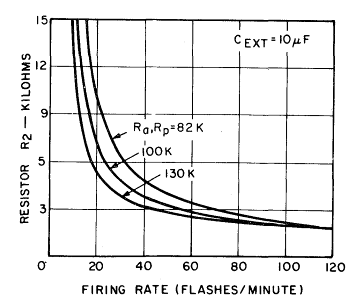


Fig. 10 - Effect of variations in time-constant elements on period.

As in the case of the hysteresis circuitry described, some special applications may require more sophisticated systems to achieve either very precise regions of control or very long periods (see ICAN-4158).

FAIL-SAFE OPERATION

A special feature of the CA3059 is the inclusion of a fail-safe circuit which removes power from the load if the sensor either shorts or opens. However, use of this circuit places certain constraints upon the user. Specifically, fail-safe operation is guaranteed under the following conditions:

1. The circuit configuration of Fig. 1 is used, with an internal supply, no external load on the supply, and terminal 14 connected to terminal 13.

2. The value of R_P and of the sensor resistance must be between 2000 ohms and 0.1 megohm.

3. The ratio of sensor resistance and R_P must be greater than 0.25 and less than 4.0 for all normal conditions (if either of these ratios is not met with an unmodified sensor, a series resistor or a shunt resistor must be added to avoid undesired activation of the circuit).

Fail-safe operation may be applied to other systems when operation of the circuit is understood. The fail-safe circuit consists of D_{12}, D_{15}, and Q_{10}. D_{12} activates the fail-safe circuit if the sensor shown in Fig. 1 shorts or drops too low in value, as follows: Q_6 is on during an output pulse so that the junction of D_8 and D_{12} is 3 diode drops (approximately 2 volts) above terminal 7. As long as V_{14} is more positive or only 0.15 volt negative with respect to that point, D_{12} does not conduct and the circuit operates normally. If the voltage at terminal 14 drops to 1 volt, the anode of D_8 can have a potential of only 1.6 to 1.7 volts, and current does not flow through D_8, D_9, and Q_6; the thyristor then turns off. The actual threshold is approximately 1.2 volts at room temperature, but decreases 4 millivolts per degree C at higher temperatures. As the sensor resistance increases, the voltage at terminal 14 rises toward the supply voltage. At a voltage of approximately 6 volts, the zener diode D_{15} breaks down and turns on Q_{10}, which then turns off Q_6 and the thyristor. If the supply voltage is not at least 0.2 volt more positive than the breakdown of D_{15}, activation of the fail-safe circuit is not possible. For this reason, loading the internal supply may cause this circuit to malfunction, as may selection of the wrong external supply voltage. Fig. 11 shows a guide for the proper operation of the fail-safe circuit when an external supply is used.

SUPPLEMENTAL CHARACTERISTICS DATA

The characteristics curves shown in Fig. 12 are similar to curves shown in the published data for the CA3059 (RCA File No. 397, dated 10/69), but have been extended to cover the entire operating range from -40°C to +85°C. Fig. 13 presents data required for operation of the CA3059 from the 220-volt, 50-Hz lines which are common in Europe and from the 220-to-240-volt, 60-Hz lines which are commonly used for high-power applications in the United States. Although the CA3059 may be operated from any line voltage or frequency, the characteristics of the output pulse change for different line voltages and frequencies. Figs. 13(a) and (b) show relative pulse width and location of the zero-voltage crossing when a 10,000-ohm series dropping resistor is used. Figs. 13(c) and (d) show the same information for an increased resistor value of 20,000 ohms.

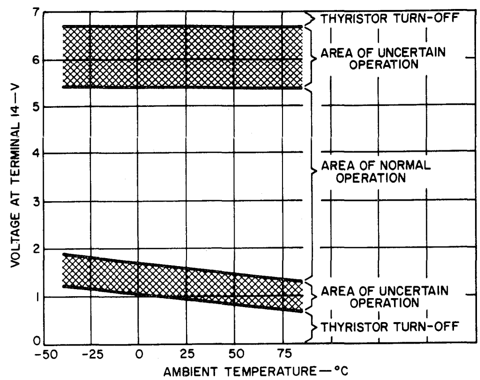


Fig. 11 - Operating regions for built-in protection circuits.

APPLICATIONS OF THE CA3059

The early sections of this Note described the basic operation of the CA3059 in heating control systems. The circuit is adaptable to many other control functions by variation of the type of sensor used or by the use of the inputs of the differential amplifier to detect the difference between two externally developed voltages. A previous Application Note (ICAN-4158) describes the following useful CA3059 systems:

1) a controller with an external fail-safe circuit for use when the sensor does not meet the requirements for use of the internal circuit,
2) a controller with provisions for accurate setting of hysteresis,
3) a proportional control system with an external ramp generator,
4) a dual-output, over-under temperature controller,
5) a heat staging controller,
6) a circuit which eliminates half-cycling,
7) a circuit with an isolated sensor,
8) a power one-shot control,
9) a synchronously switched traffic flasher,
10) transient-free switch controllers.

Although most of these circuits illustrate a heating control circuit, they are all adaptable to other control functions by change of the control logic or sensor.

SWITCHING INDUCTIVE LOADS

For proper driving of a thyristor in full-cycle operation, gate drive must be applied soon after the voltage across the device reverses. When resistive loads are used, this reversal

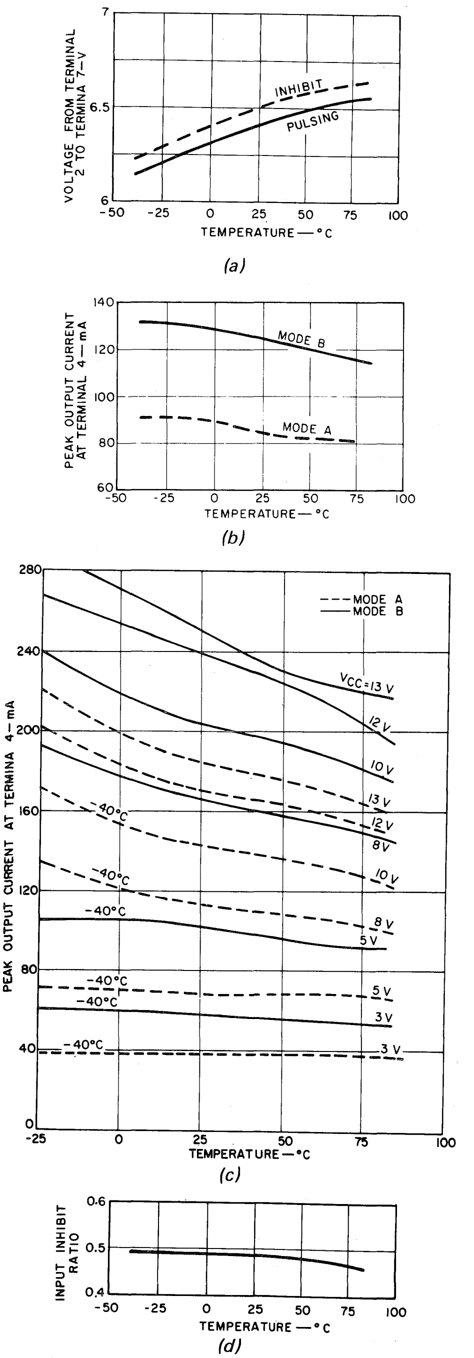


Fig. 12 - Characteristics curves of the CA3059 extended to cover the operating range from -40 to +85°C.

occurs as the line voltage reverses. With loads of other power factors, however, it occurs as the current through the load becomes zero and reverses.

There are several methods for switching an inductive load at the proper time. If the power factor of the load is high (i.e., if the load is only slightly inductive), the pulse may be delayed by addition of a suitable capacitor between terminals 5 and 7, as described in the published data for the CA3059. For highly inductive loads, however, this method is not suitable and different techniques must be used.

One technique is suggested in the circuit description section of this Note. If gate current is continuous, the triac automatically commutates because drive is always present when the voltage reverses. This mode is established by connection of terminals 7 and 12. The zero-crossing detector is then disabled so that current is supplied to the triac gate whenever called for by the sensing amplifier. Although the RFI-eliminating function of the CA3059 is inhibited when the zero-crossing detector is disabled, there is no problem if the load is highly inductive because the current in the load cannot change abruptly.

The limitation to this mode of operation is that the internal power supply cannot deliver a large average current; therefore, a sensitive-gate triac is required. Because these triacs have somewhat limited load-carrying capacity, this approach cannot be used universally.

The previous Note ICAN-4158 showed circuits which used a sensitive-gate triac to shift the firing point of the power triac by approximately 90 degrees. If the primary load is inductive, this phase shift corresponds to firing at zero current in the load. However, changes in the power factor of the load or tolerances of components will cause errors in this firing time.

The circuit shown in Fig. 14 uses a CA3018 integrated-circuit transistor array to detect the absence of load current by sensing the voltage across the triac. The internal zero-crossing detector is disabled by connection of terminal 12 to terminal 7, and control of the output is made through the external inhibit input, terminal 1. The circuit permits an output only when the voltage at point A exceeds two V_{BE} drops or 1.3 volts. When A is positive, Q_3 and Q_4 conduct and reduce the voltage at terminal 1 below the inhibit state. When A is negative, Q_1 and Q_2 conduct. When the voltage at point A is less than ±1.3 volts, neither of the transistor pairs conducts; terminal 1 is then pulled positive by the current in R_3 and output is inhibited.

The circuit of Fig. 14 forms a pulse of gate current in the manner described below, and can supply high peak drive to power triacs with low average current drain on the internal supply. The gate pulse will always last just long enough to latch the thyristor so that there is no problem with delaying the pulse to an optimum time. As in other circuits of this type, RFI results if the load is not suitably inductive because the zero-crossing detector is disabled and initial turn-on occurs at random.

The gate pulse forms because the voltage at point A when the thyristor is on is less than 1.3 volts; therefore, the

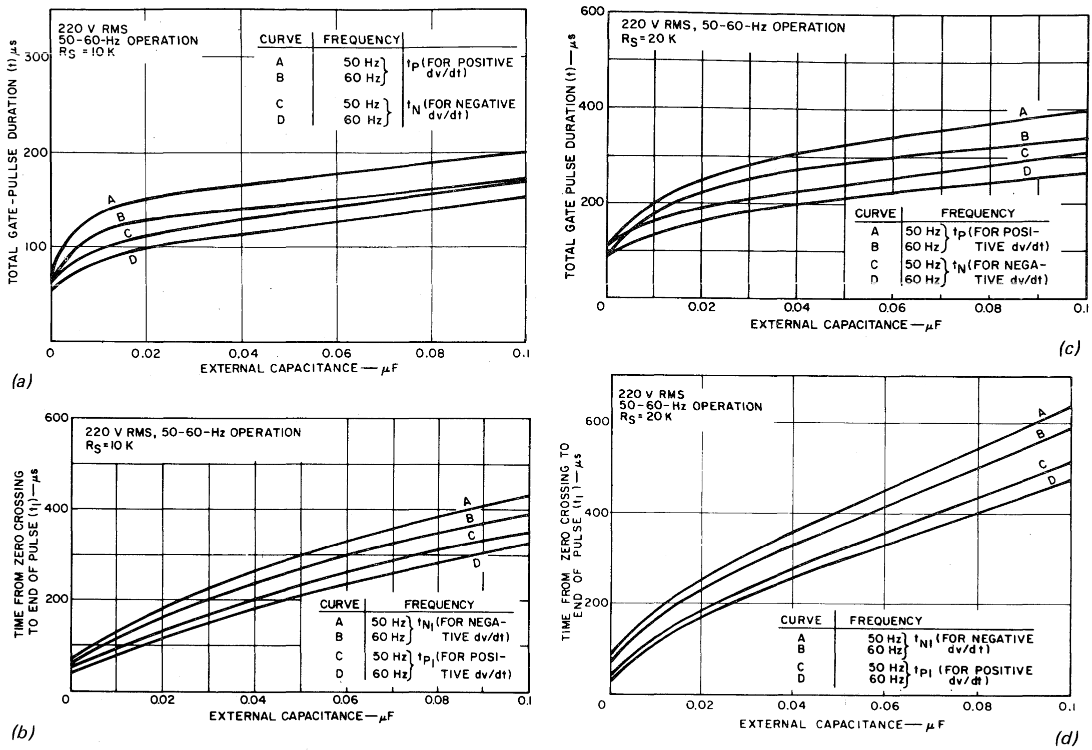


Fig. 13 - Relative pulse width and location of zero-voltage crossing for 220-volt operation.

output of the CA3059 is inhibited, as described above. The resistor divider R_1 and R_2 should be selected to assure this condition. When the triac is on, the voltage at point A is approximately one-third of the instantaneous on-state voltage (v_T) of the thyristor. For most RCA thyristors, v_T (max) is less than 2 volts and the divider shown is a conservative one. When the load current passes through zero, the triac commutates and turns off. Because the circuit is still being driven by the line voltage, the current in the load attempts to reverse, and voltage increases rapidly across the "turned-off" triac. When this voltage exceeds 4 volts, one portion of the CA3018 conducts and removes the inhibit signal to permit application of gate drive. Turning the triac on causes the voltage across it to drop and thus ends the gate pulse. If the holding current has not been attained, another gate pulse forms, but no discontinuity in the load current occurs.

PROVIDING NEGATIVE GATE CURRENT

Triacs trigger with optimum sensitivity when the polarity of the gate voltage and the voltage at the main terminal 2 are similar (I^+ and III^- modes). Sensitivity is degraded when the polarities are opposite (I^- and III^+ modes). Although RCA triacs are designed and specified to have the same sensitivity in both I^- and III^+ modes, some other types have very poor sensitivity in the III^+ condition. Because the CA3059

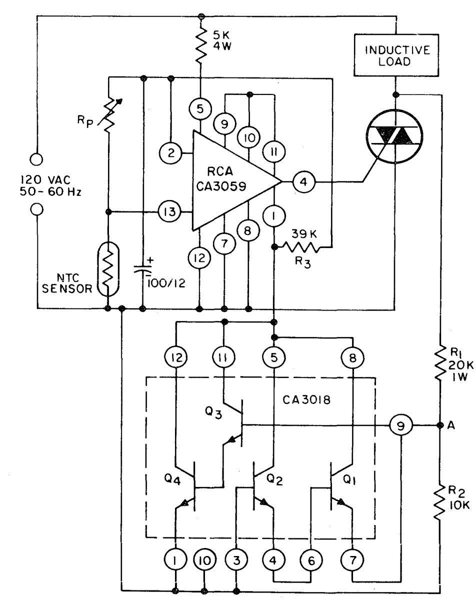


Fig. 14 - Circuit for switching inductive loads.

supplies positive gate pulses, it may not directly drive some higher-current triacs of these other types.

The circuit shown in Fig. 15 (a) uses the negative-going voltage at terminal 3 of the CA3059 to supply a negative gate pulse through a capacitor. The curve in Fig. 15 (b) shows the approximate peak gate current as a function of gate voltage V_G. Pulse width is approximately 80 microseconds.

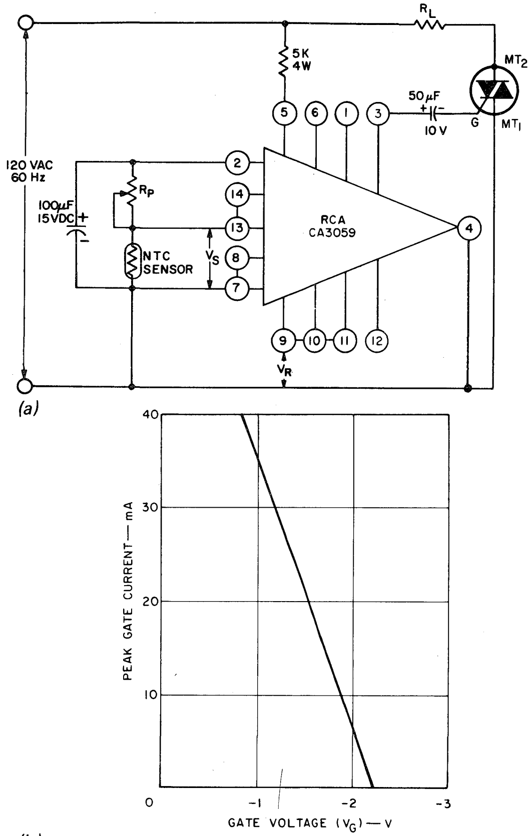


Fig. 15 - Use of the CA3059 to provide negative gate pulses: (a) schematic diagram; (b) peak gate current (at terminal 3) as a function of gate voltage.

OPERATING WITH LOW-IMPEDANCE SENSORS

Although the CA3059 can operate satisfactorily with a wide range of sensors, sensitivity is reduced when sensors with impedances greater than 20,000 ohms are used. Typical sensitivity is one per cent for a 5000-ohm sensor and increases to three per cent for a 0.1-megohm sensor.

Low-impedance sensors present a different problem. The sensor bridge is connected across the internal power supply and causes a current drain. A 5000-ohm sensor with its associated 5000-ohm series resistor draws less than 1 milliampere. On the other hand, a 300-ohm sensor draws a current of 8 to 10 milliamperes from the power supply.

Fig. 16 shows the 600-ohm load line of a 300-ohm sensor on a redrawn power-supply regulation curve for the CA3059. When a 10,000-ohm series resistor is used, the voltage across the circuit is less than 3 volts and both sensitivity and output current are significantly reduced. When a 5000-ohm series resistor is used, the supply voltage is nearly 5 volts and operation is approximately normal. For more consistent operation, however, a 4000-ohm series resistor is recommended.

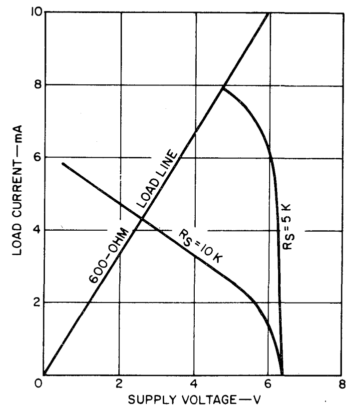


Fig. 16 - Power-supply regulation of the CA3059 with a 300-ohm sensor (600-ohm load) for two values of series resistor.

SYNCHRONOUS LIGHT FLASHER

The circuit shown in Fig. 17 is a simplified version of the system shown in the previous Note ICAN-4158. Flash rate is set by use of the curve shown in Fig. 10. If a more precise flash rate is required, the ramp generator described in the previous Note may be used. In this circuit, IC_1 is the master control unit and IC_2 is slaved to the output of IC_1 through

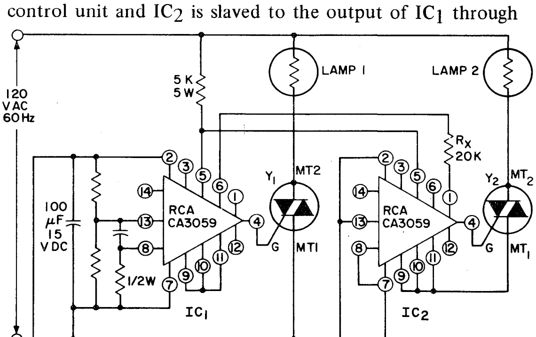


Fig. 17 - CA3059 synchronous light flasher.

its inhibit terminal (terminal 1). When power is applied to lamp No. 1, the voltage of terminal 6 on IC_1 is high and IC_2 is inhibited by the current in R_X. When lamp No. 1 is off, IC_2 is not inhibited and triac Y_2 can fire. The power supplies operate in parallel. The on-off sensing amplifier in IC_2 in not used.

Guide to RCA Solid-State Devices

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TA148	RECT	1N540	3	SSD-206A	265
TA149	RECT	1N1095	3	SSD-106A	265
TA1000	RECT	1N547	3	SSD-206A	265
TA1003	RECT	1N440B	5	SSD-206A	262
TA1004	RECT	1N441B	5	SSD-206A	262
TA1005	RECT	1N442B	5	SSD-206A	262
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TA1007	RECT	1N444B	5	SSD-206A	262
TA1008	RECT	1N445B	5	SSD-206A	262
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TA1016	RECT	1N2864A	91	SSD-206A	280
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TA1052	RECT	1N1195A	6	SSD-206A	326
TA1053	RECT	1N1196A	6	SSD-206A	326
TA1054	RECT	1N1197A	6	SSD-206A	326
TA1055	RECT	1N1198A	6	SSD-206A	326
TA1066	RECT	1N2858A	91	SSD-206A	280
TA1076	RECT	1N1199A	20	SSD-206A	320
TA1077	RECT	1N1200A	20	SSD-206A	320
TA1078	RECT	1N1202A	20	SSD-206A	320
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TA1086	RECT	1N1184A	38	SSD-206A	332
TA1087	RECT	1N1186A	38	SSD-206A	332
TA1095	RECT	1N1197A	6	SSD-206A	326
TA1096	RECT	1N3194	41	SSD-206A	268
TA1111	RECT	1N3193	41	SSD-206A	268
TA1112	RECT	1N3195	41	SSD-206A	268
TA1113	RECT	1N3196	41	SSD-206A	268
TA1120	RECT	1N3253	41	SSD-206A	268
TA1121	RECT	1N3254	41	SSD-206A	268
TA1122	RECT	1N3255	41	SSD-206A	268
TA1123	RECT	1N3256	41	SSD-206	268
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TA1195	RECT	1N3756	39	SSD-206A	258
TA1197	RECT	1N3754	39	SSD-206A	258
TA1198	RECT	1N3755	39	SSD-206A	258
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TA1205	SCR	2N1843A	28	SSD-206A	221
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TA1209	SCR	2N1847A	28	SSD-206A	221
TA1210	SCR	2N1848A	28	SSD-206A	221
TA1211	SCR	2N1849A	28	SSD-206A	221
TA1212	SCR	2N1850A	28	SSD-206A	221
TA1214	RECT	1N1187A	38	SSD-206A	332
TA1215	RECT	1N1188A	38	SSD-206A	332
TA1216	RECT	1N1189A	38	SSD-206A	332
TA1217	RECT	1N1190A	38	SSD-206A	332
TA1222	SCR	2N3228	114	SSD-206A	161
TA1225	SCR	2N3525	114	SSD-206A	161
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TA1680G	PWR	40050	14	SSD-204A	572
TA1680G	PWR	40051	14	SSD-204A	572
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TA1932	PWR	2N1184	14	SSD-204A	572
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TA2053B	PWR	2N2102	106	SSD-204A	323
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TA2267	RF	2N2631	32	SSD-205A	26
TA2275	PWR	2N2895	143	SSD-204A	342
TA2276	PWR	2N2896	143	SSD-204A	342
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TA2447	SCR	2N3872	578	SSD-206A	243
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TA2462	RF	2N3118	42	SSD-205A	35
TA2463	RF	2N3119	44	SSD-205A	39

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TA2493	PWR	2N3264	54	SSD-204A	354
TA2494	PWR	2N3265	54	SSD-204A	354
TA2495	PWR	2N3266	54	SSD-204A	354
TA2501	RF	2N3262	56	SSD-205A	46
TA2509	PWR	2N3878	299	SSD-204A	360
TA2509A	PWR	2N3879	299	SSD-204A	360
TA2510	PWR	2N3583	138	SSD-204A	229
TA2511	PWR	2N3584	138	SSD-204A	229
TA2512	PWR	2N3585	138	SSD-204A	229
TA2515	SCR	2N690	96	SSD-206A	233
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TA2591	RECT	1N1347RB	58	SSD-206A	317
TA2592	RECT	1N1348RB	58	SSD-206A	317
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TA2598	SCR	2N3669	116	SSD-206A	214
TA2600	RF	40282	68	SSD-205A	268
TA2606	RF	2N3478	77	SSD-205A	58
TA2616	RF	2N3632	386	SSD-205A	50
TA2617	SCR	2N3529	114	SSD-206A	161
TA2618	SCR	2N3670	116	SSD-206A	214
TA2620	RF	40281	68	SSD-205A	268
TA2621	SCR	2N3668	116	SSD-206A	214
TA2644	MOS/FET	3N140	285	SSD-201A	610
TA2645A	PWR	2N3773	526	SSD-204A	60
TA2650	PWR	2N3771	525	SSD-204A	52
TA2651	PWR	2N4036	216	SSD-204A	428
TA2653	SCR	40553	306	SSD-206A	175
TA2654	SCR	40554	306	SSD-206A	175
TA2655	SCR	40555	306	SSD-206A	175
TA2657	RF	40341	74	SSD-205A	295
TA2657A	RF	40340	74	SSD-205A	295
TA2658	RF	2N3866	80	SSD-205A	71
TA2669	PWR	2N5039	367	SSD-204A	371
TA2669A	PWR	2N5038	367	SSD-204A	371
TA2670	PWR	2N4037	216	SSD-204A	428
TA2670A	PWR	2N4314	216	SSD-204A	428
TA2672	PWR	40462	14	SSD-204A	572
TA2675	RF	2N5016	255	SSD-205A	94
TA2676	TRI	40429	351	SSD-206A	41
TA2685	TRI	40430	351	SSD-206A	41
TA2692	RF	2N3733	72	SSD-205A	62
TA2694	SCR	2N3896	578	SSD-206A	243
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